CERTIFICATION

Document Identification: **C-404 Landfill Source Demonstration**
Paducah Gaseous Diffusion Plant, Paducah, Kentucky
(PRS-ENM-0031/R2)

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Paducah Remediation Services, LLC
Co-Operator

Russell Boyd, P.E.
Site Manager

8/1/07
Date Signed

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

U.S. Department of Energy
Owner and Operator

Reinhard Knerr
Paducah Site Lead
Portsmouth/Paducah Project Office

8/1/07
Date Signed

PRS-ENM-0031/R2

C-404 Landfill
Source Demonstration
Paducah Gaseous Diffusion Plant,
Paducah, Kentucky

CLEARED FOR PUBLIC RELEASE

PRS-ENM-0031/R2

C-404 Landfill
Source Demonstration
Paducah Gaseous Diffusion Plant,
Paducah, Kentucky

Date Issued—August 2007

Prepared for the
U.S. Department of Energy
Office of Environmental Management

Prepared by
PADUCAH REMEDIATION SERVICES, LLC
managing the
Environmental Management activities at the
Paducah Gaseous Diffusion Plant
under contract DE-AC30-06EW05001

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ACRONYMS

amsl	above mean sea level
ANOVA	analysis of variance (statistical method)
BGOU	Burial Grounds Operable Unit
DOE	U.S. Department of Energy
DNAPL	dense nonaqueous-phase liquid
KDWM	Kentucky Division of Waste Management
LOD	Limit of Detection
MW	monitoring well
NSDD	North-South Diversion Ditch
PGDP	Paducah Gaseous Diffusion Plant
RCRA	Resource Conservation and Recovery Act
RGA	Regional Gravel Aquifer
RI	Remedial Investigation
SWMU	solid waste management unit
^{99}Tc	technetium-99
TCE	trichloroethene
UCRS	Upper Continental Recharge System
USEC	United States Enrichment Corporation

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1. BACKGROUND

The C-404 Low-Level Radioactive Waste Burial Ground [Solid Waste Management Unit (SWMU) 3] is surrounded by a network of compliance monitoring wells (MWs) sampled on a semiannual basis. Figure 1 shows this network. Results of the semiannual sampling are evaluated statistically for increases in permit-required analytes relative to background concentrations using the analysis of variance method (ANOVA). Background analytical values for the C-404 compliance MWs are calculated continually (rolling average) on a semiannual basis.

Both background and downgradient MWs at C-404 have shown detections of trichloroethene (TCE) for several years. Statistical analyses performed on the July 2006 sampling data, however, indicate a statistically significant increase of TCE above background in one of three downgradient compliance wells (MW84). The TCE concentration in MW84 was 370 µg/L. Two background wells, MW227 and MW93, monitor the same portion of the aquifer as MW84. TCE values for these background MWs were 61 µg/L and 390 µg/L, respectively. The rolling average for the statistical background was calculated using TCE values from MW227 and MW93 collected July 2004, January 2005, July 2005, January 2006, and July 2006. Additional information regarding the C-404 statistics is presented in Section 5.

In accordance with the Hazardous Waste Facility Operating Permit, KY8-890-008-982, dated April 24, 2006, the Kentucky Division of Waste Management, Hazardous Waste Branch manager was notified of the intent to demonstrate a source other than the regulated unit as the cause of a confirmed statistically significant increase from background values of a contaminant (Condition T-57, page 68 of 69) by receipt of the *C-404 Hazardous Waste Landfill November 2006 Semiannual Groundwater Report, Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, on November 29, 2006 (PRS 2006).

This document presents the source demonstration consistent with the condition stated above.

2. AREA DESCRIPTION AND PROCESS HISTORY

C-404 is a 1.2-acre facility located in the west-central portion of the Paducah Gaseous Diffusion Plant (PGDP). The unit originally was constructed as a rectangular, aboveground surface impoundment measuring 387 ft by 137 ft with a floor area of approximately 53,000 ft^2. The floor of the surface impoundment was constructed of well-tamped earth and clay dikes to a height of 6 ft. The C-404 impoundment was designed with an overflow weir at its southwest corner. From the weir, the surface impoundment effluent flowed west in a ditch [not the North-South Diversion Ditch (NSDD)] and eventually discharged into Kentucky Pollutant Discharge Elimination System Outfall 015.

C-404 operated as a surface impoundment from approximately 1952 until early 1957. During this time, all influents to the impoundment originated from C-400. In 1957, the C-404 surface impoundment was converted to a solid waste disposal facility for uranium-contaminated solid wastes and these wastes were disposed at the former C-404 surface impoundment until its closure in 1986. The wastes consisted of uranium precipitated from aqueous solutions, uranium tetrafluoride, uranium metal, uranium oxides, and radioactively contaminated trash. In 1983, a partial clay cap was installed on the eastern end of the unit.

When the C-404 impoundment was converted into a disposal facility, a sump was installed at the weir. The sump was used to pump leachate into an underground transfer line. The transfer line discharged into a northeast-southwest ditch just east of C-404. From this ditch, the leachate flowed into the NSDD. Prior to

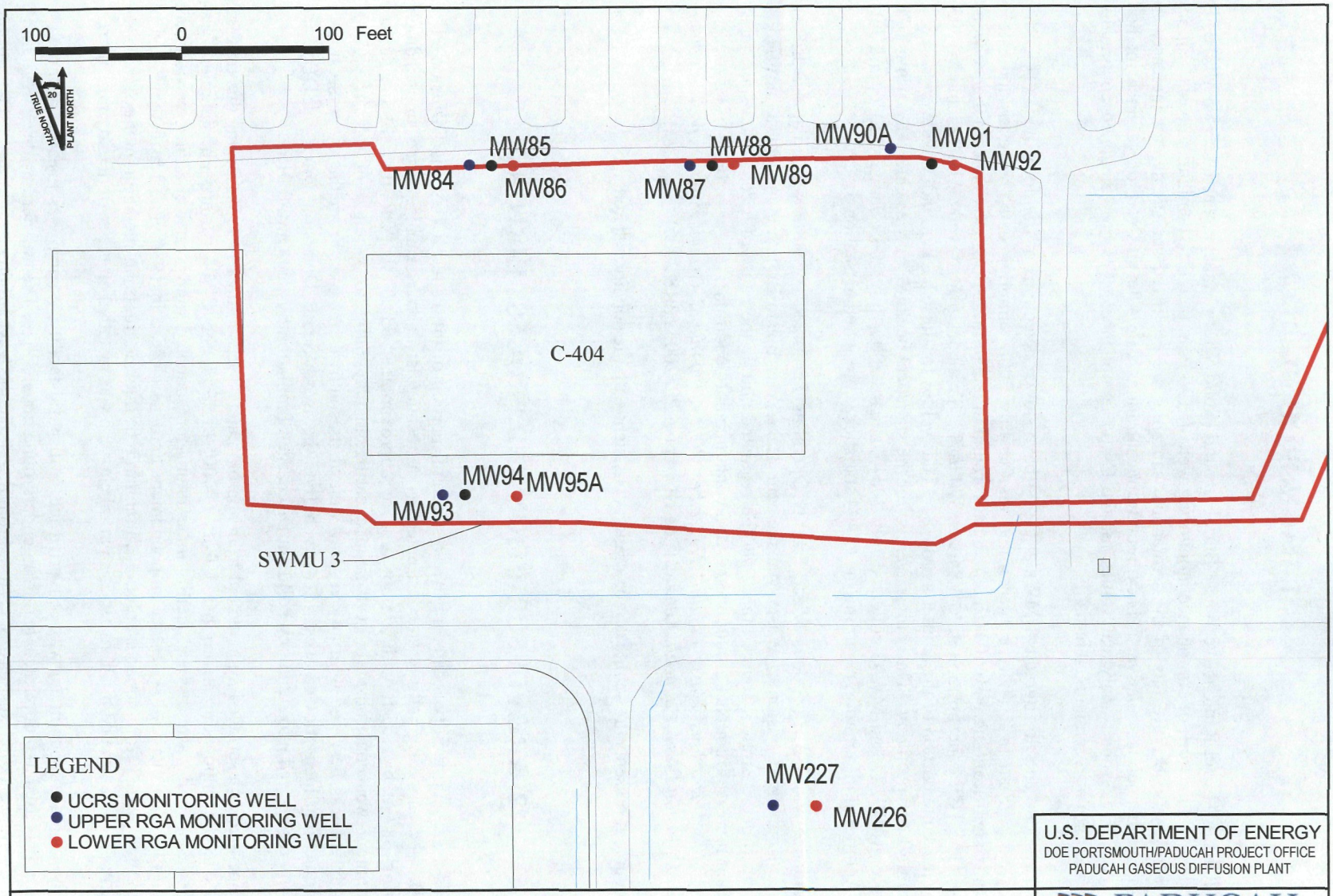

Figure 1. C-404 Monitoring Well Network

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landfill closure in 1986, this underground transfer line into the NSDD was not in operation, and leachate from the C-404 Landfill was being collected in the sump for treatment at the C-400 Cleaning Building.

After a portion of the waste buried in C-404 was discovered to be Resource Conservation and Recovery Act (RCRA)-hazardous in 1986, C-404 was closed as a hazardous waste landfill. The landfill was covered with a RCRA multilayered cap and certified closed in 1987. It currently is regulated under RCRA as a land disposal unit in accordance with a RCRA postclosure permit issued in 1992. This closure plan requires continued groundwater monitoring (DOE 1989).

Approximately 6,615,000 lb of uranium-contaminated wastes were disposed of in C-404. The total volume is approximately 260,000 ft^3. Some uranium-contaminated waste also is contaminated with TCE, radionuclides, and metals.

Previous documents that included information from investigations in the area surrounding C-404 were completed in 1995, 1996, 1997, and 2003. See Section 6 for references. In addition, data are collected continually from MWs positioned throughout PGDP.

3. HYDROGEOLOGIC SETTING

Information presented herein regarding the groundwater setting was derived from the *Report of the Paducah Gaseous Diffusion Plant Groundwater Investigation Phase III* (Clausen et al. 1992). The discussion is intended to provide the reader with a general overview of the groundwater flow regime for PGDP. The local groundwater flow system at the PGDP site occurs within the sands of the Cretaceous McNairy Formation, Pliocene terrace gravels, Pleistocene lower continental gravel deposits and upper continental deposits, and Holocene alluvium. Four specific components have been identified for the groundwater flow system and are defined in the following paragraphs:

1. **McNairy Flow System.** Formerly called the deep groundwater system, this component consists of the interbedded and interlensing sand, silt, and clay of the Cretaceous McNairy Formation. Sand facies account for 40 to 50% of the total formation's thickness of ~225 ft. Groundwater flow is predominantly north.

2. **Terrace Gravels.** This component consists of Pliocene (?)-aged gravel deposits and later reworked sand and gravel deposits found at elevations higher than 320 ft above mean sea level (amsl) in the southern portion of the plant site; they overlie the Paleocene Porters Creek Clay and Eocene sands. These deposits usually lack sufficient thickness and saturation to constitute an aquifer.

3. **Regional Gravel Aquifer (RGA).** This component consists of the Quaternary sand and gravel facies of the lower continental deposits and Holocene alluvium found adjacent to the Ohio River and is of sufficient thickness and saturation to constitute an aquifer. These deposits are commonly thicker than the Pliocene (?) gravel deposits, having an average thickness of 30 ft, and range up to 50 ft along an axis that trends east–west through the plant site. The RGA is the primary local aquifer. Groundwater flow is predominantly north toward the Ohio River.

