

Table 1
Chronology of Events, Broadway-Pantano WQARF Site, Tucson, Arizona

Date	Description
Early 1940s to Early 1970s	Sand and gravel mining operations occur at and near the BSL and/or BNL
1953 to Early 1960s	Land filling occurs at the BSL.
Approx. 1960 - early 1970s	Land filling occurs at the BNL.
1976	City production well C-022A is removed from the active list for groundwater supply
January 1983	PCE and TCE are first detected in a well downgradient of BNL and BSL (ADEQ, 1995)
June/July, 1987	PCE is detected in city well D-022A at concentrations as high as 13.5 µg/L. The well is taken out of service due to PCE concentrations exceeding the EPA's recommended MCL of 5 µg/L.
1988	PCE and TCE are detected in city wells C-021A, C-022A, D-021A. (C-021A and D-021A remain in service because concentrations do not exceed the recommended MCL. Well C-022A was already out of service in 1976 due to water supply reasons.)
April, 1989	The PCE concentration in well C-021A increases to 8.4 µg/L and the well is taken out of service.
June - August 1990	Tucson Water installs five monitor wells (WR-177A, WR-178A, WR-179A, WR-180A, and WR-181A).
September 14, 1990	Broadway Pantano WQARF site placed on the WQARF priority list (ADEQ, 1995a)
January - August 1991	Tucson Water installs two additional monitor wells (WR-186A in January; and WR-207A in August).
August 2, 1991	BSL is identified as a potential hazardous waste site and entered into CERCLIS (EPA, 1995).
May, 1991	The PCE concentration in city well D-021A exceeds the proposed MCL and the well is taken out of service.
1993	Tucson Water adopts policy to shut down wells that exceed 1/2 of the MCL for any VOC constituent.
1994	Mayor and Council request Tucson Water to restrict use of five closest municipal supply wells to meeting peak demand only. Wells are listed "last on, first off" in the following order of use: C-058B, C-056B, C-026B, C-114A, C-020B. Action is taken as a result of PCE detections in some of these active wells.
June 1995	ADEQ conducts PA/SIs at both BNL and BSL. PCE in WR-178A is found to exceed the MCL. ADEQ concludes that BSL and BNL are potential sources of groundwater contamination.
September, 1995	PCE at a concentration of 4.9 µg/L is found at St. Joseph's Hospital well. City water is provided to the hospital until St. Joseph's Hospital and City of Tucson select a wellhead treatment system. The City of Tucson funds the design and installation of the system.
January, 1997	City of Tucson and Pima County complete the installation of monitor wells WR-273A, WR-274A, and WR-275A adjacent to the BNL as part of the LOU Remedial Investigation. The wells are constructed with 40-foot screens to intercept only the uppermost portion of the aquifer.
May, 1997 - present	The wellhead treatment system for St. Joseph's Hospital is completed by a contractor working for the COT. St. Joseph's resumes use of its private well. All ensuing results show non-detect for PCE and TCE after treatment. The City provides ongoing regulatory monitoring and reporting for the wellhead treatment system. In 2009, St. Joseph's Hospital shut down the well because of production problems. The Hospital plans to install a replacement water supply well in the same general area in 2013 or 2014.
1997	COT undertakes a landfill well inventory study to field verify location and use of private wells within a one mile radius of each landfill with City involvement. An extended search area is used for BNL. Search shows a limited number of active private wells in the area.

