VULNERABILITY OF SCHOOLS IN PUERTO RICO TO TSUNAMI EVENTS

By

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RESEARCH FINAL REPORT

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Abstract

Puerto Rico is in an area of high seismicity, due to the presence of seismic faults around and within the Island. These faults have the potential to generate earthquakes that cause tsunamis, as occurred in 1918 in the western area of Puerto Rico. Considering that the school population between students and teachers is around 600,000 people, schools are essential facilities to safeguard against extreme events on the Island. For this reason, the objective of the research is to evaluate if the schools of Puerto Rico are vulnerable to tsunamis. To do this, the schools that are in a tsunami hazard zone were first identified and quantified for all the coastal municipalities of the Island. Then, two municipalities were selected as case studies in which a vulnerability assessment process was developed, which includes the analysis of pedestrian routes for the evacuation process and evacuation times to safe places. The study found that two schools are critical in vulnerability, one in each study municipality with excessive evacuation times and evacuation routes that are unsafe and unfit for the evacuation process.

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1 Introduction

Puerto Rico is susceptible to earthquakes and consequently tsunamis. Although tsunamis are rare in Puerto Rico, their historical events, seismic hazards, and other active earthquake-forming faults represent a potential threat of tsunami generation. In addition, the Puerto Rico Seismic Network, the National Tsunami Hazard Mitigation Program, and other institutions have studied the danger of tsunamis in Puerto Rico, creating risk maps. According to the National Tsunami Hazard Mitigation Program (2019), Puerto Rico has the highest tsunami danger in the Atlantic of the US due to the risk of earthquakes that can occur in the Puerto Rico Trench, a dangerous subduction zone. Also, the Federal Emergency Management Agency (2019) considers that Puerto Rico has a high potential for tsunami-generating events in the United States based on historical records and earthquake probabilities. In addition, it reports that the number of deaths in Puerto Rico and the U.S. Virgin Islands due to tsunamis is 164, and an estimated damage of $63 million. Since 1530, 13 tsunami events have been reported in Puerto Rico and the U.S. Virgin Islands. In 1867 and 1918, significant tsunamis with magnitudes greater than 7.0 were recorded for the Puerto Rico region that were caused by earthquakes in the Puerto Rico Trench. In the tsunami generated by a magnitude 7.5 earthquake in 1918, approximately 140 people died (FEMA, 2019). On the other hand, the University of the West Indies Seismic Research Center (n.d.) suggests that destructive tsunamis occur at an average rate of 1 to 2 each century in the Caribbean.

Tsunamis can have catastrophic impacts on human health and infrastructure in and out of coastal areas. This human security and infrastructure can be at risk and therefore be vulnerable. Some of the infrastructures that may be at risk and vulnerable are schools. According to a statistic made in 2015-2016 from the Statistics Institute of Puerto Rico (2019), Puerto Rico consists of a total of 1,418 schools, head starts, and early head starts within the public sector. The total of schools in the private sectors are 795. This country has around a total of 417,101 students in the public sector (this data includes special education and head starts), in the private sector the number of students is around 142,235 (this includes special education). Puerto Rico has 33,700 teachers in the public sector within the Department of Education and in Head Starts. In the private sector it has a total of 11,536 teachers. Most students in the country are in elementary or lower within both the public and the private sectors (Statistics Institute of Puerto Rico, 2019). Another essential way the schools are used in addition to teaching, is to serve as refuge (the ones that are eligible) to those in danger during natural disasters such as storms or people who lost their homes due to earthquakes. Also, the main place for voting in Puerto Rico are the schools. The schools are an essential place not just from the ones in it but also the communities that surround it.

This research aims to make an analysis of the vulnerability of schools, identifying those that are in danger and at risk of tsunamis. Given the importance of the safety of the vulnerable population in the educational infrastructures of Puerto Rico, the incidents, severity, and consequences of tsunami events are examined. The goal is to search for educational institutions that are in areas prone and under high potential to be affected by a tsunami generated by an earthquake. It is desired to make a record of the number and quantity of these schools, the density of people who are in danger and the characteristics of the areas at risk. Also, it is planned to contribute to the people and school infrastructures with the results. The vulnerability found in this research can serve as a means of resilience and mitigation of damage to tsunami events. This research can contribute to better planning of schools and tsunami hazard zones, helping them reduce vulnerability and losses. Similarly, it can help improve education efforts to develop preparedness plans for the population at risk and contribute to the safety of vulnerable people.

2 Literature Review

This chapter develops the theoretical framework for this research. It explains, synthesizes and documents the study topics, such as: earthquakes, tsunamis, vulnerability, risk, danger, schools, among others. The chapter shows the importance of discussing these important topics to face the existing problem in Puerto Rico under investigation. In addition, it shows a literature review that records and identifies some of the possible tools to use in the methodology.

2.1 Earthquakes

Earthquakes are unpredictable natural phenomena. The Puerto Rico Seismic Network (n.d.) defines an earthquake as the oscillatory, rapid, and sudden movement caused by the release of energy that arises from the interior of the Earth. This movement occurs along fractures in the earth's crust or geological faults produced by this release of energy. The energy generated propagates in the form of seismic waves that propagate through the interior of the Earth.

2.1.1 Generation

The Earth's crust is made up of large fragments of plates known as tectonic plates that are kept in continuous motion due to the Earth's rotation and gravitational forces. The map shows the types of plates: oceanic, mixed and continental (Figure 2-1). The oceanic plates are: Pacific Plate, Nazca Plate, Cocos Plate, Caribbean Plate and Philippine Plate. The oceanic and continental plates are: South American Plate and Eurasian Plate. The continental plates are: Arabian Plate, African Plate, and Indian Plate. These plates that move in different directions and at different rates of motion are thin rigid bodies with large and different horizontal dimensions. When there is contact at the boundaries between two tectonic plates, a fracture or failure occurs in the rocks of the earth's crust and a large amount of energy accumulates. The earthquakes generated by this release of energy along the fault are known as earthquakes of tectonic origin. However, there are other generating causes of earthquakes such as: landslides, volcanic eruptions, collapse of subsurface cavities and anthropogenic reasons (Sinvhal, 2010).

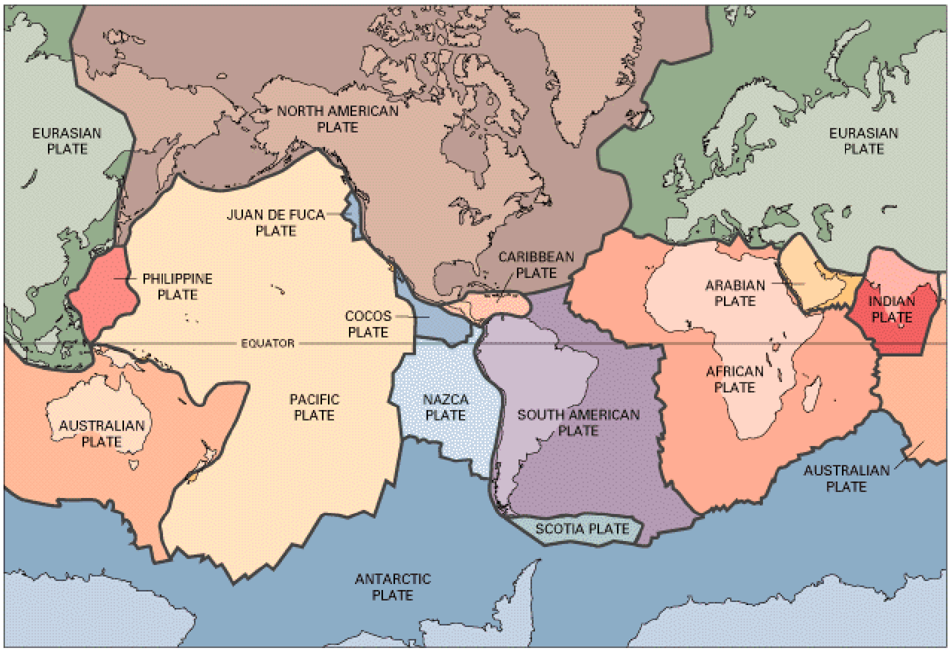


Figure 2-1 Distribution map of the tectonic plates of the world that are part of the lithosphere

From "Tectonic Plates of the Earth", by U.S. Geological Survey, n.d., USGS Multimedia Gallery, (https://www.usgs.gov/media/images/tectonic-plates-earth). In the public domain.

According to Sinvhal (2010), earthquakes of tectonic origin can occur in pre-existing faults or create new faults when the earthquake occurs. Faults are fractures along the displacement of blocks in the earth's crust in the rupture plane as shown in Figure 2-2. The hypocenter is the point of failure or focus where energy is released, and the earthquake originates. The epicenter is the point on the Earth's surface directly above the hypocenter.

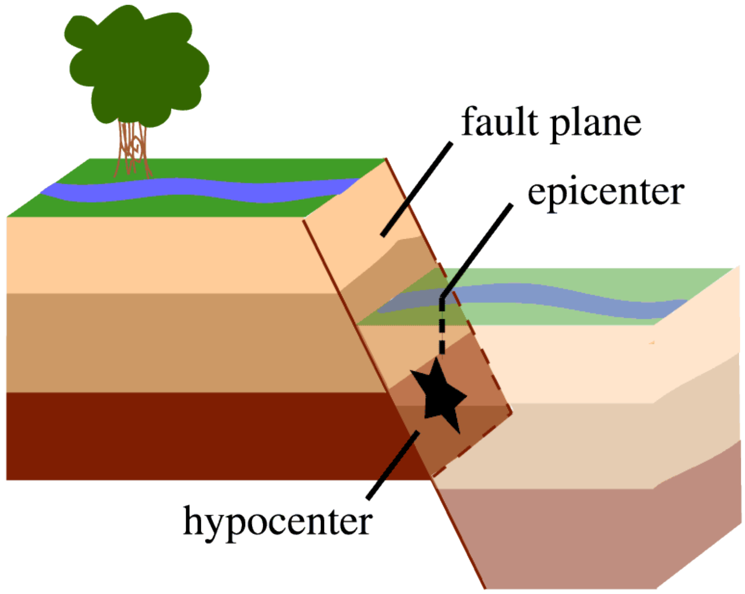


Figure 2-2 A Normal Fault

From "A Normal (Dip-Slip) Fault", by U.S. Geological Survey, n.d., USGS Multimedia Gallery, (https://www.usgs.gov/media/images/a-normal-dip-slip-fault). In the public domain.

2.1.2 Types of plate boundaries

There are three main types of contact margin between tectonic plates. These are: convergent, divergent, and transform boundaries. According to Sinvhal (2010), the convergence that is the collision between plates can be: between two oceanic plates, between an oceanic plate and a continental one, and between two continental plates. Oceanic plates are massive, of similar density and thickness, so one of the plates subducts. This means that one of the plates sinks or slides under the other. On oceanic and continental plates, one is heavier, and the other is lighter, and one of them is subducted as well. Continental plates are light and of the same density, so one is not subducted, but juxtaposed. Divergence is when plates separate, and transform boundaries occur when one plate slides horizontally over the other. The convergent boundaries between ocean and ocean are: Caribbean Plate and North American Plate; between ocean and continent: Nazca Plate and South American Plate; and between continent and continent: Indian-Australian Plate and Eurasian Plate (Figure 2-3).

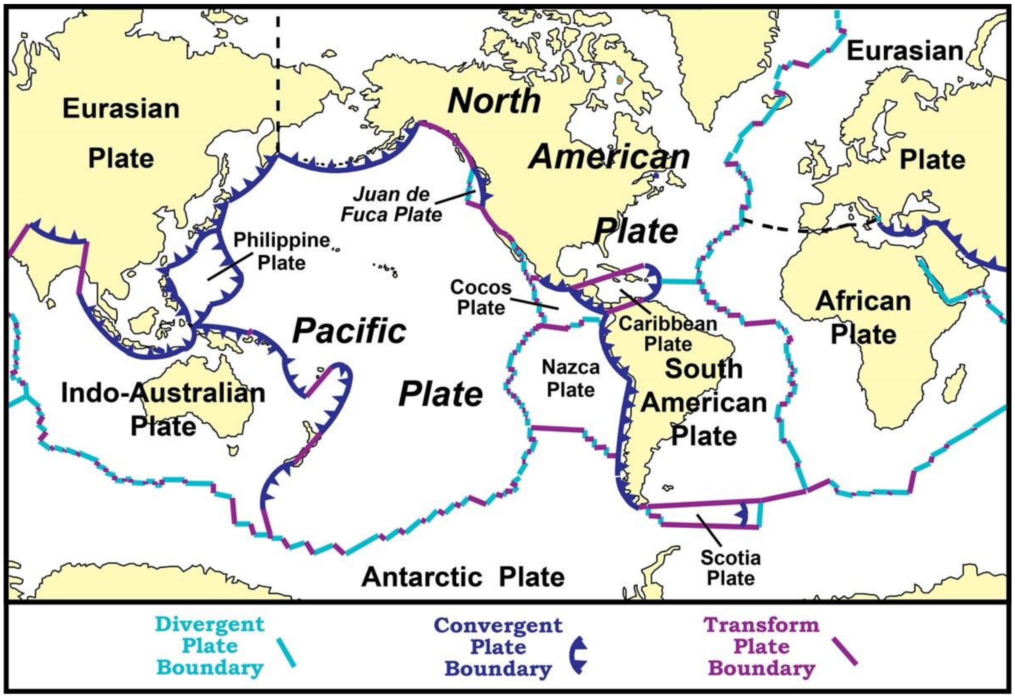


Figure 2-3 Map of the divergent, convergent and transform boundaries of tectonic plates
From "World Map of Plate Boundaries", by B. Lillie, 2015, Beauty from the Beast: Plate Tectonics and the Landscapes of the Pacific Northwest, p. 69, (https://ceetep.oregonstate.edu/sites/ceetep.oregonstate.edu/files/workshops/2014-08-aberdeen/2-tectonics-bob-lillie.pdf). Copyright 2015 by Robert J. Lillie.

2.1.3 Measurement

The measures of an earthquake are magnitude, intensity, and acceleration. The magnitude is a number on a logarithmic scale that defines the size of an earthquake and the amount of seismic energy released from it. The intensity lies in the qualitative effects of the earthquake. The Puerto Rico Seismic Network (n.d.) defines intensity as "a measure of non-instrumental perceptibility of damage to structures, surface effects of the soil and human reactions to the earthquake's tremor." On the other hand, acceleration is the change in speed in a unit of time that is expressed with respect to gravity to determine the size of the earthquake, the displacement of the earth and the properties of the waves, (Puerto Rico Seismic Network, n.d.)

2.1.4 Magnitude

As mentioned above, the magnitude of the earthquake measures the size of the earthquake and the energy it releases. It can be expressed in the following ways:

2.1.4.1 Modified Mercalli Intensity

This scale measures the earthquake's intensity by measuring the effects of it on the surface of the earth. It rates each earthquake on a scale of 1 to 12, 1 being the weakest and 12 the strongest. The rating of the earthquakes is based on subjective standards, how people, structures and other objects react to it near the epicenter.

Table 2-1 Mercalli Modified Intensity Table

Intensity	Shaking	Description/Damage (Near Epicenter)
I	Not Felt	Not felt except by a very few under favorable conditions.
II	Weak	Only felt by a few people at rest.
III	Weak	Noticeably felt by people indoors. Many people do not recognize it as an earthquake. Standing motors cars may rock slightly, vibrations like the passing of a truck, and duration estimated.
IV	Light	Felt by many people indoors, outdoors by few in the day. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking buildings. Standing motor cars rocked noticeably.
V	Moderate	Felt by nearly everyone, at night many awakened. Some dishes, windows broken. Unstable objects overturned and pendulum clocks may stop.
VI	Strong	Felt by everyone, many frightened. Some heavy furniture moved; a few instances of fallen plaster, damage slight.
VII	Very strong	Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed.
VIII	Severe	Damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse. Damage is great in poorly built structures. Fall factory stacks, columns, monuments, and walls. Heavy furniture overturned.
IX	Violent	Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb. Damage is great in substantial buildings, with partial collapse. Buildings shifted off foundations.
X	Extreme	Some well-built wooden structures are destroyed; most masonry, frame structures destroyed with foundations and rails bent.

From "The Modified Mercalli Intensity Scale", by U.S. Geological Survey, n.d., Earthquake Hazards, (https://www.usgs.gov/natural-hazards/earthquake-hazards/science/modified-mercalli-intensity-scale?qt-science_center_objects=0#qt-science_center_objects). In the public domain.

2.1.4.2 Richter Scale

This scale calculates the magnitude based on the amplitude of the largest seismic wave recorded for the earthquake. It is based on a logarithmic scale of base 10, there is no limit on the measuring size. The scale starts from 1 to 10, 1 is the smallest and 10 the biggest (Phillips, 2017).

2.1.4.3 Moment Magnitude Scale

This scale compares energy released by each earthquake based on the moment of it. This is a successor of the Richter scale, it is more accurate measuring strong earthquakes than its predecessor and it is used by the U.S. Geological Survey to estimate magnitudes for modern strong earthquakes (Phillips, 2017).

Figure 2-4 shows the different magnitudes, notable earthquakes, energy equivalents and energy release equivalent of explosives.

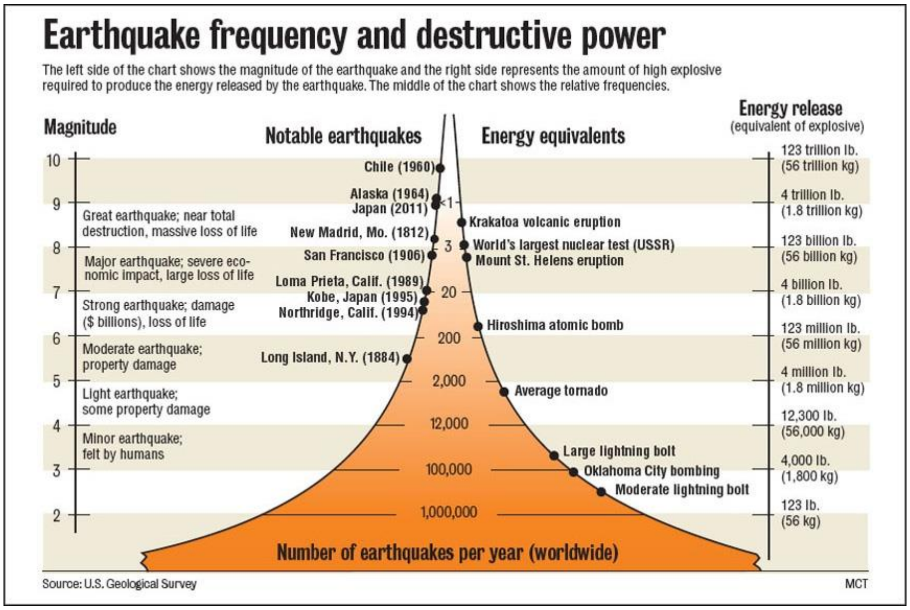


Figure 2-4 Graph of the Moment Magnitude Scale

From "How We Measure Earthquakes", by Rhino Steel Building System, 2018, Earthquakes and Steel Buildings, (https://www.rhinobldg.com/how-we-measure-earthquakes/). Copyright 2020 by Rhino Steel Building System.

2.1.5 Effects

According to The University of West Indies (n.d.) the earthquakes effects are the following:

2.1.5.1 Collapsing structures or objects

Strong enough earthquakes can provoke debris to fall from collapsing buildings and other structures, big falling debris can be fatal to people around that area, it also can break glass windows as shown in Figure 2-5. Earthquake aftershocks can completely take down the buildings that were highly damaged by the first wave.

Figure 2-5 Building collapse in the earthquake of 1995 in Kobe, Japan
From "Earthquake", by R. Hutchison, 1995, Britannica, (https://www.britannica.com/science/earthquake-geology/Tectonics). Copyright 2020 by Encyclopedia Britannica.

2.1.5.2 Falling electricity lines and fires

Electricity poles can fall and expose the wires which is extremely dangerous, and those exposed wires can also start fires, there can be ruptured gas lines and spillage of flammable substances around as shown in Figure 2-6. These types of fires can cause massive damage after a big earthquake (The University of West Indies, n.d.).

Figure 2-6 Fire on a flooded street after the earthquakes of 1994 on Northridge in California
From “What Will Really Happen When San Andreas Unleashes the Big One?”, by S. Starr, 2015, CORBIS, (https://www.smithsonianmag.com/science-nature/what-will-really-happen-california-when-san-andreas-unleashes-big-one-180955432/). Copyright 2020 by Smithsonian Magazine.

2.1.5.3 Rockslides and/or landslides on mountains and hillsides

Process where large rocks and portions of earth high up in the hills can become dislodged and rapidly roll down, hit cars, go into streets, or slide down into the valleys (Figure 2-7).

2.1.5.4 Floods caused by the collapse of dam walls

Strong earthquakes can provoke dam walls to crack and later subside, causing severe flooding to areas nearby (Figure 2-8).

Figure 2-7 A slope giving way after the 2001 earthquake in San Salvador

From "The Impacts of Earthquakes", by U. S. Geological Survey, 2001, University of Saskatchewan, (https://openpress.usask.ca/physicalgeology/chapter/12-4-the-impacts-of-earthquakes-2/). In the public domain.

Figure 2-8 Collapse of the Shih-Kang dam

From "Gravity and Buttress Dams", by R. Charlwood and T. Little, 2000, Observed Performance of Dams During Earthquakes, (http://www.ussdams.org/wpcontent/uploads/2016/05/ObservedPerformanceII_V2.pdf). Copyright 2000 by U. S. Committee on Large Dams.

2.1.5.5 Liquefaction

Liquefaction can be defined when loosely packed sediments that are saturated with water near the ground lose their strength when a strong earthquake occurs (USGS, n.d. b). This can occur beneath buildings, houses, or other structures, it can sink it completely to the ground or overturn and buried tanks and other cavities rise to the top. The increased use of reclaimed land for urbanization has increased the vulnerability of many parts in the Eastern Caribbean (The University of West Indies) as shown in Figure 2-9.

Figure 2-9 Landfill liquefied in the 1989 Loma Prieta earthquake.
From "The Loma Prieta Earthquake, 25 Years Later", by U. S. Geological Survey, 2014, AIR Worldwide, (https://www.air-worldwide.com/publications/air-currents/2014/the-loma-prieta-earthquake-25-years-later/). In the public domain.

2.1.5.6 Tsunamis

According to The University of West Indies a tsunami is a large wave or series of waves that can be generated by an earthquake, large waves can completely devastate low-lying coastal areas. For an earthquake to create a tsunami certain different triggers need to transpire: the earthquake happens beneath the ocean floor, it has vertical movement up to several meters beneath the ocean, it ruptures the earth surface at least 70 km below it, causes big material to fall into the ocean, or have a magnitude higher than 6.5 as shown in Figure 2-10.

Figure 2-10 Tsunami wave hitting a street in Miyako, northeast Japan
From “Seawalls Offered Little Protection Against Tsunami’s Crushing Waves”, by Mainichi Shimbun, 2011, The New York Times, (https://www.nytimes.com/2011/03/14/world/asia/14seawalls.html). Copyright 2011 by the Mainichi Shimbun.

2.1.6 Seismicity of Puerto Rico

Puerto Rico is located on a microplate between the edge of the North American Plate and the extreme northwest of the Caribbean Plate (Figure 2-11). The interaction between these two plates has generated several significant faults for the region. Seismic faults are one of the main sources of seismicity in Puerto Rico as shown in Figure 2-11. The Great Southern Puerto Rico Fault Zone (GSPRFZ), the Great North Puerto Rico Fault Zone (GNPRFZ) and the Cerro Golden Fault (CGF) are inactive old faults that represent weak zones in the earth's crust, and that therefore could be generators of an earthquake when activated again.

Figure 2-11 shows the main tectonic structures of seismic activity in the region GSPRFZ, GNPRFZ, SLF, South Lajas fault.

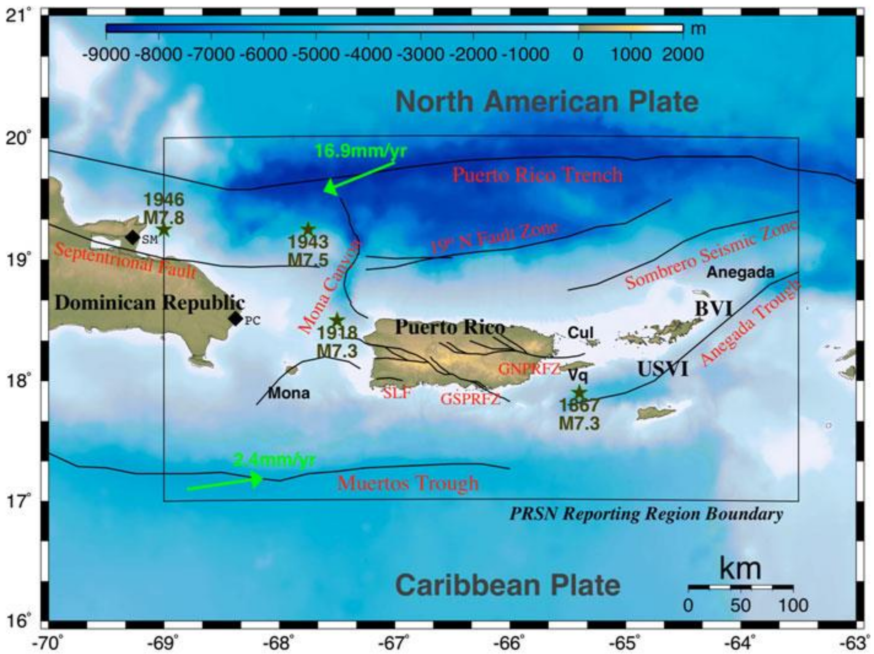


Figure 2-11 Tectonic setting of Puerto Rico

From "Map showing geological faults and approximate location of significant earthquakes", by Puerto Rico Seismic Network, n.d., Earthquakes in Puerto Rico, (https://ecoexploratorio.org/amenazas-naturales/terremotos/terremotos-en-puerto-rico/#prettyPhoto). Copyright 2020 by EcoExploratorio.

Another source of seismicity in this region is the Puerto Rico Trench (Figure 2-12). According to (Brink, n.d.), trenches are in areas where a subduction process occurs. As mentioned in Types of plate boundaries, subduction occurs when an oceanic tectonic plate slide under another oceanic one. In the case of Puerto Rico, the North American Plate and the Caribbean Plate are oceanic plates. The Puerto Rico Trench is located on the border between these two tectonic plates, and with depths below sea level that exceed 8,400 meters, it is the deepest part of the Atlantic Ocean.

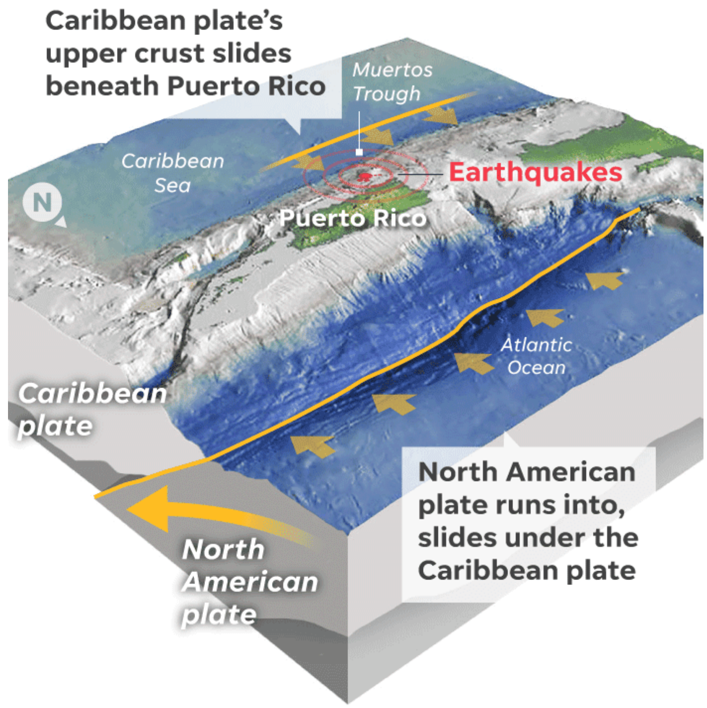


Figure 2-12 Subduction process model at the northern edge of the Puerto Rico Trench
From "Magnitude 5.0 earthquake strikes Puerto Rico amid ongoing aftershocks", by K. Gelles, 2020,USA Today,(https://www.usatoday.com/story/news/nation/2020/01/25/puerto-rico-earthquake-magnitude-5-0-quake-shakes-island/4576991002/). Copyright 2020 by USA Today.

According to the Puerto Rico Seismic Network (n.d.), seismic activity is concentrated in eight zones (Figure 2-11): Puerto Rico Trench in the North, Slope faults in the North and South, Sombrero Fault Zone in the Northeast, Mona Canyon in the West, Anegada Passage in the East, Muertos Trough in the South, and Southeast of Puerto Rico. Other seismic zones that surround the Puerto Rico region are: Saint Croix, Septentrional Fault Zone, Mona Passage, 19 N Fault Zone, and Sombrero Fault Zone.

Seismic activity in Puerto Rico is evidenced by seismic hazard maps (Figure 2-13). Both maps display gridded seismic hazard curve data, gridded ground motion data, and ground motion values. In addition, these maps show the eventuality of agitation with a maximum acceleration of the soil determined with units of gravity in percentage (% g), where g corresponds to gravity. The map on the left shows a 2% probability in 50 years, corresponding to a 250-year earthquake. While the map on the right shows the 10% chance in 50 years as a representation of a 500-year earthquake (United States Geological Survey [USGS], n.d. b).

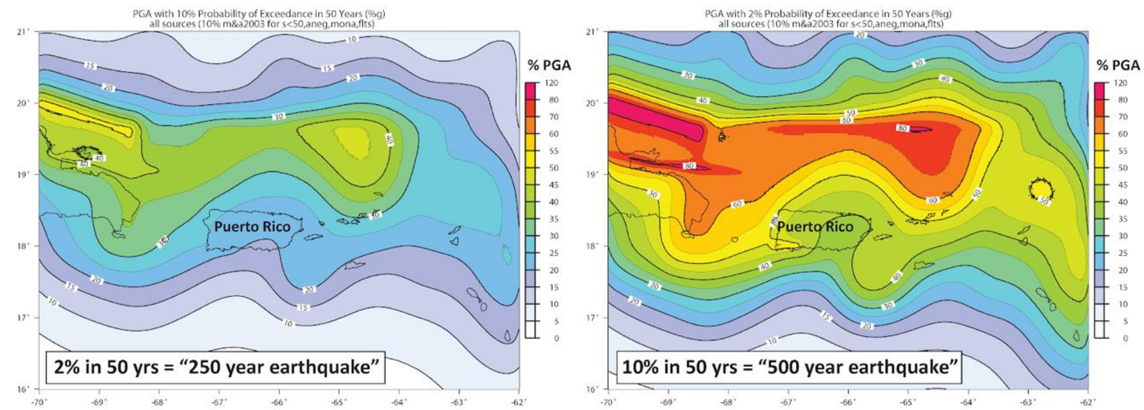


Figure 2-13 Seismic Hazard for Puerto Rico

From "Seismic Hazard for Puerto Rico", by Mueller et al., 2010, New Seismic Hazard Maps for Puerto Rico and the U.S. Virgin Islands, 26(1), p.169-185 (https://doi.org/10.1193/1.3277667). Copyright 2010 by Mueller et al.

2.1.6.1 Seismic history in Puerto Rico

The Puerto Rico Seismic Network (PRSN) of the Geology Department of the University of Puerto Rico Mayagüez Campus (UPR-Mayagüez) is the entity in charge of detecting, monitoring, processing, and investigating seismic activity in the Puerto Rico Region. whose latitude is 17.00˚- 20.00˚N and longitude is 63.50˚-69.00˚W. From 1987 to 2019, this entity located a total of 56,760 earthquakes (Figure 2-14). Of those events, only 928 earthquakes have been recorded as felt. The distribution of localized and registered earthquakes shows an increase in earthquakes for each year. However, the data collected is influenced by the evolution and increase of the instrumentation used by the PRSN. In 1987, the PRSN was transferred to the Department of Geology of the University of Puerto Rico in Mayagüez, after being installed by the United States Geological Survey (USGS) in 1974 to collaborate with the Puerto Rico Electric Power Authority. Since then, the PRSN consists of 25 seismic stations that include three main types of sensors: Short Period, Broadband, and Accelerometer. Starting in the year 2000, data was saved based on the implementation of new data location and analysis program PRDANIS (Puerto Rico Data Analysis and Information System), (Puerto Rico Seismic Network, n.d.).

From 1987 to 2019, the Puerto Rico Seismic Network (PRSN) located a total of 56,760 earthquakes (Figure 2-14). Of those events, only 928 earthquakes have been felt considering the Richter scale.

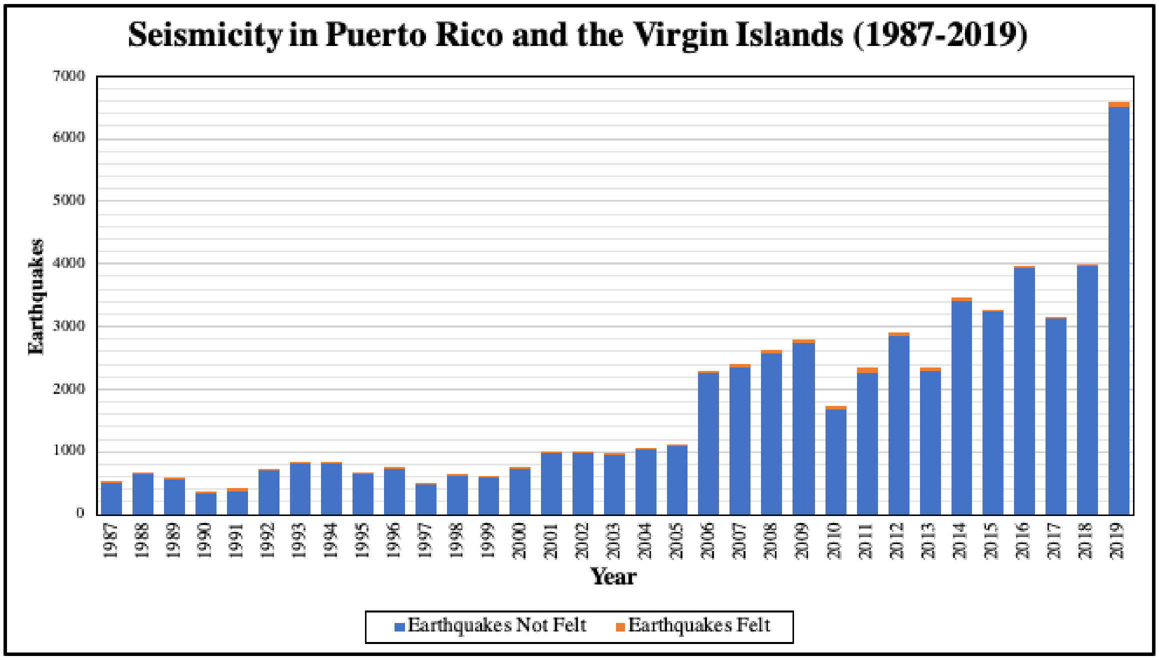


Figure 2-14 Distribution of earthquakes (1987-2019)

From "Sismicidad anual en Puerto Rico e Islas Vírgenes", by Puerto Rico Seismic Network, University of Puerto Rico Mayagüez, n.d., (http://redsismica.uprm.edu/Spanish/sismos/repanual.php). Copyright 2020 by Puerto Rico Seismic Network and University of Puerto Rico Mayagüez.

2.1.6.2 Earthquake log

The PRSN located the largest earthquakes corresponding to each year between 2008 and 2020. The summary (Table 2-2) of the seismic activity is recorded with the magnitude of Coda. This size of the earthquake and the seismic energy released is obtained from the duration of the seismic record.

Table 2-2 Earthquakes felt in Puerto Rico and the Virgin Islands between 2008 and 2020 (PRSN-UPRM)

Date	Magnitude (coda)	Depth (km)	Location
October 11, 2008	6.1	26.0	Sombrero Seismic Zone
August 13, 2009	5.2	10	19°N Fault Zone
May 16, 2010	5.86	113.1	Moca, PR
December 24, 2010	5.40	102.0	1.3 km W-NW of Aguas Buenas, PR
November 28, 2011	5.2	15	19°N Fault Zone
January 19, 2012	5.03	82.7	Eastern Dominican Republic Zone
February 26, 2013	5.12	8	Septentrional Fault Zone
January 13, 2014	6.4	36	19°N Fault Zone
March 20, 2015	4.6	8	Virgin Island Platform
November 13, 2016	4.7	10	Septentrional Fault Zone
June 22, 2017	4.32	95	Eastern Dominican Republic Zone
November 14, 2018	4.9	85	Puerto Rico Trench
February 4, 2019	5.3	74	Eastern Dominican Republic Zone
January 6, 2020	5.8	6	Southern Zone of Puerto Rico
January 7, 2020	6.4	6	South Region of Puerto Rico

From "Formulario Búsqueda de Sismos", by Puerto Rico Seismic Network, University of Puerto Rico Mayagüez, n.d., Earthquake Search Registry, (http://www.prsn.uprm.edu/Spanish/php/CatalogS/busqueda.php). Copyright 2020 by Puerto Rico Seismic Network and University of Puerto Rico Mayagüez.

The events mentioned in Table 2-2 are shown according to their location by size due to magnitude and color due to depth (Figure 2-15). The map shows the epicentral origin where the seismic events occurred from 2008 to 2020. The earthquakes are shown with their respective size of figures due to the number of magnitude and depth in the intensity of colors.

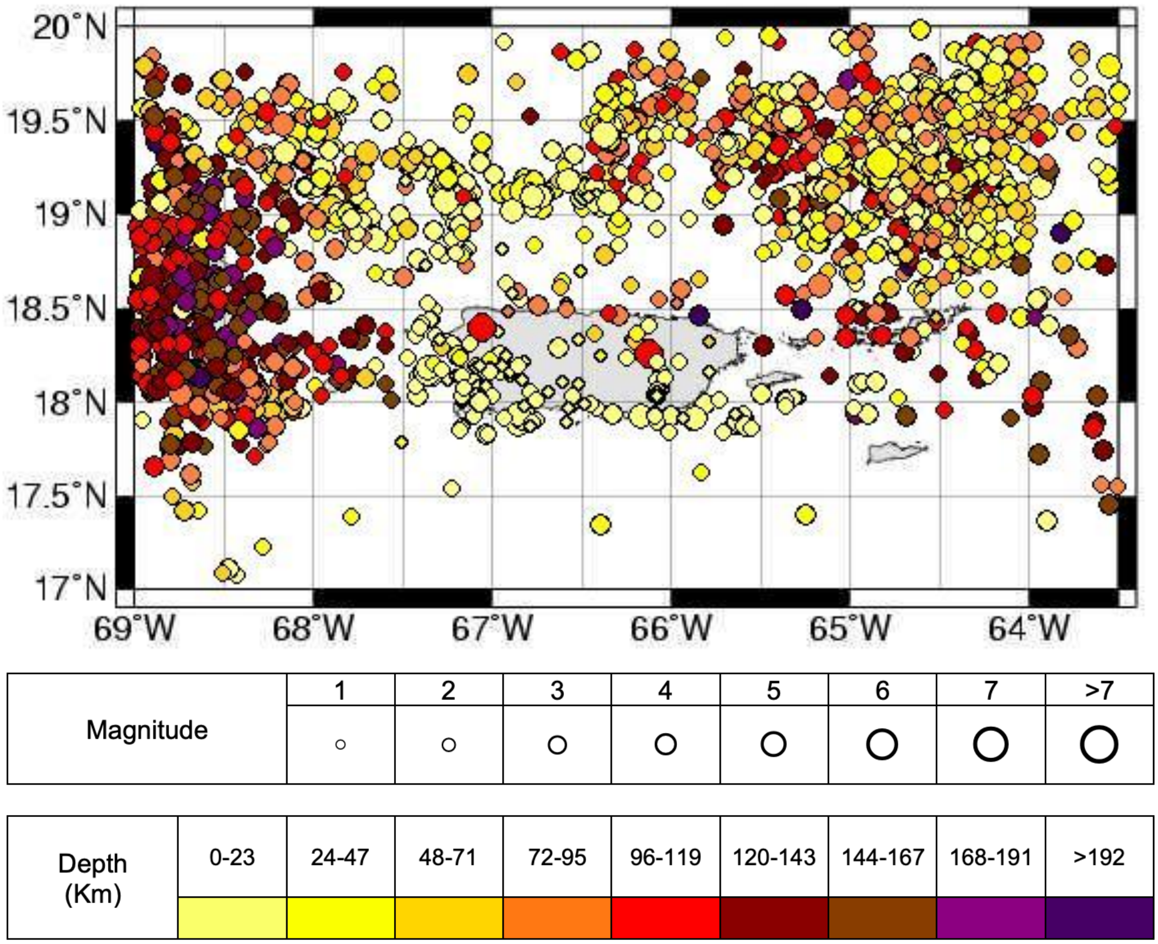


Figure 2-15 Epicentral map of the earthquakes felt in Puerto Rico and the Virgin Islands from 2008 to 2020 (PRSN-UPRM)

From "Formulario Busqueda de Sismos", by Puerto Rico Seismic Network, University of Puerto Rico Mayagüez, n.d., Earthquake Search Map, (http://www.prsn.uprm.edu/Spanish/php/CatalogS/busqueda.php). Copyright 2020 by Puerto Rico Seismic Network and University of Puerto Rico Mayagüez.

2.1.6.3 Most significant earthquakes

According to the EcoExploratorio (n.d.), there are 5 earthquakes that influenced the most in the Puerto Rico region given its proximity to the epicenter, magnitude on the Richter scale and intensity to the Rossi-Forel used at that time (Table 2-3 and Figure 2-11). Table 2-3 shows the most powerful earthquakes that have impacted Puerto Rico in history. Four of these events were tsunamigenic. In the 1918 earthquake, around 116 people died.

Table 2-3 Chronology of significant earthquakes that have affected Puerto Rico

Date	Magnitude	Intensity	Location	Effects
May 2, 1787	8.0	VII-VIII	Puerto Rico	Cracks in structures
November 18, 1867	7.3	VIII	Virgin Islands	Tsunami
October 11, 1918	7.3	VIII-IX	Puerto Rico	Tsunami
July 28, 1943	7.5	V	Puerto Rico	Tsunami
August 4, 1946	7.8	VI	Dominican Republic	Tsunami

From "Terremotos en Puerto Rico", by EcoExploratorio, n.d., Terremotos, (https://ecoexploratorio.org/amenazas-naturales/terremotos/terremotos-en-puerto-rico/#prettyPhoto). Copyright 2020 by EcoExploratorio.

2.2 Seismic Hazards, Risk and Vulnerability

Seismicity at a specific location is a measure of seismic activity that links hazard, risk, and vulnerability. The well-known statement "Earthquakes don't kill people, buildings do" highlights the close relationship that exists between seismic hazard, risk, and vulnerability. The connection between these three factors lies in the seismic safety of the structures and, consequently, in the safety of life. All three components are useful for preparing for earthquakes or other types of disasters, evaluating, and estimating losses, and for building maintenance. On the other hand, danger, risk, and vulnerability are associated with the density of the population and its exposure (Mihai, 2014).

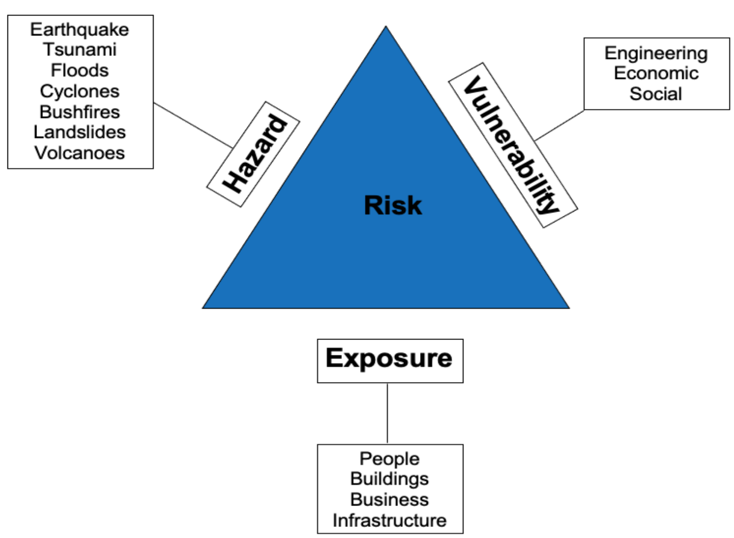


Figure 2-16 Trigram of disaster risk
From "Exposure and Vulnerability", by C. Cervaño, 2017, SlideShare, (https://www.slideshare.net/CharizaCervao/exposure-and-vulnerability). Copyright 2020 by SlideShare.

The diagram represents the relationship between risk and the components associated with harm through descriptions of hazard, exposure, and vulnerability (Figure 2-16).

2.2.1 Seismic Hazards

The Federal Emergency Management Agency (FEMA) describes the hazard as "something that is potentially dangerous or harmful, and that is often the primary cause of an unwanted outcome." Hazard refers to the event that threatens the well-being of the human being, structure, or environment. This is characterized by the possibility and probability of a harmful event happening and threatening this well-being. Additionally, it has the potential to cause death and damage to property and infrastructure. The probability of a hazard-producing event occurring responds to risk. This does not imply that high danger corresponds to high risk, limited by low vulnerability.

Hazard "reflects the probability of a destructive event occurring within a well-defined area and for a specified time." (Mihai, 2014) The event corresponds to any unforeseen event defined as a disaster. In seismic terms, the event classified as a disaster is an earthquake capable of destroying a defined area.

Seismic hazard is defined as any geological or structural hazard associated with an earthquake that can affect the normal activities of humans and their environments. This associated hazard may be due to surface faults, ground shaking, landslides, liquefaction, tectonic deformation, and tsunamis. Seismic hazard is a measure of the potential for an earthquake to occur at a given location. (United States Geological Survey, n.d.) This hazard is linked to the exposure and risk of a particular region. For this, coastal topography, land use, population, concentration of industries, characteristics of residents, planning progress, among many other factors are considered.

The map shows the seismic hazard for the United States, Alaska and Puerto Rico through colors representing the level of hazard (Figure 2-17).

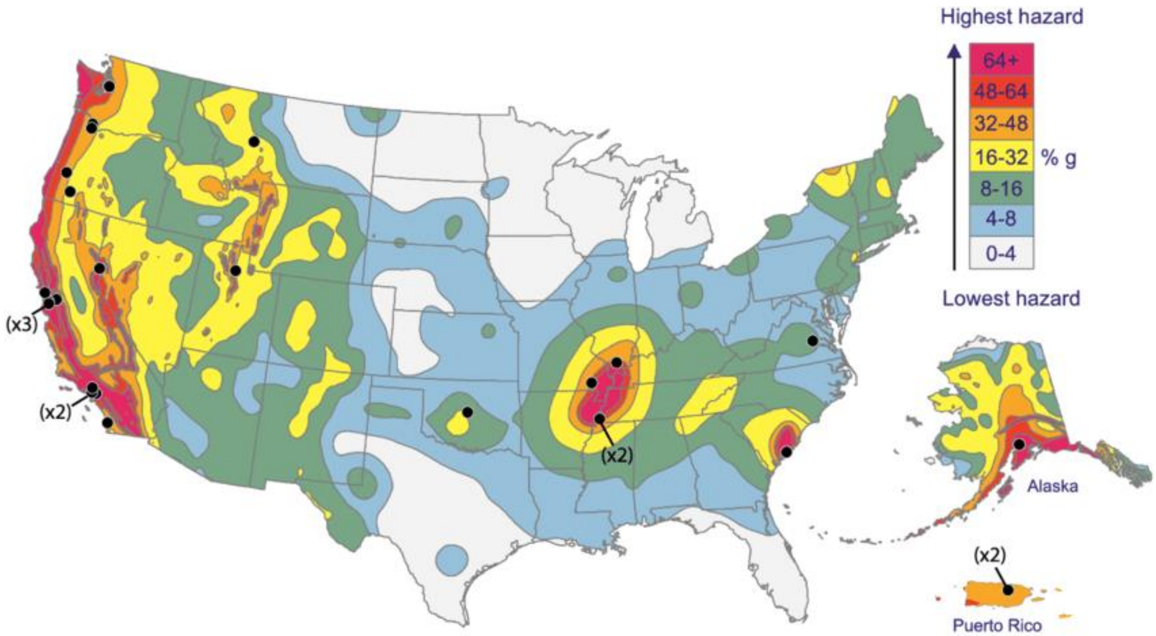


Figure 2-17 Seismic hazard map of United States, Alaska, and Puerto Rico

From "Advanced Earthquake Monitoring System for U.S. Department of Veterans Affairs Medical Buildings", by E. Kalkan, 2012, ResearchGate, (https://www.researchgate.net/figure/Seismic-hazard-map-of-the-conterminous-United-States-Alaska-and-Puerto-Rico-showing_fig2_274638758). Copyright 2020 by ResearchGate.

2.2.2 Seismic Risk

Risk is a measure of the consequences of a harmful event occurring. This measure is characterized by losses in the functioning of a community or region and of lives, as well as injuries to them. Risk depends on the vulnerability and density of the population of a region.

Seismic risk is "the likely damage to the building and the number of people expected to be injured or killed if a possible earthquake occurs on a particular fault" (United States Geological Survey, n.d.).

Mihai (2014) defines seismic risk as the "degree associated with an event that has a probability of occurrence." It also suggests that the concept of seismic risk "is related to the probability that a certain event, based on decisions, produces unexpected effects." These decisions or assumptions inform the seismic risk analysis through predictions that are directly associated with vulnerability. The effects of these predetermined decisions can be catastrophic in terms of loss of buildings and lives. This is due to the close relationship that seismic risk has with the structural performance of the building and the human being.

Seismic risk comprises three elements: hazard, exposure, and vulnerability. The risk is proportional to the product of these three elements. It is the probability of the hazard multiplied by the consequences of the hazard: exposure and vulnerability (Figure 2-18) (Ramboll, 2019).

$$\boldsymbol{Risk} = \boldsymbol{Hazard} \times \boldsymbol{Exposure} \times \boldsymbol{Vulnerability}$$

Where the danger is the event that causes the loss; exposure is everything that is threatened, such as: property, people, and the environment; and vulnerability is the susceptibility to harm of those exposed to the threat.

Seismic risk is "the probable damage to the building and the number of people expected to be injured or killed if a possible earthquake occurs on a particular fault" (United States Geological Survey, n.d.).

Figure 2-18 Representative risk diagram

From "What we talk about when we talk about climate risk," by Ramboll, 2019, HazAtlas, (https://www.hazatlas.com/post/what-we-talk-about-when-we-talk-about-climate-risk). Copyright 2019 by HazAtlas.

2.2.3 Seismic Vulnerability

Vulnerability is obtained when “personal or situational conditions increase the susceptibility of people or resources to be harmed by the hazard” (National Research Council, 2011). Also, Pine (2008) defines vulnerability as: "a measure of the propensity of a community to suffer losses."

The concept of seismic vulnerability is defined by Mihai (2014) as “the degree of damage of a structural element exposed to seismic risk, or of a combination of said elements under the action of an earthquake with certain characteristics.

Seismic vulnerability is the propensity to suffer physical and structural damage in response to the occurrence of a seismic movement. This vulnerability can qualify structures impacted by a seismic event as "more vulnerable" or "less vulnerable". For this, the type of material, construction method, and technological means that avoid the effects of a seismic movement are considered. Therefore, it is a damage mitigation mode that is influenced by the structural mode because of seismic action. According to the Office of Disaster Preparedness and Management (n.d.), the aspects that can qualify as vulnerable to a structure or community are: “bad design and construction of buildings, inadequate protection of assets, lack of information and public awareness, limited official recognition risks and preparedness measures, and disregard for smart environmental management.”

2.3 Tsunamis

Tsunami is a Japanese word derived from the terms: "tsu" which means port and "nami" which means wave. The term "tsunami" is defined as a series of giant, traveling waves that is generated by large-scale impulsive disturbances on the ocean floor. Once the tsunami is generated, it moves out of its region of origin as a series of waves. The speed and height of the waves of this phenomenon depend on the depth of the water through which it travels. So as the waves get closer to the shallower waters of the coast, the speed decreases while the height increases. Tsunamis can have heights of up to 30 m and reach a speed that fluctuates between 500 km/hr to 950 km/hr (United Nations Educational, Scientific and Cultural Organization, 2019).

2.3.1 Generation

Tsunami-generating disturbances are movements caused by a variety of natural events such as earthquakes, volcanic eruptions, landslides, and meteorites. Generally, the movement occurs along a seismic fault due to an earthquake in marine and coastal regions (Figure 2-19).

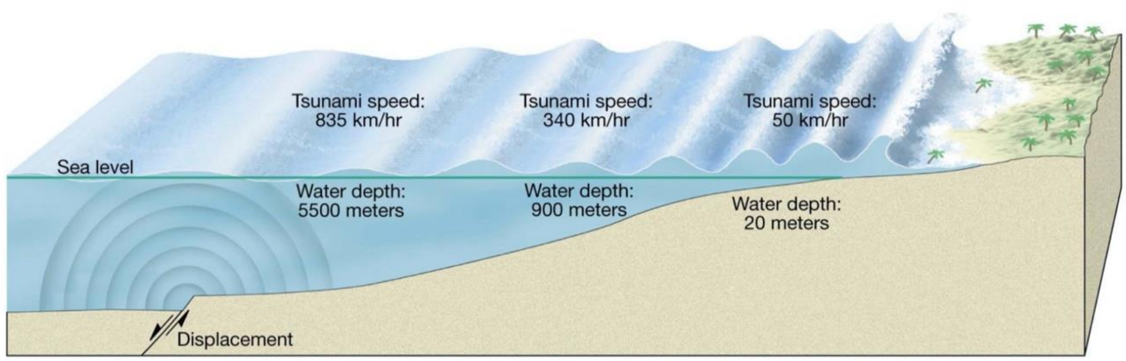


Figure 2-19 Schematic Diagram of Tsunami Generation

From "Earthquake and earthquake resistant design", by P. Jangra, 2015, SlideShare, (https://www.slideshare.net/ParveenJangra4/earthquake-and-earthquake-resistant-design-50931676). Copyright 2020 by SlideShare.

2.3.1.1 Earthquakes

According to the College of Engineers and Surveyors of Puerto Rico et al. (n.d.), a tsunami "consists of a series of waves caused by a vertical displacement of the seabed caused by an earthquake under the seabed." The magnitude of the earthquake is the generating agent of the tsunami. According to historical observations and the Pacific Tsunami Warning Center (U.S. Geological Survey, n.d.), earthquakes with a magnitude greater than 6.5 on the Richter scale are more likely to cause a tsunami. Vertical motion along the fault displaces the water column by releasing energy in response to the large earthquake. This release of energy causes an abrupt alteration of the sea surface in the form of waves (Figure 2-19), and consequently a tsunami.

2.3.1.2 Volcanic Eruptions

Tsunamis of volcanic origin generate waves turned into waves that move vertically due to sudden movement. This can be caused by underwater explosions, caldera collapses (the volcano collapses into itself), volcanic activity or pyroclastic flows, which refers to flows composed of gases and solid material (National Tsunami Hazard Mitigation Program, 2019).

2.3.1.3 Landslides

Tsunamis can be generated when there is a movement of a landslide mass rapidly displacing water up or down the seafloor. Tsunami-generating landslides, in turn, can be triggered by earthquakes, (National Tsunami Hazard Mitigation Program, 2019).

2.3.1.4 Meteorites

Although tsunamis generated by the impact of a meteorite or asteroid are highly unlikely, the fall of one of these fragments of the celestial body into the Earth's oceans has the potential to generate tsunamis of catastrophic proportions (International Tsunami Information Center, n.d.).

2.3.2 Types of tsunamis

The types of tsunamis that exist are the local tsunami, the regional tsunami, and the tele-tsunami. According to (United Nations Educational, Scientific and Cultural Organization, 2019), a local tsunami also known as a “near-field” tsunami, is defined as “that coming from a nearby source whose destructive effects affect coasts located less than an hour away of travel of the tsunami wave or generally within a radius of 200 km from the origin. " On the other hand, UNESCO defines the regional tsunami, also known as “mid-source” tsunami, as “one that can affect coastal areas within 1000 km from its origin, or in areas located between 1 to 3 hours of tsunami waves travel. " In addition, UNESCO defines the tele-tsunami also known as “far-field” tsunami, as “that originated by a distant source, generally more than 1,000 km or more than 3 hours of travel time of the tsunami waves from its origin." These types of tsunamis are synthesized as one generated near the coast, "near-field" tsunami; and one generated by a source far from the impact zone, the “far-field” tsunami. Both the “near-field” tsunami and the “far-field” tsunami can be destructive and deadly due to the lack of warning time due to the duration of arrival at the point of impact.

2.3.3 Effects of tsunamis

Tsunamis can be destructive and damaging when they make landfall. These can be long-lasting and impact distant areas of the coast. The result of this destruction occurs due to direct effects: flooding, impact of waves on structures, and erosion. Indirect effects in response to the above effects are ground instability, fire spread by floating materials, and wind induced by tsunamis. These factors affect the human, social and economic environment of any region. The United Nations Educational, Scientific and Cultural Organization (2019) indicates that during the last 3,600 years, around 252 tsunamis have resulted in more than 540,000 deaths. According to (United Nations Educational, Scientific and Cultural Organization, 2019), the effects caused by a tsunami are the following:

2.3.3.1 Flooding

The flooding caused by a tsunami is one of the main effects that damages the impacted coastal infrastructure. This effect causes the elevation and transport of building structures, houses, cars, boats, among many others. The transportation of these floating objects can become dangerous projectiles when colliding with another element.

The Figure 2-20 shows the flooding from the March 11, 2011, tsunami and earthquake in Yamada city in northern Japan transported houses in collision.

Figure 2-20 Effect of Tsunami Flooding in Yamada, Japan
From "Tsunami Inundation", by Earthquake Memorial Museum, 2011, National Weather Service, (https://www.weather.gov/jetstream/tsu_ inundation). Copyright 2011 by Yamada.

2.3.3.2 Wave Impact

The waves of a tsunami flow with great forces destroying and dragging different structures around it. This impact turns that destruction of structures into rubble that is transported far from its original location. These are the product of significant fires generated by floating debris mixed with toxic substances spilled by the force of the tsunami.

The city of Sendai in Japan was hit by waves of the tsunami on March 11, 2011, that caused a fire between flooded houses (Figure 2-21).

Figure 2-21 Impact of Tsunami Wave Impact in Sendai, Japan
From "Tsunami Pictures: Epic Waves, Earthquake Shock Japan", by Kyodo, 2011, National Geographic, (https://www.nationalgeographic.com/news/2011/3/110311-tsunami-earthquake-japan-hawaii-science- world-waves /). Copyright 2011 by Reuters.

2.3.3.3 Erosion

Tsunami waves and winds that impact coastal areas carry vegetation and marine debris, as well as invasive species that deteriorate coastal structures and natural resources.

The March 11, 2011, tsunami in Japan left debris and marine life on an abandoned Japanese dock (Figure 2-22).

Figure 2-22 Effect of Erosion Caused by Tsunami Waves on The Japanese Dock
From "Can Invasive Species Travel on Marine Debris?", By Oregon State University, 2019, OR & R's Marine Debris Division, (https://blog.marinedebris.noaa.gov/can-invasive-species-travel-marine-debris?fbclid =IwAR0motkAnXVgVV5f5XJuSTW8VEh6l_7n96JH8S7gW0TmEZnwcAR45wGJGRU). Copyright 2020 by OSU's Hatfield Marine Science Center.

2.3.4 International and FEMA Guidelines for Design and Protection

The following are key comparison in tsunami design guidance between the Japanese guidance and the US Guidance (Macabuag et al., 2018):

2.3.4.1 Tsunami hazard assessment

Based on J. Macabuag in the Japanese guidelines (MLIT 2570) the tsunami inundation maps are defined from deterministic tsunami hazard assessments based on source earthquakes with two approximate return periods 1 in 100 years and the other 1 in 1000 years (MLIT, 2011b). Based on A. Raby in the US guidance (ASCE 7-16) the offshore tsunami wave amplitude maps, it is determined from probabilistic tsunami hazard assessment. The maximum considered tsunami corresponds to a 1 in a 2475-year event (ASCE, 2016: Ch. 6).

2.3.4.2 Sea defense design

Based on A. Pomonis in the Japanese guidelines (MLIT 2570) the sea defense design guidance was developed by the Japan Society of Civil Engineers and other institutions. The design procedure is to prevent inundation from a level 1 event and prevent structural failure for a level 2 event (Raby et al., 2015). Based on I. Nistor in the US guidance (ASCE 7-16) there is currently no code accepted of practice which addresses tsunami design of sea defenses in the USA except for design guidelines such as CCH-2000 (CCH, 2000) or FEMA P646-2012 (FEMA, 2012).

2.3.4.3 Building design procedure

Based on S. Wilkinson in the Japanese guidelines (MLIT 2570), buildings designed to withstand tsunami loading are designed for inundation corresponding to a level 2 event. Member and structure design need to account for lateral fluid loads, buoyancy, retained water and secondary effects of debris impact and scour, though little guidance is provided for the quantification of these secondary effects (MLIT, 2011b). Based on T. Rossetto in the US guidance (ASCE 7-16) performance-based design using tsunami risk categories and performance level objectives based on building function and occupancy. Member and structure design need to account for lateral fluid loads, buoyancy, retained water, and secondary effects of debris impact and scour. The guidance is given on quantification of secondary effects of debris impact and estimated scour depth (ASCE, 2016: Ch. 6).

2.3.4.4 Load assessment for buildings

Based on S. Wilkinson in the Japanese guidelines (MLIT 2570) lateral fluid load is calculated as an equivalent hydrostatic load applied to one side of the structure. The height of hydrostatic load profile is taken as the design inundation depth multiplied by a factor which accounts for distance from shore and presence/absence of seaward obstacles.

Calculations require a design inundation depth, provided by coastal municipalities (MLIT, 2011b). Based on A. Raby in the US guidance (ASCE 7-16) the lateral fluid load is calculated for hydrostatic and hydrodynamic force components using calculated inundation depths and velocities. Calculations require design inundation depth and velocity (ASCE, 2016: Ch. 6).

2.3.5 US Guidelines for Schools

The United Nations Development Program (UNDP) project that aimed to strengthen school tsunamis preparedness and awareness in 90 schools that were in tsunami prone areas. Based on the result of the project that UNDP did they came to many conclusions, like the following. The evacuation drills tested the preparedness measures and plan and helped address gaps and improve them overall. The evacuation drills must be part of the plan for it to be successful. In the project they left the school to start their drills so they could be evaluated. The measures that are going to be mentioned up next that are included in their plans must be gender sensitive and inclusive in the approach, address special needs for people with disabilities or injuries, and must consider the context of the school (UNDP, 2018).

2.3.5.1 Assessing the existing school tsunami preparedness through the collection of baseline data

This data can be collected in two different ways, the schools collect general information, or the schools assess their existing safety information across five parameters.

2.3.5.1.1 General Information

The school should information about total staff and student numbers, the emergency contact numbers and all available facilities.

2.3.5.1.2 Safety Information

Based in the School Preparedness Assessment Manual (Intergovernmental Oceanographic Commission of UNESCO (IOC-UNESCO) and LIPI Indonesia) the five preparedness parameters are:

a) policy
b) knowledge
c) preparedness and response plan
d) early warning system
e) resource mobilization capacity

2.3.5.2 Identifying gaps in preparedness and making recommendations

Based on the drills conducted in the project, they identified gaps across the five parameters and gave some recommendations.

2.3.5.2.1 Policy

After evaluating the different schools in tsunami prone areas, the level of preparedness between schools varied, preparedness education was not in the school curriculum, some teachers did not find it easy to understand, schools did not have committees to carry out drills, training, and coordination with external partners. Based on the evaluation of the project, they recommended for the schools that the education should include disaster preparedness education to the curriculum, including what can and cannot be done in those types of situations. Put a policy to formalize the preparedness and include collaboration with other partners depending on the context of the country, every school should also establish teams and assign roles and responsibility for the drills.

2.3.5.2.2 Knowledge

Many of the students and staff members were not aware of the risk of tsunamis that exist in their area, before developing plans they needed to be educated. They recommended the school raise awareness to the students and staff members of the hazard risk by putting posters, signages, instructions and events. The school should also collaborate with other schools and local nonprofit organizations to hold the events to raise awareness for people inside the community. Teachers can encourage their students to share the knowledge about tsunamis and drills they learned at school with their families and neighbors.

2.3.5.2.3 School Preparedness and Response Plan

Many schools did not count with a preparedness plan for tsunamis/disasters, the few that did were not tested or fixed. They did not have hazard maps or inundation data to have safety evacuation routes, they did not carry the proper equipment for the drills nor enough first aid kits, some of the teachers and students needed extra help in the drills because of their physical condition. They recommended the school that the ones that are in tsunami prone areas they should have unique plans taking to account their location, topography, and cultural context, it should be developed in a collaborative and consultative way, they should determine alternative evacuation routes just in case and make sure they can communicate with others throughout the process.

2.3.5.2.4 School Early Warning System

"Most of the schools did not have the proper tools or an alarm system to receive and disseminate early warning messages from reliable sources" (UNDP, 2018). They recommended the school that they should have official warning information so they can understand natural warning signs and official warnings. Schools should have different types of devices to perform an evacuation like bells, speakers, and other devices, all the equipment should be checked occasionally, to make sure they are maintained in the best conditions when it needs to be used.

2.3.5.2.5 Resource Mobilization Capacity

Evacuation drills that require teachers and students to leave to another location needs to be supported by a host of external partners, (UNDP, 2018). They recommended the school that the committees should engage with local authorities and the parents of the students to make plans for temporary shelter and others preparation previously stated, the school should also partner up with local hotel and hospital as a last resort if there is not a safe location to be found. Announce the drills to parents and students with anticipation so that they can be prepared mentally and physically.

2.3.5.3 Procuring equipment required by the school

"The school preparedness plan lists basic equipment that is required for preparedness and response to a tsunami event." (UNDP, 2018). For safe evacuation and addressing special needs of students with disabilities or injuries all the equipment is needed. The list proposed by the UNDP shown below, depends on the resources available for each school. This equipment listed up next must be included in the emergency backpack of the teachers:

- Student attendance sheet
- Classroom number sign
- Copy of the tsunami risk and resource map
- Pens and notepads
- Trash bag (biohazard) and plastic bags
- Hand sanitizers and tissues
- Flashlight

- Walkie talkies/ mobile phones

The following contents are recommended for a First Aid Kit:

- 25 adhesive bandages
- absorbent compress dressings
- Adhesive tape
- Gauze pads
- Alcohol swabs or antiseptic wipe packets
- Hand sanitizer
- Q-tips
- 2 Airway masks/breathing barrier
- Ice pack /instant cold compress
- Antibiotic ointment packets
- Antiseptic wipe packets
- Packets of aspirin
- Scissors and tweezers
- 25 pairs of non-latex gloves
- Thermometer
- First aid instruction booklet

2.3.5.4 Raising awareness of tsunami risks through a range of activities

"Regular awareness and education activities are a vital part of the schools' tsunami preparedness process" (UNDP, 2018). The whole communities around the school, the teacher and the students should be involved in learning about the evacuation plans and the risk they are in depending on their area. Depending on the age of the students, additional resources can be used like the following to help them understand the topic better. Learning materials that can be used are guidebooks, flyers, brochures, booklets, workbooks, meetings, quiz nights, videos, comics, and games. For the parents, the school should prepare materials to inform them of their role during the drills, the parents should be included in some of the drills. They should know the emergency contacts of the schools to learn more about the evacuation, also they must know the temporary evacuation center of the schools and the equipment that could be donated to use for the drills. For the community, the school can raise awareness by doing campaigns and themed days. (UNDP, 2018)

2.3.5.5 Supporting students after a real tsunami event

After a real tsunami event the students are the most who experience serious trauma after going through that sort of experience, most of them cannot not express their feelings clearly and tend to have different behavioral changes as coping mechanism for the grief they feel, like acting out, anxiety, perfectionism, somatic responses (frequently complaining over vague pains) and cognitive functioning. The adults that are more able to help the students recover and cope, are the teachers because of the time they spend interacting with them. They should be more sensitive to the change in behavior of their students, (UNDP, 2018).

The project suggested that teachers can support students by conducting several different exercises like the following. Check in on them in the morning and after school, to help them have a space where they can share their emotions. Relaxation exercise consists typically of breathing deeply, visualization, physical movement and/or other exercises that are appropriate depending on the culture, this should be conducted at the beginning and end of each class. When they have trouble putting their emotions into words it is best to put them in drawing classes to help them express themselves and encourage parents to give better support to their children in and outside the house. The teachers are very likely to be suffering from the same traumas as their students, so they need to hold group meetings with the staff to give themselves emotional support and help better the techniques to support the students, (UNDP, 2018).

2.4 Evacuation Processes

The evacuation process is the operational development of eviction from a place or region vulnerable to a tsunami disaster. It is an important element to ensure the safety of people in areas threatened by a tsunami event. This process involves a set of phases that guide emergency services and secure evacuation areas. The evacuation process considers an evacuation plan, tsunami arrival time, evacuation time, evacuation sites and routes as safe areas. This requires being aware of the population density of all susceptible ages in coastal regions.

2.4.1 Evacuation sites

The evacuation sites correspond to the safety zones outside the area of the flood effect that makes up the tsunami. These safe areas allow a horizontal evacuation model in which you can walk to areas whose height exceeds ten meters or the terrain is open and inaccessible to flooding. Gallaudet University (n.d.) suggests that horizontal evacuation represents "moving away from the danger area to a safer place on the same floor as the person at the time of the tsunami emergency." Areas that are tested as unsafe require a vertical evacuation model. This evacuation, unlike horizontal, means moving away from the area of imminent danger of the tsunami at a safe distance that passes from one floor to another or to the outside. This type of evacuation is the preferred method of exiting a building. This is because ladders are used in vertical evacuation, which can be used by those who can evacuate with or without help (Gallaudet University, n.d.).

The most common places of assembly become essential public establishments such as: municipalities, schools, parks, among many others. For this reason, these establishments need to be in safe areas. (Intergovernmental Oceanographic Commission, 2008). According to the IOC-UNESCO, the sites designated in the eviction process are temporary evacuation sites, larger evacuation sites, and evacuation sites. Temporary evacuation sites are meeting points mostly located in green areas. On the other hand, larger evacuation sites refer to places with larger terrain such as parks. While evacuation sites are shelters to temporarily house evacuees. These are commonly located in schools.

2.4.2 Evacuation time

The evacuation time requires knowledge of the distance of the person to the safe area and the speed at which the person is moving. The evacuee's route represents the shortest route in terms of time to save as many lives to evacuate as possible. The evacuation time is the equivalent of the estimated time for the tsunami waves to reach the shore. The arrival time of the tsunami (Table 2-4) depends on the distance between a tsunamigenic source and the place to be impacted. A local tsunami as discussed in Types of , originates from a source close to shore, so it would take less than 1 hour to impact it. In this case, the evacuation time should be less than 1 hour. A regional tsunami could reach the place of interest in 1 to 3 hours. This means that the evacuation time would have to be less than this arrival time range. On the other hand, a distant tsunami could take more than 3 hours to make landfall, where the evacuation time would also be much shorter. (Federal Emergency Management Agency, 2019)

The Table 2-4 shows the approximate times of the duration of arrival of a tsunami to the coast based on the distance between the source of the tsunami and that coast.

Table 2-4 Tsunami Sources and Approximate Arrival Times

Location of Source	Approximate Time (t)
Far-source-generated tsunami	t > 3 hours
Mid-source-generated tsunami	1 hour < t > 3 hours
Near-source-generated tsunami	T < 60 min

From "Guidelines for Design of Structures for Vertical Evacuation from Tsunamis", by Federal Emergency Management Agency, 2019, FEMA P-646, 3rd ed., (https://www.fema.gov/media-library-data/1570817928423-55b4d3ff4789e707be5dadef163f6078/FEMAP646_ThirdEdition_508.pdf). Copyright 2019 by Federal Emergency Management Agency.

According to the "Pedestrian Evacuation Analyst" model developed by the United States Geological Survey (USGS) and accessed through the Puerto Rico Tsunami Program of the

Puerto Rico Seismic Network (PRSN) for use in a Geographic Information System (GIS), the evacuation time is obtained by dividing the evacuation route distance measured in miles by the average speed of 2.5 mph. The result is multiplied by 60 min to perform the conversion so that the time is obtained in units of minutes. The evacuation time is obtained by means of the equation:

$$\boldsymbol{Time} = \left(\frac{Distance\ in\ miles}{2.5\ \text{mph}}\right) \times\ (60\ minutes)$$

The average speed of 2.5 mph proposed by this analysis is provided considering three speeds taken from previous studies. These speeds are: 2.46 mph for slow walking, 2.7 mph for average walking, and 3.4 mph for brisk walking (PRSN, n.d.).

2.4.3 Evacuation routes

Evacuation routes or escape routes are the ways to evacuate to safe areas. According to the Intergovernmental Oceanographic Commission (2008), evacuation routes must consider the daily life of the population to ensure that the evacuation is carried out successfully. Also, IOC-UNESCO suggests that "the shortest and most direct route to the temporary evacuation site is the highest priority." When routes are not topographically safe, evacuation routes require the use of shelters as an emergency. The type of shelter suitable for this type of case is vertical. Federal Emergency Management Agency (2019) defines a shelter as "an evacuation facility that is intended to serve as a safe haven until an imminent danger has passed (e.g., a few hours)." In addition, (FEMA, 2019) explains that a vertical evacuation shelter is “a structure or earthen mound designated as a place of refuge in the event of a tsunami, with sufficient height to elevate evacuees above the tsunami inundation depth, designed and constructed to resist tsunami load effects. "

2.4.4 Evacuation zones

Evacuation zones represent areas with potential tsunami flooding. They are evacuation zones that are in imminent danger from a tsunami. These evacuation zones are defined by low-risk boundaries. These zones depend on the accessibility of escape routes, as well as the orientation system with information about the danger for evacuees. Evacuation zones are defined by evacuation or evacuation maps. These maps are tools for the evacuation process and planning. Eviction maps are "strategies to help communities in coastal areas to identify and reduce their vulnerability to the effect of flooding caused by tsunamis." (Puerto Rico Seismic Network, n.d.) Evacuation zones are identified in yellow on the map (Figure 2-23). It stands out with this color as a distinction of coverage of all credible peak tsunamis based on coastal risk.

Figure 2-23 Evacuation Map of San Juan, Puerto Rico in PDF
From "Puerto Rico Evacuation Maps", by Puerto Rico Seismic Network, University of Puerto Rico Mayagüez, 2014, Tsunami Program, (http://redsismica.uprm.edu/English/tsunami/tsunamiprogram/prc/maps/all.php). In the public domain.

2.4.5 Perception and Reaction of Kids and Young People

According to the Puerto Rico Emergency Management Agency (2011), children are at greater risk of a disaster event because they respond to an increase in the mortality rate.

This is due to the susceptibility that minors have to dependence on adults for their protection. The study entitled “Children and Disasters: Understanding Vulnerability, Developing Capacities, and Promoting Resilience” suggests that the factors that affect children and young people in reaction to the impact of a disaster depend on the types of vulnerability they face. That disaster may be the tsunami that leads to an evacuation process that, in turn, makes a strong impression on the evacuated children and youth. According to the study, the types of vulnerability that can influence the reaction of minor evacuees are psychological, physical, and educational (Table 2-5) (Peek, 2008).

Table 2-5 Types of vulnerability faced by children and youth

Psychological Vulnerability	Physical Vulnerability	Educational Vulnerability
• Depression • Anxiety • Emotional distress • Sleep disorders • Behavioral problems	• Death • Injury • Illness and disease • Malnutrition • Heat stress	• Missed school • Poor academic performance • Delayed progress • Failure to complete education

From “Children and Disasters: Understanding Vulnerability, Developing Capacities, and Promoting Resilience”, by L. Peek, 2008, Children, Youth and Environments, 18(1), p.5, (https://www.jstor.org/stable/10.7721/chilyoutenvi.18.1.0001). Copyright 2008 by Children, Youth and Environments.

In addition to vulnerability, children's impression of a tsunami disaster event may be influenced by their preparedness for emergency plans. In a study conducted in two Washington school districts, children's adaptive learning was assessed as responsiveness to the Shakeout. For this, an earthquake and tsunami drill were experienced where students acquired skills in responding to these disasters with the practice of "Drop, cover and hold on." According to this study, disaster drills in schools provide tsunami protection actions learning for students to react effectively. It also suggests that “response ability helps to improve children's self-confidence and resilience to disasters, particularly when children have the opportunity to receive positive feedback constructs during practices”. The knowledge of children and young people about these practices can save their lives when reacting to the event. However, the study also explains the increase in anxiety exerted by drills in schools as a negative factor towards students' perception of the evacuation process.

It also mentions that poorly executed drills, because they are considered mandatory exercises with little meaning, can be a challenge and negatively influence the reaction of children and young people (Johnson et al., 2014).

According to the study, data collected using quantitative questionnaires tends to be used to collect data on outcomes based on children's knowledge and not on correct protective action. This limits the ability to know if children and young people learn and successfully apply knowledge that can help in the perception of the evacuation process. The survey asked: "During the Shakeout Earthquake Drill in your School, did you Practice Evacuation for a Tsunami?" 71.3% of the students answered yes, 22% answered no, 5% answered that they were not sure, and 1.8% answered that they were not when the simulation was carried out. On the other hand, she asked herself: "If you hear the Words" Drop, Cover and Hold On ", what would you do?" 96.9% answered the option “Drop to the ground, take cover under a desk or table if nearby, hold on to the desk or table until the shaking stops”, 0.8% answered “Drop what you are doing, cover your ears, hold on to your belongings ”, 0.6% answered“ Drop what you are doing, run for cover, hold on to your belongings ”, 0.8% answered“ None of the above ”, and 0.8% answered“ I don't know ” (Johnson et al., 2014).

2.4.6 Strategies to Evacuate Large number of people

The viability of evacuation due to a tsunami requires strategies that ensure protection and security for the affected population. This requires being aware of the population density of all susceptible ages in coastal regions. According to the Intergovernmental Oceanographic Commission of UNESCO (IOC-UNESCO), evacuation strategies consider evacuation planning, signaling, and exercising. Strategies for evacuating large numbers of people depend on these factors to reduce the risk of a tsunami disaster (Intergovernmental Oceanographic Commission, 2008, p.3).

2.4.6.1 Evacuation planning

The evacuation plan is a process of identifying zones or areas with potential tsunami risk. For this reason, it is important that it is complemented by tsunami warning and guidance systems. On the other hand, this planning establishes the means of action to be carried out as a guarantee of the evacuees' safety. Intergovernmental Oceanographic Commission of UNESCO (IOC-UNESCO) suggests that evacuation planning is made up of types of evacuation and management of procedural phases. The types of evacuation are voluntary or compulsory, while the management phases of the process are decision, notification, process, shelter, and return (Intergovernmental Oceanographic Commission, 2008, p.3).

2.4.6.2 Signage

Signage is a guidance system that informs the danger within tsunami vulnerable regions by means of signs composed of symbols. Intergovernmental Oceanographic Commission (2020) explains that signage is "an effective mechanism for public education about the risk posed by tsunamis and the appropriate evacuation response to a tsunami event." In addition, it suggests that the types of tsunami signs are evacuation zone, evacuation route, safe evacuation zones or assembly places and information board. According to the National Tsunami Signage Technical Standard (2008), evacuation zone signs indicate "areas with potential tsunami risk and raise awareness of the need to evacuate in the event of a natural or official warning." Likewise, it defines that the information board signs must be in places with public access to the beach to help understand the risk and its alert response. Furthermore, this technical standard state that evacuation route signs "direct people along a predefined best route out of evacuation zones." Safe location evacuation signs “indicate safe locations for people evacuating from a tsunami hazard” and are divided into safe location signs for evacuation routes on foot and safe place signs for evacuations in place. While the signs of past events create "awareness of the existence and magnitude of past events" (Tsunami Signage Technical Standard, 2008).

On the other hand, there are international tsunami signs approved by the International Organization for Standardization (ISO) in 2008. These provide information on hazards, their marking in areas, and the action that needs to be taken to avoid them. International tsunami signs are based on design standards for safety signs and graphic symbols prescribed by ISO 3864-1 and ISO 3864-3. (International Tsunami Information Center, n.d.) This information helps to indicate and identify danger zones. In the same way, it serves as a guide to evacuation routes and places of assembly for evacuees to safe areas. The purpose of these guidance systems is to reduce the risk of the tsunami impact. Informational signs are found mostly in key places in the area.

International Organization for Standardization (ISO) signs show (Figure 2-24): (a) danger zone, (b) evacuation zone (horizontal shelter), and (c) evacuation construction sign (vertical shelter).

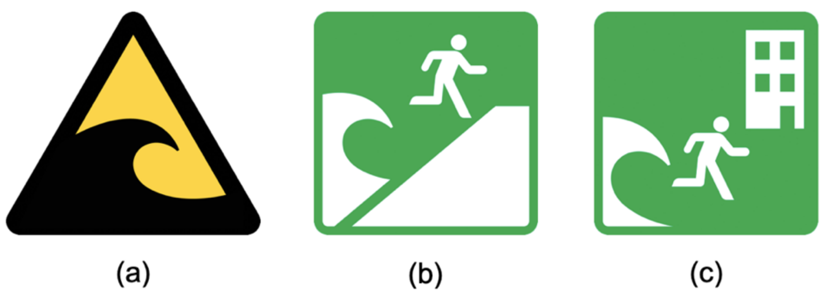


Figure 2-24 Signs approved by the International Organization for Standardization (ISO)
From "Signs & Symbols", by International Tsunami Information Center, 2003, ITIC, (http://itic.ioc-unesco.org/index.php?option=com_content&view=category&layout=blog&id=1406&Itemid=1406). In the public domain.

Figure 2-25 Tsunami sign in America
From "Signs & Symbols", by International Tsunami Information Center, 2003, ITIC, (http://itic.ioc-unesco.org/index.php?option=com_content&view=category&layout=blog&id=1406&Itemid=1406). In the public domain.

The Figure 2-25 shows the signs: (a) indicates the danger zone sign, (b) shows the evacuation route, (c) exposes the evacuation shelter sign.

The Figure 2-26 shows an example of a sign to indicate the tsunami evacuation route at an intersection in Nehalem, Oregon.

Figure 2-26 Tsunami Evacuation Route Sign in Oregon
From "Tsunami Evacuation Sign", by N. Wood, 2015, USGS Multimedia Gallery, (https://www.usgs.gov/media/images/tsunami-evacuation-sign). In the public domain.

2.4.6.3 Exercising

The exercise of the evacuation planning, the process as well as the guidance and implementation of the signals allows the action and execution of gaining experience and evacuation skills. Practicing these processes enables validation, augmentation, awareness, and preparation. This exercise is used through orientations, tests, and large-scale evacuations to evacuate large numbers of people (Intergovernmental Oceanographic Commission, 2008).

2.4.7 Walking Speed of the Masses

Intergovernmental Oceanographic Commission of UNESCO (IOC-UNESCO) suggests that the walking speed of evacuees is equivalent to the normal walking speed of masses of older people or people unfamiliar with the area. This is a standard velocity of 1.0 m / s. This standard speed varies to 0.5 m / s considering the walking speed of children, the disabled, and other vulnerable people. According to the IOC-UNESCO, the average walking speed during the 1993 Hokkaido Nansei earthquake tsunami in Japan (Table 2-6), is: 0.87 m/s for ages 20 to 29 years, 1.47 m/s for 30 years 39 years, 1.03 m/s for 40 to 49 years, 0.68 m/s for 50 to 59 years, and 0.58 m/s for 60 years or more. It also mentions that the walking speed of the masses also varies depending on the places through which they evacuate: flat areas or stairs. The walking speed for people unfamiliar with areas or routes is 1.0 m/s for flat areas and 0.5 m/s for stairs. (IOC-UNESCO, 2020, p.40)

Table 2-6 Average walking speed in the 1993 Japan tsunami

Age	20-29	30-39	40-49	50-59	60 and older
Average Speed	0.87 m/s	1.47 m/s	1.03 m/s	0.68 m/s	0.58 m/s

From "Preparing for Community Tsunami Evacuations: From inundation to evacuation maps, response plans and exercises", by UNESCO/IOC, 2020, Manuals and Guides, 82 (Suppl. 1), (https://reliefweb.int/sites/reliefweb.int/files/resources/373019eng.pdf). Copyright 2020 by UNESCO.

2.5 Tsunamis Studies for Puerto Rico

In Puerto Rico, studies have been carried out for a possible tsunami impact due to its geographic condition discussed in Seismicity of Puerto Rico.

One of the tsunami studies for Puerto Rico is the "Puerto Rico Hypothetical Tsunami" investigated by the National Oceanic and Atmospheric Administration (NOAA) and the Pacific Marine Environmental Laboratory (PMEL). According to the National Oceanic and Atmospheric Administration (n.d.), it explains that the Puerto Rico Trench is a place that "has attracted much attention from scientists for being the deepest place in the Atlantic Ocean." In addition, it states that the study shows the possible impact that a tsunami would have in the Puerto Rico Trench. The study scenario is a tsunami generated by a magnitude

7.5 earthquake. NOAA's National Center for Tsunami Research created an interactive sphere propagation model to present the hypothetical tsunami study simulation for Puerto Rico (Figure 2-27). According to the National Oceanic and Atmospheric Administration (n.d.), the propagation colors correspond as follows:

> The yellow shading represents the crest of the wave, which is over 10 cm above sea level and the red shading represents the trough of the wave, which is over 10 cm below sea level. The purple shading shows subsequent peaks 0 – 10 cm high and the green shading equates to subsequent troughs 0 – 10 cm.

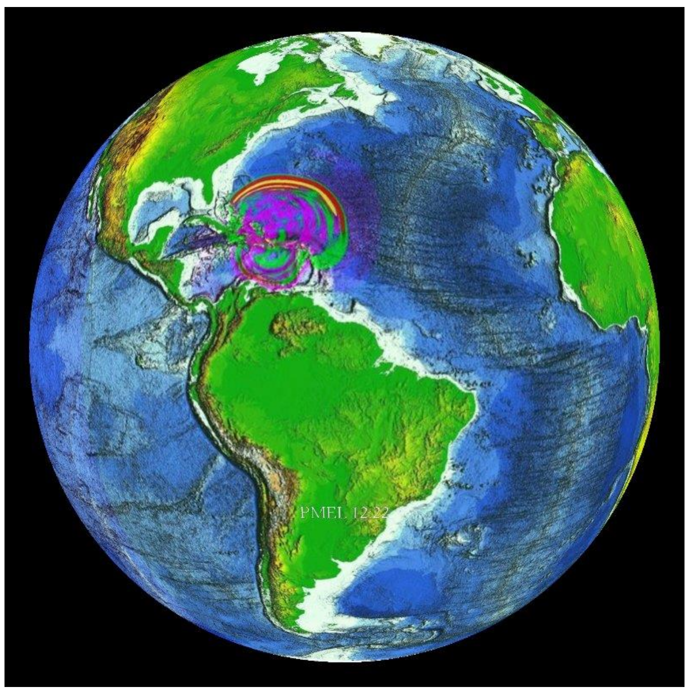


Figure 2-27 Puerto Rico Hypothetical Tsunami Visualization

From "Puerto Rico Hypothetical Tsunami", by D. Himes, n.d., Pacific Marine Environmental Laboratory, (https://sos.noaa.gov/datasets/puerto-rico-hypothetical-tsunami/). Copyright 2017 by National Oceanic and Atmospheric Administration.

2.5.1 Zoning

Puerto Rico is divided into 78 municipalities of which 44 are coastal. The zoning of Puerto Rico has been studied for possible tsunami events by the Puerto Rico Seismic Network (PRSN), the National Tsunami Hazards Mitigation Program (NTHMP), the University of

Puerto Rico in Mayagüez (UPRM), and the IOC Sub-commission for the Caribbean and Adjacent Regions (IOCARIBE) of the United Nations Educational, Scientific and Cultural Organization (UNESCO). The PRSN manages the Tsunami Program with the entities mentioned above. Through this program, the PRSN develops tools such as: tsunami evacuation and flood maps, web applications, and tsunami evacuation signs. In addition, it includes educational material such as training and knowledge about the tsunamis in Puerto Rico. Efforts coordinated by the entities are carried out to mitigate the damage and impact of a possible tsunami event on the Island through evacuation plans, educational material and the Tsunami Ready Program of the National Oceanic and Atmospheric Administration (NOAA) (PRSN, n.d.).

Figure 2-28 Model tsunami flood zone "MOM" (2012)
From "Modelo de inundación y mapas de desalojo", by Puerto Rico Seismic Network, 2019, Guía de Preparación ante Tsunamis: Comunidad Marítima y Portuaria de Puerto Rico, 3rd ed., p.8, (http://redsismica.uprm.edu/Spanish/educacion/Brochures/GuiadeTsunamis_Comunidad_Maritima_Final2017_rev2019.pdf). Copyright 2019 by Puerto Rico Seismic Network.

In 2012, the Puerto Rico Seismic Network (PRSN) suggests a tsunami flood model made for the Island known as "MOM" that means "maximum of maximums" as a representation of the sum of all simulated floods in the model. According to the Puerto Rico Seismic Network (2019), to generate this model "hundreds of sources of earthquakes around the island were simulated, including a catastrophic event magnitude 8.5 in the Puerto Rico

Trench north of Puerto Rico ". Based on this model, the eviction zones were delimited (Figure 2-28) under the following criteria: 2012 tsunami flood model, site topography, natural barriers, and a safety factor. Therefore, the PRSN worked on the tsunami flood and evacuation maps (Puerto Rico Seismic Network [PRSN], 2019).

The tsunami flooding and evacuation maps studied by the University of Puerto Rico at Mayagüez (UPRM) and the Puerto Rico Seismic Network (PRSN) cover the flood zones determined for the worst-case scenario by tsunamis generated by local earthquakes. According to the PRSN (n.d.), these maps were prepared with the characterization of local fault systems as the main threat to seismic tsunamis and with the use of data recorded by the entity itself. In addition, for its generation, tsunami parameters were included: seismic moment, fault dimensions and rupture geometry. The maps are designed as a resource to assist communities in coastal areas. With them, vulnerability to the effect of floods caused by tsunamis can be identified. The maps identify: evacuation zones, evacuation routes, assembly places, signs, emergency sirens, among many others (PRSN, n.d.).

Figure 2-29 Evacuation Map of San Juan, Puerto Rico on the Web
From "Puerto Rico Tsunami Program Map Tool", by Puerto Rico Seismic Network, University of Puerto Rico Mayagüez, n.d., Tsunami Program, (http://prddst.uprm.edu/apps/prtmp/). In the public domain.

The evacuation maps are available on the PRSN website as PDF format (Figure 2-23) and as Web maps applications (Figure 2-29). Web maps applications can be accessed from the

PRSN browser through the Puerto Rico Tsunami Program Map Tool. These are tools based on the Geographic Information System (GIS) that allow containing multiple layers of information such as: evacuation zones, routes evacuation, flood patterns, etc. On the other hand, in these evacuation maps as Web maps applications are interactive and incorporate tsunami flood values cataloged as "MOMRAS" according to the flood model studied in 2012 (PRSN, n.d.).

2.5.2 Evacuation Routs

Evacuation routes are the routes or paths established for people to evacuate any structure or facility in the shortest time possible, as discussed in Evacuation routes. According to the Puerto Rico Seismic Network (2019), different eviction routes were established and marked in Puerto Rico by the Tsunami Ready. These were created according to the program compliance guidelines. Likewise, the PRSN explains that these guidelines or criteria are the following:

- Minimize the time to evacuate or leave the risk zone (yellow zone on tsunami evacuation maps)
- Minimize the time spent walking along the routes along the coast (parallel)
- Minimize the crossing of bridges
- Provide greater accessibility to agencies that provide services in emergencies
- Suggested evacuation routes are via known roads or paths

Evacuation routes in Puerto Rico can be identified through the evacuation and tsunami flood maps discussed earlier in Zoning. These routes are represented in red by the roads ending in arrows (Figure 2-29).

2.6 School System in Puerto Rico

According to Sinvhal (2010), schools are important because they house children and must continue to function after the impact of a tsunami, and they are vulnerable because they are built on the availability of funds. On the other hand, the school's function is to "celebrate activities and orientation programs, and community service in collaboration with the Department of Family, the Department of Health, the Environmental Quality Board, the Agricultural Extension Service and the Police of Puerto Rico", "Ley Orgánica del Departamento de Educación de Puerto Rico" (1999). Schools in Puerto Rico are vulnerable due to the density of people that form it: students, academic components, managerial components, external components, and representatives of the community served by the school.

2.6.1 General Information

The Puerto Rico school system consists of the public and private sectors. The island's public schools are the responsibility of the Puerto Rico Department of Education.

2.6.1.1 Population

The school population refers to the entire set of people that make up a school. All those people who are part of the school structure are considered as its population. Schools in Puerto Rico consist of a large population: students and teaching and non-teaching staff. According to the Statistics Institute of Puerto Rico (2019), the total number of schools in 2015 and 2016 was 2,213 (Table 2-7). Of this total amount, 1,418 schools correspond to the public sector and 795 schools represent the private sector. According to this statistic, there were 417,101 students and 33,700 teachers in public schools. For private schools, 142,235 were students and the number of teachers was 11,536. The total population as inclusion of the public and private sector corresponds to 559,336 students and 45,236 teachers (Table 2-8).

Table 2-7 Puerto Rico School Statistics (2015-2016)

Number of Schools in Puerto Rico (2015-2016)		
Public Sector	Private Sector	Total
1,418	795	2,213

From "Anuario Estadístico del Sistema Educativo: 2015-2016", by O. M. Disdier Flores and L. J. Cruz Soto, 2019, Anuario Estadístico Del Sistema Educativo, 2016th ed., (https://estadisticas.pr/files/Publicaciones/Anuario%20Estadistico%20del%20Sistema%20Educativo%202015-2016.pdf). Copyright 2019 by Instituto de Estadísticas del Gobierno de Puerto Rico.

Table 2-8 Puerto Rico School Population Statistics (2015-2016)

Population of Schools in Puerto Rico (2015-2016)			
	Public Sector	Private Sector	Total
Students	417,101	142,235	559,336
Teachers	33,700	11,536	45,236

From "Anuario Estadístico del Sistema Educativo: 2015-2016", by O. M. Disdier Flores and L. J. Cruz Soto, 2019, Anuario Estadístico Del Sistema Educativo, 2016th ed., (https://estadisticas.pr/files/Publicaciones/Anuario%20Estadistico%20del%20Sistema%20Educativo%202015-2016.pdf). Copyright 2019 by Instituto de Estadísticas del Gobierno de Puerto Rico.

The "Council of Education of Puerto Rico (CEPR)" has a School Finder on its digital platform. In this search engine you can find information about private schools in Puerto Rico. On the other hand, the Puerto Rico School Profile from the Puerto Rico Department of Education presents the population in synthesis of the schools on the Island. According to this School Profile, in the 2018-2019 school year the student population was a total of 307,282.

2.6.1.2 Function

Schools in Puerto Rico have other functions in addition to education. On the island, schools are used as teaching facilities, as shelters and as voting centers. The Puerto Rico Emergency Management Agency (PREMA) offers a 2020 list of schools that are used as shelter in an emergency in the event of a disaster. On the other hand, the Puerto Rico State

Elections Commission offers a 2020 list of schools that are used as voting centers. Due to these operations, the population mentioned above would increase for each school.

