



DEPARTMENT OF  
**HOUSING**



# CDBG-MIT

COVERED PROJECTS NARRATIVE  
**PATILLAS DAM SEISMIC RETROFIT**

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## 1 Patillas Dam Seismic Retrofit Project

### Project information

<b>Subrecipient Type:</b>	Puerto Rico State Agency
<b>Subrecipient Name:</b>	PR ELECTRIC POWER AUTHORITY (PREPA)
<b>Project Name:</b>	Patillas Dam Seismic Retrofit
<b>Project Number:</b>	4339-0011
<b>Project Address/ Location:</b>	Patillas Lake (Municipality of Patillas) 18.019128, -66021508
<b>Eligible Activity:</b>	Section 105(a)(2) – Public Facilities and Improvements
<b>National Objective:</b>	Low-to-Moderate Income Area Benefit (LMA) (24 C.F.R. § 570.483 (b)(1)) HUD alternative national objective for Covered Projects as described at 84 FR 45838 section V.A.13.
<b>Point(s) of Contact:</b>	Ing. José Bermúdez

## 2 Covered Project Requirements

Projects must follow and meet the requirements for Covered Projects as described in detail in the Covered Projects Section of the CDBG-MIT Action Plan.

## 3 COVERED PROJECT ANALYSIS & DESCRIPTION

### Project Description and Eligibility

#### 1.1 Project Scope

The Patillas Dam is an earthen embankment dam located at the confluence of the Lago Patillas and Río Marin in the south-eastern region of Puerto Rico. It was designed and constructed by the Puerto Rico Irrigation Service in 1913, and is now owned and operated by the Puerto Rico Electric Power Authority (**PREPA**). The Patillas dam and reservoir is part of the island's critical water resource infrastructure and provides water for power generation, agricultural irrigation, and public water supply for 100,000 persons in the island's southeast sector.

The purpose of the Patillas Dam Seismic Retrofit Project (**Patillas Dam Project** or **Project**) is to reduce the probability of seismic-induced embankment deformations that could result in a dam breach with an uncontrolled release of the reservoir causing downstream flooding.

The Federal Emergency Management Agency (**FEMA**) Hazard Mitigation Grant Program (**HMGP**) approved the Project as a Phase Project. Phase 1 project costs will be funded by FEMA-HMGP funds, and Phase 2 project costs will be funded by CDBG-MIT funds. The Project is under evaluation for funding by CDBG-MIT HMGP Global Match,<sup>1</sup> which will provide the non-federal match share through the global match strategy.

#### 1.2 Project Scope

The Patillas Dam was built using the hydraulic fill method, which consists of building two (2) starter dikes while dumping material between them. Subsequently, the material is irrigated with water creating a puddle for the impermeabilization core on the dam. This method was widely used in 1913, but years later, it was discovered that the construction method is not adequate for use in highly seismic areas, such as Puerto Rico. Specifically,

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<sup>1</sup> Global Match is a cost share method for the Non-Federal cost share portion of twenty-five percent (25%) required for eligible hazard mitigation measures under the HMGP that contributes not more than seventy-five percent (75%) of the total eligible project costs as per Section 404 of the Stafford Act. When using Global Match, the Non-Federal cost share does not need to be twenty-five percent (25%) for each individual project, rather the Non-Federal cost share for all the Applicants' submitted projects combined must equal twenty-five percent (25%) for the overall portfolio.



because these embankments are susceptible to liquefaction induced by seismic dynamic loads.

Since hydraulic fill dams lose their stability under the dynamic loads during a seismic event, the U.S. Bureau of Reclamation (**USBR**) recommended reinforcing the existing dam to increase and maintain stability under MCE (maximum credible earthquake) induced loads.

The proposed reinforcement methodology will create an overlay over the existing dam footprint with a sand filter stable enough to stand on its own should the original dam deform.<sup>2</sup> This will prevent a catastrophic loss of the embankment by reducing the flooding risk to the entire municipality of Patillas in case of a dam failure. The developed concept will be built over the existing dam on the dry side of the embankment, all within the property of PREPA. The project does not modify the original impoundment capacity of the reservoir and does not change the operational level to begin the activation of the spillway gates, which is 222 feet above sea level.

It will also include the reinforcement and extension of an existing tunnel in the dam along with the construction of a new waterway system to supply water to the Patillas Irrigation Canal. The Patillas Dam Project will fortify the existing dam to reduce the deformation of the embankment during a seismic event, allowing enough time for warnings and evacuations. It will also avoid flooding damages caused by a dam failure event.

To mitigate the risks, a confining berm will be made over the existing embankment. The berm will be composed of three (3) sections:

- A dam core material on the crest of the Dam;
- A sand filter with a pipping system to collect any seepage; and
- A gravel and cobble drain section with an undifferentiated structural fill in the outer section with a rip rap finish.

The top of the embankment will be excavated down to solid bedrock and a keystone will be constructed to increase the stability of the structure.

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<sup>2</sup> As established by PREPA on the Patillas Dam Covered Project Request for Information Answer Memorandum, included as reference in Appendix A.

### 1.3 Project Location

The proposed Project site of the Patillas Dam is located in the southeastern area of Puerto Rico. It is accessible primarily by Puerto Rico Road 799 (PR-799).



**Figure 1: Project Location Aerial View**

#### I. HUD Eligible Activity

Construction of the project is an eligible activity under Section 105(a)(2) - *Public Facilities and improvements* of Title I of The Housing and Community Development Act of 1974 (**HCDA**). The Patillas Dam project is a Public Facility owned by PREPA, a state authority of the Government of Puerto Rico.

#### II. Project Cost and Estimated Timeframe

The Project includes the construction of an embankment over the original dam footprint. Currently, the approximate size of the embankment would be 1,024 feet long, 30 feet above the top of the existing embankment, and it would extend over 350 feet from the toe of the embankment, including the demolition of existing structures and related appurtenances. Project costs are estimated based on a six-part work breakdown including the following:

- Execute additional geotechnical investigations.
- Prepare a detailed survey of the area.
- Revise the risk analysis and how the alternatives reduce risk and if the risk reduction is acceptable.
- Prepare detailed plans and specifications on how to implement the design alternative.
- Bid process.
- Project construction.

Based on the initial budget submitted, the maximum total project cost for both Phase I and Phase II of the HMGP Global Match project does not exceed \$558,000,000. Funding will be made available in an amount not to exceed the total Phase I cost of \$2,635,000.00, which will be funded by FEMA. The remaining Project funding of \$555,365,000.00 is being reserved for Phase II, subject to its approval by FEMA. Phase II activities will be funded with CDBG-MIT funds through HMGP. A breakdown of cost classification can be found in **Table 1**.

As a part of the planning activities performed by PREPA for the development of the proposed project, a preliminary schedule was prepared including the expected timeframes for the completion of development and construction phases. This preliminary schedule contemplates a timeframe of almost four (4) years for the project's implementation. The proposed project schedule is expected to be modified as the project's development advances, and design and environmental review activities are completed.

**Table 1: Preliminary Project Costs & Duration Breakdown**

Task Name	Total Cost	Expected Duration (weeks)
PHASE 1 -Conceptual Design & Analysis	\$1,160,000.00	41
PHASE 2 - Engineering & Design	\$1,475,000.00	38
PHASE 3 - Procurement	\$55,000.00	20
PHASE 4 - Construction	\$555,310,000.00	87
<b>Total Expected Cost &amp; Duration</b>	<b>\$558,000,000.00</b>	<b>186</b>

### III. Area of Impact

Patillas Dam supplies water to two (2) main critical facilities (1) the AES power plant, which provides more than 400 megawatts of base generation and (2) the Puerto Rico Aqueduct and Sewer Authority (**PRASA**), which provides potable water to more than 100,000 citizens residing in the municipalities of Patillas, Guayama, Arroyo, and Salinas. It is also the only source of irrigation water in the southeast. Therefore, continued operation of the plant is a critical health and safety measure considering that water availability cannot be supplied by other means. The USBR developed a mitigation strategy using best dam engineering practices allowing for the retrofit without compromising water availability or water requirements as described above.

Improvements to the Dam will result in stable services for water and energy beneficiaries in the service area.

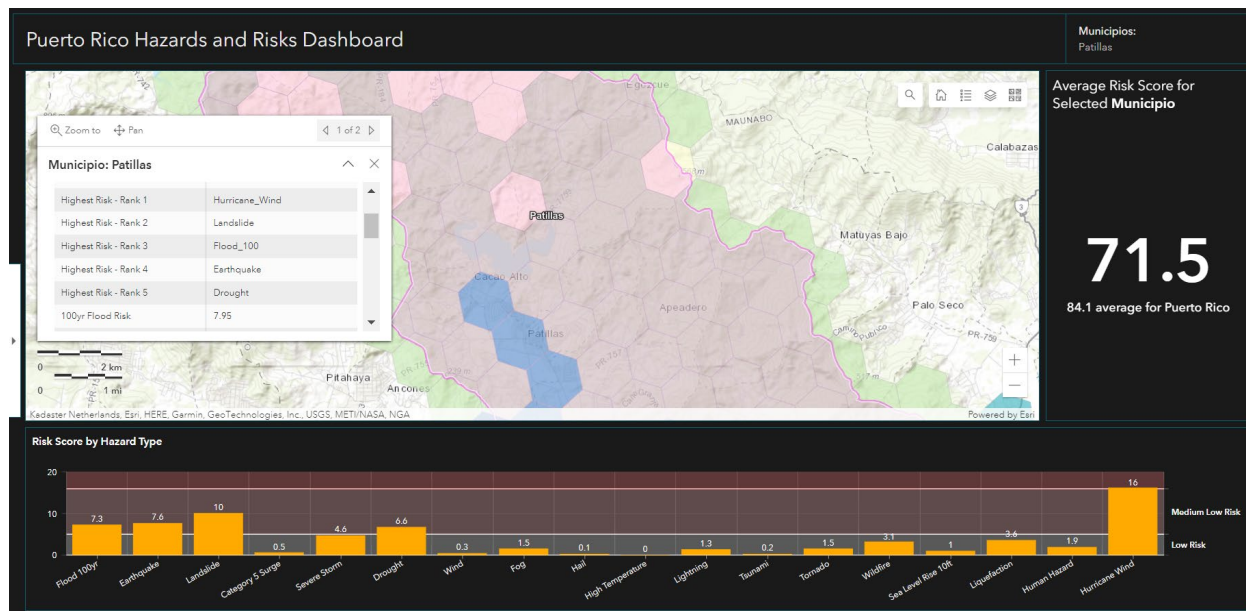
### Consistency with Mitigation Needs Assessment

The Patillas Dam was constructed by hydraulic backfill methods, which typically produces zones of low-density soils within the embankment. The low density of embankment and foundation soils has been confirmed by subsurface investigations. Therefore, Patillas Dam is susceptible to significant deformations caused by seismically induced ground motions.

