USA – FLORIDA

Broward County

NOAA

Data Acquisition and Processing Report
Horizontal and Vertical Control Report
& Separates Report
to accompany
Descriptive Reports
H12116 – H12118

Surveyed by Fugro LADS, Incorporated
2009

OPR-H328-KRL-09
October 28, 2009

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL OCEAN SERVICE

Horizontal and Vertical Control Report

Type of Survey Hydrographic Lidar

Project No. OPR-H328-KRL-09

Time frame July – August 2008

LOCALITY

State Florida

General Locality Broward County

2009

HYDROGRAPHER
MARK SINCLAIR

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LIBRARY & ARCHIVES

DATE

NOAA FORM 77-28 (11-72)	U.S. DEPARTMENT OF COMMERCE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION	REGISTRY No.
HYDROGRAPHIC TITLE SHEET		**H12116 – H12118**

State Florida

General Locality Broward County

Scale 1:10,000 **Date of Survey** July 12 – August 24, 2008

Instructions dated June 17, 2009 **Project No** OPR-H328-KRL-09

Vessel Fugro LADS Aircraft, call sign VH-LCL

Hydrographer M.J. Sinclair **Chief of Party** S.R. Ramsay

Surveyed by J.G. Guilford, D.J. Stubbing, J.K. Young, W.T. Newsham, B.A. Weidman, K.J. Oberhofer, C.N. Waite, R.B. Touchstone, V. Sicari

Soundings by Laser Airborne Depth Sounder

Graphic record scaled by B.A. Weidman

Graphic record checked by S.R. Ramsay, J.G. Guilford **Automated Plot** N/A

Soundings in Meters at MLLW

REMARKS

Requisition / Purchase Req. # NCNJ3000-9-15915

Contractor Fugro LADS, Incorporated, 925 Tommy Munro Dr., Suite J, Biloxi, MS 39532

Sub-Contractors Baxley Ocean Visions, Inc., 5018 Harrison Street, Hollywood, FL 33021
Coastal Planning and Engineering, Inc., 2481 NW Boca Raton Blvd., Boca Raton, FL 33431
Quester Tangent Corp., 6582 Bryn Road, Saanichton, British Columbia V8M 1X6, Canada

Times All times are recorded in UTC.

Datum and Projection NAD83, UTM (N) Zone 17

Purpose The purpose of this survey is to provide NOAA with modern, accurate hydrographic survey data with which to update the nautical charts of the assigned area. This project was initially conducted by Tenix LADS, Inc., under contract to Baxley Ocean Visions, Inc., for Coastal Planning and Engineering, Inc. and Broward County. The survey has been re-processed and deliverables prepared in accordance with NOS specifications, for use by NOAA.

Acronyms A complete list of all acronyms used throughout this report is provided at Appendix I of the Separates Report.

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A. VERTICAL CONTROL

The initial vertical control for this survey was based on the National Water Level Observation Network (NWLON) station at Virginia Key, FL (8723214). Refer to Appendix I for the Virginia Key tide station description. Preliminary tidal zoning for the project was set out using time and range correctors relative to the continuously operating Virginia Key NWLON tide station. Preliminary tide corrections were used to reduce depth soundings during the data collection period, in order to assess the integrity of bathymetry and plan necessary reflies.

Final vertical control was based on tide stations established on Deerfield Pier, Anglin's Pier and Dania Pier by Baxley Ocean Visions, Inc. (BOV). These gauges were initially related to NAVD88 by Coastal Planning & Engineering, Inc. (CPE), the survey datum specified for work conducted for Broward County in 2008. The three tide stations were later related to NOAA survey datum (MLLW) by Fugro LADS on April 23, 2009, using NAVD88 – MLLW vertical datum offsets from a number of tidal benchmarks in the vicinity of the project area. The tide gauges operated continuously from July 12, 2008 until August 24, 2008. The tide data supplied by BOV was reduced to MLLW for final tide application (see Section A.3.2 for details).

The Tide Data Collection Report is presented at Appendix II and tide data is provided on the USB hard drive.

A.1 TIDE STATIONS

A.1.1 Virginia Key

The NOAA NWLON station (8723214) located at Virginia Key was used for the application of preliminary tides to soundings during the data collection phase of the project. This tide gauge recorded continuously over the entire survey period.

		NAD83	
Gauge	**Location**	**Latitude (N)**	**Longitude (W)**
8723214	Virginia Key	25° 43.9'	80° 09.7'

Figure 1 – Virginia Key tide gauge

A.1.2 Deerfield Pier, Anglin's Pier and Dania Pier

The Deerfield Pier, Anglin's Pier and Dania Pier tide stations were established by BOV on July 12, 2008, and ran continuously until August 24, 2008. These gauges were used to establish the final zoning for the project area and record water levels for final reduction of depth soundings. The positions used for these stations were entered into the Ground System (GS) and tide zones were created to encompass the whole survey area.

	NAD83	
Location	**Latitude (N)**	**Longitude (W)**
Deerfield Pier	26° 19.0'	80° 08.3'
Anglin's Pier	26° 11.4'	80° 08.4'
Dania Pier	26° 03.3'	80° 10.8'

A.2 TIDE ZONES

A.2.1 Preliminary Tide Zoning

A preliminary tide zone was established (from information obtained from National Ocean Services, NOAA) to cover the extents of the survey area. This tide zone used time and range correctors relative to Mean Lower Low Water (MLLW) reduced tides at the Virginia Key tide station. These are as follows:

Tide Zone	GS Identifier	Time Corrector	Range Corrector	Reference Station
SA227	TA1	-54 minutes	x1.22	8723214

Coordinates of the tide station and turning points (TP) for the preliminary tide zone are as follows (positions in NAD83):

SA227 (TA 1)	Latitude (N)	Longitude (W)
Virginia Key	25° 43.9’	80° 09.7'
TP 1	26° 28.7’	80° 08.3’
TP 2	26° 28.3’	79° 48.6’
TP 3	25° 50.0’	79° 48.8’

A.2.2 Final Tide Zoning

The final tide zones were designed to incorporate at least one observed tide station. In some of the zones two observed tide stations were used to provide a co-tidal model (refer to Figure 2). These final tide zones superseded the preliminary tide zone.

Coordinates of the tide stations and turning points for the final tide zones are as follows (positions in NAD83):

Tide Zone 1	Latitude (N)	Longitude (W)
Deerfield Pier	26° 19.0'	80° 08.3'
TP 1	26° 29.3'	80° 08.2'
TP 2	26° 29.2'	79° 56.8'
TP 3	26° 18.9'	79° 56.9'

Tide Zone 2	Latitude (N)	Longitude (W)
Deerfield Pier	26° 19.0'	80° 08.3'
TP 3	26° 18.9'	79° 56.9'
TP 4	26° 11.3'	79° 57.0'
Anglin’s Pier	26° 11.4'	80° 08.4'

Tide Zone 3	Latitude (N)	Longitude (W)
Anglin's Pier	26° 11.4'	80° 08.4'
TP 4	26° 11.3'	79° 57.0'
TP 5	26° 03.2'	79° 57.0'
Dania Pier	26° 03.3'	80° 10.8'
TP 8	26° 11.4'	80° 10.8'

Tide Zone 4	Latitude (N)	Longitude (W)
Dania Pier	26° 03.3'	80° 10.8'
TP 6	25° 49.1'	79° 57.1'
TP 7	25° 49.2'	80° 10.9'
TP 8	26° 11.4'	80° 10.8'

