Bay of Saint Louis, Mississippi

14USM02 Horizontal and Vertical Control Report

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Short Details

Title	New Marina and Bay Waveland Yacht Club
Registry Number	14USM02
Team Members	Kira Fargo Matthew Niles Monica Price Hembal Teckmun William Tubbs Mohammad Uddin Antonio Williams
Locality	United States - Gulf Coast - Mississippi
Chart No. and Scale	NOAA Chart 11372, Scale 1:40,000
Product Scale	1:500 1:750 1:5000
Positional Accuracy	IHO Order 1a NOAA 1m Object Detection Survey
Horizontal Datum	NAD83 (print charts), WGS84 (ENC)
Vertical Datum	MLLW
Charts Affected	NOAA Charts 11372, 11371
ENC Affected	US5MS11M, US4MS10M, US3GC04M, US2GC09M, US1GC09M
Prior Surveys	H11617 (2007), 11USM01 (2011)

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Introduction

The following report describes vertical and horizontal components for the survey conducted in Bay of Saint Louis during summer of 2014. All of the data is referenced to the horizontal datum NAD83 and the vertical datum MLLW NTDE1983-2001.

A Vertical Control

A.1 Vertical Datum

The vertical datum calculated to correct bathymetry was MLLW NTDE 1983-2001. Ellipsoid reference techniques were used to correct the majority of the data, except five survey lines in Area 3. Insufficient GPS data required the application of tides. The separation between MLLW to GRS80 was calculated using:

- Tides collected from a USM gauge and NOAA CO-OPS gauge 8747437
- Four hour GNSS static survey over the primary Bench Mark (BM)
- 3-wire leveling connecting the USM gauge to secondary tidal staff and three BMs.
- Range ratio tidal datum transfer from USM tide gauge to CO-OPS gauge 8747437.

A.2 Existing Tidal Infrastructure

NOAA operates a tidal station outside the Bay Waveland Yacht Club in the northern section of the survey area, station 8747437. This gauge has been in continuous operation since 1978 and therefore was designated the primary gauge and used for the tidal datum transfer. Tides from this gauge were also used to correct soundings where GPS tides could not be applied.

Station 8747437	
Latitude	30° 19.5' N
Longitude	089° 19.5' W
MHW	1.225
MSL	0.994
DTL	0.993
NAVD88	0.728
MLLW	0.822
GT	0.529
MN	0.462
STND	0

Table A.1 NOAA tide station 8747437 station location and datums.

Figure A.1 Images of tide gauge locations in the survey area.

In Figure A.1 the Google Earth image on the left shows the location of the NOAA tide gauge with respect to the USM installed tide gauge. In the image on the right, the NOAA gauge is represented by the largest balloon-shaped marker, and the smaller red markers represent NOAA BMs in the area.

A.3 Tide Gauge Calibration

The tide gauge was calibrated before and after deployment in the freshwater tank in building 1029. A comparison between the tide gauge's pressure measurements and the readings from the tide staff are shown in Figures A.2 – A.3. The tide gauge used follows the NOAA specifications for 1 mm resolution.

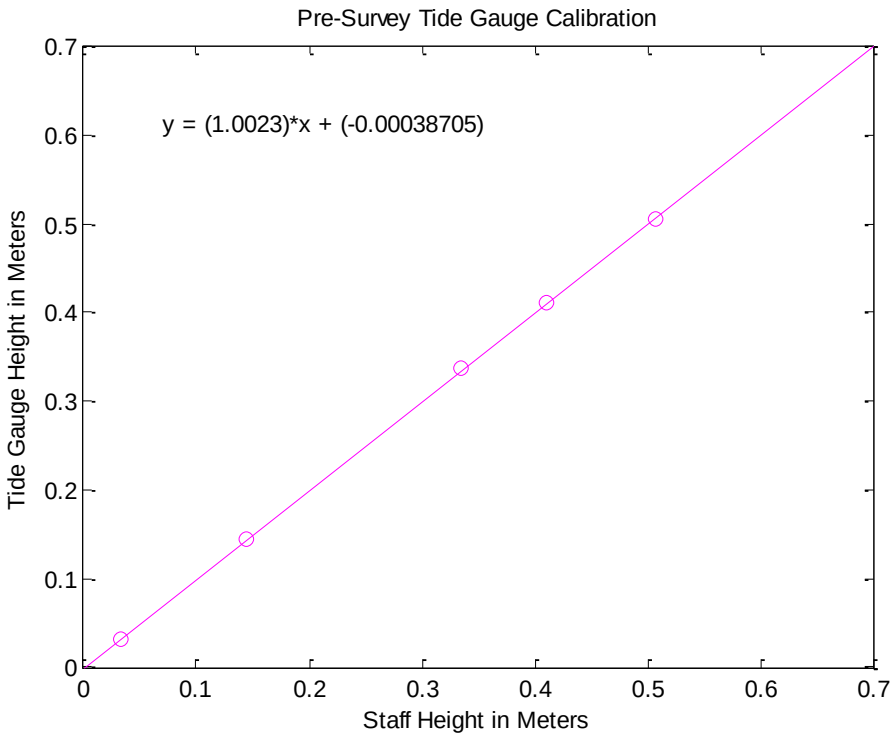


Figure A.2 Pre-Installation Tide Gauge Calibration.

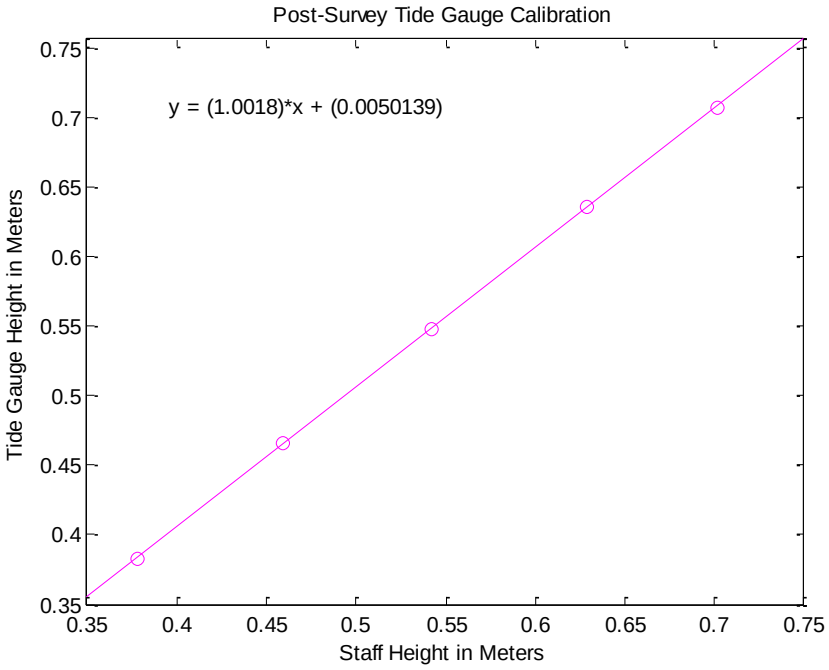


Figure A.3 Tide Gauge Removal Calibration.

Calibration Results	RMS
Pre Survey	0.0007
Post Survey	0.0009
Average	0.0008

Table A.2 Calibration Results

A.4 Tide Gauge Installation

The tide gauge was installed on the Jimmy Rutherford Fishing Pier at the Bay St. Louis Municipal Harbor on May 22, 2014. A Level TROLL 700, serial number 144380, recorded water levels every six minutes, set up to average 180 samples. The gauge collected data from May 22 to July 1, 2014. Bay St. Louis has brackish waters, with heavy influence from the Gulf of Mexico, Wolf River, and Jordan River. The brackish water setting was selected in Win Situ software for data collection. In Figure A.4, the red dot represents the location of the tide gauge and the green dot represents the location of the staff.

Figure A.4 View of the Jimmy Rutherford Fishing Pier.

Figure A.5. Tide gauge and tide staff images.

In Figure A.5 the image on the left shows the tide gauge set up and the image on the right is the supplementary tide staff. Please see Table A.3 to their locations relative to each other on the pier.

Tide Gauge Location	
Tide Gauge	30° 18' 24.72" N 089° 19' 24.72: E
Tide Staff	30° 18' 24.72" N 089° 19' 19.2" E

Table A.3 Tide gauge and staff latitude and longitude.

A.5 Tide Zoning

NOAA requires tide zone delineation for phase differences greater than 18 minutes and amplitude differences greater than 6 cm between tidal stations. Ellipsoid referencing techniques eliminates the need for tide zoning. However, five survey lines in area 3 required tide measurements for vertical correction. Pre-survey, tides from Station 8747437 and Pascagoula NOAA Lab Station 8741533 were used to determine one tide zone can be used to survey Bay of St. Louis.

Figure A.6 Bay St. Louis Station and the Pascagoula station.

	Station ID	GT	HWI in minutes	Distance in KM
Bay St. Louis	8747437	0.529	90	75
Pascagoula	8741533	0.468		

Table A.4 Showing tidal characteristics between Bay St. Louis and Pascagoula.

Looking at Table A.4, the difference between the great diurnal range at Pascagoula and Bay St. Louis is 0.06 cm. The amplitude between the two stations changes only 6 cm, falling within NOAA specifications for one tidal zone. The High water interval (HWI) between Pascagoula and Bay St. Louis is 90 minutes, and using a ratio, it was determined the HWI between the top of the survey area to bottom of the survey area to be less than 3 minutes, and therefore only on tide zone is required for the entire survey area.

The requirement for only one tide zone was also verified using NAVOTAS and Tide Analyst. Two tide stations within Bay St. Louis were selected and harmonic constituents were derived from each one, see Figure A.7. Using those harmonic constituents, tides were generated from five points within the survey area to determine if the differences between phase and amplitude were small enough to justify one tide zone. There was little phase offset, and the largest amplitude offset was 4 cm. See Figures A.7 – A.10.

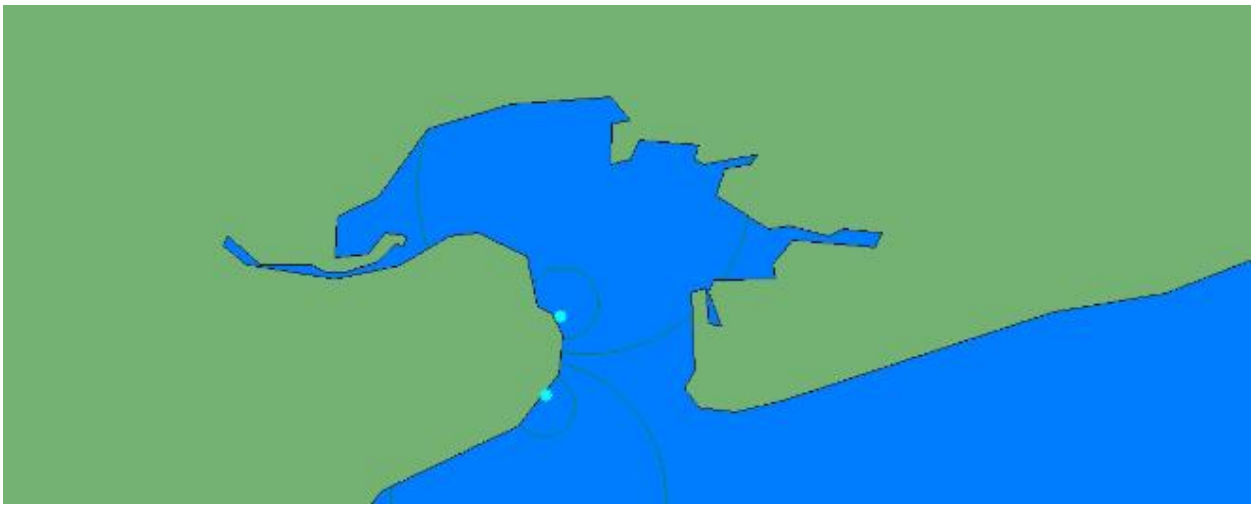


Figure A.7 Tide stations in Tide Analyst.

