

Control Survey Report
For
Lehigh University



LEHIGH
UNIVERSITY.

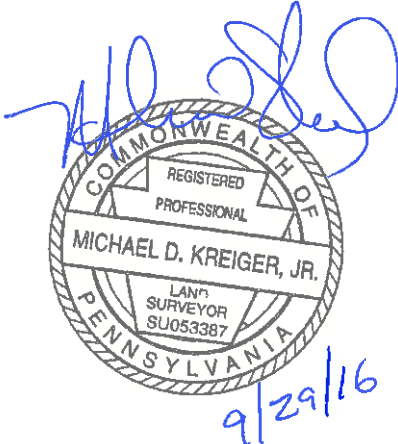


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Lehigh University
Northampton County, PA
Control Survey Report

Introduction

In May 2016, a request was made by Lehigh University to establish a network of eleven (11) permanent geodetic control monuments across all of the university's three campuses. These control monuments will be used to support future design and construction efforts ensuring that infrastructure improvements will be based on a consistent horizontal and vertical datum. Six (6) monuments (P-1 – P-6) were set at the Asa Packer Campus; three (3) monuments (M-1 – M-3) were set at the Mountaintop Campus; and two (2) monuments (G-1 and G-2) were set at the Goodman Campus. These monuments will be able to support both Global Navigational Satellite System (GNSS) surveys and conventional optical survey methods. Herbert, Rowland & Grubic, Inc. (HRG) survey staff worked closely with Lehigh University personnel to select areas convenient to potential development, but also in places where the likelihood of disturbance was minimal. Due to the wooded nature of much of the project area and the limitations of GNSS positioning, special consideration was also taken to minimize the effect of overhead obstructions on GNSS satellite reception. A PA ONE CALL was performed to ensure that no underground utilities were disturbed by the installation of the monuments. Field work consisted of three (3) phases and took place between June 20, 2016 and August 3, 2016.

Monumentation

The first phase involved installing the monuments at eleven (11) pre-selected locations. The installation consisted of hand digging a hole 12 inches wide at the top, 18 inches wide at the bottom, and 48 inches deep, or to the depth of bedrock. The holes were then filled with concrete and a steel rebar was inserted for added strength. The concrete was of the pre-bagged type and was mixed with water to the proper consistency at each monument location. A bronze monument disk bearing the name of the university, the name of the campus, and the name of the monument was inserted into the top of the wet concrete. The top of the monuments were set flush with or slightly below ground level to prevent disturbance by mowing and other activities. The monument disk contains a rare earth magnet on its underside to aid in recovery with a magnetic locator. The surface of the concrete was finished in a way to minimize the likelihood of damage from freezing and vandalism.

Differential Leveling

The second phase of the project began after the concrete was allowed to cure for two weeks. At this time, a three (3) person survey crew established elevations at each monument. Elevations were established by differential leveling using a Trimble DiNi digital level and a pair of four (4) meter barcoded digital leveling rods. Differential leveling is the only reliable method to measure high accuracy elevations within a control network, especially due to the forested nature of much of the project area. The National Geodetic Survey (NGS) benchmark KV1791, also known as "LEHIGH" was used as vertical control. This benchmark is designated as having a first order elevation and is conveniently located in the center of the Packer Campus. Each monument was surveyed as part of a "closed level loop." Proper survey practice dictates keeping these level loops reasonably short; in this case less than 3 km in length. To accommodate this, temporary benchmarks or "Temp BMs" consisting of steel rebars with HRG survey caps were set and used to complete three (3) of the level loops. These were especially useful when leveling between the Mountaintop Campus and the Goodman Campus due to the distance between the two. Loop closures

were expected to pass NGS first order class 1 criteria to be accepted. Loop closures were not to exceed the values calculated using the formula $4\sqrt{F}$, where F is the length of the level loop in kilometers and closures are shown in millimeters. Observed loop closures, as well as maximum acceptable loop closures are shown in Table 1. All level loop misclosures were adjusted in the office using Trimble Business Center (TBC) software. The level loop adjustment essentially forces the loop closed and propagates the misclosure error throughout the level run. The expected accuracy at the end station of each level run is approximately one half of the raw misclosure value. The accumulated error of level loops performed in series, such as those performed in this survey, tend to become normally distributed, as errors in the positive direction offset errors in the negative direction and vice versa.

Table 1. Level Loop Closure

| LEVEL RUN | STATIONS | LENGTH (km) | CLOSURE (mm) | MAX CLOSURE (mm) |
|-----------|--------------|-------------|--------------|------------------|
| 1 | P-4, P-5,P-6 | 1.23 | 0.27 | 4.43 |
| 2 | P-2,P-3 | 1.05 | 1.89 | 4.10 |
| 3 | P-1 | 1.92 | 1.04 | 5.54 |
| 4 | Temp BM1 | 2.75 | 5.73 | 6.63 |
| 5 | M-1,M-2 | 1.92 | 1.89 | 5.54 |
| 6 | Temp BM2 | 1.88 | 0.50 | 5.48 |
| 7 | Temp BM3 | 1.90 | 1.95 | 5.51 |
| 8 | G-1,G-2 | 2.81 | 0.82 | 6.71 |

Horizontal Control Survey

The third phase of the project involved establishing horizontal coordinates on the monuments using GNSS. A combination of six (6) Trimble R8 and R10 GNSS receivers mounted on Seco brand fixed height tripods were used to occupy and observe the monuments. Before beginning the survey campaign, each tripod was inspected and calibrated to minimize setup error. The level adjustment of each tripod was also checked and corrected if necessary at the beginning of each observation. Start and stop times for each observation were recorded as well as the receiver serial number to aid in data processing. GNSS observations were performed simultaneously so that baseline vectors could be processed between each station forming a “static network.” Network surveys of this type provide maximum accuracy and redundancy. Each monument was occupied between two and four times with occupation times varying from one to four hours in length. After field observations were performed, the GNSS data was downloaded from the receivers and processed using Trimble Business Center (TBC). At this time, the horizontal control data was obtained from the NGS. The Continuously Operating Reference Stations (CORS) NJHC, NJWC, and PASS were selected because of their proximity to the project and the fact that they surround the project area. It is desirable to use CORS stations that surround a project area because it enables the correction of atmospheric interference through interpolation rather than extrapolation. It was HRG’s intent to use data from the CORS station located on the Mountaintop Campus known as LUMT. However, this was not possible because LUMT was not operational at the time of the control survey. After the CORS data and field data were combined in TBC, baseline vectors were processed and a series of least squares adjustments were performed. The first, a minimally constrained adjustment, only holds one CORS as control and tests the integrity of the network by demonstrating how much error is propagated throughout the network. It does so by comparing the observed values to the known values of the remaining CORS in the network. Once acceptable results are obtained from the minimally constrained adjustment, a fully constrained adjustment is performed holding the remaining two CORS as control also. It is then that the final coordinate values can be computed for the new control points. In addition to the GNSS processing performed using TBC, all of the GNSS field data was submitted to NGS’s Online Positional

User Service (OPUS) Projects web utility. A similar network least squares adjustment was performed using OPUS Projects to provide a redundant check for the previously adjusted data. The attached OPUS Projects Network Adjustment report shows the coordinates and elevations obtained from OPUS. It is important to note that the OPUS coordinate and elevation values are for comparison purposes and should not be used as survey control. Table 3 is a listing of the final coordinates and elevations for the new Lehigh monuments.

On September 14, 2016, a return visit was made to the University to perform supplemental GNSS observations for and Quality Assurance/Quality Control (QA/QC) check observations. Because LUMT was operational at this time, it was able to be included in the GNSS network as a check; however, a significant duplication of efforts would have been required to fully incorporate LUMT into the network and hold it as control. It was found that the results of the network adjustment based on the CORS stations NJHC, NJWC, and PASS agree with the location of LUMT by 7mm or .023 feet horizontally. This check is sufficient to conclude that the GNSS derived positions of the newly established control monuments are consistent with that of LUMT.

Quality Assurance/Quality Control

Before the coordinates and elevations for the new control monument could be accepted, QA/QC measures were taken. In order to check the consistency of the results of the monument survey, a series of quality control checkpoints were measured at each monument. A GNSS receiver was placed at monument M-3 to serve as a GNSS “base” station. Each monument was occupied with another GNSS receiver and observed for eight minutes using the Trimble “fast static” routine. The resulting GNSS vectors were then processed radially from M-3 to calculate coordinates and elevations. Elevations were calculated at each checkpoint using Geoid 12B. This methodology is not intended to provide “control” level accuracy results. It merely serves as a check for gross survey blunders and calculation errors. The differences between the coordinates and elevations of the QA/QC checkpoints and the final coordinates and elevations are shown below. The error represented in the table is the result of short term satellite conditions and overhead obstructions at the time of the QA/QC survey. The long observation times and redundant observations performed during the GNSS network survey were more than sufficient to counteract these variables.

Table 2. QA/QC Results

| Station | Δ H. (Inverse) Feet | Δ V. Feet | Δ H. (Inverse) Meters | Δ V. Meters |
|---------|-------------------------------|---------------------|---------------------------------|-----------------------|
| P-1 | .056 | .011 | 0.017 | 0.003 |
| P-2 | .031 | .047 | 0.009 | 0.014 |
| P-3 | .035 | .107 | 0.011 | 0.033 |
| P-4 | .083 | .059 | 0.025 | 0.018 |
| P-5 | .051 | .046 | 0.016 | 0.014 |
| P-6 | .032 | .023 | 0.010 | 0.007 |
| M-1 | .014 | .017 | 0.004 | 0.005 |
| M-2 | .015 | .006 | 0.005 | 0.002 |
| M-3 | CONTROL | | | |
| G-1 | .012 | .000 | 0.004 | 0.000 |
| G-2 | .034 | .002 | 0.010 | 0.001 |

Conclusions

The horizontal accuracy of control networks are defined by the NGS in terms of order. First order being the most accurate classification. The various order classes are defined by the distance accuracy ratio calculated using the equation $a=d/s$, where a = the distance accuracy denominator, s = the propagated standard deviation of the distance between survey points, and d =the distance between survey points. To achieve first order classification, a network must meet a ratio no less than 1:100,000. Using the horizontal precision and ellipsoid distance values shown in Table 4, the lowest ratio calculated was 1:203,552, clearly exceeding first order accuracy.

In an effort to preserve the integrity of the control network, measures must be taken to ensure the continued stability and observability of the monuments. This applies not just to the physical condition of the monuments, but also that of the surrounding area. Overhanging vegetation and manmade obstructions, such as signs and billboards should be minimized. Routine recovery and inspection should be performed periodically to monitor the condition of the monuments.

In the future, it is likely that NGS will be making adjustments to the coordinates and elevations published for both its CORS stations and passive benchmarks as it has in the past. Variables such as plate tectonics and crustal rebound mean that the relationship between the state plane coordinate system and the International Terrestrial Reference Frame (ITRF) is ever changing. In order to stay up to date, it will be necessary to evaluate the need to update the coordinates and elevations for the new Lehigh monuments from time to time. Only time will tell to what extent these adjustments will affect the practical function of this control, but it will be an important consideration in the years to come.

