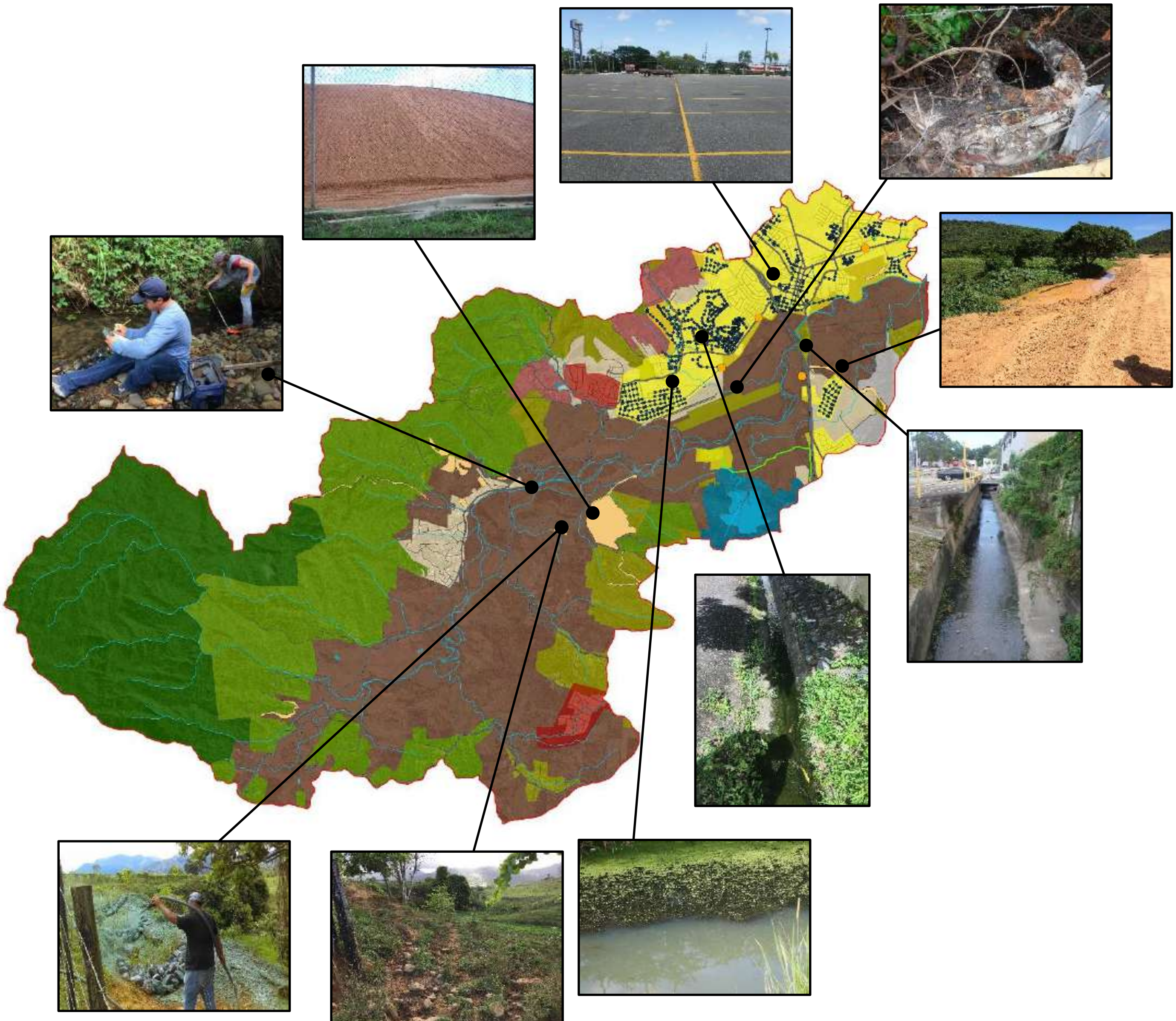
Rio Fajardo Watershed Pollution Threat Analysis

Recommended Integrated Watershed Management Actions
Demonstrative Pilot Project
March, 2017



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In Collaboration with:
Ridge to Reefs, Inc.

Submitted to:
Department of Environment and Natural Resources
National Oceanic and Atmospheric Administration

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Best Management Practice (BMP's)
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 Wastewater Treatment Plant (FWTP)
Floating Treatment Wetland (FTW)
Geographic Information System (GIS)
Green Infrastructure (GI)
Illicit Discharge Detection and Elimination (IDDE)
Land Based Sources of Pollution (LBSP)
Land Use Plan (LUS)
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 (RFW)
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ACKNOWLEDGEMENTS

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We want to also recognize the comments and recommendations feedback to this report in particular from RTR, DNER, NOAA……

EXECUTIVE SUMMARY

This Watershed Pollution Threat Analysis has been conducted with the intent to build upon the work of Puerto Rico Department of Natural and Enviromental Resources (DNER) and the National Oceanic and Atmospheric Administration (NOAA) and other organizations like the Centro para la Conservación del Paisaje (CCP) efforts in the Río Fajardo Watershed (RFW) in order to identify potential watershed restoration projects and cost estimates through a scientific and participatory stakeholder approach for the area. The completed project provides a prioritized list of potential projects and restoration concepts with cost estimates to address Land Based Sources of Pollution (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 RFW. As part of this effort Protectores de Cuencas, Inc. (PDC) included the implementation of a small scale demonstrative Best Management Practices (BMP's) project selected from the provided potential project list.

In March 2015, the CCP, in collaboration with the U.S. Forest Service (USFS), the DNER and NOAA developed the ***Río Fajardo Watershed Management Plan (RFWMP)*** for the RFW under a contractual agreement with the DNER. The main purpose of this Watershed Pollution Threat Analysis and the recommended Integrated Watershed Management Actions is to serve as a complement of the exiting RFWMP. This work also represents a follow up effort on initial screening efforts of LBSP recently completed in December 2015 entitled: Strategies for the Identification of Sources of Pollution and the Establishment of Erosion and Sedimentation Control Practices in the Municipalities of the Northeastern Ecological Corridor, Puerto Rico) conducted by PDC and funded by the (DNER) through the Coastal Zone Management Program (CZMP).

The RFW is a conservation priority area for the DNER and 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.

INTRODUCTION

The Rio Fajardo Watershed (RFW) is a conservation priority area for the DNER and NOAA's Coral Reef Conservation Program (CRCP) and NOAA Restoration Center (RC). 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 (the Habitat Focus Areas), and leveraging internal and external collaborations to achieve measurable benefits within a short time frame. As a result of this initiative, the Puerto Rico's North East Corridor including the RFW and Culebra Island were selected to be one of the priority areas for habitat conservation (Figure 1).

Unfortunately, Puerto Rico's northeastern coastal habitats are some of the most impacted ecosystems throughout the Caribbean. The eastern region of Puerto Rico, in the last fifteen years, has experienced one of the largest increases in coastal infrastructure.

Increased levels of land-based sediment loads associated with coastal development is one of the most important factors affecting coastal marine ecosystems in Puerto Rico. Puerto Rico coral reefs are among the most threatened marine ecosystems in the Caribbean. High sediment loads to marine environments resulting from poorly maintained dirt roads and other bare soil areas including construction without the installation of proper management practices is a very common problem in coastal areas.

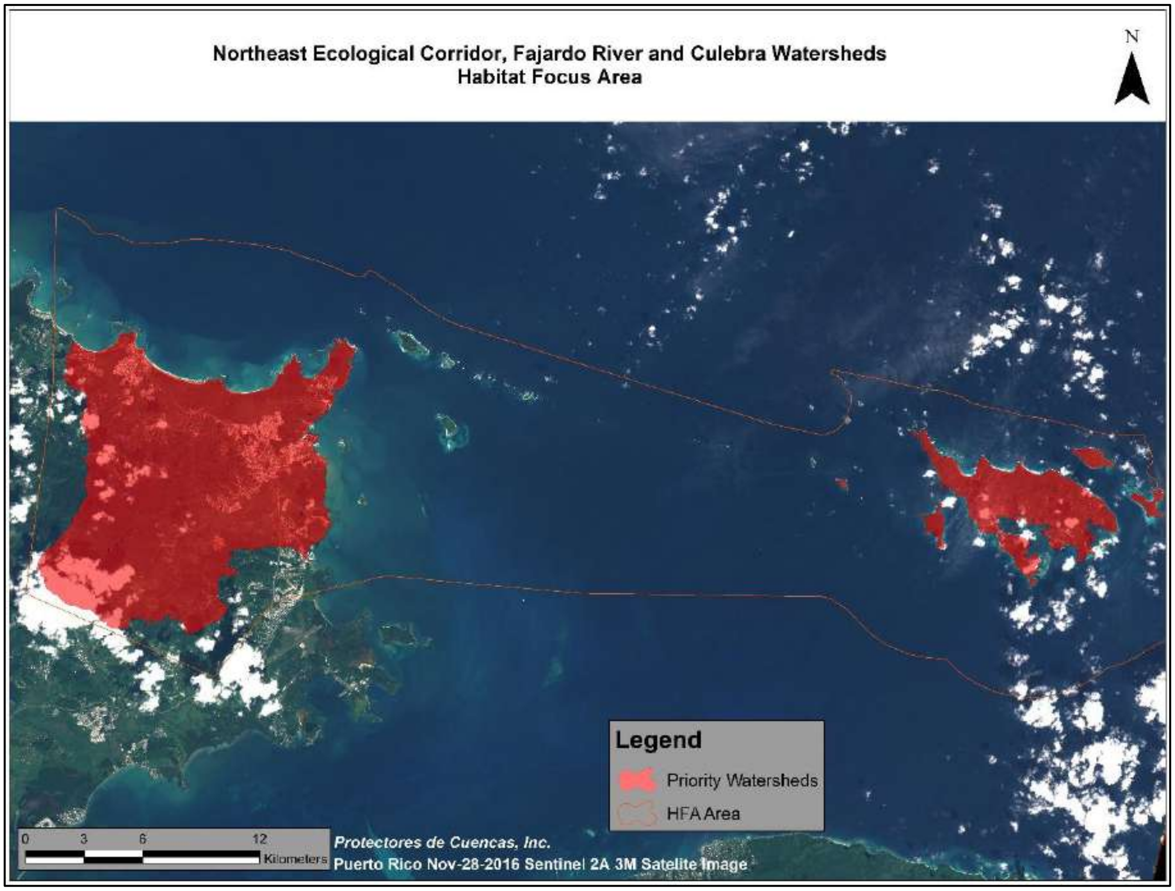


Figure 1. Habitat Focus Area Priority Watersheds

The degradation of coastal water quality in Puerto Rico has been one of the main causes of a decline in the population and health of coral reefs. The ability of reefs to survive is gradually being reduced as fine sediment and nutrient discharges from the land to the coastal waters of Puerto Rico increase. From the standpoint of marine ecosystem conservation, degradation of water quality due to dispersed 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, excess nutrients from agriculture, urbanization and sanitary sewage overflow are the main causes of the degradation of marine ecosystems.

This phenomenon is mainly due to the lack of sustainable management from the perspective of integrated watershed management planning. Erosion and habitat degradation are other serious problems that our wetlands, estuaries and coastal waters face. In particular, the removal of vegetation and land clearing activities for construction without proper erosion and sedimentation control practices, impact marine and coastal ecosystems and diminishes the attractiveness of coastal areas for recreation and tourism.

Summary of the Río Fajardo Watershed Management Plan

In March 2015, the CCP, in collaboration with the U.S. Forest Service (USFS), the DNER and NOAA developed the Río Fajardo Watershed Management Plan (RFWMP) of the RFW under a contractual agreement with the DNER. The RFWMP focused on the land uses in the watershed and recommendations for the application of conservation practices and potential community watershed integration projects. It serves as a guide to integrate and analyze key scientific information related to the watershed's environmental condition, identify the actors and institutions responsible for the implementation, monitoring and enforcement of environmental regulation (legal framework) and to present a series of management strategies that can be implemented in order to improve land-use planning at different scales, environmental stewardship and sustainable resource-use activities.

The RFWMP is divided into five sections that include a RFW description, a physical modeling of the watershed, and a human characterization of the watershed, a summary of results, management issues and potential conservation objectives for the RFW and management zones with practices recommended. Demographic, socioeconomic and cultural factors from residents of Fajardo and Ceiba are also included as important information that was useful in designing public outreach strategies, identify specific subpopulations to target during the implementation phase, or help determine future trends and needs of the populations. Annual estimates of the resident population were obtained from April 1, 2010 to July 2014 data. The RFWMP also indicates that is of 96.2% of the total and in Ceiba 76.6% is urban. For Fajardo, around 57% of the municipality is contained within the Río Fajardo watershed. Fajardo's population is classified as urban (96.2%) and the infrastructure to manage or mitigate this population's impact over the natural resources should be appropriately scaled. Population changes in recent years for the region associated with the Río Fajardo watershed include the population decline between 2000 and 2010, mostly due to the closure of Roosevelt Roads Naval Base in 2004.

Some socioeconomic condition indicators of the levels of education and employment rates include; 3:1 ratio of people, 25 years of age and over, with high school diploma vs. the people with a bachelor degree represents a big gap in the levels of education in both municipalities. In 2013, the labor force (16 years and over) of the total population was 51.4% from which 40.1% were employed and 11.3% were unemployed. For Ceiba, the 2013 labor force (16 years and over) of the total population was 41.8% from which 36.2% were employed and 5.6% were unemployed. The principal occupations in Ceiba (29.2%) and Fajardo (26.3%) are sales and office occupations respectively. This information might need further analysis at the ward (barrio) scale to direct potential programs at the community level that might require labor.

CCP designed a public participation strategy to trigger the mobilization and participation of residents living in the RFW. Through the strategy, CCP performed several community meetings and interviews to include the participation of people, agencies and personnel from the municipalities of Fajardo and Ceiba to exchange valuable information between the communities and the organization. Community concerns were documented during the process, some of these include: floods, runoff, sanitary waters, damaged/lack of sewage system, illegal landfills, deforestation and its consequence of sedimentation and erosion problems.

Residential uses within the watershed constitute roughly less than 10% of the total land uses in the region. Within these communities there are different practices and human activities that have direct relationship with land-use patterns and planning decisions. The local fishermen were identified as important stakeholder within the river basin. Several fish markets are located throughout the lower basin communities, therefore local fishermen constitute an influential stakeholder within the community. Additionally, is was determined that the communities and residents east of PR-3 are associated with a denser urban and institutional environment until the coastal areas are reached. This is creating two distinct problems, impact on the river due to the proximity of the houses to the river bank in the loop of the natural river channel, plus the issue that there are no sanitary sewage connections in these residences. The land use and cover in the flood plain presents another issue that was discussed by the local communities and that was documented by field visits.

Some of the recommended actions in the RFWMP are:

1. The areas associated with forest coverage should be conserved or increased especially in areas with slopes over 40%. The use of the proclamation limits of El Yunque National Forest as a guide to provide additional incentives to the private landowners of these areas should be considered by the agencies that could facilitate this strategy. The DNER should evaluate the Auxiliary Forest Program

(see Appendix H) to consider the legal or legislative process to increase the incentive reflected under this program for any landowner with a forested property within the watershed limit and inside the proclamation limits of El Yunque National Forest.

2. Additional attention needs to be directed to the waste water management in the houses in the steep areas of Naranjo, Río Abajo and Río Arriba wards. A review and monitoring process for the septic tanks in these wards should be implemented in the first two years of the plan.
3. Special attention needs to be given to the sewage water discharges that are flowing from the failure infrastructure of Puerto Rico Aqueduct and Sewer Authority (PRASA) through the storm water drainages to the water bodies and streams associated with the watershed drainage. The implementation of minimum control measures of Illicit Discharge Detection and Elimination (IDDE) should be a priority.
4. The identified cattle grazing farmlands areas show an overgrazing pattern that is causing sediment and erosion of bare soils on these areas.
5. Additional issues recognized are the activities taking place around the agricultural areas that are not managed by the farmers. The barren area identified in the analysis associated with the location of the landfill is next to a farm that is used for pasture and it's connected to the floodplain zone. This zone is one of the top sediment production areas and the analysis identifies the point

source in the agricultural areas. After consulting with stakeholders, CCP recognized that the sediment load could be produced in the landfill area, but reflected in the agricultural areas next to the landfill.

The RFWMP concluded that some of the findings can be categorized as more critical than others depending on the scale and different actors, but some specific results that the authors considered important to point out are:

1. There is an average sediment yield for the entire basin of 19.73 tons per hectare per year (tons/ha/yr) with a standard deviation of 86.45. This sediment yield represents a serious problem that is affecting the coastal resources associated with the watershed. Sediment generation was associated with land uses without the best management practices applications.
2. There is a need to establish a watershed management governance structure to apply, stir and supervise the plan application. Recommendations and strategies are presented in the document.
3. Environmental problems are associated to agricultural activities, waste water management infrastructure through the urban, septic tanks maintenance, and land use in rural areas other activities in the watershed.

The RFWMP can be downloaded in the following link:

http://drna.pr.gov/wp-content/uploads/2017/02/FINAL_Fajardo_Watershed_Management.pdf

GENERAL WATERSHED CHARACTERIZATION

This watershed characterization has been conducted by PDC in order to develop a comprehensive pollutant threat analysis for the RFW that will isolate specific sources of contamination through the use of the Watershed Treatment Model (WTM). 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 watershed in the project site. For the land use information, we have used GIS data provided by the Puerto Rico Planning Board (PRPB) 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 16,756 acres (26 miles^2) within the municipalities of Fajardo and Ceiba. The area covers approximately 62% of the territorial boundaries of the Fajardo Municipality and 30% of the Ceiba Municipality. The geographic area of the RFW concentrates on the areas that drains to the Fajardo river and does not include any coastal areas (Figure 2 and 3).

