

Note: Pie chart diameters are relative to total load.

Figure 225. Relative Average Annual Total U Loads from Major COU Drainages and Former WWTP

3.1.5 Groundwater Data Interpretation and Evaluation

This section provides a summary of groundwater monitoring performed in 2011, separated into RFLMA-required and non-RFLMA-required. A discussion of groundwater conditions during 2011, focusing on the most important water-quality aspects in the areas of interest (i.e., the main plumes), is then presented.

3.1.5.1 RFLMA Groundwater Monitoring Activities of 2011

Routine activities of the groundwater monitoring program in 2011 included sample collection, water-level measurement, groundwater treatment system maintenance, and well maintenance. “Groundwater” monitoring also includes monitoring activities at several surface-water locations,

as well as at some locations that may not clearly belong to either category. (Examples of the former include Surface Water Support location SW018 and groundwater treatment system-related performance monitoring locations within streams and ponds; examples of the latter include locations monitoring effluent from a treatment system.) However, because all of these locations support groundwater monitoring objectives, the data collected from them in support of these objectives are included as part of the groundwater discussion.

Special, non-RFLMA monitoring was also performed in 2011 to support various objectives. This is discussed in Section 3.1.5.2. The majority of this monitoring focused on the MSPTS and SPPTS. Validated analytical data and other information generated via RFLMA (i.e., routine) and non-RFLMA (i.e., nonroutine) sampling have been reported in the corresponding quarterly reports for 2011 (DOE 2011e, 2011f, 2012a) and are included in Appendix B for the fourth quarter of CY 2011. Unvalidated data are not reported but are summarized in this document.

There were two changes to the network of groundwater monitoring locations during 2011: Boundary wells were removed from the network, and a damaged Sentinel well was replaced. The groundwater monitoring network set forth in RFLMA is subdivided and categorized as shown in Table 87. Because the two Boundary wells were part of the RFLMA network for part of the calendar year, they are included in this table.

Table 87. RFLMA Monitoring Classifications for the Groundwater Monitoring Network

Well Classification	General Objective	Number of Wells^a	Monitoring Frequency
AOC	Monitor groundwater quality and water levels in a drainage downgradient of a contaminant plume or group of plumes	9	Semiannual (2x/year)
Boundary ^b	Monitor groundwater quality and water levels in Woman Creek and Walnut Creek drainages at eastern (downgradient) Site boundary	2	Annual ^b (1x/year)
Sentinel	Monitor groundwater quality and water levels near contaminant plume edges and in drainages	28	Semiannual (2x/year)
Evaluation	Monitor groundwater quality and water levels in or near contaminant source areas and in the former IA	42	Biennial (1x/every 2 years)
RCRA	Monitor groundwater quality and water levels upgradient and downgradient of the PLF and the OLF	10	Quarterly (4x/year)
Treatment System ^{c,d}	Monitor quality of groundwater treatment system influent, effluent, and downgradient surface water	9	Semiannual (2x/year)
Surface-Water Support ^c	Monitor quality of surface water downgradient of contaminant plume	1	Semiannual (2x/year)

^a The numbers of locations listed are current through 2011.

^b Boundary wells were deleted from the RFLMA monitoring network in early 2011, shortly after the 2011 samples were collected. These wells will no longer be monitored, but are included in the table because they were part of the RFLMA network at the start of 2011.

^c Treatment system and surface-water support locations are not monitoring wells but are included for completeness.

^d The PLFTS is discussed separately.

Table 88 presents the full 2011 schedule for RFLMA groundwater sample collection, a subset of which is summarized in Table 89 as those scheduled samples that were not successfully collected (e.g., due to dry conditions). Corresponding analytical results are published in the associated quarterly reports (DOE 2010c, 2010e, 2011b) and Appendix B.

Table 88. Summary of Scheduled RFLMA-Required Groundwater Sampling in CY 2011 (by Quarter)

Area	Classification or Type	Location ID	Analytes					
			VOCs	U	Nitrate	Metals	Pu/Am	SVOCs
Boundary Wells	B	10394	2	2	2			
	B	41691	2	2	2			
Present Landfill	RCRA	70193	1,2,3,4			1,2,3,4		
	RCRA	70393	1,2,3,4			1,2,3,4		
	RCRA	70693	1,2,3,4			1,2,3,4		
	RCRA	73005	1,2,3,4			1,2,3,4		
	RCRA	73105	1,2,3,4			1,2,3,4		
	RCRA	73205	1,2,3,4			1,2,3,4		
	AOC	4087	2,4	2,4	2,4			
	AOC	B206989	2,4	2,4	2,4			
Original Landfill	RCRA	P416589	1,2,3,4			1,2,3,4		1,2,3,4
	RCRA	80005	1,2,3,4			1,2,3,4		1,2,3,4
	RCRA	80105	1,2,3,4			1,2,3,4		1,2,3,4
	RCRA	80205	1,2,3,4			1,2,3,4		1,2,3,4
	AOC	11104	2,4	2,4				
MSPTS	S	15699	2,4					
	TS	MOUND R1-0	2,4					
	TS	MOUND R2-E	2,4					
	TS	GS10	2,4					
ETPTS	S	04091	2,4					
	S	95099	2,4					
	S	95199	2,4					
	S	95299	2,4					
	S	23296	2,4	2,4				
	TS	ET INFLUENT	2,4					
	TS	ET EFFLUENT	2,4					
SPPTS	TS	POM2	2,4					
	S	P210089	2,4	2,4	2,4			
	S	70099		2,4	2,4			
	TS	SPIN		2,4	2,4			
	TS	SPOUT		2,4	2,4			
Drainages Below Impacted Areas	AOC	10594	2,4	2,4	2,4			
	AOC	00997	2,4	2,4	2,4			
	AOC	00193	2,4	2,4				
Former B371/374	S	37405	2,4	2,4	2,4		2,4	
	S	37505	2,4	2,4	2,4			
	S	37705	2,4	2,4	2,4		2,4	
Former B771/774	S	20205	2,4	2,4			2,4	
	S	20505	2,4	2,4			2,4	
	S	20705	2,4	2,4	2,4		2,4	
Former North-Central IA	S	52505	2,4					
	AOC	42505	2,4					
Former IHSS 118.1	SS	SW018	2,4					
Former B444 Complex	S	11502	2,4	2,4				
	S	40305	2,4	2,4				
Former B881	S	00797	2,4	2,4				
	S	88104	2,4	2,4				

Table 88 (continued). Summary of Scheduled RFLMA-Required Groundwater Sampling in CY 2011
(by Quarter)

Area	Classification or Type	Location ID	Analytes					
			VOCs	U	Nitrate	Metals	Pu/Am	SVOCs
Former B991	S	99305	2,4	2,4	2,4			
	S	99405	2,4	2,4	2,4			
	S	91305	2,4	2,4	2,4			
Former Oil Burn Pit No. 1	S	33703	2,4					
Former Oil Burn Pit No. 2	S	91203	2,4					
Former SW056	S	45608	2,4					
OU1 Plume	AOC	89104	2,4					
903 Pad/Ryan's Pit Plume	S	90299	2,4					
	S	90399	2,4					
	AOC	10304	2,4	2,4	2,4			
PU&D Yard Plume	S	30002	2,4					

Notes: ID = Identification (name) of well/sampling location
 Location classifications: AOC = Area of Concern, B = Boundary, S = Sentinel, RCRA = Resource Conservation and Recovery Act, and SS = Surface Water Support
 Location types: TS = Treatment System, all others are groundwater monitoring wells or Surface Water Support
 SVOCs = semivolatile organic compounds
 2 (or other numeral) = Analyte requested for that quarter; if blank, analyte not requested

Table 89. Summary of RFLMA-Required Groundwater Samples Not Successfully Collected in 2011
(by Quarter)

Location		Analytes						Comments
ID	Classification	VOCs	U	Nitrate	Metals	Pu/Am	SVOCs	
95299	S	2, 4						Dry well

Notes: ID = Identification (name) of well/sampling location
 RFLMA classifications: S = Sentinel
 SVOCs = semivolatile organic compounds
 2 (or other numeral) in analyte column = Corresponding analyte requested in the indicated calendar quarter of 2011; if blank, analyte not requested

3.1.5.2 Non-RFLMA Groundwater Monitoring Activities of 2011

Non-RFLMA (i.e., nonroutine) groundwater monitoring was performed in 2011 in support of several data needs, which generally fall within the following two categories:

- Investigative sampling; and
- Performance sampling.

Table 90 summarizes non-RFLMA groundwater sample collection performed in 2011. In addition to this non-RFLMA sampling, additional non-RFLMA monitoring was performed through the Site-wide measurement of water levels as discussed in Section 3.1.3.

As in recent years, most of the non-RFLMA monitoring performed in 2011 was focused on the SPPTS. Most of the additional analytical data collected for the SPPTS were generated by an in-house laboratory and cannot be validated. This topic is discussed separately in Section 3.1.2.10.

3.1.5.3 Groundwater at the Rocky Flats Site: Discussion and Interpretations

This section presents a summary evaluation of groundwater quality at the Site during 2011. Groundwater quality is addressed first, followed by descriptions of special studies and activities. Included in the discussion of water quality are descriptions of the behavior of and any notable activities at the groundwater treatment systems during 2011.

Groundwater quality data were obtained for all monitored areas in 2011. Analytical data have been published in quarterly reports issued for 2011 (DOE 2011e, 2011f, 2012a), plus Appendix B, and will not be duplicated here. Appendix B also includes trend plots for CY 2011.

Groundwater quality at the Site in 2011 was largely consistent with data reported in prior years, as can be deduced from the summary of statistical trends presented in Table 91. Generally speaking, groundwater quality within plumes that were identified and characterized through the decades of pre-closure groundwater monitoring at the Site has not changed much over the years since the Site was closed.

Trend Plots

Numerous statistical trend plots were constructed for this report using analytical data collected from Sentinel, Evaluation, and RCRA wells (see Sections 3.1.2.8 and 3.1.2.9 for discussion of RCRA wells). Although not required by RFLMA, trend plots were also constructed for selected AOC wells and constituents. Trend plots and corresponding summary tables are presented in Appendix B. In addition to these statistical trend plots, many time-series plots were prepared and are included in this report.

The Sanitas software package (version 9.2.10; Sanitas Technologies 2011) was used for statistical calculations, including the ANOVA analyses and construction of statistical trend plots. (This is noted for the purpose of completeness only; this report does not make software recommendations.) For simplicity, trend calculations performed for any but RCRA wells assign the given well a downgradient position. This is appropriate because the fundamental objective of the other wells is related to detection monitoring or the exit strategy; no interwell statistics were planned for these classes of wells (only intrawell assessment of the trend of an analyte over time at each given well). Only RCRA wells were assigned either upgradient or downgradient positions to support the related statistical evaluations, as described in Section 3.1.2.8 and Section 3.1.2.9.

Analytical data are handled as described in Section 3.1.1.2. Trends for wells sampled more than once a year are calculated and plotted using the S-K statistical method, as recommended for Rocky Flats groundwater data (K-H 2004a) and in accordance with the RFSOG (DOE 2011a). Trends calculated for wells that are sampled less than twice per year, removing aspects of seasonality, employ the Mann-Kendall (M-K) statistical method. S-K trends are only plotted where they are calculated to be at least 80 percent significant, and M-K trends are plotted if at least 95 percent significant.

Table 91 summarizes the results of these trend calculations. Only increasing and decreasing trends calculated to be at least 80 percent significant using the S-K test (or, for Evaluation wells, at least 95% significant using the M-K test) are included in this table. (Therefore, even if 95 percent significant, trends with zero slope are not included.) Monitoring well classifications that require statistical evaluation of concentration trends according to RFLMA (i.e., Sentinel and downgradient RCRA wells) are included, as are calculations for several Evaluation wells sampled in 2011 and selected AOC wells. Refer to Appendix B for the trend plots and associated summary tables, and Figure 2 for well locations. Significant trends for selected analytes and locations are discussed later in this section in the context of their respective groundwater contaminant plumes.

Table 90. Summary of Non-RFLMA-Required Groundwater Samples Collected in CY 2011 (by Quarter)

Area	Location ID	Analytes ^a												
		VOCs	U	Nitrate	Nitrites	NH ₃ -NH ₄	U isotopes	PO4	TOC	Ca	Fe	Pu/Am	DNBART	
SPPTS ^b	GS13		1(6), 2(6), 3(4), 4(6)	1(9), 2(7), 3(2), 4(3)			2							
	SPIN		1(7) 2(4), 3(7) 4(5)	1(7) 2(4), 3(7) 4(5)	3(5), 4(5)	3(5), 4(5)				1(7), 2(3), 3(5), 4(5)	1(7), 2(3), 3(5), 4(5)			
	SPOUT		1(13), 2(11), 3(13), 4(12)	1(13), 2(11), 3(13), 4(12)	3(7), 4(5)	1(13), 2(11), 3(13), 4(12)		2	1(5)	1(13), 2(11), 3(12), 4(12)	3(5), 4(5)	1(7), 2(3), 3(6), 4(5)		
	SPPDISCHARGE GALLERY		1, 2, 3, 4(2)	1, 2, 3, 4(2)	1, 3, 4	1, 3, 4				1, 3, 4	1, 3, 4	1, 3, 4		
	SPCAE		1(7), 2(4), 3(6), 4(5)	1(7), 2(4), 3(6), 4(5)	3(6), 4(5)	1(7), 2(4), 3(6), 4(5)			1(5)	1(7), 2(4), 3(6), 4(5)	3(5), 4(5)	3(5), 4(5)		1(7), 2(4), 3
	SPCBE		1	1		1				1				1
	SPZE		1(7), 2(4), 3(5), 4(5)	1(7), 2(4), 3(5), 4(5)	3(5), 4(5)	1(7), 2(4), 3(5), 4(5)					1(7), 2(3), 3(5), 4(5)	1(7), 2(3), 3(5), 4(5)		
	SPILCA								1(5)	1(7), 2(4), 4				
	ITSS		1	1							1	1		
	RISERPIPE1		1	1	1	1					1	1		
	RISERPIPE2		1	1	1	1					1	1		
	RISERPIPE3		1	1	1	1					1	1		
	RISERPIPE4		1	1	1	1					1	1		1
	79502			4	4									
	79605			4	4									
	00203			4	4									
	P210089							2						
	70099							2						
B210489							2							
51605							2							
ETPTS ^c	ET EFFLUENT	4												
	ET INFLUENT	4												
MSPTS ^d	MOUND R1-0	3	4											
	MOUNDMH	1(12)												
	ASHINF	2(2), 3(8), 4												
	ASHEFF	2(2), 3(23), 4	2											
	GS10		1(6), 2(7), 3(6), 4(7)	4									4	
	15699	4	4											
Former IHSS 118.1	18199	2												
Former North-Central IA	21505	2												
903 Pad/Ryan's Pit Plume	00191	2												
Former Oil Burn Pit #2	07391	2												
	91203		4											
Former B991	91105	2												
	91305						4							
Former Oil Burn Pit #1	99405						2							
	33502	2												
	33604	2												
Former SW056	33711	3												
	45608		4											

Notes: ^a The numeral in the "analyte" column (e.g., 2) indicates the 2011 quarter in which the analyte was requested; if blank, analyte not requested. For those locations where more than one non-RFLMA-required sample was collected in the indicated quarter(s), the total number of non-RFLMA samples collected is indicated in parentheses.

^b The Solar Ponds Plume Discharge Gallery (SPPDischargeGallery) is sampled in accordance with the RFSOG (DOE 2011a). Locations SPIN, SPOUT, SPCAE, SPZE, and SPILCA are associated with the Phase II/III upgrades to the system and were sampled to evaluate the system effectiveness.

^c The East Trenches Plume Treatment System (ETPTS) has several associated sampling locations.

Table 90 (continued). Summary of Non-RFLMA-Required Groundwater Samples Collected in CY 2011 (by Quarter)

^d Several sampling locations are associated with the Mound Site Plume Treatment System to evaluate the effectiveness of groundwater treatment.

IA = Industrial Area

ID = Identification (name) of well/sampling location

IHSS = individual Hazardous Substance Site

Ca = calcium

Fe = iron

NH₃-N = ammonia (as nitrogen)

P₀₄ = phosphate

Pu/Am = plutonium/ameridium

TOC = total organic carbon

VOCs = volatile organic compounds

Table 91. Summary of Statistical Trend Calculations by Location

Well	Analyte	Trend	Significant at 95%?
Sentinel Wells			
00797	Uranium	Increasing	Yes
04091	Carbon tetrachloride	Decreasing	Yes ^c
	PCE	Decreasing	Yes ^c
11502	PCE	Decreasing	No
15699	1,1,1-TCA	Decreasing	No
	1,1-DCE	Decreasing	Yes
	Chloroform	Decreasing	Yes ^c
	PCE	Decreasing	Yes
	<i>trans</i> -1,2-DCE	Increasing	Yes ^c
	TCE	Decreasing	Yes
	Vinyl chloride	Increasing	Yes ^c
20205	PCE	Increasing	Yes ^c
	Uranium	Increasing	Yes
20505	1,1-DCE	Increasing	No
	<i>cis</i> -1,2-DCE	Decreasing	Yes ^b
	TCE	Decreasing	Yes ^b
20705	Am-241	Decreasing	Yes ^{c,d,e}
	<i>cis</i> -1,2-DCE	Increasing	No
	Uranium	Increasing	Yes ^d
	Vinyl chloride	Increasing	No
23296	1,1-DCE	Increasing	Yes ^c
	Carbon tetrachloride	Decreasing	Yes ^c
	Chloroform	Decreasing	Yes ^c
	<i>cis</i> -1,2-DCE	Increasing	Yes
	PCE	Decreasing	Yes
	<i>trans</i> -1,2-DCE	Increasing	Yes ^c
	Uranium	Decreasing	Yes
	Vinyl chloride	Increasing	Yes ^{a,c}
33711	1,4-DCB	Increasing	Yes
	Chlorobenzene	Decreasing	Yes
	<i>cis</i> -1,2-DCE	Increasing	Yes ^d
	Toluene	Increasing	No
	<i>trans</i> -1,2-DCE	Increasing	Yes ^d
	Vinyl chloride	Increasing	Yes ^{c,d}
37405	Nitrate	Increasing	Yes
	Uranium	Decreasing	No
37505	Uranium	Increasing	Yes
37705	Nitrate	Increasing	No
40305	PCE	Increasing	No
	Uranium	Increasing	No
45608	1,1-DCE	Increasing	Yes ^{c,d}
	<i>cis</i> -1,2-DCE	Decreasing	No
	PCE	Increasing	Yes ^{c,d}
	<i>trans</i> -1,2-DCE	Decreasing	Yes ^d
	TCE	Increasing	Yes ^{c,d}
	Vinyl chloride	Increasing	Yes ^{b,d}
52505	<i>cis</i> -1,2-DCE	Increasing	Yes ^c
70099	Nitrate	Decreasing	Yes
	Uranium	Increasing	Yes ^b

Table 91 (continued). Summary of Statistical Trend Calculations by Location

Well	Analyte	Trend	Significant at 95%?
88104	Uranium	Decreasing	Yes ^d
90299	Carbon tetrachloride	Decreasing	Yes ^c
	Chloroform	Decreasing	Yes
	TCE	Decreasing	Yes
90399	1,1-DCE	Increasing	Yes
	<i>cis</i> -1,2-DCE	Increasing	Yes
	TCE	Increasing	Yes
91203	1,1,1-TCA	Increasing	Yes ^{b,c}
	1,1-DCE	Increasing	Yes ^c
	<i>cis</i> -1,2-DCE	Increasing	Yes ^c
	PCE	Increasing	Yes ^b
	TCE	Increasing	Yes ^b
91305	Uranium	Decreasing	Yes ^b
95199	1,1-DCE	Increasing	No
	<i>cis</i> -1,2-DCE	Increasing	No
	PCE	Increasing	Yes
	TCE	Increasing	No
99305	<i>cis</i> -1,2-DCE	Increasing	Yes
	Nitrate	Increasing	No
	PCE	Increasing	Yes
	TCE	Increasing	Yes
	Uranium	Increasing	Yes
99405	<i>cis</i> -1,2-DCE	Increasing	Yes
	TCE	Increasing	Yes ^c
	Uranium	Decreasing	Yes
P210089	Nitrate	Increasing	Yes ^b
	Uranium	Increasing	Yes
RCRA Wells			
73005	Boron	Increasing	No
	Chromium	Increasing	Yes ^c
	Selenium	Increasing	Yes ^b
73105	Boron	Increasing	Yes
	Nickel	Increasing	No
	Uranium	Decreasing	Yes ^b
	Boron	Increasing	No
80005	Boron	Decreasing	Yes
80105	Uranium	Decreasing	No
80205	Boron	Increasing	No
	Uranium	Decreasing	Yes
Selected AOC Wells			
B206989	Nitrate	Decreasing	Yes
	Uranium	Decreasing	No
00193	Uranium	Decreasing	No
10594	Uranium	Decreasing	Yes
Selected Evaluation Wells			
07391	Chloroform	Decreasing	Yes
	<i>cis</i> -1,2-DCE	Increasing	Yes
18199	Carbon tetrachloride	Decreasing	Yes ^f
	PCE	Decreasing	Yes ^f

Table 91 (continued). Summary of Statistical Trend Calculations by Location

Well	Analyte	Trend	Significant at 95%?
21505	PCE	Decreasing	Yes ^f
	TCE	Decreasing	Yes ^f
33502	1,2,4-TCB	Decreasing	Yes ^c
	Naphthalene	Decreasing	Yes ^c
	PCE	Decreasing	Yes ^c
33604	TCE	Decreasing	Yes
79502	Uranium	Decreasing	Yes
91105	Carbon tetrachloride	Decreasing	Yes ^{c,d}

Notes: Only increasing and decreasing trends are included; indeterminate and zero-slope trends are not. Trends are listed if there is an 80% statistical significance; any decisions that may be made would be based on trends having a 95% significance. Only those trends having a 95% significance were assessed for applicability of the footnotes below.

Calculating trends for AOC wells is not required by RFLMA, but is provided for informational purposes.

^a Trend was not calculated to be significant at 80% level in previous (2009) report, but with 2011 data is now 95% significant.

^b Trend was calculated to be significant in previous (2009) report, but at less than a 95% significance; it now meets the 95% level of significance.

^c Trend calculated to be significant may not be valid because 25.0 percent or more of the analytical data used to calculate this trend are nondetects. See Section 3.1.1.2 for discussion of how nondetects were handled in trending calculations.

^d Although the trend is calculated to have a 95% significance, the data used to calculate this trend may be affected by well replacement. Results for this constituent in samples from the original well are markedly different from those from the replacement well. These data sets may be separated in the future, rather than continue to be pooled, as additional data are collected from the replacement well and are sufficient for trending separately.

^e Samples collected in 2005 were affected by very high turbidity (i.e., muddy water) immediately following installation of the replacement well. Thorough redevelopment reduced the turbidity and, therefore, the Am-241 as well.

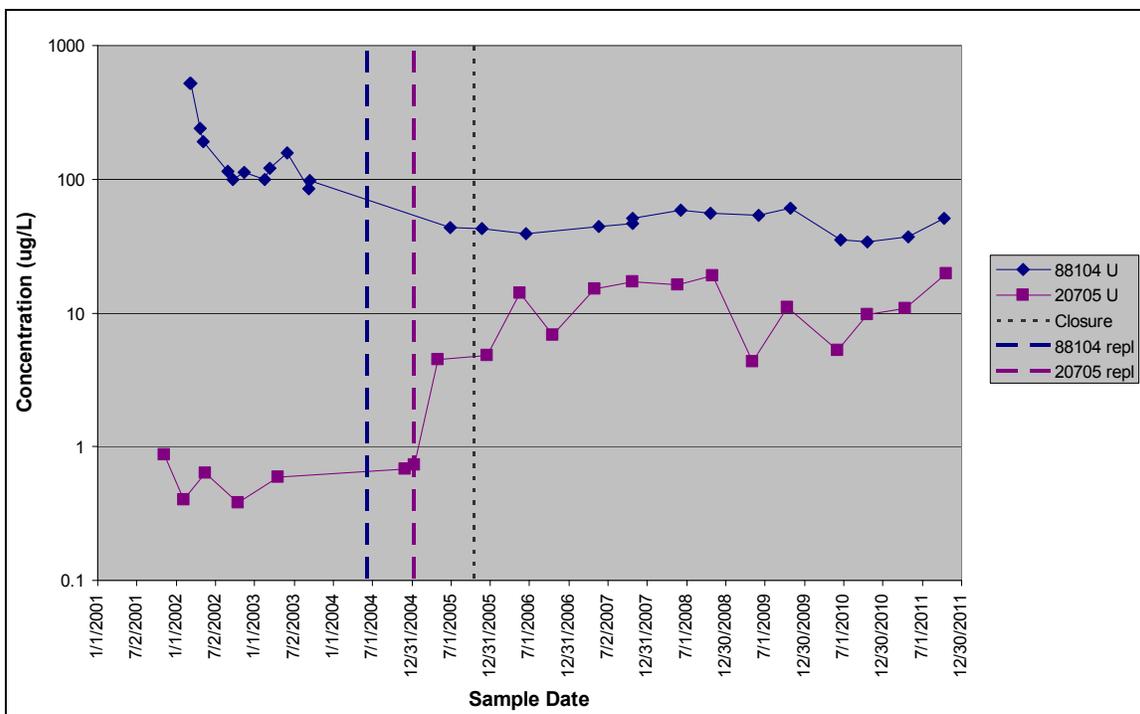
^f Trend was not found to be 95% significant in 2011 report. (Concentration trends in Evaluation wells are only evaluated for 95% significance, not 80% or greater significance as with wells of other classifications.)

DCA = dichloroethane; DCE = dichloroethene; DCB = dichlorobenzene; OBP = Oil Burn Pit; PCE = tetrachloroethene; TCB = trichlorobenzene

As indicated in Table 91, there are a few instances in which a concentration trend did not meet the 95 percent level of significance using 2010 data, but with 2011 data that level was attained; these instances are identified in the table. There are also instances in which a trend that had been calculated to be significant no longer met that test when 2011 data were included in the calculation.

Additional data will be collected in accordance with RFLMA and will further refine the concentration trends. Given that much of the analytical data used in trend calculations were collected before the Site was closed, and in many cases are from wells that were replaced as Site closure proceeded, some instances of slope change due to well replacement are to be expected. This may impact analytical and water elevation data. Figure 226 shows data that appear (even on a logarithmic concentration scale) to be strongly impacted by well replacements, as noted in the summary of calculated trends above. If one ignored the fact that these wells were replaced, one might conclude that uranium in well 88104 was on a decreasing trend, and in 20705 was increasing, just as the S-K trending calculations conclude. However, considering the well replacements, it may be more reasonable to conclude that there is no clear trend as of the end of 2011.

For a cross-walk of closure-era original and replacement wells, refer to the *Rocky Flats Site 2006 Integrated Monitoring Plan Background Document*, also known as the 2006 IMP (DOE 2006c, Appendix B, Table B-4); since that date, the only well replacements completed have been the abandonment of wells 45605 and 33703 and their replacement with wells 45608 and 33711, respectively.



Notes: Well 88104 is located immediately south of former B881, and well 20705 is located immediately north of former B771. “Repl” = well replacement date; “Closure” = Site closure date (in this case, declaration that closure activities were complete). The date of well replacement is represented by the date the original well was abandoned, because this is the last possible date on which samples from the original location could have been collected.

Figure 226. Time-Series Plot Showing Possible Well-Replacement Artifacts in Concentration Data

Groundwater Plumes with Treatment Systems

This section describes the general groundwater quality in 2011 at the three main groundwater contaminant plume treatment systems (MSPTS, ETPTS, and SPPTS) and the associated plumes these systems are designed to treat.

Mound Plume, Oil Burn Pit #2 (OBP#2) Plume, and MSPTS

The Mound Plume (also called the Mound Site Plume) is located north of the former 903 Pad. The source of the plume is a former drum storage area (“the Mound”) that was in use in the 1950s. Some of the drums leaked, creating a groundwater contaminant plume extending north toward South Walnut Creek. The drums were removed in 1970, and contaminated soils were removed in 1997. A groundwater treatment system was installed in 1998 to intercept and treat contaminated groundwater before it reaches the creek.

Oil Burn Pit #2 (OBP#2) was located just west of the Mound source area, at the southeast corner of the former Protected Area fence. Characterization and groundwater monitoring of OBP#2 was not feasible due to security infrastructure until the Protected Area was decommissioned. Groundwater and soil were subsequently sampled, and elevated concentrations of VOCs were detected. This led to a source removal action in 2005 that addressed elevated concentrations in the soils. Supplemental carbon (in the form of Hydrogen Release Compound [HRC]) was added to the backfill as electron donor material, to enhance biodegradation of residual VOCs. Because the flow path for the OBP#2 Plume is toward FC-4 to the north (generally parallel to the flow direction of the nearby Mound Plume) and potentially along the preferential pathway provided by a utility corridor left by a former storm drain, a gravel drain was installed in 2005 as part of the OBP#2 remediation. This gravel drain intercepts and directs groundwater flowing northward from the OBP#2 source area into the MSPTS intercept trench, from which it is directed to the MSPTS for treatment.

The following paragraphs describe these plumes and the MSPTS.

Mound Plume and OBP#2 Plume

Annual reports for 2006 and 2007 (DOE 2007c, 2008c) provide separate discussions of the Mound Plume and the nearby OBP#2 Plume. Because groundwater flow from the Mound Plume as well as the OBP#2 Plume is captured and treated by the MSPTS, the two plumes have since been discussed as a group. Refer to previous reports for additional detail on closure-era activities in these areas and their impacts on the local groundwater.

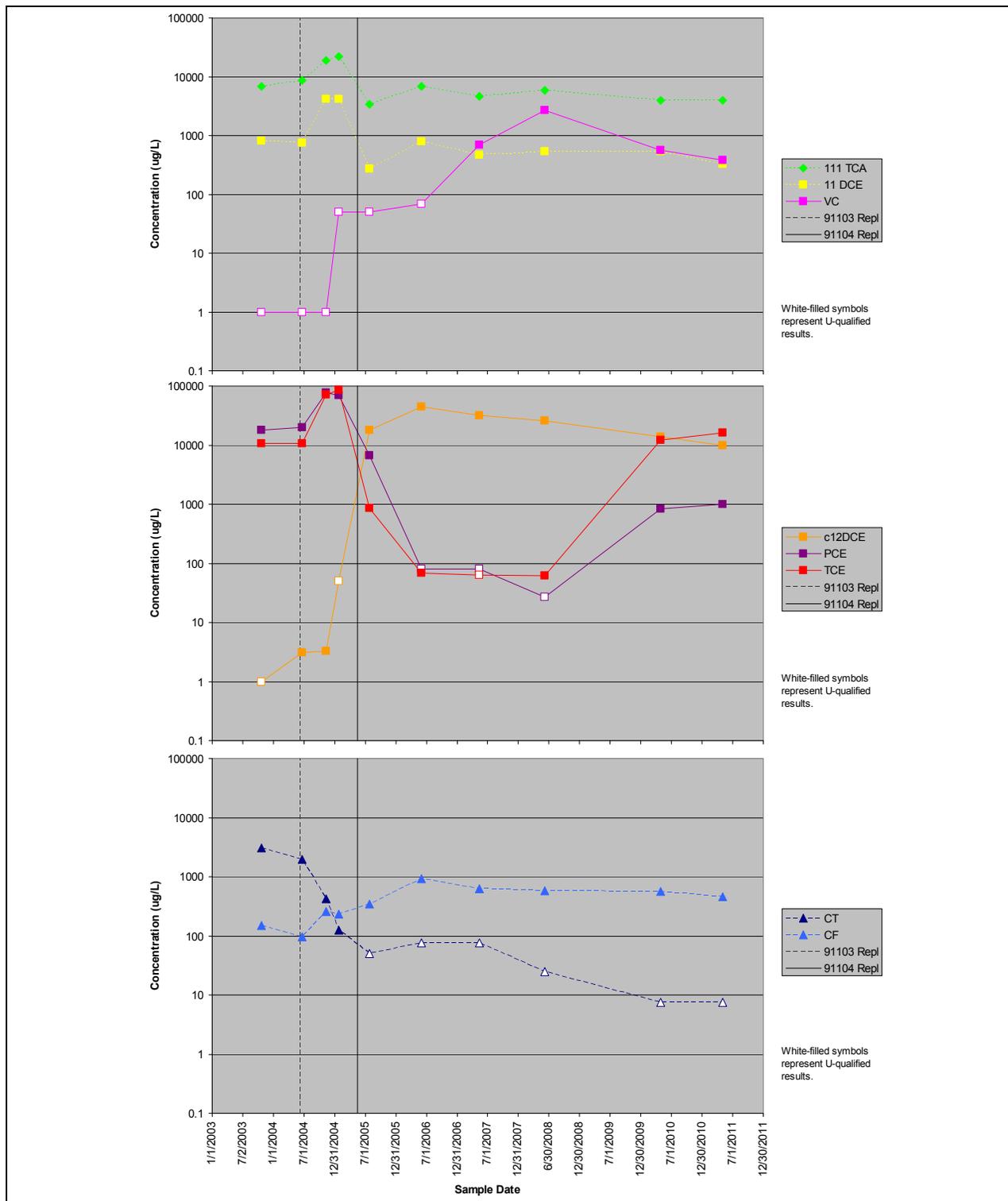
Consistent with the technical design of the groundwater monitoring network at the RFS, the two source-area wells, 00897 (Mound) and 91105 (OBP#2), are Evaluation wells that are scheduled for routine monitoring every other year. Neither were scheduled for routine RFLMA sampling in 2011, but will be sampled along with all other Evaluation wells in 2012. Although not scheduled for RFLMA monitoring, well 91105 was sampled in 2011 to evaluate changing conditions there (both for MSPTS objectives and considerations regarding groundwater monitored by Sentinel well 91203, located a short distance north-northwest of OBP#2).

At its source area, the Mound Plume is characterized by elevated concentrations of PCE and TCE. The 2010 Annual Report documents that concentrations of these constituents have remained fairly consistent since 2000, as has that of the primary metabolic byproduct from degradation of these compounds, *cis*-1,2-DCE (DOE 2011d). This suggests the degree to which these VOCs are degrading is low.

In contrast to the Mound source area, groundwater in the OBP#2 source area was originally characterized by elevated concentrations of 1,1,1-trichloroethane (TCA), PCE, TCE, and 1,1-dichloroethene (DCE). Well 91105 is the third to monitor the OBP#2 source area; the previous two (91103, 91104) were installed directly within the contaminated soils, while the current well is on the downgradient edge of the backfilled source-removal excavation. These two predecessor wells therefore produced samples with much higher concentrations of VOCs than does the current monitoring well. Since the OBP#2 source removal and addition of electron donor material to the backfill to enhance biodegradation of residual VOCs, concentrations of some parent compounds, such as carbon tetrachloride, PCE, and TCE, decreased sharply (Figure 227). At the same time, concentrations of daughter products such as *cis*-1,2-DCE and

vinyl chloride (VC) increased in samples from the OBP#2 source-area well. Similarly, concentrations of carbon tetrachloride have decreased to the point that this constituent is no longer detected in samples from well 91105, as its primary daughter product, chloroform, has increased in concentration. (This enhanced degradation of carbon tetrachloride and increasing concentration of chloroform is not seen at Individual Hazardous Substance Site (IHSS) 118.1, despite a similar source removal activity and addition of electron donor material, as discussed separately in a later section of this report.) Concentrations of carbon tetrachloride in samples from well 91105 are calculated to be on a decreasing trend with a 95 percent statistical significance (Table 91), although the trend is complicated by well replacements and the presence of numerous nondetects in the dataset.

