Maryland Department of Natural Resources
Resource Assessment Service
MARYLAND GEOLOGICAL SURVEY
Stephen Van Ryswick, Director

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LAND SUBSIDENCE MONITORING TO ASSESS POTENTIAL EFFECTS OF GROUNDWATER WITHDRAWALS FROM COASTAL PLAIN AQUIFERS IN MARYLAND:

FALL, 2024 SURVEY

by

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Prepared in cooperation with the
Anne Arundel County Department of Public Works, Dominion Cove Point LNG/LP,
and the U.S. Geological Survey

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FALL, 2024 SURVEY

KEY RESULTS

A GPS campaign was conducted October 27, 2024 to November 4, 2024 to determine heights of eight 3d marks to assess the potential effect of groundwater withdrawals from aquifers in the Coastal Plain of Maryland. Three marks are located at major well fields in Anne Arundel County, Maryland, at the Arnold Water Treatment Plant (ARNO), the Broad Creek Water Treatment Plant (BROA), and the Crofton Meadows Water Treatment Plant (CROF). Three marks are located at or near major well fields in southern Maryland, at Cove Point State Park (COV1), Lexington Park (LEX1), and Waldorf (WAL1). Two marks are located on the Eastern Shore of Maryland in the Blackwater National Wildlife Refuge in Dorchester County, at Money Stump (MSTP) and Peter's Neck (PTNK). The marks at the Blackwater National Wildlife Refuge are located in low-lying areas near the shoreline of the Chesapeake Bay where inundation, caused by relative sea-level rise, makes assessing the role of land subsidence all the more critical. The GPS data were processed using the National Geodetic Survey's Online Positioning User Service (OPUS) Projects (5.2) utility in the International Terrestrial Reference System of 2014. The 2024 ellipsoid heights determined through OPUS Projects processing of GPS data were 3.599 meters at ARNO, -6.227 meters at BROA, 7.050 meters at CROF, -1.559 meters at COV1, -2.110 meters at LEX1, 28.730 meters at WAL1, -35.679 meters at MSTP, and -36.076 meters at PTNK. GPS data were not acquired at Rosaryville State Park (ROS1) due to previous survey data from the site not meeting OPUS Projects data quality thresholds and the continued obstruction of satellite visibility by vegetation. Following the final network adjustment in OPUS Projects, computed height uncertainty is +/- 0.1 cm, and computed uncertainty for the latitudinal and longitudinal positions is smaller than could be detected by OPUS Projects at all MGS marks. Vertical velocities have been updated for the eight 3d marks using ellipsoid height data from 2024. In Anne Arundel County, ARNO is subsiding at 3.1 mm/yr, BROA is subsiding at 2.5 mm/yr, and CROF is subsiding at 2.6 mm/yr In southern Maryland, COV1 is subsiding at 4.9 mm/yr, LEX1 is subsiding at 3.3 mm/yr, and WAL1 is subsiding at 6.7 mm/yr In the Blackwater National Wildlife Refuge, MSTP is subsiding at 10.6 mm/yr and PTNK is subsiding at 8.4 mm/yr.

INTRODUCTION

Parts of the Atlantic Coastal Plain region are experiencing elevated rates of land subsidence compared to physiographic provinces west of the Fall Line (Karegar and others, 2016; Ulizio, 2021). The Fall Line is a boundary that separates the unconsolidated Atlantic Coastal Plain sediments from the consolidated bedrock of the Piedmont province (fig. 1). Two dominant processes responsible for the elevated land subsidence rates include the collapse of the forebulge of the former Laurentide Ice Sheet due to glacial isostatic adjustment (GIA) and land subsidence due to decreases in hydrostatic pressure in unconsolidated sediments of the Atlantic Coastal Plain in response to groundwater withdrawal (Eggleston and Pope, 2013; Johnson and others, 2017). A recent model of the effects of GIA on vertical displacement in the Atlantic coastal plain suggests that subsidence rates of 1.4 to 2.2 millimeters per year (mm/yr) is due to GIA in the Chesapeake Bay region (Williams and others, 2024).

Groundwater from the confined aquifers of the Maryland coastal plain has been withdrawn for decades as the primary source of water supply. The geological formations of the coastal plain are composed of stacked layers of predominantly unconsolidated sediment consisting of gravel, sand, silt, and clay. Sand and gravel layers contain water stored in interstitial pore spaces between the sediment grains with relatively high permeability, forming aquifers. Clay layers, with relatively low permeability, form confining units. Withdrawal of water from confined aquifers has lowered groundwater levels in Maryland's coastal plain aquifer systems (Staley and others, 2020). A lowering of groundwater levels in a confined aquifer corresponds to a decrease in hydrostatic pressure in the interstitial pore spaces of the aquifer sediments and in the adjacent confining units. A decrease in hydrostatic pressure can lead to the compaction of unconsolidated sediment and the subsidence of the land surface as the load from overlying sediment increases. Land subsidence rates attributable to groundwater withdrawals from the Potomac Group aquifer system in the Lower Chesapeake Bay region (Franklin and Suffolk, Virginia) have been reported in the range of 1.5 to 3.7 millimeters per year (mm/yr) (Davis, 1987; Pope and Burbey, 2004; Eggleston and Pope, 2013).

HISTORICAL GPS DATA

Starting in 1994, the Maryland State Highway Administration Division of Plats and Surveys began GPS surveys in Anne Arundel County at 3d rod marks at the Arnold Water Treatment Plant (ARNO) and the Broad Creek Water Treatment Plant (BROA), and a bronze survey disk embedded in a concrete structure at the Crofton Meadows Water Treatment Plant (CROF). The surveys were conducted on a yearly basis, occupying marks for a minimum of 5.5 hours over three consecutive days. In 2016, the Maryland Geological Survey took over the surveying of the marks. In 2015, four 3d rod marks were constructed and added to the monitoring network at Cove Point State Park (COV1), Lexington Park (LEX1), Rosaryville State Park (ROS1), and Waldorf (WAL1) to bring the total monitoring network to seven. In 2019 and 2020, two additional 3d rod marks were constructed and added to the network in the Blackwater National Wildlife Refuge (BWNWR) at Money Stump (MSTP) and Peter's Neck (PTNK). The historical GPS data from the Maryland State Highway Administration, as well as, GPS data collected since 2016 by the Maryland Geological Survey were reprocessed in OPUS Projects using the International Terrestrial Reference System of 2014 (ITRF2014). Data available for reprocessing began in 1999.

GPS SURVEY

A GPS occupation of marks ARNO, COV1, CROF, LEX1, MSTP, and WAL1 was conducted beginning October 28, 2024. Accessibility to mark BROA was limited prior to October 31, 2024, delaying the

occupation of the mark prior to that date. Mark PTNK was occupied beginning October 24, 2024. Trimble NetR9 receivers and Zephyr 3 Geodetic Antennas were used for all marks[1].

The GPS occupation of each survey mark was documented on a standardized observation log sheet (app A). Observation log sheets contain information that is essential in data processing about equipment deployed at each mark, such as antenna type and antenna reference point (ARP). Observation log sheets and RINEX data files will be archived, as in previous years, for open access at EarthScope (formerly UNAVCO) and Zenodo as part of a larger archive of data for the Chesapeake Bay region (Fry and others, 2023; Kronebusch and others, 2022; Troia and others, 2020 and 2022; Williams and others, 2024).

The data were processed using the National Geodetic Survey's (NGS) OPUS Projects (5.2) online utility to determine ellipsoid heights of the marks. Ellipsoid heights were used, as opposed to orthometric heights, to avoid potential loss of accuracy associated with geoid models. OPUS Projects provides geodetic network solutions through baseline processing of simultaneous GPS observations. A detailed technical discussion of the concepts and processing used in OPUS Projects is provided in Armstrong (2015). The occupation period was divided into five sessions (tab. 1). Data processing parameters specified in OPUS Projects included a piecewise linear tropospheric model with an interval of 7,200 seconds, an elevation cutoff of 15.0 degrees, and normal constraint weights. Session processing was performed using user-established data quality thresholds. The minimum percentage of observations used to generate a solution for a given GPS day, at an individual survey mark, was lowered from the default 80% to 70%. The maximum height uncertainty allowable for solution on a given GPS day for individual marks was set to 1.5 cm. If GPS data did not meet these data quality thresholds for a given GPS day of occupation, they were removed from that GPS day's session processing. In the past two surveys (2022 and 2023), data collected at ROS1 did not meet any of the data quality thresholds and were excluded from each GPS day's session processing step and the final network adjustment. The ROS1 benchmark is located among large standing vegetation that diminishes satellite visibility and likely contributes to the poor data quality; therefore, the decision was made not to survey ROS1 in 2024. Data for PTNK was processed from October 27, 2024 to October 30, 2024 to only include data that was collected concurrently with the other survey benchmarks. Data for WAL1 was processed through October 31, 2024. Southern Maryland marks COV1 and LEX1 as well as MSTP in the BWNWR were occupied and processed through November 1, 2024. The three marks in Anne Arundel County, ARNO, BROA, and CROF, were processed through November 4, 2024. Data from CROF were not processed for the day of Nov. 2 due to errors in raw data collection that rendered the data unusable. The final network adjustment used ten Continuously Operating Reference Stations (CORS) to establish baselines with MGS survey marks. All CORS data were constrained in three dimensions during the network adjustment, except for the distant CORS STKR used for tropospheric correction. CORS stations used to process session network baselines and in network adjustment are shown in Table 2. Ellipsoid heights determined by OPUS Projects network adjustment are given in Table 3.

