NORTHEAST ECOLOGICAL CORRIDOR NATURAL RESERVE INTEGRATED WATERSHED MANAGEMENT PLAN

Final Integrated Watershed Management Plan
March 2017

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Prepared for:
Department of Natural and Environment Resources
National Oceanic and Atmospheric Administration

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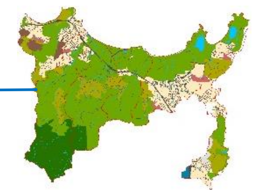

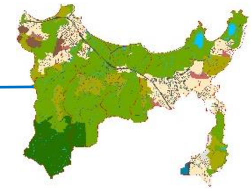

LIST OF ACRONYMS

Best Management Practice (BMP)
Centro para la Conservación del Paisaje (CCP)
Coastal Zone Management Program (CZMP)
Coral Reef Conservation Program (CRCP)
Department of Natural and Enviromental Resources (DNER)
Enviromental Protection Agency (EPA)
Enviromental Quality Board (EQB)
Fajardo Regional Wastewater Treatment Plant (FRWTP)
Floating Treatment Wetland (FTW)
Geographic Information System (GIS)
Green Infrastructure (GI)
Habitat Focus Area (HFA)
Illicit Discharge Detection and Elimination (IDDE)
Land Based Sources of Pollution (LBSP)
Land Use Plan (LUS)
La Cordillera Natural Reserve (LNR)
National Environmental Policy Act (NEPA)
National Fish and Wildlife Foundation (NFWF)
National Oceanic and Atmospheric Administration (NOAA)
National Hydrography Dataset (NHD)
National Pollutant Discharge Elimination System (NPDES)
National Wetland Inventory (NWI)
Natural Resources Conservation Service (NRCS)
North East Reserve (NER)
Nutrient Reduction Projects (NRP)
Protectores de Cuencas, Inc. (PDC)
Puerto Rico Aqueduct and Sewer Authority (PRASA)
Puerto Rico Planning Board (PRPB)
Restoration Center (RC)
Río Fajardo Watershed (NEC)
Río Fajardo Watershed Management Plan (NECMP)
Riparian Forested Buffer (NECB)
Stormwater Treatment Projects (STP)
U.S. Forest Service (USFS)
U.S. Fish and Wildlife Service (USFWS)
Total Nitrogen (TN)
Total Phosphorus (TP)
Total Suspended Solids (TSS)
Treatment Wetlands (TW)
Watershed Treatment Model (WTM)

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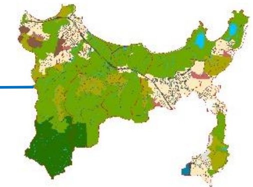

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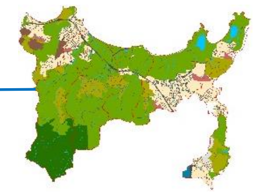
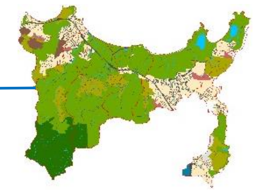
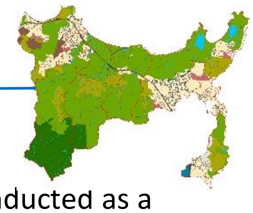


ACKNOWLEDGEMENTS



Funding for this project was provided by the Department of Natural and Enviromental Resources (DNER) in collaboration with the National Oceanic and Atmospheric Administration (NOAA). Protectores de Cuencas, Inc. will like to acknowledge the collaboration of the following agencies and organizations. Ridge to Reefs (RTR) for helping with the pollution threat analysis and water quality assessments. Centro para la Conservación del Paisaje (CCP) for leading the outreach and public participatory process as well as engaging multiple partners. Fajardo Municipality Planning Board Office and the DNER personnel for their technical support and collaboration during the field assessments. Puerto Rico Aqueduct and Sewer Authority (PRASA) for all the collaboration and GIS characterization of the sewer infrastructure for the study areas within the watershed. Gregory L. Morris Engineering COOP for their collaboration on the recommended implementation actions descriptions and calculations of the possible needs.

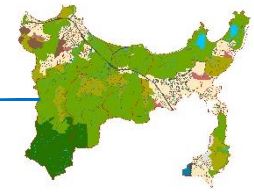
EXECUTIVE SUMMARY



A Watershed Characterization and Water Quality Assessment has been conducted as a baseline for the development of an integrated watershed management plan for Puerto Rico's Northeast Ecological Corridor. The Northeast Ecological Corridor (NEC) is a conservation priority area for the Department of Natural and Environmental Resources (DNER) and the National Oceanic and Atmospheric Administration (NOAA). This region is renowned for its natural beauty and ecological importance that attracts millions of tourists every year. Hence, Puerto Rico's northeastern coastal habitats are some of the most impacted ecosystems throughout the Caribbean. This area has experienced one of the largest development pressures in coastal infrastructure in the past decades having a direct impact in the impairment of water quality. This watershed management plan includes the watersheds that drain to the Northeastern Ecological Corridor and la Cordillera Marine Reserve in the coastal waters of the municipalities of Luquillo and Fajardo. The main goal of the final watershed management plan is to help chart a course of action for the improvement of water quality and coral reefs, and to serve the goals of the citizens involved in the process. To this end, the project has identified 83 projects and actions to be taken to improve the quality of coastal waters and resilience in the NEC with specific projects and policies to reduce nitrogen and sediment pollution by at least 20% and identify the potential resources and partners needed to accomplish the effort as well as a monitoring approach to measure the results.

A stakeholder involvement process was developed for this project. This task was led by the Centro para la Conservación del Paisaje (CCP), in collaboration with PDC. This component was designed to conduct participatory engagement to inform key participants about the Watershed Management Plan. In addition, several participatory mapping exercises were developed to brainstorm ideas to address the issues. These efforts aimed at engaging the community in the implementation of future management strategies within the watersheds. The public participation strategy included an educational campaign about the project's scope and importance of employing an integrated watershed management approach to study environmental issues throughout the region. Local stakeholders directly participated in the identification and analysis of environmental problems within the watersheds while providing the basis for a strategic collaboration towards the implementation of best management practices to restore and conserve the NEC watersheds.

INTRODUCTION



The Northeast Ecological Corridor (NEC) is a conservation priority area for the Department of Natural and Environmental Resources (DNER) and the National Oceanic and Atmospheric Administration (NOAA). This region is renowned for its natural beauty and ecological importance that attracts millions of tourists every year. Hence, Puerto Rico's northeastern coastal habitats are some of the most impacted ecosystems throughout the Caribbean. This area has experienced one of the largest development pressures in coastal infrastructure in the past decades having a direct impact in the impairment of water quality. The degradation of coastal water quality in Puerto Rico has caused a decline in the population and health of coral reefs and associated ecosystems. The ability of reefs to survive is gradually reduced as fine sediment and nutrient discharged from land enters coastal waters. From the standpoint of marine ecosystems conservation, degradation of water quality due to dispersed land-based sources of pollution (LBSP) has negative and sometimes irreversible damage to the integrity of the coral reef communities, sea grasses, mangroves and other highly valued coastal ecosystems.

High rates of sedimentation, excessive nutrients, urbanization, septic failures, and sanitary sewage overflows are the main causes of degradation in our marine ecosystems. Erosion and habitat degradation are other serious problems that wetlands, estuaries, and coastal waters encounter. Further, the removal of vegetation and land clearing activities without proper sediment and erosion control practices, creates huge pressure over coastal ecosystems and diminishes the attractiveness for recreation and tourism. To address this scenario, in 2011, NOAA launched the initiative entitled *Habitat Blueprint* to address the growing challenge of coastal and marine habitat loss and degradation by integrating habitat conservation projects throughout the agency, focusing efforts in ten key locations identified as the Habitat Focus Areas (HFA), and leveraging internal and external collaborations to achieve measurable benefits within a short time frame. In 2014, NOAA selected Puerto Rico's Northeast Marine Corridor and Culebra Island as the Caribbean region's HFA to apply the principles of the Habitat Blueprint.

Based on the forecasts and modeling done as part of the Puerto Rico's State of the Climate Report; prediction of increased warm temperatures including the number of days above 90 degrees as well as increased high intensity rainfall and considerable increases in average rainfall annually in May. In terms of impacts to the watersheds in the NEC, this has the potential to increase pollutant transport including sediment, nutrients, and bacteria to the coast from stormwater runoff and sanitary sewer overflows as well as from flooding events. This will have an impact on streams and rivers as well as coastal habitats. Increased air temperatures my also contribute to higher sea surface temperatures and with potentially longer duration exceedance of bleaching thresholds to coral reefs.

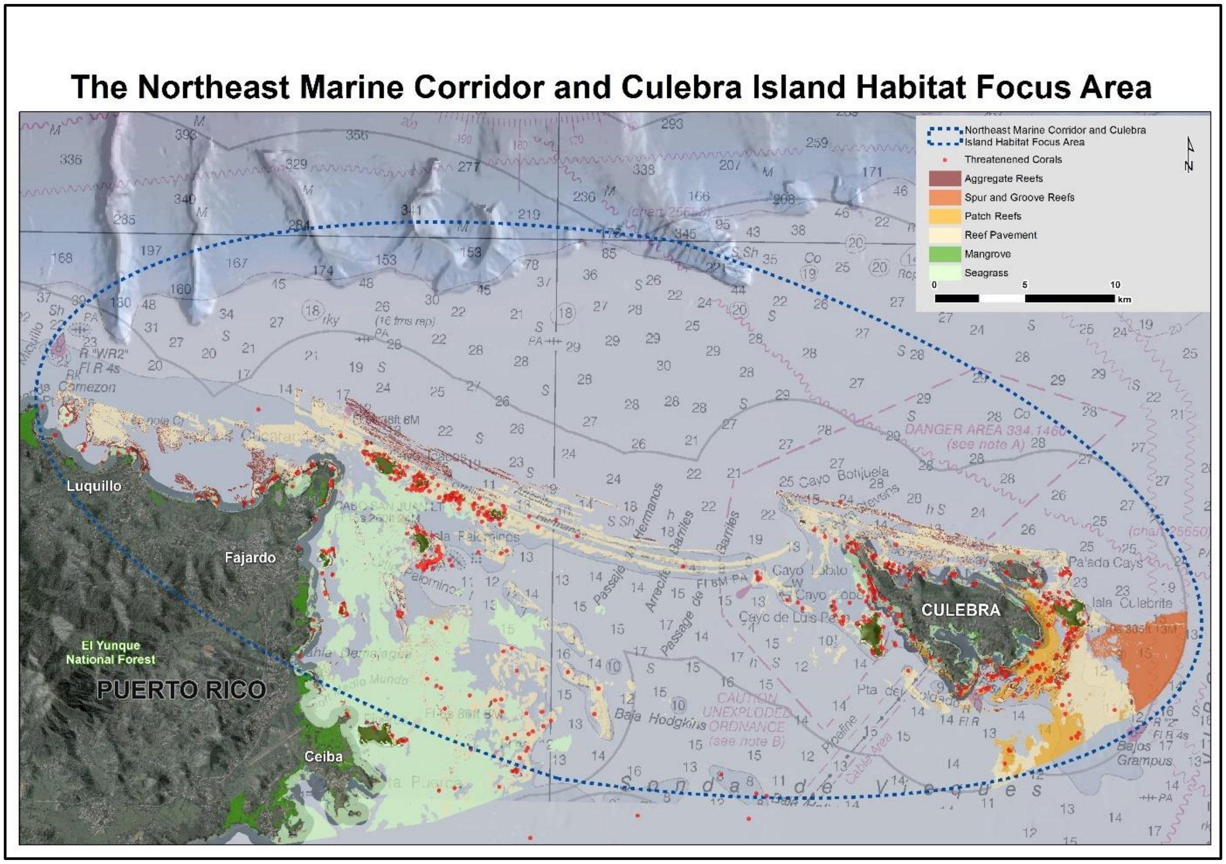
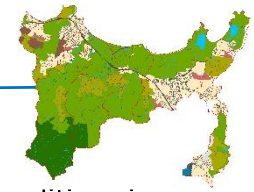


Figure 1. Habitat Focus Area Priority area. Map provided by NOAA National Centers for Coastal Ocean Science.

GENERAL WATERSHED CHARACTERIZATION



The watershed characterization is a useful tool for describing watershed conditions in the planning process of creating an integrated watershed management plan. By using a watershed approach, information can then be used for the identification of potential threats and possible solutions and for planning for future land uses. The characterization process of a watershed covers the nature of the different components of the watershed, as well as the determination of issues, vulnerability, and opportunities for development restoration interventions.

A combination of Geographic Information Systems (GIS), the use of areal imagery and field assessment has been implemented as tools to describe the different components of the watersheds in the project site. For the land use information, we have used GIS data provided by the Puerto Rico Planning Board including the land use layer from the Land Use Plan (LUP) (2015). The land use layer from the LUP was updated using actual satellite imagery and corroborated conducting field assessments.

PROJECT LOCATION

The study area is located in northeastern Puerto Rico and it covers a geographical extension area of approximately 20,369 acres (32 miles^2) within the municipalities of Luquillo and Fajardo. The area covers 80% of the territorial boundaries of the Luquillo Municipality and 38% of the Fajardo Municipality. A total of 25 miles of coastline are present on the project site and the majority are sandy beaches (22 miles). To the north, there are five mayor streams, Quebrada Mata de Pálatano, Río Sabana, Río Pitahaya, Rió Juan Martín and Quebrada Fajardo. To the east, there is the Fajardo River that has been worked separately in another watershed management plan.

The area can be divided into seven principal subwatersheds based on the existing topographic conditions and the drainage areas of the most significant streams that transports runoff to the marine environment. To the north, the subwatersheds are; Quebrada Mata de Plátano, Río Sabana, Río Pitahaya, Río San Martín, Quebrada Fajardo and to the east, Bahia Fajardo and Puerto del Rey (Figures 2 and 3).

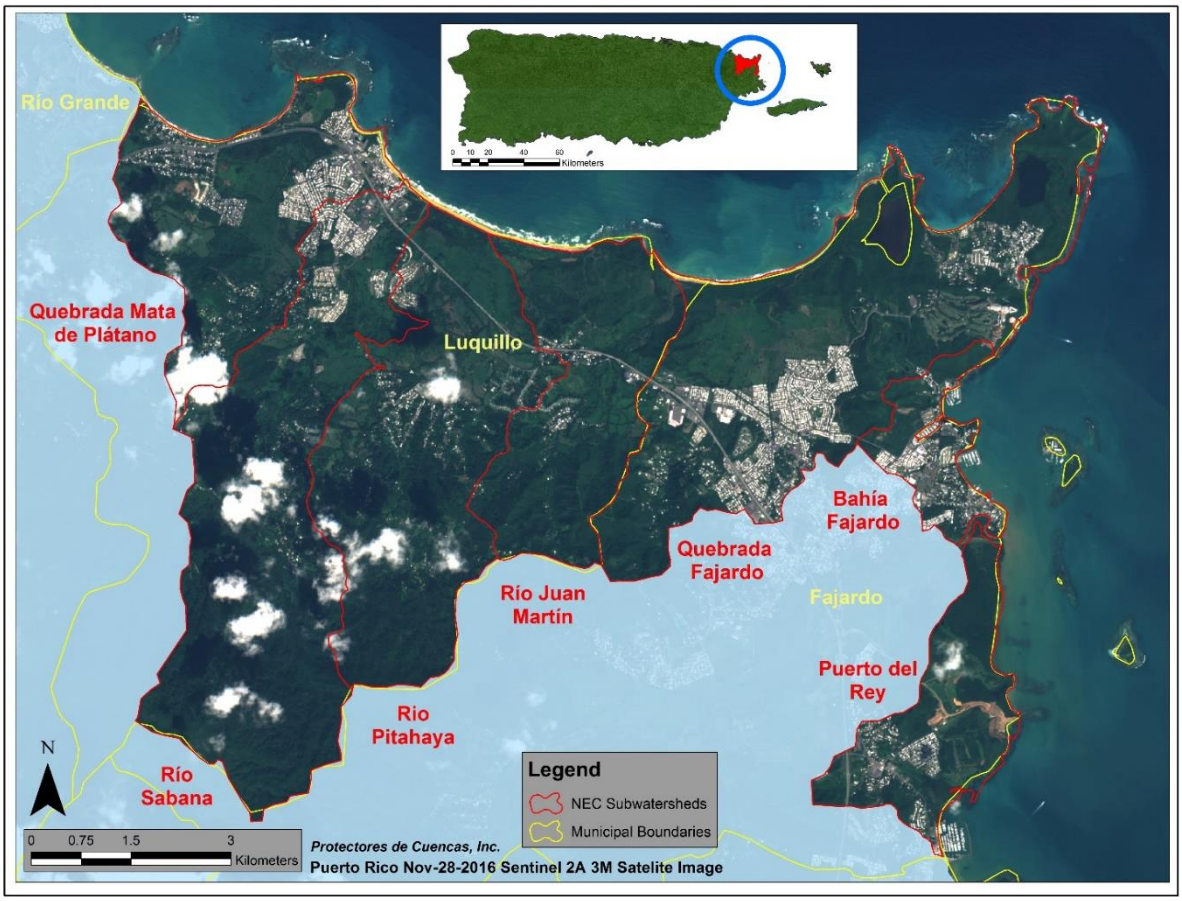


Figure 2. Map created using an actual satellite image of the study area with the subwateresheds and municipal boundaries.

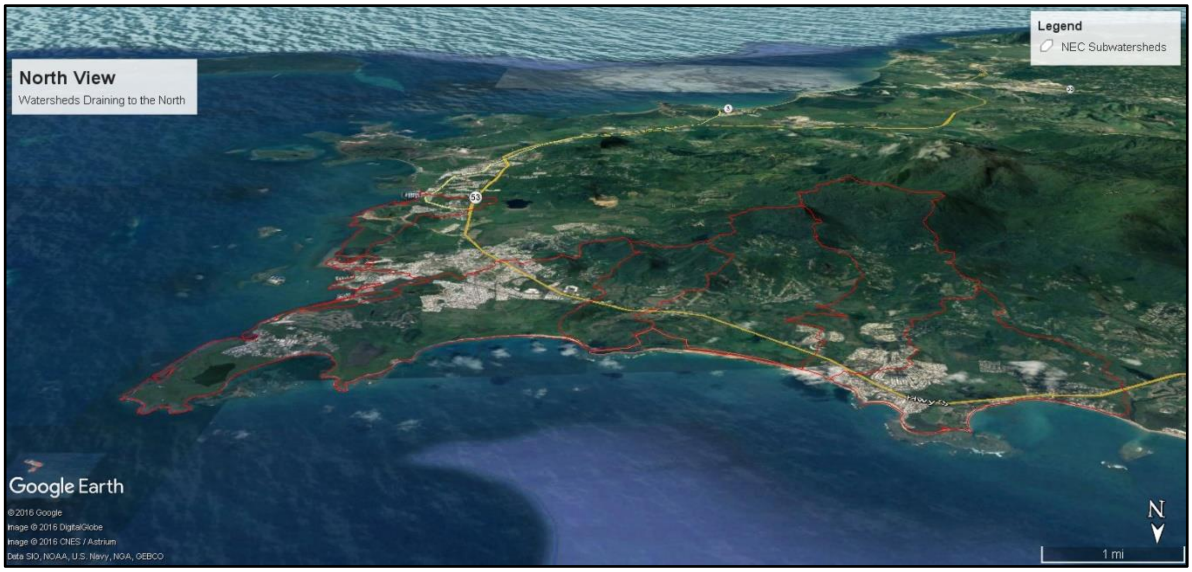


Figure 3. Google Earth map of a ground view perspective of the NEC Watersheds

HISTORIC LAND USE

Northeastern Puerto Rico was mostly cleared for agriculture up to the 1950's. There are still in-stream sediment deposits that can be traced to that era. With the economical paradigm shift that happened in the island between 1950's and 1960's agricultural activity decreased while urbanization and industrialization increased. Thus, coastal waters in this region received a mixture of large yields of sediment, pollutants and nutrients from eroding land and developing coastal areas.

The watersheds of the northeast region also receive the island's highest mean precipitation. Streamflow gaging stations used to characterize water and sediment discharge to coastal waters estimate that from 1990 to 2000, rivers in eastern Puerto Rico contributed between 51,000 to 180,000 metric tons of suspended sediments to coastal waters per year (Warne et al., 2005). This mosaic area includes the presence of different ecosystems such as lagoons, mangrove forests, coastal dry forest, Thalassia grass beds and coral reefs. This Critical Wildlife Area, as designated by the DNER, has two main lagoons: Laguna Grande and Aguas Prietas. These lagoons are important because they are surrounded by mangrove forest, producing a buffer zone and important habitat for bird species to forage and reproduce, as well as habitat for important fish species. Laguna Grande (78 acres) is a bioluminescent lagoon located 5 km to the north of Fajardo. The bottom of the lagoon is sandy with Thalassia beds and Acetabularia grass. The lagoon is surrounded by red mangrove. The Aguas Prietas Lagoon has an area of approximately 110 acres and is connected to the sea. At least four heron species nest in the mangrove forest that surrounds Aguas Prietas Lagoon (Rivera-Ortiz et al. 1981). Furthermore, the sandy beaches of these areas represent the most important nesting habitat for the leatherback turtle *Dermochelys coriacea* in Puerto Rico. In the easternmost part of the NEC there is La Cordillera Natural Reserve (LNR). This is a shallow, narrow submarine ridge approximately 29 km long, turning east-southeast and supporting several islets with high quality fringing reefs. Some of the cays are: Los Farallones, Icacos, Ratones, Diablos, Blanquilla, Cucaracha, Hermanos reef, Barriles reef and Lobos. These cays are abundant in *Thalassia testudinum* and are surrounded by different species of coral. Surrounding these islands are the best-developed fringing reefs of the northeast coast of Puerto Rico (CWA, 2005).

Between 1936 and 2004, the watersheds of the northeast region experienced major changes including natural reforestation of former sugar cane fields and a ten-fold increase in urban areas (Ramos-Scharrón et al., 2015). Between 1977 and 1999, urban spaces doubled in northeast Puerto Rico and increased by 16% between 1991 and 2003. Overall population trends were characterized by suburbanization of the rural landscape. The urbanization process became evident to the south of Finca Convento Sur, where communities such as Fajardo Gardens, Vistas del Convento and Monte Brisas were developed, establishing a physical limit to the forested areas of the corridor. The construction of PR highway # 3 and the consolidation of the Borras community in Luquillo did the same in the western portion of the NEC. Between the second half of the 1970s and the beginning of the 1980s, the public housing complexes El Cemí and Yuquiyú were built just west of the Sabana River. Further, in the mid 1990's, El Conquistador Resort & Country Club built a parking lot and a big cistern facility adjacent to the east of the NEC. In the second half of the 1990's, the apartment complex known as Vistas del Convento was built on top of the mountain southeast of Finca las Paulinas.

To the southwest corner of Finca el Convento, Eastern Plaza Shopping Center was built. In the same timeframe, several high-cost residences began construction in the Cascajo sector, to the east of Convento Norte. In addition, south of the Finca Seven Seas, land movement work began for the construction of the Seven Seas Hotel and Resort which was never completed. During the second half of the 1990's development of rural areas increased and continued their movement towards the Caribbean National Forest (El Yunque). This caused a significant fragmentation of the zones designated as agricultural lands.

Currently, in the rural and urban area within the delimitation of the adjacent areas to the NEC south of the PR-3 to the delimitation of the El Yunque National Forest, we find the following areas and sectors developed: The urban area Los Paisajes, Hacienda Margarita, Los Palacios and Hacienda Consuelo, as well as the Sectors Borras, Boquerón and Las Paulinas; Towards the interior, we find the existing communities Sabana and its Sectors Las Viudas, Taní and Yuquiyú; The Casablanca Community and its sectors such as Cuesta del Gato, Cuesta del León, Cuenta del Tigre and Los Barros; The Community Juan Martín; The Community Ramos; New Plots, Santo Domingo, Río Chiquito and Gabina.

Actual Land Use

By using the most actualized land use information (Figure 4) combined with the use of aerial images and field assessments we have created the following land use categories for the area to be used in the water quality assessment process. The land use data provided by the Puerto Rico Planning Board from the Land Use Plan (2015) was updated with aerial images and field assessments to reflect, not just planed uses, but to include actual existing uses. These categories have been summarized into Forest, Urban, Agriculture, Water, Roads, Projected Urban and Bare Soils (Table 1, Graph 1). The Forest category includes all area that currently contains vegetative cover. The Urban category combines Low, Medium and High Density Urban as well as, Industrial, Comercial and Institutional. The Agriculture Category includes areas that are currently on active agricultural use or are designated to be preserve as agricultural land. The road category includes all the road network from the area that is mostly paved. The water category includes all the open water bodies present on the area. Projected Urban category is composed of land that is mostly covered by vegetation but has been identified for future urban development. The Bare Soil areas includes all the land cover that has been identified as perturbed by the removal of most of its vegetative cover and it includes active and abandoned construction sites, dirt road networks and areas of unstable soils.

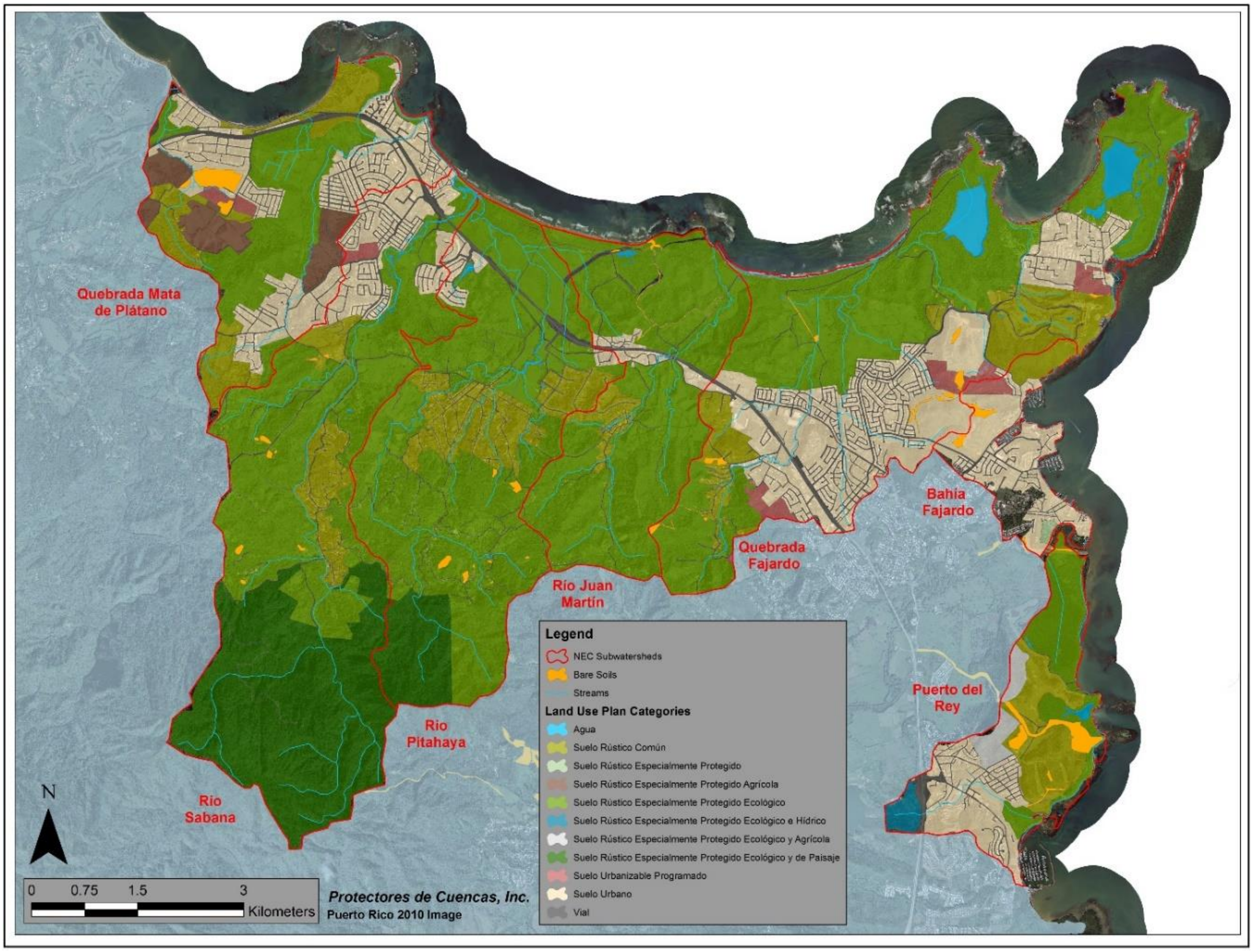
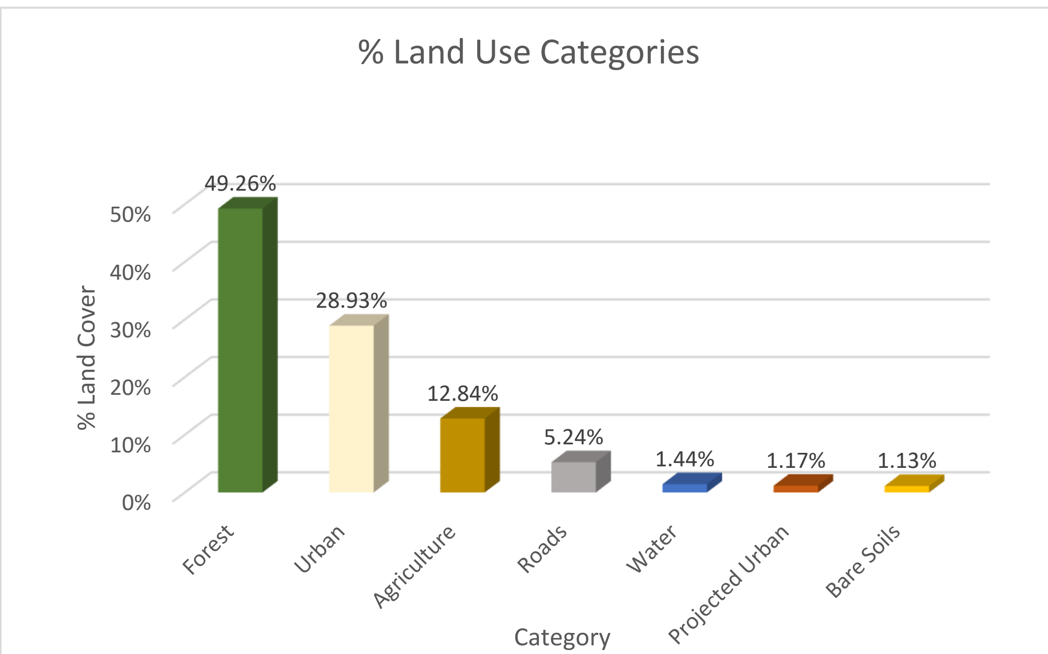


Figure 4. Map created using the most actual land use information from the Land Use Plan. Puerto Rico Planning Board (2015).

Table 1. Land use categories.

Category	Acres	% Land Cover
Forest	10,028.21	49.23%
Agriculture	2,628.96	12.91%
Low Density Urban	2,398.72	11.78%
High Density Urban	2,329.43	11.44%
Roads	1,067.56	5.24%
Medium Density Urban	691.29	3.39%
Comercial	305.03	1.50%
Water	292.31	1.44%
Projected Urban	237.40	1.17%
Industrial	145.74	0.72%
Bare Soils	170.00	0.83%
Institutional	75.14	0.37%
TOTALS	***20,369.79***	***100%***

Graph 1. Summarized land use categories (urban is a combination of urban, commercial and industrial land uses)

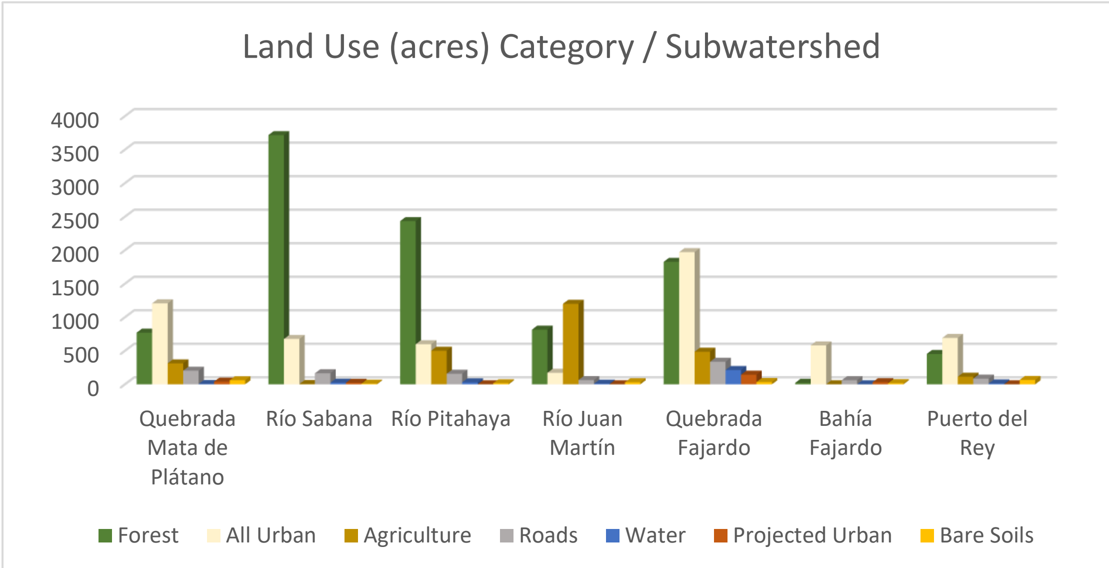


At present, most of the land use (49.26%) has been identified as forest cover followed by the urban category (28.93%), agriculture (12.84%), roads (5.24) water (1.44%), projected urban (1.17%) and bare soils (1.13%). Urban areas are mostly concentrated in the Quebrada Fajardo and Mata de Plátano subwatersheds. Río Sabana and Río Pitahaya subwatersheds have the most forest cover. Most of the agriculture activities are concentrated in the Río Juan Martín, Río Pitahaya and Quebrada Fajardo subwatersheds. Most of the Bare Soils areas are present in the Puerto del Rey and Mata de Plátano Subwatershed. Quebrada Fajardo has the most projected urban planned (Table 2, Graph 2 and Figures 5 to 11). In terms of protected land, it is estimated that 31% (6,241 acres) of all land cover within the project site is protected (Figures 12 and Table 3).

Table 2. Land Use Categories by Subwatershed in Acres.