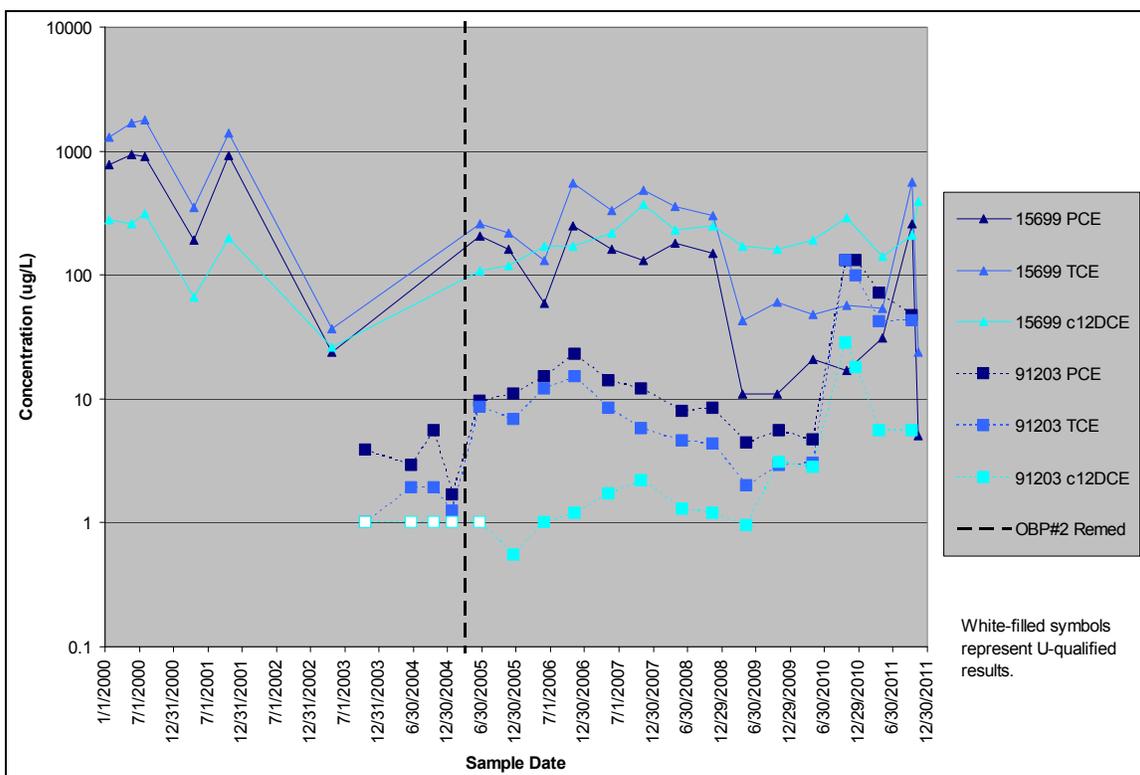
As shown on Figure 227, concentrations of some parent compounds (e.g., TCE, PCE) have rebounded somewhat since 2008, as concentrations of daughters simultaneously exhibited a much smaller decrease (*cis*-1,2-DCE, VC) or have appeared to stabilize (chloroform, 1,1-DCE). This may indicate depletion of the added electron donor material and/or reduction in biodegradation due to changing geochemical conditions, since the bacteria performing the reductive dechlorination of these constituents favor reducing conditions. At Rocky Flats, such changes would be an expected outcome of donor material depletion, but could also be simply from a surplus of normally oxygenated groundwater flushing through the area. Data from samples collected in future years will help determine the longer-term trends of these contaminant concentrations.



Notes: 111TCA = 1,1,1-trichloroethane (RFLMA Table 1 standard = 200 µg/L); 11DCE = 1,1-dichloroethene (7 µg/L); VC = vinyl chloride (0.2 µg/L); CT = carbon tetrachloride (1 µg/L); CF = chloroform (3.4 µg/L); c12DCE = *cis*-1,2-dichloroethene (70 µg/L); PCE = tetrachloroethene (1 µg/L); TCE = trichloroethene (2.5 µg/L). 91103 Repl and 91104 Repl are dates on which those wells were abandoned and replaced by the next well, ultimately the current well, 91105. Several detections are qualified but for simplicity are not shown differently. Note logarithmic concentration scales.

Figure 227. Primary VOCs in OBP#2 Source Area Well 91105 (and Predecessors)

The Mound and OBP#2 Plumes are also monitored by Sentinel wells positioned generally downgradient of the source areas, along flow paths to surface water. Figure 228 displays reported concentrations of PCE, TCE, and *cis*-1,2-DCE in samples from Sentinel wells 15699 (downgradient of the Mound and MSPTS groundwater intercept trench) and 91203 (generally downgradient to sidegradient of OBP#2). As noted in previous annual reports (e.g., DOE 2010d, 2011d) and illustrated on Figure 228, the concentrations of these constituents in samples from well 15699 that were collected prior to closure show fairly close correlation, and the relative concentration of each reflected its use during the operational history of the Site and its position in the degradation pathway of PCE and TCE. (With successive dechlorination, PCE is transformed to TCE and then to *cis*-1,2-DCE, 1,1-DCE, and VC [K-H 2004d, ATSDR 2007].) Since mid-2006, however, concentrations of these constituents have followed a different pattern: those of PCE and TCE have continued to show correlation, while concentrations of *cis*-1,2-DCE have increased relative to the parent compounds PCE and TCE; this increase has been especially evident since 2008. (Although not included on the figure, a similar pattern is evident for VC.) This is interpreted as a reflection of the reconfiguration of source waters to the MSPTS—i.e., the addition of the OBP#2 plume, which contains relatively higher concentrations of daughter products such as *cis*-1,2-DCE and VC following the addition of electron donor material to the OBP#2 source-area backfill at the completion of source removal activities. Given that well 15699 is positioned downgradient of the MSPTS groundwater collection trench, this trench has received significantly more *cis*-1,2-DCE since 2006, and the trench is not fully lined, it is not surprising that samples from this well would show a change in water quality similar to that expressed by MSPTS influent. That the OBP#2 area plays a role in this change in water quality is also suggested by the hydrograph for well 15699 (Appendix A): prior to Site closure, this well was frequently dry, but since closure the water level has been consistently above the bottom of the well screen. This is attributed to the additional water routed to the leaky MSPTS groundwater intercept trench, located immediately upgradient of well 15699.

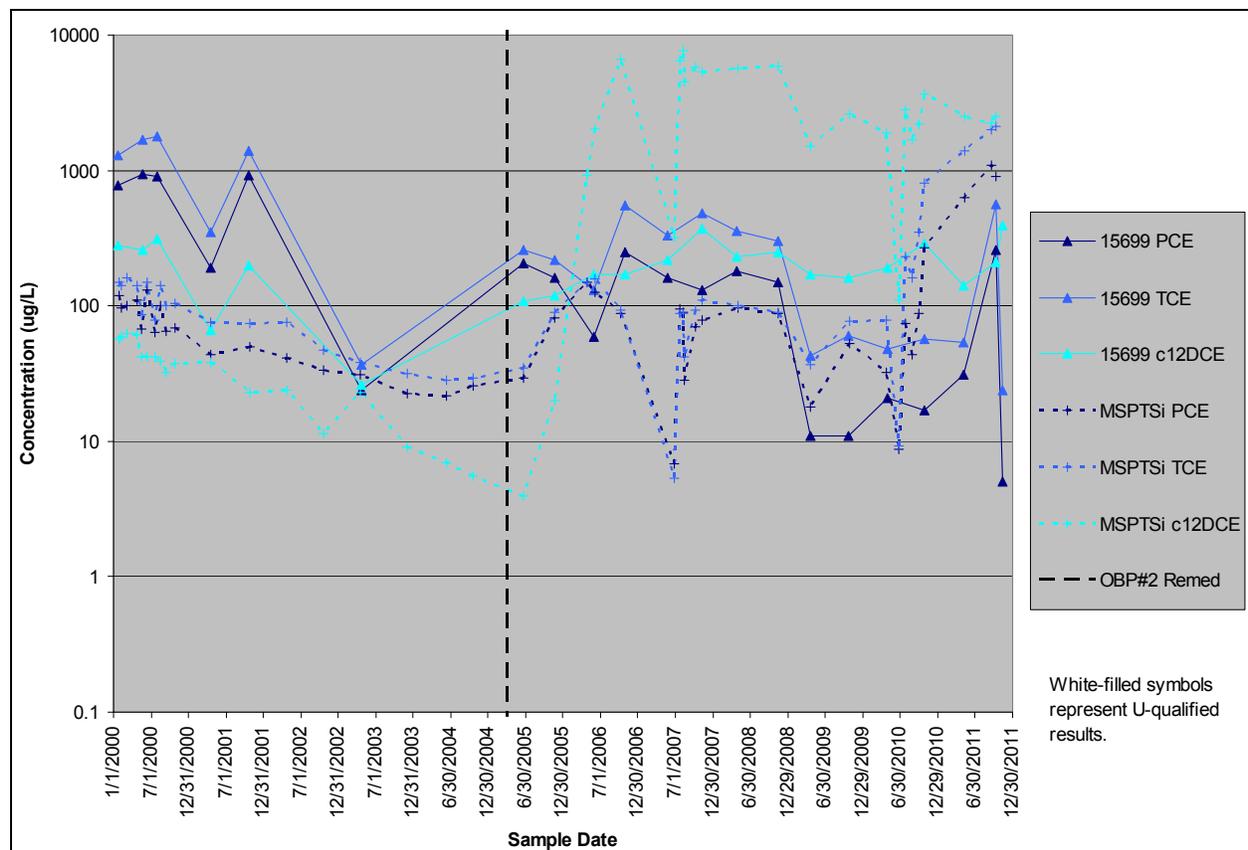


Notes: OBP#2 Remed indicates the date on which source removal and backfilling of the OBP#2 was completed (April 1, 2005). PCE (RFLMA Table 1 standard = 1 µg/L); TCE (2.5 µg/L); *cis*-1,2-DCE (c12DCE in the figure above, 70 µg/L). Several results are qualified (qualifier J; and the qualifier “D” that indicates analysis was performed at a dilution), but for simplicity are not shown differently. Note logarithmic concentration scale.

Figure 228. VOC Concentrations in Samples from Mound/OBP#2 Plume Downgradient Wells 15699 and 91203

Samples collected from well 15699 in October 2011 show a significant increase in contaminant concentrations, particularly TCE and PCE (Figure 228 and Figure 229, the latter of which also illustrates MSPTS influent concentrations). This may reflect operational measures undertaken to support the MSPTS media replacement and associated activities in early 2011. As that work was being performed, groundwater that was intercepted by the MSPTS collection trench was stored within the trench rather than being routed directly to the treatment cells; once the work was complete, the stored water was routed through the system for treatment. Just as described above with respect to the general change in water quality shown at this well following the OBP#2 work, with the additional head related to several feet of water in the trench, some of this stored water may have seeped into the subsurface and was later intercepted by the well. Although not required by RFLMA, confirmatory samples were collected in November to evaluate the October results, given their anomalous appearance. (Since 2009, concentrations of TCE in samples from well 15699 typically ranged between 40 and 60 µg/L; in 2011, TCE increased from 54 µg/L in May, to 560 µg/L in October.) As illustrated on Figure 228 and Figure 229, concentrations in the confirmatory sample dropped to be more consistent with previous data. The *cis*-1,2-DCE concentration remained elevated, but parent products PCE and TCE had decreased sharply (TCE was reported at 24 µg/L in the November confirmatory sample).

From a statistical perspective, trends calculated at the 95 percent level of significance in samples from well 15699 include decreasing 1,1-DCE, chloroform, PCE, and TCE (comprising parent as well as daughter products); and increasing *trans*-1,2-DCE and VC (both daughter products; see Table 91 and Appendix B). Again, some of these are complicated by the presence of numerous nondetects (such as with chloroform, *trans*-1,2-DCE, and VC).

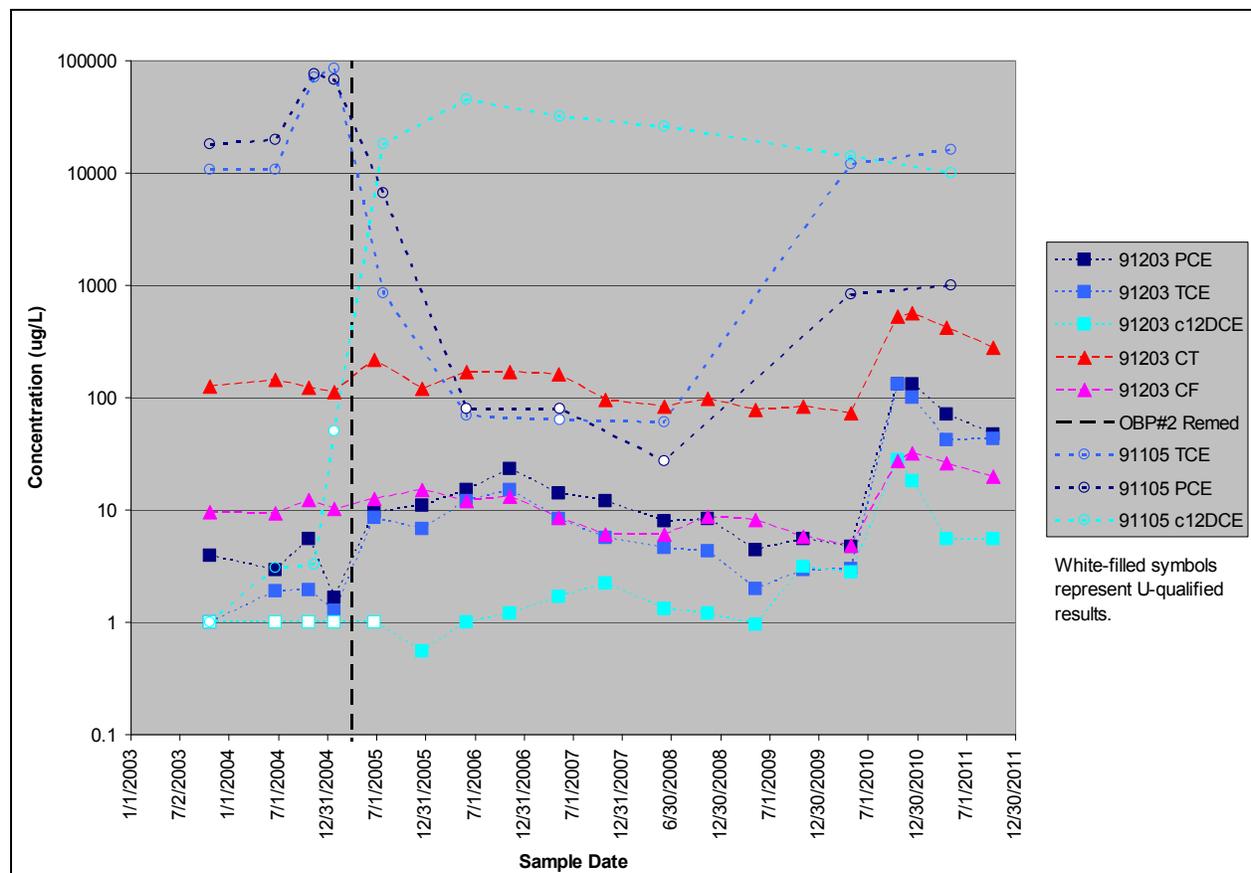


Notes: MSPTSi = MSPTS influent (actual sample location name is R1-0). OBP#2 Remed indicates the date on which source removal and backfilling of the OBP#2 was completed (April 1, 2005). PCE (RFLMA Table 1 standard = 1 µg/L); TCE (2.5 µg/L); *cis*-1,2-DCE (c12DCE in the figure above, 70 µg/L). Several results are qualified (J, D), but for simplicity are not shown differently. Note logarithmic concentration scale.

Figure 229. Concentrations of TCE, PCE, and *cis*-1,2-DCE in Samples from Sentinel Well 15699 and MSPTS Influent

Samples from Sentinel well 91203 show an increase in the concentrations of some VOCs that generally coincides with the disruption associated with remediation of OBP#2 completed on April 1, 2005 (Figure 228 and Figure 230). These concentration increases leveled off and began to decrease somewhat, but more recently—particularly in the fourth quarter of 2010—concentrations of VOCs in samples from well 91203 were higher. Figure 230 includes VOCs such as carbon tetrachloride and chloroform that are not typically detected, or are present at relatively lower concentrations, in samples from well 15699. Some of these constituents are also not as strongly elevated in samples from OBP#2 source-area well 91105 (Figure 227), such as carbon tetrachloride (which has not even been detected in samples from that well collected since 2005). Clearly visible on Figure 230 is the increase in VOC concentrations in the fourth quarter of 2010, followed by a more gradual decline extending through 2011.

Reasons for the observed increase in VOC concentrations at well 91203 are uncertain. One possible cause is the relatively wetter spring of 2010, which may have mobilized residual contaminants in the vadose zone that reached the well later in the year. OBP#2 source area well 91105, which is located upgradient and sidegradient of well 91203, also produced samples with increased concentrations of PCE and TCE in 2010 (Figure 227, Figure 230). However, the contaminant distributions in wells 91105 and 91203 are significantly different, most obviously in the lack of carbon tetrachloride at the OBP#2 source-area well and the spike in this constituent at well 91203. This suggests OBP#2 is probably not the source of the elevated VOCs reported in samples from well 91203, though it should be kept in mind that prior to remediation of that source area, carbon tetrachloride was present at significantly elevated concentrations.



Notes: Data from OBP#2 source area well 91105 are designated as such, all other are from well 91203. CT = carbon tetrachloride (RFLMA Table 1 standard = 1 µg/L); CF = chloroform (3.4 µg/L); PCE = tetrachloroethene (1 µg/L); TCE = trichloroethene (2.5 µg/L); c12DCE = *cis*-1,2-dichloroethene (70 µg/L); 111TCA = 1,1,1-trichloroethane (200 µg/L); 11DCE = 1,1-dichloroethene (7 µg/L). OBP#2 Remed = date on which source removal and backfilling of the OBP#2 was completed (April 1, 2005). Several results are qualified (J, D), but are not shown differently for the sake of simplicity. Note logarithmic concentration scales.

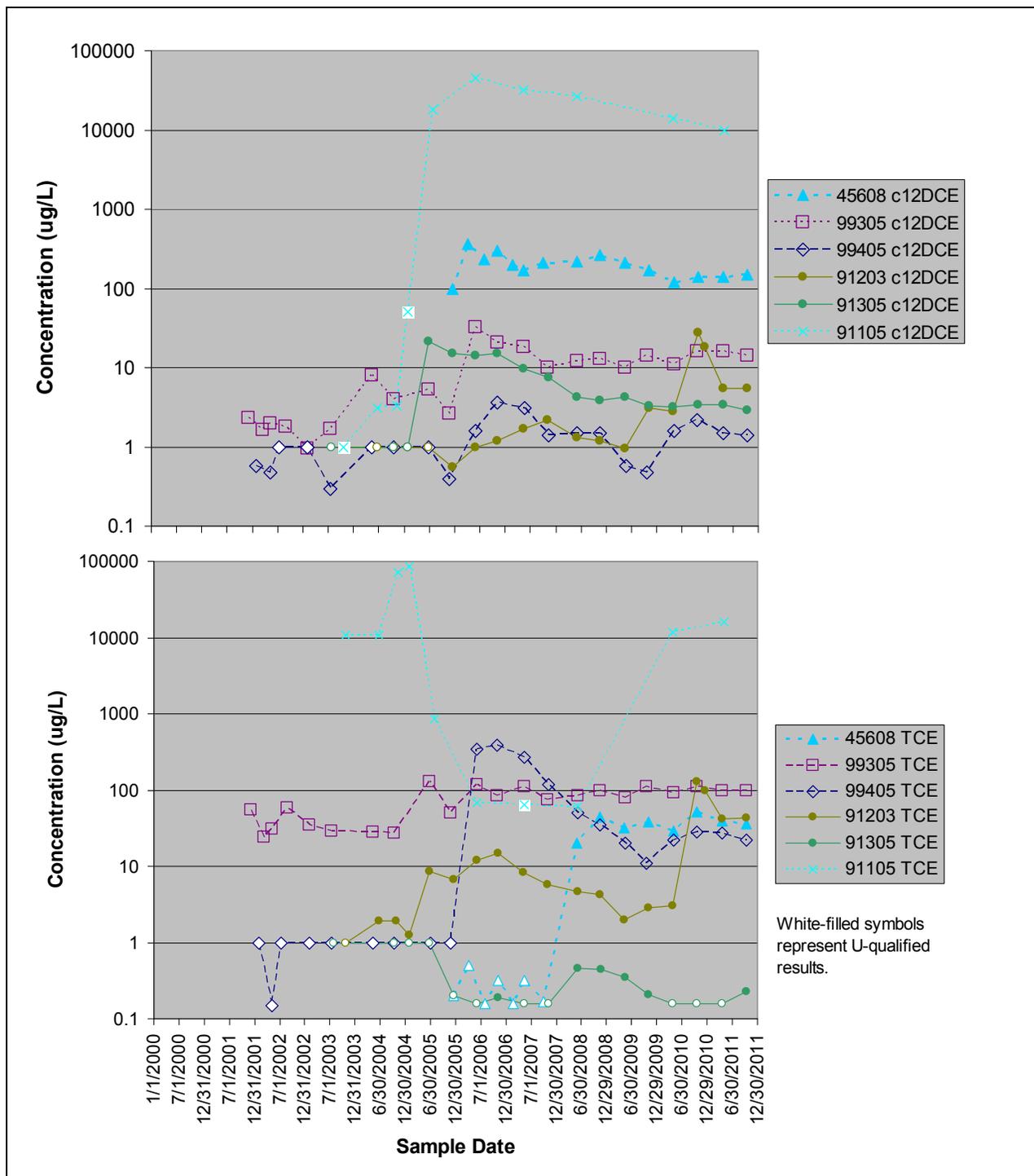
Figure 230. VOCs in Well 91203, Downgradient of OBP#2

Estimated travel times (discussed in Section 3.1.3.5 and summarized in Table 52) from well 91105 to 91203 typically have been in the range of 3.5 to 4 years. However, in the second quarter of 2010 they were estimated at under 2 years. Data collected in 2011 suggest a return to more normal flow conditions for this well pair, with estimated travel times of approximately

3.3 and 3.4 years. (As noted in Section 3.1.3.5, these calculated travel times are estimates only and apply to pure water, not dissolved constituents such as VOCs, which would be retarded to some degree and would take longer to move the same distance. Therefore, given the travel time estimates, the elevated detections could relate to VOC source-removal activities in early 2005 or some other mechanism. In addition, because well 91203 is not directly downgradient from well 91105, this velocity estimate may not be completely applicable.) Additional sampling may help to identify the cause of these increased concentrations, particularly if fluctuations in VOC concentrations generally correspond to larger-scale fluctuations in water level.

S-K trend calculations for 91203 (Table 91 and Appendix B) suggest the presence of several trends having a 95 percent level of significance. Increasing trends in 1,1,1-TCA; 1,1-DCA; and *cis*-1,2-DCE are complicated by the presence of numerous nondetects in the corresponding datasets, which may mean the calculated trends are not valid. Also calculated to be increasing are PCE and TCE, which are visually apparent on Figure 230.

Sentinel well 91305 is also located in this area, west of well 91203 and adjacent to FC-4. Concentrations of VOCs in samples from well 91305 remain low, and do not suggest an increase similar to that observed at 91203. Data from this well suggest it monitors a mix of waters. Comparisons of degradation byproducts and parent compounds suggest the low concentrations of contaminants reported in well 91305 are contributed by the French-drain-affected hillside south of former B991 (located west-southwest of well 91305) as well as the B991 hillside itself (due west of the well) and potentially other areas. Figure 231 illustrates concentrations of *cis*-1,2-DCE and TCE in samples from wells in this area, including 91105 (the OBP#2 source-area well), 45608 (on the hillside south of B991), 99305 and 99405 (on the 991 hillside), 91203 (north of OBP#2), and 91305. Both of these VOCs are daughter products of the partial dechlorination of PCE, though TCE was also used as an industrial solvent in its own right during the production era at Rocky Flats. As shown on this figure, TCE concentrations in samples from well 91305 are substantially lower than those reported by its neighbors, while *cis*-1,2-DCE concentrations are more comparable with those of its nearest neighbors, 91203 and 99405. This may be due to enhanced biodegradation related to reducing conditions in the subsurface of the FC-4 constructed wetland, which would support dechlorination and potentially reduce TCE more than *cis*-1,2-DCE. Monitoring will continue according to RFLMA, and additional data may help to explain specific relationships.



Notes: Top graph represents *cis*-1,2-DCE (c12DCE), bottom is for TCE. Corresponding applicable RFLMA surface-water action levels, respectively: 70 µg/L, 2.5 µg/L (DOE 2007a). In addition to nondetects on both graphs, several results are qualified detections but for simplicity are not shown differently. Note logarithmic concentration scales.

Figure 231. Concentrations of *cis*-1,2-DCE and TCE in Samples from Wells Near FC-4 Constructed Wetland

Mound Site Plume Treatment System

The MSPTS was the first groundwater intercept/treatment system installed at the Site to incorporate ZVI and is actually among the first of its type in the world. This work was completed in 1998. The first media replacement activity was conducted in the summer of 2006, and the media was replaced again in 2011. As a part of this second replacement activity, an air stripper was installed in the effluent manhole to polish the effluent. Routine maintenance activities performed at the MSPTS in 2011, including the media replacement activity, are discussed in Section 2.5.1. Additional information on and discussion of the air stripper is also provided in that section, and in the paper attached as Appendix F.

As with all years from 2005 on, flow rates through the MSPTS in 2011 were above pre-2005 levels. This is attributed to the routing of groundwater flow from the OBP#2 area into the MSPTS intercept trench. (For additional background, see the 2005 Annual Report.) Table 92 provides annual estimates of the volume of water treated by the MSPTS, which in 2011 is estimated at approximately 546,000 gallons—the most of any year to date—and Table 93 provides annual averages of the volume of water treated by this system. (Table 93 includes an annual pre-closure volume average that omits 2005 flows because the volume treated in that year was abnormally high, not representative of typical pre-closure conditions.) As summarized by this table, the flow to the MSPTS more than doubled following completion of the OBP#2 connection.

Figure 232 presents a hydrograph illustrating flows from January 1, 2000 through the end of 2011, and Figure 233 provides a hydrograph focusing on CY 2011. The period of no flow evident in the first part of the year on Figure 233 corresponds to taking the system off-line in order to replace the media.

The period of no flow indicated on Figure 233 during the first quarter of 2011 represents the media replacement activity. Flow to the treatment cells was shut off to allow the ZVI media within the cells to be removed and replaced with fresh media. At the same time, the subsurface effluent discharge gallery was repaired to address clogged conditions, and a prototype air stripper was installed in the effluent manhole. These activities are discussed in greater detail in Section 2.5.1. This work was completed in March 2011.

During the media replacement work, groundwater continued to be intercepted by the trench. The water was stored in the trench until the system was put back online. This may be a factor in the higher water levels and contaminant concentrations in well 15699 during 2011.

Table 92. Estimated Volumes of Water Treated by the MSPTS

Calendar Year	Annual Estimates of Volume Treated (gallons)	Estimated Cumulative Volume Treated (gallons)
2000	258,000	660,000
2001	119,000	780,300
2002	53,000	833,000
2003	82,000	915,000
2004	86,000	1,001,000
2005	506,000	1,507,000
2006	430,000	1,937,000
2007	326,000	2,263,000
2008	358,000	2,621,000
2009	287,000	2,908,000
2010	420,000	3,328,000
2011	546,000	3,874,000

Note: Estimates for years 2000 through 2004 are compiled from K-H (2000a, 2000b, 2000c, 2000d, 2002b, 2003, 2005a, 2005b).

Table 93. Average Volumes Treated by the MSPTS

Time Period	Average Volume Treated Per Year
Pre-closure, 2000–2005	184,000
Pre-closure, 2000–2004	119,600
Post-closure, 2005–2011	394,500

Note: Average volumes are based on estimates of volumes treated, as presented in Table 92. Time periods shown include complete years, and do not correspond to exact date of closure; for example, the pre-closure estimate for the 2000-2005 period spans January 1, 2000, through December 31, 2005.

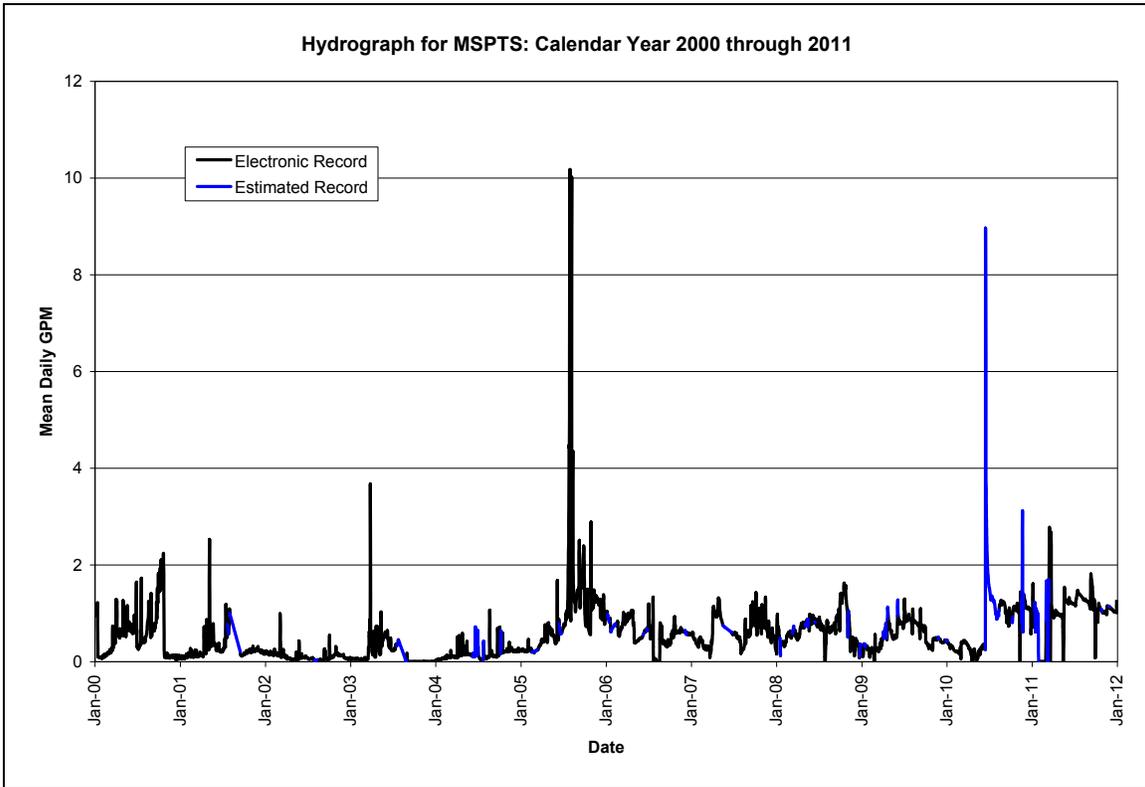


Figure 232. Hydrograph for MSPTS from 2000 Through 2010

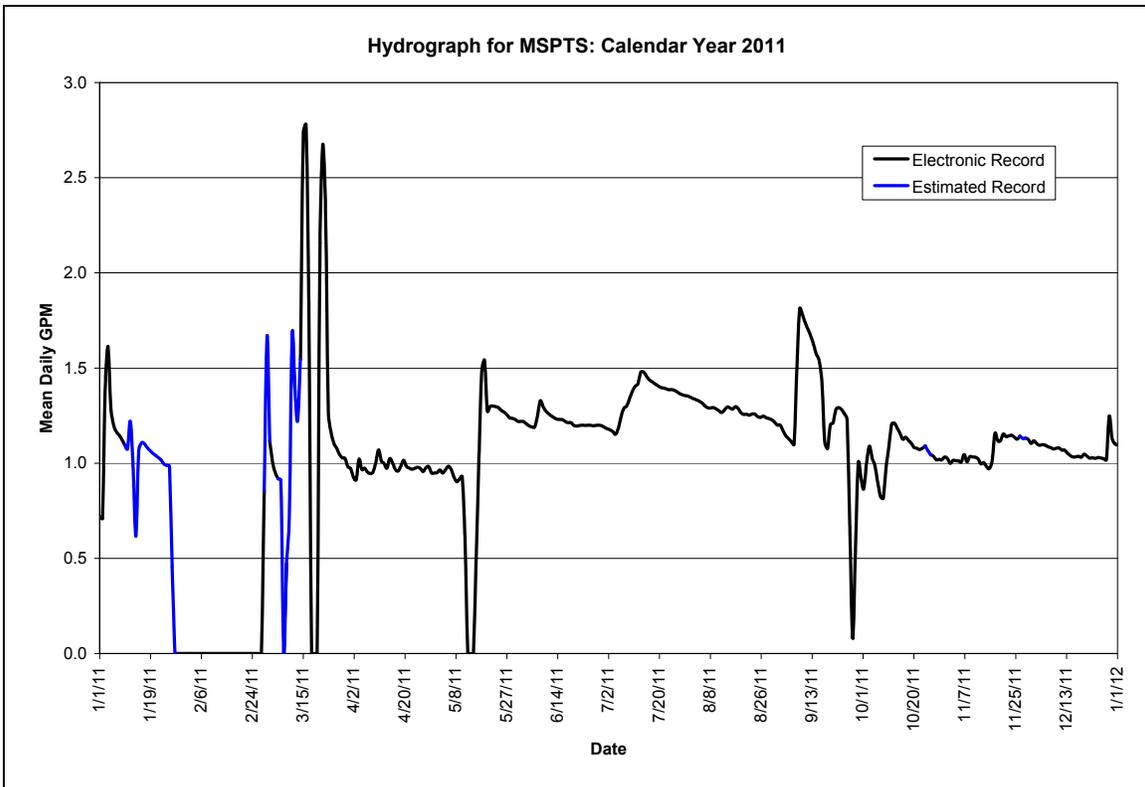


Figure 233. Hydrograph for MSPTS for CY 2011

The MSPTS was sampled twice in 2011 (May, October) in accordance with RFLMA. In addition, the influent was sampled in September to support air stripper optimization efforts. Most of the optimization sampling was conducted at specially-designed sampling locations that are not RFLMA locations. Refer to Appendix F for more information on the MSPTS air stripper design, installation, and optimization.

Analytical data representing MSPTS influent and effluent continue to illustrate the dramatic effect the addition of OBP#2-related groundwater has on the system. As in 2010, nine VOCs were detected in 2011 in MSPTS influent at concentrations exceeding their respective Table 1 levels (DOE 2007a). The VOCs that exceeded Table 1 levels in 2011 included 1,1,1-TCA, 1,1-DCE, 1,2-DCA, carbon tetrachloride, chloroform, *cis*-1,2-DCE, PCE, TCE, and VC. This is the same set of VOCs as was elevated in 2010 influent except in 2010, methylene chloride was present at levels above the RFLMA standards, while 1,2-DCA was not. The presence of 1,1,1-TCA in MSPTS influent was not prevalent until 2007 and represents a primary contaminant from the OBP#2 source area.

Concentrations of TCE and PCE rose throughout 2011 in MSPTS influent, as illustrated above on Figure 229. At the same time, concentrations of *cis*-1,2-DCE were relatively uniform or slightly decreasing. There is some similarity with the past few years of analytical data representing samples from OBP#2 source-area well 91105, discussed above and illustrated on Figure 227. Additional data will help to clarify any longer-term trends that may be indicated by these 2011 data.

In 2009, two VOCs were detected in MSPTS treated effluent at concentrations exceeding RFLMA Table 1 values; due to the moist spring, in 2010 eight VOCs exceeded their respective Table 1 values. The system performance improved slightly in 2011, when six VOCs exceeding RFLMA standards were reported in system effluent: chloroform, *cis*-1,2-DCE, methylene chloride, PCE, TCE, and VC. As in previous years, some of these constituents are more recalcitrant; the reductive dechlorination of polychlorinated constituents (such as PCE, TCE, and carbon tetrachloride) occurs more readily than that of mono- and dichlorinated compounds (e.g., *cis*-1,2-DCE, VC, methylene chloride) (EPA 2000). Therefore, these partially chlorinated daughter products require a greater residence time in ZVI media for adequate treatment to be accomplished. However, under conditions of higher flow rates, the residence time instead decreases.

Table 94 summarizes MSPTS influent and effluent analytical data for selected constituents. Refer to the quarterly reports (DOE 2011e, 2011f, 2012a) and Appendix B for additional water-quality data for the MSPTS. Data representing MSPTS influent clearly show the impact of closure activities performed upgradient of the system, particularly the installation of an engineered preferential pathway (the backfilled storm drain corridor and associated cross-cutting gravel drain) that now routes groundwater impacted by the OBP#2 into the MSPTS groundwater intercept trench. (For more information on this feature, see K-H 2005c.)

The impact on water quality related to the addition of OBP#2 flow is more concisely summarized in Table 95, which presents average MSPTS influent concentrations generally prior to and following the contribution of OBP#2 water to MSPTS influent. (Note that these averages incorporate all results at face value, including nondetects, regardless of qualifiers. In addition,

the “pre-closure” time period is approximated by data from January 1, 2000, through December 31, 2005; “post-closure” is represented by data from January 1, 2006, through the end of 2011.) With the exception of carbon tetrachloride, all constituents shown in this table increased in concentration following OBP#2 remediation. The average concentrations of chloroform and methylene chloride, both daughter products of carbon tetrachloride degradation, appeared to increase relatively little, while the concentrations of the other constituents summarized here increased from one to two orders of magnitude. Note that the averages for methylene chloride, however, are based largely on nondetects (Table 94) and therefore simply incorporate the associated detection limits; therefore, the average methylene chloride values should not be taken as representative of actual water quality. The averages displayed for other constituents represented in Table 94 by numerous nondetects are less likely to be misleading, in a general sense, though the calculated pre-closure average VC concentration is higher than actual (again, due to nondetects and incorporation of the associated detection limits).

