Regulatory Review Report

For

Groundwater: Site-Wide Groundwater Model Review and Verification and Regulatory Requirement Review

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List of Acronym and Abbreviation

The following list of acronyms and abbreviations is intended to assist you in the review of this document.

40 CFR	40 Code of Federal Regulations
5 CCR 1002-41	Code of Colorado Regulations - Basic Standards for Ground Water
ACL	Alternative Concentration Limit
AGWQMP	Ambient ground-water quality monitoring program
AMD	Acid Mine Drainage
ANGB	Air National Guard Base
ARAR	Applicable or Relevant and Appropriate Requirements
ATSDR	Agency for Toxic Substance and Disease Registry
BAT	Best Available Technology
BRL	Buckeye Reclamation Landfill
BTEX	Benzene, Toluene, Ethylbenzene, xylene
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CO	Consent Order
COPCs	Chemicals of Potential Concern
CWA	Clean Water Act
DCE	1,2-Dichloroethene
DDT	dichlorodiphenyltrichloroethane
DNAPL	Dense Non-aqueous Phase Liquid
DOE	Department Of Energy
DWPF	Defense Waste Processing Facility
ELCR	Excess Lifetime Cancer Risk
EMWMF	Environmental Management Waste Management Facility
EPA	Environmental Protection Agency
ESD	Explanation of Significant Differences
ETTP	Eastern Tennessee Technology Park
FEMP	Fernald Environmental Management Project
FS/PP-FEIS	Feasibility Study/Proposed Plan-Final Environmental Impact Statement
GWPS	Groundwater Protection Strategy
HI	Hazard Index
IRP	Installation Restoration Programs
LDRs	Land Disposal Restrictions

MCL	Maximum contaminant level
MCLGs	Maximum contaminant level goals
MNA	Monitored natural attenuation
MODFLOW	USGS Modular Three- Dimensional Groundwater Flow Model
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
OAC	Ohio Administrative Code
ODH	Ohio Department of Health
ORR	Oak Ridge Reservation
OSHA	Occupational Safety and Health Act
OU#	Operable Unit#
PAHs	Polyaromatic Hydrocarbons
PCE	Perchloroethylene
PGDP	Paducah Gaseous Diffusion Plan
PORTS	Portsmouth Gaseous Diffusion Plant
ppb	Parts Per Billion
PRP	Prior Responsible Party
RAO	Remedial Action Objectives
RCRA	Resource Conservation Recovery Act
RFCA	Rocky Flats Clean-up Agreement
RFETS	Rocky Flats Environmental Technology Site
RFI/RI	RCRA Facility Investigation/Remedial Investigation
RGA	Regional Gravel Aquifer
RI	Remedial Investigation
RMPE	Risk Management for Public Entities
ROD	Record Of Decision
RPA	Rickenbacker Port Authority
SARA	Superfund Amendments and Reauthorization Act
SCDHEC	South Carolina Department of Health and Environmental Control
SDWA	Safe Drinking Water Act
SRS	Savannah River Site
SVE	Soil Vapor Extraction
TCE	Trichloroethylene
TDS	Total Dissolved Solids

U-235	Isotope Uranium -235
U-238	Isotope Uranium-238
UCRS	Upper Continental Recharge
ug/l	micro-gram per liter
USAF	United States Air Force
USGS	United States Geological Survey
VOC	Volatile Organic Compounds
WAC	Waste Acceptance Criteria
WPAFB	Wright-Patterson Air Force Base

Section 1. Executive Summary

The site of the former Portsmouth Gaseous Diffusion Plant, PORTS, is located in a rural area of Pike County, Ohio. The U.S. Department of Energy is responsible for decontamination and decommissioning of the gaseous diffusion process buildings and associated facilities which were operational from 1954 to 2001.

The PORTS site is underlain by two distinct units – unconsolidated strata from the Teays Valley system river channel and consolidated sedimentary structures. The hydraulic conductivity of the unconsolidated Gallia Sand aquifer causes it to be the primary geologic strata to contain groundwater contamination; minimal contamination has migrated from the Gallia Sand aquifer. The Gallia Aquifer contains the majority of the groundwater contamination from the PORTS site, although some contamination has also migrated into the underlying Sunbury Shale layer. The groundwater contamination primarily consists of dense non-aqueous phase liquids, namely chlorinated solvents including trichloroethylene and its bi-products (i.e. DCE, vinyl chloride, etc.). The MCLs for chlorinated solvents are quite low, 0.005 mg/L for TCE, 0.007 mg/L for DCE and 0.002 mg/L for vinyl chloride. Total dissolved solids monitored in the Gallia aquifer are well within Ohio EPA's standards for drinking water; however, other constituents found in the water exceed drinking water standards.

Groundwater resources are abundant in Ohio, existing in one of three major aquifer types: unconsolidated sand and gravel, the most productive water bearing formations in Ohio, consolidated sandstone and shale in the eastern half of the state, and consolidated carbonate aquifers in the western half of the state.

Groundwater contamination is most commonly due to onsite sewage systems, petroleum products (BTEX), volatile organic compounds, and heavy metals. While specifically in the southwest, there is an increase of groundwater contamination related to the effects of urbanization and industrial activities and in eastern Ohio there is localized degradation from surface coal mining (Lane & Swisshelm 1988).

The Ohio EPA defines aquifers as any water bearing strata from which a significant amount of water can be withdrawn through a well or a spring. Further, the OEPA defines an underground source of drinking water as an aquifer that has sufficient yield to supply a public drinking water supply and has a total dissolved solids level of less than 10,000 mg/L (OEPA 2009b). The USEPA designates the lowest classification of drinking water aquifers as those with TDS levels of less than 10,000 mg/L, a yield of at least 150 gallons per day and any naturally occurring contamination should be treatable using technology typically implemented at public water treatment plants. On average, sand and gravel aquifers in Ohio have 466 mg/L of total dissolved solids (OEPA 2008). While sparse water quality data are available for pre-operation conditions on site, groundwater analyses performed on site between 1977 and 1999 show a maximum concentration of 4,967 mg/L of TDS with an average concentration of 330 mg/L TDS. Pump tests performed in 1996 show that the median yield of the Gallia Aquifer is approximately 950 gallons per day. There are elevated natural levels of several constituents, including arsenic and beryllium, but each is treatable using common technology. It would, therefore, be protective of human health to consider the Gallia Aquifer as a potential source of drinking water and set cleanup goals based upon that designation.

At all of the sites reviewed in this study, risk based cleanup levels were developed based on a range of scenarios from resident farmer to trespasser. However, cleanup levels for groundwater were set based primarily on health-based levels for consumption of groundwater. For some cases, institutional controls on groundwater consumption were applied for short term protection of human health before cleanup goals were reached, for example, at Tri-City Disposal Company's site in Kentucky. At each of the Department of Energy sites reviewed, groundwater cleanup levels for TCE were set at drinking water levels based on the assumption of either groundwater consumption or accidental groundwater consumption.

The cleanup levels negotiated at the DOE sites that we reviewed were consistently protective of human health. At Fernald the cleanup was directed at protecting a recreational user of the site or a trespasser to the disposal area. At Paducah, the interim measures to control the Northern Plume's offsite migration were based upon future ingestion and household use of contaminated groundwater despite the Paducah Water Policy that restricts groundwater use. The pump and treat system implemented at Paducah discharges based on a NPDES permit which restricts discharge of TCE and its products and Technetium-99 to drinking water standards. At Oak Ridge, in Zone 2, an 800 acre area within fenced security, the cleanup levels were determined based on future industrial uses with limitations to activities below 10 feet. The remedial action included excavation of at least 10 feet of soil, but with the potential to excavate to the water table or bedrock to maintain groundwater concentrations of contaminants at or below MCL. At Rocky Flats, groundwater cleanup goals were set based upon the Colorado Basic Standards for Groundwater. This was accomplished through soil excavation and pumping of groundwater. The excavation was, however, limited to the areas that were identified as the largest pollution sources and some minor sources were left untouched due to their low levels and the limited risk due to their continued existence given the restrictions on water use. These minor sources are typically at or less than MCL and only exceed in limited isolated on-site areas. At Savannah River Site, the cleanup is complex due to the number of contaminated sites, but all groundwater is intended to be cleaned and meeting MCL, although limited monitored natural attenuation is being used to reduce cleanup costs. With the exception of Paducah's interim action, all cleanup levels were set in order to comply with the Safe Drinking Water Act. At Paducah, the interim cleanup action was developed to comply with RCRA. The individual site reviews are included in Appendix A, although the information provided in each Record of Decision was inconsistent, leading to some variability in the reviews.

At all privately owned sites reviewed, protection of human health from consumption of contaminated groundwater was the driving force for cleanup. At each site, the cleanup goal was set to MCL, although some were derived through application of the Safe Drinking Water Act and some were derived through risk assessments. The individual site reviews are included in Appendix A, although the information provided in each Record of Decision was inconsistent, leading to some variability in the reviews.

Overall, this review has demonstrated the continued effort by DOE and the regulators in each decision to protect human health and groundwater quality. Overwhelmingly, MCL concentrations were the cleanup goals for groundwater regardless of future use or prior quality of groundwater. Cleanup goals are set at each site considering three main factors: groundwater quality regulations, human health impacts and ecological impacts. Groundwater regulations typically apply to water supplies supplying at least 15 households or 25 users, sole-source aquifers or aquifers that have the potential to be used as water supply. In this case, state or federal water quality standards (MCL) would be met during cleanup. In some cases, health based cleanup levels are used based on both on-site and off-site future use. Typically, off-site resources will be cleaned to MCLs, but on-site levels may be decided based on future use. The future use scenarios for risk assessments can range from a resident farmer to a trespasser on a fenced in site. The future uses may differ across a site and lead to different cleanup levels across site, for example, part of Fernald is now used for recreation and part is fenced in, leading to two scenarios—a recreationalist and a trespasser. Finally, the cleanup levels must be protective of ecological health, usually this is accomplished by the more conservative of the other two levels.

Section 2. PORTS Site Groundwater and Contamination

2.1 PORTS Background

The site of the former Portsmouth Gaseous Diffusion Plant, PORTS, is located in a rural area of Pike County, Ohio, on a 3,700 acre site (see Figure 2.1). The site is 2 miles east of the Scioto River in a small valley running parallel to and approximately 120 feet above the Scioto River floodplain. Figure 2.2 depicts the plant site and its surroundings.

Figure 2.1 Location of PORTS in Ohio

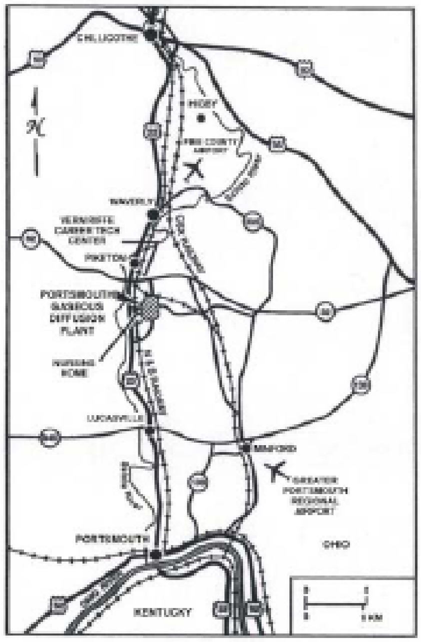


Figure 2.2 Regional Map Surrounding PORTS

Pike County has approximately 27,700 residents. Scattered rural development is typical; however, the county contains a number of small villages such as Piketon and Beaver that lie within a few miles of the plant. The county's largest community, Waverly, is about 10 miles north of the plant and has a population of about 4,400 residents. The nearest residential center in this area is Piketon, which is about 5 miles north of the plant on U.S. Route 23 with a population of about 1,900. Several residences are adjacent to the southern half of the eastern boundary and along Wakefield Mound Road (old U.S. 23), directly west of the plant (DOE 2012).

PORTS, which produced enriched uranium via the gaseous diffusion process from 1954 through 2001, is owned by DOE. In 1993, DOE leased the uranium production facilities at the site to United States Enrichment Corporation (USEC), which was established by the Energy Policy Act of 1992. DOE is responsible for decontamination and decommissioning (D&D) of the gaseous diffusion process buildings and associated facilities, environmental restoration, waste management, uranium operations, and management of facilities that are not leased to USEC, Inc. or USEC Government Services.

D&D includes the gaseous diffusion process buildings and associated facilities subject to the D&D Orders. D&D activities consist of deactivation of equipment; removal and cleaning of process residues from equipment, structures, and piping; and dismantling, demolition, and removal of equipment, structures, piping, and concrete foundations. The D&D Program is also responsible for conducting an evaluation of alternatives for disposition of waste generated by D&D.

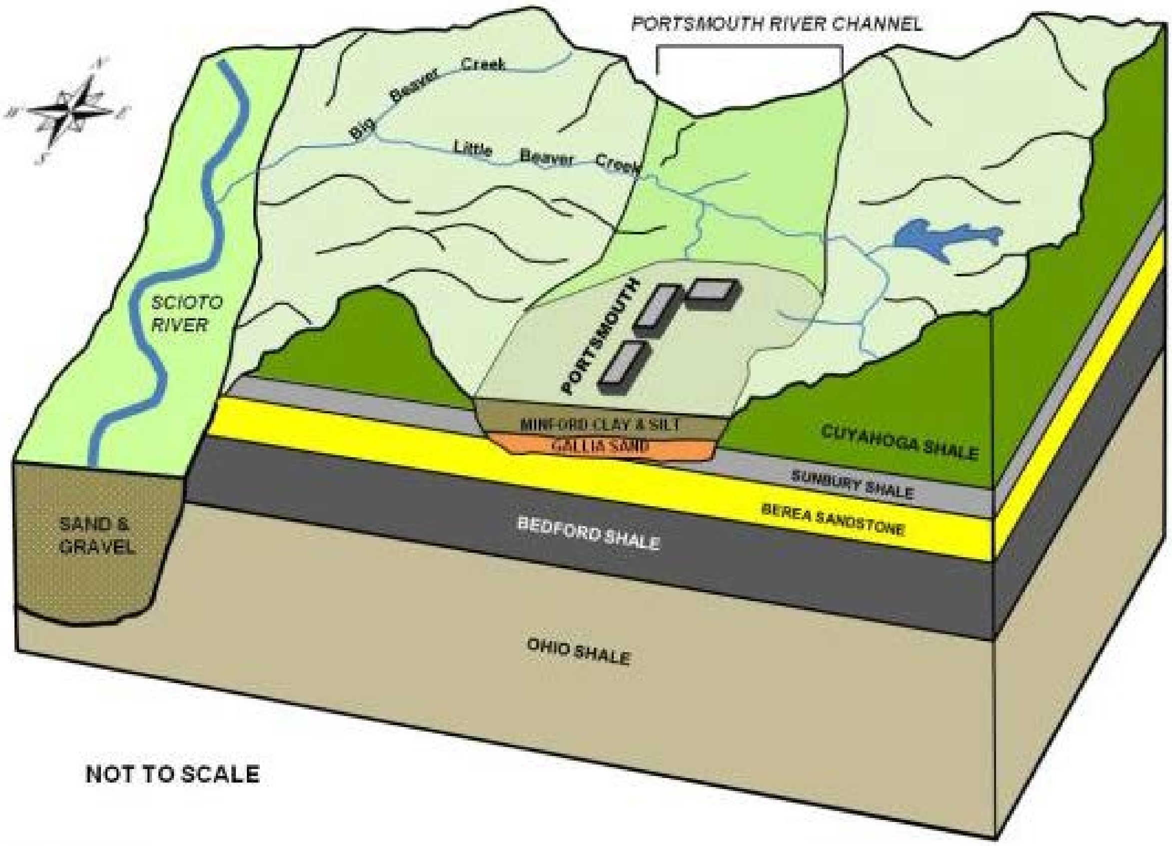
2.2 PORTS Site Geology and Aquifers

The PORTS site spans across a valley created by the paleochannel of the Portsmouth River. The plant site is located primarily within the channel, underlain by unconsolidated sediments of the Teays Valley system river channel, as seen in Figure 2.3. The geology of the PORTS site is formed by two distinct units—the consolidated sedimentary structures and the unconsolidated strata of the paleochannel. The hydraulic conductivity of the unconsolidated Gallia Sand aquifer causes it to be the primary geologic strata to contain groundwater contamination. The Gallia Sand is confined from the underlying consolidated Berea Sandstone, another water bearing unit, by the discontinuous Sunbury Shale layer. While minimal groundwater contamination has migrated from the Gallia Sand into the Sunbury Shale and Berea Sandstone, the bulk of the contamination, mostly in the form of chlorinated solvents (PCE, TCE, DCE), is found in the Gallia Sand.

Beyond the boundary of the plant site, the DOE reservation continues onto the hillsides surrounding the Portsmouth River Channel valley structure. The valley is oriented north to south and is bounded on the east and west by ridges or low-lying hills that have been deeply dissected by present and past drainage features. These ridges consist of Mississippian formations of Sunbury and Cuyahoga shales. While there is limited water in the upland shales, mostly in perched aquifers, they tend to be lower permeability than the unconsolidated zones; while they may be important for the design of an on-site disposal cell, they are not as important for establishing cleanup levels due to unpermitted discharges. Another significant landform is the small valley formed by Little Beaver Creek, which flows northwesterly across the middle of the DOE property, just north and east of the main plant area.

The hydrogeologic conditions underlying the DOE site are similar to those of the Teays River valley. The shale and sandstone bedrock underlies the entire property and outcrops in the hills along the east and west portions of the facility. This bedrock contains little or no water. The unconsolidated alluvial deposits are the Minford Clays and the Gallia Sand formations. A moderate amount of free water is contained in the gravelly Gallia Sand but is not easily obtainable because of the large percentage of clay mixed in the gravel. The Minford Clays are essentially impermeable except in the weathered surface layers (DOE 1990).

An analysis of topographic maps, surface water drainage, and past aerial photos of the site led to the prediction of groundwater divides and an interpretation of groundwater flow directions (see Figure 2.4). In general, groundwater in the northern part of the site flows toward Little Beaver Creek. In the vicinity of the X-701B Holding Pond Monitoring Area (eastern portion of the site), it flows eastward toward the creek. Little Beaver Creek eventually discharges into Big Beaver Creek. The flow direction at X-616, Chromium Sludge Surface Impoundment Area, is westward toward a small, unnamed, intermittent tributary of the Scioto River. Subsurface flow at X-749, Contaminated Materials Disposal Facility, is divided between a westward component and an eastward component conforming to the upper reaches of the Big Run drainage basin. The upper tributaries of the Big Run drain the area of X-231B, Oil Biodegradation Plot. Groundwater flow in this flat area is probably toward the south (DOE 2010b).



SOURCE: DOE 1996a

Figure 2.3. Cross section of PORTS site located above the unconsolidated alluvium of the Portsmouth River, part of the Teays River system (Provided by J.D. Chiou, 2012).

Groundwater underneath PORTS is not used as a domestic, municipal, or industrial water supply,and contaminants in the groundwater beneath PORTS do not affect the quality of the water in the Scioto River buried aquifer. PORTS is the largest industrial user of water in the region and it obtained water from three water supply well fields south of Piketon in the Scioto River Valley buried aquifer. DOE has filed a deed restriction at the Pike County Auditor's Office that prevents the use of groundwater beneath the PORTS site (DOE 1990).

2.3 Gallia Sand and the Berea Sandstone Aquifers

The Gallia Sand and the Berea Sandstone are two shallow aquifers below the PORTS infrastructure. The Minford Clay overlies the Gallia Sand and is hydraulically connected. The Minford Clay acts as a vertical contaminant pathway to the Gallia Sand, which is the most permeable unit at the site and the primary pathway of contaminant migration to Little Beaver Creek and Big Run. The groundwater flow beneath PORTS is dissected and flows towards one of the various drainage areas (i.e. Little Beaver Creek, West Drainage Ditch, and Big Run), thus dividing the site into multiple quadrants or areas of general flow direction (Figure 2.4). Many extraction wells have been drilled for treatment of groundwater contamination and to alter contaminant plume migration. These wells affect groundwater flow within their areas of influence. Neither the Gallia Sand nor the Berea Sandstone are Sole Source Aquifers.

Where present, the Sunbury Shale provides a hydraulic barrier that limits vertical movement of groundwater between the Gallia and Berea Sandstone (USGS 1995). Figure 2.5 shows a stratigraphic section of the PORTS site; the Gallia Sand is the highest hydraulic conductivity unit and the main unit that is contaminated by discharges from the plant.

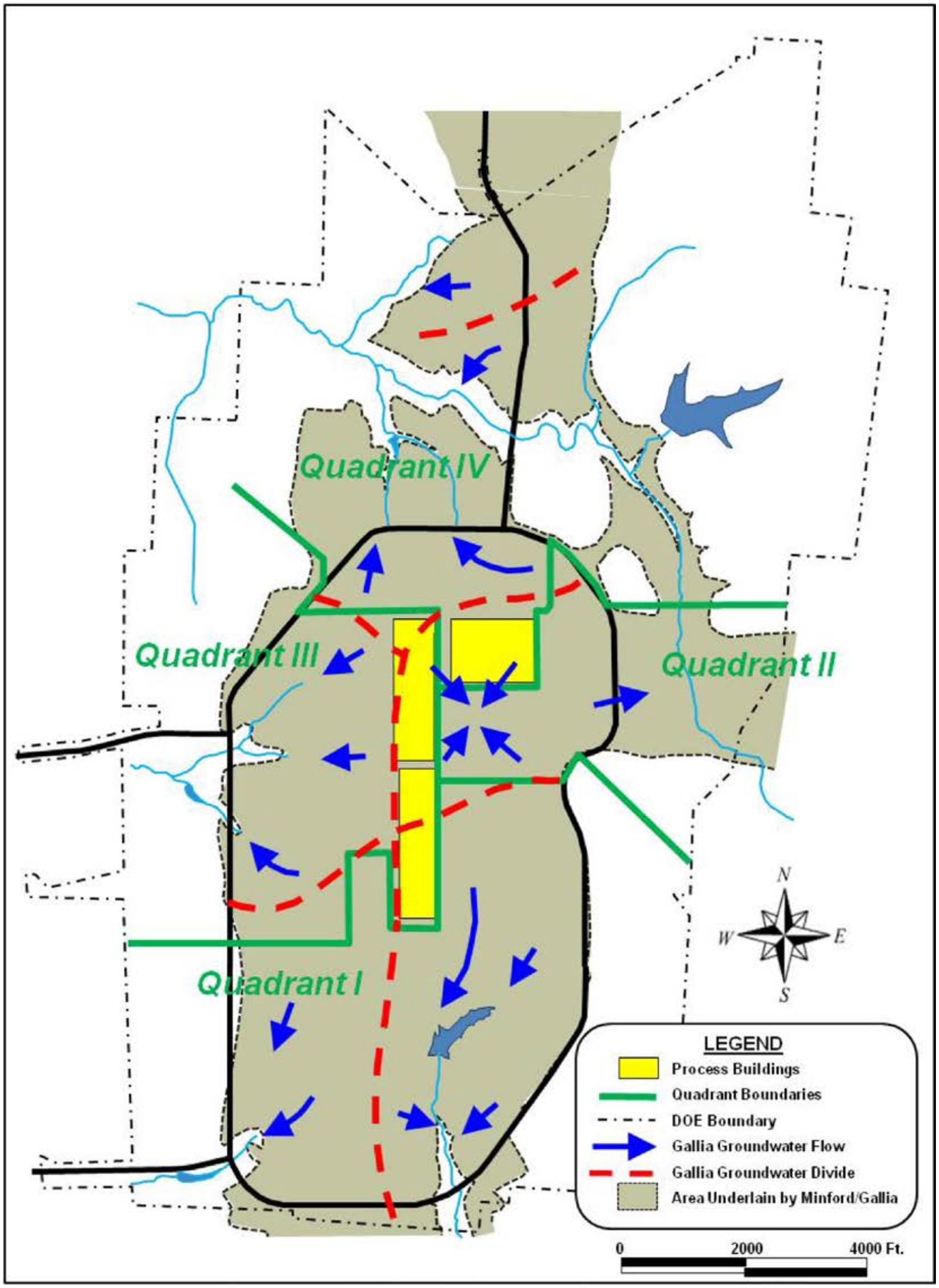


Figure 2.4. Dissected groundwater flow direction beneath PORTS (Provided by J.D. Chiou, 2012)

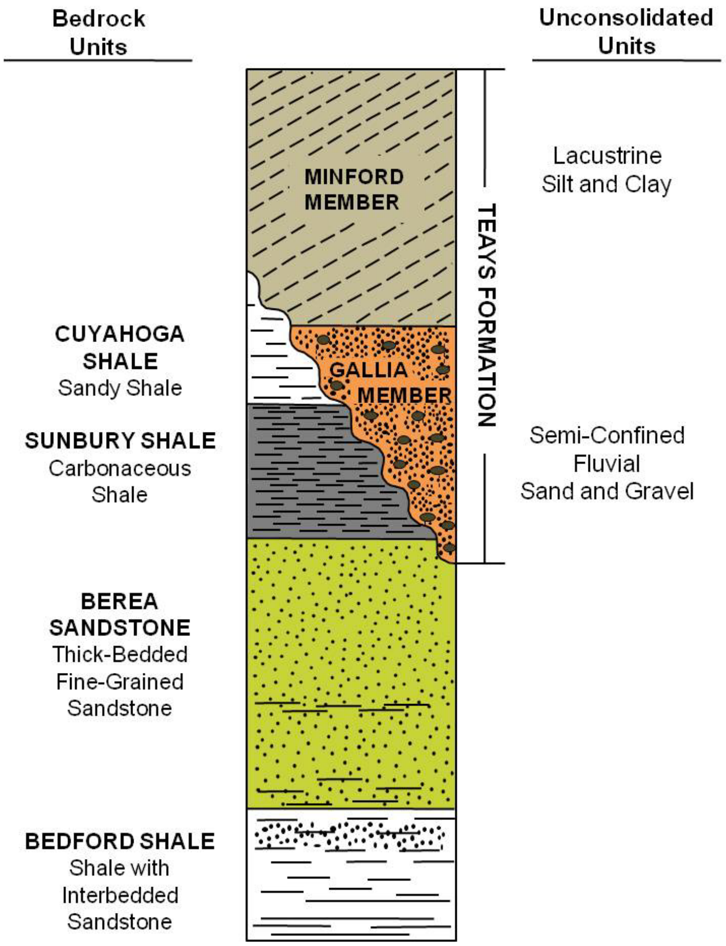


Figure 2.5. Stratigraphic profile of the unconsolidated and consolidated geologic units underlying the PORTS site (Provided by J.D. Chiou, 2012).