As per the information included in the Patillas Dam Issue Evaluation Risk Analysis completed by PREPA, there is a potential for very severe earthquakes in the Patillas Dam vicinity due to the proximity of several major geologic faults, including the Great Southern Puerto Rico Fault Zone and the Muertos Trough off the southern coast of Puerto Rico.

There is a potential for seismic ground motions in the vicinity of Patillas Dam to be large enough to induce soil liquefaction due to the low density of the embankment and foundation soils. This can result in a dam breach and catastrophic loss of stored water in the reservoir.

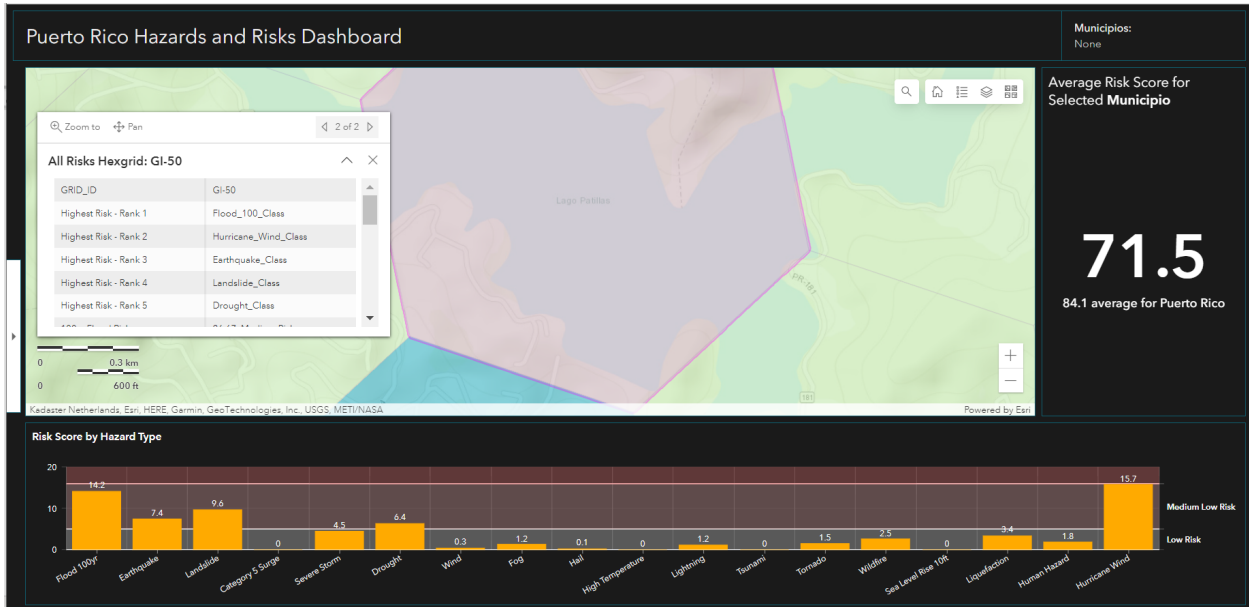
This Puerto Rico Department of Housing (**PRDOH**) risk assessment indicates earthquakes to be the 4th highest risk in the municipality of Patillas (See **Figure 2**).



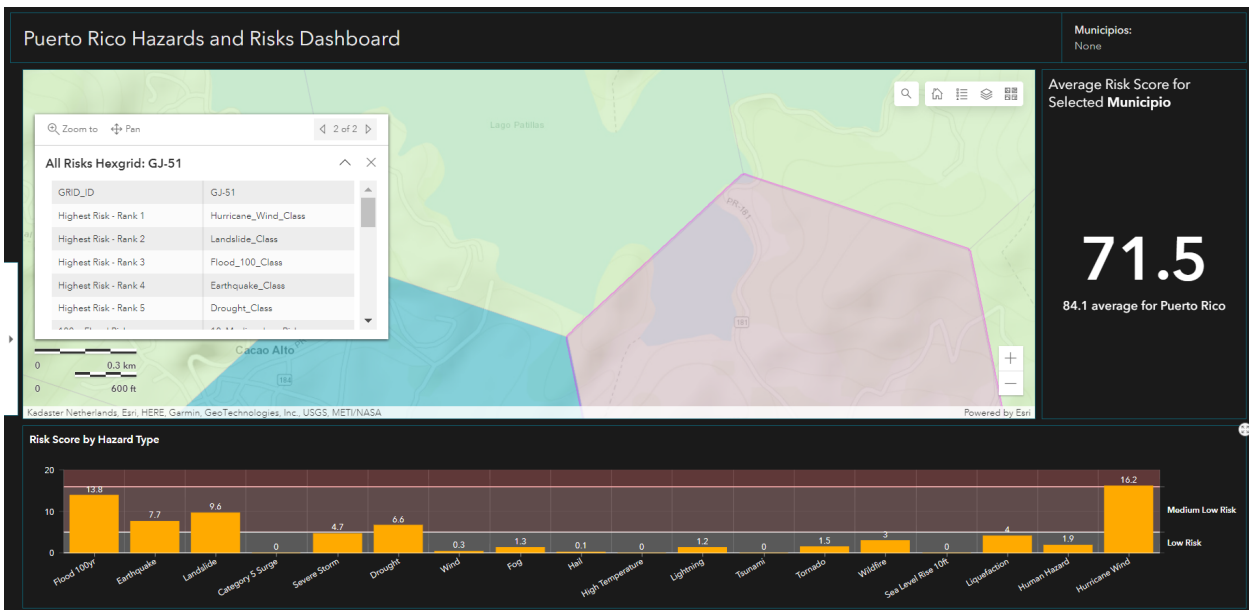
**Figure 2: Municipality of Patillas Average Risk Score**

The specific vicinity of the Patillas Dam is located in hex grids GI-50 and GJ-51, where the earthquake appears as the 3rd and 4th top risks, respectively (See **Figures 3** and **4**).<sup>3</sup>

<sup>3</sup> Information accessed through PRDOH website, in English and Spanish at: <https://cdbg-dr.pr.gov/iframes/PRhazardandrisksIFRM> and <https://cdbg-dr.pr.gov/iframes/PRpeligrosyriesagosIFRM>.



**Figure 3: Risk Score for Project Location Hex grid**



**Figure 4: Risk Score for Project Location Hex grid**

As a consequence of this risk, PREPA has implemented a voluntary temporary reduction in the reservoir water surface elevation to increase the liquefaction safety factor in the dam embankment. A seismic retrofit for the Patillas Dam will allow the restoration of



normal reservoir water surface elevations required to meet critical water resources for power, irrigation, and public water supply.

Based on an extensive analysis of hazards, risks, and lifeline assets in Puerto Rico, PRDOH has determined that critical lifelines are those upon which other lifelines depend. These include sectors within Energy, Transportation, Communications, Food, Water, and Shelter. The project falls within the water and wastewater sector of the Food, Water, and Shelter lifeline. It directly aligns with the PRDOH Needs Based Risk Assessment by strengthening two (2) lifeline sectors considered critical in Puerto Rico: the energy and water, and wastewater services sectors. As improvements to the Patillas Dam will prevent a failure in the event of impending seismic activity, the two (2) lifelines sectors will continue to operate, giving public confidence in the asset protected by this project.<sup>4</sup>

### **Compliance with National Objective for Covered Projects**

The following Area of Benefit (**AOB**) determination is preliminary in nature and is based on the current state of project design, Benefit-Cost Analysis (**BCA**), and other studies. The determined AOB may change upon completion of the design and other studies.

It is worth noting that, in the event of an operational failure of the Patillas Dam caused by a seismic event, the Patillas Dam would be left with no redundant system or any possible way to supply potable water to the southeastern region beneficiaries.

The project directly serves residents receiving water and power services in the municipalities of Patillas, Arroyo, Guayama, and Salinas. These municipalities demonstrate a primarily Low-and Moderate Income (**LMI**) population with a combined 86% of residents being of LMI designation. This provides an indication that the AOB, including the direct 87,400 estimated beneficiaries, is predominantly LMI, complying with HUD LMI National Objective.

**Table 2** identifies the total number of beneficiaries, the total number of LMI beneficiaries, and the percentage of LMI beneficiaries served by the Patillas Dam Seismic Retrofit project.

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<sup>4</sup> See more in the CDBG-MIT Action Plan, available in English and Spanish at <https://cdbg-dr.pr.gov/en/action-plan/> and <https://cdbg-dr.pr.gov/plan-de-accion/>.

