# Reduction and Control of Sediment-Laden Runoff to Coastal Waters through the Implementation of Best Management Practices (BMP's), Coastal Habitat Rehabilitation and Delimitation of Public Access at Culebra, Puerto Rico

FINAL REPORT

August, 2015

*Projects toward the implementation of the Culebra Community Watershed Action Plan for Coral Reefs and Water Quality*

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Culebra Municipality

# I. Executive Summary

As part of the efforts to implement the ***Culebra Community Watershed Action Plan for Coral Reefs and Water Quality***, two projects where carried out from October to December 2014; one at Zoní Beach and the other in Downtown Culebra near the Water Tank (Figure 1). These projects represent efforts to address untreated stormwater runoff and sediment and erosion from parking areas and unpaved road systems impacting Culebra's coastal and marine resources. Both projects were chosen after several meetings with strong community participation as part of the stakeholder process for the development of the watershed plan (Figure 2). The town site represents a site draining to the Lobina channel, the last stop before predominant currents carry sediment and pollutants towards sensitive coral reef communities within the Luis Peña Marine Reserve.

**Figure 2.** An example of the community meeting process in Culebra.

The main goal for these projects was to address runoff from the adjacent roads and bare soil areas prior to being discharged to the marine environment. These two projects were high priorities due to the nearby reefs and the level of existing negative impacts to the nearshore marine ecosystems.


**Figure 1**. Map with project sites identification.

Zoní was selected as a high priority location due to the erosion occurring on the road network driving down to the beach and of the parking lot which allowed conveyance of untreated stormwater into the nearshore marine environment and coral reefs (Figure 3). The Townsite was identified as a priority due to extensive sediment transport from a dirt road and conveyance of stormwater runoff in a small eroding channel out to the Lobina Channel (Figure 4). This projects were also part of the Sustainable Forestry Network of the Department of Natural and Environmental Resources of Puerto Rico (DNER) coordinated through the Division of Forest Service and the Coastal Zone Management Program. These efforts had the endorsements of the Municipality of Culebra, the Conservation and Development Authority of Culebra (ACDEC) and the support of the community. Funding for this project was possible thanks to the Coastal Zone Management Program of the DNER and to the Coral Reef Conservation Program and the Restoration Center of the

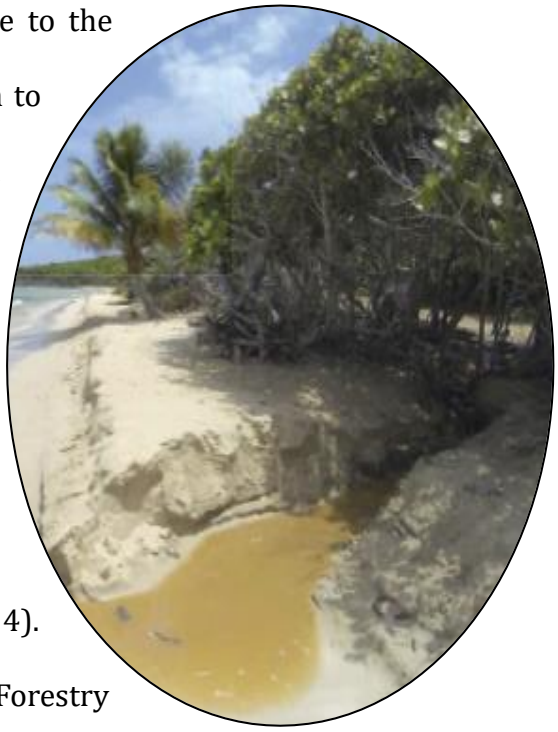


**Figure 3** (Top). Runoff with fine sediments and beach erosion problems at Zoní Beach prior stabilization. Picture from the UPRM Sea Grant Program Marejada Magazine. **Figure 4** (Bottom). Sediment plume out to the Lobina Channel from the town site prior stabilization.

National Oceanic and Atmospheric Administration (NOAA). These projects were designed and implemented by the nonprofit organization Protectores de Cuencas, Inc. with the collaboration of Ridge to Reefs, Inc. and cooperation and active participation of the community and the Culebra Municipality. It is important to point out that the majority of the hired labor for this effort was from Culebra. These projects received technical assistance from the DNER, the US Fish and Wildlife Service (USFWS) and NOAA. USFWS and DNER also provided native trees planted as part of the reforestation program and provided logistical support and accommodation for the work team in their facilities in Culebra.

# II. Introduction

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 without the installation of proper management practices is a very common problem in Culebra (Figure 5).

The degradation of coastal water quality in Puerto Rico has caused 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 ecosystems conservation, degradation of water quality due to dispersed land-based sources of pollution (LBSP) has negative and sometimes irreversible damage to the integrity of the coral reef communities, sea grasses, mangroves and other highly valued coastal ecosystems.

**Figure 5**. Example actual unstable dirt roads in Culebra.

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. 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 attractive of coastal areas for recreation and tourism.