Table 94. Selected VOC Data (µg/L) from MSPTS Influent and Effluent

DATE	1,1,1-TCA		1,1-DCE		CT		CF		cis-1,2-DCE		MCI		PCE		TCE		VC	
	R1-0	R2-E	R1-0	R2-E	R1-0	R2-E	R1-0	R2-E	R1-0	R2-E	R1-0	R2-E	R1-0	R2-E	R1-0	R2-E	R1-0	R2-E
1/27/2000	8 (J)	1 (U)	10	1 (U)	110	1 (U)	25	1 (U)	57	1	5 (BJ)	1 (B)	120	0.1 (J)	150	1 (U)	10 (U)	1 (U)
2/8/2000	9 (J)	1 (U)	10	1 (U)	110	1 (U)	25	1 (U)	59	2	6 (JB)	2 (B)	96	1 (U)	140	1 (U)	10 (U)	0.1 (J)
3/7/2000	9 (J)	1 (U)	12	1 (U)	110	1 (U)	26	1 (U)	62	2	14 (B)	0.9 (JB)	100	1 (U)	160	1 (U)	10 (U)	1 (U)
4/26/2000	7 (J)	1 (U)	10	1 (U)	96	1 (U)	24	1 (U)	61	4	20 (B)	0.8 (JB)	110	1 (U)	140	1 (U)	10 (U)	0.2 (J)
5/15/2000	6	1 (U)	8	1 (U)	49 (D)	1 (U)	19	1 (U)	42 (D)	3	0.1 (JB)	0.7 (BJ)	68 (D)	1 (U)	87 (D)	1 (U)	0.3 (J)	1 (U)
6/14/2000	8	1 (U)	10	1 (U)	130	1 (U)	24	1 (U)	42	1	3 (BJ)	0.2 (BJ)	130	1 (U)	150	1 (U)	10 (U)	1 (U)
7/19/2000	4 (J)	1 (U)	6	1 (U)	63	1 (U)	12	1 (U)	42	2	4 (JB)	0.9 (JB)	64	1 (U)	79	1 (U)	5 (U)	1 (U)
8/16/2000	10 (J)	1 (U)	10 (J)	1	180	1 (U)	31	1 (U)	39	1 (J)	23 (B)	0.3 (BJ)	100	1 (U)	140	1 (U)	10 (U)	1 (U)
9/13/2000	5.9	0.5 (U)	7	0.5 (U)	122	0.5 (U)	25.4	0.5 (U)	32.1	0.74	1 (U)	0.57	65.3	0.5 (U)	99.9	0.5 (U)	1 (U)	0.5 (U)
10/25/2000	6.3	0.5 (U)	8	0.5 (U)	133	0.5 (U)	25.6	0.5 (U)	37.3	0.69	1 (U)	0.5 (U)	68.7	0.33 (J)	104	0.5 (U)	1 (U)	0.5 (U)
4/19/2001	4 (D)	1 (U)	5 (D)	1 (U)	73 (D)	1 (U)	20 (D)	0.6 (J)	38 (D)	3	2 (U)	6	44 (D)	1 (U)	76 (D)	1 (U)	2 (U)	1 (U)
10/25/2001	3.4	1 (U)	5.1	1 (U)	130	1 (U)	23	1 (U)	23	0.9 (J)	1 (U)	1 (U)	50	1 (U)	74	1 (U)	1 (U)	1 (U)
4/25/2002	2.9	1 (U)	4.5	1 (U)	110	1 (U)	26	1 (U)	24	1.8	1 (U)	1 (U)	41	1 (U)	76	1 (U)	1 (U)	1 (U)
10/21/2002	2.6	1 (U)	1.06	1 (U)	155	1 (U)	27.5	1 (U)	11.3	1 (U)	1 (U)	1 (U)	33.6	1 (U)	46.8	1 (U)	1 (U)	1 (U)
4/17/2003	2.8	1 (U)	2.5	0.23 (J)	73	1 (U)	19	0.93 (J)	23	4.4	1 (U)	3.5 (B)	31	0.38 (J)	38	0.31 (J)	0.81 (J)	1 (U)
12/1/2003	2	1 (U)	2	1 (U)	104 (D)	1 (U)	21.4	1 (U)	9	1	1 (U)	1 (U)	22.6	1 (U)	31.4	1 (U)	1 (U)	1 (U)
6/9/2004	1.34	1 (U)	1.49	1 (U)	91.9	1 (U)	22.4	1 (U)	6.98	1 (U)	1 (U)	1 (U)	21.5	1 (U)	28.3	1 (U)	1 (U)	1 (U)
10/20/2004	2.07	1 (U)	2.47	1 (U)	100	1 (U)	24.6	1 (U)	5.59	0.83 (J)	1 (U)	1 (U)	25.7	0.72 (J)	29.4	2.74	1 (U)	1 (U)
6/21/2005	1 (U)	1 (U)	1.58	1 (U)	110	1 (U)	30.4	0.48 (J)	3.93	2.04	0.74 (J)	1 (U)	29.1	1.66	34.9	1.28	1 (U)	1 (U)
11/18/2005	11 (J)	1 (U)	5.2	0.67 (J)	150	1 (U)	31	0.42 (J)	20	6.3	1 (U)	1 (U)	81	4.5	90	1.6	1 (U)	1 (U)
4/25/2006	35	0.16 (U)	18	4.8	81	0.19 (U)	56	0.16 (U)	920	390	20	1.7	150	5.7	150	7.6	0.68 (U)	5.6
6/5/2006	27.4	1 (U)	1 (U)	1 (U)	60.1	1 (U)	45	1 (U)	2040 (D)	793 (D)	27.2	1 (U)	125 (D)	3	158 (D)	4.6	6	8.6
10/5/2006	53.3	1 (U)	73.1	1 (U)	60.1	1 (U)	45.1	1 (U)	6580 (D)	0.78 (J)	6.9	7.3	87.2	1 (U)	93.7	1 (U)	26.1	1 (U)
6/26/2007	11	0.43 (U)	5.2	1.4 (J)	3.4 (J)	0.51 (U)	4.1	0.43 (U)	320	590	0.32 (U)	2.6 (J)	6.8	0.53 (U)	5.3	0.43 (U)	12	48
7/24/2007	290	0.32 (U)	95	0.52 (J)	48 (J)	0.38 (U)	77	0.32 (U)	6500	330	21 (U)	6.7	94	0.4 (U)	88	0.32 (U)	350	18
8/6/2007	370	0.16 (U)	99	0.35 (J)	58	0.19 (U)	99	0.16 (U)	7700	130	8.5 (U)	3.3	89	0.2 (U)	88	0.16 (U)	420	8.6
8/16/2007	180	0.32 (U)	47	0.4 (J)	24	0.38 (U)	67	0.32 (U)	4500	190	4.1 (U)	5.4 (U)	28	0.4 (U)	42	0.32 (U)	420	34
10/9/2007	300	0.16 (U)	93	0.44 (J)	42	0.19 (U)	88	0.16 (U)	5800	300	13 (U)	4.8	70	0.2 (U)	93	0.16 (U)	470	36
11/8/2007	270	0.16 (U)	94	0.5 (J)	40	0.19 (U)	85	0.16 (U)	5400	140	13 (U)	4.7	78	0.2 (U)	110	0.16 (U)	590	36
4/29/2008	340	0.16 (U)	94 (J)	1.3 (J)	30	0.19 (U)	100	0.45 (J)	5700	310	6.4 (J)	6.2 (J)	97	0.32 (J)	100	0.56 (J)	44	28
11/11/2008	310	0.16 (U)	71	0.14 (U)	35	0.19 (U)	80	0.16 (U)	5900	2.2	9.2 (U)	1.3 (U)	88	0.2 (U)	89	0.17 (J)	32 (J)	4.2 (J)
4/21/2009	45	0.16 (U)	27	1.6	7.2	0.19 (U)	8.6	0.16 (U)	1500	95	1.6 (U)	4.1 (B)	18	0.53 (J)	37	1.9	92	47
10/26/2009	110	0.16 (U)	36	0.14 (U)	27	0.19 (U)	19	0.16 (U)	2600	1.8	1.6 (U)	0.46 (J)	53	0.2 (U)	77	0.58 (J)	130 (J)	1.5 (J)
4/27/2010	75	0.16 (U)	25	5.6	3.3	0.19 (U)	6.3	0.16 (U)	1900	360	2.1	0.82 (J)	32	0.2 (U)	79	3.5	79	150
6/22/2010	6	35	2.2	24	0.4	1.3 (U)	0.46	9.9	110	1800	0.39	5.6 (U)	8.7	29	9.3	77	0.4	270
7/28/2010	190	15	42	8.5	11	0.76 (U)	22	3.3 (J)	2800	790	7.7	6.4	74	11	230	40	70	40
8/26/2010	120	12	22	12	9.7	0.38 (U)	15	3.5	1700	960	3.1	4.3 (B)	44	20	160	84	2	160
9/29/2010	220	8.3	43	10	19	0.38 (U)	27	3	2200	690	1.6	0.64 (U)	88	11	350	93	9	130
10/28/2010	400	9.7	68	7.5	27	0.38 (U)	49	3.4	3700	590	3.2	2.2 (U)	270	6.5	810	100	64	75
5/9/2011	450	0.16 (U)	90	1.9	120	0.19 (U)	130	0.3 (J)	2500	210	1.8 (U)	9.7	630	5.5	1400	6.6	8.4	3.3
10/10/2011	580	0.16 (U)	76	0.33 (J)	180	0.19 (U)	150	3.5	2500	240	3.2 (U)	4.9	910	0.34 (J)	2100	0.29 (J)	19	2.3

Notes: 1,1,1-TCA = 1,1,1-trichloroethane; 1,1-DCE = 1,1-dichloroethene; CT = carbon tetrachloride; CF = chloroform; cis-1,2-DCE = cis-1,2-dichloroethene; MCI = methylene chloride; PCE = tetrachloroethene; TCE = trichloroethene; VC = vinyl chloride. R1-0 = influent, R2-E = effluent; formal sampling location names are Mound R1-0 and Mound R2-E. Shaded, bold value indicates detected concentration exceeds corresponding applicable level stipulated in RFLMA Attachment 2, Table 1 (DOE 2007a); if detection limit exceeded that concentration and constituent was qualified as nondetect, result is not highlighted as an exceedance. Laboratory and validation qualifiers (wherein the validation qualifier supersedes the lab qualifier if they differ): J = result is estimated below the sample quantitation limit; U = analyte not detected at the indicated concentration; B = constituent was also detected in the blank; D = analysis was performed at a dilution.

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Table 95. Average Contaminant Concentrations in MSPTS Influent, Pre- vs. Post-Closure, in µg/L

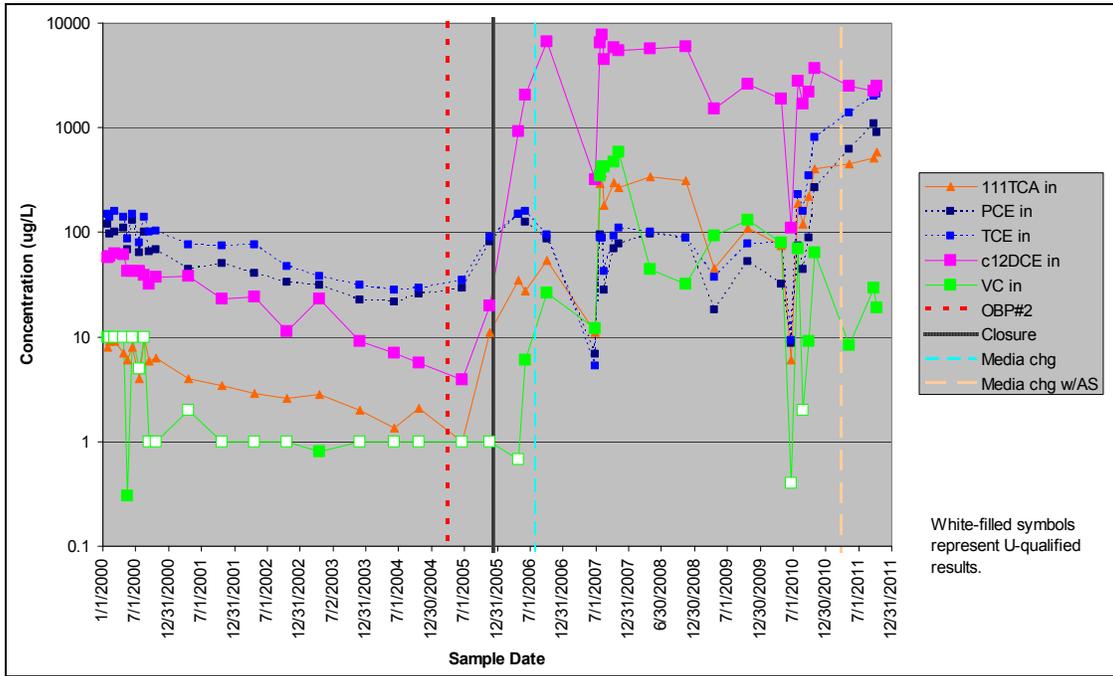
	111TCA	11DCE	CT	CF	c12DCE	MCI	PCE	TCE	VC
Through 2005	5.3	6.1	110.0	24.1	31.9	4.4	65.1	88.7	3.9
2005 through 2011	222.7	54.6	46.9	59.2	3415.0	7.1	187.8	375.9	130.6

Notes: For convenience and to reflect the lag time between OBP#2 remediation and resulting changes in MSPTS influent water quality, pre-closure averages include data from January 1, 2000, through December 31, 2004; post-closure averages include data collected since January 1, 2006. To calculate these averages, all data, including nondetects, were taken at face value regardless of qualifier.

A critical point is that because the OBP#2 source area was remediated and electron donor material was added to the backfill to stimulate biodegradation of residual VOCs, the concentrations of daughter products such as *cis*-1,2-DCE and VC in MSPTS influent have increased more than have those of their parent compounds. While a larger increase in daughter products relative to parent compounds is indicative of desirable dechlorination, as explained above these two daughter products represent some of the more recalcitrant constituents.

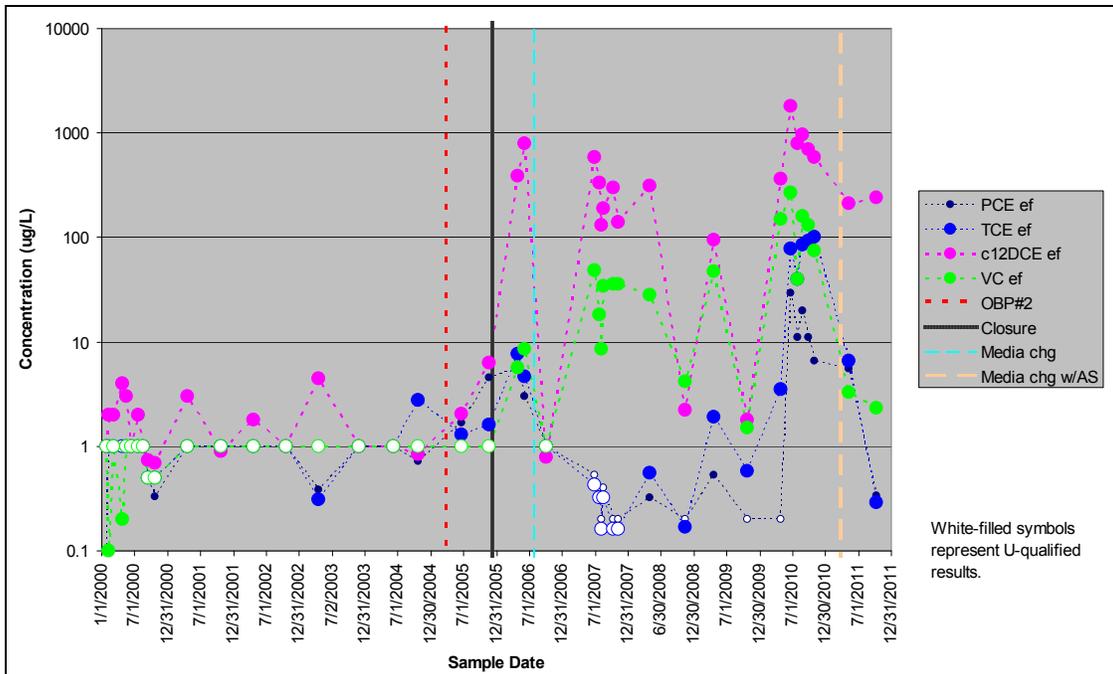
The late-2010 through 2011 data provided in Table 94 illustrate a sharp increase in the concentrations of several contaminants in MSPTS influent. These include 1,1,1-TCA, carbon tetrachloride, and especially PCE and TCE. These increases are not reflected in the concentrations of their metabolic byproducts, as most clearly demonstrated in the concentrations of PCE and TCE compared with their daughter products *cis*-1,2-DCE and VC. (Note that TCE is both a daughter product of the dechlorination of PCE, and a primary product—an industrial solvent—used during the production era at Rocky Flats.) Exact causes of this behavior are not certain, but may be related to the relatively higher water levels in 2010, which could have flushed additional residual contamination from the vadose zone into the saturated zone and thence to the MSPTS. In addition or alternatively, a dwindling reservoir of electron donor material within the OBP#2 backfill, supporting a reduced population of dechlorinating bacteria and allowing parent compounds to migrate from the area relatively unaffected rather than biologically degraded, may be the primary cause. Either mechanism could be reflected in a relative increase in the concentrations of parent compound compared to daughter compounds, which is suggested in the data summarized in Table 94. This change is particularly clear when comparing influent concentrations of *cis*-1,2-DCE, VC, TCE, and PCE in 2007 and 2008 with their influent concentrations in 2010 and 2011.

Figure 234 provides graphic illustration of how concentrations of some of these constituents in MSPTS influent were affected by closure activities, and how conditions have evolved since then. While closure-related work did not appear to affect influent concentrations of PCE or TCE markedly, those of *cis*-1,2-DCE increased by two to three orders of magnitude. And, as noted above and demonstrated by the data in Table 94, a sharp increase in concentrations of parent compounds (including PCE, TCE, and—to a lesser degree—1,1,1-TCA) in system influent has continued from 2010 through 2011. This was not reflected in the concentrations of daughter products, as illustrated by *cis*-1,2-DCE and VC in Figure 234. Figure 235 illustrates the concentrations of the same constituents in MSPTS effluent. Refer to the 2010 Annual Report (DOE 2011d) for additional discussion of the changed conditions in 2010 and the regulatory consultations and additional activities that culminated in the installation of the air stripper.



Notes: Constituents and their respective, applicable RFLMA Table 1 standards ($\mu\text{g/L}$; DOE 2007a): 1,1,1-TCA, 200; PCE, 1; TCE, 2.5; *cis*-1,2-DCE, 70; in = influent (Mound R1-0); media changes in 2006 and 2011 indicated, with the latter including addition of an air stripper (AS). Lab qualifiers not indicated except for U (analyte not detected at the indicated concentration); other qualified data plotted at reported value for simplicity. Note logarithmic concentration scale.

Figure 234. Concentrations of Selected Constituents in MSPTS Influent



Notes: Constituents and their respective, applicable RFLMA Table 1 standards ($\mu\text{g/L}$; DOE 2007a): 1,1,1-TCA, 200; PCE, 1; TCE, 2.5; *cis*-1,2-DCE, 70; ef = effluent (Mound R2-E); media changes in 2006 and 2011 indicated, with the latter including addition of an air stripper (AS). Lab qualifiers not indicated except for U (analyte not detected at the indicated concentration); other qualified data plotted at reported value for simplicity. Note logarithmic concentration scale.

Figure 235. Concentrations of Selected Constituents in MSPTS Effluent

No VOCs other than those summarized in Table 94 were detected in 2011 in MSPTS effluent at concentrations exceeding the RFLMA standards.

Two grab samples for the analysis of VOCs were collected in 2011 at the surface-water performance location for the MSPTS, surface-water station GS10. As in prior years, very low concentrations of VOCs were detected (Table 96). None exceeded the corresponding RFLMA standards.

Table 96. Summary of VOCs Detected in 2011 at GS10

Date	Constituent	Result (µg/L)	Qualifier
5/9/2011	<i>cis</i> -1,2-Dichloroethene	10	
5/9/2011	Tetrachloroethene	0.21	J
5/9/2011	Trichloroethene	0.34	J
10/10/2011	<i>cis</i> -1,2-Dichloroethene	6.6	

The detections reported in 2011 at GS10 are generally consistent with conditions reported in previous post-closure years. They are improved over conditions of 2010, when high flows and aged ZVI treatment media limited the treatment effectiveness of the MSPTS and more VOCs were detected, at higher concentrations. Detections of *cis*-1,2-DCE and TCE have been most common at location GS10. Note that more detections were reported in the wetter second-quarter sample than the drier fourth-quarter sample. This may be due to the reduced residence time within the MSPTS treatment media under higher-flow conditions, when water is pushed through the treatment cells faster than when there is less water available.

MSPTS Effluent Polishing Component

This section provides a brief explanation of the need for and development of the air stripper installed at the MSPTS. For additional information, refer to Section 2.5.1 and the paper attached as Appendix F.

Before groundwater from the OBP#2 source area was routed to the MSPTS for treatment, system effluent typically reported few, if any, detectable concentrations of VOCs. This changed in 2006, when the effects of increased contaminant load and flows to the MSPTS from the OBP#2 source area became evident. From that point on, system effluent has contained residual VOCs (see preceding text and associated figures, and Table 94 for data summary). These constituents typically include low concentrations of parent compounds and more elevated concentrations of the daughter products *cis*-1,2-DCE and VC. Concentrations in 2010 were more strongly elevated with respect to previous data, particularly for parent compounds; this was attributed to the higher flows (leading to a correspondingly shorter residence time within the treatment media) together with the aged condition of the ZVI, which was due for replacement. (Refer to the 2010 Annual Report, DOE 2011d, for additional discussion.)

These conditions led to consultation with CDPHE (see Contact Record 2010-07), with the short-term result including additional data collection and evaluation, and the longer-term result being the decision to install an effluent polishing component. While it was recognized that the fresh

ZVI media scheduled for installation in early 2011 should significantly improve the treatment effectiveness at this system, additional measures were desired. The detections of VOCs in the effluent, even shortly after the previous media replacement in 2006, and the fact that the MSPTS was not designed to treat elevated concentrations of recalcitrant daughter products of chlorinated ethenes, supported the addition of an effluent polishing component to further reduce residual concentrations of VOCs present in MSPTS effluent.

The effort to design an appropriate polishing component began in the latter half of 2010. Installing a third ZVI-filled treatment cell was ruled out due to costs and ongoing maintenance needs. As discussed in the annual report for that year (DOE 2011d), the initial focus was on an engineered riffle system, such as that comprising the PLFTS. However, the eventual design selected for such a component carried a relatively high construction cost (approximately \$100,000)—and this cost did not include installation of the power infrastructure and equipment required to pump water to the inlet of the riffles, nor did it consider the continuing costs of operations and maintenance.

A readily-available, prefabricated stacking-tray or tower air stripper was then evaluated for this application. The cost of the air stripper itself was found to be very reasonable, but the cost for the solar power infrastructure required to support the associated blowers and pumps would be on the order of \$375,000. This was infeasible, even without considering the cleaning and other maintenance needed for such a system.

A third alternative was developed, and was based on applying the air stripping technology via a lower-powered, smaller unit that could be optimized as performance data were collected and equipment modified in response. A rough prototype was tested in January 2011 using a generator-powered sump pump to drive water through inexpensive helical cone nozzles, and the effluent manhole to house the air stripper. The success of this testing led to design and construction of a more permanent prototype that would include a solar/battery power source to drive a submersible pump; it would operate 12 hours per day, allowing optimization at this lower-cost configuration before being expanded to full-time operation. Additional information is provided in the paper included as Appendix F.

Optimization of this air stripper continued through 2011 and into 2012. Extended testing was desired in order to assess performance and maintenance requirements through the winter and varying water quality and flow conditions. Unfortunately, equipment malfunction not related to climate or application hampered optimization efforts; in addition, the winter of 2011–2012 did not provide much longer-duration inclement weather in which to test air stripper performance and operation. Even so, the data that were collected in 2011 and early 2012, particularly if typical higher spring flows occur, may still be sufficient to develop this part-time prototype into a full-scale component. Evaluation and testing will continue in 2012 and may lead to installation the same year of the additional power infrastructure and other equipment necessary to make this transition.

East Trenches Plume and Treatment System

The East Trenches Plume is an area of groundwater contamination named after several buried disposal trenches. These trenches are located on the pediment south of South Walnut Creek, in former OU 2. The source of this plume is residual VOC contamination associated predominantly

with Trenches T-3 and T-4, which were remediated in 1996. In addition, a portion of the 903 Pad Plume flows from its source area toward the northeast and merges with the East Trenches Plume. A treatment system (the ETPTS) was installed in 1999 to intercept and treat contaminated groundwater flowing toward the B-Series Ponds and South Walnut Creek.

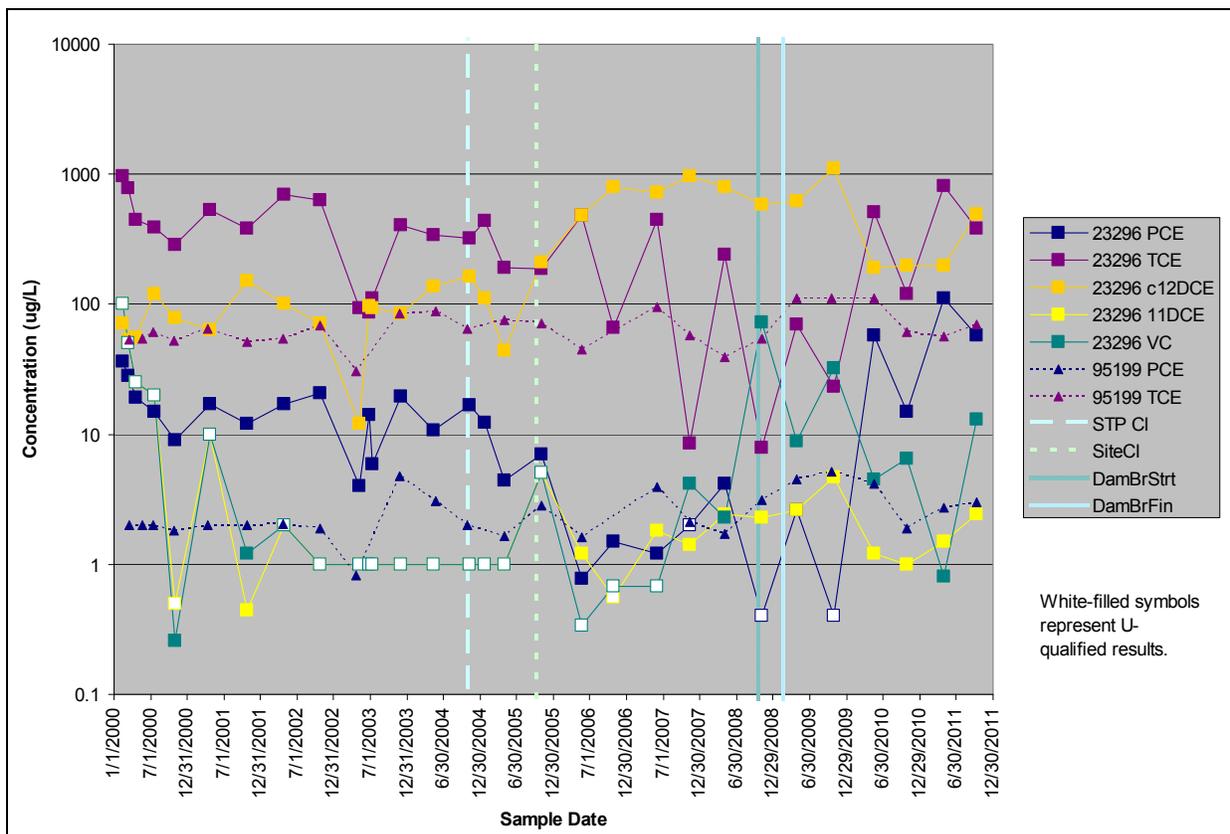
East Trenches Plume

Evaluation wells 3687 and 05691 monitor the primary source areas of the East Trenches Plume, Trenches T-3 and T-4, respectively. More distal portions of the plume are monitored by Evaluation well 03991 and Sentinel well 04091 to the east-northeast. Sentinel wells 95099, 95199, 95299, and 23296 monitor the ETPTS and downgradient portions of the plume along South Walnut Creek. AOC well 00997, situated at the mouth of Pond B-5 in the South Walnut Creek drainage, also supports monitoring of this plume. Well 00191 monitors groundwater closest to the source area of the 903 Pad Plume and is discussed in the context of the 903 Pad/Ryan's Pit Plume later in this section.

None of the East Trenches Plume Evaluation wells was scheduled for RFLMA sampling in 2011, as these wells are routinely scheduled for sampling every other year. However, all Sentinel wells and the AOC well at Pond B-5 were sampled twice in 2011. Analytical data for these wells in 2011 were generally consistent with those from recent years.

Of the wells sampled along South Walnut Creek in support of the East Trenches Plume, well 95299 was dry, and RFLMA Table 1 standards were exceeded in samples from wells 23296 and 95199. This is consistent with past conditions, as is the fact that samples from well 23296 contained the highest concentrations of VOCs of this group of wells.

Figure 236 displays several VOCs that are commonly detected in one or both of wells 23296 and 95199 at concentrations exceeding the corresponding RFLMA action level: PCE, TCE, *cis*-1,2-DCE, 1,1-DCE, and VC. Concentrations of *cis*-1,2-DCE in samples from well 23296 show a fairly gradual increase at this logarithmic scale, with an apparently short-term decrease in 2010 and early 2011. When detected, concentrations of 1,1-DCE exhibit a very similar pattern. Statistical calculations confirm the visual appearance of trends in samples from well 23296, as noted in Table 91: S-K calculations indicate 95 percent significant increasing trends are present in 1,1-DCE, both 1,2-DCE isomers, and VC. In addition, similarly significant decreasing trends are calculated for carbon tetrachloride, chloroform, and PCE. Several trends incorporate numerous nondetects in the dataset, however, suggesting the associated trend significance may not be valid.



Notes: Constituents and their respective, applicable RFLMA Table 1 standards ($\mu\text{g/L}$; DOE 2007a): PCE, 1; TCE, 2.5; c12DCE = *cis*-1,2-DCE, 70; 1,1-DCE = 7; VC, 0.2. STP Cl = approximate closure date of former Building 995, the Sewage Treatment Plant; Site Cl = closure of the Site; DamBrStrt and DamBrFin = start and finish, respectively, of the project that breached the B-1, B-2, B-3, and B-4 dams on South Walnut Creek. Several detections are qualified but for simplicity are not shown differently. Note logarithmic concentration scale.

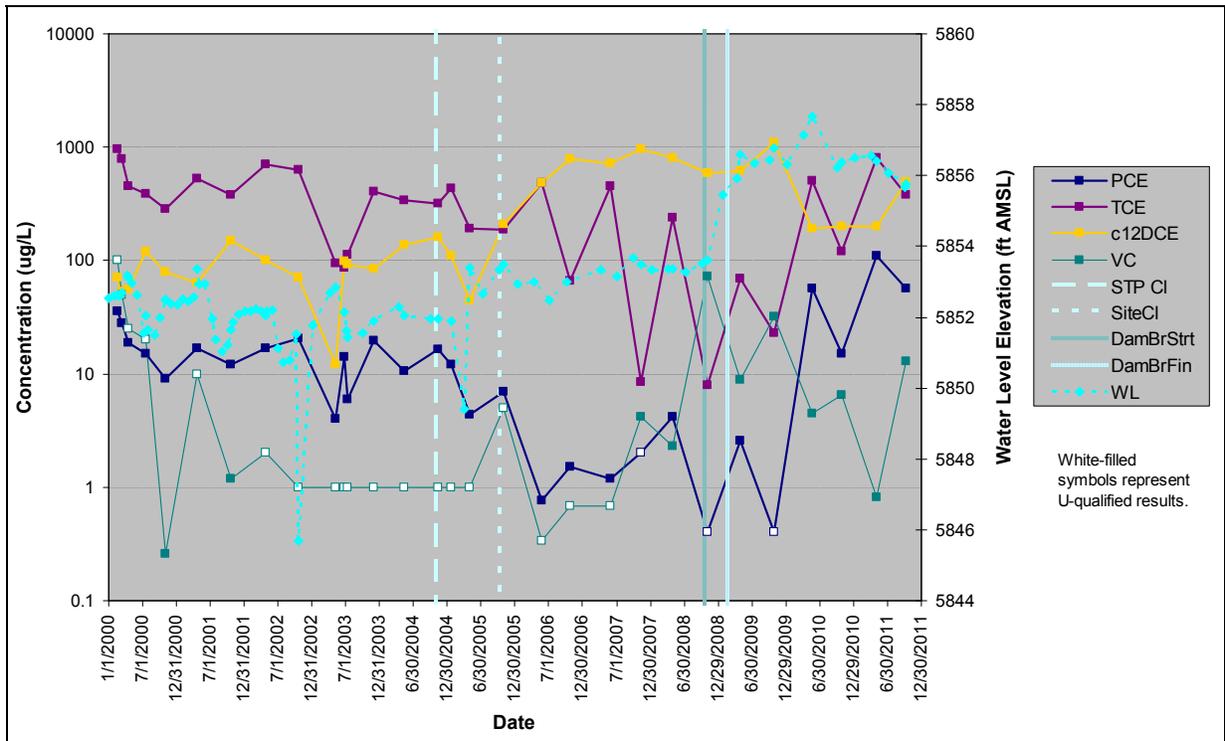
Figure 236. Most Commonly Detected VOCs in Sentinel Wells Downgradient of the ETPTS

Compared with data for samples collected prior to about 2007 from well 23296, more recent concentrations of TCE, PCE, and VC have varied sharply from sample to sample. A seasonal pattern is visually apparent (Figure 236). Concentrations of VC are seen to vary inversely with those of PCE and TCE: concentrations of TCE and PCE are relatively higher, and concentrations of VC are relatively lower in the second calendar quarters, and then in the fourth quarters this is reversed. Conversely, PCE and TCE concentrations in samples from well 95199, which is located between former Ponds B-1 and B-2, appear more uniform. An increasing trend in PCE concentrations at the 95 percent statistical significance is calculated for this well (Table 91), and increasing trends of lesser significance are also calculated for 1,1-DCE, *cis*-1,2-DCE, and TCE. As noted in the 2010 Annual Report (DOE 2011d), depth differences and distances from surface water with respect to wells 23296 and 95199 may help to explain the differences in water quality and contaminant variability.

The variations in contaminant concentrations reported in samples collected from well 23296 may be due to seasonal effects on biodegradation, wherein reduced recharge in the fourth quarter allows groundwater monitored by this well to become more locally reducing, supporting increased levels of reductive dechlorination of parent compounds; conversely, the second quarter

may be marked by greater amounts of oxygenated recharge, which would act to decrease this dechlorination and potentially flush contaminants into the saturated zone. However, given that *cis*-1,2-DCE and 1,1-DCE are intermediate metabolic byproducts between the parent compounds (PCE and TCE) and the final chlorinated byproduct (VC), one might expect those intermediate constituents to also reflect a seasonal pattern. Instead, over the same timeframe they have varied less systematically. Additional factors, therefore, must be affecting the concentrations reported in samples from well 23296.

