ASSESSMENT OF CONTAMINATION IN THE NORLEDGE AREA AT THE AMOCO REFINERY IN SUGAR CREEK

INDEPENDENCE, MISSOURI

Summary of Expert Opinions of

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SECTION 1:

Purpose

I was retained on this case for the purpose of evaluating the groundwater contamination at the Amoco Refinery located in Independence, Missouri.

Experience

My educational background, research and professional experience, and the review of documents provided are the basis of my opinions. I hold the Ph.D. degree from the University of Florida in Environmental Engineering Sciences, and I have attached a curriculum vita including a list of peer-reviewed publications. I am professor of Civil and Environmental Engineering at Rice University, where I have been on faculty since 1975. I hold the Herman Brown Professor of Engineering and was head of the department from 1991 through 1999.

Site Description

The Amoco Refinery, located at 1000 North Sterling Road in Sugar Creek, Missouri was opened in 1904. The refinery occupies approximately 500 acres on both sides of Sugar Creek along the Missouri River. Products manufactured at the refinery included gasoline, distillate fuels, jet fuels, residual fuels, asphalt, petroleum coke, liquefied petroleum gases (LPG), sulfur, and polymers. Products were shipped by rail or pipeline till about 1950, after which truck shipping was used. Some shipping in later years relied on river barges. The refinery closed in 1982 and was dismantled between 1986 and 1991. Storage tanks in the Gerber Tank Farm are still used for product storage and transfer.

During its seventy-eight years of operation, the crude refining capacity at the refinery increased from 12,000 barrels per day to a final capacity of 100,000 barrels per day (total capacity approximately between 340 billion to 2.8 trillion gallons over 78 yrs). The facility has three major areas: the Lower Refinery (from about 1904), the Crawford Area (from about 1920), and the West Plant Process Area (from about 1947). This report mainly deals with the Crawford Area, the West Plant Process Area, the West Hill Tanks and the West Tank Areas as the source

of contamination in the Norledge residential community to the south and southwest of the facility. Particular emphasis is placed on contaminant conditions at the confluence of Sugar Creek and its southern tributary near MW-107 and on the residential area between Evans and Chicago Streets in the Norledge community.

Spills, Leaks and Releases to Soil, Water and Air

It is clear from reviewing the records for the facility that numerous releases, spills and leaks have occurred throughout all facility areas since it began operations. It is also clear from the materials and documents reviewed to date that many of the causes/sources of these spills and releases were not addressed and went unchecked for an extended period of time resulting in extensive contamination of the surface water, soil, groundwater and air at the refinery and the adjacent residential Norledge neighborhood. In particular, and as will be discussed later in this document, releases into a spring located at Burton Street and into Sugar Creek near residential areas were not addressed for a number of years, and caused exposure to relatively high levels of contaminants.

There were no records kept of spills and leaks prior to 1950 (more than 45 yrs after the facility began its operations) and few records are available from 1950 to the present. The reports that do exist, however, document more than 160 release incidents and report the presence of significant amounts of fuel in the subsurface due to releases from the refinery. For example, T. Gogel in an unpublished report in 1982, reported that approximately 196,000 bbls (over 8 million gallons) have accumulated in the subsurface in the lower refinery area due to massive discharges from the refinery directly into the ground. Additionally, the spills that were documented by Amoco after 1950 total 32,000 barrels, of which 31,500 barrels were discharged directly into Sugar Creek.

Internal crude and product lines at the refinery were underground and were the sources of frequent leaks. These leaks were first noted as seepage into Sugar Creek and other areas outside the refinery in 1950. Even when it was recognized that the lines should be moved above ground in the 1960s, this was not begun till the late 70s. As late as 1980, oil was released during a pipeline repair operation (no spill containment equipment was available at the facility even in 1980).

The Amoco refinery has had an NPDES permit since 1973. The facility was limited to three hundred sixty-seven pounds per day discharge of oil and grease. Amoco has had numerous NPDES violations, described in an internal memo as having "exceeded those reported by other refiners by 10 to 100 fold."

In addition to spills and leaks, poor operating practices caused releases of untreated waste. For example, storm water runoff was channeled through the process water facility, resulting in numerous releases of untreated wastewater during heavy rains. Oil seepage into Sugar Creek was discharged to the Missouri River and water flushing was used to prevent oil accumulation in the creek.