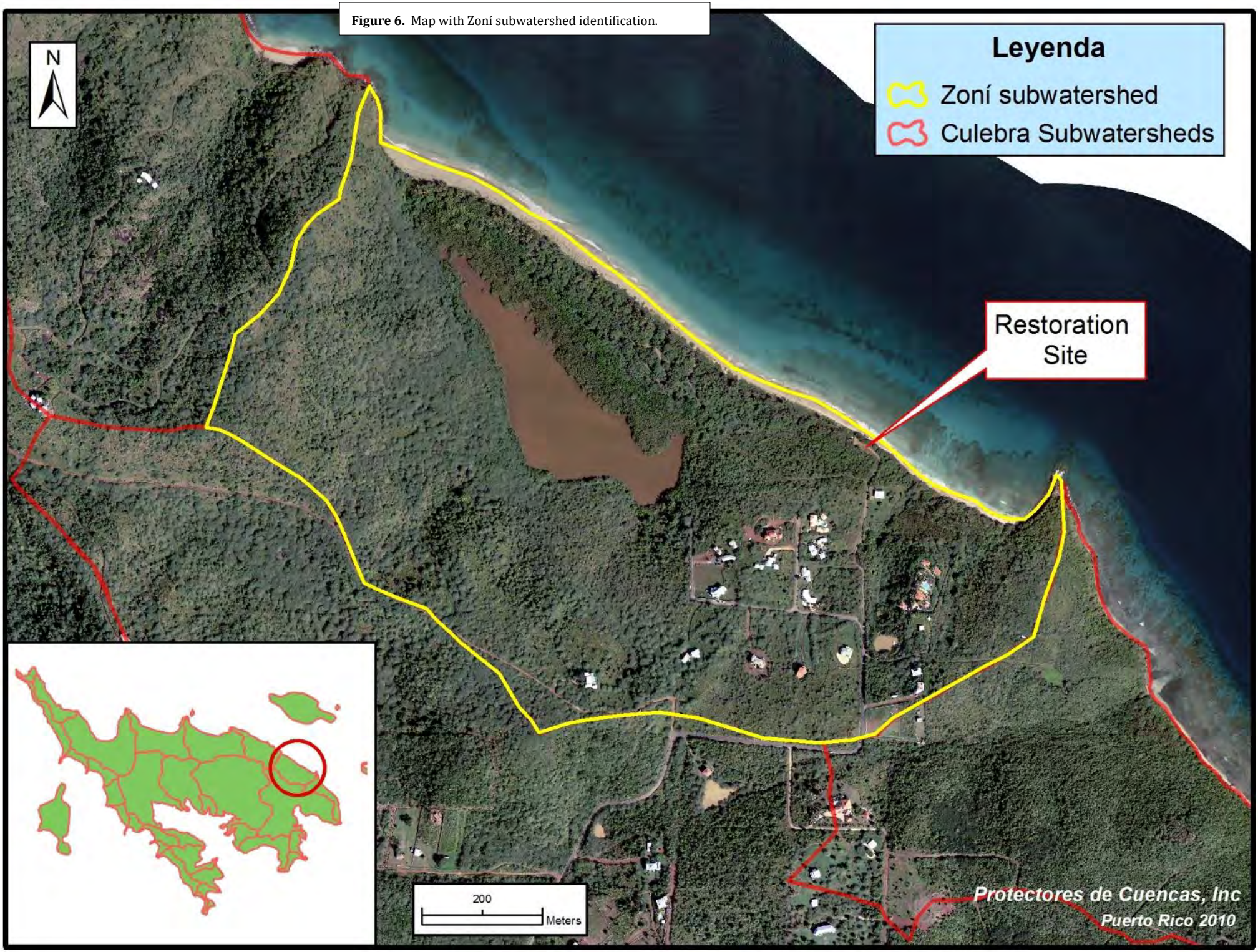
In order to assess these issues we established two restoration projects as described in the ***Culebra Community Watershed Action Plan for Coral Reefs and Water Quality*** (See http://www.coris.noaa.gov/activities/projects/watershed/); one at Zoní beach and another at downtown near the Lobina Chanel. Zoní beach is one of the most important nesting sites for sea turtles (leatherback sea turtle: *Dermochelys coriacea* and hawksbill sea turtle: *Eretmochelys imbricata*) and offers one of the most beautiful scenic views in the Caribbean. It is also considered critical habitat for listed green sea turtles that includes waters extending seaward 3 nm (5.6 km) from the mean high water line of Culebra Island, Puerto Rico. The beach is one of the most important ecosystems in the Island, not just for it natural values, but also for the benefit it provides to the local economy. These factors attract a wide variety of visitors and has created a huge demand for space (e.g. parking area and real estate), which has resulted in an increase of illegal activities such as unauthorized

parking, deforestation, camping grounds and land clearing. A micro-watershed approach can be used as an important management unit for this coastal area (Figure 6). The high visitation in this area has resulted in an increased pressure on natural resources and has increased the need for implementation of management practices to ensure both the enjoyment of visitors to the area as well as the protection and conservation of this unique coastal resource. The lack of proper planning and management practices of erosion and sediment has led to an increase in contamination of Zoní Beach.

