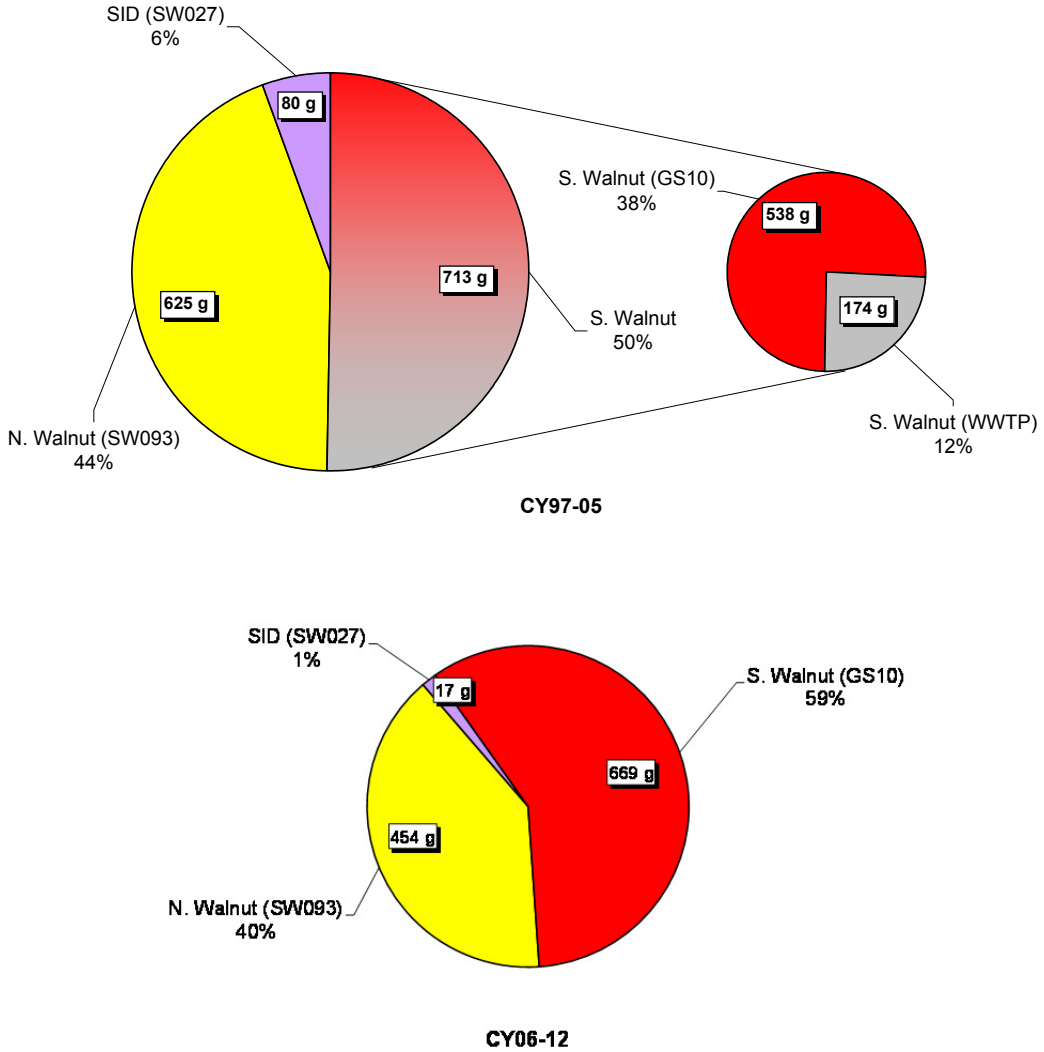


Note: Pie chart diameters are relative to total load.

Figure 205. 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 2012. A discussion of groundwater conditions during 2012, 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 2012

Routine activities of the groundwater monitoring program in 2012 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 treatment system-related

performance monitoring locations within streams and former 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 2012 to support various objectives. This is summarized 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 2012 (DOE 2012b, 2012e, 2013a) 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 no changes to the network of groundwater monitoring locations during 2012. The groundwater monitoring network set forth in RFLMA is subdivided and categorized as shown in Table 86.

Table 86. RFLMA Monitoring Classifications for the Groundwater Monitoring Network

Well Classification[a]	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)
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)

Notes:
[a] Locations are referred to as "wells" for convenience even if they do not represent wells, as is the case with treatment system and surface water locations.
[b] The numbers of locations listed are current through 2012.
[c] Treatment system and surface-water support locations are not monitoring wells but are included for completeness.
[d] The PLFTS is discussed separately.

Table 87 presents the full 2012 schedule for RFLMA groundwater sample collection, a subset of which is summarized in Table 88 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 2012b, 2012e, 2013a) and Appendix B.

Table 87. Summary of Scheduled RFLMA-Required Groundwater Sampling in CY 2012 (by Quarter)

Area	Classification or Type	Location ID	Analytes					
			VOCs	U	Nitrate	Metals	Pu/Am	SVOCs
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					
	E	00897	2					
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					
	TS	POM2	2,4					
	E	3687	2					
	E	05691	2					
	E	03991	2					
SPPTS	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			
	TS	GS13		2,4	2,4			
	E	P210189	2	2	2			
	E	79102	2	2	2			
	E	79202	2	2	2			
	E	P208989	2	2	2			
	E	79302		2	2			
	E	79402		2	2			
	E	79502		2	2			
	E	79605		2	2			
	E	00203	2	2	2			
	E	22205	2	2	2			

Table 87 (continued). Summary of Scheduled RFLMA-Required Groundwater Sampling in CY 2012 (by Quarter)

Area	Classification or Type	Location ID	Analytes					
			VOCs	U	Nitrate	Metals	Pu/Am	SVOCs
SPPTS	E	B210489		2	2			
	E	51605		2	2			
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					
	E	P114689	2					
	E	P115589	2					
	E	70705	2	2				
	E	33905	2					
	E	21505	2					
	E	20902	2					
Former B559	E	55905	2	2	2			
	E	56305	2	2	2			
Former IHSS 118.1	SS	SW018	2,4					
	E	18199	2					
Former B444 Complex	S	11502	2,4	2,4				
	S	40305	2,4	2,4				
	E	40005	2	2				
	E	40205	2	2				
	E	P419689	2	2				
	E	P416889	2	2				
Former B881	S	00797	2,4	2,4				
	S	88104	2,4	2,4				
	E	88205	2	2				
Former B886	E	22996	2	2				
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	33711	2,4					
	E	33502	2					
	E	33604	2					
Former Oil Burn Pit No. 2	S	91203	2,4					
	E	91105	2					
Former SW056	S	45608	2,4					
OU 1 Plume	AOC	89104	2,4					
	E	891WEL	2					

Table 87 (continued). Summary of Scheduled RFLMA-Required Groundwater Sampling in CY 2012 (by Quarter)

Area	Classification or Type	Location ID	Analytes					
			VOCs	U	Nitrate	Metals	Pu/Am	SVOCs
903 Pad/Ryan's Pit Plume	S	90299	2,4					
	S	90399	2,4					
	AOC	10304	2,4	2,4	2,4			
903 Pad/Ryan's Pit Plume	E	00191	2					
	E	50299	2					
	E	90402	2					
	E	00491	2					
	E	07391	2	2				
	E	90804	2					
PU&D Yard Plume	S	30002	2,4					
	E	30900	2					

Notes: ID = Identification (name) of well/sampling location. Location classifications: AOC = Area of Concern, S = Sentinel, E = Evaluation, 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 88. Summary of RFLMA-Required Groundwater Samples Not Successfully Collected in 2012 (by Quarter)

Location		Analytes						Comments
ID	Classification	VOCs	U	Nitrate	Metals	Pu/Am	SVOCs	
95299	S	2, 4						Dry well
POM2	TS	4						Dry location

Notes: ID = identification (name) of well/sampling location. RFLMA classifications: S = Sentinel, TS = Treatment System. SVOCs = semivolatile organic compounds. 2 (or other numeral) in analyte column = corresponding analyte requested in the indicated calendar quarter of 2012; if blank, analyte not requested

3.1.5.2 Non-RFLMA Groundwater Monitoring Activities of 2012

Non-RFLMA (i.e., nonroutine) groundwater monitoring was performed in 2012 in support of several data needs, which generally fall within the following two categories:

- Investigative sampling; and
- Performance sampling.

Table 89 summarizes non-RFLMA groundwater sample collection performed in 2012. In addition to this non-RFLMA sampling, additional non-RFLMA monitoring was performed through the Sitewide measurement of water levels as discussed in Section 3.1.3.

As in recent years, most of the non-RFLMA monitoring performed in 2012 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 3.1.2.9.

Table 89. Summary of Non-RFLMA-Required Groundwater Samples Collected in CY 2012 (by Quarter)

Area	Location ID	Analytes[a]												
		VOCs	U	Nitrate	Nitrites	NH_3-NH_4	U isotopes	PO4	TOC	Ca	Fe	Pu/Am	*DNBART*	Other
	SPIN		1(7), 2(24), 3(23), 4(7)	1(7), 2(24), 3(23), 4(7)	1(3), 2(5), 3(14), 4(7)	1(3), 2(5), 3(14), 4(7)			2(1), 3(1)	1(3), 2(4), 3(13), 4(7)	1(7), 2(11), 3(13), 4(7)		2(1), 3(1)	
	SPOUT		1(8), 2(11), 3(20), 4(12)	1(8), 2(11), 3(20), 4(13)	1(3), 2(5), 3(13), 4(8)	1(3), 2(5), 3(13), 4(8)		4	1(3), 2(5), 4(3)	1(3), 2(5), 3(13), 4(7)	1(3), 2(5), 3(13), 4(7)		4	
	SPZE		1(3), 2(4), 4(4)	1(3), 2(4), 4(7)	1(3), 2(4), 4(7)	1(3), 2(4), 4(7)			4(7)	1(3), 2(4)	1(3), 2(4)		4(7)	
	ITSS		3(16), 4(7)	3(16), 4(7)	3(14), 4(7)	3(14), 4(7)				3(14), 4(7)	3(14), 4(7)			
	ITSSEAST		3	3										
	ITSSWEST		3	3										
	SPPDISCHARGE GALLERY		2	2										
	15699		4									4		
	1786		2	2										
	GS13		1(5), 2(5), 4(2)	1(5), 2(5), 4(2)										
	Lagoon Testing													
	SPCA		4(7)	4(8)	4(7)	4(7)			4(7)				4(7)	
	SPCAE		1(3), 2(6), 3(1), 4(4)	1(3), 2(6), 3(1), 4(7)	1(3), 2(6), 3(1), 4(7)	1(3), 2(6), 3(1), 4(7)		4	1(3), 2(6), 3(1), 4(7)	1(3), 2(5)	1(3), 2(5)		2, 3(1), 4(7)	DOC: 4(7)
	SPCAMID		4(4)	4(7)	4(7)	4(7)			4(7)				4(7)	
	SPCABOT		4(4)	4(7)	4(7)	4(7)			4(7)				4(7)	
	SPLA		2(13)	2(19)	2(16)	2(16)			2(18)				2(16)	DOC: 2(7)
	SPLA2		3(10)	3(10)	3(10)	3(10)			3(10)				3(10)	DOC: 3(5)
	SPLA2U		3(3)	3(3)	3(3)	3(3)			3(3)				3(3)	
	SPLA2L		3(3)	3(3)	3(3)	3(3)			3(3)				3(3)	
SPPTS[b]	SPLA3		3(11), 4(6)	3(11), 4(7)	3(11), 4(7)	3(11), 4(7)			3(11), 4(7)				3(11), 4(7)	DOC: 3(6), 4(2)
	SPCB		4(7)	4(8)	4(7)	4(7)			4(7)				4(7)	
	SPCBE		4(4)	4(7)	4(7)	4(7)		4	4(7)				4(7)	DOC: 4(7)
	SPCBMID		4(4)	4(7)	4(7)	4(7)			4(7)				4(7)	
	SPCBBOT		4(4)	4(7)	4(7)	4(7)			4(7)				4(7)	
	SPLB		2(13)	2(19)	2(16)	2(16)			2(18)				2(16)	DOC: 2(7)
	SPLB2		3(10)	3(10)	3(10)	3(10)			3(10)				3(10)	DOC: 3(5) TSS: 3(1)
	SPLB2U		3(3)	3(3)	3(3)	3(3)			3(3)				3(3)	
	SPLB2L		3(3)	3(3)	3(3)	3(3)			3(3)				3(3)	
	SPLB3		3(11), 4(6)	3(11), 4(7)	3(11), 4(7)	3(11), 4(7)			3(11), 4(7)				3(11), 4(7)	DOC: 3(6), 4(2)
	ZVI Microcell Testing													
	MICROCELLZVIA		1(27)	1(27)							1(27)			
	MICROCELLZVIB		2(10)	2(10)							2(10)			
	MICROCELLZVIC		2(47)	2(47)							2(47)			
	MICROCELLZVID		3(28)	3(28)										
	SPIXMICROCELLD1		2(23)	2(23)										
	MICROCELLZVID2		3(10)	3(10)										
	MICROCELLZVIE		3(73)								3(73)			
	MICROCELLZVIF		3(13)	3(2)	3(2)	3(2)				3(2)	3(13)			
	MICROCELLZVIF2		4(9)								4(9)			
	MICROCELLZVIG		3(29), 4(19)								3(29), 4(19)			
	MICROCELLZVIH		4(16)								4(16)			

Table 89 (continued). 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*	Other
SPPTS[b] (cont.)	MICROCELLZVIJ		4(12)								4(12)			
	SPIXMICROCELLXLT		2(7)	2(7)										
	SPIXMICROCELLXLT2		2(11), 3(3)	2(11), 3(3)										
	SPCAERESIN1		2	2										
	SPCAERESIN21K		2	2										
	SPCAERESINXLT		2	2										
	SPPTSRESIN1		2	2										
	SPPTSRESIN21K		2	2										
	SPPTSRESINXLT		2	2										
ETPTS[c]	ET EFFLUENT	1												
	ET INFLUENT	1												
MSPTS[d]	MOUND R1-0	3												
	MOUND R2-E		4									4		
	ASHINF	1, 2(3), 3(2), 4(1)												
	ASHEFF	1, 2(4), 3(2), 4(1)												
	GS10		1(5), 2(6), 3(7), 4(6)											
U Geochemistry Evaluation														
	GEOA1		4											
	GEOA1INF		4											Fe, H2S, SO4: 4
	GEOA3EFF		4											
	GEOA3INF		4											
	GEOB1INF		4											Fe, H2S, SO4: 4 (2)
	GEOB4		4											
	GEOB5INF		4											
	GEOFC3EFF		4											Fe, H2S, SO4: 4 (2)
	GEOFC3INF		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.

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

Abbreviations:

ID = Identification (name) of well/sampling location
Ca = calcium
Fe = iron
NH_3-N = ammonia (as nitrogen)
$P0_4$ = phosphate
Pu/Am = plutonium/americium
TOC = total organic carbon
VOCs = volatile organic compounds

A substantial amount of non-RFLMA monitoring was also performed in 2012 for the MSPTS air stripper. These samples were submitted to contract laboratories and validated as if they were RFLMA data. These data have been reported in previous quarterly and annual reports, but are summarized and discussed at greater length in the text focusing on the MSPTS in the next section.

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 2012, and also provides 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 2012.

Groundwater quality data were obtained for all monitored areas in 2012. Analytical data have been published in quarterly reports issued for 2012 (DOE 2012b, 2012e, 2013a), plus Appendix B, and will not be duplicated here. Appendix B also includes statistical trend plots for CY 2012.

Groundwater quality at the Site in 2012 was largely consistent with data reported in prior years, as can be deduced from the summary of statistical trends presented in Table 90. 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 calculations were completed for this report per RFLMA using analytical data collected from Sentinel, Evaluation, and RCRA wells (see Sections 3.1.2.7 and 3.1.2.8 for discussion of RCRA wells). In addition to the requirements of RFLMA, statistical trending was performed for upgradient RCRA wells, selected AOC wells and constituents, and for influent to the three main groundwater treatment systems (MSPTS, ETPTS, and SPPTS). 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 9.3.22; Sanitas Technologies 2013) was used for statistical calculations, including 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 3.1.2.7 and Section 3.1.2.8.

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 by Kaiser-Hill Company LLC (K-H) 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 98 percent significant.

Table 90. Summary of Statistical Trend Calculations by Location

Well	Analyte	Trend	Significant at 95%?[a]
Sentinel Wells			
00797	Uranium	Increasing	Yes
04091	Carbon tetrachloride	Decreasing	Yes[c]
	PCE	Decreasing	Yes[c]
11502	PCE	Decreasing	No
15699	1,1-DCE	Decreasing	Yes
	Chloroform	Decreasing	Yes[c]
	PCE	Decreasing	Yes
	trans-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
	cis-1,2-DCE	Decreasing	Yes
	TCE	Decreasing	Yes
	Uranium	Decreasing	Yes
20705	Am-241	Decreasing	Yes[c,d,e]
	cis-1,2-DCE	Increasing	Yes
	Uranium	Increasing	Yes[d]
	Vinyl chloride	Increasing	No[c]
23296	1,1-DCE	Increasing	Yes[c]
	Carbon tetrachloride	Decreasing	Yes[c]
	Chloroform	Decreasing	Yes[c]
	cis-1,2-DCE	Increasing	Yes
	trans-1,2-DCE	Increasing	Yes[c]
	Uranium	Decreasing	Yes
	Vinyl chloride	Increasing	Yes[c]
33711	1,4-DCB	Increasing	Yes
	Chlorobenzene	Decreasing	Yes
	cis-1,2-DCE	Increasing	Yes
	Toluene	Increasing	Yes[c]
	trans-1,2-DCE	Increasing	Yes
	Vinyl chloride	Increasing	Yes[c,d]
37405	Nitrate	Increasing	Yes
	Uranium	Decreasing	No
37505	PCE	Increasing	No
	Uranium	Increasing	Yes
45608	1,1-DCE	Increasing	Yes[d]
	cis-1,2-DCE	Decreasing	Yes
	PCE	Increasing	Yes[c,d]
	trans-1,2-DCE	Decreasing	Yes[d]
	TCE	Increasing	Yes[c,d]
	Vinyl chloride	Increasing	No[d]
52505	*cis*-1,2-DCE	Increasing	Yes[c]
70099	Nitrate	Decreasing	Yes
	Uranium	Increasing	No

Table 90 (continued). Summary of Statistical Trend Calculations by Location

Well	Analyte	Trend	Significant at 95%?[a]
88104	Uranium	Decreasing	Yes[d]
90299	Carbon tetrachloride	Decreasing	Yes[c]
	Chloroform	Decreasing	Yes
	TCE	Decreasing	Yes
90399	1,1-DCE	Increasing	Yes
	cis-1,2-DCE	Increasing	Yes
	PCE	Increasing	No
	TCE	Increasing	Yes
91203	1,1,1-TCA	Increasing	Yes[c]
	1,1-DCE	Increasing	Yes
	cis-1,2-DCE	Increasing	Yes
	PCE	Increasing	Yes
	TCE	Increasing	Yes
91305	*cis*-1,2-DCE	Decreasing	No
	Uranium	Decreasing	Yes
95199	1,1-DCE	Increasing	No
	cis-1,2-DCE	Increasing	Yes
	PCE	Increasing	Yes
	TCE	Increasing	No
99305	*cis*-1,2-DCE	Increasing	Yes
	PCE	Increasing	Yes[d]
	TCE	Increasing	Yes[d]
	Uranium	Increasing	Yes
99405	*cis*-1,2-DCE	Increasing	Yes
	TCE	Increasing	No[c]
	Uranium	Decreasing	Yes
P210089	Nitrate	Increasing	Yes
	Uranium	Increasing	Yes
RCRA Wells[b]			
70193	Boron	Increasing	No
	Uranium	Decreasing	Yes[c]
70393	1,1,1-TCA	Decreasing	Yes
	1,1-DCE	Decreasing	Yes
	Boron	Decreasing	No[c]
	PCE	Decreasing	Yes
	TCE	Decreasing	Yes
	Uranium	Decreasing	Yes[c]
70693	1,1,1-TCA	Decreasing	Yes
	1,1-DCE	Decreasing	Yes
	Boron	Increasing	No
	Carbon tetrachloride	Decreasing	Yes[c]
	Chloroform	Decreasing	Yes[c]
	PCE	Decreasing	Yes
	TCE	Decreasing	Yes
73005	Boron	Increasing	No
	Chromium	Increasing	Yes[c]
	Selenium	Increasing	Yes

Table 90 (continued). Summary of Statistical Trend Calculations by Location

Well	Analyte	Trend	Significant at 95%?[a]
73105	Boron	Increasing	Yes
	Nickel	Increasing	Yes[c]
	Uranium	Decreasing	Yes
73205	Boron	Increasing	Yes
80005	Boron	Decreasing	Yes
	Uranium	Increasing	No[c]
80105	Uranium	Decreasing	No
80205	Boron	Increasing	Yes
	Uranium	Decreasing	Yes
P416589	Boron	Increasing	No[c]
Selected AOC Wells and Constituents[c]			
00193	Uranium	Decreasing	No
4087	Nitrate	Increasing	No
10304	Uranium	Increasing	No
10594	Uranium	Decreasing	Yes
11104	Uranium	Decreasing	Yes
B206989	Nitrate	Decreasing	Yes
Evaluation Wells[a]			
00491	Chloroform	Decreasing	Yes
00897	TCE	Decreasing	Yes
03991	Carbon tetrachloride	Decreasing	Yes
	Chloroform	Decreasing	Yes[c]
	PCE	Decreasing	Yes
	TCE	Decreasing	Yes
05691	Carbon tetrachloride	Decreasing	Yes
	Chloroform	Decreasing	Yes
	cis-1,2-DCE	Decreasing	Yes
	PCE	Decreasing	Yes
	TCE	Decreasing	Yes
07391	*cis*-1,2-DCE	Increasing	Yes
3687	*cis*-1,2-DCE	Increasing	Yes
18199	Carbon tetrachloride	Decreasing	Yes
	PCE	Decreasing	Yes
21505	PCE	Decreasing	Yes[d]
	TCE	Decreasing	Yes[d]
22205	Nitrate	Increasing	Yes[d]
30900	1,1,1-TCA	Decreasing	Yes[c]
	cis-1,2-DCE	Increasing	Yes
33502	1,2,4-TCB	Decreasing	Yes[c]
	PCE	Decreasing	Yes[c]
33604	PCE	Decreasing	Yes
	TCE	Decreasing	Yes
40205	1,1-DCE	Decreasing	Yes
	cis-1,2-DCE	Decreasing	Yes
	PCE	Decreasing	Yes[d]
56305	PCE	Increasing	Yes[d]
70705	Chloroform	Increasing	Yes[c,d]

Table 90 (continued). Summary of Statistical Trend Calculations by Location

Well	Analyte	Trend	Significant at 95%?[a]
79202	Carbon tetrachloride	Decreasing	Yes
	Chloroform	Decreasing	Yes
	TCE	Decreasing	Yes
79302	Uranium	Increasing	Yes
79402	Uranium	Decreasing	Yes
79502	Uranium	Decreasing	Yes
88205	Total Xylenes	Increasing	Yes[c,d]
891WEL	Chloroform	Increasing	Yes[c]
	cis-1,2-DCE	Increasing	Yes[c]
91105	Carbon tetrachloride	Decreasing	Yes[c,d]
P114689	Carbon tetrachloride	Decreasing	Yes
	TCE	Increasing	Yes
P210189	*cis*-1,2-DCE	Decreasing	Yes
	TCE	Decreasing	Yes
P416889	*cis*-1,2-DCE	Decreasing	Yes
Treatment System Influent[b]			
2000 through 2012			
MSPTS	1,1,1-TCA	Increasing	Yes
	1,1-DCE	Increasing	Yes
	Carbon tetrachloride	Decreasing	Yes
	Chloroform	Increasing	Yes
	cis-1,2-DCE	Increasing	Yes
	trans-1,2-DCE	Increasing	Yes[c]
	TCE	Increasing	Yes
	Vinyl chloride	Increasing	Yes[c]
ETPTS	1,1,1-TCA	Decreasing	Yes
	1,1-DCE	Increasing	Yes
	Carbon tetrachloride	Decreasing	Yes
	cis-1,2-DCE	Increasing	Yes
	PCE	Decreasing	No
SPPTS	Nitrate	Increasing	Yes
	Uranium	Increasing	Yes
2006 through 2012			
MSPTS	1,1,1-TCA	Increasing	Yes
	PCE	Increasing	No
	trans-1,2-DCE	Decreasing	Yes
	TCE	Increasing	Yes
	Vinyl chloride	Decreasing	No
ETPTS	Chloroform	Increasing	Yes
	cis-1,2-DCE	Increasing	No
	TCE	Increasing	No
SPPTS	Nitrate	Increasing	Yes
	Uranium	Increasing	Yes

Notes:

Only increasing and decreasing trends are included; indeterminate and zero-slope trends are not.

[a] Trends for AOC wells, Sentinel wells, RCRA wells, and treatment systems are listed if there is at least an 80% statistical significance, and if at least 95% significant are so defined; trends for Evaluation wells are only listed if there is at least a 98% significance. Any decisions that may be made would be based on trends having a 95% significance.

[b] Calculating trends for AOC wells, upgradient RCRA wells, and treatment systems is not required by RFLMA; these trends are provided for informational purposes.

Table 90 (continued). Summary of Statistical Trend Calculations by Location

[c] Trend calculated to be significant may not be valid because 25 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% (or 98%) 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 at some point 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.

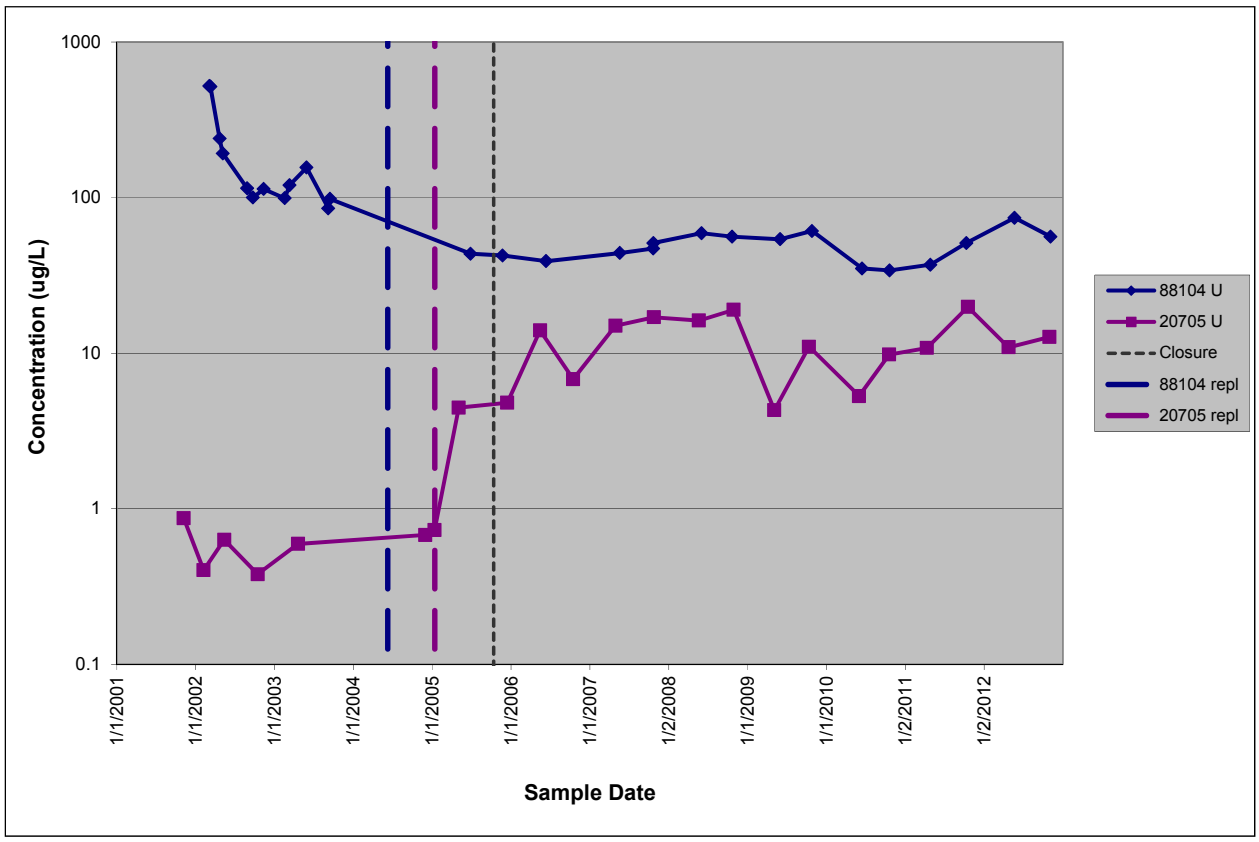
Abbreviations:
DCA = dichloroethane; DCE = dichloroethene; DCB = dichlorobenzene; OBP = Oil Burn Pit;
PCE = tetrachloroethene; TCA = trichloroethane; TCB = trichlorobenzene

Table 90 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 98 percent 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, Evaluation, and downgradient RCRA wells) are included, as are calculations for upgradient RCRA wells, selected AOC wells and constituents, and influent to the MSPTS, ETPTS, and SPPTS. 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.

There are a few instances in which a concentration trend did not meet the 95 percent level of significance using 2011 data, but with 2012 data that level was attained; there are also instances in which a trend that had been calculated to be significant no longer met that test when 2012 data were included in the calculation. Refer to previous annual reports to compare results of statistical trending calculations from year to year.

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. Replacement of a well may impact analytical and water elevation data. Figure 206 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 2012.

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

Calculations of statistical trends may also be affected by changes to detection limits. For example, this appears to be a significant factor in the calculations for certain metals in downgradient wells at the PLF and OLF. With respect to Cr (the subject of Figure 4) and Ni, data reported before mid-2008 were nondetect at higher detection limits, and more recent data may be reported as detections at concentrations that are lower than the earlier detection limits. Due to data replacement of nondetects (i.e., wherein the reported value, which is equivalent to the detection limit, is replaced with a value of 0.001), the overall appearance is one in which the concentration is increasing—changing from a steady "concentration" of 0.001 to the reported detections. At some point these early data may be omitted from the calculations in order to remove this artifact; or, these earlier data may be allowed to gradually be overwhelmed by the quantity of newer data, yielding reliable calculations of trend.

Groundwater Plumes with Treatment Systems

This section describes the general groundwater quality in 2012 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, resulting in a groundwater contaminant plume extending north toward South Walnut Creek (now part of the FC-4 segment). 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 the 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 stimulate naturally-occurring bacteria and enhance biodegradation of residual VOCs. (This action and its corresponding effects on groundwater quality will be referenced and discussed frequently in the text below.) 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 to the MSPTS intercept trench. This combined flow is then directed to the MSPTS for treatment.

The following paragraphs describe these plumes and the MSPTS.

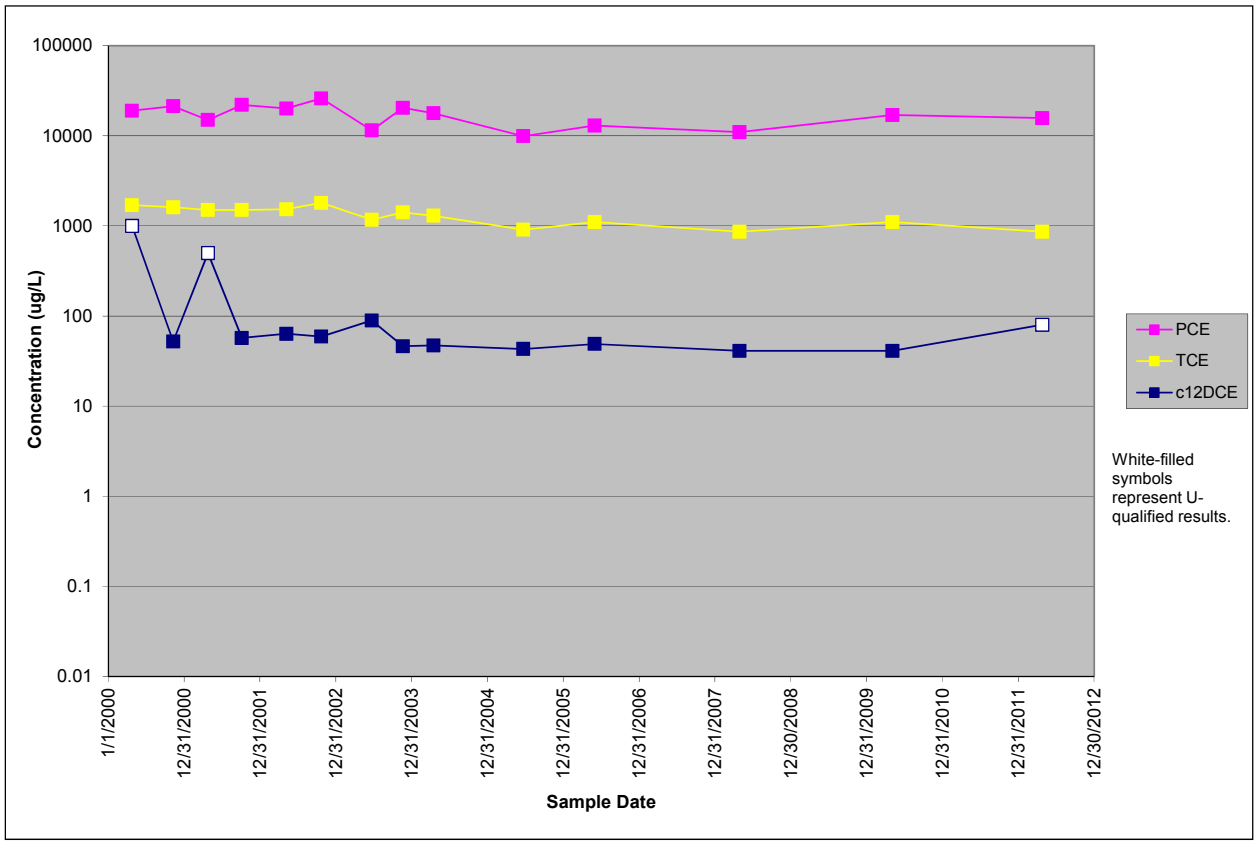
Mound Plume and OBP#2 Plume

Annual reports for 2006 and 2007 (DOE 2007b, 2008c) provide separate discussions of the Mound Plume and the nearby OBP#2 Plume. As described above, 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. Both were scheduled for routine RFLMA sampling in 2012.

At its source area, the Mound Plume is characterized by elevated concentrations of tetrachloroethene (PCE) and TCE. Consistent with the conditions summarized in previous annual reports (e.g., for 2010; DOE 2011d) and dating back to 2000, concentrations of these constituents in 2012 remained fairly consistent, as has that of the primary metabolic byproduct from degradation of these compounds, *cis*-1,2- dichloroethene (DCE) (Figure 207). This suggests the degree to which these VOCs are degrading is low; with increasing degradation, this and other byproducts (such as vinyl chloride [VC], which has not been detected in samples from this well)

would likely increase in concentration. Although the 2012 result for *cis*-1,2-DCE is a nondetect, the consistent pattern in previous years suggests the actual concentration is not substantially different from previously-reported concentrations. Even so, a decreasing trend with a 95 percent level of significance is calculated for *cis*-1,2-DCE at well 00897 (Table 90).



Notes: PCE = tetrachloroethene (RFLMA Table 1 standard = 1 µg/L); TCE = trichloroethene (2.5 µg/L); c12DCE = *cis*-1,2-dichloroethene (70 µg/L). Several detections are qualified, but for simplicity are not shown differently. Note logarithmic concentration scales.

Figure 207. Primary VOCs in Mound Source Area Well 00897

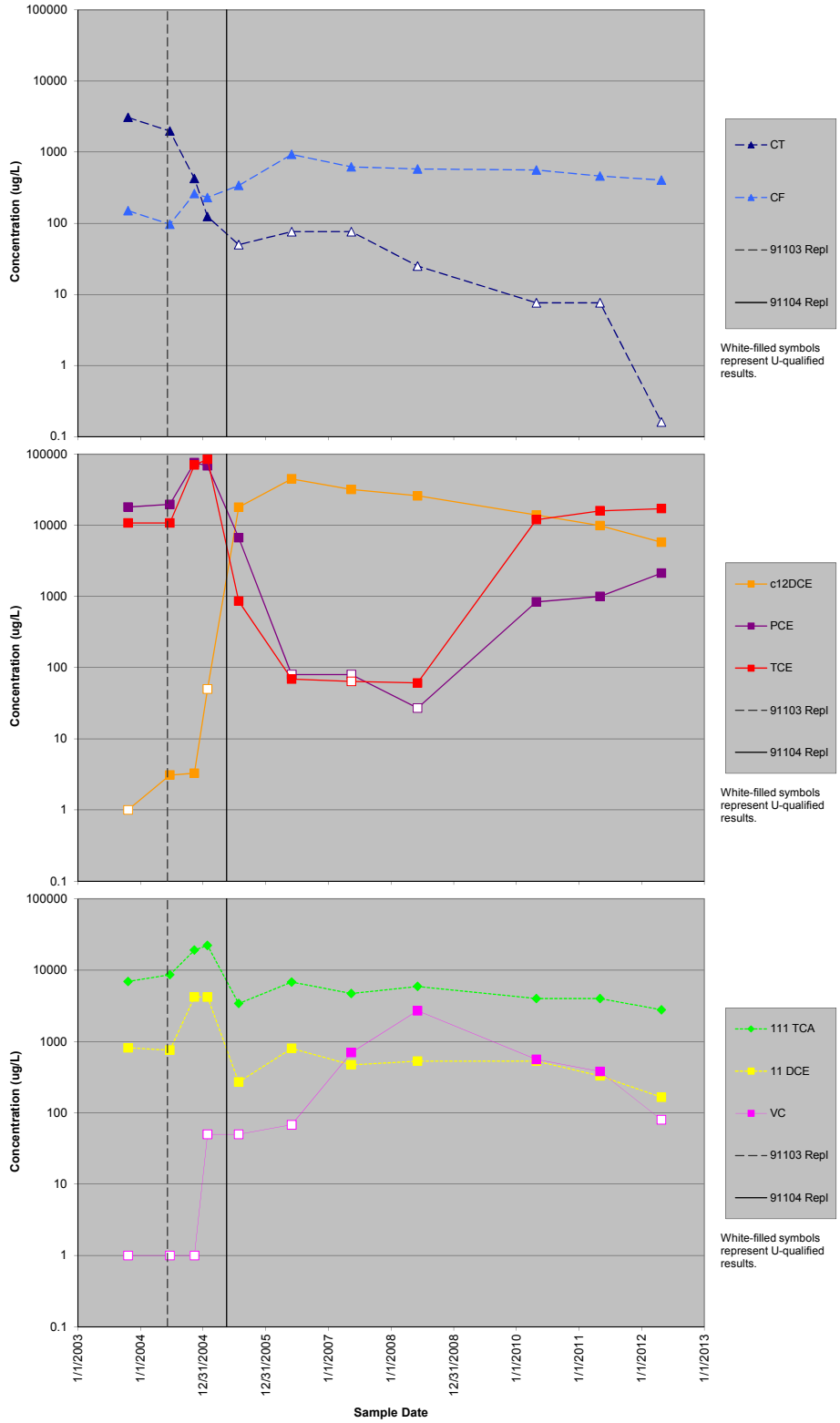
In contrast to the primary contaminants in the Mound source area, groundwater in the OBP#2 source area was originally characterized by elevated concentrations of 1,1,1-trichloroethane (TCA), PCE, TCE, and 1,1-DCE. Well 91105 is the third to monitor the OBP#2 source area; the previous two wells (91103, 91104) were installed directly within the contaminated soils, while the current well is on the downgradient edge of the backfilled source-removal excavation. The two predecessor wells therefore produced samples with much higher concentrations of VOCs than does the current monitoring well. Following 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 208). At the same time, concentrations of daughter products such as *cis*-1,2-DCE and VC increased in samples from the OBP#2 source-area well. Concentrations of carbon tetrachloride decreased to the point that this constituent is no longer detected in samples from well 91105, but its primary daughter product, chloroform, initially increased in concentration and has since leveled off. (As discussed later in this section as part of the text on

IHSS 118.1, despite a similar source removal activity and addition of electron donor material, the contaminant distribution there does not illustrate a similar pattern.) Concentrations of carbon tetrachloride in samples from well 91105 are calculated to be on a decreasing trend with a 95 percent statistical significance (Table 90), although the trend is complicated by well replacements and the continuous lack of carbon tetrachloride detections in the post-closure well.

As shown on Figure 208 and initially discussed in the 2010 and 2011 Annual Reports (DOE 2011d and 2012f, respectively), concentrations of some parent compounds (e.g., TCE, PCE) have rebounded since 2008, as concentrations of their daughter products simultaneously exhibited a much smaller decrease (*cis*-1,2-DCE, VC). While carbon tetrachloride has still not been detected, concentrations of its primary daughter product (chloroform) appear to have stabilized or be slowly decreasing. These patterns may indicate depletion of the added electron donor material and/or reduction in biodegradation due to changing geochemical conditions, since the bacteria acting to reductively dechlorinate 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. Such a surplus was present in the wet year of 2010, as demonstrated by the hydrographs for that year (see DOE 2011d; also visible in subsequent hydrographs, as in Appendix A). The generally drier climate since then should have led to more stable groundwater elevations and geochemical conditions, which—if typical of normal Rocky Flats groundwater—would include more elevated concentrations of dissolved oxygen.

Other parent compounds, such as 1,1,1-TCA, appear to show fairly stable concentrations since closure, though a slight decrease is suggested in data from the most recent years. One of its daughter products, 1,1-DCE, shows a very similar concentration pattern, suggesting the degradation of 1,1,1-TCA was not heavily affected by the addition of electron donor material.

The only statistical trend having a 95 percent level of confidence at well 91105 is for carbon tetrachloride, which is calculated to be decreasing (Table 90). As shown on the top portion of Figure 208, this constituent has not been detected since the remedial action was completed in 2005. Although the early post-closure detection limits were high and, as previously discussed, nondetects can lead to false conclusions with respect to calculated trends, this particular decreasing trend appears reasonable. Data from samples collected in future years will help reveal the longer-term trends of the various OBP#2 contaminants monitored at well 91105.