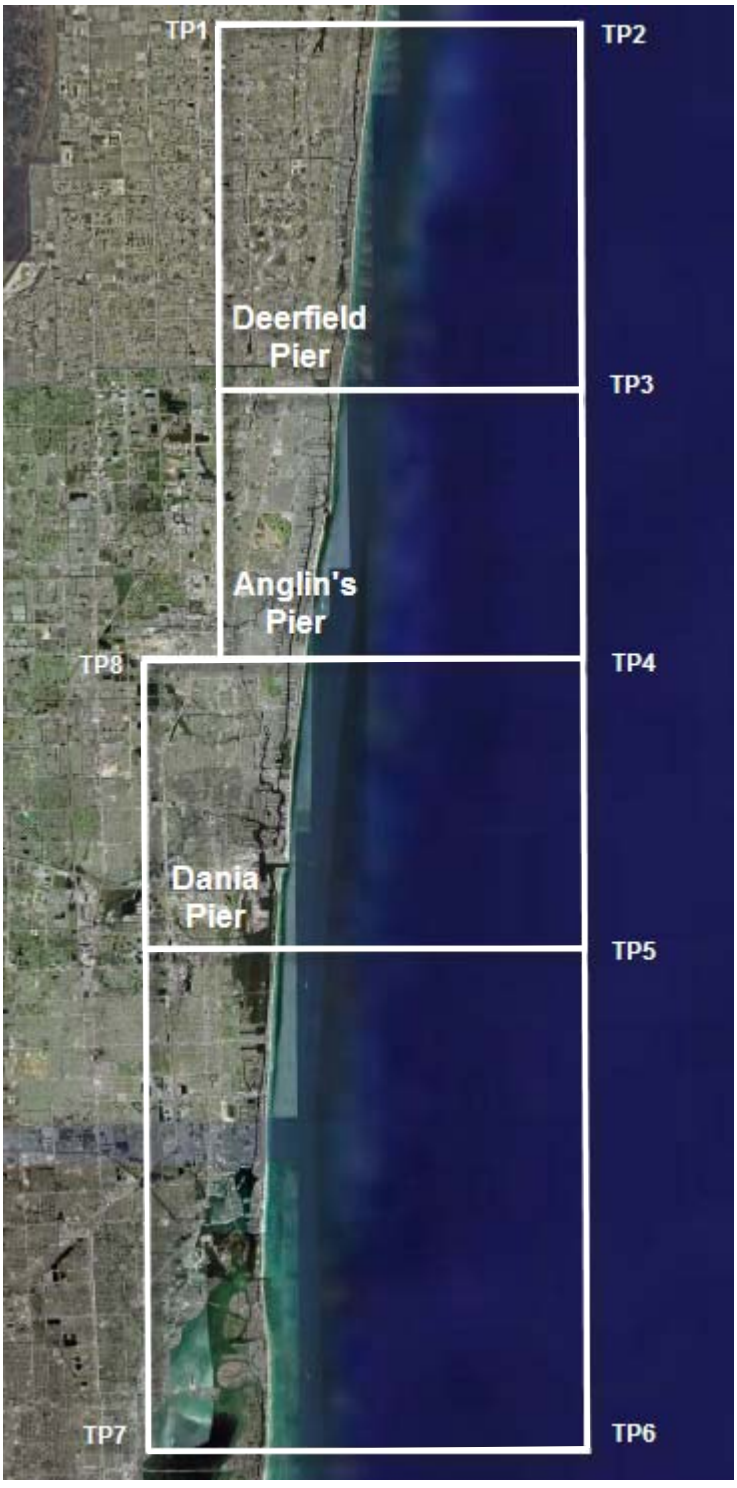

Figure 2 – Final Tide Zones in the LADS GS

A.3 TIDAL REDUCTION

For Tide Zones 2 and 3 there are two tide stations. Soundings have been reduced using a linear interpolation of tide observations between the two stations. In Tide Zones 1 and 4, where there is only one tide station, soundings have been reduced by tides from that station only.

A.3.1 Sounding Datum

All depth soundings were reduced to Mean Lower Low Water (MLLW). All drying feature heights are also related to MLLW.

As all tide records from the gauges at Deerfield Pier, Anglin's Pier and Dania Pier were initially related to NAVD88, a correction to MLLW was required for NOAA deliverables. The datum offsets were sourced from 4 tidal benchmarks in the vicinity of each tide gauge used during data acquisition.

- Lake Wyman (3.7 miles north of Deerfield Pier)
  PID# AD5830 = NAVD88 is 0.638m above MLLW

- Hillsboro (4 miles south of Deerfield Pier)
  PID# AD5849 = NAVD88 is 0.681m above MLLW

- Lauderdale-by-the-Sea (0.1 miles south of Anglin's Pier)
  PID# AD5853 = NAVD88 is 0.702m above MLLW

- South Dania Sound (0.3 miles south of Dania Pier)
  PID# AD5887 = NAVD88 is 0.623m above MLLW

Refer to Appendix III for the tidal benchmark data sheets.

The final NAVD88 – MLLW corrections used for each tide station's records, and the re-application of tides to soundings, were:

- Deerfield Pier = **+ 0.660**
- Anglin's Pier = **+ 0.702**
- Dania Pier = **+ 0.623**

A.3.2 Tides and Water Levels

After each survey flight, preliminary tide observations for Virginia Key were downloaded from the CO-OPS website for the interim reduction of soundings within the survey area. The format of this data was in UTC and meters, reduced to MLLW.

BOV supplied final tides for the Deerfield Pier, Anglin's Pier and Dania Pier tide stations after survey operations concluded. The format of this data was in UTC and meters, reduced to NAVD88. To relate the tide data to MLLW, the differences between NAVD88 and MLLW at the Primary Benchmarks closest to the tide stations were applied to the final tide data set. The final tide data (reduced to MLLW) was subsequently reapplied to all soundings following field operations.

Tidal information used to reduce soundings is forwarded in digital format on the USB hard drive. Below is a description of the digital files:

Verified Tides	Tide files supplied by BOV.
Tide Station Reports	Reports for each tide station of water levels entered into the GS for reduction of soundings.
Tide Application Reports	Reports on tide zone used in tidal application of each line of survey.

A.4 ACCURACY OF SOUNDINGS – DEPTH

A.4.1 LADS Mk II Vertical System Accuracy

A vertical accuracy of ± 0.3m (95% confidence) for the LADS Mk II system is considered appropriate from historical system performance and trials.

A.4.2 Tidal Accuracy

The error budget for tides can be assessed from three sources: Measurement Error, Datum Computation Error and Tidal Zoning Error. The following tidal error estimates are based on BOV's installation of three tide gauges along the Broward County coastline, CPE's establishment of each tide station's vertical datum, and the reported NAVD88 – MLLW offsets for each tidal benchmark:

Source	Estimate	Error Type
Measurement Error		
Calibration	0.01m	Systematic
Dynamic Effects	0.02m	Systematic
Processing to datum		
Staff / Gauge	0.01m	Random
Leveling	0.01m	Random
Interpolation	0.01m	Random
NAVD88 – MLLW Reduction	0.10m	Random
Datum Computation Error	0.02m	Systematic
Tidal Zoning Error	0.05m	Random
Total systematic errors	0.05m	
Total random errors	0.11m	
TOTAL TIDE ERROR = 0.05 + 1.96 X 0.11 = 0.27m		

A.4.3 Swell

Swell had little effect on survey operations. An allowance of ± 0.05m (95% confidence) has been incorporated into the depth accuracy assessment for the effects of swell.

A.4.4 Accuracy of Soundings

An assessment of the final sounding accuracy can be determined by combining the errors due to the LADS Mk II system, tidal model and swell. These are combined using a Gaussian model as follows:

σ^2 survey = σ^2 LADS Mk II + σ^2 Tide Model + σ^2 swell

95% confidence limit = 1.96σ

[For a single dimensional distribution]

Survey Accuracy = $\sqrt{(0.3^2 + 0.27^2 + 0.05^2)} = 0.41$m

From the assessment above, it is considered depth accuracy meets IHO Order-1 standard throughout the survey area. The agreement observed between adjacent survey lines in overlap areas and the crossline comparison results are also consistent with IHO Order-1 depth accuracy.

B. HORIZONTAL CONTROL

Data collection and processing were conducted on the Airborne and Ground Systems in World Geodetic System 1984 (WGS84) on Universal Transverse Mercator (Northern Hemisphere) projection UTM (N) in Zone 17, Central Meridian 81˚ West. This data was post-processed and all soundings are positioned relative to the North American Datum 1983 (NAD83). All units are in meters.

B.1 GEODETIC CONTROL STATIONS

B.1.1 LADS Local Base Station – Ft. Lauderdale

A local GPS base station was established by CPE on the top of a light tower at the Ft. Lauderdale Executive Airport on July 10, 2008. The coordination was undertaken using Trimble R8 and Trimble 5700 24-channel dual-frequency RTK GPS receivers. The base station position was differentially post-processed using National Geodetic Survey's Online Positioning Users Service software. The antenna mount was determined using a 120-minute fast static GPS session. Position checks were conducted and differences between the measurements were negligible.