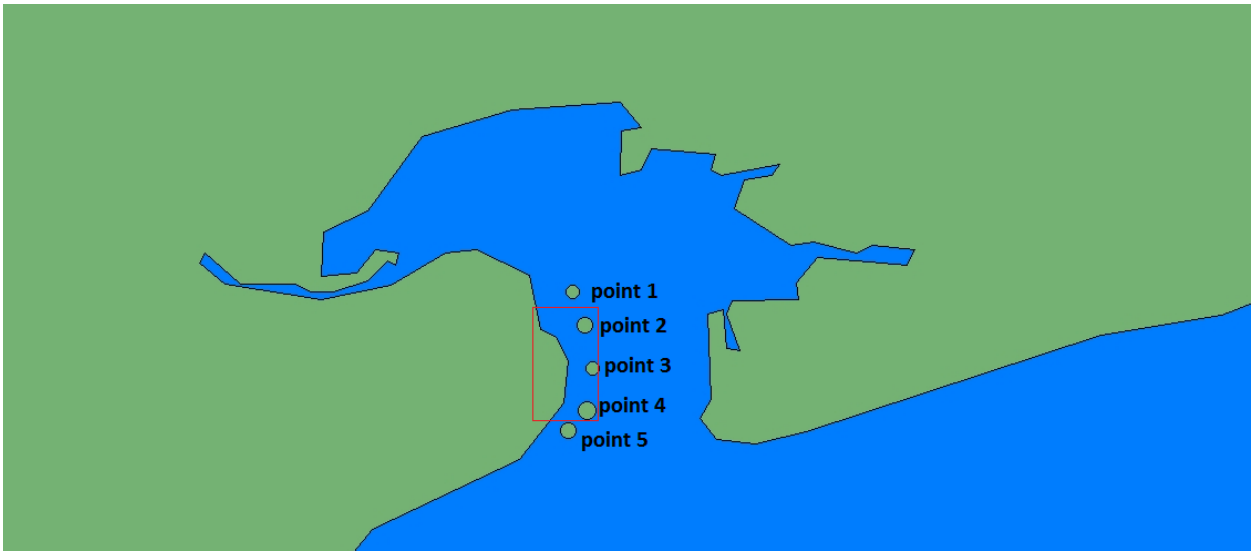


Figure A.8 Tide Analyst points

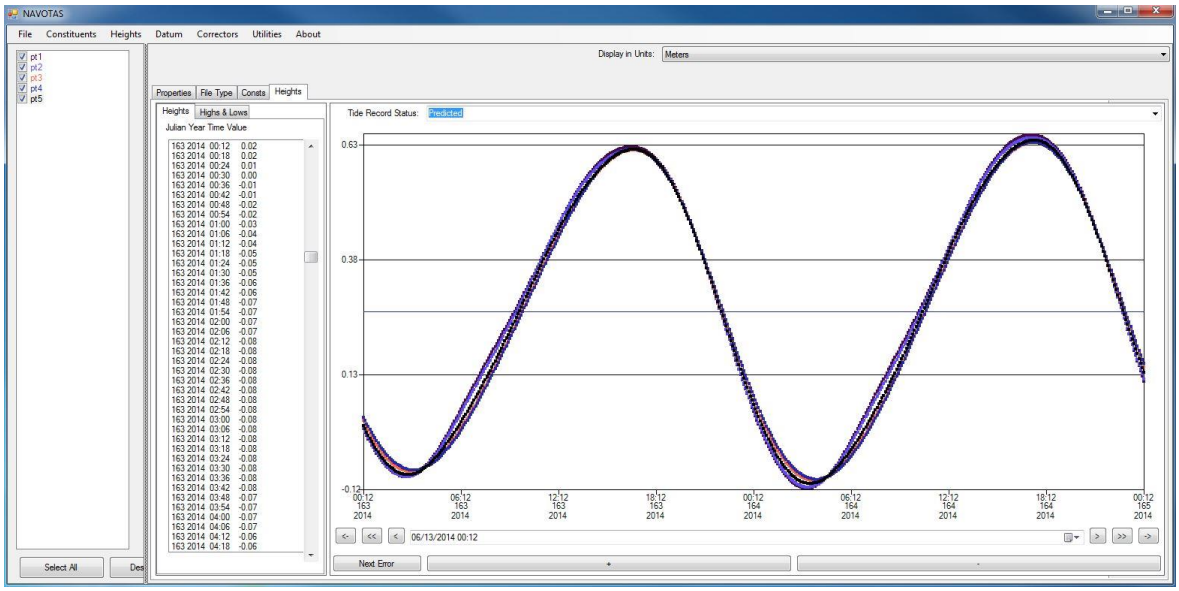


Figure A.9 Two days of data from the five points chosen in NAVOTAS.

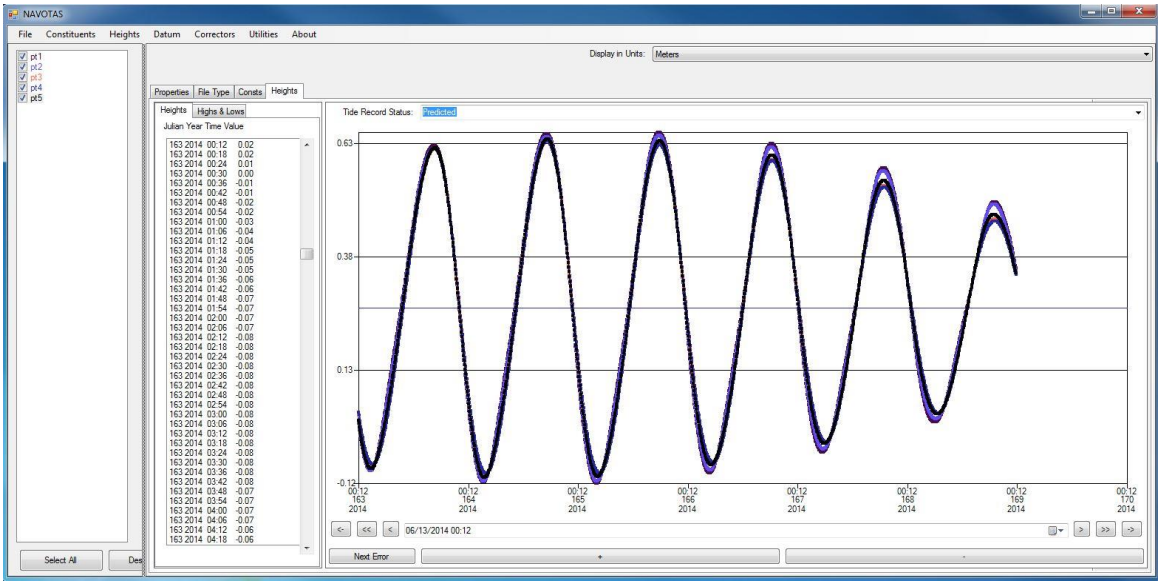


Figure A.10 Seven days of data from the five points chosen in NAVOTAS.

Figure A.11 shows the tides collected from the USM tide gauge and the tides collected by the NOAA gauge during the survey. The tides directly correlate: the highs and lows are synchronized, showing no difference in phase and similar peak to peak amplitude values.

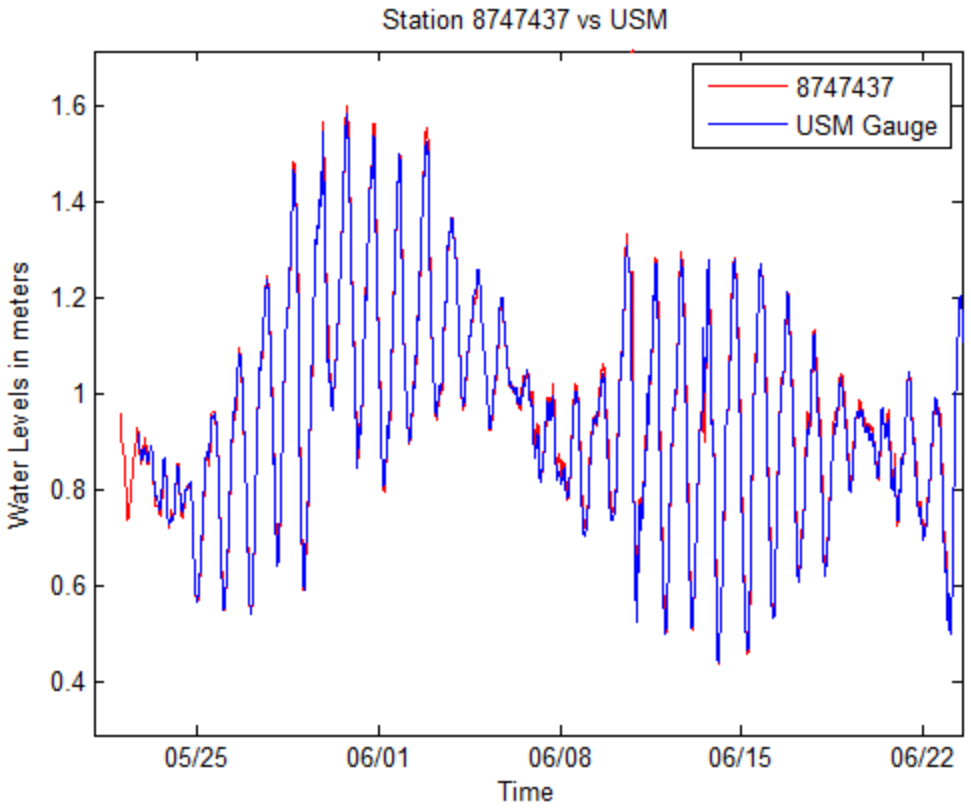


Figure A.11 USM tides and NOAA 8747437 tides

A.6 SEP Value:

There are several calculations required in order to determine the separation between ellipsoid and MLLW NTDE 1983-2001. A leveling line to the tide gauge establishes the heights of BMs relative to the tide gauge. A four hour GNSS static survey over the primary BM gives the ellipsoid to BM heights, and a minimum of 30 days of tidal data along with a tidal datum transfer gives MLLW NTDE 1983-2001. The static session was sent to OPUS for processing, and they found BM 1 was 24.984 m below the ellipsoid. A summary of the results are in Table A.5 and in more detail in Appendix II.