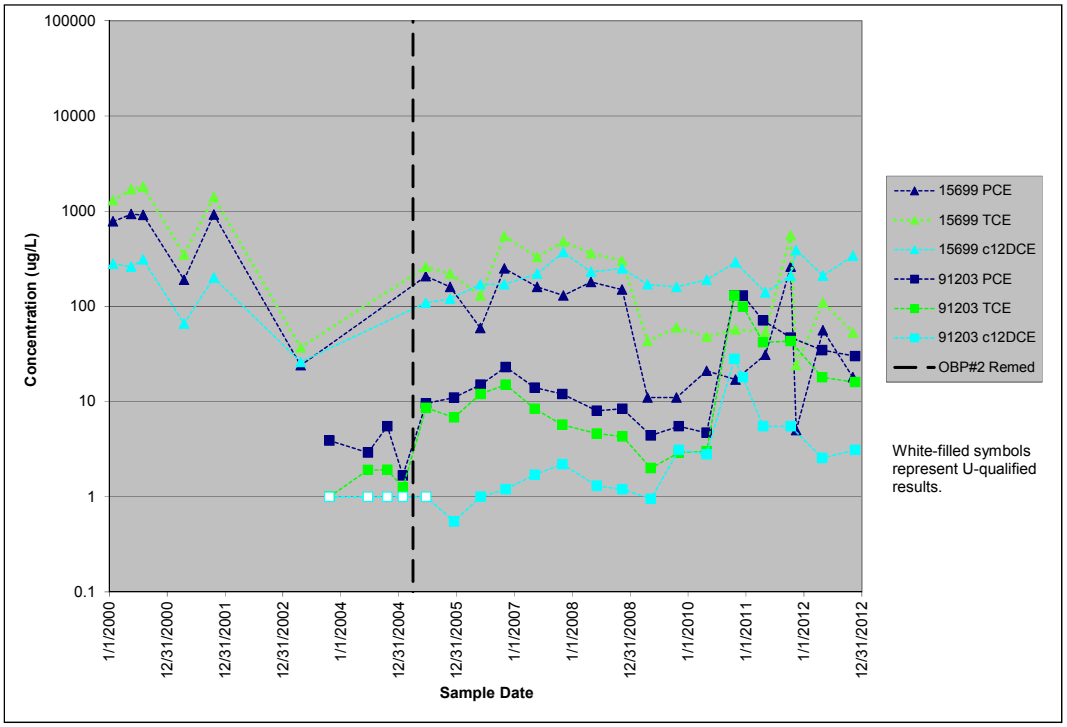


Notes: CT = carbon tetrachloride (RFLMA Table 1 standard = 1 µg/L); CF = chloroform (3.4 µg/L); c12DCE = *cis*-1,2-dichloroethene (70 µg/L); PCE = tetrachloroethene (1 µg/L); TCE = trichloroethene (2.5 µg/L) ; 111TCA = 1,1,1-trichloroethane (200 µg/L); 11DCE = 1,1-dichloroethene (7 µg/L); VC = vinyl chloride (0.2 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 208. Primary VOCs in OBP#2 Source Area Well 91105 (and Predecessors)

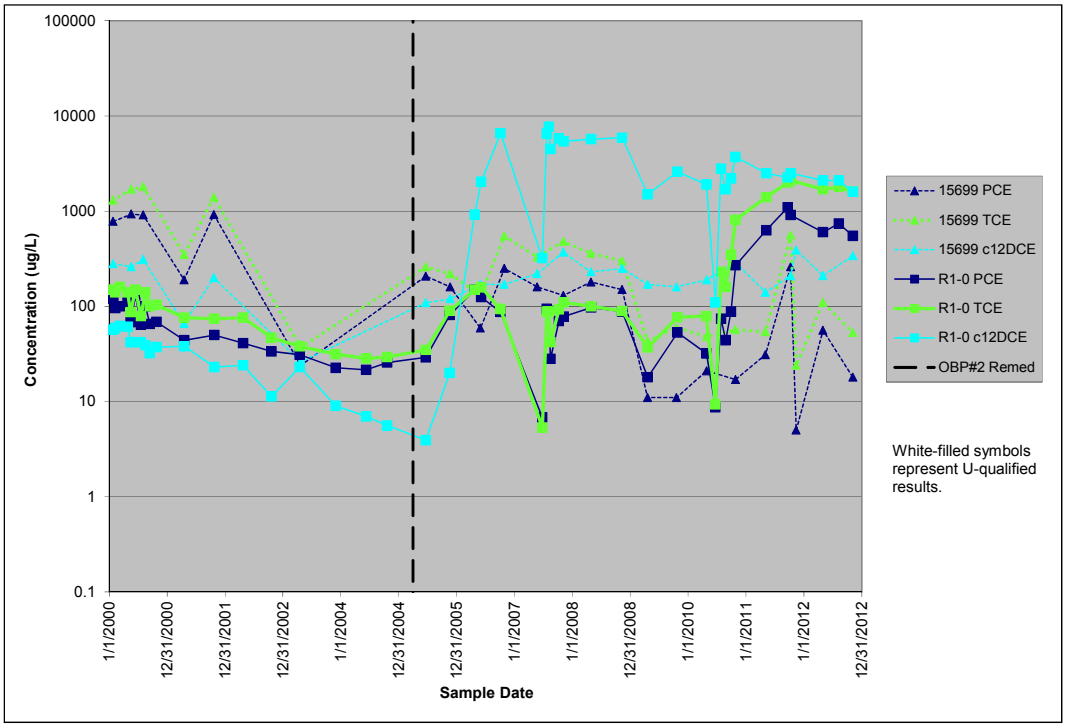
The Mound and OBP#2 Plumes are also monitored by Sentinel wells positioned generally downgradient of the source areas, along flow paths to surface water. Figure 209 displays reported concentrations of PCE, TCE, and *cis*-1,2-DCE in samples from Sentinel wells 15699 (downgradient of the Mound source area and MSPTS groundwater intercept trench) and 91203 (generally sidegradient to downgradient of OBP#2). As noted in previous annual reports (e.g., DOE 2010d) and illustrated on Figure 209, the concentrations of these constituents in samples from well 15699 that were collected prior to closure show fairly close correlation and reflected the position of each constituent in the PCE/TCE degradation pathway (K-H 2004d, ATSDR 2007). Concentrations of these constituents have followed a different pattern since mid-2006, when the redirected flow from the OBP#2 area reached the MSPTS area. Concentrations of PCE and TCE have continued to vary similarly, but appear to have decreased compared with pre-closure levels. However, concentrations of *cis*-1,2-DCE are now consistently higher than those of these parent compounds. (Although not included on the figure, concentrations of VC have also shown a substantial post-closure increase in samples from well 15699.) A short-lived return to the pre-closure distribution in late 2011 is evident on the figure, with concentrations highest for TCE, then PCE, then cis-1,2-DCE, but did not persist into 2012. As noted in the 2011 Annual Report (DOE 2012f), this change may be related to the MSPTS maintenance activity performed earlier in that year, wherein the ZVI media was replaced and other work was completed. During that effort, water was stored in the subsurface trench adjacent to monitoring well 15699 rather than passed through the treatment cells.

The change at well 15699 in relative concentrations among parents and daughter product reflects 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 the facts that well 15699 is positioned downgradient of the MSPTS groundwater collection trench, this trench has received groundwater with significantly higher concentrations of *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 (Figure 210). 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; only in late 2012 (a relatively drier year) did it drop below that level, and it is still well above the pre-closure norm. This post-closure rise in water levels is largely attributed to the additional water routed to the unlined trench, located immediately upgradient of well 15699. More recent changes in sampling methods that lead to reduced volumes of purge water removed from the well have also affected water availability.



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 detections are qualified, but for simplicity are not shown differently. Note logarithmic concentration scale.

Figure 209. Concentrations of Selected VOCs at Mound/OBP#2 Plume Wells 15699 and 91203



Notes: R1-0 = MSPTS influent. 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, but for simplicity are not shown differently. Note logarithmic concentration scale.

Figure 210. Concentrations of Selected VOCs in Samples from Sentinel Well 15699 and MSPTS Influent

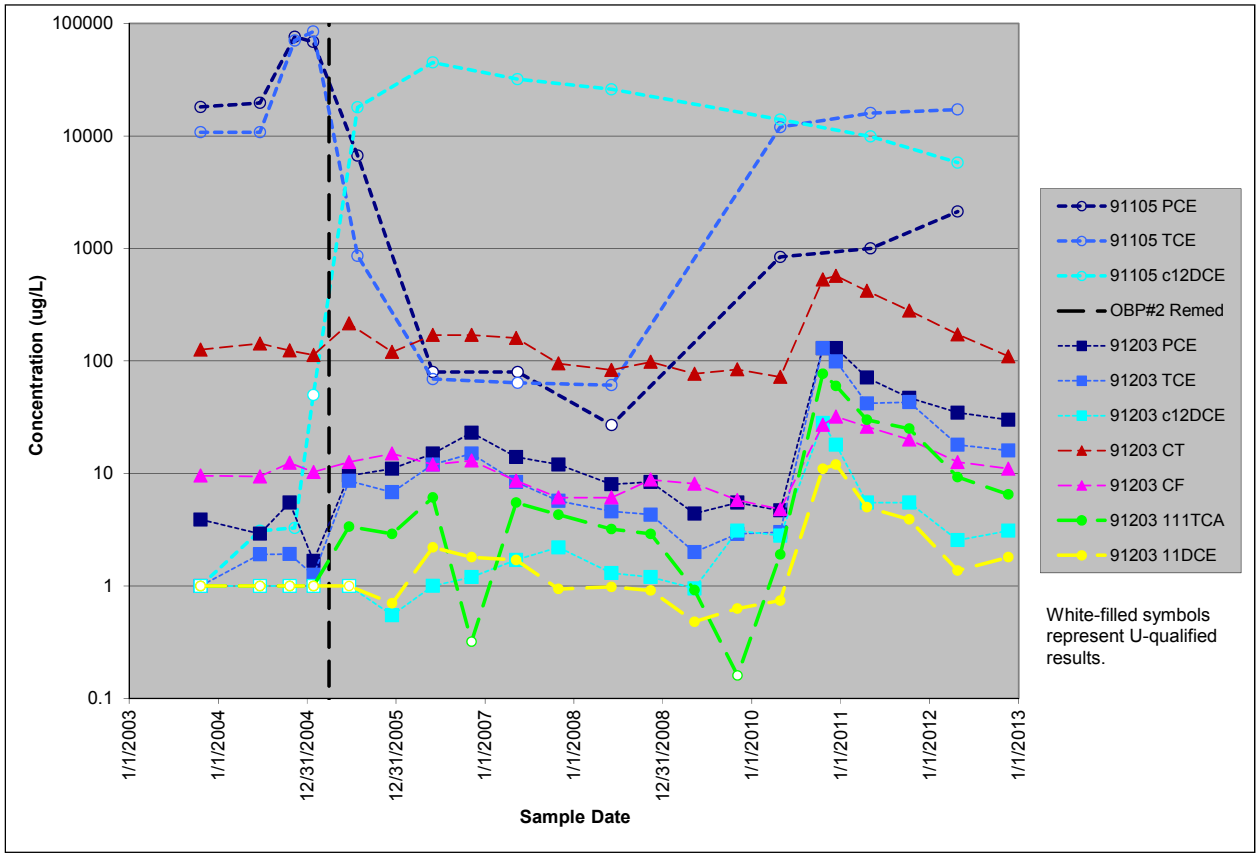
The aforementioned effects of the OBP#2 remediation on MSPTS influent are clearly evident in the time-series plots of Figure 210. System influent showed a low and decreasing concentration of *cis*-1,2-DCE until shortly after remediation was complete, when it began a sharp increase of three orders of magnitude. Concentrations of this constituent subsequently leveled off and began to decrease since about 2008, even as concentrations of PCE and TCE have rebounded. Over the past year to two years, these three constituents in MSPTS influent have appeared to level off at concentrations that are approximately one order of magnitude higher than they were in 2000. This confirms that the MSPTS is capturing and treating significantly more contaminant load than was present prior to closure. Additional detail on the system itself is presented later in this section.

From a statistical perspective, trends calculated to have a 95 percent level of significance in samples from well 15699 include several increasing and decreasing trends. The parent products PCE and TCE are calculated to be decreasing, while those of 1,1-DCE, chloroform, *trans*-1,2-DCE and VC are increasing (see Table 90 and Appendix B). Again, some of these calculated trends are complicated by the presence of numerous nondetects (such as with chloroform, *trans*-1,2-DCE, and VC).

Samples from Sentinel well 91203 show a distribution of contaminants that is generally unlike that at OBP#2 well 91105. This well is positioned near the gravel drain that was installed to route OBP#2 groundwater to the MSPTS intercept trench, but is slightly west (generally sidegradient) of that trench; with respect to OBP#2 itself, well 91203 is downgradient to sidegradient. An

increase in the concentrations of some VOCs is seen in samples from well 91203 that generally coincides with the disruption associated with remediation of OBP#2 completed on April 1, 2005. However, other constituents do not seem to relate to activities at OBP#2 (see Figure 208, Figure 209, and Figure 211). Concentrations of PCE and TCE in samples from well 91203 increased shortly after the OBP#2 remediation, but concentrations of carbon tetrachloride were unaffected (despite dropping to below detection limits at the downgradient edge of the former OBP#2), and VC has never been detected in samples from well 91203 even though detection limits are typically below 1 µg/L. A late-2010 increase in the concentrations of several constituents is apparent in samples from well 91203 (Figure 211), and include carbon tetrachloride (which is not detected at OBP#2 source-area well 91105). This condition is attributed to the higher water levels that year, but the affected VOCs may not correlate to an OBP#2 source. Since 2010, these constituents have steadily decreased in concentration at well 91203.

Estimated travel times (discussed in Section 3.1.3.5 and summarized in Table 49) from well 91105 to 91203 typically have been in the range of 3.5 to 4 years, but in the second quarter of 2010 they were estimated at under 2 years (DOE 2011d). Data collected since then suggest a return to more normal flow conditions for this well pair, with estimated travel times in 2012 of approximately 3.2 and 3.4 years. But as noted in Section 3.1.3.5, these calculated travel times are estimates only and apply to pure water. They do not apply to dissolved constituents such as VOCs, which would be retarded to some degree and would take longer to move the same distance. In addition, because well 91203 is not directly downgradient from well 91105, this velocity estimate may not be directly applicable to this well pair. Even so, the length of time between the OBP#2 remediation and late-2010 increase in concentrations observed at well 91203 is about 5 ½ years, and the distribution of several contaminants resembles those in the pre-remediation OBP#2 groundwater. Additional monitoring data may help to identify factors in the VOC distribution and variability observed at well 91203.



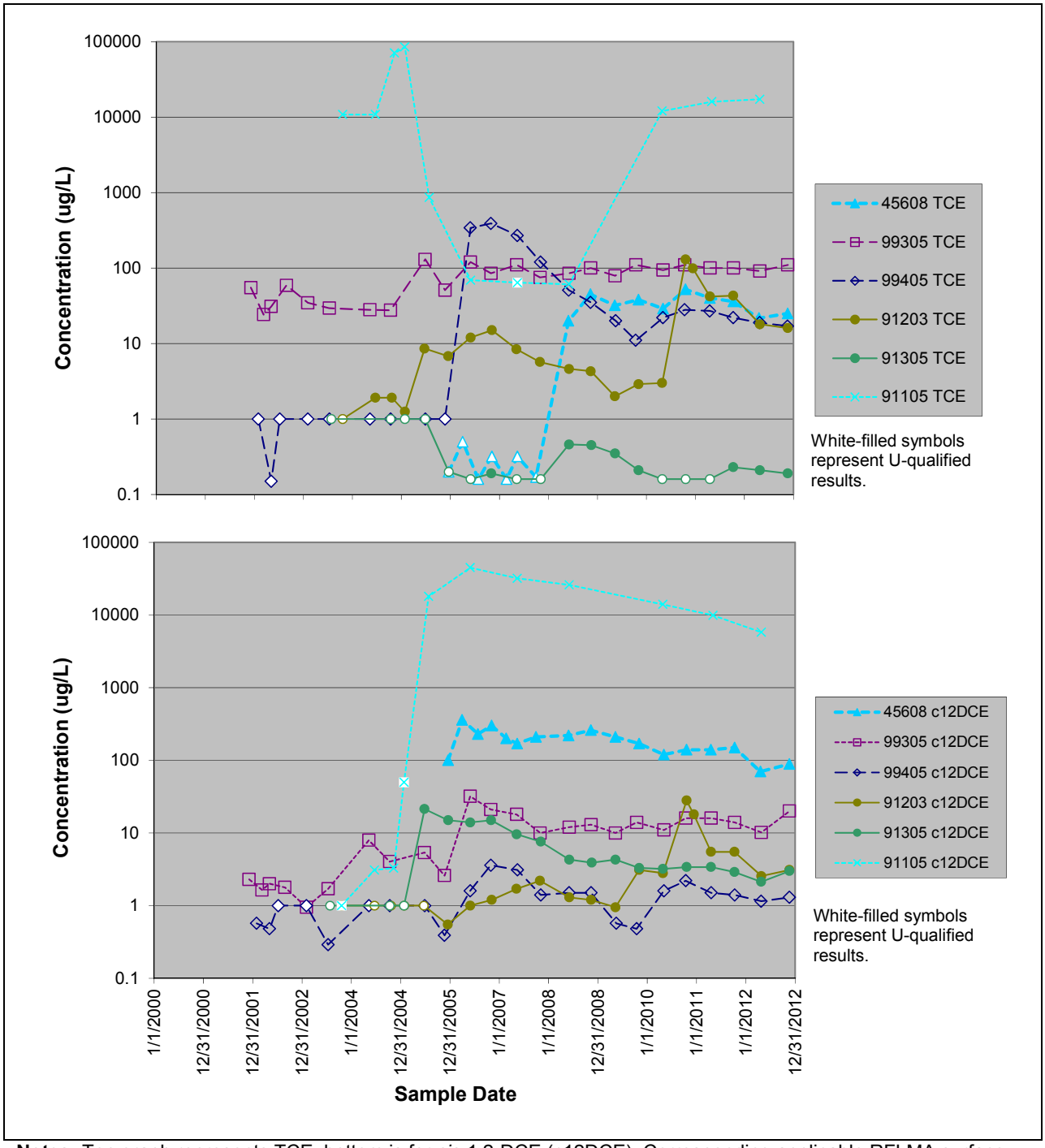
Notes: Data from OBP#2 source area well 91105 are designated as such, all other are from well 91203.
CT = carbon tetrachloride (RFLMA Table 1 standard = 1 µg/L); CF = chloroform (3.4 µg/L);
PCE = tetrachloroethene (1 µg/L); TCE = trichloroethene (2.5 µg/L); c12DCE = *cis*-1,2-dichloroethene (70 µg/L); 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 detections are qualified, but are not shown differently for the sake of simplicity. Note logarithmic concentration scales.

Figure 211. VOCs in Well 91203, Downgradient of OBP#2

S-K trend calculations for 91203 (Table 90 and Appendix B) suggest the presence of several trends having a 95 percent level of significance, all of which are increasing. Calculated trends in PCE and TCE are visually apparent on Figure 211, while those for 1,1,1-TCA, 1,1-DCE, and *cis*-1,2-DCE are complicated by the presence of numerous early nondetects, subsequent estimated values, and variability in the corresponding datasets; therefore, the calculated trends for these latter constituents may not be valid.

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 overall increase similar to that observed at 91203. Instead, an overall decrease is visually apparent for the few VOCs detected here (most often including *cis*-1,2-DCE, TCE, and VC, each of which is reported at low concentrations if detected). With the addition of the 2012 data, a decreasing trend is now suggested for *cis*-1,2-DCE at well 91305 but does not meet a 95 percent level of significance (Table 90). 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 212 illustrates concentrations of TCE and *cis*-1,2-DCE 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 (both on the B991 hillside), 91203 (north of OBP#2), and 91305. Both of these VOCs are partially-dechlorinated daughter products of PCE, though TCE itself was also used as an industrial solvent 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. (Note that both of these neighboring wells and nearby well 99305 are represented by calculated increasing trends in *cis*-1,2-DCE and TCE, though not all meet the 95 percent level of significance. Refer to Table 90 for a summary of these and other calculated trends for wells in this general area.) The lower TCE and higher *cis*-1,2-DCE concentrations at well 91305 may relate to enhanced biodegradation fostered by 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. Similarly, the wetland that existed immediately west of this well prior to B991 demolition and closure may also have contributed to the development of biogeochemical conditions here that promote reductive dechlorination. Monitoring will continue according to RFLMA, and additional data may help to explain specific relationships.



Notes: Top graph represents TCE, bottom is for *cis*-1,2-DCE (c12DCE). Corresponding applicable RFLMA surface-water action levels, respectively: 2.5 µg/L, 70 µg/L (CDPHE et al. 2012). In addition to nondetects on both graphs, several results are qualified detections but for simplicity are not shown differently. Note logarithmic concentration scales.

Figure 212. 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, a small, prototype air stripper was installed in the effluent manhole to polish the effluent. Section 2.4 discusses routine maintenance activities performed at the MSPTS in 2012, much of which focused on testing the prototype air stripper. For additional detail on the air stripper, refer to the annual report for 2011 (DOE 2012f).

As with all years from 2005 on, flow rates through the MSPTS in 2012 were above pre-2005 levels. This is attributed to the intentional routing of groundwater from the OBP#2 area into the MSPTS intercept trench. (For additional background, see the 2005 Annual Report, DOE 2006d.) Table 91 provides annual estimates of the volume of water treated by the MSPTS, which in 2012 was approximately 461,000 gallons. Despite the dry conditions, this represents the second highest volume treated since closure. Table 92 provides averaged annual flow volumes at this system before vs. after Site closure. (A pre-closure volume average that omits 2005 flows is also included because the volume treated in that year was abnormally high, not representative of typical pre-closure conditions.) As summarized by this table, if 2005 is omitted the flow to the MSPTS more than tripled following completion of the OBP#2 connection.

Figure 213 presents a hydrograph illustrating flows from January 1, 2000 through the end of 2012, and Figure 214 provides a hydrograph focusing on CY 2012. The flow in 2012 appears unusually uniform, not as episodic as previous years. This may result from the relatively dry conditions in which precipitation events were rare, even during the normally-wetter spring. The higher volume in dry 2012 than in wet 2010, and the highest-ever volume in 2011 (despite the system being shut down for the media replacement activity), suggests that perhaps the increased recharge from a wet year does not impact MSPTS flows until the following year; if so, the lower recharge from the dry year of 2012 may not be evident in system flows until 2013.

Table 91. 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
2012	461,000	4,335,000

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

Table 92. 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, 2006–2012	404,000

Note: Average volumes are based on estimates of volumes treated, as presented in Table 91. 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, and the post-closure period begins January 1, 2006.

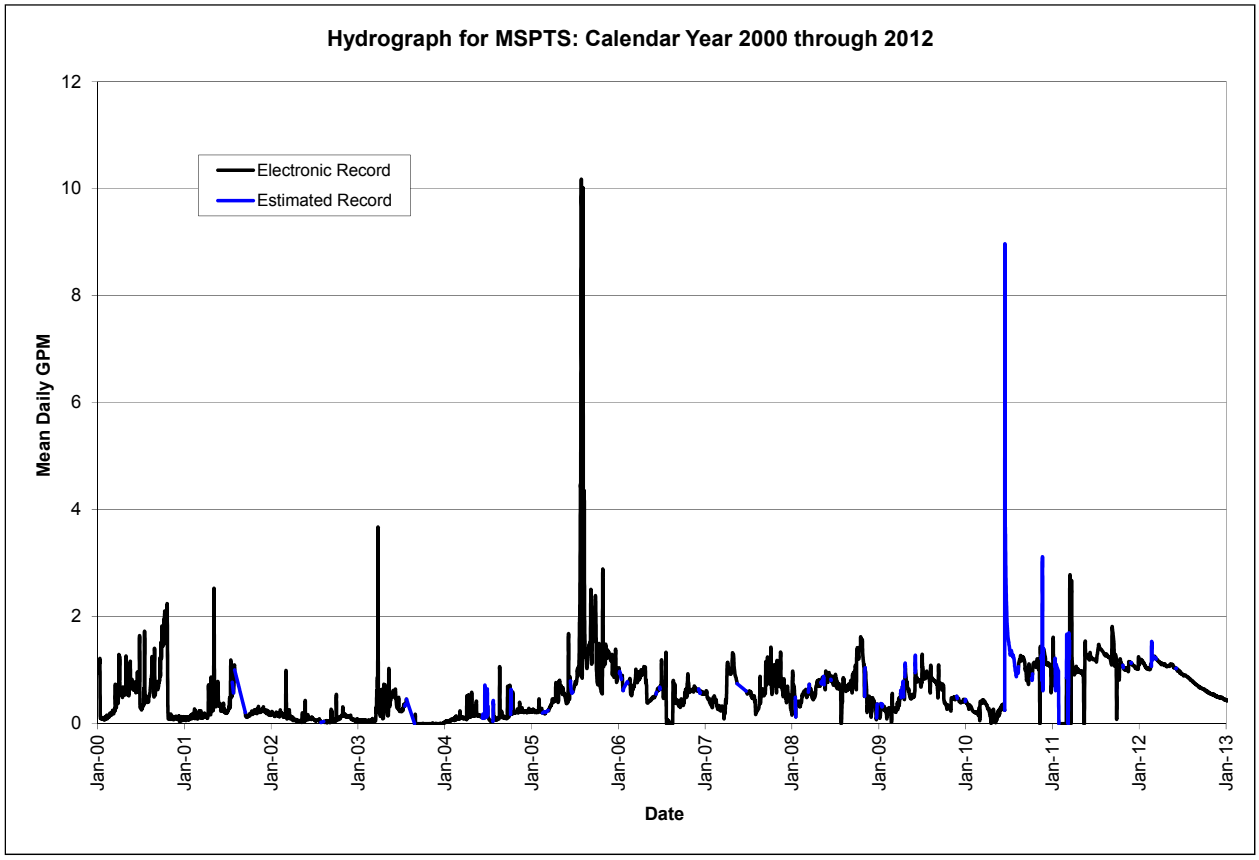


Figure 213. Hydrograph for MSPTS from 2000 Through 2012

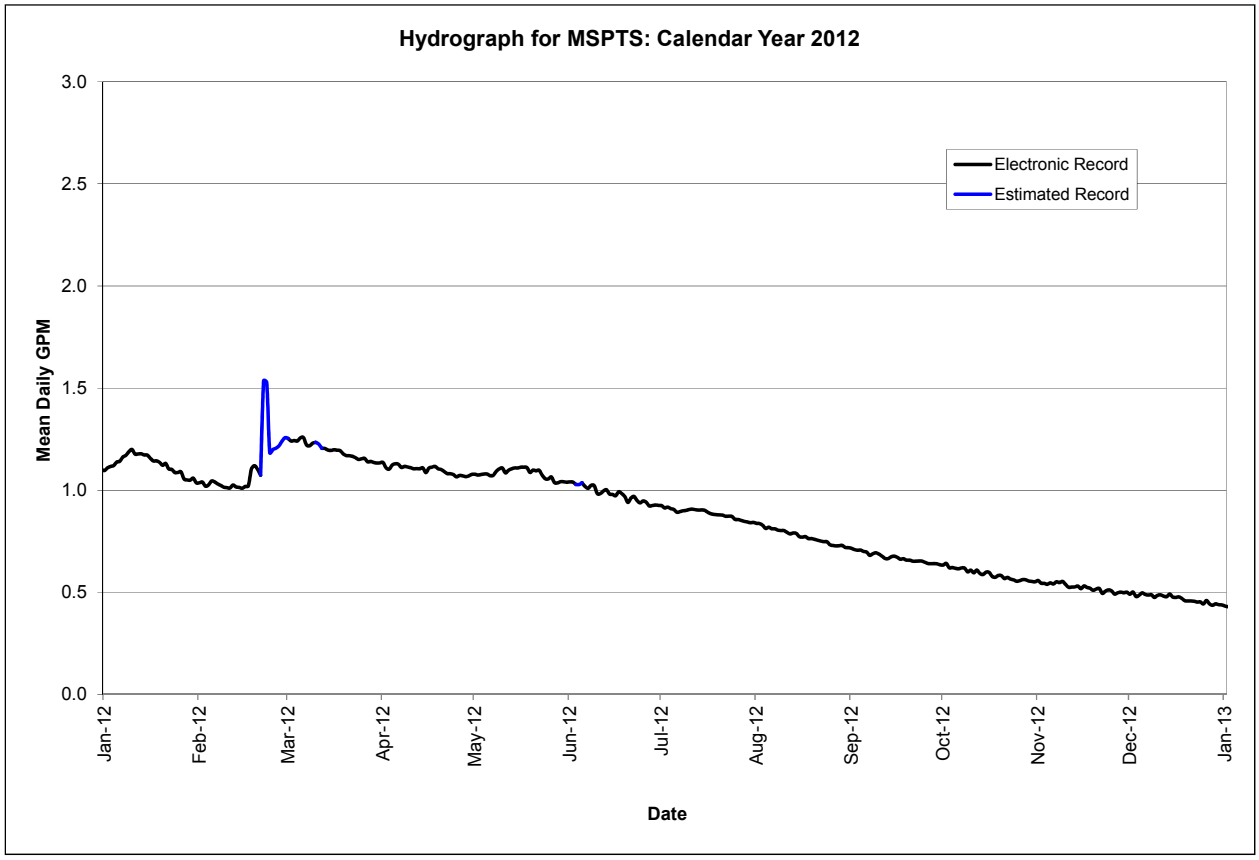


Figure 214. Hydrograph for MSPTS for CY 2012

The MSPTS was sampled twice in 2012 (May, November) in accordance with RFLMA. Analytical data representing MSPTS influent and effluent continue to illustrate the dramatic effect the addition of OBP#2-related groundwater has on the system. In addition, the influent was sampled in August to support air stripper optimization efforts, and the effluent was sampled in November to support investigations at surface water POE GS10. Most of the sampling conducted to support the prototype air stripper efforts was performed at specially-designed sampling locations that are not RFLMA locations. These air stripper locations are referred to as ASHINF (referring to "air stripper housing influent") and ASHEFF (referring to "air stripper housing effluent"). Activities related to the air stripper are discussed together with analytical results below. See Appendix F of the 2011 Annual Report (DOE 2012f) for additional detail on the MSPTS prototype air stripper design, installation, and optimization.

Concentrations of TCE and PCE in MSPTS influent leveled off in 2012 after rising throughout 2011, as illustrated above on Figure 210. At the same time, concentrations of *cis*-1,2-DCE continued to slowly decrease, and concentrations of VC remained low compared to early post-closure years, particularly 2007. The relative increases in parent compound concentrations and decreases in daughter product concentrations suggests a general waning of the degree of biodegradation taking place in the OBP#2 source area and flow path, as discussed above in the text focusing on OBP#2 source-area well 91105.

Eight VOCs were detected in 2012 in MSPTS influent at concentrations exceeding their respective RFLMA Table 1 levels (CDPHE et al. 2012): 1,1,1-TCA, 1,1-DCE, 1,2-dichloroethane, chloroform, *cis*-1,2-DCE, PCE, TCE, and VC. This is the same set of VOCs as was elevated in 2011 influent, except in 2012 carbon tetrachloride fell below its Table 1 level. The presence of concentrations of 1,1,1-TCA in MSPTS influent as high as the RFLMA Table 1 standard was unknown until 2007 and represents a primary contaminant from the OBP#2 source area.

In 2012, five VOCs were detected in MSPTS treated effluent at concentrations exceeding RFLMA Table 1 values: chloroform, *cis*-1,2-DCE, PCE, TCE, and VC. Some of these constituents are more recalcitrant; the reductive dechlorination of polychlorinated constituents (such as PCE, TCE, and carbon tetrachloride) occurs more readily than for 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 within the ZVI media for adequate treatment to be accomplished. However, under the post-closure conditions of higher flow rates, the residence time instead decreases. The addition of the prototype air stripper at the MSPTS has assisted in decreasing concentrations of these constituents in system effluent, as discussed further below.

Table 93 summarizes MSPTS influent and effluent analytical data for selected constituents. Refer to the quarterly reports (DOE 2012b, 2012e, 2013a) and Appendix B for additional 2012 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 the 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.)

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Table 93. Summary of VOC Data (µg/L) for MSPTS Influent and Effluent

DATE	1,1,1-TCA		1,1-DCE		CT		CF		cis-1,2-DCE		MCl		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**
5/1/2012	**300**	0.16 (U)	**46**	1.8	**93**	0.19 (U)	**52**	**5.7**	**2100**	**410**	3.2 (U)	1.9	**600**	**3.6**	**1700**	**4.7**	**8 (J)**	**2.3**
11/6/2012	**220**	0.16 (U)	**46**	0.47 (J)	**64**	0.19 (U)	**39**	0.34 (J)	**1600**	**90**	1.3 (U)	0.32 (U)	**550**	.81 (J)	**1600**	0.53 (J)	**3.5 (J)**	**4.5**

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; MCl = 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 (CDPHE et al. 2012); 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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The impact on water quality related to the addition of OBP#2 flow is more concisely summarized in Table 94, which presents average MSPTS influent concentrations generally prior to and following the diversion 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 2012.) 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 (as indicated in Table 93) 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 93 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). Comparison with the same table in the 2011 report (DOE 2012f) shows the post-closure average concentrations of several constituents changing markedly. In particular, the average PCE and TCE concentrations have sharply increased, from the 2011 values of 187.8 µg/L (PCE) and 375.9 µg/L (TCE) to the 2012 values of 240.8 µg/L and 534.8 µg/L, respectively. Concentrations of their daughter products, *cis*-1,2-DCE and VC, have decreased somewhat (*cis*-1,2-DCE from 3,415 µg/L to 3,237.2 µg/L, and VC from 130.6 µg/L to 115.7 µg/L) but remain elevated with respect to pre-closure conditions. The average post-closure concentrations of other constituents did not change as much from 2011 to 2012.

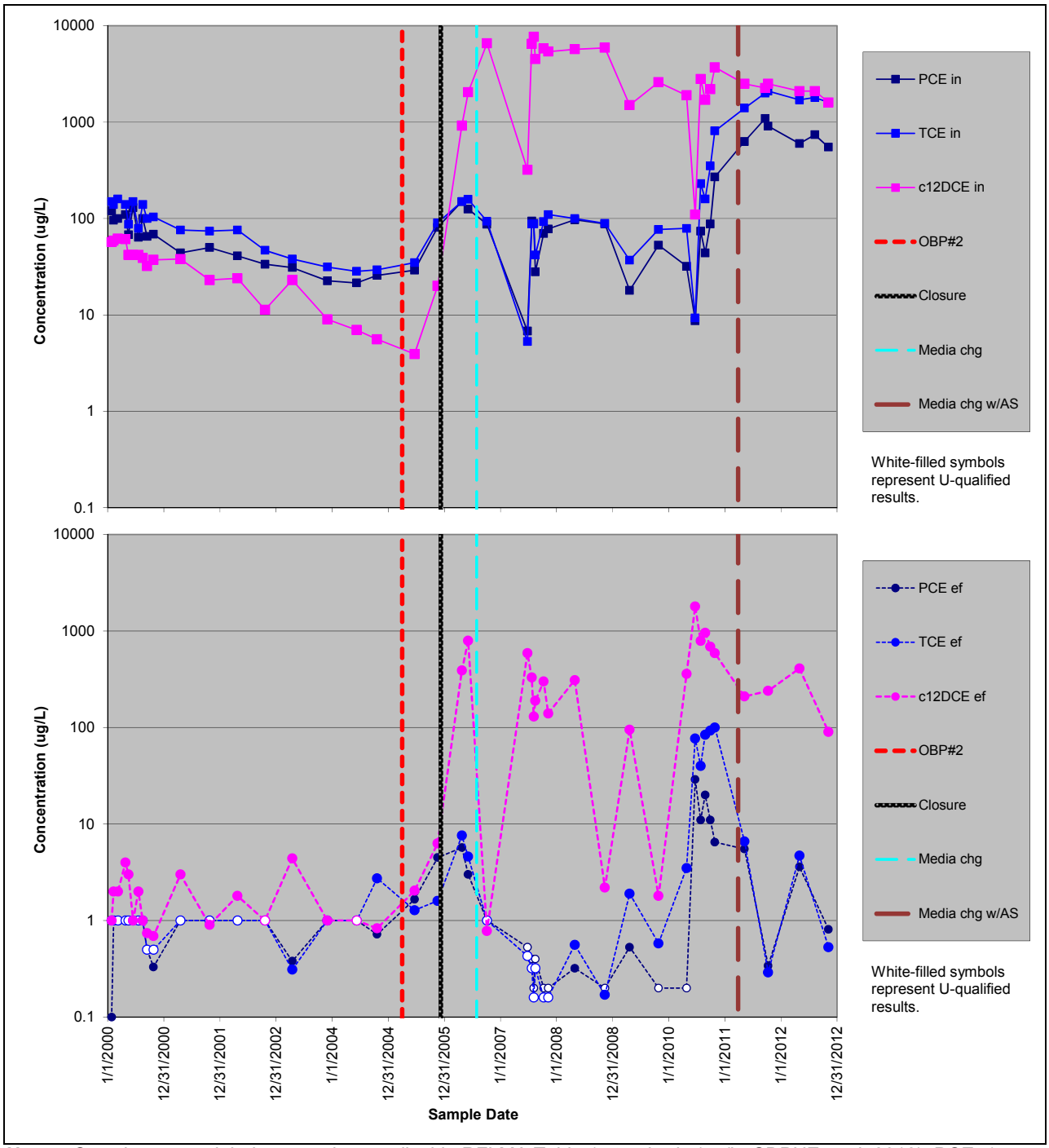
Table 94. Average Contaminant Concentrations in MSPTS Influent, Pre- vs. Post-Closure, in µg/L

	111TCA	11DCE	CT	CF	c12DCE	MCl	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 2012	229.9	53.7	51.0	57.6	3237.2	6.5	240.8	534.8	115.7

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, 2005; 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.

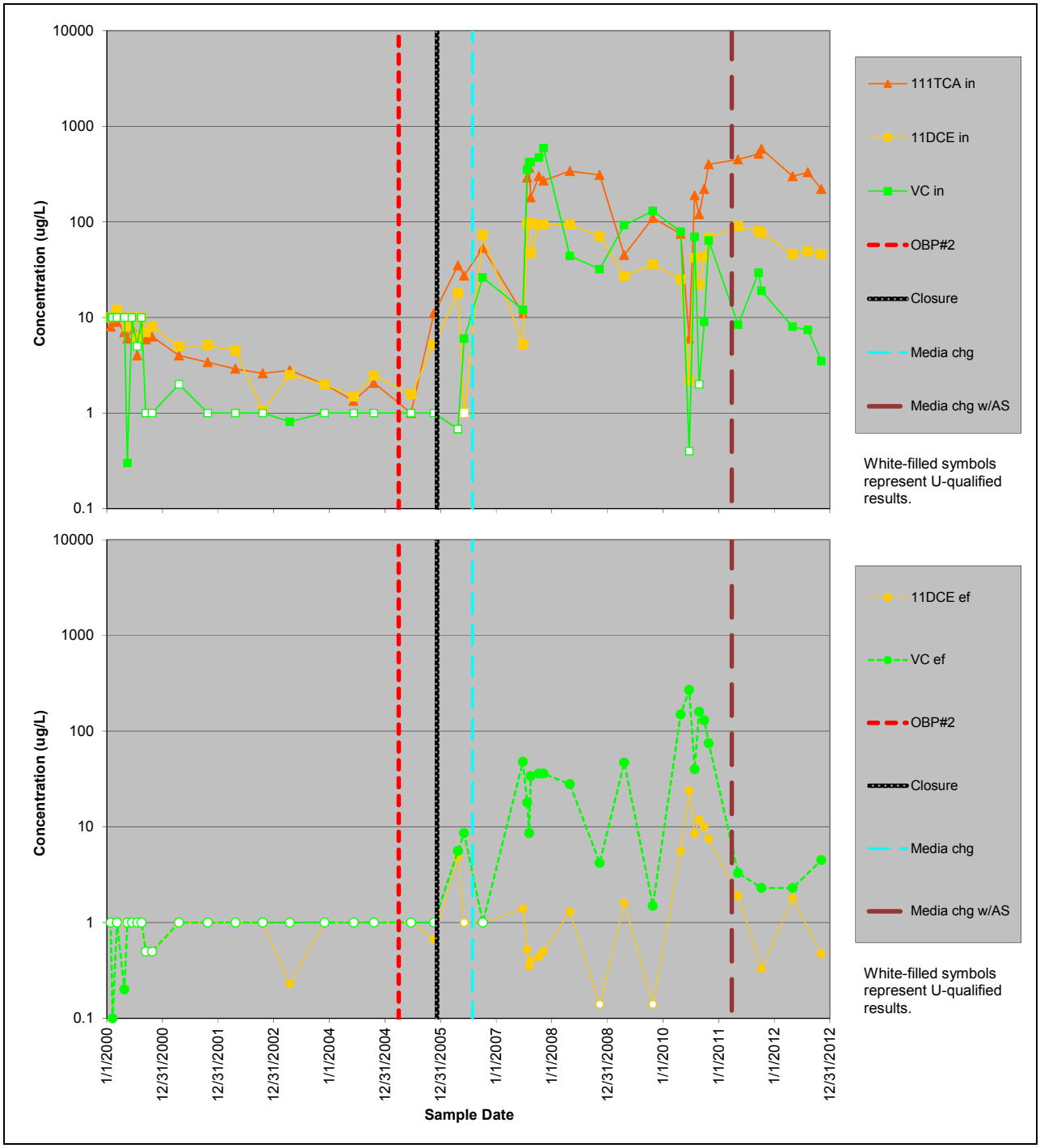
A critical point is that the addition of electron donor material to the OBP#2 source area excavation, and the resulting stimulation of (incomplete) biodegradation of residual VOCs, led to the concentrations of daughter products such as *cis*-1,2-DCE and VC in MSPTS influent increasing more than have 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.

Figure 215 and Figure 216 illustrate 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 initially appear to strongly affect influent concentrations of PCE or TCE (see the upper portion of Figure 215), those of *cis*-1,2-DCE very quickly increased by three orders of magnitude. More recently, samples of system influent collected since late 2010 contain PCE and TCE at concentrations that are about an order of magnitude higher than prior to closure,



Notes: Constituents and their respective, applicable RFLMA Table 1 standards (µg/L; CDPHE et al. 2012): PCE, 1; TCE, 2.5; *cis*-1,2-DCE, 70; in = influent (location Mound R1-0), ef = effluent (Mound R2-E); media changes in 2006 and 2011 are indicated, with the latter including addition of an air stripper (AS). Several results are qualified detections but for simplicity are not shown differently. Note logarithmic concentration scales.

Figure 215. Concentrations of PCE, TCE, and cis-1,2-DCE in MSPTS Influent and Effluent



Notes: Constituents and their respective, applicable RFLMA Table 1 standards (µg/L; CDPHE et al. 2012): 1,1,1-TCA, 200; 1,1-DCE, 7; VC, 0.2; in = influent (location Mound R1-0), ef = effluent (Mound R2-E); media changes in 2006 and 2011 are indicated, with the latter including addition of an air stripper (AS). Several results are qualified detections but for simplicity are not shown differently. Note logarithmic concentration scales.

Figure 216. Concentrations of 1,1,1-TCA, 1,1-DCE, and VC in MSPTS Influent and Effluent

and over the same period those of *cis*-1,2-DCE have undergone a more gradual decline. As shown in the upper portion of Figure 216, VC in system influent has followed a similar pattern to that of *cis*-1,2-DCE, but with a more rapid decline since late 2010. Concentrations of 1,1,1-TCA (a useful marker for OBP#2 groundwater) and 1,1-DCE both increased substantially following remediation of the OBP#2 and the routing of associated groundwater to the MSPTS; these increases occurred at about the same time as that of *cis*-1,2-DCE. Concentrations of 1,1,1-TCA and 1,1-DCE have fluctuated, but overall show little change since 2007.

These figures also illustrate the treatment effectiveness of the MSPTS. Prior to closure and diversion of OBP#2 groundwater to the treatment system, concentrations of these VOCs in system effluent were consistently low. That action affected effluent concentrations substantially for several constituents, most notably the recalcitrant daughter products *cis*-1,2-DCE and VC, but also PCE and TCE as the ZVI media aged (evident in 2005 and early 2006, and again in 2010). Effluent concentrations of 1,1,1-TCA are not illustrated because this constituent is consistently removed to below its RFLMA standard (see Table 93). Treatment of 1,1-DCE has also typically been adequate, except during the high-flow year of 2010. Those conditions and the resulting decrease in MSPTS performance led to the installation of the air stripper discussed below; refer to the 2010 Annual Report (DOE 2011d) for more detail on the changed conditions and regulatory consultations that culminated in the installation of the air stripper.

Finally, although not required by the RFLMA, S-K trend calculations were performed for MSPTS influent. The data evaluated included all influent from January 2000 through the end of 2012, and (separately) post-closure influent only (i.e., data reported beginning in 2006). The trend calculations for each of these approaches identify several represented by a statistical confidence of 95 percent (Table 90; see also the trend plots in Appendix B). The trends identified for the entire period are obviously affected by the addition of OBP#2 flow, as previously discussed. Trends at this level of significance include some affected by a consistent record of nondetects prior to the OBP#2 work (increasing 1,1,1-TCA, VC, and both *cis*- and *trans*-1,2-DCE) but which can be accepted as generally valid given that these constituents were either not detected or present at lower levels than has been the case since closure. Others include increasing 1,1-DCE, decreasing carbon tetrachloride, increasing chloroform, and increasing TCE. When only post-closure data are evaluated, trends at the 95 percent level of significance include increasing 1,1,1-TCA and TCE, and decreasing *trans*-1,2-DCE. These increasing trends are readily apparent on the time series plots above. For the post-closure era, trends of this significance are not identified for other primary constituents such as 1,1-DCE, *cis*-1,2-DCE, carbon tetrachloride, PCE, and VC. With more data, additional trends will be identified at this 95 percent level of confidence.

