Community Based Climate Adaptation Plan for Rincón Municipality, Puerto Rico

PROGRAMA DE MANEJO ZONA COSTANERA

Submitted by:

TETRA TECH

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Community Based Climate Adaptation Plan for Rincón Municipality, Puerto Rico

Volume 1 – Site Description and Initial Stakeholder Outreach and Engagement Report

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The Plan was written by Tetra Tech, Inc., led by Hope Herron and Fernando Pagés Rangel, with support from Cenilda Ramírez, Bill Bohn, Antonio Fernández-Santiago, Jaime R. Calzada, and Christian Hernández Negrón. The report was prepared with the guidance and direction of Ernesto Díaz, Director of CZMP-DNER and Director of PRCCC, with substantial contributions and input from Vanessa Marrero Santiago, Project Manager, DNER.

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Key Terms and Concepts

Key Concepts and Terms

Adapt, adaptation: "Adjustment in natural or human systems to a new or changing environment that exploits beneficial opportunities or moderates negative effect."*

Climate: The weather averaged over a long period of time, typically 30 years or more.**

Climate change: "A change in the state of the climate that can be identified (e.g., using statistical tests) by changes in the mean and/or the variability of its properties that persist for an extended period, typically decades or longer."**

Hazard: "The potential occurrence of a natural or human-induced physical event or trend or physical impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems, and environmental resources."**

Resilience: "A capability to anticipate, prepare for, respond to, and recover from significant multi-hazard threats with minimum damage to social well-being, the economy, and the environment."*

Risk: "A combination of the magnitude of the potential consequence(s) of climate change impact(s) and the likelihood that the consequence(s) will occur."*

Vulnerability: "The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its ability to adapt."*

Weather: The atmospheric conditions at a particular place in terms of air temperature, pressure, humidity, wind speed, and rainfall. Weather is what is happening now or is likely to happen in the very near future.

* National Research Council (NRC). *America's Climate Choices: Panel on Adapting to the Impacts of Climate Change*. National Academy of Sciences, 2010. p. 19. www.nap.edu/catalog.php?record_id=12783.

** Agard, J., E.L.F. Schipper, J. Birkmann, M. Campos, C. Dubeux, Y. Nojiri, L. Olsson, B. Osman-Elasha, M. Pelling, M.J. Prather, M.G. Rivera-Ferre, O.C. Ruppel, A. Sallenger, and K.R. Smith, A.L. St. Clair, Eds. "Annex II: Glossary". *In IPCC, 2014: Climate Change 2014: Impacts, Adaptation, and Vulnerability.* [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L.White (Eds.)]. Cambridge University Press, Cambridge, UK. http://www.ipcc.ch/report/ar5/wg2/.

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1.0 INTRODUCTION

As a municipality located directly on the northwest coast of Puerto Rico, Rincón is sensitive to natural hazards such as hurricanes, extreme precipitation events, and coastal storm surges. Additionally, Rincón is experiencing long-term erosion, which has accelerated in recent years and further increased the municipality's vulnerability to natural hazards. Climate change is expected to exacerbate current challenges and could present new risks to Rincón.

Puerto Rico's Coastal Zone Management Program (PRCZMP), Department of Natural and Environmental Resources (DNER), initiated this study to address the need to better understand how to assess and address climate change related risks to Puerto Rico's municipalities. Pursuant to Section 309 (§309) of the Coastal Zone Management Act (CZMA), PRCZMP completed its Assessment and Strategies report for fiscal period 2011-2015. The report identified: (1) the need for local mitigation strategies, for the prevention of increment of sea level, (2) strategies for adapting to climate change effects, and (3) vulnerability analysis and integration of risk data into local plans, regulations, projects, policies, management plans for special areas, and disaster risk mitigation plans. PRCZMP designed a program to work with local municipalities to better understand their vulnerability to climate change and to develop adaptation strategies to become more resilient. The program initially targets the municipalities of Rincón, Culebra, and Dorado, and is anticipated to include Salinas and Loíza at a later date.

Tetra Tech is supporting PRCZMP and the municipality of Rincón to analyze climate variability and impacts on the municipality and to develop an adaptation plan to respond to natural hazard risks. This report details the approach and findings of the Rincón pilot project. The report is organized into the following volumes, which follow major project activities:

- **Volume 1 – Site Description and Initial Stakeholder Outreach and Engagement**. Provides a community profile of Rincón to introduce the report. Identifies the findings and recommendations from initial stakeholder outreach and engagement efforts, including a technical site visit with municipal staff and two public stakeholder workshops.
- **Volume 2 – Vulnerability Assessment.** Assesses the climate risk to Rincón, and summarizes the climate, vulnerability, and impact assessment which was conducted.
- **Volume 3 – Risk Profiles and Climate Change Adaptation Plan**. Summarizes key risks from the vulnerability assessment in an index, and details the approach and outcomes of the adaptation plan, which was refined with stakeholder input.

This report is **Volume 1 – Site Description and Initial Stakeholder Outreach and Engagement**. It has been developed as a stand-alone document that presents the community profile of Rincón, as well as initial stakeholder outreach and engagement efforts.

2.0 METHODOLOGY

The project team has used a five step process to assess current and future hazards to Rincón and to develop adaptation strategies to mitigate that risk. The methodology has used a robust stakeholder engagement process to solicit input and feedback on methodology and findings, which has involved municipal staff, local technical resources and civic organizations, and the general public. Engagement with local stakeholders is considered critical, as implementation of the adaptation plan will rely on their commitment to action.

Figure 2-1 below identifies the five step methodology used by the team, and identifies the corresponding report volume that details each step.

Figure 2-1. Project Methodology and Associated Report Volume

2.1 MUNICIPALITY OF RINCÓN

The Municipality of Rincón is a coastal community, located on the west coast of Puerto Rico (Figure 2-2). Rincón is also called Santa Rosa de Rincón and was officially incorporated as a Municipality in 1771. The Caribbean Sea serves as border to the North West and West, Aguada to the North East and Añasco to the South. Rincón is one of the smaller municipalities in the Island, covering approximately 13.8 square miles (36 square kilometers).

Figure 2-2. Location of the Municipality of Rincón, Puerto Rico (in red).

Rincón is located on the coastal plain of the western San Francisco mountain range, with its highest point being the summit of Atalaya Mountain at 1,187 feet. Figures 2-3, 2-4, and 2-5 show the topography of Rincón. The Municipality's boundary to the North East is the Río Grande, while other natural surface waters in the Municipality include the Quebradas Calvache, Los Ramos, Piletas and García. Figure 2-6 illustrates the hydrography of Rincón.

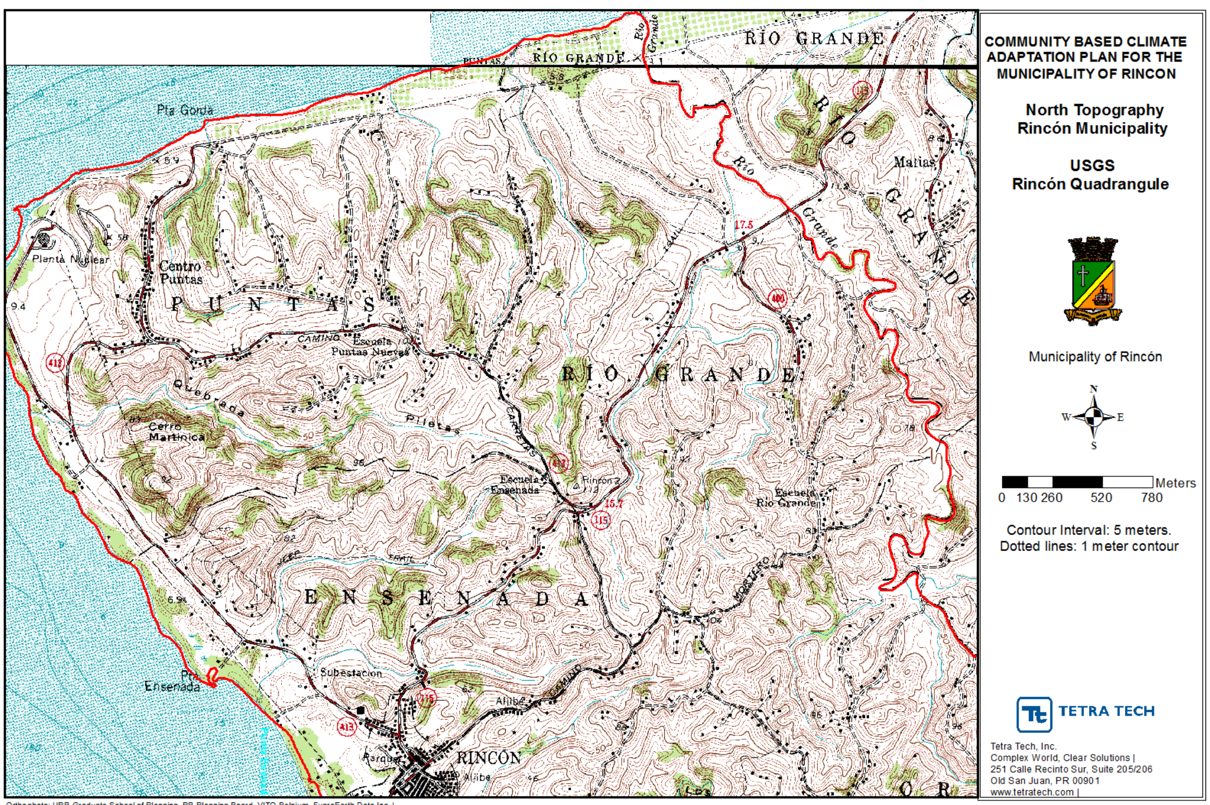
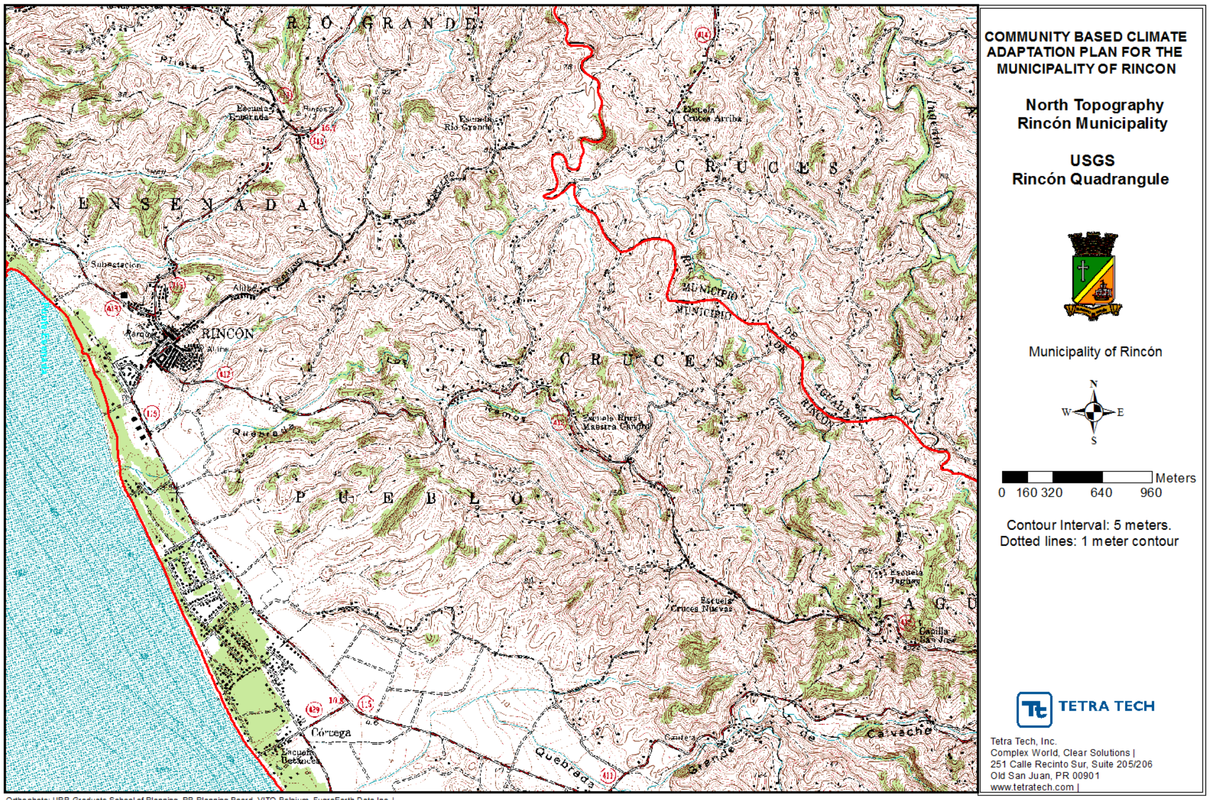
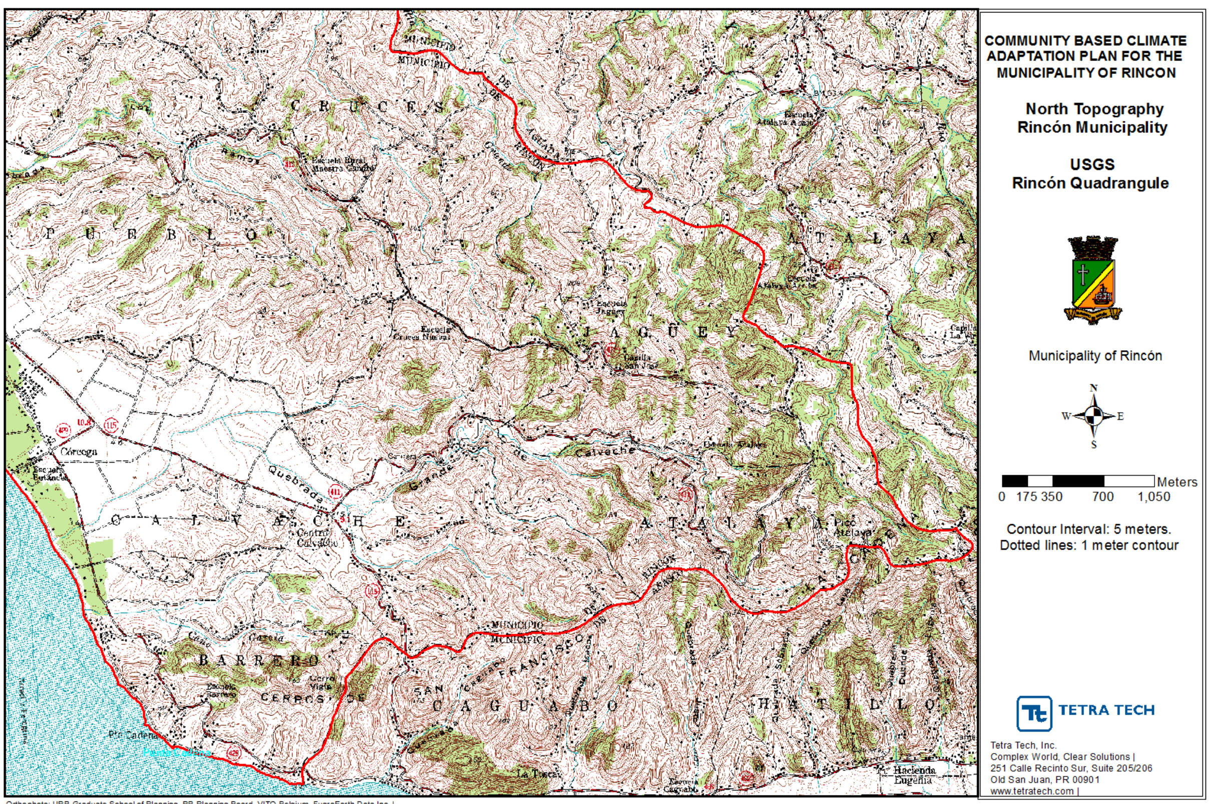


Figure 2-3. Rincón Topography (North)



Orthophoto: UPR-Graduate School of Planning, PR Planning Board, VITO Belgium, FugroEarth Data Inc.|

Figure 2-4. Rincón Topography (Central)



Orthophoto: UPR-Graduate School of Planning, PR Planning Board, VITO Belgium, FugroEarth Data Inc.|

Figure 2-5. Rincón Topography (South)

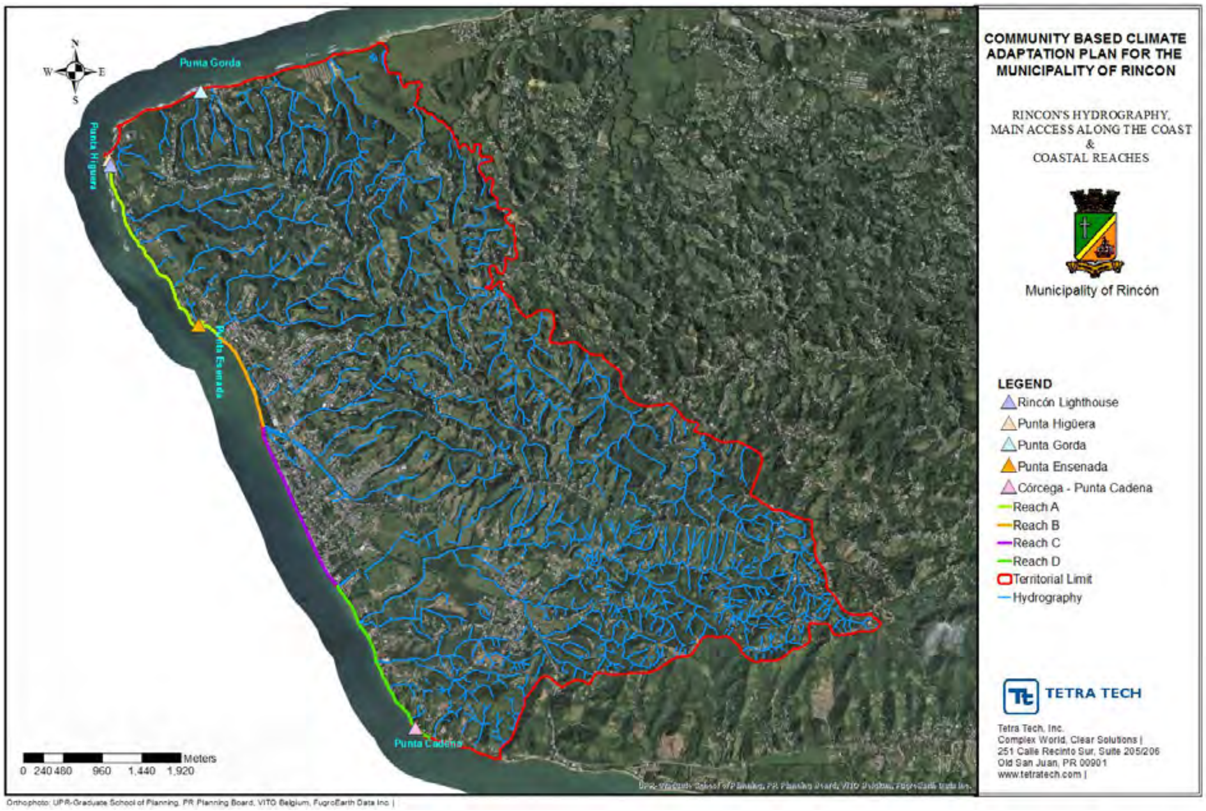


Figure 2-6. Rincón Hydrology

Rincón's population of 15,200 resides in its nearly 13.8 square miles of territory, resulting in a population density of 410 persons per square mile (Census 2010). According to the 2010 US Census, most of its population resides in urban areas and 26 percent of its population are under 18 years of age. Figure 2-7 illustrates the population density of Rincón. Many of the more densely populated areas are adjacent to the shoreline. The vulnerability of Rincón's population will be further explored in Volume 2 of this report series.

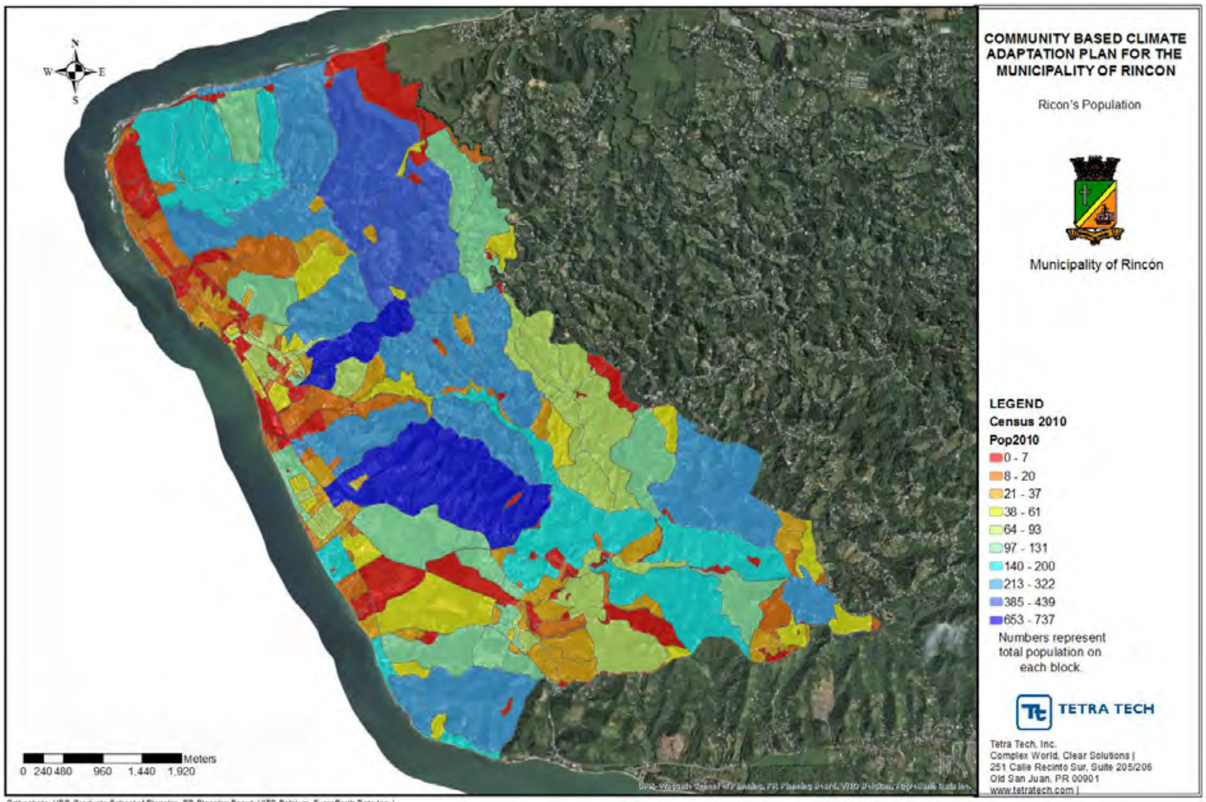


Figure 2-7. Rincón's Population Density

The Municipality is a travel destination both for residents throughout Puerto Rico and internationally because of its natural beauty and excellent surfing conditions from October through March. These attractions have produced substantial development pressures in the Municipality, consisting of new resorts, condominiums, and second home construction along the coast. The value of undeveloped land in the coastal area has increased significantly over the past ten years.

Economically, the Municipality of Rincón is less well off than Puerto Rico overall. It should be noted that economic statistics for Puerto Rico are heavily biased towards the San Juan Metropolitan Area. The 2000 median family income for Rincón was $12,852, which is substantially lower than the overall median family income for Puerto Rico of $17,485. Fifty six percent (56%) of the population of Rincón lives below the poverty level, and Rincón has one of the highest unemployment rates in Puerto Rico, estimated at 28.7 percent. Figure 2-8 shows those households making less than $20,000 per year as a percent of the population. Many of these households also are adjacent to the shoreline. The vulnerability of Rincón's population will be further explored in Volume 2 of this report series.

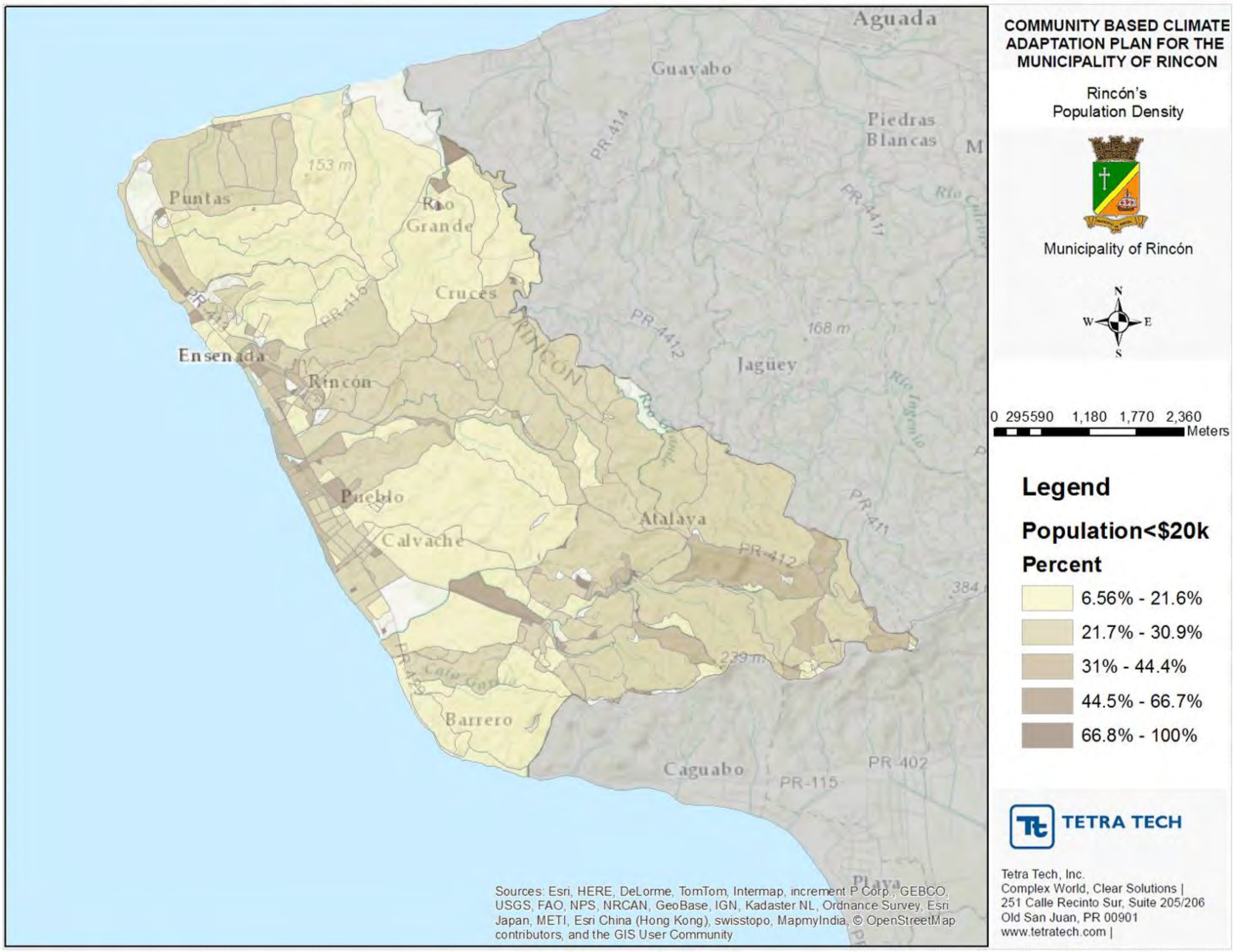


Figure 2-8. Rincón Population with Annual Income < $20,000

3.0 STAKEHOLDER OUTREACH AND ENGAGEMENT

Extreme weather events and weather variability can have severe consequences for communities; posing risks to economic development and human health. Climate change is causing temperatures and sea levels to rise, and precipitation patterns to shift. These weather changes will result in more extreme and frequent natural hazards, such as flooding, hurricanes, prolonged drought periods, and extreme heat conditions. Figure 3-1 illustrates some of the primary climate risks.

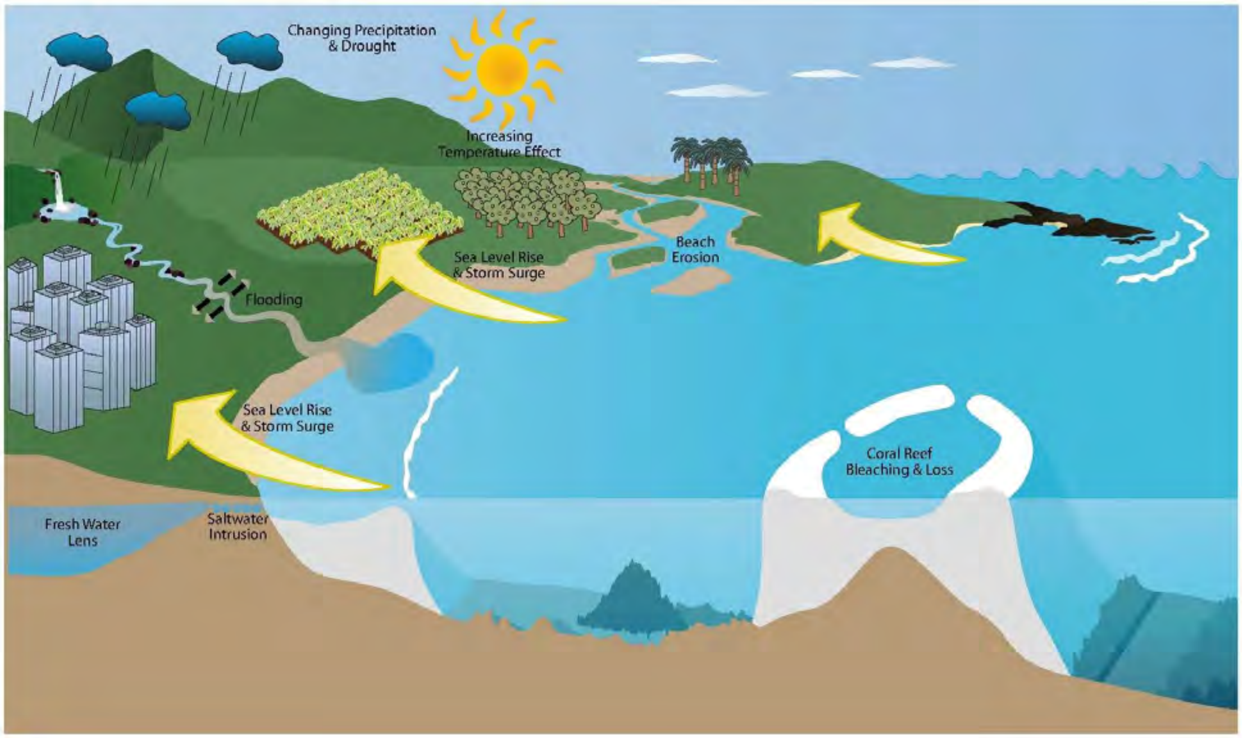


Figure 3-1. Typical Climate Risks of Coastal Communities.

Planning climate resilient economic measures requires integrated strategies with multiple sectors working together to identify gaps and opportunities to integrate climate adaptation into existing plans, programs, and policies, as well as ongoing economic development efforts of the region and the island itself.

Thus, this project was structured as a stakeholder centric process, whereby stakeholders were provided opportunities to shape the approach and recommendations at the onset. Identifying and integrating local early actions to address climate adaptation requires a collaborative approach bringing together technical expertise and local knowledge. This section details the process and critical information that was provided by local stakeholders. This information is carried forward through the subsequent phases of the project.

> The project explores the questions of - How is Rincón vulnerable to climate variability and change? What actions could Rincón take to reduce that vulnerability?

3.1 TECHNICAL SITE VISIT

As a first step of the project, the project team identified and contacted key stakeholders from different sectors of the municipality to identify highly vulnerable and critical facilities. Municipal representatives were asked to identify those locations deemed most at risk (based on observed impacts and exposure) and most critical to the municipality. A technical site visit was arranged to visit those locations. The objective of the technical site visit was to explore the key factors of vulnerability and potential adaptation solutions for those sites. The site visit took place on Tuesday, May 12, 2015, from 9:00 a.m. to 12:00 p.m.

3.1.1 Participants

The participants of the technical site visit included representatives from the Municipality of Rincón and DNER as project co-sponsors. The site visit also included representatives from the University of Puerto Rico (UPR), Puerto Rico Water Resources and Environmental Research Institute (PRWRERI), and Sea Grant, due to local technical knowledge and to leverage ongoing relevant studies in the area.

Table 3-1. Participants for Technical Site Visit

Name	Department/Position	Affiliation
Héctor Martínez	Emergency Management Department Director	Municipality of Rincón
Juan Carlos Pérez	Public Relations Manager	Municipality of Rincón
Manuel González	Recycling Dept. Director & Stormwater Coordinator	Municipality of Rincón
William Ventura (Eng.)	Planning and Engineering Department Director	Municipality of Rincón
Vanessa Marrero Santiago	Environmental Planner	Coastal Zone Management Program/DNER
Jean-edouard Faucher Legitime	Flood Exposure & Sensitivity Index, UPRM Graduate Program	UPR-Mayagüez Campus
Roy Ruiz Vélez	Research Assistant III – GIS Technician	PR Water Resources & Environmental Research Institute (PRWRERI) / Puerto Rico Seismic Network (PRSN)
Ruperto Chaparo	Sea Grant Director	Sea Grant and PRCCC Council
Cenilda Ramírez	Water Resources and Environmental Compliance Projects Manager & Education & Outreach Specialist	Tetra Tech
Hope Herron	Climate Change Specialist	Tetra Tech

The Team used the Municipal Trolley to conduct the Technical Site visit

The Team summarized findings after the Technical Site visit

3.1.2 Critical Facilities Technical Site Visit Findings

The team visited several locations (Figure 3-2), that were identified as critical to the Municipality (e.g., facilities providing critical support to Rincón, environmental areas of concern, or areas/infrastructure supporting economic development), including the following sites:

1. Domes Beach and Boiling Nuclear Superheater (BONUS) Reactor
2. Spanish Wall Beach Site (including the Spanish wall and wastewater conveyance pipeline)
3. Wastewater Pumping Station
4. Historic Landfill
5. Rincón Public/Recreational Beach Site and Rincón COOP Facilities
6. Los Ramos Channel
7. Corcega Beach Site

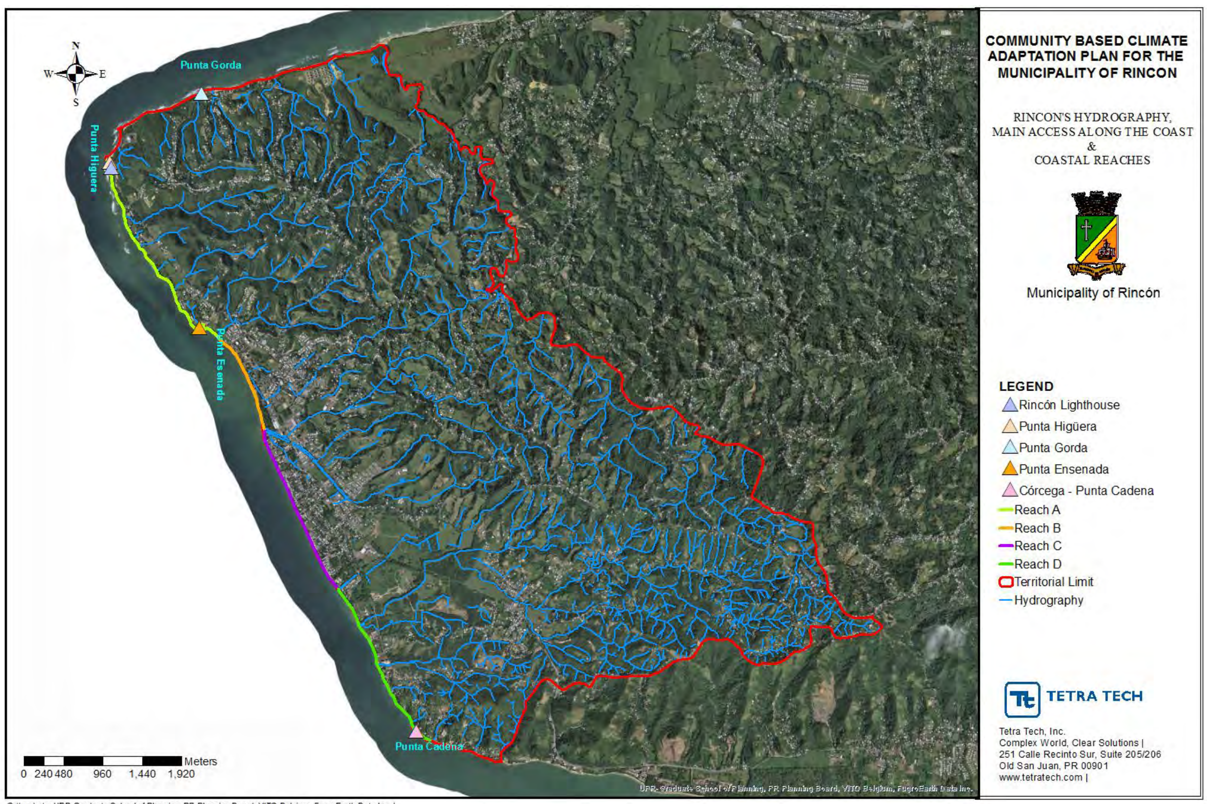


Figure 3-2. Rincón Technical Site Visit Locations

The following sub-sections describe the baseline conditions and initial findings for each of these sites, beginning with the cross-cutting issue of coastal erosion that impacts each of the locations.

The vulnerability assessment presented in Section 3 provides robust analysis of the vulnerability of these locations and for the municipal infrastructure and natural resources of Rincón generally. The site descriptions below discuss exposure and any issues identified at the site; thus, these sections should not be considered vulnerability assessments.

Cross-cutting Issues

There were several issues that spanned across each of the sites visited. **Coastal erosion** rates have been significant along the Rincón coast; which poses a serious risk to all of the resources, facilities and infrastructure in proximity to the coast. Severe erosion rates have been established in numerous studies and reports, such as the U.S. Geological Survey (USGS) "Historical Shoreline Changes at Rincón, Puerto Rico, 1936-2006",[1] while the USACE, UPR-Mayagüez, and DNER-CZMP are currently conducting a Sediments Dynamic study along the Rincón Coast. The USGS report identified long-term erosion rates and identified four distinct coastal reaches for Rincón, between Punta Higüero and Punta Cadena shown in Figure 3-3:

Figure 3-3. Rincón Erosion Areas (From Thieler, E.R., R.W. Rodríguez, and E.A. Himmelstoss, 2007)

[1] Thieler, E.R., R.W. Rodríguez, and E.A. Himmelstoss, 2007. Historical Shoreline Changes at Rincón, Puerto Rico, 1936-2006, available online at: <http://woodshole.er.usgs.gov/pubs/of2007-1017/>. Accessed September 2015.

- Reach A, from Punta Higüero to just south of Punta Ensenada, was characterized as a relatively stable to slowly eroding coast comprised of a thin sandy beach overlying various indurated (rocky) substrates. Erosion rate of 0.2+/- 0.1 m/yr.
- Reach B, from south of Punta Ensenada to south of Quebrada los Ramos, was characterized as a rapidly eroding sandy coast backed by unconsolidated alluvial deposits. Erosion rate of 1.1+/- 0.3 m/yr.
- Reach C, from south of Quebrada los Ramos to Córcega, was characterized as a slowly eroding sandy coast backed by unconsolidated alluvial deposits. Erosion rate of 0.4+/- 0.2 m/yr.
- Reach D, from Córcega to Punta Cadena, was characterized as a stable to slowly eroding sandy coast backed primarily by unconsolidated alluvial deposits.[2] Erosion rate of 0.2+/- 0.2 m/yr.

The erosion of Rincón's public beaches poses serious risks to the **local economy**. Rincón's economy is based on island and external tourism. The Municipality has been host to several international surfing contests, symposiums, and other events, which include the Rincón International Film Festival, the Rincón Beachboy Standup Paddleboarding Contest, the Rincón Triathlon, and the Rincón Oktoberfest. Rincón's tourism industry involves promotion and support to recreational activities such as snorkeling, surfing, and fishing, among others. These recreational activities depend on healthy marine resources and coastal infrastructure.

Erosion of the beaches also poses risks to **Threatened and Endangered Species**. Local beaches are potential nesting habitat for the endangered Hawksbill Sea Turtle and Leatherback Sea Turtle. Figure 3-4 identifies the beaches and wetland systems as these are important habitat for marine protected species, as well as terrestrial flora and fauna.

Rincón is also home to unique Elkhorn coral (*Acropora palmata*) thickets, which is a listed "threaten" species under the Endangered Species Act. Steps and Tres Palmas reefs are some of the best-developed fringing coral reefs found off the west coast of Puerto Rico.[3] Figure 3-4 identifies the location of the Tres Palmas Marine Reserve. Climate change could pose risks to coral reefs due to ocean acidification, rising temperatures and seal levels.

The unique natural resources of Rincón that help drive the tourism economy and provide habitat for threatened and endangered species, are currently vulnerable due to significant erosion rates. This vulnerability is expected to be exacerbated by climate change.

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[2] Ibid.

[3] Surfrider Foundation, 2015. Coral Reefs, available online at: <https://rincon.surfrider.org/coral-reefs/>. Accessed September 2015.

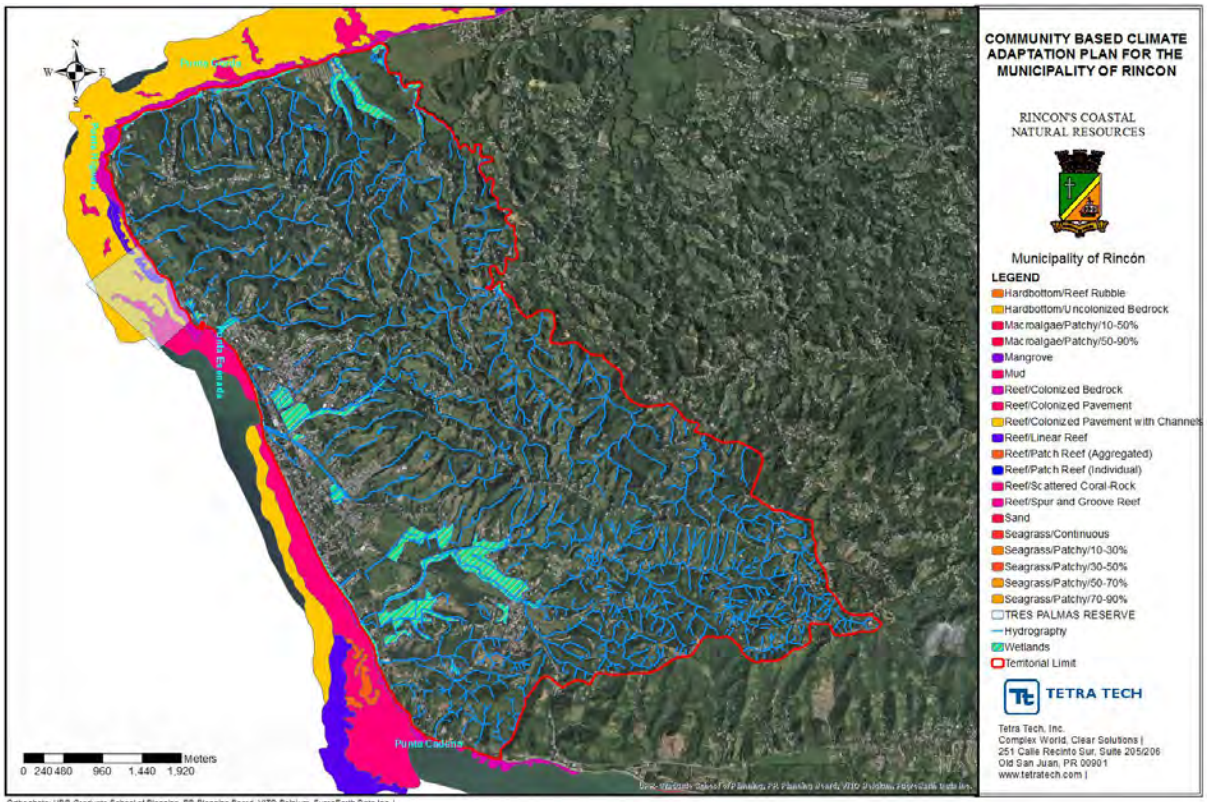

Figure 3-4. Rincón's Natural Resource Areas

Site 1. Domes Beach Site and BONUS Reactor

Domes Public Beach has been recognized as one of the most famous surfing beaches in Puerto Rico and around the world. The beach primarily consists of semi-shallow coral reefs and flat-rock bottom. It is named after the dome shaped decommissioned nuclear power plant located alongside the beach, the Boiling Nuclear Superheater (BONUS) Reactor. An artificial reef has been constructed to protect BONUS.