BM1	
Latitude	30° 18' 42.1" N
Longitude	089° 19' 27.3" W
MLLW at BM 1	2.6786
NAD 83	-24.984
SEP	-27.6626

Table A.5 Separation summary.

Table A.5 summarizes the separation value process. From the level line, it is known BM 1 is 3.1846 m above station datum zero (see Appendix I for leveling results), and therefore 2.6786 m above MLLW. Therefore the ellipsoid is 27.6626 m above MLLW.

NOAA's Geoid 12A model was used to justify using one separation value within the survey area. Five points within the survey area shows very little difference. The difference between the extremes was only 0.047m, see Table A.6 for the model's values.

Geoid 12A		
Point 1	30 19 30.99 N 089 19 26.76 W	-27.477
Point 2	30 19 16.39 N 089 19 12.72 W	-27.469
Point 3	30 18 56.70 N 089 19 6.82 W	-27.453
Point 4	30 18 45.22 N 089 19 9.4 W	-27.441
BM 1	30 18 42.14 N 089 19 27.29 W	-27.43
Differences		0.047

Table A.6 Geoid 12A.

The Tide Zoning section proved insignificant tidal variation between the top and bottom of the survey area, and Geoid12a shows miniscule changes between the ellipsoid and NAVD88 within the survey area. All of these statistics verify the need for only one separation value within the survey area.

	BM1
Ellipsoid to NAVD88	-27.43
Geoid12a	-27.43

Table A.8 BM1

To verify the separation value at the primary BM calculated by OPUS and the leveling, it was compared to the value within Geoid12a. Table A.8 shows there are no differences in the ellipsoid to NAVD88 value at BM1 derived from OPUS results and the leveling runs, and the Geoid12a model.

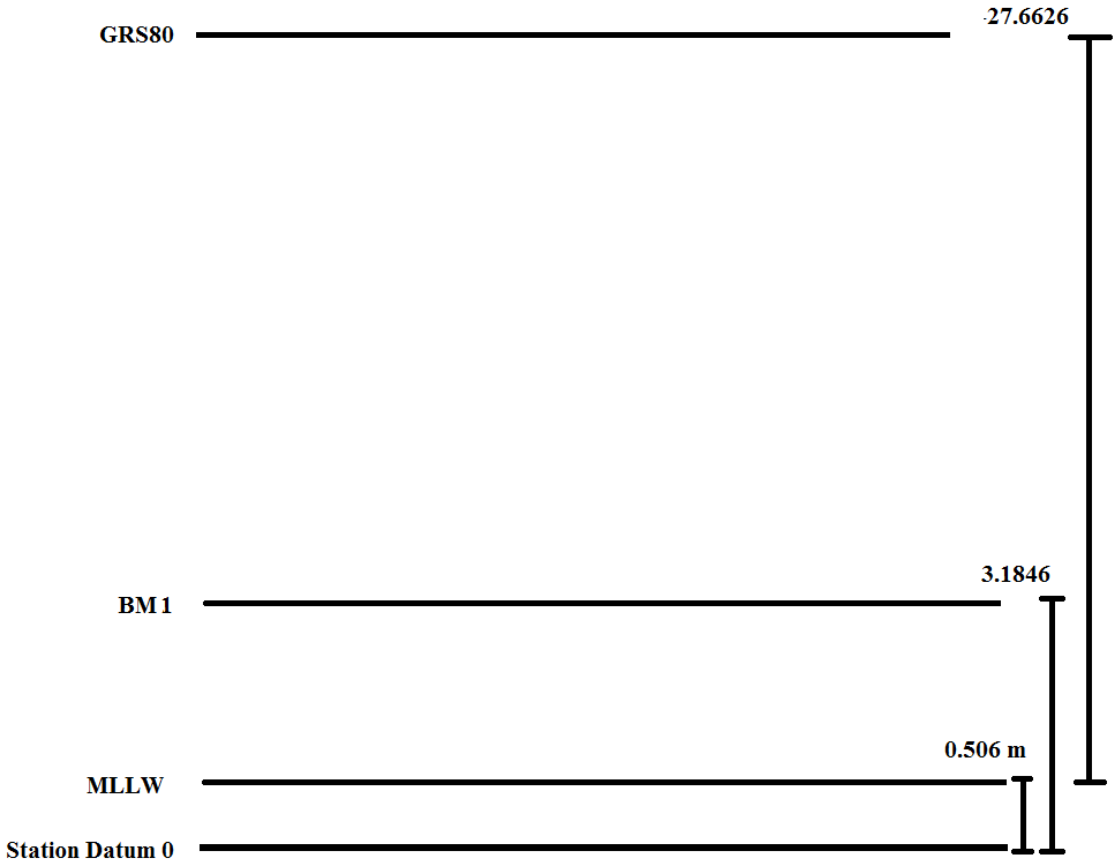


Figure A.12 SEP Value Calculation with respect to Station Datum.

A.7 Uncertainty from SEP Value:

The uncertainty of the separation value comes from several components:

- Leveling
- The GNSS static survey
- The tidal datum transfer
- Error from the tide gauge.

	SEP Uncertainty
Tide Gauge Clock Drift	0.001
Instrument Uncertainty	0.001
Tidal Datum Transfer	0.055
Leveling Error	0.001
GPS Error	0.004
Tide Gauge Calibration	0.001
$\sum\sqrt{\sigma^2}$	0.055
$1.96*\sum\sqrt{\sigma^2}$ 95% Confidence	0.108

Table A.9 SEP Uncertainty

The uncertainty was calculated by summing the square root of the sum of the squares of each uncertainty component. Looking at Table A.9, the tide gauge uncertainty is calculated from the tide gauge drift. There was a small drift between UTC and the tide gauge's clock. Over the duration of tide data collection, the tide gauge clock drifted one minute, which is still within NOAA specifications. The uncertainty value calculated by the clock drift is the standard deviation of the difference between the tide gauge's readings and water levels corrected by one minute. The tidal datum transfer uncertainty is the uncertainty value for the Gulf Coast region calculated by Swanson. Leveling error is the average error of closure between the level in and level out runs. Uncertainty from the GNSS was calculated by OPUS with "peak to peak" deviations. Tide gauge calibration uncertainty is the difference in the root mean squares from pre-deployment and post-deployment.

B. Horizontal Control

B.1 Positioning Methodology

The survey vessel was fitted with a Trimble NetRS, CNAV 3050, and an Applanix Position and Orientation System for Marine Vehicles (POSMV) v4 Wavemaster. Both the Trimble NetRS GNSS and the CNAV 3050 were configured to log dual frequency raw positioning data at a rate of 1Hz. The POSMV unit logged all raw Ethernet data, including dual frequency positioning data at 50Hz. Real-time positioning for data collection was obtained from the POSMV system supported by Real-Time gypsy (RTG) via the CNAV GNSS. Moreover, to increase the accuracy of the survey, the raw data from the CNAV and Trimble GNSS receivers were post-processed to generate a Post Processed Kinematic (PPK) solution. The most accurate system varied by day and the one chosen by day can be seen in Table B.1.

Date	Julian Day	Source
11 June 14	162	Trimble PPK
12 June 14	163	Trimble PPK
16 June 14	167	Trimble PPK
17 June 14	168	CNAV PPK
18 June 14	169	Trimble PPK
19 June 14	170	CNAV PPK

Table B.1 GNSS Equipment and PPK Solutions

The CNAV 3050 and Trimble NetRs GNSS data were processed against the Gulf Coast Geospatial Consortium (GCGC) Continuously Operating Reference Station (CORS), which is stationed at BWYC (Station ID MSWV). This is a 1Hz reference station. All navigation coordinates were generated using the North American Datum of 1983 (NAD83) (2011/PA11/MA11) epoch 2010.0 datum. This was sourced from the GCGC website [GCGC, 2014]. The base station was located within the survey area and the furthest extent of the survey area is 2.5 km from the base station. This is in accordance with the NOAA 2014 requirement for a maximum PPK baseline length less than 30km.

B.2 Navigation Validation

Navigation was validated by using a junction area between survey areas 1 and 3 as well as 2 and 3. Area 1 and 2 were processed using the Trimble NetRS PPK data. Area 3 was processed using

the CNAV 3050 data. The mean vertical difference between each surface, for the MB1 and Edgetech can be seen in the tables below.

	Max Diff	Min Diff	Mean Diff	Std Dev	Total Counts
BWYC Junction	0.15 m	-0.86 m	-0.35 m	0.14 m	3468
Marina Junction	1.87 m	-1.31 m	0.04 m	0.27 m	1504

Table B2. Junction Differences (Edgetech)

	Max Diff	Min Diff	Mean Diff	Std Dev	Total Counts
BWYC Junction	0.24 m	-0.30 m	0.02 m	0.07 m	1175
Marina Junction	0.45 m	-0.23 m	0.04 m	0.10 m	235

Table B3. Junction Differences (MB1)

B.3 Navigation Accuracy

The overall observed standard deviations achieved during each day, for the GNSS receivers are shown in Table B.4.

Date	**Julian Day**	**Source**	**Horizontal σ (m)**	**Height σ (m)**
11 June 14	162	Trimble PPK	0.0283	0.0452
12 June 14	163	Trimble PPK	0.0218	0.0321
16 June 14	167	Trimble PPK	0.0524	0.0636
17 June 14	168	CNAV PPK	0.0686	0.0858
18 June 14	169	Trimble PPK	0.0297	0.0462
19 June 14	170	CNAV PPK	0.0732	0.0882

Table B.4 Standard Deviation

I. Leveling :

Three- wire leveling techniques connected three BMs, a tide gauge, and a supplementary staff along the Jimmy Rutherford Fishing Pier at the Bay Saint Louis Municipal Harbor. Leveling was completed before and after surveying. A diagram of the pier and BMs are found in Figure I.2. The red square represents the location of the tide gauge, and the grey square to the right of it represents the location of the tide staff. The green circles are the BMs along the pier.

