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Wisconsin Department of Natural Resources
223 East Steinfest Road
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Subject: Technical Memorandum - Analysis of Benzene Plumes and Assessment of Co-mingling

Dear Mr. Hunt:

At the meeting between Antea Group, BP and the Wisconsin Department of Natural Resources (WDNR) on September 16, 2019 one of the topics discussed was whether the source of the benzene plume identified in the groundwater north and west of Winter Street is from the Terminal or co-mingled with benzene that originates from an elongated area of residual petroleum that extends under the C. Reiss Coal and Hallett Dock properties.

This Technical Memorandum will present groundwater quality data, in the context of the revised hydrostratigraphic model, that supports the conclusion that the groundwater benzene plume identified north and west of Winter Street does not receive any contribution of benzene from the residual petroleum identified on the C. Reiss Coal and Hallett Dock properties.

Background:

The question has been posed as to whether the benzene plume delineated in the "D" Level and considered to have originated at the Terminal is co-mingled with a benzene plume emanating from western portion of AOC 8 ("Finger Plume"). From a regulatory and administrative perspective, a co-mingled plume would require delineation and remedial evaluation for the dissolved-phase plumes from the Terminal (AOC 1 through AOC 5) and AOC 8. Well locations and AOC designations at the Terminal are depicted on Figure 1, while Figure 2 portrays the same information for the Barge Dock, which encompasses several properties located north of Winter Street.

Benzene is the primary contaminant-of-concern (CoC) in the dissolved-phase plume, which is most extensive in the "D" Level (defined as wells completed at a target elevation of 555 to 575 feet amsl, or typically 50 to 55 feet below ground surface). An updated hydrogeologic section (see attached Figure 3) depicts a dissolved-phase petroleum hydrocarbon (PHC) plume, dominated by benzene, that originates at the Terminal and migrates northwest in the shallow water-bearing zone ("S" Level). The "S" Level water-bearing zone, which is defined by monitor wells terminated from 10 to 30 feet below ground surface (bgs), is overlain by an extensive surficial clay unit.

Based on chromatograms of light non-aqueous phase liquid (LNAPL) samples from wells RW-2, RW-4, and RW-6 at the Terminal, more than 75% of the PHCs in the LNAPL are in the gasoline range, and more than 70% of the PHCs identified in the “Finger Plume” eluted in the gasoline range (based on chromatograms LNAPL samples collected from TMW-3 and TMW-6). The difference between the gasoline range PHCs at the Terminal compared to the “Finger Plume” (western portion of AOC 8) is the proportion of aromatics (which includes all BTEX compounds). Aromatics compose 23% to 44% of the LNAPL at the Terminal, but only 10% to 12% for the LNAPL in the “Finger Plume”. The differences in the LNAPL composition at the Terminal and in the “Finger Plume” would be expected to produce differences in any subsequent dissolved-phase plumes.

Benzene Plume Contributors and Distinction:

To distinguish the dissolved-phase plume that may originate from the “Finger Plume”, groundwater samples at or near the “Finger Plume” were evaluated. As discussed at our meeting held on September 16, 2019, groundwater samples collected from a monitor well that currently or typically contains measurable LNAPL and is known to span the smear zone of residual LNAPL beneath the clay, would be helpful to assess the dissolution of benzene from the "Finger Plume" and evaluate the potential for co-mingling with the benzene plume in the "D" Level that originates at the Terminal.

During a period of a relatively low water table, water samples were able to be collected on October 31, 2014 and May 6, 2015 from monitor well MWM-6, which typically contains measurable LNAPL. Groundwater samples were also collected from monitor wells located up-gradient and down-gradient of monitor well MWM-6 (see tabulation of sampled monitor wells below). The samples from monitor well MWM-6 represent the dissolved-phase petroleum volatile organic compounds (PVOCs) immediately under the “Finger Plume” in AOC 8.

The results (in ug/L) for BTEX analytes for the groundwater samples collected from key monitor wells, in the "S" and "D" Levels, are compiled in the table below. The wells are listed in descending order from up-gradient to down-gradient of AOC 8. The monitor wells and selected laboratory results also appear in Figure 3.