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Date	Description
March 1998	CDM completes a Draft Remedial Investigation for the BNL under contract with Pima County. It focuses on the LOU and was designed to evaluate whether the BNL is a potential source of groundwater contamination.
June, 1998	Tucson Water shuts down well C-026B, which is one of its "last on, first off" wells, due to detection of PCE at concentrations over one-half of the MCL. COT adds this well to its annual list of monitor wells to be sampled.
June - July, 1998	COT and Pima County recommend ADEQ install and sample three additional monitor wells. The well locations are jointly selected by the three agencies. The ADEQ installs wells SJ-1, SJ-2 and SE-1 downgradient of the LOU.
1998	COT obtains access to sample an active private well at the Simoniz Car Wash northwest of the groundwater plume. The well is identified during the well inventory and is added to the annual list of wells to be sampled.
December 1998 - September 2000	COT's groundwater flow model is developed and interim groundwater containment plan is devised. The model is completed with the documentation report submitted to ADEQ in March 2000. The Interim Containment Plan - Conceptual Design is completed and submitted to ADEQ in September 2000.
November - December 1999	The COT installs four additional monitoring wells downgradient of the BNL (WR-352A, WR-353A, WR-354A, WR-358A) to assist with containment plume delineation in the GOU.
2000	Tucson Water, concerned about increasing PCE concentrations in a monitoring well on the southern edge of the plume (WR-179A), voluntarily restricts pumpage in the two closest southern production wells to summer peak demand and contingency use only.
June, 2000	COT installs the first groundwater monitoring well at the Broadway South Landfill (WR-367A). Results are provided to ADEQ showing PCE concentrations exceeding the MCL.
June, 2000	The BNL Early Response Action SVE/AI System installation by the COT and Pima County starts operation.
December, 2000	Home Depot completed a report regarding an investigation in the southern part of the BNL which indicated the presence of dross. Home Depot covered the dross site with soil and temporarily fenced off the portion of the dross site that was not covered by buildings or pavement. ADEQ later replaced the temporary fence with a permanent fence and warning signs.
From 2001 to the present - all site work was performed by ADEQ and its contractors unless indicated otherwise.	
January, 2001	The design for the Early Response Action Western Containment System (WCS) is completed by COT and approved by ADEQ. The design for the smaller Southern Containment System is suspended pending additional field investigations by ADEQ to be completed December 2001.
June, 2001	ADEQ and COT execute a work share agreement under which COT will contract for and oversee construction of the WCS, with reimbursement of all direct costs by ADEQ; ADEQ will take over responsibility for O&M of the SVE system; and COT will grant ADEQ access to COT rights-of-way for installation of groundwater monitor wells needed for the investigation of the site.
July 2001	COT installs monitor well WR-435A in the northern part of Gollob Park, downgradient of wastes buried in the Park. PCE has been detected in this monitor well, there have been no exceedances of the MCL.
2001 - 2002	13 new deep monitoring wells are installed in the GOU downgradient of the BNL and BSL. The wells are installed as part of the GOU RI.
July - August 2001	ADEQ takes over (from COT) the annual Site groundwater monitoring.

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Date	Description
January - February, 2002	Initial Site RI field work is initiated at the BNL by ADEQ.
September, 2002	The SVE system at BNL is shut down because of low recovery rates, and periodic rebound testing is initiated.
November, 2002	A Focused Investigation is conducted to evaluate the need for an Early Response Action to protect two COT supply wells, D-18A and C-25B. The study found that groundwater in the vicinity of the BNL has been impacted by PCE. The study also determined that an ERA was not warranted.
February, 2003	A detailed BNL site walk is performed to identify areas of concern on landfill surface to be addressed during follow-on surface soil sampling.
March, 2003	WCS operation begins.
May, 2003	Post startup monitoring of the WCS is initiated. ADEQ completes a vertical flow evaluation in selected GOU monitoring wells. ADEQ conducts surface soil sampling at BNL.
June, 2003	The ADEQ/COT work share agreement is amended to provide for COT responsibility for reimbursement of COT for all direct costs for COT's O&M work.
August, 2005	COT installs two BP-series wells (BP-20 and BP-21) near the leading edge of the GOU.
September, 2005	ADEQ initiates remedial investigations of the BSL as part of the GOU RI.
April, 2006	Field investigations are conducted at BSL by ADEQ. Four deep nested vapor probe wells (BSDP 1-4) and two combination groundwater monitoring wells and nested deep vapor probe wells (BP-22 and BP-23) are installed.
April, 2007	Draft Remedial Investigation Report for GOU is issued for public comment by ADEQ.
November/December, 2007	BP-24A/B/C shallow-/intermediate-/deep-screened groundwater monitor well cluster is installed approximately 1500 feet downgradient of the BNL to assist in vertical delineation of the plume.
May, 2008	BP-25 groundwater monitor well is installed at the northwestern edge of the BNL to help delineate the BNL plume to the north.
November, 2008	Proposed GOU Remedial Objectives Report is issued for public comment by ADEQ.
December, 2008	ADEQ/COT work share agreement is amended to provide for ADEQ reimbursement of COT for direct costs for installation of three groundwater monitor wells west of BP-21, and COT to perform quarterly sampling of select groundwater monitor wells.
January, 2009	WCS Effectiveness Evaluation is completed.
January, 2009	Under ADEQ/COT work share agreement, COT installs WR-702A, WR-703A, and WR-704A groundwater monitor wells to the west of BP-21 and begins quarterly monitoring of these wells and other select wells at western part of site.
June, 2010	Groundwater fate-and-transport model construction and preliminary simulations are completed by ADEQ with input from COT and Tucson Water.
July, 2010	Human Health Risk Assessment (HHRA) for the shallow soil gas pathway between BNL and adjacent residences is completed. The HHRA is conducted by Stantec under contract with ADEQ.
June, 2012	The Final Remedial Investigation for the Groundwater Operable Unit (which includes the Final Remedial Objectives Report and responsiveness summaries) is issued by ADEQ.
October, 2012	WCS is shut down due to PCE concentrations in the extracted groundwater continuing to be non-detect or well below the Aquifer Water Quality Standards. Pursuant to the shutdown plan outlined in the ADEQ letter sent to the City of Tucson on August 31, enhanced monitoring commences and the WCS is continued to be maintained so that it is readily available for turn-on if ADEQ determines that is warranted.
December, 2012	Work to complete the LOU Remedial Investigation begins.

