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MEMORANDUM

TO:	Monica McQuillan, REP, Energy Transfer		
FROM:	Timothy D. Bechtel, PhD, PG, RETTEW Associates, Inc.		
DATE:	March 23, 2022		
PROJECT NAME:	Energy Transfer Mariner East 2	**PROJECT NO.:**	096303002
SUBJECT:	W-B71 (Library Bore) Summary of Geophysical and Geotechnical Investigations and Results		

The W-B71 (Library Bore) site is mapped by the PA Geologic Survey (PA GS) as being underlain by the Ledger Formation (Cl), which is composed of light-gray, locally mottled, massive, pure, coarsely crystalline dolomite, siliceous in the middle part. The Ledger Formation is carbonate and is well known for karstification and subsidence. In this setting, natural subsidence may occur (particularly during periods of intense precipitation and infiltration), but no historical surface depressions or sinkholes have been mapped by the PA GS along or near the WB-71 bore path. This lack of historical subsidence may be related to the fact that the wetland is in a groundwater discharge zone where natural water movement is upwards rather than downward, so there is generally no infiltration to flush soil down into karstic conduits. A timeline of geotechnical and geophysical investigations, construction activities, and earth feature occurrences during construction is included as **Appendix A**.

The mapped geology and karstic conditions were confirmed prior to commencement of the bore by four geotechnical borings by Professional Service Industries, Inc. (PSI) in February 2020 and Geostructures (commissioned by Chester County) in December 2020 (see **Appendix A** timeline) and 27 top-of-rock probes by Michels (the boring contractor) – see **Figure 1**. The borings in these investigations revealed an irregular (pinnacled) top-of-rock, locally highly fractured dolomite, and a few soil- or water-filled voids with vertical dimensions up to two feet. No open (air-filled) voids were reported. RETTEW also performed a pre-bore geophysical survey in July 2020, and a follow-up re-survey in August 2020. The July 2020 survey detected a low-gravity zone, with an associated low-resistivity feature at depth (below the water table) which was labeled as Anomaly A. The August 2020 survey was performed to confirm the presence of this anomaly and check for any changing conditions. The anomaly was confirmed and no significant changes were observed. As a precaution, RETTEW recommended geotechnical investigation of this anomaly, with pressure grouting to treat karstic conditions. PSI performed 15 geotechnical borings in December 2020 with 8 (in the footprint of Anomaly A) used as grout injection points. Grouting was performed in these at 2-foot intervals and a pressure of 50 PSI. Total grout takes ranged from 0.09 to 0.5 cubic yards, with an average for the eight borings of 0.27 cubic yards. The boring locations (that fall within the bore path construction window) are shown on **Figure 1**.

The pilot bore began on January 9, 2021 and was completed on January 21, 2021 (see timeline in **Appendix A**). Auger boring began on February 4, 2021 and the change from augering to driving the casing occurred on July 23, 2021. Driving the casing was completed on August 1, 2021.

During boring, 14 subsidence features developed (see **Figure 2** and the timeline in **Appendix A**). These features were also described in a memo dated (revised) January 20, 2022 (see **Appendix B**). As detailed in the **Appendix B** memo, a review of these events indicates ongoing boring activity itself is not an accurate predictor or indicator of a potential subsidence event

The events appear to have two characteristics in common. The subsidence occurred behind the leading end of the casing and many of the events, particularly the last two in the creek, were associated with heavy precipitation and enhanced flow in the stream. A summary report dated January 20, 2022, detailing the earth features was previously submitted. See copy in **Appendix B** for more details.

This bore was started as a cased auger bore in which the casing was advanced behind a cutting head that was several inches in diameter larger than the casing. This would leave a small annulus which could accept soil mobilized by infiltrating water. In July 2021, the method was changed to a pneumatic ramming tool to further minimize and/or eliminate the potential for subsidence. During the pipe ramming process, soils, boulders, and/or rocks are "swallowed up" as the casing progresses forward, thereby eliminating the potential for excess material from being displaced in front of the casing. The leading end of the casing is reinforced with a drive shoe which has a slightly larger diameter. In addition, during drilling, dewatering of the entry/exit pits could remove mobilized soils even when active drilling and precipitation were not occurring.

The flume which had been diverting the stream flow through the Library Bore site had just been removed on August 27, 2021, which directly related to the two features in the stream. The returning stream flow and re-saturation of the stream bed material most likely caused this feature to rise to the surface. On September 1 and 2, 2021, the remnants of Hurricane Ida passed through eastern Pennsylvania. A total of 9.8 inches of rainfall occurred at the site over these two days. Valley Creek overflowed its banks and flooded the area. In karst terrain it is not an unusual occurrence for subsidence features to surface after an extremely heavy precipitation event.