The CPE report on the coordination of the local GPS base station is provided at Appendix IV.

The derived NAD83 coordinates for the local GPS base station, as supplied by CPE, are:

NAD83			UTM (N) Zone 17	
Latitude (N)	**Longitude(W)**	**Ellip. Height (m)**	**Easting (m)**	**Northing (m)**
26˚ 11' 42.4877"	80˚ 10' 17.4843"	-14.957	582776.318	2897558.340

The ellipsoidal height is relative to the bottom of the threads of the antenna pole.

B.1.2 Local GPS Base Station Site Confirmation

The local GPS base station was checked for obstructions and multipath over a 24-hour period on July 18 and 19, 2008. A second 'rover' GPS antenna was established 0.423m from the local GPS base station site. GPS data was logged at the base and rover position simultaneously over a single session. This enabled statistical analysis for the computed position of the rover in a spreadsheet utility. The GPS data was processed with GrafNav software for KGPS (L1 + L2 carrier phase, fixed ambiguities and forward / backward processing) position solutions. The results of the site confirmation are detailed below:

Solution	Taped Distance (m)	Observed Distance (m)	St. Dev. 1σ Eastings (m)	St. Dev. 1σ Northings (m)	St. Dev. 1σ Positions (m)
KGPS	0.423	0.424	0.016	0.015	0.022

Scatter plots for the computed position of the rover are presented in the Separates Report. The results presented above and scatter plots produced, reveal that the local GPS base site is free from site specific problems such as multipath and obstructions.

B.1.3 Static Position Check Control Network

The coordination of the three-point static position check control network at the Ft. Lauderdale Executive Airport was conducted by CPE on July 10, 2008, using Trimble 24-channel dual-frequency RTK GPS receivers with Trimble Maxwell technology. A 20-minute fast static GPS solution was undertaken for each of the three points.

The NAD83 positions for the control points, as provided by CPE, are listed below:

	NAD83			**UTM (N) Zone 17**	
Control Points	**Latitude (N)**	**Longitude (W)**	**Ellip. Ht. (m)**	**Easting (m)**	**Northing (m)**
Nose	26° 11’ 44.7758”	80° 10’ 18.6046”	-22.493	582744.776	2897628.534
R Wing	26° 11’ 45.2696”	80° 10’ 18.3678”	-22.485	582751.250	2897643.768
L Wing	26° 11’ 44.8427”	80° 10’ 17.9710”	-22.478	582762.348	2897630.704

The report on the coordination of the three control points for the static position check is provided at Appendix IV.

B.1.4 Static Position Check – Laser Source Position

On July 13, 2008 the LADS Mk II aircraft was positioned at the Ft. Lauderdale Executive Airport within the three-point static position check control network. An aircraft grid heading of 237° was determined from a Ground Compass Alignment using the LADS Mk II Attitude and Heading Reference System (AHRS). The position of the laser source was plumbed from the laser bay window to the tarmac and clearly marked with fluorescent paint.

The laser source position was determined by measuring distances to the three static control points with a tachometric tape and making trigonometric calculations. The spreadsheet used to conduct the computations was checked using manual computations, and is located at Appendix V. The NAD83 coordinates for the position of the laser source are:

NAD83		**UTM (N) Zone 17**	
Latitude (N)	**Longitude (W)**	**Easting (m)**	**Northing (m)**
26° 11’ 44.9709”	80° 10’ 18.2946	582753.342	2897634.591

B.1.5 Static Position Check – GPS Antenna Position

The derived GPS antenna position was determined by applying the laser source – antenna x and y offsets to the laser source position. This resulted in the determination of reference

coordinates for the comparisons of the static position check on the aircraft GPS antenna. The derived NAD83 coordinates for the GPS antenna position during the static position check are:

NAD83		UTM (N) Zone 17	
Latitude (N)	**Longitude (W)**	**Easting (m)**	**Northing (m)**
26° 11’ 44.9259”	80° 10’ 18.3437”	582751.987	2897633.198

A copy of the coordinate derivation is presented at Appendix VI. It was also necessary to compute the WGS84 coordinates for the GPS antenna position, in order to compare static position check sessions configured to autonomous GPS and WADGPS modes. The derived WGS84 coordinates for the GPS antenna position during the static position check are:

WGS84		UTM (N) Zone 17	
Latitude (N)	**Longitude (W)**	**Easting (m)**	**Northing (m)**
26° 11’ 44.9438”	80° 10’ 18.3585”	582751.573	2897633.748

The difference between NAD83 and WGS84 at the Ft. Lauderdale Executive Airport is:

	Easting	**Northing**
WGS84 – NAD83	0.414m	-0.550m

B.2 POSITIONING FIXING SYSTEMS

Throughout the survey the real-time position of the LADS Mk II system was derived from an Ashtech GG24 receiver with differential GPS corrections from a Fugro Omnistar receiver (WADGPS mode). The KGPS (L1 + L2 carrier phase) position was obtained by simultaneous data logging throughout each sortie with two Ashtech Z12 dual-frequency GPS receivers: the reference receiver at the coordinated local GPS base station on the light pole at the Ft. Lauderdale Executive Airport and the roving receiver onboard the aircraft. Following each flight the post-processed GrafNav KGPS data was imported into the GS where the dynamic position check function was used to calculate statistics on the accuracy of the real-time positioning system. The KGPS post-processed position solution was subsequently applied to all soundings.

B.3 GPS STATIC POSITION CHECK

On July 13, 2008 static position checks of the LADS Mk II positioning systems were undertaken relative to the aircraft GPS antenna absolute position. Two observation sessions took place: one using autonomous GPS and the second using WADGPS for real-time positioning.

Additionally, during these periods the roving receiver at the aircraft logged data simultaneously with the local GPS base station on the light pole at the Ft. Lauderdale

Executive Airport. Post-processing of this data provided KGPS (L1 + L2 carrier phase) positions for the aircraft GPS antenna, throughout the GPS static position check.

The real-time autonomous GPS and WADGPS positions are relative to the WGS84 reference framework and the post-processed positions are referenced to the NAD83 horizontal datum. Logging commenced on the local GPS base station at the Ft. Lauderdale Executive Airport and the roving receiver prior to the commencement of logging on the Airborne System (AS). During Session 1 the AS was configured to receive no differential corrections, and this resulted in autonomous GPS positioning. During Session 2 the Fugro Omnistar receiver was configured to differentially correct autonomous GPS positions from the AS GG24 receiver, providing a WADGPS solution. Position data was recorded on Digital Linear Tape (DLT) using the manual logging function on the AS. The recording period was approximately four hours, or two hours per session.

B.3.1 Observations

The observation periods were as follow:

	Start Time (UTC)	**Stop Time (UTC)**	**Logging Duration**	**Average Number of GPS Satellites**
Session 1	18:30	20:30	2 hours	9
Session 2	20:40	22:40	2 hours	10

The AS GPS observables were recorded manually every ten minutes. The real-time number of GPS satellites used, Positional Dilution of Precision (PDOP), Estimate of Horizontal Error (EHE), Easting and Northing were noted and were within normal acceptable limits.

B.3.2 Processing

The KGPS positions were produced by processing the base station file and the aircraft file with GrafNav software. The KGPS position was produced by solving for the carrier phase ambiguity using double differencing and forward and backward processing techniques. The autonomous GPS and WADGPS files were produced in real-time on the AS and the solution was logged directly to DLT. All real-time and post-processed files were then compared using Position Analysis Software on the GS.

B.3.3 Results

The final coordinates from each positioning system were exported to a commercial spreadsheet / graphical based software package, where calculations of means and standard deviations of positions were conducted and scatter plots produced.

The following tables show the comparison of different static GPS solutions for the position of the aircraft GPS antenna:

Note: Absolute Accuracy (95% Confidence) = $2.45(\sigma_E^2 + \sigma_N^2)^{1/2} + (\Delta east^2 + \Delta north^2)^{1/2}$

AS autonomous GPS and WADGPS positions are relative to WGS84, and post-processed (GrafNav) KGPS positions are relative to NAD83.

