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Seagrass bed preservation through the reduction of land-based sources of pollution in Tamarindo, Culebra, Puerto Rico

Final Report – July 2022




Submitted to:
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Submitted by:
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I. INTRODUCTION

In 2014, the National Oceanic and Atmospheric Administration (NOAA) identified Culebra as a critical Habitat Focus Area to address the growing challenge of coastal and marine habitat loss by integrating habitat conservation projects. High sediment loads threaten Culebra's nearshore coastal habitats, and the source of the vast majority of these sediments is the dirt road network, as it lacks proper management practices. Erosion of unpaved roads in Culebra contributes to nearly 400 metric tons of sediment delivery to the coast per year (Ramos-Scharrón et al., 2012). Seagrass beds, coral reefs and associated ecosystems of Culebra provide habitat and/or feeding grounds for over 17 federally listed species, including green and hawksbill sea turtles and all seven Endangered Species Act (ESA) listed Caribbean corals. Since 2013, Protectores de Cuencas (PDC) has implemented land-based sources of pollution (LBSP) management practices towards the stabilization of over 28 miles of unpaved roads in Culebra. These efforts have followed the recommendations in the *Culebra Community Watershed Action Plan for Water Quality and Coral Reefs* (Sturm et al., 2014). In addition to the chronic effect that roads can represent in delivering sediments to Culebra's waters (Ramos-Scharrón and LaFevor, 2016, 2018), extreme events like hurricanes can expose these ecosystems to degraded water conditions for an extended time period. The goal of this project is to implement BMPs to address LBSP and to improve nearshore water quality for seagrass habitat. Through this project, PDC expects to reduce the amount of sediment reaching these habitats.

The project site is located in the nearshore areas of Tamarindo Beach, Culebra Island, Puerto Rico, to the east of mainland Puerto Rico (Figures 1 and 2). It is located in the marine reserve Canal Luis Peña. The coordinates to the central location of Tamarindo Beach are 18.318575, -65.31729, and the project focus will be on the seagrass habitats directly west of the beach. The project, detailed below, will be implemented in a 12-month period.

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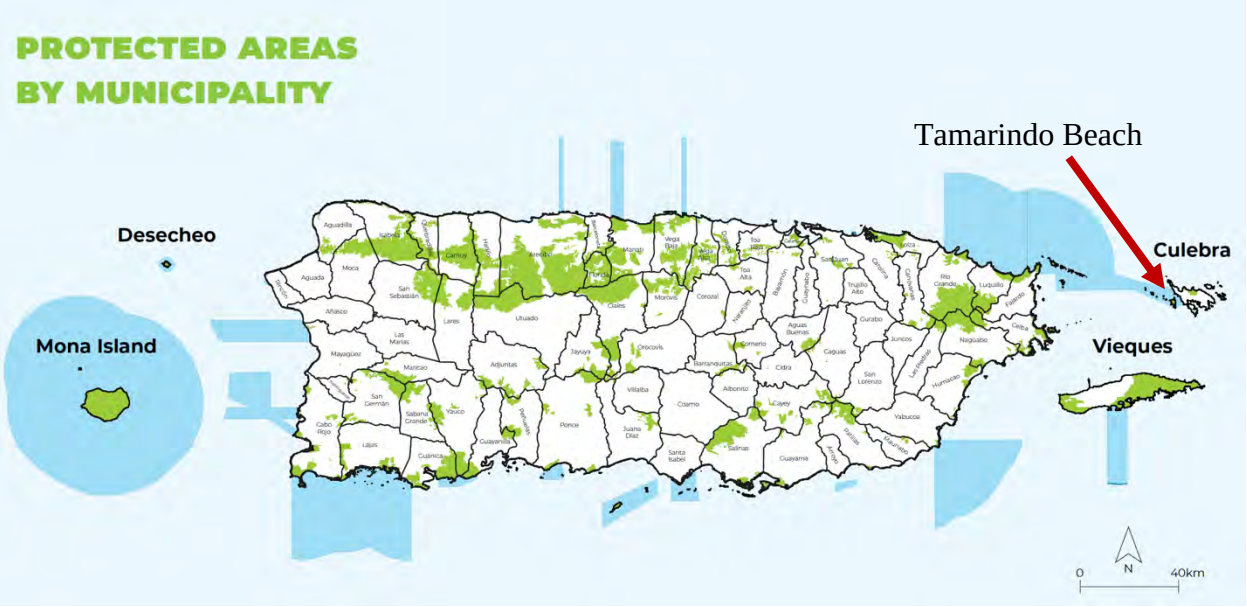


Figure 1. A map of all protected areas (green) and marine protected areas (dark blue) in Puerto Rico. The location of the project site, Tamarindo, Culebra Island, is shown with the red arrow, and is within the Canal Luis Peña Marine Reserve. Source: Castro-Prieto (2019).

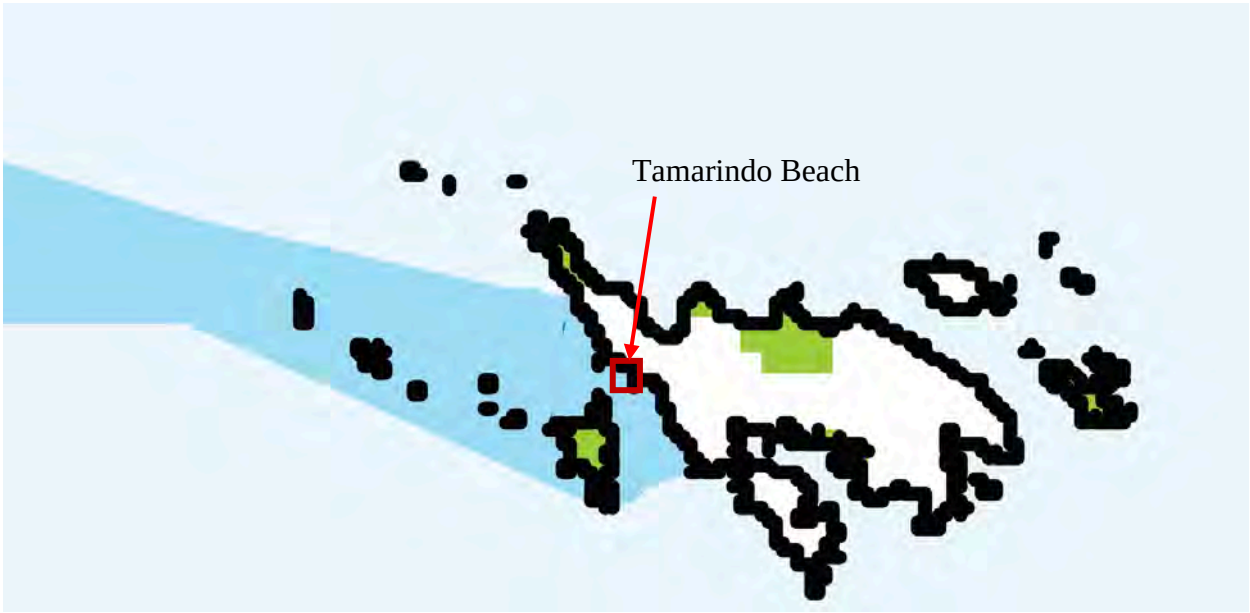


Figure 2. A close up map of the Canal Luis Peña Marine Reserve off of Culebra Island (dark blue) in Puerto Rico. The location of the project site Tamarindo Beach, Culebra is shown in the red box. Source: Castro-Prieto (2019).

Hurricanes Irma and Maria passed through Puerto Rico in 2017 and caused substantial damage to seagrass (Hernández-Delgado et al., 2018), coral reefs (NOAA, 2018), and mangroves (Cuevas et al., 2018). Afterwards, a seagrass assessment was conducted throughout Culebra to quantify the magnitude and spatial extent of impacts on seagrass communities due to the hurricanes. This assessment included seagrass habitat in Tamarindo, as well as seagrasses in adjacent areas such as Punta Tamarindo Chico (Hernández-Delgado et al., 2018). In the analysis, GIS was used to look at the spatial extension before and after hurricane impacts, and after-hurricanes groundtruthing was conducted by sampling seagrass ecological condition. In Tamarindo, seagrass spatial extension declined from 27,481 m^2 in 2010 to 19,897.6 m^2 in 2017, or a 27.6% loss since the hurricanes (Figure 3). The main impacts observed from the hurricanes on seagrass in Tamarindo were sediment loading and burial. The approximate cover in 2018 of seagrasses in Tamarindo were: 75% *Thalassia testudinum*, 5% *Syringodium filiforme*, 0.02% *Halodule wrightii* and 1% *H. stipulacea.* In Punta Tamarindo Chico, seagrass cover decline by approximately 5% during this time period, and approximate cover was 48% *Thalassia testudinum*, 5% *Syringodium filiforme*, and 0% *Halodule wrightii* and *H. stipulacea.* This study can be found at: https://www.drna.pr.gov/wp-content/uploads/2018/06/Culebras-seagrass-assessment-after-hurricane-Maria-SAM-compressed.pdf

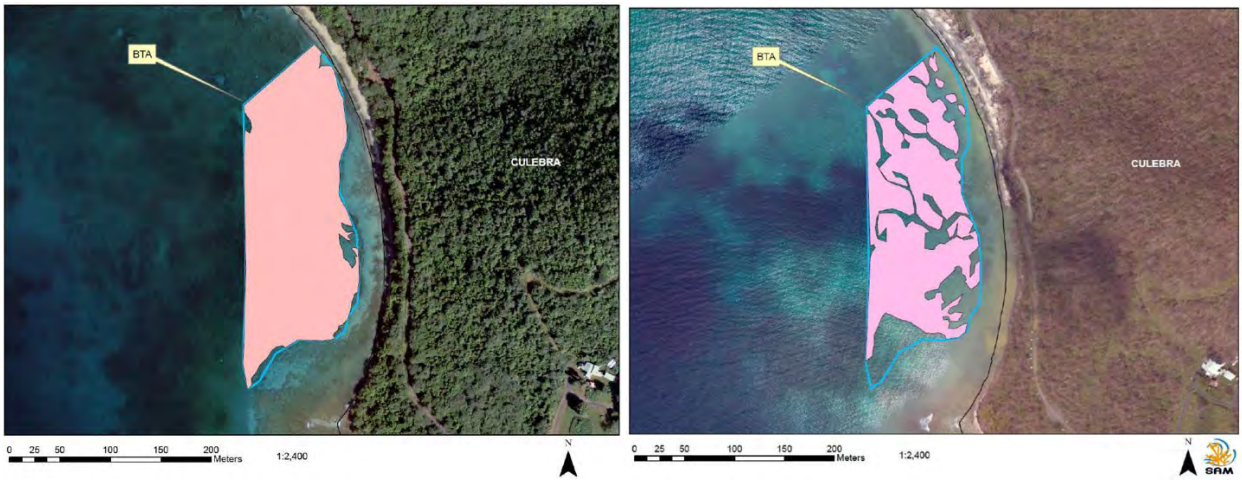


Figure 3. The before (2010 - left) and after (2017 - right) hurricanes spatial extension of seagrass habitats in a 28,632 m^2 study area in Tamarindo. Source: Hernández-Delgado et al. (2018)

