STATE OF MICHIGAN

IN THE CIRCUIT COURT FOR THE COUNTY OF WASHTENAW

ATTORNEY GENERAL for the
STATE OF MICHIGAN, et al,
MICHIGAN NATURAL RESOURCES
COMMISSION, MICHIGAN WATER
RESOURCES COMMISSION, and
MICHIGAN DEPARTMENT OF NATURAL
RESOURCES,

Plaintiffs,

Case No. 88-34734-CE

vs

Hon. Donald E. Shelton

GELMAN SCIENCES INC.,
a Michigan corporation,

Defendant.

_______________________________________/

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Affidavit of James W. Brode, Jr., CPG

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I, JAMES W. BRODE, JR., CPG, being first duly sworn, depose and say:

I. Background

1. I am a practicing professional hydrogeologist with over 25 years of experience. I am employed as a Senior Hydrogeologist by Fishbeck, Thompson, Carr and Huber, Inc. I am a Certified Professional Geologist by the American Institute of Professional Geologists. A copy of my professional qualifications is provided as Attachment 1.

2. I have been involved in investigations of the soils, groundwaters, and surface waters at and in the vicinity of the Gelman Sciences Inc. (Gelman) facility in Scio Township, Ann Arbor, Michigan, since 1986. I performed many of these investigations personally, in my professional capacity, on behalf of Gelman/Pall Life Sciences (PLS). Other investigations have been performed under my direct supervision. I am also familiar with data and interpretations generated by Gelman/PLS and the Michigan Department of Environmental Quality (MDEQ) related to investigations of soils and groundwaters in the vicinity of Gelman/PLS.

3. Based on my 25 years of experience as a professional hydrogeologist, working primarily in Michigan, it is my opinion that the Gelman/PLS site is one of the most thoroughly investigated sites in the State of Michigan. Since the discovery of 1,4-dioxane at the Gelman/PLS site, the investigations of soil and groundwater performed by Gelman/PLS have included: 1) the drilling/installation of over 200 borings/wells, including one of the world's longest horizontal environmental wells, 2) the collection and analysis of thousands of groundwater samples, 3) the collection of hundreds of soil samples, 4) the collection of thousands of water level measurements, and 5) aquifer testing at numerous sites. These investigations have covered an area of approximately 2.5 square miles and have extended as deep as 300 feet below the ground surface (bgs).

4. I have been involved in the development of proposed modifications to the cleanup program, and I have participated in meetings between PLS and the MDEQ regarding modifications to the cleanup program.

II. Western Area

A. Source Areas of Contamination

5. Contrary to the assertions contained in the memorandum authored by Mr. James Coger, the MDEQ geologist assigned to the Gelman site since 2005, which is attached to the MDEQ's June 15, 2009, correspondence, PLS has thoroughly characterized the source areas west of Wagner Road. Investigations have been conducted in all areas considered to be historical sources for 1,4-dioxane, including: Ponds I and II, the former Burn Pit, the Lift Station, the Spray Irrigation Field, and overflow from Pond II into the Marshy Area. Borings and wells have been drilled/installed in all these areas to characterize both the nature and extent of 1,4-dioxane in all of these potential source areas. This work was conducted working closely with the MDEQ. A list of correspondence and submittals exchanged between PLS and the MDEQ regarding the source area investigations is provided as Attachment 2.

6. The MDEQ has conducted its own investigations of these identified source areas, including the drilling of numerous borings and soil and groundwater sampling. In addition, the United States Environmental Protection Agency (USEPA) has conducted investigations in these source areas, including soil and groundwater sampling.

7. Ponds I and II, the former Burn Pit, and the Lift Station became part of what has been referred to as the "Soils System." The Spray Irrigation and Marshy Areas have been addressed separately.

8. Isolated "pockets" of higher levels of 1,4-dioxane are known to remain in the soils and groundwater in the Soils System. Much of this 1,4-dioxane is in fine-grained soils or very

thin water-bearing zones located above the regional aquifers. Because these areas are localized horizontally and vertically, they account for a very small percentage of the remaining mass of 1,4-dioxane at the site.

9. The primary source of 1,4-dioxane in the environment around the PLS site was Pond II. Pond II was unlined and, unlike the other aforementioned sources, Pond II had a good hydraulic connection to the underlying aquifer. Pond I, the Former Burn Pit, and the Lift Station were not significant sources for the 1,4-dioxane that has migrated into the groundwater and resulted in the extensive plumes observed in the PLS area. These sources were not well-connected to the underlying aquifers; therefore, contamination from these sources did not readily leach into the aquifers.

10. In the MDEQ's June 15, 2009, letter to PLS, the MDEQ indicated, "there is very limited understanding of the sources of the remaining groundwater contamination." As indicated above, this is untrue - PLS, the MDEQ, and the USEPA have all thoroughly studied and evaluated the identified source areas.

11. The lone example of a "remaining source area" referenced in the MDEQ letter that requires further evaluation is MW-5d. MW-5d is a shallow well (approximately 19 feet bgs) in the area of former Pond I. Consistent with PLS' evaluation of the Pond I source area discussed above, this well is completed in a shallow, very low-producing water-bearing zone above the regional aquifer. This well produces so little water that PLS often struggles to draw enough water to obtain a valid sample. Although relatively high groundwater concentrations exist at this location, the residual 1,4-dioxane mass is minor because the water-bearing zone is thin (approximately 5 feet) and discontinuous. Again, this is consistent with the parties' conclusion that the Soils System source area, including the Pond I area, is a minor source of 1,4-dioxane.

B. Groundwater Aquifers Are Not "Source Areas"

12. The MDEQ correspondence and Mr. Coger's memo suggest the MDEQ has broadened the traditional understanding of "source areas" to include the receiving aquifers into which 1,4-dioxane has migrated from the historical source areas. Although this characterization is inconsistent with well-established hydrogeological analysis, PLS has in fact successfully defined the extent of contamination in these aquifers (see below) and reduced contaminant concentrations in the Western Area significantly.

13. As a result of remedial actions taken by PLS in the Western Area, particularly the accelerated groundwater extraction that has occurred since the Five-Year Plan was implemented in 2000, concentrations in all aquifers have been significantly reduced to where only isolated areas of high contaminant concentrations exist west of Wagner Road, including Unit E. PLS has operated one of the most intensive groundwater extraction sites in the United States. It is only logical that the extraction and treatment of billions of gallons of groundwater has had a profound impact on reducing contaminant concentrations in the aquifers west of Wagner Road. Attachment 3 includes isoconcentration maps that illustrate the effect the remediation authorized by PLS' Five-Year Plan has had on lowering 1,4-dioxane concentrations since 2000 in both the shallower (C3, D_2) and deeper (Unit E) aquifers.

14. The MDEQ letter states, "*There are no monitoring wells in the Unit E source area, and/or west of Wagner Road that have the capability of determining how much contaminant mass remains in the Western area.*" The MDEQ's characterization of contamination that has migrated into the Unit E aquifer in the Western Area as a "source area" is not supported by available data, which indicate that it is a receiving aquifer. It is also inconsistent with the parties' agreement to attempt to establish cleanup objectives for the entire aquifer system (rather than on an aquifer by aquifer basis).

15. Even if one considers the 1,4-dioxane in the Unit E west of Wagner Road to be a "source area," 1,4-dioxane concentrations in this aquifer have steadily reduced since extraction began. This dramatic decrease in observed concentrations indicates there is no significant Unit E source area. For example, 1,4-dioxane concentrations at TW-11 and TW-17 (and all surrounding monitoring wells) would not be declining if there were a significant mass/source of 1,4-dioxane hydraulically upgradient (west) of these wells. Similarly, if there was an ongoing *source* of 1,4-dioxane upgradient of TW-12, a Unit E extraction well near Wagner Road that was turned off after concentrations fell below 85 micrograms per liter (µg/L), concentrations in this area would have rebounded by now, because it has been years since this well was operated. Data from MW-65s/i/d, nearby monitoring wells, indicate this is not the case.

16. Because the MDEQ and PLS have agreed to set cleanup objectives for the entire aquifer system, rather than on an aquifer by aquifer basis, there is no technical reason to, or benefit from, further characterizing the Unit E.

C. Existing Monitoring Well Network/Delineation of the Extent of Groundwater Contamination

17. Since 1992, PLS has been obligated under the Consent Judgment (CJ) to define the extent of the groundwater contamination. To accomplish this CJ obligation, PLS has prepared, and the MDEQ has approved (or commented on), various monitoring plans over the years. Since the beginning of full-scale remediation in 1997, there have been ten plans submitted to the MDEQ, including the most recent plan submitted with the Comprehensive Proposal to Modify the Cleanup Program (May 2009). The dates of these submittals were: November 11, 1998, January 29, 1999, April 8, 2009, January 25, 2000, December 15, 2000, December 10, 2001, September 4, 2002, January 29, 2004, August 15, 2007, and May 4, 2009.

18. Over 200 monitoring wells and borings have been installed west of Wagner Road. These wells/borings have been used to define and monitor shallow unsaturated or water-bearing

zones (Soils System, Marshy Area, Spray Irrigation Area), the intermediate aquifers (Units C3/D_2/D0), and more recently, the deeper aquifers (Unit E).

19. Vertical aquifer sampling/profiling of the subsurface has been conducted at approximately 31 locations on the west side of Wagner Road, and there are 32 nested well groups being used to monitor groundwater vertically.

20. Although PLS and the MDEQ have from time to time agreed to supplement the monitoring well network by adding certain monitor wells, the current monitoring well network has been deemed to be sufficient to define the extent of groundwater contamination west of Wagner Road for at least the last ten years. This conclusion is based on my review of historical correspondence between PLS and the MDEQ and my personal involvement in the discussions with MDEQ technical staff regarding this issue. The last time the parties agreed to additional investigations west of Wagner Road to define the plume was in 2007 (soil boring MW-109).

21. Recently, and particularly in response to PLS' Comprehensive Proposal to Modify the Cleanup Program (PLS' Proposal), the MDEQ has unexpectedly questioned the adequacy of the previously agreed upon delineation.