SESSION 1

	UTM Zone 17				
Positioning System	**Easting WGS84**	**Northing WGS84**			
Absolute Position of GPS Antenna	582751.573	2897633.748			
Session 1	**Mean Easting +/- 1σ (m)**	**Mean Northing +/- 1σ (m)**	**Δ East C – O (m)**	**Δ North C – O (m)**	**Absolute Accuracy 95% Confidence (m)**
Autonomous GPS	582752.544 +/- 0.852	2897636.859 +/- 1.993	-0.971	-3.111	8.569

	UTM Zone 17				
Positioning System	**Easting NAD83**	**Northing NAD83**			
Absolute Position of GPS Antenna	582751.987	2897633.198			
Session 1	**Mean Easting +/- 1σ (m)**	**Mean Northing +/- 1σ (m)**	**Δ East C – O (m)**	**Δ North C – O (m)**	**Absolute Accuracy 95% Confidence (m)**
Post-processed KGPS	582752.075 +/- 0.014	2897633.122 +/- 0.025	-0.088	0.076	0.186

SESSION 2

	UTM Zone 17				
Positioning System	**Easting WGS84**	**Northing WGS84**			
Absolute Position of GPS Antenna	582751.573	2897633.748			
Session 2	**Mean Easting +/- 1σ (m)**	**Mean Northing +/- 1σ (m)**	**Δ East C – O (m)**	**Δ North C – O (m)**	**Absolute Accuracy 95% Confidence (m)**
WADGPS	582752.202 +/- 0.638	2897634.274 +/- 0.473	-0.629	-0.526	2.766

	UTM Zone 17				
Positioning System	**Easting NAD83**	**Northing NAD83**			
Absolute Position of GPS Antenna	582751.987	2897633.198			
Session 2	**Mean Easting +/- 1σ (m)**	**Mean Northing +/- 1σ (m)**	**Δ East C – O (m)**	**Δ North C – O (m)**	**Absolute Accuracy 95% Confidence (m)**
Post-processed KGPS	582752.080 +/- 0.014	2897633.139 +/- 0.012	-0.093	0.059	0.155

The stated theoretical accuracy of each of the positioning systems has been compared against the absolute accuracy achieved during the static position check in the following table:

Positioning System	Baseline Distance (km)	Theoretical GPS Accuracy 95% Confidence (m)	Absolute Accuracy 95% Confidence (m)	Notes
Autonomous GPS	-	13.0	8.569	
WADGPS	-	-	2.766	
Session 1 - KGPS	0.1	0.3	0.186	1, 2
Session 2 - KGPS	0.1	0.3	0.155	1, 2

Notes

1. This solution may be affected slightly by the aircraft not being totally static during the data logging due to wind and personnel movements onboard the aircraft.
2. The KGPS solution was the most accurate and within the theoretical accuracy.

A compilation of graphs, illustrating the spread of solved positions for the static position check session and the report, is included within the Separates Report. These graphs show the mean point of recorded positions and the position of the actual antenna as determined by the static position checkpoint coordination.

B.3.4 Conclusion

The accuracy of the logged autonomous GPS position was within the theoretical accuracy. The WADGPS result was significantly more accurate and subsequently used as the real-time positioning mode during operations.

The KGPS positioning yielded an even more accurate result, and this positioning solution was subsequently post-applied to all survey data. The static position check shows that there were no gross errors with any of the LADS Mk II positioning systems at the commencement of operations.

B.4 DYNAMIC POSITION CHECK

During each sortie, GPS data was logged both on the aircraft and at the base station, which enabled a KGPS position solution to be determined. These position fixes were then compared to the coordinates as determined by the real-time positioning system (WADGPS). For each survey line the mean difference and standard deviation of the position fix differences have been calculated. The following table shows the mean and standard deviation of the difference in the positions between the real-time WADGPS and the post-processed KGPS for each sortie during which data was collected in support of the survey:

Sortie No.	Lines Flown	Max. Difference AS-KGPS (m)	Mean Difference AS-KGPS (m)	Overall Average Standard Deviation (m)
2	3	1.786	0.815	0.106
3	2	1.024	0.525	0.017
4	19	2.682	0.941	0.138
5	18	2.568	0.825	0.124
7	11	2.302	1.181	0.119
11	18	1.994	0.817	0.070
12	9	2.352	0.992	0.108
13	5	1.707	0.866	0.091
14*	3	-	-	-
15	3	1.470	0.819	0.030

* Data from sortie 14 was not processed due to poor water clarity. A dynamic position check was not performed for this sortie.

These results show a very good agreement between the real-time WADGPS positioning and the post-processed KGPS positioning. An extract from the Sortie 4 Dynamic GPS Position Check Report is provided in the Separates Report.

B.5 NAVIGATION POSITION CHECK

Due to night time operations no navigation position checks were conducted.

B.6 ACCURACY OF SOUNDINGS – HORIZONTAL POSITION

B.6.1 Theoretical Accuracy

The theoretical accuracy of the positioning systems is related to the distance of the GPS receiver from the base station. The relationship between baseline distance and theoretical accuracy was provided by Waypoint and is based on empirical data.

B.6.1.1 Waypoint GrafNav

The theoretical accuracy of the post-processed GrafNav positional data has been determined from the GrafNav Software User's Manual and through consultation with Waypoint Consulting, Inc. For a PDOP of less than 4, the following GrafNav data processing accuracy has been quoted:

- L1/L2 carrier phase, float ambiguities,
  fwd / backwd processing (KGPS) = 0.3m + 1ppm (worse case)

For the survey area the maximum baseline distance between the local GPS base station and the survey area is approximately 85km. Therefore, the expected accuracy of the post-processed solutions is:

- L1/L2 carrier phase = ±0.39m @ 95% confidence

B.6.2 Practical Accuracy

The actual performance of the positioning solutions was checked by:

a. Static position check

b. Dynamic position check

B.6.2.1 Static Position Check

Static position checks were conducted for the following GPS solutions:

a. KGPS – Forward and backward processed L1+L2 carrier phase, float ambiguities (offline)

b. Autonomous GPS – GPS receiver operating in stand alone mode.

c. WADGPS – GPS positions differentially corrected by Fugro Omnistar receiver in real-time.

The static position check results are provided in Section B.3.3 and in the Separates Report.

B.6.2.2 Dynamic Position Monitoring

During the survey, GPS data was logged on the aircraft and at the local base station, which enabled post-processing to produce KGPS result files. These result files were then compared to the position as determined by the real-time WADGPS solution on the AS. For each survey line, the mean difference and standard deviation have been calculated. The dynamic position check results for each sortie are enclosed in Section B.4.

B.6.3 LADS Mk II Positioning Accuracy

The total expected error of the LADS Mk II positioning is a combination of the following errors:

a. GPS errors (Egps), as previously stated, have a theoretical maximum of ± 0.39m (95% confidence - KGPS).

b. Errors in assigning frame center reference positions from GPS fixes (Eframe ref) have been assessed as ± 0.66m (95%).

c. Platform and laser positioning errors (Eplat, this includes such errors as gimbal angles, optical alignment, AHRS angles, AHRS mount, Optical Coupler mount, Scanner mount, Laser output, Laser mount, mirrors, timing and aircraft height). The resultant error in position has been assessed as ± 1.30m (95%).

d. Position errors of detecting objects due to the distance between laser spots (Espot). With a 4m laser spot spacing, it is considered the maximum position error is half of the sample interval distance, or ± 2.0m.

e. Sea surface errors (Esurface) due to swell. These are variable and dependant on the angle of incidence of the laser beam at the air / sea boundary, the depth of water and sea state. They have been assessed and are tabled below:

Depth (m)	Sea State 1	Sea State 2	Sea State 3	Sea State 4
5	0	0.03	0.31	0.55
10	0.01	0.06	0.62	1.10
15	0.01	0.09	0.93	1.65
20	0.02	0.12	1.24	2.20

Seas were slight during all survey flights and swell was considered minimal. A maximum sea state of 2 was observed during survey operations, and the maximum depth achieved by Lidar was well beyond 20m.

- Total Expected Error $= ((Egps)^2 + (Eframe\ Ref)^2 + (Eplat)^2 + (Espot)^2 + (Esurface)^2)^{½}$

The maximum error expected, at 85km from the local GPS base station at Ft. Lauderdale Executive Airport, in a depth beyond 20m, with sea state 2 is:

- Total Expected Error $= (0.39)^2 + (0.66)^2 + (1.30)^2 + (2.00)^2 + (0.12)^2)^{½}$
  $= 2.51$m at the 95% confidence level

Analyzing the positional data obtained from both the static and dynamic position checks, it has been concluded that during the survey, IHO Order-1 precision for position was achieved.