Newer habitat maps that show marine habitat classes, such as the Caribbean habitat map project by The Nature Conservancy, are useful to track more recent changes in seagrass cover and distribution. This map shows that the majority of habitat within the nearshore Tamarindo site is made up of seagrass. This map can be accessed at: https://caribbeanscienceatlas.tnc.org/

The Puerto Rico [long-term] Coral Reef Monitoring Program, run by the Puerto Rico Department of Natural and Environmental Resources (DNER), includes five permanent transect stations in Carlos Rosario, just north of Tamarindo Beach, and five permanent transect stations in the Luis Peña Reef, west of Tamarindo Beach. Coral reef ecosystems in these transects are monitored every two years. Due to the close proximity to Tamarindo Beach, similar fish and invertebrate species that use seagrass beds are expected to be found in or near Tamarindo, such as the long-spined sea urchin, three-spot damselfish, blue tang, dusky damselfish, butter hamlet, Caribbean puffer, French grunt, doctorfish, tomtate, sergeant major, five-band surgeonfish, four-eye butterflyfish, and striped parrotfish. It is also important to note that seagrass is an essential habitat for larvae recruitment for various fish and invertebrate species. The final report to the 2018 PRCRMP can be found here: https://gcrmn.net/resource/puerto-rico-coral-reef-monitoring-program-2017-2018/

II. PROJECT DETAILS

Throughout this project, PDC is protecting and conserving seagrass habitat in Tamarindo Beach by reducing current threats due to land-based sources of pollution (LBSP) and erosion which cause sediment and nutrient loads to reach nearshore seagrass and coral reef ecosystems. PDC will implement a variety of best management practices (BMPs) that are tailored to the conditions and threats of each area. Best management practices will be used to stabilize a permeable parking lot, improving delimitation of public access and ecologically sensitive areas, and for coastal habitat restoration at Tamarindo Beach. The implementation of this project will not negatively affect the condition of nearby ecosystems, which include coastal forest habitat, mangroves and other wetlands, coral reefs, sand dunes, and beaches.

This project is complementing a current effort in project design and permitting, which are the first steps towards implementing BMPs in Tamarindo Beach. Funding from the Puerto Rico Department of Natural and Environmental Resources (DNER) was used for PDC to hold a kick-off meeting with key stakeholders to discuss the project, to complete the project design, and to acquire all permits needed for environmental compliance. This opportunity is providing the necessary funding for the next phase of the project, which is the implementation of BMPs and coastal restoration described in this proposal.

Project Progress

Project design

Using funding from the DNER project, PDC contracted Tetra Tech to complete a project design that includes the areas where vegetative barriers will be created and the location and specifications of best management practices that will be used to reduce land-based sources of pollution entering the nearshore seagrass beds in Tamarindo Beach. The project design can be found in *Appendix I*.

Three native species were chosen for reforestation in the coastal zone: buttonwood mangrove (*Conocarpus erectus*), portia tree *(Thespesia populnea*), and seagrape (*Coccoloba uvifera*). Additionally, vetiver grass will be used since it has a dense root system for nutrient absorption and soil stabilization, can live in high salinity level soils, and it requires minimal maintenance. The DNER and the US Department of Agriculture Natural Resources Conservation Service have approved the use of this plant.

A kayak staging area was included in the design. The Department of Natural and Environmental Resources limited the number of businesses that can rent out kayaks and snorkel gear used in the area because it is a Marine Protected Area and because the excessive number of people renting out gear took up large parts of the beach and prevented the public from using the beach freely. The Community Advisory Board for the Collaborative Management of the Canal Luis Peña Natural Reserve has been pushing for the rental business to move to one area instead of spreading out across the beach.

Presentations

Presentation to key stakeholders

On August 25, 2021, Protectores de Cuencas Inc. participated in a virtual meeting and presented the details and design of this project to the Community Advisory Board for the Collaborative Management of the Canal Luis Peña Natural Reserve. As the seagrasses that are being preserved through this project fall into the Luis Peña Natural Reserve, it was very important to involve the Advisory Board to gain project support and for the opportunity to receive any comments and recommendations that can improve this project.

Presentation to the Mayor and Community

PDC met with the Culebra Mayor, the Community Advisory Board, and local kayak and tour companies to present this project. Between March 7 and March 18, the Municipality of Culebra closed down recreational activities at Tamarindo Beach to allow for project construction.

Implementation of best management practices and coastal restoration

PDC purchased the materials and completed the implementation of the best management practices at Tamarindo Beach. The Municipality of Culebra closed down Tamarindo Beach, so that PDC could complete the stabilization of the Tamarindo Beach paved access road, the stabilization of the permeable parking lot area, the delineation of public access areas, installation of boardwalks, and coastal habitat restoration.

Coastal habitat restoration: In order to restore coastal habitat, PDC planted a total of 650 individual plants from the following species: *Conocarpus erectus*, *Coccoloba uvifera*, *Cordia rickseckeri*, *Tabebuia heterophylla*, *Thespessia populnea*, *Terminalia catappa*, and *Guaiacum officinale* (Figure 4).

Figure 4. Coastal habitat restoration using native species at Tamarindo Beach, Culebra

Paved access road and permeable parking lot: PDC and partners used the project design to stabilize the Tamarindo Beach access road and to create the permeable parking lot.

The permeable parking lot was developed (Figure 5). As there is a kayak company with a trailer that parks at the beach on a daily basis, a parking area specifically for this trailer was created to provide more space in the parking area for locals and visitors.

Figure 5. The process of developing the permeable parking lot at Tamarindo Beach.

Delineation of public access areas: *Previously installed and damaged wooden posts (Figure 6) were removed and replaced with new wooden posts and boardwalks to guide pedestrians to the beach without disrupting existing and newly planted coastal habitat.*

Figure 6. Previously installed and damaged wooden posts (left) were removed and replaced with new wooden posts and wooden boardwalks (right).

Follow-up visits to ensure proper maintenance and evaluate functionality: PDC has been conducting follow-up visits for irrigation and maintenance of the BMPs (Figure 7). All implemented BMPs, including the permeable parking lot, the wooden boardwalks, the paved access road, and the delineation using the wooden posts and boulders are functioning as intended. PDC has observed visitors in the area and have noticed that the kayak trailer is consistently parked within its designated parking spot, and that visitors are not stepping on coastal vegetation and are instead using the boardwalks to enter the beach.

Figure 7. PDC water truck used to irrigate planted trees. While irrigating, PDC personnel also review functionality of the implemented best management practices and apply maintenance, as needed.

Ecological study of the Tamarindo seagrass beds

An ecological study was conducted on June 11 and 12, 2022 to evaluate the nearshore seagrass bed in front of the Tamarindo Beach area. The methodology used was the Braun-Blanquet Survey, developed to assess seagrass and macroalge abundance. Details on the methodology of this survey can be found at: http://serc.fiu.edu/seagrass/!CDreport/methodsbb.htm. Five 50 meter transects were set perpendicular to the beach. In a 2 meter by 50 meter transect, fish species, size, and abundance were recorded, as well as invertebrate species and abundance. In addition, ten quadrats were set on each 50 meter transect and seagrass species were identified, and percent cover was documented. Algae, sponges, and invertebrates within each quadrat were noted. Afterwards, a roving diver survey within the seagrass bed and bordering coral reef was conducted to identify any additional species of seagrass, fish, or invertebrates in the area, as well as additional threats to the seagrass bed.

The results of the seagrass ecological survey can be found in Appendix II.

III. SUMMARIZED SCOPE OF WORK

A description of the above tasks is summarized in Table 1.

Table 1. Summarized task descriptions in Tamarindo Beach, Culebra.

TASK #	TASK DESCRIPTION	DELIVERABLE	PERIOD
1	BMP installation and repairs - **Completed**	- Submit bi-monthly reports and participate in monthly video meeting - Stabilization of the Tamarindo Beach paved access road - Stabilization of the permeable parking lot	Months 1-6
2	Coastal habitat restoration - **Completed**	- Improved delimitation of public access and ecologically sensitive areas - Coastal habitat restoration - Submit bi-monthly reports and participate in monthly video meeting	Months 5-6
3	Follow-up visits – **Completed**	- Certify functionality of implemented practices - Provide maintenance to coastal habitat and BMPs as needed - Submit bi-monthly reports and participate in monthly video meeting	Months 6-11
4	Final report – **Completed**	- Conduct an ecological study of the seagrass beds - Submit the final report	Month 11