Table 3. Final Coordinates

| North American Datum of 1983 (NAD 83) State Plane Coordinate System, South Zone North American Vertical Datum of 1988 (NAVD 88) | | | |
|--|---------------------|--------------------|----------------------|
| NAME | NORTHING (m) | EASTING (m) | ELEVATION (m) |
| G-1 | 141775.552 | 802154.057 | 96.448 |
| G-2 | 141853.144 | 802696.363 | 98.363 |
| M-1 | 143398.610 | 801799.716 | 252.875 |
| M-2 | 143372.428 | 802155.431 | 263.477 |
| M-3 | 143483.897 | 802435.617 | 273.277 |
| P-1 | 143501.537 | 800400.007 | 202.159 |
| P-2 | 143912.276 | 800493.513 | 129.210 |
| P-3 | 144062.908 | 800455.955 | 108.355 |
| P-4 | 144308.674 | 800683.307 | 90.767 |
| P-5 | 144100.943 | 801026.805 | 109.805 |
| P-6 | 144293.695 | 801026.805 | 91.803 |

| NAME | NORTHING (sft) | EASTING (sft) | ELEVATION (sft) |
|-------------|-----------------------|----------------------|------------------------|
| G-1 | 465141.958 | 2631733.769 | 316.43 |
| G-2 | 465396.522 | 2633512.984 | 322.71 |
| M-1 | 470466.940 | 2630571.233 | 829.64 |
| M-2 | 470381.041 | 2631738.277 | 864.42 |
| M-3 | 470746.751 | 2632657.521 | 896.58 |
| P-1 | 470804.626 | 2625979.024 | 663.25 |
| P-2 | 472152.191 | 2626285.801 | 423.92 |
| P-3 | 472646.390 | 2626162.580 | 355.50 |
| P-4 | 473452.709 | 2626908.484 | 297.79 |
| P-5 | 472771.178 | 2628035.442 | 360.25 |
| P-6 | 473403.565 | 2628035.442 | 301.19 |

Table 4. GNSS Vector List From Trimble Business Center

| Precision Confidence Level: 1-sigma | | | | | | | |
|-------------------------------------|---------------|-------------|----------------|----------|--------------------|--------------------|---------------------|
| Vector ID | From Point ID | To Point ID | Start Time | Duration | H Precision Meters | V Precision Meters | Ellip. Dist. Meters |
| PV163 | <u>G-2</u> | <u>G-1</u> | 8/1/2016 9:24 | 3:51:00 | 0.0003 | 0.0006 | 547.8462 |
| PV150 | <u>G-2</u> | <u>G-1</u> | 8/2/2016 12:42 | 3:43:45 | 0.0003 | 0.0006 | 547.8513 |
| PV168 | <u>G-2</u> | <u>G-1</u> | 8/3/2016 7:44 | 1:57:30 | 0.0004 | 0.0009 | 547.8501 |
| PV164 | <u>G-2</u> | <u>M-3</u> | 8/1/2016 9:55 | 3:20:15 | 0.0005 | 0.0012 | 1651.531 |
| PV133 | <u>G-2</u> | <u>M-3</u> | 8/3/2016 8:18 | 1:23:45 | 0.0007 | 0.0017 | 1651.529 |
| PV157 | <u>G-2</u> | <u>M-3</u> | 8/2/2016 14:54 | 1:19:00 | 0.0011 | 0.0018 | 1651.521 |
| PV56 | <u>M-3</u> | <u>M-2</u> | 8/3/2016 8:18 | 3:02:00 | 0.0003 | 0.0007 | 301.5583 |
| PV103 | <u>M-3</u> | <u>M-2</u> | 8/1/2016 9:55 | 1:23:00 | 0.0004 | 0.001 | 301.5522 |
| PV124 | <u>M-3</u> | <u>M-2</u> | 8/2/2016 14:54 | 1:13:45 | 0.0006 | 0.0009 | 301.551 |
| PV211 | <u>NJHC</u> | <u>G-1</u> | 8/1/2016 9:24 | 4:03:00 | 0.0012 | 0.0061 | 40122.46 |
| PV223 | <u>NJHC</u> | <u>G-1</u> | 8/2/2016 12:42 | 3:49:15 | 0.0015 | 0.0062 | 40122.47 |
| PV237 | <u>NJHC</u> | <u>G-1</u> | 8/3/2016 7:44 | 2:05:00 | 0.0017 | 0.0091 | 40122.47 |
| PV267 | <u>NJWC</u> | <u>P-3</u> | 8/2/2016 7:48 | 4:00:15 | 0.0012 | 0.0076 | 33281.31 |
| PV282 | <u>NJWC</u> | <u>P-3</u> | 8/3/2016 11:47 | 2:59:30 | 0.0016 | 0.0081 | 33281.32 |
| PV251 | <u>NJWC</u> | <u>P-3</u> | 8/1/2016 14:28 | 2:23:15 | 0.0021 | 0.0098 | 33281.32 |
| PV35 | <u>P-1</u> | <u>M-1</u> | 8/1/2016 10:08 | 3:29:30 | 0.0006 | 0.0013 | 1403.538 |
| PV38 | <u>P-1</u> | <u>M-1</u> | 8/1/2016 14:11 | 2:07:45 | 0.0007 | 0.0014 | 1403.54 |
| PV39 | <u>P-1</u> | <u>M-1</u> | 8/1/2016 13:39 | 0:30:30 | 0.0011 | 0.0024 | 1403.541 |
| PV18 | <u>P-2</u> | <u>P-1</u> | 8/1/2016 14:19 | 1:59:30 | 0.0006 | 0.0011 | 421.2689 |
| PV71 | <u>P-2</u> | <u>P-1</u> | 8/2/2016 7:38 | 0:49:00 | 0.0007 | 0.0022 | 421.26 |
| PV119 | <u>P-4</u> | <u>P-6</u> | 8/2/2016 8:14 | 4:01:15 | 0.0003 | 0.0007 | 343.8337 |
| PV26 | <u>P-5</u> | <u>P-6</u> | 8/2/2016 8:44 | 3:31:15 | 0.0003 | 0.0008 | 192.7622 |
| PV81 | <u>P-5</u> | <u>P-6</u> | 8/3/2016 10:25 | 3:34:30 | 0.0004 | 0.0008 | 192.7582 |
| PV68 | <u>P-5</u> | <u>P-6</u> | 8/1/2016 15:07 | 1:53:00 | 0.0007 | 0.001 | 192.7528 |
| PV70 | <u>P-5</u> | <u>P-2</u> | 8/2/2016 8:44 | 2:55:45 | 0.0005 | 0.0012 | 565.7033 |
| PV84 | <u>P-5</u> | <u>P-2</u> | 8/3/2016 11:40 | 2:19:30 | 0.0007 | 0.0012 | 565.7024 |
| PV8 | <u>P-5</u> | <u>P-2</u> | 8/1/2016 15:01 | 1:45:00 | 0.0008 | 0.0013 | 565.6987 |
| PV69 | <u>P-2</u> | <u>P-3</u> | 8/2/2016 7:48 | 3:51:00 | 0.0003 | 0.0008 | 155.2524 |
| PV60 | <u>P-2</u> | <u>P-3</u> | 8/3/2016 11:47 | 2:59:30 | 0.0004 | 0.0008 | 155.2463 |
| PV108 | <u>P-2</u> | <u>P-3</u> | 8/1/2016 14:28 | 2:17:45 | 0.0005 | 0.0009 | 155.2472 |
| PV160 | <u>G-1</u> | <u>M-1</u> | 8/1/2016 9:36 | 3:51:30 | 0.0005 | 0.0011 | 1661.346 |
| PV169 | <u>G-1</u> | <u>M-1</u> | 8/3/2016 8:00 | 1:49:15 | 0.0007 | 0.0016 | 1661.352 |
| PV144 | <u>G-1</u> | <u>M-1</u> | 8/2/2016 14:34 | 1:26:45 | 0.001 | 0.0017 | 1661.35 |
| PV276 | <u>NJWC</u> | <u>P-6</u> | 8/2/2016 8:14 | 4:01:15 | 0.0012 | 0.0074 | 32703.49 |
| PV284 | <u>NJWC</u> | <u>P-6</u> | 8/3/2016 10:25 | 3:40:30 | 0.0013 | 0.007 | 32703.5 |