The bore was completed on August 1, 2021. It is our interpretation the three events in the following month, on August 5th and 27th and September 3rd, were the result of excessive infiltration mobilizing soils that then filled the small annulus outside the casing. Previous events may have been due to filling of the annulus or flushing of soils into the entry/exit pits during dewatering. The last occurrence was September 3, 2021. The lack of subsequent subsidence activity suggests that the annular space is now filled, and with dewatering having ceased months ago, the site has reached equilibrium.

The pre-bore geotechnical borings indicated that natural karst conduits were soil- or water-filled, with (based on drilling logs and low grout takes) relatively small volumes. Their filling with soil or water, and the grouting in Anomaly A suggest that the earth features during boring were not related to natural karstification.

Following completion of the W-B71 bore, RETTEW completed a multi-technique geophysical survey at the site. The purpose of the survey was to detect changes in the shallow subsurface that could precede development of potential earth features at the site. The fieldwork was completed in November 2021 and the final report is dated December 14, 2021. The survey area extended from the north/upstream entry to the south/downstream entry and included the area of the late August/early September subsidence events. The flow in the Valley Creek tributary was low enough that measurements ran across the streambed. The geophysics survey did not detect or identify any significant issues in the streambed. The results of the microgravity survey are shown on the **Figure 1** Boring Map and the **Figure 2** Earth Features Map.

The earth features were all remediated by excavating and filling with flowable fill following the guidance in the "Void Mitigation Plan for Karst Terrain". In addition, a series of borings was completed in and around anomalies identified by the geophysical surveys. Grout was injected into the borings within Anomaly A to remediate these potential areas where subsidence might occur. The locations of these borings are shown on **Figure 1**.

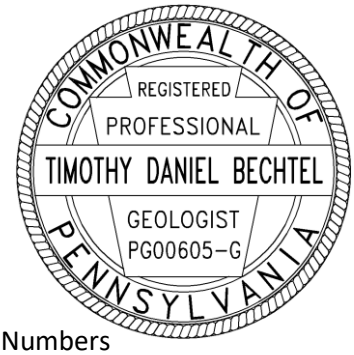
Our conclusion, based on the geology, geophysics, and augering method/equipment is that the earth features were the result of water flushing soils into the casing due to bore pit dewatering. Since the dewatering has ceased, no additional earth features resulting from pipeline activity are anticipated. No new earth features have been observed at the site since the September 3, 2021 Hurricane Ida-related event.

The final post-construction geophysical survey was completed on November 23, 2021 (report date December 14th, 2021) and covered a wider and longer area than previous surveys. This survey (as did all previous surveys) showed the gravity low at Anomaly A. When processed to match the previous survey extents, Anomaly A is relatively unchanged. Its persistence despite the December 2020 pre-bore grouting suggests that it is largely related to a locally deeper top-of-rock. The seismic refraction and MASW data in that report (and in general) do not have the resolution to show individual rock pinnacles and cutters, but they are surely present (as also indicated by prior geotechnical borings and rock probes). Instead, the "transition zone" on the seismic cross sections is the epikarst where pinnacles and cutters inter-finger. Regions where velocity contours are depressed may indicate steeply-dipping karstified fractures (or bedding planes). The resistivity profiles show relatively resistive material in the near-surface and lower resistivity at depth. Resistivity of earth materials is dominated by water content and/or chemistry, so the deeper low-resistivity materials are interpreted as water-saturated, fractured rock. The high-seismic velocities for these deeper materials indicate that they are competent (albeit fractured and locally karstified) rock.

With the completion of the WB-71 cased auger bore and the filling (partially by shallow earth feature development) of the minor annular space outside the casing, and cessation of dewatering of the (now former) pits, no further earth features are expected. The natural karst openings are filled with water, soil, or grout and groundwater movement should have re-established its general upward movement. Therefore, there should be a very low risk for natural sinkhole activity (as there was pre-construction).

Certification

This assessment was prepared by a professional geologist (PG) with the assistance of the horizontal directional drilling team, relying on information gathered and prepared by others. By affixing my seal to this document, I am certifying that the hydrogeologic and geologic information contained herein is true and correct, to my knowledge and belief. I further certify that I am licensed to practice in the Commonwealth of Pennsylvania.