Subwatershed	Forest	All Urban	Agriculture	Roads	Water	Projected Urban	Bare soils
Quebrada Mata de Plátano	769	1,207	312	203	5	40	60
Río Sabana	3716	676	3	164	24	23	10
Río Pitahaya	2,433	597	500	157	29	0	15
Río Juan Martín	815	172	1200	63	9	0	30
Quebrada Fajardo	1,826	1,971	486	336	213	143	34
Bahía Fajardo	21	580	0	61	0.3	32	16
Puerto del Rey	452	691	114	84	12	0	65
TOTALS	**10,033**	**5,894**	**2,615**	**1,068**	**292**	**237**	**230**

Graph 2. Summarized land use categories (urban is a combination of urban, commercial and industrial land uses)



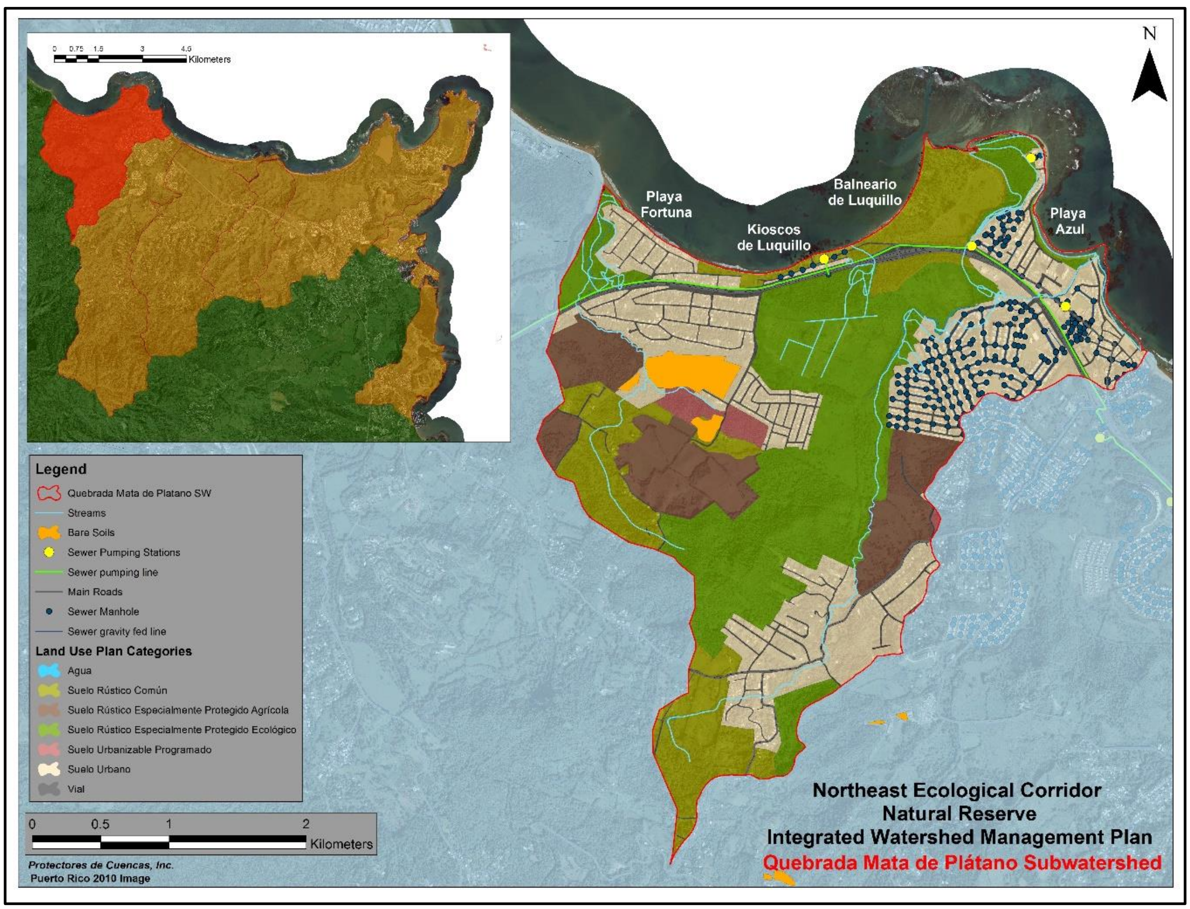


Figure 5. Quebrada mata de Plátano Subwatershed actual land uses.

Figure 6. Río Sabana Subwatershed actual land uses.

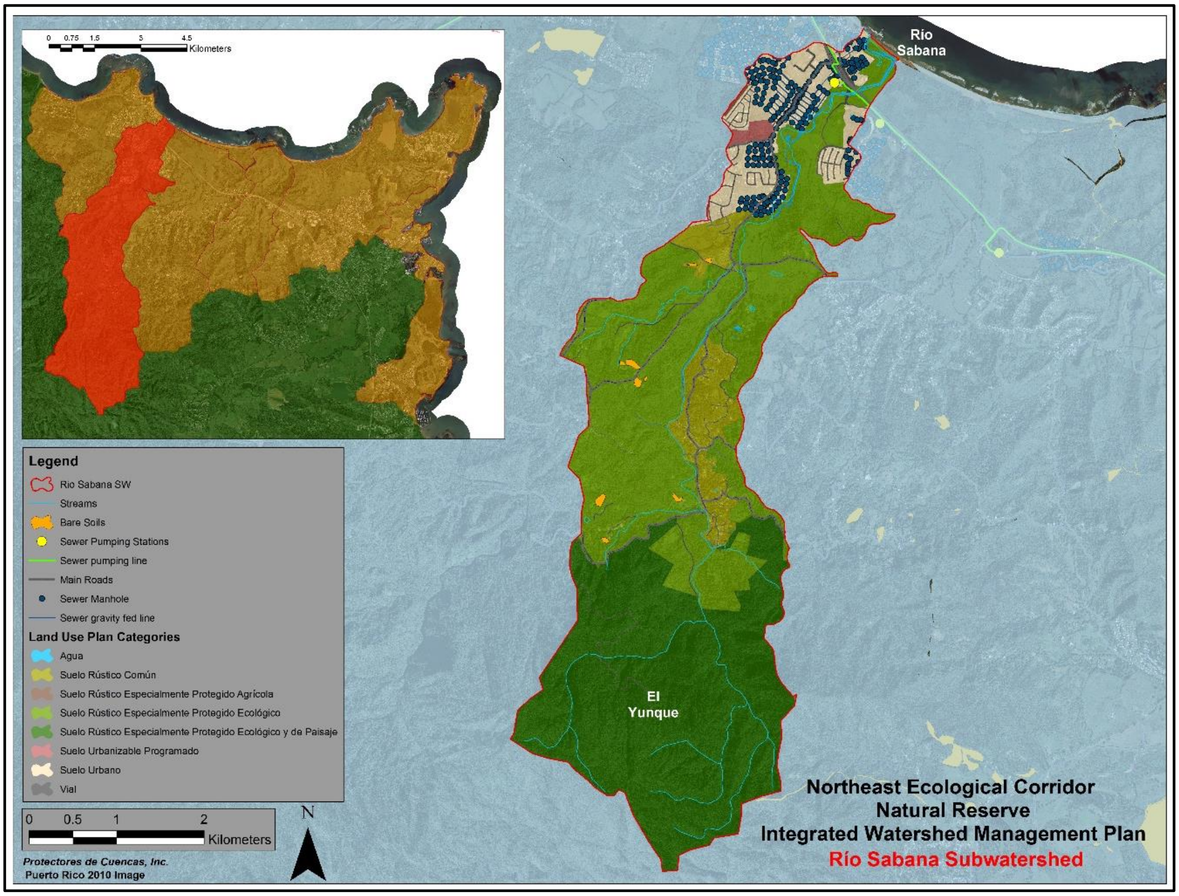


Figure 7. Río Pitahaya Subwatershed actual land uses.

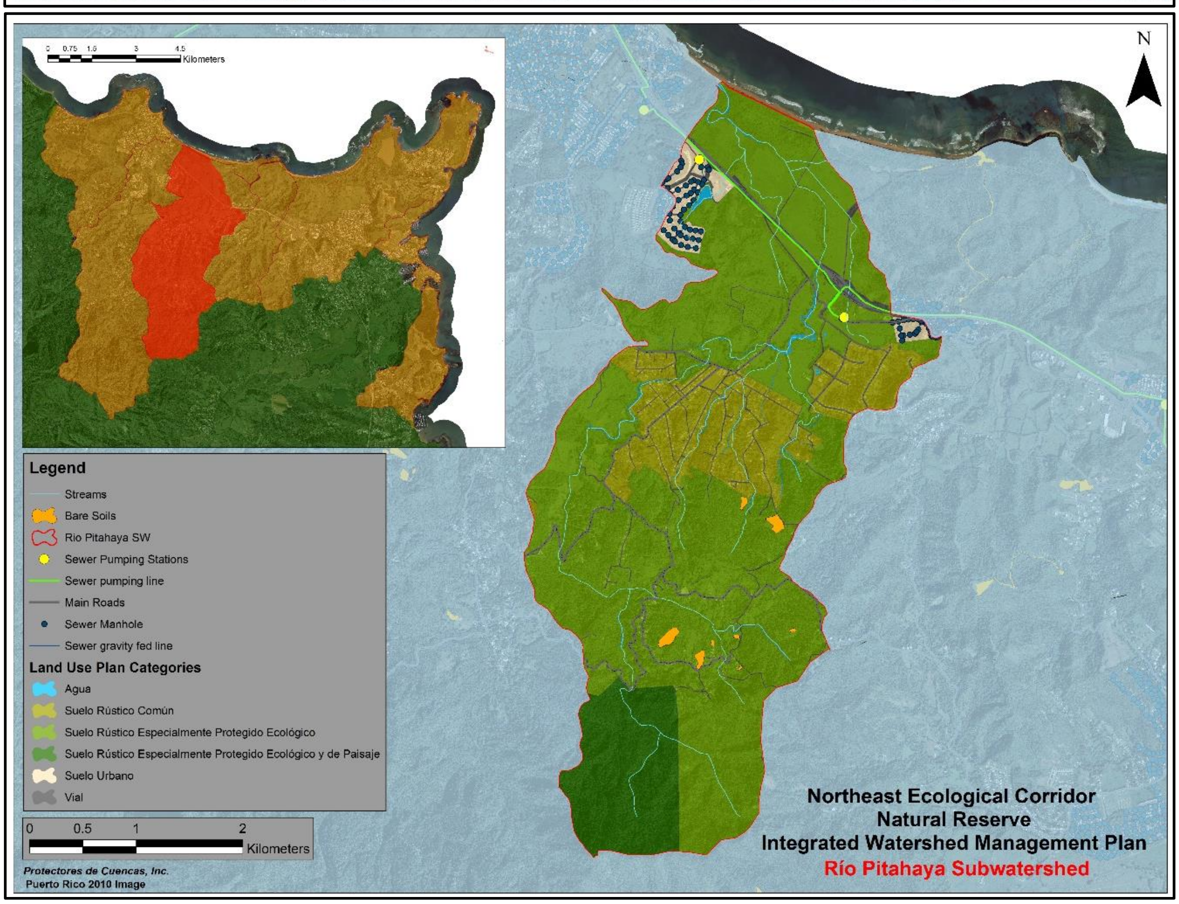


Figure 8. Río Juan Martín Subwatershed actual land uses.

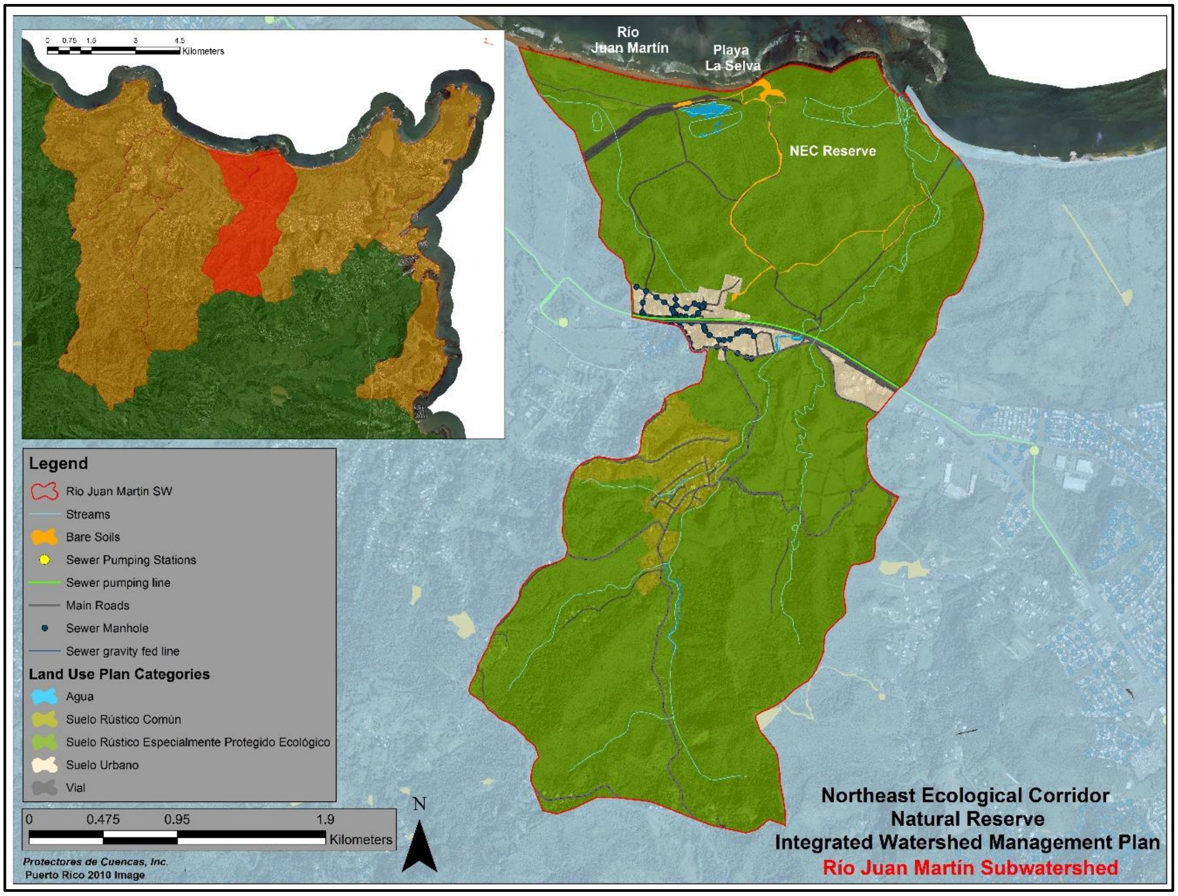


Figure 9. Quebrada Fajardo Subwatershed actual land uses.

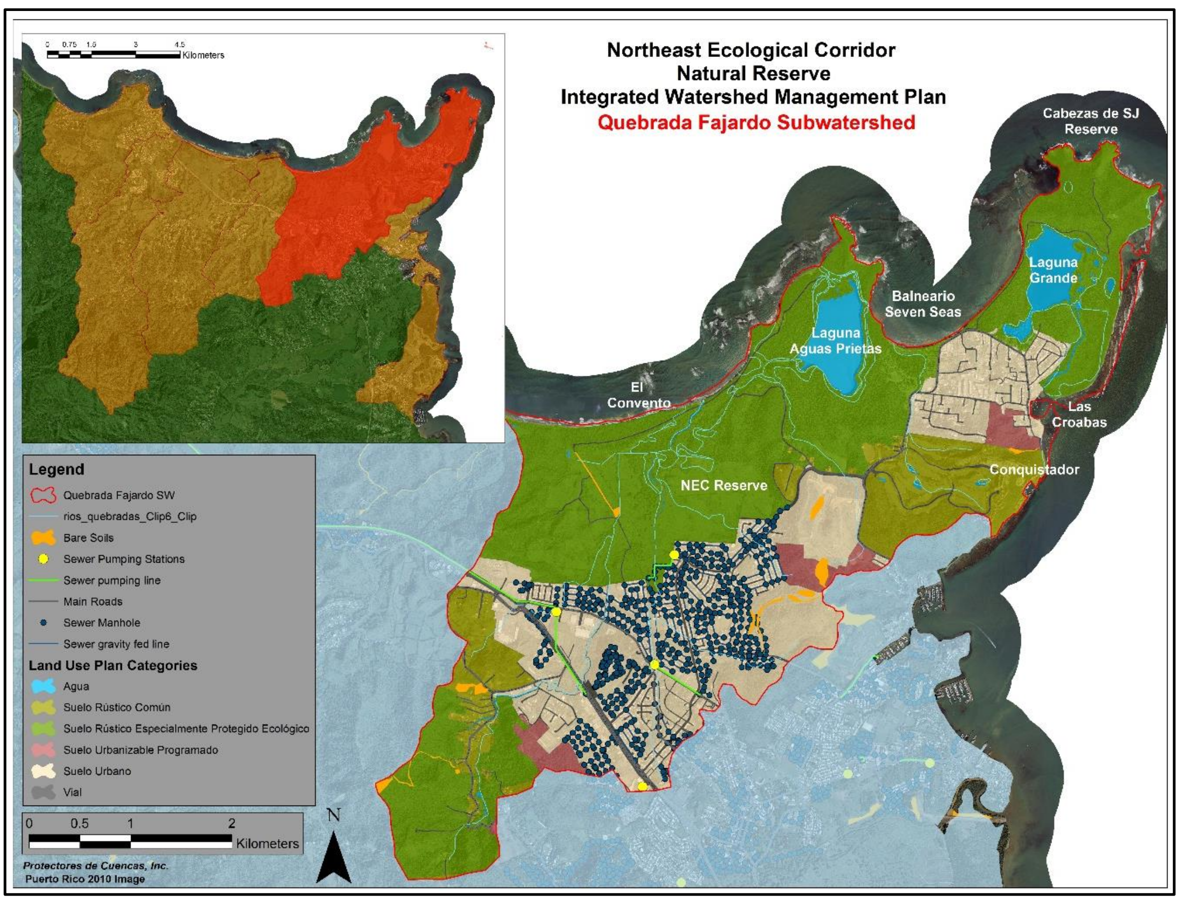


Figure 10. Bahía Fajardo Subwatershed actual land uses.

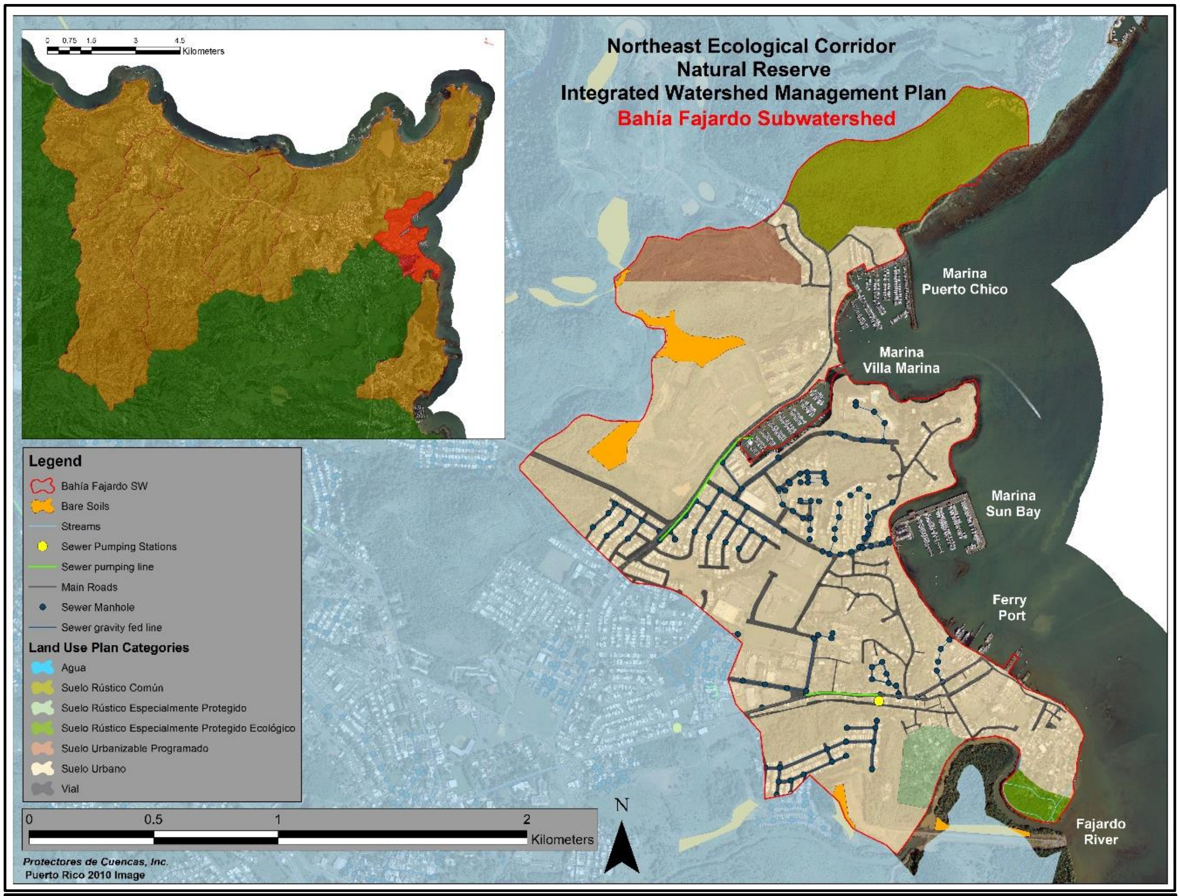
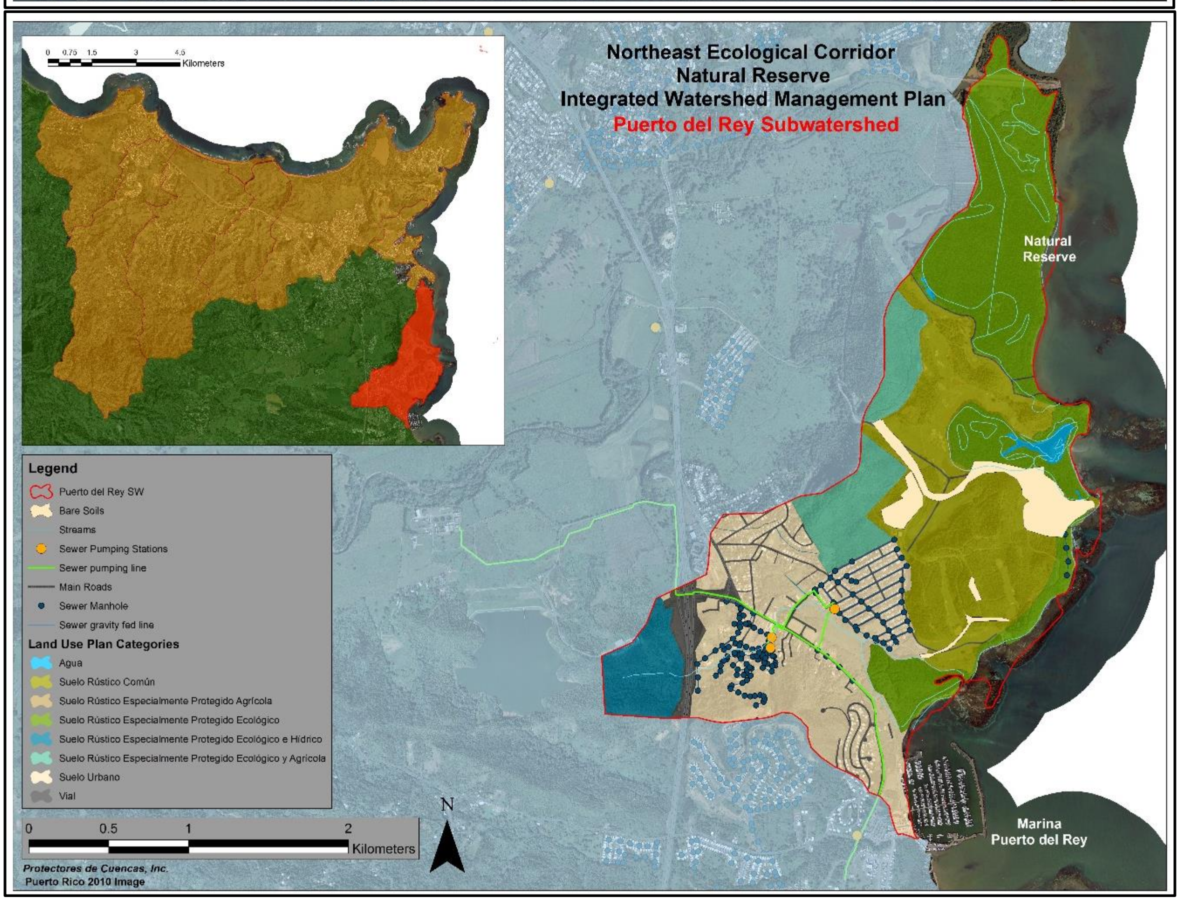


Figure 11. Puerto del Rey Subwatershed actual land uses.



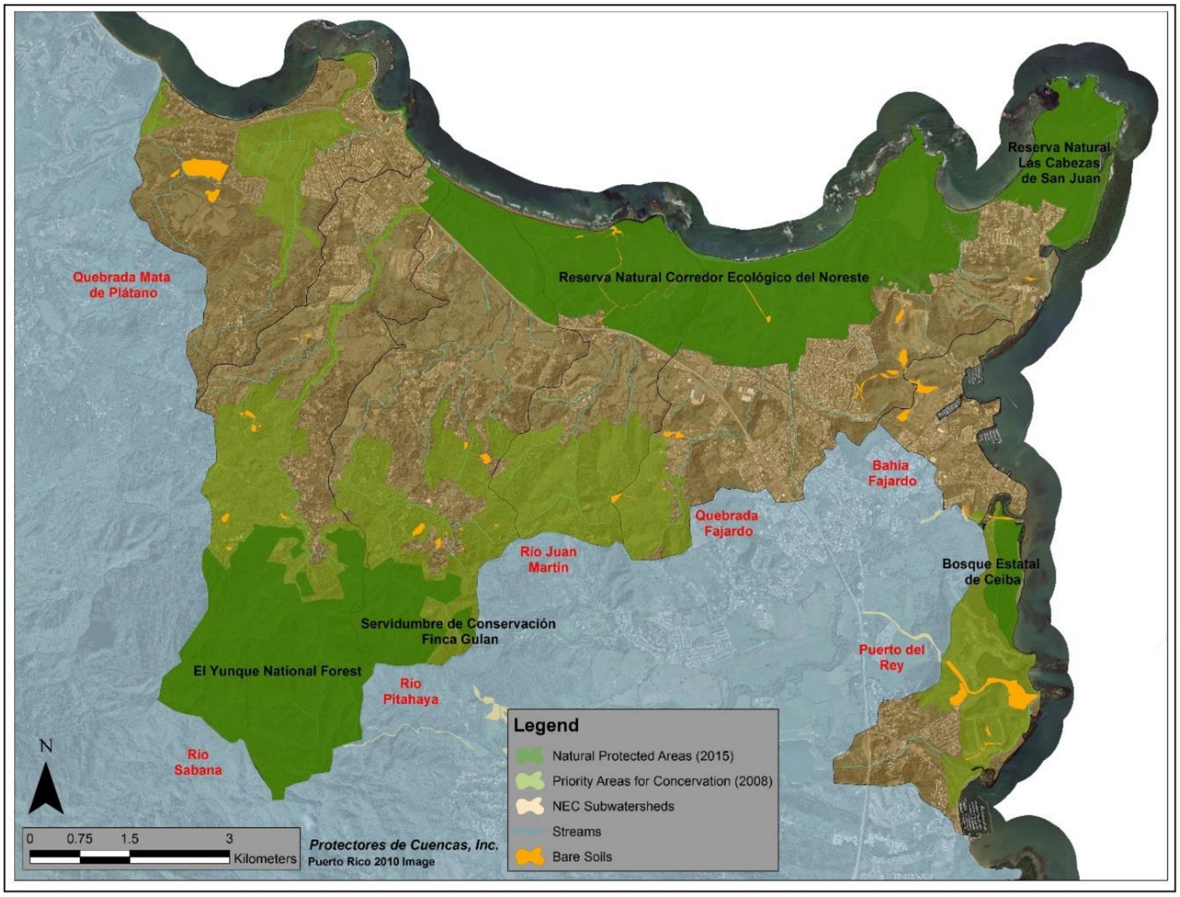


Figure 12. Map of the Natural Protected Areas (2015) and areas designated as priority for conservation (2008).

Table 3. Natural Protected Areas of the NEC.

Category	Manager	Acres	% Land Cover
El Yunque National Forest	**US Forest Service**	2385	12%
Bosque Estatal de Ceiba	**DRNA**	171	1%
Reserva Natural Corredor Ecológico del Noreste	**DRNA**	2901	14%
Reserva Natural Finca Seven Seas	**DRNA**	205	1%
Reserva Natural Las Cabezas de San Juan	**Para la Naturaleza**	554	3%
Servidumbre de Conservación Finca Gulán	**Para la Naturaleza**	25	0%
	TOTALS	**6,241**	**31%**

SEWER INFRASTRUCTURE

The Fajardo Regional Wastewater Treatment Plant (FRWTP) provides tertiary treatment to wastewater generated in the municipalities of Fajardo, Luquillo and Ceiba with a total population served of approximately 95,588 (from the NECMP) residents (Figure 13). The

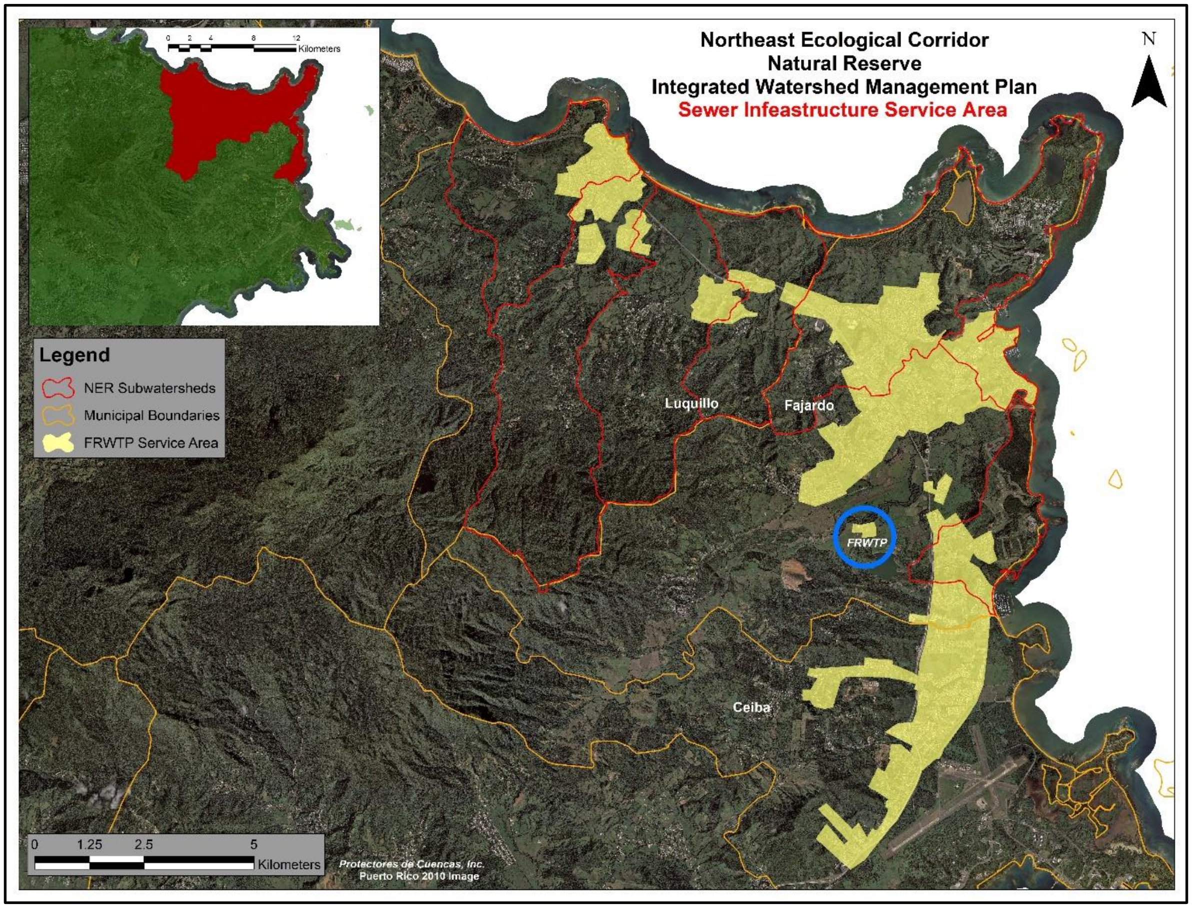


Figure 13. FRWTP total service areas (data provided by PRASA).

plant is operated by PRASA. The FRWTP discharges between 5 and 8 million gallons per day of tertiary treated wastewater to the Fajardo River each day with an estimated concentration of 6 mg per liter of total nitrogen and 0.5 mg per liter of total phosphorus based on EPA Echo Reporting. It is located south of the river bank in the eastern part of the watershed approximately at 1 mile from PR-3 highway. The total area of service for the NECWTP is estimated to be of 6,977 acres.

Of the NER watersheds, it is estimated that roughly 18% (3,411.10 acres) of the watershed is serviced for sewer infrastructure. This represents that 100% of the urban areas have sewer infrastructure. Another 8% of the low-density areas have been identified by PRASA with the conditions to expand sewer service and another 1% is pending an expansion project (Las Croabas area) (Figure 14, Table 4).