| Precision Confidence Level: 1-sigma | | | | | | | |
|-------------------------------------|---------------|---------------|----------------|----------|--------------------|--------------------|---------------------|
| Vector ID | From Point ID | To Point ID | Start Time | Duration | H Precision Meters | V Precision Meters | Ellip. Dist. Meters |
| PV253 | <u>NJWC</u> | <u>P-6</u> | 8/1/2016 15:07 | 1:59:00 | 0.0029 | 0.011 | 32703.5 |
| PV24 | <u>P-5</u> | <u>M-2</u> | 8/2/2016 8:44 | 2:29:00 | 0.0007 | 0.0016 | 1343.371 |
| PV80 | <u>P-5</u> | <u>M-2</u> | 8/3/2016 10:17 | 1:03:15 | 0.0011 | 0.0023 | 1343.378 |
| PV233 | <u>NJHC</u> | <u>M-2</u> | 8/2/2016 7:12 | 4:00:30 | 0.0013 | 0.0067 | 40476.16 |
| PV242 | <u>NJHC</u> | <u>M-2</u> | 8/3/2016 8:11 | 3:08:30 | 0.0014 | 0.0073 | 40476.16 |
| PV220 | <u>NJHC</u> | <u>M-2</u> | 8/1/2016 9:45 | 1:32:45 | 0.002 | 0.0094 | 40476.16 |
| PV224 | <u>NJHC</u> | <u>M-2</u> | 8/2/2016 14:43 | 1:24:30 | 0.0028 | 0.0123 | 40476.16 |
| PV165 | <u>G-2</u> | <u>M-1</u> | 8/1/2016 9:36 | 3:39:30 | 0.0005 | 0.0012 | 1786.806 |
| PV130 | <u>G-2</u> | <u>M-1</u> | 8/3/2016 8:00 | 1:41:45 | 0.0007 | 0.0018 | 1786.81 |
| PV153 | <u>G-2</u> | <u>M-1</u> | 8/2/2016 14:34 | 1:26:45 | 0.0011 | 0.002 | 1786.808 |
| PV14 | <u>KV1791</u> | <u>M-3</u> | 8/3/2016 8:36 | 2:49:45 | 0.0009 | 0.002 | 1853.446 |
| PV12 | <u>KV1791</u> | <u>M-3</u> | 8/2/2016 14:54 | 0:55:30 | 0.002 | 0.004 | 1853.444 |
| PV107 | <u>P-3</u> | <u>P-1</u> | 8/1/2016 14:28 | 1:51:00 | 0.0005 | 0.001 | 564.1731 |
| PV43 | <u>P-3</u> | <u>P-1</u> | 8/2/2016 7:48 | 0:39:00 | 0.0007 | 0.0021 | 564.1701 |
| PV58 | <u>P-3</u> | <u>KV1791</u> | 8/3/2016 11:54 | 2:33:15 | 0.0007 | 0.0014 | 244.2711 |
| PV44 | <u>P-3</u> | <u>KV1791</u> | 8/2/2016 11:32 | 0:16:45 | 0.0012 | 0.0042 | 244.2635 |
| PV75 | <u>M-2</u> | <u>M-1</u> | 8/3/2016 8:11 | 1:49:30 | 0.0004 | 0.0009 | 356.6856 |
| PV36 | <u>M-2</u> | <u>M-1</u> | 8/1/2016 9:45 | 1:32:45 | 0.0004 | 0.0009 | 356.695 |
| PV101 | <u>M-3</u> | <u>M-1</u> | 8/1/2016 9:55 | 3:42:30 | 0.0003 | 0.0008 | 641.6193 |
| PV78 | <u>M-3</u> | <u>M-1</u> | 8/3/2016 8:18 | 1:43:00 | 0.0004 | 0.001 | 641.6157 |
| PV28 | <u>M-3</u> | <u>M-1</u> | 8/2/2016 14:54 | 1:07:30 | 0.0008 | 0.0012 | 641.6219 |
| PV100 | <u>M-3</u> | <u>M-1</u> | 8/1/2016 13:39 | 0:17:15 | 0.0011 | 0.002 | 641.6186 |
| PV167 | <u>M-2</u> | <u>G-2</u> | 8/1/2016 9:45 | 1:32:45 | 0.0007 | 0.0016 | 1612.768 |
| PV131 | <u>M-2</u> | <u>G-2</u> | 8/3/2016 8:11 | 1:30:15 | 0.0007 | 0.0018 | 1612.772 |
| PV151 | <u>M-2</u> | <u>G-2</u> | 8/2/2016 14:43 | 1:24:30 | 0.0011 | 0.0018 | 1612.77 |
| PV255 | <u>NJWC</u> | <u>M-1</u> | 8/1/2016 9:36 | 4:01:45 | 0.0012 | 0.0065 | 32757.95 |
| PV254 | <u>NJWC</u> | <u>M-1</u> | 8/1/2016 13:39 | 2:49:30 | 0.0018 | 0.0086 | 32757.95 |
| PV281 | <u>NJWC</u> | <u>M-1</u> | 8/3/2016 8:00 | 2:01:00 | 0.0017 | 0.0095 | 32757.95 |
| PV268 | <u>NJWC</u> | <u>M-1</u> | 8/2/2016 14:34 | 1:26:45 | 0.0028 | 0.0142 | 32757.95 |
| PV313 | <u>PASS</u> | <u>P-1</u> | 8/1/2016 10:08 | 4:01:45 | 0.0028 | 0.0108 | 65821.92 |
| PV312 | <u>PASS</u> | <u>P-1</u> | 8/1/2016 14:11 | 2:07:45 | 0.0034 | 0.0132 | 65821.93 |
| PV328 | <u>PASS</u> | <u>P-1</u> | 8/2/2016 7:25 | 1:02:00 | 0.0047 | 0.0233 | 65821.93 |
| PV122 | <u>M-1</u> | <u>M-2</u> | 8/2/2016 14:43 | 1:18:15 | 0.0006 | 0.001 | 356.6973 |
| PV20 | <u>M-2</u> | <u>P-1</u> | 8/2/2016 7:25 | 1:02:00 | 0.001 | 0.0027 | 1760.231 |
| PV349 | <u>M-3</u> | <u>M-2</u> | 9/14/2016 9:11 | 2:08:45 | 0.0004 | 0.0008 | 301.5601 |

| Precision Confidence Level: 1-sigma | | | | | | | |
|-------------------------------------|---------------|-------------|----------------|----------|--------------------|--------------------|---------------------|
| Vector ID | From Point ID | To Point ID | Start Time | Duration | H Precision Meters | V Precision Meters | Ellip. Dist. Meters |
| PV358 | P-5 | P-6 | 9/14/2016 9:52 | 3:36:30 | 0.0004 | 0.0007 | 192.7579 |
| PV357 | P-4 | P-6 | 9/14/2016 9:52 | 3:19:30 | 0.0004 | 0.0009 | 343.8383 |
| PV352 | P-5 | M-2 | 9/14/2016 9:42 | 1:38:00 | 0.001 | 0.0018 | 1343.382 |
| PV347 | P-1 | M-2 | 9/14/2016 9:19 | 2:00:45 | 0.0009 | 0.0018 | 1760.233 |
| PV363 | LUMT | P-4 | 9/14/2016 9:32 | 3:39:45 | 0.002 | 0.0035 | 1930.849 |
| PV374 | NJHC | M-2 | 9/14/2016 9:11 | 2:08:45 | 0.0018 | 0.0076 | 40476.16 |
| PV390 | PASS | P-1 | 9/14/2016 9:19 | 3:05:30 | 0.0028 | 0.0107 | 65821.92 |
| PV377 | NJWC | P-6 | 9/14/2016 9:52 | 3:36:30 | 0.0015 | 0.0068 | 32703.48 |
| PV113 | P-4 | P-3 | 8/2/2016 8:02 | 3:46:30 | 0.0003 | 0.0007 | 334.8112 |
| PV366 | LUMT | P-1 | 9/14/2016 9:19 | 3:05:30 | 0.0012 | 0.0054 | 2066.24 |
| PV161 | G-1 | P-1 | 8/1/2016 10:08 | 3:19:15 | 0.0007 | 0.004 | 2460.928 |

Opus Projects Adjustment Report

SUBMITTED BY: zlupold
SOLUTION FILE NAME: network-final.sum
SOLUTION SOFTWARE: GPSCOM(1504.23)
SOLUTION DATE: 2016-09-15T12:00:54 UTC
STANDARD ERROR OF UNIT WEIGHT: 0.813
TOTAL NUMBER OF OBSERVATIONS: 134989
TOTAL NUMBER OF MARKS: 16
NUMBER OF CONSTRAINED MARKS: 3

START TIME: 2016-08-01T00:00:00 GPS
STOP TIME: 2016-09-14T18:13:30 GPS
FREQUENCY: L1 -> ION-FREE (L6)
OBSERVATION INTERVAL: 30 s
ELEVATION CUTOFF: 15 deg
TROPIC INTERVAL: 1800 s [STEP-OFFSET PARAMETERIZATION]
DD CORRELATIONS: ON

| INCLUDED SOLUTION | RMS | SOFTWARE | RUN DATE |
|-------------------|--------|-----------------|----------------------|
| 1) 2016-214 A | 0.9 cm | page5 (1509.10) | 2016-09-15T11:40 UTC |
| 2) 2016-214 B | 2.0 cm | page5 (1509.10) | 2016-09-15T11:41 UTC |
| 3) 2016-215 A | 1.5 cm | page5 (1509.10) | 2016-09-15T11:44 UTC |
| 4) 2016-215 B | 1.9 cm | page5 (1509.10) | 2016-09-15T11:46 UTC |
| 5) 2016-216 A | 1.5 cm | page5 (1509.10) | 2016-09-15T11:48 UTC |
| 6) 2016-216 B | 1.0 cm | page5 (1509.10) | 2016-09-15T11:50 UTC |
| 7) 2016-258 A | 1.2 cm | page5 (1509.10) | 2016-09-15T11:53 UTC |

| BASILINE | LENGTH | RMS | OBS | OMITTED | FIXED IN SOLUTION(S) |
|------------|----------|--------|------|---------|----------------------|
| LUMT-M-3 | 0.087 km | 0.6 cm | 3773 | 8.7% | 100.0% 7 |
| P-3-P-2 | 0.157 km | 0.7 cm | 5379 | 19.2% | 98.9% 2, 3, 6 |
| P-6-P-5 | 0.194 km | 0.8 cm | 2133 | 15.2% | 100.0% 7 |
| Lehigh-P-3 | 0.244 km | 1.3 cm | 1212 | 41.9% | 100.0% 6 |
| M-3-M-2 | 0.302 km | 0.6 cm | 1727 | 8.9% | 100.0% 7 |
| P-4-P-3 | 0.335 km | 0.5 cm | 2466 | 8.6% | 100.0% 3 |
| P-4-P-5 | 0.402 km | 0.8 cm | 2063 | 12.2% | 96.3% 7 |

| | | | | | | |
|-------------|-----------|--------|-------|-------|--------|---------|
| P-1-P-2 | 0.428 km | 0.6 cm | 1069 | 18.8% | 100.0% | 2 |
| G-1-G-2 | 0.548 km | 0.6 cm | 2767 | 4.9% | 93.8% | 4 |
| P-5-P-3 | 0.572 km | 0.7 cm | 3123 | 15.8% | 100.0% | 3, 6 |
| P-6-P-3 | 0.616 km | 0.8 cm | 4067 | 9.2% | 100.0% | 3, 6 |
| P-5-P-1 | 0.872 km | 1.1 cm | 1584 | 21.7% | 97.0% | 7 |
| Lehigh-M-1 | 1.327 km | 1.1 cm | 713 | 34.5% | 94.7% | 5 |
| M-2-P-5 | 1.352 km | 1.0 cm | 1092 | 11.1% | 96.0% | 7 |
| P-1-M-1 | 1.404 km | 0.7 cm | 2349 | 12.2% | 100.0% | 1 |
| P-2-M-1 | 1.409 km | 0.8 cm | 1156 | 19.2% | 100.0% | 2 |
| M-2-G-2 | 1.621 km | 0.5 cm | 1072 | 11.1% | 100.0% | 5 |
| M-3-G-2 | 1.661 km | 0.6 cm | 3476 | 7.3% | 100.0% | 1, 5 |
| M-2-P-3 | 1.841 km | 0.7 cm | 2364 | 6.7% | 100.0% | 3 |
| G-1-P-1 | 2.463 km | 0.7 cm | 2257 | 10.8% | 100.0% | 1 |
| G-1-Lehigh | 2.760 km | 1.7 cm | 662 | 28.5% | 80.0% | 5 |
| G-2-P-1 | 2.829 km | 0.7 cm | 2166 | 6.1% | 100.0% | 1 |
| G-2-Lehigh | 3.023 km | 1.1 cm | 548 | 41.6% | 100.0% | 5 |
| njwc-M-3 | 32.248 km | 1.7 cm | 9008 | 8.7% | 98.1% | 1, 5, 7 |
| njwc-M-2 | 32.525 km | 1.7 cm | 2893 | 4.9% | 97.1% | 3 |
| njwc-M-1 | 32.759 km | 1.9 cm | 1967 | 4.9% | 100.0% | 2 |
| njwc-G-2 | 33.247 km | 1.8 cm | 2905 | 3.6% | 100.0% | 4 |
| njwc-P-3 | 33.282 km | 1.7 cm | 2297 | 6.7% | 100.0% | 6 |
| njhc-njwc | 36.557 km | 1.8 cm | 36510 | 1.8% | 98.8% | 2, 3 |
| njhc-G-2 | 39.608 km | 1.7 cm | 4537 | 3.5% | 94.3% | 4, 5 |
| njhc-M-3 | 40.233 km | 1.8 cm | 6850 | 7.9% | 98.7% | 1, 7 |
| njhc-P-3 | 42.293 km | 1.8 cm | 2280 | 7.3% | 100.0% | 6 |
| pass-P-1 | 65.823 km | 1.8 cm | 6716 | 5.1% | 97.5% | 1, 2, 7 |
| pass-P-3 | 65.858 km | 1.6 cm | 5160 | 5.1% | 100.0% | 3, 6 |
| pass-Lehigh | 66.094 km | 2.0 cm | 1822 | 19.2% | 84.6% | 5 |
| pass-G-1 | 67.667 km | 2.5 cm | 2826 | 5.8% | 88.9% | 4 |