CHANGE IN ELLIPSOID HEIGHT OVER TIME

The changes in ellipsoid height relative to the 1999 measurement at marks ARNO, BROA, and CROF are shown in Figure 2. Over a 26-year period of record, the ellipsoid height decreased by 87 mm at ARNO, 68 mm at BROA, and 61 mm at CROF. The changes in ellipsoid height relative to the 2016 measurement at the marks COV1, LEX1, and WAL1 are shown in Figure 3. Over a 9-year period of record, the ellipsoid heights decreased by 38 mm at COV1, 26 mm at LEX1and 49 mm at WAL1. The changes in ellipsoid height relative to the 2020 measurement at the marks MSTP and PTNK are shown in Figure 4. Over a 4-year period of record, the ellipsoid heights decreased by 39 mm at MSTP and 33 mm at PTNK.

Vertical velocities for each mark were computed by plotting the ellipsoid height derived from data processing in OPUS Projects versus time (figs. 2, 3, and 4). A linear trendline was fit to the ellipsoid height

[1] The use of company names, trade names, or product names in this report is for identification purposes only and does not constitute endorsement by the Maryland Geological Survey.

data, and the slope of that trendline is the reported vertical velocity (tab. 3). The vertical velocities for the three Anne Arundel County marks ARNO, BROA, and CROF are -3.1 mm/yr, -2.5 mm/yr, and -2.6 mm/yr respectively. The vertical velocities for the three southern Maryland marks, COV1, LEX1, WAL1, are -4.9 mm/yr, -3.3 mm/yr, and -6.7 mm/yr respectively. The vertical velocities for the two marks on the eastern shore of Maryland, MSTP and PTNK are -10.6 mm/yr and -8.4 mm/yr respectively.

The variance around the trendline is quantified by the coefficients of determination (R^2) seen in Figures 2-4. Values of R^2 greater than 0.8 show a high correlation between ellipsoid height and time. The correlation between ellipsoid height and time is not as strong for the southern Maryland marks COV1, LEX1, ROS1, and WAL1. The shorter period of record at these marks, compared to the three marks in Anne Arundel County, does not provide as much data to reveal as strong of a trend. The R^2 values quantifying the correlation between ellipsoid height and time at these southern Maryland benchmarks have been increasing as the survey continues year to year. For example, following the 2020 GPS occupation of the LEX1 benchmark, the correlation between ellipsoid height and time could be quantified by an R^2 value of 0.1827. This indicates that the slope of the linear trendline (taken as the rate of subsidence) does not fully describe the correlation between ellipsoid height and time. Following the 2024 occupation of LEX1, an R^2 value of 0.7745 quantifies the correlation. This indicates that the slope of the trendline is improving in describing how ellipsoid height changes in time; therefore, we can gain confidence in the rate of subsidence. A similar situation exists for the data from the Eastern Shore marks (MSTP and PTNK), having only a 5-year period of record. Year-to-year variation in computed ellipsoid heights and a shorter length of data record may obscure trends that would be present over a longer period of record. However, an R^2 value of 0.9368 and 0.8996 at MSTP and PTNK show that one can have confidence that the linear trendline is describing how the ellipsoid height changes through time. The larger coefficients of determination for marks MSTP and PTNK over a shorter period of record may reflect the consistency in the survey over the past 5 years. The same survey equipment has been used each year, and the survey was conducted during the month of October each of the past 5 years. Other marks, specifically the marks in Anne Arundel County, were not surveyed with the same consistency in the late 1990's and early 2000's. Different equipment was used in different surveys, and the time of year the survey was conducted was not always consistent. This may explain why there is more variability in ellipsoid heights for these marks prior to the Maryland Geological Survey's participation in the project.

ACKNOWLEDGMENTS

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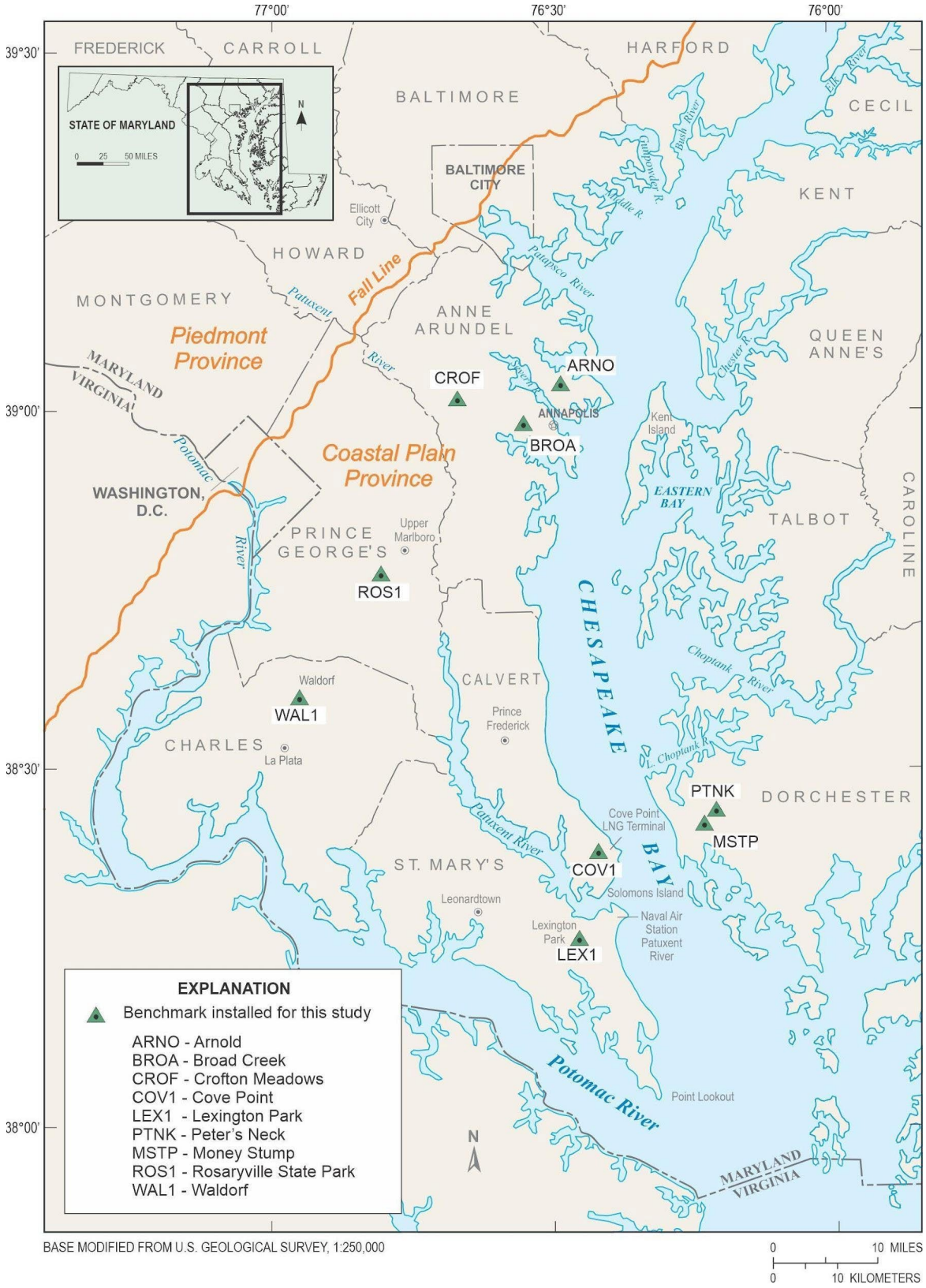


Figure 1. Location of the study area and MGS survey marks.