B.6.4 GPS Positional Accuracy – Summary

B.6.4.1 Static Position Check

- Absolute accuracy of GrafNav post-processed KGPS (mean of two sessions, 0.1km baseline) = 0.171m

B.6.4.2 Dynamic Position Check

- Mean value of position differences, over all lines of survey, between real-time WADGPS and post-processed KGPS = 0.865m

- Maximum value of position differences, over all lines of survey, between real-time WADGPS and post-processed KGPS = 2.682m

B.6.5 Horizontal Accuracy of Final Soundings

- Theoretical Accuracy
  (Depth = 20m, Sea State 2, Baseline 85km) = 2.51m

- IHO Order-1 Horizontal Accuracy
  (95% confidence) = 5m + 5% of the depth

- **Survey Horizontal Accuracy**
  (95% confidence) = better than 3m

C. APPROVAL SHEET

LETTER OF APPROVAL – OPR-H328-KRL-09

This report and the accompanying digital data are respectfully submitted.

Field operations contributing to the accomplishment of this survey were conducted under my direct supervision with frequent personal checks of progress and adequacy. This report and the accompanying digital data have been closely reviewed and are considered complete and adequate as per the Hydrographic Survey Project Instructions.

Report	Submission Date
Horizontal and Vertical Control Report	October 28, 2009

Mark Sinclair
Hydrographer

Fugro LADS, Incorporated

Date: October 28, 2009

APPENDIX I – NOAA VIRGINIA KEY TIDE STATION DESCRIPTION

TIDES & CURRENTS

Search

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Station Home Page
Station Information
Tide / Water Level Data
Tide Predictions
Current Data
Meteorological Observations
Conductivity
PORTS
Operational Forecast System
Bench Mark Sheets
Datums
Harmonic Constituents
Sea Level Trends

Virginia Key, FL

Station ID: 8723214

Station Information

Latitude: **25° 43.9' N**
Longitude: **80° 9.7' W**
Established: **Jan 26 1994**
Present Installation: **Jan 17 1994**
NOAA Chart #: **11465**
Time Meridian: **75 W**

Mean Range: **2.05 ft.**
Diurnal Range: **2.24 ft.**

Click image for larger image.

Data Types Available:	Station and Bench Mark Drawing	Station Location Chartlet
Primary Water Level	Click HERE for Drawing (Not for navigational use)	Click HERE for Map (Not for navigational use)

EPOCH Update Information:

EPOCH Datum Comparison:	**Click HERE -**	check datum differences between the old epoch (1960-1978) and the new epoch (1983-2001)
Superceded Bench Mark Data Sheet:	**Click HERE -**	bench mark sheet on the old Tidal Datum Epoch (1960-1978)
Superceded Datums:	**Click HERE -**	datums on the old Tidal Datum Epoch (1960-1978)
Mean Sea Level Differences List:	**Click HERE -**	mean sea level differences between the two epochs for all stations.

Mean Sea Level Difference: for 8723214 Virginia Key, FL	1983-2001	1960-1978	Difference:
	11.26 ft.	11.05 ft.	0.21 ft.

Location:

To reach the tidal bench marks from the intersection of U.S. Route 1 and Rickenbacker Causeway, proceed 5 km (3 mi) east on Rickenbacker Causeway to the entrance of the Rosenstiel School of Marine and Atmospheric Science (Univ. of Miami). The bench marks are located in the vicinity of the concrete pier and on the School grounds. The tide station is located at the outer end of the concrete pier.

Nov 24 2008 12:06 ELEVATIONS ON STATION DATUM
National Ocean Service (NOAA)

Station: 8723214 T.M.: 0 W
Name: VIRGINIA KEY, BISCAYNE BAY, FL Units: Meters
Status: Accepted Epoch: 1983-2001

Datum	Value	Description
MHHW	3.774	Mean Higher-High Water
MHW	3.752	Mean High Water
DTL	3.432	Mean Diurnal Tide Level
MTL	3.439	Mean Tide Level
MSL	3.431	Mean Sea Level
MLW	3.126	Mean Low Water
MLLW	3.090	Mean Lower-Low Water
GT	0.684	Great Diurnal Range
MN	0.626	Mean Range of Tide
DHQ	0.021	Mean Diurnal High Water Inequality
DLQ	0.037	Mean Diurnal Low Water Inequality
HWI	1.62	Greenwich High Water Interval (in Hours)
LWI	7.82	Greenwich Low Water Interval (in Hours)
NAVD	3.698	North American Vertical Datum
Maximum	4.353	Highest Water Level on Station Datum
Max Date	19941115	Date Of Highest Water Level
Max Time	11:12	Time Of Highest Water Level
Minimum	2.697	Lowest Water Level on Station Datum
Min Date	19940329	Date Of Lowest Water Level
Min Time	21:42	Time Of Lowest Water Level

To refer Water Level Heights to a Tidal Datum, apply the desired Datum Value.

APPENDIX II – BAXLEY OCEAN VISIONS TIDE DATA COLLECTION REPORT

Broward County LADS Tide Data Collection Report

Baxley Ocean Visions, Inc.
Hollywood, Florida
August 22, 2008

Overview

Baxley Ocean Visions, Inc. (BOV) of Hollywood, Florida, under contract to Coastal Planning and Engineering, Inc. (Contract number RLI #040897-RB), collected tide level data during the bathymetric survey of the nearshore area of Broward County, Florida, during the summer of 2008. Tenix LADS surveyed the nearshore area of the county using an airborne laser system, and in order to properly correlate measurements to a known vertical datum, accurate and actual tide level information was required. BOV installed three gauges along the coastline, and provided recovery and data download support for the project.

Equipment and Installation

The tide gauges utilized were Coastal Leasing's MacroTide units, equipped with a 30 psi pressure sensor and internal recording capability. The gauges recorded tide level using the pressure sensor in units of pounds per square inch absolute (psia), averaging 60 samples over a 30 second interval every six minutes throughout the duration of the project. The sensor specified accuracy was 0.1%, at 12 bit resolution. The time used was Eastern Daylight Time (EDT), or -5 hours from GMT.

The gauges were installed on July 12, 2008 on three piers in Broward County; Dania Pier, Commercial (Anglin's) Pier, and Deerfield Pier. Each gauge was installed in about 10 ft of water, about 2 ft above the seafloor. CPE surveyors shot the elevations of the gauges and seafloor during installation and after removal for reference to the project vertical datum.

The gauges were secured to the pilings by nylon ratchet straps, along with a 1/8" diameter steel cable shackled to restrain the unit in the event the straps failed. The housings were also wrapped with rubber sheeting to protect them from growth and damage from the pilings.

The installation times were staggered to maximize storage and to provide for travel between piers, with the Dania gauge starting at 10:00 EDT, the Commercial gauge at 14:00 EDT, and the Deerfield unit commencing measurements at 17:00 EDT. The respective raw data files reflect this difference in start time, while the Excel data has been aligned in time to begin at 17:00 EDT. The gauges were removed on August 24, 2008 at the conclusion of LADS flights.

Data

Each gauge was offloaded on Monday, August 25 and produced two datafiles per unit; one raw binary file and one processed file in engineering units. The filenames are given below, with the "R" signifying raw data, and the "A" indicating a processed ASCII text file:

- Dania Pier, serial number 10672, filenames
  - 1930672R.001
  - 1930672A.001
- Commercial Pier, serial number 10737, filenames
  - 1930737R.001
  - 1930737A.001
- Deefield Pier, serial number 10740, filenames
  - 1930740R.001
  - 1930740A.001

All data time stamps are in Eastern Daylight Time (-5 hrs GMT), and tide units are in pounds per square inch (psi). Also provided in the files are the battery voltage in DC volts, and the internal gauge temperature in degrees C.