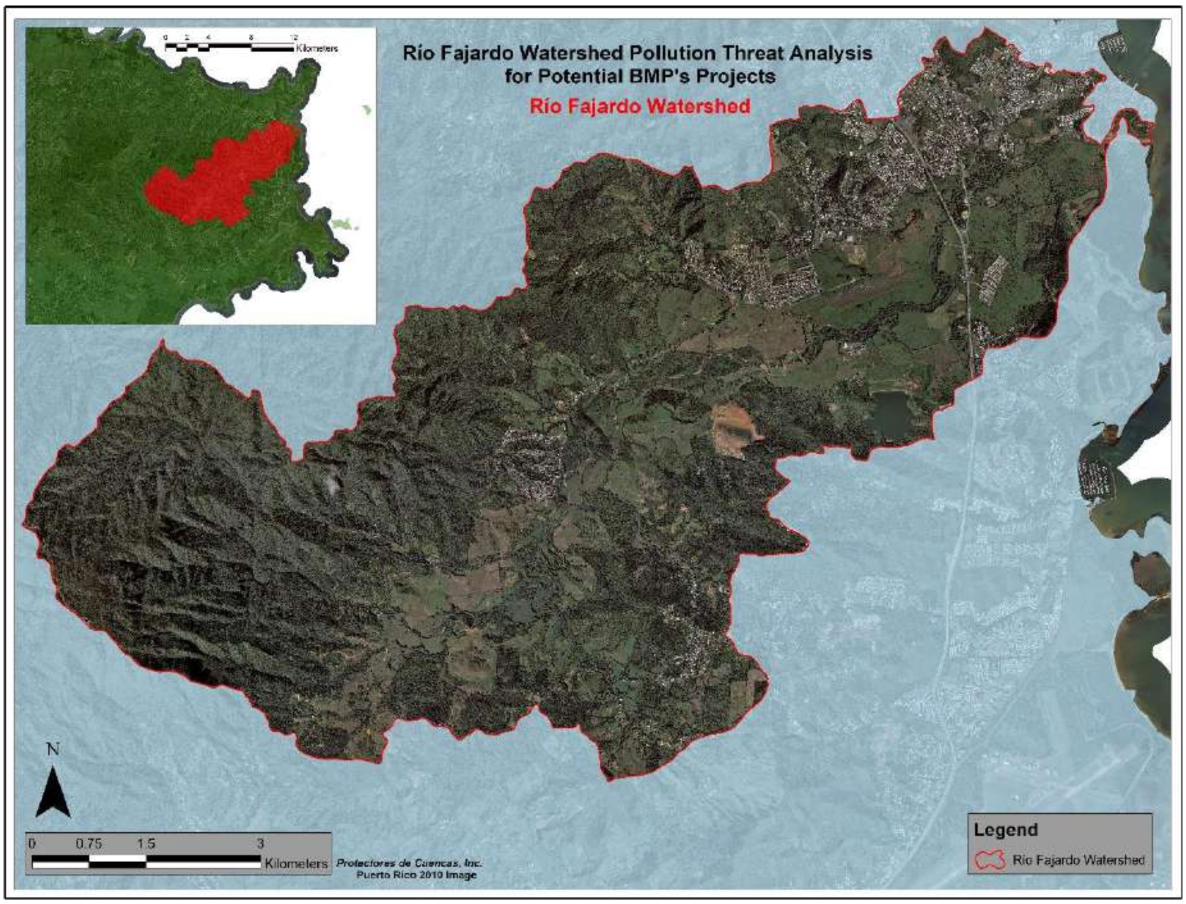


Figure 2. Map of the project location, the Río Fajardo Watershed delimitation.

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

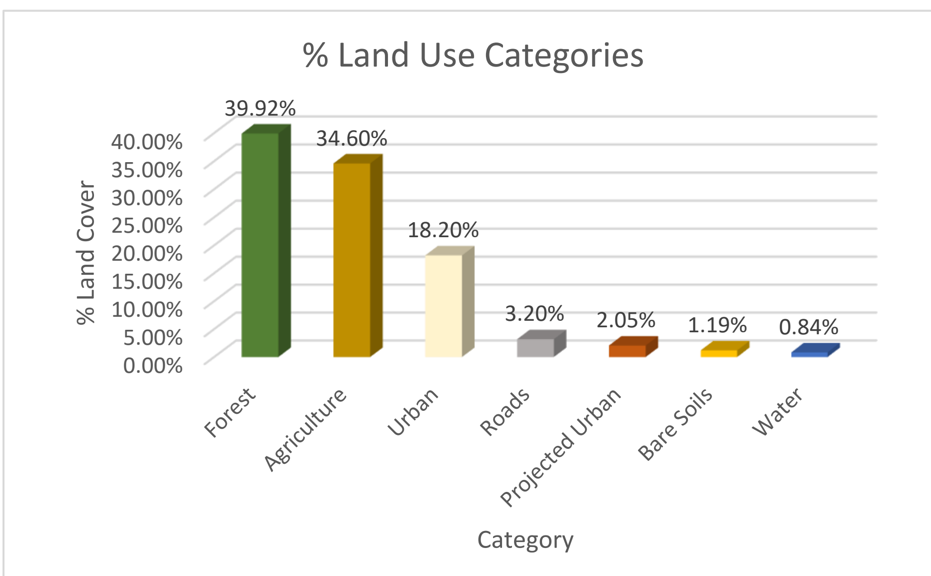
Actual Land Use

The land use data provided by the Puerto Rico Planning Board from the LUP (2015) was updated with aerial images and field assessments to reflect, not just planed uses, but to include actual existing uses (Figure 4). 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 is currently in continues vegetative cover. The Urban category combines Low, Medium and High Density Urban as well as, Industrial, Commercial 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 disturbed 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.

Table 1. Land use categories.

Category	Acres	% Land Cover
Forest	6,689.88	39.92%
Agriculture	5,796.91	34.60%
High Density Urban	1,290.42	7.70%
Low Density Urban	1,063.94	6.35%
Roads	535.61	3.20%
Medium Density Urban	397.05	2.37%
Projected Urban	344.15	2.05%
Bare Soils	200.00	1.19%
Commercial	198.53	1.18%
Water	140.46	0.84%
Industrial	59.56	0.36%
Institutional	39.71	0.24%
TOTALS	***16,756.22***	***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 (39.92%) has been identified as forest cover followed by the agriculture category (34.60%), urban (18.20%), roads (3.20%), projected urban (2.05%), bare soils (1.19%), and water (0.84%). Urban areas are mostly concentrated on the northeastern part of the watershed. Most of the Bare Soils areas are associated to the operation of the landfill followed by dirt road networks, active and abandoned construction sites and agriculture (Figure 5). Currently, approximately 17% of the RFW is protected as a Natural Protected Area (NPA). Most of the protected land forms part of El Yunque National Forest to the west area and a few acres that belong to the Bosque Estatal de Ceiba to the east of the watershed (Table 2). A total of additional 4,117 acres are designated as priority for conservation by the DNER (2008).

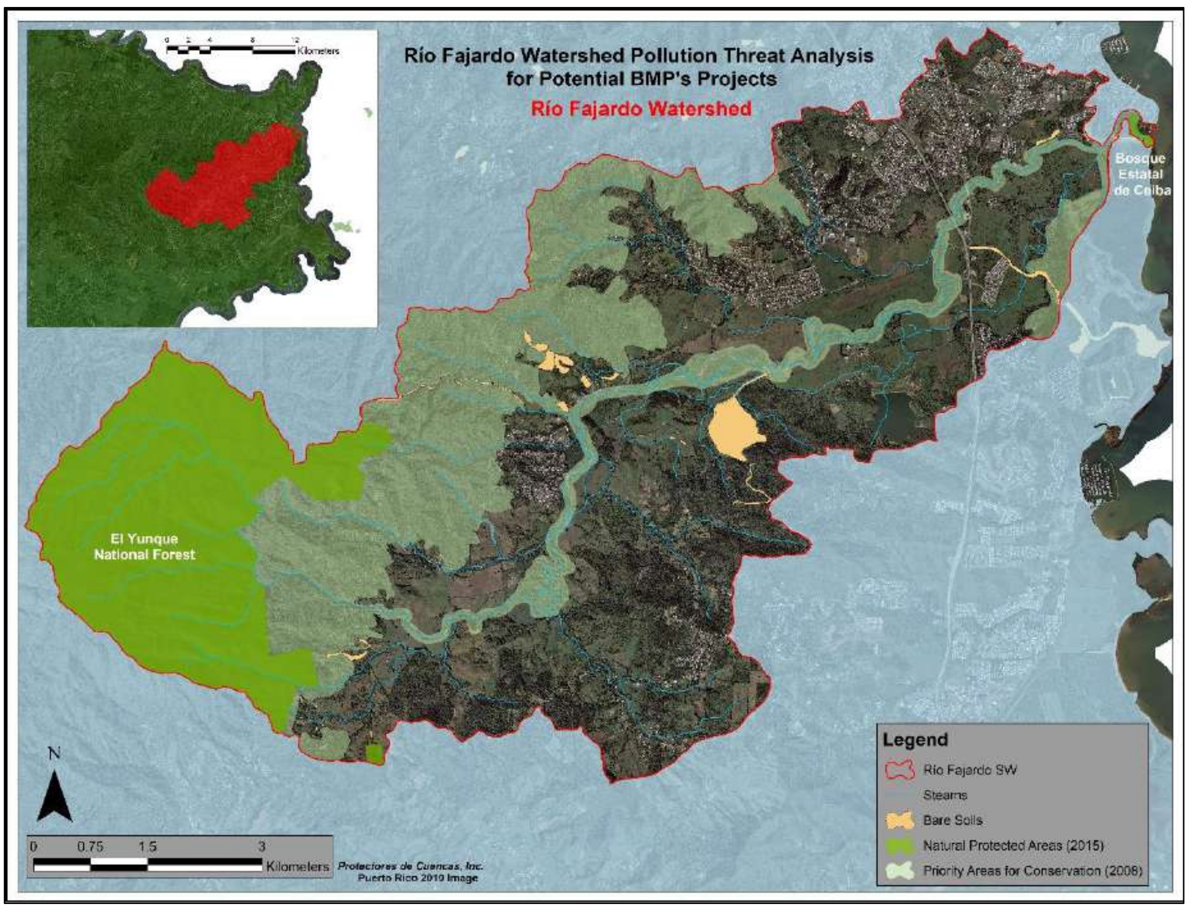


Figure 4. Map of the Natural Protected Areas (2015) and areas designated as priority for conservation (2008).

Table 2. Natural Protected Areas of the RFW.

Category	Manager	Acres	% Land Cover
El Yunque National Forest	US FS	2,822.80	16.85%
Bosque Estatal de Ceiba	DRNA	13.62	0.08%
	TOTALS	***2,836.42***	**16.93%**

Sewer Infrastructure

The Fajardo Wastewater Treatment Plant (FWTP) 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 RFWMP) residents (Figure 5). The

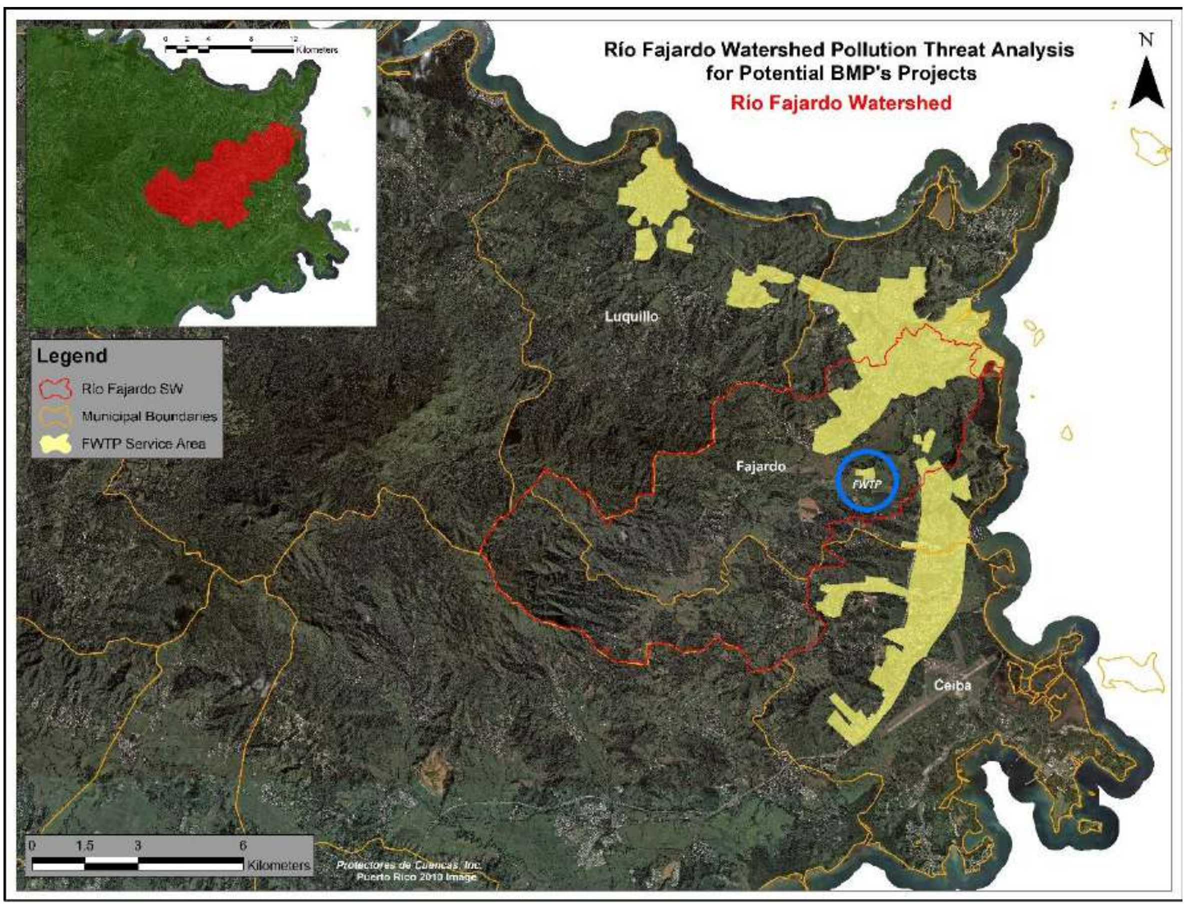


Figure 5. FWTP total service areas (data provided by PRASA).

plant is operated by PRASA. The FWTP 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 RFWWTP is estimated to be of 6,977 acres.

Of the RFW area it is estimated that 11% (1,779 acres) of the watershed is serviced for sewer infrastructure. This represents that 100% of the high-density urban areas have sewer infrastructure. For all join urban areas (low, medium and high density urban, industrial, comercial and institutional) it is estimated that 58% of the combined areas are serviced for

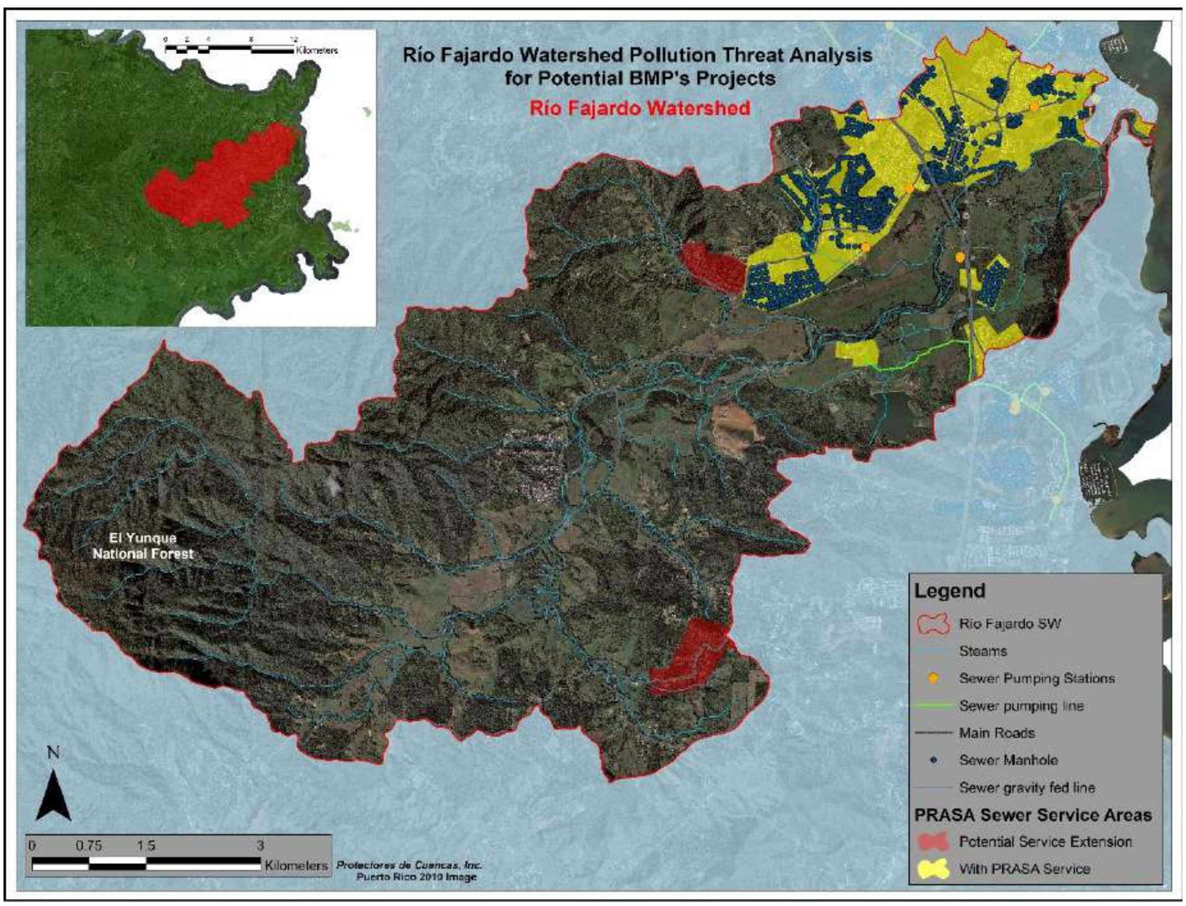


Figure 6. Map of the RFW areas that have sewer infrastructure service managed by PRASA.

sewer. Another 2% of the RFW has been identified by PRASA with the conditions to expand sewer service (Figure 6 and 7, Table 3).

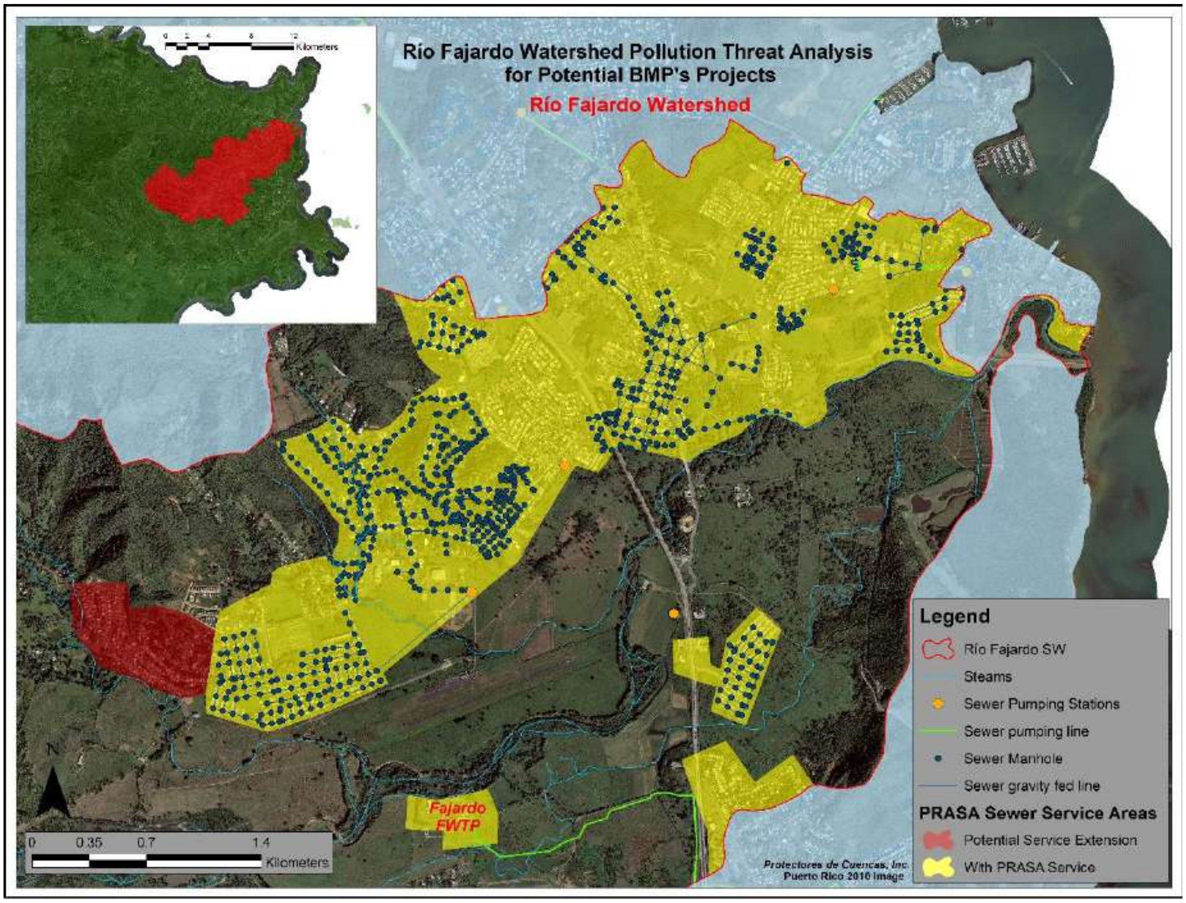


Figure 7. Map of the sewer infrastructure utilities. It is important to state that the actual layer is not fully updated. Pumping stations and other infrastructure is up to date but the main pumping line to the FWTP has not been updated yet by PRASA.