22. In his June 5, 2009, memo, Mr. Coger characterizes PLS' previously approved monitoring network as, "a patchwork of wells installed historically to evaluate the extent of contamination in various aquifers near the plant site." Mr. Coger also claims that, "The monitoring well network west of Wagner Road is not adequate for assessing cleanup objectives."

23. This characterization is contradicted by both the MDEQ's previous approvals of PLS' monitoring plans and the extensive nature of PLS' monitoring well network. It also reflects an inappropriately narrow focus on only one type of data (data from monitoring wells) to define the extent of contamination.

24. The existing monitoring well network is the product of a well thought out analysis of all available data, in which the MDEQ has participated.

25. Contaminant plumes are defined by analyzing multiple sources of information, establishing hydrogeological relationships, measuring hydraulic heads, and measuring contaminant concentrations. This type of multifaceted analysis has been successfully used over the years by PLS and MDEQ technical staff to define the extent of contamination and identify appropriate monitoring well locations. Placing wells or borings, without recognition of all these relationships, results in unnecessary data collection. Recently, the MDEQ appears to have abandoned this industry-wide practice and has begun insisting on installing monitoring wells at locations where no wells were previously deemed necessary.

26. One example of the MDEQ's failure to incorporate all the available data is in its unnecessary request for a deeper well at the MW-13 location (Attachment 4 – map showing MDEQ proposed monitor well locations).

27. MW-13 was drilled/installed in 1986 and completed at a depth of 135 feet bgs. Water samples from this well have been non-detect for 1,4-dioxane since the well was installed. Mr. Coger has demanded that PLS install a deeper monitoring well at this location to define the extent of contamination in the Unit E aquifer. The extent of contamination in the Unit E is, however, already defined in this area by MW-66, a Unit E well installed in 2001 within a few hundred feet of the MW-13 location. The highest 1,4-dioxane concentration detected in MW-66 has been 2 µg/L. The hydraulic head at MW-66 is higher than at MW-64 (a well located in Unit E to the southeast) and approximately 3 feet higher than Unit E wells along Wagner Road. These elevations demonstrate that groundwater flow is to the east from MW-66, toward Wagner Road and the Prohibition Zone (PZ). As such, this well clearly defines the upgradient boundary

of the Unit E plume in this area. Installing another Unit E well in the area where the plume is already defined by MW-66 makes no sense.

28. Similar analysis leads to the conclusion that the remaining monitoring wells the MDEQ has requested in the Unit E are unnecessary to delineate the extent of contamination. In each case, there are either existing monitoring wells near the requested location and/or groundwater flow directions and other data indicate the plume is already well defined in that area.

D. MDEQ Request for Rotosonic Drilling and Vertical Aquifer Sampling Using Temporary Wells

29. PLS currently installs monitoring wells using the well-established hollow-stem aquifer drilling method. This method is used all over the world for monitoring well installation, and it is a proven and well-accepted technology for environmental investigations. It has also been proven to work well under the difficult drilling conditions in the PLS site area, which often include hard clay/silt deposits.

30. Rotosonic drilling is a relatively new technology in the environmental field. The main advantage of this technology over hollow-stem augers is the ease of collecting continuous samples (cores). Disadvantages of the Rotosonic technology include the need to add significant amounts of water during drilling, difficulties drilling through hard clay/silt deposits, and the expense. PLS currently collects soil samples at 10-foot intervals during drilling and geophysically logs monitoring well borings to supplement the sample information. Over the geographic scale of the PLS site investigation, collecting vertical soil samples at 10-foot intervals using the hollow-stem methods, coupled with the geophysical logging, is adequate to characterize the geological conditions of the site area, hence there is little or no advantage in switching to this technology for the PLS site.

31. I have been involved in the drilling of between 60 and 70 borings where a Simulprobe™ sampler has been used to collect Vertical Aquifer Samples (VAS). The sampler is Simulprobe™, a well-recognized sampling device used for the collection of both water samples and groundwater samples during the drilling of a boring. This device has been used extensively at sites of contamination, and it is one of the most recognized tools for VAS. The Simulprobe™ has been evaluated by the USEPA, state regulatory agencies, university researchers, and private companies.

32. PLS has used VAS data from the Simulprobe™ to make decisions regarding the depth intervals monitoring wells should be installed. Monitoring wells are typically installed at depths exhibiting the highest VAS concentrations.

33. The MDEQ has routinely questioned the use of the Simulprobe™ for the PLS site and has claimed the results from this sampling device are not representative, such as in the case of the Nancy Drive boring. The MDEQ has never provided PLS any references, data, or statistical analysis to support this claim.

34. I have compared the Simulprobe™ VAS samples and initial well samples from 66 locations and have found an excellent correlation between Simulprobe™ samples and initial well samples (Pearsons coefficient "r" = of 0.912). All statistical outliers in the data comparison were explainable.

35. The MDEQ has requested that future monitoring wells be installed using "Rotosonic Methods" and that "temporary well screens" be used to collect VAS.

36. The use of Rotosonic Methods and temporary well screens will result in a significant increase in both drilling time and cost. This is supported by testing done at the PLS site, and a study sponsored by the MDEQ (The Mannik & Smith Group and Boart Longyear, *Push-Ahead TE Vertical Aquifer Sampling Methodology with Sonic Drilling*) (Attachment 5).

The study indicated that the required inducement of fluids during drill stem advancement using Rotosonic can "greatly increase time and expense" where the collection of vertical aquifer profile sampling is desired.

37. In the same study, a statistical analysis of samples collected using temporary wells was performed. The analysis compared VAS samples and well samples. The authors determined that samples collected using temporary wells had a Pearsons coefficient of 0.846. This correlation coefficient is less than the Simulprobe™ (Pearsons coefficient of 0.912). In the same study, the authors tested another technique (Push-Ahead™ sampler) and compared results to well samples. That technique had a Pearsons coefficient of 0.651. Our analyses indicate the Simulprobe™ samples are very representative of aquifer conditions and are superior to both temporary wells and the Push-Ahead™ sampler in collecting vertical aquifer samples during drilling.

E. <u>Feasibility of Proposed Remedial Objective of Preventing Expansion</u>

38. The data gathered over the last 20 years demonstrate that the proposed Western Area remedial objective of preventing expansion is feasible.

39. Initial investigations conducted long before groundwater extraction was initiated revealed that 1,4-dioxane had historically migrated a short distance north and west from the source areas in the shallower C3 aquifer. As the plume expanded in these directions, the vertical hydraulic gradients overcame horizontal gradients, and the 1,4-dioxane migrated vertically downward, rather than continuing to expand to the north and west. This contamination ultimately migrated vertically into lower aquifers (D_2 and Unit E).

40. Groundwater level measurements taken in these lower aquifers have consistently shown a strong groundwater flow to the east, toward Wagner Road, regardless of whether groundwater extraction was underway. Potentiometric surface maps showing interpretations of

groundwater flow in 1986 are provided in Attachment 6. This well-documented natural groundwater flow pattern has historically contained the migration of contamination to the north and west and directed the plume east of Wagner Road. Moreover, PLS was never required to install extraction wells in the northern and western portions of the Western Area in order to prevent expansion, so this occurred naturally. Therefore, expansion of the plume beyond any areas where it historically migrated is extremely unlikely, even if all groundwater extraction is eventually terminated. This is particularly true because contaminant concentrations in the Western Area aquifers have been significantly reduced from past levels.

41. 1,4-Dioxane concentrations north of Third Sister Lake were once very high (over 60,000 µg/L). By extensive purging of TW-1 and TW-3, these concentrations were reduced by orders of magnitude. MW-18d, a monitoring well near TW-1, was reduced from 50,000 µg/L to less than 300 µg/L. MW-37, a well positioned south of TW-3, was reduced from 60,000 µg/L to approximately 300 µg/L.

42. Data from the westernmost extraction wells, TW-1 and TW-3 and associated monitoring wells, indicate the mass that was once available to migrate to the north and west has now been reduced considerably and has stabilized, even with these wells no longer running. Through its extensive remedial efforts to date, PLS has effectively eliminated any significant mass of 1,4-dioxane and the formerly steep chemical gradients that could potentially "push" the edge of the plume to the north and west.

43. Despite this significant reduction of mass and contaminant concentrations, the areal extent of the groundwater with concentrations above 85 parts per billion (ppb) has not significantly changed since PLS began purging in the Western Area. As noted above, the expansion of the plume in the northern and western directions is contained by natural gradients and groundwater flow patterns independent of groundwater extraction. Therefore, both logic and

all of the available data dictate that reducing and even eventually terminating groundwater extraction in the Western Area will not cause the plume to expand in directions that do not lead to the PZ.

F. Mass Removal Comparison

44. I have analyzed mass removal under two scenarios: 1) terminating existing extraction wells when concentrations in the wells reach 500 µg/L, as recently proposed by PLS, and 2) continuing to operate the existing extraction wells at their current flow rates. I used available extraction well data for this analysis, and projected 1,4-dioxane trends out ten years.

45. I have determined that the difference in mass removed from the groundwater under the two scenarios is very similar; there is approximately a 10 percent difference between the two scenarios. This is due to the fact that at concentrations less than 500 µg/L, the extraction wells become relatively inefficient in reducing mass.

III. Evergreen Area

A. MDEQ Demand for Additional Delineation of Evergreen Plume

46. The MDEQ has demanded that PLS install a nested well at the former technical boring location GSI96-01 (Rose and Valley Areas) (Coger Memo, p. 3).

47. This MDEQ location is internal in the plume. Further definition (confirmation) of 1,4-dioxane levels internally, within the plume, will provide little benefit to the understanding of plume migration or PLS' ability to comply with cleanup goals and objectives.

48. The MDEQ has requested additional monitoring wells be installed west of the Evergreen Subdivision Area, near Columbus Drive and I-94 and midway between the new well and the existing monitoring well, MW-121 (see Attachment 4 - showing existing monitoring wells and well locations requested by the MDEQ). The MDEQ claims these "well(s) are needed

to define the western extent of contamination and to establish that the source of contamination in DuPont Circle is not from an area west of, or outside of the proposed expanded PZ."