2.6.1.3 Structure of schools in Puerto Rico

According to Ratay (2012), have an age and need evaluation of their state. It also highlights that they deteriorate over time due to repeated loads, exposure to the elements, aging of materials, wear and tear due to normal use, improper maintenance, and other factors. Ratay suggests that the design of the structures should have strength, stability, or serviceability. The evaluation of the state of the structures requires the need for maintenance, repair, and rehabilitation of infrastructure due to deterioration, damage suffered due to a natural hazard, among others (Ratay, 2012).

Schools are part of these structures. Therefore, the structural conditions of schools must comply with strength, rigidity, and stability. Furthermore, the school infrastructure is made up of structural characteristics corresponding to their age. According to the "Ley de Reforma Educativa de Puerto Rico" (2018), many school infrastructures were built more than 50 years ago, so they require constant renovation in addition to the monthly maintenance provided. " Like Ratay, this Law mentions that the deterioration of school buildings increases due to: "continuous use, inclement weather, vandalism, frequent maintenance and the passing of time." It also suggests that changes in infrastructure regulations and building codes require updating to modify the structure of the schools (Ley de Reforma Educativa de Puerto Rico, 2018).

Schools must comply with all Building Codes established in Puerto Rico (Ley de Reforma Educativa de Puerto Rico, 2018). These are regulations for building constructions with safety and quality. As indicated by the Secretary of the Department of Education (DE), Eligio Hernández in a publication for "NotiCel" on January 7, 2020, 95% of schools in Puerto Rico are not established under the current Building Code. This is because schools in Puerto Rico have designs under expired Building Codes. The Puerto Rico Emergency

Management Agency (PREMA) suggests that the schools corresponding to the Department of Education cannot be used as a refuge in an emergency (NotiCel, 2020).

2.6.2 Location

The schools in Puerto Rico are in the island's municipalities. These can be located through the resource offered by the Homeland Infrastructure Foundation-Level Data (HIFLD). This resource provides geospatial data to support preparedness, resilience, and research. Data on schools in Puerto Rico, including their location, can be accessed through the HIFLD website. On the HIFLD map, schools in Puerto Rico are represented in blue circles (Figure 2-30). The HIFLD registers the public and private schools of Puerto Rico. This resource has information on public schools with data obtained from the Puerto Rico Department of Education for the 2017-2018 school year. On the other hand, the location of these schools can be obtained through Google Maps using their addresses provided by the School Search and the Comprehensive Directory of Public Schools of Puerto Rico (2018).

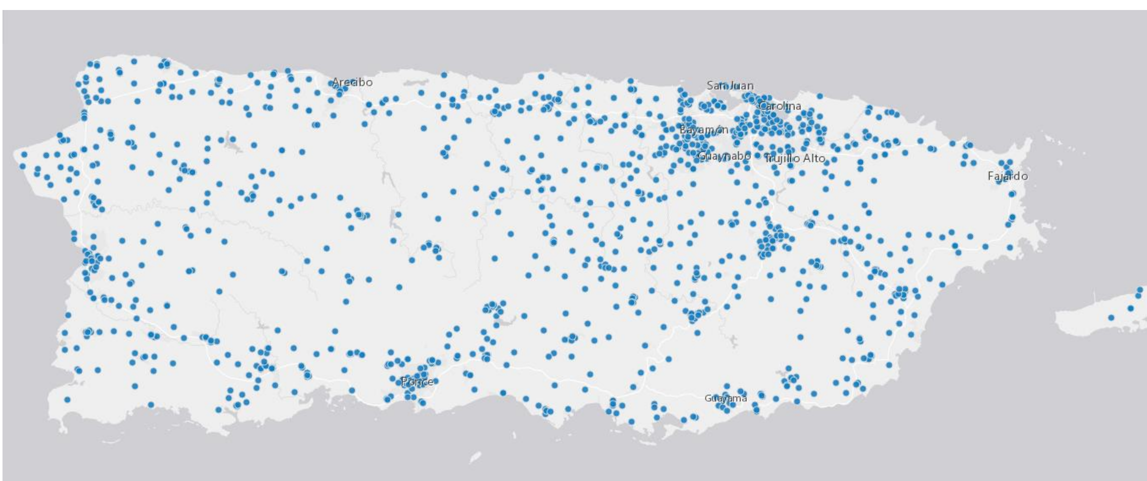


Figure 2-30 Location of public schools in Puerto Rico

From "Public Schools," by Homeland Infrastructure Foundation-Level Data, 2020, Homeland Infrastructure Foundation-Level Data, (https://hifld-geoplatform.opendata.arcgis.com/datasets/public-schools?geometry=-67.882%2C17.736%2C-64.213%2C18.649). Copyright 2017 by U.S. Department of Homeland Security.

2.6.3 Design and Operation Guidelines

During the literature review, it was not possible to successfully find any of the design and operation guidelines for schools in Puerto Rico. Only the emergency plan for these schools on the Island for 2001 was found. What the Model Emergency Plan for Puerto Rico schools establishes is the following (Comité de Planes de Emergencia, 2001):

2.6.3.1 School Campus Preparation

This is the planning process of the schools in Puerto Rico for a disaster event according to (Comité de Planes de Emergencia, 2001).

2.6.3.1.1 Have a checklist for the director

The following list corresponds to the aspects that the school principal should consider:

- Instructions for the director
    - Determine the person in charge when absent in case of emergency.
    - Relate to local police and fire departments to operate under the Standardized Emergency Management System emergency plan.
    - Review an emergency plan each year with local police and firefighters.
    - Contact your City Council Emergency Services Office or county.
    - Review the emergency plan annually with staff to ensure the knowledge of all members, responsibilities, and actions in the event of an emergency.
    - Check with the staff for the procedure to call 911.
    - Assess the risk of the school grounds.
    - Eliminate the risks encountered in the school grounds' assessment of risks.
    - Prepare a register of students and staff vulnerable to breathing problems.
    - Perform emergency preparedness simulations.

- Instructions for staff
    - Record staff knowledge and skills as an emergency response.
    - Instruct staff in the preparation of emergency classroom backpacks and individual emergency kits for students.
- Family instructions
    - Maintain communication with families about the school's emergency plans.
    - Report family responsibilities in emergencies.
    - Motivate the participation of family volunteers.

- Earthquake Preparedness
    - Prepare a service map of multiple school grounds.
    - Conduct annual simulations for earthquake "Bend-Cover-Hold" and guide on meeting points.
    - Record the school's earthquake supplies.

- Preparation for Evacuation
    - Prepare the school grounds evacuation plan.
    - Identify evacuation sites.
    - Know the evacuation routes.
    - Determine the buses needed to evacuate the entire school population.
    - Perform evacuation simulations annually.

2.6.3.1.2 Having a checklist for staff

Below is the list of instructions to be followed by school staff.

- Review emergency plans.
- Prepare emergency classroom backpacks and individual emergency kits for students.

- Correct existing risks in the relevant area identified in the school grounds risk assessment.
- Instruct students on emergency preparedness.
- Participate in emergency simulations.

2.6.3.1.3 Assess the risks of the school grounds

The risk assessment of the school grounds should be carried out by a structural or civil engineer as appropriate. Part of the assessment requires examining potential risks with potential impact to the school grounds.

2.6.3.1.4 Having an emergency backpack for the classroom

The backpack is an emergency item that teachers should have in their classroom as an emergency measure. This backpack should include: a first aid kit, medicines (if necessary), flashlights, radio, water, food, notebook, documents, and additional materials (if necessary).

2.6.3.1.5 Have individual emergency kits for students

Individual kits are emergency resources that students must have whenever an evacuation occurs. The kit should include food, entertainment items for children (toys), contact documents, additional materials (if necessary).

2.6.3.2 Procedure for Evacuating a School Campus

The process of evacuating a school in Puerto Rico involves: the evacuation of the building, the abandonment of school infrastructure if necessary, and the evacuation by bus and walking.

2.6.3.2.1 Evacuate the building

The evacuation process of the building must be ordered. The entire school population must leave the building using the specific fire routes and considering people with disabilities. Students and teachers must carry emergency backpacks and individual kits. The school population should head to the safe meeting place away from the building. Staff must record the evacuees and report it to the designated person in the emergency.

2.6.3.2.2 Leave school grounds

The evacuation of the school site should be done when it is not safe to remain on the school grounds. This process must be carried out on board a vehicle or on foot.

2.6.3.2.3 Evacuate by bus

The school population must reach safe places by means of school-available buses heading on non-hazardous roads. Teachers should take care of their group together and take a list before and after leaving the precinct.

2.6.3.2.4 Evacuate aboard other vehicles

If buses are not available to the entire school population, evacuees should consider other modes of transport. If so, the alternate vehicles used, and the students transported by each of the different means must be recorded. Drivers should take the safest route to eviction sites. Teachers must keep track of students on the safe site. This method of evacuation should be considered for extreme emergencies.

2.6.3.2.5 Evacuate walking

In this process the school population must walk safely and orderly to nearby evacuation sites to get away from danger. The walk should follow the safest route. Teachers must take lists of students before evicting the precinct and after reaching a safe zone.

2.6.3.3 Important Maps of the School Grounds

These are resources to guide all personnel during the evacuation process. The maps that make up this process in schools are:

2.6.3.3.1 Fire simulation map

These maps must meet primary and alternate building evacuation routes. It is recommended to do so by colors.

2.6.3.3.2 Map with evacuation plan

Evacuation maps must have primary and alternate routes to one or more safe sites outside the enclosure.

2.6.3.3.3 Safeguard map of where you are located

The map must include the identified areas. Identified areas should be easy to seal to prevent outside air from entering.

2.6.3.3.4 Map of hostel sites against severe weather

The areas identified on this map should have few windows and have no large ceilings.

2.6.3.4 Earthquake emergency

In the event of an earthquake during school hours that could threaten the safety of students or personal, the following should be done:

2.6.3.4.1 During an earthquake

If the earthquake occurs while the population is indoors:

- Stay inside, get away from windows and heavy furniture. Cover yourself under a desk and run the "Crouch, cover and hold".
- Move to the interior wall in case you are in the hallway and stairs.
- Move away and turn off any laboratory equipment that may cause accidents if you are in a laboratory.

If the earthquake occurs while the population is out in the open:

- Go to an open space that is away from buildings. Get down on the ground and duck. Observe the dangers around.

2.6.3.4.2 After the earthquake

- Evacuate students from the building. For this process, students and teachers must carry emergency kits and backpacks with them. Staff should check that all students have evacuated the building.
- Teachers must pass a list of students at the identified secure site and report it to the principal or designated.
- The director must establish an Emergency Operations Center with his Or her Emergency Operations Center team. The latter must notify the police and firefighters of trapped or missing persons to organize search and rescue teams. You must also organize emergency response teams.
- The security team should inspect utilities for leaks.
- The director must report any breakdowns in service lines.
- First aid equipment should prepare the area, categorize the wounds of affected people, and care for them. You must report the injured people to the principal.
- The student release team must give students to their authorized adults and record them.

2.6.3.4.3 Evacuate the school building

The process mentioned below is a post-earthquake process.

- Before evacuating the building, staff should consider hazards outside the building before evacuating students. You should also consider that there is no safe meeting area, eviction routes, or lighting. '
- Before evacuating students, staff must assess the situation. In addition, you must determine whether eviction routes are clear, whether the meeting site is safe, evade hazardous items, and consider students with disabilities.
- Staff should evacuate once they feel the process is safe.

- The school grounds should take care of students for up to 3 days after the earthquake in case it is a severe event.

2.6.3.4.4 Having earthquake articles

The items needed in a school grounds in the event of an earthquake event are: immediately accessible items, water, sanitary items, non-perishable food, first aid, tools for additional search and rescue uses, and other items as needed.

2.7 Previous works

The previous works considered in this research have only studied the vulnerability of a certain population of Puerto Rico without specifying in schools. One of the antecedents under study is the one entitled "A Look at Vulnerable Populations in Puerto Rico in the Face of Disasters." The other antecedent that has investigated vulnerability is entitled "Analysis of Threats, Vulnerability and Risks of the Public Health Systems, Medical Services and Mental Health of Puerto Rico." Both consider the vulnerability of a population to disasters.

The investigation "Analysis of Threats, Vulnerability and Risks of the Public Health Systems, Medical Services and Mental Health of Puerto Rico" was carried out between 2012 and 2013 by the Center for Preparation in Public Health of the Graduate School of Public Health of the Medical Sciences Campus of the University of Puerto Rico and the Office of Preparation and Coordination of Public Health Response. It analyzed the vulnerability to the possible impact of six main threats: hurricanes, tsunamis, floods, tropical cyclones, epidemics, and pandemics for Puerto Rico. In this project, the island's experience in its past 25 years was considered and forms were made to more than 60 professionals in the study area. Although its content could not be accessed, the information described above is explained according to Padilla et al. (2016). For this reason, in this background description for this investigation, the results obtained in it were not known.

The study of "A Look at Vulnerable Populations in Puerto Rico Faced with Disasters" was investigated in 2016 by Nilsa D. Padilla, Julieanne Miranda, Gabriela A. Algarín, Marisol Peña, Ralph Rivera, Alejandro A. Nieves, Juan A. González, Mónica R. Castellano, and Héctor Robles. The purpose of this research was to study the vulnerable population affected by disastrous events in Puerto Rico. It considered that the vulnerable population found should be part of the planning and preparations for disasters and offered possible strategies for this. For its development, it used databases from the "Analysis of Threats, Vulnerability and Risks of the Public Health Systems, Medical Services and Mental Health of Puerto Rico" mentioned above. The results of this research showed that 21% of the population is of vulnerable ages. Of this percentage, 6% represents the population of children under 5 years of age and 15% of the population corresponds to people over 65 years of age (Padilla et al., 2016).

3 Research Program

In this chapter, the specific objectives such as the expected intentions of the research and the scope of the study are exposed by describing the schools under analysis. Also, the methodology to carry out the study is explained, and the resources that served as reference. In addition, the data collection procedures and the quantitative analysis used to describe and explain the findings are all described. The chapter includes the itinerary of the structured activities of the methodology with their respective estimated duration times.

3.1 Objectives and Scope

The objective of this research project is to study the areas with potential tsunami risk and to identify the schools located and exposed in these areas. Also, develop and implement a methodology to identify the schools that are more vulnerable to tsunamis in Puerto Rico. Also, evaluate and identify the conditions of vulnerability in schools of Puerto Rico. Explore mitigation alternatives that can reduce such vulnerabilities and risk to schools. After determining all the schools located in tsunami-prone areas, a municipality will be selected as a case study to apply the developed methodology.

3.2 Methodology

The methodology consists of four phases that employ the quantitative assessment and analysis process. Phase I is based on hazard identification, Phase II focuses on the case study, Phase III is based on vulnerability analysis, and Phase IV is the analysis of the results. In the development of Phase I, the tsunami event is used as a danger that threatens schools. While in Phase II the case study is investigated with justification. In Phase III vulnerability is used as a function of exposure, frailty, and adaptive capacity. For the study of vulnerability in schools, the need to know the danger, exposure, fragility, and response capacity of schools in Puerto Rico is raised. The tsunami is exposed as the independent variable of danger; the elements of the exhibition: the schools, their population, and their location as independent variables; the structural conditions of schools and tsunami hazard zones as independent variables of fragility; the evacuation plan as an independent variable of response capacity; and vulnerability as a dependent variable to be investigated. On the other hand, Phase IV investigates the results obtained in the previous phases.

For the data collection process, databases of the "Perfil Escolar" for 2018-2019 corresponding to the Department of Education are used to find the population of the schools. In addition, the Eviction Maps studied by the University of Puerto Rico-Mayagüez Campus and the Puerto Rico Seismic Network are used, which cover the flood zones determined for the worst-case scenario due to tsunamis generated by local earthquakes. The maps are used in PDF and digital format accessed through the Puerto Rico Seismic Network browser to know the schools that are in danger zones. Likewise, the satellite map is used through the Google Maps program to locate schools. On the other hand, the 2020 list of shelters from the Puerto Rico Emergency Management Agency (PREMA) and the 2020 list of voting centers from the Puerto Rico State Elections Commission are used for the use of schools. In the data analysis process, Google Earth and ArcGIS programs are used to georeference the evacuation maps and the maps of each municipality. Figure 3-1 presents a summary of the study methodology.

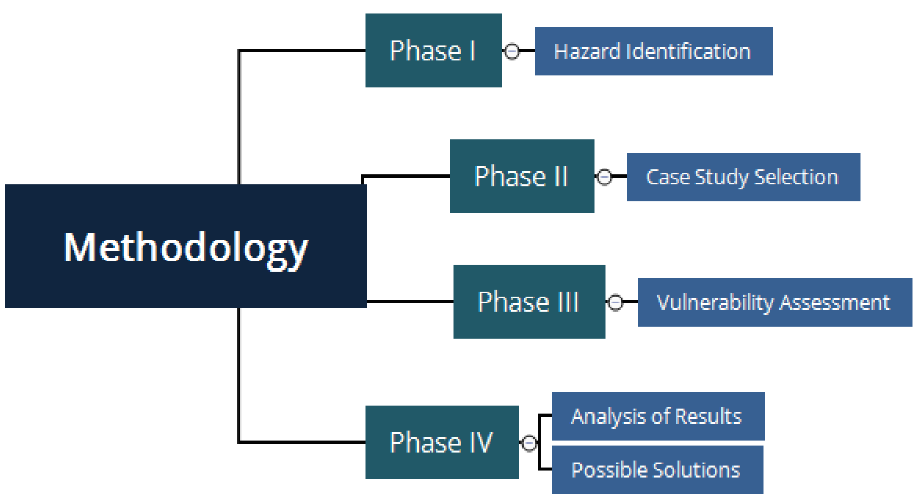


Figure 3-1 Diagram of the Methodology to be Developed in the Study

The activities of each phase are described in detail below:

3.2.1 Phase I - Hazard identification

Phase I focuses on examining and identifying the tsunami hazard. In this stage, the number of schools that are in danger of a tsunami for each municipality is synthesized. With this, it is possible to identify the municipalities where there is more danger, which is equivalent to a higher risk.

3.2.1.1 Identification of schools in hazard zone

For this process, the tsunami hazard zones are first examined through the evacuation maps of the Puerto Rico Seismic Network. Then, the schools available in each coastal municipality are located and quantified. The school search resource is the 2018-2019 Puerto Rico School Profile database from the Puerto Rico Department of Education. In addition, the schools that are used as shelters and as voting centers are quantified. To obtain this information, the 2020 list of shelters from the Puerto Rico Emergency Management Agency (PREMA) and the 2020 list of voting centers of the Puerto Rico State Elections Commission are used. The identification of schools includes the public sector for each town and the possibility of finding information on the private sector is considered. Once the schools have been located, those in the tsunami hazard zones are identified and quantified according to the evacuation and evacuation maps corresponding to each coastal municipality. To do this, a site diagram is made with the Puerto Rico Seismic Network evacuation map and the Google Maps satellite map using the ArcGIS software to georeferenced these sites.

3.2.1.2 Assessment of the population of schools that could be affected

In this process, the school population that could be affected by the impact of a tsunami is quantified. For this, the population of the schools located in the hazard zones of their respective municipalities are used and considered using the Puerto Rico School Profile database for 2018-2019 of the Puerto Rico Department of Education. Therefore, the population of schools that could be affected by a tsunami represents the population of schools that are in the hazard zone.

3.2.2 Phase II - Selection of the case study

In this phase, the case study for this research is evaluated and determined. A region or municipality with schools located in danger zones is selected to determine its vulnerability. For this, the following selection criteria are considered as justification:

3.2.2.1 Researchers' accessibility

This is a criterion that considers the viable aspects of the researchers in terms of their location. It can contribute to the successful development of research to facilitate and enable further exploration. Visits to the field to examine the distinctive elements of each area, the structural conditions of schools and evacuation routes, and to document urban furniture are some of the aspects that are considered in the accessibility of researchers to determine the case of study.

3.2.2.2 Number of schools located in the tsunami hazard zone

This justification corresponds to the number of schools in the hazard zone of each municipality. The greater the number of schools located in tsunami danger, the greater the possibility of finding and identifying the case study.

3.2.2.3 Number of schools used as shelters or voting centers located in tsunami hazard zone

This criterion considers the number of schools that are listed as shelters and voting centers. As in the previous one, the greater the number of schools with a use other than academic, the greater the chance of finding the case study.

3.2.2.4 Amount of population that could be affected by a tsunami

This criterion is relevant to the number of people in schools that could be affected by the impact of a tsunami. As in the previous criterion, the greater the number of school population affected by the danger of a tsunami, the greater the possibility of determining the case study.

3.2.3 Phase III - Vulnerability Assessment

This phase studies the vulnerability of schools by means of the study parameters: evacuation plans, year of construction of the school structure, safe zones, and evacuation time. These criteria or indicators of vulnerability are described below:

3.2.3.1 Evaluation of evacuation plans

In this process, the evacuation plans of the schools studied are analyzed as a response capacity to the danger of tsunami. A form is used as a resource to learn about the evacuation plan and strategies for evacuating people from each of the schools. This examination includes consideration of educational and informational material such as training and drill experience.

3.2.3.2 Structural examination of schools

The school infrastructure and its conditions are studied through visits to the schools determined in the case study of Phase II using Google Earth Pro. As part of the condition of the school structure, its age and the floors of the building are considered.

3.2.3.3 Identification of safe areas

The safety zones of each coastal town are recognized. To do this, they are visited or located through the Google Earth Pro satellite map. The number of safe zones is quantified.

3.2.3.4 Determination of evacuation time

To determine the evacuation time, the walking speeds recommended by the United States Geological Survey (USGS) and practiced in the "Pedestrian Evacuation Analyst" are used. Through Plot A Route these times are determined for each school under study.

3.2.3.5 Evaluation of Evacuation Routes

This process is carried out by visiting the school evacuation routes using Google Earth Pro. For the evacuation routes to be suitable during the evacuation, four conditions are considered:

- That the route moves away from the coast in the shortest possible time.
- That the route avoids walking parallel to the sea.
- That the route avoids possible obstructions to the route, such as bridges that may collapse.
- That the route has adequate width and does not present obstacles to the pedestrian flow, such as urban furniture.

3.2.3.6 Determination of vulnerability

The vulnerability is defined by means of the parameters studied in the previous steps. In this process, the most vulnerable schools are identified using as a fundamental basis the evacuation time obtained and the evaluation of evacuation routes.

3.2.4 Phase IV - Analysis of Results and Proposal of Solutions

In this process the results are examined, conclusions are reached, and recommendations are offered. The main causes of vulnerability are identified as part of the analysis of the results. Solutions are proposed based on the results obtained for each of the schools of study. The solutions are based on the findings determined by the evacuation plan, the danger, and the vulnerability of the schools. Its presentation is intended to reduce vulnerability and mitigate damage, as well as better preparation in case of not having it.

3.3 Itinerary

The itinerary show in Figure 3-2 present the methodology activities completed and to be completed using the Gantt chart. Each of the tasks is identified with its start and end date to complete Phase I, Phase II, Phase III and Phase IV of this investigation.

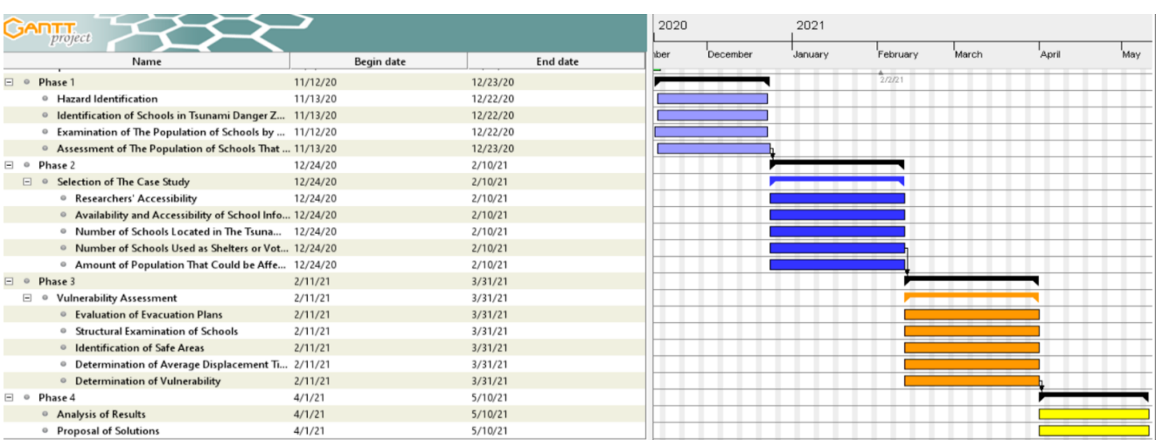


Figure 3-2 Itinerary of the Methodology Process in Gantt Chart

4 Data Collection and Processing

This chapter describes how the base data for this research was found, used, and processed. This synthesizes the resources used to find data sets on schools and tsunamis, as well as other topics needed to assess the vulnerability of schools. In addition, it explains the way in which said data was processed. That is, it presents the data based on its processing. On the other hand, it shows a map representation that will be used to interact in the next chapter for each study municipality.

4.1 Data Collection

The data used for the development of the project methodology are presented below. In addition, all the resources used to obtain said data are exposed and explained. Those resources used to verify that the data were accurate are also identified. The data and their respective sources range from a set of data, databases, to values obtained from previous research, as well as data assumed by state agencies. All the data used is explicitly detailed to understand how its processing works later. The data are related as they are exposed, for this reason they appear in the order in which they are developed.

4.1.1 Schools Data

School data are downloaded as a layer in a KML file for use in a Geographical Information System (GIS). These include geolocation and public sector population. They are obtained through the Homeland Infrastructure Foundation-Level Data (HIFLD). The HIFLD is being developed through a committee established in February 2002 to address improvements in the collection, processing, sharing, and protection of infrastructure geospatial information. As mentioned in Location, the HIFLD is a site that provides geospatial data to support community preparedness, resilience, research, among many others.

Geospatial data is accessible to the public domain and downloaded as CSV, KML, and Shapefile. These files are formats that contain geographic data for use, but not all, in a Geographical Information System (GIS) as mentioned above. HIFLD data (Figure 4-1) is accessed through web services that support application development and data visualization.

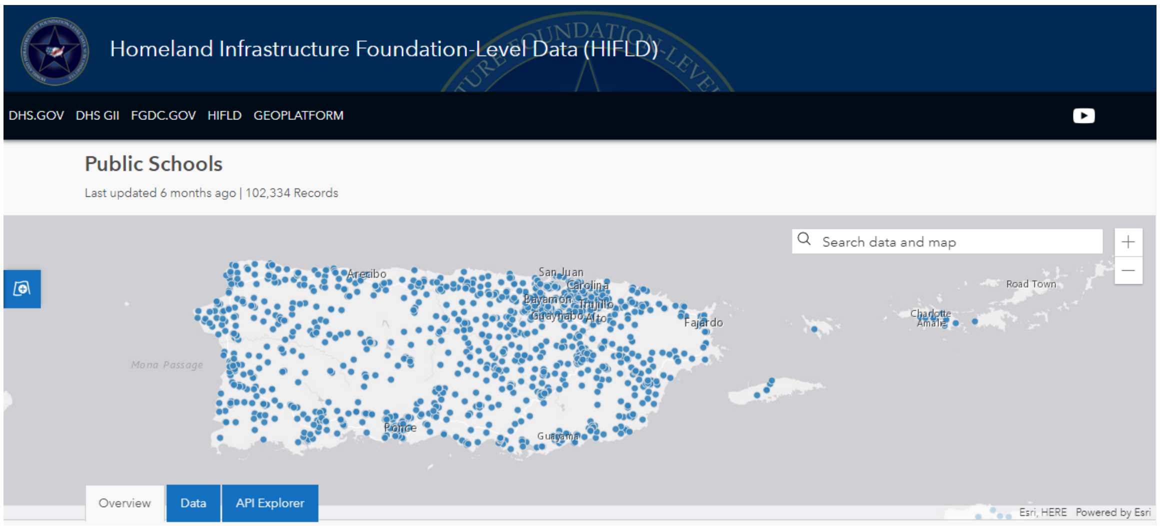


Figure 4-1 Layer of Public Schools in HIFLD Web

From "Public Schools," by Homeland Infrastructure Foundation-Level Data, 2020, Homeland Infrastructure Foundation-Level Data, (https://hifld-geoplatform.opendata.arcgis.com/datasets/public-schools?geometry=-67.882%2C17.736%2C-64.213%2C18.649). Copyright 2017 by U.S. Department of Homeland Security.

Public schools are represented on a map (Figure 4-2) by compressed layer files containing their information: name, address, phone number, status, town, source date, level, latitude, longitude, and more. In a Map Viewer, the layer of the schools is displayed with icons for better representation and contrast with the rest of the geolocated elements on the map of Puerto Rico explained later.

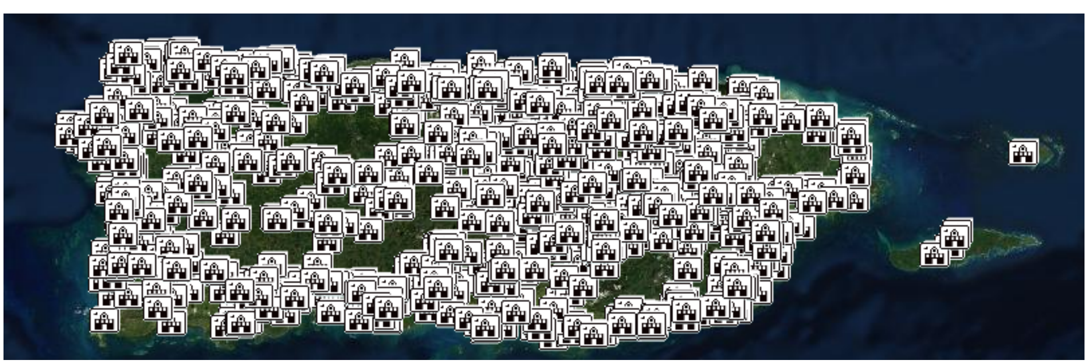


Figure 4-2 Layer of public schools in Map Viewer

The population of students and teachers in the schools is verified through the “Busca tu Escuela” platform for the 2018-2019 academic year (Figure 4-3). On the other hand, closed schools and those that remain open are also corroborated.

The schools that are used as shelters are using the 2020 Puerto Rico State Agency for Emergency and Disaster Management (NMEAD) list of shelters as a reference (Figure 4-4). On the other hand, Annex 7 of the "Operational Plan for Emergencies and Catastrophic Incidents (POEIC)" of 2019 is also used (Figure 4-5).

Figure 4-3 Busca tu Escuela Platform

From “Busca tu Escuela - 2018-2019,” by Departamento de Educación, n.d., Busca tu Escuela, (https://buscatuescuela.dde.pr/). Copyright 2019 by Departamento de Educación.

MUNICIPIO	FACILIDADES
ADJUNTAS	ESC. JOSÉ EMILIO LUGO
ADJUNTAS	ESC. RAFAEL APARICIO JIMÉNEZ
AGUADA	ESC. ELADIO TIRADO LÓPEZ
AGUADA	ESC. INTERMEDIA PROF. JUANA ROSARIO
AGUADA	ESC. LYDIA MELÉNDEZ (ELEM. URB. NUEVA)
AGUADA	ESC. S.U. EPIFANIO ESTRADA
AGUADILLA	ESC. BENITO CEREZO VÁZQUEZ

Figure 4-4 List of Shelters (NMEAD)

From "Listado de Refugios," by Puerto Rico State Agency for Emergency and Disaster Management, 2020, Departamento de Seguridad Pública, (https://manejodeemergencias.pr.gov/wp-content/uploads/2020/08/NMEAD2020-LISTADO-REFUGIOS-v2agosto222020-min.pdf). In the public domain.

MUNICIPIO	ZONA AEMEAD	REGIÓN EDUCATIVA	ESCUELA	CÓDIGO	FACILIDADES	CAPACIDAD DE	CAPACIDAD DE REFUGIADOS (Urgencia)
Adjuntas	Ponce	Ponce	1	50294	Esc. José Emilio Lugo	137	274
Adjuntas	Ponce	Ponce	1	54551	Esc. Rafael Aparicio Jimenez	102	204
Aguada	Aguadilla	Mayaguez	1	46086	Esc. Eladio Tirado López	150	300
Aguada	Aguadilla	Mayaguez	1	47951	Esc Intermedia Prof. Juana Rosario	150	300
Aguada	Aguadilla	Mayaguez	1	46813	Esc. Lydia Meléndez (Elem. Urb. Nueva)	239	478
Aguada	Aguadilla	Mayaguez	1	40220	Esc. S.U. Epifanio Estrada	120	240
Aguadilla	Aguadilla	Mayaguez	1	46656	Esc. Benito Cerezo Vázquez	87	174
Aguadilla	Aguadilla	Mayaguez	1	47647	Esc. Sup. Juan Suárez Pelegrina	250	500
Aguadilla	Aguadilla	Mayaguez	1		Esc.Conchita Igartua de Suarez	70	140
Aguas Buenas	Caguas	Caguas	1	27540	Esc. Dr. Pedro Albizu Campos (Int.)	80	160
Aguas Buenas	Caguas	Caguas	1	25783	Esc. Luis Muñoz Marín	120	240
Aguas Buenas	Caguas	Caguas	1	28571	Esc. Superior Urbana	120	240
Aibonito	Caguas	Caguas	1	20289	Esc. Dra. Carmen D Colon	350	700
Aibonito	Caguas	Caguas	1	20362	Esc. Superior Dr. José N. Gándara	250	500

Figure 4-5 List of Shelters (POEIC)

From "Refugios," by J. Rivera, 2020, Planes y Protocolos de emergencias del Departamento de Educación, (https://issuu.com/june-rivera/docs/dept._educacion_final). Copyright 2020 by Issuu.

In schools that are voting centers, the official list of the Puerto Rico State Elections Commission (CEE) for 2020 is used as a resource (Figure 4-6).

CENTROS DE VOTACIÓN
ELECCIONES GENERALES
MARTES, 3 DE NOVIEMBRE DE 2020

COMISIÓN ESTATAL DE ELECCIONES
DE PUERTO RICO
PLANIFICACIÓN GEOELECTORAL

FINAL
Rev. 2 nov 2020
11:50am

Municipio	Pre	UE	Tipo	Centro de Votación	Dirección	Colegio Regular	Colegio Añadido a Mano	Total Colegios
San Juan	001	01	Esc.	Albert Einstein	Cll Haydee Rexach, Esq. Ave. Borinquen	2	1	3
San Juan	001	02	Esc.	Abraham Lincoln	351, Calle Sol, Viejo San Juan	4	1	5
San Juan	001	03	Esc.	Dr. José Celso Barbosa	Parada 4 !/2, Ave Ponce de León, Viejo San Juan	4	1	5
San Juan	001	04	Col.	San Juan Bosco	Cll. Constitución, Sect. Cantera	2	1	3
San Juan	001	05	Acad.	Perpetuo Socorro	707 Cll. José Martí, Sect. Miramar, Bo. Santurce	7	1	8
San Juan	001	06	Esc.	Julián E. Blanco	Cll. Martín Travieso Esq, Cll. Estrella, San Juan	3	1	4
San Juan	001	07	Col.	Saint John's School	1454 Ave. Dr. Ashford, Condado	8	1	9
San Juan	001	08	Esc.	Ernesto Ramos Antonini	Ave. Borinquen, Sect. Barrio Obrero, Bo. Santurce	4	1	5
San Juan	001	09	Univ.	Sagrado Corazón	Cll. Rosales Pda. 26, Bo. Santurce	4	1	5
San Juan	001	10	Esc.	Alejandro Tapia y Rivera	369 Cll. Bellevue, Villa Palmeras	5	1	6
San Juan	001	11	Esc.	Federico Asenjo	Ave. Borinquen 2017, Sect. Barrio Obrero	3	1	4
San Juan	001	12	Esc.	Rafael Cordero	Cll. Hoare, Esq. Cll. Aurora, Santurce	2	1	3
San Juan	001	13	Esc.	Rafael María de Labra	Ave. Ponce de León, Pda. 18, Esq. Cll. Roberto H. Todd	3	1	4

Figure 4-6 List of Voting Centers

From "Centros de Votación," by Comisión Estatal de Elecciones de Puerto Rico, 2020, Comisión Estatal de Elecciones de Puerto Rico, (https://ceepur.org/Elecciones/docs/centrosvotacion.pdf). Copyright 2020 by Comisión Estatal de Elecciones de Puerto Rico.

4.1.2 Tsunami Data

Tsunamigenic data are obtained through the Puerto Rico Seismic Network GIS Data (Figure 4-7). The Puerto Rico Seismic Network (PRSN) offers data sets available for download in GEODATABASE (ESRI) format. This Environmental Systems Research Institute (ESRI) is an international provider of GIS and the creator of ArcGIS, the mapping and spatial analysis software that we use to create layers with the tsunami data for Puerto Rico. As a reference, the evacuation and flood maps of the Puerto Rico Seismic Network are used (Figure 2-23 and Figure 2-29).

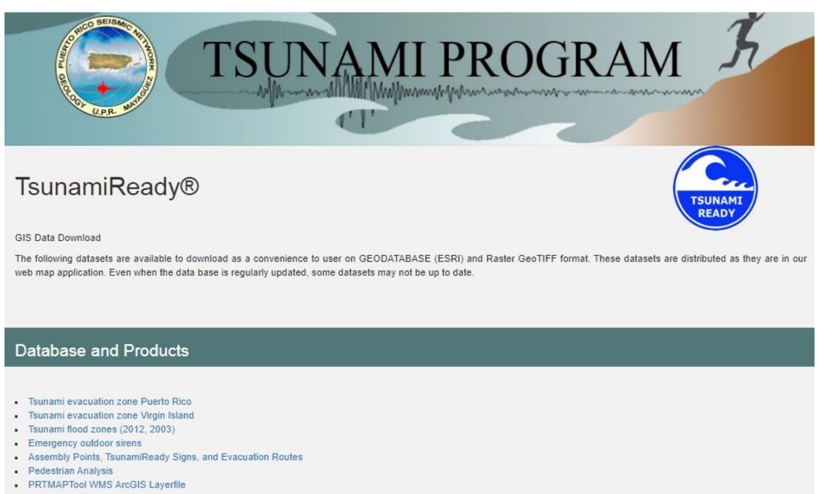


Figure 4-7 PRSN GIS Data Download

From "GIS Data Download", by Puerto Rico Seismic Network, University of Puerto Rico Mayagüez, n.d., Tsunami Program, (http://redsismica.uprm.edu/English/tsunami/tsunamiprogram/prc/gisdataenglish.php). In the public domain.

4.1.3 Walking Speeds Data

Walking speeds are acquired from the Pedestrian Evacuation Analyst. These are speeds recommended by the United States Geological Survey (USGS). The travel-speed names and corresponding values in the Pedestrian Evacuation Analyst (Figure 4-8) are: slow walk of 2.46 mph, moderate walk of 2.70 mph, fast walk of 3.40 mph and average walk of 2.50 mph. These speeds are in turn obtained by previous researchs by the Federal Highway Administration (2009) and by Wood and Schmidtlein (2011).

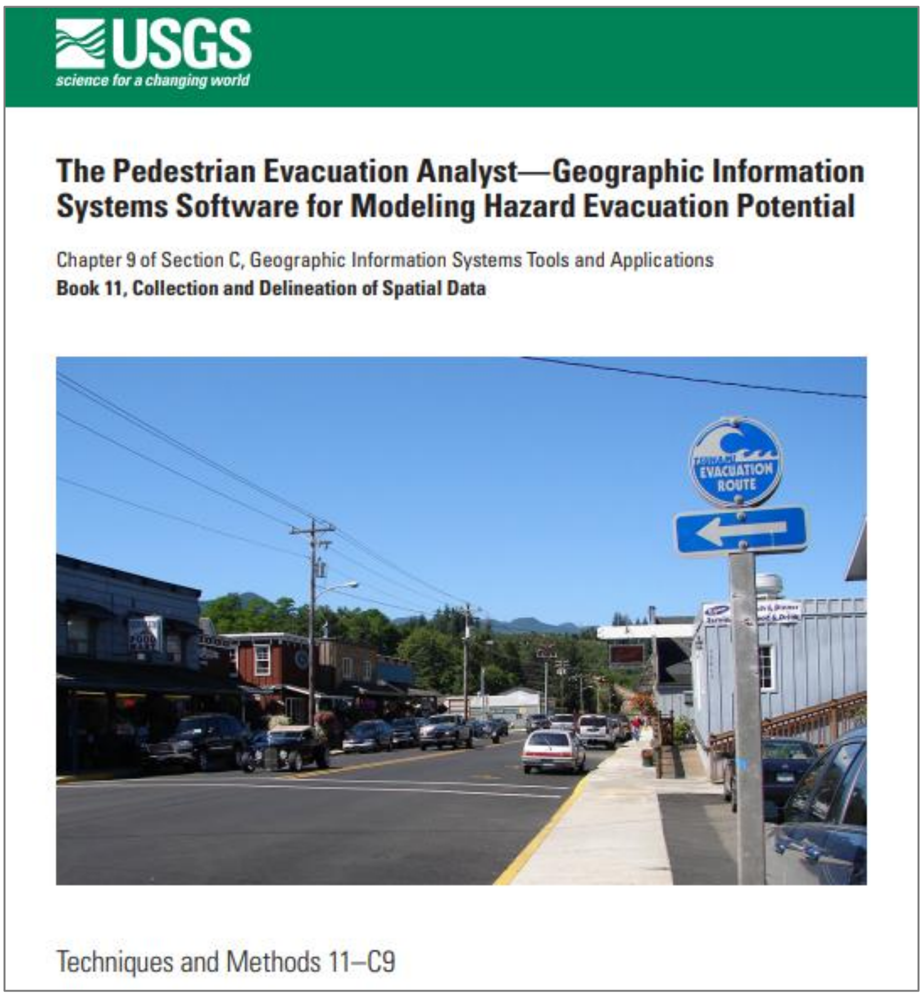


Figure 4-8 Pedestrian Evacuation Analyst (USGS)

From "The pedestrian evacuation analyst: Geographic information systems software for modeling hazard evacuation potential" by J. M. Jones, P. Ng, and N. J. Wood, 2014, Collection and delineation of spatial data, (https://doi.org/10.3133/tm11C9). Copyright 2014 by U.S. Geological Survey.

The average speed of 1.22 m/s (2.7 mph) is obtained from the Federal Highway Administration (2009). Federal Highway Administration (2009) indicates that a walking speed of up to 4 ft / s (2.7 mph) can be used to assess the adequacy of pedestrian-free time (p. 497). This recommended speed is also referenced by The High-Capacity Manual. The Literature Review in Chapter 13 of this manual describes the recommendations for a pedestrian crosswalk walking speed value of 1.2 m / s for most conditions. According to The High-Capacity Manual, these conditions may be due to environmental factors that contribute to the walking experience and, therefore, to the perception of the level of service, or the comfort, convenience, safety and economy of the walking system. In turn, comfort factors include weather protection, transit shelters, and other pedestrian amenities. Convenience factors include walking distance, slopes, sidewalk ramps, directional signs, directory maps, and other features that make positional travel easier than hassle-free. Safety is provided by separating pedestrians from vehicular traffic, or horizontally in shopping malls and other vehicle-free areas, and by the rigid use of overpasses and underpasses. Traffic control devices can provide temporary separation of pedestrian and vehicular traffic. Safety features include lighting, open sight lines, and the degree and type of street activity. The economics relate to the cost to the user associated with travel delays and inconvenience, and to the rental value of a retail development as a pedestrian-influenced environment. The recommendations in Chapter 13 are a pedestrian crossing speed of 1.0 m/s in areas with many older pedestrians. Regarding the grades and stairs, it is recommended that the walking speed be reduced by 0.1 m/s as an approximation. Despite these recommendations, the study does not indicate the assumptions regarding the conditions of the sidewalks, or the volume established to obtain the value of the speed of 1.2 m/s. For this reason, it can be assumed that the velocity is based on uniform flow.

Wood and Schmidtlein (2011) evaluate the potential for pedestrian evacuation in the Long Beach Peninsula, Washington, related to a Cascadia tsunami. In their study they show modeled travel times to safety, that is, to areas out of flooding from the pedestrian tsunami. The study assumes a constant travel speed of 1.1 m / s (2.46 mph), a distance that represents the 15th percentile of the walking speeds of a mixed population, corresponding to the slow walk of the Pedestrian Evacuation Analyst whose speed is recommended by the standards. speed when walking at crosswalks in the United States (the previously mentioned resource) (Wood and Schmidtlein, 2011, p. 280). The assumption of this speed is based on the study entitled "Field Studies of Pedestrian Walking Speed and Start-up Time", in which it was obtained that, for design purposes, the values of 1.22 m / s for young pedestrians and 0.91 m / s for older pedestrians are appropriate. These values are justified by the influence of a variety of factors such as functional classification, the volume of vehicles on the street, the width of the street, the weather conditions, the number of pedestrians crossing in a group, the length of the cycle of the signal, the timing of the various phases of the pedestrian signal, pedestrian signals, crosswalk markings, and street parking. To obtain the design speeds recommended in the study, 16 pedestrian crossings were selected at intersections controlled by 4 urban areas in (1) Richmond, Virginia; (2) Washington, D.C.; (3) Baltimore, Maryland; and (4) Buffalo, New York. The data were collected through observations during three climatic conditions: no rain (dry, with dry roads and sidewalks), with rain (wet roads) and with snow (when there was snow or ice in the atmosphere, road, or sidewalk, or both). The subjects that were studied were a group of pedestrians older than 65 years. These speeds do not specifically include the following subjects: children under 13 years of age, pedestrians with a load, pedestrians pushing strollers or grocery carts, pedestrians holding hands or helping others to cross the street, pedestrians using a vehicle of some kind. cane or crutch, people in wheelchairs, and pedestrians riding bicycles or dogs. They also do not consider the following behaviors: crossing diagonally, stopping or resting in the median, entering the road running, entering the road before starting to cross or waiting for traffic during the crossing, and entering or leaving the road more than 1.2 m (4 ft) outside the crosswalk (Knoblauch, Pietrucha, & Nitzburg, 1995).

4.1.4 Other relevant school data

Google Forms is used to obtain the other relevant data from the schools. In this, a form is developed that includes the year the school was built, the details of the evacuation plan, evacuation times obtained in previous drills, and special cases from the school. The form is made so that it can be completed by a person in charge of the school to study. In addition, it is carried out anonymously, so that the school that completes it is not known.

4.1.4.1 School Municipality

The municipality of the school is important to know since the school that completes the form is unknown. The form offers the options of the municipalities used as a case study.

4.1.4.2 Education Level

The factor of the educational level of the school appears as three alternatives: primary school, secondary school and high school. This information is necessary to know the variety of ages of the school population that could be affected by the possible tsunami event, and that would affect walking speeds.

4.1.4.3 Year Built

Information about the year of construction of the school building is associated with the design and year of the building code. That is, the year of construction corresponds to the age of the building, which in turn is directly related to design and construction practices. This form establishes exactly the age of the building at the mercy of 1987, the year in which the building codes were modified in Puerto Rico. Starting this year, Puerto Rico implemented an earthquake-proof building code as an amendment adapted to the “Reglamento de Edificación”, also “Reglamento de Planificación Núm. 7”. This amendment to Part IV of “Solidez Estructural” establishes that the design and construction of structures in Puerto Rico must be governed by technological advances regarding the risk of earthquakes (Reglamento de Edificación de PR, 1987). The school manager who completes the form has the option to select the year of construction as before or after 1987. In this way, it becomes a very important factor in assessing the vulnerability of schools. If the school was built before 1987, it means that it may not be structurally suitable for a major earthquake. On the contrary, if it was built after this year, it may not represent a risk in this regard.

4.1.4.4 Tsunami Knowledge

This information corresponds to the school's prior knowledge of a tsunami event. For example, knowledge about the risk that the school has due to its location to the event.

4.1.4.5 Evacuation Plan

The tsunami evacuation plan information has been divided into two stages. The first stage corresponds to the process of gathering the entire school campus in an internal assembly place of the school, after the tsunami alarm sounds. The second stage comprises the procedures for pedestrian mobilization of the entire school campus from the internal assembly site to the external assembly site outside the tsunami evacuation zone, in the event of a horizontal evacuation. This second stage could also consist of a vertical evacuation to raised floors of appropriate buildings. This information is extremely relevant as it establishes the principle of the general vulnerability analysis of schools.

4.1.4.6 Comments

In this section, the person completing the form may be free to provide any other important and specific information about the school that has not been offered in the questions available on the form.

The form appears in Figure 4-9, Figure 4-10, Figure 4-11, Figure 4-12, Figure 4-13 and Figure 4-14, as it appears in Google Forms, and as it was sent to schools for completion.

Vulnerability of Schools in Puerto Rico to Tsunami Events

This form was created for the research project entitled "The Vulnerability of Schools in Puerto Rico to Tsunami Events" at the Polytechnic University of Puerto Rico. The study aims to make an analysis of the vulnerability of schools, identifying those that are in tsunami evacuation zones, evacuation trajectories, the condition of these routes and other factors that may impact the evacuation time. With these objectives in mind, the purpose of this form is to collect relevant data from public schools that are in the tsunami evacuation zone. This data will be used for strictly academic purposes.

The tsunami evacuation or evacuation plan has been divided into two stages. The first stage corresponds to the process of gathering the entire school campus in an internal assembly place of the school, after the tsunami alarm sounds. The second stage comprises the procedures for pedestrian mobilization of the entire school campus from the internal assembly site to the external assembly site outside the tsunami evacuation zone, in the case of a horizontal evacuation. This second stage could also consist of a vertical evacuation to raised floors of appropriate buildings.

We hope that this study can contribute to identify areas of opportunity to improve evacuation processes and propose alternatives for it.

We appreciate your collaboration.

* Mandatory

1. Municipality *

Mark only one oval.

- Catano
- San Juan

2. Please indicate the educational level of the school. (Select all that apply).*

Select all that apply.

- Primary school
- High school
- High school

Figure 4-9 Schools Form on Google Form - Part I

3. When was your school built? *

Mark only one oval.

- Before 1987
- After 1987

4. Have you been oriented about the tsunami hazard for your school? *

Mark only one oval.

- Yes
- No

5. Have you received any training or lectures on tsunami preparedness at your school? *

Mark only one oval.

- Yes
- No

6. Does your school have a tsunami evacuation plan? *

Mark only one oval.

- Yes
- No

7. Has the tsunami warning system at your school been clearly audible? *

Mark only one oval.

- Yes
- No

Figure 4-10 Schools Form on Google Form - Part II

8. Do you have a student with a physical disability? If so, have you developed special evacuation plans for this population?*

Mark only one oval.

- There are students with physical disabilities in the school, and special eviction procedures have been developed for this population.
- There are students with physical disabilities in the school, and no special evacuation procedures have been developed for this population.
- There are no students with physical disabilities in the school, and special eviction procedures have been developed for this population.
- There are no students with physical disabilities in the school, and no special evacuation procedures have been developed for this population.

9. Have you practiced the first stage of the tsunami evacuation plan at your school? (Drill mobilizing the entire school campus to the internal assembly site).*

Mark only one oval.

- Yes
- No

10. Please indicate how often you have practiced this first stage of the evacuation plan at your school (Drill). *

Mark only one oval.

- It has never been practiced
- Once every two years
- Once a year
- Twice a year
- Others: ______________________

11. What is the name of the internal assembly place, indicated for your school? (The name of the safe area or assembly point within the school to go to in the event of a tsunami alarm, as the first stage of the evacuation plan). If you do not have an evacuation plan, answer N / A.*

____

Figure 4-11 Schools Form on Google Form - Part III

12. If you have practiced the eviction plan, what has been the total time in this first stage in minutes? (The time elapsed from when the tsunami warning alarm sounds until the entire school population arrives at the internal assembly place). If you have not practiced an evacuation plan, answer 0.*

Example: 4:03:32 (4 hours, 3 minutes, 32 seconds)

13. What is the name of the outside assembly location indicated for your school? (The name of the safe zone or assembly point outside the school, and outside the tsunami danger zone, to go to in case of a tsunami alarm, in the second stage of the evacuation plan).
If you do not have or know of an assembly place indicated in the evacuation plan, answer I do not know. *

14. Have you practiced the second stage of the tsunami evacuation plan at your school? (Drill walking with the entire campus to the external assembly site).*

Mark only one oval.

- Yes
- No

15. Please indicate how often you have practiced this second stage of the evacuation plan at your school (drill). *

Mark only one oval.

- It has never been practiced
- Once every two years
- Once a year
- Twice a year
- Others: ______

Figure 4-12 Schools Form on Google Form - Part IV

16. If you have practiced the eviction plan, what was the total time for this second stage in minutes? (The time elapsed since the eviction begins until the entire school population reaches the external assembly place). If you have not practiced an evacuation plan, answer 0.*

Example: 4:03:32 (4 hours, 3 minutes, 32 seconds)

17. Does your school have a vertical eviction plan? (An evacuation plan targeting upper floors of the building, high enough to raise the evacuated population above the tsunami flood elevation.)*

Mark only one oval.

- Yes
- No

18. If you have a vertical evacuation plan, indicate which building would be used for this purpose.

Mark only one oval.

- The same building as the school campus
- Others: ____________________

19. If you have practiced the vertical evacuation plan, what was the total time for this stage in minutes? (The time elapsed from the start of the vertical evacuation until the entire school population reaches the raised floors predetermined in the plan).

Example: 4:03:32 (4 hours, 3 minutes, 32 seconds)

Figure 4-13 Schools Form on Google Form - Part V

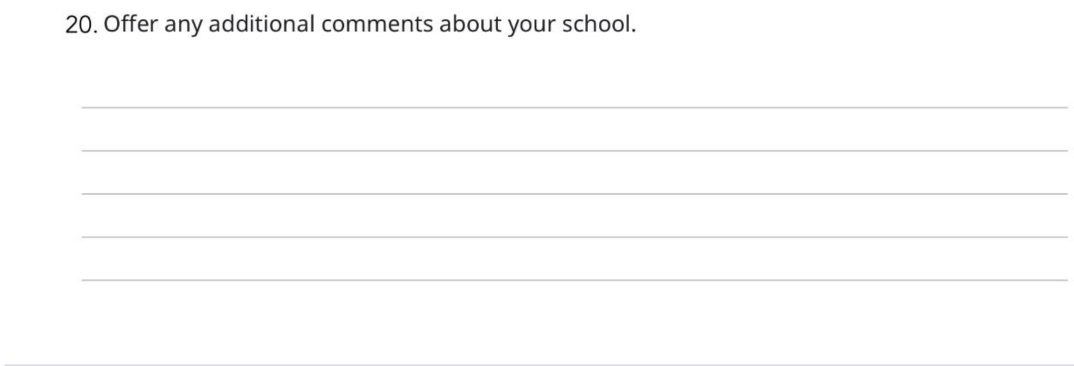

20. Offer any additional comments about your school.

Figure 4-14 Schools Form on Google Form - Part VI

4.2 Data Processing

The way in which each of the data is used is detailed below. The resources used to work the data are presented and explained. Most of these media are software that allow data processing and development to be efficient. Each of them is used as a reference. Some of the data is put together and completed to form the process.

4.2.1 Schools and Tsunami Data

All data obtained and downloaded from schools and possible tsunami events in Puerto Rico are published as layers in ArcGIS Online. ArcGIS Online is a geographic information system for interactively working with maps and geolocating data. This allows to analyze, visualize, and explore the data under study through the creation of maps.

Layers are published within the ArcGIS Online organization with all required account creation and publishing permissions. The steps to publish a layer are the following:

1. Access to ArcGIS Online.

2. Open “My Content” and then to “Add Item” (Figure 4-15).

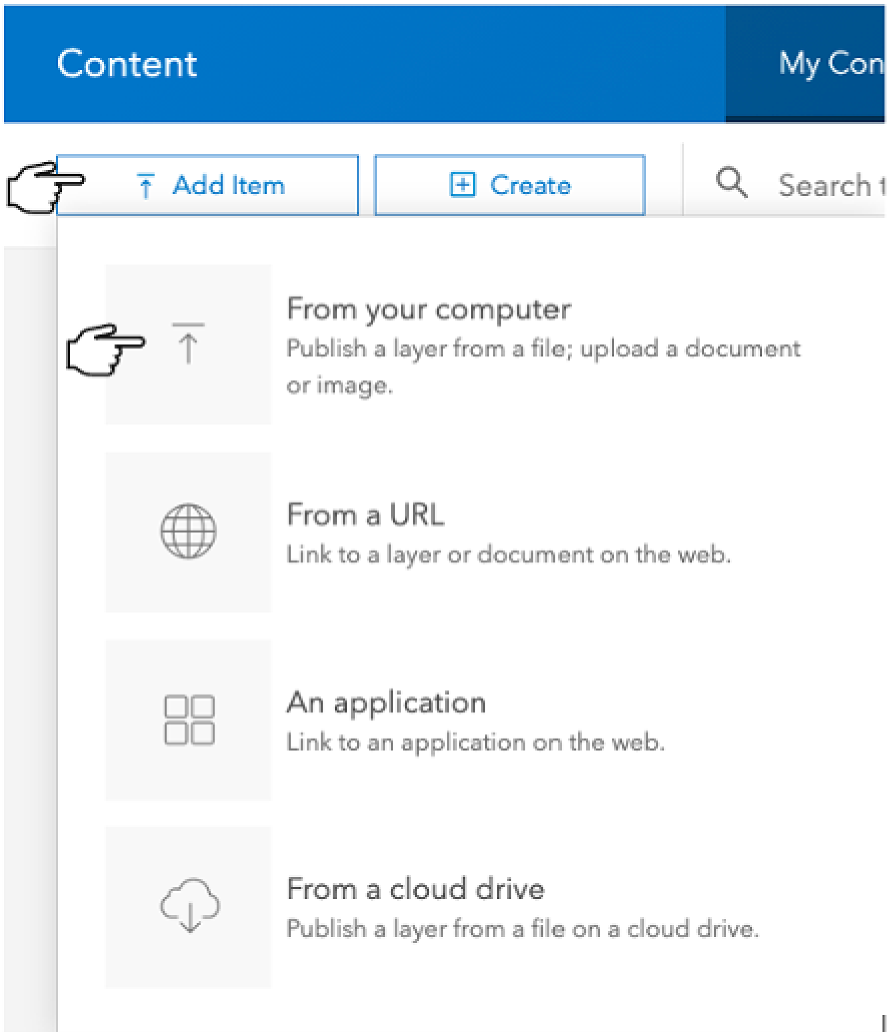


Figure 4-15 Item addition step from computer in ArcGIS Online

3. Select "From my Computer" to add a downloaded item of the PRSN data set from the file (Figure 4-16).

4. Select the type of file and the "hosted as feature layer" to publish the layer (Figure 4-16).

5. Place a title and add item identification tags to facilitate the search for the layer when applying it to a map (Figure 4-16).

6. The item is added to the account (Figure 4-16).

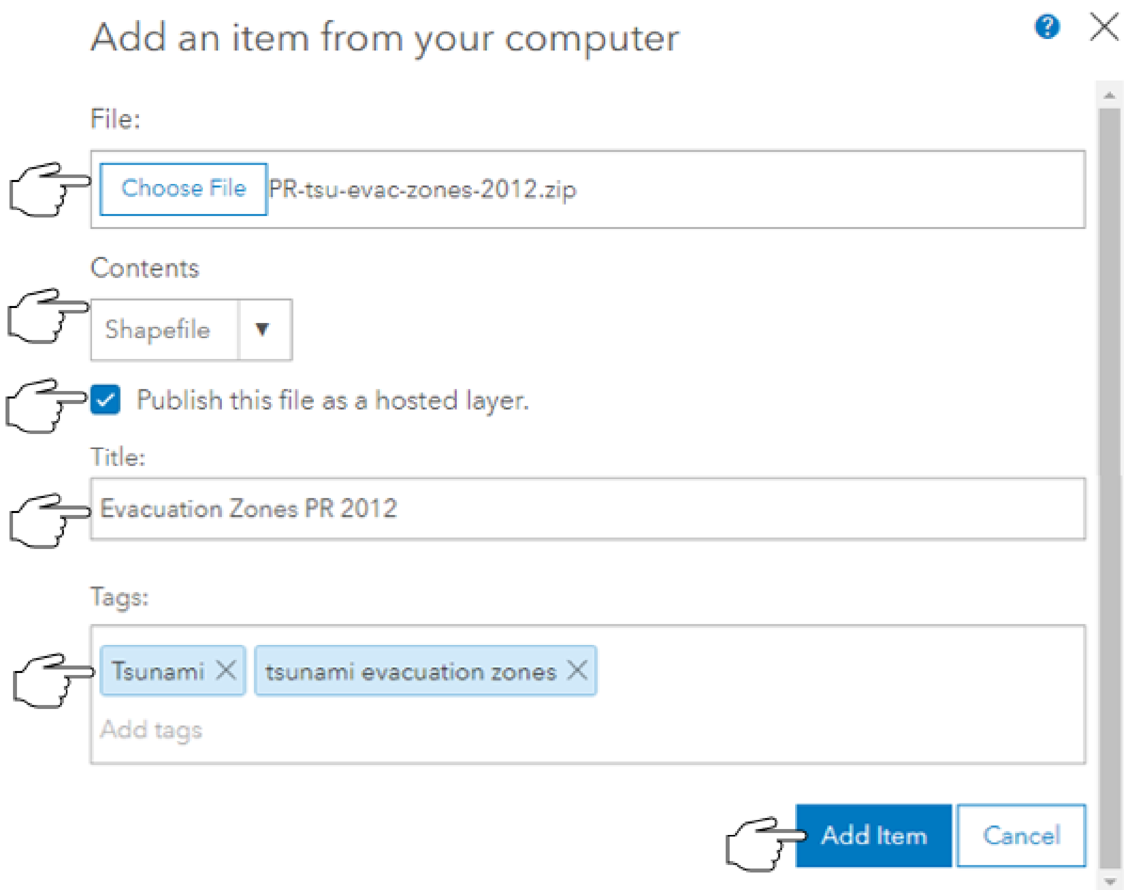


Figure 4-16 Layer publishing step in ArcGIS Online

The layers that are created are those of the tsunami evacuation and flood zones, sirens, assembly areas and evacuation signals, and evacuation routes. These layers are represented in the Map Viewer or added directly in the creation of a map in ArcGIS Online (Figure 4-17).

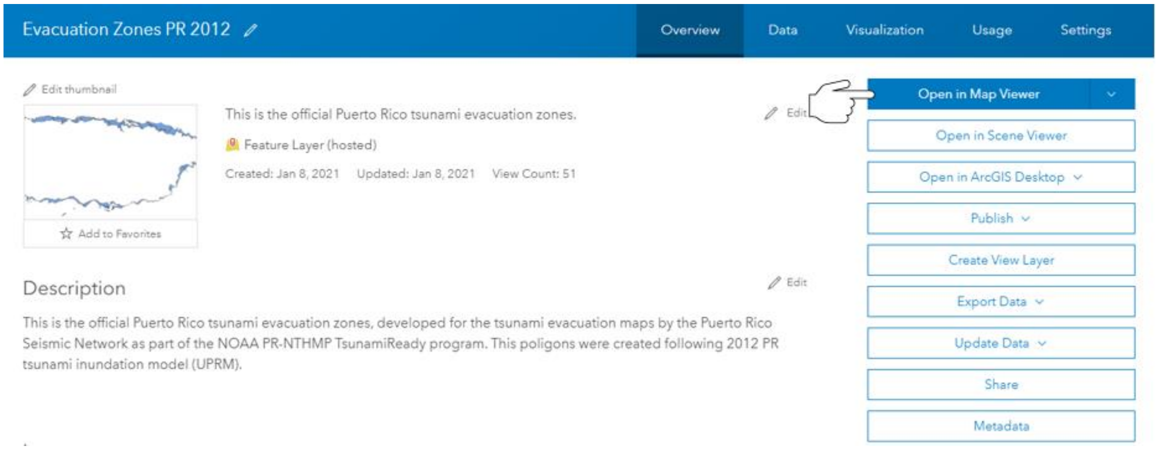


Figure 4-17 Layer display step in ArcGIS Online

These are added to a Web Map to visualize them all together and thus determine the vulnerability of the schools. The Web Map is an interactive display of geographic information used to recreate scenarios and answer possible questions.

The Web Map used in the next chapter to represent the findings by municipality contains an imaginery basemap and a set of data layers (Figure 4-18). The layers that make up the map are (Figure 4-20): public schools, assembly places, evacuation route sign, sirens, evacuation zones, flood zones, municipality boundaries and roads. In Figure 4-19 the layers added to the municipality of San Juan are displayed.

Figure 4-18 Schools in Puerto Rico in Tsunami Hazard Zones Web Map

Figure 4-19 Evacuation Web Map with Schools of San Juan, Puerto Rico

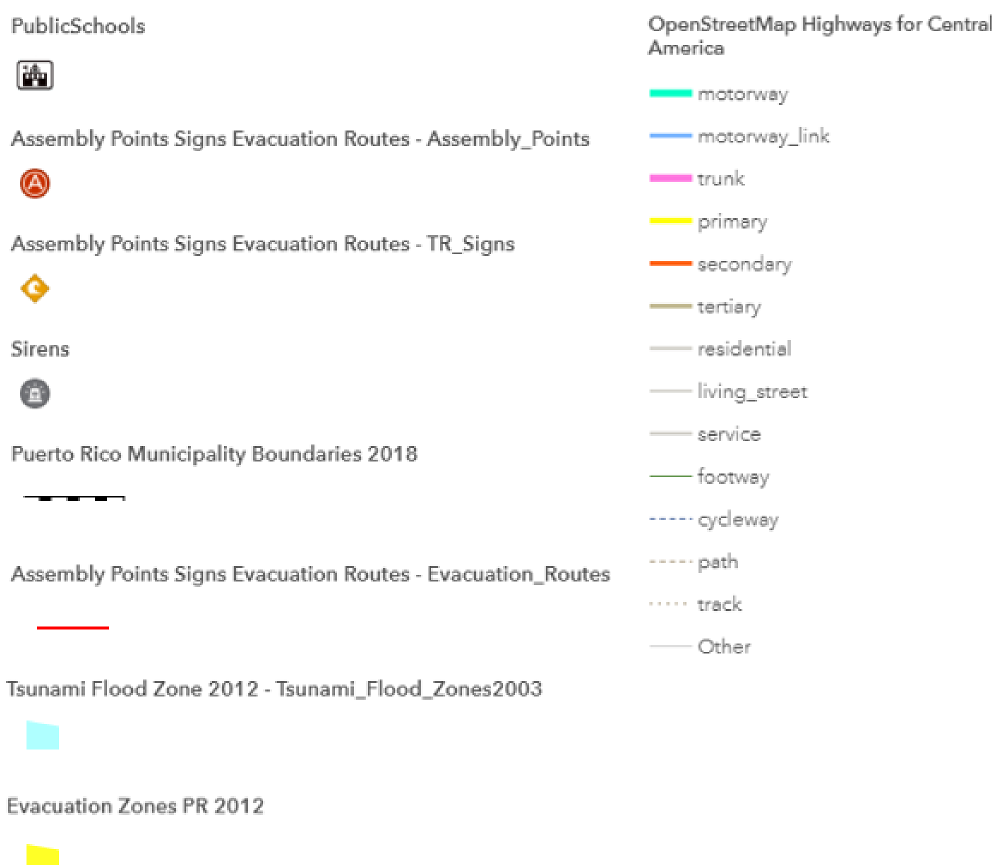


Figure 4-20 Legend of Schools in Puerto Rico in Tsunami Hazard Zones Web Map

4.2.2 Evacuation Routes

The Pedestrian Evacuation Analyst walking speeds are used as the primary parameter for evacuation routes from schools. The Plot A Route (Figure 4-21) resource is used to draw the routes corresponding to those that will later be evacuation routes. This is an accurate route mapping tool that makes route planning and measurement easy (plotaroute.com, n.d.).

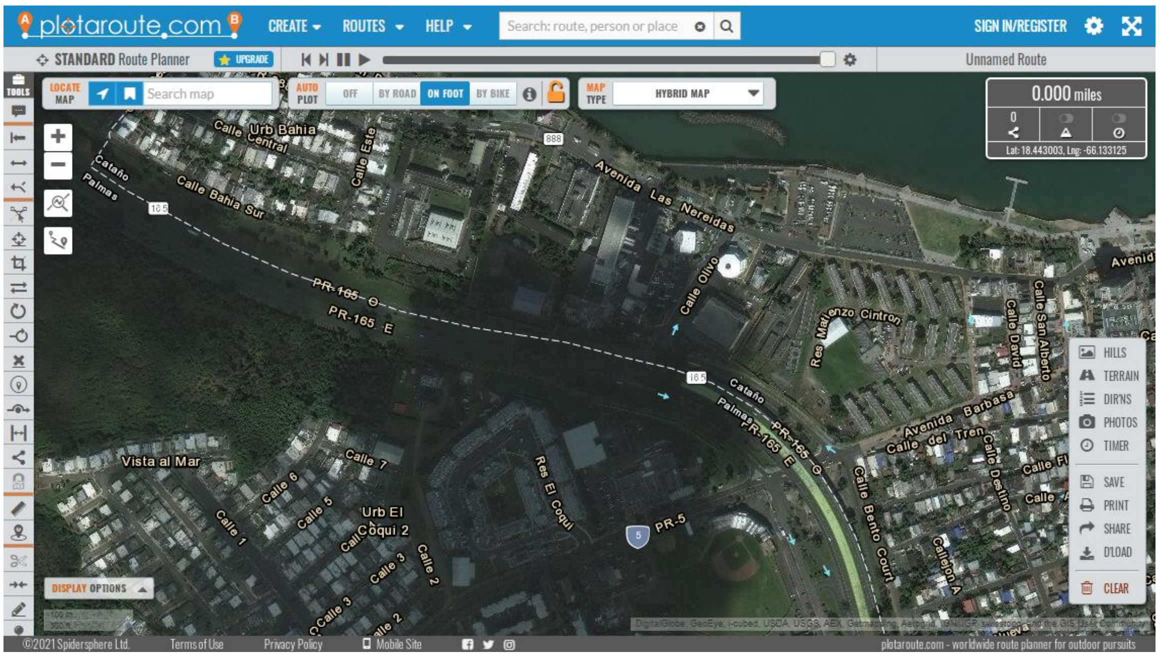


Figure 4-21 Plot A Route Display

From "Free route planner for outdoor pursuits" by Plot A Route, n.d., plotaroute.com, (https://www.plotaroute.com/routeplanner). Copyright 2021 by Spidersphere Ltd.

Plot A Route allows to draw a route and to measure the distance of a run, walk or cycle. However, for this study only the tracing and measuring tool of a walk is used, that is, on foot as shown in Figure 4-22. Before tracing the route, the option "On Foot" must be selected to consider walking the route on foot.

Figure 4-22 Plot A Route with "On Foot Selection"

In this resource the entry and exit point is located by means of the locater map with the use of the data of the schools and the places of assembly. This locator (Figure 4-23) requires the physical address or the coordinates of both points to locate them on the map. The departure point has a symbol with a letter A while the point of arrival has a symbol with the letter B (Figure 4-24).

Figure 4-23 Locator in Plot A Route

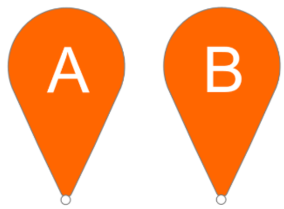


Figure 4-24 Route Departure and Arrival Symbols in Plot A Route

Once the route has been plotted, this resource displays a box in the upper right corner of the map with the distance of the route in miles and the time of the route in hours minutes and seconds, as shown in Figure 4-25.

Figure 4-25 Distance and Time of the Route in Plot A Route

The time of the route offered by the resource is equivalent to the evacuation time to be evaluated. This time is a function of walking speed in miles per hour. The speed is changed by an interactive bar (Figure 4-27) that appears by pressing the "TIMER" icon on route timer of Plot A Route (Figure 4-26).

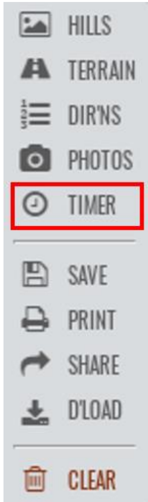


Figure 4-26 Route Timer in Plot A Route

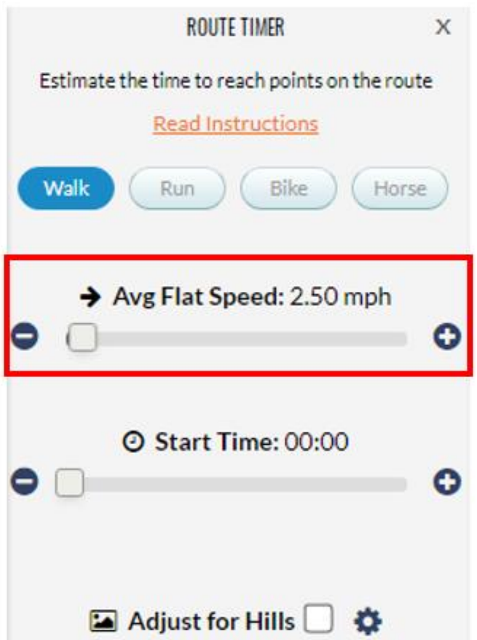


Figure 4-27 Walking Speed Change in Route Timer in Plot A Route

A variety of map types are also available in Plot A Route (Figure 4-28). These base maps could be street map, terrain map, satellite map, hybrid map, trails map, cycle map, transport map, world topo map, USGS topo map, among others. This selection icon is at the top center of the map.

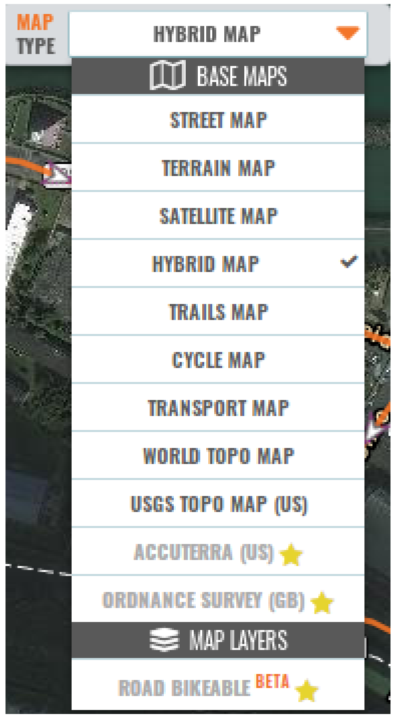


Figure 4-28 Base Maps in Plot A Route

Once all the necessary elements for the evacuation route are selected on the map, it is displayed in Figure 4-29. In this case, an example is presented for one of the schools to be evaluated later. This school is Francisco Oller at Cataño.

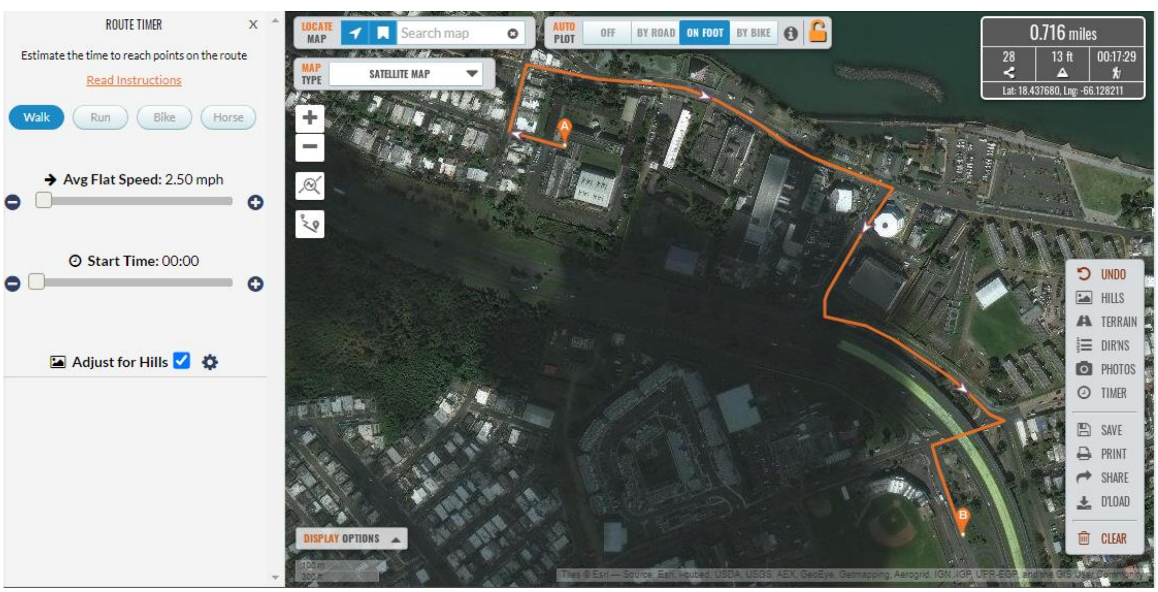


Figure 4-29 Example of Route of Francisco Oller at Cataño in Plot A Route

With the route already drawn in Plot A Route, the conditions of the sidewalks of the route are evaluated using Google Earth Pro. The route is downloaded from Plot A Route with the “D’load” icon (Figure 4-30). When pressing this icon, a box immediately appears in which the file type is selected, the file format in KML to be able to add it to Google Earth Pro and the name of the route. Then, the “Download” icon is pressed to obtain the path (Figure 4-31).

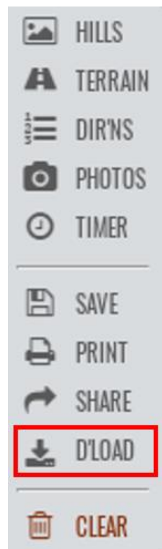


Figure 4-30 Download Tool in Plot A Route

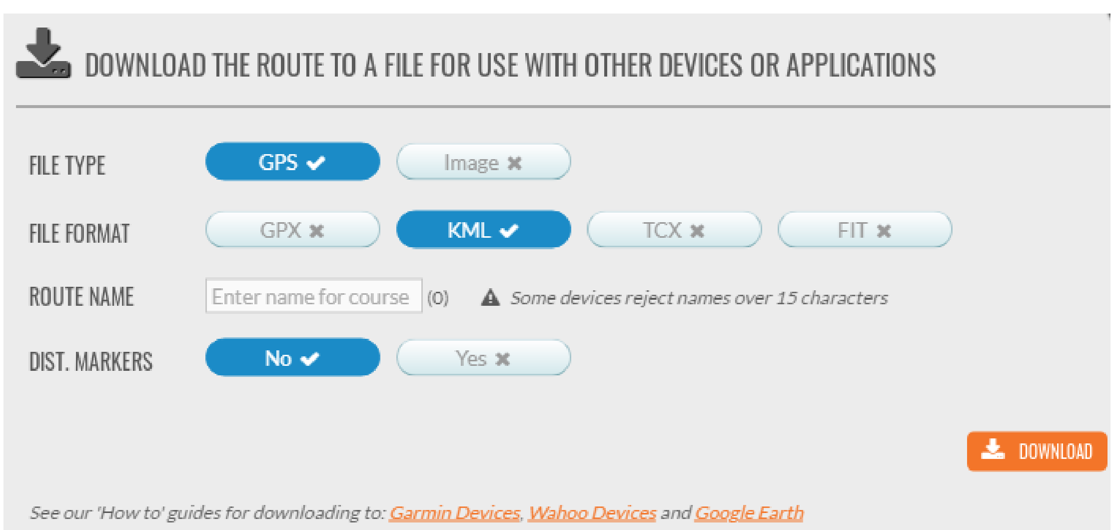


Figure 4-31 Step of how to download the route in Plot A Route

The evacuation route downloaded from Plot A Rout is embedded or added to Google Earth to assess sidewalk conditions using the Street View feature. This tool allows you to take a 360˚ view of the map and all the surroundings of the route and school that are evaluated. To add this downloaded route, it is necessary to have it saved as KML since it is the type of format acceptable for Google Earth Pro. The following steps are carried out:

1. Access Google Earth Pro.
2. Go to "File" and select "Import" (Figure 4-32).
3. Select the saved route from Plot A Route and insert it.

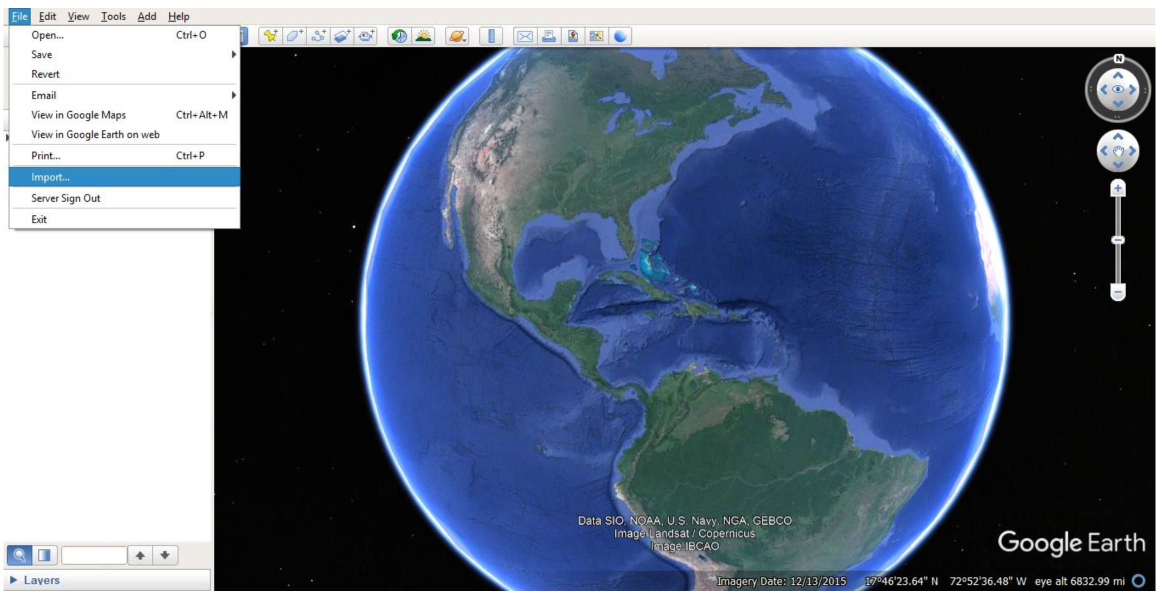


Figure 4-32 Step of Importing the Route to Google Earth

After having the route added, the rest of the information layers obtained from the previous resources are added with the same steps followed to add the route to the map. By incorporating all the data into Google Earth Pro, the evacuation routes can be better visualized as shown in Figure 4-33. Figure 4-34 shows the legend of all the signs that appear on the map in Google Earth Pro.

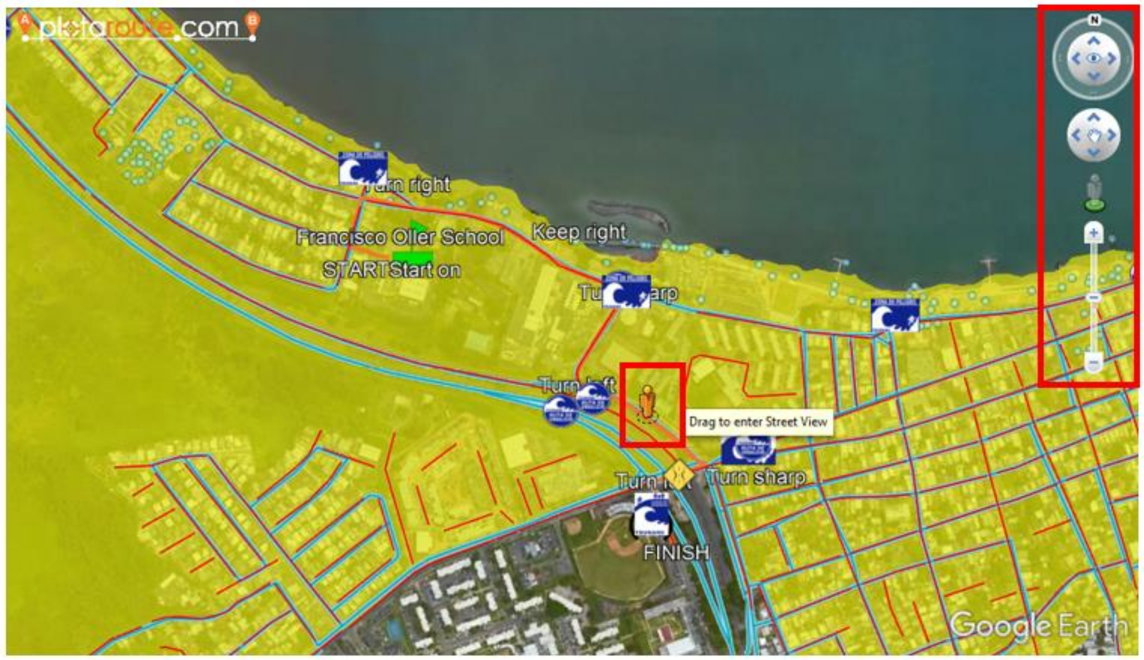


Figure 4-33 Visualization of the Map with the Route in Google Earth Pro

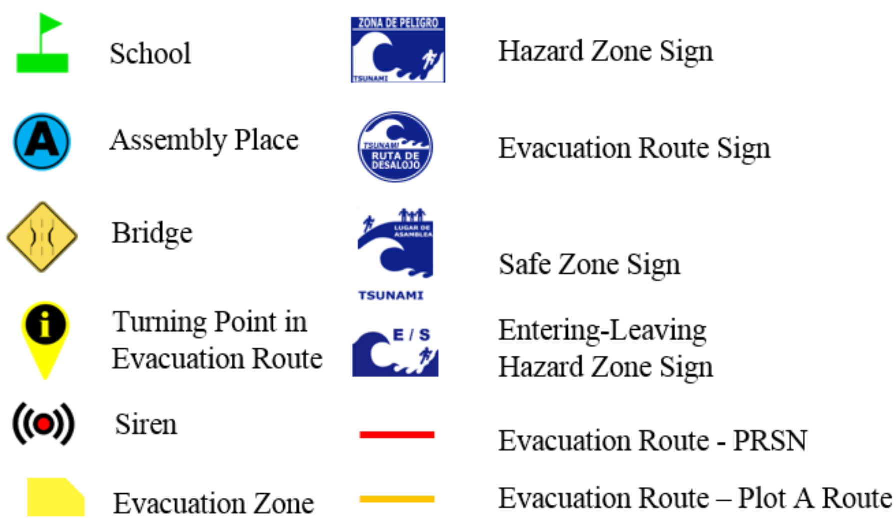


Figure 4-34 Map Legend with Route in Google Earth Pro

The way the route is traversed in Google Earth is through Street View. As shown in Figure 4-33, the icon of the person moves along the route, once the determined path is selected, the interactive view is displayed as in Figure 4-35.

Figure 4-35 Visualization of the Street Map in Google Earth Pro

5 Analysis and Results Interpretation

This chapter presents the identification of schools in a tsunami hazard zone, the selection of the case study, and a summary of the findings.

5.1 Hazard Identification

Below is the identification of the schools that are in tsunami danger zones for each municipality that has the maps of flooding and tsunami evacuation of the Model 2012 of the Puerto Rico Seismic Network. The data of the schools correspond to the year 2010. A table was made for each municipality which had school inside a tsunami danger zone. The table includes the name of the school, number of students, teacher and the total of students and teacher in the schools, and if the school is used as voting center

5.1.1 Aguada

In this municipality there are a total of 18 schools, of which 3 are in a tsunami hazard zone according to evacuation maps as shown in Figure 5-1 and Figure 5-2

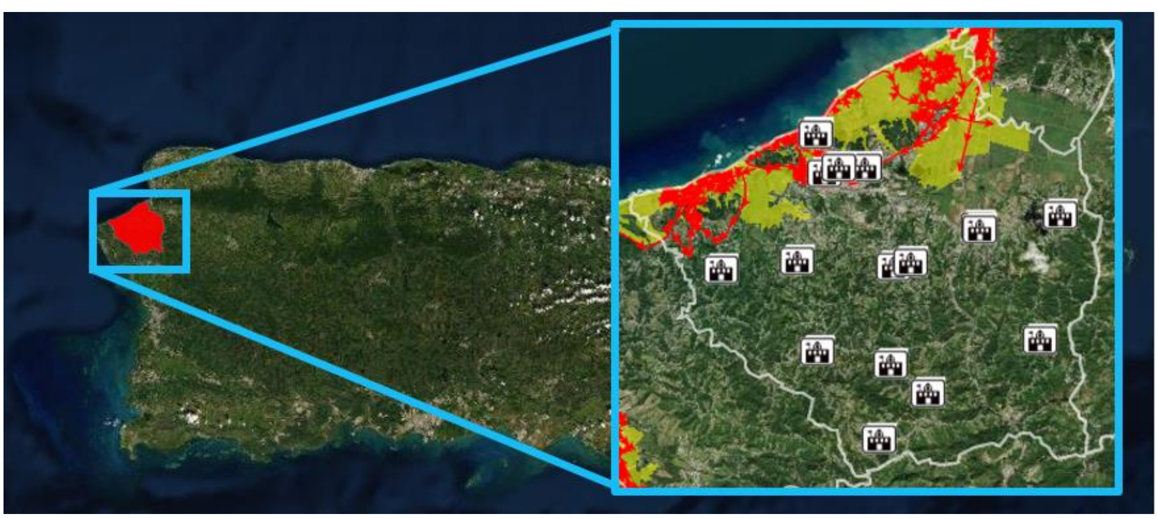


Figure 5-1 Location of Schools in Aguada

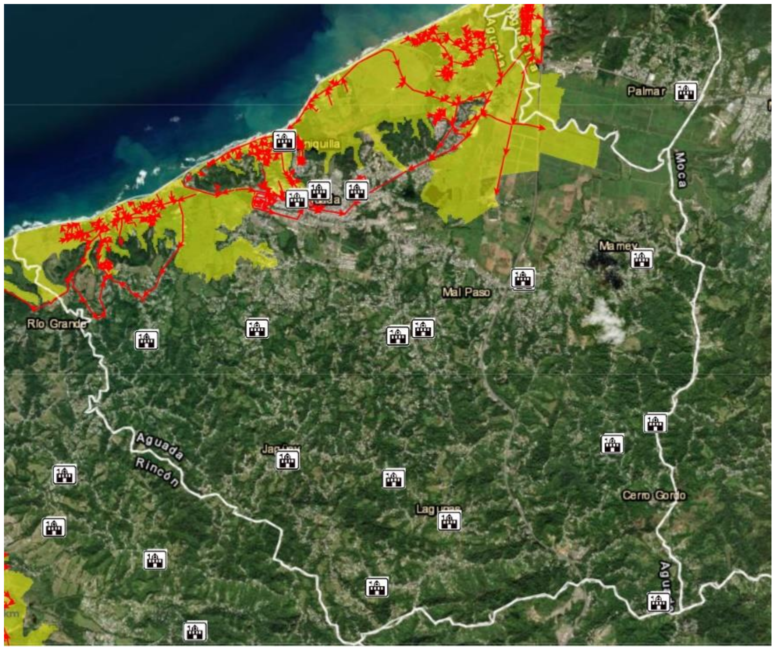


Figure 5-2 Location of Schools in Aguada [Zoom]

The schools in danger (Figure 5-3) are: Arsenio Martinez with a population of 578 people, Dr. Carlos González with a population of 879 people and Eugenio González González which is already permanently closed. The total population that could be affected by the impact of a tsunami in the municipality of Aguada is 1,457 people. This information is summarized in Table 5-1.

Figure 5-3 Schools located in tsunami hazard zones in Aguada

Table 5-1 shows the schools in the tsunami hazard zone for the municipality of Aguada. Of the total number of schools, one is used as a voting center and none as a refuge.

Table 5-1 Summary of schools in tsunami hazard in Aguada

Schools	Students	Teachers	Population	Voting Center	Refuge
Arsenio Martínez	543	35	578	No	No
Dr. Carlos González	832	47	879	Yes	No
Eugenio González González	0	0	0 (close)	No	No
Total			1457	1	0

5.1.2 Aguadilla

There are 22 schools in this municipality (Figure 5-4). Out of all of them only 3 are in a tsunami danger zone according to evacuation maps. The schools in danger are as shown in Figure 5-5 are: Dr. Agustín Stahl with a population of 138 students, Eladio J. Vega with a population of 122 students, and José De Diego with a population of 259 people.

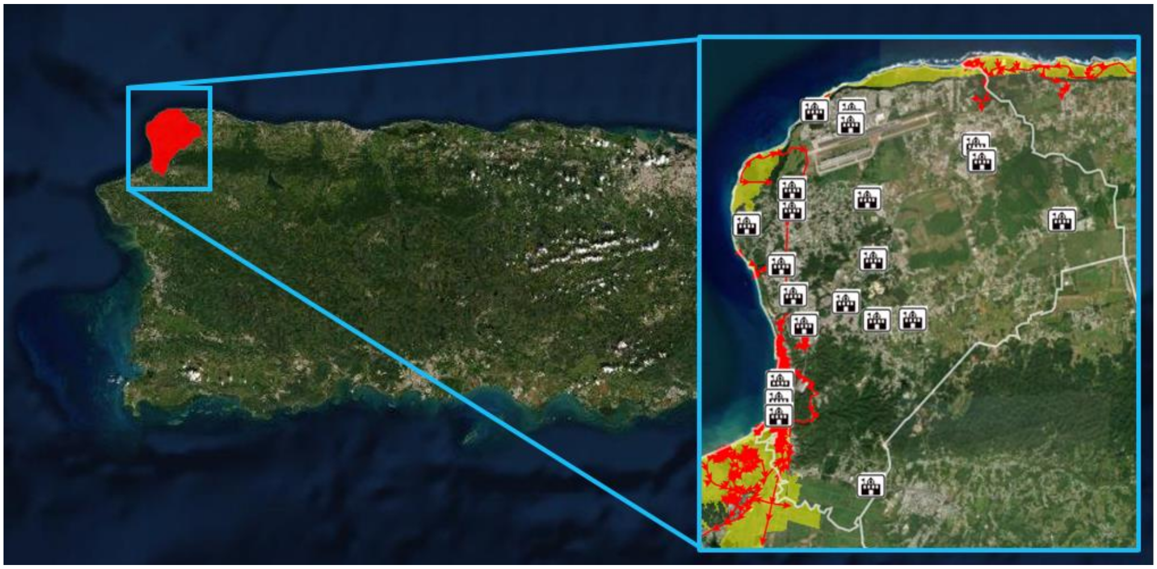


Figure 5-4 Location of Schools in Aguadilla

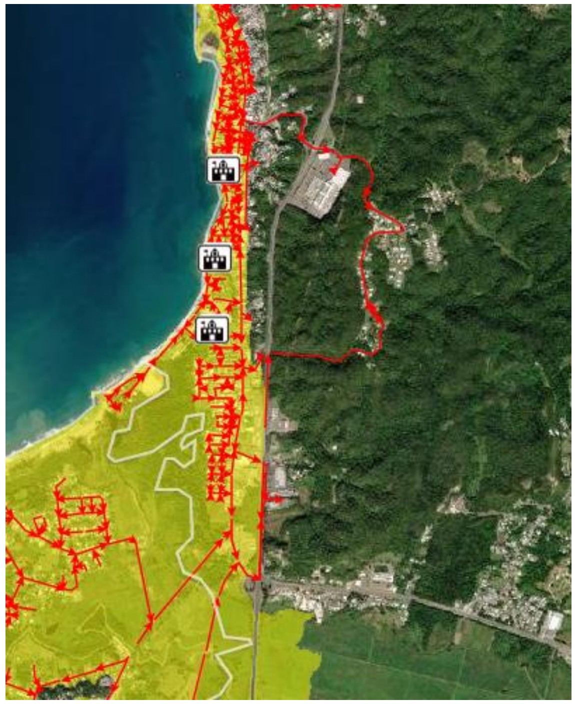


Figure 5-5 Schools located in tsunami hazard zones in Aguadilla

As shown in Table 5-2, for this municipality, the total population that could be affected by the impact of a tsunami is 519 people, of which one is used as a refuge and none as a voting center.

