COOPER RIVER BRIDGES PROJECT
CHARLESTON, SOUTH CAROLINA

Project Report

National Geodetic Survey
Instrumentation & Methodologies Branch
Corbin, Virginia

March 3, 1999

Report by:
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A. Location

Charleston, South Carolina at, on and in the vicinity of the Grace Memorial Bridge and the Silas Pearlman Bridge over the Cooper River (U.S. Highway 17).

B. Scope

1. Purpose.

   This project was a joint effort by the National Ocean Service's Oceanographic Products and Services Division (OPSD), the Coast Survey, and the National Geodetic Survey's (NGS) Instrumentation & Methodologies Branch (I&M Branch) in accordance with NOAA's goal to Promote Safe Navigation and the Physical Oceanographic Real-Time System (PORTS). The objective is to develop a real-time system using GPS to determine the maximum height of a vessel at the lowest point of a bridge. Two bridges over the Cooper River in Charleston, S.C., the Grace Memorial and Silas Pearlman, are the subject of this project.

   The task of the I&M Branch was to determine the physical height of the bottom of the bridges below three GPS antennas (two on the Silas Pearlman bridge and one on the Grace Memorial bridge) and determine orthometric heights (elevations) of the antennas and various points (profiles) along the bottom of the bridges to a minimum of 150 feet out on both sides of the centerline of the bridges over the shipping channel. Accomplishment of these tasks was to be done employing special trigonometric leveling techniques developed by the I&M Branch.

2. Specifications.

   To determined height differences and elevations to a 2 centimeter or less accuracy.

3. Monumentation.

   A new bench mark was set on each of the bridges to serve as a starting reference for future surveys should they occur. These stations were SILAS 1999 on the Silas Pearlman bridge and GRACE 1999 on the Grace Memorial bridge. Each was set in the bridge highway curb near the centerline below the GPS antenna reference points (ARP).

The GPS antenna references points on the Silas Pearlman bridge consisted of aluminum angle brackets bolted to safety railing uprights at the top of the bridge. One on the north side and one on the south side of the bridge. These should be considered semi-permanent. The ARP on the Grace Memorial bridge consisted of a special tribrach with 3 magnetic feet. This was mounted on a horizontal gusset plate at the top of the bridge and secured with tie down cables. This should also be considered semi-permanent.

Recoverable temporary points were established on both bridges. These were SILAS TP1 and GRACE TP1 and were described and marked but not monumented. Both were the top of flat sturdy metal railings that allowed easy attachment of a trig-leveling target mounted on a three inch magnet base.

Non-recoverable temporary points were created to transfer heights to the bottom of the bridges at the centerlines and along the tops of the beams at the bottom of the bridges for the profile observations.

4. Instrumentation. (See Equipment List - ATTACHMENT C)

Primary instrumentation was a Leica TC2002 Total Station providing high accuracy in horizontal (0.5"), vertical (0.5"), and distance measurements (+\-1 mm + 1 ppm). Other equipment used with it were various retro-prism targets, target supports, and range poles. These various components of equipment were tested and calibrated prior to the project.

C. Comments

1. Reconnaissance and Planning

A special reconnaissance trip was taken to Charleston a month earlier than the project to determine location of the GPS antennas, recover local horizontal and vertical control stations, and determine how the heights of the bottom of the bridges might be measured.

After study and evaluation of the information and pictures gathered from the reconnaissance trip, several methods for measuring the height difference between the GPS antennas mounted on top of the bridges and the bottom of the bridges were tested at the I&M Branch facility in Corbin, Va.

The methods tested consisted of trigonometric leveling, remote height measurments, vertical electronic distance measurements (EDMI), and vertical taping. Trig leveling appeared to the most expedient method followed by remote height measurements (a variation of trig-leveling where the distance is measured to a point below the unknown height point), and finally vertical EDMI distances. The last two methods would require a way to collimate directly below the GPS antenna locations. At the time of the tests, it was not known if this would be possible. Vertical taping was a last resort method if none of the others were possible. The only significant unknown affecting the methods involving the use of the total station instrument was the effects from vibration and movement of the bridges due to traffic.

2. Specifications and Procedures.

The first day on the Silas Pearlman bridge an experiment was conducted to test the leveling compensators of the total station. The results were very close with this function turned on and off. However, with it on, the constant traffic induced vibration made the spreads large in the difference of elevation measurements. The compensators were turn off and the instrument kept level manually. A little time was lost at each setup, but otherwise this worked ok. With this problem resolved, the measurements could be started.

<u>Height Differences Using Trig-leveling</u>

Height differences using trigonometric leveling is accomplished by measuring a zenith distance angle and a slope distance to a target forming a right triangle. The base of the triangle is through the vertical center of rotation of the total station instrument (TSI). The slope distance is the hypotenuse and 90 degrees minus the zenith distance is the angle at the intersection of the base and hypotenuse. Given these values, the length of the opposite side of the right triangle can be solved for yielding the height difference between the target and the vertical center of rotation of the TSI. Calculation of the height difference is performed by on-board software stored in the instrument and the value is shown in one of the LCD display windows. It can also be recorded to an on-board data storage recording module. Previous testing of this function has proven its validity when compared to computing the height outside the instrument.

Corrections Applied to Trig-leveling

Prior to observing the measurements, both meteorological data (air temperature and pressure) and instrument and prism offset constants values must be stored into the instrument. The met data is used to compute the refractive index correction of the atmosphere for the EDMI being used. The instrument and prism offset constants were determined by calibration prior to the project. These values are stored in the TSI as a parts per million (PPM) correction from the met data and a combined offset constant (in millimeters) for the EDMI and retro-prism being used.

Also, a standard correction for curvature and refraction is applied to each height difference measurement based on the following formula:

Height Difference = (SD*COS(ZD))+(1-k/2R)*(SD*SIN(ZD))^2

where: k = 0.13 (mean value for coefficient of refraction)
R = 6.37*10E6 meters (earth radius)
SD = measured Slope Distance
ZD = measured Zenith Distance

This correction is also performed by the TSI’s on-board software.

Height Difference Determination

The height difference or difference of elevation (d.e.) between two points is obtained by first measuring to a backsight (BS) target which gives the d.e. from the target to TSI. Next, a measurement is taken to a foresight (FS) target which gives the d.e. from the target to the TSI. The foresight d.e. minus the backsight d.e. yields the height difference with the correct sign between the two targets. The relationship of the target to the point to which the height difference is to be established must be considered and appropriate corrections made. In most cases, if both the BS and FS targets are of equal height above the respective points, then the resulting d.e. between the targets is the d.e. between the two points. In other cases, as in this project, corrections for the physical height of the target above or below a reference point must be applied. Figure #1 in ATTACHMENT A illustrates how the height difference from the GPS antennas on top of the Silas Pearlman bridge to reference point Silas TP1 was determined for this project. This case required corrections for both of the targets. Figures #2 and #3 in ATTACHMENT A illustrate the more common scenario where both targets are of equal height above the elevation points. This method was used to measure the height difference from the GPS antenna on top of the Grace Memorial bridge to the Grace TP1 reference point. Figure #3 depicts how the height differences were transferred to the bottom of the bridges at the centerlines and for the profiles.

For all of the height transfers from the antennas down to the bottom of the bridges, multiple measurements from 5 to 10 or more were taken in both direct and reverse positions of the TSI. The average of these was used as the final difference of elevation. For the profile measurements, a minimum of two sets (1 set = direct/reverse on each target) were taken.

Elevation Ties to Local Vertical Control

Once the height differences on the bridges were established double run trig-leveling was run from BM R16 to BM Y151 to reference mark SILAS 1999, and finally to BM X151. Elevations were transferred to the Grace Memorial Bridge through BMs Silas 1999 to Silas TP1 to Grace TP1 using trig-leveling. Observations were made from each bridge to the other on two different days.

D. Closures and Field Checks

1. Blunder checks

These measurements were by no means very precise but provided an in the ball park check on the trig-leveling measurements.

a. Silas Pearlman Bridge

The height from SILW ARP (Silas West Antenna Reference Point) to Silas TP1 was measured with a tape. This was not a perfectly vertical measurement, but close. A reasonablely good check was made.