49. Over the years, PLS has installed several borings and/or wells along the northern/western boundary of the 1,4-dioxane plume migrating northeast to the Evergreen Subdivision Area. These borings/wells include PLS-08-07, MW-14d, MW-118, GSI-94-01 and MW-121s/d. Data from these borings/wells provide clear definition of the northern/western boundary of the plumes migrating toward Evergreen and Dupont Areas.

50. The MDEQ is now requesting two closely spaced wells be installed between two recently installed well locations (MW-118 and MW-121s/d) to define the western extent of contamination and to establish that the source of contamination in the Dupont Area is not from an unknown source of contamination located west or outside of the PZ. MW-118, MW-121s/d, and PLS-08-07 were all recently installed/drilled for the same general purpose, to further define the northern boundary of the plume and further investigate the MDEQ's hypothesis regarding the 1,4-dioxane in the Dupont Area.

51. None of the data collected from these or any other PLS boring/well locations support the MDEQ's hypothesis regarding the Dupont Area. The data are unequivocal that the axis of the plume migrating into the Dupont/Evergreen Area is east of MW-118 and MW-121s/d, and migrates toward the Dupont Area from the Sisters Lake region. The additional investigations in the areas proposed by the MDEQ are unjustified.

B. Groundwater Flow Direction in Evergreen Area

52. PLS studied the natural groundwater flow patterns that existed in the Evergreen Area before PLS began purging from LB-1 in 1992. These early investigations show that groundwater in the Evergreen Area naturally flows east as it passes through the subdivision. There is, therefore, no reason to believe that the natural groundwater flow pattern will not

continue to control the migration of the plume after the Evergreen extraction is reduced or terminated.

53. After hearing the MDEQ's continued concerns regarding the possible change in groundwater flow direction, PLS agreed to further study what effect, if any, reducing and terminating the Evergreen extraction would have. With significant input from MDEQ technical staff, PLS developed a testing procedure for determining whether lowering purge rates in this area would affect groundwater flow direction. PLS agreed to install three new monitoring well clusters (MW-120, 121, and 122) to further define the extent of contamination and to provide additional data points from which to gather groundwater elevation data. The MDEQ approved that work plan. The results of this investigation were described in PLS' March 2009 Report on Water Level Testing Under Reduced Flow Conditions (the "Evergreen Groundwater Flow Report") (Attachment 7).

54. This investigation demonstrated that even with no extraction, groundwater in the area continues to flow east, consistent with the natural flow pattern observed before purging began (Evergreen Groundwater Flow Report, pp. 10-12).

55. I am aware that the MDEQ has questioned the validity of the groundwater elevation data from MW-120s. There is no technical reason for discounting the MW-120s data. The MDEQ, however, demanded that PLS install two new monitoring well clusters to obtain data to corroborate the MW-120s data.

56. Although neither I nor Mr. Fotouhi believed it was necessary to corroborate the MW-120s data, PLS agreed to try to address the MDEQ's concerns in this regard by installing one of the two well clusters that the MDEQ had requested. We concluded that the second location requested by the MDEQ was too far away from MW-120s to provide any useful data

and, at best, it would provide data redundant of the data to be obtained from the MW-123 well cluster that PLS agreed to install.

57. The data obtained from the MW-123 well cluster corresponded very well with the MW-120s data and corroborated that data and the easterly groundwater flow direction revealed by the previously completed Evergreen Groundwater Flow test. PLS has prepared and provided the MDEQ with updated potentiometric maps that confirmed groundwater flow was to the east.

58. Based on the historical information regarding the natural groundwater flow patterns in the Evergreen Subdivision Area and analysis of the data gathered from the signficant number of monitoring wells installed in the area, including the Evergreen Groundwater Flow Test/Report, it is clear that the groundwater contamination in the Evergreen Area will flow east, even if groundwater extraction in the area is either reduced or terminated.

59. These data also demonstrate that groundwater contamination above 85 ppb in either the D_2 or Unit E aquifers in the Evergreen Area will not migrate or expand north of the proposed expanded northern PZ boundary under either reduced or no purging conditions.

C. <u>Fate of Evergreen Plume</u>

60. If PLS' proposal is approved, the portion of the Evergreen plume not removed by the LB wells will migrate east, within the expanded PZ, and eventually merge with the Unit E plume, which is located a few hundred feet south of the Evergreen Area. The combined plume will vent to the Huron River, well downstream of the City of Ann Arbor's Barton Pond water intake.

61. The City of Ann Arbor's Barton Pond water intake on the Huron River is located approximately 11,000 feet northeast of the Evergreen plume. Allowing the Evergreen plume to merge with the Unit E plume will not bring groundwater contamination significantly closer to the City's intake.

62. Even if groundwater contamination in the Evergeen Area hypothetically flowed directly toward Barton Pond (which will not happen), it would take approximately 30 years for the plume to reach the pond, assuming a conservatively rapid groundwater flow velocity of 1 foot per day.

D. Relationship Between the Evergreen and Unit E Plumes

63. The shallower portion of the Unit E plume, located just south of the Evergreen Area, flows at approximately the same depth as the D_2/Evergreen plume and the two aquifers are hydraulically connected. The MDEQ has recognized this fact by asking PLS to prepare potentiometric surface maps that are based on data from both aquifers.

64. Operating at their current purge rates, the Evergreen extraction wells may actually be pulling contaminated groundwater from the Unit E plume north into the Evergreen Subdivision Area.

E. Dupont Area

65. The nature and extent of 1,4-dioxane in the Dupont Area of the Evergreen Subdivision has been analyzed through the installation of borings and wells, the collection of water level and water quality data, and two pumping tests (April 2001 and January/February 2009). The following has been determined from this work:

a. Contaminated groundwater in the Dupont Area migrates to the east, toward the existing extraction wells.

b. The potential for flow to the northwest from the Dupont Area has been ruled out by investigations conducted by PLS.

66. In the PLS proposed monitoring plan provided in the Comprehensive Plan to Modify the Cleanup Program, PLS proposes to routinely monitor MW-121s/d. These shallow and deep wells are positioned along the proposed PZ boundary northwest (upgradient) of the

Dupont Area. These wells are strategically located to monitor for northwest migration of 1,4-dioxane and to demonstrate the plume(s) are, and remain within, the PZ in this area.

FURTHER, AFFIANT SAYETH NOT.

JAMES W. BRODE, JR., CPG

Subscribed and sworn to before
me this 19 day of August, 2009.

Notary Public, Kalamazoo County, Michigan
My commission expires: 8-22-2010

MICHIGAN DEPARTMENT OF ENVIRONMENTAL QUALITY
JACKSON DISTRICT
REMEDIATION AND REDEVELOPMENT DIVISION

MAILINGS TO INFORMATION REPOSITORIES
OCTOBER 1992 TO DECEMBER 2008

Category: MARSHY SYSTEM

03/22/93	GSI submittal of "Marshy Area System Work Plan"
04/28/93	CDM review of Marshy Area System Work Plan
05/20/93	MDNR response to Marshy Area work plan
06/10/93	GSI response to MDNR rejection of Marshy Area System Work Plan
09/21/93	MDNR response to GSI revision of Marshy Area Work Plan
12/15/93	GSI submittal of Marshy Area System Work Plan Update
01/20/94	Letter from GSI to MDNR regarding delay Marshy Area Work Plan Implementation
03/08/94	GSI revision of Marshy Area System schedule
07/01/94	Analytical results of Marsh Sump sample
08/02/94	Analysis of Marshy Area Discharge
08/04/94	MDNR response to GSI submittal on Marshy Area System
03/03/95	GSI submittal of Marshy Area System pilot test report
07/17/95	MDNR memo from L. Lipinski to S. Kolon (re: Marshy Pilot Test)
07/26/95	MDNR response to GSI submittal on Marshy Area Pilot Test
04/13/98	Letter from F. Fotouhi to S. Kolon (schedule for submittals)
04/21/98	Letter from S. Kolon to F. Fotouhi (response to 4/13 letter)
7/24&28	E-mails between F. Fotouhi & S. Kolon (extension of time to submit Marshy report)
08/07/98	GSI submittal of Marshy Area System Pilot Test Report
12/22/98	DEQ memo from L. Lipinski to S. Kolon (review of Pilot Test Report)
01/06/99	DEQ response to Pilot Test Report dated 8/7/98
02/19/99	Letter from F. Fotouhi to S. Kolon (response to 1/6/99 letter)
03/19/99	DEQ memo from L. Lipinski to S. Kolon (review of 2/19/99 letter)
03/22/99	Letter from S. Kolon to F. Fotouhi & R. Connors (response to 2/19/99 letter)
04/03/00	E-mail note from F. Fotouhi to S. Kolon w/attachment (sampling schedule)
05/05/00	P/GSI submittal of Final Design, Effectiveness Monitoring Plan
06/30/00	Letter from S. Kolon to F. Fotouhi (maps needed to complete review)
07/25/00	Letter from L. Beyer to S. Kolon (w/maps from 6/30/00 report)
08/29/00	DEQ memo from L. Lipinski to S. Kolon (re: 6/30/00 report)
08/31/00	DEQ response to Final Design
09/15/00	Letter from F. Fotouhi to S. Kolon (response to letter of 8/31/00)
08/20/01	E-mail from F. Fotouhi to S. Kolon (system status)
08/21/01	Letter from L. Beyer to S. Kolon (w/borehole log for PW-2)
10/15/01	PLS submittal of Status Report
01/23/02	PLS submittal of Status Report
03/22/02	DEQ response to Marshy System Status Report
05/01/02	Letter from F. Fotouhi to S. Kolon (re: Marshy System Report)
03/18/03	PLS submittal of Status Report
04/30/04	PLS submittal of Marshy System Annual Report