2.4 Ground Water Quality and Types in Ohio

The overall ground water quality within the State of Ohio is described here using the Ambient Ground Water Quality Monitoring Program (AGWQMP) database, consisting of approximately 6,000 inorganic and 2,000 organic water quality samples distributed across 337 active and inactive wells in Ohio (OEPA 2008). Ambient ground water quality data collected from sites across Ohio are presented in Table 2.1. The data in Table 2.1 summarizes the geochemistry by major aquifer type. This table provides the arithmetic mean, median, minimum value, value of the 95th percentile, standard deviation, total number of samples, number of samples below the reporting limit, and the percent non-detect for inorganic and field parameters in each aquifer type as of December 2007. In Table 2.1, refer to the data for the sand and gravel aquifers, this data pertains to the Gallia Sand Aquifer (OEPA 2008).

The piper diagram (Figure 2.6) provides a summary of cation data (left triangle), anion data (right triangle) and a composite diamond (center) to visually distinguish waters of different chemistries and origin. The small diamond points are the individual mean concentrations for each ambient station, and the squares are the average concentrations for the aquifer type. The following description, describes the different data presented in the Piper diagram (OEPA 2008);

BLUE POINTS: The carbonate ground waters in the piper diagram trend toward a more sulfate-rich composition, reflecting the dissolution of strontium- and calcium-bearing minerals. These waters display a wide range in alkalinity concentrations.

GREEN POINTS: The overlap between the carbonate and sand and gravel aquifer water chemistries is due to the fact that much of the aquifer material in the unconsolidated (sand and gravel) units is actually carbonate in origin.

RED POINTS: The sandstone water chemistry reveals a higher mean sodium, potassium, and chloride content than the other two systems, indicating a probable natural source for these ions, apparently from dissolution of simple salts or matrix cement.

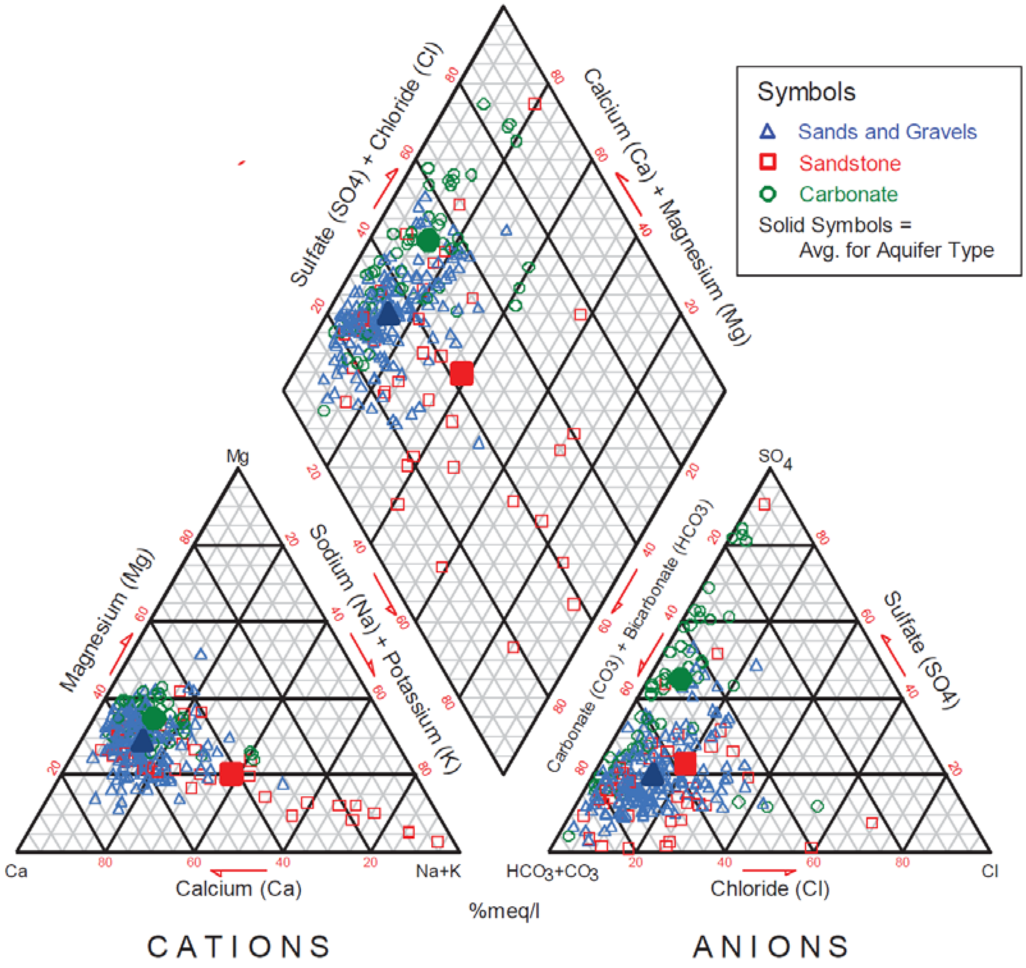


Figure 2.6: Major cation and anion data for different aquifer types. Sand and Gravel aquifer data is presented with blue triangles (OEPA 2008).

Table 2.1: AQWQA summary by major Aquifers as of December 2007. Refer to “sand and gravel” aquifer, Gallia is a sand and gravel aquifer (OEPA 2008).

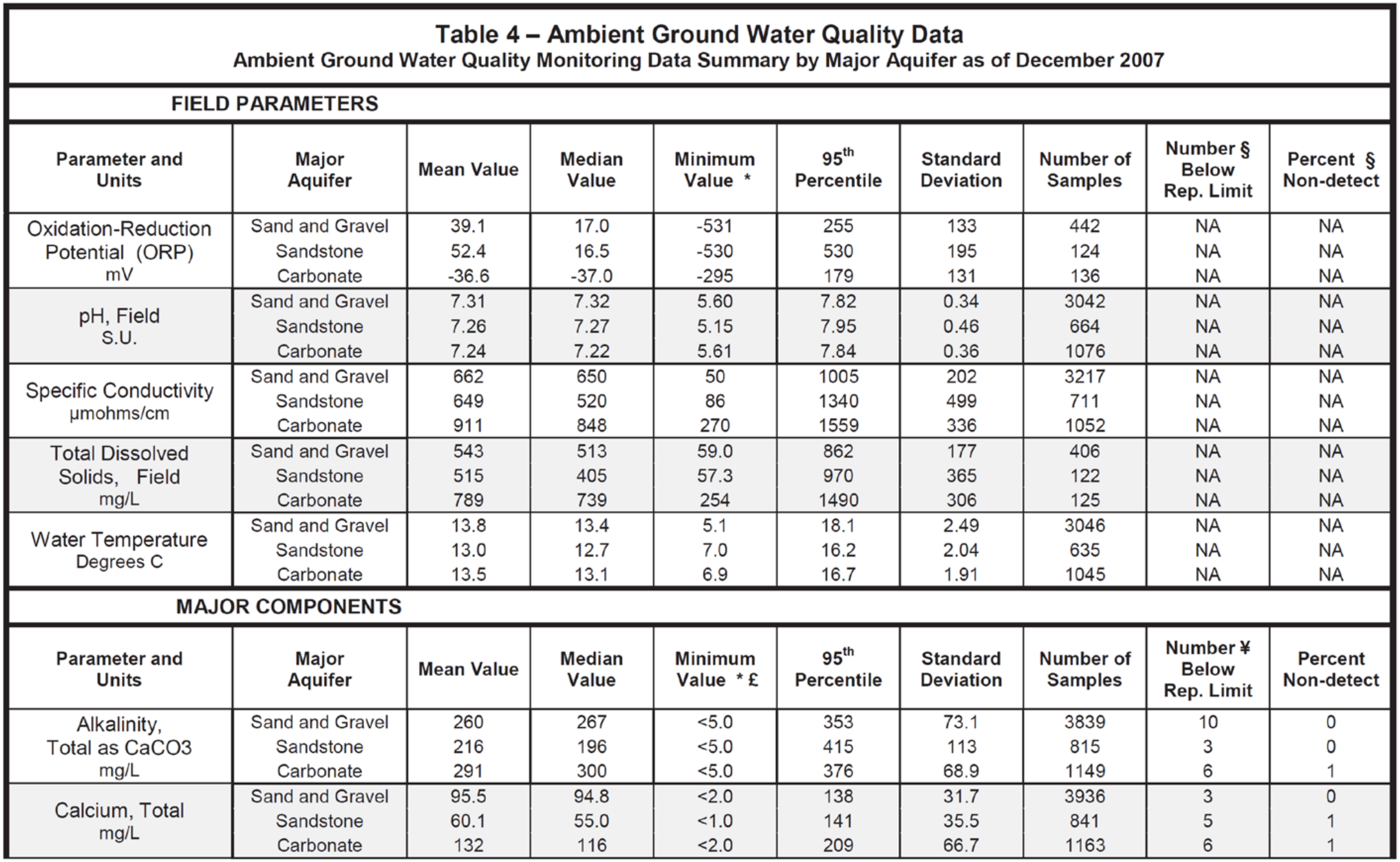


Table 4 – Ambient Ground Water Quality Data

Ambient Ground Water Quality Monitoring Data Summary by Major Aquifer as of December 2007

FIELD PARAMETERS

Parameter and Units	Major Aquifer	Mean Value	Median Value	Minimum Value *	95th Percentile	Standard Deviation	Number of Samples	Number § Below Rep. Limit	Percent § Non-detect
Oxidation-Reduction Potential (ORP) mV	Sand and Gravel	39.1	17.0	-531	255	133	442	NA	NA
	Sandstone	52.4	16.5	-530	530	195	124	NA	NA
	Carbonate	-36.6	-37.0	-295	179	131	136	NA	NA
pH, Field S.U.	Sand and Gravel	7.31	7.32	5.60	7.82	0.34	3042	NA	NA
	Sandstone	7.26	7.27	5.15	7.95	0.46	664	NA	NA
	Carbonate	7.24	7.22	5.61	7.84	0.36	1076	NA	NA
Specific Conductivity µmohms/cm	Sand and Gravel	662	650	50	1005	202	3217	NA	NA
	Sandstone	649	520	86	1340	499	711	NA	NA
	Carbonate	911	848	270	1559	336	1052	NA	NA
Total Dissolved Solids, Field mg/L	Sand and Gravel	543	513	59.0	862	177	406	NA	NA
	Sandstone	515	405	57.3	970	365	122	NA	NA
	Carbonate	789	739	254	1490	306	125	NA	NA
Water Temperature Degrees C	Sand and Gravel	13.8	13.4	5.1	18.1	2.49	3046	NA	NA
	Sandstone	13.0	12.7	7.0	16.2	2.04	635	NA	NA
	Carbonate	13.5	13.1	6.9	16.7	1.91	1045	NA	NA

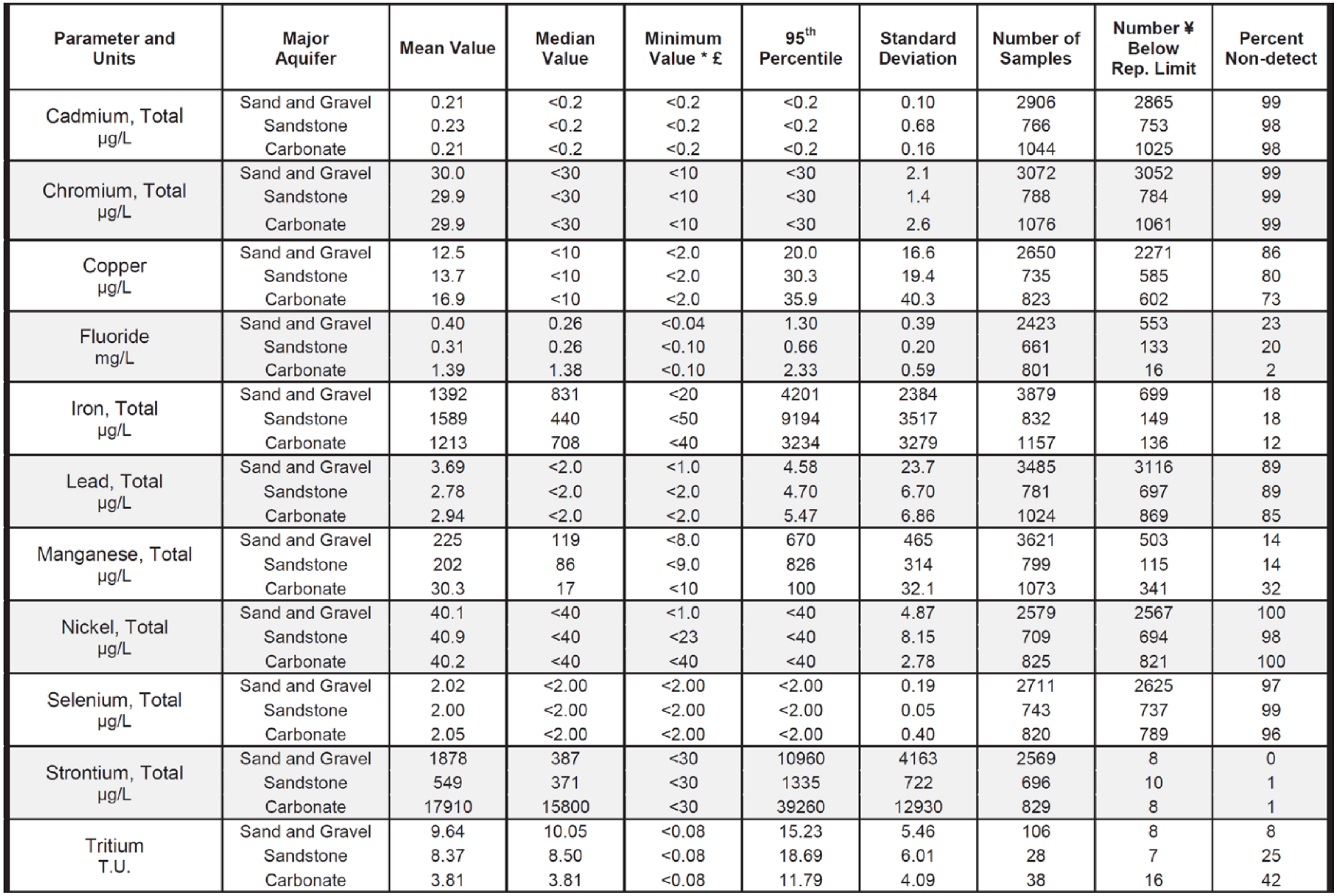
MAJOR COMPONENTS

Parameter and Units	Major Aquifer	Mean Value	Median Value	Minimum Value * £	95th Percentile	Standard Deviation	Number of Samples	Number ¥ Below Rep. Limit	Percent Non-detect
Alkalinity, Total as CaCO3 mg/L	Sand and Gravel	260	267	<5.0	353	73.1	3839	10	0
	Sandstone	216	196	<5.0	415	113	815	3	0
	Carbonate	291	300	<5.0	376	68.9	1149	6	1
Calcium, Total mg/L	Sand and Gravel	95.5	94.8	<2.0	138	31.7	3936	3	0
	Sandstone	60.1	55.0	<1.0	141	35.5	841	5	1
	Carbonate	132	116	<2.0	209	66.7	1163	6	1

Parameter and Units	Major Aquifer	Mean Value	Median Value	Minimum Value * £	95th Percentile	Standard Deviation	Number of Samples	Number ¥ Below Rep. Limit	Percent Non-detect
Chloride mg/L	Sand and Gravel	40.1	30.0	<2.0	111	36.7	3898	117	3
	Sandstone	40.7	22.8	<1.0	147	51.7	833	75	9
	Carbonate	31.1	15.0	<2.0	102	54.9	1130	114	10
Hardness, Total as CaCO3 mg/L	Sand and Gravel	355	358	<10.0	488	86.0	2910	5	0
	Sandstone	228	202	<10.0	565	130	656	3	0
	Carbonate	537	464	<10.0	898	243	893	7	1
Magnesium, Total mg/L	Sand and Gravel	28.7	29.0	<1.0	42.0	10.2	3936	7	0
	Sandstone	19.1	16.0	<1.0	53.0	13.4	842	6	1
	Carbonate	50.7	45.0	<1.0	92.0	19.6	1165	7	1
Potassium, Total mg/L	Sand and Gravel	2.45	2.0	<0.7	4.0	1.57	3490	482	14
	Sandstone	2.56	2.0	<0.6	5.0	1.14	788	196	25
	Carbonate	3.02	3.0	<1.1	6.0	1.31	1052	27	3
Sodium, Total mg/L	Sand and Gravel	26.1	21.0	<2.0	63.0	23.8	3929	82	2
	Sandstone	63.4	27.0	<4.0	223	91.7	842	38	5
	Carbonate	37.5	29.0	<5.0	93.5	33.9	1166	13	1
Sulfate mg/L	Sand and Gravel	80.1	67.1	<4.0	163	78.8	3897	38	1
	Sandstone	84.3	43.0	<5.0	268	148	837	73	9
	Carbonate	279	199	<5.0	810	249	1163	13	1
Total Dissolved Solids mg/L	Sand and Gravel	466	450	<5.0	680	164	3948	29	1
	Sandstone	429	336	<8.0	920	318	846	9	1
	Carbonate	743	664	<10	1421	412	1170	55	5

TRACE CONSTITUENTS

Parameter and Units	Major Aquifer	Mean Value	Median Value	Minimum Value * £	95th Percentile	Standard Deviation	Number of Samples	Number ¥ Below Rep. Limit	Percent Non-detect
Aluminum µg/L	Sand and Gravel	203	<200	<84.0	<200	80.9	2490	2482	100
	Sandstone	200	<200	<200	<200	1.5	683	681	100
	Carbonate	204	<200	<200	<200	67.6	783	776	99
Arsenic, Total µg/L	Sand and Gravel	5.69	<2.0	<2.0	17.6	8.58	3484	1801	52
	Sandstone	3.06	<2.0	<2.0	7.70	4.60	771	586	76
	Carbonate	4.04	<2.0	<2.0	15.8	4.27	1083	648	60
Barium µg/L	Sand and Gravel	173	125	<15.0	476	196	3439	129	4
	Sandstone	162	65	<15.0	675	326	752	78	10
	Carbonate	73.9	40	<7.0	230	84.0	1092	131	12



Parameter and Units	Major Aquifer	Mean Value	Median Value	Minimum Value * £	95th Percentile	Standard Deviation	Number of Samples	Number ¥ Below Rep. Limit	Percent Non-detect
Cadmium, Total µg/L	Sand and Gravel	0.21	<0.2	<0.2	<0.2	0.10	2906	2865	99
	Sandstone	0.23	<0.2	<0.2	<0.2	0.68	766	753	98
	Carbonate	0.21	<0.2	<0.2	<0.2	0.16	1044	1025	98
Chromium, Total µg/L	Sand and Gravel	30.0	<30	<10	<30	2.1	3072	3052	99
	Sandstone	29.9	<30	<10	<30	1.4	788	784	99
	Carbonate	29.9	<30	<10	<30	2.6	1076	1061	99
Copper µg/L	Sand and Gravel	12.5	<10	<2.0	20.0	16.6	2650	2271	86
	Sandstone	13.7	<10	<2.0	30.3	19.4	735	585	80
	Carbonate	16.9	<10	<2.0	35.9	40.3	823	602	73
Fluoride mg/L	Sand and Gravel	0.40	0.26	<0.04	1.30	0.39	2423	553	23
	Sandstone	0.31	0.26	<0.10	0.66	0.20	661	133	20
	Carbonate	1.39	1.38	<0.10	2.33	0.59	801	16	2
Iron, Total µg/L	Sand and Gravel	1392	831	<20	4201	2384	3879	699	18
	Sandstone	1589	440	<50	9194	3517	832	149	18
	Carbonate	1213	708	<40	3234	3279	1157	136	12
Lead, Total µg/L	Sand and Gravel	3.69	<2.0	<1.0	4.58	23.7	3485	3116	89
	Sandstone	2.78	<2.0	<2.0	4.70	6.70	781	697	89
	Carbonate	2.94	<2.0	<2.0	5.47	6.86	1024	869	85
Manganese, Total µg/L	Sand and Gravel	225	119	<8.0	670	465	3621	503	14
	Sandstone	202	86	<9.0	826	314	799	115	14
	Carbonate	30.3	17	<10	100	32.1	1073	341	32
Nickel, Total µg/L	Sand and Gravel	40.1	<40	<1.0	<40	4.87	2579	2567	100
	Sandstone	40.9	<40	<23	<40	8.15	709	694	98
	Carbonate	40.2	<40	<40	<40	2.78	825	821	100
Selenium, Total µg/L	Sand and Gravel	2.02	<2.00	<2.00	<2.00	0.19	2711	2625	97
	Sandstone	2.00	<2.00	<2.00	<2.00	0.05	743	737	99
	Carbonate	2.05	<2.00	<2.00	<2.00	0.40	820	789	96
Strontium, Total µg/L	Sand and Gravel	1878	387	<30	10960	4163	2569	8	0
	Sandstone	549	371	<30	1335	722	696	10	1
	Carbonate	17910	15800	<30	39260	12930	829	8	1
Tritium T.U.	Sand and Gravel	9.64	10.05	<0.08	15.23	5.46	106	8	8
	Sandstone	8.37	8.50	<0.08	18.69	6.01	28	7	25
	Carbonate	3.81	3.81	<0.08	11.79	4.09	38	16	42

2.5 Sand and Gravel Aquifer Groundwater Quality

The total dissolved solids for sand and gravel aquifers throughout Ohio have a median value of 466 mg/L (Table 2.1 and Figure 2.7). The mean water chemistries are presented in Table 2.1. These waters show high bicarbonate alkalinity. Another visible trend is decreasing chloride and sodium composition which is shown in the Piper diagram in Figure 2.6. These typical compositions could be controlled by the high hydraulic conductivities seen in sand and gravel aquifers resulting in low residence times.

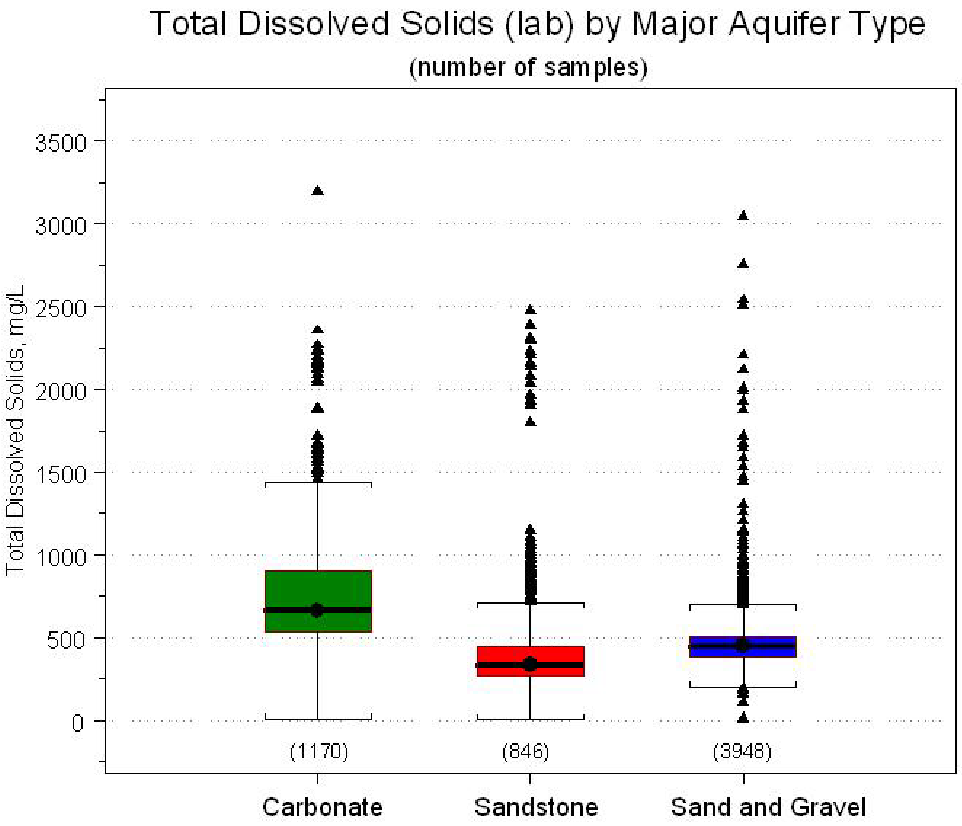


Figure 2.7: Box plot of total dissolved solids for AGWQMP data (OEPA 2008)

2.6 TDS Relationships to well depth for Sandstone aquifers

TDS is one of the best parameters to illustrate distinct water quality differences between bedrock aquifers in Ohio and is used as a regulatory indicator of drinking water suitability. The eastern half of Ohio exhibits lower TDS concentrations. Sand and gravel and sandstone aquifers have the lowest TDS values. The TDS relationship to well depth and aquifer type are illustrated in Figure 2.8. Sand and gravel aquifers (blue triangles) show concentrations of TDS that are well within the underground source of drinking water standard of 10,000 mg/L (OEPA 2008).

2.7 Water Quality in the Gallia Aquifer

The Ohio EPA designates aquifers as underground sources of drinking water if they have sufficient well yield to supply a public drinking water supply and have total dissolved solids below 10,000 mg/L (OEPA 3745-34-01). As shown in the box plots in Figure 2.9, no measurements of dissolved solids on site between 1977 and 1999 neared the 10,000 mg/L limit. While there is sparse pre-operation groundwater quality data, it can be inferred by these groundwater analyses during operation that the baseline water quality of the Gallia aquifer meets the definition of an underground source of drinking water if there is sufficient yield. While there are deed limitations on use of the Gallia aquifer in the area near PORTS, the Ohio EPA definition is more protective of human health given any future use of the site and the surrounding areas.