Well Sampled	Date Sampled	Benzene	Toluene	Ethylbenzene	Xylenes
MWT-2S	10/10/2018	<0.31	<0.49	<0.33	<0.98
MWT-2D	5/5/2015	3720	224	277	377
MWM-9RS	10/5/2015	<0.40	<0.39	<0.39	<1.2
MWM-9RD	5/5/2015	3020	164	225	269
MWM-6	10/31/2014	3.3	<0.39	24.3	25.9
MWM-6	5/6/2015	3.2	1.3	7.7	16.2
MWM-7	10/29/2014	0.60J	<0.39	<0.39	<1.2
MWM-7	10/6/2015	8.8	<0.39	<0.39	<1.2
MWM-7	10/5/2016	4	<0.39	<0.39	<1.2
MWM-7D	10/30/2014	1370	39.3	34.4	35.6
MWM-7D	5/5/2015	1630	36.7	33.7	30.5J

Benzene concentrations in “S” Level monitor wells immediately up-gradient of monitor well MWM-6 are typically reported at non-detectable (ND) concentrations. At monitor well MWM-6, detectable concentrations of benzene, toluene, ethylbenzene and xylenes (BTEX) have been reported for the two sampling events. Note that despite the proximity of mobile LNAPL, the reported BTEX concentrations for monitor well MWM-6 are all less than their respective Enforcement Standards.

Down gradient of MWM-6 the BTEX concentrations are typically reported at non-detectable concentrations. Laboratory results for BTEX are typically non-detectable for samples collected from a "S" Level monitor well (MWM-7) that is down-gradient of AOC 8 and monitor well MWM-6. In contrast, groundwater samples collected from “D” Level monitor wells up-gradient and down-gradient of MWM-6 (MWT-2D, MWM-9RD, and MWM-7D) reported benzene concentrations greater than 1,000 ug/L.

Finally, the hydrostratigraphy and vertical hydraulic gradients, as depicted on Figure 3, are helpful for explaining and understanding the migration of BTEX in the groundwater and establishing that the dissolved-phase BTEX originating at AOC 8 does not co-mingle with the benzene plume in the "D" Level. A fine-grained sedimentary unit that underlies the Terminal property is interpreted to pinch out under Winter Street, just north of monitor well MW-26. Despite the downward vertical hydraulic gradients, the dissolved-phase BTEX is impeded from migrating below the fine-grained unit. However, as depicted on Figure 3 the fine-grained unit pinches out north of monitor well MW-26, which allows the vertical gradient to transport the BTEX to the "D" Level.

As depicted in Figure 3, the benzene plume in the "D" Level is isolated from the "S" Level by additional intervening fine-grained sedimentary units. And, though the fine-grained sedimentary units are discontinuous in the vicinity of AOC 8, the lack of dissolved-phase BTEX in the "S" Level at or immediately down-gradient of AOC 8 precludes the likelihood of co-mingled plumes.

Conclusions

The data and analyses presented above support the conclusion that the benzene plume in the "S" Level that originates from the "Finger Plume" (AOC 8) is of limited extent and concentration and does not contribute to the benzene plume identified at the “D” Level that originates at the Terminal. The key points of the analysis are as follows:

1. Groundwater samples collected at monitor well MWM-6, during a period when LNAPL was absent, reported BTEX concentrations less than the respective Enforcement Standards.

2. The updated hydrogeologic section (Figure 3) shows that the “S” Level benzene plume is essentially at non-detectable concentrations at or beyond monitor well MWT-2S.

3. Groundwater samples collected at monitor well MWM-7 (the “S” Level monitor well down gradient of and closest to AOC 8, or the “Finger Plume”) 16 times over a 13-year period (2003 – 2016) and have been at or near non-detectable concentrations for all BTEX compounds. Only two benzene analytical results exceeded the NR140 ES (5 ug/L), at 6.8 ug/L and 8.8 ug/L, during this period demonstrating that the “Finger Plume” LNAPL in the vicinity of monitor well MWM-7 is not a contributor to the dissolved-phase benzene plume identified in the “D” Level.

4. The benzene mass in the “S” Level, which originated at the Terminal, migrates vertically to the “D” Level through a gap in a fine-grained sedimentary unit that is interpreted to be present north of monitor well MW-26 to the vicinity of the monitor well MW-30 Well Nest.

5. Hydrogeological and hydrochemical analysis shows that the benzene that dissolves into the groundwater at AOC 8 does not contribute to the mass of the plume in the “D” Level water-bearing zone.

We appreciate your offer and willingness to review the hydrogeological and hydrochemical data and analysis presented in this Technical Memorandum to describe and distinguish dissolved-phase benzene that originates at the Terminal or the “Finger Plume”. We would very much appreciate your review and response pertaining to this assessment.