Table 3. Main communities that have sewer infrastructure serve.

Communities with sewer infrastructure service			
Vista del Mar	Urbanización Altamira	Villa Clarita	Alturas de San Pedro
Barriada Viera	Alhambra	Espanta Sueño	Estancias de San Pedro
Santa Isidra I and II	Jerusalén	San Pedro	Buena Vista
Villa Fajardo	Meléndez	Alturas de San Pedro	Vega Baja
Pueblo	Residencial Puerto Real	Santa Rita	Fortuna

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 8). 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 8. Examples of failing sewer infrastructure across the RFW 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 of the RFW 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 in the watershed. A total of approximately 68 miles of streams are present in the project site. Aquifers are most restricted to the Río Fajardo flood plains areas (Figure 9).

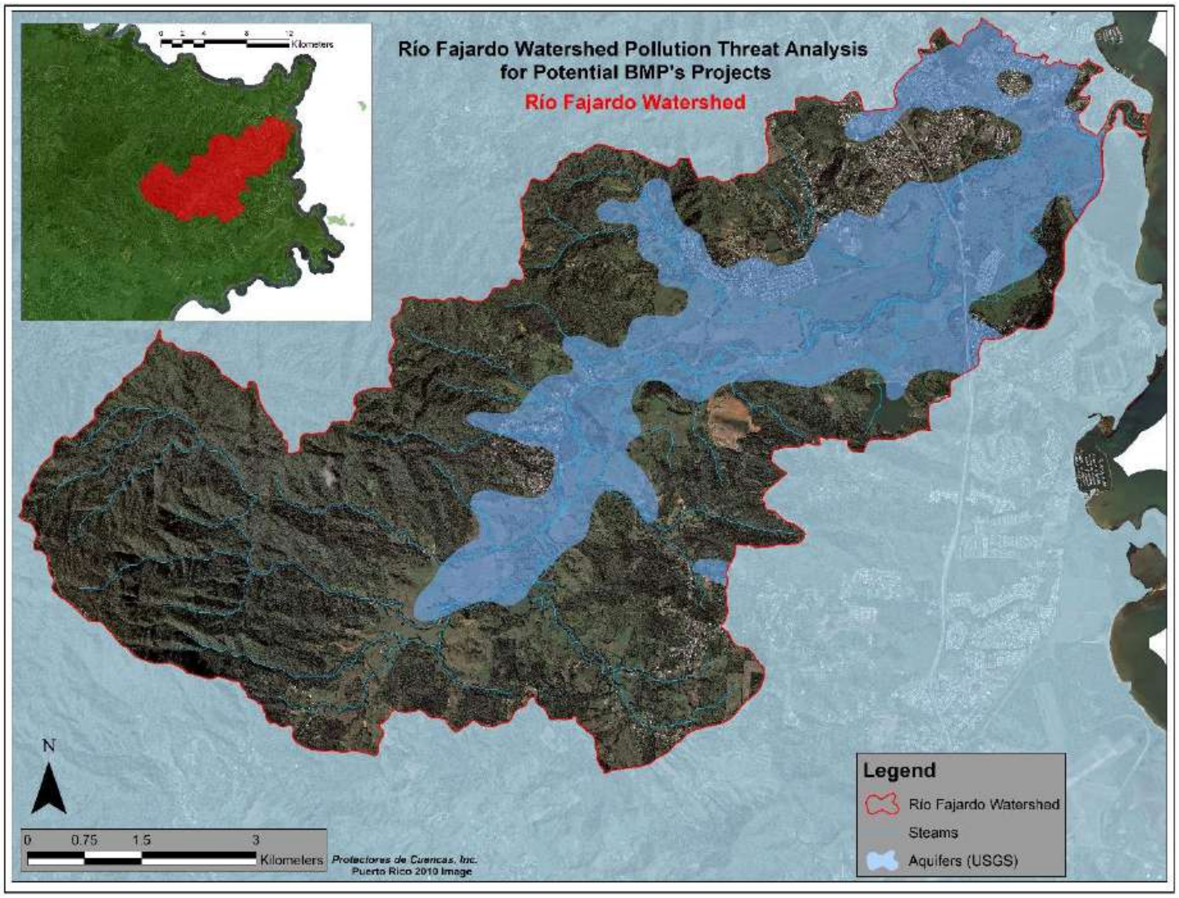


Figure 9. Map of the water resources on the RFW.

Using the National Wetland Inventory (NWI) (2010), we have estimated that 4% (606 acres) of the RFW is classified as wetland (Figure 10). The most common wetland type in the area is Riverine followed by Freshwater Emergent, Fresh Forested/Shurb, Estuarine and Marine Wetland, Estuarine and Marine Deepwater, and Fershwater Pond (Table 4, Graph 2).

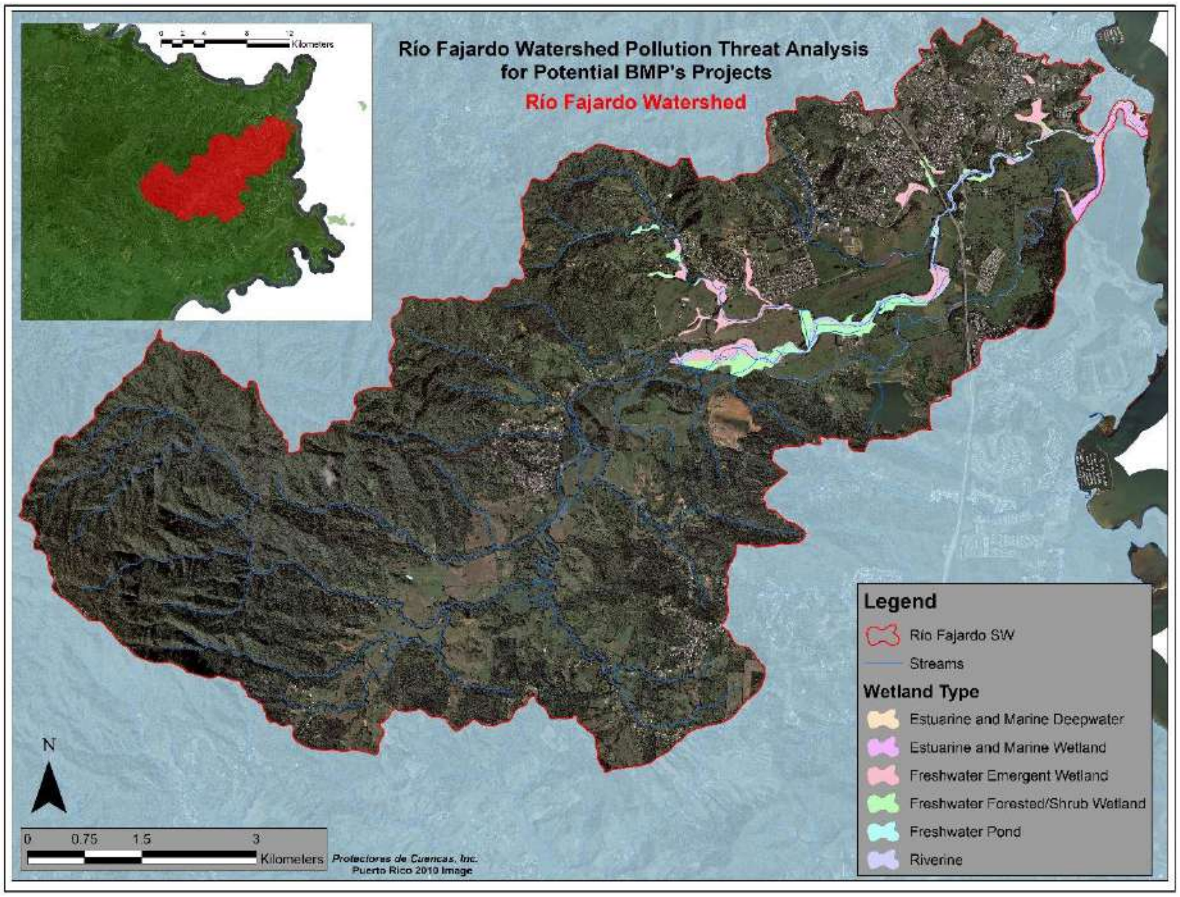
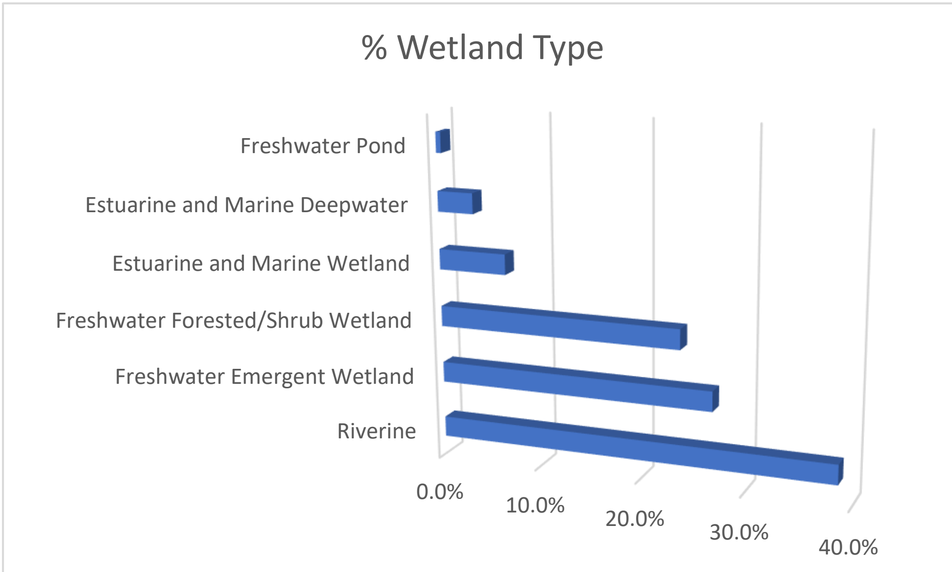


Figure 10. Map with wetland areas from the National Wetland Inventory

Table 4. Wetland Types.

Wetland Type	Acres	% Land Cover
Riverine	234	38.7%
Freshwater Emergent Wetland	163	26.9%
Freshwater Forested/Shrub Wetland	144	23.8%
Estuarine and Marine Wetland	41	6.7%
Estuarine and Marine Deepwater	21	3.5%
Freshwater Pond	3	0.5%
TOTALS	606	***100%***

Graph 2. Wetland cover (%) per category.



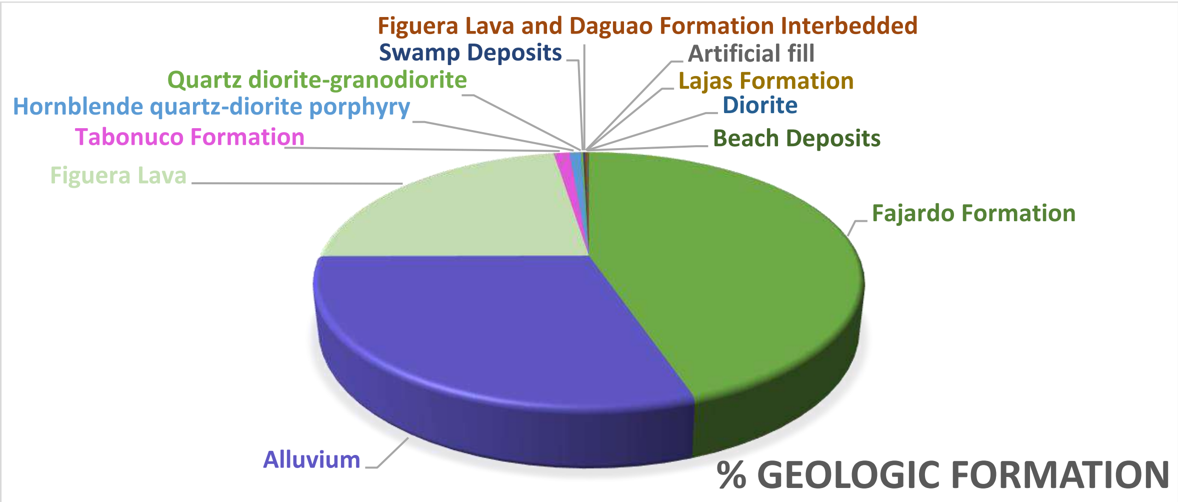
GEOLOGY

Geologic formations in the area are mainly dominated by the Fajardo (44.8%), the Alluvium (30.2%) and the Figuera Lava (22.6%) formations (Table 5, Graph 3, Figure 11). 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, 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 Figuera Lava Formation (kf) is a volcanic assumed to be of Early Cretaceous age.

Table 5. Geologic formations present in the RFW.

Subwatershed	Acres	% Land Cover
Fajardo Formation	7,501.2	44.77%
Alluvium	5,054.9	30.17%
Figuera Lava	3,783.2	22.58%
Tabonuco Formation	184.8	1.10%
Hornblende quartz-diorite porphyry	137.4	0.82%
Quartz diorite-granodiorite	25.7	0.15%
Swamp Deposits	20.4	0.12%
Figuera Lava and Daguao Formation Interbedded	20.1	0.12%
Artificial fill	12.1	0.07%
Lajas Formation	6.1	0.04%
Diorite	5.3	0.03%
Beach Deposits	5.1	0.03%
TOTALS	16,756	100%

Graph 3. Geologic formation cover (%) for the RFW area.



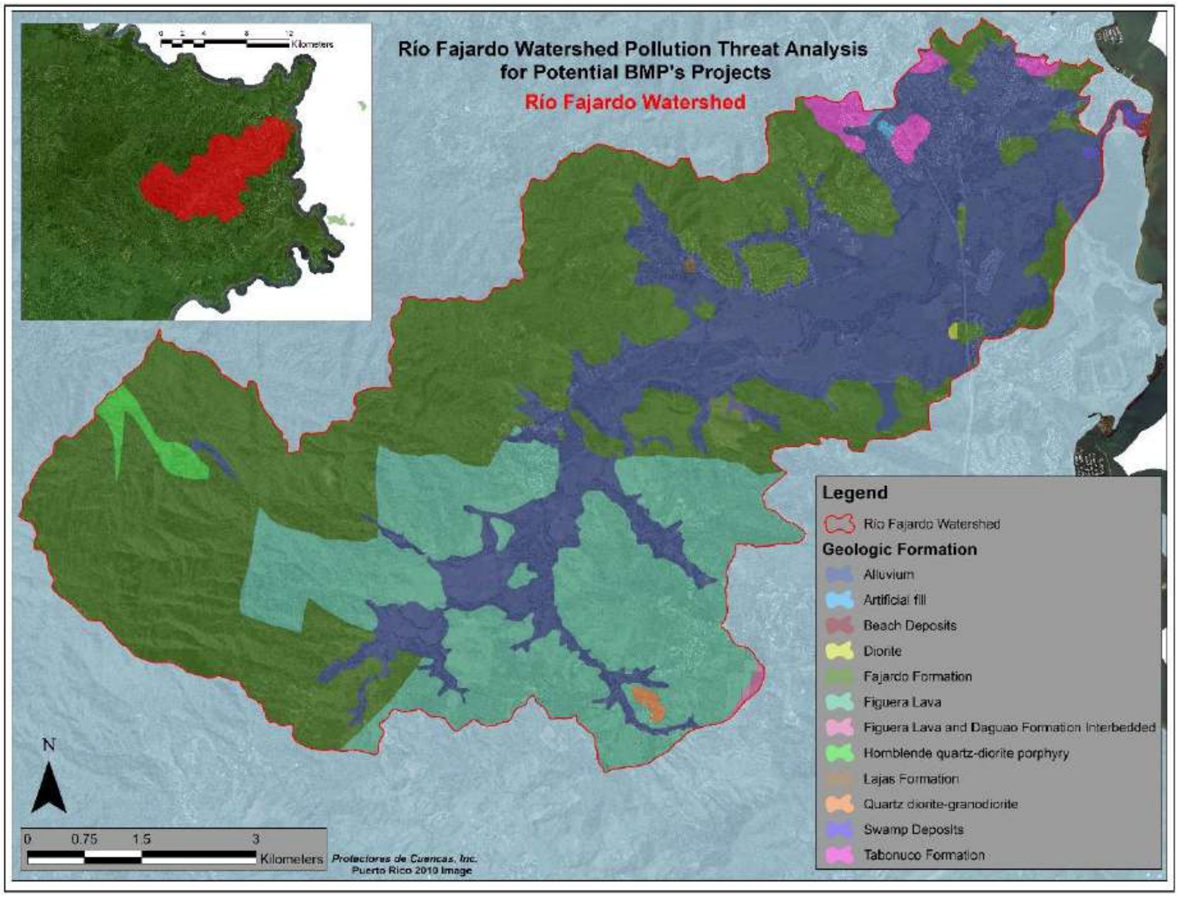


Figure 11. Map of the geological formations in the RFW area.

SOILS

Soil composition for the project area is a very complex mixture of 28 soil class features (Figure 12). 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.

The most common soil composition varies in the watershed are Humatas clay (21%) and Zarzal Complex (16%). Soils of the RFW are also influenced by the elevation stratification of the landscape. The soil types dominating the higher elevations of the watershed are the Dwarf, Yunque and Zarzal complex while in the flood plain the Toa, Vega Baja and Reilly dominates the area. The Humatas series consists of very deep, well drained, moderately slowly permeable soils on side slopes and ridges of strongly dissected uplands. They formed in clayey and loamy material that weathered from igneous rocks with slopes that range from 5 to 60 percent. The Zarzal series consists of very deep, well drained soils on mountain sides in uplands. They formed in residuum that weathered from sandstone with slopes that range from 10 to 90 percent. The Yunque Series consists of very deep, moderately well drained, slowly permeable soils on ridgetops and upper side slopes of strongly dissected uplands. They formed in a mix of colluvium and residuum that weathered from andesitic to basaltic, marine deposited, volcanic and volcanoclastic sandstone and mudstone. With slopes that range from 10 to 90 percent. The Dwarf series consists of very deep, poorly drained, moderately slowly permeable soils on side slopes and ridges of mountains. They formed in organic accumulations and residuum from metamorphosed andesitic to basaltic, marine deposited volcanic sandstone rocks that has been effected by soil creep with slopes that range from 5 to 65 percent. The Toa series consists of very deep, well drained, moderately permeable soils are on river flood plains. They formed in stratified alluvial sediments of mixed origin with slopes that range from 0 to 2 percent. The Vega Baja series consists of very deep, somewhat poorly drained, slowly permeable soils on alluvial fans and coastal plains. They formed in alluvial sediments and the underlying coastal plain sediments with slopes that range from 0 to 35 percent. The Reilly series consists of very deep, excessively drained, rapidly permeable soils on slightly higher natural levees along stream and river channels of floodplains. They formed in stratified alluvial deposits of mixed origin and its slopes that range from 0 to 2 percent.