MICHIGAN DEPARTMENT OF ENVIRONMENTAL QUALITY
JACKSON DISTRICT
REMEDIATION AND REDEVELOPMENT DIVISION

MAILINGS TO INFORMATION REPOSITORIES
OCTOBER 1992 TO DECEMBER 2008

Category: SOILS SYSTEM

Soils System

05/24/93	GSI submittal of "Soils System Plan"
06/30/93	CDM review of Soil Remediation Plan
07/22/93	MDNR response to Work Plan for Soils System
08/11/93	GSI reply to 7/22/93 MDNR response to Soils System Plan
12/13/93	GSI submittal of Soils System schedule and sample results
08/03/94	MDNR response to GSI submittal on Soils System
10/04/94	GSI response to MDNR comments on Soils System
03/10/95	MDNR response to Soils System data set
04/25/95	GSI submittal of remedial options for Soil System
08/25/95	GSI submittal of Soils System Remedial Action Plan
10/30/95	MDEQ response to 8/25/95 GSI submittal of Soils System Characterization Report and Remedial Action Plan
11/30/96	GSI submittal of Revised Soils Remedial Action Plan
01/31/97	MDEQ response to GSI submittal of Revised Soils System Remedial Action Plan
03/27/97	GSI submittal of amendments to Revised Soils System Remedial Action Plan
06/23/97	MDEQ response to 3/31/97 GSI submittal of Amendment to Soils System RAP
10/28/97	GSI submittal of Soils System Remedial Action Plan - Revision II
12/29/97	Letter from S. Kolon to F. Fotouhi and R. Connors (acknowledging receipt of RAP)
03/30/98	Letter from F. Fotouhi to S. Kolon (recently collected soils data to support RAP)
04/29/98	Letter from S. Kolon to F. Fotouhi & R. Connors (proposed RAP)
05/15/98	Letter from F. Fotouhi to S. Kolon (withdrawal of proposed RAP)
07/30/98	GSI submittal of Soil Sampling Plan
09/03/98	DEQ response to Soil Sampling Plan
10/30/98	Letter from F. Fotouhi to S. Kolon (soil sampling results)
12/17/98	Letter from S. Kolon to F. Fotouhi & R. Connors (approval of Soils System report of 10/30/98)
05/16/01	P/GSI submittal of soil sampling schedule
10/01/04	PLS submittal of Soils System Work Plan
11/29/04	Letter from S. Kolon to F. Fotouhi (re: 9/30/04 work plan)
01/14/05	DEQ Interoffice Memorandum from L. Lipinski to S. Kolon (re: Soils System Work Plan)
01/14/05	DEQ response to Soils System Work Plan

MICHIGAN DEPARTMENT OF ENVIRONMENTAL QUALITY
JACKSON DISTRICT
REMEDIATION AND REDEVELOPMENT DIVISION

MAILINGS TO INFORMATION REPOSITORIES
OCTOBER 1992 TO DECEMBER 2008

Category: SPRAY IRRIGATION FIELD

Spray Irrigation Field

04/26/93	GSI submittal of Spray Irrigation Field work plan
05/28/93	CDM review of Spray Irrigation Field RI Work Plan
06/22/93	MDNR response to Spray Irrigation Field Work Plan
06/23/93	GSI submittal of Spray Irrigation Field Soil Flushing System Work Plan
07/13/93	GSI clarification of Spray Irrigation Field Work Plan
07/28/93	CDM review of Spray Irrigation Field Soil Flushing System
08/06/93	MDNR response to Spray Irrigation Field Soil Flushing System Work Plan
09/22/93	GSI submittal of revisions to Spray Irrigation Field Soil Flushing Work Plan
04/17/96	Letter from S. Kolon to F. Fotouhi (re: change in criteria requires no further action)

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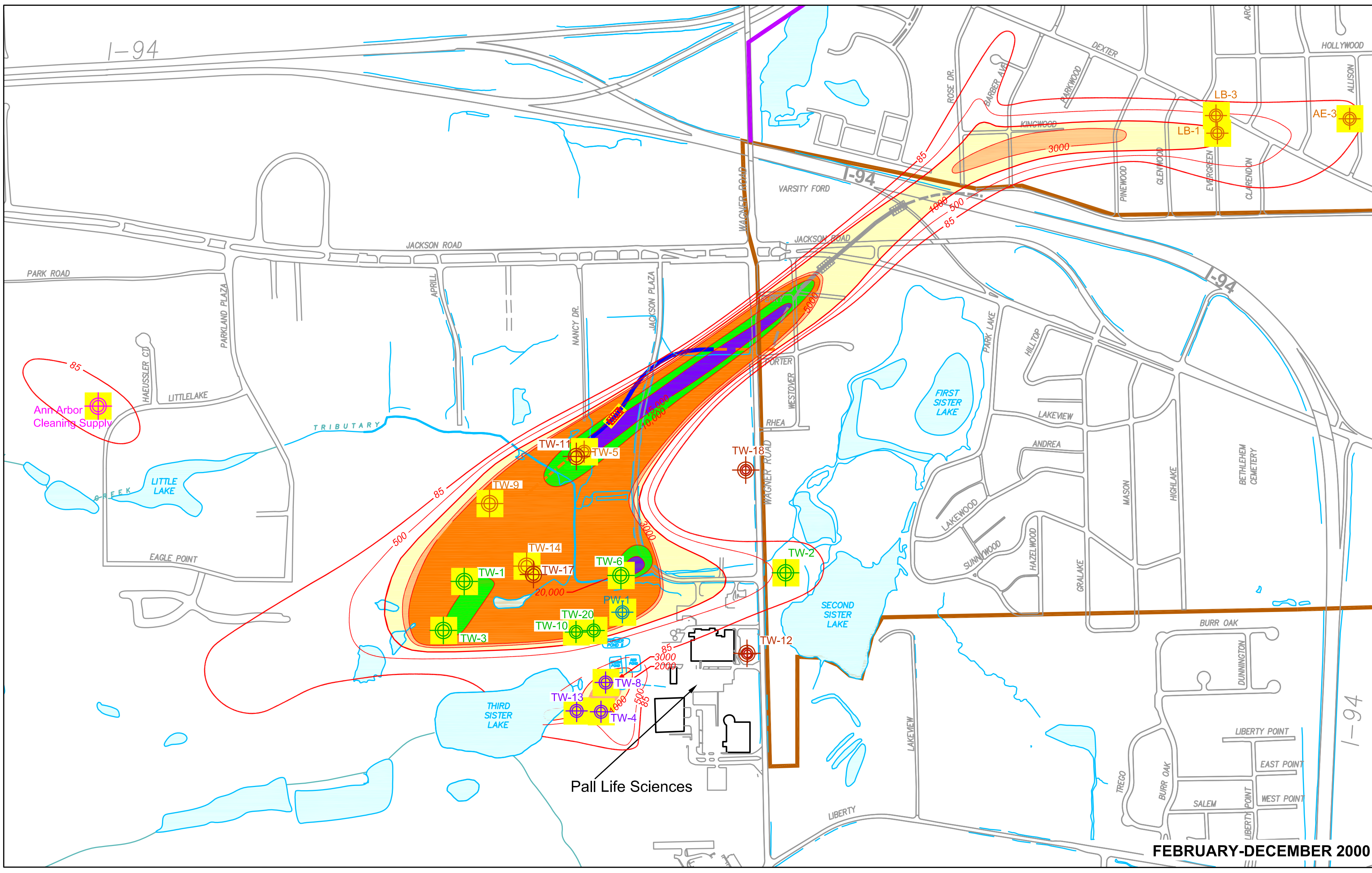
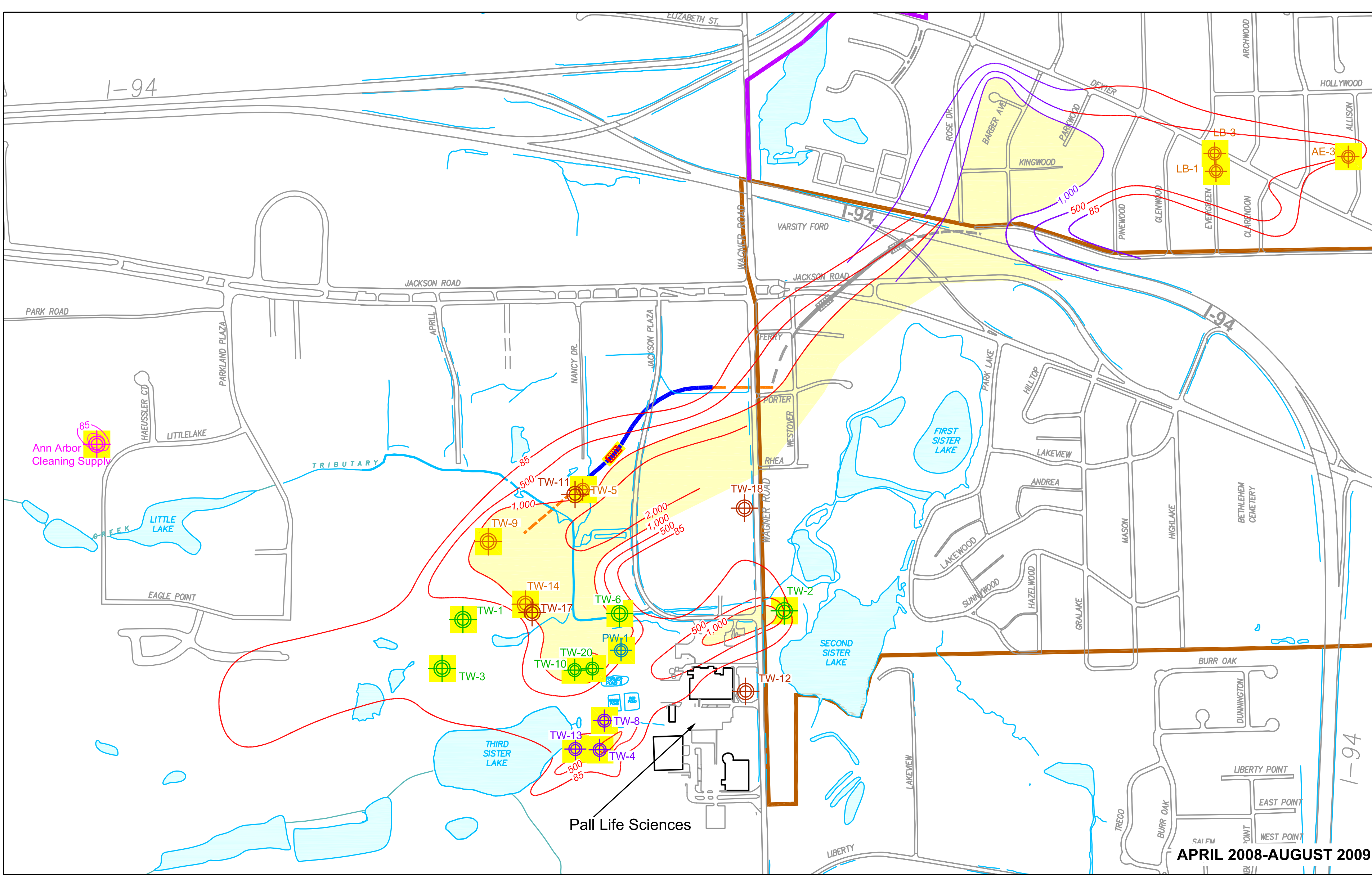