BONUS was developed as a prototype nuclear power plant to investigate the technical and economic feasibility of the integral boiling superheating concept. It was one of two boiling–water superheater reactors developed in the United States. Construction began in 1960 and a controlled chain reaction was conducted on April 13, 1964. However, the operation of BONUS reactor was ended in June 1968, because of technical difficulties and the ensuing need for high –cost modifications. BONUS was decommissioned between 1969 and 1970 by the Puerto Rico Water Resources Authority. Ore radioactive contamination was identified in portions of the building, and additional cleanup and shielding activities were conducted in the 1990 and early 2000s.[4]

The Puerto Rico Electric Power Authority (PREPA), as successor agency to the Puerto Rico Water Resources Authority, owns the land, buildings and other improvements. DOE and PREPA are responsible for the long-term surveillance and the maintenance of the site. The Office of Legacy Management manages the BONUS Decommissioned Reactor Site and ensures compliance with applicable federal, state, and local environmental protection laws and regulations, executive orders and internal DOE policies.

[4] U.S. Department of Energy (DOE), 2008. BONUS, Puerto Rico, Decommissioned Reactor, Factsheet, available online at: <www.lm.doe.gov/BONUS/BON00000103.pdf>. Accessed September 2015.

BONUS is listed in the National Register of Historic Places (ID # 07001194); the only historic site listing in Rincón (Figure 3-5). A museum was constructed at the site, which was named the Dr. Modesto Iriarte Technological Museum.

Figure 3-5. Aerial view of the site visited, showing the BONUS Museum, the Domes and Secret Beach located in Domes Rincón, PR (taken from www.rincon.org website).

BONUS has a high degree of exposure to natural hazards, such as storm surge, due to proximity of the site to the ocean. An elevation of approximately 10 meters and a distance of approximately 50 meters to beach was estimated during the site field visit.

There have been several studies that have examined the vulnerability of the site to current natural hazards and for the potential of radiation releases as part of the decommissioning process. Extensive soil and groundwater sampling was conducted fairly recently for an Environmental Assessment (EA) for Authorizing PREPA to allow public access to the BONUS Reactor Building. The EA found that no radionuclides potentially attributable to BONUS operations were identified in any soil or groundwater sampling. [5]

The facility has been subject to historical flooding. The containment building flooded in September 1998 during Hurricane Georges due to plugged storm drains and leaking door seals.[6] Since that time, the storm drains were unplugged and the rubber door seals around the basement doors were replaced (after being in place for more than 28 years). A few inches of concrete were added to the basement floor of the containment building to provide shielding for some isolated and discrete areas of fixed radioactive contamination on the basement floor. However, filling the floor drains also raised the question of effective water drainage from the facility should it flood again.[7]

[5] DOE, 2003. Environmental Assessment for Authorizing PREPA to Allow Public Access to the BONUS Reactor Building, available online at: <http://energy.gov/sites/prod/files/nepapub/nepa_documents/RedDont/EA-1394-FEA-2003.pdf>. Accessed September 2015.

[6] DOE, 2013. Inspection and Status Report for the Former Boiling Nuclear Superheater (BONUS) Reactor Facility, Rincón, Puerto Rico, available online at: <http://www.lm.doe.gov/bonus/Documents.aspx>. Accessed September 2015.

[7] Ibid.

The 2003 EA noted that the BONUS facility has weathered multiple earthquakes and hurricanes, without evidence of major damage. Critically, the report notes that "the physical characteristics of residual radioactive materials at the facility, particularly the concrete monolith that contains the primary radiological inventory, would preclude releases to the environment even in the event of structural damage to the facility."[8]

It should be noted however, that the 2011 Comprehensive Annual Survey submitted to PREPA mentioned that "Inspection of the surrounding property and slopes to the beach revealed no significant changes or signs of excessive erosion. Dense vegetation on the slopes from the facility to the beach appears to be effectively controlling erosion. No immediate action is necessary."[9] The technical site visit indicated that the beach has experienced erosion, and specifically that the concrete barriers at the base of the facility have been damaged (see picture to the left).

However, it should also be noted that in 2010, a recommendation was made that PREPA provide DOE the plans that will be followed to address future flooding events at the facility.[10]

Site 2. Spanish Wall Site

A historic sea-wall was built by the Spanish approximately 300 years ago, which runs along the coast north of Domes Beach. A dirt road runs parallel to the wall and beach, which previously served as a historic train bed. The main wastewater system pipeline for the municipality was laid in concrete in the center of the road.

Based on information provided by the municipality staff team, maintenance of the wall is a joint USACE and Commonwealth responsibility. Any work undertaken by the city on the wall or in the vicinity would require a permit.

The field visit found that severe erosion has impacted the beach, wall, and road. In several places, the road was eroded within just a few inches of the concrete pipe. Figure 3-6 shows the location of this wastewater pipeline.

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[8] DOE, 2003. Environmental Assessment for Authorizing PREPA to Allow Public Access to the BONUS Reactor Building, available online at: <http://energy.gov/sites/prod/files/nepapub/nepa_documents/RedDont/EA-1394-FEA-2003.pdf>. Accessed September 2015.

[9] MMG, 2011. 2011 Annual Survey, Memorandum, available online at: <file:///C:/Users/hope.herron/Downloads/2011AnnRadSurvey.pdf>. Accessed September 2015.

[10] DOE, 2010. Inspection and Status Report for the Former Boiling Nuclear Superheater (BONUS) Reactor Facility, Rincón, Puerto Rico, available online at: <http://www.lm.doe.gov/bonus/Documents.aspx>. Accessed September 2015.

Figure 3-6. Exposed Wastewater Pipeline

Erosion of Spanish Wall and Road

Distance from Wastewater Pipeline to Eroded Area 1

Exposed Wastewater Pipeline

Distance from Wastewater Pipeline to Eroded Area 2

Site 3. Wastewater Pumping Station

The location of this site is a public beach that was referred to by locals as "La Mojonera" because it was consistently polluted with fecal coliform bacteria. A wastewater pumping station was constructed in the area to alleviate the localized pollution. While the wastewater pumping station has alleviated most recurrence, sanitary sewer system overflows occasionally occur due to failure of the electrical system. The name of the beach has been recently changed to Lala's Beach to eliminate the negative perception of polluted waters.

The station is located approximately 20 meters from water line as observed during the site visit; although the water line changes with tidal conditions. The municipal representatives noted that the beach has experienced erosion. Several mitigation borrow pits were observed near the pumping station.

The site is in close proximity (0.15 km) to the Tres Palmas Marine Reserve, which hosts Elkhorn coral populations. A 2011 analysis of 223 colonies of Elkhorn coral in Tres Palmas Marine Reserve found that the corals showed "unmistakable historical signs of partial mortality of colonies associated with recurrent rainfall runoff". [11] The study confirmed the presence of microbiological contamination by rainfall runoff and possible overflows of septic tanks located close to the coast. Thus, the Elkhorn coral populations are considered currently vulnerable to microbiological contamination.

Due to proximity to the shoreline, the wastewater pumping station is exposed to coastal flooding (both electrical and infrastructure failure). Sanitary sewer system overflows or infrastructure failure of the wastewater pumping station could cause microbiological pollution, which could affect human and marine health, including to Elkhorn coral populations.

[11] Ramírez, J.N., P.M. Lázaro, E. A. Hernández Delgado, and L.C. Rivera (2011), *Impact of Septic Tanks on Water Quality and Coral Reef Communities in Tres Palmas Marine Reserve*, presented at Retos Ambientales y Oportunidades en Norte América y el Caribe, available online at: <http://www.aidis-pr.org/B-09-Norat-PR-1.pdf>. Accessed September 2015.

Site 4. Historic Landfill

The Team next visited an historic landfill, located approximately 100 feet to the north of the wastewater pumping station. The abandoned waste dumping site was active several decades ago; although no formal records were kept on the years of operation and extent. Solid waste, medical waste, and potentially other toxic or hazardous materials were disposed in the site and burned. Liners were not used at the site.

The Rincón coastal landfill site is located immediately adjacent to the shoreline which is being gradually reclaimed by the ocean. The shoreline receded by approximately 72 feet from 1993 to 2006.[12] While the original site was not immediately adjacent to the beach, the landfill in now fully exposed to wave action. An attempt to provide shoreline protection by anchoring the shoreline with rocks has failed. The waste is being transported into the ocean and along the beach by the predominantly southern offshore current in Añasco Bay. The exposed ash area was estimated at approximately 3 feet high and extends several feet. Glass and other solid waste materials were visible in the ash.

The municipality previously submitted a Brownfield grant application, which was rejected because the Municipality was the responsible party and the current owner of the property (as opposed to the federal government). A proposal was also submitted to request funds from NOAA in 2012, but the area was not in the priority areas listed in Puerto Rico NOAA's Coral Reef Conservation Program. The proposed scope of work included conducting the environmental and oceanographic base line studies necessary to support a feasibility study which would assess possible alternatives to mitigate the impacts of coastal erosion and continued pollution of the Rincón's coastal landfill into US coastal waters, the Tres Palmas Marine Reserve ecosystem, and adjacent coral reefs.

A portion of the landfill is currently exposed to wave action, and continued coastal erosion, sea level rise, and storm surge will exacerbate exposure. The waste constitutes a health hazard that can seriously injure people and marine animals/fish (both directly and indirectly). There is also the potential of contamination from hazardous and toxic waste. The site is in close proximity to Rincón's Public Beach and Lala's Beach and Marine Reserve Tres Palmas.

Exposed trash breaking onto the beach

Broken glass and solid waste visible in ash

Layers of ash and trash exposed

[12] Thieler, E.R., R.W. Rodríguez, and E.A. Himmelstoss, 2007. Historical Shoreline Changes at Rincón, Puerto Rico, 1936-2006, available online at: <http://woodshole.er.usgs.gov/pubs/of2007-1017/>. Accessed September 2015.

Site 5. Rincón Public/Recreational Beach and Rincón COOP Facilities

Balneario de Rincón is a public recreational beach located between the Tres Palmas Marine Reserve and Lala's Beach. The beach hosted the 2010 Central American and Caribbean Games Triathlon and continues to host an annual triathlon. The beach is a potential nesting habitat for the endangered Hawksbill Sea Turtle and Leatherback Sea Turtle. The area is also in proximity to the Marine Reserve Tres Palmas.

COOP Rincón is the largest cooperative financial institution in Puerto Rico. It has more than $616 million in total assets and about 27,000 members from the local community of Rincón, other municipalities in Puerto Rico, and from the United States of America. The facility is located approximately 80 feet from shoreline (the rear of the building faces the public beach). The 2011 revision of Rincón's FEMA Hazard Mitigation Plan documented that the Rincón COOP was in need of drainage improvement. COOP Rincón is currently working on improvements to one section of the storm drainage channel as per the request of DNER (Approximately 80 feet). The team also noted that construction and expansion was occurring in the rear of the facility.

Site 6. Los Ramos Channel

The United States Army Corps of Engineers (USACE), through the Puerto Rico Department of Housing, funded the construction of gabion walls to control erosion and reduce flooding along the *Canal Los Ramos*. The Channel extends approximately 1 mile inland. This construction took place approximately 10 years ago and has never over-topped. Saltwater caused corrosion of the gabion enclosures and has led to the premature collapsing of the vertical walls. The failure of the gabion structures may represent an increase in erosion and may potentially impact the adjacent Sea Beach Apartments development. The USACE has replaced/repaired the walls as a reactive maintenance.

Not addressing the repair of these gabion walls may aggravate the existing vulnerability to flooding in adjacent communities. However, the practicality or applicability of gabions should be re-evaluated and reconsidered by the USACE.

Site 5. Córcega Beach Site

Córcega is known as the best swimming beach in Rincón. The water is usually calm, even in winter. Córcega is a quieter, uncrowded beach, close to Route 115. The Municipality staff mentioned that approximately 20 years ago, the beach used to extend 100 feet from current shoreline, but due to coastal erosion there is no sand available. There are several condos, apartments, and homes that have been impacted by the erosion rate. Several abandoned homes were observed, representing a health and safety risk to the community and marine life.

The beach is a potential nesting habitat for the endangered Hawksbill Sea Turtle and Leatherback Sea Turtle.

The significant erosion of the Córcega Beach impacts marine animals as well as local tourism derived from visitors to the beach. Individual property owners are impacted by structure failure, and the municipality is often left responsible for the waste.

Abandoned home on Corcega Beach

Threatened home on Corcega Beach

3.2 STAKEHOLDER WORKSHOPS

3.2.1 Workshop Design and Agenda

Stakeholder workshops were held on May 12 and May 13, 2015 in the Municipality of Rincón City Hall. The meetings were open to the public and advertised electronically on local facebook pages (hotels and businesses, municipal and community organizations), via email to key community and environmental organizations, and via flyers posted in strategic locations.

Local experts and stakeholders were invited to present on climate change related issues and research that they were leading. This provided an opportunity to directly engage local experts in this project and to also build awareness of the public on relevant activities.

The following agenda includes the list of the key stakeholders that were speakers during the community meetings and workshops.

Stakeholder Workshop Agenda

TUESDAY MAY 12TH 2015

Climate Change / Municipal Adaptation Plan Community Meeting **Municipality of Rincón, City Hall 3rd Floor**	
1:00–5:00PM	1:00PM Welcome Message from the Municipality of Rincón 1:15PM – 1:30PM Hope Herron, Climate Change Specialist -Tetra Tech Inc. 1:30PM – 1:45PM Vanessa Marrero, DNER 1:45PM - 2:00PM Ruperto Chaparro, Director-Sea Grant 2:00PM - 2:15PM Jean Eduardo-UPR-RUM 2:15PM – 2:30PM Christa Vonh/ Carolina Hincapie, NOAA 2:30PM - 2:45PM Edgardo Romero – ADS - *Cancelled* 2:45PM - 3:00PM Ernesto Morales, NWS 3:00PM - 3:20PM Coffee Break

	3:30PM – 4:30PM WORKSHOP – VULNERABILITIES, RISKS & MAIN CONCERNS IDENTIFICATION – Led by: Hope Herron & Cenilda Ramírez-Tetra Tech and Vanessa Marrero-DNER 4:30 Closure Comments

WEDENESDAY MAY 13 2015

Climate Change / Municipal Adaptation Plan Community Meeting **Municipality of Rincón, City Hall 3rd Floor**	
1:00–5:00PM	1:00PM Welcome Message - Municipality of Rincón Mayor–Hon. Carlos Lopez 1:15PM – 1:30PM Hope Herron, Climate Change Specialist-Tetra Tech Inc. 1:30PM – 1:45PM Carl Soderberg, EPA Caribbean Division 1:45PM - 2:00PM David Ortiz-El Puente- Enlace Latino Acción Climática en PR - Cancelled 2:00PM - 2:15PM Saylisse Davila – UPR-RUM 2:15PM – 2:30PM Christa Vonh/ Carolina Hincapie, NOAA 2:30PM - 2:45PM Edgardo Romero – ADS - Cancelled 2:45PM - 3:00PM Ernesto Morales, NWS 3:00PM - 3:20PM COFFEE BREAK 3:30PM – 4:30PM WORKSHOP – VULNERABILITIES, RISKS & MAIN CONCERNS IDENTIFICATION – Lead by: Cristina Canals, Hope Herron & Cenilda Ramírez-Tetra Tech and the Municipality of Rincón Staff 4:30 Closure Comments

The second portion of the agenda consisted of an interactive community workshop. The workshop was designed with the objective of working with the key stakeholders and community members to identify current climate change related concerns, municipal vulnerabilities, risks, and critical ecosystems. The information gathered from this workshop was directly incorporated into the adaptation plan presented as Section 3.

3.2.2 Interactive Workshop Description

The interactive workshop was divided into four sections: (1) Overview and directions, (2) Activity #1, (3) Activity #2, and (4) Report Outs. Each section is described below in detail.

- Overview and Directions – 5 min
  - Participants were divided into small groups (3 or 4 groups) –presenters were included in each group (mixed into the groups, not as stand-alone)
  - The activities and materials were reviewed. Each group had the following materials:
    - Map of the area – a large tsunami inundation map of Rincón was provided so that each group had an idea of potential vulnerability.
    - Sticker pad, flip-chart, eraser board, and markers.

        - Climate Change Risk Development Options factsheets – these factsheets were developed by Tetra Tech for the Inter-American Development Bank (IDB) and identify general adaptation options per sector.[13]

- Activity 1 – Identify which Resources are Highly Vulnerable to Climate Change Impacts – 15 min
    - Each group identified with stickers vulnerable resources on the map.
    - Participants were encouraged to discuss the following questions:
        - What are and where are the key habitats, cultural resources, and critical infrastructure for the community? (e.g., mangroves, coral reefs, schools, churches, water utilities, evacuation routes etc.)?
        - What is the community's current level of dependence on this resource (high, medium, low)?
        - Briefly discuss the habitat or quality of each key resource (e.g. good reef areas, damaged reef, healthy streams, polluted streams, good roads, washed out roads, etc.).
        - How severely were the resources impacted by past weather events and hazards?
    - Based on this discussion, the groups were asked to identify those resources that are most vulnerable (e.g. priority vulnerabilities) for their community.

- Activity 2 - Identify Actions to Address Climate Change Impacts – 15 min
    - Each group was instructed to identify with stickers and/or on the erasable board actions to address climate change impacts.
    - Group members were encouraged to refer to the Climate Change Risk Development Option factsheets to look for ideas on adaptation strategies for priority vulnerabilities.
    - For each of the priority vulnerabilities, the group was asked to discuss the following:
        - Are there any existing resilience/adaptation strategies and community strengths that could be leveraged?
        - Review the list of best management practices/actions to identify which ones may help to reduce vulnerability of your priority vulnerabilities.
        - Can any or all of these actions be integrated into existing and relevant development plans, policies, or programs and do they have the support to be implemented in these programs? For example, environmental management plans, national conservation strategies, disaster preparedness and/or management plans, sustainable development plans for specific sectors (e.g., agriculture, forestry, transportation, fisheries)?
        - Are any of these actions going to create new social or natural resource problems in your community if they are implemented or not implemented properly?
- Report outs and Discussion – 15 min
    - Each group reported out on their discussion.

[13] Addressing Climate Change within Disaster Risk Management: A Practical Guide for IDB Project Preparation can be found online here. The sector factsheets are available here: Tourism, Transportation, Agriculture, Energy, Urban Infrastructure, Water and Sanitation.

3.2.3 Interactive Workshop Findings

Participants were divided into small groups and asked to identify which resources are highly vulnerable to climate change impacts (Activity 1) and actions to address climate change impacts (Activity 2).

For Activity 1, participants in all groups noted that erosion is currently a significant consideration in current vulnerability and that climate change could increase this vulnerability in the future. Activity 1 responses are summarized below in Table 1-2. Note that these findings are incorporated in Volume 2: Vulnerability Assessment (refer to critical facilities map).

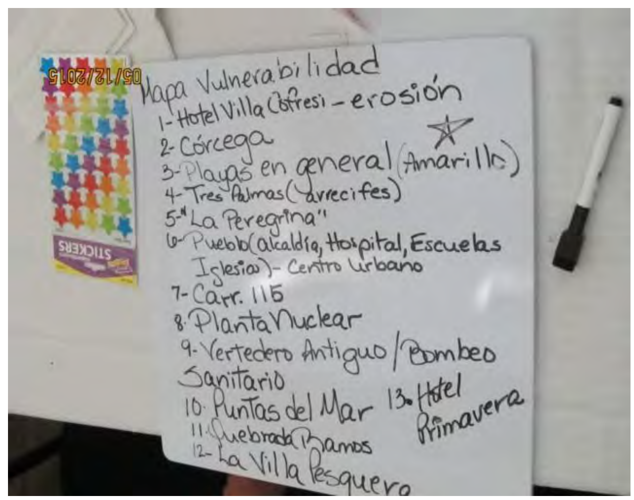
Activity 1 Results

Table 1-2. Activity 1 Results - *Identify which Resources are Highly Vulnerable to Climate Change Impacts*

Vulnerable Resource/Infrastructure	Type	Identified by Multiple Groups	Identified in Technical Site Visit
Los Ramos USACE Channel	Coastal Infrastructure	X	X
BONUS	Critical Infrastructure		X
Communication Antennas (Channel 12)	Critical Infrastructure		
Drinking Water [Pumping station and two reserve tanks (0.5 MG and1.0 MG)]	Critical Infrastructure	X	
Emergency Assembly Designated Place-Recreational Park	Critical Infrastructure		
Geriatric Center	Critical Infrastructure		
Hospital	Critical Infrastructure	X	
Hotels	Critical Infrastructure	X	
Police Station	Critical Infrastructure	X	
Refugees Facilities- Juan Pedroza School and Manuel Gonzalez School	Critical Infrastructure		

Vulnerable Resource/Infrastructure	Type	Identified by Multiple Groups	Identified in Technical Site Visit
Road 115	Critical Infrastructure		
Sanitary System (Pumping Station and Discharges)	Critical Infrastructure	X	
Schools	Critical Infrastructure		
Town Center Facilities (City Hall, Hospitals, Schools, Churches)	Critical Infrastructure		
Transportation Infrastructure	Critical Infrastructure		
Tourism Activity	Economy		
“La Peregrina”	Natural Resource		
Beaches	Natural Resource		
Corcega Beach	Natural Resource	X	X
Endangered Species Forest (near BONUS Facility)	Natural Resource		
Fisheries	Natural Resource		
Mangroves Critical Habitat	Natural Resource		
Marias Beach	Natural Resource		
Rincón Recreational Public Beach	Natural Resource		X
Sandy Beach	Natural Resource		
Tinglar Turtles Nesting Areas	Natural Resource		
Tres Palmas Marine Reserve	Natural Resource	X	X
Ventana al Mar	Natural Resource		
Corcega Housing Development	Public Infrastructure		
Estella Community	Public Infrastructure		
Horn Dorset Primavera Resort	Public Infrastructure	X	
Hotel Villa Cofresi	Public Infrastructure		
La Cambija (Potential Historic Site)	Public Infrastructure		
La Villa Pesquera	Public Infrastructure		
Lighthouse (Historic)	Public Infrastructure		
Parcelas Stella	Public Infrastructure		

Vulnerable Resource/Infrastructure	Type	Identified by Multiple Groups	Identified in Technical Site Visit
Puntas del Mar	Public Infrastructure		
Puntas Ward	Public Infrastructure		
Residential Areas	Public Infrastructure		
Rincón COOP and Banco Popular de PR	Public Infrastructure	X	X
Rincón Cultural Center	Public Infrastructure		
Spanish Wall (Potential Historic Site)	Public Infrastructure		
Vista Sur	Public Infrastructure		
Old Landfill	Solid/Hazardous Waste	X	X



Activity 2 Results

Participants discussed several adaptation options that could be implemented to increase resiliency of Rincón. Adaptation options included the following:

- Reforestation of beaches
- Education within the community of climate change impacts and adaptation options
- Planning efforts and relocation of at-risk facilities
- Continue hurricane awareness and preparedness - adequate hurricane shelters and tie non secure tin roofs.
- Encourage the implementation of stormwater harvesting projects
- Tsunami Ready – leverage outreach and communication platforms
- Impose limits to new developments
- Design a pumping system to prevent future floods damages

ESTUDIO SOBRE LA PERCEPCIÓN PÚBLICA DE LOS CAMBIOS CLIMÁTICOS Y LOS RIESGOS NATURALES SEGMENTO OESTE DE PUERTO RICO

In 2009, PR DNER commissioned a survey of climate change perceptions in the territory. The survey questions were designed to explore risk perception and attitudes toward climate change. Rincón was one of the communities surveyed.

The survey found that a majority of responders are aware of risk of coastal hazards. Approximately 58% of responders identified climate change as "very important", and 25% identified climate change as "important".

The survey established that Puerto Rico has a relatively high awareness of coastal hazard risk generally, and to climate change.

4.0 CONCLUSION

The stakeholder engagement process conducted for this project consisted of a technical site visit and two public workshops. These activities were critical to the project and used to identify stakeholder issues and recommendations, build awareness of climate change, and the findings were carried throughout the project. The project team continued dialogue with key stakeholders throughout the project to ensure that vulnerabilities and strategies were applicable to the area.

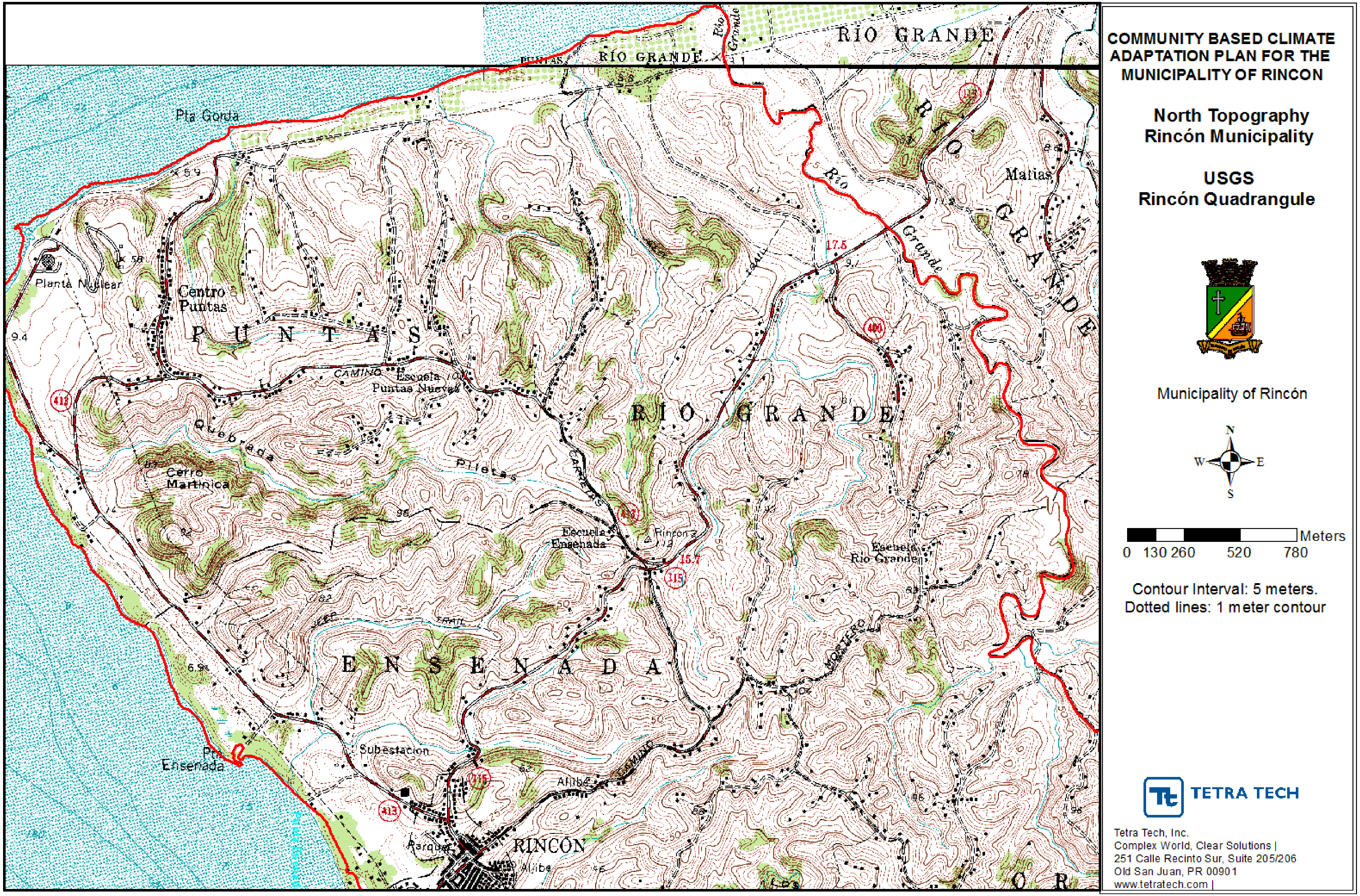
Community Based Climate Adaptation Plan for Rincón Municipality, Puerto Rico

Volume 1 – Site Description and Initial Stakeholder Outreach and Engagement Report

APPENDIX 1 - FIGURES

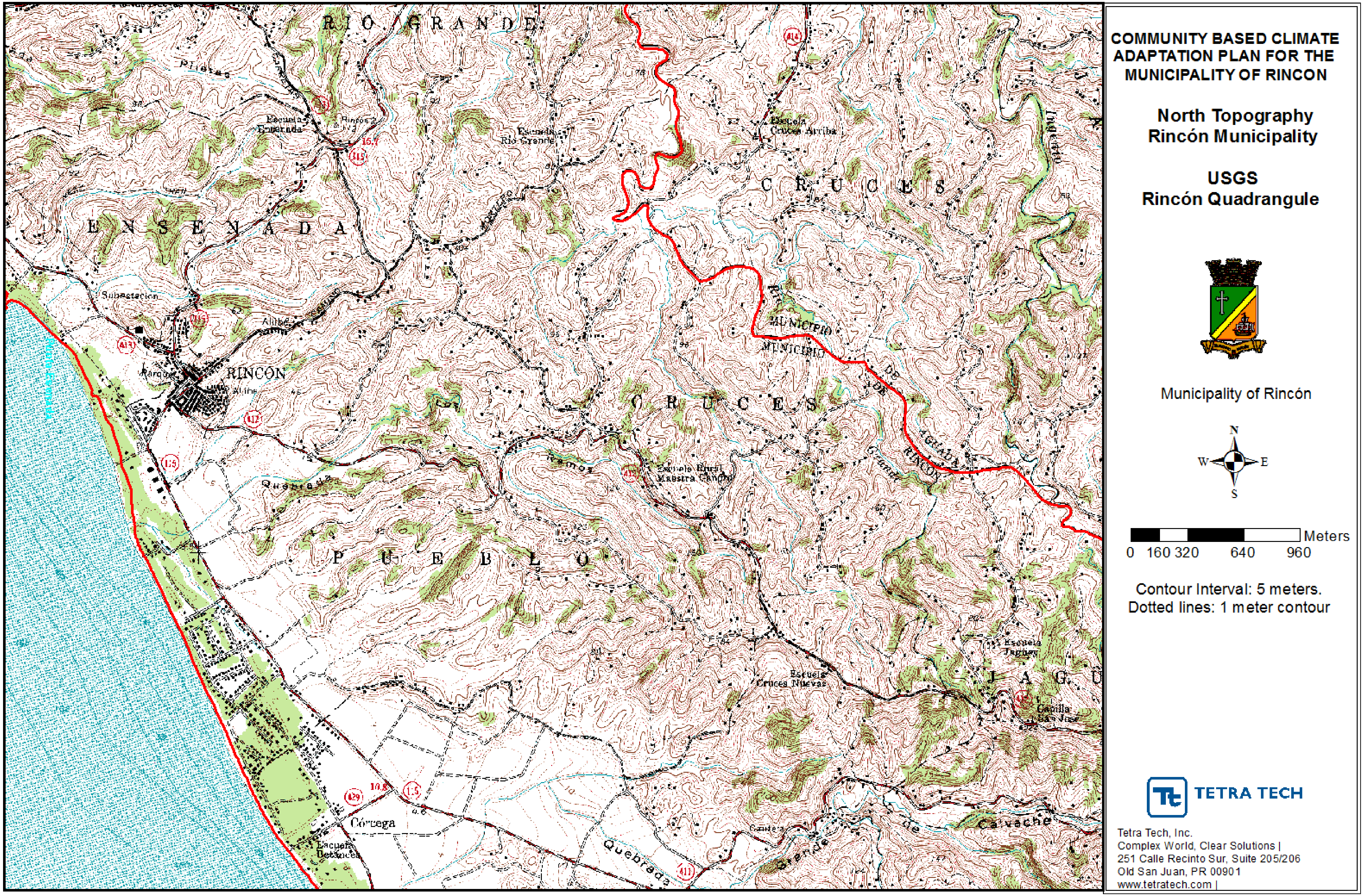
TETRA TECH

December 2015



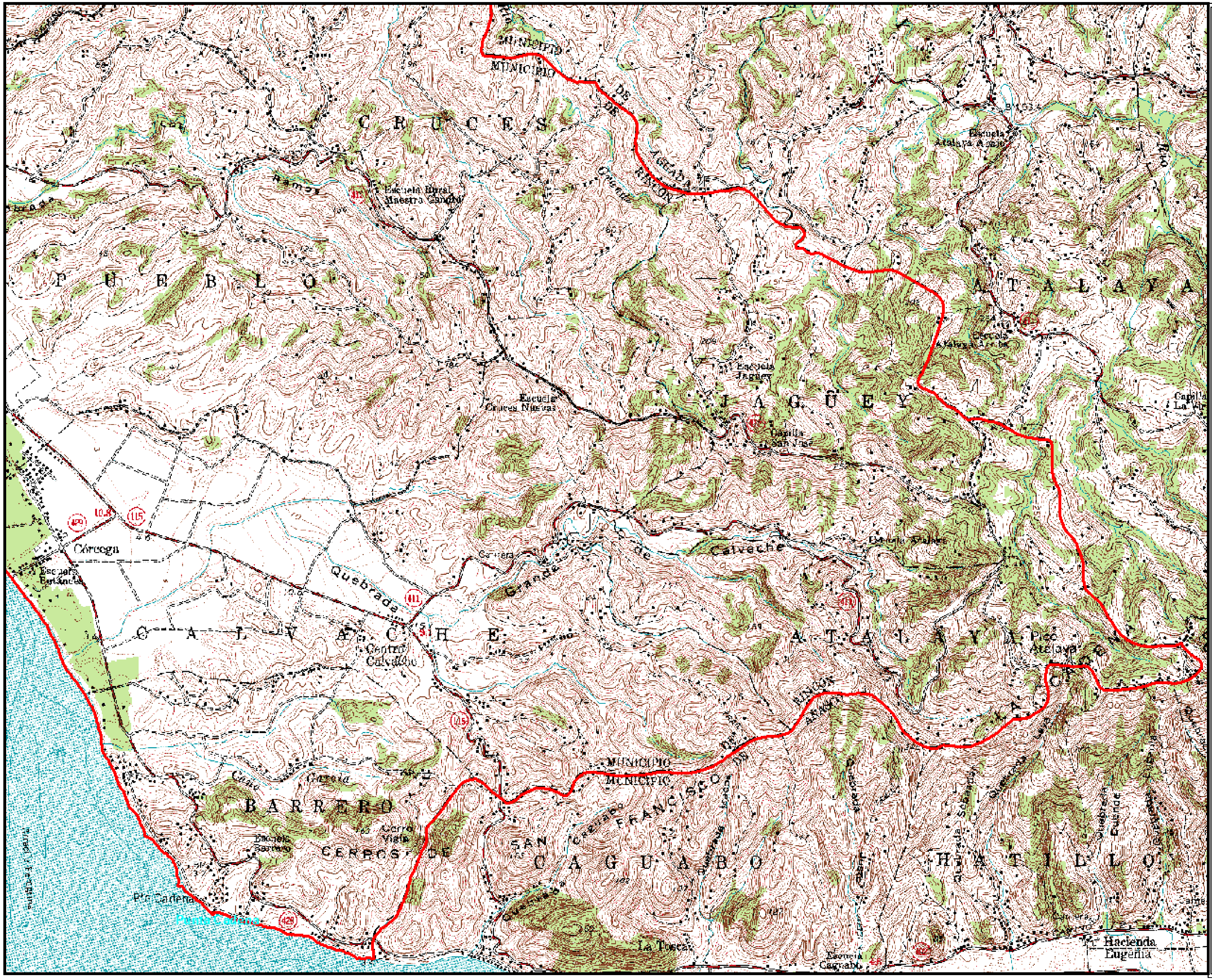
Orthophoto: UPR-Graduate School of Planning, PR Planning Board, VITO Belgium, FugroEarth Data Inc. |

Figure 2-3. Rincón Topography (North)



Orthophoto: UPR-Graduate School of Planning, PR Planning Board, VITO Belgium, FugroEarth Data Inc. |

Figure 2-4. Rincón Topography (Central)



Orthophoto: UPR-Graduate School of Planning, PR Planning Board, VITO Belgium, FugroEarth Data Inc. |

COMMUNITY BASED CLIMATE ADAPTATION PLAN FOR THE MUNICIPALITY OF RINCON

North Topography Rincón Municipality

USGS Rincón Quadrangule

Municipality of Rincón

N
W E
S

Meters
0 175 350 700 1,050

Contour Interval: 5 meters.
Dotted lines: 1 meter contour

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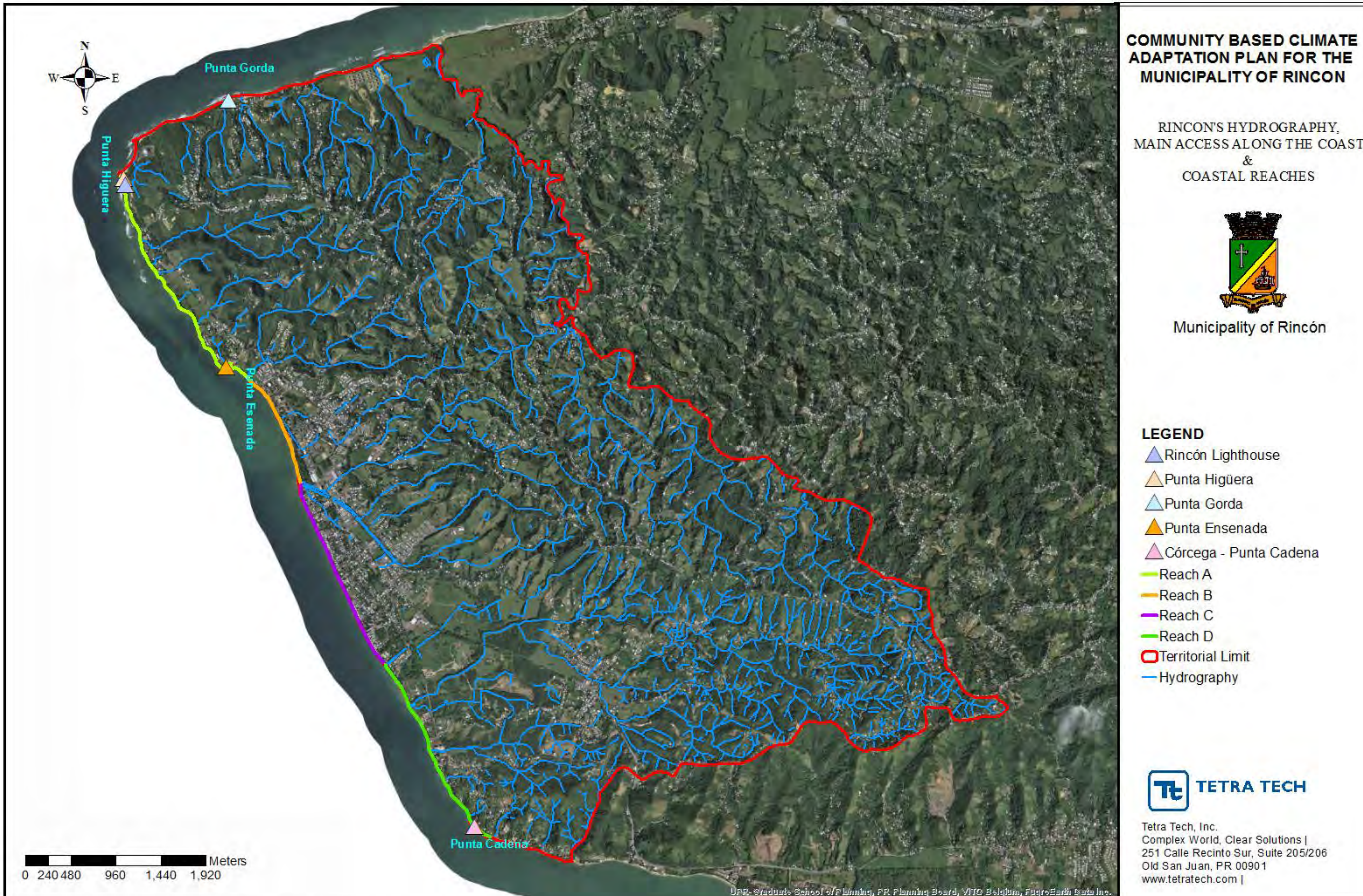
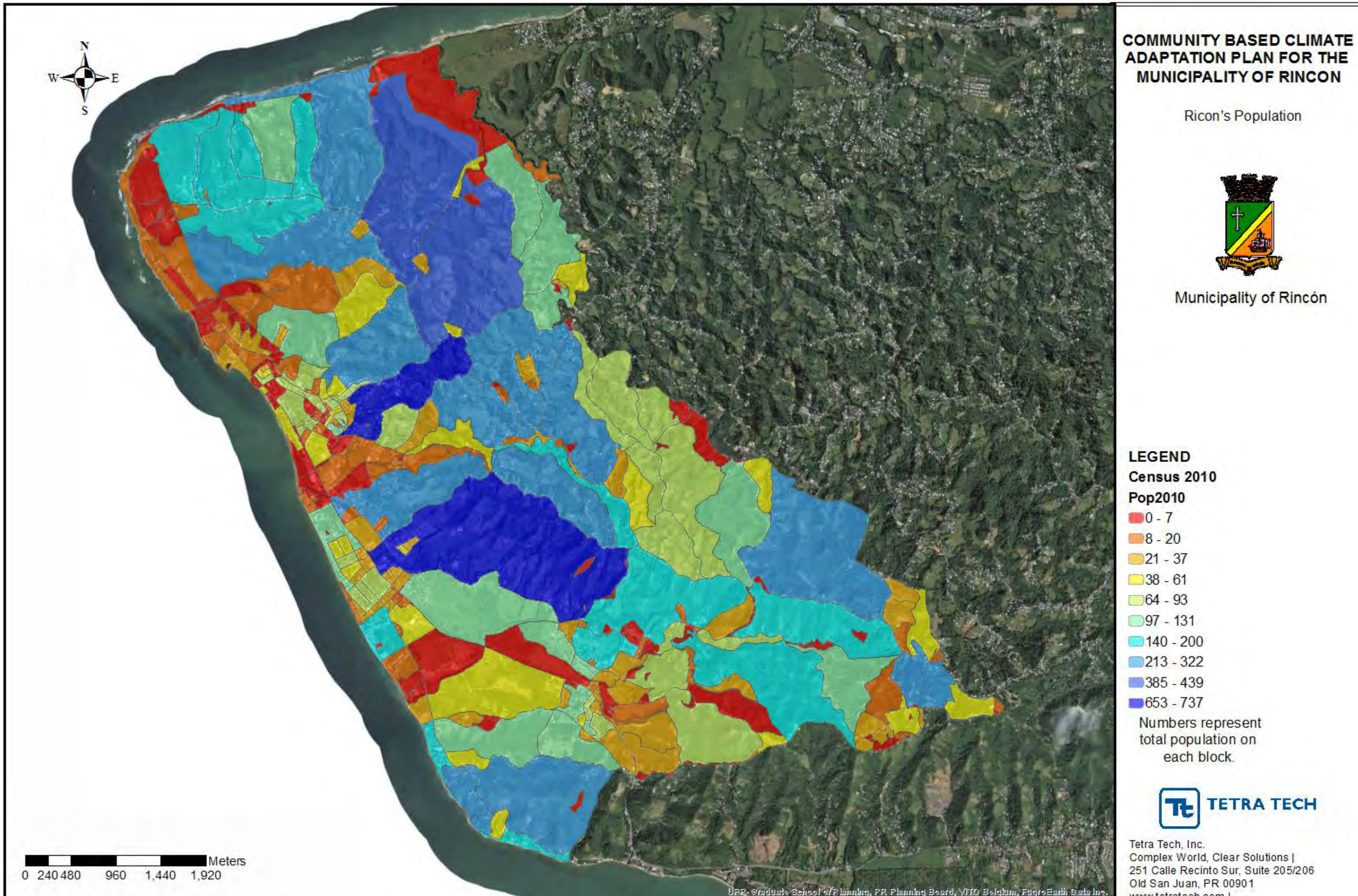
Complex World, Clear Solutions |
251 Calle Recinto Sur, Suite 205/206
Old San Juan, PR 00901
www.tetratech.com |