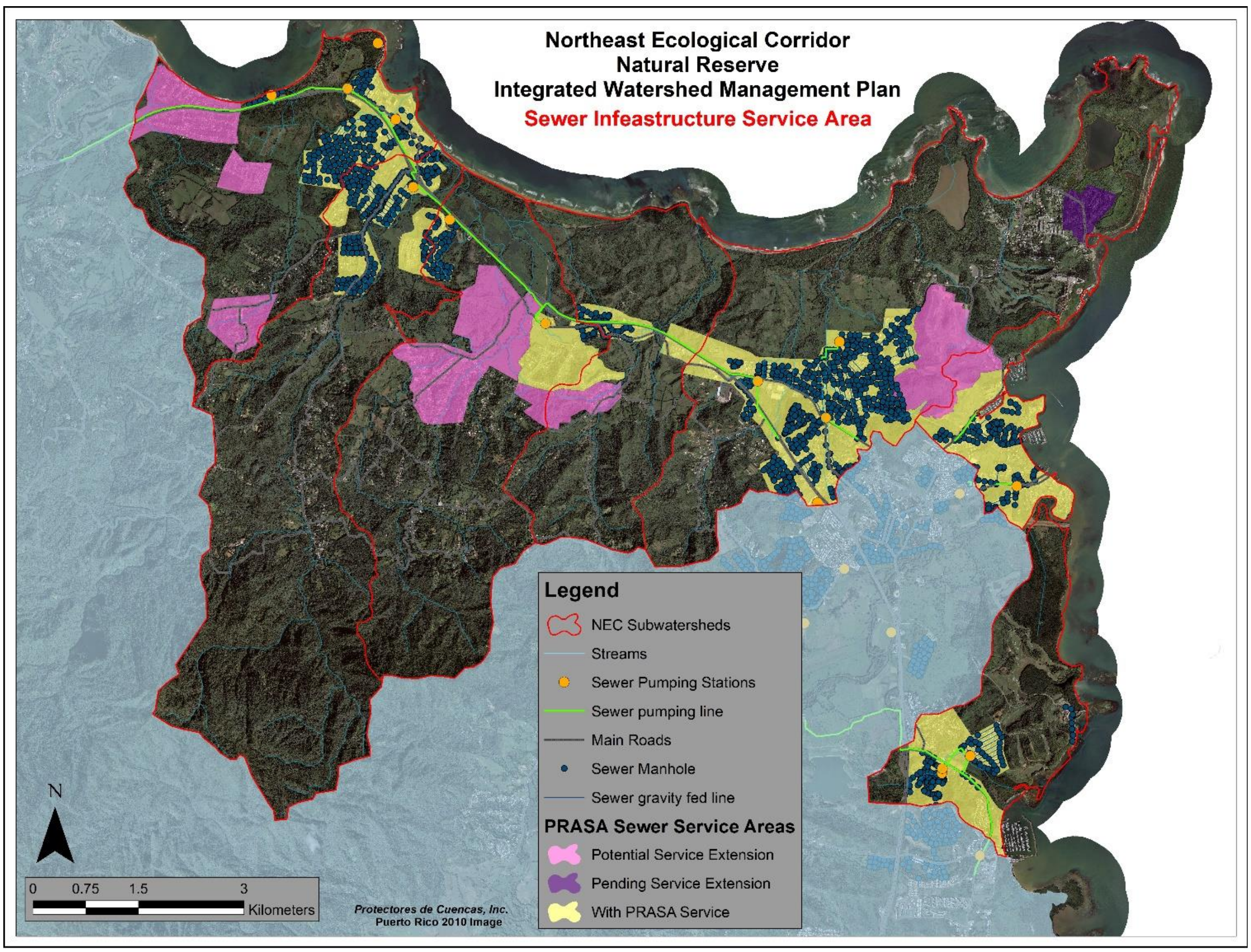


Figure 14. Map of the NECW areas that have sewer infrastructure service managed by PRASA.

Table 4. Main communities that have sewer infrastructure serve.

Communities with sewer infrastructure service			
Vista del Convento	Puerto Real	Sardinera	Alamar
Monte Brisas	Reparto La Plata	Baralt	Residencial el Yuquiyú
Fajardo Gardens	Villas de Puerto Rico	Boquerón	Luquillo Lomas
Reparto Valle Verde	Beltrán	Borras	Villa Angelina
Villas de Luquillo	Luquillo Mar	Costa Sur	Solimar

It is important to mention that even if most of the urban areas are serviced for sewer treatment, it is a system that has constant failures and overflows to the stormwater system (Figure 15). This is mainly caused by clogged manholes and pumping issues. The system requires an intense, constant maintenance protocol. The other main problem encountered with the sewer system is that there's a high percent of homeowners that are not connected to the system and there is very little information about the percent of people that are actually connected. The main reasons causing these problems are in most cases, the lack of financial resources from the homeowners, the lack of enforcement protocols and actions. PRASA charges a fee to homeowners when a sewer system is available in the area and the connection point offered to people is installed adjacent to each property and the homeowner is responsible for the cost and installation and connecting their home or business to the system. Sometimes in the lower parts of the watershed, it requires a pumping system at the expense of the owner. The best scenario estimates that people connected to the system are less than 40% of the total population of areas with sewer system in place (from conversations with PRASA personnel, 2017).

Figure 15. Examples of failing sewer infrastructure across the area. Images provided by Hector Sanchez from the Fajardo Municipality Planning Board and PDC staff. Pictures are from 2014, 2016 and 2017 showing persistent problems of sewage overflows.

HYDROLOGY

Landscape range from elevations around 1,100 meters at the headwaters to coastal floodplains that stretch to the sea. Climate is mostly influenced by these elevations that dominate the area. Wind circulation is dominated by trade winds that flow from East to West. These winds change near the surface due to local effects, particularly the breeze generated on land and sea in coastal areas and the breezes generated in the interior between valleys and mountains. Sea breezes occur in the afternoon, because of the heat transfer that occurs at the surface of the land and the sea. The eastern winds of the tropical ocean and local breezes in the afternoons produce a continuous flow of moist air inland that when condensed in the mountains generate downpours. The watersheds of the northeast region receive the island's highest mean precipitation. The orographic effect is notorious in the region due to the action of the winds against the slopes of the mountains. For this reason, the annual precipitation averages reported in this area have variations between the mountain and the coast. That is, in the mountainous region an annual average of 279.4 to 381.0 cm (110-150 inches) can be reported, while on the coast these amounts can vary from 177.8 to 200.0 mm (70-78.7 inches).

Using GIS data from the National Hydrography Dataset (NHD) (feature-based database that interconnects and uniquely identifies the stream segments or reaches that make up surface water drainage system) we have calculated the number of miles of streams present at each subwatershed. A total of approximately 70 miles of streams are present in the project site. Most streams are percent in the Quebrada Fajardo and Rio Pitahaya subwatersheds. To the North, there are five mayor streams, Quebrada Mata de Pálatano, Río Sabana, Río Pitahaya, Río Juan Martín and Quebrada Fajardo. To the east, there is the Fajardo River that has been worked separately in another watershed management plan. Aquifers are most restricted to the coastal valleys areas (Figure 16).

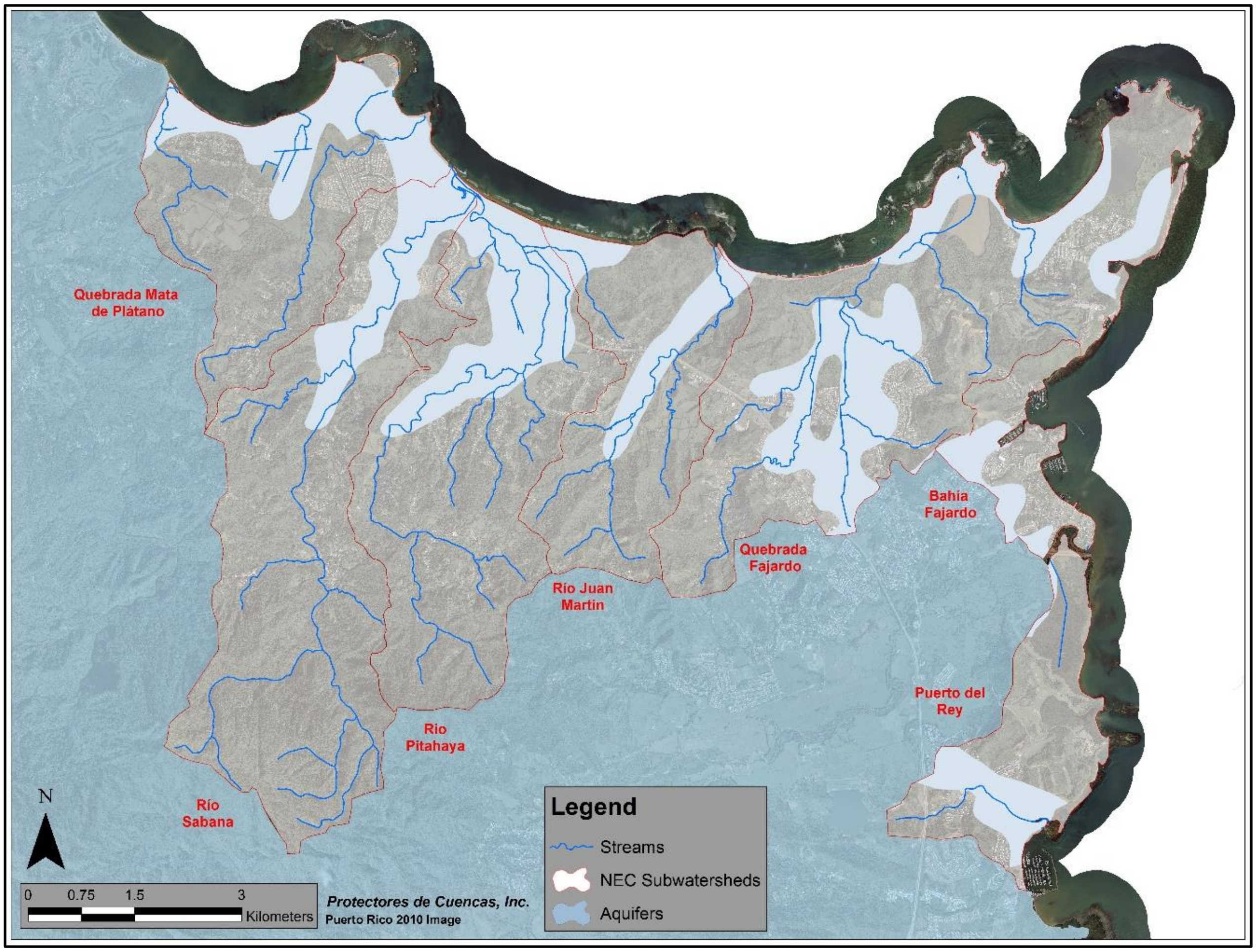


Figure 16. Map of the water resources on the NECW.

Using the National Wetland Inventory, we have estimated that 15% (2,993 acres) of the project site is classified as wetland (Figure 17-24). The most common wetland type in the area is Estuarine and Marine Wetland followed by Freshwater Emergent, Estuarine and Marine Deepwater, Fresh Forested/Shrub, Riverine and Freshwater Pond (Table 5, Graph 3).

Quebrada Fajardo and Quebrada Mata de Platano subwatersheds have the vastest concertation of wetlands (Table 6, Graph 4).

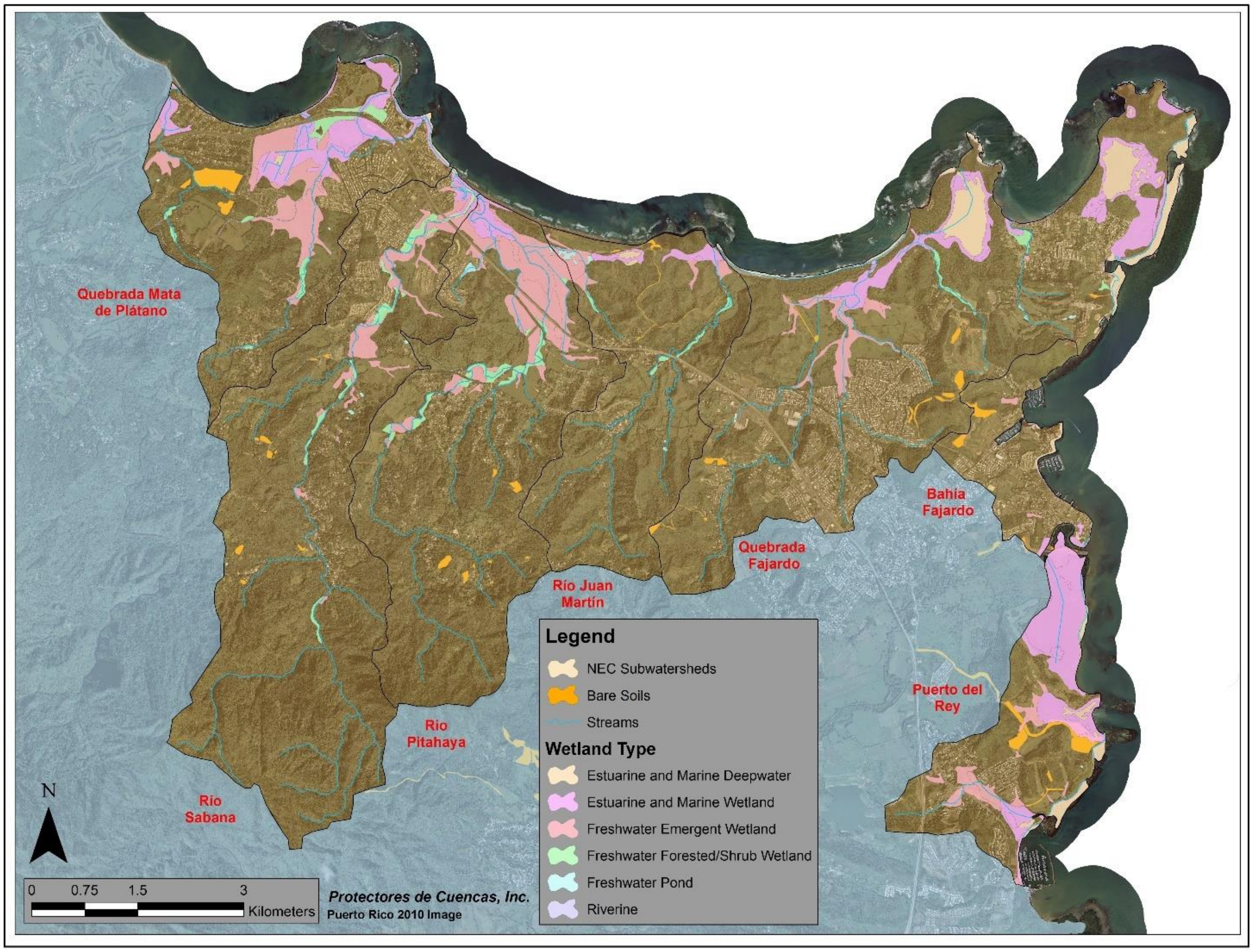


Figure 17. Map with wetland areas from the National Wetland Inventory

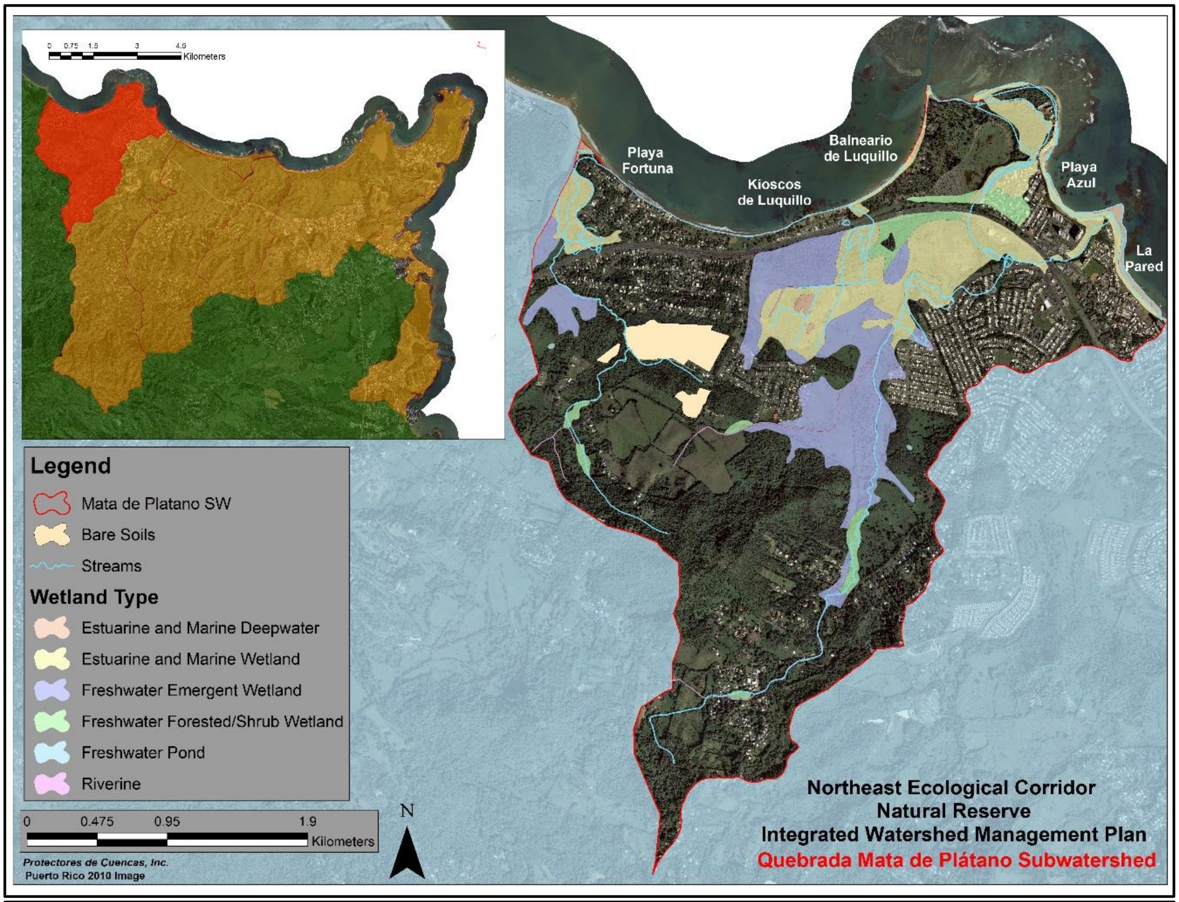


Figure 18. Mata de Plátano Subwatershed wetland areas.

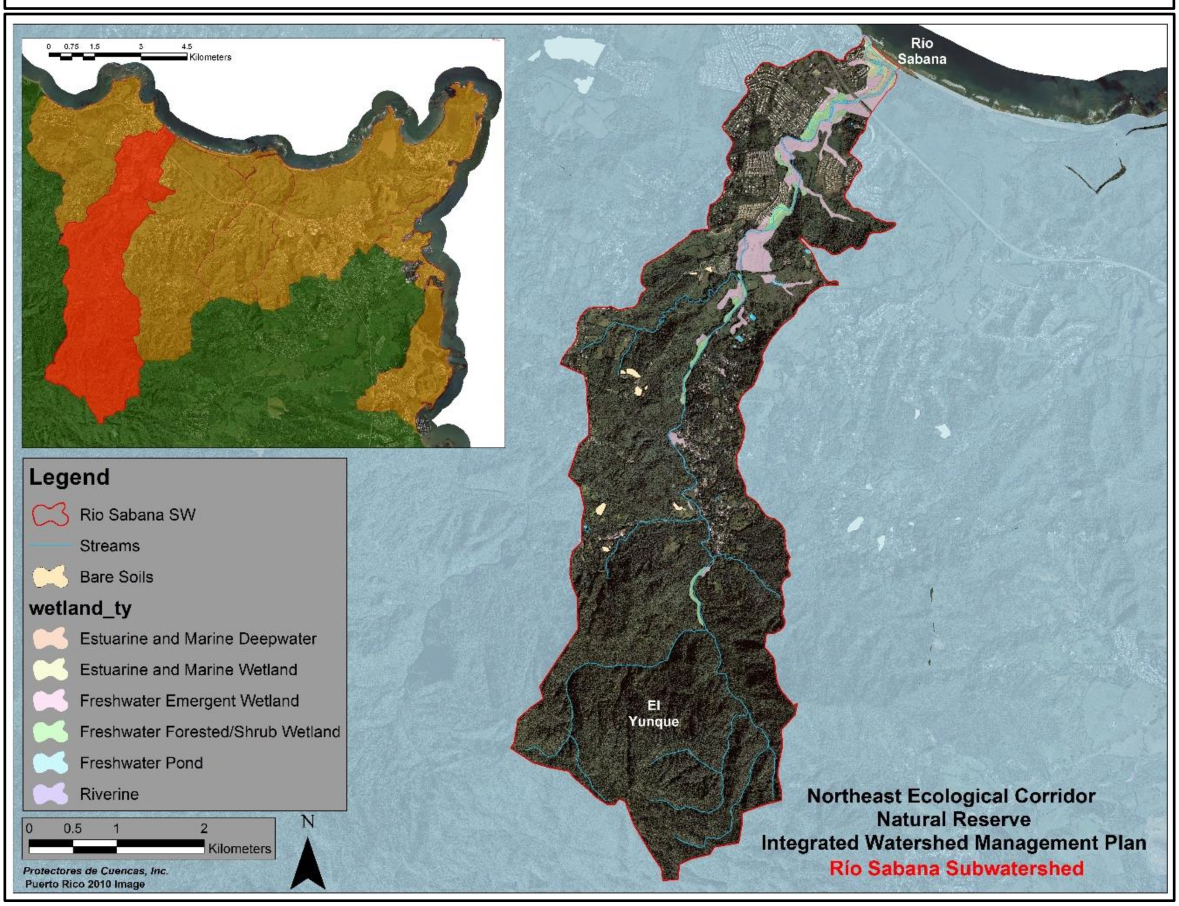


Figure 19. Río Sabana Subwatershed wetland areas.

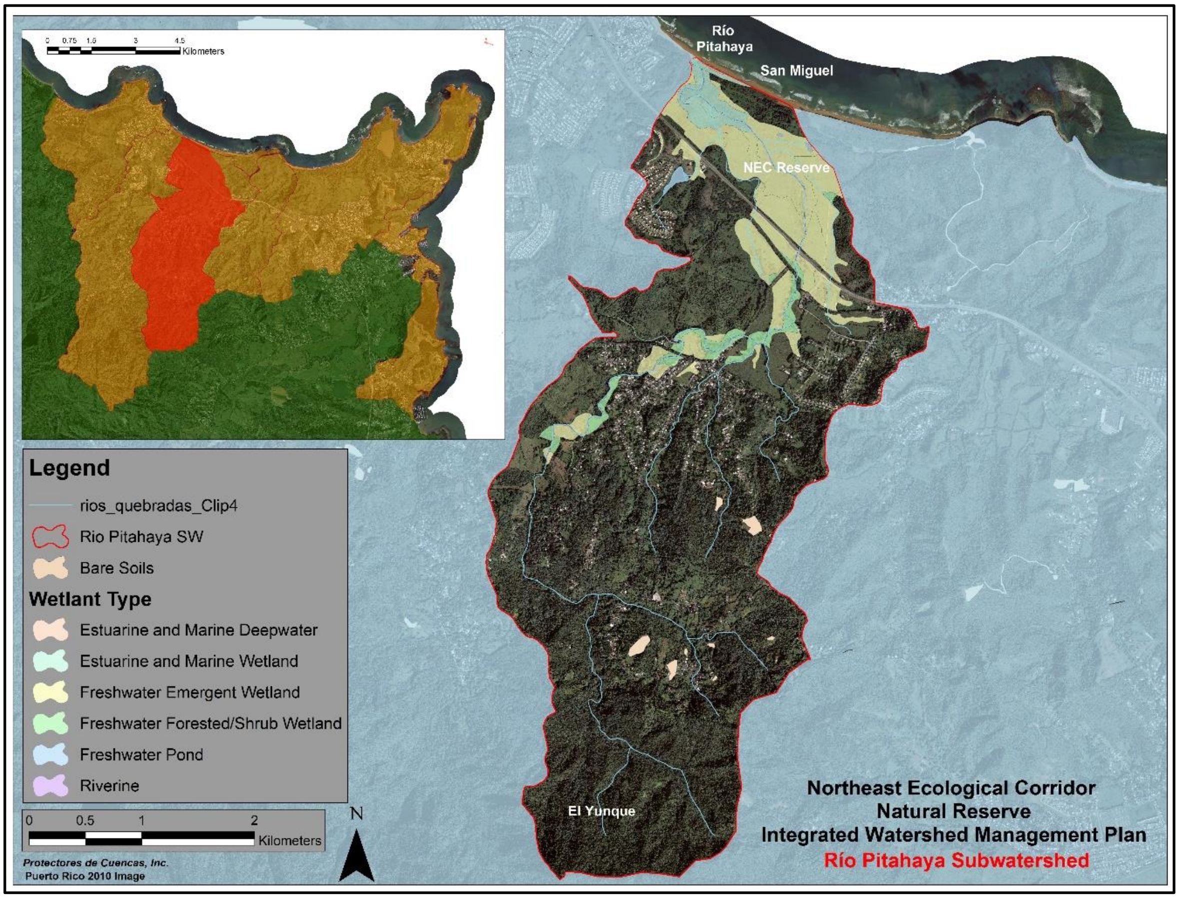


Figure 20. Río Pitahaya Subwatershed wetland areas.

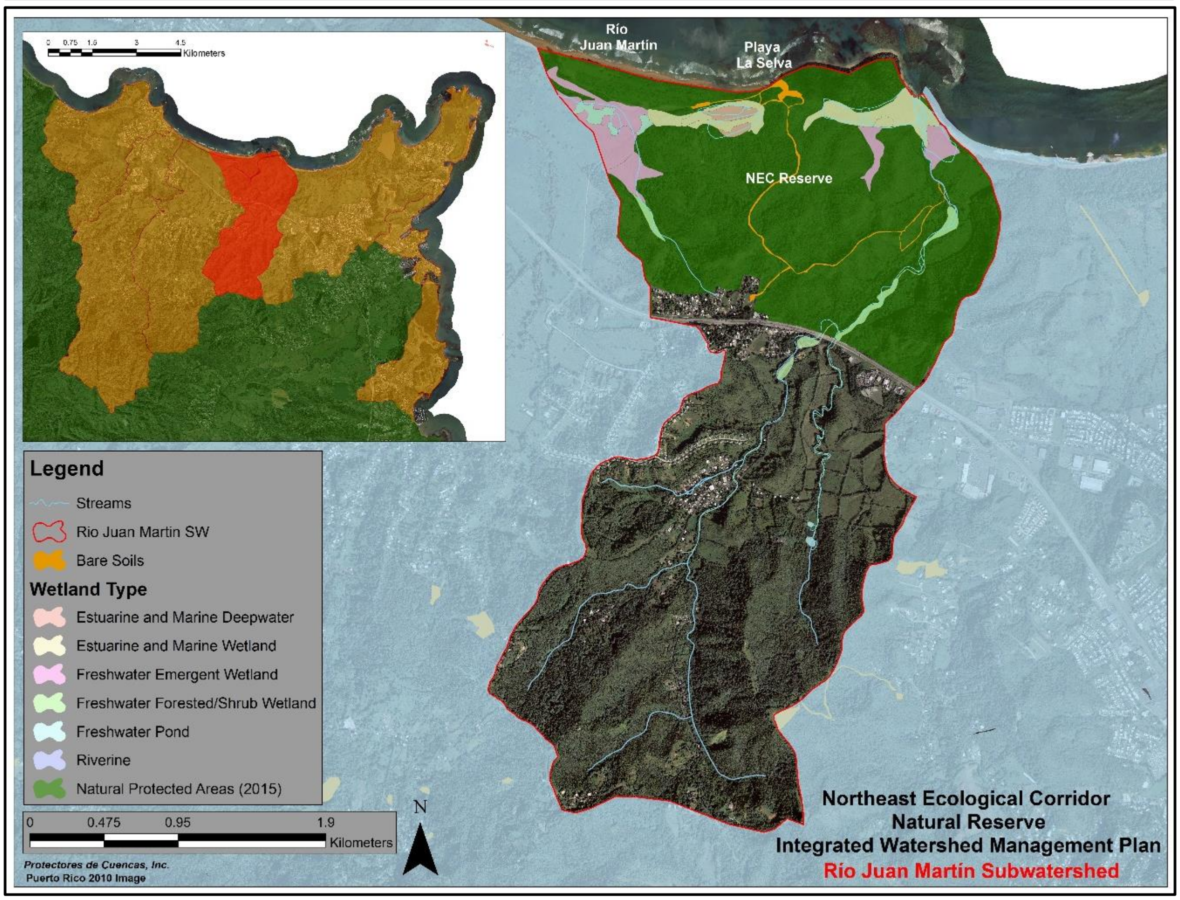


Figure 21. Río Juan Martín Subwatershed wetland areas.

Figure 22. Quebrada Fajardo Subwatershed wetland areas.

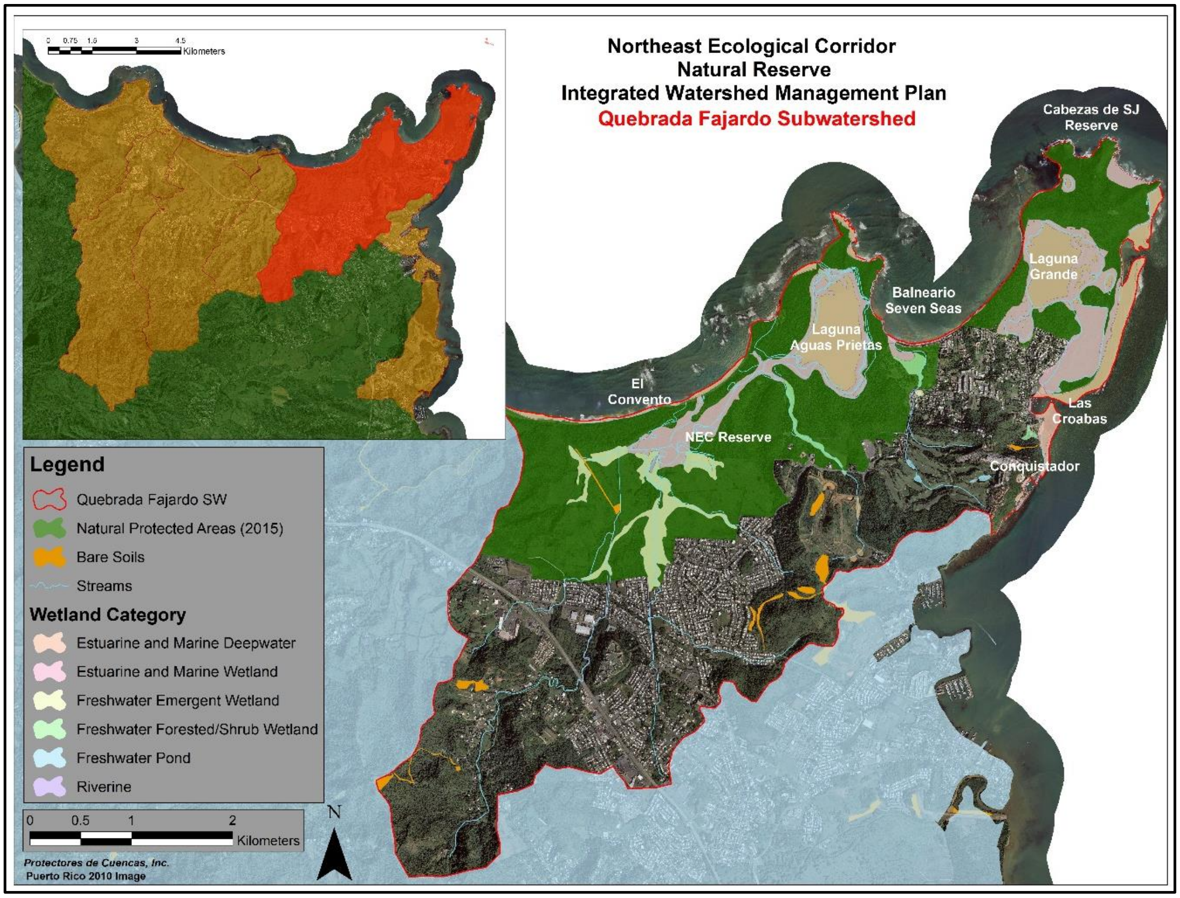
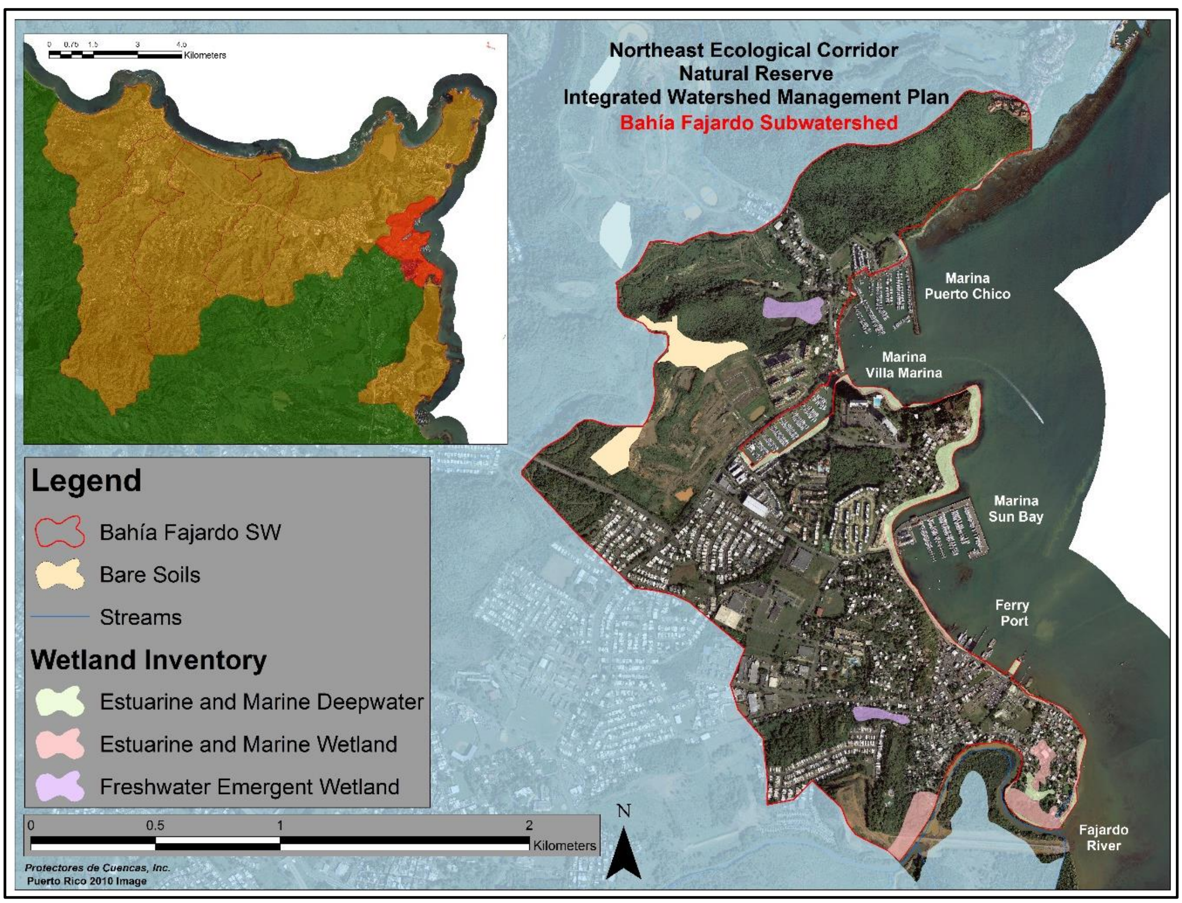


Figure 23. Bahía Fajardo Subwatershed wetland areas.