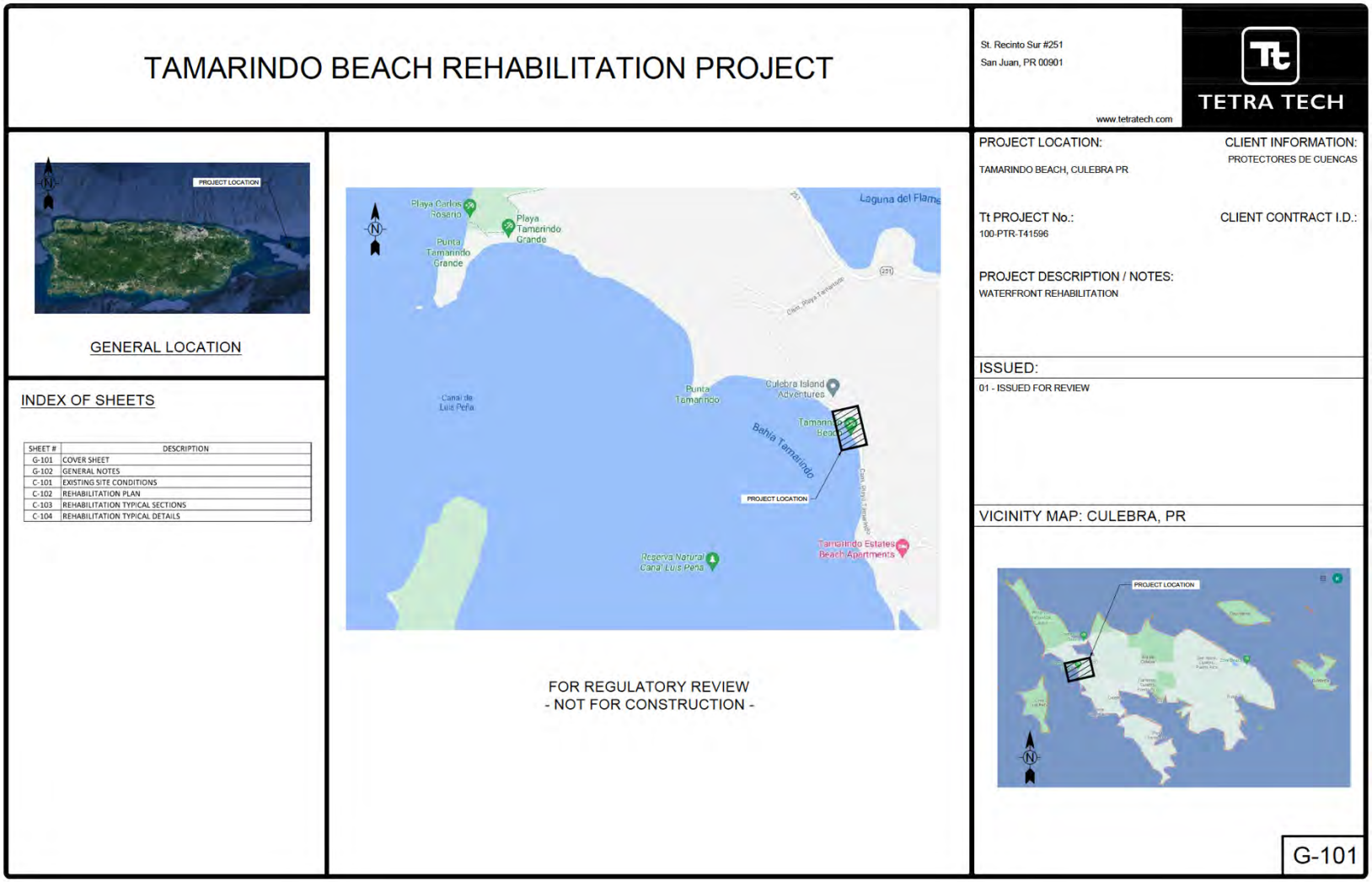
IV. COSTS

The cost for the work is **$21,262 with a match of $54,009,** as summarized in Table 5.

Table 2. Total project cost divided by task and by funds requested and in-kind.

Category	Requested Funds	In-kind Match
BMP installation and repairs	$9,855	$15,410
Coastal habitat restoration	$6,950	$33,599
Follow-up visits	$2,024	$4,300
Final report	$500	$700
Indirect Costs (5%)	$1,933	$0
TOTALS	**$21,262.00**	**$54,009.00**

APPENDIX I: PROJECT DESIGN



MANGLE DE BOTÓN, CONOCARPUS ERECTUS

EMAJAGUILLA, THESPESIA POPULNEA

VETIVER GRASS, CHRYSOPOGON ZIZANIOIDES

UVA DE PLAYA, COCOLOBA UVIFERA

CONCRETE SPECIFICATIONS

GENERAL NOTES

1. THE DESIGN SECTIONS AND ALIGNMENTS SHOWN ON THE PLANS ARE BASED ON A TOPOGRAPHIC SURVEY CONDUCTED BY LUIS BERRIOS MONTES & ASSOC. IN MARCH 2021. FIELD CONDITIONS MAY HAVE CHANGED. IT IS THE CONTRACTOR'S RESPONSIBILITY TO LAY THE SPECIFIED WORK AS SHOWN IN THE PLANS, AND PROVIDE CLEAN FILL MATERIAL TO REGRADE THE SECTIONS TO THE LINES AND GRADES SHOWN IN THE PLANS. ANY IMPORTED FILL MATERIAL SHOULD BE CLEAN GRANULAR, CLASSIFIED CRUSHED ROCK OR AN APPROVED "SELF-COMPACTING" MATERIAL AND SHALL BE PLACED ON A GEOTEXTILE FILTER FABRIC AS SHOWN AND SPECIFIED IN THE PLANS.
2. ALL ELEVATIONS AND DISTANCES ON PLAN VIEW ARE IN METERS. DIMENSIONS SHOWN ON SECTIONS AND DETAILS ARE IN FEET/INCHES.
3. THE HORIZONTAL COORDINATE SYSTEM IS STATE PLANE COORDINATE SYSTEM FOR PUERTO RICO AND THE US VIRGIN ISLANDS, NAD83 (NA2011) EPOCH 2010, LAMBERT PROJECTION.
4. ELEVATIONS ARE REFERENCED TO PR VERTICAL DATUM OF 2002 (PRVD02).
5. BENCHMARK TIDAL DATUMS ARE SHOWN BELOW FOR NOAA STATION ID: 9752235 CULEBRA, PUERTO RICO AND ARE REFERENCED TO PRVD02.
6. THE CONTRACTOR SHALL COMPLY WITH THE REQUIREMENTS OF THE "TRENCH SAFETY ACT" IN ANY AREA THAT SHALL REQUIRE EXCAVATION . CONTRACTOR SHALL ALSO COMPLY WITH ALL O.S.H.A. REQUIREMENTS AT ALL PHASES OF CONSTRUCTION.
7. THE CONTRACTOR SHALL USE HAND DIGGING WHEN EXCAVATING NEAR EXISTING UTILITIES. EXTREME CAUTION SHALL BE EXERCISED WHILE EXCAVATING, INSTALLING, BACKFILLING, OR COMPACTING AROUND UTILITIES.
8. THE CONTRACTOR SHALL BE RESPONSIBLE TO REPLACE, AT HIS OWN COST, ANY DAMAGE PERFORMED BY HIS PERSONNEL OR EQUIPMENT INSIDE AND/OR OUTSIDE OF THE CONSTRUCTION AREA, AND SHALL COMPLY WITH THE CONSTRUCTION AND MAINTENANCE RULES SPECIFIED HEREIN.
9. ALL CONSTRUCTION STAKEOUT SHALL BE PERFORMED UNDER THE SUPERVISION OF A REGISTERED SURVEYOR.
10. THE CONTRACTOR SHALL FURNISH ALL MATERIAL, EQUIPMENT, LABOR AND OTHER FACILITIES NECESSARY FOR THE EXECUTION OF THE WORK. ALL MATERIALS AND WORKMANSHIP SHALL BE OF NEW QUALITY AND CONDITION. THE CONTRACTOR SHALL, IF REQUIRED, FURNISH SATISFACTORY EVIDENCE AS TO THE MATERIALS USED.
11. THE CONTRACTOR SHALL COORDINATE WITH THE DNER TO OBTAIN ALL REQUIRED CONSTRUCTION PERMITS.
12. THE CONTRACTOR SHALL COMPLY WITH ALL APPLICABLE LOCAL, STATE, AND FEDERAL BUILDING CODES, INCLUDING THE IMPLEMENTATION OF THE SEDIMENTATION AND EROSION PROTECTION PLAN.

ENVIRONMENTAL MONITORING

1. CONTRACTOR SHALL PROVIDE ALL PERSONNEL REQUIRED TO MEET THE SITE SPECIFIC PERMIT CONDITIONS.

REPAIR OF EXISTING CONDITIONS

1. THE CONTRACTOR IS REQUIRED TO DOCUMENT THE EXISTING CONDITIONS OF THE ACCESS ROADWAY AND STAGING AREA PRIOR TO CONSTRUCTION ACTIVITIES. CONTRACTOR IS REQUIRED TO RESTORE SITE ACCESS AND STAGING AREAS TO EXISTING CONDITIONS INCLUDING, BUT NOT LIMITED TO, REPLACEMENT OF ALL DAMAGED VEGETATION (NOT DIRECTLY AFFECTED BY OR WITHIN THE PROJECT FOOTPRINT).
2. RE-VEGETATION OR TRANSPLANTATION OF EXISTING VEGETATION IS ALLOWED. ALL IMPACTED VEGETATION WITHIN THE PROJECT FOOTPRINT SHALL BE REMOVED AND PROPERLY DISPOSED OF OR RECYCLED AS DIRECTED BY DNER.

DESCRIPTION OF GENERAL WORK

PRE-CONSTRUCTION PREPARATION & BEST MANAGEMENT PRACTICES.

1. PRIOR TO MOBILIZING HEAVY EQUIPMENT TO THE SITE, A SERIES OF BMPS SHALL BE IMPLEMENTED TO REDUCE TEMPORARY CONSTRUCTION IMPACTS. SILT FENCES AND HAY BAILS SHALL BE INSTALLED ALONG AREAS OF POTENTIAL SURFACE WATER RUNOFF. THE LIMITS OF THE PROJECT WILL BE STAKED FOR FINAL ALIGNMENT AND APPROVAL. IN ADDITION, A SURVEYOR WILL BE ON SITE DURING CONSTRUCTION ACTIVITIES TO ENSURE THAT ALL ALIGNMENTS AND LIMITS OF WORK ARE OBSERVED.

TRANSPORTATION OF MATERIAL FROM MAIN STAGING AREA.

2. ROCK MATERIAL WILL BE TRANSPORTED AND UNLOADED INTO THE MAIN STAGING AREA AND TRANSPORTED TO THE BEACH STAGING AREA IF REQUIRED. THIS DOUBLE HANDLING WILL REDUCE THE VISUAL IMPACTS AND SIZE OF THE BEACH STAGING AREA AND MAINTAIN A CONTINUOUS SOURCE OF ROCK SUPPLY TO THE PROJECTS DURING CONSTRUCTION.