Taped height ....: -45.8 ft.
Trig-level height: -45.7 ft.
Difference: 0.1 ft. (1.2 inches)

b. Grace Memorial Bridge

Prior to this project the South Carolina Dept. of Transportation (SCDOT) measured the height of the Grace Memorial bridge at the centerline upright of the bridge (midspan at U22 L22 chord to chord). The trig-leveling height measured was from the top edge of the horizontal gusset plate on which the antenna was mounted to the bottom edge of the horizontal gusset plate at the bottom of the bridge. SCDOT did not show us exactly where they measured from and to and we forgot to have them show us. The difference is larger than hoped for.
Trig-levels height: -63.96 ft
SCDOT taped height: -63.55 ft

Difference: 0.41 ft (4.92 inches)

2. Leveling Closures

A line tie was made from several bench marks to the east of the bridges and through several bench marks at the east end of the bridges. Double Run Trig-leveling was used from BM R16 (east end of Grace Memorial bridge) to Y151 (east end of Silas Pearlman bridge) to Silas 1999 (on Silas Pearlman bridge) to X151 (also on Silas Pearlman bridge). A new minus old comparison was done between previous First Order leveling (1979) and the current trig-leveling. Since Silas 1999 was new mark between Y151 and X151, the difference of elevation (d.e.) between Y151 and X151 was computed using the sum of the d.e. from Y151 to Silas 1999 and the d.e. from Silas 1999 to X151.

R16 to Y151

Published NAVD88 elevation R16 .... =	3.1810 m
Published NAVD88 elevation Y151 ... =	8.3473 m
Difference of elevation .... =	5.1663 m
R16 to Y151 trig observed d.e. .... =	5.1661 m
R16 to Y151 published NAVD88 d.e... =	5.1663 m
New-Old. =	**-0.0002 m**

Y151 to X151

Published NAVD88 Elevation X151 ... =	42.6961 m
Published NAVD88 Elevation Y151 ... =	8.3473 m
Difference of elevation .... =	34.3488 m
Y151 to Silas 1999 trig observed... =	41.0962 m
Silas 1999 to X151 trig observed... =	-6.7459 m
Y151 to X151 trig-leveling observed =	34.3503 m
Y151 to X151 published NAVD88 d.e.. =	34.3488 m
New-Old =	**0.0015 m**

3. Summary of Individual Height Measurements (See sketches in Attachment B showing location of points)

a. Silas Pearlman Bridge

SILE ARP to Silas TP1
Silas TP1 to SILE CL
SILW ARP to Silas TP1
Silas TP1 to SILW CL
Silas TP1 to Silas 1999
Silas 1999 to Profile Points 1-16
Silas TP1 to Grace TP1

b. Grace Memorial Bridge

Grace TP1 to Silas TP1
GRAC ARP to Grace TP1
Grace TP1 to Grace CL
Grace TP1 to Grace 1999
Grace 1999 to Profile Points 1-10

c. Leveling Ties (Double-Run Trig-Levels)

R16 to Y151
Y151 to Silas 1999
Silas 1999 to X151

E. Recommendations

Despite the constraints of limited time and persistent traffic on the bridges, the results of this project are very good. It appears that heights and elevations determined using trig-leveling techniques fall within about a centimeter or less. This is well within the 2 centimeters desired. All objectives were met.

1. Determine the physical height of the bottom of the bridges below three GPS antennas.

2. Determine orthometric heights (elevations) of the antennas and various points (profiles) along the bottom of the bridges to a minimum of 150 feet out on both sides of the centerline.

For similar future projects, the use of trig-leveling techniques should provide a viable means for height transfers if the following procedures are adhered to.

1. Use a total station instrument (TSI) with at least a 1 second or better angulation capability and an electronic distance measuring accuracy of +/- 3 mm + 2 ppm or better.

2. Be sure all parameters and corrections are dialed into the TSI correctly (i.e. temperature, pressure, offset constant corrections, and refraction/curvature correction on).

3. Keep height transfer sight lengths as short as possible (50 meters or less) and angle to upper target 45 degrees or less if possible.

4. Keep TSI as level as possible. Monitor instrument level often. In most cases, if bridge is shaky, it will not be possible to use TSI electronic leveling compensation.

5. Take 5 or more sets (1 set = 1 direct/reverse pointing) on each backsight and foresight targets.

6. Take two independent sets of measurements. Measure one set of 5, BS/FS, then reset the instrument and take another set of 5. This will constitute a forward and backward running providing some redundancy.

7. Keep good notes and sketches on target placement, heights above references points, reflector constants, for application to post observation computations.

8. If profiling bottom of bridge, double run between all points and carefully determine distance from centerline to each profile point.

Other Recommendations

It is not necessary to make a direct height measurement between two points of interest. Temporary points can be used as in the case of this project. To determine the height difference from the antenna reference points to the bottom of the bridge, four measurements had to be taken. SILE ARP to SILAS TP1, SILAS TP1 to SILAS 1999, SILAS 1999 to Top of the Beam, and finally the thickness of the beam (See Attachment B Figure #3). The sum of these, after applying corrections, yields the final height difference. Choose temporary points that can be remeasured and are stable.

Stability is a key component of good survey measurements. In most normal environments, stability of the instrument platform is achieved. However, when working on bridges carrying traffic, movement of the bridges is inevitable and natural to the bridge design. So, if it is possible to set up on a stable platform (a pier, an island, another bridge) nearby, do so and make height transfers from there. Of course, the points of interest on the bridge must be visible from there.

Data collection for this project could have been better implemented. Although trig-leveling software had been previously developed, it needed modification to be applied to this projects specifications. The I&M Branch will address this for future application. This was not a major problem given that there was a small amount of data.

TABULATED ELEVATIONS AND HEIGHT DIFFERENCES

Antenna Reference Points to Bottom Centerline of Bridges

From Point		**To Point**		**Height Difference**	
SPSN Designation	**Elevation (m)**	**SPSN Designation**	**Elevation (m)**	**Meters**	**Feet**
0009 SILE ARP	65.2046	0010 SILE CL	46.5969	-18.6077	-61.0488
0008 SILW ARP	65.2104	0011 SILW CL	46.5903	-18.6201	-61.0894
0013 GRAC ARP	66.9055	0015 GRACE CL	47.3507	-19.5548	-64.1560

Antenna Reference Points to Bottom of Bridge Profile Points
(South Side of Silas Pearlman Bridge)

From Point		**To Point**		**Height Difference**	
SPSN Designation	**Elevation (m)**	**SPSN Designation**	**Elevation (m)**	**Meters**	**Feet**

0009	SILE ARP	65.2046	0020	SILAS PF5	46.2159	-18.989	-62.300
			0021	SILAS PF6	46.4376	-18.767	-61.571
			0022	SILAS PF7	46.5052	-18.699	-61.348
			0023	SILAS PF8	46.5941	-18.611	-61.050
			0010	SILE CL	46.5969	-18.608	-61.049
			0031	SILAS PF16	46.5900	-18.615	-61.073
			0030	SILAS PF15	46.5761	-18.629	-61.119
			0029	SILAS PF14	46.4372	-18.767	-61.571
			0028	SILAS PF13	46.2126	-18.992	-62.310

Antenna Reference Points to Bottom of Bridge Profile Points
(North Side of Silas Pearlman Bridge)