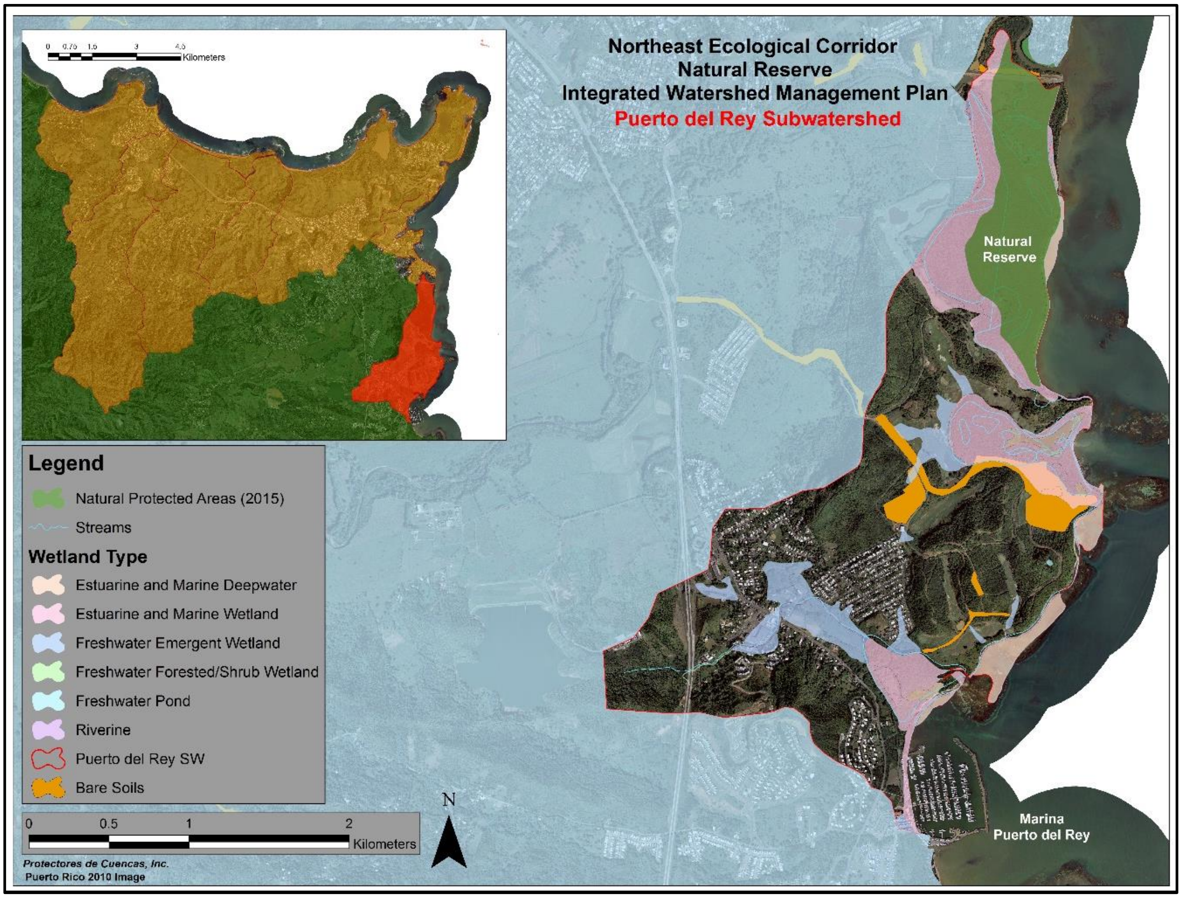


Figure 24. Puerto del Rey Subwatershed wetland areas.

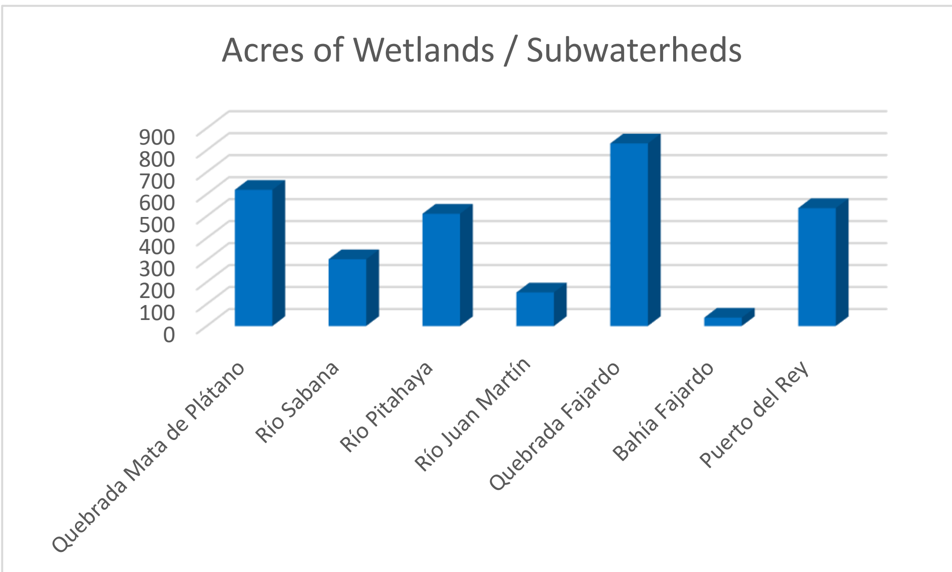
Table 5. Wetland Types for all Subwatersheds.

Wetland Type	Acres	% Land Cover
Estuarine and Marine Wetland	1,147	38.31%
Freshwater Emergent Wetland	1,040	34.74%
Estuarine and Marine Deepwater	402	13.43%
Freshwater Forested/Shrub Wetland	232	7.74%
Riverine	152	5.08%
Freshwater Pond	21	0.70%
TOTALS	2,994	***100%***

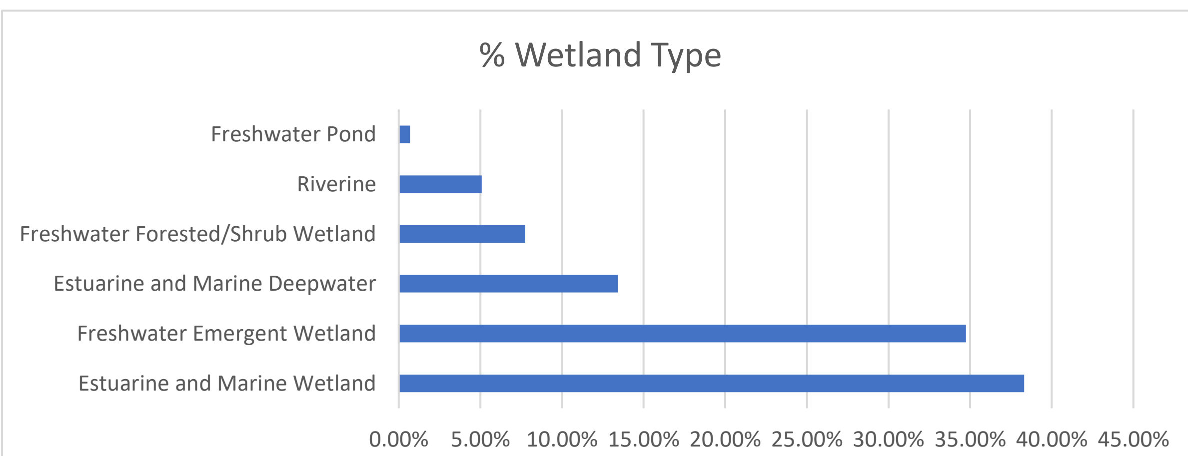
Table 6. Wetland Types per Subwatershed.

Subwatershed	Acres	% Land Cover
Quebrada Mata de Plátano	619.67	3.0%
Río Sabana	303.94	1.5%
Río Pitahaya	511.04	2.5%
Río Juan Martín	152.94	0.8%
Quebrada Fajardo	830.96	4.1%
Bahía Fajardo	38.37	0.2%
Puerto del Rey	536.66	2.6%
TOTALS	***2,993.58***	***14.70%***

Graph 3. Acres of wetland per subwaterhsed.



Graph 4. Wetland cover (%) per category.



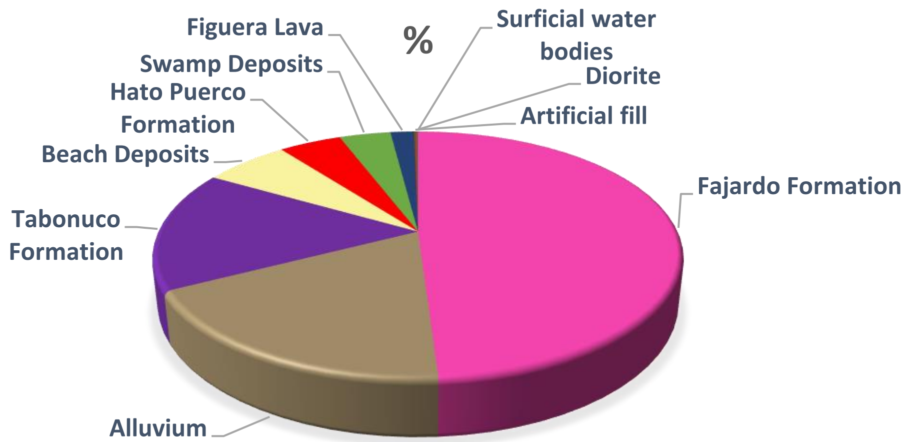
GEOLOGY

Geologic formations in the area are mainly dominated by the Fajardo (48.5%), the Alluvium (18.3%) and the Tabonuco (15.5%) Formations (Table 7, Graph 5 and Figure 25). Fajardo Formation (Kfa) is composed of fine strata of silt and sandstone. The strata are between 3 and 30 centimeters thick. There are some calcareous layers near the top. It is weathered into a brown-yellowish textured floor. Thickness of the unit range from 170 to 250 m (560 to 820 feet). The Alluvium Formation (Qa) is composed mostly of unconsolidated sands, gravels and clays, is moderately drawn and commonly layered and of great thickness. Present in river valleys and ravines and near mountainous areas and is composed of rocks, up to 3 m in diameter and sand. It can be up to 35 thick. The Tabonuco Formation (kta) is a calcareous tuff composed of inter-stratified sandstone with calcareous clays and gaps. These gaps are composed mostly of limestone fragments in a matrix of calcareous sands. Some parts contain volcanic fragments up to 15 m in diameter. Weathered volcanoclastic gap lenses also exist. At the top of the formation there are some lava flows and a thickness between 800 and 1,000 m. Other geologic formations that exist in the area are the; Hato Puerco (Kh) that is mainly volcanoclastic gap that occurs in outcrops of the Northeast region and is mainly in the form of a volcanic origin gap and volcanic sandstone and calcareous clay subordinate in strata ranging from fine to coarse. In Las Cabezas de San Juan, it is composed of a volcanoclastic breccia rock in transition to tuff. Thickness between 360 to 400 m; Diorita (TKdi) with intrusive rock of thin to thick crystals, commonly hornblend, porphyritic and diorite; Swamp Deposit (Qs) composed mostly of clays and silts with high content of organic material, commonly saturated with water, containing some grains of sand and a thickness between 2 to 5 m, approximately; and the Beach Deposit (Qb) with sands containing pieces of volcanic rocks, undivided, thick and little to moderately drawn composed mostly of calcium carbonate and a thickness from 2 to 6 m.

Table 7. Acres of geological characteristics per subwatershed.

Subwatershed	Acres	% Land Cover
Fajardo Formation	9881	48.5%
Alluvium	3724	18.3%
Tabonuco Formation	3203	15.7%
Beach Deposits	1462	7.2%
Hato Puerco Formation	928	4.6%
Swamp Deposits	762	3.7%
Figuera Lava	352	1.7%
Artificial fill	32	0.2%
Diorite	24	0.1%
SuNECicial water bodies	1	0.0%
TOTALS	20370	100.0%

Graph 5. Geologic formation cover (%) for the area.



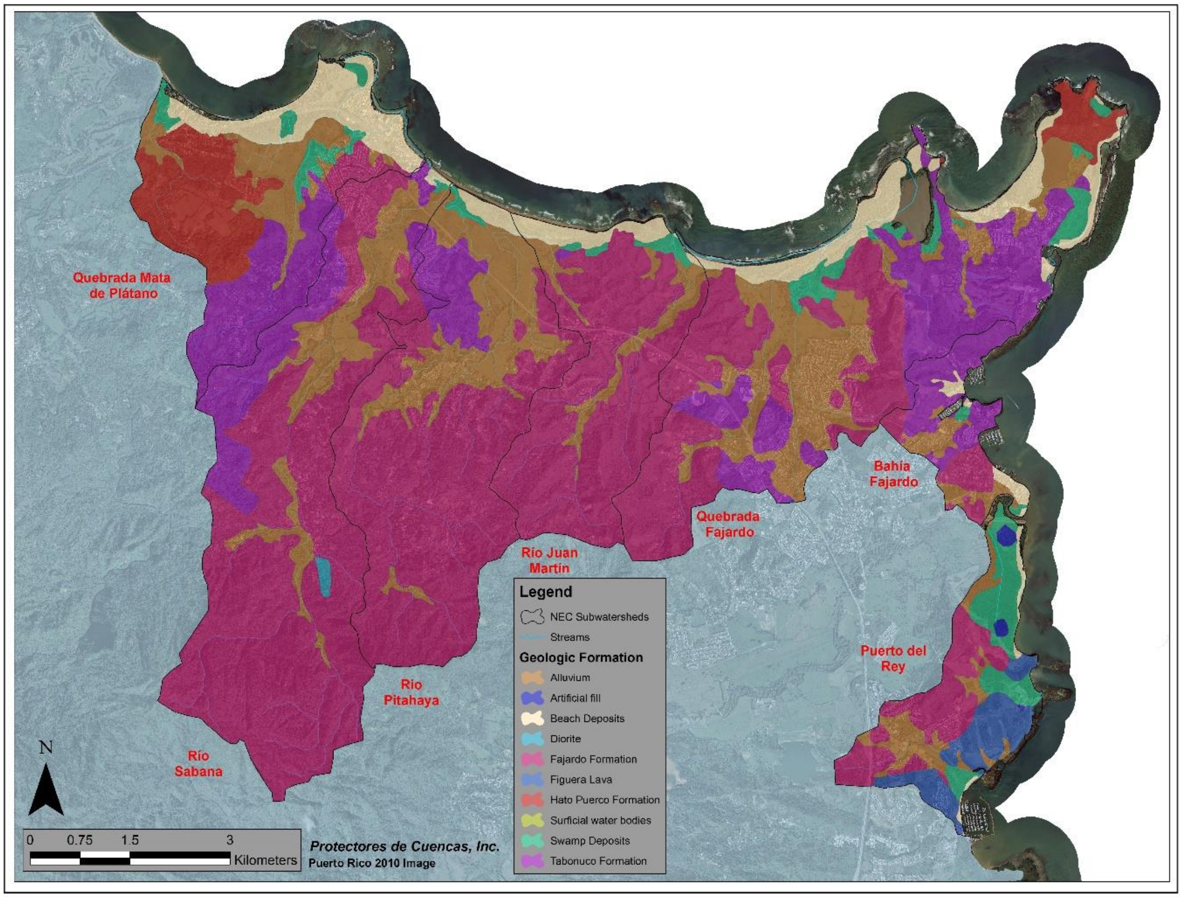


Figure 25. Map of the geological formations in the area.

Soils

Soil composition for the project area is a very complex mixture of 50 soil class features (Figure 26). The majority of these soils are relatively clayey, impermeable, and not well draining. Meaning they aren't great for siting septic tanks and when they do erode they become a significant source of clay and silt which (when combined with river flow) remains in solution and can be discharged onto nearby coral reefs. Furthermore, contaminants readily bind to clays versus sands. Soils of the area are also influenced by the elevation stratification of the landscape.

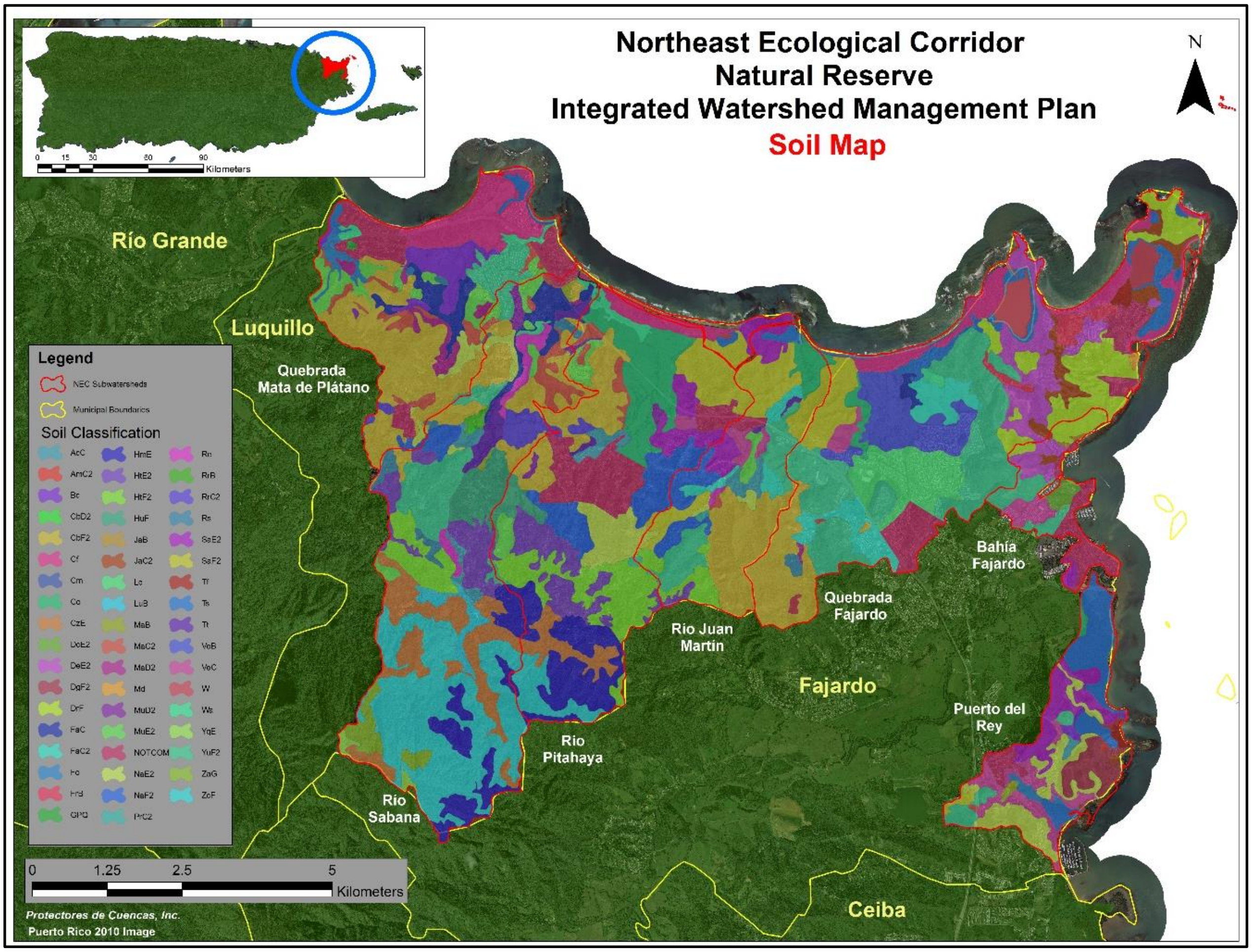


Figure 26. Map of the different soil types present in the project site.

Comprehensive Pollutant Threat Analysis

A pollution threat analysis is composed of a pollution loading analysis which takes into consideration both primary loads (land use driven loads) and secondary loads (which exist in addition to basic land use information) as well as baseline pollution monitoring and verification. The combination of modeling and real-world sampling of existing conditions and pollution sources allows for better calibration and estimation of pollution loading and insight into sources of pollution. Most typical modeling efforts do not take into consideration secondary loads and do not perform basic water quality monitoring and pollution source identification as we have done. Secondary sources of pollution include the number of homes on septic systems versus on central sewer and other pollution sources which may include channel erosion, point sources and the frequency of illicit discharges. The pollution threat analysis also includes an analysis of the suite of Best Management Practices (BMPs) and where they can be specifically implemented within a watershed in order to define a watershed plan that can actually be implemented and the estimated effectiveness at reducing pollution loads within a watershed. Hence providing an actionable plan containing cost estimates, specific locations, and responsibilities to in turn meet EPA's A - I criteria for watershed planning.

Pollution Loading Estimates

A watershed pollution loading and restoration treatment model was constructed for the NEC for key priority pollutants in the region including nitrogen, phosphorus and sediment.

The model used is based on the Watershed Treatment Model (WTM) developed originally for USEPA. The model uses typical pollutant loading coefficients for the different land uses, such as forest, cleared land, low, medium and high-density development and commercial, institutional, and industrial land uses (modified from Caraco, 2002) (Figure 27). Loads from urban land uses are generated by using the simple method which relies on the impervious cover model and average concentrations in stormwater from urban land uses from the watershed characterization. The model has been adapted for use in the Caribbean by the project team and has been used in other watersheds in Puerto Rico including Cabo Rojo, Culebra, Guánica, La Parguera and the Fajardo River watershed. Information collected during our GIS analysis, fieldwork and water quality monitoring was also used to help populate the model.

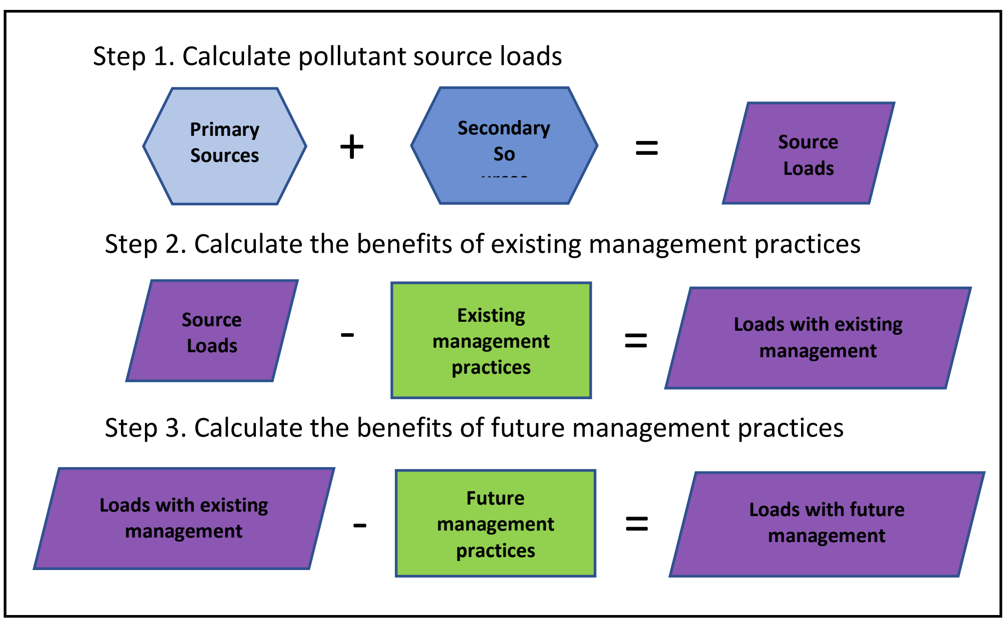


Figure 27. Watershed Treatment Model structure diagram adapted from Carraco 2002.

Output from the model helps to measure pollution estimates and prioritize and implement solutions to reduce pollution in subwatersheds. Presented are sediment and nitrogen sources in the NEC as well as loading on a per acre and a subwatershed basis. This allows us to identify key sources and subwatersheds across the entire NEC as well as to generate loading data for each of the subwatersheds which sets a baseline for future improvements.

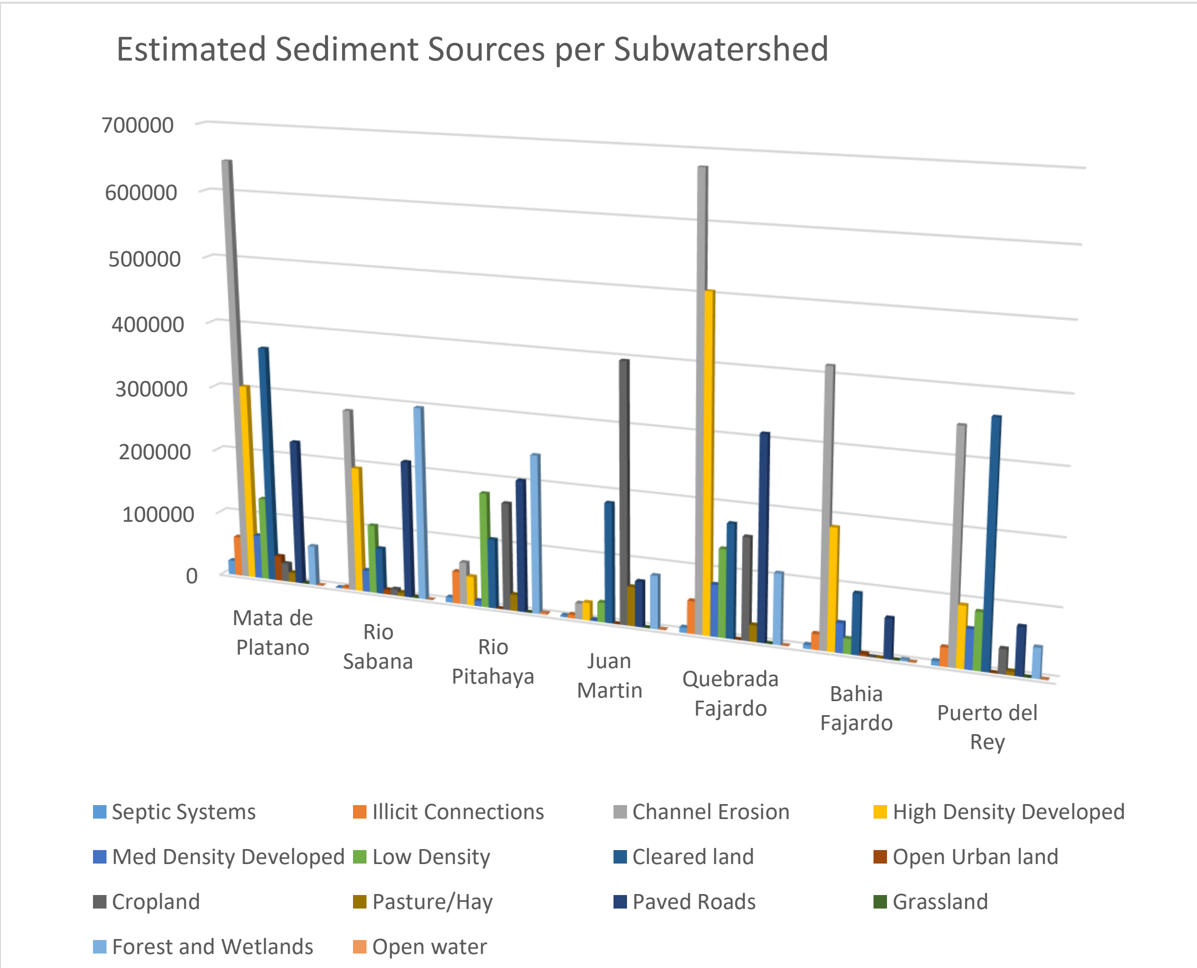
RESULTS

Sediment sources in the NEC are dominated by channel erosion which is a source of background sediment loading and is present in all stream channels. Walling and Woodward (1992) estimated that bank and channel erosion make up between 40-80% of sediment yields in watersheds. As a sediment source, it is followed by cleared land (bare soil) and high-density development as sources across the NEC. Cleared land has the highest yield of sediment on a per acre basis compared to other land uses and should be a focus of implementation efforts as well as developed areas and agricultural areas where BMPs can be implemented. Graphs 6 and 7 shows the loading estimates for various sources of sediment within the watershed.

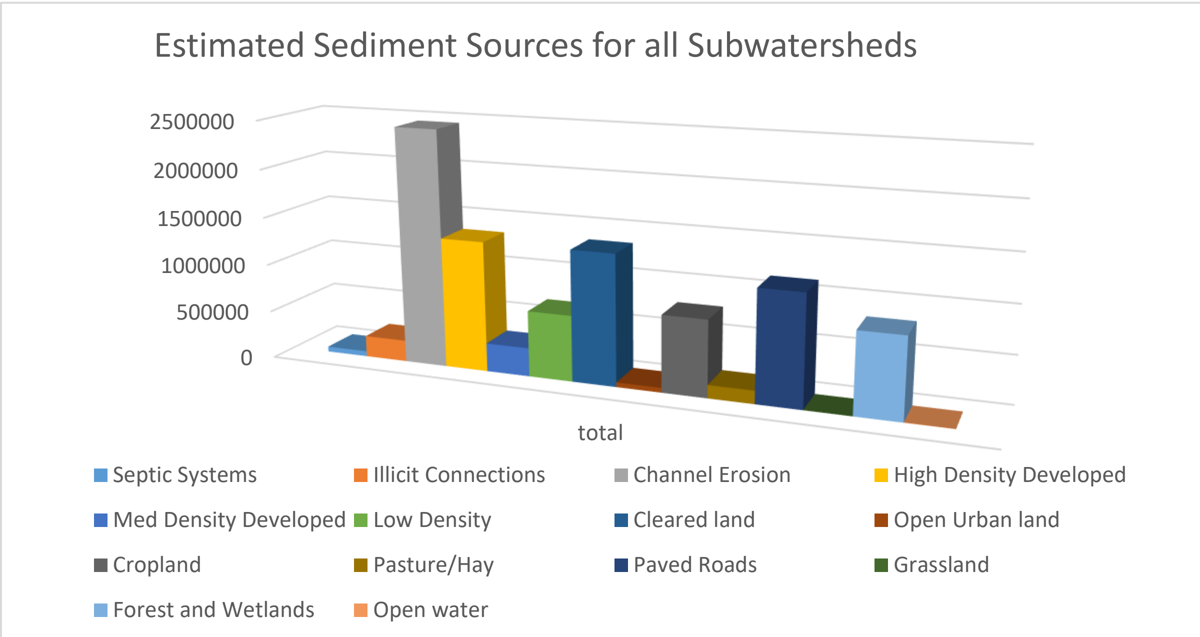
Sediment sources in the Northeast Ecological Corridor are dominated by channel erosion (which is a source of background sediment loading and is present in all stream channels) but is closely followed by bare soils and dirt roads (exposed). An additional source of sediment is the high-density development in the subwatersheds particularly around

Luquillo and Fajardo. Bare soil lands areas (which included dirt roads in our analysis) have the highest yield of sediment on a per acre basis compared to other land uses and should be a focus of implementation efforts as well as developed areas and agricultural areas where BMPs can be implemented. Graph 8 shows the sediment loading estimates for each subwatershed.

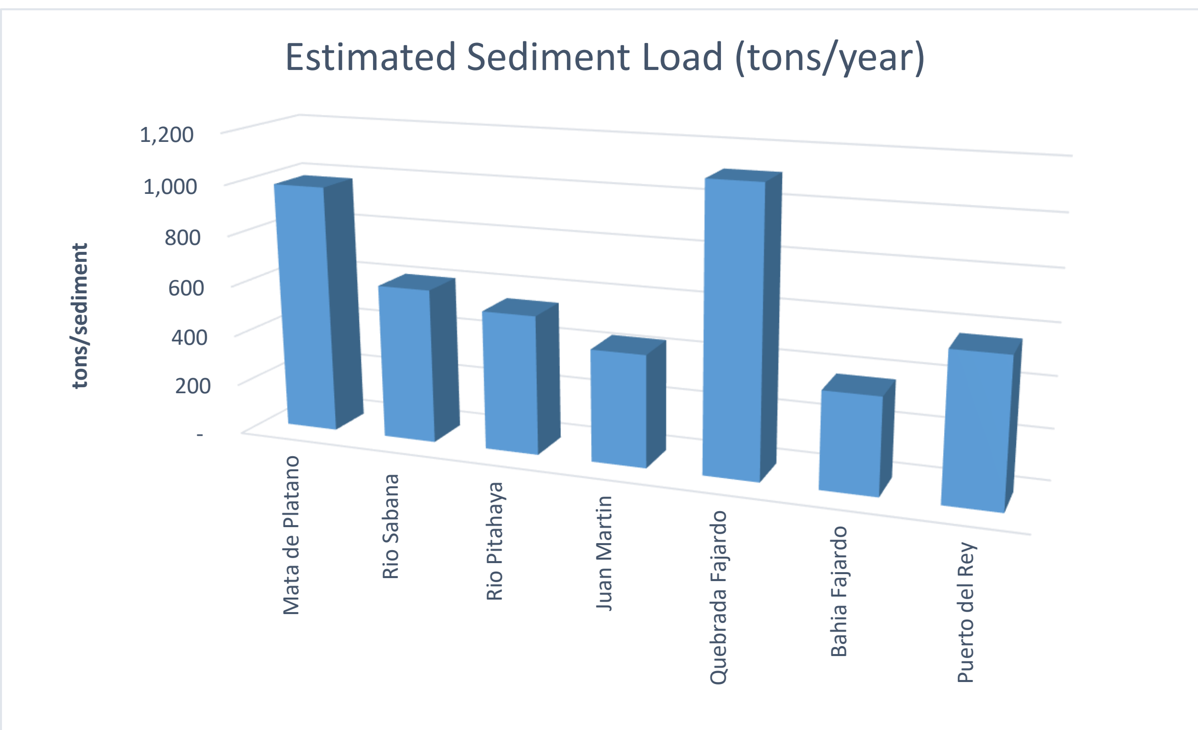
Graph 6. Estimated sediment loads for multiple land uses per subwatershed.



Graph 7. Estimated sediment loads for multiple land uses for all subwatersheds.