LEGEND

1,4-DIOXANE (µg/L)

- 1,000 - 3,000
- 3,000 - 5,000
- 5,000 - 10,000
- 10,000 - 20,000
- >20,000

EXTRACTION WELLS

- MARSHY AREA
- UNIT C3
- SOUTHWEST AREA
- WESTERN SYSTEM
- UNIT D2
- UNIT E

NORTH

GRAPHIC SCALE 0 500 1000

COMPARISON OF 2000–2009 1,4–DIOXANE CONCENTRATIONS

Pall Life Sciences

Scio Twp., Washtenaw County, Michigan

Brode Affidavit

PROJECT NO. F96502

ftc&h engineers scientists architects constructors

fishbeck, thompson, carr & huber, inc.

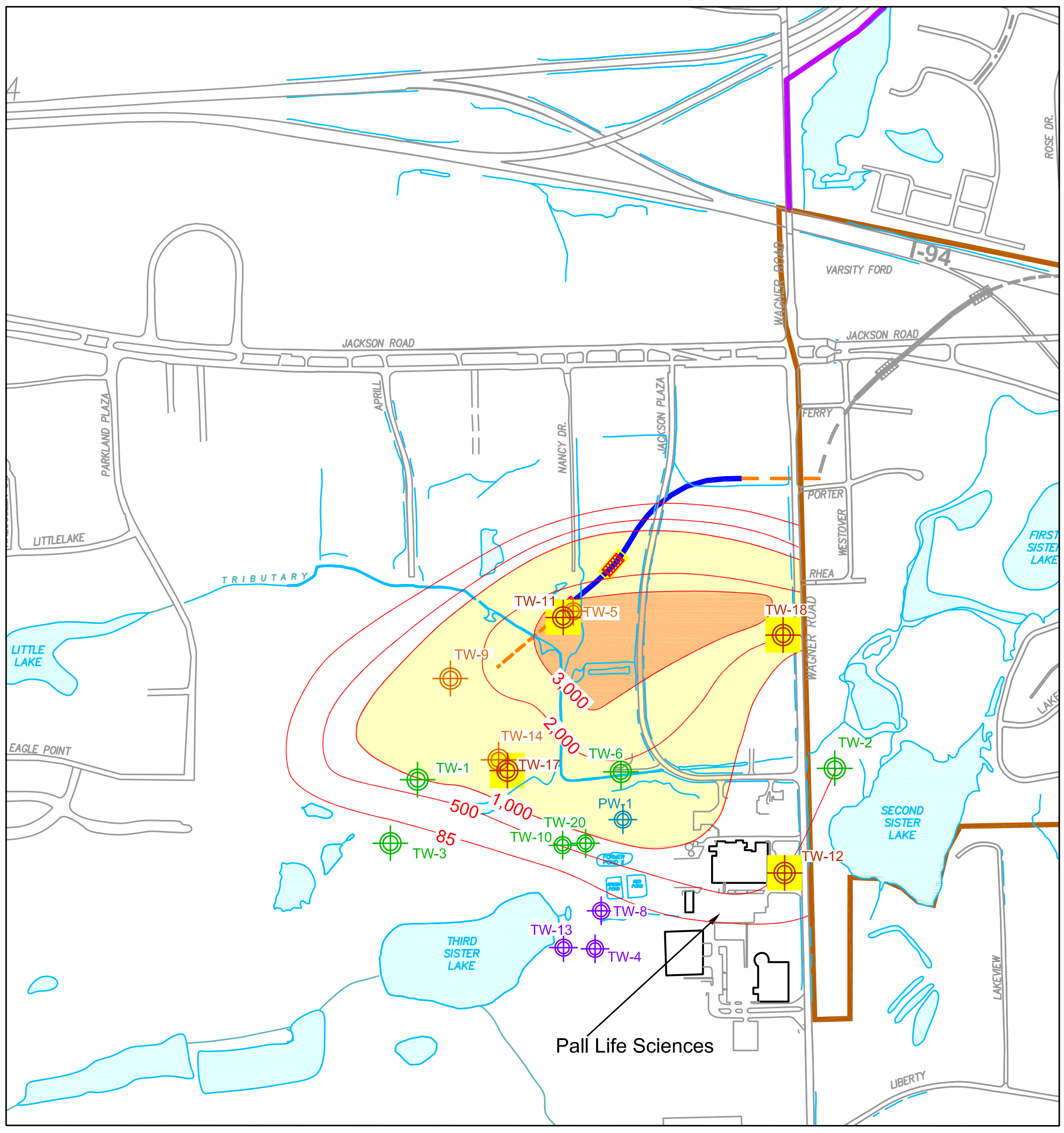
Hard copy is intended to be 11"x17" when plotted. Scale(s) indicated and graphic quality may not be accurate for any other size.

PLOT INFO: U:\CADD\96502\DWG\TIME-SERIES 2008 FOR OVERVIEW 2.DWG DATE: 8/13/2009 TIME: 3:57:01 PM USER: ADE

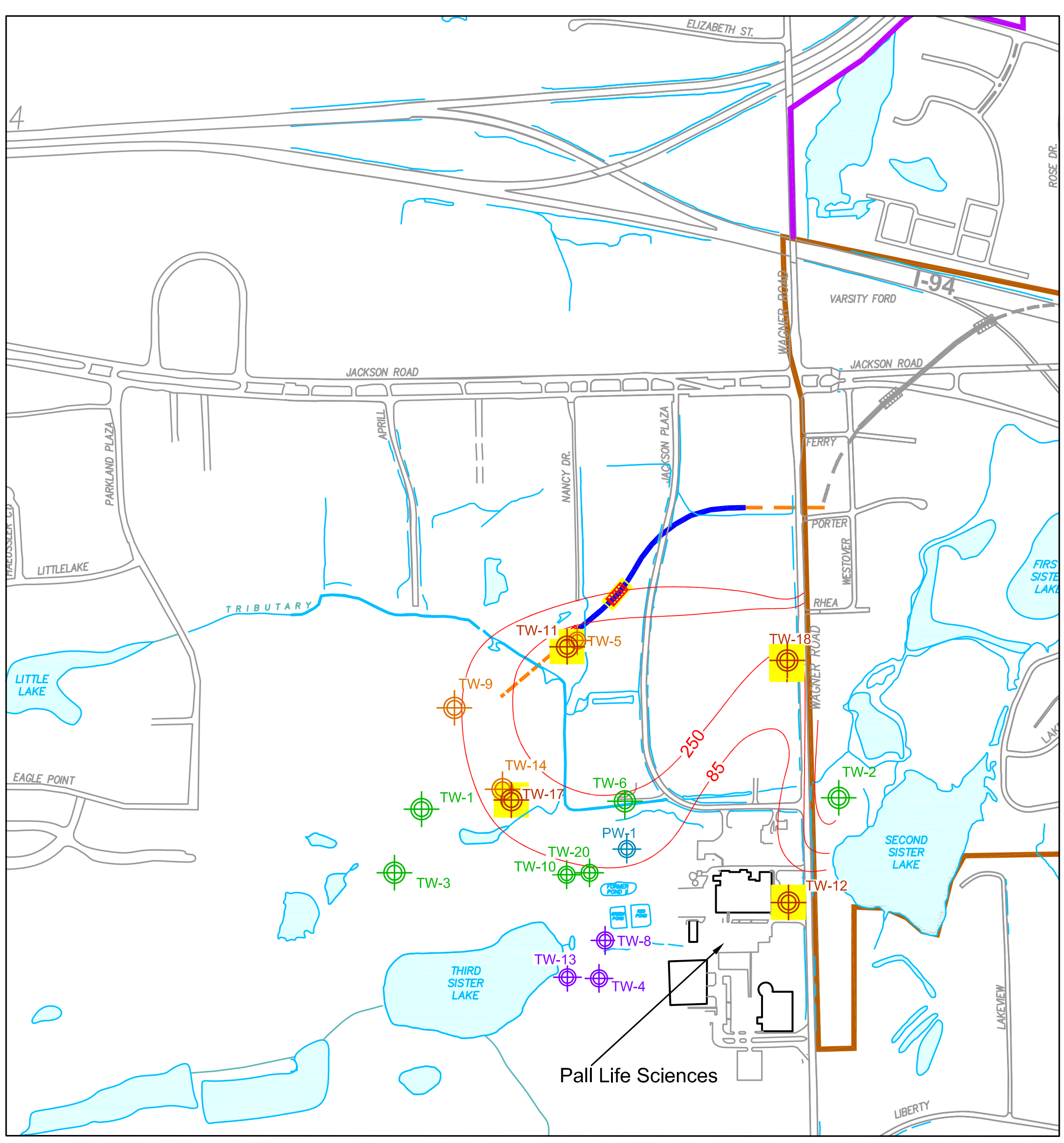
NORTH

GRAPHIC SCALE

0 500 1000



APRIL - MAY 2002



OCTOBER 2008 - MARCH 2009

LEGEND

1,4-DIOXANE (µg/L)

- 1,000 - 3,000
- 3,000 - 5,000
- 5,000 - 10,000
- 10,000 - 20,000
- >20,000

EXTRACTION WELLS

- **MARSHY AREA**
- **UNIT C3**
- **SOUTHWEST AREA**
- **WESTERN SYSTEM**
- **UNIT D2**
- **UNIT E**

WESTERN AREA
COMPARISON OF 2002–2009 1,4–DIOXANE CONCENTRATIONS FOR UNIT E

Pall Life Sciences

Scio Twp., Washtenaw County, Michigan

Brode Affidavit

PROJECT NO.

