2019 Galveston Island
Topographic and Hydrographic Survey Report

Prepared for:
CITY OF GALVESTON, TEXAS

Prepared by:
Aptim Environmental & Infrastructure, LLC

Prepared Date:
November 2019

Revised: January 2020
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ABSTRACT

Aptim Environmental & Infrastructure, LLC (APTIM) was contracted by City of Galveston, Texas to provide topographic and hydrographic beach survey services as part of the City’s annual beach monitoring program along Galveston Island. The intended use of the survey data collected by APTIM as part of the annual monitoring program is to: (1) provide a data set for annual City of Galveston Beach Maintenance Permits that are required for maintenance activities along Galveston Island’s beachfront; (2) map and maintain a record of the City’s Dune Protection Line in accordance with the Texas Administrative Code (31 TAC Rule § 15.3); and (3) to document beach conditions for potential FEMA assistance after storm events.

The monitoring survey was conducted from reference stations 550+00.00 through 567+49.11 which includes 44 depth of closure profiles, and 96 wading depth profiles along Galveston Island. In addition, APTIM conducted a UAS/Drone proof of methodology study. The results of this study are included as an Appendix to this report. APTIM surveyors conducted the beach profile survey and acquired UAS data from 9 July 2019 through 2 August 2019.

The 2019 annual beach monitoring of Galveston Island includes topographic and hydrographic surveys of the beach and offshore areas. The survey data is used to satisfy the Department of the Army permit conditions associated with SWG-2014-00448, which requires beach surveys to provide sufficient data to locate the Typical Jurisdictional Limit, approximate line of vegetation, high tide line and the low tide line. The survey data is also used to monitor the three (3) beach nourishment projects constructed by the City along Galveston Island, namely Historic Seawall Beach, Babe’s Beach, and Dellanera Beach.

The scientific monitoring process employed by APTIM provides information necessary to plan, design, and optimize subsequent follow up projects, potentially reducing the need and cost of unnecessary work as well as potentially reducing environmental impact that may have or are expected to occur.

SURVEY METHODOLOGIES

All work was conducted under the direct supervision and responsible charge of a Texas Registered Professional Land Surveyor (RLPS). In addition, all hydrographic surveying was conducted under the direct supervision of an American Congress of Surveying and Mapping (ACSM) Certified Hydrographer (CH). A signed and sealed Topographic and Hydrographic Survey Report and Map Set is provided at the end of this survey report. Thirty-five (35) maps are presented, one (1) project location map, one (1) control data sheet, and thirty-three (33) plan view maps. The plan view maps show reduced elevation data collected during the survey as well as the feature lines as required by scope.
1. 4’ contour
2. Approx. Line of Veg
3. South Toe of Dune
4. North Toe of Dune
5. Mean High Water
6. Mean Low Water
7. 25’ offset North Toe of Dune
8. Enhanced Construction Zone

Vertical data was collected in the North American Vertical Datum of 1988 (NAVD 88), Geoid 12b. All horizontal data is provided in the Texas State Plane Coordinate System, South Central Zone, North American Datum of 1983/2011 (NAD 83/11). The location of all published control, as well as control found and used for survey purposes, is presented in Appendix 1.

The profile data is presented in xyz format relative to NAVD 88 in Appendix 2. GIS data files include ArcGIS 10.7.1 formatted metadata and is presented in Appendix 3. Profile plots of the survey are presented in Appendix 4. Profiles plots are presented with UAS photography and plan-view location to illustrate beach conditions and spatial location of the 2D-profile. Copies of all field book pages are provided in Appendix 5. Ground digital photographs obtained at the time of the survey are provided in Appendix 6.

The field survey and data collection activities encompassed four (4) phases. Brief descriptions of each survey phase, including methodologies and quality control/quality assurance procedures, are described below.

**Phase One:  Control Reconnaissance/Establishment/Verification**

Prior to the start of the survey, reconnaissance of the monuments was conducted to confirm that survey control was in place and undisturbed. Real Time Kinematic Global Positioning System (RTK GPS) was used to locate and confirm survey control for this project. In order to achieve required accuracy, the topographic and hydrographic surveys were controlled using National Geodetic Survey (NGS) 2nd order control (or higher) control monuments. Horizontal and vertical positioning checks were conducted at the beginning and end of each day using at least two 2nd order National Geodetic Survey (NGS) monuments in the project area. The RTK GPS utilizes statistical methods to ensure accuracy of RTK GPS data remains within the 95% confidence interval. The control check shots were acquired using a Trimble survey style *Topo Shot*. Results from 2nd order NGS monument control checks are displayed showing northing, easting, monument elevation, inverses, horizontal and vertical root mean square error, location description and photographs as indicated in the Control Monument Information (Appendix 1).
Control for the individual profile monument locations were verified using RTK GPS. Profile control information for all station monuments and other control stations was digitally inserted into all Trimble TSC3 data collectors prior to field work. Control information includes the northing, easting, elevation, and profile azimuth of the station. This information is vital to quickly access station monuments for RTK GPS topo shots or otherwise set profile control.

**Phase Two: Beach Profiles**

Upon completion of the control reconnaissance survey, beach/upland and nearshore operations were initiated. Cross-sections of the beach in the project area were surveyed using extended rod RTK GPS rovers, standard RTK GPS rovers, and differential leveling techniques (if/when needed). Extended rod RTK GPS rovers were used to augment RTK GPS survey capability into the nearshore. The current systems allow surveyors from APTIM to collect the entire beach profile with RTK GPS technology.

Wading depth surveys were conducted at all profile stations included in the scope of work. Data were collected from a point 150 feet landward of the vegetation line or landward of the vegetation line until an obstacle was encountered, to the -1 foot contour (NAVD). Elevations were collected at a maximum spacing of twenty-five (25) feet along each profile line and at all grade breaks to provide an accurate representation of the beach profile including all grade breaks and required features.

The forty-four (44) depth of closure beach profiles were collected in two (2) stages: upland and nearshore. The nearshore portion of the survey commenced from a point landward of the waterline and extended seaward to a point overlapping the offshore data, collected by the survey vessel in phase three (3), by a minimum of fifty (50) feet. The nearshore portion of the profiles was surveyed by two (2) surveyors with an Extended Rod Trimble R10 RTK GPS rover who entered the water wearing Personal Floatation Devices (PFD). Measurements obtained from the rover required the use of Bluetooth enabled TSC data collectors, allowing surveyors from APTIM to obtain RTK GPS data in the nearshore area while maintaining data accuracy and personal safety.

The upland portion of the survey commenced fifty (50) feet seaward of the nearshore point of commencement and extended 150 feet landward of the vegetation line or until an obstacle was encountered. The upland portion of the profiles was surveyed using an RTK GPS. If dense vegetation and/or tree canopy was present, extended rod RTK GPS was deployed to mitigate data collection in locations that would otherwise receive poor GPS reception.

Elevations for both the nearshore and upland portions of the survey were taken at approximately twenty-five (25) foot intervals along each profile line and at all grade breaks in order to accurately highlight features along the given azimuth. In order to ensure online accuracy along these azimuths, APTIM surveyors utilized the RTK GPS feature *Stakeout*.
Point. Stakeout Point allows for the quick verification of azimuth values from profile control information, and real time actual azimuth values. This gives APTIM surveyors the ability to maintain the given profile azimuth without relying on survey lathe or conventional compass bearing techniques. A three (3) foot profile line variance along the azimuths is maintained at all times, with exception to instances where this is not achievable due to obstructions or hazardous conditions, such as dense vegetation or strong nearshore currents. In these conditions, surveyors from APTIM maintain the required thirty (30) foot profile line variance.

Phase Three: Nearshore and Offshore Profiles

The nearshore/offshore profiles were conducted at each of the forty-four (44) depth of closure profiles identified in the scope of work. Offshore profile data was collected 4,000 to 11,000 feet seaward of the profile station to reach a depth equal or greater than twenty-four (24) feet NAVD. The landward limits of the nearshore profiles were based on a minimum overlap of fifty (50) feet beyond the seaward extent of beach profile data collected by the survey vessel. Soundings were sorted at ten (10) foot intervals with a maximum of twenty five (25) foot intervals, sufficient to provide an accurate depiction of the seafloor.

The offshore survey was conducted using an ODOM Hydrotrac sounder with digitizer on APTIM's 24-foot Privateer survey vessel with a centrally located hull-mounted transducer. Data was digitally stored using HYPACK 2019 Software. A Trimble R8 RTK GPS and a TSS DMS-25 dynamic motion sensor were used onboard the survey vessel to provide instantaneous tide corrections as well as heave, pitch, and roll corrections. Manual tide readings were taken while conducting the onshore portion of the profile to verify onboard tide readings. In order to maintain the vessel navigation along the profile lines, HYPACK navigation software was used. This software provided horizontal position to the sounding data which allowed real-time review of the data in plan view or cross-section format and minimized vessel deviation from the online azimuth.

Horizontal and Vertical positioning checks were conducted at the beginning and end of each day using published NGS monuments or temporary benchmarks established in the project area. The sounder was calibrated via bar-checks and a sound velocity probe at the beginning and end of each day. The Valleport SWiFT SVP Sound Velocity Profiler offers a fast additional calibration for sound velocity as compared to the traditional bar-check. Bar-checks were performed from a depth of five (5) feet to a minimum depth of twenty (25) feet. Analog data showing the results of the bar-check calibration was displayed on the sounder charts at five (5) foot increments during descent of the bar.

Phase Four: Data Reduction/Submittals

Upon completion of the field work, data was edited and reduced with Trimble Business Center, HYPACK 2019, and APTIM’s internal software programs. The upland
and nearshore portions of the beach profile were viewed and edited in Trimble Business Center and a comma delimited XYZ file was created. The offshore raw digital data was viewed and edited in HYPACK 2019’s Single Beam Editor. The offshore RTK GPS tide data that was collected was compared to the manually collected RTK GPS nearshore tide data, local observed and predicted tides for data verification purposes. Tide corrected offshore data was exported and a comma delimited XYZ file was created. All overlapping profile data was compared in cross sections to ensure system accuracy. The edited beach profile data and offshore profile data were merged and a representative cross-section was derived for each profile line. The cross sections were developed using internal APTIM plotting programs.

The final plots were edited and reviewed with comparisons to previous years; seawalls, boardwalks, rocks, and other features were noted. The final approved cross-section data was prepared in the required formats for submittal (Appendices 2 and 4). Digital data is provided in the vertical datum NAVD88.

**SHORELINE AND VOLUME CHANGE ANALYSIS**

Wading and Depth of Closure beach profile surveys conducted by Atkins along Galveston Island in June 2014 and July 2017 were compared with beach profile data collected by APTIM in July 2019 to assess the change in the positions of the berm elevation (+4.0 ft. NAVD88) contour and MHW (+1.23 ft. NAVD88) contour. The July 2019 positions were analyzed to assess the recent changes defined as the changes that occurred between July 2017 and July 2019 and the long-term changes defined as the changes that occurred between June 2014 and July 2019. The recent and long-term changes were calculated by dividing the shoreline change for the berm and MHW contours by the time period (number of years) between survey events (i.e. feet per year). These rates are described in terms of positive (“+”) or advance (shoreline moving seaward) and negative (“−”) or recession (shoreline moving landward). A summary of the recent and long-term average annualized shoreline change rates computed for the berm and MHW contours for each region are provided in Table 1 and Table 2.
Table 1. Summary of Recent and Long-Term +4.0 ft. NAVD88 Shoreline Change Rates

<table>
<thead>
<tr>
<th>Regions</th>
<th>Survey Limits (Sta. to Sta.)</th>
<th>Recent Change July 2017 to July 2019 (ft./yr)</th>
<th>Long-Term Change June 2014 to July 2019 (ft./yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>East of Historic Seawall Beach</td>
<td>(550+00 to 420+00)</td>
<td>12.9</td>
<td>5.7</td>
</tr>
<tr>
<td>Historic Seawall Beach</td>
<td>(410+00 to 160+00)</td>
<td>-4.0</td>
<td>15.7</td>
</tr>
<tr>
<td>Babe's Beach</td>
<td>(160+00 to 60+00)</td>
<td>-2.4</td>
<td>5.9</td>
</tr>
<tr>
<td>Gap</td>
<td>(50+00 to 30+00)</td>
<td>-0.9</td>
<td>-0.2</td>
</tr>
<tr>
<td>Dellanera Beach</td>
<td>(20+00 to 1470+00)</td>
<td>2.8</td>
<td>1.0</td>
</tr>
<tr>
<td>Dellanera Beach to Jamaica Beach</td>
<td>(1460+00 to 1210+00)</td>
<td>3.6</td>
<td>-0.4</td>
</tr>
<tr>
<td>West of Jamaica Beach</td>
<td>(1090+00 to 570+00)</td>
<td>18.4</td>
<td>8.3</td>
</tr>
</tbody>
</table>

Table 2. Summary of Recent and Long-Term MHW Shoreline Change Rates

<table>
<thead>
<tr>
<th>Regions</th>
<th>Survey Limits (Sta. to Sta.)</th>
<th>Recent Change July 2017 to July 2019 (ft./yr)</th>
<th>Long-Term Change June 2014 to July 2019 (ft./yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>East of Historic Seawall Beach</td>
<td>(550+00 to 420+00)</td>
<td>14.1</td>
<td>5.4</td>
</tr>
<tr>
<td>Historic Seawall Beach</td>
<td>(410+00 to 160+00)</td>
<td>-1.3</td>
<td>19.2</td>
</tr>
<tr>
<td>Babe's Beach</td>
<td>(160+00 to 60+00)</td>
<td>0.8</td>
<td>11.2</td>
</tr>
<tr>
<td>Gap</td>
<td>(50+00 to 30+00)</td>
<td>-4.9</td>
<td>1.3</td>
</tr>
<tr>
<td>Dellanera Beach</td>
<td>(20+00 to 1470+00)</td>
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<td>3.2</td>
</tr>
<tr>
<td>Dellanera Beach to Jamaica Beach</td>
<td>(1460+00 to 1210+00)</td>
<td>8.0</td>
<td>-0.7</td>
</tr>
<tr>
<td>West of Jamaica Beach</td>
<td>(1090+00 to 570+00)</td>
<td>22.8</td>
<td>9.4</td>
</tr>
</tbody>
</table>
Volume Changes

A volumetric analysis of the survey data collected by APTIM during the July 2019 monitoring event was conducted to assess the volume changes along the engineered beaches previously constructed along Galveston Island to the Depth of Closure. The volume changes were computed between the Post-Hurricane Harvey Depth of Closure survey performed in Oct./Nov. 2017 (Atkins) and the July 2019 APTIM Depth of Closure survey. The analysis calculated the volume changes at each monitoring station above the -24 ft. NAVD88 contour. Total volume changes within each of the engineered beach areas were calculated using the average end area method and are provided in Table 3. However, it should be noted that vertical discrepancies were observed in the offshore segment of the profile when comparing the Atkins Post-Hurricane Harvey survey to the July 2019 survey data. Though APTIM stands by the method used to calculate the volumetric changes included in Table 3, the resulting values may be influenced by the discrepancies between the two data sets.