4. **Upper Continental Recharge System (UCRS).** This component consists of the surficial alluvium and upper continental deposits. Sand and gravel lithofacies appear relatively discontinuous in cross section, and portions may be interconnected. The most prevalent sand and gravel deposits occur at an elevation of ~345 to 351 ft amsl; less prevalent deposits occur at elevations of 337 to 341 ft amsl. Groundwater flow is predominantly downward into the RGA from the UCRS, which has a limited horizontal component in the vicinity of PGDP.

As indicated above, the current conceptual model of the groundwater hydraulics within the UCRS shows groundwater flows primarily downward. This downward migration flows through interconnected sand lenses within the UCRS and is driven by the vertical gradients, which are much greater than the horizontal gradients. The effective lateral extent of horizontal gradients is difficult to define due to the lenticular nature of these sand deposits.

The Hazardous Waste Facility Operating Permit requires annual determination of hydraulic flow rate and direction of flow in the uppermost aquifer, the RGA, at C-404. Water level measurements are taken from several wells at the perimeter of C-404 on a semiannual basis and used to plot the potentiometric surface of the upper RGA and the lower RGA. For the 2006 sampling events, the flow velocity within the RGA near C-404 was calculated to range between 0.49 ft/day and 4.7 ft/day (PRS 2006). The current compliance monitoring well network for C-404 (initially installed in 1988) is based on the assumption that the area groundwater flow trends northward. Potentiometric and dissolved contaminant trends demonstrate that the prevailing groundwater flow path directly beneath C-404 remains northward, but commonly varies from the northeast to the northwest. However, the prevailing groundwater flow path immediately south of C-404 (passing through the area of wells MW226 and MW227) is northwestward. This divergence of the groundwater flow system is explained in more detail in *Well Plan for Addition of Wells for C-404 Monitoring Well Network Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (PRS 2007).

4. CONTAMINANT GROUNDWATER PLUMES

TCE, a common solvent, and technetium-99 (^{99}Tc), a man-made radioisotope, are the most widespread groundwater contaminants associated with the PGDP. TCE occurs as pure phase (free-product) dense nonaqueous-phase liquid (DNAPL) at multiple locations in the silts and clays overlying the RGA and, most probably, in the RGA itself at some locations. Technetium-99 is a widespread soil contaminant at the PGDP and a common contaminant in many PGDP burial grounds. Both dissolved TCE and ^{99}Tc migrate with downward percolating water to the RGA. In addition, pools of TCE, believed to exist within the RGA, are able to yield much higher dissolved levels in groundwater. These contaminants have resulted in large-scale dissolved-phase plumes that are migrating from the PGDP toward the Ohio River. Figures 2 and 3 present an illustration of the PGDP groundwater plumes.

5. C-404 STATISTICAL ANALYSIS OF CURRENT MONITORING

The statistical analyses conducted on the data collected from C-404 Hazardous Waste Landfill are performed in accordance with procedures provided in Attachment VIII, Appendix C of the C-404 Hazardous Waste Management Permit and previously have been approved by the Kentucky Division of Waste Management (KDWM). The percent of censored (nondetected) data points for individual parameters is calculated for the combined analytical data. The percent of censored data was used to select the types of statistical analyses to determine if test well concentrations differed from background well concentrations. For the November report, the reporting period data set was data from second quarter 2004 through second quarter 2006.

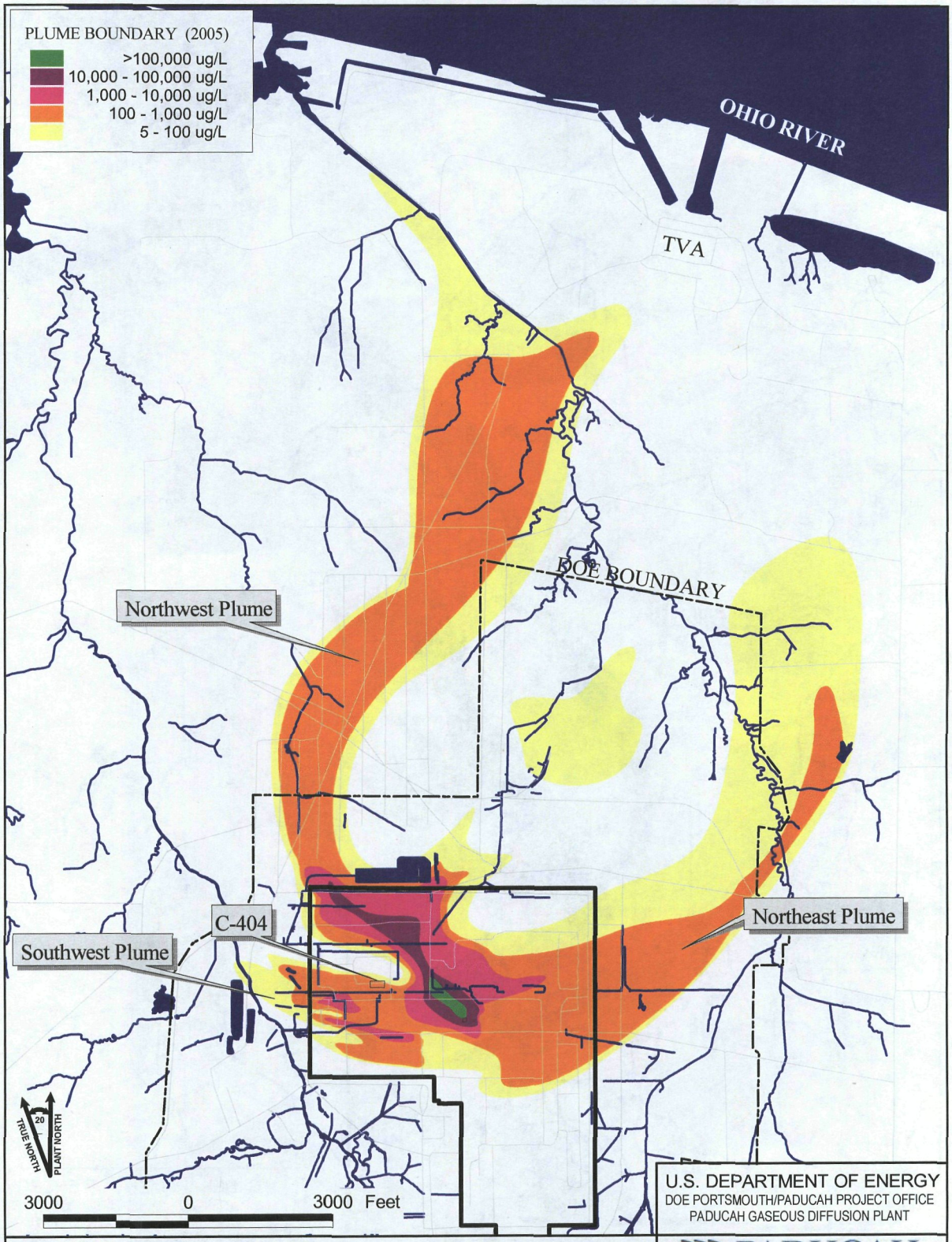

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Figure 2. 2005 TCE Plumes

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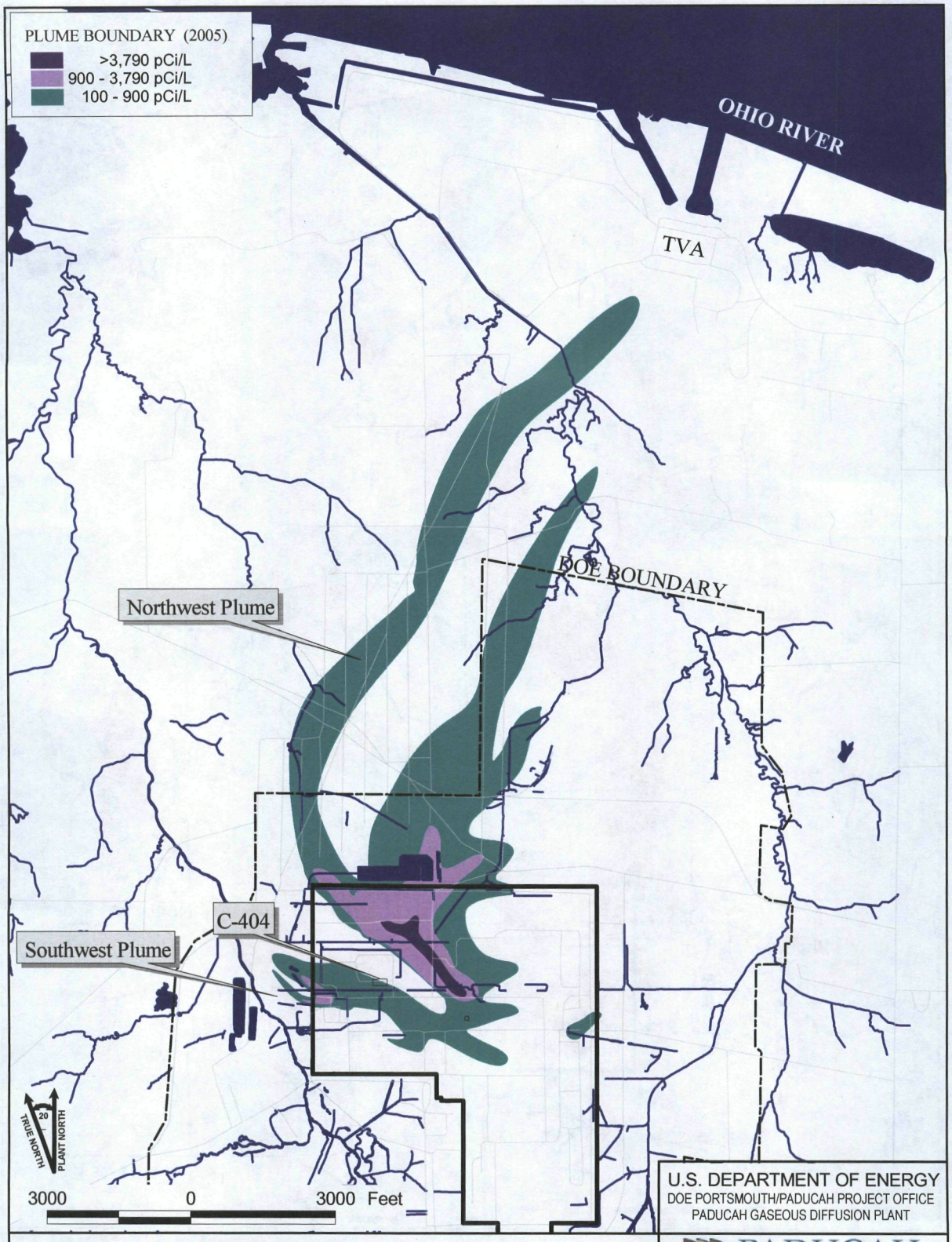

Figure 3. 2005 ^{99}Tc Plumes

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The ANOVA procedure, specified in the Permit, is found in the Environmental Protection Agency (EPA) guidance document, *Statistical Analysis of Ground-water Monitoring Data at RCRA Facilities, Internal Final Guidance* (EPA 1989). The type of statistical test conducted for each chemical data set is a function of the number of samples and proportion of nondetects (censored data) to detects (uncensored data) in each group. The percent of censored (nondetected) data points for individual parameters was calculated for the combined analytical data. The statistical procedures (EPA 1989) applied to the data are summarized as follows:

- Determine the percentage of the censored data using the reporting period data set.
- Group by percentage censored data where the following apply:
  - Statistical Test 1: censored data are greater than or equal to 90%, determine the Limit of Detection (LOD) and half of the LOD (1/2 LOD).
  - Statistical Test 2: censored data are between 50% and 90%, perform a Test of Proportions. If the analysis indicates a significant proportional difference in compliance test wells, further analyze through nonparametric ANOVA Test.
  - Statistical Test 3: censored data are between 15% and 50%, perform nonparametric ANOVA Test. If results exceed the critical value, compute the critical difference used to identify individual well concentrations, which are significantly elevated compared with background.
  - Statistical Test 4: censored data are less than 15%, actual data values are analyzed using parametric ANOVA procedures. If the wells exhibit equal variances, then the data is used as presented. If the wells do not exhibit equal variances, the log of the data is taken and then used in the calculations. Where statistical testing indicates elevated test well concentrations, Bonferroni's Test of Contrasts is performed.