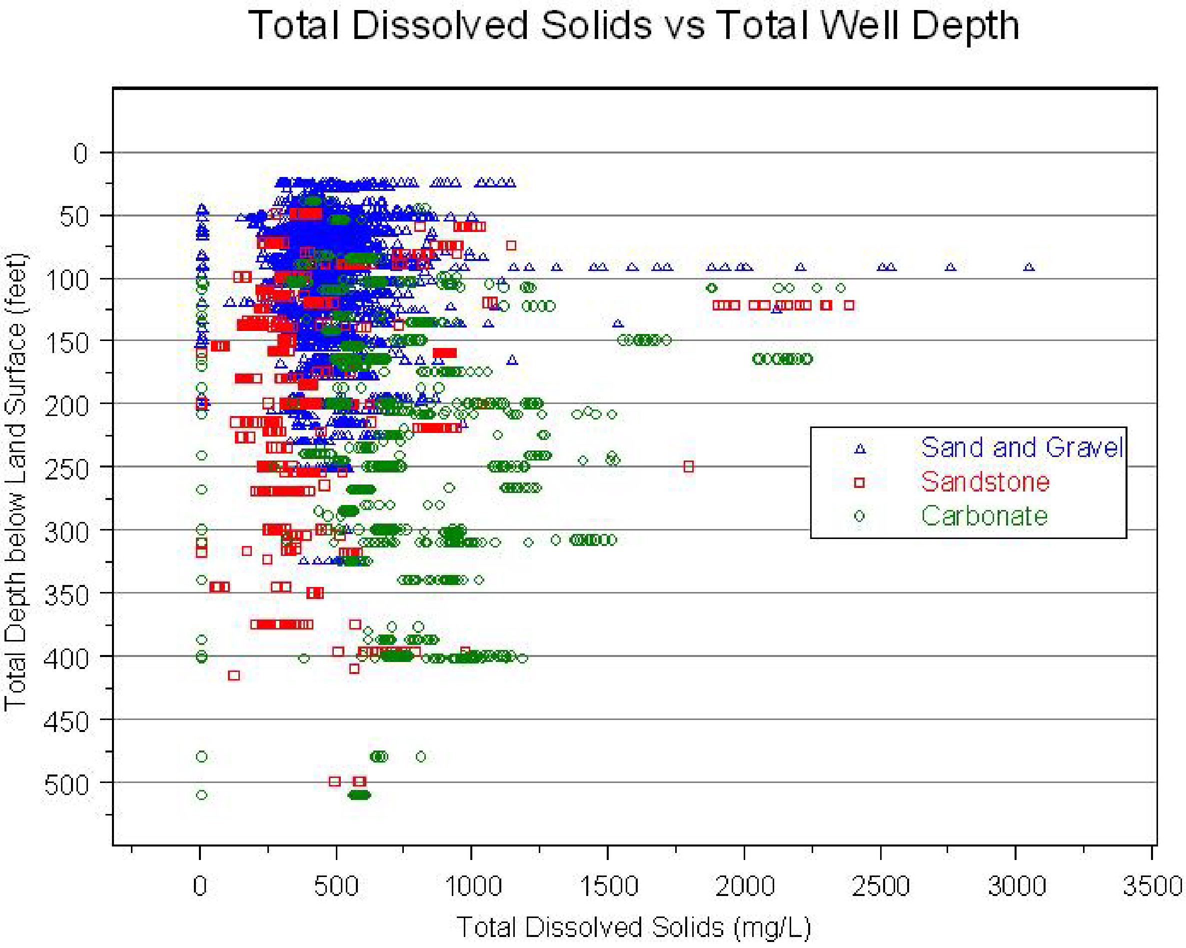


Figure 2.8: AGQQMP TDS data relative to well depth and aquifer type (OEPA 2008)

While the total dissolved solids found in the on-site wells in the Gallia aquifer are well within the OEPA's standards for underground sources of drinking water, there are other constituents found in the water in off-site wells that are above drinking water standards. Having quality exceeding drinking water standards does not exclude a water source from being treated as a source of drinking water nor does it imply anything about the treatability of the water for consumption.

OEPA lists both primary and secondary drinking water standards (OAC 3745-81 and 3745-82); primary standards are typically health based levels whereas secondary standards are typically for aesthetics of the drinking water. Primary and secondary drinking water standards applicable to the off-site groundwater quality analyses available are listed in Table 2.2; complete MCLs dictated by the Safe Drinking Water Act are listed in Appendix C.

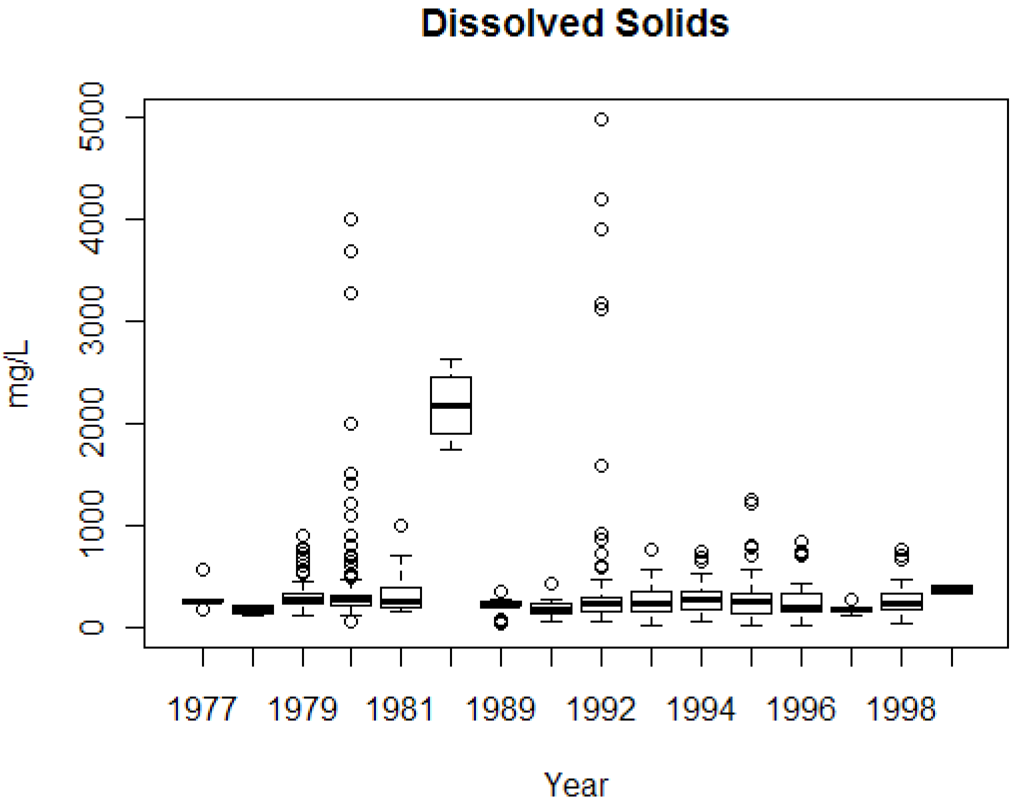


Figure 2.9. Box plots showing the measured total dissolved solids concentrations in mg/L at all wells on the PORTS site that conducted TDS readings from 1977 to 1999. None exceed 5000 mg/L (Nor the 10,000 mg/l OEPA definition for drinking water aquifer source).

The off-site wells analyzed by FBP show that off of the PORTS site, several of the primary and secondary limits are exceeded in the groundwater. The wells used in this analysis may have limited influence from the PORTS site (as seen from the alpha and beta activities and levels of benzene, toluene and xylenes off-site). The off-site groundwater data is visually presented in Appendix B in Figures Ba-Bz. As shown in Figures Ba, Bb, Bd, Be, Bo, Bp, Bv and Bw, alpha activity, arsenic, benzene, beryllium, iron, lead, sulfate and suspended solids consistently exceed either primary or secondary MCLs. While excess alpha activity and benzene could potentially have originated from the PORTS site, the elevated metal, sulfate and solids levels are more likely to be naturally occurring levels in the groundwater. The naturally occurring contaminants are treatable with in-house (e.g. ion exchange) or full scale treatment (i.e. public drinking water supply) systems. While arsenic is considered quite toxic in water, it is also possible to remove arsenic from drinking water to below the 10 µg/L standard. Arsenic tends to co-precipitate with iron in oxidized environments and it is likely that much of the arsenic could be removed from drinking water as a secondary benefit of air-stripping (with additional settling time) for removal of benzene to MCL.

Table 2.2 Ohio EPA Drinking Water Standards (OEPA 2010d)

Constituent	MCL/SMCL	Units	Comments
Alpha Activity	15	pCi/L	Primary Standard
Arsenic	10	µg/L	Primary Standard
Barium	2	mg/L	Primary Standard
Benzene	5	µg/L	Primary Standard
Beryllium	4	µg/L	Primary Standard
Beta Activity	4	mrem/yr	Primary Standard**
Cadmium	5	µg/L	Primary Standard
Chloride	250	mg/L	Secondary Standard
Chromium	100	µg/L	Primary Standard
Copper	1.3	mg/L	Primary Standard*
Fluoride	4	mg/L	Primary Standard
Iron	0.3	mg/L	Secondary Standard
Lead	15	µg/L	Primary Standard*
Selenium	50	µg/L	Primary Standard
Sulfate	250	mg/L	Secondary Standard
Toluene	1	mg/L	Primary Standard
Total Dissolved Solids	500	mg/L	Secondary Standard
Xylenes (total)	10	mg/L	Primary Standard
Zinc	5	mg/L	Secondary Standard

*In greater than 10% of tap samples over compliance period.

**Data not available for beta activity levels in mrem/year.

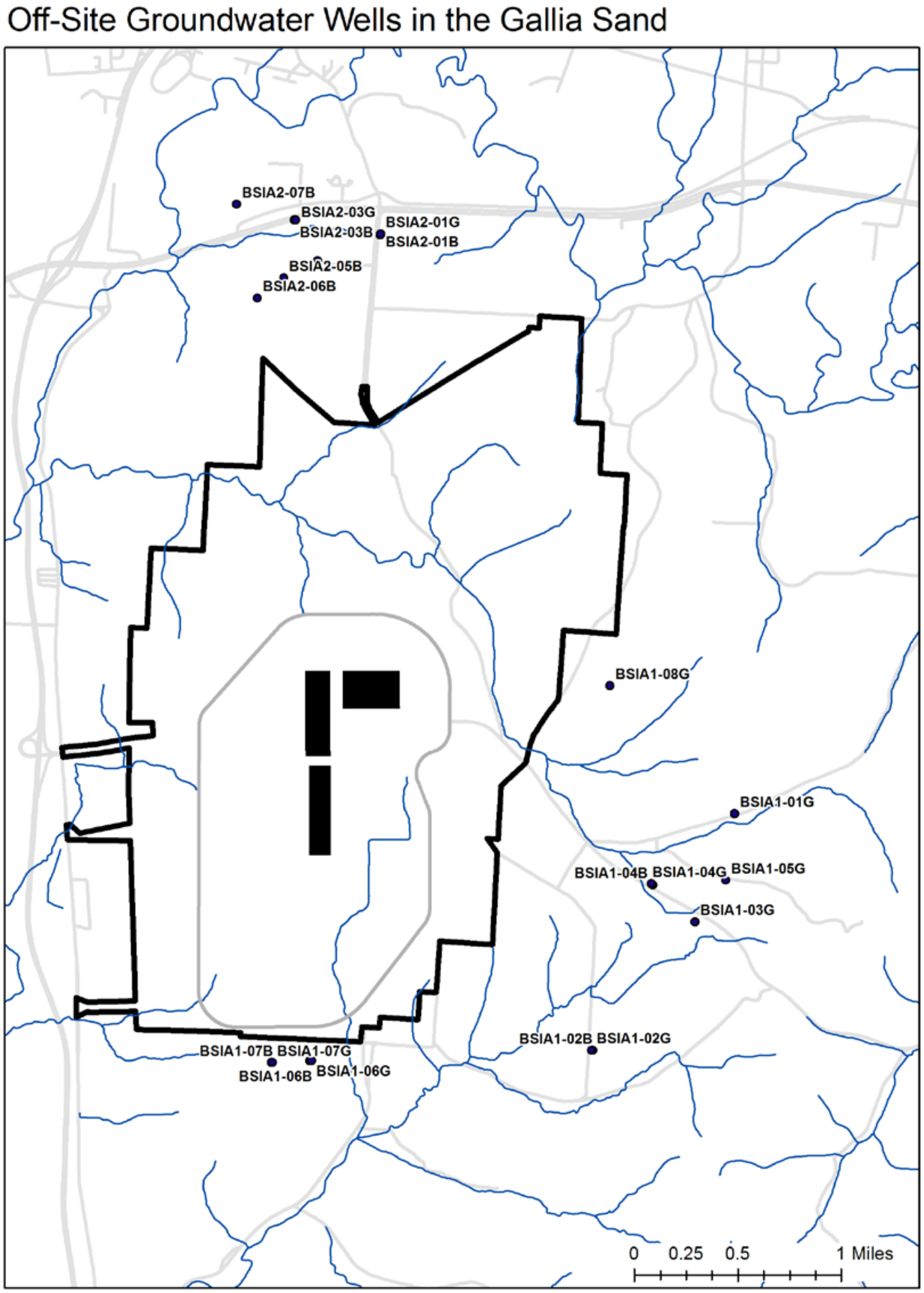


Figure 2.10 Location of Off-Site Groundwater Wells

2.8 Yield of the Gallia Aquifer

Ohio EPA defines an aquifer based on its ability to yield a significant amount of water to wells and springs. While a numeric value is not placed on the yield necessary, comparison to other regional aquifers is used to determine significance of yield. The two aquifers underlying the PORTS site which should be compared for future domestic or industrial use are the Gallia Sand and the Berea Sandstone. The well yield from the Berea Sandstone is thought to be in the order of 1-2 gpm and the hydraulic conductivity of the Berea Sandstone varies from 1.5 x 10^{-3} to 5 meters/day (DOE 2009). The higher conductivity areas tend to be in the areas where the Sunbury Shale is absent.

Based on the analysis of DOE's 1996 data collection in the Gallia Sand, the average yield was 2.5 gpm with a median value of 0.66 gpm. This is in the same order of magnitude of the Berea Sandstone aquifer. The hydraulic conductivity of the Gallia is 3.3 meters/day on average with a median value of 0.85 meters/day. Histograms of both yield and hydraulic conductivity in the Gallia as measured by Department of Energy in 1996 are shown in Figures 2.11 and 2.12.

This comparison suggests that, although the yields of both the Berea Sandstone and the Gallia Sand are both low, they are well within the same order of magnitude and, therefore, neither should be eliminated as a potential future source of domestic water. The high hydraulic conductivity of the Gallia Sand could make it a promising future water source over the Berea Sandstone. The Scioto River Aquifer is a high yield regional aquifer, but has been excluded from this comparison because it does not underlie the PORTS site.

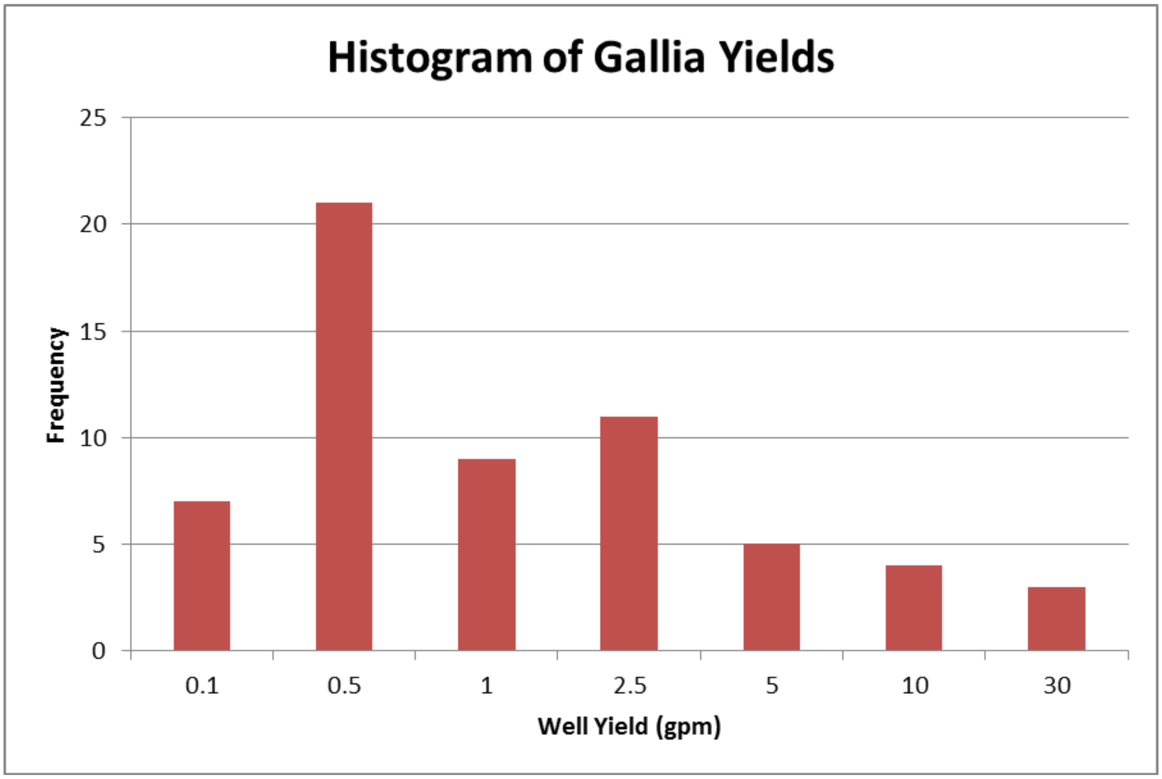


Figure 2.11. Histogram of measured well yield from the Gallia Sand.

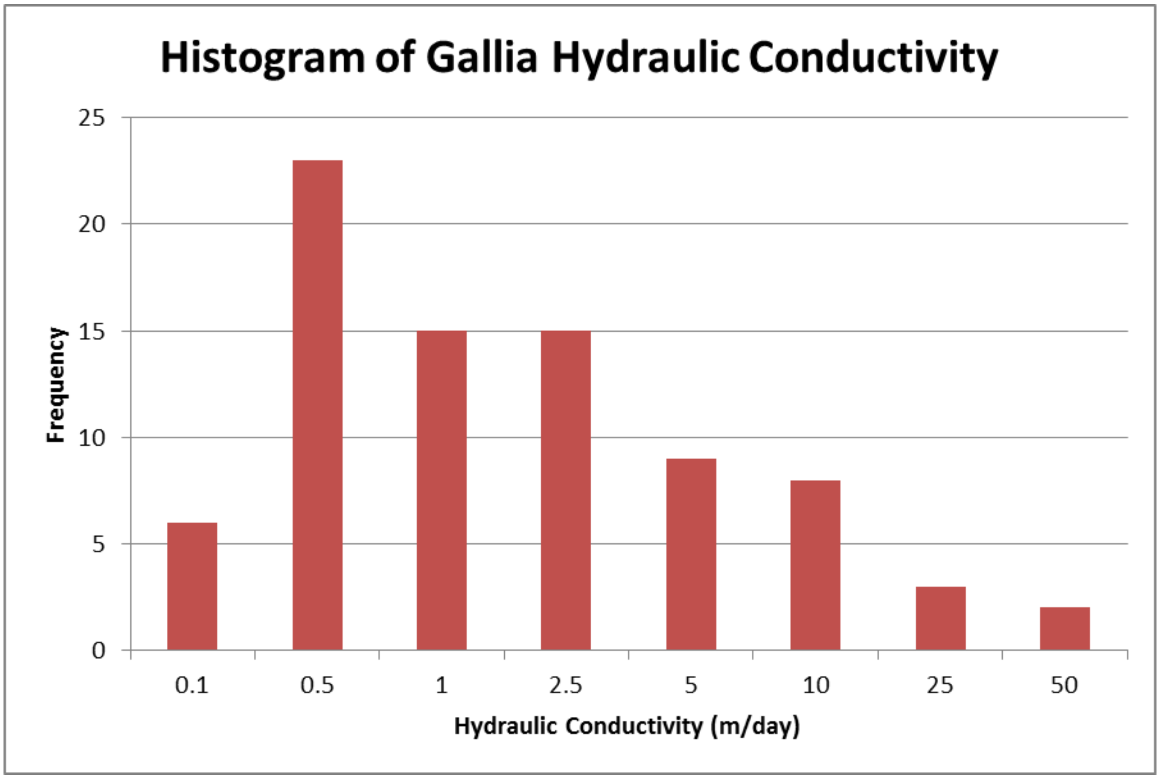
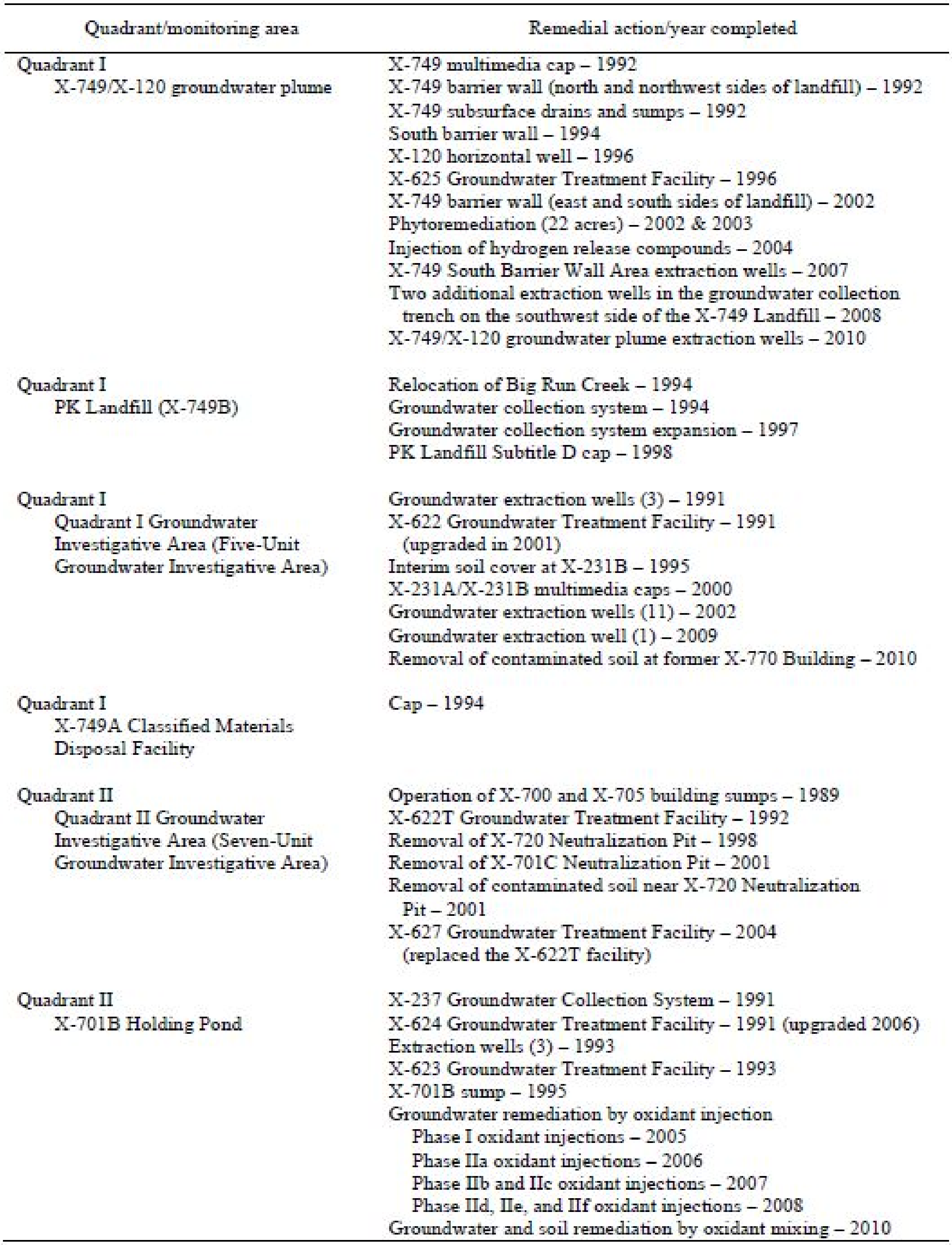


Figure 2.12. Histogram of calculated hydraulic conductivity from the Gallia Sand.

2.9 Environmental Restoration and Groundwater Monitoring

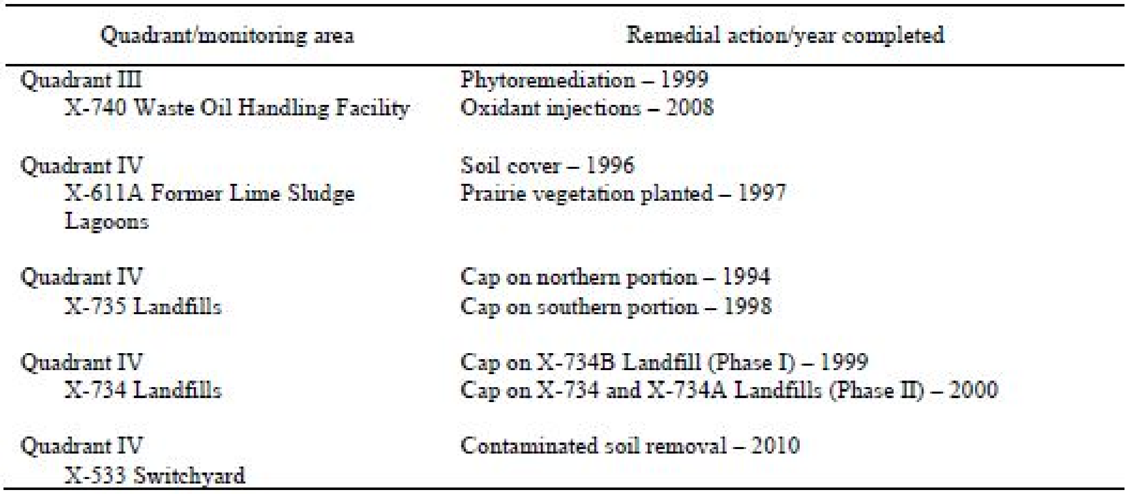
An Environmental Restoration Program was established by DOE in 1989 to identify, control, and remediate environmental contamination at PORTS. The 1989 Ohio Consent Decree and the 1989 U.S. EPA Administrative Consent Order (as amended in 1994 and 1997) require investigation and cleanup of environmental media at PORTS in accordance with the Resource Conservation and Recovery Act (RCRA) Corrective Action Program. The site was divided into quadrants to facilitate the investigation and cleanup. Corrective actions, also called remedial actions, are underway in each quadrant. The goal of the Environmental Restoration Program is to verify that releases from past operations at PORTS are thoroughly investigated and that remedial actions are taken to protect human health and the environment. Table 2.3 shows remedial actions to improve environmental conditions at PORTS.