Figure 2-5. Rincón Topography (South)



Orthophoto: UPR-Graduate School of Planning, PR Planning Board, VITO Belgium, FugroEarth Data Inc. |

Figure 2-6. Rincón Hydrology



Orthophoto: UPR-Graduate School of Planning, PR Planning Board, VITO Belgium, FugroEarth Data Inc. |

Figure 2-7. Rincón's Population Density

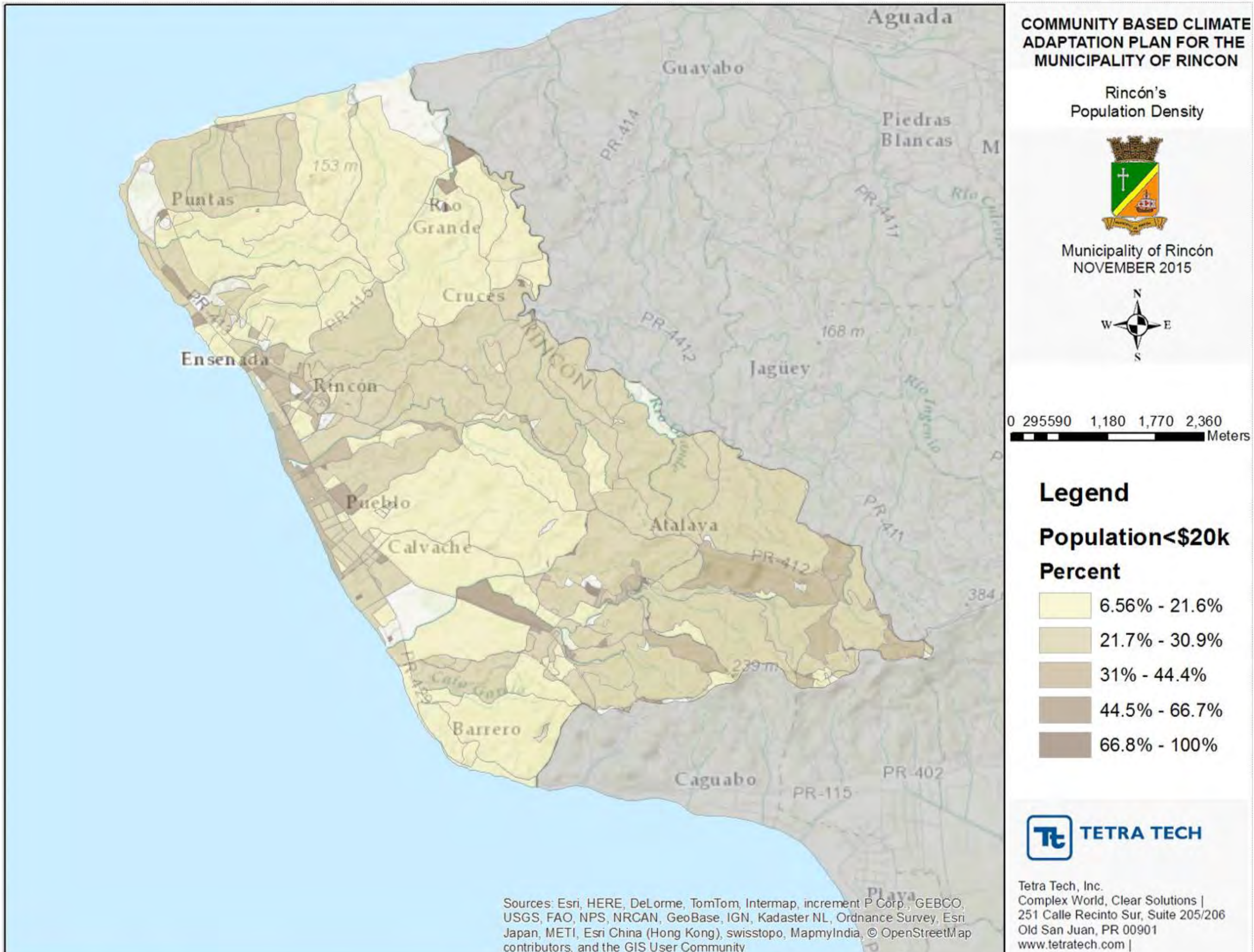
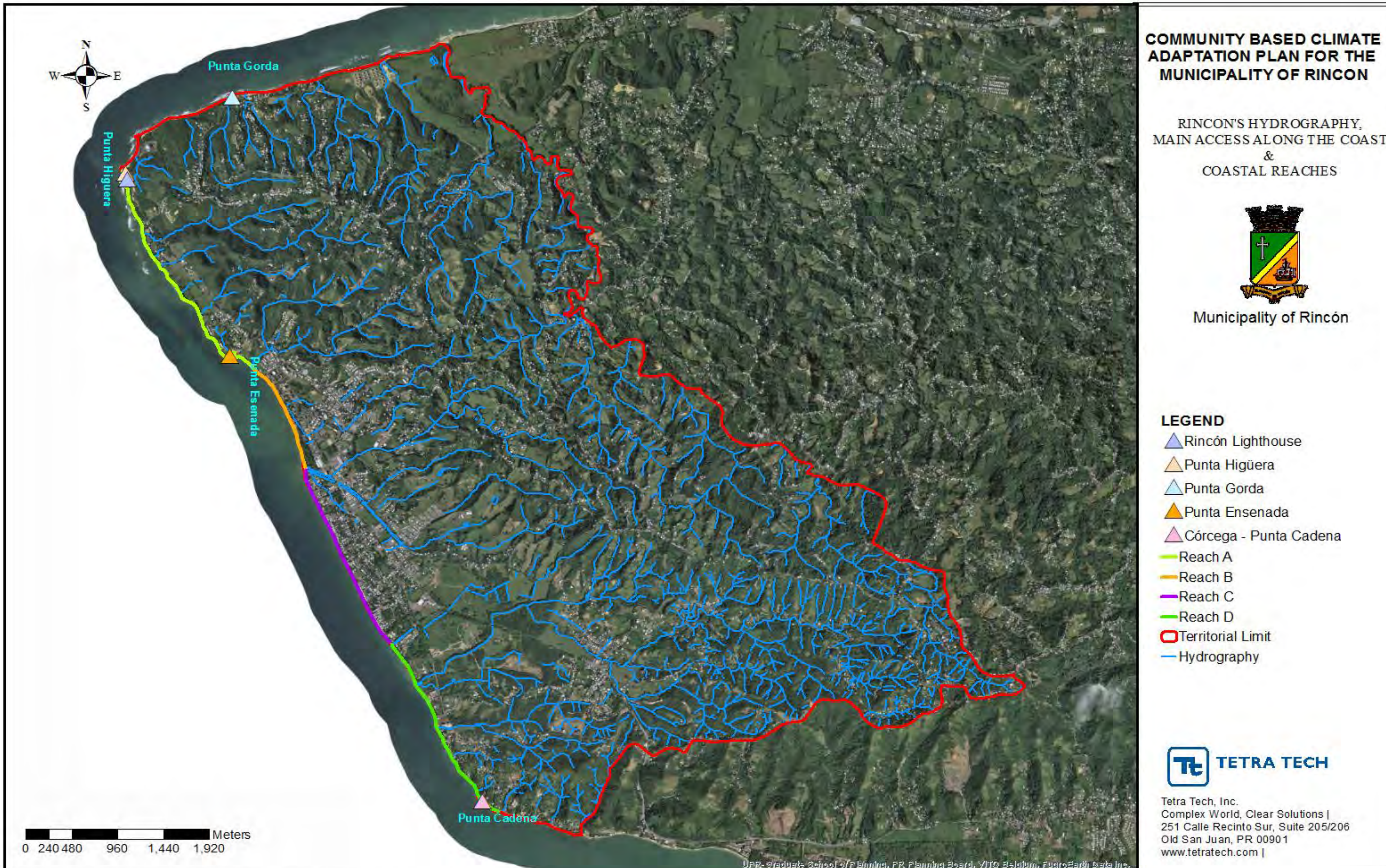


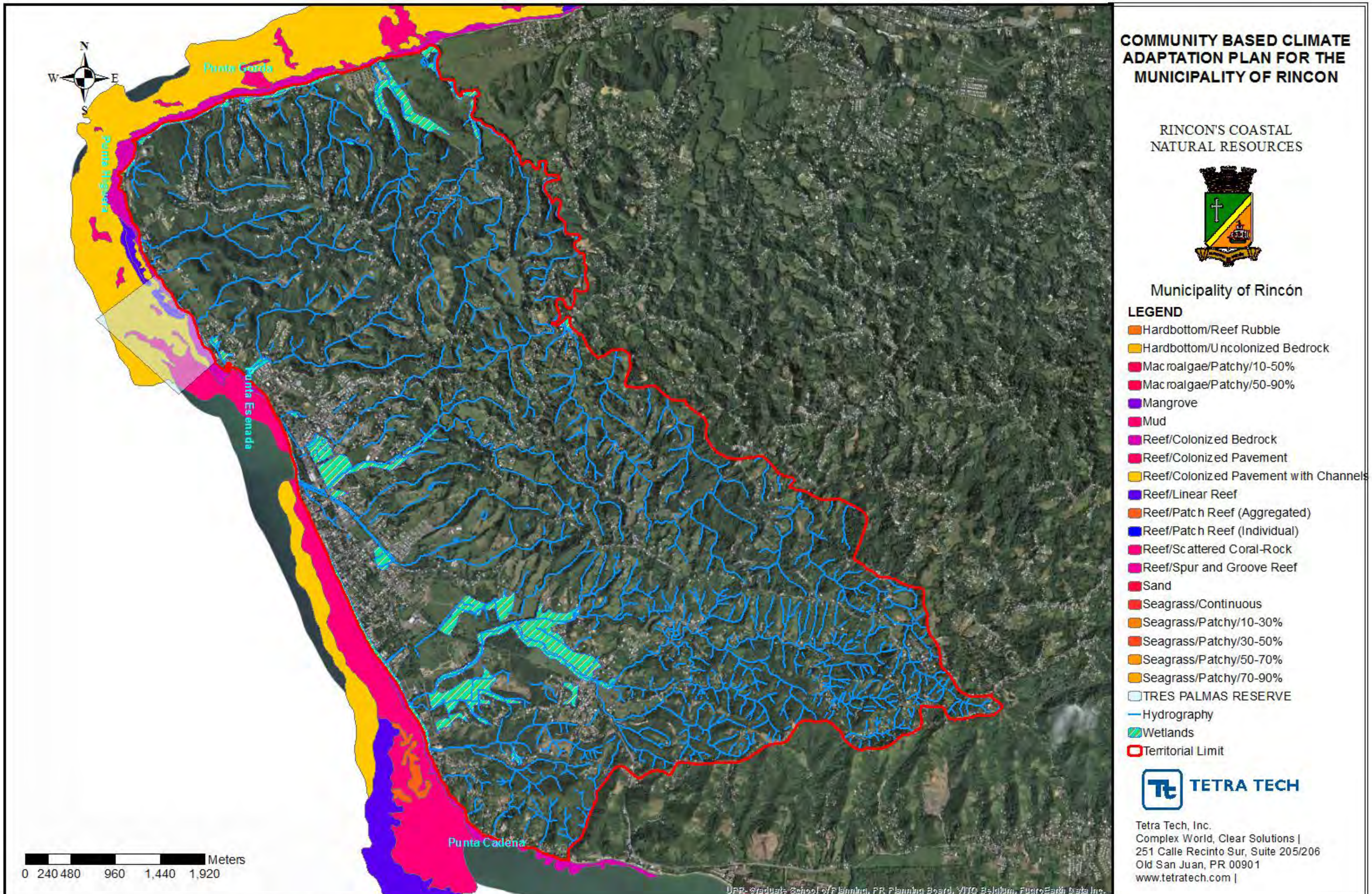
Figure 2-8. Rincón Population with Annual Income < $20,000



Orthophoto: UPR-Graduate School of Planning, PR Planning Board, VITO Belgium, FugroEarth Data Inc. |

Figure 3-2. Rincón Technical Site Visit Locations

Figure 3-3. Rincón Erosion Areas (From Thieler, E.R., R.W. Rodríguez, and E.A. Himmelstoss, 2007)



Orthophoto: UPR-Graduate School of Planning, PR Planning Board, VITO Belgium, FugroEarth Data Inc. |

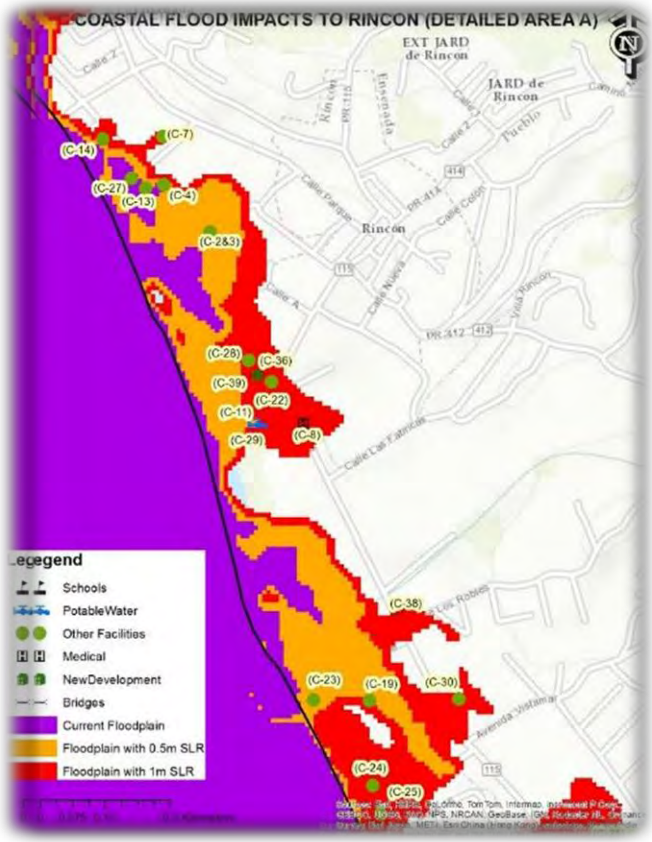
Figure 3-4. Rincón's Natural Resource Areas

Orthophoto: UPR-Graduate School of Planning, PR Planning Board, VITO Belgium, FugroEarth Data Inc. |

Figure 3-6. Exposed Wastewater Pipeline

Community Based Climate Adaptation Plan for Rincón Municipality, Puerto Rico

Volume 2 – Vulnerability Assessment Report



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The Community Based Climate Change Vulnerability Assessment and Adaptation Plan for Rincón Municipality was prepared for Puerto Rico's Coastal Zone Management Program (PRCZMP), Department of Natural and Environmental Resources (DNER).

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Technical inputs and review comments were provided by Rincón Municipality, including: Héctor Martínez, Municipal Emergency Management Office Director; William Ventura, Planning and Engineering Department Director; Manuel González, Recycling Department, Director and Stormwater Coordinator, and; Juan Carlos Pérez, Public Relations Manager. Technical input was also provided by Dr. Ruperto Chaparro, Sea Grant Director; Jean-Edouard Faucher Legitime, University of Puerto Rico at Mayagüez (UPRM), and; Roy Ruiz Vélez, Puerto Rico Water Resources and Environmental Research Institute (PRWRERI). A wide range of stakeholders contributed to the development and findings of this report via consultations and surveys, as identified in Volume 1 and 3 of this report. We are grateful for the significant contributions of these individuals and stakeholders.

Key Terms and Concepts

Key Concepts and Terms

Adapt, adaptation: "Adjustment in natural or human systems to a new or changing environment that exploits beneficial opportunities or moderates negative effect."*

Climate: The weather averaged over a long period of time, typically 30 years or more.**

Climate change: "A change in the state of the climate that can be identified (e.g., using statistical tests) by changes in the mean and/or the variability of its properties that persist for an extended period, typically decades or longer."**

Hazard: "The potential occurrence of a natural or human-induced physical event or trend or physical impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems, and environmental resources."**

Resilience: "A capability to anticipate, prepare for, respond to, and recover from significant multi-hazard threats with minimum damage to social well-being, the economy, and the environment."*

Risk: "A combination of the magnitude of the potential consequence(s) of climate change impact(s) and the likelihood that the consequence(s) will occur."*

Vulnerability: "The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its ability to adapt."*

Weather: The atmospheric conditions at a particular place in terms of air temperature, pressure, humidity, wind speed, and rainfall. Weather is what is happening now or is likely to happen in the very near future.

* National Research Council (NRC). *America's Climate Choices: Panel on Adapting to the Impacts of Climate Change*. National Academy of Sciences, 2010. p. 19. www.nap.edu/catalog.php?record_id=12783.

** Agard, J., E.L.F. Schipper, J. Birkmann, M. Campos, C. Dubeux, Y. Nojiri, L. Olsson, B. Osman-Elasha, M. Pelling, M.J. Prather, M.G. Rivera-Ferre, O.C. Ruppel, A. Sallenger, and K.R. Smith, A.L. St. Clair, Eds. "Annex II: Glossary". *In IPCC, 2014: Climate Change 2014: Impacts, Adaptation, and Vulnerability.* [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L.White (Eds.)]. Cambridge University Press, Cambridge, UK. http://www.ipcc.ch/report/ar5/wg2/.

TABLE OF CONTENTS

1.0 INTRODUCTION

As a municipality located directly on the northwest coast of Puerto Rico, Rincón is sensitive to natural hazards such as hurricanes, extreme precipitation events, and coastal storm surges. Additionally, Rincón is experiencing long-term erosion, which has accelerated in recent years and further increased the municipality's vulnerability to natural hazards. Climate change is expected to exacerbate current challenges and could present new risks to Rincón.

Puerto Rico's Coastal Zone Management Program (PRCZMP), Department of Natural and Environmental Resources (DNER), initiated this study to address the need to better understand how to assess and address climate change related risks to Puerto Rico's municipalities. Pursuant to Section 309 (§309) of the Coastal Zone Management Act (CZMA), PRCZMP completed its Assessment and Strategies report for fiscal period 2011-2015. The report identified: (1) the need for local mitigation strategies, for the prevention of increment of sea level, (2) strategies for adapting to climate change effects, and (3) vulnerability analysis and integration of risk data into local plans, regulations, projects, policies, management plans for special areas, and disaster risk mitigation plans. PRCZMP designed a program to work with local municipalities to better understand their vulnerability to climate change and to develop adaptation strategies to become more resilient. The program initially targets the municipalities of Rincón, Culebra, and Dorado, and is anticipated to include Salina and Loíza at a later date.

Tetra Tech is supporting PRCZMP and the municipality of Rincón to analyze climate variability and impacts on the municipality and to develop an adaptation plan to respond to natural hazard risks. This report details the approach and findings of the Rincón pilot project. The report is organized into the following volumes, which follow major project activities:

- **Volume 1 – Site Description and Initial Stakeholder Outreach and Engagement**. Provides a community profile of Rincon to introduce the report. Identifies the findings and recommendations from initial stakeholder outreach and engagement efforts, including a technical site visit with municipal staff and two public stakeholder workshops.
- **Volume 2 – Vulnerability Assessment.** To assess the climate risk to Rincón, a climate, vulnerability, and impact assessment were conducted.
- **Volume 3 – Risk Profiles and Climate Change Adaptation Plan**. Summaries key risks from the vulnerability assessment in an index, and details the approach and outcomes of the adaptation plan.

This report is **Volume 2 – Vulnerability Assessment.** It has been developed as a stand-alone document that summarizes the vulnerability assessment findings. This report is organized into the following sections:

- Section 2 presents the Methodology;
- Section 3 presents the Climate Assessment
- Section 4 presents Rincón's Exposure and Vulnerability;
- Section 5 presents Rincon's Impact Assessment; and
- Section 6 presents the Climate Risk Index.

2.0 METHODOLOGY

The project team has used a five step process to assess current and future hazards to Rincón and to develop adaptation strategies to mitigate that risk. The methodology has used a robust stakeholder engagement process to solicit input and feedback on methodology and findings, which has involved municipal staff, local technical resources and civic organizations, and the general public. Engagement with local stakeholders is considered critical, as implementation of the adaptation plan will rely on their commitment to action.

Figure 2-1 below identifies the five step methodology used by the team, and identifies the corresponding report volume that details each step.

Figure 2-1. Project Methodology and Associated Report Volume

3.0 CLIMATE ASSESSMENT

This section will present the key sources of climate information that were used to develop the vulnerability assessment, including data on air temperature, sea surface temperature, precipitation, sea level rise, and acidification changes. The impacts that these changes could have on Rincón are described in Sections 4 and 5.

3.1 TEMPERATURE CHANGES

Reviewing the climate model outputs available for the region, there is consensus on continued warming into the future. Over the coming century, projected temperature increases for the Caribbean are slightly below the global average of 2.5 - 4°C (4.5 – 7.2°F) by 2100, but slightly above the tropical average. Projected temperature increases are expected to be significant by late century at all locations. Projections for Puerto Rico show as little as 0.02°C /year warming through 2050, in other words at least 0.8 ºC (1.44 ºF) by mid-century, and as much as 2-5 ºC (3.6-9 ºF) by 2100. Figure 3-1 shows the change in annual temperature for 2080 using the A2 emissions scenario and the highest ensemble Global Circulation Model. This information will be used in the excessive heat impact assessment.

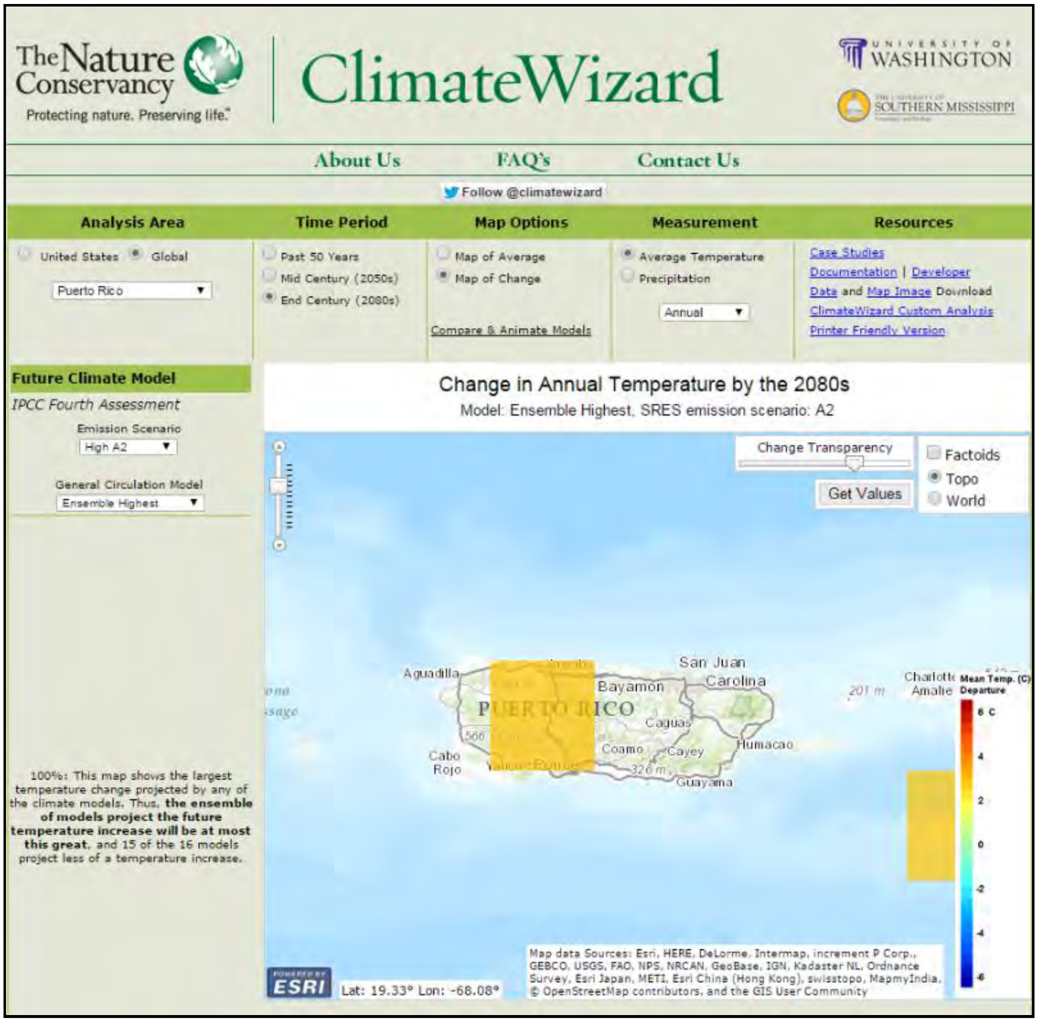


Figure 3-1. Change in Annual Temperature (A2 emissions scenario, highest ensemble, 2080)

3.2 SEA SURFACE TEMPERATURE (SST) CHANGES

Caribbean sea surface temperatures (SST) have increased by 1.5°C over the last century. Three SST analyses were conducted for the Puerto Rico Climate Change Council (PRCCC 2013):

- The West Tropical Atlantic Prediction and Research Moored Array (PIRATA) station data was used, and results showed an increase of 0.026 (+/-0.002)°C per year from 1981 to 2010;
- The optimum interpolation SST analysis product (OI.v2 SST) was used, which is operationally issued weekly for one degree grid for the global ocean, and results showed an increase of 0.023 degrees (+/-0.002) °C per year from 1982 to 2011; and
- Observed SST trends near Puerto Rico were analyzed and found to be 0.008°C/year over the 20th century.

Thus, all trends show a clear warming. Different SST trends are found depending on the length of time analyzed. If data for recent decades are considered, then the SST trend is higher.

Critically, the PRCCC results found SST above the threshold for coral bleaching and will be exceeded over a third of the year.

3.3 PRECIPITATION CHANGES

Reviewing the climate model outputs available for the region, trends in precipitation for Puerto Rico as a whole are unclear. An analysis for the PRCCC shows that since 1948 the Caribbean Basin has seen decreasing precipitation (-0.01 to -0.05 mm/day/year), with a greater drying trend for the Eastern Caribbean. The Caribbean region experiences a decadal oscillation and El Niño Southern Oscillations, which create periodic anomalous conditions in atmospheric circulation patterns and ocean temperatures that impact Puerto Rico. To illustrate the challenge in understanding rainfall, the PRCCC (2013) presented three different studies: an analysis of weather station data for Puerto Rico from the period of 1948 to 2007, which found no clear trends in total annual rainfall for the island as a whole, while another analysis showed decreases in rainfall for the island as a whole, and another analysis showed decreases in rainfall from -0.01 to -0.1 mm/day/year (PRCCC 2013).

Regionally within the island, there are indications that the southern region of Puerto Rico has experienced positive trends in annual rainfall while the western and a portion of the northern region (which includes Rincón) showed decreases. Additionally, seasonal trends with observations show negative trends in summer and positive trends in winter.

In order to simulate future climate change, global climate models need to accurately represent observed climate. There is a lot of uncertainty in the magnitude of precipitation changes in the Caribbean, though a majority of global climate models used by the IPCC show future decreases in precipitation are likely. Most IPCC models project decreases in annual precipitation, varying from -39 to + 11%, with a median of -12%. The annual mean decrease is projected to be spread across the entire region. Specifically, the PRCCC analysis found that past and future trends are similar, a decrease of rainfall of - 0.0012 to -0.0032 mm/day/year, that are projected to continue through 2050.

Extreme Precipitation Events Regional downpours, defined as intense precipitation at sub daily (often sub hourly) timescales, are likely to increase in frequency and intensity in a warmer climate due to the greater capacity of warmer air to hold water vapor. Although projections concerning extreme events in the sub-tropics remain uncertain, all projections report higher risk of increased daily intensity of rainfall. Puerto Rico climate projections for the future show a probable increase in regional downpours.

Thus, while long-term precipitation rates are expected to decrease, the frequency of increased rainfall events is expected to increase for the area. To find the worst case scenario for the flood assessment in Rincón, precipitation changes were assessed for each month for the highest ensemble. Figure 3-2 shows the change in August precipitation (A2 emissions scenario, highest ensemble) for 2050 while Figure 3-3 shows the change in September precipitation (A2 emissions scenario, highest ensemble) for 2080. The end of the summer can often bring flood conditions to the area. Both worst case scenarios show an increase of 50%.

Extreme precipitation events can also trigger landslides in many parts of Puerto Rico based on elevation changes, land cover, and soil types. These conditions are not very prevalent in Rincón, however. The Hazard Mitigation Plan that was prepared for the municipality rated the landslide risk very low in 2010 (Figure 3-4).

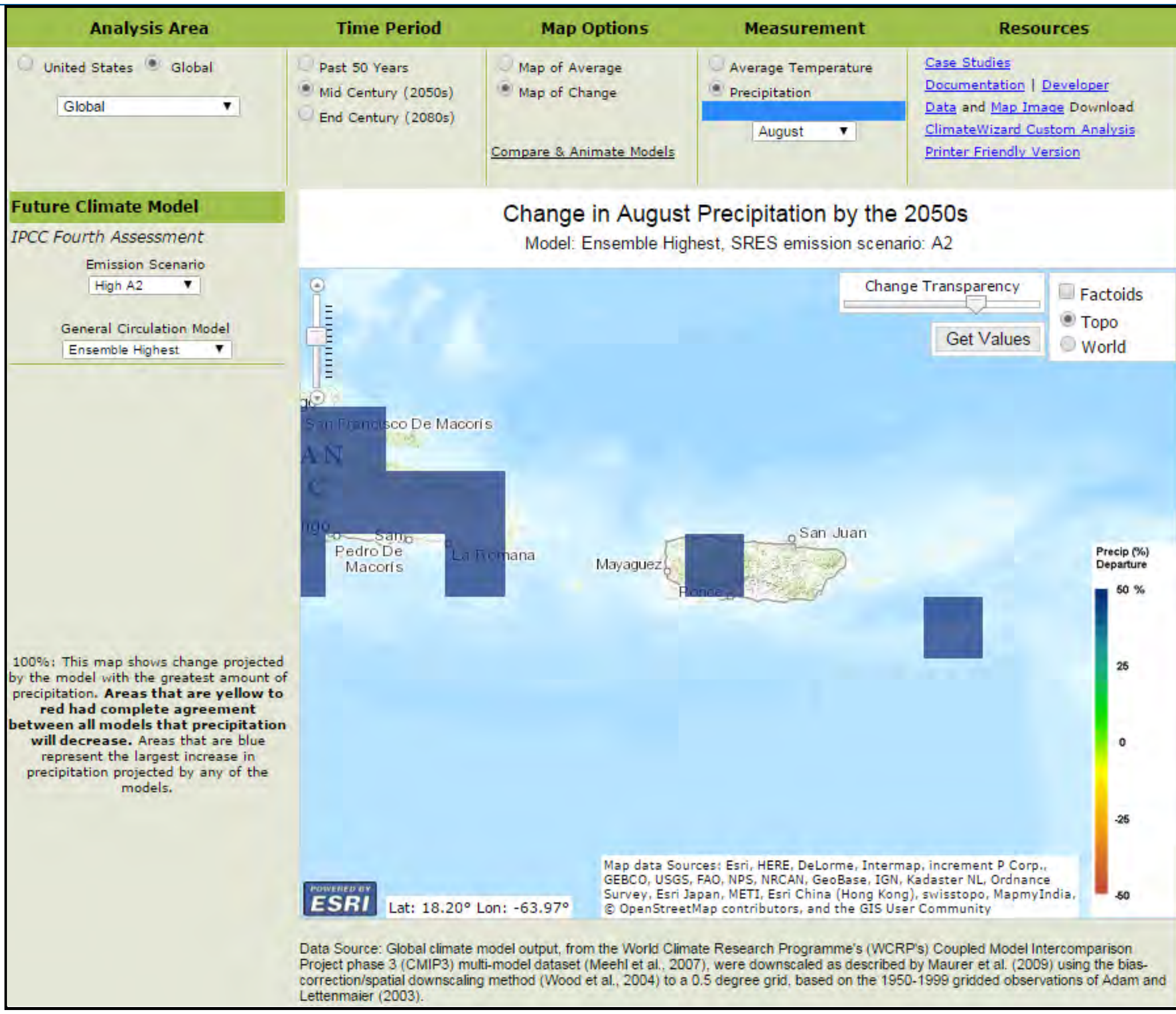


Figure 3-2. Change in August Precipitation (A2 emissions scenario, highest ensemble, 2050)

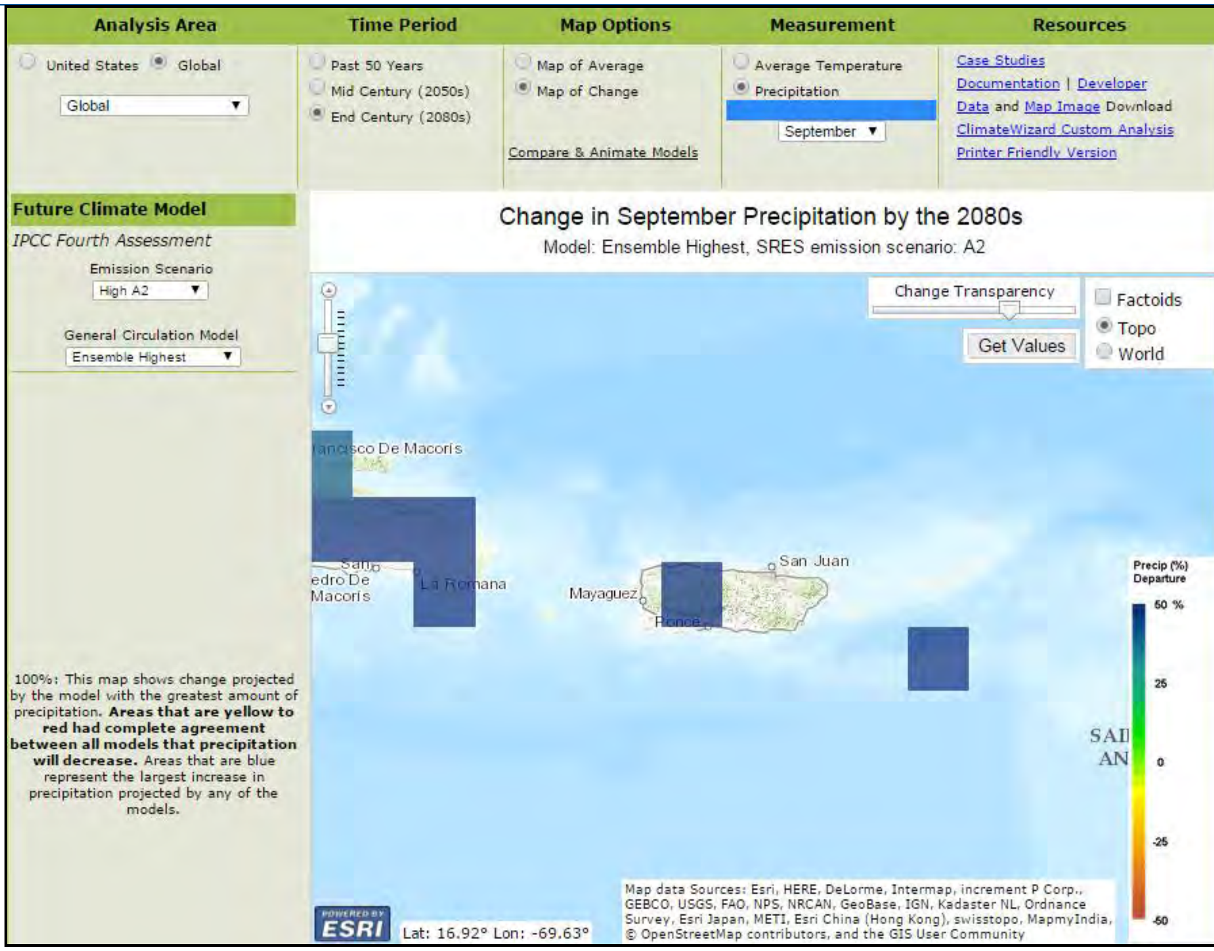


Figure 3-3. Change in September Precipitation (A2 emissions scenario, highest ensemble, 2080)

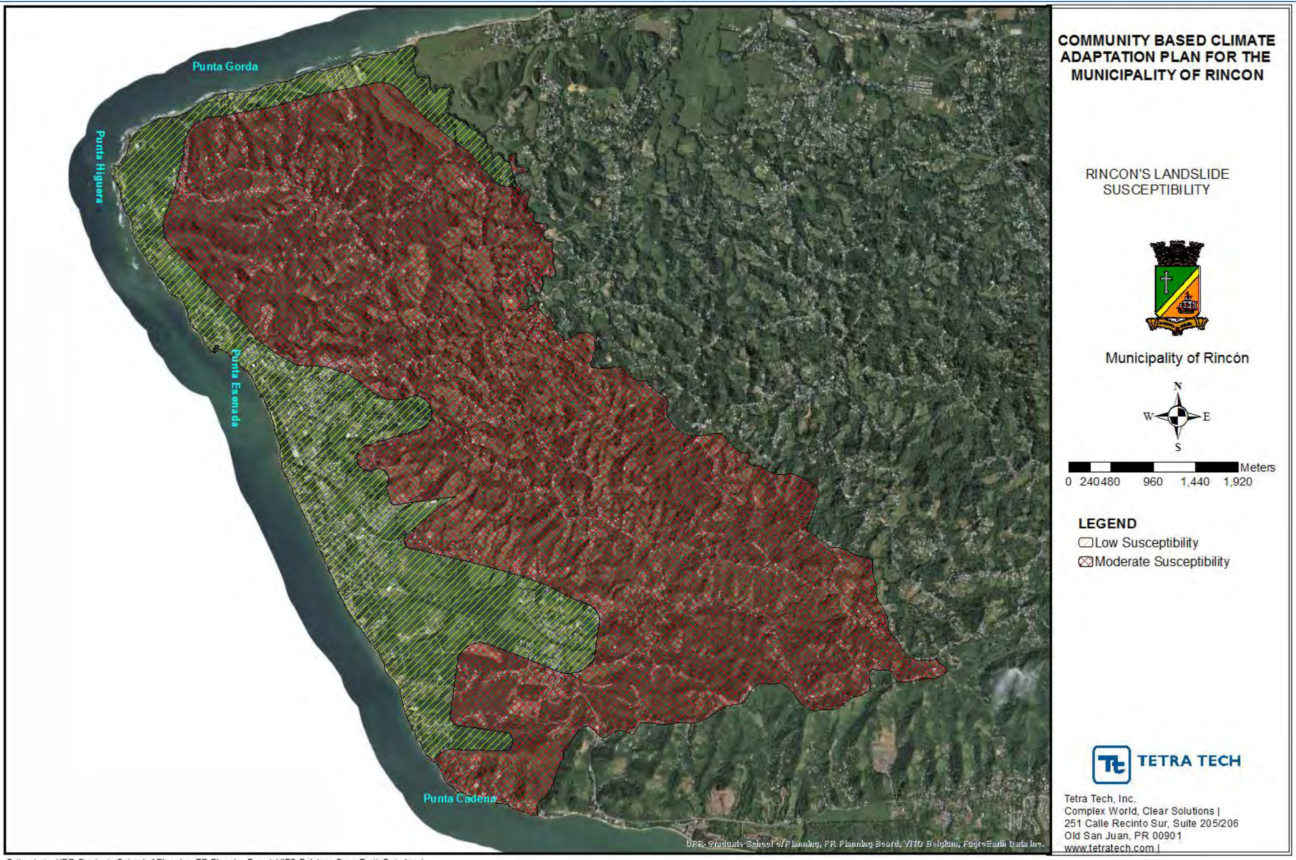


Figure 3-4. Rincon's Landslide Susceptibility Map.

3.4 SEA LEVEL RISE AND EROSION

Both mean conditions and extremes of sea level will change over a range of time scales. Global sea levels have been rising via thermal expansion resulting from warming of the oceans, as well as freshwater input from the melting of a majority of Earth's glaciers and ice sheets.

Tide gauge records from Isla Magueyes (shown in Figure 3-5) and from San Juan (shown in Figure 3-6) contain the longest sea level time series in the U.S. Caribbean. Three analysis were conducted for the PRCCC: (1) Dr. Jorge Capella with UP-R's CariCOOS; (2) UPR Professor Aurelio Mercado; and (3) UPR's Dr. Mark Jury. All three studies show sea level rise trends for Puerto Rico. Analyses of Puerto Rico's tide gauges show a rise of at least 1.4 mm/year, which is expected to continue and possibly will accelerate. As a result of the already observed sea level rise as well as weak shoreline management practices, coastal erosion is causing a retreat of the coastline of up to one meter per year (1.0 m/yr) in some coastlines of Puerto Rico, including Rincón, according to a USGS report that considered sequences of past aerial photos. The erosion rates for Rincón may be seen in Figure 3-7 and show how many centimeters are eroded annually. Refer to section 3.2 in Volume 1 for a full breakdown of historic erosion rates per reach.