Table 3. Summary of Volume Changes Above -24 ft. NAVD88

<table>
<thead>
<tr>
<th>ENGINEERED BEACHES</th>
<th>Survey Limits (Sta. to Sta.)</th>
<th>Volume Change Post Harvey 2017 to July 2019 (CY)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Historic Seawall Beach</td>
<td>380+00 to 160+00</td>
<td>-1,888,300</td>
</tr>
<tr>
<td>Babe's Beach</td>
<td>160+00 to 100+00</td>
<td>-391,100</td>
</tr>
<tr>
<td>Dellanera Beach</td>
<td>10+00 to 1490+00</td>
<td>-127,400</td>
</tr>
</tbody>
</table>

MAP PREPARATION

Upon completion of the surveys and data reduction, the profile survey maps were prepared in ArcGIS 10.6.1. In order to avoid congestion, the maps do not show all of the collected elevations, but enough to give an accurate depiction of the cross sections. The survey maps display all data and profile locations plotted against aerial photography and UAS imagery collected.

The maps also display feature line work, including the 4’ contour, the approx. line of vegetation, the south toe of dune, the north toe of dune, the mean high water level, the mean low water level, a 25’ offset (north toe of dune), and the enhanced construction zone. These were all derived from 2019 survey data as described previously in this report. The landward (north) toe of dune line was delineated based on a combination of the topographic profile data collected in the field, photos of the profile locations taken during the survey, UAS imagery collected during the survey, satellite imagery obtained from Google Earth, and satellite imagery retrieved from the ArcGIS library. In most cases, when interpreting
the topographic data for the landward toe of dune line, the highest elevation point was noted, and the corresponding landward low point was used the mark the toe. In some cases, where a foredune, primary, and secondary dune were present, the highest elevation of the most landward dune was noted (which may not be the highest elevation on the profile), and the corresponding landward low point was used to mark the toe. Common patterns of dune vegetation (visible in the field photos, UAS imagery, and satellite imagery) were also considered when creating the landward toe of dune line. Feature lines were derived from the 2017 ATKINS topographic survey data received from the City of Galveston and were plotted on the survey maps (Appendix 3).

Areas in which UAS orthoimagery was acquired as part of the proof of methodology study is also included on the survey maps (Appendix 3). This includes PV-1, PV-2, PV-5, PV-6, PV-32, and PV-33.

**GROUND DIGITAL PHOTOGRAPHY**

APTIM surveyors collected three (3) digital photos at a mid-beach location at all profile locations. The three (3) photos included one (1) in each shore-parallel direction and one (1) landward toward the monument. If a 3rd order monument was found, an additional digital photo was taken of the TBM identification or stamping on the monument.
Survey Report Notes and Certification

Survey Title: 2019 Galveston Island Topographic and Hydrographic Survey Report

Prepared Date: November 2019 (Revised January 2020)

Prepared By: Aptim Environmental & Infrastructure, LLC

Prepared For: City of Galveston, Texas

Dates of Profile Survey: July 9, 2019 through August 3, 2019

Survey Location: Galveston Island, TX

DOC Profiles: 410+00 to 60+00 and 20+00 to 1470+00
Wading Depth Profiles: 550+00 to 420+00, 50+00 to 30+00, 1460+00 to 1210+00, and 1090+00 to 570+00

Notes:

1. This survey report has been prepared to accompany Survey Charts entitled “2019 Galveston Island Topographic and Hydrographic Survey” as prepared by Aptim Environmental & Infrastructure, LLC.

2. The survey is neither valid nor complete without both the survey report and described survey charts. Digital data files encompassing the following have also been provided in the following formats listed.
   - Control Monument Information (Appendix 1)
   - Beach Profile XYZ Data (Appendix 2)
   - GIS Metadata (Appendix 3)
   - Profile Plots (Appendix 4)
   - Field Book Pages (Appendix 5)
   - Ground & Aerial Digital Photography (Appendix 6)

3. The survey maps and report or copies thereof are not valid without the signature and seal of a Registered Professional Land Surveyor

4. The information on this map represents the results of the survey on the dates indicated and can only be considered as indicating the general conditions existing at the time.
5. Additions or deletions to survey maps or report by other than signing party or parties is prohibited without written consent of the signing party or parties.

6. Revisions shown hereon do not represent a “field survey update” unless otherwise noted.

7. The coordinates are in US survey feet based on the vertical and horizontal data that was collected and presented relative to the North American Vertical Datum of 1988 (NAVD88) and the Texas State Plane Coordinate System based on the Transverse Mercator Projection, South-Central Zone, North American Datum of 1983 (2011).

8. Vertical measurements are based on National Geodetic Survey (NGS) Second Order monuments as listed in Appendix one (1) of this report.

9. Bearings are based on a grid north bearing relative to the Texas State Plane Coordinate System, South-Central Zone.

10. Lands were not abstracted for rights-of-way, easements, ownership or other instruments of record.

11. Underground and subaqueous improvements and/or utilities were not located as part of this survey and should be field verified prior to any dredging or construction activities.

12. Refer to APTIM field book #485 and #514 for the nearshore and upland portion of survey and APTIM Nav book #56 for the offshore portion.

13. Aids to navigation were not located during this survey.

14. Soundings were collected using an ODOM Hydrotrac, Single Frequency (200 kHz), Survey Grade Sounder. The sounder was calibrated prior to the start of the survey following manufacturer recommended procedures.

15. Survey plan views are intended to be viewed at a scale of 1”/300’ or smaller.

16. This topographic and hydrographic survey, conducted for the City of Galveston, TX, is intended to provide: (1) data set for annual City of Galveston Beach Maintenance Permits that are required for maintenance activities along Galveston Island’s beachfront; (2) map and maintain a record of the City’s Dune Protection Line in accordance with the Texas Administrative Code (31 TAC Rule § 15.3); and (3) to document beach conditions for potential FEMA assistance after storm events.
Certification:

I hereby certify that this hydrographic and topographic survey is true and correct to the best of my knowledge and belief as delineated under my direction. I further certify that the products provided, and this report comply with the Professional and Technical Standards as codified in Title 22, Part 29, Chapter 663, Texas Administrative Code.

P. Chad Maxwell, RPLS #6547
Aptim Environmental and Infrastructure, LLC
2481 N.W. Boca Raton Blvd., Boca Raton, Florida 33431
CITY OF GALVESTON
2019 BEACH PROFILE SURVEY

INDEX TO SHEETS
1 COVER SHEET AND PROJECT LOCATION MAP
2 CONTROL DATA SHEET (CD)
3-35 PROJECT PLAN VIEWS (PV)

Legend:
2019 Survey
Layer
- 4' Contour
- MHW
- MLW
- Edge of Vegetation
- Landward Toe of Dune
- Seaward Toe of Dune
- Enhanced Construction Zone
- Dune Conservation Area

2017 Survey
Layer
- 4' Contour
- MHW
- MLW
- Edge of Vegetation
- Landward Toe of Dune
- Seaward Toe of Dune
- Enhanced Construction Zone
- Dune Conservation Area

NOT TO SCALE
GRID
<table>
<thead>
<tr>
<th>MON ID</th>
<th>Northing</th>
<th>Easting</th>
<th>Azimuth</th>
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<tbody>
<tr>
<td>MON000</td>
<td>13645727.12</td>
<td>13602086.97</td>
<td>877 1510 TIDAL 44</td>
</tr>
</tbody>
</table>

**2019 GALVESTON ISLAND CONTROL**

Datums: NAD83/2011 / NAVD88 (U.S Survey Feet)

**Control MON ID**

Control MON ID: 13645727.12

**Checked by:**

November 2019

**Comm. No.:**

631226097

**No. Description**

MON 000

**MON000**

13645727.12 13602086.97 877 1510 TIDAL 44
NOTES:
1. DATES OF SURVEY: JULY 9, 2019 - AUGUST 3, 2019
2. COORDINATES ARE IN FEET BASED ON THE TEXAS PLANE COORDINATE SYSTEM, SOUTH CENTRAL ZONE, NORTH AMERICAN DATUM (NAD) 1983/2011.
4. DATE OF AERIAL PHOTOGRAPHY: APRIL 2018

GALVESTON ISLAND

GULF OF MEXICO
**NOTES:**
1. DATES OF SURVEY: JULY 9, 2019 - AUGUST 3, 2019
2. COORDINATES ARE IN FEET BASED ON THE TEXAS PLANE COORDINATE SYSTEM, SOUTH CENTRAL ZONE, NORTH AMERICAN DATUM (NAD) 1983/2011
4. DATE OF AERIAL PHOTOGRAPHY: APRIL 2018

**Legend:**
- 2019 Survey
  - Landward Toe of Dune
  - 4' Contour
  - MLW
  - MHW
  - Enhanced Construction Zone
- 2017 Survey
  - Landward Toe of Dune
  - 4' Contour
  - MLW
  - MHW
  - Enhanced Construction Zone
- **Dune Conservation Area**
- **Edge of Vegetation**

**Matchline PV-3**

**Matchline PV-1**

**Plot Scale:**
- GRAPHIC SCALE IN U.S. SURVEY FOOT
- 150'-00.00
- 300'-00.00
- 450'-00.00
- 600'-00.00

**Comm. No.:**
- 01

**Submitted by:**
- H. Vollmer
- M. Lowiec

**Reviewed by:**
- M. Lowiec

**Checked by:**
- M. Lowiec

**Designed by:**
- P. Maxwell

**Description:**
- UAS ORTHOIMAGERY
- 2019 APTIM UAS ORTHOIMAGERY

**Date:**
- November 2019

**City of Galveston**

**Galveston Island**

**Gulf of Mexico**
NOTES:
1. DATES OF SURVEY: JULY 9, 2019 - AUGUST 3, 2019
2. COORDINATES ARE IN FEET BASED ON THE TEXAS PLANE COORDINATE SYSTEM.
4. DATE OF AERIAL PHOTOGRAPHY: APRIL 2018
5. DATES OF CONSTRUCTION: JULY 9, 2019 - AUGUST 3, 2019
6. SURVEYED FOR CITY OF GALVESTON, TEXAS
7. SURVEY TAKEN BY M.Lowiec, APTIM ENVIRONMENTAL & INFRASTRUCTURE, LLC
8. DRAWN BY H. Vollmer, APTIM ENVIRONMENTAL & INFRASTRUCTURE, LLC
9. DESIGNED BY M. Lowiec, APTIM ENVIRONMENTAL & INFRASTRUCTURE, LLC
10. CHECKED BY M. Lowiec, APTIM ENVIRONMENTAL & INFRASTRUCTURE, LLC

GALVESTON ISLAND

GULF OF MEXICO
MATCHLINE PV-8

NOTES:
1. DATES OF SURVEY: JULY 9, 2019 - AUGUST 3, 2019
2. COORDINATES ARE IN FEET BASED ON THE TEXAS PLANE COORDINATE SYSTEM, SOUTH CENTRAL ZONE, NORTH AMERICAN DATUM (NAD) 1983/2011
3. ELEVATIONS ARE BASED ON THE NORTH AMERICAN VERTICAL DATUM (NAVD) 1988
4. DATE OF AERIAL PHOTOGRAPHY: APRIL 2018
NOTES:
1. DATES OF SURVEY: JULY 9, 2019 - AUGUST 3, 2019
2. COORDINATES ARE IN FEET BASED ON THE TEXAS PLANE COORDINATE SYSTEM, SOUTH CENTRAL ZONE, NORTH AMERICAN DATUM (NAD) 1983/2011
3. ELEVATIONS ARE BASED ON THE NORTH AMERICAN VERTICAL DATUM (NAVD) 1988
4. DATE OF AERIAL PHOTOGRAPHY: APRIL 2018