F96502

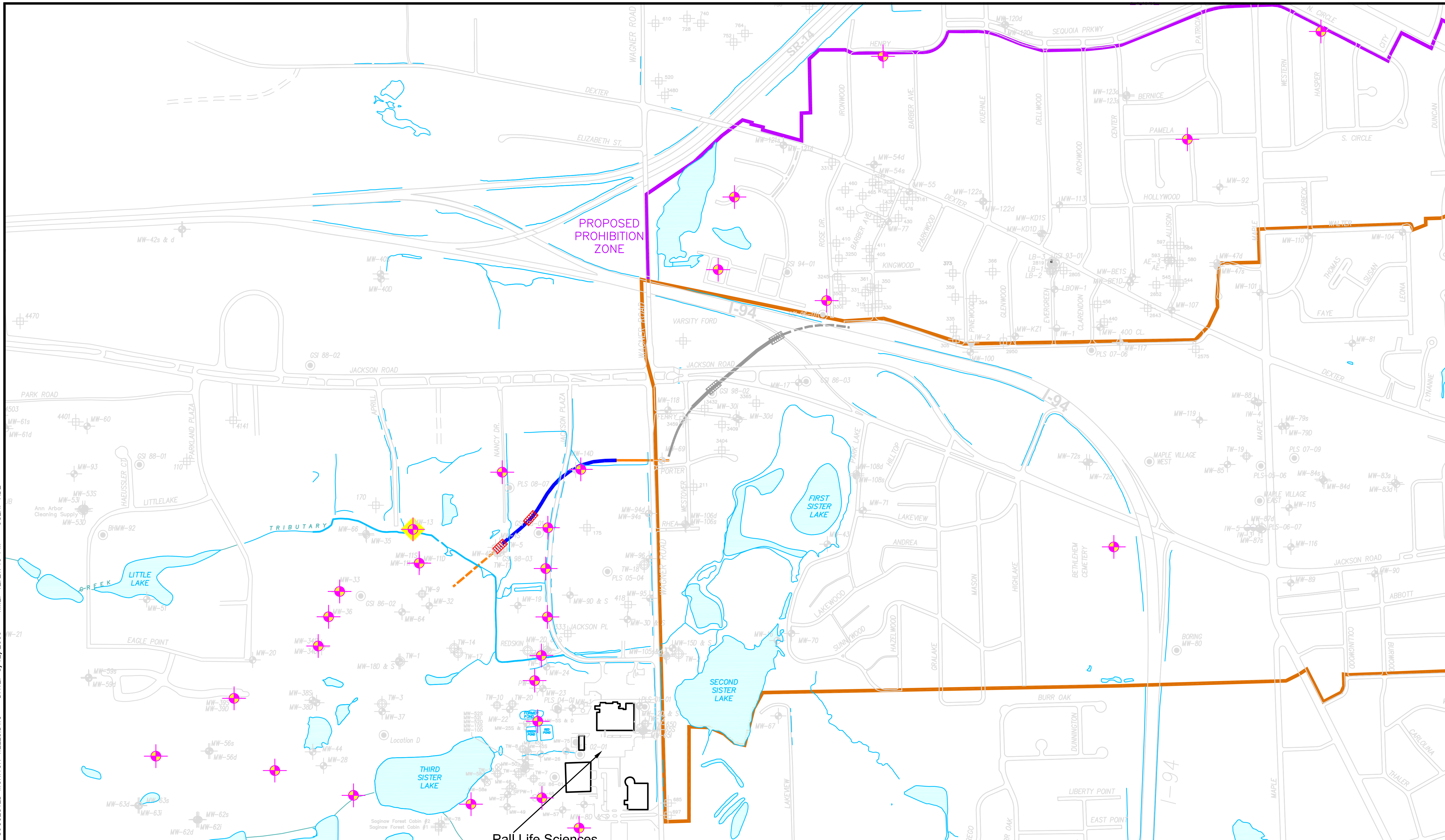
ftc&h

engineers
scientists
architects
constructors

fishbeck, thompson, carr & huber, inc.

Hard copy is intended to be 11"x17" when plotted. Scale(s) indicated and graphic quality may not be accurate for any other size.


HONEY CREEK
I-94
JACKSON ROAD
JACKSON ROAD
PARK ROAD
HONEY CREEK TRIBUTARY
HONEY CREEK TRIBUTARY
LITTLE LAKE
FIRST SISTER LAKE
SECOND SISTER LAKE
THIRD SISTER LAKE
GELMAN SCIENCES
POND II
POND III
PARKLAND PLAZA
JACKSON PLAZA
LITTLE LAKE
EDISON
PARKLAND CENTER
SUBARU DEALER
ALPHA HOUSE MACAULEY HEALTH CENTER
MERCYWOOD
HURON VALLEY SWIM CLUB
GEOSPECTRA
KAISER OPTICAL SYSTEMS
SCRAP JUNK YARD
WAGNER
LIBERTY
FERRY
PORTER
HILLTOP
LAKEVIEW
ANDREA
BAY
LAKEWOOD
DOLPH
ELIZABETH ROAD
DEXTER - ANN ARBOR RD.
KINGWOOD
VALLEY
MW-14S&D
MW-4S&D
MW-11S,I&D
MW-13
MW-9S&D
MW-3S&D
MW-2S&D
MW-15S&D
MW-16
MW-17
MW-5
MW-1
MW-6
MW-7
MW-12S&D
MW-10S&D
MW-8S&D
GSI 86-01
GSI 86-02
GSI 86-03
880
881
882
883
884
885
886
887
882.36
880.80
880.58
880.53
883.13
887.77
880.09
.647
.480
.024
.0017
.001
ND
DIRECTION OF GROUNDWATER FLOW
884.39 POTENTIOMETRIC ELEVATION
884 POTENTIOMETRIC SURFACE CONTOUR
1,4 DIOXANE DETECTED IN p.p.m. (mg/l)
1,4 DIOXANE NOT DETECTED IN SAMPLE
REFER TO 1,4 DIOXANE RESULTS FOR SAMPLING DATES
DOMESTIC WELL LOCATION
WATER LEVEL DATA 6/86
CONTOUR INTERVAL = 1 FOOT
NORTH
0 200 400 FEET
PLATE XI
POTENTIOMETRIC SURFACE & WATER QUALITY OF THE UNIT E AQUIFER
GELMAN SCIENCES, INC.
T.2S.,R.5E., SECTION 25 & 26, SCIO TOWNSHIP, WASHTENAW COUNTY, MICHIGAN
MAP ADAPTED FROM U.S.G.S. TOPOGRAPHIC QUAD ANN ARBOR WEST, PR 1983
REVISED BY KCS 3/6/87
KECK CONSULTING SERVICES, INC.



LEGEND

- MDEQ PROPOSED MONITOR WELL
- MONITOR WELL
- RESIDENTIAL WELL
- PURGE WELL
- HYDROGEOLOGIC TEST BORING
- UV/OX. TREATMENT SYSTEM
- TEMPORARY PURGE WELL
- SURFACE WATER ELEVATION POINT

NORTH

SCALE: 1" = 800'

0 400 800

BASE MAP ADAPTED FROM USGS 7.5' TOPOGRAPHIC QUADRANGLE
ANN ARBOR WEST, MICHIGAN
WASHTENAW COUNTY AND THE CITY OF ANN ARBOR
AERIAL PHOTOS PROVIDED BY WASHTENAW COUNTY – 1999 AND THE CITY OF ANN ARBOR – 1997

MDEQ PROPOSED MONITOR WELL LOCATIONS

ftc&h

engineers
scientists
architects
constructors

fishbeck, thompson, carr & huber, inc.

Hard copy is intended to be 11"x17" when plotted. Scale(s) indicated and graphic quality may not be accurate for any other size.

Pall Life Sciences
Scio Twp., Washtenaw County, Michigan

Brode Affidavit

PROJECT NO.
F96502

ATTACHMENT

PLOT INFO: U:\CADD\96502\DWG\DEQ SUGGESTED MONITOR WELLS.DWG DATE: 8/12/2009 TIME: 12:21:40 PM USER: ADE

Push-Ahead™ Vertical Aquifer Sampling Methodology with Sonic Drilling

Abstract

Ground water investigations of dense non-aqueous phase liquid (DNAPL) or brine plumes that extend hundreds of feet deep into unconsolidated sediments present drilling and sampling challenges that can greatly increase investigation time and cost. Sonic drilling methodology is a preferred sampling method in these environments for its superior drilling speed, good recovery of undisturbed, large-diameter core samples, significant reduction of derived waste, uniform boreholes with a minimum of drift and the ability to seal off saturated zones from one another without setting permanent multiple outer-well casings. However, the required inducement of fluids during drill stem advancement can greatly increase time and expense where the collection of vertical aquifer profile (VAP) sampling is desired. PROSONIC Corporation (recently purchased by Boart Longyear Inc., hereafter Boart) has developed a new Push-Ahead™ sampling device that can collect representative ground water VAP samples while minimizing purge volumes and sampling time.

The sonic drilling Push-Ahead™ sampler was developed to overcome sampling difficulties at a State of Michigan Department of Environmental Quality (MDEQ) Site investigation of a 7-mile long TCE plume located in the vicinity of Mancelona, Michigan. From 2004 through 2006, the State retained Boart to advance 26 VAP borings and install 32 monitoring wells . Glacial alluvial sediments were explored to depths approaching 600 feet below ground level. Use of the Push-Ahead™ VAP sampling device resulted in significantly reduced purge water volumes and sampling time. Comparison of data and quality objectives are assessed using the new sonic drilling Push-Ahead™ sampler for VAP sampling method from those employed using traditional sonic drilling VAP sampling techniques.