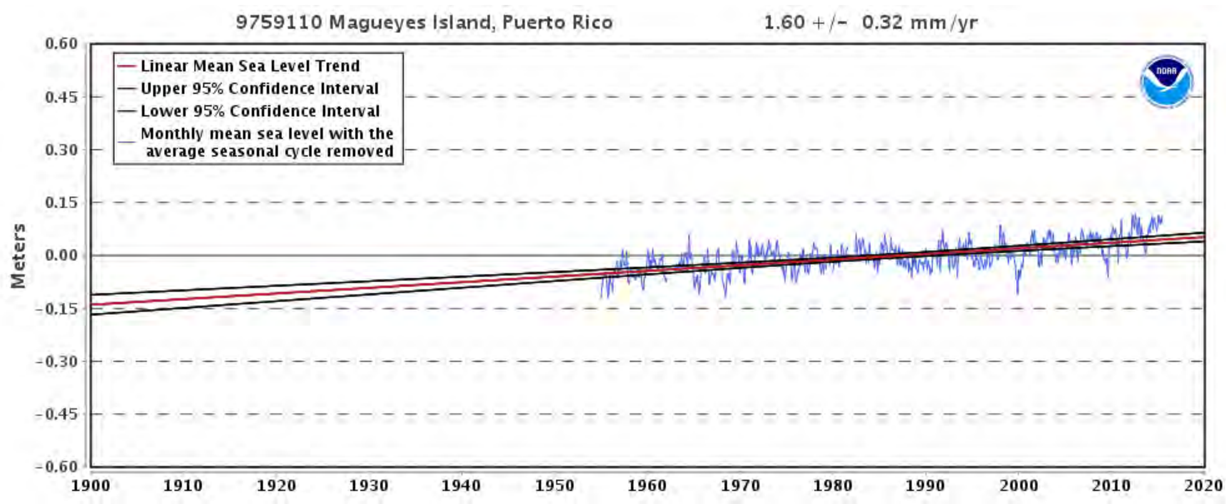


Figure 3-5. Sea Level Rise Trends for Magueyes Island, Puerto Rico

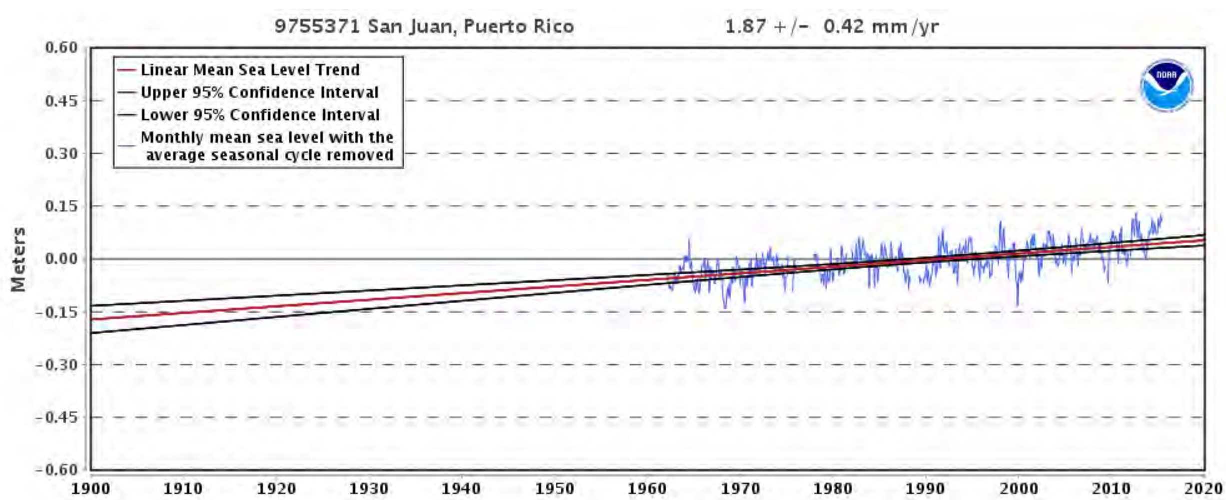


Figure 3-6. Sea Level Rise Trends for San Juan, Puerto Rico

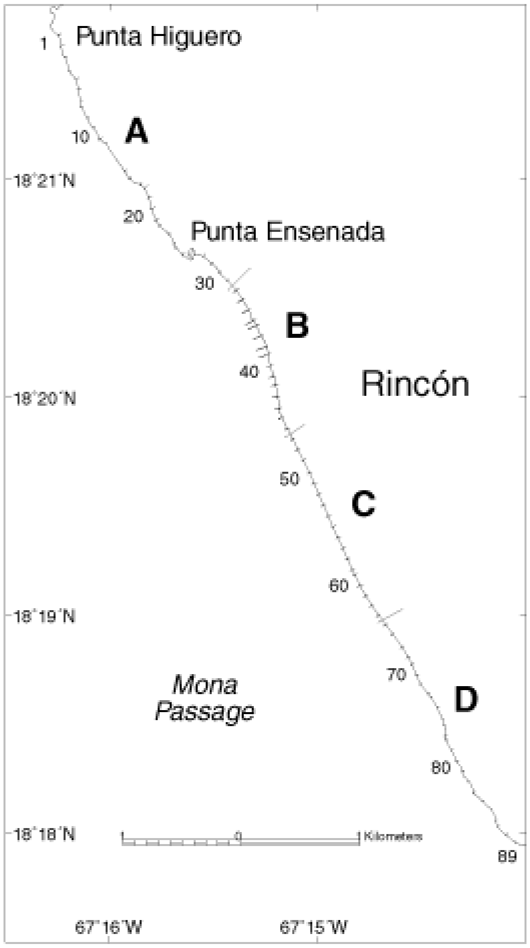


Figure 3-7. Erosion Rates (cm/year)

The extent of sea level rise is dependent on interactions between the climate system, thermal expansion of ocean water, the breakup of polar ice, melting of glaciers and permafrost and local geological height changes due to tectonic plate movement. The effects of rising sea level will be amplified by the short-term impacts of storm surges. The risk of large sea-level rise already in the 21st century is now estimated to be much greater than the IPCC estimates of 0.18-0.59 meters. The IPCC Special Report on Climate Extremes states that it is very likely that mean sea level rise will contribute to upward trends in extreme coastal high water levels in the future. There is high confidence that locations currently experiencing adverse impacts such as coastal erosion and inundation will continue to do so in the future due to increasing sea levels, all other contributing factors being equal.

Combining climate modeling and paleoclimatic data, total sea-level rise of about 2.0 m by 2100 has been estimated as the maximum that could occur, with a best estimate of about 0.8 meters. Based on information provided by the US Army Corps of Engineers and NOAA for future projections for sea level rise, the PRCCC recommends planning for a rise of 0.5-1.0 meters by 2100. For this report, SLR estimates of 0.5 and 1.0 meters will be used.

3.5 ACIDIFICATION

Currently, atmospheric carbon dioxide concentration has reached 395 ppm globally and because half of the carbon dioxide released both naturally and by humans is taken up by the oceans, the average pH of the oceans has dropped from 8.16 to 8.05 since the year 1800. This change in seawater chemistry is equivalent to an increase of carbon dioxide concentration of about 35% and a decrease in pH of 0.1 units. As a result, there has been a global decrease in surface seawater carbonate saturation states and thus, the rate of calcification in marine calcifying organisms and the precipitation of carbonate minerals like calcite and aragonite are decreasing as well. The Caribbean and Puerto Rico saturate states of carbonate minerals reflects this global trend. For example, the values of aragonite saturate states are declining within the Puerto Rico-Caribbean region at a rate about 3% per decade.

4.0 RINCÓN EXPOSURE AND VULNERABILITY

Rincón is located on the coastal plain of the western San Francisco mountain range, with its highest point being the summit of *Atalaya* Mountain at 1,187 feet. The Municipality's boundary to the North East is the *Río Grande* and other natural surface waters in the Municipality include the *Quebradas Calvache, Los Ramos, Piletas and García*.

The Municipality is a travel destination both for residents throughout Puerto Rico and internationally because of its natural beauty and excellent surfing conditions from October through March. These attractions have produced substantial development pressures in the Municipality, consisting of new resorts, condominiums, and second home construction along the coast. The value of undeveloped land in the coastal area has increased significantly over the past ten years.

Rincón's population of 15,200 resides in its nearly 13.8 square miles of territory, resulting in a population density of 410 persons per square mile (Census 2010). According to the 2010 US Census, most of its population resides in urban areas and 26 percent of its population are under 18 years of age. Many of the more densely populated areas are adjacent to the shoreline. Fifty six percent (56%) of the population of Rincón lives below the poverty level, and Rincón has one of the highest unemployment rates in Puerto Rico, estimated at 28.7 percent. Figure 2-8 shows those households making less than $20,000 per year as a percent of the population. Many of these households also are adjacent to the shoreline. Thus, Rincón's population is highly exposed to coastal hazards due to the high percentage of the population in proximity to the shoreline. Refer to the Section 2 of Volume 1 for a full site description, including maps.

4.1 GENERAL BUILDING STOCK

Building distribution and occupancy information collected during field surveys was integrated into a database to determine the number of representative building types across the Municipality. The compilation of this data provided the Consultant Project Team with the ability to differentiate between building types with substantially different damage and loss characteristics. It also provided critical information to assess the values of the general building stock across the municipality. Table 4-1 below lists the estimated value for general occupancy classes used for this risk assessment.

Table 4-1. Aggregated Building Stock Values

Building Occupancy Class	Estimated Aggregate Replacement Cost ($)	Estimated Aggregate Content Cost ($)	Total Value ($)
Residential	803,740,033	359,481,801	1,163,221,834
Commercial	374,502,967	229,856,199	604,359,166
Total	**1,178,243,000**	**589,338,000**	**1,767,581,000**

Exposure estimates are based on aggregated building replacement costs (dollars per square foot).

4.2 CRITICAL FACILITIES

Facilities such as schools, police and fire stations, and hospitals, are known as "critical facilities." Other critical facilities include lifelines which may be divided into two distinct classes that have substantially different damage and loss characteristics: (1) transportation systems (key roads, ports, etc.) and (2) utility infrastructure (electric power stations, potable water filtration plants, wastewater treatment plants, water pumps, etc.).

A detailed list of critical facilities was created using the list developed by the Hazard Mitigation Committee and Director of Emergency Management in addition to a list provided during this project kick-off. Critical facilities are defined as those facilities that provide essential services and functions. Table 4-2 lists the number of facilities identified during this study effort and the average estimated exposure value for each facility class. Figure 4-1 provides a map of critical facility locations throughout the Municipality.

Table 4-2. Critical Facilities

Name	Address	Facility Type*	Occupancy Type**	Replacement Cost (Structural value)	Building Type***	Backup Power
City Hall	Calle Muñoz Rivera #5	City Hall	Municipal Government	$4.5 million	Concrete	Yes
Rincón Health Center	Calle Muñoz Rivera #58	Hospital	Medical	$5.6 million	Concrete with fire proof gypsum board	Yes
State Police Station	Calle Nueva Final	Police	Government	$800 thousand	Concrete	Yes
Elderly Home	Calle Nueva Final	Residential Elderly Home	Residential	$800 thousand	Concrete Galvalum roof	No

Name	Address	Facility Type*	Occupancy Type**	Replacement Cost (Structural value)	Building Type***	Backup Power
Emergency Management Department	Calle Nueva Final	Emergency Management	Municipal Government	$300 thousand	Concrete	Yes
Conrado Rodríguez Elementary School	Calle Nueva Final	School	Education	$1 million	Concrete	No
Head Start Pueblo Urbano Ward	Calle Nueva Final	School	Education	$300 thousand	Concrete	No
Manuel García High School	Calle German Chaparro	School	Education	$2.5 million	Concrete	No
Public Works Department	Calle German Chaparro	Vehicle Maintenance, Recycling, Diesel Storage	Municipal Government	$1 million	Concrete, wood and zinc roof	Yes
Fire Station	Calle Germán Chaparro Interior	Fire Station	Government	$1 million	Concrete	Yes
Flood Mitigation Channel	Road 115 Pedro Albizu Campo Avenue Km. 12.3	Bridge	Transportation	$1 million	Concrete	No
Quebrada Los Ramos Bridge	Road 115 Pedro Albizu Campo Avenue Km. 12.3	Bridge	Transportation	$800 thousand	Concrete	No
Pumping Station and Diesel Reserve	Road 115 Pedro Albizu Campos Avenue Km 11.4	Potable Water Facility	Utility	$300 thousand	Concrete	Yes
Head Start Stella Community	Estella Community Street #11	School	Education	$100 thousand	Concrete and Galvanize roof	No
Sports Multi-Complex (Stella Community Assembly Point)	Road 115 Km 10.6	Coliseum, Athletes Track, Baseball Stadium and Tennis Courts	Government	$11 million	Concrete	No
Electrical Sub-Station for Sports Complex	Road 115 Km 10.6	Electrical Facility	Utility	$100 thousand	Concrete and Steel	Yes
Corcega Community Bridge Road 429	Barrio Calvache Road 429 Km 1.9	Bridge	Government	$500 thousand	Concrete and Asphalt	No
Manuel González Meló Elementary and Middle School	Barrio Calvache, Pedro Albizu Campos Avenue Km 9	School	Education	$3 million	Concrete	No

Name	Address	Facility Type*	Occupancy Type**	Replacement Cost (Structural value)	Building Type***	Backup Power
Pumping Station and Reservoir Tank 500K gallons	Barrio Calvache, Los Pichones Sector	Potable Water Facility	Utility	2.6 million	Concrete	Yes
Bridge- Road 411	Barrio Calvache Km 1	Bridge	Transportation	$500 thousand	Concrete and Asphalt	No
Bridge Braulio Pérez	Barrio Calvache	Bridge	Transportation	$200 thousand	Concrete and Asphalt	No
TV Station WOLE CH. 12 (Repetition)	Barrio Atalaya, La Torre Sector	Broadcasting Facility	Communication	$1 million	Concrete and Steel	Yes
TV Station WTPM CH. 67 (Repetition)	Barrio Atalaya, La Torre Sector	Broadcasting Facility	Communication	$1 million	Concrete and Steel	Yes
Wireless Communication Antenna Barrio Atalaya	Barrio Atalaya, La Torre Sector	Wireless Communication	Communication	$500 thousand	Steel	Yes
Electrical Sub-Station	Barrio Atalaya, La Torre Sector	Utility – Energy Facility	Utility	$100 thousand	Steel	No
Drinking Water Well for Emergency Use Barrio Atalaya	Barrio Atalaya, Road 411	Potable Water Facility	Utility	$110 thousand	Concrete	Yes
Octavio Cumpiano Elementary School	Barrio Atalaya, Road 411	School	Education	$250 thousand	Concrete	No
Maestro Gandía Middle School	Barrio Cruces, Road 412 , Km. 3.2	School	Education	$200 thousand	Concrete	No
Rincón Medical Center	Road 115 Pedro Albizu Campos Avenue Km. 12.1	Hospital	Medical	$6 million	Concrete	Yes
Bridge Road 115 Barrrio Calvache Km. 10	Road 115 Barrrio Calvache Km. 10	Bridge	Transportation	$250 thousand	Concrete and Asphalt	Yes
Water Wells Pumping Station Rincón I	Barrio Pueblo Km. 12.1	Potable Water Facility	Utility	$300 thousand	Concrete and Asphalt	Yes
Bridge- Road 115	Road 115 Km 12.1	Bridge	Transportation	$100 thousand	Concrete and Asphalt	No
Jorge Seda Crespo Middle School	Cambija Street	School	Education	$2.5 million	Concrete	No
Electrical Sub-Station Barrio Ensenada	Barrio Ensenada Km 0.6	Utility - Electrical Facility	Utility	$100 thousand	Concrete and Steel	No

Name	Address	Facility Type*	Occupancy Type**	Replacement Cost (Structural value)	Building Type***	Backup Power
Genoveva Pérez Elementary School	Barrio Puntas	School	Education	$350 thousand	Concrete	No
Pumping Station Reservoir tank (1 million gallons)	Barrio Ensenada, Ismael Sánchez Sector Road 413	Potable Water Facility	Utility	$1 million	Concrete	Yes
Wireless Communication Antenna	Barrio Ensenada, Ismael Sánchez Sector Road 413	Wireless Communication	Communication	$500 thousand	Steel	No
Pumping Station Puntas II	Barrio Río Grande Road 115 Km. 16.7	Potable Water Facilty	Utility	$100 thousand	Concrete	No
Electrical Sub-Station Barrio Río Grande	Barrio Río Grande	Utility - Electrical Facility	Utility	$250 thousand	Steel and Aluminum	No
Bridge on Intersection between Road 115 and 400	Intersection between Road 115 and 400, Km 17.5	Bridge	Transportation	$100 thousand	Concrete and Asphalt	No
Bridge on Road 115	Road 115 Km. 17.8	Bridge	Transportation	$100 thousand	Concrete and Asphalt	No
Drinking Water Pumping Station Puntas I	Barrio Ensenada Km 17.2	Potable Water Facility	Utility	$100 thousand	Concrete	No
Juan Ruiz Pedroza Elementary and Middle School	Sol Street, Ramón Amaes Street Corner	School	Education	$1 million	Concrete	No
Municipal Police Station	Sol Street, Ramón Amaes Street Corner	Police	Government	$250 thousand	Concrete	No
Texaco Road 115 intersection with Road 411Km. 8.8	Road 115 intersection with Road 411 Km 8.8	Gas Station	Commercial	$300 thousand	Concrete	No
Texaco Road115 Km. 11.4	Road 115 Km. 11.4	Gas Station	Commercial	$300 thousand	Concrete	No
Texaco Road 115 Calle Muñoz Rivera	Road 115 Calle Muñoz Rivera	Gas Station	Commercial	$300 thousand	Concrete	No
Texas Road 115 Calle Sol	Road 115 Calle Sol	Gas Station	Commercial	$300 thousand	Concrete	No
Ramos Service Center Gas Station	Road 115	Gas Station	Commercial	$300 thousand	Concrete	No

Name	Address	Facility Type*	Occupancy Type**	Replacement Cost (Structural value)	Building Type***	Backup Power
Puntas Park-Assembly Point	Road 413 Km 2.5	Park	Recreation	$250 thousand	Concrete	No
Pueblo Park-Assembly Point	Road 115	Park	Recreation	$500 thousand	Concrete	No
Lighthouse	Road 413 Km 2.5	Lighthouse	Government	$850 thousand	Concrete	Yes
Nuclear Plant-Domes Facility	Road 413 Km 2.5	Nuclear Plant	Industrial	$26 million	Concrete	No
Rafucci Gas Warehouse	Colinas de Ensenada	Propane Gas Distributors	Commercial	N/A	Concrete	No
Public Transportation Terminal	Calle Nueva Final	Public Trans-portation Terminal	Transportation	$100 thousand	Concrete	No
Spanish Wall Site, Wastewater Pipeline	Beach	Public Pipeline	Utility	$100 thousand	Concrete	No
Historic Landfill	Near Pump Station	Hazardous Site	Landfill	-------------	N/A	No
Los Ramos Channel	Extends 1 mile inland	Channel	Channel	-------------	N/A	No
Córcega Beach	Close to Route 115	Recreation	Beach	-------------	N/A	No

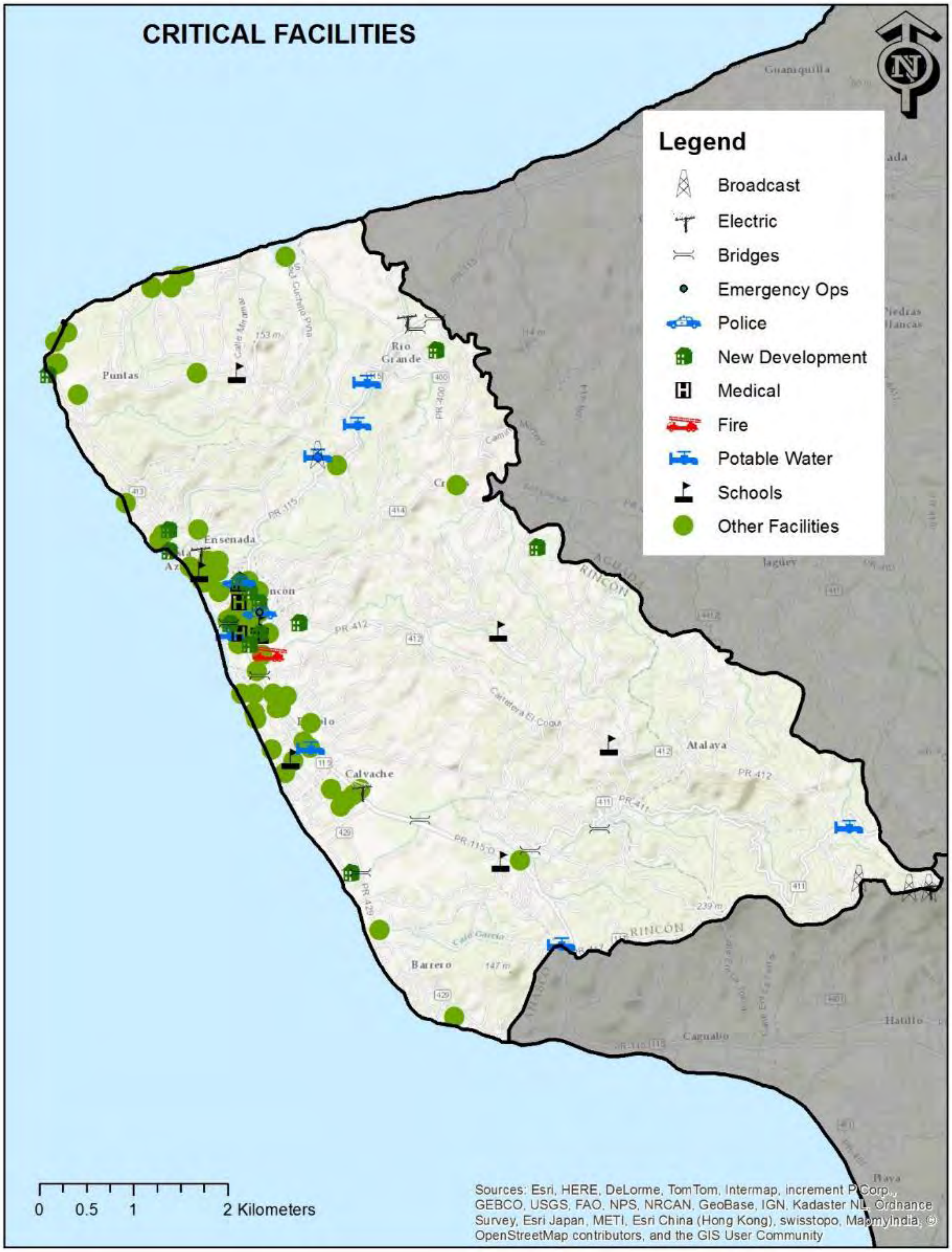


Figure 4-1. Critical Facilities

5.0 RINCÓN IMPACT ASSESSMENT

To understand potential impacts, a community must evaluate what assets are exposed or vulnerable in the identified hazard area. For the climate-induced and exacerbated hazards in this report, the community information described in Section 3.0 was used to better quantify potential impacts. FEMA's Hazus software was used to determine quantitative infrastructure loss estimates for the following natural hazards: sea-level rise, coastal flood, riverine flood, and hurricane surge. For each of those natural hazards, the following sub-sections were developed to detail methodology and impacts:

- the methodology used for the evaluation,
- impacts to the general building stock,
- impacts to the critical facilities, and
- impacts to the people and the environment

Additionally the impacts from drought; coral bleaching, sea temperatures, and ocean acidification; and extreme temperatures were considered.

5.1 SEA-LEVEL RISE AND COASTAL EROSION

The sea-level rise assessment involved identifying two time horizons or water heights to be analyzed. Since the PRCCC has identified values of 0.5 and 1.0 meters and since the storm surge maps also include those values, they were adopted for the rest of the analysis. For the coastal erosion analysis, the erosion rates identified in Section 2 (10 to 89 cm/year) were used and increased to account for sea-level rise.

An aim of this analysis is to consider how sea level rise combined with coastal erosion could impact Rincon for two time horizons: mid- and late-century. Assuming an erosion rate of over 1m/year, a buffer of 50 and 100 meters was created using Geographic Information System (GIS) software to illustrate the potential of future impacts for these two time horizons. This buffer is simply the distance from the shoreline inland and does not account for elevation changes. A detailed erosion model would have required a high resolution digital elevation model (DEM) and additional resources. Thus, this approach only looks at the distance from the shore and not the vertical distance, which is a limitation. However, current sea level rise estimates/viewers do not include coastal erosion, which is of concern for Rincon; thus, these buffers are useful to start to understand the potential impacts if coastal erosion rates continue unabated. The development of a high resolution DEM combined with sea level rise would provide better site specific analysis.

For the purposes of this assessment, infrastructure projected to be underwater because of sea-level rise for the two depths are considered a total loss for the purposes of this study; this is because it is assumed adaptation will not take place and losses to current systems are desired. It should be noted that infrastructure reclamation estimates were not conducted for this project. Infrastructure located in the buffer areas was considered as "proximity" to the shoreline. Due to the limitations of the study this was not modeled as total loss but rather as infrastructure that should be carefully considered as environmental conditions (coastal erosion combined with sea level rise) change in the future.

This section describes how the sea-level rise estimates were developed and the results of the analysis.

5.1.1 Methodology

To assess vulnerability, all the infrastructure located within the sea-level rise was considered a total loss while everything within the buffers was considered in proximity to the shoreline. All families living in residences within these buffers would be considered in proximity (50m or 100m) to the shore.

Figure 5-1 depicts the areas subjected to 0.5m and 1.0m of sea-level rise while Figure 5-2 depicts the areas subjected to 50m and 100m of coastal erosion and the critical facilities in proximity to the shore.

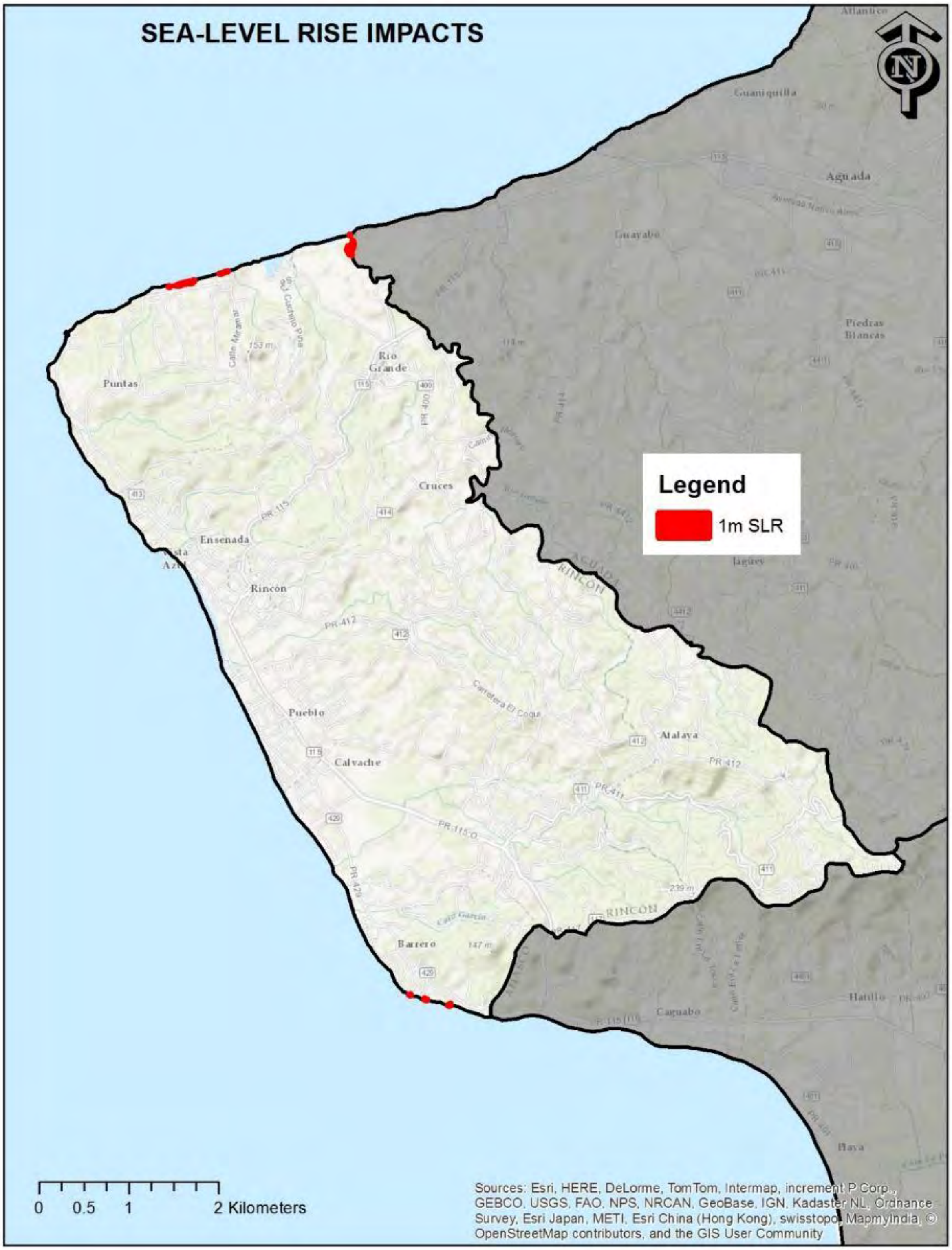


Figure 5-1. Sea-Level Extents

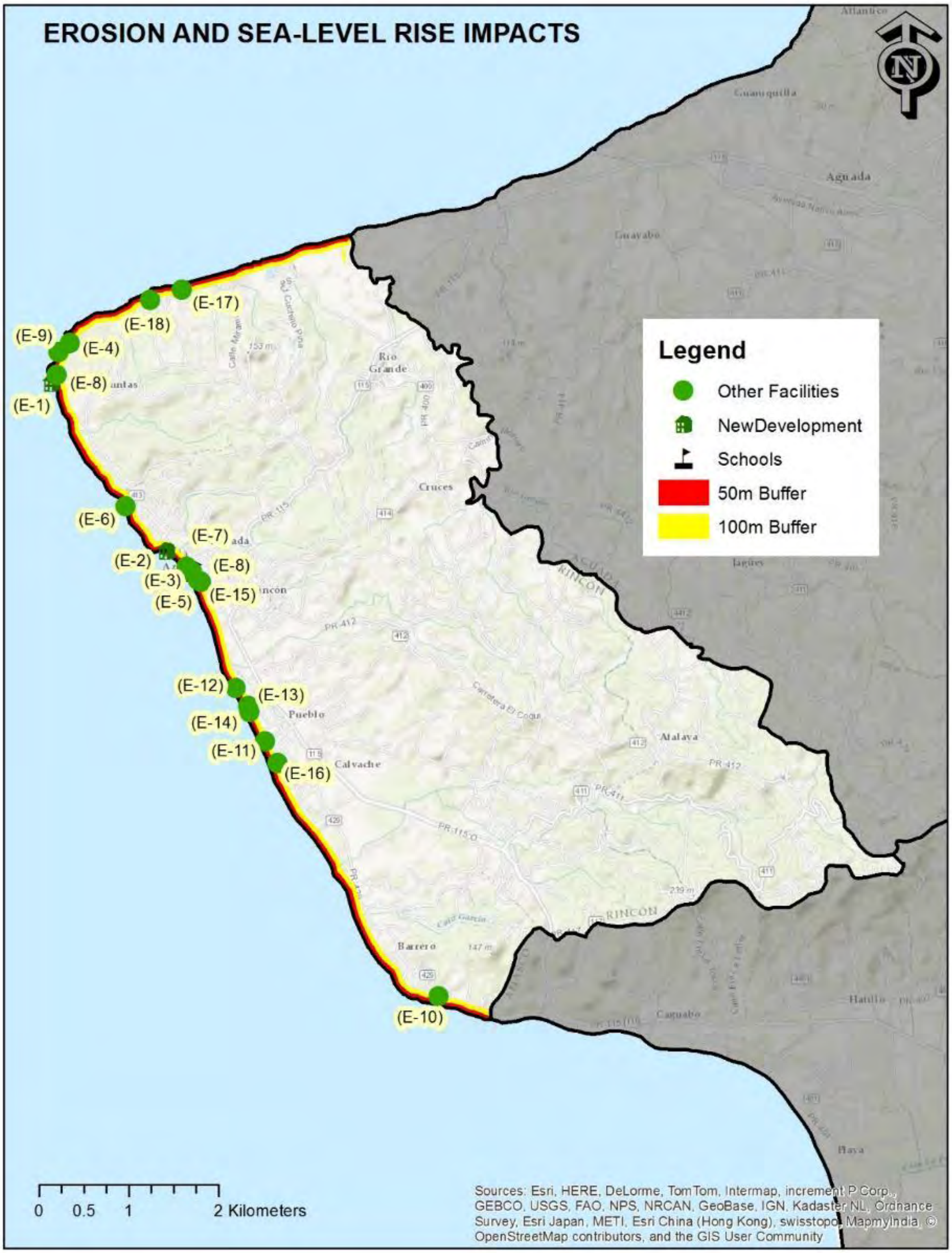


Figure 5-2. Erosion and Sea-Level Rise Proximity Areas

5.1.2 Proximity of General Building Stock

Using the general building stock exposure values in FEMA's Hazus software and the buffered areas indicating erosion, Table 5-1 was developed to show what would be in proximity to the shore. Although there may not be 7 percent of the residences within 100 meters of the shoreline, the structures that are there are more valuable and worth 7 percent of the total residential building stock for the municipality.

Table 5-1. Erosion and Sea-Level Rise Impacts to General Building Stock

		50m	100m
		Exposure ($)	**Exposure ($)**
Residential	Structure	28,229,000	53,899,000
	Contents	14,118,000	26,958,000
	Total	**42,347,000**	**80,857,000**
	% of Total	**3.64%**	**6.95%**
Commercial	Structure	13,153,000	34,463,000
	Contents	6,579,000	17,238,000
	Total	**19,732,000**	**51,701,000**
	% of Total	**3.26%**	**8.55%**

5.1.3 Proximity of Critical Facilities

Using the critical facilities identified in Section 3.0 and the buffered areas, Table 5-2 was developed to show what would be in proximity to the shore.

Table 5-2. Erosion and Sea-Level Rise Proximity of Critical Facilities

Map ID	Facility	50m	100m
E-1	Faro (Second Phase)		X
E-2	Marina		X
E-3	Jorge Seda Crespo Middle School	X	X
E-4	Nuclear Plant	X	X
E-5	Parking Balneario	X	X
E-6	Parking	X	X
E-7	Restaurant: Harbor Restaurant		X
E-8	Parking		X
E-9	Beach: Domes Beach		X
E-10	Horned Dorset Primavera	X	X
E-11	Coconut Palms Inn	X	X
E-12	Tres Sirenas Beach Inn		X

Map ID	Facility	50m	100m
E-13	Hotel Villa Cofresi	X	X
E-14	Porta del Sol Inn	X	X
E-15	Balneario Municipal	X	X
E-16	Parque de Pelota Stella	X	X
E-17	Guest House/Rest.: Tamboo Beside the Pointe		X
E-18	Hotel: Pool Beach Caba		X

5.1.4 Impacts to the People and Environment

The results indicate a former nuclear power plant is within 50m of the shoreline although the facility is elevated above future sea-level rise estimates. A GIS overlay estimates that the Jorge Seda Crespo Middle School is within proximity of the shore along with more than 100 residences all along the coast. Several employers in the tourism sector may be impacted affecting the livelihoods of many employees.

5.2 COASTAL FLOOD

Coastal flooding can be a result of storm surge, wind-driven waves, coastal erosion, and sea-level rise. Everything which could cause inundation is included in the coastal flood analysis. These events can work alone or together to create coastal flooding in Rincón. As the climate changes, sea-level rise, increased precipitation, and increased storminess could affect the extent and depth of the coastal floodplains and the resulting damage to infrastructure. To better understand the impacts, the future floodplain needs to be identified.

5.2.1 Methodology

The coastal flood assessment integrated data on sea-level rise (described in Section 3.1) and a Federal Emergency Management Agency (FEMA) Flood Insurance Study (FIS) (FEMA 2009). Coastal floodplains were developed for 100-year events at two sea-level rise scenarios.

The methodology used to delineate the future coastal floodplains involved a three-step process: (1) conduct an erosion assessment (single storm not long term); (2) run a simplified Wave Height Analysis for Flood Insurance Studies (WHAFIS) model; and (3) run a Wave Runup Model following the procedures in the U.S. Army Corps of Engineers Coastal Engineering Manual (USACE 2003). FEMA's Hazus software was used to complete these steps using inputs from the FIS concerning Stillwater Elevations. This methodology considers all inundation events including storm surge, wind-driven waves, tsunami, etc. since they are captured in the FIS. It does not include riverine flooding which is captured in section 5.3, nor does it account for long term erosion (refer to the buffer zones above for long term erosion rates combined with sea level rise).

A digital elevation model with a resolution of one-third arc second (~10 meters) was used because of its accuracy and the ability for the model to process quickly. The coastal floodplain modeling methodology produced a flood depth grid that estimates the extents and depth of flooding. For each sea-level rise scenario, a flood depth grid was developed. These flood depth grids were then overlaid on the general building stock and critical facilities to generate damage and loss estimates. Hazus provided these loss estimates on the basis of vulnerability functions associated with the infrastructure type; in contrast to sea-level rise where submerged facilities are lost permanently, the vulnerability functions assume a percent of loss associated with a flood event with infrastructure being repaired following the event. So unlike sea level rise where the infrastructure was considered a total loss, this would be the loss associated with the flood. An example of one of these vulnerability functions is shown in Figure 5-3. The vulnerability functions differ for coastal (V zones) and riverine (A zones) areas due to wave action.

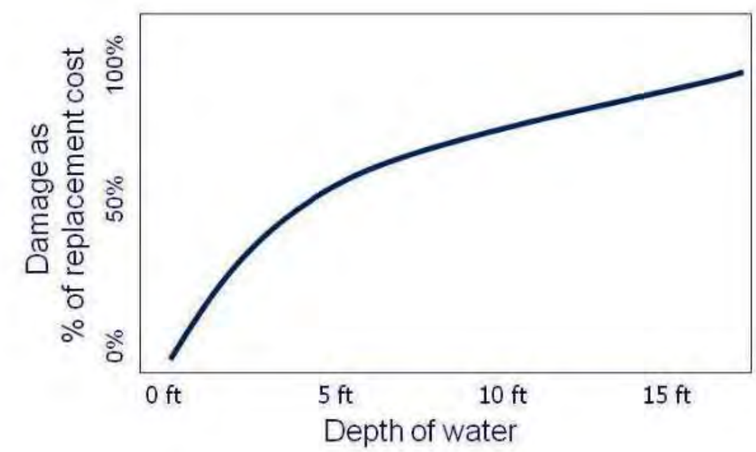


Figure 5-3. Flood Vulnerability Function

5.2.2 Impacts to General Building Stock

The modeled loss to residential and commercial structures in Rincón can be seen in Table 5-3. These values represent **the loss** which would be associated with a coastal flood under different sea-level scenarios. This is **not the total amount of exposure** in the coastal floodplain.

Table 5-3. Coastal Flooding Impacts to General Building Stock

		Current	0.5m SLR	1.0m SLR
		Loss ($)	Loss ($)	Loss ($)
Residential	Structure	3,334,356	5,725,841	13,746,714
	Contents	1,978,921	3,666,563	8,242,435
	Total	**5,313,277**	**9,392,404**	**21,989,148**
	% of Total	**0.46%**	**0.81%**	**1.89%**
Commercial	Structure	1,553,644	3,661,159	6,405,286
	Contents	922,079	2,344,437	3,840,565
	Total	**2,475,723**	**6,005,596**	**10,245,852**
	% of Total	**0.41%**	**0.99%**	**1.70%**

5.2.3 Impacts to Critical Facilities

The impacts to the critical facilities including structural (bldg.) and content (cont.) losses for current coastal flooding, flooding with 0.5m of sea-level rise, and 1m of sea-level rise may be seen in Figures 5-4 – 5-6. The map id column in Tables 5-4, 5-5, and 5-6 corresponds with the number in the maps. For the bridge inventory and future growth areas, a depth is provided to indicate magnitude.