In previous reports, TCE for the upper RGA has been statistically analyzed utilizing the Statistical Test 3. For the November report, however, MW90A showed a detection of TCE at the detection limit of 1 ug/L. This detection caused the statistical analysis for TCE to be performed by the Statistical Test 4, which is the most sensitive test. Calculations are provided in Appendix C.

6. SOURCE DEMONSTRATION

Based on currently available data, as presented in Appendices A and B, the statistical increase is the result of a migration in location of the northern spur of the southwest groundwater plume of contamination that flows beneath the C-404 Landfill. Investigation of contamination sources is ongoing under the existing Federal Facility Agreement and approved work plans.

Potentiometric surface contours are generated on a semiannual basis for inclusion in C-404 Permit Reporting. Typically, these contours indicate a northwestern trend to the groundwater direction. The semiannual potentiometric surfaces were reviewed for the years 2001 through 2005. These contours provide a localized interpretation of the hydraulic gradient in both the upper and lower RGA. All of these semiannual potentiometric maps indicate localized groundwater flow to the northwest/west-northwest. Both upper and lower RGA gradients appear consistent within each mapped time frame.

Of interest, within the 2004 potentiometric surfaces reported in *Trichloroethene and Technetium-99 Groundwater Contamination in the Regional Gravel Aquifer for Calendar Year 2004 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky,* BJC-PAD-169/R5 Final, (BJC 2006) is the indication of a slight groundwater mound southeast of the C-404 Landfill. Further, semiannual potentiometric surface contours from May 2002 through November 2006 C-404 permit reporting were reassessed and are presented in Appendix A. Datum elevations of two key wells, MW227 and MW93, were resurveyed in April 2007 and corrections to well level measurements made, as appropriate. Datum elevations for the remainder of the RGA wells in the C-404 area were resurveyed in May 2007. The September 2006 water levels were recontoured based on the April and May 2007 resurveys and are presented in Figure 4. Based on the data, a groundwater mound, as previously suggested in the 2004 plume report, is not evident.

Additional information regarding the hydrogeology in the C-404 area is presented in the *Well Plan for Addition of Wells for C-404 Monitoring Well Network Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (PRS 2007).

Research into a possible explanation for a potential groundwater mound southeast of the C-404 Landfill initially yielded the potential that the 36-inch raw water line located south of the landfill could be leaking. Figure 4 illustrates the proximity of the water line to the landfill, together with the potentiometric surface mapped for the area. In order for a leak to be large enough to affect groundwater flow, evidence of the leak would be shown on the surface and in the water levels of the wells. However, there is no indication of a leak in the water line near the landfill. The United States Enrichment Corporation (USEC), who leases the facility from DOE, was consulted and evaluated the area. USEC concurred that a leak is not likely.

The majority of the MW network was installed for the C-404 Landfill in 1988. Information available at that time indicated a more northern trend to the groundwater flow direction. In 1993, two additional wells were installed as part of the monitoring system to act as background monitoring locations. When the BGOU RI hydrogeological study determines groundwater flow direction, a more appropriate upgradient and downgradient MW may be installed or rehabilitated, if necessary.

UCRS MWs in the area are not compliance wells, but are sampled in conjunction with the compliance MWs at C-404. Analytical results from these wells indicate a TCE release from C-404 is possible. Figure 5 illustrates the location of these UCRS MWs and shows a graph of each MW's TCE results. The BGOU RI will seek to determine whether the landfill is a current source of TCE contamination in the RGA.

Although C-404 may be a source of groundwater contamination, the statistically significant increase of TCE in the downgradient well, MW84, appears to be due to an upgradient source whose TCE is migrating through the C-404 area. Definitive in demonstrating a source of TCE groundwater flow direction across C-404 are the TCE trends through the area on sitewide maps. Appendix B illustrates the combined upper and middle RGA TCE plumes documented in the annual plume map reports. These maps depict the TCE plume as interpreted and documented during each annual report. Contaminant contours have not been revised from the 2001 through 2005 reports for this demonstration. Both the upgradient wells at the southern side of the landfill (MW93 and MW95A) and the downgradient wells at the northwestern side (MW84 and MW86) show the same trend of increasing TCE, indicating the same source of TCE is migrating through the area and affecting the wells similarly. This similar trend is evident in both upper and lower RGA wells.

The upgradient source of the TCE plume identified in Figure 2 causing the increase in TCE concentration at MW84 is uncertain. The BGOU RI is designed to identify additional sources for TCE groundwater contamination. In addition to sources being investigated by the BGOU RI, one potential source for the TCE trends along the western portion of C-404 (near MW84) is SWMU 4, directly south of the area.