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UNCONSTRAINED MARKS
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MARK: G-1 (G-1 1)

REF FRAME: NAD_83(2011) (2010.0000) IGS08 (2016.5862)
X: 1225845.093 m 0.001 m 1225844.228 m 0.001 m
Y: -4693256.338 m 0.002 m -4693254.905 m 0.002 m
Z: 4127620.422 m 0.002 m 4127620.377 m 0.002 m
LAT: 40 35 08.02249 0.000 m 40 35 08.05522 0.000 m
E LON: 284 38 17.57880 0.000 m 284 38 17.55863 0.000 m
W LON: 75 21 42.42120 0.000 m 75 21 42.44137 0.000 m
EL HGT: 62.038 m 0.002 m 60.790 m 0.002 m
ORTHO HGT: 96.454 m 0.013 m (H = h - N WHERE N = GEOID12B HGT)

| | UTM COORDINATES | STATE PLANE COORDINATES |
|-----------------|-----------------|-------------------------|
| | UTM (Zone 18) | SPC (3702 PA S) |
| NORTHING (Y) | 4492815.035 m | 141775.553 m |
| EASTING (X) | 469383.624 m | 802154.058 m |
| CONVERGENCE | -0.23537208 deg | 1.54945840 deg |
| POINT SCALE | 0.99961154 | 0.99996226 |
| COMBINED FACTOR | 0.99960181 | 0.99995253 |

US NATIONAL GRID DESIGNATOR: 18TVK6938392815 (NAD 83)

+++++

MARK: G-2 (G-2 1)

REF FRAME: NAD_83(2011) (2010.0000) IGS08 (2016.5865)
X: 1226361.677 m 0.000 m 1226360.813 m 0.000 m
Y: -4693080.595 m 0.001 m -4693079.162 m 0.001 m
Z: 4127669.423 m 0.001 m 4127669.378 m 0.001 m

LAT: 40 35 10.06113 0.000 m 40 35 10.09388 0.000 m
 E LON: 284 38 40.72104 0.000 m 284 38 40.70088 0.000 m
 W LON: 75 21 19.27896 0.000 m 75 21 19.29912 0.000 m
 EL HGT: 63.950 m 0.002 m 62.702 m 0.002 m
 ORTHO HGT: 98.360 m 0.013 m (H = h - N WHERE N = GEOID12B HGT)

| | UTM COORDINATES | STATE PLANE COORDINATES |
|-----------------|-----------------|-------------------------|
| | UTM (Zone 18) | SPC (3702 PA S) |
| NORTHING (Y) | 4492875.679 m | 141853.147 m |
| EASTING (X) | 469927.890 m | 802696.361 m |
| CONVERGENCE | -0.23119245 deg | 1.55362910 deg |
| POINT SCALE | 0.99961113 | 0.99996229 |
| COMBINED FACTOR | 0.99960110 | 0.99995226 |

US NATIONAL GRID DESIGNATOR: 18TVK6992792875 (NAD 83)

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MARK: Lehigh (Lehigh 1)

REF FRAME: NAD_83(2011) (2010.0000) IGS08 (2016.5891)
 X: 1224104.751 m 0.001 m 1224103.886 m 0.001 m
 Y: -4692118.378 m 0.003 m -4692116.946 m 0.003 m
 Z: 4129435.551 m 0.003 m 4129435.506 m 0.003 m
 LAT: 40 36 25.20408 0.000 m 40 36 25.23682 0.000 m
 E LON: 284 37 18.18674 0.000 m 284 37 18.16652 0.000 m
 W LON: 75 22 41.81326 0.000 m 75 22 41.83348 0.000 m
 EL HGT: 73.365 m 0.004 m 72.118 m 0.004 m
 ORTHO HGT: 107.771 m 0.014 m (H = h - N WHERE N = GEOID12B HGT)

| | UTM COORDINATES | STATE PLANE COORDINATES |
|-----------------|-----------------|-------------------------|
| | UTM (Zone 18) | SPC (3702 PA S) |
| NORTHING (Y) | 4495200.711 m | 144117.725 m |
| EASTING (X) | 467997.700 m | 800693.987 m |
| CONVERGENCE | -0.24621300 deg | 1.53875475 deg |
| POINT SCALE | 0.99961261 | 0.99996321 |
| COMBINED FACTOR | 0.99960111 | 0.99995170 |

US NATIONAL GRID DESIGNATOR: 18TVK6799795200 (NAD 83)

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MARK: lumt (lumt a 1)

REF FRAME: NAD_83(2011) (2010.0000) IGS08 (2016.7039)
 X: 1225936.373 m 0.001 m 1225935.506 m 0.001 m
 Y: -4692183.518 m 0.002 m -4692182.082 m 0.002 m
 Z: 4129095.711 m 0.002 m 4129095.669 m 0.002 m
 LAT: 40 36 05.74782 0.000 m 40 36 05.78072 0.000 m
 E LON: 284 38 32.86610 0.000 m 284 38 32.84587 0.000 m
 W LON: 75 21 27.13390 0.000 m 75 21 27.15413 0.000 m
 EL HGT: 251.322 m 0.003 m 250.073 m 0.003 m
 ORTHO HGT: 285.714 m 0.013 m (H = h - N WHERE N = GEOID12B HGT)

| | UTM COORDINATES | STATE PLANE COORDINATES |
|-----------------|-----------------|-------------------------|
| | UTM (Zone 18) | SPC (3702 PA S) |
| NORTHING (Y) | 4494593.463 m | 143565.166 m |
| EASTING (X) | 469750.215 m | 802465.188 m |
| CONVERGENCE | -0.23268531 deg | 1.55221348 deg |
| POINT SCALE | 0.99961126 | 0.99996296 |
| COMBINED FACTOR | 0.99957185 | 0.99992354 |

US NATIONAL GRID DESIGNATOR: 18TVK6975094593 (NAD 83)

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MARK: M-1 (M-1 1)

| | | | | |
|------------|---------------------------|---------|------------------------------------|---------|
| REF FRAME: | NAD 83 (2011) (2010.0000) | | IGS08 (2016.5846) | |
| X: | 1225306.451 m | 0.001 m | 1225305.586 m | 0.001 m |
| Y: | -4692422.162 m | 0.002 m | -4692420.729 m | 0.002 m |
| Z: | 4128961.577 m | 0.002 m | 4128961.532 m | 0.002 m |
| LAT: | 40 36 00.93358 | 0.000 m | 40 36 00.96634 | 0.000 m |
| E LON: | 284 38 04.37935 | 0.000 m | 284 38 04.35915 | 0.000 m |
| W LON: | 75 21 55.62065 | 0.000 m | 75 21 55.64085 | 0.000 m |
| EL HGT: | 218.471 m | 0.003 m | 217.223 m | 0.003 m |
| ORTHO HGT: | 252.869 m | 0.013 m | (H = h - N WHERE N = GEOID12B HGT) | |

| | | |
|-----------------|-----------------|-------------------------|
| | UTM COORDINATES | STATE PLANE COORDINATES |
| | UTM (Zone 18) | SPC (3702 PA S) |
| NORTHING (Y) | 4494447.770 m | 143398.613 m |
| EASTING (X) | 469080.112 m | 801799.714 m |
| CONVERGENCE | -0.23782869 deg | 1.54707959 deg |
| POINT SCALE | 0.99961177 | 0.99996290 |
| COMBINED FACTOR | 0.99957751 | 0.99992863 |

US NATIONAL GRID DESIGNATOR: 18TVK6908094447 (NAD 83)

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MARK: M-2 (M-2 1)

| | | | | |
|------------|---------------------------|---------|------------------------------------|---------|
| REF FRAME: | NAD 83 (2011) (2010.0000) | | IGS08 (2016.6228) | |
| X: | 1225657.753 m | 0.001 m | 1225656.888 m | 0.001 m |
| Y: | -4692362.801 m | 0.002 m | -4692361.368 m | 0.002 m |
| Z: | 4128941.304 m | 0.001 m | 4128941.260 m | 0.001 m |
| LAT: | 40 35 59.77351 | 0.000 m | 40 35 59.80627 | 0.000 m |
| E LON: | 284 38 19.47358 | 0.000 m | 284 38 19.45339 | 0.000 m |
| W LON: | 75 21 40.52642 | 0.000 m | 75 21 40.54661 | 0.000 m |
| EL HGT: | 229.070 m | 0.002 m | 227.822 m | 0.002 m |
| ORTHO HGT: | 263.466 m | 0.013 m | (H = h - N WHERE N = GEOID12B HGT) | |

| | | |
|-----------------|-----------------|-------------------------|
| | UTM COORDINATES | STATE PLANE COORDINATES |
| | UTM (Zone 18) | SPC (3702 PA S) |
| NORTHING (Y) | 4494410.537 m | 143372.433 m |
| EASTING (X) | 469434.712 m | 802155.427 m |
| CONVERGENCE | -0.23509848 deg | 1.54979988 deg |
| POINT SCALE | 0.99961150 | 0.99996288 |
| COMBINED FACTOR | 0.99957558 | 0.99992695 |

US NATIONAL GRID DESIGNATOR: 18TVK6943494410 (NAD 83)

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MARK: M-3 (M-3 1)

| | | | | |
|------------|---------------------------|---------|------------------------------------|---------|
| REF FRAME: | NAD 83 (2011) (2010.0000) | | IGS08 (2016.6473) | |
| X: | 1225916.483 m | 0.000 m | 1225915.617 m | 0.000 m |
| Y: | -4692233.043 m | 0.001 m | -4692231.610 m | 0.001 m |
| Z: | 4129026.525 m | 0.001 m | 4129026.481 m | 0.001 m |
| LAT: | 40 36 03.14010 | 0.000 m | 40 36 03.17287 | 0.000 m |
| E LON: | 284 38 31.51517 | 0.000 m | 284 38 31.49495 | 0.000 m |
| W LON: | 75 21 28.48483 | 0.000 m | 75 21 28.50505 | 0.000 m |
| EL HGT: | 238.860 m | 0.002 m | 237.612 m | 0.002 m |
| ORTHO HGT: | 273.253 m | 0.013 m | (H = h - N WHERE N = GEOID12B HGT) | |

| | | |
|--|-----------------|-------------------------|
| | UTM COORDINATES | STATE PLANE COORDINATES |
| | UTM (Zone 18) | SPC (3702 PA S) |

| | | |
|-----------------|-----------------|----------------|
| NORTHING (Y) | 4494513.186 m | 143483.899 m |
| EASTING (X) | 469718.139 m | 802435.618 m |
| CONVERGENCE | -0.23292610 deg | 1.55197002 deg |
| POINT SCALE | 0.99961129 | 0.99996293 |
| COMBINED FACTOR | 0.99957384 | 0.99992546 |