Timothy D. Bechtel, PhD, PG
License No. PG000605G

Enclosures
Figure 1: Boring Locations
Figure 2: Earth Feature Locations and Numbers
Appendix A: Timeline
Appendix B: 01/20/2022 Memo (W-B71 (Library Bore) Response to PA DEP NOVs Item 2)

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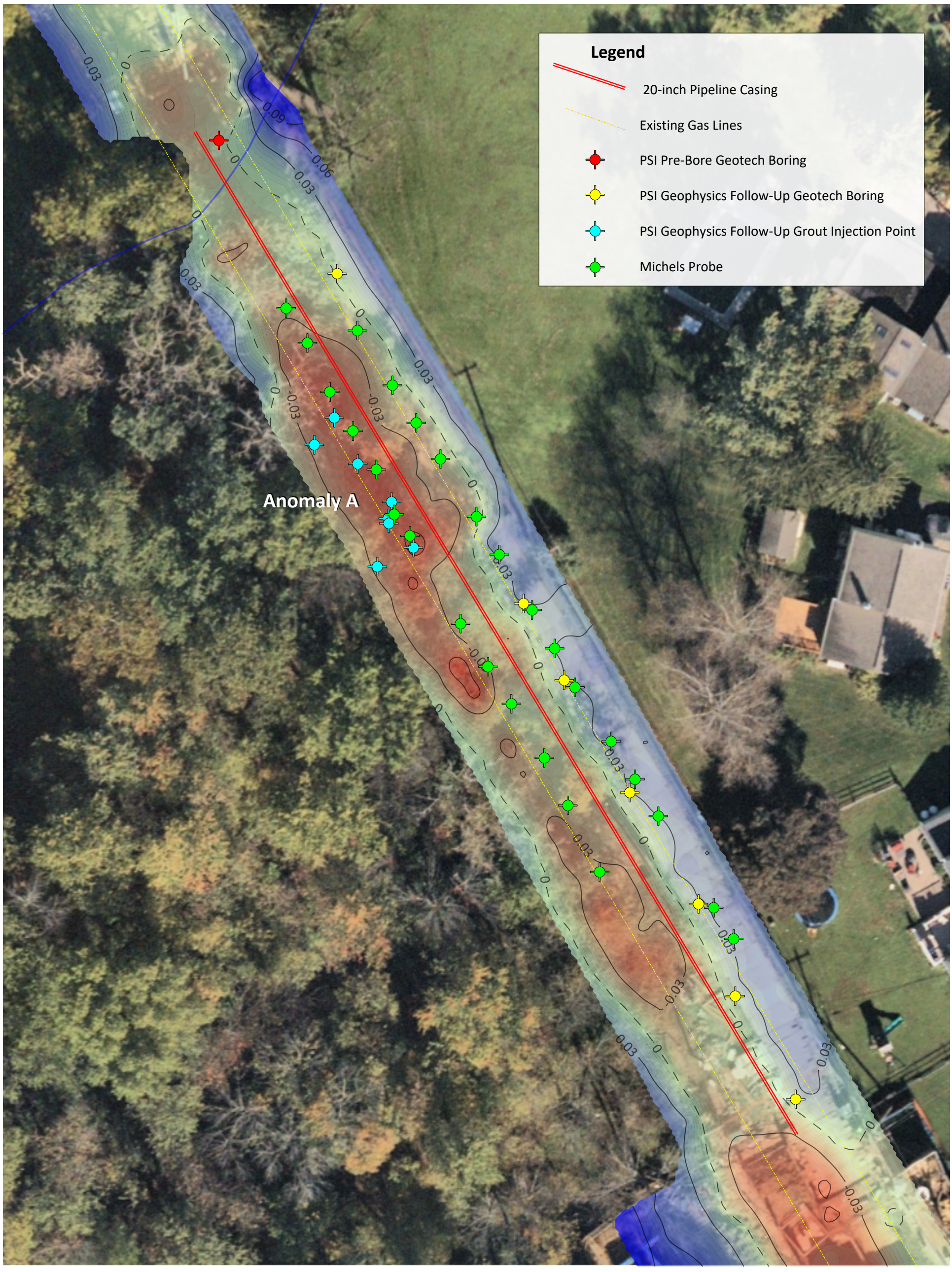
ENCLOSURES



Notes:

Basemap from Nearmap, September 2021.
Pipelines and feature locations from TetraTech.
Gravity from RETTEW November 2021 survey.
Borings from contractor reports.

Residual Gravity (milligals)

Mass Deficiency — Mass Excess

-0.09 -0.06 -0.03 0 0.03 0.06 0.09

Scale (ft)