No VOCs other than those summarized in Table 93 were detected in 2012 in MSPTS effluent at concentrations exceeding the RFLMA standards.

Two grab samples for the analysis of VOCs were collected in 2012 at the surface-water performance location for the MSPTS, surface-water station GS10. Very low concentrations of VOCs were detected (Table 95). None exceeded the corresponding RFLMA standards.

Table 95. Summary of VOCs Detected in 2012 at GS10

Date	Constituent	Result (µg/L)	Qualifier
5/1/2012	*cis*-1,2-Dichloroethene	36	
5/1/2012	Trichloroethene	0.55	J
11/6/2012	*cis*-1,2-Dichloroethene	1.2	

The detections reported in 2012 at GS10 are generally consistent with conditions reported in previous post-closure years. VOCs detected most commonly at location GS10 are *cis*-1,2-DCE and TCE. Note that more detections were reported in the wetter second-quarter sample than the drier fourth-quarter sample. This is also typical, and 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.

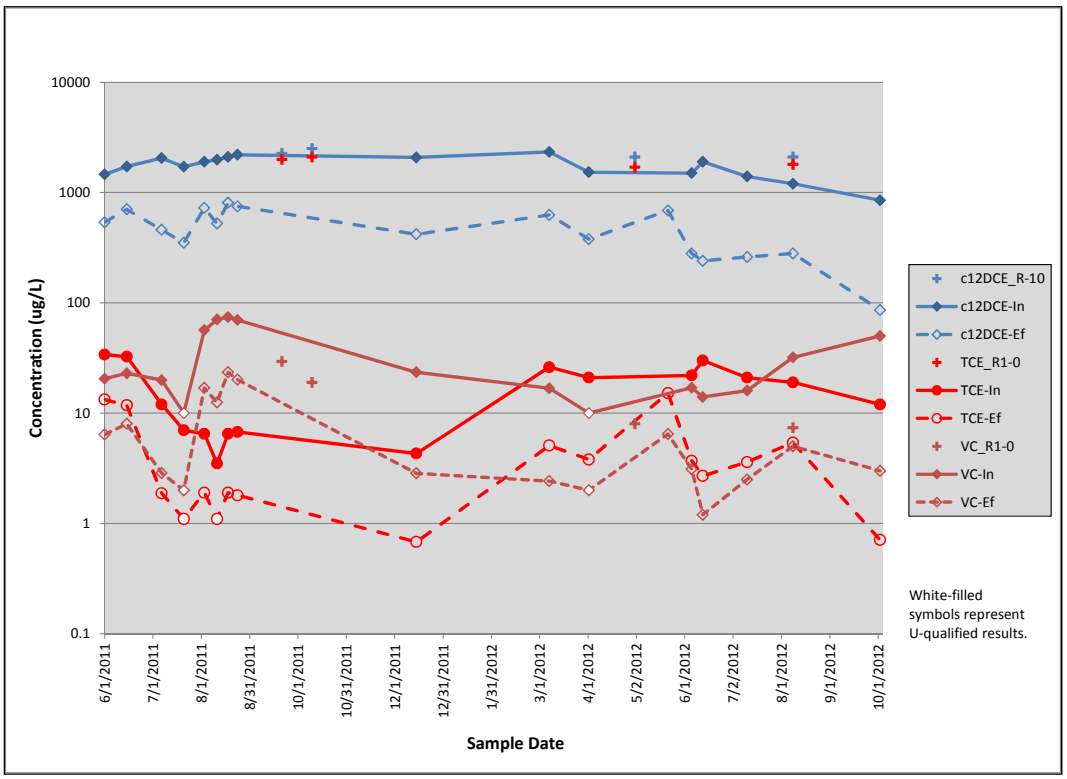
MSPTS Effluent Polishing Component: Air Stripper

The 2011 Annual Report (DOE 2012f) provided a discussion of the decision to install an effluent polishing component at the MSPTS. A pilot-scale air stripper was selected, and was installed within the effluent manhole in March 2011. The unit was based on a spray-aeration approach and was designed to operate for only 12 hours per day because it represented an untested prototype. Operation of this unit was tested and adjusted through 2012, leading to confirmation that it would provide effective reduction of residual VOCs remaining in effluent from the ZVI-filled treatment cells. As a result, a larger, permanent air stripper is being installed—still within the effluent manhole—and will be completed in 2013. (A similar unit will be installed in 2013 at the ETPTS, as discussed in the corresponding section below.) Refer to the 2011 Annual Report for a more detailed description of the background on the selection of the air stripper, and associated developmental testing; the text below focuses more on optimization efforts and results.

Testing of the air stripper begun in 2011 continued in 2012. The main adjustments included changing the configuration or number of spray nozzles, the pump flow rate, the number of pumps, and adding active ventilation. Between two and six nozzles and one or two pumps at a time were operated. Each pump was rated at approximately 4 gallons per minute (gpm). Active ventilation was later provided by an inexpensive 10-watt attic fan with attached solar panel; its operation was strongly affected by the amount of available sunlight. The fan was mounted on the manhole lid to draw air out of the manhole. (A passive air inlet and exhaust vent had been installed as part of the original design; the former was not modified for this ventilation testing, but the passive exhaust vent was replaced by the solar-powered fan.)

Due to the prototypical nature of this unit, high-cost pumps were not purchased for the testing phase. Instead, if testing proved successful, the final air stripper design would include a more durable, long-lasting pump. There were occasional test postponements as a result of issues such as diminished solar production in the winter and failures of the inexpensive pumps.

Figure 217 shows the prototype air stripper's effects on concentrations of some of the primary residual contaminants present in effluent from the ZVI-filled treatment cells. Note that treatment cell effluent represents influent to the air stripper, while effluent from the air stripper represents overall "system" effluent—treated water that is discharged to groundwater.

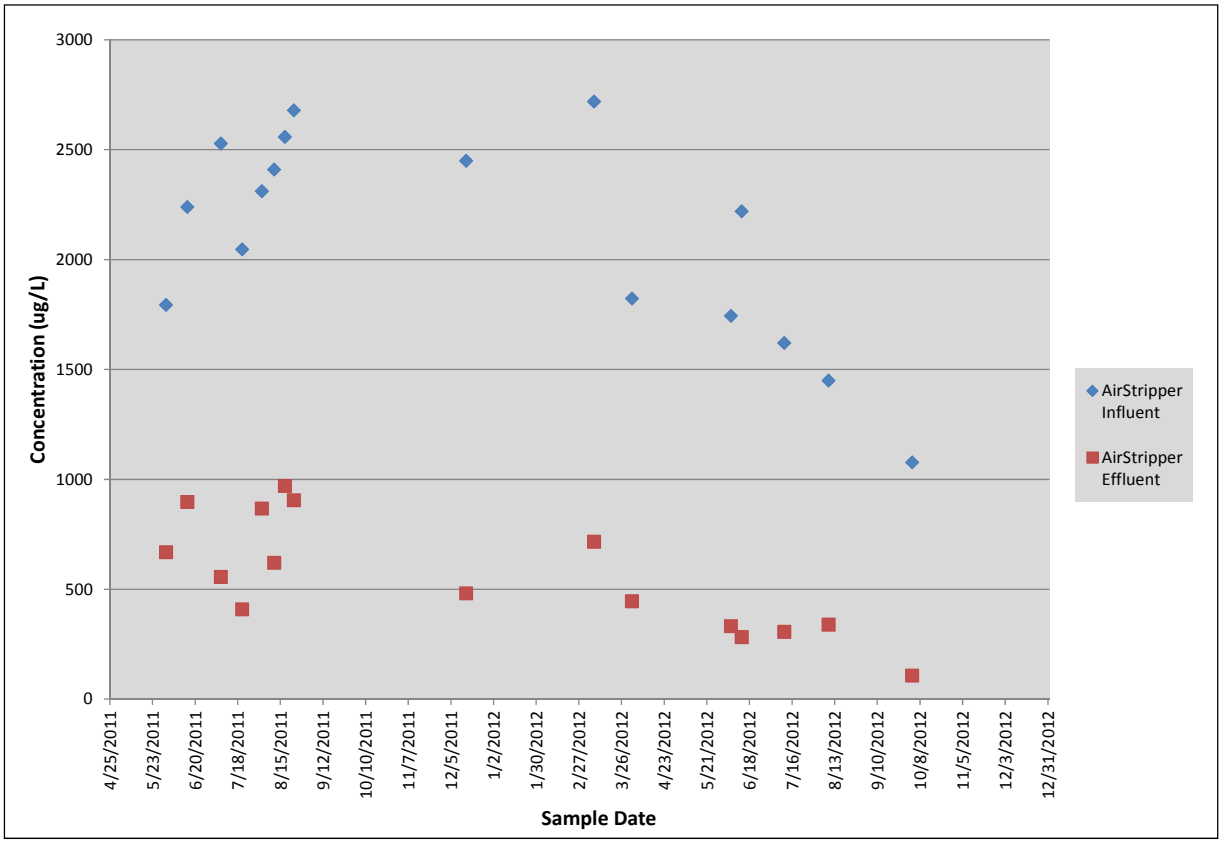


Notes: R1-0 = raw influent to treatment system; In = influent to air stripper (equivalent to effluent from ZVI-filled treatment cells); Ef = effluent from air stripper (same as effluent from treatment system). Constituents and their respective, applicable RFLMA Table 1 standards (µg/L; CDPHE et al. 2012): TCE, 2.5; c12DCE = *cis*-1,2-DCE, 70; VC = 0.2. Note logarithmic concentration scale.

Figure 217. Concentrations of Selected VOCs in MSPTS Air Stripper Influent and Effluent

Figure 217 suggests that the ZVI media within the treatment cells reduces concentrations of primary compounds such as TCE much more effectively than it reduces those of partially-dechlorinated compounds such as *cis*-1,2-DCE and VC. This is evident in a comparison of raw influent concentrations (as measured at location R1-0) with those in air stripper influent (which represents effluent from the ZVI-filled treatment cells). In addition, at least some portion of these daughter products in the air stripper influent is created within the ZVI-filled cells through partial dechlorination of parent products. As previously reported (e.g., DOE 2012f), complete dechlorination of these daughter products requires longer residence times within the ZVI media than has been the case in recent years; this condition, and the presence of residual VOCs in effluent from the treatment cells, drove the installation of the air stripper.

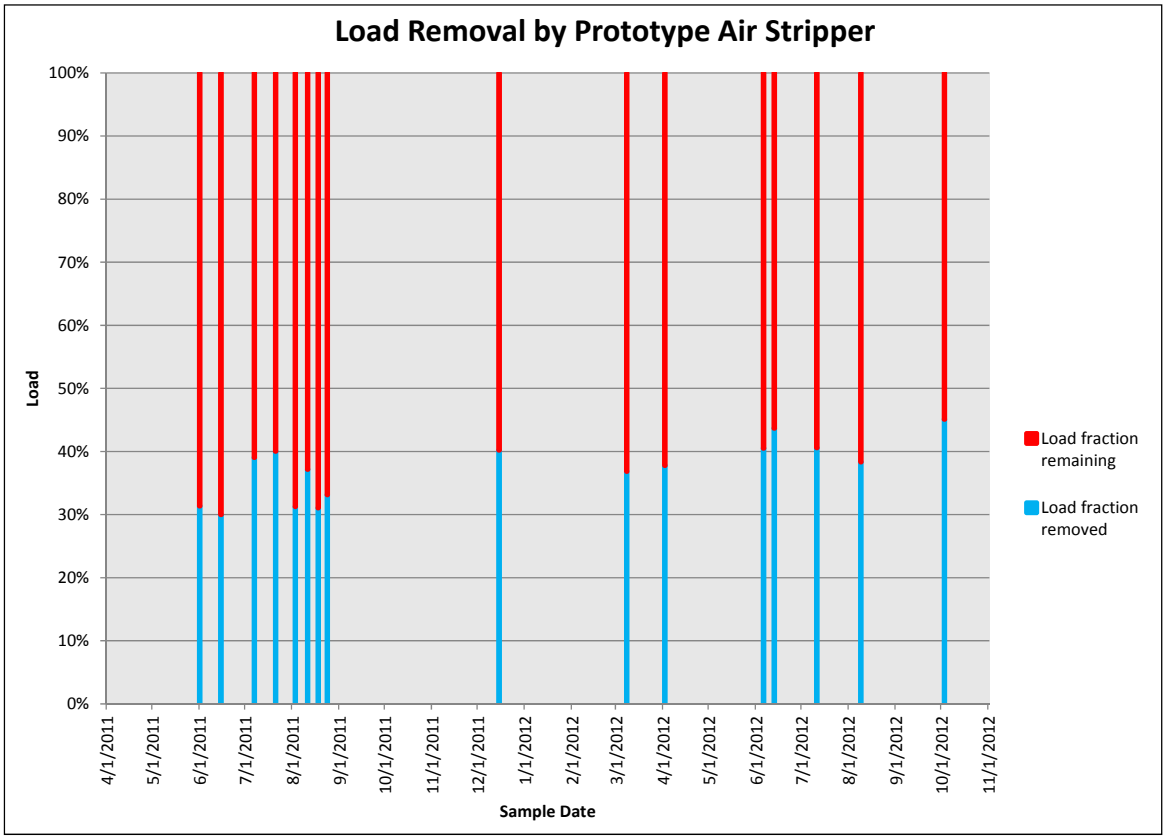
These results can also be considered in terms of total VOCs, as opposed to selected VOCs. For each date on which both influent and effluent to the air stripper were sampled, reported concentrations of the detected constituents were summed and plotted (Figure 218). The calculated total VOC concentrations presented on this figure only omit nondetects; unless assigned a U (nondetect) qualifier during validation, estimated values (i.e., J-qualified) and those that were also detected in the blank (B-qualified) are included in the sums at face value.



Notes: Plotted values represent the sum of reported concentrations of VOCs detected in influent to air stripper (equivalent to effluent from ZVI-filled treatment cells) and effluent from air stripper (same as effluent from treatment system). Specific VOCs vary by location and date, but in all cases, *cis*-1,2-DCE is reported with the highest concentration (multiple hundred to over 2,000 µg/L, except the last effluent data point of 86 µg/L).

Figure 218. Comparison of Total VOCs in Air Stripper Influent and Effluent

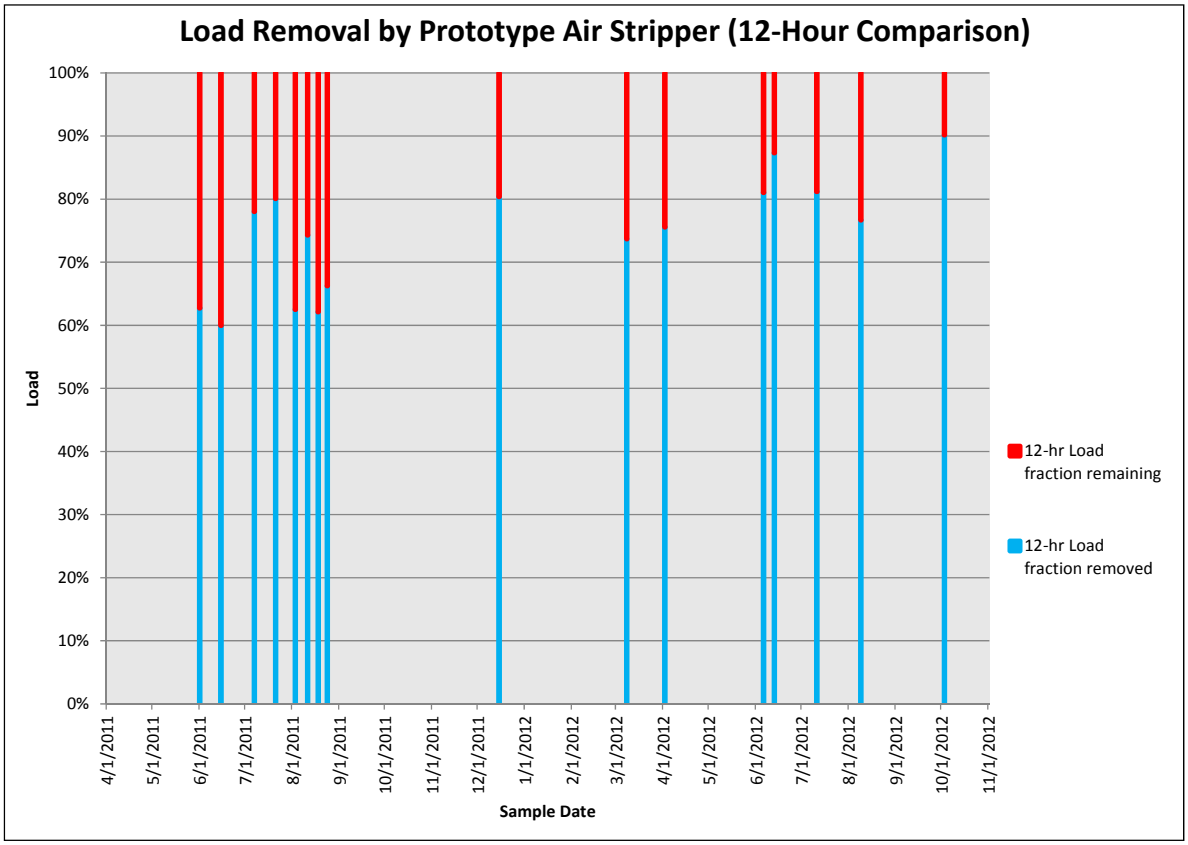
While Figure 217 and Figure 218 illustrate the effects of the MSPTS prototype air stripper on concentrations of VOCs, Figure 219 presents these air stripper data differently. Flow rates through the treatment system are measured at the MSPTS; on each sample date, these data were used to estimate the total volume of water discharged on those dates. The concentration data were then converted to estimated loads—that is, the total mass of VOCs in air stripper influent and effluent on the sample dates. Each calculated air stripper influent load was assumed to fairly represent the entire sample date, while the effluent loads were adjusted to reflect the fact that the air stripper was only operating for 12 hours on the given date. That is, for 12 hours influent water passed through the air stripper housing (the effluent manhole) without receiving further treatment, and for 12 hours that influent was treated by the prototype air stripper. The resulting reduction in VOC loads attributed to the air stripper is illustrated in Figure 219.



Notes: Plotted load fractions reflect total of detected VOCs and measured flows for the given sample dates. Assumptions include: reported concentrations of all detections, including data with B and J qualifiers, are accurate and representative of the water at the given location for the full 24-hour period for influent, or the full 12-hour period during which the air stripper was treating effluent; similarly, the total flow on each date can be split in half to represent the time the air stripper operated or didn't operate. Influent to the air stripper is equivalent to effluent from ZVI-filled treatment cells; effluent from the air stripper is equivalent to effluent from the treatment system.

Figure 219. VOC Loads in Prototype Air Stripper Influent and Effluent

Figure 219 illustrates how effectively the prototype air stripper removed the total VOC load on each date. However, as previously explained, the air stripper was only operating for 12 hours per day. If the calculated air stripper influent loads are halved to represent loads for 12-hour periods (ignoring variations in concentration and flow over these dates) and are compared with the air stripper effluent loads (which also represent a 12-hour period), the results more clearly show how well a full-time air stripper might operate. This is illustrated in Figure 220. The improvements in treatment effectiveness are more evident on this figure.



Notes: Plotted load fractions reflect total of detected VOCs and half the total measured flows for the given sample dates (to approximate flows over 12-hour periods). Assumptions include: reported concentrations of all detections, including data with B and J qualifiers, are accurate and representative of the water at the given location for the full 12-hour period; and half the 24-hour flow is approximately equal to the flow in the given 12-hour period. Influent to the air stripper is equivalent to effluent from ZVI-filled treatment cells; effluent from the air stripper is equivalent to effluent from the treatment system.

Figure 220. VOC Loads in Prototype Air Stripper Influent and Effluent (12-Hour Basis)

Several variables affect the MSPTS air stripper performance, as summarized below.

- Influent flow rate—the lower the flow rate, the more time water is able to spend in the air stripper housing, and therefore is available to be cycled through the air stripper more times;
- Temperature—the volatility of the constituents being stripped is proportional to temperature, based on Henry's Law; the warmer the temperature, the more effective the air stripping;
- Ventilation—the more effectively the air within the air stripper housing is ventilated, the less apt that air is to become saturated with water vapor or gas-phase VOCs;
- Droplet size—the finer the droplets from the spray nozzles, the more total surface area is represented by the sprayed water, and therefore the more likely VOCs are to move from liquid (dissolved in water) to gas (air) phase.

Other variables also affect performance, but are closely tied to those above. For example, the rate at which water is pumped through the air stripper nozzles affects droplet size, as does the number of nozzles and whether nozzles are partially clogged; this also relates to influent flow rate, because a higher pump rate can compensate for a higher influent flow rate. Full-cone, spiral nozzles (by BETE) were used, and are available with varying orifice diameters and spray

patterns. If the cone-shaped spray pattern from one nozzle intersects that from another, the droplets may coalesce and decrease the available surface area. If the ventilation consists of cold air, it can reduce the effectiveness of the air stripper due to the temperature dependence on VOC volatility.

For the first 15 months of operation, the unit received only passive ventilation via a vent pipe providing air to the deeper portion of the air stripper housing, and a small passive attic vent on the housing lid. The last months of operation incorporated a solar-powered attic fan that operated only when the sun shined on its photovoltaic panel. Many other changes and adjustments were made to the air stripper configuration, particularly with respect to nozzle number and design (orifice diameter and angle of spray) but also in terms of pump voltage (higher voltage provides higher pump rate) and, for a short time, the number of pumps. These modifications are summarized in Table 96.

Table 96. Summary of Configurations and Settings Tested with Prototype Air Stripper

Date	Air Stripper Configuration/Setting
3/30/2011	12V, one #8 90-degree nozzle
7/6/2011	24V, two #8 90-degree nozzles
8/2/2011	24V, two #10 90-degree nozzles
8/16/2011	12V, two #6 90-degree nozzles
9/20/2011	24V, two #8 90-degree nozzles
5/15/2012	Added second pump; 24V, two #8 90-degree nozzles
5/16/2012	24V, six #8 90-degree nozzles, 2 pumps
5/23/2012	24V, four #8 90-degree nozzles, 2 pumps
6/12/2012	24V, six #8 90-degree nozzles, 2 pumps
6/13/2012	24V, six #8 90-degree nozzles, 2 pumps
7/3/2012	Add powered ventilation; 24V, six #8 90-degree nozzles, 2 pumps
7/23/2012	One pump failed, date uncertain, other still operating; 24V, six #8 90-degree nozzles
9/13/2012	Remaining pump failed, date uncertain; no air stripping at this time
9/20/2012	Resumed air stripping using single pump; 24V, six #8 90-degree nozzles

Notes: V = voltage. Numbers associated with nozzles pertain to orifice diameter and angle of spray for the full-cone, spiral nozzles used. Each pump operated at up to approximately 4 gpm at 24V, and about half that at 12V.

As demonstrated by the water quality data and summarized in the figures above, the air stripper had a marked effectiveness in removing residual VOCs from the ZVI-treated effluent at the MSPTS. In addition, maintenance needs were minimal, mainly being associated with the inexpensive pumps used for testing purposes. Therefore, in the summer of 2012 plans were being developed to transform the prototype air stripper to a larger-capacity, full-time air stripper in the same housing (the MSPTS effluent manhole). Although this would require more solar panels and more batteries, because the expansion was seen as a possibility during the design and construction of the prototype unit, no additional concrete or earthwork would be necessary. The initial battery pad and footers for the solar array were purposely oversized to allow the power infrastructure to increase in size.

Construction on the larger, full-time air stripper began in December 2012 with removal of the prototype unit's solar array and batteries, preparation of the footers installed in 2011 to enable them to support the new array, and preparation of the battery pad and other electrical components

for the expanded application. The new air stripper was scheduled to be completed and proven successful in early spring, 2013. The 2013 Annual Report will include information and discussion of this larger unit and its performance.

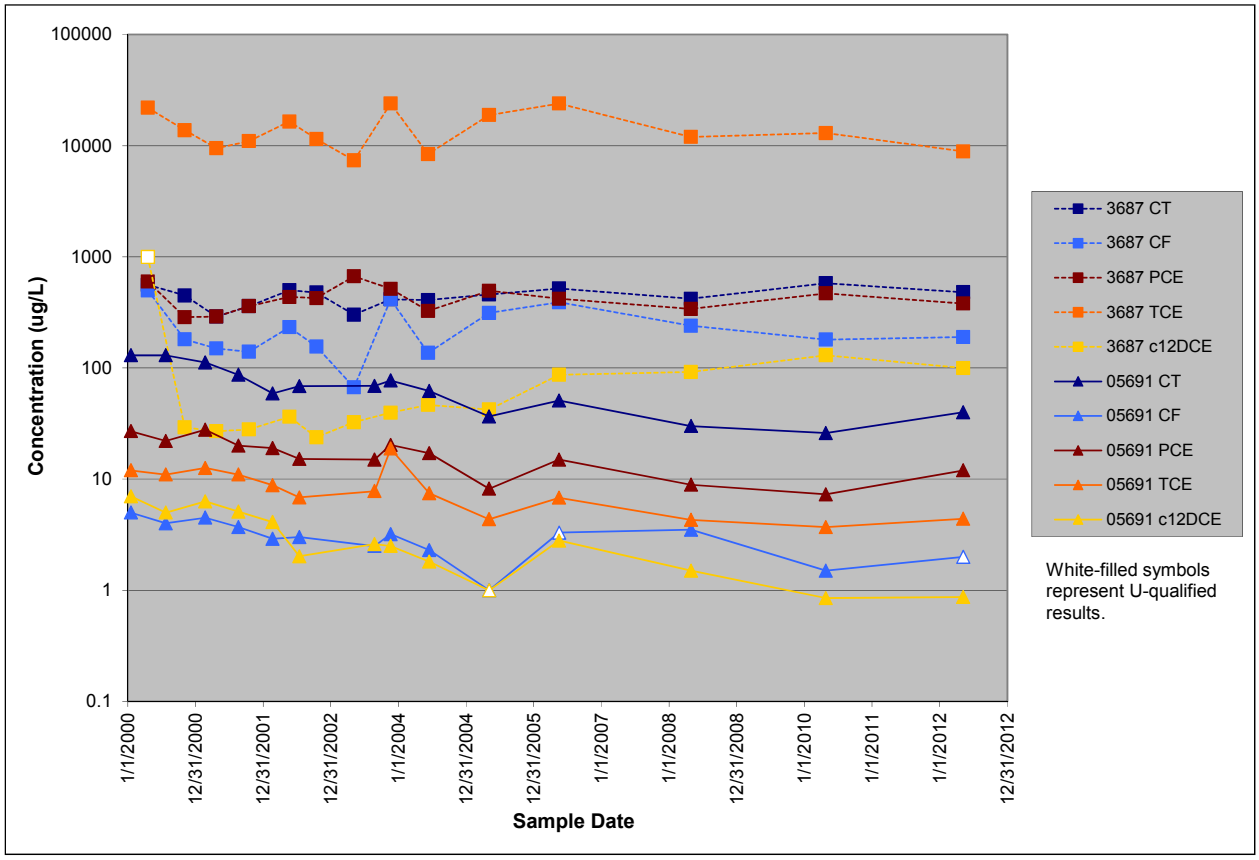
East Trenches Plume and Treatment System

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. Following the successful testing of the MSPTS, a similar treatment system (the ETPTS) was designed and 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 (as well as the Mound Plume, which is farther upgradient—west—of the East Trenches Plume). Well 00191 monitors groundwater closest to the source area of the 903 Pad Plume (a portion of which joins the East Trenches Plume) and is discussed in the context of the 903 Pad/Ryan's Pit Plume later in this section.

All of the East Trenches Plume Evaluation wells were scheduled for RFLMA sampling in 2012. The source-area wells, 3687 and 05691, produced samples with concentrations of VOCs that were fairly consistent with previous results (Figure 221). As can be seen on this figure, there is not a strong suggestion of biodegradation of parent compounds, as might be indicated by decreasing concentrations of parent compounds and increasing concentrations of daughter products. The concentration of *cis*-1,2-DCE does appear to be increasing in samples from well 3687, which primarily monitors Trench T-3; this visual appearance is confirmed through statistical calculations of an increasing trend having a 95 percent level of significance. Other trends having this level of statistical confidence include decreasing trends at well 05691 in carbon tetrachloride, chloroform, *cis*-1,2-DCE, PCE, and TCE. No other trends are identified for samples from well 3687.



Notes: Constituents and their respective, applicable RFLMA Table 1 standards (µg/L; CDPHE et al. 2012): CT (1), CF (3.4), PCE (1), TCE (2.5), c12DCE (70). 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.

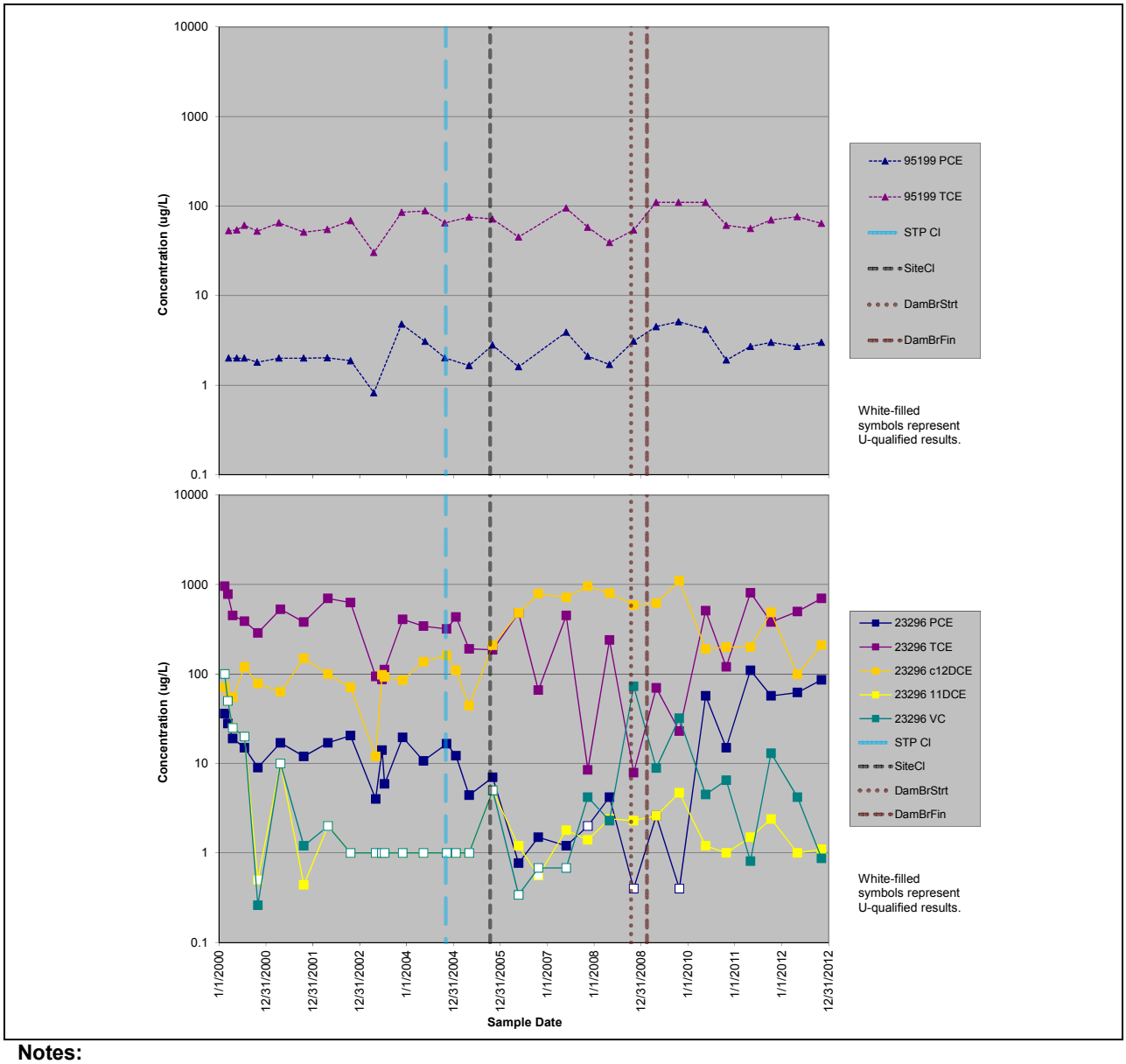
Figure 221. Concentrations of Primary VOCs in East Trenches Plume Source-Area Wells

Evaluation well 03991, located farther east of the trenches, monitors groundwater with much lower concentrations of VOCs. Those that are most commonly detected include carbon tetrachloride, chloroform, PCE, and TCE. Each of these was detected in the sample collected in 2012; levels of chloroform and TCE were below the RFLMA Table 1 value, but carbon tetrachloride was reported at 9.1 µg/L and PCE at 2.2 µg/L. No other VOCs were detected here in 2012. Each of these constituents supports a decreasing trend with a 95 percent level of statistical significance.

Sentinel well 04091, located farther east but still on the pediment surface, most often reports very low (<1 µg/L) concentrations of carbon tetrachloride, as was the case in 2012 when results were estimated (both J-qualified) at 0.32 µg/L (May) and 0.24 µg/L (November). No other VOCs were detected at this location in 2012. Until mid-2007, PCE was also detected here fairly regularly, also at very low (estimated) concentrations, but it has not been reported since May 2007. Both of these constituents are calculated to be on a decreasing trend with a 95 percent level of confidence. However, there are numerous nondetects in the data, leading to questions of the viability of these calculations. Either way, VOC concentrations remain very low.

The Sentinel wells sampled along South Walnut Creek in support of the East Trenches Plume and ETPTS showed water quality in 2012 that was consistent with previous years. Well 95299, which is located near the western end of the ETPTS groundwater intercept trench, was dry; this has been the case for the entire period of record (since January 1, 2000) except for one occasion in 2006. RFLMA Table 1 standards were exceeded in samples from wells 23296 and 95199, but as with preceding years, the highest concentrations of VOCs were reported at well 23296.

Figure 222 displays several VOCs that are commonly detected in one or both of wells 95199 and 23296 at concentrations exceeding the corresponding RFLMA Table 1 standards: PCE, TCE, *cis*-1,2-DCE, 1,1-DCE, and VC. As is typically the case at well 95199, only PCE and TCE exceeded their RFLMA values (top portion of Figure 222). Also consistent with past conditions, VOCs at well 23296 included higher concentrations of more constituents (lower portion of Figure 222). Concentrations of *cis*-1,2-DCE in samples from well 23296 show a fairly gradual increase through 2009, then what appears to be a slow decrease beginning in 2010 and continuing through 2012. These patterns are not clear due to the natural data variability. When detected, concentrations of 1,1-DCE have exhibited a very similar pattern. Statistical calculations confirm the visual appearance of trends in samples from well 23296, as noted in Table 90.: 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 uranium. 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 (µg/L; CDPHE et al. 2012): PCE, 1; TCE, 2.5; c12DCE = *cis*-1,2-DCE, 70; 1,1-DCE, 7; VC, 0.2. Several detections are qualified but for simplicity are not shown differently. Note logarithmic concentration scales.

Abbreviations:
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.
SiteCl = closure of the Site.
STP Cl = approximate closure date of former Building 995, the Sewage Treatment Plant (STP).

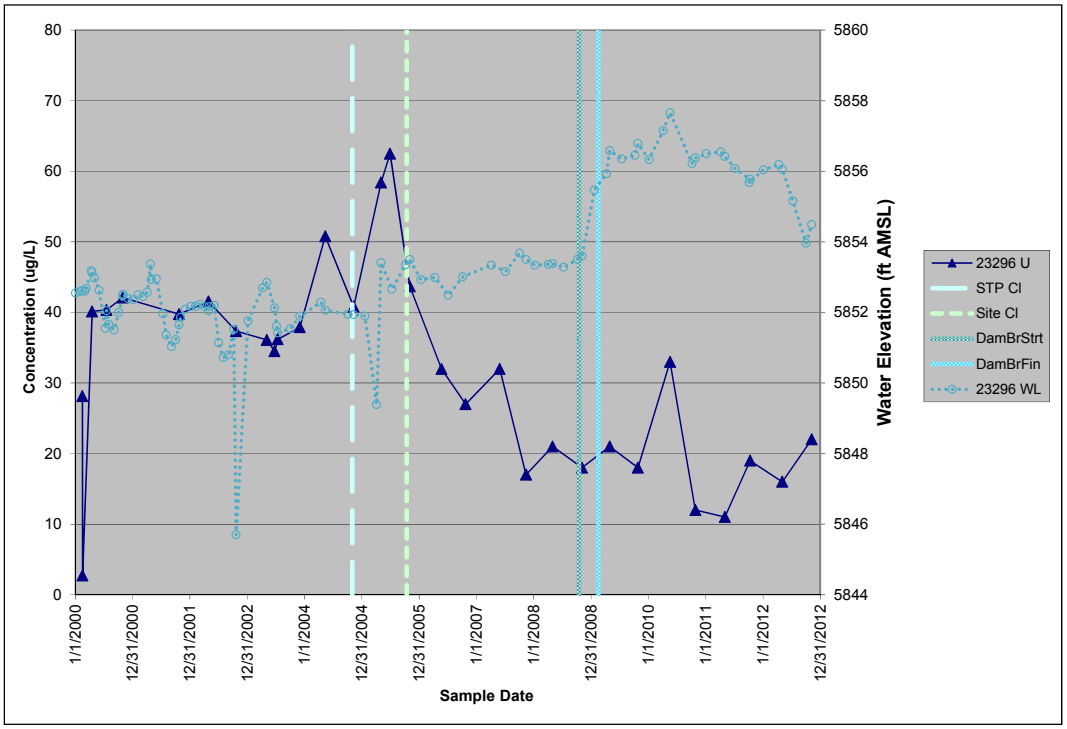
Figure 222. Most Commonly Detected VOCs in Sentinel Wells Downgradient of the ETPTS

Concentrations of TCE, PCE, and VC in samples from well 23296 show seasonal variation. This began in about 2006 for TCE, and perhaps a year later for PCE and VC. (Earlier data, such as for PCE, may also reflect a seasonal pattern, but not as clearly; the presence of nondetects hides an early pattern in VC data.) Closure-related factors that may relate to these behaviors are shown on Figure 222. The data from well 23296 appear to suggest the removal of the former Sewage

Treatment Plant most strongly affected VOC concentrations at this location. The dam breach activities in late 2008-early 2009 affected groundwater availability (see the hydrograph for this well in Appendix B, also superimposed on the figure below), and may have initiated a gradual overall increase in TCE and PCE concentrations and decrease in VC concentrations (all of which still vary seasonally).

The product of dechlorination of PCE and TCE, concentrations of VC are typically higher in fourth-quarter samples than in the preceding and following second-quarter samples. Conversely, concentrations of PCE and TCE are higher in the second quarters. The intermediate degradation product, *cis*-1,2-DCE, does not show a strong seasonal component. This is discussed in the 2011 Annual Report (DOE 2012f) and will not be reiterated except to note that this pattern appears to suggest seasonal increases and decreases in biodegradation. However, why *cis*-1,2-DCE concentrations are not also behaving seasonally is not clear. Additional data may help to define trends as well as forcing mechanisms.

Sentinel well 23296 is also monitored for U. As noted above, and consistent with previous trend calculations, S-K statistical calculations indicate a decreasing trend with a 95 percent level of significance (Table 90 and Appendix B; see also time-series plot, Figure 223). Uranium also shows variable concentrations that are relatively minor compared to those exhibited by some VOCs. Seasonality is also suggested, but the higher second-quarter and lower fourth-quarter concentrations reported from 2005 through 2010 reverses in 2011, calling into question whether seasonal effects are real. Breaching the adjacent dams, and the subsequent increasing water availability, may also have affected uranium concentrations as shown on Figure 223. The suggestion is that these vary inversely, with higher water levels coinciding with lower uranium concentrations, and vice versa. Additional data may help to confirm whether this pattern is real.



Notes:
Applicable RFLMA value for uranium (µg/L; CDPHE et al. 2012) is the groundwater threshold of 120 µg/L.

Abbreviations:
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.
ft AMSL = feet above mean sea level.
Site Cl = closure of the Site.
STP Cl = approximate closure date of former Building 995, the Sewage Treatment Plant (STP).
U = uranium
WL = water level within the well.

Figure 223. Concentrations of Uranium in Samples from Well 23296

AOC well 00997 is located near the inlet to Pond B-5. This well was sampled twice in 2012 (May and November). All constituents were below the RFLMA Table 1 levels or uranium threshold. One VOC was detected in the November sample: 1,3-dichlorobenzene (DCB) was estimated (J-qualified) at 0.16 µg/L. The corresponding RFLMA standard is 94 µg/L. The only other detection of this constituent in the data set was in November 2007 (0.36 µg/L, estimated). U was detected in the samples from well 00997 at concentrations of 23 µg/L (estimated) in May and 13 µg/L in November, which is within the typical range at this well. Both samples contained less than 1 mg/L of nitrate.

East Trenches Plume groundwater will continue to be monitored in accordance with RFLMA. As more data are collected, additional patterns and 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 622,000 gallons of water in 2012, which is fairly consistent with other post-closure besides the wet year of 2010 (Table 97). The volume treated in 2012 is significantly lower than the average volume treated in a post-closure year (Table 98), even if the wet year of 2010 is omitted from the calculation: the average post-closure volume, omitting 2010, is 695,500 gallons. This is consistent with the precipitation for the year, which was below average (Section 3.1.3.4).

Figure 224 presents a hydrograph showing ETPTS flow estimates since January 2000. (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 225 provides a hydrograph for CY 2012 at the ETPTS and shows the continuing gradual decrease in flows following the higher-water year of 2010. Also evident on this figure is the effect of the September 2012 biogrowth removal, during which the influent valve was closed (see Section 2.4).

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
2012	622,000	16,879,000

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, 2006–2012	825,600

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: the pre-closure estimate spans January 1, 2000, through December 31, 2005, and the post-closure period begins January 1, 2006.