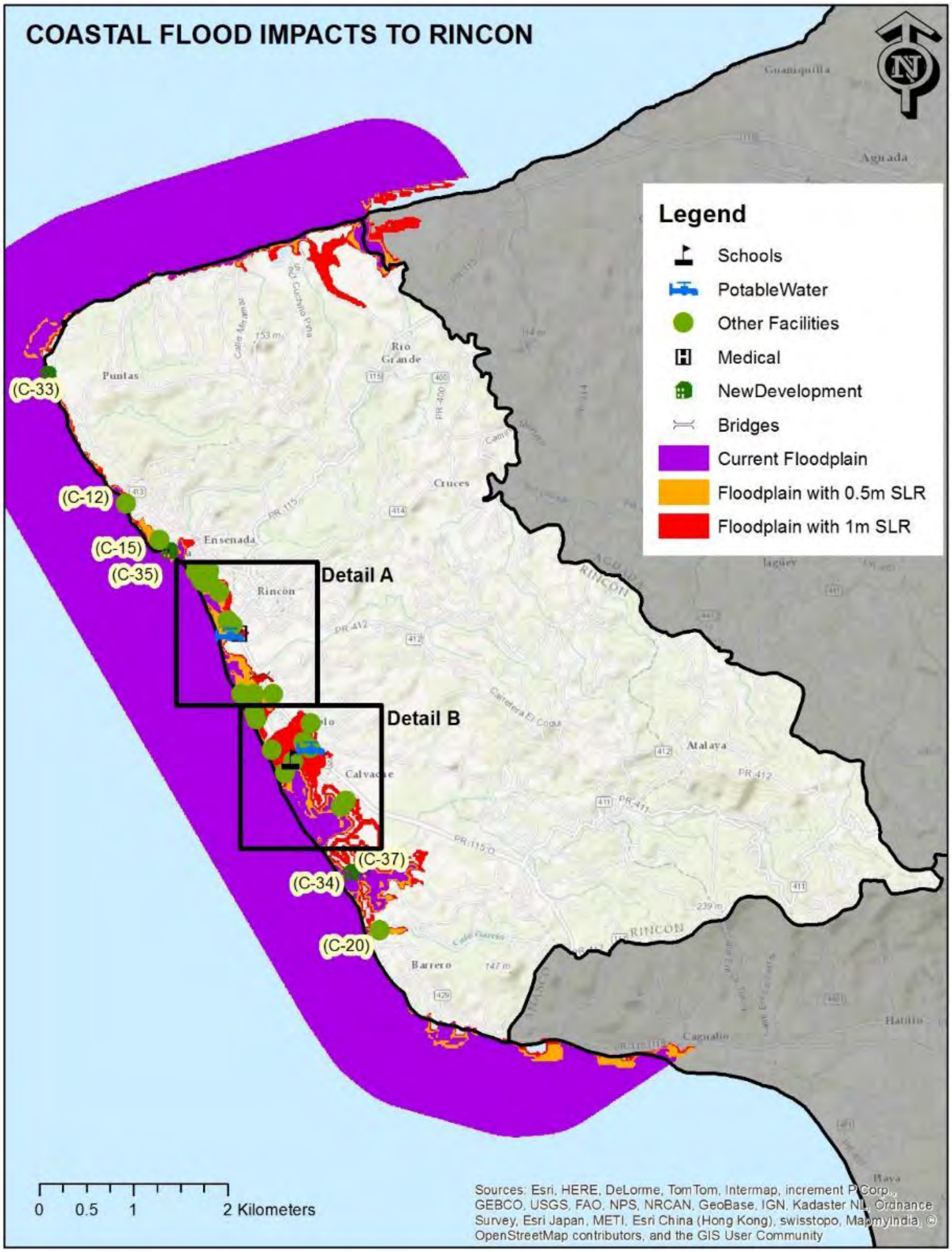


Figure 5-4. Coastal Flood Impacts (current floodplain from FEMA 2013, 0.5m and 1.0m from Section 5.2 methodology)

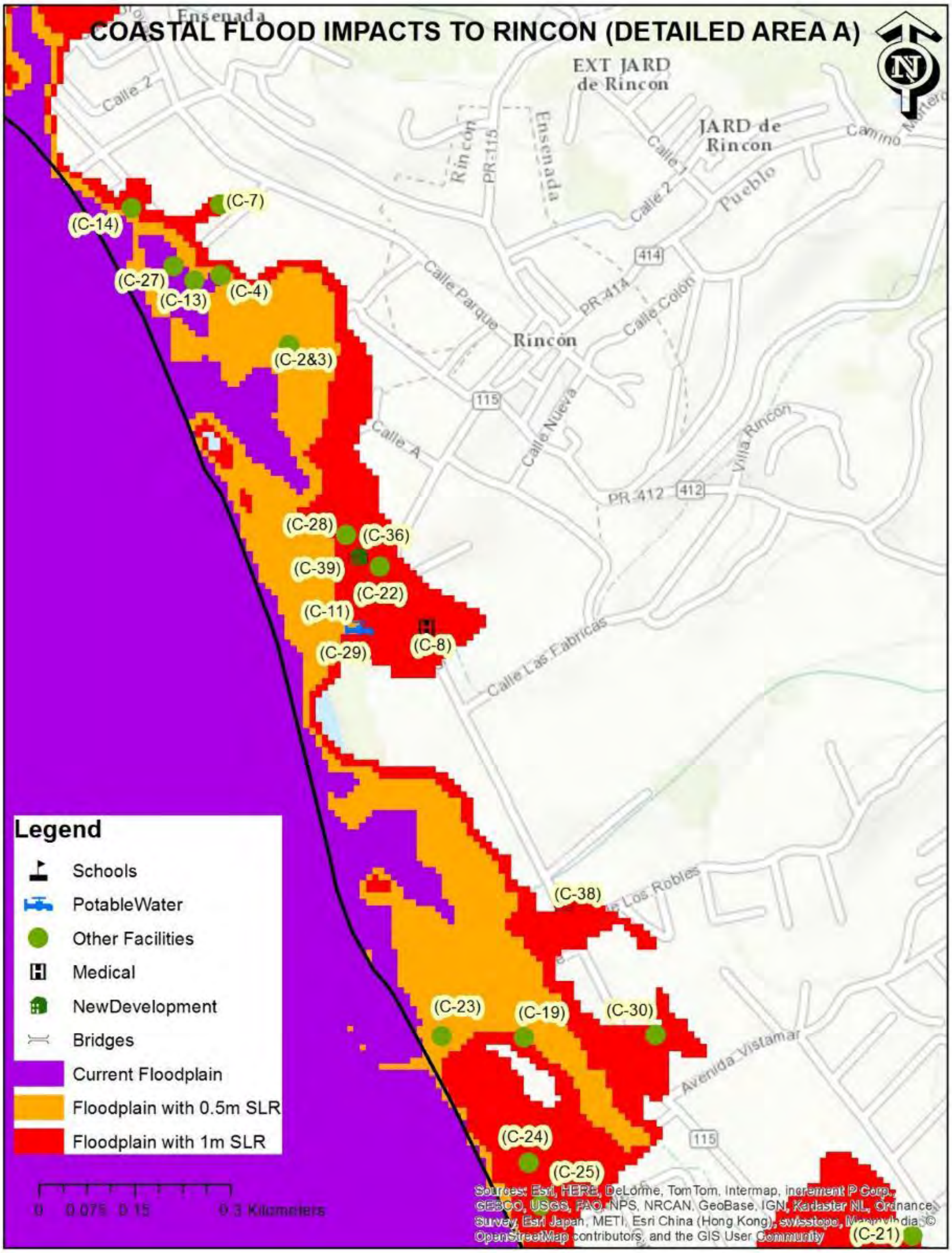


Figure 5-5. Coastal Flood Impacts - Detail A (current floodplain from FEMA 2013, 0.5m and 1.0m from Section 5.2 methodology)

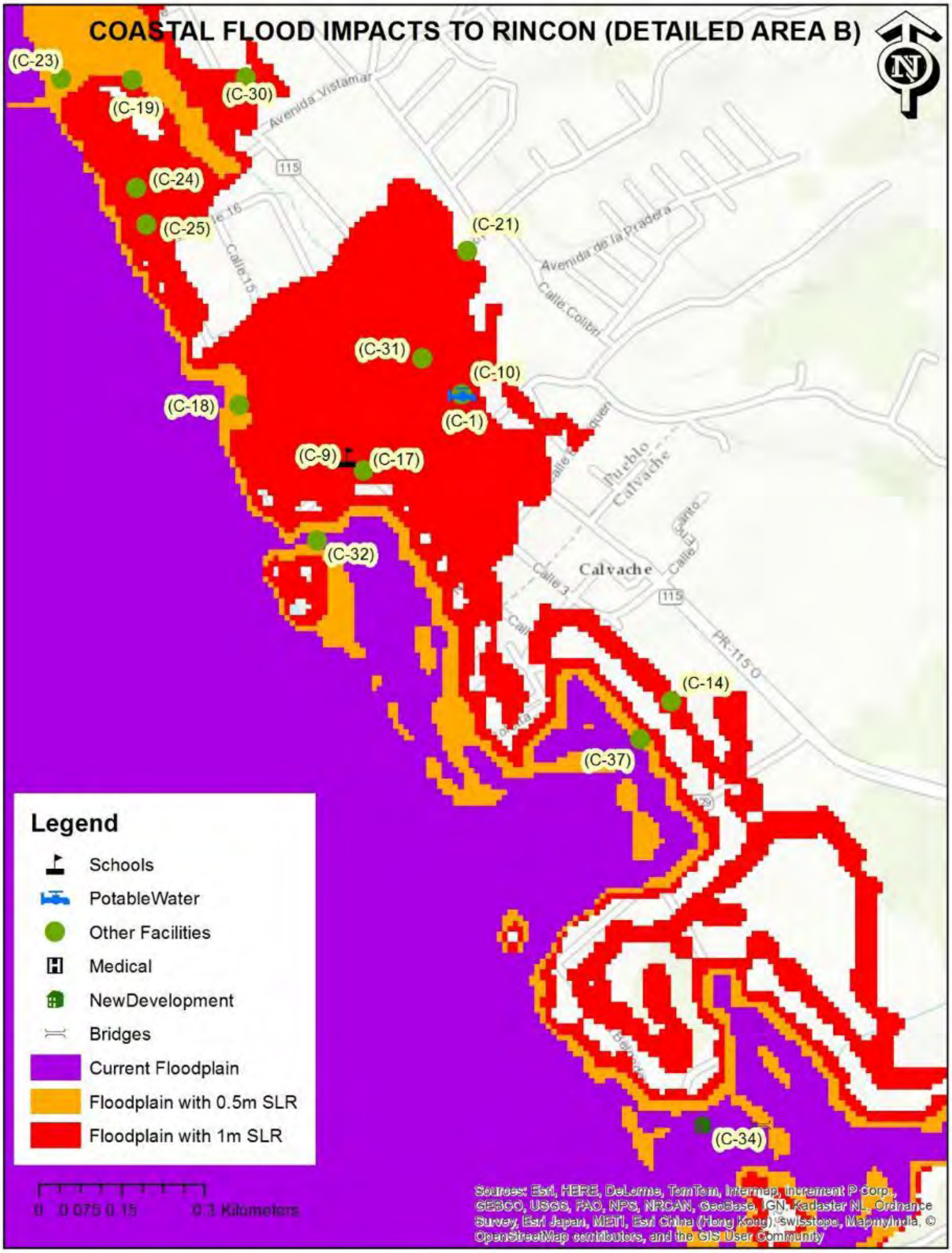


Figure 5-6. Coastal Flood Impacts - Detail B (current floodplain from FEMA 2013, 0.5m and 1.0m from Section 5.2 methodology)

Table 5-4. Coastal Flooding Impacts to Critical Facilities

MAP ID	Facility	Current		0.5m SLR		1m SLR	
		Bldg. Damage	Cont. Damage	Bldg. Damage	Cont. Damage	Bldg. Damage	Cont. Damage
C-1	Texaco Road					Minimal	Minimal
C-2	Sea Beach Village Condo			Minimal	Minimal	20%	18%
C-3	Chalet del Mar Condo			Minimal	Minimal	20%	18%
C-4	Rincón Bay Condo			2%	18%	21%	22%
C-5	Rincón by the Sea Condo			2%	18%	21%	22%
C-6	Rincón Ocean View Condo			2%	18%	21%	22%
C-7	Costa Ensenada Condo					Minimal	Minimal
C-8	Rincón Medical Center					Minimal	Minimal
C-9	Head Start Stella Community					2%	9%
C-10	Pump Station					Minimal	Minimal
C-11	Water Wells			Minimal	Minimal	2%	5%
C-12	Parking			Minimal	Minimal	2%	6%
C-13	Parking Balneario	Minimal	Minimal	Minimal	Minimal	4%	13%
C-14	Parking					Minimal	Minimal
C-15	Restaurant: Shipwreck Bar & Grille			1%	9%	10%	49%
C-16	Parking			Minimal	Minimal	3%	10%
C-17	The Pineapple Inn					Minimal	Minimal
C-18	Coconut Palms Inn			Minimal	Minimal	1%	3%
C-19	Rincón of the Seas			Minimal	Minimal	1%	5%
C-20	Puente Grande Creek			8%	5%	22%	26%
C-21	Puente Channel					Minimal	Minimal
C-22	Centro Cultural de Rincón					Minimal	Minimal
C-23	Tres Sirenas Beach Inn			Minimal	Minimal	4%	15%
C-24	Hotel Villa Cofresi					Minimal	Minimal
C-25	Porta del Sol Inn					Minimal	Minimal
C-26	Complejo Deportivo de Rincón					Minimal	Minimal
C-27	Balneario Municipal	Minimal	Minimal	Minimal	Minimal	7%	45%
C-28	Coop Rincón					Minimal	1%

MAP ID	Facility	Current		0.5m SLR		1m SLR	
		Bldg. Damage	Cont. Damage	Bldg. Damage	Cont. Damage	Bldg. Damage	Cont. Damage
C-29	Sistema de Bombas Sanitaria			Minimal	Minimal	12%	8%
C-30	Banco Popular					Minimal	Minimal
C-31	Gasolinera Puma					Minimal	Minimal
C-32	Parque de Pelota Stella	Minimal	Minimal	2%	17%	11%	53%

Table 5-5. Coastal Flooding Depths at Future Development

MAP ID	Future Development	Current	0.5m SLR	1m SLR
C-33	Faro (Second Phase)	Minimal	2'	4'
C-34	Hotel Corcega	2'	4'	6'
C-35	Marina		2'	3'
C-36	Ventana al Mar Project			1'

Table 5-6. Coastal Flooding Depths at Bridges

ID	Bridges	Current	0.5m SLR	1m SLR
C-37	Bridge Rd 429		1'	3'
C-38	Flood Mitigation Channel			Minimal
C-39	Road 115 Km 17			1'
C-40	Quebrada Los Ramos			Minimal

5.2.4 Impacts to the People and Environment

The results indicate a medical center, water utilities, schools, and tourist areas would be impacted. Several employers in the tourism sector would also be impacted affecting the livelihoods of many employees. Hazus estimates more than 300 households would be displaced during a current flood, more than 500 with .5m of sea-level rise, and more than 1200 with 1m of sea-level rise.

5.3 RIVERINE FLOOD

Floods can be extremely destructive in Puerto Rico because of the island's topography. The stream valleys are narrow, relatively short, and steep-features that make the streams susceptible to flooding, particularly flash flooding. Flash floods typically result from rainfall that is intense in the upper basins but that is sparse or nonexistent on the coast. Although Rincón is more susceptible to coastal flooding, there are a few reaches which can become inundated. As the climate changes, increased precipitation, and increased storminess could affect the extent and depth of the riverine floodplains and the resulting damage to the community. To better understand the impacts, the future floodplain must be identified.

5.3.1 Methodology

The FEMA FIS used to support the coastal flood, did not have information concerning riverine flooding in Rincón. To model the riverine flood, the Hazus hydrological and hydraulic models were used. Hazus uses USGS regression equations to identify flows for each reach. The reaches are developed by Hazus using a DEM. They hydraulic model takes the flow information and uses Manning's Equation to calculate the flood elevation. The flood elevation is then subtracted from the DEM to get the flood depth grid.

The current base flood was then modeled and the precipitation data from the Climate Wizard site was used to increase the flows using the conservative GCMs described in Section 2. Since the most conservative model predicted a potential 50% additional flow in both the mid- and late-century time horizons, only one floodplain was modeled.

A digital elevation model with a resolution of one-third arc second (~10 meters) was used because of its accuracy and the ability for the model to process quickly. The riverine flood depth grids were then overlaid on the general building stock and critical facilities to generate damage and loss estimates. Hazus provided these loss estimates on the basis of vulnerability functions associated with the infrastructure type; in contrast to sea-level rise where submerged facilities are lost permanently, the vulnerability functions assume a percent of loss associated with a flood event with infrastructure being repaired following the event. So unlike sea level rise where the infrastructure was considered a total loss, this would be the loss associated with the flood. An example of one of these vulnerability functions is shown in Figure 5-7. The vulnerability functions differ for coastal (V zones) and riverine (A zones) areas due to wave action.

5.3.2 Impacts to General Building Stock

The modeled loss to residential and commercial structures in Rincón can be seen in Table 5-7. These values represent **the loss** which would be associated with a riverine flood in the current environment and a mid/late-century scenario. This is **not the total amount of exposure** in the riverine floodplain.

Table 5-7. Riverine Impacts to General Building Stock

		Current	Mid/Late Century
		Loss ($)	**Loss ($)**
Residential	Structure	14,597,356	17,322,697
	Contents	9,024,180	10,714,221
	Total	**23,621,536**	**28,036,919**
	% of Total	**2.03%**	**2.41%**
Commercial	Structure	6,801,644	11,076,303
	Contents	4,204,820	6,850,779
	Total	**11,006,464**	**17,927,081**
	% of Total	**1.82%**	**2.97%**

5.3.3 Impacts to Critical Facilities

The impacts to the critical facilities including structural (bldg.) and content (cont.) losses for current riverine flooding, and potential future flooding may be seen in Figures 5-7 and 5-8-15. The map id column in Tables 5-8, 5-9, and 5-10corresponds with the number in the maps. For the bridge inventory and future growth areas, a depth is provided to indicate magnitude.

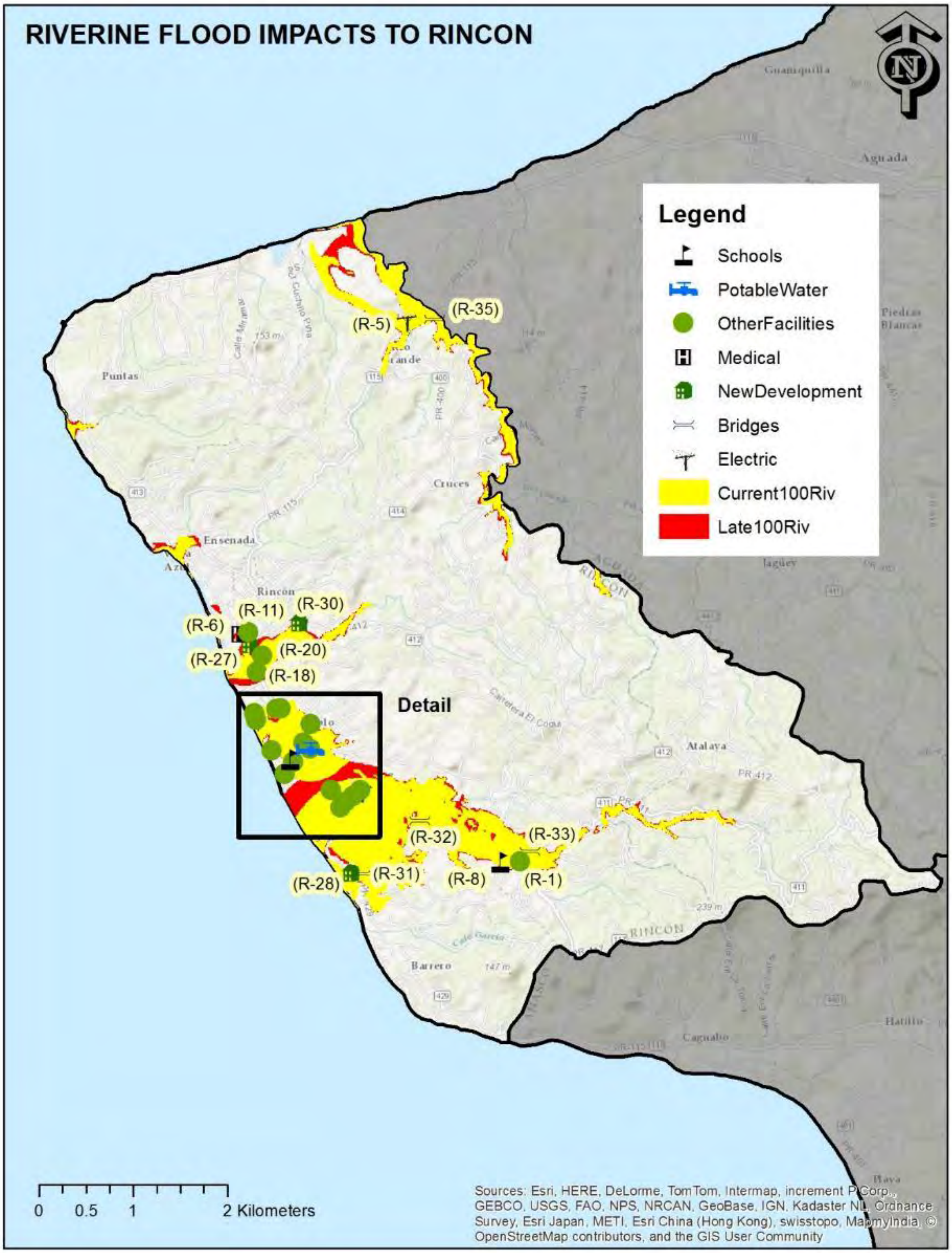


Figure 5-7. Riverine Flood Impacts

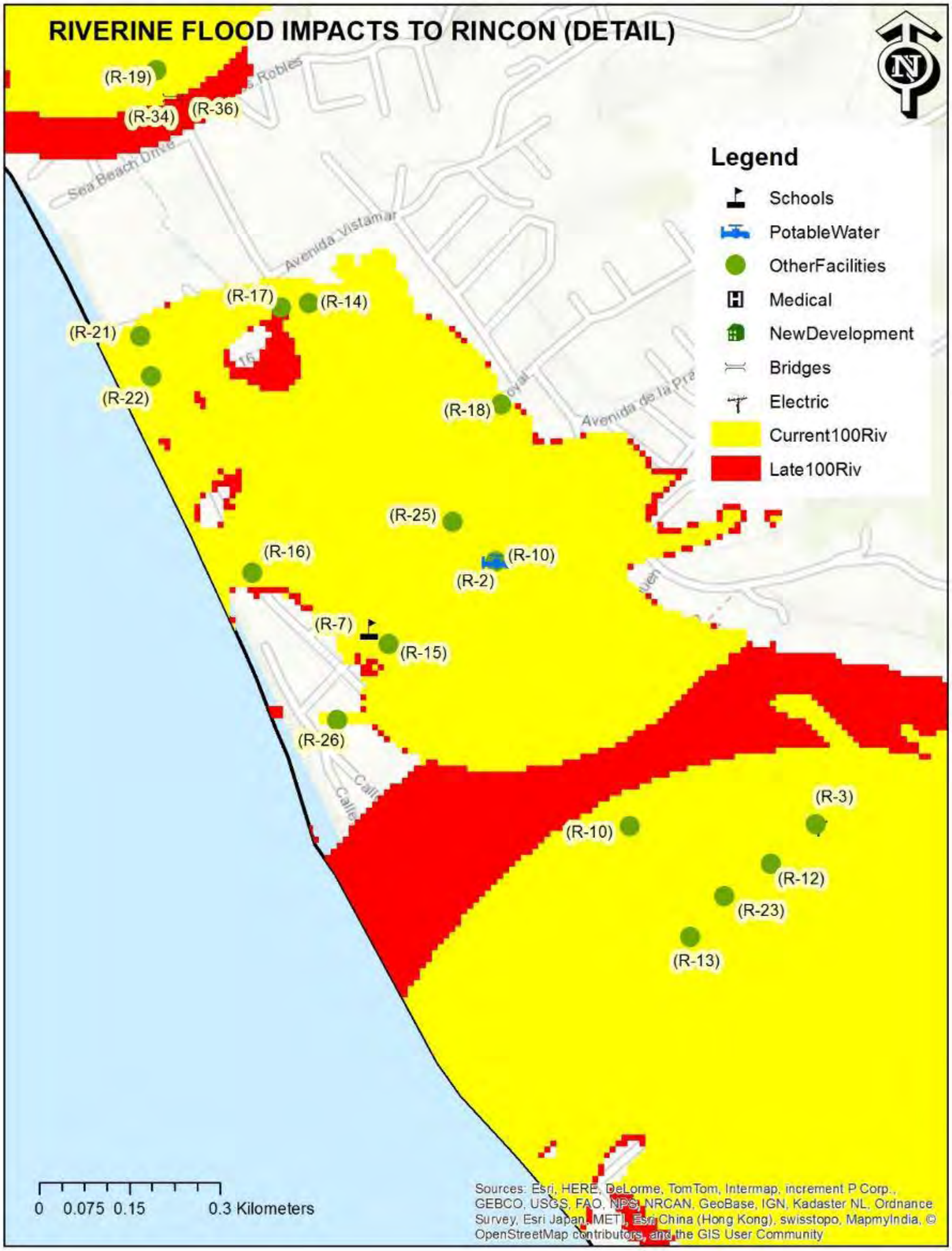


Figure 5-8. Riverine Flood Impacts (Detail)

Table 5-8. Coastal Flooding Impacts to Critical Facilities

ID	Facility	Current		Mid/Late-Century	
		Bldg. Damage	Cont. Damage	Bldg. Damage	Cont. Damage
R-1	Texaco Road 115 Intersect Rd 411 km. 8.8	27%	36%	30%	38%
R-2	Texaco Road 115 km 11.4	18%	13%	20%	19%
R-3	Sports Multi-Complex - Stella Com. Asmbly	28%	36%	30%	39%
R-4	Substation Sports Comp Corcega Com	8%	NA	9%	NA
R-5	Substation Barrio Rio Grande	6%	NA	6%	NA
R-6	Rincón Medical Center	Minimal	Minimal	Minimal	Minimal
R-7	Head Start Stella Community	4%	22%	5%	30%
R-8	Manuel Gonzalez Melo Elem and Mid School	10%	68%	11%	70%
R-9	Fire Station	13%	58%	14%	65%
R-10	Pump Station and Diesel Res Stella Co	2%	NA	4%	NA
R-11	Parking	7%	24%	7%	24%
R-12	Parking	6%	19%	6%	21%
R-13	Parking	0	0	Minimal	Minimal
R-14	Centros de deposito comunitarios perman	4%	27%	6%	43%
R-15	The Pineapple Inn	Minimal	Minimal	Minimal	Minimal
R-16	Coconut Palms Inn	Minimal	Minimal	Minimal	Minimal
R-17	Parador Villa Antonio			Minimal	Minimal
R-18	Puente Channel	3%	2%	11%	7%
R-19	Puente Channel	19%	15%	22%	25%
R-20	Centro Comercial	2%	3%	9%	25%
R-21	Hotel Villa Cofresi	Minimal	Minimal	Minimal	Minimal
R-22	Porta del Sol Inn	Minimal	Minimal	Minimal	Minimal
R-23	Complejo Deportivo de Rincón	11%	53%	12%	60%
R-24	Bomberos de Puerto Rico	25%	35%	27%	36%
R-25	Gasolinera Puma	Minimal	1%	1%	2%
R-26	Parque de Pelota Stella	Minimal	Minimal	Minimal	Minimal

Table 5-9. Riverine Flooding Depths at Future Development

ID	Future Development	Current	Mid/Late
R-27	Aquatic Park	1'	1'
R-28	Hotel Corcega	4'	4'
R-29	Marina	2'	3'
R-30	Public Work Re-Location	3'	5'

Table 5-10. Riverine Flooding Depths at Bridges

ID	Bridges	Current	Mid/Late
R-31	Bridge Rd 429	2'	2'
R-32	Rd 115 Barrio Calvache	1'	2'
R-33	Bridge Road 411	5'	6'
R-34	Flood Mitigation Channel	3'	4'
R-35	Road 115 Km 17	7'	10'
R-36	Quebrada Los Ramos	3'	4'

5.3.4 Impacts to the People and Environment

The results indicate a medical center, water utilities, schools, and tourist areas would be impacted. Several employers in the tourism sector would also be impacted affecting the livelihoods of many employees. Hazus estimates more than 1500 households would be displaced during a current flood and more than 1900 with a future conditions flood.

5.4 HURRICANE SURGE

The high winds and surge of a hurricane often result in power outages, disruptions to transportation corridors and equipment, loss of workplace access, significant property damage, injuries and loss of life, and the need to shelter and care for individuals impacted by the events. A large amount of damage can be inflicted by trees, branches, and other objects that fall onto power lines, buildings, roads, vehicles, and, in some cases, people. Additionally, hurricanes can bring heavy rainfall causing flooding and cause storm surge related damages along the coast. For this assessment, only potential surge produced by hurricane events is considered (which is different than the coastal flood analysis which encompasses all coastal inundation events).

5.4.1 Methodology

Hurricane surge maps have been developed for the Caribbean Coastal Ocean Observing System (CariCOOS)/NOAA using version 50.99 of the tightly-coupled hydrodynamic and wind wave models ADCIRC+SWAN, both running in the same unstructured mesh. This allows the computation of the three storm surge components: pressure, wind, and wave setups. These surge maps provide inundation information for category 1, 2, 3, 4, and 5 hurricanes in current, 0.5m, and 1.0m sea-level rise conditions (NOAA 2014). These inundation zones were brought into Hazus and the enhanced quick look tool was used to develop a depth grid using the inundation zones and a DEM. This was completed for the category 5 storms for the three sea-level scenarios. The depth grid was input into Hazus and was assigned a surge damage function which produced losses for the critical facilities and general building stock in Hazus. Hurricanes usually impact Puerto Rico from the east. The majority of the model's hurricane tracts were moving east to west although two followed a reverse path coming from the southwest and heading northeast. This means most of the inundation is going to occur on the other side of the Island rather than impacting Rincón directly. This can be seen with the very limited inundation occurring in Rincón even for category 5 events. The model only accounts for hurricane surge and no other inundation producing phenomena. It should also be noted that long-term erosion is not included in the modeled results (refer to the buffer zones above for long term erosion rates combined with sea level rise).

5.4.2 Impacts to General Building Stock

The modeled loss to residential and commercial structures in Rincón can be seen in Table 5-11. These values represent **the loss** which would be associated with a hurricane surge in the current environment and a mid/late-century scenario. This is **not the total amount of exposure** in the surge zone.

Table 5-11. Hurricane Surge Impacts to General Building Stock

		Current Loss ($)	0.5m SLR Loss ($)	1.0m SLR Loss ($)
Residential	Structure	-	545,039	4,009,980
	Contents	-	335,618	2,463,081
	Total	**-**	**880,657**	**6,473,061**
	% of Total	**0.00%**	**0.08%**	**0.56%**
Commercial	Structure	-	253,961	2,564,020
	Contents	-	156,382	1,574,919
	Total	**-**	**410,343**	**4,138,939**
	% of Total	**0.00%**	**0.07%**	**0.68%**

5.4.3 Impacts to Critical Facilities

The impacts to the critical facilities including structural (bldg.) and content (cont.) losses for current hurricane surges, and potential future surge zones may be seen in Figure 5-9. The map id column in Tables 5-12 and 5-13 corresponds with the number in the maps. For the future growth areas, a depth is provided to indicate magnitude.

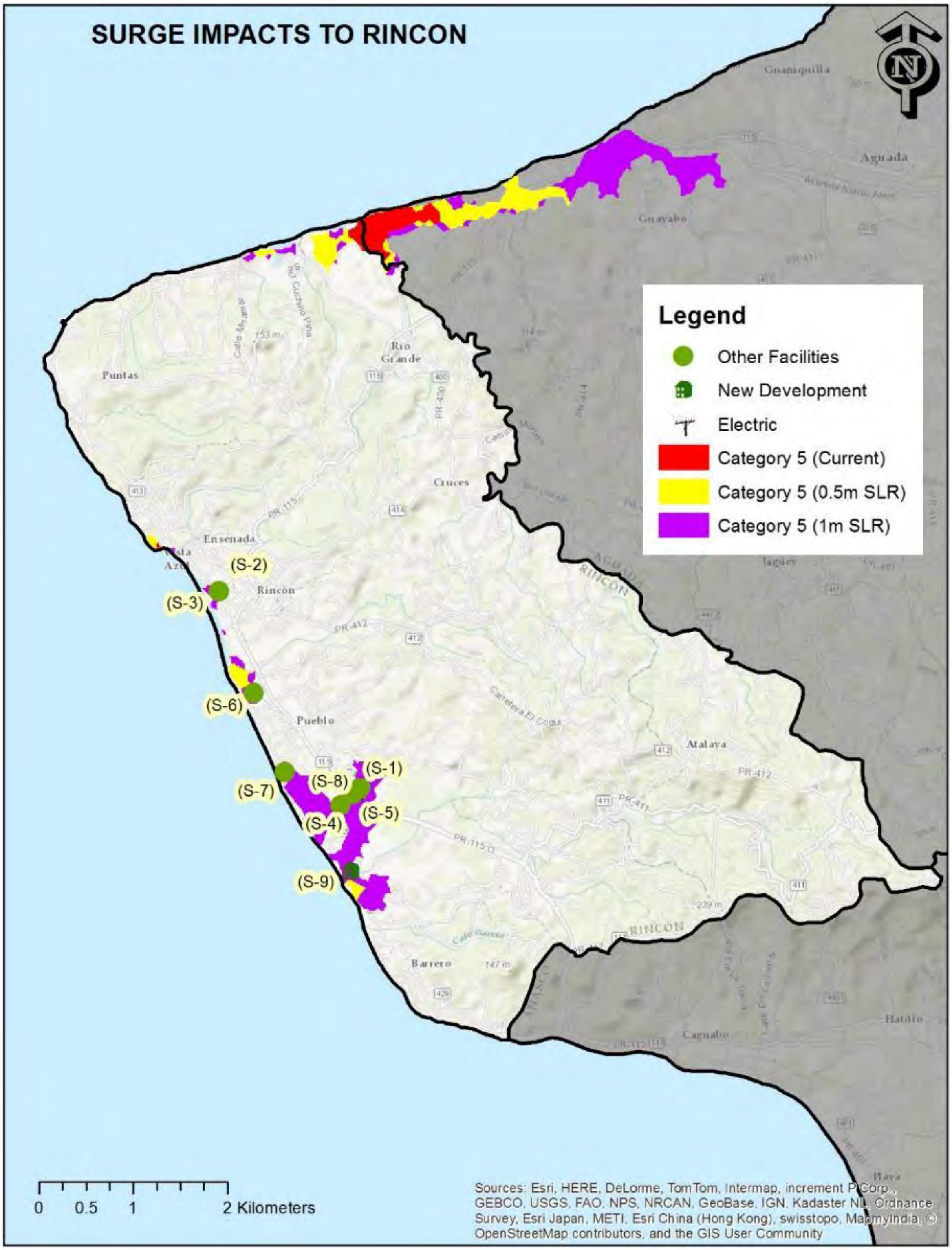


Figure 5-9. Surge Impacts

Table 5-12. Surge Impacts to Critical Facilities

ID	Facility	Current		0.5m SLR		1m SLR	
		Bldg Damage	Cont Damage	Bldg Damage	Cont Damage	Bldg Damage	Cont Damage
S-1	Sports Multi-Complex-Stella Com Asmly Pt					Minimal	Minimal
S-2	Sea Beach Village Condo					Minimal	Minimal
S-3	Chalet del Mar Condo					Minimal	Minimal
S-4	Parking					4%	14%
S-5	Parking					Minimal	Minimal
S-6	Rincón of the Seas					3%	11%
S-7	Parque de Pelota Stella					10%	48%
S-8	Substation Sports Comp Córcega Com					Minimal	Minimal

Table 5-13. Surge Depths at Future Development

ID	Future Development	Current	0.5m SLR	1m SLR
S-9	Hotel Córcega			5'

5.4.4 Impacts to the People and Environment

The results indicate a utility, complex, and tourist areas would be impacted. Several employers in the tourism sector would also be impacted affecting the livelihoods of many employees. Hazus estimates nearly 500 households would be displaced due to surge of a category 5 hurricane with 1 meter of sea-level rise.

5.5 DROUGHT

Climate change can exacerbate the impacts of a drought because of decreased precipitation and increased evapotranspiration, reducing the surface water flows and groundwater availability. These issues can be exacerbated by other stressors such as an increased population and water demand. According to the U.S. Geological Survey, a drought is a lack or insufficiency of rain for an extended period that severely disturbs the hydrologic cycle in an area. Droughts involve water shortages, crop damage, stream flow reduction, and depletion of groundwater and soil moisture. They occur when evaporation and transpiration exceed precipitation for a considerable period.

While there are no uniform annual trends across the island, precipitation trends in the western coastal region, where Rincón is located, have shown an annual decrease in total precipitation over the last 100 years (PRCCC 2013). Island-wide, summer precipitation has been trending downward. Projections from climate change models project decreasing annual rainfall extending the current trend through 2050 (PRCCC 2013).

According to the U.S. Geological Survey, approximately two-thirds of the public supply water provided by the Puerto Rico Aqueduct and Sewer Authority (PRASA) to the service area that includes Rincón is from surface water. The remaining third is from groundwater sources (USGS, 2012). Across Puerto Rico as a whole, over 85 percent of the public supply water is derived from PRASA surface water sources (USGS 2012). As drought is exacerbated by climate change, surface water supplies could become depleted. Similarly, drought can diminish the recharge of groundwater aquifers, as well as promote salt water intrusion into the aquifer (Miller et al. 1999). This can have impacts on both drinking water supplies and agricultural irrigation supplies. According to the USGS, the Isabella Irrigation District located just to the northeast of Rincón relies on groundwater withdraws to supply two-thirds of the irrigation water (Miller et al. 1999). Any salt water intrusion into the aquifers or depletion of the aquifers from drought could impact crop viability. Because drought covers such a large area when it occurs, all of Rincón could potentially be impacted.

5.6 CORAL BLEACHING – SEA TEMPERATURES – OCEAN ACIDIFICATION

Coral reefs play a critical role in Puerto Rico's tourism, as well as serving as important fish habitats. In 2014, approximately 3.2 billion tourists arrived in Puerto Rico and spent over $3.4 billion (UNWTO 2015). In a 2007 study, the Department of Natural and Environmental Resources found the economic value of coral reefs in eastern Puerto Rico was $939.8 million via recreational activities and tourism, with $2.7 million being spent directly on diving and associated activities (PRCCC 2013). Figures were not available for western Puerto Rico, but the economic impacts of coral reefs are clear. Coral reefs are an important tourist attraction. As climate change impacts exacerbate coral reef destruction, the tourist industry will suffer declining economic importance, affecting the immediate tourism industry and ancillary businesses.

Increased sea surface temperatures can cause coral bleaching, a process where the symbiotic dinoflagellates (zooxanthellae) responsible for photosynthesis and the carbon source for the coral, are expelled from the coral, turning the coral white. These bleached coral are more susceptible to destruction through disease and death (PRCCC 2013). A 1 °C increase in temperature can cause mass bleaching and mortality, if the temperature increase is sustained over 2-3 months (PRCCC 2013).

Incidences of mass bleaching have been observed in the Caribbean since the early-1980s. Increased temperatures may also affect the species composition of the coral reefs, and the depths at with coral reefs are able to exist. As coral reefs die off under increased temperatures, reef fish will also decline in abundance and diversity (PRCCC 2013). As coral die-off there can be a conversion to an algae dominated community, affecting reef diversity and community structure (PRCCC 2013).

Ocean acidification is another contributor to coral reef degradation and an effect from increased CO2 concentrations in the ocean. As the ocean becomes more acidic, the calcium carbonate saturation state declines and the rate of calcification in marine calcareous organisms (coral, mollusks, and crustacean species) decreases, compromising skeleton and shell production and strength, as well as potentially affecting recruitment, reproduction, survival and overall food web function (PRCCC 2013).

As coral reefs ecosystems decline, including the decline of reef fish and the increase in algae dominated habitats, both the diving/snorkeling and recreational fishing industries will be impacted. Both are important tourism sectors in Puerto Rico. Economic impacts from a declining tourism industry include loss of port fees from cruise ships, declining tourist populations which lower income at beach resorts, outfitters and restaurants, and loss of direct and indirect tourism-related jobs, which are currently in excess of 50,000 jobs throughout Puerto Rico (PRCCC 2013).

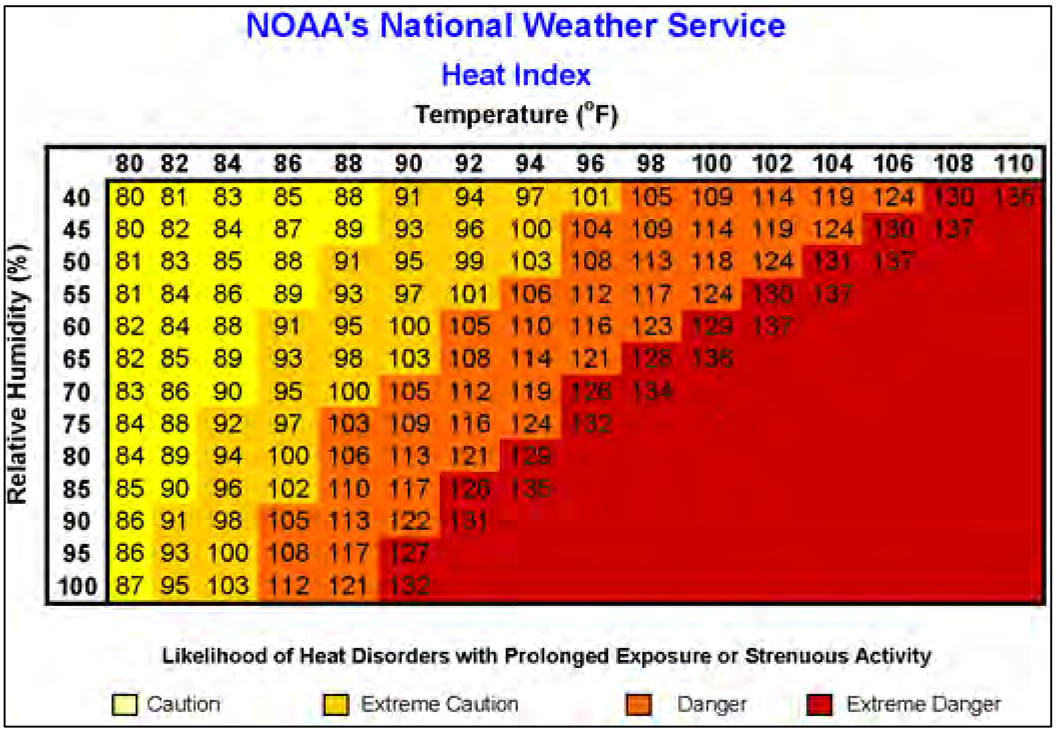
Rincón is a coastal community with coral reefs (see coral reef map in the Volume 1 report), surfing locations, and many hotels and stores catering to tourists. If the natural environment is disturbed or destroyed, it could also result in an economic loss as well. It is estimated that 11% of all earnings reported in Rincón come from tourist accommodations while 56% of all retail earnings are from tourists and when all of these are combined, 40% of all reported income for Rincón comes from tourism and 60% of the work force is supported by tourism (Pendleton, 2002).

5.7 EXTREME TEMPERATURES AND TEMPERATURE VARIABILITY

Temperature modeling predictions estimate that Puerto Rico could warm by 1.44° F (0.8° C) by around 2050, and up to 3.6-9° F (2-5° C) by 2100 (PRCCC 2013). Within the San Juan metro area, the annual number of days with a maximum temperature of 90° F (32.2° C) or above has been increasing in recent decades (PRCCC 2013). While some of these increases can be attributed to the urban heat island effect and to El Niño conditions, the overall increasing trend is consistent with climate change prediction (PRCCC 2013). In addition, the occurrence of warm nights, those above 75° F (23.9° C) have been increasing as well (PRCCC 2013).

Heat exposure can cause a range of negative health effects, from mild heat rashes to deadly heat stroke depending on the amount of direct sun exposure, humidity, and temperature. Heat can also exacerbate numerous chronic diseases, such as cardiovascular and respiratory disease.

One of the most obvious potential health impacts of climate change is direct stress from increased air temperature. However, direct health impacts result from the combined effects of heat and humidity. To account for the combined effects of heat and humidity, the National Weather Service (NWS) has adopted the Heat Index (Figure 5-10), which attempts to calculate the apparent "felt" temperature by adjusting for humidity. As the number of days with high temperatures and high humidity increases, there will likely be an increase in the number of heat advisory days. These conditions can result in heat cramps, heat exhaustion and heat stroke, all of which become more likely as the temperature increases (NWS 2013).


NOAA's National Weather Service

Heat Index

Temperature (°F)

Relative Humidity (%)	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110
40	80	81	83	85	88	91	94	97	101	105	109	114	119	124	130	136
45	80	82	84	87	89	93	96	100	104	109	114	119	124	130	137	
50	81	83	85	88	91	95	99	103	108	113	118	124	131	137		
55	81	84	86	89	93	97	101	106	112	117	124	130	137			
60	82	84	88	91	95	100	105	110	116	123	129	137				
65	82	85	89	93	98	103	108	114	121	128	136					
70	83	86	90	95	100	105	112	119	126	134						
75	84	88	92	97	103	109	116	124	132							
80	84	89	94	100	106	113	121	129								
85	85	90	96	102	110	117	126	135								
90	86	91	98	105	113	122	131									
95	86	93	100	108	117	127										
100	87	95	103	112	121	132										

Likelihood of Heat Disorders with Prolonged Exposure or Strenuous Activity

Caution | Extreme Caution | Danger | Extreme Danger

Figure 5-10. NWS Heat Index Chart Including Hazard Zones (NWS 2013)

In addition to an increased number of high heat days, research reported by Zanobetti et al. (2012) show that the variability of summer temperatures has an important influence on health outcomes, particularly among the elderly. Specifically, large temperature fluctuations have been shown to have a greater effect on health risk than sustained high temperatures, which allow for adaptation.

Zanobetti et al, (2012) found that for every 1° C increase in the standard deviation of summer temperatures, there is an increased risk of mortality (hazard ratio) for populations afflicted with chronic obstructive pulmonary disease (COPD), congestive heart failure (CHF), diabetes, or myocardial infarction (MI) for all climate zones in the United States, except climate zone 1 – Northern New England. Puerto Rico most closely matches Climate Zone 5, which includes Florida and Hawaii. Table 5-14 summarizes the hazard ratio for a 1° C increase in the summer temperature standard deviation. This represents the increased number of deaths over existing conditions attributable to the temperature increase and variability.

Table 5-14. Hazard Ratio for a 1° C increase in yearly summer temperature standard deviation by Climate Zone (Zanobetti et al. 2012).

	Hazard Ratio (*HR*)				
Climate Zone	**CHF**	**MI**	**Diabetes**	**COPD**	**Average**
1 (coldest)	0.997	0.984	0.998	1.015	0.999
2	1.013	1.020	1.020	1.019	1.018
3	1.020	1.030	1.022	1.021	1.023
4	1.042	1.051	1.052	1.047	1.048
5 (hottest)	1.057	1.095	1.098	1.078	1.082

Increasing temperatures can also impact tourism, if Puerto Rico is considered too hot. European tourists have expressed that ideal conditions for beach tourism is in the 80-90° F (27-32° C) range (PRCCC 2013). Puerto Rico is increasingly experiencing daytime highs above this range, and increasingly elevated low temperatures as well, preventing an evening cool down.

In addition to impacts on the human population, increased temperatures can have a negative impact on sea turtle populations. Sand temperature determines the sex ratio of turtle hatchlings, causing an imbalance as temperatures increase (PRCCC 2013). Temperature can also affect nest survival and development and growth of hatchlings.

6.0 RISK INDEX

Using the information from Sections 2.0 through 4.0, a risk index was created with an economic, social, and environmental component. These maps will help identify areas of high risk in Rincón.

- Economic Risk Index is shown in Figure 6-1 and includes economic losses due to sea-level rise, erosion, surge, coastal flooding, riverine flooding, and drought.
- Social Risk Index is shown in Figure 6-2 and includes general population, impoverished population, elderly population, young population, vacant homes, hospitals, and utilities impacted by sea-level rise, erosion, surge, coastal flooding, riverine flooding, and drought.
- Environmental Risk Index is shown in Figure 6-3 and includes wetlands, recreational areas, marine habitat, and hazardous materials impacted by sea-level rise, erosion, surge, coastal flooding, riverine flooding, and drought.

The economic risk index includes economic losses due to sea-level rise, erosion, surge, coastal flooding, riverine flood, and drought. The losses were normalized using the Census Block area and then added together across hazards. The maximum value was found and all the values were divided by this maximum to produce an index with values from 0 to 1. Areas with more economic loss and especially areas impacted by several climate changes will have a higher value index.

The social risk index is built using the population per square kilometer, the percent of impoverished population, the percent of elderly population (>65 years), the percent of young population (<16 years), the percent of vacant homes, percent hospitals impacted, and the percent of utilities impacted. These percentages were added across all climate changes (sea-level rise, erosion, surge, coastal flooding, riverine flooding, and drought), then the maximum value was used to create an index from 0 to 1.

The environmental index is built using the locations of wetlands, recreational areas, marine habitats, and hazardous materials locations to determine which Census Blocks are more susceptible to climate changes. Those blocks which are exposed to the different climate changes (sea-level rise, erosion, surge, coastal flooding, riverine flooding, and drought) and contain one of the environmental variables (wetlands, recreational areas, marine habitats, and hazardous materials locations) are assigned a 1, if two are found in the block, a 2 is assigned, etc.