CONSTRUCTION OF PERMEABLE PARKING

3. THE PERMEABLE PARKING WILL BE CONSTRUCTED WITH CONVENTIONAL EARTHMOVING EQUIPMENT. THE ERODED SURFACES WILL BE RE-GRADED TO THE LINES AND GRADES SPECIFIED IN THE PLANS TO REDUCE THE AMOUNT OF IMPORTED MATERIAL. A FILTER FABRIC WILL THEN BE PLACED CONTINUOUSLY OR WITH A MINIMUM OF 18" OVERLAP. THE PAVEMENT ROCK WILL THEN PIN THE FILTER FABRIC COVERING IT ENTIRELY. THE IN-SITU ROCK MATERIAL MAY BE REUSED. THE MATERIAL SHALL BE COMPATED AND SHALL FOLLOW THE FINISH GRADE SHOWN ON THE PLANS.

ROCK APRON

1. ALL IMPORTED ROCK MATERIAL SHALL BE SOUND AND DURABLE AND HAVE A MINIMUM DENSITY OF 165 LB/CU. FT. THE MATERIAL SHALL BE FREE OF CRACKS, SOFT SEAMS, AND OTHER STRUCTURAL DEFECTS. THE PIECES SHALL BE ROUGHLY ANGULAR AND SHALL BE REASONABLY FREE FROM THIN, FLAT, OR ELONGATED PIECES (ASPECT RATIO GREATER THAN 3:1 SHALL BE REJECTED).
2. ARMOR ROCK SHALL BE PLACED TO THE LINES AND GRADES SHOWN ON THE PLANS. THE PLACEMENT TOLERANCE OF ANY INDIVIDUAL ARMOR ROCK FROM THE REQUIRED LINES AND GRADES SHALL BE 0.25 D50 WHERE D50 IS THE NOMINAL DIMENSION OF THE ROCK SIZE THAT IS 50 PERCENT LESS THAN BY WEIGHT OF THE MAXIMUM ARMOR ROCK SIZE GRADATION CALLED FOR.

GEOTEXTILE FABRIC

GEOTEXTILE FABRIC SHALL BE 802 NONWOVEN TENCATE MIRAFI 180N OR APPROVED EQUAL MEETING THE FOLLOWING SPECIFICATIONS. FABRIC SHALL OVERLAP A MINIMUM OF 18" AT THE SEAMS.

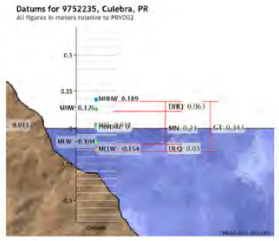
- SPECIFICATION: AASHTO M288-06 SEPARATION NON--WOVEN CLASS 1
- APPLICATION: PERMANENT EROSION CONTROL ITD
  - IPRAP/EROSIONCONTROL TYPE II
- SURVIVABILITY CLASS: CLASS 1
- FABRIC: NONWOVEN
- SAND BERM - 510 CU. M.
- IMPORTED SAND FOR NOURISHMENTS - 420 CU. M.
- FILTER FABRIC - 4,100 SQ. M

CONSTRUCTION AND STRUCTURE MAINTENANCE RULES

1. DURING THE CONSTRUCTION PERIOD, THE CONSTRUCTION SITE SHALL BE KEPT NEAT AND SHALL BE PROPERLY POLICED TO PREVENT DEBRIS, MATERIALS OR CONSTRUCTION TOOLS/EQUIPMENT STORAGE FROM BECOMING A PUBLIC EYESORE. STORAGE OF GARBAGE IN THE WORK AREA IS NOT PERMITTED. WORK SITE MUST BE FREE OF GARBAGE, PAPER PLATES, ETC. AT ALL TIMES. BURNING GARBAGE IS NOT ALLOWED. CONSTRUCTION PERSONNEL ARE NOT ALLOWED TO HAVE THEIR MEALS OUT OF THE CONSTRUCTION AREA. PARKING IS NOT PERMITTED OUTSIDE OF CONSTRUCTION SITE OR DESIGNATED AREAS.
2. GARBAGE BIN MUST BE PROVIDED AND EMPTIED ON A REGULAR BASIS, A SEPARATE SEALED BIN MUST BE PROVIDED FOR FOOD AND PERISHABLE WASTE AND EMPTIED REGULARLY.
3. MIXING CEMENT ON PUBLIC ROADS OR GREEN AREAS IS NOT PERMITTED UNLESS OTHERWISE APPROVED BY THE MUNICIPALITY OF CULEBRA. A WOOD PANEL AND/OR PLASTIC COVER MUST BE USED TO PROTECT STREET FROM CEMENT SPILL.
4. SAFETY CONSTRUCTION FENCING OR MARKERS SHOULD BE INSTALLED TO PROTECT THE PUBLIC USING THE BEACH.
5. PROTECTIVE MEASURES (WARNING TAPE, REFLECTIVE, BARRELS, ETC.) MUST BE PROVIDED WHENEVER AN EXCAVATION IS BEING PERFORMED. STORAGE OF ROCK, SAND AND CONSTRUCTION MATERIALS WHICH OBSTRUCTS TRAFFIC OR PEDESTRIANS IS NOT PERMITTED. SAFETY SIGN SHOULD BE INTALLED ACCORDINGLY AND MAINTAINED FOR THE DURATION OF THE PROJECT.
6. HOURS OF CONSTRUCTION AND STRUCTURE MAINTENANCE:

MONDAY TO FRIDAY:	7:00AM TO 5:00PM
SATURDAY:	8:00AM TO 5:00PM (LIGHT WORK ONLY/DNER APPROVAL IS REQUIRED)
SUNDAY	NO WORK PERMITTED (DNER APPROVAL IS REQUIRED)

7. EFFECTIVE EROSION CONTROL AND SEDIMENT PLAN MUST BE IN PLACE AT ALL TIMES TO PREVENT SEDIMENTS RUN OFF FROM THE CONSTRUCTION SITE.
8. NO HEAVY CONSTRUCTION EQUIPMENT WITH CLEATS IS ALLOWED ON PUBLIC ROADS. ONLY VEHICLES WITH TIRES ARE ALLOWED.
9. THE USE OF LOUD AUDIO EQUIPMENT IS PROHIBITED AT ALL TIMES.



Elevations on PRVD02

Station: 9752235, Culebra, PR
Status: Accepted (May 22 2020)
Units: Meters
Control Station: 975537 I San Juan, La Puntilla, San Juan Bay, PR
TM: 9
Epoch: 1983-2001
Datum: PRVD02

Datum	Value	Description
MHHW	0.189	Mean Higher-High Water
MHW	0.126	Mean High Water
MTL	0.011	Mean Tide Level
MSL	0.011	Mean Sea Level
DTL	0.018	Mean Diurnal Tide Level
MLW	-0.104	Mean Low Water
MLLW	-0.154	Mean Lower-Low Water
PRVD02	0.000	Puerto Rico Vertical Datum of 2002

TETRA TECH
www.tetratech.com
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San Juan, PR 00920

PROTECTORES DE CUENCAS
73-66 CALLE COMERCIO
YAUCO, PR 00698

MARK	DATE	DESCRIPTION	BY
1	--	--	--

TAMARINDO BEACH
CULEBRA, PR

GENERAL NOTES

PROJ:
DESN: F. PAGES
DRWN: K. SANABRIA
CHKD:

G-102

Bar Measures 1 inch, otherwise drawing not to scale

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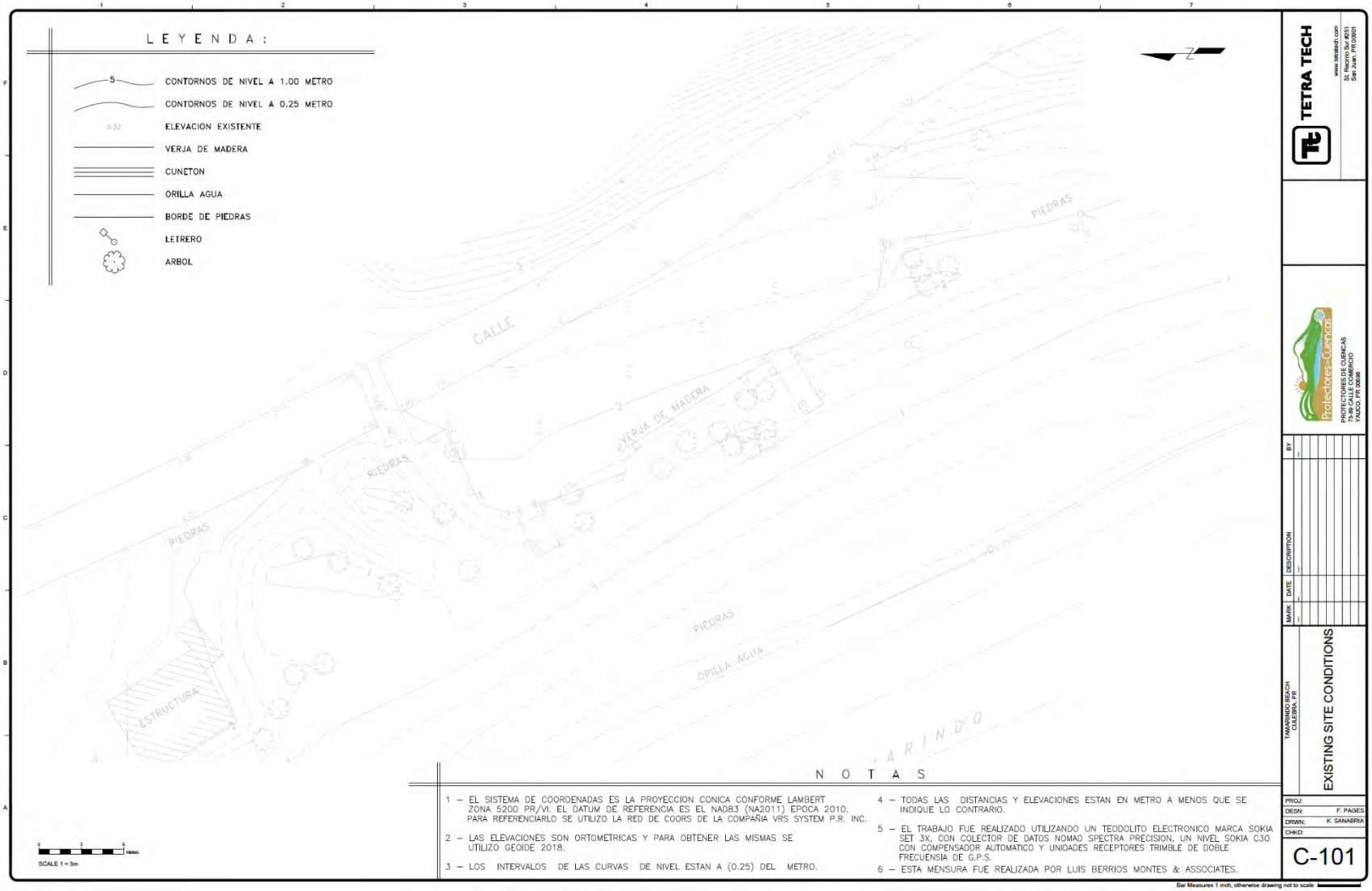