**Table 2: Summary of LMI Persons within the Project Service Area**

<b>Total Persons</b>	<b>Total LMI Persons</b>	<b>Area of Benefit LMI Percentage</b>
101,526	87,400	86%





Adjusted LMI Tracts - Island Level



Esri, HERE, Garmin, USGS, NSA

**Figure 5: Project Service Area**

**Table 3: Adjusted Census Tracts within the Project Service Area**

#	Census Tracts	Total Persons	Total LMI Persons	LMI %	Municipality
1	Census Tract 9530, Municipality of Salinas, Puerto Rico	2,683.00	2,338.00	0.87	Salinas
2	Census Tract 9531, Municipality of Salinas, Puerto Rico	2,230.00	1,886.00	0.85	Salinas
3	Census Tract 9532, Municipality of Salinas, Puerto Rico	4,096.00	3,598.00	0.88	Salinas
4	Census Tract 9526, Municipality of Salinas, Puerto Rico	3,046.00	2,764.00	0.91	Salinas
5	Census Tract 9528, Municipality of Salinas, Puerto Rico	6,522.00	5,739.00	0.88	Salinas
6	Census Tract 9529, Municipality of Salinas, Puerto Rico	7,465.00	5,968.00	0.80	Salinas
7	Census Tract 9527, Municipality of Salinas, Puerto Rico	2,105.00	1,979.00	0.94	Salinas
8	Census Tract 2902, Municipality of Patillas, Puerto Rico	5,490.00	4,571.00	0.83	Patillas
9	Census Tract 2904, Municipality of Patillas, Puerto Rico	3,387.00	3,041.00	0.90	Patillas
10	Census Tract 2901, Municipality of Patillas, Puerto Rico	3,438.00	3,180.00	0.92	Patillas
11	Census Tract 2903, Municipality of Patillas, Puerto Rico	5,118.00	4,368.00	0.85	Patillas
12	Census Tract 2708, Municipality of Guayama, Puerto Rico	8,331.00	7,404.00	0.89	Guayama
13	Census Tract 2702.02, Municipality of Guayama, Puerto Rico	2,942.00	2,682.00	0.91	Guayama
14	Census Tract 2702.01, Municipality of Guayama, Puerto Rico	5,105.00	3,829.00	0.75	Guayama
15	Census Tract 2703, Municipality of Guayama, Puerto Rico	5,270.00	4,237.00	0.80	Guayama

#	Census Tracts	Total Persons	Total LMI Persons	LMI %	Municipality
16	Census Tract 2701, Municipality of Guayama, Puerto Rico	4,884.00	4,364.00	0.89	Guayama
17	Census Tract 2704, Municipality of Guayama, Puerto Rico	2,494.00	2,264.00	0.91	Guayama
18	Census Tract 2707, Municipality of Guayama, Puerto Rico	2,786.00	2,357.00	0.85	Guayama
19	Census Tract 2705, Municipality of Guayama, Puerto Rico	3,501.00	2,538.00	0.72	Guayama
20	Census Tract 2706, Municipality of Guayama, Puerto Rico	2,990.00	2,705.00	0.90	Guayama
21	Census Tract 2802.01, Municipality of Arroyo, Puerto Rico	4,632.00	3,991.00	0.86	Arroyo
22	Census Tract 2802.02, Municipality of Arroyo, Puerto Rico	4,186.00	3,585.00	0.86	Arroyo
23	Census Tract 2801.01, Municipality of Arroyo, Puerto Rico	2,881.00	2,576.00	0.89	Arroyo
24	Census Tract 2801.02, Municipality of Arroyo, Puerto Rico	5,944.00	5,436.00	0.91	Arroyo

Service to residents within the census block areas is estimated to serve LMI residents.

### **Long-term efficacy and sustainability of the project**

The proposed retrofit will serve to extend the useful life of the dam by at least 100 years. The project is composed of an actual fill overlay under the existing dam providing all safety considerations in the design of a new earth embankment dam. As such, all maintenance, operation, and conservation activities to be performed on the new dam will be consistent with the same activities that the South Coast Irrigation District has used for the past 100 years to operate, maintain, and conserve the retrofitted dam. In terms of risks, this seismic retrofit is being designed by the USBR. As part of this design, a Risk Analysis was performed to quantify the risk to the public of operating the earth embankment and

how much of this risk is reduced by implementing the seismic retrofit alternative. Refer to Appendix C: Patillas Dam Issue Evaluation Risk Analysis.<sup>5</sup>

PREPA has analyzed all operations and maintenance (**O&M**) activities that will be required to ensure the effective preservation of this asset throughout its useful life. O&M activities considered include, but are not limited to, the following: periodic inspections of the dike, weed and grass control, and inspection of electrical and mechanical components (and their replacement as needed). As part of the O&M after an atmospheric event, a rigorous inspection will be carried out to verify the stability of the embankment, surveying to verify any displacements, diving inspections and any other activities or studies are needed to warrant the stability and performance of the reservoir. Once the design phase is completed, the frequency of the periodic inspections will be established. As this is an existing asset, there is already a maintenance plan in place for the reservoir. The proposed retrofit allows for current maintenance activities to be implemented in step with the new required activities.

Patillas Dam is part of PREPA's South Coast Irrigation District (East Section) and has an O&M Plan in place tied to an annual revenue budget of \$5 million assigned by law. This budget considers the estimated \$1 million annual O&M cost specifically required for Patillas Dam.

## **Demonstration of Benefit to Most Impacted and Distressed Area<sup>6</sup>**

### **I. BCA Methodology**

In accordance with the PRDOH Benefit Cost Analysis (**BCA**) Guidelines, the Patillas Dam Project BCA has been prepared using the FEMA BCA methodology and latest version of the Toolkit Calculator v6.0.0. PRDOH has confirmed no other Federal agency has rejected a BCA for this Covered Project, including any BCA for an earlier version of the current proposed Covered Project. Additionally, the Project has been analyzed and approved by FEMA.

FEMA has a well-established BCA method and software tools to assess the cost-effectiveness of hazard mitigation projects for the various FEMA mitigation grant programs. The Robert T. Stafford Disaster Relief and Emergency Assistance Act (Stafford Act), 42 U.S.C. 5121 *et seq.*, requires FEMA hazard mitigation projects be proven cost-

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<sup>5</sup> Due to file size, document containing Patillas Dam Issue Evaluation Risk Analysis it is available upon request.

<sup>6</sup> See 84 FR 35838, section II. C. Most Impacted and Distressed Areas. The entire Island of Puerto Rico is considered most impacted and distressed area.

effective using the BCA approach defined in Section 3 of the PRDOH BCA Guidelines. Using the FEMA method, a project is considered cost-effective when the Benefit-Cost Rate (**BCR**) is 1.0 or greater, indicating the benefits of a prospective hazard mitigation or resilience project are sufficient to justify the costs:

$$BCR = \frac{Benefits}{Costs} \geq 1.0$$

Additionally, in accordance with OMB Circular A-94, *Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs*, FEMA BCAs are prepared on a net present value basis, meaning the present value of the benefits gained over the life of the project are compared to the total project costs to establish the BCR. Because most project benefits accumulate over time, project benefits can be calculated on an average annual basis ("annualized") and then multiplied by a Present Value Coefficient (PVC) using the formula shown below to determine the present value of the annualized benefits.

$$PVC = \left[ \frac{1 - (1 - r)^{-T}}{r} \right]$$

Where:  $r$  is the discount rate (7.00% per OMB Guidance) and  $T$  is the useful life of the project (typically 25-50 years for most public building and infrastructure projects). Refer to Appendix D: Project Useful Life Summary of the FEMA BCA Reference Guide (June 2009) for a summary of FEMA project useful life values for flood, hurricane wind, and seismic mitigation measures.

## II. Factors Considered in the BCA

Patillas Dam is an earth embankment dam built in 1913 using hydraulic fill methods. Dams built under this methodology are highly susceptible to liquefaction and thus are not recommended to be used on a highly seismic potential area as Puerto Rico. A catastrophic loss of the reservoir due to liquefaction (as expected during a major seismic event) may cause the loss of many residents' lives due to the location of the reservoir since the dam is five (5) minutes from the town of Patillas. The Risk Analysis prepared by the USBR provided that, in case of an embankment failure due to a seismic deformation, there is a high potential for loss of life in the areas surrounding the dam. This situation gets worst if we consider the data from the 2020 Census, where per capita income of the town residents is \$10,142.00 and the percentage of people living within poverty levels is close to 50.8%. Taking this into consideration, along with the fact that the FEMA-approved BCR achieved is currently **5.76**, there is high confidence that the Patillas Dam Seismic Retrofit will serve all the population living downstream of the dam area including persons that

are less able to mitigate risks or respond to and recover from disasters, as required by CDBG-MIT.

The BCA has been prepared using historic damages to calculate estimated losses in the event of dam failure for personal loss factors including loss of life for residents and students, burial expenses for residents and students, structural housing damage, loss of contents within the home, and damage to personal vehicles.

Losses have also been estimated for damage to public roads and sand and beach loss due to the flooding from the Patillas Dam.

**Table 4: BCA Data – Expected Losses Due to Dam Failure**

EXPENSE	AMOUNT	COMMENTS	DOCUMENTATION
<b>Losses Due to Dam Failure</b>			
Life Losses Residents	\$ 23,865,000,000.00	3,182 Lives will be lost if the Dam Fails. Value of Statistical Life (per person): \$7,500,000	<b>References:</b> 1. Loss of Life - DOI USBR Patillas Dam Issue Evaluation Risk Analysis. Page 45 2. FEMA VALUES - FEMA BCA Toolkit Release Notes July 2020.
Life Losses Students	\$ 975,000,000.00	130 Students will be Lost if the Dam Fails. Value of Statistical Life (per person): \$7,500,000	<b>References:</b> 1. Loss of Life - DOI USBR Patillas Dam Issue Evaluation Risk Analysis. Page 53 2. FEMA VALUES - FEMA BCA Toolkit Release Notes July 2020.