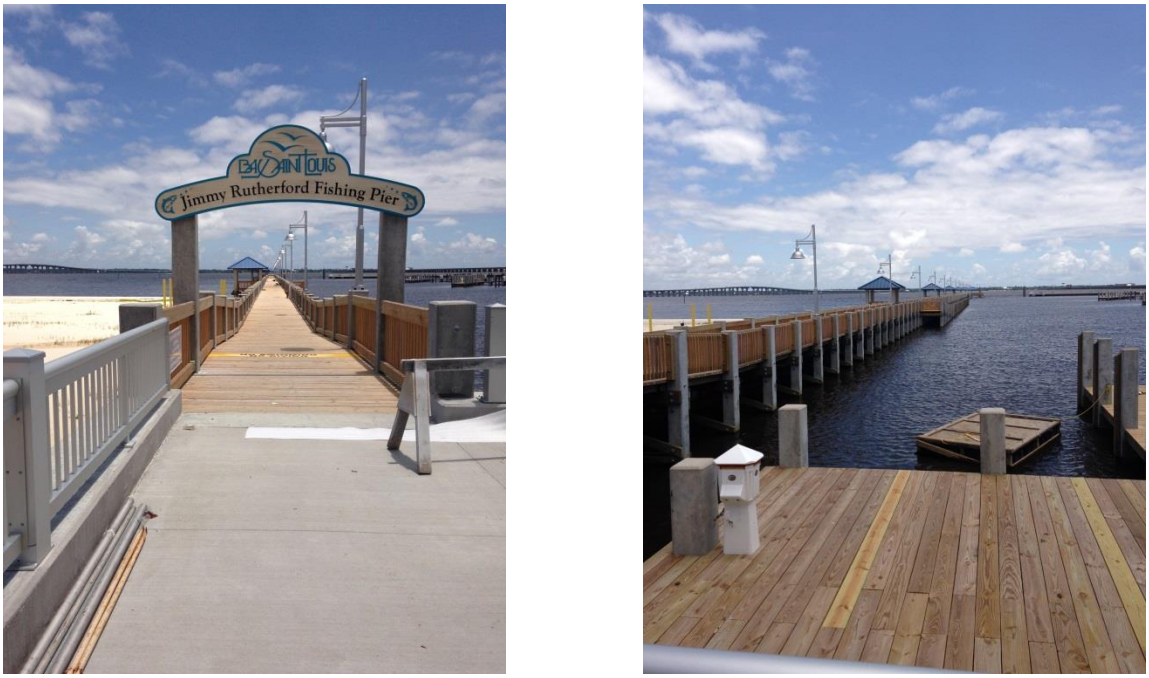


Figure I.1 The Jimmy Rutherford Fishing Pier

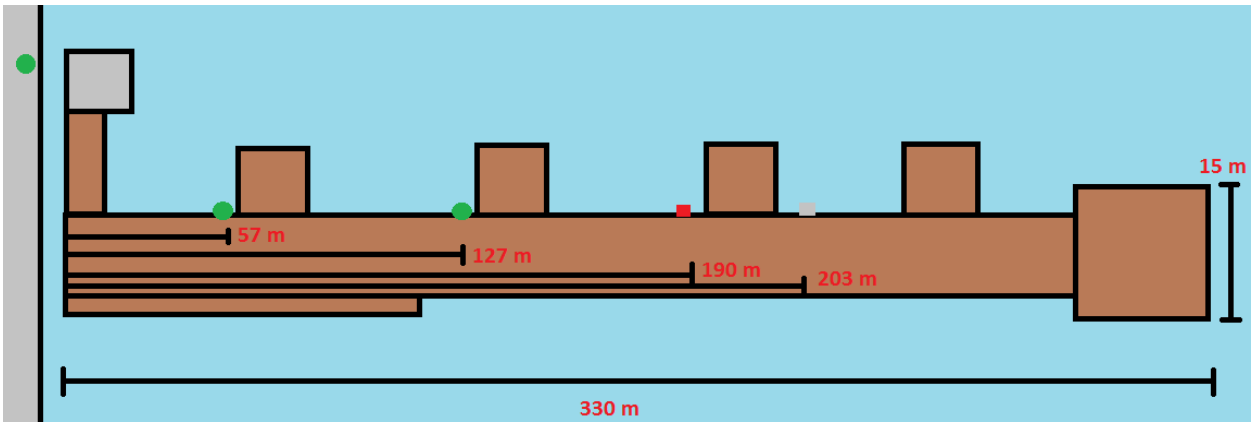


Figure I.2 Diagram of the Jimmy Rutherford Fishing Pier.

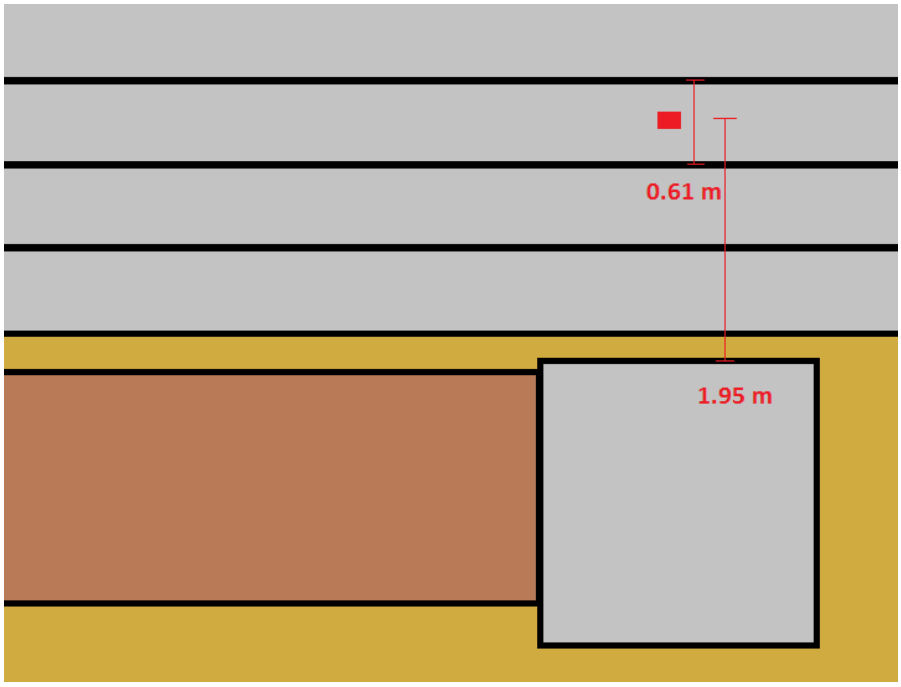


Figure I.3 Diagram of the primary BM.

BM1:

A diagram of BM1 exists in Figure I.3. It's located across from the cement pad in front of the walkway leading to the pier. BM1 is a half inch hexagon shaped bolt that has been drilled into the seawall. It's on the third step from the bottom. BM1 is designated the primary BM. Four hour static GNSS survey has been performed to verify its position relative to GRS-80.

BM 1	
Latitude	30° 18' 42" N
Longitude	089° 19' 27" W

Table I.1 Location of BM1.

Figure I.4 Views of BM 1.

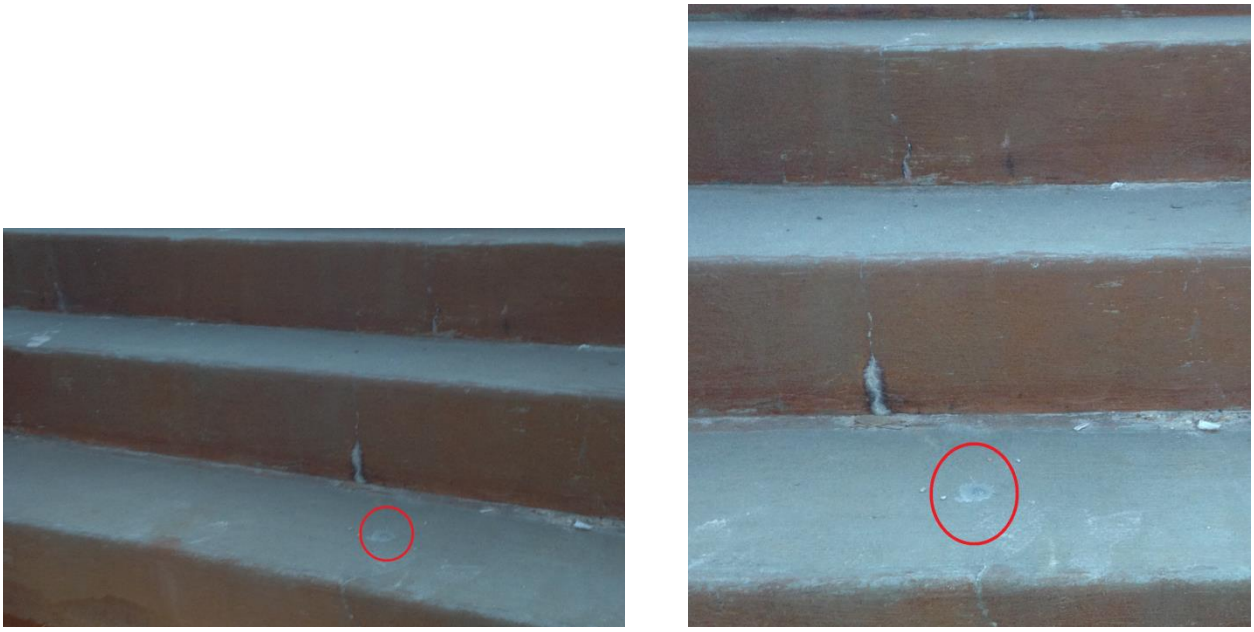


Figure I.5 More pictures of BM.

In Figure I.4, the picture on the left is the top view, and the picture on the right is a picture facing north. The image on the right is facing BM 1 from the bottom of the seawall. In both figures, the red circles highlight the location of the bolt

BM 2 and 3:

BM 2 and BM 3 are bolts along the pier. There are four covered gazebos on the left hand side when walking from the shore to the end of the pier. On each cement pillar on the pier, there are two bolts on each side vertically aligned. BM 2 and 3 are designated as the head of bolts on the cement pillars facing the entrance of the pier. The cement pillars containing the bolts designated

as BMs are forward of the covered gazebos along the pier. BM 2 is forward of the first gazebo, BM 3 is forward of the second gazebo, the tide gauge is forward of the third gazebo, and the tide staff was stationed aft of the third gazebo. Both BMs are the top bolts. When leveling, the rod was placed on the top of the bolts, adjacent to the cuffs. Please see Figures I.6 – I.9 for images. BM 2 is over the sandy beach (even at high tide), and BM 3 is over the water.

Bench Mark Locations	
Bench Mark 2	30° 18' 41.5" N 089° 19' 24.6" W
Bench Mark 3	30° 18' 41.52" N 089° 19 22.14" W

Table I.2 BM 2 and 3

Figure I.6 BM 2.

In Figure I.6, the image on the left shows BM2 towards the southeast. It's on the cement pillar forward of the shelter. The image on the right shows the horizontal view of BM2 from the beach zoomed in.

Figure I.7 More views of BM2.