The Town site is located in a small subwatershed that drains to the Lobina Channel. Most of the access roads in the area are paved except for the road that goes to the main potable water reservoir in the top of the hill. This dirt road is very steep and serves as the major source of sediment laden runoff to the Lobina Channel.

The purpose of these projects was to implement sediment and erosion control measures to reduce sediment loads into the marine ecosystems. We aimed to improve water quality in the near shore, contribute to the health of adjacent coral reefs and ultimately support the Culebra local economy.

**Figure 6.** Map with Zoní subwatershed identification.



# III. Acknowledgements

This project could not have taken place without the active participation of the community of Culebra. In particular we want to acknowledge all the help and support from Omar Villanueva, Ana Ayala, Hector Díaz (Tyson) and Tomás Ayala (Tomasito) and Abbie and the students from Abbies School. Omar, Ana, Hector and Tomás were heavily involved in the construction and carpentry for the project including Tomasito's and Omar's donation of time and labor. Abbie's School assisted with planting trees and shrubs and will be continuing to water the plants twice a week for the next six weeks. We also acknowledge the support and assistance provided by the following persons and entities: the Mayor of Culebra, Honorable Iván Solís, for the support given to the project and their active participation in community meetings and for providing water for the site to enable watering of the over 250 plants. Thanks also to the Secretary of the DNER Carmen Guerrero and Ernesto Diaz, Director of the Coastal Zone Management Program who supported the project and its planning, helping to to make this project successful including providing lodging at the DNER house. Mr. Robert Matos, (DNER), for his coordination on the use of the facilities of the Department in Culebra. Damaris Delgado, Director of the Bureau of Coastal Reserves and Refuges (DNER) for all the help in the development of the management plan for Culebra. From NOAA, Lisa Vandiver and Rob Ferguson, for all the hard work in order to secure funding for the project and providing technical support and labor. Ricardo Colón

from USFWS, Wildlife Biologist in Culebra, for his technical assistance and logistical support (Figure 7).

**Figure 7** (From left to right). Omar Villanueva, Ricardo Colón (FWS), Tomasito, Anita, Tomasito and Tyson, and Abby's School.

# IV. Implementation

## ZONÍ BEACH

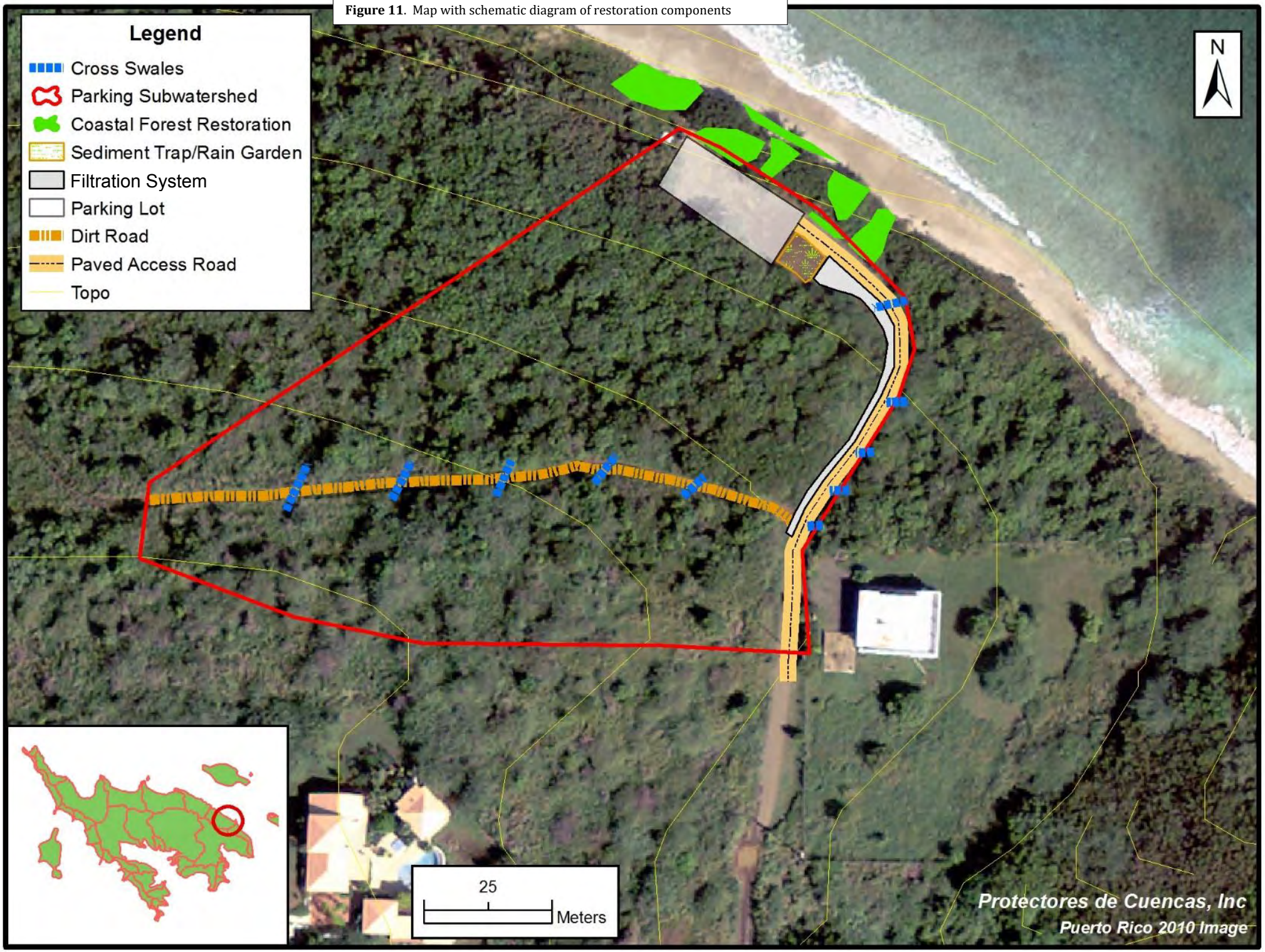
The problems identified in Zoní beach were mainly associated with runoff generated from the dirt parking lot (Figure 8) and the unpaved road network that provides vehicular access to areas adjacent to the beach (Figure 9). Existing infrastructure was in a critical state of disrepair with rutting and small undesirable watercourses conveying runoff and sediment down to Zoní Beach (Figure 10). The dirt parking lot covers approximately 500 $m^2$ and vehicles had direct access to the permanent vegetation areas of the beach. The lack of proper planning and management of erosion and sediment led to an increase in contamination of the beach with sediment and pollutants associated with motor vehicles. After several field evaluations, input from the local community, DNER, FWS and NOAA the following restoration components were established (Figure 11):