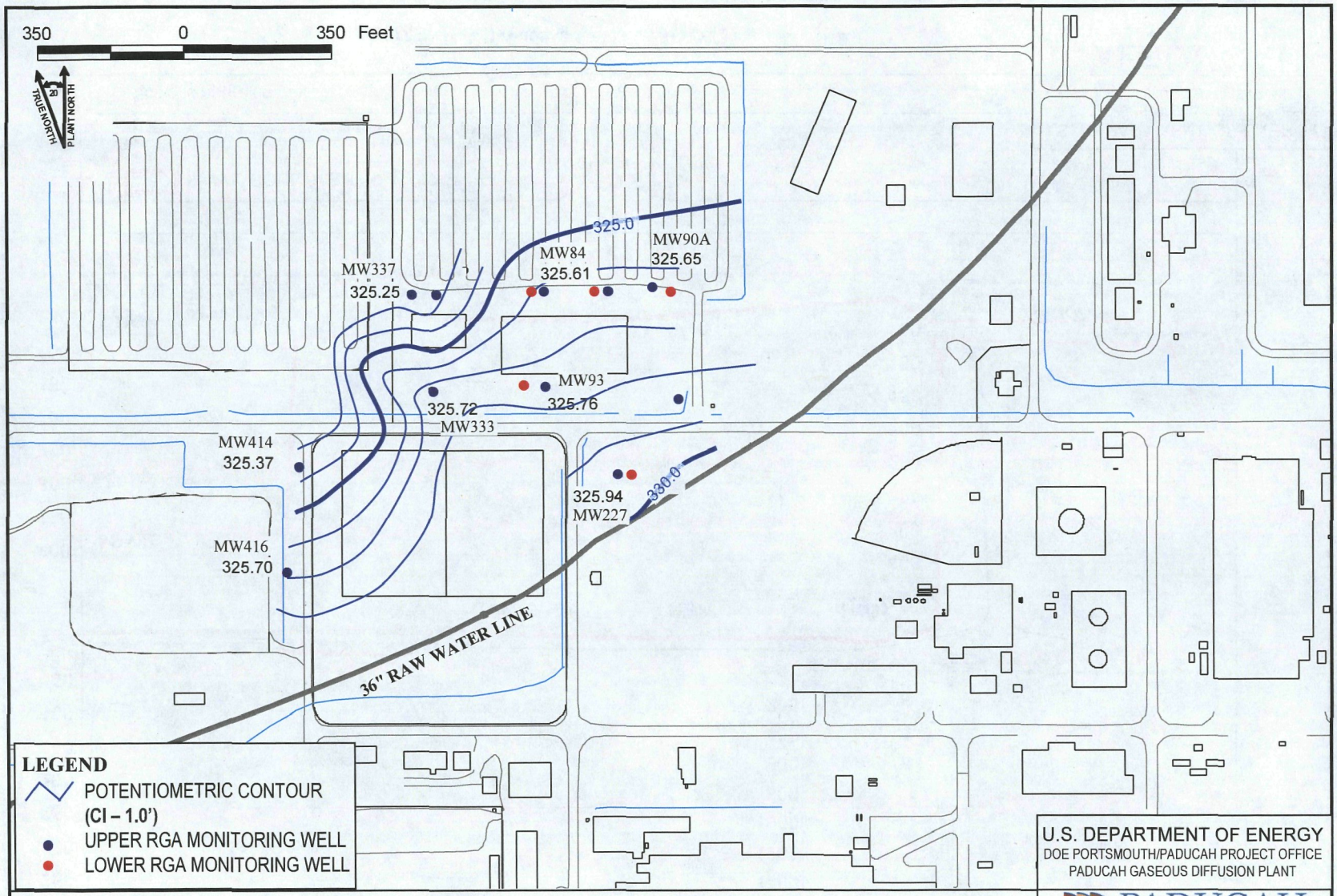

Figure 4. September 6, 2006 Upper RGA Potentiometric Surface

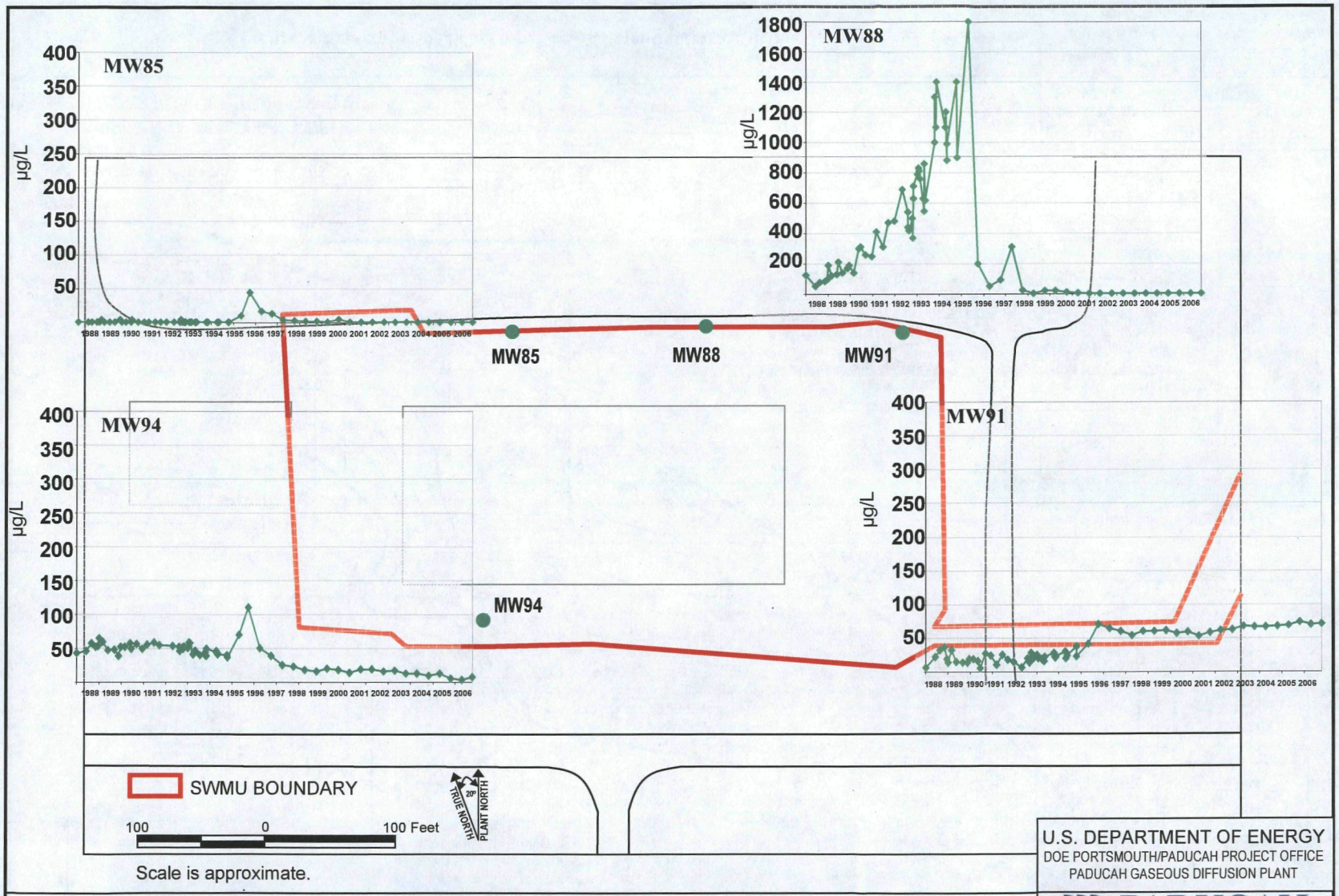

Figure 5. TCE Trends in C-404 UCRS MWs

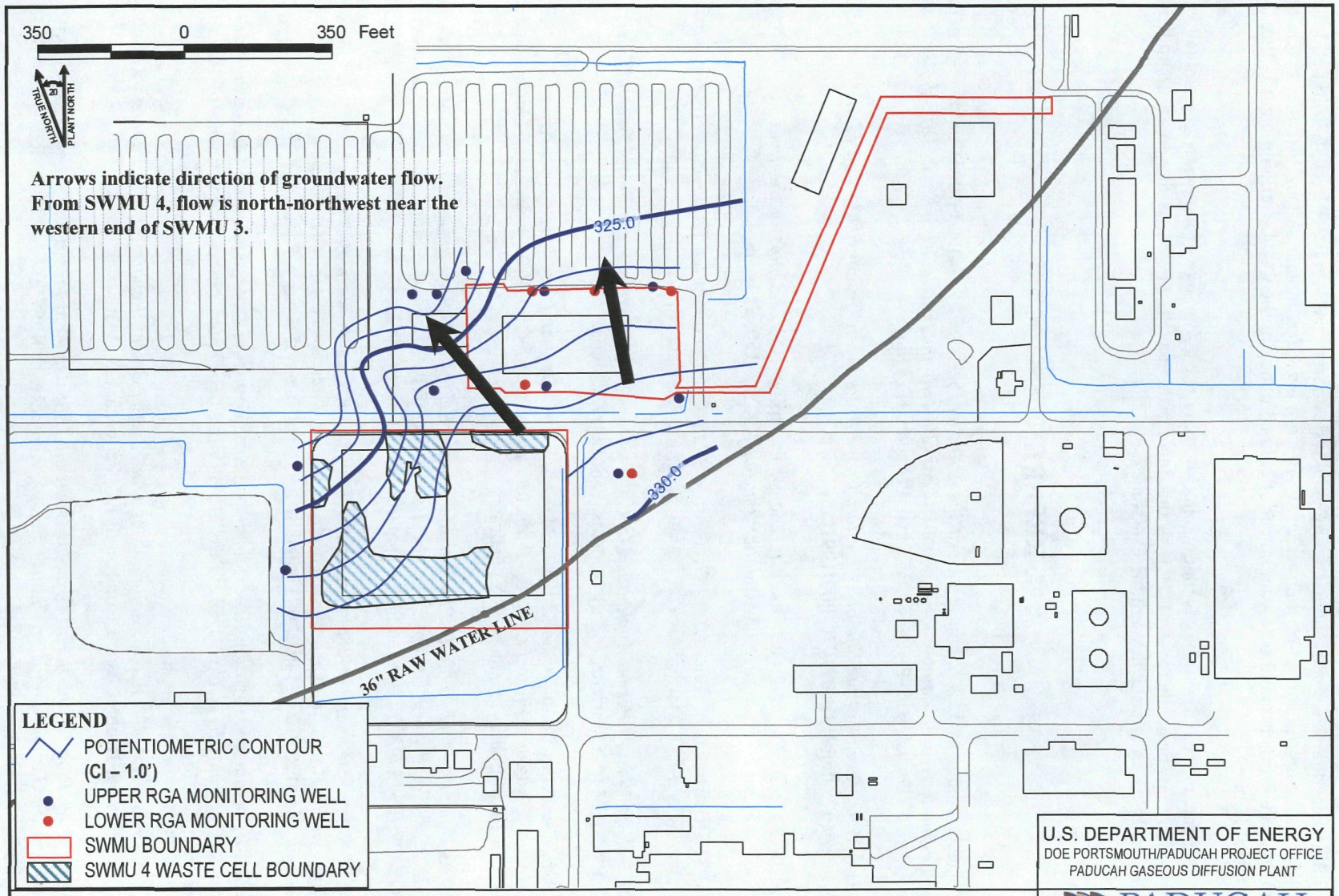

Figure 6. Potential Source of Western C-404 TCE Contamination

Figure 6 illustrates the waste cells delineated by geophysics during the WAG 3 RI (DOE 2001) and the potential for its being the source of the western C-404 groundwater contamination. Another potential source for the TCE trends could be a component of contamination at the C-400 Building contributing to the Southwest Plume.

The data presented herein demonstrates that, while C-404 may be a source of groundwater contamination, the statistically significant increase of TCE in the downgradient well, MW84, is due to an upgradient source whose TCE is migrating through the C-404 area.

7. REFERENCES

Bechtel Jacobs Company LLC 2006. *Trichloroethene and Technetium-99 Groundwater Contamination in the Regional Gravel Aquifer for Calendar Year 2004 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky,* BJC-PAD-169/R5 Final, Paducah, KY, May.

CH2M Hill 1992. *Results of the Site Investigation, Phase II, Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, KY/Sub/13B-97777C P03/1991/1.

Clausen, J. L., K. R. Davis, J. W. Douthitt, and B. E. Phillips 1992. *Report of the Paducah Gaseous Diffusion Plant Groundwater Investigation Phase III,* KY/E-150, Paducah, KY.

DOE (U.S. Department of Energy) 1987. *Closure Plan C-404 Low-Level Radioactive Waste Burial Ground,* KY/B-257, Martin Marietta Energy Systems, Paducah, KY, April.

DOE 1989. *Post Closure Permit Application C-404 Low-Level Radioactive Waste Burial Ground*, KY/H-35, Rev. 1, Martin Marietta Energy Systems, Paducah, KY, June.

DOE 1995. *Feasibility Study for Solid Waste Management Units 2 and 3 of Waste Area Group 22 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky,* DOE/OR/06-1246&D2, United States Department of Energy, Paducah, KY, February.

DOE 1996. *Sampling and Analysis Plan for the Interim Remedial Design at Solid Waste Management Unit 2 of Waste Area Group 22 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky,* DOE/OR/07-1374&D2, United States Department of Energy, Paducah, KY, February.

DOE 1997. *Data Summary and Interpretation Report for Interim Remedial Design at Solid Waste Management Unit 2 of Waste Area Group 22 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky,* DOE/OR/07-1549&D1, United States Department of Energy, Paducah, KY, February.

DOE 2001. *Remedial Investigation Report for Waste Area Grouping 3 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky,* DOE/OR/07-1895/V1&D2, United States Department of Energy, Paducah, KY, May.

DOE 2003. *Revised Solid Waste Management Unit 3 Assessment Report for the Paducah Gaseous Diffusion Plant,* Bechtel Jacobs Company LLC, Paducah, KY, March.

DOE 2006. *Work Plan for the Burial Grounds Operable Unit Remedial Investigation/Feasibility Study at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky,* DOE/OR/07-2179&D2/R1, United States Department of Energy, Paducah, KY, August.

EPA 1989. *Statistical Analysis of Ground-water Monitoring Data at RCRA Facilities, Internal Final Guidance*, U.S. Environmental Protection Agency, February.

PRS (Paducah Remediation Services, LLC) 2006. *C-404 Hazardous Waste Landfill November 2006 Semiannual Groundwater Report/Annual Flow Rate and Direction, Paducah Gaseous Diffusion Plant, Paducah, Kentucky,* PRS-ENM-005/V2, Paducah Remediation Services, LLC, Paducah, KY, November.

PRS 2007. *Well Plan for Addition of Wells for C-404 Monitoring Well Network Paducah Gaseous Diffusion Plant, Paducah, Kentucky,* PRS/PROJ/0028, Paducah Remediation Services, LLC, Paducah, KY, July.

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PROFESSIONAL GEOLOGIST AUTHORIZATION

DOCUMENT IDENTIFICATION: C-404 Landfill Source Demonstration
Paducah Gaseous Diffusion Plant, Paducah, Kentucky
(PRS-ENM-0031/R2)

Stamped and signed pursuant to my authority as a duly registered geologist under the provisions of KRS Chapter 322A.

Kenneth R. Davis — 07-26-07

Kenneth R. Davis | PG1194 | Date

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APPENDIX A

REASSESSMENT OF SEMIANNUAL POTENTIOMETRIC SURFACE MAPS OF THE RGA FROM C-404 PERMIT REPORTING

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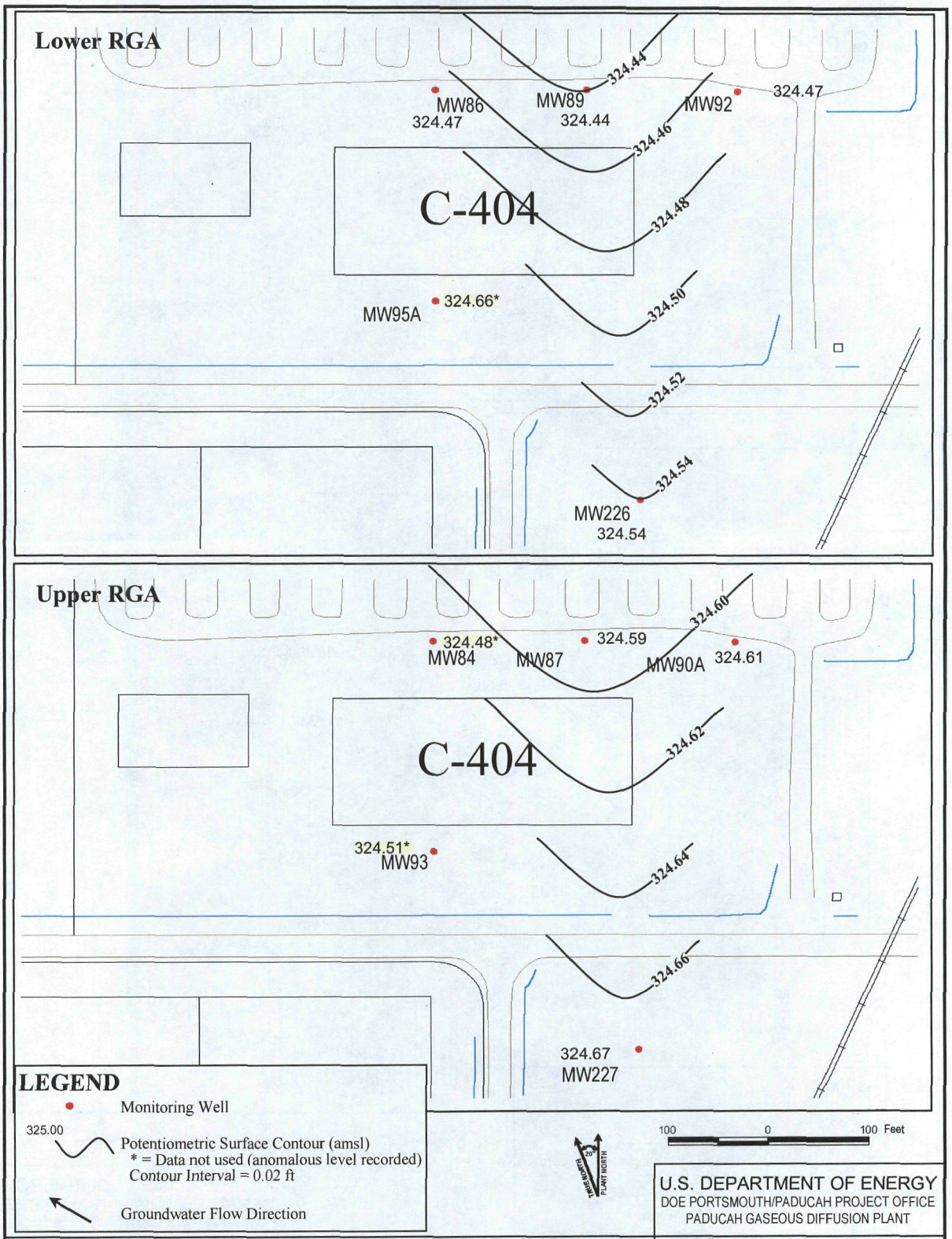