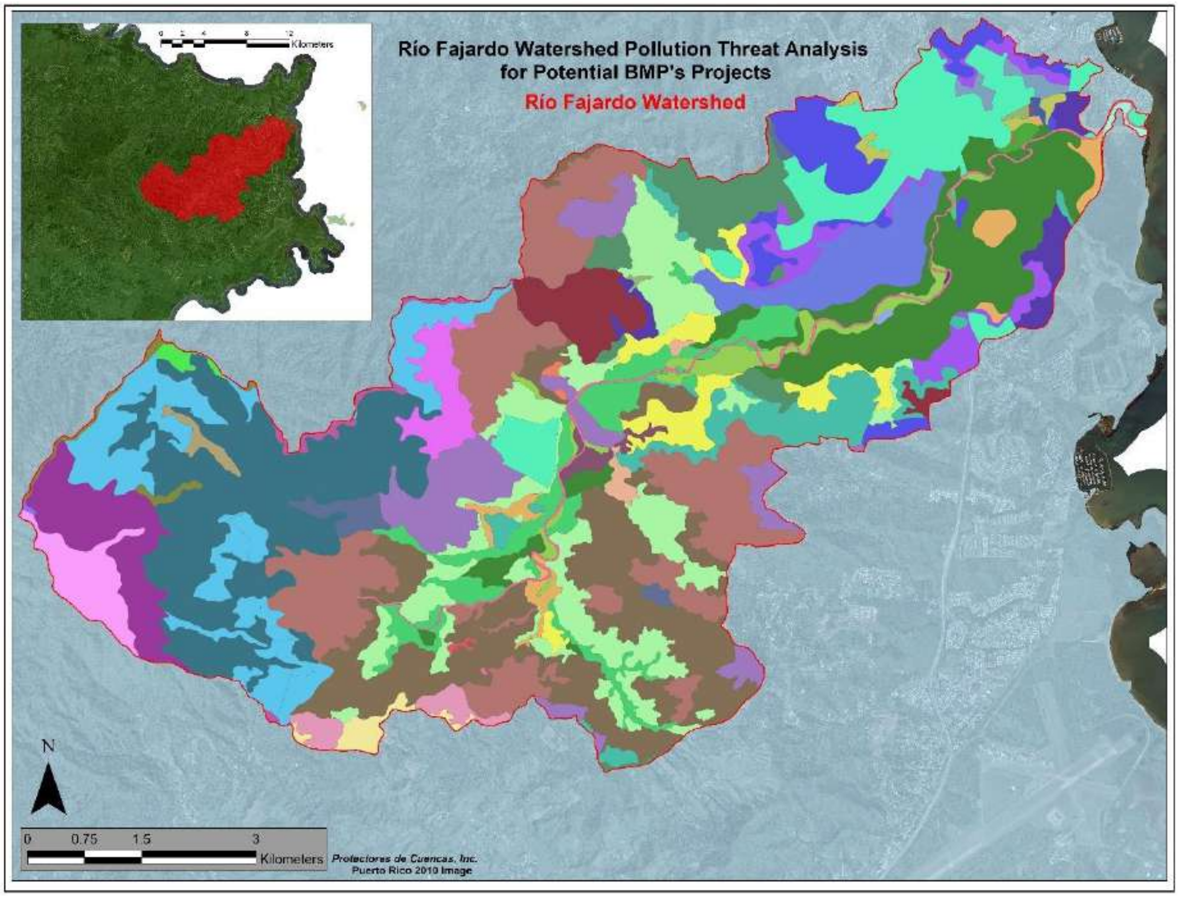
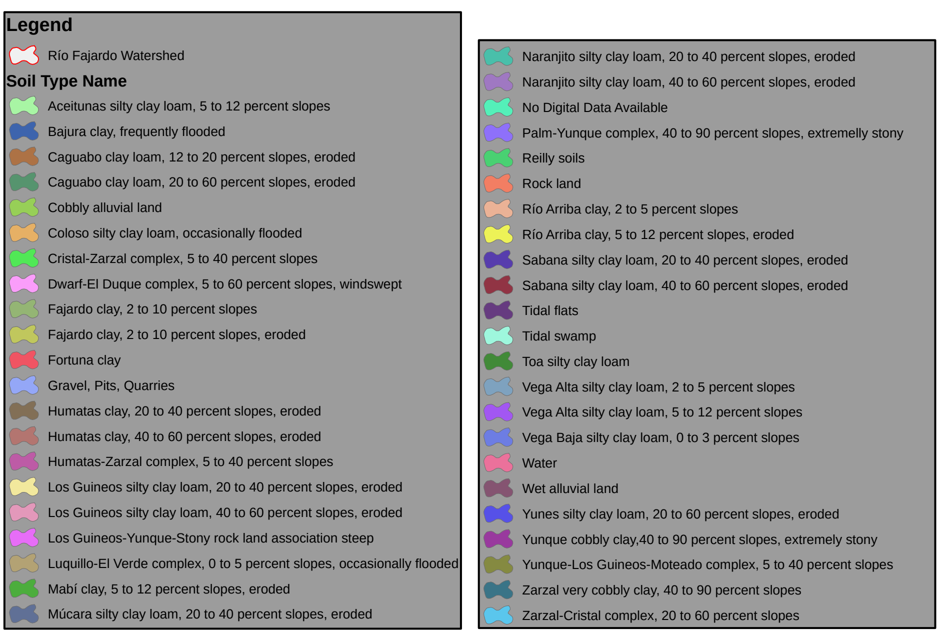


Figure 12. Map of the different soil types present in the RFW area.



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 RFW 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 13). 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 Northeast Ecological Corridor. Information collected during our GIS analysis, fieldwork and water quality monitoring was also used to help populate the model as were major point sources within the watershed including the FWTP.

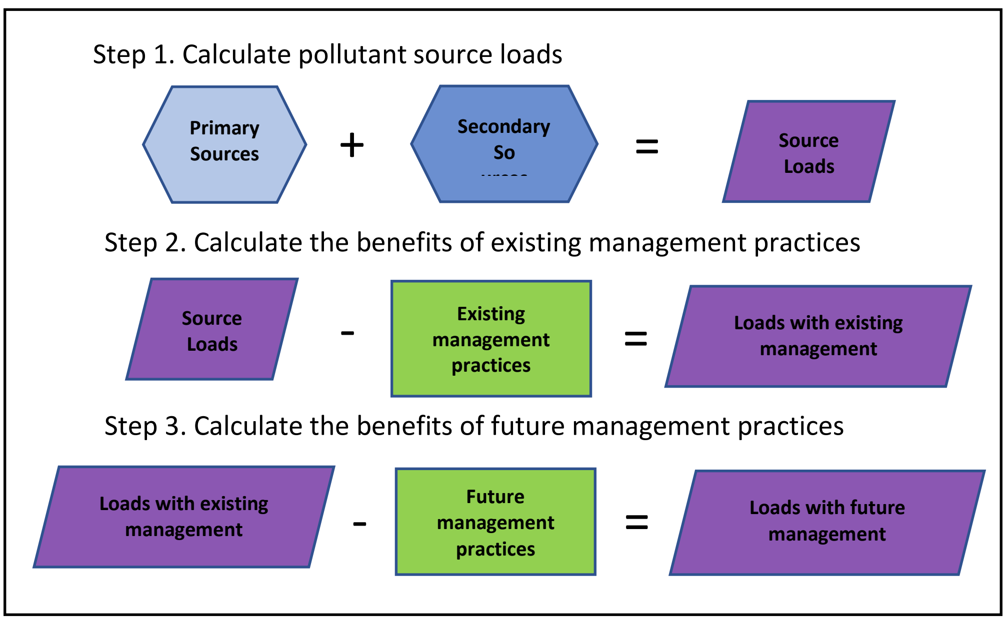


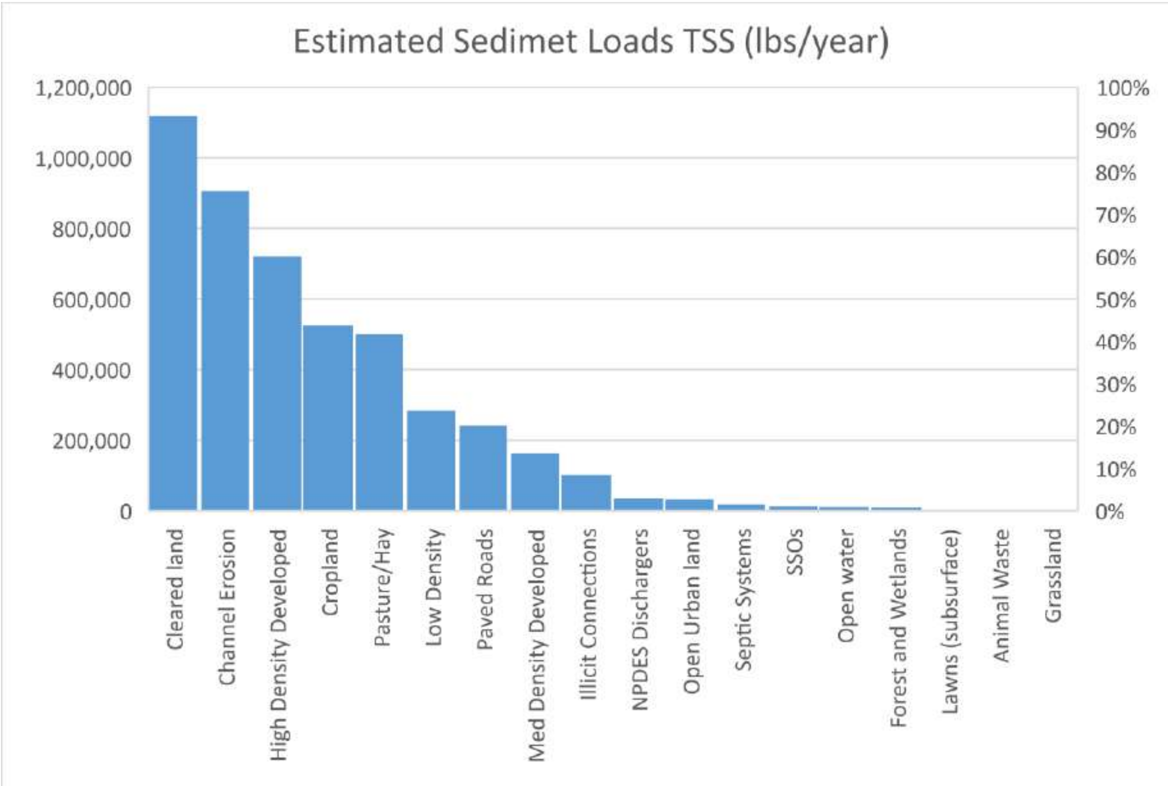
Figure 13. Watershed Treatment Model structure diagram adapted from Carraco 2002.

Output from the model helps to measure pollution estimates, prioritize and implement restoration projects and strategies to reduce pollution in this watershed that impacts important and sensitive coastal habitats.

RESULTS

Sediment sources in the Rio Fajardo Watershed are dominated by cleared lands (bare soils and dirt roads (exposed roadways), but closely followed by channel erosion which is a source of background sediment loading and is present in all stream channels. An additional source of sediment is the high density development in the middle and lower portion of the RFW. Bare soil lands areas 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 BMP's can be implemented. Graph 4 shows the loading estimates for various sources of sediment within the watershed.

Graph 4. RFW Estimated nitrogen loads for multiple land uses.



Nitrogen loading in the RFW is dominated by National Pollutant Discharge Elimination System dischargers (NPDES) specifically the FWTP and followed to a lesser extent by failing septic systems (Graph 5, Table 6). The FWTP sewage contamination and the export of washwater and stormwater containing nutrients is common in all sewered and unsewered areas. 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 RFW, as well as the reduction of pathogenic bacteria as seen in our illicit discharge monitoring

Graph 5. Estimated Nitrogen loads for multiple land uses in the RFW.

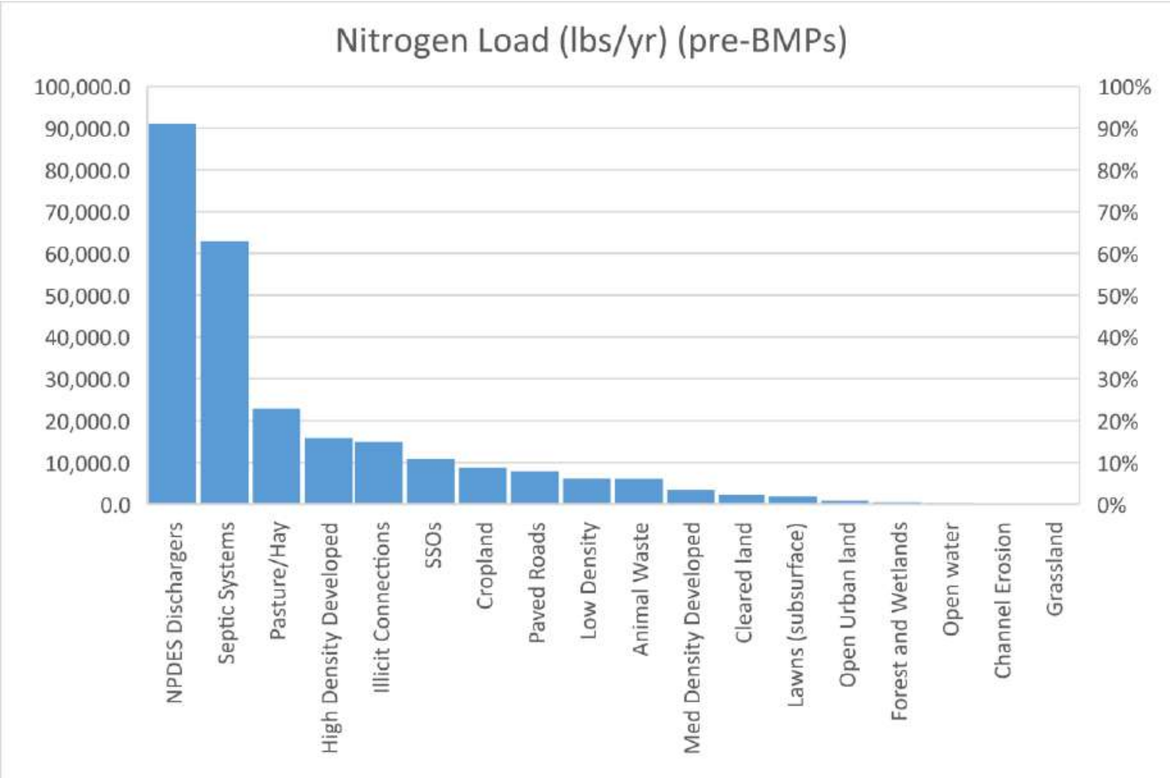


Table 6. Nutrient and sediment load estimates for the Fajardo watershed based on land use and secondary sources.

Source	N Load (lbs/year)	P Load (lbs/year)	TSS Load (lbs/year)
NPDES Dischargers	91,170	9,117	36,468
Septic Systems	62,945	461	18,471
Pasture/Hay	23,000	3500	50,0000
High Density Developed	15,874	2886	72,1561
Illicit Connections	14,942	2,946	102,581
Sanitary Sewer Overflows (SSO's)	10,965	360	13,523
Cropland	8,767	3,108	526,020
Paved Roads	7,929	769	242,254
Low Density	6,252	1,136	284,213
Animal Waste	6,192	662	0
Med Density Developed	3,566	648	162,105
Cleared land	2,237	223	1,118,700
Lawns (subsurface)	1,949	39	0
Open Urban land	939	187	32,864
Forest and Wetlands	513	338	9,000
Open water	374	35	10,530
Channel Erosion	0	906	906,783
Grassland	0	0	0
TOTALS	**257,618**	**27,327**	**4,685,075**

Load Reduction Estimates

Reductions of nutrients from proposed implementation efforts would largely be achieved through the implementation of Illicit Discharge Detection and Elimination (IDDE) program and the implementation of Green Infrastructure (GI) projects with various BMP's for Stormwater Treatment and Nutrient Reduction. Sediment load reductions would be achieved through stabilization of bare soils and 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 (Table 7).

Table 7. BMP summary and load reduction estimates for the RFW. Estimates are based on the amount of practices implemented and load reductions can increase as more practices are implemented.

BMPs	TN	TSS	TP	Assumption
Soil Stabilization		279000		Based on 100 acres stabilized
Stormwater Management	254	26822	72	Based on 40 acres of impervious cover treated
IDDE (not a BMP but can reduce loads if illicit discharges are fixed)	10000		500	IDDE detection and treatment -- removal of 50% of found discharges
Nutrient Reduction Practices	68000		3600	1 acre of Bioretention (surface area) Specially constructed to remove nutrients
Estimated Reductions	**78254**	**573594**	**4172**	
Projected Load Reductions (%)	**32.1%**	**10.2%**	**14.2%**	

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 RFW and the Adjacent North East Reserve (NER) 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 8) 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 8. The table also shows what the parameters indicate as well as the equipment and thresholds used.

Table 8. 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 prolonged) sewer infrastructure failures. Sites with indicators of contamination are summarized by station (Figure 14). These discharges all reflect nutrient contamination as well as bacteria in most instances (Table 9).