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C	317957.235	254005.799	1.81	m	2.20	m
D	317967.176	254005.850	2.21	m	2.30	m
E	317967.271	253997.597	2.13	m	2.50	m
F	317970.402	253992.446	2.18	m	2.50	m
G	317968.105	253987.861	1.97	m	2.27	m
H	317964.223	253985.327	1.52	m	2.80	m
I	317977.965	253989.604	2.65	m	2.80	m
J	317973.167	253987.236	2.33	m	2.60	m
K	317982.486	253983.107	2.87	m	2.90	m
L	317979.463	253980.261	2.52	m	2.80	m
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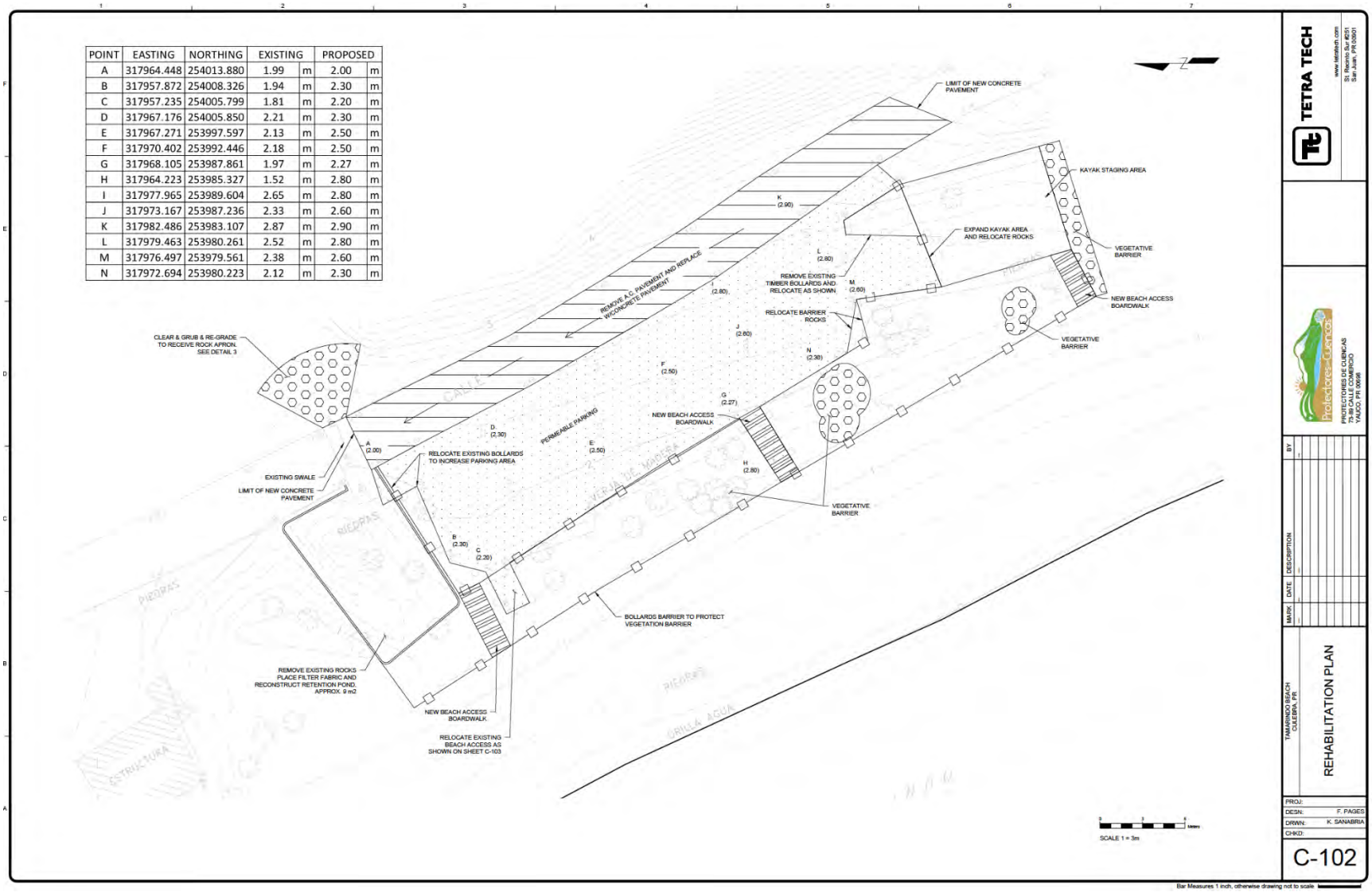
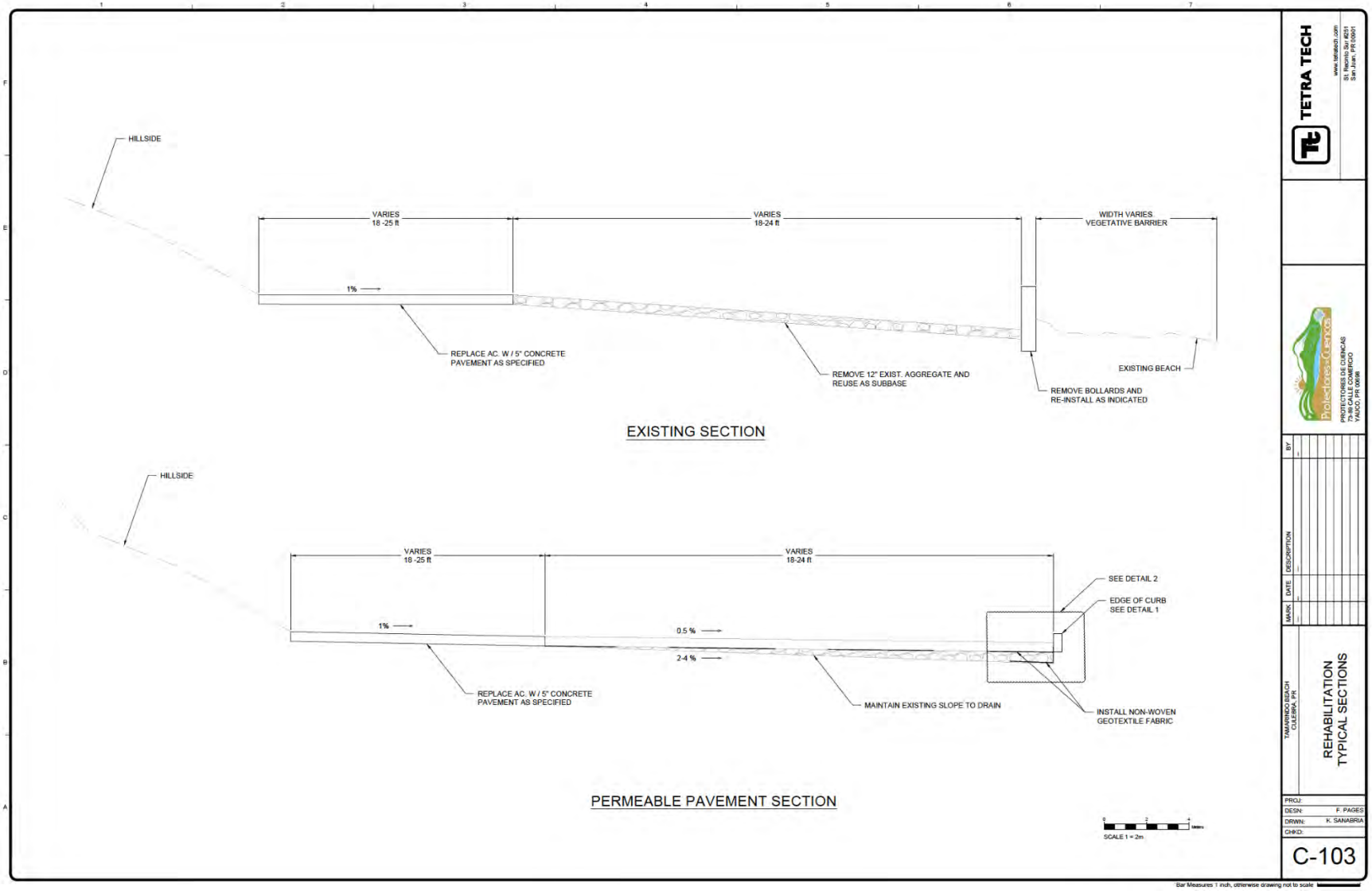
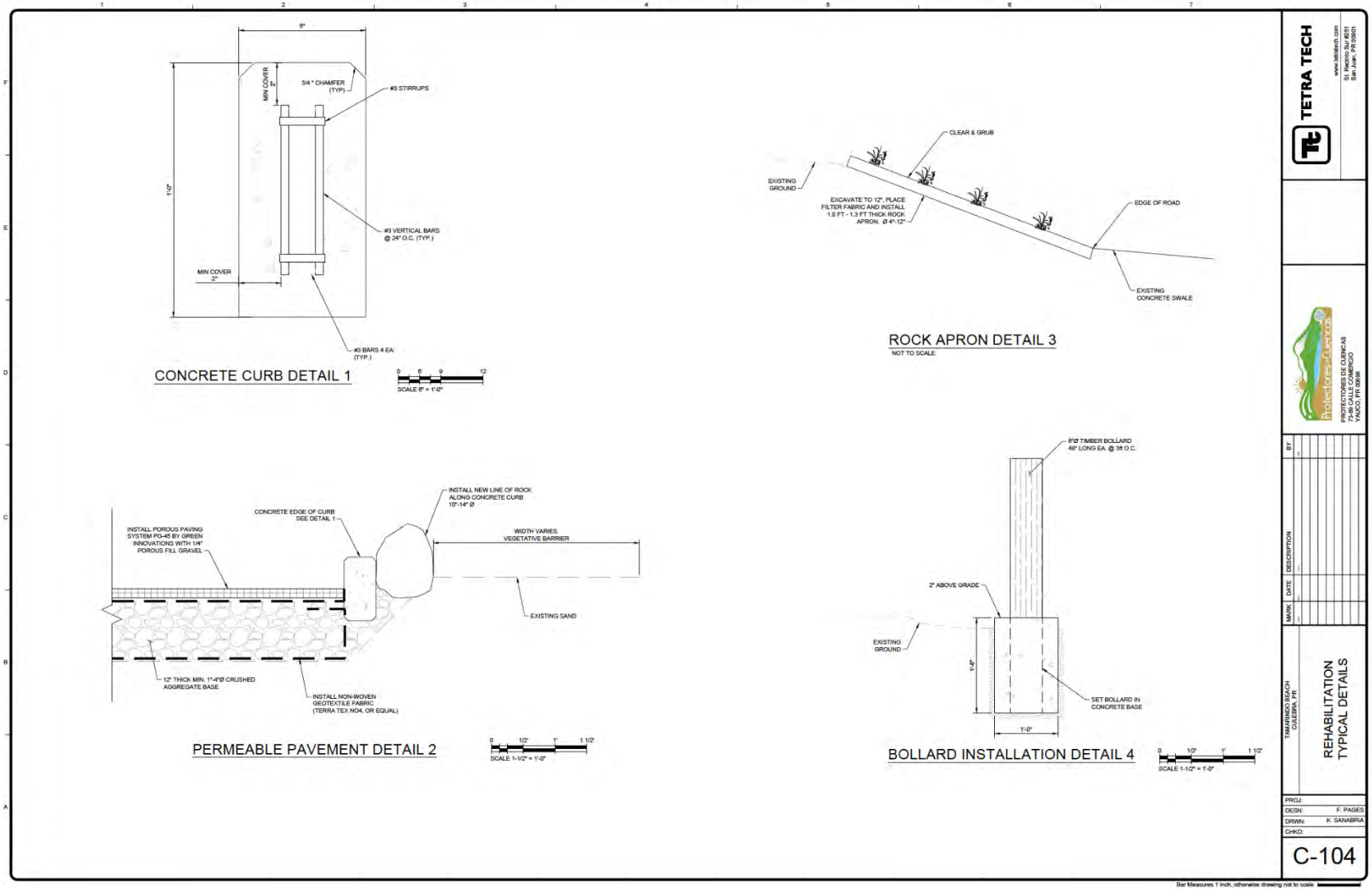
N	317972.694	253980.223	2.12	m	2.30	m