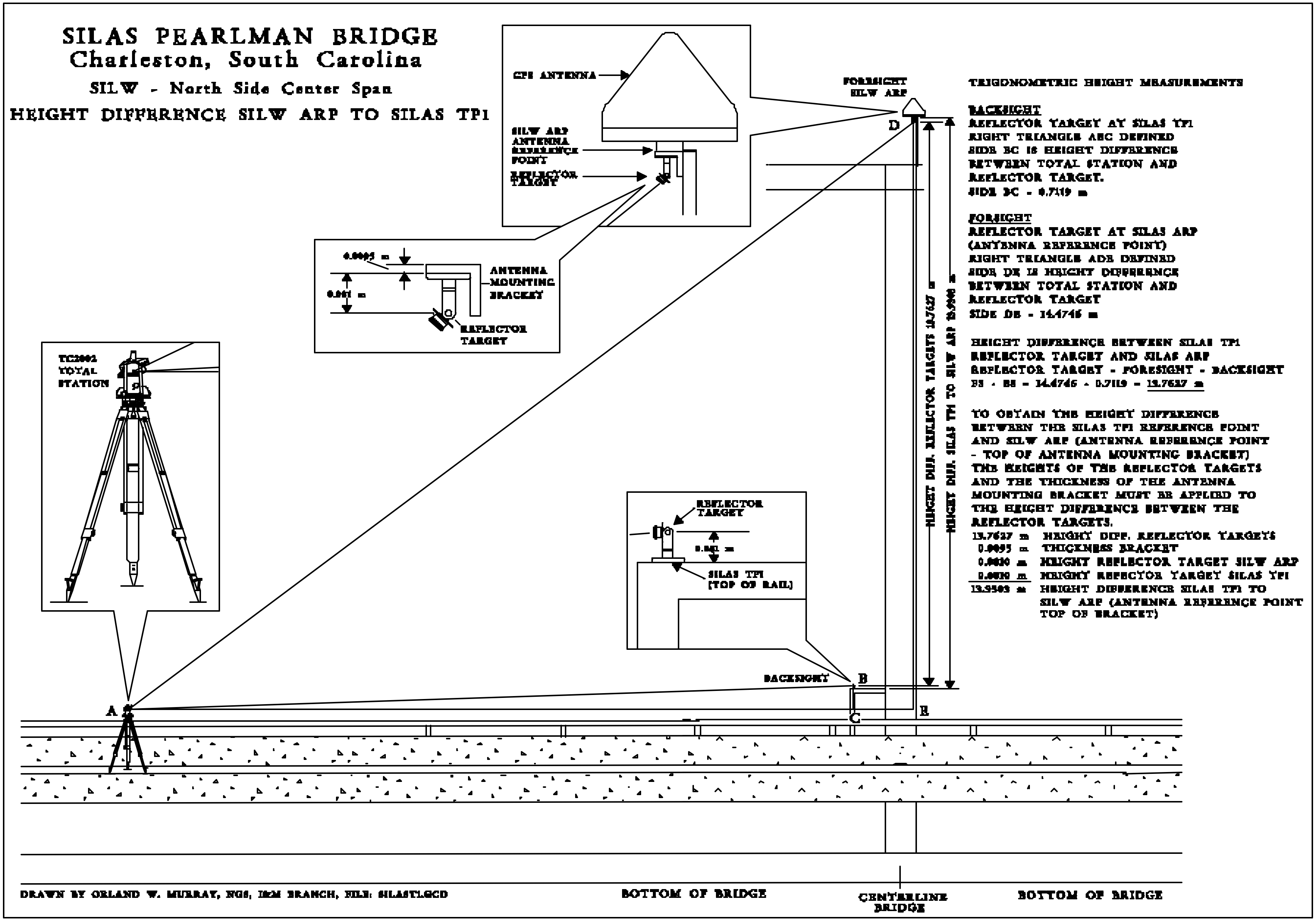
From Point			**To Point**			**Height Difference**	
SPSN	**Designation**	**Elevation (m)**	**SPSN**	**Designation**	**Elevation (m)**	**Meters**	**Feet**
0008	SILW ARP	65.2104	0019	SILAS PF4	46.2123	-18.998	-62.329
			0018	SILAS PF3	46.3293	-18.881	-61.945
			0017	SILAS PF2	46.4935	-18.717	-61.407
			0016	SILAS PF1	46.5563	-18.654	-61.201
			0011	SILW CL	46.5903	-18.620	-61.089
			0024	SILAS PF9	46.5880	-18.622	-61.096
			0025	SILAS PF10	46.4995	-18.711	-61.388
			0026	SILAS PF11	46.4295	-18.781	-61.617
			0027	SILAS PF12	46.2096	-19.001	-62.339

Antenna Reference Points to Bottom of Bridge Profile Points
(North Side of Grace Memorial Bridge)

From Point			**To Point**			**Height Difference**	
SPSN	**Designation**	**Elevation (m)**	**SPSN**	**Designation**	**Elevation (m)**	**Meters**	**Feet**
0013	GRAC ARP	66.9055	0041	GRACE PF10	42.4869	-24.419	-80.113
			0040	GRACE PF9	43.8047	-23.101	-75.790
			0039	GRACE PF8	45.1317	-21.774	-71.436
			0038	GRACE PF7	46.3189	-20.587	-67.541
			0037	GRACE PF6	47.1003	-19.805	-64.978
			0015	GRACE CL	47.3507	-19.555	-64.157
			0032	GRACE PF1	47.3552	-19.550	-64.141
			0033	GRACE PF2	46.8308	-20.075	-65.862
			0034	GRACE PF3	45.7661	-21.139	-69.355
			0035	GRACE PF4	44.4580	-22.448	-73.647
			0036	GRACE PF5	43.1436	-23.762	-77.959