An Excel spreadsheet was also generated including the text data from each pier, and a sheet where the times are adjusted so that all measurements start at 17:00 EDT, and the pressure is converted to inches, after which the respective offset from the datum is adjusted. The datum used for the tide data is NAVD88 US Survey Feet, and the elevations were:

- Dania Pier -6.48 ft
- Commercial Pier -8.78 ft
- Deerfield Pier -8.66 ft

The raw ASCII data files are provided, however, in the event either CPE or TENIX LADS would rather process the data independently.

Conclusion

The tide gauge installation was a success, and good, high resolution tidal data was collected from July 12 to August 23, 2008. The gauges were securely fastened to the piers, and although a minor tropical system passed over, the gauges did not move from their locations. If any additional information is required, please contact Bill Baxley at (772) 321-2450 or via email at baxleywe@earthlink.net.

APPENDIX III – NOAA TIDAL BENCHMARK DATA SHEETS

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Ocean Service

Station ID: 8722802 **PUBLICATION DATE:** 05/23/2003
Name: LAKE WYMAN FLORIDA
NOAA Chart: 11466 **Latitude:** 26° 22.2' N
USGS Quad: BOCA RATON **Longitude:** 80° 4.3' W

T I D A L D A T U M S

Tidal datums at LAKE WYMAN based on:

LENGTH OF SERIES:	1 MONTH
TIME PERIOD:	April 1973 - April 1973
TIDAL EPOCH:	1983-2001
CONTROL TIDE STATION:	8722706 BOYNTON BEACH

Elevations of tidal datums referred to Mean Lower Low Water (MLLW), in METERS:

MEAN HIGHER HIGH WATER (MHHW)	=	0.759
MEAN HIGH WATER (MHW)	=	0.721
NORTH AMERICAN VERTICAL DATUM-1988 (NAVD)	=	0.638
MEAN TIDE LEVEL (MTL)	=	0.385
MEAN SEA LEVEL (MSL)	=	0.370
MEAN LOW WATER (MLW)	=	0.049
MEAN LOWER LOW WATER (MLLW)	=	0.000

National Geodetic Vertical Datum (NGVD 29)

Bench Mark Elevation Information In METERS above:

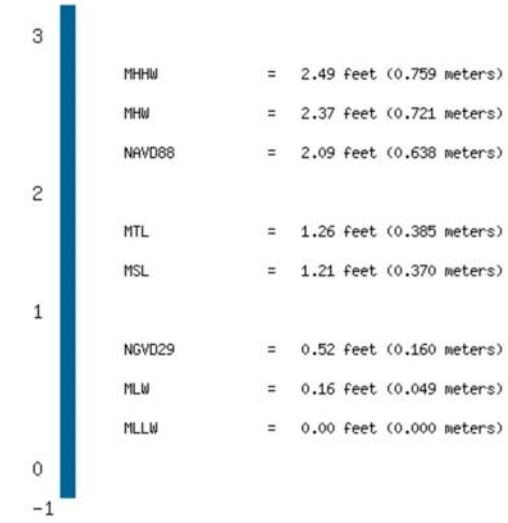
Stamping or Designation	MLLW	MHW
NO 1 1973	1.811	1.090
X 312 1970	7.297	6.576
NO 2 1973	1.824	1.103
NO 5 1973	1.817	1.096
NO 3 1973	1.855	1.134
NO 4 1973	1.885	1.164

Foot Notes:

Bench mark X 312 1970 is based on one differential leveling connection and does not meet the quality control standards of the NOS. Therefore, caution should be used when deriving elevations for this mark.

Elevation Information

PID: AD5830
VM: 5642
Station ID: 8722802
Epoch: 1983-2001
Date: Thu Apr 23 14:24:28 EDT 2009



The NAVD 88 and the NGVD 29 elevations related to MLLW were computed from Bench Mark, 872 2802 TIDAL 1, at the station.

Displayed tidal datums are Mean Higher High Water(MHHW), Mean High Water (MHW), Mean Tide Level(MTL), Mean Sea Level (MSL), Mean Low Water(MLW), and Mean Lower Low Water(MLLW) referenced on 1983-2001 Epoch.

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Ocean Service

Station ID: 8722859 **PUBLICATION DATE:** 12/12/2003
Name: HILLSBORO FLORIDA
NOAA Chart: 11466 **Latitude:** 26° 15.6' N
USGS Quad: BOCA RATON **Longitude:** 80° 5.1' W

T I D A L D A T U M S

Tidal datums at HILLSBORO based on:

LENGTH OF SERIES:	6 MONTHS
TIME PERIOD:	May 1973 - October 1973
TIDAL EPOCH:	1983-2001
CONTROL TIDE STATION:	8723170 MIAMI BEACH (CITY PIER)

Elevations of tidal datums referred to Mean Lower Low Water (MLLW), in METERS:

MEAN HIGHER HIGH WATER (MHHW)	=	0.816
MEAN HIGH WATER (MHW)	=	0.777
NORTH AMERICAN VERTICAL DATUM-1988 (NAVD)	=	0.682
MEAN TIDE LEVEL (MTL)	=	0.411
MEAN SEA LEVEL (MSL)	=	0.407
MEAN LOW WATER (MLW)	=	0.045
MEAN LOWER LOW WATER (MLLW)	=	0.000

National Geodetic Vertical Datum (NGVD 29)

Bench Mark Elevation Information	In METERS above: MLLW	MHW
NO 1 1973	1.576	0.799
Y 311 1970	3.614	2.837
NO 2 1973	1.596	0.819
NO 3 1973	1.329	0.552
NO 4 1973	2.420	1.643
NO 5 1973	1.685	0.908
16.770	5.295	4.518
18.090	5.697	4.920

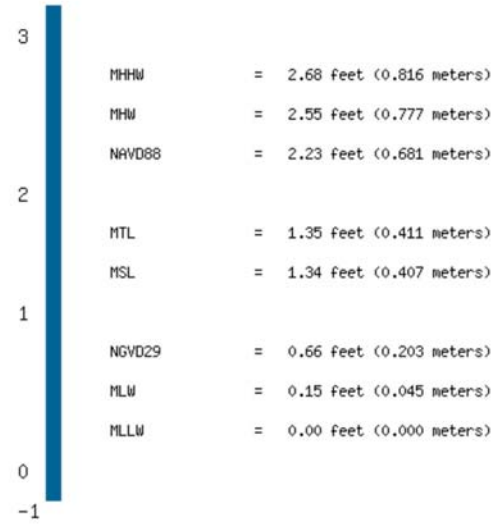
Foot Notes:

Bench marks Y 311 1970, 16.770, and 18.090 are based on one differential leveling connection and do not meet the quality control standards of the NOS. Therefore, caution should be used when deriving elevations for these marks.

COOPS/NGS Elevation Data Graphics http://www.ngs.noaa.gov/newsys-cgi-bin/ngs_opsd.prl?PID=AD5849

Elevation Information

PID: AD5849
VM: 5665
Station ID: 8722859
Epoch: 1983-2001
Date: Thu Apr 23 14:25:41 EDT 2009



The NAVD 88 and the NGVD 29 elevations related to MLLW were computed from Bench Mark, 872 2859 TIDAL 1, at the station.

Displayed tidal datums are Mean Higher High Water(MHHW), Mean High Water (MHW), Mean Tide Level(MTL), Mean Sea Level (MSL), Mean Low Water(MLW), and Mean Lower Low Water(MLLW) referenced on 1983-2001 Epoch.