EXPENSE	AMOUNT	COMMENTS	DOCUMENTATION
<b>Losses Due to Dam Failure</b>			
Burial Expenses for Residents	\$ 8,476,639.34	3,182 Lives will be Lost if the Dam Fails. As per the GAO Report Disaster Response Deaths from 2017 Hurricanes Summary, Funeral assistance totals were \$2,600,000.00 for 976 people.	<b>References:</b> 1. Loss of Life - DOI USBR Patillas Dam Issue Evaluation Risk Analysis. Page 45 2. GAO Report Disaster Response Deaths from 2017 Hurricanes Summary. Page 3.
Burial Expenses for Students	\$ 346,311.47	130 Lives will be Lost if the Dam Fails. As per the GAO Report Disaster Response, Deaths from 2017 Hurricanes Summary, Funeral assistance totals were \$2,600,000.00 for 976 people.	<b>References:</b> 1. Loss of Life - DOI USBR Patillas Dam Issue Evaluation Risk Analysis. Page 53. 2. GAO Report Disaster Response Deaths from 2017 Hurricanes Summary. Page 3.
Housing Losses	\$ 202,840,000.00	2,200 houses will be lost, with a Median value of owner-occupied housing units of \$92,200.	<b>References:</b> 1. Houses Loss - DOI USBR Patillas Dam Issue Evaluation Risk Analysis. Page 44 2. Houses Loss - Values - U.S. Census Bureau QuickFacts_ Patillas Municipio, Puerto Rico. Page 1.

EXPENSE	AMOUNT	COMMENTS	DOCUMENTATION
<b>Losses Due to Dam Failure</b>			
Housing Contents	\$ 2,376,127.95	Estimated contents for each house is calculated at 28% of the value of a house, as per FEMA BCA Values.	<b>References:</b> 1. Houses Loss - DOI USBR Patillas Dam Issue Evaluation Risk Analysis. Page 44 2. Houses Loss - Values - U.S. Census Bureau QuickFacts_ Patillas Municipio, Puerto Rico. Page 1. 3. FEMA's Contents Percentage BCA Supplement.
Cars	\$ 8,800,000.00	2,200 units (average of one car per household), at FEMA value of \$4,000 each one.	<b>References:</b> 1. Houses Loss - DOI USBR Patillas Dam Issue Evaluation Risk Analysis. Page 44 2. FEMA Total Loss Car Value
State Roads	\$ 28,000,000.00	According to Puerto Rico Highway Administration analysis, the preliminary estimate of road damages could reach \$28,000,000.00. If we consider the need of a temporary bridge installation and road repairs to bring immediate access, including the dam and town, it could take approximately six (6) months.	<b>References:</b> 1. DTOP Certification Letter Days to Fix the Roads - 6 Months



EXPENSE	AMOUNT	COMMENTS	DOCUMENTATION
<b>Losses Due to Dam Failure</b>			
Ecosystem Sand Loss - Beach Loss due to heavy hit of water	\$ 9,519,151.91	5,711 linear feet x \$1,653.00 Sand lost caused by the strength of the river flood is estimated for a length of 179.77 meters, or 591 feet long. Using Hawaii's beach nourishment project of 2012 for a length of 1700 linear feet, costing \$2,500,000.00, or \$2,833,577.97 with inflation in 2020, totals the cost per l/f at \$1,666.81. Using those numbers for comparison, the 5,711 l/f of Patillas expected sand beach loss equals approximately \$9,519,151.91 in natural ecosystemic sand bar protection that will be lost, due to the heavy hit of polluted water flood from the Patillas Dam.	<p><b>References:</b></p> <ol style="list-style-type: none"> <li>1. Sand Beach Loss 2017 FEMA Flood Simulation. Page 14.</li> <li>2. Length of Sand Beach Loss Due to Dam Failure.</li> <li>3. Inflation Calculator from 2012 to 2020.</li> <li>4. Hawaii Beach Restoration Project. Page 10.</li> </ol>

**Safety and Security Response, Detours, and Lost Time**

The impact of dam failure would be substantial in the south region resulting in detoured emergency and police service routes due to flooded and inaccessible routes. Residents in need of emergency care would be detoured from the nearest hospitals requiring a longer travel time that could result in compounded medical needs.

**Table 5** lists the quantified losses that are avoided by the project improvements.

**Table 5: BCA Data – Expected Losses Due to Detours and Lost Time**

EXPENSE	AMOUNT	COMMENTS	DOCUMENTATION
<b>Detours and Lost Time</b>			
Detour Hospital	\$ 6,334,545.00	<p>In the event of a dam failure, the Patillas Hospital will be a total loss. Total Households of Patillas Barrios, as per the 2010, Census that will be affected with the loss of PR-184 with the Dam Failure, per two-way trips to the downtown Guayama Hospital, per day. Households per "Barrio" are: Cacao Alto (1,115), Jagual (181), Mulas (197), Quebrada Arriba (326), and Muñoz Rivera (331). Total Households equals 2,150. Considering a one way trip daily, it would take 60 additional minutes and 28 miles, multiplied for \$.575 federal mile rate, equals \$34,615.00 per day, multiplied for 183 days equals \$6,334,545.00.</p>	<p><b>References:</b></p> <ol style="list-style-type: none"> <li>1. Flood Map Prediction due to Dam Failure.</li> <li>2. 2010 Census Patillas Barrios Data.</li> <li>2. Detour Hospital PR-184 Patillas to Menonita Medical Center Guayama - Google Maps.</li> <li>3. DTOP Certification Letter Days to Fix the Road.</li> </ol>

EXPENSE	AMOUNT	COMMENTS	DOCUMENTATION
<b>Detours and Lost Time</b>			
Lost Time Detour Hospital	\$ 12,779,256.00	<p>In the event of a dam failure, the Patillas Hospital will be total loss. Total Households of Patillas Barrios, as per the 2010 Census, that will be affected with the loss of PR-184 with the dam failure, per two-way trips to downtown Guayama Hospital, per day. Households per "Barrio" are: Cacao Alto (1,115), Jagual (181), Mulas (197), Quebrada Arriba (326) and, Muñoz Rivera (331). Total Households equals 2,150, once a day, multiplied for 183 days (six months). It will take 56 additional minutes to get from PR 184 to Guayama Hospital, instead of Patillas Hospital, multiplied for \$.58 minute (\$34.72/hour as per FEMA Value), equals \$64.96 x 2,150 households' trips per day, multiplied for 183 days equals \$12,779,256.00.</p>	<p><b>References:</b></p> <ol style="list-style-type: none"> <li>1. Flood Map Prediction due to Dam Failure.</li> <li>2. 2010 Census Patillas Barrios Data.</li> <li>2. Detour Hospital PR-184 Patillas to Menonita Medical Center Guayama - Google Maps.</li> <li>3. DTOP Certification Letter Days to Fix the Road.</li> </ol>

EXPENSE	AMOUNT	COMMENTS	DOCUMENTATION
<b>Detours and Lost Time</b>			
Detour Police	\$ 6,334,545.00	<p>In the event of a dam failure, the Patillas Police Station will be total loss. Total Households of Patillas Barrios, as per the 2010 Census, that will be affected with the loss of PR-184 with the Dam Failure, per one-way trips to downtown Guayama Police, per day. Households per "Barrio" are: Cacao Alto (1,115), Jagual (181), Mulas (197), Quebrada Arriba (326), and Muñoz Rivera (331). Total Households equals 2,150, one way trip daily, it will take 60 additional minutes and 28 miles, multiplied for \$.575 federal mile rate, equals \$34,615.00 per day, multiplied for 183 days equals \$6,334,545.00.</p>	<p><b>References:</b></p> <ol style="list-style-type: none"> <li>1. Flood Map Prediction due to Dam Failure.</li> <li>2. 2010 Census Patillas Barrios Data.</li> <li>2. Detour Hospital PR-184 Patillas to Menonita Medical Center Guayama - Google Maps.</li> <li>3. DTOP Certification Letter Days to Fix the Road.</li> </ol>

EXPENSE	AMOUNT	COMMENTS	DOCUMENTATION
<b>Detours and Lost Time</b>			
Lost Time Detour Police Station	\$12,779,256.00	<p>In the event of a dam failure, the Patillas Police Station will be total loss. Total Households of Patillas Barrios, as per the 2010 Census, that will be affected with the loss of PR-184 with the Dam Failure, per two-way trips to downtown Guayama Hospital, per day. Households per "Barrio" are: Cacao Alto (1,115), Jagual (181), Mulas (197), Quebrada Arriba (326), and Muñoz Rivera (331). Total Households equals 2,150, once a day. It will take 56 additional minute, 28 miles to get from PR-184, instead of Patillas Police Station, multiplied for \$.58 minute (\$34.72/hour as per FEMA Value), equals \$32.48 x 2,150 households' trips per day, multiplied for 183 days equals \$12,779,256.00.</p>	<p><b>References:</b></p> <ol style="list-style-type: none"> <li>1. Flood Map Prediction due to Dam Failure.</li> <li>2. 2010 Census Patillas Barrios Data.</li> <li>2. DETOUR Police Station PR-184 Patillas to Calle 41 Guayama Police Station.</li> <li>3. DTOP Certification Letter Days to Fix the Road.</li> </ol>

EXPENSE	AMOUNT	COMMENTS	DOCUMENTATION
<b>Detours and Lost Time</b>			
Detour Fire Station	\$ 6,425,038.50	<p>In the event of a dam failure, the Patillas Fire Station will be total loss. Total Households of Patillas Barrios, as per the 2010 Census, that will be affected with the loss of PR 184 with the Dam Failure, per one-way trips to downtown Guayama Fire Station, per day. Households per "Barrio": Cacao Alto (1,115), Jagual (181), Mulas (197), Quebrada Arriba (326), and Muñoz Rivera (331). Total Households equals 2,150, one-way trip daily, It will take 61 additional minutes and 28.4 miles, multiplied for \$.575 federal mile rate, equals \$35,109.50 per day, multiplied for 183 days equals \$6,425,038.50.</p>	<p><b>References:</b></p> <ol style="list-style-type: none"> <li>1. Flood Map Prediction due to Dam Failure.</li> <li>2. 2010 Census Patillas Barrios Data.</li> <li>2. DETOUR Fire Station PR-184 Patillas to Calle 41 Guayama Fire Station.</li> <li>3. DTOP Certification Letter Days to Fix the Road.</li> </ol>