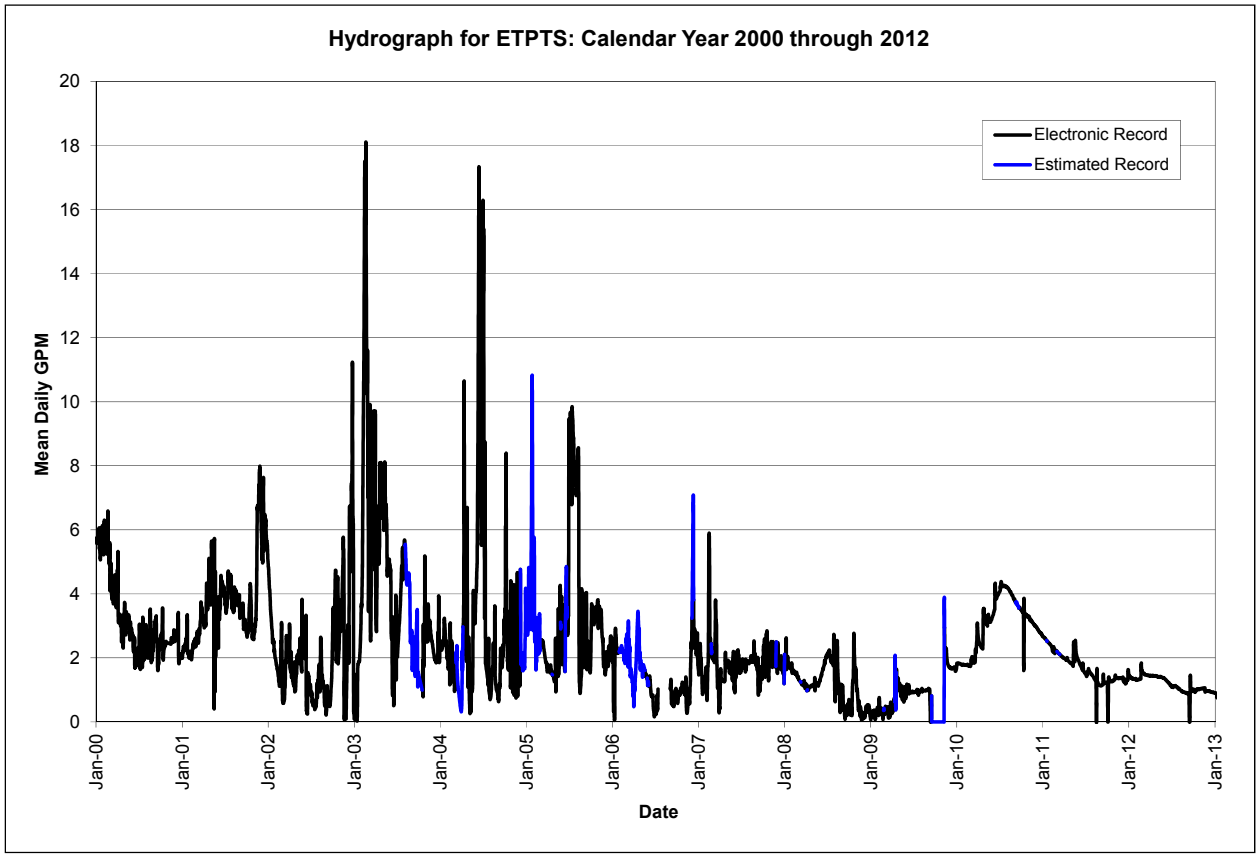


Figure 224. Hydrograph for ETPTS from 2000 Through 2012

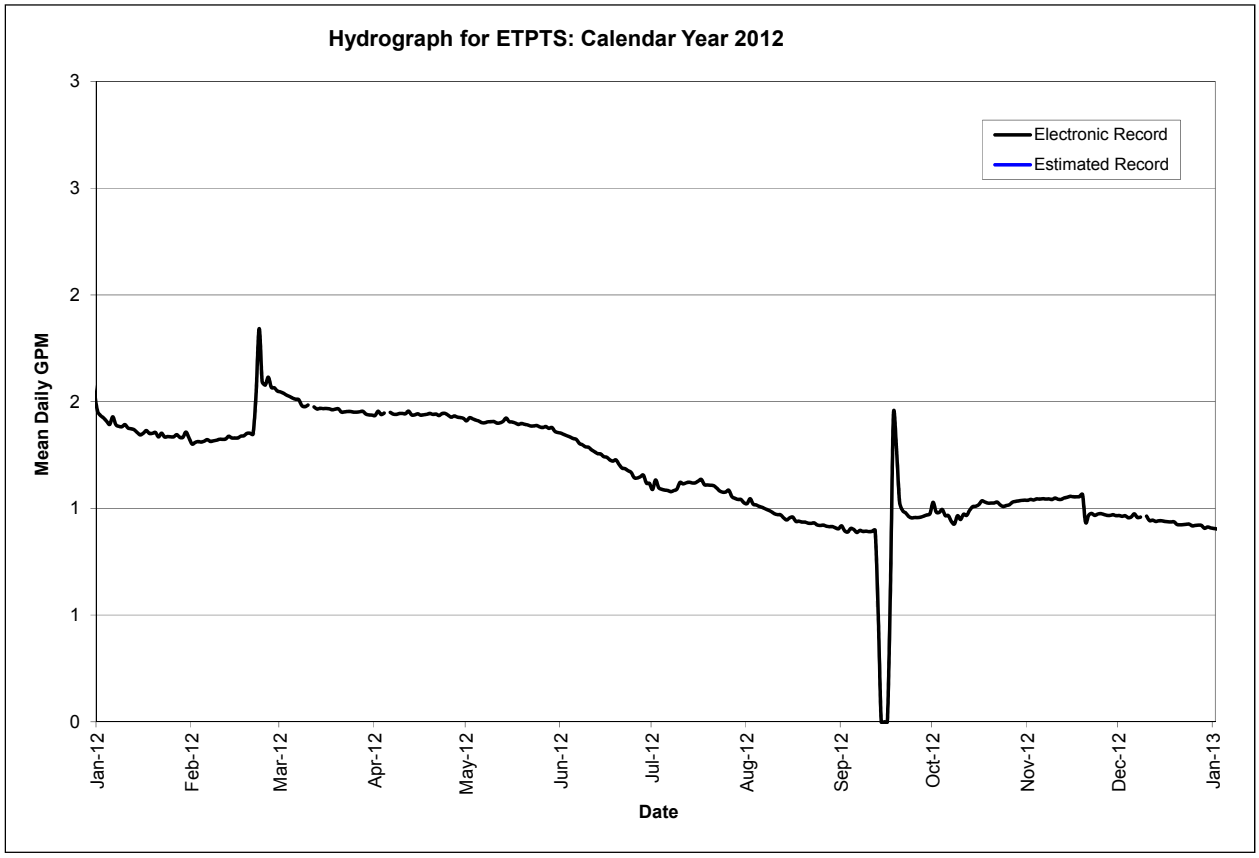


Figure 225. Hydrograph for ETPTS for CY 2012

The ETPTS was sampled three times in 2012: twice for routine RFLMA requirements (May and November), plus one additional time for non-required confirmatory purposes (January) as discussed in the annual report for 2011 (DOE 2012f).

ETPTS effluent water quality in 2012 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 2012b, 2012e, and 2013a) and Appendix B.6 for additional data from 2012. As with the MSPTS, S-K trending was used to evaluate ETPTS influent data; this is not required by RFLMA, but was conducted for informational purposes. Data from the entire period of record (January 2000 through the end of 2012) were evaluated, as were the subset of data collected only during the post-closure period (2006 through 2012). Results having a 95 percent level of statistical significance (Table 90) for the entire period include increasing 1,1-DCE and *cis*-1,2-DCE, and decreasing 1,1,1-TCA and carbon tetrachloride; for the post-closure years, a similarly-significant increasing trend is identified for chloroform, and no decreasing trends are identified. Refer to Appendix B for additional information and the trend plots.

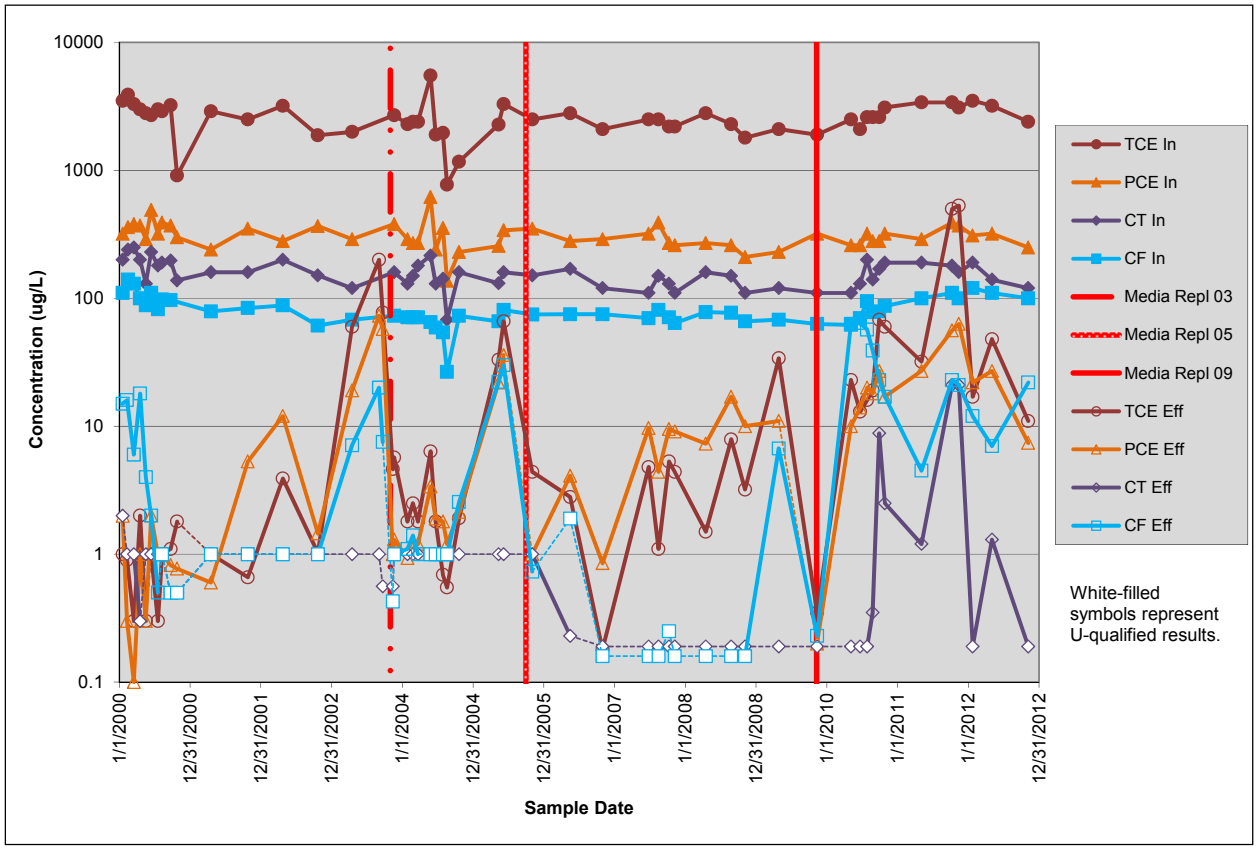
Table 99 illustrates the effects of the change in flow configuration made in early 2012 in response to an increase in the late 2011 concentrations of TCE in system effluent (see 2011 Annual Report, DOE 2012f, for discussion). Changing from parallel upflow to a series configuration in which influent passed through Cell 1 first (upflow) and then Cell 2 (downflow) exposed the water to relatively fresher ZVI in the upper portion of Cell 2. A solar-powered air stripper similar to that at the MSPTS was being installed at the ETPTS as 2012 ended. Scheduled to be completed in early 2013, it should further improve treatment.

Table 99. Summary of VOC Data (µg/L) for ETPTS Influent and Effluent

Date	CT		CF		MCl		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)**
1/24/2012	**190**	0.19 (U)	**120**	**12**	6.7 (U)	**8.5 B)**	**310 (J)**	**22 (J)**	**3500**	**17**	49	**94**	1 (U)	0.1 (U)
5/3/2012	**140**	**1.3**	**110**	**7**	3.2 (U)	2.3	**320**	**27**	**3200**	**48**	42	**76**	1 (U)	**1.1**
11/6/2012	**120**	0.19 (U)	**100**	**22**	3.2 (U)	2.3	**250**	**7.4**	**2400**	**11**	36	**210**	1 (U)	**0.69 (J)**

Notes: Constituents and their respective, applicable RFLMA levels (µg/L; CDPHE et al. 2012): CT = carbon tetrachloride, 1; CF = chloroform, 3.4; MCl = 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 226. This figure is crowded, but it illustrates several conditions. First, influent concentrations of TCE, PCE, carbon tetrachloride, and chloroform have remained fairly consistent since 2000 for each of the VOCs illustrated, though an increase in each except PCE from early 2010 into 2012 is apparent even on this logarithmic concentration scale. This may relate to higher groundwater levels in the wetter year of 2010 flushing residual VOCs from the vadose zone. Conversely, concentrations in system effluent have varied widely, and not always with respect to influent concentrations, media replacement, or other maintenance activities.



Notes: Constituents and their respective, applicable RFLMA Table 1 standards (µg/L; CDPHE et al. 2012): 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 226. 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. Effluent quality in 2012 was fairly consistent with that of recent years, except in the case of *cis*-1,2-DCE. Its concentration increase from influent to effluent indicates some parent compounds (PCE, TCE) are only being partially dechlorinated by the ZVI media, thereby creating additional *cis*-1,2-DCE. With extended contact time (i.e., a longer residence time in the ZVI media), the VOCs would be completely dechlorinated. However, the residence time is subject to water availability—the greater the volume of water that is intercepted and directed to

the treatment cells, the shorter its residence time. As the effects of the drier conditions of 2012 extend throughout the hydrologic system, a decrease in influent volume may be observed, which should lead to improved dechlorination. Perhaps more importantly for the short term, the addition of an air stripper to the ETPTS in early 2013 should improve treatment effectiveness.

In addition to using time series plots to evaluate influent quality, as discussed above, S-K trending was performed for ETPTS influent. This is not required by RFLMA, but can help to identify whether any long-term trends are present. As with MSPTS influent, trend calculations were performed for all data collected from January 2000 through the end of 2012, and for only the post-closure era—the years from 2006 through 2012. Results of these calculations are summarized in Table 90, and the associated trend plots are included in Appendix B. Statistical trends with a 95 percent level of confidence include increasing 1,1,1-TCA, 1,1-DCE, chloroform, *cis*- and *trans*-1,2-DCE, TCE, and VC; and a decreasing trend is identified for carbon tetrachloride. When only post-closure data are evaluated, the only trend with this level of significance is for increasing chloroform.

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. The location was visited twice in 2012 for sampling, in May and November, but the location was dry in November. No VOCs were detected in the sample that was successfully collected.

Solar Ponds Plume and Treatment System

The 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 in this document 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 2012 at this system; see also Section 2.4 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 distribution of VOC contamination, it is not considered part of the SPP, but rather as a separate plume.

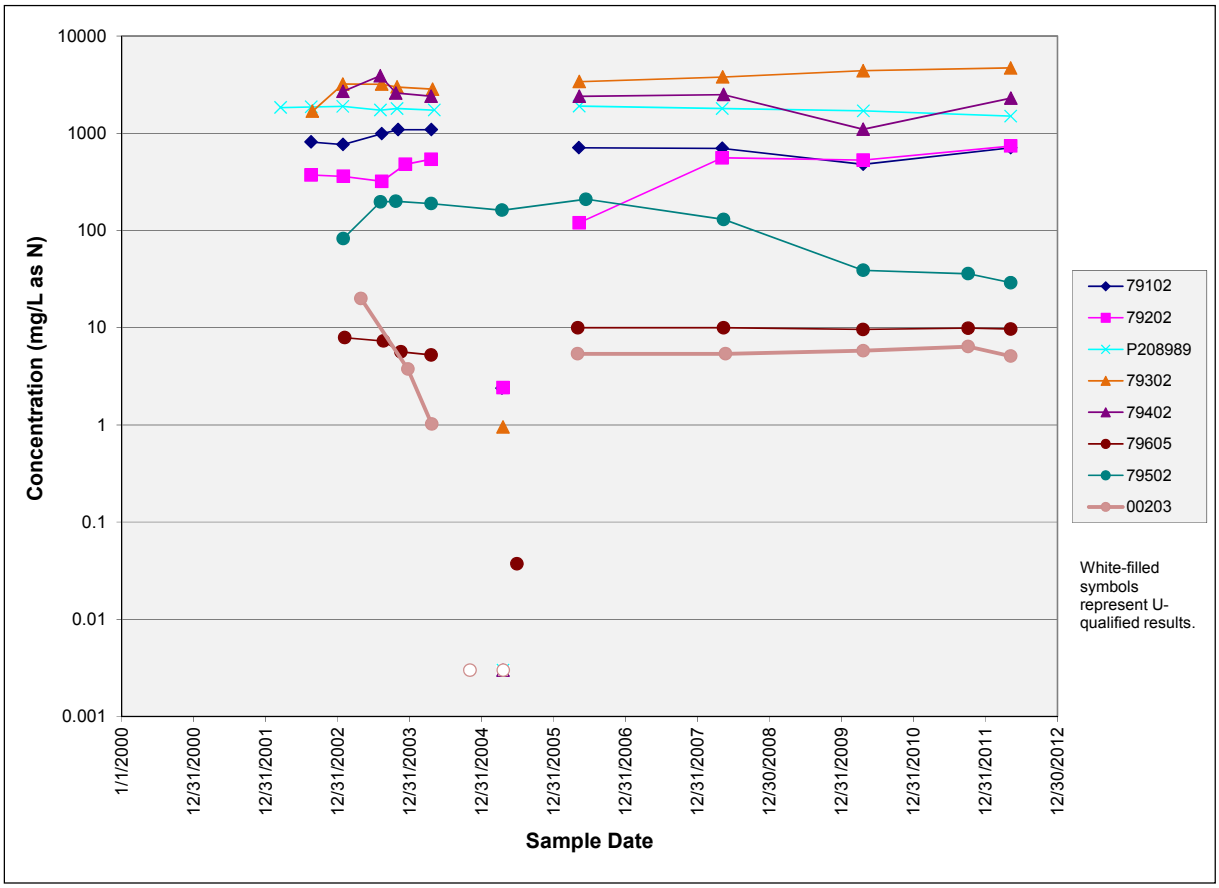
The source area of the SPP (the former SEPs) is monitored by eight Evaluation wells installed immediately downgradient of the SEPs (generally along the north, east, and south sides of the former SEPs). Another Evaluation well is positioned at the south edge of former Pond 207C, in the vicinity of the 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 in North Walnut Creek near former Pond A-1. An AOC well in South Walnut Creek supports monitoring of any southeastward contaminant migration from the SEPs; conditions at this well (well 00997) were summarized above in the text on the East Trenches Plume.

All of the Evaluation wells supporting the SPP and SPPTS were scheduled for RFLMA sampling in 2012. These wells were each sampled once, and the Sentinel and AOC wells were each sampled twice. Results were generally consistent with past data

The highest concentration of nitrate reported in the vicinity of the former SEPs was in the sample from well 79302, where the concentration was 4700 mg/L. This well is typically where the highest concentrations are reported. Three wells—79302, 79402, and P208989—consistently report concentrations of nitrate exceeding 1,000 mg/L, and all are situated near the northeastern corner of the former SEPs (see Figure 2 for well locations). These data are illustrated below in Figure 227.

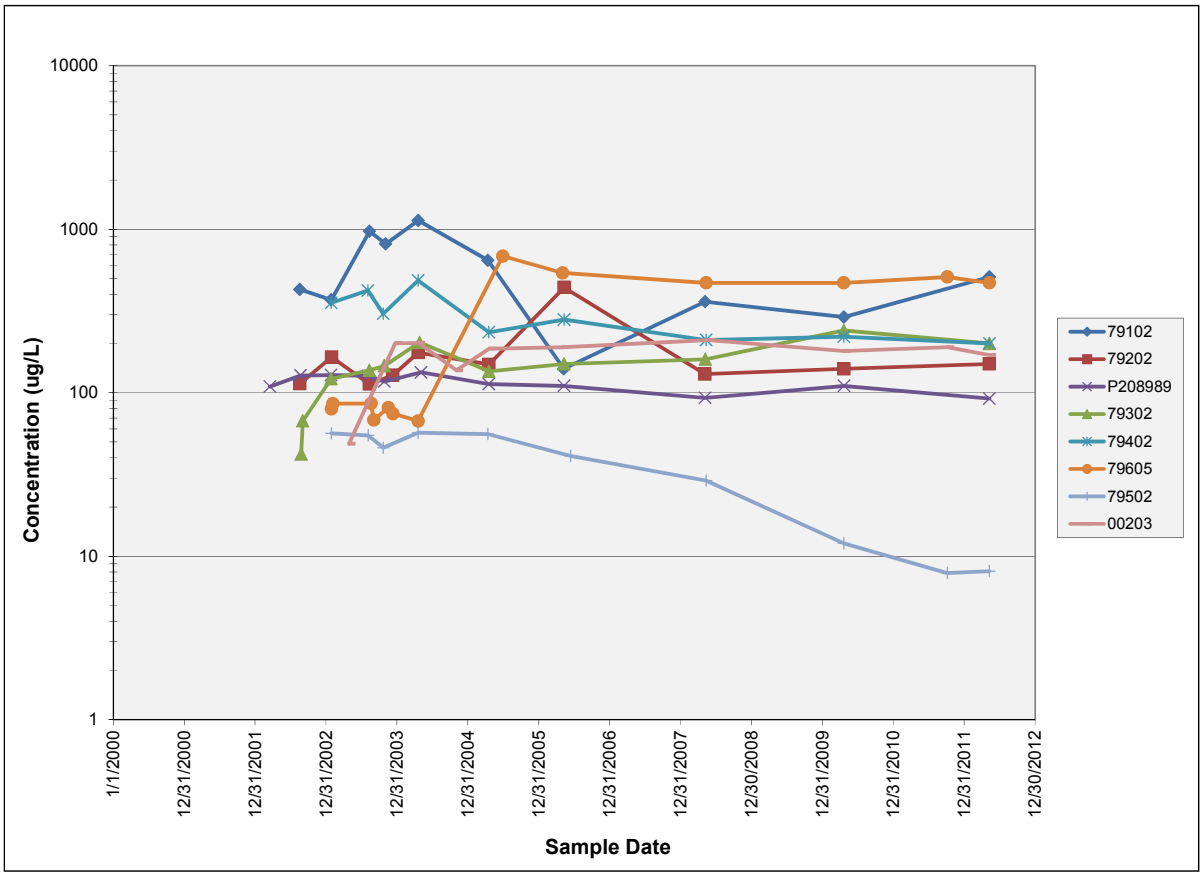


Notes: RFLMA Table 1 value for nitrate (reported by the laboratory as nitrate+nitrite as nitrogen) is 10 mg/L (CDPHE et al. 2012). Refer to the 2006 Annual Report (DOE 2007b) for discussion of the discontinuous data in 2005. Several results are qualified but are not shown differently for the sake of simplicity. Note logarithmic concentration scale.

Figure 227. Concentrations of Nitrate in SPP Source-Area Evaluation Wells

Concentrations of nitrate in well 79302 appear to be increasing, while nitrate in 79502 looks to be decreasing. (The latter well is located on the east side of the former SEPs, a short distance south of well 79402.) Most of the other of these Evaluation wells show no strong visual trend in nitrate over their entire data set, though shorter segments of increasing or decreasing concentrations are suggested (as with the post-closure data from well 79202). Concentrations of nitrate in wells 79605 and 00203 (eastern and southern sides of the former SEPs, respectively; see Figure 2) are consistently at or below the RFLMA value of 10 mg/L. No trends having a 95 percent statistical confidence were calculated for nitrate in these wells. Additional data may confirm the presence of significant concentration trends, but as the contaminated groundwater extends into the relatively tight claystone it may require an extended period of time before the nitrate is flushed or degraded.

The SPP also includes elevated concentrations of uranium, as noted above. Similar to the data reported for nitrate, concentrations of uranium in the Evaluation wells nearest the source area are consistent with past results. The highest concentration of uranium in these wells in 2012 was reported at well 79102 (510 µg/L). The well that most typically produces groundwater samples with the highest uranium concentration is well 79605; in 2012, the sample from this well contained 470 µg/L uranium. Well 79605 is located on the eastern edge of the former SEPs, while 79102 is on the northern edge of former Pond 207C (Figure 2). None of the samples collected from these wells since closure has exceeded 1,000 µg/L. Figure 228 presents time-series plots of uranium data at the Evaluation wells ringing the former SEPs.



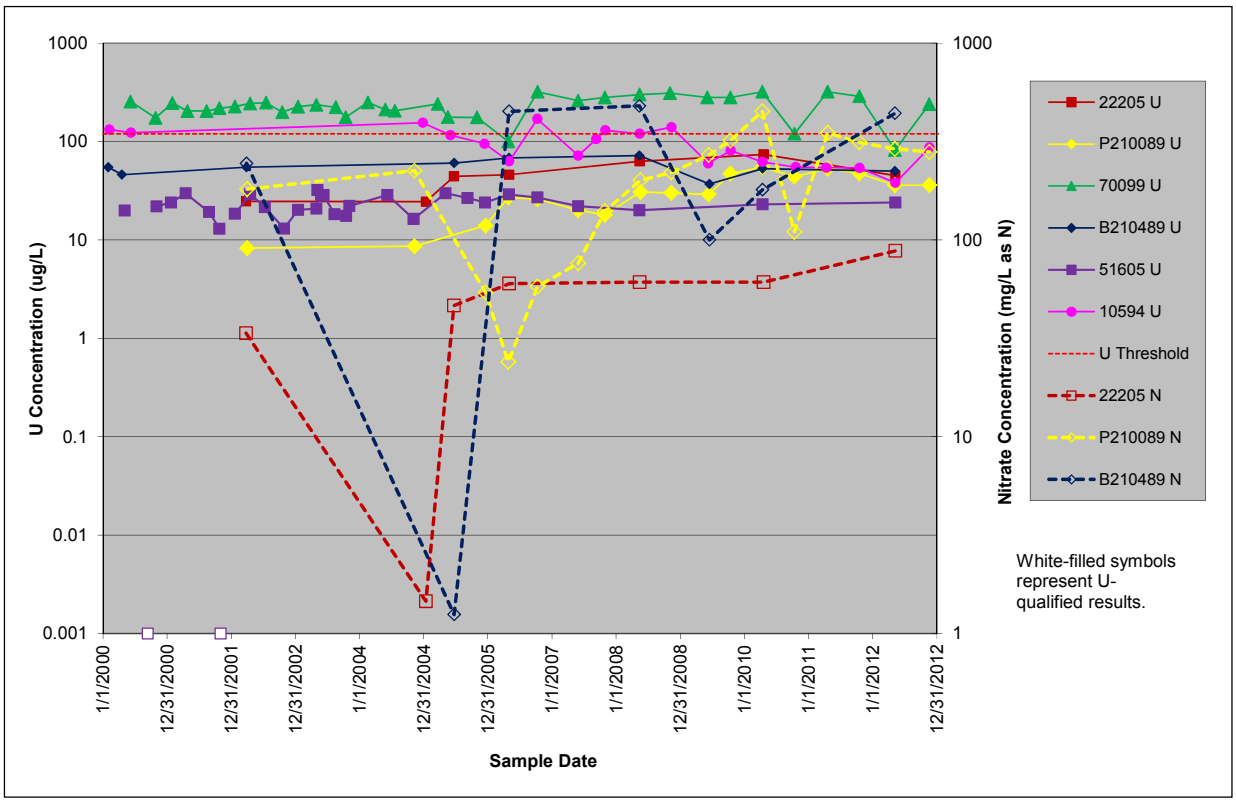
Notes: RFLMA U threshold value is 120 µg/L. Several results are qualified but are not shown differently for the sake of simplicity. Note logarithmic concentration scale.

Figure 228. Concentrations of Uranium in SPP Source-Area Evaluation Wells

The Evaluation wells monitoring the former SEP source area are represented by several trends in uranium concentration that have 95 percent level of statistical significance. These include well 79302, which is calculated to have an increasing trend in uranium; and wells 79402 and 79502, which have decreasing trends in uranium. Each of these trends is visually apparent on Figure 228. As with nitrate in the source area, discussed above, uranium-contaminated groundwater is present within the claystone beneath the alluvium and colluvium, and will take some time to flush.

Figure 229 displays U and, where meaningful, nitrate concentrations from Evaluation, Sentinel, and AOC wells downgradient (north-northeast) of the SPP source area. This represents the most meaningful flow direction for the uranium- and nitrate-contaminated groundwater of the SPP, which is why the Interceptor Trench System (ITS) and SPPTS are situated between the source area and North Walnut Creek.

Wells that are illustrated on Figure 229 include Evaluation well 22205, located north of former Pond 207C about halfway to the SPPTS (Figure 2); Sentinel wells P210089 and 70099 located farther from the source area, near the western end of the SPPTS groundwater collection trench; Evaluation well B210489 next to North Walnut Creek east of the SPPTS Discharge Gallery; Evaluation well 51605, also next to North Walnut Creek at surface water station GS13 and the inlet to former Pond A-1; and AOC well 10594 located between former Pond A-1 and Pond A-2.



Note: U = total uranium, N = nitrate+nitrite as nitrogen. RFLMA values are 120 µg/L (uranium threshold) and 10 mg/L (nitrate standard). The wells are listed in the legend in order of increasing distance from the former SEPs (the source area). The two U nondetects at well 51605 are separated from the rest of the data for this well due to their discontinuous nature. Note logarithmic concentration scales.

Figure 229. U and Nitrate Concentrations in Wells Downgradient of the Former SEPs

As shown on this figure, there appears to be little or no correlation between contaminant concentration and distance from the source. In fact, nitrate is not displayed for wells 70099, 51605, and 10594 because concentrations since January 2000 are uniformly low or nondetect—typically under 1 mg/L, and always less than 5 mg/L. The well closest to the source, 22205, produces samples with lower concentrations of both nitrate and uranium than other wells located farther away.

Two main factors are thought to drive the absence of a clear relationship between concentration and distance from the source: First, with respect to nitrate, infrastructure such as the SPPTS trench and the ITS and associated components (such as the former Interceptor Trench Pump House sump) likely contributed to higher concentrations observed downgradient, such as nitrate in wells P210089 and B210489. These wells were installed in 1989, and until the SPPTS was constructed, waters collected by the ITS were routed to the Interceptor Trench Pump House sump and pumped from there to other locations for management. After the SPPTS was constructed, its collection trench probably contributed high-nitrate groundwater to well P210089, given this well's proximity to the western end of that trench. In addition, removal of culverts and regrading for closure now allows surface flow, including any seepage from the north-facing hillside below the SEPs, to infiltrate the flat area around P210089, rather than drain away. (The location of FC-3 is farther from this well than the drainage that originally routed surface flow from the area.) Evidence for this is seen in the rising water levels shown on the hydrograph for the well (Appendix B), and was discussed in context with nitrate and uranium at this well in the 2011 report (DOE 2012f). Both of these changes are likely causing the increasing concentrations of nitrate in samples from well P210089. Evaluation well B210489 was probably not effected so much by the reconfiguration at closure as by the changes to the ITS as part of the SPPTS installation. As previously discussed with respect to the SPPTS Phase I upgrades designed to capture more contaminated groundwater (for example, see DOE 2009d, 2010d), the SPPTS Discharge Gallery previously was marked by waters with higher concentrations of nitrate and uranium than untreated SPPTS influent. This water would have saturated the area around the DG, leading to the elevated concentrations seen at B210489. With the installation of the Phase I upgrades in late 2008 and continuing improvements to nitrate treatment, concentrations reported at well B210489 may begin to decrease.

Second, with respect to uranium, the same infrastructure-related effects likely contribute to the increasing uranium observed at well P210089. However, the uranium at wells 70099, 51605, and 10594 is a reflection of the high natural uranium content of much of Rocky Flats groundwater (including in these wells), the source of which is not the former Solar Ponds but instead regional mineralization. This has been discussed at greater length in previous annual reports (e.g., DOE 2012f) and will not be reiterated here. The most important point to be made is that nitrate is a clear marker for SPP groundwater, while uranium, unless isotopically evaluated and found to be anthropogenic, does not signify SPP contamination.

Calculated trends having a 95 percent level of confidence are reported for several of these wells (see summary in Table 90 and trend plots and reports in Appendix B). Evaluation well 22205 shows an increasing trend in nitrate that is readily apparent on Figure 229, ignoring the anomalously low result in January 2005. Sentinel wells P210089 has increasing trends in both nitrate and uranium, also evident on the figure; and 70099 shows a decreasing trend in nitrate and lower-confidence increasing trend in uranium. Neither of the downgradient Evaluation wells,

B210489 and 51605, was calculated to support any concentration trends with this level of confidence. Finally, AOC well 10594 is represented by a decreasing trend in uranium concentrations that has a 95 percent level of significance. This is also visually apparent on Figure 229.

As described above, Sentinel wells 99305 and 99405, both located in the South Walnut Creek drainage adjacent to former B991, are monitored to evaluate a potential southeastern flowpath for SPP groundwater. Water quality at these wells is discussed later in this report, but with respect to the SPP, nitrate concentrations in samples collected in 2012 were consistent with previous data. The highest nitrate concentrations reported in 2012 were 1.28 mg/L and 1.8 mg/L, respectively, for wells 99305 and 99405. As with previous conditions, uranium concentrations are very consistent and relatively low at well 99305 while they are highly variable and elevated at nearby well 99405. Both have been characterized as producing groundwater with uranium that is 100 percent natural. Uranium and other constituents monitored at these wells is discussed later in this report.

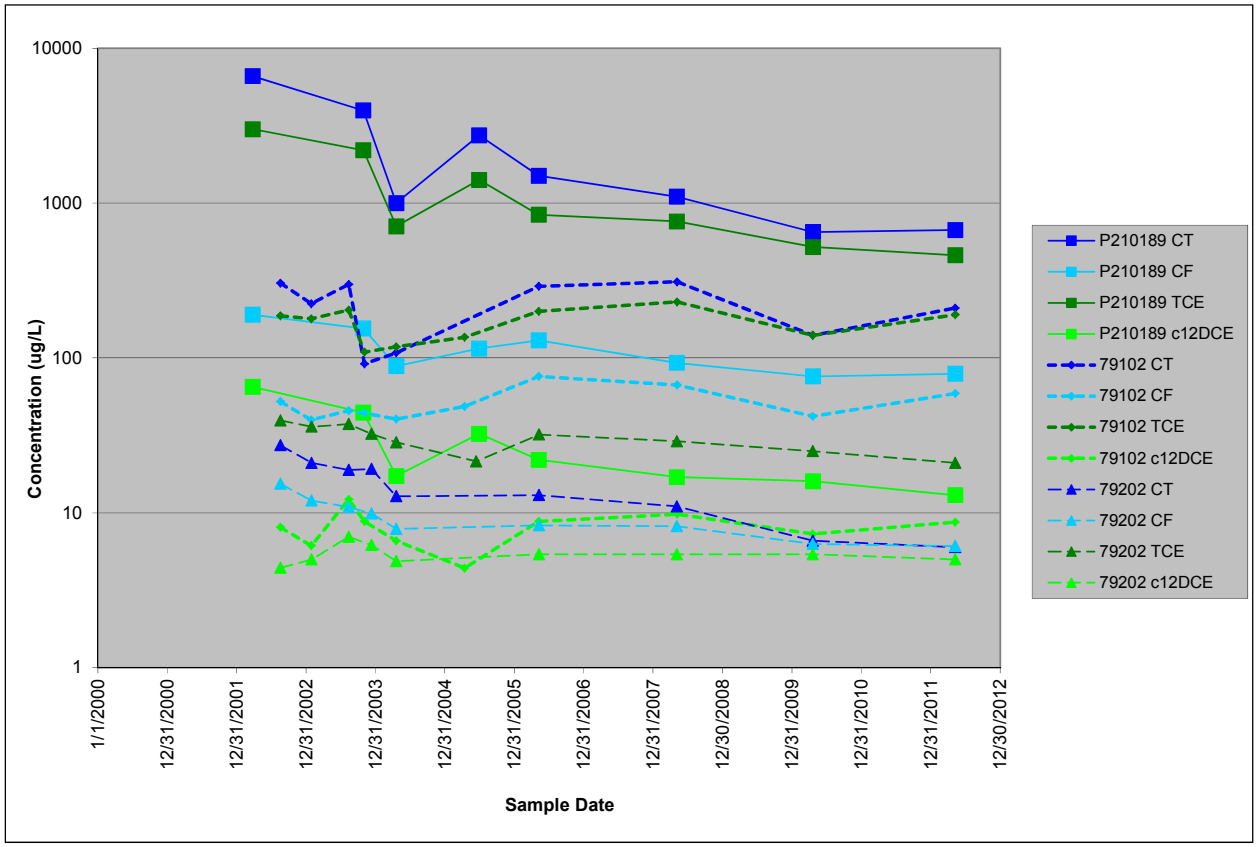
Solar Ponds-Area VOC Plume

All Evaluation wells designated to monitor the VOC plume in the western SEP area were sampled in 2012. These wells include P210189 on the southern edge of former Pond 207C and in the vicinity of the VOC source area; wells 79102 and 79202 to the north, along the pathway to the North Walnut Creek drainage; and well 22205 about halfway between the source area and the drainage. In addition, Sentinel well P210089 is also monitored for VOCs.

As defined by conditions at well P210189, this plume is characterized predominantly by elevated concentrations of carbon tetrachloride, lower but still elevated concentrations of TCE, and chloroform.

Data reported for second-quarter 2012 samples at the Evaluation wells were consistent with past results, though decreasing trends are evident in several cases (Figure 230). This figure shows fairly obvious decreasing VOC concentration trends at source-area well P210189, but the nearest downgradient well, 79102, does not show similar reductions. However, well 79202, also downgradient but monitoring water with lower concentrations of VOCs, shows some constituents are decreasing. The fact that both parent and daughter-product compounds are decreasing in the source area well suggests the degree of biodegradation is not high, otherwise the daughter products would likely be increasing.

Trend calculations conclude that in well P210189, only the decreasing trends in TCE and *cis*-1,2-DCE rise to the 95 percent level of significance; the visually-apparent decreasing trends in carbon tetrachloride and chloroform are of lower statistical confidence. However, trends at well 79202 include decreasing trends in carbon tetrachloride, chloroform, and TCE, all at the 95 percent level of significance. As expected, no increasing or decreasing trends with this level of significance are calculated for VOCs at well 79102.



Notes: Constituents and their respective, applicable RFLMA Table 1 standards (µg/L; CDPHE et al. 2012): CT, 1; CF, 3.4; TCE, 2.5; c12DCE, 70. Several detections are qualified but are not shown differently for the sake of simplicity. Note logarithmic concentration scale.

Figure 230. Primary VOCs in SEP VOC Plume Wells

Farther downgradient, conditions at Evaluation well 22205 in 2012 with respect to VOCs were consistent with those in previous years. There is no strong suggestion of the VOC plume migrating toward the North Walnut Creek drainage. A single detection of TCE, estimated (J-qualified) at 0.21 µg/L, was reported in 2012. This constituent was last detected here in 2006, at the same concentration. Beyond well 22205, Sentinel well P210089 did not report any VOC detections in 2012, nor did AOC well 10594.

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 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 2007b, 2008c, 2009d, 2010d), which have 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 a number of 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 2012 and are reported in Section 2.4. The text below provides a summary of the results related to water treatment.

The SPPTS treated approximately 498,000 gallons of groundwater in 2012. This is fairly similar to volumes treated in other years following installation of the Phase I upgrades in late 2008, except for the relatively wetter year of 2010 (Table 100). (The Phase I upgrades collect additional contaminated groundwater and route it through the SPPTS for treatment. These upgrades are summarized below and discussed at greater length in the annual reports for 2008 and 2009, DOE 2009d and 2010d respectively.) However, as a consequence of the dry conditions this year, the total for 2012 is the lowest volume treated since those Phase I upgrades were installed. Figure 231 presents a hydrograph showing flow from January 2000 through the end of 2012. Clearly evident is the effect of the Phase I upgrades on the total volume treated by the SPPTS. The hydrograph for CY 2012 is presented as Figure 232.

Table 100. 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
2012	498,000	4,209,000

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

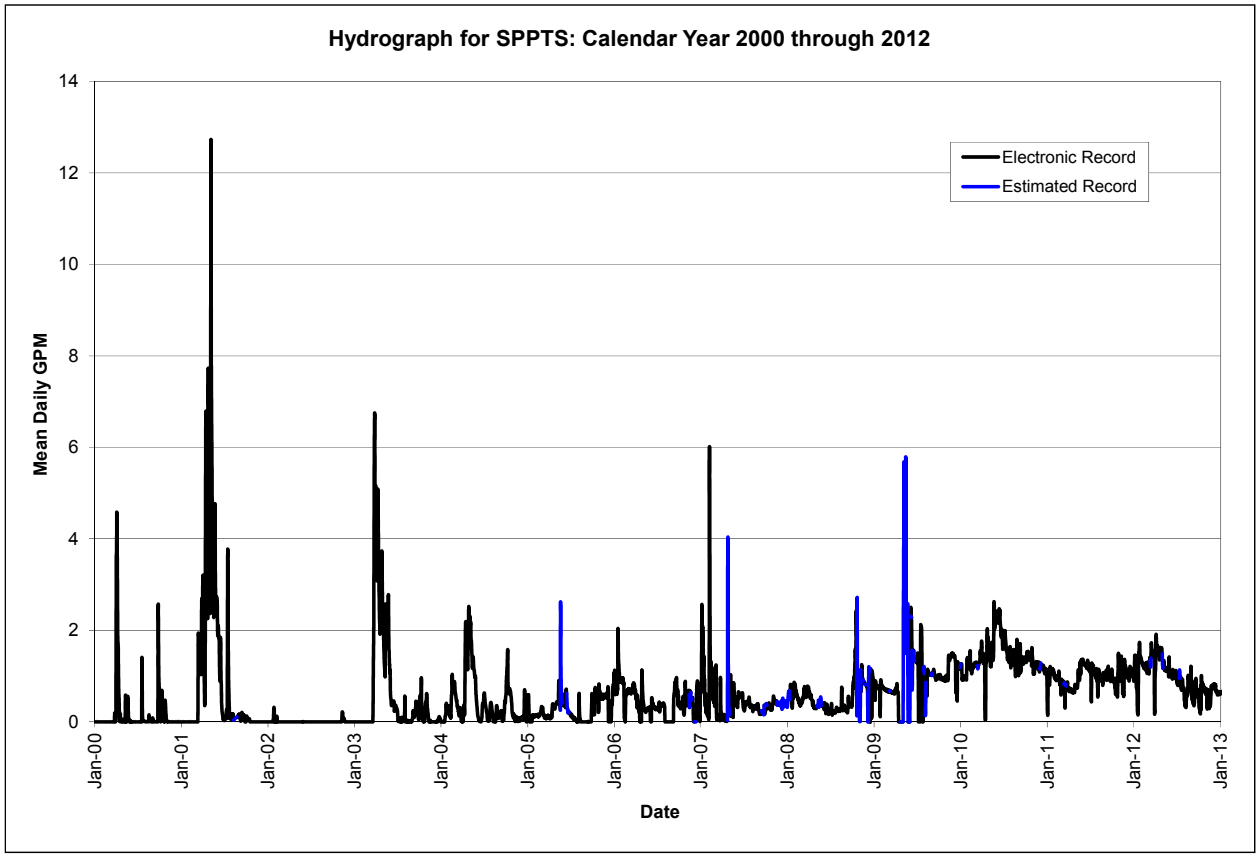


Figure 231. Hydrograph for SPPTS from 2000 Through 2012

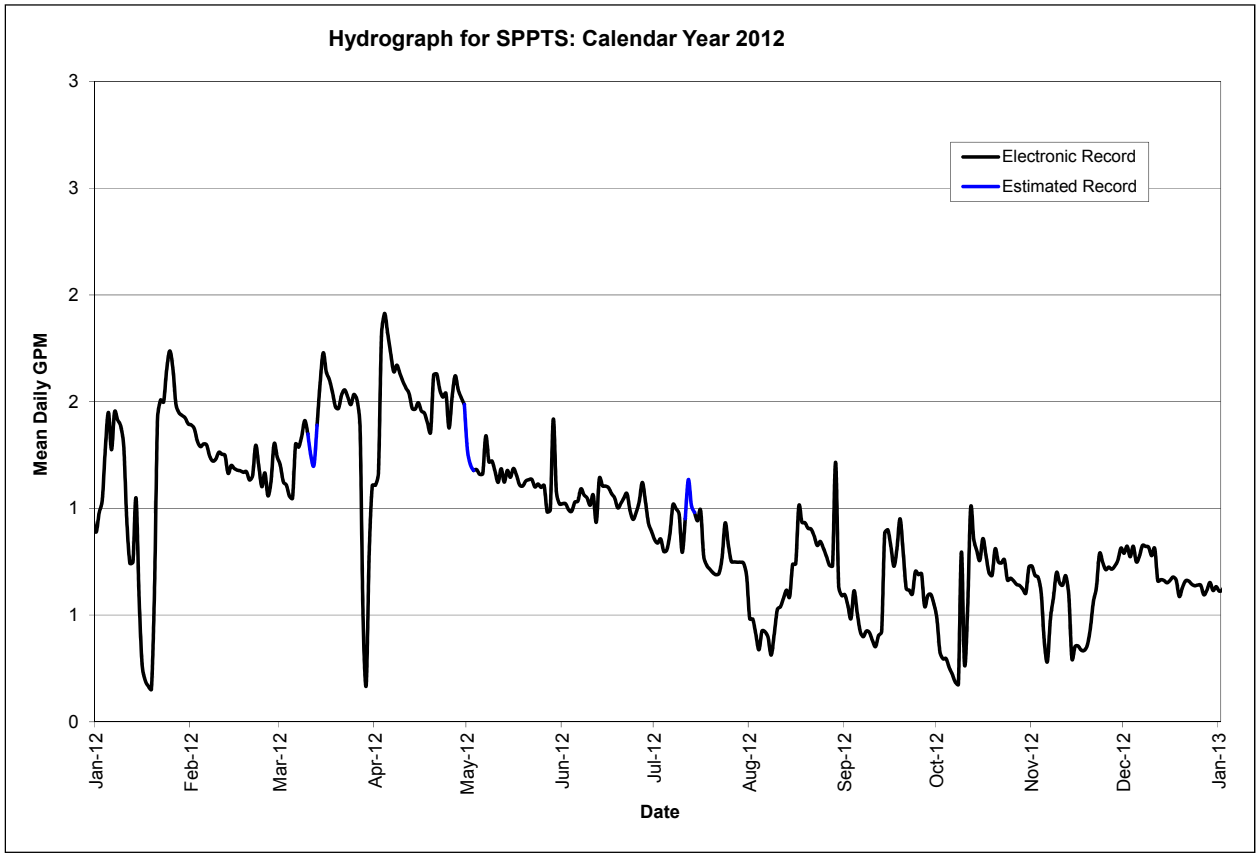


Figure 232. Hydrograph for SPPTS for CY 2012

On average, the SPPTS has treated about 324,000 gallons per year since January 1, 2000. From Table 100, 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; as is visually evident on Figure 231, flow was irregular until after this pump was added. The late-2008 installation of the Phase I upgrades comprises another significant factor in the volumes of water treated by the SPPTS.