Table 5-2 Summary of schools in tsunami hazard in Aguadilla

Schools	Students	Teachers	Population	Voting Center	Refuge
Dr. Agustin Stahl	124	14	138	No	No
Eladio J. Vega	110	12	122	No	No
José De Diego	242	17	259	Yes	No
Total			519	1	0

5.1.3 Añasco

In this municipality there are 10 schools (Figure 5-6). Out of all the schools only one is in a tsunami hazard zone according to evacuation maps (Figure 5-7). The school in danger is Su Playa, which is already permanently closed, therefore, no school population in Añasco could be affected by the impact of a tsunami (Table 5-3). So, no school is used in addition to education.

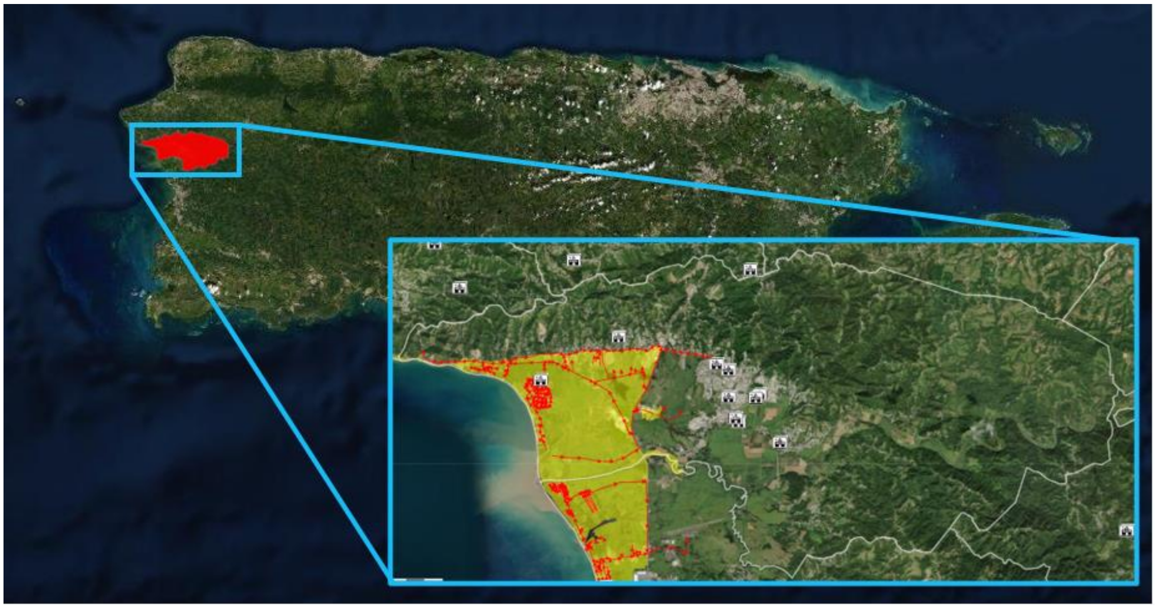


Figure 5-6 Location of Schools in Añasco

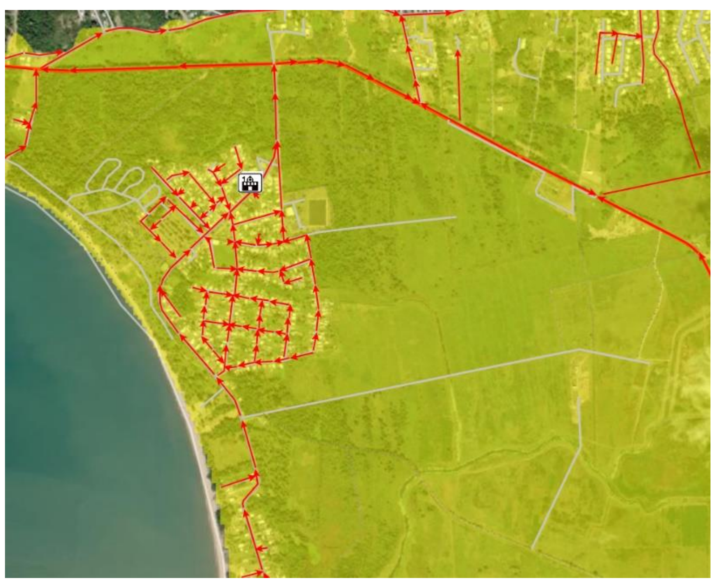


Figure 5-7 Schools located in tsunami hazard zones in Añasco

Table 5-3 Summary of schools in tsunami hazard in Añasco

Schools	Students	Teachers	Population	Voting Center	Refuge

Su Playa	0	0	0	No	No
Total			0	0	0

5.1.4 Arecibo

This municipality has 24 schools, of which only one is in a tsunami hazard zone. All schools are shown located in Figure 5-8 and Figure 5-9. While Figure 5-10 presents in Zoom the only school in danger.

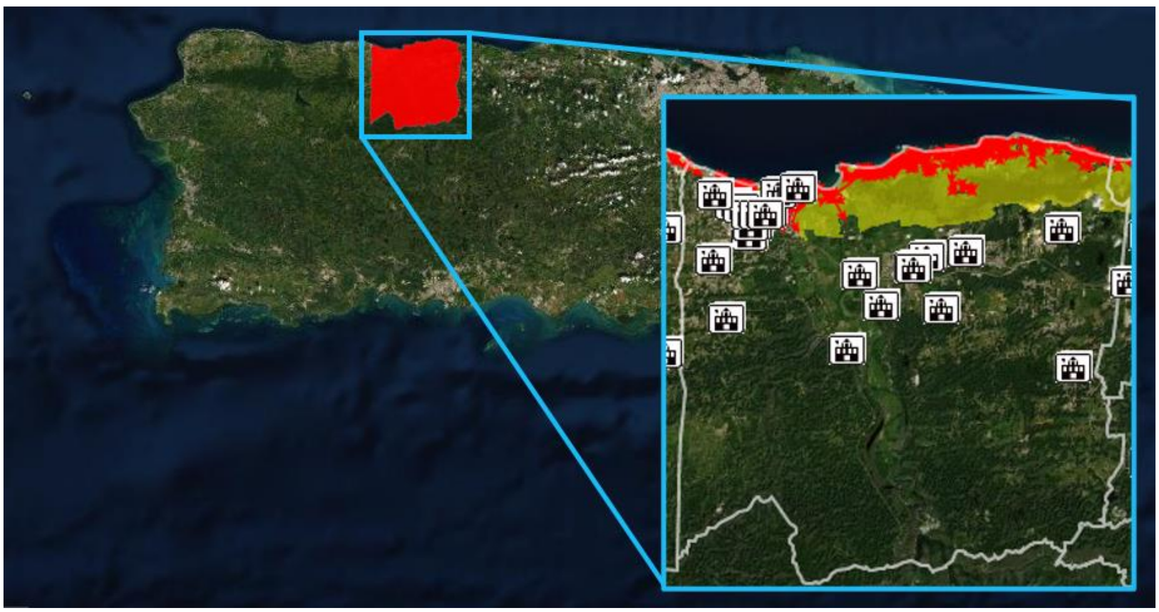


Figure 5-8 Location of Schools in Arecibo

Figure 5-9 Schools located in tsunami hazard zones in Arecibo

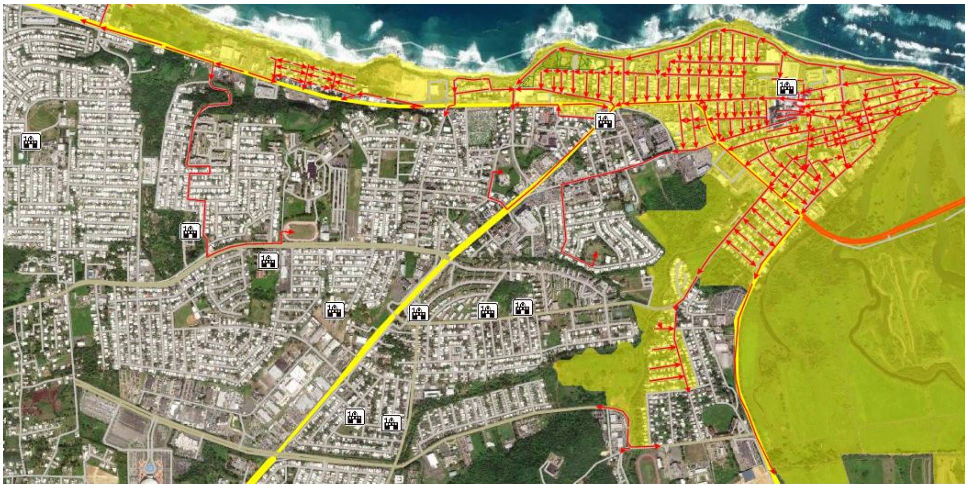


Figure 5-10 Schools located in tsunami hazard zones in Arecibo [Zoom]

The school in danger is the Escuela Libre De Música (Especializada) with a population of 97 people. Therefore, the total school population that could be affected by a tsunami for this municipality is 97 people. Also, this school is not used as a polling station or refuge (Table 5-4).

Table 5-4 Summary of schools in tsunami hazard in Arecibo

Schools	Students	Teachers	Population	Voting Center	Refuge
Escuela Libre De Música (Especializada)	78	19	97	No	No
Total			97	0	0

5.1.5 Arroyo

In this municipality there are 8 schools (Figure 5-11) and none of them are located in a tsunami hazard zone. This means that no school population in Arroyo could be affected by the impact of a tsunami. For this reason, for this municipality there is no table that summarizes the data of schools in hazard zone. However, Figure 5-12 and Figure 5-13 shows that there are only schools outside the tsunami hazard zone.

Figure 5-11 Location of Schools in Arroyo

Figure 5-12 Schools located outside the tsunami hazard zones in Arroyo

Figure 5-13 Schools located outside the tsunami hazard zones in Arroyo [Zoom]

5.1.6 Barceloneta

This municipality has a total of 9 schools (Figure 5-14) and none of them are in a tsunami hazard zone. Therefore, no school population in Barceloneta could be affected by the impact of a tsunami ash shown in Figure 5-15 and Figure 5-16. Because there are no schools in the hazard zone, a table with the data for the schools is not presented.

Figure 5-14 Location of Schools in Barceloneta

Figure 5-15 Schools located outside the tsunami hazard zones in Barceloneta

Figure 5-16 Schools located outside the tsunami hazard zones in Barceloneta [Zoom]

5.1.7 Bayamón

In this municipality there are a total of 56 schools as shown in Figure 5-17. No schools are in a tsunami danger zone (Figure 5-18). This means that no school population in Bayamón could be affected by the impact of a tsunami and that none has a use other than school.

Figure 5-17 Location of Schools in Bayamón

Figure 5-18 Schools located outside the tsunami hazard zones in Bayamón

5.1.8 Cabo Rojo

In this municipality there are 3 schools that are in a tsunami hazard zone out of 15 schools (Figure 5-19). Figure 5-20, Figure 5-21, Figure 5-22 and Figure 5-23 presents Zoom images of the west central area of the municipality. Figure 5-24 presents the northwest in Zoom with the schools in danger zone. While Figure 5-25 shows the danger zone in Zoom of the southwest of the municipality with the school in danger.

Figure 5-19 Location of Schools in Cabo Rojo

Figure 5-20 Schools located in tsunami hazard zones in Cabo Rojo [Zoom]

Figure 5-21 Schools located in tsunami hazard zones in Cabo Rojo [Zoom]

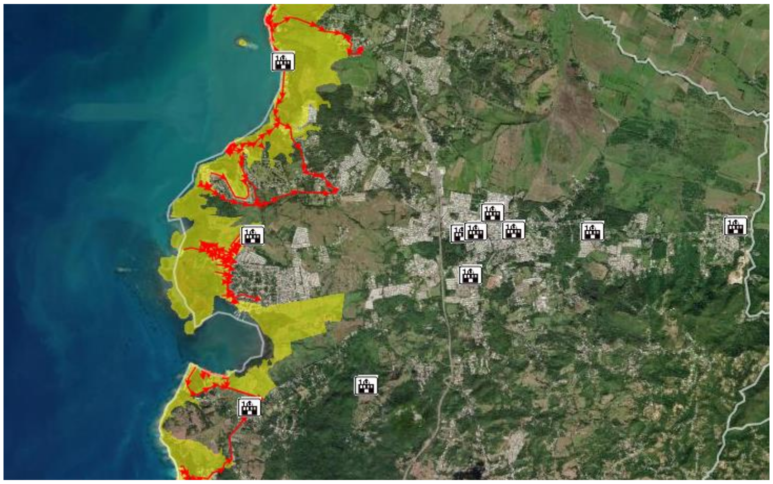


Figure 5-22 Schools located in tsunami hazard zones in Cabo Rojo

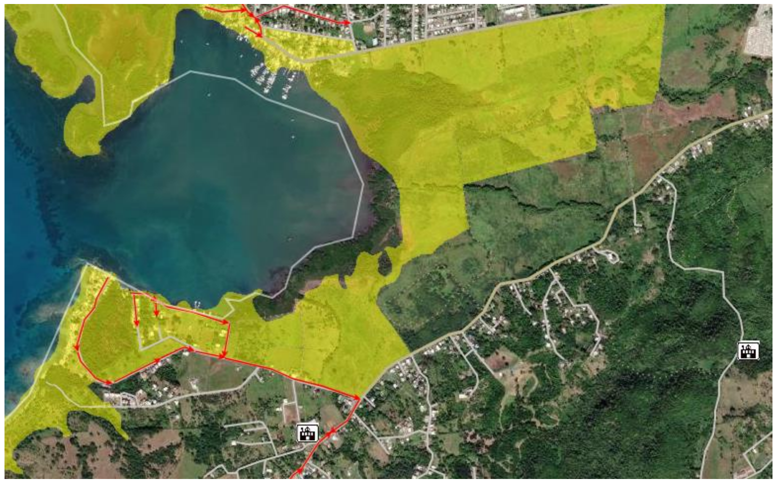


Figure 5-23 Schools located outside the tsunami hazard zones in Cabo Rojo [Zoom]

Figure 5-24 Schools located in tsunami hazard zones in Cabo Rojo [Zoom]

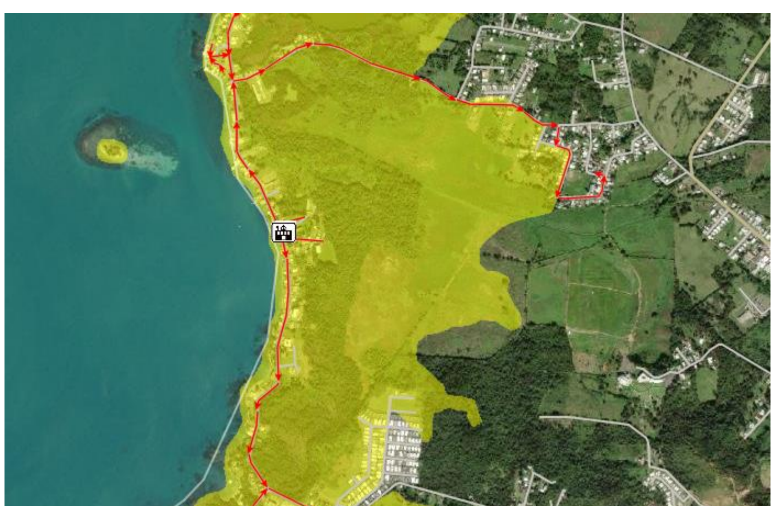


Figure 5-25 Schools located in tsunami hazard zones in Cabo Rojo [Zoom]

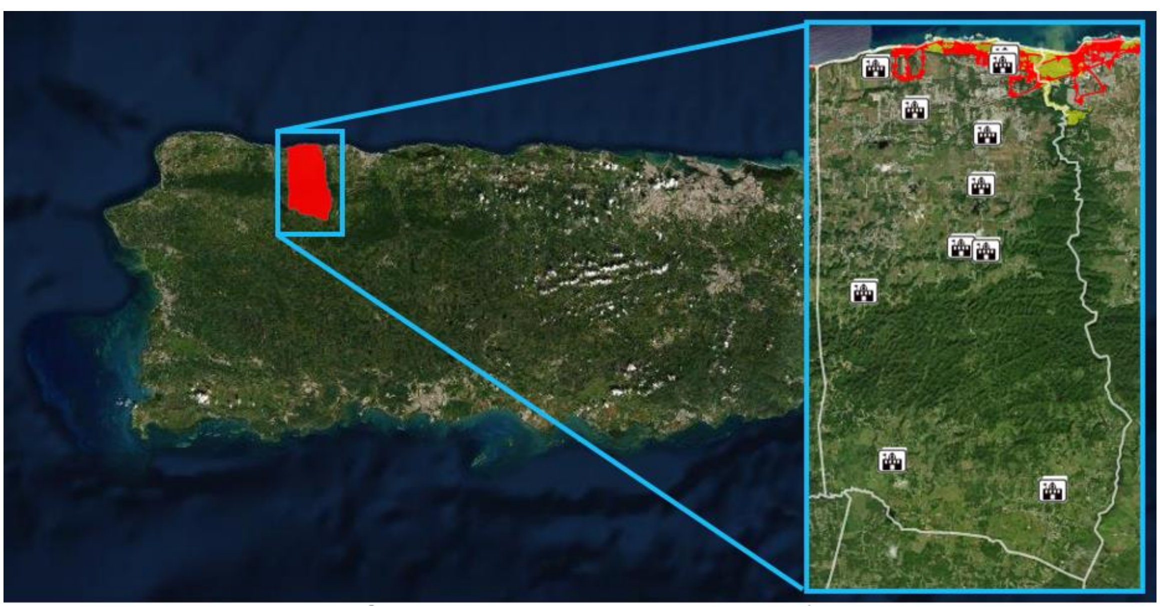
The schools in danger are: Luis Muñiz Souffront which is already permanently closed, Monserrate León De Irizarry with a population of 526 people, and Segunda Unidad Bo Puerto Real with a population of 405 people. As shown in Table 5-5, the total population that could be affected by the impact of a tsunami in the municipality of Cabo Rojo is 931 people. Of this totality, only one school is used as a voting center, but none as a refuge.

Table 5-5 Summary of schools in tsunami hazard in Cabo Rojo

Schools	Students	Teachers	Population	Voting Center	Refuge
Luis Muñiz Souffront	0	0	0 (Close)	No	No
Monserrate León De Irizarry	494	32	526	Yes	No
Segunda Unidad Bo Puerto Real	373	32	405	No	No
Total			931	1	0

5.1.9 Camuy

This municipality has 12 schools (Figure 5-26), and one is in a tsunami hazard zone (Figure 5-27 and Figure 5-28).



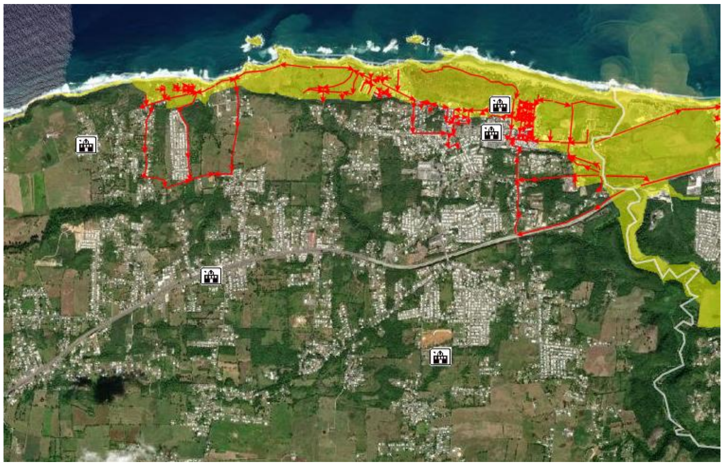


Figure 5-27 Schools located in tsunami hazard zones in Camuy

Figure 5-28 Schools located in tsunami hazard zones in Camuy

The school in danger is permanently closed, therefore, no school population in Camuy could be affected by the impact of a tsunami (Table 5-6). However, when it was open it was used as a voting center but not as a refuge.

Table 5-6 Summary of schools in tsunami hazard in Camuy

Schools	Students	Teachers	Population	Voting Center	Refuge
Pablo Ávila González	0	0	0 (Close)	Yes	No
Total			0	1	0

5.1.10 Canóvanas

This municipality has 13 schools (Figure 5-29), and none are in a tsunami hazard zone as shown in Figure 5-30. Therefore, no school population in Canóvanas could be affected by the impact of a tsunami. For this reason, no tabulated data is presented with schools in a tsunami danger zone for this municipality.

Figure 5-29 Location of Schools in Canóvanas

Figure 5-30 Schools located outside the tsunami hazard zones in Canóvanas

5.1.11 Carolina

In this municipality there are a total of 36 schools (Figure 5-31), of which 2 are in a tsunami danger zone according to evacuation maps (Figure 5-32 and Figure 5-33). The schools in danger are: Roberto Alberty (Cacao Centro) and Julia de Burgos, both of which are permanently closed, therefore, no school population in Carolina could be affected by the impact of a tsunami.

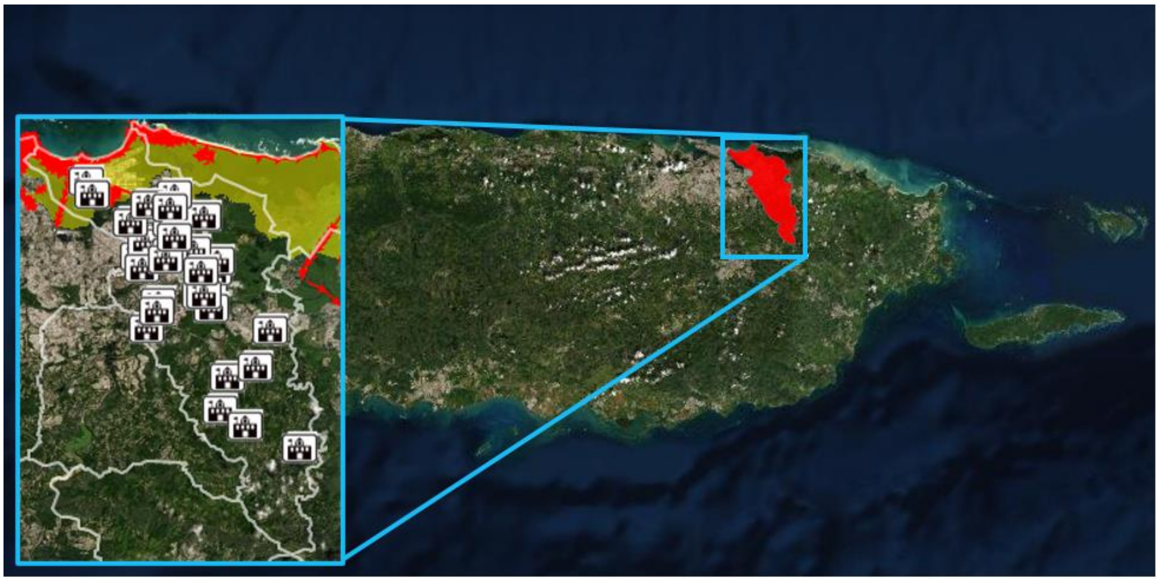


Figure 5-31 Location of Schools in Carolina

Figure 5-32 Schools located in tsunami hazard zones in Carolina

Figure 5-33 Schools located in tsunami hazard zones in Carolina [Zoom]

As shown in Table 5-7, although there are schools in hazard zone, they are not open. Therefore, there is no other use for schools in this municipality.

Table 5-7 Summary of schools in tsunami hazard in Carolina

Schools	Students	Teachers	Population	Voting Center	Refuge
Julia De Burgos	0	0	0 (Close)	No	No
Roberto Alberty (Cacao Centro)	0	0	0 (Close)	No	No
Total			0	0	0

5.1.12 Cataño

This municipality has 12 schools (Figure 5-34). The total number of schools in the tsunami hazard zone is 4 as shown in Figure 5-35 and Figure 5-36. These are: Francisco Oller with a population of 723 people, Horace Mann with a population of 201 people, Onofre Carballeira with a population of 252, Rosendo Matienzo Cintrón with a population of 289 people. Therefore, the total school population that could be affected by a tsunami for this municipality is 1,465 people. Of the totality of schools, 2 of them are used as voting centers and none as shelters. This total data is shown in detail in Table 5-8.

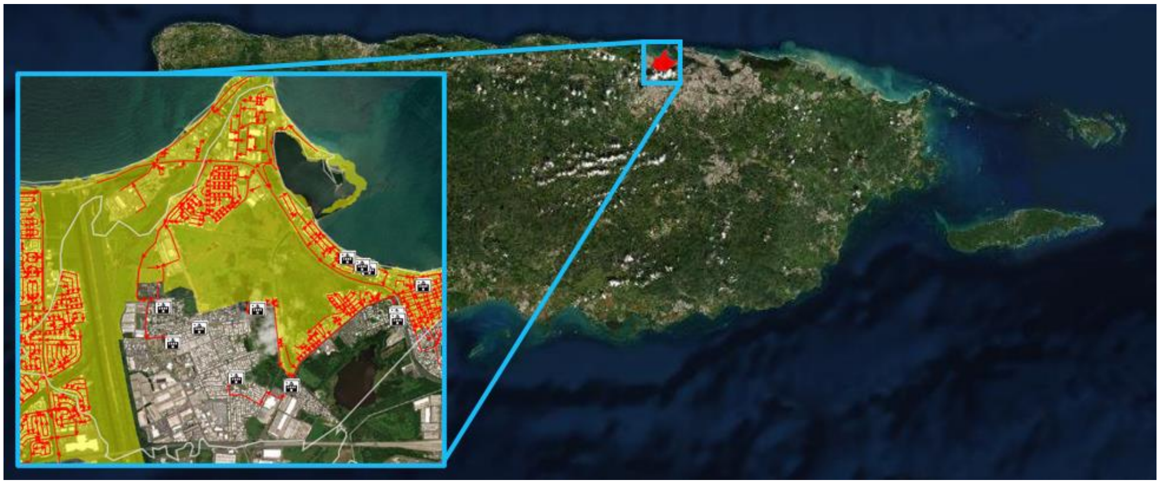


Figure 5-34 Location of Schools in Cataño

Figure 5-35 Schools located in tsunami hazard zones in Cataño

Figure 5-36 Schools located in tsunami hazard zones in Cataño [Zoom]

Table 5-8 Summary of schools in tsunami hazard in Cataño

Schools	Students	Teachers	Population	Voting Center	Refuge
Francisco Oller	678	45	723	Yes	No
Horace Mann	188	13	201	No	No
Onofre Carballeira	236	16	252	Yes	No
Rosendo Matienzo Cintrón	265	24	289	No	No
Total			1465	2	0

5.1.13 Ceiba

In this municipality there are 5 schools and none of them are in a tsunami hazard zone. Figure 5-37 shows all the schools in the municipality, while Figure 5-38 shows the hazard zone without any schools. This means that no school population in Ceiba could be affected by the impact of a tsunami. This is the reason why there is no table that presents data for schools in the tsunami danger zone.

Figure 5-37 Location of Schools in Ceiba

Figure 5-38 Schools located in tsunami hazard zones in Ceiba [Zoom]

5.1.14 Culebra

This municipality has only 1 school, which is in a tsunami danger zone. This school is Ecológica De Culebra with a school population of 190 people. Therefore, the population of the school that could be affected in Culebra is 190 people.

Figure 5-39 Location of Schools in Culebra

Figure 5-40 Schools located in tsunami hazard zones in Culebra [Zoom]

Schools located in tsunami hazard zones are summarized in Table 5-9. This shows that the only school that is in the tsunami hazard zone is in turn used as a voting center and shelter.

Table 5-9 Summary of schools in tsunami hazard in Culebra

Schools	Students	Teachers	Population	Voting Center	Refuge
Ecológica De Culebra	173	17	190	Yes	Yes
Total			190	1	1

5.1.15 Dorado

In this municipality there is one school that is in a tsunami hazard zone out of 12 schools. The school in danger is José Santos Alegría with a population of 937 people. Figure 5-41 shows the location of all schools for this municipality. On the other hand, Figure 5-42 presents the evidence that there is only one school in the tsunami hazard zones. The total population that could be affected by the impact of a tsunami in the municipality of Dorado is 937 people. This school is used as a shelter but not as a voting center (Table 5-10).

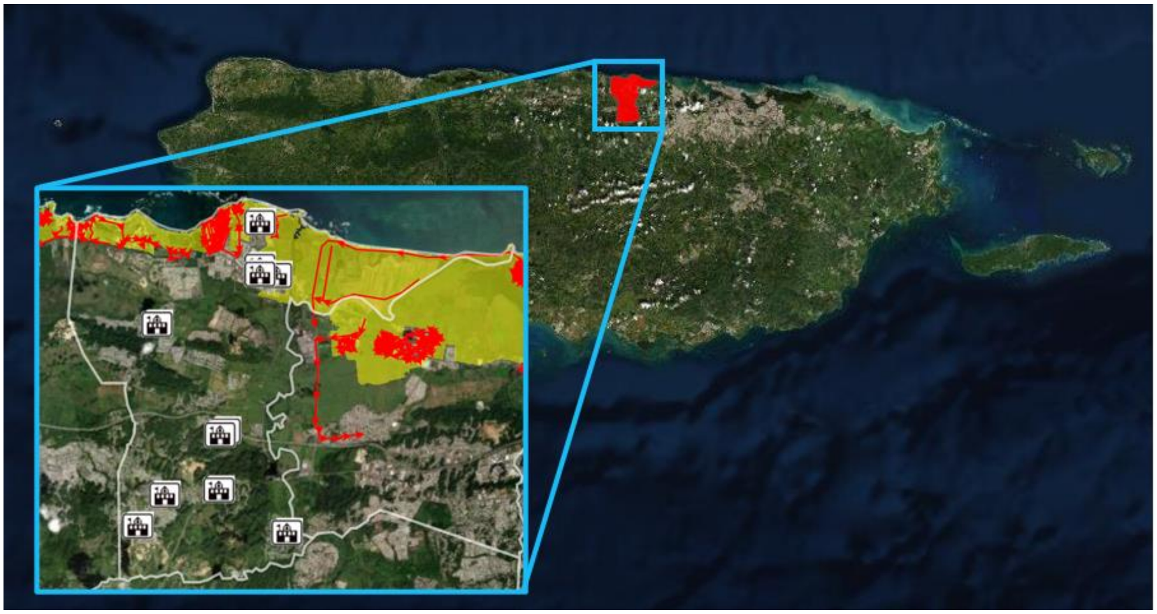


Figure 5-41 Location of Schools in Dorado

Figure 5-42 Schools located in tsunami hazard zones in Dorado [Zoom]

Table 5-10 Summary of schools in tsunami hazard in Dorado

Schools	Students	Teachers	Population	Voting Center	Refuge
José Santos Alegría	882	55	937	No	Yes
Total			937	0	1

5.1.16 Fajardo

In this municipality there are 11 schools (Figure 5-43) and none of them are in a tsunami hazard zone (Figure 5-44). Therefore, no school population in Fajardo could be affected by the impact of a tsunami. For this reason, a table with the data for the schools is not shown.

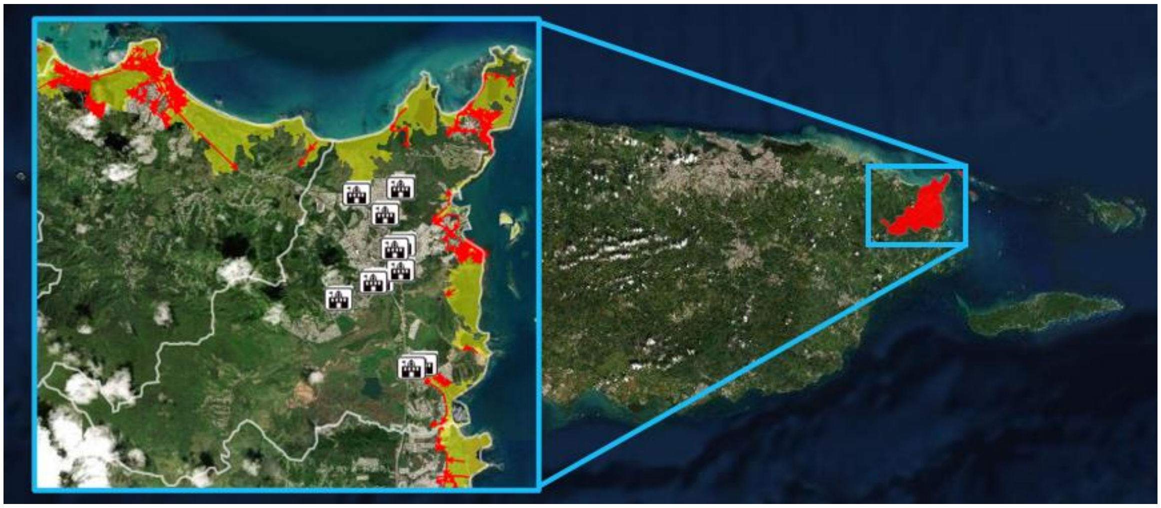


Figure 5-43 Location of Schools in Fajardo

Figure 5-44 Schools located outside the tsunami hazard zones in Fajardo

5.1.17 Guánica

There are 9 schools in this municipality (Figure 5-45). Of that total, none is in a tsunami danger zone (Figure 5-46). Therefore, no school population in Guánica could be affected by the impact of a tsunami.

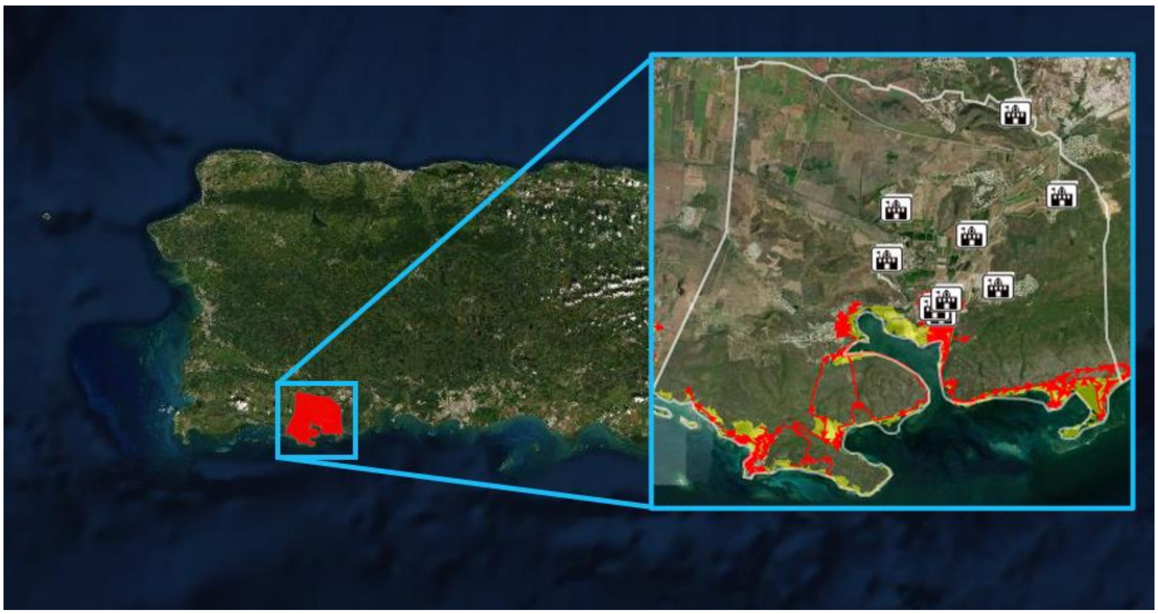


Figure 5-45 Location of Schools in Guánica

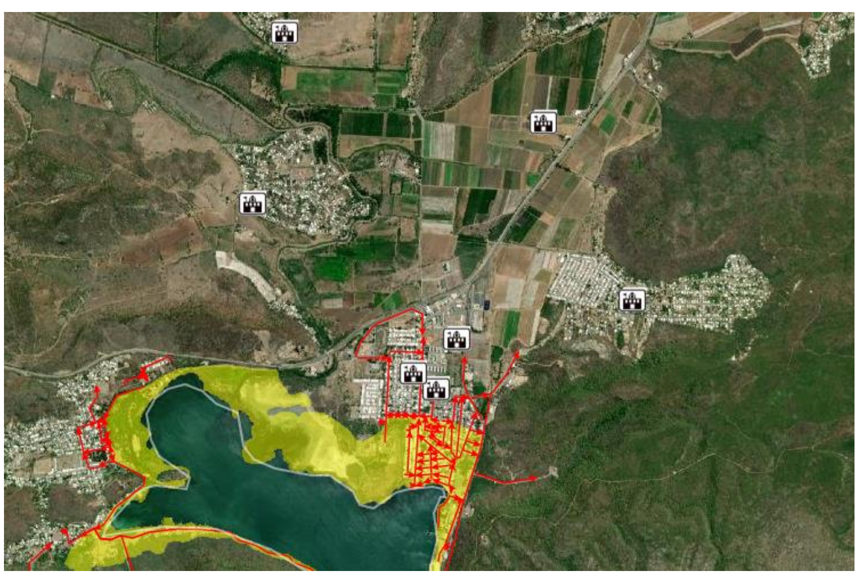


Figure 5-46 Schools located outside the tsunami hazard zones in Guánica

5.1.18 Guayama

This municipality has 18 schools (Figure 5-47), of which only one is in a tsunami danger zone (Figure 5-48). This school is the Marcela García Cora with a population of 115 people. The total school population that could be affected by a tsunami for Guayama is 115 people.

Figure 5-47 Location of Schools in Guayama

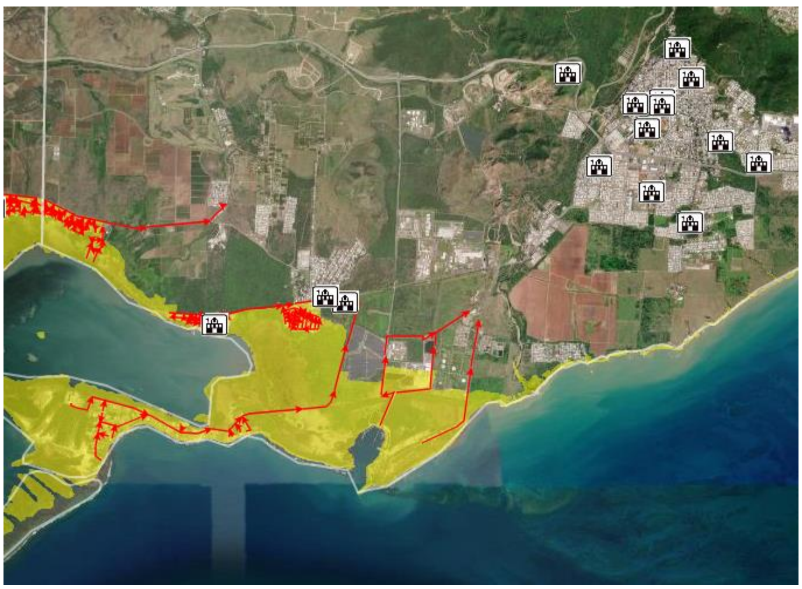


Figure 5-48 Schools located in tsunami hazard zones in Guayama

School located in tsunami hazard zones are shown in Table 5-11. For this school there is no use as a voting center or refuge.

Table 5-11 Summary of schools in tsunami hazard in Guayama

Schools	Students	Teachers	Population	Voting Center	Refuge
Marcela García Cora	106	9	115	No	No
Total			115	0	0

5.1.19 Guayanilla

In this municipality there are a total of 9 schools ash shown in Figure 5-49. None of these schools is in a tsunami hazard zone, and Figure 5-50 shows it. This means that no school population in Guayanilla could be affected by the impact of a tsunami.

Figure 5-49 Location of Schools in Guayanilla

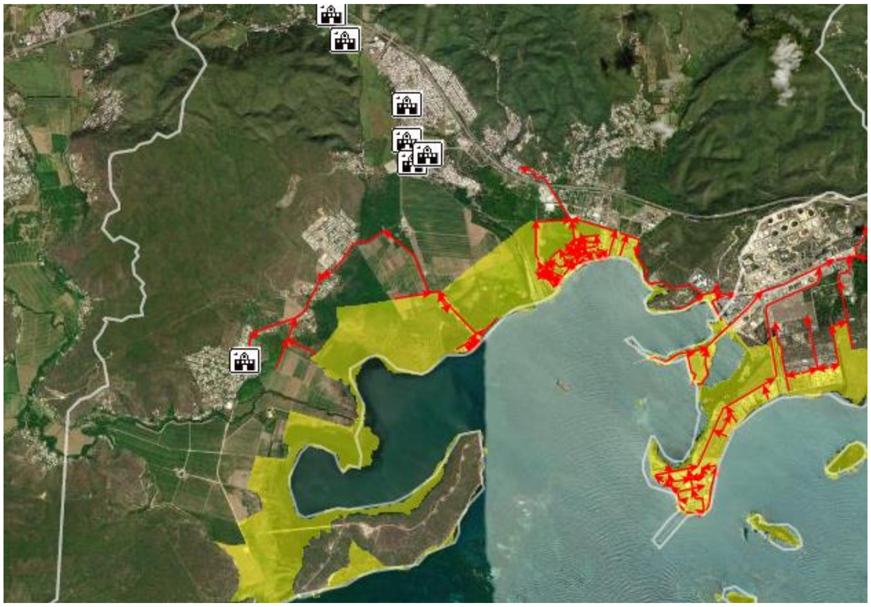


Figure 5-50 Schools located outside the tsunami hazard zones in Guayanilla

5.1.20 Guaynabo

This municipality has a total of 18 schools (Figure 5-51) and none of them are in a tsunami hazard zone (Figure 5-52). This means that no school population in Guaynabo could be affected by the impact of a tsunami.

Figure 5-51 Location of Schools in Guaynabo

Figure 5-52 Schools located outside the tsunami hazard zones in Guaynabo

5.1.21 Hatillo

This municipality has 12 schools (Figure 5-53), and one is in a tsunami hazard zone (Figure 5-54). The school in danger is closed, therefore, no school population in Hatillo could be affected by the impact of a tsunami.

Figure 5-53 Location of Schools in Hatillo

Figure 5-54 Schools located in tsunami hazard zones in Hatillo

The data for the only school in a tsunami hazard zone for this municipality is found in Table 5-12. However, as it is closed there is no data for it.

Table 5-12 Summary of schools in tsunami hazard in Hatillo

Schools	Students	Teachers	Population	Voting Center	Refuge
Adrián Martínez Gandía	0	0	0 (Close)	No	No
Total			0	0	0

5.1.22 Humacao

In this municipality there is one school that is in a tsunami hazard zone out of 22 schools. Figure 5-55 shows the total of schools located and Figure 5-56 shows only the zoom with the schools in hazard zone. The school in danger is Su Agapito López Flores with a population of 386 people. The total population that could be affected by the impact of a tsunami in the municipality of Humacao is 386 people.

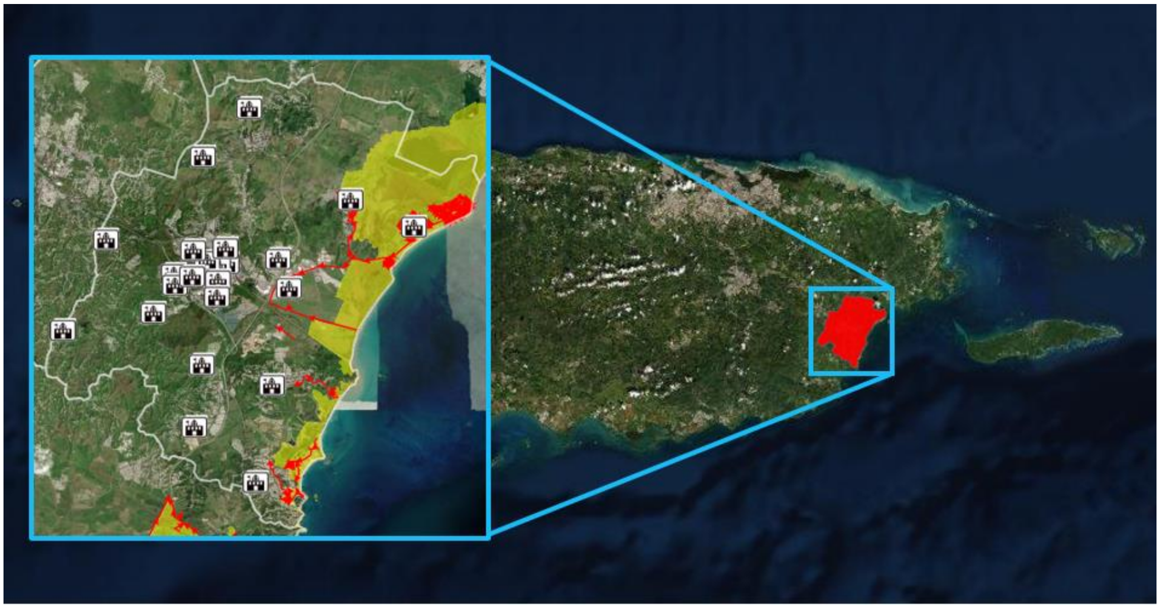


Figure 5-55 Location of Schools in Humacao

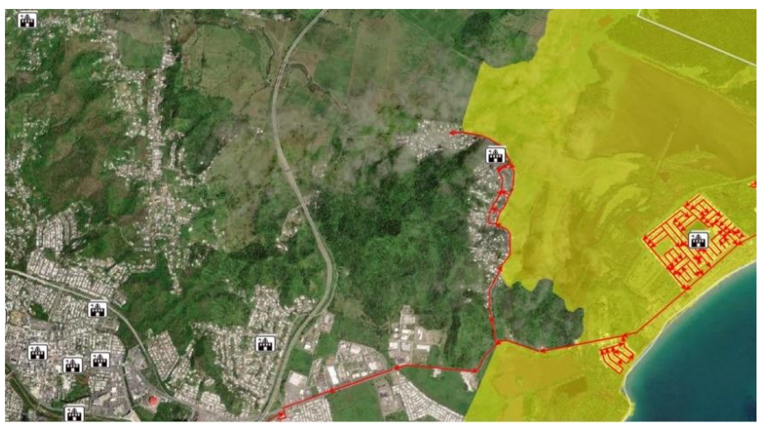


Figure 5-56 Schools located in tsunami hazard zones in Humacao

School located in tsunami hazard zones in Table 5-13.

Table 5-13 Summary of schools in tsunami hazard in Humacao

Schools	Students	Teachers	Population	Voting Center	Refuge
Su Agapito López Flores	361	25	386	Yes	No
Total			386	1	0

5.1.23 Isabela

In this municipality there are a total of 18 schools (Figure 5-57). No schools are in a tsunami hazard zone as shown in Figure 5-58. This means that no school population in Isabela could be affected by the impact of a tsunami. Therefore, there is no table for this municipality.

Figure 5-57 Location of Schools in Isabela

Figure 5-58 Schools located outside the tsunami hazard zones in Isabela

5.1.24 Juana Díaz

In this municipality there are 2 schools that are in a tsunami hazard zone (Figure 5-59) out of 14 schools (Figure 5-60). The school in danger is Juan Serapio Mangual with a population of 314 people and "Luis Muñoz Marín" with a population of 215 people. The total population that could be affected by the impact of a tsunami in the municipality of Juana Díaz is 529 people. Of this totality, there is one school that is used as a voting center, and none is used as a shelter (Table 5-14).

Figure 5-59 Location of Schools in Juana Díaz

Figure 5-60 Schools located in tsunami hazard zones in Juana Díaz

Table 5-14 Summary of schools in tsunami hazard in Juana Díaz

Schools	Students	Teachers	Population	Voting Center	Refuge
Juan Serapio Mangual	290	24	314	Yes	No

Luis Muñoz Marín	195	20	215	No	No
Total			529	1	0

5.1.25 Lajas

In this municipality there is one school that is in a tsunami danger zone out of 9 schools. The total number of schools is shown in Figure 5-61 and the schools in danger are shown in Figure 5-62.

Figure 5-61 Location of Schools in Lajas

Figure 5-62 Schools located in tsunami hazard zones in Lajas

The school in danger is Alejandro Tapia y Rivera with a population of 108 people. The total population that could be affected by the impact of a tsunami in the municipality of Lajas is 108 people. The school in this municipality is not used as a shelter or voting center. This is summarized in Table 5-15.

Table 5-15 Summary of schools in tsunami hazard in Lajas

Schools	Students	Teachers	Population	Voting Center	Refuge
Alejandro Tapia y Rivera	98	10	108	No	No
Total			108	0	0

5.1.26 Loíza

In this municipality there are 8 schools that are in tsunami hazard zones (Figure 5-64 and Figure 5-65) out of 9 schools (Figure 5-63). The school in danger is: Belén Blanco de Zequeira with a population of 192 people, Carlos Escobar López with a population of 210 people, Celso González Vaillant with a population of 349 people, Emiliano Figueroa Torres with a population of 86 people, Jobos with a population of 111 people, Mediana Alta Elemental with a population of 712 people, Nueva Superior de Loíza (Super Vocaciona) with a population of 584 people, and Parcelas Vieques with a population of 157 people.

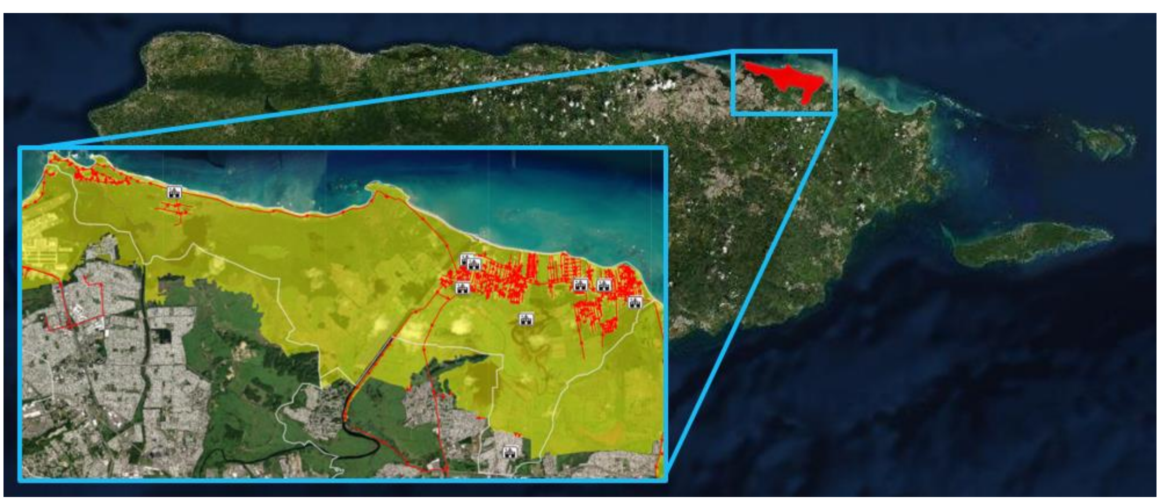


Figure 5-63 Location of Schools in Loíza


Figure 5-64 Schools located in tsunami hazard zones in Loíza


Figure 5-65 Schools located in tsunami hazard zones in Loíza [Zoom]

The total population that could be affected by the impact of a tsunami in the municipality of Loíza is 2,401 people. Of the total of 8 schools that are in the tsunami danger zone, 4 are used as a voting center and 3 as a refuge. Schools located in tsunami hazard zones are shown in Table 5-16.

Table 5-16 Summary of schools in tsunami hazard in Loíza

Schools	Students	Teachers	Population	Voting Center	Refuge
Belén Blanco de Zequeira	174	14	192	Yes	No
Carlos Escobar López	191	19	210	No	Yes
Celso González Vaillant	323	26	349	No	Yes

Emiliano Figueroa Torres	78	8	86	No	No
Jobos	105	6	111	Yes	No
Medianía Alta Elemental	678	34	712	Yes	Yes
Nueva Superior de Loíza (Super Vocacional)	552	32	584	Yes	No
Parcelas Vieques	145	12	157	No	No
Total			2401	4	3

5.1.27 Luquillo

This municipality has 7 schools (Figure 5-66), of which 3 are in a tsunami hazard zone (Figure 5-67 and Figure 5-68). These schools are: Pablo Suarez Ortiz which is permanently closed, Rafael N. Coca with a population of 458, and Rosendo Matienzo Cintrón with a population of 138. The total school population that could be affected by a tsunami for Luquillo is 596 people. Of the total of schools, only one is used as a voting center, while none is used as a refuge. The data for these schools is summarized in Table 5-17.

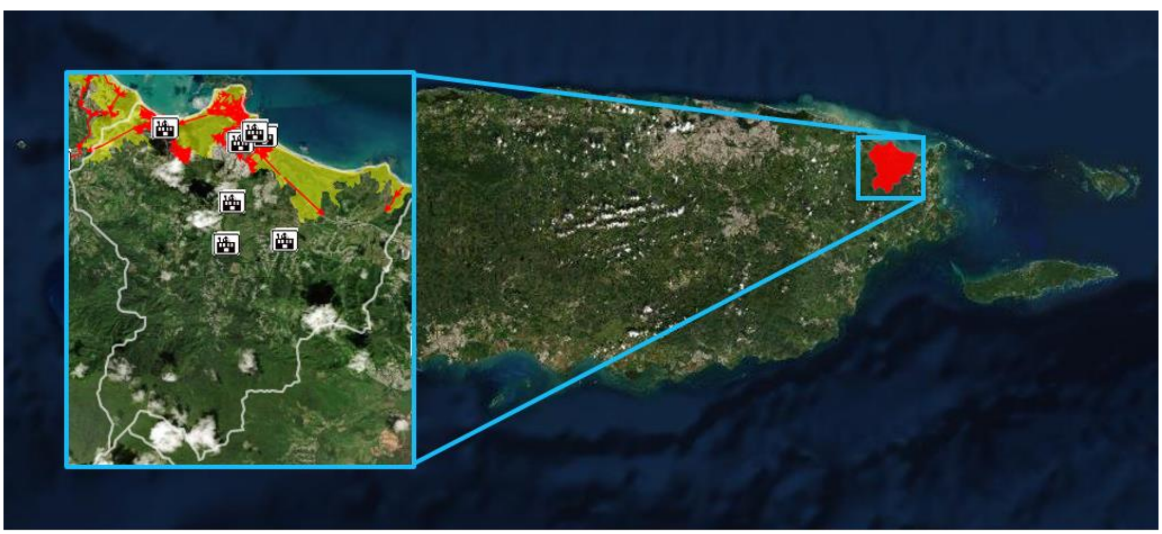


Figure 5-66 Location of Schools in Luquillo

Figure 5-67 Schools located in tsunami hazard zones in Luquillo

Figure 5-68 Schools located in tsunami hazard zones in Luquillo [Zoom]

Table 5-17 Summary of schools in tsunami hazard in Luquillo

Schools	Students	Teachers	Population	Voting Center	Refuge
Pablo Suárez Ortiz	0	0	0 (Close)	No	No
Rafael N. Coca	432	26	458	Yes	No
Rosendo Matienzo Cintrón	123	15	138	No	No
Total			596	1	0

5.1.28 Manatí

This municipality has a total of 15 schools (Figure 5-69) and none of them are in a tsunami hazard zone (Figure 5-70). This means that no school population in Manatí could be affected by the impact of a tsunami.

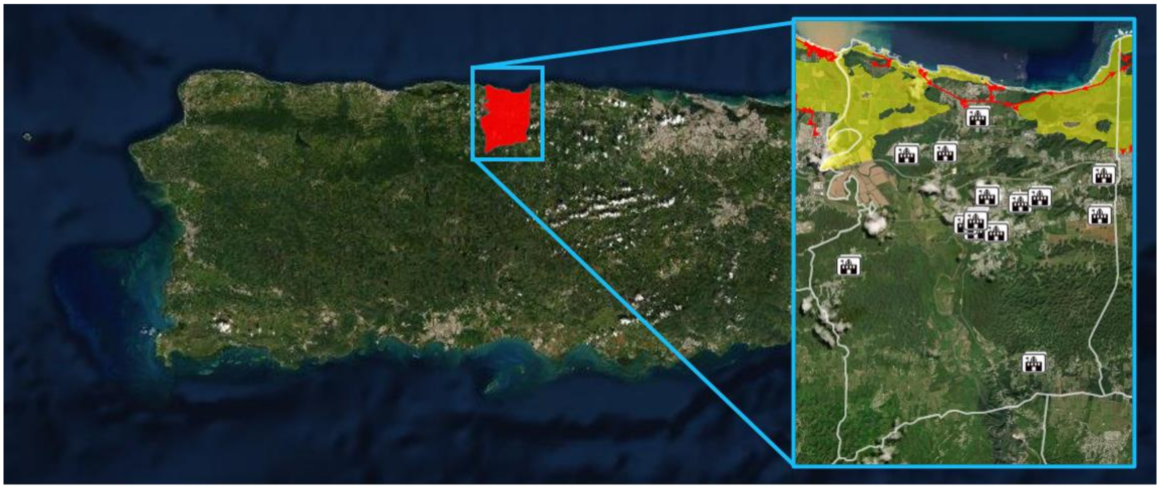


Figure 5-69 Location of Schools in Manatí

Figure 5-70 Schools located outside the tsunami hazard zones in Manatí

5.1.29 Maunabo

In this municipality there are 6 schools (Figure 5-71) and none of them are in a tsunami hazard zone.

Figure 5-71 Location of Schools in Maunabo

Therefore, no school population in Maunabo could be affected by the impact of a tsunami. Figure 5-72 evidence that there are no schools in a tsunami hazard zone for this municipality.

Figure 5-72 Schools located outside the tsunami hazard zones in Maunabo

5.1.30 Mayagüez

This municipality has 31 schools that are shown in Figure 5-73. Of this total, 9 are in the tsunami hazard zone (Figure 5-74, Figure 5-75, Figure 5-76 and Figure 5-77). The schools are: Concordia, which is already permanently closed, Dr. Pedro Perea Fajardo with a population of 1,019, Esteban Rosado Báez with a population of 306, Eugenio María De Hostos (Superior) with a population of 945, Libre De Música y Bellas Artes Ernesto Ramos Antonini with a population of of 36, María Dolores Faría with a population of 214, Mariano Riera Palmer with a population of 271, Sabanetas Mani with a population of 213, and Segundo Ruiz Belvis with a population of 243. Therefore, the total school population that could be affected by a tsunami for Mayagüez is 3,247 people. Of the total of 9 schools that are in danger, 5 are used as voting centers and one is used as a shelter. All the data for this municipality are summarized in Table 5-18.

Figure 5-73 Location of Schools in Mayagüez

Figure 5-74 Schools located in tsunami hazard zones in Mayagüez

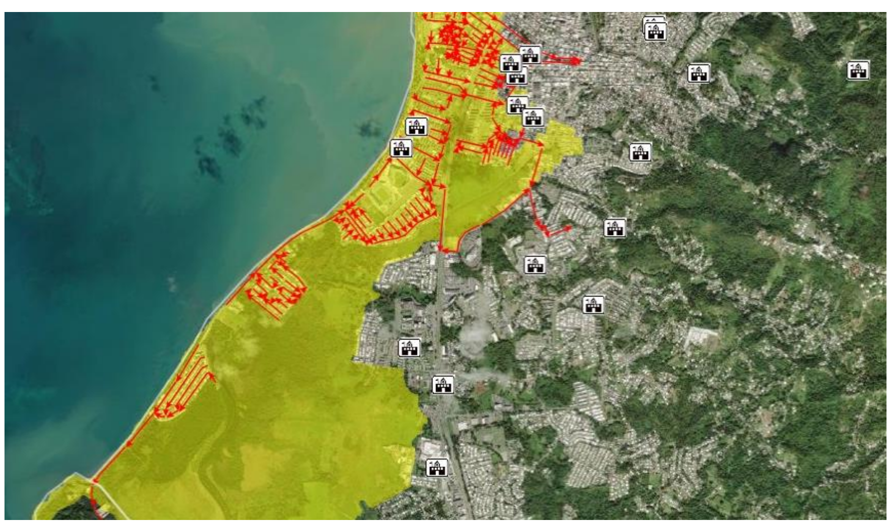


Figure 5-75 Schools located in tsunami hazard zones in Mayagüez [Zoom]

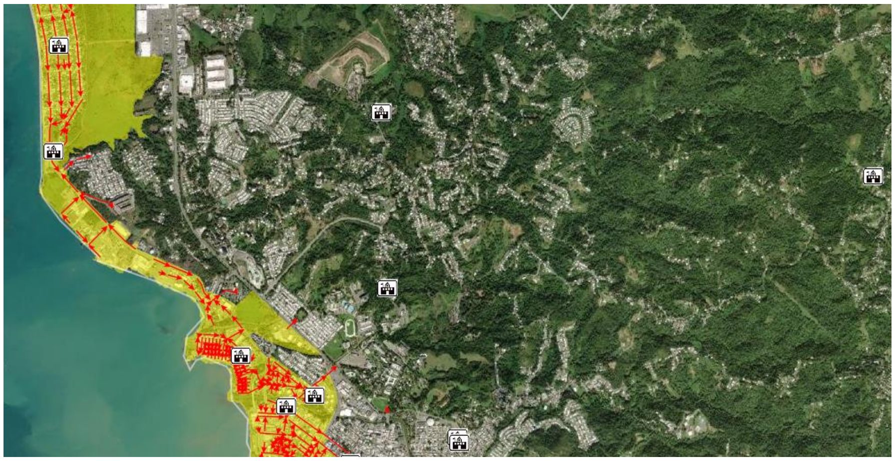


Figure 5-76 Schools located in tsunami hazard zones in Mayagüez [Zoom]

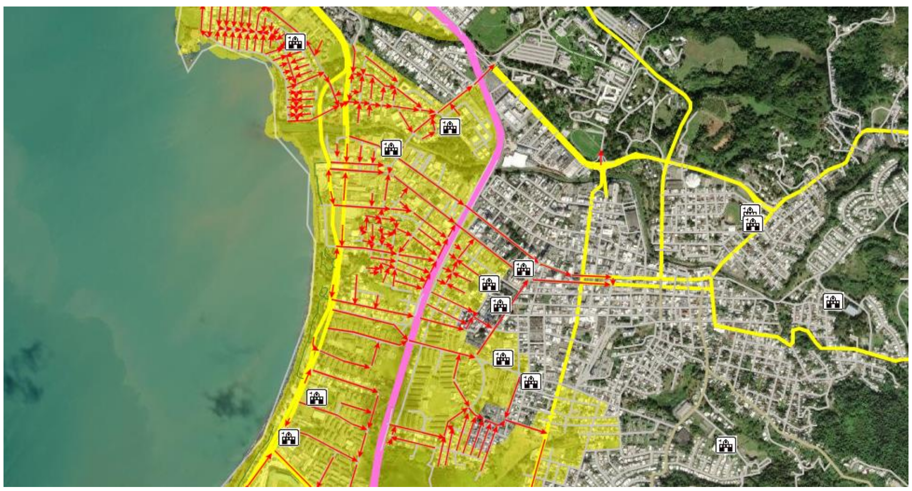


Figure 5-77 Schools located in tsunami hazard zones in Mayagüez [Zoom]

Table 5-18 Summary of schools in tsunami hazard in Mayagüez

Schools	Students	Teachers	Population	Voting Center	Refuge
Concordia	0	0	0 (Closed)	No	No
Dr. Pedro Perea Fajardo	956	63	1,019	Yes	No
Esteban Rosado Báez	277	29	306	Yes	No
Eugenio María De Hostos (Superior)	892	53	945	Yes	Yes
De Música y Bellas Artes Ernest Libre o Ramos Antonini	-	36	36	No	No
María Dolores Faría	184	30	214	No	No

Mariano Riera Palmer	257	14	271	Yes	No
Sabanetas Mani	199	14	213	No	No
Segundo Ruíz Belvis	222	21	243	Yes	No
Total			3247	5	1

5.1.31 Naguabo

This municipality has a total of 9 schools (Figure 5-78) and none of them are in a tsunami hazard zone (Figure 5-79). This means that no school population in Naguabo could be affected by the impact of a tsunami. For this reason, the data is not tabulated.

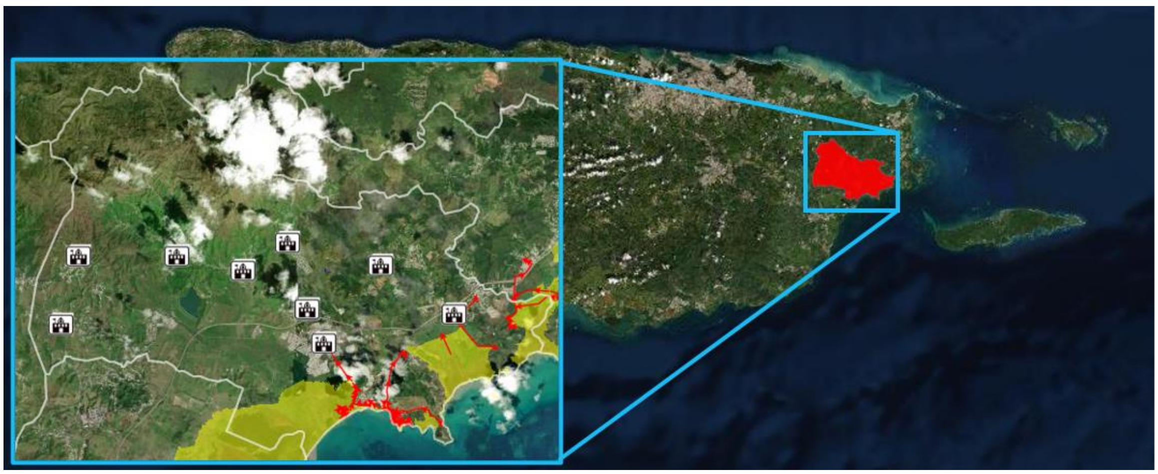


Figure 5-78 Location of Schools in Naguabo

Figure 5-79 Schools located outside the tsunami hazard zones in Naguabo

5.1.32 Patillas

There are 11 schools in this municipality (Figure 5-80). Out of all the schools, none is in a tsunami hazard zone (Figure 5-81 and Figure 5-82). Therefore, no school population in the municipality of Patillas could be affected by the impact of a tsunami.

Figure 5-80 Location of Schools in Patillas

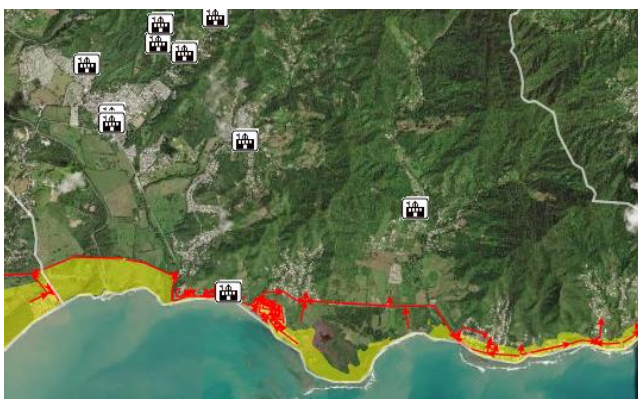


Figure 5-81 Schools located outside the tsunami hazard zones in Patillas

Figure 5-82 Schools located outside the tsunami hazard zones in Patillas [Zoom]

5.1.33 Peñuelas

This municipality has 11 schools (Figure 5-83), of which only one is in a tsunami hazard zone (Figure 5-84 and Figure 5-85). The school in danger is Su Jorge Lucas Valdivieso with a population of 245 people. The total school population that could be affected by a tsunami for the municipality of Peñuelas is 245 people.

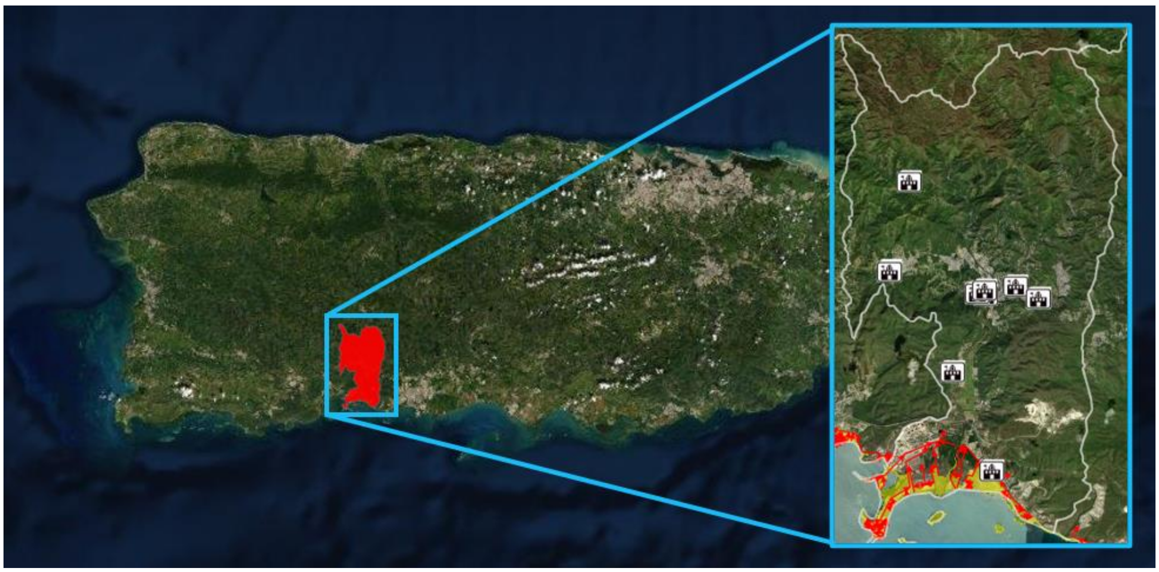


Figure 5-83 Location of Schools in Peñuelas

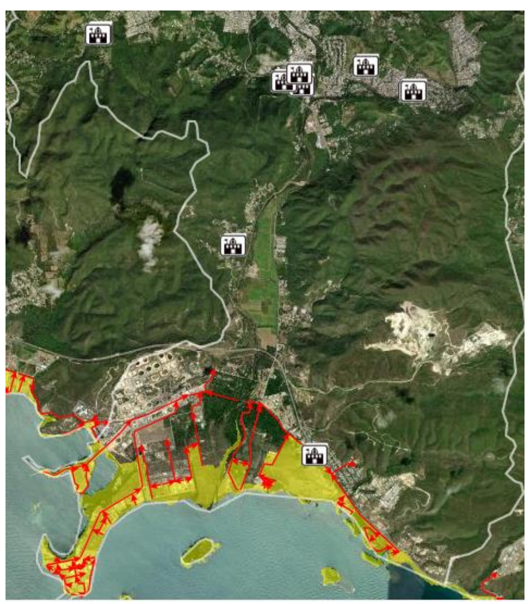


Figure 5-84 School located in tsunami hazard zone in Peñuelas

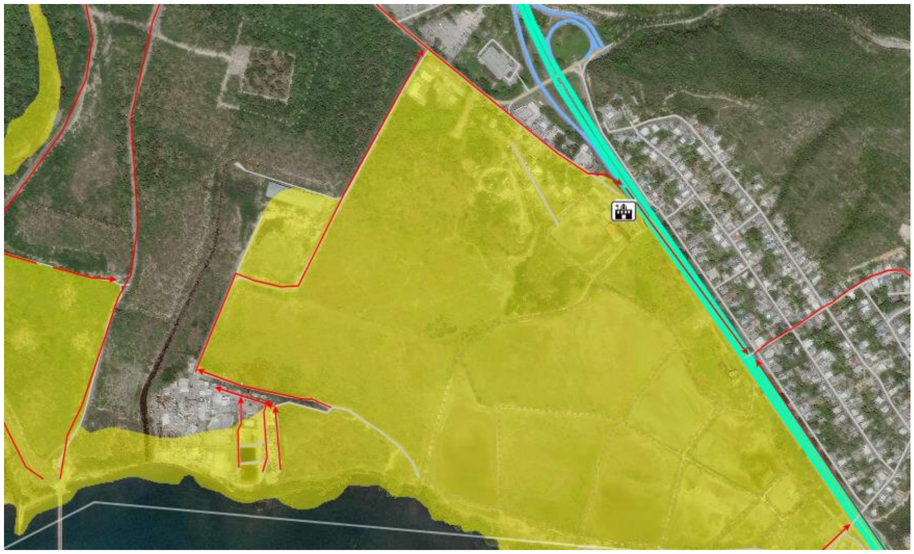


Figure 5-85 School located in tsunami hazard zone in Peñuelas [Zoom]

School located in tsunami hazard zone is shown in Table 5-19. This school does not have any additional use other than academic.

Table 5-19 Summary of schools in tsunami hazard in Peñuelas

Schools	Students	Teachers	Population	Voting Center	Refuge
Su Jorge Lucas Valdivieso	221	24	245	No	No
Total			245	0	0

5.1.34 Ponce

There are 59 schools in this municipality (Figure 5-87). Of this total, only 4 are in a tsunami hazard zone according to evacuation maps (Figure 5-86 and Figure 5-88). The schools in danger are: Angela Cordero Bernard with a population of 648 people, Dr. Alfredo M. Aguayo with a population of 272 people, Lucy Grillasca with a population of 258 people, and Sor Isolina Ferré (Villa Del Carmen) with a population of 399 people. This means that, for this municipality, the total population that could be affected by the impact of a tsunami is 1,577 people. In addition, Table 5-20 shows that 2 schools are used as voting centers and none as shelters of the total of 4 schools in this municipality.

Figure 5-87 Location of Schools in Ponce

Figure 5-86 Schools located in tsunami hazard zones in Ponce

Figure 5-88 Schools located in tsunami hazard zones in Ponce [Zoom]

Table 5-20 Summary of schools in tsunami hazard in Ponce

Schools	Students	Teachers	Population	Voting Center	Refuge
Ángela Cordero Bernard	648	41	648	No	No
Dr. Alfredo M. Aguayo	248	24	272	Yes	No
Lucy Grillasca	231	27	258	No	No
Sor Isolina Ferré (Villa Del Carmen)	370	29	399	Yes	No
Total			1577	2	0

5.1.35 Quebradillas

This municipality has a total of 9 schools and none of them are in a tsunami hazard zone. Therefore, no school population in Quebradillas could be affected by the impact of a tsunami. Figure 5-89 shows the total number of schools in this municipality. On the other hand, Figure 5-90 presents the tsunami hazard zone with no schools falling within it.

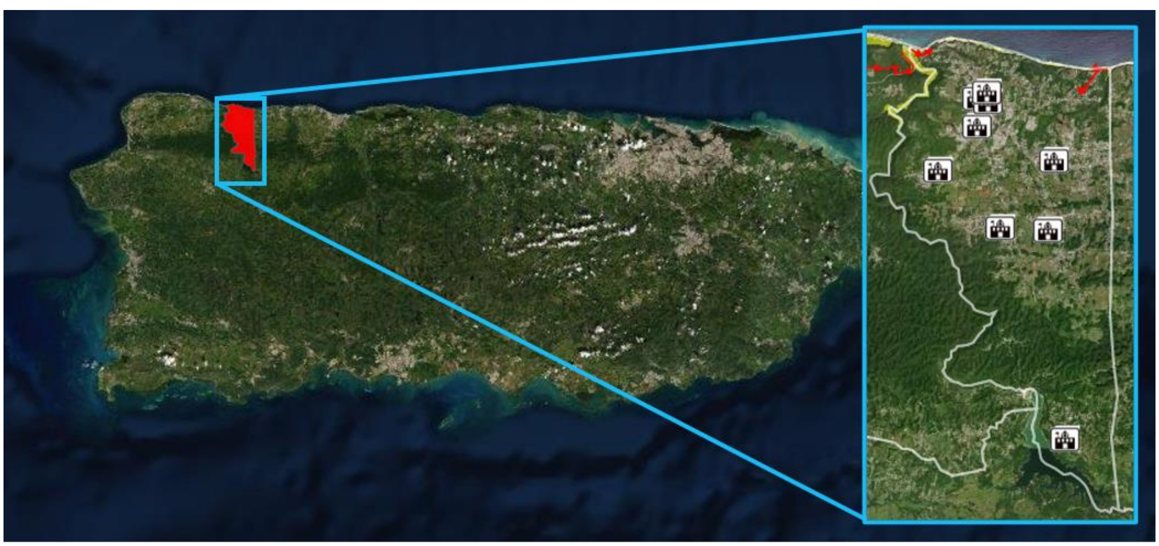


Figure 5-89 Location of Schools in Quebradillas

Figure 5-90 Schools located outside the tsunami hazard zones in Quebradillas

5.1.36 Rincón

This municipality has 6 schools in total (Figure 5-91). Only one is in the tsunami hazard zone (Figure 5-92). This school in danger is Jorge Seda Crespo with a population of 183 people. This means that the total school population that could be affected by a tsunami for Rincón is 183 people. This school has no other additional use (Table 5-21).

Figure 5-91 Location of Schools in Rincón

Figure 5-92 School located in tsunami hazard zone in Rincón

Table 5-21 Summary of schools in tsunami hazard in Rincón

Schools	Students	Teachers	Population	Voting Center	Refuge
Jorge Seda Crespo	166	17	183	No	No
Total			183	0	0

5.1.37 Río Grande

This municipality has 13 schools (Figure 5-93). None of the schools are in a tsunami hazard zone (Figure 5-94). Therefore, no school population in the municipality of Río Grande could be affected by the impact of a tsunami.

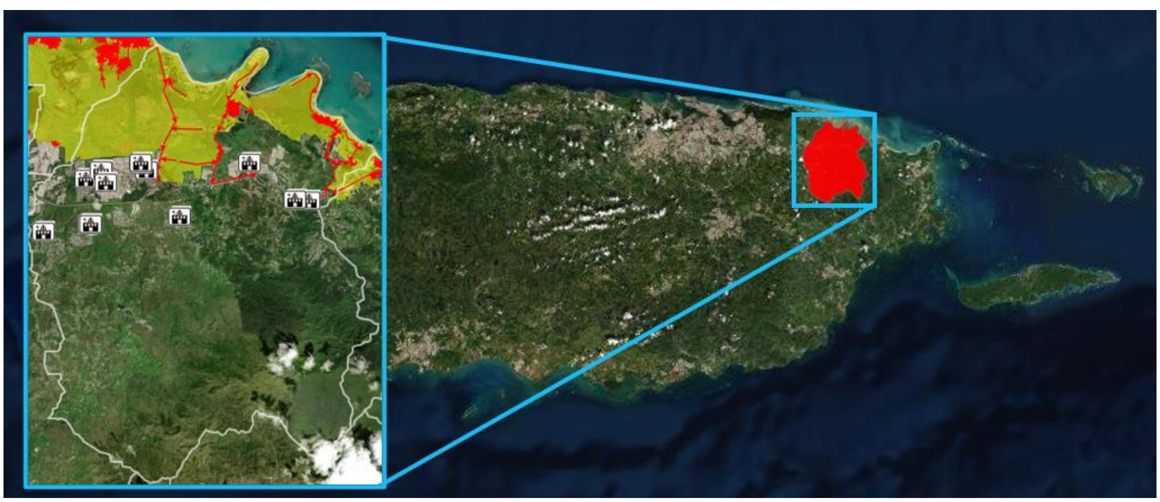


Figure 5-93 Location of Schools in Río Grande

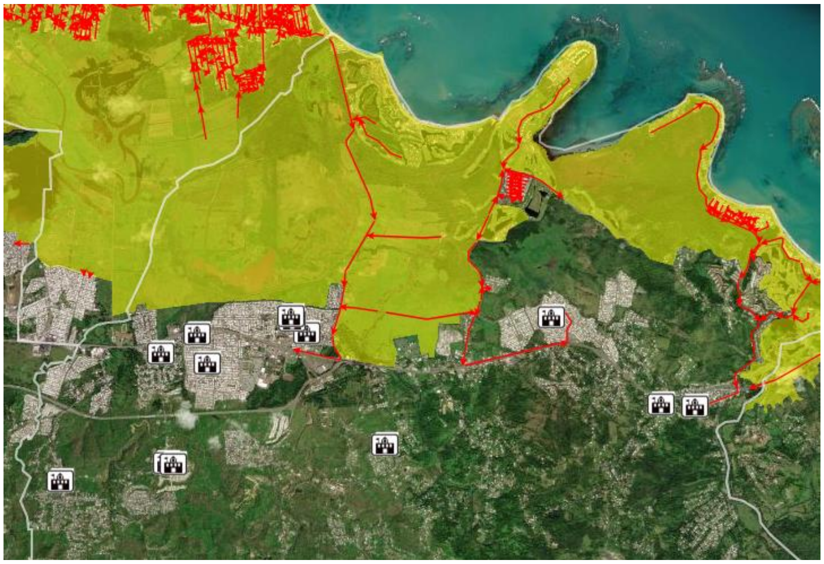


Figure 5-94 Schools located outside the tsunami hazard zones in Río Grande

5.1.38 Salinas

This municipality has 17 schools in total (Figure 5-95). Out of all the schools, 4 are in the tsunami hazard zone (Figure 5-96 and Figure 5-97). These schools in hazard are: Francisco Mariano Quiñones with a population of 177 people, Guillermo González (Playita) with a population of 131 people, Las Mareas with a population of 141 people, and Pedro Soto Rivera with a population of 92 people. The total school population that could be affected by a tsunami for the municipality of Salinas is 541 people.

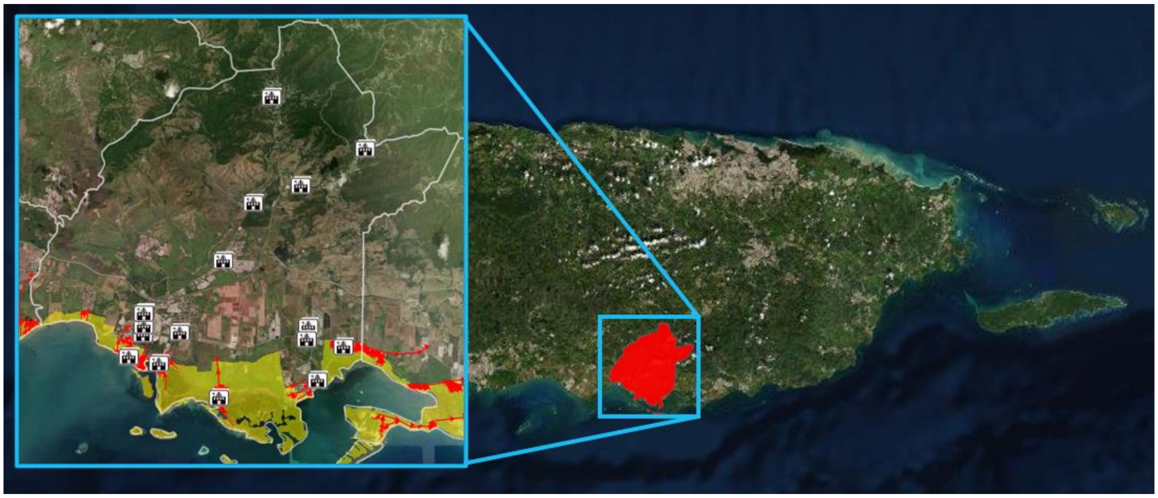


Figure 5-95 Location of Schools in Salinas

Figure 5-96 Schools located in tsunami hazard zones in Salinas

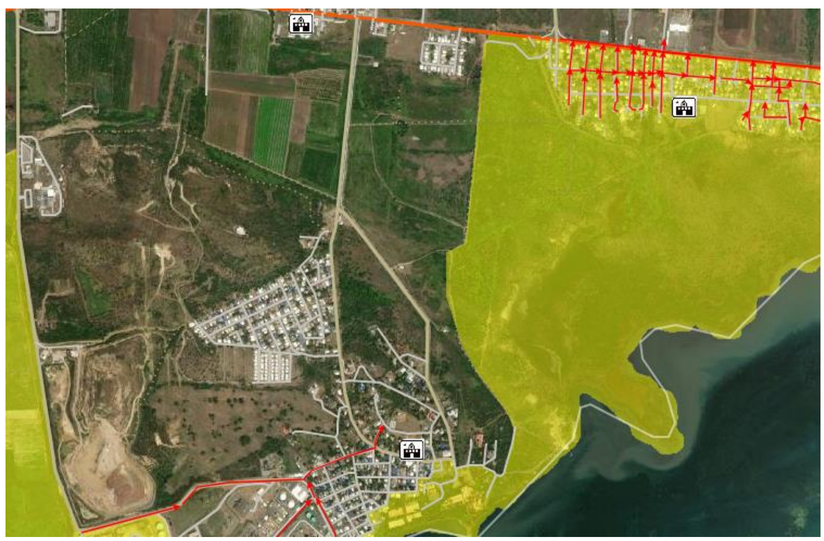


Figure 5-97 Schools located in tsunami hazard zones in Salinas

Schools located in tsunami hazard zones are shown in Table 5-22. This municipality has 3 schools used as voting centers and none as shelters.

Table 5-22 Summary of schools in tsunami hazard in Salinas

Schools	Students	Teachers	Population	Voting Center	Refuge
Francisco Mariano Quiñones	159	18	177	Yes	No

Guillermo González (Playita)	121	10	131	Yes	No
Las Mareas	132	9	141	Yes	No
Pedro Soto Rivera	81	11	92	No	No
Total			541	3	0

5.1.39 San Juan

This municipality has 133 schools (Figure 5-98), of which 9 are in a tsunami hazard zone (Figure 5-99, Figure 5-100, Figure 5-101, Figure 5-102 and Figure 5-103). These schools in hazard are: Dr. Julio J. Henna with a population of 314 people, Jaime Rosario (Buena Vista Elemental) with a population of 127, Julián E. Blanco (Ballet) with a population of 127, Luis Llorens Torres with a population of 358, Luis Rodríguez Cabrero with a population of 290, Madame Luchetti with a population of 224, Moisés Meléndez with a population of 142, Ramón Power Y Giralt with a population of 293, and República Del Perú with a population of 208. The total school population that could be affected by a tsunami for the municipality of San Juan is 2,083 people. Of the 9 schools in total that are in the tsunami danger zone in San Juan, 5 of them are used as voting centers and none as shelters. The data of each school for this municipality is summarized in Table 5-23.

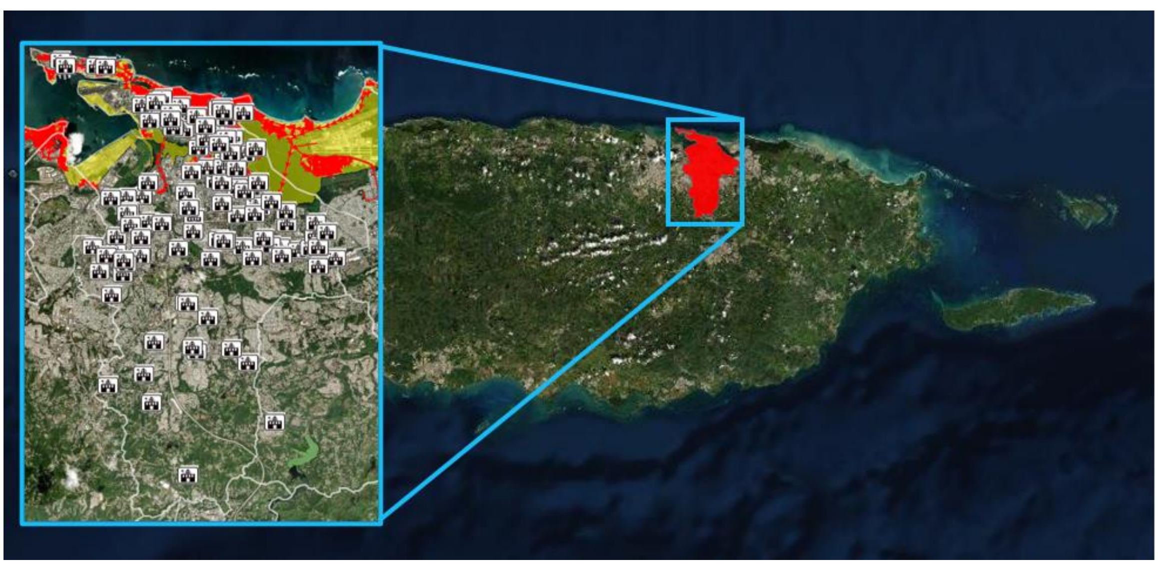


Figure 5-98 Location of Schools in San Juan

Figure 5-99 Schools located in tsunami hazard zones in San Juan

Figure 5-100 Schools located in tsunami hazard zones in San Juan

Figure 5-101 Schools located in tsunami hazard zones in San Juan [Zoom]

Figure 5-102 Schools located in tsunami hazard zones in San Juan [Zoom]

Figure 5-103 Schools located in tsunami hazard zones in San Juan [Zoom]

Table 5-23 Summary of schools in tsunami hazard in San Juan

Schools	Students	Teachers	Population	Voting Center	Refuge
Dr. Julio J. Henna	294	20	314	Yes	No
Jaime Rosario (Buena Vista Elemental)	118	9	127	No	No
Julián E. Blanco (Ballet)	110	17	127	Yes	No
Luis Llorens Torres	332	26	358	Yes	No
Luis Rodríguez Cabrero	267	23	290	Yes	No
Madame Luchetti	208	16	224	No	No
Moisés Meléndez	130	12	142	No	No
Ramón Power Y Giralt	271	22	293	No	No
República Del Perú	190	18	208	Yes	No

Total	2083	5	0

5.1.40 Santa Isabel

In this municipality there is one school that is in a tsunami hazard zone (Figure 5-105) out of 10 schools (Figure 5-104). The school in hazard is Pedro Meléndez Santiago with a population of 486 people. The total population that could be affected by the impact of a tsunami in the municipality of Santa Isabel is 486 people.

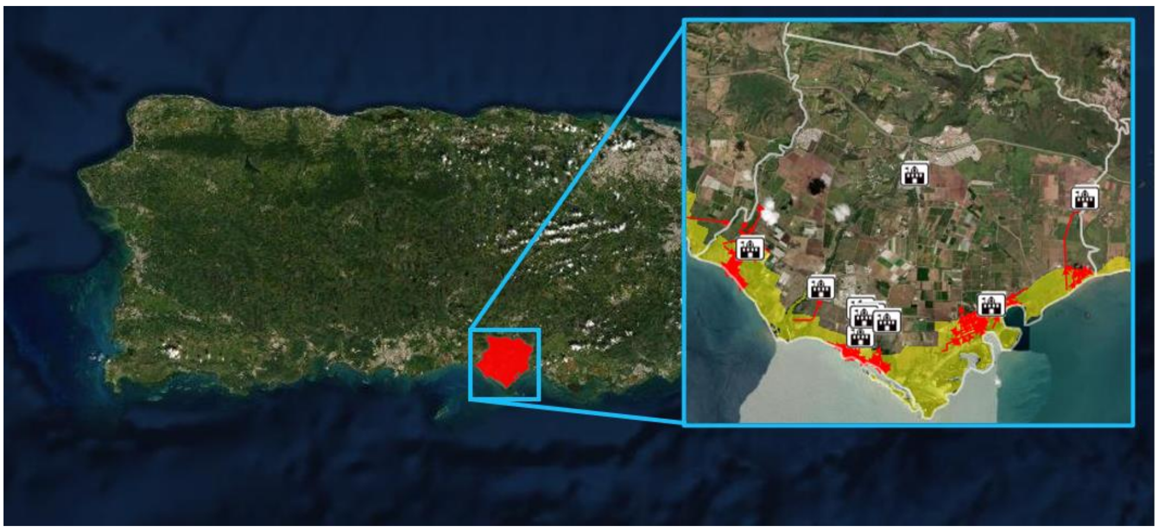


Figure 5-105 Location of Schools in Santa Isabel

Figure 5-104 School located in tsunami hazard zone in Santa Isabel

The data from this school for Santa Isabel is summarized in Table 5-24. This school is used both as a shelter and as a voting center.

Table 5-24 Summary of schools in tsunami hazard in Santa Isabel

Schools	Students	Teachers	Population	Voting Center	Refuge
Pedro Meléndez Santiago	449	37	486	Yes	Yes
Total			486	1	1

5.1.41 Toa Baja

This municipality has 20 schools (Figure 5-106), of which 8 are in a tsunami hazard zone as shown in Figure 5-107. These schools are: Amalia López De Vila with a population of 163 people, Basilio Milán Hernández with a population of 698, Carmen Barroso Morales with a population of 246, Delia Dávila De Cabán with a population of 263, Dr. Pedro Albizu Campos with a population of 749, Dr. Efraín Sánchez Hidalgo with a population of 339, John F. Kennedy with a population of 175 and Lorencita Ramírez De Arellano with a population of 169. The total school population that could be affected by a tsunami for Toa Baja is 2,802 people (Table 5-25).

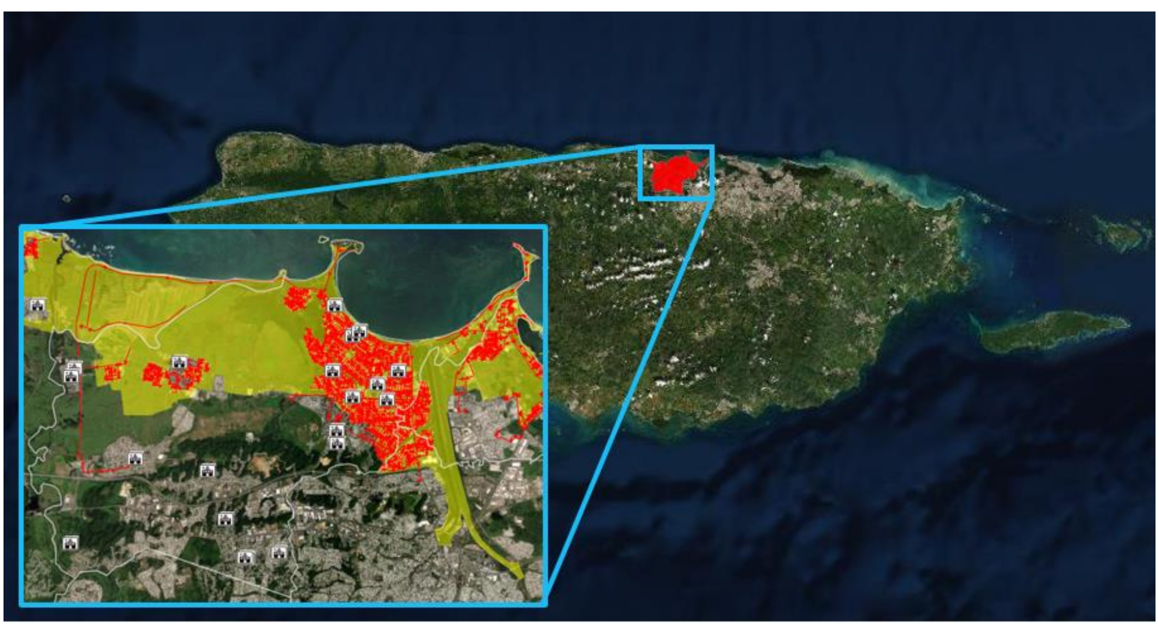


Figure 5-106 Location of Schools in Toa Baja

Figure 5-107 Schools located in tsunami hazard zones in Toa Baja

The data for each school is summarized in Table 5-25. For this municipality there are 4 schools that are used as voting centers and 2 as shelters of the total of 8 schools that are in the tsunami hazard zone.