EXPENSE	AMOUNT	COMMENTS	DOCUMENTATION
<b>Detours and Lost Time</b>			
Lost Time Detour Fire Station	\$ 13,007,457.00	<p>In the event of a dam failure, the Patillas Fire Station will be total loss. Total Households of Patillas Barrios, as per the 2010 Census, that will be affected with the loss of PR 184 with the Dam Failure, per two-way trips to downtown Guayama Hospital, per day. Households per "Barrio": Cacao Alto (1,115), Jagual (181), Mulas (197), Quebrada Arriba (326), and Muñoz Rivera (331). Total Households equals 2,150, once a day. It will take 57 additional minutes, 28.4 miles to get from PR-184, instead of Patillas Fire Station, multiplied for \$.58 minute (\$34.72/hour as per FEMA Value), equals \$33.06 x 2,150 household trips per day, equals \$71,079.00, multiplied for 183 days equals \$ 13,007,457.00.</p>	<p><b>References:</b></p> <ol style="list-style-type: none"> <li>1. Flood Map Prediction due to Dam Failure.</li> <li>2. 2010 Census Patillas Barrios Data.</li> <li>2. DETOUR Fire Station PR-184 Patillas to Calle 41 Guayama Fire Station.</li> <li>3. DTOP Certification Letter Days to Fix the Road.</li> </ol>

**I. Disaster Relief**

Additionally, by implementing the project scope, future impacts of dam failure caused by earthquake activity can be avoided. The services have been estimated in the form of FEMA assistance, as listed in **Table 6**.

**Table 6: BCA Data – Mitigation of Future Impacts of Dam Failure (as per avoided FEMA assistance costs)**

EXPENSE	AMOUNT	COMMENTS	DOCUMENTATION
<b>Disaster Relief: FEMA</b>			
FEMA Disaster Relief – Individual Assistance (IA)	\$ 2,151,550.85	Taking as based on what FEMA has invested in Puerto Rico to December 2020, related to the PR Year 2020 Earthquakes: 1. Individual Assistance: \$68,849,627.32 for 32 municipalities.	<b>References:</b> FEMA Puerto Rico Earthquakes (DR-4473-PR) Relief Investment
FEMA Disaster Relief – Other Needs Assistance (ONA)	\$ 156,705.55	Taking as based what FEMA has invested in Puerto Rico to December 2020, related to the PR Year 2020 Earthquakes: 1. Other Needs \$2,193,877.72 for 14 Municipalities.	<b>References:</b> FEMA Puerto Rico Earthquakes (DR-4473-PR) Relief Investment
FEMA Disaster Relief – Public Assistance (PA) Emergency	\$ 17,236,570.72	Taking as based what FEMA has invested in Puerto Rico to December 2020, related to the PR Year 2020 Earthquakes: 1. Public Assistance Emergency \$241,311,990.14 for 14 Municipalities.	<b>References:</b> FEMA Puerto Rico Earthquakes (DR-4473-PR) Relief Investment



EXPENSE	AMOUNT	COMMENTS	DOCUMENTATION
<b>Disaster Relief: FEMA</b>			
FEMA Disaster Relief - Permanent Work	\$ 23,178.87	Taking as based what FEMA has invested in Puerto Rico to December 2020, related to the PR Year 2020 Earthquakes: 1. Public Assistance Permanent Work \$324,504.17 for 14 Municipalities.	<b>References:</b>  FEMA Puerto Rico Earthquakes (DR-4473-PR) Relief Investment

## II. Public Buildings

In the event of dam failure, flood impact to surrounding buildings is estimated to impact in the amount of \$18,565,125.23. **Table 7** lists the sites and associated cost estimates.

**Table 7: BCA Data – Mitigation of Future Impacts of Dam Failure (as per estimated damage to Public Buildings in the Region)**

EXPENSE	AMOUNT	COMMENTS	DOCUMENTATION
<b>Buildings and Contents</b>			
Municipal Buildings Structures	\$6,760,301.50	There are 20 public buildings located within the affected area of the Dam failure. The properties are included in the Report of Properties for the Period 2020-2021. This report is produced annually, and it is submitted by the Municipal Property Director, to the Insurance Company.	<b>References:</b> 1. Patillas Dam Break Flood Municipal Assets Affected LIST.pdf 2. Patillas Dam Break Flood Municipal Assets Affected MAP.pdf

EXPENSE	AMOUNT	COMMENTS	DOCUMENTATION
<b>Buildings and Contents</b>			
Municipal Buildings - Contents	\$1,816,108.15	There are 20 public buildings located within the affected area of the Dam failure. The properties are included in the Report of Properties for the Period 2020-2021. This report is produced annually, and it is submitted by the Municipal Property Director, to the Insurance Company.	<b>References:</b> 1. Patillas Dam Break Flood Municipal Assets Affected LIST.pdf 2. Patillas Dam Break Flood Municipal Assets Affected MAP.pdf
Escuela Joaquín Parrilla	\$ 3,086,880.22	School Value as per the Department of Education.	<b>References:</b> Department of Education Schools Replacement Value Email
Contents Escuela Joaquín Parrilla	\$ 864,326.46	Content Values of the School, equals 28% of the School Value (FEMA given BCA Tool Average for Building Contents).	<b>References:</b> 1. Department of Education Schools Replacement Value Email. 2. FEMAs Contents Percentage BCA Supplement.

EXPENSE	AMOUNT	COMMENTS	DOCUMENTATION
<b>Buildings and Contents</b>			
Escuela María Dávila	\$ 1,643,734.67	School Value as per the Department of Education.	<b>References:</b>  1. Department of Education Schools Replacement Value Email.
Contents Escuela María Dávila	\$ 460,245.71	Content Values of the School, equals 28% of the School Value (FEMA given BCA Tool Average for Building Contents).	<b>References:</b>  1. Department of Education Schools Replacement Value Email. 2. FEMAs Contents Percentage BCA Supplement.
Escuela Cecilio Lebrón	\$ 3,073,069.16	School Value as per the Department of Education.	<b>References:</b>  1. Department of Education Schools Replacement Value Email.
Contents Escuela Cecilio Lebrón	\$ 860,459.36	Content Values of the School, equals 28% of the School Value (FEMA given BCA Tool Average for Building Contents).	<b>References:</b>  1. Department of Education Schools Replacement Value Email. 2. FEMAs Contents

EXPENSE	AMOUNT	COMMENTS	DOCUMENTATION
Buildings and Contents			
			Percentage BCA Supplement.

**III. Additional Benefits**

The implementation of this important project will provide resiliency to the Patillas Dam and strengthen the economic stability of the agricultural sector due to reliable water service, among other benefits for the citizens of the southeastern region of Puerto Rico.

By implementing this Project, State agencies that operate water and electrical equipment and services will avoid income losses and increased costs associated with emergency response. Specifically, unearned income from the delivery of water services is estimated at a combined value of over \$167 million. A profile of the costs can be found in **Table 8**.

**Table 8: BCA Data – Additional Estimated Benefits Provided by the Project**

EXPENSE	AMOUNT	COMMENTS	DOCUMENTATION
Unearned Income and Additional Costs			

Unearned Income Residential Services PRASA	\$ 50,338,701.00	25,275 clients (76% of the total of 33,256 clients) of which 76% will not have water x \$23.71 x 84 months.	<b>References:</b> 1. Operational Consequences AAA Patillas Dam Failure PRASA. 2. PRASA Residential Rate Structure.
AES	\$ 117,485,545.00	Additional Cost of Combustion Substitution for Having AES out of service due to the lack of water to the power plant.	<b>References:</b> 1. Operational Consequences AAA Patillas Dam Failure PRASA. 2. Energy Replacement Cost.

#### IV. Community Characteristics

Additional community impact can be considered in the demographics of the residents who benefit. Social vulnerability describes an area's capacity to prepare for, respond to, and rebound from disaster events<sup>7</sup>, and has a long conceptual and theoretical history in social and disaster science fields. Socially vulnerable populations have fewer resources to aid in preparation for disasters, are often the hardest hit and take the longest to recover.