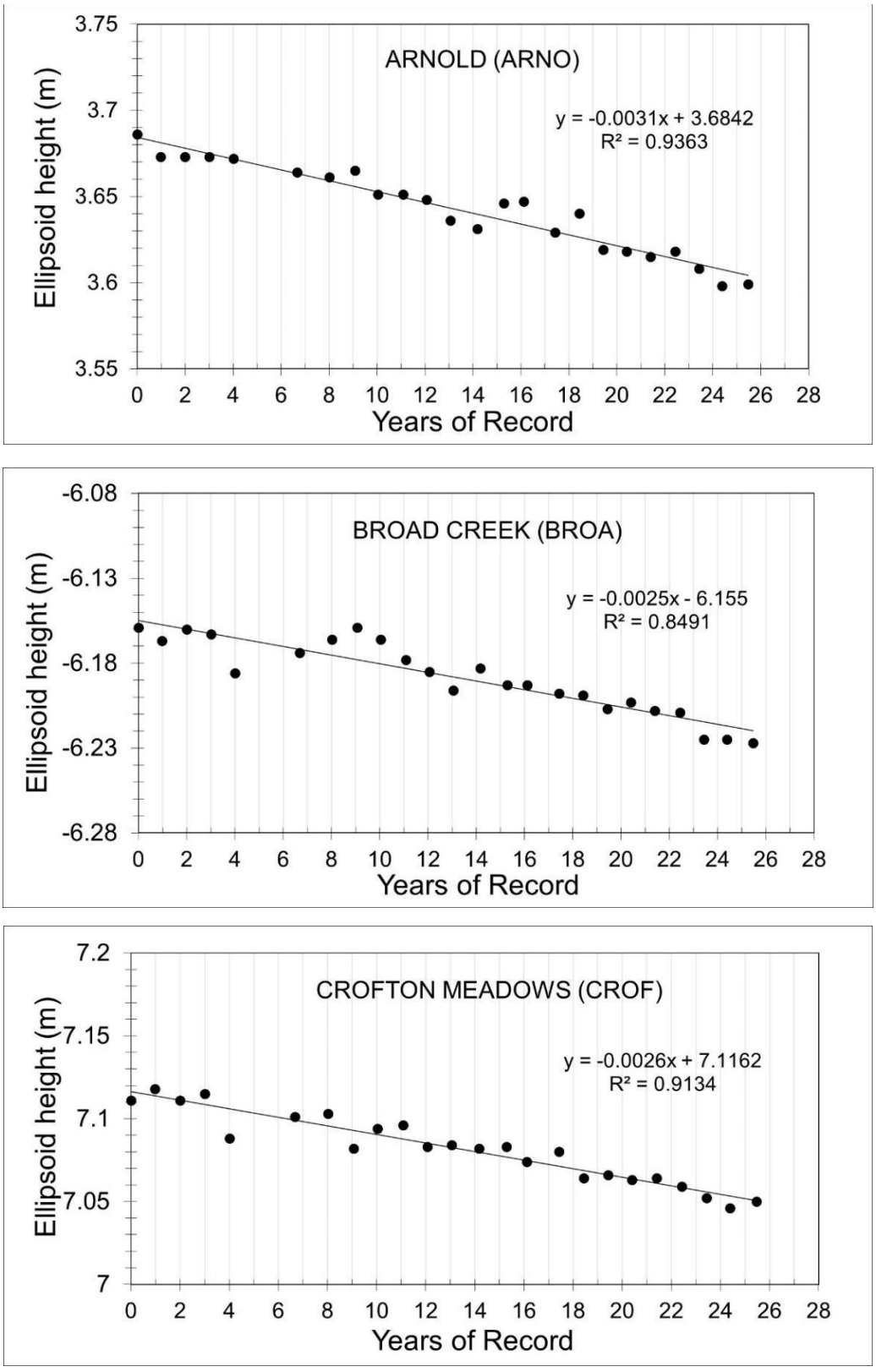


Figure 2. Change in ellipsoid heights from 1999 to present for marks ARNO, BROA, and CROF.

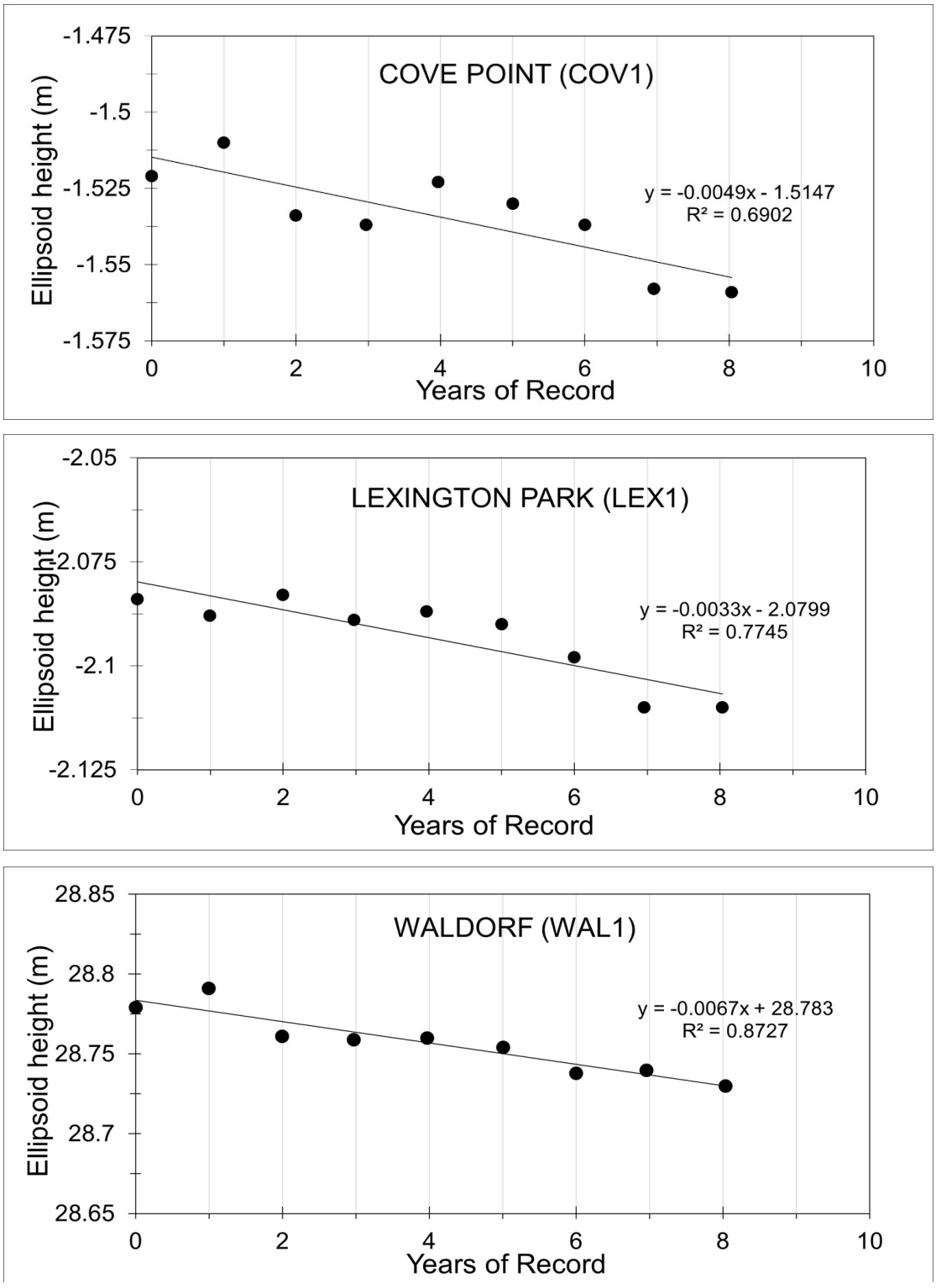
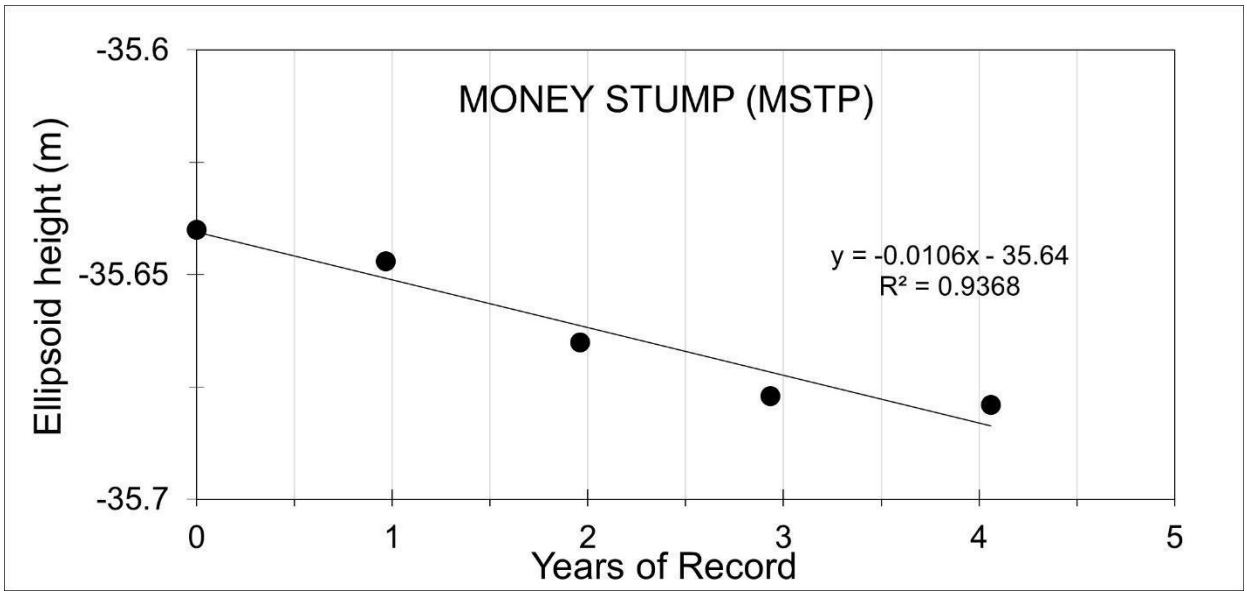


Figure 3. Change in ellipsoid heights from 2016 to present for marks COV1, LEX1, and WAL1.