Thus, to summarize, the facility has had a long history of un-permitted discharges to the environment and the nearby residences and neighborhoods: (i) numerous instances of seepage discharging into creeks and the Missouri River and its tributaries; (ii) spills of oil and products in and around the facility; and (iii) accumulation of oil below the facility. These releases exposed the residents in the local community to hazardous materials including benzene, benzo(a)pyrene, and lead among others as will be discussed further in this report.

Cleanup of Spills, Leaks and Releases and Contaminated Media

It is noteworthy that there are very few assessments of pollution at the refinery prior to 1980 (more than 75 yrs after the facility began its operations). Also, noteworthy is the fact that the refinery had knowledge that contaminants were leaving the site, but took little action to address the problem. Gasoline product was known to be seeping from natural springs at the south boundary of the plant in the Norledge Street area as early as the 1950's. An interceptor trench to collect contaminants that were moving offsite, however, was not installed in the Norledge area till after the mid-60s. Even then, seepage into the adjoining creeks continued. In 1964-65, spring water contained up to 25% oil products and gasoline. Residential properties were bought and an expanded interceptor trench was installed instead of eliminating the source of the seepage. In 1975, a survey of oil leaks on the perimeter of the refinery estimated product loss in the Norledge area to be over 5.7 million gallons per year. A further extension of the interceptor trench network was not constructed till the 1990's.

Similarly, cleanup in other parts of the facility did not occur till the 80's (more than 80 yrs after facility began its operations). Recovery wells recovered 1.9 million gallons of free product from ground water below the lower refinery area between 1988 and 1995.

Tables reporting constituents with respect to the groundwater contamination are spotty and inconsistent. For instance the table shown in Appendix C (Retec Group, 2002) show gaps of data between 1992 and 1995, while a map reporting free product thickness (GeoWest Golden Inc., 1994) show free product encountered at MW-62R and MW-54 in February 1994. The encounter of free product was not reported in the historic table, making the available data reported by Amoco questionable at best.

An Amoco 1995 study estimated that 1.3 million gallons remain underground in the lower refinery area. This is likely a low estimate especially in light of the more than 8 million gallons estimated by T. Gogel in 1982.

Surface soils at the refinery are contaminated with lead and benzo(a)pyrene. Benzene is found in the soil in about fifteen free product areas below the site, totaling about 73 acres.

Contamination and Exposure in the Norledge Area

The off-site Norledge Area is a residential neighborhood located adjacent to the southwestern border of the refinery. The contamination in the Norledge area has been attributed in numerous site reports to leaks and spills from the Norgaard Tank Area, the West Hills Tank, West Plant Process, and West Tank Areas as well as the oil seepage mentioned earlier in this report to the spring at Burton Street and into Sugar Creek. Liquid hydrocarbons were detected in wells in all those areas in the 80's. Hydrocarbons (dissolved and separate phase) were also detected in wells north and south of Norledge Street.

A Norledge street sump and interceptor sewer system was installed in 1959 and 1960, and was expanded in the mid-1970's and in 1983. Product recovery rates as high as 650 bbl/day were achieved at times from this system during refinery operations (Woodward-Clyde report, 1987).

An extensive benzene plume has been mapped beneath the Norledge Area in May 1997 with benzene concentrations exceeding 100 times the MCL (maximum contaminant levels). The

mapped benzene plume extends beneath the refinery where concentrations exceed 1000 times the MCL. A recent report from RETEC (Norledge Area Corrective Measures Study Addendum Phase 2 Area Redesign, May 31, 2002) attributes the contamination in the Norledge Area to two different sources from the refinery. The southernmost part of the Norledge plume that is adjacent to the interceptor trench along Norledge is attributed to the West Hills Tank Area while the northerly component of the plume that parallels Willow Avenue between Gill and Evans St. is attributed to the West Tank and/or West Process Area.

Many of the wells in the Norledge area show relatively high levels of benzene as late as the 90's. Among these are the wells along the southern boundary of the facility and north of the residential neighborhood. For example, wells MW-014, -018, 019A, 019B, and MW-107showed benzene concentrations in the 1 – 20 mg/L range when they were sampled in the mid- to late 80's and into the 90's. These wells would have had much higher concentrations while the facility was in operation and experiencing leaks and spills from the underground piping and tanks.