Table 5-25 Summary of schools in tsunami hazard in Toa Baja

Schools	Students	Teachers	Population	Voting Center	Refuge
Amalia López De Vila	149	14	163	No	No
Basilio Milán Hernández	651	47	698	Yes	No
Carmen Barroso Morales	227	19	246	Yes	No
Delia Dávila De Cabán	247	16	263	Yes	No
Dr. Pedro Albizu Campos	703	46	749	Yes	Yes
Dr. Efraín Sánchez Hidalgo	315	24	339	No	Yes
John F. Kennedy	157	18	175	No	No
Lorencita Ramírez De Arellano	153	16	169	No	No
Total			2802	4	2

5.1.42 Vega Alta

This municipality has a total of 11 schools and none of them are in a tsunami hazard zone as shown in Figure 5-108. Therefore, no school population in Vega Alta could be affected by the impact of a tsunami.

Figure 5-108 Location of Schools in Vega Alta

5.1.43 Vega Baja

This municipality has a total of 20 schools (Figure 5-109) and none of them are in a tsunami danger zone as shown in Figure 5-110.

Figure 5-109 Location of Schools in Vega Baja

Therefore, no school population in Vega Baja could be affected by the impact of a tsunami. For this reason, summary data for schools is not presented in a table.

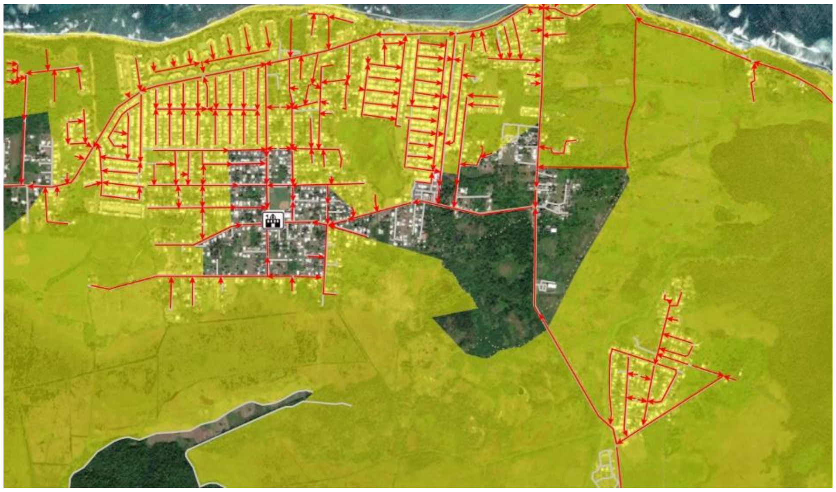


Figure 5-110 Schools located outside the tsunami hazard zones in Vega Baja [Zoom]

5.1.44 Vieques

This municipality has a total of 4 schools (Figure 5-111) and none of them are in a tsunami hazard zone (Figure 5-112). Therefore, no school population on Vieques could be affected by the impact of a tsunami.

Figure 5-111 Location of Schools in Vieques

Figure 5-112 Schools located outside the tsunami hazard zones in Vieques [Zoom]

5.1.45 Yabucoa

This municipality has a total of 4 schools as shown in Figure 5-113 and none of them are in a tsunami hazard zone (Figure 5-114). Therefore, no school population in Yabucoa could be affected by the impact of a tsunami. Data on schools are not tabulated since they are not in danger for this municipality, for this reason they are evident in both figures.

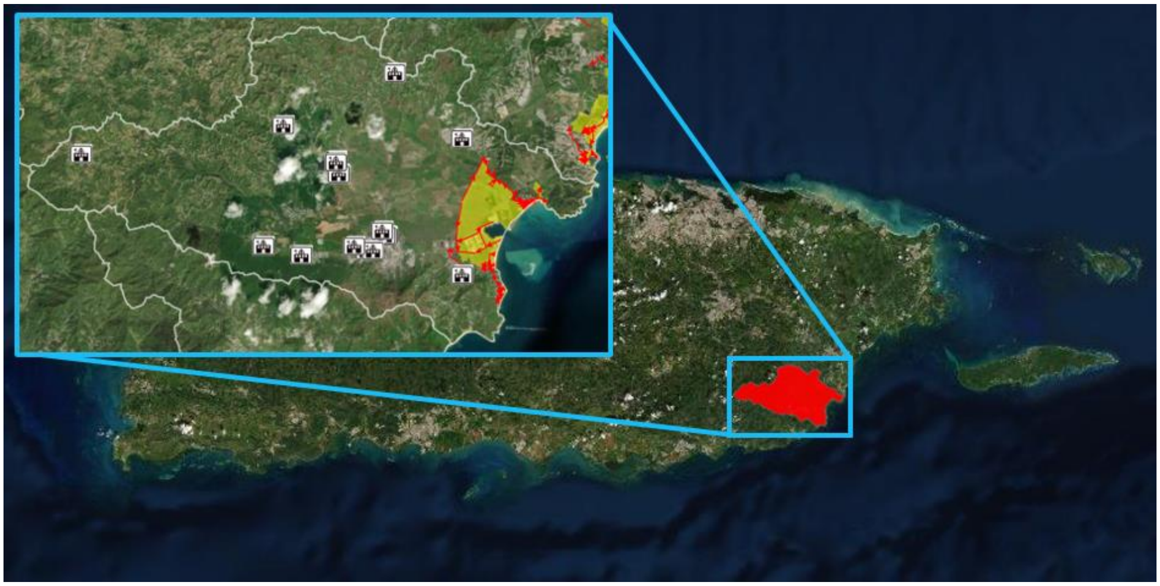


Figure 5-113 Location of Schools in Yabucoa

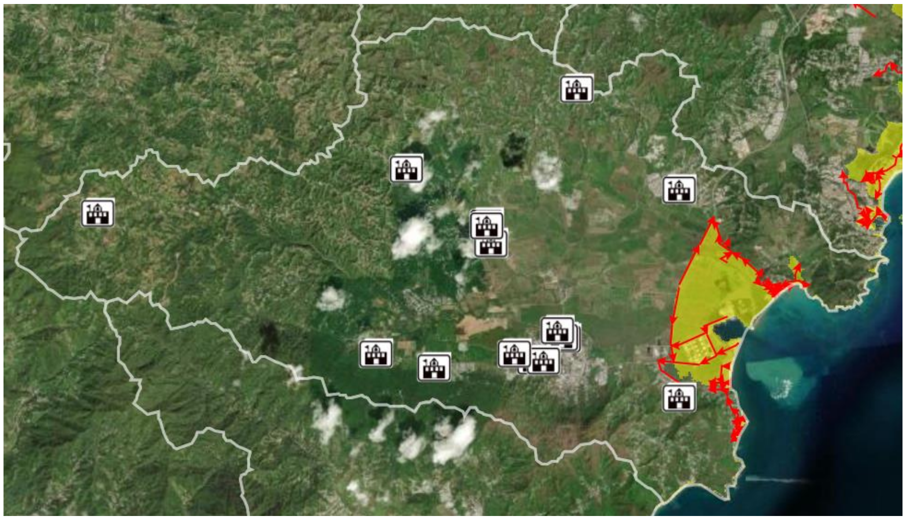


Figure 5-114 Schools located outside the tsunami hazard zones in Yabucoa

5.1.46 Yauco

This municipality has a total of 4 schools and none of them are in a tsunami hazard zone as shown in Figure 5-115. Therefore, no school population in Yauco could be affected by the impact of a tsunami.

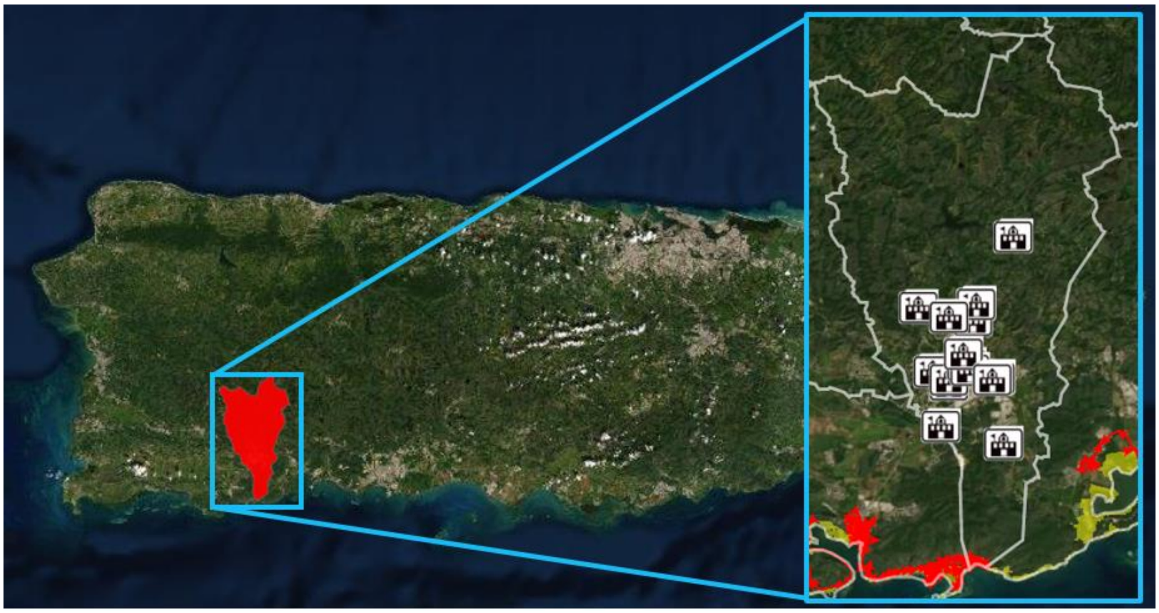


Figure 5-115 Location of Schools in Yauco

5.2 Case Study Selection

The selection of two municipalities with schools in a tsunami hazard zone is shown below to determine their vulnerability as a case study. For this, the selection criteria mentioned in Phase II - Selection of the case study are used. These are: the accessibility of the researchers, the number of schools located in the tsunami hazard zone, the number of schools used as shelters or voting centers located in the tsunami hazard zone, and the number of the population that could be affected by a tsunami.

Table 5-26 summarizes the findings of the Hazard Identification developed municipality by municipality of study shown above considering the selection criteria for the case study. This shows the study municipalities in the first column. The second, third and fourth column is the accessibility of the researchers, in which the second and third column shows the travel distance for the researchers considered individually from their starting point to the study municipality. Fourth column shows the accessibility measured at an average travel distance in kilometers. The fifth column shows the number of schools that are in a tsunami hazard zone. The sixth column lists the schools that are used as voting centers and the seventh shows those schools that are used as shelters. Finally, the eighth column presents the total population of each municipality between teachers and students that could be affected by a tsunami. The light blue in Table 5-26, shows the municipalities that do not have schools in a tsunami hazard zone are represented in light blue, municipalities that have between 1 to 3 schools in a tsunami hazard zone correspond to the orange color, and municipalities that have 4 or more schools in the tsunami hazard zone are shown in yellow color.

According to the findings, at the island level 74 schools are in a tsunami hazard zone, of which 34 are used as voting centers, and 9 are used as shelters. On the other hand, the total school population between students and teachers that could be affected by the impact of a tsunami in all of Puerto Rico is approximately 21,000 people.

Table 5-26 Hazard Identification Findings Summary by Municipality

[1] Municipality	Researchers' accessibility (km)			[5] Schools	[6] Voting Center	[7] Shelter	[8] Population
	[2] Verónica	[3] Joel	[4] Average				
Aguada	170.0	155	162.5	3	1	0	1,457
Aguadilla	153.0	146	149.5	3	1	0	519
Añasco	171.0	163	167	1	0	0	0
Arecibo	98.4	95.6	97	1	0	0	97
Arroyo	45.8	93.5	69.65	0	0	0	0
Barceloneta	75.5	72.7	74.1	0	0	0	0
Bayamón	32.2	33.4	32.8	0	0	0	0
Cabo Rojo	161.0	182	171.5	3	1	0	931
Camuy	112.0	112	112	1	1	0	0
Canóvanas	33.2	9.9	21.55	0	0	0	0
Carolina	25.4	0	12.7	2	0	0	0
Cataño	34.6	27.5	31.05	4	2	0	1,465
Ceiba	49.7	49	49.35	0	0	0	0
Culebra	107.0	94.7	100.85	1	1	1	190

Dorado	48.3	42.9	45.6	1	0	1	937
Fajardo	55.5	41.8	48.65	0	0	0	0
Guánica	128.0	154	141	0	0	0	0
Guayama	59.5	86.5	73	1	0	0	115
Guayanilla	110.0	137	123.5	0	0	0	0
Guaynabo	17.5	16.2	16.85	0	0	0	0
Hatillo	110.0	105	107.5	1	0	0	0
Humacao	28.7	45.5	37.1	1	1	0	386
Isabela	137.0	130	133.5	0	0	0	0
Juana Díaz	75.9	103	89.45	2	1	0	529
Lajas	144.0	171	157.5	1	0	0	108
Loíza	41.8	20.7	31.25	8	4	3	2,401
Luquillo	54.0	32.5	43.25	3	1	0	596
Manatí	71.0	65.5	68.25	0	0	0	0
Maunabo	45.0	70.6	57.8	0	0	0	0
Mayagüez	161.0	168	164.5	9	5	1	3,247
Naguabo	36.4	61.8	49.1	0	0	0	0
Patillas	44.5	69.8	57.15	0	0	0	0
Peñuelas	108.0	135	121.5	1	0	0	245
Ponce	87.2	114	100.6	4	2	0	1,577
Quebradillas	124.0	119	121.5	0	0	0	0
Rincón	169.0	162	165.5	1	0	0	183
Río Grande	37.8	20.9	29.35	0	0	0	0
Salinas	49.7	72.3	61	4	3	0	541
San Juan	32.9	20.4	26.65	9	5	0	2,083
Santa Isabel	65.7	92.7	79.2	1	1	1	486
Toa Baja	48.8	41.7	45.25	8	4	2	2,802
Vega Alta	53.9	48.5	51.2	0	0	0	0
Vega Baja	63.0	60.3	61.65	0	0	0	0
Vieques	91.0	111	101	0	0	0	0
Yabucoa	36.0	61.3	48.65	0	0	0	0
Yauco	117.0	144	130.5	0	0	0	0
Total				74	34	9	20,895

Municipalities with no schools in tsunami hazard zone
Municipalities with 1 to 3 schools in a tsunami hazard zone
Municipalities with 4 to more schools in a tsunami hazard zone
Total results

The selection of the case study is summarized in Table 5-27. In this study, the selection criterion is that the shorter the average travel distance and the greater accessibility. The greater accessibility, the number of schools that are in a tsunami hazard zone, and of these those that are used as voting centers and shelters, and the amount of population that could be affected, the greater the fulfillment of the selection criteria for determine the case study.

Table 5-27 Summary of Municipalities for Case Study

Municipality	Researchers' accessibility (km)			Schools	Voting Center	Shelter	Population
	Verónica	Joel	Average				
Cataño	34.6	27.5	31.05	4	2	0	1,465
Loíza	41.8	20.7	31.25	8	4	3	2,401
Mayagüez	161.0	168	164.5	9	5	1	3,247
Ponce	87.2	114	100.6	4	2	0	1,577
Salinas	49.7	72.3	61	4	3	0	541
San Juan	32.9	20.4	26.65	9	5	0	2,083
Toa Baja	48.8	41.7	45.25	8	4	2	2,802

Considering each of these criteria and the results shown for each municipality in Table 5-27, the two municipalities that considerably meet all the selection criteria are Cataño and San Juan. Both municipalities met the selection criteria with the greatest influence in determining the case study, which is the accessibility of the researchers to be able to visit the schools. Cataño, with an average travel distance of 31.05 km, and San Juan, with an average of 26.65 km, have the lowest average travel distances between both researchers compared to the rest of the municipalities.

Figure 5-116 shows the number of schools that are in the tsunami hazard zone in blue bars and the municipalities selected for this project are shown with yellow bars. The orange line corresponds to the percentage of the population between students and teachers that could be affected by the impact of a tsunami.

Although there are other municipalities with a large number of schools that are in a tsunami hazard zone and with a large population that could be affected, they do not comply with the accessibility of the researchers. This is the case of the municipalities in blue bars shown in Figure 5-116 such as Mayagüez, which has 9 schools in a tsunami hazard zone, just like San Juan. And that in addition, Mayaguez has 6% more population that could be affected by a tsunami than San Juan, but it has the least accessibility with an average travel distance greater of 164.5 km.

The municipality of Loíza does not fully meet this criterion. Although it has a lower accessibility of 31.25 km like Cataño and San Juan, for both researchers the distance is not equitable. One of the researchers has a travel distance of 41.8 km, while the other has a travel distance of 20.7 km. The selection criterion considers an equitable average for both researchers individually. For this reason, Loíza is not part of the case study, considering only Cataño and San Juan.

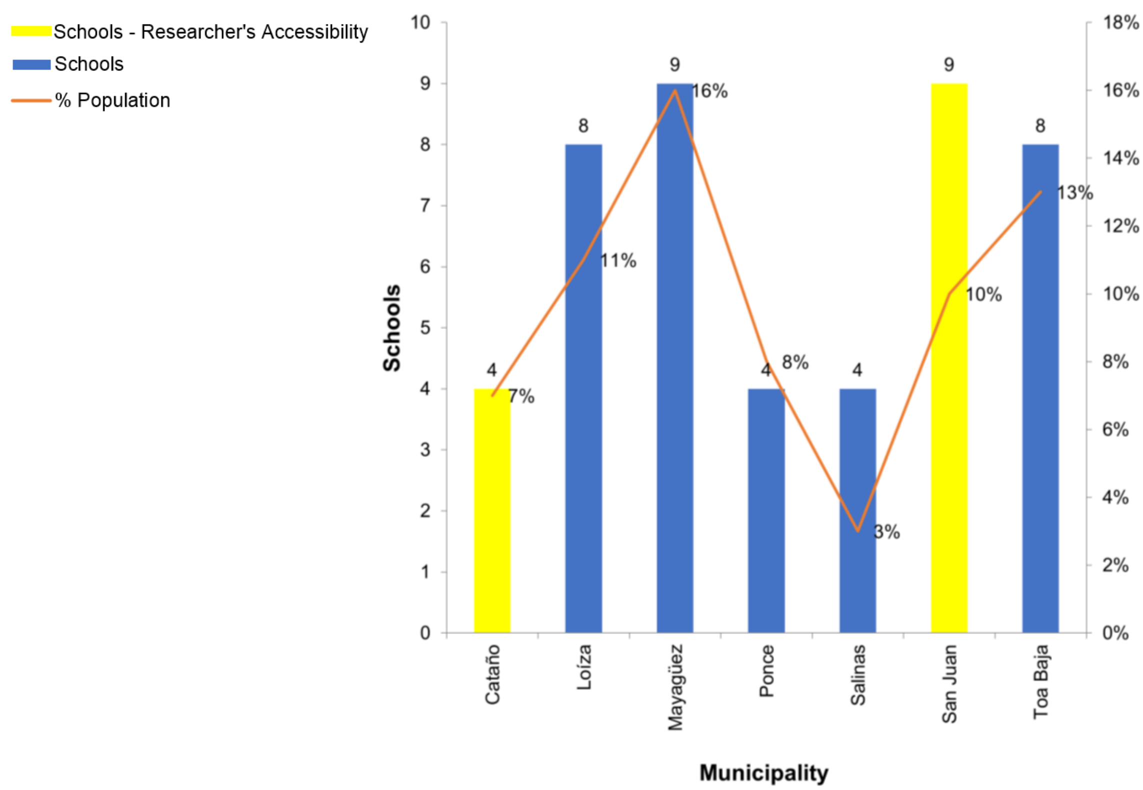


Figure 5-116 Schools and Population of Municipalities for Case Study

6 Vulnerability Assessment

The assessment of the vulnerability of schools is presented below. As a parameter of vulnerability, evacuation times are first presented for the shortest routes to schools. Subsequently, the alternate routes that are available to schools are displayed. On the other hand, the conditions of the evacuation routes available to schools are exposed.

6.1 Evacuation Times

In this section the evacuation time of the selected schools (Cataño and San Juan) will be determined, is this the time spent on foot from the school to the assembly place. An evacuation by vehicle is not considered because of the hazard and risk it poses, such as stalling in traffic instead of moving out of the hazard zone. This is an estimated evacuation time determined for four walking speeds of the Pedestrian Evacuation Analyst recommended by the U.S. Geological Survey (USGS). These speeds are: slow walk of 2.46 mph, moderate walk of 2.70 mph, fast walk of 3.40 mph, and an average walking speed of 2.50 mph of the previous three speeds. These speeds are considered to evaluate how evacuation times would be and how they would be affected for different walking speed scenarios. On the other hand, this time does not consider the start time and assumes that there are no obstacles on the route. Likewise, it corresponds to the minimum time that the school population can evacuate. These times are then determined from the school to the assembly place and then from the school to the point where the tsunami hazard zone ends. That is the time within the tsunami hazard zone and the time outside the evacuation zone. To determine the estimated evacuation time for different speeds and destinations, the route planner “Plot a Route” is used. This resource gives a single distance for the route, but different evacuation times for the different walking speeds.

6.1.1 Time It Takes for the School Population to Get Out of the Tsunami Hazard Zone and to the Assembly Site

To determine the time, it takes for the school population to leave the tsunami hazard zone, routes are plotted from the school campus location to the predetermined assembly locations on the Puerto Rico Seismic Network (PRSN) evacuation and flood maps. These assembly places located in safe areas have the names known to the community of municipalities. For this time, the shortest routes are selected. Thus, the evacuation time corresponds to the shortest possible time to reach the assembly place. For this, to trace the evacuation routes for each of the schools in the municipalities, the assembly place closest to the location of the school is assumed. However, in the following section, possible evacuation routes for different assembly locations are presented by way of comparison of evacuation times.

6.1.1.1 Cataño

The municipality of Cataño has four schools in a tsunami danger zone: Francisco Oller, Horace Mann, Onofre Carballeira and Rosendo Matienzo Cintrón. From each of their locations, routes are plotted closer to the assembly places, corresponding to the evacuation routes. Cataño has three assembly places available (Figure 6-1), they are: “Parque de Pelota Res. Palmas”, “Pista Atlética Urb. Las Vegas” and “Peruchin Cepeda Stadium”. At first glance, for Cataño, the closest assembly place to the schools is “Estadio Peruchin Cepeda”. For this reason, this park is assumed for all the routes of the four schools in this municipality.

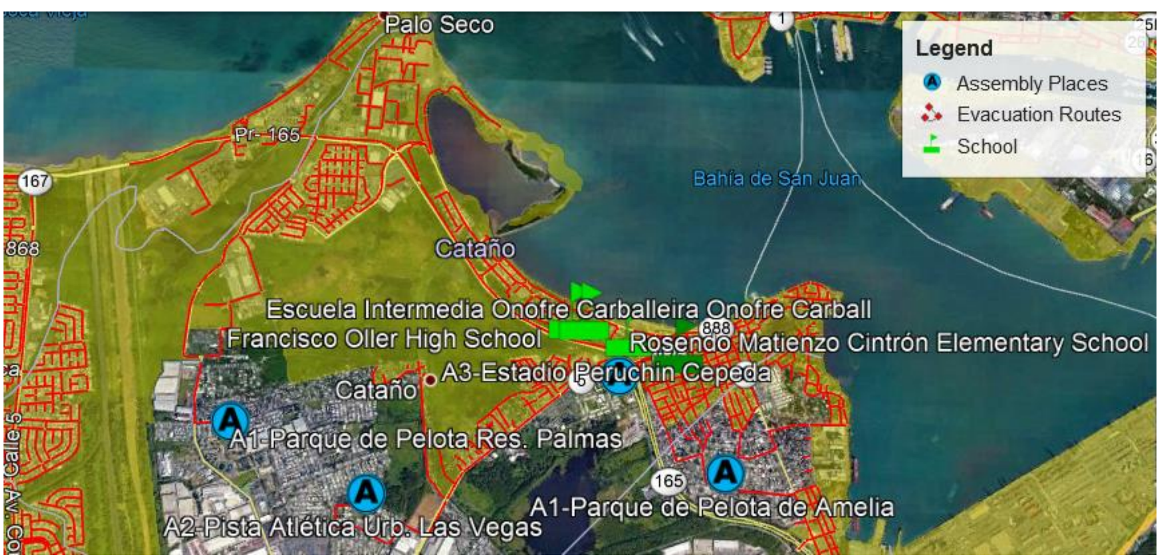


Figure 6-1 Assembly Places for Cataño

6.1.1.1.1 Francisco Oller

The Francisco Oller school evacuation route starts from "Calle Este" and turns onto Las Nereidas Avenue (PR-88). Then, it turns along Olivo Street, exit at the El Caño Avenue terminal of PR-165 and turns onto José Celso Barbosa Avenue (PR-5) until reaching the predetermined assembly place (Figure 6-2).

The route of this school has a distance of 0.716 miles (Figure 6-2). Figure 6-3 is zoomed in with the information obtained from "Plot a Route" for an average walking speed. Table 6-1 shows the evacuation times for the different walking speeds.

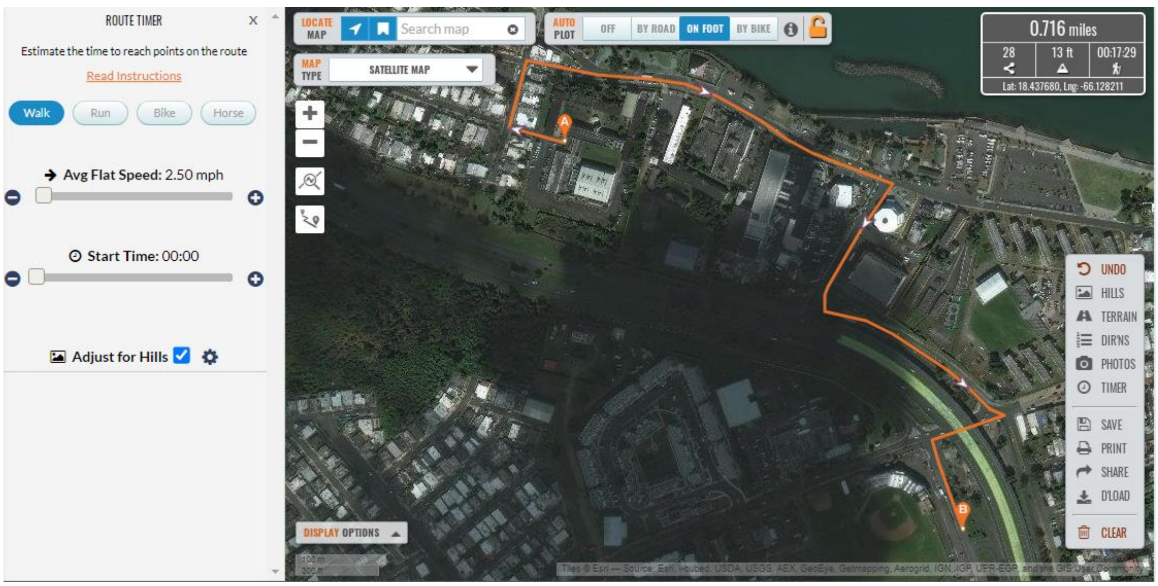


Figure 6-2 Route for Average Walking Speed of Francisco Oller School at Cataño

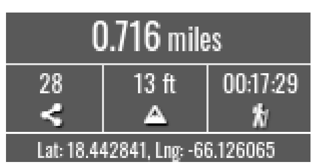


Figure 6-3 Evacuation Time and Routes for Average Walking Speed of Francisco Oller School

Table 6-1 Evacuation Time for Every Speed of Francisco Oller School at Cataño

Walking Speed (mph)	Evacuation Time (min)
2.46	17.46
2.70	16.11

3.40	12.51
2.50	17.29
Distance (miles)	0.716

6.1.1.1.2 Horace Mann

The Horace Mann school evacuation route starts from PR-875 turn slight to “Calle Barbosa” and then make a left turn until reaching the predetermined assembly place (Figure 6-4).

The route of this school has a distance of 0.301 miles (Figure 6-4). Figure 6-5 is zoomed in with the information obtained from “Plot a Route” for an average walking speed. Table 6-2 shows the evacuation times for the different walking speeds.

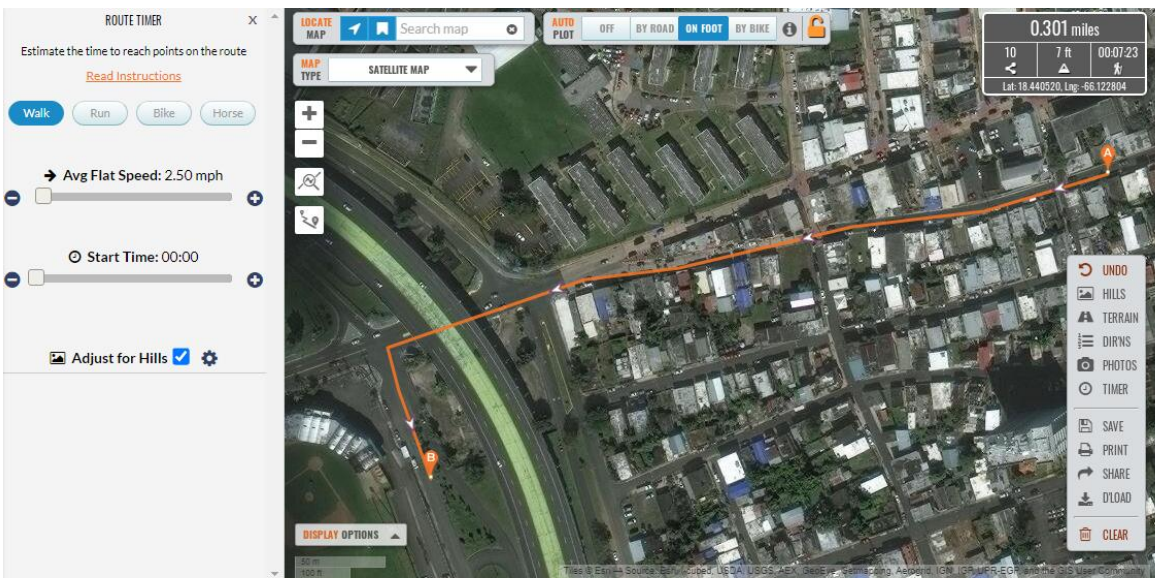


Figure 6-4 Route for Average Walking Speed of Horace Mann School at Cataño

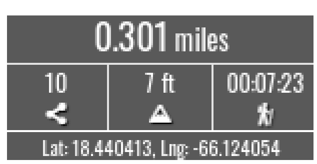


Figure 6-5 Evacuation Time And Route’s Distance of Routes for Average Walking Speed of Horace Mann School

Table 6-2 Evacuation Time for Every Speed of Horace Mann School at Cataño

Walking Speed (mph)	Evacuation Time (min)
2.46	7.30
2.70	6.50
3.40	5.26
2.50	7.23
Distance (miles)	0.301

6.1.1.1.3 Onofre Carballeira

The Onofre Carballeira school evacuation route starts from Ave. “Las Nereidas” PR-888 keep right and then turn sharp right onto “Calle Olivo”. Then make a left turn keep going straight and turn sharp right onto “Ave. José Celso Barbosa” PR-5. Make a left turn until reaching the predetermined assembly place (Figure 6-6).

The route of this school has a distance of 0.512 miles (Figure 6-6). Figure 6-7 is zoomed in with the information obtained from “Plot a Route” for an average walking speed. Table 6-3 shows the evacuation times for the different walking speeds.

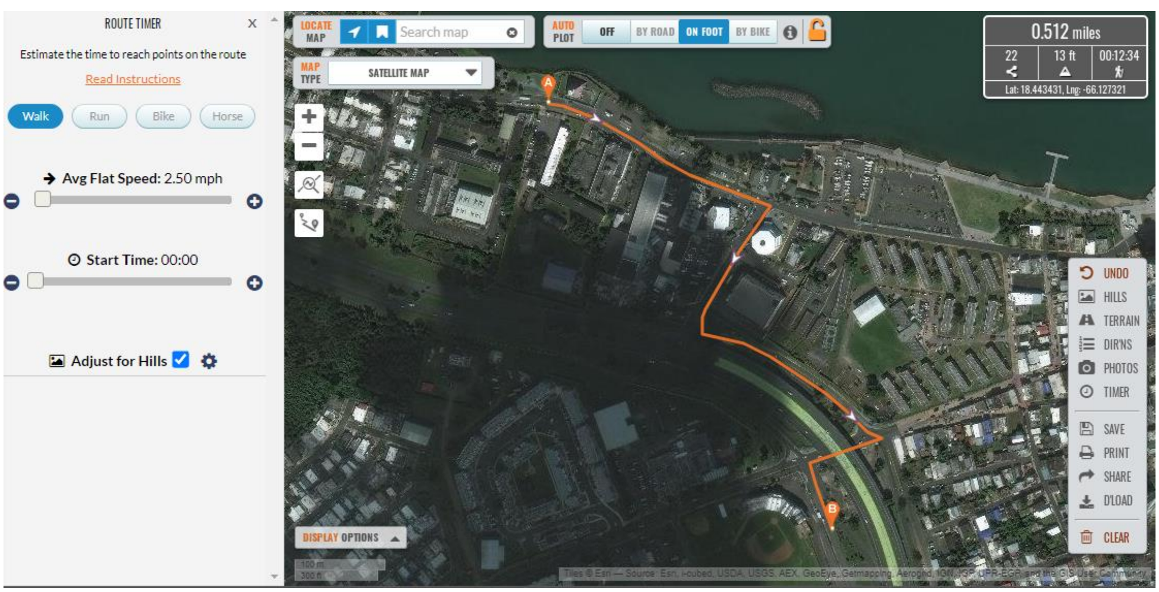


Figure 6-6 Route for Average Walking Speed of Onofre Carballeira School at Cataño

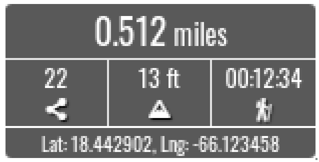


Figure 6-7 Evacuation Time and Route's Distance of Routes for Average walking Speed of Onofre Carballeira School

Table 6-3 Evacuation Time for Every Speed of Onofre Carballeira School at Cataño

Walking Speed (mph)	Evacuation Time (min)
2.46	12.46
2.70	11.38
3.40	9.14
2.50	12.34
Distance (miles)	0.512

6.1.1.1.4 Rosendo Matienzo Cintrón

The Rosendo Matienzo Cintrón school evacuation route starts from from "Ave. Las Nereidas" PR-888, turn right onto "Calle Destino", turn right onto "Ave. José Celso Barbosa" PR-5 and then make a left turn until reaching the predetermined assembly place (Figure 6-8).

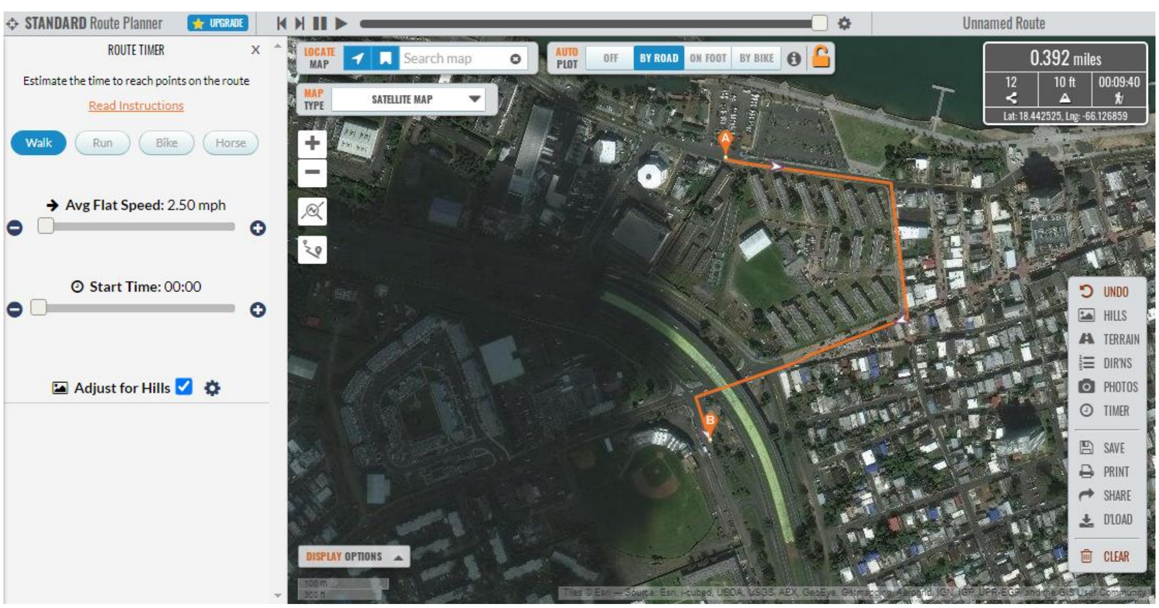


Figure 6-8 Route for Average Walking Speed of Rosendo Matienzo Cintrón School at Cataño

The route of this school has a distance of 0.392 miles (Figure 6-8). Figure 6-9 is zoomed in with the information obtained from “Plot a Route” for an average walking speed. Table 6-4 shows the evacuation times for the different walking speeds.

Figure 6-9 Evacuation Time and Route’s Distance of Routes for Average Walking Speed of Rosendo Matienzo Cintrón School

Table 6-4 Evacuation Time for Every Speed of Rosendo Matienzo Cintrón School at Cataño

Walking Speed (mph)	**Evacuation Time (min)**
2.46	9.50
2.70	8.57
3.40	7.07
2.50	9.40
Distance (miles)	0.392

6.1.1.2 San Juan

The municipality of San Juan has nine schools in a tsunami hazard zone: Dr. Julio J. Henna, Jaime Rosario (Buena Vista Elemental), Julián E. Blanco (Ballet), Luis Llorens Torres, Luis Rodríguez Cabrero, Madame Luchetti, Moisés Meléndez, Ramón Power Y Giralt, and República Del Perú. From each of their locations, routes are plotted closer to the assembly places, corresponding to the evacuation routes.

San Juan has six assembly places available (Figure 6-10), their names are: “Campo del Morro”, “Plaza de Colón”, “Plaza Barceló”, “Plaza del Choliseo”, “Parque de Pelota de Las Gladiolas”, and “Complejo Deportivo Hiram Bithorn”.

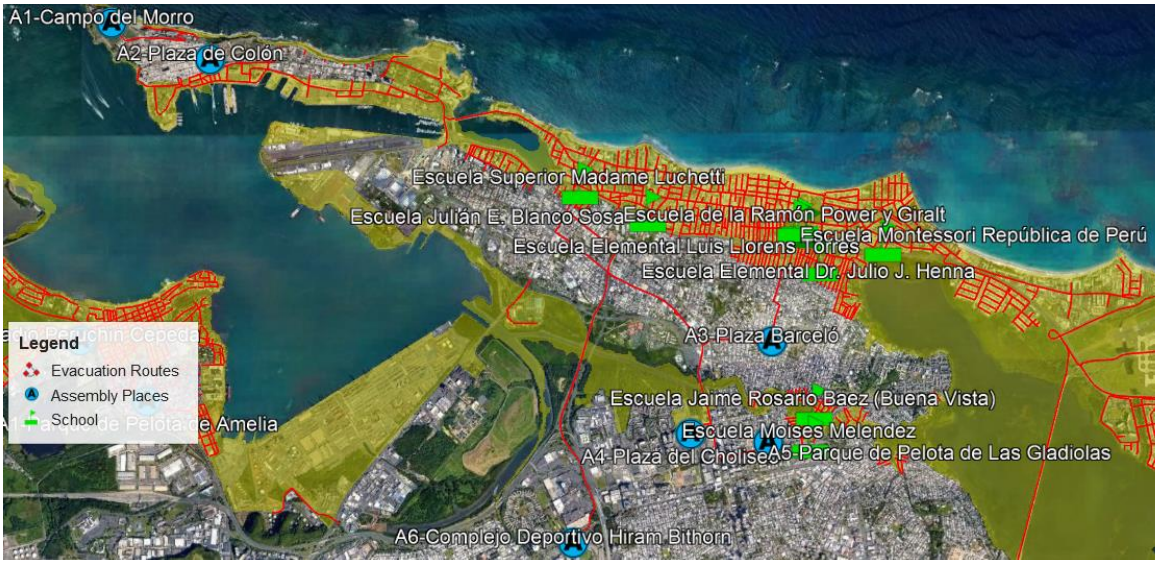


Figure 6-10 Assembly Places for San Juan

6.1.1.2.1 Dr. Julio J. Henna

The Dr. Julio J. Henna school evacuation route starts from "Calle Dr. Julio J. Henna", turn left onto "Calle Pellín Rodríguez" / "Calle Providencia" and keep going straight and make a right onto "Ave. Eduardo Conde", then turn left onto "Calle Los Santos". Keep going straight then turn left onto "Calle Lippit" / "Calle 17", turn right onto "Ave. Catalino "Tite" Curet Alonzo" / "Ave. D". Make left turn onto "Calle Felipe R. Goyco" / "Calle 15" until reaching the predetermined assembly place (Figure 6-11).

The route of this school has a distance of 0.708 miles (Figure 6-11). Figure 6-12 is zoomed in with the information obtained from "Plot a Route" for an average walking speed. Table 6-5 shows the evacuation times for the different walking speeds.

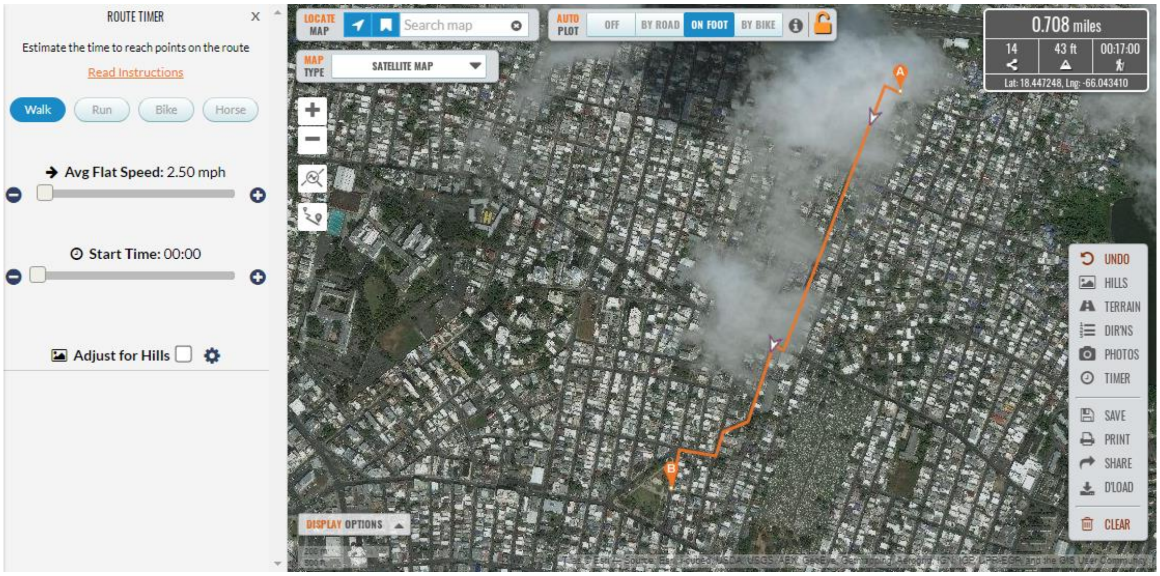


Figure 6-11 Route for Average Walking Speed of Dr. Julio J. Henna School at San Juan

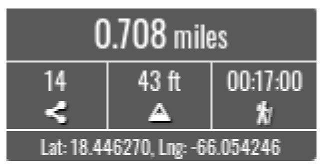


Figure 6-12 Evacuation Time And Route's Distance of Routes for Average Walking Speed of Dr. Julio J. Henna School

Table 6-5 Evacuation Time for Every Speed of Dr. Julio J. Henna School at San Juan

Walking Speed (mph)	Evacuation Time (min)
2.46	17.17
2.70	15.45
3.40	12.30
2.50	17.00
Distance (miles)	0.708

6.1.1.2.2 Jaime Rosario (Buena Vista Elemental)

The Jaime Rosario (Buena Vista Elemental) school evacuation route starts from "Calle Dr. Julio J. Henna", turn left onto "Calle Pellín Rodríguez" / "Calle Providencia" and keep going straight and make a right onto "Ave. Eduardo Conde", then turn left onto "Calle Los Santos". Keep going straight then turn left onto "Calle Lippit" / "Calle 17", turn right onto

"Ave. Catalino "Tite" Curet Alonzo" / "Ave. D". Make left turn onto "Calle Felipe R. Goyco" / "Calle 15" until reaching the predetermined assembly place (Figure 6-13).

The route of this school has a distance of 0.676 miles (Figure 6-13). Figure 6-14 is zoomed in with the information obtained from "Plot a Route" for an average walking speed. Table 6-6 shows the evacuation times for the different walking speeds.

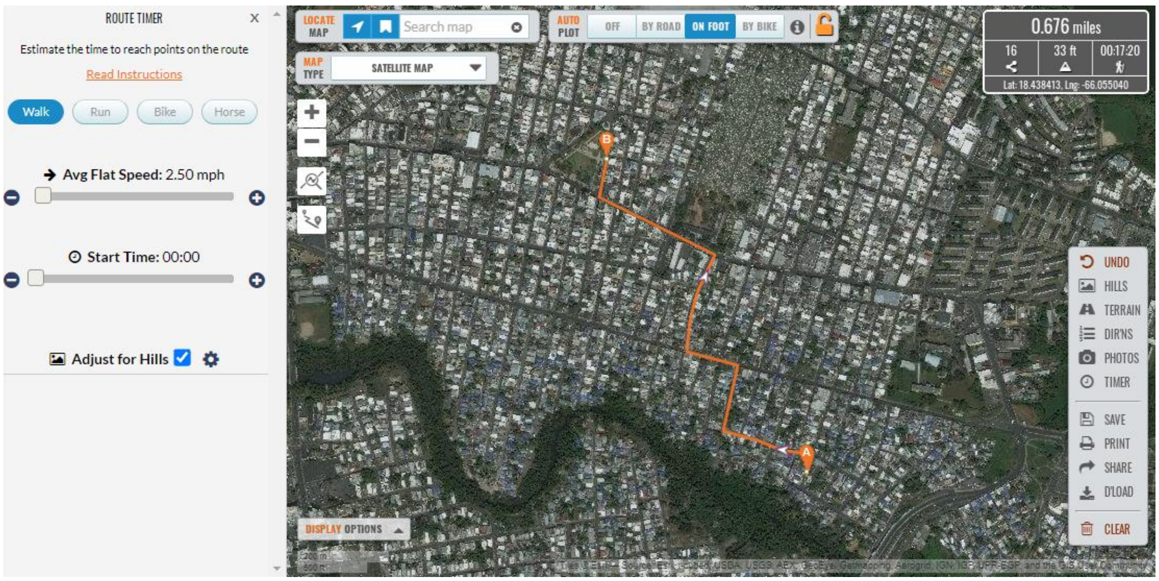


Figure 6-13 Route for Average Walking Speed of Jaime Rosario (Buena Vista Elemental) School at San Juan

Figure 6-14 Evacuation Time And Route's Distance of Route for Average Walking Speed of Jaime Rosario (Buena Vista Elemental) School

Table 6-6 Evacuation Time for Every Speed of Jaime Rosario (Buena Vista Elemental) School at San Juan

Walking Speed (mph)	Evacuation Time (min)
2.46	17.37
2.70	16.03
3.40	12.45
2.50	17.20

Distance (miles)	0.676

6.1.1.2.3 Julián E. Blanco (Ballet)

The Julián E. Blanco (Ballet) school evacuation route starts from “Calle Estrella” turn right onto “Calle Estrella”, then turn slight right onto “Calle Julián Blanco”, later turn left onto “Calle Martín Travieso”, turn sharp right onto “Ave José de Diego (PR-37), turn left onto “Ave. Román Baldorioty de Castro”, turn right onto “Calle San Jorge” and turn left onto “Calle Pumarada”. Keep straight and turn right onto “Calle Castelar”, turn left onto “Ave. Gilberto Monroig” / “Ave. Puerto Rico”, make a right turn onto “Calle Salgado”, later make a turn left onto “Ave. Eduardo Conde”. Maker right turn onto “Calle Profesor Ernesto Vigoreaux” / “Calle 14” and then turn slight right onto “Ave. Orlando “Peruchin” Cepeda” / “Ave. C” until reaching the predetermined assembly place (Figure 6-15).

The route of this school has a distance of 1.606 miles (Figure 6-15). Figure 6-16 is zoomed in with the information obtained from “Plot a Route” for an average walking speed. Table 6-7 shows the evacuation times for the different walking speeds.

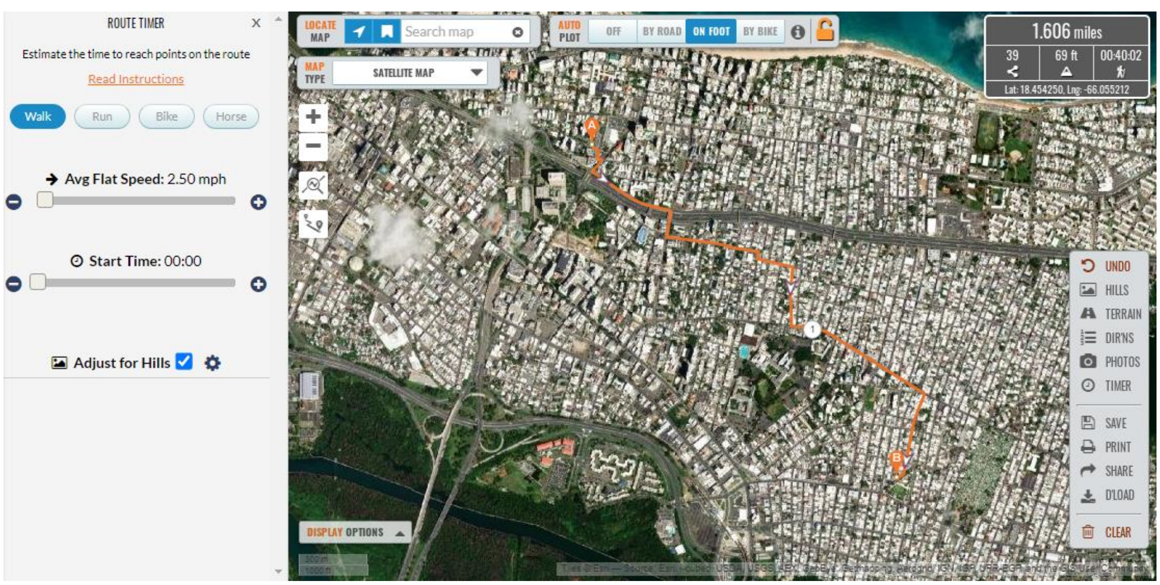


Figure 6-15 Route for Average Walking Speed of Julián E. Blanco (Ballet) School at San Juan

Figure 6-16 Evacuation Time and Route's Distance of Route for Average Walking Speed of Julián E. Blanco (Ballet) School

Table 6-7 Evacuation Time for Every Speed of Julián E. Blanco (Ballet) School at San Juan

Walking Speed (mph)	Evacuation Time (min)
2.46	40.41
2.70	37.04
3.40	29.26
2.50	40.02
Distance (miles)	1.606

6.1.1.2.4 Luis Llorens Torres

The Luis Llorens Torres school evacuation route starts from "Calle María Isabel" turn left onto "Calle Marina", later turn left onto "Calle Pellín Rodríguez" / "Calle Providencia", keep straight and make a turn right onto "Ave. Eduardo Conde" right after, turn left onto "Calle Los Santos". Turn left onto "Calle Lippit" / "Calle 17", later turn right onto "Ave. Catalino "Tite" Curet Alonso" / "Ave. D" and turn left onto "Calle Felipe R. Goyco" / "Calle 15" until reaching the predetermined assembly place (Figure 6-17).

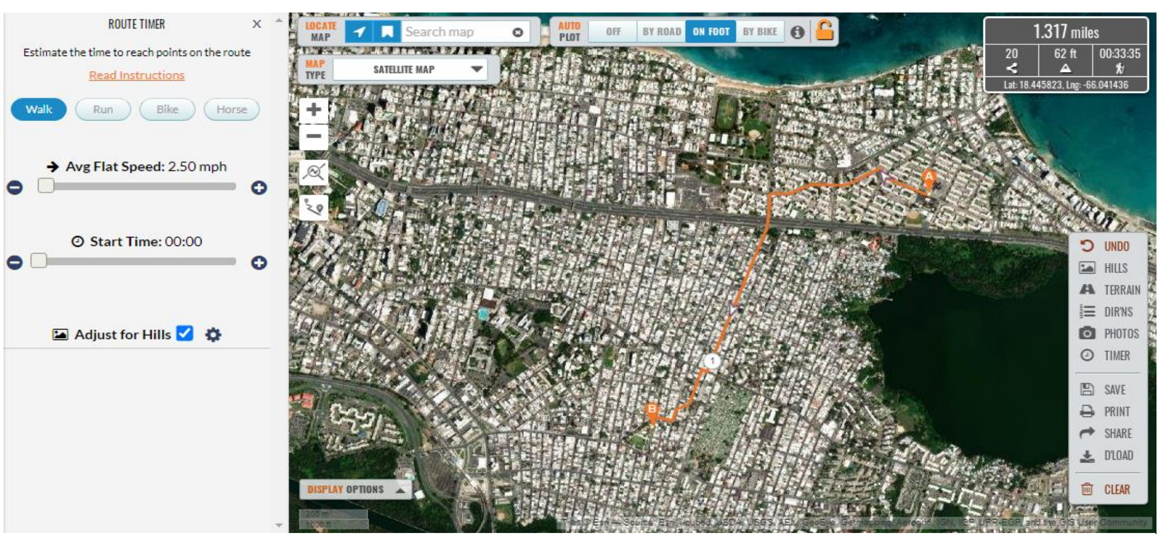


Figure 6-17 Route for Average Walking Speed of Luis Llorens Torres School at San Juan

The route of this school has a distance of 1.317 miles (Figure 6-17). Figure 6-18 is zoomed in with the information obtained from "Plot a Route" for an average walking speed. Table 6-8 shows the evacuation times for the different walking speeds.

Figure 6-18 Evacuation Time and Route's Distance of Route for Average Walking Speed of Luis Llorens Torres School

Table 6-8 Evacuation Time for Every Speed of Luis Llorens Torres School at San Juan

Walking Speed (mph)	**Evacuation Time (min)**
2.46	34.08
2.70	31.06
3.40	24.42
2.50	33.35
Distance (miles)	1.317

6.1.1.2.5 Luis Rodríguez Cabrero

The Luis Rodríguez Cabrero evacuation route starts from "Calle Corona" turn right onto "Calle Pellín Rodríguez" / "Calle Providencia" keep straight, make a turn right onto "Ave. Eduardo Conde" right after, turn left onto "Calle Los Santos". Turn left onto "Calle Lippit" / "Calle 17", later turn right onto "Ave. Catalino "Tite" Curet Alonso" / "Ave. D" and turn left onto "Calle Felipe R. Goyco" / "Calle 15" until reaching the predetermined assembly place (Figure 6-19).

The route of this school has a distance of 0.975 miles (Figure 6-19). Figure 6-20 is zoomed in with the information obtained from "Plot a Route" for an average walking speed. Table 6-9 shows the evacuation times for the different walking speeds.

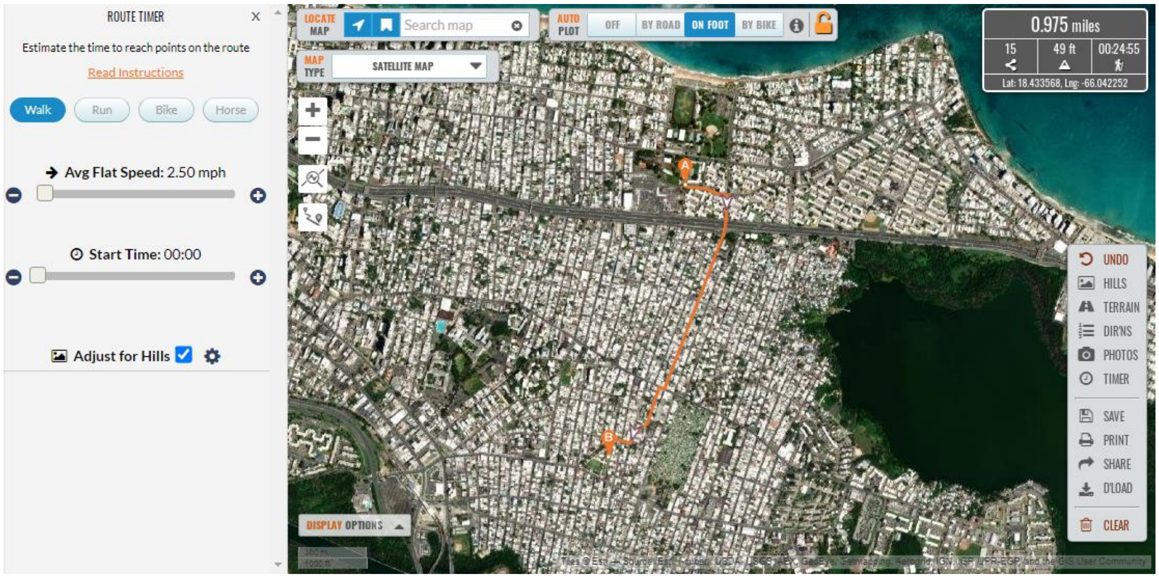


Figure 6-19 Route for Average Walking Speed of Luis Rodríguez Cabrero School at San Juan

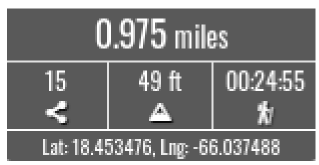


Figure 6-20 Evacuation Time and Route's Distance of Route for Averge Walking Speed of Luis Rodríguez Cabrero School

Table 6-9 Evacuation Time for Every Speed of Luis Rodríguez Cabrero School at San Juan

Walking Speed (mph)	Evacuation Time (min)
2.46	25.20
2.70	23.05
3.40	18.20
2.50	24.55
Distance (miles)	0.975

6.1.1.2.6 Madame Luchetti

The Madame Luchetti evacuation route starts from "Calle Luchetti" turn right onto "Marginal Román Baldorioty de Castro", turn left onto "Calle Condado", turn left onto "Ave. Juan Ponce de León" PR-25, keep left onto "Calle Cayey" PR-36, later turn slightly left onto "Ave. Borinquen" PR-36, keep straight and turn sharp left onto "Calle Felipe R. Goyco" / "Calle 15" until reaching the predetermined assembly place (Figure 6-21).

The route of this school has a distance of 2.077 miles (Figure 6-21). Figure 6-22 is zoomed in with the information obtained from “Plot a Route” for an average walking speed. Table 6-10 shows the evacuation times for the different walking speeds.

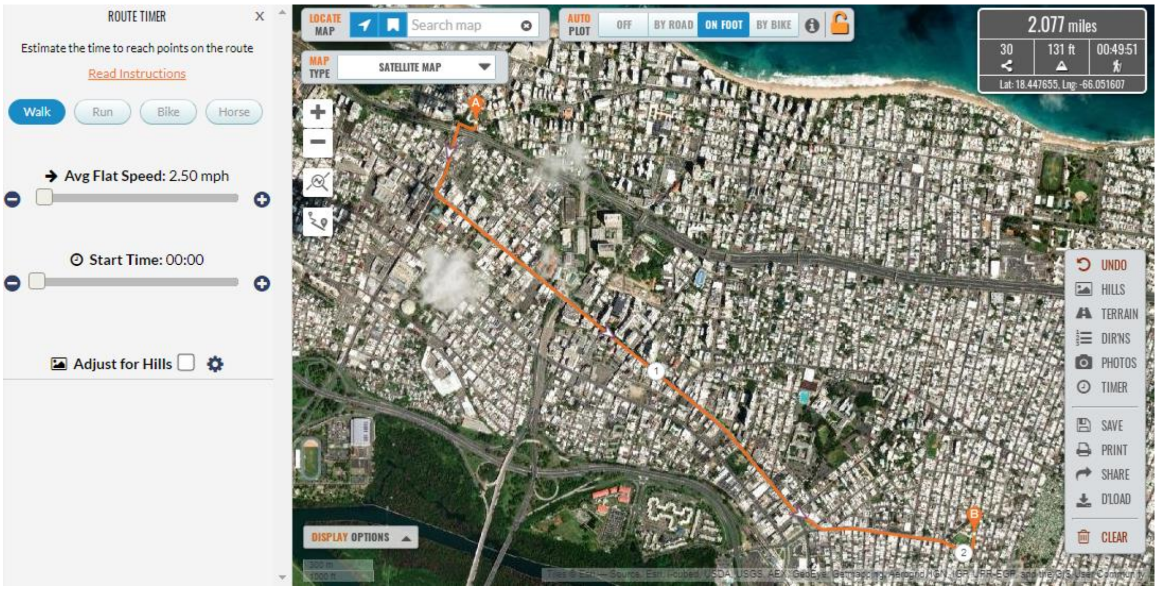


Figure 6-21 Route for Average Walking Speed of Madame Luchetti School at San Juan

Figure 6-22 Evacuation Time and Route’s Distance of Route for Avergae Walking Speed of Madame Luchetti School

Table 6-10 Evacuation Time for Every Speed of Madame Luchetti School at San Juan

Walking Speed (mph)	Evacuation Time (min)
2.46	50.39
2.70	46.09
3.40	36.39
2.50	49.51
Distance (miles)	2.077

6.1.1.2.7 Moisés Meléndez

The Moisés Meléndez evacuation route starts from “Calle B” turn left and later make a right turn onto “Ave. Quisqueya” PR-40 keep straight until reaching the predetermined assembly place (Figure 6-23).

The route of this school has a distance of 0.365 miles (Figure 6-23). Figure 6-24 is zoomed in with the information obtained from “Plot a Route” for an average walking speed. Table 6-11 shows the evacuation times for the different walking speeds.

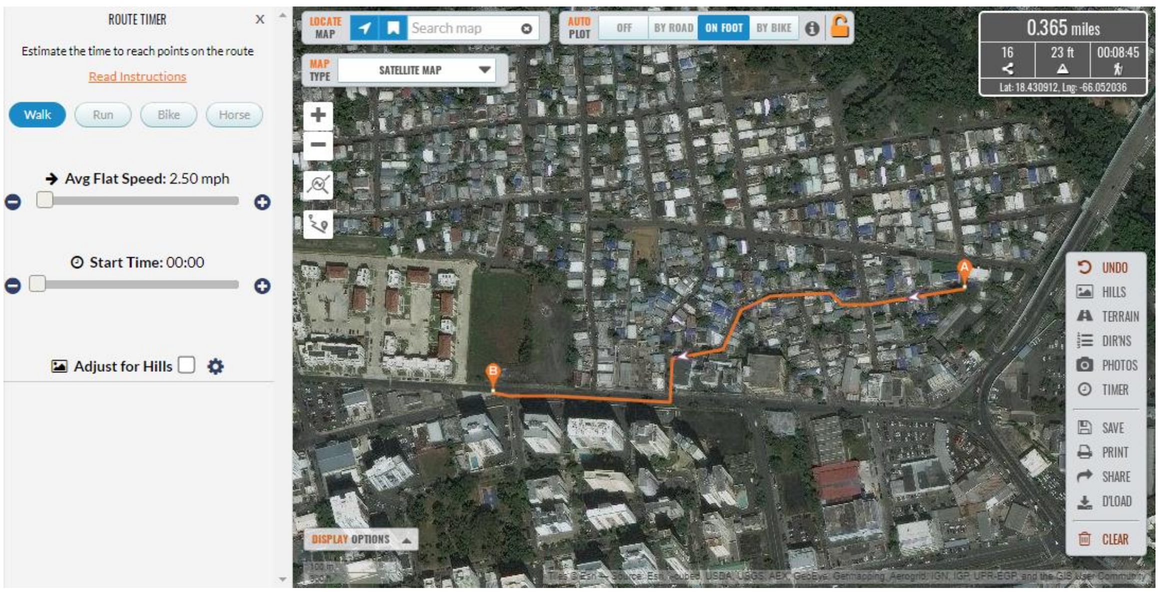


Figure 6-23 Route for Average Walking Speed of Moisés Meléndez School at San Juan

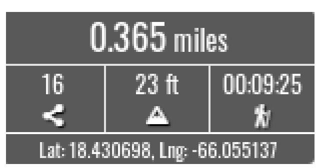


Figure 6-24 Evacuation Time and Route’s Distance of Route for Average Walking Speed of Moisés Meléndez School

Table 6-11 Evacuation Time for Every Speed of Moisés Meléndez School at San Juan

Walking Speed (mph)	Evacuation Time (min)
2.46	9.34
2.70	8.43
3.40	6.55
2.50	9.25
Distance (miles)	0.365

6.1.1.2.8 Ramón Power Y Giralt

The Ramón Power Y Giralt evacuation route starts from "Calle Corona" turn left onto "Calle Degetau", keep straight, then turn left onto "Ave. Eduardo Conde", turn right onto "Calle Profesor Ernesto Vigoreaux" / "Calle 14". Turn left onto "Ave. Catalino "Tite" Curet Alonso" / "Ave. D and turn right onto "Calle Felipe R. Goyco" / "Calle 15" until reaching the predetermined assembly place (Figure 6-25).

The route of this school has a distance of 0.991 miles (Figure 6-25). Figure 6-26 is zoomed in with the information obtained from "Plot a Route" for an average walking speed. Table 6-12 shows the evacuation times for the different walking speeds.

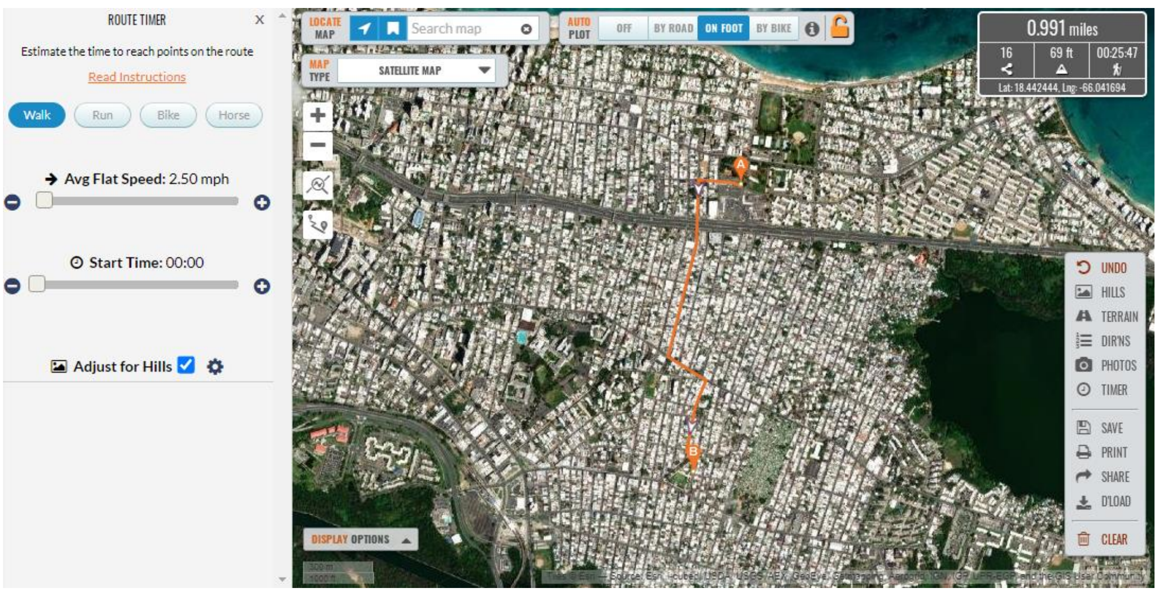


Figure 6-25 Route for Average Walking Speed of Ramón Power Y Giralt School at San Juan

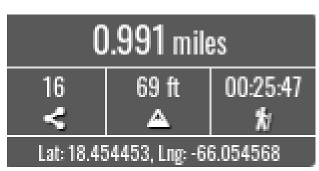


Figure 6-26 Evacuation Time and Route's Distance of Route for Avergae Walking Speed of Ramón Power Y Giralt School

Table 6-12 Evacuation Time for Every Speed of Ramón Power Y Giralt School at San Juan

Walking Speed (mph)	Evacuation Time (min)

2.46	26.12
2.70	23.52
3.40	18.58
2.50	25.47
Distance (miles)	0.991

6.1.1.2.9 República Del Perú

The República Del Perú evacuation route starts from "Calle Loíza" PR-37 turn right onto "Calle Añasco", make a right turn onto "Calle Corona" right after turn right onto "Calle Degetau", turn left onto "Ave. Eduardo Conde". Turn sharp right onto "Calle Profesor Ernesto Vigoreaux" / "Calle 14" keep straight, turn left onto "Ave. Catalino "Tite" Curet Alonso" / "Ave. D", turn right onto "Calle Felipe R. Goyco" / "Calle 15" until reaching the predetermined assembly place (Figure 6-27).

The route of this school has a distance of 1.105 miles (Figure 6-27). Figure 6-28 is zoomed in with the information obtained from "Plot a Route" for an average walking speed. Table 6-13 shows the evacuation times for the different walking speeds.

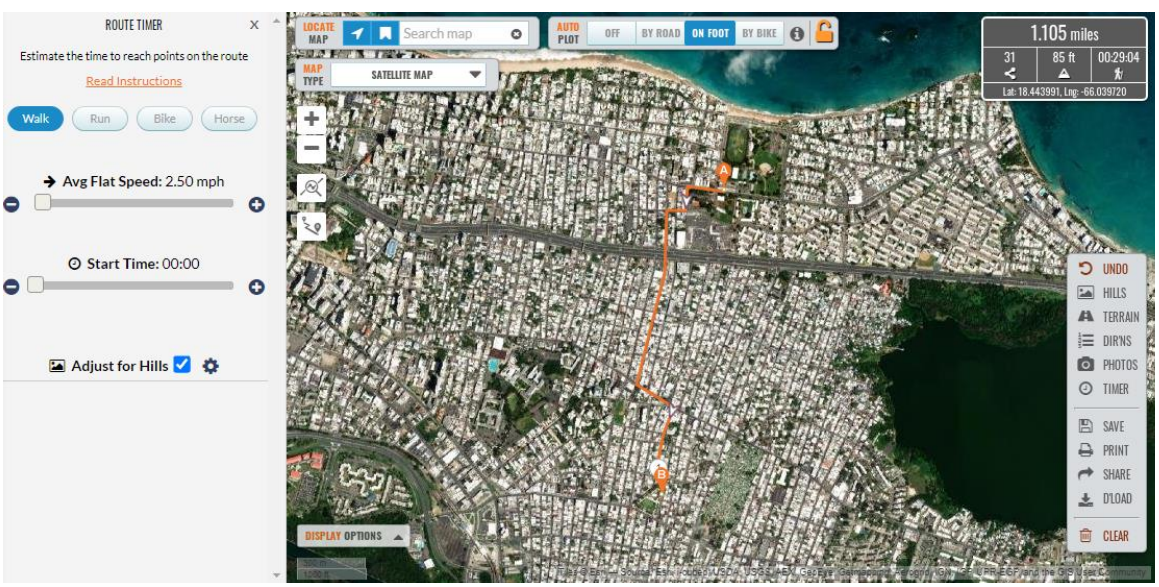


Figure 6-27 Route for Average Walking Speed of República Del Perú School at San Juan

Figure 6-28 Evacuation Time and Route's Distance of Route for Average Walking Speed of República Del Perú School

Table 6-13 Evacuation Time for Every Speed of República Del Perú School at San Juan

Walking Speed (mph)	Evacuation Time (min)
2.46	29.32
2.70	26.54
3.40	21.22
2.50	29.04
Distance (miles)	1.105

6.1.2 Time It Takes for the School Population to Get Out of the Tsunami Hazard Zone.

To determine the time, it takes for the school population to be outside the tsunami hazard zone, routes are plotted from the school campus location to outside the hazard zone using the previously stablished routes. For this time, the shortest routes are selected based on the previously stablished routes. Therefore, the evacuation time corresponds to the shortest possible time to reach the end of the tsunami hazard zone. For this, the already trace routes were used and shorten to the end of the hazard zone in that previously designated route.

6.1.2.1 Cataño

Evacuation times for all Cataño schools correspond to those that leave the school until leaving the hazard zone at the Barbosa Avenue address in Cataño, Puerto Rico, 00962.

6.1.2.1.1 Francisco Oller

The route of this school has a distance of 0.991 miles (Figure 6-29). Figure 6-30 is zoomed in with the information obtained from "Plot a Route" for an average walking speed. The evacuation time for that speed is 16 minutes and 4 seconds. Table 6-14 shows the evacuation times for the different walking speeds.

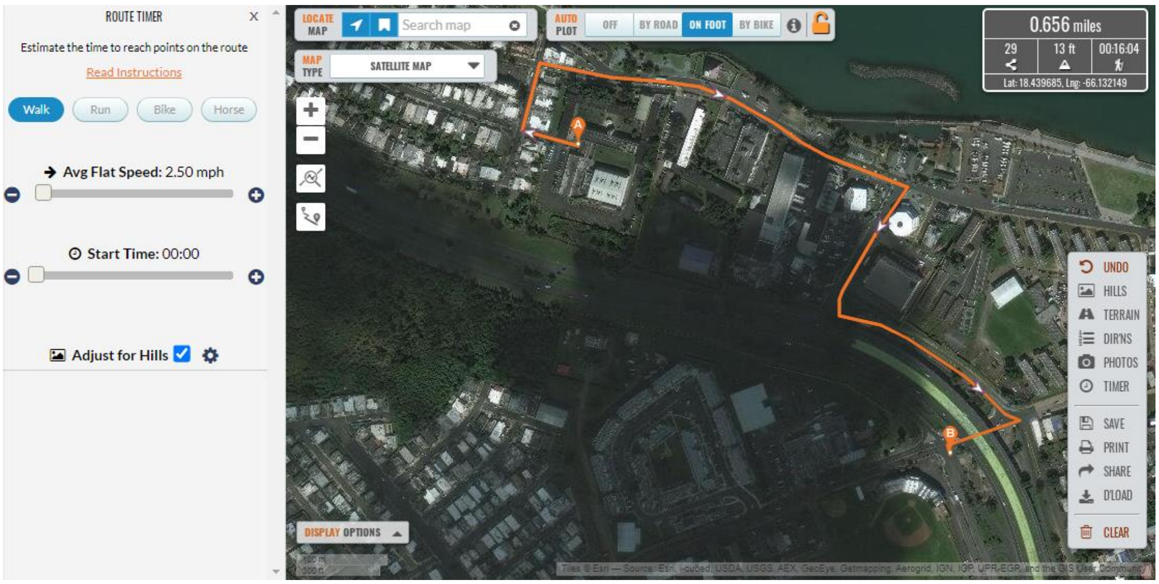


Figure 6-29 Route for Average Walking Speed of Francisco Oller School at Cataño

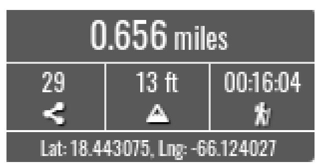


Figure 6-30 Evacuation Time and Route's Distance of Route for Average Walking Speed of Francisco Oller School

Table 6-14 Evacuation Time for Every Speed of Francisco Oller School at Cataño

Walking Speed (mph)	Evacuation Time (min)
2.46	16.20
2.70	14.53
3.40	11.49
2.50	16.04
Distance (miles)	0.656

6.1.2.1.2 Horace Mann

The route of this school has a distance of 0.258 miles (Figure 6-31). The evacuation time is 6 minutes and 23 seconds for an average walking speed (Figure 6-32). Table 6-15 shows the evacuation times for the different walking speeds.

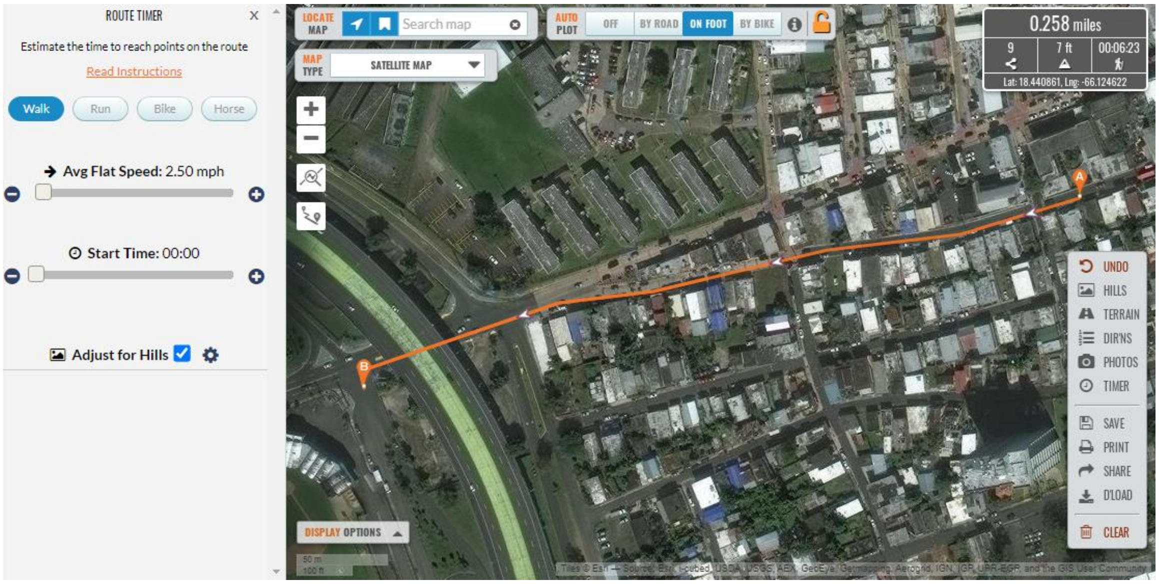


Figure 6-31 Route for Average Walking Speed of Horace Mann School at Cataño

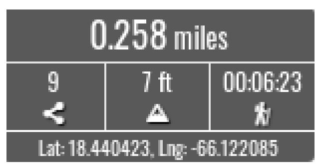


Figure 6-32 Evacuation Time and Average Walking Speed of Horace Mann School

Table 6-15 Evacuation Time for Every Speed of Horace Mann School at Cataño

Walking Speed (mph)	Evacuation Time (min)
2.46	6.30
2.70	5.55
3.40	4.42
2.50	6.23
Distance (miles)	0.258

6.1.2.1.3 Onofre Carballeira

The route of this school has a distance of 0.476 miles (Figure 6-33). Figure 6-34 is zoomed in with the information obtained from "Plot a Route" for an average walking speed with an evacuation time of 11 minutes and 44 seconds. Table 5-16 shows the evacuation times for the different walking speeds.

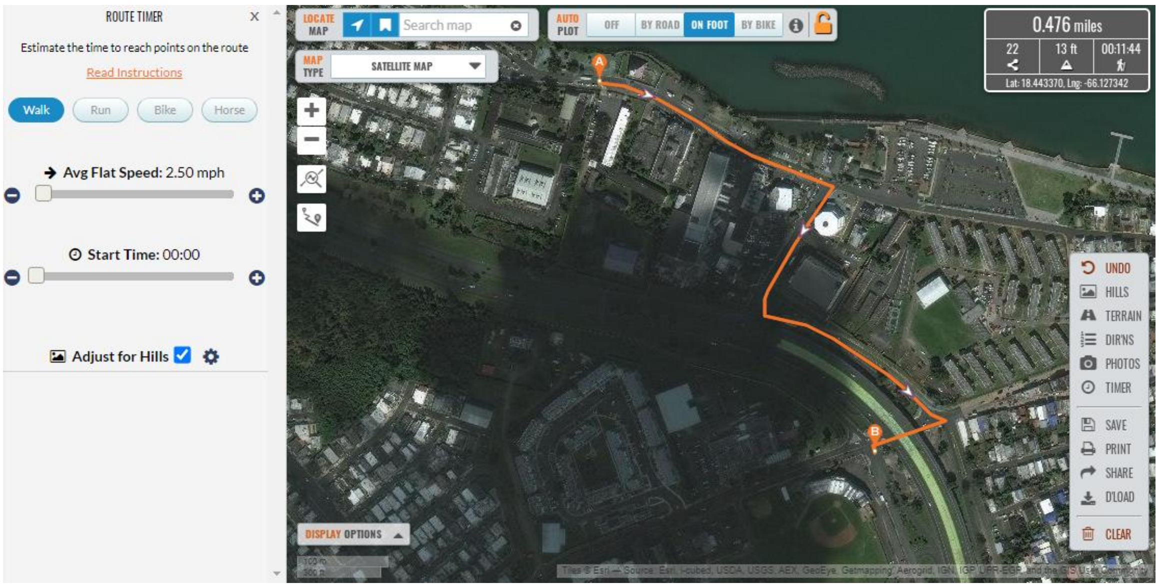


Figure 6-33 Route for Average Walking Speed of Onofre Carballeira School at Cataño

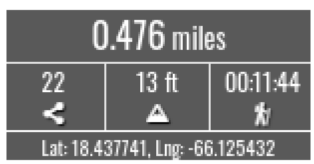


Figure 6-34 Evacuation Time and Route's Distance of Route for Average Walking Speed of Onofre Carballeira School

Table 6-16 Evacuation Time for Every Speed of Onofre Carballeira School at Cataño

Walking Speed (mph)	Evacuation Time (min)
2.46	11.55
2.70	10.52
3.40	8.37
2.50	11.44
Distance (miles)	0.476

6.1.2.1.4 Rosendo Matienzo Cintrón

The route of this school has a distance of 0.369 miles (Figure 6-35). Figure 6-36 is zoomed in with an evacuation time of 9 minutes and 10 seconds for an average walking speed. Table 6-17 shows the evacuation times for the different walking speeds.

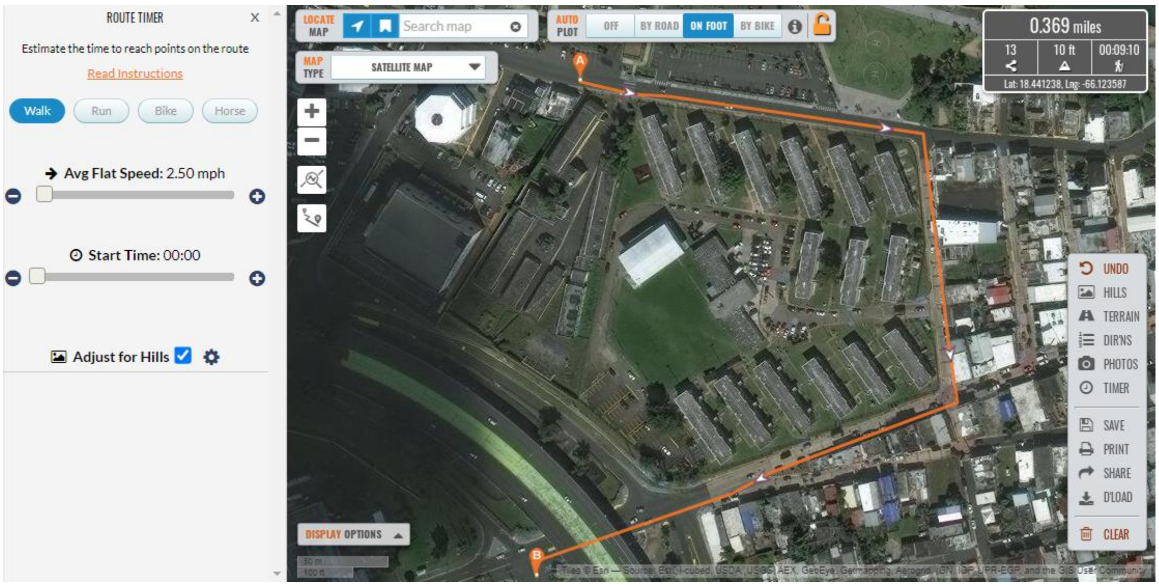


Figure 6-35 Route for Average Walking Speed of Rosendo Matienzo Cintrón School at Cataño

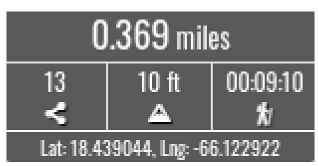


Figure 6-36 Evacuation Time and Route's Distance of Route for Average Walking Speed of Rosendo Matienzo Cintrón School

Table 6-17 Evacuation Time for Every Speed of Rosendo Matienzo Cintrón School at Cataño

Walking Speed (mph)	Evacuation Time (min)
2.46	9.19
2.70	8.29
3.40	6.45
2.50	9.10
Distance (miles)	0.369

6.1.2.2 San Juan

Evacuation routes out of the tsunami hazard zone for San Juan schools follow the same routes above. However, for all of them it does not end in the same direction. In other words, each school has a different exit point from the hazard zone.

6.1.2.2.1 Dr. Julio J. Henna

For this school the hazard zone ends at 2218 Pellín Rodríguez Street # 285, San Juan, 00915, Puerto Rico. This route has a distance of 0.154 miles (Figure 6-37). The evacuation time is 3 minutes and 47 seconds as shown in Figure 6-38. Table 6-18 shows the evacuation times for the different walking speeds.

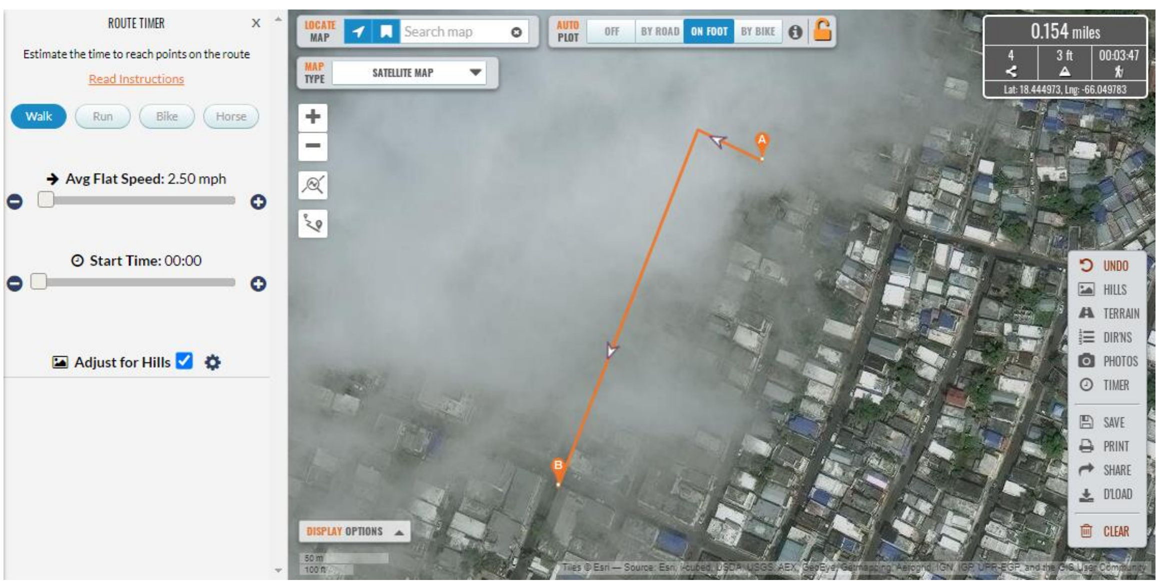


Figure 6-37 Route for Average Walking Speed of Dr. Julio J. Henna School at San Juan

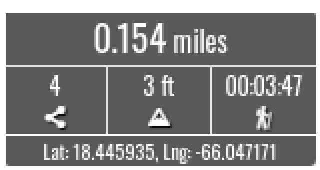


Figure 6-38 Evacuation Time and Route's Distance of Route for Average Walking Speed of Dr. Julio J. Henna School

Table 6-18 Evacuation Time for Every Speed of Dr. Julio J. Henna School at San Juan

Walking Speed (mph)	Evacuation Time (min)
2.46	3.50
2.70	3.30
3.40	2.47
2.50	3.47
Distance (miles)	0.154

6.1.2.2.2 Jaime Rosario (Buena Vista Elemental)

The hazard zone for Jaime Rosario school ends at Williams Street in San Juan, Puerto Rico, 00915. The route of this school has a distance of 0.258 miles (Figure 6-39). Figure 6-40 is zoomed in with an evacuation time of 5 minutes and 2 seconds for an average walking speed. Table 6-19 shows the evacuation times for the different walking speeds.

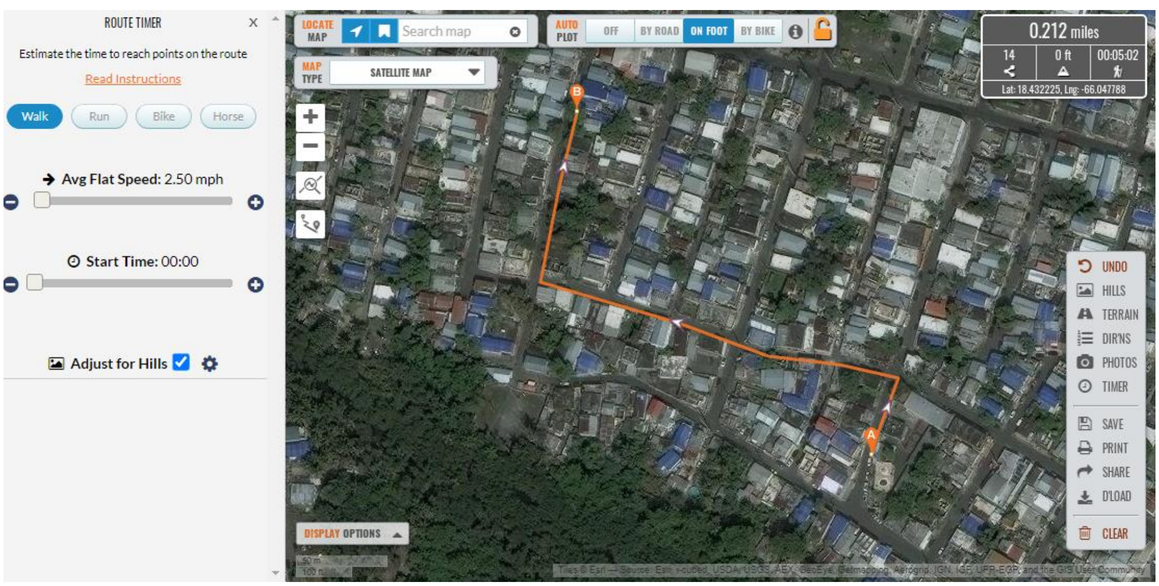


Figure 6-39 Route for Average Walking Speed of Jaime Rosario (Buena Vista Elemental) School at San Juan

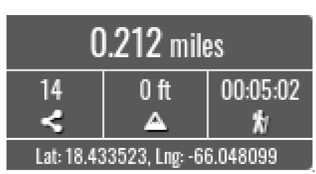


Figure 6-40 Evacuation Time and Route's Distance of Route for Average Walking Speed of Jaime Rosario (Buena Vista Elemental) School

Table 6-19 Evacuation Time for Every Speed of Jaime Rosario (Buena Vista Elemental) School at San Juan

Walking Speed (mph)	Evacuation Time (min)
2.46	5.07
2.70	4.40
3.40	3.42
2.50	5.02
Distance (miles)	0.212

6.1.2.2.3 Julián E. Blanco (Ballet)

Ending the hazard zone on San Jorge Street in San Juan, Puerto Rico, 00911, the route of this school has a distance of 0.362 miles (Figure 6-41). Figure 6-42 is zoomed in with the information obtained from "Plot a Route" for an average walking speed. Table 6-20 shows the evacuation times for the different walking speeds.

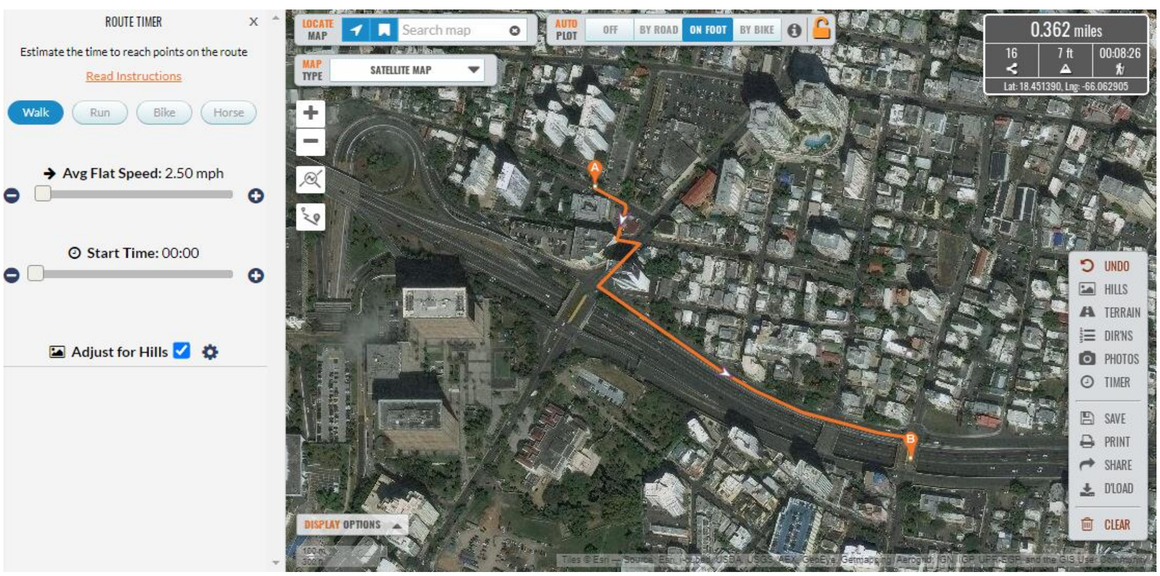


Figure 6-41 Route for Average Walking Speed of Julián E. Blanco (Ballet) School at San Juan

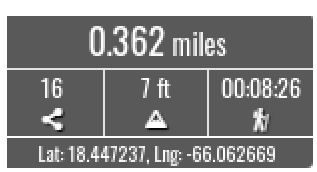


Figure 6-42 Evacuation Time and Route's Distance of Route for Average Walking Speed of Julián E. Blanco (Ballet) School

Table 6-20 Evacuation Time for Every Speed of Julián E. Blanco (Ballet) School at San Juan

Walking Speed (mph)	Evacuation Time (min)
2.46	8.35
2.70	7.49
3.40	6.12
2.50	8.26
Distance (miles)	0.362

6.1.2.2.4 Luis Llorens Torres

The route of Luis Llorens Torres school ends the danger zone at 285 Pellín Rodríguez Street in San Juan, Puerto Rico, 00915.The route of this school has a distance of 1.074 miles (Figure 6-43). Figure 6-44 is zoomed in with the information of an evacuation time of 26 minutes and 38 seconds for an average walking speed.