US NATIONAL GRID DESIGNATOR: 18TVK6971894513 (NAD 83)

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MARK: P-1 (P-1 1)

| | | |
|------------|---------------------------|------------------------------------|
| REF FRAME: | NAD_83 (2011) (2010.0000) | IGS08 (2016.6130) |
| X: | 1223922.357 m 0.001 m | 1223921.491 m 0.001 m |
| Y: | -4692649.030 m 0.002 m | -4692647.597 m 0.002 m |
| Z: | 4129035.286 m 0.001 m | 4129035.242 m 0.001 m |
| LAT: | 40 36 05.49017 0.000 m | 40 36 05.52295 0.000 m |
| E LON: | 284 37 04.98298 0.000 m | 284 37 04.96274 0.000 m |
| W LON: | 75 22 55.01702 0.000 m | 75 22 55.03726 0.000 m |
| EL HGT: | 167.746 m 0.002 m | 166.498 m 0.002 m |
| ORTHO HGT: | 202.158 m 0.013 m | (H = h - N WHERE N = GEOID12B HGT) |

| | UTM COORDINATES | STATE PLANE COORDINATES |
|-----------------|-----------------|-------------------------|
| | UTM (Zone 18) | SPC (3702 PA S) |
| NORTHING (Y) | 4494594.193 m | 143501.539 m |
| EASTING (X) | 467684.777 m | 800400.004 m |
| CONVERGENCE | -0.24857254 deg | 1.53637516 deg |
| POINT SCALE | 0.99961285 | 0.99996296 |
| COMBINED FACTOR | 0.99958655 | 0.99993665 |

US NATIONAL GRID DESIGNATOR: 18TVK6768494594 (NAD 83)

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MARK: P-2 (P-2 1)

| | | |
|------------|---------------------------|------------------------------------|
| REF FRAME: | NAD_83 (2011) (2010.0000) | IGS08 (2016.5861) |
| X: | 1223942.457 m 0.001 m | 1223941.592 m 0.001 m |
| Y: | -4692312.070 m 0.002 m | -4692310.637 m 0.002 m |
| Z: | 4129297.667 m 0.002 m | 4129297.622 m 0.002 m |
| LAT: | 40 36 18.72030 0.000 m | 40 36 18.75306 0.000 m |
| E LON: | 284 37 09.42742 0.000 m | 284 37 09.40720 0.000 m |
| W LON: | 75 22 50.57258 0.000 m | 75 22 50.59280 0.000 m |
| EL HGT: | 94.811 m 0.003 m | 93.563 m 0.003 m |
| ORTHO HGT: | 129.220 m 0.013 m | (H = h - N WHERE N = GEOID12B HGT) |

| | UTM COORDINATES | STATE PLANE COORDINATES |
|-----------------|-----------------|-------------------------|
| | UTM (Zone 18) | SPC (3702 PA S) |
| NORTHING (Y) | 4495001.678 m | 143912.278 m |
| EASTING (X) | 467790.993 m | 800493.509 m |
| CONVERGENCE | -0.24778761 deg | 1.53717614 deg |
| POINT SCALE | 0.99961277 | 0.99996313 |
| COMBINED FACTOR | 0.99959790 | 0.99994826 |

US NATIONAL GRID DESIGNATOR: 18TVK6779095001 (NAD 83)

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MARK: P-3 (P-3 1)

| | | |
|------------|---------------------------|------------------------|
| REF FRAME: | NAD_83 (2011) (2010.0000) | IGS08 (2016.5876) |
| X: | 1223881.138 m 0.001 m | 1223880.273 m 0.001 m |
| Y: | -4692209.741 m 0.002 m | -4692208.309 m 0.002 m |
| Z: | 4129399.189 m 0.001 m | 4129399.144 m 0.001 m |

LAT: 40 36 23.63474 0.000 m 40 36 23.66749 0.000 m
 E LON: 284 37 08.00220 0.000 m 284 37 07.98199 0.000 m
 W LON: 75 22 51.99780 0.000 m 75 22 52.01801 0.000 m
 EL HGT: 73.963 m 0.002 m 72.717 m 0.002 m
 ORTHO HGT: 108.372 m 0.013 m (H = h - N WHERE N = GEOID12B HGT)

| | UTM COORDINATES | STATE PLANE COORDINATES |
|-----------------|-----------------|-------------------------|
| | UTM (Zone 18) | SPC (3702 PA S) |
| NORTHING (Y) | 4495153.354 m | 144062.911 m |
| EASTING (X) | 467758.156 m | 800455.950 m |
| CONVERGENCE | -0.24805218 deg | 1.53691928 deg |
| POINT SCALE | 0.99961280 | 0.99996319 |
| COMBINED FACTOR | 0.99960120 | 0.99995159 |

US NATIONAL GRID DESIGNATOR: 18TVK6775895153 (NAD 83)

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MARK: P-4 (P-4 1)

REF FRAME: NAD_83(2011) (2010.0000) IGS08 (2016.6399)
 X: 1224064.711 m 0.001 m 1224063.846 m 0.001 m
 Y: -4691986.897 m 0.002 m -4691985.464 m 0.002 m
 Z: 4129569.632 m 0.002 m 4129569.588 m 0.002 m
 LAT: 40 36 31.40177 0.000 m 40 36 31.43454 0.000 m
 E LON: 284 37 17.95055 0.000 m 284 37 17.93032 0.000 m
 W LON: 75 22 42.04945 0.000 m 75 22 42.06968 0.000 m
 EL HGT: 56.376 m 0.003 m 55.129 m 0.003 m
 ORTHO HGT: 90.782 m 0.013 m (H = h - N WHERE N = GEOID12B HGT)

| | UTM COORDINATES | STATE PLANE COORDINATES |
|-----------------|-----------------|-------------------------|
| | UTM (Zone 18) | SPC (3702 PA S) |
| NORTHING (Y) | 4495391.834 m | 144308.676 m |
| EASTING (X) | 467992.971 m | 800683.303 m |
| CONVERGENCE | -0.24626434 deg | 1.53871218 deg |
| POINT SCALE | 0.99961261 | 0.99996329 |
| COMBINED FACTOR | 0.99960377 | 0.99995445 |

US NATIONAL GRID DESIGNATOR: 18TVK6799295391 (NAD 83)

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MARK: P-5 (P-5 1)

REF FRAME: NAD_83(2011) (2010.0000) IGS08 (2016.6676)
 X: 1224430.865 m 0.001 m 1224429.999 m 0.001 m
 Y: -4692052.197 m 0.002 m -4692050.764 m 0.002 m
 Z: 4129417.355 m 0.002 m 4129417.311 m 0.002 m
 LAT: 40 36 24.37017 0.000 m 40 36 24.40296 0.000 m
 E LON: 284 37 32.31970 0.000 m 284 37 32.29946 0.000 m
 W LON: 75 22 27.68030 0.000 m 75 22 27.70054 0.000 m
 EL HGT: 75.412 m 0.003 m 74.165 m 0.003 m
 ORTHO HGT: 109.814 m 0.013 m (H = h - N WHERE N = GEOID12B HGT)

| | UTM COORDINATES | STATE PLANE COORDINATES |
|-----------------|-----------------|-------------------------|
| | UTM (Zone 18) | SPC (3702 PA S) |
| NORTHING (Y) | 4495173.579 m | 144100.942 m |
| EASTING (X) | 468329.713 m | 801026.800 m |
| CONVERGENCE | -0.24365660 deg | 1.54130179 deg |
| POINT SCALE | 0.99961235 | 0.99996320 |
| COMBINED FACTOR | 0.99960052 | 0.99995137 |

US NATIONAL GRID DESIGNATOR: 18TVK6832995173 (NAD 83)

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MARK: P-6 (P-6 1)

| | | | |
|------------|---------------------------|---------|------------------------------------|
| REF FRAME: | NAD 83 (2011) (2010.0000) | | IGS08 (2016.6276) |
| X: | 1224400.764 m | 0.001 m | 1224399.899 m 0.001 m |
| Y: | -4691916.319 m | 0.002 m | -4691914.886 m 0.002 m |
| Z: | 4129551.938 m | 0.002 m | 4129551.894 m 0.002 m |
| LAT: | 40 36 30.61704 | 0.000 m | 40 36 30.64982 0.000 m |
| E LON: | 284 37 32.54021 | 0.000 m | 284 37 32.51998 0.000 m |
| W LON: | 75 22 27.45979 | 0.000 m | 75 22 27.48002 0.000 m |
| EL HGT: | 57.425 m | 0.002 m | 56.178 m 0.002 m |
| ORTHO HGT: | 91.827 m | 0.013 m | (H = h - N WHERE N = GEOID12B HGT) |

| | | |
|-----------------|-----------------|-------------------------|
| | UTM COORDINATES | STATE PLANE COORDINATES |
| | UTM (Zone 18) | SPC (3702 PA S) |
| NORTHING (Y) | 4495366.172 m | 144293.697 m |
| EASTING (X) | 468335.714 m | 801026.799 m |
| CONVERGENCE | -0.24362534 deg | 1.54134153 deg |
| POINT SCALE | 0.99961234 | 0.99996328 |
| COMBINED FACTOR | 0.99960334 | 0.99995427 |

US NATIONAL GRID DESIGNATOR: 18TVK6833595366 (NAD 83)

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CONSTRAINED MARKS
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MARK: njhc (njhc a 2)

CONSTRAIN: 3-D TIGHT

| | | | | | |
|-----------|-----------------|----|------------------|----|-----------------|
| ADJUST X: | 0.000m (0.000m) | Y: | -0.000m (0.000m) | Z: | 0.000m (0.000m) |
| ADJUST N: | 0.000m (0.000m) | E: | 0.000m (0.000m) | H: | 0.000m (0.000m) |

| | | | |
|------------|---------------------------|---------|------------------------------------|
| REF FRAME: | NAD 83 (2011) (2010.0000) | | IGS08 (2016.5941) |
| X: | 1265124.859 m | 0.000 m | 1265123.991 m 0.000 m |
| Y: | -4689124.127 m | 0.000 m | -4689122.684 m 0.000 m |
| Z: | 4120558.335 m | 0.000 m | 4120558.292 m 0.000 m |
| LAT: | 40 30 05.80472 | 0.000 m | 40 30 05.83777 0.000 m |
| E LON: | 285 05 55.98449 | 0.000 m | 285 05 55.96487 0.000 m |
| W LON: | 74 54 04.01551 | 0.000 m | 74 54 04.03513 0.000 m |
| EL HGT: | 95.919 m | 0.000 m | 94.660 m 0.000 m |
| ORTHO HGT: | 129.785 m | 0.011 m | (H = h - N WHERE N = GEOID12B HGT) |

| | | |
|-----------------|-----------------|-------------------------|
| | UTM COORDINATES | STATE PLANE COORDINATES |
| | UTM (Zone 18) | SPC (2900 NJ) |
| NORTHING (Y) | 4483438.406 m | 185284.900 m |
| EASTING (X) | 508378.672 m | 116002.513 m |
| CONVERGENCE | 0.06422255 deg | -0.26051470 deg |
| POINT SCALE | 0.99960086 | 0.99991422 |
| COMBINED FACTOR | 0.99958582 | 0.99989917 |