Source: modified from Stantec, 2012 unless otherwise noted.

Note: Chronology of events for period from 1976 through January 2001 based primarily on Table 1-1 of URS (2002a).

Table 2
Summary of Perimeter Shallow Soil Gas Sampling Results 2002 and 2006
Broadway North Landfill

CAS No.	Parameter	December 2002 Sampling Event				April 2006 Sampling Event				Soil Remediation Levels ₂				Minimum GPL (mg/kg)
		Max Soil Gas Result ₁ (ppbv)	Max Soil Gas Result ₁ (mg/m ³)	Max Soil Gas Result Location ₁	Soil Equivalent of Max Soil Gas Result ₂ (mg/kg)	Max Soil Gas Result ₁ (ppbv)	Max Soil Gas Result ₁ (mg/m ³)	Max Soil Gas Result Location ₁	Soil Equivalent of Max Soil Gas Result ₂ (mg/kg)	Residential SRL			Non-Residential SRL (mg/kg)	
										Carcinogen		Non-Carcinogen (mg/kg)		
										10 ⁻⁶ Risk (mg/kg)	10 ⁻⁵ Risk (mg/kg)			
67-64-1	Acetone	NA	NA	NA	NA	1.8	0.00428	BN-10-20	0.000342			14,000	54,000	
71-43-2	Benzene	200	0.639	GP-2-20	0.00139	0.89	0.00284	BN-14-15	0.000006	0.65	NA		1.4	0.7
100-44-7	Benzyl Chloride	NA	NA	NA	NA	0.28	0.00145	BN-13-20	0.000239	0.92	9.2		22	
75-15-0	Carbon Disulfide	NA	NA	NA	NA	1.3	0.00405	BN-4-15	0.000002			360	720*	
108-90-7	Chlorobenzene	190	0.875	GP-2-20	0.00830	ND	ND	NA	NA			150	530	16.5
67-66-3	Chloroform	60	0.293	BN-7-20	0.00072	5	0.0244	BN-13-20	0.00006	0.94	9.4		20	
74-87-3	Chloromethane (Methyl Chloride)	1.1	0.00227	BN-7-5	0.000002	0.85	0.00176	BN-13-20Dup	0.000001			48	160	
110-82-7	Cyclohexane	NA	NA	NA	NA	0.68	0.00234	GP-7-20	0.000001			140*	140*	
106-93-4	1,2-Dibromoethane (1,2-EDB)	0.5	0.00384	BN-14-16	0.000036	ND	ND	NA	NA	0.029	0.29		0.63	
106-46-7	1,4-Dichlorobenzene	880	5.29	GP-2-20	0.127	1.8	0.0108	GP-6-20	0.00026	3.5	35		79	27
75-34-3	1,1-Dichloroethane (1,1-DCA)	0.72	0.00291	BN-9-10	0.000004	ND	ND	NA	NA			510	1,700*	0.85
75-35-4	1,1-Dichloroethene (1,1-DCE)	0.88	0.00349	BN-1-20	0.000002	ND	ND	NA	NA			120	410	
156-59-2	cis-1,2-Dichloroethene (cDCE)	330	1.31	BN-12-5	0.00270	ND	ND	NA	NA			43	150	5.3
78-87-5	1,2-Dichloropropane	ND	ND	NA	NA	3.5	0.0162	BN-13-20	0.000054	0.34	3.4		7.4	0.36