Table 2.3 Remedial Actions Performed at PORTS Groundwater Monitoring Sites (DOE 2012)



Quadrant/monitoring area	Remedial action/year completed
Quadrant I X-749/X-120 groundwater plume	X-749 multimedia cap – 1992 X-749 barrier wall (north and northwest sides of landfill) – 1992 X-749 subsurface drains and sumps – 1992 South barrier wall – 1994 X-120 horizontal well – 1996 X-625 Groundwater Treatment Facility – 1996 X-749 barrier wall (east and south sides of landfill) – 2002 Phytoremediation (22 acres) – 2002 & 2003 Injection of hydrogen release compounds – 2004 X-749 South Barrier Wall Area extraction wells – 2007 Two additional extraction wells in the groundwater collection trench on the southwest side of the X-749 Landfill – 2008 X-749/X-120 groundwater plume extraction wells – 2010
Quadrant I PK Landfill (X-749B)	Relocation of Big Run Creek – 1994 Groundwater collection system – 1994 Groundwater collection system expansion – 1997 PK Landfill Subtitle D cap – 1998
Quadrant I Quadrant I Groundwater Investigative Area (Five-Unit Groundwater Investigative Area)	Groundwater extraction wells (3) – 1991 X-622 Groundwater Treatment Facility – 1991 (upgraded in 2001) Interim soil cover at X-231B – 1995 X-231A/X-231B multimedia caps – 2000 Groundwater extraction wells (11) – 2002 Groundwater extraction well (1) – 2009 Removal of contaminated soil at former X-770 Building – 2010
Quadrant I X-749A Classified Materials Disposal Facility	Cap – 1994
Quadrant II Quadrant II Groundwater Investigative Area (Seven-Unit Groundwater Investigative Area)	Operation of X-700 and X-705 building sumps – 1989 X-622T Groundwater Treatment Facility – 1992 Removal of X-720 Neutralization Pit – 1998 Removal of X-701C Neutralization Pit – 2001 Removal of contaminated soil near X-720 Neutralization Pit – 2001 X-627 Groundwater Treatment Facility – 2004 (replaced the X-622T facility)
Quadrant II X-701B Holding Pond	X-237 Groundwater Collection System – 1991 X-624 Groundwater Treatment Facility – 1991 (upgraded 2006) Extraction wells (3) – 1993 X-623 Groundwater Treatment Facility – 1993 X-701B sump – 1995 Groundwater remediation by oxidant injection Phase I oxidant injections – 2005 Phase IIa oxidant injections – 2006 Phase IIb and IIc oxidant injections – 2007 Phase IId, IIe, and IIf oxidant injections – 2008 Groundwater and soil remediation by oxidant mixing – 2010

Table 2.3 (continued) Remedial Actions Performed at PORTS Groundwater Monitoring Sites



Quadrant/monitoring area	Remedial action/year completed
Quadrant III X-740 Waste Oil Handling Facility	Phytoremediation – 1999 Oxidant injections – 2008
Quadrant IV X-611A Former Lime Sludge Lagoons	Soil cover – 1996 Prairie vegetation planted – 1997
Quadrant IV X-735 Landfills	Cap on northern portion – 1994 Cap on southern portion – 1998
Quadrant IV X-734 Landfills	Cap on X-734B Landfill (Phase I) – 1999 Cap on X-734 and X-734A Landfills (Phase II) – 2000
Quadrant IV X-533 Switchyard	Contaminated soil removal – 2010

Groundwater monitoring at PORTS is performed at RCRA hazardous waste units, solid waste disposal units, and RCRA Corrective Action Program units. The *Integrated Groundwater Monitoring Plan* (IGWMP) describes the groundwater monitoring program for PORTS, which has been reviewed and approved by Ohio EPA. The IGWMP establishes economies of scale for groundwater monitoring by focusing activities over larger areas rather than on individual wells or waste management units within an area. Specifically, the identity and location of the appropriate subset of monitoring wells, the identity of constituents for sampling, and the frequency of sampling are determined on the basis of an evaluation of historical monitoring results, process knowledge, and other information and requirements from previous investigations conducted at PORTS (DOE 2010b).

Samples are collected from wells at 12 groundwater monitoring areas and 13 surface water locations that are part of the groundwater monitoring program. Samples are analyzed for metals, volatile organic compounds, and/or radiological constituents. Constituents detected in the groundwater are then evaluated to assess the potential for each constituent to affect human health and the environment.

The 12 groundwater monitoring areas are as follows (see Figure 2.13, Groundwater Monitoring Areas)

Quadrant I

– X-749/X-120/PK Landfill,

– Quadrant I Groundwater Investigative Area/X-749A Classified Materials Disposal Facility,

Quadrant II

– Quadrant II Groundwater Investigative Area,

– X-701B Holding Pond,

– X-633 Pumphouse/Cooling Towers Area,

Quadrant III

– X-616 Chromium Sludge Surface Impoundments,

– X-740 Waste Oil Handling Facility,

Quadrant IV

– X-611A Former Lime Sludge Lagoons,

– X-735 Landfills,

– X-734 Landfills,

– X-533 Switchyard Area, and

– Former X-344C Hydrogen Fluoride Storage Building.

Water samples are collected from wells (or surface water locations) at each area listed above and are analyzed for metals, volatile organic compounds, and/or radionuclides. The following table (Table 2.4) lists the requirements for each groundwater monitoring area. Constituents detected in the groundwater are then compared to standards called preliminary remediation goals to assess the potential for each constituent to affect human health and the environment (DOE 2012).

Five areas of groundwater contamination have been identified at PORTS. Groundwater contamination consists of volatile organic compounds (primarily trichloroethene) and radionuclides such as technetium-99. The areas that contain groundwater plumes are:

- X-749/X-120/PK Landfill, Quadrant I Groundwater Investigative Area
- X-749A Classified Materials Disposal Facility
- Quadrant II Groundwater Investigative Area
- X-701B Holding Pond
- X-740 Waste Oil Handling Facility.

Other areas are monitored to evaluate groundwater contaminated with metals, to ensure past uses of the area, such as a landfill, have not caused groundwater contamination, or to monitor remediation that has taken place in the area. The groundwater monitoring areas have many monitoring and extraction wells used to analyze contaminant plumes, pump and treat contaminated groundwater, and alter groundwater flow to keep contaminants contained to specific regions. Table 2.4 lists the analytical parameters for the wells in the various monitoring areas. In 2010, a combined total of almost 36 million gallons of water were treated at the X-622, X-623, X-624, and X-627 Groundwater Treatment Facilities. Approximately 197 gallons of trichloroethene were removed from the water (DOE 2012).

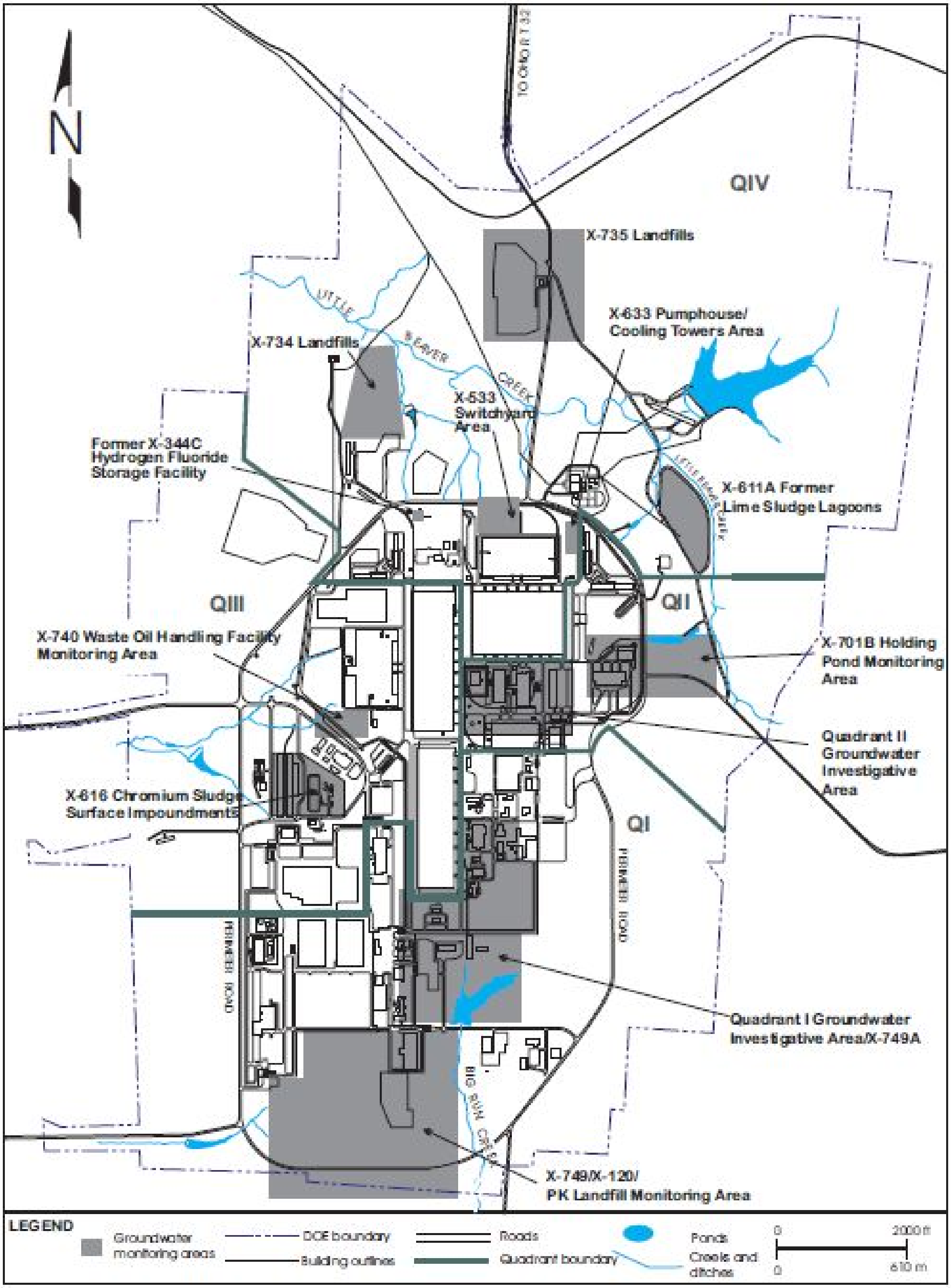
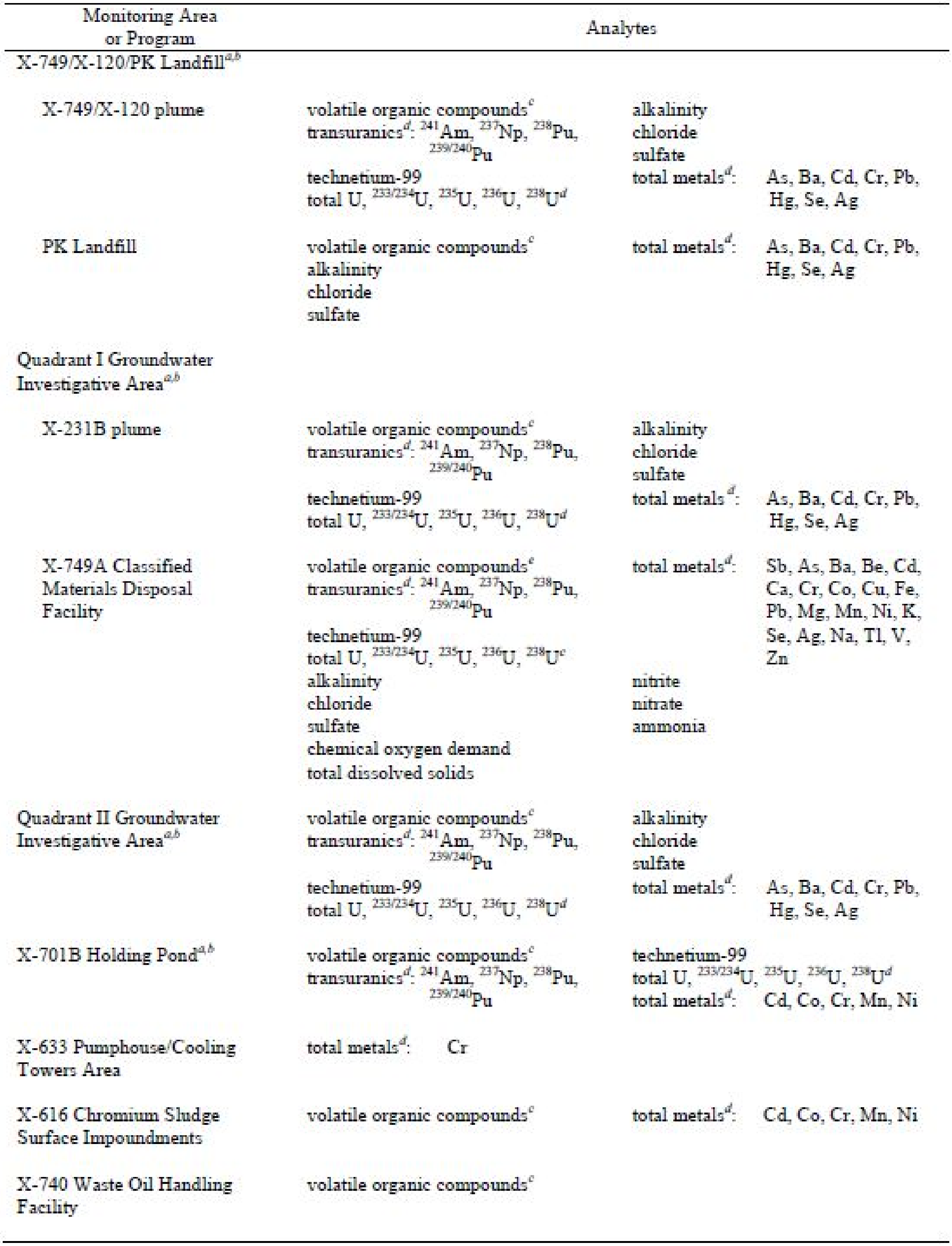


Figure 2.13 Groundwater Monitoring Areas (DOE 2012)

Table 2.4 Analytical Parameters for Monitoring Areas (DOE 2012)



Monitoring Area or Program	Analytes		
X-749/X-120/PK Landfill[a,b]			
X-749/X-120 plume	volatile organic compounds[c] transuranics[d]: ^{241}Am, ^{237}Np, ^{238}Pu, $^{239/240}$Pu technetium-99 total U, $^{233/234}$U, ^{235}U, ^{236}U, ^{238}U[d]	alkalinity chloride sulfate total metals[d]:	As, Ba, Cd, Cr, Pb, Hg, Se, Ag
PK Landfill	volatile organic compounds[c] alkalinity chloride sulfate	total metals[d]:	As, Ba, Cd, Cr, Pb, Hg, Se, Ag
Quadrant I Groundwater Investigative Area[a,b]			
X-231B plume	volatile organic compounds[c] transuranics[d]: ^{241}Am, ^{237}Np, ^{238}Pu, $^{239/240}$Pu technetium-99 total U, $^{233/234}$U, ^{235}U, ^{236}U, ^{238}U[d]	alkalinity chloride sulfate total metals[d]:	As, Ba, Cd, Cr, Pb, Hg, Se, Ag
X-749A Classified Materials Disposal Facility	volatile organic compounds[c] transuranics[d]: ^{241}Am, ^{237}Np, ^{238}Pu, $^{239/240}$Pu technetium-99 total U, $^{233/234}$U, ^{235}U, ^{236}U, ^{238}U[e] alkalinity chloride sulfate chemical oxygen demand total dissolved solids	total metals[d]: nitrite nitrate ammonia	Sb, As, Ba, Be, Cd, Ca, Cr, Co, Cu, Fe, Pb, Mg, Mn, Ni, K, Se, Ag, Na, Tl, V, Zn
Quadrant II Groundwater Investigative Area[a,b]	volatile organic compounds[c] transuranics[d]: ^{241}Am, ^{237}Np, ^{238}Pu, $^{239/240}$Pu technetium-99 total U, $^{233/234}$U, ^{235}U, ^{236}U, ^{238}U[d]	alkalinity chloride sulfate total metals[d]:	As, Ba, Cd, Cr, Pb, Hg, Se, Ag
X-701B Holding Pond[a,b]	volatile organic compounds[c] transuranics[d]: ^{241}Am, ^{237}Np, ^{238}Pu, $^{239/240}$Pu	technetium-99 total U, $^{233/234}$U, ^{235}U, ^{236}U, ^{238}U[d] total metals[d]:	Cd, Co, Cr, Mn, Ni
X-633 Pumphouse/Cooling Towers Area	total metals[d]: Cr		
X-616 Chromium Sludge Surface Impoundments	volatile organic compounds[c]	total metals[d]:	Cd, Co, Cr, Mn, Ni
X-740 Waste Oil Handling Facility	volatile organic compounds[c]		

Table 2.4 (continued) Analytical Parameters for Monitoring Areas

Monitoring Area or Program	Analytes	
X-611A Former Lime Sludge Lagoons	total metals[d]: Be, Cr	
X-735 Landfills	volatile organic compounds[e] transuranics[d]: ^{241}Am, ^{237}Np, ^{238}Pu, $^{239/240}$Pu technetium-99 total U, $^{233/234}$U, ^{235}U, ^{236}U, ^{238}U[d] alkalinity chloride sulfate chemical oxygen demand	total metals[d]: Sb, As, Ba, Be, Cd, Ca, Cr, Co, Cu, Fe, Hg, Pb, Mg, Mn, Ni, K, Se, Ag, Na, Tl, V, Zn nitrite nitrate ammonia total dissolved solids
X-734 Landfills	volatile organic compounds[e] technetium-99 total U, $^{233/234}$U, ^{235}U, ^{236}U, ^{238}U[d] alkalinity chloride sulfate chemical oxygen demand	total metals[d]: Cd, Co, Cr, Mn, Ni, Na nitrite nitrate ammonia total dissolved solids
X-533 Switchyard Area	total metals[d]: Cd, Co, Ni	
Former X-344C Hydrogen Fluoride Storage Building	volatile organic compounds[c]	
Surface Water	volatile organic compounds[c] transuranics[d]: ^{241}Am, ^{237}Np, ^{238}Pu, $^{239/240}$Pu	technetium-99 total U, $^{233/234}$U, ^{235}U, ^{236}U, ^{238}U[d]
Water Supply	volatile organic compounds[c] transuranics[d]: ^{241}Am, ^{237}Np, ^{238}Pu, $^{239/240}$Pu	technetium-99 total U, $^{233/234}$U, ^{235}U, ^{236}U, ^{238}U[d]
Exit Pathway[b]	volatile organic compounds[c] transuranics[d]: ^{241}Am, ^{237}Np, ^{238}Pu, $^{239/240}$Pu	technetium-99 total U, $^{233/234}$U, ^{235}U, ^{236}U, ^{238}U[d]

[a] Selected well(s) in this area are sampled once every two years for a comprehensive list of over 200 potential contaminants (Title 40, Code of Federal Regulations, Part 264 Appendix IX – Appendix to Ohio Administrative Code Rule 3745-54-98).

[b] Not all wells in this area are analyzed for all listed analytes.

[c] Acetone, benzene, bromodichloromethane, bromoform, carbon disulfide, carbon tetrachloride, chlorobenzene, chloroethane, chloroform, dibromochloromethane, 1,2-dichlorobenzene, 1,4-dichlorobenzene, 1,1-dichloroethane, 1,2-dichloroethane, 1,1-dichloroethene, cis-1,2-dichloroethene, trans-1,2-dichloroethene, ethylbenzene, bromomethane, chloromethane, methylene chloride, 2-butanone (methyl ethyl ketone), 4-methyl-2-pentanone (methyl isobutyl ketone), 1,1,2,2-tetrachloroethane, tetrachloroethene, toluene, 1,1,1-trichloroethane, 1,1,2-trichloroethane, trichloroethene, trichlorofluoromethane (CFC-11), vinyl chloride, xylenes (M+P xylenes).

[d] Appendix C lists the symbols for metals and transuranic radionuclides.

[e] Volatile organic compounds listed in footnote c plus: acrylonitrile, bromochloromethane, 1,2-dibromo-3-chloropropane, 1,2-dibromoethane, trans-1,4-dichloro-2-butene, 1,2-dichloropropane, cis-1,3-dichloropropene, trans-1,3-dichloropropene, 2-hexanone (methyl butyl ketone), dibromomethane, iodomethane, styrene, 1,1,1,2-tetrachloroethane, 1,2,3-trichloropropane, and vinyl acetate.

Section 3. Groundwater Quality and Quantity in Ohio

3.1 Ohio Groundwater Quality and Quantity

According to Ohio Environmental Protection Agency’s 2012 integrated report of groundwater quality in Ohio, Ohio has abundant groundwater resources. In Ohio average rainfall ranges between 30 and 44 inches per year, providing valuable recharge to the regional aquifers. Ohio has seven principal aquifers (Figure 3.1) that can be divided into three major types: the unconsolidated sand and gravel buried valley aquifers throughout the state, consolidated sandstone and shale on the eastern half of the state, and consolidated carbonate aquifers on the western half of the state (OEPA 2012a).

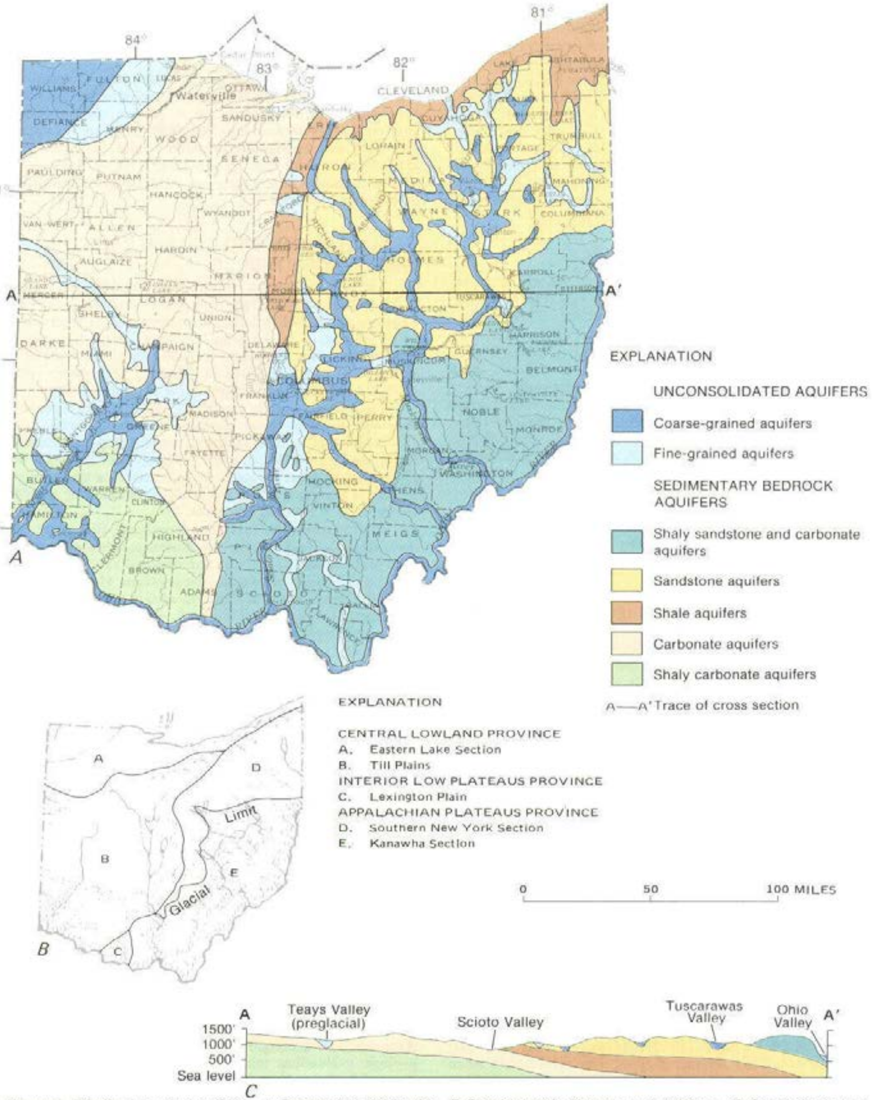


Figure 1. Principal aquifers in Ohio. *A*, Geographic distribution. *B*, Physiographic diagram and divisions. *C*, Generalized cross section (A-A'). (See table 2 for a more detailed description of the aquifers. Sources: *A*, Files of the Ohio Department of Natural Resources, Division of Water. *B*, Fenneman, 1938; Raisz, 1954. *C*, Files of the Ohio Department of Natural Resources, Division of Geological Survey.)

Figure 3.1. Mapped Unconsolidated and Consolidated Aquifers in Ohio (OEPA 2012a)

Unconsolidated sand and gravel aquifers are the most productive water bearing formation in Ohio. These buried valley aquifers exist beneath and adjacent to the Ohio

River, its tributaries, and pre-glacial stream channels of the Teays River system (Figure 3.2). Formation of these buried valley aquifers occurred as stream channels were cut into the bedrock of pre-glacial valleys, followed by back-filling with glacial deposits of sand and gravel as the glaciers advanced and receded. The coarser grained thick sand and gravel deposits can yield groundwater quantities from 500 to 1,000gpm. The consolidated sandstone aquifers in eastern Ohio yield an average of 25gpm, while in the southeastern part of the state aquifer exhibit much lower yields of approximately 5gpm (Figure 3.3). The consolidated carbonate aquifer in western Ohio yields 100-500gpm, this higher yield is associated with the fractures and dissolution that further increase permeability. In southwestern Ohio where the geology is dominated by shale the yields are less than 10gpm. In this area, public water systems depend on the buried valley aquifers as their main ground water source, as well as in central Ohio where the Devonian shale dominates aquifers are poor and yields are low (OEPA 2012a).

According to National Water Summary from 1986, most groundwater is very hard with median hardness of 216 mg/l in the sandstones and 447 mg/l in the carbonate aquifers. "Groundwater contamination problems are generally of limited extent and involve no more than one or two wells close to a pollution source" (Palmstrom 1984). In general the leading sources of groundwater contamination statewide are onsite sewage systems primarily from septic tanks. While specifically in the southwest, there is an increase of groundwater contamination related to the effects of urbanization and industrial activities and in eastern Ohio there is localized degradation from surface coal mining (Lane & Swisshelm 1988).

From the 2012 integrated groundwater report, Table 3.1 provides a summary of the verified groundwater contamination in Ohio from various state programs. The National Priorities List (NPL) states there are 35 sites in Ohio on the NPL that are affecting groundwater with contamination from VOCs and heavy metals. According to the federal CERCLIS database 58 of the 402 listed sites in Ohio have had a release to groundwater. DOD/DOE states 68 of the 124 sites listed have confirmed releases to groundwater. In Ohio 32,000 underground storage tanks have been found to be leaking, of these 1,231 have confirmed releases with 660 releasing to groundwater. The primary contaminants are petroleum products (BTEX). RCRA shows all 130 facilities in corrective action have confirmed releases of VOCs and heavy metals to groundwater. There are thousands of underground injection wells of various classes of which fluids are injected beneath the lowermost aquifer. "State sites" include landfills, RCRA-regulated hazardous waste sites, Pre-RCRA sites, and sites investigated through the Voluntary Action Program (VAP). Groundwater contamination is tracked in the Ground Water Impacts Database, of the 617 sites, 246 sites have affected groundwater quality within the uppermost aquifer or lower aquifer.