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 195,000 gallons per year were treated from 2000 through 2005 (Table 101), assuming the volumes for 2000 through 2002 are accurate. (The year 2005 is included with the pre-closure average.) Since closure, average annual flows through the system have more than doubled: it has treated approximately 435,000 gallons per year. 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 gives a pre-Phase I average of approximately 215,000 gallons per year, while the post-Phase I average is well over twice that, at about 565,000 gallons per year.

Table 101. Average Volumes Treated by the SPPTS

Time Period	Average Volume Treated Per Year
Overall since Jan. 1, 2000	324,000
Pre-closure, 2000–2005	194,500
Post-closure, 2006–2012	434,600
Pre-Phase I upgrades, 2000–2008	215,800
Post-Phase I upgrades, 2009–2012	566,800

Note: Average volumes are based on estimates of volumes treated, as presented in Table 100. Time periods shown include complete years, and do not correspond to exact date of closure: the pre-closure estimate for the 2000–2005 period spans January 1, 2000, through December 31, 2005; the post-closure period begins January 1, 2006; and the post-Phase I period begins January 1, 2009.

Summary of SPPTS Upgrades

As noted above, several upgrades have been made to the SPPTS since Site closure. These upgrades have been discussed in greater detail in previous annual reports (particularly DOE 2009d, 2010d, and 2011d) and are summarized below in Table 102. Refer to Section 2.4 for information on operation and maintenance in 2012.

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.	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 III, Part 2[a] (2012)	Reconfigured Phase III cells described above to allow testing of lagoon-style approach to nitrate treatment. See text for information.	Cell A = pilot-scale nitrate treatment cell using inert media dosed with liquid carbon; equipped with recirculation pump Cell B = pilot-scale nitrate treatment cell using inert media dosed with liquid carbon, no recirculation pump 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

Notes: [a] Phase III cells were cleaned out in 2012 and modified to support different pilot-scale testing. See text for details.

Summary of SPPTS Treatment

The SPPTS through 2012 was the subject of continuing efforts to identify methods by which uranium and nitrate treatment could be improved for the long term. Although simply replacing

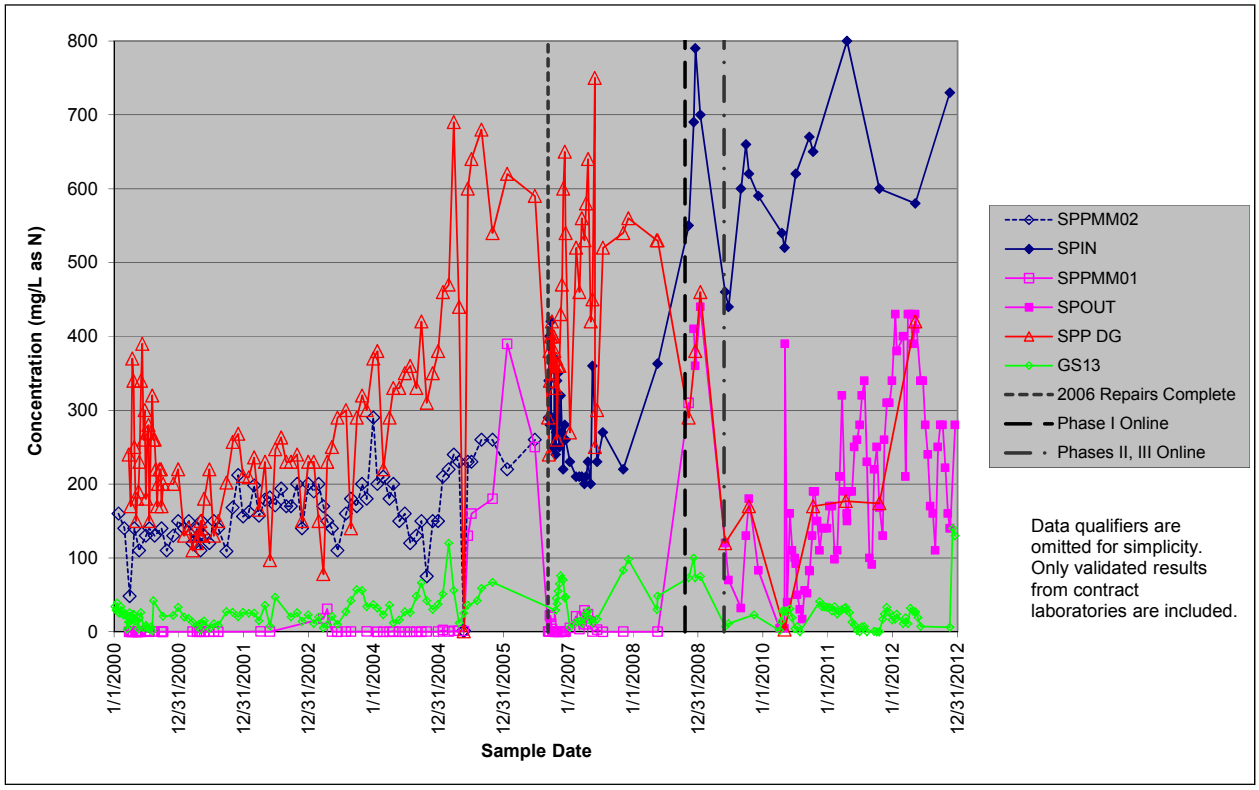
the media in the treatment cells would improve treatment substantially, that improvement would not last long and the cost to complete the media replacement activity would be high. The operation and maintenance costs associated with the system are not sustainable; a new treatment approach is needed in order to effectively treat the roughly 1 to 1.5 gpm average flow at a reasonable cost.

Therefore, because work was underway to identify the appropriate long-term system improvements, effluent conditions in 2012 were not improved over those in 2011.

As illustrated below on Figure 233, concentrations of nitrate in system influent continued to rise in 2012. Typical influent nitrate concentrations are now approximately triple those reported prior to Site closure. These higher concentrations, coupled with higher flows (as described above and summarized in Table 101), present a challenge to the SPPTS. Even so, the water at the discharge gallery generally contains lower concentrations of nitrate compared to pre-closure conditions. Dry conditions in 2012 led to this location being dry in the latter portion of the year, resulting in no fourth-quarter sample that could have helped to clarify the validity of the elevated result from May (420 mg/L).

Effluent concentrations of nitrate measured at SPOUT remained elevated in 2012 due to the aged nitrate treatment media and its relatively small volume compared to this nitrate load, though as shown on the figure a significant amount of nitrate continued to be removed from the influent. The continued operation of the Phase III cells would also have helped to remove nitrate, but only a small flow was routed through these pilot-scale cells. Nitrate at surface water location GS13 was generally consistent with pre-closure conditions except for a late fourth-quarter sample that reported an anomalously high 140 mg/L nitrate.

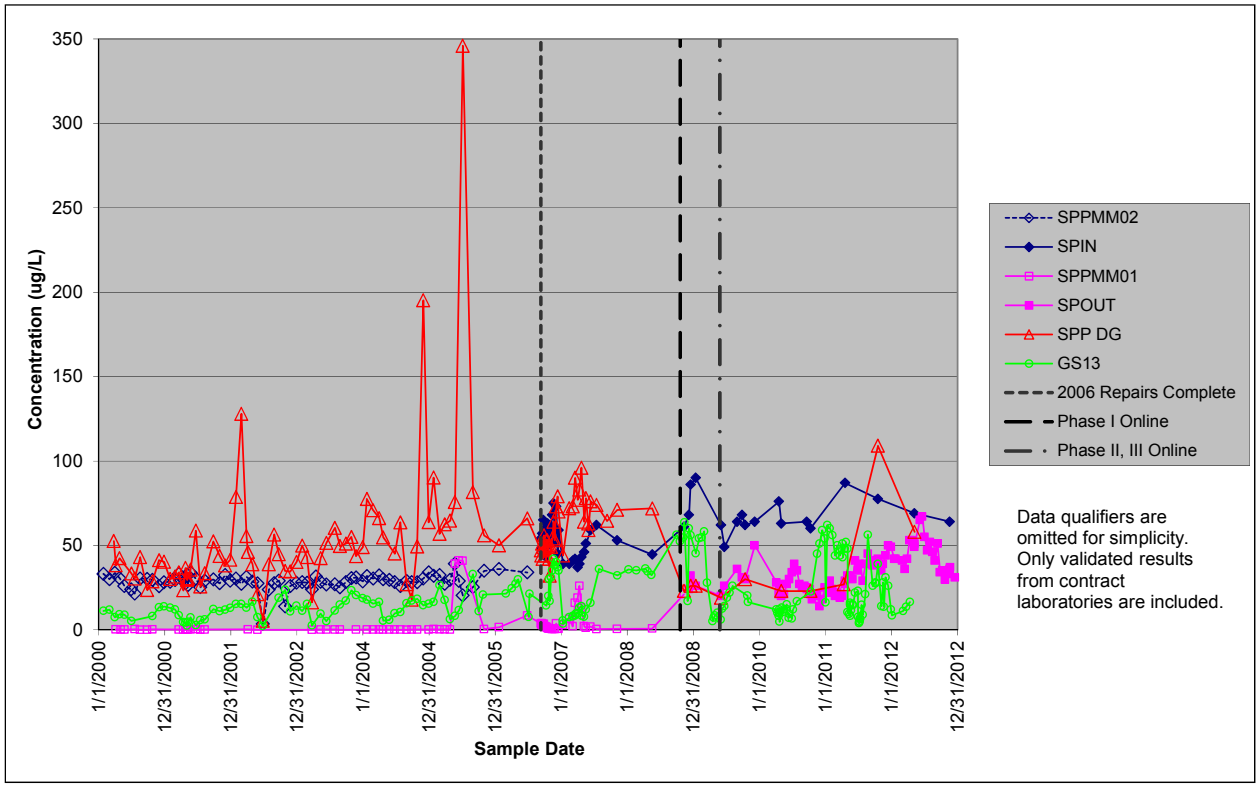
Additional data will continue to be collected and will help in defining longer-term trends, as well as the effects of ongoing efforts to improve the system's effectiveness.



Notes: SPPMM02 = original system "influent"; SPIN = true system influent; SPPMM01 = original system effluent; SPOUT = system effluent; SPP DG = SPP Discharge Gallery; GS13 = surface water performance location. Refer to previous annual reports (DOE 2007b, 2008c, 2009d, 2010d, and 2011d) for more information on events related to system repairs and modifications, including Phases I, II, and III. Some data are qualified but are not displayed differently for simplicity.

Figure 233. Concentrations of Nitrate at Selected SPPTS Monitoring Locations

Uranium in system influent has also increased (Figure 234). But, as with nitrate, conditions at the DG are generally improved compared to those prior to closure, despite the anomalous late-2011 result of 109 µg/L. Also similar to observations related to nitrate, system effluent monitored at SPOUT continued through 2012 to contain elevated concentrations of uranium. While the system continues to remove some uranium, the Phase II cell is of limited benefit because its ZVI-based media has been passivated with the high concentrations of nitrate. The original Cell 2, designed to remove uranium, is not sufficiently effective, and the small portion of flow treated via test microcells (described below) does not contribute substantially to the overall removal of uranium. Conditions at GS13 were also generally consistent with previous post-closure data, though improved over results from 2011. The absence of data later in 2012 is due to sampling method. Opportunistic grab samples are collected here for the analysis of nitrate, but the uranium sampling that supports the SPPTS utilizes automated equipment to collect flow-paced samples. Because of the low flows and frequently dry conditions, the associated container—which was installed on May 21—was not full before the end of 2012.



Notes: SPPMM02 = original system "influent"; SPIN = true system influent; SPPMM01 = original system effluent; SPOUT = system effluent; SPP DG = SPP Discharge Gallery; GS13 = surface water performance location. Refer to previous annual reports (DOE 2007b, 2008c, 2009d, 2010d, and 2011d) for more information on events related to system repairs and modifications, including Phases I, II, and III. Some data are qualified but are not displayed differently for simplicity.

Figure 234. Concentrations of Uranium at Selected SPPTS Monitoring Locations

S-K trend calculations were performed for SPPTS influent. This is not required by RFLMA, but can help to identify long-term trends in concentrations. The results of these calculations were affected by two primary events that have been discussed in this and previous reports. Both events impacted concentrations as reported for system influent. The first, which took place in 2006, was reassignment of the influent monitoring location from a trench piezometer (sampled as SPPMM02, but also referred to as piezometer 71099) to SPIN. The effect of this was an immediate increase in both nitrate and uranium concentrations of about 20 percent; refer to the annual report for 2006 (DOE 2007b) for more information on this change. The second event affecting influent water quality had a much greater effect: this was the completion of the Phase I upgrades in late 2008, as discussed in previous annual reports (for example, DOE 2009d and 2012f). Again, both of these changes affected influent data, but only the latter truly affected influent water quality; the change in sampling location did not represent an actual change in water quality, only where it was measured. For the trend calculations, results for both locations—SPPMM02 and SPIN—were grouped and evaluated as a single data set.

As summarized in Table 90, S-K trends calculated to have a 95 percent level of confidence over the entire period of record, January 2000 through the end of 2012, include increasing nitrate and uranium in SPPTS influent. The same results are identified when only post-closure (since 2006) data are evaluated. The associated trend plots are provided in Appendix B. Calculations were

also performed to assess whether trends are evident using only data collected since the Phase I upgrades were completed in October, 2008, but insufficient data have been collected to identify any statistically-significant trends in this data set. With more years of data, trends should become evident.

Uranium Microcell Testing and Development

As discussed in the 2011 Annual Report (DOE 2012f), laboratory tests were conducted in 2008–2009 at the Environmental Sciences Laboratory (ESL) in Grand Junction, CO, which is operated for the DOE. These tests supported design of the Phase II Cell, and 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 in the original system design.) However, when constructed and placed online, the Phase II Cell treated U to target levels only for approximately 200 pore volumes—a matter of a few weeks.

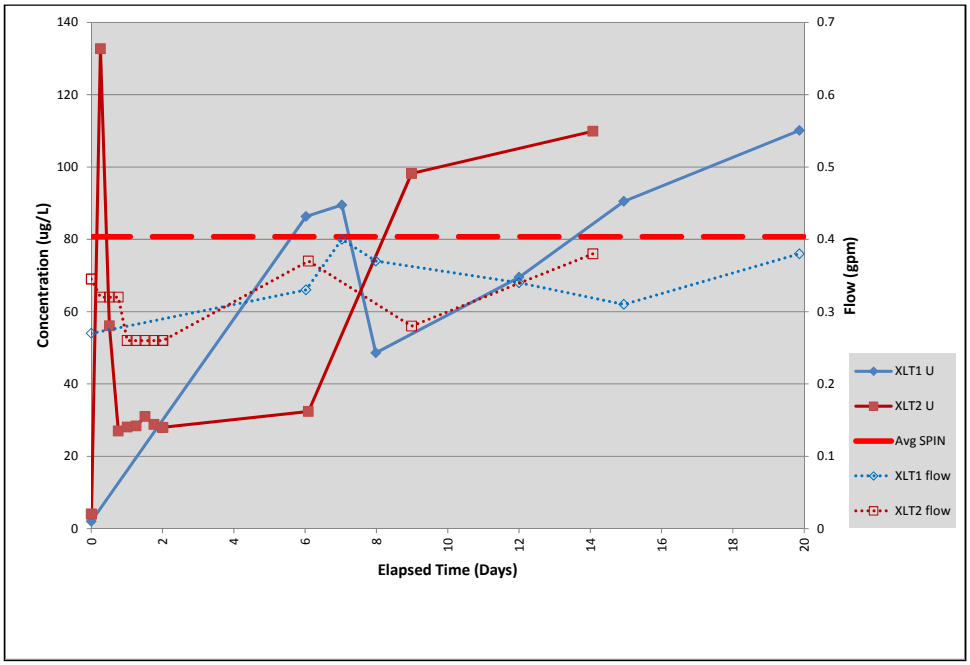
Therefore, in late 2011 planning was underway to develop and perform tests intended to implement treatment via a process that would more closely replicate the successful lab studies. The underlying hypothesis goes to the kinetics of two chemical reactions, and assumes the high nitrate concentrations in SPIN water caused the early loss of treatment effectiveness observed in effluent from the Phase II cell. The primary reactions of interest are U removal (by whatever mechanism—sorption or precipitation/coprecipitation) and ZVI passivation by nitrate. To clarify, the ZVI is also adversely affected by the naturally-high levels of dissolved oxygen in Rocky Flats groundwater, and by the groundwater's predominant calcium-bicarbonate character. These qualities also passivated and clog the ZVI media via development of iron oxides and oxyhydroxides, and precipitation of minerals such as calcite and siderite. However, these groundwater traits do not cause the ZVI at the other systems—MSPTS and ETPTS—to experience a similar drop in effectiveness after only weeks in operation. This is why the high nitrate in SPPTS influent is seen as the primary reason for the ZVI behavior at that system.

The ESL studies using SPIN water were conducted with a residence time (i.e., how long the water took to move through the media) of about half an hour, while the Phase II cell residence time is on the order of 8 hours. Similar lab studies using other U-contaminated water tested residence times of several minutes, and U was still effectively removed. Therefore, it was reasonable to investigate whether the lab studies using SPIN water were so successful because the shorter residence time allowed the U to be removed adequately before the ZVI became 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 1.1 gpm since the Phase I upgrades were installed, based on the annual average (Table 101)—the system is amenable to using very small cells operated at this flow. Conversely, it is not really 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, and a batched approach to treatment would present other issues.

Tests were conducted beginning in January 2012 using relatively small, media-filled "microcells" for U removal. Dimensions varied, but these units were generally on the order of 2 feet long by 4 inches in diameter. Both ZVI and specialized ion-exchange (IX) resins were tested.

IX resins had also been tested during conceptualization and design of the Phase II cell, and had been found to provide reduced U removal compared with ZVI. The same was true during these microcell tests. Strong base anion resins from Dow Chemical that are designed for selective uranium/mineral removal were used, including DOWEX 1, DOWEX 21K, and DOWEX 21K XLT. While some uranium was removed during these microcell tests, removal did not continue for very long and often included early "spikes" in uranium that could significantly exceed the influent concentration. Figure 235 below illustrates results from two of the IX resin microcell tests. The short duration of IX resin effectiveness may be due to the relatively miniscule concentrations of uranium compared to those of nitrate. In units of µg/L, the approximate concentrations are about 70 µg/L uranium to about 650,000 µg/L as N (or close to 3,000,000 µg/L as nitrate). Given that analytical results confirmed each of the resins tested started out removing nitrate as well as uranium, the IX resins probably became saturated with nitrate fairly quickly and were subsequently ineffective for uranium treatment.



Notes: U = uranium. Nondetects not shown differently; detection limit was 4 µg/L.
All analyses performed by ESL.

Figure 235. Performance of IX Resin-Based Microcells XLT1 and XLT2

Unlike the IX resins, however, the ZVI was able to treat adequately. The tests of ZVI-based microcells were complicated by the need to revise system plumbing on more than one instance in order to provide a configuration that would be suitable for the test objectives. Maintaining desired flow rates through each microcell also proved difficult because of the gradual accumulation of precipitates clogging the ZVI, which in turn reduce flow rates. Sample collection presented additional challenges. Samples were submitted to the ESL. Although data

from the ESL are not validated, occasional checks using split samples sent to contract labs indicate ESL results are representative.

As indicated above, the ZVI-based microcells experienced the same fouling with mineral precipitates, including "rust" (iron oxides and oxyhydroxides) and carbonates, that larger-scale ZVI-based treatment media suffers. And, while coarser ZVI reduced the potential for fouling, the coarser media also provided reduced U treatment because of its decreased surface area available for treatment. Testing continues in 2013 to define a more optimal balance between such variables as ZVI grain size, microcell size (which constrains ZVI volume and mass), influent flow rate, influent water pressures (as the ZVI clogs), and degree and duration of U treatment. Other factors are also necessarily considered, most notably suitable and cost-effective plumbing components and microcell materials of construction.

Table 103 provides summary information on the IX resin and ZVI microcells tested during 2012.

Table 103. Microcells Tested in 2012

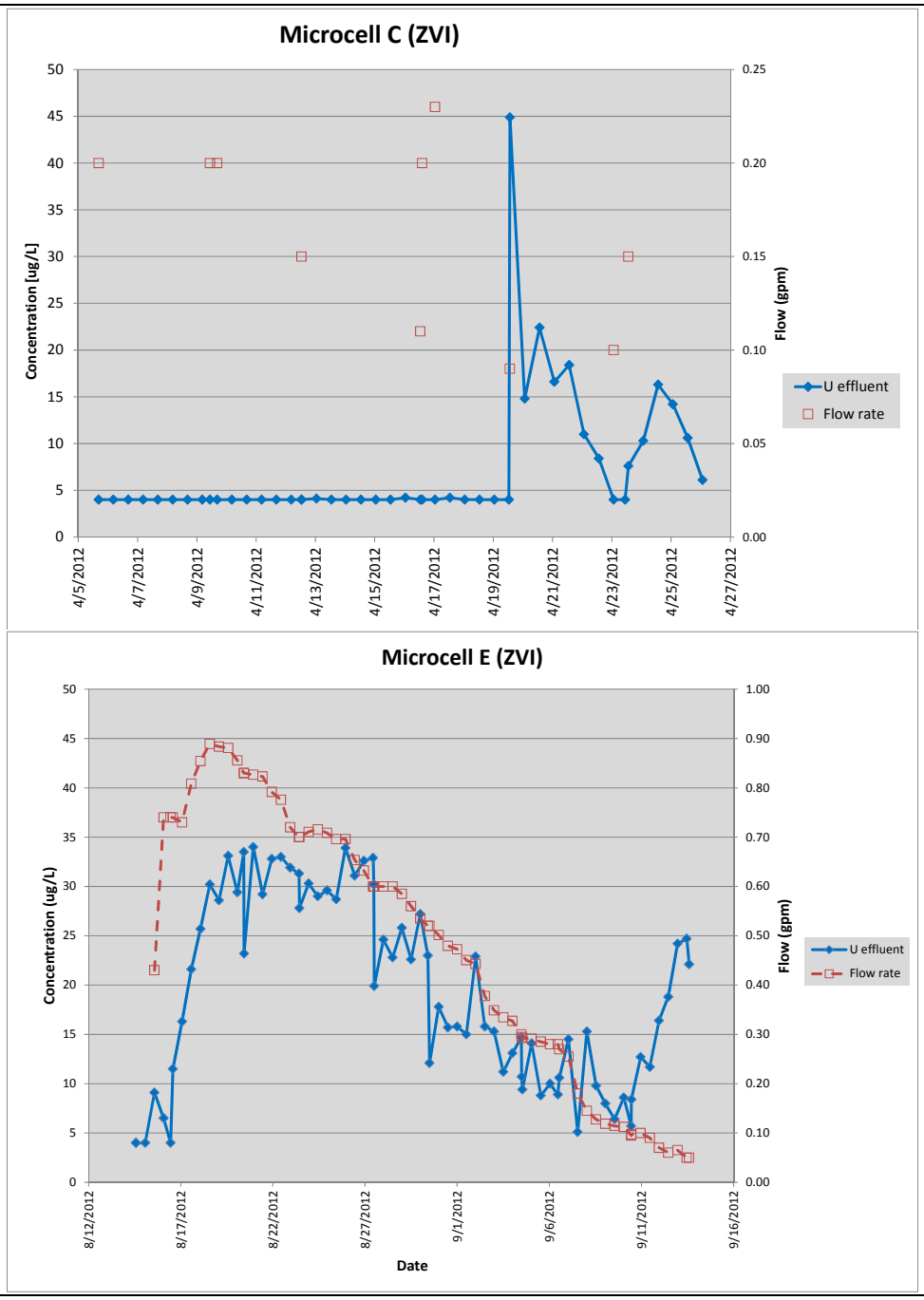
Microcell	Test Purpose	Start Date	Promising?
IX Resin-Based Microcells			
Microcell Resin 1	Proof of principle	4/16/2012	Uncertain
Microcell Resin 21K	Proof of principle	4/16/2012	Uncertain
Microcell Resin XLT	Proof of principle	4/16/2012	Uncertain
D1	Longer test, larger microcell	6/12/2012	No
XLT	Longer test, larger microcell	5/23/2012	No
XLT2	Longer test, larger microcell	6/26/2012	No
ZVI-Based Microcells			
A	Proof of principle	1/10/2012	Uncertain
B	Proof of principle refinement	4/5/2012	Yes
C	Refinement	4/5/2012	Yes
D	Refinement	7/11/2012	Uncertain
E	Refinement	8/14/2012	Yes
F[a]	Static test of nitrate effects	9/13/2012	N/A
F[a]	Static test of nitrate effects	10/9/2012	N/A
G	Alternate (coarse) grain size	9/18/2012	Uncertain
H	Alternate grain size refinement	10/15/2012	No
J	Alternate grain size refinement	10/31/2012	No

Notes: Resins by Dow Chemical, see text for more information.

[a] Microcell not put online, but merely filled with untreated influent and allowed to sit for approximately one month to evaluate effects of nitrate on ZVI. ZVI material used in A through F was -8/+50 mesh; that used in G through J was -4/+8 mesh.

Figure 236 presents analytical data from two of the better-performing ZVI-based microcells, C (top portion of figure) and E (bottom portion of figure). Both used finer-grained ZVI. Microcell C was constructed of 4-inch PVC pipe cut 24 inches long and filled with approximately 24 pounds of ZVI; microcell E was 4-inch PVC cut 30 inches long and filled with about 39 pounds of ZVI. (Microcell C incorporated plumbing fittings within its 24-inch length, while microcell E's 30-inch length excludes the length of the additional fittings.) Also shown on these graphs are estimated flow rates through these microcells. Although the influent concentration of uranium is not shown, it can be estimated at approximately 70 to 80 µg/L uranium. As the ZVI media clogs, the flow rate decreases – not intentionally and via system controls, but due to increasing pressure required to force water through the media. At the same

time, a higher flow rate results in shorter residence time and correspondingly reduced uranium treatment. Both of these are fairly intuitive, and the time series plots on Figure 236 reflect both of these effects.



Notes: U = uranium. Nondetects not shown differently; detection limit was 4 µg/L. All analyses performed by ESL.

Figure 236. Performance of ZVI-Based Microcells C and E

Microcell testing and development continued into 2013 and is expected to be optimized and integrated into the system in 2013. The corresponding annual report will provide additional information and discussion.

Phase III Pilot Studies: New Focus on Lagoon Treatment

The initial representation of the Phase III pilot studies were concluded in 2011, though the cells continued to be operated in that configuration for the first part of 2012. During this time, bench-scale studies were underway to evaluate a different approach to nitrate treatment.

The 2011 Annual Report (DOE 2012f) summarized the challenges posed by the original pilot-scale treatment approaches and noted that efforts were underway to identify a more appropriate response to the SPP. An approach to treating SPP nitrate was identified that might provide adequate treatment while minimizing construction, operation, and maintenance costs. This treatment approach is referred to as lagoon-style treatment.

Lagoons are used across the world to treat water, and in rural communities in the US often represent a primary approach to wastewater treatment; the technology reportedly is over 3,000 years old (Montana Water Center 2005). Lagoons may operate aerobically (incorporating oxygenated waters) or anaerobically (no oxygen), and may be implemented as constructed tanks or bermed ponds; the water treatment objectives also vary. At Rocky Flats, the lagoon approach envisioned would be anaerobic and, if possible, would utilize existing concrete containers.

Questions of scale were under consideration from the beginning of the proposal to treat nitrate using a lagoon approach. The original concrete structure containing treatment Cell 1 and 2 was envisioned as a possible container for some future, full-scale lagoon. This structure has internal dimensions of 17 feet wide by 42 feet long, and a depth that varies because of the sloping side walls but can be approximated as 22 feet. There is an internal wall separating Cell 1 and Cell 2; it is 1 feet thick and extends 12 feet up from the floor. These dimensions lead to an internal volume of 15,708 cubic feet, or 117,504 gallons if the internal wall is removed; if the wall is retained, this is reduced to approximately 15,504 cubic feet (115,977 gallons). With an annualized average flow for the years 2009 through 2012 of 566,800 gals (Table 101), this converts to an average flow rate of just under 1.1 gpm. The total residence time for a 1.1 gpm flow through a 115,000 gallon container is 104,545 minutes, or about 73 days. However, it would be advantageous to design for several feet of freeboard below the top of the structure, and it could be necessary to incorporate internal plumbing or other components to assist maintenance. Therefore, for the purposes of initial lagoon testing, a residence time of some 50 days was targeted. The question then became whether a lagoon could achieve adequate nitrate removal in roughly 50 days, and do so economically (i.e., not requiring too much MicroCg) and with minimal maintenance requirements.

The lagoon approach was pursued because not only does it have a successful record of water treatment, but it avoids a prime challenge of the Phase III Cell A pilot-scale study: Although effective in removing nitrate, the inert plastic media tended to clog with biomass, requiring extensive maintenance to keep Cell A operating effectively.

Three sets of bench-scale tests were performed to test the lagoon approach to nitrate treatment. Each time, the bench tests incorporated untreated water from SPIN (the collection well in the SPPTS groundwater intercept trench), MicroCg as a liquid carbon source (the same product used in the first pilot-scale tests in Cell A, and referred to herein as MCG), water that is rich in denitrifying bacteria (either from Cell A or from a previous bench-scale test), and two identical

open-topped 30-gallon plastic containers. Tests were performed in a subsurface vault to protect them from weather events and add a measure of environmental control (including elimination of UV radiation in sunshine), and reduce evaporation over the course of these multi-week experiments.

Samples were collected regularly throughout these tests. In addition, field staff documented observations such as smells and water appearance, and measured field parameters (e.g., pH, turbidity). As the tests proceeded, additional efforts were made to remove any accumulations of mold or other biomass present on the water surface in case these bacteria were competing with the desirable denitrifying bacteria for the carbon nutrients.

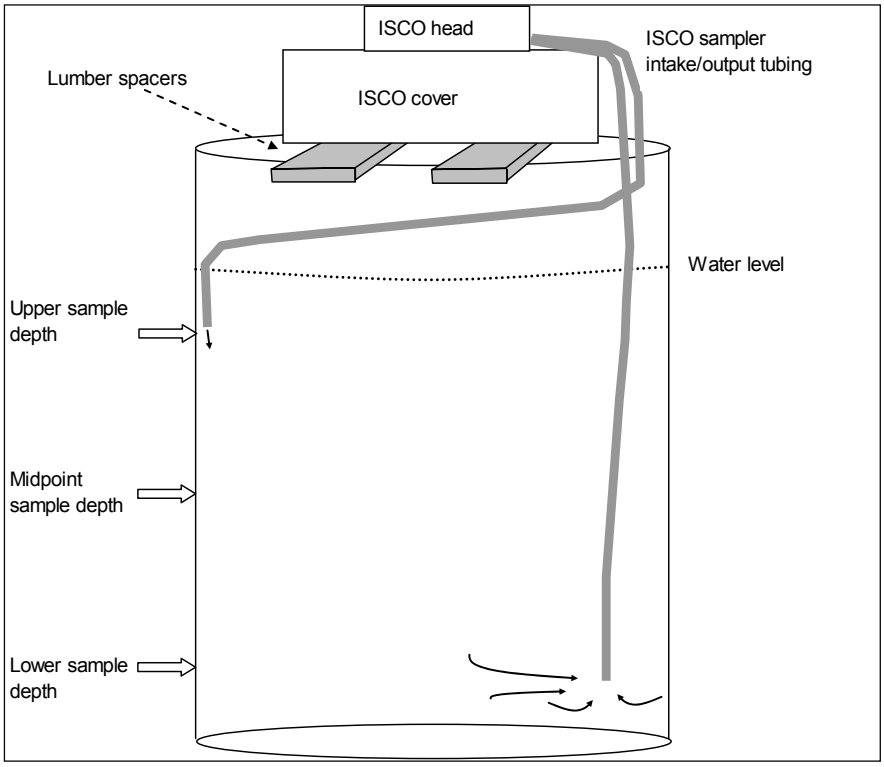
In Part 1 of the tests, the basic objective was to test proof of principle: would this approach remove nitrate? In Part 2, the objective was to begin to refine nutrient (MCG) requirements. Part 3 tested treatment effectiveness depending on the proportions of untreated water to bacteria-rich water.

Bench-Scale Lagoon Test, Part 1

Each of the two containers was filled with 25 gallons of MCG-dosed SPIN water. The dose rate was 40 mL MCG for every 10 gallons of water, for a total of 100 mL MCG in each container. Once the MCG was thoroughly (but gently, to minimize aeration) mixed into the SPIN water, 1 gallon of bacteria-rich water (referred to as "inoculum") from Phase III Cell A was added to each container and gently mixed. (Cell A was still operating at this time.)

Each container was then equipped with an ISCO sampler head propped on boards, with both ends of the ISCO tubing extending into the water. The sampler on one container was left inactive, while the other was programmed to collect a sample every hour. Therefore, because both ends of the sampler tubing were in the water, this acted to circulate the contents every hour. The intent of this was to test whether recirculation of the water would improve treatment, given that Phase III Cell A incorporates a recirculation pump and moving water is known to provide improved nitrate treatment (e.g., in fluidized bed reactors).

A sample was collected of the SPIN water before mixing with MCG, and then each container was sampled at three depths over the course of the test. Figure 237 shows the general design of each of these containers, with flow arrows that indicate this pertains specifically to the container with the active ISCO sampler, and Figure 238 is a photograph showing the tests as they were being conducted.



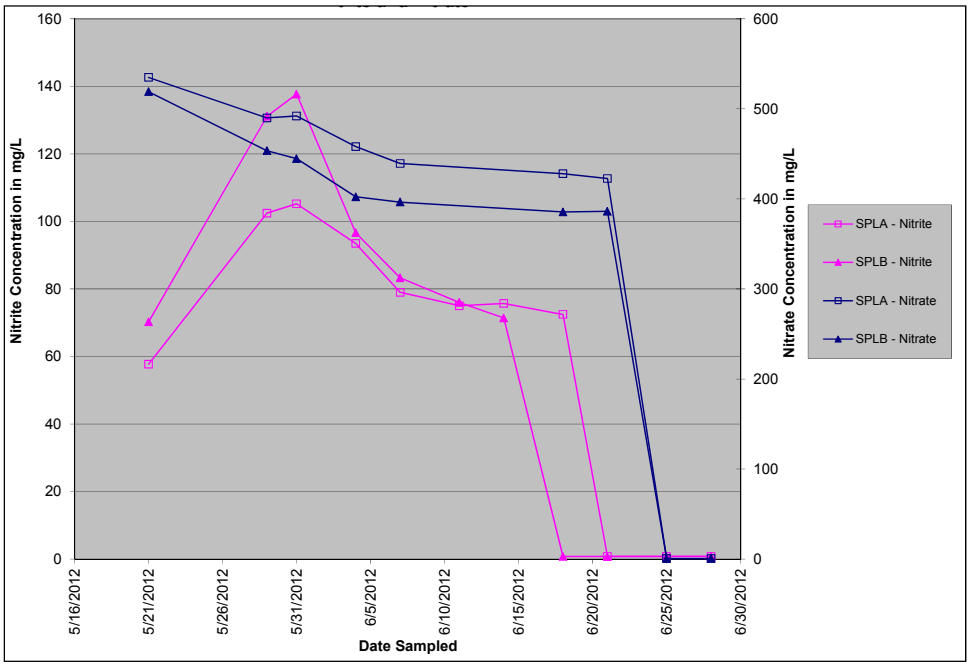
Notes: Conceptual drawing only, not to scale, showing main features of the container that was agitated using ISCO sampler equipment. Solid arrows indicate general direction of water flow when this ISCO equipment was operating, outline arrows show depths (but not locations) of sample collection. The other container also had the ISCO cover and tubing present, but the sampler was not active.

Figure 237. Drawing of Bench-Scale Lagoon Test Apparatus for Part 1 Tests

Figure 238. Photograph of Bench-Scale Lagoon Part 1 Tests in Operation

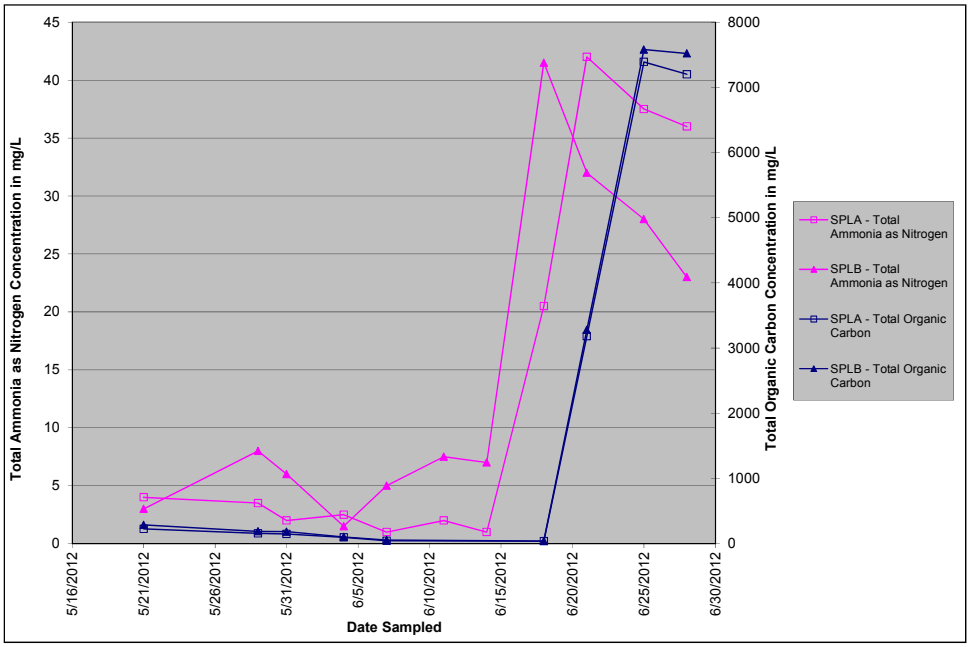
The Part 1 tests were begun on May 21, 2012. Samples were collected once to twice weekly. Figure 239 illustrates results of these tests in terms of nitrate and nitrite. The container that remained passive was identified as SPLA, while the container that was being automatically mixed every hour by the ISCO sampler was identified as SPLB. Within about 2 ½ weeks of operation (from startup on May 21 to the fifth data point on June 7), it was fairly clear that nitrate removal was inadequate to meet test objectives. After operating for one month (May 21 to June 21), removal had nearly ceased. However, it was also clear that nitrate could be treated through this approach, since significant removal had occurred. Therefore, on June 14 another dose of MCG was added to each container. However, these doses were inadvertently too large—an additional 3.5 L was added to each container, when the initial dose was only 0.1 L. It was not surprising, therefore, that concentrations of nitrate and nitrite quickly dropped to nondetect.

The opposite pattern is demonstrated by concentrations of ammonia, which rose sharply following the additional MCG dose (Figure 240). As shown on this figure, ammonia began to decrease within a week after that dose was applied. Concentrations of total organic carbon (TOC) are also shown and clearly illustrate the carbon supplement represented by the MCG addition on June 14. Prior to the MCG addition, TOC had dropped from over 200 mg/L initially to between 27 mg/L and 46 mg/L, depending on the container and depth measured.



Notes: SPLA = passive container, SPLB = container that was automatically mixed via ISCO sampler every hour. When multiple depths were sampled, concentrations shown are averages of results from the various depths. Concentrations are reported in terms of mg/L as nitrogen. Nondetects are not shown differently for convenience. All samples were analyzed and data generated by the ESL.

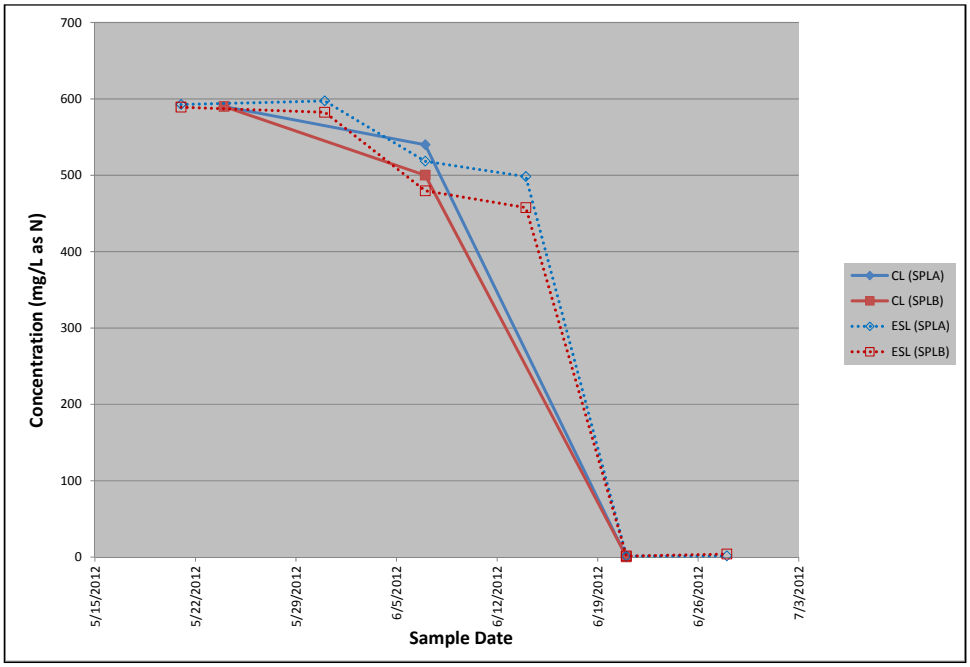
Figure 239. Nitrate and Nitrite Concentrations in Part 1 Bench-Scale Lagoon Tests



Notes: SPLA = passive container, SPLB = container that was automatically mixed via ISCO sampler every hour. When multiple depths were sampled, concentrations shown are averages of results from the various depths. Concentrations of ammonia are reported in terms of mg/L as nitrogen. Nondetects are not shown differently for convenience. All samples were analyzed and data generated by the ESL.