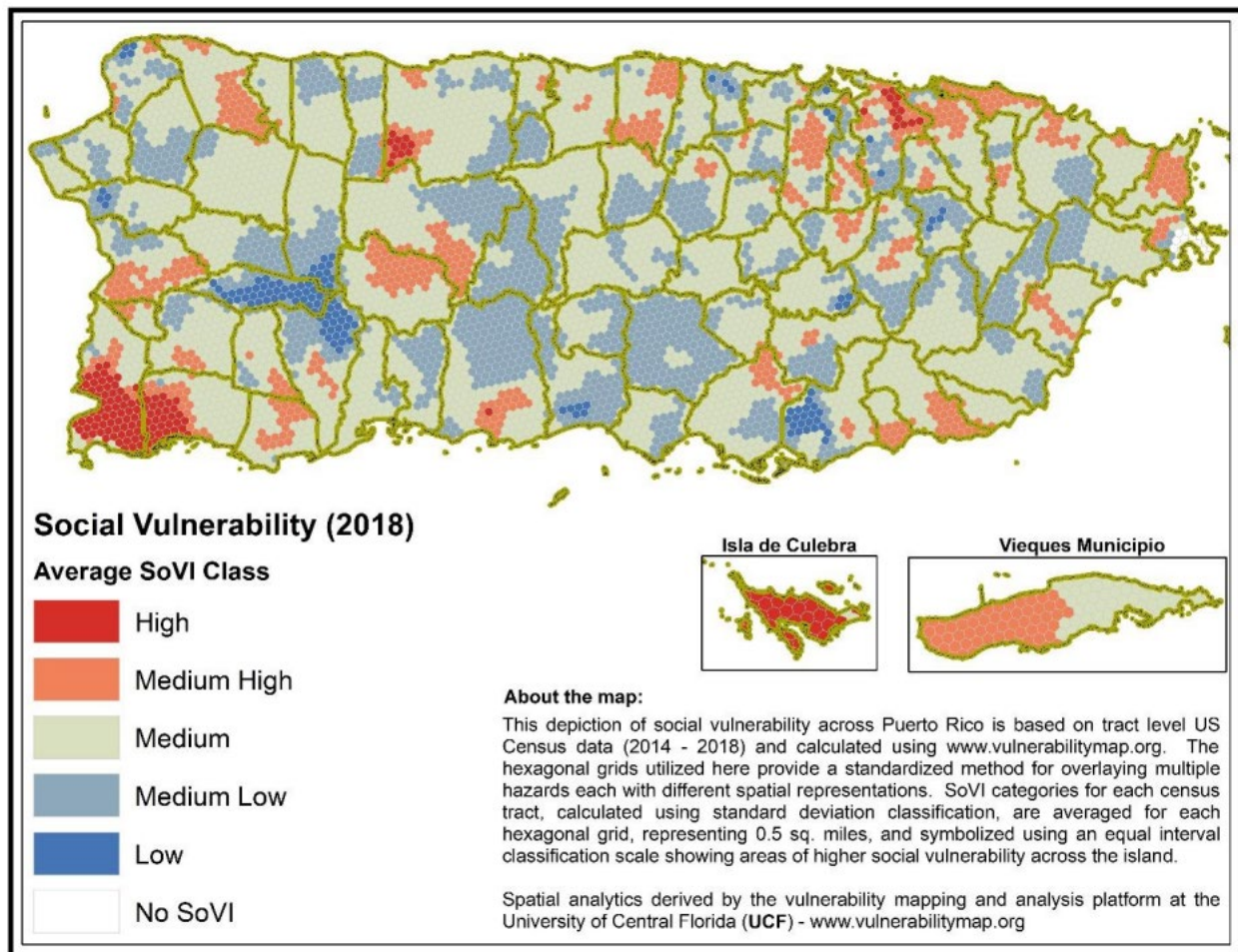
As shown in **Figure 6**, the four (4) municipalities with improved water service and mitigated effects during earthquake risk have medium-low to high concentrations of socially vulnerable populations. See the Risk Analysis section of the CDBG-MIT Action Plan for additional information on the Social Vulnerability Index (**SoVI**).

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<sup>7</sup> Cutter, Susan L., Emrich, Christopher T. Moral Hazard, Social Catastrophe: The Changing Face of Vulnerability along the Hurricane Coasts. The ANNALS of the American Academy of Political and Social Science. March 1, 2006.

Patillas, Arroyo, Guayama, and Salinas all demonstrate a high concentration of SoVI populations within the boundaries of the municipality.

Improved services for the residents of these municipalities are presumed to serve SoVI populations proportional to the regional characteristics assessed at the municipal level.



**Figure 6: Social Vulnerability Area Map**

Another important consideration of the community impacts the project will have on the area pertain to protected classes as defined in the Civil Rights Act of 1964 (CRA) and subsequent federal laws.

The social vulnerability index implemented in Puerto Rico's CDBG-MIT risk assessment includes at least ten (10) indicators of protected classes, including: race, sex, familial

status, and a certain measure of disability. However, several protected classes, identified in the Fair Housing Act, are not included in the social vulnerability index. Recognizing the importance of identifying these populations and building programs that do not disadvantage them, requires additional analysis beyond that provided by the social vulnerability index. To the extent possible, extra analytic steps were taken to ensure that these protected classes are identified and monitored throughout the CDBG-MIT process.

In the municipalities benefited by the project, identifying and accounting for persons of differential ability is considered as an important facet of disaster mitigation activities. To this end, data on disability and “difficulty” from the United States Census<sup>8</sup> will be assessed in order to identify the location in which differently abled populations are residing. The Census has evolved its understanding (and measurement) of disabilities. Beginning in ACS 2008, the census moved from the strict use of the term disability to a more broadly inclusive term of “difficulty”.<sup>9</sup> Census defines several disabilities/difficulties in the following ways.

Hearing Difficulty	“deaf or ... [had] serious difficulty hearing.”
Vision Difficulty	“blind or ... [had] serious difficulty seeing even when wearing glasses.”
Cognitive Difficulty	“serious difficulty concentrating, remembering, or making decisions.”
Ambulatory Difficulty	“serious difficulty walking or climbing stairs.”
Self-care Difficulty	“difficulty dressing or bathing.”
Independent Living Difficulty	“doing errands alone such as visiting a doctor’s office or shopping.”

As shown in **Table 9**, each of the benefiting municipalities demonstrate the presence of these populations.

**Table 9: Summary of Socially Vulnerable Persons Living within the Project Area of Benefit**

<sup>8</sup> ACS2015-2019, 5-Year census product, table S1810.

<sup>9</sup> American Community Survey and Puerto Rico Community Survey. 2019 Subject Definitions. Accessed at: [https://www2.census.gov/programs-surveys/acs/tech\\_docs/subject\\_definitions/2019\\_ACSSubjectDefinitions.pdf](https://www2.census.gov/programs-surveys/acs/tech_docs/subject_definitions/2019_ACSSubjectDefinitions.pdf)

Municipality	Total Population (2019)	Hearing difficulty	Vision difficulty	Cognitive difficulty	Ambulatory difficulty	Self-care difficulty	Independent living difficulty
Arroyo	17,791	488 (2.74%)	466 (2.62%)	1118 (6.28%)	2490 (14%)	486 (2.73%)	1258 (7.07%)
Guayama	38,730	845 (2.18%)	1265 (3.27%)	3164 (8.17%)	6138 (15.85%)	1127 (2.91%)	2403 (6.2%)
Patillas	16,913	402 (2.38%)	294 (1.74%)	776 (4.59%)	875 (5.17%)	633 (3.74%)	1448 (8.56%)
Salinas	27,995	1395 (4.98%)	3724 (13.3%)	2390 (8.54%)	1846 (6.59%)	784 (2.8%)	2610 (9.32%)

Additionally, gender, or specifically being female, is an important driver of social vulnerability to disasters. Patriarchic structures and power imbalances tend to reduce women's status in society, their access to resources, opportunities and power, and subsequently lead to higher female vulnerability to adverse hazard and disaster outcomes.<sup>10</sup> Age, another key characteristic influencing social vulnerability, is normally recognized at the two (2) extremes of the age continuum—children and older adults are more vulnerable than others.<sup>11</sup> Both age cohorts (young and old) need special care, are often more susceptible to harm, and may have mobility constraints, all of which influence the ability to get out of harm's way.<sup>12,13</sup> For this assessment, a focus on aging populations is required by Fair Housing regulations. Similarly, families with large numbers of dependents or single-parent households may be more vulnerable because of the need to rely on paid caregivers. Like sex and age, identifying areas based on familial status, or those with children in the home, is of particular interest here to address Fair Housing regulations. Each of these three (3) indicators of socially vulnerable areas is mapped and discussed here.

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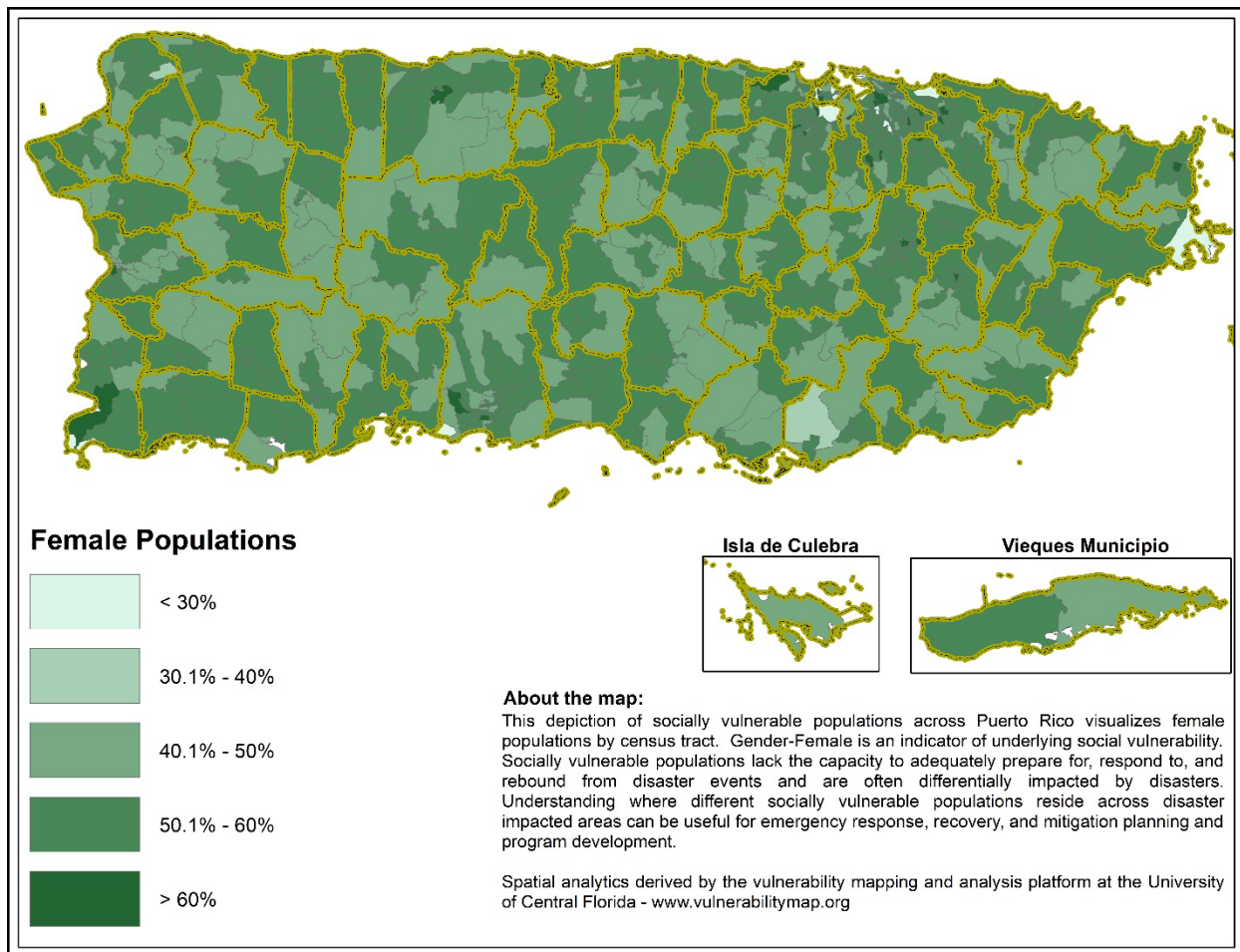
<sup>10</sup> Trieb, Carolin-Anna. *Vulnerability to Natural Hazards: A Gender Perspective in Disasters*, Management Center Innsbruck. Accessed at: [http://www.ibgeographypods.org/uploads/7/6/2/2/7622863/university\\_dissertation\\_ib\\_dp\\_geography.pdf](http://www.ibgeographypods.org/uploads/7/6/2/2/7622863/university_dissertation_ib_dp_geography.pdf)

<sup>11</sup> Rodriguez, Donner & Trainor. *Handbook of Disaster Research*. 2018.