LEGEND:
- Landward Toe of Dune
- Seaward Toe of Dune
- MHW
- Enhanced Construction Zone
- MLW
- Dune Conservation Area
- Edge of Vegetation

DRAWING NO. PV-8
Sheet 10 of 35

PLAN VIEW

CITY OF GALVESTON
2019 BEACH PROFILE SURVEY

GALVESTON ISLAND

GULF OF MEXICO
**Legend:**

- **2019 Survey**
  - 4' Contour
  - MHW
  - MLW
  - Edge of Vegetation
- **2017 Survey**
  - 4' Contour
  - MHW
  - MLW
  - Enhanced Construction Zone
  - Dune Conservation Area

**NOTES:**

1. **DATES OF SURVEY:** JULY 9, 2019 - AUGUST 3, 2019
3. **DATES OF AERIAL PHOTOGRAPHY: APRIL 2018**

**CITY OF GALVESTON**

**2019 BEACH PROFILE SURVEY**

**PLAN VIEW**

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**GALVESTON ISLAND**

**MATCHLINE:**

- PV-10
- PV-15
- PV-20
- PV-25
- PV-30
- PV-35
- PV-40
- PV-45
- PV-50
- PV-55
- PV-60
- PV-65
- PV-70
- PV-75
- PV-80
- PV-85
- PV-90
- PV-95
- PV-100
- PV-105
- PV-110
- PV-115
- PV-120
- PV-125
- PV-130
- PV-135
- PV-140
- PV-145
- PV-150

---

**MATCHLINE LEGEND:**

- **Landward Toe of Dune**
- **Seaward Toe of Dune**
- **Enhanced Construction Zone**
- **Dune Conservation Area**
- **Edge of Vegetation**

---

**GRAPHIC SCALE:**

- *U.S. SURVEY FEET*

---

**DOCUMENT PATH:** G:\Enterprise\Texas\6311142521_Galveston_Beach_Monitoring\mxd\PV-1toPV-39_Bottom Legend.mxd

**Sheet 11 of 35**
**Legend:**

- **2019 Survey**
  - 4' Contour
  - MLW
  - Edge of Vegetation
  - Enhanced Construction Zone
  - Seaward Toe of Dune
  - Landward Toe of Dune
- **2017 Survey**
  - 4' Contour
  - MLW
  - Edge of Vegetation
  - Enhanced Construction Zone
  - Seaward Toe of Dune
  - Landward Toe of Dune

**NOTES:**

1. **DATES OF SURVEY:** JULY 9, 2019 - AUGUST 3, 2019
2. **COORDINATES ARE IN FEET BASED ON THE TEXAS PLANE COORDINATE SYSTEM,**
3. **ELEVATIONS ARE BASED ON THE NORTH AMERICAN VERTICAL DATUM (NAVD) 1988.**
4. **DATE OF AERIAL PHOTOGRAPHY:** APRIL 2018
5. **Dune Conservation Area**
6. **Enhanced Construction Zone**

**Legend:**

- **77TH ST**
- **PV-33**
- **MLW**
- **4' Contour**

**Matchline PV-9**

**Matchline PV-11**

**GALVESTON ISLAND**

**GULF OF MEXICO**

**2019 BEACH PROFILE SURVEY**

**CITY OF GALVESTON**

**PLAN VIEW**

**GRAPHIC SCALE IN U.S. SURVEY FEET**

**Drawing by:** H. Vollmer

**Drawn by:** M. Lowiec

**Designed by:** P. Maxwell

**Submitted by:** M. Lowiec

**Reviewed by:** M. Lowiec

**Checked by:** M. Lowiec

**Comm. No.:** 631226097

**Galveston, Galveston County, Texas, December 2019**

**ENVIRONMENTAL & INFRASTRUCTURE, LLC**

**BOCA RATON, FL 33431**

**2481 N. W. BOCA RATON BOULEVARD**

**PH. (561) 391-8102**

**FAX (561) 391-9116**
NOTES:

1. DATES OF SURVEY: JULY 9, 2019 - AUGUST 3, 2019
2. COORDINATES ARE IN FEET BASED ON THE TEXAS PLANE COORDINATE SYSTEM, SOUTH CENTRAL ZONE, NORTH AMERICAN DATUM (NAD) 1983/2011.
4. DATE OF AERIAL PHOTOGRAPHY: APRIL 2018

GALVESTON ISLAND

PV-11
Sheet 13 of 35
NOTES:
1. DATES OF SURVEY: JULY 9, 2019 - AUGUST 3, 2019
2. COORDINATES ARE IN FEET BASED ON THE TEXAS PLANE COORDINATE SYSTEM, SOUTH CENTRAL ZONE, NORTH AMERICAN DATUM (NAD) 1983/2011.
4. DATE OF AERIAL PHOTOGRAPHY: APRIL 2018

Checked by: M. Lowiec
Reviewed by: M. Lowiec
Submitted by: P. Maxwell
Comm. No.: 631226097

Designed by: M. Lowiec
Drawn by: H. Vollmer
Date: November 2019
Plot Scale: AS NOTED

CITY OF GALVESTON
2019 BEACH PROFILE SURVEY
PLAN VIEW

GALVESTON ISLAND

GULF OF MEXICO
Legend:
- 2019 Survey
  - 4' Contour
  - MHW
  - Elevated Vegetation
- 2017 Survey
  - 4' Contour
  - Seaward Toe of Dune
  - MHW
  - Elevated Vegetation

**NOTES:**
1. DATES OF SURVEY: JULY 9, 2019 - AUGUST 3, 2019
2. COORDINATES ARE IN FEET BASED ON THE TEXAS PLANE COORDINATE SYSTEM, SOUTH-CENTRAL ZONE, NORTH AMERICAN DATUM (NAD) 1983/2011.
4. DATE OF AERIAL PHOTOGRAPHY: APRIL 2018

**DRAWING NO.:**
Landward Toe of Dune

**DATE OF AERIAL PHOTOGRAPHY: APRIL 2018**

**COORDINATES ARE IN FEET BASED ON THE TEXAS PLANE COORDINATE SYSTEM, SOUTH-CENTRAL ZONE, NORTH AMERICAN DATUM (NAD) 1983/2011.**
NOTES:
1. DATES OF SURVEY: JULY 9, 2019 - AUGUST 3, 2019
2. COORDINATES ARE IN FEET BASED ON THE TEXAS PLANE COORDINATE SYSTEM, SOUTH CENTRAL ZONE, NORTH AMERICAN DATUM (NAD) 1983/2011.
4. DATE OF AERIAL PHOTOGRAPHY: APRIL 2018
NOTES:
1. DATES OF SURVEY: JULY 9, 2019 - AUGUST 3, 2019
2. COORDINATES ARE IN FEET BASED ON THE TEXAS PLANE COORDINATE SYSTEM, SOUTH CENTRAL ZONE, NORTH AMERICAN DATUM (NAD), 1983/2011.
4. DATE OF AERIAL PHOTOGRAPHY: APRIL 2018

CITY OF GALVESTON
2019 BEACH PROFILE SURVEY
PLAN VIEW

GALVESTON ISLAND

Legend:
- Landward Toe of Dune
- Seaward Toe of Dune
- MHW
- MLW
- 4' Contour
- Enhanced Construction Zone
- Dune Conservation Area
- Edge of Vegetation

GULF OF MEXICO

DRAWING NO. 631226097
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APTIM
ENVIRONMENTAL & INFRASTRUCTURE, LLC
205 N. W. BEACON RD
BOCA RATON, FL 33431
PH: (561) 391-8102
FAX: (561) 391-9116

Document Path: G:\Enterprise\Texas\6311142521_Galveston_Beach_Monitoring\mxd\PV-1toPV-39_Bottom Legend.mxd
NOTES:
1. DATES OF SURVEY: JULY 9, 2019 - AUGUST 3, 2019
2. COORDINATES ARE IN FEET BASED ON THE TEXAS PLANE COORDINATE SYSTEM, SOUTH CENTRAL ZONE, NORTH AMERICAN DATUM (NAD) 1983/2011.
4. DATE OF AERIAL PHOTOGRAPHY: APRIL 2018

GALVESTON ISLAND

GULF OF MEXICO

2019 Survey
- 4' Contour
- MHW
- MLW
- Edge of Vegetation
- Landward Toe of Dune
- Seaward Toe of Dune
- Enhanced Construction Zone
- Dune Conservation Area

2017 Survey
- 4' Contour
- MHW
- MLW
- Edge of Vegetation
- Landward Toe of Dune
- Seaward Toe of Dune
- Enhanced Construction Zone
- Dune Conservation Area

Legend:

MATCHLINE PV-20
MATCHLINE PV-22

DRAWING NO.
Sheet 23 of 35

CITY OF GALVESTON
2019 BEACH PROFILE SURVEY
PLAN VIEW

ARC GIS VERSION 10.0 03/10/2011

APTIM
ENVIRONMENTAL & INFRASTRUCTURE, LLC
205 N. W. BEACH AMERICAN BOULEVARD
BOCA RATON, FL 33431

PH. (561) 391-8102
FAX (561) 391-9116
NOTES:
1. DATES OF SURVEY: JULY 9, 2019 - AUGUST 3, 2019
2. COORDINATES ARE IN FEET BASED ON THE TEXAS PLANE COORDINATE SYSTEM, SOUTH CENTRAL ZONE, NORTH AMERICAN DATUM (NAD) 1983/2011.
4. DATE OF AERIAL PHOTOGRAPHY: APRIL 2018
NOTES:
1. DATES OF SURVEY: JULY 9, 2019 - AUGUST 3, 2019
2. COORDINATES ARE IN FEET BASED ON THE TEXAS PLANE COORDINATE SYSTEM.
   SOUTH CENTRAL ZONE, NORTH AMERICAN DATUM (NAD) 1983/2011
4. DATE OF AERIAL PHOTOGRAPH: APRIL, 2018

GALVESTON ISLAND
Note:
2019 surveys extended to the landward toe of the primary dune observed by surveyors in the field. The survey did not encompass the entirety of the "dune" as defined by the Dune Protection and Beach Access Plan. Therefore the Landward Toe of Dune, Enhanced Construction Zone, and Dune Conservation Areas, were not mapped along the project area south of Station 680+00.
Note:
2019 surveys extended to the landward toe of the primary dune observed by surveyors in the field. The survey did not encompass the entirety of the "dune" as defined by the Dune Protection and Beach Access Plan. Therefore the Landward Toe of Dune, Enhanced Construction Zone, and Dune Conservation Areas, were not mapped along the project area south of Station 680+00.

Legend:
- 2019 Survey
  - 4' Contour
  - MHW
  - MLW
  - Dune Conservation Area
  - Edge of Vegetation
- 2017 Survey
  - 4' Contour
  - MHW
  - MLW
  - Dune Conservation Area
  - Edge of Vegetation

Notice:
- Beach Access Plan. Therefore the Landward Toe of Dune, Enhanced Construction Zone, and Dune Conservation Areas, were not mapped along the project area south of Station 680+00.
Note:
2019 surveys extended to the landward toe of the primary dune observed by surveyors in the field. The survey did not encompass the entirety of the "dune" as defined by the Dune Protection and Beach Access Plan. Therefore the Landward Toe of Dune, Enhanced Construction Zone, and Dune Conservation Areas, were not mapped along the project area south of Station 680+00.

Legend:
- Landward Toe of Dune
- Seaward Toe of Dune
- Enhanced Construction Zone
- Dune Conservation Area
- Edge of Vegetation
- MHW
- MLW
- 4' Contour

ELEVATIONS ARE BASED ON THE NORTH AMERICAN VERTICAL DATUM (NAVD) 1988.
SOUTH CENTRAL ZONE, NORTH AMERICAN DATUM (NAD) 1983/2011.
COORDINATES ARE IN FEET BASED ON THE TEXAS PLANE COORDINATE SYSTEM, SAN LUIS PASS RD.
APPENDIX 1:
CONTROL MONUMENT INFORMATION
CONTROL MONUMENT USED BY APTIM
FOR 2019 GALVESTON ISLAND HYDROGRAPHIC AND TOPOGRAPHIC
SURVEY REPORT
AUGUST 2019

DATUMS: NAD83/11 - NAVD88

Designation: E 168
Stamping: E 168 1936 ELEV. 15.502 FT.
Northing: 13676792.23
Easting: 3310374.27
Horizontal Root Mean Square Error: 0.114
Elevation: 14.436
Vertical Root Mean Square Error: 0.045

Description:
At Galveston, about 114 yards southwest of the junction of Seawall Boulevard and 23rd Street North, across the boulevard from Playland Park, in the top of the center of the concrete seawall, in line with the center of a rock bracker, 17.8 feet southeast of the southeast curb of the boulevard, 27.8 feet southwest of the south corner of a concrete block planter with two palm trees, 69.5 feet northeast of the northeast end of a concrete bench, 3.1 feet north of the northwest end of a pipe handrail along steps leading to the beach, and about 1 foot higher than the boulevard.