ATTACHMENT A

Trigonometric Leveling
Height Measurement Diagrams

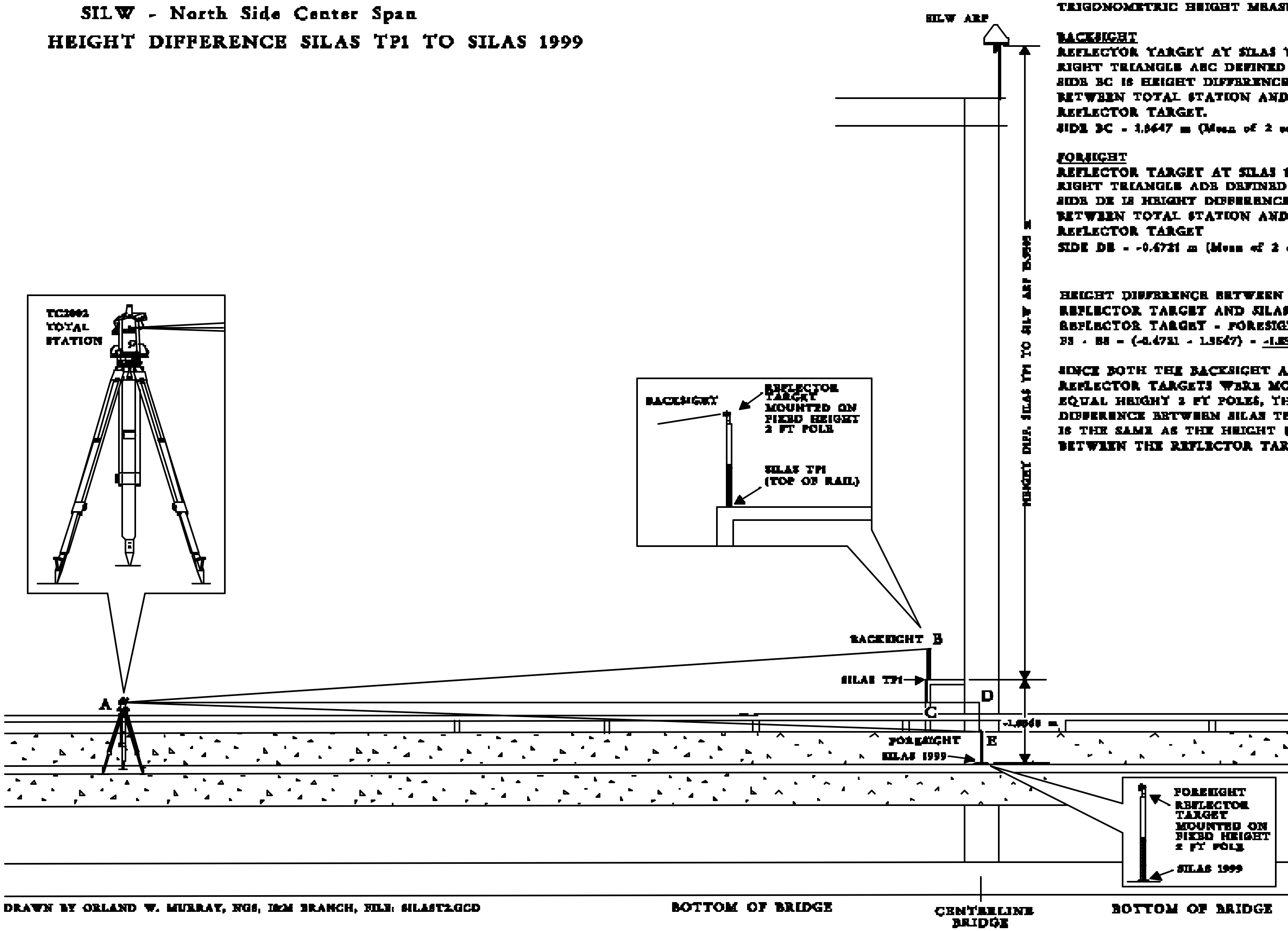


SILAS PEARLMAN BRIDGE
Charleston, South Carolina
SILW - North Side Center Span
HEIGHT DIFFERENCE SILW ARP TO SILAS TP1
GPS ANTENNA
SILW ARP ANTENNA REFERENCE POINT
REFLECTOR TARGET
0.0095 m
0.081 m
ANTENNA MOUNTING BRACKET
REFLECTOR TARGET
TC2002 TOTAL STATION
FORESIGHT SILW ARP
D
REFLECTOR TARGET
0.081 m
SILAS TP1 (TOP OF RAIL)
BACKSIGHT
B
A
C
E
HEIGHT DIFF. REFLECTOR TARGETS 13.7627 m
HEIGHT DIFF. SILAS TP1 TO SILW ARP 13.9503 m
TRIGONOMETRIC HEIGHT MEASUREMENTS
BACKSIGHT
REFLECTOR TARGET AT SILAS TP1
RIGHT TRIANGLE ABC DEFINED
SIDE BC IS HEIGHT DIFFERENCE
BETWEEN TOTAL STATION AND
REFLECTOR TARGET.
SIDE BC - 0.7119 m
FORSIGHT
REFLECTOR TARGET AT SILAS ARP
(ANTENNA REFERENCE POINT)
RIGHT TRIANGLE ADE DEFINED
SIDE DE IS HEIGHT DIFFERENCE
BETWEEN TOTAL STATION AND
REFLECTOR TARGET
SIDE DE - 14.4746 m
HEIGHT DIFFERENCE BETWEEN SILAS TP1
REFLECTOR TARGET AND SILAS ARP
REFLECTOR TARGET - FORESIGHT - BACKSIGHT
FS - BS - 14.4746 - 0.7119 = 13.7627 m
TO OBTAIN THE HEIGHT DIFFERENCE
BETWEEN THE SILAS TP1 REFERENCE POINT
AND SILW ARP (ANTENNA REFERENCE POINT
- TOP OF ANTENNA MOUNTING BRACKET)
THE HEIGHTS OF THE REFLECTOR TARGETS
AND THE THICKNESS OF THE ANTENNA
MOUNTING BRACKET MUST BE APPLIED TO
THE HEIGHT DIFFERENCE BETWEEN THE
REFLECTOR TARGETS.
13.7627 m HEIGHT DIFF. REFLECTOR TARGETS
0.0095 m THICKNESS BRACKET
0.0810 m HEIGHT REFLECTOR TARGET SILW ARP
0.0810 m HEIGHT REFECTOR TARGET SILAS TP1
13.9503 m HEIGHT DIFFERENCE SILAS TP1 TO SILW ARP (ANTENNA REFERENCE POINT TOP OF BRACKET)
DRAWN BY ORLAND W. MURRAY, NGS, I&M BRANCH, FILE: SILASTP1.GCD
BOTTOM OF BRIDGE
CENTERLINE BRIDGE
BOTTOM OF BRIDGE

SILAS PEARLMAN BRIDGE
Charleston, South Carolina

SILW - North Side Center Span

HEIGHT DIFFERENCE SILAS TP1 TO SILAS 1999



TRIGONOMETRIC HEIGHT MEASUREMENTS

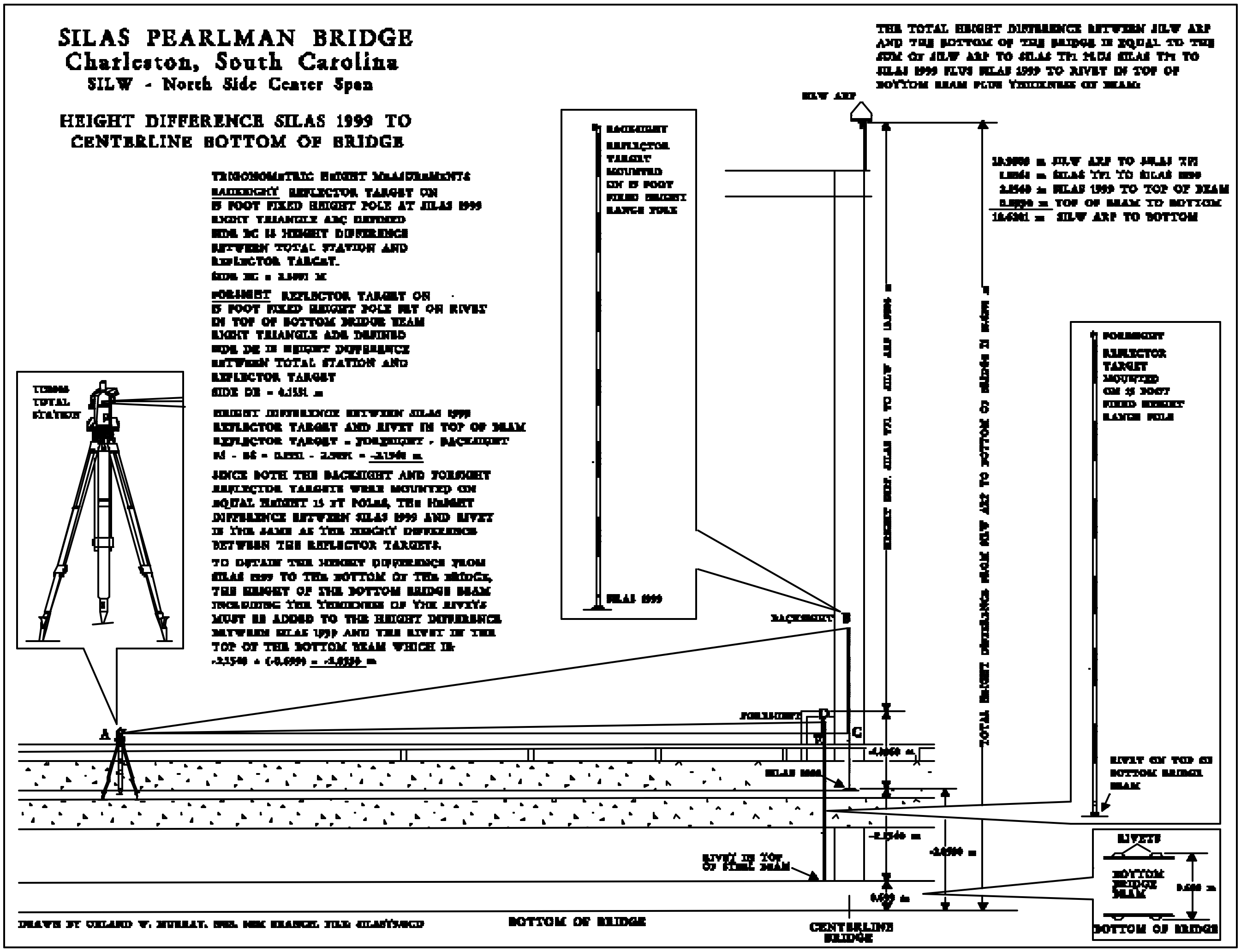
BACKSIGHT
REFLECTOR TARGET AT SILAS TP1
RIGHT TRIANGLE ABC DEFINED
SIDE BC IS HEIGHT DIFFERENCE
BETWEEN TOTAL STATION AND
REFLECTOR TARGET.
SIDE BC = 1.3647 m (Mean of 2 sets)