In cooperation with Patrick Agostino I have prepared a plume map (Figure 1 and Figure 2) that shows all maximum benzene concentrations encountered in the reported data that I have been able to review. This map includes the reported free product encounters and treats these occasions as sources of benzene contamination. From this figure it becomes clear that the contamination in the subsurface is massive and clearly protrudes extensively underneath the residential neighborhoods south and southwest of the tank farm. The full magnitude of contamination cannot be assessed from the limited data and the poor sampling procedures that have been performed by Amoco and its consultants. It is more than likely that the subsurface contaminant concentration were higher in the past when the refinery was still operational. It is obvious, from the multitude of reported oil-product seeps, that the plume was formed before 1950's and certainly existed by 1960 and the years afterwards. On one reported occasion (MW-63R) there is even free product encountered in a monitor well that is located within the residential area southwest and downgradient of the tank farm.

Contamination and Exposure from Seepage into Sugar Creek

The Sugar Creek drainage basin encompasses 2,700 acres. The Amoco site occupies 423 acres within this basin (except for 57 acres). A 10-yr, 24-hour rainfall event in Sugar Creek leads to an

estimated maximum flow rate of 3,000 cfs according to the Woodward-Clyde 1987 report. Groundwater from the West Bluff area (since there is a topographic high in the West Plant Process area, see Figure 3 and Figure 4) discharges east to Sugar Creek and south to an unnamed tributary of Sugar Creek. Upland ground water flow moves off site to the south and southwest and is likely to cross the unnamed tributary.

Sugar Creek has received significant amounts of fuel released from the site via seepage into the Burton Street spring and ground water discharge from the topographic highs. Site records, as mentioned previously, report spring water containing 25% oil products and gasoline. In a report from Woodward-Clyde in 1978, flow from the spring is estimated to range between 1.5 and 5 gpm. Assuming an average flow of 3 gpm and assuming the 25% oil products and gasoline is by volume, this would translate to almost 4 million gallons of fuel transported into Spring Creek over a 10-yr period (not taking into account additional releases from ground water discharge into the Creek). Clearly, significant amounts of fuel ended up in Sugar Creek and resulted in exposure of residents in the community, including children. Likely routes of exposure include dermal, ingestion (of Creek water and fish), and inhalation.

SECTION 2: OPINIONS

1.) Heavy contamination emerging from the site was reported as early as the 1920's when a lawsuit was filed by the city of Independence due to the drinking water intake being downstream of hydrocarbon releases. It is very rare to be documented in that early time period and is indicative of the seriousness of the contamination and the operating practices of the Refinery.

2.) The operating and remedial practices of the Amoco Refinery as of today are relatively unchanged when compared to the past, and have severely contaminated groundwater, subsurface soils, and surface water with extensive chemical contamination (i.e. hydrocarbons). Impacts have been both on-site and off-site. It is clear that off-site impacts from the Refinery continue to be a threat to the environment and for surrounding residential areas, given the poorly designed and implemented remediation system.

3.) The French Drain Trench system currently installed has shown to be inadequate for removal and containment of the extensive contamination. The French Drain has evolved over time with multiple add-ons because it was not well designed in the first place, and had numerous failures in terms of capturing contaminants.

4.) Free product has been encountered numerous times off-site and is clearly indicative of a massive subsurface hydrocarbon contamination. Free product has been observed and reported down gradient of the Refinery holding tanks. Some of the free product observations include; free product seeping out of the southern bank of the tributary at the confluence with Sugar Creek; free product encountered in the residential neighborhood in MW-062; free product floating in the tributary south of the site. The inadequate sampling and remediation strategies are a clear sign of the negligent operating practices of the Amoco Refinery.

5.) Given the steep topography on-site, the locations of leaking tanks upgradient, and the confirmed contamination on-site and off-site, it is evident that the Amoco Refinery has contributed massive subsurface contamination to the residential neighborhoods located to the south and south-west of the site.

6.) Due to its geographic location and the combined topography, the Amoco Refinery also heavily contaminated neighborhood streams and springs, and the Missouri river. Most of these contaminations have been documented over the years.