HILLSIDE
VARIES
18 -25 ft
VARIES
18-24 ft
WIDTH VARIES
VEGETATIVE BARRIER
1%
REPLACE AC. W / 5" CONCRETE
PAVEMENT AS SPECIFIED
REMOVE 12" EXIST. AGGREGATE AND
REUSE AS SUBBASE
EXISTING BEACH
REMOVE BOLLARDS AND
RE-INSTALL AS INDICATED
EXISTING SECTION
HILLSIDE
VARIES
18 -25 ft
VARIES
18-24 ft
SEE DETAIL 2
EDGE OF CURB
SEE DETAIL 1
1%
0.5 %
2-4 %
REPLACE AC. W / 5" CONCRETE
PAVEMENT AS SPECIFIED
MAINTAIN EXISTING SLOPE TO DRAIN
INSTALL NON-WOVEN
GEOTEXTILE FABRIC
PERMEABLE PAVEMENT SECTION
SCALE 1 = 2m
TETRA TECH
REHABILITATION
TYPICAL SECTIONS
PROJ:
DESN: F. PAGES
DRWN: K. SANABRIA
CHKD:
C-103


CONCRETE CURB DETAIL 1
#3 STIRRUPS
#3 VERTICAL BARS @ 24" O.C. (TYP.)
#3 BARS 4 EA. (TYP.)
MIN COVER 2"
3/4 " CHAMFER (TYP.)
ROCK APRON DETAIL 3
NOT TO SCALE
CLEAR & GRUB
EXISTING GROUND
EXCAVATE TO 12", PLACE FILTER FABRIC AND INSTALL 1.0 FT - 1.3 FT THICK ROCK APRON. Ø 4"-12"
EDGE OF ROAD
EXISTING CONCRETE SWALE
PERMEABLE PAVEMENT DETAIL 2
INSTALL NEW LINE OF ROCK ALONG CONCRETE CURB 12"-14" Ø
CONCRETE EDGE OF CURB SEE DETAIL 1
INSTALL POROUS PAVING SYSTEM PG-46 BY GREEN INNOVATIONS WITH 1/4" POROUS FILL GRAVEL
WIDTH VARIES VEGETATIVE BARRIER
EXISTING SAND
12" THICK MIN. 1"-4"Ø CRUSHED AGGREGATE BASE
INSTALL NON-WOVEN GEOTEXTILE FABRIC (TERRA TEX NO4, OR EQUAL)
BOLLARD INSTALLATION DETAIL 4
8"Ø TIMBER BOLLARD 48" LONG EA. @ 3ft O.C.
2" ABOVE GRADE
EXISTING GROUND
SET BOLLARD IN CONCRETE BASE
TETRA TECH
PROTECTORES DE CUENCAS
REHABILITATION
TYPICAL DETAILS
TIMPARNO BEACH
CULEBRA, PR.
PROJ:
DESN: F. PAGES
DRWN: K. SANABRIA
CHKD:
C-104
Bar Measures 1 inch, otherwise drawing not to scale

APPENDIX II. SEAGRASS ECOLOGICAL STUDY RESULTS

An ecological study was conducted on June 11 and 12, 2022 to evaluate the nearshore seagrass bed in front of the Tamarindo Beach area. The methodology used was the Braun-Blanquet Survey, developed to assess seagrass species abundance, density, and frequency. Details on the methodology of this survey can be found at http://serc.fiu.edu/seagrass/!CDreport/methodsbb.htm. Five 50 meter transects were set in the water perpendicular to the beach, with each starting point at the beginning of the seagrass bed. In a 2 meter by 50 meter belt transect, fish species, size, and abundance were recorded, as well as invertebrate species and abundance. In addition, ten quadrats were set at randomly select points along each 50 meter transect. Seagrass species and the percent cover of each species within each quadrat was documented. Algal species within each quadrat were identified. Afterwards, a roving diver survey within the seagrass bed and bordering coral reef was conducted to identify any other species of seagrass, fish, or invertebrates in the area, as well as threats to the seagrass bed. Water quality parameters were also taken on both survey days. A YSI-multiparameter was used to record temperature, dissolved oxygen, conductivity, and pH, while a Hach turbidimeter was used to measure turbidity.

The data collected during each transect were:

- Start and end of transect latitude and longitude
- Date
- Start and end time
- Distance of each quadrat from the starting point of each transect
- Depth
- Percent cover of each seagrass species
- Presence of algae species

Results

Water Quality Parameters

Table 3. Water quality parameters taken on the seagrass bed at a 10 feet depth on both survey dates.

Parameter	6/11/2022	6/12/2022
Temperature (°C)	28.5	28.7
Barometer (mmHg)	761.3	761
Dissolved oxygen (%)	57.5	50.2
Dissolved oxygen (mg/L)	3.56	3.22
Conductivity (us/cm)	58994	59201
pH	8.82	8.84
Turbidity (ntu)	0.71	0.83

Seagrass bed

Only three seagrass species were documented during the surveys: *Thalassia testudinum* (TT), *Syringodium filiforme* (SF), and *Halophila stipulacea* (HS). Seagrass species cover (Table 4), density (Figure 8), abundance (Figure 9), and frequency (Figure 10) was calculated for each species in each transect.

Table 4. Transect and quadrat data collected during the seagrass ecological survey. Percent cover of each seagrass species documented in randomly placed quadrats within five 50m transects.

Transect Number	Start Lat	Start Long	End Lat	End Long	Date	Start Time	End Time	Quadrat Number	Transect Distance (m)	Depth (ft)	% Cover		
											TT	SF	HS
1	18.31818	-65.3179	18.31787	-65.3183	6/11/2022	10:33	11:20	1	4	6	5	15	0
								2	5	7	2	10	0
								3	9	8	70	10	0
								4	14	7	75	10	0
								5	19	8	25	25	0
								6	26	9	40	15	0
								7	34	10	35	15	0
								8	37	11	35	10	0
								9	43	11	70	15	0
								10	50	12	80	15	0
2	18.31847	-65.3182	18.31822	-65.31856	6/11/2022	12:02	12:50	1	1	5	15	15	0
								2	4	6	20	10	0
								3	6	7	20	10	0
								4	8	8	40	30	0
								5	15	8	10	5	50
								6	16	8	2	10	45
								7	22	8	50	15	0
								8	18	9	35	35	1
								9	35	10	50	25	0
								10	49	12	65	15	0

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Transect Number	Start Lat	Start Long	End Lat	End Long	Date	Start Time	End Time	Quadrat Number	Transect Distance (m)	Depth (ft)	% Cover		
											TT	SF	HS
3	18.31796	-65.3179	18.31761	-65.3181	6/12/2022	7:38	8:08	1	3	5	40	35	0
								2	8	6	70	20	0
								3	17	8	20	10	30
								4	22	8	5	5	80
								5	29	9	60	5	0
								6	31	10	60	3	0
								7	35	10	40	5	0
								8	42	10	50	5	1
								9	48	11	90	5	0
								10	49	11	85	8	0
4	18.31759	-65.3176	18.31726	-65.31788	6/12/2022	8:26	8:48	1	8	6	0	55	10
								2	9	6	5	40	5
								3	13	7	25	25	3
								4	18	8	85	5	0
								5	28	10	20	25	20
								6	29	10	20	25	5
								7	34	9	90	5	0
								8	35	9	95	4	0
								9	36	9	5	93	0
								10	44	10	80	5	0
5	18.31739	-65.3175	18.31725	-65.31792	6/12/2022	9:06	9:42	1	14	6	10	30	0
								2	15	7	15	35	0
								3	19	8	20	15	0
								4	29	9	70	10	0
								5	31	9	90	8	0
								6	35	9	92	5	0
								7	37	9	85	8	0
								8	40	10	80	10	0

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Transect Number	Start Lat	Start Long	End Lat	End Long	Date	Start Time	End Time	Quadrat Number	Transect Distance (m)	Depth (ft)	% Cover		
											TT	SF	HS
								9	41	10	75	10	0
								10	48	11	90	7	0