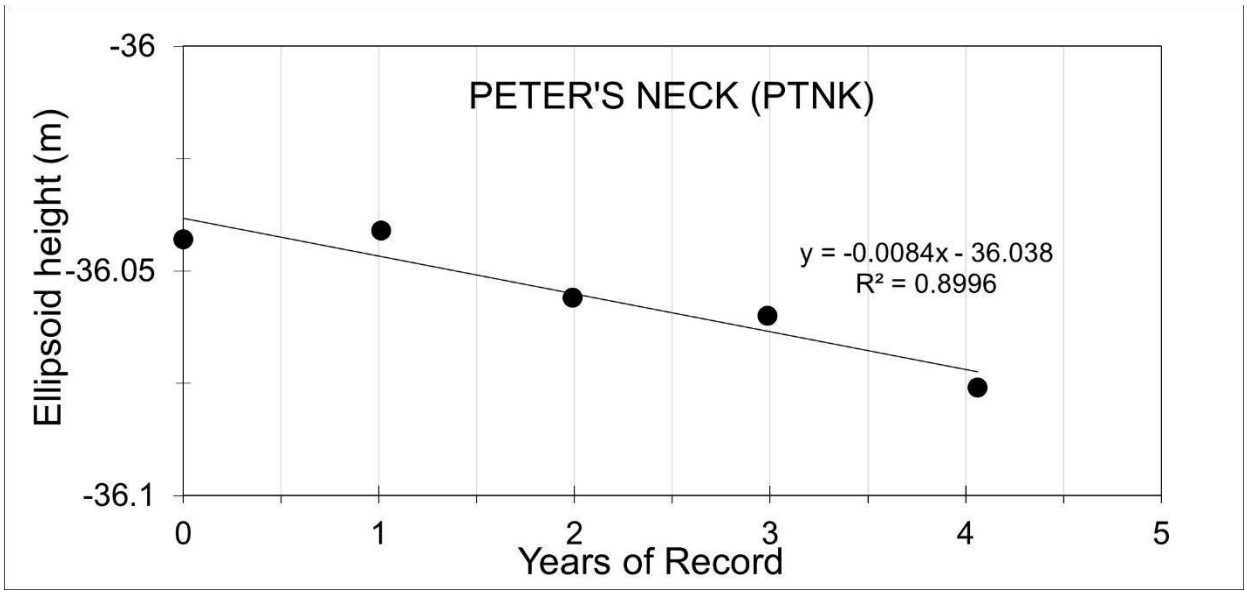


Figure 4. Change in ellipsoid heights from 2020 to present for marks MSTP and PTNK.

Table 1. GPS Sessions processed by OPUS Projects.

Session	Period (Coordinated Universal Time)	Hub CORS
1 (Day 301-A)	10/27/2024 0:00 to 23:59	GODE
2 (Day 302-A)	10/28/2024 0:00 to 23:59	GODE
3 (Day 303-A)	10/29/2024 0:00 to 23:59	GODE
4 (Day 304-A)	10/30/2024 0:00 to 23:59	GODE
5 (Day 305-A)	10/31/2024 0:00 to 23:59	GODE
6 (Day 306-A)	11/01/2024 0:00 to 23:59	GODE
7 (Day 307-A)	11/02/2024 0:00 to 23:59	GODE
8 (Day 308-A)	11/03/2024 0:00 to 23:59	GODE
9 (Day 309-A)	11/04/2024 0:00 to 23:59	GODE

Table 2. CORS sites used in processing GPS data.

CORS site	Start of record	State	Use in OPUS Projects	
BACO	1999	MD		Constrained
GODE	1993	MD	Hub	Constrained
GODS	2012	MD		Constrained
HNPT	1995	MD		Constrained
LOYF	2006	MD		Constrained
LOYO	2006	VA		Constrained
MDAI	2017	MD		Constrained
STKR	2000	OH	Troposphere Correction	Constrained
UMBC	2002	MD		Unconstrained
ZDC1	2003	VA		Constrained

Table 3. Summary of 2024 (Fall) GPS data.

Mark	Horizontal (ITRF2014)		Vertical (ITRF2014)	
	Latitude	Longitude	Ellipsoid height (m)	Vertical Velocity (mm/yr)
ARNO	39.03487°	-76.49035°	3.599	-3.1
BROA	38.98176°	-76.55864°	-6.227	-2.5
COV1	38.38644°	-76.42280°	-1.559	-4.9
CROF	39.01710°	-76.67458°	7.050	-2.6
LEX1	38.26324°	-76.45570°	-2.110	-3.3
MSTP	38.42996°	-76.22607°	-35.679	-10.6
PTNK	38.45108°	-76.20378°	-36.076	-8.4
WAL1	38.59907°	-76.93986°	28.730	-6.7

Appendix A. Observation form used to document the occupation of GPS benchmark.

Chesapeake Bay Regional Vertical Land Motion Project

STATIC GNSS OBSERVATION FORM

CAMPAIGN YEAR (circle one): 2020 2021 2022 ✓ 2024
STATION 4CID: ARNO
DAY OF YEAR: 302

NAME / PARTY	STATION NAME / DESCRIPTION	NGS PID (if applicable)
Thomas Ulizio	Arnold Water Treatment Plant (ARNO)	N/A

AFFILIATION	CONTACT INFORMATION
Maryland Geological Survey	PHONE NUMBER (____) ____ - _____ EMAIL thomas.ulizio@maryland.gov

STATION CITY	STATION STATE	GEOGRAPHIC INFORMATION
Arnold	MD	SOURCE Google Earth Pro ELEVATION 126 ✓ Feet Meters (Circle one) +/- _____ DATUM WGS84 LAT (Dec.Deg) 39 . 03467 LONG (Dec.Deg) -76 . 49047 DATUM WGS84

OBSERVATION SESSION START TIME (GMT)	OBSERVATION SESSION END TIME (GMT)	TIME DATUM ADJUSTMENT
DATE 10 / 28 / 2024 TIME 15 : 54	DATE 11 / 04 / 2024 TIME 12 : 54	EST + 5 = GMT EDT + 4 = GMT

EQUIPMENT INVENTORY

GNSS RECEIVER
Model: Trimble Net R9
Part no: 67668-30
S/N: 5834R50357
Firmware version: _____
Agency ID: NGS Net R9 Set K

GNSS ANTENNA
Model: Zephyr 3
Part no: TRM 115000-00
S/N: 6122223804
Agency ID: NGS Net R9 Set K
Radome: Yes ✓ No

TRIPOD
Type: Collapsible ✓ Fixed-Height
Agency ID: MGS 27
Calibration date: 11 / 20 / 2024

BATTERY
Voltage: 12 V Amp-hr: 18
Start: _____ V End: _____ V

SOLAR PANEL ✓ Yes No
Wattage 50 W
Agency ID: MGS

ANTENNA HEIGHT (m)
START: 1.9987 m
END: 1.9987 m
(1 ft = 0.3048 m)

RECEIVER PROGAMMING INFORMATION
COLLECTION INTERVAL 30 seconds (30-seconds is standard)
ELEVATION MASK 0 degrees (0 degrees is standard)

PHOTOGRAPHS (Take the following photographs and archive in campaign database)

	Description	Filename	Comments
1.	Close-up of monument	ARNO_closeup_20241028.jpg	
2.	Equipment setup	ARNO_setup_20241028.jpg	
3.	Horizon view North	ARNO_north_20241028.jpg	
4.	Horizon view East	ARNO_east_20241028.jpg	
5.	Horizon view South	ARNO_south_20241028.jpg	
6.	Horizon view West	ARNO_west_20241028.jpg	
7.	Receiver serial number	ARNO_receiver_20241028.jpg	
8.	Antenna serial number	ARNO_antenna_20241028.jpg	

GENERAL COMMENTS

File Download Date: 11 / 04 / 2024
Downloaded by: Thomas Ulizio
Raw Filename: ARNO302-ARNO309.T02
Raw File Size: 0.163-0.482 MB
Edits made to raw file? Yes
If edits made to raw file, explain: Changed raw file name to reflect VLM group naming conventions, 4CID, GPS day

RINEX Conversion Date: 11 / 04 / 2024
Converted by: Thomas Ulizio
RINEX filename: ARNO302-ARNO309.24o
RINEX File Size: 0.61-1.849 MB