7.) A number of wells located on-site show high benzene concentration when extrapolated back over time.

8.) The site is one of the worst I have seen in terms of lack of care in handling contamination and remediation.

SECTION 3: BASIS AND REASONS FOR OPINIONS

These above opinions are based on a review and analysis of site documentation (see Section 4), one site visit, as well as my knowledge of the fate and transport of contaminants in soils and

groundwater. The above opinions are based only on the information reviewed to date and are subject to change if and when additional information becomes available from the site.

SECTION 4: DATA AND OTHER INFORMATION CONSIDERED IN FORMING MY OPINIONS.

Following is a list of documents used in forming my opinions regarding the groundwater contamination at the Amoco Refinery located in Independence, Missouri.

Literature

1.) P.B. Bedient, H.S. Rifai, and C.J. Newell, "Ground Water Contamination", Prentice Hall PTR, Upper Saddle River, NJ, 2nd Edition 1999.

Other Documents

2.) GeoWest Golden, Inc., CME Work Plan, Extent of Free Phase Product Map, February 1994, April 9, 1994.

3.) Retec Group, Inc., Norledge Area Corrective Measures Study Addendum, Phase 2 Area Redesign, BP products North America, Inc., Sugar Creek, Missouri, May 31, 2002

4.) The RETEC Group, Inc., West Plant Process Area Investigation Work Plan, 11/22/02

5.) Amoco Oil Company, Corrective Measures Inspection, 09/07/90

6.) Woodward-Clyde Consultants, Perimeter Ground Water Sampling, 11/03/89

7.) Amoco Oil Company, Volume IV Appendices C through M, 05/29/87

8.) The RETEC Group, Inc., Norledge Area Corrective Measures Study Addendum Phase 2 Area Redesign, 05/31/02

9.) The RETEC Group, Inc., Corrective Measures Study Norledge Area Addendum Phase 2 Area Redesign, 05/31/02

10.) Refinery-Wide Geology, Hydrology and Groundwater Investigation, Volume 2

11.) American Oil Company, Norledge Trench Design and Operation Information, 10/10/66

12.) Amoco Oil Company, Corrective Measures Inspection, 09/22/94

13.) The RETEC Group, Inc., Benzene Concentrations in Groundwater Figure 3, 05/01/97

14.) Environmental Technologies Inc., , 07/01/96

15.) E.S.S, Extent of Free Phase Product and Dissolved Plume Map, 03/01/91

16.) The RETEC Group, Inc., Benzene Concentrations in Unconfined Groundwater Figure 4-2, 08/01/99

17.) Woodward-Clyde Consultants, Analyte Concentration Map:Btex, TPH, and measured Hydrocarbon thickness, 10/20/89

18.) Woodward-Clyde Consultants, Surface Water and Drainage Features Map, 05/19/87

19.) Woodward-Clyde Consultants, Site Topographic Map, 05/01/87

20.) Woodward-Clyde Consultants, Geologic Cross Sections C-C', B-B', 05/17/87

21.) Woodward-Clyde Consultants, Geologic Cross Section D-D', 05/20/87

22.) Woodward-Clyde Consultants, Residual Soil Thickness Map, 05/04/87

23.) Woodward-Clyde Consultants, Cross Section/ Survey Baseline Location Map, 04/30/87

24.) Woodward-Clyde Consultants, Till Isopach Map, 04/22/87

25.) Woodward-Clyde Consultants, Overburden Isopach Map, 04/22/87

26.) Woodward-Clyde Consultants, Boring Location Map, WCC Drilled October 1986-April 1987, 04/22/87

27.) Amoco Oil Company, Refinery-Wide Geology, Hydrology and Groundwater Investigation, Volume 1, 05/29/87

28.) Woodward-Clyde Consultants, 10-Year Event, 24 Hour Hydrograph for the Amoco Site Drainage Basins, 05/27/87

29.) Woodward-Clyde Consultants, Site Strategraphic Column, 05/29/87

30.) Woodward-Clyde Consultants, Regional Hydrogeologic Characteristics of the Missouri River, 05/29/87

31.) Woodward-Clyde Consultants, 10-Year Event, 24 Hour Hydrograph for the Sugar Creek Watershed, 05/29/87