<sup>12</sup> Anderson, William A. *Bringing children into focus on the social science disaster research agenda*, International Journal of Mass Emergencies and Disasters. Accessed at: <http://ijmed.org/articles/376/download/>

<sup>13</sup> Smith, Susan M. *Disaster planning and response: considering the needs of the frail elderly*, International Journal of Emergency Management. Accessed at: [https://www.researchgate.net/publication/244924906\\_Disaster\\_planning\\_and\\_response\\_Considering\\_the\\_needs\\_of\\_the\\_frail\\_elderly](https://www.researchgate.net/publication/244924906_Disaster_planning_and_response_Considering_the_needs_of_the_frail_elderly)

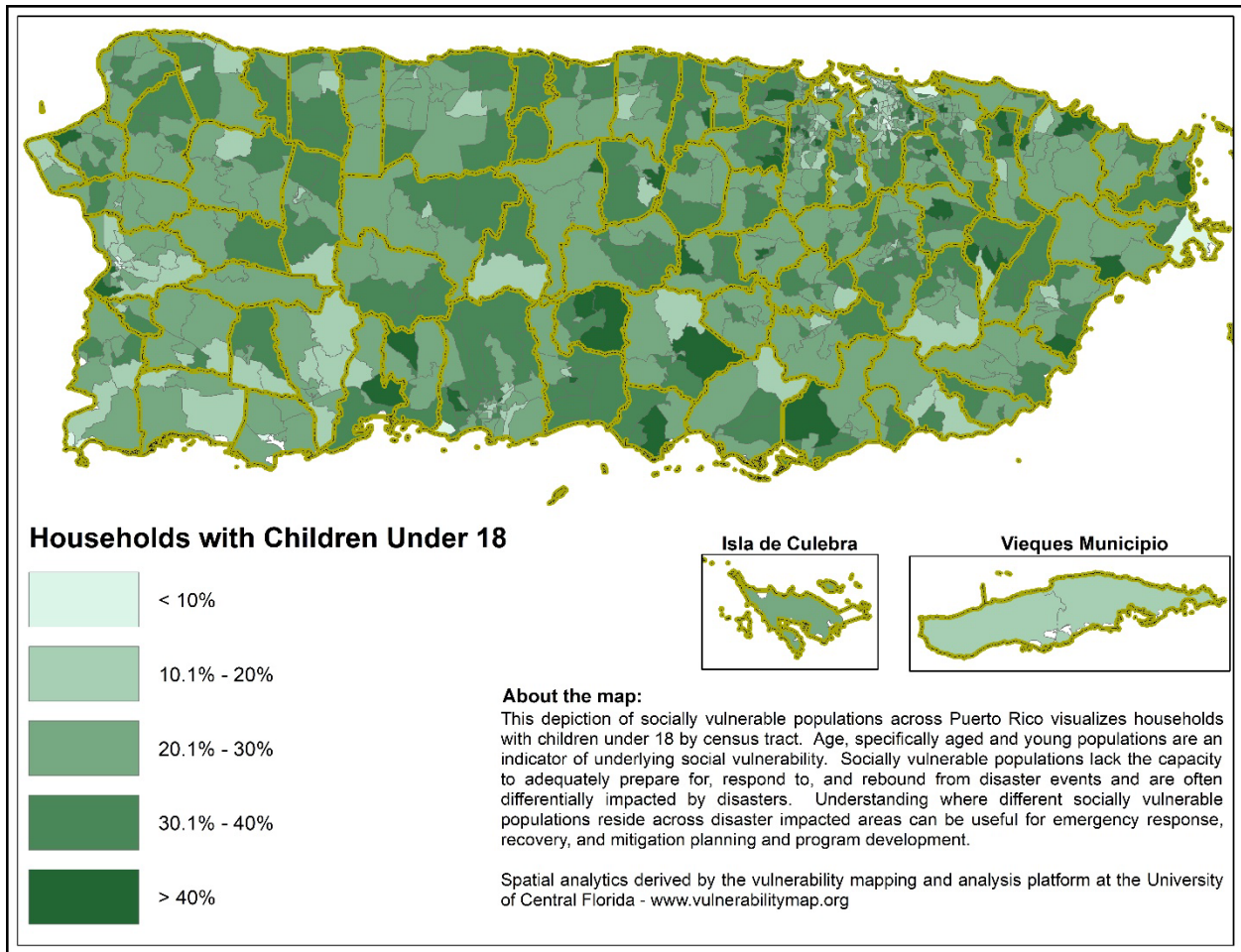




**Figure 7: Female Population Area Map**

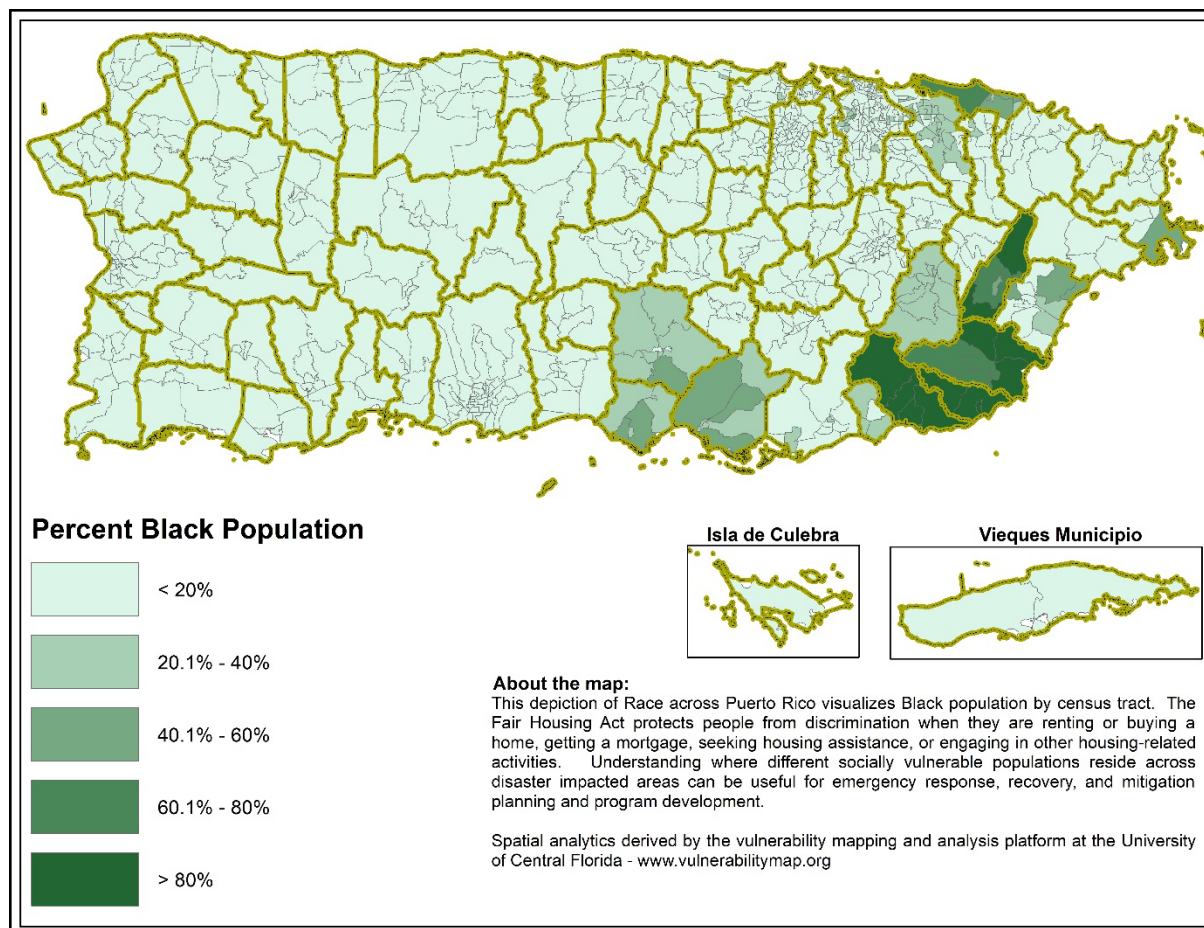
Municipalities benefiting from the Project demonstrate a strong presence of female residents with census areas indicating a range of 30% or less to the highest concentration of 60% concentration of female residents.

Regarding age, the four (4) municipalities benefiting from the project did not demonstrate a high concentration of residents over 65 years of age, however, they do show a strong concentration of households with children under 18 as shown in **Figure 8**.



**Figure 8: Area Map of Households with Children (under 18 years of age)**

Racial concentrations are also demonstrated in the AOB with Patillas having 80% or more black population.