0 30 60

N

Figure 1: Boring Locations

Wetland Bore W-B71

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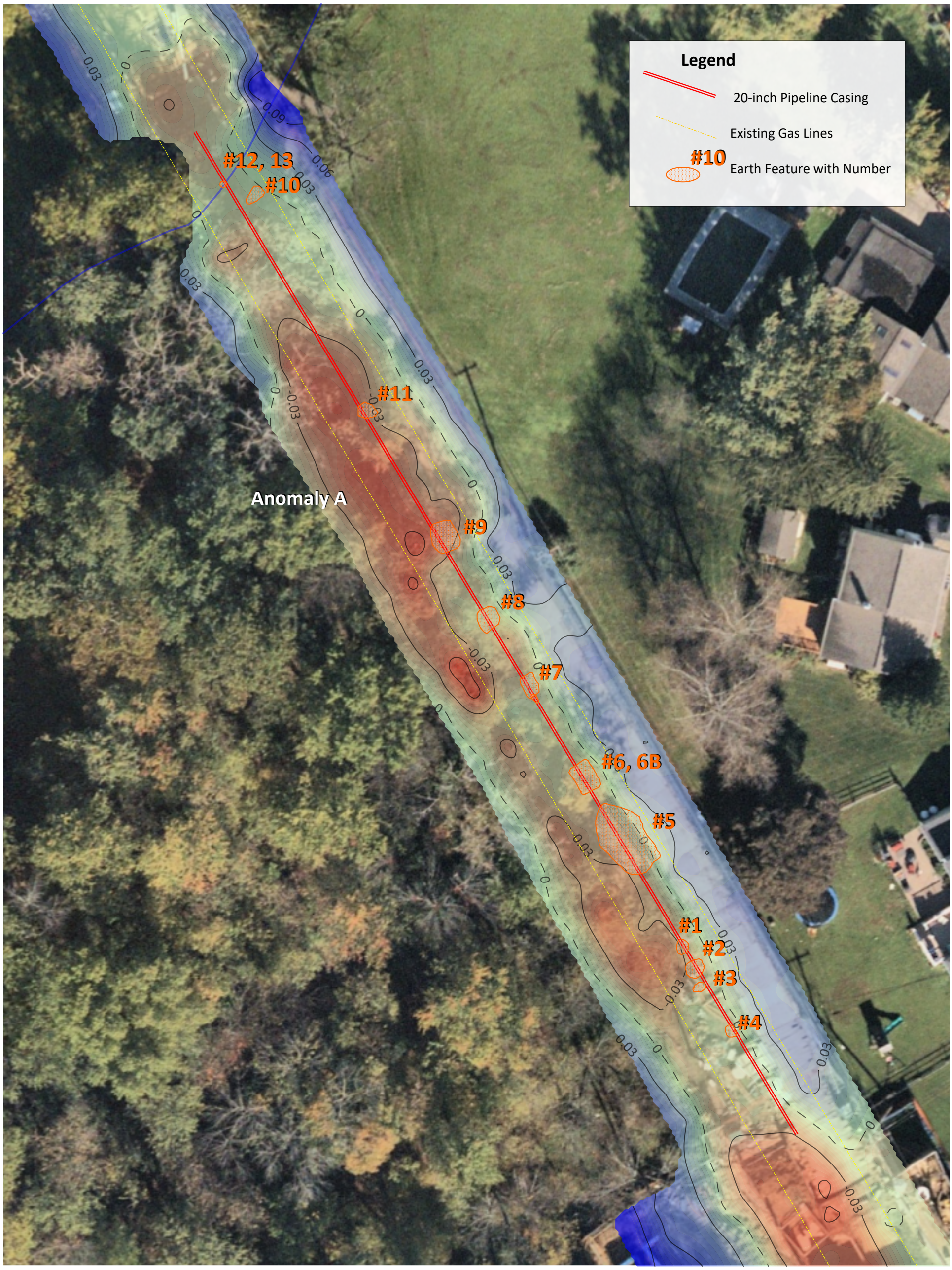
FIGURE NO.	1 of 2



Residual Gravity (milligals)

Mass Deficiency — Mass Excess

-0.09 -0.06 -0.03 0 0.03 0.06 0.09

Scale (ft)

0 30 60

N

Notes:

Basemap from Nearmap, September 2021.
Pipelines and feature locations from TetraTech.
Gravity from RETTEW November 2021 survey.