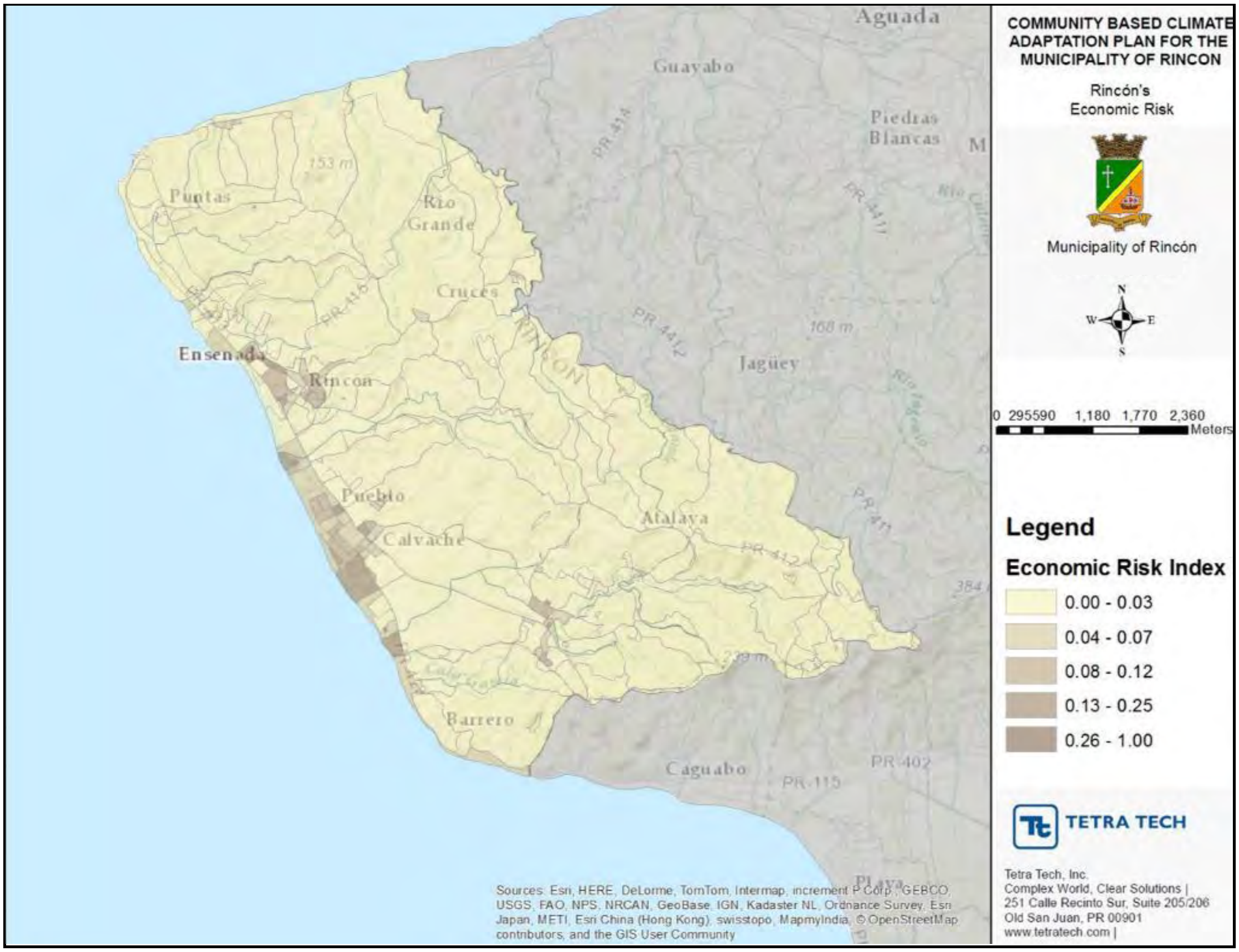


Figure 6-1. Economic Risk Index

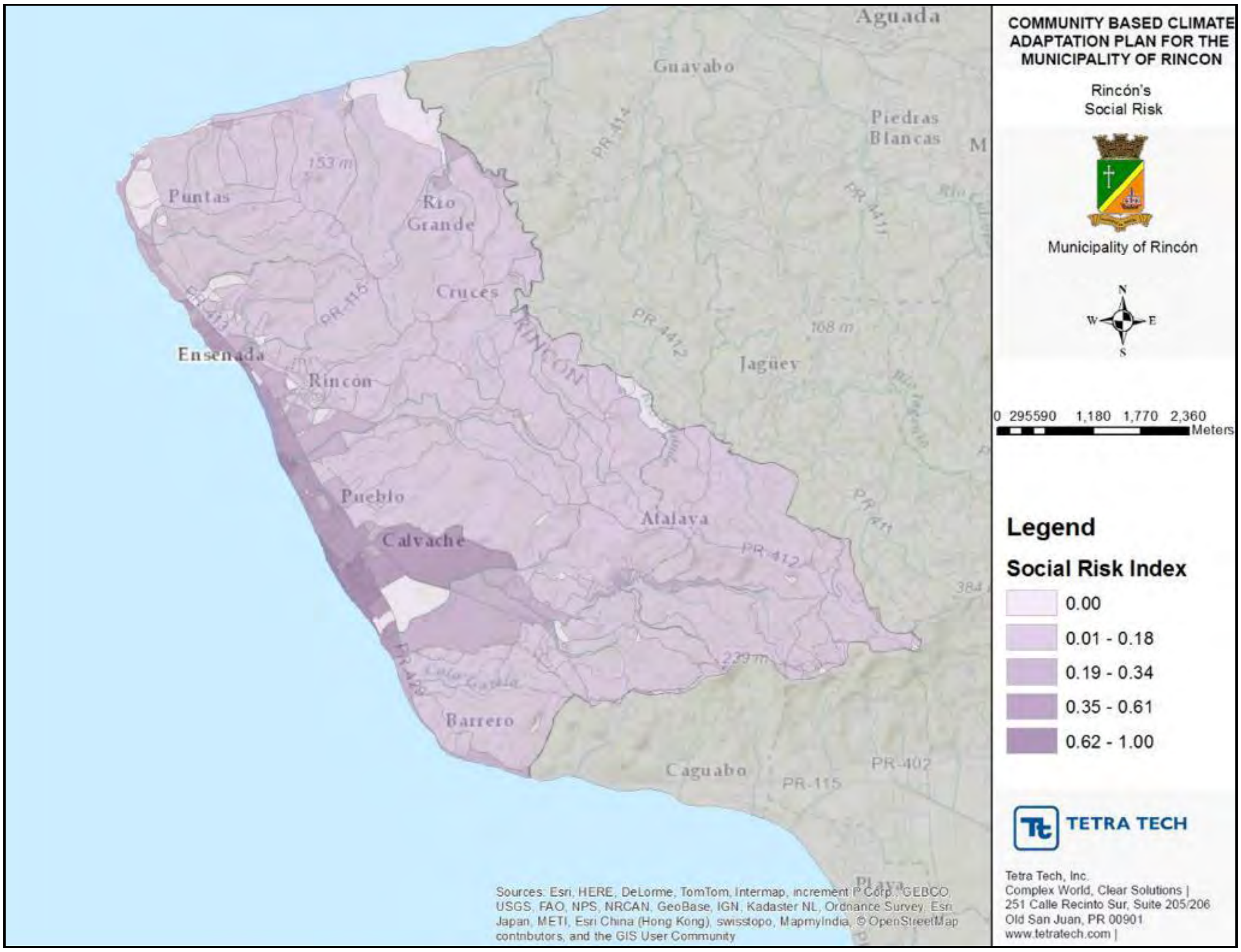


Figure 6-2. Social Risk Index

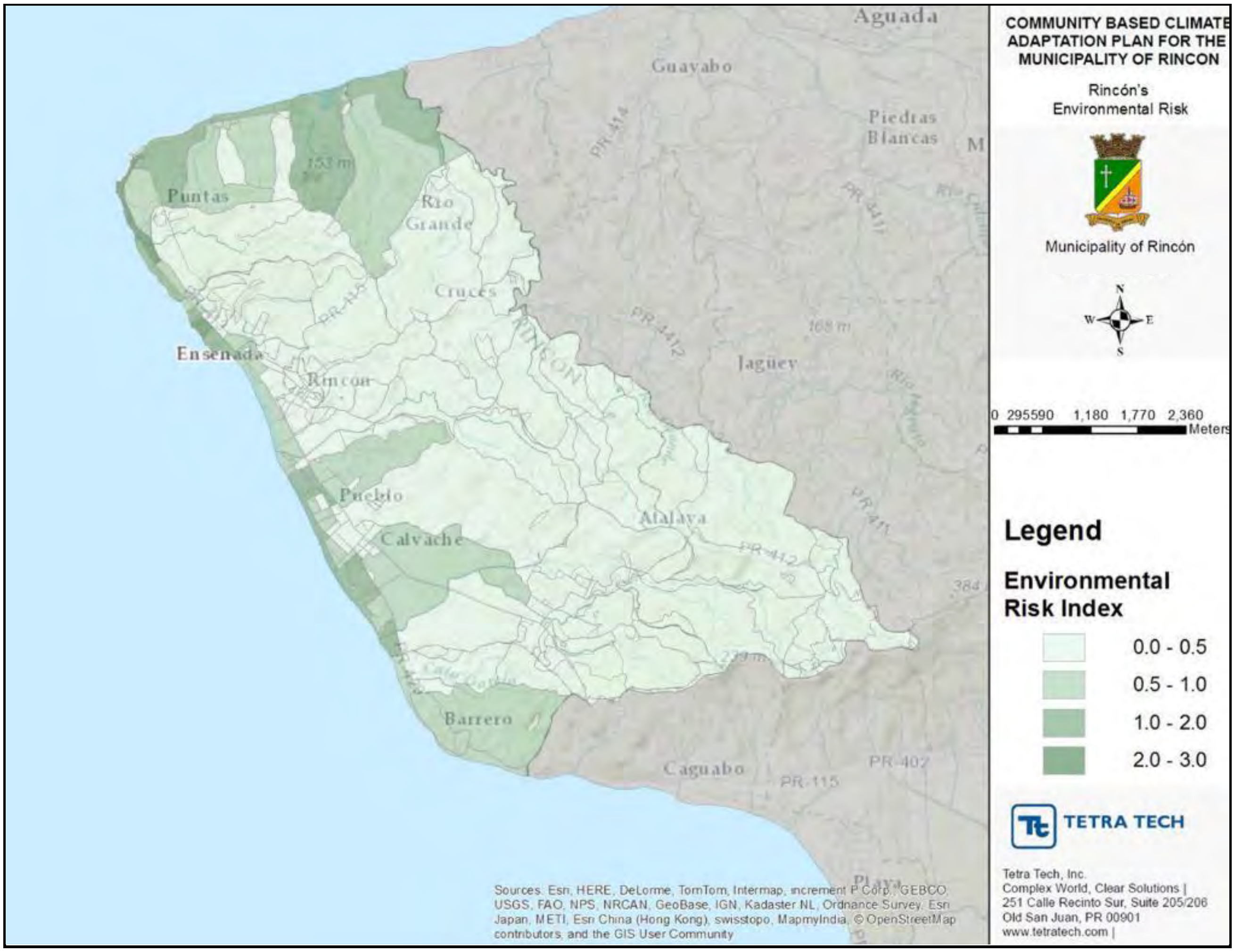


Figure 6-3. Environmental Risk Index

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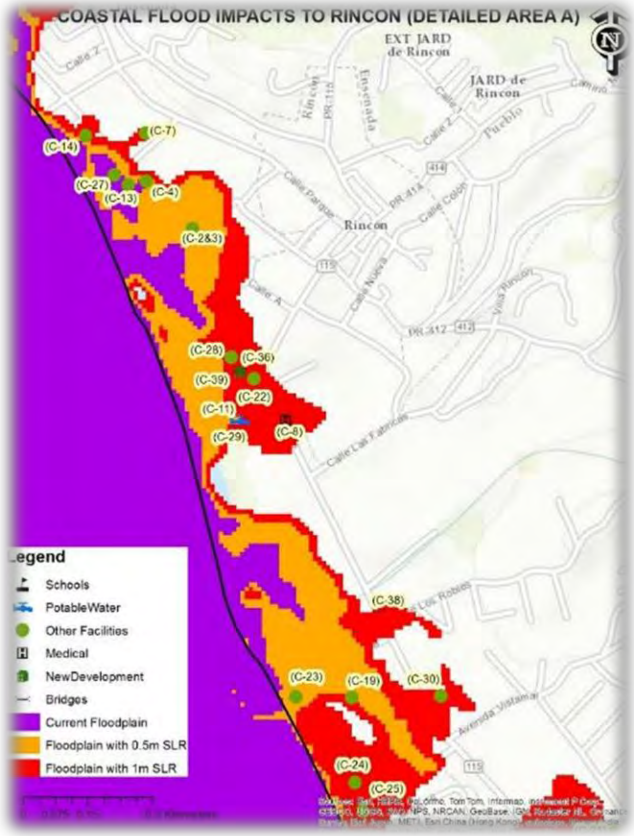
Volume 2 – Vulnerability Assessment Report

APPENDIX 1 - FIGURES



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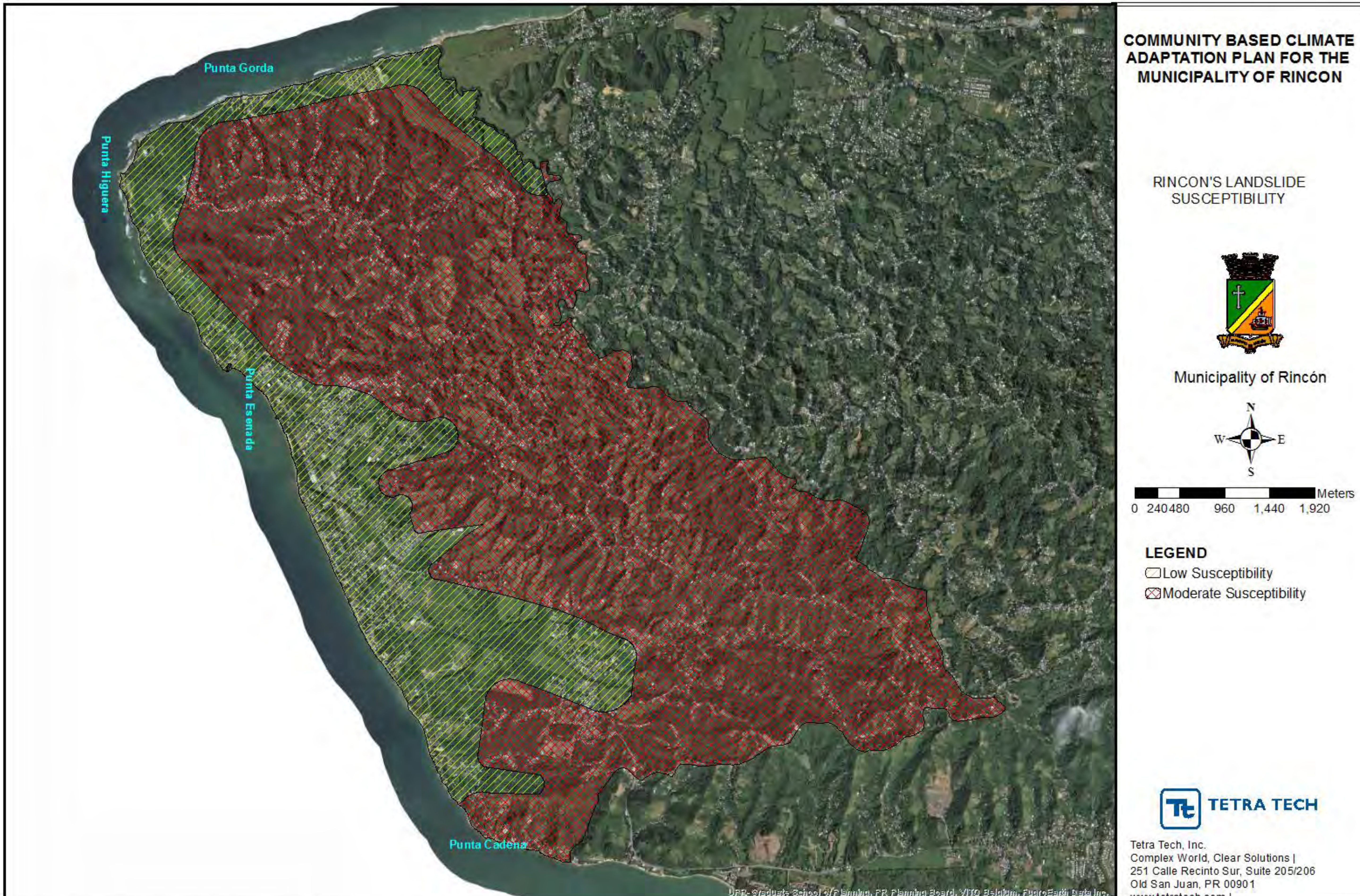

Orthophoto: UPR-Graduate School of Planning, PR Planning Board, VITO Belgium, FugroEarth Data Inc. |

Figure 3-4. Rincon's Landslide Susceptibility Map.

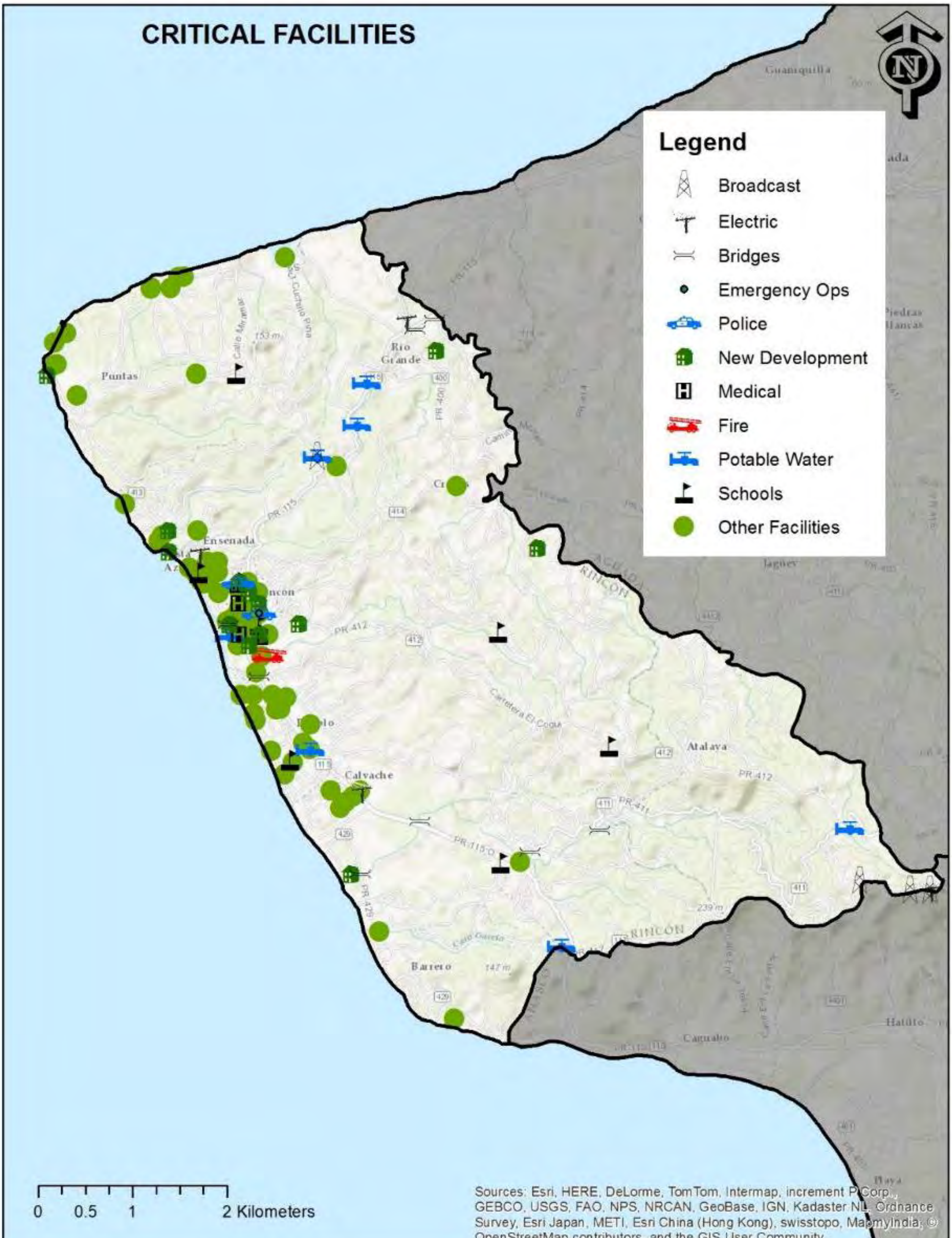

Figure 4-1. Critical Facilities

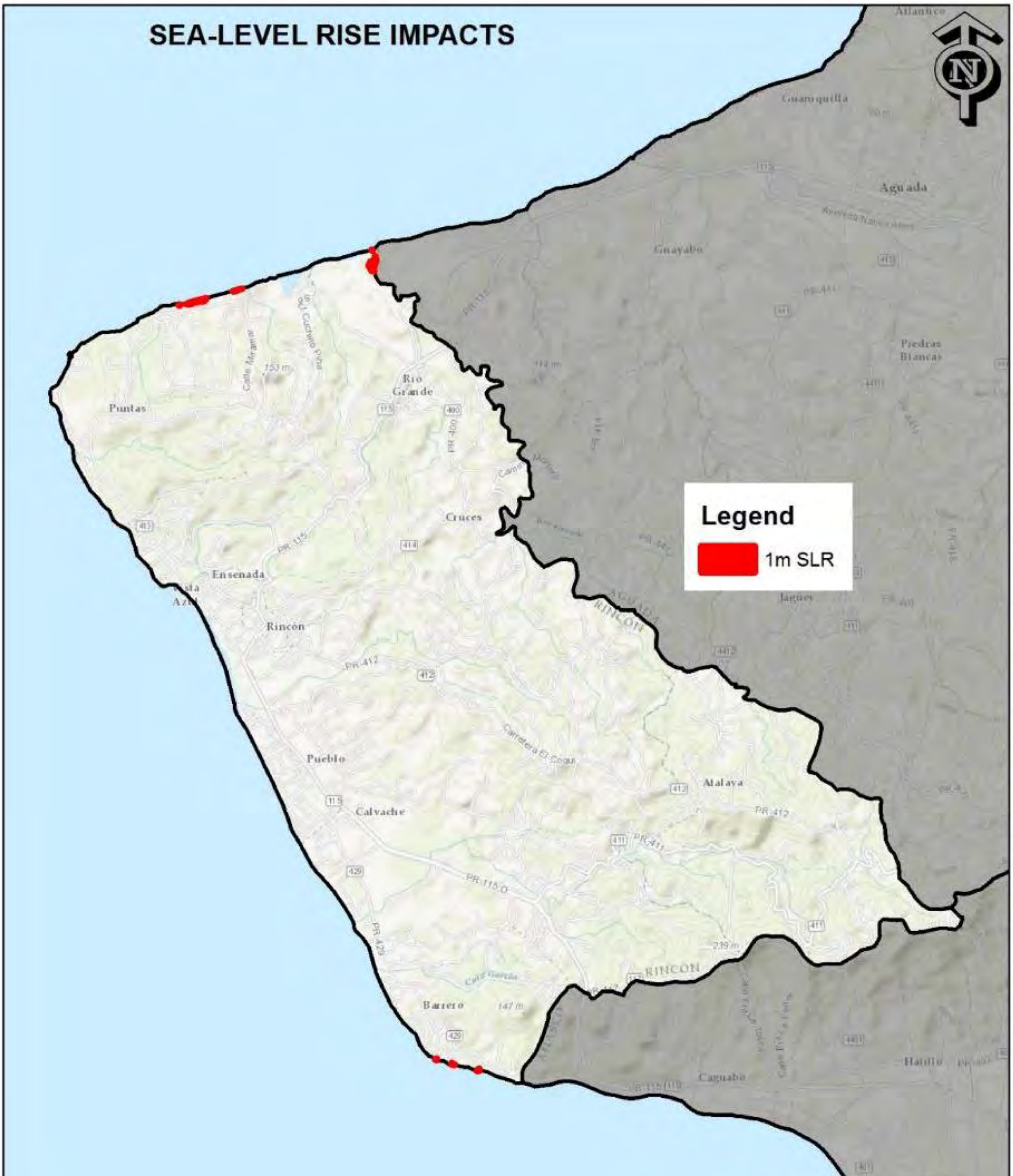

Figure 5-1. Sea-Level Extents

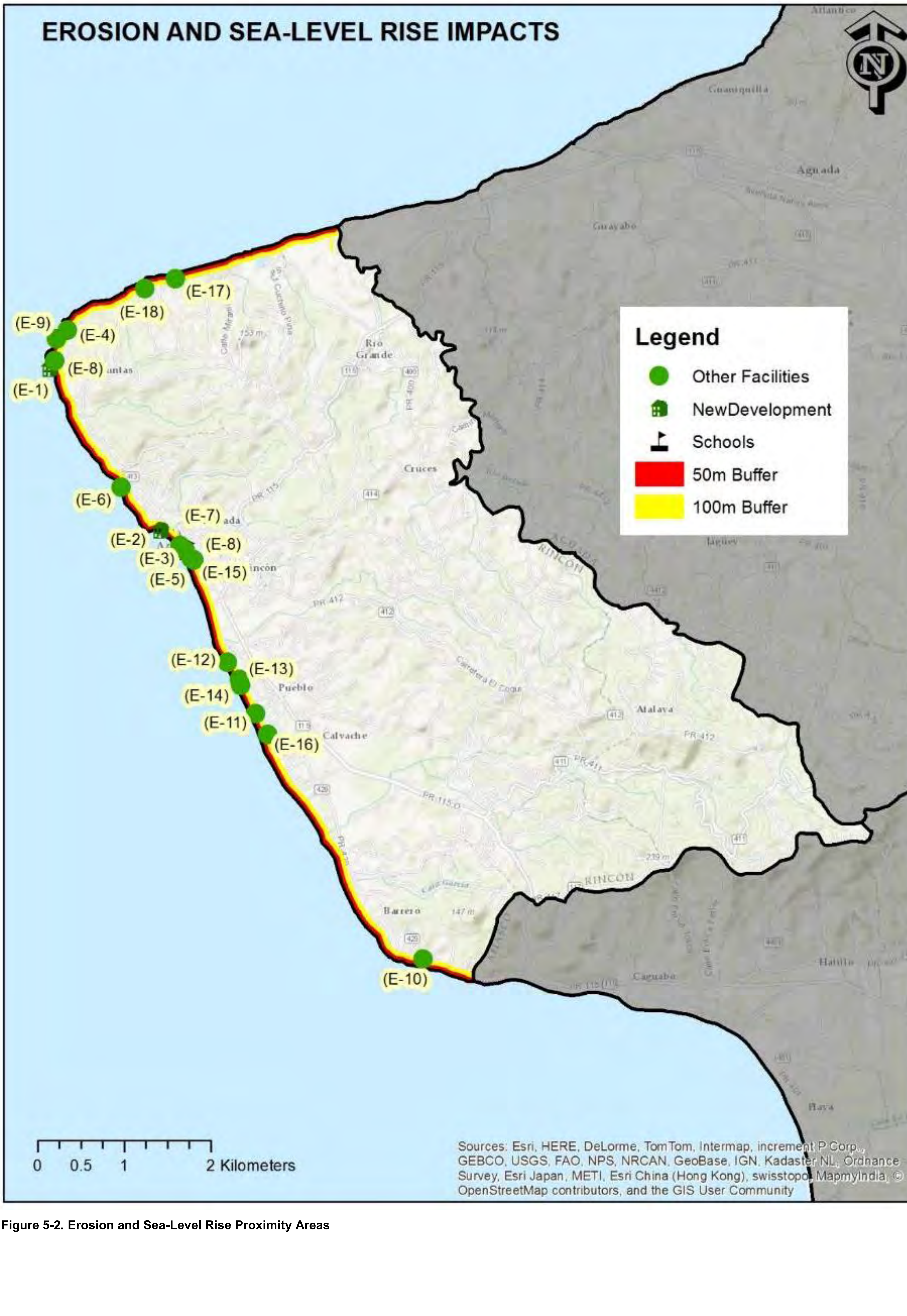

Figure 5-2. Erosion and Sea-Level Rise Proximity Areas

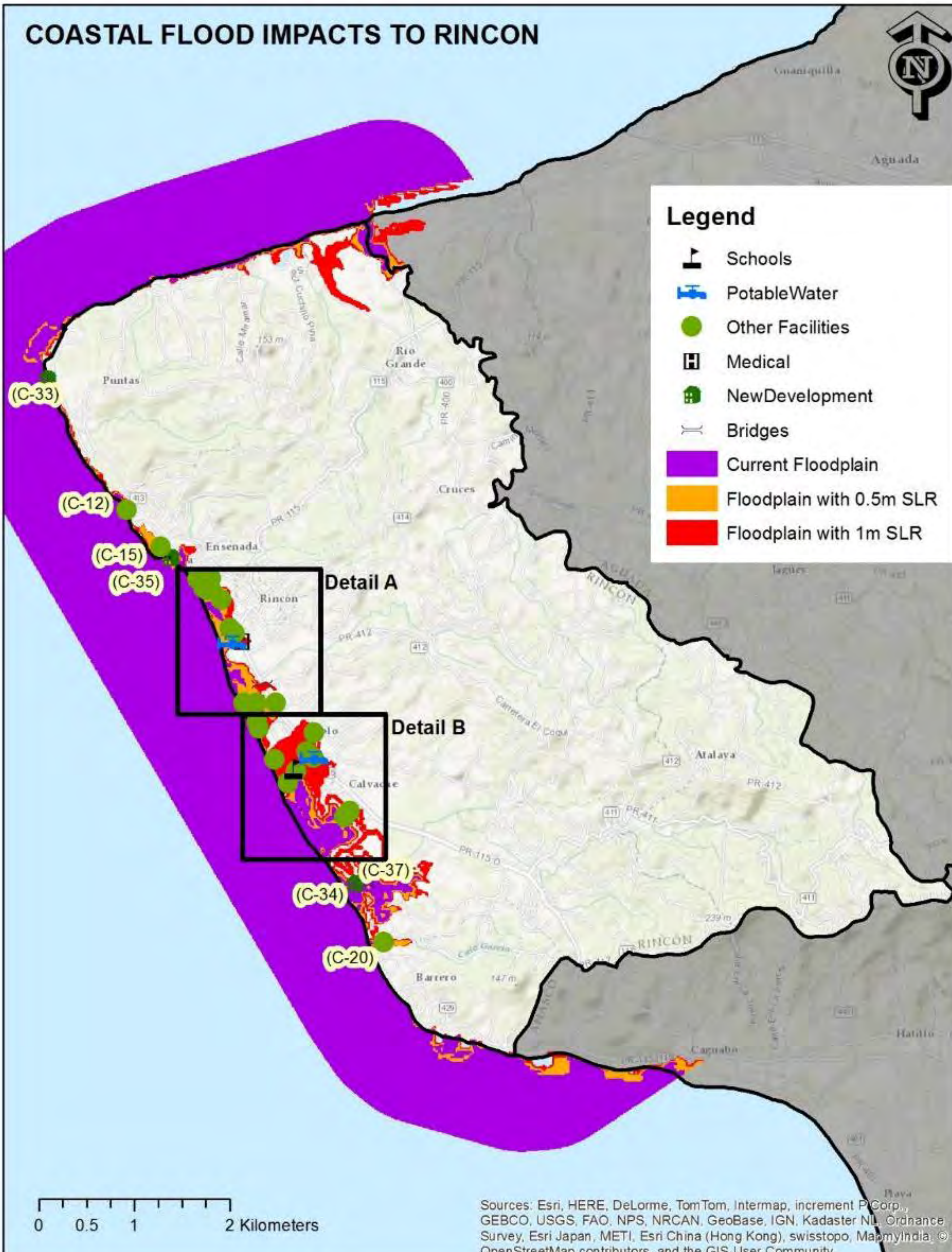

Figure 5-4. Coastal Flood Impacts (current floodplain from FEMA 2013, 0.5m and 1.0m from Section 5.2 methodology)

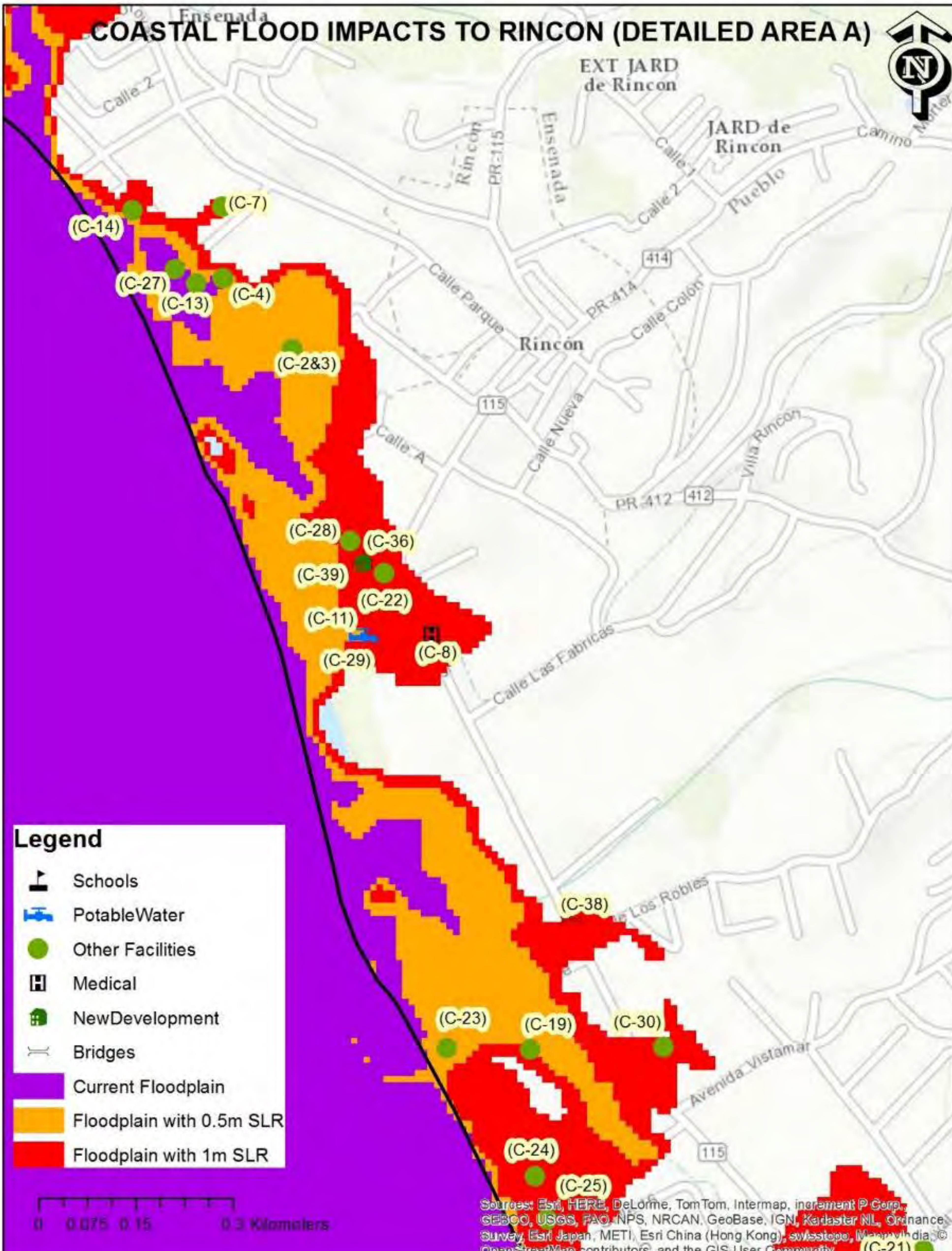

Figure 5-5. Coastal Flood Impacts - Detail A (current floodplain from FEMA 2013, 0.5m and 1.0m from Section 5.2 methodology)

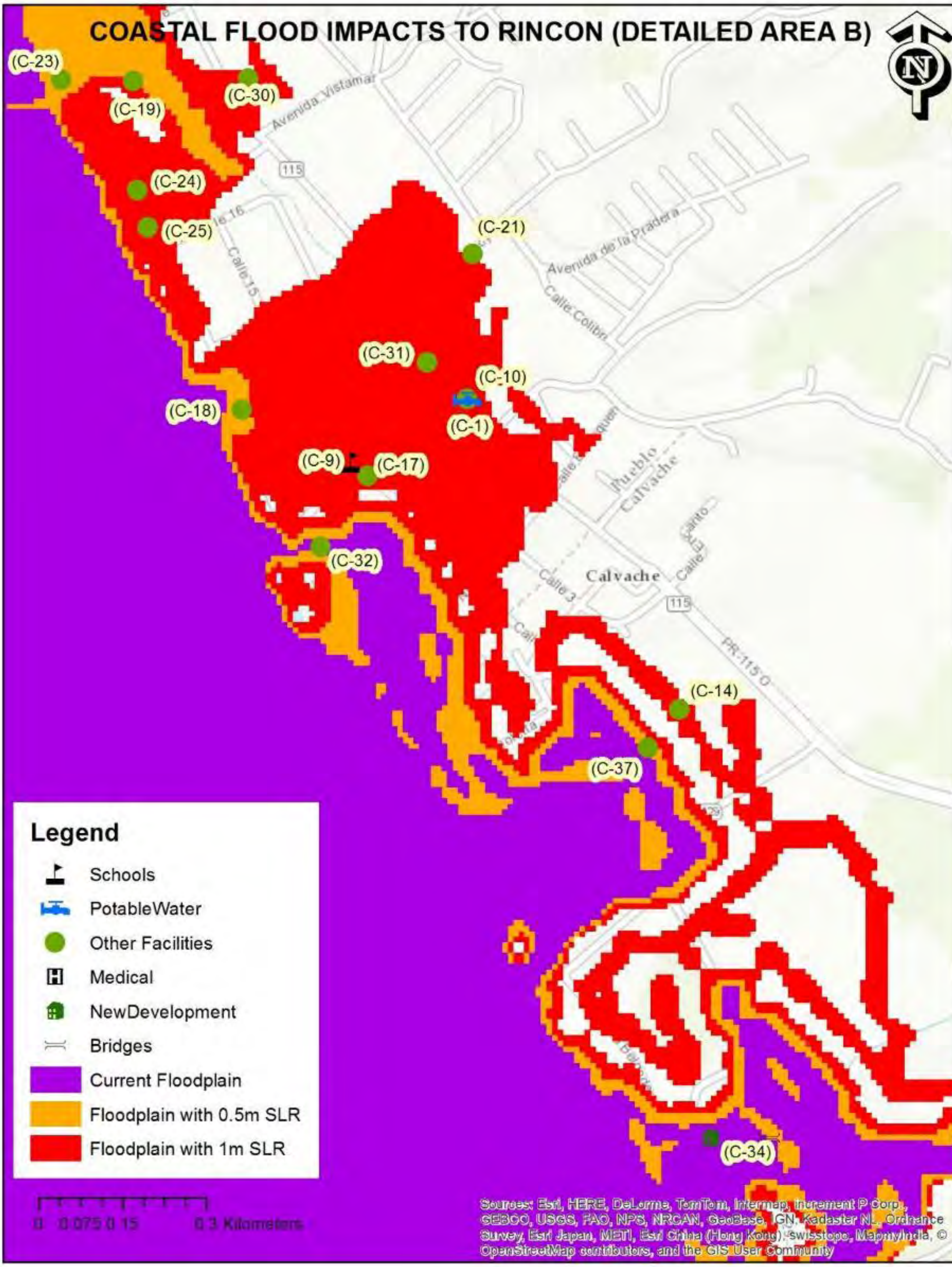

Figure 5-6. Coastal Flood Impacts - Detail B (current floodplain from FEMA 2013, 0.5m and 1.0m from Section 5.2 methodology)

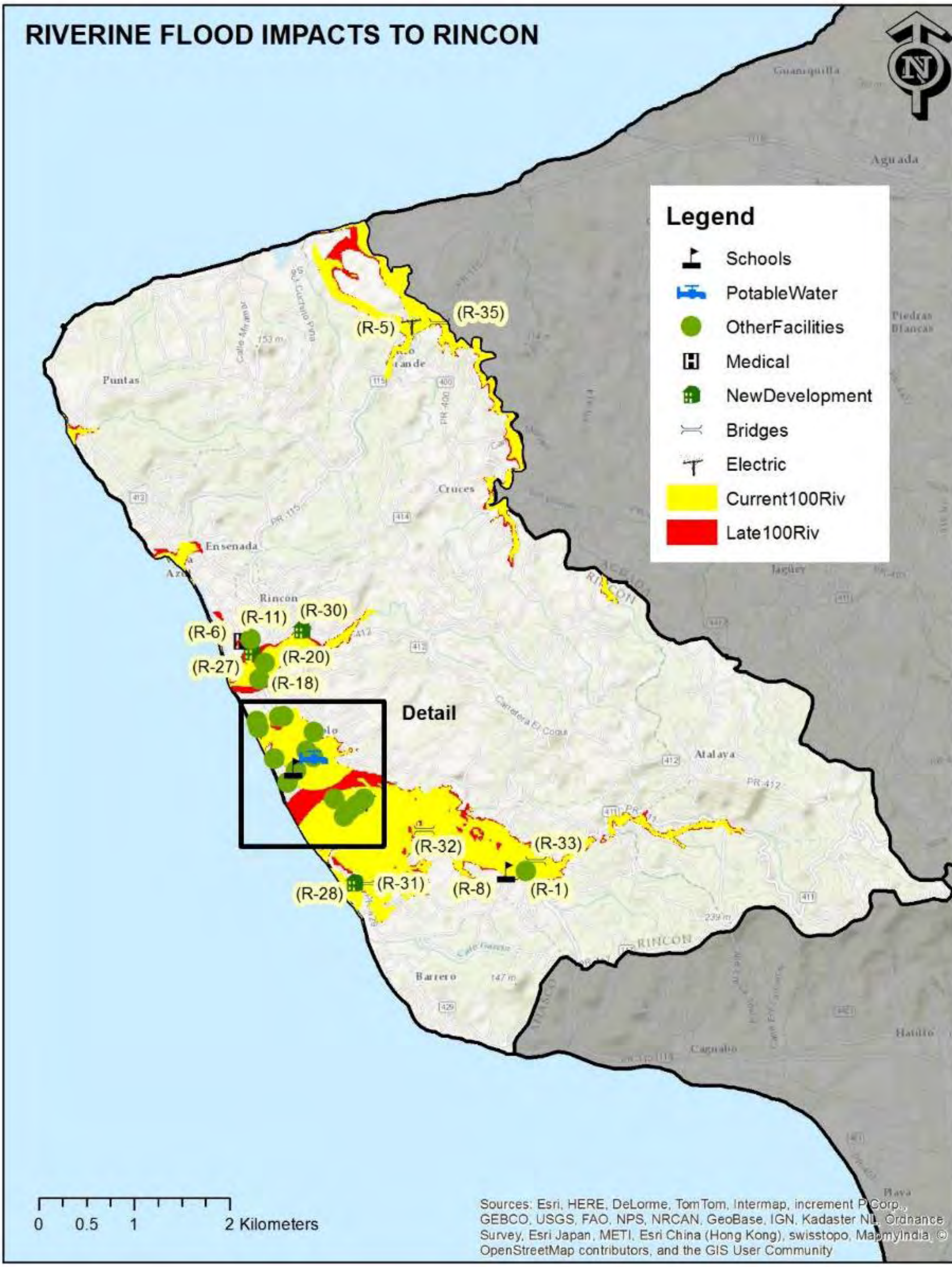

Figure 5-7. Riverine Flood Impacts

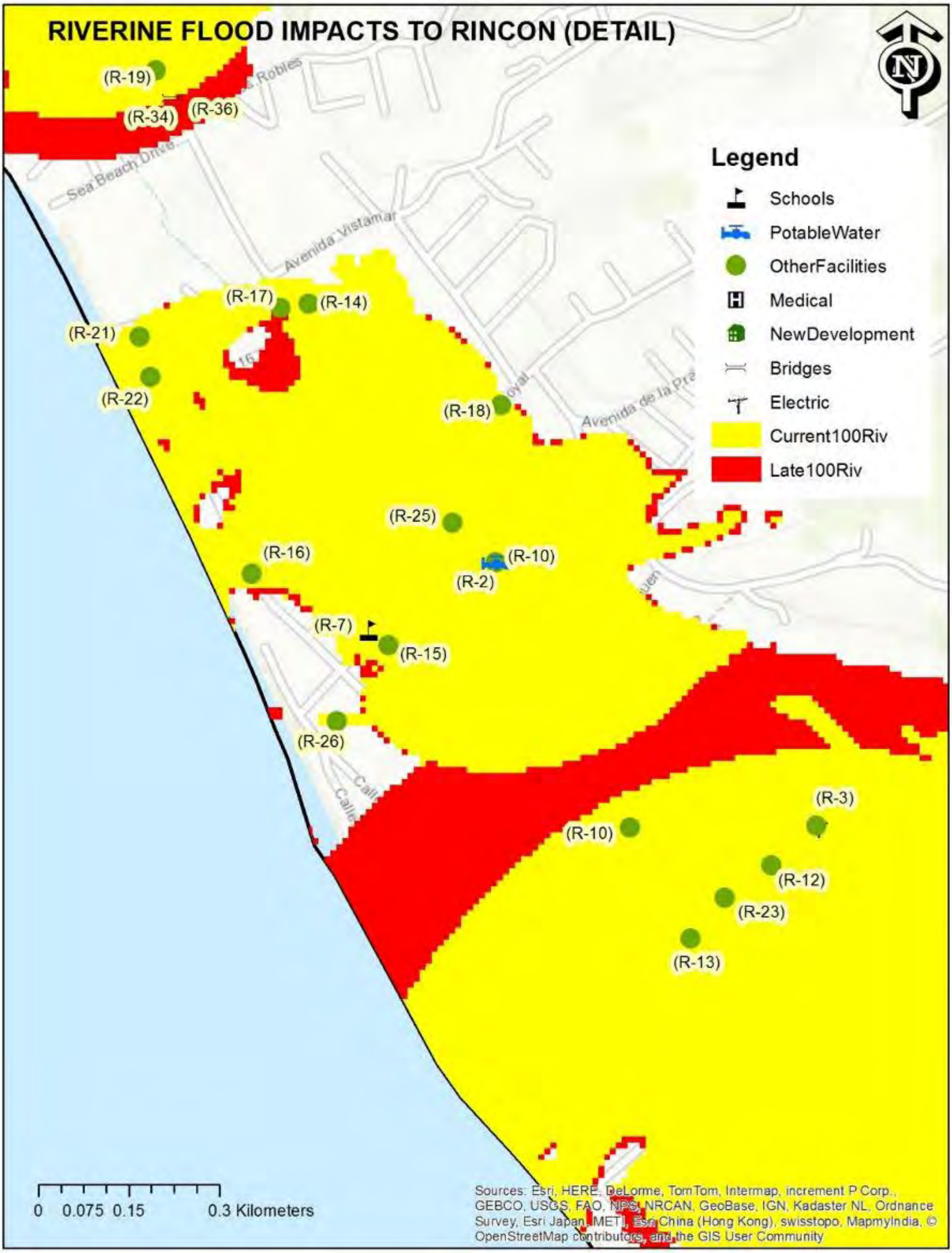

Figure 5-8. Riverine Flood Impacts (Detail)