Figure A.1. Potentiometric Surface of the Regional Gravel Aquifer at the C-404 Landfill, January 7, 2002

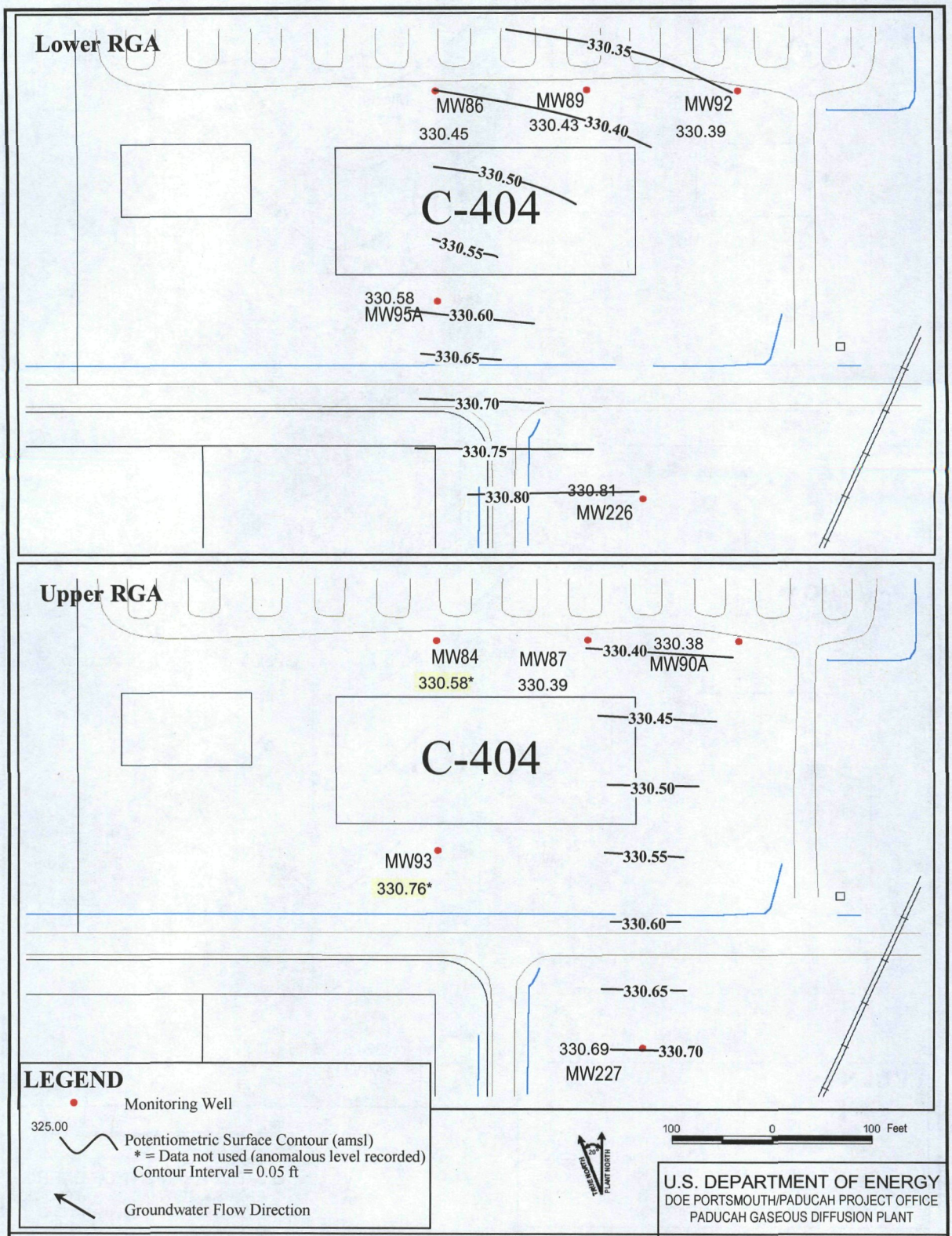

Figure A.2. Potentiometric Surface of the Regional Gravel Aquifer at the C-404 Landfill, July 22, 2002

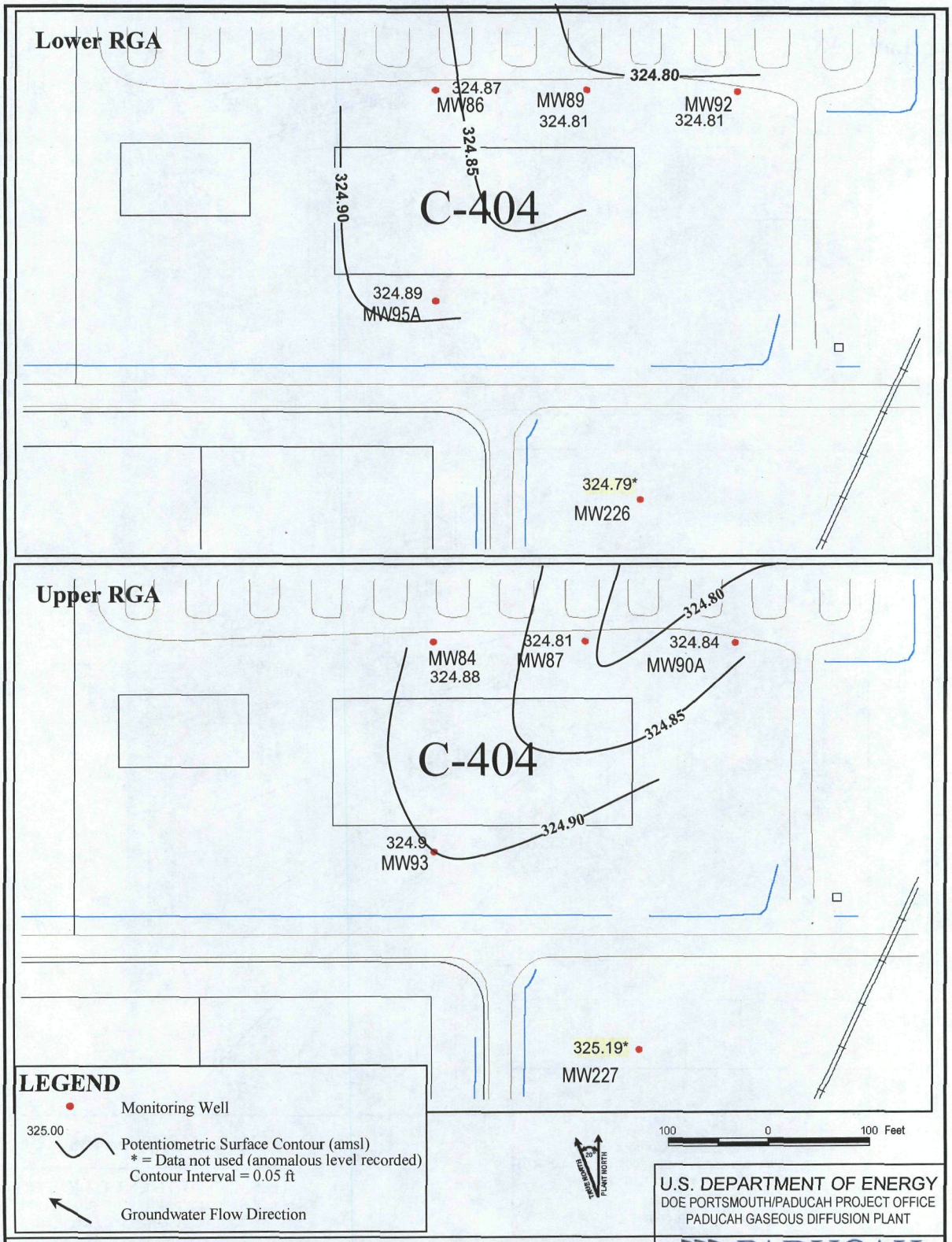

Figure A.3. Potentiometric Surface of the Regional Gravel Aquifer at the C-404 Landfill, January 21, 2003