**Figure 8.** Parking lot prior stabilization.

**Figure 9**. Dirt road prior stabilization.

**Figure 10**. Undesirable watercourses prior stabilization.

**Figure 11**. Map with schematic diagram of restoration components



### 1. Dirt road stabilization

**Figure 12.** Dirt road prior stabilization.

This dirt road was built to provide access to land lots that are for sale and no residential housing have been established in this area. Currently, this particular road does not receive too much vehicular traffic. However, it is a serious contributor of sediment laden runoff to Zoni Beach. The stabilization of this dirt road has significantly reduced the amount of flow and the velocity of water and sediment sent downhill. Water had converted this road into a drainage channel increasing the velocity of the water running towards the road to Zoní Beach (Figure 12). Restoration work at this site consisted of diverting runoff water to forested areas in 4 to 6 segmented locations. To stabilize this section of road, we installed dirt swales, thus reducing flow and diverting water to adjoining forested areas.

### 2. Stabilization of the Zoní Beach paved access road

Previous to our intervention the paved access road served as the flow pattern of runoff to the parking lot area (Figure 13). In order to reduce runoff and dissipate its energy, water was conveyed to intercepts at 3 locations on both sides of the road that will

break up flow paths and reduce concentrated flow of runoff over the parking lot (Figure 14). The excess runoff will be forced to a riprap and Vetiver swale built parallel to the south side of the road to take water off the road and it will end in a wider concrete bio-filter system with built-in large stones that promote sheet flow towards the sediment trap after passing through several lines of Vetiver grass (Figure15). Damaged section of this road were repaired to prevent soils to be carried to the stabilized parking lot (Figure 16).

**Figure 13**. Paved road prior stabilization.

**Figure 14.** Flow intercepts.

**Figure 15**. Riprap and Vetiver Swale.

**Figure 16.** Pre and Post stabilization of paved road (Top) and repaired segment of the road (Bottom).

### 3. Creation of a sediment trap/rain Garden

A Rain Garden/Sediment Trap system was designed to help filter storm water that was discharged to Zoní Beach. The entire filtration process consists in three filtration chambers, a Rain garden and a permeable parking system (Figure 17). This practice was designed to treat residual runoff coming from the dirt and access roads that could not be addressed with stabilization practices discussed in the previous sections. Water is conveyed to the sediment trap by a concrete swale. In this design the three filtration chamber has a variable substrate particles in order to provide a reduction of sediment and hydraulic energy. This will allow water to pass throughout the chamber slowly while reducing sediment load. All of the chambers where design to hold a rain fall event of 10yr-24hr, which represent more than 90% of the rainfall that occurs in Culebra. The first filtration chamber was filled with 3" to 12" diameter rock, this will trap larger particle material transported by the storm water. The secondary chamber uses stones that vary between ⅛" to ½". The purpose is to trap sediment between the macro voids created in the substrate. While the third and final chamber, contains a blend of mostly sand with topsoil. Vetiver was planted in this chamber to further aid in the filtration process (Figure 18).