Figure 2: Earth Feature Locations and Numbers

Wetland Bore W-B71

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FIGURE NO.	2 of 2

APPENDIX A

Timeline

Appendix A Timeline

Event	Fieldwork Complete	Report Date	Scope	Summary Results	Notes
PSI Geotech Borings	2/14/2020	2/20/2020	Four geotech borings from Rt 30 to north end of bore path		Pre-boring evaluation
Geophysical Survey	7/24/2020	8/14/2020	Gravity, Refraction, MASW, ERI (five profiles)	Gravity Anomaly A with distinct resistivity low on north end	Pre-boring evaluation
Geophysical Survey	8/3/2020	8/14/2020	Gravity, ERI re-survey of Anomaly A area	Confirmed Anomaly A	Pre-boring evaluation
Geostructures Study	11/20/2020	12/21/2020	Literature review and 8 borings	Definitely karst, but low sinkhole risk	Commissioned by Chester County
PSI Geotech and Grout Borings	12/10/2020	12/18/2020	15 geotech, 8 grouted	Grout in Anomaly A	
Bore Status	1/9/2021		Start pilot boring		
Bore Status	1/21/2021		Finish pilot boring		
Bore Status	2/4/2021		Start auger boring		
Earth Feature	2/27/2021				Feature 1
Earth Feature	3/1/2021				Feature 2
Earth Feature	3/7/2021				Feature 3
Geophysical Survey	3/10/2021	Draft 4/2/2021	Gravity, refraction and MASW from south pit across creek in north	Messy due to mats	Never went final due to poor data quality. Tested various methods for monitoring bore for developing earth features.
Geophysical Survey	3/17/2021	Draft 4/2/2021	Refraction and MASW only	Messy due to mats	Never went final due to poor data quality. Tested various methods for monitoring bore for developing earth features.
Earth Feature	3/18/2021				Feature 4
Michels Probes	5/12/2021		27 probes to top-of-rock on either side of bore path	Irregular top-of-rock	
Earth Feature	6/4/2021				Feature 5
Geophysical Survey	6/16/2021		GPR		GPRS
Geophysical Survey	6/17/2021	6/25/2021	Gravity (3 profiles), refraction, MASW (2 profiles)	Four minor gravity lows recommended for further inspection	
Earth Feature	6/18/2021				Feature 6A
Earth Feature	6/21/2021				Feature 6B
Geophysical Survey	6/24/2021 to 8/1/2021				GPRS
Earth Feature	7/7/2021				Feature 7
Earth Feature	7/12/2021				Feature 8
Earth Feature	7/14/2021				Feature 9
Bore Status	7/23/2021		Started hammering casing		
Earth Feature	7/31/2021				Feature 10
Bore Status	8/1/2021		Finished casing		
Earth Feature	8/5/2021				Feature 11
Earth Feature	8/27/2021				Feature 12
Earth Feature	9/3/2021				Feature 13
Geophysical Survey	8/10/2021	9/29/2021		No significant changes	
Geophysical Survey	11/23/2021	12/14/2021	Gravity, Refraction, MASW, ERI; five profiles, pit-to-pit coverage	No significant changes	

APPENDIX B

W-B71 (Library Bore) Response to PA DEP NOVs Item 2 Memo

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MEMORANDUM

TO:	Monica Styles, REP, Energy Transfer		
FROM:	David M. Anderson, PG and Timothy D. Bechtel, PhD, PG, RETTEW Associates, Inc.		
DATE:	September 22, 2021, **Revised January 20, 2022**		
PROJECT NAME:	Energy Transfer Mariner East 2	**PROJECT NO.:**	096303002
SUBJECT:	W-B71 (Library Bore) Response to PA DEP NOVs Item 2		

The Pennsylvania Department of Environmental Protection (PA DEP) issued Notices of Violation (NOV) on September 1 and 9, 2021 regarding subsidence events which occurred within Stream S-B81 (Valley Creek). The events referenced in the NOVs occurred on August 27, 2021 and September 3, 2021. In response to PA DEP letter of January 7, 2022, this memo has been updated and figures added to provided additional details regarding the subsidence events.

Item 2 in both NOVs was the following request:

> ***Conduct a geologic investigation and provide an assessment that explains why the August 27/ September 3 subsidence occurred in the stream bed when no boring activity was taking place.***

The W-B71 (Library Bore) site is underlain by the Ledger Formation (Cl), which is composed of light-gray, locally mottled, massive, pure, coarsely crystalline dolomite, siliceous in the middle part. The Ledger Formation is carbonate and is well known for karstification and subsidence[1]. In this setting, subsidence could occur at any time. A subsidence feature may have been developing in the subsurface for a long period of time before any visible surface feature occurs.

There have been fourteen subsidence features develop at the Library Bore site since February 2021 (see **Figure 1** and **Table 1**). A review of these events indicates ongoing boring activity itself is not an accurate predictor or indicator of a potential subsidence event. The following is a summary of the site activity at the time a subsidence event occurred:

- <u>No drilling activity 10 events</u>
  - Occurred at night/Sunday 5 events
  - Drilling crew on standby 2 events
  - After boring was completed 3 events
- <u>Active drilling operations 4 events</u>
  - Augering 3 events
  - Tripping auger bit into casing 1 event

The events appear to have two characteristics in common. The subsidence occurred behind the leading end of the casing (see red bars on **Figure 2** – note that negative distances indicate that the feature is behind the leading end of the casing). In addition, many of the events, particularly the last two in the creek, were associated with heavy precipitation (dark blue bars on **Figure 2**) and enhanced flow in the stream (light blue hydrograph on **Figure 2**).