Thank you for your attention to and consideration of the conclusions in this Technical Memorandum. If you have any questions or requests, please call or send e-mail message.

Sincerely,

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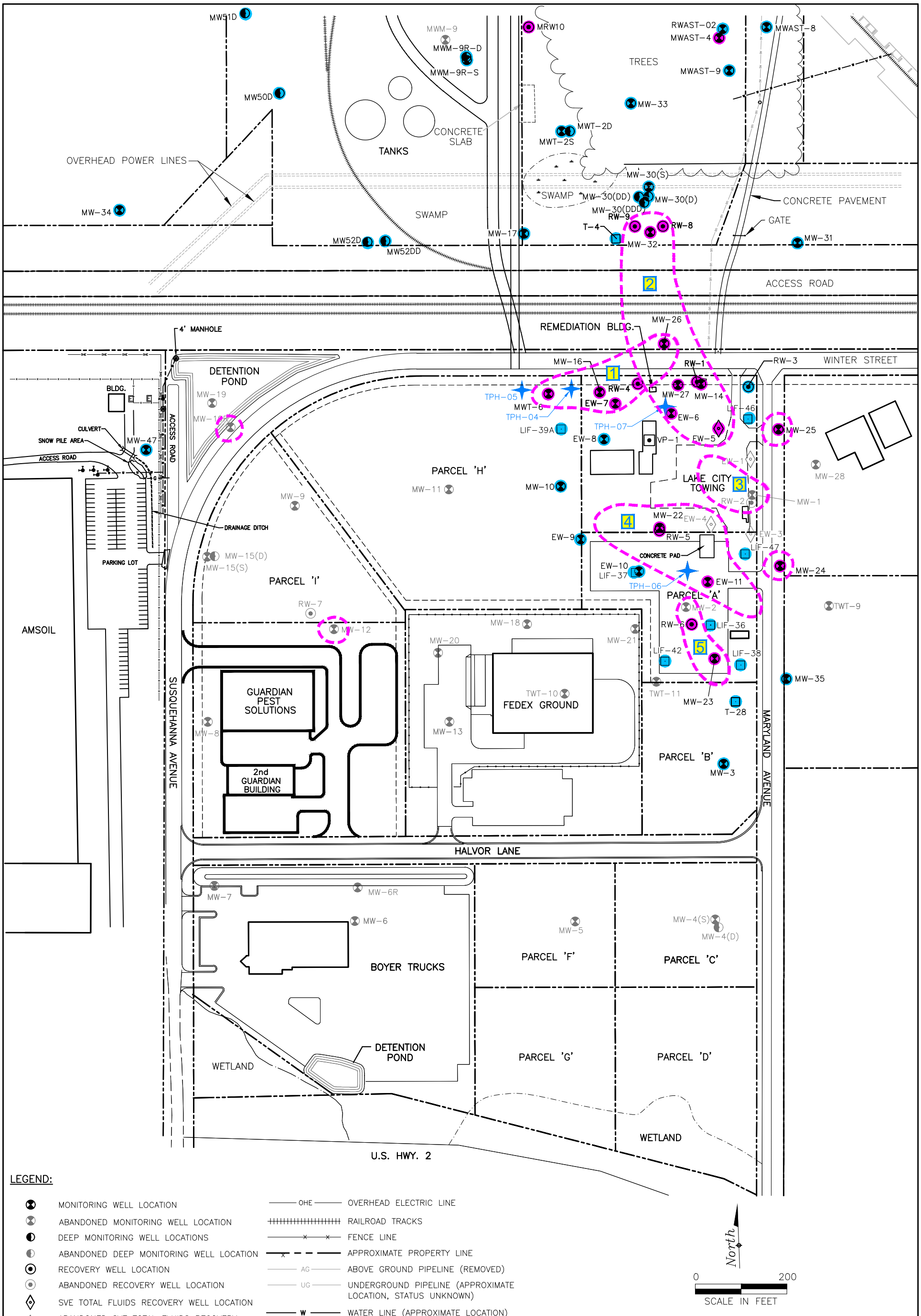

LEGEND:

- MONITORING WELL LOCATION
- ABANDONED MONITORING WELL LOCATION
- DEEP MONITORING WELL LOCATIONS
- ABANDONED DEEP MONITORING WELL LOCATION
- RECOVERY WELL LOCATION
- ABANDONED RECOVERY WELL LOCATION
- SVE TOTAL FLUIDS RECOVERY WELL LOCATION
- ABANDONED SVE TOTAL FLUIDS RECOVERY WELL LOCATION
- LIF–TPH BORING LOCATION
- CPT–LIF BORING LOCATION
- VAPOR MONITORING POINT LOCATION
- MANHOLE
- FIRE HYDRANT
- ELECTRICAL BOX

- OHE — OVERHEAD ELECTRIC LINE
- RAILROAD TRACKS
- FENCE LINE
- APPROXIMATE PROPERTY LINE
- AG — ABOVE GROUND PIPELINE (REMOVED)
- UG — UNDERGROUND PIPELINE (APPROXIMATE LOCATION, STATUS UNKNOWN)
- W — WATER LINE (APPROXIMATE LOCATION)
- G — NATURAL GAS LINE (APPROXIMATE LOCATION)
- 1 — LNAPL EXTENT (PLUME I.D. REFERENCED IN TEXT)
- POINTS WITH LNAPL
- LOW/NO LNAPL

NOTE:
PLUME 3 IS INFERRED, BASED ON HISTORICAL DATA

FIGURE 1
LNAPL EXTENT MAP –SEPTEMBER 2019 (TERMINAL)
FORMER AMOCO TERMINAL
SUPERIOR, WISCONSIN

PROJECT NO.	PREPARED BY	DRAWN BY
WISUP181	LK	DD/SAA/JH
DATE	REVIEWED BY	FILE NAME
9/11/19		TERM–0618–LNAPL

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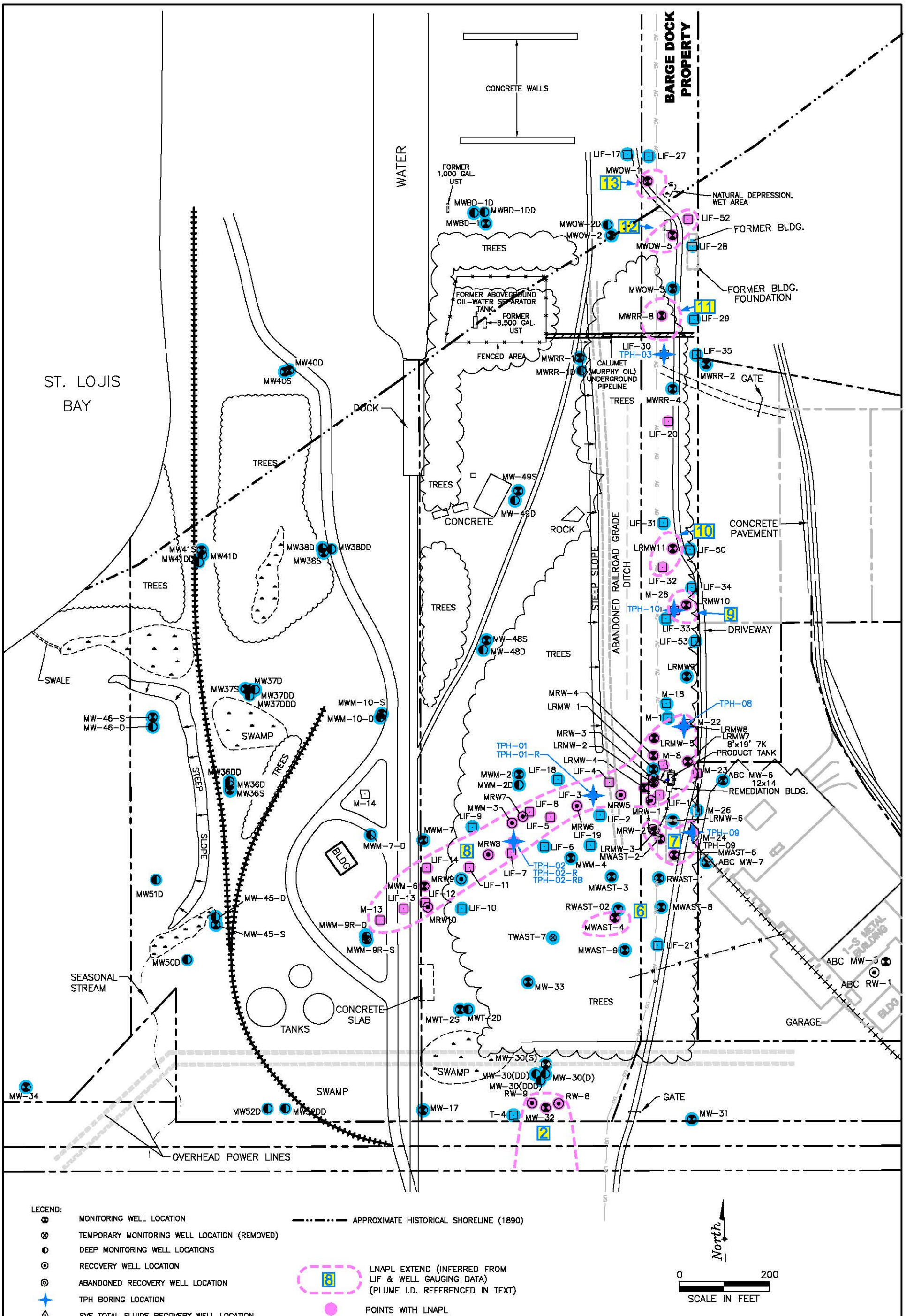