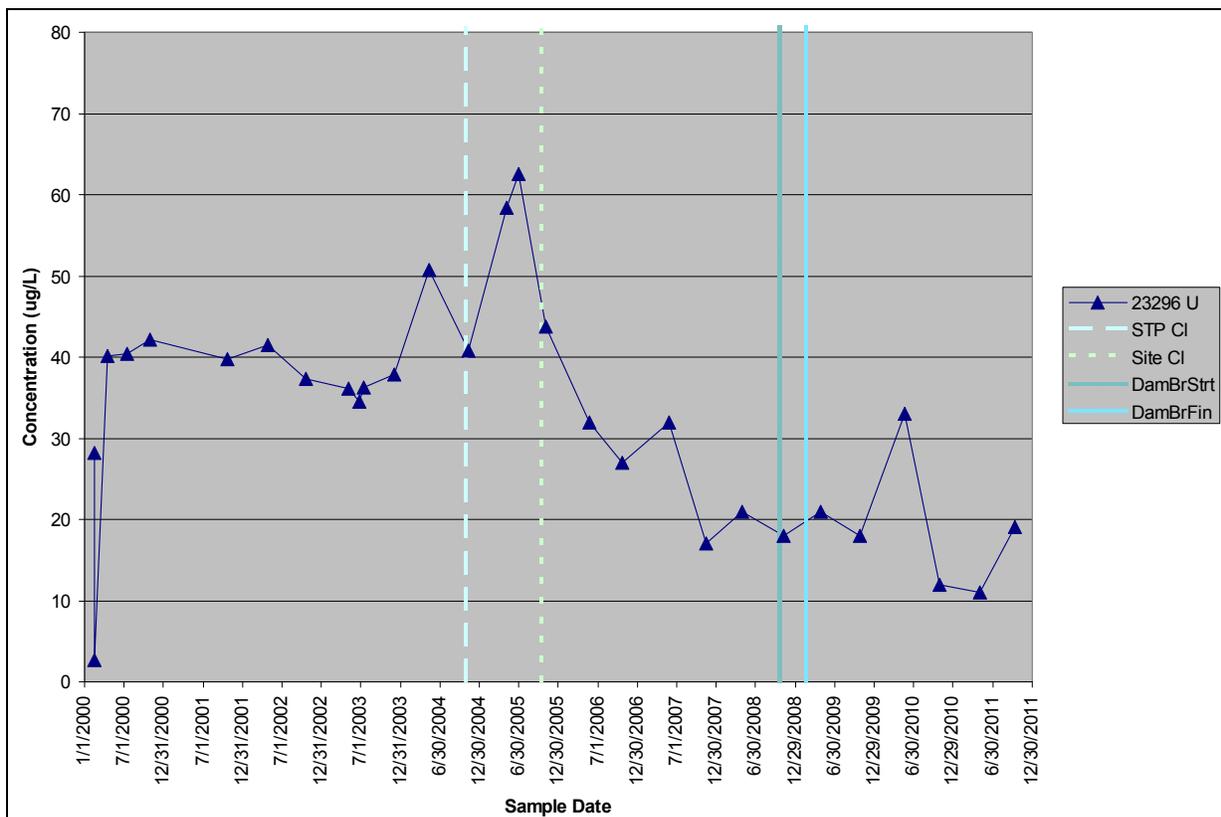
The approximate timing of significant events that may be affecting water quality at well 23296 are also illustrated on Figure 236. Figure 237 shows these events together with concentrations of PCE, TCE, and *cis*-1,2-DCE, and water level measurements in this well. Illustrated events include removal of former Building 995 (the Sewage Treatment Plant, or STP), Site closure, and the approximate start and end of the project that breached the B-1, B-2, B-3, and B-4 Dams. Removal of the STP would have eliminated a source of recharge to well 23296. Large volumes of treated water (which had been imported to the Site) were piped from the STP to a discharge point at former Pond B-3. Well 23296 is located on the inlet of this pond, and therefore would have been impacted to some degree by this localized discharge of treated water. Also, prior to closure, South Walnut Creek water was routed through a bypass pipeline around Ponds B-1, B-2, and B-3, eliminating this water as a source of recharge to the well. Following closure, water was either routed to Pond B-4 or occasionally to Pond B-1 to maintain associated vegetation; the other B-ponds were not able to receive this bypass water. As illustrated on Figure 237, the hydrograph for this well suggests no decrease in water level in response to removal of the STP and associated discharge; in fact, water levels rise slightly from shortly after this event through closure and the start of the dam breach project. Concentrations of PCE and TCE, however, appear to have decreased with removal of the STP, as those of *cis*-1,2-DCE increased. Breaching of the South Walnut Creek dams B-1, B-2, and B-3 had an obvious effect on water levels in this well, with the hydrograph showing a sharp rise of some two to three feet. This is potentially associated with a later irregular increase in PCE and TCE and corresponding decrease in *cis*-1,2-DCE. In summary, each of these events—and possibly others, such as construction of FC-4—may have affected groundwater quality at well 23296. Additional data will be collected per the RFLMA and should help to define longer-term trends.



Notes: Constituents and their respective, applicable RFLMA Table 1 standards ($\mu\text{g/L}$; DOE 2007a): PCE, 1; TCE, 2.5; c12DCE = *cis*-1,2-DCE, 70. STP CI = approximate closure date of former Building 995, the Sewage Treatment Plant; Site CI = closure of the Site; DamBrStrt and DamBrFin = start and finish, respectively, of the project that breached the B-1, B-2, B-3, and B-4 dams on South Walnut Creek; WL = groundwater level, in feet above mean sea level (ft AMSL). Several detections are qualified but for simplicity are not shown differently. Note logarithmic concentration scale.

Figure 237. Concentrations of Selected VOCs vs. Water Level in Sentinel Well 23296

Sentinel well 23296 is also monitored for U, for which S-K statistical calculations indicate a decreasing trend with a 95 percent level of significance (Table 91 and Appendix B; see also time-series plot, Figure 238). Uranium also shows variable concentrations, but these relatively minor compared to those exhibited by some VOCs. The results from 2004 and 2005 are most likely affected by closure activities, while the results in later years are more likely to reflect seasonal conditions. Five samples from well 23296 have been analyzed for anthropogenic U, with results ranging from 88.5 percent natural U to 96.4 percent natural U.



Notes: DamBrStrt and DamBrFin = start and finish, respectively, of the project that breached the B-1, B-2, B-3, and B-4 dams on South Walnut Creek.
 Site CI = closure of the Site
 STP CI = approximate closure date of former Building 995, the Sewage Treatment Plant
 U= uranium; applicable RFLMA value (µg/L; DOE 2007a) is the groundwater threshold of 120 µg/L

Figure 238. Concentrations of Uranium in Samples from Well 23296

Sentinel well 04091 is located on the eastern edge of the East Trenches Plume and was sampled twice in 2011 (May and October). Carbon tetrachloride was detected in both samples, at concentrations under 0.5 µg/L. Samples from this well are represented by significant (at the 95 percent confidence level) decreasing trends for carbon tetrachloride and PCE, although the data sets for these constituents include numerous nondetects.

AOC well 00997 is located near the inlet to Pond B-5. This well was sampled twice in 2011 (May and October). All constituents were below the RFLMA Table 1 levels or uranium threshold. No VOCs were detected. U was detected at concentrations of 21 µg/L in May and estimated at 15 µg/L in October, which is within the typical range at this well. Nitrate is also analyzed at this location, and in 2011 the results were 0.02 mg/L (J-qualified; an estimated value) in the second-quarter sample and nondetect in the fourth-quarter sample.

East Trenches Plume groundwater will continue to be monitored in accordance with RFLMA. As more data are collected, additional significant trends should become evident.

East Trenches Plume Treatment System

The ETPTS was installed in 1999. Its design is very similar to that of the MSPTS, but the intercept trench for the ETPTS is 1,200 feet long, compared to the 220-foot-long MSPTS trench. The longer trench is required to intercept the broader East Trenches Plume as it flows toward South Walnut Creek and the former B-Series Ponds.

The ETPTS treated approximately 890,000 gallons of water in 2011, which represents a volume more consistent with other post-closure years than did 2010 (Table 97). The volume treated in 2011 is also very close to the average volume treated in a post-closure year (Table 98). Figure 239 presents a hydrograph showing ETPTS flow estimates since January 2001. (Refer to the 2009 Annual Report [DOE 2010d] for information on correction of anomalous flows previously reported for the year 2006). The higher flows in 2010, and the return to more typical flows in 2011, are clearly evident on this figure.

Figure 240 provides a hydrograph for CY 2011 at the ETPTS and shows the continuing gradual decrease in flows following the higher-water year of 2010.

Table 97. Estimated Volumes of Water Treated by the ETPTS

Calendar Year	Annual Estimates of Volume Treated (gallons)	Estimated Cumulative Volume Treated (gallons)
2000	1,633,000	2,800,000
2001	1,900,000	4,700,000
2002	≤1,000,000	5,700,000
2003	2,100,000	7,800,000
2004	1,500,000	9,300,000
2005	1,800,000	11,100,000
2006	675,000	11,775,000
2007	951,000	12,726,000
2008	629,000	13,355,000
2009	406,000	13,761,000
2010	1,606,000	15,367,000
2011	890,000	16,257,000

Note: Estimates for years 2000 through 2004 are compiled from K-H (2000a, 2000b, 2000c, 2000d, 2002b, 2003, 2005a, 2005b).

Table 98. Average Volumes Treated by the ETPTS

Time Period	Average Volume Treated Per Year
Pre-closure, 2000–2005	1,655,500
Post-closure, 2005–2011	859,500

Note: Average volumes are based on estimates of volumes treated, as presented in Table 97. Time periods shown include complete years, and do not correspond to exact date of closure; for example, the pre-closure estimate for the 2000-2005 period spans January 1, 2000, through December 31, 2005.

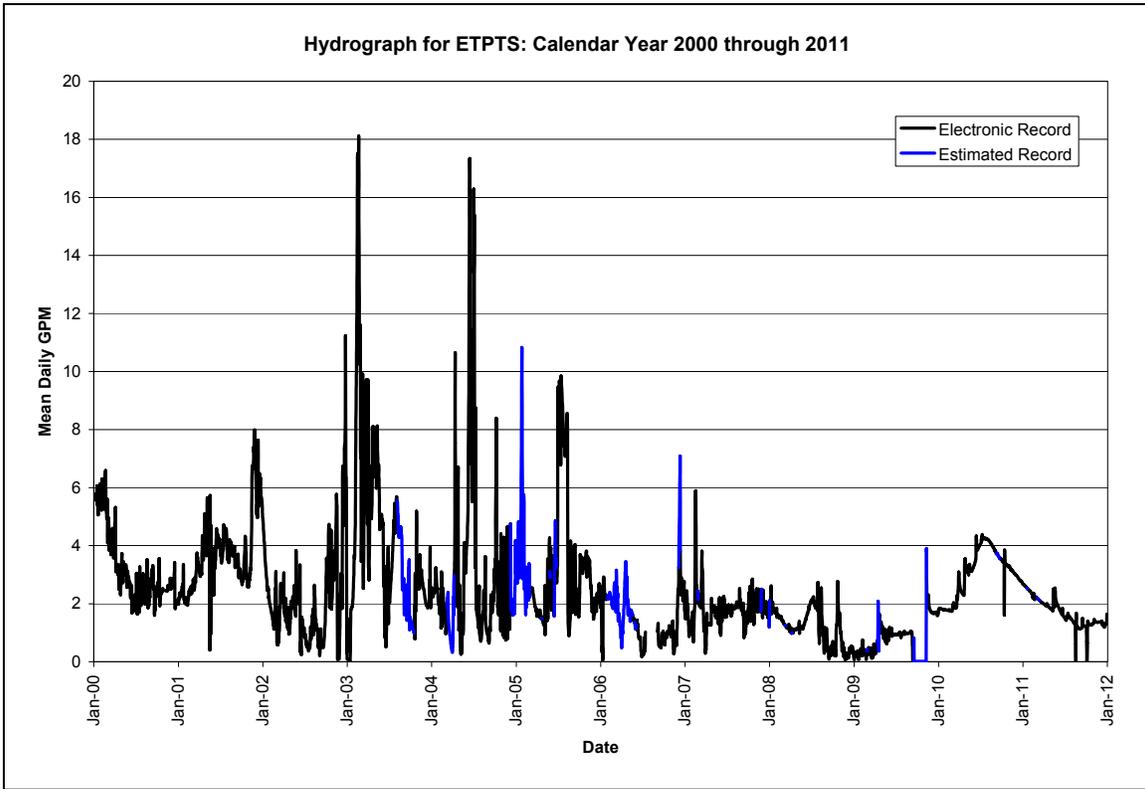


Figure 239. Hydrograph for ETPTS from 2000 Through 2011

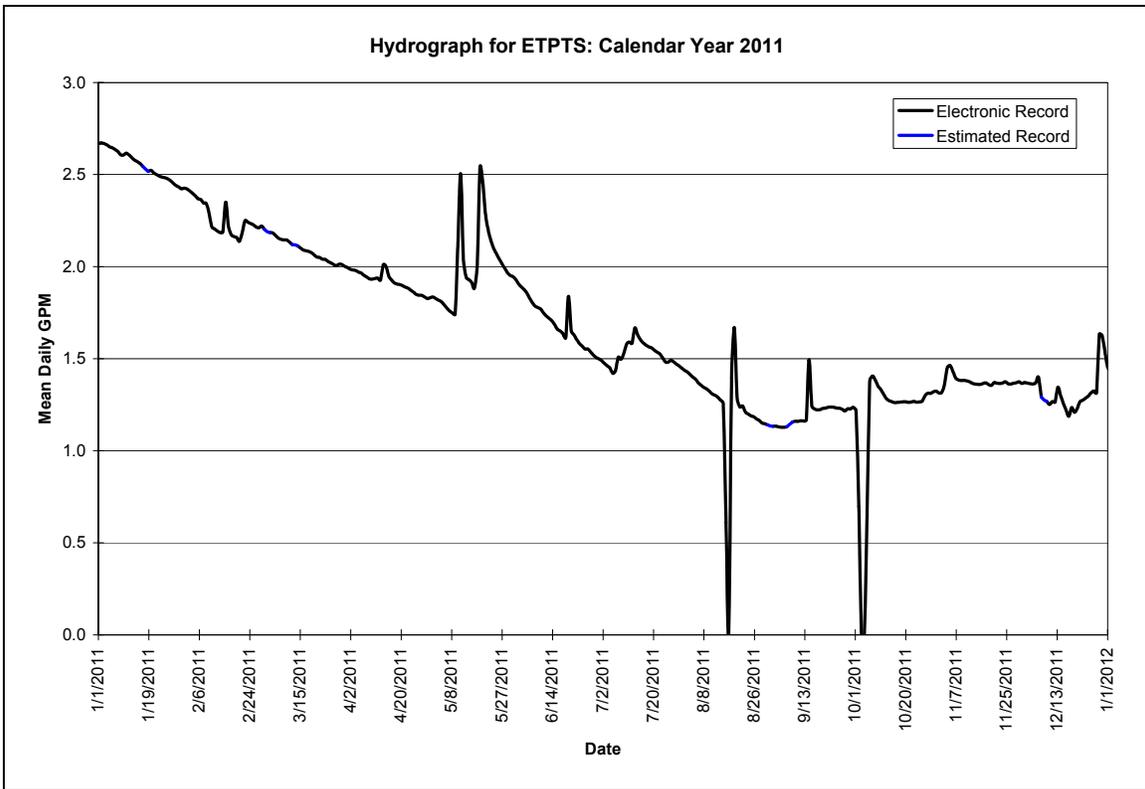


Figure 240. Hydrograph for ETPTS for CY 2011

Routine maintenance activities at the ETPTS were conducted through 2011, as discussed in Section 2.5.2. The ETPTS was sampled twice in 2011 for routine RFLMA requirements (May and October), plus one additional time for non-required confirmatory purposes (November) as discussed below.

ETPTS effluent water quality in 2011 continued to reflect a dramatic reduction in VOC load. However, certain VOCs were detected in the effluent, including some present at concentrations exceeding the respective RFLMA Table 1 values. This is consistent with the past performance of the ETPTS. VOCs have been routinely detected in ETPTS effluent since the system was installed in 1999 and have been reported and discussed as the data are issued.

A summary of the VOCs that most commonly exceed RFLMA Table 1 values in system influent, plus *cis*-1,2-DCE and VC as dechlorination-related constituents, is presented in Table 99; refer to quarterly reports (DOE 2011e, 2011f, 2012a) and Appendix B.6 for additional data from 2011. As shown on Table 99, the October 2011 concentration of TCE in system effluent increased by over an order of magnitude relative to TCE in the spring 2011 sample. A confirmatory sample was collected in November and results were similar to those in the October sample. This led to reconfiguration of the flow through the treatment cells in early 2012 (see Section 2.5.2) from parallel upflow to series flow (upflow through Cell 1, then downflow through Cell 2). Samples were collected after this change was made. Because this took place in 2012, the associated data are not included in the table or in this report. However, the preliminary, unvalidated results from the samples collected in January 2012 indicated a return to the prior level of treatment effectiveness, with TCE decreasing from the November level of 530 µg/L to 17 µg/L in January 2012.

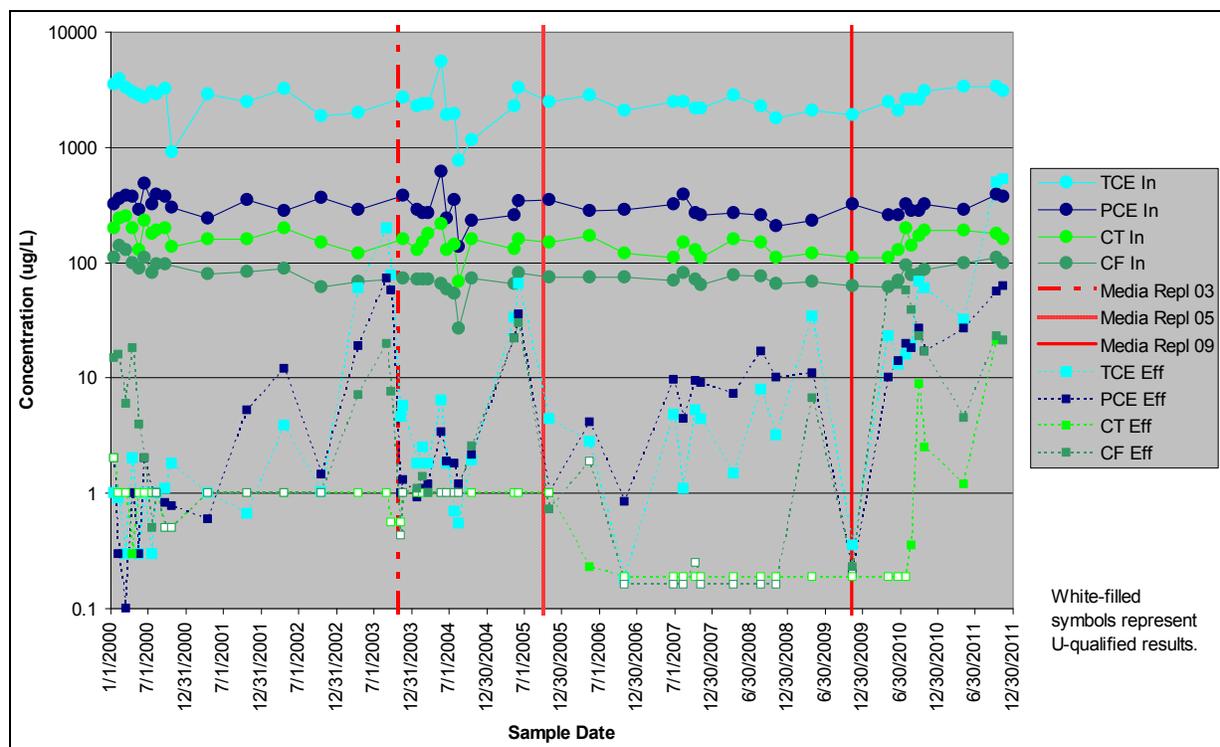
Discussions with the regulators have supported a plan to install a treatment upgrade at the ETPTS. The preliminary plan is to install an air stripper similar to that at the MSPTS, but contained within the influent manhole rather than the effluent manhole. This air stripper would also be designed for an increased capacity and would operate 24 hours per day. This plan will be developed and is anticipated to be implemented in 2012. More information will be included in the annual report for 2012.

Table 99. Summary of Recent VOC Data from ETPTS Influent and Effluent

DATE	CT		CF		MCI		PCE		TCE		cis-1,2-DCE		VC	
	ET In	ET Ef	ET In	ET Ef	ET In	ET Ef	ET In	ET Ef	ET In	ET Ef	ET In	ET Ef	ET In	ET Ef
1/28/2004	130	1 (U)	71	1.1	5 (U)	20	290	0.93 (J)	2300	1.8	40	9.5	5 (U)	1 (U)
2/25/2004	150	1 (U)	71	1.4	2.7 (JB)	19 (B)	270	1.1	2400	2.5	40	10	10 (U)	1 (U)
3/22/2004	180	1 (U)	71	1	2.6 (JB)	21	270	1.2	2400	1.8	39	9.7	6.7 (U)	0.39 (J)
5/26/2004	216	1 (U)	65.1	1 (U)	1 (U)	17	618 (D)	3.38	5510 (D)	6.36	28	11.5	1 (U)	1 (U)
6/22/2004	130	1 (U)	59	1 (U)	6.7 (JB)	14 (B)	240	1.9	1900	1.8	29	8	10 (U)	1 (U)
7/29/2004	142 (D)	1 (U)	54.1	1 (U)	2.3	14.1 (B)	354 (D)	1.8	1960 (D)	0.69 (J)	29.4	7.7	1 (U)	1 (U)
8/19/2004	68.1	1 (U)	26.6	1 (U)	1 (U)	13.7	137 (D)	1.2	774 (D)	0.55 (J)	13.3	7.4	1 (U)	1 (U)
10/20/2004	160	1 (U)	72.9	2.56	1 (U)	15.6	230 (D)	2.13	1170 (D)	1.91	32.6	11.3	1 (U)	1 (U)
5/12/2005	131	1 (U)	66	22.2	1 (U)	14.6	256 (D)	21.9	2280 (D)	33.1	30.4	36.4	1 (U)	1 (U)
6/7/2005	160	1 (U)	81	30	10 (U)	22 (B)	340	36	3300	66	33	44	10 (U)	1 (U)
11/2/2005	151	1 (U)	74.8	0.73 (J)	250 (U)	18.2	350	1 (U)	2500	4.4	50.7	39.6	50 (U)	1.2
5/17/2006	170	0.23 (J)	75 (J)	1.9	0.32 (U)	32	280	4.1	2800	2.8	46	27	0.17 (U)	0.77 (J)
10/31/2006	120	0.19 (U)	75	0.16 (U)	6.4 (U)	0.32 (U)	290	0.85 (J)	2100	0.18 (J)	40 (J)	4.3 (J)	3.4 (U)	0.17 (U)
6/26/2007	110	0.19 (U)	70	0.16 (U)	1.6 (U)	0.32 (U)	320	9.7	2500	4.8	30	40	0.85 (U)	1.2
8/16/2007	150	0.19 (U)	81	0.16 (U)	8 (JB)	0.73 (JB)	390	4.4	2500	1.1	32	51	2.7 (U)	1.7
10/9/2007	130	0.19 (U)	71	0.25 (J)	3.2 (U)	1.7	270	9.5	2200	5.3	34	22	1.7 (U)	0.43 (J)
11/8/2007	110	0.19 (U)	64	0.16 (U)	3.2 (U)	0.32 (U)	260	9.1	2200	4.4	32	21	1.7 (U)	0.46 (J)
4/16/2008	160	0.19 (U)	78	0.16 (U)	36 (B)	1.5 (B)	270	7.3	2800	1.5	43	30	7.6 (U)	1
8/25/2008	150	0.19 (U)	77	0.16 (U)	1.6 (U)	0.89 (J)	260	17	2300	7.9	42	20	1.9 (U)	0.38 (U)
11/5/2008	110	0.19 (U)	66	0.16 (U)	9.7 (J)	0.88 (J)	210	10	1800	3.2	31	16	3.8 (U)	0.5 (J)
4/28/2009	120	0.19 (U)	68	6.7 (J)	8.9 (U)	4.5 (U)	230	11 (J)	2100	34	30	45	3.8 (U)	0.38 (U)
11/12/2009	110	0.19 (U)	63 (J)	0.23 (J)	0.32 (U)	6.3 (J)	320	0.2 (U)	1900	0.35 (J)	36	0.3 (J)	0.4 (U)	0.4 (U)
5/6/2010	110	0.19 (U)	62	63	2.3 (U)	8.2 (B)	260	10	2500	23	30	57	2 (U)	0.4 (U)
6/22/2010	130	0.19 (U)	70	64	2.1 (U)	8.4 (B)	260	14	2100	13	34	55	2.7 (U)	0.4 (U)
7/28/2010	200	0.19 (U)	95	57	3.7 (J)	15	320	20	2600	16	43	55	4 (U)	0.76 (J)
8/26/2010	140	0.35 (J)	78	39	5.8 (JB)	19 (B)	280	18	2600	19	37	56	4 (U)	0.4 (U)
9/29/2010	170	8.8	79	23	1.6 (U)	14	280	27	2600	68	39	50	2 (U)	0.4 (U)
10/28/2010	190	2.5	87	17	1.3 (U)	11	320 (*)	17	3100	60	44 (J)	59	1.6 (U)	0.84 (J)
5/5/2011	190	1.2	100	4.5	4.5 (JB)	1.6 (B)	290	27	3400	32	48	56	1 (U)	1.2
10/10/2011	180	21	110	23	3.2 (U)	3.9	390	56	3400	500	45	42	1 (U)	0.46 (J)
11/14/2011	160	21	100	21	3.2 (U)	5.7	370	63	3100	530	51	69	1 (U)	0.83 (J)

Notes: Constituents and their respective, applicable RFLMA levels (µg/L; DOE 2007a): CT = carbon tetrachloride, 1; CF = chloroform, 3.4; MCI = methylene chloride, 4.6; PCE, 1; TCE, 2.5; cis-1,2-DCE, 70; VC, 0.2. ET In = influent (ET INFLUENT), ET Ef = effluent (ET EFFLUENT). Shaded, bold value indicates detected concentration exceeds corresponding RFLMA standard. Lab qualifiers: J = an estimated value; U = analyte not detected at the indicated concentration; B = constituent was also detected in the blank; D = analysis was performed at a dilution.

Several of the primary VOCs in ETPTS influent are presented in the time-series plots in Figure 241. This figure is crowded, but it illustrates several conditions. First, influent concentrations have remained fairly consistent since 2000 for each of the VOCs illustrated, though an increase since early 2010 is apparent even on this logarithmic concentration scale. This may relate to higher groundwater levels flushing residual VOCs from the vadose zone, as suggested for other locations (e.g., Sentinel well 91203, discussed above). Conversely, concentrations in system effluent have varied widely, and not always with respect to media replacement or other maintenance activities.



Notes: Constituents and their respective, applicable RFLMA Table 1 standards ($\mu\text{g/L}$; DOE 2007a): PCE, 1; TCE, 2.5; CT, 1; CF, 3.4. Media Repl (year abbreviation) = year in which complete media replacement was performed. Other attempts to restore media effectiveness prior to closure are not illustrated; see previous annual reports (e.g., DOE 2011d) and treatment system reports (e.g., KH 2005b) for related information. Several detections are qualified but are not shown differently for the sake of simplicity. Note logarithmic concentration scale.

Figure 241. Primary VOCs in ETPTS Influent and Effluent

Although concentrations in ETPTS effluent demonstrate that the bulk of the VOCs is consistently removed from the influent, water quality of the effluent does not always meet treatment targets. Most notably, as described above, elevated concentrations in the sample collected in the fourth quarter of 2011 (October) led to collection of a confirmatory sample the next month, followed by reconfiguration of the flow through the treatment cells. The subsequent sample, collected in January 2012, confirmed that treatment effectiveness has returned to previous levels.

The performance monitoring location for the ETPTS is POM2, which is located in former (now breached) Pond B-4. Sampling at this location in support of the ETPTS began in 2005. Grab

samples were collected from POM2 in May and October 2011. No VOCs were detected. This is an improvement compared with 2010, when several VOCs were detected at concentrations estimated well below their respective RFLMA standards (DOE 2011d).

Solar Ponds Plume and Treatment System

The Solar Ponds Plume (SPP) is an area of elevated nitrate and U concentrations in groundwater. (**Note:** The analytical data report concentrations of nitrate+nitrite as nitrogen; this is referred to herein simply as nitrate.) Liquid wastes generated during the production era at Rocky Flats were stored in the former SEPs, which were located on the pediment in the northeastern portion of the former IA. Leakage from these ponds over the years is the source of the groundwater plume. The following paragraphs describe the plume, the treatment system installed to address this contamination, and activities conducted in 2011 at this system; see also Section 2.5.3 for information on operation and maintenance activities.

Solar Ponds Plume

Groundwater in the SEP area is contaminated with nitrate and U. Groundwater in the westernmost portion of this area, generally coinciding with the location of former Pond 207C, is also contaminated with VOCs. However, due to the more localized nature of VOC contamination, it is not considered part of the SPP, but rather as a separate plume.

The source area of the SPP (the former SEPs) is monitored by eight Evaluation wells installed immediately downgradient of the SEPs (generally along the north, east, and south sides of the former SEPs). Another Evaluation well is positioned at the south edge of former Pond 207C, in the vicinity of the VOC source area. This distribution effectively monitors groundwater flowing north/northeastward, the primary contaminant flow path, as well as eastward and southeastward, which are (at most) much less significant flow paths.

Additional wells monitoring the SPP are located at greater distances from the source. This includes Evaluation wells situated both upgradient and downgradient of the SPPTS groundwater intercept trench as well as along North Walnut Creek, Sentinel wells adjacent to that trench and along South Walnut Creek near former B991, and an AOC well near former Pond A-1.

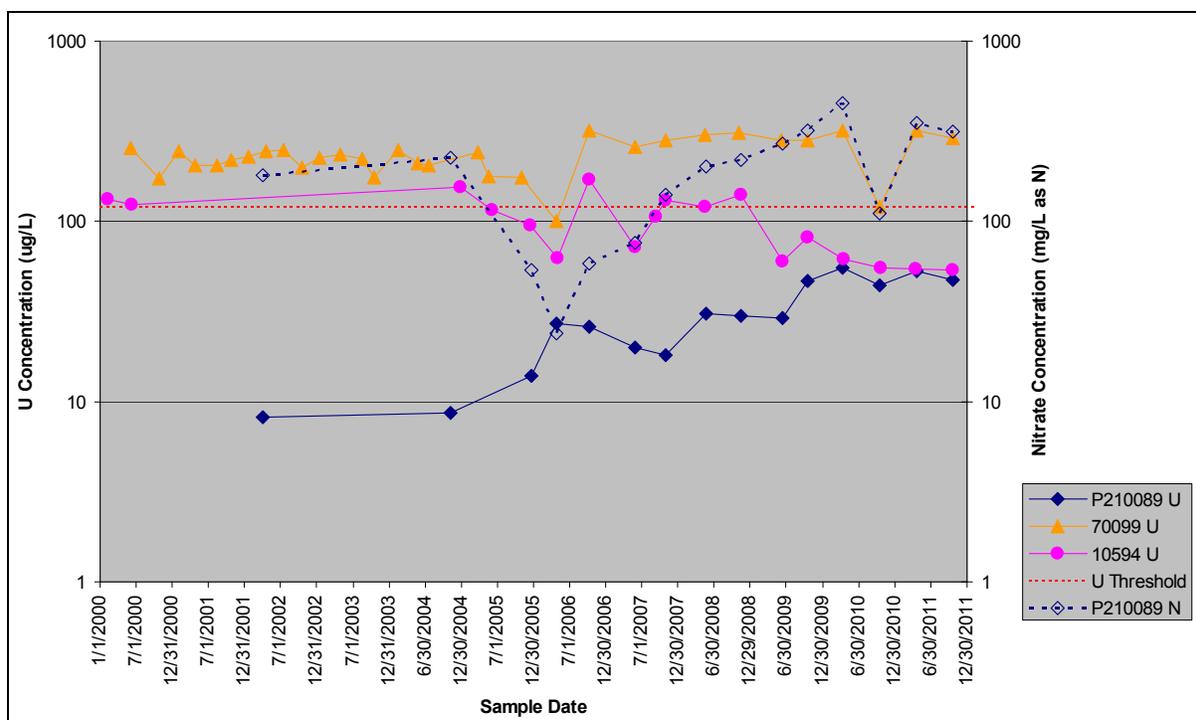
None of the Evaluation wells was scheduled for RFLMA sampling in 2011. However, three of those situated along the eastern and southeastern margins of the former SEPs were sampled to support evaluation of surface-water quality at GS10. All of the Sentinel and AOC wells were sampled twice in accordance with RFLMA.

Because the source area was not scheduled for sampling, only those three locations along the eastern and southeastern sides of the SEPs provided data in 2011 (i.e., wells 79502, 79602, and 00203). None of these are within the higher-concentration portions of the nitrate plume, and results ranged from 6.4 mg/L to 36 mg/L nitrate as N. Much higher concentrations than these are typically observed north and northeast of the SEPs, but those locations did not support the GS10-related objectives that drove sampling of the three southeastern Evaluation wells.

These three Evaluation wells were also sampled for U at the same time. Values of U had a much wider range than those of nitrate, from 7.9 µg/L to 510 µg/L, which is consistent with the general

water quality from these three wells. However, in keeping with the decreasing trend in U calculated to be 95 percent significant at well 79502 (Table 91); see also trend plots in Appendix B), the U result at this well (7.9 $\mu\text{g/L}$) was the lowest reported to date. Additional discussion of SPP source-area groundwater quality will be provided in the 2012 Annual Report, which will include data from all Evaluation wells.

Figure 242 displays U and, where meaningful, nitrate concentrations from Sentinel and AOC wells downgradient of the SPP source area. With respect to the SPPTS and associated groundwater intercept trench, wells that are illustrated include side-gradient (P210089 and, to some extent, 70099) and downgradient (10594) wells. Nitrate data for wells 70099 and 10594 are not included on the figure because concentrations are low (nondetect to low single-digit mg/L). Data from wells 99305 and 99405, both located in the South Walnut Creek drainage adjacent to former B991, are not illustrated because nitrate concentrations are uniformly low—in 2011, the highest level reported in samples from these two wells was 2.5 mg/L—and U present in these wells has been repeatedly shown to be natural (and is discussed elsewhere in this report). The U in AOC well 10594 has also been shown to be natural, and as in 2010 was calculated to be on a decreasing trend with 95 percent significance (Table 91, Appendix B). With respect to Figure 242, other concentration trends with equivalent statistical significance include increasing nitrate and U at well P210089, and increasing U but decreasing nitrate at well 70099.



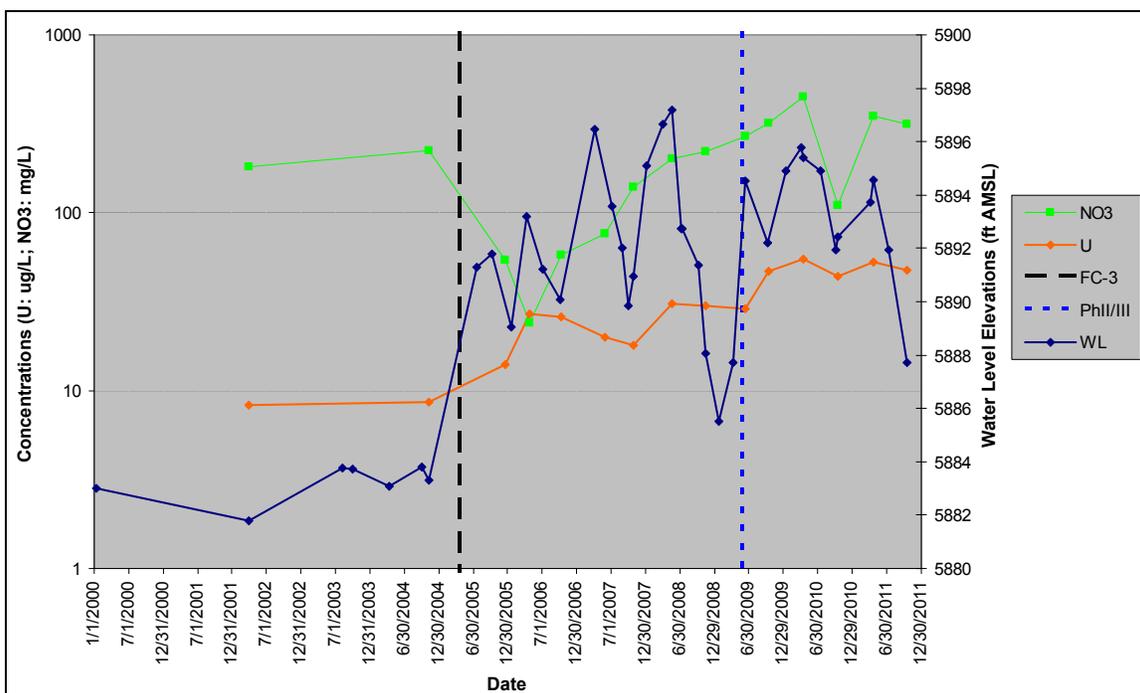
Note: U = total uranium, N = nitrate+nitrite as nitrogen. Note logarithmic concentration scales.

Figure 242. U and Nitrate Concentrations in Wells Downgradient of the Former SEPs

Nitrate and U concentration trends at well P210089 appear to be related to a few specific events and conditions. Prior to closure, the land surface adjacent to this well included a small drainage that emptied via a culvert under the former North Perimeter Road to surface water at location SW093. However, land surface reconfiguration associated with removal of the road and

culverts in this area, construction of FC-3, and addition of fill to achieve the final land surface in spring 2005 led to creation of a broad, flat area around the well. Consequently, surface water now ponds around the well, to the point that additional fill was placed in 2009 to provide better access for sampling staff. Comparison of the P210089 nitrate and U concentrations, together with the corresponding hydrograph, with timing of SPPTS changes is illustrative (Figure 243). Groundwater elevations clearly show the impact of the land surface reconfiguration in 2005. A slow rise in nitrate and U concentrations appears to begin within a year or so after this event. These increasing concentrations may be a result of seepage from the north-facing SEP hillside: Prior to the regrading activity, this seepage would have immediately drained to North Walnut Creek via the small channel and associated culvert, but with their removal and the new land surface, this water was now ponding and infiltrating the ground around well P210089.

The SPPTS groundwater intercept trench is expected to represent an additional influence on water quality at well P210089, given that the western end of the trench is located just a few feet from the well. As shown on Figure 243, variations in the concentrations of nitrate and U began to more closely reflect variations in groundwater levels in late 2009. This correlates with installation and operation of the SPPTS Phase II and III upgrades, one aspect of which included more uniform metering of influent to the SPPTS treatment cells. This metering allowed groundwater to store in the trench, which was desired so that there would be a continuous flow of influent to treatment components. Prior to this, influent flows pulsed, and there had been periods when the system went dry for some time as shown on the hydrographs for the SPPTS presented below. Continuous influent flow was desired because Phase II operates in upflow configuration and could experience problems if operated in pulsed fashion or allowed to drain; and Phase III components operate in upflow and required continuous flow to support the associated pilot-scale treatment studies. (A summary of these upgrades is provided below, and more detail is provided in previous annual reports, particularly DOE 2010d and 2011d.) Maintaining a reservoir of water in the trench led to both increasing water levels and increasing concentrations in adjacent well P210089. Although not a response to contaminant or water level conditions in well P210089, operation of the SPPTS now targets lower trench water levels that should help to stabilize well-specific conditions that may be related to the trench. Note that similar patterns as are discussed here for well P210089 are not clearly evident at nearby Sentinel well 70099.