Monument: E 168
Location Verification: E 168

<table>
<thead>
<tr>
<th>Monument</th>
<th>No. of Shots</th>
<th>ΔN</th>
<th>ΔE</th>
<th>ΔZ</th>
</tr>
</thead>
<tbody>
<tr>
<td>E 168</td>
<td>31</td>
<td>0.03</td>
<td>0.05</td>
<td>0.04</td>
</tr>
</tbody>
</table>
### CONTROL MONUMENT USED BY APTIM FOR 2019 GALVESTON ISLAND HYDROGRAPHIC AND TOPOGRAPHIC SURVEY REPORT

**AUGUST 2019**

<table>
<thead>
<tr>
<th>DATUMS: NAD83/11 - NAVD88</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Designation</strong></td>
</tr>
<tr>
<td><strong>Stamping</strong></td>
</tr>
<tr>
<td><strong>Northing</strong></td>
</tr>
<tr>
<td><strong>Easting</strong></td>
</tr>
<tr>
<td><strong>Horizontal Root Mean Square Error</strong></td>
</tr>
<tr>
<td><strong>Elevation</strong></td>
</tr>
<tr>
<td><strong>Vertical Root Mean Square Error</strong></td>
</tr>
</tbody>
</table>

**Description**

At Galveston, at the junction of Seawall Boulevard and Buttcrone (61st Street), in the top of the seawall, 11.9 feet southeast of the southeast curb of the boulevard, 2.5 feet west of the corner of county plaque, 95 feet east of the extended center line of the street, 94.3 feet northeast of the northeast edge of concrete steps leading down to the beach, and about ½ foot lower than the boulevard.

<table>
<thead>
<tr>
<th>Monument</th>
<th>No. of Shots</th>
<th>∆N</th>
<th>∆E</th>
<th>∆Z</th>
</tr>
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<tbody>
<tr>
<td>H 168</td>
<td>21</td>
<td>-0.36</td>
<td>-0.43</td>
<td>0.19</td>
</tr>
</tbody>
</table>
CONTROL MONUMENT USED BY APTIM FOR 2019 GALVESTON ISLAND TOPOGRAPHIC AND HYDROGRAPHIC SURVEY REPORT AUGUST 2019

DATUMS: NAD83/11 - NAVD88

<table>
<thead>
<tr>
<th>Designation</th>
<th>NASS RM 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stamping</td>
<td>NASS NO 1 1933 1978</td>
</tr>
<tr>
<td>Northing</td>
<td>13659075.36</td>
</tr>
<tr>
<td>Easting</td>
<td>3281657.80</td>
</tr>
<tr>
<td>Horizontal Root Mean Square Error</td>
<td>0.162</td>
</tr>
<tr>
<td>Elevation</td>
<td>4.06</td>
</tr>
<tr>
<td>Vertical Root Mean Square Error</td>
<td>0.079</td>
</tr>
<tr>
<td>Description</td>
<td>2.1 miles southwest along Stewart Road from the junction of 89th Street in Galveston, 64 Feet west of the centerline of Stewart Road, 85 feet north of a power line pole, 1 foot east of a fence line, about 0.15 mile south of the extended centerline of 7 ½ Mile Road.</td>
</tr>
</tbody>
</table>

Monument: NASS RM 1

Location verification: NASS RM 1

<table>
<thead>
<tr>
<th>Monument</th>
<th>No. of Shots</th>
<th>∆N</th>
<th>∆E</th>
<th>∆Z</th>
</tr>
</thead>
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<tr>
<td>NASS RM 1</td>
<td>26</td>
<td>0.11</td>
<td>0.06</td>
<td>0.06</td>
</tr>
</tbody>
</table>
CONTROL MONUMENT USED BY APTIM
FOR 2019 GALVESTON ISLAND TOPOGRAPHIC AND HYDROGRAPHIC
SURVEY REPORT
AUGUST 2019

DATUMS: NAD83/11 - NAVD88

<table>
<thead>
<tr>
<th>Designation</th>
<th>877 1510 TIDAL 44</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stamping</td>
<td>NO 44 1957</td>
</tr>
<tr>
<td>Northing</td>
<td>13676511.34</td>
</tr>
<tr>
<td>Easting</td>
<td>3310080.48</td>
</tr>
<tr>
<td>Horizontal Root Mean Square Error</td>
<td>0.175</td>
</tr>
<tr>
<td>Elevation</td>
<td>14.37</td>
</tr>
<tr>
<td>Vertical Root Mean Square Error</td>
<td>0.070</td>
</tr>
</tbody>
</table>

Description
At Galveston, at the junction of Seawall Boulevard and Rosenberg Avenue (25th Street) North, in the top of the center of the concrete seawall, 2.3 Feet north of the northwest corner of a chain link fence around the Flagship Motor Hotel, 10 feet southwest of the center line of a concrete ramp leading down to the beach, 2.9 feet northwest of the extended concrete curb of the ramp leading up along the northeast side of the Flagship Motor Hotel pier, and about 2 feet higher than the boulevard.

Monument: Tidal 44
Location Verification: Tidal 44

<p>| Mean of Inverse Shots - Published Versus CPE Found |
|---------------------------------|-----|-----|-----|</p>
<table>
<thead>
<tr>
<th>Monument</th>
<th>No. of Shots</th>
<th>∆N</th>
<th>∆E</th>
<th>∆Z</th>
</tr>
</thead>
<tbody>
<tr>
<td>877 1510 TIDAL 44</td>
<td>6</td>
<td>-0.02</td>
<td>-0.02</td>
<td>0.06</td>
</tr>
</tbody>
</table>
### CONTROL MONUMENT USED BY APTIM
FOR 2019 GALVESTON ISLAND TOPOGRAPHIC AND HYDROGRAPHIC
SURVEY REPORT
AUGUST 2019

<table>
<thead>
<tr>
<th>DATUMS: NAD83/11 - NAVD88</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Designation</strong></td>
</tr>
<tr>
<td><strong>Stamping</strong></td>
</tr>
<tr>
<td><strong>Northing</strong></td>
</tr>
<tr>
<td><strong>Easting</strong></td>
</tr>
<tr>
<td><strong>Horizontal Root Mean Square Error</strong></td>
</tr>
<tr>
<td><strong>Elevation</strong></td>
</tr>
<tr>
<td><strong>Vertical Root Mean Square Error</strong></td>
</tr>
</tbody>
</table>

**Description**
In Galveston, set in the top of the seawall near the junction of Seawall Boulevard and 18th Street, 49.3 feet southeast of the center line of Seawall Boulevard, 24.1 feet southwest of the southwest corner of a planter with two palm trees and 2.6 feet northwest of the seaward side of the seawall.

### Mean of Inverse Shots - Published Versus CPE Found

<table>
<thead>
<tr>
<th>Monument</th>
<th>No. of Shots</th>
<th>ΔN</th>
<th>ΔE</th>
<th>ΔZ</th>
</tr>
</thead>
<tbody>
<tr>
<td>877 1510 TIDAL 46</td>
<td>15</td>
<td>-0.03</td>
<td>0.03</td>
<td>0.04</td>
</tr>
</tbody>
</table>

Monument: Tidal 46
Location Verification: Tidal 46
## CONTROL MONUMENT USED BY APTIM FOR 2019 GALVESTON ISLAND TOPOGRAPHIC AND HYDROGRAPHIC SURVEY REPORT AUGUST 2019

**DATUMS:** NAD83/11 - NAVD88

<table>
<thead>
<tr>
<th>Designation</th>
<th>MOTTO</th>
</tr>
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<tbody>
<tr>
<td>Stamping</td>
<td>MOTTO 1933</td>
</tr>
<tr>
<td>Northing</td>
<td>13603049.05</td>
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<tr>
<td>Easting</td>
<td>3210150.27</td>
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<tr>
<td>Horizontal Root Mean Square Error</td>
<td>0.116</td>
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<tr>
<td>Elevation</td>
<td>3.38</td>
</tr>
<tr>
<td>Vertical Root Mean Square Error</td>
<td>0.169</td>
</tr>
</tbody>
</table>

### Description
Station is located on the southwest end of Galveston Island, about 2-1/2 miles southwest of San Luis Coast Guard Station, and about 0.3 mile from the extreme end of the island. It is 80 meters ESE of the West Bay Shore, 30.5 meters NE of fence line leading NE and SW, 10 meters east from center line of road running along the shore, and 346 meters SE of Windmill NE of Gasper Amatos House. Surface, underground, and reference marks are bronze disks set in concrete.

### Mean of Inverse Shots - Published Versus CPE Found

<table>
<thead>
<tr>
<th>Monument</th>
<th>No. of Shots</th>
<th>ΔN</th>
<th>ΔE</th>
<th>ΔZ</th>
</tr>
</thead>
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<tr>
<td>MOTTO</td>
<td>10</td>
<td>-0.07</td>
<td>0.04</td>
<td>-0.17</td>
</tr>
</tbody>
</table>
CONTROL MONUMENT USED BY APTIM FOR 2019 GALVESTON ISLAND TOPOGRAPHIC AND HYDROGRAPHIC SURVEY REPORT AUGUST 2019

<table>
<thead>
<tr>
<th>DATUMS: NAD83/11 - NAVD88</th>
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<tr>
<td>Designation</td>
</tr>
<tr>
<td>Stamping</td>
</tr>
<tr>
<td>Northing</td>
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<tr>
<td>Easting</td>
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<tr>
<td>Horizontal Root Mean Square Error</td>
</tr>
<tr>
<td>Elevation</td>
</tr>
<tr>
<td>Vertical Root Mean Square Error</td>
</tr>
</tbody>
</table>

Description:
10.9 miles SW from Jamaica Beach. 10.9 miles SW along FM 3005 (San Luis Pass Road) from the junction of Buccaneer Drive in the small village of Jamaica Beach to the toll booth at the NE end of the San Luis Pass bridge, 17 feet NW of the centerline of FM 3005, 67 feet north of the NW corner of the toll booth, 2 feet SE of a San Luis Pass Vacek bridge County of Galveston Plaque which is attached to the bride handrail, set in the NW curb at the NE end of the bridge.

Monument: W 1237
Location Verification: W 1237

<table>
<thead>
<tr>
<th>Mean of Inverse Shots - Published Versus CPE Found</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monument</td>
</tr>
<tr>
<td>----------</td>
</tr>
<tr>
<td>W 1237</td>
</tr>
</tbody>
</table>
#CONTROL MONUMENT USED BY APTIM FOR 2019 GALVESTON ISLAND TOPGRAPHIC AND HYDROGRAPHIC SURVEY REPORT AUGUST 2019

<table>
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<tr>
<th>DATUMS: NAD83/11 - NAVD88</th>
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<tbody>
<tr>
<td><strong>Designation</strong></td>
</tr>
<tr>
<td><strong>Stamping</strong></td>
</tr>
<tr>
<td><strong>Northing</strong></td>
</tr>
<tr>
<td><strong>Easting</strong></td>
</tr>
<tr>
<td><strong>Horizontal Root Mean Square Error</strong></td>
</tr>
<tr>
<td><strong>Elevation</strong></td>
</tr>
<tr>
<td><strong>Vertical Root Mean Square Error</strong></td>
</tr>
</tbody>
</table>

**Description**: 4.3 miles SW from Jamaica Beach. 4.2 miles SW along FM 3005 (San Luis Pass Road) from the junction of Buccaneer Drive in the small village of Jamaica Beach, at the junction of a road leaning NW. 6.6 miles NE along FM 3005 from the toll booth at San Luis Pass bridge (north end), 60 feet NW of FM 3005, 36 feet south of the south corner of a cattle guard, 13 feet W of a power line pole, 1 foot SE of a fence line.

| Monument: T 1237 | Location Verification: T 1237 |

<table>
<thead>
<tr>
<th>Mean of Inverse Shots - Published Versus CPE Found</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monument</td>
</tr>
<tr>
<td>----------</td>
</tr>
<tr>
<td>T 1237</td>
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</table>
CONTROL MONUMENT USED BY APTIM FOR 2019 GALVESTON ISLAND TOPGRAPHIC AND HYDROGRAPHIC SURVEY REPORT AUGUST 2019

<table>
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<th>DATUMS:</th>
<th>NAD83/11 - NAVD88</th>
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<tbody>
<tr>
<td>Designation</td>
<td>HGCSD 61 – HORIZONTAL ONLY</td>
</tr>
<tr>
<td>Stamping</td>
<td>HGCSD 61 1986</td>
</tr>
<tr>
<td>Northing</td>
<td>13602086.97</td>
</tr>
<tr>
<td>Easting</td>
<td>3210358.58</td>
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<tr>
<td>Horizontal Root Mean Square Error</td>
<td>0.117</td>
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<tr>
<td>Elevation</td>
<td>5.6</td>
</tr>
<tr>
<td>Vertical Root Mean Square Error</td>
<td>N/A</td>
</tr>
</tbody>
</table>

**Description**: 10.95 miles SW from Jamaica Beach. The mark is above level with the road. 10.95 miles SW along Farm Road 3005 from its junction with Buccaneer Drive in Jamaica Beach, 0.05 miles NE of the NE end of the San Luis Pass Bridge, 40.4 feet NW of the center of the road, 154.9 feet NE of the NE end of a metal guard rail leading to the bridge, and 25 feet SE of the center of a road leading under the bridge. Access to datum point is had through a 5 inch logo cap. The mark is 0.6 meter W from a witness post.

| Monument: HGCSD 61 | Location Verification: HGCSD 61 |

| Mean of Inverse Shots - Published Versus CPE Found |
|------------------|------------------|---|---|---|
| Monument       | No. of Shots | ∆N | ∆E | ∆Z |
| HGCSD 61       | 4            | -0.03 | 0.02 | N/A |
## CONTROL MONUMENT USED BY APTIM FOR 2019 GALVESTON ISLAND TOPOGRAPHIC AND HYDROGRAPHIC SURVEY REPORT

### AUGUST 2019

**DATUMS:** NAD83/11 - NAVD88

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<tr>
<th>Designation</th>
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<td>Elevation</td>
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<tr>
<td>Vertical Root Mean Square Error</td>
<td>0.097</td>
</tr>
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</table>

### Description
12.05 miles SW from Galveston. 6.15 miles SW along Seawall Boulevard from Moody Center in Galveston, 5.15 miles SW along Farm Market Road 3005, or 2.8 miles NE along Farm Market road 3005 from its junction with Buccaneer Drive in Jamaica beach, 200.1 feet SW of the centerline of the drive, 52.2 feet N-NW of the centerline of the SW bound lands of the road, 47.2 feet SE of the SE face of a retaining wall for a small parking lot, 29.9 feet SW of the center of the NE entrance to the MRC Realty Office, and 12.1 feet SW of the NW corner of the concrete foundation of a US mail pickup box. Access to Datum point is had through a 5 inch logo cap. The mark is above level with the highway.