FORESIGHT
REFLECTOR TARGET AT SILAS 1999
RIGHT TRIANGLE ADE DEFINED
SIDE DE IS HEIGHT DIFFERENCE
BETWEEN TOTAL STATION AND
REFLECTOR TARGET
SIDE DE = -0.4721 m (Mean of 2 sets)

HEIGHT DIFFERENCE BETWEEN SILAS TP1
REFLECTOR TARGET AND SILAS 1999
REFLECTOR TARGET = FORESIGHT - BACKSIGHT
FS - BS = (-0.4721 - 1.3647) = -1.8368 m

SINCE BOTH THE BACKSIGHT AND FORESIGHT
REFLECTOR TARGETS WERE MOUNTED ON
EQUAL HEIGHT 2 FT POLES, THE HEIGHT
DIFFERENCE BETWEEN SILAS TP1 AND SILAS 1999
IS THE SAME AS THE HEIGHT DIFFERENCE
BETWEEN THE REFLECTOR TARGETS.

DRAWN BY ORLAND W. MURRAY, NGS, I&M BRANCH, FILE: SILAST2.GCD

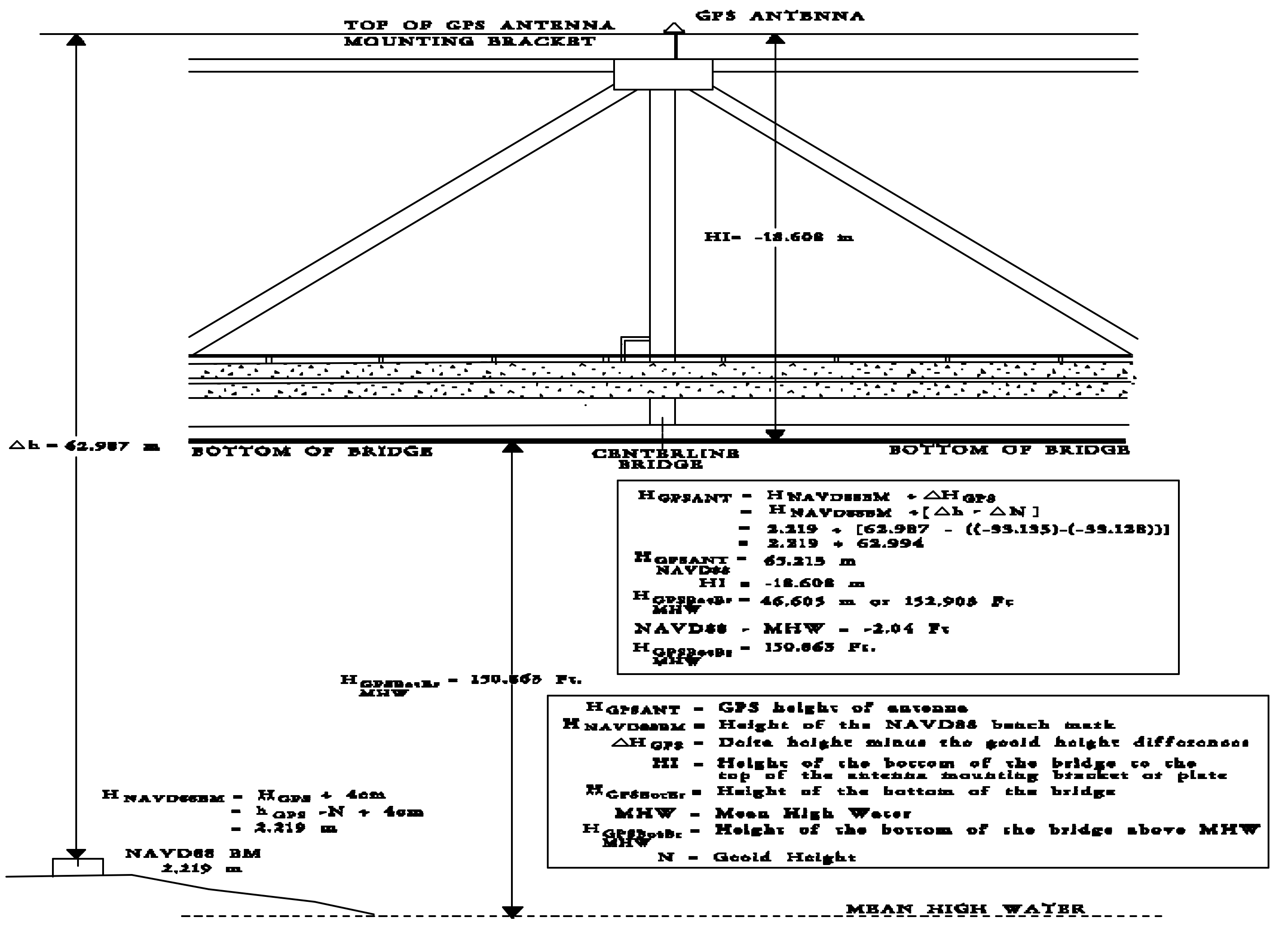


ATTACHMENT B

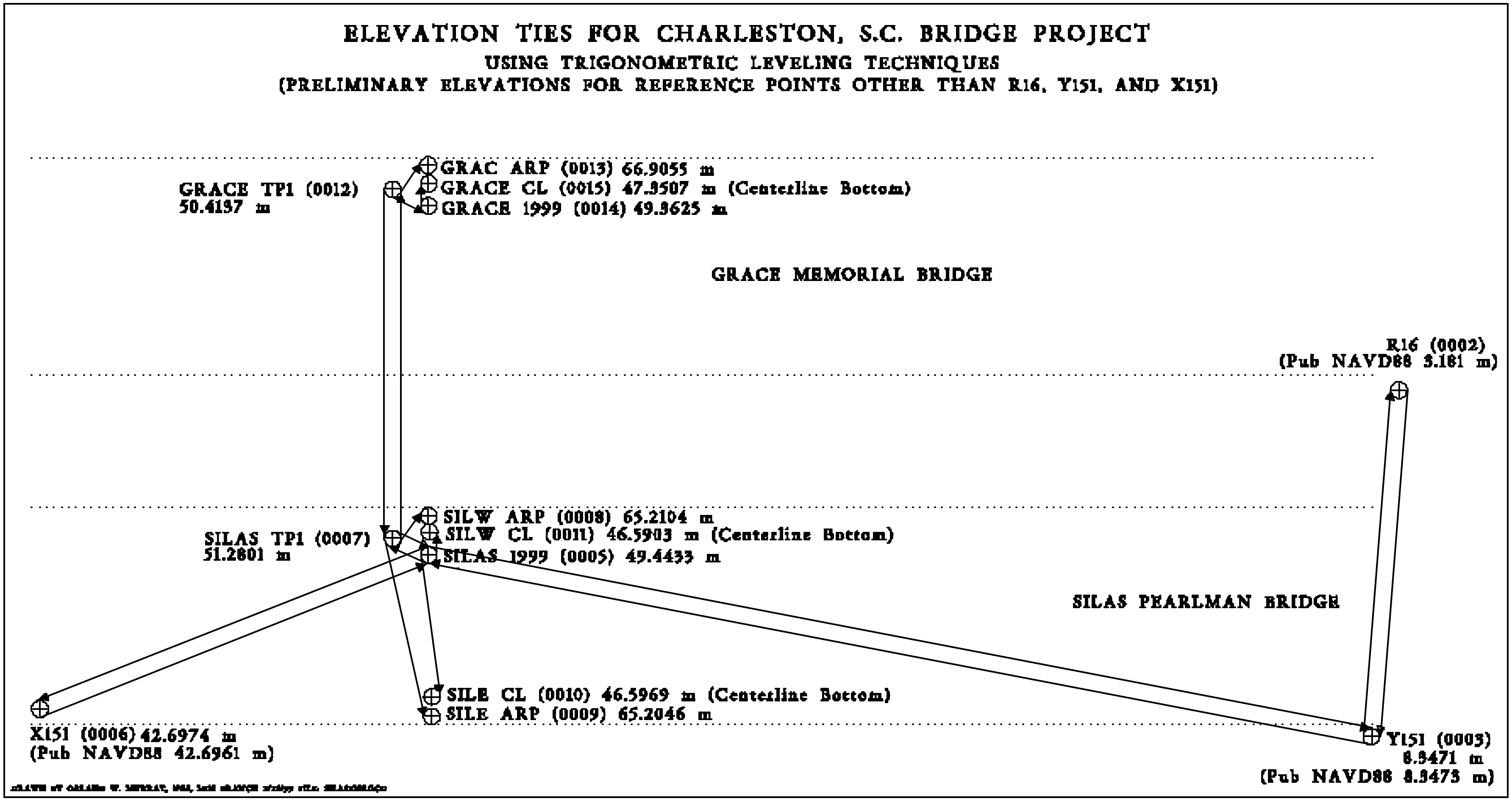
Project Sketches
Height Diagrams
Profile Diagrams