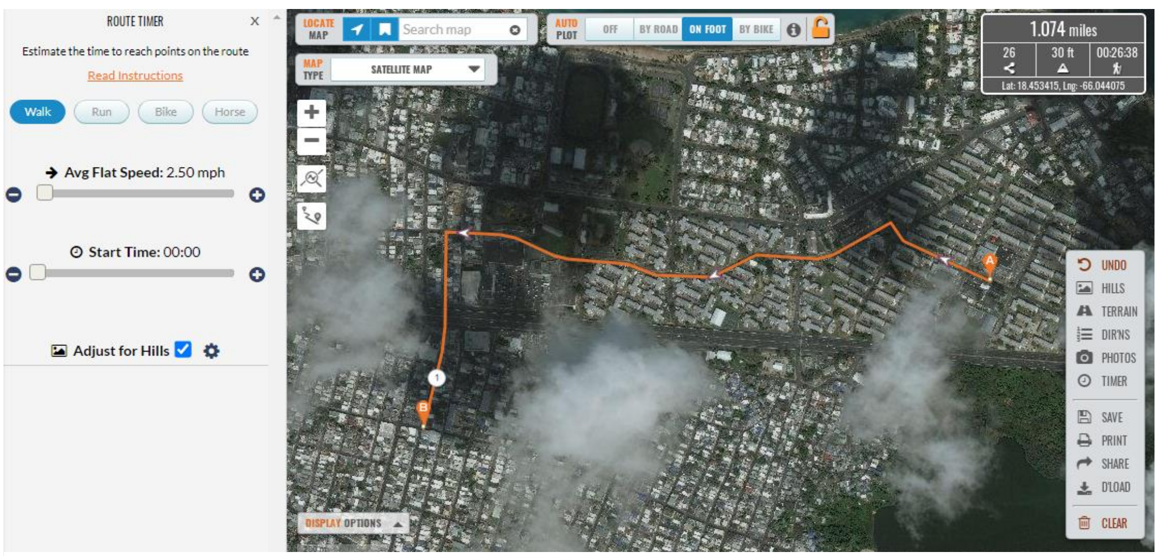


Figure 6-43 Route for Average Walking Speed of Luis Llorens Torres School at San Juan

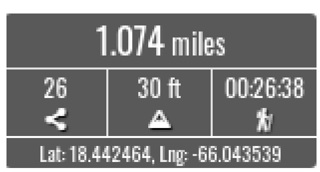


Figure 6-44 Evacuation Time and Route's Distance of Route for Average Walking Speed of Luis Llorens Torres School

Table 6-21 shows the evacuation times for the different walking speeds.

Table 6-21 Evacuation Time for Every Speed of Luis Llorens Torres School at San Juan

Walking Speed (mph)	Evacuation Time (min)
2.46	27.04
2.70	24.40
3.40	19.35
2.50	26.38
Distance (miles)	1.074

6.1.2.2.5 Luis Rodríguez Cabrero

The hazard zone for this school's route also ends at 285 Pellín Rodríguez Street in San Juan, Puerto Rico, 00915. The route of this school has a distance of 0.485 miles (Figure 6-45). Figure 6-46 is zoomed in with the information obtained from "Plot a Route" for an average walking speed with an evacuation time of 11 minutes and 53 seconds.

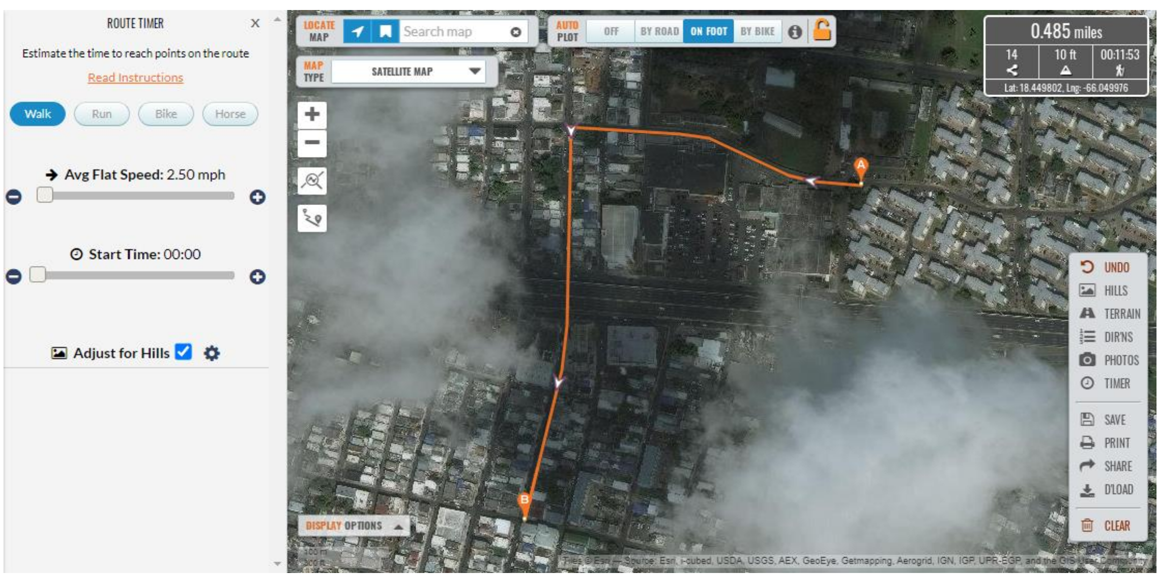


Figure 6-45 Route for Average Walking Speed of Luis Rodríguez Cabrero School at San Juan

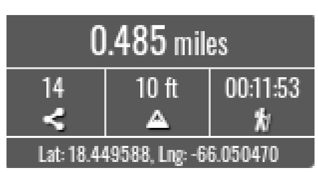


Figure 6-46 Evacuation Time and Route's Distance of Route for Average Walking Speed of Luis Rodríguez Cabrero School

Table 6-22 shows the evacuation times for the different walking speeds.

Table 6-22 Evacuation Time for Every Speed of Luis Rodríguez Cabrero School at San Juan

Walking Speed (mph)	Evacuation Time (min)
2.46	12.04
2.70	11.00
3.40	8.44
2.50	11.53
Distance (miles)	0.485

6.1.2.2.6 Madame Luchetti

The route out of the tsunami danger zone ends at 903 Street Puerto Rico 2, San Juan, Puerto Rico, 00907. This route has a distance of 0.191 miles (Figure 6-47). Figure 6-48 is zoomed in with the information obtained from "Plot a Route" for an average walking speed. The evacuation time is 4 minutes and 57 seconds for that speed. Table 6-23 shows the evacuation times for the different walking speeds.

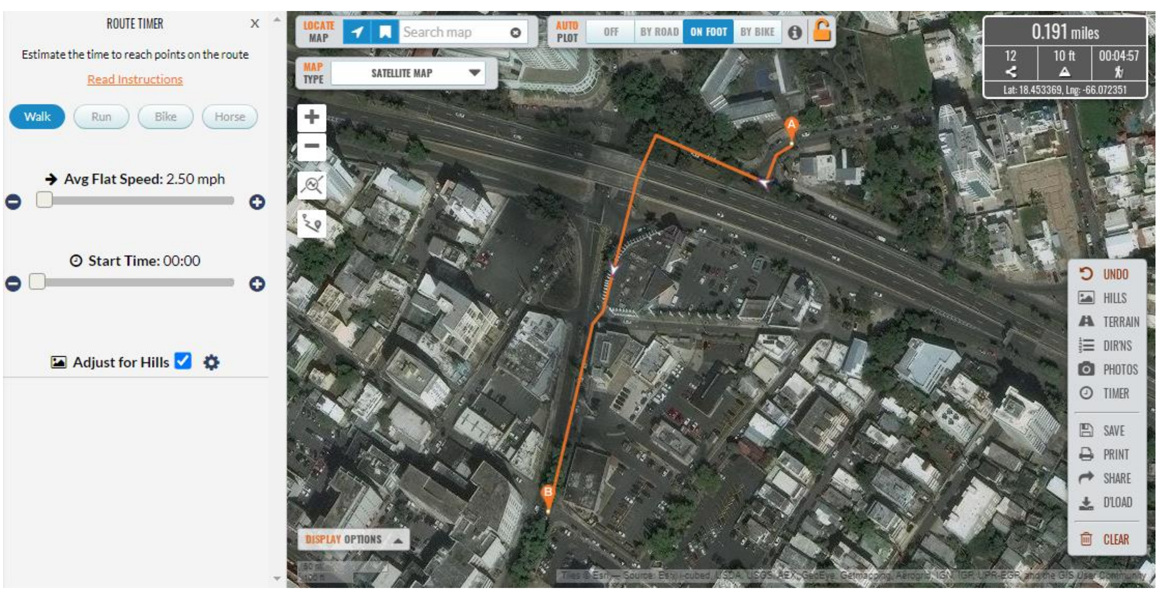


Figure 6-47 Route for Average Walking Speed of Madame Luchetti School at San Juan

Figure 6-48 Evacuation Time and Route's Distance of Route for Average Walking Speed of Madame Luchetti School

Table 6-23 Evacuation Time for Every Speed of Madame Luchetti School at San Juan

Walking Speed (mph)	Evacuation Time (min)
2.46	5.02
2.70	4.35
3.40	3.38
2.50	4.57
Distance (miles)	0.191

6.1.2.2.7 Moisés Meléndez

The route of this school has 0.064 miles (Figure 6-49) ending the danger zone at Street 3 in San Juan, Puerto Rico, 00917. Figure 6-50 is zoomed in with the information obtained from "Plot a Route" for an average walking speed with an evacuation time of one minute and 29 seconds. Table 6-24 shows the evacuation times for the different walking speeds.

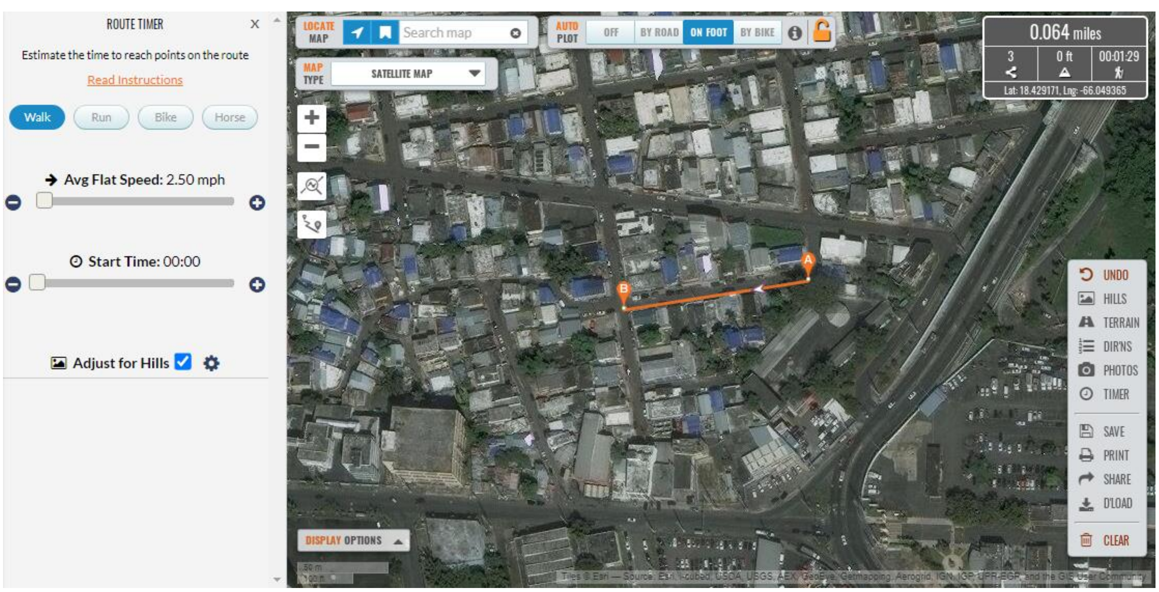


Figure 6-49 Route for Average Walking Speed of Moisés Meléndez School at San Juan

Figure 6-50 Evacuation Time and Routes's Distance of Route for Average Walking Speed of Moisés Meléndez School

Table 6-24 Evacuation Time for Every Speed of Moisés Meléndez School at San Juan

Walking Speed (mph)	Evacuation Time (min)
2.46	1.31
2.70	1.23
3.40	1.06
2.50	1.29
Distance (miles)	0.064

6.1.2.2.8 Ramón Power Y Giralt

For this school the route out of the tsunami danger zone ends at 2055 Gilberto Monroig Avenue in San Juan, Puerto Rico, 00912. For this route the travel distance is 0.471 miles (Figure 6-51).

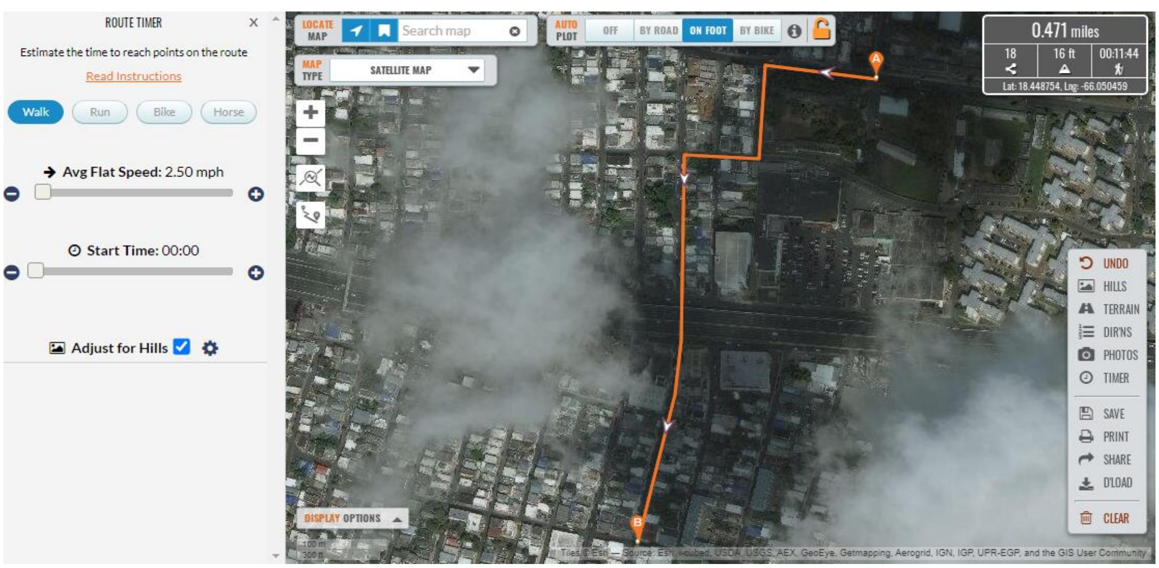


Figure 6-51 Route for Average Walking Speed of Ramón Power Y Giralt School at San Juan

For this speed the evacuation time is 11 minutes and 44 seconds Figure 6-52. Table 6-25 shows the evacuation times for the different walking speeds.

Figure 6-52 Evacuation Time and Route's Distance of Route for Average Walking Speed of Ramón Power Y Giralt School

Table 6-25 Evacuation Time for Every Speed of Ramón Power Y Giralt School at San Juan

Walking Speed (mph)	Evacuation Time (min)
2.46	11.55
2.70	10.52
3.40	8.38
2.50	11.44
Distance (miles)	0.471

6.1.2.2.9 República Del Perú

This school has a route to get out of the tsunami danger zone that leaves from the school to the address 2055 Gilberto Monroig Avenue in San Juan, Puerto Rico, 00912. For this route, the distance is 0.498 miles, and the evacuation time is 12 minutes and 30 seconds for an average walking speed (Figure 6-53). Figure 6-54 is zoomed in with the information obtained from "Plot a Route" for an average walking speed. Table 6-26 shows the evacuation times for the different walking speeds.

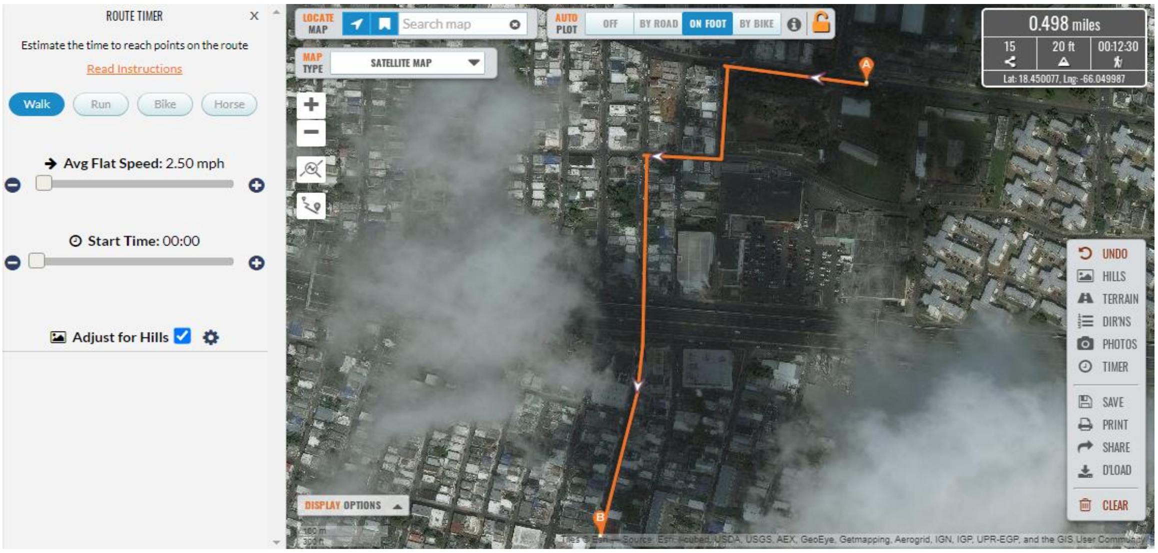


Figure 6-53 Route for Average Walking Speed of República Del Perú School at San Juan

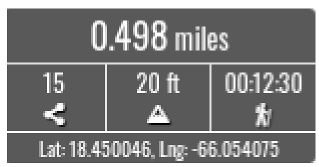


Figure 6-54 Evacuation Time and Route's Distance of Route for Average Walking Speed of República Del Perú School

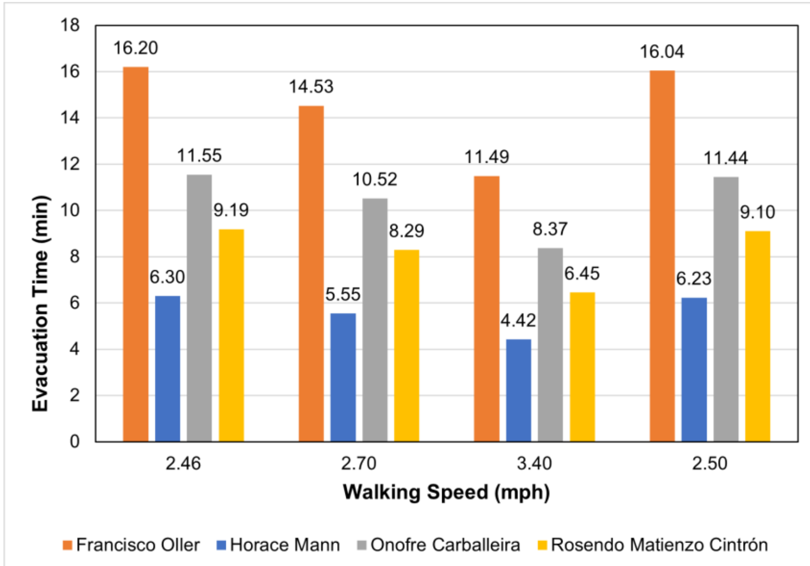
Table 6-26 Evacuation Time for Every Speed of República Del Perú School at San Juan

Walking Speed (mph)	Evacuation Time (min)
2.46	12.42
2.70	11.34
3.40	9.11
2.50	12.30
Distance (miles)	0.498

6.2 Summary of Evacuation Times

Below is a summary of the findings obtained for the two school evacuation times. The time (a) it takes from the school to leave the tsunami hazard zone and the time (b) it takes for the school population to leave the school facilities and reach the assembly place. Figure 6-55 presents the evacuation times for the municipality of Cataño. Both graphs show evacuation times for schools for different walking speeds.

(a)



(b)

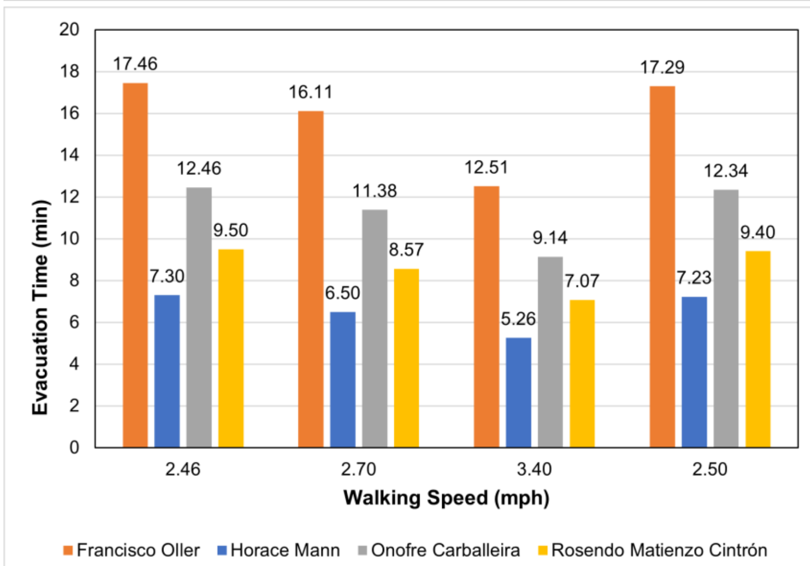
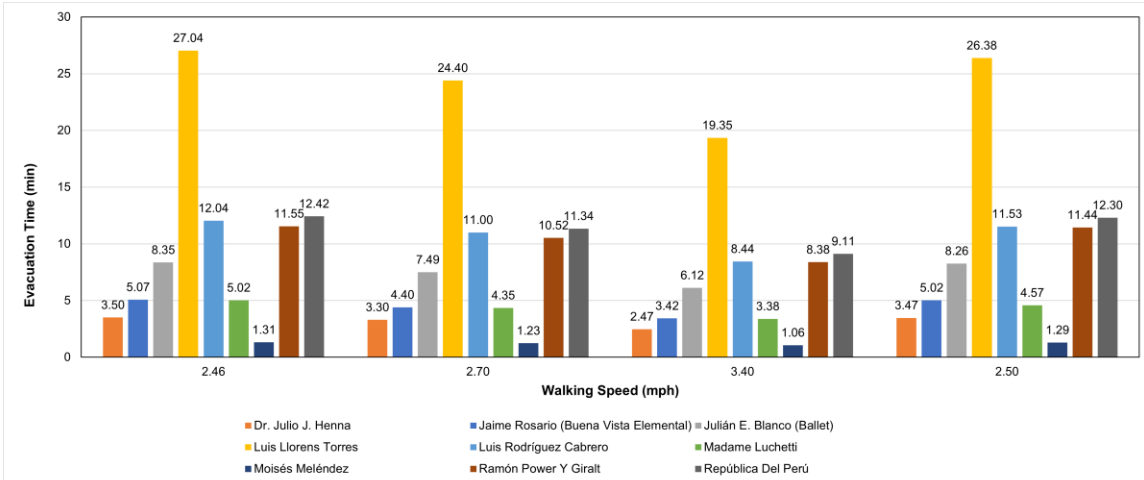


Figure 6-55 Evacuation Times Chart for Cataño Schools

Figure 6-56 shows both times for the municipality of San Juan.

(a)



(b)

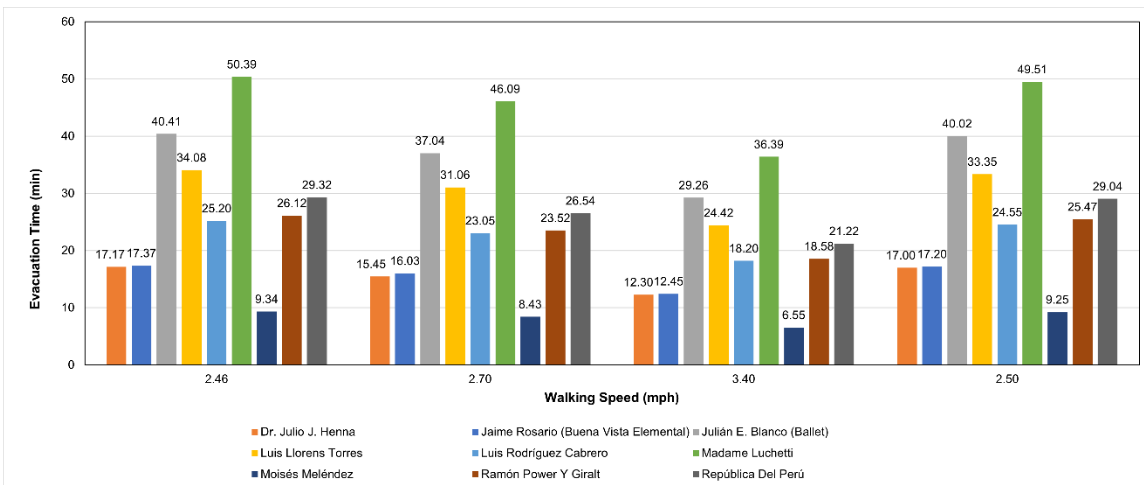
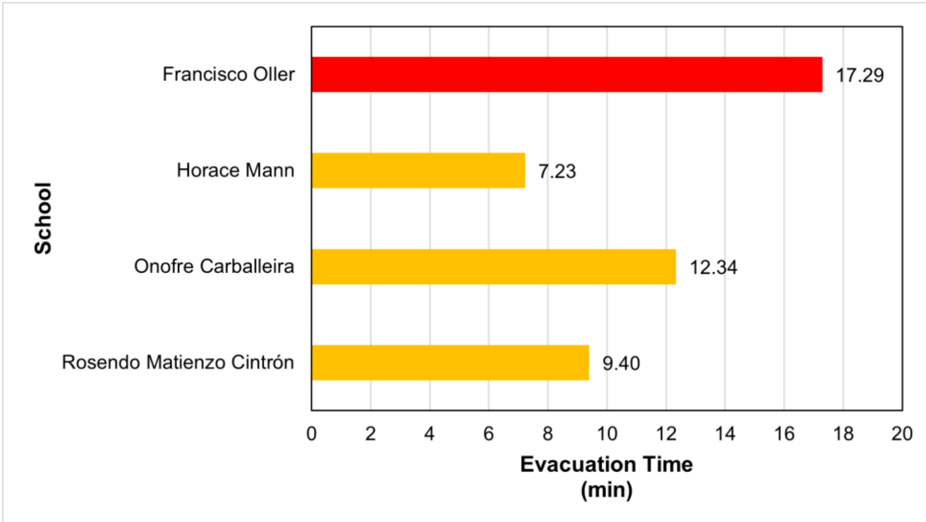


Figure 6-56 Evacuation Times Chart for San Juan Schools

From graphs of both municipalities the following is summarized for an average walking speed of 2.50 mph:

- For the evacuation time outside the tsunami hazard zone (1), the critical schools were Francisco Oller school for Cataño and Luis Llorens Torres school for San Juan, with times of 16.04 min and 26.38 min respectively (Figure 6-57).

(a)



(b)

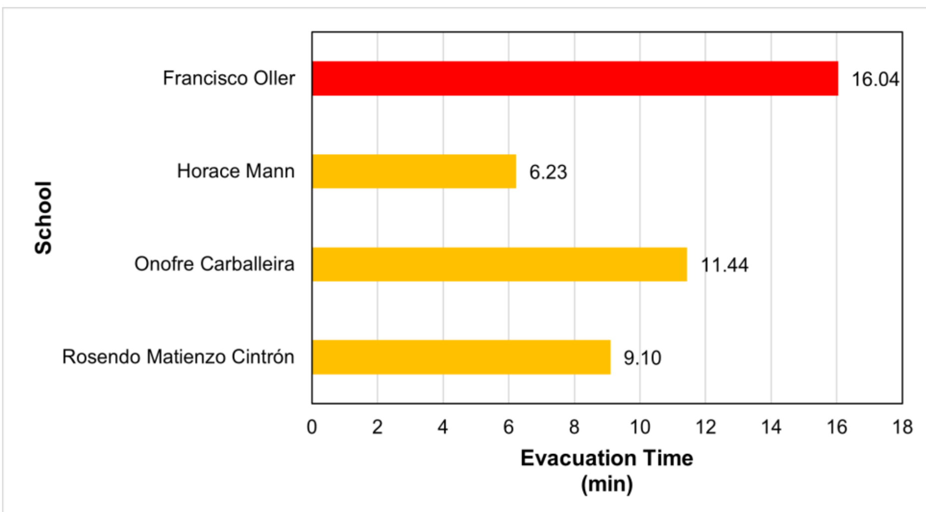
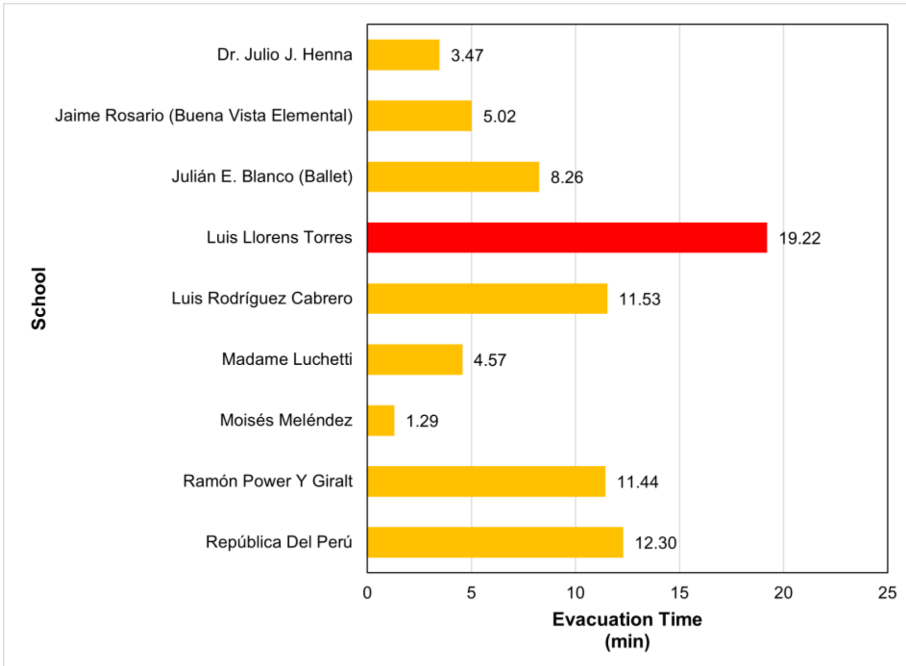


Figure 6-57 Evacuation Times Graph for Average Walking Speed for Cataño Schools

- For the primary evacuation time elapsed until reaching the assembly site (2), the subcritical schools were Francisco Oller school for Cataño and Madame Luchetti school for San Juan, with times of 17.29 min and 49.51 min respectively (Figure 6-58).
- Because the potential hazard of vulnerability for schools lies in leaving the tsunami hazard zone, those schools with the largest evacuation times until they leave the tsunami evacuation zone are considered critical; the evacuation time until reaching assembly site was considered a secondary condition, since although they are outside

the tsunami impact area, this is the site were assistance and help will be channelized (so reaching this site is important).

(a)



(b)

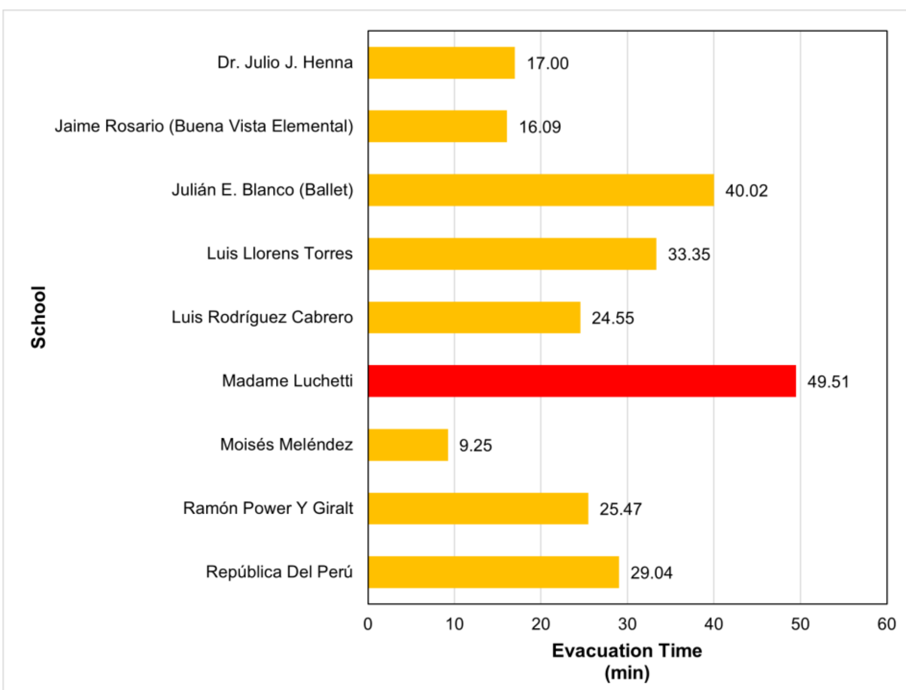


Figure 6-58 Evacuation Times Graph for Average Walking Speed for Cataño Schools

6.3 Alternate Routes

The alternate routes discussed below use the same route planner (Plot a Route) resource used in the evacuation routes section above. The alternate routes of the case study schools represent only the possible ways to get to the safe place. However, there may be several routes for each of the schools. These were not selected as a breakdown of the previous section since they present greater distances and evacuation times that would worsen the vulnerability of schools. Likewise, for this section, the routes close to the evacuation routes previously analyzed are considered because a greater route would also correspond to a greater vulnerability.

Unlike the previous evaluation, this section shows the routes on a satellite map and on a street map to better represent the crossing of each route. Also consider only the average travel speed of 2.50 mph to compare evacuation times. On the other hand, these routes use the same assembly places assumed in the previous section. But in some schools, other nearby assembly places are presented for comparison.

6.3.1 Cataño

The alternate evacuation routes of the four schools in this municipality travel from their respective origins to the same assembly place used in the previous routes. This is Peruchin Cepeda Stadium.

6.3.1.1 Franciso Oller

Francisco Oller school has two other possible routes to get to the assembly site. The first alternate route close to the previously described route is shown in Figure 6-59. This route has a distance of 0.800 miles for an evacuation time of 19 minutes 35 seconds. This route has 2 minutes and 6 seconds more compared to the evacuation time of the route used for the vulnerability assessment of 17 minutes and 29 seconds (Figure 6-61).

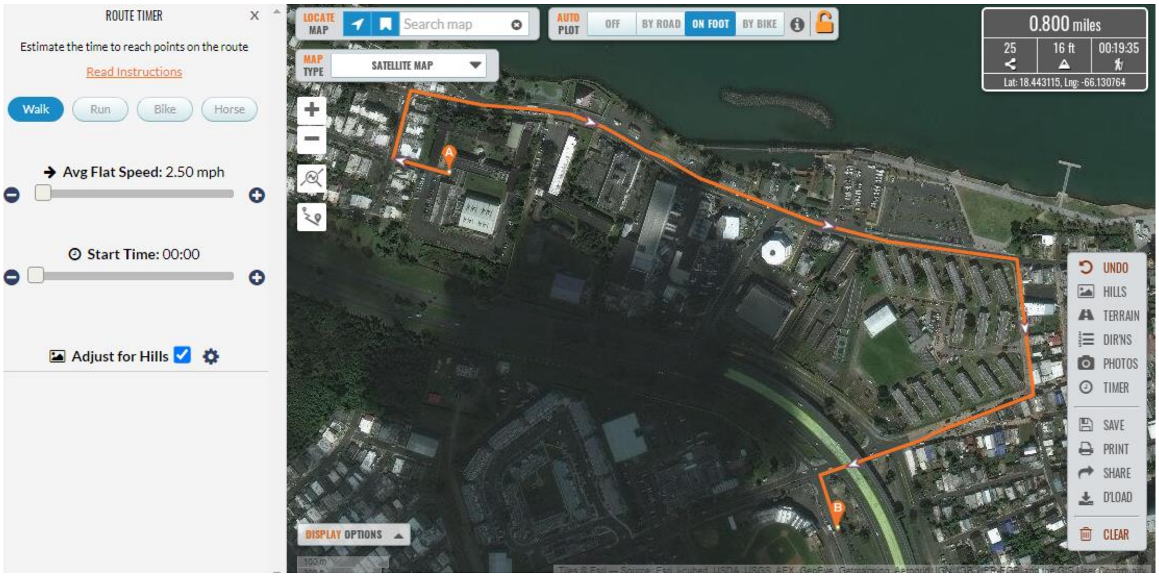


Figure 6-59 First Alternate Route of Francisco Oller School at Cataño

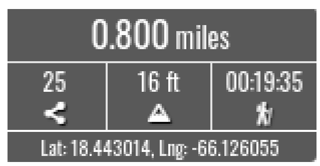


Figure 6-61 Evacuation Time and Route's Distance of First Alternate Route of Francisco Oller School

Figure 6-60 Streets of First Alternate Route of Francisco Oller School

This route turns right onto East Street towards PR-88 along Las Nereidas Avenue. Then, turn onto Destino Street in direction to PR-5 along José Celso Barbosa Avenue until it reaches the predestined assembly place (Figure 6-60).

The second alternate route is shown in Figure 6-62. This route has a distance of 1.459 miles for an evacuation time of 35 minutes 22 seconds. This route is 18 minutes and 33 seconds more compared to the time of 17 minutes and 29 seconds (Figure 6-63).

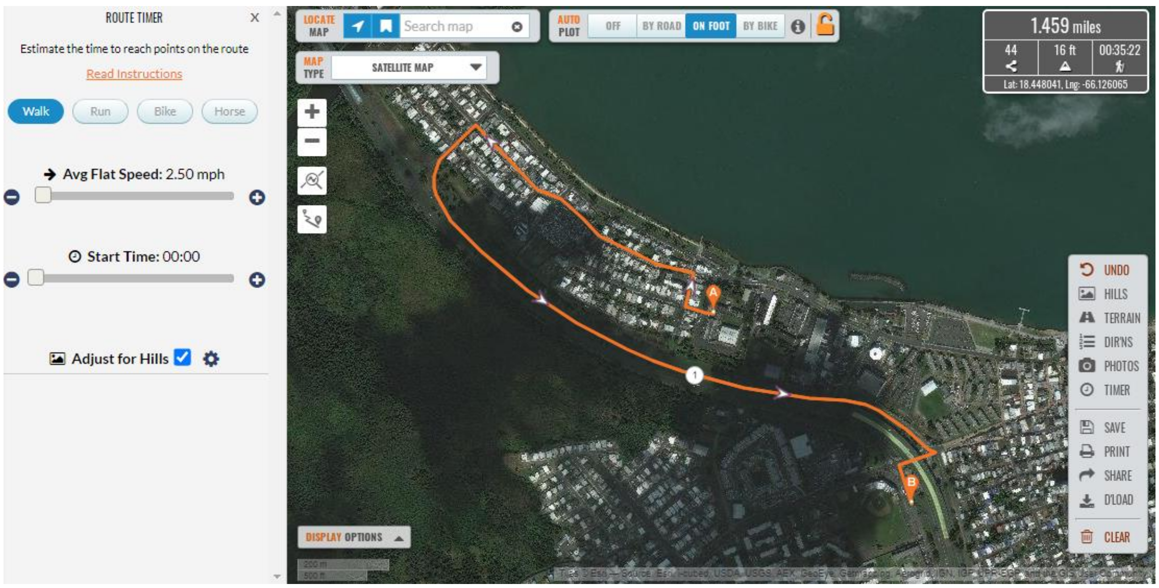


Figure 6-62 Second Alternate Route of Francisco Oller School at Cataño

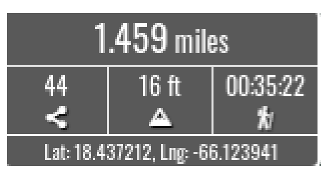


Figure 6-63 Evacuation Time and Route's Distance of Second Alternate Route of Francisco Oller School

This route turns right onto East Street towards PR-88 along Las Nereidas Avenue. Then, turn onto Otero Street in direction to PR-165 along El Caño Avenue until it reaches PR-5 in direction to José Celso Barbosa Avenue. Eventually, it arrives at the predestined assembly place (Figure 6-64).

Figure 6-64 Streets of Second Alternate Route of Francisco Oller School

6.3.1.2 Horace Mann

This school has two other possible alternate routes to reach the predestined place corresponding to the assembly place. The first alternate route is shown in Figure 6-65. This route has a distance of 0.374 miles for an evacuation time of 9 minutes and 3 seconds. In this way, this route takes 2 minutes and 20 seconds more compared to the evacuation time of the route from the previous section of 7 minutes and 23 seconds (Figure 6-66).

This route leaves from El Tren Street, turns onto Las Flores Street in direction to Bento Ct Street. Then, it goes to PR-5 along José Celso Barbosa Avenue until it reaches the predestined assembly place (Figure 6-67).

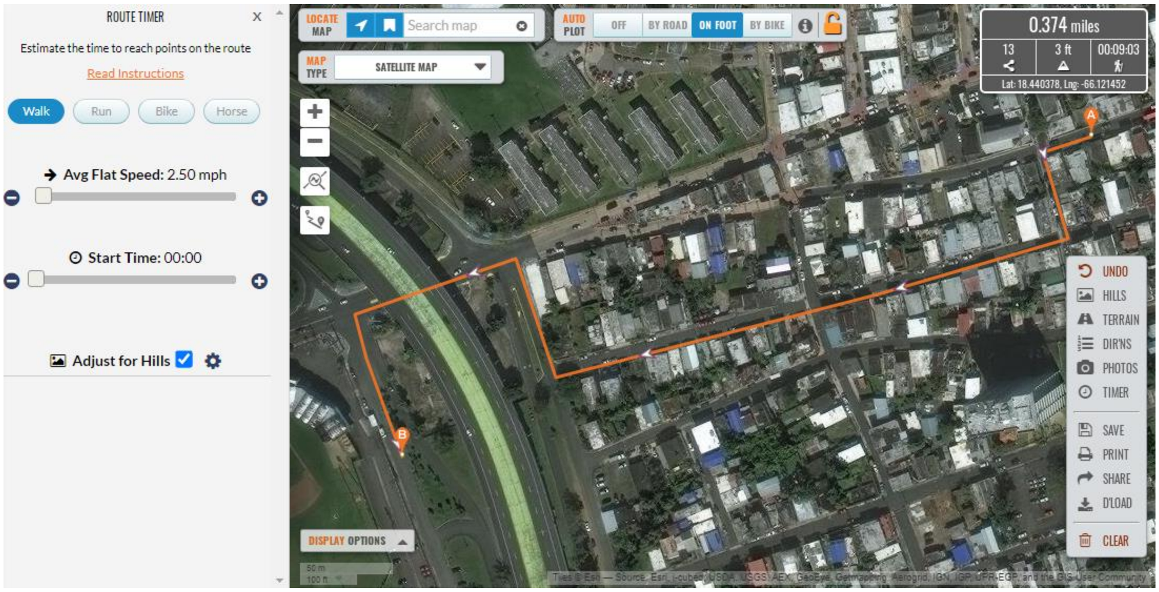


Figure 6-65 First Alternate Route of Horace Mann School at Cataño

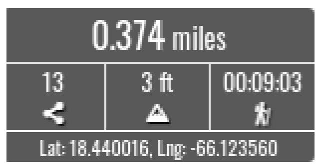


Figure 6-66 Evacuation Time and Route's Distance of First Alternate Route of Horace Mann School

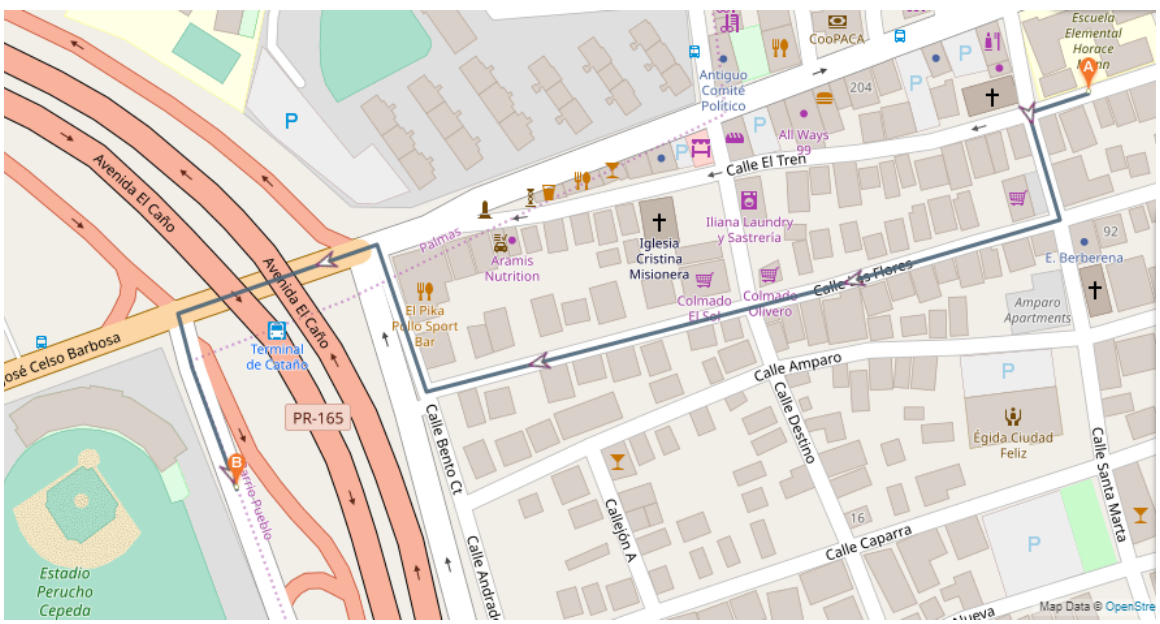


Figure 6-67 Streets of First Alternate Route of Horace Mann School

The second alternate route is shown in Figure 6-68. This route has a distance of 0.334 miles for an evacuation time of 8 minutes 17 seconds. This route is one minute and 34 seconds more compared to the time of 7 minutes and 23 seconds (Figure 6-69).

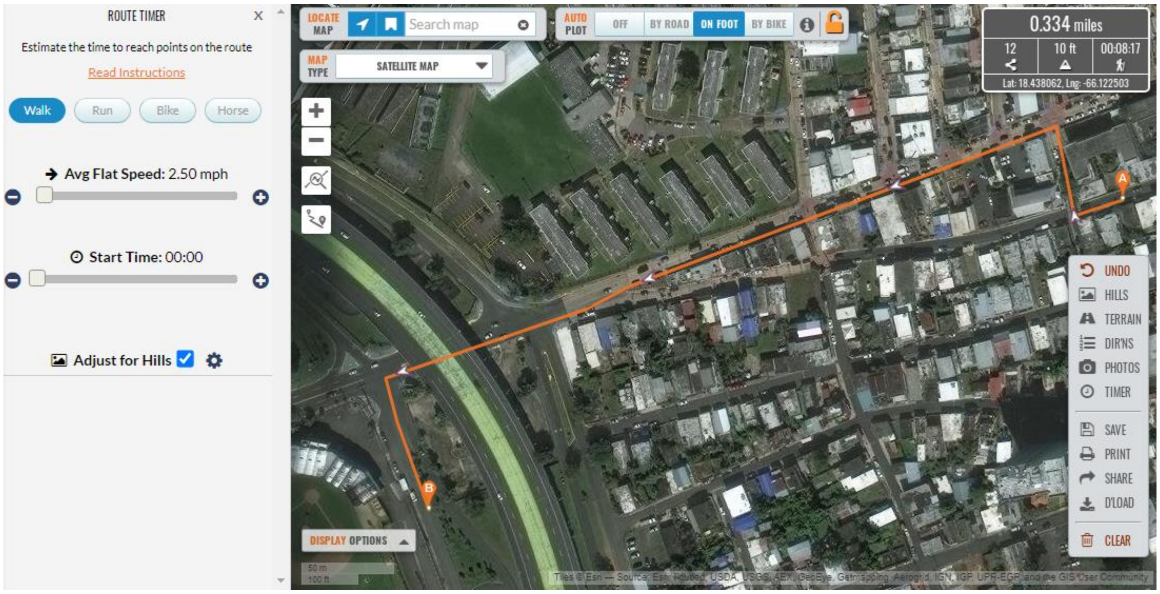


Figure 6-68 Second Alternate Route of Horace Mann School at Cataño

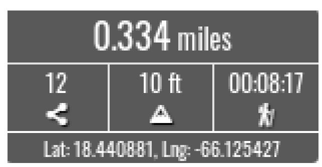


Figure 6-69 Evacuation Time and Route's Distance of Second Alternate Route of Horace Mann School

Figure 6-70 Streets of Second Alternate Route of Horace Mann School

This route leaves from El Tren Street and turns onto Santa Marta Street in direction to José Celso Barbosa Avenue. Later, it joins the PR-5 until it reaches the assembly place (Figure 6-70).

6.3.1.3 Onofre Carballeira

Onofre Carballeira school has two other possible routes to get safe to the assembly site. Both routes correspond to the same Francisco Oller school alternate routes discussed above. The first alternate route is shown in Figure 6-71. This route has a distance of 0.634 miles for an evacuation time of 15 minutes 33 seconds. Therefore, this route has 3 minutes and 39 seconds more compared to the evacuation time of the route used for the vulnerability assessment of 12 minutes and 34 seconds (Figure 6-72).

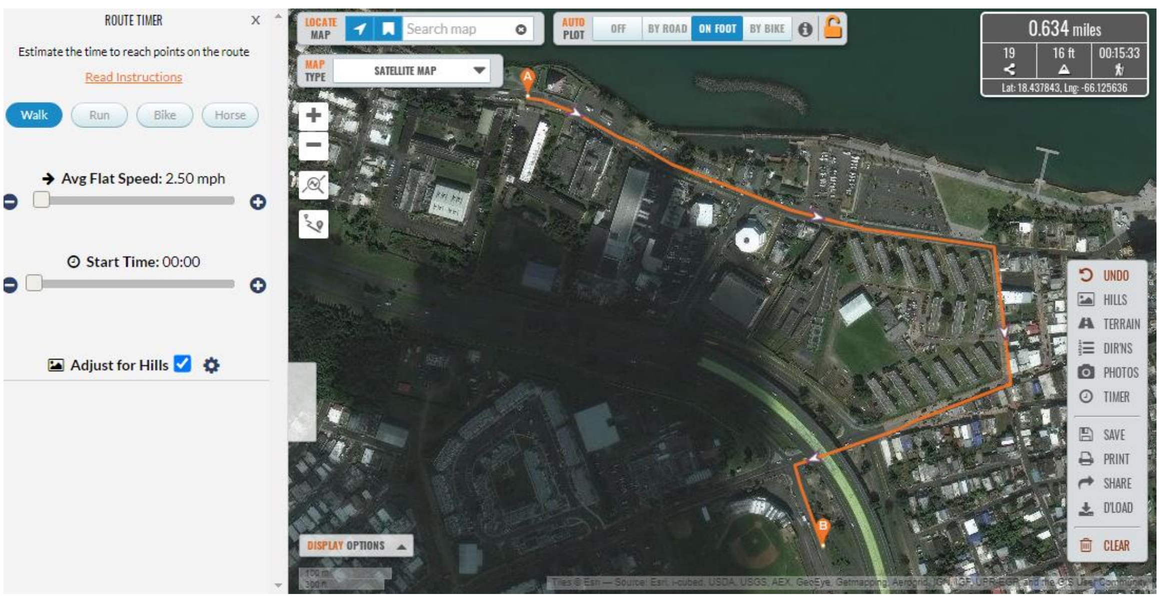


Figure 6-71 First Alternate Route of Onofre Carballeira School at Cataño

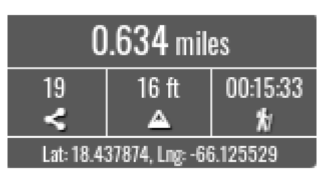


Figure 6-72 Evacuation Time and Route's Distance of First Alternate Route of Onofre Carballeira School

This route leaves from PR-88 along Las Nereidas Avenue. Then, like the first alternate route of Francisco Oller school, it turns onto Destino Street in direction to PR-5 along José Celso Barbosa Avenue until it reaches the predestined assembly place (Figure 6-73).

Figure 6-73 Streets of First Alternate Route of Onofre Carballeira School

The second alternate route is shown in Figure 6-74. This route has a distance of 1.482 miles for an evacuation time of 35 minutes 59 seconds. This route is 23 minutes and 25 seconds more compared to the time of 12 minutes and 34 seconds (Figure 6-75).

This route leaves from PR-88 along Las Nereidas Avenue. Then, like the Francisco Oller School's second alternate route, turn onto Otero Street in direction to PR-165 along El Caño Avenue until it reaches PR-5 in direction to José Celso Barbosa Avenue. Later, it arrives at the predestined assembly place (Figure 6-76).

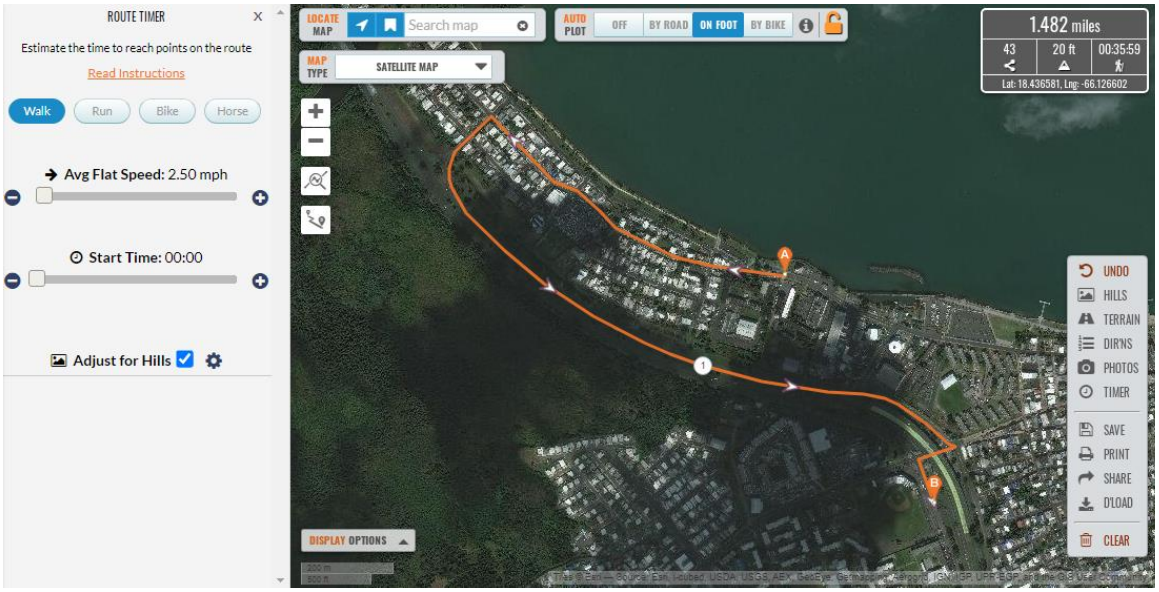


Figure 6-74 Second Alternate Route of Onofre Carballeira School at Cataño

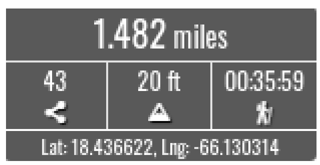


Figure 6-75 Evacuation Time and Route's Distance of Second Alternate Route of Onofre Carballeira School

Figure 6-76 Streets of Second Alternate Route of Onofre Carballeira School

6.3.1.4 Rosendo Matienzo Cintrón

This school has three other possible routes to get to the assembly site. The first alternate route is shown in Figure 6-77and Figure 6-71. This route has a distance of 0.414 miles for an evacuation time of 10 minutes 13 seconds. This first alternate route has 1 minute, and 13 seconds more compared to the evacuation time of the route used for the vulnerability assessment of 9 minutes and 40 seconds (Figure 6-78).

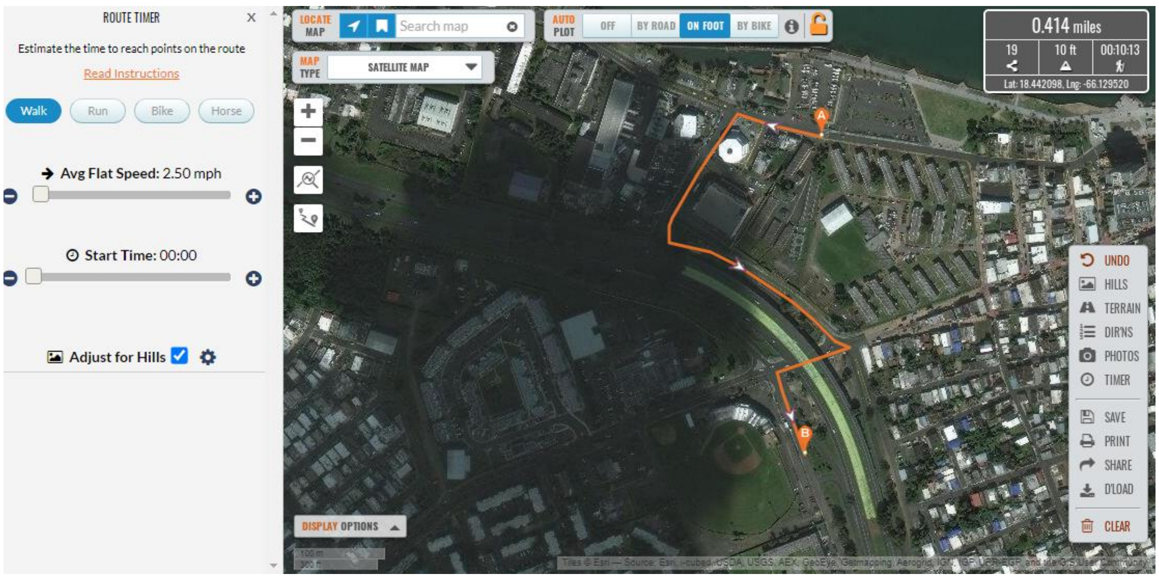


Figure 6-77 First Alternate Route of Rosendo Matienzo Cintrón School at Cataño

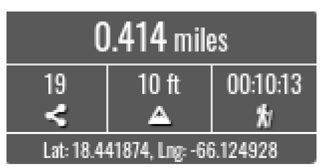


Figure 6-78 Evacuation Time and Route's Distance of First Alternate Route of Rosendo Matienzo Cintrón School

This first route leaves from PR-88 along Las Nereidas Avenue and turns onto Olivo Street towards the exit of PR-165 at El Caño Avenue. Then, it reaches the PR-5 in direction to José Celso Barbosa Avenue to the predestined assembly place (Figure 6-79).

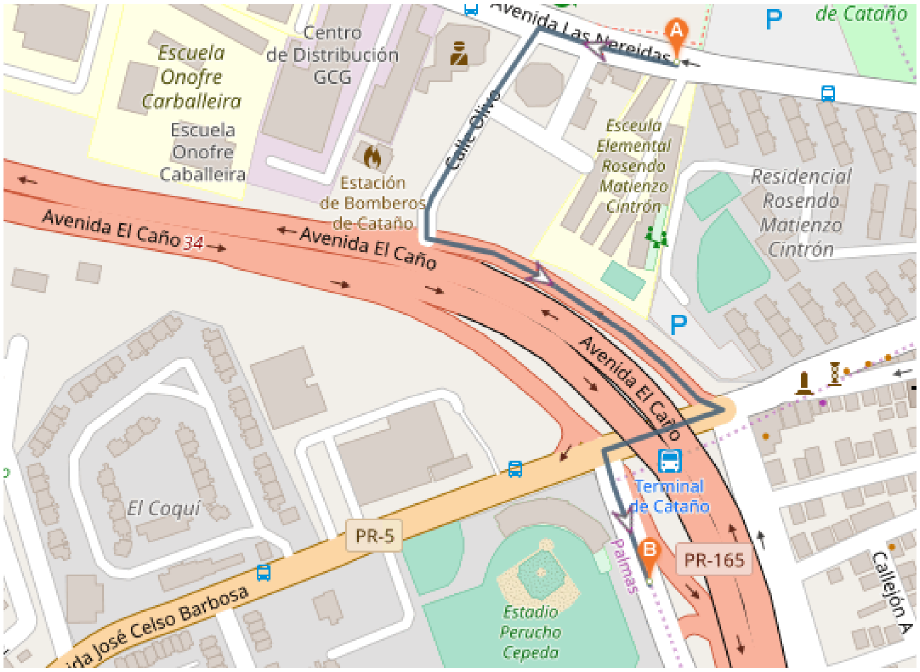


Figure 6-79 Streets of First Alternate Route of Rosendo Matienzo Cintrón School

The second alternate route of Rosendo Matienzo Cintrón School is shown in Figure 6-80. This route has a distance of 0.446 miles for an evacuation time of 11 minutes 1 second. This route is 2 minutes and 1 second more compared to the time of 9 minutes and 40 seconds (Figure 6-81).

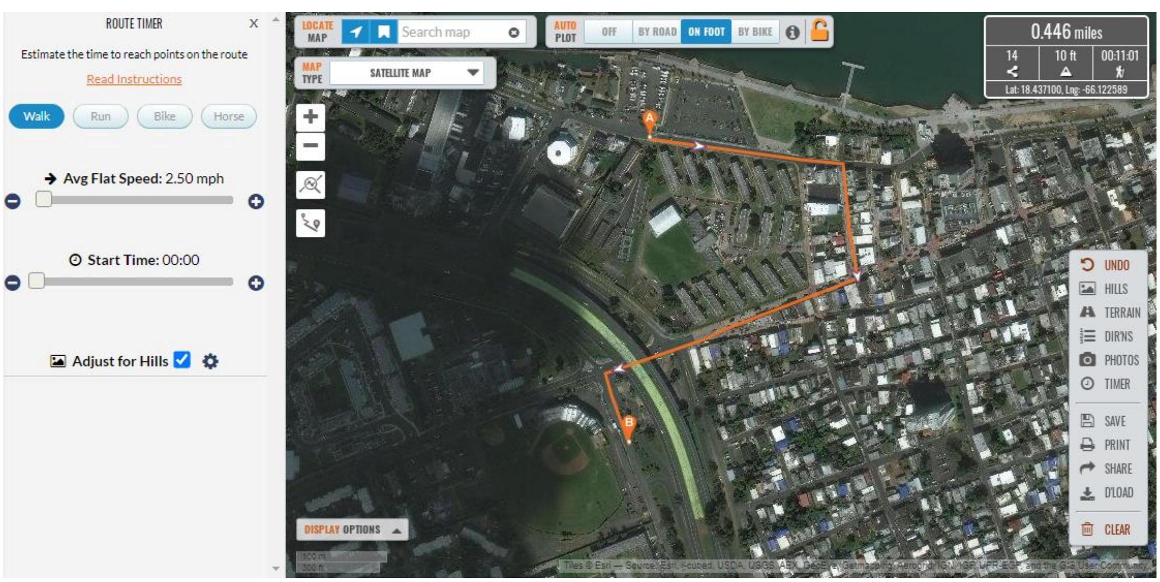


Figure 6-80 Second Alternate Route of Rosendo Matienzo Cintrón School at Cataño

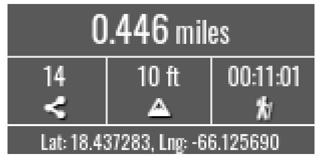


Figure 6-81 Evacuation Time and Route's Distance of Second Alternate Route of Rosendo Matienzo Cintrón School

This route leaves the PR-88 by Las Nereidas Avenue. It turns onto David Street parallel to Destino Street, where it can get to its destination faster according to the evaluation of the route in the previous section. Then, it joins the PR-5 in the direction of José Celso Barbosa Avenue until it reaches the meeting place (Figure 6-82).

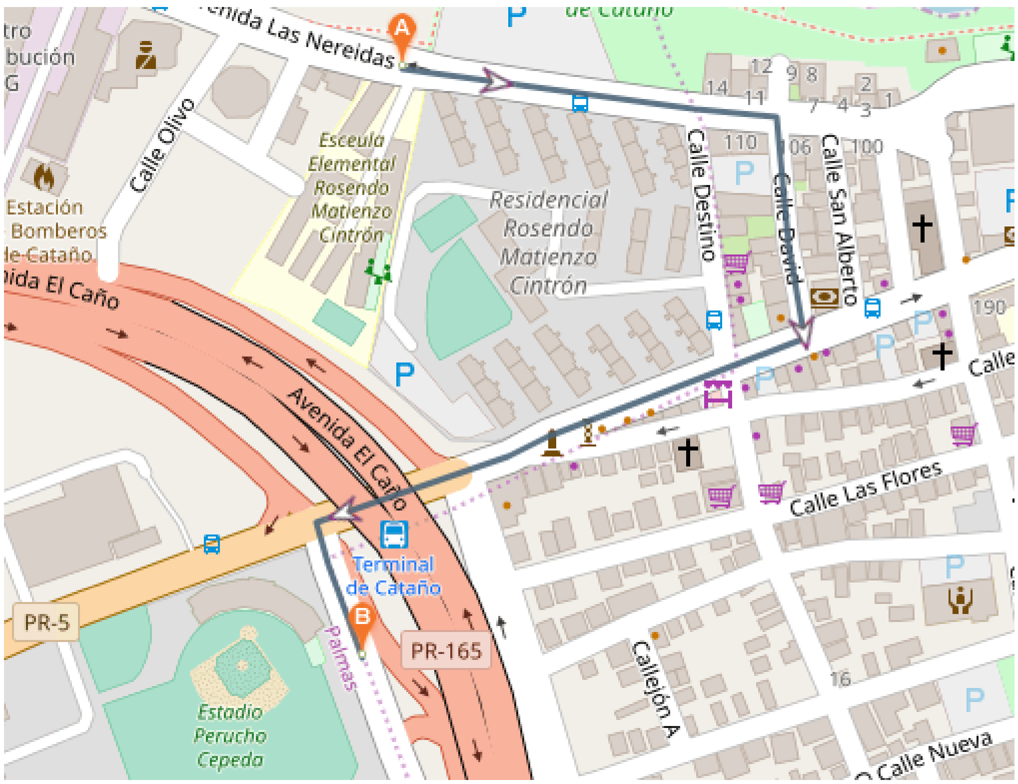


Figure 6-82 Streets of Second Alternate Route of Rosendo Matienzo Cintrón School

The third alternate route of this school is shown in Figure 6-83. This possible route is further away than the previous ones, but as in the cases of the Francisco Oller and Onofre Carballeira schools, it is presented for a better comparison of greater distances and evacuation times on the route. This route has a distance of 1.697 miles for an evacuation time of 41 minutes 33 seconds. This route is 2 minutes and 1 second more compared to the time of 32 minutes and 33 seconds (Figure 6-84).

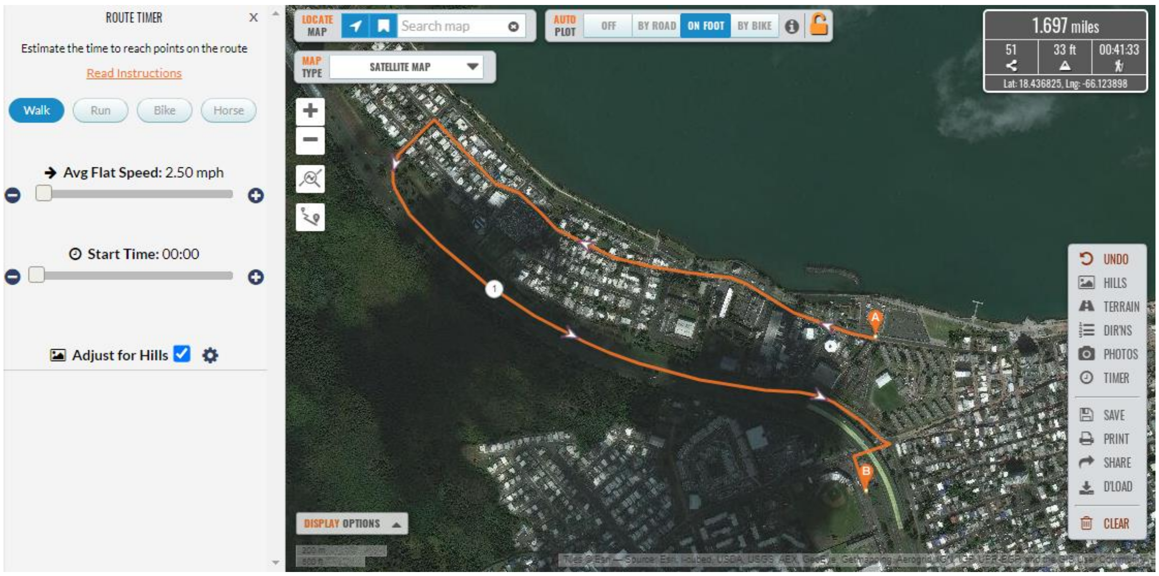


Figure 6-83 Third Alternate Route of Rosendo Matienzo Cintrón School at Cataño

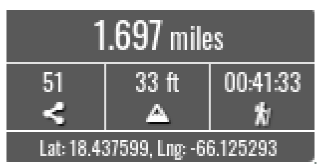


Figure 6-84 Evacuation Time and Route's Distance of Third Alternate Route of Rosendo Matienzo Cintrón School

This route for Rosendo Matienzo Cintrón school leaves from PR-88 along Las Nereidas Avenue. Then, like the second alternates routes of the Francisco Oller and Onofre Carballeira schools, it turns onto Otero Street in direction to PR-165 along El Caño Avenue until it reaches PR-5 in direction to José Celso Barbosa Avenue. Then, it arrives at the predestined assembly place (Figure 6-85).

Figure 6-85 Streets of Third Alternate Route of Rosendo Matienzo Cintrón School

For the four schools in the municipality of Cataño, other possible evacuation routes could be those that start from PR-88 through Las Nereidas Avenue and that pass either through San Alberto, Santa Teresa, or Santa Marta Streets. These to then join the PR-5 through José Celso Barbosa Avenue until reaching the assembly place.

6.3.2 San Juan

The alternate routes of the schools of the municipality of San Juan vary according to the assembly place. Unlike the evacuation routes in the previous section, to evaluate the different possible evacuation times, this section considers only five of the six assembly places available for this municipality. These are: “Plaza de Colón”, “Plaza Barceló”, “Plaza del Choliseo”, “Parque de Pelota Las Gladiolas”, and “Complejo Deportivo Hiram Bithorn”.

6.3.2.1 Dr. Julio J. Henna

This school has three other possible routes to get to the assembly site. The first two routes use the same "Plaza Barceló" assembly place from the evaluation in the previous section. The only aspect that varies in them is the street through which they are heading towards their destination. The first alternate route is shown in Figure 6-86. This route has a distance of 0.709 miles for an evacuation time of 18 minutes 23 seconds. This route has 1 minute and 23 seconds more compared to the evacuation time of the route used for the vulnerability assessment of 17 minutes (Figure 6-87).

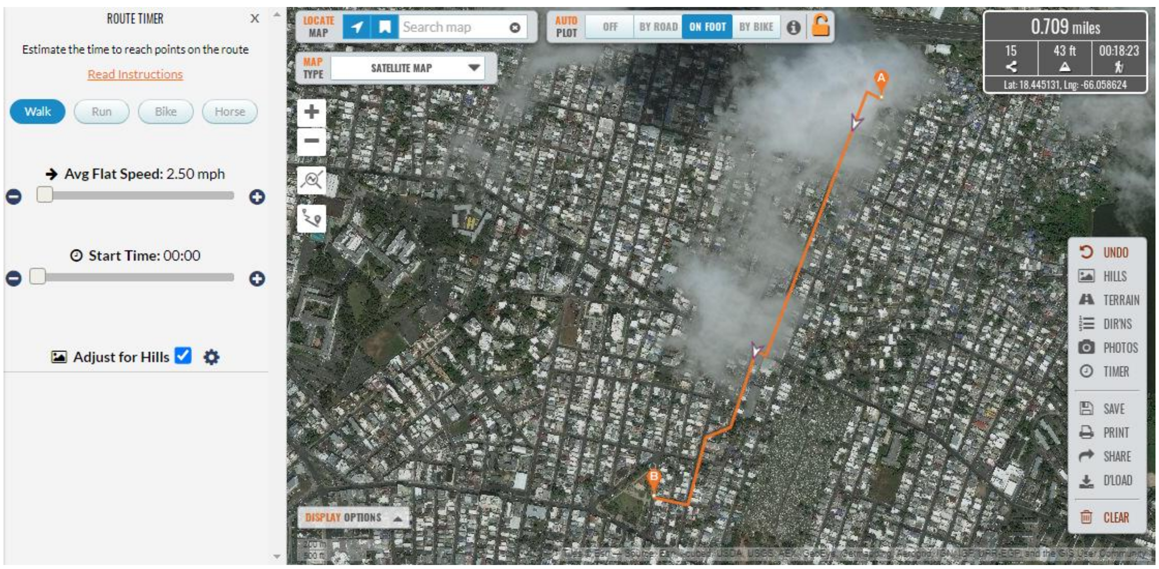


Figure 6-86 First Alternate Route of Dr. Julio J. Henna School at San Juan

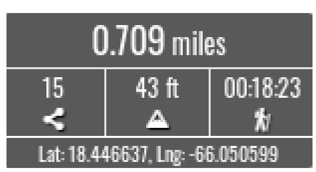
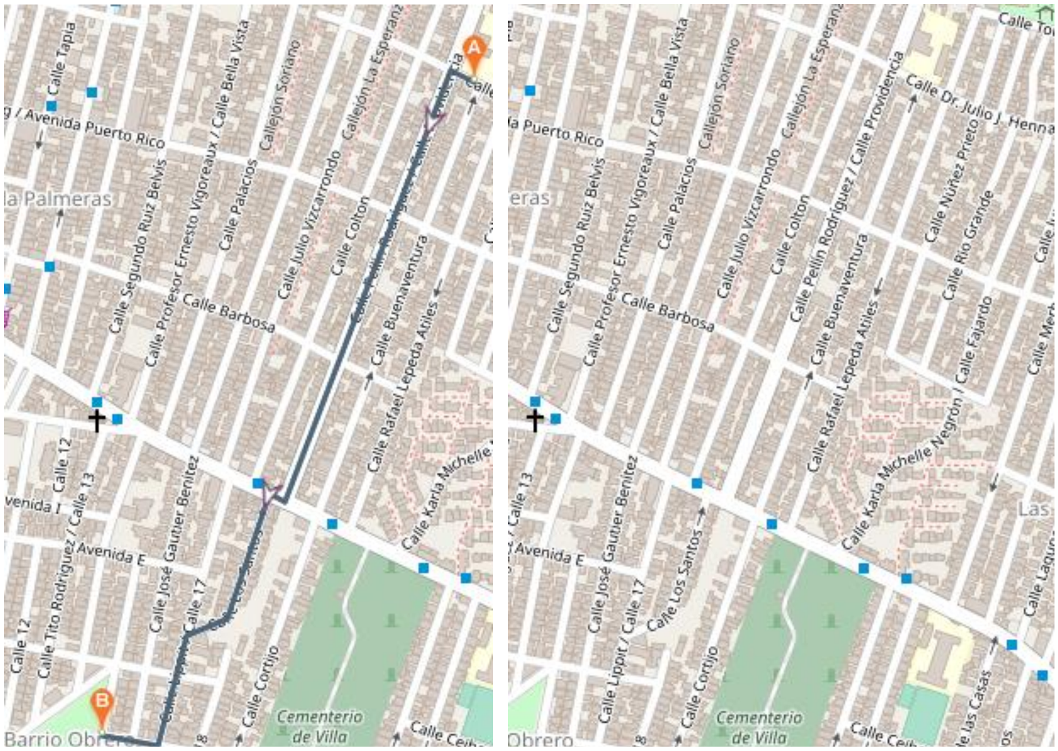


Figure 6-87 Evacuation Time and Route's Distance of First Alternate Route of Dr. Julio J. Henna School

This first route leaves from Dr. Julio Henna Street and turns onto Pellín Rodríguez Street. Then, it turns onto Eduardo Conde Avenue towards Los Santos Street. It turns down Lippit Street and turns onto Hermanas Mirabal Avenue until it reaches Felipe R. Goyco Street, which is where the assembly place, Plaza Antonio R. Barceló is located. Figure 6-88 shows

(a) the first route for Dr. Julio J. Henna school and (b) the map of the area to visibly identify the streets and avenues of the route.



(a) (b)

Figure 6-88 Streets of First Alternate Route of Dr. Julio J. Henna School

The second alternate route of this school is shown in Figure 6-89.

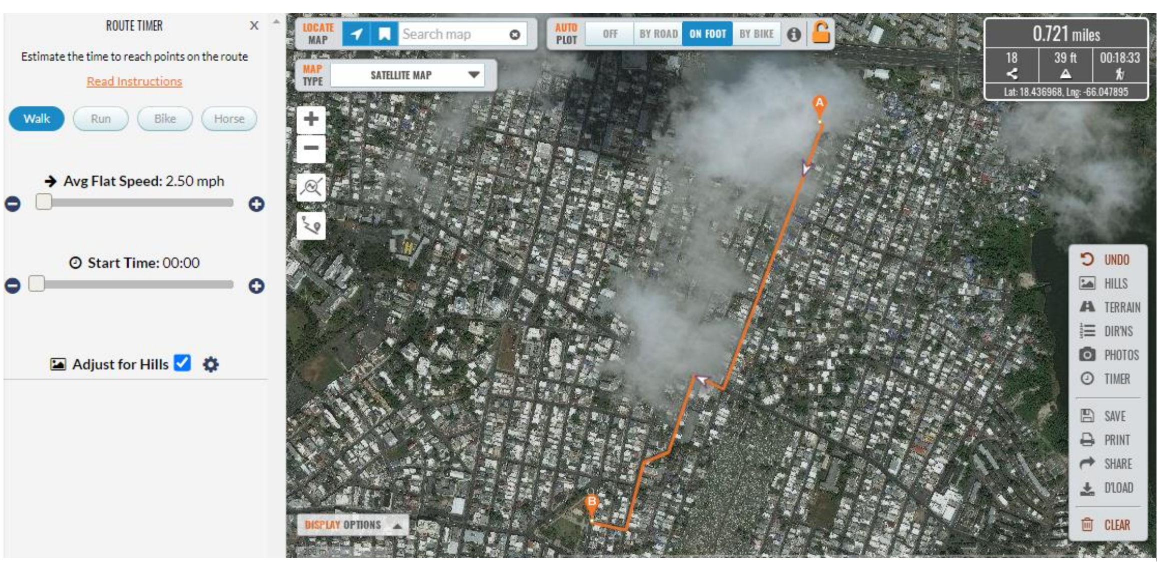


Figure 6-89 Second Alternate Route of Dr. Julio J. Henna School at San Juan

This route has a distance of 0.721 miles for an evacuation time of 18 minutes 33 seconds. This route is 1 minute and 33 seconds more compared to the time of 17 minutes (Figure 6-90).

Figure 6-90 Evacuation Time and Route's Distance of Second Alternate Route of Dr. Julio J. Henna School

This second route is the same as the first, but instead of turning onto Pellín Rodríguez Street, turn onto Buenaventura Street and follow the same route until it reaches the predetermined assembly location.

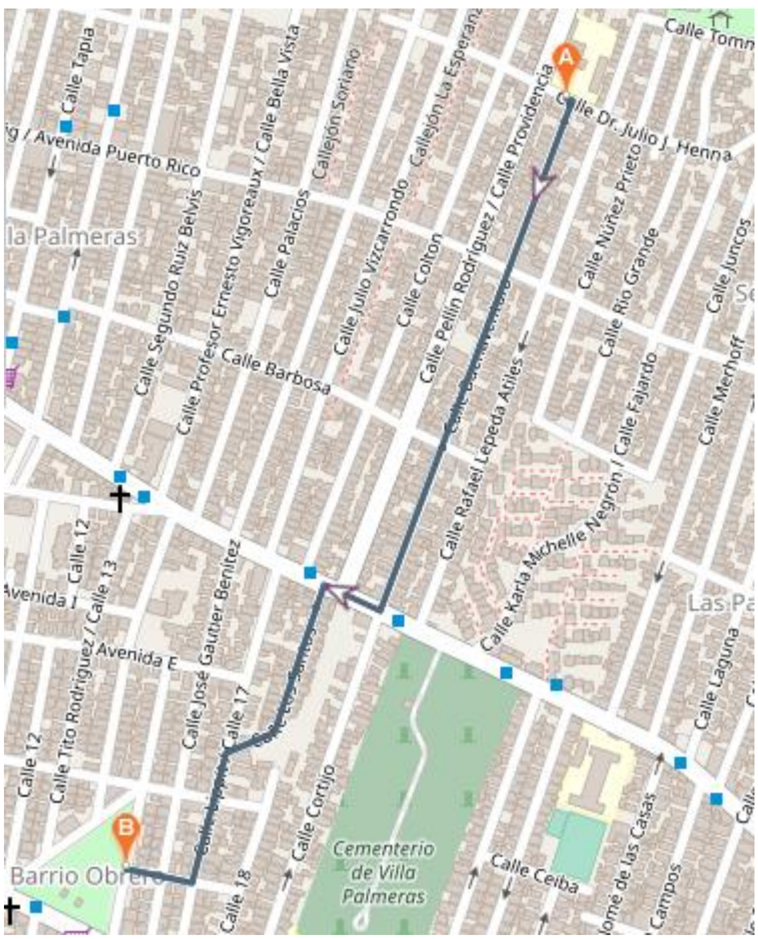


Figure 6-91 Streets of Second Alternate Route of Dr. Julio J. Henna School

The first two routes shown are the closest and most like the route from the evaluation in the previous section. However, for this school and for the place of assembly ("Plaza Barceló"), other possible alternative routes could be those that turn through Rafael Lepeda Atiles Street towards Cortijo Street. Others also that turn down Borinquen Avenue and José Gautier Benítez until they reach the assembly place.

The third alternate route of this school is shown in Figure 6-92. This possible alternate route is evaluated with the assembly place "Parque de Pelota de Las Gladiolas" even though it is visibly further from the school but is shown for comparison purposes. This route has a distance of 1.992 miles for an evacuation time of 49 minutes 57 seconds. This route is 32 minutes and 57 seconds more compared to the time of 17 minutes (Figure 6-93). This evacuation time represents almost twice the evacuation times of the previous routes.

Figure 6-92 Third Alternate Route of Dr. Julio J. Henna School at San Juan

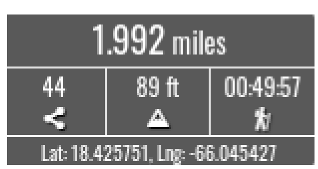


Figure 6-93 Evacuation Time and Route's Distance of Third Alternate Route of Dr. Julio J. Henna School

This route goes through many streets and avenues to reach the safe place of assembly. It leaves from Dr. Julio J. Henna and turns onto Rafael Lepeda Atiles Street. Then it goes down Nuñez Prieto Street followed by Barbosa Street in direction to Karla Michelle Negrón Street (Fajardo Street) and Eduardo Conde Avenue. Later, it turns onto Haydeé Rexach Street towards Borinquen Avenue and then onto PR-27 along Dr. José Celso Barbosa Avenue. Later, it cross “Calle del Pilán” to PR-27 along Dr. José Celso Barbosa Avenue. Finally, it turns onto PR-40 towards Quisqueya Avenue until it reaches the assembly place (Figure 6-94).

Figure 6-94 Streets of Third Alternate Route of Dr. Julio J. Henna School

6.3.2.2 Jaime Rosario (Buena Vista Elemental)

Jaime Rosario school has three possible nearby assembly locations to go in the event of a tsunami evacuation. These are: “Plaza Barceló”, “Plaza del Choliseo”, and “Parque de Pelota de Las Gladiolas” (Figure 6-95).

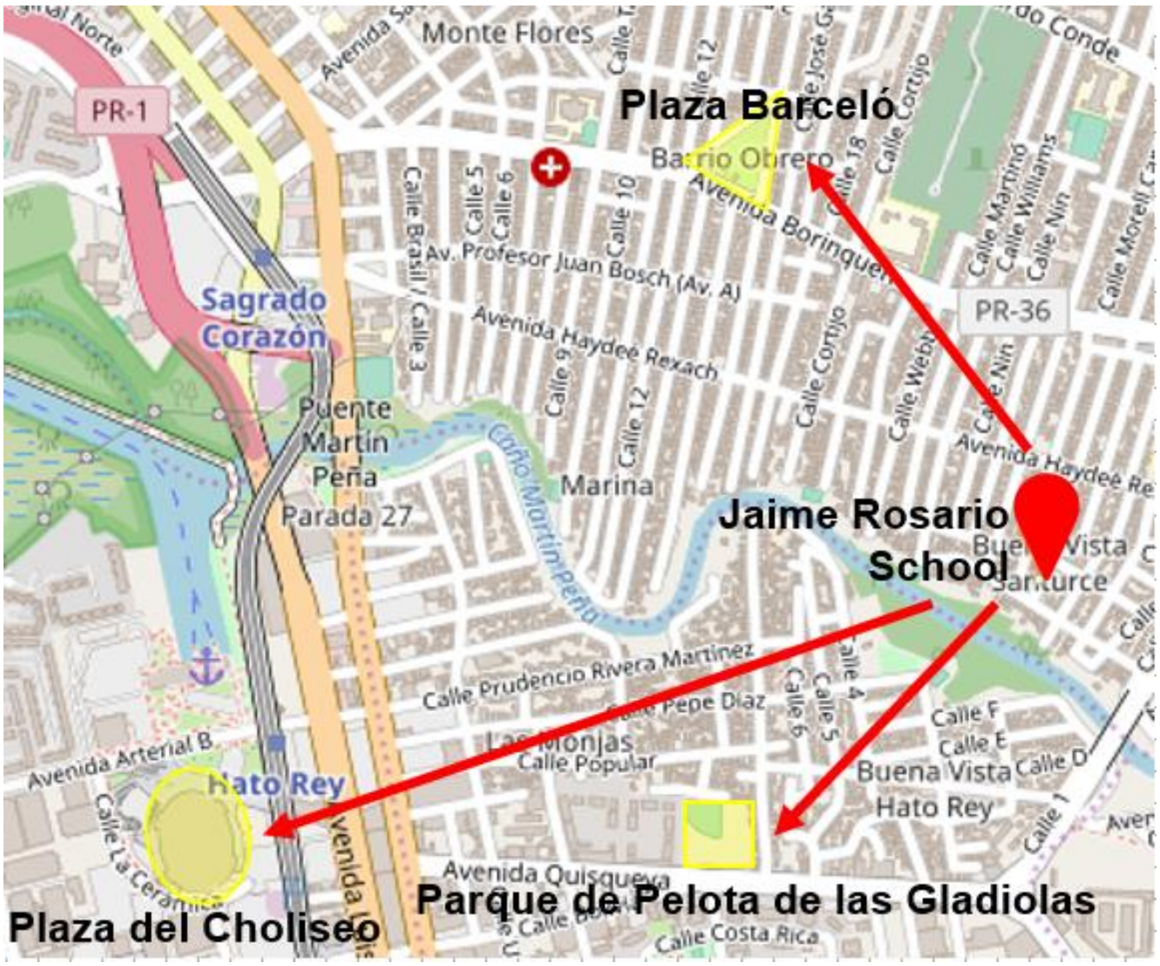


Figure 6-95 Assembly Places for the Jaime Rosario School

The following is a possible alternate route to each of the assembly locations. The routes and their respective assembly places appear in descending order of proximity to the school location.

The first alternate route is shown in Figure 6-96. This route goes from the location of the school to the destination “Plaza Barceló”, corresponding to the closest one and previously used in the evaluation of the evacuation routes in the previous section. This route has a distance of 0.698 miles for an evacuation time of 17 minutes 43 seconds. In this way, this first alternative involves traveling 23 seconds longer than the evacuation time of the route used for the vulnerability assessment of 17 minutes and 20 seconds (Figure 6-97). Although the difference is relatively small, those 23 seconds could be increased by possible interruptions along the way.

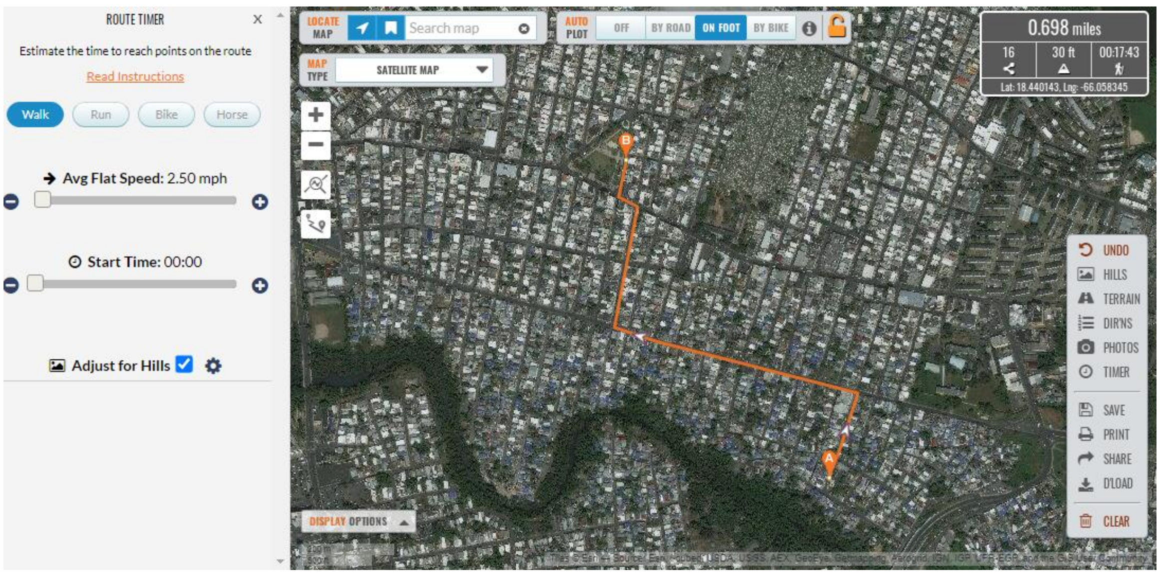


Figure 6-96 First Alternate Route of Jaime Rosario (Buena Vista Elemental) School at San Juan

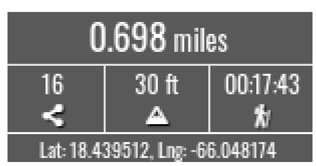


Figure 6-97 Evacuation Time and Route's Distance of First Alternate Route of Jaime Rosario (Buena Vista Elemental) School

This first possible route leaves from Buenos Aires Street in direction to Haydeé Rexach Avenue where it turns. Then, it turns onto José Gautier Benitez Street until it reaches Borinquen Avenue. Eventually, it turns onto Felipe R. Goyco Street where the predestined assembly place is located (Figure 6-98).

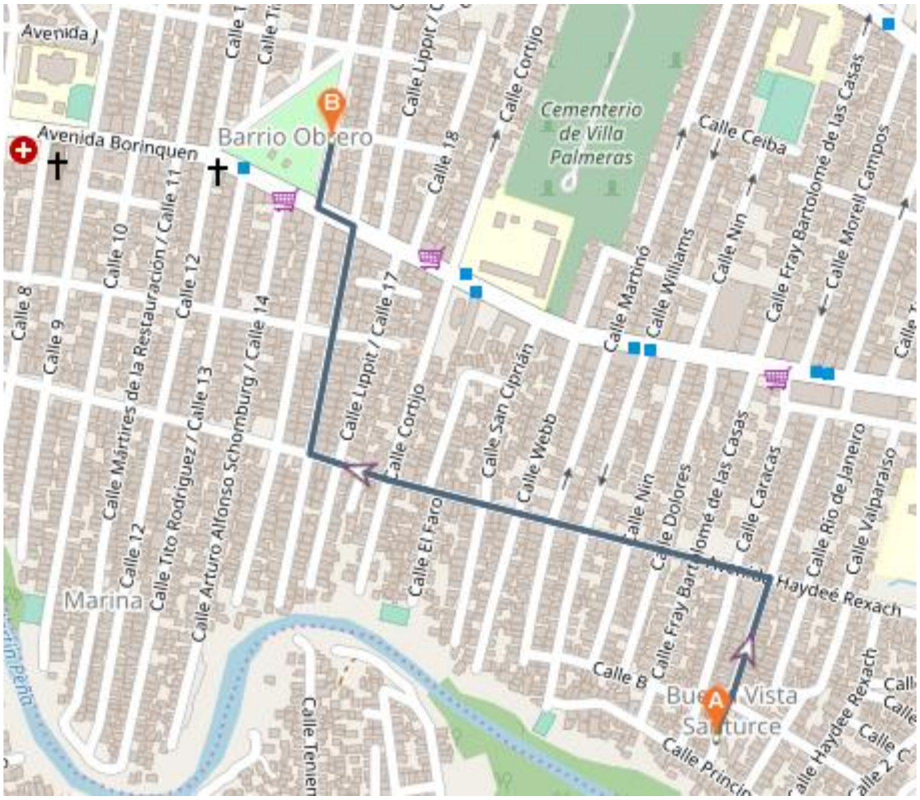


Figure 6-98 Streets of First Alternate Route of Jaime Rosario (Buena Vista Elemental) School

The second possible alternative route corresponds to the one that leaves from the school location to the assembly place “Parque de Pelota de Las Gladiolas”. This is shown in Figure 6-99. This route has a distance of 0.951 miles for an evacuation time of 23 minutes 31 seconds. Therefore, this second route is 6 minutes and 11 seconds more compared to the time of 17 minutes and 20 seconds (Figure 6-100).

Although at first glance the “Plaza Barceló” and “Parque de Pelota de Las Gladiolas” seem to be the same distance from their locations to the school, the distances of their routes and their evacuation times are not (Figure 6-95).

This route, like the previous one, leaves from Buenos Aires Street, but turns onto Principal Street. Then, it turns towards “Calle del Pilar” in direction to Dr. José Celso Barbosa Avenue through PR-27. Later, it takes PR-40 towards Quisqueya Avenue until it reaches the assembly place (Figure 6-101).