### Mean of Inverse Shots - Published Versus CPE Found

<table>
<thead>
<tr>
<th>Monument</th>
<th>No. of Shots</th>
<th>ΔN</th>
<th>ΔE</th>
<th>ΔZ</th>
</tr>
</thead>
<tbody>
<tr>
<td>62</td>
<td>25</td>
<td>0.06</td>
<td>0.09</td>
<td>-0.07</td>
</tr>
</tbody>
</table>
CONTROL MONUMENT USED BY APTIM
FOR 2019 GALVESTON ISLAND TOPOGRAPHIC AND HYDROGRAPHIC SURVEY
REPORT
AUGUST 2019

DATUMS: NAD83/11 - NAVD88

Designation | G 460 RESET
Stamping | G 460 RESET 1955
Northing | 13621154.13
Easting | 3233204.29
Horizontal Root Mean Square Error | 0.186
Elevation | 8.75
Vertical Root Mean Square Error | 0.059

Description
18.1 miles SW from Galveston. 2.8 miles SW along Seawall Boulevard from the Buccaneer Hotel at Galveston, 15.3 miles SW along the beach, 0.15 miles SW of a windmill, 254 feet NW of the storm tide water line, 15 feet NE of the center line of a gate and a dim trail, 2 feet SE of a fence, 2 feet SW of a witness post, set in the top of a concrete post which projects 0.4 feet above the ground.

Monument: G460 RESET
Location Verification: G460 RESET

<table>
<thead>
<tr>
<th>Monument</th>
<th>No. of Shots</th>
<th>∆N</th>
<th>∆E</th>
<th>∆Z</th>
</tr>
</thead>
<tbody>
<tr>
<td>G 460 RESET</td>
<td>8</td>
<td>0.08</td>
<td>0.07</td>
<td>0.05</td>
</tr>
</tbody>
</table>
## CONTROL MONUMENT USED BY APTIM FOR 2019 GALVESTON ISLAND TOPOGRAPHIC AND HYDROGRAPHIC SURVEY REPORT
### AUGUST 2019

<table>
<thead>
<tr>
<th>DATUMS: NAD83/11 - NAVD88</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Designation</strong></td>
</tr>
<tr>
<td><strong>Stamping</strong></td>
</tr>
<tr>
<td><strong>Northing</strong></td>
</tr>
<tr>
<td><strong>Easting</strong></td>
</tr>
<tr>
<td><strong>Horizontal Root Mean Square Error</strong></td>
</tr>
<tr>
<td><strong>Elevation</strong></td>
</tr>
<tr>
<td><strong>Vertical Root Mean Square Error</strong></td>
</tr>
</tbody>
</table>

### Description
At Galveston, about 0.6 miles SW along Seawall Boulevard from the junction of 61st street, about 14 yards SW of the prolongation of the center line of 69 Street, 52 feet SE of the center line of the boulevard, 29.5 feet southwest of a concrete stairway leading down to the beach, and about level with the boulevard.

### Mean of Inverse Shots - Published Versus CPE Found

<table>
<thead>
<tr>
<th>Monument</th>
<th>No. of Shots</th>
<th>ΔN</th>
<th>ΔE</th>
<th>ΔZ</th>
</tr>
</thead>
<tbody>
<tr>
<td>30+00</td>
<td>6</td>
<td>N/A</td>
<td>N/A</td>
<td>0.09</td>
</tr>
</tbody>
</table>
CONTROL MONUMENT USED BY APTIM
FOR 2019 GALVESTON ISLAND TOPGRAPHIC AND HYDROGRAPHIC SURVEY
REPORT
AUGUST 2019

DATUMS: NAD83/11 - NAVD88

<table>
<thead>
<tr>
<th>Designation</th>
<th>74+0.945</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stamping</td>
<td>74+0.945</td>
</tr>
<tr>
<td>Northing</td>
<td>13664001.48</td>
</tr>
<tr>
<td>Easting</td>
<td>3292879.48</td>
</tr>
<tr>
<td>Horizontal Root Mean Square Error</td>
<td>0.724</td>
</tr>
<tr>
<td>Elevation</td>
<td>15.11</td>
</tr>
<tr>
<td>Vertical Root Mean Square Error</td>
<td>0.077</td>
</tr>
</tbody>
</table>

Description: 4.35 miles SW from Galveston. About 4.35 miles SW along Seawall Boulevard from the Moody Center at Galveston, about 50 yards SW of 81st Street, 52 fee SE of the center line of the boulevard, 118 ½ feet NE of bench mark 75+28, set in the center of the top of a 3-foot wide sea wall, and about level with the boulevard.

Monument: 74+09.45
Location Verification: 74+09.45

<table>
<thead>
<tr>
<th>Mean of Inverse Shots - Published Versus CPE Found</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monument</td>
</tr>
<tr>
<td>-----------</td>
</tr>
<tr>
<td>74+0.945</td>
</tr>
</tbody>
</table>
CONTROL MONUMENT USED BY APTIM
FOR 2019 GALVESTON ISLAND TOPGRAPHIC AND HYDROGRAPHIC SURVEY
REPORT
AUGUST 2019

DATUMS: NAD83/11 - NAVD88

<table>
<thead>
<tr>
<th>Designation</th>
<th>Wall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stamping</td>
<td>Wall 1933 Elev. 15.279 Ft.</td>
</tr>
<tr>
<td>Northing</td>
<td>13680085.77</td>
</tr>
<tr>
<td>Easting</td>
<td>3313815.445</td>
</tr>
<tr>
<td>Horizontal Root Mean Square Error</td>
<td>0.158</td>
</tr>
<tr>
<td>Elevation</td>
<td>14.268</td>
</tr>
<tr>
<td>Vertical Root Mean Square Error</td>
<td>0.035</td>
</tr>
<tr>
<td>Description</td>
<td>At Galveston, Between Twelfth and Thirteenth Streets, directly opposite the SW outdoor advertising building, at an angle in the sea wall, 1.03 meters from the SE edge, and 0.73 meter SW of a P.I. marker of the wall. The marker is an iron bolt with cross, ½ inch above the surface of the wall.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Monument</th>
<th>No. of Shots</th>
<th>∆N</th>
<th>∆E</th>
<th>∆Z</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wall</td>
<td>2</td>
<td>0.12</td>
<td>-0.10</td>
<td>-0.03</td>
</tr>
</tbody>
</table>
## CONTROL MONUMENT USED BY APTIM FOR 2019 GALVESTON ISLAND TOPOGRAPHIC AND HYDROGRAPHIC SURVEY REPORT

**AUGUST 2019**

**DATUMS:** NAD83/11 - NAVD88

<table>
<thead>
<tr>
<th>Designation</th>
<th>SAN RM 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stamping</td>
<td>ELEV 15.282 FT SAN 1933 NO 2</td>
</tr>
<tr>
<td>Northing</td>
<td>13686408.40</td>
</tr>
<tr>
<td>Easting</td>
<td>3318018.867</td>
</tr>
<tr>
<td>Horizontal Root Mean Square Error</td>
<td>0.116</td>
</tr>
<tr>
<td>Elevation</td>
<td>14.193</td>
</tr>
<tr>
<td>Vertical Root Mean Square Error</td>
<td>0.022</td>
</tr>
</tbody>
</table>

**Description:**

About 2.2 miles NE along Sea Wall Boulevard from the Moody Center at Galveston, 37 feet SE of the center line of the Boulevard, 96 ½ feet SE of SAN 1933, 10 feet NW of the SE edge of the sea wall, and set in the center of the top of a concrete sidewalk.

<table>
<thead>
<tr>
<th>Monument</th>
<th>No. of Shots</th>
<th>∆N</th>
<th>∆E</th>
<th>∆Z</th>
</tr>
</thead>
<tbody>
<tr>
<td>SAN RM 2</td>
<td>2</td>
<td>0.04</td>
<td>-0.11</td>
<td>-0.02</td>
</tr>
</tbody>
</table>

Monument: SAN RM 2

Location Verification: SAN RM 2

Mean of Inverse Shots - Published Versus CPE Found

No Image

No Image
CONTROL MONUMENT USED BY APTIM
FOR 2019 GALVESTON ISLAND TOPGRAPHIC AND HYDROGRAPHIC SURVEY
REPORT
AUGUST 2019

DATUMS: NAD83/11 - NAVD88

<table>
<thead>
<tr>
<th>Designation</th>
<th>Buss TBM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stamping</td>
<td>CPE</td>
</tr>
<tr>
<td>Northing</td>
<td>13692236.73</td>
</tr>
<tr>
<td>Easting</td>
<td>3326505.575</td>
</tr>
<tr>
<td>Horizontal Root Mean Square Error</td>
<td>0.206</td>
</tr>
<tr>
<td>Elevation</td>
<td>6.811</td>
</tr>
<tr>
<td>Vertical Root Mean Square Error</td>
<td>0.032</td>
</tr>
</tbody>
</table>

Description

Buss TBM was set on the far eastern side of Galveston Island. It was hammered into asphalt in a parking area within Apffel Park. To reach the location you drive south along Boddeker Rd and take the first right turn before you reach East Beach Park.

<table>
<thead>
<tr>
<th>Monument</th>
<th>No. of Shots</th>
<th>ΔN</th>
<th>ΔE</th>
<th>ΔZ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buss_TBM</td>
<td>16</td>
<td>0.06</td>
<td>0.10</td>
<td>0.00</td>
</tr>
</tbody>
</table>

Monument: Buss TBM

Location Verification: Buss TBM
CONTROL MONUMENT USED BY APTIM
FOR 2019 GALVESTON ISLAND TOPOGRAPHIC AND HYDROGRAPHIC SURVEY
REPORT
AUGUST 2019

DATUMS: NAD83/11 - NAVD88

<table>
<thead>
<tr>
<th>Designation</th>
<th>Ritt TBM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stamping</td>
<td>CPE</td>
</tr>
<tr>
<td>Northing</td>
<td>13619265.07</td>
</tr>
<tr>
<td>Easting</td>
<td>3231490.518</td>
</tr>
<tr>
<td>Horizontal Root Mean Square Error</td>
<td>0.140</td>
</tr>
<tr>
<td>Elevation</td>
<td>5.914</td>
</tr>
<tr>
<td>Vertical Root Mean Square Error</td>
<td>0.044</td>
</tr>
<tr>
<td>Description</td>
<td>Ritt TBM is an iron rod and cap hammered into the dunes on Galveston island. It is east of Galveston Island State Park, and past the western end of the seawall.</td>
</tr>
</tbody>
</table>

Monument: Ritt TBM
Location Verification: Ritt TBM

<table>
<thead>
<tr>
<th>Mean of Inverse Shots - Published Versus CPE Found</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monument</td>
</tr>
<tr>
<td>Ritt_TBM</td>
</tr>
</tbody>
</table>
CONTROL MONUMENT USED BY APTIM FOR 2019 GALVESTON ISLAND TOPOGRAPHIC AND HYDROGRAPHIC SURVEY REPORT
AUGUST 2019

**DATUMS:** NAD83/11 - NAVD88

<table>
<thead>
<tr>
<th><strong>Designation</strong></th>
<th>Shahan TBM</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Stamping</strong></td>
<td>CPE</td>
</tr>
<tr>
<td><strong>Northing</strong></td>
<td>13677393.27</td>
</tr>
<tr>
<td><strong>Easting</strong></td>
<td>3311048.601</td>
</tr>
<tr>
<td><strong>Horizontal Root Mean Square Error</strong></td>
<td>0.000</td>
</tr>
<tr>
<td><strong>Elevation</strong></td>
<td>6.135</td>
</tr>
<tr>
<td><strong>Vertical Root Mean Square Error</strong></td>
<td>0.000</td>
</tr>
</tbody>
</table>

**Description**
The iron rod and cap was placed just east of Murdoch’s Pier on Galveston Island. It was set in the dune just south of the sea wall, and east of the first staircase on the east side of Murdoch’s.