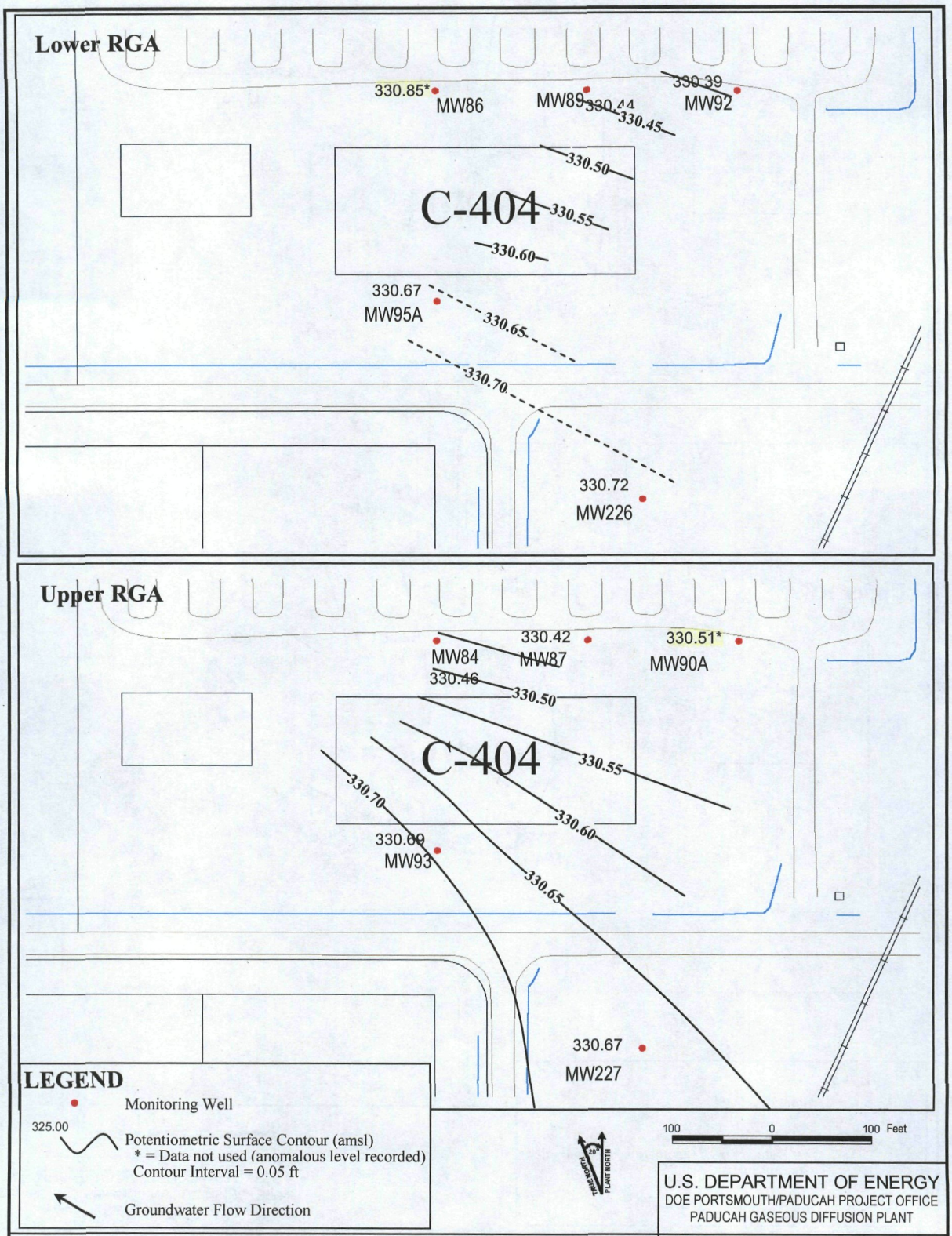

Figure A.4. Potentiometric Surface of the Regional Gravel Aquifer at the C-404 Landfill, July 21, 2003

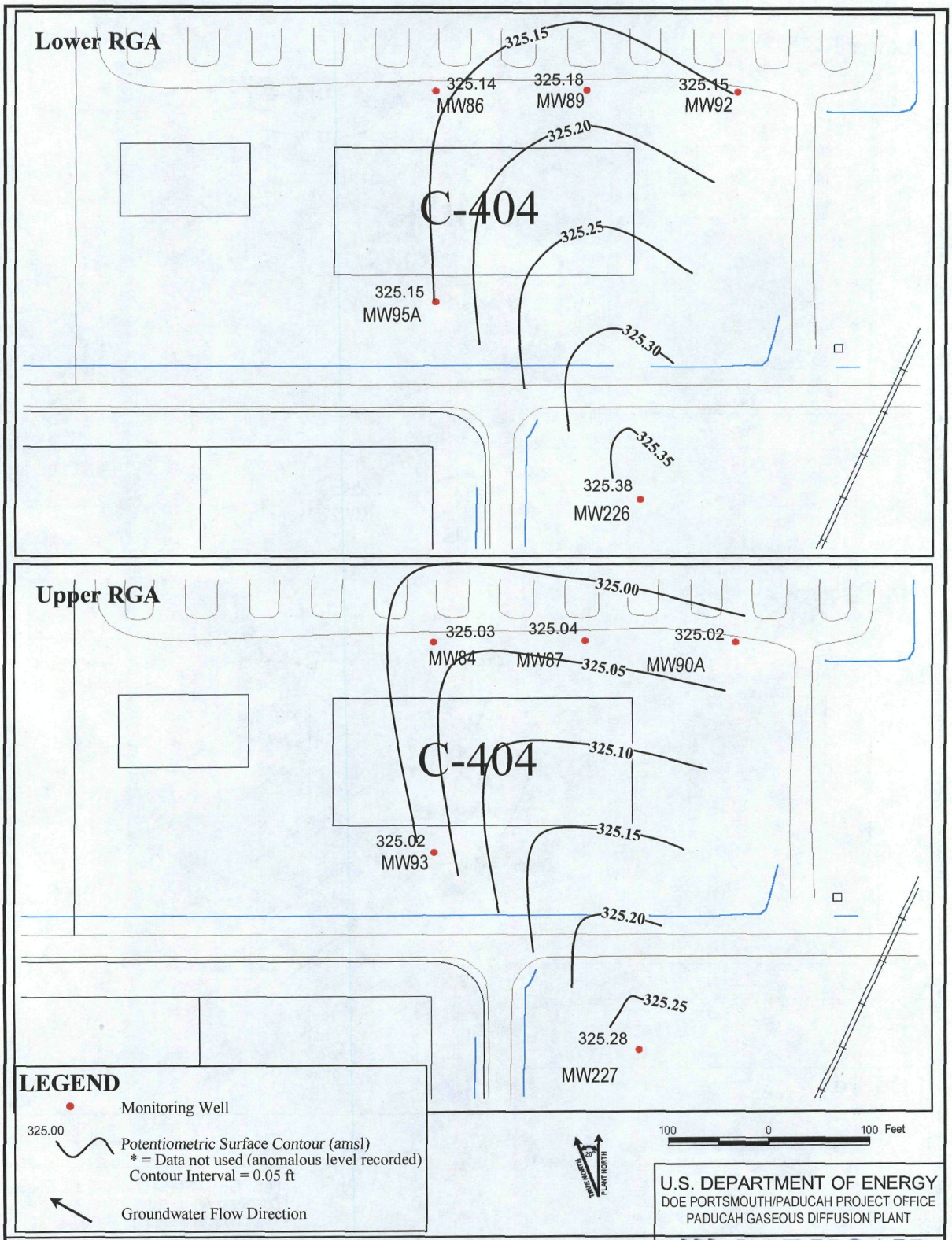

Figure A.5. Potentiometric Surface of the Regional Gravel Aquifer at the C-404 Landfill, January 8, 2004

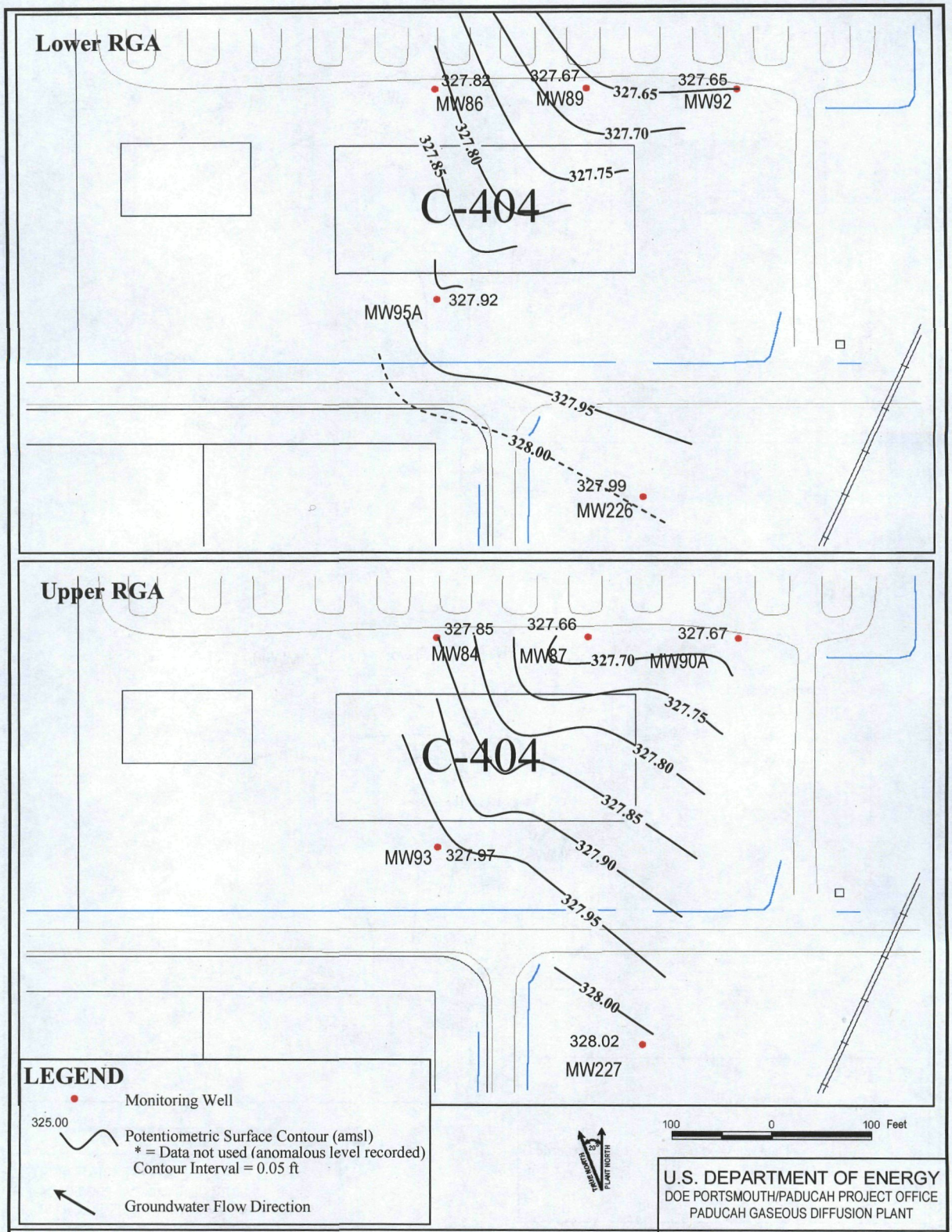

Figure A.6. Potentiometric Surface of the Regional Gravel Aquifer at the C-404 Landfill, July 9, 2004