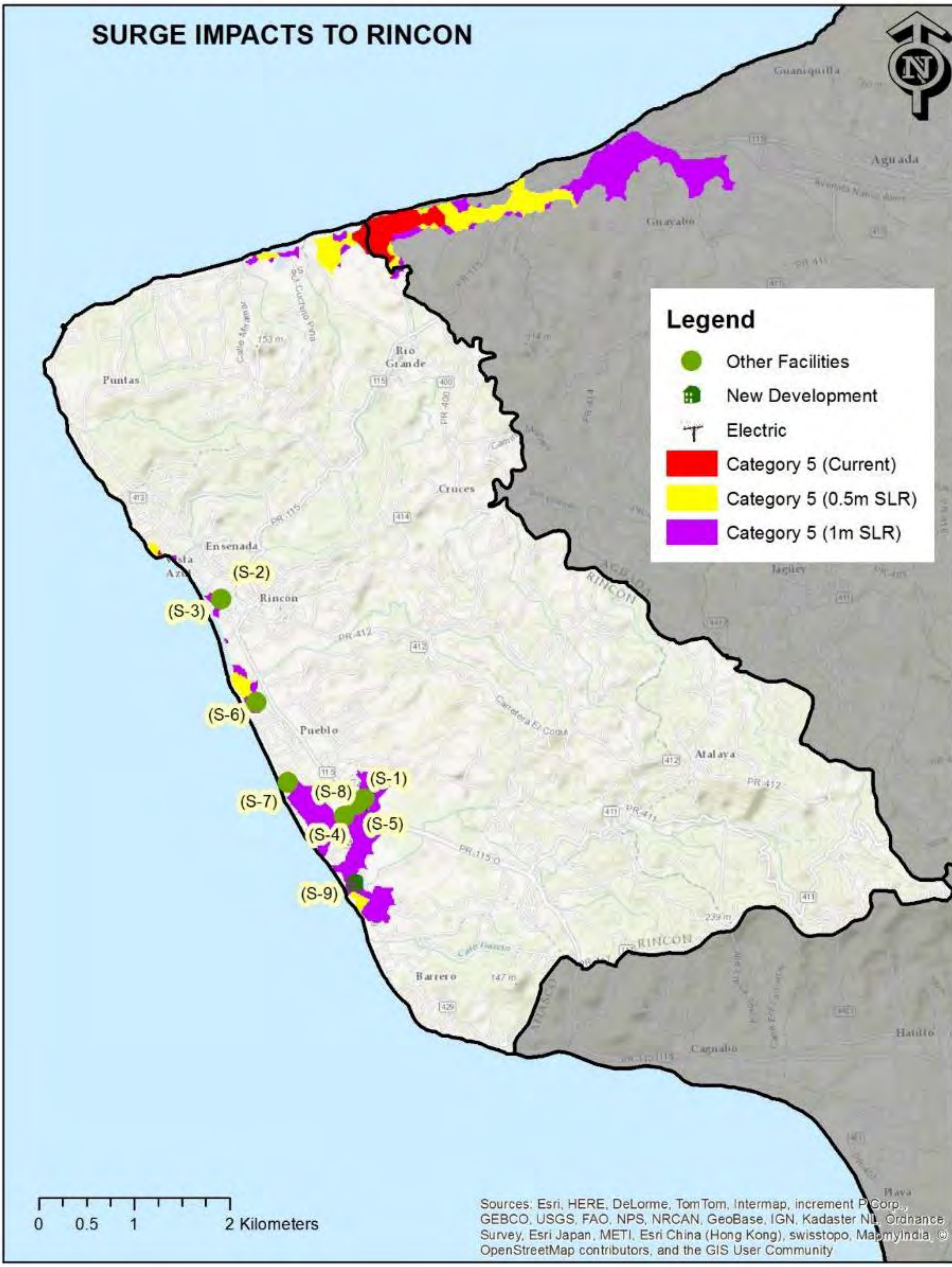

Figure 5-9. Surge Impacts

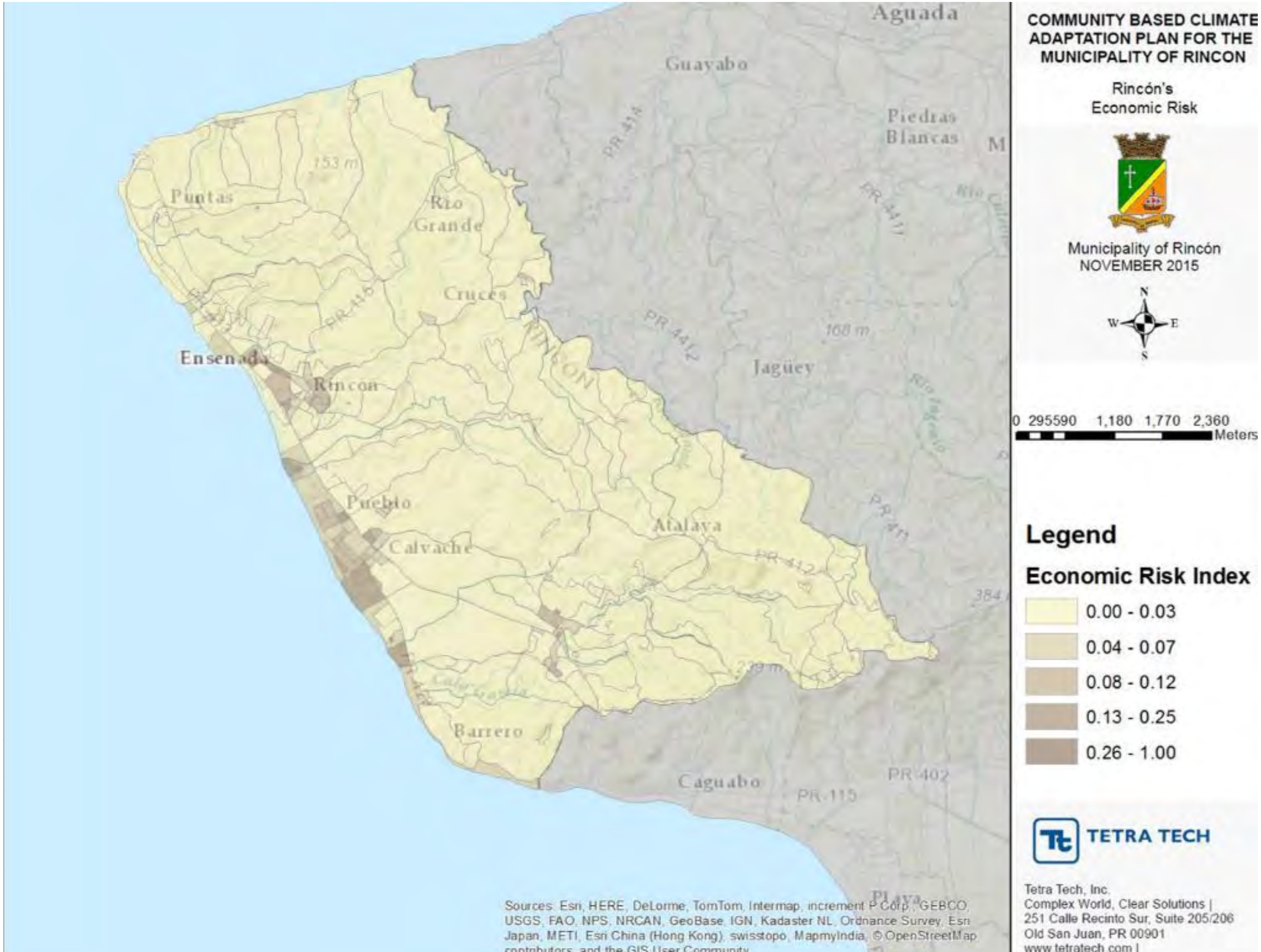

Figure 6-1. Economic Risk Index

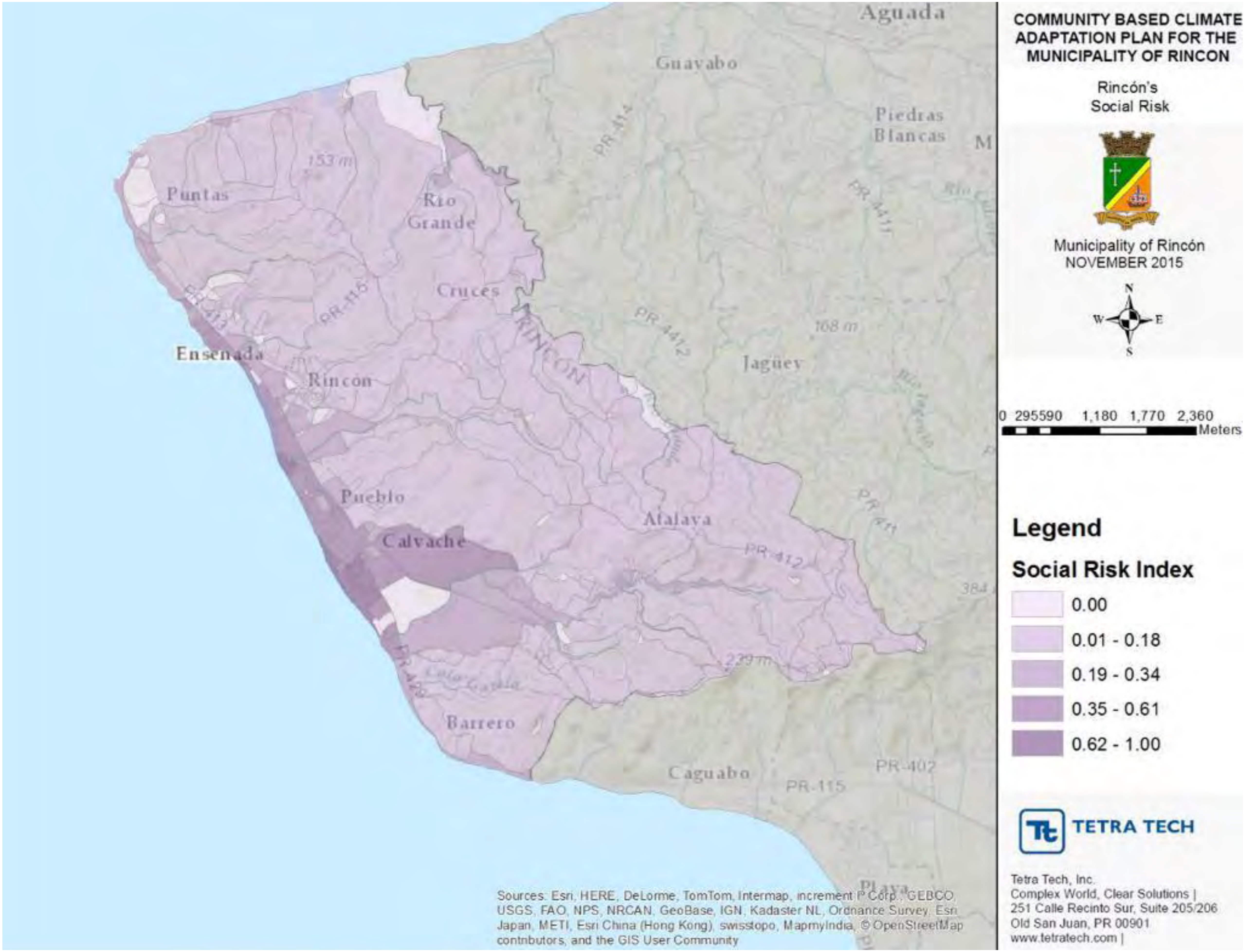

Figure 6-2. Social Risk Index

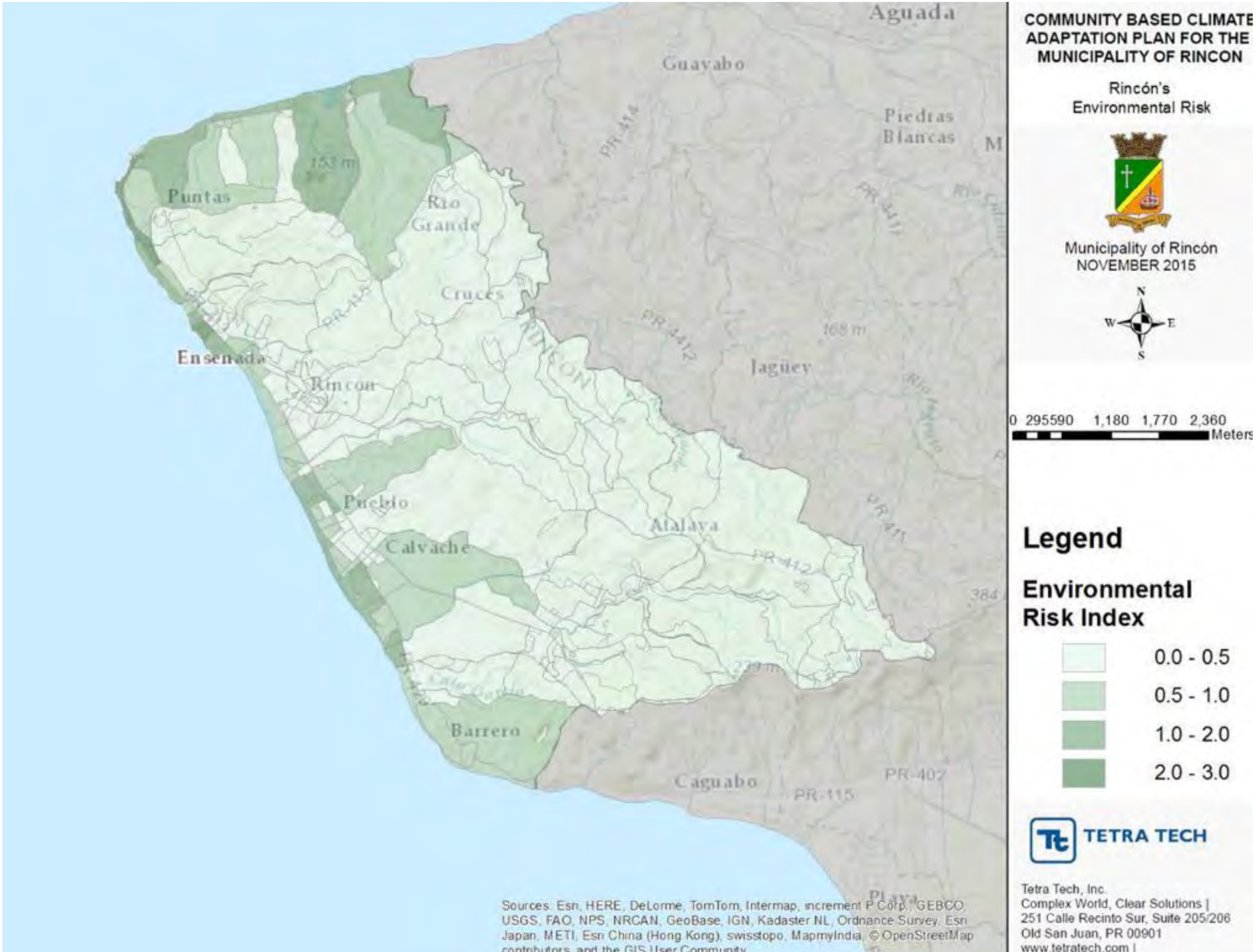

Figure 6-3. Environmental Risk Index

Community Based Climate Adaptation Plan for Rincón Municipality, Puerto Rico

Volume 3 – Risk Profile and Climate Change Adaptation Plan

Submitted to:

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TETRA TECH

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The Community Based Climate Change Vulnerability Assessment and Adaptation Plan for Rincón Municipality was prepared for Puerto Rico's Coastal Zone Management Program (PRCZMP), Department of Natural and Environmental Resources (DNER).

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Technical inputs and review comments were provided by Rincón Municipality, including: Héctor Martínez, Municipal Emergency Management Office Director; William Ventura, Planning and Engineering Department Director; Manuel González, Recycling Department, Director and Stormwater Coordinator, and; Juan Carlos Pérez, Public Relations Manager. Technical input was also provided by Dr. Ruperto Chaparro, Sea Grant Director; Jean-Edouard Faucher Legitime, University of Puerto Rico at Mayagüez (UPRM), and; Roy Ruiz Vélez, Puerto Rico Water Resources and Environmental Research Institute (PRWRERI). A wide range of stakeholders contributed to the development and findings of this report via consultations and surveys, as identified in Volume 1 and 3 of this report. We are grateful for the significant contributions of these individuals and stakeholders.

Key Terms and Concepts

Key Concepts and Terms

Adapt, adaptation: "Adjustment in natural or human systems to a new or changing environment that exploits beneficial opportunities or moderates negative effect."*

Climate: The weather averaged over a long period of time, typically 30 years or more.**

Climate change: **"**A change in the state of the climate that can be identified (e.g., using statistical tests) by changes in the mean and/or the variability of its properties that persist for an extended period, typically decades or longer."**

Hazard: **"**The potential occurrence of a natural or human-induced physical event or trend or physical impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems, and environmental resources."**

Resilience: "A capability to anticipate, prepare for, respond to, and recover from significant multi-hazard threats with minimum damage to social well-being, the economy, and the environment."*

Risk: "A combination of the magnitude of the potential consequence(s) of climate change impact(s) and the likelihood that the consequence(s) will occur."*

Vulnerability: "The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its ability to adapt."*

Weather: The atmospheric conditions at a particular place in terms of air temperature, pressure, humidity, wind speed, and rainfall. Weather is what is happening now or is likely to happen in the very near future.

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1.0 INTRODUCTION

As a municipality located directly on the northwest coast of Puerto Rico, Rincón is sensitive to natural hazards such as hurricanes, extreme precipitation events, and coastal storm surges. Additionally, Rincón is experiencing long-term erosion, which has accelerated in recent years and further increased the municipality's vulnerability to natural hazards. Climate change is expected to exacerbate current challenges and could present new risks to Rincón.

Puerto Rico's Coastal Zone Management Program (PRCZMP), Department of Natural and Environmental Resources (DNER), initiated this study to address the need to better understand how to assess and address climate change related risks to Puerto Rico's municipalities. Pursuant to Section 309 (§309) of the Coastal Zone Management Act (CZMA), PRCZMP completed its Assessment and Strategies report for fiscal period 2011-2015. The report identified: (1) the need for local mitigation strategies, for the prevention of increment of sea level, (2) strategies for adapting to climate change effects, and (3) vulnerability analysis and integration of risk data into local plans, regulations, projects, policies, management plans for special areas, and disaster risk mitigation plans. PRCZMP designed a program to work with local municipalities to better understand their vulnerability to climate change and to develop adaptation strategies to become more resilient. The program initially targets the municipalities of Rincón, Culebra, and Dorado, and is anticipated to include Salina and Loíza at a later date.

Tetra Tech is supporting PRCZMP and the municipality of Rincón to analyze climate variability and impacts on the municipality and to develop an adaptation plan to respond to natural hazard risks. This report details the approach and findings of the Rincón pilot project. The report is organized into the following volumes, which follow major project activities:

- **Volume 1 – Site Description and Initial Stakeholder Outreach and Engagement**. Provides a community profile of Rincón to introduce the report. Identifies the findings and recommendations from initial stakeholder outreach and engagement efforts, including a technical site visit with municipal staff and two public stakeholder workshops.
- **Volume 2 – Vulnerability Assessment.** To assess the climate risk to Rincón, a climate, vulnerability, and impact assessment were conducted.
- **Volume 3 – Risk Profiles and Climate Change Adaptation Plan**. Summaries key risks from the vulnerability assessment in an index, and details the approach and outcomes of the adaptation plan.

This report is Volume 3 – Risk Profiles and Climate Change Adaptation Plan. It has been developed as a stand-alone document that summarizes the primary risks to the municipality and presents an Adaptation Plan that can be used to start to address these risks.

2.0 METHODOLOGY

The project team has used a five step process to assess current and future hazards to Rincón and to develop adaptation strategies to mitigate that risk. The methodology has used a robust stakeholder engagement process to solicit input and feedback on methodology and findings, which has involved municipal staff, local technical resources and civic organizations, and the general public. Engagement with local stakeholders is considered critical, as implementation of the adaptation plan will rely on their commitment to action.

Figure 2-1 below identifies the five step methodology used by the team, and identifies the corresponding report volume that details each step.

Figure 2-1. Project Methodology and Associated Report Volume

3.0 VULNERABILITY INDEX AND RISK MANAGEMENT PROFILES

Volume 2 of this report provides detailed information on the climate, vulnerability, and impact assessment conducted for this project. Impact maps were developed using a GIS modeling tool, Hazus, to illustrate the potential of future impact from sea level rise, coastal storm surge, and riverine flood. Infrastructure loss estimates were identified for critical infrastructure that could be impacted by each hazard.

To further explore the vulnerability of Rincón, this section presents risk profiles that estimate the likelihood and consequences of risk facing the city's people, economy, and infrastructure. Developing a risk management framework provides a systematic method to select the best course of action in uncertain situations. The framework also helps prioritize risks and better link adaptation strategies to risk mitigation.

3.1 LIKELIHOOD OF CLIMATE RISK

There is a great deal of uncertainty in predicting future climate impacts and when those impacts could occur. Thus, it is important to estimate the likelihood or probability that a climate change scenario will occur in a given time-frame. Climate change projections will increase the probability of a significant single event, such as storm surge or riverine flooding to occur, as well as cumulative impacts from slow on-set events, such as increases in sea levels and temperature.

Based on the climate change analysis conducted in Volume 2, there are six scenarios that are likely to impact Rincón's resources: increased sea level rise (SLR) and coastal erosion, increased coastal storm surge, increased hurricane intensity, increased extreme precipitation events and riverine flooding, decreased annual precipitation, increased sea surface temperature (SST) and ocean acidification, and more days over 95° Fahrenheit (F). The historic and projected conditions for each of these scenarios is briefly described below, using summary information from Rincón's Hazard Mitigation Plan (Tetra Tech, 2011) to describe historic conditions and information from Volume 2 of this report to describe projections. Considering the historic trends of the natural hazard alongside future projections for the area helps to qualitatively assess and estimate the likelihood of each scenario.

Increased Sea Level Rise (SLR)/ Coastal Erosion

- Historic/observed conditions: SLR of 1.4 millimeters (mm) per year has been recorded for Puerto Rico over the past century. Rincón has also experienced significant levels of erosion over the past few decades; with a retreat of 1 meter (3.3 feet) recorded by the USGS. There are several areas that are currently being impacted by coastal erosion as identified in the technical site visits conducted for this report (refer to Volume 1).
- Projected future conditions: SLR estimates of 0.5 m (1.65 ft) for mid-century and 1 meter (3.3 ft) for end of century were identified as conservative estimates of future SLR. Assuming an erosion rate of over 1m/year, a buffer of 50 and 100 meters was created using Geographic Information System (GIS) software to illustrate the potential of future impacts for two time horizons (mid- and late- century). This buffer is simply the distance from the shoreline inland and does not account for elevation changes. Current sea level rise estimates/viewers do not include coastal erosion, which is of concern for Rincón; thus, these buffers are useful to start to understand the potential impacts if coastal erosion rates continue unabated.

There is a clear trend of both erosion and sea level rise recorded for the area, which impacts will become more pronounced in the future.

Increased Coastal Storm Surge

- Historic/observed conditions: Tropical storms and hurricanes are one of the more common hazards in the area. In the past two decades, there have been several recorded storm events including two Category 4, two Category 3, one Category 2, and several named tropical storms.[1] There is currently an estimated 42 percent chance of experiencing a strike by a tropical storm or hurricane in the Puerto Rico.
- Projected future conditions: 100-year surge with .5m SLR for mid-century and 100-year surge with 1 m SLR for end of century. The assessment methodology considers all inundation events including storm surge, wind-driven waves, tsunami, etc. However, it does not include riverine flooding, nor does it account for long term erosion (refer to the buffer zones above for long term erosion rates combined with sea level rise).

Coastal storm surge is a common hazard for Rincón, which will become more pronounced in the future.

Increased Hurricane Intensity

- Historic/observed conditions: Refer to coastal storm surge above. Category 3 to 5 hurricanes have caused historic damages in Rincón.
- Projected future conditions: Category 5 surge and wind-speed with 0.5 m SLR for mid-century and Category 5 Surge with 1 m SLR. The majority of the model's hurricane tracts were moving east to west although two followed a reverse path coming from the southwest and heading northeast. This means most of the inundation is going to occur on the other side of the Island rather than impacting Rincón directly. It should also be noted that long-term erosion is not included in the modeled results (refer to the buffer zones above for long term erosion rates combined with sea level rise).

Hurricanes are a common hazard for Rincón; however, storm surges associated with hurricanes have traditionally impacted the southern and eastern portions of Puerto Rico. Climate change could cause more intense hurricanes.

[1] As measured on the Saffir-Simpson scale.

Increased Extreme Precipitation Events and Riverine Flooding

- Historic/observed conditions: Riverine flooding in Rincón generally occurs along the Río Culebrinas and Río Añasco and in low-lying coastal areas. Smaller tributaries are also susceptible to flooding from large meteorological systems, especially tropical storms. There have been at least six flood events in the area since 2000; although with fairly minimal property damage.
- Projected future conditions: 50% increase in base flow for precipitation events (same projections for mid and late-century)

Riverine flooding is fairly common in Rincón. Although there is an overall negative median trend in precipitation projected for the area (see below); the number of extreme precipitation events is projected to increase. Thus, even though the total amount of precipitation could decrease, the amount of precipitation during a single precipitation event could increase.

Decrease in Annual Precipitation

- Historic/observed conditions: Puerto Rico does not often experience drought conditions, with only two historic events identified prior to 2015. However, Rincón (and Puerto Rico as a whole) did experience drought conditions in the summer of 2015. Currently two-thirds of Rincón public water supply is surface water. Wildfire poses a risk to the area; however, has not historically been considered to have significant fire potential (based on historic rainfall data and vegetation).
- Projected future conditions: Median decrease in precipitation of -12% for region; decreases in summer expected.

Drought and wildfire have not posed historic hazards to Rincón. However, these could present new hazards in the future based on projected precipitation.

Increased Sea Surface Temperature (SST) and Ocean Acidification

- Historic/observed conditions: Increased 2.7° F (1.5° C) over the last century
- Projected future conditions: Clear warming trend; SST above threshold for coral bleaching could be exceeded 1/3 of the year.

There is a clear trend of increased SST, which will continue and possibly accelerate in the future.

More Days over 95° F

- Projected future conditions: Likely increase of 1.4° F by mid-century; possible as much as 9° F by 2100.

There is a clear trend of increased air temperature, which will continue and possibly accelerate in the future.

It is also important to consider how the scenario could impact the social, economic, and environmental factors of the community. Table 3-1 below presents the impacts of climate change variables on social, economic, and environmental factors of Rincón. The color coding in each cell identifies the likelihood that a climate change scenario will occur in a given time-frame, with the darker red signifying higher likelihood of impacts in the near term and lighter orange signifying impacts that could occur over a longer period of time. The corresponding likelihood ranges have been assigned a relative point scale for comparative purposes (refer to the table guide for shading and points).

Table 3-1. Estimates of Likelihood of Risks to Rincón

Climate Change Scenario		Social Factors		Economic Factors			Environmental Factors		
	Notes	Displacement	Health and Safety	Property Loss/ Loss of Livelihood	Critical Infrastructure	Operational Impact	Air Quality	Water Resources	Marine Resources
Increased Sea Level Rise (SLR)/ Coastal Erosion^	Current erosion rates of 1 meter per year SLR estimates of 0.5 m (1.65 ft) and 1 meter (3.3 ft)	Potential for residences on coastline to be impacted (coastal erosion currently impacting residences)	Abandoned structures currently pose health and safety risk (pollution, debris)	Potential for businesses on coastline to be permanently impacted. Loss of surf beaches could impact tourism.	Potential for critical infrastructure damage and loss (roads, utilities, hospitals, etc.)	Loss of critical infrastructure and transportation routes could cause operation impacts	n/a	Salt-water intrusion could impact freshwater resources and sensitive ecosystems	Loss of beaches could decrease sea turtle nesting habitat. Erosion could increase sedimentation impacts to coral reefs.
Increased Coastal Storm Surge and Wind (Hurricane and Storm Events)*	Storm surge expected to be greater due to SLR/erosion; also potential for more intense hurricanes	Potential for temporary evacuation; residences to be impacted	Storm surge could pose risk to human life, create debris and cause pollution impacts. Impacts to critical infrastructure could challenge emergency response/relief	Potential for businesses on coastline to be permanently impacted by flood/wind impacts. Loss of surf beaches could impact tourism.	Potential for critical infrastructure damage and loss (roads, utilities, hospitals, etc.)	Loss/disruption of critical infrastructure and transportation routes could cause operation impacts, including temporary closure and loss of tourism	n/a	Short-term salt-water intrusion could temporarily impact freshwater resources and sensitive ecosystems. Potential water pollution from debris, waste, nutrients from flooding	Loss of beaches could decrease sea turtle nesting habitat; potential to damage coral reefs and other sensitive habitat (Tres Palmas Marine Reserve). Increased sedimentation impacts.

Climate Change Scenario		Social Factors		Economic Factors			Environmental Factors		
	Notes	Displacement	Health and Safety	Property Loss/ Loss of Livelihood	Critical Infrastructure	Operational Impact	Air Quality	Water Resources	Marine Resources
Increased Extreme Precipitation Events and Riverine Flooding*	Frequency of intense precipitation events likely to increase	Potential for increase in flooding and landslides that could cause temporary evacuation or permanent impact.	Landslides and flooding could pose risk to human life, create debris and cause pollution impacts. Impacts to critical infrastructure could challenge emergency response/relief	Potential for businesses in flood prone areas to be permanently impacted	Potential for critical infrastructure damage and loss (roads, utilities, hospitals, etc.); damage to storm water management systems	Loss/disruption of critical infrastructure and transportation routes could cause operation impacts, including temporary closure and loss of tourism	n/a	Short-term freshwater intrusion could damage sensitive ecosystems. Potential water pollution from debris, waste, nutrients from flooding	Increased pollution and sedimentation from storm water management system
Decrease in Annual Precipitation ^	Precipitation likely to decrease in summer, which could cause drought and increase risk of wildfires	Potential for increase in wildfires that could cause temporary evacuation or permanent impact.	Potential for increase in droughts and wildfires, particularly in summer	Potential for businesses in areas prone to wildfire be permanently impacted. Potential for decreases in agricultural yield/ production.	Potential for critical infrastructure damage and loss from wildfires	Potential for operational impacts from decrease in fresh-water supplies	Smoke from wildfires and increase in dust could impact air quality	Freshwater resources and sensitive ecosystems could be impacted	n/a
Increased Sea Surface Temp. (SST) and Ocean Acidification^	SST and ocean acidification will increase	n/a	n/a	Potential for businesses that rely on healthy reefs and fisheries to be permanently impacted.	n/a	n/a	n/a	n/a	Coral bleaching, impacts to fisheries

Climate Change Scenario		Social Factors		Economic Factors			Environmental Factors		
	Notes	Displacement	Health and Safety	Property Loss/ Loss of Livelihood	Critical Infrastructure	Operational Impact	Air Quality	Water Resources	Marine Resources
More Days over 95 degrees F	Air temperature will increase	n/a	Increase in number of heat-related illnesses (particularly for vulnerable populations). Changes in ecosystems/ disease vectors could cause increase in diseases such as malaria	Tourism industry could be impacted during summer	Critical infrastructure will require greater operating costs for energy for air cooling	Businesses will require greater operating costs for energy for air and industrial cooling	Increased evapo-transpiration rates; potential for increased dust could impact air quality	Changes in air temperature and precipitation could cause ecosystem shifts.	Could cause impacts to sea turtle nesting (sensitive to temperature). Corals also sensitive to temperature.

Guide Estimates of Likelihood of Risks					
Probability Range by Type of Event	**Very Low - 0**	**Low Risk - 1**	**Moderate Risk - 2**	**High Risk - 3**	**Very High Risk - 4**
Significant Single Event*	Not likely to occur	Likely to occur once between 30 and 50 years	Likely to occur once between 10 and 30 years	Likely to occur at least once a decade	Likely to occur once or more annually
Ongoing/Cumulative Occurrence^	Not likely to become critical	Likely to become critical in 30-50 years	Likely to become critical in 10-30 years	Likely to become critical in a decade	Likely to become critical within several years

3.2 MAGNITUDE OF RISK

The potential consequences, or relative magnitude of risk, is also important to understand for each one of the climate scenarios. In other words, if an event occurs, how significant would the impact be to the people, economy, and environment of Rincón? Table 3.2 estimates the consequence levels from the six scenarios identified above.

The color coding in each cell identifies the magnitude of consequences for each climate scenario, with the darker red signifying higher impacts and lighter orange signifying lower impacts. The corresponding magnitudes have been assigned a relative point scale for comparative purposes (refer to the table guide for shading and points).

Table 3-2. Magnitude of Consequence of Climate Impact

Climate Change Scenario		Social Factors		Economic Factors			Environmental Factors		
	Impact Scenario	Displacement	Health and Safety	Property Loss/ Loss of Livelihood	Critical Infrastructure	Operational Impact	Air Quality	Water Resources	Marine Resources
Increased Sea Level Rise (SLR)/ Coastal Erosion^	50 meters from shore	More than 130 residences in potential displacement zone. Residential losses of $42,347,000 (3.65% of total residential properties)	Pollution, debris from impacted structures. DOMES nuclear facility potentially at risk (but more study recommended)	Loss of 6 businesses (hotels) that support tourism Commercial losses of $19,732,000 (3.26% of total commercial properties)	One middle school, wastewater pipe	Loss of Domes beach, other municipal parking areas	n/a	Salt-water intrusion could impact freshwater resources and sensitive ecosystems	Loss of Domes Beach; reduction in critical sea turtle habitat; increased sedimentation
	100 meters from shore	More than 250 residences in potential displacement zone. $80,857,000 (6.95% of total residential properties)	Pollution, debris from impacted structures. DOMES nuclear facility potentially at risk (but more study recommended)	Loss of 11 businesses (hotels, restaurants) that support tourism Commercial losses of $51,701,000 (8.55% of total building stock)	One middle school, marina, wastewater pipe	Loss of Domes beach, other municipal parking areas		Salt-water intrusion could impact freshwater resources and sensitive ecosystems	Loss of Domes Beach; reduction in critical sea turtle habitat; increased sedimentation
Increased Coastal Storm Surge (All Storm Events)*	100-year Surge with 0.5 m SLR	500 households displaced Residential losses of $9,392,404 (0.81% of total residential properties)	Need for evacuation and emergency response. Impacts to bridges, water utilities, medical center and school.	Loss/impacts to 10 businesses (hotels, restaurants) that support tourism Commercial losses of $6,005,596 (0.99% of total building stock)	Healthcare pump systems, Grande Creek bridge	Loss/impacts to roads and bridges and other critical infrastructure	n/a	Bank scouring/ erosion, water pollution from debris, waste, nutrients from flooding	Beach scouring/ erosion, impacts to coral reefs and sensitive habitat

Climate Change Scenario		Social Factors		Economic Factors			Environmental Factors		
	Impact Scenario	Displacement	Health and Safety	Property Loss/ Loss of Livelihood	Critical Infrastructure	Operational Impact	Air Quality	Water Resources	Marine Resources
	100-year Surge with 1 m SLR	1,200 households displaced Residential losses of $21,989,148 (1.89% of total residential properties)	Need for evacuation and emergency response. Impacts to transportation networks, utilities, medical center, etc. important to health and safety	Loss/impacts to 14 businesses (hotels, restaurants) that support tourism Commercial losses of $10,245,852 (1.7% of total building stock)	Healthcare pump systems, Rincón Medical Center, Head Start, Pump Station, Texaco Road, water wells, Grande Creek bridge and channel, sports complex, two banks, gas station	Loss/impacts to roads and bridges and other critical infrastructure	n/a	Potential bank scouring/erosion, water pollution from debris, waste, nutrients from flooding	Beach scouring/ erosion, impacts to coral reefs and sensitive habitat
Increased Hurricane Intensity* - Hurricane Surge only	Category 5 Surge with 0.5 m SLR	40 households displaced Residential losses of $880,657 (.08% of total)	Need for evacuation and emergency response. Impacts to transportation networks	Commercial losses of $410,343 (0.07% of total building stock)	Roads temporarily inundated	Roads temporarily inundated	n/a	Bank scouring/erosion, water pollution from debris, waste, nutrients from flooding	Beach scouring/ erosion, impacts to coral reefs and sensitive habitat
	Category 5 Surge with 1 m SLR	500 households displaced Residential losses of $6,473,061 (0.56% of total residential properties)	Need for evacuation and emergency response. Impacts to transportation networks	Loss/impacts to 4 businesses (hotels, condos) that support tourism Commercial losses of $4,138,939 (0.68% of total building stock)	Sub-station impacted, roads inundated	Sub-station impacted, roads inundated	n/a	Bank scouring/erosion, water pollution from debris, waste, nutrients from flooding	Beach scouring/ erosion, impacts to coral reefs and sensitive habitat

Climate Change Scenario		Social Factors		Economic Factors			Environmental Factors		
	Impact Scenario	Displacement	Health and Safety	Property Loss/ Loss of Livelihood	Critical Infrastructure	Operational Impact	Air Quality	Water Resources	Marine Resources
Increased Extreme Precipitation Events and Riverine Flooding*	50% increase in base flow for precipitation events (same projections for mid and late-century)	1,900 households displaced Residential losses of $28,036,919 (2.41% of total residential properties)	Need for evacuation and emergency response. Impacts to transportation networks, utilities, medical center, etc. important to health and safety	Loss/impacts to 8 businesses (hotels) that support tourism Commercial losses of $17,927,081 (2.97% of total building stock)	Inundation/ damage to six bridges and two road sections; medical center; fire station; two schools; two sub-stations; two gas stations	Loss/impacts to roads and bridges; impacts to community recreational centers; several parking areas	n/a	Bank scouring/erosion, water pollution from debris, waste, nutrients from flooding	Increased pollution and fresh water from flooded rivers; storm water management system
Decrease in Annual Precipitation ^	Median decrease in precipitation of -12% for region; decreases in summer expected	Potential for increase in wildfires that could cause temporary evacuation or permanent impact.	2/3 of Rincón public water supply is surface water Potential for increase in droughts and wildfires, particularly in summer	Potential for businesses in areas prone to wildfire be permanently impacted. Potential for decreases in agricultural yield/ production.	Potential for critical infrastructure damage and loss from wildfires	Shortages from decrease in water supplies could cause operational impacts; agriculture supply could be impacted	Smoke from wildfires and increase in dust could impact air quality	Freshwater resources and sensitive ecosystems could be impacted	n/a
Increased Sea Surface Temp. (SST) and Ocean Acidification^	SST above threshold for coral bleaching could be exceeded 1/3 of the year; ocean acidification will impact growth rates	Significant impact to tourism and economy could cause residents to move elsewhere.	n/a	Potential for businesses that rely on healthy reefs and fisheries to be permanently impacted.	n/a	n/a	n/a	n/a	Coral bleaching, migration and distribution for many marine species. Tres Plamas could be severely impacted, including Elkhorn Coral.

Climate Change Scenario	Impact Scenario	Social Factors		Economic Factors			Environmental Factors		
		Displacement	Health and Safety	Property Loss/ Loss of Livelihood	Critical Infrastructure	Operational Impact	Air Quality	Water Resources	Marine Resources
More Days over 95° F	Likely increase of 1.4° F by mid-century; possible as much as 9° F by 2100.	Significant impact to tourism and economy could cause residents to move elsewhere.	Increase in number of heat-related illnesses and death (particularly for vulnerable populations). Changes in ecosystems/ disease vectors could cause increase in diseases such as malaria	Tourism industry could be impacted during summer.	Critical infrastructure will require greater operating costs for energy for air cooling	Businesses will require greater operating costs for energy for air and industrial cooling	Increased evapo-transpiration rates; potential for increased dust could impact air quality	Changes in air temperature and precipitation could cause ecosystem shifts.	Could cause impacts to sea turtle nesting (sensitive to temperature)

Table 3-2 Guide Magnitude of Consequence of Climate Impact

	Low - 1	Moderate - 2	High - 3
Description	✓ No to little interruption to critical services/operations ✓ None to a small number of people affected ✓ No potential for injuries to employees ✓ No pollution or toxin release above current operations ✓ Insignificant impact on biodiversity or ecosystems ✓ No or minor impact on cultural/historical sites	✓ Moderate disruption of service (including number of people impacted and duration of disruption), but easily repaired ✓ Substantial sections of the facility affected ✓ Some potential for injuries to employees ✓ Minor pollution release above current operations, but can be mitigated or cleaned-up ✓ Long-term impact on some biodiversity or specific ecosystems (including beach erosion), including possible permanent damage ✓ Moderate, but not permanent, impact on a cultural/historical site	✓ Significant disruption or loss of service/operations that can either a) not be easily repaired or b) would last for a prolonged period of time ✓ Significant portion of the community affected ✓ Significant potential for injuries to employees ✓ Significant pollutants released above current operations. ✓ Substantial long-term impact on biodiversity or ecosystems, including the potential for significant permanent damage ✓ Permanent damage or destruction of a cultural/historical site

3.3 RISK PROFILES

To better understand the risk profile for each of the climate scenarios, an overall risk rating was developed. The risk rating is the combination of the likelihood and magnitude of risk for each scenario and community factor. For each cell, the point score from the previous two tables was added together and presented in Table 3-2. The risk evaluation matrix was then used to compare the risk ratings; with the color coding assigned based on the associated risk.