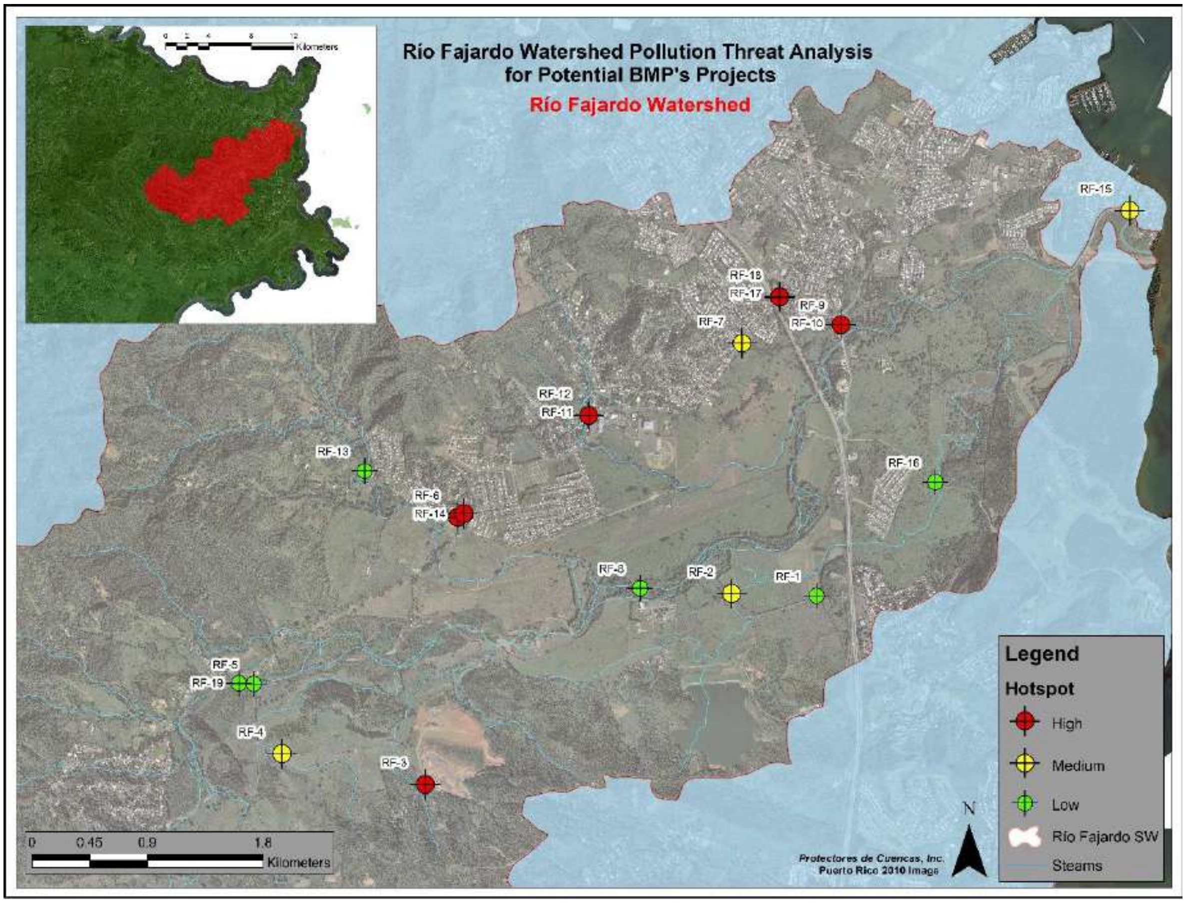


Figure 14. Map of the IDDE sample sites.

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. However, due to dilution it does not appear to have significant impacts on the upper mainstem of the river particularly during baseflow conditions. The middle portion of the watershed has newer development and is mostly connected to sewer when compared to older downtown areas in Fajardo. The large Fajardo landfill is one exception to this trend where we did see elevated ammonia and other parameters (optical brighteners) being very elevated and indicative of illicit discharges.

Table 9. Summarized IDDE sample sites

Site ID	Coordinates	Opt B (RFU)	Chll a (µG/L)	NH4 (MG/L)	E. Coli (count/100)	Notes	Hotspot
RF-1	18.30361/ -65.652102	n/a	n/a	n/a	n/a	low probability of contamination, water looks clean and clear and almost no visible flow (no sample taken)	Low
RF-2	18.30368/ -65.658356	14.05	66.37	0.49	n/a	water ponded-results could be high due to decomposition	Medium
RF-3	18.28996/ -65.680699	27.79	89.37	1.91	n/a	effluent coming out of landfill	High
RF-4	18.29198/ -65.691281	13.39	55	0	n/a	n/a	Medium
RF-5	18.29685/ -65.693439	2.387	25.49	0	n/a	n/a	Low
RF-6	18.30877/ -65.678594	RAW SEWAGE	RAW SEWA	RAW SEWA	n/a	Failing septic/raw sewage on road goes straight to stream	High
RF-7	18.321291/ -65.657859	6.318	26.84	0	n/a	2-3 potable leaks on an area of 2 blocks	Medium
RF-8	18.303967/ -65.665089	0.107	0	0.3	4900	upstream of FWTP	Low
RF-9	18.322715/ -65.650591	0.029	0	0.11	0	pipe	Low
RF-10	18.322693/ -65.650592	0.958	8.644	1.75	20000	stream	High
RF-11	18.316088/ -65.66909	0.658	1.324	0	9300	stream	Low
RF-12	18.316063/ -65.669051	1.178	7.049	2.53	28000	sewage/septate	High
RF-13	18.311929/ -65.685503	0.306	0.624	0.15	8800	n/a	Low
RF-14	18.309041/ -65.678152	0.369	1.981	>1	>2419.6	sewage/stream	High
RF-15	18.331002/ -65.62945	0.423	0.728	0.92	14800	outlet of Rio Fajardo	Medium
RF-16	18.311723/ -65.643477	0.84	7.749	0.8	11100	Abandoned development site	Low
RF-17	18.32461/ -65.655125	1.176	16.14	12.38	TNTC	Channel in downtown Fajardo	High
RF-18	18.32458/ -65.655147	1.607	2.528	11.96	TNTC	outfall draining river	High
RF-19	18.296861/ -65.694513	0.081	0	0.081	1300	mainstem in upper watershed	Low

Finally, the lower watershed (closest to the coast) displayed problematic water quality beginning at about PR-3 highway. This particular area between PR-3 and the old sewage treatment plant should receive additional attention due to the high concentration of nitrogen measured in the water there in our survey but also measured by the USGS at their nearby gauge station. We have identified an urban drainage pipe and concrete channel system that has been highly contaminated with sewage but it did not appear to account for all of the nitrogen being seen in the Fajardo River in this area. It should be noted that when evaluating the PRASA data for sewer connections, a number of older small housing subdivisions close to the river and in other parts of the City appear to not be connected to sewer. This may have a lot to do with the high concentrations measured of ammonia, optical brighteners and E.Coli.

Studies of water quality within the Fajardo watershed include some recent work done by students and their professors at local universities which show very similar findings for water quality – though the data is limited as they only looked at four sites on the mainstream. The data indicates relatively clean water coming from El Yunque, still relatively clean water in the middle watershed and poor water quality in the lower portion of the watershed in below PR-3.

Further IDDE illicit discharge work and finding and fixing problems is recommended to occur at both the upper and lower portions of the watershed. Other researchers have also noted these issues in the watershed including recent work in 2016 by a number of entities including local universities under a student monitoring program called Proyecto de

Liderazgo Ambiental Comunitario (PLAC) (Torres-Abreu, and Forestil, A., 2016). Their results were particularly dramatic for the lower watershed in particular, despite that the data indicating very poor water quality little to no action has been taken to address these issues or further determine the causes. Some additional sewer connections have taken place in Fajardo but even these connections have not been targeted to improve the urgent water quality problems. Finally, most all the areas within the watershed were elevated for E.Coli which is a pathogenic bacteria and therefore compromised as samples generally exceed the EPA and EQB standards. The EPA standard for recreational waters with water contact is <126 col/100ml. Our findings in the RFW are consistent with our previous findings from 2014, where high levels of contamination (based on EPA thresholds) were found consistently including many of the same stations (PDC and Lilly, 2014).

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 RFW 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 RFW.

This list of potential BMP's 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 RFW 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. This effort also included the construction of a small scale demonstrative BMP project selected from the provided potential project list. The pilot project implemented is described in the last section of this document. Recommended projects where systematically chosen in collaboration with Fajardo Municipality Staff and DNER personnel as well as following recommendations of the Fajardo Watershed Management Plan. The selection process was based primarily on the following categories:

1. Its impact on water quality focused on the priority pollutants established for the RFW (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 15). 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 RFW, 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.

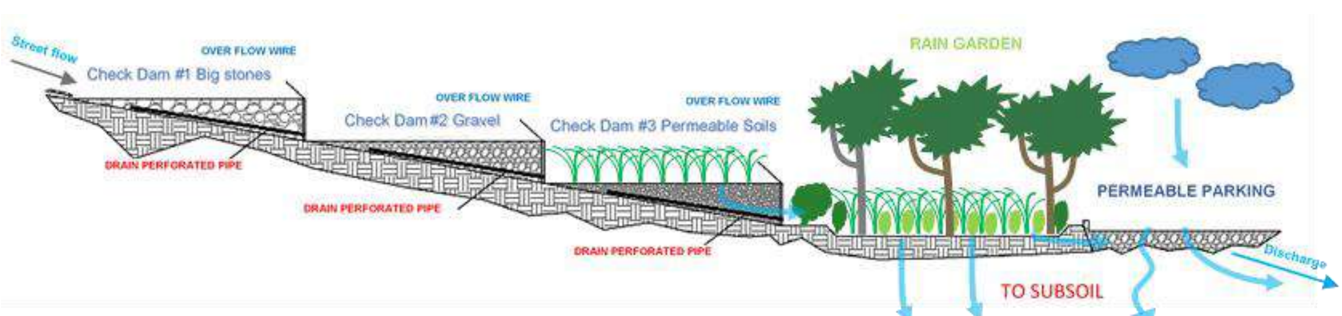


Figure 15. Schematic diagram of an example of a train treatment approach implemented by PDC in Zoní Beach in Culebra, Puerto Rico

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 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 RFW 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 16). 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.

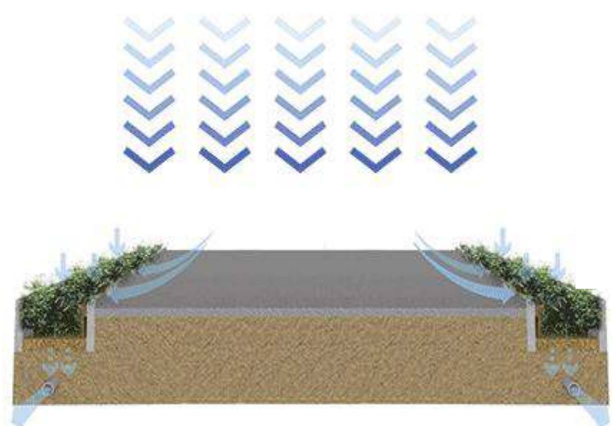


Figure 16. Diagram of a raingarden adapted from the Houston-Galveston Area Council.

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 17). 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 17. 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 18).

Figure 18. 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 19).

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

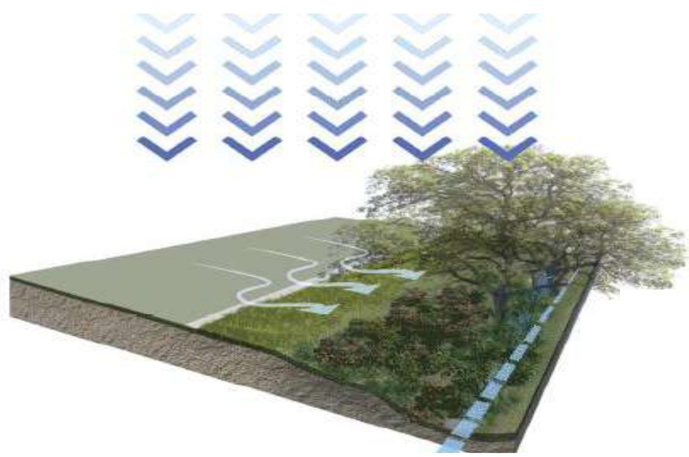


Figure 19. Diagram of a Vegetated Swale adapted from the Houston-Galveston Area Council.

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 20). 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.

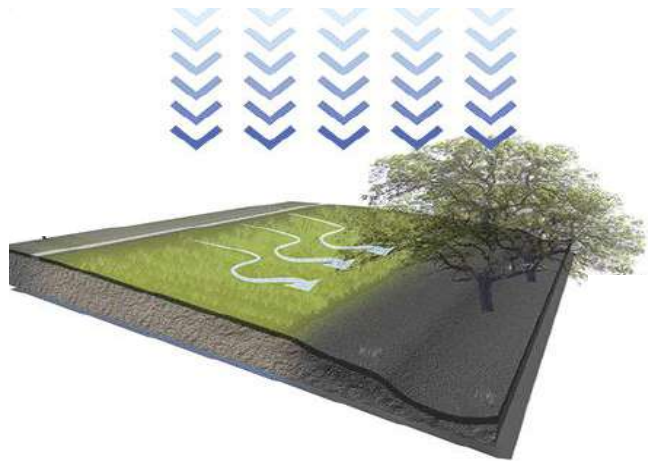


Figure 20. Diagram of a Vegetated Filter Strip adapted from the Houston-Galveston Area Council.

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 21).

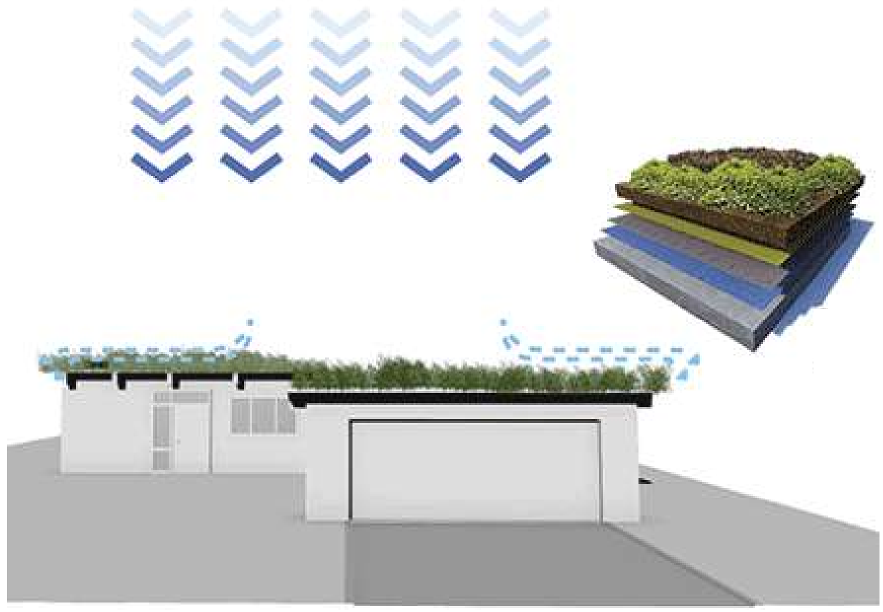


Figure 21. Diagram of a Green Roof adapted from the Houston-Galveston Area Council.

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 22). 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.

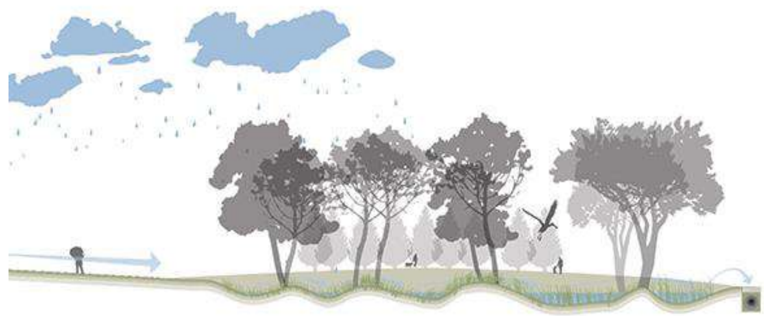


Figure 22. Diagram of a Constructed Stormwater Wetland adapted from the Houston-Galveston Area Council.

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 23-28). 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 RFW. 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 23. BMP's 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 24. BMP's implemented following a train treatment approach in Zoní Beach at Culebra Puerto Rico. Practices include bioswales, bioretentions, raingardens and permeable parking.

Figure 25. BMP's implemented following a train treatment approach in Punta Soldado in Culebra, Puerto Rico. Practices include bioswales, bioretentions, raingardens, sediment traps and permeable parking.

Figure 26. BMP's implemented following a train treatment approach in Fulladosa Culebra, Puerto Rico. Practices include bioswales and raingardens.

Figure 27. BMP's implemented following a train treatment approach in Puerto del Manglar in Culebra, Puerto Rico. Practices include bioswales and sediment traps.

Figure 28. BMP's implemented following a train treatment approach in Yauco, Puerto Rico. Practices include bioswales, bioretentions and raingardens.

Recommended Stormwater Treatment Practices

A total of sixteen (16) stormwater treatment projects have been selected in this initial assessment of the RFW (Figure 29). The proposed sites, if implemented, will have a direct impact for the benefit of coral reefs and other important coastal and marine ecosystems as the have been identified as the most problematic in terms of pollutant sources. A total of six large parking lot areas have been identified in the RFW with the potential to be transformed to be able to implement green infrastructure projects without greatly affecting its utility as a parking area. Other smaller parking areas can be incorporated into this list later in the process of implementation of restoration efforts. Instead of flowing directly to

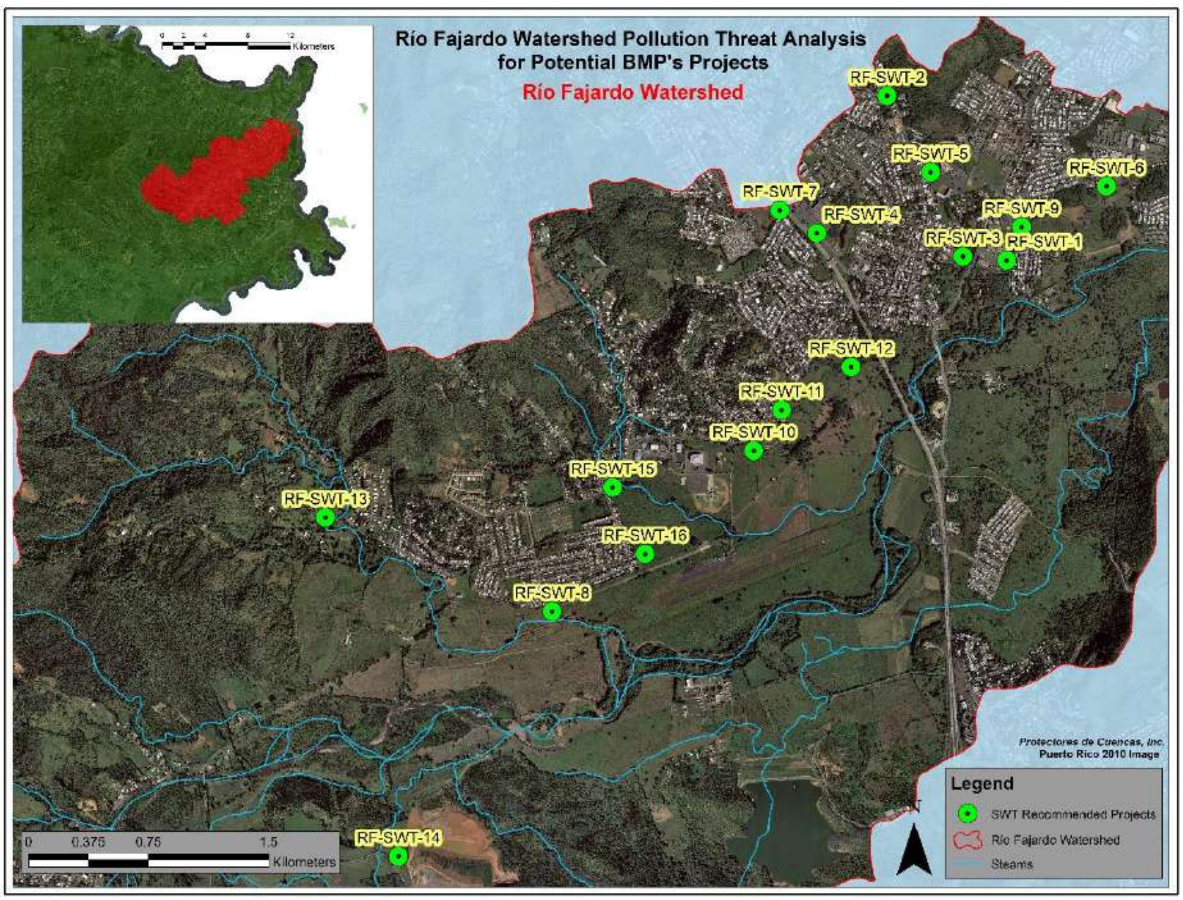


Figure 29. Recommended Stormwater Treatment Projects for the RFW.