Ver. 20200909

page 1 of 1

Appendix B. OPUS Projects network adjustment for the Fall, 2024 GPS survey.

```
NGS OPUS-Projects 5.2.0 NETWORK ADJUSTMENT REPORT
               ================================================

 All coordinate accuracies reported here are 1x the formal
 uncertainties from the solution. For additional information:
 geodesy.noaa.gov/OPUS/Using_OPUS-Projects.html#accuracy

 These positions were computed without any knowledge by the National
 Geodetic Survey regarding the equipment or field operating procedures used.

 SUBMITTED BY:                   thomas.ulizio
 SOLUTION FILE NAME:             network-final_GODE.sum
 SOLUTION SOFTWARE:              GPSCOM(2008.25)
 SOLUTION DATE:                  2025-03-25T13:13:45 UTC
 STANDARD ERROR OF UNIT WEIGHT: 0.826
 TOTAL NUMBER OF OBSERVATIONS:  1504324
 TOTAL NUMBER OF MARKS:          19
 CONSTRAINED MARKS:              9 HORIZONTAL, 0 VERTICAL
 baco N39:23:58.06805 W076:36:24.45999 127.0283m        ITRF2014 @ 2010.0000
 baco         0.12cm           0.12cm     0.12cm        NEU SIGMAS
 gode N39:01:18.21996 W076:49:36.59163  14.4978m        ITRF2014 @ 2010.0000
 gode         0.12cm           0.12cm     0.12cm        NEU SIGMAS
 gods N39:01:13.86263 W076:49:38.36014  19.0901m        ITRF2014 @ 2010.0000
 gods         0.14cm           0.04cm     0.14cm        NEU SIGMAS
 hnpt N38:35:19.74021 W076:07:49.34788 -27.9747m        ITRF2014 @ 2010.0000
 hnpt         0.08cm           0.16cm     0.09cm        NEU SIGMAS
 loyf N38:58:28.10461 W076:31:19.90184 -15.7881m        ITRF2014 @ 2010.0000
 loyf         0.12cm           0.10cm     0.13cm        NEU SIGMAS
 loyo N38:03:00.65565 W077:20:51.19103  41.8661m        ITRF2014 @ 2010.0000
 loyo         0.12cm           0.10cm     0.12cm        NEU SIGMAS
 mdai N38:08:20.62172 W075:11:19.85741 -34.4832m        ITRF2014 @ 2010.0000
 mdai         0.12cm           0.12cm     0.12cm        NEU SIGMAS
 umbc N39:15:24.38997 W076:42:41.48499  64.6647m        ITRF2014 @ 2010.0000
 umbc         0.13cm           0.08cm     0.13cm        NEU SIGMAS
 zdc1 N39:06:05.74479 W077:32:33.88523  79.6180m        ITRF2014 @ 2010.0000
 zdc1         0.14cm           0.06cm     0.14cm        NEU SIGMAS

 START TIME:                     2024-10-28T00:00:00 GPS
 STOP TIME:                      2024-11-04T23:59:30 GPS
 FREQUENCY:                      L1-ONLY TO ION-FREE [BY BASELINE LENGTH]
 OBSERVATION INTERVAL:           30 s
 ELEVATION CUTOFF:               15 deg
 TROPO INTERVAL:                 7200 s [PIECEWISE LINEAR PARAMETERIZATION]
 DD CORRELATIONS:                ON

     INCLUDED SOLUTION             RMS    SOFTWARE         RUN DATE
 ------------------------------------------------------------------------------
  1) 2024-302 A-A-A-GODE          1.3 cm  page5(2008.25)   2025-03-25T12:25 UTC
  2) 2024-303 A-GODE              1.4 cm  page5(2008.25)   2025-03-25T12:36 UTC
  3) 2024-304 A-GODE              1.3 cm  page5(2008.25)   2025-03-25T12:46 UTC
  4) 2024-305 A-GODE              1.2 cm  page5(2008.25)   2025-03-25T12:58 UTC
  5) 2024-306 A-GODE              1.5 cm  page5(2008.25)   2025-03-25T13:09 UTC
  6) 2024-307 A-GODE              1.2 cm  page5(2008.25)   2025-03-11T10:44 UTC
  7) 2024-308 A-GODE              1.1 cm  page5(2008.25)   2025-03-11T10:44 UTC
  8) 2024-309 A-GODE              1.1 cm  page5(2008.25)   2025-03-11T10:45 UTC

   BASELINE      LENGTH          RMS       OBS   OMITTED    FIXED IN SOLUTION(S)
 ------------------------------------------------------------------------------
  gods-gode      0.141 km      0.3 cm    91213     0.5%   100.0%    1, 2, 3,...
  crof-gode     13.195 km      1.2 cm    83780     6.8%    99.0%    1, 2, 3,...
```

Appendix B. Continued.

```
 broa-gode     23.651 km      1.4 cm    44905     7.2%    97.4%    4, 5, 6,...
 loyf-gode     26.907 km      1.2 cm   119148     0.8%    89.1%    1, 2, 3,...
 umbc-gode     27.934 km      1.3 cm   119921     0.7%    99.8%    1, 2, 3,...
 arno-gode     29.173 km      1.3 cm    93574     3.3%    98.5%    2, 3, 4,...
 84tb-gode     34.288 km      1.1 cm    61735     1.4%    99.7%    1, 2, 3, 4
 baco-gode     46.042 km      1.2 cm   118728     1.3%    96.5%    1, 2, 3,...
 wal1-gode     47.936 km      1.7 cm    52889    18.6%    95.0%    1, 2, 3, 4
 zdc1-gode     62.595 km      1.4 cm   108244     1.8%    96.9%    1, 2, 3,...
 hnpt-gode     77.261 km      1.4 cm   102925     1.0%    93.6%    1, 2, 3,...
 cov1-gode     78.794 km      1.4 cm    58676     4.6%    95.8%    1, 2, 3, 4
 ptnk-gode     83.350 km      2.0 cm    39897    19.2%    95.9%    1, 2, 3
 mstp-gode     83.930 km      1.5 cm    52472    17.9%    92.2%    1, 2, 3,...
 lex1-gode     90.184 km      1.6 cm    62799    17.6%    94.3%    1, 2, 3,...
 loyo-gode    117.013 km      1.5 cm    92377     1.4%    92.3%    1, 2, 3,...
 mdai-gode    173.112 km      1.0 cm    96459     0.5%    99.9%    1, 2, 3,...
 stkr-gode    457.384 km      1.2 cm   104582     1.4%    94.3%    1, 2, 3,...

 MARK  ESTIMATED - A PRIORI COORDINATE SHIFTS
-------------------------------------------------------------------------------
 84tb  N:      0.001 m (0.000 m) E:     -0.001 m (0.000 m) H:     -0.008 m (0.001 m)
 arno  N:      0.004 m (0.000 m) E:     -0.003 m (0.000 m) H:     -0.093 m (0.001 m)
 baco  N:      0.002 m (0.000 m) E:     -0.001 m (0.000 m) H:     -0.006 m (0.000 m)
 broa  N:      0.002 m (0.000 m) E:     -0.001 m (0.000 m) H:      0.000 m (0.001 m)
 cov1  N:     -0.003 m (0.000 m) E:      0.001 m (0.000 m) H:      0.002 m (0.001 m)
 crof  N:      0.002 m (0.000 m) E:     -0.007 m (0.000 m) H:     -0.005 m (0.001 m)
 gode  N:     -0.002 m (0.000 m) E:      0.001 m (0.000 m) H:      0.001 m (0.000 m)
 gods  N:     -0.007 m (0.000 m) E:      0.001 m (0.000 m) H:      0.015 m (0.001 m)
 hnpt  N:      0.001 m (0.000 m) E:      0.000 m (0.000 m) H:     -0.001 m (0.000 m)
 lex1  N:     -0.001 m (0.000 m) E:      0.000 m (0.000 m) H:     -0.011 m (0.001 m)
 loyf  N:      0.000 m (0.000 m) E:     -0.001 m (0.000 m) H:      0.000 m (0.000 m)
 loyo  N:      0.002 m (0.000 m) E:      0.000 m (0.000 m) H:      0.002 m (0.001 m)
 mdai  N:     -0.001 m (0.000 m) E:     -0.001 m (0.000 m) H:     -0.005 m (0.000 m)
 mstp  N:     -0.005 m (0.000 m) E:     -0.005 m (0.000 m) H:      0.025 m (0.001 m)
 ptnk  N:      0.002 m (0.000 m) E:     -0.003 m (0.000 m) H:      0.003 m (0.001 m)
 stkr  N:     -0.007 m (0.000 m) E:      0.003 m (0.000 m) H:      0.002 m (0.001 m)
 umbc  N:      0.003 m (0.000 m) E:     -0.003 m (0.000 m) H:     -0.001 m (0.000 m)
 wal1  N:      0.001 m (0.000 m) E:     -0.001 m (0.000 m) H:      0.008 m (0.001 m)
 zdc1  N:     -0.004 m (0.000 m) E:      0.000 m (0.000 m) H:      0.000 m (0.000 m)

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UNCONSTRAINED MARKS
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MARK:      84tb (84tb    1)

REF FRAME:    NAD_83(2011) @ 2010.00000000          ITRF2014 @ 2024.82875898
X:                1147537.214 m    0.000 m          1147536.234 m    0.000 m
Y:               -4809805.646 m    0.001 m         -4809804.209 m    0.001 m
Z:                4015048.329 m    0.001 m          4015048.291 m    0.001 m
LAT:           39 15 50.88790      0.000 m       39 15 50.92031      0.000 m
E LON:        283 25 08.16590      0.000 m      283 25 08.14005      0.000 m
W LON:         76 34 51.83410      0.000 m       76 34 51.85995      0.000 m
EL HGT:              -23.618 m    0.001 m             -24.900 m    0.001 m
ORTHO HGT:             9.230 m    0.015 m  (= EL HGT - -32.848 GEOID18 HGT)

                UTM COORDINATES    STATE PLANE COORDINATES
                 UTM (Zone 18)         SPC (1900 MD)
NORTHING (Y)      4347279.910 m         177411.813 m
EASTING (X)        363599.803 m         436154.403 m
CONVERGENCE       -1.00080556 deg       0.26293889 deg
POINT SCALE        0.99982908           0.99997277
```

Appendix B. Continued.