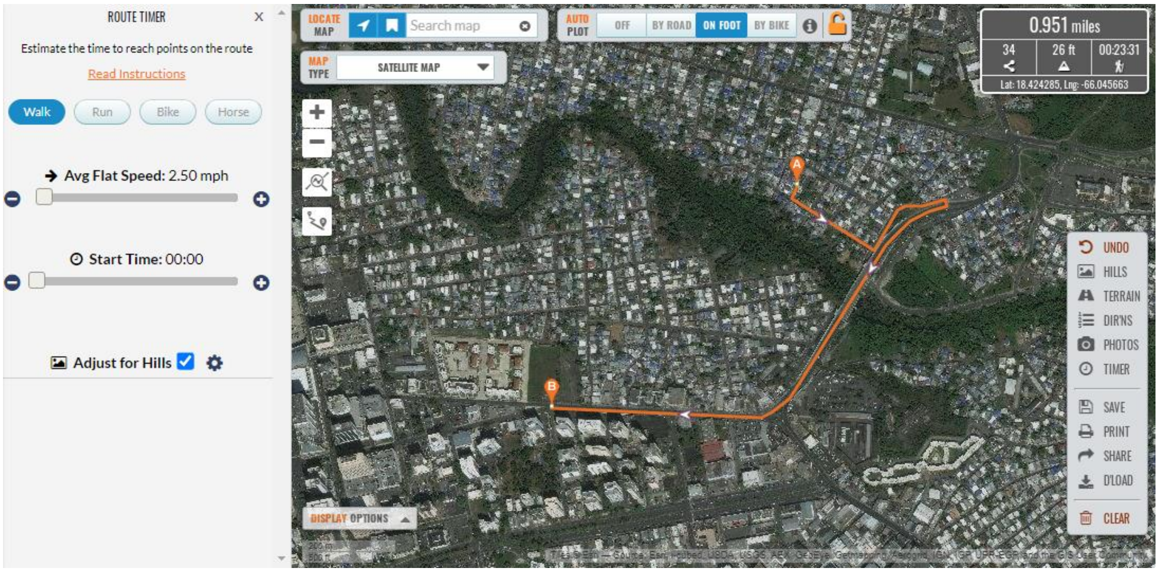


Figure 6-99 Second Alternate Route of Jaime Rosario (Buena Vista Elemental) School at San Juan

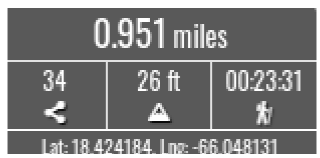


Figure 6-100 Evacuation Time and Route's Distance of Second Alternate Route of Jaime Rosario (Buena Vista Elemental) School

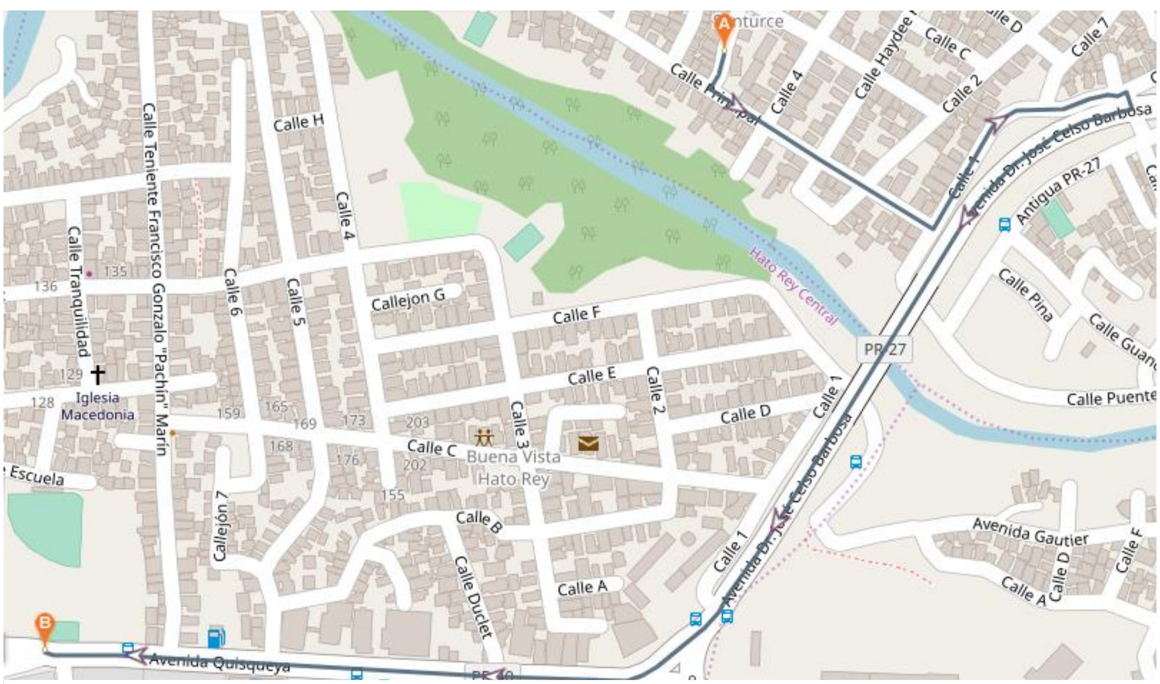


Figure 6-101 Streets of Second Alternate Route of Jaime Rosario (Buena Vista Elemental) School

The third route goes to the farthest assembly place, “Plaza del Choliseo”. This route is shown in Figure 6-102. This route has a distance of 1,680 miles for an evacuation time of 42 minutes 28 seconds. This route is 25 minutes and 8 seconds more compared to the time of 17 minutes and 20 seconds (Figure 6-103).

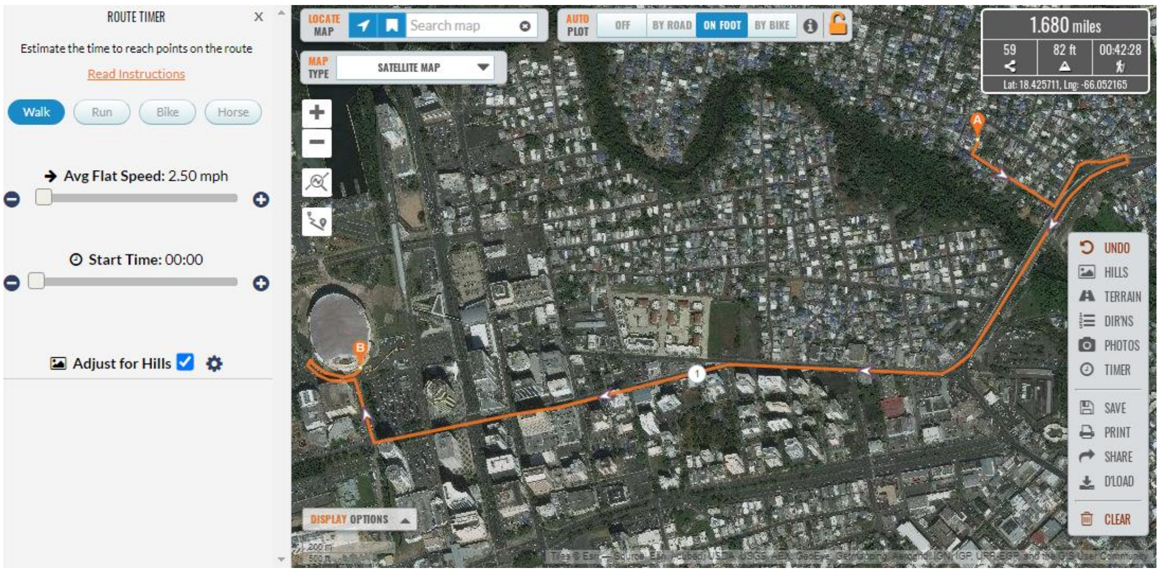


Figure 6-102 Third Alternate Route of Jaime Rosario (Buena Vista Elemental) School at San Juan

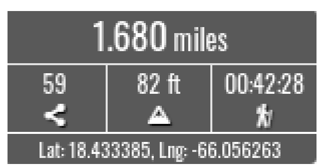


Figure 6-103 Evacuation Time and Route’s Distance of Third Alternate Route of Jaime Rosario (Buena Vista Elemental) School

Like the second route, this third route leaves from Buenos Aires Street and turns onto Principal Street. Then, it turns towards “Calle del Pilar” in direction to Dr. José Celso Barbosa Avenue through PR-27. Later, it takes PR-40 towards Quisqueya Avenue. The difference is that on this route, it turns from PR-40 to Bolivia Street in direction to Carlos E. Chardón Avenue. Then, it turns to the Escuela Libre de Música Street and "Calle La Cerámica" until it reaches the assembly place (Figure 6-104).

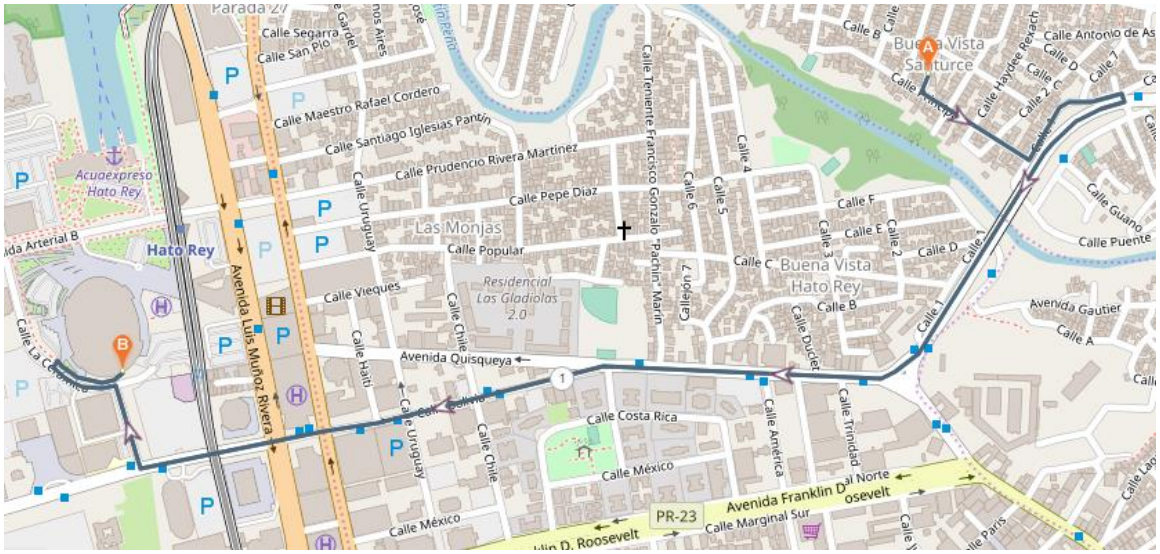


Figure 6-104 Streets of Third Alternate Route of Jaime Rosario (Buena Vista Elemental) School

6.3.2.3 Julián E. Blanco (Ballet)

This school has two other possible routes to get to the assembly site. For reasons of proximity, the possible alternative routes use the assembly place closest to the school, “Plaza Barceló”. The rest of the assembly locations are within 2 miles to 4 miles of the school location (Figure 6-105). This represents a very long evacuation time compared to previous schools whose times are kept between 10 min to 20 min.

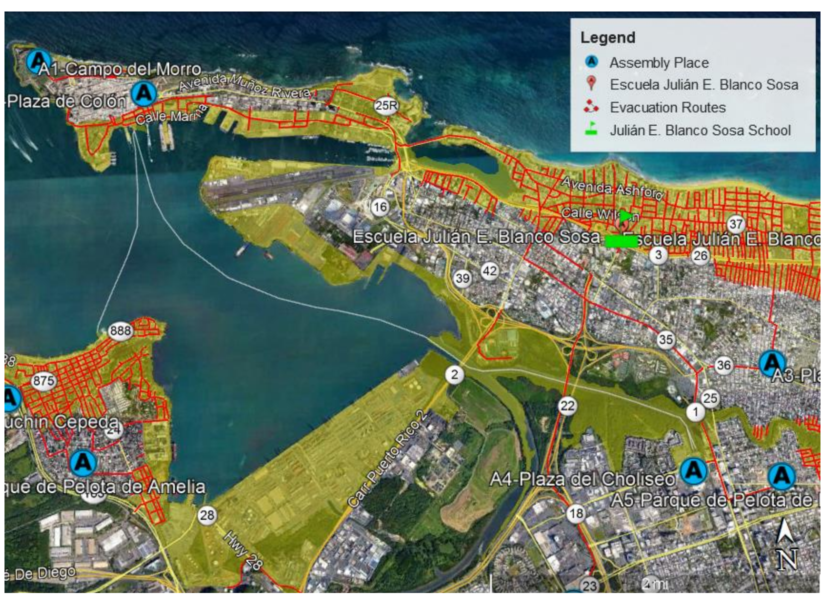


Figure 6-105 Location of Assembly Places with Respect to Julián E. Blanco School

The first alternate route is shown in Figure 6-106. This route has a distance of 1.642 miles for an evacuation time of 40 minutes 36 seconds. This route has 34 seconds more compared to the evacuation time of the route used for the vulnerability assessment of 40 minutes and 2 seconds (Figure 6-107). Like the first alternate route of Jaime Rosario, seconds apart can prove disastrous for tsunami evacuations.

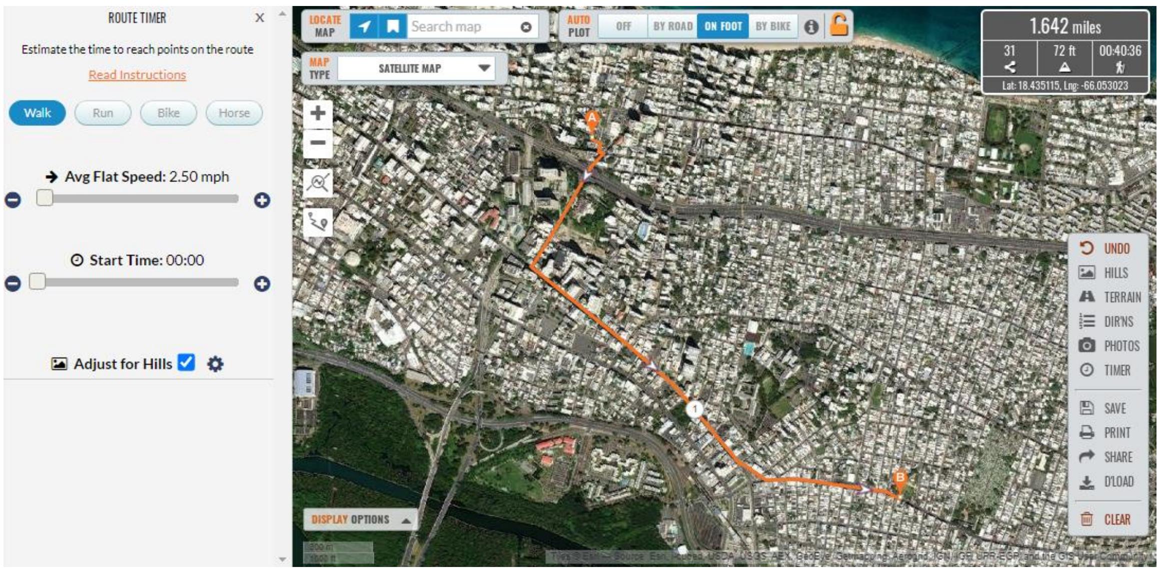


Figure 6-106 First Alternate Route of Julián E. Blanco (Ballet) School at San Juan

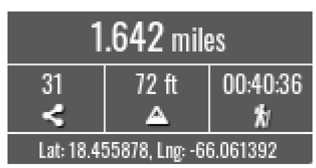


Figure 6-107 Evacuation Time and Route's Distance of First Alternate Route of Julián E. Blanco School

This first route from Julián E. Blanco school leaves from Estrella Street and turns onto Julián Blanco Street. Then, it turns towards Martín Travieso Street and José de Diego (PR-37) Avenue. Eventually, it turns onto Juan Ponce de León Avenue (PR-25) and turns down Cayey Street towards Borinquen Avenue until it reaches the assembly place (Figure 6-108).

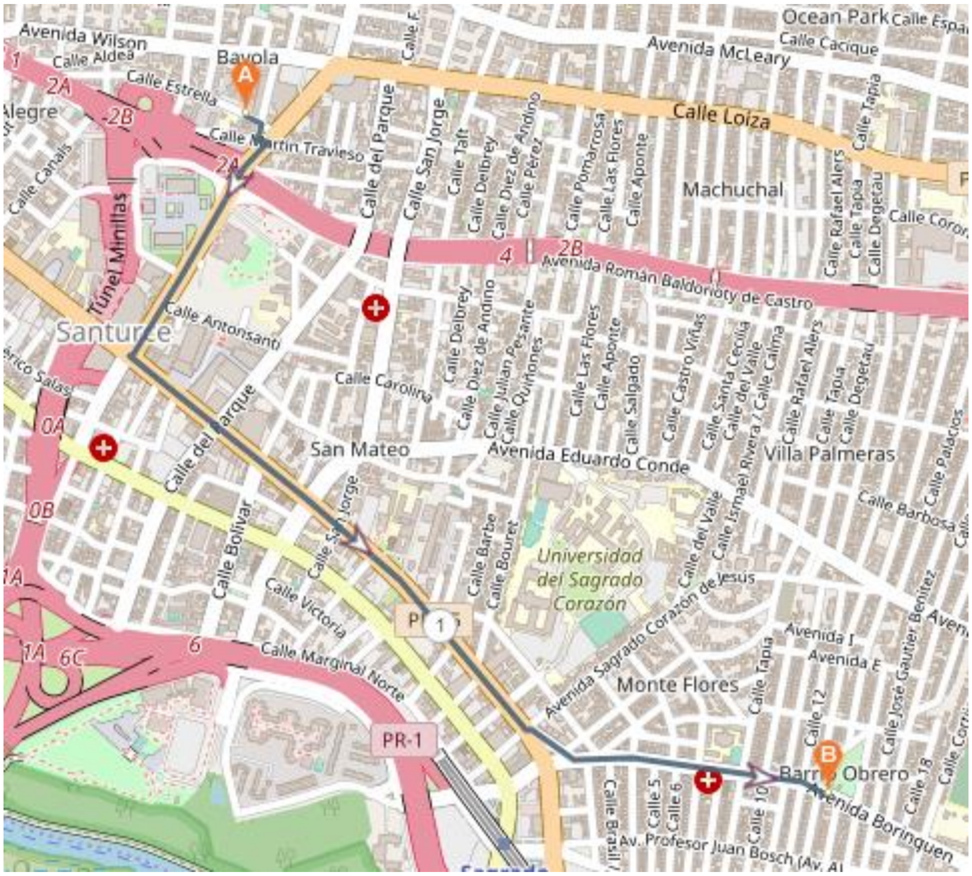


Figure 6-108 Streets of First Alternate Route of Julián E. Blanco School

The second alternate route of Julián E. Blanco school is shown in Figure 6-109. This is the closest route to the evacuation route presented in the evaluation in the previous section. This second alternate route has a distance of 1.647 miles for an evacuation time of 42 minutes 45 seconds. This route is 2 minutes and 43 seconds more compared to the time of 40 minutes and 2 seconds (Figure 6-110).

This route leaves from Estrella Street and turns onto Julián Blanco Street in direction to PR-37 on José de Diego Avenue. Then, it turns onto Román Baldorioty de Castro Avenue and turns onto San Jorge Street. Subsequently, it turns onto Eduardo Conde Avenue, San Mateo Street, “Calle El Bosque”, Barbe Street, and San Antonio Street until reaching Borinquen Avenue on PR-36 where the assembly place is located (Figure 6-111).

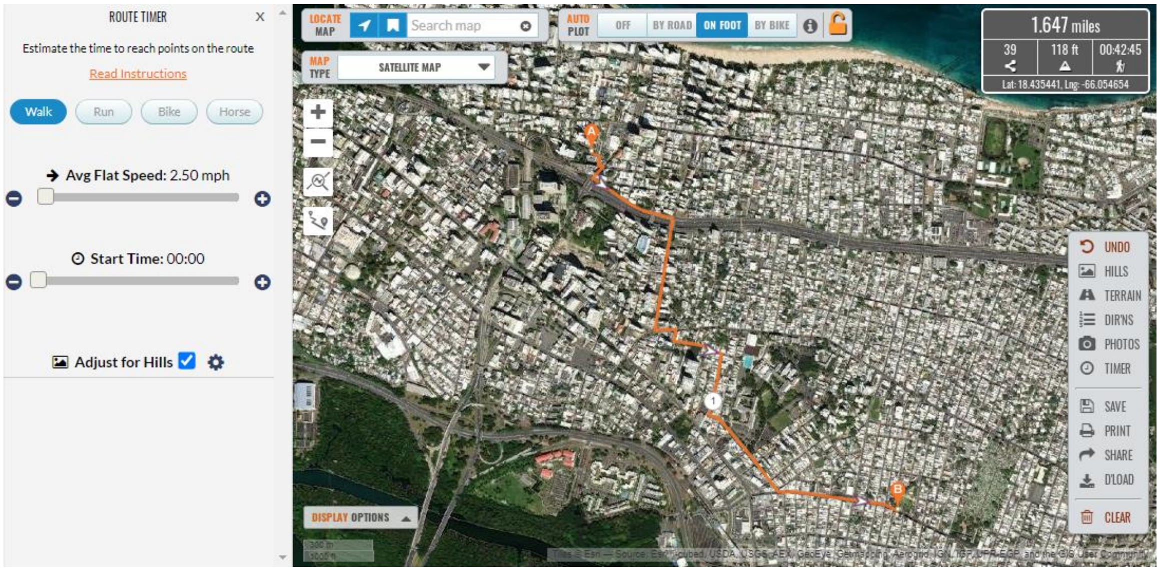


Figure 6-109 Second Alternate Route of Julián E. Blanco (Ballet) School at San Juan

Figure 6-110 Evacuation Time and Route's Distance of Second Alternate Route of Julián E. Blanco School

Figure 6-111 Streets of Second Alternate Route of Julián E. Blanco School

6.3.2.4 Luis Llorens Torres

Luis Llorens Torres school has two other possible routes to get safe to the assembly site with the same place of assembly "Plaza Barceló". Like the previous Julián E. Blanco school, at first glance the rest of the assembly places are far from this school (Figure 6-112). This represents a danger for the school, as the ideal is to get out of the coast and the tsunami hazard zone as soon as possible. However, a third route is presented with the nearest assembly place after "Plaza Barceló" as a comparison of the long evacuation times.

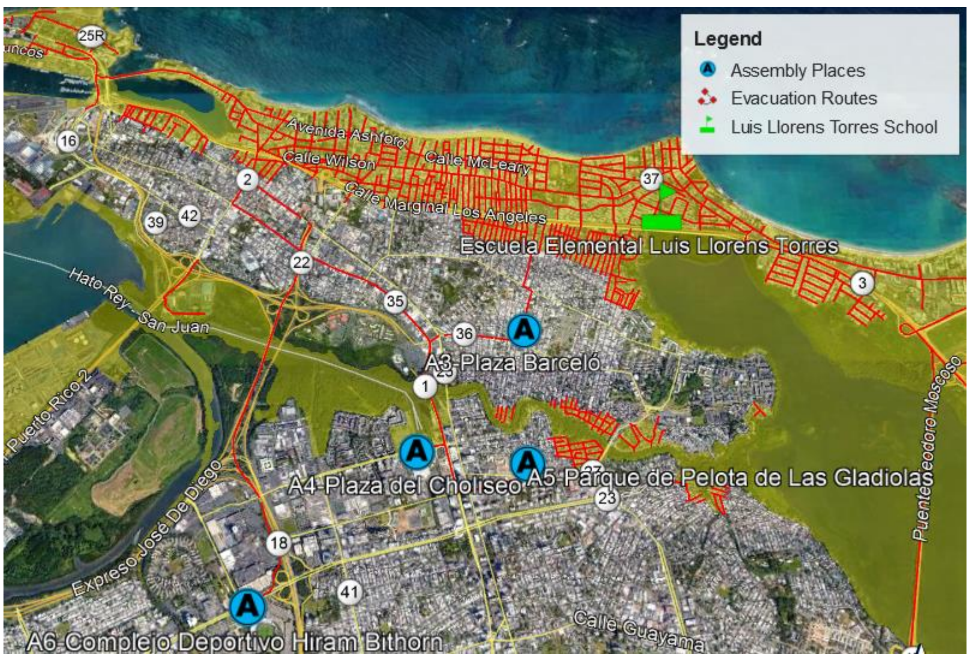


Figure 6-112 Location of Assembly Places with Respect to Luis Llorens Torres School

The first alternate route is shown in Figure 6-113. This route has a distance of 1.492 miles for an evacuation time of 37 minutes 58 seconds. Therefore, this route has 4 minutes and 23 seconds more compared to the evacuation time of the route used for the vulnerability assessment of 33 minutes and 35 seconds (Figure 6-114).

This route leaves from María Isabel Street in direction to Marina Street. Then, it turns towards José Gautier Benitez Street until it reaches Borinquen Avenue, the avenue where the "Plaza Barceló" assembly place is located (Figure 6-115).

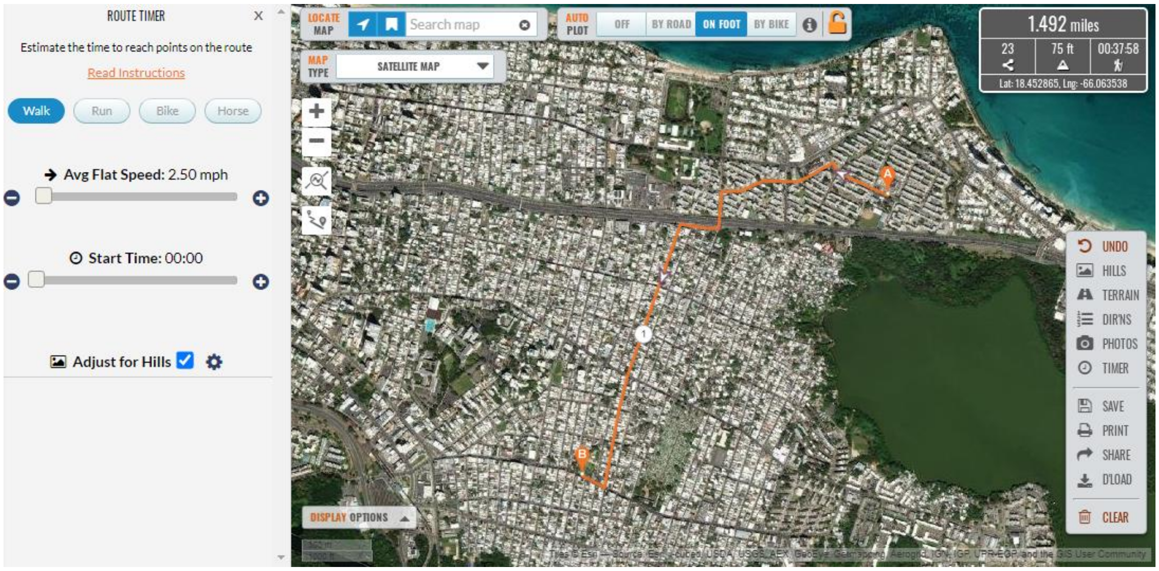


Figure 6-113 First Alternate Route of Luis Llorens Torres School at San Juan

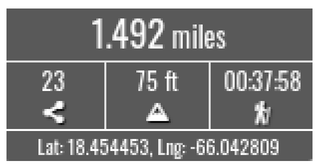


Figure 6-114 Evacuation Time and Route's Distance of First Alternate Route of Luis Llorens Torres School

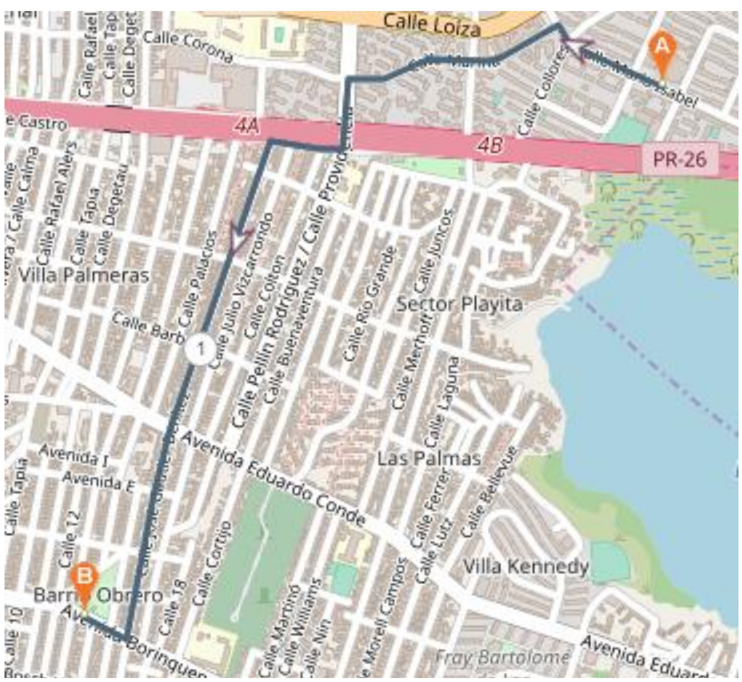


Figure 6-115 Streets of First Alternate Route of Luis Llorens Torres School

The second possible evacuation route for the Luis Llorens Torres school is shown in Figure 6-116. This route also uses the "Plaza Barceló" as the assembly place. This second alternate route has a distance of 1.439 miles for an evacuation time of 37 minutes. This route is 4 minutes and 5 seconds more compared to the time of 33 minutes and 35 seconds (Figure 6-117).

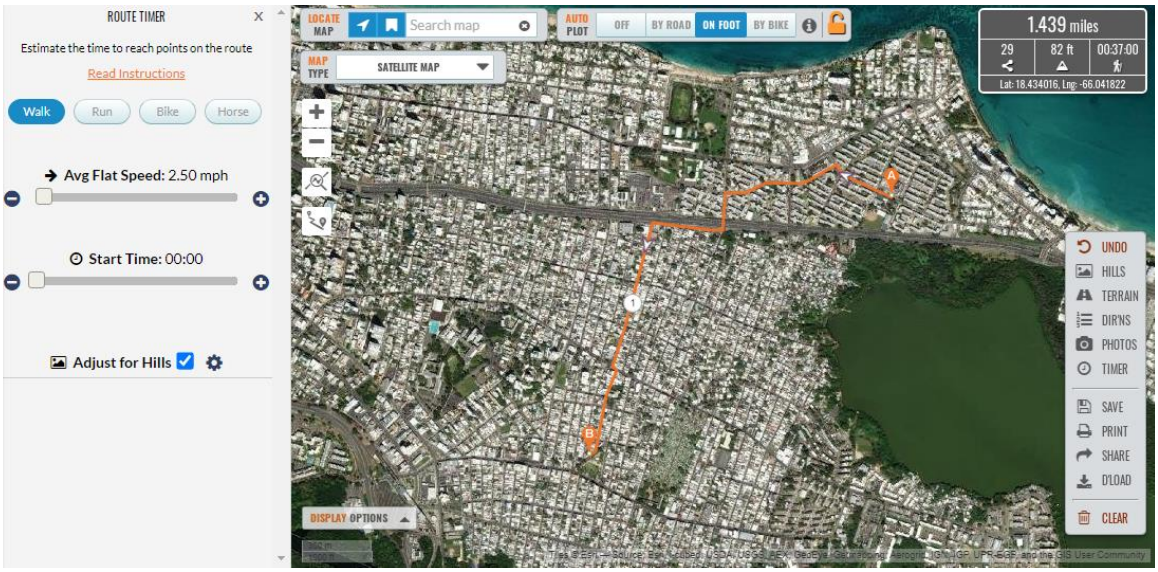


Figure 6-116 Second Alternate Route of Luis Llorens Torres School at San Juan

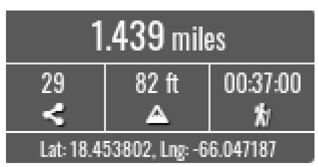


Figure 6-117 Evacuation Time and Route's Distance of Second Alternate Route of Luis LLorens Torres School

The second route leaves from María Isabel Street towards Marina Street and turns onto Pellín Rodríguez Street (Providencia Street). Then, it tours by Román Baldorioty de Castro Avenue, tours by Professor Ernesto Vigoreaux Street in direction of Peruchin Cepeda Avenue until reaching the assembly place "Plaza Barceló" (Figure 6-118).

Figure 6-118 Streets of Second Alternate Route of Luis Llorens Torres School

The third alternate route is shown in Figure 6-119. This route has a distance of 2.670 miles for an evacuation time of 1 hour 6 minutes 34 seconds. This route is 33 minutes and 39 seconds more compared to the time of 33 minutes and 35 seconds (Figure 6-120).

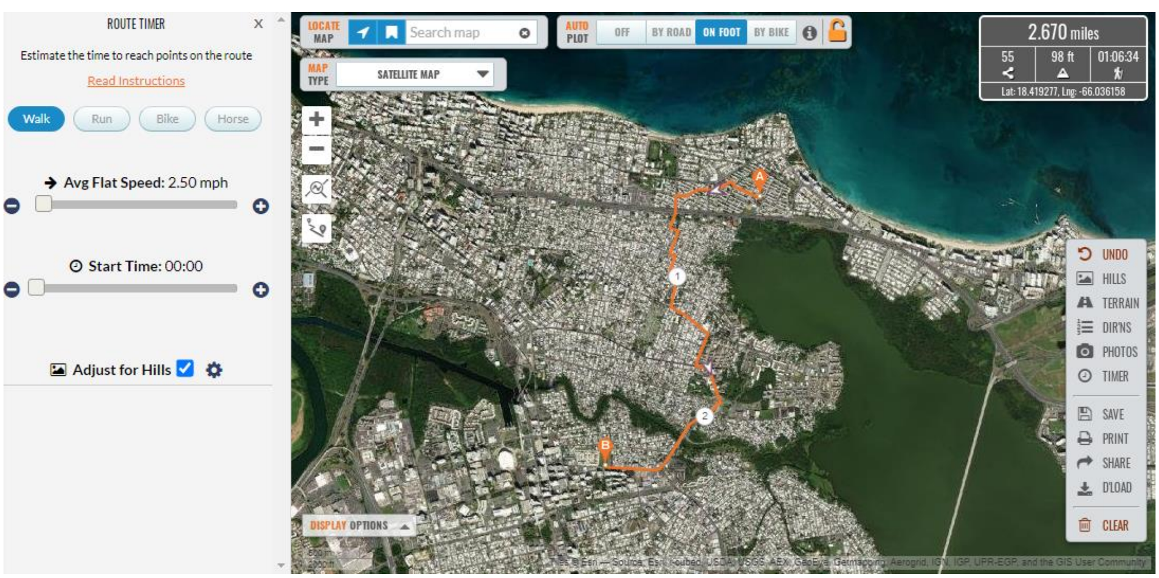


Figure 6-119 Third Alternate Route of Luis Llorens Torres School at San Juan

Figure 6-120 Evacuation Time and Route's Distance of Third Alternate Route of Luis Llorens Torres School

This route has a distance greater than 2 miles, representative of a hazard for the school population that evacuates the campus to a safe zone. As mentioned above, contrary to the first two routes, this route reaches the assembly place of "Parque de Pelota de Las Gladiolas", corresponding to the nearest assembly place after "Plaza Barceló". This route leaves from María Isabel Street, turns onto Marina Street and then onto Pellín Rodríguez Avenue. Then, it turns onto Dr. Julio J. Henna Street, onto Rafael Lepeda Atiles Street, onto Nuñez Prieto Street, onto Barbosa Street and then onto Karla Michelle Negrón Street towards Eduardo Conde Avenue. Later, it turns onto Haydeé Rexach Street towards PR-27 via Dr. José Celso Barbosa. Eventually, it turns towards Quisqueya Avenue on PR-40 until reaching the assembly place "Parque de Pelota de Las Gladiolas" (Figure 6-121).

Figure 6-121 Streets of Third Alternate Route of Luis Llorens Torres School

6.3.2.5 Luis Rodríguez Cabrero

This school has three other possible routes to get the closest assembly place. Two of them use the "Plaza Barceló" assembly place as their destination. The third route departs from the location of the school to the next nearest assembly place, "Parque de Pelota de Las Gladiolas". The rest of the assembly places are not considered in comparison because they are far from this school (Figure 6-122). Which leads to evacuation times between 40 minutes to 2 hours approximately.

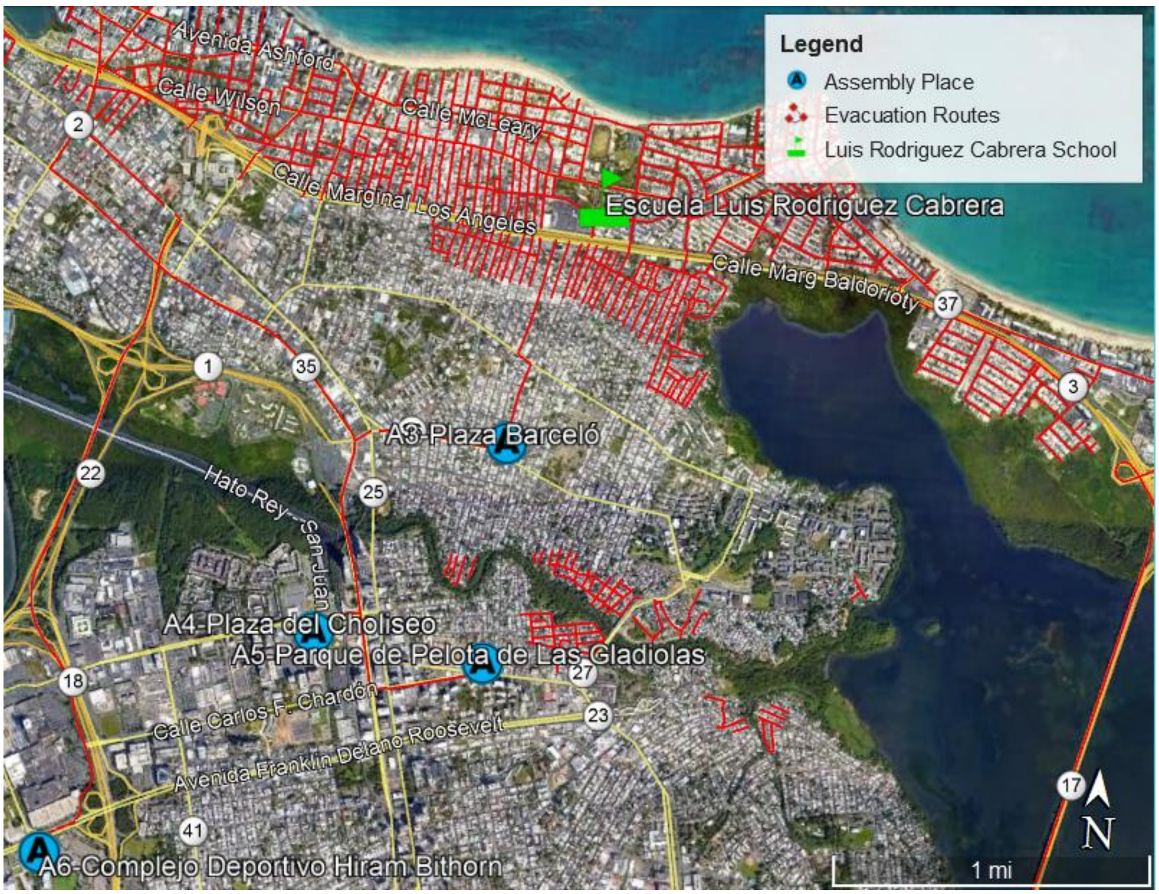


Figure 6-122 Location of Assembly Places with Respect to Luis Rodríguez Cabrero School

The first alternate route is shown in Figure 6-123. This route goes from the location of the school to the destination "Plaza Barceló". As mentioned above this assembly place is the closest one and was previously used in the evaluation of the evacuation routes in the previous section for this school. This route has a distance of 1.133 miles for an evacuation time of 29 minutes 41 seconds. In this way, this first alternative involves traveling 5 minutes and 26 seconds longer than the evacuation time of the route used for the vulnerability assessment of 24 minutes and 55 seconds (Figure 6-124).

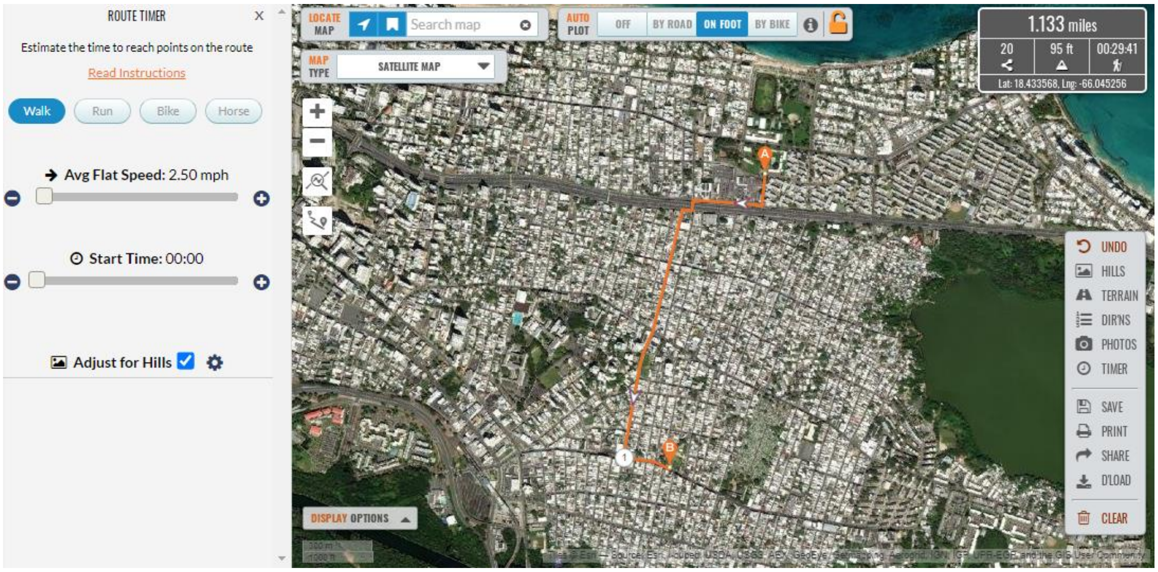


Figure 6-123 First Alternate Route of Luis Rodríguez Cabrero School at San Juan

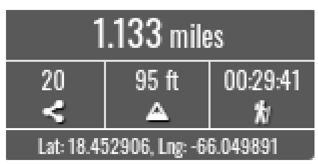


Figure 6-124 Evacuation Time and Route's Distance of First Alternate Route of Luis Rodríguez Cabrero School

This first possible route leaves Corona Street and turns onto Arco Iris Street in direction to Román Baldorioty de Castro Avenue. Then, it turns onto Degetau Street, onto Román Baldorioty de Castro Avenue, and onto Tapia Street in a straight direction until it turns onto Borinquen Avenue and reaches the "Plaza Barceló" assembly place (Figure 6-125).

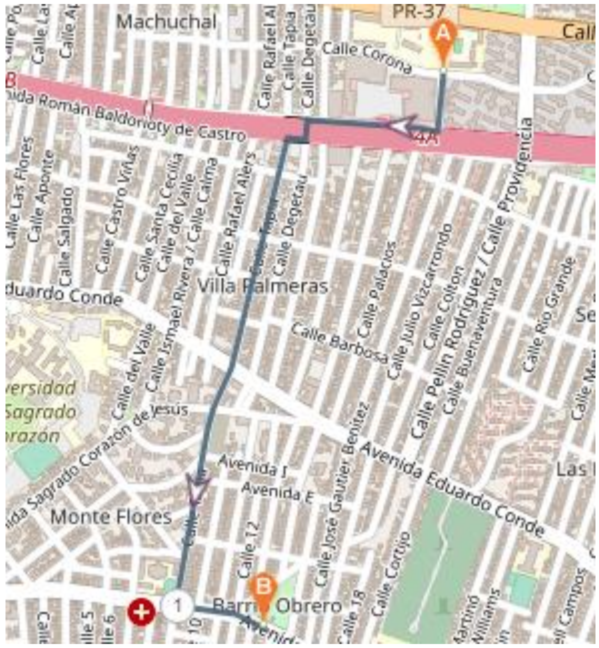


Figure 6-125 Streets of First Alternate Route of Luis Rodríguez Cabrero School

The second alternate route is shown in Figure 6-126. This route has a distance of 1.040 miles for an evacuation time of 27 minutes 14 seconds. This route is 2 minutes and 59 seconds, that is, 3 minutes approximately more compared to the time of 24 minutes and 55 seconds (Figure 6-127).

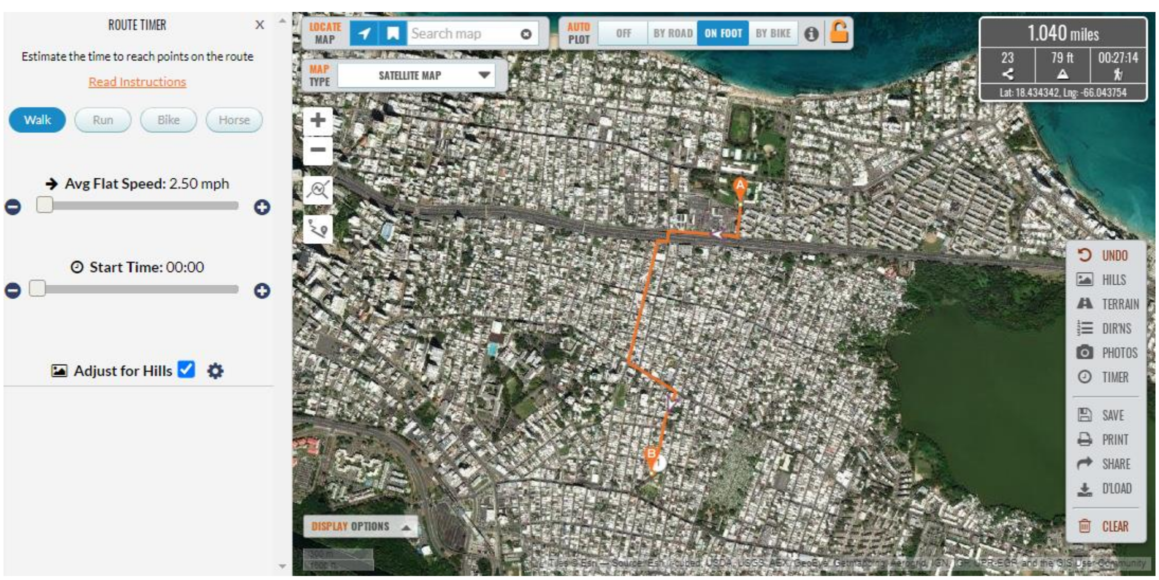


Figure 6-126 Second Alternate Route of Luis Rodríguez Cabrero School at San Juan

Figure 6-127 Evacuation Time and Route's Distance of Second Alternate Route of Luis Rodríguez Cabrero School

This second route follows the same direction as the previous route. It leaves Corona Street and turns onto Arco Iris Street in direction to Román Baldorioty de Castro Avenue. Then, it turns onto Degetau Street, onto Román Baldorioty de Castro Avenue, and onto Tapia Street. But unlike the first alternate route, this route bends from Wall Street to Eduardo Conde Avenue and makes a turn for Professor Ernesto Vigoreaux. Later, it turns to Orlando Peruchin Cepeda Avenue and arrives at the "Plaza Barceló" assembly place.

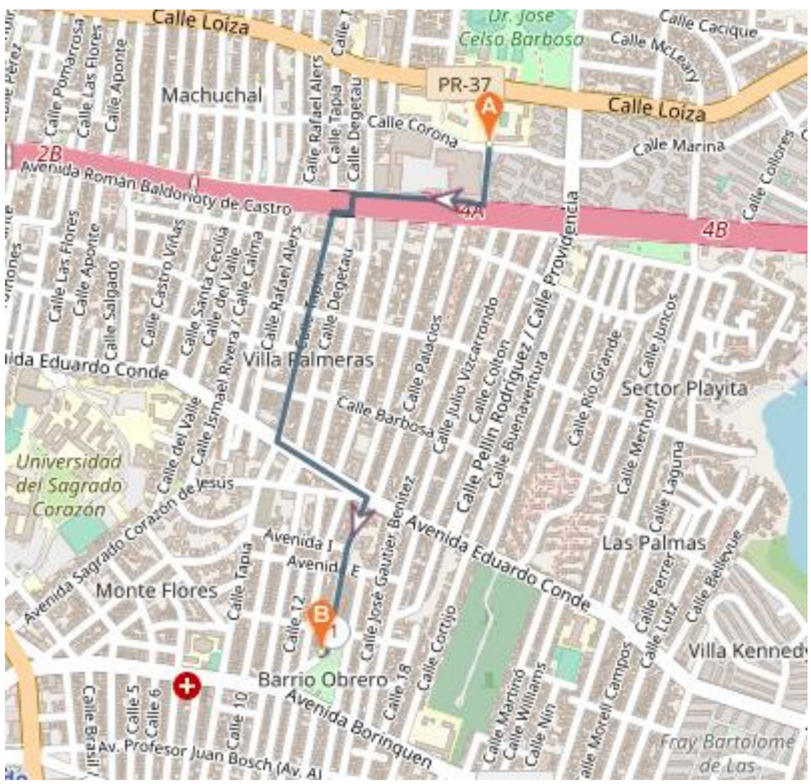


Figure 6-128 Streets of Second Alternate Route of Luis Rodríguez Cabrero School

As mentioned above, the third possible route leads to another assembly location that is further away from the school. The third alternate route is shown in Figure 6-129. This route has a distance of 1.040 miles for an evacuation time of 27 minutes 14 seconds. This route is 2 minutes and 59 seconds, that is, 3 minutes approximately more compared to the time of 24 minutes and 55 seconds (Figure 6-130).

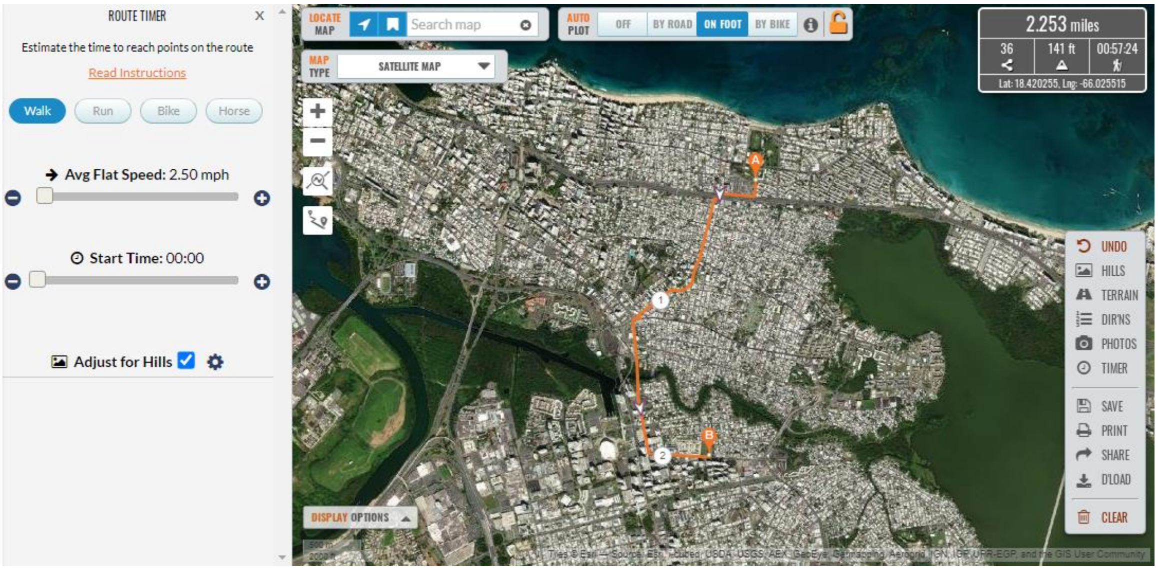


Figure 6-129 Third Alternate Route of Luis Rodríguez Cabrero School at San Juan

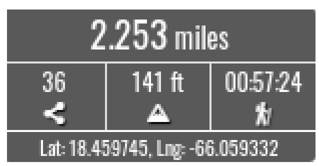


Figure 6-130 Evacuation Time and Route's Distance of Third Alternate Route of Luis Rodríguez Cabrero School

This third route leaves Corona Street and then turns onto Arco Iris Street, through Román Barldorioty de Castro Avenue, through Degetau Street, through Román Barldorioty de Castro Avenue, through Tapia Street, through Flamboyán Street, through the Dr. Luis Izquierdo Mora Street, and down Cayey Street until reaching Borinquen Avenue. This is the avenue where the "Plaza Barceló" assembly place of the other two previous routes is located. However, this route continues and turns towards Juan Ponce de León (PR-25) Avenue until Quisqueya Avenue (PR-40), by which it turns and reaches the assembly place "Parque de Pelota de Las Gladiolas" (Figure 6-131).

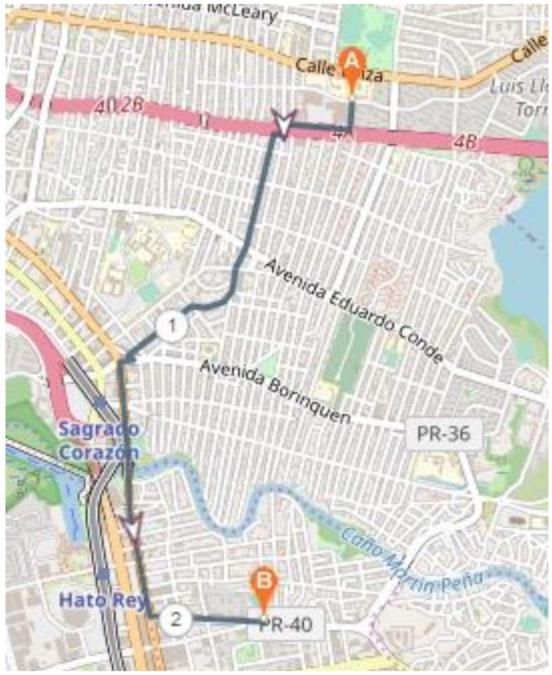


Figure 6-131 Streets of Third Alternate Route of Luis Rodríguez Cabrero School

6.3.2.6 Madame Luchetti

This school has three possible alternate routes to get to the appropriate assembly location. Like the previous school, the first two routes of this school reach "Plaza Barceló" as an assembly place. While the third route uses an assembly place that no other school has come close to. This is "Plaza de Colón". The rest of the assembly places are not considered due to the distance of the school from them (Figure 6-133).

The first alternate route is shown in Figure 6-132. This route has a distance of 2.168 miles for an evacuation time of 55 minutes 46 seconds. This possible route is 6 minutes and 35 seconds longer than the evacuation time of the route used for the vulnerability assessment of 49 minutes and 51 seconds (Figure 6-134).

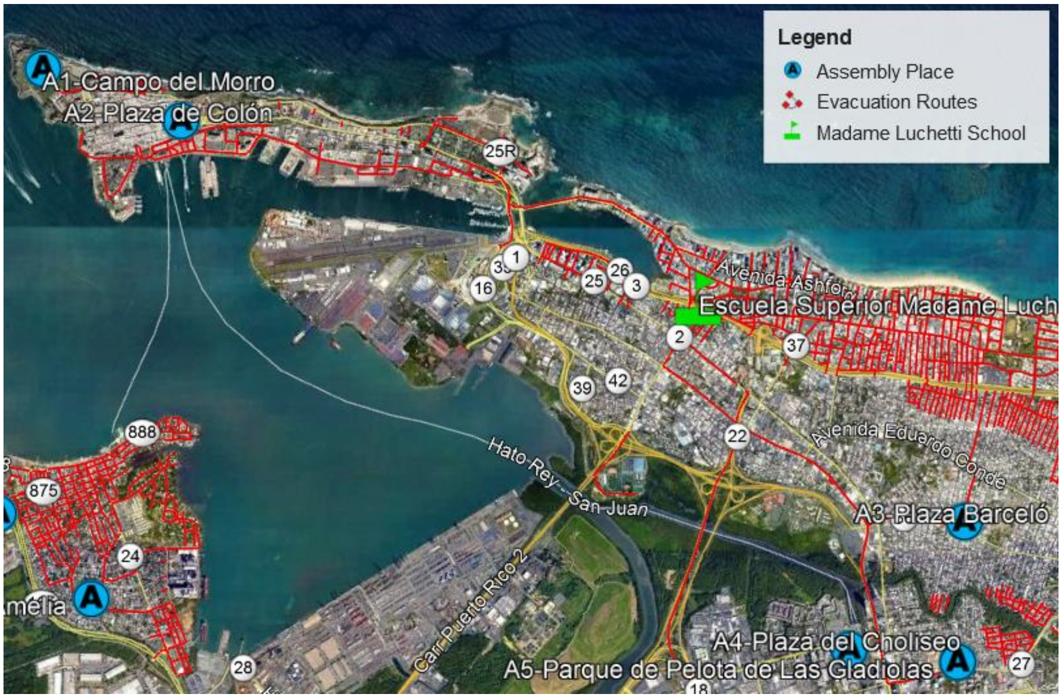


Figure 6-133 Location of Assembly Places with Respect to Madame Luchetti School

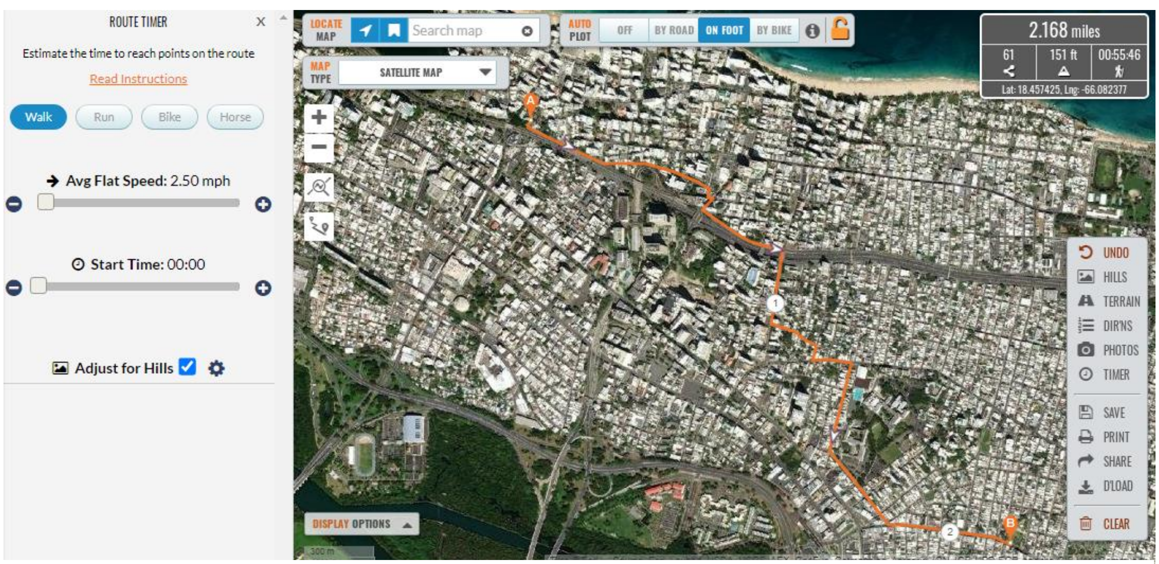


Figure 6-132 First Alternate Route of Madame Luchetti School at San Juan

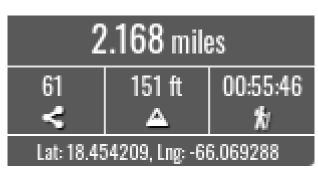


Figure 6-134 Evacuation Time and Route's Distance of First Alternate Route of Madame Luchetti School

This route leaves from Luchetti Street, turns along Marginal Román Baldorioty de Castro towards Estrella Street. Then, takes a tour of Julián Blanco Street, Martín Travieso Street, José de Diego Avenue (PR-37), Román Baldorioty de Castro Avenue, San Jorge Street, Carolina Street, and Diez de Andino Street, by Eduardo Conde Avenue, by Bouret Street, and by San Antonio Street until arriving at Borinquen Avenue (PR-26). Eventually, it arrives at the assembly place closest to the school, "Plaza Barceló" (Figure 6-135).

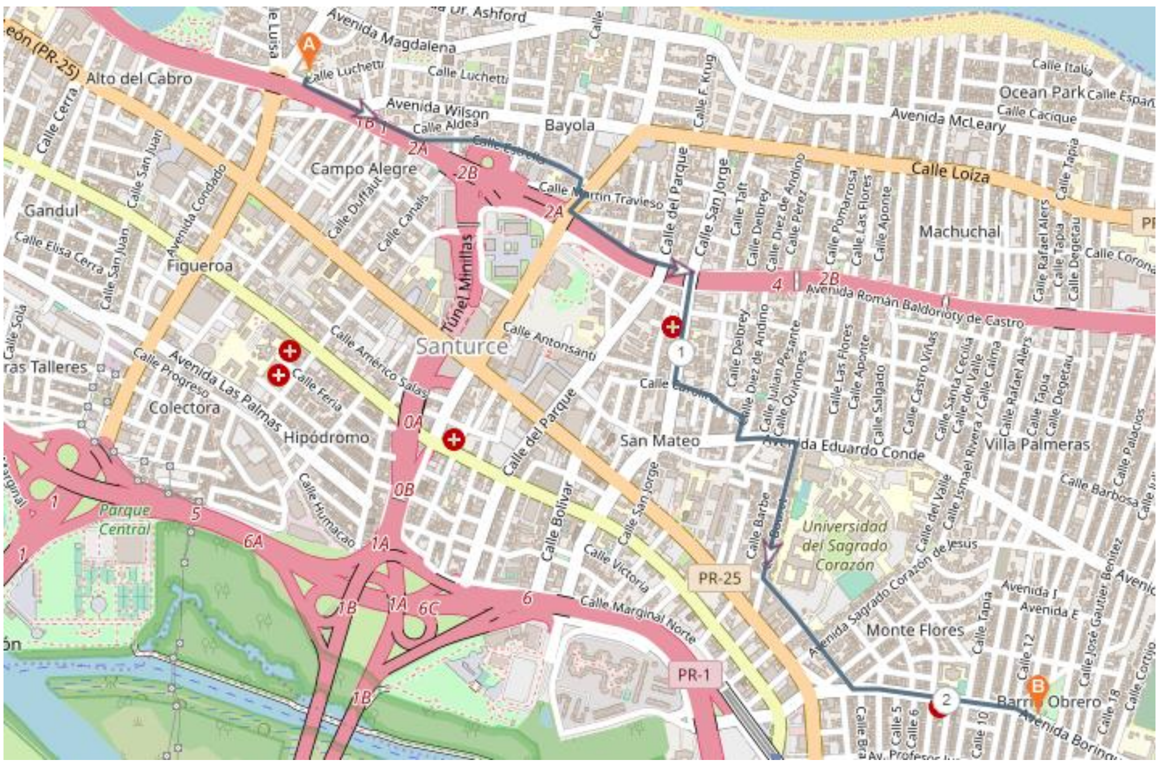


Figure 6-135 Streets of First Alternate Route of Madame Luchetti School

The second alternate route is shown in Figure 6-136. This route has a distance of 2.209 miles for an evacuation time of 56 minutes 21 seconds. This route is 7 minutes and 10 seconds more compared to the time of 49 minutes and 51 seconds (Figure 6-137).

This route leaves from Luchetti Street, turns along Marginal Román Baldorioty de Castro and enters through Roberto H. Todd Avenue (PR-2) and turns onto Juan Ponce de León Avenue (PR-25). Then, turns along José Fidalgo Díaz Street, Eduardo Conde Avenue, San

Mateo Street, El Bosque Street, Barbe Street, and San Antonio Street in direction to Borinquen Avenue until it reaches the “Plaza Barceló” (Figure 6-138).

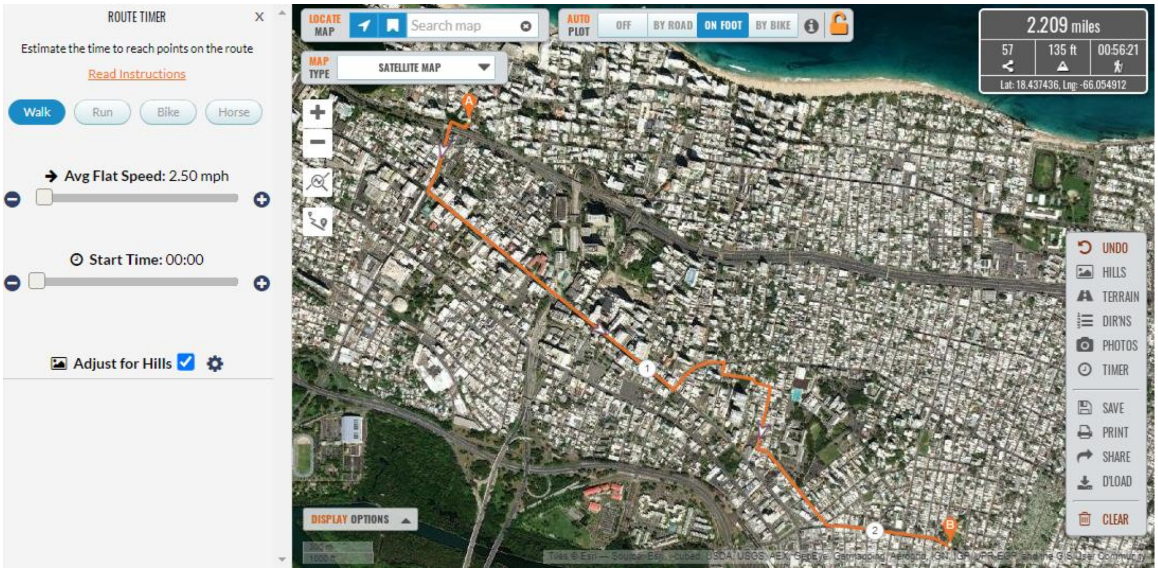


Figure 6-136 Second Alternate Route of Madame Luchetti School at San Juan

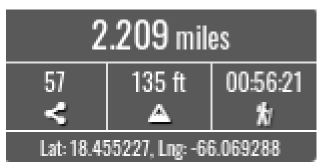


Figure 6-137 Evacuation Time and Route’s Distance of Second Alternate Route of Madame Luchetti School

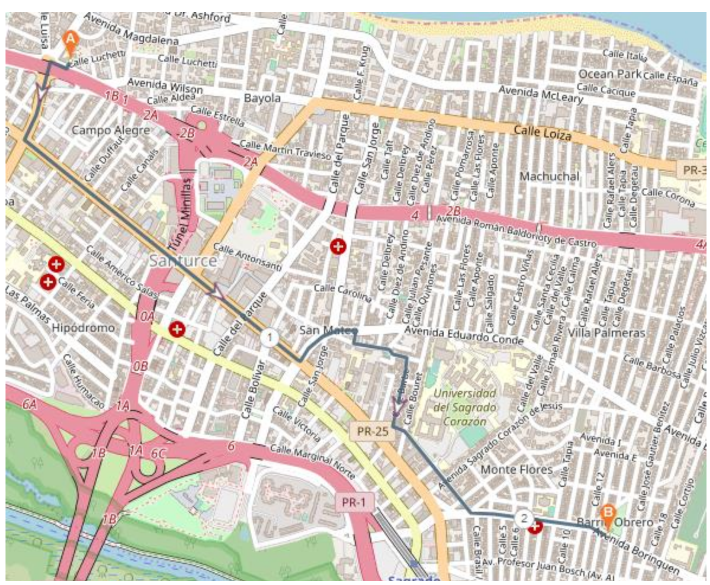


Figure 6-138 Streets of Second Alternate Route of Madame Luchetti School

The third alternate route is shown in Figure 6-139. This route has a distance of 2.944 miles for an evacuation time of 1 hour 14 minutes 12 seconds. This third route is 25 minutes and 1 second more compared to the time of 49 minutes and 51 seconds (Figure 6-140).

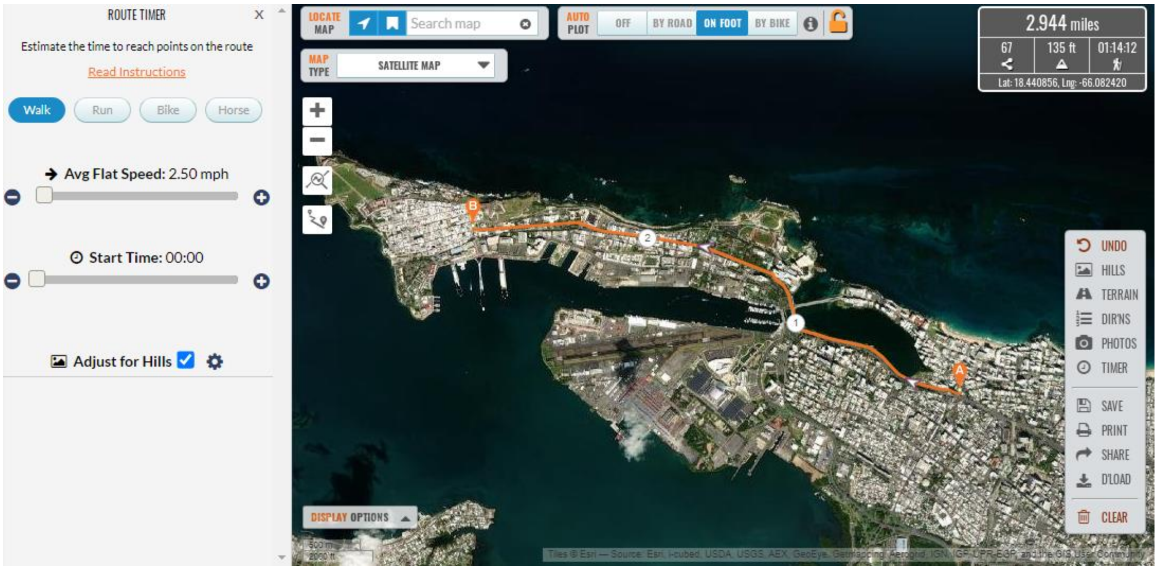


Figure 6-139 Third Alternate Route of Madame Luchetti School at San Juan

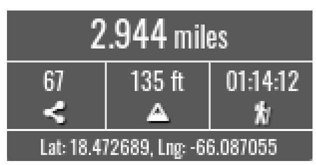


Figure 6-140 Evacuation Time and Route's Distance of Third Alternate Route of Madame Luchetti School

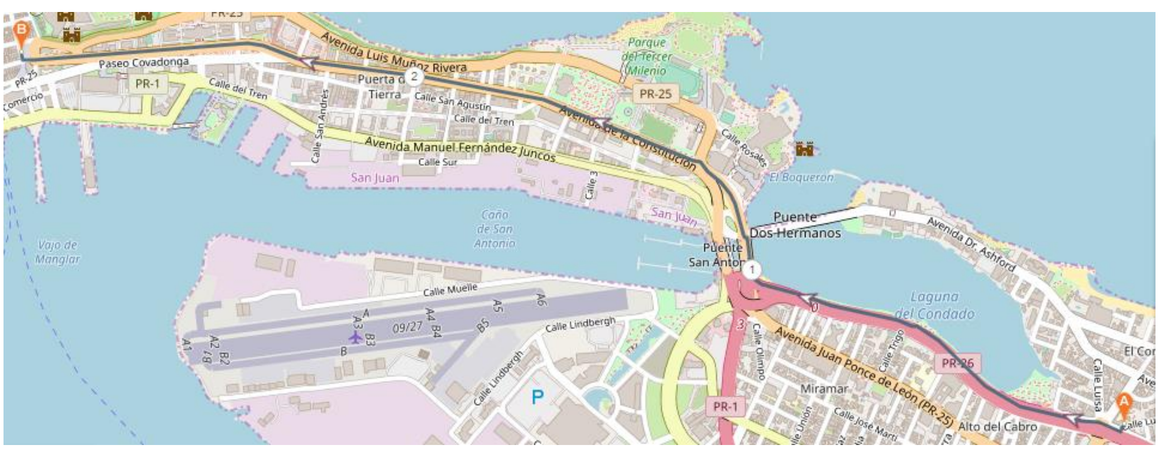


Figure 6-141 Streets of Third Alternate Route of Madame Luchetti School

This route leaves from Luchetti Street and turns onto Marginal Román Baldorioty de Castro towards the Expreso Román Baldorioty de Castro (PR-26). Then, it goes through Luis Muñoz Rivera Avenue (PR-1 and PR-25) and turns along “Ciclovía Avenida de la Constitución” through Constitución Avenue until reaching “Calle de la Fortaleza”. Subsequently, it turns onto “Calle O'Donell” until it reaches the “Plaza Colón” as the assembly place (Figure 6-141).

6.3.2.7 Moisés Meléndez

Moisés Meléndez school has four possible alternate routes to get from the school to the assembly site during the evacuation process. The assembly places that are considered for this school according to their descending order of proximity are: “Parque de Pelota de Las Gladiolas”, “Plaza del Choliseo”, and “Plaza Barceló” (Figure 6-142). The first alternate route is shown in Figure 6-143. This route has a distance of 0.409 miles for an evacuation time of 10 minutes 25 seconds. This possible route is 1 minute longer than the evacuation time of the route used for the vulnerability assessment of 9 minutes and 25 seconds (Figure 6-144).

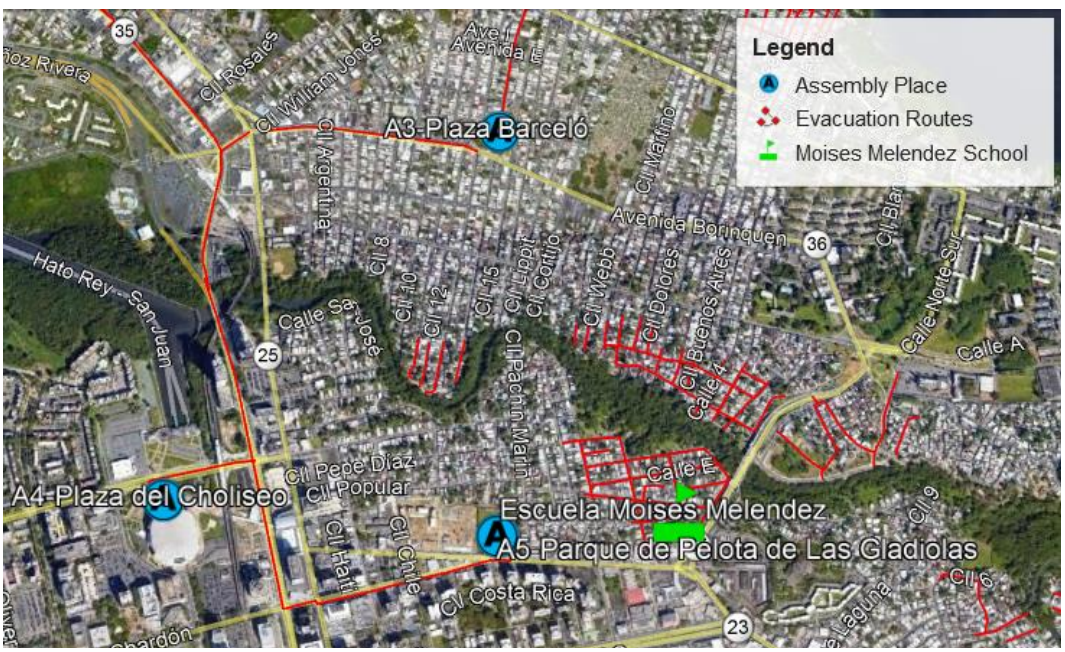


Figure 6-142 Location of Assembly Places with Respect to Moisés Meléndez School

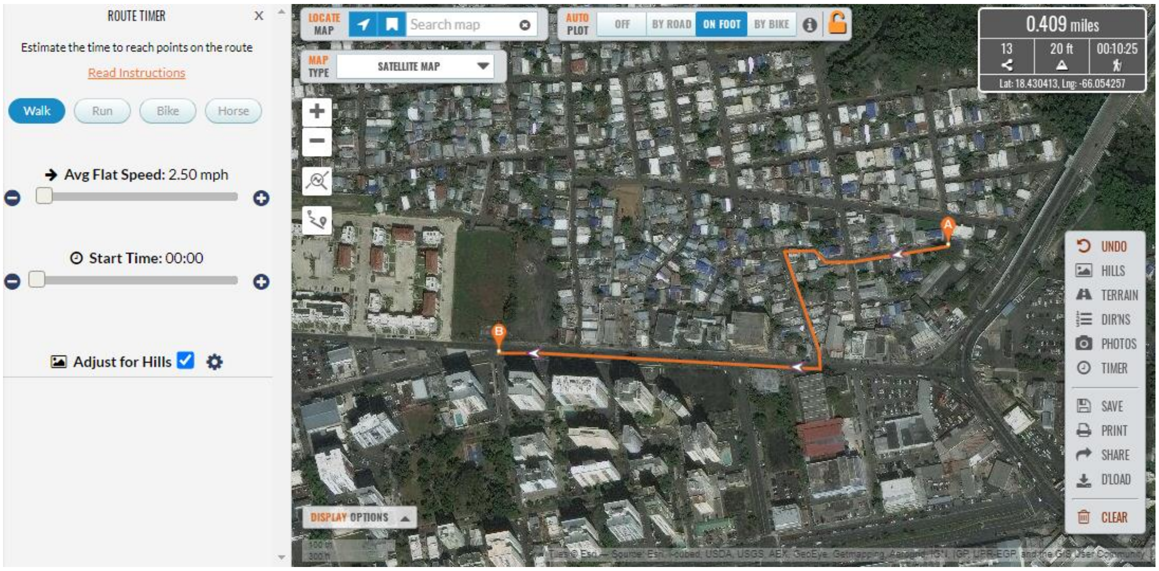


Figure 6-143 First Alternate Route of Moisés Meléndez School at San Juan

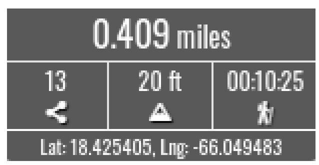


Figure 6-144 Evacuation Time and Route's Distance of First Alternate Route of Moisés Meléndez School

This route leaves from Street B and turns onto Duclet Street in direction to Quisqueya Avenue (PR-40) until it reaches the assembly place, "Parque de Pelota de Las Gladiolas" (Figure 6-145).

Figure 6-145 Streets of First Alternate Route of Moisés Meléndez School

This second route will also go to the “Parque de Pelota de Las Gladiolas” as the assembly place. This is shown in Figure 6-146. This route has a distance of 0.438 miles for an evacuation time of 11 minutes 3 seconds. This route is 2 minutes and 18 seconds more compared to the time of 9 minutes and 25 seconds (Figure 6-147).

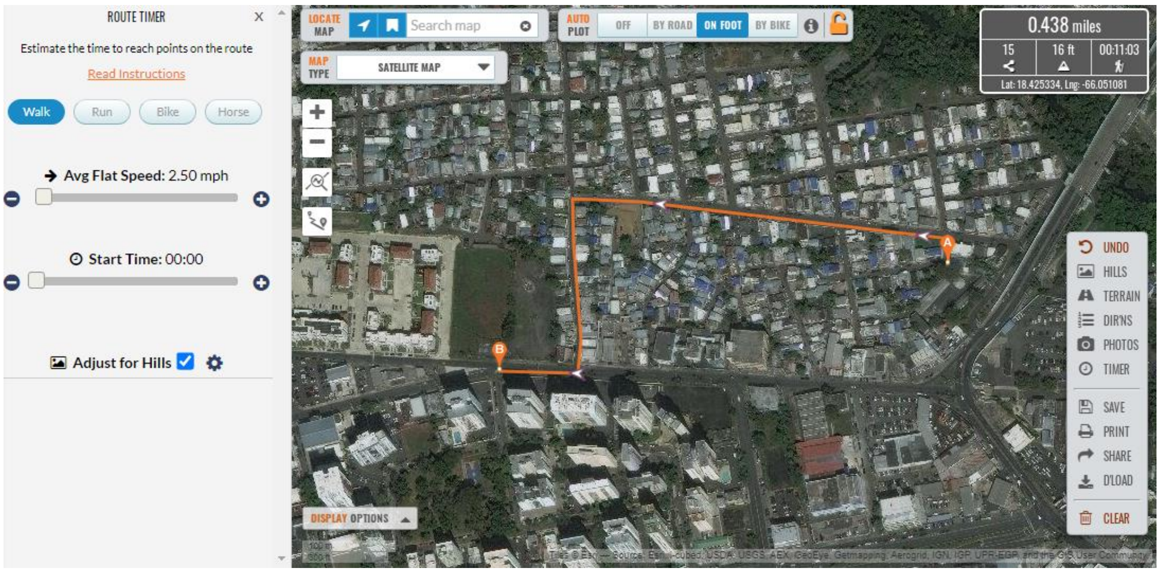


Figure 6-146 Second Alternate Route of Moisés Meléndez School at San Juan

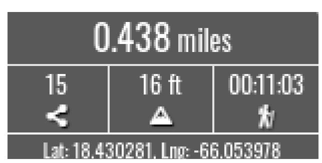


Figure 6-147 Evacuation Time and Route’s Distance of Second Alternate Route of Moisés Meléndez School

Figure 6-148 Streets of Second Alternate Route of Moisés Meléndez School

This second alternate route leaves from Street B, turns onto Street C, and then onto Lieutenant Francisco Gonzalo "Pachín" Marín Street. Afterwards, turn onto Quisqueya Avenue (PR-40) until it reaches the assembly place "Parque de Pelota de Las Gladiolas" (Figure 6-148).

The third route is shown in Figure 6-149. This route has a distance of 1.119 miles for an evacuation time of 29 minutes 2 seconds. In this way, this third alternate route is 20 minutes and 17 seconds more compared to the time of 9 minutes and 25 seconds (Figure 6-150). This is because a point farther from the school is used as the assembly location.

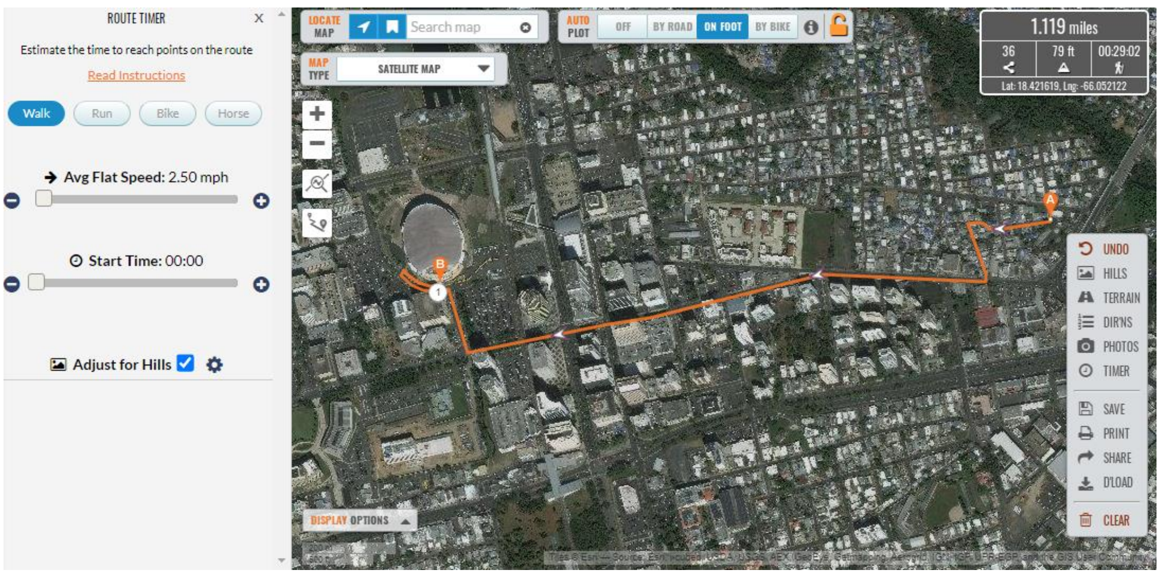


Figure 6-149 Third Alternate Route of Moisés Meléndez School at San Juan

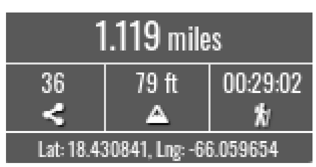


Figure 6-150 Evacuation Time and Route's Distance of Third Alternate Route of Moisés Meléndez School

This third alternate route leaves from Street B and turns onto Duclet Street towards Quisqueya Avenue (PR-40). But instead of arriving at the assembly place "Parque de Pelota de Las Gladiolas", it turns down Bolivia Street in direction to Carlos E. Chardón

Avenue. Then, turns through the Escuela Libre de Música Street and La Cerámica Street until it reaches the "Plaza del Choliseo" assembly place (Figure 6-151).

Figure 6-151 Streets of Third Alternate Route of Moisés Meléndez School

The fourth alternate route goes to "Plaza Barceló" and is shown in Figure 6-152. This alternate route has a distance of 1.323 miles for an evacuation time of 33 minutes 12 seconds. This means that this alternate route takes 24 minutes and 27 seconds more compared to the time of 9 minutes and 25 seconds (Figure 6-153). This time is almost three times the minimum evacuation time.

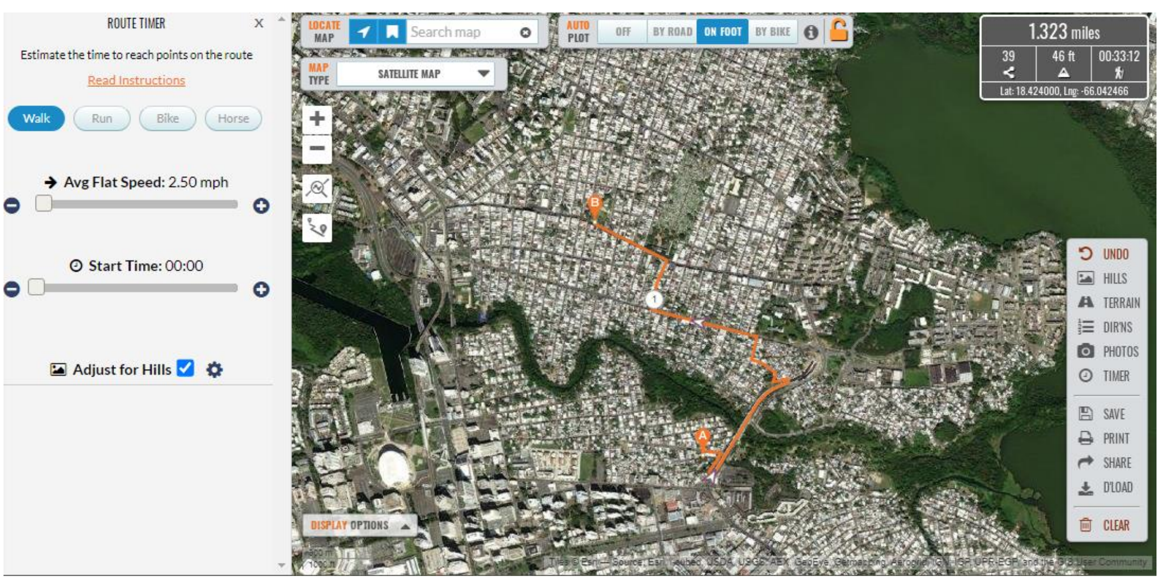


Figure 6-152 Fourth Alternate Route of Moisés Meléndez School at San Juan

Figure 6-153 Evacuation Time and Route's Distance of Fourth Alternate Route of Moisés Meléndez School

This route starts from Street C, turns onto Street 1 and onto Dr. José Celso Barbosa Avenue (PR-27). Then, turns down D Street, Haydeé Rexach Street, and San Cipran Street. Later, it goes towards Borinquen Avenue until it reaches the "Plaza Barceló" assembly place (Figure 6-154).

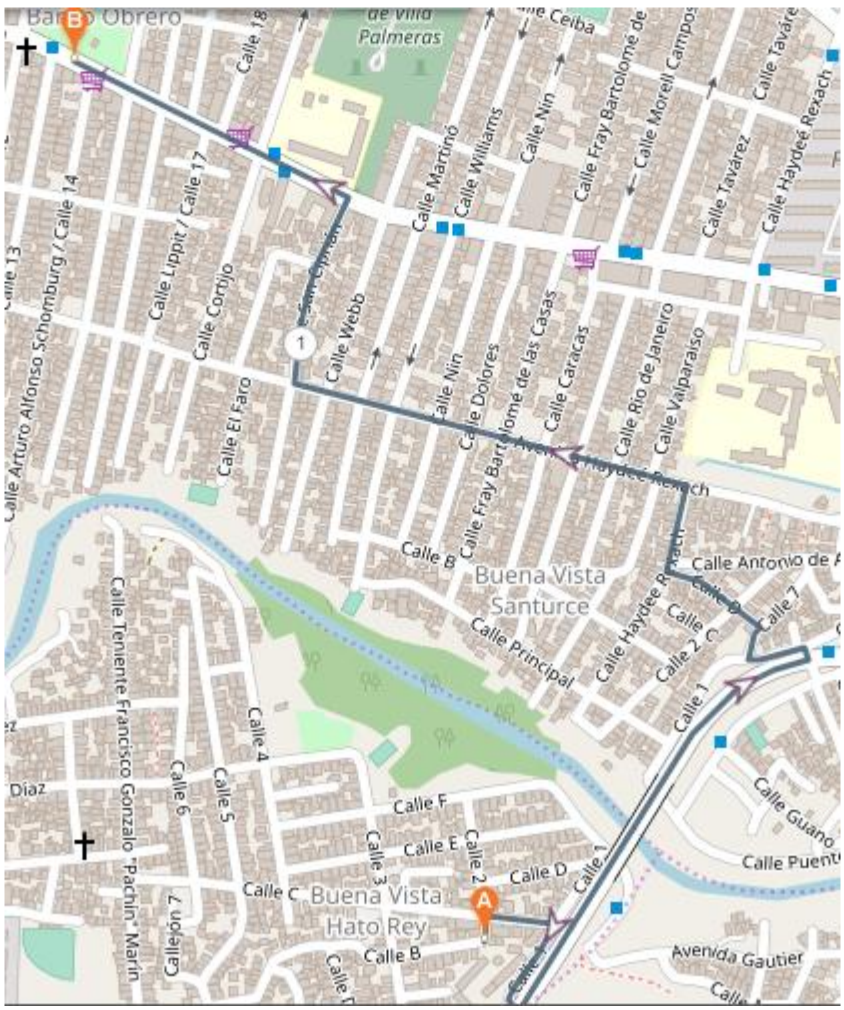


Figure 6-154 Streets of Fourth Alternate Route of Moisés Meléndez School

A possible alternative route for this school could be one that goes to “Complejo Deportivo Hiram Bithorn”, as the assembly place. However, this is not considered because it is the most distant place compared to the rest of the assembly places of the previous routes. This is one of the schools that is closest to an assembly place such as the “Parque de Pelota de Las Gladiolas”. In this way, it is neither favorable nor convenient to move from the school to another assembly place such as the “Complejo Deportivo Hiram Bithorn”, in which the travel distance would be greater than approximately 2 miles for an evacuation time greater than 48 minutes.

6.3.2.8 Ramón Power Y Giralt

Ramón Power Y Giralt school has two possible alternate routes to get to the assembly site. They use only the closest assembly place as in the case of the previous schools. This is “Plaza Barceló”. The first alternate route for this school is shown in Figure 6-155.

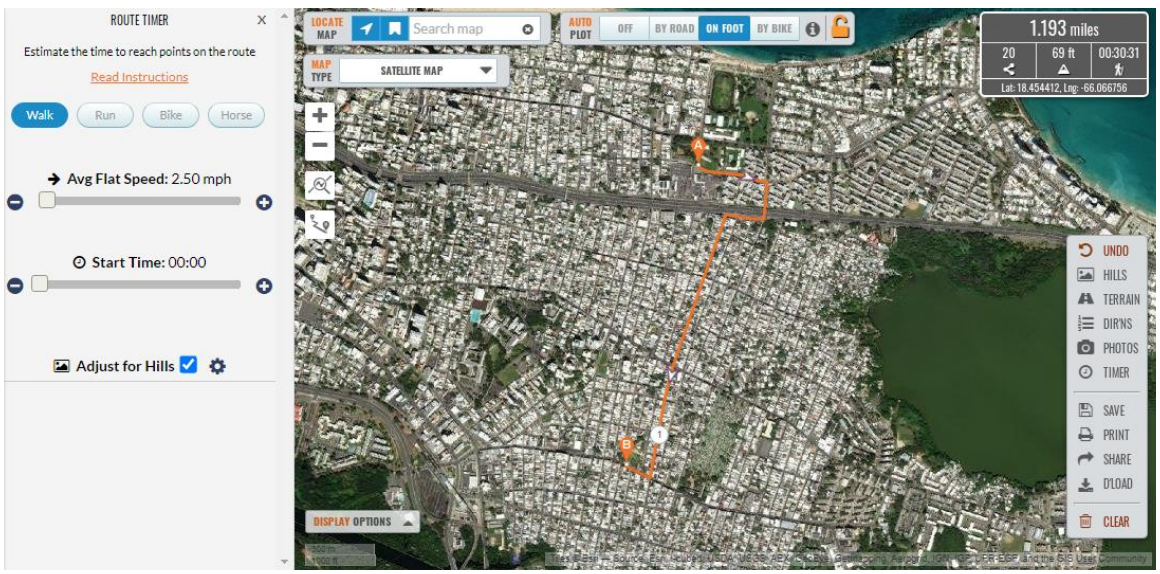


Figure 6-155 First Alternate Route of Ramón Power Y Giralt School at San Juan

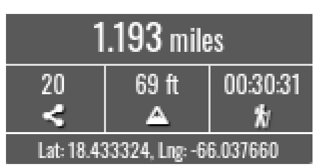


Figure 6-156 Evacuation Time and Route’s Distance of First Alternate Route of Ramón Power Y Giralt School

This route has a distance of 1.193 miles for an evacuation time of 30 minutes 31 seconds. This possible route is 5 minutes and 24 seconds more than the evacuation time of the route used for the vulnerability assessment of 25 minutes and 47 seconds (Figure 6-156).

This route begins from Corona Street, turns onto Pellín Rodríguez Street (Providencia Street) and onto Román Baldorioty de Castro Avenue. Then, turns onto José Gautier Benítez Street and turns onto Borinquen Avenue until it reaches the "Plaza Barceló" assembly place (Figure 6-157).

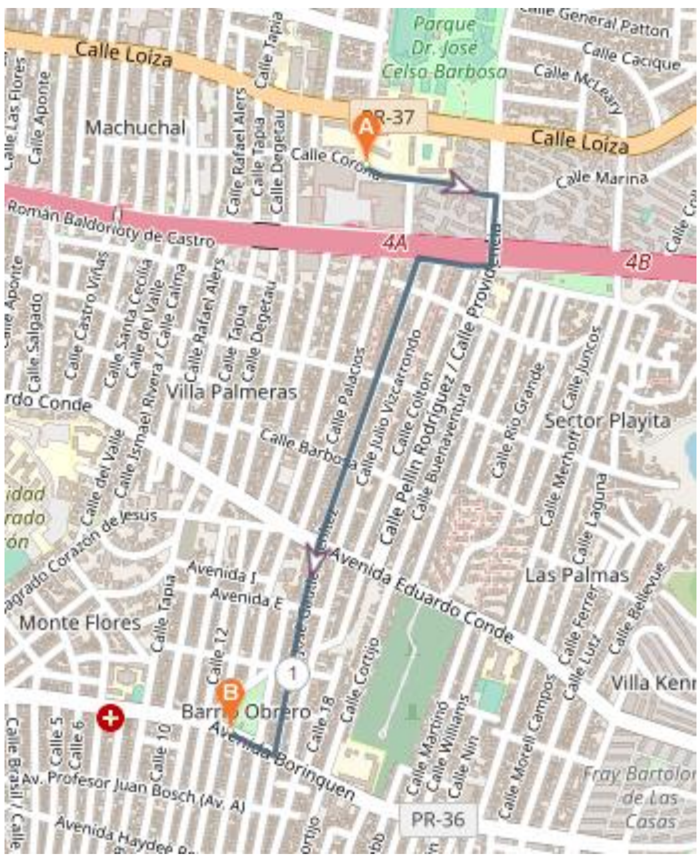


Figure 6-157 Streets of First Alternate Route of Ramón Power Y Giralt School

The second route for Ramón Power Y Giralt is shown in Figure 6-158. This route has a distance of 1.032 miles for an evacuation time of 26 minutes 53 seconds. This route is 1 minute and 6 seconds more compared to the time of 25 minutes and 47 seconds (Figure 6-159).