**Mean of Inverse Shots - Published Versus CPE Found**

<table>
<thead>
<tr>
<th>Monument</th>
<th>No. of Shots</th>
<th>ΔN</th>
<th>ΔE</th>
<th>ΔZ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shahan_TBM</td>
<td>1</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>
### CONTROL MONUMENT USED BY APTIM
FOR 2019 GALVESTON ISLAND TOPGRAPHIC AND HYDROGRAPHIC SURVEY
REPORT
AUGUST 2019

<table>
<thead>
<tr>
<th>DATUMS: NAD83/11 - NAVD88</th>
</tr>
</thead>
<tbody>
<tr>
<td>Designation</td>
</tr>
<tr>
<td>Stamping</td>
</tr>
<tr>
<td>Northing</td>
</tr>
<tr>
<td>Easting</td>
</tr>
<tr>
<td>Horizontal Root Mean Square Error</td>
</tr>
<tr>
<td>Elevation</td>
</tr>
<tr>
<td>Vertical Root Mean Square Error</td>
</tr>
<tr>
<td>Description</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Monument: Becker TBM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location Verification: Becker TBM</td>
</tr>
</tbody>
</table>

### Mean of Inverse Shots - Published Versus CPE Found

<table>
<thead>
<tr>
<th>Monument</th>
<th>No. of Shots</th>
<th>∆N</th>
<th>∆E</th>
<th>∆Z</th>
</tr>
</thead>
<tbody>
<tr>
<td>Becker TBM</td>
<td>2</td>
<td>0.04</td>
<td>-0.06</td>
<td>0.14</td>
</tr>
</tbody>
</table>
# Control Monument Used by APTIM for 2019 Galveston Island Topographic and Hydrographic Survey Report

**August 2019**

**Datums:** NAD83/11 - NAVD88

<table>
<thead>
<tr>
<th>Designation</th>
<th>Tex TBM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stamping</td>
<td>Iron rod and cap</td>
</tr>
<tr>
<td>Northing</td>
<td>13638345.39</td>
</tr>
<tr>
<td>Easting</td>
<td>3257062.127</td>
</tr>
<tr>
<td>Horizontal Root Mean Square Error</td>
<td>0.128</td>
</tr>
<tr>
<td>Elevation</td>
<td>7.273</td>
</tr>
<tr>
<td>Vertical Root Mean Square Error</td>
<td>0.192</td>
</tr>
</tbody>
</table>

**Description:**
Tex TBM is an iron rod and cap placed in the dunes on Galveston Island. It was placed just east of Jamaica Beach, on the Western end of Galveston Island State Park.

---

**Monument: Tex TBM**

**Location Verification: Tex TBM**

### Mean of Inverse Shots - Published Versus CPE Found

<table>
<thead>
<tr>
<th>Monument</th>
<th>No. of Shots</th>
<th>ΔN</th>
<th>ΔE</th>
<th>ΔZ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tex_TBM</td>
<td>2</td>
<td>0.07</td>
<td>0.11</td>
<td>-0.19</td>
</tr>
</tbody>
</table>
APPENDIX 2:
BEACH PROFILE XYZ DATA (DIGITAL COPY ONLY)
“GAL0719_NAVD.XYZ”
APPENDIX 3:
GIS DELIVERABLES

(Digital Copy Only)
APPENDIX 4:
PROFILE PLOTS
City of Galveston Monitoring Surveys
Station: 550+00.00

Drone View

Map View

Photo Date: Jul 2019
Aerial Date: Apr 2018

Station: 550+00.00

ELEVATION (FEET - NAVD88)

DISTANCES REFERENCED TO: N = 13692381 FEET, E = 3329149 FEET, AZIMUTH = 142 DEGREE

DISTANCE ALONG PROFILE (FEET)
City of Galveston Monitoring Surveys
Station: 530+00.00

Photo Date: Jul 2019
Aerial Date: Apr 2018

Aerial View

Map View

Distance referred to N = 13691222 FEET, E = 3327520 FEET, AZIMUTH = 142 DEGREE
City of Galveston Monitoring Surveys
Station: 520+00.00

Drone View

Map View

Aerial Date: Apr 2018
Photo Date: Jul 2019
City of Galveston Monitoring Surveys
Station: 500+00.00

Drone View
Photo Date: Jul 2019

Map View
Aerial Date: Apr 2018

STATION: 500+00.00

DISTANCES REFERENCED TO: N = 13689425 FEET, E = 3325117 FEET, AZIMUTH = 142 DEGREE
City of Galveston Monitoring Surveys
Station: 470+00.00

Drone View

Photo Date: Jul 2019

Map View

Aerial Date: Apr 2018

ELEVATION (FEET - NAVD88)

DISTANCES REFERENCED TO: N = 13687560 FEET, E = 3322768 FEET, AZIMUTH = 142 DEGREE

DISTANCE ALONG PROFILE (FEET)
City of Galveston Monitoring Surveys
Station: 460+00.00

Drone View

Map View

Station: 460+00.00
Aerial Date: Apr 2018
Photo Date: Jul 2019

ELEVATION (FEET - NAVD88)
DISTANCES REFERENCED TO:
N = 13686926 FEET, E = 3321994 FEET, AZIMUTH = 142 DEGREE

DISTANCE ALONG PROFILE (FEET)

Jun 2014
 Jul 2017
 Jul 2019
City of Galveston Monitoring Surveys
Station: 450+00.00

Drone View

Map View

Photo Date: Jul 2019
Aerial Date: Apr 2018

ELEVATION (FEET - NAVD88)

DISTANCES REFERENCED TO: N = 13686285 FEET, E = 3321227 FEET, AZIMUTH = 142 DEGREE
City of Galveston Monitoring Surveys
Station: 430+00.00

Drone View
Photo Date: Jul 2019

Map View
Aerial Date: Apr 2018

STATION: 430+00.00

DISTANCES REFERENCED TO: N = 13685020 FEET, E = 3319677 FEET, AZIMUTH = 142 DEGREE
City of Galveston Monitoring Surveys
Station: 420+00.00

Drone View
Photo Date: Jul 2019

Map View
Aerial Date: Apr 2018

Graph:
- Jun 2014
- Jul 2017
- Jul 2019

ELEVATION (FEET - NAVD88)

DISTANCES REFERENCED TO: N = 13684391 FEET, E = 3318900 FEET, AZIMUTH = 142 DEGREE

DISTANCE ALONG PROFILE (FEET)
City of Galveston Monitoring Surveys
Station: 350+00.00

Photo Date: Jul 2018

Aerial Date: Apr 2018

DISTANCES REFERENCED TO: N = 13679855 FEET, E = 3313573 FEET, AZIMUTH = 137 DEGREE

ELEVATION (FEET-NVD88)
City of Galveston Monitoring Surveys
Station: 335+94.85

Photo Date: Jul 2019

Drone View

Map View

Aerial Date: Apr 2018

Station: 335+94.85

ELEVATION (FEET-NAVD88)

DISTANCES REFERENCED TO: N = 13678886 FEET, E = 3312555 FEET, AZIMUTH = 137 DEGREE

DISTANCE ALONG PROFILE (FEET)

STATION: 335+94.85

-30 -20 -10 0 10 20
-700 -350 0 350 700 1050 1400 1750 2100 2450 2800 3150 3500 3850 4200 4550 4900 5250 5600

Jun 2014

Jul 2017

Oct 2017

Jul 2019
City of Galveston Monitoring Surveys
Station: 290+00.00

Drone View

Photo Date: Jul 2019

Map View

Aerial Date: Apr 2018

Station: 290+00.00

ELEVATION (FEET - NAVD88)

DISTANCES REFERENCED TO: N = 13675776 FEET, E = 3309176 FEET, AZIMUTH = 142 DEGREE

DISTANCE ALONG PROFILE (FEET)
City of Galveston Monitoring Surveys
Station: 270+00.00

Drone View

Map View

Station: 270+00.00

Aerial Date: Apr 2018

Photo Date: Jul 2019

ELEVATION (FEET-NAV/D88)

DISTANCES REFERENCED TO: N = 13674530 FEET, E = 3307612 FEET, AZIMUTH = 142 DEGREE

DISTANCE ALONG PROFILE (FEET)

-700 -350 0 350 700 1050 1400 1750 2100 2450 2800 3150 3500 3850 4200 4550 4900 5250 5600

-30 -20 -10 0 10 20

Jun 2014
Jul 2017
Oct 2017
Jul 2019
City of Galveston Monitoring Surveys
Station: 260+00.00

Drone View

Map View

Station: 260+00.00

Aerial Date: Apr 2018
Photo Date: Jul 2019

Graph:

ELEVATION (FEET - NAVD88)

DISTANCES REFERENCED TO: N = 13673907 FEET, E = 3306830 FEET, AZIMUTH = 142 DEGREE

DISTANCE ALONG PROFILE (FEET)

Jun 2014
Jul 2017
Oct 2017
Jul 2019
City of Galveston Monitoring Surveys
Station: 250+00.00

Drone View

Map View

Photo Date: Jul 2019
Aerial Date: Apr 2018

STATION: 250+00.00

ELEVATION (FEET - NAVD88)

DISTANCES REFERENCED TO: N = 13673284 FEET, E = 3306047 FEET, AZIMUTH = 142 DEGREE

DISTANCE ALONG PROFILE (FEET)

Jun 2014
Jul 2017
Oct 2017
Jul 2019
City of Galveston Monitoring Surveys
Station: 220+00.00

Photo Date: Jul 2019
Aerial Date: Apr 2018

ELEVATION (FEET - NAVD88)

DISTANCES REFERENCED TO: N = 13671538 FEET, E = 3303608 FEET, AZIMUTH = 142 DEGREE

DISTANCE ALONG PROFILE (FEET)
City of Galveston Monitoring Surveys
Station: 210+00.00

Drone View

Map View

Photo Date: Jul 2019

Aerial Date: Apr 2018

STATION: 210+00.00

DISTANCES REFERENCED TO: N = 13670935 FEET, E = 3302811 FEET, AZIMUTH = 142 DEGREE

ELEVATION (FEET - NAVD88)

DISTANCE ALONG PROFILE (FEET)
City of Galveston Monitoring Surveys
Station: 180+00.00

Drone View

Map View

Aerial Date: Apr 2018

Photo Date: Jul 2019

ELEVATION (FEET - NAVD88)

DISTANCES REFERENCED TO: N = 13669236 FEET, E = 3300345 FEET, AZIMUTH = 144 DEGREE
City of Galveston Monitoring Surveys
Station: 160+00.00

Photo Date: Jul 2019
Aerial Date: Apr 2018

DISTANCES REFERENCED TO: N = 13668038 FEET, E = 3298744 FEET, AZIMUTH = 144 DEGREE
City of Galveston Monitoring Surveys
Station: 140+00.00

Aerial Date: Apr 2018
Photo Date: Jul 2019

STATION: 140+00.00

DISTANCES REFERENCED TO: N = 13666923 FEET, E = 3297084 FEET, AZIMUTH = 144 DEGREE

ELEVATION (FEET NAVD88) vs. DISTANCE ALONG PROFILE (FEET)

-30 -20 -10 0 10 20
-700 -350 0 350 700 1050 1400 1750 2100 2450 2800 3150 3500 3850 4200 4550 4900 5250 5600

Jun 2014
Jul 2017
Oct 2017
Jul 2019
City of Galveston Monitoring Surveys
Station: 130+00.00

Drone View

Map View

Aerial Date: Apr 2018

Photo Date: Jul 2019

Station: 130+00.00

DISTANCES REFERENCED TO: N = 13666365 FEET, E = 3296254 FEET, AZIMUTH = 144 DEGREE

ELEVATION (FEET-NAVD88)

DISTANCE ALONG PROFILE (FEET)

Graph showing elevation changes at Station 130+00.00 with data points from June 2014, July 2017, October 2017, and July 2019.
City of Galveston Monitoring Surveys

Station: 100+00.00

Drone View

Map View

Aerial Date: Apr 2018

Photo Date: Jul 2019
City of Galveston Monitoring Surveys

Station: 50+00.00

Drone View

Photo Date: Jul 2019

Map View

Aerial Date: Apr 2018

STATION: 50+00.00

DISTANCES REFERENCED TO: N = 13661713 FEET, E = 3289747 FEET, AZIMUTH = 144 DEGREE

ELEVATION (FEET NAVD88)

DISTANCE ALONG PROFILE (FEET)

-30 -20 -10 0 10 20

-700 -350 0 350 700 1050 1400 1750 2100 2450 2800 3150 3500 3850 4200 4550 4900 5250 5600

Jun 2014
Jul 2017
Jul 2019
City of Galveston Monitoring Surveys
Station: 10+00.00

Aerial View: Apr 2018
Map View: Station: 10+00.00

Photo Date: Jul 2019

Elevation vs Distance Along Profile (FEET-NAVD88)

Distances referenced to: N = 13659354 FEET, E = 3286516 FEET, Azimuth = 144 Degree
City of Galveston Monitoring Surveys
Station: 0+00.00

Drone View

Map View

Aerial Date: Apr 2018

Photo Date: Jul 2019

### Graph

**STATION: 0+00.00**

- **Blue line**: Jun 2014
- **Red line**: Jul 2017
- **Green line**: Oct 2017
- **Black line**: Jul 2019