32.) TriTechnics, Sub Surface Gas Sampling Locations ,

33.) TriTechnics, Background Soil Sampling Results,

34.) Woodward-Clyde Consultants, Piezometric Contour Map Water Levels measured 22 December, 04/28/87

35.) Woodward-Clyde Consultants, Area Key Plan, 04/03/87

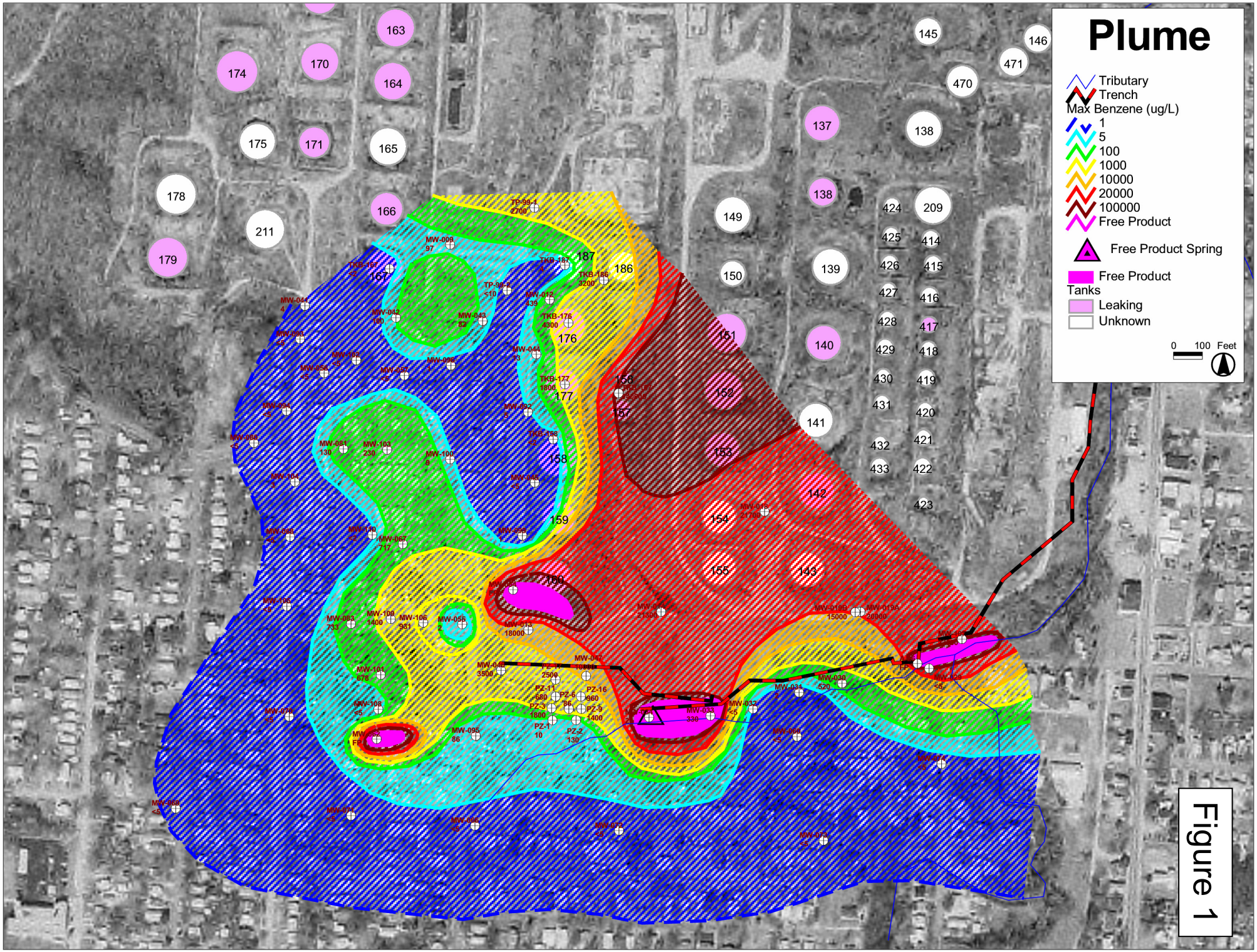
36.) Woodward-Clyde Consultants, Hydrocarbon Thickness Map December 1986-February 1987, 05/07/87