Note: NO3 = nitrate+nitrite as N, U = total uranium, FC-3 = approximate completion of area reconfiguration described in text, PhII/III = completion of Phase II and III upgrades to SPPTS, and WL = water level in feet above mean sea level (ft AMSL). Note logarithmic, dual-unit concentration scales.

Figure 243. U and Nitrate Concentrations vs. Water Level in Sentinel Well P210089

Several wells and other locations associated with the SPP were also sampled in 2011 for high-resolution U isotopic analysis by LANL. The objective of these analyses is to determine the percentage of anthropogenic (i.e., Site-related) U in the total U content of a sample. The associated analytical results are summarized below in Table 100.

Table 100. Summary of 2011 Sample Results Analyzed for High-Resolution U Isotopes by LANL

Sample Location	Date Collected	Total U (µg/L)	Percent Natural	Percent Anthropogenic	Previous Number of Sample Events	Average Natural Percentage of Past Samples
99405	4/20/11	411.1	100.0	0.0	3*	100.0
P210089	4/20/11	52.7	81.5	18.6	1	100.0
70099	4/20/11	306.5	100.0	0.0	1	99.4
B210489	4/20/11	52.6	84.8	15.2	4	88.3
51605	4/20/11	22.3	97.6	2.4	1*	99.9
SPIN	4/20/11	85.8	47.8	52.2	2	62.0
SPOUT	4/20/11	27.4	57.7	42.3	1	65.1
SW093	4/20/11	8.8	92.0	8.0	2	91.8
GS13	4/20/11	48.2	73.0	27.0	4	72.5

Notes: Total U concentrations in source report are given in units of ug/kg, which is equivalent to µg/L in pure water and negligibly different in Site water. * = predecessor well supplied sample(s), which are grouped with current samples. Percentages may not add to 100.0 due to rounding. Data provided by LANL on March 1, 2012, as revised version of February 9, 2012, report, which followed the draft report received September 8, 2011.

These LANL results are generally consistent with past data from the same locations, though meaningful differences do exist. The greatest change is seen at SPIN, the SPPTS influent location, where the average natural U based on previously-collected samples was calculated at 62 percent, while the 2011 result was about 48 percent. This change is due to SPPTS modifications. Previous SPIN samples submitted to LANL were all collected prior to construction of the Phase I upgrades, which acted to capture more of the contaminant plume and more anthropogenic U. With the addition of this water to SPIN, the anthropogenic U content increased.

The spring 2011 sample collected from well P210089, located at the base of the north-facing Solar Ponds hillside, indicates anthropogenic U content increased at this location from 0 percent in a sample collected in 2004 to 18.5 percent in 2011. This may be due to migration of the SPP in a downgradient direction, as also suggested by the increasing trends calculated for both U and nitrate at this well (Table 91). Other mechanisms that may be affecting the proportion of anthropogenic content in samples from well P210089 include the seepage from the north-facing SEP hillside that now ponds in the immediate vicinity of the well, and is therefore able to serve as direct recharge to this well during the spring and early summer months; and the proximity of the SPPTS groundwater intercept trench, which can contribute collected groundwater to the well. As suggested by the higher anthropogenic U content of trench water as represented by samples collected from SPIN (Table 100), water within the trench could contribute enough anthropogenic U to well P210089 to yield the result provided in that table.

It is important to note that concentrations of U in samples from well P210089 still are lower than the natural U in AOC well 10594, and are much lower than the natural U in Sentinel well 70099 (Figure 242). This reiterates the point that Rocky Flats groundwater in many places is naturally elevated with respect to U, and the mere presence of U—even at relatively high concentrations (e.g., 70099, 99405)—does not signify contamination.

Solar Ponds-Area VOC Plume

Evaluation wells designated to monitor the VOC plume in the western SEP area were not scheduled for sampling in 2011. Each will be sampled in 2012, and the corresponding annual report will include an updated description of conditions related to this plume. Downgradient of the plume source area, Sentinel well P210089 is also monitored for VOCs. One detection of naphthalene, at an estimated (J-qualified) concentration of 0.85 µg/L, was reported in October 2011. Like elsewhere at Rocky Flats, this VOC plume is not characterized by elevated concentrations of naphthalene, so this result is likely anomalous. No other VOCs were detected in this well, nor were any VOCs detected in downgradient AOC well 10594, located between former Ponds A-1 and A-2.

Solar Ponds Plume Treatment System

Like the ETPTS, the SPPTS was installed in 1999. In basic terms, the system is very similar to the MSPTS and ETPTS, with an intercept trench (1,100 feet long) and two original treatment cells. However, unlike the ETPTS and MSPTS, this system is designed to treat water with elevated concentrations of nitrate and U rather than VOCs. As such, the treatment media in the original SPPTS treatment cells differs from the ZVI media in the MSPTS and ETPTS treatment

cells. The treatment media in these SPPTS cells consists of organic material (sawdust) with a small fraction of ZVI in the first cell and ZVI with pea gravel in the second cell.

In addition, unlike the gravity-flow operation of the MSPTS and ETPTS, water that is collected in the SPPTS intercept trench is actively pumped into the treatment cells. This is accomplished using a solar-charged, battery-powered pump system. This component of the SPPTS, together with the collection well that houses the pump and is installed within the trench, was installed in 2002.

The SPPTS has been the focus of extensive study and modification over the past several years to improve collection and treatment of contaminated groundwater. Several factors drove these efforts, including (1) historically, concentrations of nitrate and uranium measured at the Discharge Gallery typically exceeded those in untreated influent to the system, even though this is where effluent confirmed to be adequately treated may surface following its discharge; (2) accessing and maintaining the treatment media and plumbing within the original structure is costly and difficult; and (3) the original treatment media used may not be optimal over the long term. Previous annual reports have discussed various SPPTS-related activities and components of the post-closure work (DOE 2007c, 2008c, 2009d, 2010d), which has included repairs, subsurface exploration, treatability studies, and the design and construction of system upgrades.

It is important to understand that a fundamental challenge to achieving consistently reliable treatment by the SPPTS is the lack of electrical power. Although it supports many tools and critical components, several kilowatts of solar-based power cannot substitute for full-time, on-demand line power. In addition, the capital costs associated with solar power are very high; when coupled with installation of a battery bank to ensure full-time operation, costs and maintenance requirements increase.

Maintenance and optimization activities were conducted at the SPPTS throughout 2011 and are reported in Section 2.5.3. The text below provides a summary of the results related to water treatment.

The SPPTS treated approximately 507,000 gallons of groundwater in 2011. This is the third-highest volume ever treated by this system (Table 101), but is also the lowest volume treated since the Phase I upgrades were installed in late 2008. Figure 244 presents a hydrograph showing flow from January 2000 through the end of 2011. The hydrograph for CY 2011 is presented as Figure 245.

On average, the SPPTS has treated about 312,000 gallons per year since January 1, 2000. From Table 101, it is evident that several significant changes have occurred. The most significant changes have come as a result of the 2002 installation of a pump to deliver influent from the collection trench to the treatment cells, and the late-2008 installation of the Phase I upgrades that collect additional contaminated groundwater (discussed at length in the annual reports for 2008 and 2009 (DOE 2009d and 2010d).

Site closure appears to have had little effect on the volume of flow treated by the SPPTS, as suggested by the volumes for the couple of years preceding and following that event. About 201,000 gallons per year were treated from 2000 through 2005, assuming the volumes for 2000 through 2002 are accurate; since closure, the system has treated approximately 424,000 gallons

per year. (The year 2005 is included with the pre-closure average.) This is a significant increase in flow, and is related to, if not entirely caused by, the installation of the Phase I upgrades in late October, 2008. Averaging the volumes treated from 2000 through 2008 shows a pre-Phase I average of approximately 220,000 gallons per year, and a post-Phase I average of about 590,000 gallons per year.

Table 101. Estimated Volumes of Water Treated by the SPPTS

Calendar Year	Annual Estimates of Volume Treated (gallons)	Estimated Cumulative Volume Treated (gallons)
2000 ^a	64,000	64,000
2001 ^a	424,000	452,700
2002	5,600 ^b	458,000
2003	340,000	797,000
2004	230,000	1,027,000
2005	140,000	1,167,000
2006	251,000	1,418,000
2007	244,000	1,662,000
2008	280,000	1,942,000
2009	524,000	2,466,000
2010	738,000	3,204,000
2011	507,000	3,711,000

Notes: Estimates for years 2000 through 2004 are compiled from K-H (2000a, 2000b, 2000c, 2000d, 2002b, 2003, 2005a, 2005b).

^a Annual and cumulative volume estimates for 2000 and 2001 are suspect, as a sum of the volumes presented in each of the quarterly reports for 2000 and statements regarding the volume for 2001 disagree by approximately 35,000 gallons.

^b Most of this volume was from the former Modular Storage Tanks (K-H 2003).

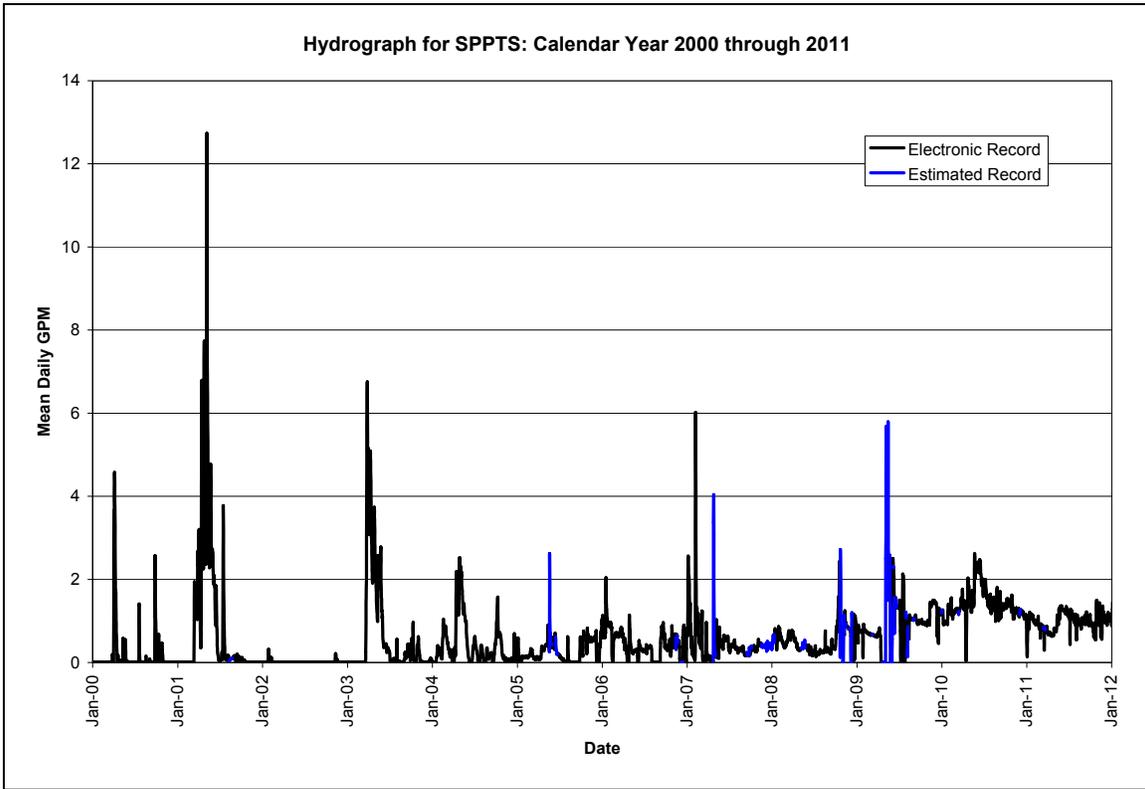


Figure 244. Hydrograph for SPPTS from 2000 Through 2011

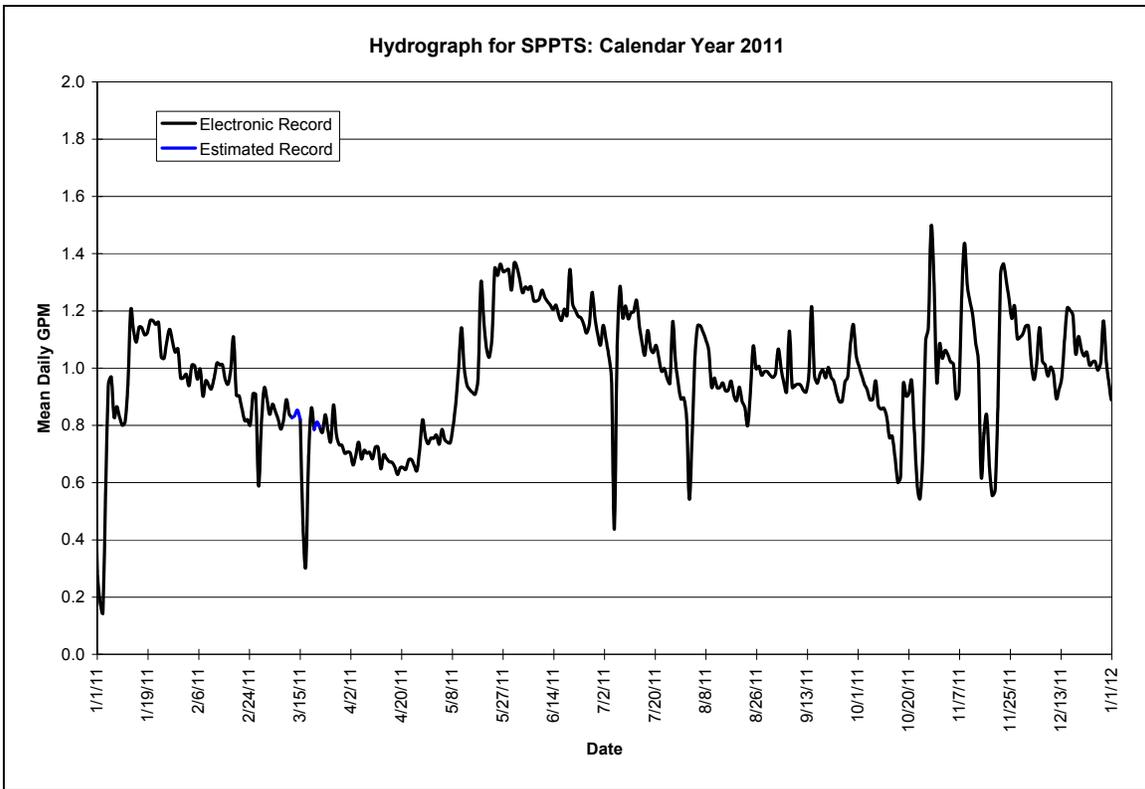


Figure 245. Hydrograph for SPPTS for CY 2011

Summary of SPPTS Upgrades

As noted above, several upgrades have been made to the SPPTS since Site closure. These upgrades are summarized below in Table 102. Refer to the previous several annual reports (particularly DOE 2009d, 2010d, and 2011d) for extended discussions of these upgrades and their environmental effects, and to Section 2.5.3 for information on their operation and maintenance in 2011.

Table 102. Summary of SPPTS Construction and Upgrades

Upgrade Phase (Year Installed)	Summary Description	Summary of Associated Features and Nomenclature
"Phase 0" (1999)	Original SPPTS constructed: Groundwater intercept trench bisects previously installed French drain network called the Interceptor Trench System, or ITS, and feeds collected water by gravity through two cells operated in series: Cell 1 contains sawdust plus 10% ZVI for nitrate treatment; Cell 2 contains pea gravel and 15% ZVI for U treatment. Effluent is routed into a downgradient limb of the ITS and thence to a line to the subsurface discharge gallery.	SPPMM02 = "influent" location accessed at piezometer a.k.a. 71099 SPPMM01 = effluent location accessed in manhole SPP Discharge Gallery in valley bottom GS13 = surface water performance at mouth of Pond A-1
"Phase 0.1" (2002)	Collection well equipped with solar-powered pump is installed to deliver collected groundwater to cells.	SPIN (name later assigned to influent flow from this pump)
Phase I (2008)	Collection sump and gravel drain installed at terminal points of ITS, adjacent to location of former Interceptor Trench Pump House (ITPH).	ITSS = Intercept Trench System Sump, the constructed sump that receives water collected by the upgrade ITSE = east ITS line where it empties into ITSS ITSW = west ITS line where it empties into ITSS
	Piping installed to transfer water from ITSS to SPIN, and to discharge treated system effluent from effluent manhole to Discharge Gallery; SPIN vault provides access point to flows from the former, and ITSS vault provides access to flows from the latter.	SPOUT = effluent location accessed in ITSS vault
Phase II (2009)	Easily accessible cell installed to treat U upstream of nitrate treatment; initially incorporates citrate dosing of influent.	SPZE = effluent from Phase II cell
Phase III (2009)	Installed: two pilot-scale nitrate treatment cells to evaluate alternative treatment approaches; associated vault to house carbon supply (added to one of the Phase III cells); vault to allow flow configuration, control, dosing, monitoring, programming, and telemetry infrastructure; associated water storage sump to provide influent in the event of dry conditions; and solar power and plumbing infrastructure to support all of this.	Cell A = pilot-scale nitrate treatment cell using inert media dosed with liquid carbon Cell B = pilot-scale nitrate treatment cell using organic (reactive) corn stover media SPILCA = dosed influent to Cell A SPCAE = effluent from Cell A SPCBE = effluent from Cell B
Phase IV (to be determined)	Install full-scale nitrate treatment component based on previous testing and results	Under consideration

Treatment effectiveness by the SPPTS has been challenged in recent years, in large part due to the fact that substantial additional contaminant load and flow is now being routed through the system. However, the overall effect has been one of significant improvement compared to pre-closure conditions. This is described in greater detail in the following section.

Summary of SPPTS Treatment

Table 103 presents summary statistics for concentrations of nitrate and U for the years 2000 through 2011 at several SPPTS monitoring locations of interest. These statistics are shown for

both contract laboratory-only results (i.e., without Environmental Sciences Laboratory [ESL] data) and for combined contract laboratory and ESL data. (For economic reasons, the ESL has been used to analyze the samples collected as often as twice weekly to evaluate the effects of the Phase I, II, and III upgrades and optimization efforts. Therefore, the data set is more robust if ESL data are included.)

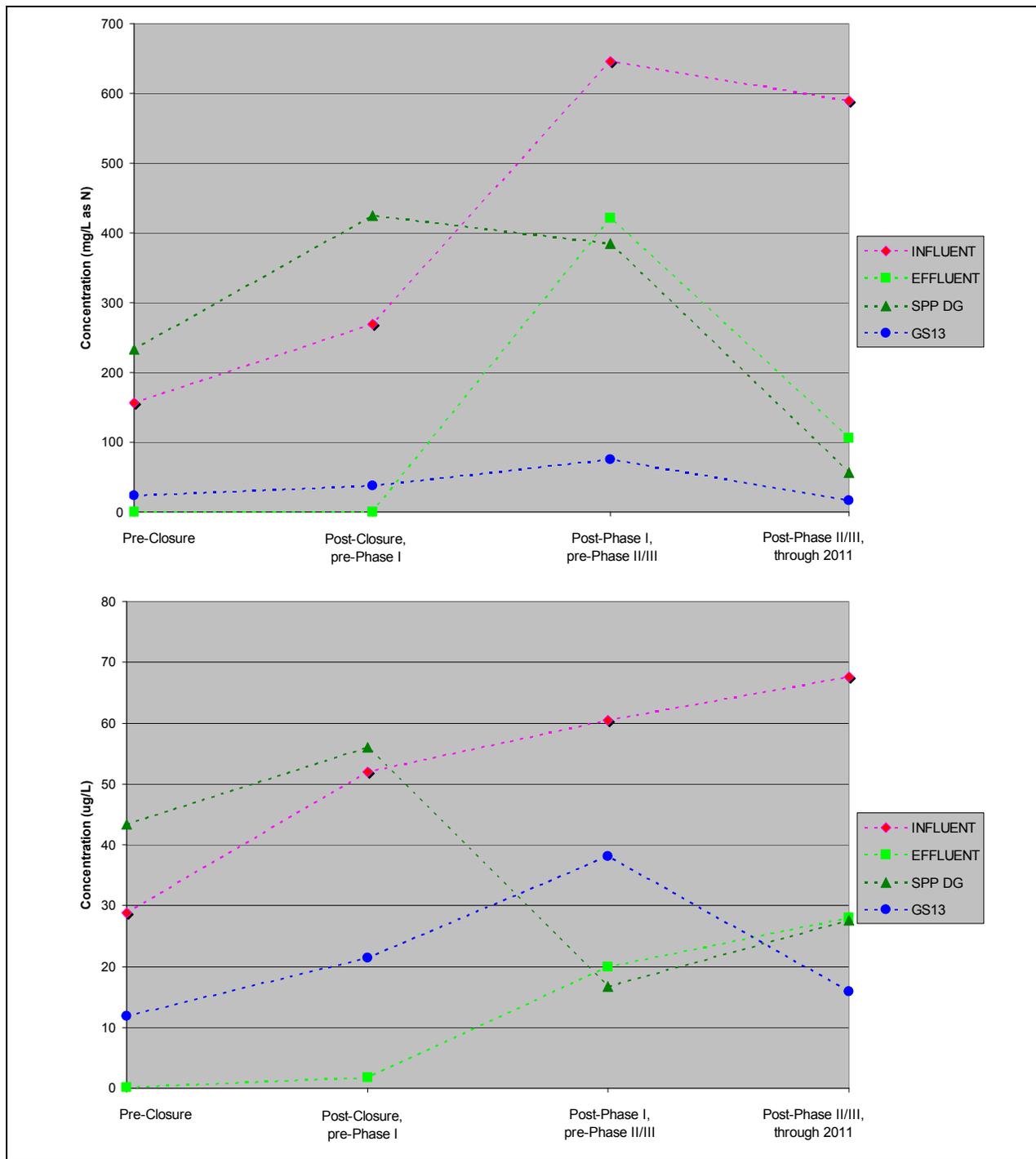
Table 103. Summary Statistics for U and Nitrate Concentrations from 2000 Through 2011 at Historical and Current SPPTS Monitoring Locations

System Influent	Nitrate			Uranium		
	Average	SD	Median	Average	SD	Median
Pre-closure (SPPMM02)	160.7	45.9	156.0	28.4	4.6	28.8
Post-closure, pre-Phase I (SPPMM02; n=3)	246.7	23.1	260.0	35.0	1.0	34.9
Post-closure, pre-Phase I (SPIN)	276.7	59.7	270.0	52.4	9.8	52.0
Post-Phase I, pre-Phase II,III (SPIN)	682.5	99.1	695.0	76.3	14.0	77.0
<i>with ESL data</i>	645.3	64.0	646.3	63.1	13.3	60.5
Post-Phase II, III (SPIN)	597.7	94.4	600.0	66.4	9.8	64.0
<i>with ESL data</i>	595.0	70.6	590.0	67.8	8.8	67.6
System Effluent						
Pre-closure (SPPMM01)	6.1	27.0	0.1	3.0	10.5	0.1
Post-closure, pre-Phase I (SPPMM01)	26.6	77.8	0.4	3.7	5.7	1.7
Post-Phase I, pre-Phase II,III (SPPMM01; n=1)	310.0	N/A	310.0	21.0	N/A	21.0
<i>with ESL data</i>	283.0	112.8	329.2	16.7	3.0	15.5
Post-Phase I, pre-Phase II,III (SPOUT)	403.3	40.4	410.0	27.3	4.2	26.0
<i>with ESL data</i>	393.5	100.6	421.0	20.3	5.5	20.0
Post-Phase II, III (SPOUT)	153.9	96.0	140.0	29.9	9.0	28.5
<i>with ESL data</i>	123.2	89.5	106.1	29.4	9.3	28.0
Discharge Gallery						
Pre-closure	259.9	123.2	233.0	52.8	44.7	43.3
Pre-closure without 3 U outliers	--	--	--	44.9	16.9	43.0
Post-closure, pre-Phase I	449.8	123.2	425.0	60.5	14.6	56.0
Post-Phase I, pre-Phase II,III	376.7	85.0	380.0	25.0	1.7	26.0
<i>with ESL data</i>	379.7	117.9	385.1	18.4	4.6	16.7
Post-Phase II, III	135.7	68.4	170.0	38.5	34.7	25.0
<i>with ESL data</i>	86.2	73.6	57.1	29.4	8.8	27.6
GS13						
Pre-closure	24.9	17.6	23.0	12.1	6.1	11.8
Post-closure, pre-Phase I	41.2	26.2	38.0	23.0	13.1	21.4
Post-Phase I, pre-Phase II,III	80.3	13.2	74.0	38.3	22.6	52.3
<i>with ESL data</i>	88.5	61.4	75.0	36.1	18.7	38.1
Post-Phase II, III	18.5	13.0	23.0	15.8	12.2	12.2
<i>with ESL data</i>	17.6	13.1	16.5	21.1	15.0	16.0

Notes: SPIN = true system influent (collection well); SPPMM02 = original "influent" monitoring location; SPPMM01 = original system effluent location, replaced in late 2008 with SPOUT; GS13 = surface water performance monitoring location. N/A indicates location was not monitored, or the indicated statistic cannot be calculated. Where three or fewer results form the basis for the statistics presented, the number of samples is indicated parenthetically (e.g., n = 3). Refer to 2009 Annual Report (DOE 2010d) for additional information on the outliers noted for the Discharge Gallery statistics. Closure date used is October 2005; Phase I date used is October 20, 2008; Phase II, III date used is May 28, 2009. Analytical data from SPPMM02 and SPPMM01 are included for comparison only; these locations are no longer monitored. See the 2006 Annual Report (DOE 2007c) for a more detailed discussion of location SPPMM02, and see the 2008 Annual Report (DOE 2009d) for more information on SPOUT. Data used to calculate the statistics were taken at face value, regardless of qualifier. Data from ESL are not validated, but typically correspond very closely to results from split samples sent to contract labs. ESL results for nitrate used to calculate the statistics include those for nitrate only as well as for nitrate plus nitrite.

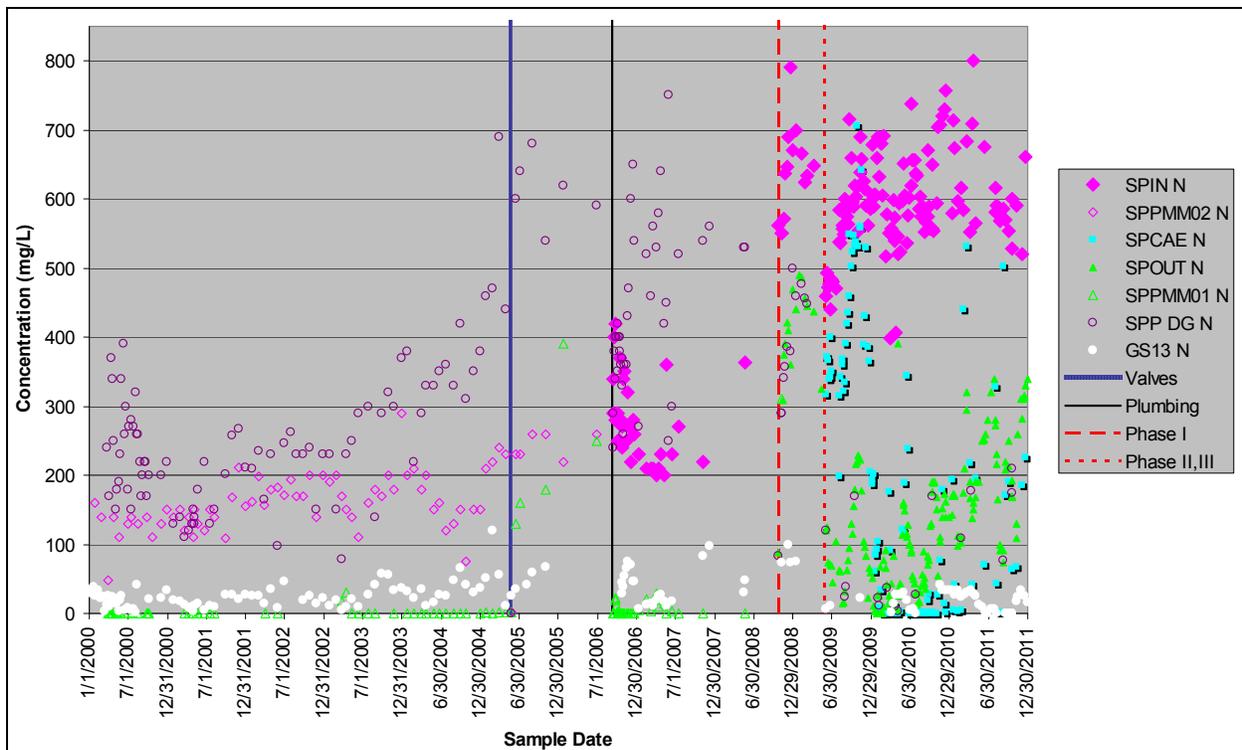
The summary data provided in Table 103 are graphically presented as Figure 246 below. Clearly evident is the general improvement in water quality at the discharge gallery, which represents water eventually reaching North Walnut Creek. Also obvious on this figure is the substantially higher influent concentration of nitrate and U since Site closure. Perhaps most importantly, concentrations of U and nitrate in North Walnut Creek, as represented by data from location GS13, has returned to near pre-closure levels: concentrations of nitrate are slightly lower, while those of U are slightly higher.

The statistical results summarized above are generally evident on the time-series plots of Figure 247 (nitrate) and Figure 248 (U). These plots provide a more detailed illustration of the effects on water quality from the installation of the phased upgrades and other SPPTS events. Specific events that are illustrated include valve changes in the spring of 2005, plumbing repairs in late 2006, and the installations of Phase I and Phases II and III upgrades. The effects of the valve changes and plumbing repairs on system effluent are obvious, and to some degree are also evident at the SPP Discharge Gallery and GS13 as well (see the 2006 Annual Report, DOE 2007c, for additional discussion of these events). The isolated late-2004 and mid-2005 spikes in U concentration at the Discharge Gallery have been discussed previously (DOE 2010d) and are not addressed here.



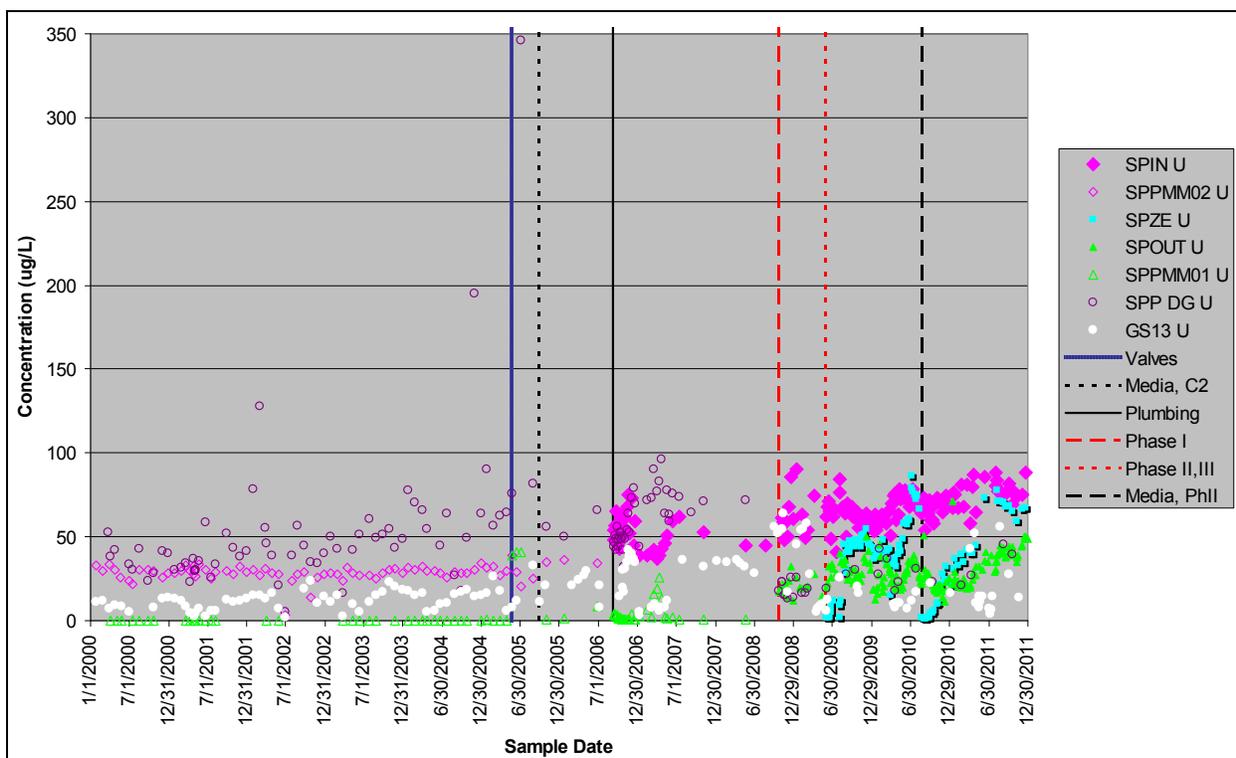
Notes: Top graph represents median nitrate concentrations (mg/L as N), bottom represents median U concentrations (µg/L). Influent = SPPMM02 data for pre-closure, then SPIN (collection well); Effluent = SPPMM01 for pre-closure and pre-Phase I, then SPOUT; SPP DG = discharge gallery; GS13 = surface water performance monitoring location. Values represent medians using both contract lab and ESL data (and LANL, for U). Data were taken at face value, regardless of qualifier (including nondetects). Data from ESL are not validated, but typically correspond very closely to results from split samples sent to contract labs. ESL results for nitrate used to calculate the statistics include those for nitrate only as well as for nitrate plus nitrite.

Figure 246. Median Nitrate and Uranium Concentrations with Respect to SPPTS Events at Selected Locations



Notes: N = uranium; SPIN = system influent; SPPMM02 = original system “influent”; SPCAE = effluent from Phase III Cell A; SPOUT = system effluent; SPPMM01 = original system effluent; SPP DG = SPP Discharge Gallery; GS13 = surface water performance location; Valves = date on which treatment cell valves were reconfigured in response to elevated water levels; Plumbing = date on which plumbing repairs were completed; Phase I = date on which those upgrades were placed online; Phase II,III = date on which those upgrades were placed online. Refer to previous annual reports (DOE 2007c, 2008c, 2009d, 2010d, and 2011d) for more information on these and other events. Some data are qualified but are not displayed differently for simplicity. Data are from contract laboratories as well as the ESL.

Figure 247. Concentrations of Nitrate at Selected SPPTS Monitoring Locations



Notes: U = uranium; SPIN = system influent; SPPMM02 = original system “influent”; SPZE = effluent from Phase II Cell; SPOUT = system effluent; SPPMM01 = original system effluent; SPP DG = SPP Discharge Gallery; GS13 = surface water performance location; Valves = date on which treatment cell valves were reconfigured in response to elevated water levels; Media = date on which media replacement was completed and the cell was placed back into operation (C2 = original Cell 2; PhII = Phase II Cell); Plumbing = date on which plumbing repairs were completed; Phase I = date on which those upgrades were placed online; Phase II,III = date on which those upgrades were placed online. Refer to previous annual reports (DOE 2007c, 2008c, 2009d, 2010d, and 2011d) for more information on these and other events. Some data are qualified but are not displayed differently for simplicity. Data are from contract laboratories as well as the ESL.

Figure 248. Concentrations of U at Selected SPPTS Monitoring Locations

Also evident in the pre-closure era is a gradual increase in influent concentrations of nitrate and U, beginning perhaps in 2003. (Note that these data actually represent pseudo-influent monitored at location SPPMM02, a piezometer installed within the groundwater intercept trench about ten yards east of the actual influent location, SPIN. Refer to the 2006 Annual Report, DOE 2007c, for a discussion of these two locations and the associated water quality differences.) Reasons for this increase, most obvious for nitrate in Figure 247, are uncertain. The SEPs were closed in 2002 and the area saw significant application of dust-suppressing water; it may be that this water leached additional contaminant and relatively quickly reached the Interceptor Trench System (ITS) to drain into the SPPTS intercept trench.

The Phase I upgrades completed in late October 2008 were extremely effective in collecting additional contaminated groundwater. This is confirmed by the jump in concentrations of nitrate especially (Figure 247), and U to a lesser degree (Figure 248), in system influent as monitored at location SPIN; these effects are also evident in the summary statistics presented in Table 103 and plotted on Figure 246. Specifically, the average nitrate concentration increased from 277 mg/L as N in the post-closure, pre-Phase I period to almost 650 mg/L as N (a 133 percent increase), and

over the same period concentrations of U increased from 52 µg/L to 63 µg/L (a 20 percent increase). A comparison with pre-closure data show an even greater increase, but part of this is due to the pre-closure data being collected at SPPMM02 rather than SPIN. At the same time, despite the reduced treatment effectiveness documented at effluent monitoring locations SPPMM01 and SPOUT, relative to pre-Phase I levels the contaminant concentrations at the Discharge Gallery remain greatly reduced. This is because the contaminated groundwater that had been issuing untreated at the Discharge Gallery is now collected by Phase I and at least partially treated by the SPPTS, resulting in overall reduced contaminant loads at the Discharge Gallery. The same effect is also evident in the summary statistics for surface water location GS13, where SPPTS performance is measured.