US NATIONAL GRID DESIGNATOR: 18TWK0837883438 (NAD 83)

+++++
CONSTRAINED MARKS
+++++

MARK: njwc (njwc a 2)

CONSTRAIN: 3-D TIGHT

| | | | | | |
|-----------|------------------|----|------------------|----|-----------------|
| ADJUST X: | -0.000m (0.000m) | Y: | -0.000m (0.000m) | Z: | 0.000m (0.000m) |
| ADJUST N: | 0.000m (0.000m) | E: | -0.000m (0.000m) | H: | 0.000m (0.000m) |

| | | | |
|------------|---------------------------|---------|------------------------|
| REF FRAME: | NAD 83 (2011) (2010.0000) | | IGS08 (2016.5931) |
| X: | 1244799.217 m | 0.000 m | 1244798.351 m 0.000 m |
| Y: | -4672148.542 m | 0.000 m | -4672147.107 m 0.000 m |


```

Z:          4145759.288 m    0.000 m    4145759.249 m    0.000 m
LAT:        40 48 03.07210    0.000 m    40 48 03.10523    0.000 m
E LON:      284 55 07.46968    0.000 m    284 55 07.44975    0.000 m
W LON:      75 04 52.53032    0.000 m    75 04 52.55025    0.000 m
EL HGT:     79.804 m    0.000 m    78.559 m    0.000 m
ORTHO HGT:  113.434 m    0.011 m    (H = h - N WHERE N = GEOID12B HGT)

```

```

                UTM COORDINATES        STATE PLANE COORDINATES
                UTM (Zone 18)           SPC (2900 NJ)
NORTHING (Y)   4516653.455 m           218596.714 m
EASTING (X)    493145.514 m            100953.596 m
CONVERGENCE    -0.05309686 deg         -0.37982034 deg
POINT SCALE    0.99960058              0.99992960
COMBINED FACTOR 0.99958807             0.99991708

```

US NATIONAL GRID DESIGNATOR: 18TVL9314516653 (NAD 83)

+++++

```

MARK:        pass (pass a 1)
CONSTRAIN: 3-D TIGHT
ADJUST X:    0.000m (0.000m)    Y:    -0.000m (0.000m)    Z:    -0.000m (0.000m)
ADJUST N:    -0.000m (0.000m)  E:     0.000m (0.000m)    H:     0.000m (0.000m)

```

```

REF FRAME:    NAD_83 (2011) (2010.0000)           IGS08 (2016.6031)
X:           1159578.322 m    0.000 m    1159577.458 m    0.000 m
Y:           -4706158.738 m    0.000 m    -4706157.300 m    0.000 m
Z:           4132205.068 m    0.000 m    4132205.016 m    0.000 m
LAT:         40 38 20.92573    0.000 m    40 38 20.95830    0.000 m
E LON:       283 50 30.22000    0.000 m    283 50 30.19893    0.000 m
W LON:       76 09 29.78000    0.000 m    76 09 29.80107    0.000 m
EL HGT:      165.703 m    0.000 m    164.453 m    0.000 m
ORTHO HGT:   199.816 m    0.013 m    (H = h - N WHERE N = GEOID12B HGT)

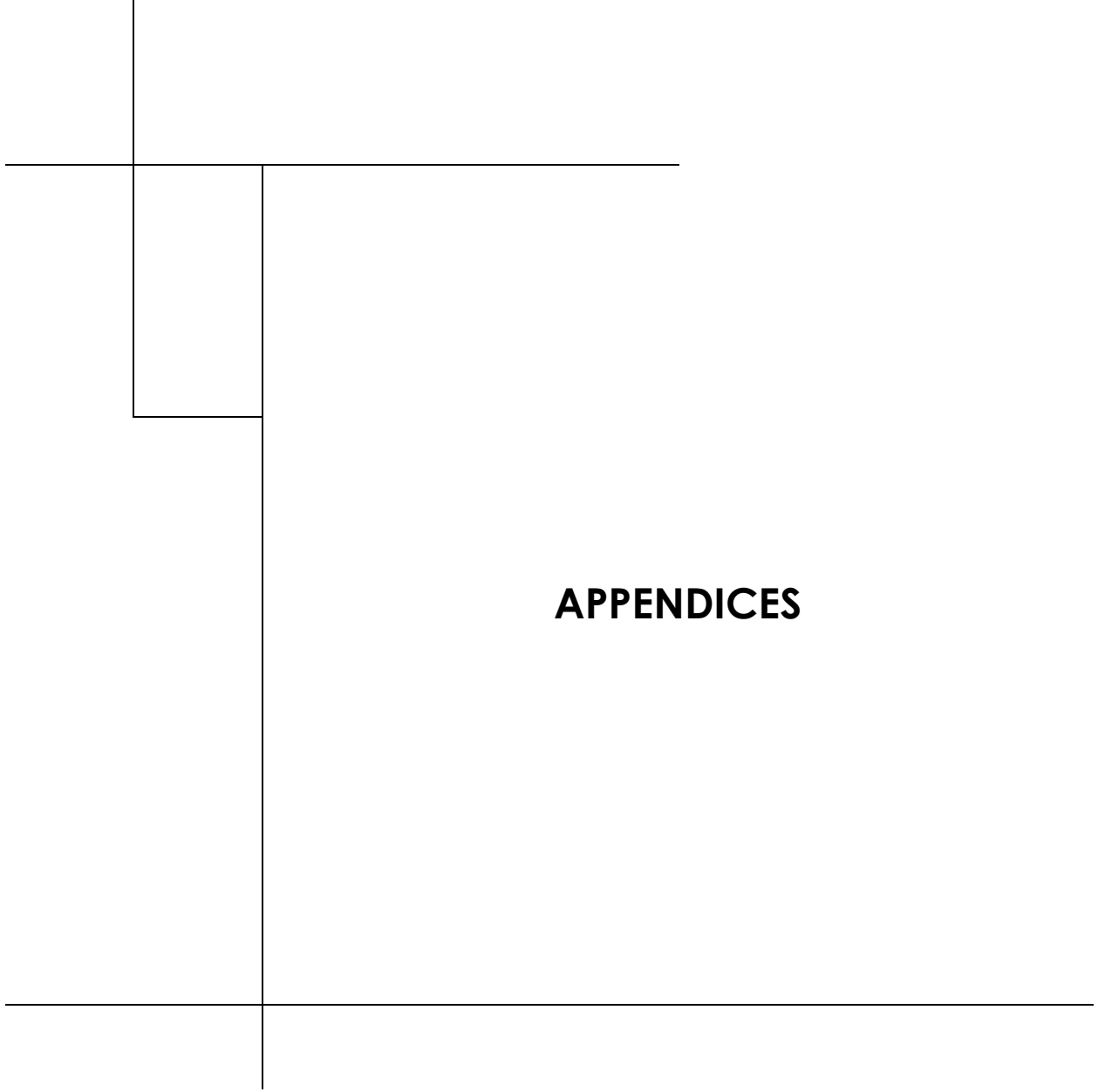
```

```

                UTM COORDINATES        STATE PLANE COORDINATES
                UTM (Zone 18)           SPC (3702 PA S)
NORTHING (Y)   4499344.926 m           146205.441 m
EASTING (X)    402057.173 m            734636.010 m
CONVERGENCE    -0.75443425 deg         1.03270208 deg
POINT SCALE    0.99971807              0.99996489
COMBINED FACTOR 0.99969208             0.99993890

```

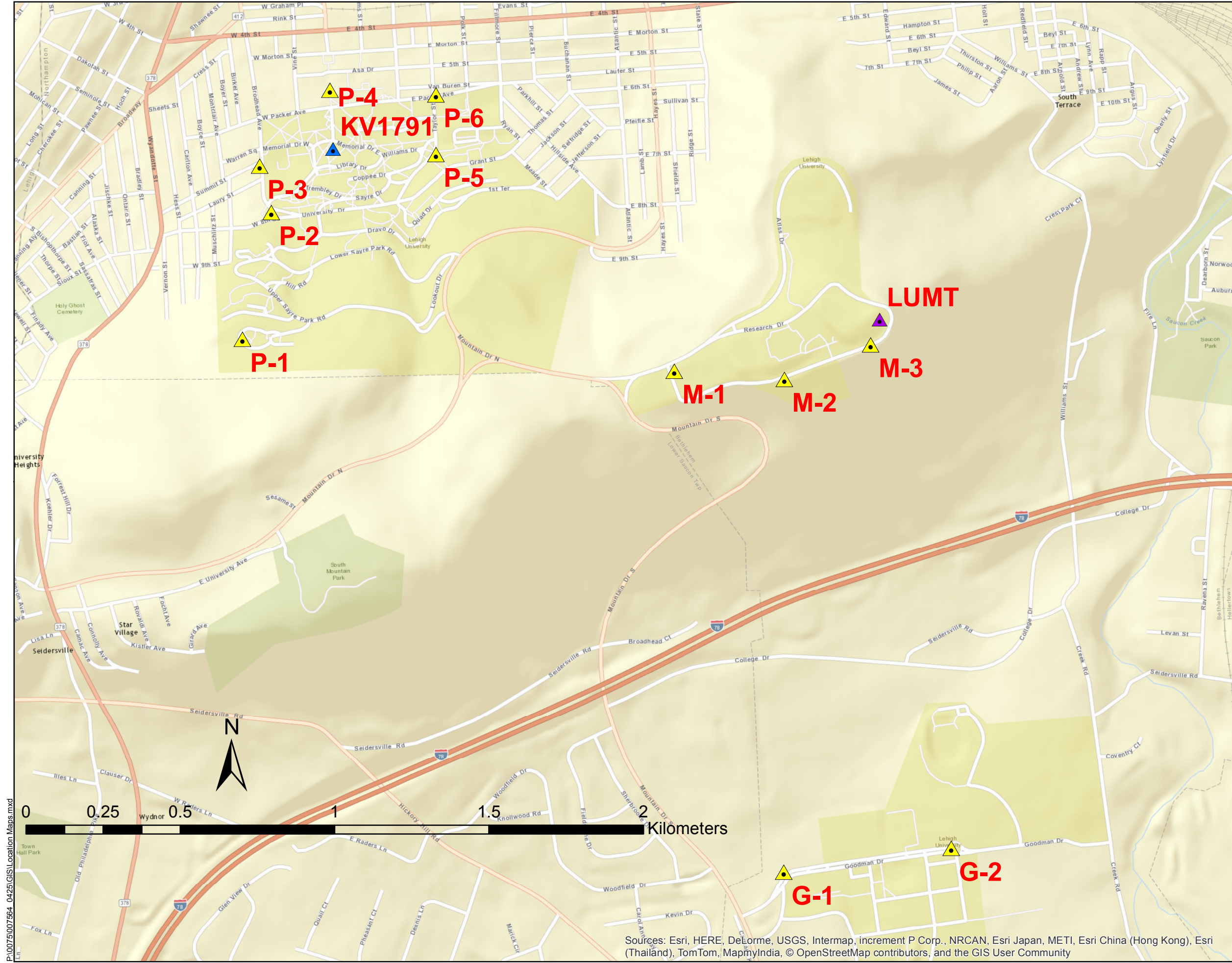
US NATIONAL GRID DESIGNATOR: 18TVK0205799344 (NAD 83)



APPENDICES

Lehigh University Control Monumentation

-  Control Monuments
-  KV1791 (LEHIGH)
-  LUMT



Mapping derived from data provided by ESRI, NGS, and field survey.