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COMBINED FACTOR    0.99983278          0.99997648

US NATIONAL GRID DESIGNATOR: 18SUJ6360047280 (NAD 83)

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MARK:      arno (arno    1)

REF FRAME:    NAD_83(2011) @ 2010.00000000          ITRF2014 @ 2024.83271839
X:                1158910.174 m    0.000 m          1158909.196 m    0.000 m
Y:               -4823629.173 m    0.001 m         -4823627.733 m    0.001 m
Z:                3995327.604 m    0.000 m          3995327.565 m    0.000 m
LAT:           39 02 05.52439      0.000 m       39 02 05.55667      0.000 m
E LON:        283 30 34.73964      0.000 m      283 30 34.71410      0.000 m
W LON:         76 29 25.26036      0.000 m       76 29 25.28590      0.000 m
EL HGT:               4.888 m    0.001 m               3.599 m    0.001 m
ORTHO HGT:           38.143 m    0.015 m  (= EL HGT - -33.255 GEOID18 HGT)

                UTM COORDINATES    STATE PLANE COORDINATES
                 UTM (Zone 18)         SPC (1900 MD)
NORTHING (Y)      4321702.617 m         152000.085 m
EASTING (X)        371008.293 m         444125.188 m
CONVERGENCE       -0.93874167 deg       0.31987500 deg
POINT SCALE        0.99980488           0.99995369
COMBINED FACTOR    0.99980411           0.99995292

US NATIONAL GRID DESIGNATOR: 18SUJ7100821703 (NAD 83)

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MARK:      broa (broa    1)

REF FRAME:    NAD_83(2011) @ 2010.00000000          ITRF2014 @ 2024.83676546
X:                1154021.080 m    0.000 m          1154020.102 m    0.000 m
Y:               -4828609.386 m    0.001 m         -4828607.945 m    0.001 m
Z:                3990739.537 m    0.001 m          3990739.497 m    0.001 m
LAT:           38 58 54.31430      0.000 m       38 58 54.34652      0.000 m
E LON:        283 26 28.89528      0.000 m      283 26 28.86969      0.000 m
W LON:         76 33 31.10472      0.000 m       76 33 31.13031      0.000 m
EL HGT:              -4.936 m    0.001 m              -6.227 m    0.001 m
ORTHO HGT:           28.249 m    0.015 m  (= EL HGT - -33.185 GEOID18 HGT)

                UTM COORDINATES    STATE PLANE COORDINATES
                 UTM (Zone 18)         SPC (1900 MD)
NORTHING (Y)      4315907.116 m         146073.161 m
EASTING (X)        364996.444 m         438241.228 m
CONVERGENCE       -0.98064722 deg       0.27701111 deg
POINT SCALE        0.99982443           0.99995155
COMBINED FACTOR    0.99982520           0.99995232

US NATIONAL GRID DESIGNATOR: 18SUJ6499615907 (NAD 83)

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MARK:      cov1 (cov1    1)