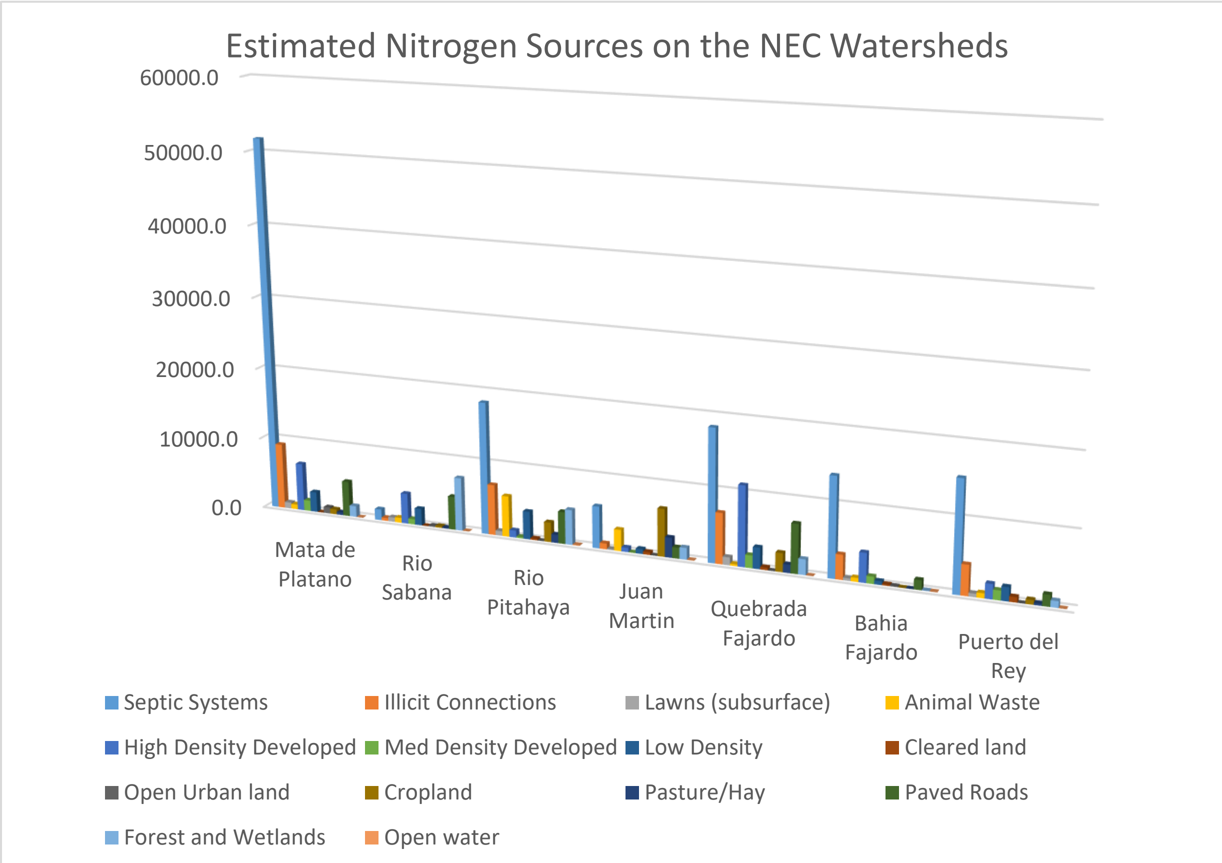
Graph 8. Estimated Sediment loads (tons/year) per subwatershed.



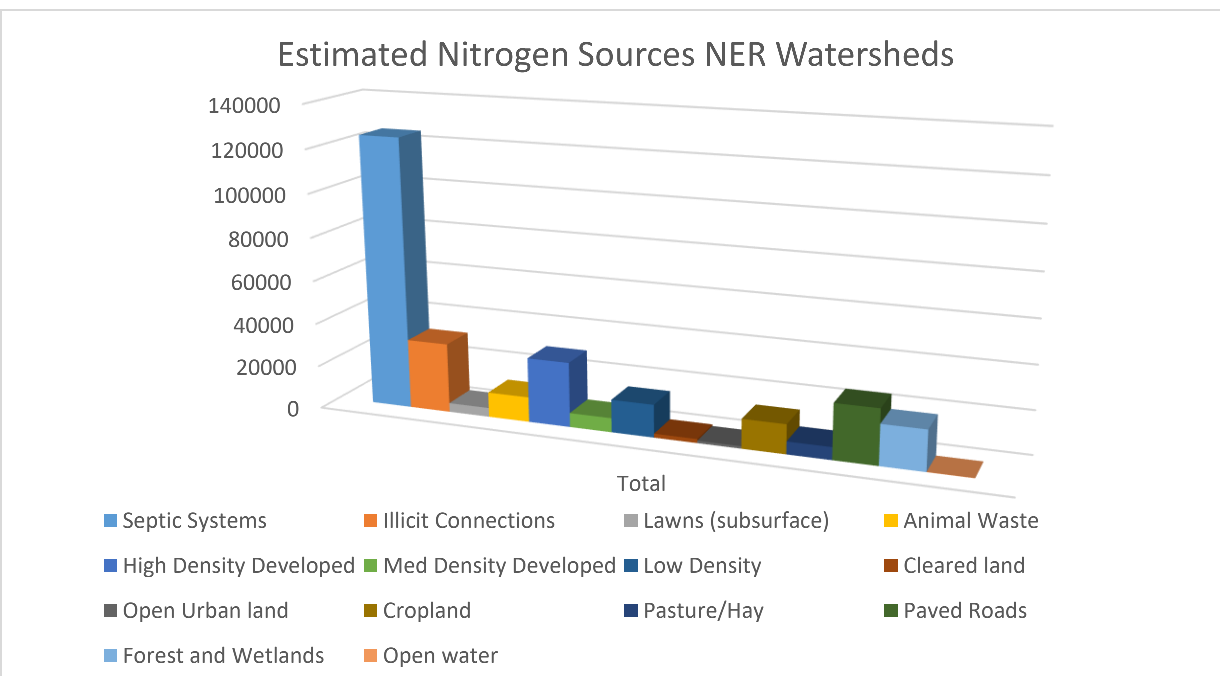
Nitrogen loading in the NEC is dominated by septic systems and to a lesser extent illicit connections and high-density development. Many of the more developed areas are sewered and sewage is exported from these subwatersheds to the FRWTP by PRASA to the Fajardo River watershed. In addition, sewage contamination and the export of washwater containing nutrients is common in unsewered areas and washwater transport to drainages is common throughout all urban areas. Efforts to connect high density septic/cesspool or treat wastewater from these sites is critical for nutrient reductions in the NEC watewrsed as well as the reduction of elevated pathogenic bacteria levels that were seen in our illicit discharge monitoring.

The loads also are reported as both total load as well as load per acre for each subwatershed. Mata de Platano, Bahia Fajardo and Puerto Del Rey subwatersheds have the highest loads per acre (loads per unit area). These subwatersheds are where the greatest potential for reduction of exported loads exist; subwatersheds where loads per unit area are low should also receive focus as these areas are more pristine and likely have healthy biota and downstream habitats. The less developed watersheds may need only several well-placed projects to reduce pollutant loading significantly and improve water quality (Graphs 9 and 10). Drivers of nitrogen loads include septic system which in poor soils create illicit discharges (washwater and sewage) and urban runoff. Efforts to connect high density septic/cesspool to sewer or to treat wastewater on-site or at the community level are critical for nutrient reductions in the NEC, as well as the reduction of pathogenic bacteria as seen in our illicit discharge monitoring (Graph 11).

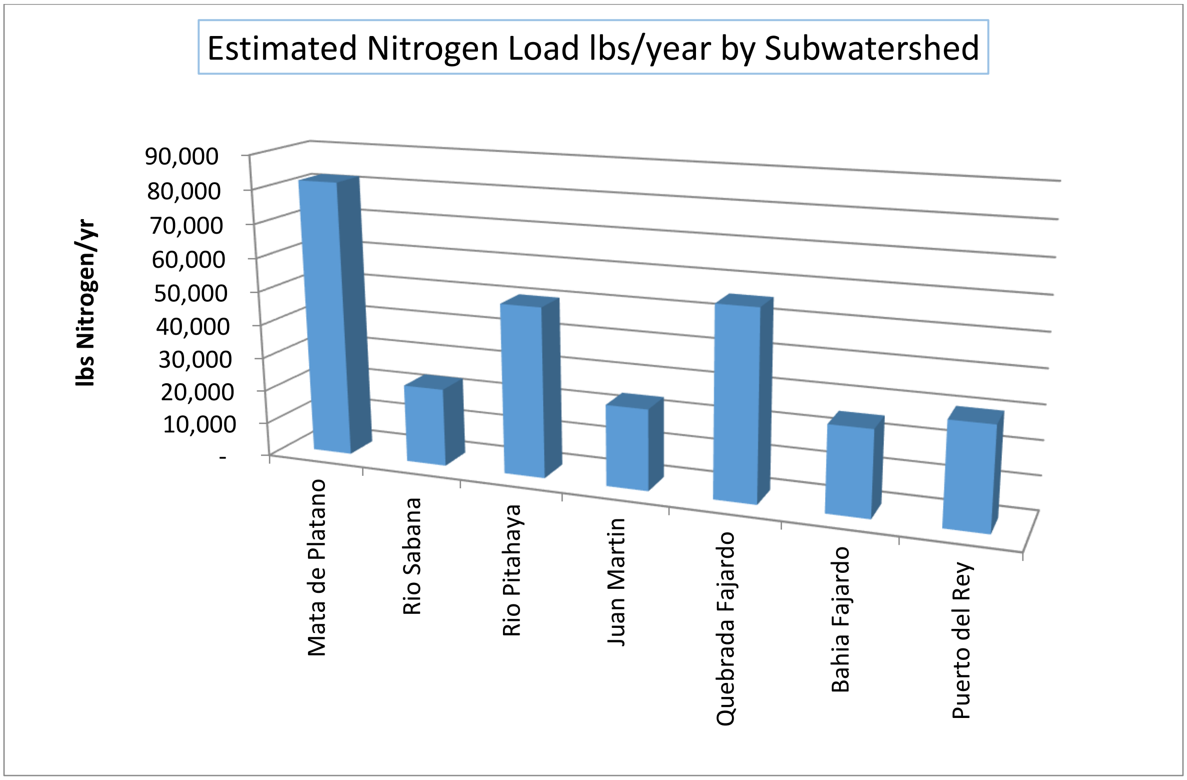
Graph 9. Estimated nitrogen loads for multiple land uses per subwatersheds.



Graph 10. Estimated nitrogen loads for multiple land uses for all subwatersheds.



Graph 11. Estimated Nitrogen loads (lbs/year) per subwatershed.



Load Reduction Estimates

Reductions of nitrogen and sediment from proposed implementation efforts would largely be achieved through the implementation of an Illicit Discharge Detection and Elimination (IDDE) program and the implementation BMP's for Stormwater Treatment and Nutrient Reduction. Sediment load reductions would be achieved through stabilization of bare soils and dirt roads as well as more advanced erosion and sediment control technical assistance for areas with bare soil. A smaller amount of sediment reduction would come from stormwater management projects and nutrient reduction practices which also address sediment (Table 8). Estimates are based on the amount of practices implemented and load reductions can increase as more practices are implemented. Actual load reductions for sediment are anticipated to be higher but it is difficult to forecast the impact of technical assistance and to project future enforcement actions.

Table 8. BMP summary and load reduction estimates for the NEC.

BMPs	TN	TSS	Assumption
Soil Stabilization	N/A	900,700	Based on 150 acres stabilized and 20 miles of roads
Stormwater Management	508	53,644	Based on 80 acres of impervious cover treated
IDDE (not a BMP but can reduce loads if illicit discharges are fixed)	20,000	100,000	IDDE detection and treatment -- removal of 50% of found discharges
Nutrient Reduction Practices	40,000	25,000	1 acre of Bioretention (suNECace area) Specially constructed to remove nutrients
Estimated Reductions	**60,508**	**1,079,344**	
Projected Load Reductions (%)	**20.1%**	**12.0%***	

*with strong outreach to ESC sites and enforcement where needed this number can be increased to over 20%

Criteria and Monitoring Metrics Plan

A series of monitoring metrics were established for the NEC watershed and are based on the work of the Ecological Indicators Subcommittee of the US Coral Reef Taskforce. Monitoring in the NEC watersheds and nearshore reefs is critical to compare future conditions after implementation to existing and historic conditions. Fortunately, due to the presence of El Yunque and the Long-Term Ecological Research (LTER) program, there are good sources of water quality information from the watershed. However, due to the poor quality on the Northeast Coast particularly closer to Fajardo on the east coast, very little coastal coral habitat quality data is available. Most of the stressors are also a threat to other coastal habitats including seagrasses, human health (bacteria) as well as aesthetics at the landscape scale at beaches (sediment) etc. Four types of monitoring are envisioned (Table 9).

Baseline fixed-station and restoration practice water quality monitoring

Several monitoring stations have been already established by the US Geological Survey (USGS) that could continue to serve as long-term baseline sampling sites. Perhaps 4-8 sites could be monitored routinely to help establish a baseline – these locations should be identified in coordination with implementation efforts to ensure best placement for also monitoring benefits of restoration practices. In addition, coastal and beach monitoring sites are also suggested. Monitoring at restoration practices should be implemented at new practices, especially large and important practices such as sewage treatment plant improvements and at restoration projects to address sediment transport associated with large bare soil areas, as well as more commonly implemented practices. In addition, adaptive management as is practiced by the restoration team (on-going evaluation and tweaking of improvements) should be a part of each project.

Nearshore reef, habitat and fish monitoring (annual or biannual)

Long-term tracking of reef health is recommended to occur every 3 - 5 years and begin immediately with fixed sites.

Remote sensing (RS)

Remote sensing could be established with existing satellites and technology by NOAA, USEPA and NASA to track water parameters including Chlorophyll a, total suspended solids (TSS), Carbon Dissolved Organic Matter (CDOM) and also sea surface temperature.

In-situ monitoring buoy

At least one in-situ real-time monitoring buoy would be useful to track on-going conditions to better understand the factors affecting change in the reef ecosystem. The in-situ buoy and a weather/rain gauge could capture a number of key parameters including: ambient temperature, rainfall, water temperature, Chlorophyll a, turbidity, oxygen and pH.

In addition, it is critical that these stations are monitored on an on-going basis with a lead entity such as a local university or watershed coordinator (this could be included in their responsibilities). Monthly baseline conditions can be established for water quality, in-situ equipment can be maintained, and coral and coral habitats can be monitored on an annual or biannual basis.

Metrics recommended to be measured were divided into the type of metric, the relative response rate (fast, moderate or slow) which the parameter may change as well as potential sources for data collection and BMP's. Stressor monitoring includes water quality measures, and response measures include secondary parameters that may change after reduction of stressors. Generally, the rate of change will be due in part to the amount of reduction of stressors. We anticipate that generally water quality parameters will change more quickly than coral conditions. Intermediate response variables may include algal cover.

There is a critical need to implement a long-term monitoring program to address changes in water quality, and in coral reef benthic and fish community dynamics across a land-based sources of pollution stress gradient. The monitoring program should also focus on coral recruitment trends (population of young corals), Diadema antillarum densities, herbivory activity across the LBSP gradient, and the interactions of corals and L. variagata. Such multi-component approach will allow response to multiple management-oriented questions addressing impacts by LBSP on coral reef ecosystems, further providing key information to design potential solutions to reduce LBSP impact.

A number of key tasks remain for monitoring including further tracking sources of pollution referenced in the watershed plan recommendations, initiating a baseline water quality assessment at inshore and mid-shelf reef sites, as well as some of the coastal sites including the islands of Icacos, Palaminos and more inshore sites.

Table 9. Recommended Monitoring Metrics for the Northeast Ecological Corridor Watersheds.

Metric	Type	Response	Source/Data collection	BMPs that address
Remote Sensing (RS), Total Suspended Sediment (TSS)	Stressor	Fast	NASA/USEPA/NOAA	ESC, dirt roads, traps, stormwater runoff
RS, Chlorophyll (a)	Response	Fast	NASA/NOAA/USEPA	IDDE, connections
Algal cover/biomass	Response	Moderate	CATEC/NOAA/ DNER/Sociedad de Ambiente Marino (SAM)	IDDE, connections, large septics
Coral cover	Response	Slow	CATEC/NOAA/ DNER/SAM	IDDE, large septics, sewer connections
Coral demographics	Response	Slow	CATEC/NOAA/ DNER/SAM	All BMPs slowly over time
Coral disease	Response	Moderate?	CATEC/NOAA/ DNER/SAM	Stormwater runoff, IDDE, failing septics
Coral recruitment	Response	Moderate	CATEC/NOAA/ DNER/SAM	All BMPs over time (perhaps nutrients which reduce algal cover)
Coral species richness	Response	Slow	CATEC/NOAA/ DNER/SAM	All BMPs over time
Fish recruitment	Response	Moderate	CATEC/NOAA/ DNER/SAM	Expansion and management of MPAs
Grazers	Response	Moderate	CATEC/NOAA/ DNER/SAM	Expansion and management of MPAs, supplemental stocking
Reef fish diversity	Response	Moderate	CATEC/NOAA/ DNER/SAM	Expansion and management of MPAs
Temperature	Ancillary	NA	NASA/NOAA/USEPA	
RS temperature	Ancillary	NA	NASA/NOAA/USEPA	
Turbidity, Nutrients, current/direction, Temperature	Response and ancillary	Real-time in situ data	NOAA/USEPA/DNER	
RS TSS	Stressor	Fast	NASA/USEPA/NOAA	ESC, dirt roads, traps, stormwater runoff
RS Chlorophyll (a)	Response	Fast	NASA/NOAA/USEPA	IDDE, connections
Algal cover/biomass	Response	Moderate	CATEC/NOAA/ DNER/SAM	IDDE, connections, large septics
Coral cover	Response	Slow	CATEC/NOAA/ DNER/SAM	IDDE, large septics, sewer connections
Coral demographics	Response	Slow	CATEC/NOAA/ DNER/SAM	All BMPs slowly over time

ILLICIT DISCHARGE DETECTION AND ELIMINATION (IDDE)

Water Quality Pollution Monitoring and Source Tracking

In many watershed plans and baseline studies additional data is not collected to fill in gaps in water quality data and information – this is problematic as even small areas can be sources of significant contamination on a watershed scale. These gaps cannot be filled by typical modelling efforts and result in an underestimation of pollution where development densities are low. To counter this trend, our team collected baseline data on water quality indicator parameters in freshwater and brackish drainages in order to begin to identify, track down and confirm sources of pollution. Typical sources of pollution include illicit discharges such as washwater and sewer system leaks, illicit connections, failing septic systems and drinking water leaks. Determining sources of contamination to the nearshore and marine ecosystems is a critical component of watershed management but is not often done in typical watershed plans. High levels of water contamination were found throughout the NEC with the highest frequency of contamination being found around Fajardo. Based on our monitoring of E. Coli bacteria, ammonia, optical brighteners, and Chlorophyll A; specific locations (Table 10) where sewage leaks and illicit discharges enter streams, rivers and tidal waters were identified. Additional IDDE tracking should be done with Enviromental Protection Agency (EPA), Enviromental Quality Board (EQB) and PRASA to determine the source and location of contamination and what restoration or infrastructure improvements are needed. Outfalls were screened for the following parameters shown in Table 10. The table also shows what the parameters indicate as well as the equipment and thresholds used.

Table 10. Indicator Parameters to Identify, and Track Illicit Discharges.

Parameter	Indicates	Equipment	Threshold
Ammonia	Sewage or wastewater, occasionally industrial processes	Hanna Medium Range, Portable Photometer, HACH H2 Ammonia Probe	0.4mg/l probable sewage contamination
Optical Brighteners	Presence of laundry detergents / wash water (useful as optical brighteners have no natural sources)	Turner Aquaflor Fluorometer	15 ug/l likely washwater contamination
Chlorophyll A	Indicator of nutrient enrichment after conversion to phytoplankton biomass (can be an indicator of harmful algal blooms) Note: healthy coral reefs have an concentration of 0.2—0.6 ug/l.	Turner Aquaflor Fluorometer	Various standards exist 30ug/l (elevated), 50ug/l, over 100 ug/l nutrient source nearby
E. Coli bacteria	Indicates potentially pathogenic bacteria	IDEXX	126 col/100 ml via EPA In most urban drainage use 100 col/100ml

Water chemistry samples were collected using sterile Whirl-Pak Water Sample Bags for analysis of optical brighteners, Chlorophyll A, E. coli and ammonia. The ammonia and E. Coli data was used primarily to establish areas for tracking and to estimate the severity of illicit discharges and for prioritizing source investigations.

The majority of the elevated discharges have a likely source of contamination. Most are a result of failing or poorly located septic systems and occasional (in some cases

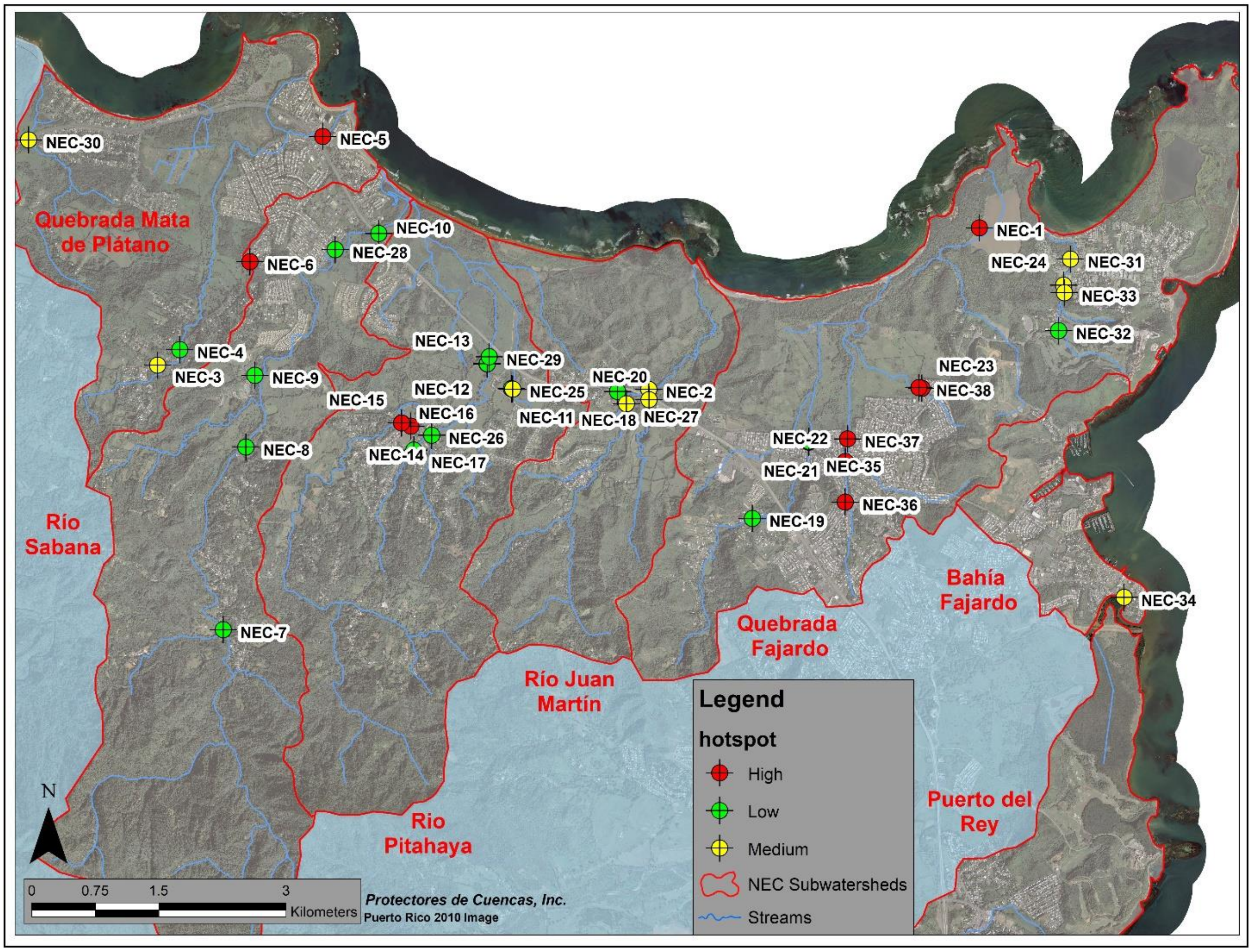


Figure 28. Map of the IDDE sample sites.

prolonged) sewer infrastructure failures. Sites with indicators of contamination are summarized by station (Figure 28). These discharges all reflect nutrient contamination as well as bacteria in most instances (Table 11).

The upper portions of the watershed are within El Yunque and contain abundant clean freshwater flows; however, coming out of the protected area many small communities particularly to the north have homes constructed very close together on relatively poor soils with apparent septic failure and water quality problems.

Table 11. Summarized IDDE sample sites

Site ID	Sub Water-shed	Lat/Long	Opt B (NECU)	Chll a (µG/L)	NH4 (MG/L)	Turb (NTU)	Tot Col (MPM)	E. Coli (MPM)	Hotspot	Notes
NEC -1	QF	18.3701° -65.64617°	10.38	0.617	37.51	18.5			H	Lagunas Aguas Prietas
NEC -2	RJM	18.3524° -65.68279°	7.537	0.439	0.08	31.5			M	Rio Juan Martin-Entrando por Finca El Convento
NEC -3	QMP	18.3542° -65.7376°	92.12	2.71	0	7.98	2,420	90.8	M	
NEC -4	QMP	18.35589° -65.73515°	6.517	0.213	0	4.68	>2419.6	21.6	L	
NEC -5	QMP	18.3788° -65.71957°	16.24	8.823	4.34	17.6	1011.2	640.5	H	Two municipal pipes discharging stormwater straight to stream
NEC -6	RS	18.36535° -65.72748°					2419.6	1732.9	H	Sewage leaking in Community
NEC -7	RS	18.32616° -65.72984°	2.979	0.19	0	2.34	6867	243	L	
NEC -8	RS	18.34562° -65.7276°	3.299	0.177	0	2.68	5,794	86	L	
NEC -9	RS	18.35327° -65.72672°	8.178	0.227	0	3.25	24,196	560	L	
NEC -10	RS	18.368565° -65.71315°	3.545	0.17	0	2.81	6,867	259	L	
NEC -11	RP	18.35226° -65.69811°	9.874	0.274	0	6.45	19,863	613	L	Next to EBAS/Juan Martin
NEC -12	RP	18.35485° -65.70087°	3.761	0.202	0	5.24	17,329	528	L	
NEC -13	RP	18.35489° -65.70083°	4.12	0.25	0	14.3	11,119	74	L	
NEC -14	RP	18.34811° -65.70927°	28.63	0.762	2.65	57.6	241,960	2210	H	Sample from curve (Intersection 988/983)
NEC -15	RP	18.34843° -65.71029°	3.437	0.191	0	4	9,804	638	L	
NEC -16	RP	18.34843° -65.71029°	201.7	1.515	2.37	6.38	241960	241960	H	Possible sanitary discharge
NEC -17	RP	18.34556° -65.70888°	5.148	0.207	0.28	4	24,196	594	L	
NEC -18	RJM	18.35213° -65.68626°	7.037	0.274	0	2.01	24,196	1081	L	Negocio Flamboyan/ Possible Rain Garden Project
NEC -19	QF	18.33884° -65.67103°	8.986	0.3	0	1.14	24,196	1281	L	BO. Quebrada Fajardo
NEC -20	RJM	18.3513° -65.68275°	15.67	0.438	0.21	6.17	24,196	2380	M	
NEC -21	QF	18.34704° -65.66484°	10.27	0.424	0.22	3.22	24,196	17329	M	Urb. Fajardo Garden
NEC -22	QF	18.34503° -65.66074°	14.9	0.44	0.58	32.7	24196	24196	H	Urb. Fajardo Garden
NEC -23	QF	18.35295° -65.65234°							H	Not reachable Apparent Sewage
NEC -24	QF	18.36414° -65.63668°	5.229	0.272	0.31	23.9	43520	630	M	Herbicide use

Site ID	Sub Water-shed	Lat/Long	Opt B (NECU)	Chll a (µG/L)	NH4 (MG/L)	Turb (NTU)	Tot Col (MPM)	E. Coli (MPM)	Hotspot	Notes
NEC -25	RP	18.352224° -65.697969°	837	4.5	0.06	1.4	101*	10100*	M	Near pumping station; surface flow ammonia 0.18
NEC -26	RP	18.347177° -65.706926°	0.309	1.115	0.19	12.4	140*	14000*	L	
NEC -27	RJM	18.35084° -65.685251°	0.554	9.924	0	39.3	105*	10500*	M	very turbid water
NEC -28	RS	18.36678° -65.717971°	0.122	0	0	0.4	12*	1200*	L	
NEC -29	RP	18.355608° -65.700636°	0.152	0	0	12.6	N/A	N/A	L	
NEC -30	QMP	18.377948° -65.752365°	0.487	3.007	0.42	17.1	TNTC	TNTC	M	
NEC -31	QF	18.366906° -65.635966°	0.425	2.604	0.6	3.5	148*	14800*	M	Near mobile home park at Seven Seas
NEC -32	QF	18.359286° -65.637168°	0.671	1.327	0	1.1	163*	16300*	L	Near hotel/rooster pens
NEC -33	QF	18.363316° -65.636586°	0.361	1.025	0.45	1.6	156*	15600*	M	Stream near gas station
NEC -34	BF	18.331002° -65.62945°	0.423	0.728	0.92	2.3	148*	14800*	M	Outlet Rio Fajardo
NEC -35	QF	18.347124° -65.664831°	0.704	6.667	0	N/A	160*	16000*	L	
NEC -36	QF	18.340709° -65.660686°	0.665	2.633	6.7	N/A	TNTC	TNTC	H	Sewage
NEC -37	QF	18.347433° -65.660538°	0.616	1.09	1.62	N/A	TNTC	TNTC	H	Sewage
NEC -38	QF	18.353005° -65.652661°	1.535	9.732	5.39	N/A	TNTC	TNTC	H	Sewage

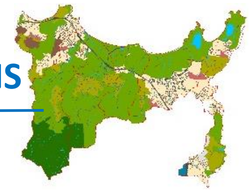
Two watersheds stand out initially in terms of major problems associated with illicit discharges – these include Mata de Platano in Luquillo and Quebrada Fajardo in the urban area of Fajardo. From our field observations, we can conclude that both represent a combination of failing septic systems high density and illicit connections from businesses or homes and runoff from washwater. Although these two watersheds stand out, all of the sampled watersheds are impacted by illicit discharges and water quality particularly bacteria that generally exceeded the EPA and EQB standards. The EPA standard for recreational waters is <126 col/100ml. Most stations exceeded that number and we used a cutoff of 1000 col/100ml to identify the sites that are most compromised and to begin restoration work.

The purpose of our IDDE approach is to find, fix and prevent illicit discharges, and a series of techniques exist to meet these objectives. Finding Illicit discharges should be the highest priority following the completion of this characterization. A range of monitoring techniques can be used to find sewage discharges. In general, monitoring techniques are used to find problem areas and then trace the problem back up the stream or pipe to identify the ultimate generating site or connection. Monitoring can sometimes pick up other types of illicit discharge that occur on a continuous or intermittent basis (e.g., wash water and liquid wastes). No single indicator parameter is perfect. However, we used some cutoff numbers to categorize sites in terms of high contamination, sites with at least half these cutoff numbers can be categorized as medium concern. We used an E. coli standard of 1,000 MPN/100 ml; Ammonia-nitrogen levels of 0.30 mg/L; and Total phosphorus (when available) of 0.40 mg/L.

These findings are consistent with data from Puerto Rico Environmental Quality Board (EQB), who conducted a sampling of the Laguna Grande and Laguna Grande Canal of Fajardo that reflected violations of water quality standards for fecal coliform and enterococci parameters in all seasons, showing that there are water pollution discharges common in the area. This information is consistent with previous samplings carried out by PDC. In this regard, the community of Las Croabas has expressed concerns about their health and their interest to establish an appropriate sanitary sewer system as current septic systems do not work properly.

Impacts of coastal water quality degradation associated to non-point pollution sources, may result in the development of algal blooms (Havens et al., 2001), a general decline of important fisheries species, and in a decline in seagrass communities (Duarte, 1995) and coral reefs. Thus, it is important to identify non-point sources of nutrients and fecal contamination in order to improve water quality, protect our coral reef ecosystems and safeguard human health.

Recommended Integrated Watershed Management Actions



The following recommended integrated watershed management actions have been identified with the intent of cataloging potential watershed restoration opportunities and cost estimates through a scientific and participatory stakeholder approach for the NEC area. The project team has provided a prioritized list of potential BMP's projects and restoration concepts with cost estimates to address LBSP at this priority location to complement ongoing management efforts. This initiative will provide direct abatement of LBSP threats, which will benefit coastal and coral reef habitats of the NEC.

This list of potential Watershed Management Actions is intended to serve as a kickoff of remediation actions and it does not intend to cover all the possible projects that can be developed in the NEC as many other possible alternatives may arise as actions begin to be implemented. Recommended BMP's have ben subdivided into the following categories; Stormwater Treatment Practices, Nutrient Reduction Practices, Soil Stabilization Practices and Pollution Prevention Practices. Recommended projects where systematically chosen in collaboration with Fajardo and Luquillo Municipalities, DNER personnel as well as following recommendations from the public participation process. The selection process was based primarily on the following categories:

1. Its impact on water quality focused on the priority pollutants established for the NEC (nutrients, sediment, and bacteria).
2. Feasibility in terms of space available, ownership, permits required and potential partnerships.

STORMWATER TREATMENT PRACTICES

Stormwater runoff occurs when precipitation from rain flows over the land surface. The addition of urban infrastructure like roads, driveways, parking lots, rooftops and other surfaces that prevent water from soaking into the ground to our landscape causes increases in the runoff volume created during storms. This runoff is carried faster to our streams, lakes, wetlands, rivers and eventually to our marine ecosystems. Urban stormwater runoff often causes flooding and erosion problems washing away many different pollutants found on paved surfaces such as sediment, nitrogen, phosphorus, bacteria, oil and grease, trash, pesticides and metals that picks up and carries them to our water resources. Stormwater runoff is the number one cause of stream impairment in urban areas.