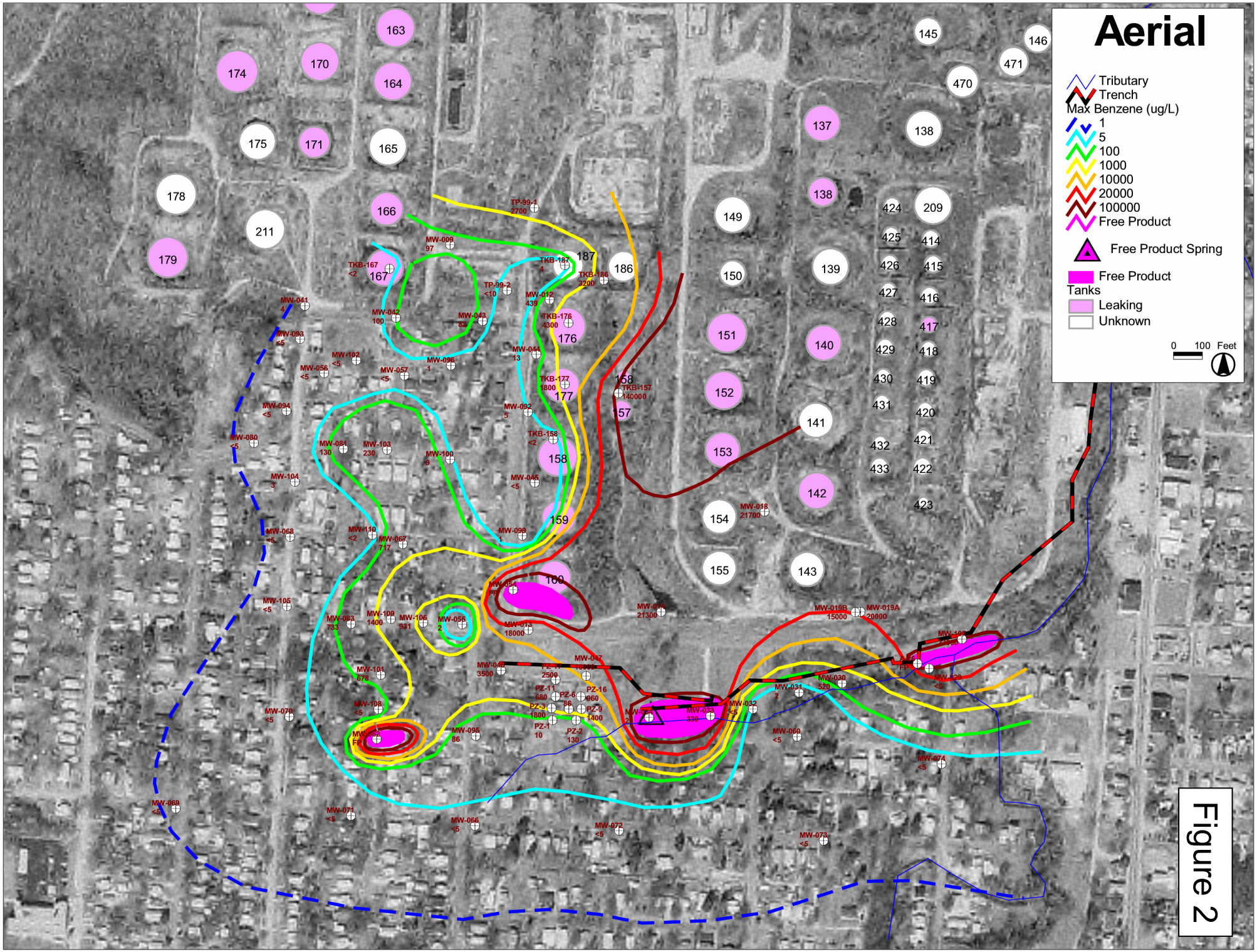
37.) Woodward-Clyde Consultants, Analyte Concentration Map, 05/01/87