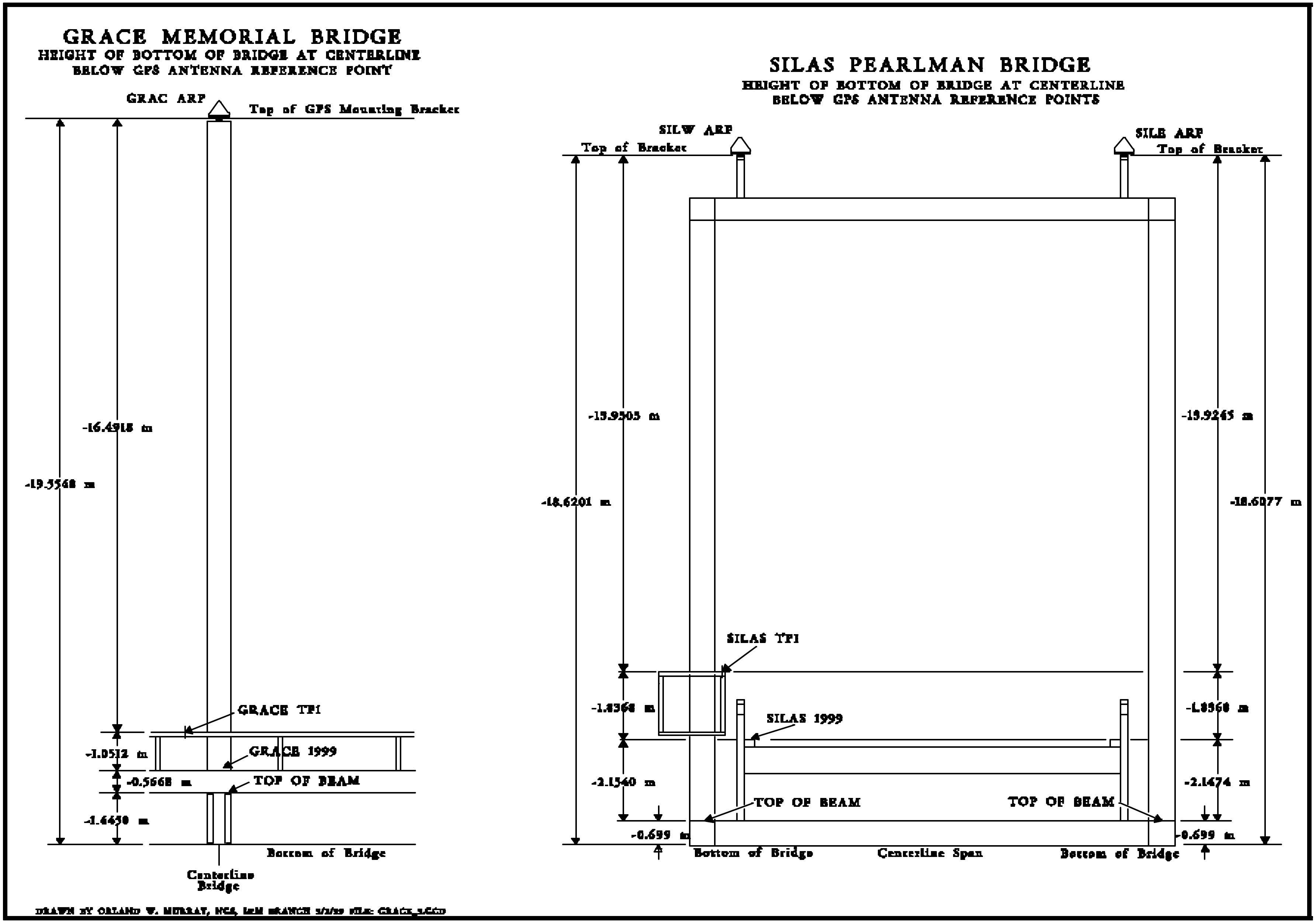
SILAS PEARLMAN BRIDGE - CHARLESTON, S.C.

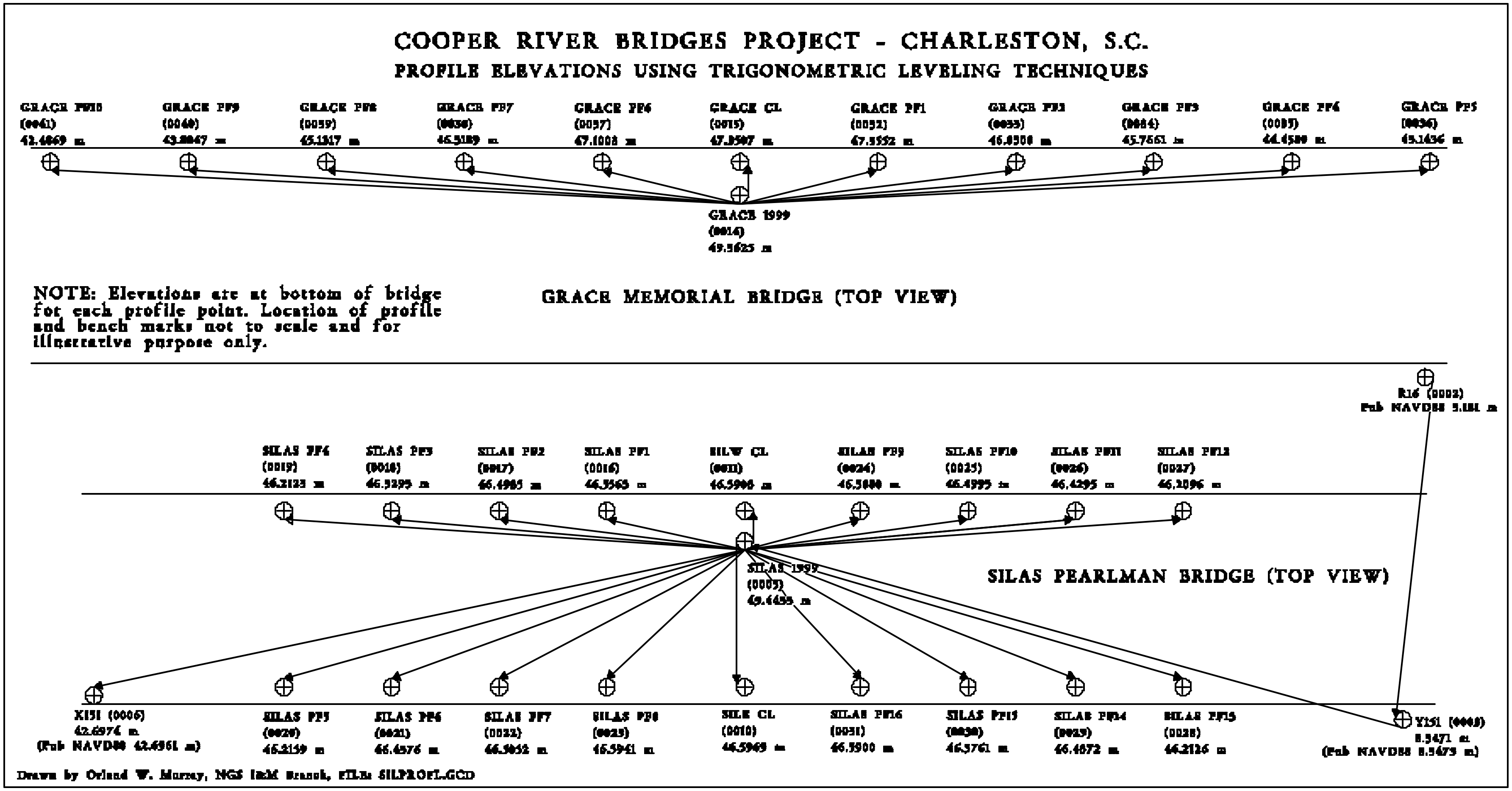
South Side Bottom - Center Span
NAVD88 - Orthometric Height
Tidal - Mean High Water (MHW) Height



