Multi-wave LiDAR for Habitat Restoration in Terra Ceia, Florida

The Restoration Project

The Surface Water Improvement and Management (SWIM) Act, authorized by the Florida Legislature in 1987, directs the Southwest Florida Water Management District (SWFWMD) and the four water management districts in Florida to protect, restore, and maintain Florida's highly threatened surface water bodies. In conjunction with the Lands Acquisitions for Conservation or Recreation Act, popularly known as "Florida Forever Act", in 2003, the SWFWMD SWIM Section purchased a 287-acre tract, known at the "Huber Tract" located in Terra Ceia Bay, a portion of the Tampa Bay Estuarine Ecosystem, for habitat restoration.

Historically, in the 1940's, the Huber Tract was ditched, drained, and put into commercial agriculture; this land use continued until the late 1990's. In the early 2000's, the private owner intended to develop the tract for residential housing, but with the housing market decline, the parcel became available to the SWFWMD. Ecologically classified as a "low-elevation upland" and with access to Terra Ceia Bay, the Huber Tract is similar to several nearby tracts of land where the SWFWMD has conducted habitat restoration and/or habitat creation projects. The SWFWMD's intent for the Huber Tract is to create a braided- tidal creek coastal wetland to resemble an earlier project at Little Cockroach Bay (see **Figure 1**).