DISTANCES REFERENCED TO: N = 13658765 FEET, E = 3285709 FEET, AZIMUTH = 144 DEGREE
City of Galveston Monitoring Surveys
Station: 1510+00.00

Drone View

Photo Date: Jul 2019

Map View

Aerial Date: Apr 2018

STATION: 1510+00.00

DISTANCES REFERENCED TO: N = 13658614 FEET, E = 3284975 FEET, AZIMUTH = 144 DEGREE
City of Galveston Monitoring Surveys
Station: 1490+00.00

Drone View

Map View

Aerial Date: Apr 2018
Photo Date: Jul 2019

STATION: 1490+00.00

DISTANCES REFERENCED TO: N = 13657462 FEET, E = 3283329 FEET, AZIMUTH = 144 DEGREE

-30 -20 -10 0 10 20
DISTANCE ALONG PROFILE (FEET)

ELEVATION (FEET - NAVD88)

Jun 2014
Jul 2017
Oct 2017
Jul 2019
City of Galveston Monitoring Surveys
Station: 1480+00.00

Aerial Date: Apr 2018
Photo Date: Jul 2019

Station: 1480+00.00

ELEVATION (FEET - NAV/D88)

DISTANCES REFERENCED TO: N = 13656875 FEET, E = 3282520 FEET, AZIMUTH = 144 DEGREE

DISTANCE ALONG PROFILE (FEET)
City of Galveston Monitoring Surveys
Station: 1460+00.00

Drone View

Map View

Photo Date: Jul 2019
Aerial Date: Apr 2018

STATION: 1460+00.00

-30 -20 -10 0 10 20
ELEVATION (FEET - NAVD88)

-700 -350 0 350 700 1050 1400 1750 2100 2450 2800 3150 3500 3850 4200 4550 4900 5250 5600
DISTANCE ALONG PROFILE (FEET)

DISTANCES REFERENCED TO: N = 13655694 FEET, E = 3280906 FEET, AZIMUTH = 144 DEGREE

Jun 2014
Jul 2017
Jul 2019
City of Galveston Monitoring Surveys
Station: 1440+00.00

Drone View

Map View

Aerial Date: Apr 2018

Photo Date: Jul 2019

Station: 1440+00.00

ELEVATION (FEET - NAVD88)

DISTANCES REFERENCED TO: N = 13654512 FEET, E = 3279293 FEET, AZIMUTH = 144 DEGREE

DISTANCE ALONG PROFILE (FEET)
City of Galveston Monitoring Surveys
Station: 1430+00.00

Aerial Date: Apr 2018

Photo Date: Jul 2019

Drone View

Map View

ELEVATION (FEET - NAVD88)

DISTANCES REFERENCED TO: N = 13653920 FEET, E = 3278487 FEET, AZIMUTH = 144 DEGREE
City of Galveston Monitoring Surveys

Station: 1420+00.00

Drone View

Aerial Date: Apr 2018

Photo Date: Jul 2019

Map View

STATION: 1420+00.00

ELEVATION (FEET-NAV/88)

-30 -20 -10 0 10 20

DISTANCES REFERENCED TO: N = 13653323 FEET, E = 3277685 FEET, AZIMUTH = 144 DEGREE

DISTANCE ALONG PROFILE (FEET)

-700 -350 0 350 700 1050 1400 1750 2100 2450 2800 3150 3500 3850 4200 4550 4900 5250 5600

- Jun 2014
- Jul 2017
- Jul 2019
City of Galveston Monitoring Surveys
Station: 1410+00.00

Drone View

Map View

Station: 1410+00.00
Aerial Date: Apr 2018

Photo Date: Jul 2019

ELEVATION (FEET - NAVD88)

-30 -20 -10 0 10 20

DISTANCES REFERENCED TO: N = 13652725 FEET, E = 3276883 FEET, AZIMUTH = 144 DEGREE

DISTANCE ALONG PROFILE (FEET)

-700 -350 0 350 700 1050 1400 1750 2100 2450 2800 3150 3500 3850 4200 4550 4900 5250 5600

- Jun 2014
- Jul 2017
- Jul 2019
City of Galveston Monitoring Surveys
Station: 1400+00.00

Drone View

Map View

Photo Date: Jul 2019

Aerial Date: Apr 2018

ELEVATION (FEET - NAVD88)

DISTANCES REFERENCED TO: N = 13652125 FEET, E = 3276083 FEET, AZIMUTH = 144 DEGREE
City of Galveston Monitoring Surveys
Station: 1390+00.00

Aerial Date: Apr 2018
Photo Date: Jul 2019
City of Galveston Monitoring Surveys
Station: 1380+00.00

Drone View

Map View

Aerial Date: Apr 2018

Photo Date: Jul 2019

STATION: 1380+00.00

DISTANCES REFERENCED TO: N = 13650938 FEET, E = 3274473 FEET, AZIMUTH = 144 DEGREE

ELEVATION (FEET-NAVD88)

DISTANCE ALONG PROFILE (FEET)
City of Galveston Monitoring Surveys
Station: 1370+00.00

Drone View

Map View

Aerial Date: Apr 2018

Photo Date: Jul 2019

ELEVATION (FEET - NAVD88)

DISTANCES REFERENCED TO: N = 13650333 FEET, E = 3273677 FEET, AZIMUTH = 144 DEGREE

DISTANCE ALONG PROFILE (FEET)
City of Galveston Monitoring Surveys
Station: 1360+00.00

Drone View
Photo Date: Apr 2019

Map View
Aerial Date: Apr 2018

STATION: 1360+00.00

ELEVATION (FEET - NAVD88)

DISTANCES REFERENCED TO: N = 13649748 FEET, E = 3272866 FEET, AZIMUTH = 144 DEGREE

DISTANCE ALONG PROFILE (FEET)

Jun 2014
Jul 2017
Jul 2019
City of Galveston Monitoring Surveys
Station: 1350+00.00

Drone View

Map View

Aerial Date: Apr 2018

Photo Date: Jul 2019

STATION: 1350+00.00

DISTANCES REFERENCED TO: N = 13649138 FEET, E = 3272076 FEET, AZIMUTH = 144 DEGREE

ELEVATION (FEET - NAVD88)

DISTANCE ALONG PROFILE (FEET)

Jun 2014
Jul 2017
Jul 2019
City of Galveston Monitoring Surveys
Station: 1330+00.00

Drone View

Photo Date: Jul 2019

Map View

Aerial Date: Apr 2018

Station: 1330+00.00

STATION: 1330+00.00

ELEVATION (FEET - NAVD88)

DISTANCES REFERENCED TO: N = 13647970 FEET, E = 3270451 FEET, AZIMUTH = 144 DEGREE

DISTANCE ALONG PROFILE (FEET)
City of Galveston Monitoring Surveys
Station: 1320+00.00

Aerial Date: Apr 2018
Photo Date: Jul 2019
City of Galveston Monitoring Surveys
Station: 1310+00.00

Drone View

Map View

Station: 1310+00.00

Aerial Date: Apr 2018

Photo Date: Jul 2019

ELEVATION (FEET - NAVD88)

DISTANCES REFERENCED TO: N = 13646784 FEET, E = 3268841 FEET, AZIMUTH = 144 DEGREE

DISTANCE ALONG PROFILE (FEET)
City of Galveston Monitoring Surveys
Station: 1270+00.00

Drone View

Map View

Photo Date: Jul 2019
Aerial Date: Apr 2018

STATION: 1270+00.00

DISTANCES REFERENCED TO: N = 13644426 FEET, E = 3265610 FEET, AZIMUTH = 144 DEGREE
City of Galveston Monitoring Surveys
Station: 1260+00.00

Aerial Date: Apr 2018
Photo Date: Jul 2019

Station: 1260+00.00

DISTANCES REFERENCED TO: N = 13643839 FEET, E = 3264800 FEET, AZIMUTH = 144 DEGREE
City of Galveston Monitoring Surveys
Station: 1210+00.00

Aerial Date: Apr 2018
Photo Date: Jul 2019

STATION: 1210+00.00

ELEVATION (FEET - NAVD88)

DISTANCES REFERENCED TO: N = 13640901 FEET, E = 3260754 FEET, AZIMUTH = 144 DEGREE

DISTANCE ALONG PROFILE (FEET)
City of Galveston Monitoring Surveys
Station: 1090+00.00

Drone View

Map View

Aerial Date: Apr 2018
Photo Date: Jul 2019

STATION: 1090+00.00

ELEVATION (FEET-NAV/D88)

DISTANCES REFERENCED TO: N = 13633846 FEET, E = 3251048 FEET, AZIMUTH = 142 DEGREE

-30 -20 -10 0 10 20
-700 -350 0 350 700 1050 1400 1750 2100 2450 2800 3150 3500 3850 4200 4550 4900 5250 5600

- Jun 2014
- Jul 2017
- Jul 2019
City of Galveston Monitoring Surveys
Station: 1080+00.00

Drone View

Map View

Photo Date: Jul 2019
Aerial Date: Apr 2018

STATION:1080+00.00

ELEVATION (FEET - NAVD88)

DISTANCES REFERENCED TO: N = 13633256 FEET, E = 3250241 FEET, AZIMUTH = 142 DEGREE

DISTANCE ALONG PROFILE (FEET)

-700 -350 0 350 700 1050 1400 1750 2100 2450 2800 3150 3500 3850 4200 4550 4900 5250 5600
City of Galveston Monitoring Surveys
Station: 1060+00.00

Aerial Date: Apr 2018
Photo Date: Jul 2019

DISTANCES REFERENCED TO: N = 13632062 FEET, E = 3248637 FEET, AZIMUTH = 142 DEGREE
City of Galveston Monitoring Surveys
Station: 1040+00.00

Photo Date: Jul 2019
Aerial Date: Apr 2018

STATION: 1040+00.00

ELEVATION (FEET - NAVD88)

DISTANCES REFERENCED TO: N = 13630889 FEET, E = 3247017 FEET, AZIMUTH = 142 DEGREE
City of Galveston Monitoring Surveys
Station: 1020+00.00

Drone View

Map View

Station: 1020+00.00

Aerial Date: Apr 2018

Photo Date: Jul 2019

ELEVATION (FEET - NAVD88)

DISTANCES REFERENCED TO: N = 13629696 FEET, E = 3245412 FEET, AZIMUTH = 142 DEGREE

DISTANCE ALONG PROFILE (FEET)

STATION: 1020+00.00

Graph showing elevation changes from June 2014, July 2017, and July 2019.
City of Galveston Monitoring Surveys
Station: 1000+00.00

Drone View

Map View

Photo Date: Jul 2019

Aerial Date: Apr 2018

ELEVATION (FEET - NAVD88)

DISTANCES REFERENCED TO: N = 13628489 FEET, E = 3243817 FEET, AZIMUTH = 142 DEGREE
City of Galveston Monitoring Surveys
Station: 990+00.00

Drone View

Map View

Photo Date: Jul 2019
Aerial Date: Apr 2018

ELEVATION (FEET - NAVD88)

DISTANCES REFERENCED TO: N = 13627886 FEET, E = 3243019 FEET, AZIMUTH = 142 DEGREE

DISTANCE ALONG PROFILE (FEET)

Jun 2014
Jul 2017
Jul 2019
City of Galveston Monitoring Surveys
Station: 980+00.00

Drone View

Map View

Photo Date: Jul 2019

Aerial Date: Apr 2018

ELEVATION (FEET-NAVD88)

DISTANCES REFERENCED TO: N = 13627285 FEET, E = 3242220 FEET, AZIMUTH = 142 DEGREE

DISTANCE ALONG PROFILE (FEET)
City of Galveston Monitoring Surveys
Station: 960+00.00

Aerial Date: Apr 2018
Photo Date: Jul 2019

Distances referenced to: N = 13626074 Feet, E = 3240628 Feet, Azimuth = 142 Degree
City of Galveston Monitoring Surveys
Station: 920+00.00

Photo Date: Jul 2019
Aerial Date: Apr 2018

Drone View
Map View

ELEVATION (FEET - NAVD88)
DISTANCES REFERENCED TO: N = 13623666 FEET, E = 3237434 FEET, AZIMUTH = 142 DEGREE

DISTANCE ALONG PROFILE (FEET)
City of Galveston Monitoring Surveys
Station: 910+00.00

Photo Date: Jul 2019
Aerial Date: Apr 2018

Station: 910+00.00

ELEVATION (FEET - NAVD88)

DISTANCES REFERENCED TO: N = 13623060 FEET, E = 3236639 FEET, AZIMUTH = 142 DEGREE

DISTANCE ALONG PROFILE (FEET)
City of Galveston Monitoring Surveys
Station: 870+00.00

Photo Date: Jul 2019

Aerial Date: Apr 2018

STATION: 870+00.00

DISTANCES REFERENCED TO: N = 13620645 FEET, E = 3233450 FEET, AZIMUTH = 142 DEGREE

ELEVATION (FEET - NAVD88)

DISTANCE ALONG PROFILE (FEET)

-30 -20 -10 0 10 20
-700 -350 0 350 700 1050 1400 1750 2100 2450 2800 3150 3500 3850 4200 4550 4900 5250 5600