38.) Woodward-Clyde Consultants, Map Bundle, 05/20/87

39.) Thermo Retec, Benzene Concentrations in Groundwater- 1997-1999

40.) RCRA Facility Investigation Report, Revision 1


Plume
Tributary
Trench
Max Benzene (ug/L)
1
5
100
1000
10000
20000
100000
Free Product
Free Product Spring
Free Product
Tanks
Leaking
Unknown
0 100 Feet
Figure 1


Aerial
Tributary
Trench
Max Benzene (ug/L)
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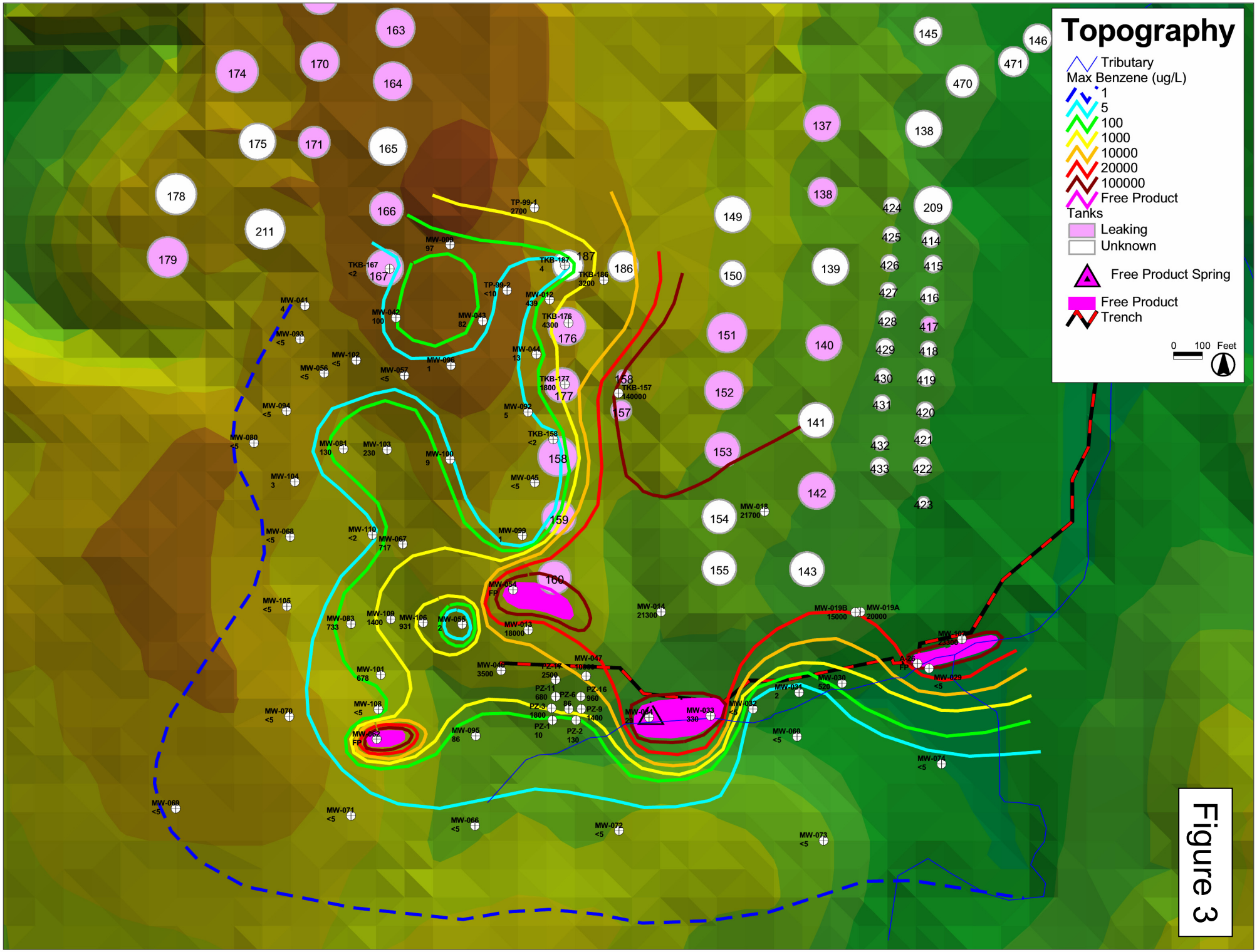
Free Product
Free Product Spring
Free Product
Tanks
Leaking
Unknown
0 100 Feet
Figure 2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Tributary
Max Benzene (ug/L)
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10000
20000
100000
Free Product
Tanks
Leaking
Unknown
Free Product Spring
Free Product
Trench
0 100 Feet
Figure 3