**Figure 9: Area Map showing the Location of Black Populations**

The Migration Policy Institute identified thirteen (13) different Caribbean countries in a Caribbean Migration Study aimed at understanding Black Caribbean immigration to the United States.<sup>14</sup> These countries include Cuba, Dominican Republic, Haiti, Jamaica, Bahamas, Barbados, Trinidad & Tobago, and Countries in the British West Indies, the U.S. Virgin Islands, and other West Indian Countries such as Grenada, St. Lucia, Antigua-Barbuda, St. Vincent, Dominica, and St. Kitts-Nevis. In Puerto Rico, the largest populations of Black Caribbean's have ancestral links to the Dominican Republic.

<sup>14</sup> Thomas, Kevin J.A. *A demographic Profile of Black Caribbean Immigrants in the United States*, Migration Policy Institute. April 2012. Accessed at: <https://www.migrationpolicy.org/pubs/CBI-CaribbeanMigration.pdf>.

An evaluation of Afro Caribbean Ancestry in the benefited area demonstrates the following:

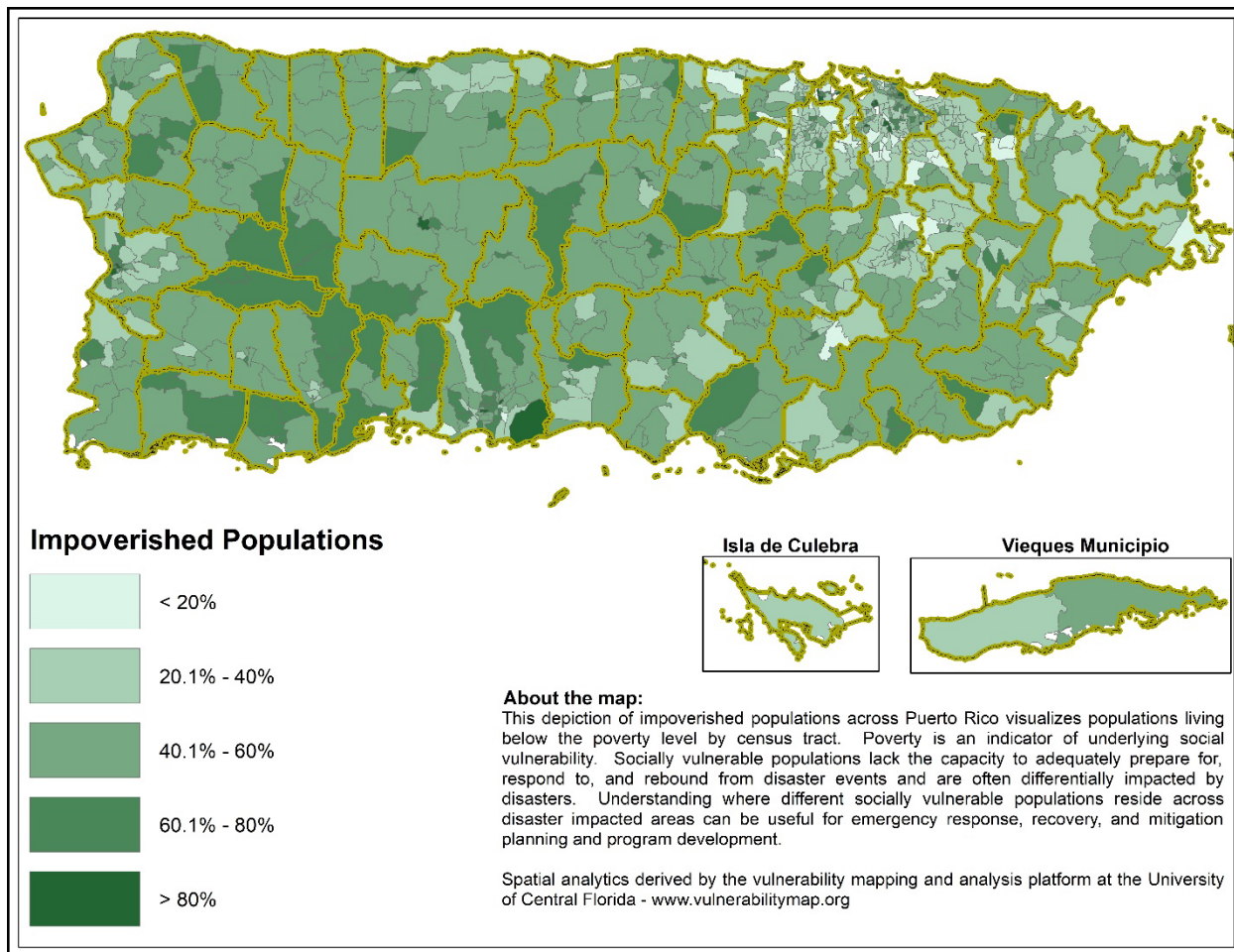
**Table 10: Summary of Estimated Persons with Afro-Caribbean Ancestry Living within the Project Area of Benefit**

<i>Municipality</i>	<i>Total Population</i>	<i>Total Afro Caribbean</i>	<i>Hispanic Total Dominicans</i>	<i>Total Cubans</i>
<i>Arroyo</i>	17,805	5	5	-
<i>Guayama</i>	40,889	69	24	45
<i>Patillas</i>	16,929	74	30	44
<i>Salinas</i>	28,109	79	54	25

Similar to the SoVI analysis, improvements to the dam for the residents of these municipalities are presumed to serve protected class populations proportional to the regional characteristics assessed at the municipal level.

Furthermore, there is a strong concentration of impoverished residents in the municipalities that stand to benefit from the Project. As shown in **Figure 10**, Arroyo has a blend of poverty levels with the highest concentration of poverty (60.1% to 80%) in the southeast corner of the municipality.





**Figure 10: Area Map showing the Impoverished Populations**

### Consistency with Other Mitigation Activities

The Project's primary purpose is to reinforce the current dam so that any potential risk to the people or infrastructure is reduced to the guidelines provided by the USBR. This purpose is compatible with the current Dam Safety Best practices. It will ensure the non-catastrophic failure of the embankment (barrier) protecting all life and property downstream of the dam break flooding zone. It will also maintain the natural water reservoir for 100,000 people depending on the reservoir and provide a water source to the AES Power Generation Plant, responsible for delivering 400 megawatts of base generation to the Puerto Rico Power Grid.

The Patillas Dam 404 Project is consistent with both the 2011 and the 2016 Puerto Rico State Hazard Mitigation Plan. Additionally, the Puerto Rico State Hazard Mitigation 2016

Plan was the approved plan at the time of the project's application submission to FEMA. PRDOH confirmed the project is still in alignment with the goals included in the approved 2021 Hazard Mitigation Plan. It is in conformance with 2011 PEMP Goal 3, Objective 3.1 and Actions 3.1.21 and 3.1.22 and the 2016 PEMP Goal 1, Objective 1.1, Actions 1.1.5 and 1.1.6.

The Project improves on an existing critical facility reducing vulnerability and thus ensuring continuity of critical services after a disaster. It provides a conceptual design for the improvement of the critical facility and draws on FEMA 404 mitigation funding and appropriate matching from CDBG-DR. It complies with the development of a Puerto Rico more resilient to disasters with less vulnerability and exposure to unnatural disasters. The concept was developed by identifying and assessing the hazard vulnerability of the critical facility and includes specific restoration that can be developed prior to the occurrence of the disaster with funding from locally matched Federal funds.

**END OF NARRATIVE**

## 4 APPENDIX A: PREPA's Patillas Dam Covered Project Request for Information Answer Memorandum

**Request 5:** *Please confirm if the Patillas Seismic Retrofit Project enlarges a dam or levee beyond the original footprint.*

Answer 5: Patilla's dam is an earth embankment dam built in 1913 using hydraulic fill methods. This method consists of building two starter dikes while dumping material in between. The material is subsequently sluiced with water creating a puddle for the impermeabilization core on the dam. This method was extensively used in 1913 but years later it was discovered that the construction method is not adequate and/or to be used in a highly seismic areas, such as Puerto Rico. More specifically because these embankments are susceptible to liquefaction induced by seismic dynamic loads.

Patillas Dam supplies water to two main critical facilities (1) the Power Plant known as AES which provides 400 megawatts of base generation and (2) the Puerto Rico Aqueduct and Sewer Authority (PRASA) which provides potable water for over 100,000 citizens of the municipalities of Patillas, Guayama and

Arroyo. Moreover, it is also the only source of water for irrigation purposes in the southeast.

Therefore, plant operation continuance is a critical health and safety measure considering that water availability cannot be supplied by other means. The United States Bureau of Reclamation (USBR) developed a mitigation strategy using best dam engineering practices allowing for the retrofit without compromising water availability or water requirements as described above.

Since hydraulic fill dams lose their stability under the dynamic loads during a seismic event, the USBR recommended reinforcing the existing dam to increase and maintain stability under the loads induced by an MCE (maximum credible earthquake). This concept will create an overlay over the existing dam footprint with a sand filter stable enough to stand by itself in case the original dam deforms. This will prevent a catastrophic loss of the embankment reducing the flooding risk all the Patilla's municipality in case of a dam failure.

The developed concept will be constructed over the actual dam on the dry side of the embankment all within the property of the Puerto Rico Electric Power Authority. This concept does not change the original impoundment capacity of the reservoir and does not change the operational level to begin the activation of the spillway gates which is 222 ft msl.

The project will also include the reinforcement and extension of an existing tunnel in the dam along the construction of a new water way system to provide water to the Patillas Irrigation Canal.

If you have any questions or require further information, please don't hesitate to contact us via email at [ezequiel.nieves@prepa.com](mailto:ezequiel.nieves@prepa.com) and [jose.bermudez@prepa.com](mailto:jose.bermudez@prepa.com)

Regards,



José M. Bermúdez  
Dams and Irrigation Division Head

Enclosed

**END**