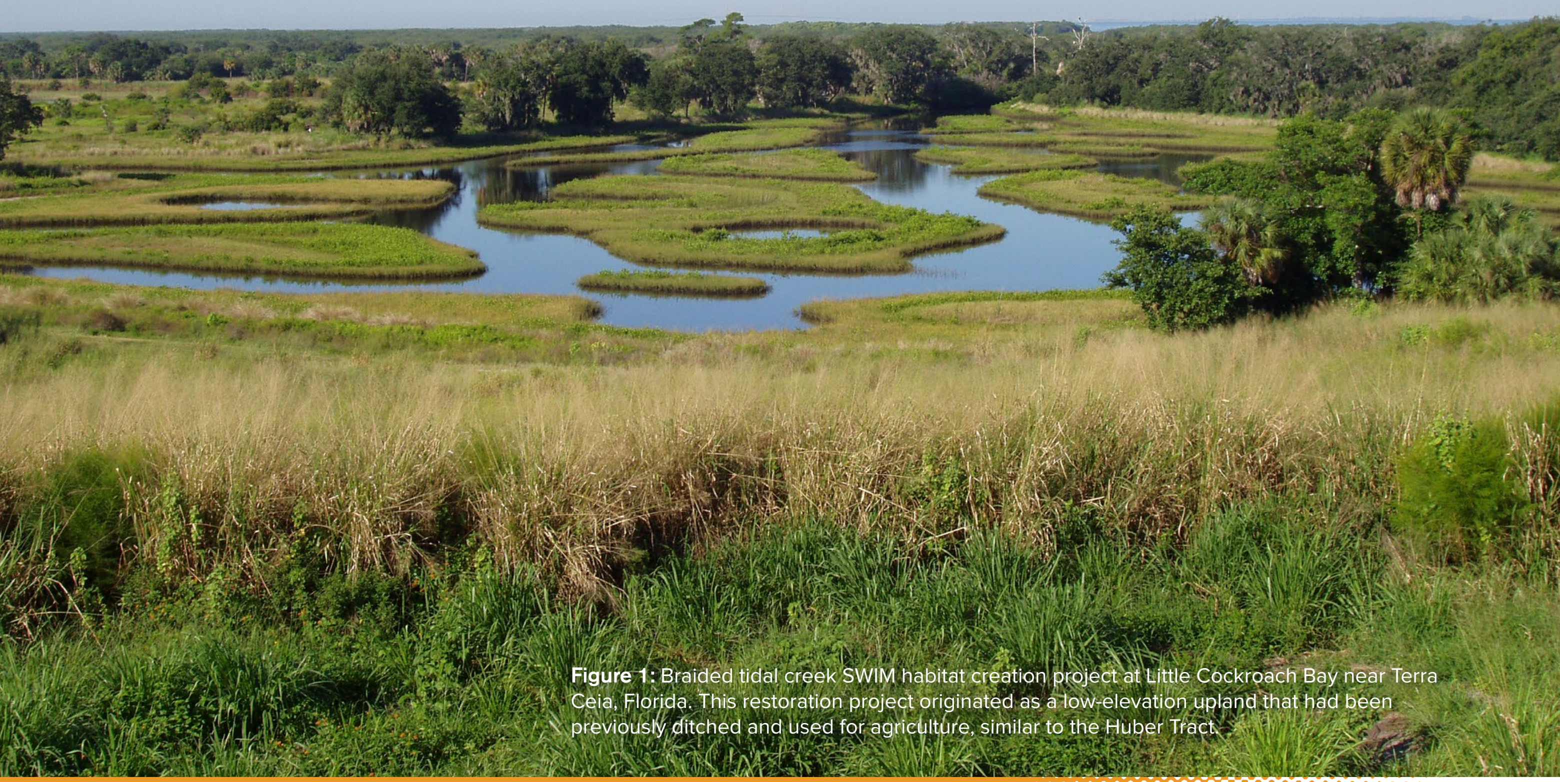

Figure 1: Braided tidal creek SWIM habitat creation project at Little Cockroach Bay near Terra Ceia, Florida. This restoration project originated as a low-elevation upland that had been previously ditched and used for agriculture, similar to the Huber Tract.

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Table 1: Table showing some general LiDAR mission parameters, with the Fundamental, and Supplemental Vertical Accuracies achieved for the Huber Tract LiDAR Mission.

Mission Parameter	Riegl LMS VQ-820-G	Riegl Q680i
Date/Time of Flight	4Nov2013: 1426-1524 EST	30Oct2013: 1544-1644 EST
Laser Wavelength	532 nm	1550 nm
Average Altitude (MSL)	1800' (550m)	1800' (550m)
Average Air Speed	100 Knots	100 Knots
Scan Rate	70 lines/sec	50 lines/sec
Scan FOV (angle)	42º	60º
Pulse Rate	512 kHz	320 kHz
Nominal Point Spacing	12 ppsm	10 ppsm
ASPRS Tested-For Accuracy		
Fundamental Vertical Accuracy (ft.)	0.201	0.159
Supplemental Vertical Accuracy (ft.)		
Low Grasses	0.141	0.089
High Grasses & Shrub	0.317	0.148
Dense Vegetation	0.299	0.148

Obtaining accurate topography of the Huber Tract was the first priority for the engineering design phase of the habitat restoration. During a site visit in early 2013, we recognized that there were several challenges to obtaining the elevation data, particularly if it was to be accomplished by conventional, on-the-ground, survey methods.

First, by 2013, Brazilian Pepper tree (*Schinus terebinthifolius*), an aggressive invasive tree that produces dense canopy which shades out most other plants, had invaded the uplands on the property. This, along with black mangrove (*Avicenna germinans*) which also produces dense canopy in the salt marsh areas, made much of the tract impenetrable or at least very time and labor intensive for ground survey. Secondly, the historic ditching performed on the property with subsequent silting in, made it hazardous for ground-level survey. Finally, the restoration would require hydrographic survey into Terra Ceia Bay to determine design elevations to insure proper water flow off of the restored parcel. These three challenges, combined with limited funding, made it necessary to find alternative means to obtain the topographic survey.

Given the above challenges to obtaining topographic data for the Huber Tract, we prioritized our goals as follows: (1) to obtain topographic data of sufficient accuracy for the restoration design, (2) to identify and map the ditches, and (3) collect bathymetric data extending 500 linear feet into Terra Ceia Bay.

Recent topographic mapping projects conducted by SWFWMD have led us to use a two-stage approach. First, we use airborne LiDAR to construct the basic Digital Terrain Model (DTM) to be used for the project. Then, in specific areas where the DTM requires additional detail, we supplement the DTM, as needed, with ground-survey. This combination has proven to be both time- and cost-effective. Based on the above mentioned challenges, this approach was chosen for the Terra Ceia restoration project.