FIGURE 2
LNAPL EXTENT MAP – SEPTEMBER 2019 (BARGE DOCK)
FORMER AMOCO TERMINAL
SUPERIOR, WISCONSIN

PROJECT NO.	PREPARED BY	DRAWN BY
WISUP181	LK	SAA/JH
DATE	REVIEWED BY	FILE NAME
9/12/119		BD-0618-LNAPL

anteagroup

FIGURE 3

HYDROSTRATIGRAPHY AND BTEX GROUNDWATER RESULTS FOR SELECT MONITOR WELLS NEAR OR AT AOC 8

FORMER AMOCO TERMINAL SUPERIOR, WISCONSIN

PROJECT NO.	PREPARED BY	DRAWN BY	
WISUP191	WH	DD/JH	anteagroup
DATE	REVIEWED BY	FILE NAME	
10/2/19		Superior-NS19_WH	

ELEVATION (FEET ABOVE MEAN SEA LEVEL)

640 630 620 610 600 590 580 570 560 550 540

MW-4S MW-4D MW-3 T-28 MW-23 LIF-36 EW-11 EW-4 T-21A FORMER TERMINAL T-17 MW-27 Winter Street MW-26 MW-32/T-4 MW-30DD MW-30D MW-30S T-14 MWT-2D/tf004(T-2) MWT-2S MWM-9RS MWM-9RD/M-13 MWM-6 (Projected) MWM-7 MWM-7D MW-37S MW-37D MW-37DD MW-37DDD MW-41S MW-41D MW-41DD

MWM-9RS	
10/5/2015	
B	<0.40
T	<0.39
E	<0.39
X	<1.2

MWM-6	
5/6/2015	
B	3.2
T	1.3
E	7.7
X	16.2

MWM-7	
10/6/2015	
B	8.8
T	<0.39
E	<0.39
X	<1.2

MWT-2S	
10/10/2018	
B	<0.31
T	<0.49
E	<0.33
X	<0.98

Clay

AOC 5 AOC 4 AOC 1 & 2 AOC 8 (Projected)

Fine-grained Sediment

Sand (variable grain sizes)

Clay

LAKE SUPERIOR

Fine-grained Sediment

Silty Fine Sand

Fine-grained Sediment

Silty Fine Sand

Fine-grained Sediment

MWT-2D	
5/5/2015	
B	3720
T	224
E	277
X	377

MWM-9RD	
5/5/2015	
B	3020
T	164
E	225
X	269

MWM-7D	
5/5/2015	
B	1630
T	36.7
E	33.7
X	30.5

Actual Elevation = 535.00' Actual Elevation = 527.60' Actual Elevation = 535.00'

LEGEND:

- EXPLORATORY BORING / MONITORING WELL
- SCREENED INTERVAL
- END OF BORING
- VERTICAL GRADIENT UPWARD (TYPICAL)
- VERTICAL GRADIENT DOWNWARD (TYPICAL)
- GROUNDWATER ELEVATION (TYPICAL)
- DISSOLVED PHASE BENZENE ISOCONTOUR LINE (5 ug/L)
- ug/L MICROGRAMS PER LITER
- AREA OF CONCERN (AOC); RESIDUAL LNAPL

VERTICAL SCALE (FEET) 10

HORIZONTAL SCALE (FEET) 300