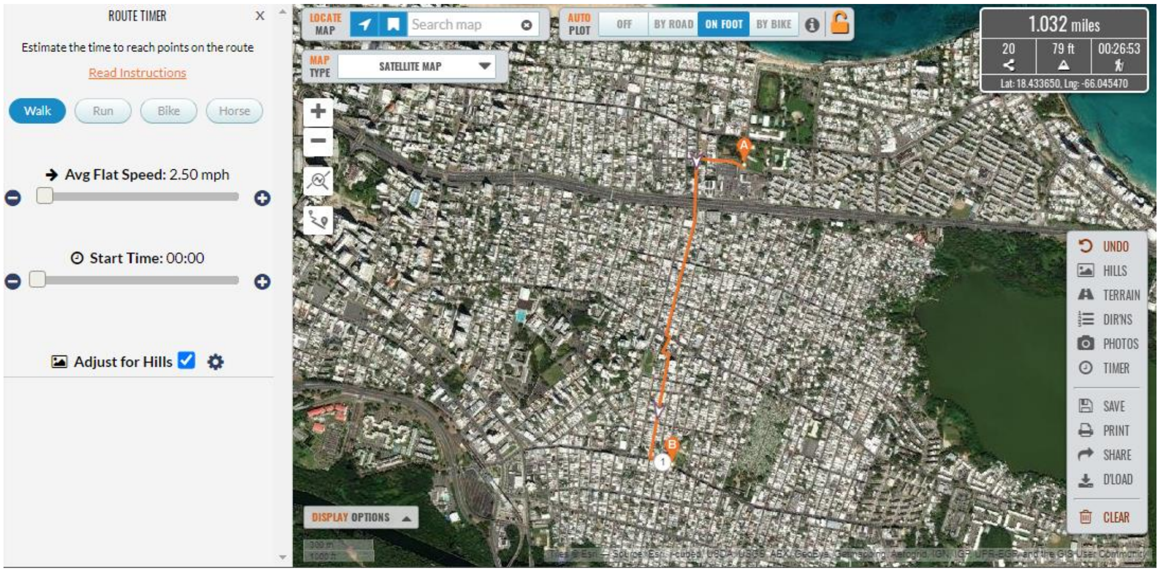


Figure 6-158 Second Alternate Route of Ramón Power Y Giralt School at San Juan

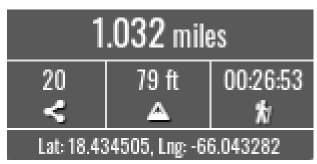


Figure 6-159 Evacuation Time and Route's Distance of Second Altenate Route of Ramóm Power Y Giralt School

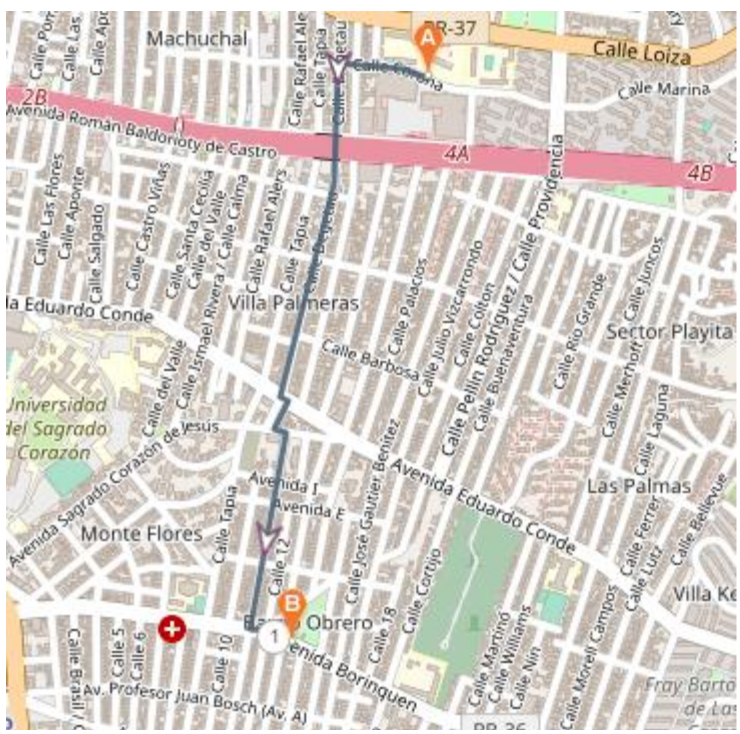


Figure 6-160 Streets of Second Alternate Route of Ramón Power Y Giralt School

This route leaves from Corona Street and turns onto Degetau Street until it reaches "Sagrado Corazón de Jesús" Avenue, where it turns onto "Mártires de la Restauración" Street (11th Street). Then, turns onto Borinquen Avenue until it reaches the "Plaza Barceló" assembly place (Figure 6-160).

Figure 6-161 Location of Assembly Places with Respect to Ramón Power Y Giralt School

Like Luis Rodríguez Cabrero school, this school could reach other distant assembly places with evacuation times that double the time it takes to reach the nearest assembly place (Figure 6-161). For this reason, the rest of the assembly places in San Juan are not recommended for this school. They are not shown as a comparison either because in the case of the second closest assembly place, corresponding to the "Parque de Pelota de Las Gladiolas", the distance and evacuation time would be approximately equal to Luis Rodríguez Cabrero school because they are in the same Street.

6.3.2.9 República Del Perú

This school has two alternate routes out of the tsunami hazard zone during the evacuation process. Both arrive at the same assembly place ("Plaza Barceló") due to its proximity (Figure 6-162). On the other hand, for the evaluation of the routes of the previous section, this is the same place of assembly. Like the Ramón Power Y Giralt school, this school does not compare routes with other assembly places due to the similarity of distances with respect to its respective establishment to the assembly place with those previously obtained for the Luis Rodríguez Cabrero school.

Figure 6-162 Location of Assembly Places with Respect to República Del Perú School

The first alternate route is shown in Figure 6-163. This route has a distance of 1.225 miles for an evacuation time of 31 minutes 38 seconds. This possible route is 2 minutes and 34 seconds more than the evacuation time of the route used for the vulnerability assessment of 29 minutes and 4 seconds (Figure 6-164).

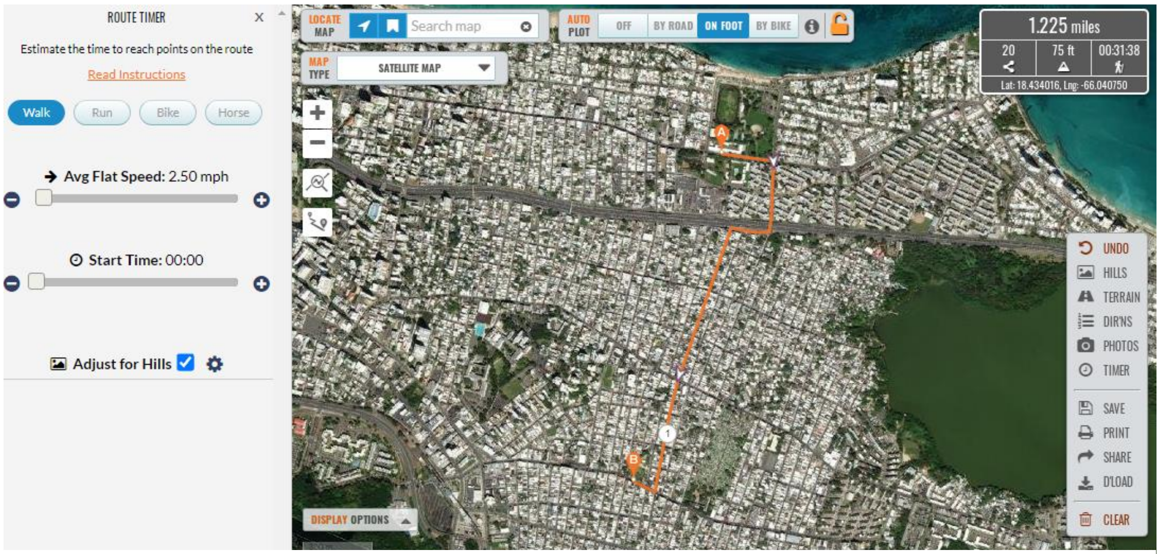


Figure 6-163 First Alternate Route of República Del Perú School at San Juan

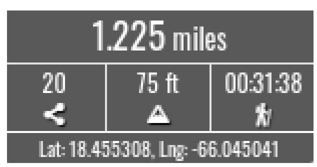


Figure 6-164 Evacuation Time and Route's Distance of First Alternate Route of República Del Perú School

This route follows the same path as the first alternate route of Ramón Power Y Giralt school. But this route starts from Loíza Street, turns onto Pellín Rodríguez Street (Providencia Street) and onto Román Baldorioty de Castro Avenue. Then, turns onto José Gautier Benítez Street and turns onto Borinquen Avenue until it reaches the "Plaza Barceló" assembly place (Figure 6-165).

The second possible and alternate route is shown in Figure 6-166. This route has a distance of 1.148 miles for an evacuation time of 30 minutes 5 seconds. Therefore, this possible route is 1 minute and 1 second, that is, 1 minute approximately more than the evacuation time of 29 minutes and 4 seconds (Figure 6-167).

Figure 6-165 Streets of First Alternate Route of República Del Perú School

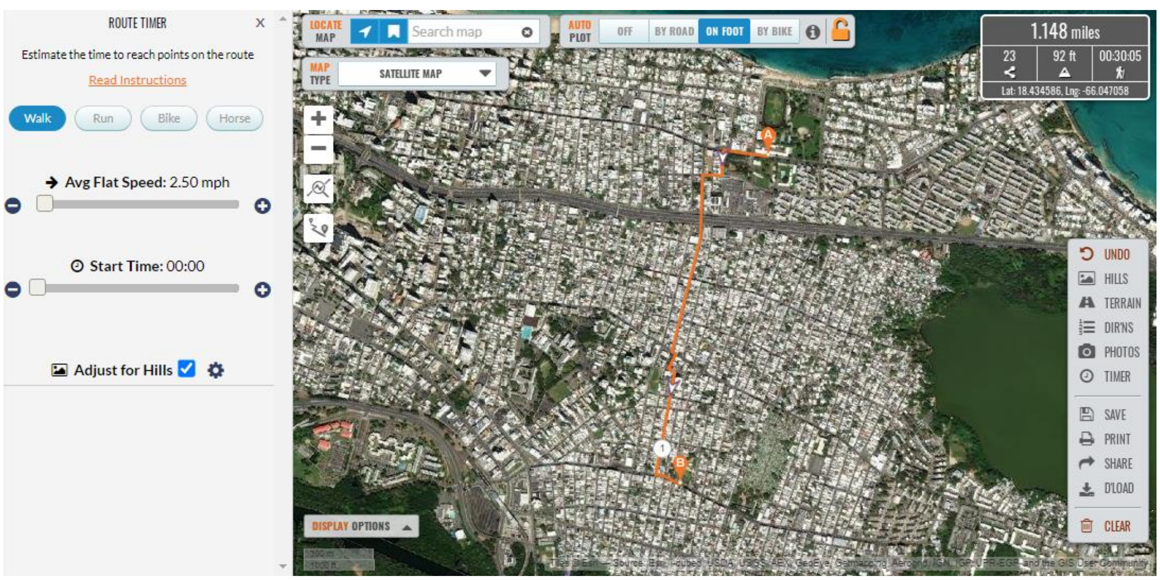


Figure 6-166 Second Alternate Route of República Del Perú School at San Juan

Figure 6-167 Evacuation Time and Route's Distance of Second Alternate Route of República Del Perú School

Like the first alternate route for the República Del Peru school, this route follows the same second alternate route from the previous school, Ramón Power Y Giralt. The difference lies in the starting points. For this school, the route leaves Loíza Street (PR-37) and turns along Añasco Street in direction to Corona Street. turns down Degetau Street until it reaches "Sagrado Corazón de Jesús" Avenue, where it turns onto "Mártires de la Restauración Street" (11th Street). Then, turns onto Borinquen Avenue until it reaches the "Plaza Barceló" assembly place (Figure 6-168).

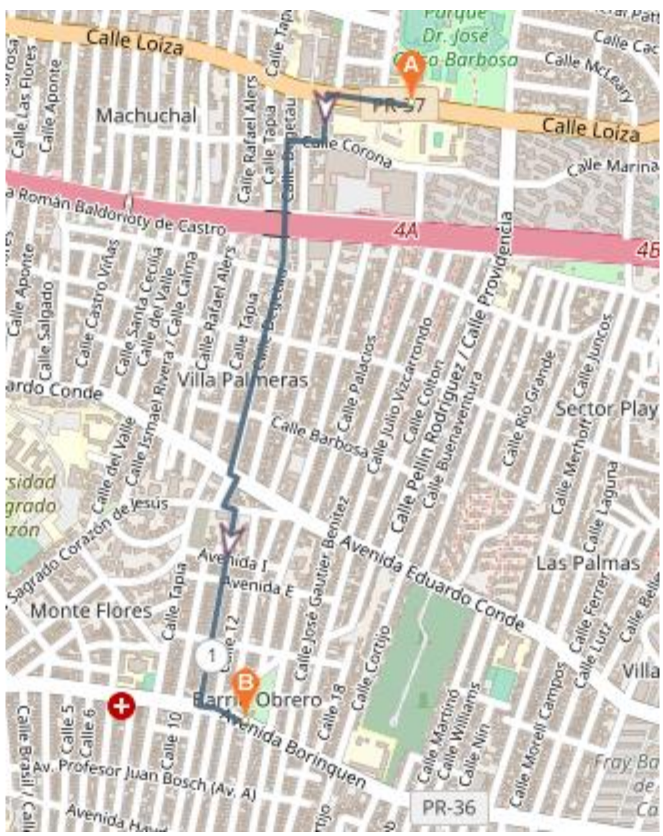


Figure 6-168 Streets of Second Alternate Route of República Del Perú School

6.4 Visit to Schools

In this evaluation, the possible characteristics of vulnerability in the schools with the highest risk are identified according to their evacuation time previously evaluated. The vulnerability characteristics considered for this are: the identification of safe zones, the evaluation of the structural conditions of the schools, and the examination of the facilities of the evacuation routes. For the municipality of Cataño, the school that takes the longest to evacuate and leave the tsunami danger zone is Francisco Oller school. While, for San Juan, the school with the longest evacuation time to reach a safe zone is Luis Llorens Torres school. This preliminary assessment is done using Google Earth and its space walk resources. This evaluation only assumes the characteristics observed through the tour in Google Earth. However, the characteristics may vary depending on the validity found in the face-to-face view of the next section.

6.4.1 Francisco Oller

The Francisco Oller school as identified in Figure 6-169 is a secondary school in the educational region of Bayamón. It is located at Las Nereidas Avenue in Cataño PR, 00962. It has a latitude of 18.4424482 and a longitude of -66.1284174 according to its coordinates.

Figure 6-169 Francisco Oller School (Google Earth – 2016)

Francisco Oller school has a total population of 723 people between 678 students and 45 teachers. It is a school used as a voting center and not as a refuge. On the other hand, it has an evacuation time from the school to the tsunami safe zone of 16 minutes 4 seconds. And an evacuation time from the school to the assembly site of 17 minutes and 29 seconds. These data or vulnerability parameters obtained in previous chapters and sections are summarized in Table 6-27. In this way, the first two columns with the number of students and teachers that could be affected by a tsunami. The third column with the amount of the total school population between students and teachers that could be affected by a possible tsunami event. The fourth and fifth column with the use or occupation of the school, whether it is a voting center or shelter. And the sixth and seventh column with the evacuation times. The sixth column with the time it takes for the population to leave the tsunami danger zone and the seventh column with the evacuation time to reach the assembly site.

Francisco Oller school has a total population of 723 people between 678 students and 45 teachers. It is a school used as a voting center and not as a refuge. On the other hand, it has an evacuation time from the school to the tsunami safe zone of 16 minutes 4 seconds. And an evacuation time from the school to the assembly site of 17 minutes and 29 seconds. These data or vulnerability parameters obtained in previous chapters and sections are summarized in Table 6-27. In this way, the first two columns with the number of students and teachers that could be affected by a tsunami. The third column with the amount of the total school population between students and teachers that could be affected by a possible tsunami event. The fourth and fifth column with the use or occupation of the school, whether it is a voting center or shelter. And the sixth and seventh column with the evacuation times for an average walking speed of 2.50 mph. The sect column with the time it takes for the population to leave the tsunami danger zone and the seventh column with the evacuation time to reach the assembly site.

Table 6-27 Summary of vulnerability parameters for Francisco Oller school

Population	Occupancy	Evacuation Time (min:sec)

(1) Students	(2) Teachers	(3) Total Population	(4) Voting Center	(5) Refuge	(6) Tsunami Hazard Zone	(7) Assembly Place
678	45	723	Yes	No	16:04	17:29

6.4.1.1 Structure Caracteristics

This school covers an area of approximately 19,500 square meters according to measurements estimated in Google Earth. Figure 6-170 represents through a polygon the delimitation of said area with (a) shaded fill and (b) marked edge.

Figure 6-170 Estimated Total Floor Area for Francisco Oller School (Google Earth – 2016)

Francisco Oller school has as part of its facilities a parking lot, a field and the structure with the classrooms. These facilities are assumed according to the distribution of spaces observed in Google Earth (Figure 6-169).

6.4.1.2 Plan Irregularities

Francisco Oller school has an irregularity in plan since it has a complex geometric shape. This is made up of more than one independent structural framing system divided by joints. A “box” type structure that connects to an “L” shaped structure and to two other rectangular shaped structures. This represents a risk and a seismic vulnerability of the building, since the ideal is that the geometry is a simple and redundant one, both in plan and elevation. Complex, irregular, or asymmetric shapes can cause poor behavior when the building is subjected to seismic loading. Irregular geometry allows the structure to twist or try to rotate out of order. The lack of uniformity makes it easier for some corners to have intense concentrations of force, which can be difficult to resist.

Figure 6-171 Structure Geometry in Plan of Francisco Oller School

The structure of this school has a simple elevation. Therefore, it does not have any elevation irregularities. On the other hand, this school has two levels as can be seen in the images from the front of the school (just to the North of it) and from the sides (to the West of the structure). Figure 6-172 shows the front and the floors that the school has with an imagery date from Google Earth 2016. While Figure 6-173 shows the same front, but with a more updated version of the 2020 image. Also, the floors and elevations of the school shown by west side images in Figure 6-174 and Figure 6-175 based on 2016 imagery date.

Figure 6-172 Front of Francisco Oller School (Google Earth - 2016)

Figure 6-173 Front of Francisco Oller School Front (Google Earth - 2020)

Figure 6-174 West Side of Francisco Oller School (April 2016)

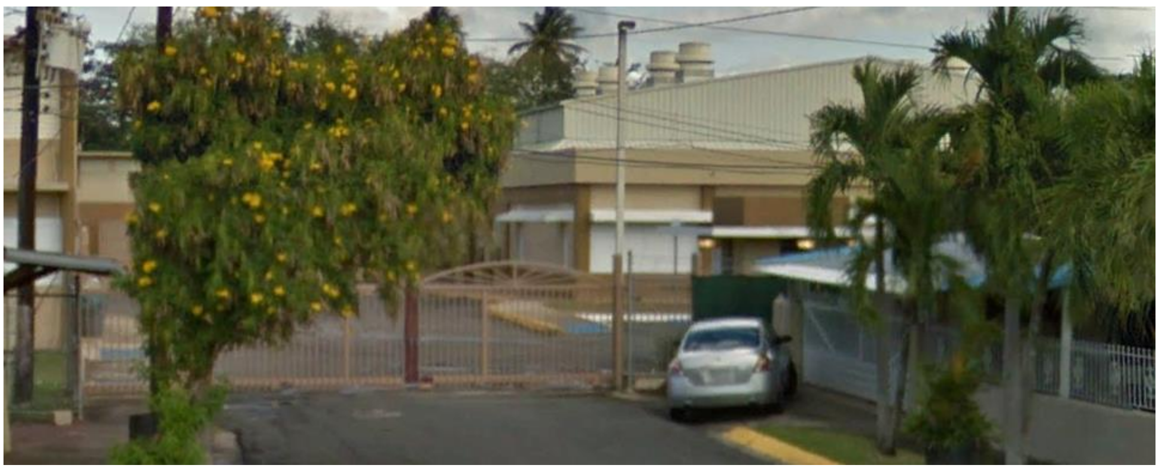


Figure 6-175 West Side of Francisco Oller School (April 2016)

6.4.1.3 Adjacency

The position in the urban block of this school is in the middle. This means that Francisco Oller school may have a critical neighboring building that surrounds it. Precisely, this school is located between two existing buildings. One is the Onofre Carballeira middle school on your right (East) and another is the Bahía Urbanization on your left (West) as shown in Figure 6-176.

Figure 6-176 Position of Francisco Oller School in Urban Block

The Onofre Carballeira school structure is less than 0.01 miles away from the Francisco Oller school structure as shown in Figure 6-178 and Figure 6-177Figure 6-179. In Figure 6-177Figure 6-179, Francisco Oller School is on the right and Onofre Carballeira School is on the left according to the frontal shot of the image. This means that the neighboring building is close to the Francisco Oller school. In this way, it represents a potential vulnerability for the school in this study since the interaction between adjacent buildings causes various types of damage during earthquakes.

The neighboring building, Onofre Carballeira school, is also a school structure used as a voting center and not as a shelter. It has two floors (Figure 6-179) and independent structures with classrooms and parking facilities. On the other hand, it has a total population of 252 people between 236 students and 16 teachers. This is the amount of population to evacuate during a tsunami event via evacuation routes. As the Onofre

Carballeira school structure is so close to the Francisco Oller school structure, both have the same evacuation routes available. Therefore, the accessible routes to evacuate are saturated by the accumulation of population between the meeting of the Onofre Carballeira school and the Francisco Oller school. Considering only these two buildings, the population between the two that pass through the available evacuation routes is 975 people.

Figure 6-178 Onofre Carballeira School as Adjacent Building to Francisco Oller School

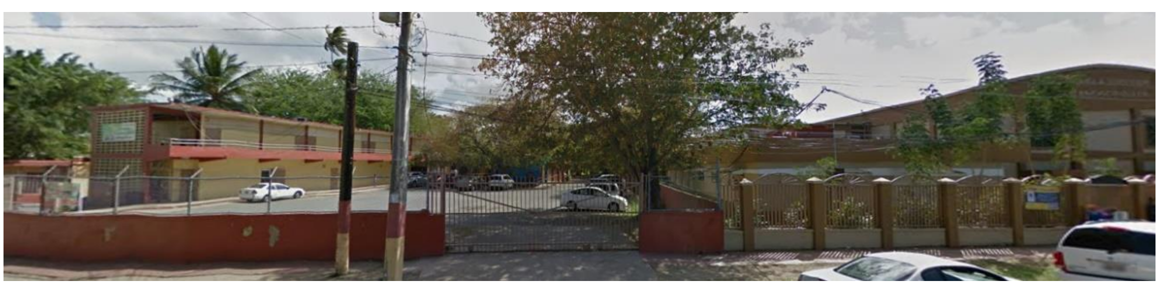


Figure 6-177 Onofre Carballeira School Adjacent to Francisco Oller School (Google Earth – 2016)

Figure 6-179 Onofre Carballeira School (Google Earth – 2016)

The other neighboring building is Bahía Urbanization, a group of buildings on Las Nereidas Avenue. The structures of this urbanization function as housing. Although the housing complex is located up to no more than 0.2 miles from the Francisco Oller school Figure 6-180, they increase the vulnerability due to the population. Like the neighboring building above, the number of people who live in this urbanization only have the same evacuation route available for the Francisco Oller school. Although the exact population of this urbanization is not known, it is estimated that it is approximately 350 to 400 people depending on the number of dwellings greater than 80 and considering that there are 4 people per dwelling.

Figure 6-180 Bahía Urbanization as Adjacent Building to Francisco Oller School

Considering the worst possible case, if the populations of this urbanization and the Francisco Oller school are found, the accumulated population is 1,123 people. And if the total population is considered according to the meeting of the Francisco Oller school (723), Onofre Carballeira School (252) and "Bahía" Urbanization (400), this is 1375 people passing through the same evacuation route to the same place of Assembly.

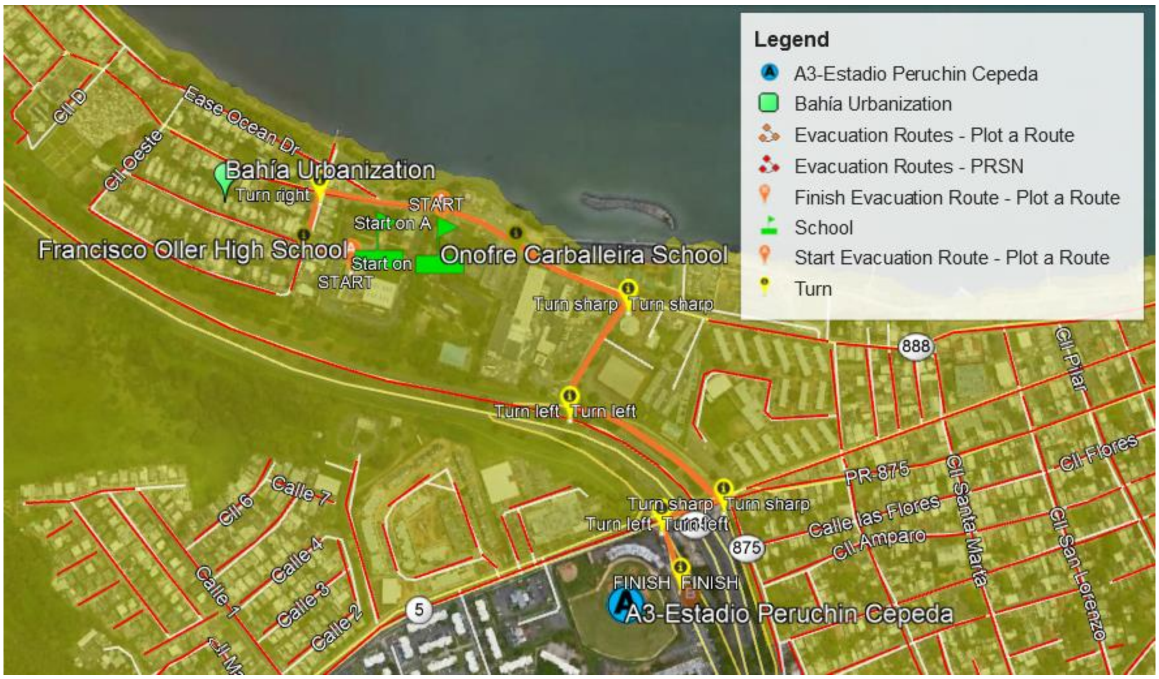


Figure 6-181 Encounter of Populations on the Evacuation Route in Cataño

This represents greater vulnerability for the school because the walking speed is inversely proportional to the amount of population and the evacuation time. While the evacuation time is directly proportional to the amount of population. That is, the larger the population, the lower the walking speed and the longer evacuation time.

6.4.1.4 Exterior Falling Hazards

Tall and heavy roof equipment and components are observed within the perimeter of the school building that could be considered a falling hazard. These can pose a life safety hazard if not properly anchored to the building Francisco Oller has nonstructural falling hazards. These are shown in Figure 6-182. Such and heavy roof equipment and components are observed within the perimeter of the school building that could be considered a falling hazard. These can pose a life safety hazard if not properly anchored to the building.

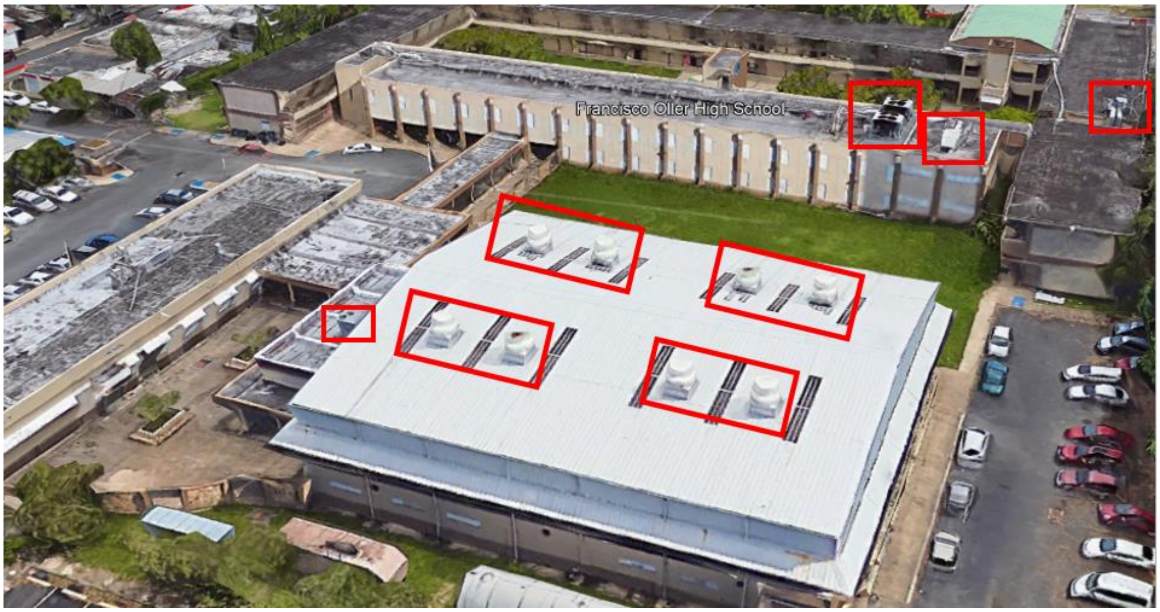


Figure 6-182 Nonstructural Falling Hazards at Francisco Oller School (Google Earth – 2016)

6.4.1.5 Damage and Deterioration

Damage and deterioration are aspects to consider the vulnerability of the school but that cannot be evaluated in this part because the images in Google Earth are not accurate with respect to the updated date they were taken. However, these are noted in the next section.

6.4.1.6 Security Measures in Hazard Zones, Evacuation Routes and Safe Zones

The vulnerability of Francisco Oller school is evaluated under the signage, accessibility, availability, and adaptation of hazard zones, evacuation routes and safe zones during the evacuation process. This considers only the shortest evacuation route so that the school population leaves the hazard zone faster.

6.4.1.6.1 Hazard Zones

The tsunami endangered zones correspond to the yellow tsunami evacuation zones developed by the Puerto Rico Seismic Network (PRSN). These are indicated by two signs that indicate these zones as shown in Figure 6-183. In Figure 6-183 and Figure 6-184, (a) one located on West Ocean Drive Street and (b) the other on PR-888 (Las Nereidas Avenue). These two signs (a and b) are the closest to the Francisco Oller school. However, there is another third sign (c) that is further away on the same PR-888 (Las Nereidas Avenue) and that could be considered for one of the alternate evacuation routes of this school and not the one found in orange.

Figure 6-183 Hazard Zone Signs Near the Perimeter of Francisco Oller School (Goole Earth – 2016)

Figure 6-184 represents the continuation of Figure 6-183. This shows an image of each hazard zone sign near the perimeter of Francisco Oller school according to their respective location.

(a)

(b)

(c)

Figure 6-184 Hazard Zone Signs Near the Perimeter of Francisco Oller School – Continue (Google Earth – 2016)

On PR-5 (José Celso Barbosa Avenue) there are two other signs that show the entrance and exit of the tsunami hazard zone as shown in Figure 6-186. Both signs are located on the same avenue, their difference lies in the direction in which they are directed. The sign (a) represents the entering to the hazard zone in a northeast direction (Figure 6-185). While the sign (b) indicates the leaving from the hazard zone (Figure 6-187).

Figure 6-186 Entering and Leaving Hazard Zone Signs Near the Perimeter of Francisco Oller School (Goole Earth – 2016)

Figure 6-185 Entering Hazard Zone Sign Near the Perimeter of Francisco Oller School (Goole Earth – 2016)

Figure 6-187 Leaving Hazard Zone Sign Near the Perimeter of Francisco Oller School (Goole Earth – 2016)

This leaving hazard zone sign initiates the course to the safe zone.

6.4.1.6.2 Safe Zones

The safe zones that are the meeting areas after the emergency do not have signs indicating their location for Francisco Oller school. This represents a risk for the school population that leaves the tsunami danger zone during the evacuation process and does not know where to go if they do not have a prior evacuation plan.

For this school, the safe zone corresponds to the assembly site. Francisco Oller school goes to the “Estadio Municipal Pedro (Perucho) Cepeda”, better known by the community as “Estadio Peruchín Cepeda”. This is the same place of assembly assumed in the previous evaluation of the evacuation routes. This assembly place covers an area of approximately 24,000 square meters according to measurements estimated in Google Earth. The delimitation of said area with (a) shaded fill and (b) marked edge are presented through a polygon in Figure 6-189.

This assembly place is shown in plan (Figure 6-188) and in Street View (Figure 6-190).

The sign showing the safe zone as an assembly location is shown in plan in Figure 6-191. In addition, it is presented in Street View just in front (at the entrance) of the "Estadio Peruchín Cepeda" in Figure 6-190.

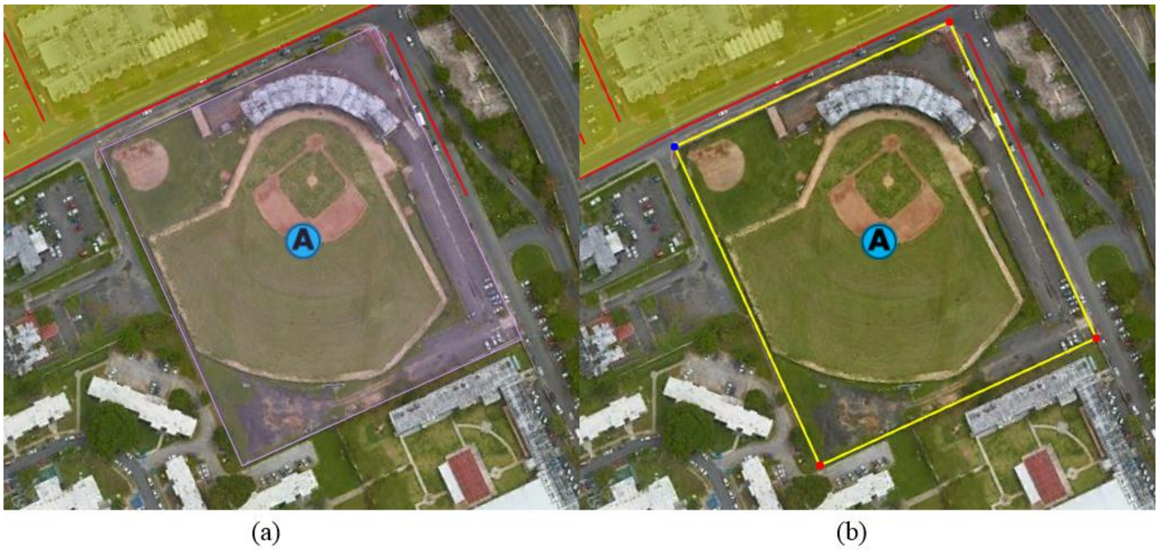


Figure 6-189 Estimated Total Floor Area for "Estadio Peruchín Cepeda" (Google Earth - 2016)

Figure 6-188 "Estadio Peruchín Cepeda" (Google Earth – 2016)

Figure 6-190 "Estado Peruchín Cepeda" in Street View (Google Earth – 2016)

Figure 6-191 Safe Zone Sign of Assembly Place Near to Francisco Oller School in Plan View (Google – 2016)

Figure 6-192 Safe Zone Sign of Assembly Place Near to Francisco Oller School in Street View (Google – 2016)

The fact that this assembly place has a safe zone sign assigned for this area implies that the assumption used for the evaluation of evacuation routes is feasible and effective according to the proximity of the school to this place.

6.4.1.6.3 Evacuation Routes

Evacuation routes are evaluated following three conditions: (1) that it moves away from the coast in the shortest possible time, (2) that it avoids walking parallel to the sea, (3) that it avoids possible obstructions to the route. Due to these conditions the evacuation route is the fastest and the evacuation time previously obtained for this school is the minimum it can have.

The first condition of early departure from the coast is reflected in the evacuation time it takes for the population to leave the tsunami danger zone obtained for the Francisco Oller school of 16 minutes and 4 seconds (Figure 6-193). And with the evacuation time it takes for the school population to reach the assembly place or meeting point in a safe zone of 17 minutes and 29 seconds (Figure 6-194).

Figure 6-193 Evacuation Route until Leaving the Hazard Zone for Francisco Oller School (Google Earth – 2016)

Figure 6-194 Evacuation Route until Reaching the Assembly Place for Francisco Oller School (Google Earth – 2016)

This evacuation route corresponds to the same route evaluated in the evacuation routes of the previous section. In which it starts from Central Street, turn East Street towards Las Nereidas Avenue (PR-88). Then, turn down Olivo Street and along the marginal of El Caño Avenue (PR-165). Eventually, turn onto José Celso Barbosa Avenue (PR-5) until you reach the "Estadio Peruchin Cepeda" assembly place.

The second condition corresponding to the avoidance of the walk parallel to the sea is not fulfilled for the Francisco Oller school. As shown in Figure 6-195, the fastest route to a safe zone runs approximately 0.300 miles parallel to the sea. This represents almost half the distance it takes for the school population to get out of the 0.656-mile tsunami hazard zone. Therefore, it represents a potential danger to the population of this school during the evacuation process.

Figure 6-195 Evacuation Route of Francisco Oller School with Signs

The third condition for evaluating evacuation routes corresponds to avoiding possible obstructions. The evacuation route from the Francisco Oller school goes through power lines. These represent possible obstructions to the evacuation route as they can impede the passage of pedestrians in case they collapse from the movement of the earthquake prior to the tsunami.

If this is the only route available to the school, it could be disastrous to have power lines obstructing the path. When considering that in a tsunami event, people could be affected by these elements as possible obstructions, it is very important to identify them. For this reason, Figure 6-196 shows the image locations of power lines arbitrarily located along the evacuation route.

There is a Street View image of each segment of the highway on the road showing the power lines. These are named with a series of letters for easy identification. Likewise, these correspond to the possible obstructions that the school population of this school could be facing. For what is mentioned and specified the name of the street to ensure the viability of the information regarding the power lines.

Figure 6-197 shows the power lines (a) along Central Street at the entrance and exit of the Francisco Oller school.

Figure 6-196 Power Lines on the Evacuation Route of Francisco Oller School (Google Earth – 2016)

Figure 6-197 Power Lines on the Evacuation Route of Francisco Oller School through Central Street (Google Earth – 2016)

Figure 6-198 shows the power lines (b) found on East Street.

Figure 6-198 Power Lines on the Evacuation Route of Francisco Oller School through East Street (Google Earth – 2016)

Those that are located (c) by Las Nereidas Avenue (PR-88), are presented in the following Figure 6-199.

Figure 6-199 Power Lines on the Evacuation Route of Francisco Oller School through Las Nereidas Avenue (Google Earth – 2016)

The power lines that are located by (d) Olivo Street (Figure 6-200), by (e) El Caño Avenue (Figure 6-201), and by (f) José Celso Barbosa Avenue (Figure 6-202) are shown according to their respective images taken from Google Earth.

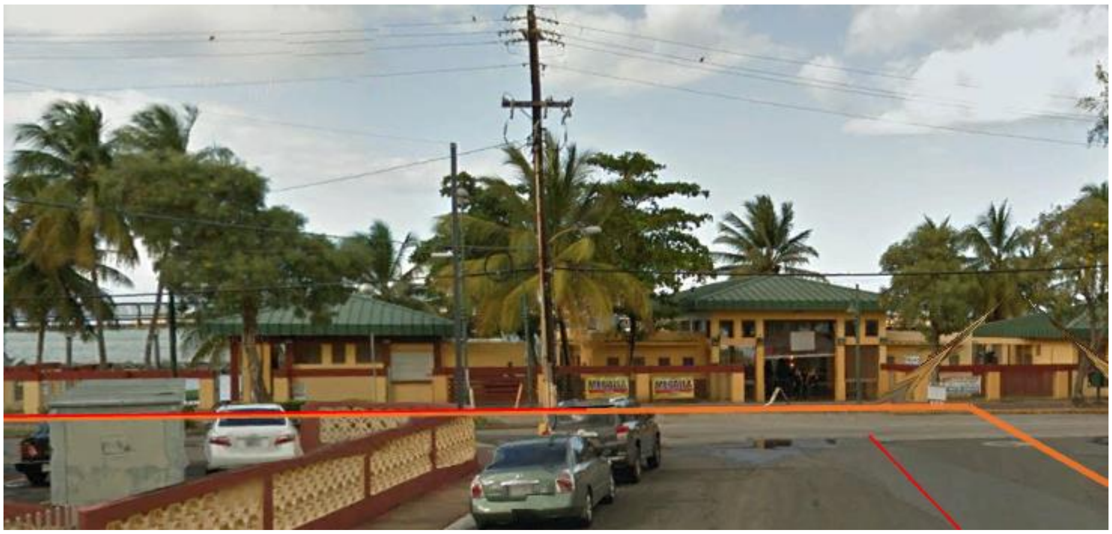


Figure 6-200 Power Lines on the Evacuation Route of Francisco Oller School through Olivo Street (Google Earth – 2016)

Figure 6-201 Power Lines on the Evacuation Route of Francisco Oller School through El Caño Avenue (Google Earth – 2016)

Figure 6-202 Power Lines on the Evacuation Route of Francisco Oller through José Celso Barbosa Avenue School (Google Earth – 2016)

In addition, this evacuation route goes under a bridge to reach a safe area. This bridge is the one located on the PR-165 (El Caño Avenue) as shown in Figure 6-203 and Figure 6-204.

Figure 6-203 Location of the Bridge on the Evacuation Route of Francisco Oller School (Google Earth – 2016)

The following Figure 6-204 shows the bridge where the evacuation route passes in Google Earth Street View mode.

Figure 6-204 Bridge on the Evacuation Route of Francisco Oller School (Google Earth – 2016)

Another obstacle that stands in the way is the condition of the sidewalks through which the evicted school population travels. The sidewalks along Central Street (Figure 6-205) have a variant width ranging from 32 inches to 44 inches. This is due to the obstructions of posts, cars and green areas that limit the pedestrian crossing.

Figure 6-205 Sidewalk on Central Street from the Evacuation Route of Francisco Oller School in Plan View (Google Earth – 2016)

Therefore, certain areas of this sidewalk do not meet the minimum clear width of 36 inches required by the ADA (Americans with Disabilities Act). The figure shows this same sidewalk, but in Street View where the trees, posts and green areas can be seen. The green area on this sidewalk is 50 inches wide.

Figure 6-206 Sidewalk on Central Street from the Evacuation Route of Francisco Oller School in Street View (Google Earth – 2016)

According to images taken in 2016 from Google Earth, the sidewalk of this street has deterioration and cracked segments as shown in Figure 6-207. Which would not make it suitable for people with disabilities. However, today this type of damage can be worse or better if it has been fixed.

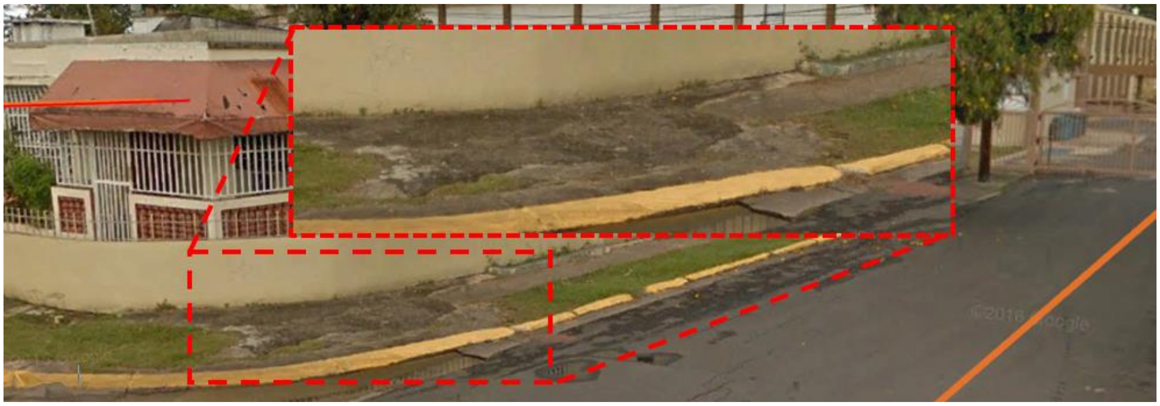


Figure 6-207 Damage of Sidewalk on Central Street from the Evacuation Route of Francisco Oller (Google Earth – 2016)

The sidewalk along East Street is also obstructed by vegetation and street furniture (Figure 6-199). In this there are posts, mailboxes and signs that can serve as an obstacle to pedestrian flow during the evacuation process.

Figure 6-208 Sidewalk on East Street from the Evacuation Route of Francisco Oller School in Plan View (Google Earth – 2016)

Figure 6-209 shows sidewalk damage with green areas and cracks interrupting the road. After this, Figure 6-211 shows the "zoom in" of both areas.

Figure 6-209 Sidewalk on East Street from the Evacuation Route of Francisco Oller School in Street View (Google Earth – 2016)

Figure 6-210 and Figure 6-212 present the interruption of the sidewalk with more vegetation, trees, palms, posts, and mailboxes. Despite the obstructions on this sidewalk, it has an effective width that varies from 38 inches to 90 inches. This means that this sidewalk is adapted for people with disabilities, although it does not have optimal conditions due to its advanced deterioration.

Figure 6-211 Damage of Sidewalk on East Street from the Evacuation Route of Francisco Oller (Google Earth – 2016)

Figure 6-210 Urban Furniture of Sidewalk on East Street from the Evacuation Route of Francisco Oller (Google Earth – 2016)

Figure 6-212 Urban Furniture of Sidewalk on East Street from the Evacuation Route of Francisco Oller (Google Earth – 2016)

The sidewalk along Las Nereidas Avenue (PR-888) is shown in different segments or sections as shown in Figure 6-213.

Figure 6-213 Sidewalk on Las Nereidas Avenue from the Evacuation Route of Francisco Oller School in Plan View (Google Earth – 2016)

The first section of this sidewalk has an effective width of 45 inches parallel to the green areas and 90 inches where the green areas are not (Figure 6-214). This width is not affected even though in this segment of the sidewalk there are posts and signs (Figure 6-215) that can serve as an obstruction for a large population that moves to a safe area in a hurry.

Figure 6-214 First Section of Sidewalk on Las Nereidas Avenue from the Evacuation Route of Francisco Oller School in Plan View (Google Earth – 2016)

Figure 6-215 First Section of Sidewalk on Las Nereidas Avenue from the Evacuation Route of Francisco Oller School in Street View (Google Earth – 2016)

Where this section ends there are some inclined poles of power lines that are inclined as shown in Figure 6-216. This poses a threat to the safety of people at the school during the evacuation process. However, the condition of this section of sidewalk is optimal. It does not have cracks or any other type of damage or deterioration, which makes it suitable for people with disabilities.

Figure 6-216 Poles with Power Lines in First Section of Sidewalk on Las Nereidas Avenue from the Evacuation Route of Francisco Oller School in Street View (Google Earth - 2016)

The second segment of this sidewalk is shown in Figure 6-217. It also has poles and signs, but they do not affect its effective width (Figure 6-218). In addition, it has acceptable conditions as it does not present any deterioration and instability. On the other hand, it has 76-inch continuous green areas and an equally continuous 54-inch effective curb width.

Figure 6-217 Second Section of Sidewalk on Las Nereidas Avenue from the Evacuation Route of Francisco Oller School in Plan View (Google Earth – 2016)

Figure 6-218 Second Section of Sidewalk on Las Nereidas Avenue from the Evacuation Route of Francisco Oller School in Street View (Google Earth – 2016)

The third section of the Las Nereidas Avenue sidewalk is shown in Figure 6-220. Like the curb segment above, this section has posts and signs that do not get in the way of the effective width of the curb (Figure 6-221) but could do so if population builds up during the evacuation process.

Figure 6-220 Third Section of Sidewalk on Las Nereidas Avenue from the Evacuation Route of Francisco Oller School in Street View (Google Earth – 2016)

This curb segment has a constant effective width of 54 inches with a green zone width of 64 inches. However, the green area ends because the sidewalk passes through a portico of the building of the "Centro de Diagnóstico y Tratamiento de Cataño" as shown in Figure

6-221. In this way, if this building were to fail during the pre-tsunami seismic event, the evacuation route could be obstructed.

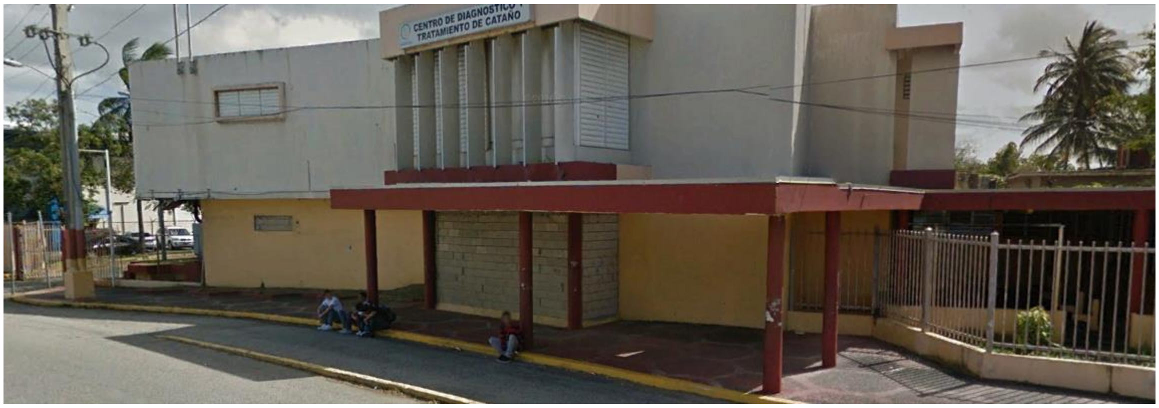


Figure 6-221 Portico on Third Section of Sidewalk on Las Nereidas Avenue from the Evacuation Route of Francisco Oller School in Street View (Google Earth - 2016)

The fourth and last segment of this sidewalk (Figure 6-222) has an effective width that varies from 65 inches to 80 inches. This sidewalk does not have green areas like the previous sidewalk segments.

Figure 6-222 Fourth Section of Sidewalk on Las Nereidas Avenue from the Evacuation Route of Francisco Oller School in Plan View (Google Earth – 2016)

This sidewalk can affect the pedestrian crossing as cars pass through it due to the surrounding establishments as shown in Figure 6-223, Figure 6-224, Figure 6-225 and Figure 6-226. Although this segment of sidewalk does not have any type of damage, it has poles and signs that obstruct the route. These are in the center of the width of the sidewalk along the entire segment (Figure 6-224 and Figure 6-225).

Figure 6-223 Building Exit in Fourth Section of Sidewalk on Las Nereidas Avenue from the Evacuation Route of Francisco Oller School in Street View (Google Earth – 2016)

Figure 6-224 Poles in Fourth Section of Sidewalk on Las Nereidas Avenue from the Evacuation Route of Francisco Oller School in Street View (Google Earth – 2016)

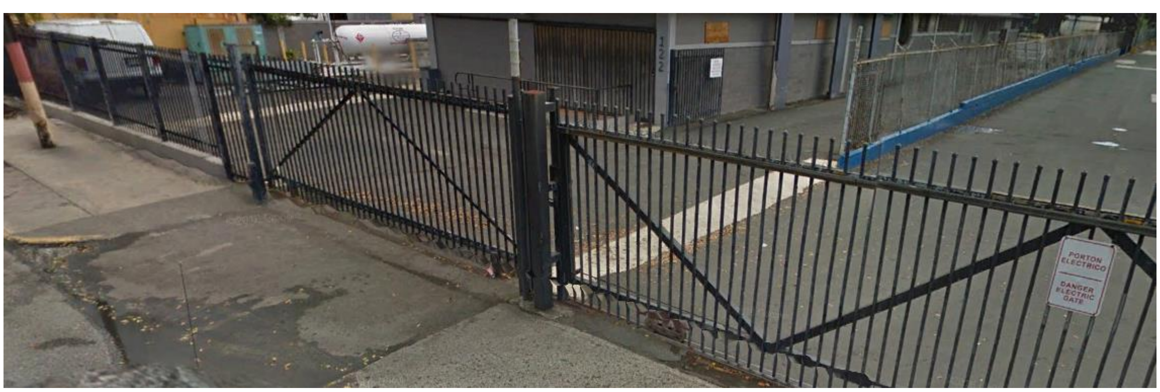


Figure 6-225 Other Building Exit in Fourth Section of Sidewalk on Las Nereidas Avenue from the Evacuation Route of Francisco Oller School in Street View (Google Earth – 2016)

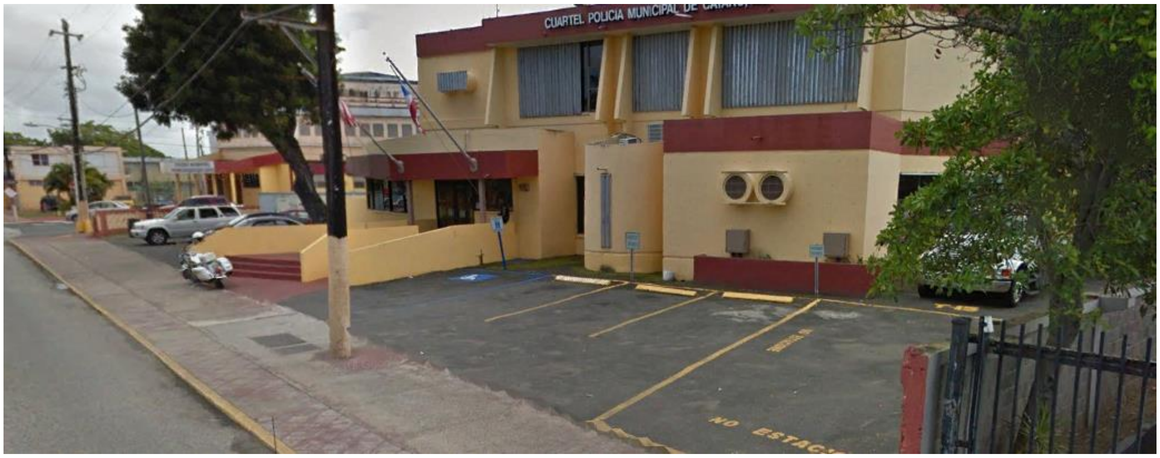


Figure 6-226 Building Exit and Poles in Fourth Section of Sidewalk on Las Nereidas Avenue from the Evacuation Route of Francisco Oller School in Street View (Google Earth – 2016)

The sidewalk along Olivo Street is shown in Figure 6-227. This sidewalk that has no vegetation (Figure 6-228), varies from 43 inches to 53 inches.

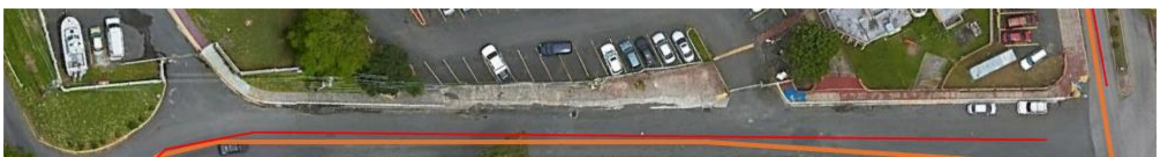


Figure 6-227 Sidewalk on Olivo Street from the Evacuation Route of Francisco Oller School in Plan View (Google Earth – 2016)

Figure 6-228 Sidewalk on Olivo Street from the Evacuation Route of Francisco Oller School in Street View (Google Earth – 2016)

This sidewalk splits (Figure 6-229), exposing it to traffic flow. This represents a danger to the school population during the evacuation process as vehicles can obstruct the pedestrian flow.

Figure 6-229 Sidewalk Division on Olivo Street from the Evacuation Route of Francisco Oller School in Street View (Google Earth – 2016)

On the continuation of this sidewalk there is deterioration, damage and cracks as shown in Figure 6-230. This unfavorable condition represents an obstacle for the school population since their condition may worsen due to the seismic event, which could prevent the passage through this evacuation route.

Figure 6-230 Sidewalk Damage on Olivo Street from the Evacuation Route of Francisco Oller School in Street View (Google Earth – 2016)

Figure 6-231 shows posts and a manhole that interrupts the effective width of the sidewalk. Due to this obstacle the width of the sidewalk is reduced to 28 inches. This means that the sidewalk does not meet 36 inches according to the ADA (Americans with Disabilities Act) requirement for people with disabilities. In this way, the school population could be forced to cross the street and continue the evacuation route on the other sidewalk that is close to the street. This other sidewalk is in optimal condition (Figure 6-232 and Figure 6-233).

That is, it has an effective width of 65 inches and does not have any urban furniture that serves as an obstruction, but the fact of having to cross the street during a tsunami evacuation process is dangerous for the population. However, this act must be carried out for Francisco Oller school because the route that continues towards El Caño Avenue only has one sidewalk. This sidewalk is the one to cross.

Figure 6-231 Manhole in Sidewalk on Olivo Street from the Evacuation Route of Francisco Oller School in Street View (Google Earth – 2016)

Figure 6-232 Other Sidewalk on Olivo Street from the Evacuation Route of Francisco Oller School in Plan View (Google Earth – 2016)

Figure 6-233 Other Sidewalk on Olivo Street from the Evacuation Route of Francisco Oller School in Street View (Google Earth – 2016)

The most convenient sidewalk for the evacuation process that is located along El Caño Avenue is the one to the North as shown in Figure 6-234. It has a constant width of 100 inches, almost triple what is required for people with disabilities. This sidewalk has trees and posts (Figure 6-235 and Figure 6-236), but they do not affect its effective width throughout the entire route. However, this assumption may vary depending on the impact of the seismic event.

Figure 6-234 Sidewalk on El Caño Avenue from the Evacuation Route of Francisco Oller School in Plan View (Google Earth – 2016)

Figure 6-235 Sidewalk on El Caño Avenue from the Evacuation Route of Francisco Oller School in Street View (Google Earth – 2016)

Figure 6-236 Poles in Sidewalk on El Caño Avenue from the Evacuation Route of Francisco Oller School in Street View (Google Earth – 2016)

On this route along El Caño Avenue, the sidewalk divides into two according to Figure 6-237. One of the parts that make up the sidewalk has green areas that invade the ideal space to pass through this route. Despite having easy access ramps for people with disabilities, the double sidewalk could represent a risk for this population during the evacuation process due to the drastic and unexpected change in level.

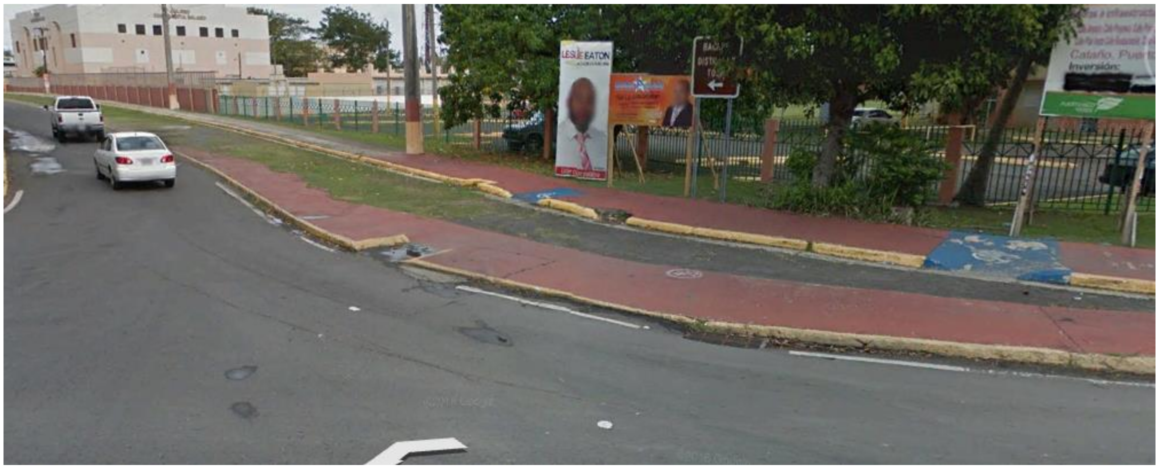


Figure 6-237 Double Sidewalk on El Caño Avenue from the Evacuation Route of Francisco Oller School in Street View (Google Earth – 2016)

The sidewalk that is to the south of this avenue (Figure 6-237) requires making a crossing on the road, which is not ideal for pedestrian flow due to the danger it represents. In addition, it is incomplete since it does not have a sidewalk in the entire route of the avenue, only in a segment of it as shown in Figure 6-238. For this reason, the most suitable route for this avenue is the North as mentioned above.

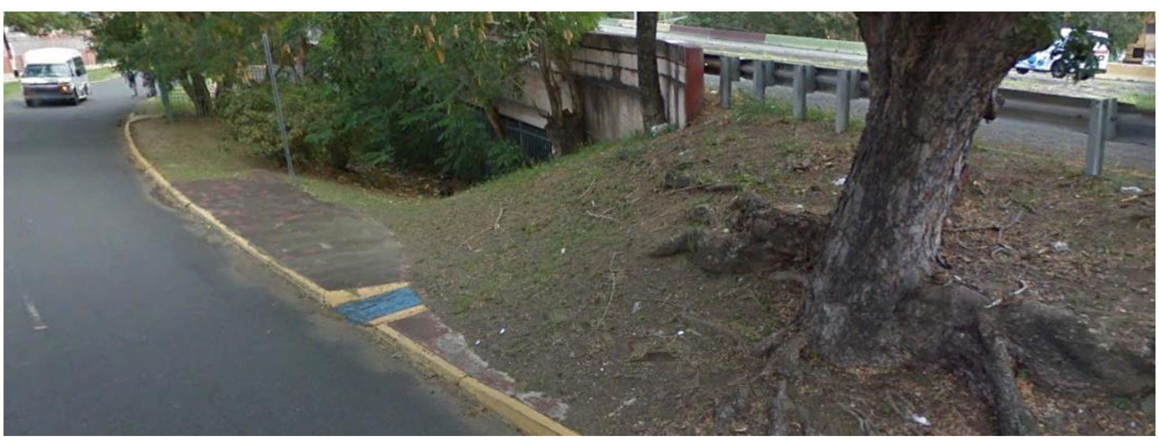


Figure 6-238 Incomplete Sidewalk on El Caño Avenue from the Evacuation Route of Francisco Oller School in Plan View (Google Earth – 2016)

The evacuation route along José Celso Barbosa Avenue has two possible sidewalks to reach the safe area as shown in Street View in Figure 6-239. Both are in good condition with an effective width of 114 inches. But the sidewalk on the left splits at a certain point when a ramp begins (Figure 6-240). This ramp is adapted for people with disabilities, including the necessary railings for it. The curb width of the ramp is 60 inches while the width of the flat curb is 54 inches. The effective width for both sidewalks is not affected despite having posts and signs on the road (Figure 6-240). However, the sidewalks are under a bridge, posing a real hazard to the pedestrian flow evacuating the school during the evacuation process as mentioned above.

Figure 6-239 Sidewalks on José Celso Barbosa Avenue from the Evacuation Route of Francisco Oller School in Street View (Google Earth – 2016)

Figure 6-240 Urban Furniture in Sidewalks on José Celso Barbosa Avenue from the Evacuation Route of Francisco Oller School in Street View (Google Earth – 2016)

With whichever sidewalk is taken, the school population must cross at least three streets to continue the evacuation route as presented in Figure 6-241. If people do not do it before entering the bridge, it must be done at the end of it. In this way, as the sidewalks are not continuous, the pedestrian crossing during an evacuation process also represents a danger for the population due to the vehicular flow.

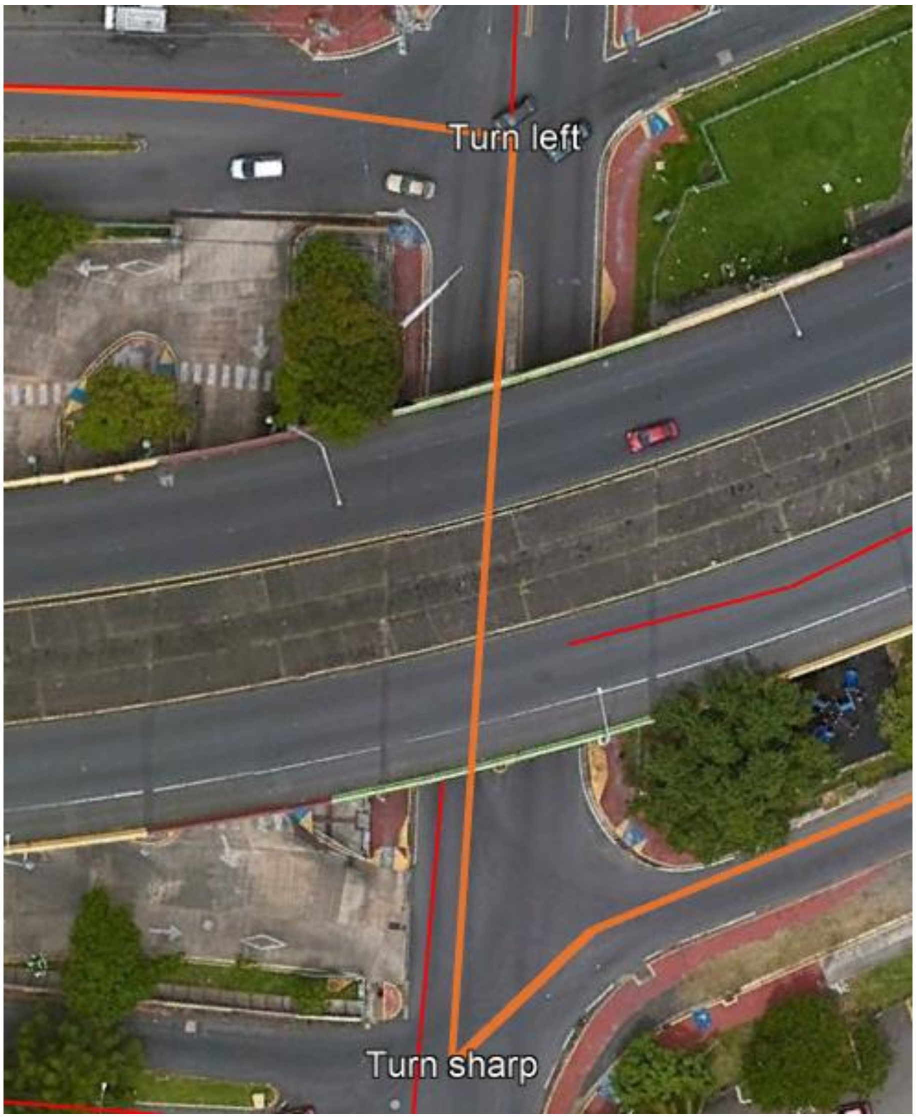


Figure 6-241 Sidewalks on José Celso Barbosa Avenue from the Evacuation Route of Francisco Oller School in Plan View (Google Earth – 2016)

Right where the tsunami hazard zone ends (shown in the blue line in Figure 6-242) is the sidewalk heading to the assembly site.

Figure 6-242 Sidewalk on Street Next to the Assembly Place from the Evacuation Route of Francisco Oller School in Street View (Google Earth – 2016)

The sidewalk to get to the assembly site is incomplete and is only at the end of it as shown in Figure 6-243 and Figure 6-244. This sidewalk is obstructed by posts and signs that affect its effective width, varying from 160 inches to 32 inches in width.

Figure 6-243 Sidewalk on Street Next to the Assembly Place from the Evacuation Route of Francisco Oller School in Plan View (Google Earth – 2016)

Figure 6-244 Sidewalk Obstacles on Street Next to the Assembly Place from the Evacuation Route of Francisco Oller School in Street View (Google Earth – 2016)

To continue the route and reach the nearest entrance of the assembly place, the population must walk down the street with the pertinent precautions regarding vehicular flow. The rest of the street has no sidewalks and has cars and other elements that can affect the passage of the school population.

In the tsunami hazard zone this would represent a danger, but this incomplete sidewalk and this street with possible obstructions are in a safe zone (outside the tsunami evacuation zone). However, it is important that people arrive at the assembly site as soon as possible and without any obstruction, even if they are in a safe zone very close to the hazard zone. According to the above hazard zone signs, Francisco Oller school evacuation route has signs indicating risk or hazard zones. This is specifically the hazard zone sign (b) shown in Figure 6-183 and Figure 6-184. On the other hand, the evacuation routes are signposted. There are seven signs near the perimeter of Francisco Oller school as shown in Figure 6-245.

Figure 6-245 Evacuation Route Signs Near the Perimeter of Francisco Oller School (Goole Earth – 2016)

The following figures present the evacuation routes signs in Google Earth's Street View as the continuation of Figure 6-245. Figure 6-246 shows the sign (a) that is located on Otero Street in the direction of El Caño Avenue (PR-165).

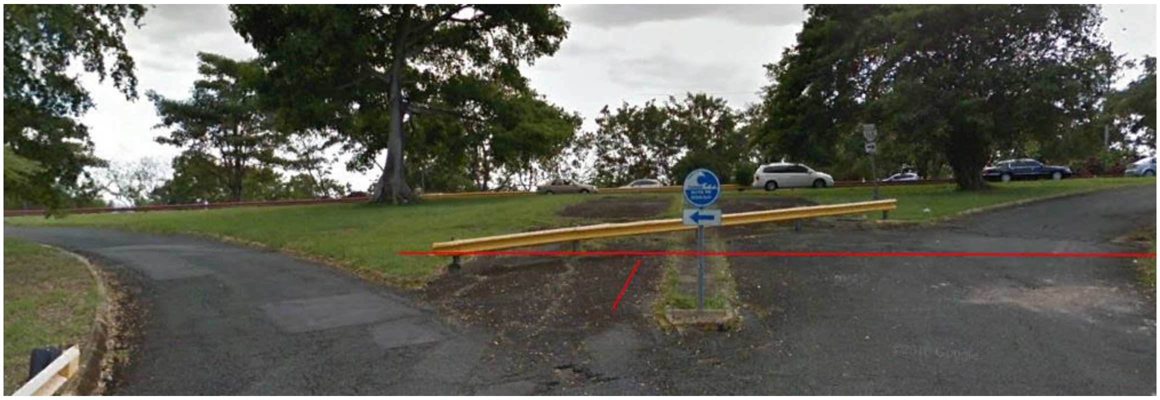


Figure 6-246 Evacuation Route Sign through Otero Street Near to Francisco Oller School (Google Earth – 2016)

Sign (b) is located at Las Nereidas Avenue (PR-888) as shown in Figure 6-247.

Figure 6-247 Evacuation Route Sign through Las Nereidas Avenue Near to Francisco Oller School (Google Earth – 2016)

The rest of the evacuation route signs can be found at: (c) by Las Nereidas Avenue (PR-888) towards Olivo Street (Figure 6-248), (d) by Olivo Street (Hernández Street) towards the marginal of El Caño Avenue (Figure 6-249), (e) El Caño Avenue (PR-165) (Figure 6-250), and (f) by José Celso Barbosa Avenue (PR-5) (Figure 6-251). This evacuation route sign (f) is located along the same avenue as the entering and leaving hazard zone signs in Figure 6-186.

Figure 6-248 Evacuation Route Sign through Las Nereidas Avenue Near to Francisco Oller School (Google Earth – 2016)

Figure 6-249 Evacuation Route Sign through Olivo Street Near to Francisco Oller School (Google Earth – 2016)

Figure 6-250 Evacuation Route Sign through El Caño Avenue Near to Francisco Oller School (Google Earth – 2016)

Figure 6-251 Evacuation Route Sign through José Celso Barbosa Avenue Near to Francisco Oller School (Google Earth – 2016)

Figure 6-252 shows the sign (g) located by Las Nereidas Avenue (PR-888).

Figure 6-252 Evacuation Route Sign through Las Nereidas Avenue Near to Francisco Oller School (Google Earth – 2016)

Although there are a variety of evacuation route signs close to the Francisco Oller school perimeter, only two of them are located along the shortest evacuation route shown in orange for this school. These two signs are the (c) (Figure 6-248) and (d) (Figure 6-249) as shown in Figure 6-245.

6.4.2 Luis Llorens Torres

The Luis Llorens Torres school is a school specialized in Montessori at the primary level in the educational region of San Juan. It is located on Marisabel Street, Residencial Luis Llorens Torres in San Juan PR, 00913 (Figure 6-253). Its coordinates are latitude 18.4476406 and longitude -66.0412818.

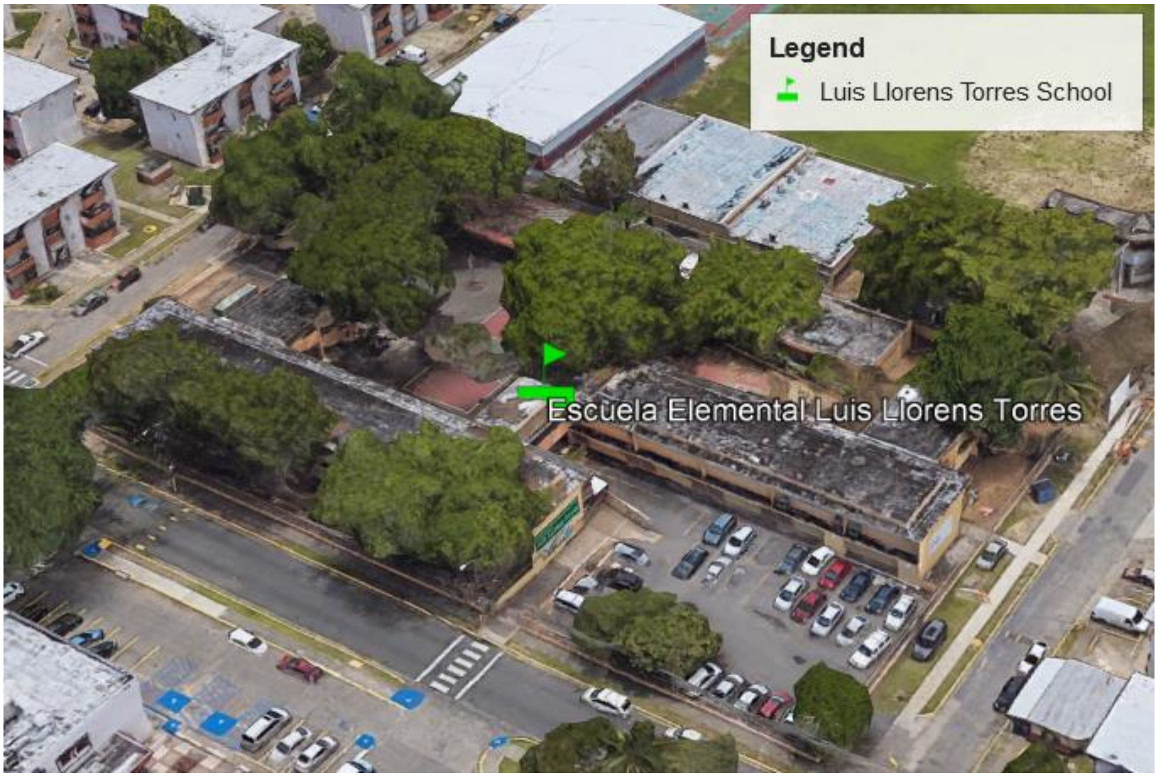


Figure 6-253 Luis Llorens Torres School (Google Earth – 2016)

Luis Llorens Torres school has a total population of 358 people between 332 students and 26 teachers. Like the Cataño school, this is a school used as a voting center and not as a refuge. On the other hand, it has an evacuation time from the school to the tsunami safe zone of 26 minutes 38 seconds. And an evacuation time from the school to the assembly site of 33 minutes and 35 seconds. Both times considered for an average walking speed of 2.50mph. These data or vulnerability parameters obtained in previous chapters and sections are summarized in Table 6-28 Summary of vulnerability parameters for Luis Llorens Torres school, as was done for the Francisco Oller de Cataño school.

Table 6-28 Summary of vulnerability parameters for Luis Llorens Torres school

Population			Occupancy		Evacuation Time (min:sec)	
(1) Students	(2) Teachers	(3) Total Population	(4) Voting Center	(5) Refuge	(6) Tsunami Hazard Zone	(7) Assembly Place
332	26	358	Yes	No	26:38	33:35

6.4.2.1 Structure Caracteristics

Luis Llorens Tores school occupies an approximate space of 5900 square meters of land according to measurements estimated in Google Earth. The delimited area of this terrain is shown in Figure 6-254 through a polygon with (a) shaded fill and (b) marked edge.

Figure 6-254 Estimated Total Floor Area for Luis Llorens Torres School (Google Earth – 2016)

This school has a parking lot, court, and separate structures that can serve as administrative offices, classrooms, and cafeteria. This assumption is based solely on the observation of a flat map in Google Earth (Figure 6-254).

6.4.2.2 Plan Irregularities

Luis Llorens Torres school is also made up of more than one independent structural framing system divided by joints. In this way it has an irregularity in plan that is shown in Figure 6-255. It has a complex geometric shape and two independent structures with a rectangular geometric shape. Therefore, irregular geometric shapes can be dangerous for the building and its population when the seismic event occurs.

Figure 6-255 Structure Geometry in Plan of Luis Llorens Torres School

Because this school is in the Residencial Luis Llorens Torres, the 360˚ panoramic images of the Street View in Google Earth are not found for this neighborhood in San Juan. Street View is only available for main roads. For this reason, the images that are seen for this school only have the 3D Buildings layer and do not have a good resolution like the one presented for the Cataño school.

Considering this aspect, Luis Llorens Torres school does not have elevation irregularity since it has a simple elevation as shown in Figure 6-256. Furthermore, according to this Figure, this school also has two levels. Unlike the irregular geometric shape of the school structure, its simple elevation does not pose a threat to the school population.

Figure 6-256 Luis Llorens Torres School in 3D Building (Google Earth – 2016)

6.4.2.3 Adjacency

Luis Llorens Torres school is located on the corner in the urban block. Its position is not a danger to the structure of the school, however, as it is in a residential area, it could be surrounded by critical neighboring buildings. This school is located next to “Parque Luis Llorens Torres” in the urban block as shown in Figure 6-257.

Figure 6-257 Position of Luis Llorens Torres School in Urban Block

Luis Llorens Torres Park is made up of “Cancha (Llorens) Monserrate Kike Ríos” or “Complejo Deportivo Monserrate (Kike) Ríos” and “Cancha Res Llorens Torres” as presented in Figure 6-258. This is an establishment whose function is for recreational and sports use. It has an indoor basketball court, and an outdoor tennis and ball court. The structure of this park is also less than 0.01 miles away from the location of Luis Llorens Torres school. Although its population is unknown, it can be assumed that since this is a facility frequented by people of all ages, it could represent a danger to the pedestrian flow of the school during the eviction process. This is because like the Cataño school of study, this school together with its surrounding buildings could only consider the same evacuation route. If so, the population would be at risk of not being able to reach a safe area in the shortest possible time.

Figure 6-258 Luis Llorens Torres Park as Adjacent Building to Luis Llorens Torres School (Google Earth – 2016)

“Cancha Res Llorens Torres” at Luis Llorens Torres Park has one floor (Figure 6-259). On the other hand, it has an irregularity in plan and elevation due to its “L” type geometric shape and its change in elevation. While Complejo Deportivo Monserrate (Kike) Ríos also from Luis Llorens Torres Park has two floors as presented in Figure 6-260. Although it does not have irregularity in elevation, it does have it in plan due to its complex geometric shape. In this way, the structures found in this neighboring park to the study school are considered critical for the vulnerability of Luis Llorens Torres school.

Figure 6-259 Cancha Res Llorens Torres as Adjacent Building to Luis Llorens Torres School (Google Earth – 2016)

Figure 6-260 Cancha (Llorens) Monserrate Kike Ríos as Adjacent Building to Luis Llorens Torres School (Google Earth – 2016)

Luis Llorens Torres school is located around other buildings that are not in its urban block but that can also significantly influence its vulnerability. These are located at a distance greater than 0.01 miles from the physical location of the Luis Llorens Torres school structure. As shown in Figure 6-261, the existing structures near this school are the Boys & Girls Club building, the CDT Llorens Torres, and the residences of the "Residencial Luis Llorens Torres".

Figure 6-261 Other Adjacent Buildings to Luis Llorens Torres School (Google Earth – 2016)

As in the Luis Llorens Torres Park, the population for these other structures is unknown. But considering that there are over 100 buildings in the "Residencial Luis Torres", and that there are more than 30 residences and that approximately 4 people live in them per residence, the population of the residential would be greater than 12,000 people. This is the population that would possibly be evacuating their respective structures by the same evacuation route from the school and the park mentioned above. This represents a greater vulnerability component for Luis Llorens Torres school because its evacuation time is much longer compared to the rest of the times obtained for the other schools in San Juan in the evaluation of evacuation routes. This, knowing that the evacuation time is less as the amount of population to be evacuated increases.

6.4.2.4 Exterior Falling Hazards

This school has nonstructural falling hazards as shown in Figure 6-262. Although the images do not have good resolution, the tall and heavy roof equipment and components can be seen in different parts of the school building. In this way, these falling hazards increase the vulnerability of the school because they threaten the life of the school population during the seismic event.

Figure 6-262 Nonstructural Falling Hazards at Luis Llorens Torres School (Google Earth – 2016)

6.4.2.5 Damage and Deterioration

As for the previous school (Cataño school), damage and deterioration are important to assess the vulnerability of Luis Llorens Torres school. But these cannot be exhaustively evaluated by means of a preliminary application with Google Earth images.

6.4.2.6 Security Measures in Hazard Zones, Evacuation Routes and Safe Zones

For this school, its vulnerability is also evaluated through the signaling, accessibility, availability and adaptation of danger zones, evacuation routes and safe zones during the evacuation process. This evaluation using Google Earth implies the insufficiency of clear images that capture the facilities of these security measures according to their respective area. This is due to the difficulty of specifically observing the elements in these areas.

The Google Earth Street View only applies to those areas that allow access, as shown in Figure 6-263 with the signs that are presented later.

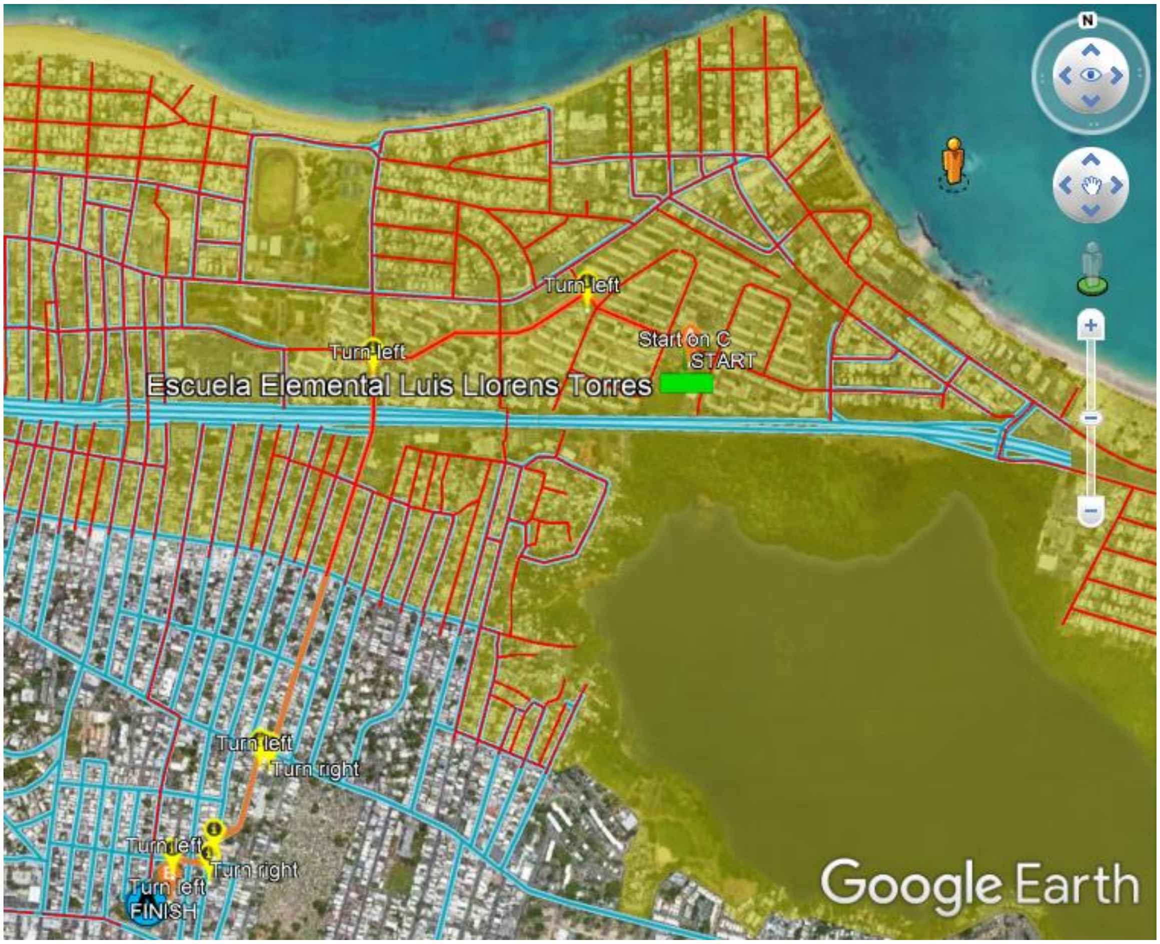


Figure 6-263 Street View Access Near Luis Llorens Torres School in San Juan

6.4.2.6.1 Hazard Zones

Tsunami evacuation zones, also tsunami danger zones are represented in yellow and are marked near the perimeter of Luis Llorens Torres school and its evacuation route. The location of the signs is arbitrarily around the entire coastline between 0.20 miles and 0.80 miles from the location of the school. Of these, four represent the tsunami danger zones and one indicates the exit from said zone, as shown in Figure 6-264.

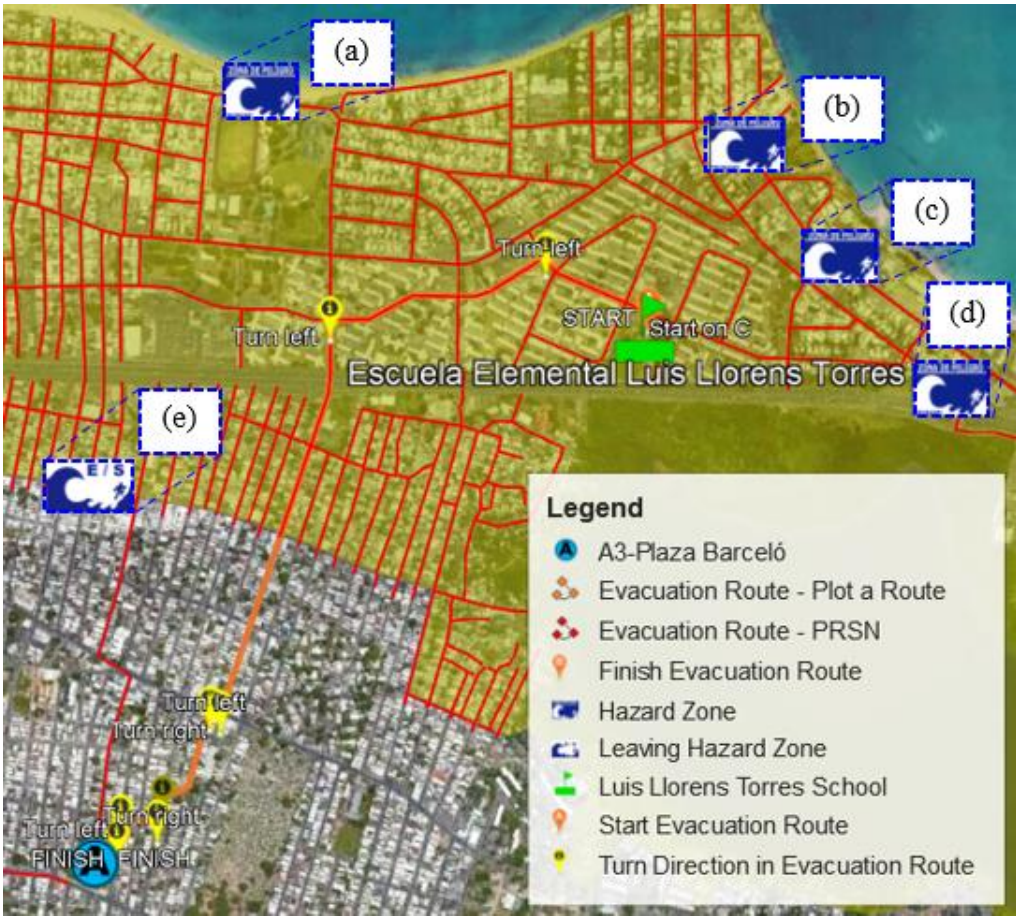


Figure 6-264 Hazard Zone Signs Near the Perimeter of Luis Llorens Torres School (Goole Earth – 2016)

As a continuation of Figure 6-264, Figure 6-265 shows the hazard zone sign (a) located on General Patton Street.

Figure 6-265 Hazard Zone Sign through General Patton Street Near the Perimeter of Luis Llorens Torres School (Google Earth – 2016)

In Loíza Street there are two signs through the PR-37. These are sign (b) in Figure 6-266 and sign (c) in Figure 6-266.

(b)

(c)

Figure 6-266 Hazard Zone Signs through Loíza Street Near the Perimeter of Luis Llorens Torres School (Google Earth – 2016)

Figure 6-267 shows the hazard zone sign (d) located on Isla Verde Avenue (PR-37) in the direction of PR-26. On the other hand, near this school the exit of the tsunami hazard zone is also signaled. This is located on Degetau Street as shown in Figure 6-268. This sign is upside down according to Google Earth images in 2016. This represents a danger for the population that evacuates during the eviction process if they do not know the signs of the area correctly. Said signage must be properly installed, so that the entire population can go to the safe area quickly. However, today this sign may be in optimal condition and correctly indicating the area. Contrary to the area near the Cataño school above, the area around Luis Llorens Torres school does not have signs indicating the entrance to the hazard zone.

Figure 6-267 Hazard Zone Sign through Isla Verde Avenue Near the Perimeter of Luis Llorens Torres School (Google Earth – 2016)

Figure 6-268 Leaving Hazard Zone Sign through Degetau Street Near the Perimeter of Luis Llorens Torres School (Google Earth – 2016)

6.4.2.6.2 Safe Zones

For Luis Llorens Torres school, the place of assembly also corresponds to the safe areas. This school leaves its physical facilities to "Plaza Antonio R. Barceló", also "Plaza Barceló", as the same assembly place evaluated for evacuation routes. Its facilities have a land area of around 7400 square meters according to measurements made in Google Earth. Figure 6-269 represents by means of a polygonal figure the area of said terrain in (a) shaded fill and (b) marked edge.

(a) (b)

Figure 6-269 Estimated Total Floor Area for “Plaza Barceló” (Google Earth - 2016)

The facilities of this assembly place are shown in Figure 6-270 and Figure 6-271. By 2016 "Plaza Barceló" was undergoing renovation. This represents a threat to the school population that comes to this safe area as a meeting place despite the fact that it is in a zone out of tsunami danger. But considering this is the only nearby assembly place in the area, the entire surrounding population could resort to the same assembly point and accumulate. And if the amount of square feet of land is not enough to house that many people, then it becomes a truly pervasive hazard. And if in the worst case, this assembly place continues with construction and remodeling processes, the land capacity would be limited and would further threaten the population. These are assumptions based on the location of this plaza, its function and importance, as well as the lack of information on the population's capacity for that location.

Figure 6-270 "Plaza Barceló" (Google Earth - 2016)

Figure 6-271 "Plaza Barceló" in Street View (Google Earth - 2016)

The facilities of this assembly place are shown in figure and figure. By 2016 "Plaza Barceló" was undergoing renovation. This represents a threat to the school population that comes to this safe area as a meeting place even though it is in a zone out of tsunami danger. But considering this is the only nearby assembly place in the area, the entire surrounding population could resort to the same assembly point and accumulate. And if the amount of square feet of land is not enough to house that many people, then it becomes a truly pervasive hazard. And if in the worst case, this assembly place continues with construction and remodeling processes, the land capacity would be limited and would further threaten the population. These are assumptions based on the location of this plaza, its function and importance, as well as the lack of information on the population's capacity for that location.

6.4.2.6.3 Evacuation Routes

For this school, three conditions are also considered regarding their evacuation routes. These three characteristics are intended for the route to: (1) move away from the coast in the shortest possible time, (2) avoid walking parallel to the sea, and (3) avoid possible obstructions to the route.

The main condition that expects the evacuation route from the school to get away from the coast as quickly as possible is justified by the evacuation time. Specifically with the evacuation time obtained of 26 minutes and 38 seconds for this school from the start of its physical facilities to leaving the tsunami danger zone (Figure 6-272). But also, with the evacuation time from the school to the assembly place obtained of 19 minutes and 22 seconds (Figure 6-273). Both evacuation times considered for an average walking speed of 2.50 mph.

The evacuation route for these times is the same evacuation route evaluated for those evacuation times from the previous section. This route starts from María Isabel Street, turns onto Marina Street, and onto Pellín Rodríguez Street (Providencia Street). Then it reaches Eduardo Conde Avenue and makes a quick turn onto Los Santos Street and immediately onto Lippit Street. Later, it goes to Catalino “Tite” Curet Alonso Avenue and turns onto Felipe R. Goyco Street until reaching the assembly place. The same assembly location indicated above in the safe areas.

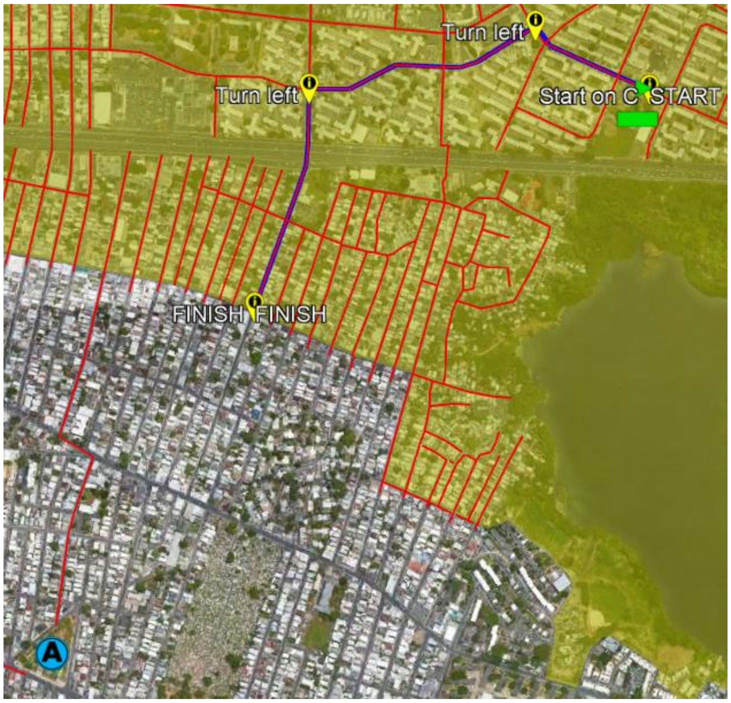


Figure 6-272 Evacuation Route until Leaving the Hazard Zone for Luis Llorens Torres School (Google Earth – 2016)

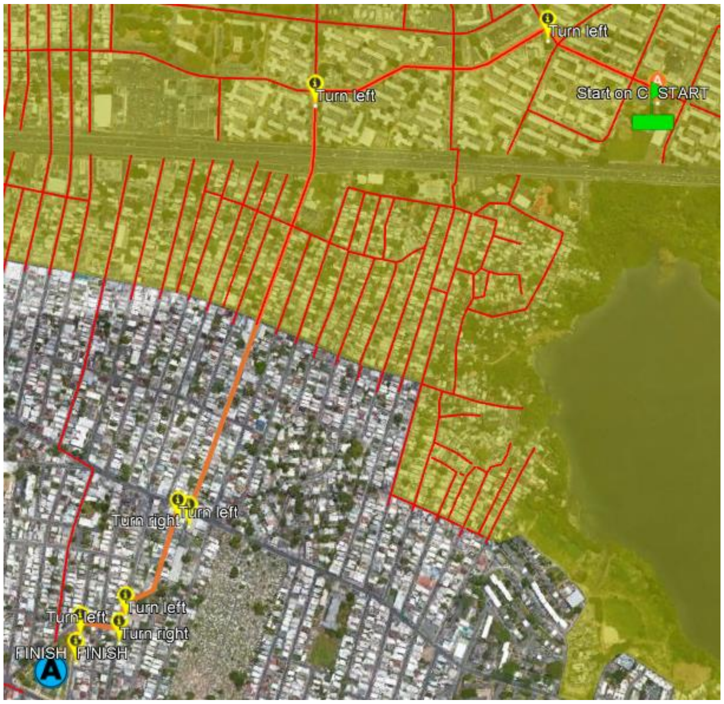


Figure 6-273 Evacuation Route until Reaching the Assembly Place for Luis Llorens Torres School (Google Earth – 2016)

The second condition that seeks a route that avoids the walk parallel to the sea is not fulfilled for Luis Llorens Torres school as presented in Figure 6-274. As assessed on the evacuation route for this school, the route distance out of the tsunami hazard zone is 0.786 miles. Of this total distance, 0.300 miles correspond to the distance you walk perpendicular to the coast and 0.486 miles to the distance you walk parallel to the sea. Although it seems that there is not much difference between the two walks, the condition regarding the avoidance of walking parallel to the sea is essential to save the lives of the school population. In this way, because in this section the school travels a greater distance and time walking practically parallel to the sea, it does not meet this condition.