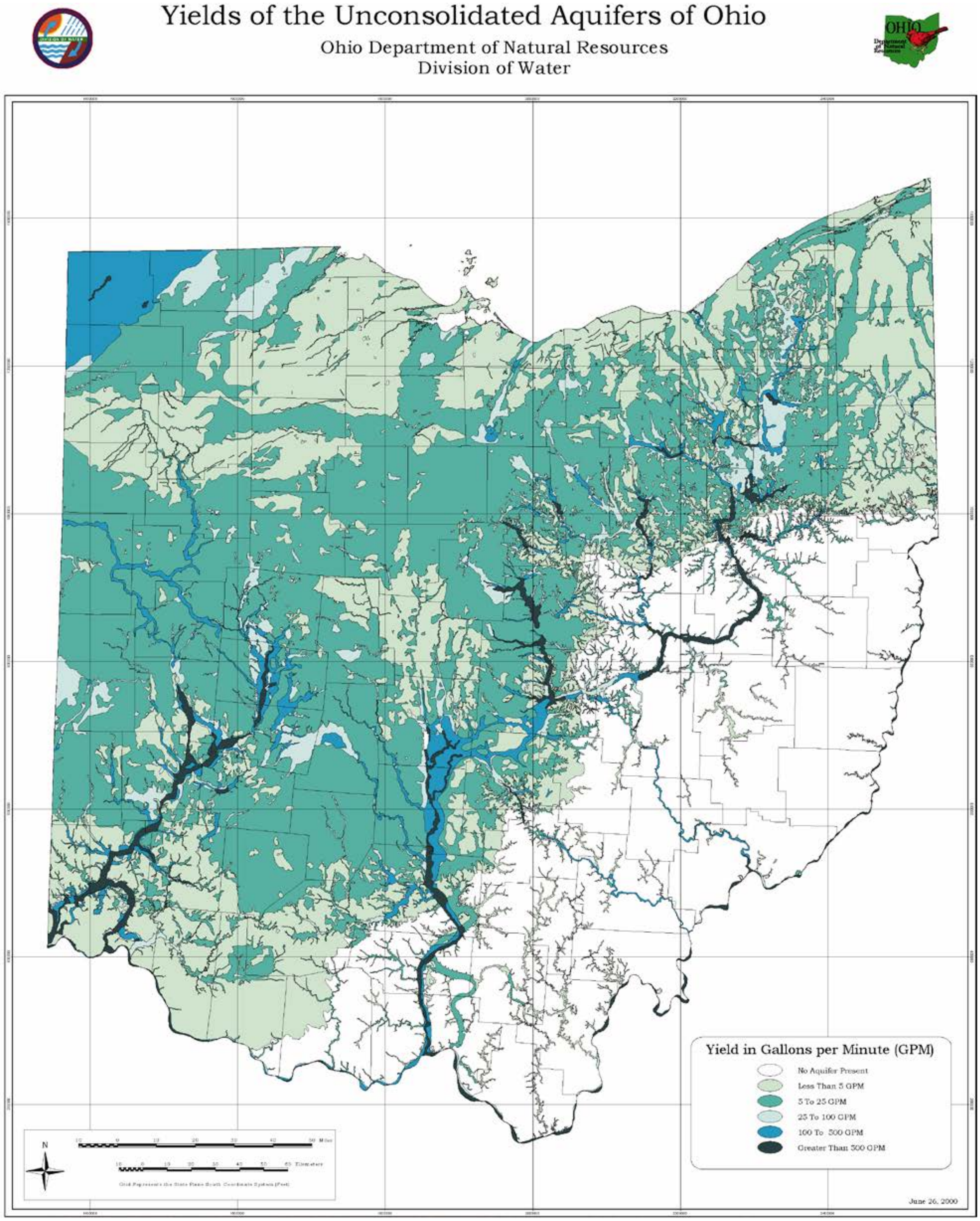


Figure 3.2. Yields of unconsolidated aquifers in Ohio (ODNR 2012a)

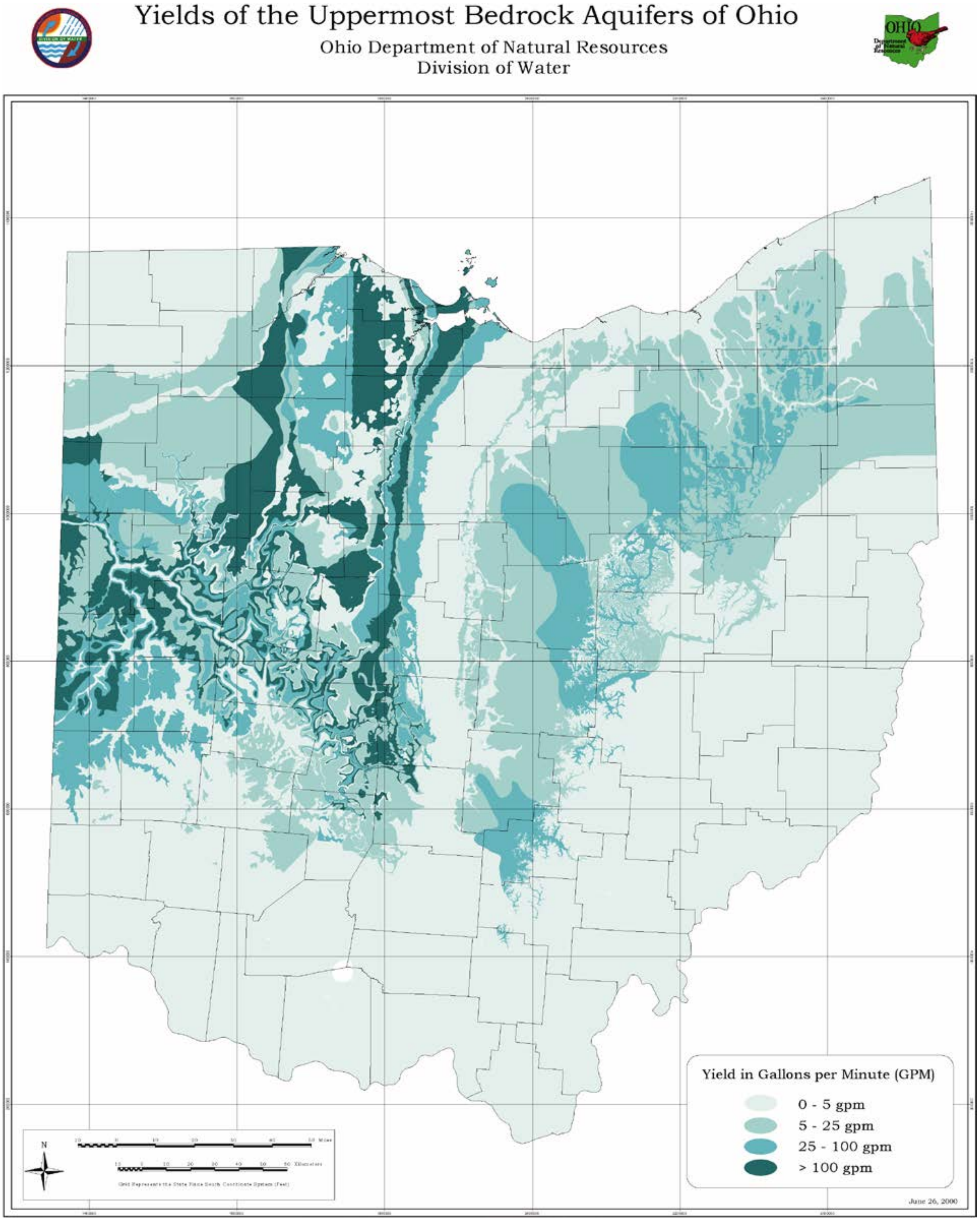
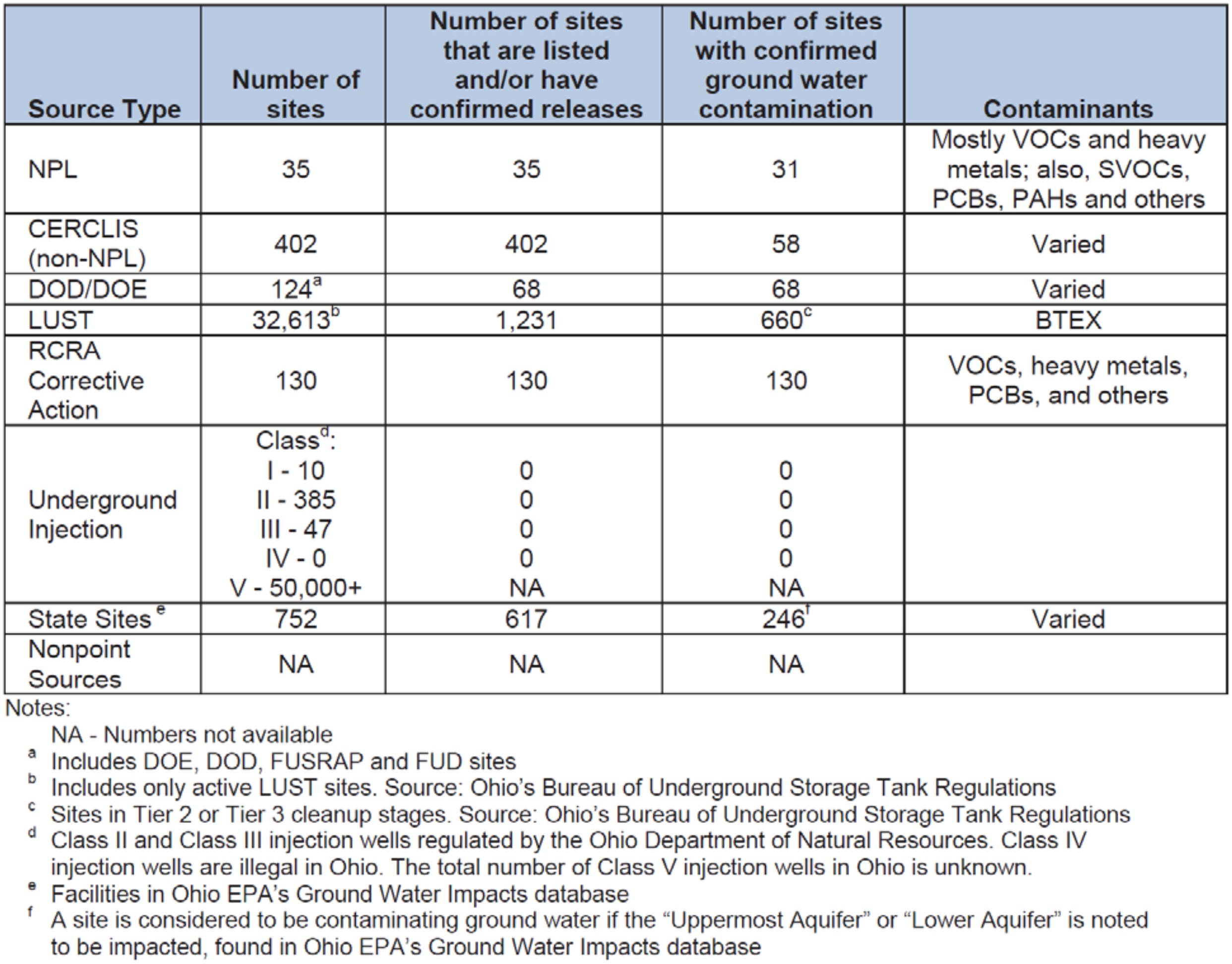


Figure 3.3. Yields of uppermost bedrock aquifers in Ohio (ODNR 2012b)

Table 3.1. Summary of the groundwater contamination in Ohio (OEPA 2012a)



Source Type	Number of sites	Number of sites that are listed and/or have confirmed releases	Number of sites with confirmed ground water contamination	Contaminants
NPL	35	35	31	Mostly VOCs and heavy metals; also, SVOCs, PCBs, PAHs and others
CERCLIS (non-NPL)	402	402	58	Varied
DOD/DOE	124[a]	68	68	Varied
LUST	32,613[b]	1,231	660[c]	BTEX
RCRA Corrective Action	130	130	130	VOCs, heavy metals, PCBs, and others
Underground Injection	Class[d]: I - 10 II - 385 III - 47 IV - 0 V - 50,000+	 0 0 0 0 NA	 0 0 0 0 NA	
State Sites [e]	752	617	246[f]	Varied
Nonpoint Sources	NA	NA	NA	

Notes:

NA - Numbers not available

[a] Includes DOE, DOD, FUSRAP and FUD sites

[b] Includes only active LUST sites. Source: Ohio's Bureau of Underground Storage Tank Regulations

[c] Sites in Tier 2 or Tier 3 cleanup stages. Source: Ohio's Bureau of Underground Storage Tank Regulations

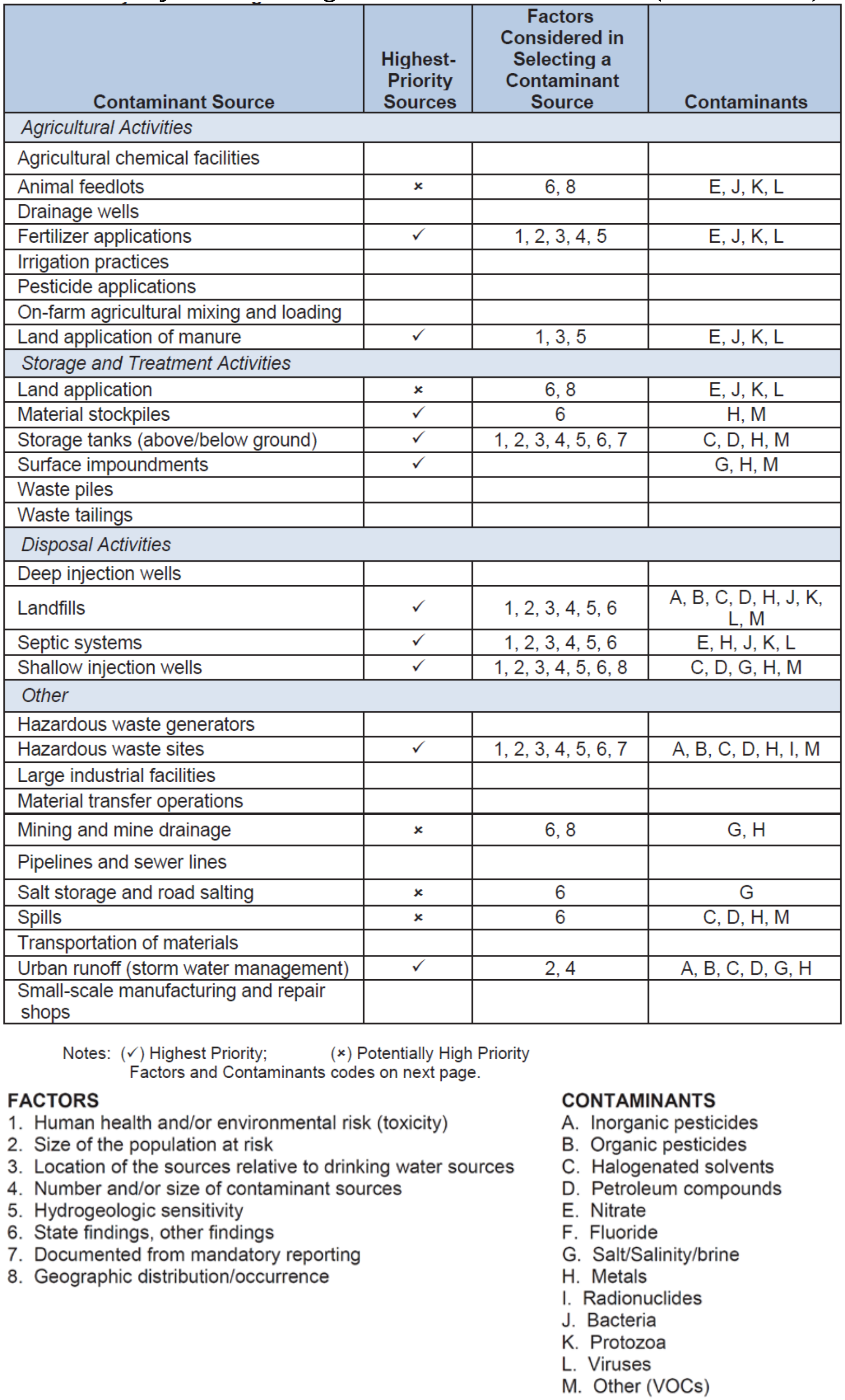
[d] Class II and Class III injection wells regulated by the Ohio Department of Natural Resources. Class IV injection wells are illegal in Ohio. The total number of Class V injection wells in Ohio is unknown.

[e] Facilities in Ohio EPA's Ground Water Impacts database

[f] A site is considered to be contaminating ground water if the "Uppermost Aquifer" or "Lower Aquifer" is noted to be impacted, found in Ohio EPA's Ground Water Impacts database

Much of Ohio's groundwater is of high quality; however, anthropogenic activities widely influence the cases of point and non-point contamination each year. Groundwater is susceptible to contamination from a range of contaminants and a variety of land uses. The EPA's integrated report for Ohio display the major sources of groundwater contamination (Table 3.2).

Table 3.2. Major sources of groundwater contamination (OEPA 2012a)



Contaminant Source	Highest-Priority Sources	Factors Considered in Selecting a Contaminant Source	Contaminants
Agricultural Activities			
Agricultural chemical facilities			
Animal feedlots	×	6, 8	E, J, K, L
Drainage wells			
Fertilizer applications	✓	1, 2, 3, 4, 5	E, J, K, L
Irrigation practices			
Pesticide applications			
On-farm agricultural mixing and loading			
Land application of manure	✓	1, 3, 5	E, J, K, L
Storage and Treatment Activities			
Land application	×	6, 8	E, J, K, L
Material stockpiles	✓	6	H, M
Storage tanks (above/below ground)	✓	1, 2, 3, 4, 5, 6, 7	C, D, H, M
Surface impoundments	✓		G, H, M
Waste piles			
Waste tailings			
Disposal Activities			
Deep injection wells			
Landfills	✓	1, 2, 3, 4, 5, 6	A, B, C, D, H, J, K, L, M
Septic systems	✓	1, 2, 3, 4, 5, 6	E, H, J, K, L
Shallow injection wells	✓	1, 2, 3, 4, 5, 6, 8	C, D, G, H, M
Other			
Hazardous waste generators			
Hazardous waste sites	✓	1, 2, 3, 4, 5, 6, 7	A, B, C, D, H, I, M
Large industrial facilities			
Material transfer operations			
Mining and mine drainage	×	6, 8	G, H
Pipelines and sewer lines			
Salt storage and road salting	×	6	G
Spills	×	6	C, D, H, M
Transportation of materials			
Urban runoff (storm water management)	✓	2, 4	A, B, C, D, G, H
Small-scale manufacturing and repair shops			

Notes: (✓) Highest Priority; (×) Potentially High Priority
Factors and Contaminants codes on next page.

FACTORS
1. Human health and/or environmental risk (toxicity)
2. Size of the population at risk
3. Location of the sources relative to drinking water sources
4. Number and/or size of contaminant sources
5. Hydrogeologic sensitivity
6. State findings, other findings
7. Documented from mandatory reporting
8. Geographic distribution/occurrence

CONTAMINANTS
A. Inorganic pesticides
B. Organic pesticides
C. Halogenated solvents
D. Petroleum compounds
E. Nitrate
F. Fluoride
G. Salt/Salinity/brine
H. Metals
I. Radionuclides
J. Bacteria
K. Protozoa
L. Viruses
M. Other (VOCs)

Section 4. Summary of Relevant Federal and Ohio State Regulations

4.1 National Oil and Hazardous Substances Pollution Contingency Plan (NCP)

NCP is the government's planning structure for responding to oil spills and hazardous substance releases. Since the creation of the first NCP which focused on response to oil spills only, it has been revised to include response to hazardous substance spills through provisions in the Clean Water Act (CWA) of 1972 and to include releases at hazardous waste sites require emergency removal actions through provisions in Comprehensive Environmental Response, Compensation and Liability Act (CERCLA). NCP establishes that organizational structure and procedures for responding to discharges of hazardous substances under the CWA and CERCLA in Section 300.415 (EPA 2011b).

NCP is the basis for the Department of Energy's implementation of CERCLA, for acting as a natural resources trustee for land that DOE manages, for performing natural resources damages assessment and for assuming authority for certain response actions (DOE 1995). NCP states that "Maximum contaminant level goals (MCLGs), established under the Safe Drinking Water Act, that are set at levels above zero, [or] maximum contaminant level (MCL) shall be attained where relevant and appropriate to the circumstances of the release (40 CFR Section 300.430(3)(B) and (C))." NCP has the general expectation that groundwater remediation will restore beneficial use of aquifers within a reasonable timeframe. When this isn't practicable, the expectation of cleanup is to prevent further plume migration, prevent exposure to contaminated groundwater and to work towards further risk reduction (40 CFR Section 300.430(a)(1)(iii)(F)).

4.2 Comprehensive Environmental Response, Compensation and Liability Act (CERCLA)

CERCLA, commonly known as Superfund, gave the federal government authority to respond directly to releases of hazardous substances that may endanger health or the environment. CERCLA established a method of determining liability for cleanup costs, prohibitions and requirements for abandoned sites and a trust fund for cleanups at sites with no responsible party. Section 120(a)(2) of CERCLA states that all guidelines, rules, regulations and criteria are applicable to both Federal and non-Federal facilities (EPA 2011c).

CERCLA groundwater cleanup actions "shall require a level or standard of control which at least attains Maximum Contaminant Level Goals established under the Safe Drinking Water Act and water quality criteria established under section 303 or 304 of the Clean Water Act, where such goals or criteria are relevant and appropriate under the circumstances of the release or potential release (CERCLA 121 (d)(2)(A))." Cleanup under CERCLA actions ought to be protective of human health and the environment and should seek to restore contaminated groundwaters to their beneficial uses, preventing migration of contaminant plumes and protecting groundwater and other environmental resources. CERCLA requires that all pathways of exposure to contaminated groundwater or related environmental media be considered in a risk assessment for human health and the environment. With the recognition that groundwater resources are valued, generally CERCLA response actions achieve MCLs and non-zero MCLGs for current or potential drinking water resources (EPA 2009b). Beneficial use designation can be derived through the classification guide developed in 1986 by the EPA (EPA 1986b). CERCLA states that cleanup must be protective and should tend towards more conservative cleanup actions (EPA 2009b).

Cleanup levels for CERCLA actions are developed through site-specific risk assessments and Applicable or Relevant and Appropriate Requirements (ARARs). CERCLA suggests Clean Water Act water quality criteria as potential cleanup goals where the water may be used for drinking. All ARARs should be protective of human health and the environment. Institutional Controls (IC) are an appropriate method of protecting human health in the short term. In general, they should not be a replacement for active remediation and instead should be used as supplementary protective measures in the short term. An IC-only solution should be a last resort decision used only after a Technical Impracticability (TI) waiver has been approved. For areas of aquifers in which it is technically impractical to remediate the site, an IC may be used to prevent exposure to the remaining contaminant. Additionally, an IC may be used to protect human health during monitored natural attenuation projects.

4.3 EPA Ground-Water Protection Strategy – Guidelines for Ground-Water Classification

The USEPA developed guidelines for classifying groundwater resources to determine necessary cleanup actions and remedial goals. The guidelines divide groundwater resources into three main classifications; Class I aquifers are special groundwater, Class II aquifers are groundwater that is either currently in use as a drinking water source or could potentially be used as a source of drinking water. Class III aquifers are not a source of drinking waters. The majority of aquifers are Class II aquifers. Class I aquifers are vulnerable to contamination and are either irreplaceable sources of drinking water or are ecologically vital. Class II aquifers are not necessarily vulnerable, but are currently used (Class IIA) or could potentially be used (Class IIB) as a source of drinking water. For an aquifer to be considered a potential source of drinking water, it must have a TDS concentration less than 10,000 mg/L which can be used without treatment or can be treated using methods reasonably employed in a public water supply and must have yields of 150 gallons/day. Class III aquifers are those that are saline (>10,000 mg/L TDS), are so contaminated that they cannot be treated using methods reasonably employed in a public water supply or have insufficient yield at any depth to supply 150 gallons/day of water. Methods of treatment that are in common use in public water treatment systems include aeration, air stripping, carbon adsorption, chemical precipitation, chlorination, flotation, fluoridation and granular media filtration; methods that are used under certain circumstances include desalination, ion exchange and ozonation (EPA 1986b).

4.4 Safe Drinking Water Act (SDWA)

The SDWA is the main regulation that protects the drinking water quality in the U.S. It focuses on all waters that are currently or could potentially be used as drinking water from both surface and underground sources. The SDWA establishes the authority for the EPA to establish standards to protect tap water and standards for public drinking water supplies. The SDWA also gives the EPA authority to establish minimum standards for underground injection control to protect underground sources of drinking water. The SDWA established the National Primary Drinking Water Regulations as shown in Appendix B (EPA 2009c). The National Primary Drinking Water Regulations are the basis for the Ohio Drinking Water Primary and Secondary Standards.

4.5 Clean Water Act (CWA)

The CWA establishes a structure for regulating discharges of pollutants into waters and regulating water quality standards for surface waters. The CWA established the National Pollution Discharge Elimination System (NPDES) permit program which dictates the quality and quantity of allowable discharges. All groundwater pump and treat systems will require discharge permits to comply with the CWA (EPA 2012a).

4.6 Resource Conservation and Recovery Act (RCRA)

RCRA gives the EPA the authority to control hazardous waste in all stages including generation, transportation, treatment, storage and disposal. RCRA also creates the framework for dealing with non-hazardous solid waste and leaking underground storage tanks. RCRA was amended in 1984 to include the Federal Hazardous and Solid Waste Amendments (HSWA) to create a focus on waste minimization, reduction of land disposal of hazardous waste and corrective actions for releases RCRA was not created to address problems at abandoned or inactive sites or to implement emergency response after a spill; these are addressed by CERCLA and NCP (EPA 2012b). While contaminated groundwater is not considered a hazardous waste because via the mixture rule, to be considered a hazardous waste the waste must be mixed with a solid waste. However, since leachate from hazardous waste is considered hazardous waste under RCRA, groundwater contaminated with hazardous waste leachate is treated as hazardous waste under RCRA. Once the groundwater is treated to a point where it no longer contains hazardous waste, it is no longer subject to regulation under RCRA (EPA 1986c).