Jun 2014

Jul 2017

Jul 2019
City of Galveston Monitoring Surveys
Station: 830+00.00

Photo Date: Jul 2019

Aerial Date: Apr 2018

DISTANCES REFERENCED TO: N = 13618202 FEET, E = 3230284 FEET, AZIMUTH = 142 DEGREE
City of Galveston Monitoring Surveys
Station: 820+00.00

Photo Date: Jul 2019
Aerial Date: Apr 2018

STATION: 820+00.00

DISTANCES REFERENCED TO: N = 13617587 FEET, E = 3229495 FEET, AZIMUTH = 142 DEGREE

ELEVATION (FEET-NAVD88)

DISTANCE ALONG PROFILE (FEET)
City of Galveston Monitoring Surveys
Station: 810+00.00

Drone View
Photo Date: Jul 2019

Map View
Aerial Date: Apr 2018

STATION: 810+00.00

DISTANCES REFERENCED TO: N = 13616973 FEET, E = 3228705 FEET, AZIMUTH = 142 DEGREE

DISTANCE ALONG PROFILE (FEET)
-30 -20 -10 0 10 20
ELEVATION (FEET - NAVD88)

Jun 2014
Jul 2017
Jul 2019
City of Galveston Monitoring Surveys
Station: 800+00.00

Photo Date: Jul 2019

Aerial Date: Apr 2018

ELEVATION (FEET - NAVD88)

DISTANCES REFERENCED TO: N = 13616358 FEET, E = 3227917 FEET, AZIMUTH = 142 DEGREE

DISTANCE ALONG PROFILE (FEET)
City of Galveston Monitoring Surveys
Station: 780+00.00

Photo Date: Jul 2019

Aerial Date: Apr 2018

DISTANCES REFERENCED TO: N = 13615107 FEET, E = 3226357 FEET, AZIMUTH = 142 DEGREE

STATION: 780+00.00

ELEVATION (FEET-NAVD88)

DISTANCE ALONG PROFILE (FEET)
City of Galveston Monitoring Surveys
Station: 770+00.00

Drone View
Photo Date: Jul 2019

Map View
Aerial Date: Apr 2018

STATION: 770+00.00

DISTANCES REFERENCED TO: N = 13614473 FEET, E = 3225584 FEET, AZIMUTH = 142 DEGREE
City of Galveston Monitoring Surveys
Station: 760+00.00

Aerial Date: Apr 2018
Photo Date: Jul 2019

STATION: 760+00.00

DISTANCES REFERENCED TO: N = 13613835 FEET, E = 3224813 FEET, AZIMUTH = 142 DEGREE

ELEVATION (FEET - NAV/D88)

DISTANCE ALONG PROFILE (FEET)
City of Galveston Monitoring Surveys
Station: 720+00.00

Aerial Date: Apr 2018
Photo Date: Jul 2019

STATION: 720+00.00

ELEVATION (FEET - NAVD88)

DISTANCES REFERENCED TO: N = 13611247 FEET, E = 3221764 FEET, AZIMUTH = 142 DEGREE

DISTANCE ALONG PROFILE (FEET)

-30 -20 -10 0 10 20

Jun 2014
Jul 2017
Jul 2019
City of Galveston Monitoring Surveys
Station: 690+00.00

Drone View

Map View

Aerial Date: Apr 2018

Photo Date: Jul 2019

Station: 690+00.00

ELEVATION (FEET - NAVD88)

DISTANCES REFERENCED TO: N = 13609259 FEET, E = 3219518 FEET, AZIMUTH = 135 DEGREE
City of Galveston Monitoring Surveys
Station: 680+00.00

Drone View

Map View

Aerial Date: Apr 2018

Station: 680+00.00

Photo Date: Jul 2019

STATION: 680+00.00

DISTANCES REFERENCED TO: N = 13608581 FEET, E = 3218782 FEET, AZIMUTH = 135 DEGREE

DISTANCE ALONG PROFILE (FEET)

ELEVATION (FEET NAVD88)

Jun 2014

Jul 2017

Jul 2019
City of Galveston Monitoring Surveys
Station: 630+00.00

Aerial Date: Apr 2018
Photo Date: Jul 2019

ELEVATION (FEET - NAVD88)

DISTANCES REFERENCED TO: N = 13605072 FEET, E = 3215221 FEET, AZIMUTH = 135 DEGREE

DISTANCE ALONG PROFILE (FEET)
City of Galveston Monitoring Surveys
Station: 600+00.00

Drone View

Map View

Aerial Date: Apr 2018

Photo Date: Jul 2019

ELEVATION (FEET-NAVD88)

DISTANCES REFERENCED TO: N = 13602807 FEET, E = 3213256 FEET, AZIMUTH = 135 DEGREE

DISTANCE ALONG PROFILE (FEET)
City of Galveston Monitoring Surveys
Station: 580+00.00

Photo Date: Jul 2019

Aerial Date: Apr 2018

STAION: 580+00.00

ELEVATION (FEET-NAV/D88)

DISTANCES REFERENCED TO: N = 13601213 FEET, E = 3212049 FEET, AZIMUTH = 135 DEGREE

DISTANCE ALONG PROFILE (FEET)
APPENDIX 5:
FIELD BOOK PAGES
(Digital Copy Only)
APPENDIX 6:
GROUND DIGITAL PHOTOGRAPHY
(Digital Copy Only)
APPENDIX 7:
UAS PROOF OF METHODOLOGY STUDY
January 31, 2020

Dustin Henry
Coastal Resources and Flood Plain Manager
City of Galveston
823 Rosenberg Street
Galveston, TX 77551

Subject: UAS/Drone Proof of Methodology Study

Dear Mr. Henry:

This letter serves as the deliverable associated with the UAS/Drone Proof of Methodology Study that APTIM Environmental & Infrastructure, Inc. (APTIM) conducted under the agreement between APTIM and the City of Galveston, executed on March 5, 2019. During the 2019 annual surveys conducted by APTIM along Galveston Island, a trial Unmanned Aircraft System (UAS) aerial survey was conducted concurrently in order to verify the quality and accuracy of UAS topographic survey methods proposed by APTIM. APTIM compared the data obtained through the use of a UAS to data collected using standard terrestrial survey techniques, which employed the use of real time kinematic (RTK) global navigation satellite systems (GNSS). This report includes a description of methodology used, a discussion of the results of the data comparison, and recommendations for the future use of this methodology to monitor the beaches of Galveston Island.

We remain at your disposal regarding this study and further inquiries. Please feel free to contact myself or Mr. Ken Willson with comments and questions about this report and the underlying data.

This report represents photogrammetric data collection performed by me or under my direct supervision and the data contained herein are accurate to the best of my knowledge and belief. The products provided and report comply with the Professional and Technical Standards as codified in Title 22, Part 29, Chapter 663, Texas Administrative Code.

P. Chad Maxwell, Texas Registration #6547
Registered Professional Land Surveyor

2/3/2020
UAS/Drone Proof of Methodology Study Report
Methodology

This report documents the photogrammetric data collection and products produced in support of the City of Galveston. The data presented herein were collected on July 11, 2019. All data were collected using a DJI small Unmanned Aircraft System (sUAS) and Trimble Global Navigation Satellite System (GNSS) receivers. These data were compiled, and the final products were produced using ArcGIS’ Drone2Map software platform, which relies on Pix4D photogrammetric modules.

Three (3), approximately 5000-foot sections, areas of interest (AOI) on Galveston Island were selected as test sites. The location of each site was chosen as a proxy to represent the varying topography along the entirety of the island’s coastline. The easternmost section was located between Stations 550+00 and 500+00 directly adjacent to the jetty. The second section was located along the seawall between Stations 360+00 and 310+00. The westernmost section was located between Stations 630+00 and 580 approximately 1 mile from San Luis Pass.

Initial Setup

A grid pattern optimized for the desired pixel size on the ground and flight time was developed for each area of interest (AOI). For this application, the flying altitude was 300 feet and 60% side- and front-lap were chosen. The resulting pixel size on the ground was expected to be about 1.29 inches per pixel.

Control Targets

Twenty (20) two-foot by two-foot (2’x2’) aerial control targets, painted in alternating checkers, were introduced to each AOI to be used as ground reference and image tie points. An example of an aerial control targets is found below.
**Additional Ground Points**

Additional photo-identifiable points were collected and introduced into the processing routine as ground reference points. Examples include the centers of manholes, ends of painted arrows and the like.

**Execution**

In each case, the ground control points (GCP) were placed just before the commencement of the UAS flight. Each point was measured using RTK GNSS workflows and extended observations were recorded at each GCP. All GCPs were collected post-flight and then placed once again in the next AOI.

After the GCPs were placed and measured, the UAS operator launched the drone to fly its predefined grid mission, taking high-resolution photographs at specified intervals in order to achieve the desired overlap and ground sampling distance. Preplanning software also ensures the drone returns to its launch point after completing its mission.

The collected UAS data were processed using ESRI ArcGIS products. The basic products produced for each AOI were an orthorectified mosaic image, a LAS-formatted point cloud and post-processing quality report. GNSS profile points were then overlaid onto the LAS point cloud for statistical comparison.

**GNSS, UAS Data Comparison**

Statistical comparisons were made between individual GNSS measurements along profile run-lines in the three (3) aerial survey areas and the UAS point-cloud points that fell within 3 feet of the GNSS measurements. Test locations with the least relief (flattest areas) were chosen for each profile line in the aerial survey area. In total, thirty-eight (38) unique GNSS locations and more than 10,000 point-cloud points were used in the analysis. Overall, the result of comparisons at the aerial survey areas indicates a Vertical Root Mean Square Error (Z_RMS) of 0.125 feet, which equates to Vertical Accuracy of 0.245 feet at the 95-percent confidence level. The distribution is found to be normal and the mean elevation difference is found to be -0.046 feet, with a median of -0.055 feet.
Example of UAS data comparison area; 3’ radius around the GNSS measured point on the beach sand.
Seawall Beach

The result of comparisons at the Seawall Beach aerial survey area indicates a Vertical Root Mean Square Error (Z_RMSe) of 0.101 feet, which equates to Vertical Accuracy of 0.198 feet at the 95-percent confidence level. The distribution is found to be normal and the mean elevation difference is found to be -0.029 feet, with a median of -0.035 feet.

East End

The result of these comparisons at the East End aerial survey area indicates a Vertical Root Mean Square Error (Z_RMSe) of 0.146 feet, which equates to Vertical Accuracy of 0.286 feet at the 95-percent confidence level. The distribution is found to be normal and the mean elevation difference is found to be -0.088 feet, with a median of -0.086 feet.
West End

The result of these comparisons at the West End aerial survey area indicates a Vertical Root Mean Square Error (Z_RMSe) of 0.129 feet, which equates to Vertical Accuracy of 0.253 feet at the 95-percent confidence level. The distribution is found to be normal and the mean elevation difference is found to be -0.026 feet, with a median of -0.041 feet.

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
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</thead>
<tbody>
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<td>0.129</td>
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<td>-0.026</td>
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Recommendations

Based on the comparison of UAS and GNNS data discussed in the preceding section, APTIM believes that a geospatial methodology optimizes data volume and robustness and meets the accuracy requirements for the City of Galveston’s beach monitoring program. Further, the UAS data acquisition method allows for full coverage of the beach by both point cloud data and ortho-photography, which will allow resolution of features such as the mean high water (MHW) line, +4.0 ft. contour, southern toe of dune, edge of vegetation, and north toe of dune that the current profile-based data acquisition does not provide, while GNSS techniques effectively control the UAS surveys, provide for ground verification and quality assurance of UAS data, and continue as the optimal method for wading-depth surveys.

Given the reliability and the strength of the data discussed in the previous section and other lessons learned from this proof of methodology study, APTIM recommends the City acquire data for the 2020 beach monitoring survey using a geospatial approach; that is UAS + GNSS tools fit for specialized purposes and locations. APTIM also provides the following recommendations for the City to consider for implementing this geospatial approach to beach monitoring for 2020:

- Because of wash and the ability to properly control the UAS survey area near the shoreline, the AOI for the UAS area should be limited to +1.0 ft. NAVD88 Elevation. If collection of data below the +1.0 ft. NAVD88 Elevation is required by the City, these data will be collected with RTK GNSSS rover systems.
- Flight plans should be modified to allow for the maximum altitude and spacing of line to achieve the necessary accuracy. Flights should be flown at 300ft with 70/70 overlap and side-lap to cut down on flight time and capture as much area as possible in each photo, keeping photosets more manageable. Optimizing altitude and line spacing minimizes overall flight times, allowing for more cost-effective data collection.
- For survey areas associated with the Galveston Seawall static GCPs in the hard structure of the seawall and groins should be used. Highly identifiable marks should be made using marking paint. This will eliminate the need for the time-consuming process of “leap frogging” GCPs down the shoreline associated with the Galveston Seawall.
• An area of the Galveston Island beaches located between Stations 20+00 and 90+00 is “geo-fenced” from UAS flights. The controlled airspace extends to the ground in this area. Authorization to fly in these areas can be obtained but the process is lengthy and obtaining clearance is not certain. The field team setting GCPs should complete a normal field survey along profiles through this section of beach.

• A verification profile every 5,000 feet is a recommended, with 8-10 intermittent GNSS points collected between profiles for ground truthing and quality monitoring.

Prior to being awarded the 2020 monitoring surveys, APTIM would like the opportunity to revise the original scope of work to reflect lessons learned through this proof of methodology study.