PRESENTED BY:

Thomas Cok, CPG
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Dennis Robins
Boart Longyear

Mark Schult, Ph.D.
The Mannik & Smith Group, Inc.

Walter Bolt, CPG
The Mannik & Smith Group, Inc.

Introduction

Ground water investigations of DNAPL or brine plumes that extend hundreds deep feet into unconsolidated drinking water aquifers can be extremely costly and time consuming to adequately investigate as required by State and Federal regulations. The drilling and sampling challenges to investigating ground water quality at these depths are beyond the capabilities of most drilling methodologies.

Sonic drilling methodology is a preferred drilling and sampling technique for deep ground water investigations. Due to it's superior drilling speed; good recovery of undisturbed, large diameter core samples; significant reduction of derived waste; uniform boreholes with a minimum of drift; and the ability to seal off saturated zones from one another without setting multiple permanent outer well casings. Sonic drilling method can extend borings in unconsolidated sediments to depths in excess of 700 feet. However, the advancement of the drill stem (multiple outer casings and core barrel) into the unconsolidated sediments, particularly angular sands, typically requires the inducement of drilling fluids. The quantity of water required to advance the casing generally increases with depth to due to increased friction against the casing. VAP sampling is generally conducted during drill stem advancement to assure proper selection of the monitoring well screened interval. The inducement of fluids during drill stem advancement can greatly increase the time and expense to collect representative VAP samples from the aquifer.

Traditional methods of VAP sampling with sonic drilling involve the installation of temporary wells within the drill stem and then retracting the drill stem to expose the screen. This leaves the temporary well casing filled with drill fluids and its screened interval in the zone of influence of the induced drilling fluids. Extensive purging of the temporary well is required to collect a representative formation sample. Other limited push ahead techniques have been developed (i.e. Simulprobe® or Hydropunch™), however, these limited push ahead techniques will generally not allow advancement more than a few feet beyond the drill stem and are still in the zone of influence of the induced drill fluids. Additionally these limited drive ahead techniques have minimal, if any, purge capabilities.

Boart has developed a new push ahead sampling device for use with the sonic drilling technique that can collect representative samples while eliminating purging requirements and minimizing sampling time. The Push-Ahead™ sampler is advanced without inducing additional drilling fluids and extends beyond the zone of influence of the drilling fluids that has been induced into the formation. Upon opening the sampling ports, an unadulterated representative VAP sample is collected directly from the zone of interest without purging requirements. If purging is desired, a sampling pump with or without a packer can be inserted into the drill rod to obtain the sample. The drill rod with the Push-Ahead™ sampler can then be removed and decontaminated for it next use.

Original Push-Ahead

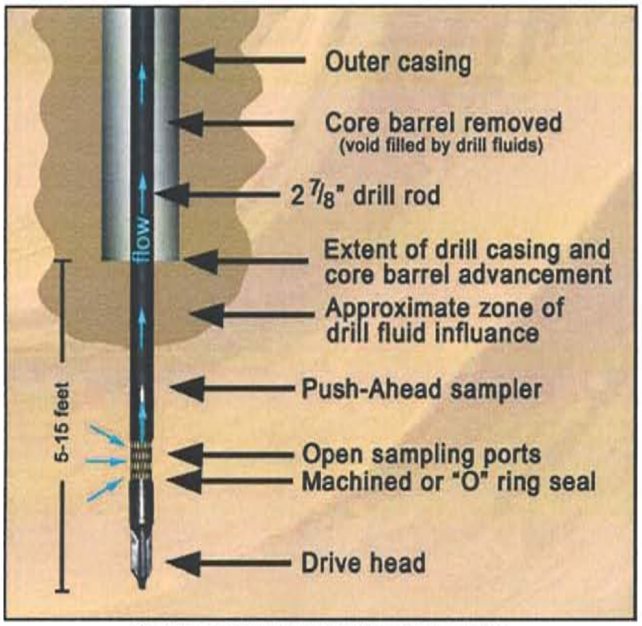
To date, the Push-Ahead™ sampler has been approved and satisfactorily utilized at two MDEQ site investigations. The Wickes Manufacturing site investigation in Mancelona, Michigan conducted VAP sampling of a TCE plume with the sonic drilling Push-Ahead™ sampler to depths approaching 600 feet below ground surface (bgs). The Hoskins Manufacturing site in Mio, Michigan investigated a chlorinated solvent plume and hexavalent chromium release associated with a brine plume through multiple aquifers to depths over 400 bgs.

MDEQ has also approved use of the Push-Ahead™ sampler at the MDEQ Rexair site in Cadillac, Michigan to conduct VAP sampling of a chlorinated solvent plume through multiple aquifers to depths of approximately 330 bgs. At the Rexair project, the MDEQ contractor, the Mannik and Smith Group (MSG), will utilize the next generation (TNG) Push-Ahead™ sampler. The TNG Push-Ahead™ sampler has an improved sampling port seal, increase sampling port capacity, and a finer sampling port opening size to minimize sediment intake (See TNG Push-Ahead™ sampler Figure, next page).

This study examines the Push-Ahead™ sampler and its use, using the Wickes Manufacturing site as a case study where both the Push-Ahead™ sampler and standard temporary well technique were utilized to conduct VAP sampling. The case study is assessed for VAP sampling cost and time savings provided by use of the Push-Ahead™ sampler in comparison to traditional temporary monitor well methodology.

Push-Ahead™ Sampler Description and Methodology

The Push-Ahead™ sampler consists of a 2 7/8-inch ID drill rod threaded onto a carbide tipped drive point with flanges and sampling ports. The drive point sampling ports have a steel machined seal that remains closed until the tool is advanced to it desired sampling interval. Once the flanged drive tip is seated in the formation, the sampling ports are exposed by rotation of the drill rod. The sampling ports consist of four ¼-inch borings located at the base of the sampler drive head (See Original Push-Ahead™ sampler, previous page.)



Next generation Push-Ahead Sampler

The VAP sampling methodology utilizing the sonic drilling Push-Ahead™ sampler involves the advancement of core barrel and outer casing(s) to the water table or chosen depth interval using standard sonic drilling technologies. After the removal of the core barrel, a decontaminated and sealed Push-Ahead™ sampler is inserted through the outer casing(s) to the bottom of the boring. The Push-Ahead™ sampler is the sonically driven beyond the boring bottom into virgin material (approximately 5 to 15 feet in advance of the outer casing depending on lithology) beyond the zone of influence from any induced drill fluids **(See Push-Ahead™ Sample Collection Illustration, left)**. A water level meter is then lowered within the drill rods to verify the seal and ensure no drill fluids has entered the drive point assembly. Once the seal is verified, the water level meter is removed and the Push-Ahead™ sampler is opened to allow formation water to enter the drill rods through the sampling ports. The water level meter is then re-lowered into the drill rods to verify formation water has entered the drill string. Since the ground water entering the drill rod through the sampling ports is representative of the formation (collected from beyond the zone of drill fluids influence), no purging is required but may be conducted if desired to reduce turbidly. Samples are collected directly from the drill rod using a bailer or submersible pump.

Draw backs to the use of the Push-Ahead™ sampler are 1) it is blindly advanced beyond the drill stem and may not obtain a sample if seated in a low permeability soil and 2) the sampler could potentially penetrate a confining layer. If a confining unit is breached, it can quickly be sealed off by advancement of the drill stem.

Case Study

The MDEQ retained Boart to conduct a Supplemental Investigation/ Monitoring Well Installation Project for the Wickes Manufacturing TCE Plume site in Mancelona, Michigan (Site). Boart retained the MSG as a subcontractor to aid them.

The former Wickes Manufacturing has operated as a manufacturing facility under various owners since the 1950's. Scrap steel saturated with chlorinated paraffins was stockpiled outside the plant and untreated wastewater was discharged to three seepage pits. TCE concentrations in ground water have been detected at levels exceeding 1,000 parts per billion. Prior investigations identified a TCE ground water plume extending approximately seven miles northwest from the former Wickes Manufacturing property.

The site lies on glacial outwash sand and gravel with post-glacial alluvium. Thickness of the unconsolidated sediments is reported to range from between 200 and 600 feet at the site. A regional aquifer exists within the unconsolidated soils and is present as inter-bedded aquifers, aquitards and aquicludes in the site vicinity. Regional ground water flow is to the northwest. Ground water is encountered at the site at depths ranging from less than 20 feet up to 260 feet below grade. From 2004 through 2006, Boart advanced 26 VAP borings and installed 32 monitoring wells. A total of 326 VAP samples were collected from the borings. Glacial alluvial sediments were explored to depths approaching 600 feet bgs.

Due to the extensive boring depths and angularity of the sands, large quantities of drilling fluids (treated city water) were required to advance the drill stem. Typically advancement of a 20 foot run of the override casing during sonic drilling requires inducing 50 to 100 gallons of drilling fluids into the formation, deeper runs requiring up to 1000 gallons.

In October 2004, the initial 15 VAP borings were completed and 188 VAP samples were collected using temporary monitoring wells to collect representative water samples. Based on the monitoring for the presences of products associated with the use of city water (trihalomethanes) and the stabilization of field monitoring parameters during purging (temperature, pH, conductivity, and turbidly), approximately 1.5 times the volume of induced drill fluids had to be purged to collect a representative sample. Approximately 120,000 gallons of purge water was generated and required off-site disposal as a result of the temporary well VAP sampling methodology.

In 2005, Boart developed the Push-Ahead™ sampler as a means to eliminate purging requirements and significantly reduce sampling time for the second phase of drilling. During the second phase of drilling, 13 VAP borings were completed and 138 VAP samples were collected, of which 129 samples were collected using the Push-Ahead™ sampler.