The main factors relevant to recent nitrate treatment include the continued high influent concentrations, biofouling in Phase III Cell A, and the clogged condition (also due to biofouling) of the original Cell 1. These factors combined to reduce the effectiveness of nitrate treatment by the SPPTS, as illustrated in Figure 247 and summarized in Table 103. Difficulties maintaining Cell A (a summary of which is provided in Section 2.5.3) contributed to its reduced treatment effectiveness, which added to the nitrate load routed to the original treatment cells. Because the original cell designed to treat nitrate—Cell 1—is not designed to treat such high concentrations of nitrate and is also clogged, the additional treatment provided by the original components is limited. Concentrations at SPOUT, the system effluent monitoring location, reflect this. However, as illustrated in this figure as well as in the summary plot presented above in Figure 246 and in Table 103, the quality of the water discharging to the North Walnut Creek drainage, as represented by samples representing the Discharge Gallery, has improved overall. In addition, concentrations of nitrate reported for location GS13 in 2011 were generally lower than those observed prior to Site closure.

Concentrations of U as illustrated on Figure 248 also reflect the impact of the additional Phase I-related load in the system influent. Also evident is the early (mid-2009) breakthrough of U in effluent from the Phase II cell (represented on the figure as sampling location SPZE). This cell had initially removed U as designed, but within weeks the effluent sampled at SPZE (the Phase II Cell effluent monitoring location; see Table 102) showed detectable concentrations of U. Over the subsequent months of 2009, the levels of U in effluent from the Phase II cell increased. Reasons for this behavior were uncertain; see the 2009 and 2010 Annual Reports for discussions (DOE 2010d and DOE 2011d, respectively).

The ZVI media in the Phase II cell was replaced in the summer of 2010, with immediate improvement in effluent water quality (see SPZE data on Figure 248). However, once again within weeks U was detectable in the effluent. Rather than change the media again, which is an involved and expensive activity (particularly if performed every few months), the treatment cell continued to be operated while additional study and investigation was conducted.

Different approaches to treating U under the specific Site conditions that apply (including very low flow, relatively low concentrations of U but high concentrations of nitrate, no line power, staff availability, and so forth) were reevaluated to determine whether a suitable alternative to the existing large Phase II cell filled with ZVI-based media could be found, while still removing U as the first step in the treatment train. Similar study had been undertaken when planning the Phase II upgrades, but at that time information on U concentrations and system flows following the Phase I upgrades was very limited. More information is now available.

U treatment media alternatives and paths forward were being evaluated as 2011 ended. The option selected to be tested first is described below.

Validated contract lab data indicate nitrate and U concentrations in 2011 at the performance monitoring location for the SPPTS, GS13, were within their typical ranges. This is evident on Figure 247 and Figure 248. As in prior years, the sample collection methods used in 2011 differed for nitrate vs. U. The former are collected as manual grab samples, while the latter represent flow-paced composite samples. As a result, the nitrate values would tend to be biased high because periods of heavy storm flow are not ideal for manual sampling, while the U data tend to be more representative of stream conditions. Sample handling and preservation requirements for nitrate include (among others) refrigeration, which is not feasible at GS13 due to the lack of electrical power. Changes in these methods are not anticipated in the immediate future.

U Microcell

The laboratory tests that were conducted to support Phase II design showed ZVI to be the most effective media in terms of cost and U treatment. In fact, these tests showed ZVI treatment to be unaffected by the high nitrate in SPIN water, with the test media performing adequately for thousands of pore volumes. (This led to placement of the Phase II cell as the first step in the treatment train, rather than following nitrate treatment as was the original system design.) In contrast, estimates of Phase II performance suggest U is adequately removed for approximately 200 pore volumes.

Therefore, in late 2011 plans were being developed to perform tests intended to more closely replicate the successful lab studies. The underlying hypothesis goes to the kinetics of two chemical reactions, and assumes the high nitrate concentrations in SPIN water are causing the early treatment reductions experienced in the Phase II cell. The reactions of interest are U removal (by whatever mechanism—sorption or precipitation/coprecipitation) and ZVI passivation by nitrate.

The lab-based studies using SPIN water were conducted with a residence time of about half an hour, while the Phase II cell residence time is on the order of 8 hours. (The residence time refers to how long water takes to move through the media.) Lab studies using other U-contaminated water tested residence times of several minutes, and U was still effectively removed. Therefore, perhaps the lab studies using SPIN water were so successful because the shorter residence time allowed the U to be removed adequately, but did not allow sufficient time for the ZVI to become passivated by the nitrate. (Again, this assumes nitrate is passivating the ZVI media. This has not been proven.)

Given the very low flow that is typical of the SPPTS—about 1.5 gallons per minute (gpm), though the arithmetic average over the last 3 years is closer to 1.1 gpm—the system is amenable to using very small cells operated at this flow. It is not feasible to operate the Phase II cell on such a short residence time, since the pore volume is calculated to be a bit less than 700 gallons, or about 500 minutes (roughly 8 hours) of flow. There is not this much groundwater available to the SPPTS.

As 2011 ended, preparations were underway to test a comparatively small (approximately 2 feet long by 4 inches in diameter) ZVI-filled container for U removal. The so-called “microcell” would, at least initially, be filled with pure ZVI, as opposed to the gravel-ZVI mix in the Phase II cell; this would yield a measured pore volume of 2.57 L, or about two-thirds of a gallon. While the ZVI within such a small volume would be exhausted fairly quickly (i.e., it would only remove U for a short amount of time), the expectation was that these small cells could be manually removed, emptied, refilled, and put back online relatively easily; and that the amount of media used to effectively remove U would be much less than that used to fill the Phase II cell. The end result would be more effective and efficient treatment of the U in the SPPTS flow.

The microcell was planned to be tested several times, with each test incorporating a fresh media fill. It would be operated at different flow rates (which results in different residence times), and effluent would be sampled using an automated sampler. Alternative media (ZVI mixed with gravel, ion exchange resin) was also being considered for use in the microcell.

The 2012 Annual Report will include discussion of the microcell tests and results.

Phase III Pilot Studies

The Phase III pilot studies were concluded in 2011, though the cells continued to be operated through the year. Refer to the annual report for 2010 (DOE 2011d) for detailed information on pilot-scale cell optimization and operation, and resulting nitrate treatment effectiveness. As noted in that report, Phase III Cell B (the cell filled with organic media, corn stover) was removed from further consideration as the future treatment approach because it could not treat to the 10 mg/L standard with a media volume of practical and manageable size. This cell continued to be operated as it was not adversely affecting water quality. Cell A (inert media, with influent dosed with liquid carbon) also continued to be operated, and would form the basis for the design of a full-scale nitrate treatment component.

As discussed in Section 2.5.3, operation of a treatment component designed around the active approach used in Phase III Cell A poses significant maintenance requirements. In particular, the development of the denitrifying bacteria must be controlled. These bacteria are desirable, in that they act to treat the nitrate and therefore are critical to the system meeting its treatment objective. However, due to natural processes (population growth, accumulation of dead bacteria) they accumulate into undesirable biomasses. Periodic removal of excess biomass is required to maintain operational and treatment efficiency. Because it was designed as a short-term, pilot-scale nitrate treatment study, Cell A did not incorporate any biocontrol equipment such as powered water jets, powered mixing blades, or similar elements that would both aggressively break apart and mix the media and allow excess biomass to be removed. Access pipes were installed that are plumbed from the top to the bottom of the cell, for example to allow vacuuming of any accumulated sludges, but no other biocontrol accessories were installed.

In a full-scale nitrate treatment component designed along the Cell A approach, active management and significant infrastructure (agitators, pumps, filtering equipment, holding tanks) would be required to address biological fouling and maintain treatment and unimpeded flow. Conceptual designs were prepared in early 2011 that considered available flows, nitrate concentrations, carbon dosing, biocontrol, and operational requirements (e.g., access, lighting, etc.). The fundamental concept was to repurpose the existing, original treatment cell

structure—the large concrete box containing original Cells 1 and 2—and convert it to a roofed building that would contain multiple treatment cells. This concept was more fully developed, and was then put to review by third-party process engineers who have abundant experience in water treatment, specifically for nitrate and in remote settings.

The recommendations from this review team were inconsistent with both available resources (financial and human) and the magnitude of the environmental problem. Although a full-scale nitrate treatment facility incorporating these aspects can be designed and built, and would be very effective at treating the nitrate, it would require much more power than is currently available and entails a high initial and continuing cost compared to what was initially anticipated. Cost estimates were developed for such a facility, but when the additional necessary biocontrols were realized those estimates were not updated. Even without the additional biocontrol infrastructure and operation/maintenance (O/M) needs, the estimated capital cost was on the order of \$1M, and 20-year O/M costs were over \$2M.

On top of this, the additional biocontrol infrastructure that was recommended included two 20,000-gallon tanks (one as an external holding tank for treated water, the second for filtrate), a filter house and concentrated filter backwash tank, and multiple pumps and mixers with a total power demand of approximately 40 horsepower. The current solar array provides approximately 5.25 kW; this additional power requirement would be about 6 times larger. A diesel-powered generator was considered as a more cost-efficient solution. In addition, the facility would require a high level of maintenance to properly, effectively, and efficiently operate the three treatment cells, the internal mixers, the pumps and filter house, and the various holding tanks. Such a facility was not consistent with the 1.5 gpm influent stream.

The process engineers reconsidered the conceptual design in an attempt to revise it to a more appropriate scale. The revised version was improved, with a single backwash tank of about 6,000 gallons; an external drying bed, evaporation pond, or filter bags; and fewer pumps and mixers. However, the scale of this facility still dwarfed that of the system influent.

As 2011 came to an end, efforts continued on developing a more appropriate response to the SPP. This response necessarily will consider the various regulatory requirements and processes; the influent quantity and contaminant levels and loads; comparisons of SPPTS influent loads with North Walnut Creek loads; the level of effort and expense required to address SPPTS influent; and the character of the surrounding environment.

In particular, continuing study of the loads and surrounding environment—especially North Walnut Creek water quality upstream and downstream of the SPPTS—shows the magnitude of the SPPTS contaminants in a different perspective. The North Walnut Creek U load that is naturally present dwarfs any realistically conceivable SPPTS effluent load, because though concentrations in the creek are lower, the flow is many orders of magnitude greater. In addition, the robust ecosystem of the North Walnut Creek valley consumes nitrate very effectively. Therefore, devoting scarce resources to perfecting the treatment of the SPP may not be prudent.

Results of these considerations and efforts will be reported in the annual report for 2012. In addition, the Adaptive Management Plan reports also provide information on North Walnut

Creek water quality. In the interim, the SPPTS continues to operate to remove U and nitrate from system influent.

Other Plumes

Other groundwater contaminant plumes at Rocky Flats were also monitored during 2011. In accordance with RFLMA, contaminant source areas (as represented by Evaluation wells) were not scheduled for routine monitoring in 2011, but downgradient contaminant migration pathways (represented by Sentinel and AOC wells) were monitored. And, as noted previously, a small amount of non-RFLMA monitoring was conducted at several Evaluation wells.

This section presents a summary discussion of data collected in 2011 from several plumes and areas of interest. These include source and/or distal locations for the 903 Pad/Ryan's Pit Plume, the collection of small plumes collectively referred to as the IA Plume, the VC Plume (or OBP#1 Plume) located south of the former B371 complex, the IHSS 118.1 Plume (also called the carbon tetrachloride plume) located north-northwest of former B776, the PU&D Yard Plume, and the OU 1 Plume. A short summary of data from other locations of special interest is then presented.

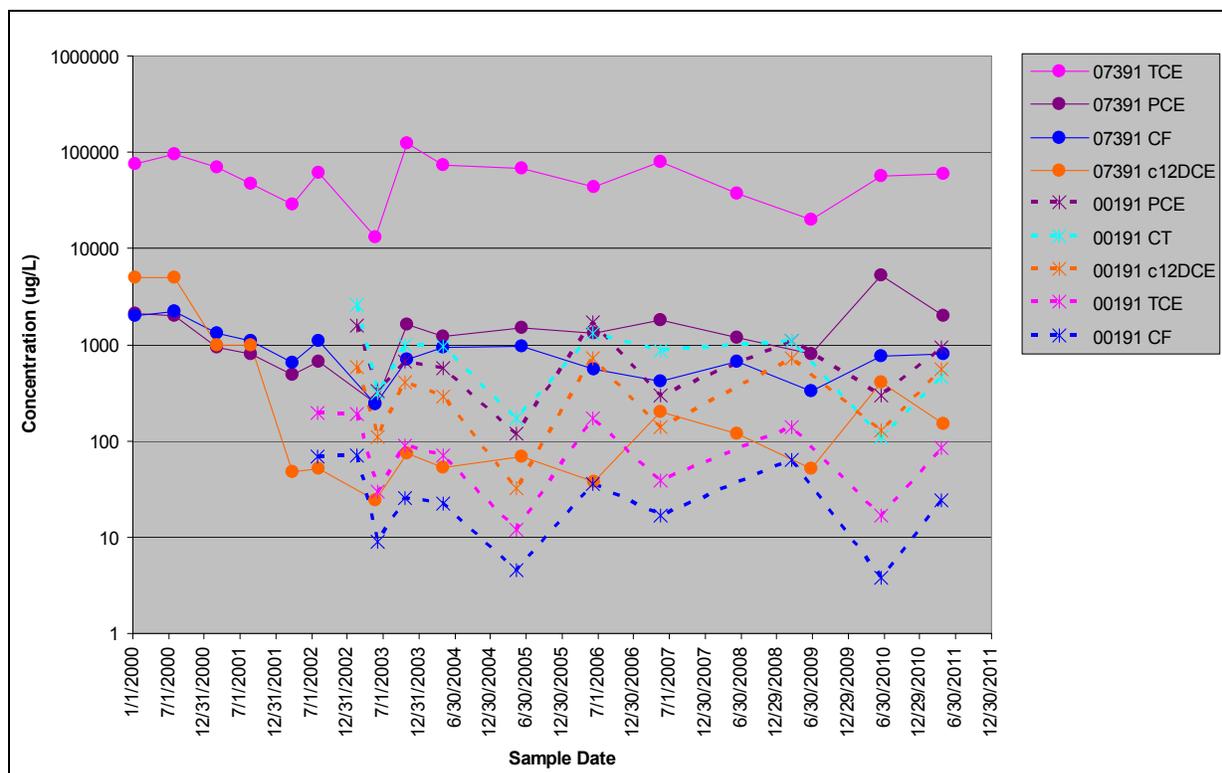
903 Pad/Ryan's Pit Plume

The two primary source area Evaluation wells and all downgradient Sentinel and AOC wells monitoring the 903 Pad/Ryan's Pit Plume were sampled in April 2011 for VOCs. Sentinel and AOC wells monitoring this plume were also sampled in October 2011. (Other Evaluation wells monitoring this plume were not sampled in 2011.) The analytical results from these samples were generally consistent with previous data. As expected, the two source-area wells, Evaluation wells 00191 just east of the former 903 Pad and 07391 just south of former Ryan's Pit, produced samples with the highest overall concentrations of contaminants. Concentrations of TCE from well 07391 continue to be present at much higher concentrations (typically 1 to 2 orders of magnitude) than any other VOCs in samples from that well and from well 00191. As is typical for these source areas, the 2011 data continue to confirm 903 Pad components are primarily carbon tetrachloride and PCE, while the main constituent in groundwater from the Ryan's Pit source area is TCE. Indeed, carbon tetrachloride is typically not even detected in Ryan's Pit source-area well 07391, although its primary degradation product, chloroform, is present at elevated levels (Figure 249). Chloroform was used in the production era at Rocky Flats (ChemRisk 1992), which would how it would occur without any carbon tetrachloride at Ryan's Pit.

The concentrations of the constituents illustrated in Figure 249 for well 07391 all appear to follow a similar pattern of increases and decreases. While the same is true for constituents in 903 Pad source-area well 00191, an inverse relationship is suggested: when concentrations in the 903 Pad well increase, they tend to decrease in the Ryan's Pit well. This pattern is most apparent for post-closure years, and therefore may be related to removal of the 903 Pad asphalt surface and some of the subsurface residual source material, as well as the direct precipitation recharge and/or increased evapotranspiration that would have been a result of the asphalt removal. The increase in PCE concentrations reported in 2010 at well 07391 (DOE 2011d) appears to have been short-lived, as the more-elevated concentrations that year were not evident in the sample collected in 2011. However, as shown on Figure 249, concentrations of PCE and chloroform prior to closure in samples from well 07391 were very similar, but have since diverged. In fact,

up until 2003 a slightly greater concentration of chloroform than PCE is typically indicated, while this has been reversed in subsequent years. Mechanisms for this distribution and the diverging concentrations are uncertain. Degradation of the chloroform would be expected to yield detectable concentrations of methylene chloride, but this constituent is rarely detected in samples from well 07391, nor is chloromethane, the next metabolic byproduct in the dechlorination pathway of chloroform.

Although an electron donor material was applied to the subsurface in both source areas shortly prior to Site closure (K-H 2005d, DOE 2006d), no strong increase in daughter products with corresponding decrease in parent products is evident. A mild increase in *cis*-1,2-DCE is visually apparent in Ryan's Pit source-area well 07391 since 2002 (Figure 249), and in fact a longer-term increasing trend in this constituent is confirmed to be present at the 95 percent level of statistical significance. In addition, chloroform is calculated to have a similarly significant decreasing trend in samples from this well (Table 91). No trends having a 95 percent level of confidence are calculated for 903 Pad source-area well 00191.

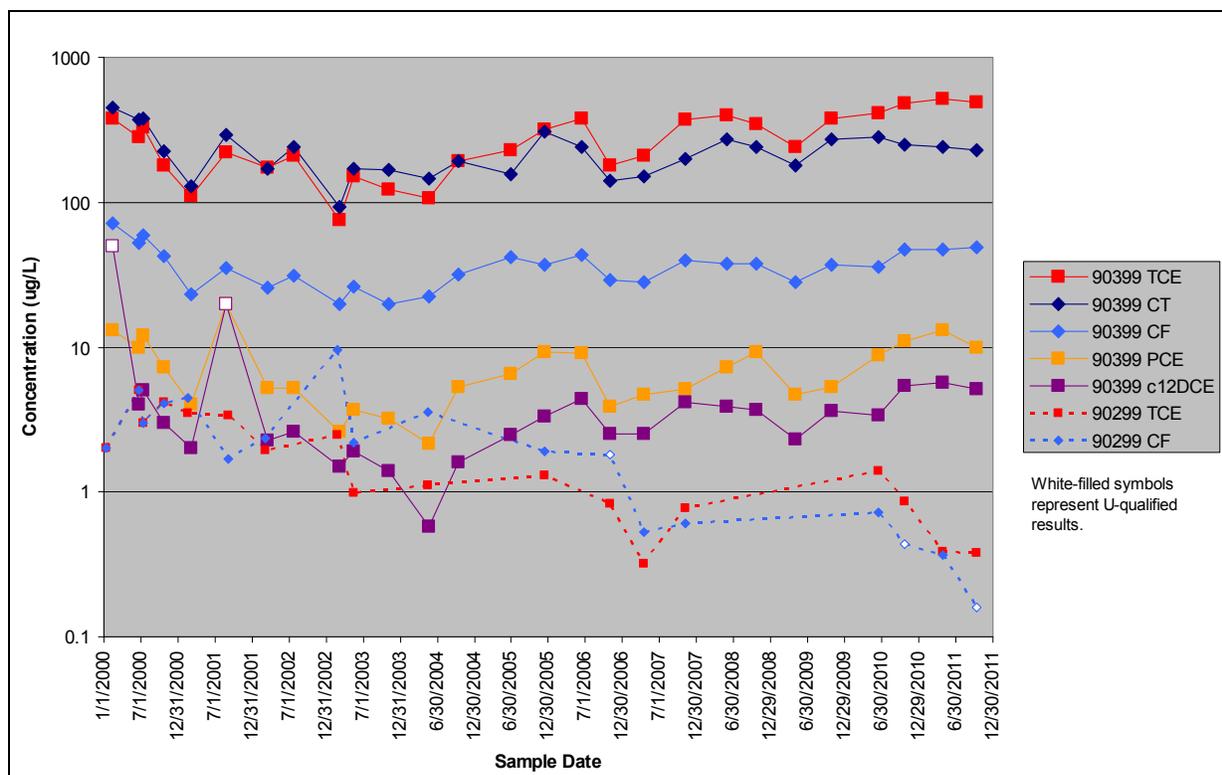


Notes: c12DCE = *cis*-1,2-DCE; CF = chloroform; CT = carbon tetrachloride. Several detections are qualified but for simplicity are not shown differently. Note logarithmic concentration scale.

Figure 249. Primary VOCs in 903 Pad/Ryan's Pit Plume Source Area Wells

Farther downgradient from these source areas, on the 903 Hillside, Sentinel wells 90399 and 90299 were both sampled twice in 2011. These wells are adjacent to the north side of the SID. For several of the past years, well 90299 has been dry, but since the wet conditions of spring 2010 it has produced sufficient water for sampling.

Figure 250 illustrates concentrations of several VOCs detected in these Sentinel wells. The gaps between data points for well 90299 represent dry periods. Several constituents are calculated to have trends of 95 percent statistical significance: at well 90399, these include increasing trends in 1,1-DCE, *cis*-1,2-DCE, and TCE; and decreasing trends at well 90299 for carbon tetrachloride, chloroform, and TCE. (Note that the decreasing trend in carbon tetrachloride may not be valid, given the numerous nondetects in the data set.) Most of these constituents are illustrated on the time-series plot included as Figure 250, and some are visually evident (e.g., TCE at 90399, TCE and chloroform at 90299). Refer to Appendix B for results of statistical trending and the associated trend plots.



Notes: CT = carbon tetrachloride; CF = chloroform; c12DCE = *cis*-1,2-DCE. Several results representing detections are also qualified but for simplicity are not shown differently. Note logarithmic concentration scale.

Figure 250. Primary VOCs in Downgradient 903 Pad/Ryan's Pit Plume Wells

Figure 250 also illustrates a gradual differentiation in the concentrations of TCE and CT at well 90399: For the first 5 or 6 years shown, these constituents were present in approximately equal concentrations. In 2006 or 2007 the concentration of TCE gradually increased as that of carbon tetrachloride remained relatively unchanged. This is similar to the diverging concentrations of PCE and chloroform discussed above for source-area well 07391. Another interesting pattern is the apparent 30-month cycle in PCE and *cis*-1,2-DCE concentrations at this well that extends from May 2004 through the end of 2011: about every 30 months, samples report lower concentrations of these constituents, with subsequent samples showing renewed concentration increases. Causes of these behaviors are not certain; additional analytical data will be collected per the RFLMA and may help to define any long-term patterns and suggest relationships with environmental conditions such as climate and groundwater elevation.

AOC well 10304, which is located on the northern bank of and along the 903 Pad/Ryan's Pit Plume flow path to Woman Creek, directly south of Sentinel well 90399, was also sampled twice in 2011 per the RFLMA. No confirmed detections of VOCs were reported in either sample. Concentrations of nitrate were reported at 0.13 mg/L as N in both samples. Concentrations of U were 13 µg/L in the April sample and 8.8 µg/L in the October sample.

AOC well 00193, located at the mouth of Pond C-2, also supports the monitoring of the 903 Pad/Ryan's Pit Plume. This well was sampled in April and October 2011. No confirmed detections of VOCs were reported in either sample. Concentrations of U were 70 µg/L and 73 µg/L, respectively. This is consistent with previous data from this well, which has been characterized as producing samples with 99.2 percent to 100 percent natural U.

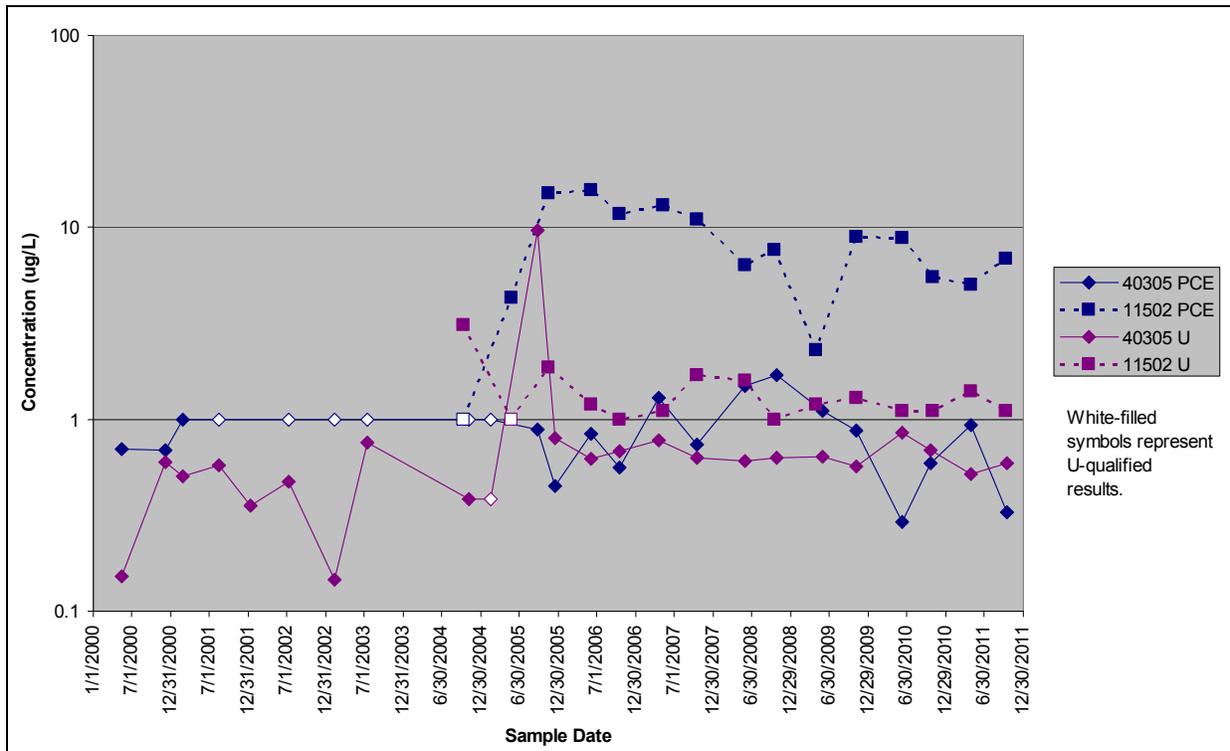
IA Plume

The IA Plume is actually a collection of several small VOC plumes grouped together for convenience and, in some cases, because of uncertainties regarding specific sources. This discussion addresses the IA Plume in terms of three loosely defined segments: the South, Central, and North IA Plumes.

The pathway to surface water for the southern portion of the IA Plume is monitored by AOC well 11104, which was sampled in May and October 2011. No confirmed VOC detections were reported in 2011. Concentrations of U, samples for which are collected to support monitoring of the OLF and former B444, continue to be well below the U threshold of 120 µg/L; results in 2011 were 22 µg/L and 23 µg/L.

Upgradient of well 11104, wells monitoring the South IA Plume include Sentinel wells 11502 and 40305, and Evaluation wells 40005, 40205, P419689, and P416889. In accordance with RFLMA, the Evaluation wells were not scheduled for sampling; only the Sentinel wells were sampled in 2011. Analytical results are consistent with past data.

As shown on Figure 251, concentrations of PCE and U are relatively low in samples from Sentinel wells 11502 and 40305. The highest concentration of PCE reported from these two wells in 2011 was 6.9 µg/L (well 11502, October sample). However, with a RFLMA Table 1 standard of 1 µg/L, concentrations of PCE in samples from well 11502 consistently exceed the standard. This has also been the case occasionally at well 40305, though not since 2009. With respect to U, all results are well below the U threshold value of 120 µg/L: in 2011, the highest concentration reported for these two wells was 1.4 µg/L (well 11502, April sample). Overall, the highest concentration of U from either well has been just under 10 µg/L at well 40305 in September 2005.



Notes: Applicable RFLMA surface-water action level for PCE is 1 µg/L, U threshold is 120 µg/L (DOE 2007a). Several detections were qualified but for simplicity are not shown differently. Note logarithmic concentration scale.

Figure 251. PCE and U in Sentinel Wells Monitoring the South IA Plume

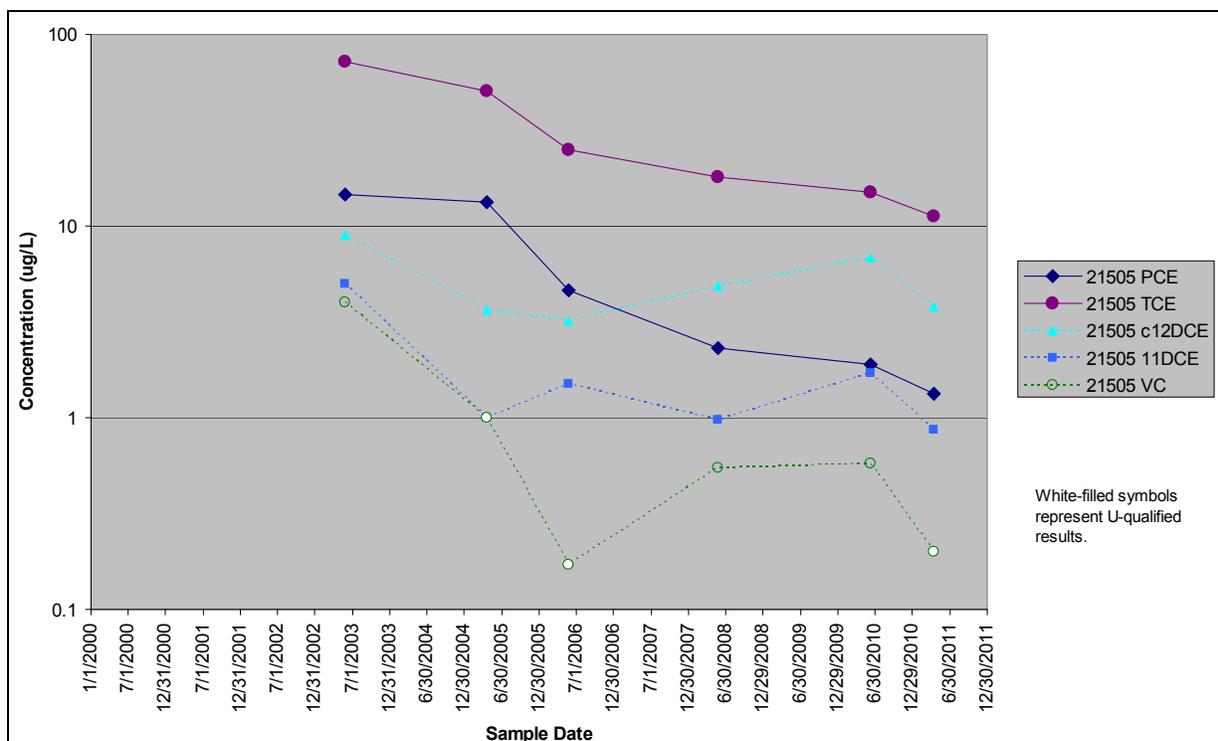
Sentinel wells 11502 and 40305 support no statistical trends with a significance of 95 percent (Table 91).

The central portion of the IA Plume, for the purposes of this report, is monitored by Evaluation wells P115589, P114689, 70705, 33905, 55905, and 56305. None of these wells was scheduled for sampling in 2011. However, all will be scheduled for sampling in 2012, and an updated discussion of water-quality conditions in this area of the IA Plume will be presented in the corresponding 2012 Annual Report.

Wells monitoring the North IA Plume include Evaluation well 21505 and Sentinel well 52505 along FC-2, and AOC well 42505 at the terminus of FC-2 at North Walnut Creek. Each of these was sampled in 2011, including the Evaluation well (to provide additional data to evaluate conditions discussed below and in the 2010 Annual Report [DOE 2011d]). Although they also monitor the North IA Plume, wells 18199, 20902, 20705, 20505, and 20205 are discussed below in the context of the IHSS 118.1 Plume; and wells 33502, 33604, and 33703 are discussed in the section on the Vinyl Chloride Plume.

Evaluation well 21505 was sampled in April 2011. Results continue to support some of the patterns suggested by previous data, as illustrated on Figure 252. With the addition of the 2011 data, concentrations of PCE and TCE are both now calculated to be on a decreasing trend with a significance of 95 percent. As noted in the 2010 Annual Report (DOE 2011d), this location is adjacent to a marshy area that is between the only two locations at which good

evidence for biodegradation was identified prior to site closure (Kaiser-Hill 2004d): well 33502, which monitors the Vinyl Chloride Plume within a buried drainage, and the predecessor to well 52505 (well 1986). Data from well 21505 suggest conditions at this location may also be conducive to biodegradation of chlorinated compounds, as concentrations of primary contaminants (in this case, PCE and TCE) are decreasing somewhat as those of their metabolic byproducts (particularly *cis*-1,2-DCE and 1,1-DCE) increase, though the 2011 results for these byproducts showed a slight drop from their 2010 levels (Figure 252). Concentrations of VC, the terminal chlorinated byproduct in the PCE/TCE degradation pathway, do not define a clear pattern.



Notes: Applicable RFLMA surface-water action level for PCE (ug/L; DOE 2007a) is 1, TCE is 2.5, *cis*-1,2-DCE is 70, 1,1-DCE is 7, and VC is 0.2. Several detections were qualified but for simplicity are not shown differently. Note logarithmic concentration scale.

Figure 252. VOC Concentrations in North IA Plume Well 21505

The terminal end of the North IA Plume is monitored by Sentinel well 52505, nearby Surface Water Support location SW018, and AOC well 42505. Both of the wells and the surface-water location were sampled twice in 2011 (April and October).

Sentinel well 52505 reported detections of *cis*-1,2-DCE in both samples (0.39 µg/L, 0.58 µg/L, respectively; RFLMA Table 1 value is 70 µg/L). These are consistent with previous data. No other detections were reported for this well. As noted in the 2010 Annual Report (DOE 2011d), the numerous nondetects in the dataset may be a factor in the calculated increasing trend in *cis*-1,2-DCE at well 52505, which has a 95 percent level of significance (Table 91). No other trends were calculated at this well.

No VOCs were detected in either sample collected from AOC well 42505, but *cis*-1,2-DCE was detected in the October 2011 sample collected from Surface Water Support location SW018. The estimated (J-qualified) result was low, at 0.28 µg/L. (The RFLMA Table 1 value is 70 µg/L.) This is not atypical: with the exception of 2008, this constituent has been detected at this location every year since the Site closed. Other VOCs have also been detected here in the past at levels well below applicable RFLMA levels, including TCE, methylene chloride, and styrene, but only the single *cis*-1,2-DCE detection was reported in 2011.

VC Plume

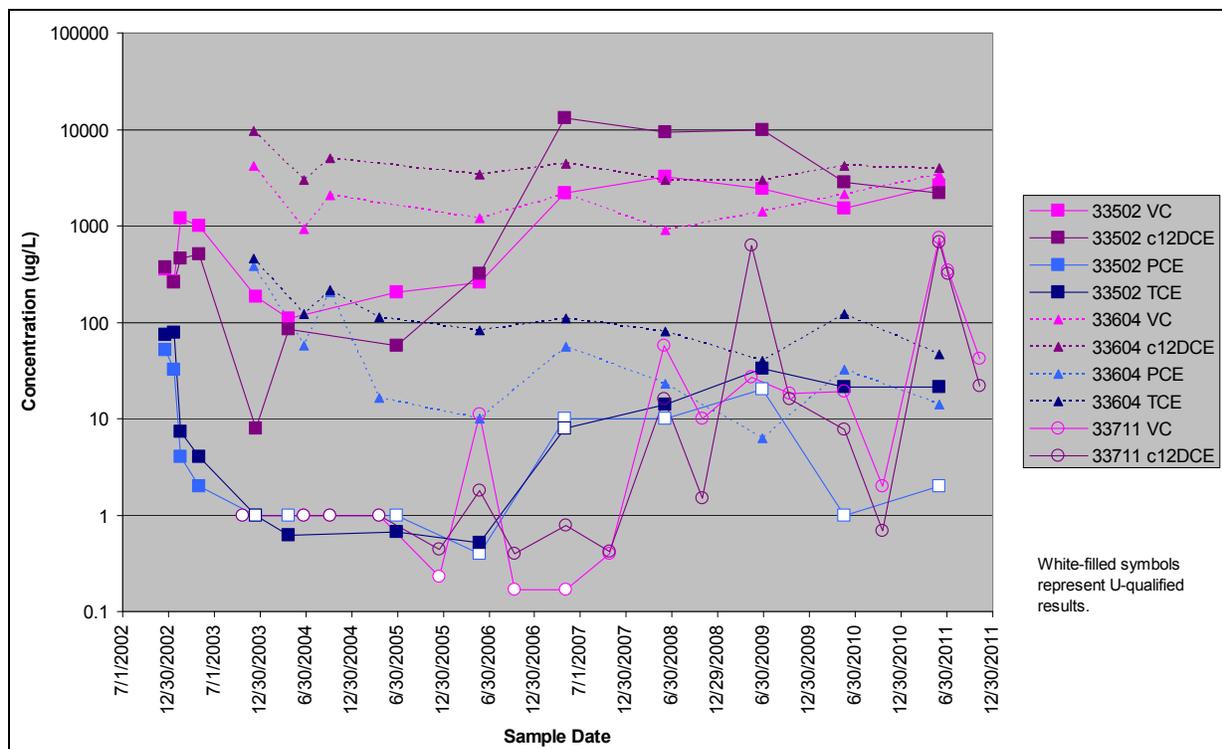
The VC Plume emanates from OBP#1 and nearby metal disposal/destruction sites. These source areas were on the margin of a valley that was filled during construction of the B371 complex and became the site of Sage Avenue and the Portal 2 parking lots, among other facilities. The plume is within the buried drainage, and groundwater flow appears to be routed by that feature. This is the only Rocky Flats area where VC is confirmed to be present at such elevated concentrations, which is one indication of the active biodegradation occurring here.