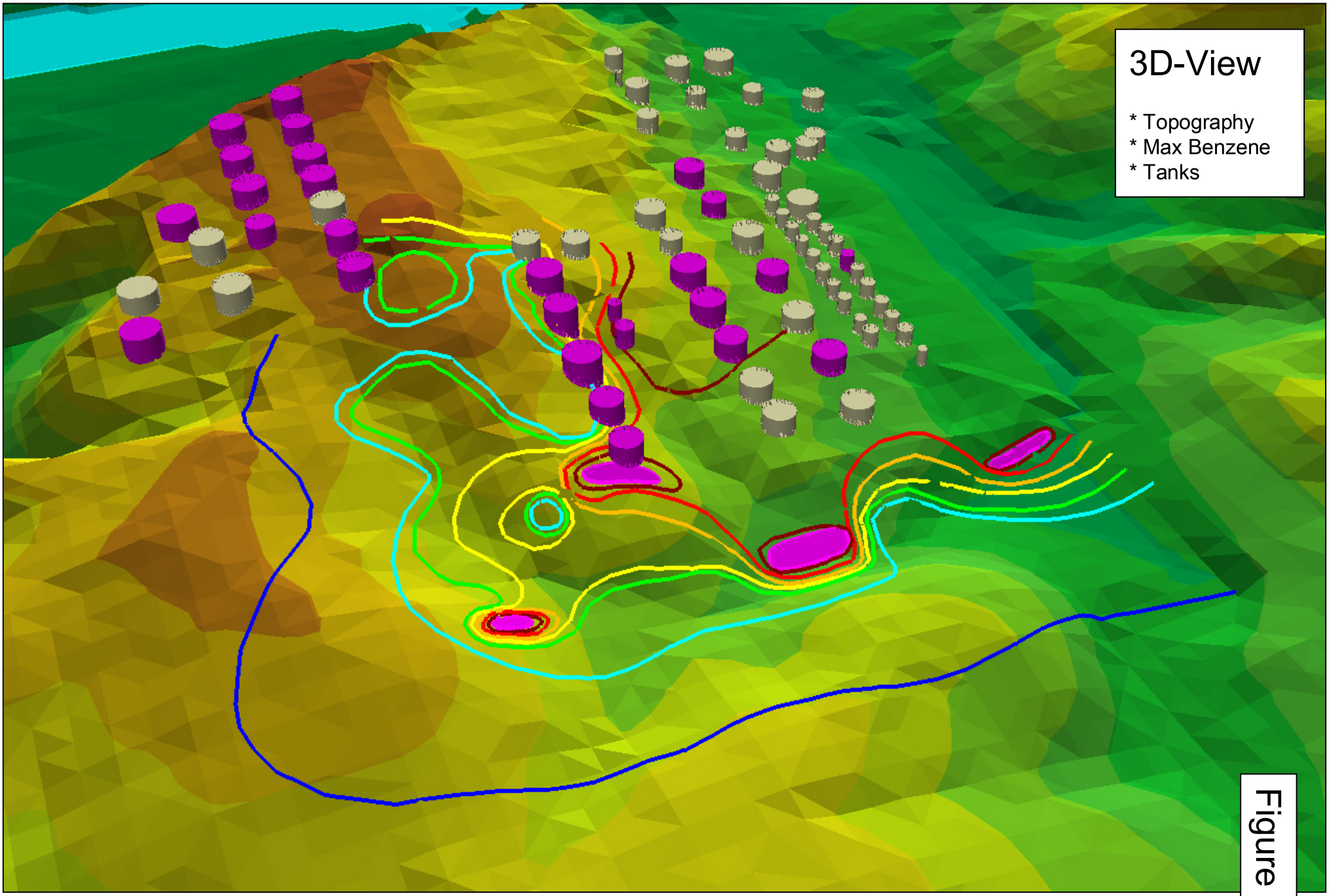

Figure 4