Figure 240. Ammonia and Total Organic Carbon in Part 1 Bench-Scale Lagoon Tests

Samples were submitted to the ESL in Grand Junction, CO for analysis. Split samples were periodically submitted to a contract laboratory as a quality check. The contract lab reported nitrate+nitrite as nitrogen, while ESL reported these analytes separately, nitrate as nitrogen and nitrite as nitrogen. Samples sent to the ESL were only chilled for preservation, while those submitted to the contract lab were acidified and chilled. One concern was that due to a lack of chemical preservation, denitrifying bacteria present in the samples sent to the ESL would continue to reduce nitrate concentrations until the sample was ultimately analyzed. A comparison of the data (Figure 241) from the different laboratories suggests concerns about continued denitrification in the sample bottles sent to the ESL did not warrant use of a different lab. The sum of the separate ESL results for nitrate and for nitrite compared well with the contract lab results.



Notes:
Samples submitted to the CL were collected from middle depth in each container, so ESL data illustrated are also from that depth. CL reports in terms of nitrate + nitrite as N; ESL analyzes nitrate and nitrite separately. ESL data shown are therefore sum of nitrate as N + nitrite as N on the given date. Qualifiers not shown for simplicity.

Abbreviations:
CL = contract laboratory with full quality assurance/quality control (QA/QC) reporting requirements.
ESL = Environmental Sciences Laboratory in Grand Junction, operated for LM.
SPLA = passive container.
SPLB = container that was automatically mixed via ISCO sampler every hour.

Figure 241. Comparison of Contract Lab and ESL Analytical Data from Part 1 Bench-Scale Lagoon Tests

As the figures above suggest, there did not appear to be a great advantage to lagoon-style treatment utilizing the mixing process. The nitrogen constituents of interest did decrease somewhat more quickly in the mixed container—and this is especially evident for ammonia after the additional MCG dose—but the data also indicate that adequate treatment could be achieved without mixing. While it would be necessary to repeat this test with a more appropriate initial MCG dose to confirm any advantage posed by mixing, the data indicate a lagoon approach to nitrate removal that does not include mixing may still achieve the desired effect. Therefore, subsequent bench-scale tests excluded the mixing option. Subsequent tests also utilized only the ESL for analytical support.

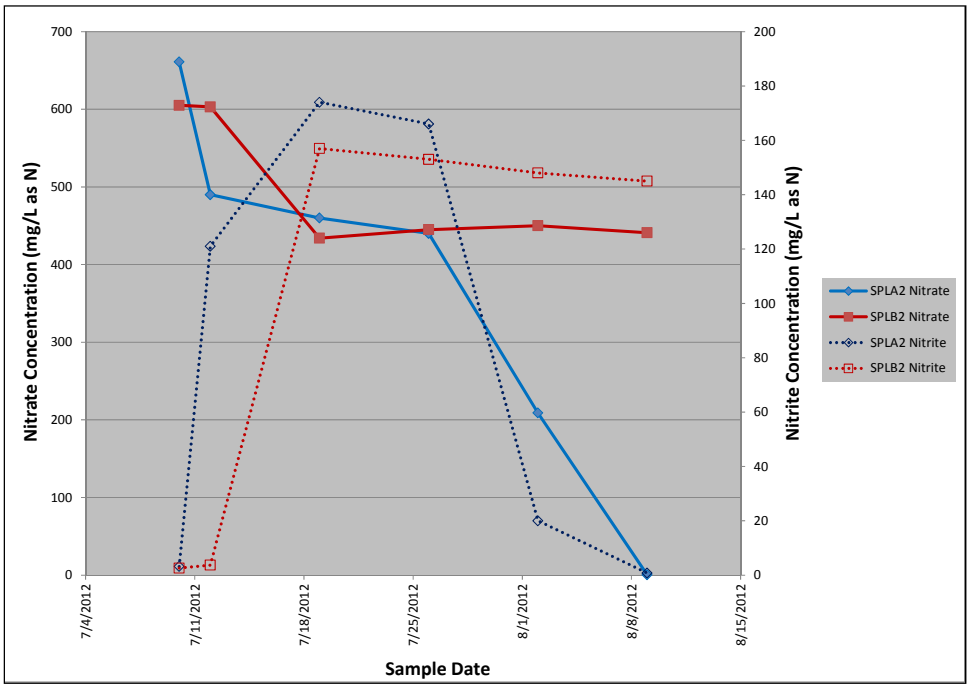
Bench-Scale Lagoon Test, Part 2

The same containers used in Part 1 were used for Part 2, after being decontaminated. As summarized above, the primary objective of the Part 2 tests was to refine the MCG dose required to achieve adequate treatment, and to omit mixing from both containers. The experimental apparatus was as illustrated above in Figure 237 except that the ISCO samplers and the lumber used to support them were omitted from the tops of the containers.

Each of the two containers was again filled with 25 gallons of MCG-dosed SPIN water. Container SPLA2 received a dose of 25 mL MCG per gallon of SPIN water, while SPLB2 received a dose of 50 mL MCG per gallon of SPIN water. Once the MCG was thoroughly (but gently, to minimize aeration) mixed into the SPIN water, 1 gallon of inoculum from Phase III Cell A was added to each container and gently mixed. (Cell A was still operating at this time.)

The Part 2 tests began on July 10 and concluded on August 16, 2012. More attention was paid to mold removal as the test proceeded. It was expected that the container receiving a higher dose of MCG, SPLB2, would perform better, but that SPLA2 might still perform adequately. These expectations were not supported by the results.

Figure 242 illustrates concentrations of nitrate and nitrite in samples collected from the Part 2 lagoon test containers. (Ammonia is not illustrated because concentrations remained below 10 mg/L as N, and TOC is not illustrated because it was not adjusted during the test.) Test container SPLA2 removed all nitrate and nitrite within one month, while SPLB2—the container receiving the higher dose of MCG—effectively stopped treating nitrate after about a week and a half. The data for the last weeks of the test suggest SPLB2 would have continued to remove both nitrate and nitrite, but there was little reason to continue operating this test given the successes of the more economical SPLA2.



Notes: All data from ESL. See text for descriptions of SPLA2 and SPLB2. Qualifiers not shown for simplicity. Note dual concentration axes.

Figure 242. Nitrate and Nitrite in Part 2 Bench-Scale Lagoon Tests

These results showed that the lagoon approach to nitrate treatment is both feasible and potentially cost-effective on a larger scale. Results also confirmed that treatment can be achieved without mixing the water, which, given the lack of line power, could be costly and difficult on a larger scale at Rocky Flats.

Bench-Scale Lagoon Test, Part 3

The same containers used in Parts 1 and 2 were used for Part 3, after being decontaminated. As summarized above, the primary objective of the Part 3 tests was to evaluate the effects of a different proportion of inoculum to untreated water. The underlying concept relates to a pilot-scale or full-scale lagoon operating in flow-through, unlike these bench-scale tests being operated as batches. In the larger flow-through approach, a small volume of untreated influent would enter a much larger volume of inoculum. (The Part 1 and Part 2 batch tests, conversely, had tested treating 25 gallons of untreated influent with only 1 gallon of inoculum.) Conceptually therefore, the denitrifying bacteria would be able to divert less energy to expanding their population and more energy on treating the nitrate. In addition, the Part 3 test was designed to repeat the test performed with the successful Part 2 container, SPLA2, and to further refine the MCG dose required. Because a residence time of some 50 days would be available in the original concrete structure, and the successful Part 2 test (SPLA2) treated nitrate in about 30 days, a reduced MCG dose might still achieve adequate treatment over a longer time frame.

One other difference in the Part 3 tests was expected to be inconsequential, but may have been an important factor. The source of inoculum was changed from Phase III Cell A, which had been used for Parts 1 and 2, to the successful Part 2 container, SPLA2. This is because the Phase III cells were to be cleaned out and there was a concern that the bacteria might no longer be robust due to only periodic dosing with SPIN water and MCG, rather than continuous flow. The "fresher" SPLA2 inoculum was seen as advantageous both because the bacteria had only recently completed denitrifying the water in that container, and also because these bacteria had essentially been selectively bred for this type of application.

The experimental apparatus was as illustrated above in Figure 237 except, as with the Part 2 tests, the ISCO samplers and the lumber used to support them were omitted from the tops of the containers.

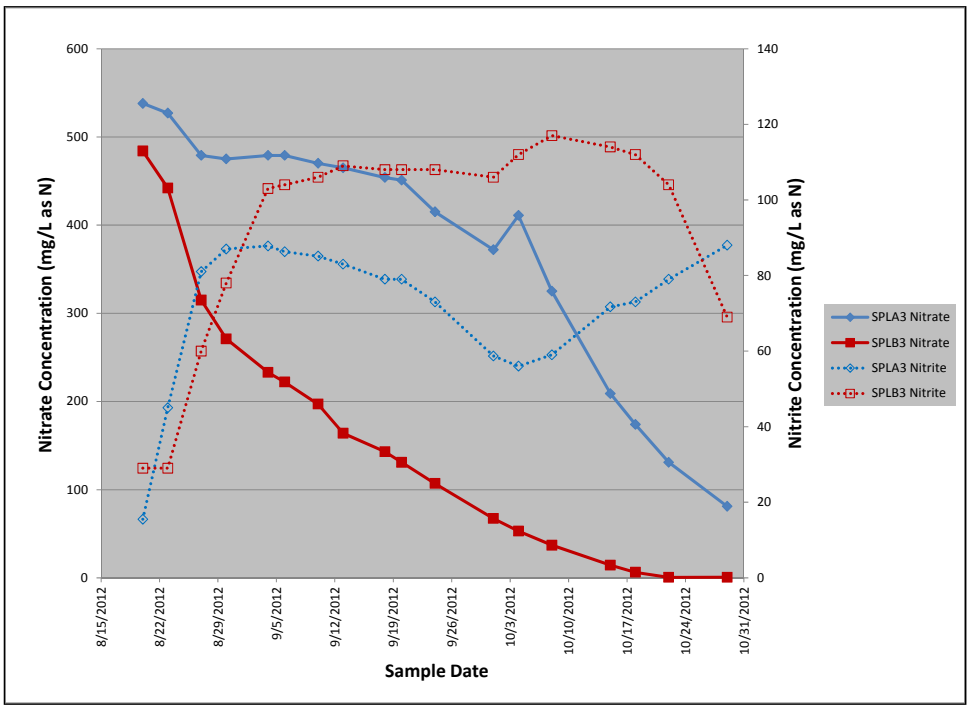
Each of the two containers was again filled with MCG-dosed SPIN water, but SPLA3 retained the proportions of SPLA2 while SPLB3 explored both a higher ratio of inoculum to SPIN water and a lower MCG dose rate. The recipe for each Part 3 test container is summarized below in Table 104.

Table 104. Recipe for Part 3 Bench-Scale Lagoon Tests

Material	Volume, SPLA3	Volume, SPLB3
SPIN water	25 gallons	23 gallons
MCG per gal	25 mL	15 mL
Total MCG	625 mL[a]	345 mL[a]
Inoculum (from SPLA2)	1 gallon	3 gallons

[a] MCG added at 25 mL MCG per gal SPIN water in SPLA3, and 15 mL MCG per gallon SPIN water in SPLB3

The Part 3 tests began on August 20 and concluded on October 29, 2012. Inspections for accumulations of mold, and removal of any identified, were a high priority during each visit. Samples were only collected from a midpoint depth in each container, as little stratification had been observed in previous tests. Summary results are illustrated below in Figure 243.



Notes: All data from ESL. See text for descriptions of SPLA3 and SPLB3. Qualifiers not shown for simplicity. Note dual concentration axes.

Figure 243. Nitrate and Nitrite in Part 3 Bench-Scale Lagoon Tests

Figure 243 shows that container SPLB3 achieved better nitrate and nitrite removal than SPLA3, even though the former received a smaller MCG dose. However, although nitrate met the treatment target, complete nitrite removal was not achieved. The tests could have been extended longer and the nitrite trend suggests it might have been completely treated SPLB3, but the residence time had been approximately 70 days. This and, more importantly, the fact that the Phase III cells were being prepared for pilot-scale lagoon treatment led to the decision to terminate the Part 3 tests. The main hypothesis for why the Part 3 tests were not as effective as the Part 2 tests focused on the different source of inoculum (the Part 2 water rather than Cell A water), and the possibility that this inoculum included sufficient mold to immediately compete with the denitrifying bacteria. This was not tested, but it was agreed that observations of mold should continue at the pilot scale, and possible correlations to treatment effectiveness should be evaluated.

Pilot-Scale Lagoon Treatment

Even as the Part 3 bench-scale lagoon tests were being conducted, efforts were underway to prepare the Phase III cells for pilot-testing the lagoon approach to nitrate treatment. The cells were dewatered on August 29 and cleanout was completed on September 5, 2012.

The plastic media from Cell A was removed and packaged for later disposition. Unnecessary internal components were removed, including the plastic grate on the bottom of the cell that had previously kept the plastic media separated from the water coming into the cell. The cell was then cleaned out with a pressure washer. The recirculation pump was left in Cell A for later use.

The corn stover media in Cell B, which also contained a small amount of crushed limestone, was removed and packaged for later disposition. The pea gravel layer at the bottom of the cell and the influent distribution gallery bedded in that gravel were also removed. (This gravel layer and the distribution gallery were analogous to those installed in the MSPTS and ETPTS treatment cells; sketches and a photograph of the ETPTS components are provided in the 2009 Annual Report, DOE 2010d.) This cell was also then cleaned out with a pressure washer.

Cell A was already configured for MCG dosing, but Cell B was not. Therefore, in preparation for the upcoming pilot-scale lagoon tests, a suitable dosing pump (i.e., that which had been used in 2009 for the addition of citrate to Phase II influent; see DOE 2010d) and the MCG feed line were installed. The dosing pump for each cell was cleaned and calibrated, as were the various lines and the flowmeter dedicated to each cell. Dedicated sample tubing was installed in each cell, one to allow sampling of the water in the bottom portion of the cell and another to allow sampling of the midpoint; no shallow tubing was installed because collecting this sample is easily achieved. Dedicated temperature sensors were also installed to allow inspection and evaluation of thermal effects in each cell. The water level sensors were reinstalled and, by September 20, 2012, the cell reconfiguration was complete. At this point, the only differences remaining between the two pilot-scale cells was that the influent line into Cell A has a diameter of 4 inches, while that in Cell B is 2 inches; and Cell A includes a recirculation pump, while Cell B does not.

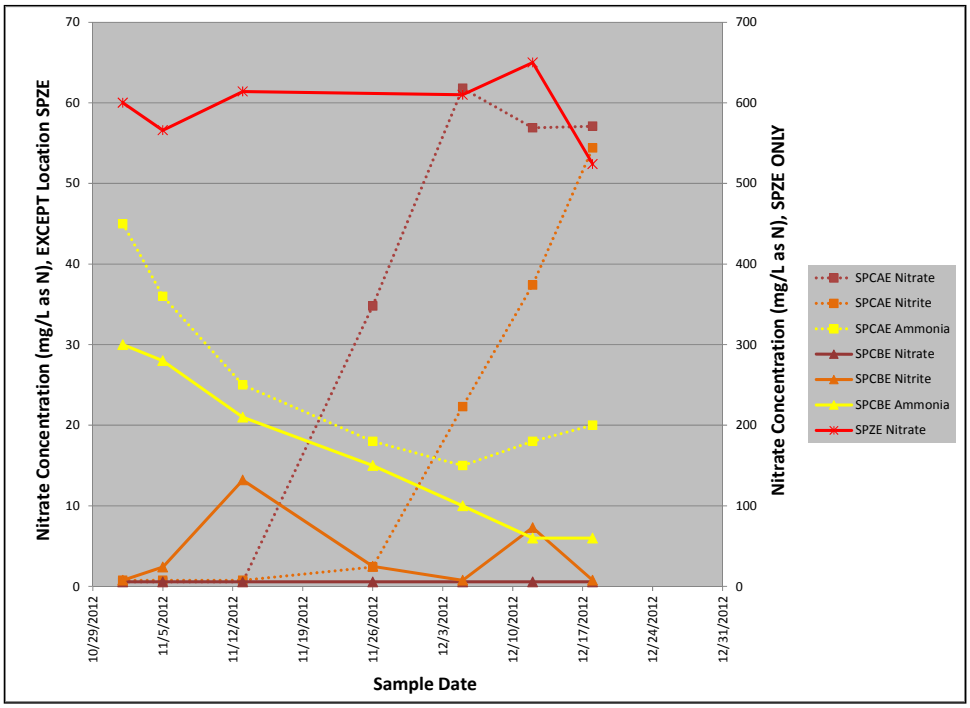
Filling the pilot cells began on September 20, 2012. This process was conducted methodically for over a month to ensure the denitrifying bacteria were able to form healthy, robust populations in each cell. Every few days, high-nitrate water was pumped from the Phase II Cell to the Phase III cells, raising the water level in the Phase III cells by several inches to a foot. At the same time, an aliquot of MCG (at a rate of 15 mL MCG per gallon of added water, based on results of the bench-scale tests) was added to the pilot-scale cells and gently mixed into the water. Samples were collected throughout the filling period primarily to evaluate TOC, dissolved organic carbon (DOC), nitrogen constituents, and bacteria. No problems were observed in the field or in the analytical data, so on November 1, 2012, the new lagoon configuration of the Phase III pilot tests was begun. (Note that the bench-scale tests treated the water in batch mode, while the pilot-scale tests operate in flow through. Flow enters each cell near the bottom, and exits near the top.)

Throughout the rest of 2012, Cell A and Cell B received the same influent flows and same influent dose rate. The flows were designed to approximate a roughly 50-day residence time in each cell. Influent flow was pulsed because the available pumps will not support the low, continuous flow rate required to achieve the desired residence time. Therefore, twice each day—at noon and midnight—a pulse of about 10 gallons was automatically pumped to each pilot cell from the Phase II cell, being dosed with MCG just before entering the pilot cell. The dose rate used was 15 mL of MCG per gallon of influent.

The operational difference between the two pilot-scale cells was the recirculation pump in Cell A, which was activated when the pilot tests began, while Cell B was essentially stagnant. The intent of operating Cell A with recirculation was to confirm, at this larger scale, whether active circulation in a lagoon would be necessary to achieve adequate nitrate treatment within the target residence time of about 50 days. If found to be necessary, it would almost certainly pose a challenge due to power limitations. The Cell A pump operates at approximately 3 gpm; using

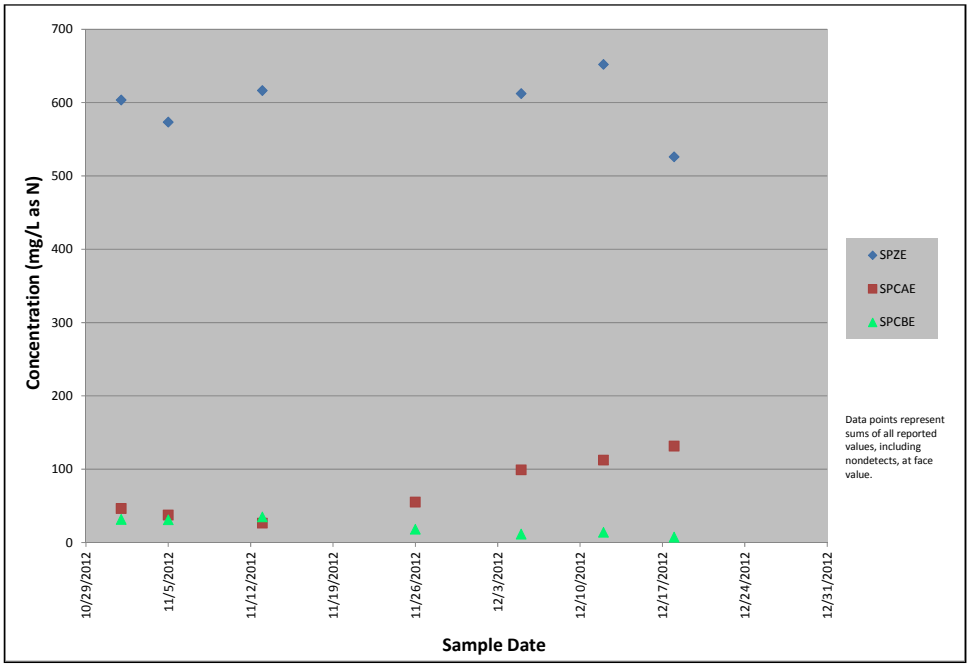
container volumes to identify the scaling factor and applying this to a full-scale pump meant that larger pump would need to be about 100 times larger than the Cell A pump (because the Cell A volume is about 1,000 gallons and that of the original structure, allowing room for plumbing and so on, would be about 100,000 gallons). Such a pump would require so much energy to operate that its installation would likely be infeasible.

The pilot cells were sampled approximately weekly through the balance of the year. Results were extremely positive, as summarized below in Figure 244 and Figure 245. These data clearly show that not only is recirculation unnecessary, but at this scale (this pump in this sized cell) it has an adverse effect on nitrate treatment. Conversely, treatment in passive Cell B started out good and generally improved through the end of the year.



Notes: SPCAE = effluent from Phase III Cell A, which includes recirculation pump; SPCBE = effluent from Phase III Cell B, which is passive; SPZE = effluent from Phase II Cell, which is not treated for nitrate. Nondetects are not shown differently for convenience. All samples were analyzed and data generated by the ESL. Note that SPZE data are shown on secondary axis to allow patterns in SPCAE and SPCBE data to be more readily apparent.

Figure 244. Concentrations of Nitrate, Nitrite, and Ammonia in Effluent From Pilot-Scale Lagoons



Notes: SPZE = effluent from Phase II Cell, which is not treated for nitrate; SPCAE = effluent from Phase III Cell A, which includes recirculation pump; SPCBE = effluent from Phase III Cell B, which is passive. All samples were analyzed and data generated by the ESL.

Figure 245. Sum of Nitrate+Nitrite+Ammonia Concentrations in Effluent from Pilot-Scale Lagoons

Operation of the pilot-scale lagoons continued into 2012 and is scheduled to continue for at least several months into 2013. As illustrated above, particularly on Figure 245, the designed 50-day residence time on which both cells are operating appears to be more than adequate to achieve desired treatment. Tests will be performed to assess whether treatment in Cell A improves if the recirculation pump is turned off, what flow rates can be accommodated and still achieve adequate treatment, and effects of a lower MCG dose. Throughout this process, maintenance needs will continue to be assessed. Other tests may also be identified to support conceptualization and design of a full-scale nitrate treatment lagoon facility.

The SPPTS continues to operate to remove U and nitrate from system influent. As 2012 came to an end, efforts continued focusing on improving ZVI-based microcell design and configuration for uranium treatment, and optimizing lagoon-style nitrate treatment. Efforts summarized in the 2011 Annual Report (DOE 2012f) to better understand the SPPTS and its role in the protection of North Walnut Creek water quality continued through 2012. This work considers applicable 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. Refer to the 2011 report (DOE 2012f) for additional discussion.

Other Plumes

Other groundwater contaminant plumes at Rocky Flats were also monitored during 2012. In accordance with RFLMA, contaminant source areas (as represented by Evaluation wells) were

scheduled for routine monitoring in 2012, as were downgradient contaminant migration pathways (represented by Sentinel and AOC wells).

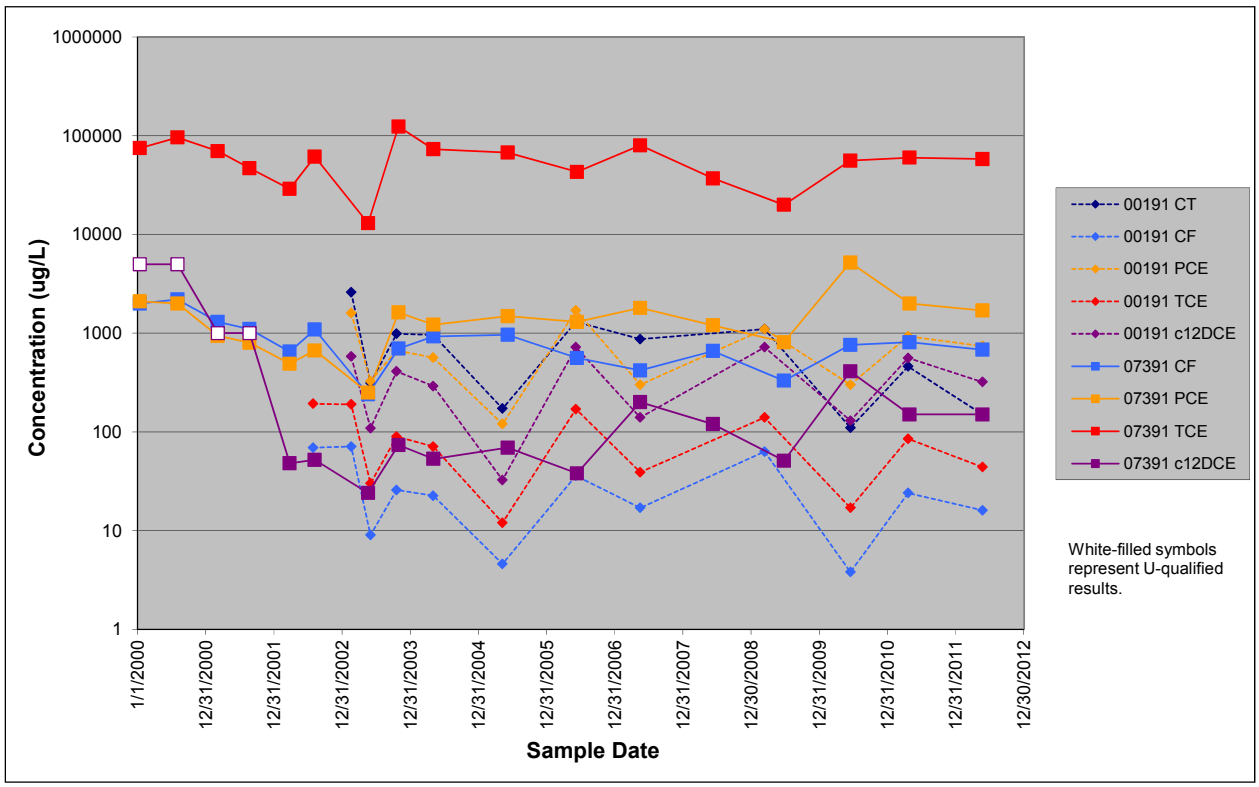
This section presents a summary discussion of data collected in 2012 from wells monitoring several plumes and areas of interest. These include source and/or distal locations for the 903 Pad/Ryan's Pit Plume, the collection of small plumes collectively referred to as the IA Plume, the VC Plume (or OBP#1 Plume) located south of the former B371 complex, the IHSS 118.1 Plume (also called the carbon tetrachloride plume) located between former B776 and B771, 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 Evaluation, Sentinel, and AOC wells monitoring the 903 Pad/Ryan's Pit Plume were sampled in 2012. Each of these wells was sampled in May, and the Sentinel and AOC wells were also sampled in October or November. The analytical results from these samples were generally consistent with previous data. The two source-area 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. The 2012 data continue to confirm the primary 903 Pad contaminants are carbon tetrachloride and PCE, while the main constituent in groundwater from the Ryan's Pit source area is TCE. In fact, 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 246). Chloroform was used in the production era at Rocky Flats (ChemRisk 1992), which explains why it might occur without any carbon tetrachloride at Ryan's Pit.

The concentrations of the constituents illustrated in Figure 246 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, the inverse relationship suggested in the 2011 Annual Report (DOE 2012f) may still be evident: during periods when concentrations of a constituent in the 903 Pad well increase, they tend to show a 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. This weak, apparent relationship is less evident in 2012, possibly due to this being a dry year.

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 increases in daughter products with corresponding decreases 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 246), and in fact a longer-term increasing trend in this constituent is confirmed to be present at the 95 percent level of statistical significance, but this may not be due to enhanced dechlorination as a result of the electron donor application. No other trends of this significance are calculated for this well or for 903 Pad source-area well 00191.



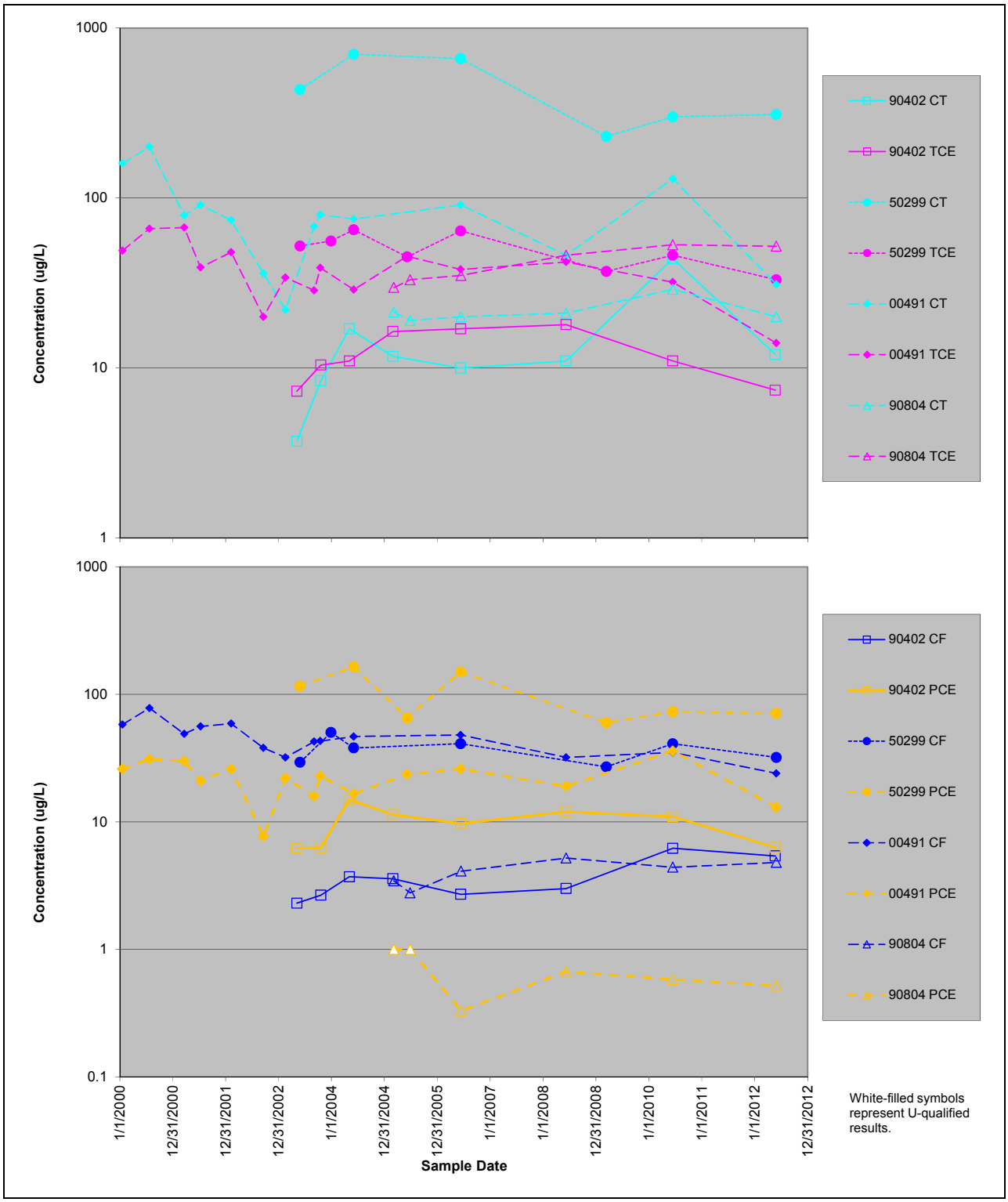
Notes: c12DCE = *cis*-1,2-DCE; CF = chloroform; CT = carbon tetrachloride. Several detections are qualified but for simplicity are not shown differently. Note logarithmic concentration scale.

Figure 246. Primary VOCs in 903 Pad/Ryan's Pit Plume Source Area Wells

Several Evaluation and Sentinel wells monitor this plume at locations farther downgradient from these source areas, on the 903 Hillside (Figure 2). Evaluation wells 90402, 00491, and 50299 are situated along the hillside, and Sentinel wells 90399 and 90299 are near the valley bottom, 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 247 provides time-series plots of several constituents in the Evaluation wells installed along the hillside. Included are the primary contaminants from the 903 Pad and Ryan's Pit source areas (carbon tetrachloride and TCE, respectively) in the top portion of the figure; and chloroform and PCE in the bottom portion. If carbon tetrachloride is a primary marker for 903 Pad contamination and TCE is the marker for Ryan's Pit contamination, then the water quality in wells 50299 and 00491 is most heavily impacted by the 903 Pad source, well 90804 is predominantly affected by Ryan's Pit source, and water in well 90402 reflects a varying mix of these source areas. This is reasonable given the locations of most of these wells with respect to the source areas, though the resulting interpretation for well 90402 is unexpected. Given it is located generally sidegradient of the Ryan's Pit source area and downgradient of the 903 Pad, it might be expected to more closely reflect a 903 Pad source. However, the concentrations of these constituents are very low in samples from well 90402, and it is not likely that the contaminants are as well-mixed this close to the source. The chemical "fingerprint" of contamination from each source area also may not be as clear as would be required to define specific sources at such a low range of concentrations. Finally, a paleoridge has been identified between the 903 Pad

source area and this well (EG&G 1995b) that would act to limit contaminant transport from the Pad to this well (and also explains why, despite the well's proximity to the Pad, VOC concentrations are so low).



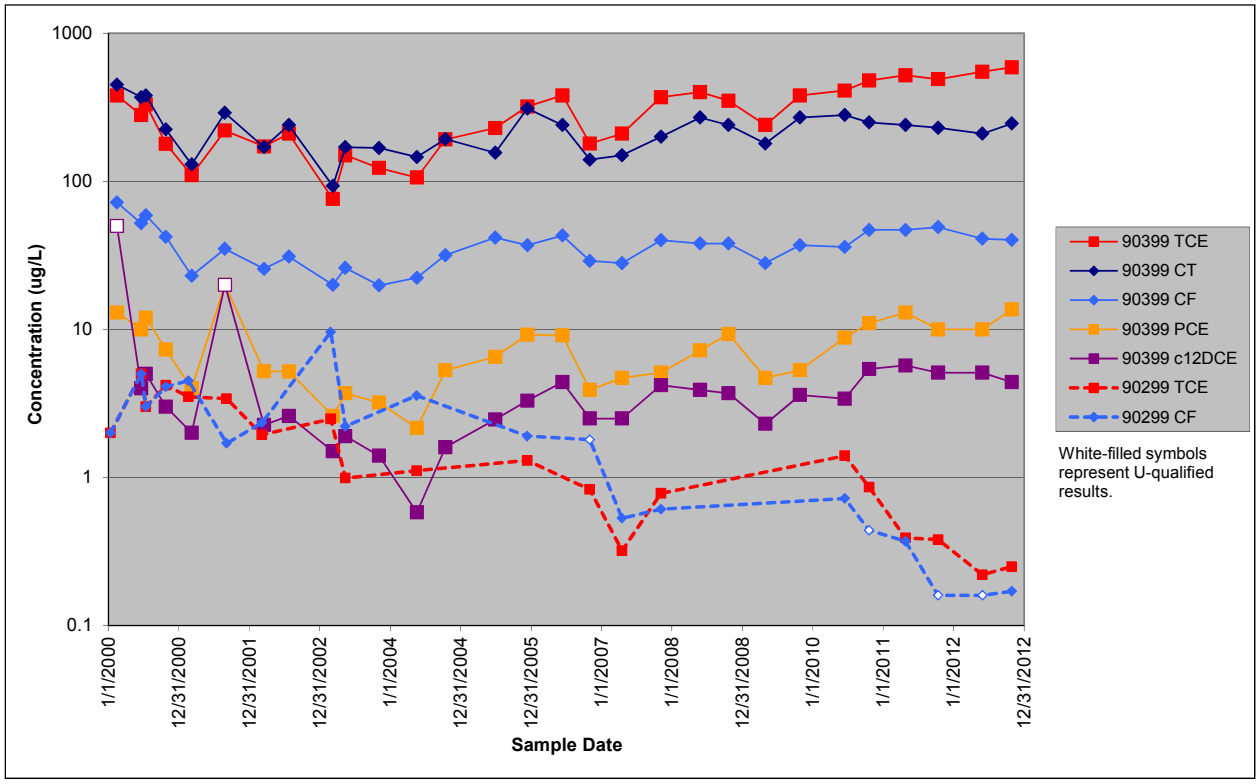
Notes: CT = carbon tetrachloride; CF = chloroform. Several detections are qualified but for simplicity are not shown differently. Note logarithmic concentration scale.

Figure 247. Primary VOCs in 903 Pad/Ryan's Pit Plume Hillside Wells

Concentrations of chloroform in samples from well 00491 support a decreasing trend calculated to have a 95 percent level of statistical confidence (Table 90, Appendix B). Of these 903 Pad Hillside wells, no other trends are calculated to have this level of significance.

Conditions reported in past years at the Sentinel wells adjacent to the SID were again confirmed with 2012 data. Well 90399 continues to report concentrations of contaminants that exceed those of some wells nearer the source areas, while 90299—which again produced samples in 2012—reported much lower concentrations. Figure 248 illustrates concentrations of several VOCs detected in these Sentinel wells. The gaps between data points for well 90299 (such as from late 2007 to mid-2010) represent dry periods when samples could not be collected. The concentrations of TCE reported in samples from well 90399 are second in this area only to those reported at source-area well 07391, concentrations of carbon tetrachloride are higher than in the 903 Pad source area well 00191, and concentrations of chloroform are in the same range as source-area well 07391. The concentrations of TCE and carbon tetrachloride at well 90399 were present through the early 2000s in fairly equivalent concentrations, but in the last several years have diverged. Concentrations of TCE are now significantly higher than those of carbon tetrachloride (Figure 248) and appear to be increasing, while those of carbon tetrachloride are relatively flat. VOCs reported at nearby well 90299 are much lower, with only TCE and chloroform detected relatively consistently.

Several constituents are calculated to have trends of 95 percent statistical significance at wells 90399 and 90299. 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 at 90299 may not be valid, given the numerous nondetects in the data set.) Some of these trends are visually evident (e.g., TCE at 90399, TCE and chloroform at 90299) on Figure 248. 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 248. Primary VOCs in Downgradient 903 Pad/Ryan's Pit Plume Wells

A roughly 30-month cycle in PCE and *cis*-1,2-DCE concentrations at well 90399 was discussed in 2011 (DOE 2012f), wherein concentrations gradually increase and then drop, only to resume an increase. (This is especially evident on Figure 248 in concentrations of PCE at this well dating back to 2004.) No mechanism for such a pattern is evident, and the 2012 data would fall within such a cycle, rather than define it. 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 2012 per the RFLMA. TCE was detected at an estimated (J-qualified) concentration of 0.29 µg/L in the sample collected in May 2012. This constituent has also been reported in samples collected in 2007 and 2010, all at estimated concentrations below 1 µg/L. Concentrations of nitrate in the samples collected in 2012 were both well below 0.1 mg/L. Concentrations of U were 11 µg/L in the May sample and 16 µg/L in the October sample.

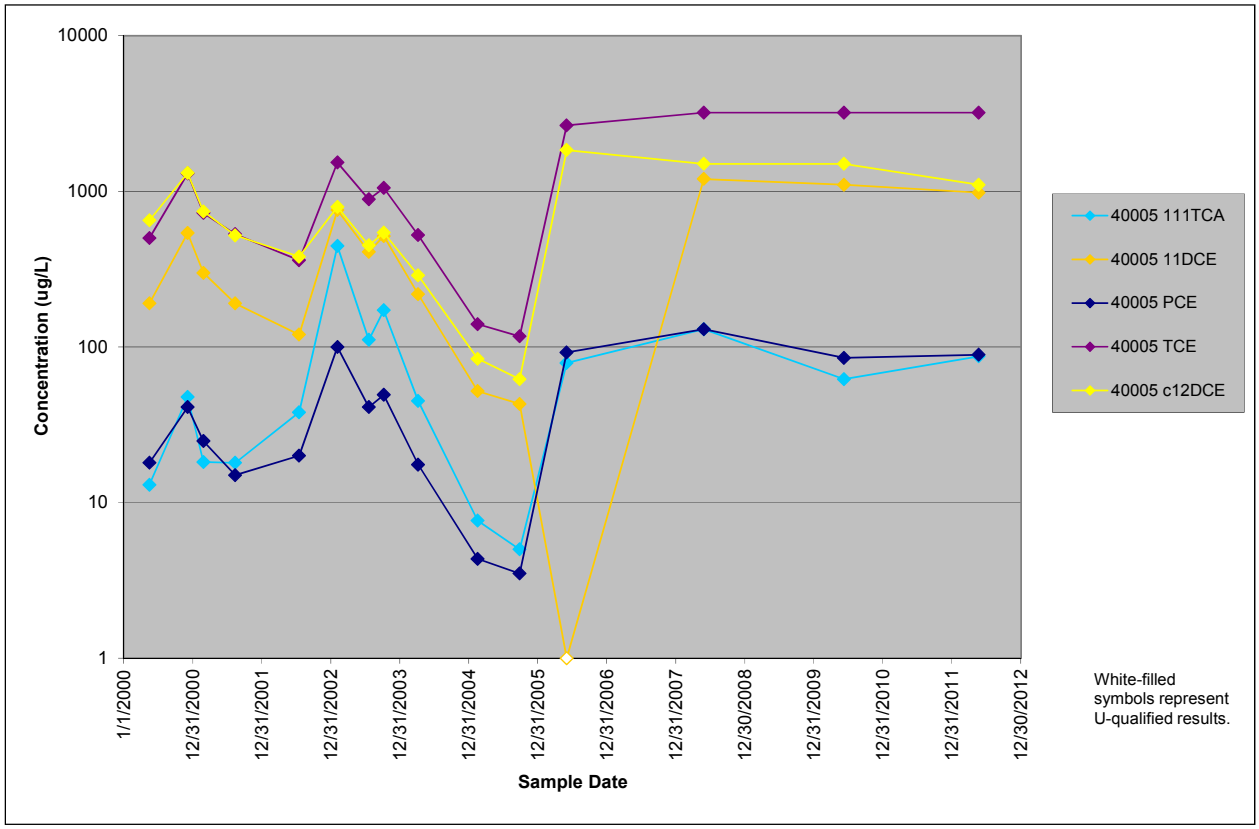
AOC well 00193, located at the mouth of Pond C-2, also supports the monitoring of the 903 Pad/Ryan's Pit Plume. This well was also sampled in May and October 2012. VOCs were not detected in either sample. Concentrations of U were reported at 74 µg/L and 73.9 µg/L, respectively. This is consistent with 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. In accordance with RFLMA, Evaluation wells were scheduled for sampling once in 2012, while the AOC and Sentinel wells were sampled twice.

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 November 2012. No confirmed VOC detections were reported in 2012. 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 2012 were 32 µg/L and 26 µg/L, respectively. These are well within the historic range at this location.