This bore was started as a cased auger bore in which the casing was advanced behind a cutting head that was several inches in diameter larger than the casing. This would leave a small annulus which could accept soil mobilized by infiltrating water. In July 2021, the method was changed to a pneumatic ramming tool to further minimize and/or eliminate the potential for subsidence. During the pipe ramming process soils, boulders, and/or rocks are “swallowed up” as the casing progresses forward thereby eliminating the potential for excess material from being displaced in front of the casing. The leading end of the casing is reinforced with a drive shoe which has

a slightly larger diameter. In addition, during drilling, dewatering of the entry/exit pits could remove mobilized soils even when active drilling and precipitation were not occurring.

Regarding the two features in the stream, on August 27, 2021, the flume which had been diverting the stream flow through the Library Bore site had just been removed. The returning stream flow and re-saturation of the stream bed material most likely caused this feature to rise to the surface. On September 1 and 2, 2021, the remnants of Hurricane Ida passed through eastern Pennsylvania. A total of 9.8 inches of rainfall occurred at the site over these two days. Valley Creek overflowed its banks and flooded the area. In karst terrain it is not an unusual occurrence for subsidence features to surface after an extremely heavy precipitation event.

The bore was completed on July 31, 2021. It is our interpretation the three events in the following month, on August 27th and September 1st or 2nd, were the result of excessive infiltration mobilizing soils that then filled the small annulus outside the casing. Previous events may have been due to filling of the annulus or flushing of soils into the entry/exit pits during dewatering. The last occurrence was September 3, 2021. The lack of subsequent subsidence activity suggests that the annular space is now filled, and with dewatering having ceased months ago, the site has reached equilibrium.

Following completion of the W-B71 bore, RETTEW completed a multi-technique geophysical survey at the site. The purpose of the survey was to detect changes in the shallow subsurface that could precede development of potential earth features at the site. The fieldwork was completed in November 2021 and the final report is dated December 14, 2021. The survey area extended from the north/upstream entry to the south/downstream entry and included the area of the late August/early September subsidence events. The flow in the Valley Creek tributary was low enough that measurements ran across the streambed. The geophysics survey did not detect or identify any significant issues in the streambed. The results of the microgravity survey are shown on the **Figure 1** Earth Features map.

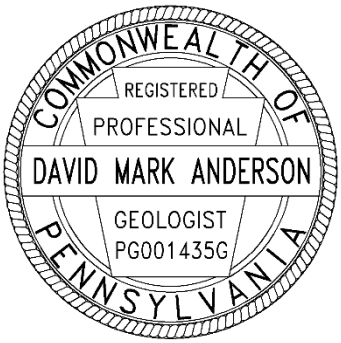
The earth features were all remediated by excavating and filling with flowable fill following the guidance in the "Void Mitigation Plan for Karst Terrain". In addition, a series of boring were completed in and around anomalies identified by a geophysical survey. Grout was injected into the boring to remediate these potential areas where subsidence might occur. The locations of these boring are show on the Figure 1 map.

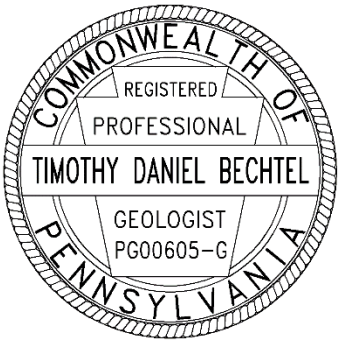
Our conclusion, based on the geology, geophysics, and augering method/equipment is that the earth features were the result of water flushing soils into the casing due to bore pit dewatering. Since the dewatering has ceased, no additional earth features resulting from pipeline activity are anticipated. No new earth features have been observed at the site since the September 3, 2021 Hurricane Ida related event. There will always be a potential for naturally occurring subsidence to develop in this area due to the underlying karst formation.

Certification

This assessment was prepared by a professional geologist (PG) with the assistance of the horizontal directional drilling team, relying on information gathered and prepared by others. By affixing my seal to this document, I am certifying that the hydrogeologic and geologic information contained herein is true and correct, to my knowledge and belief. I further certify that I am licensed to practice in the Commonwealth of Pennsylvania.