To reduce the negative impacts of stormwater runoff from urban areas to our water resources, a series of Green Infrastructure (GI) projects can be implemented. GI projects are constructed to intercept stormwater runoff and utilize plants (native vegetation recommended), soils and natural processes to filter and reduce runoff pollution through incorporation into vegetation and evapotranspiration. These projects have the ability to infiltrate, evaporate and slow the velocity of the water at the same time that it reduces the erosion rates and pollutant loads. There is a wide range of possible GI projects that can be implemented, the limiting factors are the amount of funds available, the space and the type of land uses affecting a specific site. In our experience, the best way to deal with runoff treatment is to try to do as many practices as possible using the available space in a treatment train approach (Figure 29). Some examples of green infrastructure projects include; raingardens, biofilters and bio retention, bioswales, treatment wetlands and other natural processes to reduce pollution loads.

Based on our field evaluations and surveys, we recommend that when possible, the stormwater practices that are built should have nutrient reduction components to deal with the occasional sewage overflow into the stormwater system. As mentioned previously, our current sewer infrastructure is in constant failure and even if it is constantly maintained, sewage is getting to our stormwater system in most of the cases. The other associated problem is that there are a considerable amount of people that have not been connected to the sewer system and failing septic systems may be another cause of sewage input to the stormwater runoff. To deal with this problem in the NEC, a house to house survey needs to be conducted in the areas were sewer infrastructure service exits and illicit discharges are persistent. With this information, we will be able to have a better understanding of the amount of actual people that are not connected, and a series of actions can be conducted to get people connected as well as cost estimates for these remediation actions.

Most of our urban infrastructure was not built with the intent of providing treatment to stormwater runoff, on the contrary, infrastructure has been constructed to get runoff out of the way as quickly as possible. This poses a challenge in terms of the available areas and

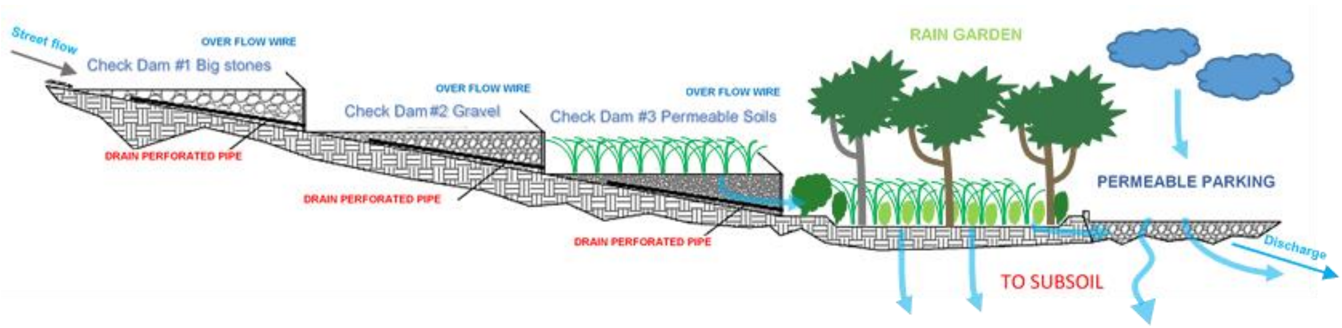


Figure 29. Schematic diagram of an example of a train treatment approach implemented by PDC in Zoní Beach in Culebra, Puerto Rico

limits the types of possible projects to implement. In this scenario, projects to be implemented must be very creative so that they don't affect the current infrastructure and it does not pose a threat of flooding to near communities or commercially important areas. We have summarized the proposed stormwater management project implementation into the following site categories; parking lots, community outfalls and industrial outfalls.

A brief description is provided for the following GI project types that have been selected as the most suitable to be implemented in the NEC urban areas.

Raingardens

Rain gardens, are vegetated depressions layered with engineered soil media that filter pollutants, increase the time water stays on the site, and provides stormwater storage (Figure 30). Raingarden systems usually have an underdrain to ensure the cell drains in a reasonable time period. Although they are applicable in most settings, rain gardens are best used on small sites, urban areas, suburban areas, and parking lots.

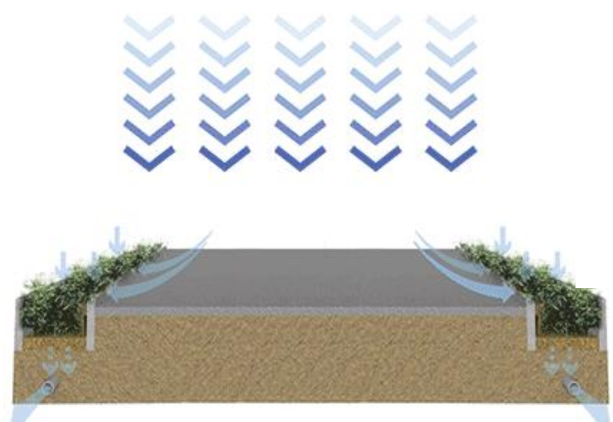


Figure 30. Diagram of a raingarden adapted from the Houston-Galveston Area Council.

Bioretention

A stormwater bioretention or planter box system is often enclosed in a concrete container that contains porous soil media and vegetation to capture, detain, and filter stormwater runoff (Figure 31). Stormwater planter boxes are lined, contain an underdrain, have various small to medium plantings, and are installed below or at grade level to a street, parking lot, or sidewalk.

Figure 31. Diagram of a Bioretention adapted from the Houston-Galveston Area Council.

Runoff is directed to the stormwater planter, where water is filtered by vegetation before percolating into the ground or discharging through an underdrain. The stormwater is also used to irrigate the tree or other vegetation in the planter box. In addition to stormwater control, stormwater planter boxes offer on-site stormwater runoff treatment and aesthetic value. Stormwater planter boxes are optimal for urban or streetscape environments. When combined with nutrient reduction techniques, planter boxes help to reduce the negative impacts of sewage overflow into the storm drain system. Techniques can include the incorporation of various layers of different granulometry stone types, biochar or woodchips.

Bioswales

Bioswales are similar to bioretention cells in design and function but are linear elements that can also be used for conveyance and storage in addition to their biofiltration function. They can be used anywhere and are best used on small sites, in urbanized and suburban commercial areas, residential areas, and parking lots (Figure 32).

Figure 32. Diagram of a Bioswale adapted from the Houston-Galveston Area Council.

Vegetated Swale

A vegetated swale is a wide, shallow channel with vegetation covering the sides and bottom. Swales are designed to convey and treat stormwater, promote infiltration, remove pollutants, and reduce runoff velocity. Vegetated swales mimic natural systems better than traditional drainage ditches (Figure 33).

Vegetated swales can be used on sites that naturally cultivate a dense vegetative cover and have an appropriate area, slope, and infiltration potential. Swales are

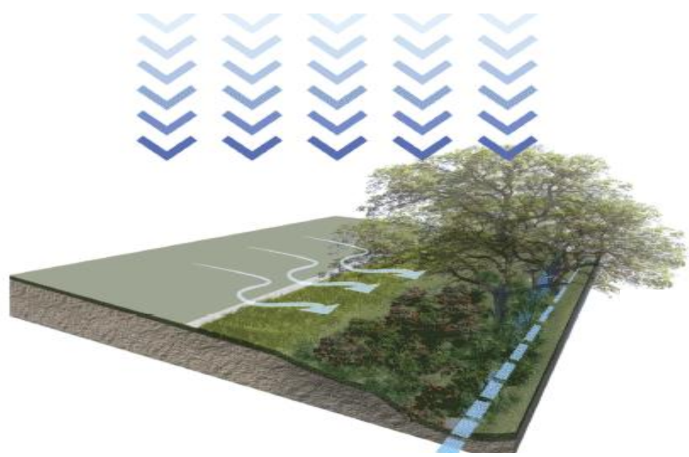


Figure 33. Diagram of a Vegetated Swale adapted from the Houston-Galveston Area Council.

most effective when used in a treatment train with other green infrastructure techniques. They are widely used to convey and treat stormwater runoff from parking lots, roadways, and residential and commercial developments and are compatible with most land uses.

Vegetated Filter Strip

A vegetated filter strip is a band of vegetation, usually a mix of grasses and native plants that acts as a buffer between an impervious surface and a waterway (Figure 34). They are designed to slow runoff from adjacent impervious surfaces, filter pollutants, and provide infiltration (depending upon the permeability of underlying soils). They can also provide aesthetic benefits, stormwater storage, and wildlife habitat. In addition to stormwater management, vegetated filter strips can add recreational value with opportunities to incorporate trails into their design.

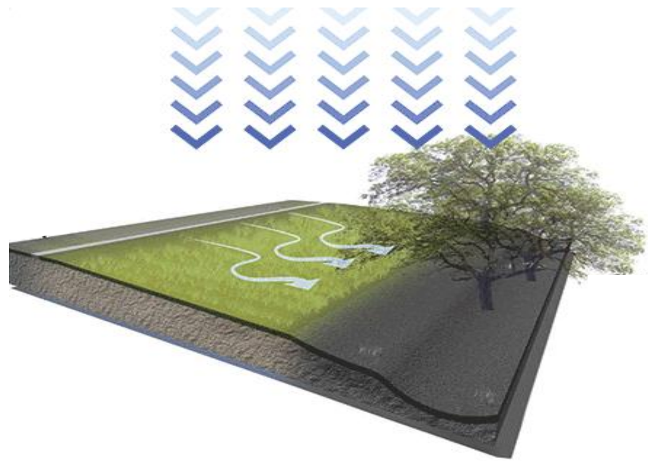


Figure 34. Diagram of a Vegetated Filter Strip adapted from the Houston-Galveston Area Council.

Filter strips are best suited on sites that naturally support dense vegetation. Filter strips are best used in treating runoff from roads, roofs, small parking lots, and other small surfaces.

Green Roof

A green roof is a vegetative layer grown on a rooftop that filters, absorbs, and/or detains rainfall. The green roof system typically contains a soil layer, a drainage layer, and an impermeable membrane (Figure 35).

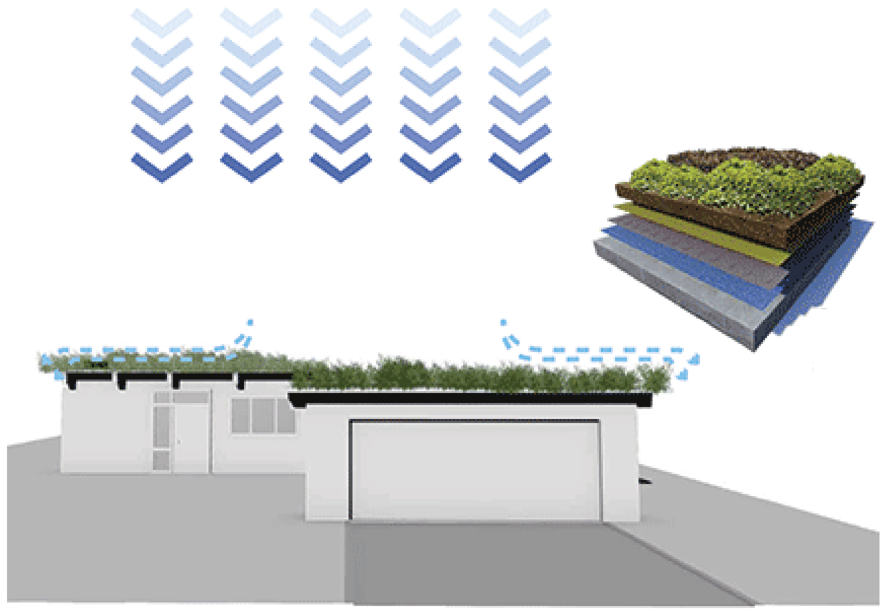


Figure 35. Diagram of a Green Roof adapted from the Houston-Galveston Area Council.

Water is captured and detained in the soil and dispersed through evaporation or transpiration by the plants. Green Roofs reduce volume and peak rates of stormwater and enhance water quality. Other benefits include reduction in heat island effect, extension of roof life, recreational and gardening opportunities, air and noise quality improvement, and reduced building heating and cooling costs. They can be integrated into new construction or added to existing buildings, including buildings with flat and sloped roofs. This practice is effective in urbanized areas where there is little room to accommodate other GI systems.

Constructed Stormwater Wetlands

Constructed stormwater wetlands are manmade shallow-water ecosystems designed to treat and store stormwater runoff (Figure 36). These wetlands allow pollutants to settle out or to be treated by vegetation. Runoff is slowly discharged over one to three days. Wetlands provide plant and wildlife habitat and can be designed as a public amenity. While constructed stormwater wetlands have limited applicability in highly urbanized settings, they are a desired technique on larger sites with relatively flat or gently sloping terrain. They are also well-suited to low-lying areas, such as along river corridors.

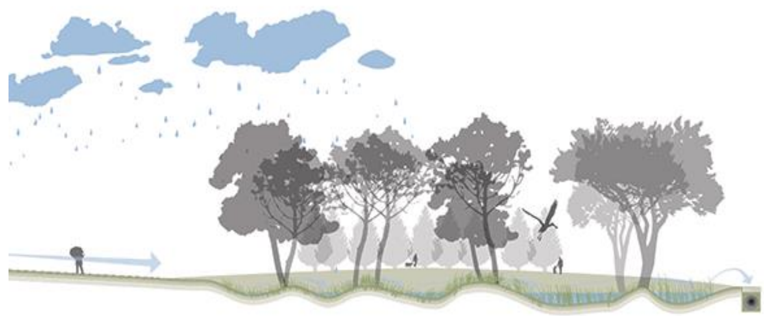


Figure 36. Diagram of a Constructed Stormwater Wetland adapted from the Houston-Galveston Area Council.

Stormwater Treatment Practices Case Studies

In the past few years PDC, in collaboration with a wide number of partners, have been implementing Stormwater Treatment Practices in different priority locations across Puerto Rico. These areas include watershed in the municipalities of; Culebra, Vieques, Cabo Rojo, Guánica, Yauco, Lajas, Luquillo and Fajardo (Figure 37-42). These green infrastructure projects were implemented with very limited space and funding and can be use as examples of possible similar projects to implement in the NEC. In most cases, a train treatment approach was used. A few pictures of these project are presented with a brief description in the following pages.

Figure 37. BMPs implemented following a train treatment approach in Mosquito Bay in Vieques Puerto Rico. Practices include bioswale, bioretention, raingardens, constructed treatment wetlands and permeable parking.

Figure 38. BMPs implemented following a train treatment approach in Zoní Beach at Culebra Puerto Rico. Practices include bioswales, bioretentions, raingardens and permeable parking.

Figure 39. BMPs implemented following a train treatment approach in Punta Soldado in Culebra, Puerto Rico. Practices include bioswales, bioretentions, raingardens, sediment traps and permeable parking.

Figure 40. BMPs implemented following a train treatment approach in Fulladosa Culebra, Puerto Rico. Practices include bioswales and raingardens.

Figure 41. BMPs implemented following a train treatment approach in Puerto del Manglar in Culebra, Puerto Rico. Practices include bioswales and sediment traps.

Figure 42. BMPs implemented following a train treatment approach in Yauco, Puerto Rico. Practices include bioswales, bioretentions and raingardens.

Recommended Stormwater Treatment Practices

A total of thirty-five (35) stormwater treatment projects have been selected in this initial assessment of the NEC (Figure 43, Tables 12 and 13). The proposed sites, if implemented, will have a direct impact for the benefit of coral reefs and other important coastal and marine ecosystems as they have been identified as the most problematic in terms of pollutant sources. Several large parking lot areas have been identified in the NEC with the potential to be transformed to be able to implement green infrastructure projects without greatly affecting its utility as a parking area.

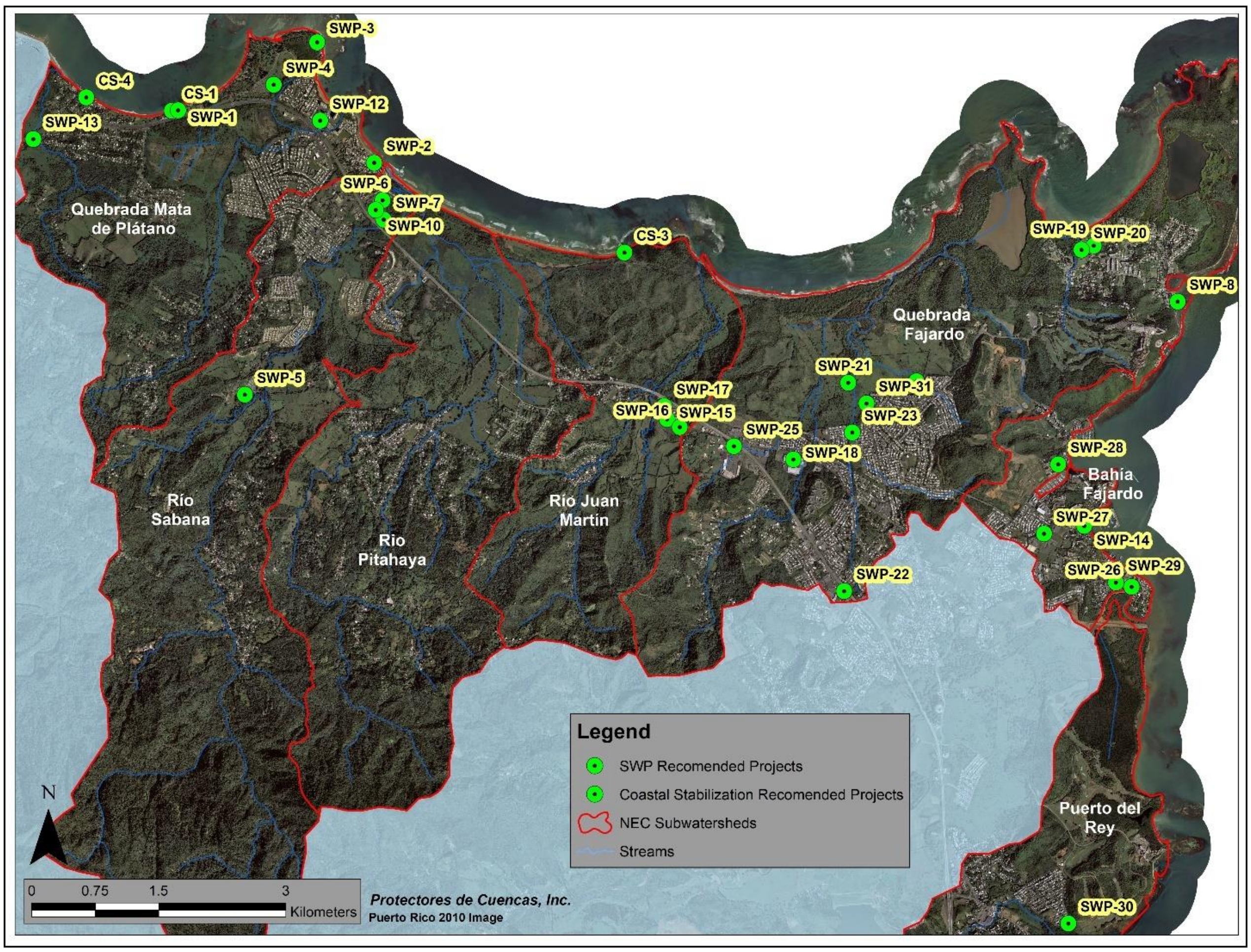


Figure 43. Recommended Stormwater Treatment Projects for the NEC.

Other smaller parking areas can be incorporated into this list later in the process of implementation of restoration efforts. Instead of flowing directly to a river, stormwater from these impermeable surfaces can be transported first to a series of planters that will serve as biofilters constructed with a series of gravel layers and vegetative cover. Where the space is available, multiple BMP's should be constructed so that they will hold the water until pollutants settle and are filtered. The treated runoff is then released slowly into the river, reducing flooding and pollution in the rest of the system. The following illustrations serve as an example of the transformations that can be achieved with the implementation of BMP's on existing parking lot areas. The left side images are from an existing parking area near road PR-3 in the NEC and on the right, we can see examples of the possible BMP's GI practices that can be implemented from similar areas where these practices have been implemented (Figure 44). These practices can be implemented without greatly altering the existing land uses. Minimal parking areas will be lost after BMP's are implemented with high improvements to the landscape as a value added to the sites that can serve as incentives to the landowners to agree to be part of these restoration efforts.

Figure 44. Images on the left are of an actual parking area near PR-3 and on the right comparative areas where BMPs have been implemented (from internet search).

Very dense urban community areas have limited space to construct GI stormwater treatment practices. For this reason, a series of sites adjacent to these communities have been identified with the potential to have GI practices implemented. The sites identified are in the areas where these communities discharge their stormwater runoff. Projects to be implemented in these areas need to have nutrient reduction components to deal with the occasional sewage overflows and failing septic systems that are a constant problem identified for the communities identified. The proposed sites have the available sufficient space to construct a series of bioretention stormwater BMP's and in some cases constructed stormwater wetland can be implemented. Most of these areas have been identified as government properties with great opportunities to implement BMP's. The main land use category on the proposed project sites is farming. Land uses from these areas is not expected to be affected by the incorporation of BMP's as they are mostly cattle grazing agricultural lands. Implemented projects have the potential added value of reducing the risk of mortality to cattle caused by excessive pollutants to available drinking water they use.

Bioretention projects for the community outfalls should have nutrient reduction components added. Adding a Biochar component to implemented projects can help reduce nutrient concentration (Figure 45). If other components like vegetative cover, gravel and sand

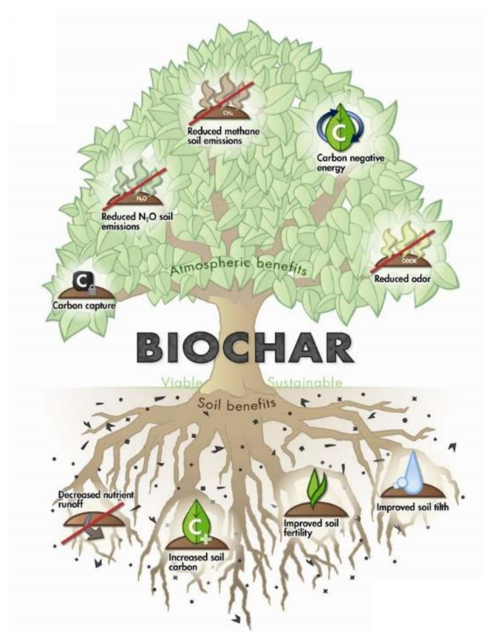


Figure 45. Biochar diagram adapted from International Biochar Initiative.

are incorporated the nutrient reduction capabilities of the projects increases. Biochar is a fine-grained, highly porous charcoal that helps soils retain nutrients and water (Figure 46). Biochar also improves water quality and quantity by increasing soil retention of nutrients and agrochemicals for plant and crop utilization. More nutrients stay in the soil instead of leaching into groundwater and stormwater causing pollution.

Figure 46. Gravel filter and parking lot stabilization by PDC in Parguera, Puerto Rico.

The following Illustrations serve as an example of the transformations that can be achieved with the implementation of BMP's on existing farm areas. The left side images are from existing community outfalls in the NEC and on the right, we can see examples of the possible BMPs GI practices that can be implemented from similar areas where these practices have been implemented (Figure 47).

Figure 47. Images on the left are of actual community outfalls of the NECW and on the right comparative areas where SWP BMPs have been implemented (up from a PDC implemented project, middle and bottom from internet search).

NUTRIENT REDUCTION PRACTICES

Nutrient Reduction Practices (NRP) are a type of stormwater treatment practice that is implemented with the purpose of reducing nutrient concentrations on areas that are known to be sources of contamination with high nutrient content. The main difference is that NRP are design to provide treatment for constant flows not just for stormwater events. NRP are also very commonly used to provide treatment from agricultural activities.

Treatment Wetlands

Treatment wetlands (TW), are shallow depressions that receive flow inputs for water quality treatment. The long residence time allows nutrient pollutants removal processes to operate. The wetland environment provides an ideal environment for gravitational settling, biological uptake, and microbial activity. Treatment Wetlands have become widely accepted as urban stormwater treatment practices and are increasingly being integrated into urban design practices. Wetland based systems offer the advantages of providing a relatively passive, low-maintenance and operationally simple treatment solution for stormwater treatment potentially enhancing habitat for wildlife and aesthetic values within the urban landscape and for passive recreational activities.

Floating Treatment Wetlands

Another type of TW is the Floating Treatment Wetland (FTW). FTW are a variant of constructed wetland technology which consist of emergent wetland plants growing hydroponically on structures floating on the surface of a pond-like basin (Figure 48). They represent a means of potentially improving the treatment performance of conventional pond systems by integrating the beneficial aspects of emergent vegetation without being constrained by the requirement for shallow water depth. FTW are a perfect solution for existing ponds that are too deep for wetland development.

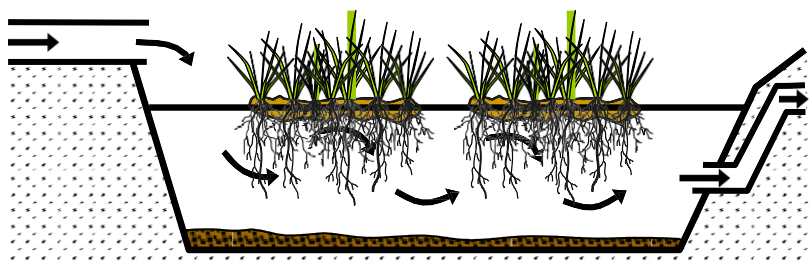


Figure 48. Diagram of a Floating Treatment Wetland adapted from Headley & Tanner, (2008)

Woodchip Bioreactor

A woodchip bioreactor (schematic shown in Figure 49) is an edge-of-field practice designed to originally treat wastewater from agricultural operations which has been adapted for use in addressing human wastewater. The main component of a woodchip bioreactor is a buried trench filled with woodchips. Using an in-line water control structure, water is diverted from a cesspool or septic system to the woodchip trench. The trench provides the proper environment (carbon from woodchips, nitrate-nitrogen from wastewater drainage and low dissolved oxygen) to promote denitrification, a process that converts nitrate to the harmless nitrogen gas that makes up 70% of the air we breathe and is the same process that naturally occurs in wetlands and mangrove areas.

The practice mimics the ecological services that occur in first-order streams and forested wetlands. In areas with intensive agriculture or urbanization, these are the very areas that are converted to agricultural or urban lands through the use of artificial drainage. Thus, bioreactors replace the ecological services of the areas that existed before they were converted to agriculture. Woodchip bioreactors are passive systems, located at the edges of farm fields or urban areas where they require little or no maintenance over their 15 – 20-year lifespan. The cost per pound of nitrogen removed is very low because of the extended life of the projects and the very high efficiency.

The power of woodchip bioreactors is their simplicity. As summarized below, they are easy to implement and maintain, efficient, inexpensive, and above all, effective.

- These practices are passive; the construction of the practice creates the conditions that biologically converts nitrate to nitrogen gas.
- They are typically constructed as an edge-of-field practice that takes very little land out of service and they are covered with a foot of soil and turf grass or native vegetation.
- They require very little maintenance. Sediment must be cleaned out of the diversion box once or twice a year.

- They are highly efficient. Data from Iowa State and Maryland project have shown that over 90% of nitrate entering the system is converted to harmless nitrogen gas (Rosen and Christenson, 2017)
- When coupled with the addition of biochar they can also reduce effectively ammonia and phosphorus (Bock et. al., 2015) (Ridge to Reefs, pers. communication) https://www.ncbi.nlm.nih.gov/pubmed/26023979

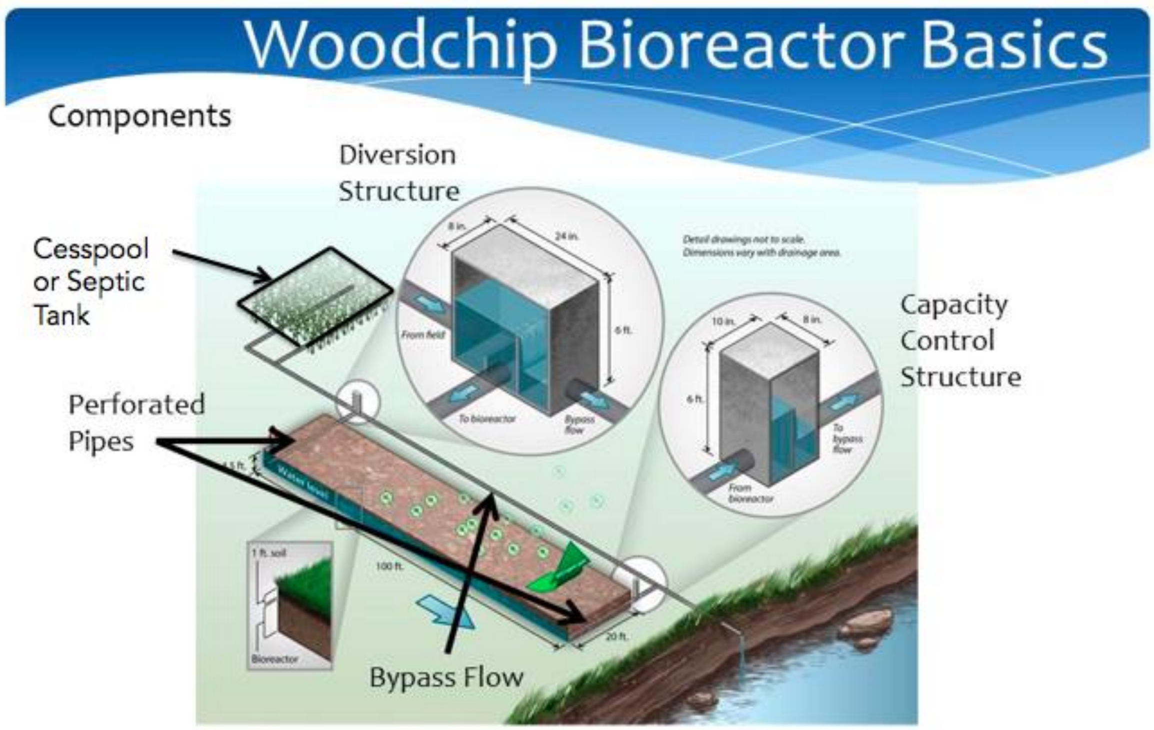


Figure 49. Woodchip Bioreactor schematic (adapted based on image by John Petersen, www.petersenart.com)

Recommended Nutrient Reduction Practices

The NRP that are been proposed to provide treatment to community outfalls are mostly treatment wetlands with bioretention components using biochar and other nutrient removal elements. The selected areas for the proposed NRP are mostly on public lands classified as agriculture land use. A total of eight (8) NRP have been identified in the NEC that will target most of the hotspots for nutrient pollution found in our field assessments (Figure 50, Tables 14 and 15). Figure 51 shows some of the community outfalls on the NECS that are suitable for the implementation of NRP.

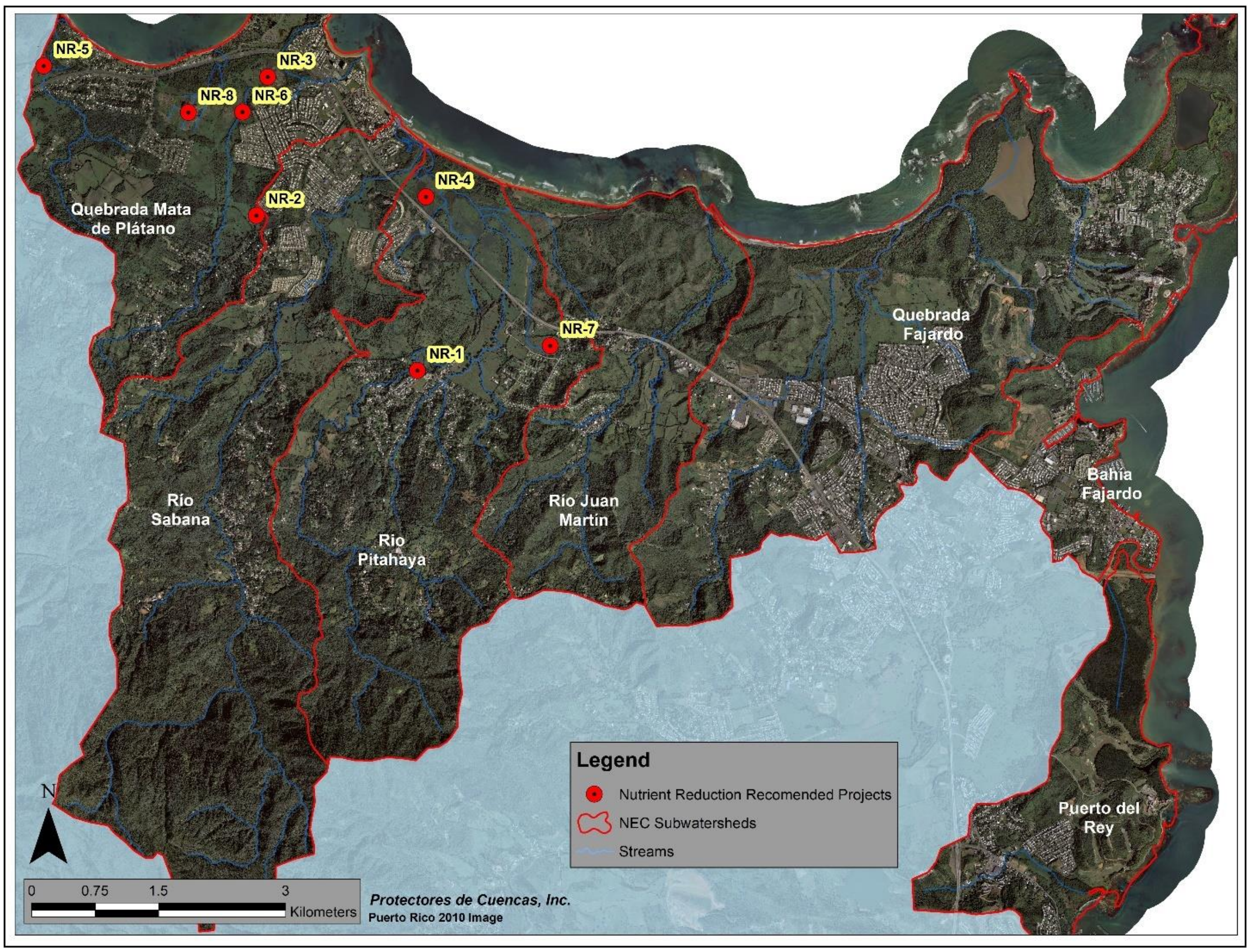


Figure 50. Nutrient Reduction recommended projects for the NECW.