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U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Ocean Service

Station ID: 8722899 **PUBLICATION DATE:** 08/03/2004
Name: LAUDERDALE-BY-THE-SEA
FLORIDA
NOAA Chart: 11466 **Latitude:** 26° 11.3' N
USGS Quad: POMPANO BEACH **Longitude:** 80° 5.6' W

T I D A L D A T U M S

Tidal datums at LAUDERDALE-BY-THE-SEA based on:

LENGTH OF SERIES: 1 YEAR
TIME PERIOD: February 1974 - January 1975
TIDAL EPOCH: 1983-2001
CONTROL TIDE STATION: 8723170 MIAMI BEACH (CITY PIER)

Elevations of tidal datums referred to Mean Lower Low Water (MLLW), in METERS:

HIGHEST OBSERVED WATER LEVEL (10/25/1973)	= 1.384
MEAN HIGHER HIGH WATER (MHHW)	= 0.873
MEAN HIGH WATER (MHW)	= 0.836
NORTH AMERICAN VERTICAL DATUM-1988 (NAVD)	= 0.701
MEAN SEA LEVEL (MSL)	= 0.446
MEAN TIDE LEVEL (MTL)	= 0.443
MEAN LOW WATER (MLW)	= 0.051
MEAN LOWER LOW WATER (MLLW)	= 0.000
LOWEST OBSERVED WATER LEVEL (01/31/1975)	= -0.408

National Geodetic Vertical Datum (NGVD 29)

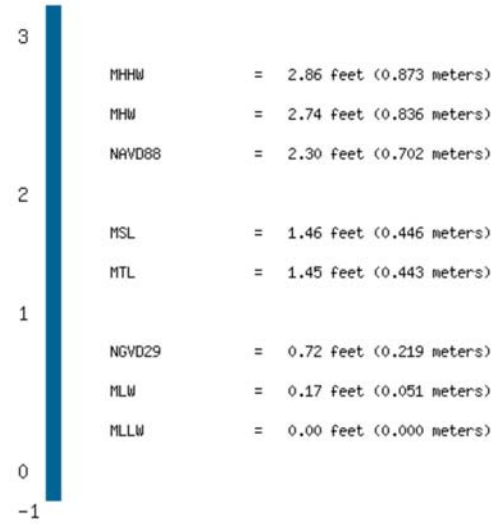
Bench Mark Elevation Information In METERS above:

Stamping or Designation	MLLW	MHW
NO 1 1973	4.120	3.284
R 311 1970	3.409	2.573
NO 2 1973	3.351	2.515
NO 3 1973	3.751	2.915
2899 F 1981	3.802	2.966
2899 G 1981	3.911	3.075

COOPS/NGS Elevation Data Graphics http://www.ngs.noaa.gov/newsys-cgi-bin/ngs_opsd.prl?PID=AD5853

Elevation Information

PID: AD5853
VM: 5683
Station ID: 8722899
Epoch: 1983-2001
Date: Thu Apr 23 14:26:17 EDT 2009



The NAVD 88 and the NGVD 29 elevations related to MLLW were computed from Bench Mark, 872 2899 TIDAL 1, at the station.

Displayed tidal datums are Mean Higher High Water(MHHW), Mean High Water (MHW), Mean Tide Level(MTL), Mean Sea Level (MSL), Mean Low Water(MLW), and Mean Lower Low Water(MLLW) referenced on 1983-2001 Epoch.

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U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Ocean Service

Station ID: 8722971 **PUBLICATION DATE:** 05/23/2003
Name: SOUTH DANIA SOUND FLORIDA
NOAA Chart: 11470 **Latitude:** 26° 3.3' N
USGS Quad: PORT EVERGLADES **Longitude:** 80° 6.8' W

T I D A L D A T U M S

Tidal datums at SOUTH DANIA SOUND based on:

LENGTH OF SERIES: 1 MONTH
TIME PERIOD: August 1973 - August 1973
TIDAL EPOCH: 1983-2001
CONTROL TIDE STATION: 8723170 MIAMI BEACH (CITY PIER)

Elevations of tidal datums referred to Mean Lower Low Water (MLLW), in METERS:

MEAN HIGHER HIGH WATER (MHHW)	=	0.750
MEAN HIGH WATER (MHW)	=	0.723
NORTH AMERICAN VERTICAL DATUM-1988 (NAVD)	=	0.623
MEAN TIDE LEVEL (MTL)	=	0.386
MEAN SEA LEVEL (MSL)	=	0.381
MEAN LOW WATER (MLW)	=	0.049
MEAN LOWER LOW WATER (MLLW)	=	0.000

National Geodetic Vertical Datum (NGVD 29)

Bench Mark Elevation Information In METERS above:

Stamping or Designation	MLLW	MHW
NO 2 1973	1.298	0.575
NO 4 1973	1.301	0.578
86 71 B19	8.095	7.372
DANIA 3 1985	6.948	6.225
DANIA 3 1985 (AZI)	6.557	5.834
DANIA 3 NO 5 1985	7.496	6.773
DANIA 3 NO 6 1985	6.638	5.915

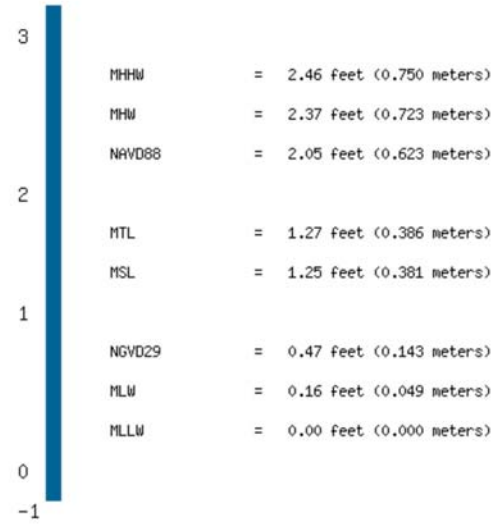
Foot Notes:

Bench marks 86 71 B19, Dania 3 1985, Dania 3 (AZI), Dania 3 NO5 1985, and Dania 3 NO6 1985 are based on one differential leveling connection and do not meet the quality control standards of the NOS. Therefore, caution should be used when deriving elevations for these marks.

COOPS/NGS Elevation Data Graphics http://www.ngs.noaa.gov/newsys-cgi-bin/ngs_opsd.prl?PID=AD5887

Elevation Information

PID: AD5887
VM: 5718
Station ID: 8722971
Epoch: 1983-2001
Date: Thu Apr 23 14:26:57 EDT 2009



The NAVD 88 and the NGVD 29 elevations related to MLLW were computed from Bench Mark, 872 2971 TIDAL 2, at the station.

Displayed tidal datums are Mean Higher High Water(MHHW), Mean High Water (MHW), Mean Tide Level(MTL), Mean Sea Level (MSL), Mean Low Water(MLW), and Mean Lower Low Water(MLLW) referenced on 1983-2001 Epoch.

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APPENDIX IV – COASTAL PLANNING AND ENGINEERING FINAL GPS REPORT

COASTAL PLANNING & ENGINEERING, INC.

2481 NW BOCA RATON BOULEVARD, BOCA RATON, FL 33431 561-391-8102 PHONE 561-391-9116 FAX
INTERNET: http://www.coastalplanning.net
e-mail: mail@coastalplanning.net

Summary of Job:

Locations for three calibration points and an antenna mount were required by Tenix LADS to support the 2008 Broward County LIDAR data acquisition. Coastal Planning & Engineering, Inc. (CPE) surveyors utilized RTK GPS confirmed with fast (rapid) static GPS methods to measure the four unknown locations. Positions for this project were collected in the North American Datum of 1983 (NAD83/90) and the North American Vertical Datum of 1988 (NAVD 88), U.S. State Plane, Florida East, U.S. Survey Feet (sft). Base station data were collected using a Trimble 5700 with a Zephyr Geodetic antenna set on a CPE monument located on Commercial Pier. The CPE monument was a PK nail based on local Florida Department of Environmental Protection (FDEP) 2nd Order "A" monuments (A13, A16, and A17). Four 180 epoch RTK GPS positions were collected at the three calibration points and the antenna mount. The RTK GPS positions for the three calibration points were confirmed with 20 minute fast static GPS solutions. The RTK GPS position for the antenna mount was confirmed with a 120 minute fast static GPS solution. All measurements were successfully tied into the local airport control monument FXE A as well as three 2nd order monuments using FDEP standards to ensure RTK GPS quality.

Equipment Description:

The Trimble R8 is a lightweight, cable-free, 24-channel dual frequency RTK GPS receiver with Trimble Maxwell technology for robust tracking in difficult GPS environments. The dual frequency Trimble antenna along with the four-point antenna feed provides submillimeter phase center stability for precise survey results. The Trimble R8 provides unfiltered, unsmoothed pseudorange measurement data for low noise, low multipath error, low time domain correlation and high dynamic response.

The Trimble 5700 is a 24-channel dual-frequency RTK GPS receiver with Maxwell technology that provides unfiltered, unsmoothed pseudorange measurement data for low noise, low multipath error, low time domain correlation and high dynamic response. When used along with a Trimble Zephyr Geodetic antenna the 5700 provides extremely low multipath with outstanding low elevation tracking and submillimeter phase center accuracy ideal for RTK measurements.