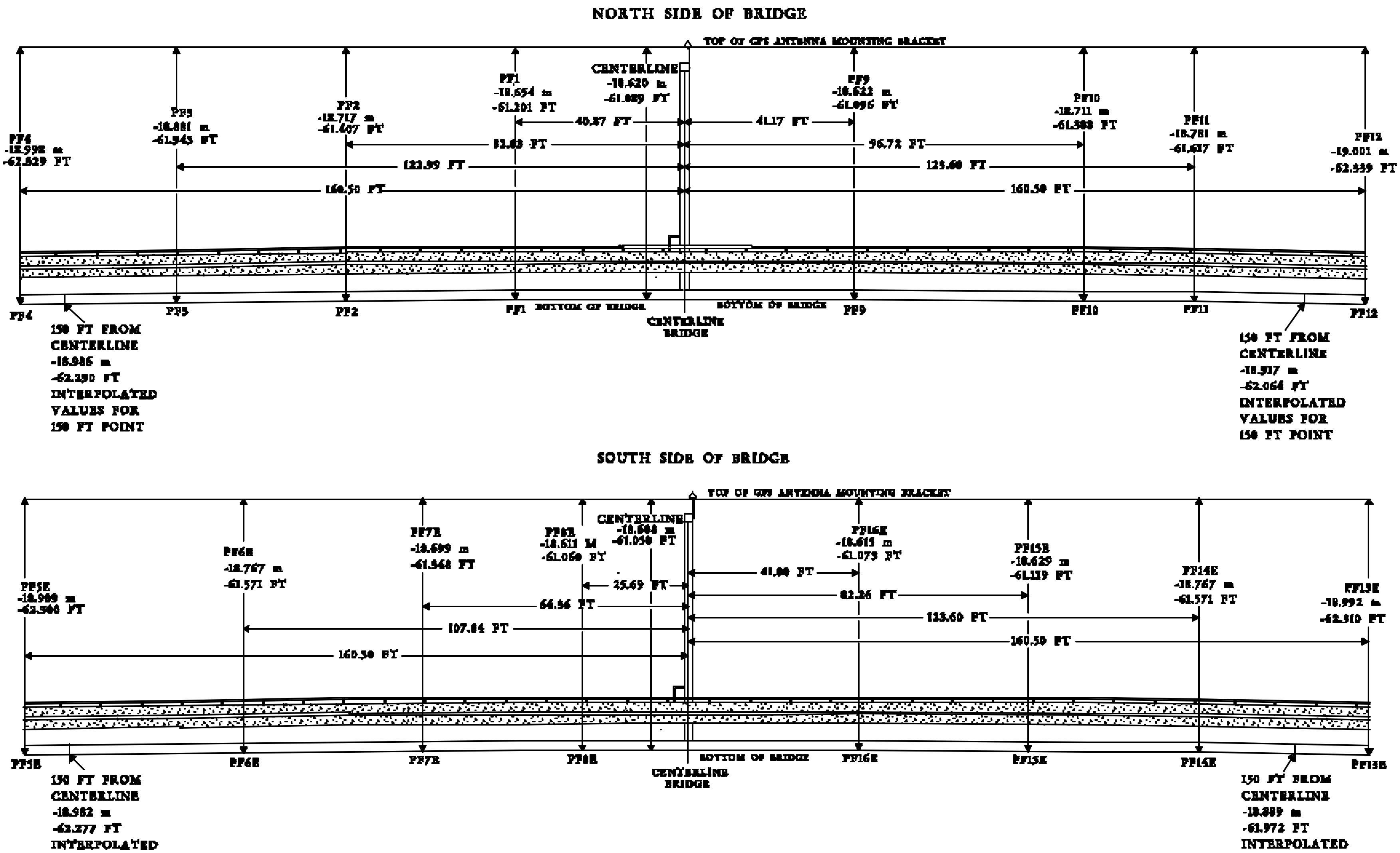
DRAWN BY ORLAND W. MURRAY, NGS, I&M BRANCH, FILE: SILAS_4.GCD


ELEVATION TIES FOR CHARLESTON, S.C. BRIDGE PROJECT
USING TRIGONOMETRIC LEVELING TECHNIQUES
(PRELIMINARY ELEVATIONS FOR REFERENCE POINTS OTHER THAN R16, Y151, AND X151)
GRACE TP1 (0012)
50.4137 m
GRAC ARP (0013) 66.9055 m
GRACE CL (0015) 47.3507 m (Centerline Bottom)
GRACE 1999 (0014) 49.3625 m
GRACE MEMORIAL BRIDGE
R16 (0002)
(Pub NAVD88 3.181 m)
SILAS TP1 (0007)
51.2801 m
SILW ARP (0008) 65.2104 m
SILW CL (0011) 46.5903 m (Centerline Bottom)
SILAS 1999 (0005) 49.4433 m
SILAS PEARLMAN BRIDGE
SILE CL (0010) 46.5969 m (Centerline Bottom)
SILE ARP (0009) 65.2046 m
X151 (0006) 42.6974 m
(Pub NAVD88 42.6961 m)
Y151 (0003)
8.3471 m
(Pub NAVD88 8.3475 m)