4.7 Clean Air Act (CAA)

The CAA defines the EPA’s responsibility for ensuring the quality of the nation’s air and stratospheric ozone layer. The last major change in the law was made in 1990. The CAA is broad in its application, with guidance on mobile and stationary sources, acid deposition, stratospheric ozone and permitting. While the impact of the CAA on groundwater classification, monitoring and treatment is minimal, certain water treatment processes require CAA permits (EPA 2012c). The prime example of this is air stripping of VOCs from contaminated water; the VOCs are stripped from the water and discharged into the air (as seen at SRS), requiring a CAA permit.

4.8 Ohio Voluntary Action Program (VAP)

VAP was created as a way for polluters to identify a problem, clean it up if necessary and receive assurances from the State of Ohio that no further cleanup is required. The program was created to avoid bureaucracy and further liability of re-developing contaminated sites. It allows anyone to undertake cleanup to a level shown to meet OEPA expectations as verified by a certified professional and laboratory. The VAP program is meant to maximize private resources to move towards redevelopment of contaminated lands. When a certified professional has verified that cleanup meets the standards set out in program rules (OAC Chapter 3745-300), No Further Action (NFA) letter is submitted to the VAP; if the NFA letter is approved, the State of Ohio creates a Covenant Not to Sue for further cleanup. An additional Memorandum of Agreement (MOA) is in place between the OEPA and the USEPA to ensure that sites cleaned up under the VAP are not at risk of additional cleanup requests by the USEPA; to qualify for protection under the MOA, cleanup must have direct OEPA oversight rather than oversight just by a certified professional (OEPA 2012b).

4.9 Ohio EPA Drinking and Ground Water Regulations

The Ohio EPA division of Drinking and Ground Water establish MCLs and BATs for inorganic chemicals, organic chemicals and radionuclide contaminants in rules 3745-81-11, 3745-81-12 and 3745-81-15 (OEPA 2010e, OEPA 2010f and OEPA 2004c). These rules establish MCLs in line with those developed in the SDWA and suggest best available technologies to achieve them; the best available technologies for removal of inorganic constituents is presented in Table 4.1 as an example.

4.10 Ohio EPA Hazardous Waste Regulations

An owner or operator that is required to pursue a corrective action program has the responsibility to make sure the regulated unit is in compliance with ground water protection standard under rules 3745-54-90 to 3745-54-95. This rule states that the concentration of hazardous constituents cannot exceed their limits in the uppermost aquifer underlying the waste management area beyond the point of compliance. The owner or operator must put in place a corrective action program that prevents hazardous constituents from exceeding concentration limits at the compliance point by either removing the contaminant or treating it onsite. The permit will specify the time period in which the corrective action program must commence. In addition to the corrective action program, a ground water monitoring program must be implemented that demonstrates the effectiveness of the corrective action program. The ground water boundary for which the corrective action program must remove or treat onsite exceeded levels of hazardous constituents includes the ground water between the compliance point and down-gradient property boundary, and the ground water beyond the facility boundary which is necessary to protect human health and the environment. Corrective action measures must persist during the compliance period to the degree that the ground water protection standard is not exceeded. At the end of the compliance period, the corrective action program must continue until compliance with the ground water protection standard is achieved. The ground water monitoring program must be employed for a period of three consecutive years after contaminate levels meet the ground water protection standard. Annual reports must be submitted on the effectiveness of the corrective action program (OEPA 2010b).

Table 4.1 BATs for Removal of Inorganic Contaminants (OEPA 2010e)

Contaminant	BATs		Key to BATs
Antimony	2,7		1 = Activated alumina
Arsenic^{a}	1,2,5,6,7,9,12^{b}		2 = Coagulation/filtration (for systems >500 service connections)
Asbestos	2,3,8		3 = Direct filtration
Barium	5,6,7,9		4 = Granular activated carbon
Beryllium	1,2,5,6,7		5 = Ion exchange
Bromate	14		6 = Lime softening (for systems >500 service connections)
Cadmium	2,5,6,7		7 = Reverse osmosis
Chlorite	15		8 = Corrosion control
Chromium	2,5,6^{c}		9 = Electrodialysis
Cyanide	5,7,13		10 = Chlorine
Mercury	2^{d},4,6^{d},7^{d}		11 = Ultraviolet
Nitrate	5,7,9		12 = Oxidation/filtration
Nitrite	5,7		13 = Alkaline chlorination (pH > 8.5)
Selenium	1,2^{e},6,7,9		14 = Control of ozone treatment process to reduce production of bromate
Thallium	1,5		15 = Control of treatment process to reduce disinfectant demand and control of disinfectant treatment processes to reduce disinfectant levels

Notes: a – BATs for arsenic (V). Pre-oxidation may be required to convert arsenic (III) to arsenic (V), b – To obtain high removals the iron to arsenic ratio must be at least 20:1, c – BAT for chromium (III) only, d – BAT only for mercury concentrations of ten micrograms per liter or less, e – BAT for selenium (IV) only.

Concentration limits of hazardous constituents for ground water will be specified in the permit. The concentration must not exceed the background level of constituent in groundwater at the time limit that is specified in the permit, or the concentration must not exceed the value given in Table 4.2, or exceed an alternative limit approved by the Ohio EPA Director (OEPA 2004a).

Table 4.2. MCL of Select Chemicals for Ground Water Protection (OEPA 2004a)

Constituent	Maximum Contaminant Concentration (mg/l)
1,1 Dichloroethylene	0.007
Tetrachloroethylene	0.005
Trichloroethylene	0.005
Vinyl Chloride	0.002

The point of compliance is defined as the vertical surface of the hydraulically down-gradient limit of the waste management area that extends down into the uppermost aquifer underlying the regulated units. The point of compliance will be specified in the permit. The waste management area is defined as the horizontal plane of the area of which waste will be placed during the active life of a regulated unit. If the facility contains more than one regulated unit, the waste management area will be defined by an imaginary line circumscribing all regulated units (OEPA 1984a).

The compliance period is defined as the number of years equal to the active life of the waste management area including waste management activity prior to the permit and the closure period. The compliance period of ground water protection standards will be specified in the permit. The compliance period commences when the owner or operator begins a compliance monitoring program. The compliance period will be extended until ground water protection standards have not been exceeded for a period of three consecutive years (OEPA 1984b).

A compliance monitoring program must be established by the owner or operator with the responsibility to monitor the ground water to determine if the regulated units are in compliance with the ground water protection standard. The permit will specify the ground water protection standard including a list of hazardous constituents, the concentration limits of the hazardous constituents, the compliance point, and the compliance period. The owner or operator is required to install a ground water monitoring system at the compliance point. The Ohio EPA Director will determine the sampling procedures and statistical methods for the compliance monitoring program. The owner or operator must conduct a sampling program for each chemical parameter or hazardous constituent and record ground water analytical data. The owner or operator is responsible for determining if there is increased contamination of ground water at each monitoring well at the compliance point that is statistically significant of the hazardous constituent listed in the permit. Once a year at minimum, the owner or operator must determine the ground water flow rate and the direction of flow in the uppermost aquifer. The Ohio EPA Director will specify the frequency of collecting samples and statistical analysis. Furthermore, an annual assessment must be conducted to determine if additional hazardous constituents are present in the uppermost aquifer which are not listed in the permit (OEPA 2010a).

The closure performance standard states that a hazardous waste facility should be closed to a final state in which no further maintenance will be required. The closure must prevent threats to human health and the environment, including post-closure escape of the hazardous waste into the ground or surface water, or atmosphere (OEPA 2010c). When closing a hazardous waste facility there must be a written closure plan. Surface impoundments and waste piles that are removed or decontaminated must also have a written closure plan. The closure plan must be submitted with the permit application (OEPA 2009a).

The closure of a hazardous waste tank system requires that all waste residues, contaminated containment system components, contaminated soils, contaminated structures and equipment are decontaminated and managed as a hazardous waste. If the owner or operator demonstrates that not all contaminated soils can be practically removed or decontaminated, then the tank system must be closed and post-closure care must follow that apply to landfills (OEPA 2004b).

4.11 Ohio EPA Definitions

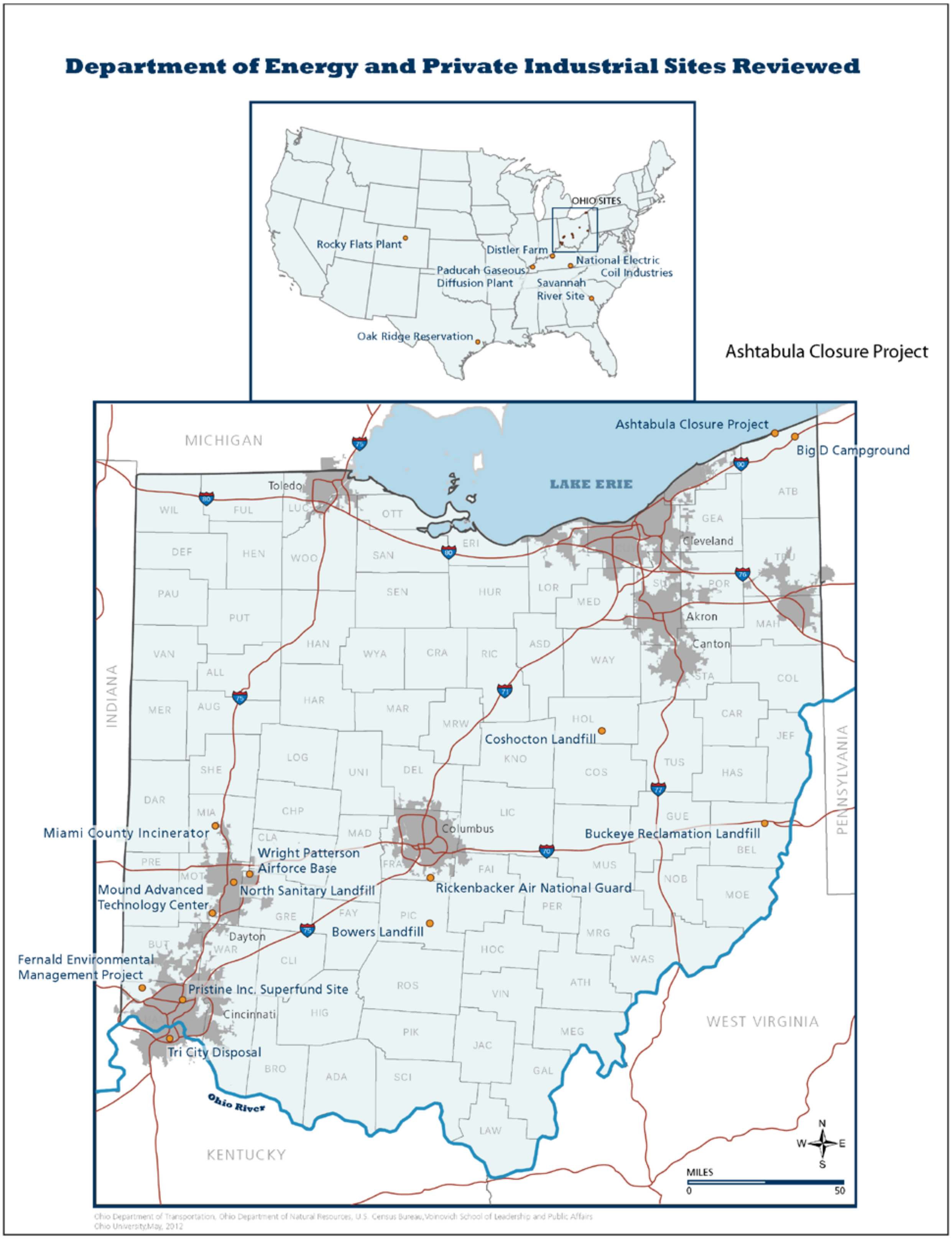
The Ohio EPA defines an aquifer and an underground source of drinking water in two sections of the Ohio Administrative Code, 3745-50-10 (OEPA 2010g) in the hazardous waste rules and 3745-34-01 (OEPA 2009b) in the underground injection control unit of the Division of Drinking and Ground Waters. An aquifer based on both definitions is “a geologic formation, group of formations, or part of a formation that is capable of yielding a significant amount of water to a well or spring (OEPA 2009b, OEPA 2010g).” According to both definitions, an underground source of drinking water is defined as an aquifer that either currently supplies a public water system or contains sufficient quantity of groundwater to supply a public water system and either currently supplies drinking water or contains fewer than ten thousand mg/l total dissolved solids (OEPA 2009b). The OEPA defines an uppermost aquifer as “the geologic formation nearest to the natural ground surface that is an aquifer, as well as lower aquifers that are hydraulically interconnected with this aquifer within the facility’s property boundary (OEPA 2010g).”

Section 5. Individual Site Reviews

5.1 Summary of Sites

The findings of this report were derived from an extensive literature review of DOE and private industrial sites across the United States (Appendix A). The DOE sites reviewed stretch across the United States (Figure 1) as well as DOE sites located in Ohio that exhibited groundwater contamination. These sites were selected due to the nature of their contamination and their similar aspects to the PORTS sites. Additional non-DOE sites that contained similar groundwater contamination to that of PORTS (i.e. TCE contamination) were chosen to review in Ohio and Kentucky (Figure 1). Each site review contains a brief general description of the site, its local geology and aquifer characteristics, brief description of its groundwater contamination, and finally a summary of the pertinent clean-up levels and removal process. The entire literature review can be found in Appendix A. A summary table of this information was compiled into two separate tables; one for DOE sites (Table 5.1) and the second for private Ohio and Kentucky industrial sites (Table 5.2).

Tables 5.1 and 5.2 summarize the pertinent information related to chemical, location, and specific applicable or relevant and appropriate requirements (ARARs) as described in their record of decision (ROD) documents as part of the CERCLA clean-up process. In addition, information related to the site's aquifer is noted as well. Table 5.1 shows the DOE sites, of these sites all are underlain by non-sole source aquifers except for Mound and Fernald. All ARARs for these sites indicated clean-up is to MCL level. Table 5.2 contains the Ohio and Kentucky sites reviewed. All sites are underlain by non-sole sources aquifers except Miami County Incinerator, North Sanitary Landfill, and Wright Patterson Air Force Base. All sites reviewed in Ohio and Kentucky had TCE contamination onsite, their clean-ups goals are to MCL.



Ohio Department of Transportation, Ohio Department of Natural Resources, U.S. Census Bureau, Voinovich School of Leadership and Public Affairs
Ohio University, May, 2012

Figure 5.1 Department of Energy and Private Industrial Sites Reviewed

Table 5.1 DOE sites reviewed

Site/location	Sole-Source Aquifer	Notes	Chemical-Specific ARAR	MCL (ug/L)	Location Specific ARAR	Action Specific ARAR
Fernald	Yes - Great Miami Aquifer	Cited from federal and State of Ohio MCLs for contaminants	Xylenes	10000		
		(Safe Drinking Water Act) (Table C.1, 1996)	Toluene	1000		
			Ethylbenzene	700		
			1, 1, 1 - trichloroethane	200		
			Chloroform	100		
			Monochlorobenzene	100		
			Styrene	100		
		VOLATILE ORGANIC CONTAMINANTS	1, 1 - dichloroethylene	7		
			benzene	5		
			Carbon tetrachloride	5		
			1, 2 - Dichloroethane	5		
			Dichloromethane	5		
			Dichloropropane (1,2-)	5		
			1, 1, 2 - Trichloroethane	5		
			Trichloroethylene	5		
			Vinyl Chloride	2		
			Dibromochloropropane (DBCP)	0.2		
			Dichlorobenzene o-	600		
			Dichlorobenzene -m	600		
			Dichlorobenzene p-	75		
			Trichlorobenzene (1,2,4)	70		
		SEMIVOLITILE ORGANIC CONTAMINANTS	Hexachlorocyclopentadiene	50		
			Hexachlorobenzene	1		
			Pentachlorophenol	1		
			Benzo (a) pyrene (PAH)	0.2		
			2,3,7,8-TCDD (Dioxin)	3E -5		
			Butyl benzyl phthalate (PAE)	100		
			Bromodichloromethane	80		
			Chloroform	80		
			Indenol(1,2,3,-c,d)pyrene (PAH)	0.4		
		NON-ZERO SEMIVOLITILE ORGANIC CONTAMINANTS	Dibenz(a,h)anthracene (PAH)	0.3		
			Benzo(b)fluoranthene (PAH)	0.2		
			Benzo(k)fluoranthene (PAH)	0.2		
			Chrysene (PAH	0.2		
			Benzo(a)anthracene (PAH)	0.1		
			Adipate (diethylbexyl)	400		
			Atrazine	3		
			Aroclor	2		
			Chlordane	2		
			Polychlorinated biphenyls (PCBs)	0.5		
		PESTICIDE/PCB CONTAMINANTS	Heptachlor	0.4		
			Heptachlor epoxide	0.4		
			Endrin	0.2		
			Lindane	0.2		
			Methoxychlor	0.2		
			Toxaphene	0.003		
			2,4-D	70		
		HERBICIDE CONTAMINANTS	2,4,5-TP	50		
			Dinoseb	7		
			Barium	2000		
		INORGANIC CONTAMINANTS	Cyanide	200		
			Nickel	100		
			Chomium (total)	50		
			Lead	50		
			Arsenic	50		
			Silver	50		
			Selenium	10		
			Antimony	6		
			Cadmium	5		
			Beryllium	4		

Table 5.1 DOE sites reviewed

Site/location	Sole-Source Aquifer	Notes	Chemical-Specific ARAR	MCL (ug/L)	Location Specific ARAR	Action Specific ARAR
Fernald (cont.)			Mercury	2		
			Thallium	2		
Paducah Gaseous	No	RCRA	1, 1 - Dichloroethene	7		
Diffusion Plant		Table 5 (1995 ROD)	TCE	5		
Oak Ridge	No	Must comply with SDWA MCLs	Nitrate	10000		
		From EPA/ROD/R04-05/035 (page 167)	Strontium-90	8 (PCL/L)		
			Toluene	1000		
			1.1,1-Trichloroethane	200		
			1,2-Dichloroethene	70		
			1,1-Dichloroethene	7		
			Chloroform	6.2		
			Bis(2-ethylhexyl)phthalate	6		
		VOLATILE ORGANIC CONTAMINANTS	1.1,2-Trichloroethane	5		
			1,2-Dichloroethane	5		
			Benzene	5		
			Carbon tetrachJoride	5		
			Methylene chloride	5		
			Telrachloroelhene	5		
			Trichloroethene	5		
			Vinyl chloride	2		
			Barium	2000		
		INORGANIC CONTAMINANTS	Chromium	100		
			Lead	15		
			Arsenic	10		
			Antimony	6		
			Thallium	2		
Rocky Flats	No; however, Arapahoe Aquifer ,	Derived from SDWA MCLs (EPA/ROD/R08-90/043, 1990)	Toluene	1000		
	used for irrigation livestock watering	(pages 47-60)	1,1,1 Trichloroethane	200		
	and domestic purposes east		Acetone	50		
	of Rocky Flats Plant		1,1 Dichloroethene	7		
			Carbon Tetrachloride	5		
		ORGANIC CONTAMINANTS	1,1 Dichloroethane	5		
			1,2 Dichloroethane	5		
			Methylene Chloride	5		
			Tetrachloroethene	5		
			1,1,2 Trichloroethane	5		
			Trichloroethene	5		
			Carbon Disulfide	5		
			Aluminum	5000		
			Lithium	2500		
		INORGANIC CONTAMINANTS	Zinc	2000		
			Barium	1000		
			Iron	300		
			Copper	200		
			Nickel	200		
			Beryllium	100		
			Molybdenum	100		
			Antimony	60		
			Arsenic	50		
			Chromium	50		
			Lead	50		
			Manganese	50		
			Silver	50		
			Cadmium	10		
			Selenium	10		
			Thallium	10		
			Mercury	2		
		CONVENTIONAL POLLUTANTS	Chloride	250,000		
			Sulfate	250,000		
			Nitrate	10000		
			Nitrite	1000		

Table 5.1 DOE sites reviewed

Site/location	Sole-Source Aquifer	Notes	Chemical-Specific ARAR	MCL (ug/L)	Location Specific ARAR	Action Specific ARAR
Rocky Flats (continued)		RADIONUCLIDES	Gross Alpha	15 (pCi/L)		
			Gross Beta	50 (pCi/L)		
			Pu (238, 239, 240)	15 (pCi/L)		
			Am241	4 (pCi/L)		
			H3	20,000 (pCi/L)		
			Sr(89,90)	8 (pCi/L)		
			Uranium (total)	40 (pCi/L)		
Savannah River	No. The deepest aquifer provides water for domestic and industrial purposes	MCLs derived from Federal Safe Drinking Water Act and South Carolina Primary Drinking Water Regulations	PCE	5		
			TCE	5		
Mound Plant	Yes - Burried Valley Aquifer	Clean Water Act - Acute freshwater toxicity criterion (CWA 304)	Tritiumc	20000 (pCi/L)	ORC 6111.03, Protection of Waters of the State ORC 3734.20, Description of Ohio EPA Director's power for Protection of Public Health and the Environment	ORC 317.08, Criteria for County Recording of Deeds ORC 5301.25(A), Proper Recording of Land Encumbrances
		MCLs derived from Safe Drinking Water Act	1,2-cis-Dichloroethene	70		
			Plutonium - 238c, 239, 240c	15		
		Other Chemical-specific ARARs:	Tetrachloroethene	5		
		OAC 3745-81-12, MCLs for Inorganic Chemicals	Tetrachloromethane	5		
		OAC 3745-81-12, MCLs for Organic Chemicals	Trichloroethene	5		
		OAC 3745-81-13, MCLs for Turbidity	Trichloromethane	5		
		OAC 3745-81-15, MCLs for Radium 226, 228, Gross Alpha	Chlordane (alpha)	2		
		OAC 3745-81-16, MCLs for Beta Particle & Photon Radioactivity	Vinyl chloride	2		
Fields Brook	No	Chemical-specific ARARs omitted from ROD, information was cited form the 5-yr review	Radium 226 & 228 (residential areas	5 pCi/g		
			Radium 226 & 228 (industrial areas)	10 pCi/g		
			U-238 (residential & industrial)	30 pCi/g		
			PCB (residential; industrial)	6; 50 ppm		
			Hexachlorobenzene (res; indust)	80; 200 ppm		
			Barium	2000 ug/L		
			Lead	15 ug/L		

Table 5.2 Ohio and Kentucky (Non-DOE) Industrial Sites Reviewed

Site/Location	Sole-Source Aquifer	Notes	Chemical - Specific ARARS	MCL (ug/L)	Location - Specific ARARS	Action - Specific ARARS
Big D Campground	No		Barium 1, 4 - Dichlorobenzene Chromium Trichloroethene Vinyl chloride	1,000 75 50 5 2	No location specific ARARS identified by EPA	Action Specific ARARS omitted from ROD
Bowers Landfill	No	Promulgated under the Safe Drinking Water Act MCLs apply to public drinking water supplies serving 25 people or more	Benzene Barium	5 1000	CONSTRUCTED, OPERATED, AND MAINTAINED TO PREVENT WASHOUT OF HAZARDOUS WASTES BY A 100-YEAR FLOOD US EPA REQUIREMENTS FOR FLOODPLAIN PROTECTION, AS DESCRIBED IN 40 CFR 6, APPENDIX A, STATEMENT OF PROCEDURES ON FLOODPLAIN MANAGEMENT AND WETLANDS PROTECTION.	OHIO REQUIREMENTS FOR THE CLOSURE OF SOLID WASTE LANDFILLS (OAC 3745-27-09 AND OAC 3745-27-10)
Buckeye Reclamation Landfill	No	The National Pollutant Discharge Elimination System and section 402 of the Clean Water Act will be met by the wetlands treatment system ARARs also may include RCRA & Safe Drinking Water Act	Table 1 -containing MCLs for contaminants - omitted from ROD			
Coshocton Landfill	No	Safe Drinking Water Act (MCLs) :	Trichloroethene	5		
Miami County	Yes - Great Miami Valley Fill Aquifer	State Sanitary Landfill Closure Law - Primary ARAR Law, regulation or standard: Source of Law/regulation Clean Water Act: Section 301(B) (2) MCLs established under Safe Drinking water Act generally ARAR	Barium 1, 1, 1, Trichloroethane TCE Vinyl chloride	1000 200 5 2	40 CFR 265.18(B) - LOCATIONAL STANDARDS, FLOOD PLAINS, WHICH REQUIRES THAT HAZARDOUS WASTE MANAGEMENT FACILITIES BE DESIGNED, CONSTRUCTED, OPERATED, AND MAINTAINED TO AVOID WASHOUT.	
Prinstine Inc.	No; however, the lower aquifer remains a potential drinking water source	Federal ARARS include RCRA, OSHA Safe Drinking Water Act, and Clean Water Act State ARARS include Ohio Revised Code	Fluoride Barium Copper 1, 1, 1, Trichloroethane Chloroform 1, 2 - Dichlorobenzene Arsenic Chromium	4000 1000 1000 200 100 75 50 50		

Table 5.2 Ohio and Kentucky (Non-DOE) Industrial Sites Reviewed

Site/Location	Sole-Source Aquifer	Notes	Chemical - Specific ARARS	MCL (ug/L)	Location - Specific ARARS	Action - Specific ARARS
Prinstine Inc. (continued)			Lead	50		
			Cadmium	10		
			1, 2 - Dichloroethene	7		
			Benzene	5		
			1, 2 - Dichloroethane	5		
			Trichloroethene	5		
			Mercury	2		
			Vinyl Chloride	2		
Rickenbacker Air National Guard	NA	Chemical-Specific ARARS from OAC 3745-81-11, 12 and 40 CFR 141.11 (Both MCLs for Inorganic Chemicals)	Toluene	1000	Table 7.2: EPA/ROD/R05-00/559 (2000)	Table 7.3: EPA/ROD/R05-00/559 (2000)
			Ethylbenzene	700		
			cis-1, 2 - Dichloroethene	70		
			1, 2 - Dichloroethene (total)	70		
			Arsenic	50		
			1, 2 - Dichloroethene	7		
			Benzene	5		
			1, 2 - Dichloroethane	5		
			1, 1, 2 - Trichloroethane	5		
			Thrichlorothene	5		
			Thallium	2		
			Vinyl Chloride	2		
Sanitary Landfill	Yes - Great Miami Valley Fill Aquifer	ARARs (if deemed necessary) include Maximum Concentration Limits (MCLs) established pursuant to the Safe Drinking Water Act (SDWA), Ambient Water Quality Criteria, and State standards which give concentration limits for drinking water and surface waters.				No location-specific ARARS identified
Wright - Patterson Air Force Base	Yes - Burried Valley Aquifer	Chemical-Specific ARARS derived from Safe Drinking Water Act & RCRA	Xylenes	10000	Table 2: EPA/ROD/R05-99/506 (1999)	Table 2: EPA/ROD/R05-99/506 (1999)
			Toluene	1000		
			Ethylbenzene	700		
			1, 2 - DCE	70		
			4, 4 - DDT	20		
			Bis(2-ethylhexyl)phthalate	6		
			Benzene	5		
			1, 2 - DCA	5		
			PCE	5		
			TCE	5		
			Vinyl Chloride	2		
			OCDD	0.045		

Table 5.2 Ohio and Kentucky (Non-DOE) Industrial Sites Reviewed

Site/Location	Sole-Source Aquifer	Notes	Chemical - Specific ARARS	MCL (ug/L)	Location - Specific ARARS	Action - Specific ARARS
Distler Farm	No	*MCL's from Health based contaminant concentration of ppb (ug/kg) from Explanation of Significant Differences (ESD)(1989) *The disposl site will be required to be in compliance with RCRA requirements, by either having interim status or being fully permitted *Must comply with the requirements of the Clean Water Act *The Groundwater Protection Strategy is also an applicable standard for this site	Toluene	2000		
			1, 1, 1 - trichloroethane	200		
			2-butanone	170		
			Trans-1, 2 - dichloroethene	70		
			Arsenic	50		
			Chromium	50		
			Lead	50		
			1, 1 - dichloroethylene	7		
			TCE	5		
			benzene	5		
National Electric Coil	No	Chemical Specific ARARS derived from Safe Drinking Water Act MCLs	trans-1, 2 - Dichloroethene	100		
			cis-1, 2 - Dichloroethene	70		
			1, 1, 2, 2, - Tetrachloroethane	10		
			1, 1 - Dichloroethene	7		
			TCE	5		
			Vinyl Chloride	2		
Tri-City Disposal Co.	No	Chemical Specific ARARS derived from Safe Drinking Water Act MCLs and Clean Water Act	Xylenes	10000		
			Toluene	1000		
			1, 1, 1-Trichloroethane	200		
			Chloroform	100		
			trans-1, 2 - Dichloroethene	100		
			cis-1, 2 - Dichloroethene	70		
			1, 1 - Dichloroethene	7		
			Tetrachloroethene	5		
			TCE	5		
			Vinyl Chloride	2		

Section 6. Main Findings

Of the DOE sites reviewed, two overlie Sole-Source Aquifers and the rest do not. Fernald and Mound both overlie Sole Source Aquifers, the Great Miami Aquifer and the Buried Valley Aquifer, respectively. RODs for each site derived cleanup levels at MCLs as derived from the Safe Drinking Water Act. At Mound, institutional controls were used to protect human health. The remaining DOE sites do not overly Sole-Source Aquifers, however aquifers underlying Rocky Flats and SRS are used for domestic, agricultural and industrial purposes. Across all of the DOE reservations except for Paducah, the chemical specific ARARs were derived from the Safe Drinking Water Act and were equal to MCLs for constituents of concern. At Paducah, the corrective action reviewed was an interim action under RCRA and dictates treatment of the contaminated aquifer to MCLs for 1,1 Dichloroethene and TCE. At Savannah River, some monitored natural attenuation has been used to remediate the margins of the A/M Area Groundwater plume to reduce the number of wells necessary to meet ARARs. A summary of ARARs applied for each site are included in Table 5.1.