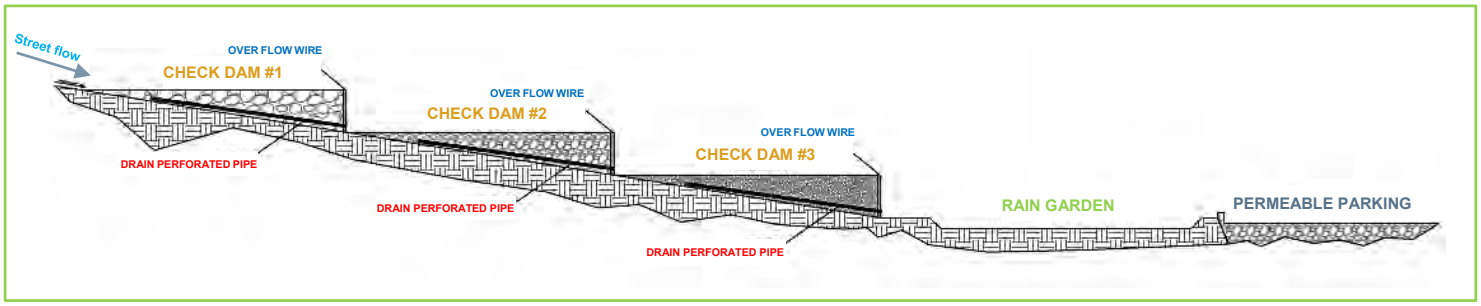



**Figure 17.** Conceptual Diagram of Filtration System.

At this point, sediment should be reduced significantly. A rain garden was placed at the end of the filtering process, this final step was designed to infiltrate small rainfall events and to discharge water slowly to the permeable parking area (Figure 19).

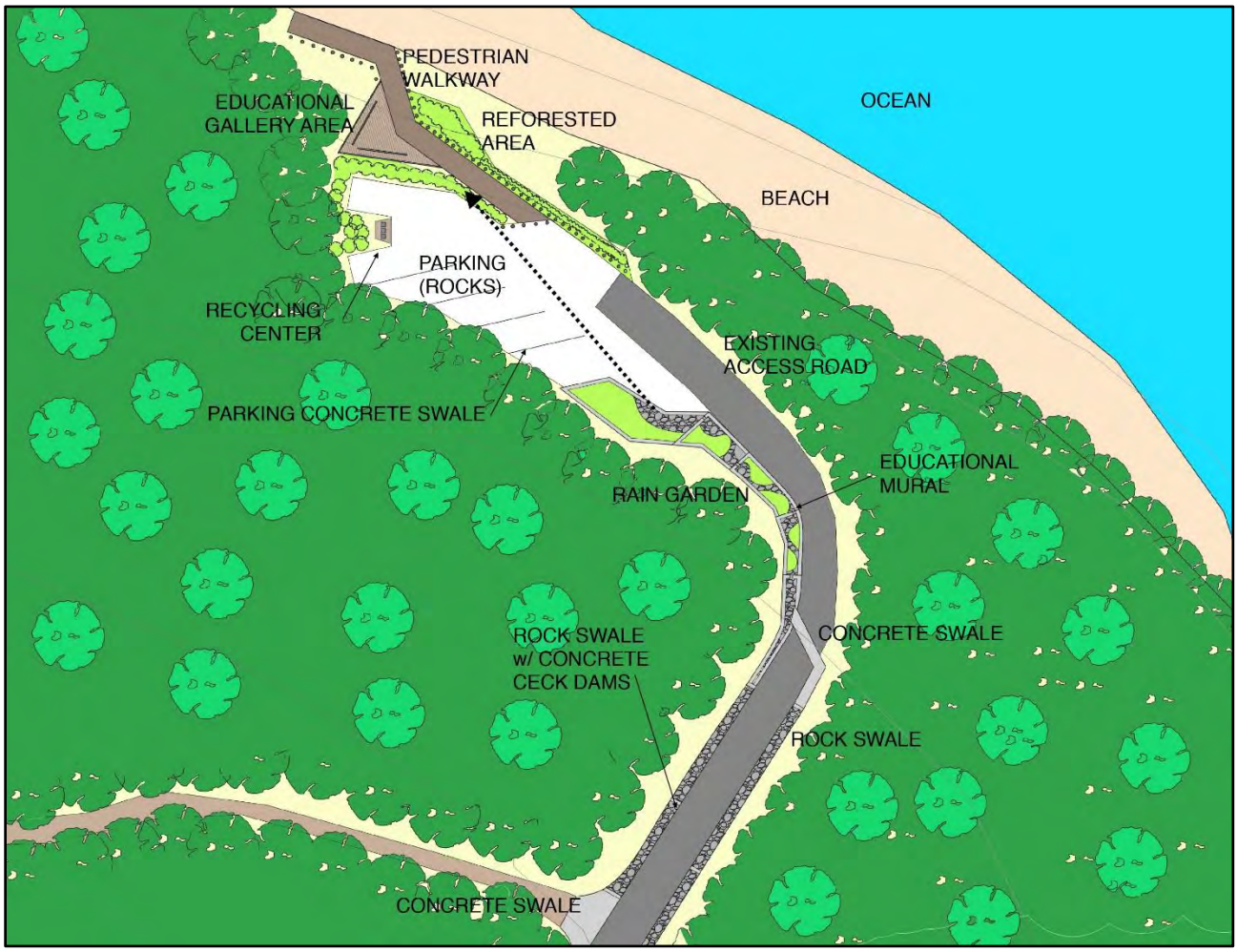
**Figure 18**. Construction of Filtration System.