As illustrated in Table 3-3, the social factors associated with increased SLR and coastal erosion ranked the highest, followed by social, economic, and environmental factors associated with increased flooding (coastal, riverine, and hurricane). Impacts to marine resources from increased SST also ranked highly.

Table 3-3. Risk Profile for Climate Change Scenarios

Climate Change Scenario	Social Factors		Economic Factors			Environmental Factors		
	Displacement	Health and Safety	Property Loss/ Loss of Livelihood	Critical Infrastructure	Operational Impact	Air Quality	Water Resources	Marine Resources
Increased Sea Level Rise (SLR)/ Coastal Erosion	7	7	6	6	6		2	5
Increased Coastal Storm Surge	6	6	6	6	6		4	5
Increased Hurricane Intensity	6	6	6	5	5		4	5
Increased Riverine Flooding	5	5	5	5	5		4	4
Drought	2	4	2	2	4	3	4	
Increased SST and Ocean Acidification	2		4					5
More Days over 95°F	2	3	4	3	3	2	3	3

Table 3-3 Guide

Likelihood			Consequence		
			1	2	3
			Low	Medium	High
	5	Very High	6	7	8
	4	High	5	6	7
	3	Moderate	4	5	6
	2	Low	3	4	5
	1	Very Low	2	3	4

4.0 ADAPTATION GOALS AND STRATEGIES

Rincón is a vibrant coastal community, with strong community networks. Rincón's economy is fueled by tourism of the community's quaint downtown, natural resources, and surfing beaches. As a coastal community, Rincón also faces a high level of risk from erosion and flooding. This section identifies adaptation goals to increase the resilience of Rincón to respond to these risks. The goals have been developed based on community input and were further refined through community consultation.

The following three adaptation goals were identified for further investigation in Section 5:

1. Increase Resiliency of Critical Infrastructure to Improve Community Reliability and Functions
2. Promote Community Health and Well-Being to Increase Resiliency of Social and Ecological Systems
3. Advance Economic Development Opportunities

The sections below elaborate on these goals and also describe any relevant planning or regulatory efforts that have been developed to help the community meet the goals so that this report will build on ongoing efforts.

The goal of this document is to provide guidance on adaptation strategies that can be implemented or promoted by Rincón to address the risks posed by climate change and increase community resilience. Adaptation strategies are identified that can support the three community resilience goals and are evaluated using multi-criteria analysis.

4.1 EVALUATION CRITERIA FOR ADAPTATION STRATEGIES

In order to evaluate each adaptation strategy, several criteria were identified to better understand the relative costs, feasibility, potential to ameliorate climate change risks, timeframe needed for implementation, acceptability to stakeholders, and potential to contribute to other community goals.

The ratings for each adaptation strategy were then assigned a numerical weighting of 0-3. The relative costs and implementation feasibility are indicated for each strategy based on the professional judgment of the authors and input from stakeholders, and only to be taken as an approximation to assist with the screening and prioritization of adaptation strategies. In all cases, the cost description refers to the costs associated with the specific risk management measure, not the costs that might occur should the adverse impact in question occur. The costs associated with these strategies will need to be estimated at the project level and will depend on the project scale and the risk level. The feasibility of implementing risk management strategies will depend on evaluating various criteria against project specific considerations.

Ratings of "Unknown" were assigned a weighting of 0 and therefore do not have any effect on the overall score of each strategy; however, they do show a deficiency in data that, when resolved, might affect the overall priority of the adaptation strategy. Input from appropriate stakeholders is recommended to address the unknown category, as well as to identify/confirm the most appropriate strategies.

Table 4-1. Adaptation strategy evaluation criteria

Evaluation Criteria	Rating			
	3	2	1	0
Relative Costs	$ = Relatively straightforward to implement, either simple changes on the ground or adoption of new regulations/guidelines	$$$ = Intermediate scale efforts, more spatially extensive, and or requiring more engineering design, scientific development, and or planning/ institutional changes	$$$$ = Major new infrastructure development with significant new design, planning and permitting requirements	Unknown – requires more information to make a determination
Feasibility	Easy = Relatively straightforward to implement, provides long-	Moderate = Intermediate scale efforts required to	Difficult = Major effort would be needed to implement; option	Unknown – requires more information to make a determination

Evaluation Criteria	Rating			
	3	2	1	0
	term benefits, has no adverse secondary impacts.	implement; option could require further assessment of environmental and social impacts, additional regulatory requirements, or capacity and technical expertise.	could result in adverse environment/social impacts, or could require significant expenditures, capacity, technical expertise, political will, or legal authority	
Ability to Ameliorate Risk	High = Will virtually overcome risk event	Moderate = Will have moderate effect on risk event	Low = Will have minor effect on risk event	Unknown – requires more information to make a determination
Time-frame	Short = can be implemented within 10 years	Medium = Can be implemented within 10-20 years	Long = Can be implemented within 20-50 years	Unknown – requires more information to make a determination
Acceptability	High = Little or no stakeholder resistance	Moderate = Moderate stakeholder resistance	Low = Significant stakeholder resistance	Unknown – requires more information to make a determination
Opportunity	High = Contributes to other community goals (has co-benefits). Considered a no-regret strategy that could be implemented regardless of climate impacts.	Moderate = Moderately contributes to other community goals (has co-benefits). Considered a low-regret strategy.	Low = Does not contribute to other community goals.	Unknown – requires more information to make a determination

The following subsections evaluate adaptation strategies for each of the three adaptation goals. Several strategies are initially proposed for each goal because (1) concurrent implementation of several strategies in coordination with each other often helps to ensure the adaptation goal is met and (2) the screening process implemented for each adaptation strategy in this section could remove some strategies from further consideration.

4.2 GOAL #1: INCREASE RESILIENCY OF CRITICAL INFRASTRUCTURE TO IMPROVE COMMUNITY RELIABILITY AND FUNCTIONS

There are several critical facilities that are at-risk to climate induced natural hazards. Critical infrastructure and facilities provide services to the community and should remain functional after a hazard event. They include: transportation systems (roads, ports), utility infrastructure (electric power stations, wastewater treatment plants), and critical facilities (hospitals, fire stations, schools, etc.). Four strategies that could help prevent losses to critical infrastructure are identified in this section.

4.2.1 Strategy 1: Prevent Service Interruptions

As detailed in Volume 2 of this report series, there is significant critical infrastructure that is at-risk of damage, particularly from coastal and riverine flood impacts. Working with managers and providers to improve the resilience of critical systems is an important step that communities can take in light of the increasing unpredictability of extreme weather events.

The overarching goal is to emphasize actions that prevent service interruptions and also those that allow for quick service restoration in the event damage or an outage does occur. The ultimate aim is to control both the duration and frequency of interruptions. There are three adaptation options that can be implemented to support this strategy:

Mutual Aid Agreements (MAAs)

MAAs are collaborative initiatives between separate utility providers that increase all parties' ability to respond to emergency situations through effective partnerships. These agreements can apply to any type of utility service and allow for providers to quickly identify and use additional resources (equipment, personnel etc.) to maintain or reinstate service during an emergency. Any given provider may join multiple different partnerships and during an emergency and may access multiple mutual aid agreements to access necessary aid.

Structural and operational improvements

Utility providers can consider one or more structural, equipment or facility related improvements to increase the reliability of service and decrease both frequency and duration of outages. Burying transmission lines, creating redundant transmission sections, and providing backup power for utilities can aid in ensuring uninterrupted service before, during and after a disaster. Installing floating or flexible infrastructure, such as flexible pipes, could also be an innovative solution. Locating new equipment and facilities in safe areas away from identified hazards is another important part of facility planning. Collectively these initiatives can add up to significant enhancements in overall reliability.

Structural and operational improvements can also increase energy and water efficiency, which could be useful when considering future impacts from extreme temperature conditions, which will raise heating and cooling costs.

Training

Improved training and exercises to enhance the knowledge and skill of operators can help minimize impacts to systems during emergencies. Improved contingency planning can include a larger number of "what if" scenarios or scenarios with greater magnitudes of failures. Certain facilities provide essential services and roles during an emergency (hospitals, police, fire) and can be prioritized for service recovery during an emergency to reduce potential risks and expedite recovery.

4.2.2 Strategy 2: Assess and Repair Critical Networks

This strategy involves making repairs to critical networks in the community. More intense rain events will cause flooding and could overwhelm stormwater infrastructure capacity. Making repairs to critical transportation and drainage networks will help prevent flooding, and ensure that evacuation and emergency relief efforts are unimpeded.

Increase Storm Drainage for Transportation Networks

For transportation networks, retrofits could involve increasing the cross drainage and culvert capacity and using green infrastructure techniques to increase resiliency. It is important to note those points where flooding could occur to consider alternate routes evacuation or emergency response routes. The existing storm drainage system along Route PR-115 (Texaco Road) is inadequate and subject to repetitive flooding during frequent storm events; which is projected to become worse in the future. This section of road is the major arterial road providing access to the Town Center. The most impacted areas are the Stella Community and the Pueblo ward. In addition to preventing the transit of emergency vehicles, the frequent flooding adversely affects a number of adjacent businesses and residences.

Inventory historic landslide events and implement a program to mitigate areas designated as having a high probability for future landslide events

In the more steeply sloping terrain of the central and southeastern portions of the Municipality there has been a history of minor landslide events that have periodically closed roads and caused limited property damage. Increases in the precipitation during rainfall events, projected under climate change, could increase the risk of landslides. There is a need to evaluate options to modify the cut and fill slopes along some road sections and stabilize eroding slopes by vegetative or structural slope protection management practices.

Rainfall-induced landslide events have the potential to block emergency access to the more remote portions of the Municipality.

Assess Bridges and Retrofit/Make Repairs

There are several bridges that are modeled as having structural impacts or will be underwater for future climate change scenarios; four bridges for coastal flooding scenarios and six for riverine flooding scenarios. Loadings caused by weather and other extreme events can cause a bridge to fail, which can cause loss to human life and affect evacuation, emergency response, and relief efforts. Under this option, bridges would be assessed for extreme weather loadings and retrofits and/or repairs made for at-risk bridges. Low-lying bridges should be replaced. Drainage channels improvements should be performed in conjunction with bridge replacement/repair.

Make Repairs to *Canal Los Ramos*

About 10 years ago, the US Army Corps of Engineers (USACE), working through the PR Dept. of Housing, funded the construction of gabion walls to control erosion and reduce flooding along the Canal Los Ramos. Faulty design, construction, or saltwater corrosion of the wire gabion enclosures has led to the premature collapsing of the vertical walls. The failure of the gabion structures will lead to continuing erosion, potentially impacting the adjacent Sea Beach Colony development. Not addressing the repair of these gabion walls may aggravate the existing vulnerability to flooding in adjacent communities.

Make Repairs to Drainage Canals

The proper functioning of drainage channels (canals) is crucial to minimize property damages from flooding. Throughout the Municipality there are numerous open drainage channels in an advanced state of disrepair, poorly designed, or undersized to carry the increased volume of storm water resulting from recent development. A thorough inventory of the drainage canals throughout the Municipality is needed and increased capacity provided in areas where repetitive flooding has occurred, as well as where modeled impacts (as identified in the Vulnerability Assessment) could occur in the future. Sector Córcega is particularly in need of improvements to its stormwater drainage system, as the area repeatedly floods, affecting adjacent industry and businesses.

Assess and Implement a Stream and Drainage Channel Cleaning Program

There are a number of dikes or obstructions in drainage channels that impede the flow of storm water. Some are inoperable tidal gates that were intended to prevent storm tidal surges and others are remnants of construction or have been placed without proper impact assessments. These not only obstruct the flow of water through the canals, they further have the negative impact of causing a backwater flooding condition causing shallow flooding in adjacent communities. Specifically, there is an obstruction in Canal 115 at Sector Turin Rosado, and an inoperable Dike in Sector Turin Rosado and Sector Praderas.

Establish a Memorandum of Understanding (MOU) with DRNA

Rincón is part of the Aguadilla region of DRNA. Developing a MOU to enable the Municipality to get technical assistance and, hopefully, cost share financial support for enhancing the flood reduction benefits of open drainage channels and periodic stream and channel maintenance. Currently DRNA indicates a willingness to grant permits for stream and drainage channel maintenance but considers it a municipal responsibility.

The Municipality should pursue an agreement with DNRA that provides for some State level cost share for flood control improvements and long-term maintenance requirements for drainage channels and minor streams in urbanized areas. An action plan and agreement with the DRNA Aguadilla Regional Office will provide important mitigation benefits to Rincón. The Municipality should lobby its State representatives to encourage a joint cost-share approach which acknowledges both State and local responsibilities to address the need to reduce the Municipality's vulnerability to recurrent flooding events.

4.2.3 Strategy 3: Retrofit, relocate, or abandon/dismantle at-risk infrastructure

Under this strategy, the municipality and infrastructure owner/operator would evaluate the modeled at-risk infrastructure and anticipated time horizon for impact and then determine whether the infrastructure could be retrofitted to withstand the impact, whether the infrastructure would need to be rebuilt in a different location outside the hazard area, or whether non-critical infrastructure should be abandoned entirely. With longer term impacts, such as projected sea level rise, there is a longer time period to act and immediate decisions are not always necessary. However, it is important to remember that identifying and mobilizing the capital expenditures necessary for these changes often requires a longer term planning horizon (10-15 years).

These three adaptation options are further described below.

Retrofit

Providing flood mitigation improvements for critical infrastructure located in hazard areas can increase public safety and position the community for greater future health and economic resiliency. Project work typically includes a combination of structural elevations to raise a building above flood levels, and wet flood-proofing or dry-proofing methods depending on the site conditions and the design of the building.

Wet flood-proofing methods prepare a structure to accommodate flooding by allowing water inside the building but working to minimize damage. This option typically involves raising first floors above the flood plain and allowing the basement to flood during times of high water. In particular wet flood-proofing is most effective by relocating the building's major mechanical systems (HVAC, electrical boxes, generators etc.) and occupied spaces above the flood waters and installing engineered flood vents which allow hydrostatic pressure on the walls to equalize, preventing wall collapse.

Dry flood-proofing, on the other hand, creates improvements that prevent water from infiltrating the building envelope through waterproofing of exterior walls, openings and basements. These systems are better suited for buildings without basements due to under seepage (water seeping up from the floor slab) and hydrostatic pressure on the basement walls. However, dry flood-proofing systems can be successfully implemented in buildings with basements, though a system to pump out water that does seep into the building is recommended. Specific actions include installing flood-resistant/watertight doors, windows and openings, waterproofing exterior walls and masonry joints in the foundation (sealant, membrane and drainage board), upgrading access doors from the basement to the outside, reinforced walls, upgrading and elevating flooring materials, and installing backflow valves to prevent water entering the building through sanitary/sewer systems.

Green infrastructure concepts can be an important component of retrofits. Green infrastructure techniques can be used to store rainwater and harvest rainwater on-site; preserve areas with high-infiltration soils; using green infrastructure practices, such as bioretention areas, to reduce localized flooding and water quality impacts; and using trees and living roofs to lower building energy use and reduce the urban heat island effect.

These improvements can also be supported by public funding sources including FEMA programs (Hazard Mitigation Grant Program, Flood Mitigation Assistance Program, Pre-Disaster Mitigation Grant Program), the Community Development Block Grant Disaster Recovery Program (CDBG-DR).

It is also important for the government and critical infrastructure facility owners, managers, and operators to coordinate to determine if linear protection measures, such as levees and seawalls, or beach restoration/living shoreline measures, would be needed. This adaptation option is explored in more detail under Goal 2 below.

The drawbacks from retrofits include the potential cost of the improvements which could become expensive if many structures are involved.

Relocate

If critical infrastructure is located in a high-hazard area, then exploring options to relocate that infrastructure in less hazardous areas may be the best alternative. This adaptation option is costly, and could require additional regulatory or legal authorizations (permits).

Abandon/dismantle

For critical infrastructure that is at significantly high risk of failure or loss, it may be necessary to consider abandoning that infrastructure. The costs for this option would be significant, and could require additional regulatory or legal authorizations (permits).

4.2.4 Strategy 4: Use Resilient Rincón products for future development

The vulnerability assessment used the Federal Emergency Management Agency's (FEMA's) Hazus software to evaluate climate change hazards posed to the municipalities' infrastructure from riverine and coastal flooding, sea level rise, and hurricanes. Hazus is an established public-domain simulation model. Under this strategy, the GIS data developed for the Resilient Rincón project and Hazus software would be recommended for use by the appropriate state and municipal personnel, to further understand the risks that climate change poses to existing infrastructure, to enable continued analysis as new data become available, and to run new scenarios for new infrastructure siting.

As part of this strategy, it is recommended that DNER explore hosting a FEMA training to enable state and municipal representatives to learn how to use this free modeling software. Tetra Tech has coordinated with FEMA on behalf of clients in the past to provide this training at no cost to the state (except for staff time to attend the training).

This adaptation strategy is considered low-cost and is not anticipated to have adverse implications for the evaluations areas.

4.2.5 Critical Infrastructure and Adaptation Options

Table 4-2 summarizes the critical infrastructure losses per hazard and identifies adaptation options (further described below). For a full breakdown of infrastructure and losses, refer to the Phase 2 Vulnerability Assessment Report.

Table 4-2. Critical infrastructure losses per hazard (Volume 2 Report) and adaptation options

Hazard	Number and Types of Impacted Infrastructure (highest scenario)	Type of Loss (highest scenario)	Adaptation Options	Recommended Time-frame
Sea level rise	Marina	Marina – unknown value	Retrofit/relocate – moveable structures where possible	Long-term
	Jorge Seda Crespo Middle School	\$2.5 M structural value – Total Loss	Relocate – identify other sites for future development Structural and operational improvements	Long-term Short-term
	DOMES Nuclear Facility (decommissioned)	\$26 M structural value – Total Loss	Further study long term erosion + SLR risk - Abandon/Dismantle as necessary	Long-term
Coastal flooding	Texaco Road	Minimal damage	Do not incorporate in emergency response and evacuation plans Increase culvert/drainage capacity	Short-term
	Rincón Medical Center	Minimal damage	Retrofit; Structural and operational improvements; Training	Short-term
	Head Start Stella Community	2% building damage	Retrofit; Structural and operational improvements	Short-term
	Pump Station	Minimal	Retrofit; MAA; Training	Short-term
	Water Well	Minimal	Retrofit; MAA; Training	Short-term
	Puente Grande Creek	22% structural damage	Repair	Short-term
	Puente Channel	Minimal	Repair; Erosion control/bank stabilization	Short-term
	Centro Cultural de Rincón	Minimal	Do not incorporate in emergency response and shelter plans Structural and operational improvements	Short-term
	Complejo Deportivo de Rincón	Minimal	Include retention basins and green infrastructure features	Long-term

Hazard	Number and Types of Impacted Infrastructure (highest scenario)	Type of Loss (highest scenario)	Adaptation Options	Recommended Time-frame
	Coop Rincón	Minimal	Structural and operational improvements	Short-term
	Healthcare Pump System	12% damage	Retrofit; MAA; Training	Short-term
	Banco Popular	Minimal	Structural and operational improvements	Short-term
	Gasolinera Puma	Minimal	Structural and operational improvements	Short-term
	4 Bridges underwater	Potential to be impassable; structural damage	Do not incorporate in emergency response and evacuation plans Assess; Retrofit/Repair	Short-term
Riverine flooding	Texaco Road (2 locations)	Potential to be impassable; structural damage	Assess use in emergency response and evacuation plans; Training Increase culvert/drainage capacity	Short-term
	Substations for Barrio Rio Grande Sports CompCorcega	9 and 6% damage	Retrofit; MAA	Short-term
	Rincón Medical Center	Minimal damage	Retrofit; Structural and operational improvements; Training	Short-term
	Head Start Stella Community	5% building damage	Retrofit; Structural and operational improvements	Short-term
	Manuel González Melo Elementary and Middle School	11% building damage; 70% content damage	Retrofit; Structural and operational improvements	Short-term
	Fire Station	14% building damage; 65% content damage	Develop alternatives for emergency response and evacuation plans; Training Retrofit; Structural and operational improvements	Short-term
	Pump Station	4% damage	Retrofit; MAA; Training	Short-term
	Centros de Depósito Comunitarios Perman	6% building damage; 43% content damage	Retrofit; Structural and operational improvements	Short-term
	Puente Channel (2 places)	11 and 22% damage	Assess; Repair; Increase culvert/drainage capacity	Short-term
	Complejo Deportivo de Rincón	12% building damage; 60% content damage	Include retention basins and green infrastructure features Retrofit; Structural and operational improvements	Long-term Short-term
	Bomberos de Puerto Rico	27% building damage; 60% content damage	Develop alternatives for emergency response and evacuation plans Retrofit; Structural and operational improvements	Short-term
	Gasolinera Puma	1% building damage; 2% content damage	Retrofit; Structural and operational improvements	Short-term

Hazard	Number and Types of Impacted Infrastructure (highest scenario)	Type of Loss (highest scenario)	Adaptation Options	Recommended Time-frame
	6 Bridges underwater	Potential to be impassable; structural damage	Assess inclusion in emergency response and evacuation plans Assess/Retrofit/Repair; Training	Short-term
Hurricane	Sports Multi-Complex	Minimal	Include retention basins and green infrastructure features	Long-term
	Substations Sports Comp Corcega	Minimal	Retrofit; Build in redundancy	Short-term

4.2.6 Adaptation Strategy Evaluation

The three adaptation strategies and associated options in this section were assessed according to the evaluation criteria (refer to Table 4-1, Adaptation strategy ranking framework), and results are presented in Table 4-3.

Table 4-3. Goal 1 – Adaptation Strategy and Option Evaluation

Strategy and Option	Hazards Addressed	Relative Costs	Feasibility	Ameliorate Risk	Time-frame	Acceptability	Opportunity	Total
Strategy 1: Prevent Service Interruptions								
Mutual Aid Agreements	Flooding, Hurricane, Drought	3	2	2	3	2	3	**15**
Structural and Operational Improvements	Flooding, Hurricane, Drought, Extreme Heat	2	3	2	3	3	3	**16**
Training	Flooding, Hurricane, Drought	3	3	1	3	3	3	**16**
Strategy 2: Assess and Repair Critical Networks								
Increase Storm Drainage for Transportation Networks	Flooding, Hurricane, SLR	2	2	2	3	3	3	**15**
Landslide Program	Flooding	2	2	2	3	3	3	**15**
Assess Bridges and Retrofit/Make Repairs	Flooding, Hurricane, SLR	1	2	3	2	3	3	**14**
Make Repairs to Canal Los Ramos	Flooding, Hurricane, SLR	2	2	2	3	3	3	**15**
Make Repairs to Drainage Canals	Flooding, Hurricane, SLR	2	3	2	3	3	3	**16**
Assess and Implement a Stream and Drainage Channel Cleaning Program	Flooding, Hurricane, SLR	3	3	2	3	3	3	**17**
Establish a Memorandum of Understanding (MOU) with DRNA	Flooding, Hurricane, SLR	3	2	2	3	3	3	**16**
Strategy 3: Retrofit, relocate, or abandon/dismantle at-risk infrastructure								
Retrofit	Flooding, SLR, Hurricane, Extreme Heat	2	2	2	3	2	3	**14**
Relocate	Flooding, SLR, Hurricane	1	1	3	2	1	1	**9**
Abandon	Flooding, SLR, Hurricane	1	1	3	1	1	1	**8**
Strategy 4: Use Resilient Rincón products for future development								
Use Resilient Rincón Products for future development siting	Flooding, Hurricane SLR	3	3	2	3	2	1	**14**
Training on Hazus use	Flooding, Hurricane SLR	3	3	1	3	2	1	**13**

4.3 GOAL #2: INCREASE RESILIENCY OF SOCIAL AND ECOLOGICAL SYSTEMS TO PROMOTE COMMUNITY HEALTH AND WELL-BEING

The adaptation strategies identified below support the goal of increasing resilience of social and ecological systems to promote community health and well-being in a comprehensive and synergistic manner.

4.3.1 Strategy 1: Incorporate Climate Change and Promote Resiliency in Local Planning Efforts

One of the first resiliency improvements a community can make is to ensure that all local plans consider a range of current and future hazards and incorporate measures to mitigate potential negative impacts. By developing local plans within the context of known hazards, the implementation of potential mitigation actions can be supported in a more comprehensive way. For example, future safer growth areas identified in comprehensive plans can be supported by other local plans including the findings of the hazard mitigation plan, infrastructure improvements/extensions identified in the capital improvement plan, and by a regulatory environment that promotes development in desirable areas and discourages development in hazardous areas. Recommendations in each local plan can include specific methods to support greater safety, resilience, and smart growth, including incentivizing desirable practices. Communities can use their capital improvement plans in concert with hazard mitigation plans to both identify infrastructure and critical facility vulnerabilities/deficiencies and proactively plan for needed improvements. Specific opportunities for Rincón are identified below.

Incorporate Resilient Rincón and the Hazard Mitigation Plan Findings into Rincón's Comprehensive Master Plan (Plan de Ordenamiento Territorial, POT)

Rincón's Comprehensive Master Plan (Plan de Ordenamiento Territorial, POT) is the key planning tool to ensure a more sustainable future for the Municipality. Rincón is currently in the fourth phase of the POT planning process; however, substantial modifications to previous phases are contemplated. The timing of the POT process provides an excellent opportunity to integrate the findings of this report, as well as Rincón's Hazard Mitigation Plan, into the Territorial Plan. The integration of a resilience perspective into the POT can be accomplished through the incorporation of the vulnerability assessment maps, by limiting future development in hazard prone areas and by channeling future development to areas of lower hazard risk.

Specific planning applications that can reduce future vulnerability are:

- Enforcing setback requirements for non-water dependent uses in the Territorial Maritime Zone (TMZ) and considering the application of coastal erosion setback requirements;
- Implementation of standards and enforcement of construction codes;
- Promoting preservation of the remaining riparian and wetland buffer zones will strengthen the Municipality's disaster resilience; and,
- Strengthen requirements for storm water management for future development.

There are potential funding sources for this option, in addition to municipal budget funds, such as from the Puerto Rico Planning Board (PRPB), foundation grant, or FEMA Pre-Disaster Mitigation (PDM) grant.

Adopt Local Zoning Ordinances

Local zoning ordinances define how a property in a specific geographic area can be used (e.g., residential, commercial, industrial, mixed use, agriculture). The zoning ordinance can also regulate lot size, placement of lots and structures, density/intensity of development on the lot, bulk, height of structures, and other factors. A local zoning ordinance must be in accord with the local government's comprehensive plan. Therefore, before using the "zoning" tool to guide development for future community resiliency, it is important to first update the local comprehensive plan to identify areas with current and likely future hazards as well as areas most suitable for safer development and redevelopment.

Hazardous areas have been identified through this study and it is recommended that those are identified in the updated POT. Georgetown Law and Climate Center and the Harrison Institute developed a model zoning ordinance for sea level rise that could be adapted for Rincón. This model ordinance, tested in communities in Connecticut and Maryland, has three adaptation districts: [2]

1. Conservation or Retreat Zone. Designed to gradually relocate development out of highly vulnerable areas and protect natural resources.
2. Accommodation Zone. Designed to allow for continued development while requiring that structures be more resilient to floods.
3. Protection Zone. Designed to permit hard shoreline armoring in areas with dense development and critical facilities.

The essence of the zoning strategies above is to make the cost of development in hazardous areas more reflective of the cost of mitigating flood hazard risks. Where development is allowed in the flood-prone areas, green infrastructure practices can be encouraged to further mitigate stormwater impacts.

4.3.2 Strategy 2: Increase Resiliency of Residences

There are several neighborhoods in Rincón that have been identified as at-risk to current and future flood impacts (please refer to volume 2). Programs to retrofit those homes or buy-out extremely flood-prone homes could be explored. Drought risk is also projected to increase in the future, and a rainwater storage program could be used to increase resiliency.

Hurricane-strength Wind Retrofit Program

Establishing wind resistance construction guidelines and implementing a retrofit program for existing residences increases public safety and can substantially reduce property damages. An emphasis should be made In Rincón's communities that are most vulnerable to high wind damage such as Barrio Cerro de Los Pobres, Atalaya, Jague, Puntas, and along routes 413, 411, 412. The Municipality might pursue an educational program, and if adequate municipal funds be available, develop a low-interest loan or rotating grant funds to increase participation by residents and businesses.

Buy-out Program

Local hazard mitigation programs throughout the U.S. receive funding from the Federal Emergency Management Agency (FEMA) to relocate or buy out buildings that cannot be made resilient. These programs are often focused on residential properties. Through a buy-out program, some buildings are demolished, and the land is used as open space or as part of a larger flood control facility. If a building has historical value, it may be relocated or redeveloped with floodproofing to maintain the community's character while mitigating for future hazards.

Buyout programs offer a number of benefits to communities. These programs offer a permanent solution to the risks and damages of repetitive flooding, and also reduce the public costs of future emergency response actions. Buyout properties can also be used for improved flood storage and conveyance and permanent open space.

Buy out programs pay the property owner a fair market value for the property based on its pre-flood value. FEMA provides 75 percent of the funding, and the remaining funding must be provided through state, local, or other funding. One exception is that funding provided to states from the federal Community Development Block Grant (CDBG) program can also be used for the non-federal share. For example, Iowa City Iowa was awarded $11.7 million in CDBG funds to buy out substantially damaged properties. Once funding is secured and applications are received from property owners, each property buy-out cost is property-specific. An assessment can be made about whether it is more cost-effective to elevate or flood-proof a property, relocate the building, or buyout the entire property.

Rainwater Storage and Water Conservation Program

Frequent water shortages in Rincón impact the community and businesses, particularly in the mountainous portion of the Municipality. Promoting water collection through the use of cisterns and water conservation practices will make Rincón more disaster resistant and enhance the quality of life of residents.

4.3.3 Strategy 3: Protect Beaches and Coastal Ecosystem

Rincón's identity is a coastal community with fantastic surfing, beautiful beaches, and a marine reserve with endangered coral species. These attributes support Rincón's tourism industry, which is its economic backbone. The adaptation options below support the protection of the municipality's beaches and coastal ecosystem.

Use Rincón's Updated Coastal Erosion Study to Prioritize Implementation of Actions to Mitigate Coastal Erosion

The coastal erosion along the Rincón coast is a serious concern that poses risk to any resources, facilities and infrastructure in proximity to the coast. Severe erosion rates have been established in studies and reports, most recently in the USGS "Historical Shoreline Changes at Rincón, Puerto Rico, 1936-2006". The construction of sea walls, previous beach sand extraction, and loss of historic riverine sand deposits has aggravated the problem. Climate change will further exacerbate these issues.

The possibility of a new municipal marina, constructed at the site of the old marina, may provide one potential source for a beach nourishment project. An updated coastal erosion study (previous USGS study was conducted about 15 years ago) is currently being conducted by NOAA Sea Grant. Identifying and implementing coastal erosion protection measures is considered critical to increasing Rincón's resilience.

It is further recommended that "living shoreline" options are explored in addition to traditional "hard infrastructure" options, such as jetties and rip-rap. Living Shorelines are intended as shoreline management options that provide erosion control while working with nature to restore, create or protect valuable habitat. The National Oceanic and Atmospheric Administration (NOAA) defines a "living shoreline" as the use of plants, sand, and limited use of rock to provide shoreline protection and maintain valuable habitat (NOAA, 2012). Generally speaking, there are several living shoreline concepts that are being used around the world: bulkhead tiering, natural fiber log (coir log), natural fiber matting, hard sill (stone, oyster reef, or similar) with or without marsh fill, and manufactured products to simulate one or more of these previous functions. The primary goal of living shorelines is to provide shoreline protection by using the living shoreline products, such as coral reefs, mangroves, and sea grass, to attenuate the wave energy that reaches the shore. Secondary goals are to increase the biodiversity in the immediate area, and allow sediment accretion between the shore and the reef if possible (thereby creating new land). While costly, living shoreline options have many benefits over traditional engineering design options; living shorelines enhance the environment (air and water quality), as well as provide quality of life benefits.

Living Shoreline – Illustrative Examples

Tiered Bulkhead

Oyster Reefballs

Natural fiber netting – before and after

Clean-up and Removal of Abandoned Solid Waste Landfill

This abandoned site was active over 20 years ago and received both solid wastes in addition to medical waste and potentially other toxic or hazardous materials. Coastal erosion has cut into the landfill and solid and medical wastes have been carried by predominant southern offshore current to Añasco. An attempt to provide shoreline protection by anchoring the shoreline with rocks has failed and the waste is currently exposed and visible as it carried down along the shoreline.

The site is vulnerable to continued coastal erosion and storm surge. A site remediation program involving testing for a range of potential pollutants, toxic and hazardous materials is necessary, the waste material removed, and disposed in an appropriately designated landfill to eliminate a public eyesore and potentially mitigate a public health issue. Given the immediate risk posed to human and environmental health, this is considered a high priority option. External funding sources should be explored through EPA, NOAA, DNER.

Implement the *Tres Palmas* Protection Plan

Preservation of the designated marine reserve of Tres Palmas is adversely affected by sediment transport from existing development and construction sites within the watershed bordering the reserve. As sea surface temperatures and ocean acidification rise, the marine reserve will be under additional stress.

The Tres Palmas Protection Plan outlines specific recommendations for the restoration and preservation of the marine reserve that will be aided by an enforcement program of sediment and erosion control measures in the surrounding drainage basin. Recently environmental groups, the Municipality Recycling Director, and DNER staff have been conducting meetings to find a way to address this situation.

4.3.4 Strategy 4: Raise Awareness of *Rincón Resilience*

A massive educational campaign was officially developed when the Municipality became Tsunami ready in 2009, although radio and other media has been used for decades to educate the community on how to react in case of a natural disaster. Every Saturday a local radio program transmits instructions to the citizens on how the newly acquired earthquake/ tsunami alarm system works. The Emergency Management Department has also developed an educational workshop program where a different community will be impacted every month. It is recommended that the results and messages from this project are incorporated into existing Tsunami Ready platforms.

4.3.5 Adaptation Strategy Evaluation

The four adaptation strategies and associated options in this section were assessed according to the evaluation criteria (refer to Table 4-1, Adaptation strategy ranking framework), and results are presented in Table 4-4.

Table 4-4. Goal 2 – Adaptation Strategy and Option Evaluation

Strategy and Option	Hazards Addressed	Relative Costs	Feasibility	Ameliorate Risk	Time-frame	Acceptability	Opportunity	Total
Strategy 1: Incorporate Climate Change and Promote Resiliency in Local Planning Efforts								
Incorporate Resilient Rincón into Rincón's Comprehensive Master Plan	All	3	2	3	2	2	3	**15**
Adopt Local Zoning Ordinances	All	3	2	3	2	2	3	**15**
Strategy 2: Increase Resiliency of Residences								
Hurricane-strength Wind Retrofit Program	Hurricane	2	1	2	3	3	2	**13**
Buy-out Program	Flooding, SLR, Hurricane	1	1	3	2	2	2	**11**
Rainwater Storage and Water Conservation Program	Drought	2	1	2	3	2	3	**13**
Strategy 3: Protect Beaches and Coastal Ecosystem								
Use Rincón's Updated Coastal Erosion Study to Prioritize Implementation of Actions to Mitigate Coastal Erosion	Flooding, SLR, Hurricane	1	2	3	2	3	3	**14**
Clean-up and Removal of Abandoned Solid Waste Landfill	Flooding, SLR, Hurricane	2	2	3	2	3	3	**15**
Implement the *Tres Palmas* Protection Plan	Flooding, SLR, Hurricane, SST	2	2	2	2	3	3	**14**
Strategy 4: Raise Awareness of *Rincón Resilience*								
Raise Awareness of *Rincón Resilience*	All	3	3	2	3	3	3	**17**

4.4 GOAL #3: ADVANCE ECONOMIC DEVELOPMENT OPPORTUNITIES

One of the important attributes of a resilient community, is a financially healthy community. It is important to protect existing businesses and industries, and to promote development of future economic development opportunities.

4.4.1 Strategy 1: Provide Emergency Preparedness and Hazard Mitigation Information to Business and Industry

Ensuring that local businesses and industries can quickly recover following disaster events will help the entire community recover from the economic impacts associated with major disasters. Municipal staff would promote the use of the FEMA document entitled, *Emergency Management Guide for Business & Industry*, to help local companies develop an emergency response and recovery plan targeted to their employees, facilities, and business operations. Focusing on Rincón's tourism sector industry will enable local resorts, hotels and inns to better prepare and recover from natural disasters.

4.4.2 Strategy 2: Promote Resiliency Actions for Business and Industry

Businesses located in flood prone areas pose potentially serious economic challenges for any community including property damage, business interruption, vacancy and tax loss, increased flood insurance costs, loss of residents and customers, and an increasing hesitancy for new investment.

Providing incentives and/or educating businesses of flood proofing actions can increase public safety and position the community for greater future health and economic resiliency. Resilience actions are generally identified and selected to address lots of buildings on a site-specific basis. Project work typically includes a combination of structural elevations to raise a building above flood levels, and wet flood-proofing or dry-proofing methods depending on the site conditions and the design of the building. See Goal 1, Strategy 3 for a description of wet and dry flood proofing.

4.4.3 Strategy 3: Identify Business Incubation Opportunities

There are economic opportunities in enhancing resilience. By addressing local needs to adapt to a changing climate, businesses in fields like engineering, planning, strategic management, or green infrastructure can develop expertise in areas with national and international market demand.

There are numerous active civic organizations in Rincón, which can be encouraged to think collectively about addressing the challenges and identifying solutions to advance Rincón Resilience. The University of Puerto Rico, Mayagüez Campus (UPRM) is also located in proximity to the community. Opportunities to incubate businesses could be explored in conjunction with UPRM. UPRM and local private businesses can collaborate to create financial incentives with a business incubator – for example, providing low-cost space for emerging businesses or other supportive mechanisms to assist with creating the desired products and/or services.

One successful example of business incubation to increase resiliency is the New York City Economic Development Corporation's (NYCEDC) Resiliency Innovations for a Stronger Economy program. In the wake of Hurricane Sandy, NYCEDC began a competition to attract ideas, concepts and projects that would assist businesses within the city to become more resilient. The City developed an award amount for winners. One of those winners is Red Hook; which winning technology consisted of a WiFi wireless network, providing small businesses with network resiliency and access to online resources and information, and allowing residents and small businesses to receive real time updates in the event of a power outage.

4.4.4 Adaptation Strategy Evaluation

The three adaptation strategies and associated options in this section were assessed according to the evaluation criteria (refer to Table 4-1, Adaptation strategy ranking framework), and results are presented in Table 4-5.

Table 4-5. Goal 3 – Adaptation Strategy and Option Evaluation

Strategy and Option	Hazards Addressed	Relative Costs	Feasibility	Ameliorate Risk	Time-frame	Acceptability	Opportunity	Total
Strategy 1: Provide Emergency Preparedness and Hazard Mitigation Information to Business and Industry	All	3	3	2	3	3	3	**17**
Strategy 2: Promote Resiliency Actions for Business and Industry	All	3	3	2	3	3	3	**17**
Strategy 3: Identify Business Incubation Opportunities	Financial Resiliency	2	2	2	2	3	2	**13**

4.5 PRIORITY RANKING

A community survey was distributed in December 2015 to community stakeholders, municipal leaders, and technical experts on the draft adaptation results. Participants were asked to rank each goal according to "Not Important, Important, or Very Important" to them. The survey results are included below as part of the prioritization process for each goal and strategy. Not all adaptation options have a priority ranking, as some options were developed after the survey was distributed, or combined for ease of survey development. Individual adaptation options have been ranked in Table 4-6 below according to their adaptation score.

Table 4-6. Priority rankings of adaptation options

Goal #	Strategy #	Adaptation Option	Adaptation Score	Priority Ranking - Survey*
1	Increase Resiliency of Critical Infrastructure to Improve Community Reliability and Functions			Very Important
1	1	Mutual Aid Agreements	15	Important
1	1	Structural and Operational Improvements	16	Important
1	1	Training	16	Very Important
1	2	Increase Storm Drainage for Transportation Networks	15	Very Important
1	2	Landslide Program	15	Very Important
1	2	Assess Bridges and Retrofit/Make Repairs	14	Important
1	2	Make Repairs to Canal Los Ramos	15	-
1	2	Make Repairs to Drainage Canals	16	Very Important
1	2	Assess and Implement a Stream and Drainage Channel Cleaning Program	17	Very Important

Goal #	Strategy #	Adaptation Option	Adaptation Score	Priority Ranking - Survey*
1	2	Establish a Memorandum of Understanding (MOU) with DRNA	16	-
1	3	Retrofit at-risk critical infrastructure	14	Important
1	3	Relocate at-risk critical infrastructure	9	Important
1	3	Abandon at-risk critical infrastructure	8	Important
1	4	Use Resilient Rincón Products for future development siting	14	-
1	4	Training on Hazus use	13	-
2	Promote Community Health and Well-Being to Increase Resiliency of Social and Ecological Systems			Very Important
2	1	Incorporate Resilient Rincón into Rincón's Comprehensive Master Plan	15	Very Important
2	1	Adopt Local Zoning Ordinances	15	Very Important
2	2	Hurricane-strength Wind Retrofit Program	13	Important
2	2	Buy-out Program	11	Very Important
2	2	Rainwater Storage and Water Conservation Program	13	Very Important
2	3	Use Rincón's Updated Coastal Erosion Study to Prioritize Implementation of Actions to Mitigate Coastal Erosion	14	Very Important
2	3	Clean-up and Removal of Abandoned Solid Waste Landfill	15	Very Important
2	3	Implement the *Tres Palmas* Protection Plan	14	Very Important
2	4	Raise Awareness of *Rincón Resiliente*	17	-
3	Advance Economic Development Opportunities			Important
3	1	Provide Emergency Preparedness and Hazard Mitigation Information to Business and Industry	17	Very Important
3	2	Promote Resiliency Actions for Business and Industry	17	Very Important
3	3	Identify Business Incubation Opportunities	13	-

**The ranking reflects the majority response rate for each goal and strategy.*

4.6 FUNDING CONSIDERATIONS

Potential funding sources have been identified as applicable in the sections above. This section provides additional detail on funding sources related to FEMA's new climate change resilience focus – these are considered new funding sources with evolving priorities and schedules.

President Obama's 2015 Opportunity, Growth, and Security Initiative focused FEMA's efforts on identifying the risks and impacts associated with climate change on community resilience to natural hazards. FEMA recently announced the eligibility of three Climate Resilient Mitigation Activities under the Hazard Mitigation Assistance programs to support communities. These activities include: aquifer storage and recovery, floodplain and stream restoration, and flood diversion and storage. Green infrastructure is now also included for funding.

FEMA encourages communities to incorporate climate resilient infrastructure into eligible HMA risk reduction activities, many of which have been identified in this report. Rincón will need to update their HMP this coming year to maintain eligibility and these new funding sources provide a tremendous opportunity for Rincón to seek funding for priority hazard reduction and adaptation strategies.