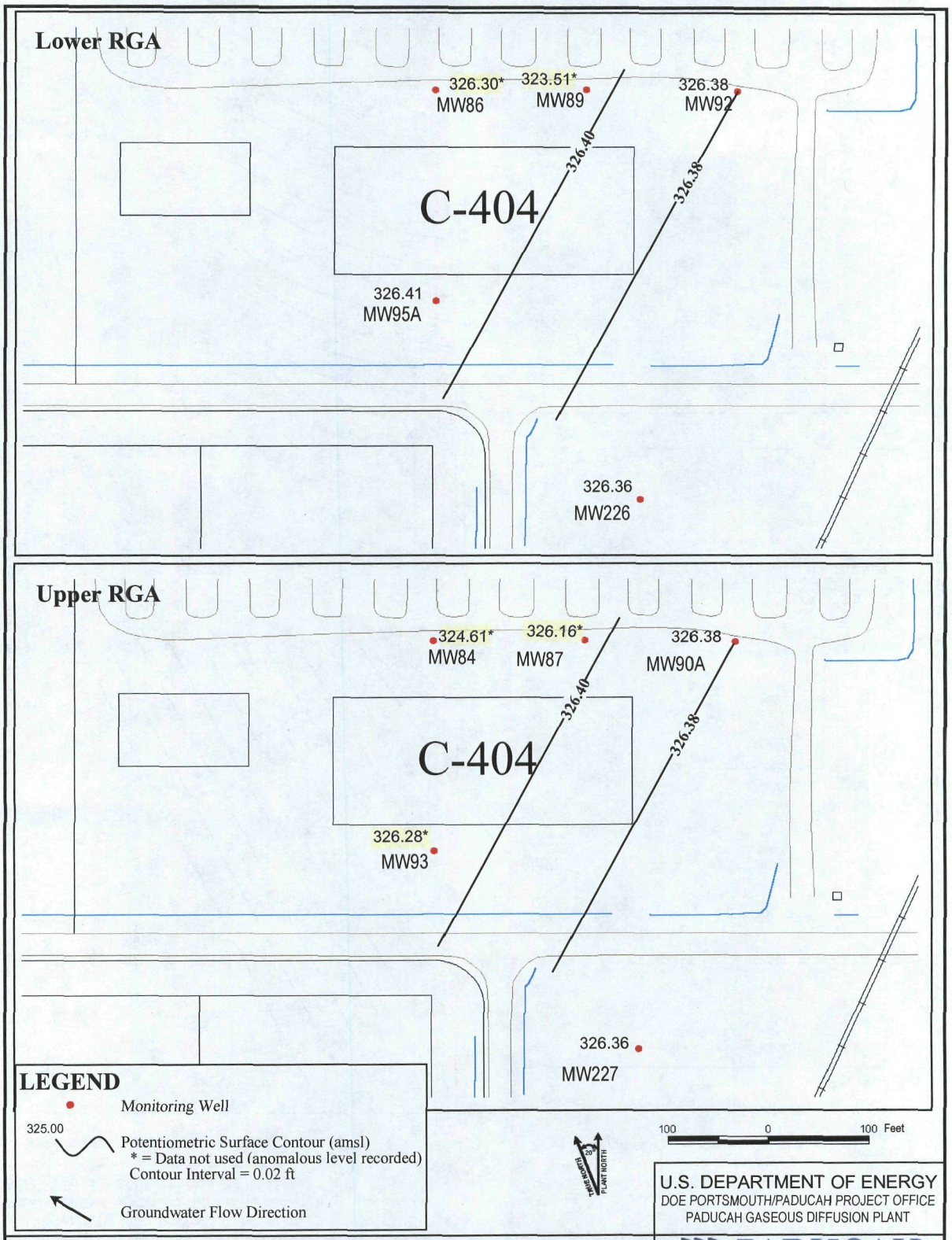

Figure A.7. Potentiometric Surface of the Regional Gravel Aquifer at the C-404 Landfill, January 24, 2005

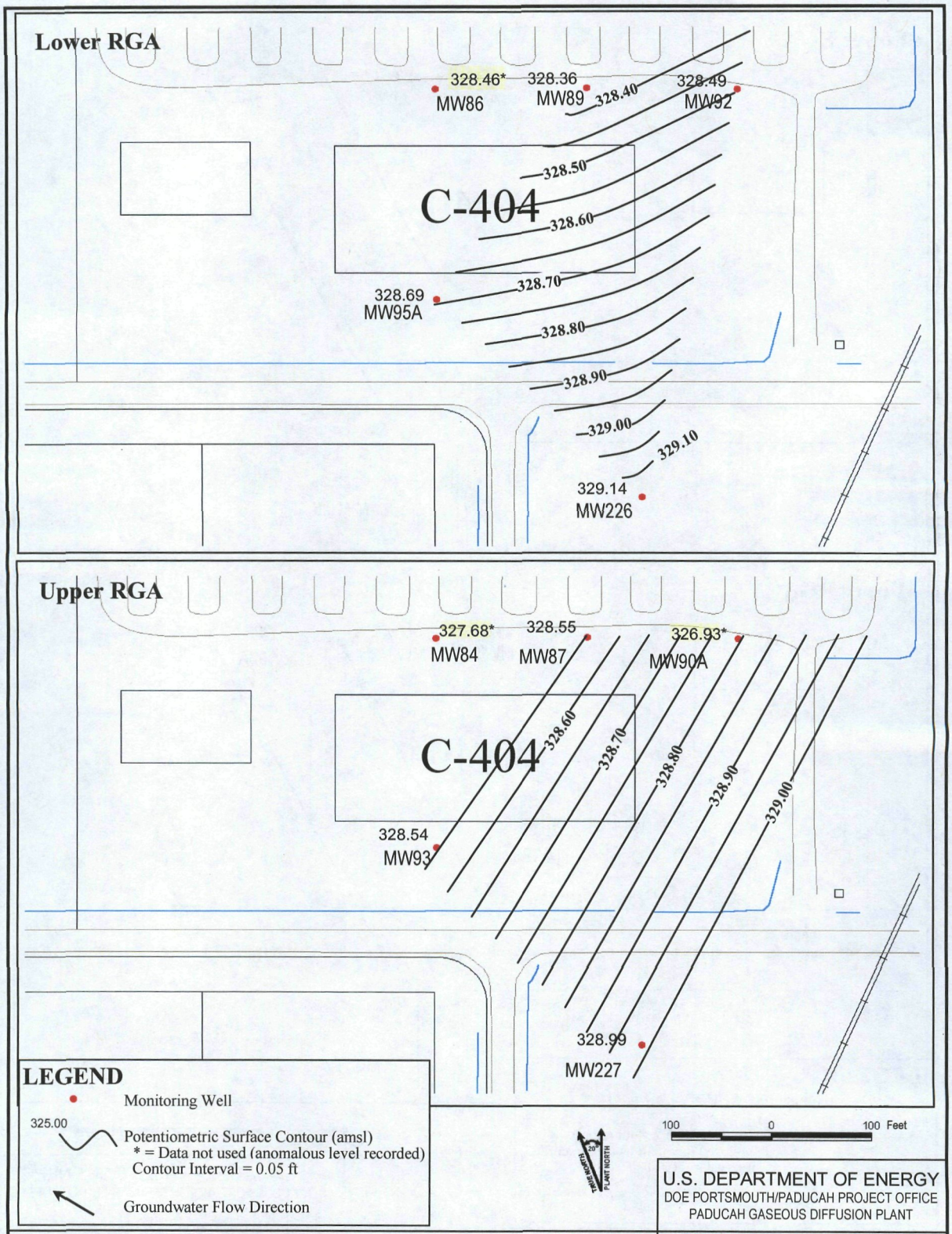

Figure A.8. Potentiometric Surface of the Regional Gravel Aquifer at the C-404 Landfill, July 9, 2005

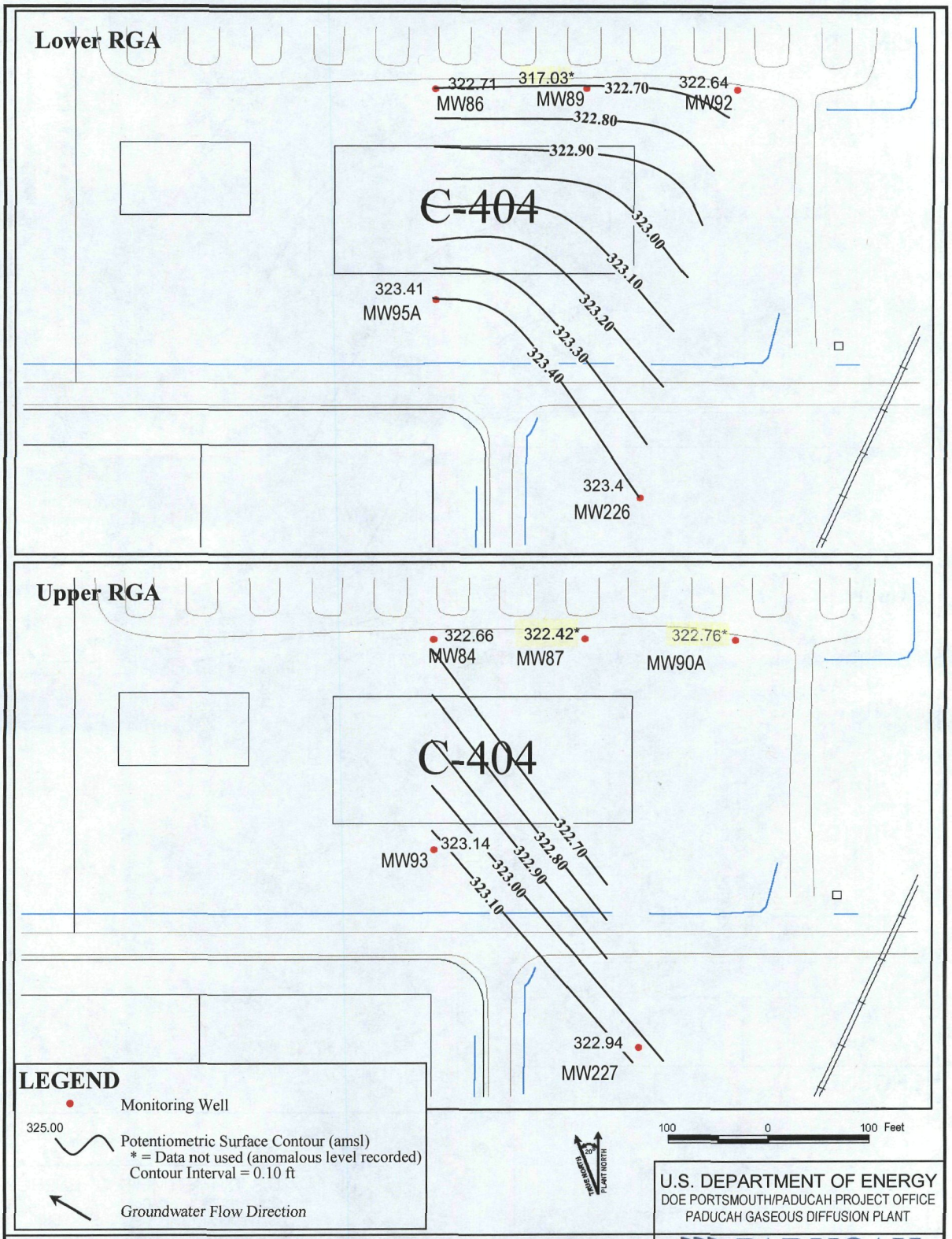

Figure A.9. Potentiometric Surface of the Regional Gravel Aquifer at the C-404 Landfill, January 24, 2006