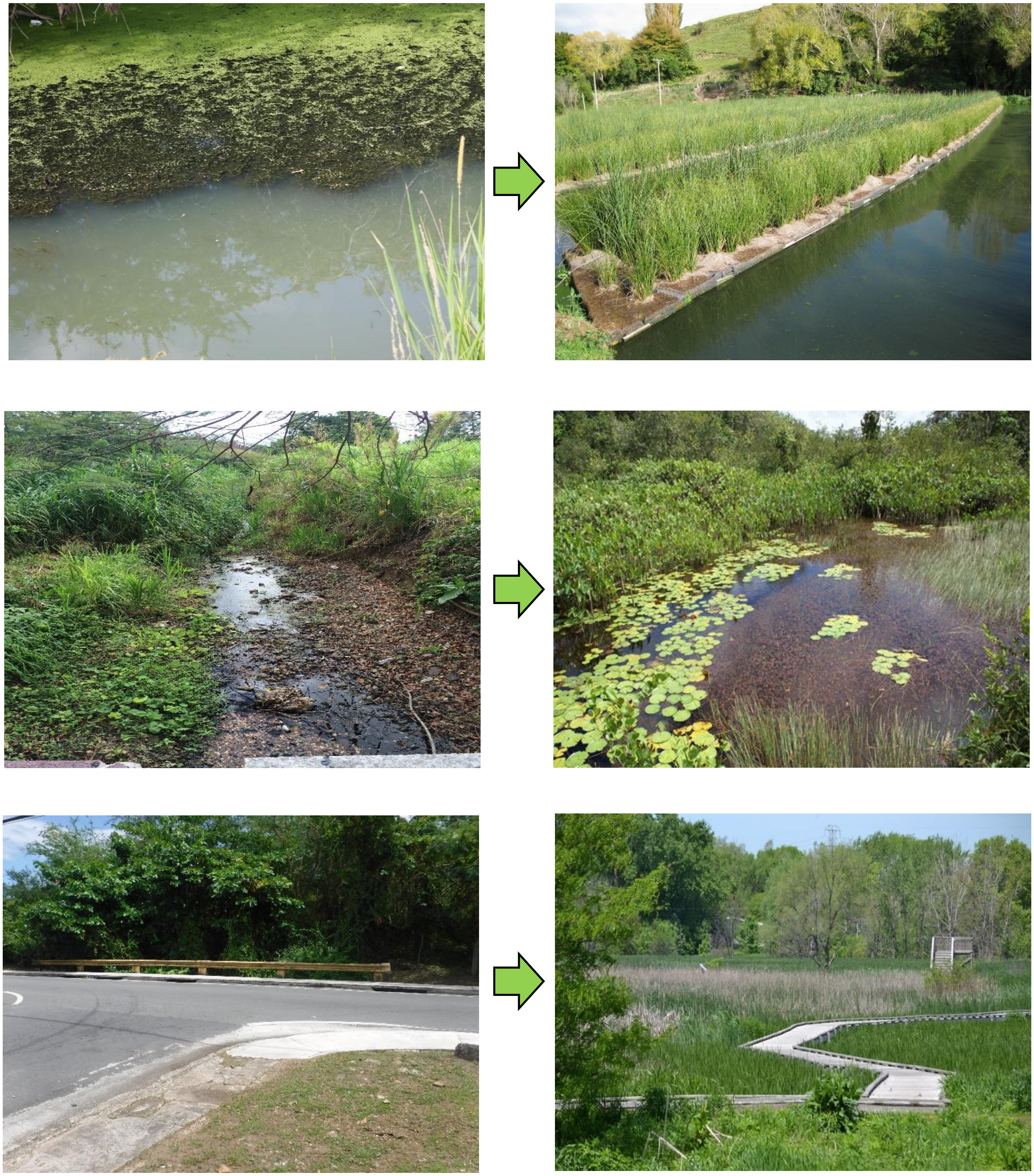


Figure 51. Images on the left are of actual community outfalls of the NEC and on the right comparative areas were NRP BMPs have been implemented (from internet search).

Soil Stabilization Practices

Stabilization of bare soils involves the rapid re-stabilization of vegetation and generally a transition to more native and stable forms of vegetation. One effective way to re-establish vegetation in an area is to utilize Hydroseeding followed by watering to rapidly transition to a more stable vegetated system where runoff is reduced. Dirt roads are stabilized using methods to remove water from the road and reduce erosion. These include concrete or dirt cross-swales, check dams and sediment traps.

It should be noted that all exposed soil and dirt roads transport sediment at a rate of 5x to 100x the natural transport rate from a forest or a field, so maximizing the number of roads and bare soil areas treated is a critical element of the watershed plan, as is reducing the impact of future dirt roads and new construction.

Hydroseeding

Hydroseeding refers to a process of planting grass using a mulch mixture that is fast, efficient and an economic alternative to restore areas of high slopes with difficult access when compared to other techniques such as turf grass. This process has proven to be more effective than traditional sowing and with lower costs than conventional transplantation. A mulch mixture composed of fibers, seeds, fertilizer and water is added to the tank of the Hydroseeding machine. Once the appropriate mulch mixture is achieved, the mixture is pumped from the tank and applied on the soil. Once the materials come in contact with the soil, they easily adhere and create favorable conditions for seed germination.

The Hydroseeding method is mostly used to restore areas devoid of vegetation affected by erosion processes and sedimentation in order to protect bodies of water and marine ecosystems from the adverse effects of sediment laden runoff. Other common uses of Hydroseeding include: at construction sites, cover crops for farm lands, revegetate green areas after road construction, residential and commercial landscaping, as well as extensive areas such as golf courses and stadiums.

A large amount of mulch options are available, from the most inexpensive (composed of 100% recycled paper or a mixture of 50% recycled paper and 50% wood fiber), intermediate costs (composed of 100% wood fiber), and the most costly, the Bounded Fiber Matrix or BFM (composed of 100% wood fiber with added polymers and other additives that maximize its attachment to the soil). Typically, the mixture chosen depends on the degree of the slope, the available budget and the quality of the desired product.

Based on PDC's experience with Hydroseeding have shown that the mulch mixture composed of paper fibers results in low quality and poor germination rates. It is for this reason that we have decided not to use paper fiber mixtures for our hydroseeding projects. We've had excellent results using mixtures of 100% wood fiber with the addition of some products found in the BFM, allowing us to reach optimum results with an intermediate budget.

There are different types of machinery or hydromulchers on the market. The main difference between these different options is the size of the machine and its tank capacity. In order to work with wood based mixtures, a specialized machine with greater power is needed. Protectores de Cuencas, Inc. has one of these specialized machines for wood based mixtures, with a water storage capacity of 325 gallons, making it the perfect combination of power and size adequate to reach areas that would be impossible to reach with larger equipment. With this equipment, we can cover an area between 1,200 and 1,500 ft² per tank applying close to 10 tanks daily in order to cover one acre of land daily, depending on the slope angle and accessibility to the area (Figure 52).

Figure 52. Hydroseeding implementation by PDC on a riverbank stabilization project in the Río Loco, Guánica Puerto Rico

Regular irrigation of restored areas during the first four to six weeks after Hydroseeding is necessary to obtain optimum results. Application should occur during dry periods, where heavy rain is not anticipated during 48 to 72 hours following application to allow product fixation to the soil.

The seed mixture to be used for the Hydroseeding applications is 70% Rye Grass and 30% Bermuda grass. The Rye Grass is the first to germinate (usually during the first 5 days) and has a life span of approximately 30 days that serves as a nursery for the Bermuda during its germination period of approximately 20 days once the Bermuda is established the Ray grass will slowly be replace by the Bermuda.

Dirt Road Stabilization

Dirt roads are stabilized using methods to remove water from the road and reduce erosion. These include concrete or dirt cross-swales, check dams and sediment traps. The severity of potential erosion is based on slope and the percentage of fine particles available for sediment transport and the perceived frequency of maintenance of the dirt road. Frequency of maintenance and the percentage of fine particles available for transport are key factors in sediment loss. Maintenance is defined as maintenance using heavy equipment backhoes and bulldozers, which results in considerable disturbance and exposure of fine soil particles.

Transport factor is the ability of the sediment to be transported to the nearshore marine environment and to a lesser degree to be transported to coastal lagoons important for processing/trapping sediment and other contaminants before reaching the marine environment. A high transport factor has greater potential of leading to the marine environment, particularly with likely transport to coral reef communities. Dirt roads can be stabilized using several BMP's depending on the slopes and available space. Based on our experience implementing BMP's, we can recommend that one practice on its own is not enough to observe an improvement. Instead, it is important to implement a series or combination of BMP's that are best suited for the location, while taking into consideration other factors such as slope gradients, soil type and composition. Some if these practices include:

Regrading

Regrading refers to the process of diverting road incline to desired topography to divert runoff to implemented BMP's. Incline of the road can be done to the inner, outside or both sides of the road depending on the treatment that will be constructed to deal with the runoff and the existing slope grade (Figure 53). This practice is highly recommended as it will be very difficult to impossible to implement other BMP's without regrading. All

Figure 53. Example of regrading and compaction by PDC on a dirt road in Culebra, Puerto Rico.

regarded roads should be compacted with a compacting roller the same day it has been regraded to prevent soil loss and damage to the work if a rain event occurs.

Check Dams

Check dams are generally used in concentrated flow sites, such as diches and swales and they can be both a temporary or permanent measurement (Figure 54).

Figure 54. Example of check dams constructed by PDC on a dirt road network in coffee farms of Yauco Puerto Rico.

They form barriers that prevent erosion and promotes sedimentation by slowing the velocity of water and filtering runoff. Check dams are best implemented in combination with a continuous swale along the inner side of the road. Check dams intersect flow at intervals of approximately 25 to 30 ft. depending on the slope. As stormwater runoff flows through the structure, the check dam catches sediment from the channel itself or from the contributing drainage area. They can be built from a combination of 8-12 inch stones and Vetiver grass.

They are most effective when used with other stormwater, erosion, and sediment-control measures. Check dams also help redirect the flow of sediments towards other practices implemented. Check dams are another cost-effective technique applicable for dirt road stabilization. If combined with the installation of erosion control blankets, vetiver grass and Hydroseeding (if the budget is available) check dams can work better and need less maintenance.

Sediment Traps

Sediment trapping techniques have demonstrated that work better when constructed with functional redundancy. Integrated sediment trapping is the most effective approach to manage sediment migration when compared with individual and combined measures alone. Sediment traps are constructed to help filter storm water that is causing erosion problems and discharging sediments (Figure 55).

Figure 55. Example of a sediment trap built by PDC in Culebra Puerto Rico.

Paving and Compaction

Dirt road stabilization techniques included using fill material to stabilize the steep segments of the roads. The fill material layer used for road stabilization contains small rocks and granulate materials that makes it a good soil mixture for compaction (Figure 56).

The use of this paving material is one of the most effective practice that can be implemented on dirt road stabilization as it is a cost-effective way of preventing road deterioration by rainfall and subsequent runoff and erosion problems.

Figure 56. Example of gavel pavement done by PDC on a coffee farm on Yauco Puerto Rico

Rip-rap

Rip-Rap consists of a permanent sediment and erosion control practice made with resistant ground cover and the use of large angular stones. It is commonly used to protect slopes, streambanks, channels, or areas subjected to erosion by wave action. Rock rip-rap protects soil from erosion due to concentrated runoff. It is used to stabilize slopes that are unstable due to seepage. It is also used to slow the velocity of concentrated runoff which in turn increases the potential for infiltration. Rip-rap offers an easy-to-use method for decreasing water velocity and protecting slopes from erosion. It is simple to install and maintain (Figures 57).

For this practice, we recommend that stones are of good quality, correctly sized, and placed to proper thickness. A filter fabric should be used to cover the soil prior to the installation of the proper size stones. Properly sized bedding or geotextile fabric is needed to prevent erosion or undermining of the natural underlying material. Another recommendation is to use hydroseeding on the areas prior to installing the stones. The rock should be placed as soon as possible after disturbing the site, before additional water is concentrated into the drainage system. Over all, rip-rap is cost effective and easy to install, requiring only that the stones be manually arranged so that they remain in a well-graded

Figure 57. Examples of rip-rap practices implemented by PDC on a coffee Farm on Yauco Puerto Rico.

mass. Where possible, rip-rap should be combined with bioengineering techniques with lines of Vetiver grass.

Vetiver Grass

Vetiver grass is a very simple, practical, inexpensive, low maintenance and very effective means of soil and water conservation, sediment control, land stabilizations and rehabilitation, and it also can be used in phyto-remediation practices. When planted in a linear pattern or in half-moons, vetiver plants will form a vegetative mass which is very effective in slowing and spreading run off water, reducing soil erosion, conserving soil moisture and trapping sediment on site. The extremely deep and massively thick root system of Vetiver binds the soil and at the same time makes it very difficult for it to be displaced under high velocity water flows. This very deep and fast growing plant can also tolerate extreme drought conditions as well as moderate soil salinity concentrations with a highly effectiveness on steep slope stabilization (Figure 58).

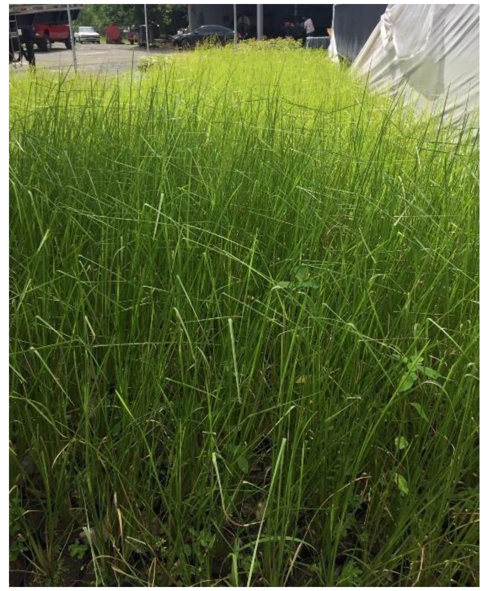


Figure 58. Vetiver plants grown on PDC's Nursery in Yauco Puerto Rico

The most commonly available Vetiver plant material comes in small plots, but the best and more rapid results are achieved when plots are transplanted to a 1 gallon pot and grown for no less than 3 months. Because of this technique, planted Vetiver grass, responds more rapidly and adapt to the site's climate condition in a more efficient way with less maintenance period.

Swales

A swale is a small channel that conveys water from one point to another. When planted with grasses or native vegetation, swales can be very useful in collecting stormwater. There are different types of swales and they can serve various purposes depending on the slope, soil type and the pollutants you will be treating. Swales can be made with stones, vegetative cover, concrete or a combination of all them (Figure 59).

Figure 59. Example of swales made by PDC in Culebra (concrete) and in a coffee farm (stones).

Agricultural Soil Stabilization Practices

Riparian Forest Buffers

Other recommended integrated management actions for agricultural lands are the establishment of Riparian Forest Buffers (RFB) along many areas of the rivers and its tributaries on active farmlands, Fencing and stabilized stream crossing for cattle and farm equipment. RFB are important for good water quality. Riparian zones help to prevent sediment, nitrogen, phosphorus, pesticides and other pollutants from reaching a stream (Figure 60). RFB are most effective at improving water quality when they include a native grass or herbaceous filter strip along with deep rooted trees and shrubs along the stream. Riparian vegetation is a major source of energy and nutrients for stream communities. RFB provide valuable habitat for wildlife. In addition to providing food and cover they are an important corridor or travel way for a variety of wildlife. Riparian vegetation slows floodwaters, thereby helping to maintain stable streambanks and protect downstream property (Figure 61). By slowing down floodwaters and rainwater runoff, the riparian vegetation allows water to soak into the ground and recharge groundwater. Slowing floodwaters allows the riparian zone to function as a site of sediment deposition, trapping sediments that build stream banks and would otherwise degrade our streams and

Figure 60. Example of a riparian forested buffer adapted from NRCS.

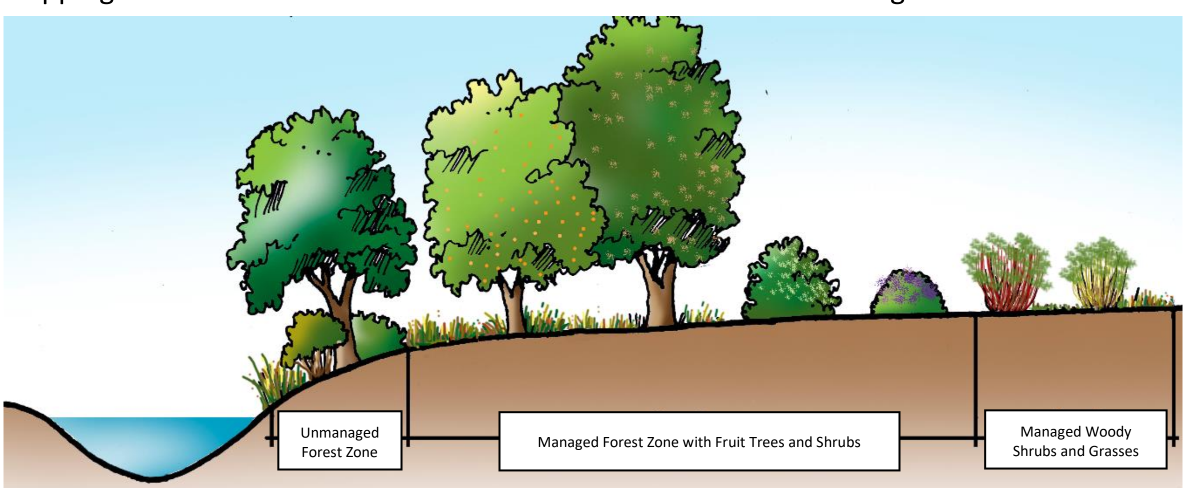


Figure 61. Diagram of a riparian forest buffer components adapted from NRCS.

rivers. Rehabilitating riparian buffers is key to restoring natural stream functions and aquatic habitats. There are many economic benefits derived from increased riparian habitat, channel stabilization, improved water quality, improved wildlife and fish populations, improved aesthetics, and other associated values. Depending on the surrounding land use and area topography, riparian buffers should range from 25 to 100 feet wide on each side of the stream.

Fencing

Fence is a practice that may be applied on any area where farmers need better control of animals or people (Figure 62). Fences are typically used to facilitate better Livestock management. Fences may be implemented to protect sensitive ecologic areas, vegetative buffers, and high erodible lands. Fences constructed to keep cattle out need to be strongly well established to prevent collapse by cattle traffic.

Figure 62. Example of a fencing practice implemented by PD on a farm in the RFW.

Stabilized Stream Crossing

Stream Crossing consists of a stabilized area or a structure constructed across a stream to provide a travel way for people, livestock, equipment, or vehicles (Figure 63). This practice can improve water quality by reducing sediment, nutrient, stream loading, reduce streambank and streambed erosion, and provide a crossing for access to other grazed lands. Stabilized stream crossing can be made of stones, concrete of using a bridge structure.

Figure 63. Example of a stabilized streambank crossing practice implemented by PDC on a farm in the RFW.

Proposed Soil Stabilization Projects

Most of the Bare Soils areas in the NEC are associated to the dirt road networks, active and abandoned construction sites and agriculture (Figure 64). The recommendations for dirt road and bare soil stabilization are found in Tables 16 and 17. Each of the bare soil restoration projects is important in its own due to the high loads associated with bare soils. Additional targeting of farms and dirt roads in the Middle and Upper watershed is necessary for the near future. A total of twenty (20) soil stabilization practices have been identified as priority implementation areas. Additionally, a series of areas along the NEC associated rivers and tributaries need to be identified for the implementation of Riparian forested buffers.

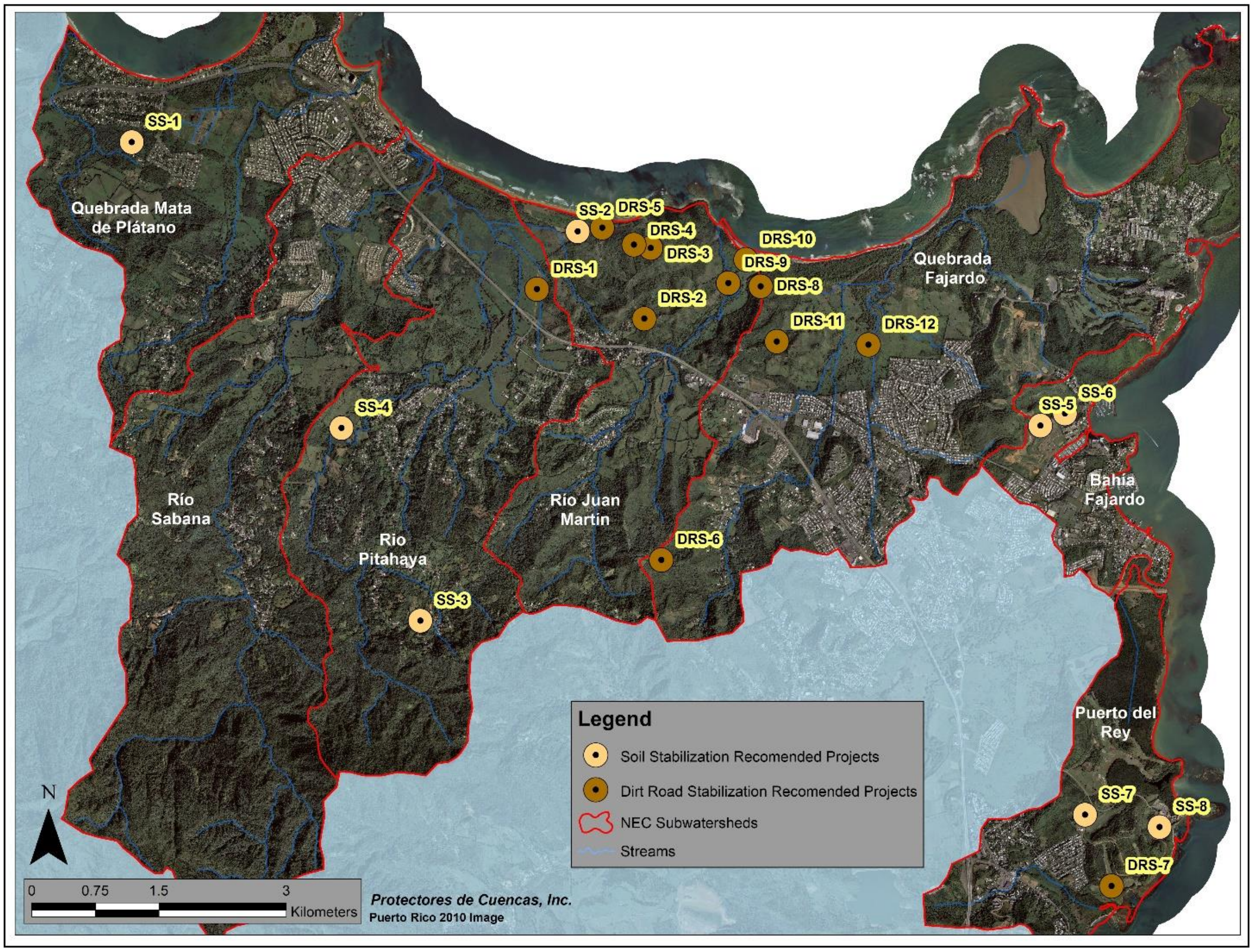


Figure 64. Soil stabilization recommended projects in the NEC.

Pollution Prevention Practices

Pollution prevention includes measures that help to reduce pollution from existing and future sources of pollution by taking a proactive preventative approach and working directly with key entities and individuals that may be responsible for pollution. In the NEC watershed, this includes increased IDDE detection and elimination of illicit discharges, increased erosion and sediment control training workshops for the jurisdictions and their developers including those in Fajardo, Luquillo and Ceiba. A door-to-door survey of areas where water pollution is persistent should be implemented to determine whether homes are properly connected to sewer or whether they have failing septic systems. Another form of pollution prevention included education and outreach and making use of opportunities to educate the public about water quality and the benefits of restoration for restoring ecosystems in which we are all dependent.

Finally, based on the team field assessments and recommendations from the public participatory process, additional watersheds of Río Grande and Ceiba should be studied and integrated to this watershed management as they have a direct impact on the marine environment that this plan seeks to protect. Opportunities to take these critical steps to effectively safeguard the natural resources of the NEC area and found in (Table 18 and Figure 65).

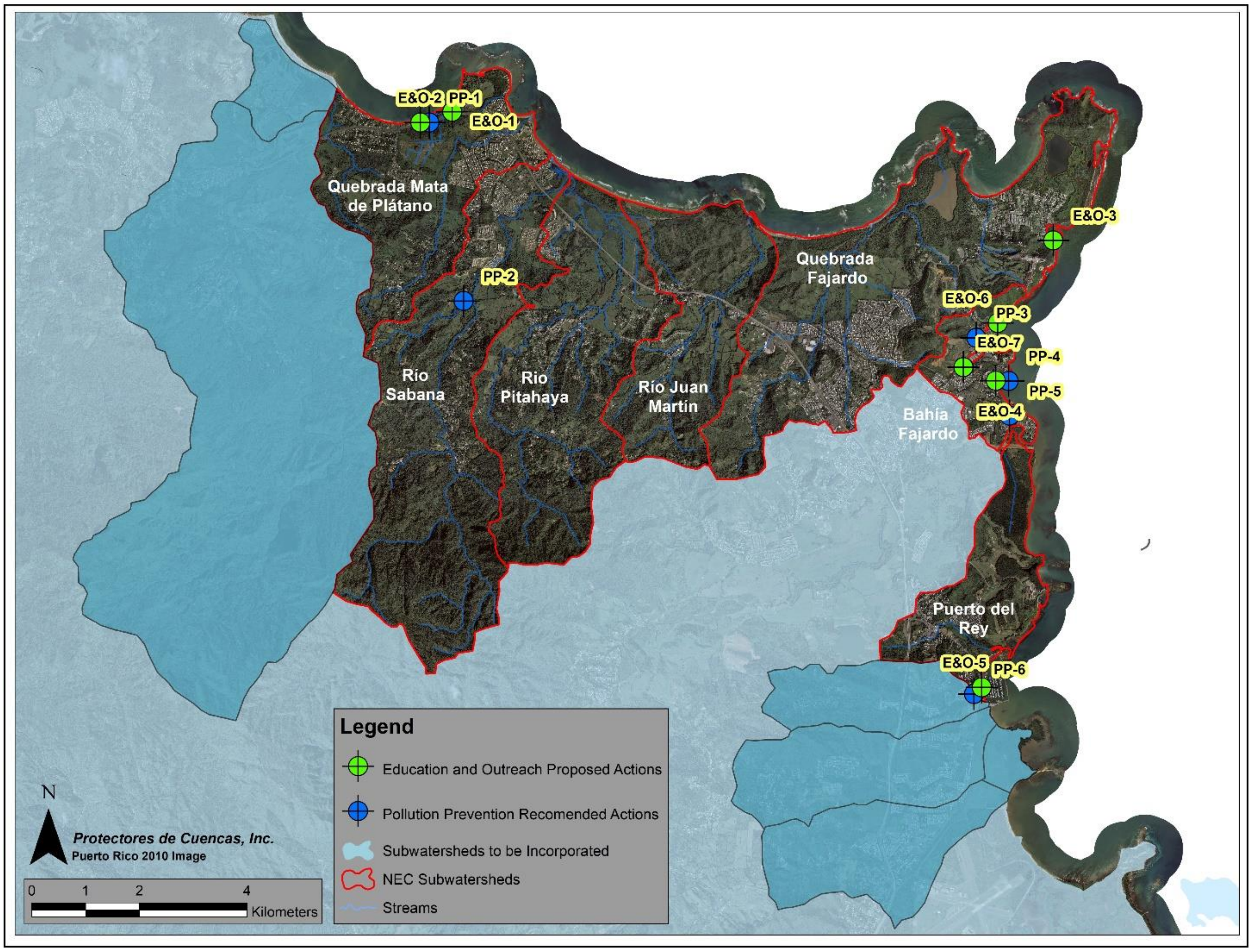


Figure 65. Pollution prevention recommended projects in the NEC.

IDDE Tracking

Increased IDDE would direct resources toward finding and fixing illicit discharges. Specifically, the monitoring methods and parameters that have been outlined in the initial illicit discharge survey in this report. Isolating and discharges is also summarized in USEPA guidance on the subject. Several areas have been identified with the need to conduct a more detailed IDDE protocol at a greater extent with the incorporation of additional testing and tracking techniques such as the use of dye, smoke and underground cameras (Figure 66).

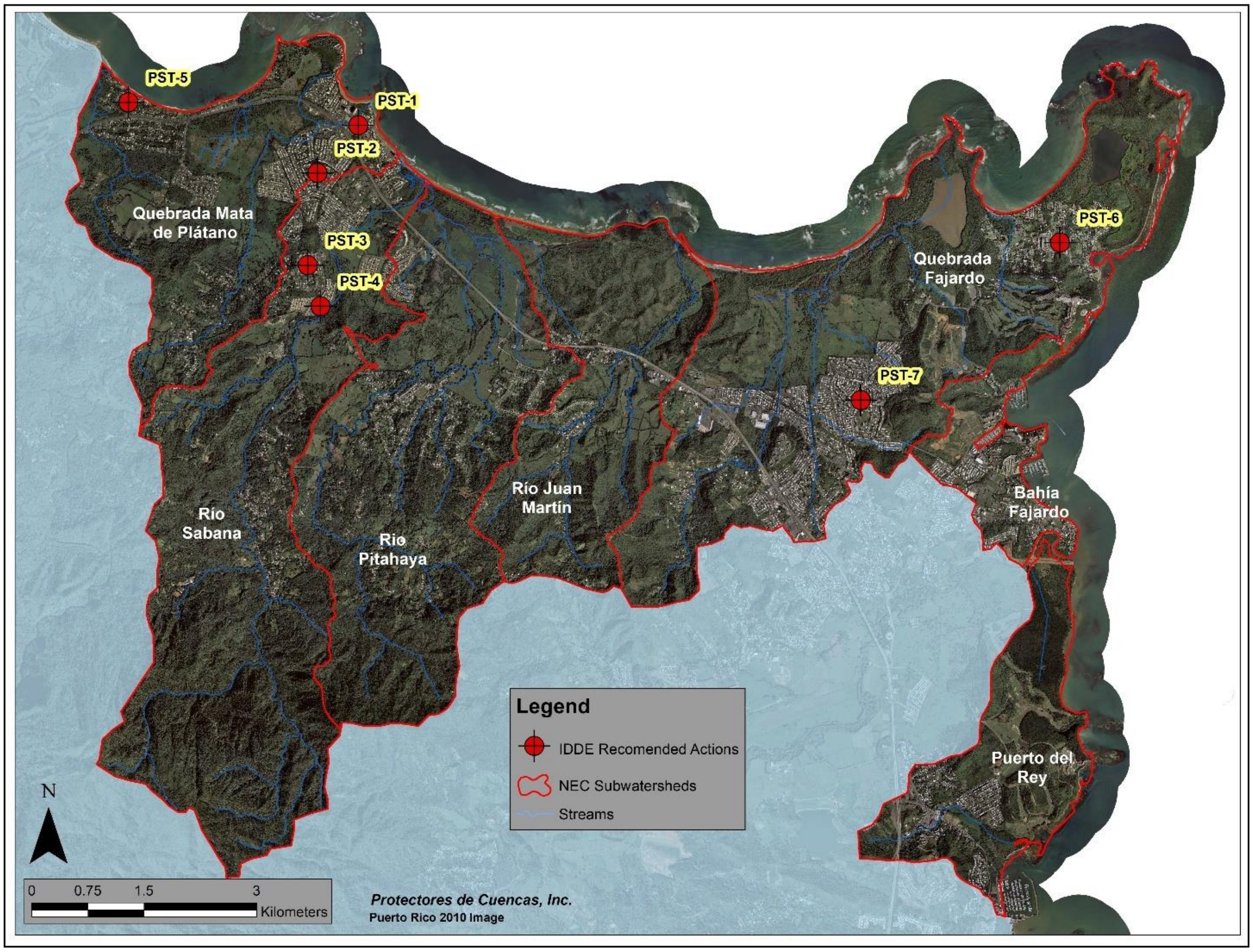


Figure 66. IDDE additional proposed sites for source taking.

Watershed Coordination

A Watershed Coordination Entity (WCE) can be funded for the coordination and implementation of the recommended actions on these report as well as the recommendations of this Plan. The WCE can also oversee coordination of all activities also recommended in the Fajardo Watershed Management Plan and Recommended Integrated

Management Actions and all Habitat Focused Area including Culebra Island. Funds for this effort can come as part of the Cooperative Agreements that the DNER has with NOAA and USFWS or another alternative is to cover the funds of the WCE is through a multi-partnership approach and partners can alternate allocating funds at a yearly basis. Some specific actions that a WCE can work include:

1. Continue with sediment and erosion control workshops for the municipalities, PRASA and private contractors.
2. Guidelines for the construction and maintenance of dirt roads can be created and adopted by municipalities in order to reduce their impact. This should include the specific options for BMP's to reduce sediment losses. These standards would be endorsed by Municipality, DNER and EPA and would be mandatory and subject to enforcement. Provide training for local contractors and agency staff.
3. Increased enforcement and education of contractors and local oversight from the municipal inspectors.
4. IDDE detection and elimination of illicit discharges and door-to-door surveys of areas where water pollution is persistent to determine whether homes are properly connected to sewer or whether they have failing septic systems.
5. Conduct a survey of all Agricultural activities in the WMP and associated pollution sources with alternative BMP's that can be implemented in the
6. Identify funding sources for the implementation of the recommended integrated watershed management actions.

Proposed Projects Description

The following tables describe each proposed project site in terms of its feasibility, existing conditions, BMP's that can be implemented as well as cost estimates and permits needed. A cost scale has been developed for proposed projects. Projects on a cost range from $25K to $125K are considered small projects, projects from $126K to $305K are considered medium scale projects, and projects with a cost range of 306K to $545K are considered big projects. Projects that have a cost higher than $545K are considered large projects. Small projects have a $20K variance of contingency cost, medium projects have $40K and big projects have a $60K variance of contingency cost. Estimated costs are real and does not include possible matching contributions. Tables of proposed projects to implement also include possible funding partners as well as matching contribution partners. The distance from streams of the bare soil areas has been measured in GIS following the exiting drainage patterns.

Stormwater Treatment Practices Proposed Projects List

Table 12. Stormwater Treatment Practices proposed projects list description.