10061-02-6	trans-1,3-Dichloropropene	ND	ND	NA	NA	0.21	0.00095	BN-13-10	0.000001					
64-17-5	Ethanol	NA	NA	NA	NA	63	0.119	BN-13-20Dup	0.0614					
100-41-4	Ethylbenzene	1200	5.21	GP-2-20	0.0377	2.1	0.00912	GP-6-20	0.000066			400*	400*	82***
622-96-8	4-Ethyltoluene	NA	NA	NA	NA	1.2	0.00590	BN-11-20	0.000242					
75-69-4	Trichlorofluoromethane (Freon 11)	15	0.0843	BN-13-20	0.000023	11	0.0618	BN-13-20	0.000017			390	1,300	
75-71-8	Dichlorodifluoromethane (Freon 12)	4700	23.24	GP-12-10	0.00494	24	0.119	BN-13-20	0.000025			94	310	
76-14-2	1,2-Dichlorotetrafluoroethane (Freon 114)	140	0.979	GP-2-20	0.00023	29	0.203	BN-13-20	0.000047					
142-82-5	Heptane	NA	NA	NA	NA	6.3	0.0258	GP-5-20	0.000020					
110-54-3	n-Hexane	NA	NA	NA	NA	0.88	0.00310	GP-6-20	0.000001			110*	110*	
78-93-3	Methyl Ethyl Ketone (2-Butanone)	NA	NA	NA	NA	33	0.0973	BN-5-20	0.00533			23,000	34,000*	
75-09-2	Methylene Chloride	110	0.382	GP-12-10	0.00080	1.5	0.00521	BN-10-10	0.000011	9.3	93		210	
91-20-3	Naphthalene	NA	NA	NA	NA	1.2	0.00629	GP-6-20	0.00328			56	190	
100-42-5	Styrene	1.7	0.00724	GP-1-19	0.00031	0.24	0.00102	BN-11-20	0.000043			1,500*	1,500*	45
127-18-4	Tetrachloroethylene (PCE)	2.6	0.0176	GP-5-20Dup	0.000027	9.6	0.0651	BN-10-20	0.000101	0.51	5.1		13	0.8
108-88-3	Toluene	46	0.173	BN-16-10	0.00079	1.9	0.00716	BN-13-20Dup	0.000033			650*	650*	159***
71-55-6	1,1,1-Trichloroethane (TCA)	9.4	0.0513	BN-15-20	0.000065	0.88	0.00480	BN-18-20	0.000006			1,200*	1,200*	0.94
79-01-6	Trichloroethylene (TCE)	33	0.177	BN-12-5	0.000494	1.4	0.0075	BN-12-5	0.000021	3.0	30	17	65	0.76
95-63-6	1,2,4-Trimethylbenzene	41	0.202	GP-1-19	0.0197	2.1	0.0103	BN-11-20	0.00101			52	170	
108-67-8	1,3,5-Trimethylbenzene	17	0.0836	GP-1-19	0.00133	0.43	0.00211	BN-11-20	0.00003			21	70	
75-01-4	Vinyl Chloride	14	0.0358	GP-2-20	0.000014	ND	ND	NA	NA	0.085	NA		0.75	
95-47-6	o-Xylene	18	0.0782	GP-1-19	0.000900	0.76	0.00330	BN-5-20	0.000038			270 ^B	420 ^{B*}	31 ^{B***}
106-42-3 (108-38-3)	m,p-Xylene	27	0.117	GP-1-19	0.000997 ^A	2	0.00868	BN-5-20	0.000074 ^A					