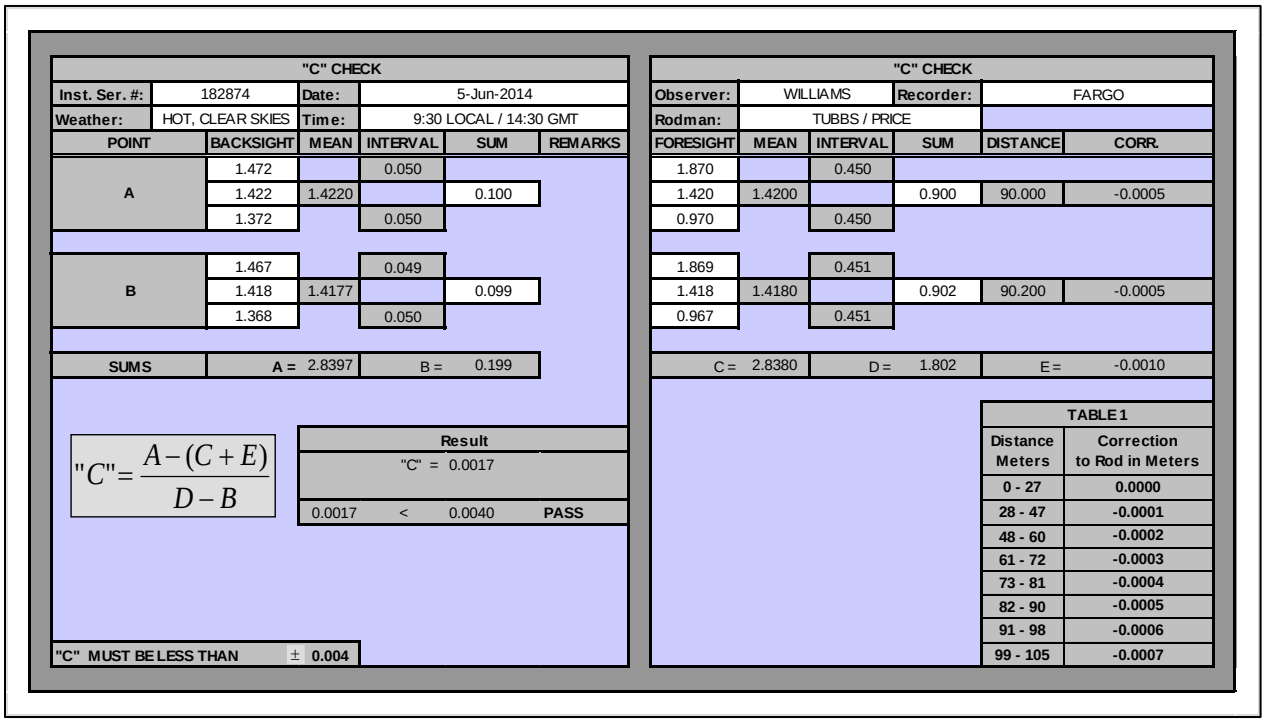
Figure I.8 Images of BM3.

Figure I.9 Topside views of BM3.

In Figure I.7, The image of the left shows the topside view of BM2. The image on the right was taken from the beach and pointing south. The level rod was placed on the edge of the top of the bolt, against the cuff behind the bolt. In Figure I.8, the image on the left shows BM3 looking south. The image on the right is the horizontal view of BM3.

There are several BMs north of the Highway 90 bridge (see Figure A.1), and an NGS and Army Corp BM close to the train bridge. At the time of leveling in and leveling out the gauge, the harbor was still under construction. The BMs associated with station 8747437 were too far away to level to, and the BMs close to the train bridge would require leveling through a construction zone. It was decided to establish our own BMs along the pier to avoid construction work and maintain proximity.

C-Check Level In:



"C" CHECK

Inst. Ser. #:	182874	Date:	5-Jun-2014
Weather:	HOT, CLEAR SKIES	Time:	9:30 LOCAL / 14:30 GMT

POINT	BACKSIGHT	MEAN	INTERVAL	SUM	REMARKS
A	1.472		0.050		
	1.422	1.4220		0.100	
	1.372		0.050		
B	1.467		0.049		
	1.418	1.4177		0.099	
	1.368		0.050		
SUMS	A = 2.8397		B = 0.199		

$$"C" = \frac{A-(C+E)}{D-B}$$

Result			
"C" = 0.0017			
0.0017	<	0.0040	PASS

"C" MUST BE LESS THAN ± 0.004

"C" CHECK

Observer:	WILLIAMS	Recorder:	FARGO
Rodman:	TUBBS / PRICE		

FORESIGHT	MEAN	INTERVAL	SUM	DISTANCE	CORR.
1.870		0.450			
1.420	1.4200		0.900	90.000	-0.0005
0.970		0.450			
1.869		0.451			
1.418	1.4180		0.902	90.200	-0.0005
0.967		0.451			
C = 2.8380		D = 1.802		E =	-0.0010

TABLE 1

Distance Meters	Correction to Rod in Meters
0 - 27	0.0000
28 - 47	-0.0001
48 - 60	-0.0002
61 - 72	-0.0003
73 - 81	-0.0004
82 - 90	-0.0005
91 - 98	-0.0006
99 - 105	-0.0007

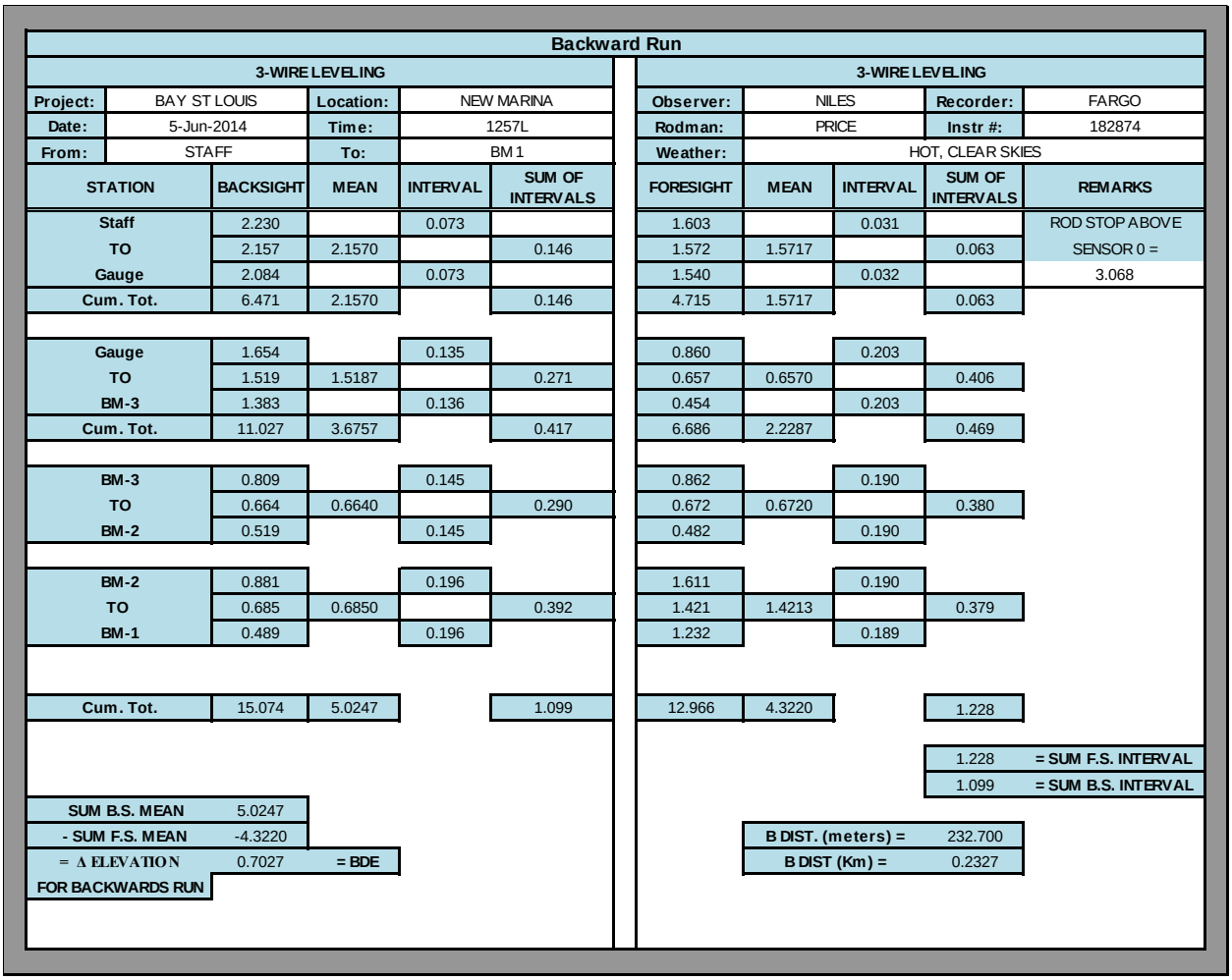
Figure I.10 C-Check before installing the tide gauge.

Leveling In:

Forward Run

3-WIRE LEVELING					3-WIRE LEVELING				
Project:	BAY ST LOUIS	Location:	NEW MARINA			NILES	Recorder:	FARGO	
Date:	5-Jun-2014	Time:	10:30:00 AM CST / 15:30 UTC		Rodman:	PRICE	Instr #:	182874	
From:	BM 1	To:	STAFF		Weather:	HOT, CLEAR SKIES			
STATION	BACKSIGHT	MEAN	INTERVAL	SUM OF INTERVALS	FORESIGHT	MEAN	INTERVAL	SUM OF INTERVALS	REMARKS
BM-1	1.580		0.190		0.850		0.196		ROD STOP ABOVE
TO	1.390	1.3903		0.379	0.654	0.6543		0.391	SENSOR 0 =
BM-2	1.201		0.189		0.459		0.195		3.068
Cum. Tot.	4.171	1.3903		0.379	1.963	0.6543		0.391	
BM-2	0.828		0.188		0.780		0.149		
TO	0.640	0.6393		0.378	0.631	0.6313		0.297	
BM-3	0.450		0.190		0.483		0.148		
Cum. Tot.	6.089	2.0296		0.757	3.857	1.2856		0.688	
BM-3	0.850		0.190		1.669		0.147		
TO	0.660	0.6597		0.381	1.522	1.5217		0.295	
TG	0.469		0.191		1.374		0.148		
TG	1.610		0.046		2.238		0.089		
TO	1.564	1.5637		0.093	2.149	2.1490		0.178	
STAFF	1.517		0.047		2.060		0.089		
Cum. Tot.	12.759	4.2530		1.231	14.869	4.9563		1.161	
								1.161	= SUM F.S. INTERVAL
								1.231	= SUM B.S. INTERVAL
SUM B.S. MEAN	4.2530								
- SUM F.S. MEAN	-4.9563					F DIST. (meters) =		239.200	
= Δ ELEVATION	-0.7033	= FDE				F DIST (Km) =		0.2392	
FOR FORWARD RUN		FDE =	-0.70330						PASS
		BDE =	0.70270		A.E. =	0.00579	PASS		BUST
		EC =	0.00060						

Figure I.11 Tide Gauge Install Level in Forward Run.