10/5/2016 | PM:MDW | GIS:ZJL | QA:MDK | R007564.0425



369 East Park Drive
Harrisburg, PA 17111
717.564.1121 [phone]
717.564.1158 [fax]
www.hrg-inc.com

Sources: Esri, HERE, DeLorme, USGS, Intermap, increment P Corp., NRCAN, Esri Japan, METI, Esri China (Hong Kong), Esri (Thailand), TomTom, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

P:\0075007564_0425\GIS\Location Maps.mxd



STATION NAME **G-1**

| NAD83(2011) PA SPC SOUTH ZONE NAVD 88 SURVEY FT. | | | |
|--|-------------|-----------|--------|
| Northing | 465141.958 | Elevation | 316.43 |
| Easting | 2631733.769 | | |

| NAD83(2011) PA SPC SOUTH ZONE NAVD 88 METERS | | | |
|--|------------|-----------|--------|
| Northing | 141775.552 | Elevation | 96.448 |
| Easting | 802154.057 | | |

| | | | |
|-----------|-------------------|--------------|-------------|
| Latitude | N 40°35'08.02246" | Scale Factor | 0.999944545 |
| Longitude | W 75°21'42.42124" | | |

STATION DESCRIPTION

The station is a standard bronze disc set in a poured concrete pier flush with ground level. The disk contains magnetic material. The station can be reached by traveling approximately 700 feet east on Goodman Drive from the intersection with Mountain Drive. The Station is 23.5 feet north of the edge of the pavement.

Date Installed: 6/20/2016

Survey Dates: 7/5/16-8/3/16

SURVEY METHODOLOGY

The NAVD 88 orthometric height was obtained by differential leveling from the NGS benchmark KV1791 located on the Packer Campus of Lehigh University. The NAD 83 NSRS 2011, PA State Plane South Zone position was obtained through GNSS static network methods with reference to NGS CORS stations; NJHC, NJWC, and PASS

LOCATION MAP



Aerial imagery courtesy of PASDA and LVPC

PHOTO



PHOTO (Looking East)





| | |
|---------------------|------------|
| STATION NAME | G-2 |
|---------------------|------------|

| NAD83(2011) PA SPC SOUTH ZONE NAVD 88 SURVEY FT. | | | |
|--|-------------|--|-----------|
| Northing | 465396.522 | | Elevation |
| Easting | 2633512.984 | | 322.71 |

| NAD83(2011) PA SPC SOUTH ZONE NAVD 88 METERS | | | |
|--|------------|--|-----------|
| Northing | 141853.144 | | Elevation |
| Easting | 802696.363 | | 98.36 |

| | | | |
|-----------|-------------------|--|--------------|
| Latitude | N 40°35'10.06102" | | Scale Factor |
| Longitude | W 75°21'19.27889" | | 0.999944545 |

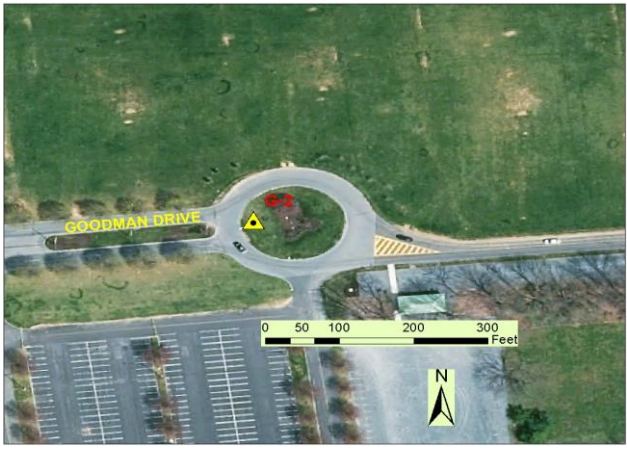
STATION DESCRIPTION

The station is a standard bronze disc set in a poured concrete pier flush with ground level. The disk contains magnetic material. The station can be reached by traveling approximately 2460 feet east on Goodman Drive from the intersection with Mountain Drive. The Station is 15.5 feet east of the edge of the pavement in the western side of the turning circle.

| | |
|------------------------|-----------|
| Date Installed: | 6/20/2016 |
|------------------------|-----------|

| | |
|----------------------|---------------|
| Survey Dates: | 7/5/16-8/3/16 |
|----------------------|---------------|

LOCATION MAP



Aerial imagery courtesy of PASDA and LVPC

SURVEY METHODOLOGY

The NAVD 88 orthometric height was obtained by differential leveling from the NGS benchmark KV1791 located on the Packer Campus of Lehigh University. The NAD 83 NSRS 2011, PA State Plane South Zone position was obtained through GNSS static network methods with reference to NGS CORS stations; NJHC, NJWC, and PASS

PHOTO



PHOTO (Looking West)





STATION NAME M-1

| NAD83(2011) PA SPC SOUTH ZONE NAVD 88 SURVEY FT. | | | |
|--|-------------|--|-----------|
| Northing | 470466.940 | | Elevation |
| Easting | 2630571.233 | | 829.64 |

| NAD83(2011) PA SPC SOUTH ZONE NAVD 88 METERS | | | |
|--|------------|--|-----------|
| Northing | 143398.610 | | Elevation |
| Easting | 801799.716 | | 252.875 |

| | | | |
|-----------|-------------------|--------------|--|
| Latitude | N 40°36'00.93349" | Scale Factor | |
| Longitude | W 75°21'55.62057" | 0.999944545 | |

STATION DESCRIPTION

The station is a standard bronze disc set in a poured concrete pier flush with the ground level. The disk contains magnetic material. The station can be reached by traveling approximately 80 feet south on Research Drive from the intersection with Mountain Drive East. The Station is approximately 46 feet east of the edge of the pavement.

Date Installed: 6/21/2016

Survey Dates: 7/5/2016-8/3/2016



Aerial imagery courtesy of PASDA and LVPC

SURVEY METHODOLOGY

The NAVD 88 orthometric height was obtained by differential leveling from the NGS benchmark KV1791 located on the Packer Campus of Lehigh University. The NAD 83 NSRS 2011, PA State Plane South Zone position was obtained through GNSS static network methods with reference to NGS CORS stations; NJHC, NJWC, and PASS

PHOTO



PHOTO (Looking West)





| | |
|---------------------|------------|
| STATION NAME | M-2 |
|---------------------|------------|

| NAD83(2011) PA SPC SOUTH ZONE NAVD 88 SURVEY FT. | | | |
|--|-------------|--|------------------|
| Northing | 470381.041 | | Elevation |
| Easting | 2631738.277 | | 864.42 |

| NAD83(2011) PA SPC SOUTH ZONE NAVD 88 METERS | | | |
|--|------------|--|------------------|
| Northing | 143372.428 | | Elevation |
| Easting | 802155.431 | | 263.477 |

| | | |
|------------------|-------------------|---------------------|
| Latitude | N 40°35'59.77335" | Scale Factor |
| Longitude | W 75°21'40.52625" | 0.999944545 |

| STATION DESCRIPTION | |
|--|--|
| <p>The station is a standard bronze disc set in a poured concrete pier flush with the ground level. The disk contains magnetic material. The station can be reached by traveling approximately 1520 feet south and east on Research Drive from the intersection with Mountain Drive East. The Station is in the middle of the grass strip between Research Drive and the parking lot 4 feet south of the edge of Research Drive.</p> | |

| | |
|------------------------|-----------|
| Date Installed: | 6/21/2016 |
|------------------------|-----------|

| | |
|----------------------|-------------------|
| Survey Dates: | 7/5/2016-8/3/2016 |
|----------------------|-------------------|

| SURVEY METHODOLOGY | |
|--|--|
| <p>The NAVD 88 orthometric height was obtained by differential leveling from the NGS benchmark KV1791 located on the Packer Campus of Lehigh University. The NAD 83 NSRS 2011, PA State Plane South Zone position was obtained through GNSS static network methods with reference to NGS CORS stations; NJHC, NJWC, and PASS</p> | |

| LOCATION MAP | |
|--------------|--|
| | |

Aerial imagery courtesy of PASDA and LVPC

| PHOTO | |
|-------|--|
| | |

| PHOTO (Looking East) | |
|----------------------|--|
| | |



| | |
|---------------------|------------|
| STATION NAME | M-3 |
|---------------------|------------|

| NAD83(2011) PA SPC SOUTH ZONE NAVD 88 SURVEY FT. | | | |
|--|-------------|-----------|--------|
| Northing | 470746.751 | Elevation | 896.58 |
| Easting | 2632657.521 | | |

| NAD83(2011) PA SPC SOUTH ZONE NAVD 88 METERS | | | |
|--|------------|-----------|---------|
| Northing | 143483.897 | Elevation | 273.277 |
| Easting | 802435.617 | | |

| | | | |
|-----------|-------------------|--------------|-------------|
| Latitude | N 40°36'03.14010" | Scale Factor | 0.999944545 |
| Longitude | W 75°21'28.48489" | | |

STATION DESCRIPTION

The station is a standard bronze disc set in a poured concrete pier flush with the ground level. The disk contains magnetic material. The station can be reached by traveling approximately 2530 feet south and east on Research Drive from the intersection with Mountain Drive East. The Station is located in the center of the grass strip between the sidewalk and the northern edge of Research Drive 3 feet north from the edge of pavement.

Date Installed: 6/21/2016

Survey Dates: 7/5/2016-8/3/2016

LOCATION MAP



Aerial imagery courtesy of PASDA and LVPC

SURVEY METHODOLOGY

The NAVD 88 orthometric height was obtained by differential leveling from the NGS benchmark KV1791 located on the Packer Campus of Lehigh University. The NAD 83 NSRS 2011, PA State Plane South Zone position was obtained through GNSS static network methods with reference to NGS CORS stations: NJHC, NJWC, and PASS

PHOTO



PHOTO (Looking South)





STATION NAME P-1

| NAD83(2011) PA SPC SOUTH ZONE NAVD 88 SURVEY FT. | | | |
|--|-------------|--|-----------|
| Northing | 470804.626 | | Elevation |
| Easting | 2625979.024 | | 663.25 |

| NAD83(2011) PA SPC SOUTH ZONE NAVD 88 METERS | | | |
|--|------------|--|-----------|
| Northing | 143501.537 | | Elevation |
| Easting | 800400.007 | | 202.159 |

| | | | |
|-----------|-------------------|--------------|--|
| Latitude | N 40°36'05.49010" | Scale Factor | |
| Longitude | W 75°22'55.01689" | 0.999944545 | |

STATION DESCRIPTION

The station is a standard bronze disc set in a poured concrete pier flush with ground level. The disk contains magnetic material. The station is located at Sayre Park Village. The Station is approximately 100 feet south of the southwest corner of House "C", 120 feet northwest of the northwest corner of the Building "D", and 12 feet east of the access drive.

| | |
|-----------------|-----------|
| Date Installed: | 6/22/2016 |
|-----------------|-----------|

| | |
|---------------|-----------------|
| Survey Dates: | 7/5/2016-8/3/16 |
|---------------|-----------------|

SURVEY METHODOLOGY

The NAVD 88 orthometric height was obtained by differential leveling from the NGS benchmark KV1791 located on the Packer Campus of Lehigh University. The NAD 83 NSRS 2011, PA State Plane South Zone position was obtained through GNSS static network methods with reference to NGS CORS stations; NJHC, NJWC, and PASS.