David M. Anderson, PG
License No. PG001435G





Timothy D. Bechtel, PhD, PG
License No. PG000605G

Enclosures

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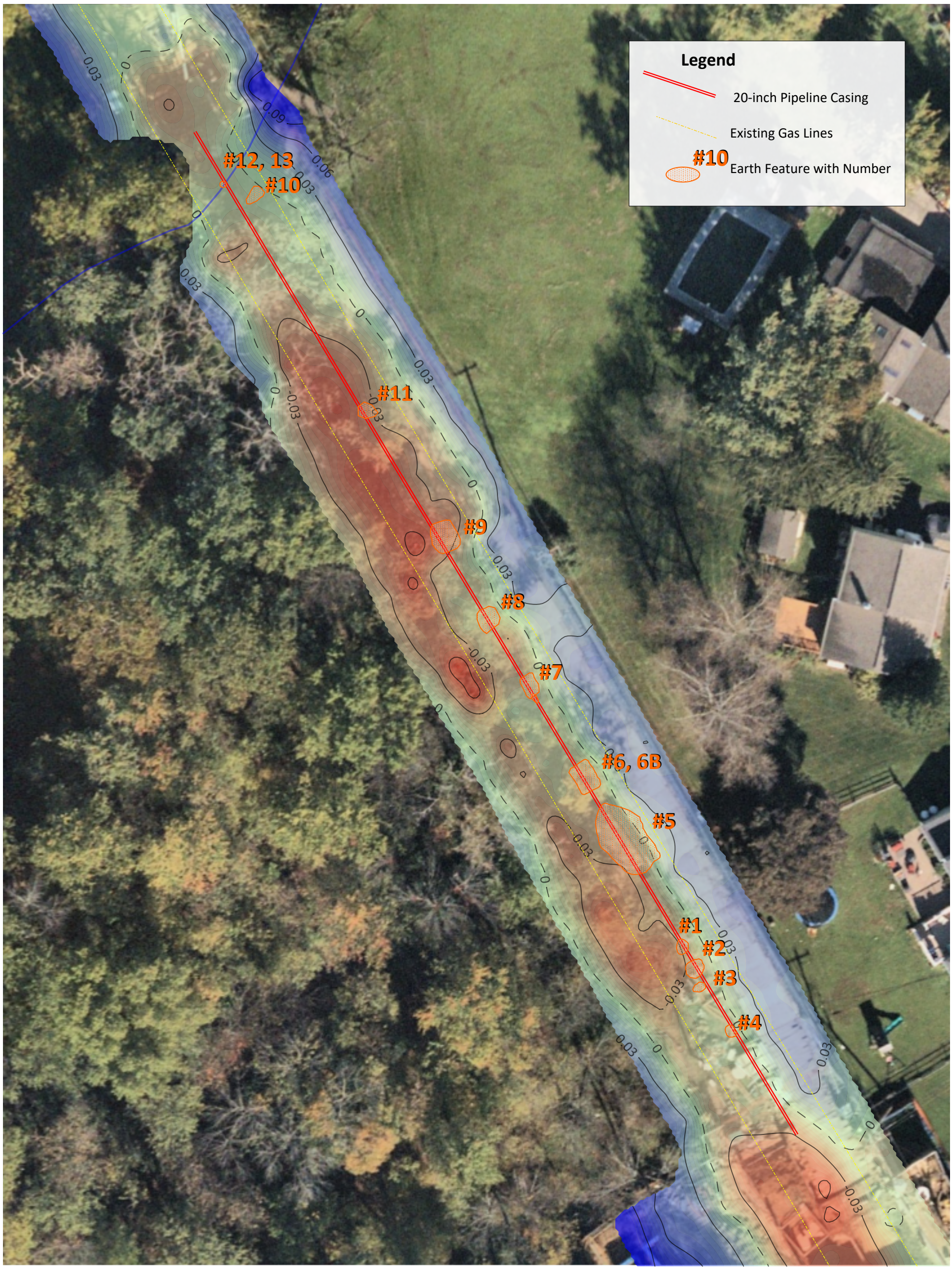
[1] Geyer, A. R., and Wilshusen, J. P., 1982, Engineering characteristics of the rocks of Pennsylvania (2nd ed.): Pennsylvania Geological Survey, 4th ser., Environmental Geology Report 1, 300 p.



Residual Gravity (milligals)

Mass Deficiency — Mass Excess

-0.09 -0.06 -0.03 0 0.03 0.06 0.09

Scale (ft)

0 30 60

N

Notes:

Basemap from Nearmap, September 2021.
Pipelines and feature locations from TetraTech.
Gravity from RETTEW November 2021 survey.