The VC Plume is monitored by source-area Evaluation wells 33502 and 33604, the former of which is located some 175 feet generally upgradient of the latter. The plume is also monitored by a Sentinel well located approximately 110 feet downgradient of 33604. (This Sentinel well developed a kink in its casing and, in 2011, was replaced. The original well identification was 33703, while its replacement—located approximately four feet from the original—is 33711. Discussions regarding conditions at this well will henceforth refer to it as 33711 unless specifically stated otherwise.)

To support continuing assessment of conditions at this plume as well as the replacement of well 33711, both Evaluation wells were also sampled in 2011 (June), and the Sentinel well was sampled in May and November 2011. Observed concentration differences in the replacement well as compared to the typical results from predecessor well 33703, as discussed further below, led to a non-RFLMA confirmatory sample being collected from well 33711 in July.

Well 33502 is one of only two locations where strong evidence for biodegradation was found (K-H 2004d); the second location identified in that report is well 1986, the predecessor to well 52505, as discussed above. (If it had existed at the time of that study, well 33604 almost certainly would have provided similarly strong evidence for biodegradation.) This is taken as an explanation for both the high concentrations of VC and *cis*-1,2-DCE as well as the extremely limited aerial extent over which these concentrations have been observed. This biodegradation is thought to be a result of the decomposing organic remains of vegetation that once grew within the now-buried valley; these wells monitor groundwater within the filled valley. This decomposition process would consume oxygen, providing both an anaerobic environment and carbon source suitable for the naturally-occurring bacteria that perform reductive dechlorination of the solvents most commonly found at the Site. Parent compounds, including PCE and TCE, are also detected in the groundwater in this area but at much lower concentrations than those of their metabolic byproducts. While VC and *cis*-1,2-DCE are reported in groundwater samples from source-area wells 33502 and 33604 at concentrations in the hundreds to thousands of micrograms per liter, PCE and TCE are typically reported in the tens to hundreds (and PCE is frequently not detected in samples from well 33502, as has been the case since late 2003, including the sample collected in 2011).

A time-series plot of the concentrations of primary parent and daughter compounds in source-area wells 33502 and 33604 and downgradient well 33711 is presented as Figure 253. Contaminant concentrations illustrated for well 33502 are fairly consistent, though concentrations of *cis*-1,2-DCE for the past two years have been significantly lower than in samples collected from 2006 through 2009. Also relatively consistent are the contaminant concentrations illustrated for well 33604. Despite these visual appearances, decreasing trends are calculated (Appendix B; Table 91) at the 95 percent level of significance for PCE at well 33502 and TCE at well 33604. However, that for well 33502 is based on a dataset that contains numerous nondetects, and therefore may not be valid.



Notes: VC = vinyl chloride; c12DCE = *cis*-1,2-DCE. Applicable RFLMA surface water action levels for these constituents (µg/L; DOE 2007a): VC, 0.2; *cis*-1,2-DCE, 70; PCE, 1; TCE, 2.5. In addition to the nondetects (U-qualified results), several detections were qualified but for simplicity are not shown differently. Note logarithmic concentration scale.

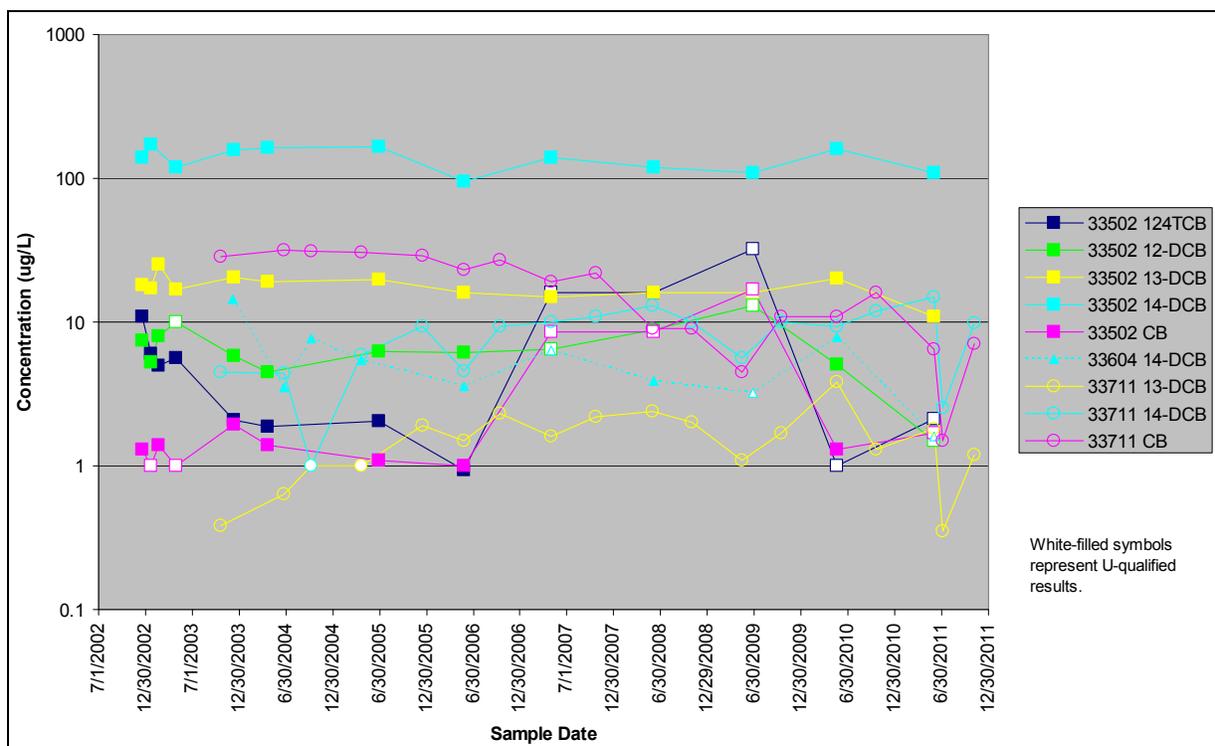
Figure 253. Primary VOCs in the VC Plume Source Area

As is expected in this area, concentrations of the daughter products *cis*-1,2-DCE and VC remain well above those of parent compounds PCE and TCE. These parent constituents are not illustrated for well 33711 because they are very often not detected. Taken together, the samples collected in 2011 from 33711 reported concentrations of PCE and TCE in the range of nondetect to an estimated concentration of 1.5 µg/L—clearly much lower than those of the daughter products. As illustrated on Figure 253, the concentrations of *cis*-1,2-DCE and VC from the replacement well, which provided all samples collected at this location in 2011, appear to be higher than those from the original well. This may or may not be indicative of any broad trends, as concentrations of *cis*-1,2-DCE in May 2009 samples from the original well are similar to those reported in the replacement well in June 2011. The 2011 concentrations of VC in the

replacement well are higher than those reported previously in the original well, but seasonal highs are evident in the dataset and may be the explanation for the increases in second-quarter 2011, rather than well replacement. The fourth quarter 2011 samples showed strong decreases in the concentrations of both of these daughter products at well 33711: *cis*-1,2-DCE dropped from a high in June of 680 µg/L to 320 µg/L in July and then to 22 µg/L in November, and VC dropped from 750 µg/L to 340 µg/L to 42.2 µg/L in the same months (Figure 253).

Several trends with a 95 percent level of statistical significance are calculated for well 33711 (see Appendix B and Table 91), including increasing concentrations of both illustrated daughter products (Figure 253). These may relate to enhanced plume migration resulting from the removal of overlying impermeable surfaces, which would in turn permit direct recharge via precipitation and snowmelt. However, despite the increase in localized recharge and the oxygenated condition of this infiltrating water, to date there appears to have been no precipitous decrease in biodegradation of the parent compounds. Note that there are numerous nondetects in the VC dataset, which could affect the validity of the calculated trend.

As previously reported (e.g., DOE 2011d), several chlorinated benzene compounds are also detected in samples from VC Plume wells. These most commonly include one or more of the following: 1,2,4-trichlorobenzene, 1,2-dichlorobenzene, 1,3-dichlorobenzene, 1,4-dichlorobenzene, and chlorobenzene. These compounds are industrial and agricultural chemicals; one of the primary uses for several are as pesticides or insecticides. Figure 254 presents time-series plots for the most commonly detected of these compounds in the three VC Plume wells. No 1,2,4-trichlorobenzene has been detected in samples from wells 33604 or 33703, and the last time it was reported in a sample from well 33502 was May 2006. (A decreasing trend that is 95 percent significant is calculated for 1,2,4-trichlorobenzene (TCB) at this location, but a third of the results in the data set are nondetects.) This compound can be degraded anaerobically to both 1,2-DCB and 1,4-DCB, which then can degrade to chlorobenzene (USGS 2006). Therefore, degradation of 1,2,4-TCB may be a factor in the presence of 1,2-DCB and 1,4-DCB, as well as the chlorobenzene that is occasionally detected in samples from well 33502.



Notes: Applicable RFLMA surface-water action levels for these constituents (µg/L; DOE 2007a): 1,2,4 TCB (trichlorobenzene) 35; 1,2-DCB (dichlorobenzene) 94; 1,4-DCB 63; CB (chlorobenzene) 100. In addition to the nondetects (U-qualified results), several other results were qualified but for simplicity are not shown differently. Note logarithmic concentration scale.

Figure 254. Chlorinated Benzene Compounds in Samples from VC Plume Wells

Nearest to well 33502 is well 33604, which has not reported any detections of 1,2-DCB. Well 33604 reports concentrations of 1,4-DCB that are low and inconsistent (and often nondetect), and chlorobenzene has only been detected once (in 2003). Conversely, concentrations of 1,4-DCB at well 33502 consistently exceed the 63 µg/L RFLMA standard. Chlorobenzene is detected more frequently at well 33502, but not consistently and only in the 1-2 µg/L range.

Downgradient of the source area monitored by Evaluation wells 33502 and 33604, Sentinel well 33711 reports infrequent detections of 1,2-DCB. Although well below the applicable RFLMA Table 1 value, concentrations of 1,4-DCB have increased in samples collected from this location, and support calculation of an increasing trend meeting the 95 percent level of significance (Table 91). An increasing trend with a 95 percent significance is also calculated at well 33711 for *trans*-1,2-DCE (see Appendix B for trend plots).

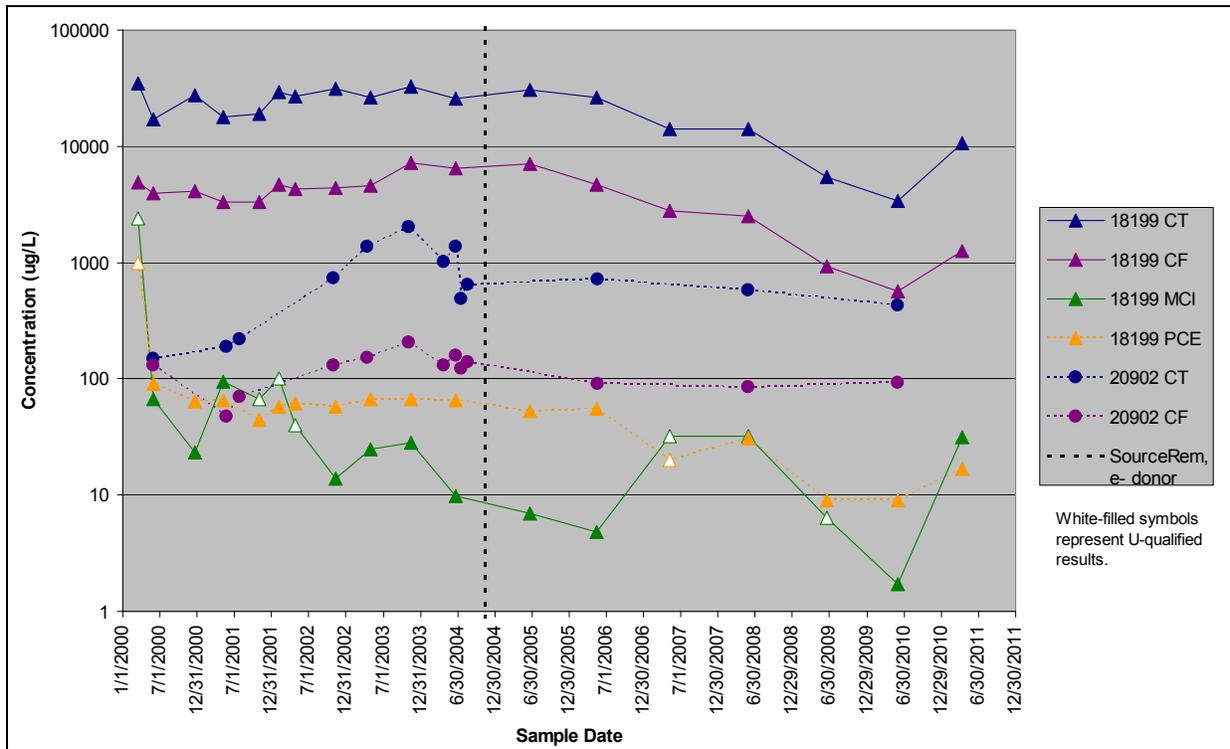
A decreasing trend with a 95 percent significance is calculated at well 33711 for chlorobenzene (Figure 254; see also Appendix B for trend plots and Table 91 for a summary of calculated trends). Suggestions of a rebound in chlorobenzene concentrations, based on results from samples collected in 2009 and 2010, were not confirmed in 2011. A decreasing trend of similar significance, which is based on a data set containing numerous nondetects, is calculated at well 33502 for naphthalene.

IHSS 118.1 (Carbon Tetrachloride) Plume

Former IHSS 118.1 is the source of a plume of groundwater contaminated with carbon tetrachloride. In late 2004, dense, nonaqueous phase liquid source material was removed along with an adjacent subsurface tank group referred to as B730. Electron donor material was added to the backfill material to enhance biodegradation of residual contamination.

Evaluation well 18199 is one of several installed in 1999 to support characterization of the source area. This well is located immediately north of the former IHSS, roughly 80 to 90 feet north-northwest of the area in which free-phase carbon tetrachloride was present and perhaps 30 feet north of the source-removal excavation boundaries. The plume has been mapped to extend to Evaluation well 20902, located approximately 350 feet to the northwest. Although Evaluation wells were not scheduled for routine RFLMA monitoring in 2011, source-area well 18199 was sampled in April. The three Sentinel wells generally north of the source area, along the northern side of former B771, were also sampled in 2011 (in April and October) and support the evaluation of this plume to determine whether a more northerly groundwater flow path from the IHSS 118.1 source area is indicated. (With the closure of B771 and abandonment of the associated foundation drain system, the anticipated flow path for this plume was more northerly). In addition, Surface Water Support location SW018 was sampled, as was AOC well 42505. These latter two locations are discussed above in the context of the North IA Plume and will not be addressed here.

In contrast to the steadily decreasing concentrations of contaminants observed through 2010 (discussed in DOE 2010d and 2011d), in 2011 the concentrations of carbon tetrachloride and its daughter products, chloroform and methylene chloride, as well as PCE, showed some rebound in the sample collected from well 18199. This is illustrated on Figure 255. Even so, with the addition of the 2011 data for well 18199, a decreasing trend in both carbon tetrachloride and PCE is now calculated at the 95 percent level of significance (Table 91 and Appendix B). As previously noted, increased rates of biodegradation due to application of electron donor material do not appear to be the mechanism of this decrease: there are no evident increasing trends in the concentrations of the principal carbon tetrachloride daughter products, chloroform, methylene chloride, and chloromethane (the terminal daughter products, methane and CO₂, are not analyzed), with corresponding decrease in carbon tetrachloride. Other daughter products, such as (for PCE) TCE, *cis*-1,2-DCE, and VC, are most often not detected, though in the 2011 sample all three were detected at very low, J-qualified (estimated) concentrations. The decreasing trends observed are therefore thought to be due to removal of the source material, rather than metabolic dechlorination of residual contamination.



Notes: CT = carbon tetrachloride; CF = chloroform; MCI = methylene chloride; Source Rem, HRC = date on which source removal and backfilling with soil and HRC was completed. Applicable RFLMA surface-water action levels for these constituents ($\mu\text{g/L}$; DOE 2007a): CT, 1; CF, 3.4; MCI, 4.6; PCE, 1. Several results were qualified (qualifier J; qualifier D; and, for methylene chloride in particular, qualifier B), but are not shown differently for simplicity. Note logarithmic concentration scale.

Figure 255. Concentrations of VOCs in the IHSS 118.1 Plume

Sentinel wells 20705, 20505, and 20205, all of which are located generally north of IHSS 118.1 and the former B771 complex, are monitored to evaluate the effects on groundwater of the closure of B771 and to determine whether a more northerly groundwater flow path from the IHSS 118.1 source area is indicated. As in previous years, such a path is not suggested by analytical data collected in 2011, which are generally consistent with pre-closure results. The three detections of low concentrations of carbon tetrachloride reported in 2008 and early 2009 were not confirmed in 2010 or 2011. The only detection of chloroform in 2011 was reported at an estimated (J-qualified) concentration of $0.27 \mu\text{g/L}$ in the fourth-quarter sample collected from well 20205, which is located at the eastern end of this line of three wells, just north (downgradient) of former Bowman's Pond and B774. Chloromethane, another metabolic byproduct of carbon tetrachloride, was also detected once and reported at an estimated, blank-contaminated concentration of $0.21 \mu\text{g/L}$ (i.e., qualified with J and B) in a sample collected from well 20705 in April. These 2011 results do not suggest a strong northerly flow component to the IHSS 118.1 Plume.

Seepage velocities summarized in Table 52 are similar to those calculated in previous years and indicate that contaminants in the groundwater migrating from source area well 18199 to downgradient well 20505 could have been detected in this downgradient well as early as 2006; the velocities calculated using 2011 water level data are slightly more than one year. (As previously explained, this estimated velocity applies to pure water, not contamination.) Based on

the analytical data collected through 2010, IHSS 118.1 contaminants have still not reached the downgradient well (20505), or others in its vicinity (20205, 20705). While it would take some time for groundwater to saturate the backfill of the former B771 area, observations of seeps on this hillside (see Section 3.1.3.6) suggest that has been completed. The lack of strongly elevated concentrations of IHSS 118.1 Plume contaminants in samples collected from downgradient wells may be evidence of contaminant retardation, or it could indicate that groundwater is being diverted in another direction. It could also indicate that these constituents are being degraded before they reach downgradient wells, though the lack of other indications of degradation suggests this is not the case. While a flow path from 18199 to 20505 appears reasonable, groundwater may be diverted (for example, around the sides of the building) by the presence of disrupted foundation drains and associated corridors, the backfilled B771, and backfilled/disrupted subsurface utility corridors. Evidence for this may be represented by the previously-reported, relatively consistent concentrations of these contaminants in well 20902, which was downgradient of the source area before the foundation drains were disrupted and the building was removed. These wells will continue to be monitored and the data assessed to evaluate the potential for contaminant migration from IHSS 118.1.

Consistent with previous years, other VOCs that are less representative of the IHSS 118.1 Plume were detected at low concentrations in samples from the B771-area Sentinel wells. Bowman's Pond-area well 20205 reported detections of PCE and TCE in both samples, and one detection of *cis*-1,2-DCE. Each of these results was J-qualified (estimated). Well 20505, which is closer to the predicted northerly flow path from IHSS 118.1, also reported detections of VOCs in both samples collected in 2011. These included 1,1-DCE, *cis*-1,2-DCE, TCE, and VC. With the exception of the *cis*-1,2-DCE detections, each result was J-qualified. Finally, well 20705, the westernmost of this line of wells and located nearest FC-2, also reported detections of daughter products *cis*-1,2-DCE and VC, with all being J-qualified except for the 1 µg/L *cis*-1,2-DCE detection in the October sample. The VOC constituents detected in B771 wells in 2011 all represent parent and daughter products from the PCE chain, not the primary IHSS 118.1 contaminant, carbon tetrachloride. These results suggest that the former B771 hillside does not represent a significant pathway for VOC migration.

Several trends were calculated for the three Sentinel wells monitoring B771 (Table 91; Appendix B). Those that are at least 95 percent statistically significant include PCE (increasing at well 20205, but the data set contains numerous nondetects), U (increasing at both 20205 and 20705, but potentially affected by well replacement), *cis*-1,2-DCE (decreasing at well 20505), TCE (decreasing at well 20505), and americium (decreasing at well 20705, but the dataset includes numerous nondetects, is potentially affected by well replacement, and reflects now-resolved borehole artifacts). Time-series plots of U concentrations in samples from all three of these wells are provided below in Figure 256. From this figure, it can be seen that concentrations of U in samples from wells 20505 and 20705 are similar, while those from well 20205 are higher. Even so, these values remain well below the U threshold.

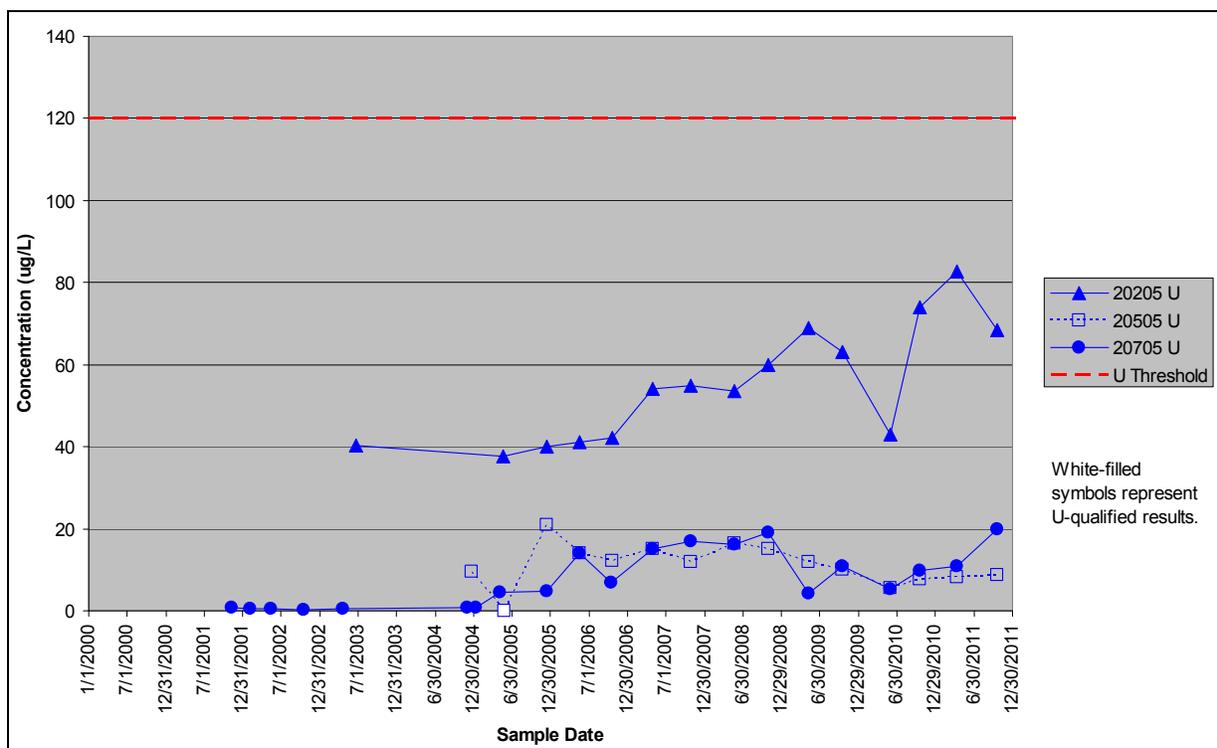


Figure 256. U in Groundwater Along North Side of Former B771

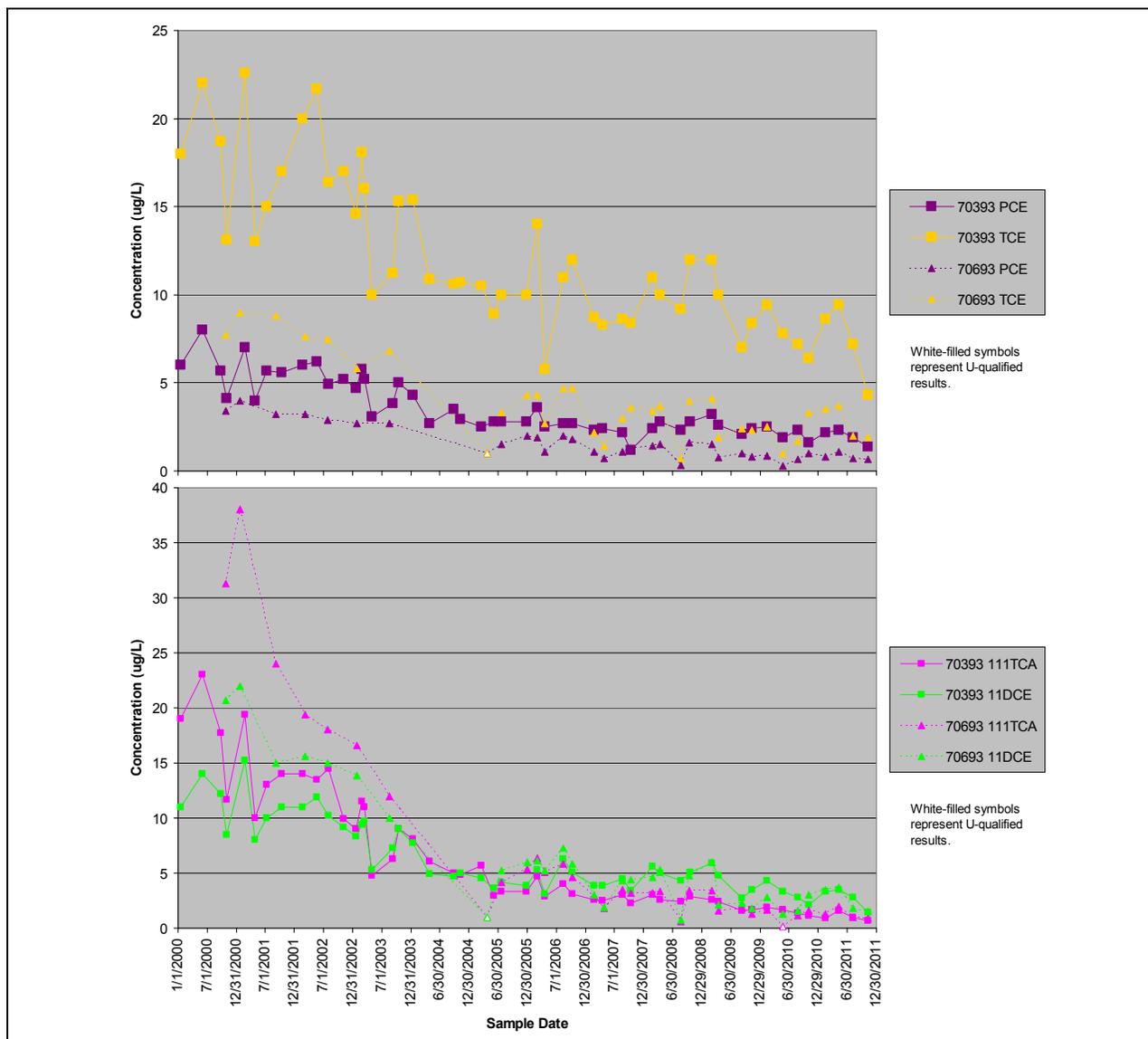
These wells will continue to be monitored and the data evaluated in accordance with RFLMA.

PU&D Yard Plume

The PU&D Yard Plume is an area of groundwater with low concentrations of primarily PCE-family VOCs (PCE, TCE, and *cis*-1,2-DCE). This area was the site of the first application at Rocky Flats of electron donor material, in which a proprietary carbon source (HRC) was tested in a treatability study begun in early 2001 (K-H 2001, 2002b; see K-H 2005b for a final summary report on this study). This plume is monitored by Evaluation well 30900 in the source area and Sentinel well 30002 to the east, at the margin of North Walnut Creek. In addition, upgradient PLF RCRA wells 70393 and 70693 monitor the plume as it flows toward the PLF. In accordance with RFLMA, the source-area Evaluation well was not scheduled for sampling but each of the other wells was monitored in 2011.

Sentinel well 30002 was sampled for VOCs in April and October 2011. No VOCs were detected in either sample. The upgradient RCRA wells were sampled quarterly, per the RFLMA, and reported VOC detections that are typical at these locations. No VOCs were detected at northern upgradient well 70193, but several VOCs were detected at both 70393 and 70693. Commonly detected VOCs at these wells include PCE, TCE, 1,1,1-TCA, and 1,1-DCE. Time-series plots of these constituents in wells 70393 and 70693 are presented as Figure 257. As illustrated, concentrations of each of these compounds are gradually decreasing. TCE is a daughter product of PCE as well as being used itself during the production era at Rocky Flats. 1,1-DCE is a daughter product of PCE, TCE, and 1,1,1-TCA dechlorination. There is no apparent relative increase in daughter products with respect to the parent products. Each constituent appears to be

decreasing at a similar rate, suggesting the degree of biologically enhanced dechlorination in this area is minor.



Notes: Applicable RFLMA surface-water action levels for these constituents ($\mu\text{g/L}$; DOE 2007a): PCE, 1; TCE, 2.5; 1,1,1-TCA, 200; 1,1-DCE, 7. Several detections were qualified but for simplicity are not shown differently.

Figure 257. Concentrations of Primary PU&D Yard Plume VOCs in Upgradient PLF RCRA Wells

OU 1 Plume

The OU 1 Plume is located on the 881 Hillside, east of former B881 and immediately south of the former Contractor Yard. Its source area, former IHSS 119.1, was a drum and scrap metal storage area. This source area is monitored by Evaluation well 891WEL (the modification of which, in 2005, has been detailed in previous documents, e.g., DOE 2006c), and the pathway to surface water is monitored by AOC well 89104, located to the south adjacent to Woman Creek (Figure 2).

Evaluation well 891WEL was not scheduled for sampling in 2011, but AOC well 89104 was sampled twice, in May and October 2011. No VOCs were detected.

Per RFLMA, all Evaluation wells will be scheduled for sampling in 2012. An updated discussion of conditions in the OU 1 Plume source area will be provided as part of the 2012 Annual Report.

Other Areas

In addition to the major plumes discussed above, other areas warrant mention because they may be of interest. These are summarized below.

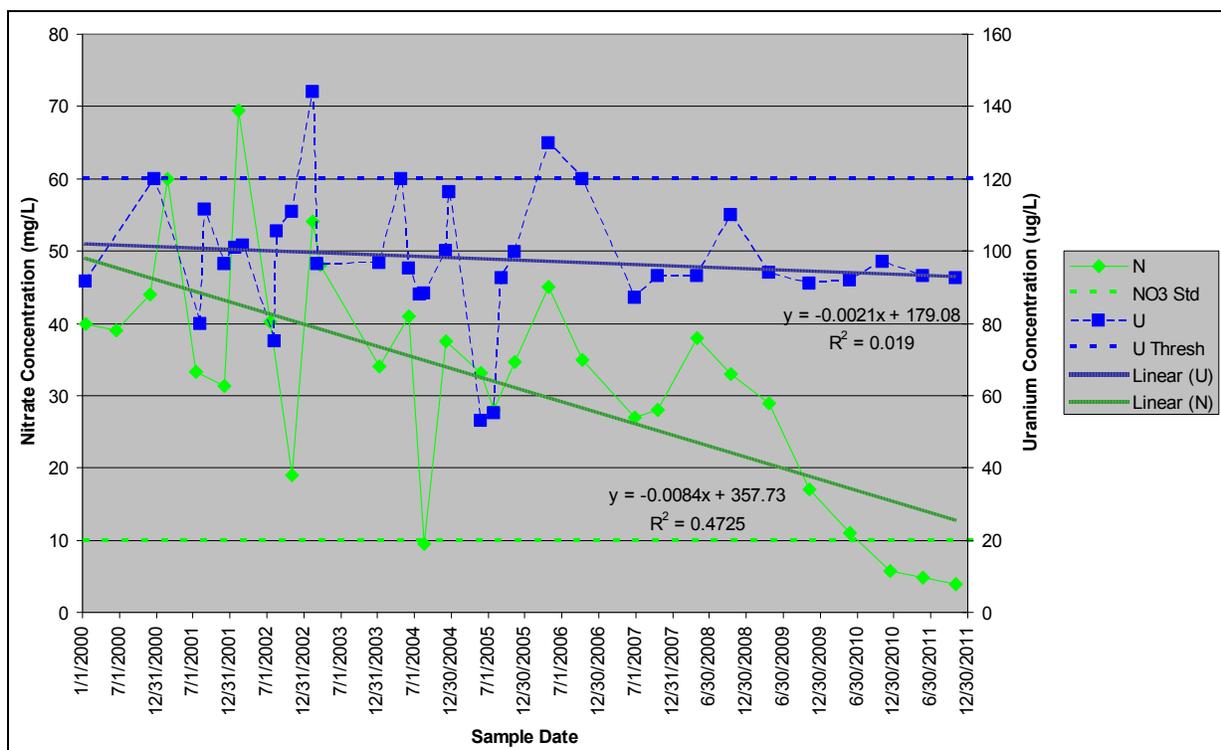
AOC well B206989: This well is located east of the Landfill Pond dam, which is scheduled to be breached in 2012. Well B206989 entered a reportable condition in 2007 due to concentrations of nitrate that exceeded the applicable RFLMA Table 1 standard of 10 mg/L for that location. (The Temporary Modification value of 100 mg/L nitrate, effective through the end of CY 2009, did not apply to the No Name Gulch drainage.) Concentrations of nitrate that exceeded 10 mg/L in samples from this well were neither new nor unexpected; instead, the reportable condition was set up by the well being reclassified from a Sentinel well, with no reportable conditions associated, to an AOC well upon the signing of RFLMA. Rather than waiting for two successive samples to exceed the 10 mg/L standard, upon receipt of the first results after RFLMA went into effect (which exceeded the applicable RFLMA standard, as expected), DOE held discussions with CDPHE, and Contact Record 2007-06 was issued to document the resulting agreement.

As reported in the 2008 Annual Report (DOE 2009d), concentrations of nitrate in the well had met the 80 percent level of significance for a decreasing trend. Additional discussions were held with CDPHE. As a result, in 2009 surface water was sampled at two locations in No Name Gulch downstream of the well (DOE 2010d). Nitrate was not detected in either sample.

In 2009, the decreasing trend in nitrate at this location was calculated to meet the 95 percent level of significance. Data collected since then, including those from 2011, continue to support this trend (see Table 91 and Appendix B.3). The results from 2011 continued to set new lows for nitrate concentrations at well B206989, with the sample collected in May reporting a concentration of 4.8 mg/L and the November sample reporting 3.87 mg/L.

At the same time, concentrations of U in groundwater samples from well B206989 have not exceeded the 120 µg/L total U threshold since 2006. Concentrations of this analyte appear to have leveled off over the past several years.

Both of these constituents (nitrate and U) are illustrated in time-series plots on Figure 258. The trend lines shown on this figure for each constituent are simple regression curves; the associated negative slopes indicate the general trends are decreasing, but the low R^2 values for each of these trend lines, especially U, confirm the data are widely variable. The statistical trend tables and plots in Appendix B offer more valid statistical results. Even so, it should be noted that in comparison with the regression lines provided in the 2010 Annual Report (DOE 2011d), the decreasing trends have steepened slightly and the associated R^2 values have increased for both constituents, particularly nitrate.