Non-DOE sites with TCE contamination in the groundwater in Ohio and Kentucky were reviewed to establish the level of consistency between the ARARs applied by the Ohio EPA and the Kentucky DEP to sites with similar groundwater contamination to that found at PORTS. Of these sites, Miami County, Sanitary Landfill and Wright Patterson Air Force Base overlie Sole-Source Aquifers. The chemical specific ARARs for each site were derived from Safe Drinking Water Act and RCRA at MCL. While the remaining non-DOE sites do not overlie Sole-Source Aquifers, some do overlie drinking water aquifers. While location specific ARARs at these sites dictate specifics of how the sites must be remediated, particularly the construction and siting of landfills within floodplain areas. The chemical specific ARARs for the majority of sites were derived from Safe Drinking Water Act MCLs, while the chemical specific ARARs at Distler Farm were derived from a health based standard. At Buckeye Remediation Landfill, the reclamation must also comply with the Clean Water Act through an NPDES permit for a wetland treatment system.

On rare occasions, institutional controls were used to protect human health either in the short term (Tri-City Disposal) or the long term (Mound Plant). CERCLA and NCP discourage the use of institutional controls for both baseline risk assessment and long term protection of human health, rather, they are used for short term protection of human health while a natural resource reaches protective cleanup goals.

The non-DOE landfill sites were all dealt with using a similar methodology. The landfills were capped to reduce further groundwater contamination. In a few cases, tanks were removed from site to reduce another source of contamination. Following capping, leachate collection and pump and treat systems were installed to remove groundwater contamination to achieve ARARs.

Waste management at Savannah River was undertaken using novel methods. Tanks containing combined low-level and high-level waste were treated by separating low-level waste and treating it for disposal as a low-level salt. The high level waste is bonded with a borosilicate glass to render it inert and contained for long-term storage.

Overwhelmingly, although not all sites overlie current sources of drinking water, the chemical specific ARARs are either developed from Safe Drinking Water Act MCLs or health-based standards that achieve MCLs. The overwhelming theme of cleanup decisions across all sites reviewed was protection of human health.

Section 7. Application to PORTS

7.1 Application of Main Findings to Gallia Aquifer Cleanup Levels

The cleanup levels within the Gallia Aquifer are likely to hinge upon the classification of the Gallia Sand as either a Class II or a Class III aquifer. This classification is based upon the potential for the aquifer to be used as a drinking water source based on both the quality and quantity of water in the aquifer. As discussed in Section 4, the USEPA has a classification system for aquifers and the Ohio EPA has definitions that pertain to distinguishing an aquifer as an underground source of drinking water. The USEPA classification system is based upon the classification of fresh water aquifers (<10,000 ppm TDS) based on yield and treatability of naturally occurring contaminants. The Ohio EPA classification is based upon total dissolved solids and yield only.

The USEPA classification system dictates that a Class IIB aquifer (i.e. a potential source of drinking water) must have a yield of at least 150 gallons per day. The Ohio EPA definition says that a potential source of drinking water must have sufficient yield to supply a public water system, but no specific value is listed. It is the impression of the authors that the USEPA standard may be more stringent and is the yield threshold used in this analysis. Based on data collected in 1996 by the Department of Energy, the minimum yield found was indeed below the 150 gallons per day threshold, however the mean and median both exceed 150 gallons per day. While the Gallia Aquifer may not be a regionally important aquifer, it would have sufficient yield for a future resident to use as a drinking water source and does meet the yield guideline set forth by the USEPA of 150 gallons per day.

Both the USEPA and the Ohio EPA require that an underground source of drinking water or a Class II aquifer meet the threshold of fresh water. This is set for both agencies at 10,000 ppm of TDS. Based on the data shown in Figure 2.9, the TDS values measured on site for several decades have not approached this threshold.

While the Ohio EPA only requires that drinking water be considered ‘fresh water’, the USEPA dictates that naturally occurring contamination must be treatable using commonly applied technology in public treatment works to be considered a potential source of drinking water (Class IIB). While some off-site wells show levels of naturally occurring arsenic, beryllium, sulfate and lead, these constituents are treatable using the BATs listed in Table 4.1. The key question that would factor into the classification of the Gallia Aquifer is the treatability of the water. Of the technologies suggested in Table 4.1, many are already employed at traditional drinking water treatment plants. These include alumina, coagulation and filtration and oxidation/precipitation. Additionally, the BATs suggest that oxidation/precipitation is only effective for arsenic removal at an iron to arsenic ratio of 20:1 or more; this ratio is exceeded in the Gallia Aquifer.

Based on this analysis, the requirements for a USEPA classification of Class IIB for the Gallia Aquifer are fulfilled. While in some tests, the yield of the aquifer did not meet the 150 gallons per day threshold, most did, therefore is would be unprotective to make decisions based on the lower yield tests and ignore the higher yield ones. The water does meet the TDS threshold for fresh water. The naturally occurring contaminants in the Gallia Aquifer are treatable using technology commonly available at public treatment works. This classification would lead to a protective cleanup level, adaptable to various future use scenarios both on-site and near the site.

Classification of the Gallia Aquifer as a potential drinking water source would require compliance of the cleanup levels with the Safe Drinking Water Act. Cleanup could take on two forms:

- Removal of the source material for each groundwater plume and pump and treat systems to treat the groundwater with institutional controls provided protection to health in the short term until cleanup levels are achieved throughout the plumes. There is a possibility for use of MNA on the margins of the plumes.
- Excavation of the plumes in their entirety to remove contamination to cleanup levels in a shorter time period. There is a possibility for use of MNA on the margins of the plumes to limit excavation volumes.

7.2 Applications of Main Findings to Natural Resources Damages Assessment

Natural Resources Damages Assessment (NRDA) are assessed when unpermitted discharges cause damage to natural resources, including groundwater, surface water and soils. The unpermitted discharges of TCE that caused the groundwater plumes at PORTS would become part of an NRDA if they are a) found to be damaging a natural resource and b) are not remediated. The basis for determining the impact of an uncontrolled release on groundwater is based on the ability of that groundwater to be a source of drinking water. Based on the assessment detailed in Section 7.1, the Gallia Aquifer would be considered a 'Natural Resource' and, therefore, to avoid a fine for damaging it, it must be treated to SDWA levels. Both methods of treatment detailed above ought to avoid Natural Resources Damages due to groundwater contamination, but the contaminated soils in the source zone of the groundwater contamination plumes would not be remediated through both methods. In order to fully avoid Natural Resources Damages due to soil contamination, it is recommended that the contaminated soils be excavated and disposed of in an on-site RCRA cell. Discharge of treated groundwater into a surface water body would not be factored into a NRDA because it would occur under a NPDES permit.

7.3 Other Considerations of Groundwater Cleanup at PORTS

While it would be most protective of both the groundwater quality and avoid the majority of Natural Resources Damages, the excavation of contaminated soils and groundwater could have potentially negative secondary effects. The excavation would occur in a developed area and should not disturb ecologically important resources with the exception of potential small wetland and pond areas located within Perimeter Road. Sufficient fill to replace excavated contaminated soil, however, could have potentially serious impacts to ecological resources. The borrow area should be carefully selected to minimize damage to sensitive or particularly high quality natural resources. Additionally, minimizing the transportation of material by disposing of it in an on-site disposal cell would minimize both environmental impacts due to the transportation and impacts on human health due to potential exposure en-route.

Both excavation and high volume pump and treat systems have the potential to effect the hydrology of the Gallia Aquifer by creating new preferential flow paths and areas of either unusually high or low permeability.

Additionally, in both scenarios, the decisions have the potential to affect the flow in surface waters on and off-site. If pump and treat were continued, stream flow would remain unnaturally high and aquatic life may be exposed to low level contamination (although in compliance with an NPDES permit). In the scenario that the site no longer employs pump and treat and reduces permitted discharges, artificial drought conditions could be imposed on the stream, affecting biological community health adversely. In either scenario, changes in discharge from the plant may have an impact on aquatic life.

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APPENDIX A – Individual Site Reviews

A1. Fernald Environmental Management Project

Fernald Environmental Management Project (FEMP) is a 1050 acre facility located about 18 miles northwest of downtown Cincinnati on the boundary of Hamilton and Butler counties. The site processed high-purity uranium products from 1951 to 1989. Operable Unit 5 addresses the environmental media on and off site contaminated by the four source areas represented by Operable Units 1 through 4. Based on the 1990 census, 22,900 people live within five miles of the site with an additional 1.7 million represented by the Cincinnati metropolitan area. The land surrounding FEMP is mainly open and agricultural land, including a dairy farm located just outside the FEMP boundary (EPA 1995a).

The Great Miami Aquifer is the principal aquifer within the Fernald Environmental Management Project (FEMP) Study Area. It is designated as a sole-source aquifer under the provisions of the Safe Drinking Water Act (SDWA). The Great Miami Aquifer is the sole source of drinking water for over 600,000 people in Southwestern Ohio and farmers not directly adjacent to the Great Miami River use well water to irrigate their fields. The Great Miami Aquifer is made up of a buried valley filled with sand and gravel. A clay interbed divides the aquifer into upper and lower sand and gravel units, the Upper Great Miami Aquifer and the Lower Great Miami Aquifer. A series of glacial overburden deposits overlay the Great Miami Aquifer. The overburden is composed primarily of till, a dense silty clay (EPA 1995a).

Isolated pockets of silty sand and gravel within the glacial overburden contain zones of perched groundwater. Perched groundwater is separated from the underlying aquifer by relatively impermeable clay and silt components in the overburden surrounding the isolated pockets of sand and gravel. The clay and silt units act as a saturated aquitard that store and slowly transmit water downward towards the Greater Miami Aquifer (EPA 1995a).

The surface of FEMP drains to Paddy's Run with the exception of 23 acres in the northeast corner of the site that drain to the Great Miami River. The site is located in the Great Miami River Basin which is both the major surface water feature in the region and the receiving water body for any surface effluent from FEMP. Paddys Run, a tributary to the Great Miami River, has eroded through the glacial overburden and is now in direct contact with the Great Miami River; Paddys Run and the storm sewer outfall ditch (another on-site drainage) lose water to the aquifer.

Groundwater Contamination

During the 38-year long operations at FEMP, contaminants from each of the four source Operable Units contaminated environmental media both on and off-site, including extensive soil and groundwater contamination. OU5 includes the soil under the production area structures and the remaining site acreage outside of the other operable units and approximately 11 square miles of contaminated land off of the FEMP site. The cleanup of OU5 addresses cleanup of groundwater contamination including pumping and treating the South Plume and perched aquifers that have the potential to communicate with the Great Miami Aquifer (EPA 1996c).

In addition to a total of approximately 12.4 square miles of land with elevated uranium concentrations (above background) due to emissions of dust particles from the plant stacks, contamination of both perched groundwater aquifers and the Great Miami Aquifer have been caused by FEMP operations. The key contaminant in groundwater is uranium. Approximately 96 acres of perched aquifer have uranium concentrations greater than 20 µg/L. Within the perched groundwater, the highest concentrations of total uranium, 9,240 µg/L were found in the area underlying the silos, these samples were taken from the 1000-series wells. The concentrations of total uranium in the perched groundwater varied from 196 to 276 µg/L (EPA 1995a). In total, 172 acres of the Great Miami Aquifer were contaminated to above 20 µg/L of uranium. Higher levels exist in a localized area beneath the production area (<50 µ/L uranium), beneath the waste storage area (<70 µg/L uranium), along Paddies Run from the waste storage area to about one mile south of FEMP property (<350 µg/L) and beneath a solid waste disposal site on the southern portion of the site (<2100 µg/L). The contamination along the length of Paddies Run is termed the South Plume (EPA 1996c).

Clean-up levels and Removal Processes

The selected remedy for OU5 at Fernald includes on-site disposal of contaminated soils and restoration of the Great Miami Aquifer to its full beneficial use. Cleanup actions include excavation of contaminated soils, extraction and treatment of sufficient contaminated groundwater to reach cleanup levels and discharge limits to the Great Miami River. Institutional controls including access controls, deed restrictions and alternate water supplies can be used to minimize the potential for human exposure to contaminants during and after remediation (EPA 1996c).

Cleanup of FEMP under the selected alternative uses a balanced approach to remediation. Soil exceeding cleanup levels will be excavated and placed in an on-site disposal cell. The disposal cell acceptance criteria has been agreed upon by the State of Ohio and is accepted by the community; waste exceeding the acceptance criteria must be disposed of off-site. Pump and treat was not a cost effective option for remediation of the perched aquifers; excavation and primarily on-site disposal is a more cost effective remedial option. The contamination in the Great Miami Aquifer will be removed using a pump and treat system to meet 20 ppb of uranium (federal drinking water standard). The water will be treated to limit the uranium loading to the Great Miami River (EPA 1996c).

The state federal ARARs met by the selected cleanup alternative include the Safe Drinking Water Act, Ohio Water Quality Standards for surface water, the Ohio general radiation protection standards, the Clean Water Act, National Emission Standards for Hazardous Air Pollutants, the Resource Conservation and Recovery Act, the Uranium Mill Tailings Radiation Control Act, protection of wetlands, flood plains, and threatened and endangered species under the National Environmental Policy Act and the Department of Transportation requirements for transport of hazardous materials. The selected remedy requires a waiver from the State of Ohio to OAC 3745-27-07 and OAC 3745-27-20 requirements dictating the allowable siting of disposal cells over high yield, sole source aquifers. The final remediation levels for the Great Miami Aquifer represent, in the majority, Safe Drinking Water Act MCLs or State of Ohio MCLs where the state requirements are more stringent. In the absence of MCLs, a 1×10^{-5} increased lifetime cancer risk or hazard quotient of 0.2 (EPA 1996c).

A2. Paducah Gaseous Diffusion Plant

The Paducah Gaseous Diffusion Plant (PGDP), owned by the United States Department of Energy , is situated on a 1,457 hectare (3,600 acre) reservation approximately 6.4 km (4 mi) south of the Ohio River and about 16 km (10 mi) west of Paducah, Kentucky. About 304 hectares (750 acres) of the reservation are within a security area and buffer zone that have restricted access to the general public. Beyond the DOE-owned buffer zone is the Western Kentucky Wildlife Management Area which covers approximately 2,428 hectares (6,000 acres). Operations at PGDP began in 1952 enriching uranium to produce uranium hexafluoride, which was later transported to USEC's enrichment facility in Piketon, Ohio, for further enrichment (EPA 1995b).

In response to discovered volatile organic compounds and radionuclides in residential wells north of PGDP in August 1988, the DOE and EPA began conducting a RI/FS. Effective July 1, 1993, the DOE leased the plant's production facilities to the United States Enrichment Corporation (USEC) which in turn contracted with Martin Marietta Utility Services, Inc., to provide operation and maintenance services. Lockheed Martin Energy Systems, Inc., manages the environmental restoration and waste management activities for the DOE at the PGDP (EPA 1995b).

The PGDP is underlain by Mississippian limestone bedrock beneath 105 meters (344 feet) of unconsolidated sediments. The unconsolidated sediments consist of upper continental deposits of sand, silt and clay with occasional gravel lenses that range from 6 to 18 meters thick (EPA 1995b).

The ultimate groundwater flow direction in the Upper Continental Recharge System (UCRS) is downwards into underlying aquifers. The Regional Gravel Aquifer (RGA) has high hydraulic conductivity and is therefore the dominant ground water flow system in the area. Its hydraulic conductivity makes it the primary aquifer of interest for remedial action (EPA 1995b).

The RGA is the uppermost aquifer at the PGDP and consists of gravel and sand facies of the Lower Continental Deposits. The McNairy Formation directly underlies the RGA; when present, the sand layer at the top of the McNairy Formation forms part of the RGA. The RGA is recharged by downward percolation of water through the UCRS and upward movement through the Terrace Gravel south of the Porters Creek terrace. From the PGDP site, groundwater flows northward towards the Ohio River. The level of the river is the base level for the regional groundwater system. The groundwater velocity in the RGA is estimated to vary from 61 to 122 meters/year towards the Ohio River (EPA 1995b).

Groundwater Contamination

Studies (DOE 2010a) show strong evidence that free-phase TCE is present as dense nonaqueous-phase liquid (DNAPL) near the contamination source areas at PGDP in the RGA. Over time, dissolved-phase TCE has moved in plumes towards the Ohio

River in the RGA. Free-phase TCE slowly dissolves into the ground water, propagating groundwater contamination down-gradient in the RGA. Concentrations of TCE in the contamination plumes increase towards the bottom of the aquifer as the distance from the source increases (DOE 2010a).

TCE concentrations were measured in groundwater extracted from soil borings located outside the plant security fence. Levels were detected up to 2,856 ug/L; this exceeds the MCL of 5ug/L. The degradation product of TCE, 1,1-DCE was detected at levels up to 15 ug/L in groundwater extracted from two soil borings from just east of the PGDP fence; this level exceeds the MCL of 7 mg/L (EPA 1995b, EPA 2002).

Clean up Levels/Process

Currently (as of December 2010), DOE is operating a pump and treat system at PGDP to control plume migration. The treatment system was designed to remove both TCE and technetium-99 from the pumped groundwater (DOE 2010a). In offsite groundwater, the key contaminants of concern are technetium-99 and TCE (EPA 1995b). This interim action does not determine site-wide post-closure cleanup goals, however, the pump and treat system must treat water in accordance with an KPDES discharge permit before discharge. KPDES permit details are not widely available online.

A3. Oak Ridge Reservation

Oak Ridge Reservation (ORR) is located within the corporate limits of the city of Oak Ridge, Tennessee, in Roane and Anderson counties (34,526 acres). The ORR is bounded to the east, south, and west by the Clinch River and on the north by the developed portion of the city of Oak Ridge. The ORR hosts three major industrial research and production facilities originally constructed as part of the World War II-era Manhattan Project: ETTP, formerly the K-25 Site and ORGDP; Oak Ridge National Laboratory (ORNL), formerly X-10; and the Y-12 National Security Complex. The area surrounding ORR is used for agricultural, residential, and recreational purposes and is sparsely populated (EPA 2005).

From 1942 to 1964, gaseous diffusion technology was used to enrich uranium for use in nuclear weapons. For the next 20 years, the primary mission of ORGDP was the production of low-enriched uranium for fabrication into fuel elements for commercial and research nuclear reactors. Secondary missions in the mid-1980s included research on new technologies for uranium enrichment such as gas centrifuge and laser isotope separation. In 1985, because of a decline in the demand for enriched uranium, DOE placed the ORGDP in standby mode. The decision to permanently shut down the facility was made in 1987. Activities at ORGDP, as well as activities at the Y-12 Complex and ORNL, have resulted in the release of contamination to the environment (volatile organic compounds and radionuclides). Because of these contaminant releases, the ORR was placed on the EPA National Priorities List (NPL) established under CERCLA (EPA 2005).

The ORR is underlain by the Rome Formation located to the east and Chickamauga Supergroup in the west. The Rome Formation consists of thin-bedded shales, siltstones and sandstones with some minor limestone beds in the lower part of the formation. The Chickamauga Supergroup generally consists of interbedded limestones, argillaceous limestones, occasional calcareous shale beds and some chert-rich zones. Aquifer thickness for the overburden in the subcrop area of the Rome Formation averages 12 feet with hydraulic conductivity averageing 0.067 ft/day. While below the overburden average aquifer thickness is 126 ft and an average of 0.095 ft/day. Aquifer thickness for the Chickamauga bedrock varies from 100 to 147 feet thick with an average thickness of 129 feet and an average hydraulic conductivity of 13 ft/day (EPA 2005).

The primary strata that transmits groundwater is the intermediate interval of the Maynardsville Limestone, between 100 and 328 feet. In this level, solution cavities and fractures enlarged by dissolution and represent an important pathway for contaminant transport (EPA 2005).

Groundwater Contamination (Eastern Tennessee Technology Park (ETTP) Zone 2)

Groundwater cleanup levels were based upon MCL’s and contaminants were identified based on which chemicals were found in the groundwater beneath the site at concentrations above MCL's; to be considered a contaminant, MCL must have been exceeded more than once in a well. Contaminants identified beneath the site were alpha activity, rune metals (arsenic, barium, beryllium, cadmium, chromium, lead, mercury, selenium, and thallium), bis(2-ethylhexyl) phthalate and six VOCs (EPA 2005).

Contaminants and their observed levels are for ETTP Zone 2 and are shown in Table A3.1 (EPA 2005). The target concentrations in groundwater are shown in Table A3.2 (EPA 2005).

Table A3.1: Groundwater contaminants at ETTP Zone 2 at Oak Ridge (EPA 2005)

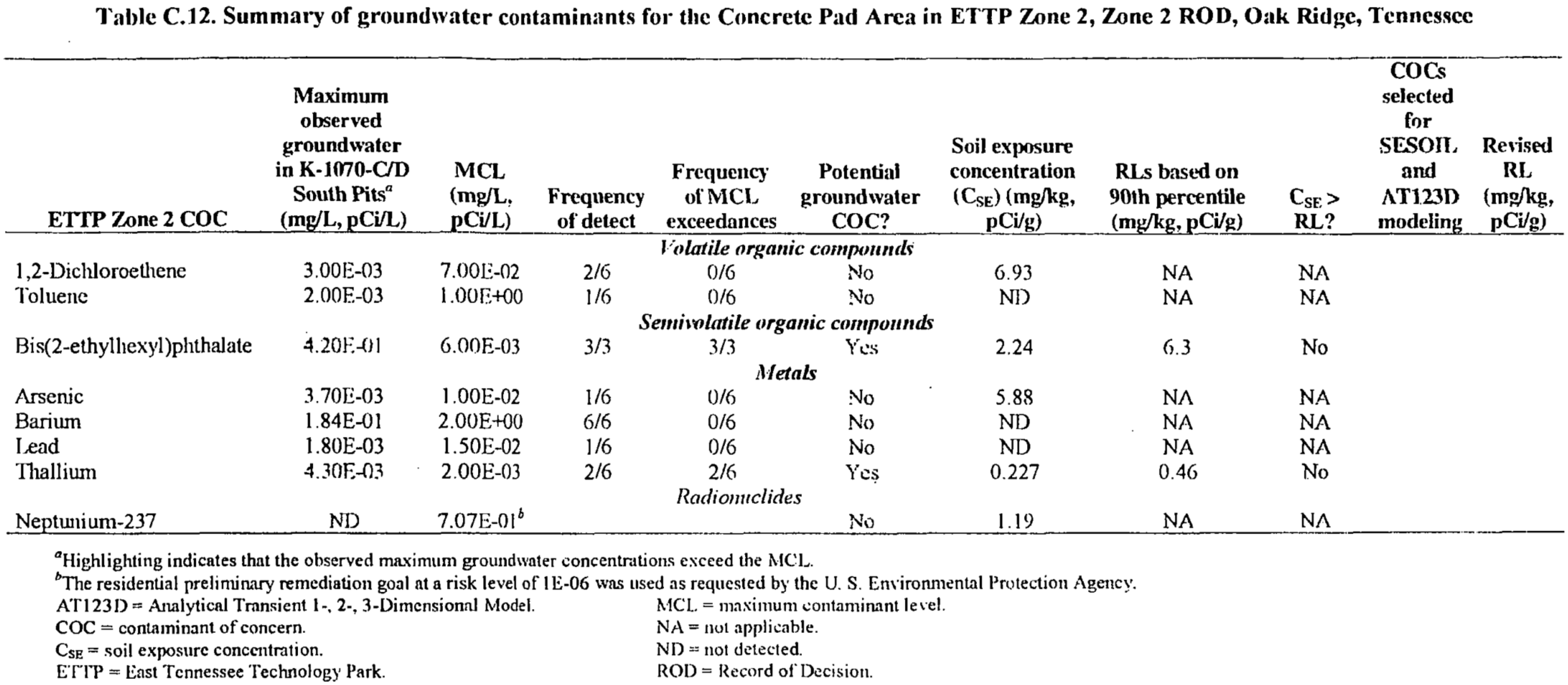


Table C.12. Summary of groundwater contaminants for the Concrete Pad Area in ETTP Zone 2, Zone 2 ROD, Oak Ridge, Tennessee

ETTP Zone 2 COC	Maximum observed groundwater in K-1070-C/D South Pits[a] (mg/L, pCi/L)	MCL (mg/L, pCi/L)	Frequency of detect	Frequency of MCL exceedances	Potential groundwater COC?	Soil exposure concentration (C_{SE}) (mg/kg, pCi/g)	RLs based on 90th percentile (mg/kg, pCi/g)	C_{SE} > RL?	COCs selected for SESOIL and AT123D modeling	Revised RL (mg/kg, pCi/g)
				Volatile organic compounds						
1,2-Dichloroethene	3.00E-03	7.00E-02	2/6	0/6	No	6.93	NA	NA		
Toluene	2.00E-03	1.00E+00	1/6	0/6	No	ND	NA	NA		
				Semivolatile organic compounds						
Bis(2-ethylhexyl)phthalate	4.20E-01	6.00E-03	3/3	3/3	Yes	2.24	6.3	No		
				Metals						
Arsenic	3.70E-03	1.00E-02	1/6	0/6	No	5.88	NA	NA		
Barium	1.84E-01	2.00E+00	6/6	0/6	No	ND	NA	NA		
Lead	1.80E-03	1.50E-02	1/6	0/6	No	ND	NA	NA		
Thallium	4.30E-03	2.00E-03	2/6	2/6	Yes	0.227	0.46	No		
				Radionuclides						
Neptunium-237	ND	7.07E-01[b]			No	1.19	NA	NA		

[a] Highlighting indicates that the observed maximum groundwater concentrations exceed the MCL.