**Figure 19.** Rain Garden Component of the Filtration System.

## 4. Stabilization of the dirt parking lot

The stabilized parking area consisted of approximately 500 $m^2$ (Figure 20). In this process, first, we delineated the parking area above the permanent vegetation zone of the beach. For this, treated wooden posts were buried about 18 inches deep and fixed with concrete at base leaving about 30 inches of pole to demarcate the area. Wooden posts were placed at a distance of three feet from each other and crossed with rope to prevent the passage of people and small vehicles such as golf carts that have become a major means of transportation in Culebra. Further, the parking area was developed using the best available technology to help in the sediment load reduction process (Figure 21). Parking was constructed with multiple layer base confined with a 1' concrete curb composed of; (1) geo-mebrane support (2) gabion with pebble stones as base, this allows support and drainage, (3) filter fabric, this eliminate the possibility of contamination of the base with sediment, and (4) a Geo-Cell with ¼" gravel infill, this will allow vehicle support and drainage of all stormwater (Figures 22, 23 and 24). Another important factor behind the parking design was the negative slope used to pond water at the center of the parking prior to its discharge throughout the beach channel. This will reduce significantly the discharge rate of storm water through the drainage channel which was re-planted with native vegetation to stabilize the erosion process affecting the beach.

**Figure 20.** Parking area before stabilization.



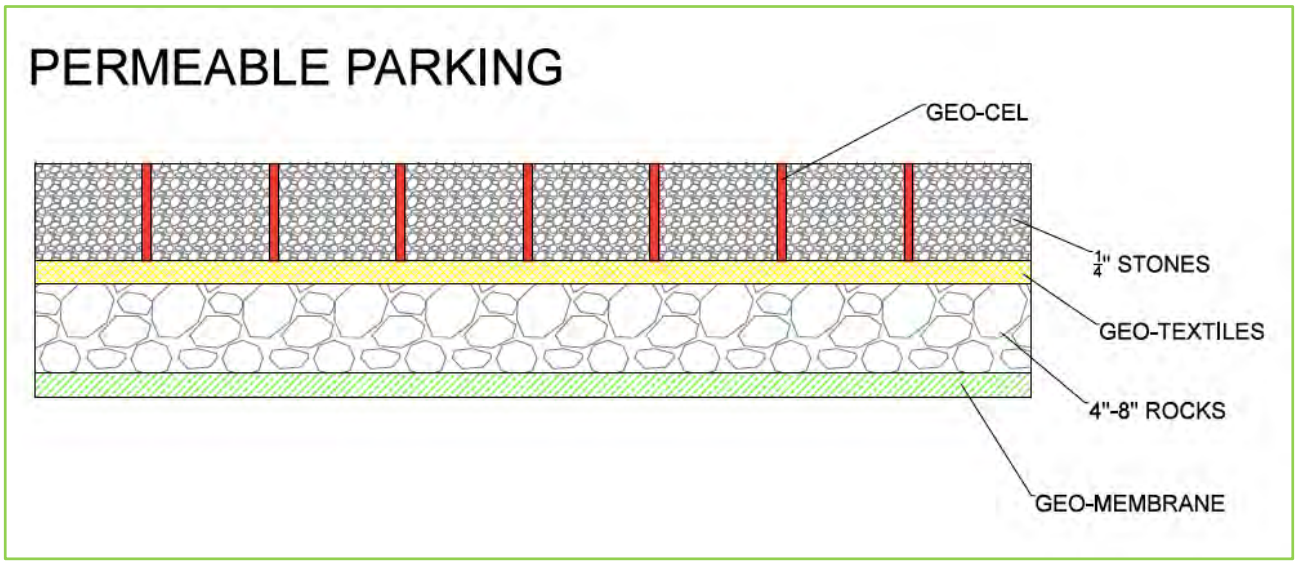




**Figure 21**. Schematic diagrams of practices Implemented (Top) and cross section diagram of parking filtration components.