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 RFW 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 30). 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 30. Images on the left are of an actual parking area near PR-3 and on the right comparative areas where BMP's 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 31). If other components like vegetative cover, gravel and sand

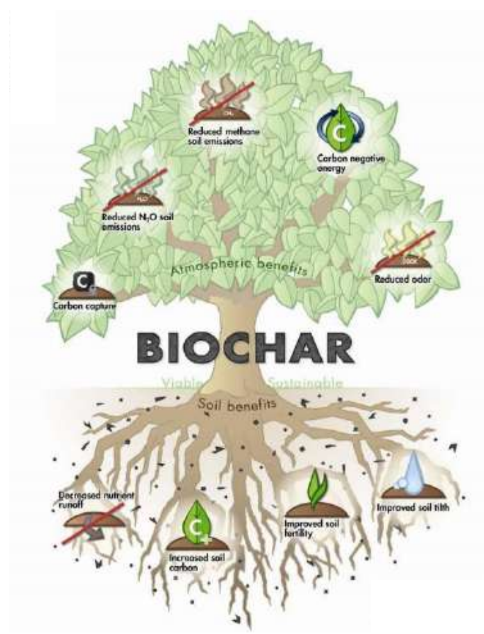


Figure 31. Biochar diagram adapted from International Biochar Initiative.

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 32). 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 32. 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 RFW 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 33).

Figure 33. Images on the left are of actual community outfalls of the RFW and on the right comparative areas where SWP BMP's 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 34). 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.

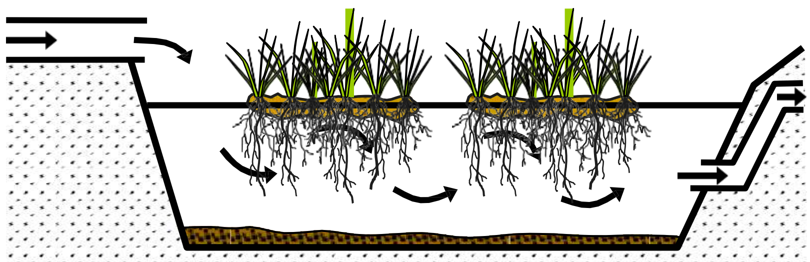


Figure 34. Diagram of a Floating Treatment Wetland adapted from Headley & Tanner, (2008)

Woodchip Bioreactor

A woodchip bioreactor (schematic shown in Figure 35) 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

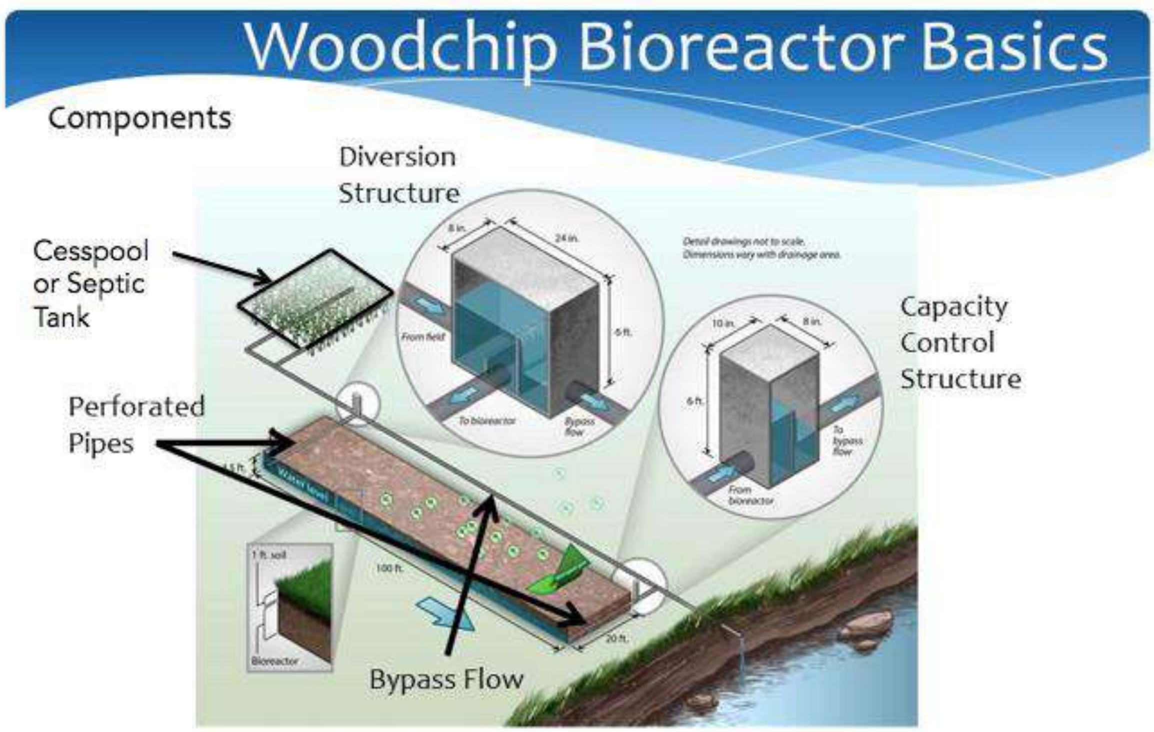


Figure 35. Woodchip Bioreactor schematic (adapted based on image by John Petersen, www.petersenart.com)

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 RFW that will target most of the hotspots for nutrient pollution found in our field assessments (Figure 36, Tables 10 and 11). Figure 37 shows some of the community outfalls on the RFS that are suitable for the implementation of NRP.

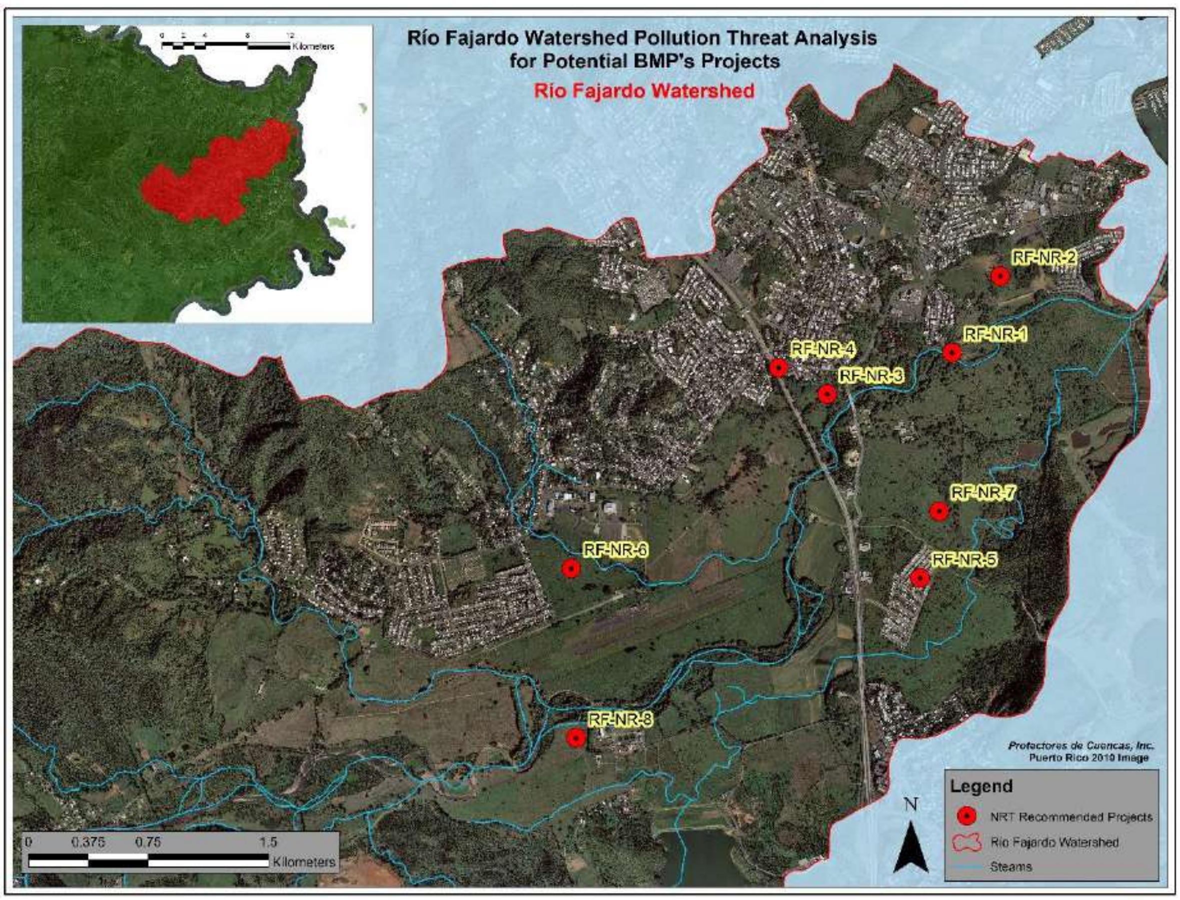


Figure 36. Nutrient Reduction recommended projects for the RFW.

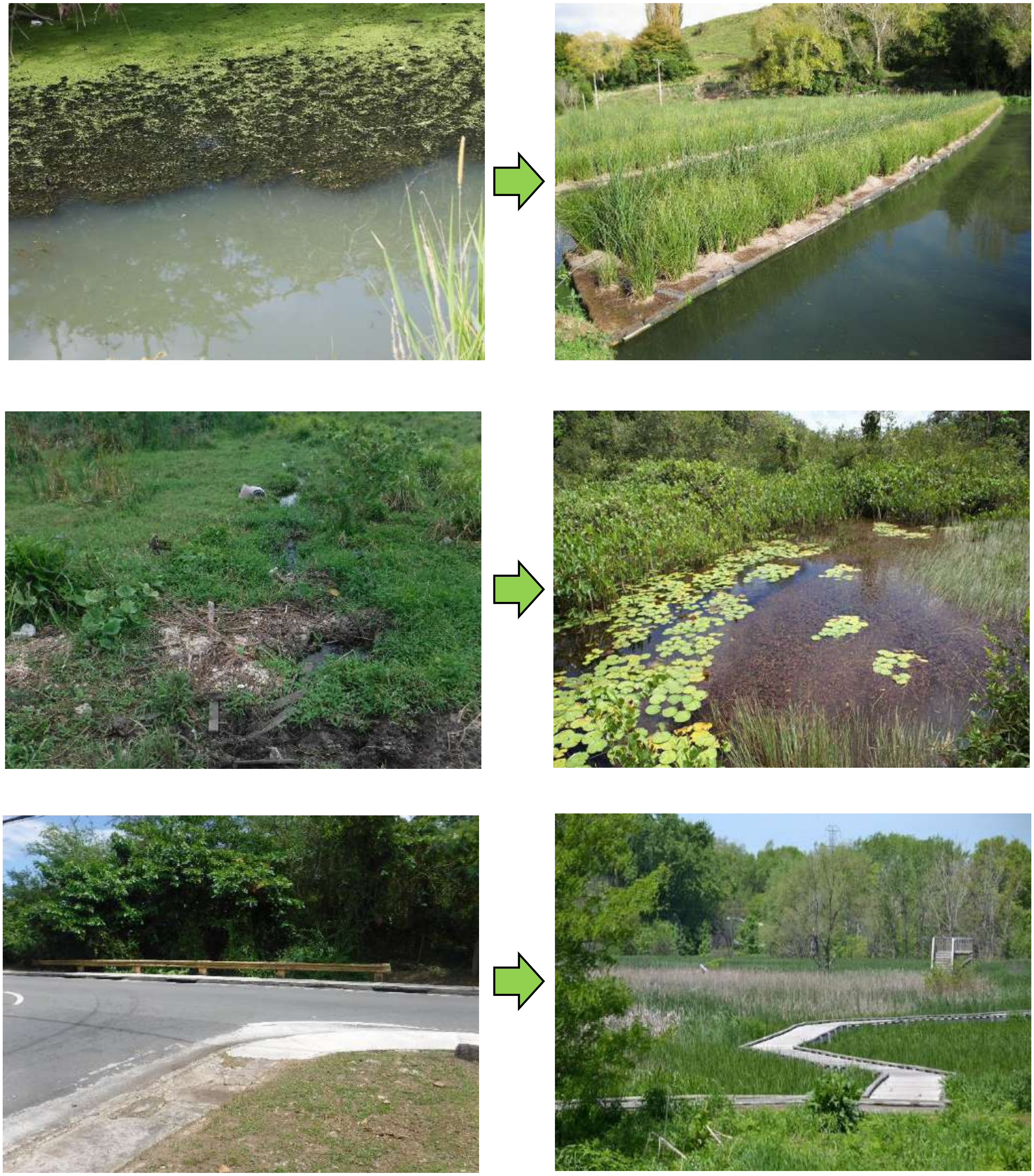


Figure 37. Images on the left are of actual community outfalls of the RFW and on the right comparative areas were NRP BMP's have been implemented (from internet search).

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 38).

Figure 38. 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 49). This practice is highly recommended as it will be very difficult to impossible to implement other BMP's without regrading. All

Figure 39. 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 40).

Figure 40. 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 41).

Figure 41. 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 42).

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 42. Examle of gavel pavemet 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 43).

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 43. 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 44).

Figure 44. 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 45).

Figure 45. 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 Fajardo River 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 46). 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 47). 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 46. Example of a riparian forested buffer adapted from NRCS.

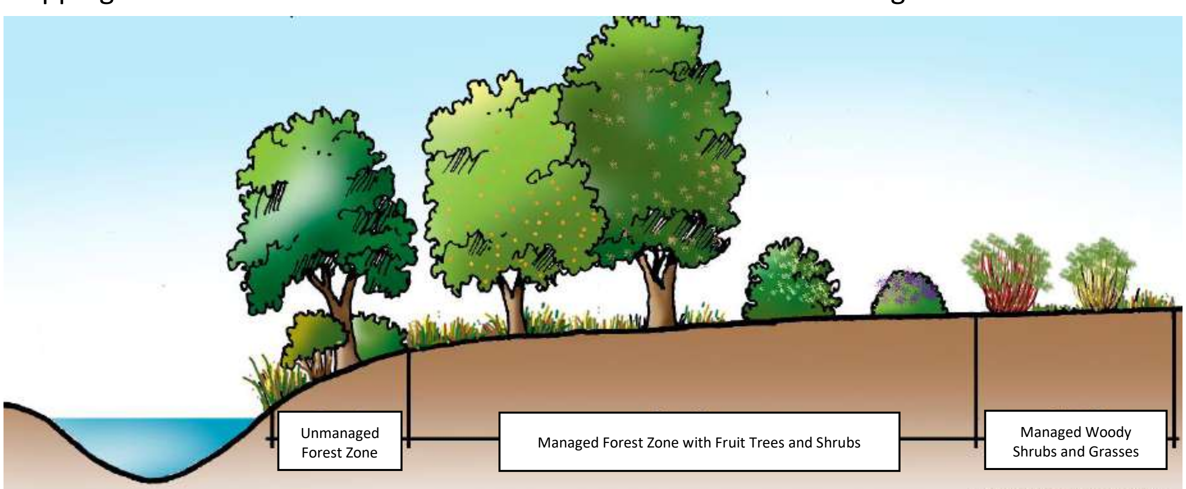


Figure 47. Diagram of a riparian forest buffer components adapted from NRCS.

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

Figure 48. Example of a fencing practice implemented by PD on a farm in the RFW.

Fence is a practice that may be applied on any area where farmers need better control of animals or people (Figure 48). 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.

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 49). 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 49. 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 RFW are associated to the dirt road networks, active and abandoned construction sites and agriculture. The recommendations for dirt road and bare soil stabilization are found in Tables 12 and 13. 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 Fajardo watershed is necessary for the near future. If sediment is to be managed at a much higher level in the Fajardo watershed – additional targeting and implementation should occur. A total of twenty-eight (28) soil stabilization practices have been identified as priority implementation areas.

Additionally, a series of areas along the Fajardo River and associated tributaries have been identified for the implementation of Riparian forested buffers (Figure 50).

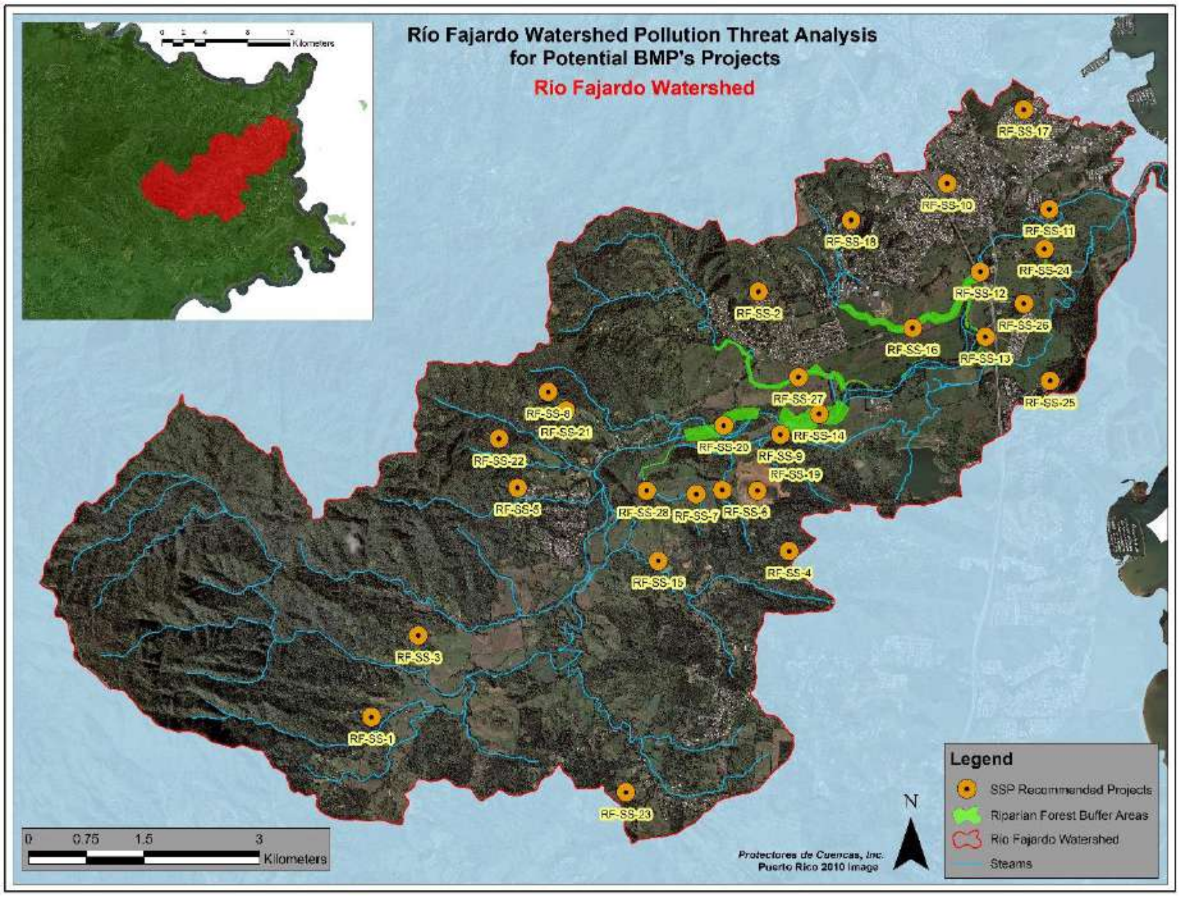


Figure 50. Soil stabilization recommended projects in the RFW.