Figure 1: Earth Feature Locations and Numbers

Wetland Bore W-B71

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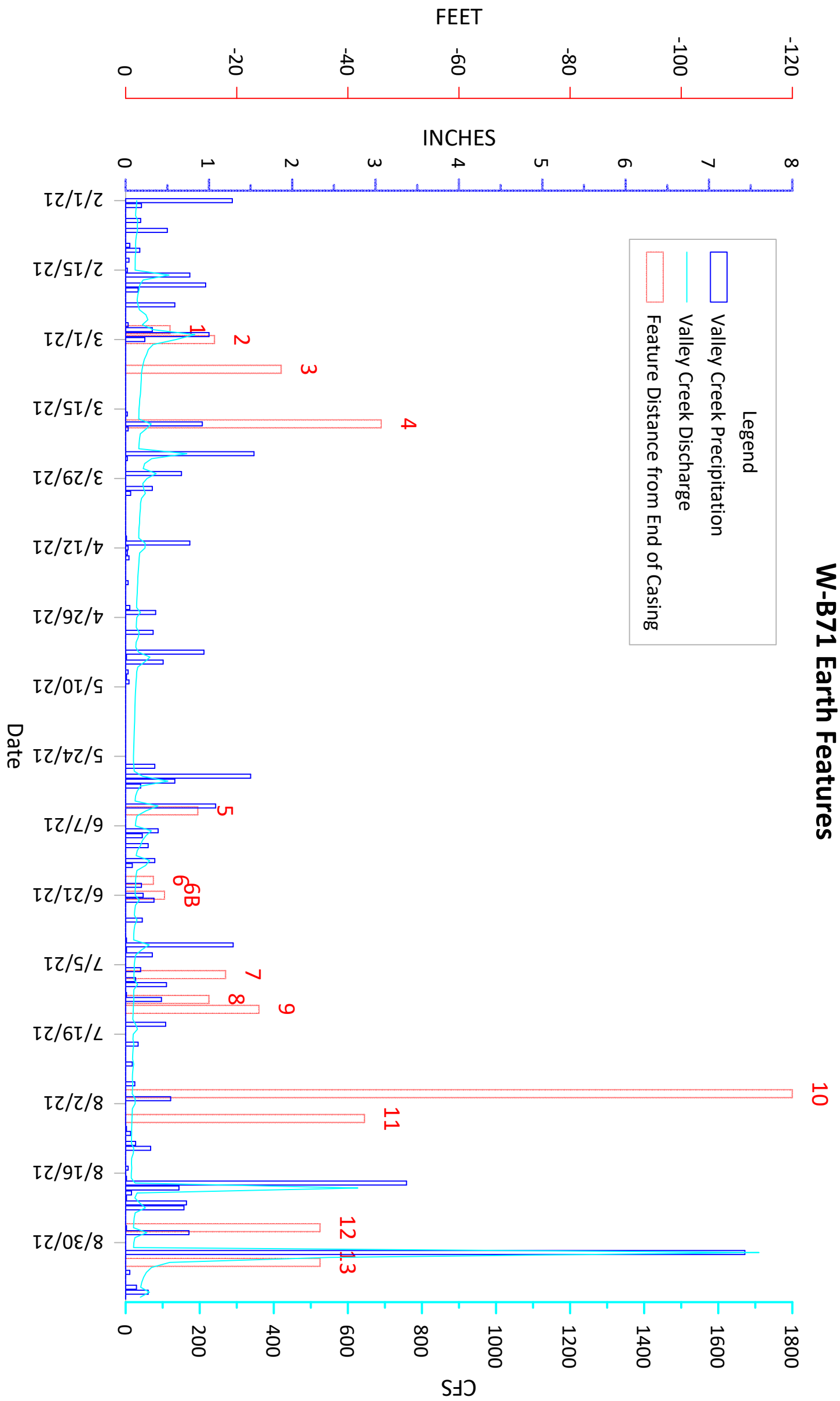
SCALE:	1' = 30'
FIGURE NO.	1 of 2



Notes:

Precipitation and discharge from USGS gaging station 01463169 (Valley Creek at PA Turnpike).
Feature position relative to end of casing from drilling logs and PG reports.

Figure 2: Precipitation, Stream Discharge, and Earth Features

Wetland Bore W-B71

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FIGURE NO.	2 of 2

Table 1
Precipitation, Stream Gaging, and Earth Features

Date	Feature No.	End of Casing (ft)	Center of Feature (ft)	Distance from End of Casing (ft)	New Footage during day shift	Notes
02/27/21	1	78	70	-8	4	Hand tunneling, Drilling on standby
03/01/21	2	78	62	-16	0	Subsidence observed prior to start of boring
03/07/21	3	84	56	-28	0	Sunday
03/18/21	4	84	38	-46	0	Boring on standby while crew addressed excess water entering the bore pit
06/04/21	5	122	109	-13	0	Subsidence occurred during the night
06/18/21	6	136	131	-5	11	Subsidence occurred during the night
06/21/21	6B	138	131	-7	2	Activated during auguring operation
07/07/21	7	184	166	-18	0	Tripping-in auger
07/12/21	8	206	191	-15	10	Active auguring operation
07/14/21	9	244	220	-24	18	Active auguring operation
07/31/21	10	354	267	-87	1	Subsidence occurred during the night
08/05/21	11	387	344	-43	0	Bore completed 8/1/21
08/27/21	12	387	352	-35	0	Diverted stream just restored to channel
09/03/21	13	387	352	-35	0	Just after Hurricane Ida