**Figure 22**. Parking filtration system construction.

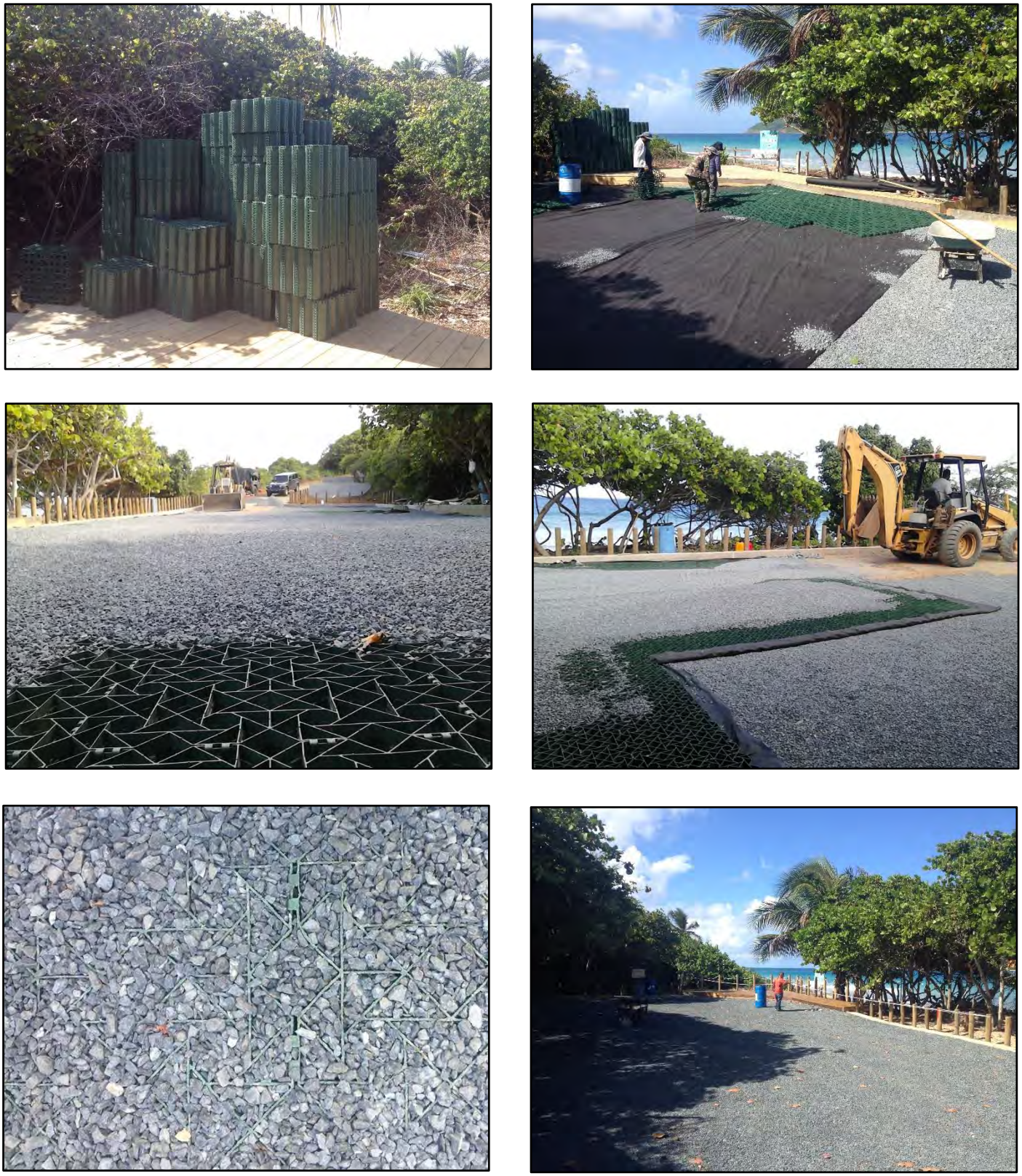


**Figure 23**. Parking filtration system construction.

**Figure 24**. Parking area pre (top) and post (bottom) system construction.

## 5. Delimitation of public access

A small elevated boardwalk was constructed for the public to access the beach without impacting vegetation and sand dunes (Figure 25). This area was closed to vehicular access by the installing wood poles and it has a defined pedestrian access area to the beach. This is accompanied by signage with educational information and rules to be followed by users.

**Figure 25.** Elevated boardwalk and access delimitation.

## 6. Reforestation of the vegetated zone of the beach

The coastal habitat at Zoní Beach has been seriously impacted by uncontrolled public access and erosion caused by concentrated flow. In order to restore the coastal vegetated berm and buffer, we re-planted the area with coastal native species. Plant material was provided by DNER and USFWS. A total of approximately 300 native trees were planted with active collaboration of local groups such as kids from Abbie's School and USFWS volunteers. Abbie's School was in charge of the watering and maintenance of the planted trees for 5 to 6 weeks. A cistern system was installed in the area and water was coordinated with the Municipality of Culebra (Figure 26).