Figure 6-274 Evacuation Route of Luis Llorens Torres School with Signs

The third and final condition that avoids possible obstructions to evacuation routes is also not met for this school. The evacuation route of Luis Llorens Torres goes through power lines according to observations of sections of the route accessible with the use of Street View in Google Earth. As mentioned for the Cataño school, these power lines can considerably obstruct the route in an emergency event and impede its passage. If so, the school population would be at risk of being hit by the tsunami waves once it makes landfall.

The section of the route where the availability of Street View begins is through Pellín Rodríguez Street (Providencia Street). Figure 6-275 shows the power lines arbitrarily located throughout the evacuation route of Luis Llorens Torres school.

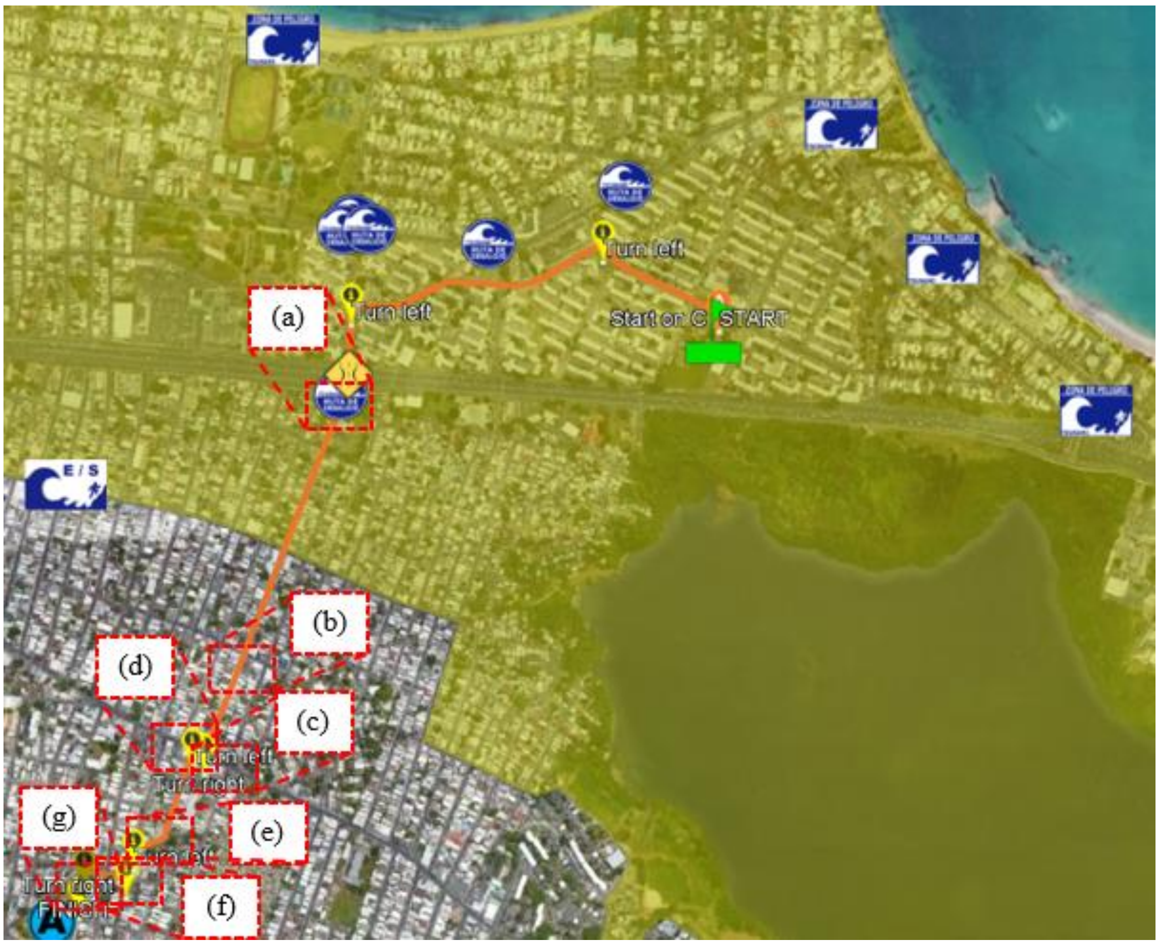


Figure 6-275 Power Lines on the Evacuation Route of Luis Llorens Torres School (Google Earth – 2016)

Figure 6-276 shows the power lines (a) as a continuation of the previous Figure 6-275 that pass through Pellín Rodríguez Street. Also, it shows the traffic lights at the beginning of this street. If these are not fixed in the correct way, they represent a danger during the emergency event. While Figure 6-277 shows the power lines (b) that pass at the end of this same street.

Figure 6-276 Power Lines on the Evacuation Route of Luis Llorens Torres School through Pellín Rodríguez Street [Beginning of the Street] (Google Earth – 2016)

Figure 6-277 Power Lines on the Evacuation Route of Luis Llorens Torres School through Pellín Rodríguez Street [End of the Street] (Google Earth – 2016)

The power lines (c) that pass-through Eduardo Conde Avenue are shown in Figure 6-279. On the other hand, through the same evacuation route are the power lines (d) that pass-through Los Santos Street (Figure 6-278) and the power lines (e) that pass through Lippit Street (Figure 6-280). In addition, the power lines (f) that go through the beginning of Tite Curet Alonso Avenue and the power lines (g) that go through the same avenue are shown in Figure 6-281 and Figure 6-282.

Figure 6-279 Power Lines on the Evacuation Route of Luis Llorens Torres School through Eduardo Conde Avenue (Google Earth – 2016)

Figure 6-278 Power Lines on the Evacuation Route of Luis Llorens Torres School through Los Santos Street (Google Earth – 2016)

Figure 6-280 Power Lines on the Evacuation Route of Luis Llorens Torres School through Lippit Street (Google Earth – 2016)

Figure 6-281 Power Lines on the Evacuation Route of Luis Llorens Torres School through Tite Curet Alonso Avenue [Beginning of the Street] (Google Earth – 2016)

Figure 6-282 Power Lines on the Evacuation Route of Luis Llorens Torres School through Tite Curet Alonso Avenue [End of the Street] (Google Earth – 2016)

Like the Cataño school (Francisco Oller school), Luis Llorens Torres school also goes under a bridge on its fastest evacuation route. This bridge is located on Pellín Rodríguez (Providencia Street). This is precisely the bridge of the "Expreso Román Baldorioty de Castro" through the PR-26 as presented in Figure 6-283. Also, Figure 6-284shows the bridge in Street View.

In this way, Luis Llorens Torres school has a vulnerable evacuation route due to the bridge through which the school population that evacuates during the eviction process is exposed. This is another reason that the third criterion is not met regarding evacuation routes for this school. Knowing that, if the bridge collapses during the pre-tsunami seismic event, the pedestrian flow would not have a faster route to reach the safe zone.

Figure 6-283 Location of the Bridge on the Evacuation Route of Luis Llorens Torres School (Google Earth – 2016)

Figure 6-284 Bridge on the Evacuation Route of Luis Llorens Torres School (Google Earth – 2016)

Another reason why there are obstacles in the evacuation route of Luis Llorens Torres school is the condition of the sidewalks of said route. Because for this evacuation route the Google Earth Street View is only available for the section that begins at Pellín Rodríguez Street, the sidewalks of the first curb segments are shown in plan view.

The sidewalk at the beginning of the route that is located by María Isabel Street is divided into different segments to facilitate its visualization, as presented in Figure 6-285.

Figure 6-285 Sidewalk on María Isabel Street from the Evacuation Route of Luis Llorens Torres School in Plan View (Google Earth – 2016)

The first segment of this sidewalk has a constant effective width of 50 inches (Figure 6-286). This width is not affected by any urban furniture or green areas with a width of 36 inches. In this way, this section of sidewalk is adapted and is ideal for people with disabilities in the event of an emergency event.

Figure 6-286 First Section of Sidewalk on María Isabel Street from the Evacuation Route of Luis Llorens Torres School in Plan View (Google Earth – 2016)

Between the end of the first segment and the beginning of the second sidewalk segment, the evacuation route crosses Cundeamor Street (Figure 6-287). This represents a threat to the population that flows through this area due to the danger that the vehicular flow represents for the passage of pedestrians. This, even though both sidewalks have accessible ramps adapted for people with disabilities as can be seen in the Google Earth images.

Figure 6-287 Crossing between First and Second Section of Sidewalk on María Isabel Street from the Evacuation Route of Luis Llorens Torres School in Plan View (Google Earth – 2016)

The second segment of this sidewalk is presented in Figure 6-288. Unlike the previous section of sidewalk, this sidewalk has no greenery, and its effective width is not continuous. This width ranges from 30 to 38 inches or less. This is due to the fact that the “Residencial Luis Llorens Torres” parking lot is located throughout the section of sidewalk. Therefore, this threatens the safety of the population and makes the sidewalk unfit for evacuation during the tsunami evacuation process. This sidewalk does not meet the effective width required for people with disabilities and presents vehicular flow along the road.

Figure 6-288 Second Section of Sidewalk on María Isabel Street from the Evacuation Route of Luis Llorens Torres School in Plan View (Google Earth – 2016)

Between the second and third segment of the sidewalk of this same street there is also a crossing. It crosses Collores Street (Figure 6-289). In this way, there is a double threat of pedestrian crossing on this street for the evacuation route of Luis Llorens Torres school.

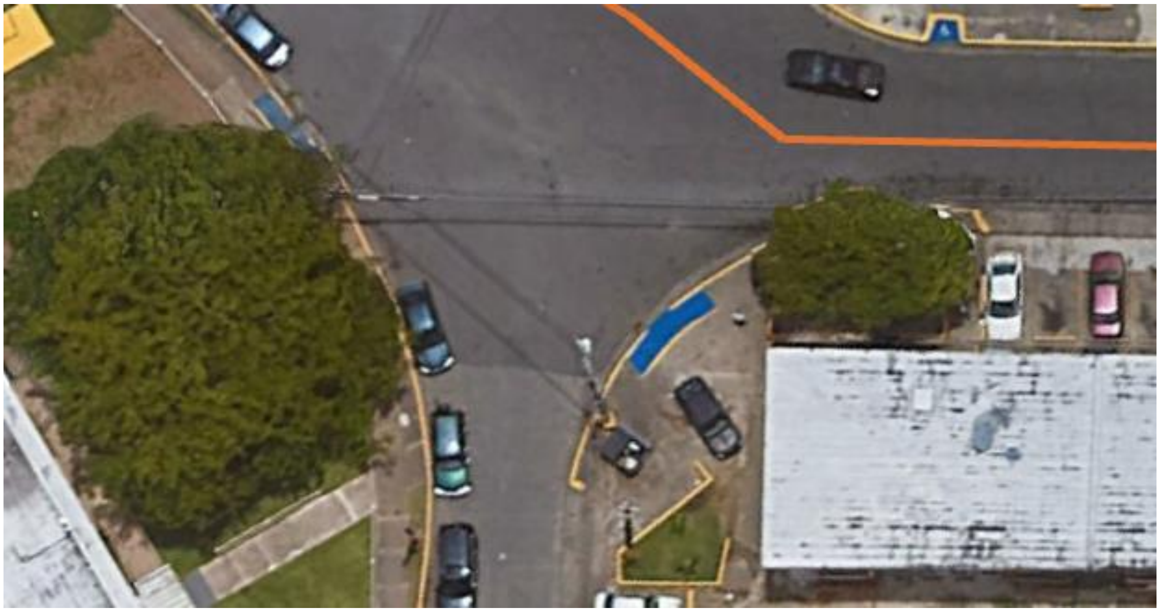


Figure 6-289 Crossing between Second and Thrid Section of Sidewalk on María Isabel Street from the Evacuation Route of Luis Llorens Torres School in Plan View (Google Earth – 2016)

The third section of sidewalk on María Isabel Street is curved (Figure 6-290). Despite its shape, it has a curb width that varies from 36 to 80 inches. In addition, it has green areas that do not interrupt the width of the sidewalk.

Figure 6-290 Thrid Section of Sidewalk on María Isabel Street from the Evacuation Route of Luis Llorens Torres School in Plan View (Google Earth – 2016)

The sidewalk of Marina Street is also subdivided into different segments due to its length (Figure 6-291).

Figure presents the first segment of this sidewalk. It has an effective width of 34 inches to 100 inches. Its variation in width is due to the interruption of the road by the parking lot and flow of vehicles of the “Residencial Luis Llorens Torres”. Therefore, this first section of the sidewalk is not suitable for the evacuation process.

Figure 6-291 Sidewalk on Marina Street from the Evacuation Route of Luis Llorens Torres School in Plan View (Google Earth – 2016)

Figure 6-292 First Section of Sidewalk on Marina Street from the Evacuation Route of Luis Llorens Torres School in Plan View (Google Earth – 2016)

The second section of this sidewalk is 36 inches to 45 inches wide (Figure 6-293). However, this segment of sidewalk also has vehicular flow that poses a hazard to pedestrian flow during the tsunami evacuation process.

Figure 6-293 Second Section of Sidewalk on Marina Street from the Evacuation Route of Luis Llorens Torres School in Plan View (Google Earth – 2016)

Between the second and third segment of the sidewalk, the evacuation route crosses Barcarola Street. Figure 6-294 presents this junction indicating a threat to the route.

Figure 6-294 Crossing between Second and Thrid Section of Sidewalk on Marina Street from the Evacuation Route of Luis Llorens Torres School in Plan View (Google Earth – 2016)

The third section of the Marina Street sidewalk is shown in Figure 6-295. It has a width of 45 inches to 55 inches, in addition, it has green areas 42 inches wide that do not interrupt its effective width.

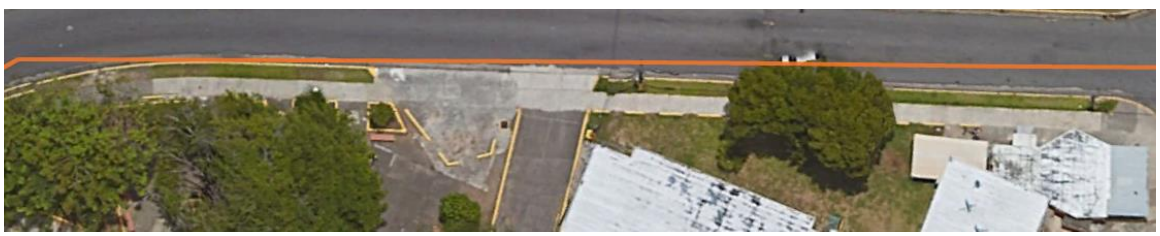


Figure 6-295 Third Section of Sidewalk on Marina Street from the Evacuation Route of Luis Llorens Torres School in Plan View (Google Earth – 2016)

Figure 6-296 presents the fourth segment of this sidewalk. This section of sidewalk has an effective width of 50 inches to 80 inches. It also has green areas like the previous segment. These areas are 30 inches wide and do not affect the width of the sidewalk. But despite complying with a good width, this sidewalk is exposed to vehicles that cross it and that can threaten the lives of the school population that travels it.

Figure 6-296 Fourth Section of Sidewalk on Marina Street from the Evacuation Route of Luis Llorens Torres School in Plan View (Google Earth – 2016)

The fifth section of this sidewalk also has a small intersection interrupted by vehicles entering and leaving the "Residencial Luis Llorens Torres" (Figure 6-297). The beginning of this segment of sidewalk (considering the continuation of the route in the direction from right to left) is 50 inches wide. This is interrupted by the intersection with the vehicular flow. Subsequently, the end of this sidewalk is obstructed by parked vehicles that affect its ideal effective width.

Figure 6-297 Fifth Section of Sidewalk on Marina Street from the Evacuation Route of Luis Llorens Torres School in Plan View (Google Earth – 2016)

The sidewalk along Pellín Rodríguez Street is shown divided into Figure 6-298.

Figure 6-298 Sidewalk on Pellín Rodríguez Street from the Evacuation Route of Luis Llorens Torres School in Plan View (Google Earth – 2016)

The first section of this sidewalk (Figure 6-299) is 115 inches wide. But this width is affected by cars parked on the same curb, reducing it to 70 inches. Although the reduction in width is sufficient for disabled pedestrian crossing, interaction with cars during the evacuation process is dangerous.

Figure 6-299 First Section of Sidewalk on Pellín Rodríguez Street from the Evacuation Route of Luis Llorens Torres School in Plan View (Google Earth – 2016)

Between the sidewalk of the first and second section of this street is the bridge and a crossing (Figure 6-300). The sidewalk under this bridge is 54 inches wide. Even though this width is not affected by any obstruction in the road and that the sidewalk is in optimal condition (Figure 6-301), the fact that the sidewalk passes under a bridge represents a sufficient danger for pedestrian flow.

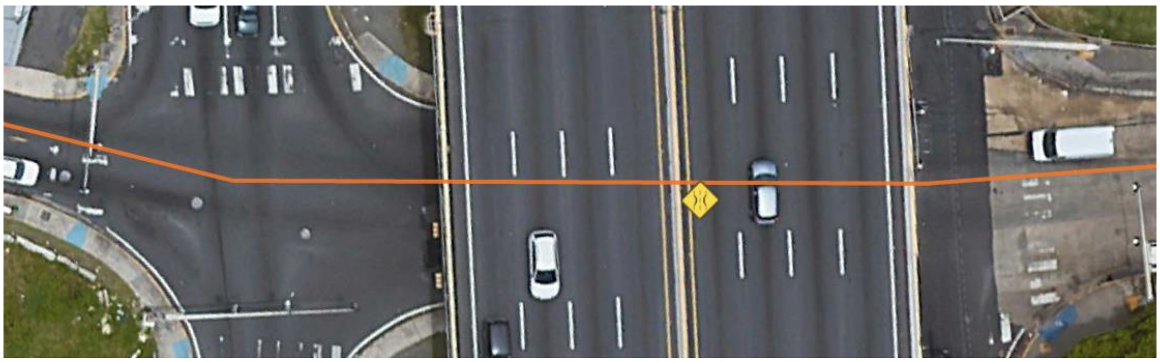


Figure 6-300 Bridge and Crossing between First and Second Section of Sidewalk on Pellín Rodríguez Street from the Evacuation Route of Luis Llorens Torres School in Plan View (Google Earth – 2016)

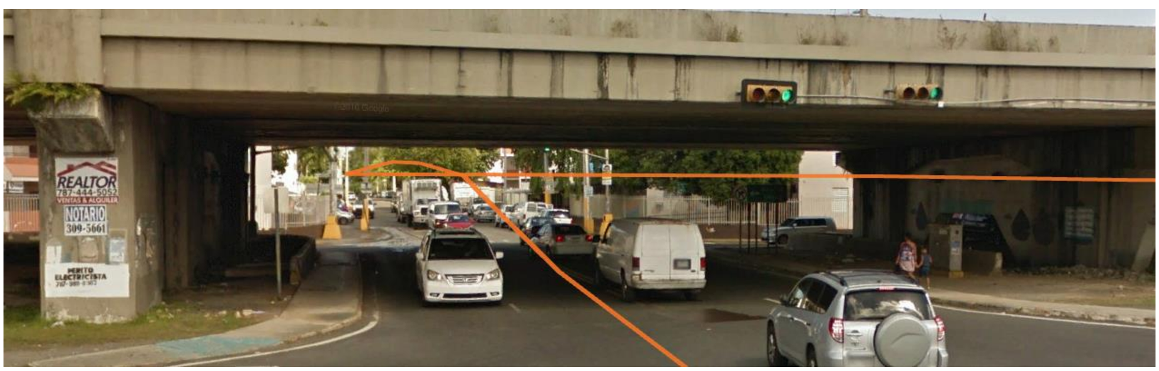


Figure 6-301 Bridge and Crossing between First and Second Section of Sidewalk on Pellín Rodríguez Street from the Evacuation Route of Luis Llorens Torres School in Street View (Google Earth – 2016)

The route is through a junction that is dangerous due to interaction with vehicles. For the second section there are two sidewalks on the North (Plan View) or right (Street View) and South (Plan View) or left (Street View) as shown in Figure 6-302 and Figure 6-303. Regardless of which of the two sidewalks are suitable for the route, for it is necessary to cross the street in order to access them. The North sidewalk has an effective width of 60 inches and is reduced to less than 12 inches. This width is affected by posts that are in the center of the sidewalk. While the South sidewalk is also 60 inches wide. But its width is affected to 20 inches due to street furniture that also obstructs the sidewalk.

Figure 6-302 Second Section of Sidewalk on Pellín Rodríguez Street from the Evacuation Route of Luis Llorens Torres School in Plan View (Google Earth – 2016)

Figure 6-303 Second Section of Sidewalk on Pellín Rodríguez Street from the Evacuation Route of Luis Llorens Torres School in Street View (Google Earth – 2016)

The third section of this sidewalk is seen in Figure 6-304. The North sidewalk (right) has a width ranging from 40 inches to 60 inches. The south sidewalk (left) has an effective width of 60 inches. Both sidewalks are obstructed by parked vehicles. Although the conditions of both sidewalks are fine without any cracks or damage, they are not suitable to be traversed during the evacuation process.

Figure 6-304 Third Section of Sidewalk on Pellín Rodríguez Street from the Evacuation Route of Luis Llorens Torres School in Plan View (Google Earth – 2016)

The south sidewalk (left) has other elements that get in the way. These correspond to those arranged by different businesses on the evacuation route.

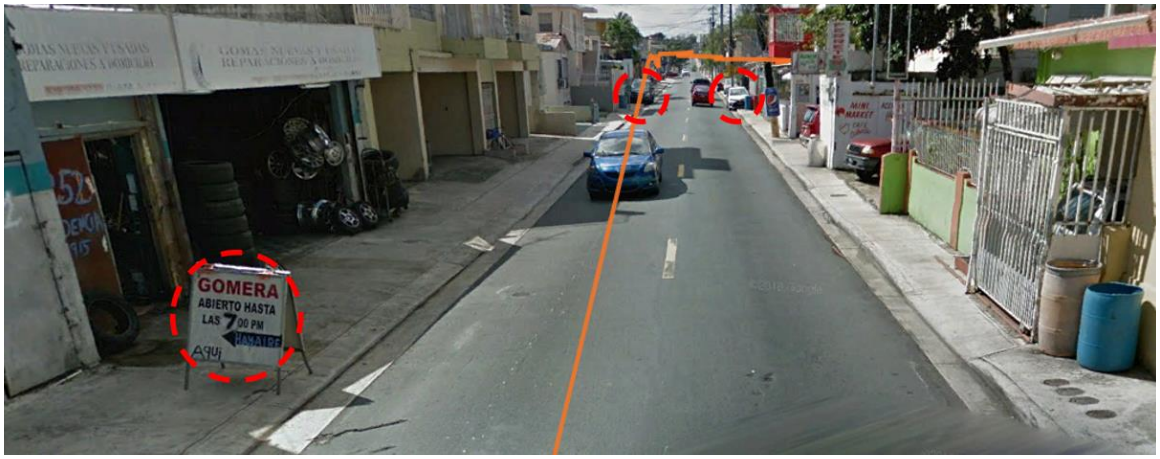


Figure 6-305 Third Section of Sidewalk on Pellín Rodríguez Street from the Evacuation Route of Luis Llorens Torres School in Street View (Google Earth – 2016)

Between the third and fourth section of the sidewalk there is a crossroads. But just where the third curb segment ends for this street, the tsunami hazard zone for this evacuation route also ends. As shown in Figure 6-306 and Figure 6-307, just where the route marked in blue ends, the tsunami evacuation zone ends. Consequently, the rest of the sidewalks (from the fourth section of the sidewalk of Pellín Rodríguez Street onwards) and their conditions are in a safe zone on the route identified in orange. In this way, in case any of the sidewalks are not in optimal conditions for pedestrian flow, the school population of Luis Llorens Torres school could consider other accessible and safe ways to reach the assembly place as soon as possible. As mentioned for the Cataño school, it is important that the school population reaches the meeting place or safe meeting point as quickly as possible during the emergency event, even if it is in a safe area.

Figure 6-306 Tsunami Hazard Zone Ends on Pellín Rodríguez Street from the Evacuation Route of Luis Llorens Torres School in Plan View (Google Earth – 2016)

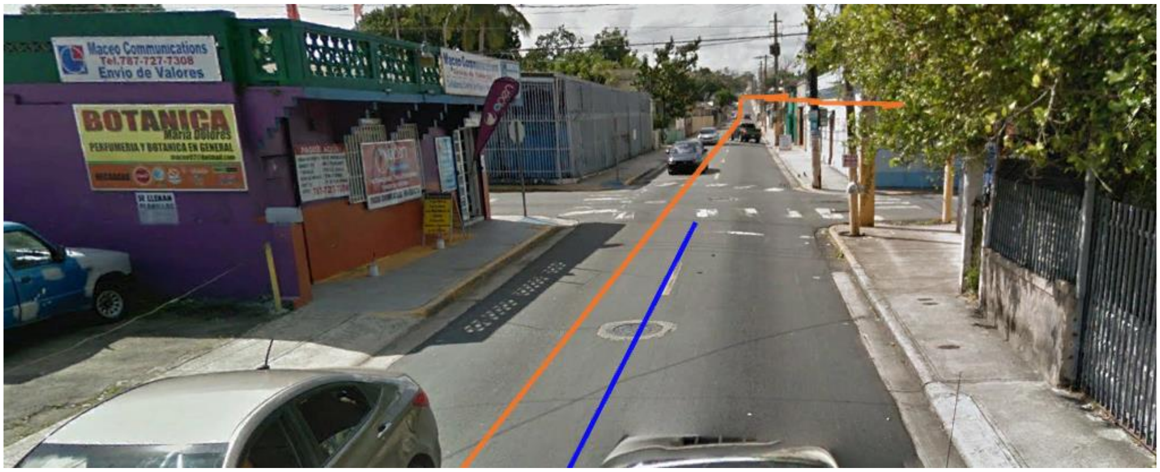


Figure 6-307 Tsunami Hazard Zone Ends on Pellín Rodríguez Street from the Evacuation Route of Luis Llorens Torres School in Street View (Google Earth – 2016)

The fourth section of this sidewalk is presented in Figure 6-308 and Figure 6-309. This section also has interaction of the vehicular flow that leaves and enters the businesses that are located on this highway. The North sidewalk (right) is 60 inches wide. But this is interrupted by posts that decrease their width to 32 inches. While the south sidewalk (left) has width variations from 40 inches to 60 inches. Both sidewalks are not in poor condition. The South sidewalk (left) is better adapted for the evacuation process. This sidewalk does not have as many obstacles as the opposite sidewalk presents.

Figure 6-308 Fourth Section of Sidewalk on Pellín Rodríguez Street from the Evacuation Route of Luis Llorens Torres School in Plan View (Google Earth – 2016)

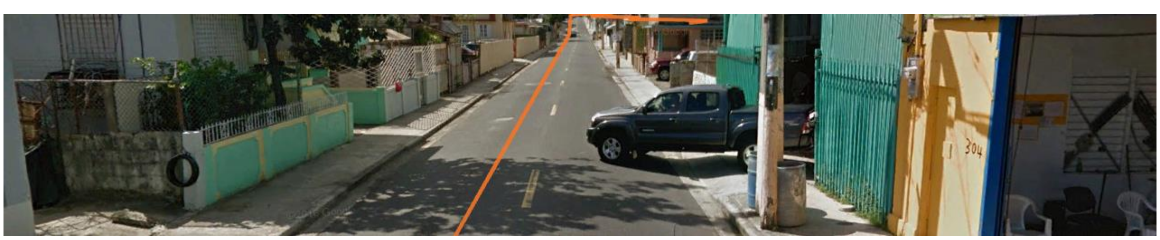


Figure 6-309 Fourth Section of Sidewalk on Pellín Rodríguez Street from the Evacuation Route of Luis Llorens Torres School in Street View (Google Earth – 2016)

There is also a junction between the fourth and fifth section of this sidewalk that is located on Pellín Rodríguez Street. Figure 6-310 shows the fifth segment of the sidewalk for this street. The two sidewalks available for this stretch are 60 inches wide that are reduced to 20 inches due to road obstructions. Both sidewalks have posts in their center that affect their width. In addition, they have parked vehicles that interrupt the sidewalk, and, therefore, the passage through that route (Figure 6-311). Although both sidewalks are in good condition, they are not adapted for people with disabilities to evacuate during the tsunami eviction process.

Figure 6-310 Fifth Section of Sidewalk on Pellín Rodríguez Street from the Evacuation Route of Luis Llorens Torres School in Plan View (Google Earth – 2016)

Figure 6-311 Fifth Section of Sidewalk on Pellín Rodríguez Street from the Evacuation Route of Luis Llorens Torres School in Street View (Google Earth – 2016)

Along Eduardo Conde Avenue there are also two sidewalks available (Figure 6-312) but depending on which one is chosen for evacuation, the route would have to cross. Both sidewalks have an effective width of 60 inches but due to obstructions by posts and traffic lights the width is reduced from 20 inches to 30 inches (Figure 6-313). The sidewalks do not have green areas or grays that hinder their conditions. However, it does not meet the adaptive requirements for the handicapped for sidewalks.

Figure 6-312 Sidewalk on Eduardo Conde Avenue from the Evacuation Route of Luis Llorens Torres School in Plan View (Google Earth – 2016)

Figure 6-313 Sidewalk on Eduardo Conde Avenue from the Evacuation Route of Luis Llorens Torres School in Street View (Google Earth – 2016)

Figure 6-314 presents the accessible sidewalks on Los Santos Street. Like the previous ones, this street has two possible sidewalks to walk on during the evacuation route. Both sidewalks have an available width of 60 inches that is reduced to 20 inches or less because of different obstacles along the route. Sidewalks have posts that meet at their center (Figure 6-314 and Figure 6-316), and cars around them and parked (**Error! Reference source not found.**).

Figure 6-314 Sidewalk on Los Santos Street from the Evacuation Route of Luis Llorens Torres School in Plan View (Google Earth – 2016)

Figure 6-316 Poles in Sidewalk on Los Santos Street from the Evacuation Route of Luis Llorens Torres School in Street View (Google Earth – 2016)

Figure 6-315 Cars in Sidewalk on Los Santos Street from the Evacuation Route of Luis Llorens Torres School in Street View (Google Earth – 2016)

At the curve of this street, the sidewalk on the left (South) ends and the sidewalk on the right (North) is reduced. After the curve, in the continuation of this street the sidewalks are interrupted by posts, vegetation and parked cars (Figure 6-317, Figure 6-318 and Figure 6-319).

Figure 6-317 Other Poles in Sidewalk on Los Santos Street from the Evacuation Route of Luis Llorens Torres School in Street View (Google Earth – 2016)

Figure 6-318 Sidewalk Reduction on Los Santos Street from the Evacuation Route of Luis Llorens Torres School in Street View (Google Earth – 2016)

Figure 6-319 Other Sidewalk Obstruction on Los Santos Street from the Evacuation Route of Luis Llorens Torres School in Street View (Google Earth – 2016)

Lippit Street also has two sidewalks available (Figure 6-320). Both have an effective width of 64 inches, but they do for positions that get in the way (Figure 6-321). They are reduced to a width of less than 36 inches, which is what is required for people with disabilities.

Their condition is quite acceptable, but regardless due to their reduced width they are not suitable for the eviction process.

Figure 6-320 Sidewalk on Lippit Street from the Evacuation Route of Luis Llorens Torres School in Plan View (Google Earth – 2016)

Figure 6-321 Sidewalk on Lippit Street from the Evacuation Route of Luis Llorens Torres School in Street View (Google Earth – 2016)

Between Lippit Street and Catalino "Tite" Curet Alonso Avenue is a junction, as shown in Figure 6-322.

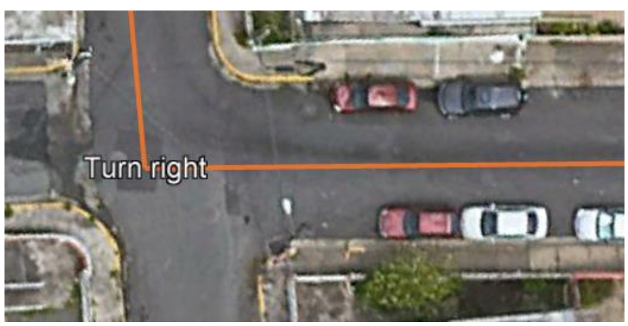


Figure 6-322 Crossing between Lippit Street and Tite Curet Alonso Avenue of Sidewalk from the Evacuation Route of Luis Llorens Torres School in Plan View (Google Earth – 2016)

Catalino "Tite" Curet Alonso Avenue sidewalks are shown in Figure 6-323. This route is interposed by a junction that crosses José Gautier Benítez Street. The sidewalks of both segments of this avenue have a continuous width of 60 inches. However, for the first section of sidewalk on this avenue there is a reduction in the width of the sidewalk to less than 20 inches due to power lines and signs that get in the way (Figure 6-324). For the second segment of the avenue, the sidewalks and their width are interrupted by cars parked along the road (Figure 6-325).

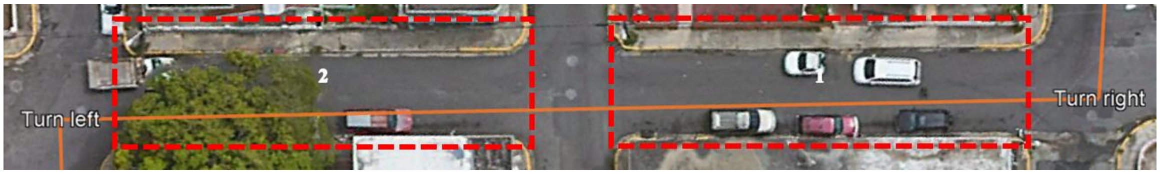


Figure 6-323 Sidewalk on Catalino "Tite" Current Alonso Avenue from the Evacuation Route of Luis Llorens Torres School in Plan View (Google Earth – 2016)

Figure 6-324 First Section of Sidewalk on Catalino "Tite'' Curet Alonso Avenue from the Evacuation Route of Luis Llorens Torres School in Street View (Google Earth – 2016)

Figure 6-325 Second Section of Sidewalk on Catalino "Tite" Curet Alonso Avenue from the Evacuation Route of Luis Llorens Torres School in Street View (Google Earth – 2016)

The sidewalks of this avenue are shown in perfect condition, but they do not meet the width necessary for the eviction process.

The last sidewalk of the route is on Felipe R. Goyco Street, right where the predetermined assembly place is located ("Plaza Antonio R. Barceló") (Figure 6-326). The sidewalk has a constant width of 150 inches. In addition, this sidewalk is not obstructed by power lines or signs. Its only obstacle lies in a power plant that reduces its width to 68 inches on the road (Figure 6-327).

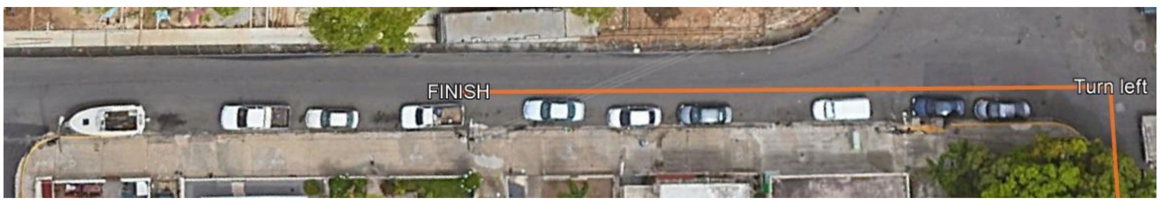


Figure 6-326 Sidewalk on Felipe R. Goyco Street from the Evacuation Route of Luis Llorens Torres School in Plan View (Google Earth – 2016)

Figure 6-327 Sidewalk on Felipe R. Goyco Street from the Evacuation Route of Luis Llorens Torres School in Street View (Google Earth – 2016)

Once the walk on this sidewalk is finished, the route should cross to the right to reach the assembly place.

Of the above Hazard zone signs, which are identified by the area near Luis Llorens Torres school, none are found along the evacuation route from this school. However, near the school there are six evacuation route signs (Figure 6-328) of which only one is on the evacuation route assumed for Luis Llorens Torres school.

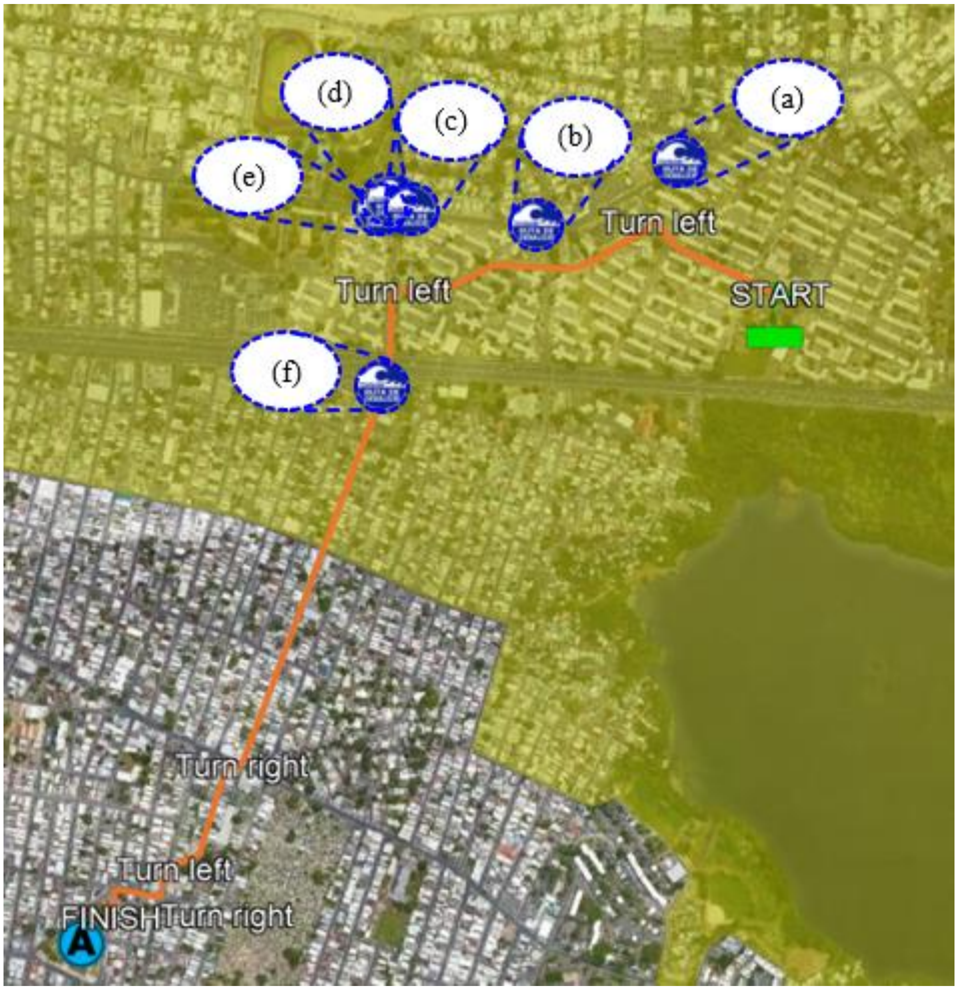


Figure 6-328 Evacuation Route Signs Near the Perimeter of Luis Llorens Torres School (Goole Earth – 2016)

Por Four of the evacuation route signs are located on Loíza Street (PR-37). These are the evacuation route sign (a) (Figure 6-329), sign (b) (Figure 6-330), sign (c) (Figure 6-331), and sign (e) (Figure 6-332). Evacuation route signs (a), (b), and (c) are identified and seen on the highway heading east to west. While the sign (e) is recognized from West to East by the same road.

Figure 6-329 Evacuation Route Sign (a) through Loíza Street Near to Luis Llorens Torres School (Google Earth – 2016)

Figure 6-330 Evacuation Route Sign (b) through Loíza Street Near to Luis Llorens Torres School (Google Earth – 2016)

Figure 6-331 Evacuation Route Sign (c) through Loíza Street Near to Luis Llorens Torres School (Google Earth – 2016)

Figure 6-332 Evacuation Route Sign (e) through Loíza Street Near to Luis Llorens Torres School (Google Earth – 2016)

Figure 6-333 shows the evacuation route sign (d) located along Las Américas Avenue. This shows on the left the front of the sign that is obstructed by a car according to the Google Earth shot. And on the right, it presents the rear of the same sign without any obstruction.

Figure 6-333 Evacuation Route Sign (d) through Las Américas Avenue Near to Luis Llorens Torres School (Google Earth – 2016)

The evacuation route sign (f) is located on Román Baldorioty de Castro Avenue as shown in Figure 6-334. This is in a direction from East to West along the avenue. This is the only sign that is found and can be seen on the evacuation route of Luis Llorens Torres school through Pellín Rodríguez (Providencia Street) in a North to South direction.

Figure 6-334 Evacuation Route Sign (f) through Román Baldorioty de Castro Avenue Near to Luis Llorens Torres School (Google Earth – 2016)

6.4.3 Summary of Evacuation Route Evaluation Results

In the evaluation of evacuation routes in Google Earth, the following was obtained:

- The Francisco Oller school in Cataño has two signs that indicate the evacuation route along the way.
- This school crosses a bridge to reach a safe area, to the place of assembly assumed in Phase III ("Estadio Peruchin Cepeda").
- This school runs 46% of the route parallel to the sea.
- The Luis Llorens Torres school in San Juan only has one sign on the road.
- This school also passes under a bridge but to reach the assumed assembly place, known in the area as "Plaza Barceló".
- This school runs 62% parallel to the sea of the total route.
- Some segments of the routes of both schools are obstructed by vehicles, street furniture and damage to their condition that affects the width available for walking.

6.5 School Form

Google Form was developed and administered to make an analysis of the vulnerability of schools in general (not individually by study municipality). By collecting data from public schools in tsunami hazard zones that includes the year the school was built, the details of the evacuation plan for two stages of evacuation (one to leave the school campus to the internal assembly site and another to exit with the entire school campus to the external assembly site), evacuation times obtained in previous drills, and special cases of the school.

The form was completed by only two schools: one from Cataño and the other from San Juan. Table 6-29 shows the results of said form where the following is summarized:

- Both schools show a varied age range due to their educational level, which affects walking speed for evacuation time.
- Both schools were built before 1987, indicating that they were not built under building codes for seismic events.
- Both have tsunami evacuation plans.
- The evacuation time for the Cataño school is not comparable to that obtained in Phase III, while for San Juan the evacuation time is comparable to the one obtained in the analysis.

Table 6-29 Form Results for Schools in Google Form

	Question		Answer		
1	Municipality		Cataño	San Juan	
			50%	50%	
2	Indicate the educational level of the school		Primary school	Secondary school	High school
			50%	0%	50%
3	When was your school built?		Before 1987	After 1987	
			100%	0%	
4	Have you been oriented about the tsunami hazard for your school?		Yes	No	
			100%	0%	
5	Have you received any training or lectures on tsunami preparedness at your school?		Yes	No	
			100%	0%	
6	Does your school have a tsunami evacuation plan?		Yes	No	
			100%	0%	
7	Has the tsunami warning system at your school been clearly audible?		Yes	No	
			50%	50%	
8	Do you have a student with a physical disability? If so, have you developed special evacuation plans for this population?				
9	There are students with physical disabilities in the school, and special	There are students with physical disabilities in the	There are no students with physical disabilities in the	There are no students with physical disabilities in the	

	evacuation procedures have been developed for this population.	school, and no special evacuation procedures have been developed for this population.	school, and special evacuation procedures have been developed for this population.		school, and no special evacuation procedures have been developed for this population.
	0%	0%	50%		50%
10	Have you practiced the first stage of the tsunami evacuation plan at your school?	Yes		No	
		100%		0%	
11	Please indicate how often you have practiced this first stage of the evacuation plan at your school (Drill).	It has never been practiced	Once every two years	Once a year	Twice a year
		0%	0%	50%	50%
12	What is the name of the internal assembly place, indicated for your school? (The name of the safe place within the school to go to in a tsunami alarm).	In the schoolyard		Backyard close to PR 5 and the third level of the school	
13	If you have practiced the evacuation plan, what was the total time in this first stage in minutes?	00:03:00		01:00:00	
14	What is the name of the outside assembly location indicated for your school? (The name of the safe zone or assembly point outside the school to go to in the event of a tsunami alarm).	"Plaza Barcelo Santurce"		"Parque Perucho Cepeda"	
15	Have you practiced the second stage of the tsunami evacuation plan at your school? (Drill walking with the school campus to the external assembly site).	Yes		No	
		100%		0%	
16	Please indicate how often you have practiced this second stage of the evacuation plan at your school (drill).	It has never been practiced	Once every two years	Once a year	Twice a year
		0%	50%	0%	50%
17	If you have practiced the evacuation plan, what was the total time for this second stage in minutes?	00:08:00		01:00:00	
18	Does your school have a vertical evacuation plan? (An evacuation plan targeting upper floors of the building, high enough to raise the evacuated population above the tsunami flood elevation.)	Yes		No	
		50%		50%	
19	If you have a vertical evacuation plan, indicate which building would be used for this purpose.	The same building as the school campus		Other	
		100%		0%	
20	If you have practiced the vertical evacuation plan, what was the total time for this stage in minutes?	00:02:30		00:45:00	

7 Other Critical Cases

There are other municipalities with critical schools in the tsunami hazard zone, which, although they were not included in the vulnerability analysis of this study, are presented below as other critical cases that may influence the vulnerability of the school. These municipalities are Loíza and Toa Baja. Two arbitrary schools with high vulnerability potential corresponding to each municipality are shown. In other words, one of them is not part of the island's public education system. For both schools, two types of evacuation times are obtained: one arriving at the assembly place and the other leaving the tsunami hazard zone. As in the previous evaluation, the closest assembly location to which to go during the evacuation process is assumed for both schools.

7.1 Medianía Alta Elemental School

Medianía Alta Elemental school is an elementary public school in the educational region of Humacao (Figure 7-1). This school is located at Carr 187 Km 5 Hm 6 Bo Medianía Alta in Loíza, Puerto Rico. Its coordinates are a latitude of 18.4265735 and a longitude of -65.8425056.

Figure 7-1 Medianía Alta Elemental School (Google Earth – 2018)

According to the platform “Busca tu Escuela” for 2020-2021, Medianía Alta Elemental school has a total population of 475 people between 447 students and 28 teachers. It is a school used as a shelter and voting center, which increases the population that could be affected.

The municipality of Loíza does not have assembly places available as shown in the flood and evacuation maps of the Puerto Rico Seismic Network (PRSN). However, around the area the following nearest assembly places are available (Figure 7-2): “Parque de Pelota San Isidro” in Canóvanas, The Oulet 66 Mall Parking in Canóvanas, “Parque de Pelota Ovidio de Jesús” in Río Grande, “Parque de Pelota Río Grande States” in Río Grande and “Parque de Pelota Poblado Palmer” in Río Grande. For the purposes of the closest evacuation route, the “Parque de Pelota Ovidio de Jesús” is used for its evaluation.

Figure 7-2 Location of Assembly Places with Respect to Medianía Alta Elemental School

The evacuation route that leaves the school to reach the nearest assembly place is located beginning on the Loíza - Río Grande Highway (PR-187) in a continuous direction to San Antonio Street. Then turn onto Acasia Street, onto Soledad Street, onto Pimentel Street onto PR-187R. Eventually, it turns onto Marginal Street until it reaches the “Parque de Pelota Ovidio de Jesús” assembly place. With this route, the evacuation time is 1 hour 58 minutes and 48 seconds for an average walking speed (Figure 7-3 and Figure 7-4). Table 7-1 shows the rest of the times for the different walking speeds evaluated.

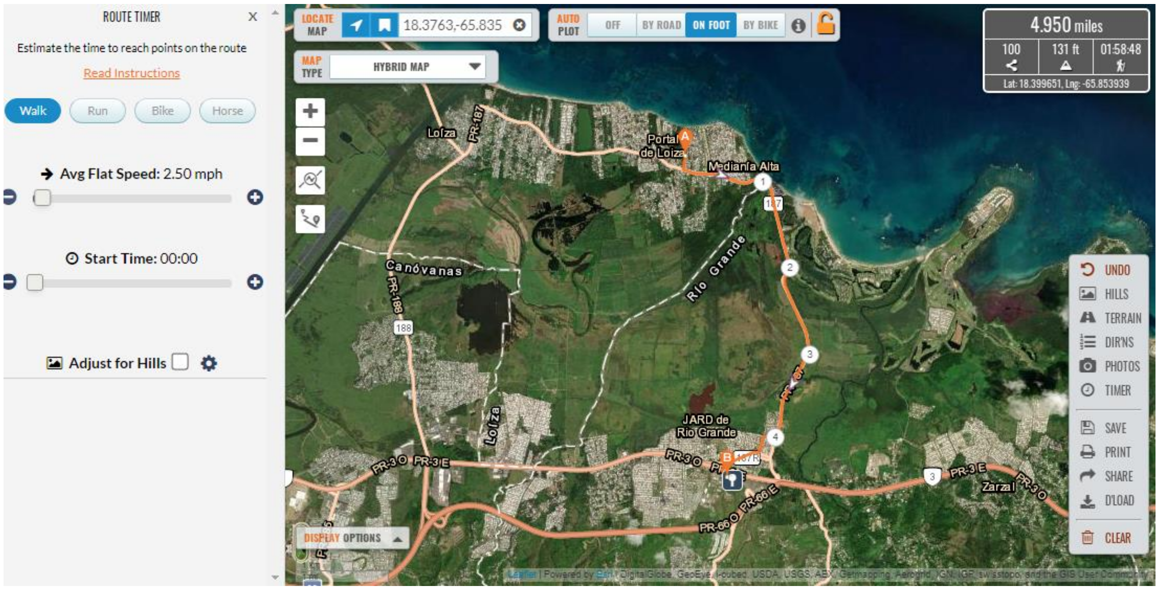


Figure 7-3 Route to Get to the Assembly Place for Average Walking Speed of Medianía Alta Elemental School at Loíza

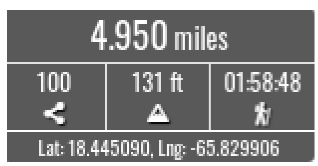


Figure 7-4 Evacuation Time and Route's Distance to Get to the Assembly Place for Average Walking Speed of Medianía Alta Elemental School

Table 7-1 Evacuation Time to Get to the Assembly Place for Every Speed of Medianía Alta Elemental Elementary School at Loíza

Walking Speed (mph)	Evacuation Time (hr:min:sec)
2.46	2:00:44
2.70	1:50:00
3.40	1:27:21
2.50	1:58:48
Distance (miles)	4.950

For the evacuation route until leaving the tsunami hazard zone, follow the same path as for the previous evacuation time. In this case, it only leaves the assembly place at the address 198 Calle San Antonio, Herreras in Río Grande, Puerto Rico. With this route, the evacuation time until leaving the safe place is 1 hour 29 minutes and 21 seconds to an average walking speed (Figure 7-5 and Figure 7-6). Table 7-2 shows the evacuation times for the rest of the walking speeds.

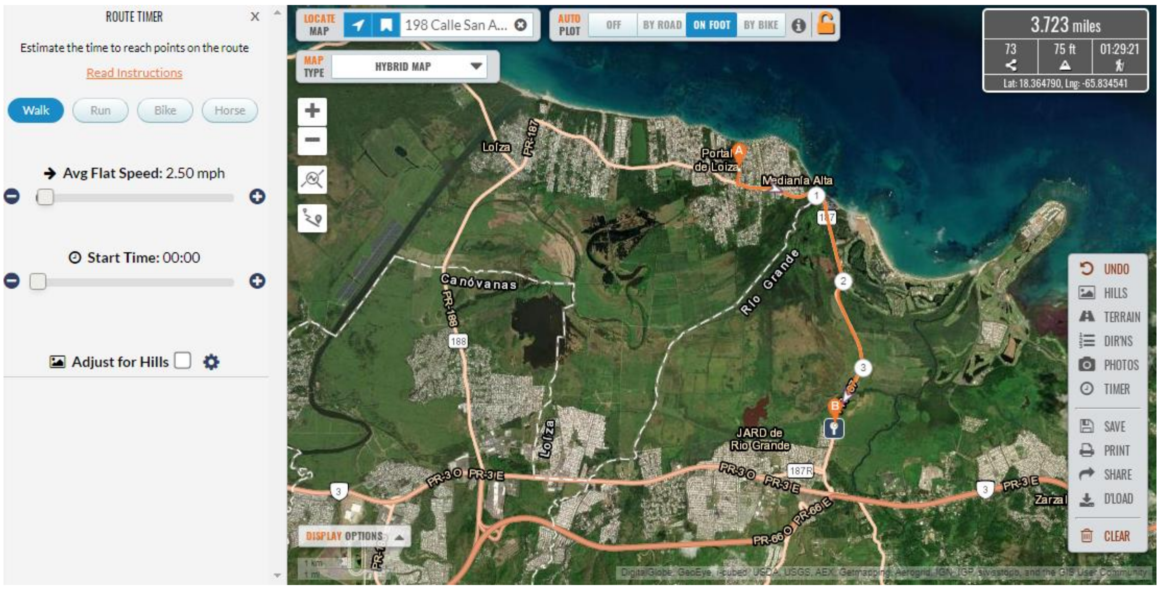


Figure 7-5 Route to Get Out of the Tsunami Hazard Zone for Average Walking Speed of Medianía Alta Elemental School at Loíza

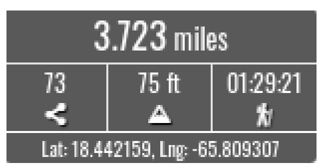


Figure 7-6 Evacuation Time and Route's Distance to Get Out of the Tsunami Hazard Zone for Average Walking Speed of Medianía Alta Elemental School

Table 7-2 Evacuation Time to Get Out of the Tsunami Hazard Zone for Every Speed of Medianía Alta Elemental Elementary School at Loíza

Walking Speed (mph)	Evacuation Time (hr:min:sec)
2.46	01:30:48
2.70	01:22:44
3.40	01:05:42
2.50	01:29:21
Distance (miles)	3.723

Figure 7-7 shows the evacuation route for this school up to the assembly site in orange and out of the tsunami hazard zone in blue.

Figure 7-7 Evacuation Route of Medianía Alta Elemental School at Loíza

7.2 Academia Espíritu Santo Levittown

Academia Espíritu Santo Levittown is a private preschool, elementary and secondary school located at 1454 Paseo Damisela in the town of Toa Baja, Puerto Rico (Figure 7-8). Its physical facilities are located at the coordinates with a latitude of 18.4540806 and a longitude of -66.1800863. For this school its population is unknown. Also, it is not a school used as a voting center or shelter.

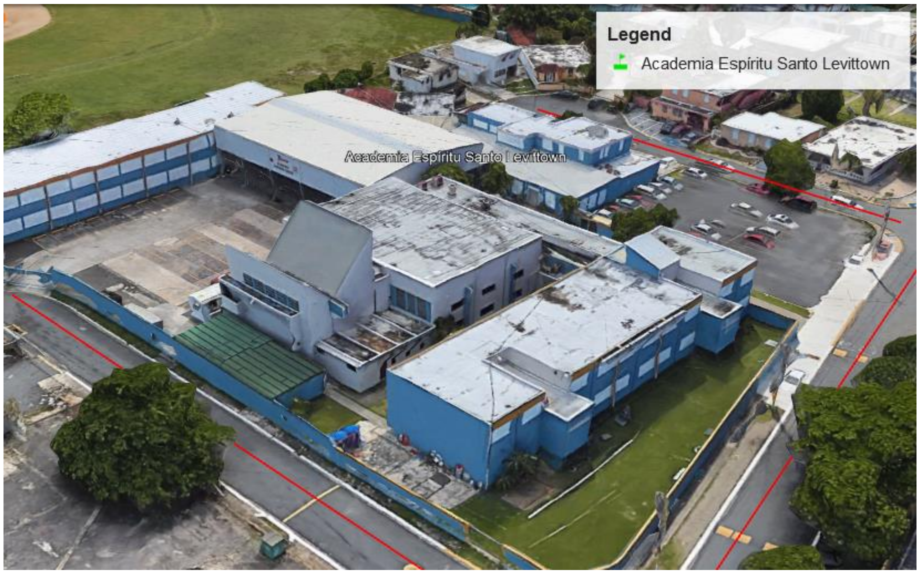


Figure 7-8 Academia Espíritu Santo Levittown (Google Earth – 2018)

For Toa Baja there are five available assembly locations closest to the area. These are "Parque de Pelota de Campanillas", "Parque de Pelota Bo. Ingenio", "Coliseo de Toa Baja (Antonio R. Barceló)" and "Parque de Pelota Sabana Seca" located in Toa Baja, as well as the "Parque de Pelota Res. Palmas" in Cataño (Figure 7-9). The assembly place used for the evacuation route from this school is "Parque de Pelota Sabana Seca".

Figure 7-9 Location of Assembly Places with Respect to Academia Espíritu Santo Levittown

The evacuation route to leave the school and reach the nearest assembly place begins at Paseo Damisela, turns along Marginal Central, and turns onto Paseo Diosa in the direction of Dos Palmas Avenue. Later, it goes through Boulevard Avenue (PR-868), turns onto Los Dominicos Avenue (PR-866) and through Rosa de Francia Street. Then, it turns onto Sabana Seca Avenue, onto Los Bravos Street, and onto Luna Street. With a quick turn along Ramón Ríos Román, it turns towards Aqueduct Street until it reaches Parque Street, where the “Parque de Pelota Sabana Seca” assembly place is located. For this route and with an average walking speed, its corresponding evacuation time is 1 hour 3 minutes and 45 seconds (Figure 7-10 and Figure 7-11). Table 7-3Table 7-1 shows the rest of the times for the different walking speeds evaluated.

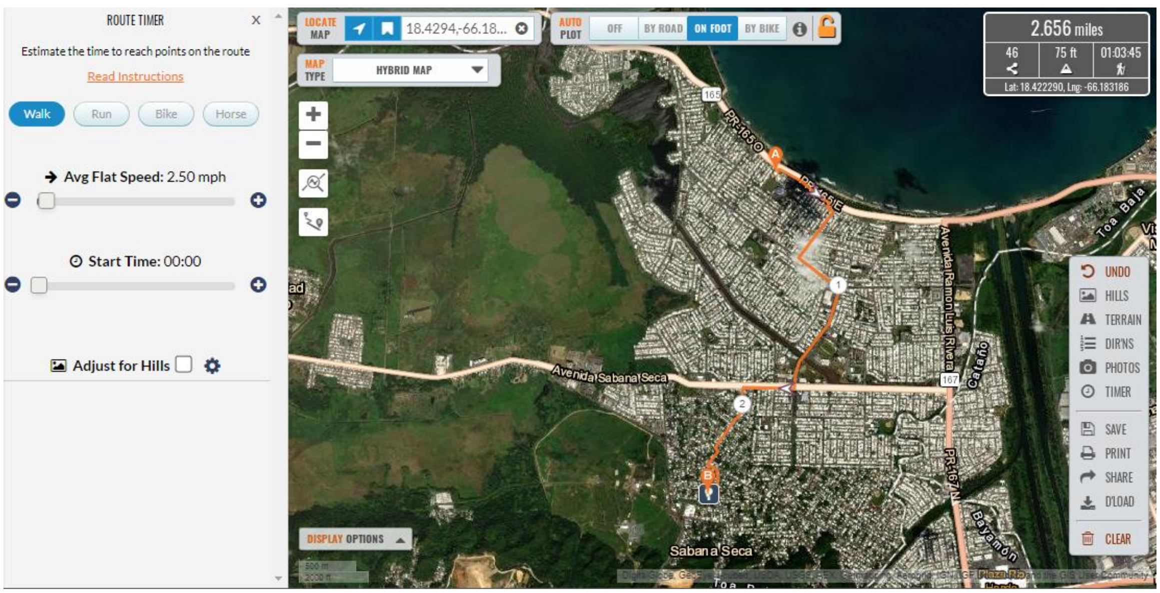


Figure 7-10 Route to Get to the Assembly Place for Average Walking Speed of Academia Espíritu Santo Levittown at Toa Baja

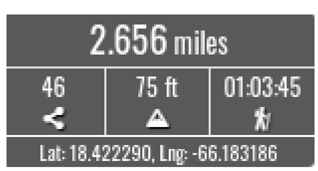


Figure 7-11 Evacuation Time and Route’s Distance to Get to the Assembly Place for Average Walking Speed of Academia Espíritu Santo Levittown

Table 7-3 Evacuation Time to Get to the Assembly Place for Every Speed of Academia Espíritu Santo Levittown at Toa Baja

Walking Speed (mph)	Evacuation Time (hr:min:sec)
2.46	01:04:34
2.70	00:58:49
3.40	00:46:43
2.50	01:03:45
Distance (miles)	2.656

The evacuation route leaving the school out of the tsunami danger zone follows the same path as for the previous evacuation time. In this case, it only leaves the assembly place at 1162 Del Carmen Street in Toa Baja, Puerto Rico. The evacuation times for this route are presented in Table 7-4. For an average walking speed this time turns out to be 50 minutes and 54 seconds (Figure 7-12 and Figure 7-13).

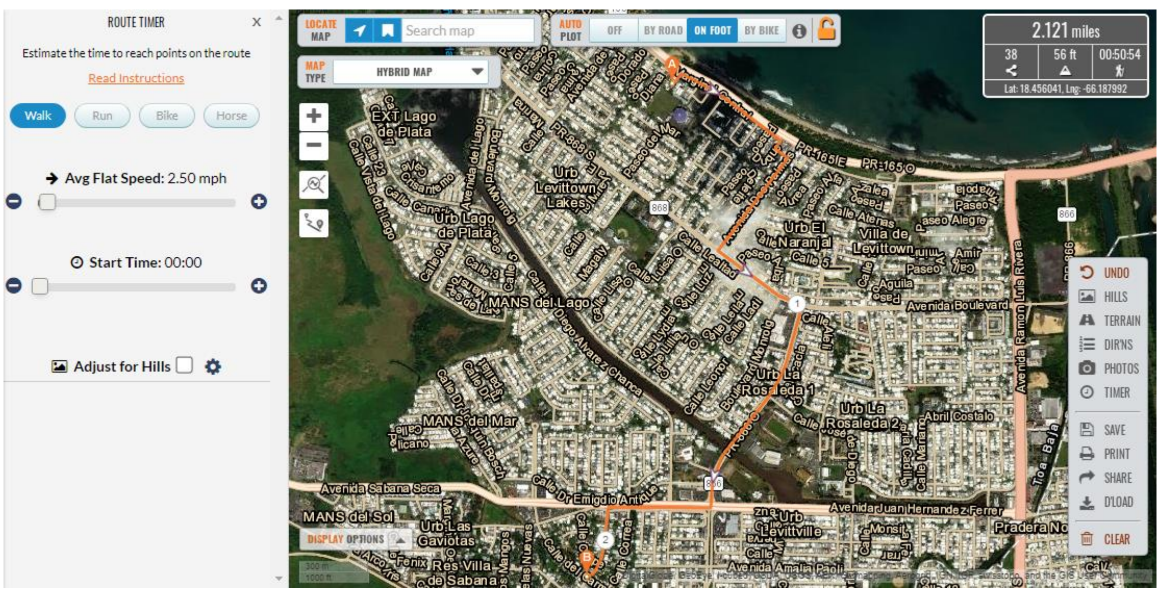


Figure 7-12 Route to Get Out of the Tsunami Hazard Zone for Average Walking Speed of Academia Espíritu Santo Levittown at Toa Baja

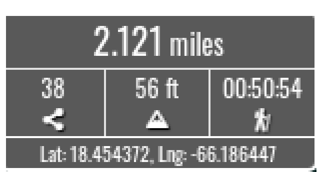


Figure 7-13 Evacuation Time and Route's Distance to Get Out of the Tsunami Hazard Zone for Average Walking Speed of Academia Espíritu Santo Levittown

Table 7-4 Evacuation Time to Get Out of the Tsunami Hazard Zone for Every Speed of Academia Espíritu Santo Levittown at Toa Baja

Walking Speed (mph)	Evacuation Time (hr:min:sec)
2.46	00:51:37
2.70	00:47:02
3.40	00:37:21
2.50	00:50:54
Distance (miles)	2.121

Figure 7-14 shows the evacuation route for this school up to the assembly site in orange and out of the tsunami hazard zone in blue.

Figure 7-14 Evacuation Route of Academia Espíritu Santo Levittown at Toa Baja

7.3 Summary of Findings

From the evaluation of vulnerability due to evacuation times of critical schools in other municipalities of the Island that are not part of the case study, the following is obtained:

- Medianía Alta Elemental school has an evacuation time to leave the hazard zone of 1 hour 29 minutes and 21 seconds. This value is almost twice the greater evacuation time of the schools corresponding to the Luis Llorens Torres school.
- Academia Espíritu Santo Levittown has an evacuation time out of the tsunami hazard zone of 50 minutes and 54 seconds. Although it does not reach twice the value of the higher time that has been seen for other schools, it is a truly critical value.
- Both schools have such long evacuation times, due to the remoteness of the assembly places with respect to the physical facilities of the schools. In the case of the Loíza school, time is the greatest of all and the school is the most critical because the municipality itself does not have an assembly place available. This entails a long journey from a safe zone to other available assembly places in surrounding municipalities.

8 Conclusions, Recommendations and Future Work

The following are conclusions, recommendations, and future work to follow based on the findings of the study.

8.1 Conclusions

The results of the evacuation times indicate that the schools with the longest times to leave the tsunami hazard zone are critical and vulnerable to a tsunami event. These show that schools in San Juan are more vulnerable than schools in Cataño. The characteristics of the evacuation routes evaluated using Google Earth Pro for the two most critical schools are not suitable for transit during the evacuation process due to the criteria used in the evaluation. Because both routes do not meet the evaluation conditions: they do not leave the coast in the shortest possible time, they walk parallel to the sea and cross obstacles that prevent a continuous passage. In this way, Google Earth Pro in conjunction with ArcGIS and PlotARoute are useful to perform analysis and evaluation of the conditions of the characteristics of schools. The results of the forms validate the established assumption regarding the assembly places.

8.2 Recommendations

As a recommendation, it would be ideal to include layers with the geolocation of private schools (not available at the time of this study), stimulating getting the answers from the school that received the Google form, and to extend the study to include all the municipalities with schools in tsunami evacuation areas. Loíza and Mayagüez are considered a high priority. A detailed evaluation of the physical condition of walkways, and their redesign to provide adequate pedestrian transit condition is advisable.

8.3 Future Work

List and describe those aspects of the project with potential for improvement or future areas of research identified during the process.

- Make a more in-depth analysis of the other municipalities that were found to have the most schools in tsunamis hazard zones (Loíza, Mayaguez, Ponce, Salinas y Toa Baja).
- Do a similar study including the private school around the island.
- Make an analysis for the factors that are affecting time and pedestrian flow:
    - Initial gathering time (the time it takes to gather everyone at the first meeting point in the school before heading out to the assembly point).
    - Volume of people (i.e., interaction with flow from other large evacuation groups, walking speed of the masses).
    - Recollection of the traffic data (AADT), in the determined evacuation routes of the schools.
    - Obstacles to the path due to structural failures during earthquake (i.e., bridges, electric lines, etc.).
    - Possible impact of human factors.
- Make and evaluation of the possibility of vertical evacuation.
- Search for studies that assess the available evacuation time, after the tsunami alarm starts.

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10 Appendix

Below are the appendices used for the development of the study.

Appendix A: List of Schools

The general list of all schools can be found for each municipality. This list includes both those that are and are not in the tsunami danger zone. It also includes those schools that are closed.

A.1 Aguada

Anselmo Villarrubia
Aquilino Caban
Arsenio Martínez
Centro Vocacional Especial
Dr. Carlos González
Eladio Tirado López
Eugenio González González
Gregorio Rodríguez Orama
José González Ruiz
Juan L. Santiago
Lydia Meléndez
Manuel Morales Feliciano
María L. Jiménez López
Profesora Juana Rosario Carrero (Escuela Intermedia Nueva)
R.P. Pablo Gutiérrez Flores
Su Epifanio Estrada
Su Juan B. Soto
Zoilo Cajigas Sotomayor

A.2 Aguadilla

Ana M. Javariz
Antonio Badillo Hernández
Antonio Badillo Hernández
Barriada Caban
Benito Cerezo Márquez
Centro De Adiestramiento Y Bellas Artes
Dr. Agustín Stahl
Eladio J. Vega
Ester Feliciano Mendoza
Extensión Borinquen
Homero Rivera Sola
José Acevedo Álvarez
José De Diego
José De Diego
Juan Suarez Pelegrina (Nueva)
Lucia Cubero
Luis Muñoz Rivera
Rafael Cordero
Rafael Fabian

Ramon Rodríguez
Salvador Fuentes
Su Conchita Iguartua De Suarez (Su Adams)

A.3 Añasco

Antonio González Suarez (Especializada)
Carmen Casasús Martí (Elem Urbana)
Escuela Especializada Bilingüe Alcides Figueroa
Espino
Isabel Suarez
Luis Muñoz Marín
Mariana Bracetti
Ovejas
Parcelas María
Su Playa

A.4 Arecibo

Abelardo Martínez Otero
Centro Pre-Voc. José Limón Arce
Cotto Anexo
Dolores Gómez De Román
Dr. Cayetano Coll Y Toste
Dra. María Cadilla De Martínez
Elba Lugo Carrión (Especializada)
Elemental Nueva (Factor V)
Escuela De Bellas Artes (Especializada)
Escuela Libre De Música (Especializada)
Félix Rosario Ríos
Francisco G. Pachín Marín
John W. Harris
Jose Gualberto Padilla
Julio Seijo
Luis Muñoz Marín
Su Enrique De Jesús Borras
Su Eugenio María De Hostos
Su Federico Degetau
Su Manuel Ruiz Gandía
Su Ramon E. Betances
Superior Vocacional (Antonio Luchetti)
Trina Padilla De Sanz
Víctor Rojas 1

A.5 Arroyo

Adalberto Sánchez Morales (Elem. Bo. Ancones)
Cayetano Sánchez
Dolores González
Enrique Huyke
José De Choudens
José Horacio Cora
José M. Massari
Su Nueva Bo. Medianía

A.6 Barceloneta

Agustín Balseiro
Dr. Francisco Vázquez
Easton
Fernando Suria Chávez
Imbery
José Cordero Rosario
Nueva Intermedia
Primitivo Marchand
Vicente Acevedo Ballester

A.7 Bayamón

Andrés C. González
Ángel Millán Huertas
Arturo Somohano
Aurelio Pérez Martínez
Bernardo Huyke
Braulio Dueño Colón
Cacique Agüeybaná
Carlos Orama Padilla
Carmen Gómez Tejera
Cristóbal Colón
Diego De Torres Vargas
Dolores Álvarez Montañez
Dr. Agustín Stahl
Dr. Hiram González
Dr. José A. Padín
Dr. Santos J. Sepúlveda
Epifanio Fernández Vanga
Faustino Santiago Montalvo
Francisco Gaztambide Vega
Francisco Manrique Cabrera
Intermedia Rexville
Jesús Sánchez Erazo
José Andino Y Amézquita
José Campeche
José Dávila Esprit
José Julián Tapia De La Rosa
José M. Torres
Josefina Barceló
Juan Morell Campos
Juan Ramon Jiménez
Julio Ressy
Ludovico Costoso
Luis Pales Matos
María E. Bas De Vázquez
María E. Rodríguez
María Vázquez De Umpierre
Mariano Feliu Balseiro
Marta Vélez De Fajardo (Especializada)
Miguel De Cervantes Saavedra

Miguel Meléndez Muñoz
Noel Estrada
Nueva Escuela Su De Bayamón
Pablo Casals
Padre Rufo M. Fernández
Papa Juan XXIII
Papa Juan XXIII
Pedro P. Casablanca
Rafael Colon Salgado
Rafael Hernández
Rafael Martínez Nadal
Ramon Morales Pena
Raúl Julia (Flamboyán Gardens)
Rexville Elemental
Su Cacique Majagua
Tomas C. Ongay
Virgilio Dávila

A.8 Cabo Rojo

Carlota Matienzo
Inés María Mendoza De Muñoz Marín
James Garfield
Luis Muñiz Souffront
Manuel Fernández Juncos
Monserrate León De Irizarry
Pedro Fidel Colberg
Pedro Nelson Colberg
Ramon E. Betances
Sebastián Pabón Alves (Corozo)
Segunda Unidad Bo Puerto Real
Severo E. Colberg Ramírez
Su Antonio Acarron Correa
Su Carmen Vignals Rosario
Su Federico Degetau

A.9 Camuy

Amalia López De Ávila
Antonio Reyes
Intermedia Román Baldorioty De Castro
José M. Hernández
Laurentino Estrella Colon
Luis F. Crespo (Sup. Nueva)
Luis Felipe Rodríguez García
Pablo Ávila González
Pedro Amador
Ralph W. Emerson
Su Joaquín Vázquez Cruz
Su Santiago R. Palmer

A.10 Canóvanas

Antonio R. Barceló

Domingo Nieves Ortiz (Palma Sola)
Dr. Pedro Albizu Campos
Georgina Baquero
José Calzada Ferrer
José Santos Quiñonez
Juana Rodríguez Mundo
Julia De Burgos
Las Parcelas De Campo Rico
Luis Hernaiz Veronne
Luis Muñoz Marín
Manuel Agosto Lebrón
William Rivera Betancourt (Bo San Isidro Vocacional)

A.11 Carolina

Agustín Cabrera
Amalia Expósito
Ángel P. Millán Rohena
Carlos F Daniels (Voc. De Área)
Cruz Salguero Torres
Dr. Clemente Fernández
Dr. José M. Lázaro
Dr. Modesto Rivera Rivera
Dr. Ramon Mellado Parsons
Eduardo J. Saldana
Francisco (Prisco) Fuentes
Francisco Matías Lugo
Gilberto Concepción De Gracia
Jesús Manuel Suarez
Jesús María Sanroma
Jesús Rivera Bultron
Jesús T. Pinero
José Severo Quiñones
Juana A Méndez (Metrópolis)
Julia De Burgos
Lorenzo Vizcarrondo
Luis Muñoz Marín
Luis Muñoz Rivera
Luz América Calderón
Manuel Febres González
María López Ponce
María Teresa Serrano
Martin González
Pascasio P. Sancerrit
Pedro J. Rodríguez Oquendo
Pedro Moczo Baniet
Rene Marques
Roberto Alberty (Cacao Centro)
Roberto Clemente
Rvdo. Félix Castro Rodríguez
Salvador Brau
Su Carlos Conde Marín

A.12 Cataño

Elisa Dávila Vázquez (Espinosa Adentro)
Francisco Oller
Horace Mann
Isaac Del Rosario
José A. Nieves
Mercedes García De Colorado
Onofre Carballeira
Puente Blanco
Rafael Cordero
Ramon B. López
Rosendo Matienzo Cintrón
Teodoro Roosevelt

A.13 Ceiba

Centro Residencial De Oportunidades Educativas De Ceiba
Don Luis Muñoz Marín (Elemental Urbana Nueva)
Intermedia Nueva
Parcelas Aguas Claras
Santiago Iglesias Pantín

A.14 Culebra

Ecológica De Culebra

A.15 Dorado

Cristóbal Santana Melecio (Nueva)
Elemental Alfonso López García
Elemental Bo Huguillar (Ecológica)
Espinosa Kuilan
Jacinto López Martínez
José Santos Alegría
Luis Muñoz Rivera
Luisa M. Valderrama (San Antonio)
Marcelino Canino Canino
Pedro López Canino
Ricardo Arroyo Laracuente
Teresa Préstamo

A.16 Fajardo

Ana Delia Flores Santana Voc.
Antonio Valero Bernabé
Berta Zalduondo
Dr. Santiago Veve Calzada
Gabino Soto
Inés Encarnación
Josefina Ferrero
María I. Dones
Pedro Rosario Nieves
Ramon Quiñones Pacheco
Rosa Pascual París

A.17 Guánica

Agripina Seda
Aurea E. Quiles Claudio
Ceferino Colon Lucca
Elsa E. Couto Annoni
Fraternidad
Luis Muñoz Rivera
Magueyes
María L. McDougal
Olga Evangelina Colón Torres (La Luna)

A.18 Guayama

Adela Brenes Texidor
Amalia Marín
Bartolo Caussade González
Beatriz Rodríguez
Dr. Rafael López Landrón
Dra. María Socorro Lacot
Francisco García Boyrie
Genaro Cautino
Jorge Washington II
José Muñoz Vázquez
Luis A. Rivera
Marcela García Cora
Oscar Hernández Guevarra
Rafael Antonio Delgado Mateo
Simón Madera
Su Juan Alemany Silva
Vicente Pales Anes
Washington I

A.19 Guayanilla

Arístides Cales Quirós
Asunción Rodríguez De Sala
Consejo
Dalila Torres
Francisco Rodríguez López
Gloria María Borrero Oliveras (Segunda Unidad Bo. Macana)
Hipólito García Borrero
Padre Nazario
Quebradas

A.20 Guaynabo

Alejandro Jr. Cruz
Betty Rosado De Vega
Hato Nuevo
Josefina Barceló
Juan E. Miranda
Juan Ponce De León (Especializada)

Juan Román Ocasio
Juanillo Fuentes
Luis Muñoz Rivera 1
Luis Muñoz Rivera 2
Margarita Janer Palacios
Mariano Abril Intermedia
Nueva Elemental Urbana De Guaynabo
Rafael Martínez Nadal
Ramon Marín Sola
Rosalina C. Martínez
Santa Rosa III
Su Rafael Hernández

A.21 Hatillo

Adrián Martínez Gandía
Carmen Noelia Peraza Toledo
Eugenio María De Hostos
Joaquín Rodríguez Ruiz
José Gautier Benítez
Lorenzo Coballes Gandía
Luis Meléndez Rodríguez
Luis Muñoz Rivera
Padre Aníbal Reyes Belén (Sup. Nueva)
Rosa E. Molinari
Su Rafael Zamot Cruz
Timoteo Delgado

A.22 Humacao

Adrián Medina
Ana Roque de Duprey
Antonia Sáez
Antonio Rosa Guzmán (Bo. Mariana)
Braulio Ayala Pérez (Mambiche Blanco)
Cándido Berrios
Carlos Rivera Ufret
Carmen Pilar Santos
Dr. Víctor Rincón
Escuela Especializada Bellas Artes de Humacao
Escuela Libre de Música Humacao (Especializada)
Juan Ponce de León (Especializada)
Lidia Fiol Scarano
Luz a Cruz de Santana
Manuel Surillo
Pepita López
Petra Mercado Bougart
Rufino Vigo
Su Agapito López Flores
Su Cruz Ortiz Stella
Su Luciano Ríos
Su Rosa María Rosario de León

A.23 Isabela

Antonio Geigel Paredes
Benjamín Corchado Juarbe
Dr. Heriberto Doménech
Elemental Ceferina Cordero
Epifanio Estrada
Francisca Chávez (La Planta)
Francisco Mendoza
Gloria González (Las Cruces)
Gracielina Rosado Alfaro
Irma Deliz De Muñoz
José C. Rosario
José Julián Acosta
Juan B. Huyke
Luis Muñoz Rivera
Manuel Corchado Y Juarbe
Mateo Hernández
Nicandro García
Su José A Vargas

A.24 Juana Díaz

Carmen Belén Veiga
Carmen Flores
Dr. Máximo Donoso Sánchez
Dr. Pedro Albizu Campos
Francisco Prado Picart
Intermedia Salvador Busquets
José A. González
Juan Serapio Mangual
Luis Llorens Torres
Luis Muñoz Marín
Pedro Colon Santiago
Santiago Collazo Pérez
Su Tomas Carrión Maduro
Su Zoilo Gracia

A.25 Lajas

Alejandro Tapia y Rivera
Antonio Pagan
Elemental Urbana Nueva
Leónides Morales Rodríguez
Luis Muñoz Rivera
Mario F. Pagan Irizarry (Sta Rosa)
Ramon Olivares
Rosendo Matienzo Cintrón
Su Juan Cancio Ortiz de La Renta

A.26 Loíza

Belén Blanco de Zequeira
Carlos Escobar López
Celso González Vaillant

Emiliano Figueroa Torres
Guillermina Rosado de Ayala
Jobos
Medianía Alta Elemental
Nueva Superior de Loíza (Super Vocacional)
Parcelas Vieques

A.27 Luquillo

Camilo Valles Matienzo
Pablo Suarez Ortiz
Pitahaya
Rafael N. Coca
Rosendo Matienzo Cintrón
Su Alejandrina Ríos (Su Sábana)
Superior Isidro A. Sánchez

A.28 Manatí

Antonio Vélez Alvarado
Augusto Cohen
Clemente Ramírez Arellano
Cruz Rosa Rivas
Evaristo Camacho
Félix Córdova Dávila
Fernando Callejo
Francisco Menéndez Balbane
Jesús T. Pinero
José A. Montañez Genaro (Voc. Área)
Juan A. Sánchez Dávila
Micaela Escudero
Nueva Juan S. Marchand
Petra Corretjer De O'Neill
Teodomiro Taboas

A.29 Maunabo

Alfonso Casta Martínez
Calzada
Elemental Urbana
Manuel Ortiz Suya
Su Higinio Figueroa Villegas
Wilfredo Lafuente Ortiz

A.30 Mayagüez

Castillo
Centro Residencial De Oportunidades Educativas De Mayagüez
Charles T. Irizarry
Concordia
Cuesta De Piedras
David G. Farragut
Dr. Pedro Perea Fajardo
Dr. Silverio Medina Gaud (Consumo)

Elpidio H. Rivera
Esteban Rosado Báez
Eugenio María De Hostos (Superior)
Felisa Rincón De Gautier (Su Limón)
Francisco Vicenty
Franklin D. Roosevelt
Jose Gautier Benitez
La Soledad
Libre De Música Y Bellas Artes Ernesto Ramos Antonini
Luis Muñoz Rivera
Manuel A. Barreto
María Dolores Faría
María Luisa Arcelay
Mariano Riera Palmer
Miradero 2
Olga Mas Ramírez
Rafael Cordero Molina
Rafael Martínez Nadal
Rio Canas Abajo
Rio Canas Arriba
Sabanetas Maní
Segundo Ruiz Belvis
Theodore Roosevelt

A.31 Naguabo

Desiderio Méndez Rodríguez (Maizales)
Eugenio Brac
Fermín Delgado Diaz (Su Bo Peña Pobre)
Fidelina Meléndez Monsanto
José R. Agosto
Lutgarda Rivera Reyes (Florida)
Lydia M López (Peña Pobre Parcelas)
Quebrada Grande
Su Silverio García

A.32 Patillas

Cecilio Lebrón Ramos
Cirilo Santiago Plaud
Guillermo Riefkhol
Josefina Muñoz De Bernier
Lamboglia
María Dávila Semidey
María Milagros Ortiz García (Jacaboa)
Marín Abajo
Rafaelina E. Lebrón Flores
Su Joaquín Parrilla
Tomas Vera Ayala

A.33 Peñuelas

Adolfo Grana Rivera
Elemental Tallaboa Alta

Elemental Tallaboa Alta
Felipe Quiñones
Intermedia Ramon Pérez Purcel
Miguel González Bauzá
Rafael Irizarry Rivera
Ramon Pérez Purcell
Su Jorge Lucas Valdivieso
Tallaboa Poniente
Webster

A.34 Ponce

Abraham Lincoln
Andrés Grillasca Salas
Ángela Cordero Bernard
Anselmo Rivera Matos
Antonio Paoli
Aurea E. Rivera Collazo
Bellas Artes De Ponce (Especializada)
Bernardino Cordero Bernard
Bethzaida Velázquez Superior
Carmen Sola De Pedreira
Cerrillos Hoyos
Dr. Alfredo M. Aguayo
Dr. Pedro Albizu Campos
Dr. José Celso Barbosa
Dr. Pila
Dr. Rafael Pujals
Eduardo Neumann Gandía
Ernesto Ramos Antonini
Eugenio Le Compte Benítez
Eugenio María De Hostos
Federico Degetau Y González
Fernando Luis Malavé Olivera
Francisco Parra Duperon
Hemeterio Colón
Herminia García
Intermedia Juan Serralles
Ismael Maldonado Lúgaro
Jaime L. Drew
Jardines De Ponce
Joaquín Ferran
Josefina Boyá León
Juan Cuevas Aboy
Juan Morell Campos (Música)
Juan Morell Campos Elemental
Julia Cordero Negrón
Julio Alvarado
Julio Collazo Silva
Las Monjitas
Librado Net
Lila María Mercedes Mayoral
Lizzie Graham
Llanos Del Sur

Lucy Grillasca
Luis Muñoz Rivera II
Manuel González Pato
Parcelas Magueyes
Parcelas Marueño
Parcelas Real
Ponce High School
Ramiro Colón Colón
Ramon Marín
Rodulfo Del Valle
Santa Teresita
Sor Isolina Ferre (Villa Del Carmen)
Su Barrio Sabana Hoyos (Nueva)
Superior Jardines De Ponce
Superior Juan Serrales
Thomas Armstrong Toro
Tomas Carrión Maduro

A.35 Quebradillas

Dr. Pedro Albizu Campos
Juan Alejo Arizmendi
Manuel Ramos Hernández
Ramon Ávila Molinari
Ramon Emeterio Betances
Ramon Saavedra
Su Eugenio María De Hostos
Su Honorio Hernández
Su Luis Muñoz Rivera

A.36 Rincón

Conrado Rodríguez
Genoveva Pérez
Jorge Seda Crespo
Manuel García Pérez (Nueva)
Manuel González Melo
Octavio Cumpiano

A.37 Río Grande

Rosa Bernard
Casiano Cepeda Pre Vocacional
Casiano Cepeda (Intermedia)
Julio Millán Cepeda
Edmundo Del Valle Cruz
Liberata Iraldo (Nueva)
Antera Rosado Fuentes
Pedro Falú Orellano
Rafael De Jesús
Casiano Cepeda (Superior)
Félix Sánchez Cruz
Carmen Feliciano Carrera (Intermedia Bo Palmer)
Rafael Rexach Dueño

A.38 Salinas

Ana Hernández Usera (Coquí - Elemental)
Coquí Intermedia
Eugenio Guerra Cruz
Félix Garay Ortiz
Francisco Mariano Quiñones
Guillermo González (Playita)
José Padín
Las Mareas
Pedro Soto Rivera
Rafael Esparra Cartagena
Román Baldorioty De Castro
Stella Márquez
Su Sabana Llana
Su Urbana Salinas
Superior Urbana
Victoria Santiago Colón (Quebrada)
Woodrow Wilson

A.39 San Juan

Abelardo Díaz Alfaro
Abraham Lincoln
Albert Einstein
Alejandro Tapia Y Rivera
Alfred Sorensen El
Amalia Marín
Amalia Marín
Amanda Garza-Peña El
Ana Roque De Duprey
Ángel Ramos
Ángeles Pastor (San Martin)
Antonia B. Caimary
Antonio Sarriera Egozcue
Arnoldo Cantú Sr El
Austin Middle
Bella Vista
Bolívar Pagan
Carmen Gómez Tejera
Carmen Sanabria De Figueroa
Central Artes Visuales (Especializada)
Centro Eugenio María De Hostos
Dr. Antonio S. Pedreira (Especializada)
Dr. Cesáreo Rosa Nieves
Dr. Facundo Bueso
Dr. Francisco Hernández Y Gaetan
Dr. Isaac González Martínez
Dr. José Celso Barbosa
Dr. José Celso Barbosa
Dr. José Gualberto
Dr. José N. Gándara
Dr. Julio J. Henna

Dra. Antonia Sáez
Drs Reed - Mock El
Edith & Ethel Carman El
El Señorial
Elemental Berwind
Elemental Nueva
Eleonor Roosevelt
Elvis J. Ballew H S
Emilio B. Huyke
Emilio Castelar
Emilio Del Toro Cuevas
Ernesto Ramos Antonini
Ernesto Ramos Antonini (Música)
Eugenio María De Hostos
Evaristo Rivera Chevremont
Federico Asenjo (Pre-Técnica)
Felipe Gutiérrez
Fray Bartolomé De Las Casas
Gabriela Mistral
Gaspar Vilá Mayans
Gerardo Selles Sola
Gustavo A. Bécquer
Haydee Rexach
Idea Academy San Juan
Idea College Preparatory San Juan
Inés M. Mendoza Vda De Muñoz Marín
Instituto Loaiza Cordero
Intermedia Berwind
Jaime Rosario (Buena Vista Elemental)
Jardines Del Paraíso
Jesús María Quiñones
John Doedyns El
José Colomban Rosario
José F. Diaz
José Julián Acosta (Teatro)
José M. Rivera Solís
Juan Antonio Corretjer
Juan José Osuna (Especializada)
Juan Ponce De León
Juan Ramon Jiménez
Juanita García Peraza
Julián E. Blanco (Ballet)
Julio Selles Sola
La Esperanza (Luis Pales Matos)
Las Américas
Las Mercedes
Las Virtudes
Lcdo. Guillermo Atiles Moreau
Luis Llorens Torres
Luis Muniz Souffront
Luis Muñoz Rivera
Luis Muñoz Rivera
Luis Rodríguez Cabrero
Luz Eneida Colon (La Cumbre)

Madame Lucchetti
Manuel A. Pérez
Manuel Boada
Manuel Cuevas Bacener
Manuel Elzaburu Vizcarrondo
Martin G. Brumbaugh
Miguel Such
Moises Meléndez
Nemesio R. Canales I
New El 133
Pachin Marin
Padre Rufo (Bilingüe)
Pedro C. Timothee Anexo
Pedro Carlos Timothee
Premier H S of San Juan
Peja Early College H S
R Yzaguirre Middle
Rafael Cordero
Rafael Hernández
Rafael Hernández Marín
Rafael María De Labra
Rafael Quiñones Vidal
Rafael Rivera Otero
Ramón Power Y Giralt
Ramón Vila Mayo
República De Brasil
República De Colombia
República De México
República Del Perú
Sabana Llana
San Agustín
Santiago Iglesias Pantin
Santiago Iglesias Pantin
Santiago Iglesias Pantin
Segundo Ruiz Belvis
Sgt. Leonel Trevino El
Sofia Rexach
Sotero Figueroa
Su Dr. Arturo Morales Carrión
Superior Berwind
Tomas Carrión Maduro
Trina Padilla De Sanz
University Gardens (Especializada)
Víctor Parez Collazo
Vida N Clover El
Villa Capri
Villa Granada
William D. Boyce

A.40 Santa Isabel

Ana L Rosa Tricoche (Velázquez)
Ana Valldejuly (Jauca)
Apolonia Valentín (Felicia)

Elvira M. Colon Negrón
Emilio Casas (Peñuelas)
Esther Rivera (Paso Seco)
John F. Kennedy
Manuel Martin Monserrate
Martin G. Brumbaugh
Pedro Meléndez Santiago

A.41 Toa Baja

Adolfina Irizarry De Puig
Altinencia Valle
Amalia López De Vila
Antonia Sáez Irizarry
Basilio Milán Hernández
Carmen Barroso Morales
Delia Dávila De Caban
Dr. Pedro Albizu Campos
Dr. Efraín Sánchez Hidalgo
Ernestina Bracero
Ernesto Juan Fonfrias Rivera
Francisca Dávila Semprit
John F. Kennedy
José Nevárez López
José Robles Otero
Lorencita Ramírez De Arellano
Luis M. Santiago
María J. Corredor Rivera
María Teresa Piñero
Martin García Giusti

A.42 Vega Alta

Antonio Paoli
Apolo San Antonio
Elemental Urbana
Francisco Felicie Martínez (Su Brenas)
Ignacio Miranda
Ileana De Gracia (Sup. Urbana)
José D. Rosado (Bajura Almirante)
José Pagan De Jesús (Elemental Bo Sabana Hoyos)
Ladislao Martínez
Rafael Hernández
Su Adelaida Vega

A.43 Vega Baja

Agapito Rosario Rosario
Almirante Sur 2
Ángel Sandín Martínez
Centro Comunal
Centro De Adiestramiento
Dr. Jesús M. Armaiz
Eugenio María De Hostos

Fernando Rosario Vazquez
José Gualberto Padilla
Juan Quirindongo Morell (Superior)
Lino Padro Rivera
Manuel Martínez Dávila
Manuel Negrón Collazo I
Manuel Padilla Dávila
Nueva Brígida Álvarez Rodríguez
Ofelia Diaz Rodríguez
Rafael Hernández
Rosa M. Rodríguez
San Vicente
Su Almirante Norte

A.44 Vieques

20 De Septiembre De 1988
Adrianne Serrano
German Rieckehoff
María M. Simmons De Rivera

A.45 Yabucoa

Cristóbal Del Campo
Jaime C. Rodríguez
José F. Cintrón Y Anexo
Juan B. Huyke
Luis Muñoz Marín
Marta Sánchez (Guayabo)
Ramon Quiñones Medina
Rosa Costa Valdiveso
Rosa Sánchez Vargas
Su Andrés Sandín Martínez
Su Asunción Lugo
Su Jesús T. Sanabria Cruz
Su Manuel Ortiz
Su Marcos Sánchez
Su Rogelio Rosado (Su Playita)
Teodoro Aguilar Mora

A.46 Yauco

Almácigo Bajo I Y II
Ana María Negrón
Arturo Lluberas
Benicia Vélez
Doris Martínez (Almácigo Alto 2)
Elvira Vicente
Ernesto Ramos Antonini
Inés María Mendoza
José Onofre Torres Fermoso
Loaiza Cordero Del Rosario
Luis A. Ferre Aguayo
Luis Muñoz Rivera

Patria Pérez
Rafael Martínez Nadal
Santiago Negroni
Su Jaime Castaner
Superior Ocupacional Y Técnica De Yauco