LOCATION MAP



Aerial imagery courtesy of PASDA and LVPC

PHOTO



PHOTO (Looking North)





| | |
|---------------------|------------|
| STATION NAME | P-2 |
|---------------------|------------|

| NAD83(2011) PA SPC SOUTH ZONE NAVD 88 SURVEY FT. | | | |
|--|-------------|--|-----------|
| Northing | 472152.191 | | Elevation |
| Easting | 2626285.801 | | 423.92 |

| NAD83(2011) PA SPC SOUTH ZONE NAVD 88 METERS | | | |
|--|------------|--|-----------|
| Northing | 143912.276 | | Elevation |
| Easting | 800493.513 | | 129.210 |

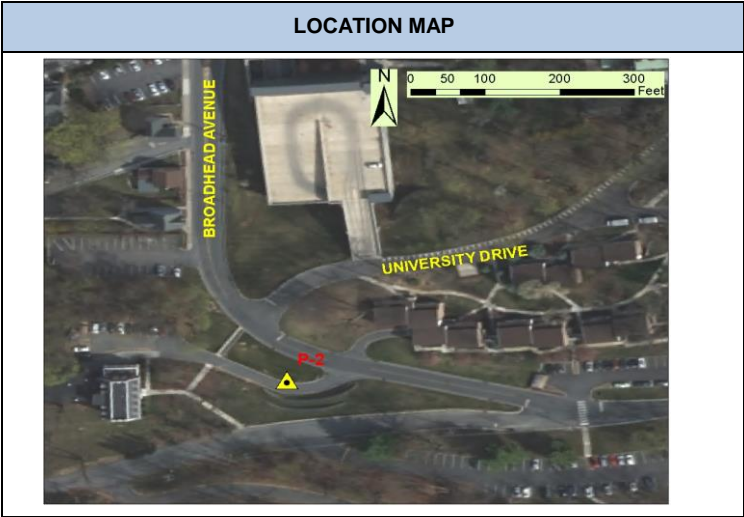
| | | | |
|-----------|-------------------|--|--------------|
| Latitude | N 40°36'18.72021" | | Scale Factor |
| Longitude | W 75°22'50.57242" | | 0.999944545 |

| STATION DESCRIPTION |
|--|
| <p>The station is a standard bronze disc set in a poured concrete pier flush with ground level. The disk contains magnetic material. The station can be reached by traveling southeast 100 feet from the intersection of University Drive and Brodhead Avenue then turning right into the driveway for the Psi Upsilon house. The station is 60 feet west of the intersection of said driveway and Brodhead Avenue. The station is 4 feet north of the edge of pavement.</p> |

| | |
|-----------------|-----------|
| Date Installed: | 6/22/2016 |
|-----------------|-----------|

| | |
|---------------|-------------------|
| Survey Dates: | 7/5/2016-8/3/2016 |
|---------------|-------------------|

| SURVEY METHODOLOGY |
|--|
| <p>The NAVD 88 orthometric height was obtained by differential leveling from the NGS benchmark KV1791 located on the Packer Campus of Lehigh University. The NAD 83 NSRS 2011, PA State Plane South Zone position was obtained through GNSS static network methods with reference to NGS CORS stations; NJHC, NJWC, and PASS</p> |



Aerial imagery courtesy of PASDA and LVPC





| | |
|---------------------|------------|
| STATION NAME | P-3 |
|---------------------|------------|

| NAD83(2011) PA SPC SOUTH ZONE NAVD 88 SURVEY FT. | | | |
|--|-------------|--|-----------|
| Northing | 472646.390 | | Elevation |
| Easting | 2626162.580 | | 355.50 |

| NAD83(2011) PA SPC SOUTH ZONE NAVD 88 METERS | | | |
|--|------------|--|-----------|
| Northing | 144062.908 | | Elevation |
| Easting | 800455.955 | | 108.355 |

| | | | |
|-----------|-------------------|--|--------------|
| Latitude | N 40°36'23.63462" | | Scale Factor |
| Longitude | W 75°22'51.99759" | | 0.999944545 |

| STATION DESCRIPTION |
|---------------------|
|---------------------|

The station is a standard bronze disc set in a poured concrete pier flush with ground level. The disk contains magnetic material. The station is located at the southwest corner of Summit Street and Brodhead Avenue. The station is approximately 3.5 feet southeast and 3.5 feet west of the concrete sidewalk in a landscaping bed.

| LOCATION MAP |
|--------------|
|--------------|



Aerial imagery courtesy of PASDA and LVPC

| | |
|-----------------|-----------|
| Date Installed: | 6/22/2016 |
|-----------------|-----------|

| | |
|---------------|-------------------|
| Survey Dates: | 7/5/2016-8/3/2016 |
|---------------|-------------------|

| SURVEY METHODOLOGY |
|--------------------|
|--------------------|

The NAVD 88 orthometric height was obtained by differential leveling from the NGS benchmark KV1791 located on the Packer Campus of Lehigh University. The NAD 83 NSRS 2011, PA State Plane South Zone position was obtained through GNSS static network methods with reference to NGS CORS stations; NJHC, NJWC, and PASS

| PHOTO | PHOTO (Looking South) |
|-------|-----------------------|
|-------|-----------------------|





| | |
|---------------------|------------|
| STATION NAME | P-4 |
|---------------------|------------|

| NAD83(2011) PA SPC SOUTH ZONE NAVD 88 SURVEY FT. | | | |
|--|-------------|--|-----------|
| Northing | 473452.709 | | Elevation |
| Easting | 2626908.484 | | 297.79 |

| NAD83(2011) PA SPC SOUTH ZONE NAVD 88 METERS | | | |
|--|------------|--|-----------|
| Northing | 144308.674 | | Elevation |
| Easting | 800683.307 | | 90.767 |

| | | | |
|-----------|-------------------|--|--------------|
| Latitude | N 40°36'31.40172" | | Scale Factor |
| Longitude | W 75°22'42.04927" | | 0.999944545 |

| STATION DESCRIPTION |
|--|
| <p>The station is a standard bronze disc set in a poured concrete pier flush with ground level. The disk contains magnetic material. The station is located in the courtyard at the E.W. Fairchild-Martindale Library. The station is located directly north of the paved walkway that leads north from the flagpole and crosses East/West Packer Avenue. The station is approximately 9.5 feet north of the concrete patio in a mulched landscape area.</p> |

| | |
|-----------------|-----------|
| Date Installed: | 6/23/2016 |
|-----------------|-----------|

| | |
|---------------|-------------------|
| Survey Dates: | 7/5/2016-8/3/2016 |
|---------------|-------------------|

| SURVEY METHODOLOGY |
|--|
| <p>The NAVD 88 orthometric height was obtained by differential leveling from the NGS benchmark KV1791 located on the Packer Campus of Lehigh University. The NAD 83 NSRS 2011, PA State Plane South Zone position was obtained through GNSS static network methods with reference to NGS CORS stations; NJHC, NJWC, and PASS</p> |



Aerial imagery courtesy of PASDA and LVPC





| | |
|---------------------|------------|
| STATION NAME | P-5 |
|---------------------|------------|

| NAD83(2011) PA SPC SOUTH ZONE NAVD 88 SURVEY FT. | | | |
|--|-------------|--|-----------|
| Northing | 472771.178 | | Elevation |
| Easting | 2628035.442 | | 360.25 |

| NAD83(2011) PA SPC SOUTH ZONE NAVD 88 METERS | | | |
|--|------------|--|-----------|
| Northing | 144100.943 | | Elevation |
| Easting | 801026.805 | | 109.805 |

| | | | |
|-----------|-------------------|--|--------------|
| Latitude | N 40°36'24.37020" | | Scale Factor |
| Longitude | W 75°22'27.68011" | | 0.999944545 |

STATION DESCRIPTION

The station is a standard bronze disc set in a poured concrete pier flush with ground level. The disk contains magnetic material. The station is located behind a stone retaining wall in the triangular lawn area in front of the Dialogue House located on the east side of Taylor Street, 160 feet south of the intersection with Sayre Drive. The station is located approximately 3 feet west of the concrete walkway at the top of the stairs.

Date Installed: 6/23/2016

Survey Dates: 7/5/2016-8/3/2016

SURVEY METHODOLOGY

The NAVD 88 orthometric height was obtained by differential leveling from the NGS benchmark KV1791 located on the Packer Campus of Lehigh University. The NAD 83 NSRS 2011, PA State Plane South Zone position was obtained through GNSS static network methods with reference to NGS CORS stations; NJHC, NJWC, and PASS





| | |
|---------------------|------------|
| STATION NAME | P-6 |
|---------------------|------------|

| NAD83(2011) PA SPC SOUTH ZONE NAVD 88 SURVEY FT. | | | |
|--|-------------|--|-----------|
| Northing | 473403.565 | | Elevation |
| Easting | 2628035.442 | | 301.19 |

| NAD83(2011) PA SPC SOUTH ZONE NAVD 88 METERS | | | |
|--|------------|--|-----------|
| Northing | 144293.695 | | Elevation |
| Easting | 801026.805 | | 91.803 |

| | | |
|-----------|-------------------|--------------|
| Latitude | N 40°36'30.61699" | Scale Factor |
| Longitude | W 75°22'27.45956" | 0.999944545 |

| STATION DESCRIPTION |
|--|
| The station is a standard bronze disc set in a poured concrete pier flush with ground level. The disk contains magnetic material. The station is located at the northeast corner of East Packer Avenue and Taylor Street. The station is approximately 24 feet east of the east edge of Taylor Street and 8 feet north of the edge of pavement on East Packer Ave. |

| LOCATION MAP |
|--------------|
| |

Aerial imagery courtesy of PASDA and LVPC

| | |
|-----------------|-----------|
| Date Installed: | 6/23/2016 |
|-----------------|-----------|

| | |
|---------------|-------------------|
| Survey Dates: | 7/5/2016-8/3/2016 |
|---------------|-------------------|

| SURVEY METHODOLOGY |
|---|
| The NAVD 88 orthometric height was obtained by differential leveling from the NGS benchmark KV1791 located on the Packer Campus of Lehigh University. The NAD 83 NSRS 2011, PA State Plane South Zone position was obtained through GNSS static network methods with reference to NGS CORS stations; NJHC, NJWC, and PASS |

| PHOTO |
|-------|
| |

| PHOTO (Looking West) |
|----------------------|
| |