Using Lidar Technology

We contacted Aerial Cartographics of America (ACA, Orlando, FL) and Riegl USA to discuss using a multi-wave LiDAR approach to obtaining both the terrestrial and bathymetric elevations required for the Huber Tract restoration. Following an on-site planning meeting, we determined that a combination of two approaches would be used. We decided to synchronize the LiDAR data collection to a local low tidal condition, so on 30 October 2013, LiDAR data were collected between 1544-1644 EST using a Riegl LMS Q680i (1550 nm: infrared) sensor and, on 4 November, LiDAR data were collected between 1426 – 1526 EST with a Riegl LMS VQ-820-G (532 nm: green) sensor over the Huber Tract.

Our first challenge was to determine the fundamental vertical (FVA) and supplemental vertical (SVA) accuracies of the LiDAR data. We used the high-accuracy Florida Permanent Reference Network (FPRN) and Leica CS-15/GS-15 GNSS receivers to determine precise ground elevations at over 90 Ground Check Points (GCPs) on and around the Huber Tract. For vertical accuracy assessments, we defined three classes of vegetation for supplemental vertical accuracy (SVA) determination,

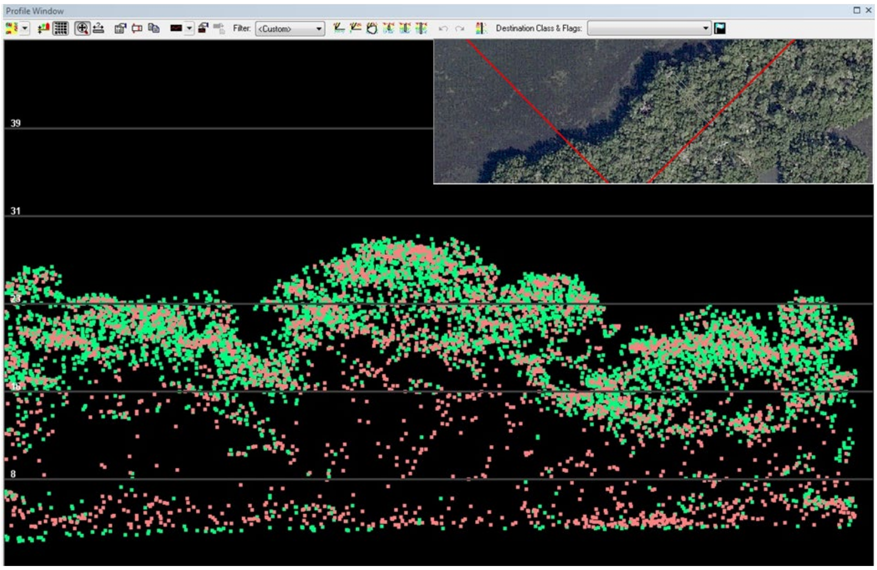

Figure 2: LiDAR profile in densely vegetated area on the Huber Tract. Pink points (Q680i sensor) show penetration to the ground while green points (VQ-820-G sensor) show high point density in the tree canopy. Insert shows ortho-image of area of the profile.