The Pacific Crest radio (PDLHPB) is a rugged radio modem data link that provides a high performance data link compatible with the Trimble RTK GPS systems for precise positioning information.

Equipment Description
August 22, 2008
Page 2

GPS Measurements:

Three 180 epoch RTK GPS sessions were run on the calibration points determined by Tenix LADS using a Trimble R8 (serial #4563). Each station was measured using a fixed bipod with an antenna height of 8.32' measured to the respective calibration point. GPS sessions were run logging every second to the R8 receiver.

A 180 epoch RTK GPS session was run on the antenna mount using a Trimble R8 (Serial #4563). The R8 antenna was set directly on top of a fixed height pole (antenna mount) on the roof and measured with an antenna height of 0.0' measured to the antenna mount. The GPS session was run logging every second to the R8 receiver.

To confirm the RTK GPS solutions, data collected at the three calibration points and the antenna mount were differentially post-processed using National Geodetic Survey's Online Positioning Users Service software. The calibration points were processed using 20 minute fast static GPS sessions. The antenna mount was processed using a 120 minute fast static GPS session. The two methods checked as differences between the measurements were negligible.

Processing Software:
TGO (Trimble Geomatics Office)
National Geodetic Survey's OPUS (Online Positioning Users Service)

Description of Stations: Stations described as if looking forward to nose of plane.
Station 1: Nose of plane
Station 2: Right wing of plane
Station 3: Left wing of plane
Base: Fixed height pole (antenna mount) located on top of roof

Control Used by CPE (PROVIDED BY FDEP):
Datum: NAD83/90/NAVD1988
Stamping: FXE A
Northing: 678187.841 sft
Easting: 929372.726 sft
Elevation: 10.385 sft
Description: Located at the Ft. Lauderdale Executive Airport on the easterly side near the compass rose.

Datum: NAD83/90/NAVD1988
Stamping: 86 92 DA13
Northing: 680254.89 sft
Easting: 952870.66 sft
Elevation: 9.329 sft
Description: Located on the east edge of A1A on the sidewalk in front of Sea Ranch Villas.

Datum: NAD83/90/NAVD1988
Stamping: 86 92 DA16
Northing: 671325.230 sft
Easting: 951632.430 sft
Elevation: 7.750 sft
Description: Located on sidewalk west of A1A adjacent to parking lot.

Datum: NAD83/90/NAVD1988
Stamping: 86 92 DA17
Northing: 669591.390 sft
Easting: 951375.150 sft
Elevation: 8.170 sft
Description: Located on west side of A1A, approx. 100 ft north form the corner of A1A and SE 36th street.

Control Located by CPE: (ft, NAD83/NAVD 88)
Station: 1 (nose of plane)
Northing: 677712.005 sft
Easting: 927731.143 sft
Elevation: 10.201 sft
Latitude: N26° 11.7462630'
Longitude: W80° 10.3100759'

Station: 2 (right wing of plane)
Northing: 677762.003 sft
Easting: 927752.391 sft
Elevation: 10.227 sft
Latitude: N26° 11.7544933'
Longitude: W80° 10.3061300'

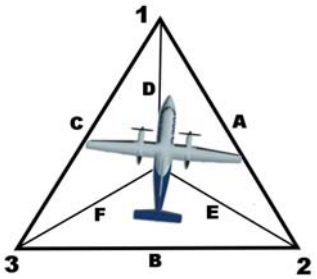
Station: 3 (left wing of plane)
Northing: 677719.126 sft
Easting: 927788.814 sft
Elevation: 10.253 sft
Latitude: N26° 11.7473776'
Longitude: W80° 10.2995161'

Station: BASE (fixed height pole on roof)
Northing: 677481.632 sft
Easting: 927834.663 sft
Elevation: 34.927 sft
Latitude: N26° 11.7081285'
Longitude: W80° 10.2914048'

APPENDIX V – STATIC POSITION CHECK – LASER SOURCE POSITION COORDINATION

Survey Title: Florida2008

Database Name: 08_10Broward



Segment	Taped (m)	Check
A	16.552	-0.001
B	17.138	-0.004
C	17.735	0.030
D	10.502	
E	9.409	
F	9.818	

Aircraft Heading	237°

Point ID	EASTING	NORTHING	DATUM	SOURCE
1	582744.776	2897628.534	NAD83	CP&E
2	582751.250	2897643.768	ZONE	
3	582762.348	2897630.704	17N	
Laser Source	582753.342	2897634.591		
GPS Absolute	582751.987	2897633.198		

	Easting	Northing			
Absolute Position	582751.987	2897633.198			
	Easting ±σE	**Northing ±σN**	**Δ East C–O (m)**	**Δ North C–O (m)**	**Absolute Accuracy (95% conf)**
Session 2 WADGPS	582752.202 +/- 0.638	2897634.274 +/-0.473	-0.629	-0.526	2.766
Session 2 KGPS	582752.080 +/- 0.014	2897633.139 +/- 0.012	-0.093	0.059	0.155
Session 1 GPS Only	582752.544 +/- 0.852	2897636.859 +/- 1.993	-0.971	-3.111	8.569
Session 1 KGPS	582752.075 +/- 0.014	2897633.122 +/- 0.025	-0.088	0.076	0.186

Note: Absolute Accuracy (95% Confidence) = 2.45 (σE2 + σN2) ½ + (Δ East2 + Δ North2)½

Triangle Solutions

Side	Side Length	Squared	Cos Rule	Acos(rad)	DD	DMS	Angle	Check	
A	16.552	273.968704	-0.3802494467	1.9608623143	112.34913	112:20:57	a		TRI 1
E	9.409	88.529281	0.8506384150	0.5535979321	31.71883	31:43:08	e		
D	10.502	110.292004	0.8097136110	0.6271324072	35.93204	35:55:55	d	180.00000	
B	17.138	293.711044	-0.5888260994	2.2004020174	126.07375	126:04:25	b		TRI 2
F	9.818	96.393124	0.8863399839	0.4814163684	27.58313	27:34:59	f		
E	9.409	88.529281	0.8961526881	0.4597742677	26.34313	26:20:35	e	180.00000	
C	17.735	314.530225	-0.5229683040	2.1211260575	121.53157	121:31:54	c		TRI 3
D	10.502	110.292004	0.8632767482	0.5290701885	30.31349	30:18:49	d		
F	9.818	96.393124	0.8816748130	0.4913964076	28.15494	28:09:18	f	180.00000	
					359.95445	359:57:16	Check		

Join Calculation between Stat-Cal Triangle marks

Line	de	dn	dist	BRG	RawDegBRG	DegBRG	DegBRG
1-2	-6.474	-15.234	16.553	0.40185	23.02406	23.02406	203.02406
2-3	-11.098	13.064	17.142	-0.70421	-40.34824	319.65176	139.65176
3-1	17.572	2.170	17.705	1.44793	82.96008	82.96008	262.96008

Bearing Quadrant Calculations

Column	Row	Quadrant	Min	Max	AntiClockwise	Clockwise
2	2	3	180	270	203.02406	23.02406
2	1	4	270	360	319.65176	139.65176
1	1	1	0	90	82.96008	262.96008

Quadrant	Min	Max
1	0	90
2	90	180
3	180	270
4	270	360

Laser Source Coordinate Calculation

From Pt	NewRawBRG	NewBRG	dist	de	dn	New E	New N	
1	54.80514	54.80514	10.502	8.582	6.053	582753.358	2897634.587	
1	54.74288	54.74288	10.502	8.576	6.062	582753.352	2897634.596	
2	167.09202	167.09202	9.409	2.102	-9.171	582753.352	2897634.597	
2	167.23489	167.23489	9.409	2.079	-9.176	582753.329	2897634.592	
3	293.30864	293.30864	9.818	-9.017	3.885	582753.331	2897634.589	
3	293.27357	293.27357	9.818	-9.019	3.879	582753.329	2897634.583	
						582753.342	2897634.591	Average
						+/- 0.009	+/- 0.000	Std Deviation

GPS Antenna Coordinate Calculation

Hypotenuse	Angle from heading	DD	NewBrgRaw	NewBRG	DMS	de	dn	GPS EAST	GPS NORTH

APPENDIX VI – STATIC POSITION CHECK – GPS ANTENNA COORDINATE DERIVATION