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 Fajardo 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 and Ceiba, 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. These steps are critical to effectively safeguard the natural resources of the Fajardo area (Table 14).

IDDE

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 51).

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 the RFWMP including the creation of a Watershed Governance Structure. The WCE can also oversee coordination of all activities also recommended in the Northeast Corridor Watershed Management Plan 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.

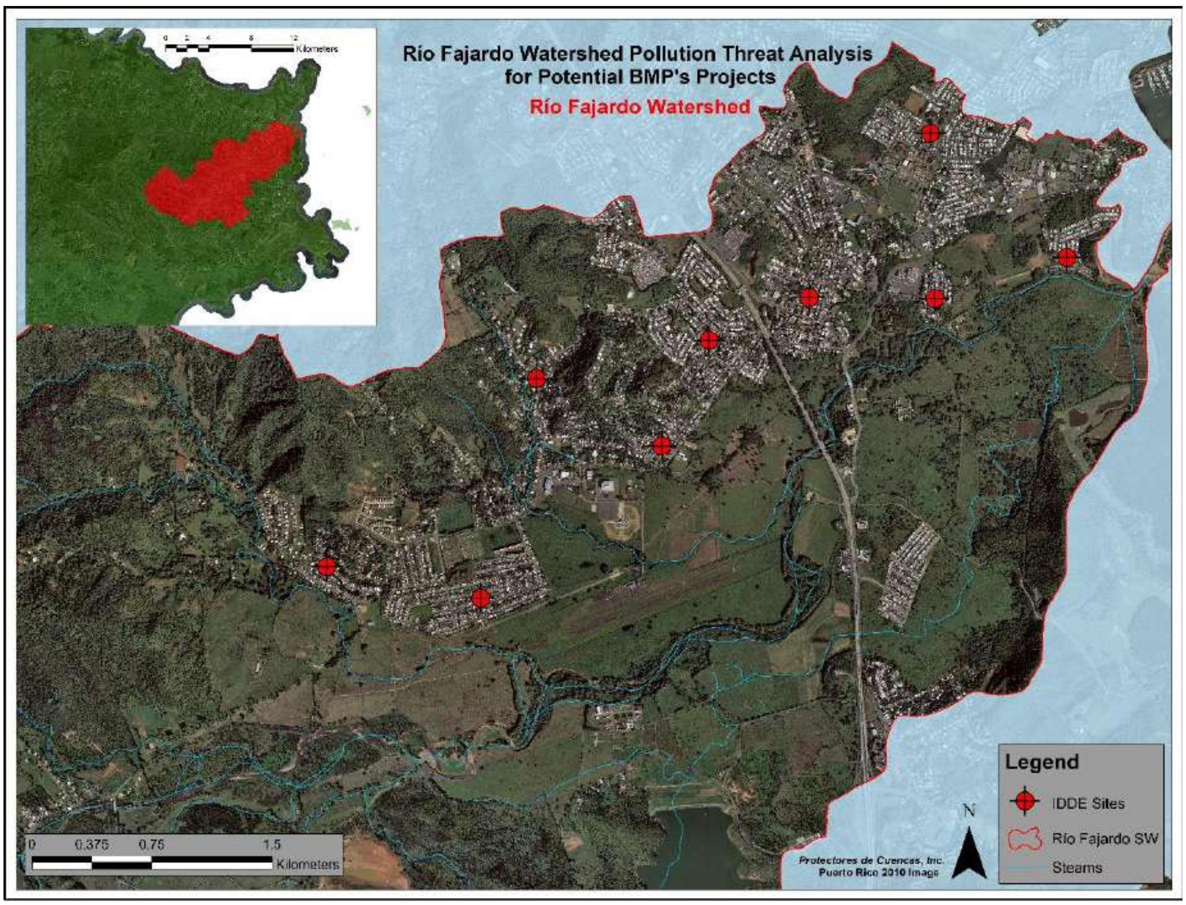


Figure 51. IDDE proposed additional sites for source taking.

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 10. Stormwater Treatment Practices proposed projects list description.

ID	Observations	Estimated Impervious Cover Area (%)	Est. Drainage Area (acres)	GPS Coordinates	Type	Ownership	Existing Land Use	Sewer Infrastructure Service
RF-SWT-1	Multiple areas for BMP implementation. Adjacent Public Land has the potential additional treatment.	100	10	18.32684° -65.646536°	Parking area	Public	Urban Institutional	Yes
RF-SWT-2	Multiple areas for BMP implementation. Adjacent green area for potential additional treatment.	85	6.5	18.336024° -65.653738°	Parking area	Private	Urban Institutional	Yes
RF-SWT-3	Multiple areas for BMP implementation. Adjacent green area for potential additional treatment.	100	5	18.327028° -65.649113°	Parking area	Public/ Private	Urban Institutional	Yes
RF-SWT-4	Multiple areas for BMP implementation. Adjacent green area for potential additional treatment.	100	11	18.328219° -65.65777°	Parking area	Private	Urban Comercial, Recreational	Yes
RF-SWT-5	Multiple areas for BMP implementation. Multiple landowners.	100	10	18.331739° -65.6511°	Multiple Parking areas	Public/ Private	High Density Urban	Yes
RF-SWT-6	Multiple areas for BMP implementation. Adjacent green area for potential additional treatment.	100	3.5	18.331095° -65.640698°	Parking area	Public/Private	High Density Urban	Yes
RF-SWT-7	Limited areas for BMP implementation.	100	7.6	18.329475° -65.659981	Parking area	Public/Private	Urban Comercial	Yes
RF-SWT-8	Suitable area for BMP implementation.	80	40	18.306679° -65.673075°	Community Outfall	Public	High Density Urban, Agriculture	Yes
RF-SWT-9	Suitable area for BMP implementation.	75	8.6	18.32873° -65.64569	Community Outfall	Public	High Density Urban, Agriculture	Yes
RF-SWT-10	Suitable area for BMP implementation.	60	100	18.315897° -65.661305°	Community Outfall	Public	High Density Urban, Agriculture	Yes
RF-SWT-11	Suitable area for BMP implementation.	70	50	18.318216° -65.659698°	Community Outfall	Public	High Density Urban, Agriculture	Yes
RF-SWT-12	Suitable area for BMP implementation.	85	250	18.320708° -65.655627°	Community Outfall	Public	High Density Urban, Agriculture	Yes
RF-SWT-13	Suitable area for BMP implementation.	20	50	18.311788° -65.686538°	Community Outfall	TBD	Low density Urban, Agriculture	No
RF-SWT-14	Multiple areas for BMP implementation. Adjacent Public Land has the potential additional treatment.	95	250	18.292743° -65.681934°	Industrial Outfall	Public/ Private	Industrial, Agriculture	No
RF-SWT-15	Multiple areas for BMP implementation. Adjacent Public Land has the potential additional treatment.	65	45	18.313721° -65.669606°	Community Outfall	Public	Medium Density Urban, Agriculture	No
RF-SWT-16	Suitable area for BMP implementation.	85	75	18.309999° -65.667634°	Community Outfall	Public	High Density Urban, Agriculture	Yes

Table 11. 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
RF-SWT-1	Bioretention, Raingarden, Bioswale, Green Roof	Small	86→105 Green Roofs not included	30%	Simple	No	NEPA, General Construction Permit, Municipal/ Public Buildings Authority	EPA, NOAA, DNER, EQB, NFWF, Municipality	PDC, Municipality
RF-SWT-2	Bioretention, Raingarden, Bioswale	Small	66→85	30%	Simple	No	NEPA, General Construction Permit, Municipal/Hospital Hima	EPA, NOAA, DNER, NFWF, Municipality	PDC, Municipality, Hospital Hima
RF-SWT-3	Bioretention, Raingarden, Bioswale, Green Roof	Small	66→85	30%	Simple	No	NEPA, General Construction Permit, Municipal/Landowner	EPA, NOAA, DNER, NFWF, Municipality	PDC, Municipality, Landowner
RF-SWT-4	Bioretention, Raingarden, Bioswale	Small	86→105	30%	Simple	No	NEPA, General Construction Permit, Municipal/Landowner	EPA, NOAA, DNER, NFWF, Municipality	PDC, Municipality, Landowner
RF-SWT-5	Bioretention, Raingarden, Bioswale	Small	86→105	30%	Simple	No	General Construction Permit, Municipal/Landowners	EPA, NOAA, DNER, NFWF, Municipality	PDC, Municipality, Landowners
RF-SWT-6	Bioretention, Raingarden, Bioswale	Small	66→85	30%	Simple	No	NEPA, General Construction Permit, Municipal/Landowners	EPA, NOAA, DNER, NFWF, Municipality	PDC, Municipality, Landowners
RF-SWT-7	Bioretention, Raingarden, Bioswale	Small	66→85	30%	Simple	No	NEPA, General Construction Permit, Municipal/Landowners	EPA, NOAA, DNER, Municipality	PDC, Municipality, Landowners
RF-SWT-8	Bioretention, Bioswale, Constructed Stormwater Wetland	Small	106→125	100%	Detailed	Yes	NEPA, ACOE, General Construction Permit, Municipal/Land Authority	NRCS, EPA, NOAA, USFS, DNER, Municipality	PDC, Municipality, Land Authority, AES
RF-SWT-9	Bioretention, Bioswale	Small	25-45	30%	Simple	No	NEPA, General Construction Permit, Municipal/Land Authority	NRCS, EPA, NOAA, DNER, Municipality	PDC, Municipality, Land Authority, PREPA
RF-SWT-10	Bioretention, Bioswale	Small	25-45	30%	Simple	No	NEPA, General Construction Permit, Municipal/Land Authority	NRCS, EPA, NOAA, DNER, NFWF, Municipality	PDC, Municipality, Land Authority, AES
RF-SWT-11	Bioretention, Bioswale	Small	25-45	30%	Simple	No	NEPA, General Construction Permit, Municipal/Land Authority	NRCS, EPA, NOAA, DNER, NFWF, Municipality	PDC, Municipality, Land Authority, AES
RF-SWT-12	Bioretention, Bioswale, Constructed Stormwater Wetland	Small	106→125	100%	Detailed	Yes	NEPA, ACOE, General Construction Permit, Municipal/Land Authority	NRCS, EPA, NOAA, USFS, DNER, NFWF, Municipality	PDC, Municipality, Land Authority, AES
RF-SWT-13	Bioretention, Bioswale, Wetland Enhancement	Small	25-45	30%	Simple	No	NEPA, ACOE, General Construction Permit, Municipal/Land Authority	NRCS, EPA, NOAA, USFS, DNER, NFWF, Municipality	PDC, Municipality, Land Autority, AES
RF-SWT-14	Bioretention, Raingarden, Bioswale, Green Roof	Large	166→205	30%	Simple	No	NEPA, General Construction Permit, Municipal/Land Authority, Landfield Administration	Municipality, Landfield Administration, NRCS, EPA, NOAA, USFS, DNER, NFWF,	PDC, Municipality, Land Authority, AES, Landfield Administration
RF-SWT-15	Bioretention, Bioswale, Wetland Enjansmet	Small	25-45	30%	Simple	No	NEPA, General Construction Permit, Municipal, Adjacent Landowners	EPA, NOAA, USFS, DNER, NFWF, Municipality	PDC, Municipality, Land Owners,
RF-SWT-16	Bioretention, Bioswale, Constructed Stormwater Wetland	Small	66→85	100%	Detailed	Yes	NEPA, ACOE, General Construction Permit, Municipal/Land Authority	NRCS, EPA, NOAA, USFS, DNER, NFWF, Municipality	PDC, Municipality, Land Authority, AES

Nutrient Reduction Practices Proposed Projects List

Table 12. Nutrient Reduction Practices proposed projects list description.

ID	Observations	Est. Treatment Practice area (acres)	Est. Drainage Area (acres)	GPS Coordinates	Type	Ownership	Existing Land Use	Sewer Infrastructure Service
RF-NR-1	Old abandoned WTP can be used for treatment practices. PRSA Pumping Station in constant failure.	2	20	18.324436° -65.644591°	Community Outfall	Public	Urban, Agriculture	Yes
RF-NR-2	Sufficient available area with apparent topographic condition suitable for Treatment Wetlands implementation.	10	180	18.328987° -65.641804°	Community Outfall	Public	Urban, Agriculture	Yes
RF-NR-3	Sufficient available area with apparent topographic condition suitable for Treatment Wetlands implementation. This project will also help reduce constant flooding problems for adjacent urban areas. Hotspot for nutrients contamination.	15	300	18.321995° -65.651937°	Community Outfall	Public	Urban, Agriculture	Yes
RF-NR-4	Stream restoration Project. Steam has been channelized with concrete. Project to be combined with RF-NR-3.	1	150	18.323447° -65.654817°	Community Outfall	Public	Urban	Yes
RF-NR-5	Santa Rita Community has sewer infrastructure but is not connected to the RFWTP. Proposed project is to connect to main line that will be done for the hew hotel development currently under construction.	N/A	32	18.311708° -65.646282°	Community Outfall	Public	Urban	Yes
RF-NR-6	Sufficient available area with apparent topographic condition suitable for Treatment Wetlands implementation. Hotspot for nutrients contamination.	20	400	18.311955° -65.666903°	Community Outfall	Public	Urban	Yes
RF-NR-7	Santa Rita sewage retention pond. Proposed project is to convert this pond into a functional Treatment Wetland	2	32	18.315534° -65.645135°	Community Outfall	Public	Urban	Yes
RF-NR-8	FWTP proposed bioreactor with biochar for nutrient reduction.	4	N/A	18.315534° -65.645135°	FWTP	Public	Agriculture	Yes

Table 13. 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
RF-NR-1	Bioretention, Raingarden, Bioswale	Small	66→85	30%	Simple	No	NEPA, General Construction Permit, Municipal/ PRASA	EPA, NOAA, DNER, NFWF, EQB, Municipality	PDC, Municipality, PRASA
RF-NR-2	Bioretention, Treatment Wetland	Small	106→125	100%	Detailed	Yes	NEPA, ACOE, General Construction Permit, Municipal/Land Authority	EPA, NOAA, DNER, NFWF, Municipality	PDC, Municipality, Land Authority
RF-NR-3	Bioretention, Treatment Wetland	Medium	266→305	100%	Detailed	Yes	NEPA, ACOE, General Construction Permit, Municipal/Land Authority	EPA, NOAA, DNER, NFWF, USFWS, Municipality	PDC, Municipality, Land Authority
RF-NR-4	Bioswale	Medium	166→205	100%	Detailed	Yes	NEPA, ACOE, General Construction Permit, Municipal/Land Authority	EPA, NOAA, DNER, NFWF, Municipality	PDC, Municipality, Land Authority
RF-NR-5	Connect to FWTP	Large	546→	100%	Detailed	Yes	NEPA, General Construction Permit, Municipal/PRASA	PRASA	Municipality, Land Authority
RF-NR-6	Bioretention, Treatment Wetland	Medium	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
RF-NR-7	Bioretention, Floating Treatment Wetland	Medium	126→165	30%	Simple	No	NEPA, General Construction Permit, Municipal/Land Authority	EPA, NOAA, DNER, NFWF, Municipality	PDC, Municipality, Land Authority
RF-NR-8	Bioreactor	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 14. Soil stabilization Practices proposed projects list description.

ID	Observations	Est. Unstable Soil Area (acres)	Est. Distance from a stream (meters)	GPS Coordinates	Type	Ownership	Existing Land Use	Slopes Type
RF-SS-1	Bare soil area since year 2004 or earlier. No farming activities are present on area. Appears to be used by ATV activities	20	100	18.265312° 65.646536	Dirt Road, Land Clarence	Private	Agriculture	High
RF-SS-2	Abandoned construction site since year 2004 or earlier for Estancias de San Pedro Urbanization expansion.	6	1000	18.315392° -65.679090°	Dirt Road, Land Clarence	Private	Urban	High to Moderate
RF-SS-3	Dirt access road for farming (cattle grazing). A small lake apparently for agriculture is near the site and attention should be given to it at it appears to be overflowing with high sediment content.	3	360	18.274503° -65.720217°	Dirt Road	Private	Agriculture	High to Moderate
RF-SS-4	Dirt road since year 1994 or earlier. No housing or agricultural activities appear to be present at this time. Road should be restored back to native forest.	6	560	18.285080° -65.674846°	Dirt Road, Land Clearance	Private	Urban/ Forest	High
RF-SS-5	Relatively new dirt road cleared in year 2013 north of Saldaña Community. Road is in the boundary of el Yunque National Forest and part may be on the Forest property. This project should be done in combination with RF-SS-22. Road should be restored back to native forest.	8	400	18.292071° -65.708286°	Dirt Road, Land Clearance	Private	Forest	High
RF-SS-6	Dirt Road for farming activities that crosses a stream several times. Stream is also being impacted by cattle grazing.	2	0	18.292129° -65.683216°	Dirt Road, Streambank Stabilization	Public	Agriculture	Low
RF-SS-7	Dirt Road for farming activities that crosses a stream. Stream is also being impacted by cattle grazing.	1	0	18.291580° -65.686360°	Dirt Road, Stream Crossing	Public	Agriculture	Low
RF-SS-8	Land clearing for housing development since year 2004 or earlier.	3	870	18.303277° -65.704682°	Land Clearance	Private	Forest	High
RF-SS-9	Dirt Road for farming activities that crosses a stream several times. Stream is also being impacted by cattle grazing. On the edge of the Fajardo River	2	0	18.292129° -65.683216°	Dirt Road, Streambank Stabilization	Public	Agriculture	Low
RF-SS-10	Cleared Land since year 1994 or earlier apparently used as a quarry but abandoned currently project. Additional land clearing nearby quarry and unstable land cut on shopping mall nearby.	6	1,400	18.328434° -65.656149°	Dirt Road, Land Clearance	Private	Urban	Moderate
RF-SS-11	Land clearance recently for demolition of old Wastewater Treatment Plant apparently abandoned. On the edge of the Fajardo River.	2	30	18.325524° -65.643514°	Dirt Road, Land Clearance	Public	Agriculture	Low
RF-SS-12	Active Construction Site on Fajardo River banks for repairs to PR-3.	3	0	18.317823° -65.652033°	Dirt Road, Streambank Stabilization	Public	Agriculture	Low
RF-SS-13	Area identified for implementation of Riparian Forested Buffer.	5	0	18.310481° -65.651256°	Streambank Stabilization	Public	Agriculture	Low
RF-SS-14	Area identified for implementation of Riparian Forested Buffer.	10	0	18.299684° -65.673404°	Streambank Stabilization	Public	Agriculture	Low