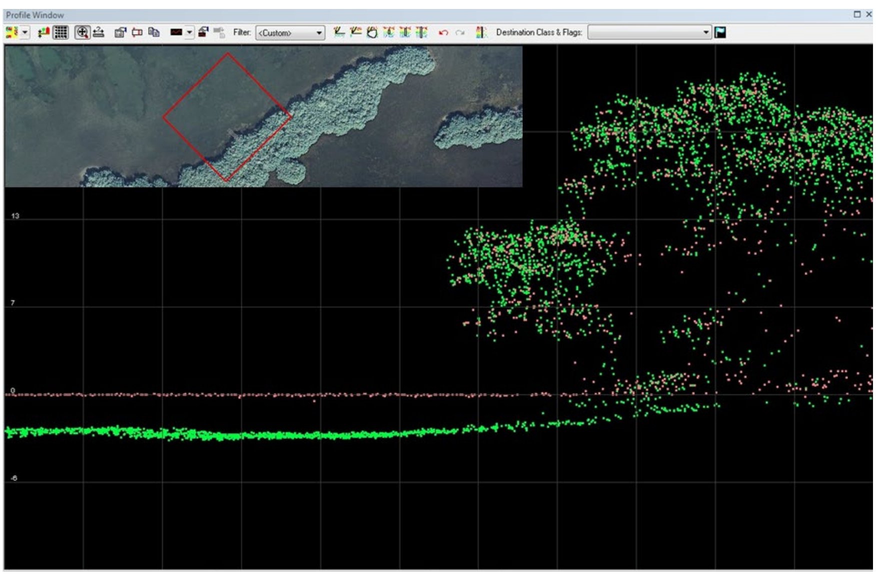

Figure 3: LiDAR profile near-offshore from the Huber Tract. Pink points (Q680i sensor) show the water surface and ground; green points (VQ-820-G sensor) show the near-shore (100' from shore) bathymetry to approximately 1,2 meters below the water surface. Inset shows ortho-image of area of the profile.

based on the vegetation structure as; (1) low grasses, 4" – 12" tall, (2) high grasses, 12" – 60" tall, and (3) dense vegetation, Brazilian pepper tree, mangrove, etc. making certain that at least 20 GCPs were measured for each vegetation class. Root Mean Square Error of Z (elevation; RMSEz) was computed as per the National Standard for Spatial Data Accuracy.

Target accuracies for this restoration design were +/- 0.3' and +/- 0.6' for the FVA and SVA, respectively for the terrestrial LiDAR elevations and +/- 0.6' for the bathymetry. Target nominal point densities were 2 – 4 points per square meter. **Table 1** shows some of the mission parameters, and the computed FVA and SVA accuracies. Both sensors exceeded the target nominal point spacing and the "tested-for" accuracies of both sensors met the FVA and SVA targets. We noticed that while the SVAs in all cases, for both sensors, met the target SVAs, those for the Q680i were, on average, 30% better than those for the VQ-820-G over the terrestrial portion of the project. The differences between the sensors was most clearly seen when we looked at profile views of the point clouds (**Figure 2**).

In **Figure 2**, where the VQ-820-G points are colored green, and the Q680i points are rendered in pink, it is clear that the VQ-820-G points are more densely represented at higher elevations in the vegetation while more of the Q680i pulses are reaching the ground. We observed this pattern through each of the vegetation classes, although it is most obvious in the high grasses and shrub class. We suspect that the combination of the plant structure and chemical composition interacts with the narrow illumination pattern of the VQ-820-G to prevent much of the energy from reaching the ground. While this general pattern was true in the low grass and dense vegetation, differences in vegetation structure may have lead to more of the energy reaching the ground and hence, lower RMSEz values in those habitats.

As a result of tidal action over the years, many of the original ditches on the property, used for drainage and mosquito control, had silted-in to various degrees. However, some of the deeper ditches still retain water and some maintain moderate flow rates. These ditches were clearly delineated in the point cloud developed from both sensors, with the VQ-820-G defining the bottom of the ditches. We used the point cloud from the VQ-820-G sensor to develop ditch-center breaklines to represent those ditches in the Digital Terrain Model.

Finally, with respect to the near-shore bathymetry required for the restoration, no Q680i pulses were returned from beneath the water column. In fact, we used the returns from the Q680i to help define the water surface to compute the refraction index for the VQ-620-G pulses that did reach the sand bottom (**Figure 3**.) Using this technique, the VQ-820-G pulses reaching the bottom of the water column clearly delineated sandy bottom, oyster bars, and other hard-bottom features in the 500-linear foot near-shore project area.

Summary

The goal of this project was to construct an accurate topographic surface, and ultimately, a Digital Terrain Model, that would be used for the engineering design for the restoration/habitat creation on the Huber Tract. For the cut-and-fill calculations necessary for the engineering design, (1) vertical accuracies in the uplands needed to be a maximum +/- 0.3' (RMSEz), (2) the ditches needed to be clearly defined such that they can be filled or re-routed, and (3) the near-shore bathymetry needed to be determined.

> “Dual-beam LiDAR proved to be an accurate and cost effective approach for a challenging restoration project.”

For this final product, we used the data from both the VQ-820-G and the Q680i sensors. We constructed a hybrid DTM using the data from the Q680i for the upland and densely vegetated portions of the project area, and the data from the VQ-820-G to help define the ditches and the near-shore bathymetry. The combination of the two sensors in this multi-wave LiDAR project produced the required DTM for the habitat restoration design.

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