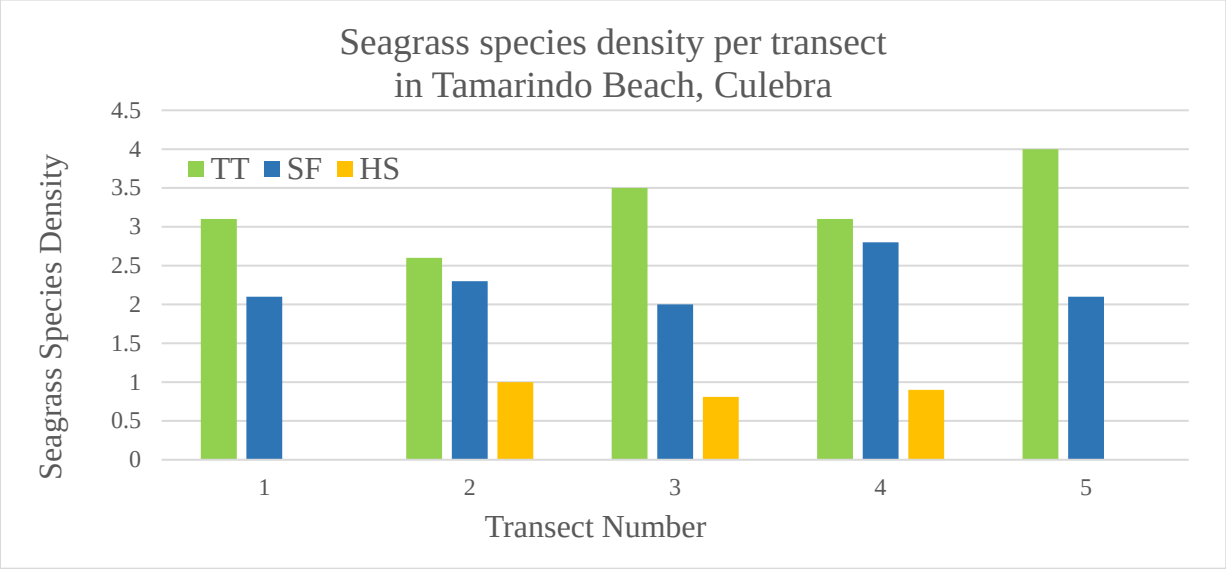

Figure 8. The density of each seagrass species per transect in Tamarindo Beach, Culebra. TT = Thalassia testudinum, SF = Syringodium filiforme, HS = Halophila stipulacea

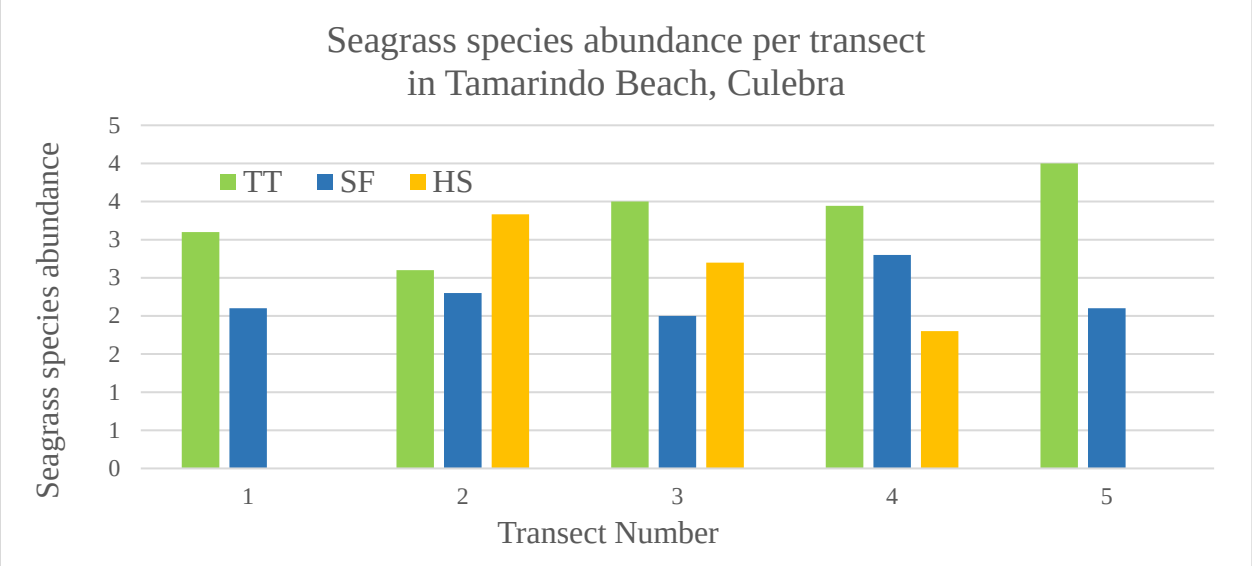

Figure 9. The abundance of each seagrass species per transect at Tamarindo Beach, Culebra. TT = Thalassia testudinum, SF = Syringodium filiforme, HS = Halophila stipulacea.

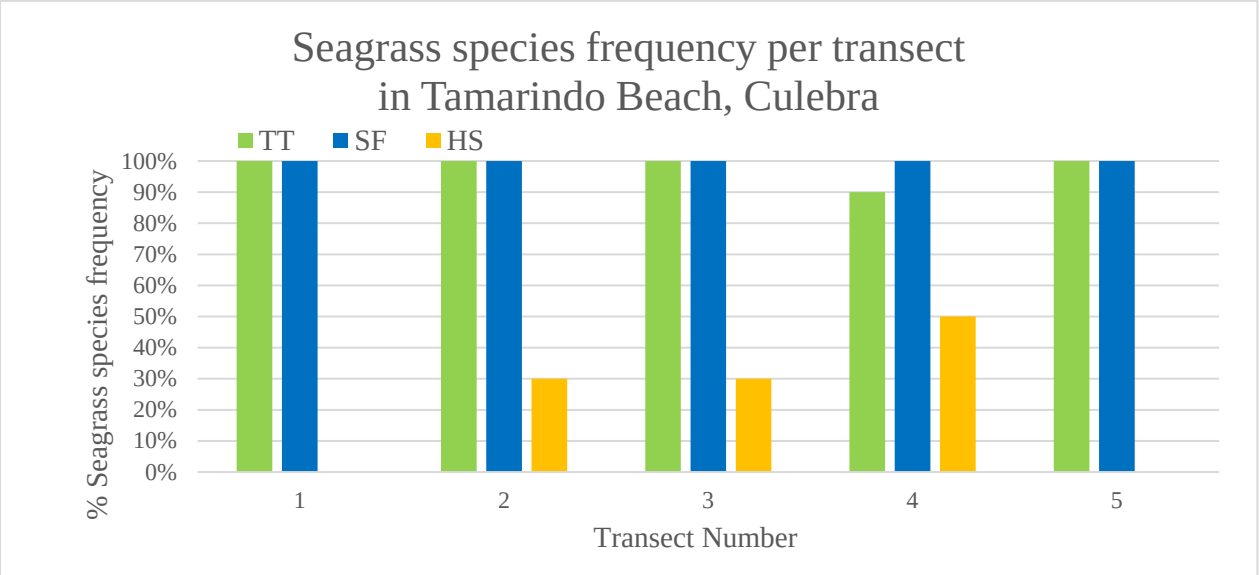

Figure 10. The frequency of each seagrass species per transect at Tamarindo Beach, Culebra. TT = Thalassia testudinum, SF = Syringodium filiforme, HS = Halophila stipulacea

Algae

The most common macroscopic algae species was *Penicillus dumetosus*, which was documented in 36 out of the 50 quadrats. However, the cover of this algae was very low, commonly under 1% of total cover. Additional species documented *Jania adhaerens* (in 6 quadrats), *Halimeda incrassata* (in 5 quadrats), *Valonia ventricosa* (in 2 transects), and *Halimeda monile* (in 1 transect). In addition to algae, cyanobacteria was noted in three transects.

Fish and Invertebrates

Table 5. A table of fish and invertebrate species, sizes, and total number of individuals documented in belt transects across Tamarindo, Culebra.

			Size					# of individuals
Type	**Common name**	**Scientific name**	**0 - 4.9 cm**	**5 - 9.9 cm**	**10m -14.9 cm**	**15 - 19.9 cm**	**35 - 49.9 cm**	**TOTAL**
Fish	Scrawled cowfish	*Acanthostracion quadricornis*				2		**2**
Fish	Peacock flounder	*Bothus lunatus*			1			**1**
Fish	Sheepshead porgy	*Calamus penna*				3		**3**
Fish	Orangespotted filefish juv	*Cantherhines pullus*	1					**1**
Fish	Bar Jack	*Caranx ruber*			2			**2**

			Size					# of individuals
Type	**Common name**	**Scientific name**	**0 - 4.9 cm**	**5 - 9.9 cm**	**10m -14.9 cm**	**15 - 19.9 cm**	**35 - 49.9 cm**	**TOTAL**
Fish	Foureye butterflyfish juvenile	*Chaetodon capistratus*	1					**1**
Fish	Spotted goby	*Coryphopterus spp*	2					**2**
Fish	Grunt juvenile	*Haemulon spp.*	16					**16**
Fish	Slippery dick juvenile	*Halichoeres bivittatus*	4	2				**6**
Fish	Smooth Trunkfish	Lactophrys triqueter		3				**3**
Fish	Snapper juvenile	*Lutjanus spp. (mahogoni or synagris)*	7					**7**
Fish	Lane snapper	*Lutjanus synagris*		2	1			**3**
Fish	Yellowtail snapper juvenile	*Ocyurus chrysurus*	4					**4**
Fish	Cero mackerel	*Scomberomorus regalis*					1	**1**
Fish	Bucktooth parrotfish juvenile	*Sparisoma radians*	7					**7**
Fish	Beaugregory	*Stegates leucostictus*	2					**2**
Invertebrate	Erect rope sponge	*Amphimedon compressa*						**2**
Invertebrate	Stocky Cerith	*Cerithium litteratum*						**58**
Invertebrate	Tube coral	*Cladocora arbuscula*						**10**
Invertebrate	Orange-veined sponge	*Clathria curacaoensis*						**52**
Invertebrate	Bearded fireworm	*Hermodice carunculata*						**2**
Invertebrate	Cake sponge	*Hyrtios violaceus*						**1**
Invertebrate	Red cushion sea star	*Oreaster reticulatus*						**1**
Invertebrate	Mustard hill coral	*Porites astreoides*						**2**
Invertebrate	Massive starlet coral	*Siderastrea siderea*						**9**

			Size					# of individuals
Type	**Common name**	**Scientific name**	**0 - 4.9 cm**	**5 - 9.9 cm**	**10m -14.9 cm**	**15 - 19.9 cm**	**35 - 49.9 cm**	**TOTAL**
Invertebrate	Unidentified Tunicate	Unidentified Tunicate						**72**

During the belt transects, fish species found outside of transects included:

- 20 <5cm juvenile sergeant major (*Abudefduf saxatilis*)
- 4 <5cm juvenile five-band surgeonfish (*Acanthurus tractus*)
- 2 10 to 14.9cm bar jacks (*Caranx ruber*)
- 1 15-19.9cm trunkfish (*Lactophrys trigonus*)
- 3 5-9.9cm smooth trunkfish (*Lactophrys triqueter*)
- 1 35-39.9 great barracuda (*Sphyraena barracuda*)

During the belt transects, invertebrates documented outside of transects included:

- 1 dwarf hairy triton (*Cymatium vespaceum*)
- 3 rose corals (*Manicina areolata*)

Additionally, rare coral species *Cladocora arbuscula* was noted in one quadrat in the transects (Figure 11). Sociedad Ambiente Marino (2018) previously recommended an extensive search of the species and propagation efforts to repopulate the species due to the lack of observation of the species after the 2017 hurricanes. Various sponge species were also noted growing on seagrass in most of the quadrats.