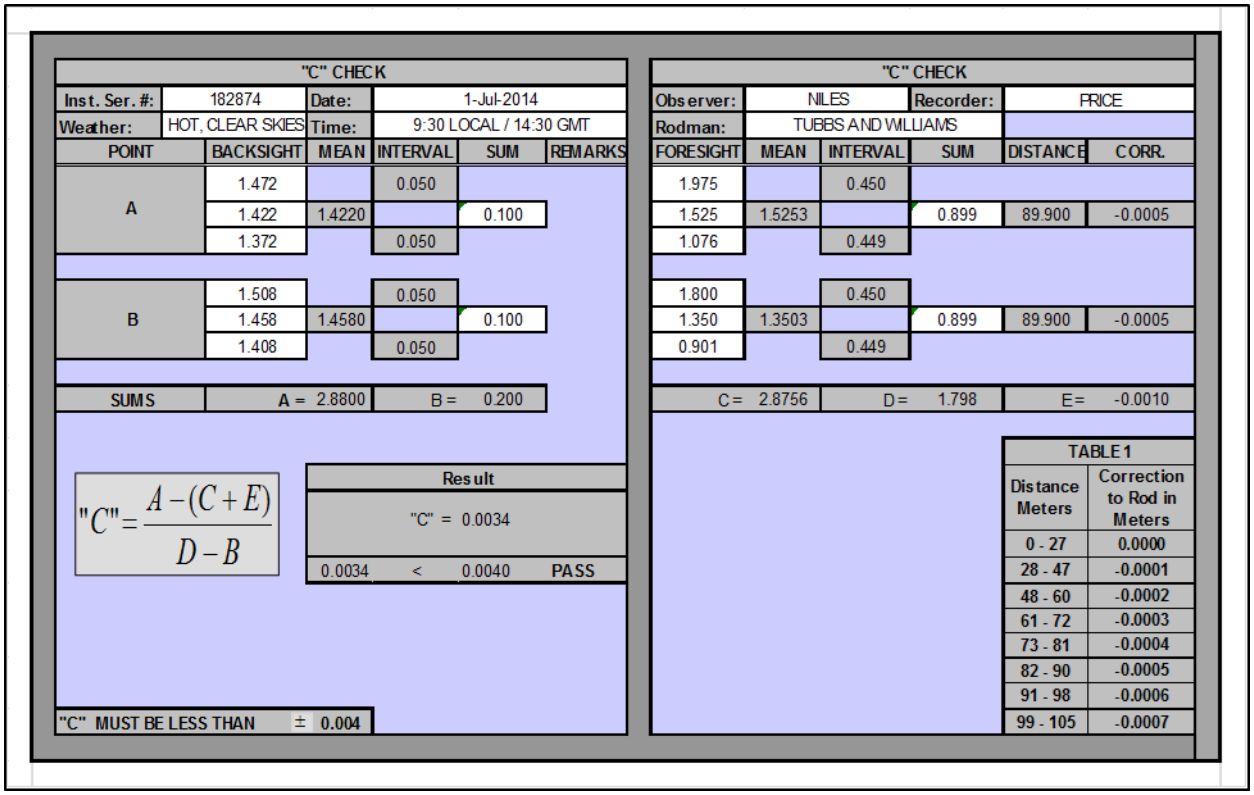


Backward Run

3-WIRE LEVELING					3-WIRE LEVELING				
Project:	BAY ST LOUIS	Location:	NEW MARINA		Observer:	NILES	Recorder:	FARGO	
Date:	5-Jun-2014	Time:	1257L		Rodman:	PRICE	Instr #:	182874	
From:	STAFF	To:	BM 1		Weather:	HOT, CLEAR SKIES			
STATION	BACKSIGHT	MEAN	INTERVAL	SUM OF INTERVALS	FORESIGHT	MEAN	INTERVAL	SUM OF INTERVALS	REMARKS
Staff	2.230		0.073		1.603		0.031		ROD STOP ABOVE
TO	2.157	2.1570		0.146	1.572	1.5717		0.063	SENSOR 0 =
Gauge	2.084		0.073		1.540		0.032		3.068
Cum. Tot.	6.471	2.1570		0.146	4.715	1.5717		0.063	
Gauge	1.654		0.135		0.860		0.203		
TO	1.519	1.5187		0.271	0.657	0.6570		0.406	
BM-3	1.383		0.136		0.454		0.203		
Cum. Tot.	11.027	3.6757		0.417	6.686	2.2287		0.469	
BM-3	0.809		0.145		0.862		0.190		
TO	0.664	0.6640		0.290	0.672	0.6720		0.380	
BM-2	0.519		0.145		0.482		0.190		
BM-2	0.881		0.196		1.611		0.190		
TO	0.685	0.6850		0.392	1.421	1.4213		0.379	
BM-1	0.489		0.196		1.232		0.189		
Cum. Tot.	15.074	5.0247		1.099	12.966	4.3220		1.228	
								1.228	= SUM F.S. INTERVAL
								1.099	= SUM B.S. INTERVAL
SUM B.S. MEAN	5.0247								
- SUM F.S. MEAN	-4.3220				B DIST. (meters) =			232.700	
= Δ ELEVATION	0.7027	= BDE			B DIST (Km) =			0.2327	
FOR BACKWARDS RUN									

Figure I.12 Tide Gauge Install Level In Backward Run.

C-Check Level Out:



"C" CHECK

Inst. Ser. #:	182874	Date:	1-Jul-2014
Weather:	HOT, CLEAR SKIES	Time:	9:30 LOCAL / 14:30 GMT

POINT	BACKSIGHT	MEAN	INTERVAL	SUM	REMARKS
A	1.472		0.050		
	1.422	1.4220		0.100	
	1.372		0.050		
B	1.508		0.050		
	1.458	1.4580		0.100	
	1.408		0.050		
SUMS		A = 2.8800		B = 0.200	

$$"C" = \frac{A-(C+E)}{D-B}$$

Result			
"C" = 0.0034			
0.0034	<	0.0040	PASS

"C" MUST BE LESS THAN ± 0.004

"C" CHECK

Observer:	NILES	Recorder:	PRICE
Rodman:	TUBBS AND WILLIAMS		

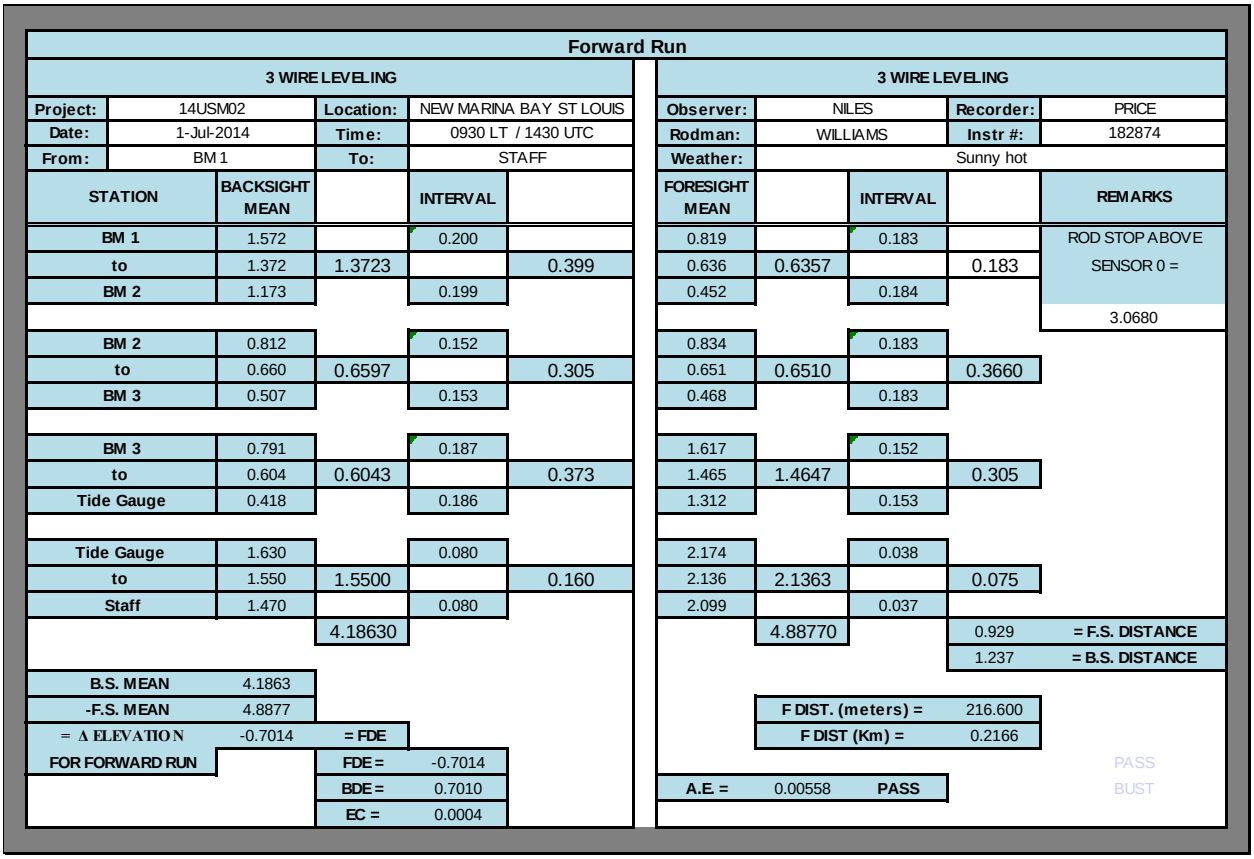
FORESIGHT	MEAN	INTERVAL	SUM	DISTANCE	CORR.
1.975		0.450			
1.525	1.5253		0.899	89.900	-0.0005
1.076		0.449			
1.800		0.450			
1.350	1.3503		0.899	89.900	-0.0005
0.901		0.449			
C = 2.8756		D = 1.798		E = -0.0010	

TABLE 1

Distance Meters	Correction to Rod in Meters
0 - 27	0.0000
28 - 47	-0.0001
48 - 60	-0.0002
61 - 72	-0.0003
73 - 81	-0.0004
82 - 90	-0.0005
91 - 98	-0.0006
99 - 105	-0.0007

Figure I.13 C-Check done before removing the tide gauge.