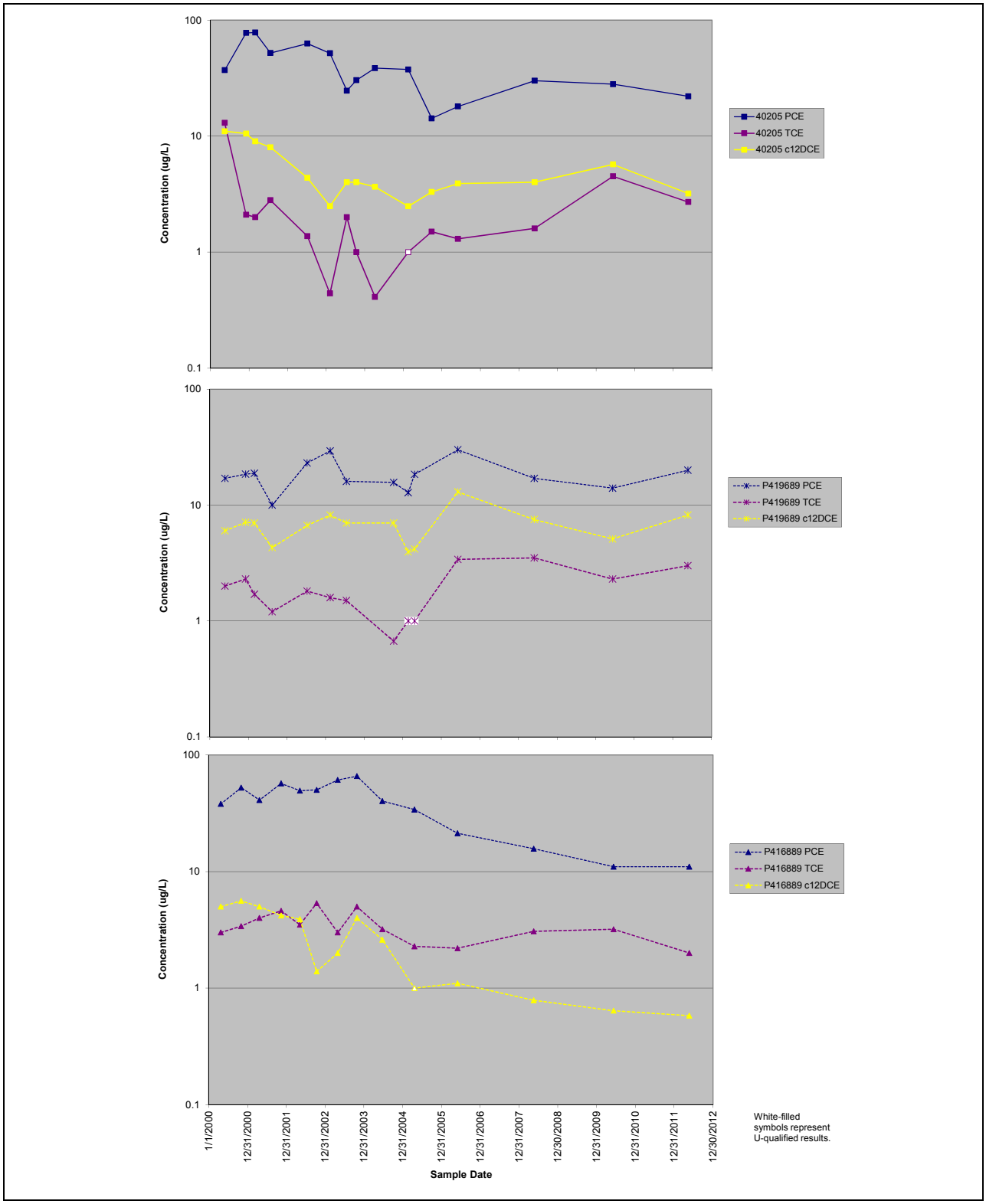
Upgradient of AOC well 11104, wells monitoring the south IA Plume include Evaluation wells 40005, 40205, P419689, and P416889, and Sentinel wells 11502 and 40305. Analytical results from these wells are consistent with past data. As in previous years, concentrations of VOCs are highest at Evaluation well 40005, located between former B444 on the east and B460 on the west. Historic aspects of the area monitored by this well have been previously described (see discussion on the original well, 40099, in Safe Sites 2002) and may explain the presence of these constituents. As illustrated in Figure 249, concentrations of TCE at this location have been reported at 3,200 µg/L in every sample collected since 2008, and exceed those of PCE by over an order of magnitude (89 µg/L in the May 2012 sample).



Notes: Applicable RFLMA surface-water action level (µg/L; CDPHE et al. 2012) for 1,1,1-TCA is 200, PCE is 1, TCE is 2.5, *cis*-1,2-DCE is 70, and 1,1-DCE is 7. Several detections were qualified but for simplicity are not shown differently. Note logarithmic concentration scale.

Figure 249. Concentrations of VOCs in South IA Plume Evaluation Well 40005

While VOCs are also detected in other wells monitoring the south IA Plume, concentrations are far lower than at well 40005. In addition, the contaminant distributions differ at these other locations: though they are similar to one another they do not show the same pattern as 40005. The nearest of these wells, approximately 250 feet southeast of well 40005, is Evaluation well 40205; it is immediately south of former B444. At this location, concentrations of PCE are highest among the VOCs detected, but have not exceeded 30 µg/L since early 2005; others (such as TCE, *cis*-1,2-DCE, 1,1-DCE, and chloroform) are also typically detected but at concentrations below 10 µg/L (Figure 250, top portion). Water quality at next-nearest well P419689, located farther south of former B444, is very similar to that in well 40205 (Figure 250, middle portion). Just as in well 40005, levels of *cis*-1,2-DCE in samples from wells 40205 and P419689 are intermediate between those of PCE and TCE, but at 40005 TCE is highest while in the other wells PCE is highest. Samples from well P416889 (Figure 250, bottom portion), which is located at the southern edge of this pediment, reflect decreasing concentrations of *cis*-1,2-DCE that for the past few years have been below those of both PCE and TCE. Perhaps most notable with respect to all four of these Evaluation wells is the fact that contaminant concentrations generally vary fairly consistently within each well, the most notable exception being the *cis*-1,2-DCE in well P416889 that is no longer intermediate between concentrations of PCE and TCE.



Notes: Data for Evaluation wells 40205 (top), P419689 (middle), P416889 (bottom). Applicable RFLMA surface-water action level (µg/L; CDPHE et al. 2012) for 1,1,1-TCA is 200, PCE is 1, TCE is 2.5, *cis*-1,2-DCE is 70, and 1,1-DCE is 7. Several detections were qualified but for simplicity are not shown differently. Note logarithmic concentration scale.

Figure 250. Concentrations of VOCs in South IA Plume Evaluation Wells

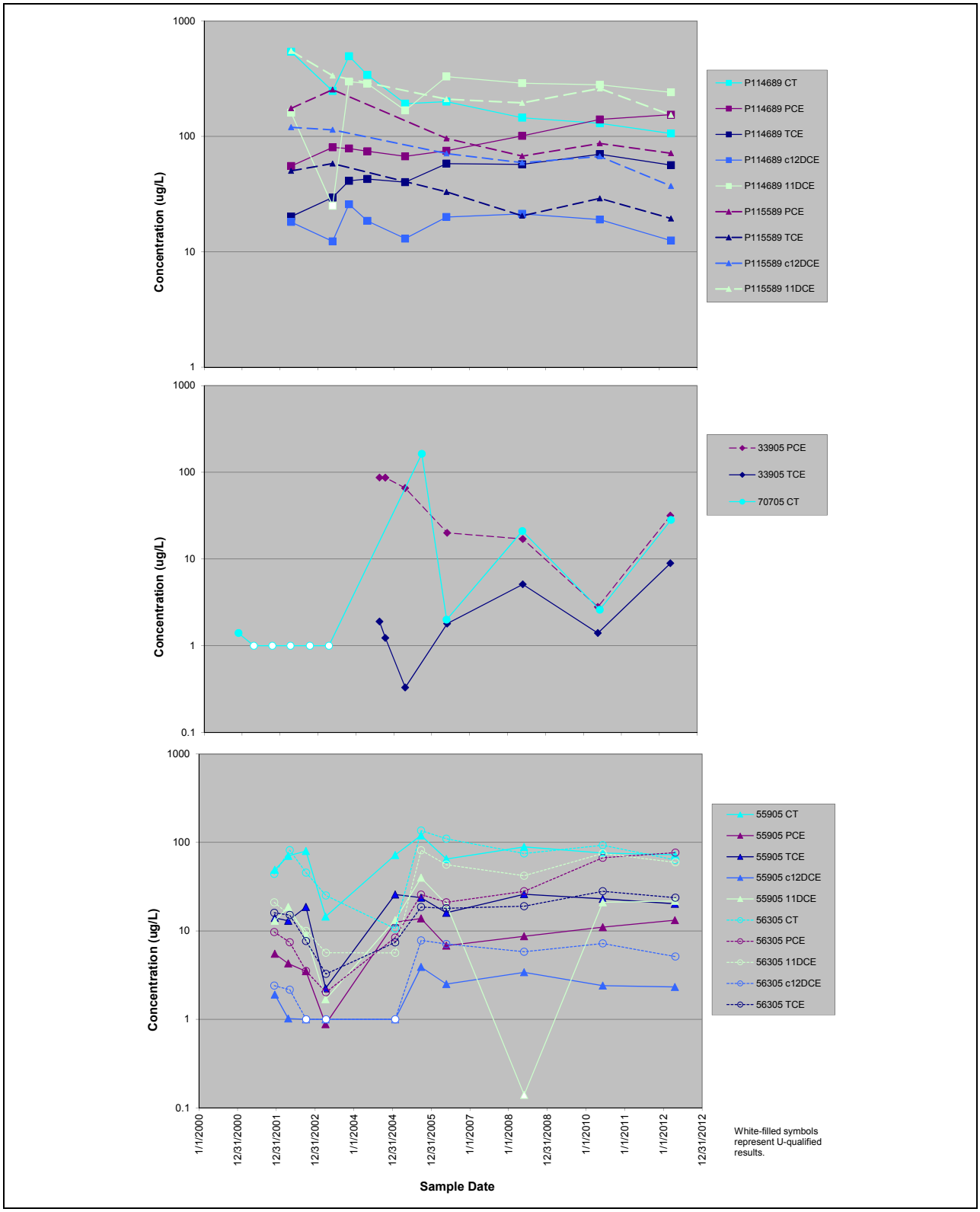
Calculated statistical trends having a 95 percent level of statistical significance at these Evaluation wells include decreasing concentrations of 1,1-DCE, *cis*-1,2-DCE, and PCE at well 40205 and *cis*-1,2-DCE at well P416889. No trends of this significance are calculated for wells 40005 or P419689.

Data from Sentinel wells in this area, including 40305 immediately east of former B444 and 11502 near the southern pediment edge and well P416889, include consistent detections of PCE. *cis*-1,2-DCE is also frequently detected in well 40305, but no other VOCs are consistently detected at either location. Neither of these wells supports any trends having a 95 percent level of confidence.

Sentinel wells 40305 and 11502 are also monitored for uranium. The highest concentration from either well reported in 2012 was 1.3 µg/L (well 11502, November sample).

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. Each of these wells was scheduled for sampling in 2012. Time-series plots of selected constituents at these wells are provided below in Figure 251. Although other constituents are detected in some of these wells, the VOCs displayed represent those most commonly detected at elevated concentrations.

The upper portion of Figure 251 shows several constituents detected in wells P114689 and P115589, which are the southernmost of these central IA Plume Evaluation wells. Patterns that are visually apparent are not all validated by the statistical trend calculations: only decreasing carbon tetrachloride and increasing TCE in well P114689 are identified as 95 percent significant. This is most likely due to the relatively few data points representing these constituents in each well; with a bit more data, other trends—such as increasing PCE in this well, for example—should be confirmed at this level of statistical significance. While the concentrations of VOCs in samples from well P114689 do not increase or decrease together, the relationships among VOCs at well P115589 are more consistent.



Notes: Data for Evaluation wells P114689 and P115589 (top), 33905 and 70705 (middle), and 55905 and 56305 (bottom). Applicable RFLMA surface-water action level (µg/L; CDPHE et al. 2012) for CT is 1, PCE is 1, TCE is 2.5, *cis*-1,2-DCE is 70, and 1,1-DCE is 7. Several detections were qualified but for simplicity are not shown differently. Note logarithmic concentration scale.

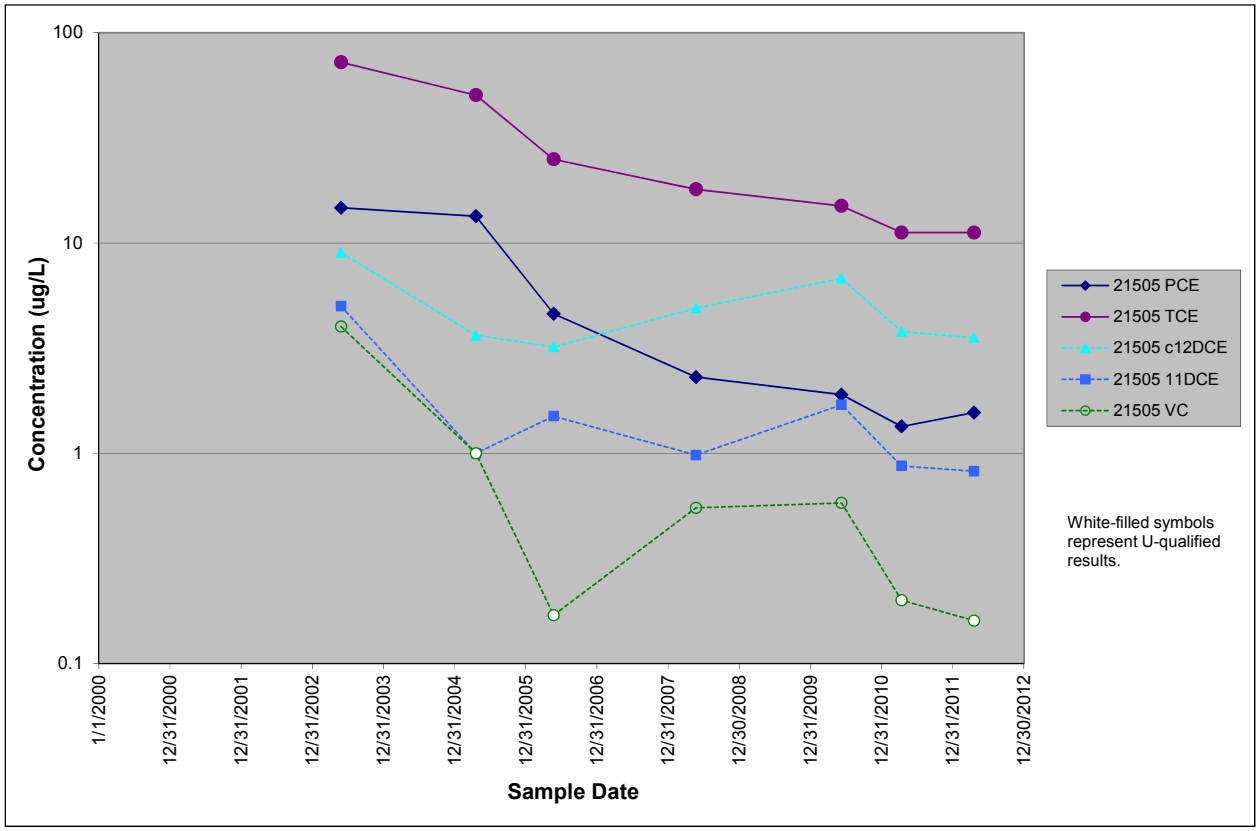
Figure 251. Concentrations of VOCs in Central IA Plume Evaluation Wells

The central portion of Figure 251 illustrates the primary contaminants in samples from wells 33905 and 70705. The former of these wells is located on the northern edge of the IA pediment, just south of FC-2 and almost due north of well P115589, discussed above. In contrast, well 70705 is located immediately adjacent to the eastern edge of former B707. Despite the almost 1,500 feet of geographic separation, the different constituents illustrated show a very close apparent correlation beginning in 2008. This is unlikely to be anything other than coincidence. Carbon tetrachloride, the primary constituent in samples from well 70705, has not been detected in samples from well 33905. PCE and TCE, the primary VOCs in well 33905, have been detected at low concentrations (no higher than 2.6 µg/L) at well 70705 since 2005, when carbon tetrachloride was first detected. The PCE and TCE at 70705 follow a similar, alternating increasing-decreasing concentration pattern to that illustrated for carbon tetrachloride, but at concentrations that are one to two orders of magnitude lower. No trends are identified for well 33905 that have a 95 percent level of significance, but at well 70705 chloroform is calculated to be increasing (Table 90). This is not illustrated on Figure 251, but the associated trend plot is included in Appendix B. This trend may not be viable due to the numerous nondetects in the data set.

The lower portion of Figure 251 illustrates the primary VOCs reported in samples from wells 55905 and 56305, both of which monitor former B559. With the exception of the anomalous nondetect for 1,1-DCE reported at well 55905 in 2008, the illustrated data vary relatively uniformly. Some differences are apparent, however. For example, in both wells the concentrations of PCE are diverging from those of TCE and *cis*-1,2-DCE, with PCE increasing since closure while the other two are relatively unchanging. Only an increasing trend in PCE at well 56305 is calculated to reach the 95 percent level of statistical confidence; no such trends are calculated for well 55905.

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 2012 in accordance with RFLMA. 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 2012. Results continue to support some of the patterns suggested by previous data, as illustrated on Figure 252. Concentrations of PCE and TCE continue to support decreasing trends with a significance of 95 percent, though both remain above the associated RFLMA Table 1 values. 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 (K-H 2004d): well 33502, which monitors the Vinyl Chloride Plume within a buried drainage, and the predecessor to well 52505 (former well 1986). Data from well 21505 continue to suggest conditions at this location may also be conducive to biodegradation of chlorinated compounds, though the concentrations of primary contaminants (in this case, PCE and TCE) did not continue decreasing in 2012 (Figure 252), nor did their metabolic byproducts continue to increase. The dry conditions in 2012 may have adversely affected the naturally-present dechlorinating bacteria, perhaps via falling water levels leaving a portion of the population in the newly unsaturated soils and therefore ineffective. Additional data should help to refine concentration trends.



Notes: Applicable RFLMA surface-water action level for PCE (µg/L; CDPHE et al. 2012) 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 2012 (April and October).

As in many previous years, Sentinel well 52505 reported low, J-qualified (estimated) detections of *cis*-1,2-DCE in both samples (1.79 µg/L, 1.54 µg/L, respectively; RFLMA Table 1 value is 70 µg/L). As noted in the 2010 and 2011 Annual Reports (DOE 2011d, 2012f), 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 90). No other trends were calculated at this well.

No VOCs were detected in either sample collected from AOC well 42505. Two VOCs were detected in samples from Surface Water Support location SW018. Both results were estimated (J-qualified): in April, *cis*-1,2-DCE was reported at an estimated concentration of 0.19 µg/L, and in October, styrene was reported at an estimated concentration of 0.32 µg/L. (The RFLMA Table 1 values for these constituents are 70 µg/L and 100 µg/L, respectively.) This is not atypical: with the exception of 2008, *cis*-1,2-DCE has been detected at this location every year since the Site closed, and styrene has been detected once before (in 2008).

VC Plume

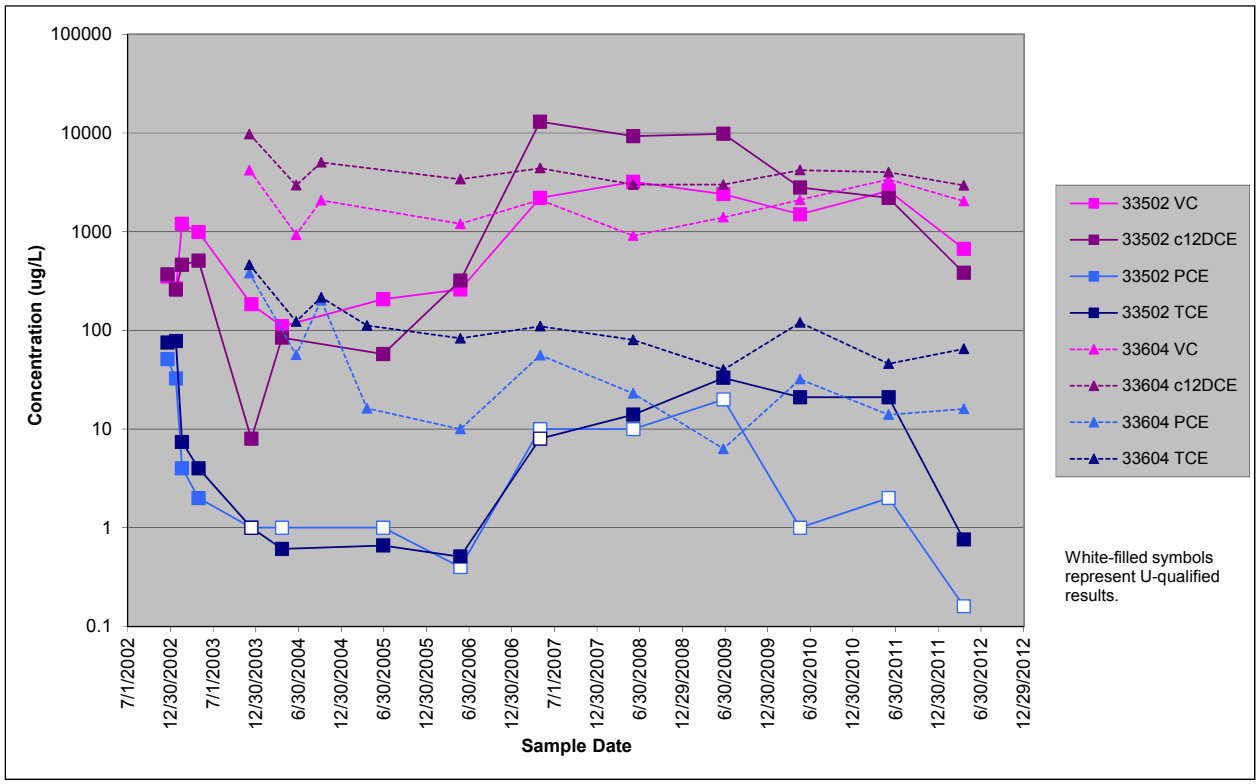
The VC Plume emanates from OBP#1 and nearby metal disposal/destruction sites. These source areas were on the margin of a valley that was filled during construction of the B371 complex and became the site of Sage Avenue and the Portal 2 parking lots, among other facilities. The contaminated groundwater plume is present 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. This is also the only area where chlorobenzenes are detected at elevated levels, as discussed below.

The VC Plume is monitored by two source-area Evaluation wells and one Sentinel well. Each of these wells was sampled in 2012. Evaluation well 33502 is located in the immediate vicinity of OBP#1. Approximately 175 feet generally downgradient is Evaluation well 33604, and Sentinel well 33711 is about 110 feet downgradient of 33604. This Sentinel well developed a kink in its casing and was replaced in 2011; see the 2011 Annual Report (DOE 2012f) for additional information, including a discussion of water quality changes potentially affected by well replacement.

Well 33502 is one of only two locations where strong evidence for biodegradation has been found at the Site (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, and very likely 33711 as well.) 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 2012). Similarly, Sentinel well 33711 reports concentrations of these daughter products at tens to hundreds of µg/L, but PCE is rarely detected and TCE is typically either not detected or is reported at concentrations of less than 1 µg/L.

A time-series plot of the concentrations of primary parent and daughter compounds in source-area wells 33502 and 33604 is presented as Figure 253. Samples from well 33502 show a sharp decrease in daughter-product concentrations over the past 1 to 3 years. *cis*-1,2-DCE decreased steadily from 2009 through 2012, dropping from a relatively uniform concentration of about 10,000 µg/L in 2007–2009 to under 400 in 2012. VC concentrations were relatively stable through most of this period, on the order of 2,000 µg/L, until dropping to 670 µg/L in 2012. TCE concentrations in samples from well 33502 were also relatively higher from 2008 through 2011, generally around 20–30 µg/L until dropping to less than 1 µg/L in 2012. PCE at this well is no

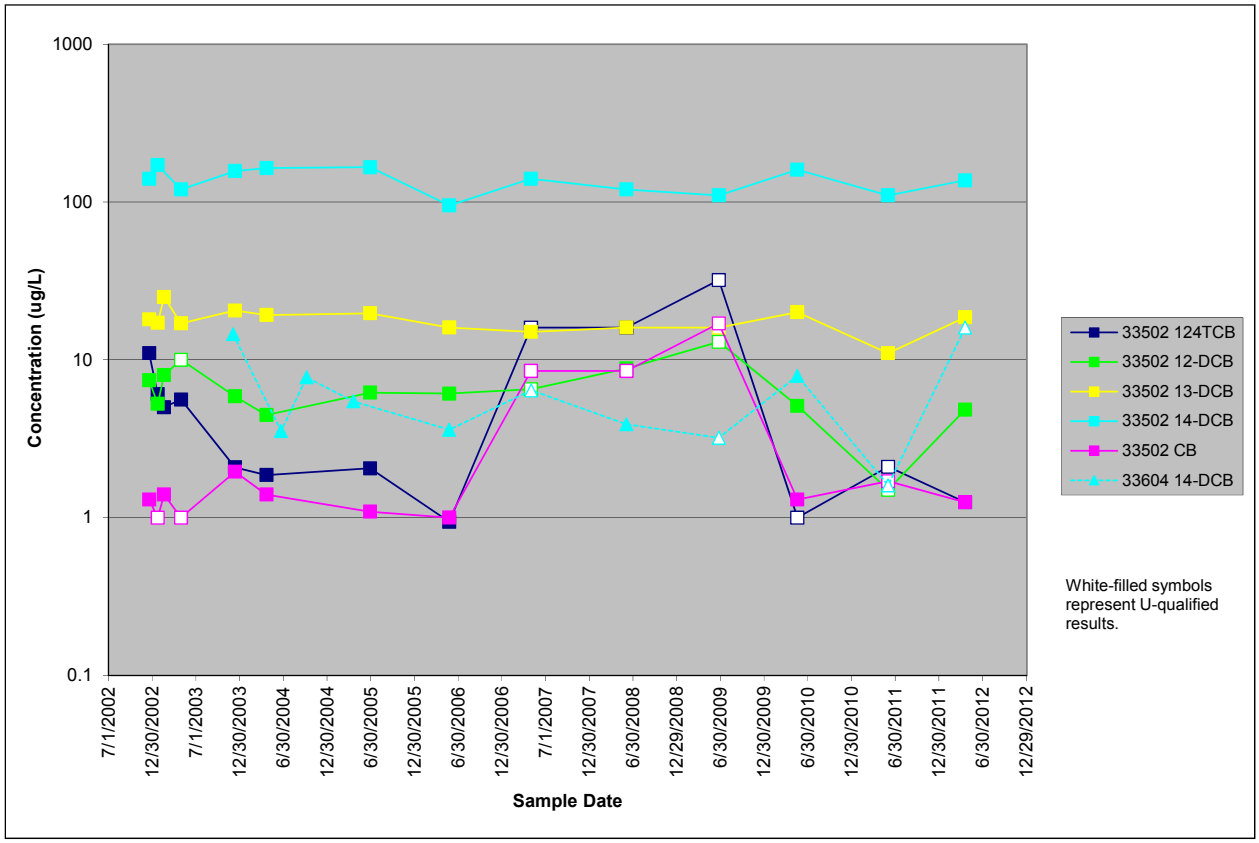
longer detected, but is included on Figure 253 for completeness. In contrast, contaminant concentrations illustrated for nearby well 33604 are much more consistent. The concentrations of daughter products also show a decrease at this location in 2012, but it is much smaller in magnitude than at 33502 and is within the range of typical variability (Figure 253).



Notes: VC = vinyl chloride; c12DCE = *cis*-1,2-DCE. Applicable RFLMA surface water action levels for these constituents (µg/L; CDPHE et al. 2012): 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 Evaluation Wells

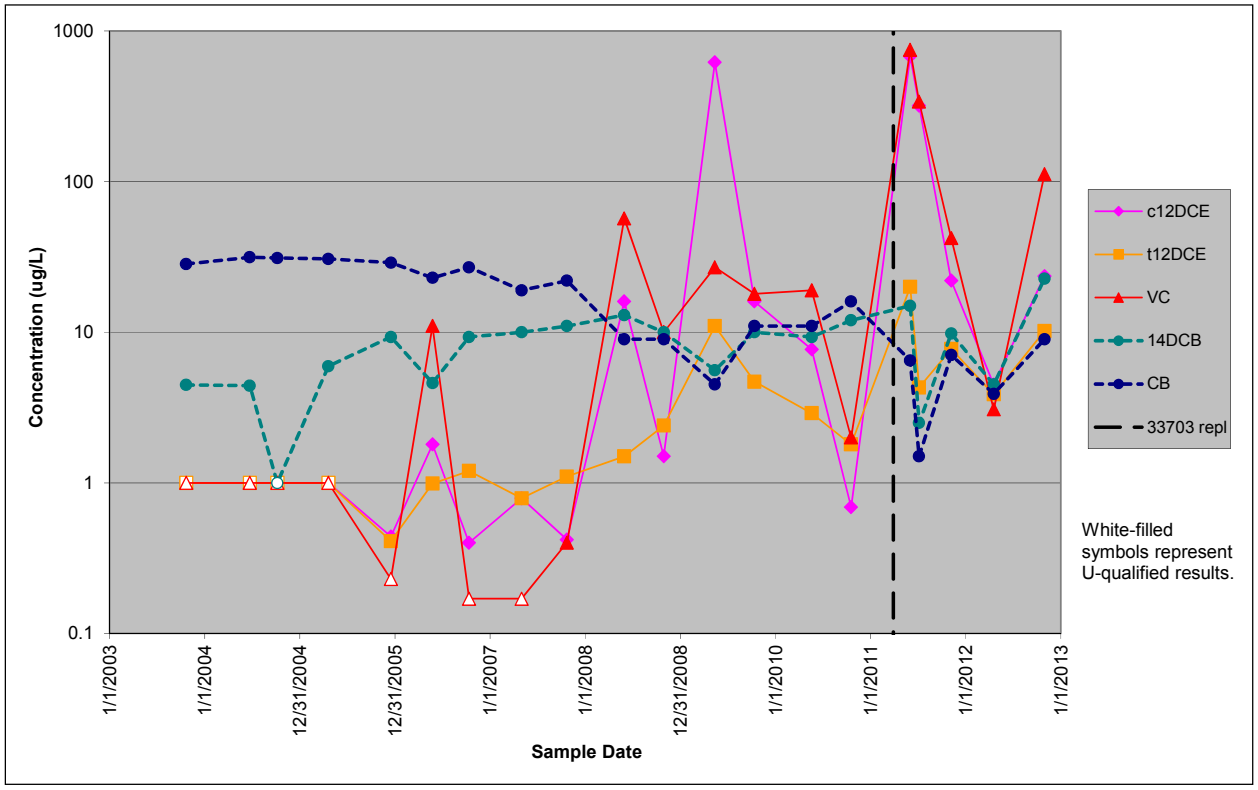
Concentrations of several chlorinated benzenes are also detected in samples from VC Plume wells. These most commonly include one or more of the following: 1,2,4-trichlorobenzene (TCB), 1,2-DCB, 1,3-DCB, 1,4-DCB, and chlorobenzene. These compounds are industrial and agricultural chemicals; primary uses for several are as pesticides or insecticides. 1,2,4-TCB 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 explain its rare detection and may also be a factor in the presence of 1,2-DCB, 1,4-DCB, and (occasionally) chlorobenzene in samples from well 33502 (Figure 254). Well 33604 has not reported any detections of chlorinated benzenes since 2010, when 1,4-DCB and 1,3-DCB were last detected. Other chlorinated benzenes have not been detected at this location in several years.



Notes: Applicable RFLMA surface-water action levels for these constituents (µg/L; CDPHE et al. 2012): 1,2,4 TCB (trichlorobenzene) 35; 1,2-DCB 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 Evaluation Wells

Several chlorinated solvents and chlorinated benzenes have been detected in Sentinel well 33711. As discussed in the 2011 Annual Report (DOE 2012f), this well was replaced and when it finally produced sufficient water for sampling, the concentration of vinyl chloride in particular was unusually elevated. Data collected since then suggest those early results were in response to seasonal effects that have been increasingly evident at this location (Figure 255), and were not anomalous. The 2012 data continue to suggest a seasonal effect, though earlier years produced higher concentrations of *cis*-1,2-DCE and VC in the second quarter, while this was reversed in 2012. As suggested above, this may relate to the dry conditions prevalent in 2012.



Notes: Applicable RFLMA surface-water action levels for these constituents (µg/L; CDPHE et al. 2012): cis-1,2-DCE 70; *trans*-1,2-DCE 100; vinyl chloride 0.2; 1,2,4 TCB (trichlorobenzene) 35; 1,2-DCB 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 255. Chlorinated Compounds in Samples from VC Plume Sentinel Well 33711

1,4-DCB and chlorobenzene are also typically detected at well 33711. Both are illustrated as time-series plots on Figure 255. These constituents have maintained relatively uniform concentrations compared to *cis*-1,2-DCE, vinyl chloride, and to a lesser extent *trans*-1,2-DCE. Prior to 2008, concentrations of chlorobenzene exceeded those of 1,4-DCB. That year, the slow decrease in chlorobenzene and a corresponding increase in 1,4-DCB resulted in the two compounds being present in fairly similar concentrations; this has been the case since then, though concentrations have varied more widely from sample to sample (though still much less than *cis*-1,2-DCE and VC) since the well was replaced. The fourth-quarter 2012 data may indicate a continuing increase in 1,4-DCB while chlorobenzene remains fairly steady. More data will help to confirm long-term trends.

Calculated trends having a 95 percent level of confidence are identified for several constituents in wells monitoring the Vinyl Chloride Plume. Decreasing trends are calculated (Appendix B; Table 90) at the 95 percent level of significance for PCE at well 33502, and PCE and TCE at well 33604. While this trend at well 33502 is based on a dataset that contains numerous nondetects, the fact that PCE has not been detected here in several years (Figure 253) suggests this is either a valid trend or a moot point. A decreasing trend in 1,2,4-TCB is also calculated at well 33502, but again many of the results in the data set are nondetects. At downgradient Sentinel well 33711, the only decreasing trend calculated at this level of significance is for chlorobenzene, while increasing trends are calculated for 1,4-DCB, *cis*-1,2-DCE, toluene,

trans-1,2-DCE, and VC. Some of these are potentially affected by well replacement or nondetects (Table 90; Appendix B).

IHSS 118.1 (Carbon Tetrachloride) Plume

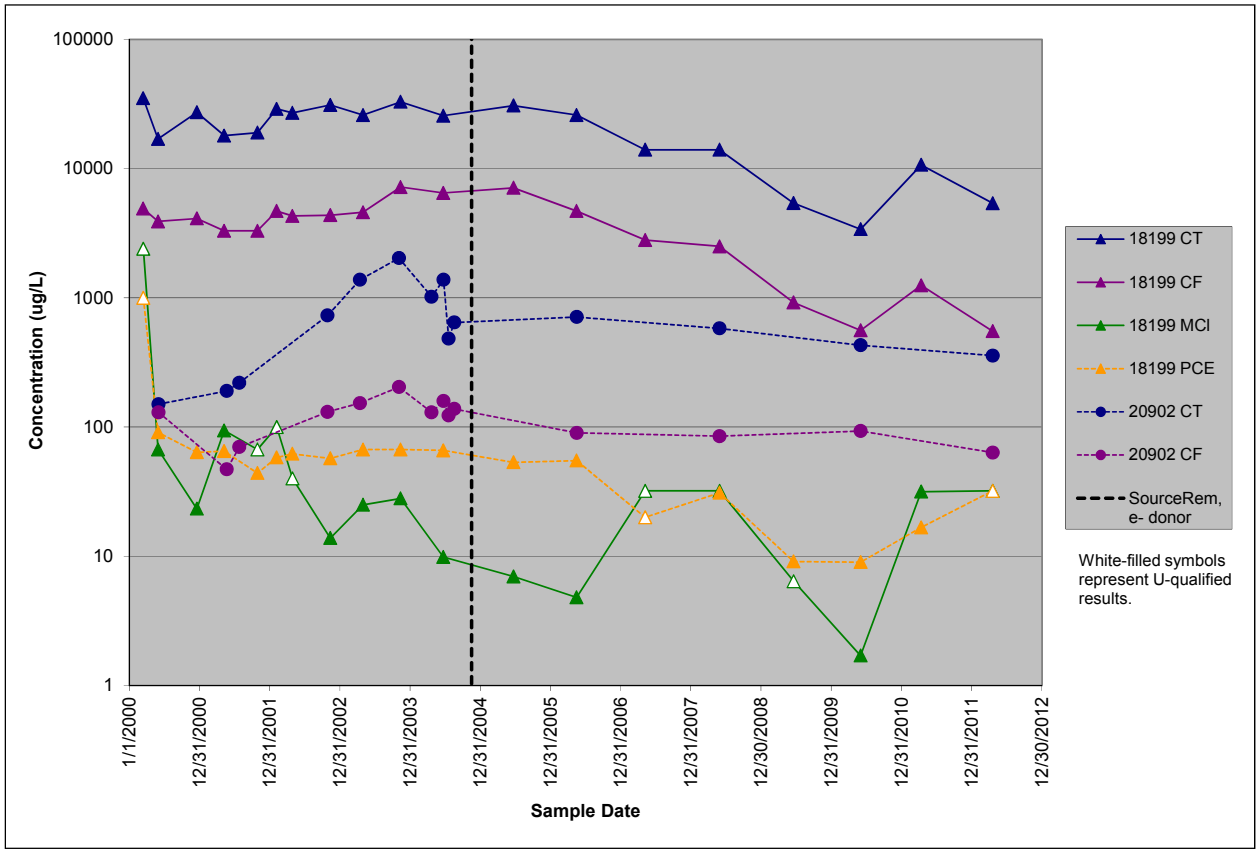
Former IHSS 118.1 is the source of a plume of groundwater contaminated with carbon tetrachloride. In late 2004, dense, nonaqueous phase liquid source material was removed along with an adjacent subsurface tank group referred to as B730. Electron donor material was added to the backfill material to enhance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

Both Evaluation wells were scheduled for routine RFLMA monitoring in 2012, as were the three Sentinel wells generally north of the source area, along the northern side of former B771. These Sentinel wells 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 except to summarize that neither produced samples suggesting impacts from former IHSS 118.1.

The interruption in 2011 of steadily decreasing concentrations of contaminants was reversed with the data from 2012 (Figure 256). The concentrations of carbon tetrachloride and its primary daughter product, chloroform, dropped back down after the increase in 2011. Both methylene chloride and PCE were reported as nondetects, but the detection limits were elevated so no conclusions can be drawn. Decreasing trends in carbon tetrachloride and PCE are calculated at the 95 percent level of significance (Table 90 and Appendix B) at well 18199. 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 CO_2, 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; this was also the case with the sample collected in 2012, though the detection limits were elevated. The decreasing trends observed are therefore thought to be due to removal of the source material, rather than metabolic dechlorination of residual contamination.

Concentrations of carbon tetrachloride and chloroform in samples from well 20902 were consistent with previous results, continuing to show a slow decline (Figure 256). No trends were calculated to have a 95 percent level of significance at this well.



Notes: CT = carbon tetrachloride; CF = chloroform; MCl = 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 (µg/L; CDPHE et al. 2012): CT, 1; CF, 3.4; MCl, 4.6; PCE, 1. Several results were qualified but are not shown differently for simplicity. Note logarithmic concentration scale.

Figure 256. Concentrations of VOCs in the IHSS 118.1 Plume

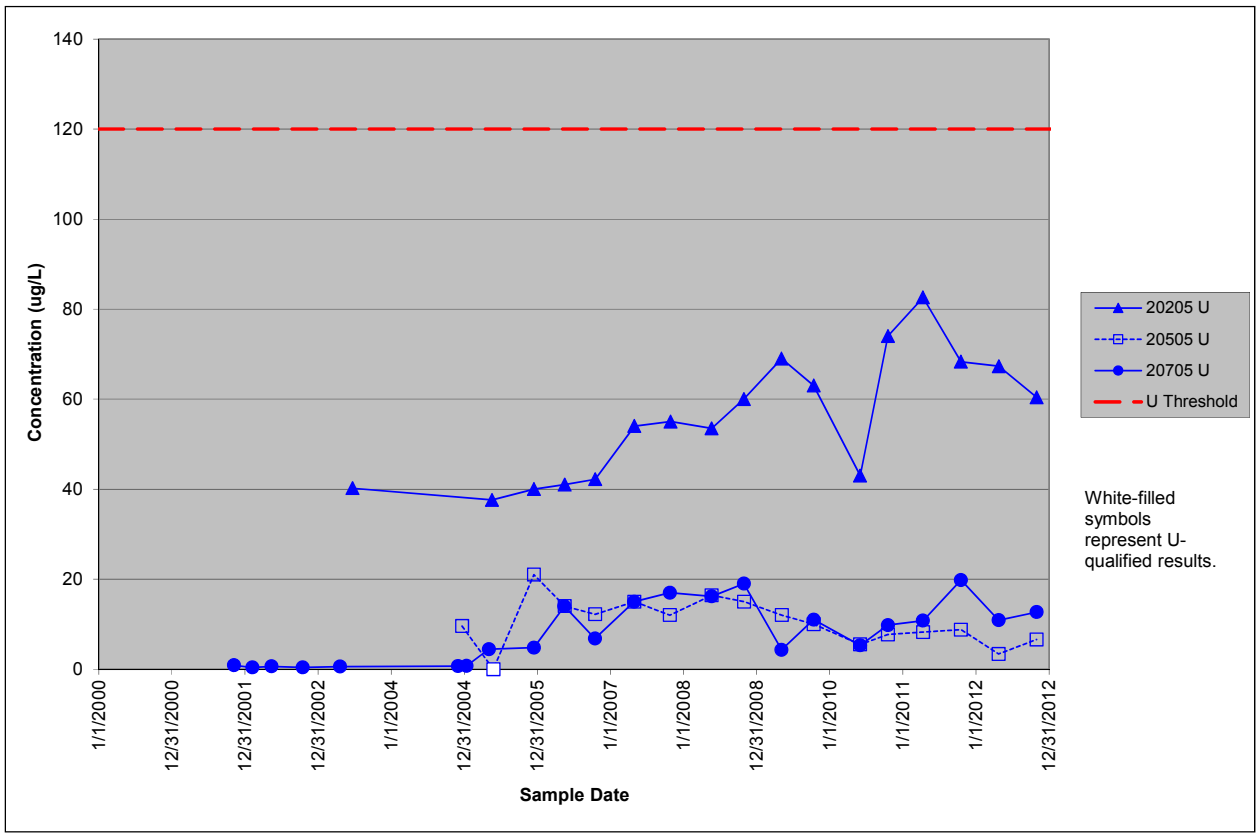
Sentinel wells 20705, 20505, and 20205, all of which are located generally north of IHSS 118.1 and the former B771 complex, are monitored to evaluate the effects on groundwater of the closure of B771 and to determine whether a more northerly groundwater flow path from the IHSS 118.1 source area is indicated. As in previous years, such a path is not suggested by analytical data collected in 2012, which are consistent with pre-closure results. Carbon tetrachloride was not detected in any of these wells, and chloroform was only detected once in 2012. This detection was reported at an estimated (J-qualified) concentration of 1.11 µg/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.

AOC well 42505, which is located north/northwest of former B771 and adjacent to the eastern edge of FC-2 near its confluence with FC-3, reported no detections of VOCs in either of the samples collected in 2012. These 2011 results do not suggest a strong northerly flow component to the IHSS 118.1 Plume.

Seepage velocities summarized in Table 49 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 2012 water level data are again slightly more than one year. (As previously explained, this estimated velocity applies to pure water, not contamination.) Based on the analytical data collected through 2012, 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 in previous years (see DOE 2011d and 2012f) suggest that has been completed. Wells monitoring former IHSS 118.1 will continue to be monitored and the data assessed to evaluate the potential for contaminant migration from that source area as well as the IA Plume and former B771.

Several trends were calculated for the three Sentinel wells monitoring B771 (Ta ble 90; 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 at the latter well; and decreasing at 20505), *cis*-1,2-DCE (decreasing at well 20505, increasing at 20705), 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 257. 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.



Notes: U = uranium. Applicable RFLMA value (µg/L; CDPHE et al. 2012) is the uranium threshold, 120 µg/L. Several results were qualified but are not shown differently for simplicity.