**Figure 26.** Process of reforestation of the vegetated zone of the beach with volunteers.

## TOWN SITE

The Town site is located in a small subwatershed that drains to the Lobina Channel (Figure 1). Most of the access roads in the area are paved except for the road that goes to the main potable water reservoir at the top of the hill (Figure 27). This dirt road is very steep and serves as the major source of sediment-laden runoff to the Lobina Chanel.

**Figure 27**. Dirt access road to the water tank prior to stabilization.

Another problem associated with this site is that when the water reservoir tank overflows it drains from top of the hill through a steep slope in a dirt channel it has created over time piping and erosion of fine sediments and carrying them to the near shore environment (Figure 28).

**Figure 28**. Water tank overflow prior to stabilization.


**Figure 29.** Schematic diagram of practices implemented.

**CONCEPTUAL DIAGRAM FOR SEDIMENTO CONTROL AT CULEBRA PUEBLO**

In order to be able to stabilize this site, a series of components were constructed to increase the effectiveness of the conservation practices implemented and help reduce sediment transport to the Lobina channel and the nearshore reefs (Figure 29). A total of three rain gardens/sediment traps where constructed. The project resulted in over 150 native trees and 1000 Vetiver plants being planted to help stabilize conveyances and re-establish native vegetation. Cross swales and a series of check dams with riprap and Vetiver were established to redirect runoff to the rain gardens and reduce the energy of the water. An infiltration gallery was created to address runoff from an uncontrolled drainage are from the overflow of the water reservoir tank (Figures 30 and 31).

**Figure 30**. Town site prior to implementation.

**Figure 31.** Town site after implementation.

# V. Costs

The work for Zoní Beach and Townsite Projects were performed for a total cost effort of $144,873 through partner contribution and in-kind match. For the Zoní Beach project, DNER provided a total of $23,000 and NOAA invested a total of $36,210 and we received $40,710 in in-kind match for a grand total of $99,920 for the project. The Town Site costs were a total of $26,663 and an in-kind match total of $18,290 for a grand total of $44,953. The overall total amount of funds invested by NOAA for this year project was $62,873; the total amount invested by DNER was $23,000; and the total in-kind (non-cash) match of $59,000 was estimated on this effort from the DNER, USFWS, PC, RTR, Culebra Municipality, Abbie's School and community volunteers as described in Table 2 for a total effort of $144,873.

Table 1. Summarized Costs per Project

| CATEGORY | ZONÍ | TOWN SITE |
|---|---|---|
| Labor and Manpower | $9,547 | $4,092 |
| Rental Equipment and Materials Transportation | $3,769 | $1,615 |
| Site and project selection, travel, pre-coordination (10%) | $4,800 | $2,800 |
| Materials | $20,906 | $8,960 |
| Project Management, Coordination, Design and Engineering | $13,938 | $6,116 |
| Travel (Gas, flights, ferry etc.) | $2,791 | $968 |
| Per Diem | $2,359 | $1,012 |
| Project report | $1,100 | $1,100 |
| **TOTALS** | **$ 59,210** | **$ 26,663** |
| **In-kind Match Totals** | **$40,710** | **$18,290** |
| **Grand Total** | **$99,920** | **$44,953** |

Table 2. Estimated In-Kind Match Contributions from Project Partners

| ENTITY | ACTIVITY | UNITS | COST/UNIT | TOTAL COST |
|---|---|---|---|---|
| DNER | Trees at a cost of $10/tree | 200 | $10 | $ 2,000 |
| DNER | Lodging for 8 persons at a rate of $80/person/day | 800 | $640 | $ 16,000 |
| DNER | Hours Labor of Technical assistance | 40 | $60 | $ 2,400 |
| DNER | Trees at a cost of $10/tree | 300 | $10 | $ 3,000 |
| USFWS | Hours Labor of Technical assistance | 40 | $60 | $ 2,400 |
| USFWS | Use of hand tools and Generator and Nursery for 30 days | 30 | $200 | $ 6,000 |
| Abbie's School Culebra | Hours labor in Assistance with maintenance and irrigation | 120 | $20 | $ 2,400 |
| Municipality of Culebra | Water Truck use for 30 days | 30 | $350 | $ 10,500 |
| Culebra Resident Tomas Ayala | Hours labor | 100 | $30 | $ 3,000 |
| Culebra Resident Omar Villanueva | Digger Rental for 2 days | 400 | $400 | $ 800 |
| Protectores de Cuencas, Inc. | Uncompensated hours at a team mean cost/hour | 100 | $75 | $ 7,500 |
| Ridge to Reefs, Inc. | Uncompensated hours | 30 | $100 | $ 3,000 |
| | | | ***TOTAL ESTIMATED*** | ***$59,000*** |