Level Out:



Forward Run

3 WIRE LEVELING					3 WIRE LEVELING				
Project:	14USM02	Location:	NEW MARINA BAY ST LOUIS		Observer:	NILES	Recorder:	PRICE	
Date:	1-Jul-2014	Time:	0930 LT / 1430 UTC		Rodman:	WILLIAMS	Instr #:	182874	
From:	BM 1	To:	STAFF		Weather:	Sunny hot			
STATION	BACKSIGHT MEAN		INTERVAL		FORESIGHT MEAN		INTERVAL		REMARKS
BM 1	1.572		0.200		0.819		0.183		ROD STOP ABOVE
to	1.372	1.3723		0.399	0.636	0.6357		0.183	SENSOR 0 =
BM 2	1.173		0.199		0.452		0.184		3.0680
BM 2	0.812		0.152		0.834		0.183		
to	0.660	0.6597		0.305	0.651	0.6510		0.3660	
BM 3	0.507		0.153		0.468		0.183		
BM 3	0.791		0.187		1.617		0.152		
to	0.604	0.6043		0.373	1.465	1.4647		0.305	
Tide Gauge	0.418		0.186		1.312		0.153		
Tide Gauge	1.630		0.080		2.174		0.038		
to	1.550	1.5500		0.160	2.136	2.1363		0.075	
Staff	1.470		0.080		2.099		0.037		
		4.18630				4.88770		0.929	= F.S. DISTANCE
								1.237	= B.S. DISTANCE
B.S. MEAN	4.1863								
-F.S. MEAN	4.8877					F DIST. (meters) =		216.600	
= Δ ELEVATION	-0.7014	= FDE				F DIST (Km) =		0.2166	
FOR FORWARD RUN		FDE =	-0.7014						PASS
		BDE =	0.7010		A.E. =	0.00558	PASS		BUST
		EC =	0.0004						

Figure I.14 Tide Gauge Removal Level Out Forward Run

Backward Run

DIGITAL LEVELING					DIGITAL LEVELING				
Project:	14USM02	Location:	NEW MARINA BAY ST LOUIS		Observer:	NILES	Recorder:	PRICE	
Date:	1-Jul-2014	Time:	0930 LT / 1430 UTC		Rodman:	WILLIAMS	Instr #:	182874	
From:	STAFF	To:	BM 1		Weather:	Sunny hot			
STATION	BACKSIGHT MEAN		DISTANCE		FORESIGHT MEAN		DISTANCE		REMARKS
STAFF	2.191		0.0370		1.648		0.079		ROD STOP ABOVE
TO	2.154	**2.1540**		0.0740	1.569	**1.5690**		**0.158**	SENSOR 0 =
TIDE GAUGE	2.117		0.037		1.490		0.079		3.0680
TIDE GAUGE	1.678		0.154		0.849		0.185		
TO	1.524	1.5240		0.308	0.664	0.6640		0.370	
BM 3	1.370		0.154		0.479		0.185		
BM 3	0.859		0.183		0.839		0.154		
TO	0.676	0.6760		0.366	0.685	0.6850		0.308	
BM 2	0.493		0.183		0.531		0.154		
BM 2	0.851		**0.1820**		1.604		0.200		
TO	0.669	0.6690		0.364	1.404	1.4040		0.400	
BM 1	0.487		**0.1820**		1.204		0.200	1.236	= F.S. DISTANCE
								1.112	= B.S. DISTANCE
B.S. MEAN	5.0230								
-F.S. MEAN	4.3220								
= Δ ELEVATION FOR BACKWARDS RUN	0.7010	= BDE							

B DIST. (meters) =	234.800
B DIST (Km) =	0.2348

Figure I.15 Tide Gauge Removal Level Out Backward Run.

:

Bench Mark	Elevation Above Sensor Zero (m)			
	Level In	Level Out	Difference	Mean
BM1	3.1856	3.1836	**0.0020**	**3.1846**
BM2	3.9218	3.9194	**0.0024**	**3.9206**
BM3	3.9298	3.9282	**0.0016**	**3.9290**
Staff	2.4827	2.4823	**0.0004**	**2.4825**

Figure I.16 BM Heights.

Figure I.16 shows BM heights relative to station datum and their differences from Level In and Level Removal relative to the tide gauge's zero.

II. OPUS Results:

BM 1 has been designated as the primary BM. A four hour static GNSS survey was conducted to determine its distance to the ellipsoid.

Figure II.1 Static survey over BM1.

Figure II.1 shows the static survey over BM1. The red circle marks the location of the bolt. The Topcon GR3 is 1.78 m above the bolt.

FILE: site156r.14o OP1402055713821

2005 NOTE: The IGS precise and IGS rapid orbits were not available
2005 at processing time. The IGS ultra-rapid orbit was/will be used to
2005 process the data.
2005

NGS OPUS SOLUTION REPORT
==========

All computed coordinate accuracies are listed as peak-to-peak values.
For additional information: http://www.ngs.noaa.gov/OPUS/about.jsp#accuracy

USER: monica.e.price@eagles.usm.edu DATE: June 06, 2014

RINEX FILE: site156r.14o TIME: 11:57:43 UTC

SOFTWARE: page5 1209.04 master93.pl 022814 START: 2014/06/05 17:59:00
EPHEMERIS: igu17954.eph [ultra-rapid] STOP: 2014/06/05 22:05:00
NAV FILE: brdc1560.14n OBS USED: 11867 / 12176 : 97%
ANT NAME: TPSGR3 NONE # FIXED AMB: 51 / 53 : 96%
ARP HEIGHT: 1.78 OVERALL RMS: 0.014(m)

REF FRAME: NAD_83(2011)(EPOCH:2010.0000) IGS08 (EPOCH:2014.4269)

X:	64994.424(m) 0.009(m)	64993.650(m) 0.009(m)
Y:	-5510493.385(m) 0.012(m)	-5510491.886(m) 0.012(m)
Z:	3200238.780(m) 0.008(m)	3200238.605(m) 0.008(m)

LAT:	30 18 42.14124 0.013(m)	30 18 42.16105 0.013(m)
E LON:	270 40 32.71151 0.009(m)	270 40 32.68320 0.009(m)
W LON:	89 19 27.28849 0.009(m)	89 19 27.31680 0.009(m)
EL HGT:	-24.984(m) 0.008(m)	-26.374(m) 0.008(m)
ORTHO HGT:	2.446(m) 0.024(m) [NAVD88 (Computed using GEOID12A)]	

	UTM COORDINATES (Zone 16)	STATE PLANE COORDINATES SPC (2301 MS E)
Northing (Y) [meters]	3355614.383	90075.893
Easting (X) [meters]	276505.359	252784.388
Convergence [degrees]	-1.17354368	-0.24777058
Point Scale	1.00021627	0.99997749
Combined Factor	1.00022019	0.99998141

US NATIONAL GRID DESIGNATOR: 16RBU7650555614(NAD 83)

BASE STATIONS USED

PID	DESIGNATION	LATITUDE	LONGITUDE	DISTANCE(m)
DK3577	ENG5 ENGLISH TURN 5 CORS ARP	N295244.246	W0895630.197	76445.3
DO8512	MARY MARY_289 LSU C4G CORS ARP	N300122.709	W0895446.801	65119.4
DG6568	COVG COVINGTON CORS ARP	N302833.269	W0900543.922	76324.7

NEAREST NGS PUBLISHED CONTROL POINT

DL8859	H 368	N301908.8	W0891923.6	830.2

This position and the above vector components were computed without any knowledge by the National Geodetic Survey regarding the equipment or field operating procedures used.

III. Datum Transfer:

In order to reference USM's tide gauge to MLLW NTDE 1983-2001, a tidal datum transfer to NOAA station 8747437 was completed. Water levels were recorded for over thirty days. High and low water levels from the spring tides were chosen from both the USM gauge and NOAA gauge.

HHW	LLW
0.848	0.756
0.812	0.569
0.951	0.558
1.083	0.547
1.237	0.651
1.457	0.591
1.545	0.971
1.575	0.905
1.531	0.809
1.466	0.899
1.516	0.955
1.364	0.976
1.296	0.681
1.272	0.551
1.277	0.506
1.246	0.512
1.272	0.465
1.265	0.468
1.213	0.536
1.117	0.615
1.03	0.624

Table III.1 Highs and lows from USM

HHW	LLW
1.072	0.963
1.027	0.788
1.181	0.775
1.309	0.762
1.462	0.869
1.695	0.814
1.739	1.187
1.812	1.105
1.768	1.018
1.68	1.117
1.76	1.17
1.584	1.187
1.539	0.98
1.5	0.788
1.51	0.721
1.482	0.727
1.497	0.71
1.487	0.677
1.432	0.762
1.348	0.84
1.262	0.851

Table III.2 Highs and lows from Station

DHHW	DLLW
-0.224	-0.207
-0.215	-0.219
-0.23	-0.217
-0.226	-0.215
-0.225	-0.218
-0.238	-0.223
-0.194	-0.216
-0.237	-0.2
-0.237	-0.209
-0.214	-0.218
-0.244	-0.215
-0.22	-0.211
-0.243	-0.299
-0.228	-0.237
-0.233	-0.215
-0.236	-0.215
-0.225	-0.245
-0.222	-0.209
-0.219	-0.226
-0.231	-0.225
-0.232	-0.227

Table III.3 Highs and Lows Differences

Transferred Datums	
DTL	0.7682619
Gt	0.52441119
MLLW	0.50605631
MHHW	1.0304675

Table III.4 Transferred datums.

Table III.1 and III.2 show the highs and lows chosen to perform the datum transfer from the USM tide gauge to NOAA's station 8747437. Table III.3 represents the differences between the highs and lows derived from USM's gauge and station 8747437. The average difference between the highs and lows between the two stations is 22 cm.

IV. Simultaneous Observations:

Jimmy Rutherford Fishing Pier Simultaneous Observations: 05/22/2014

UTC	Tide Staff (m)	Level TROLL 700 (m)	Difference (m)	Residuals (m)
1706	0.670	0.918	0.248	-0.007
1712	0.650	0.917	0.267	0.012
1718	0.660	0.912	0.252	-0.003
1724	0.680	0.910	0.230	-0.025
1730	0.660	0.908	0.248	-0.007
1736	0.660	0.903	0.243	-0.012
1742	0.650	0.902	0.252	-0.003
1748	0.650	0.901	0.251	-0.004
1754	0.650	0.900	0.250	-0.005
1800	0.650	0.899	0.249	-0.006
1806	0.640	0.896	0.256	0.001
1812	0.640	0.893	0.253	-0.002
1818	0.640	0.889	0.249	-0.006
1824	0.630	0.886	0.256	0.001
1830	0.630	0.883	0.253	-0.002
1836	0.630	0.883	0.253	-0.002
1842	0.620	0.881	0.261	0.006
1848	0.620	0.879	0.259	0.004
1854	0.620	0.875	0.255	0.000
1900	0.620	0.876	0.256	0.001
1906	0.620	0.874	0.254	-0.001
1912	0.610	0.871	0.261	0.006
1918	0.610	0.869	0.259	0.004
1924	0.610	0.870	0.260	0.005
1930	0.610	0.869	0.259	0.004
1936	0.600	0.866	0.266	0.011
1942	0.600	0.867	0.267	0.012
1948	0.600	0.866	0.266	0.011
1954	0.600	0.863	0.263	0.008
2000	0.610	0.863	0.253	-0.002
2006	0.610	0.866	0.256	0.001
		Average	0.255	0.000
		Standard Deviation	0.008	0.008

Jimmy Rutherford Fishing Pier Simultaneous Observations: 05/28/2014 & 05/30/2014

5/28/2014

UTC	Tide Staff (m)	Level TROLL 700 (m)	Difference (m)	Residuals (m)
1606	0.930	1.433	0.503	0.075
1612	0.910	1.448	0.538	0.110
1618	0.890	1.455	0.565	0.137
1624	0.900	1.456	0.556	0.128
1630	0.850	1.462	0.612	0.184
1636	0.840	1.450	0.610	0.182
1642	0.800	1.455	0.655	0.227
1648	0.790	1.453	0.663	0.235
1654	0.780	1.462	0.682	0.254
1700	0.760	1.466	0.706	0.278
1706	0.750	1.462	0.712	0.284