REF FRAME:    NAD_83(2011) @ 2010.00000000          ITRF2014 @ 2024.82880401
X:                1175163.267 m    0.000 m          1175162.294 m    0.000 m
Y:               -4866014.456 m    0.001 m         -4866013.006 m    0.001 m
Z:                3939155.571 m    0.001 m          3939155.528 m    0.001 m
LAT:           38 23 11.16066      0.000 m       38 23 11.19254      0.000 m
```

Appendix B. Continued.

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E LON:        283 34 37.91873      0.000 m      283 34 37.89379      0.000 m
W LON:         76 25 22.08127      0.000 m       76 25 22.10621      0.000 m
EL HGT:               -0.249 m    0.001 m              -1.559 m    0.001 m
ORTHO HGT:            34.143 m    0.017 m  (= EL HGT - -34.392 GEOID18 HGT)

               UTM COORDINATES    STATE PLANE COORDINATES
                UTM (Zone 18)         SPC (1900 MD)
NORTHING (Y)      4249650.216 m          80056.590 m
EASTING (X)        375737.324 m         450428.644 m
CONVERGENCE       -0.88361944 deg       0.36226944 deg
POINT SCALE        0.99979016           0.99998609
COMBINED FACTOR    0.99979020           0.99998613

US NATIONAL GRID DESIGNATOR: 18SUH7573749650 (NAD 83)

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MARK:      crof (crof    1)

REF FRAME:    NAD_83(2011) @ 2010.00000000          ITRF2014 @ 2024.83164646
X:                1143680.963 m    0.000 m          1143679.985 m    0.000 m
Y:               -4828541.799 m    0.001 m         -4828540.360 m    0.001 m
Z:                3993797.473 m    0.000 m          3993797.433 m    0.000 m
LAT:           39 01 01.56295      0.000 m       39 01 01.59514      0.000 m
E LON:        283 19 31.50629      0.000 m      283 19 31.48053      0.000 m
W LON:         76 40 28.49371      0.000 m       76 40 28.51947      0.000 m
EL HGT:               8.338 m    0.001 m              7.050 m    0.001 m
ORTHO HGT:           41.153 m    0.015 m  (= EL HGT - -32.815 GEOID18 HGT)

               UTM COORDINATES    STATE PLANE COORDINATES
                UTM (Zone 18)         SPC (1900 MD)
NORTHING (Y)      4320008.250 m         149954.806 m
EASTING (X)        355025.628 m         428181.652 m
CONVERGENCE       -1.05441944 deg       0.20424444 deg
POINT SCALE        0.99985880           0.99995288
COMBINED FACTOR    0.99985749           0.99995157

US NATIONAL GRID DESIGNATOR: 18SUJ5502620008 (NAD 83)

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MARK:      lex1 (lex1    1)

REF FRAME:    NAD_83(2011) @ 2010.00000000          ITRF2014 @ 2024.82965518
X:                1174354.961 m    0.000 m          1174353.989 m    0.000 m
Y:               -4874932.323 m    0.001 m         -4874930.871 m    0.001 m
Z:                3928427.059 m    0.001 m          3928427.014 m    0.001 m
LAT:           38 15 47.65626      0.000 m       38 15 47.68804      0.000 m
E LON:        283 32 39.48257      0.000 m      283 32 39.45768      0.000 m
W LON:         76 27 20.51743      0.000 m       76 27 20.54232      0.000 m
EL HGT:               -0.795 m    0.001 m              -2.110 m    0.001 m
ORTHO HGT:            33.709 m    0.017 m  (= EL HGT - -34.504 GEOID18 HGT)

               UTM COORDINATES    STATE PLANE COORDINATES
                UTM (Zone 18)         SPC (1900 MD)
NORTHING (Y)      4236024.443 m          66364.189 m
EASTING (X)        372648.469 m         447635.908 m
CONVERGENCE       -0.90160000 deg       0.34162222 deg
POINT SCALE        0.99979974           1.00000660
COMBINED FACTOR    0.99979986           1.00000672
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Appendix B. Continued.

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US NATIONAL GRID DESIGNATOR: 18SUH7264836024 (NAD 83)

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MARK:      mstp (mstp    1)

REF FRAME:    NAD_83(2011) @ 2010.00000000          ITRF2014 @ 2024.82923823
X:                1191143.023 m    0.000 m          1191142.050 m    0.000 m
Y:               -4859009.462 m    0.001 m         -4859008.013 m    0.001 m
Z:                3942920.434 m    0.001 m          3942920.391 m    0.001 m
LAT:           38 25 47.85553      0.000 m       38 25 47.88748      0.000 m
E LON:        283 46 26.14144      0.000 m      283 46 26.11672      0.000 m
W LON:         76 13 33.85856      0.000 m       76 13 33.88328      0.000 m
EL HGT:              -34.369 m    0.001 m             -35.679 m    0.001 m
ORTHO HGT:             0.539 m    0.015 m  (= EL HGT - -34.908 GEOID18 HGT)

                UTM COORDINATES    STATE PLANE COORDINATES
                 UTM (Zone 18)         SPC (1900 MD)
NORTHING (Y)      4254233.468 m          85015.137 m
EASTING (X)        392983.819 m         467575.056 m
CONVERGENCE       -0.76214722 deg       0.48574444 deg
POINT SCALE        0.99974104           0.99997993
COMBINED FACTOR    0.99974643           0.99998532

US NATIONAL GRID DESIGNATOR: 18SUH9298454233 (NAD 83)

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MARK:      ptnk (ptnk    1)

REF FRAME:    NAD_83(2011) @ 2010.00000000          ITRF2014 @ 2024.82585692
X:                1192685.673 m    0.000 m          1192684.700 m    0.000 m
Y:               -4857129.957 m    0.001 m         -4857128.508 m    0.001 m
Z:                3944756.393 m    0.001 m          3944756.351 m    0.001 m
LAT:           38 27 03.88496      0.000 m       38 27 03.91694      0.000 m
E LON:        283 47 46.38790      0.000 m      283 47 46.36318      0.000 m
W LON:         76 12 13.61210      0.000 m       76 12 13.63682      0.000 m
EL HGT:              -34.766 m    0.001 m             -36.076 m    0.001 m
ORTHO HGT:             0.179 m    0.015 m  (= EL HGT - -34.945 GEOID18 HGT)

                UTM COORDINATES    STATE PLANE COORDINATES
                 UTM (Zone 18)         SPC (1900 MD)
NORTHING (Y)      4256551.344 m          87376.079 m
EASTING (X)        394960.116 m         469500.858 m
CONVERGENCE       -0.74863611 deg       0.49973333 deg
POINT SCALE        0.99973588           0.99997715
COMBINED FACTOR    0.99974133           0.99998260

US NATIONAL GRID DESIGNATOR: 18SUH9496056551 (NAD 83)

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MARK:      stkr (0011; stkr a  3)

REF FRAME:    NAD_83(2011) @ 2010.00000000          ITRF2014 @ 2024.83082808
X:                 678451.047 m    0.000 m           678450.069 m    0.000 m
Y:               -4893799.723 m    0.001 m         -4893798.289 m    0.001 m
Z:                4020496.777 m    0.000 m          4020496.699 m    0.000 m
LAT:           39 19 33.82470      0.000 m       39 19 33.85471      0.000 m
E LON:        277 53 34.37039      0.000 m      277 53 34.33817      0.000 m
W LON:         82 06 25.62961      0.000 m       82 06 25.66183      0.000 m
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Appendix B. Continued.

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EL HGT:               178.037 m    0.001 m              176.785 m    0.001 m
ORTHO HGT:            212.223 m    0.018 m  (= EL HGT - -34.186 GEOID18 HGT)

               UTM COORDINATES    STATE PLANE COORDINATES
                UTM (Zone 17)         SPC (3402 OH S)
NORTHING (Y)      4353545.413 m         147284.033 m
EASTING (X)        404572.971 m         633874.821 m
CONVERGENCE       -0.70166944 deg       0.24929167 deg
POINT SCALE        0.99971212           0.99993642
COMBINED FACTOR    0.99968420           0.99990849

US NATIONAL GRID DESIGNATOR: 17SMD0457353545 (NAD 83)

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MARK:      wal1 (wal1    1)

REF FRAME:    NAD_83(2011) @ 2010.00000000          ITRF2014 @ 2024.82856289
X:                1127888.794 m    0.000 m          1127887.820 m    0.000 m
Y:               -4862133.226 m    0.001 m         -4862131.781 m    0.001 m
Z:                3957648.533 m    0.001 m          3957648.489 m    0.001 m
LAT:           38 35 56.63664      0.000 m       38 35 56.66846      0.000 m
E LON:        283 03 36.50701      0.000 m      283 03 36.48131      0.000 m
W LON:         76 56 23.49299      0.000 m       76 56 23.51869      0.000 m
EL HGT:               30.030 m    0.001 m              28.730 m    0.001 m
ORTHO HGT:            62.940 m    0.016 m  (= EL HGT - -32.910 GEOID18 HGT)

               UTM COORDINATES    STATE PLANE COORDINATES
                UTM (Zone 18)         SPC (1900 MD)
NORTHING (Y)      4274070.445 m         103501.658 m
EASTING (X)        331073.115 m         405238.856 m
CONVERGENCE       -1.21050000 deg       0.03774722 deg
POINT SCALE        0.99995142           0.99996145
COMBINED FACTOR    0.99994671           0.99995674

US NATIONAL GRID DESIGNATOR: 18SUH3107374070 (NAD 83)


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CONSTRAINED MARKS
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MARK:      baco (0001; baco a  2)
CONSTRAIN: 3-D NORMAL
     N39:23:58.06805 W076:36:24.45999 127.0283m        ITRF2014 @ 2010.0000
            0.12cm           0.12cm     0.12cm        NEU SIGMAS
SHIFTS N:      0.002 m (0.000 m) E:     -0.001 m (0.000 m) H:     -0.006 m (0.000 m)

REF FRAME:    NAD_83(2011) @ 2010.00000000          ITRF2014 @ 2024.83132498
X:                1143199.184 m    0.000 m          1143198.202 m    0.000 m
Y:               -4801171.602 m    0.000 m         -4801170.165 m    0.000 m
Z:                4026765.136 m    0.000 m          4026765.099 m    0.000 m
LAT:           39 23 58.03751      0.000 m       39 23 58.07005      0.000 m
E LON:        283 23 35.55686      0.000 m      283 23 35.53083      0.000 m
W LON:         76 36 24.44314      0.000 m       76 36 24.46917      0.000 m
EL HGT:               128.299 m    0.000 m              127.019 m    0.000 m
ORTHO HGT:            160.867 m    0.015 m  (= EL HGT - -32.568 GEOID18 HGT)

               UTM COORDINATES    STATE PLANE COORDINATES
                UTM (Zone 18)         SPC (1900 MD)
NORTHING (Y)      4362337.561 m         192424.923 m
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Appendix B. Continued.

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EASTING (X)        361647.404 m         433869.644 m
CONVERGENCE       -1.02002778 deg       0.24679167 deg
POINT SCALE        0.99983568           0.99999155
COMBINED FACTOR    0.99981556           0.99997142

US NATIONAL GRID DESIGNATOR: 18SUJ6164762338 (NAD 83)

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MARK:      gode (0002; gode a  4)
CONSTRAIN: 3-D NORMAL
     N39:01:18.21996 W076:49:36.59163  14.4978m        ITRF2014 @ 2010.0000
             0.12cm           0.12cm     0.12cm        NEU SIGMAS
SHIFTS N:     -0.002 m (0.000 m) E:      0.001 m (0.000 m) H:      0.001 m (0.000 m)

REF FRAME:    NAD_83(2011) @ 2010.00000000          ITRF2014 @ 2024.83060049
X:                1130774.429 m    0.000 m          1130773.447 m    0.000 m
Y:               -4831255.027 m    0.000 m         -4831253.570 m    0.000 m
Z:                3994200.519 m    0.000 m          3994200.470 m    0.000 m
LAT:            39 01 18.18965      0.000 m       39 01 18.22193      0.000 m
E LON:         283 10 23.42531      0.000 m      283 10 23.39938      0.000 m
W LON:          76 49 36.57469      0.000 m       76 49 36.60062      0.000 m
EL HGT:               15.785 m    0.000 m              14.479 m    0.000 m
ORTHO HGT:            48.165 m    0.015 m  (= EL HGT - -32.380 GEOID18 HGT)

               UTM COORDINATES    STATE PLANE COORDINATES
                UTM (Zone 18)         SPC (1900 MD)