Notes:

mg/m³ milligrams per cubic meter
mg/kg milligrams per kilogram
ppbv parts per billion by volume
DUP Duplicate sample
NA Not analyzed or not applicable
ND Analyte not detected above reporting limit
SRL Soil Remediation Level
GPL Groundwater Protection Level
Bold Value Max Soil Equivalent Result for 2002 and 2006

Notes continued:

1 From Stantec, 2010, Human Health Risk Assessment, Broadway North Landfill, ADEQ Broadway-Pantano WQARF Site, July 6, 2010.
2 Calculated according to ADEQ (2011) guidance. Constants for chemical properties were obtained from USEPA (2013) if not provided by ADEQ (2011). Soil equivalents were not calculated if constants were not provided by ADEQ (2011) or USEPA (2013)
3 Arizona Administrative Code Title 18, Article 2, Effective as May 5, 2007- http://www.azsos.gov/public_services/title_18/18-07.htm
A Used the chemical properties constants for P-xylene for calculation because it produced a larger value (in 2002 m-Xylene = 0.00959 mg/kg and 2006 m-Xylene 0.000071 mg/kg)
B SRLs and GPLs are for Total Xylene (CAS No. 1330-20-7)
GPL Groundwater Protection Levels, Arizona Department of Environmental Quality, A Screening Method to Determine Soil Concentrations Protective of Groundwater Quality, September 1996, VOCs revised 2008
* Indicates SRL is based on the chemical-specific saturation level in soil for volatile organic chemicals only
** Based on SRL for CAS 542-75-6
*** Indicates GPL based upon saturation limit

Table 3
Broadway North Landfill--Comparison of Predicted Indoor Air Concentrations to Regional Screening Levels,