5/30/2014

UTC	Tide Staff (m)	Level TROLL 700 (m)	Difference (m)	Residuals (m)
1218	1.050	1.258	0.208	-0.220
1224	1.050	1.271	0.221	-0.207
1230	1.050	1.278	0.228	-0.200
1236	1.050	1.286	0.236	-0.192
1242	1.050	1.284	0.234	-0.194
1248	1.060	1.288	0.228	-0.200
1254	1.050	1.288	0.238	-0.190
1300	1.050	1.292	0.242	-0.186
1306	1.050	1.30	0.250	-0.178
1312	1.050	1.308	0.258	-0.170
1318	1.050	1.317	0.267	-0.161
		Average	0.428	0.000
		Standard Deviation	0.201	0.201

Jimmy Rutherford Fishing Pier Simultaneous Observations: 06/04/2014

UTC	Tide Staff (m)	Level TROLL 700 (m)	Difference (m)	Residuals (m)
1506	0.930	1.182	0.252	0.013
1512	0.940	1.184	0.244	0.005
1518	0.950	1.187	0.237	-0.002
1524	0.950	1.190	0.240	0.001
1530	0.950	1.193	0.243	0.004
1536	0.950	1.191	0.241	0.002
1542	0.950	1.192	0.242	0.003
1548	0.960	1.196	0.236	-0.003
1554	0.960	1.196	0.236	-0.003
1600	0.960	1.201	0.241	0.002
1606	0.960	1.202	0.242	0.003
1612	0.960	1.203	0.243	0.004
1618	0.970	1.202	0.232	-0.007
1624	0.970	1.203	0.233	-0.006
1630	0.970	1.205	0.235	-0.004
1636	0.970	1.206	0.236	-0.003
1642	0.970	1.209	0.239	0.000
1648	0.970	1.210	0.240	0.001
1654	0.980	1.208	0.228	-0.011
1700	0.970	1.210	0.240	0.001
1706	0.980	1.213	0.233	-0.006
		Average	0.239	0.000
		Standard Deviation	0.005	0.005

Jimmy Rutherford Fishing Pier Simultaneous Observations: 06/12/2014

UTC	Tide Staff (m)	Level TROLL 700 (m)	Difference (m)	Residuals (m)
1512	0.990	1.244	0.254	0.020
1518	1.010	1.250	0.240	0.006
1524	1.010	1.254	0.244	0.010
1530	1.020	1.259	0.239	0.005
1536	1.030	1.262	0.232	-0.002
1542	1.040	1.266	0.226	-0.008
1548	1.040	1.269	0.229	-0.005
1554	1.040	1.271	0.231	-0.003
1600	1.040	1.275	0.235	0.001
1606	1.050	1.278	0.228	-0.006
1612	1.050	1.278	0.228	-0.006
1618	1.050	1.275	0.225	-0.009
1624	1.040	1.276	0.236	0.002
1630	1.040	1.277	0.237	0.003
1636	1.040	1.276	0.236	0.002
1642	1.040	1.273	0.233	-0.001
1648	1.040	1.271	0.231	-0.003
1654	1.030	1.268	0.238	0.004
1700	1.030	1.263	0.233	-0.001
1706	1.030	1.260	0.230	-0.004
1712	1.020	1.257	0.237	0.003
		Average	0.234	0.000
		Standard Deviation	0.007	0.007

Jimmy Rutherford Fishing Pier Simultaneous Observations: 06/21/2014

UTC	Tide Staff (m)	Level TROLL 700 (m)	Difference (m)	Residuals (m)
1942	0.520	0.764	0.244	-0.005
1948	0.520	0.760	0.240	-0.009
1954	0.520	0.759	0.239	-0.010
2000	0.520	0.756	0.236	-0.013
2006	0.510	0.751	0.241	-0.008
2012	0.510	0.752	0.242	-0.007
2018	0.510	0.750	0.240	-0.009
2024	0.500	0.750	0.250	0.001
2030	0.500	0.749	0.249	0.000
2036	0.500	0.748	0.248	-0.001
2042	0.500	0.747	0.247	-0.002
2048	0.500	0.748	0.248	-0.001
2054	0.490	0.747	0.257	0.008
2100	0.490	0.749	0.259	0.010
2106	0.490	0.750	0.260	0.011
2112	0.490	0.753	0.263	0.014
2118	0.500	0.752	0.252	0.003
2124	0.500	0.751	0.251	0.002
2130	0.500	0.748	0.248	-0.001
2136	0.490	0.750	0.260	0.011
2142	0.490	0.751	0.261	0.012
		Average	0.249	0.000
		Standard Deviation	0.008	0.008

Jimmy Rutherford Fishing Pier Simultaneous Observations: 06/26/2014

UTC	Tide Staff (m)	Level TROLL 700 (m)	Difference (m)	Residuals (m)
2100	0.620	0.880	0.260	0.008
2106	0.620	0.879	0.259	0.007
2112	0.610	0.873	0.263	0.011
2118	0.610	0.862	0.252	0.000
2124	0.600	0.848	0.248	-0.004
2130	0.580	0.833	0.253	0.001
2136	0.570	0.822	0.252	0.000
2142	0.560	0.816	0.256	0.004
2148	0.550	0.809	0.259	0.007
2154	0.550	0.803	0.253	0.001
2200	0.550	0.804	0.254	0.002
2206	0.520	0.781	0.261	0.009
2212	0.530	0.789	0.259	0.007
2218	0.550	0.770	0.220	-0.032
2224	0.520	0.763	0.243	-0.009
2230	0.500	0.754	0.254	0.002
2236	0.500	0.756	0.256	0.004
2242	0.480	0.735	0.255	0.003
2248	0.480	0.711	0.231	-0.021
2254	0.450	0.703	0.253	0.001
2300	0.440	0.694	0.254	0.002
		Average	0.252	0.000
		Standard Deviation	0.010	0.010

Jimmy Rutherford Fishing Pier Simultaneous Observations: 07/01/2014

UTC	Tide Staff (m)	Level TROLL 700 (m)	Difference (m)	Residuals (m)
1318	0.470	0.741	0.271	0.011
1324	0.470	0.742	0.272	0.012
1330	0.490	0.741	0.251	-0.009
1336	0.490	0.744	0.254	-0.006
1342	0.490	0.741	0.251	-0.009
1348	0.490	0.743	0.253	-0.007
1354	0.490	0.742	0.252	-0.008
1400	0.490	0.741	0.251	-0.009
1406	0.480	0.736	0.256	-0.004
1412	0.480	0.735	0.255	-0.005
1418	0.470	0.733	0.263	0.003
1424	0.470	0.728	0.258	-0.002
1430	0.470	0.724	0.254	-0.006
1436	0.470	0.727	0.257	-0.003
1442	0.480	0.730	0.250	-0.010
1448	0.470	0.734	0.264	0.004
1454	0.470	0.734	0.264	0.004
1500	0.480	0.736	0.256	-0.004
1506	0.470	0.734	0.264	0.004
1512	0.470	0.737	0.267	0.007
1518	0.470	0.737	0.267	0.007
1524	0.480	0.739	0.259	-0.001
1530	0.480	0.740	0.260	0.000
1536	0.490	0.748	0.258	-0.002
1542	0.490	0.753	0.263	0.003
1548	0.490	0.756	0.266	0.006
1554	0.500	0.759	0.259	-0.001
1600	0.500	0.762	0.262	0.002
1606	0.500	0.771	0.271	0.011
1612	0.510	0.776	0.266	0.006
1618	0.510	0.776	0.266	0.006
		Average	0.260	0.000
		Standard Deviation	0.006	0.006

V. Tidal Data Analysis:

tide	frequ	amp	amp err	ph	ph err	snr
*MM	0.001512	0.0798	0.044	190.26	34.38	3.2
*MSF	0.002822	0.067	0.041	101.1	35.95	2.7
ALP1	0.034397	0.0113	0.017	66.8	88.1	0.47
2Q1	0.035706	0.005	0.014	278.23	155.65	0.13
*Q1	0.037219	0.0357	0.017	22.56	27.43	4.3
*O1	0.038731	0.1924	0.018	45.33	6.18	1.20E+02
NO1	0.040269	0.0141	0.015	353.52	68.88	0.91
*K1	0.041781	0.2098	0.019	56.63	4.56	1.20E+02
J1	0.043293	0.0105	0.013	29.72	98.44	0.62
OO1	0.044831	0.0135	0.021	32.43	118.71	0.43
UPS1	0.046343	0.0139	0.022	52.96	105.4	0.42
EPS2	0.076177	0.0083	0.008	241	66.46	0.97
MU2	0.07769	0.0037	0.008	210.25	133.68	0.22
*N2	0.078999	0.0194	0.008	251.18	26.43	5.5
*M2	0.080511	0.0323	0.009	206.73	19.16	12
L2	0.082024	0.0038	0.007	353.01	129.54	0.28
*S2	0.083333	0.0211	0.01	221.28	27.47	4.6
ETA2	0.085074	0.0081	0.013	201.95	117.23	0.4
MO3	0.119242	0.0029	0.006	203.68	123.92	0.26
M3	0.120767	0.0009	0.004	346.95	213.96	0.046
*MK3	0.122292	0.0101	0.006	212.41	41.12	2.7
SK3	0.125114	0.0086	0.007	271.45	44.04	1.6
MN4	0.159511	0.0033	0.003	216.46	67.79	1.1
*M4	0.161023	0.008	0.004	209.84	25.18	5
SN4	0.162333	0.0024	0.003	332.97	82.07	0.5
MS4	0.163845	0.0033	0.003	18.69	63.44	0.97
S4	0.166667	0.0029	0.003	338.99	76.75	0.79
2MK5	0.202804	0.0009	0.003	121.88	183.2	0.1
2SK5	0.208447	0.0021	0.004	62.79	105.44	0.34
2MN6	0.240022	0.0017	0.002	341.77	53.57	0.86
M6	0.241534	0.0007	0.001	150.41	126.96	0.27
2MS6	0.244356	0.0004	0.001	127.04	195.68	0.066
2SM6	0.247178	0.0012	0.002	63.94	90.18	0.5
3MK7	0.283315	0.0011	0.001	307.45	57.42	1.1
M8	0.322046	0.0007	0.001	222.33	65.14	1.4

Table V.1 Constituents derived from T Tides.

Name	Amplitude	Phase	Speed
M2	0.03	205.7	28.9841
S2	0.026	216.1	30
K1	0.169	58.5	15.04107
O1	0.154	48.8	13.94304

Table V.2 Constituents from NOAA 8747437

Table V.1 and Table V.2 show the constituents for the survey area. Table V.1 were derived using the Matlab routine T Tides from the USM gauge. Table V.2 are published from NOAA.

Looking at Figure A.11, the NOAA gauge and the USM tide gauge directly correlate. For the five lines that required tide data, data from the NOAA gauge was used to apply corrections. Tides were applied to the times listed in Table V.3 for Julian Day 168. The tides applied to the bathymetry data were relative to MLLW and reviewed using the tides editor in Caris HIPS.

	Start Time	End Time
JD 168	13:47	14:00
	14:01	14:15
	14:15	14:28
	14:29	14:43
	14:44	14:51

Table V.3 Times for tides.

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