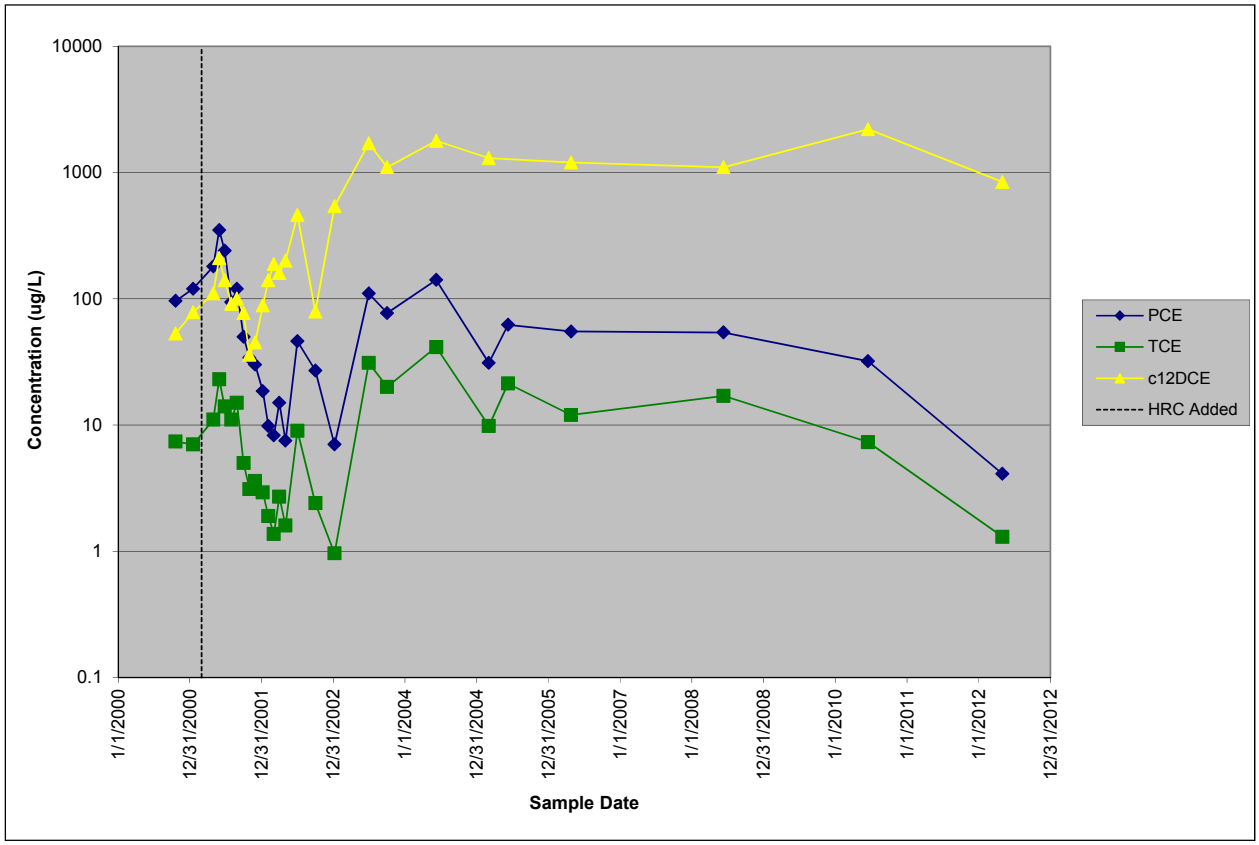
Figure 257. U in Groundwater Along North Side of Former B771

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 north edge 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 sampled in 2012, as was each of the other wells.

Source-area Evaluation well 30900 was sampled in May of 2012. Analytical results for *cis*-1,2-DCE, the primary daughter product from the partial dechlorination of PCE and TCE, were consistent with previous data. However, concentrations of PCE and TCE were substantially lower than in previous samples dating back to approximately the beginning of 2003. As mentioned above with respect to other plumes, the dry year in 2012 may have affected reported concentrations; given that 2002 was a drought year and 2012 was also dry, the similarity in water quality at well 30900 during these years—at least, with respect to these parent compounds—may relate to those environmental conditions. Increased biodegradation of PCE and TCE may also be a factor: with one exception no other VOCs were detected in the sample collected in 2012 other than *cis*-1,2-DCE, PCE, and TCE. That exception was VC, the final chlorinated compound in the dechlorination pathway of PCE and TCE. This constituent was last detected in 2001 at a concentration of 0.21 µg/L but in 2012 was reported at a concentration of 360 µg/L. Additional sample data will need to be compiled to assess whether this spike in VC and the continuing decreases in PCE and TCE are anomalies or represent changed conditions at this well. If increased biodegradation is occurring, it would be unexpected and would presumably not be due to the one-time application of HRC in 2001. As explained in reports on that treatability study (e.g., KH 2005b), the HRC was expected to be effective for about a year and a half. Even with the excess HRC installed above the water table, after more than 11 years this should all have been consumed/metabolized or otherwise degraded.

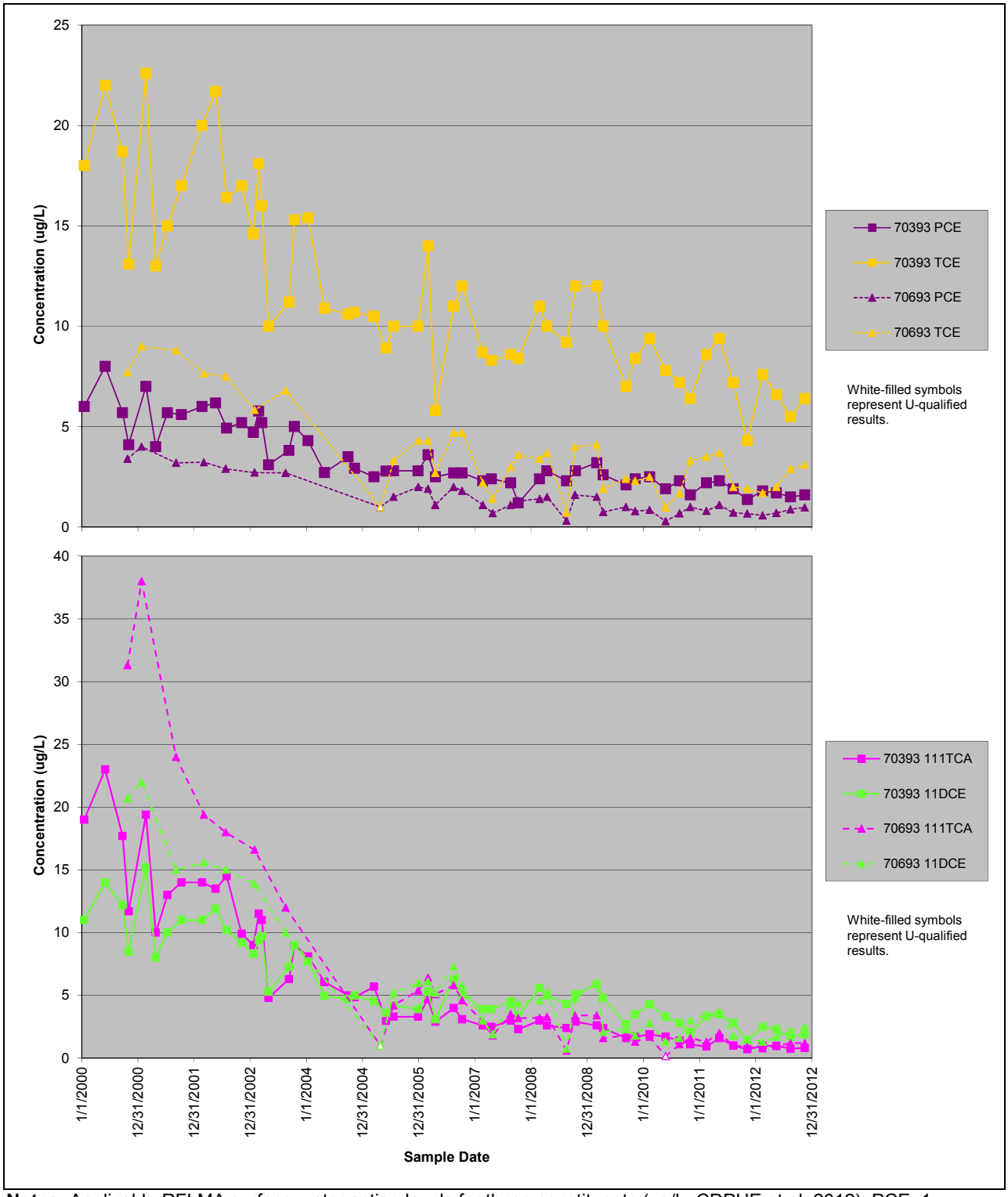


Notes: c12DCE = *cis*-1,2-DCE; HRC Added = date on which the HRC application via numerous boreholes in the source area was completed. Applicable RFLMA standards for these constituents (µg/L; CDPHE et al. 2012): PCE, 1; TCE, 2.5; *cis*-1,2-DCE, 70. Several results were qualified but are not shown differently for simplicity. Note logarithmic concentration scale.

Figure 258. Concentrations of VOCs in the PU&D Yard Plume Source Area

Sentinel well 30002 was sampled for VOCs in April and October 2012. Results from the October sample included a detection of 1,3-DCB at an estimated (J-qualified) concentration of 0.64 µg/L. No other VOCs were detected. This constituent has also been detected in 2008 and 2010, also at estimated concentrations under 1 µg/L.

The upgradient RCRA wells were sampled quarterly, per the RFLMA. Those most affected by the PU&D Yard Plume, wells 70393 and 70693, reported low concentrations of VOCs that are typical at these locations. 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 259. As illustrated, concentrations of each of these compounds generally have been gradually decreasing since 2000. 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 (µg/L; CDPHE et al. 2012): 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 259. Concentrations of Primary PU&D Yard Plume VOCs in Upgradient PLF RCRA Wells

Upgradient well 70193, located farther north than upgradient wells 70393 and 70693 (Figure 2), reported VOC detections including 1,1,1-TCA, PCE, and toluene in the May 2012 sample. The results for 1,1,1-TCA and toluene were both J-qualified and both 0.93 µg/L, while that for PCE was reported at 1.4 µg/L. None of these constituents has been detected since January 2000 in samples from well 70193. As all three VOCs were detected in the same May sample but not in subsequent samples collected in 2012, the results are suspect. Additional data will be required to ascertain whether these detections were truly representative of groundwater at this well.

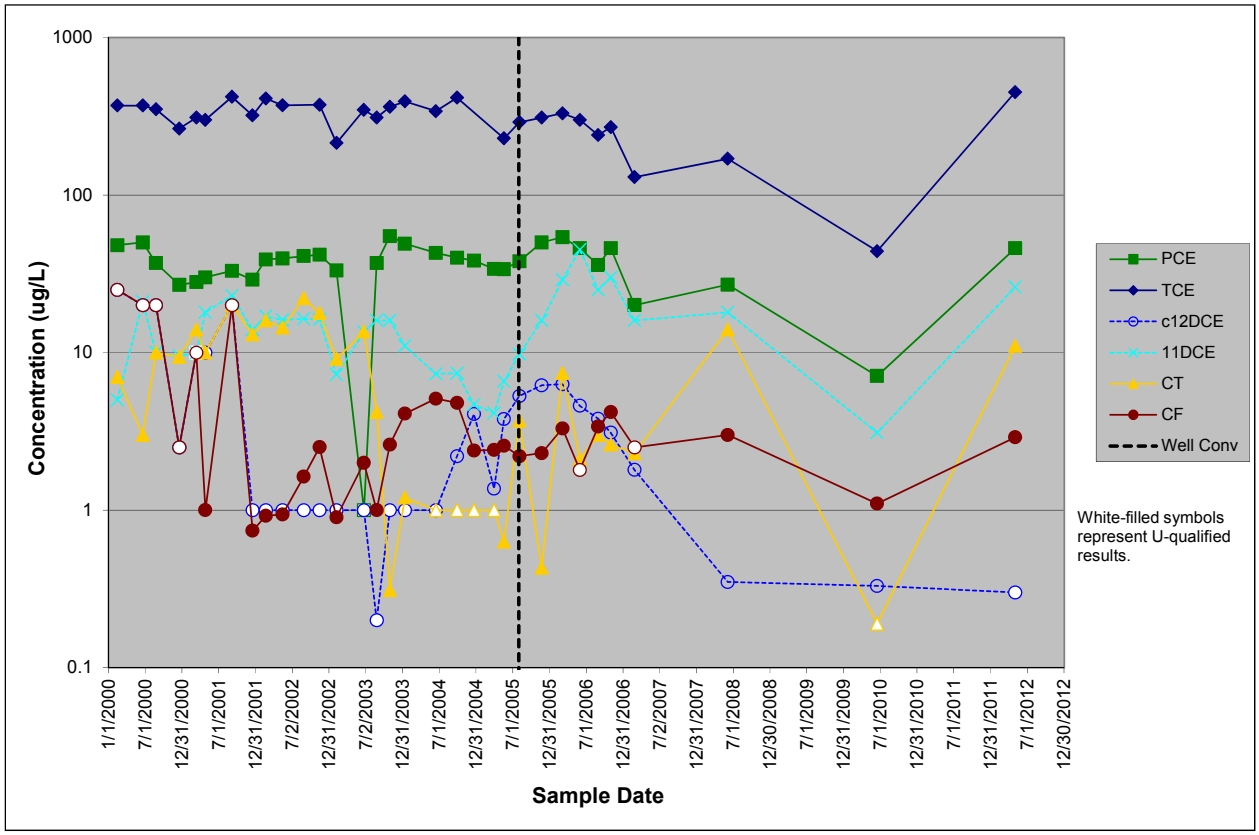
Evaluation well 30900 supports a decreasing trend in 1,1,1-TCA and increasing trend in *cis*-1,2-DCE, both at a 95 percent level of significance. 1,1,1-TCA has been rarely detected at this location since the early 2000s, but the detection limit is low so whether the trend is viable is not particularly important. Although not required by RFLMA, statistical trending was also performed for the upgradient RCRA wells at the PLF. Those calculated to have a 95 percent level of confidence are all decreasing, and include 1,1,1-TCA, 1,1-DCE, PCE, TCE, and uranium at 70393; 1,1,1-TCA, 1,1-DCE, carbon tetrachloride, chloroform, PCE, and TCE at 70693; and uranium at 70193. No increasing or decreasing trends are supported at downgradient Sentinel well 30005, since VOCs are typically not detected here.

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 sampling in 2012 in accordance with the RFLMA. Concentrations of VOCs were generally consistent with previous data, and generally reflected a return to conditions that could be considered “normal” prior to the lower concentrations reported in the 2010 sample (Figure 260). Results for *cis*-1,2-DCE did not follow this pattern, however, being undetected in the 2012 sample when a previously “normal” result would have been between 1 and 10 µg/L. With respect to the 2010 data, it may be important to note that this was a wet year, while 2012 was a dry year; and, as well 891WEL is still a collection well that has merely been converted to support manual sampling, the relative differences in water availability may have played an important role in the results from the 2010 and 2012 samples. Additional samples will be needed to determine how this area is changing over the longer term.

Increasing trends with a 95 percent level of statistical confidence are calculated at 891WEL for chloroform and *cis*-1,2-DCE.



Notes: c12DCE = *cis*-1,2-DCE; 11DCE = 1,1-DCE; CT = carbon tetrachloride; CF = chloroform. Well Conv = date on which the former industrial pump-operated collection well was converted to a manually sampled well. Applicable RFLMA surface-water action level (µg/L; CDPHE et al. 2012) for PCE is 1, TCE is 2.5, *cis*-1,2-DCE is 70, 1,1-DCE is 7, CT is 1, and CF is 3.4. Several detections were qualified but for simplicity are not shown differently. Note logarithmic concentration scale.

Figure 260. Primary VOCs in the OU 1 Plume Source Area

Downgradient of source-area location 891WEL is AOC well 89104. This location was sampled twice, in April and October 2012. No VOCs were detected.

Other Areas

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

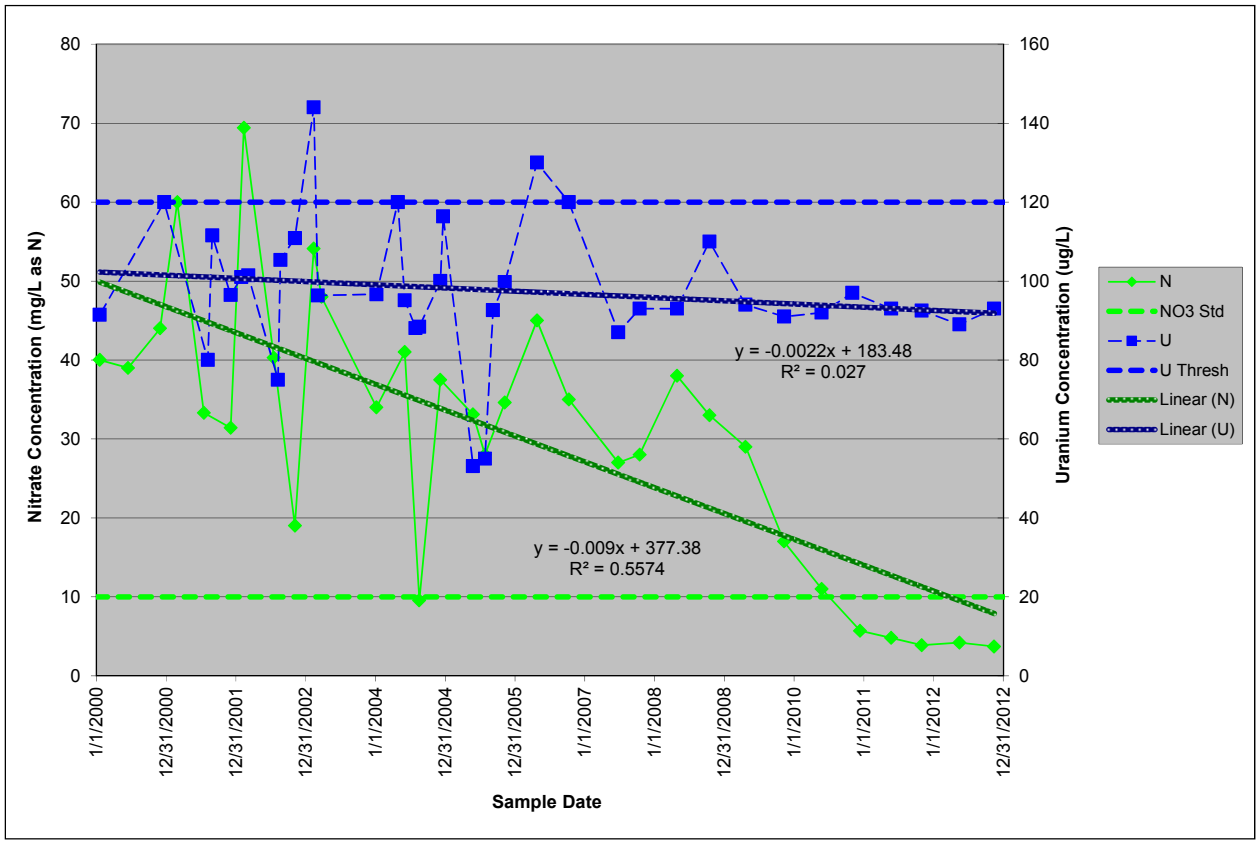
AOC well B206989: This well is located immediately east of the former Landfill Pond dam, which was breached in early 2012. Refer to previous annual reports (e.g., DOE 2012f) for information on and discussion of the expected reportable condition for nitrate that was initiated in 2007 and the related Contact Record 2007-06.

Annual reports issued since the report for 2008 (DOE 2009d) have noted the calculation of a decreasing trend in nitrate, with the associated level of statistical confidence reaching 95 percent in the 2009 report (DOE 2010d). Data collected since then, including those from 2012, continue to support this trend (see Table 90 and Appendix B.3). The results from 2012 continued to be

well below the applicable 10 mg/L standard, with the highest concentration in the two samples collected reported at 4.2 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 and are now consistently between 40 and 50 µg/L.

Both of these constituents (nitrate and U) are illustrated in time-series plots on Figure 261. 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 and 2011 Annual Reports (DOE 2011d and 2012f, respectively), the R^2 values associated with these trend lines have increased for both constituents. This is further evidence for the visually-evident decrease in the variability of the analytical data.



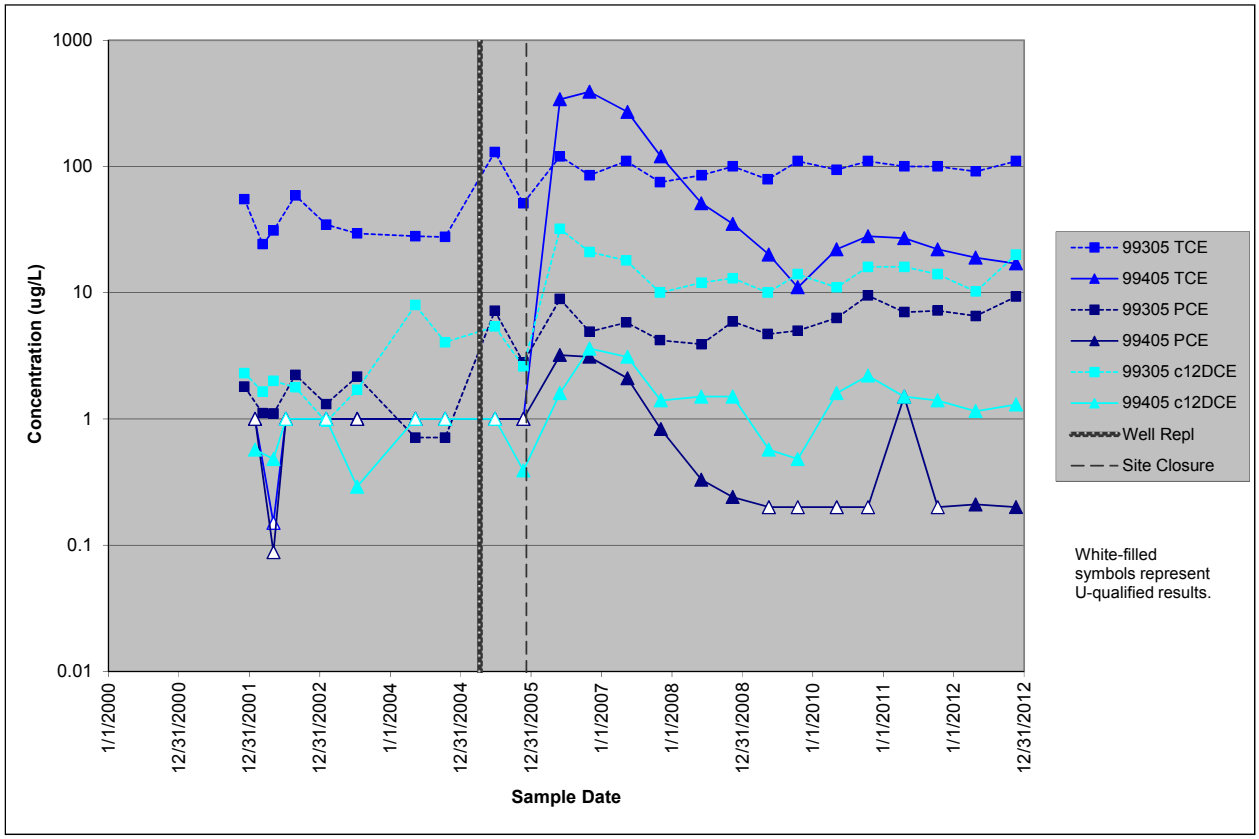
Notes: N = nitrate, NO3 Std = nitrate standard, U = uranium, U Thresh = uranium threshold. The applicable action level for nitrate is 10 mg/L; that for U is 120 µg/L (CDPHE et al. 2012). Simple linear regression trend lines are shown for each ["Linear (N)" and "Linear (U)", respectively], together with the corresponding equation and correlation coefficient. Note the use of two *y* axes to help illustrate the concentrations of the different constituents.

Figure 261. Concentrations of Nitrate and U in Groundwater Samples from AOC Well B206989

The mechanism responsible for the smoothing of these data is the sampling method, as discussed in the 2011 Annual Report (DOE 2012f). This change has also resulted in continued rising water level in well B206989, as shown on the corresponding hydrograph (Appendix A). Refer to the 2011 report for additional information and discussion.

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 November 2012 continued the post-closure pattern of higher concentrations of VOCs than were typical prior to closure. Noteworthy constituents continue to include PCE, TCE, and *cis*-1,2-DCE.

Figure 262 illustrates results for these VOCs 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. The changes are less marked in samples from well 99305, though well replacement may also be a factor here. (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 of PCE have decreased and are now typically nondetect. Conversely, concentrations of TCE exhibited a short-term increase starting in 2010, but in 2011 began to decrease again. Concentrations of *cis*-1,2-DCE here appear to follow those of TCE, though less uniformly. In nearby well 99305, these VOCs exhibit a series of increases beginning as early as 2004 for *cis*-1,2-DCE, and 2005 for PCE and TCE (again, well replacement may play a role). Closure appears to have affected concentrations of *cis*-1,2-DCE but not PCE or TCE. Since 2006, these three constituents show fairly uniform concentrations from year to year that generally appear to be slowly increasing. The results from the fourth quarter of 2012 show a more obvious rise. Whether the dry conditions of 2012 may be a factor is not known.

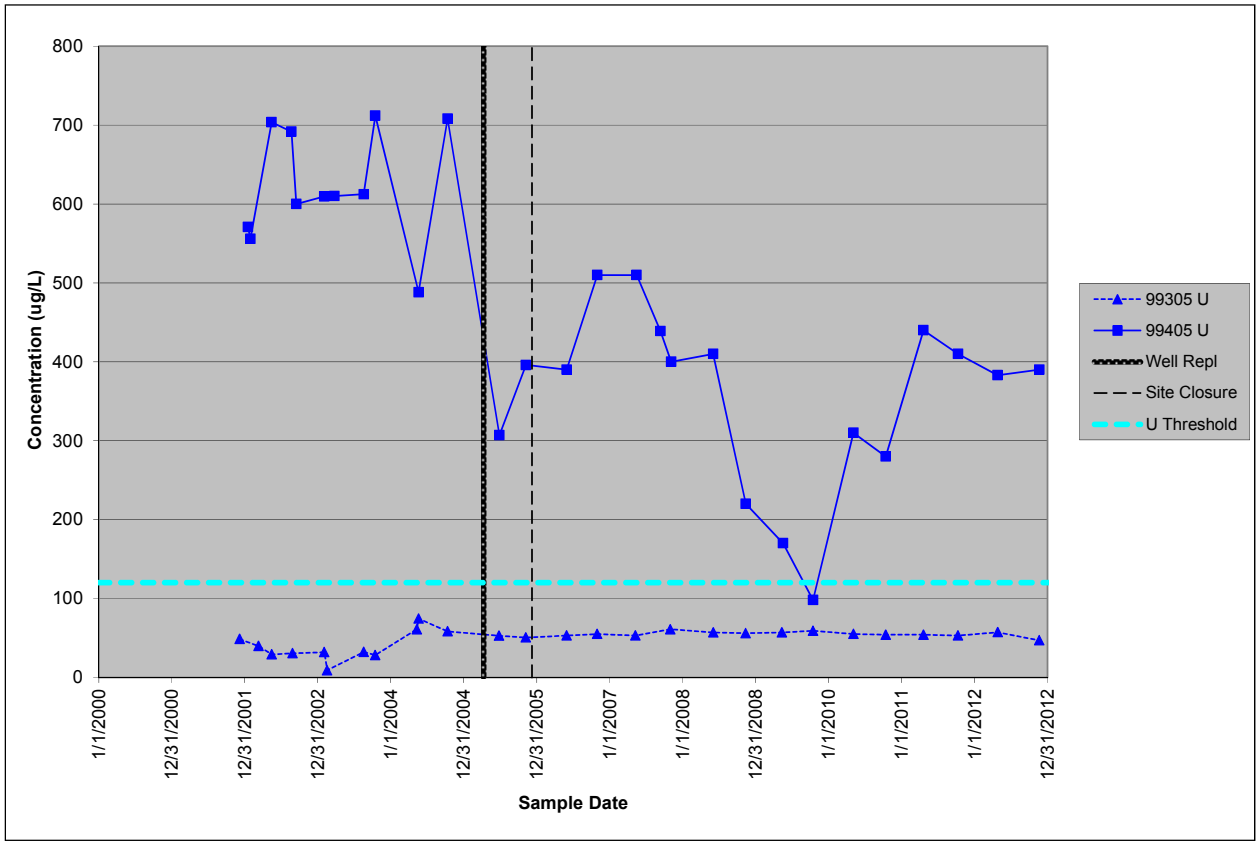


Notes: c12DCE = *cis*-1,2-DCE; Well Repl = well replacement. Applicable RFLMA action levels for these constituents (µg/L; CDPHE et al. 2012): PCE, 1; TCE, 2.5; *cis*-1,2-DCE, 70. In addition to the nondetects (U-qualified results), several other results were qualified but are not shown differently for simplicity. Note logarithmic concentration scale.

Figure 262. Concentrations of Primary VOCs in B991-Area Groundwater

Statistical trends with a 95 percent level of significance apply to several VOCs detected in samples from these wells. Each of these trends is increasing; they apply to *cis*-1,2-DCE, PCE, and TCE at well 99305, and *cis*-1,2-DCE at well 99405. The calculated trends at well 99305 are visually apparent on Figure 262, but that for *cis*-1,2-DCE at 99405 is less obvious. The nondetects in the early portion of the data set may be affecting this calculated trend.

Concentrations of U in samples collected from 2006 through 2009 at well 99405 displayed a remarkable decrease (Figure 263), but rebounded starting in 2010. Uranium concentrations since 2011 have been fairly uniform here at about 400 µg/L. Despite the increasing concentrations since 2010, a decreasing trend having a 95 percent level of statistical significance is still calculated for U at this location (Table 90, Appendix B).



Notes: Applicable RFLMA action level (µg/L; CDPHE et al. 2012) 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 263. Concentrations of U in B991 Sentinel Wells

Mechanisms responsible for the variable U concentrations in samples from well 99405 remain uncertain. Climate, sampling methods, and conditions in the adjacent constructed wetland may each play an important role. Refer to the annual report for 2011 (DOE 2012f) for additional discussion.

Located only about 115 feet from well 99405, well 99305 produces samples with very uniform U concentrations. Uranium concentrations reported here are about an order of magnitude lower than those from 99405. From late 2004 until mid-2012, concentrations of U in samples from this well have been consistently within the range from 50.6 µg/L to 61 µg/L. Given this consistency, the November 2012 result was unusually low at 47 µg/L. Although not obvious on Figure 263, 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 both well 99405 and well 99305 is not Site-related: it has been repeatedly characterized as 100 percent natural.

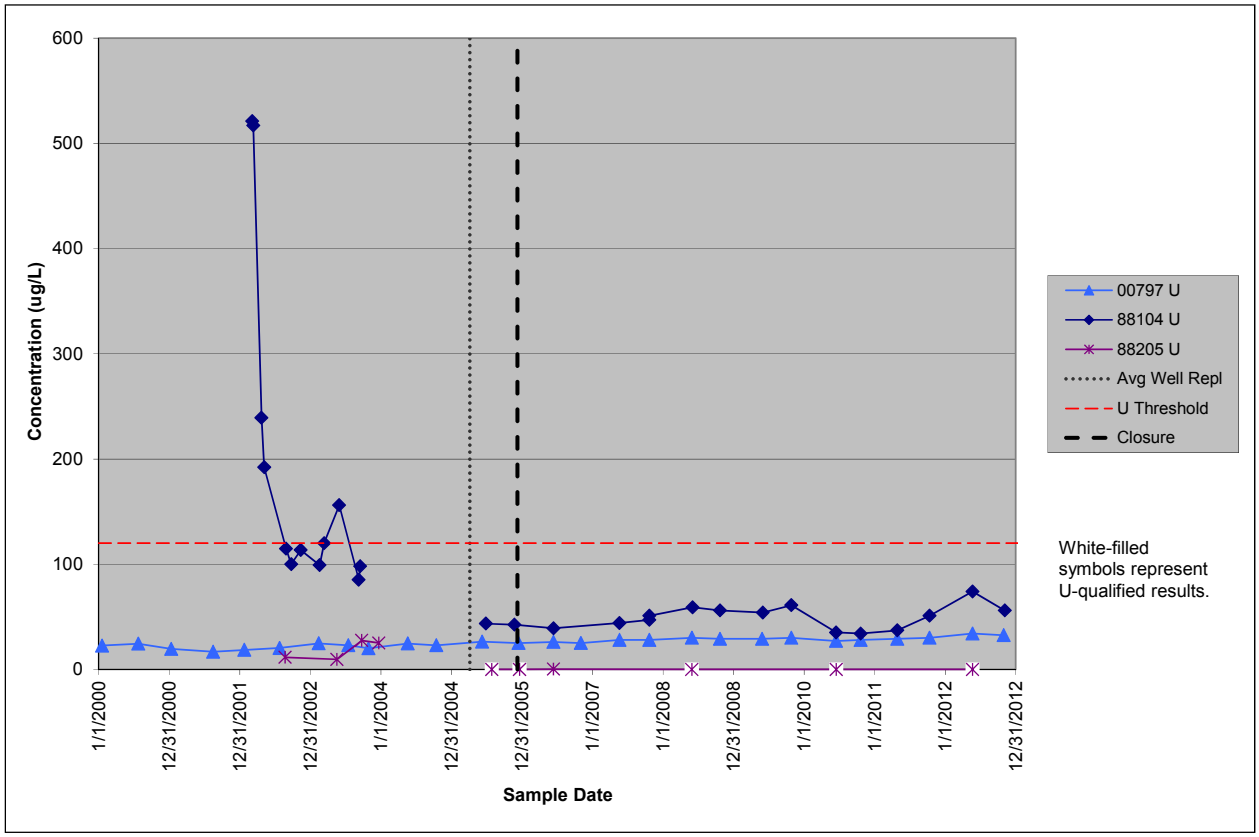
The discussion on the SPP provided above notes that a southeast-trending groundwater pathway historically has been postulated for SPP contaminants. As noted in that text, nitrate is analyzed in

samples from wells 99305 and 99405 for this reason. The maximum concentration of nitrate in 2012 at well 99305 was 1.28 mg/L, and in well 99405 was 1.8 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 2011 [DOE 2012f]), S-K calculations performed in 2012 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 90, Appendix B). Time-series plots of U for both wells are provided in Figure 264. 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 at well 88104 in 2012 were reported at 74 µg/L and 56 µg/L in the May and November samples, respectively. While the November result is consistent with data obtained from this well since the replacement was installed, the May result of 74 µg/L is higher than any sample since 2003. This may relate to the dry spring of 2012, but additional data will need to be collected to confirm any longer-term trends and patterns.

Evaluation well 88205, located within the former B881 south dock area and very near well B88104, was also scheduled for RFLMA sampling in 2012. Uranium was not detected in the sample collected in May 2012. This is consistent with most other samples collected here since 2005 (Figure 264).

Concentrations of U in samples collected in 2012 from Sentinel well 00797, located approximately 250 feet south of well 88104, were slightly higher than usual. Uranium has ranged between 16.78 µg/L to 30 µg/L since 2000, but the May and October 2012 samples reported U concentrations of 34 µg/L and 32.4 µg/L, respectively. The dry conditions in 2012 may have affected uranium concentrations in available groundwater, but additional samples will be required to confirm whether any longer-term and more pronounced increase in uranium concentrations is beginning. As illustrated on Figure 264, 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.)



Notes: Avg Well Repl = averaged date of replacement of wells 88104 and 88205. (Actual dates are less than six months apart.) Applicable RFLMA action level (µg/L; CDPHE et al. 2012) 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 264. Concentrations of U in Samples from B881 Sentinel Wells

Statistical calculations indicate the presence of trends in uranium concentrations that have a 95 percent level of confidence. At well 88104, located nearer the former building, concentrations are reported to be on a decreasing trend. (As previously discussed in this and prior annual reports, this trend is strongly affected by the well replacement; the effect of this event on uranium concentrations is also visually apparent on Figure 264.) Conversely, as in previous years, well 00797 data support an increasing trend in uranium concentrations.

Wells monitoring the area downgradient of former B881 are also sampled for VOCs. However, few VOCs are routinely detected. None were detected in samples from Sentinel wells 88104 and 00797. Evaluation well 88205 produced a sample in which several VOCs were detected. Results were similar to those from previous samples, and included the more commonly-detected constituents *cis*-1,2-DCE, PCE, and TCE. Concentrations were uniformly low, but the PCE result of 2.5 µg/L exceeded the RFLMA Table 1 value. Well 88205 was calculated to have an increasing trend in total xylenes that has a 95 percent level of confidence. However, results have been consistently below the RFLMA standard (10 µg/L) and many nondetects are present in the data set.

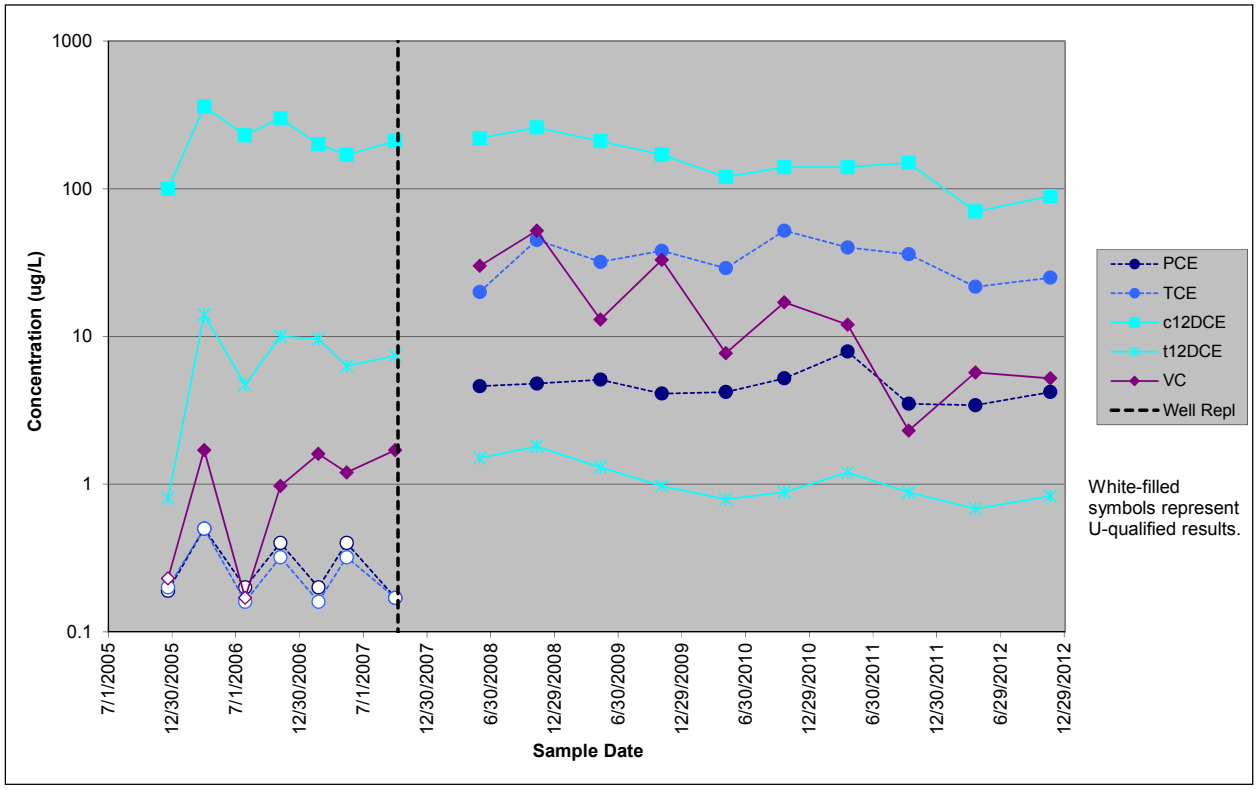
Elsewhere in the former 800 Area, Evaluation well 22996 monitors groundwater downgradient of former B886, as well as other 800-Area buildings that are farther upgradient (such as B865

and B883). This well was sampled in 2011 and the associated analytical results were consistent with previous data. No VOCs were detected, and the concentration of uranium, 10.2 µg/L, was within its typical range here. Well 22996 was not associated with any increasing or decreasing trends at a 95 percent level of confidence.

Hillside south of former B991: The north-facing 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 itself 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. Well 45605 was properly abandoned, the area was regraded, and Sentinel well 45608 was installed to replace 45605. For more detail on the hillside and French drain, see the 2006 Annual Report (DOE 2007b); for information on the well abandonment and hillside regrading, see the 2007 and 2008 Annual Reports (DOE 2008c, 2009d). Refer to the 2010 Annual Report (DOE 2011d) for a discussion of potential well replacement-related effects on contaminant concentrations.

Well 45608 was sampled twice in 2012 (April, November). 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 are clearly, but erratically, decreasing since the well replacement in 2008 (Figure 265). Also, with the 2012 data a visible but more gradual decreasing trend is also seen in concentrations of the two DCE isomers. Concentrations of PCE and TCE are generally more consistent.

Concentrations of VC in the replacement well are seen to vary seasonally until being reversed after 2010. Up to 2011, concentrations were slightly higher in fourth quarter samples than in second quarter samples; since then, the second-quarter concentrations are higher. The wet conditions in 2010 and dry conditions in 2012 may have affected contaminant concentrations, as discussed throughout this report, though the exact mechanism or mechanisms are uncertain. Higher water levels have been seen to flush contaminants from the vadose zone (e.g., see discussions of the OBP#2 area in the annual reports for 2010 and 2011); lower water levels can therefore decrease contaminant availability. With respect to degradation byproducts such as vinyl chloride, an influx of oxygenated groundwater can curtail dechlorinating bacteria, while groundwater that is more reducing can enhance the biological dechlorination of constituents such as PCE, TCE, and *cis*-1,2-DCE. These various conditions can be modulated by rising and falling groundwater levels.



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 (CDPHE et al. 2012): 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 265. Concentrations of VOCs in Sentinel Well 45608, South of Former B991

The relatively consistent levels of PCE and TCE coupled with decreasing daughter-product concentrations may indicate a longer-term reduction in the amount of dechlorination occurring in this area. Additional data may help to clarify whether this is occurring.

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, and TCE; and decreasing *cis*- and *trans*-1,2-DCE (Table 90).

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, as in previous years, 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 2012, just as in previous years, the five wells monitored for Pu and Am (Sentinel wells 20205, 20505, and 20705 at former B771; and 37405 and 37705 at former B371) only reported values qualified as nondetects for these radionuclides. Reported values in 2012 ranged from –0.00464 pCi/L to 0.00922 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 µg/L) is of PCE in samples collected from well 37505. The highest concentration reported in 2012 was estimated at 0.55 µg/L. VOCs were not detected in 2012 in samples collected from wells 37405 and 37705 and historically have been detected only rarely in samples from these wells.

S-K trending results (Table 90) 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. The associated trend plots are provided in Appendix B. Given that the concentrations are so low, time series plots are not included in this report. For 2012, the highest concentration of nitrate reported for well 37405 was 5.68 mg/L, and the highest concentration of uranium at well 37505 was 8.48 µg/L. Both of these results are well below their respective RFLMA values (10 mg/L and 120 µg/L, respectively).

3.2 Ecological Monitoring

3.2.1 Introduction

The Ecology group conducts ecological monitoring of the Site's ecological resources to ensure regulatory compliance and to preserve, protect, and manage those resources. Ecological monitoring is an integral aspect of determining whether the management objectives and goals for the natural resources at the Site are being achieved. This report summarizes the results of the ecological monitoring that was conducted at the Site during 2012. It includes a brief summary of the monitoring conducted for Preble's meadow jumping mouse (*Zapus hudsonius preblei*; Preble's mouse) mitigation and wetland mitigation activities; however, the details of those