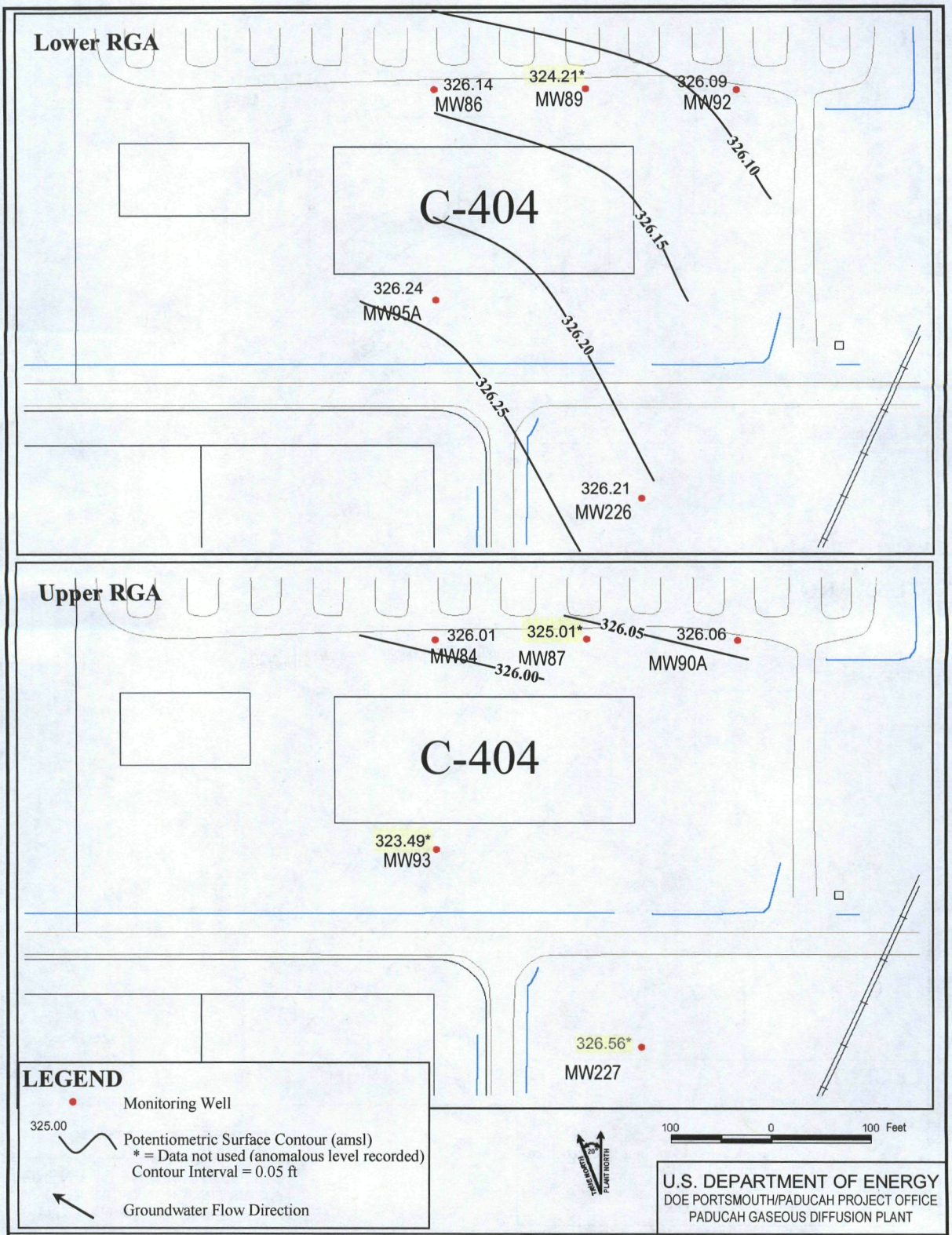

Figure A.10. Potentiometric Surface of the Regional Gravel Aquifer at the C-404 Landfill, July 18, 2006

APPENDIX B

TCE CONCENTRATION CONTOURS FROM 2001 THROUGH 2005 ANNUAL PLUME MAP DOCUMENTS AND GRAPHS

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APPENDIX C

C-404 STATISTICAL CALCULATIONS FOR MW84 FROM NOVEMBER 2006 REPORT

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Attachment 11: Statistical Test 4, Parametric ANOVA
July 2006
Trichloroethene URGA

STEPS 1 and 2

Well No.	Observations (n in µg/L) Jul-04	Jan-05	Jul-05	Jan-06	Jul-06	x_i Well Total	$(x_i)_{avg}$ Well Mean	n_i	f_i	$(x_i)^2$	n^2				
MW93	200	200	300	340	390	1430	286	5	4	2044900	40000	40000	90000	115600	152100
MW227	39	76	45	38	61	259	52	5	4	67081	1521	5776	2025	1444	3721
MW84	150	160	210	290	370	1180	236	5	4	1392400	22500	25600	44100	84100	136900
MW87	17	19	30	43	72	181	36	5	4	32761	289	361	900	1849	5184
MW90A	1	2.4	1	1	1	6.4	1	5	4	41	1	6	1	1	1
Grand Total/Mean						3056.4	122	25	20	3537183					

NOTE: MW93 and MW 227 are BG wells.

$x = 3056.40$

$(x_{avg}) = 122.26$

$n_i = 5$

$p = 5$

$N = 25$

$f_i = 4$

p = number of wells

n_i = number of data points per well

N = total sample size

S^2 = the square of the standard deviation

$\ln(S_i^2)$ = natural logarithm of each variance

f = total sample size minus the number of wells (groups)

$f_i = n_i - 1$

S_i	S_i^2	$\ln(S_i^2)$	$f_iS_i^2$	$f_i\ln(S_i^2)$
84.73	7180	8.9	28720	35.5
16.36	268	5.6	1071	22.4
93.17	8680	9.1	34720	36.3
22.53	508	6.2	2031	24.9
0.63	0.39	-0.9	2	-3.7

$\sum(S_i^2) =$ 16635.79 $\quad \sum f_i\ln(S_i^2) =$ 115.3

Equality of Variance: Bartlett's Test

$f =$ 20

$S_p^2 =$ 3327.158

$\ln S_p^2 =$ 8.110

$c^2 =$ 46.873 (If calculated $c^2 \leq$ tabulated c^2, then variances are equal at the given significance level.)

tabulated c^2 * = 9.488 at a 5% significance level with 4 degrees of freedom (p-1)

Since calculated c2 > tabulated c2, then the log of the numbers must be taken.

* Table 1, Appendix B, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities,* Interim Guidance, USEPA, 1989.

Attachment 11: Statistical Test 4, Parametric ANOVA
July 2006
Trichloroethene URGA

STEPS 1 and 2 **Lognormal Data for TCE**

Well No.	Observations (n) Jul-04	Jan-05	Jul-05	Jan-06	Jul-06	x_i Well Total	$(x_i)_{avg}$ Well Mean	n_i	f_i	$(x_i)^2$	n^2				
MW93	5.2983	5.2983	5.7038	5.8289	5.9661	28.0955	5.6191	5	4	789.36	28.07	28.07	32.53	33.98	35.59
MW227	3.6636	4.3307	3.8067	3.6376	4.1109	19.5494	3.9099	5	4	382.18	13.42	18.76	14.49	13.23	16.90
MW84	5.0106	5.0752	5.3471	5.6699	5.9135	27.0163	5.4033	5	4	729.88	25.11	25.76	28.59	32.15	34.97
MW87	2.8332	2.9444	3.4012	3.7612	4.2767	17.2167	3.4433	5	4	296.42	8.03	8.67	11.57	14.15	18.29
MW90A	0.0000	0.8755	0.0000	0.0000	0.0000	0.8755	0.1751	5	4	0.77	0.00	0.77	0.00	0.00	0.00
Grand Total/Mean						92.75	3.71	25	20	2198.60					

NOTE: MW93 and MW 227 are BG wells.

$x = 92.75$
$(x_{avg}) = 3.71$
$n_i = 5$
$p = 5$
$N = 25$
$f_i = 4$

p = number of wells
n_i = number of data points per well
N = total sample size
S^2 = the square of the standard deviation
$\ln(S_i^2)$ = natural logarithm of each variance
f = total sample size minus the number of wells (groups)
$f_i = n_i - 1$

S_i	S_i^2	$\ln(S_i^2)$	$f_iS_i^2$	$f_i\ln(S_i^2)$
0.31	0.0944	-2.4	0.3775	-9.4
0.30	0.0907	-2.4	0.3630	-9.6
0.39	0.1491	-1.9	0.5964	-7.6
0.60	0.3546	-1.0	1.4184	-4.1
0.39	0.1533	-1.9	0.6132	-7.5
$\sum(S_i^2)=$	0.84		$\sum f_i\ln(S_i^2)=$	-38.3

Equality of Variance: Bartlett's Test

f = 20
S_p^2 = 0.1684
$\ln S_p^2$ = -1.7813
c^2 = 2.677 (If $c^2 \le$ tabulated c^2, then variances are equal at the given significance level.)
tabulated c^2 *= 9.488 at a 5% significance level with 4 degree of freedom (p-1)

CONCLUSION: Since calculated c2 < tabulated c2, then the analysis can proceed as normal with Step 3.

* Table 1, Appendix B, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities,* Interim Guidance, USEPA, 1989.

Attachment 11: Statistical Test 4, Parametric ANOVA
July 2006
Trichloroethene URGA

STEPS 3, 4, 5, 6, 7 (Between Well Sum of Squares with Log Transformed Data)

Source of Variation	Sums of Squares		Degrees of Freedom	Mean Squares	F	F Statistic**
Between Wells	SS_{wells} =	95.59	4	23.90	141.90	2.87
Error (within wells)	SS_{Error} =	3.37	20	0.168		
Total	SS_{Total} =	98.96	24			

If calculated F > F statistic, then reject the hypothesis of equal well means. If calculated F is less than or equal to F statistic, it can be concluded that there is no significant difference between concentrations; therefore, there is no evidence of well contamination.

CONCLUSION: **Calculated F > F statistic; therefore, evidence of well contamination. Additional comparisons must be made.**

NOTE: ** Table 2, Appendix B, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Guidance*, USEPA, 1989. F statistic taken at the 5% significance level.

STEP 8 Comparison of Compliance Wells to Background Wells

n_b = 10 N-p = 20 α = 0.05 n_b = total sample size of all background wells

$(x_b)_{avg}$ = 4.764 m = 3 $1-\alpha/m$ = 0.9833333 $(x_b)_{avg}$ = average concentration from all background wells

Well No.	Well Mean $(x_i)_{avg}$	Differences of Avg. $(x_i)_{avg}-(x_b)_{avg}$	Standard Error SE_i	Bonferroni's t**** $t_{(N-p),(1-\alpha/m)}$	D_i	Conclusion
MW93	$(x_b)_{avg}$					
MW227	$(x_b)_{avg}$					
MW84	5.4033	0.64	0.225	2.27	0.510	evidence of contamination
MW87	3.4433	-1.32	0.225	2.27	0.510	not contaminated
MW90A	0.1751	-4.59	0.225	2.27	0.510	not contaminated

CONCLUSION: **After performing Bonferroni's t calculation, it can be concluded the following:**

MW84 is contaminated; MW87 and MW90A are not contaminated.

NOTE: ****Table 3, Appendix B, *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities*, Interim Guidance, USEPA, 1989.

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APPENDIX D

C-404 SURVEYOR'S REPORT

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TETRA TECH, INC.

July 30, 2007 PAD-072507-01

Karen A. Holland
Paducah Remediation Services, LLC
761 Veterans Ave.
Kevil, KY 42053

SUBJECT: Vertical data for 15 Monitoring Wells (MW) and 2 Piezometers (PZ) C-404 Landfill at Paducah Gaseous Diffusion Plant (PGDP)

Dear Ms. Holland:

This survey report is to document the re-survey of the following MW and PZ in the C-404 Landfill area of the PGDP. The wells were surveyed using the existing plant vertical control datum as established from the PGDP north-south and east-west coordinate system.

The elevations are as follows:

STATION	REF. MARK (FOUND)	REF. MARK (MARCH 1998)	ELEVATION
MW 84	Well Wiz. Plate	WWP	375.91
MW 86	Well Wiz. Plate	WWP	375.90
MW 87	Well Wiz. Plate	WWP	375.79
MW 89	Well Wiz. Plate	WWP	375.71
MW 90A	Top Grey Rim	-----	374.28
MW 92	Well Wiz. Plate	WWP	374.54
MW 93	Top Plate inside Casing	WWP	377.59
MW 95A	Top Grey Rim	------	376.94
MW 226	Open Top Ext. Casing	TOC	378.59
MW 227	Open Top Ext. Casing	TOC	378.74
MW 333	Top White Rim	WWR	377.27
MW 337	Top White Rim	WWR	374.52
MW 338	Top White Rim	WWR	374.72
MW 414	Top Grey Rim	-------	374.21
MW 416	Top Grey Rim	-------	377.65
PZ 76	Top Inner Most Casing	TIC	376.29
PZ 67	Top Plate Seat	WWP	374.86

The survey exceeded minimum standards for Class A, Standards of Practice 201 KAR 18:150 and Third-Order, USACE Point Closure Standards for Vertical Control Surveys.

Sincerely,

M. D. Stewart

Mitchell D. Stewart, P.G., P.L.S.
Kentucky P.L.S. No. 3237

STATE of KENTUCKY
MITCHELL D. STEWART
3237
LICENSED PROFESSIONAL LAND SURVEYOR
7-30-07

101 Liberty Drive, Suite #1, Kevil, KY 42053
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