NORTHING (Y)      4320774.468 m         150431.506 m
EASTING (X)        341854.667 m         414996.115 m
CONVERGENCE       -1.15043611 deg       0.10868889 deg
POINT SCALE        0.99990796           0.99995308
COMBINED FACTOR    0.99990548           0.99995060

US NATIONAL GRID DESIGNATOR: 18SUJ4185520774 (NAD 83)

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MARK:      gods (0003; gods a  1)
CONSTRAIN: 3-D NORMAL
     N39:01:13.86263 W076:49:38.36014  19.0901m        ITRF2014 @ 2010.0000
             0.14cm           0.04cm     0.14cm        NEU SIGMAS
SHIFTS N:     -0.007 m (0.000 m) E:      0.001 m (0.000 m) H:      0.015 m (0.001 m)

REF FRAME:    NAD_83(2011) @ 2010.00000000          ITRF2014 @ 2024.82920816
X:                1130753.102 m    0.000 m          1130752.113 m    0.000 m
Y:               -4831350.585 m    0.000 m         -4831349.112 m    0.000 m
Z:                3994099.021 m    0.000 m          3994098.970 m    0.000 m
LAT:            39 01 13.83215      0.000 m       39 01 13.86475      0.000 m
E LON:         283 10 21.65681      0.000 m      283 10 21.63075      0.000 m
W LON:          76 49 38.34319      0.000 m       76 49 38.36925      0.000 m
EL HGT:               20.392 m    0.001 m              19.071 m    0.001 m
ORTHO HGT:            52.772 m    0.015 m  (= EL HGT - -32.380 GEOID18 HGT)

               UTM COORDINATES    STATE PLANE COORDINATES
                UTM (Zone 18)         SPC (1900 MD)
NORTHING (Y)      4320640.986 m         150297.056 m
EASTING (X)        341809.439 m         414953.829 m
CONVERGENCE       -1.15071389 deg       0.10838056 deg
POINT SCALE        0.99990814           0.99995303
COMBINED FACTOR    0.99990494           0.99994983
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Appendix B. Continued.

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US NATIONAL GRID DESIGNATOR: 18SUJ4180920641 (NAD 83)

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MARK:      hnpt (0004; hnpt a  4)
CONSTRAIN: 3-D NORMAL
     N38:35:19.74021 W076:07:49.34788 -27.9747m        ITRF2014 @ 2010.0000
            0.08cm           0.16cm     0.09cm        NEU SIGMAS
SHIFTS N:      0.001 m (0.000 m) E:      0.000 m (0.000 m) H:     -0.001 m (0.000 m)

REF FRAME:    NAD_83(2011) @ 2010.00000000          ITRF2014 @ 2024.82992885
X:                1196627.025 m    0.000 m          1196626.039 m    0.000 m
Y:               -4846359.960 m    0.000 m         -4846358.483 m    0.000 m
Z:                3956723.211 m    0.000 m          3956723.152 m    0.000 m
LAT:           38 35 19.71010      0.000 m       38 35 19.74239      0.000 m
E LON:        283 52 10.66804      0.000 m      283 52 10.64313      0.000 m
W LON:         76 07 49.33196      0.000 m       76 07 49.35687      0.000 m
EL HGT:              -26.671 m    0.000 m             -28.013 m    0.000 m
ORTHO HGT:             8.229 m    0.015 m  (= EL HGT - -34.900 GEOID18 HGT)

               UTM COORDINATES    STATE PLANE COORDINATES
                UTM (Zone 18)         SPC (1900 MD)
NORTHING (Y)      4271753.565 m         102722.196 m
EASTING (X)        401553.852 m         475762.994 m
CONVERGENCE       -0.70510000 deg       0.54580833 deg
POINT SCALE        0.99971935           0.99996232
COMBINED FACTOR    0.99972353           0.99996650

US NATIONAL GRID DESIGNATOR: 18SVH0155471754 (NAD 83)

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MARK:      loyf (0005; loyf a  2)
CONSTRAIN: 3-D NORMAL
     N38:58:28.10461 W076:31:19.90184 -15.7881m        ITRF2014 @ 2010.0000
            0.12cm           0.10cm     0.13cm        NEU SIGMAS
SHIFTS N:      0.000 m (0.000 m) E:     -0.001 m (0.000 m) H:      0.000 m (0.000 m)

REF FRAME:    NAD_83(2011) @ 2010.00000000          ITRF2014 @ 2024.83132210
X:                1157209.557 m    0.000 m          1157208.572 m    0.000 m
Y:               -4828362.000 m    0.000 m         -4828360.535 m    0.000 m
Z:                3990104.481 m    0.000 m          3990104.428 m    0.000 m
LAT:           38 58 28.07431      0.000 m       38 58 28.10670      0.000 m
E LON:        283 28 40.11463      0.000 m      283 28 40.08904      0.000 m
W LON:         76 31 19.88537      0.000 m       76 31 19.91096      0.000 m
EL HGT:              -14.497 m    0.000 m             -15.817 m    0.000 m
ORTHO HGT:            18.783 m    0.015 m  (= EL HGT - -33.280 GEOID18 HGT)

               UTM COORDINATES    STATE PLANE COORDINATES
                UTM (Zone 18)         SPC (1900 MD)
NORTHING (Y)      4315044.792 m         145279.935 m
EASTING (X)        368140.227 m         441403.598 m
CONVERGENCE       -0.95755556 deg       0.29988889 deg
POINT SCALE        0.99981410           0.99995133
COMBINED FACTOR    0.99981637           0.99995360

US NATIONAL GRID DESIGNATOR: 18SUJ6814015045 (NAD 83)

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MARK:      loyo (0006; loyo a  3)
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Appendix B. Continued.

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CONSTRAIN: 3-D NORMAL
     N38:03:00.65565 W077:20:51.19103  41.8661m        ITRF2014 @ 2010.0000
             0.12cm           0.10cm     0.12cm        NEU SIGMAS
SHIFTS N:      0.002 m (0.000 m) E:      0.000 m (0.000 m) H:      0.002 m (0.001 m)

REF FRAME:    NAD_83(2011) @ 2010.00000000          ITRF2014 @ 2024.82919702
X:                1101542.004 m    0.000 m          1101541.032 m    0.000 m
Y:               -4906910.941 m    0.000 m         -4906909.477 m    0.000 m
Z:                3909857.638 m    0.000 m          3909857.580 m    0.000 m
LAT:           38 03 00.62633      0.000 m       38 03 00.65765      0.000 m
E LON:        282 39 08.82596      0.000 m      282 39 08.80021      0.000 m
W LON:         77 20 51.17404      0.000 m       77 20 51.19979      0.000 m
EL HGT:               43.181 m    0.001 m              41.853 m    0.001 m
ORTHO HGT:            75.865 m    0.021 m  (= EL HGT - -32.684 GEOID18 HGT)

                UTM COORDINATES    STATE PLANE COORDINATES
                 UTM (Zone 18)         SPC (4501 VA N)
NORTHING (Y)      4213983.648 m        2043203.431 m
EASTING (X)        294018.051 m        3601150.708 m
CONVERGENCE       -1.44742222 deg       0.71926667 deg
POINT SCALE        1.00012258           0.99999707
COMBINED FACTOR    1.00011580           0.99999029

US NATIONAL GRID DESIGNATOR: 18STH9401813984 (NAD 83)

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MARK:      mdai (0010; mdai a  1)
CONSTRAIN: 3-D NORMAL
     N38:08:20.62172 W075:11:19.85741 -34.4832m        ITRF2014 @ 2010.0000
             0.12cm           0.12cm     0.12cm        NEU SIGMAS
SHIFTS N:     -0.001 m (0.000 m) E:     -0.001 m (0.000 m) H:     -0.005 m (0.000 m)

REF FRAME:    NAD_83(2011) @ 2010.00000000          ITRF2014 @ 2024.83167100
X:                1284020.345 m    0.000 m          1284019.374 m    0.000 m
Y:               -4855993.772 m    0.000 m         -4855992.315 m    0.000 m
Z:                3917574.576 m    0.000 m          3917574.538 m    0.000 m
LAT:           38 08 20.59161      0.000 m       38 08 20.62382      0.000 m
E LON:        284 48 40.15711      0.000 m      284 48 40.13385      0.000 m
W LON:         75 11 19.84289      0.000 m       75 11 19.86615      0.000 m
EL HGT:             -33.164 m     0.000 m             -34.490 m     0.000 m
ORTHO HGT:            3.127 m     0.019 m  (= EL HGT - -36.291 GEOID18 HGT)

                UTM COORDINATES    STATE PLANE COORDINATES
                 UTM (Zone 18)         SPC (1900 MD)
NORTHING (Y)      4221260.289 m          54012.449 m
EASTING (X)        483451.241 m         558771.981 m
CONVERGENCE       -0.11662500 deg       1.13674167 deg
POINT SCALE        0.99960337           1.00003190
COMBINED FACTOR    0.99960857           1.00003710

US NATIONAL GRID DESIGNATOR: 18SVH8345121260 (NAD 83)

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MARK:      umbc (0008; umbc a  4)
CONSTRAIN: 3-D NORMAL
     N39:15:24.38997 W076:42:41.48499  64.6647m        ITRF2014 @ 2010.0000
             0.13cm           0.08cm     0.13cm        NEU SIGMAS
SHIFTS N:      0.003 m (0.000 m) E:     -0.003 m (0.000 m) H:     -0.001 m (0.000 m)
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Appendix B. Continued.

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REF FRAME:    NAD_83(2011) @ 2010.00000000          ITRF2014 @ 2024.83132463
X:                1136717.984 m    0.000 m          1136717.001 m    0.000 m
Y:               -4812977.310 m    0.000 m         -4812975.863 m    0.000 m
Z:                4014471.565 m    0.000 m          4014471.521 m    0.000 m
LAT:           39 15 24.35964      0.000 m       39 15 24.39206      0.000 m
E LON:        283 17 18.53178      0.000 m      283 17 18.50574      0.000 m
W LON:         76 42 41.46822      0.000 m       76 42 41.49426      0.000 m
EL HGT:               65.943 m    0.000 m              64.650 m    0.000 m
ORTHO HGT:            98.408 m    0.015 m  (= EL HGT - -32.465 GEOID18 HGT)

               UTM COORDINATES    STATE PLANE COORDINATES
                UTM (Zone 18)         SPC (1900 MD)
NORTHING (Y)      4346666.790 m         176550.113 m
EASTING (X)        352329.289 m         424898.762 m
CONVERGENCE       -1.08323889 deg       0.18106111 deg
POINT SCALE        0.99986850           0.99997190
COMBINED FACTOR    0.99985816           0.99996155

US NATIONAL GRID DESIGNATOR: 18SUJ5232946667 (NAD 83)

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MARK:      zdc1 (0012; zdc1 a  2)
CONSTRAIN: 3-D NORMAL
     N39:06:05.74479 W077:32:33.88523  79.6180m        ITRF2014 @ 2010.0000
            0.14cm           0.06cm     0.14cm        NEU SIGMAS
SHIFTS N:     -0.004 m (0.000 m) E:      0.000 m (0.000 m) H:      0.000 m (0.000 m)

REF FRAME:    NAD_83(2011) @ 2010.00000000          ITRF2014 @ 2024.83082347
X:                1069126.501 m    0.000 m          1069125.512 m    0.000 m
Y:               -4839600.097 m    0.000 m         -4839598.650 m    0.000 m
Z:                4001126.299 m    0.000 m          4001126.244 m    0.000 m
LAT:           39 06 05.71457      0.000 m       39 06 05.74644      0.000 m
E LON:        282 27 26.13252      0.000 m      282 27 26.10534      0.000 m
W LON:         77 32 33.86748      0.000 m       77 32 33.89466      0.000 m
EL HGT:               80.897 m    0.000 m              79.600 m    0.000 m
ORTHO HGT:           113.250 m    0.016 m  (= EL HGT - -32.353 GEOID18 HGT)

               UTM COORDINATES    STATE PLANE COORDINATES
                UTM (Zone 18)         SPC (4501 VA N)
NORTHING (Y)      4331128.270 m        2159710.544 m
EASTING (X)        280119.882 m        3582802.375 m
CONVERGENCE       -1.60434167 deg       0.59744167 deg
POINT SCALE        1.00019535           0.99998402
COMBINED FACTOR    1.00018266           0.99997133

US NATIONAL GRID DESIGNATOR: 18STJ8012031128 (NAD 83)
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Deputy Secretary

A message to Maryland's citizens

The Maryland Department of Natural Resources (DNR) seeks to balance the preservation and enhancement of the living and physical resources of the state with prudent extraction and utilization policies that benefit the citizens of Maryland. This publication provides information that will increase your understanding of how DNR strives to reach that goal through the earth science assessments conducted by the Maryland Geological Survey.

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