ID	Sub Water -shed	Observations	Estimated Impervious Cover Area (%)	Estimated Drainage Area (acres)	GPS Coordinates	Type	Ownership	Existing Land Use	Sewer Infrastructure Service
SWP-1	QMP	Multiple areas for BMP implementation. Should be done in combination with CS-1.	60	20	18.38095° -65.73633°	Parking & Road area	Public	Urban Recreational	Yes
SWP-2	QMP	Multiple green areas for BMP implementation	95	25	18.375662° -65.714362°	Parking & road area	Public	Urban Institutional	Yes
SWP-3	QMP	Multiple adjacent green areas for BMP implementation	95	3	18.388433° -65.720915°	Parking area	Public	Urban Institutional	No
SWP-4	QMP	Large area for BMP implementation.	95	30	18.383838° -65.725701°	Parking area	Private	Urban Recreational	No
SWP-5	RS	Limited available space for BMP. Needs to be combined with Soil Stabilization Practices.	60	15	18.350761° -65.728406°	Parking area	Public	Low Density Urban	No
SWP-6	RS	Limited available space for BMP. Adjacent green area for potential additional treatment.	100	10	18.371693° -65.713345	Parking & Housing area	Public	High Density Urban	Yes
SWP-7	RS	Limited available space for BMP. Adjacent green area for potential additional treatment.	100	10	18.369642° -65.713204°	Parking & Housing area	Public	High Density Urban	Yes
SWP-8	QF	Multiple areas for BMP implementation. Project can be Phased.	75	10	18.362139 -65.624436	Parking, Recreational & road area	Public	Medium Density Urban Comercial	No
SWP-9	PR	Limited available space for BMP	100	5	18.284434° -65.635036°	Marina	Private	Comercial	No
SWP-10	RS	Limited available space for BMP. Adjacent green area for potential additional treatment.	100	10	18.37065° -65.714113°	Parking & Housing area	Public	High Density Urban	Yes
SWP-11	PR	Limited available space for BMP.	100	15	18.287437 -65.636036	Marina	Private	Comercial	No
SWP-12	QMP	Multiple areas for BMP implementation. Project can be Phased.	90	15	18.380085° -65.720442°	Parking & Recreational Area	Private	High Density Urban Comercial	Yes
SWP-13	MP	Limited available space for BMP	85	5	18.377651° -65.75245°	Gas Station	Private	Low Density Urban	No
SWP-14	BF	Limited available space for BMP	100	5	18.338094° -65.634497°	Marina	Private	Comercial	Yes
SWP-15	RJM	Suitable area for BMP implementation. Should be done in conjunction with SWP-16 and SWP-17	100	20	18.348829° -65.681239°	Parking area	Private	Comercial	Yes
SWP-16	RJM	Suitable area for BMP implementation. Should be done in conjunction with SWP-15 and SWP-17	100	20	18.348° -65.679822°	Parking area	Private	Comercial	Yes
SWP-17	RJM	Suitable area for BMP implementation. Should be done in conjunction with SWP-15 and SWP-16	100	20	18.350188° -65.681578°	Parking area	Private	Comercial	Yes
SWP-18	QF	Suitable area for BMP implementation.	100	20	18.344723° -65.667088°	Parking area	Private	Comercial	Yes

SWP-19	QF	Multiple areas for BMP implementation. Adjacent green area for potential additional treatment. Should be done in conjunction with SWP-20.-16	10	5	18.367975° -65.633896°	Parking area	Public	Recreational	No
SWP-20	QF	Multiple areas for BMP implementation. Adjacent green area for potential additional treatment. Should be done in conjunction with SWP-19.	95	10	18.367517° -65.635263°	Parking area	Public	Recreational	No
SWP-21	QF	Multiple areas for BMP implementation. Adjacent green area for potential additional treatment.	0	100	18.352982° -65.661089°	Preserve Area	Public & Private	Conservation	No
SWP-22	QF	Suitable area for BMP implementation.	100	15	18.330771° -65.66119°	Parking Area	Private	Comercial	Yes
SWP-23	QF	Multiple areas for BMP implementation. Adjacent green area for potential additional treatment.	0	10	18.347692° -65.66055°	Preserve Area	Public & Private	Conservation	No
SWP-24	QF	Multiple areas for BMP implementation. Adjacent green area for potential additional treatment.	0	25	18.353242° -65.653459°	Preserve Area	Public & Private	Conservation	No
SWP-25	QF	Multiple areas for BMP implementation. Adjacent green area for potential additional treatment.	90	25	18.346031° -65.673716°	Parking Area	Public & Private	Comercial	Yes
SWP-26	BF	Suitable area for BMP implementation.	40	5	18.331687° -65.629111°	Housing Area	Public	High Density Urban	Yes
SWP-27	BF	Suitable area for BMP implementation.	100	5	18.337213° -65.638988°	Housing Area	Public	High Density Urban	Yes
SWP-28	BF	Suitable area for BMP implementation.	85	10	18.344618° -65.637496°	Parking Area	Private	Comercial	Yes
SWP-29	BF	Suitable area for BMP implementation.	80	5	18.332113° -65.630869°	Housing Area	Public	High Density Urban	Yes
SWP-30	PR	Multiple areas for BMP implementation. Adjacent green area for potential additional treatment.	90	30	18.2957° -65.635622°	Housing Area	Public	High Density Urban	Yes
SWP-31	QF	Multiple areas for BMP implementation. Adjacent green area for potential additional treatment.	0	10	18.3508° -65.659	Preserve Area	Public & Private	Conservation	No
CS-1	MP	Multiple areas for BMP implementation	20	15	18.380901° -65.737022°	Beach area	Public	Recreational	Yes
CS-2	PR	Multiple areas for BMP implementation	45	10	18.284458° -65.635071°	Beach area	Public	Recreational	No
CS-3	MP	Multiple areas for BMP implementation. Should be completed in conjunction with soil stabilization practices.	20	5	18.366509° -65.686282°	Beach area	Public	Recreational	No
CS-4	QMP	Retreat from coastal area	NA	NA	18.382179° -65.746592°	Beach area	Public	Urban	No

Table 13. Stormwater Treatment Practices proposed projects list recommended actions.

ID	BMP's Types	Cost Scale	Est. cost ($K) range	Est. Eng. % design	Topo Survey	H&H Study	Permits/Authorization	Possible Funding Partners	Possible Matching Partner
SWP-1	Bioretention, Raingarden, Bioswale	Small	46→65	30%	Simple	No	NEPA, General Construction Permit, Municipal	EPA, NOAA, DNER, EQB, NFWF, Municipality	PDC, Municipality
SWP-2	Bioretention, Raingarden, Bioswale	Small	66→85	30%	Simple	No	NEPA, General Construction Permit, Municipal	EPA, NOAA, DNER, NFWF, Municipality	PDC, Municipality
SWP-3	Bioretention, Raingarden, Bioswale	Small	66→85	30%	Simple	No	NEPA, General Construction Permit, Municipal/Landowner	EPA, NOAA, DNER, NFWF, Municipality	PDC, Municipality, Landowner
SWP-4	Bioretention, Raingarden, Bioswale, Constructed Stormwater Wetland	Mid	166→205	100%	Detailed	Yes	NEPA, ACOE, General Construction Permit, Municipal/Landowner	EPA, NOAA, DNER, FWS, NFWF, Municipality	PDC, Municipality
SWP-5	Bioretention, Raingarden, Bioswale	Small	86→105	30%	Simple	No	General Construction Permit, Municipal/Landowners	EPA, NOAA, DNER, NFWF, Municipality	PDC, Municipality
SWP-6	Bioretention, Raingarden, Bioswale	Small	66→85	30%	Simple	No	NEPA, General Construction Permit, Municipal/Landowners	EPA, NOAA, DNER, NFWF, Municipality	PDC, Municipality
SWP-7	Bioretention, Raingarden, Bioswale	Small	66→85	30%	Simple	No	NEPA, General Construction Permit, Municipal/Landowners	EPA, NOAA, DNER, Municipality	PDC, Municipality
SWP-8	Bioretention, Raingarden, Bioswale	Mid	265→305	30%	Simple	No	NEPA, General Construction Permit, Municipal	NRCS, EPA, NOAA, USFS, DNER, Municipality	PDC, Municipality, DNER
SWP-9	Bioretention, Raingarden	Small	46→65	30%	Simple	No	NEPA, General Construction Permit, Municipal/Land Authority	NRCS, EPA, NOAA, DNER, Municipality, Land Owner	PDC, Municipality, Land Owner
SWP-10	Bioretention, Raingarden	Small	66→85	30%	Simple	No	NEPA, General Construction Permit, Municipal	NRCS, EPA, NOAA, DNER, NFWF, Municipality	PDC, Municipality
SWP-11	Bioretention, Bioswale	Small	46→65	30%	Simple	No	NEPA, General Construction Permit, Municipal, Land Owner	NRCS, EPA, NOAA, DNER, NFWF, Municipality, Land Owner	PDC, Municipality, Land Owner
SWP-12	Bioretention, Raingarden, Bioswale	Small	66→85	30%	Simple	No	NEPA, General Construction Permit, Municipal, Land Owner	NRCS, EPA, NOAA, USFS, DNER, NFWF, Municipality	PDC, Municipality, Land Owner
SWP-13	Bioretention, Raingarden	Small	25→45	30%	Simple	No	NEPA, General Construction Permit, Municipal, Land Owner	NRCS, EPA, NOAA, USFS, DNER, NFWF, Municipality	PDC, Municipality, Land Owner
SWP-14	Bioretention, Raingarden	Small	25→45	30%	Simple	No	NEPA, General Construction Permit, Municipal, Land Owner	NRCS, EPA, NOAA, USFS, DNER, NFWF, Municipality	PDC, Municipality, Land Owner
SWP-15	Bioretention, Raingarden, Bioswale	Small	25→45	30%	Simple	No	NEPA, General Construction Permit, Municipal, Land Owner	NRCS, EPA, NOAA, USFS, DNER, NFWF, Municipality	PDC, Municipality, Land Owner
SWP-16	Bioretention, Raingarden, Bioswale	Small	25→45	30%	Simple	No	NEPA, General Construction Permit, Municipal, Land Owner	NRCS, EPA, NOAA, USFS, DNER, NFWF, Municipality	PDC, Municipality, Land Owner
SWP-17	Bioretention, Raingarden, Bioswale	Small	25→45	30%	Simple	No	NEPA, General Construction Permit, Municipal, Land Owner	NRCS, EPA, NOAA, USFS, DNER, NFWF, Municipality	PDC, Municipality, Land Owner
SWP-18	Bioretention, Raingarden, Bioswale	Small	66→85	30%	Simple	No	NEPA, General Construction Permit, Municipal, Land Owner	NRCS, EPA, NOAA, USFS, DNER, NFWF, Municipality	PDC, Municipality, Land Owner

SWP-19	Constructed Stormwater Wetland	Small	86→105	100%	Detailed	Yes	NEPA, ACOE, General Construction Permit, Municipal	EPA, NOAA, DNER, FWS, NFWF, Municipality	PDC, Municipality, DNER
SWP-20	Bioretention, Raingarden, Bioswale,	Small	86→105	30%	Simple	No	NEPA, General Construction Permit, Municipal	EPA, NOAA, DNER, NFWF, Municipality	PDC, Municipality, DNER
SWP-21	Constructed Stormwater Wetland	Mid	166→205	100%	Detailed	Yes	NEPA, ACOE, General Construction Permit, Municipal	EPA, NOAA, DNER, FWS, NFWF, Municipality	PDC, Municipality, DNER
SWP-22	Bioretention, Raingarden, Bioswale,	Small	66→85	30%	Simple	No	NEPA, General Construction Permit, Municipal	EPA, NOAA, DNER, NFWF, Municipality	PDC, Municipality, Land Owner
SWP-23	Constructed Stormwater Wetland	Small	46→65	100%	Detailed	Yes	NEPA, ACOE, General Construction Permit, Municipal	EPA, NOAA, DNER, FWS, NFWF, Municipality	PDC, Municipality, DNER
SWP-24	Constructed Stormwater Wetland	Small	46→65	100%	Detailed	Yes	NEPA, ACOE, General Construction Permit, Municipal	EPA, NOAA, DNER, FWS, NFWF, Municipality	PDC, Municipality, DNER
SWP-25	Bioretention, Raingarden, Bioswale	Small	66→85	30%	Simple	No	General Construction Permit, Municipal/Landowners	EPA, NOAA, DNER, NFWF, Municipality	PDC, Municipality, Land Owner
SWP-26	Bioretention, Raingarden, Bioswale	Small	25→45	30%	Simple	No	General Construction Permit, Municipal/Landowners	EPA, NOAA, DNER, NFWF, Municipality	PDC, Municipality, Land Owner
SWP-27	Bioretention, Raingarden, Bioswale	Small	66→85	30%	Simple	No	General Construction Permit, Municipal/Landowners	EPA, NOAA, DNER, NFWF, Municipality	PDC, Municipality, Land Owner
SWP-28	Bioretention, Raingarden, Bioswale	Small	66→85	30%	Simple	No	General Construction Permit, Municipal/Landowners	EPA, NOAA, DNER, NFWF, Municipality	PDC, Municipality, Land Owner
SWP-29	Bioretention, Raingarden, Bioswale	Small	46→65	30%	Simple	No	General Construction Permit, Municipal/Landowners	EPA, NOAA, DNER, NFWF, Municipality	PDC, Municipality, Land Owner
SWP-30	Constructed Stormwater Wetland	Med	166→205	100%	Detailed	Yes	NEPA, ACOE, General Construction Permit, Municipal	EPA, NOAA, DNER, FWS, NFWF, Municipality	PDC, Municipality, DNER
SWP-31	Constructed Stormwater Wetland	Small	46→65	100%	Detailed	Yes	NEPA, ACOE, General Construction Permit, Municipal	EPA, NOAA, DNER, FWS, NFWF, Municipality	PDC, Municipality, DNER
CS-1	Bioretention, Raingarden, Bioswale, Coastal Stabilization, Reforestation	Small	106→125	30%	Simple	No	NEPA, General Construction Permit, Municipal, Adjacent Landowners	EPA, NOAA, USFS, DNER, NFWF, Municipality	PDC, Municipality, DNER
CS-2	Bioretention, Raingarden, Bioswale, Coastal Stabilization, Reforestation	Small	106→125	30%	Simple	No	NEPA, General Construction Permit, Municipal, Adjacent Landowners	EPA, NOAA, USFS, DNER, NFWF, Municipality	PDC, Municipality, DNER
CS-3	Bioretention, Raingarden, Bioswale, Coastal Stabilization, Reforestation	Small	66→85	30%	Simple	No	NEPA, General Construction Permit, Municipal, Adjacent Landowners	EPA, NOAA, USFS, DNER, NFWF, Municipality	PDC, Municipality, DNER
CS-4	Demolition	Large	TBD	100%	Detailed	Yes	NEPA, ACOE, General Construction Permit, Municipal	EPA, NOAA, DNER, FWS, NFWF, Municipality	PDC, Municipality, DNER

Nutrient Reduction Practices Proposed Projects List

Table 14. Nutrient Reduction Practices proposed projects list description.

ID	Sub Water-shed	Observations	Est. Treatment Practice area (acres)	Est. Drainage Area (acres)	GPS Coordinates	Type	Ownership	Existing Land Use	Sewer Infrastructure Service
NR-1	RP	Constant sewage overflows. Ideal communal area that can be converted into a treatment area with the potential of passive recreation.	1	25	18.348274° -65.710063°	Community Outfall	Public	Urban	No
NR-2	QMP	Sufficient available area with apparent topographic condition suitable for Treatment Wetlands implementation.	8	30	18.364551° -65.728363°	Community Outfall	Public	Urban Agriculture	No
NR-3	QMP	Sufficient available area with apparent topographic condition suitable for Treatment Wetlands implementation. This project also has the potential to help reduce flooding problems	60	80	18.379346° -65.727330°	Community Outfall	Public	Urban Agriculture	No
NR-4	RP	Sufficient available area with apparent topographic condition suitable for Treatment Wetlands implementation. This project also has the potential to help reduce flooding problems	50	100	18.366802° -65.709419°	Community Outfall	Public	Conservation	No
NR-5	QMP	Sufficient available area with apparent topographic condition suitable for Treatment Wetlands implementation.	20	100	18.380215° -65.752407°	Community Outfall	Public	Conservation	No
NR-6	QMP	Sufficient available area with apparent topographic condition suitable for Treatment Wetlands implementation.	20	40	18.375425° -65.730093°	Community Outfall	Public	Urban Agriculture	No
NR-7	RP	Sufficient available area with apparent topographic condition suitable for Treatment Wetlands implementation.	20	80	18.351230° -65.695255°	Community Outfall	Public	Urban Agriculture	No
NR-8	QMP	Sufficient available area with apparent topographic condition suitable for Treatment Wetlands implementation. This project also has the potential to help reduce flooding problems	80	140	18.375502° -65.736164°	Community Outfall	Public	Urban Agriculture	No

Table 15. Nutrient Reduction Practices proposed projects list recommended actions.

ID	BMP's Types	Cost Scale	Est. cost ($K) range	Est. Eng. % design	Topo Survey	H&H Study	Permits/Authorization	Possible Funding Partners	Possible Matching Partner
NR-1	Bioretention, Bioreactor	Small	66→85	30%	Simple	No	NEPA, General Construction Permit, Municipal/ PRASA	EPA, NOAA, DNER, NFWF, EQB, Municipality	PDC, Municipality, PRASA
NR-2	Bioretention, Treatment Wetland	Small	126→165	100%	Detailed	Yes	NEPA, ACOE, General Construction Permit, Municipal/Land Authority	EPA, NOAA, DNER, NFWF, Municipality	PDC, Municipality, Land Authority
NR-3	Bioretention, Treatment Wetland	Med	266→305	100%	Detailed	Yes	NEPA, ACOE, General Construction Permit, Municipal/Land Authority	EPA, NOAA, DNER, NFWF, USFWS, Municipality	PDC, Municipality, Land Authority
NR-4	Bioretention, Treatment Wetland	Med	266→305	100%	Detailed	Yes	NEPA, ACOE, General Construction Permit, Municipal/Land Authority	EPA, NOAA, DNER, NFWF, Municipality	PDC, Municipality, Land Authority
NR-5	Bioretention, Treatment Wetland	Med	266→305	100%	Detailed	Yes	NEPA, General Construction Permit, Municipal/PRASA	PRASA	Municipality, Land Authority
NR-6	Bioretention, Treatment Wetland	Med	266→305	100%	Detailed	Yes	NEPA, ACOE, General Construction Permit, Municipal/Land Authority, PRASA, EPA	PRASA, EPA, NOAA, DNER, NFWF, USFWS, Municipality	PDC, Municipality, Land Authority, PRASA
NR-7	Bioretention, Treatment Wetland	Med	126→165	30%	Simple	No	NEPA, General Construction Permit, Municipal/Land Authority	EPA, NOAA, DNER, NFWF, Municipality	PDC, Municipality, Land Authority
NR-8	Bioretention, Treatment Wetland	Big	426→485	100%	Detailed	Yes	NEPA, ACOE, General Construction Permit, Municipal/Land Authority	NRCS, EPA, NOAA, USFS	PDC, Municipality, Land Authority, PRASA

Soil Stabilization Practices Proposed Projects List

Table 16. Soil stabilization Practices proposed projects list description.

ID	Sub Water-shed	Observations	Est. Unstable Soil Area (acres)	Est. Distance from a stream (meters)	GPS Coordinates	Type	Owner ship	Existing Land Use	Slopes Type
SS-1	MP	Active construction site since year 2013 or earlier for urbanization expansion. Appears to be inactive at the moment	40	230	18.373525° -65.743184°	Land Clarence	Private	Urban	Low
SS-2	RJM	Dirt parking area very close to shore.	3	130	18.364917° -65.692986°	Dirt Parking	Private	Urban	Low
SS-3	RP	Land clearing for housing development since year 2004 or earlier.	10	60	18.335131° -65.703936°	Land Clearance	Private	Low Density Urban	High
SS-4	RP	Active farmland	6	560	18.343473° -65.719539°	Land Clearance	Private	Agriculture	Moderate
SS-5	BF	Land clearing for tourism development since year 2004 or earlier.	30	60	18.344919° -65.641706°	Land Clearance	Private	High Density Urban	High to Moderate
SS-6	BF	Land clearing for tourism development since year 2004 or earlier.	2	20	18.346237° -65.638976°	Land Clearance	Private	Low Density Urban	High to Moderate
SS-7	BF	Land clearing for construction of urbanization. Abandoned lot remnant with severe erosion rates.	2	375	18.345016° -65.651108°	Land Clearance	Public	High Density Urban	High to Moderate
SS-8	BF	Land clearing for tourism complex development. Active construction site.	100	1	18.302392° -65.627740°	Land Clearance	Private	Low Density Urban	High to Moderate
DRS-1	RP	Dirt access road in sever erosion conditions that drains to adjacent water bodies that drain directly to the marine environment.	5	1	18.358593° -65.698015°	Dirt Road	Public	Conservati on	Low
DRS-2	RJM	Dirt access road in sever erosion conditions that drains to adjacent water bodies that drain directly to the marine environment.	5	350	18.355659° -65.686076°	Dirt Road	Public	Conservati on	High to Moderate
DRS-3	RJM	Dirt access road in sever erosion conditions that drains to adjacent water bodies that drain directly to the marine environment.	3	1	18.363184° -65.685539°	Dirt Road	Public	Conservati on	Low
DRS-4	RJM	Dirt access road in sever erosion conditions that drains to adjacent water bodies that drain directly to the marine environment.	5	1	18.363496° -65.687456°	Dirt Road	Public	Conservati on	Low
DRS-5	RJM	Dirt access road in sever erosion conditions that drains to adjacent water bodies that drain directly to the marine environment.	10	45	18.365288° -65.690334°	Dirt Road	Public	Conservati on	Low
DRS-6	QF	Dirt access road in sever erosion conditions that drains to adjacent water bodies that drain directly to the marine environment.	10	100	18.330009° -65.683968°	Dirt Road	Private	Low Density Urban	High to Moderate
DRS-7	PR	Dirt access road in sever erosion conditions that drains to adjacent water bodies that drain directly to the marine environment.	20	80	18.296092° -65.633131°	Dirt Road	Private	Tourism Developme nt	High to Moderate
DRS-8	RJM	Dirt access road in sever erosion conditions that drains to adjacent water bodies that drain directly to the marine environment.	10	250	18.359284° -65.673093°	Dirt Road	Public	Conservati on	Low
DRS-9	RJM	Dirt access road in sever erosion conditions that drains to adjacent water bodies that drain directly to the marine environment.	10	1	18.359611° -65.676712°	Dirt Road	Public	Conservati on	Low

DRS-10	RJM	Dirt access road in sever erosion conditions that drains to adjacent water bodies that drain directly to the marine environment.	4	100	18.362114° -65.674814°	Dirt Road	Public	Conservation	Low
DRS-11	QF	Dirt access road in sever erosion conditions that drains to adjacent water bodies that drain directly to the marine environment.	12	600	18.353393° -65.671324°	Dirt Road	Public	Conservation	High to Moderate
DRS-12	QF	Dirt access road in sever erosion conditions that drains to adjacent water bodies that drain directly to the marine environment.	10	50	18.353248° -65.661003°	Dirt Road	Public	Conservation	Low

Table 17. Soil stabilization Practices proposed projects list recommended actions.

ID	BMP's Types	Cost Scale	Est. cost ($K) range	Est. Eng. % design	Topo Survey	H&H Study	Permits/ Authorization	Possible Funding Partners	Possible Matching Partner
SS-1	Hydroseeding, Sediment Traps, Vegetated Swales, Regrading, Vetiver grass.	Small	66→85	30%	Simple	No	NEPA, Municipal/ Land owner	NRCS, NOAA, DNER, NFWF, Land owner	PDC, Municipality, Landowner
SS-2	Permeable parking, Hydroseeding, Sediment Traps, Vegetated Swales, Regrading, Vetiver grass.	Med	126→ 165	30%	Simple	No	NEPA, DNER, General Construction Permit Municipal	NOAA, DNER, NFWF	PDC, Municipality, DNER
SS-3	Hydroseeding, Sediment Traps, Vegetated Swales, Regrading, Vetiver grass, Fencing, Stabilized Stream crossing, Riparian Forested Buffer.	Small	25→45	30%	Simple	No	NEPA, Municipal/ Landowner	NRCS, NOAA, DNER, NFWF, USFWS	PDC, Municipality, Landowner
SS-4	Hydroseeding, Sediment Traps, Vegetated Swales, Regrading, Vetiver grass, Fencing, Stabilized Stream crossing, Riparian Forested Buffer.	Small	66→85	30%	Simple	No	NEPA, Municipal/Farmer	USFS, NOAA, DNER, NFWF, USFWS, Municipality	PDC, Municipality, Landowner
SS-5	Hydroseeding, Sediment Traps, Vegetated Swales, Regrading, Vetiver grass, Reforestation.	Small	25→45	30%	Simple	No	NEPA, Municipal/ Landowner	USFS, NOAA, DNER, NFWF, USFWS, Municipality	PDC, Municipality, Landowner
SS-6	Hydroseeding, Sediment Traps, Vegetated Swales, Regrading, Vetiver grass, Reforestation.	Small	66→85	30%	Simple	No	NEPA, Municipal/ Landowner	NRCS, NOAA, DNER, NFWF, USFWS	PDC, Municipality, Landowner
SS-7	Hydroseeding, Sediment Traps, Vegetated Swales, Regrading, Vetiver grass	Small	25→45	30%	Simple	No	NEPA, Municipal	NRCS, NOAA, DNER, NFWF, USFWS	PDC, Municipality,
SS-8	Hydroseeding, Sediment Traps, Vegetated Swales, Regrading, Vetiver grass, Reforestation	Med	266→305	30%	Simple	No	NEPA, General Construction Permit, Municipal/Landowner	Landowner	PDC
DRS-1	Hydroseeding, Sediment Traps, Vegetated Swales, Regrading, Vetiver grass, Fencing, Stabilized Stream crossing, Riparian Forested Buffer.	Med	266→305	30%	Simple	No	NEPA, Municipal, DNER	NRCS, NOAA, DNER, NFWF	PDC, Municipality, DRNA
DRS-2	Hydroseeding, Sediment Traps, Vegetated Swales, Regrading, Vetiver grass	Small	66→85	30%	Simple	No	NEPA, Municipal, DNER	NRCS, NOAA, DNER, NFWF	PDC, Municipality, DRNA
DRS-3	Hydroseeding, Sediment Traps, Vegetated Swales, Regrading, Vetiver grass	Small	66→85	30%	Simple	No	NEPA, Municipal, DNER	NRCS, NOAA, DNER, NFWF	PDC, Municipality, DRNA
DRS-4	Hydroseeding, Sediment Traps, Vegetated Swales, Regrading, Vetiver grass	Small	66→85	30%	Simple	No	NEPA, Municipal, DNER	NRCS, NOAA, DNER, NFWF	PDC, Municipality, DRNA
DRS-5	Hydroseeding, Sediment Traps, Vegetated Swales, Regrading, Vetiver grass	Small	66→85	30%	Simple	No	NEPA, Municipal, DNER	NRCS, NOAA, DNER, NFWF	PDC, Municipality, DRNA
DRS-6	Hydroseeding, Sediment Traps, Vegetated Swales, Regrading, Vetiver grass	Small	66→85	30%	Simple	No	NEPA, Municipal, DNER	NRCS, NOAA, DNER, NFWF, Landowner	PDC, Municipality, DRNA, Landowner
DRS-7	Hydroseeding, Sediment Traps, Vegetated Swales, Regrading, Vetiver grass	Small	66→85	30%	Simple	No	NEPA, Municipal, DNER	NRCS, NOAA, DNER, NFWF	PDC, Municipality, DRNA
DRS-8	Hydroseeding, Sediment Traps, Vegetated Swales, Regrading, Vetiver grass Buffer	Small	66→85	30%	Simple	No	NEPA, Municipal, DNER	NRCS, NOAA, DNER, NFWF	PDC, Municipality, DRNA

DRS-9	Hydroseeding, Sediment Traps, Vegetated Swales, Regrading, Vetiver grass	Small	66→85	30%	Simple	No	NEPA, Municipal, DNER	NRCS, NOAA, DNER, NFWF	PDC, Municipality, DRNA
DRS-10	Hydroseeding, Sediment Traps, Vegetated Swales, Regrading, Vetiver grass	Small	66→85	30%	Simple	No	NEPA, Municipal, DNER	NRCS, NOAA, DNER, NFWF	PDC, Municipality, DRNA
DRS-11	Hydroseeding, Sediment Traps, Vegetated Swales, Regrading, Vetiver grass	Small	66→85	30%	Simple	No	NEPA, Municipal, DNER	NRCS, NOAA, DNER, NFWF	PDC, Municipality, DRNA
DRS-12	Hydroseeding, Sediment Traps, Vegetated Swales, Regrading, Vetiver grass	Small	66→85	30%	Simple	No	NEPA, Municipal, DNER	NRCS, NOAA, DNER, NFWF	PDC, Municipality, DRNA

Pollution Prevention Proposed Projects List

Table 18. Pollution prevention proposed projects list recommended actions.

ID	Sub Water-shed	Lat/Long	Action Description	Cost Scale	Est. cost ($K) range	Possible Funding Partners	Possible Matching Partner
PP-1	QMP	18.380492° -65.735163°	Luquillo Kiosks area. Implement a series of practices to reduce oil and grease. Creation of a permeable parking system	Med	266→305	EPA, NOAA, DNER, NFWF, EQB, Municipality	PDC, Municipality
PP-2	RS	18.350621° -65.727825°	Luquillo Public Works facilities. Implement a series of practices to reduce oil and grease.	Small	106→125	EPA, NOAA, DNER, NFWF, Municipality	PDC, Municipality
PP-3	BF	18.346101° -65.637659°	Marinas Puerto Chico and Villa Marina. Implement a series of practices to reduce water contamination.	Med	266→305	EPA, NOAA, DNER, NFWF, Marina Managers	PDC, Municipality, Marina managers
PP-4	BF	18.338357° -65.632467°	Marina Sun Bay. Implement a series of practices to reduce water contamination.	Small	106→125	EPA, NOAA, DNER, NFWF, USFWS, Marina Managers	PDC, CCP, Marina Managers
PP-5	BF	18.331870° -65.631458°	Fajardo Port Facilities. Construction of a sewage recollection system to pump sewage from the cargo and passenger ferries.	Large	TBD	Port Authority, PRASA	PDC
PP-6	PR	18.285703° -65.636632°	Marina Puerto del Rey. Implement a series of practices to reduce water contamination.	Med	266→305	EPA, NOAA, DNER, NFWF, USFWS, Marina Managers	PDC, CCP, Marina Managers
O&E-1	QMP	18.382426° -65.730369°	Balniario de Luquillo area. Implementation of a social marketing campaign for behavior change, natural resources conservation and pollution prevention	Small	25→45	EPA, NOAA, DNER, NFWF, EQB, Municipality	PDC, Municipality, DNER
O&E-2	QMP	18.380607° 18.380607°	Luquillo Kiosks area. Implementation of a social marketing campaign for behavior change, natural resources conservation and pollution prevention	Small	25→45	EPA, NOAA, DNER, NFWF, EQB, Municipality	PDC, Municipality, DNER
O&E-3	QF	18.362341° -65.624467°	Las Croabas area. Implementation of a social marketing campaign for behavior change, natural resources conservation and pollution prevention	Small	25→45	EPA, NOAA, DNER, NFWF, EQB, Municipality	PDC, Municipality, DNER
O&E-4	BF	18.338620° -65.633742°	Sun Bay Marina. Implementation of a social marketing campaign for behavior change, natural resources conservation and pollution prevention	Small	25→45	EPA, NOAA, DNER, NFWF, EQB, Municipality, Marina managers	PDC, Municipality, DNER. Marina Managers
O&E-5	PR	18.286322° -65.635593°	Puerto del Rey Marina. Implementation of a social marketing campaign for behavior change, natural resources conservation and pollution prevention	Small	25→45	EPA, NOAA, DNER, NFWF, EQB, Municipality, Marina managers	PDC, Municipality, DNER. Marina Managers

O&E-6	BF	18.348452° -65.634099°	Puerto Chico Marina. Implementation of a social marketing campaign for behavior change, natural resources conservation and pollution prevention	Small	25→45	EPA, NOAA, DNER, NFWF, EQB, Municipality, Marina managers	PDC, Municipality, DNER. Marina Managers
O&E-7	BF	18.340888° -65.639948°	Villa Marina. Implementation of a social marketing campaign for behavior change, natural resources conservation and pollution prevention	Small	25→45	EPA, NOAA, DNER, NFWF, EQB, Municipality, Marina managers	PDC, Municipality, DNER. Marina Managers
SW	New		The incorporation of additional subwatershed from Río Grande and Ceiba	Small	106→125	EPA, NOAA, DNER, NFWF, EQB, Municipality	PDC, Municipality, DNER

IDDE Proposed Projects List

Table 19. Pollution prevention proposed projects list recommended actions.

ID	Sub Water-shed	Lat/Long	Action Description	Cost Scale	Est. cost ($K) range	Possible Funding Partners	Possible Matching Partner
PST-1	QMP	18.378916° -65.718349°	Solimar, Costa Azul and Sandy Hills IDDE additional tracking	Med	266→305	EPA, NOAA, DNER, NFWF, EQB, PRASA, Municipality	PDC, Municipality, PRASA
PST-2	QMP	18.373103° -65.723397°	Luquillo Mar and Luquillo Lomas IDDE additional tracking	Small	106→125	EPA, NOAA, DNER, NFWF, EQB, PRASA, Municipality	PDC, Municipality, PRASA
PST-3	RS	18.362217° -65.724402°	Villa Angelina IDDE additional tracking	Small	25→45	EPA, NOAA, DNER, NFWF, EQB, PRASA, Municipality	PDC, Municipality, PRASA
PST-4	RS	18.357165° -65.722704°	Los Cocos IDDE additional tracking	Small	86→105	EPA, NOAA, DNER, NFWF, EQB, PRASA, Municipality	PDC, Municipality, PRASA
PST-5	QMP	18.381260° -65.747340°	Playa Fortuna IDDE additional tracking	Small	25→45	EPA, NOAA, DNER, NFWF, EQB, PRASA, Municipality	PDC, Municipality, PRASA
PST-6	QF	18.366120° -65.629611°	Las Croabas IDDE additional tracking	Small	46→65	EPA, NOAA, DNER, NFWF, EQB, PRASA, Municipality	PDC, Municipality, PRASA
PST-7	QF	18.346868° -65.654476°	Fajardo Gardens, Monte Brisas and Vistas del Convento IDDE additional tracking	Small	25→45	EPA, NOAA, DNER, NFWF, EQB, PRASA, Municipality	PDC, Municipality, PRASA

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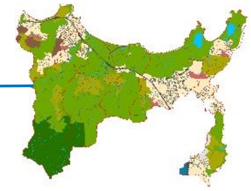
APPENDIXES



MAPS PRESENTED