RF-SS-15	Active farm with suitable areas to implement BMP for sediment and erosion control.	40	200	18.283754° -65.690891°	Dirt Road, Land Clearance	Public	Agriculture	Low
RF-SS-16	Area identified for implementation of Riparian Forested Buffer.	30	0	18.310853° -65.661087°	Streambank Stabilization	Public	Agriculture	Low
RF-SS-17	Abandoned construction site since year 2014.	2	1,800	18.337168° -65.647094°	Land Clearance	Private	Urban	Low
RF-SS-18	Abandoned construction site since year 2004. Additional clearance made in 2016.	1	300	18.323559° -65.668304°	Land Clearance	Private	Urban	Low
RF-SS-19	Landfill operation.	50	60	18.292190° -65.678827°	Dirt Road, Land Clearance	Public	Common	High
RF-SS-20	Area identified for implementation of Riparian Forested Buffer.	12	0	18.300337° -65.677843°	Streambank Stabilization	Public	Agriculture	Low
RF-SS-21	Land Clearance and dirt road for agriculture	2	500	18.301142° -65.702503°	Dirt Road, Land Clearance	Private	Agriculture, Forest	High
RF-SS-22	Relatively new dirt road cleared in year 2013 north of Saldaña Community. This project should be done in combination with RF-SS-5. Road should be restored back to native forest.	2	200	18.297736° -65.710683°	Dirt Road, Land Clearance	Private	Forest	High
RF-SS-23	Abandoned Construction site since year 204 or earlier	2	450	18.256426° -65.694434°	Dirt Road, Land Clearance	Private	Agriculture	Moderate
RF-SS-24	Area identified for implementation of Riparian Forested Buffer.	5	0	18.320865° -65.644058°	Streambank Stabilization	Public	Agriculture	Low
RF-SS-25	Dirt Road Network.	1	370	18.305383° -65.643160°	Dirt Road	Private	Forest, Agriculture	Moderate
RF-SS-26	Active Construction Site on Cayo Largo Hotel Complex.	20	0	18.314404° -65.646510°	Dirt Road, Streambank Stabilization	Public, Private	Agriculture	Low
RF-SS-27	Area identified for implementation of Riparian Forested Buffer.	35	0	18.305110° -65.674600°	Streambank Stabilization	Public	Agriculture	Low
RF-SS-28	Area identified for implementation of Riparian Forested Buffer.	5	0	18.292261° -65.692598°	Streambank Stabilization	Public	Agriculture	Low

Table 15. 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
RF-SS-1	Hydroseeding, Sediment Traps, Vegetated Swales, Regrading, Vetiver grass.	Small	46→65	30%	Simple	No	NEPA, Municipal/ Land owner	NRCS, NOAA, DNER, NFWF	PDC, Municipality, Landowner
RF-SS-2	Hydroseeding, Sediment Traps, Vegetated Swales, Regrading, Vetiver grass.	Small	25→45	30%	Simple	No	NEPA, Municipal/ Land owner	NOAA, DNER, NFWF	PDC, Municipality, Landowner
RF-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
RF-SS-4	Hydroseeding, Sediment Traps, Vegetated Swales, Regrading, Vetiver grass, Reforestation.	Small	66→85	30%	Simple	No	NEPA, General Construction Permit, Municipal/Landowner	USFS, NOAA, DNER, NFWF, USFWS, Municipality	PDC, Municipality, Landowner
RF-SS-5	Hydroseeding, Sediment Traps, Vegetated Swales, Regrading, Vetiver grass, Reforestation.	Small	66→85	30%	Simple	No	NEPA, Municipal/ Landowner	USFS, NOAA, DNER, NFWF, USFWS, Municipality	PDC, Municipality, Landowner
RF-SS-6	Hydroseeding, Sediment Traps, Vegetated Swales, Regrading, Vetiver grass, Fencing, Stabilized Stream crossing, Riparian Forested Buffer.	Small	25→45	30%	Simple	No	NEPA, Municipal/ Farmer, Land Authority	NRCS, NOAA, DNER, NFWF, USFWS	PDC, Municipality, Land Authority, Farmer, Landfill Administration
RF-SS-7	Hydroseeding, Sediment Traps, Vegetated Swales, Regrading, Vetiver grass, Fencing, Stabilized Stream crossing, Riparian Forested Buffer.	Small	25→45	30%	Simple	No	NEPA, Municipal /Farmer, Land Authority	NRCS, NOAA, DNER, NFWF, USFWS	PDC, Municipality, Land Authority, Farmer, Landfill Administration
RF-SS-8	Hydroseeding, Sediment Traps, Vegetated Swales, Regrading, Vetiver grass, Reforestation	Small	25→45	30%	Simple	No	NEPA, General Construction Permit, Municipal/Landowner	USFS, NOAA, DNER, NFWF, USFWS	PDC, Municipality, landowner
RF-SS-9	Hydroseeding, Sediment Traps, Vegetated Swales, Regrading, Vetiver grass, Fencing, Stabilized Stream crossing, Riparian Forested Buffer.	Small	25→45	30%	Simple	No	NEPA, Municipal/ Farmer, Land Authority	NRCS, NOAA, DNER, NFWF	PDC, Municipality, Land Authority, Farmer, Landfill Administration
RF-SS-10	Hydroseeding, Sediment Traps, Vegetated Swales, Regrading, Vetiver grass	Small	25→45	30%	Simple	No	NEPA, Municipal/ Landowners	EPA, NOAA, DNER, NFWF	PDC, Municipality, Landowners
RF-SS-11	Hydroseeding, Sediment Traps, Vegetated Swales, Regrading, Vetiver grass	Small	25→45	30%	Simple	No	NEPA, General Construction Permit, Municipal/PRASA	PRASA, EPA, NOAA, DNER, NFWF	PDC, Municipality, PRASA
RF-SS-12	Sediment and erosion control practices, Vetiver, Reforestation	Small	46→65	30%	Simple	No	NEPA, Municipal/ PRASA	Private Contractor	
RF-SS-13	Riparian Forested Buffer	Small	46→65	30%	Simple	No	NEPA, Municipal/ Farmers, Land Authority	NRCS, USFS, NOOA, USFWS, NFWF, DNER	PDC, Municipality, Land Authority
RF-SS-14	Riparian Forested Buffer	Small	86→ 105	30%	Simple	No	NEPA, Municipal/ Farmers, Land Authority	NRCS, USFS, NOOA, USFWS, NFWF, DNER	PDC, Municipality, Land Authority
RF-SS-15	Riparian Forested Buffer, Sediment Trap, Vegetated Swale, Vetiver grass	Small	25→45	30%	Simple	No	NEPA, Municipal/ Farmers, Land Authority	PRASA, EPA, NOAA, DNER, NFWF	PDC, Municipality, PRASA

RF-SS-16	Riparian Forested Buffer	Medium	126→165	30%	Simple	No	NEPA, Municipal/ Farmers, Land Authority	NRCS, USFS, NOOA, USFWS, NFWF, DNER	PDC, Municipality, Land Authority
RF-SS-17	Hydroseeding, Sediment Traps, Vegetated Swales, Regrading, Vetiver grass, Reforestation.	Small	25→45	30%	Simple	No	NEPA, Municipal/ Landowner	USFS, NOAA, DNER, NFWF, USFWS	PDC, Municipality, landowner
RF-SS-18	Hydroseeding, Sediment Traps, Vegetated Swales, Regrading, Vetiver grass, Reforestation.	Small	25→45	30%	Simple	No	NEPA, Municipal/ Landowner	USFS, NOAA, DNER, NFWF, USFWS	PDC, Municipality, landowner
RF-SS-19	Hydroseeding, Sediment Traps, Vegetated Swales, Regrading, Vetiver grass, Reforestation.	Small	66→85	30%	Simple	No	NEPA, Municipal/ Landfill Administration	Landfill Adm., Municipality	PDC, Municipality, Landfill Administration
RF-SS-20	Riparian Forested Buffer	Small	66→85	30%	Simple	No	NEPA, Municipal/ Farmers, Land Authority	NRCS, USFS, NOAA, NFWF, USFWS, DNER	PDC, Municipality, Land Authority
RF-SS-21	Hydroseeding, Sediment Traps, Vegetated Swales, Regrading, Vetiver grass, Reforestation.	Small	25→45	30%	Simple	No	NEPA, Municipal/ Landowner	NRCS, NOAA, DNER, NFWF	PDC, Municipality, landowner
RF-SS-22	Hydroseeding, Sediment Traps, Vegetated Swales, Regrading, Vetiver grass, Reforestation.	Small	25→45	30%	Simple	No	NEPA, Municipal/ Landowner	NRCS, NOAA, DNER, NFWF	PDC, Municipality, landowner
RF-SS-23	Hydroseeding, Sediment Traps, Vegetated Swales, Regrading, Vetiver grass, Reforestation.	Small	25→45	30%	Simple	No	NEPA, Municipal/ Landowner	NRCS, NOAA, DNER, NFWF	PDC, Municipality, landowner
RF-SS-24	Riparian Forested Buffer	Small	25→45	30%	Simple	No	NEPA, Municipal/ Farmers, Land Authority	NRCS, USFS, NOAA, NFWF, DNER	PDC, Municipality, Land Authority
RF-SS-25	Hydroseeding, Sediment Traps, Vegetated Swales, Regrading, Vetiver grass, Reforestation.	Small	25→45	30%	Simple	No	NEPA, Municipal/ Landowner,	NRCS, NOAA, DNER, NFWF	PDC, Municipality, landowner
RF-SS-26	Sediment and erosion control practices, Vetiver, Reforestation, Streambank Stabilization	Small	46→65	30%	Simple	No	NEPA, Municipal/ PRASA	Private Contractor	
RF-SS-27	Riparian Forested Buffer	Medium	126→165	30%	Simple	No	NEPA, Municipal/ Farmers, Land Authority	NRCS, USFS, NOOA, NFWF, USFWS, DNER	PDC, Municipality, Land Authority
RF-SS-28	Riparian Forested Buffer	Medium	25→45	30%	Simple	No	NEPA, Municipal/ Farmers, Land Authority	NRCS, USFS, NOOA, NFWF, USFWS, DNER	PDC, Municipality, Land Authority

Pollution Prevention Proposed Projects List

Table 16. Pollution prevention proposed projects list recommended actions.

ID	Action Description	Cost Scale	Est. cost ($K) range	Possible Funding Partners	Possible Matching Partner
RF-PP-1	IDDE Tracking sources of pollution	Small	106→125	EPA, NOAA, DNER, NFWF, EQB, Municipality	PDC, Municipality, PRASA
RF-PP-2	House to House Survey for connections to the sewer system	Small	106→125	EPA, NOAA, DNER, NFWF, Municipality	PDC, Municipality, PRASA
RF-PP-3	Sediment and Erosion Control Workshops.	Small	25→45	EPA, NOAA, DNER, NFWF, Municipality	PDC, Municipality, PRASA
RF-PP-4	Watershed Coordination at a yearly basis.	Small	86→105	EPA, NOAA, DNER, NFWF, USFWS, Municipality	PDC, CCP, Municipality,
RF-PP-5	Dirt Road Guidance Document	Small	25→45	PRASA	PDC, RTR, Municipality, Land Authority
RF-PP-6	Farm Inventory for BMP's implementation	Small	46→65	PRASA, EPA, NOAA, DNER, NFWF, Municipality	PDC, Municipality, Land Authority

PILOT BMP PROJECT IMPLEMENTED

Site RF-SS-7 was selected from the SSP project list as the Pilot implementation project for this effort. The selected project was chosen for its characteristics that included various components like nutrient reduction and soil stabilization in a relatively small area. Several types of BMP's where implemented. Project site is located on a cattle farm managed by farmer Esteban Rivera near PR-982 adjacent to the Fajardo Landfill disposal area. This site also has been identified as a priority action in the RFWMP. The implemented actions are described in the following sections. Matching contributions were also secured for the selected site from the farmer and the Landfill administration.

EVALUATION

The main environmental concerns of the proposed project are based on a poorly managed farm access dirt road and cattle streambank crossing areas. The reference site is adjacent to a tributary stream that discharges directly to the Fajardo River transporting sediment-laden runoff. The completed work includes the stabilization of bare soil areas and the incorporation of vegetative buffers (Figure 52). Installed BMP's include, check dams, swales, regrading, stabilized stream crossing, Fencing, rip-raps, Hydroseeding, Vetiver grass and paving with granulate fill material and compacting.

The farm manager has collaborated on this effort by providing a signed agreement for conservation and maintenance of the implemented practices as well as providing labor and materials. Further, there was a small network of unstable dirt roads and cattle streambank crossings through bare soil areas (Figures 53).

The primary goal of this project was to stabilize bare soils in the farm to reduce sediment loads to the Fajardo River. This will protect and build resilience of coral reef ecosystems in this priority area.

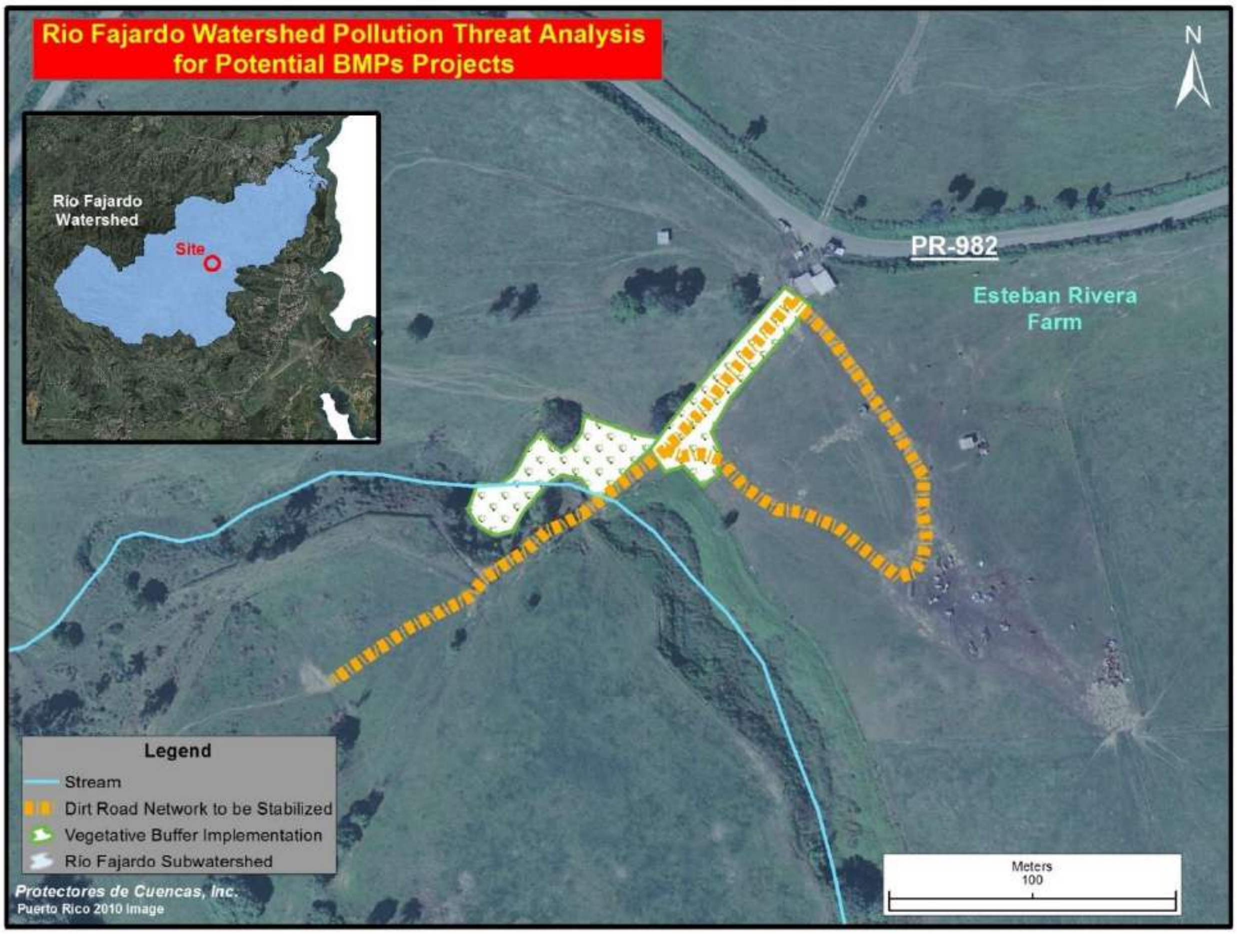


Figure 52. Schematic conceptual design of the implemented pilot BMP project.

Figure 53. Images showing prior existing conditions of the project site selected.

COMPLETED TASKS

This section describes in detail all the proposed restoration components, the methods, and tasks to be performed to achieve project goals. Based on PDC's experience in dirt road stabilization and combining the management of ecological sensitive areas with a responsible planning and implementation process, the following tasks where developed

The following restoration components where implemented; *rehabilitation and stabilization of dirt roads with granulated pavement*, e*stablishment of vegetative buffers with vetiver and native plants, delimitation of sensitive areas with barbed wire to keep cattle out and follow up visits to ensure proper maintenance and evaluate functionality (Figure 54)***.**

Rehabilitation and stabilization of dirt roads with granulated pavement

Conditions of this road network were critical due to erosion and the generation of significant runoff from this area to the adjacent stream. Road was regraded and compacted and runoff was diverted to forested areas by installing check dams, swales and rip-rap. We will install small check dams to build terraces filed with appropriate stones to increase surface contact to treat contaminants and to reduce the erosive force of water. Further, road was stabilized by with a layer of crushed stones and compacted using a compaction roller. The expected result is to have a better water management that is both, safe for the environment and the farm daily operations.

Establishment of vegetative buffers with vetiver and native trees

The more sensitive areas on the streambanks were stabilized with a vegetated buffer zone between the constructed BMP's and the natural areas. Hydroseeding application was implemented to all bare soil areas on the project site particularly the ones closer to the stream. This will help filter excess runoff and support soil conservation practices. Vetiver grass was planted in half-moon patterns on discharge runoff areas and native trees were planted as part of the vegetative buffer zone along the banks of the adjacent stream.

Delimitation of sensitive areas with barbed wire to keep cattle out

Fencing techniques were implemented to restrain cattle movement on restored areas. Barbed wires fences were also constructed along the riverbanks to keep cattle out of the stream as a permanent strategy. The stream crossing area for cattle and farm management was stabilized with stones and gravel infill and compacted. Rip-rap structures were implemented on erodible areas on both sides of the stream crossing designated area. This will ensure a proper life expectancy to the practices and will let certain areas recover from heavy grazing.

Follow up Visits to Ensure Proper Maintenance and Evaluate Functionality

Follow up visits to the project site have been conducted to provide feedback to farmer and assess sediment and erosion control practices effectiveness, particularly after rain events. Problems encountered were fixed during this period. Farm manager has compromised to provide maintenance the implemented practices.

Figure 54. Images of the project site after implementation of all BMP's.

REFERENCES

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