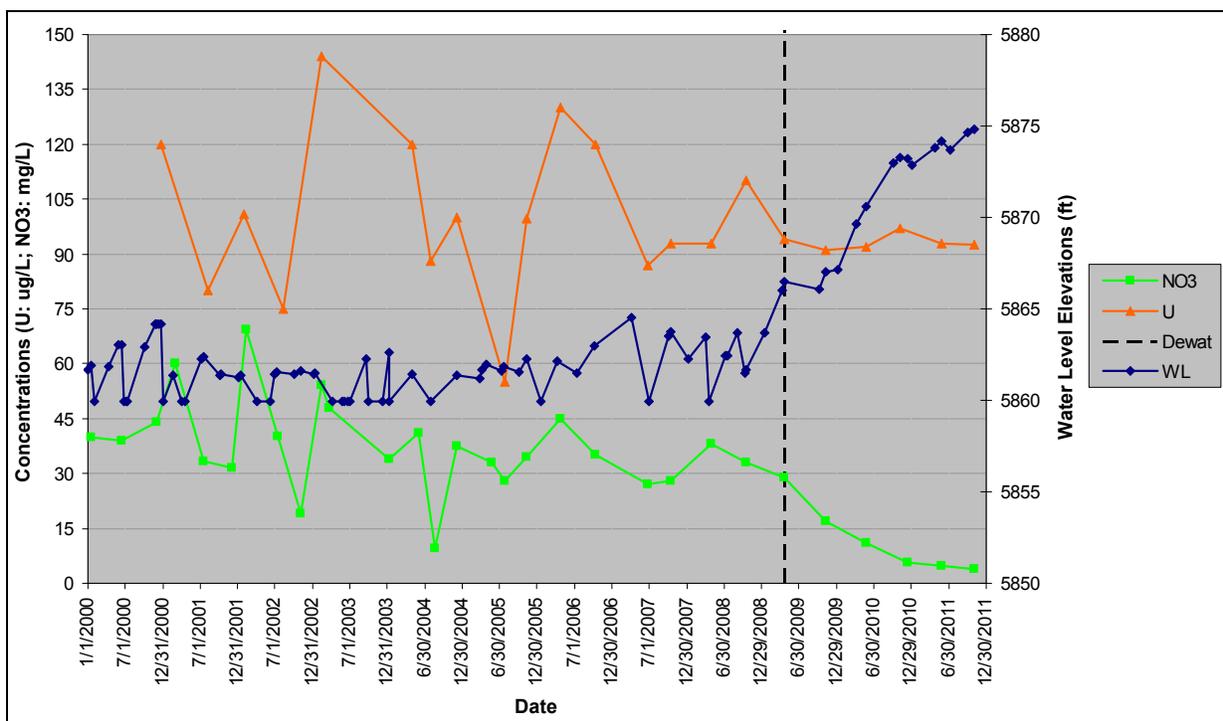


Notes: N = nitrate, NO3 Std = nitrate standard, U = uranium, U Thresh = uranium threshold. The applicable action level for nitrate is 10 mg/L; that for U is 120 µg/L (DOE 2007a). Simple linear regression trend lines are shown for each, together with the corresponding equation and correlation coefficient. Note the use of two y axes to help illustrate the concentrations of the different constituents.

Figure 258. Concentrations of Nitrate and U in Groundwater Samples from AOC Well B206989

Figure 259 illustrates how concentrations of nitrate and U have varied with respect to the groundwater levels in this well as controlled by sampling method. An obvious rise in the water level in this well is seen starting in late 2008, the same time concentrations of nitrate started to decrease sharply and those of U leveled off. These changes have nothing to do with Site closure, but rather are reflections of a change in how samples are collected from low-producing wells (such as B206989) at Rocky Flats. The standard approach had been to purge stagnant water from the well and then sample fresh recharge. This particular well—and several other low-producing wells at the Site—typically dewatered during the purging process. Samples were then collected from the recharge, which would have cascaded into the well casing down and through the filter pack and casing perforations; with the exception of samples for VOCs, these recharge samples might be collected some days later. The last time this process was followed at well B206989 was in April 2009. Data reported after that date reflect a procedural modification: now, a minimal volume of water is purged solely to rinse and acclimate sampling equipment to the well water, and then samples are collected. Aquifer tests have documented that it can take many months for water levels in some low-producing wells to stabilize. Figure 259 suggests that the historic sampling procedure for well B206989 did not allow the water level in this well to stabilize, and one result of this was erratic and elevated concentrations of nitrate and U.

If the reduced variability in water levels and concentrations seen over the recent past continues, these patterns will be more strongly confirmed.



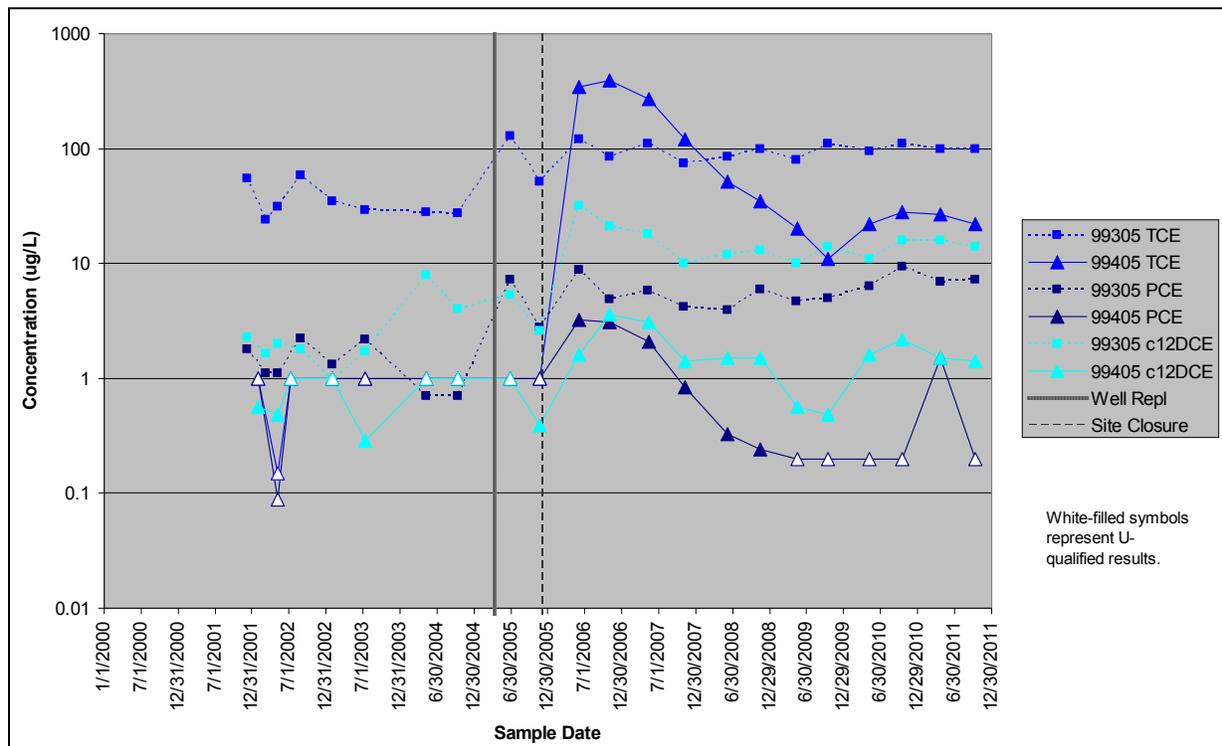
Notes: NO3 = nitrate, U = uranium; Dewat = last sampling date on which the well was dewatered. Note dual-unit concentration scales.

Figure 259. U and Nitrate Concentrations vs. Water Level and Sampling Method in AOC Well B206989

Former B991: Groundwater samples from wells 99305 and 99405 are monitored for VOCs, nitrate, and U. Both of these wells are located near the eastern edge of former B991, with well 99405 positioned in the east loading dock area, slightly southwest of well 99305 and closer to FC-4 and the valley bottom. Samples collected in April and October 2011 continued the post-closure pattern of higher concentrations of VOCs than were typical prior to closure. Noteworthy constituents include PCE, TCE, and *cis*-1,2-DCE.

Figure 260 illustrates results for these constituents in both wells, and indicates when the wells were replaced (when 99305 replaced 99301, and 99405 replaced 99401) and when the Site closed. As shown on this figure, VOC-related water quality changes occurred suddenly and uniformly for these three constituents at well 99405, and seemed to coincide more closely with Site closure than B991 demolition, though well replacement may also be a factor, especially at well 99305. (The original wells were abandoned prior to building demolition, and the replacement wells were installed after building closure and hillside grading had been completed. Therefore, B991 demolition took place between the last data points from the original wells—in late 2004—and the indicated well replacement date.) Since that initial increase in VOC concentrations reported at well 99405, concentrations have been generally decreasing, though concentrations in 2010 and 2011—particularly for *cis*-1,2-DCE—are not consistent with this pattern. Conversely, concentrations of PCE, TCE, and *cis*-1,2-DCE in samples from well 99305 appear to have started to increase earlier, perhaps coinciding with B991 closure. However, because their increase was more erratic and not as sharp as at well 99405, the timing is less certain: concentrations of *cis*-1,2-DCE in well 99305 show some increase as early as 2004, with a second increase in 2006, while PCE and TCE data suggest a single increase in 2005. In

addition, subsequent to Site closure, concentrations of these constituents in samples from well 99305 have not followed the same decreasing pattern as at 99405, instead remaining comparatively uniform.

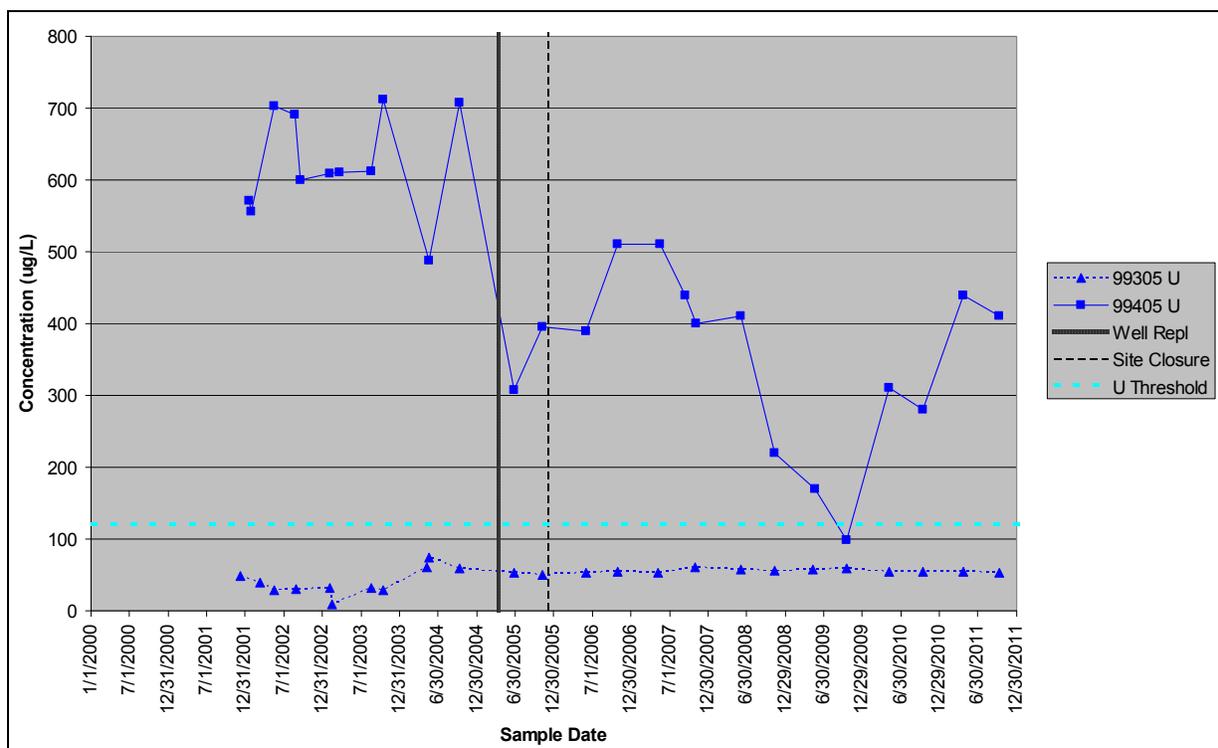


Notes: c12DCE = *cis*-1,2-DCE; Well Repl = well replacement. Applicable RFLMA action levels for these constituents (µg/L; DOE 2007a): PCE, 1; TCE, 2.5; *cis*-1,2-DCE, 70. In addition to the nondetects (U-qualified results), several other results were qualified but are not shown differently for simplicity. Note logarithmic concentration scale.

Figure 260. Concentrations of Primary VOCs in B991-Area Groundwater

Statistical trends with a 95 percent level of significance apply to several constituents detected in samples from these wells. With one exception discussed below, each of these trends is increasing; they apply to *cis*-1,2-DCE, PCE, and TCE at well 99305, and *cis*-1,2-DCE and TCE at well 99405. The trend for TCE at well 99405 is suspect due to the numerous nondetects in the data set.

Concentrations of U in samples collected from 2006 through 2009 at well 99405 displayed a remarkable decrease (Figure 261), but since 2010 the concentrations have increased to levels that are generally more consistent with previous conditions. From an overall high slightly greater than 700 µg/L prior to closure, in 2009 the concentration of U at this location had decreased to 98 µg/L. However, concentrations in 2010 were in the 300 µg/L range and in 2011 were in the low 400 µg/L range (440 µg/L in April, 410 µg/L in October). Despite the increasing concentrations over the last two years, a decreasing trend having a 95 percent level of statistical significance is still calculated for U at this location (Table 91, Appendix B).



Notes: Applicable RFLMA action level ($\mu\text{g/L}$; DOE 2007a) for U (threshold), 120. U data include results for U-mass and converted isotopic activities. Several detections were qualified but for simplicity are not shown differently.

Figure 261. Concentrations of U in B991 Sentinel Wells

Mechanisms responsible for the variable U concentrations in samples from well 99405 are not certain. The springs of 2009 and 2010 were both relatively moist, and although concentrations of U did not behave similarly in those two years, the increases seen in 2010 and 2011 may reflect a delayed response to the additional recharge. The change in sampling methods mentioned previously, from purging and potentially dewatering low-producing wells (including well 99405) to a more limited purge, also may have had some effect on U and VOC concentrations in this well. This well was not dewatered after the sampling event of November 2007, but the associated data (Figure 260 and Figure 261) do not suggest a strong correlation with the change in methods. Other possible mechanisms include hydrologic and geochemical changes that have occurred as a result of Site closure, such as removal of the water supply, associated leakage, and chlorinated water; removal of impermeable surfaces and resumption of direct recharge of groundwater by precipitation; removal of foundation drains; and so on, with possible changes in redox conditions as a result of some of these factors.

Located only about 115 feet from well 99405, well 99305—which also was typically dewatered through the November 2007 sampling event—produces samples with U concentrations that are about an order of magnitude lower than those from 99405. Since late 2004, samples from this well have reported concentrations of U that are consistently within the range from 50.6 $\mu\text{g/L}$ to 61 $\mu\text{g/L}$. Compared with results from well 99405, U data from well 99305 have remained remarkably uniform since late 2004 (Figure 261), and in 2011 were reported at 54 $\mu\text{g/L}$ and 53 $\mu\text{g/L}$ for April and October, respectively. Although not apparent on Figure 261, concentrations of U at well 99305 are calculated to be on an increasing trend with a 95 percent

level of statistical significance. The early (2001–2003) lower-concentration data from this well may be responsible for this statistical result.

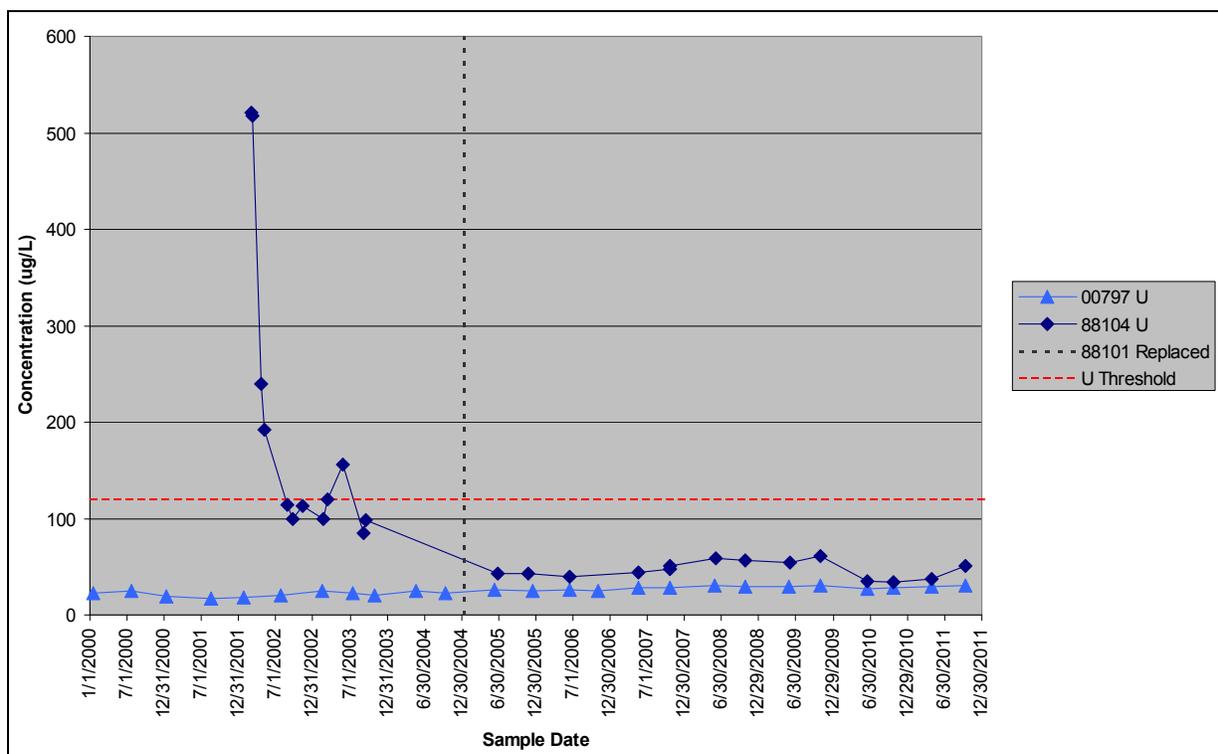
As previously reported, the elevated U at well 99405 is not Site-related: U in this well, as in well 99305, has been repeatedly characterized as 100 percent natural.

The discussion on the SPP provided above notes that a southeast-trending groundwater pathway historically has been postulated for SPP contaminants. This South Walnut Creek pathway is the rationale for several RFLMA monitoring requirements, including monitoring groundwater around the southeastern margin of the former SEPs and incorporating nitrate in the analytical suites for wells 99305 and 99405. The maximum concentration of nitrate in 2011 at well 99305 was 1 mg/L, and in well 99405 was 2.5 mg/L, both of which are consistent with past data. Therefore, as in previous years, these data continue to indicate a southeastern flowpath is not effective for migration of the SPP constituents.

Former B881 and 800 Area: Consistent with many previous annual reports (most recently for 2010 [DOE 2011d]), S-K calculations performed in 2011 indicate a statistically significant (at the 95 percent confidence level) decreasing trend for U in Sentinel well 88104, while in Sentinel well 00797 the trend for this analyte is increasing (Table 91, Appendix B). Time-series plots of U for both wells are provided in Figure 262. The trend calculated for well 88104 is affected by the well replacement, as explained in the 2010 Annual Report (DOE 2011d) and suggested by this figure. Concentrations of U in 2011 were reported at 37 µg/L and 51 µg/L in the April and October samples, respectively; these results are consistent with data obtained from this well since the replacement was installed. Evaluation well 88205, located nearby, was not scheduled for RFLMA sampling in 2011.

Concentrations of U in samples from Sentinel well 00797, located approximately 250 feet south of well 88104, have ranged between 16.78 µg/L to 30 µg/L since 2000. The April and October 2011 samples reported U concentrations of 29 µg/L and 30 µg/L, respectively. As illustrated on Figure 262, concentrations of U at wells 88104 and 00797 have been consistently well below the U threshold since before Site closure. (This has also applied to samples from well 88205, which often reports nondetects for U.)

Wells monitoring the area downgradient of former B881 are also sampled for VOCs. However, few VOCs are routinely detected. Most common detections include *cis*-1,2-DCE, PCE, and TCE in samples from well 88205 (which was not sampled in 2011); and carbon tetrachloride from well 00797. The only VOC detected in 2011 in the B881 area was reported at well 00797, where TCE was reported at an estimated (J-qualified) concentration of 0.39 µg/L in the October sample. This represents the third detection of TCE at this well, the previous two being in the years 2000 and 2005. No VOCs were detected in samples from well 88104 in 2011.



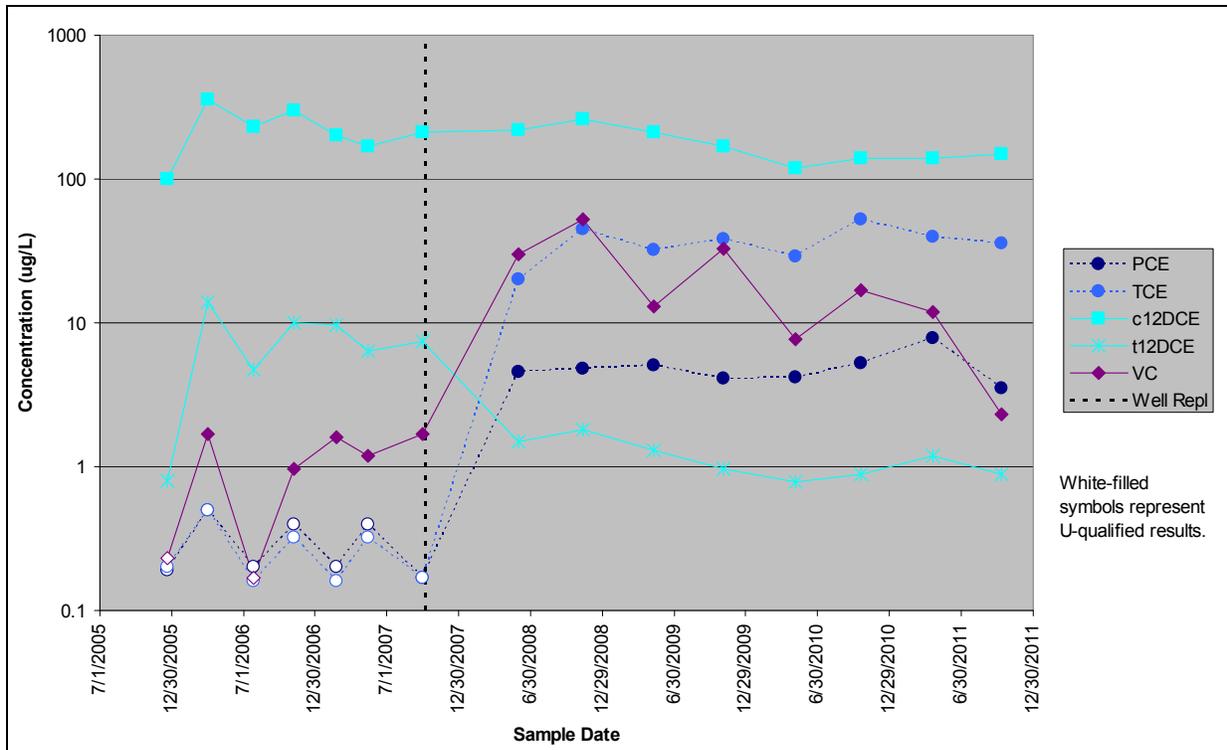
Notes: Applicable RFLMA action level (ug/L; DOE 2007a) for U (threshold), 120. U data include results for U-mass and converted isotopic activities. Several detections were qualified but are not shown differently for simplicity.

Figure 262. Concentrations of U in Samples from B881 Sentinel Wells

Elsewhere in the former 800 Area, Evaluation well 22996 monitors groundwater downgradient of former B886, as well as other 800-Area buildings that are farther upgradient (such as B865 and B883). This well was not scheduled for sampling in 2011.

Hillside south of former B991: The hillside south of former B991 contains the remains of a French drain that was installed during the construction of the hillside to stabilize it. Because the drain outfall (former surface water location SW056) produced water containing VOCs, prior to closure the outfall from this drain was removed, the drain was interrupted, and electron donor material was added to the backfill to enhance biodegradation of VOCs. Sentinel well 45605 was installed to monitor groundwater adjacent to the drain interruption, but the hillside slumped. The area was regraded, and Sentinel well 45608 was installed to replace the abandoned 45605. For more detail on the hillside and French drain, see the 2006 Annual Report (DOE 2007c); for information on the well abandonment and hillside regrading, see the 2007 and 2008 Annual Reports (DOE 2008c, 2009d).

Well 45608 was sampled twice in 2011 (April, October). The continuing detections of 1,2-DCE and VC are an indication that biodegradation is still occurring upgradient of the well, though whether this is related to placement of the electron donor material in 2005 is not known. Concentrations of VC appear to be gradually decreasing since the well replacement in 2008 (Figure 263), with the fourth-quarter 2011 sample reporting the lowest concentration collected from this replacement well. The same applies to concentrations of PCE, but those of TCE and the two DCE isomers are not similarly affected. Refer to the 2010 Annual Report (DOE 2011d) for a discussion of potential well replacement-related effects on contaminant concentrations.



Notes: c12DCE = *cis*-1,2-DCE; t2DCE = *trans*-1,2-DCE; Well Repl = date on which well 45605 was abandoned, with subsequent samples collected from its replacement, well 45608. RFLMA Table 1 values (DOE 2007a): PCE, 1; TCE, 2.5; *cis*-1,2-DCE, 70; *trans*-1,2-DCE, 100; VC, 0.2. In addition to the nondetects (U-qualified results), several detections were qualified but are not shown differently for simplicity. Note logarithmic concentration scale.

Figure 263. Concentrations of VOCs in Sentinel Well 45608, South of Former B991

Concentrations of VC in the replacement well are seen to vary seasonally until 2011, being slightly higher in fourth quarter samples than in second quarter samples. As noted in the 2010 Annual Report (DOE 2011d), this is similar to the behavior at ETPTS-area well 23296 and may be related to the typically drier conditions in the fourth quarter than the second quarter, which could relate to reduced infiltration of oxygenated recharge, for example. It was also noted that TCE concentrations follow a similar but more muted seasonal pattern. The reversal of this pattern in data from samples collected in 2011 may actually support this explanation, as precipitation data for the Site indicate the fourth quarter was wetter than the second. The lack of a similar pattern in data for other daughter products is consistent with previous data at this location.

Trends identified as statistically significant with a 95 percent level of confidence at well 45608 are all complicated by well replacement, and most are also of questionable validity due to the inclusion of numerous nondetects in the data set. These trends include increasing 1,1-DCE, PCE, TCE, and VC; and decreasing *trans*-1,2-DCE (Table 91). Only the VC and *trans*-1,2-DCE data do not include numerous nondetects.

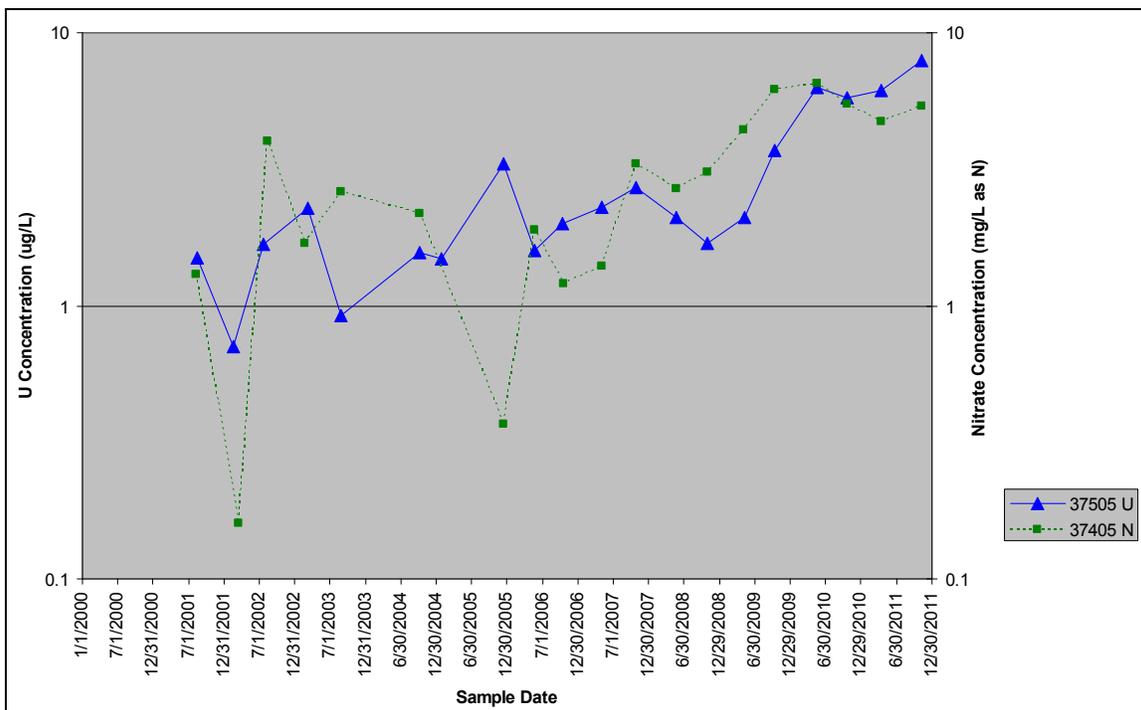
Areas monitored for Plutonium and Americium, and B371 groundwater conditions:

Groundwater immediately downgradient of the former B371 and B771 complexes is monitored for Pu and Am. Abundant technical research (much of which focused specifically on Rocky Flats) has indicated that the groundwater regime does not constitute a meaningful migration pathway for these constituents. Therefore, it is not surprising that the groundwater monitoring wells at Rocky Flats that are sampled for Pu and Am consistently report results for these constituents that are qualified as nondetects. However, due to the production-era missions of these buildings Pu and Am were included in the RFLMA monitoring for these wells to provide stakeholder assurance.

In 2011, just as in 2010, the five wells monitored for Pu and Am (Sentinel wells 20205, 20505, and 20705 at former B771; and 37405 and 37705 at former B371) reported values qualified as nondetects for these radionuclides. Reported values in 2011 ranged from -0.00508 pCi/L to 0.0159 pCi/L, again all qualified as nondetects. (As an activity-based analysis that is compared against the activity in a laboratory blank, the analysis always generates a number.) In fact, the only Pu or Am results reported since Site closure that are not qualified as nondetects have been three J-qualified results in samples collected in December 2005, the highest activity of which was 0.0238 pCi/L (representing Am in a sample from well 20705).

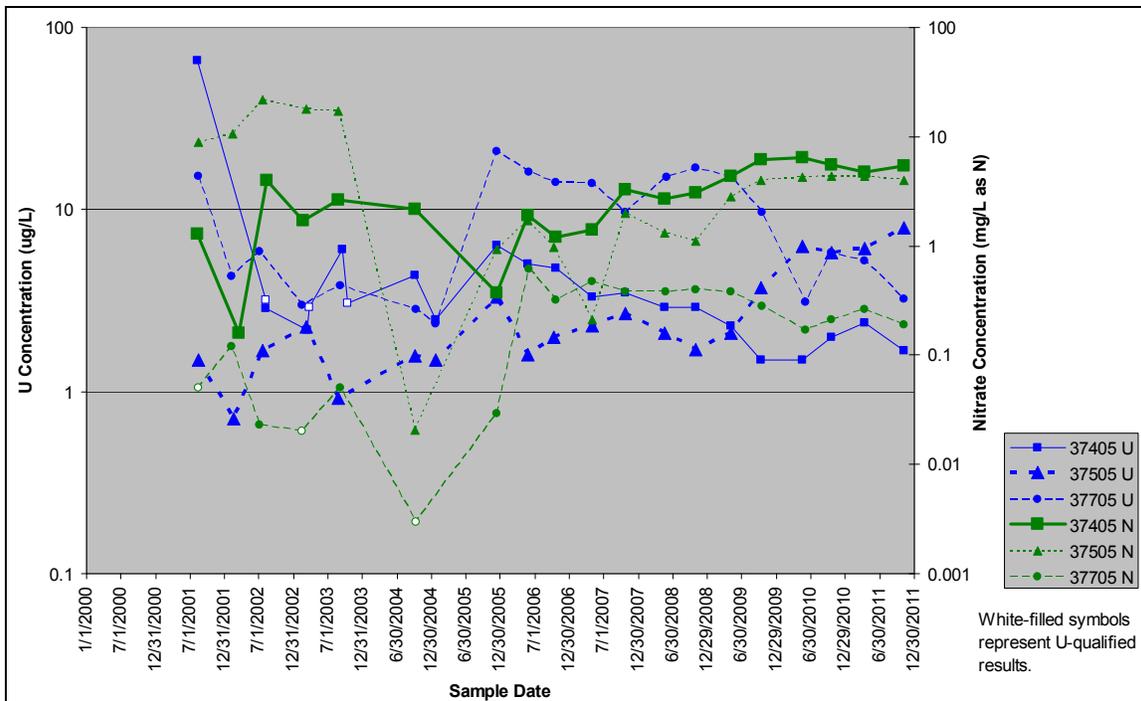
These areas are also monitored for other constituents. The groundwater downgradient of the former B771 complex is discussed above in the context of the IHSS 118.1 Plume and will not be repeated here. Groundwater at the former B371 complex is also analyzed for VOCs, nitrate, and U. Of the VOCs, the most commonly reported detection (consistently reported at J-qualified concentrations below 1 $\mu\text{g/L}$) is of PCE in samples collected from well 37505. The highest concentration reported in 2011 was estimated at 0.46 $\mu\text{g/L}$. VOCs were not detected in 2011 in samples collected from wells 37405 and 37705 and historically have been detected only rarely in samples from these wells.

S-K trending results (see summary in Table 91, and Appendix B) indicate an increasing trend meeting the 95 percent level of confidence for nitrate in samples from well 37405 and for U in samples from well 37505. These data are presented below in time-series plots (Figure 264), and shows the calculated trends to be visually evident. For context, Figure 265 includes concentrations of these constituents reported in samples from each of the 371-area wells.



Notes: U data include results for U-mass and converted isotopic activities. Several detections were qualified but are not shown differently for simplicity. Note dual logarithmic concentration scales.

Figure 264. Concentrations of U and Nitrate with Significant Trends in Samples from B371 Sentinel Wells



Notes: U data include results for U-mass and converted isotopic activities. Several detections were qualified but are not shown differently for simplicity. Note dual logarithmic concentration scales.

Figure 265. Concentrations of U and Nitrate in Samples from B371 Sentinel Wells

Continuing studies of uranium isotopic distribution using high-resolution analytical

methods: As discussed above, several samples were collected and submitted to LANL for high-resolution U isotopic analysis. The objective of these analyses is to evaluate Site impact, through the presence of anthropogenic U, on groundwater and surface water at selected locations.

Two primary areas were targeted for this highly specialized and costly U analysis in 2011. These included locations related to North Walnut Creek and the SPP in the spring of 2011 (discussed above and summarized in Table 100), and locations related to South Walnut Creek focusing on surface water location GS10 in the fall of 2011. Two batches of 14 samples total were submitted for the former, and one batch of 6 samples for the latter.

Results for the nine groundwater and treatment-system samples related to the SPP are provided above in Table 100. The GS10-related effort only included one groundwater sample for LANL analysis, although several samples were collected to identify the LANL candidate. Samples were collected for standard contract lab analysis of U from several wells in the vicinity of GS10, including three wells not routinely monitored for U. These included Sentinel wells 45608 (located on the hillside south of former B991), 91203 (north-northwest of OBP#2), and 15699 (adjacent to the MSPTS). Also analyzed were samples from Evaluation wells 00203, 79502, and 79605, all located adjacent to the former SEPs and all routinely monitored for U. Concentrations of U in 2011 from the SEP-area samples were not anomalous (refer to section above on the SPP and SPPTS), and those from the area nearer GS10 were uniformly low (ranging from approximately 3.5 µg/L at well 91203 to 45 µg/L at well 91305). As a result of these data, the split sample collected from well 91305 for LANL analysis was selected for submittal to LANL for high-resolution U analysis. The result of this analysis was 39.9 µg/L total U, with a natural U content of 90.8 percent and anthropogenic (depleted) U of 9.2 percent.

East Government property boundary (former Rocky Flats Environmental Technology Site

[RFETS] boundary): Two monitoring wells located on the eastern boundary of Government property were part of the RFLMA monitoring network at the beginning of 2011. The CAD/ROD and RFLMA were subsequently revised in 2011 and as noted in Section 3.1.2.4 these wells, classified as Boundary wells, were deleted from the RFLMA network. There had been no technical justification for the inclusion of these wells in the monitoring network prior to removing them from the RFLMA; they were included solely for stakeholder assurance purposes.

These two wells are identified as 10394 (Woman Creek and Indiana Street) and 41691 (Walnut Creek and Indiana Street). They are located far outside the DOE-controlled area of the COU, on refuge lands managed by the U.S. Fish and Wildlife Service. Prior to confirmation of their removal from the CAD/ROD and RFLMA, these wells were each sampled once in 2011 (April). No VOCs were detected in either sample. Nitrate was reported in the sample from well 10394 (Woman Creek location) at 0.081 mg/L, and at well 41691 (Walnut Creek location) at 0.65 mg/L. Both locations reported a U concentration of 5.4 µg/L.

No further monitoring is planned for these wells. It is anticipated that they will be abandoned in 2012.