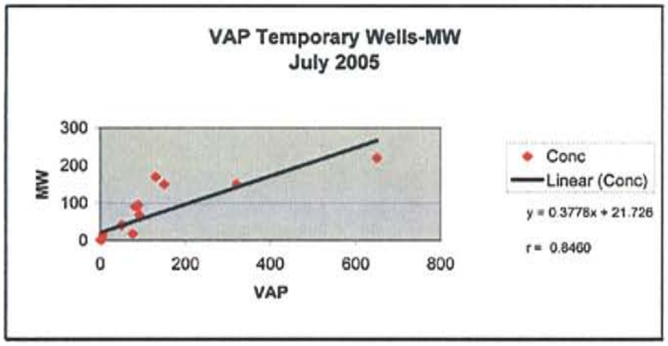
Statistical Comparison of Sampling Data

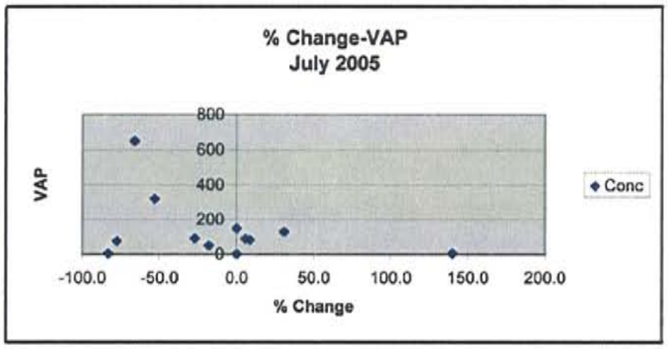
The data set consists of sample results from the VAP samples, sampling time, and purge water quantities during both phases, and the first following monitoring well sampling event. The VAP sample from the interval closest to the monitoring well screened interval was used for the comparisons. The VAP concentrations were plotted against the corresponding monitoring well concentrations from the monitoring well sampling event immediately after well installation (i.e., the July 2005 data from VAP borings installed in 2004 and the November 2006 data for VAP borings installed in 2005-2006). Linear regressions were then performed on the TCE concentration results from the traditional temporary monitoring well VAP sample collection data and the Push-Ahead™ sampler VAP data.

As part of the analysis, the Pearson's coefficient (also known as the correlation coefficient) was calculated for each data set. The Pearson's coefficient is a measure of the strength of the linear relationship between two variables. Pearson's coefficient values range from +1 to -1, with +1 indicating a direct relationship and -1 indicating an inverse relationship. The Pearson's coefficients were compared to $r_{.005}$ (the critical value for statistical significance), which indicates the correlation is significant at the 99.5 percent level (or that there is a 0.5 percent chance that the correlation appears to be true but is not).

R:\ 96502 \ VAS..

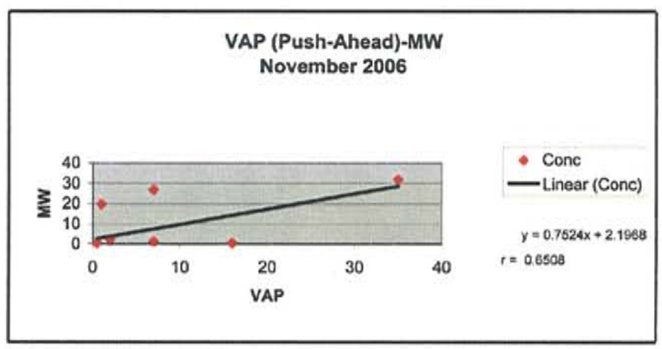
The temporary well VAP data shows a statistically significant linear relationship with the subsequent monitoring well sampling event (See VAP Temporary Wells – MW July 2005 Figure, below), with a Pearson's coefficient of 0.846 and a $r_{.005}$ value of 0.590. Most temporary well VAP sample results were higher than the corresponding monitoring well's results.

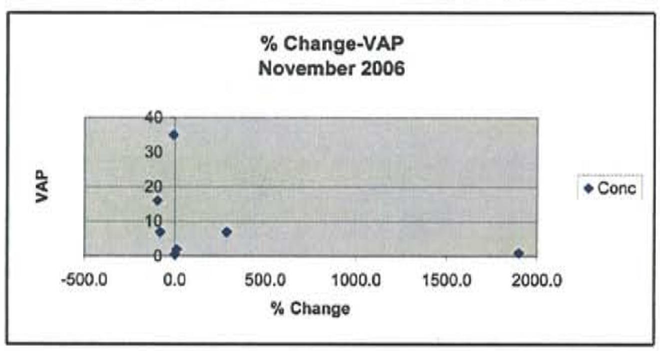




The Push-Ahead™ sampler VAP data shows a statistically significant linear relationship with the subsequent monitoring well sampling event (See VAP Push-Ahead – MW November 2006 Figure). However, the Pearson's coefficient is 0.651, slightly above the $r_{.005}$ value of 0.641. The Push-Ahead™ sampler VAP results were quite variable compared to the corresponding monitoring well's results. One major factor for the lower Pearson's coefficient and the variability may be that the Push-Ahead™ VAP locations and monitoring wells were near the edge of the plume and thus lower overall chemical concentrations were obtained. Additionally, monitoring wells installed at the plumes edge may be more prone to temporal variation as the plume expands or due to minor seasonal variations in ground water flow direction. As a result, a difference of a few micrograms per liter would cause more scatter of the data and a much larger percentage change than the data from locations with higher concentrations, where a small absolute difference between the temporary well and monitoring well data would not influence the correlation as much.

Both the temporary wells and Push-Ahead™ sampler data show a statistically significant linear trend when compared to the monitoring well data. The different strengths of correlation is likely due to sample locations and not sampling methodology as additional data collected from future investigation are obtain with the Push-Ahead™ sampler, including VAP sampling through highly concentrated portions of the plumes, this data should be statistically evaluated to assess the technique correlation with traditional VAP sampling methods.





Time and Purge Water Disposal Cost Savings

During the 2004 VAP sampling, 188 VAP samples were collected using temporary wells in approximately 120 days of fieldwork (typically 10 hour work days).

The average boring length during this sampling event was 371 feet. The average collection rate was approximately 1.6 samples per day.

During the 2005-2006 VAP sampling, 128 samples were collected in 69 days of fieldwork. Temporary well VAP sampling was conducted in one boring to a depth of 457 feet. A total of 13 samples were collected in 9 days from this boring, for an average collection rate of 1.4 samples per day. Twelve VAP borings were sampled utilizing the Push-Ahead™ sampler device to an average depth of 419 feet. A total 129 Push-Ahead™ VAP samples were collected in 60 days, for an average collection rate of 2.2 samples per day.

Comparisons of the VAP sample collection rates from temporary wells and Push-Ahead™ technique indicates a field time saving of approximately 30 percent. Utilization of the Push Ahead™ technique during the 2004 VAP boring would likely have reduce the field duration by 40 out of the 120 days and cost savings at standard sonic drill crew rates in excess of $240,000. Purging of the temporary wells prior to sampling generated approximately 120,000-gallons (on average 638 gallons per sample) impacted water requiring off-site disposal. At $0.25 per gallon for non-hazardous disposal, this volume would cost $30,000 for disposal.

Conclusions

The Push-Ahead™ sampler was developed to overcome sampling difficulties associated with induced drilling fluids. Use of the Push-Ahead™ sampler resulted in the elimination of purge water and greatly reduced VAP sampling time and cost. Comparison of data and quality objectives using the new Push-Ahead™ sampler device to traditional sonic drilling VAP sampling techniques found both methods provide statistically correlated data to formation conditions (permanent monitoring well results). In the case study, the degree of correlation to permanent monitoring well results was slightly better with the traditional VAP sampling, however this may be due to the selected Push-Ahead™ sampler boring locations at the plume edges.

Acknowledgements

We greatly acknowledge the cooperation and information provided by Boart Longyear in the development and use of the Push-Ahead™ VAP sampler. The authors also wish to thank the Michigan Department of Environmental Quality (MDEQ) and their Level of Effort project contractor, Mactec Engineering and Consulting of Michigan for providing the analytical data evaluated in this study.


HONEY CREEK
I-94
JACKSON ROAD
PARK ROAD
DEXTER - ANN ARBOR RD.
ELIZABETH ROAD
LUELLA
BURTON
MYRTLE
COTTAGE
WEST DELHI
EDISON
HONEY CREEK TRIBUTARY
ALPHA HOUSE MACAULEY HEALTH CENTER
MERCYWOOD
PARKLAND CENTER
SUBARU DEALER
PARKLAND PLAZA
HURON VALLEY SWIM CLUB
LITTLE LAKE
GEOSPECTRA 884.39
KAISER OPTICAL SYSTEMS
AQUIFER BOUNDARY
AMBELL ROAD
NANCY BREYE
JACKSON PLAZA
WAGNER
WESTOVER
FERRY
PORTER
REHA
PARKLAKE
FIRST SISTER LAKE
SECOND SISTER LAKE
THIRD SISTER LAKE
POND II
POND III
GELMAN SCIENCES
HILLTOP
LAKEVIEW
ANDREA
SEALAKE
MARSH
HIGHLAKE
HAZELWOOD
SUNNYWOOD
DOLPH
KINGWOOD
VALLEY
SCRAP JUNK YARD
RENDELS
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DIRECTION OF GROUNDWATER FLOW
884.39 POTENTIOMETRIC ELEVATION
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1,4 DIOXANE DETECTED IN p.p.m. (mg/l)
1,4 DIOXANE NOT DETECTED IN SAMPLE
REFER TO 1,4 DIOXANE RESULTS FOR SAMPLING DATES
DOMESTIC WELL LOCATION
? WELL SUSPECTED OF BEING COMPLETED IN THE D2 AQUIFER
REFER TO 1,4 DIOXANE RESULTS FOR SAMPLE DATES
CONCENTRATIONS IN mg/l (ppm)
WATER LEVEL DATA 6/86
CONTOUR INTERVAL = 1 FOOT
NORTH
0 200 400 FEET
PLATE X
POTENTIOMETRIC SURFACE & WATER QUALITY OF THE UNIT D2 AQUIFER
GELMAN SCIENCES, INC.
T.2S.,R.5E., SECTION 25 & 26,
SCIO TOWNSHIP, WASHTENAW COUNTY, MICHIGAN
MAP ADAPTED FROM U.S.G.S. TOPOGRAPHIC QUAD
ANN ARBOR WEST, PR 1983
REVISED BY KCS 3/6/87
KECK CONSULTING SERVICES, INC.