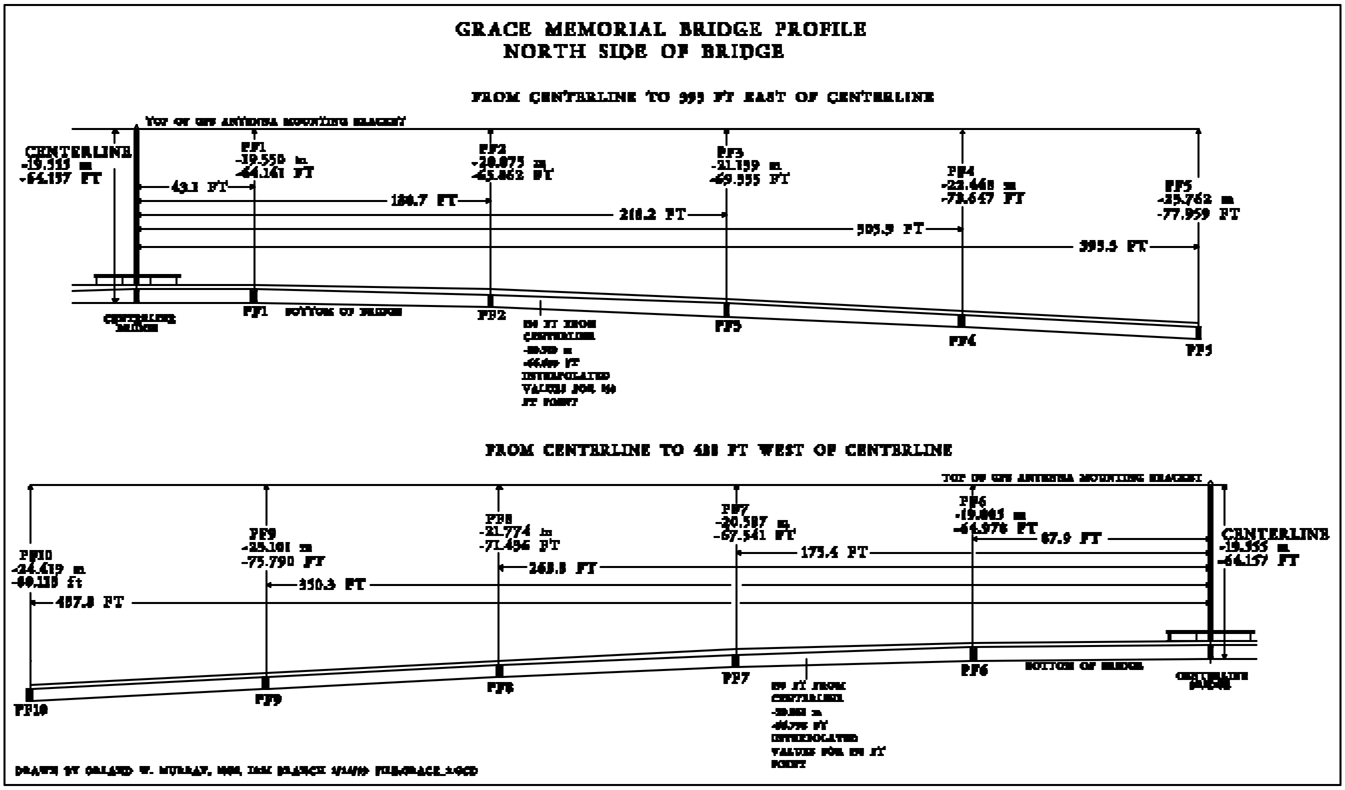

GRACE MEMORIAL BRIDGE
HEIGHT OF BOTTOM OF BRIDGE AT CENTERLINE
BELOW GPS ANTENNA REFERENCE POINT
GRAC ARP
Top of GPS Mounting Bracket
-16.4918 m
-19.5568 m
GRACE TP1
-1.0512 m
GRACE 1999
-0.5668 m
TOP OF BEAM
-1.6450 m
Bottom of Bridge
Centerline
Bridge
DRAWN BY ORLAND W. MURRAY, NGS,
SILAS PEARLMAN BRIDGE
HEIGHT OF BOTTOM OF BRIDGE AT CENTERLINE
BELOW GPS ANTENNA REFERENCE POINTS
SILW ARP
Top of Bracket
SILE ARP
Top of Bracket
-15.9305 m
-18.6201 m
-15.9245 m
-18.6077 m
SILAS TP1
-1.8368 m
SILAS 1999
-1.8368 m
-2.1540 m
-2.1474 m
TOP OF BEAM
TOP OF BEAM
-0.699 m
-0.699 m
Bottom of Bridge
Centerline Span
Bottom of Bridge


COOPER RIVER BRIDGES PROJECT - CHARLESTON, S.C.
PROFILE ELEVATIONS USING TRIGONOMETRIC LEVELING TECHNIQUES
GRACE PF10 (0041) 42.4069 m
GRACE PF9 (0040) 43.8047 m
GRACE PF8 (0039) 45.1317 m
GRACE PF7 (0038) 46.5189 m
GRACE PF6 (0037) 47.1008 m
GRACE CL (0015) 47.3507 m
GRACE PF1 (0032) 47.3552 m
GRACE PF2 (0033) 46.8308 m
GRACE PF3 (0034) 45.7661 m
GRACE PF4 (0035) 44.4589 m
GRACE PF5 (0036) 43.1436 m
GRACE 1999 (0014) 49.5625 m
NOTE: Elevations are at bottom of bridge for each profile point. Location of profile and bench marks not to scale and for illustrative purpose only.
GRACE MEMORIAL BRIDGE (TOP VIEW)
R16 (0002)
Pub NAVD88 3.181 m
SILAS PF4 (0019) 46.2123 m
SILAS PF3 (0018) 46.5295 m
SILAS PF2 (0017) 46.4985 m
SILAS PF1 (0016) 46.5563 m
SILW CL (0011) 46.5906 m
SILAS PF9 (0024) 46.5080 m
SILAS PF10 (0025) 46.4995 m
SILAS PF11 (0026) 46.4295 m
SILAS PF12 (0027) 46.2096 m
SILAS 1999 (0003) 49.4455 m
SILAS PEARLMAN BRIDGE (TOP VIEW)
X151 (0006) 42.6974 m
(Pub NAVD88 42.6961 m)
SILAS PF5 (0020) 46.2159 m
SILAS PF6 (0021) 46.4576 m
SILAS PF7 (0022) 46.5052 m
SILAS PF8 (0023) 46.5941 m
SILE CL (0010) 46.5969 m
SILAS PF16 (0031) 46.5900 m
SILAS PF15 (0030) 46.5761 m
SILAS PF14 (0029) 46.4072 m
SILAS PF13 (0028) 46.2126 m
Y151 (0008) 8.5471 m
(Pub NAVD88 8.5473 m)
Drawn by Orland W. Murray, NGS I&M Branch, FILE: SILPROFL.GCD

SILAS PEARLMAN BRIDGE PROFILES
FROM CENTERLINE TO 160.5 FEET EACH SIDE OF CENTERLINE



DRAWN BY ORLAND W. MURRAY, NGS, I&M BRANCH 2/23/99, FILE SILAS_3.GCD



ATTACHMENT C

Equipment List

Equipment List for Charleston Bridge Project

1 TC2002 Total Station   Sn:359817 NOAA:529697
4 Instrument Batteries GEB64
1 Battery Saver 3 Quick Charger and adaptors
1 Standard Leica battery charger for both TC2002 and NA3003 batteries
1 GTS-700 Total Station Sn:KE0136 NOAA:529647 Battery Charger   in case
1 GTS-700 Battery extra
1 Laptop Computor Sn:5021 NOAA:493813 Mod#: 48431

1 Metal Scale 300 mm
1 Thermistor temperature probe and display unit
2 Tribrachs
5 Tribrach Adaptors
1 Alti-plus digital barometer
1 Psychrometer
1 NA3003 Digital Level Sn:92430 NOAA:529526
2 Leveling Rod 3-meter invar bar-coded
Sn:27236 NOAA:529636
Sn:27229 NOAA:529635
1 60 CM invar strip

1 Small Kern Collimator
2 Trig Leveling Targets
2 GPS magnetic antenna mounts (Dave Crump's) Note: Height to top of yellow surface 61.0 mm
2 SECO Trig-leveling poles
Various adaptors for targets (bayonets, 5/8x11 adaptors)
2 Two meter GPS poles
Range pole sets (2-15 ft and parts, 1ft , 2 ft, Seco 5 m adjustable,bubbles, braces and clamps)
4 Peanut prism targets (0 or -30.0 mm constants)
2 Tapes 30 meter (standardized and non)
Various mounting magnets (big and little)
6 Radios (two-way walkie talkie)
CBL#3 Sn : 651ARU0210
CBL#2 Sn : 65IARU0209
Corbin Sn: 651ARU0212
Corbin Sn: 651ARU0213
Corbin Sn: 651ARU0214
Corbin Sn: 651ARU0215
4 Radio chargers
1 Umbrella
Rope and haulup bag
Various Tools (hammer, chisels, wrenches, C-clamps, tie straps,etc.)
Mark and mark setting material (epoxy)
Various angle iron pieces to mount targets
1 Slip-leg Tripod
1 T-3 Fixed leg
1 Level tripod fixed leg
Recording forms and field books
Bridge Diagrams and notes
1 HP-41 Calculator
1 HP-200LX handheld computer
Duct tape

Standard batteries (D, C, AA etc.)
Cameras
Safety Vests
Binoculars
Flashlights
2 Tripod Holders
2 Leveling turning pins and hammer
2 12 volt Flashing Warning Lights