Figure 11. Coral species Cladocora arbuscula noted in the Tamarindo seagrass bed.

Roving diver survey

During the roving survey in the seagrass bed, a sharp boundary between the coral reef and the seagrass bed was noted. Additional species, not observed in the transects, included southern stingrays (*Dasyatis americana*), queen conch (*Lobatus gigas*), and cushion sea star (*Oreaster reticulatus*).

Some bare sandy patches were noted in various areas throughout the seagrass bed during the roving diver survey (Figure 12).

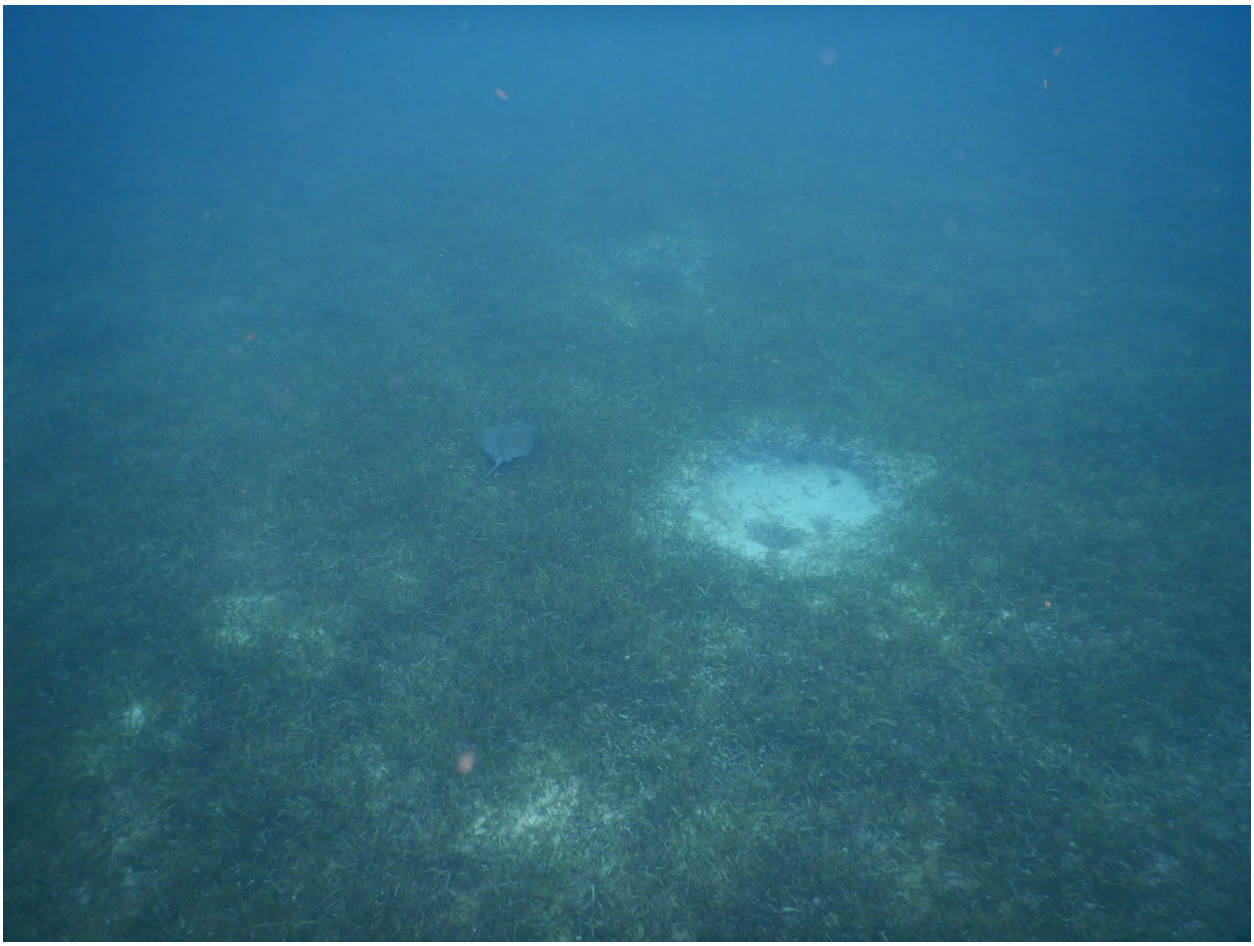

Figure 12. An example of a bare area found in the Tamarindo seagrass bed.

Just south of the seagrass bed there is a patchy coral reef with little biodiversity and noticeable recent mortality. Although no signs were evident of stony coral tissue loss disease (SCTLD), the disease has passed through and greatly affected Culebra's coral reefs, so this likely was a site that was affected. The predominant coral species is *Diploria labyrinthiformis*, which is an SCTLD susceptible species. In addition, *Pseudodiplora strigosa* and *Orbicella annularis* was documented.

Discussion

Seagrass: Overall, the seagrass bed at Tamarindo beach appeared to be in healthy conditions and was dominated by *Thalassia testudinum*, followed by *Syringodium filiforme*, but with presence of the seagrass *Halophila stipulacea*. The first two species are native in Puerto Rico, while the third is an invasive species, known to displace the native seagrass species (Willette & Ambrose, 2012; Smulders et al., 2017).

In 2018, Hernandez *et al.* reported the approximate cover of seagrasses in Tamarindo as 75% *Thalassia testudinum*, 5% *Syringodium filiforme*, 0.02% *Halodule wrightii* and 1% *H. stipulacea.* With this study's methodology, the approximate cover of seagrasses during this study was 46% *Thalassia testudinum*, 17% *Syringodium filiforme*, and 5% *H. stipulacea*, with no observations of *Halodule wrightii.* Most of the rest of the percent cover in the quadrats was sand. It is important to note that the methodology to calculate seagrass cover in this study is very different to that used in the study by Hernandez *et al.*, so a direct comparison cannot be made between the two. Even so, both studies documented that *T. testudinum* was the dominant seagrass, followed by *S. filiforme* and *H. stipulacea.*

Fishes and Invertebrates: Tamarindo's seagrass ecosystem acts as a nursery for juvenile reef fish species, which, as they mature, may migrate to nearby coral reefs in Tamarindo. Juveniles of two commercially important snappers, lane snapper (*Lutjanus synagris*) and yellowtail snapper (*Ocyurus chrysurus*), were observed during the survey. Additionally, juvenile five-band surgeonfish (*Acanthurus tractus*), an important reef herbivore (Gonzalez, 2020), were observed. In addition to acting as a nursery for juveniles, it also functions as feeding grounds for the smooth trunkfish (*Lactophrys triqueter*) and trunkfish (*Lactophrys trigonus*), that consume small crustaceans, as well as Endangered Species Act listed sea turtles such as *Chelonia mydas*, that feed mainly on seagrass. Although only one individual of the white egg sea urchin (*Tripneustes ventricosus*) was recorded, it indicates that juveniles could be recruiting in the seagrasses. No long-spined sea urchin (*Diadema antillarum*) were spotted in this reef, however, have been seen previously in the area (Melissa Gonzalez, *pers. comm.*). *D. antillarum* is a keystone herbivore in Puerto Rico; however, with the recent die-off in the Caribbean, including Culebra, it is important to have presence of other herbivorous sea urchins and fishes that can migrate to reef area and graze on detrimental algae for coral survivorship. This ecosystem shows the potential for a continuous input of developing individuals for the reef, a juvenile nursery, feeding ground, tourism attraction and a support lifeline to the likely SCTLD affected nearby reefs.

Threats: Hernández-Delgado et al. (2018) reported seagrass loss due to sediment bedload and burial in Tamarindo. During this project's surveys, low amounts of sedimentation was noted on some seagrass, which did not appear to be at the same extent of what was reported in 2018. Bare sandy patches were noted in the roving diver surveys and indicate a disturbance to the seagrass bed. The cause of these bare areas is unknown; however, they could be due to the effects of hurricane damage, anchoring, recreational use, and debris, among other reasons. Some debris, including metal structures and poles, were found within the ecosystem, and some found within the sandy patches.

The presence of *H. stipulacea* highlights the importance of reducing disturbance that causes mechanical damage to the seagrass beds, such as anchoring, as it has been previously observed at other sites where anchors damage seagrass and create bare sand patches can cause faster spread of

H. stipulacea compared to *T. testudinum* (Manuel Olmeda, *pers. comm.*). In the survey area, *H. stipulacea* was found starting at 8m from the transect starting point all the way to 42m from the starting point, and between depths of 6ft to 10ft. This species was not found at the very beginning or end of any of the transects, and therefore appears to inhabit the central sections of the seagrass bed.

Since the methodology used to collect data is different from previously used methodologies to evaluate seagrass in Tamarindo, this data is recommended to be used as a baseline for a simple, cost-effective monitoring program for the Tamarindo seagrass bed every few months. In addition, designating this site as a citizen science water quality monitoring site is recommended, as it will help track any water quality changes due to the implementation of land-based sources of pollution reduction measures.

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