CAS No.	Parameter	2006 Sampling Event			2006 Max Predicted Indoor Air Conc (µg/m ³) ₁	EPA Carcinogenic RSL ₄ (µg/m ³)	EPA Non-Carcinogenic RSL ₄ (µg/m ³)-- TQH = 0.1	Exceed EPA Carcinogenic RSL (2006)?	Exceed EPA Non-Carcinogenic RSL (2006)?
		Max Soil Gas Result ₂ (ppbv)	Max Soil Gas Result ₂ (mg/m ³)	Max Soil Gas Result Location ₂					
67-64-1	Acetone	1.8	0.00428	BN-10-20	0.128274 ⁺³	---	3200		
71-43-2	Benzene	0.89	0.00284	BN-14-15	0.085299	0.31	3.1		
100-44-7	Benzyl Chloride	0.28	0.00145	BN-13-20	0.043488	0.05	0.1		
75-15-0	Carbon Disulfide	1.3	0.00405	BN-4-15	0.121449	---	73		
108-90-7	Chlorobenzene	ND	ND	NA		---	5.2		
67-66-3	Chloroform	5	0.0244	BN-13-20	0.732453	0.11	10	YES	
74-87-3	Chloromethane (Methyl Chloride)	0.85	0.00176	BN-13-20Dup	0.052659	---	9.4		
110-82-7	Cyclohexane	0.68	0.00234	GP-7-20	0.070218	---	---		
106-93-4	1,2-Dibromoethane (1,2-EDB)	ND	ND	NA		0.004	0.94		
106-46-7	1,4-Dichlorobenzene	1.8	0.0108	GP-6-20	0.324684	0.22	83	YES	
75-34-3	1,1-Dichloroethane (1,1-DCA)	ND	ND	NA		1.5	---		
75-35-4	1,1-Dichloroethene (1,1-DCE)	ND	ND	NA		---	21		
156-59-2	cis-1,2-Dichloroethene (cDCE)	ND	ND	NA		---	---		
78-87-5	1,2-Dichloropropane	3.5	0.0162	BN-13-20	0.485232	0.24	0.42	YES	YES
10061-02-6	trans-1,3-Dichloropropene	0.21	0.00095	BN-13-10	0.028593	---	---		
64-17-5	Ethanol	63	0.119	BN-13-20Dup	3.561240	---	---		
100-41-4	Ethylbenzene	2.1	0.00912	GP-6-20	0.273540	0.97	100		
622-96-8	4-Ethyltoluene	1.2	0.00590	BN-11-20	0.176982	---	---		
75-69-4	Trichlorofluoromethane (Freon 11)	11	0.0618	BN-13-20	1.854210	---	73		
75-71-8	Dichlorodifluoromethane (Freon 12)	24	0.119	BN-13-20	3.560835	---	10		
76-14-2	1,2-Dichlorotetrafluoroethane (Freon 114)	29	0.203	BN-13-20	6.082173	---	---		
142-82-5	Heptane	6.3	0.0258	GP-5-20	0.774552	---	---		
110-54-3	n-Hexane	0.88	0.00310	GP-6-20	0.093042	---	73		
78-93-3	Methyl Ethyl Ketone (2-Butanone)	33	0.0973	BN-5-20	2.919387	---	520		
75-09-2	Methylene Chloride	1.5	0.00521	BN-10-10	0.156330	96	63		
91-20-3	Naphthalene	1.2	0.00629	GP-6-20	0.188703	0.072	0.31	YES	
100-42-5	Styrene	0.24	0.00102	BN-11-20	0.030666	---	100		
127-18-4	Tetrachloroethylene (PCE)	9.6	0.0651	BN-10-20	1.953570	9.4	4.2		
108-88-3	Toluene	1.9	0.00716	BN-13-20Dup	0.214782	---	520		
71-55-6	1,1,1-Trichloroethane (TCA)	0.88	0.00480	BN-18-20	0.144060	---	520		
79-01-6	Trichloroethylene (TCE)	1.4	0.0075	BN-12-5	0.225717	0.43	0.21		YES
95-63-6	1,2,4-Trimethylbenzene	2.1	0.0103	BN-11-20	0.309693	---	0.73		
108-67-8	1,3,5-Trimethylbenzene	0.43	0.00211	BN-11-20	0.063417	---	---		
75-01-4	Vinyl Chloride	ND	ND	NA		0.16	10		
95-47-6	o-Xylene	0.76	0.00330	BN-5-20	0.099006	---	10		
106-42-3 (108-38-3)	m,p-Xylene	2	0.00868	BN-5-20	0.260541	---	10		

Acronyms:
mg/m³ milligrams per cubic meter
mg/kg milligrams per kilogram
ppbv parts per billion by volume
DUP Duplicate sample
RSL Regional Screening Levels
NA Not analyzed or not applicable
ND Analyte not detected above reporting limit
USEPA United States Environmental Protection Agency
Converting ppbv to mg/m3; <http://www.airtoxics.com/cclases/unitcalc.html>

- Notes:
1. The maximum shallow soil-gas concentration was multiplied by an attenuation factor of 0.03 and the resulting value (a conservatively-predicted potential indoor air concentration) is compared to the USEPA Region 9 regional screening level (see Note #3 below).
 2. From Stantec, 2010, Human Health Risk Assessment, Broadway North Landfill, ADEQ Broadway-Pantano WQARF Site, July 2, 2010.
 3. Maximum predicted indoor air concentration is calculated by multiplying the maximum soil gas concentration by an assumed conservative attenuation factor of 0.03. Attenuation factor obtained from page 50 of EPA's Vapor Intrusion Database: Evaluation and Characterization of Attenuation Factors for Chlorinated Volatile Organic Ompounds and Residential Buildings; EPA 530-R-10-002; March 16, 2012; http://www.epa.gov/oswer/vaporintrusion/documents/OSWER_2010_Database_Report_03-16-2012_Final_witherratum_508.pdf.
 4. From United States Environmental Protection Agency, Pacific Southwest, Region 9, website-- <http://www.epa.gov/region9/superfund/prg/> downloaded September 2013. *Regional Screening Levels (formerly PRGs)*, Residential Air, "New" Tables (with Target Hazard Quotient = 0.1, Target Cancer Risk = 1E-06).
 5. A dash (---) in the field means there is no carcinogenic RSL or i