[b] The residential preliminary remediation goal at a risk level of 1E-06 was used as requested by the U. S. Environmental Protection Agency.

AT123D = Analytical Transient 1-, 2-, 3-Dimensional Model.
COC = contaminant of concern.
C_{SE} = soil exposure concentration.
ETTP = East Tennessee Technology Park.
MCL = maximum contaminant level.
NA = not applicable.
ND = not detected.
ROD = Record of Decision.

Table A3.2: Target Groundwater concentrations for ETTP Zone 2 at Oak Ridge (EPA 2005)

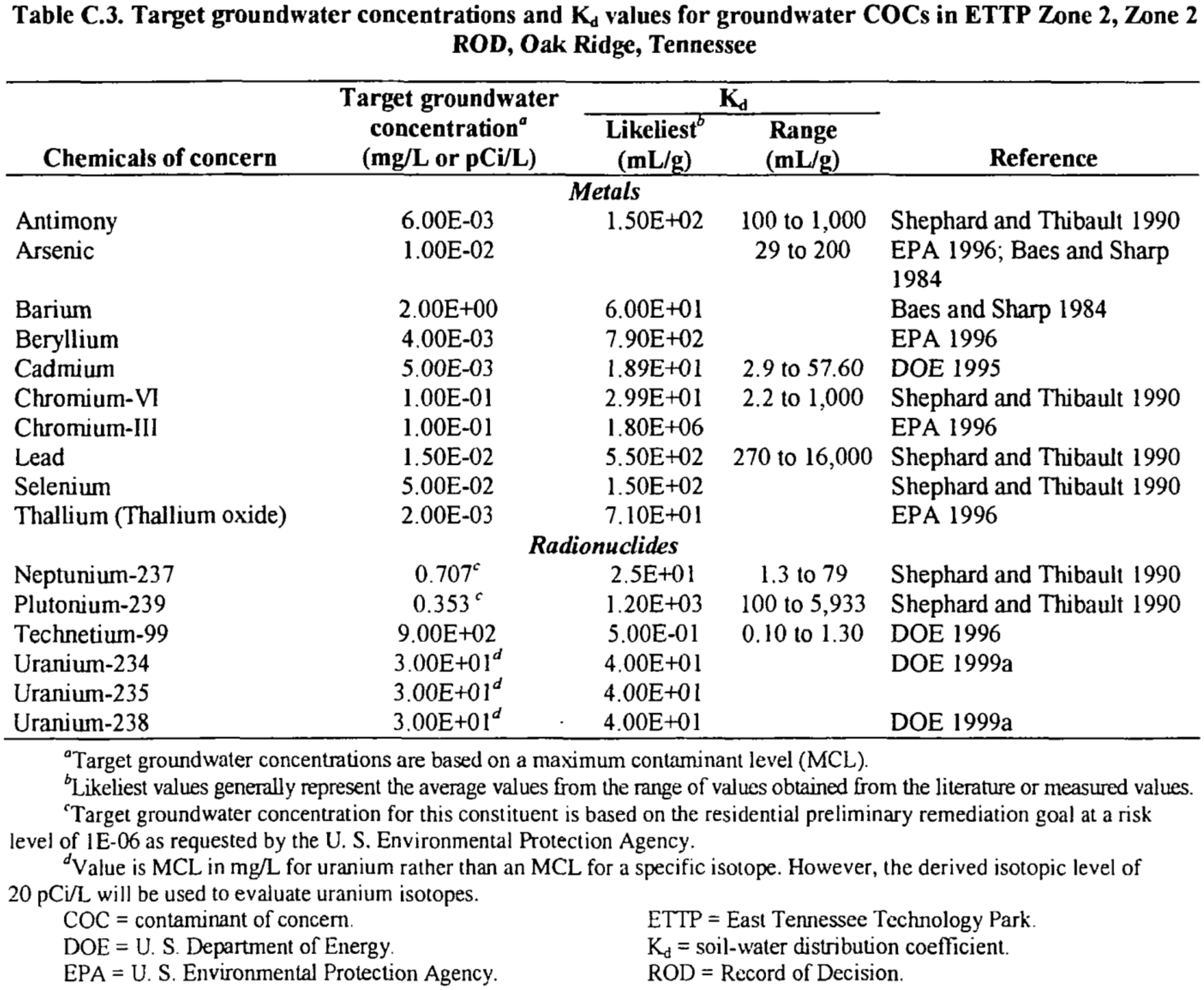


Table C.3. Target groundwater concentrations and K_d values for groundwater COCs in ETTP Zone 2, Zone 2 ROD, Oak Ridge, Tennessee

	Target groundwater concentration[a] (mg/L or pCi/L)	K_d		
Chemicals of concern		Likeliest[b] (mL/g)	Range (mL/g)	Reference
		Metals		
Antimony	6.00E-03	1.50E+02	100 to 1,000	Shephard and Thibault 1990
Arsenic	1.00E-02		29 to 200	EPA 1996; Baes and Sharp 1984
Barium	2.00E+00	6.00E+01		Baes and Sharp 1984
Beryllium	4.00E-03	7.90E+02		EPA 1996
Cadmium	5.00E-03	1.89E+01	2.9 to 57.60	DOE 1995
Chromium-VI	1.00E-01	2.99E+01	2.2 to 1,000	Shephard and Thibault 1990
Chromium-III	1.00E-01	1.80E+06		EPA 1996
Lead	1.50E-02	5.50E+02	270 to 16,000	Shephard and Thibault 1990
Selenium	5.00E-02	1.50E+02		Shephard and Thibault 1990
Thallium (Thallium oxide)	2.00E-03	7.10E+01		EPA 1996
		Radionuclides		
Neptunium-237	0.707[c]	2.5E+01	1.3 to 79	Shephard and Thibault 1990
Plutonium-239	0.353[c]	1.20E+03	100 to 5,933	Shephard and Thibault 1990
Technetium-99	9.00E+02	5.00E-01	0.10 to 1.30	DOE 1996
Uranium-234	3.00E+01[d]	4.00E+01		DOE 1999a
Uranium-235	3.00E+01[d]	4.00E+01		
Uranium-238	3.00E+01[d]	4.00E+01		DOE 1999a

[a] Target groundwater concentrations are based on a maximum contaminant level (MCL).

[b] Likeliest values generally represent the average values from the range of values obtained from the literature or measured values.

[c] Target groundwater concentration for this constituent is based on the residential preliminary remediation goal at a risk level of 1E-06 as requested by the U. S. Environmental Protection Agency.

[d] Value is MCL in mg/L for uranium rather than an MCL for a specific isotope. However, the derived isotopic level of 20 pCi/L will be used to evaluate uranium isotopes.

COC = contaminant of concern.
DOE = U. S. Department of Energy.
EPA = U. S. Environmental Protection Agency.
ETTP = East Tennessee Technology Park.
K_d = soil-water distribution coefficient.
ROD = Record of Decision.

Groundwater (Contaminated Soils and Scrapyard in Upper East Fork Poplar Creek, Oak Ridge, Tennessee)

Groundwater has been found to have both VOC and chlorinated organic contamination at this facility. The signature VOCs are benzene, toluene, ethylbenzene and xylenes (BTEX).

The contaminated soils and scrapyard in the Upper East Fork Poplar Creek contain sufficiently high levels of soluble contaminants and can be a source of contamination to surface water and groundwater. Soils identified as a source of groundwater contamination will be remediated. Soils will be remediated if they contribute to an excess lifetime cancer risk (ELCR) greater than 1 x 10^{-4} or an Hazard Index (HI) greater than one for industrial drinking water use (EPA 2005).

It is assumed that because of the age of the contamination, contaminants in soils that are not already causing groundwater contamination are either immobile or at significantly low enough levels to not cause future risk of groundwater contamination. Soils with unacceptable contamination levels are excavated to the water table or bedrock to prevent release into groundwater or surface water. These soils will either be disposed of at the EMWMF or other appropriate ORR disposal facility if they meet the waste acceptance criteria (WAC) or will be sent off-site for disposal if they do not meet the ORR WACs (EPA 2005).

Clean-up Levels/Process

The groundwater cleanup levels are based upon MCLs. Cleanup on the site is compliant with Clean Water Act of 1972 NPDES compliance program, RCRA facility investigations, RCRA interim status and post-closure monitoring, DOE Order 5400.1 compliance, Risk Management for Public Entities (RMPE) program, Biological Monitoring and Abatement Program and sampling is conducted specifically to support the RI. The selected remedies protect human health and the environment, complies with ARARs, offers the best balance in satisfying the CERCLA evaluation criteria, and meet the remedial action objectives (RAO) (EPA 2005).

A4. Rocky Flats Environmental Technology Site

The Rocky Flats Plant (RFP) is located approximately sixteen miles northwest of downtown Denver, in northern Jefferson County, Colorado. Most Rocky Flats structures are located within the industrialized area of Rocky Flats, which occupies approximately four hundred acres and is surrounded by a buffer zone of approximately 6,150 acres (EPA 1997b).

The RFP is a government-owned, contractor-operated facility. It is part of a nation-wide nuclear weapons research, development, and production complex administered by the Albuquerque Operations Office of the U.S. Department of Energy. The operating contractor for the Rocky Flats Plant is Rockwell International. The facility manufactures components for nuclear weapons and has been in operation since 1951. RFP fabricates components from plutonium, uranium, beryllium, and stainless steel. Production activities include metal fabrication, machining, and assembly. Both radioactive and nonradioactive wastes are generated in the process. Current waste handling practices involve on-site and off-site recycling of hazardous materials and off-site disposal of solid radioactive materials at other DOE facilities (EPA 1990b).

Rocky Flats Environmental Technology Site (RFETS) is located along the eastern edge of the southern Rocky Mountain region, immediately east of the Colorado Front Range. The site is located on a broad, eastward-sloping pediment that is capped by alluvial deposits of Quaternary age. The tops of alluvial-covered pediments are nearly flat but slope eastward at fifty to two hundred feet per mile (EPA 1997b). Groundwater is present in this surficial colluvium under unconfined conditions with recharge from infiltration of precipitation and seepage from creeks. This is a dynamic system with groundwater velocities estimated at 780 ft/yr to 150 ft/yr (EPA 1990b)

The bedrock geology underlying RFETS is marked by two regional sedimentary formations, the Arapahoe Formation underlied by the Laramie Formation. The Laramie Formation consists of a thick upper claystone (700 ft) and a lower sandstone. The lower sandstone and underlying Fox Hills Sandstone is a regionally aquifer with a thickness 200 to 300 ft thick (EPA 1991b). Both the Arapahoe Formation and the claystone of the Laramie Formation have low transmissivities which makes deep vertical migration of groundwater contamination from the shallow aquifer at RFETS into the Fox Hills Sandstone nearly impossible, thus making the Fox Hill Sandstone a very important aquifer. Groundwater in the Rocky Flats Alluvium flows laterally across the top of the Arapahoe Formation (EPA 1997a, EPA 1997b).

Groundwater Contamination

In the two groundwater wells installed during the RFI/RI, the only radiological constituents that exceed maximum background levels were U-235 and U-238. Groundwater monitoring at RFETS, including wells in the Rocky Flats Alluvium at the site boundaries show that shallow groundwater contamination is not migrating off site in the Alluvium aquifer. The groundwater in OU1 is contaminated by VOCs and metals, Table A4.1 summarizes the contaminants found in the surface soil, subsurface soil, groundwater, surface water seeps and sediment (EPA 1997b).

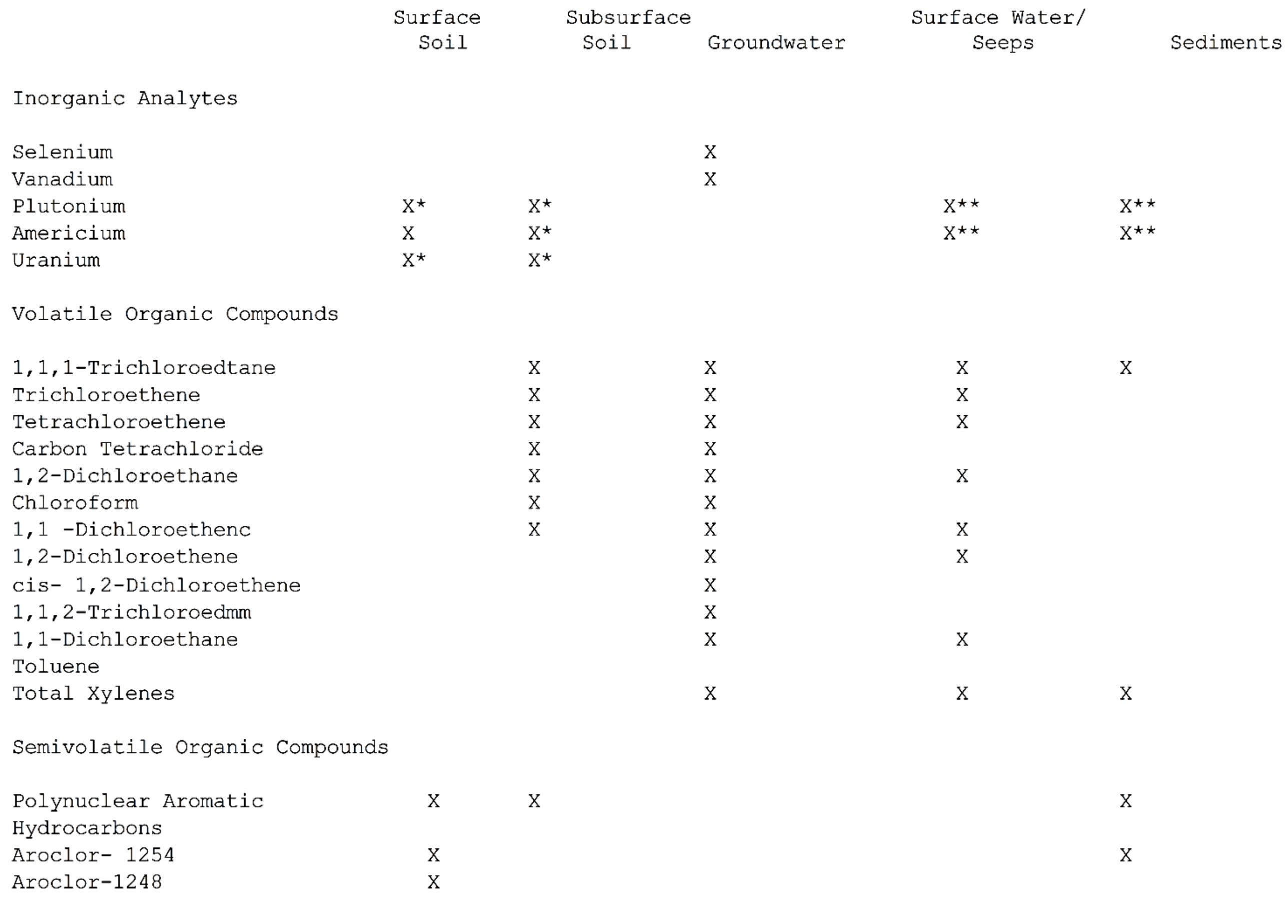
During Phase III RFI/RI, the primary contaminants in subsurface soils and groundwater were carbon tetrachloride, 1,1-dichloroethene, tetrachloroethene, 1,1-trichloroethane, trichloroethene and selenium. Occurrence of contaminants in the lower hydrostratigraphic units of the alluvium was limited to low levels of VOCs (summarized in Table A4.2) and localized metal contamination, particularly of selenium (EPA 1997a, EPA 1997b).

Clean-up/Processes

Two groundwater wells were installed during the RFI/RI. Point source discharges and stormwater discharges are monitored for non-radiological parameters to meet the requirements of the site's NPDES permit. Groundwater and surface water monitoring on site and at the site boundary for many parameters including plutonium-239/240 and americium-241 is conducted to meet RFCA requirements (EPA 1997a, EPA 1997b).

Extracted groundwater is treated with ultraviolet/hydrogen peroxide oxidation and ion exchange before discharge. Since groundwater ingestion was found to have the highest potential risk for future use of the site, Colorado Basic Standards for Groundwater, found in 5 CCR 1002-41 (Code of Colorado - Regulation 41) and equal to national MCLs for TCE were used as cleanup levels for OU 1 (EPA 1997b, CCR 2008).

Table A4.1: Summary of Contaminants at Operable Unit 1 at Rocky Flats (EPA 1997b)

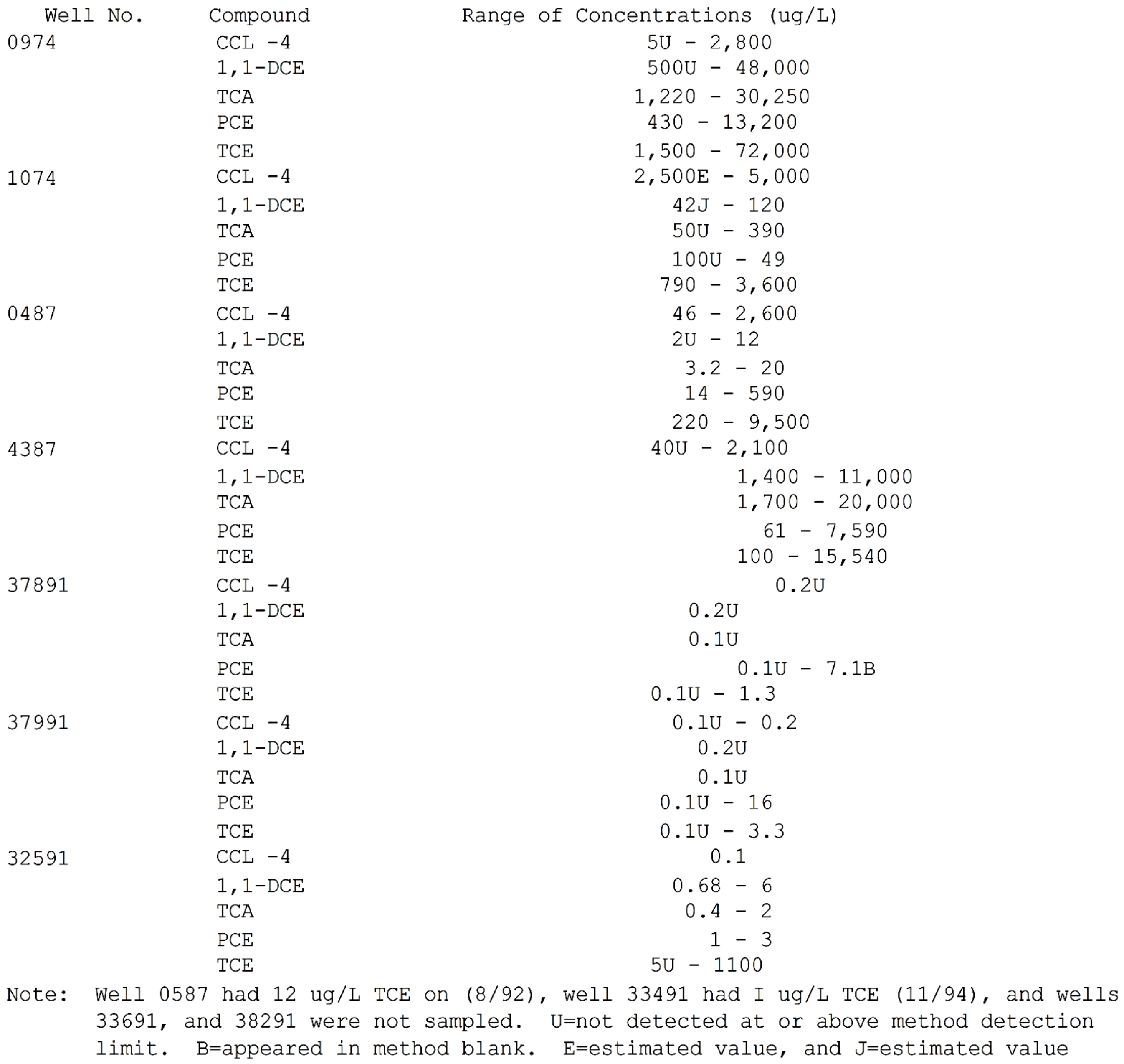


	Surface Soil	Subsurface Soil	Groundwater	Surface Water/ Seeps	Sediments
Inorganic Analytes					
Selenium			X		
Vanadium			X		
Plutonium	X*	X*		X**	X**
Americium	X	X*		X**	X**
Uranium	X*	X*			
Volatile Organic Compounds					
1,1,1-Trichloroedtane		X	X	X	X
Trichloroethene		X	X	X	
Tetrachloroethene		X	X	X	
Carbon Tetrachloride		X	X		
1,2-Dichloroethane		X	X	X	
Chloroform		X	X		
1,1 -Dichloroethenc		X	X	X	
1,2-Dichloroethene			X	X	
cis- 1,2-Dichloroethene			X		
1,1,2-Trichloroedmm			X		
1,1-Dichloroethane			X	X	
Toluene					
Total Xylenes			X	X	X
Semivolatile Organic Compounds					
Polynuclear Aromatic Hydrocarbons	X	X			X
Aroclor- 1254	X				X
Aroclor-1248	X				

*Presence in these media is based on hot spot data.

** Presumed to be present as a contaminant of these media because of the widespread nature of the contamination originalting from an off-site source.

Table A4.2: Summary of VOC Concentrations in Groundwater wells (1987-1995) (EPA 1997b)



Well No.	Compound	Range of Concentrations (ug/L)
0974	CCL -4	5U - 2,800
	1,1-DCE	500U - 48,000
	TCA	1,220 - 30,250
	PCE	430 - 13,200
	TCE	1,500 - 72,000
1074	CCL -4	2,500E - 5,000
	1,1-DCE	42J - 120
	TCA	50U - 390
	PCE	100U - 49
	TCE	790 - 3,600
0487	CCL -4	46 - 2,600
	1,1-DCE	2U - 12
	TCA	3.2 - 20
	PCE	14 - 590
	TCE	220 - 9,500
4387	CCL -4	40U - 2,100
	1,1-DCE	1,400 - 11,000
	TCA	1,700 - 20,000
	PCE	61 - 7,590
	TCE	100 - 15,540
37891	CCL -4	0.2U
	1,1-DCE	0.2U
	TCA	0.1U
	PCE	0.1U - 7.1B
	TCE	0.1U - 1.3
37991	CCL -4	0.1U - 0.2
	1,1-DCE	0.2U
	TCA	0.1U
	PCE	0.1U - 16
	TCE	0.1U - 3.3
32591	CCL -4	0.1
	1,1-DCE	0.68 - 6
	TCA	0.4 - 2
	PCE	1 - 3
	TCE	5U - 1100

Note: Well 0587 had 12 ug/L TCE on (8/92), well 33491 had I ug/L TCE (11/94), and wells 33691, and 38291 were not sampled. U=not detected at or above method detection limit. B=appeared in method blank. E=estimated value, and J=estimated value

A5. Savannah River Site

The Savannah River Site (SRS) is an approximately 300 square mile site near Aiken, South Carolina, adjacent to the Savannah River. The population within a 50 mile radius of SRS was 555,100 based on the 1980 census data. The SRS is co-operated by the US Department of Energy and Westinghouse Savannah River Company (WSRC). SRS produced special nuclear materials for national security, the space program and medical and industrial research, including plutonium and tritium. The site has been divided into Areas to focus cleanup efforts. The A/M area is located in the northwest portion of the site and contains nuclear fuel fabrication buildings, office buildings and research areas. The A/M area groundwater plume is the focus of this section due to its similarity to PORTS. The A and M areas are divided into several operable units; the A/M Area groundwater unit is a media-specific operable unit addressing groundwater contamination within the A/M Area Fundamental Study Area (SRS 2005).

The A/M Area is underlain by three key aquifers; the Steed Pond Aquifer is the uppermost aquifer receiving the bulk of the contamination from the surface and consisting of the M-Area Aquifer and the Lost Lake Aquifer; the Crouch Branch Aquifer is the principle confined aquifer and the McQueen Branch Aquifer is the deepest aquifer. Crouch Branch and McQueen Branch are both names originating at SRS and are equivalent to the USGS named Dublin and Midville Aquifers, respectively (SRS 2005).

Groundwater Contamination

The groundwater beneath the A/M Area is contaminated primarily by organic solvents including TCE and PCE. The 1200 acre plume has not migrated off site. In the period of operation from 1952 to 1981, about 13 million pounds of chlorinated solvents were used in the A/M Area; most of the solvent evaporated during degreasing operations. The remainder was either discharged to the sewer system or inadvertently spilled. Before 1976, waste solvents were discharged to the A-014 Outfall (Tims Branch); after 1976, all waste solvents were transferred to the M-Area Settling Basin. The Outfall, the Settling Basin, the Hazardous Waste Management Facility and the Solvent Storage Areas were the four key sources of chlorinated solvents to the groundwater (EPA 1992b).

Beginning with voluntary corrective action in June 1981, extensive work has been done to characterize and remediate the A/M groundwater plume, including installation of over 350 monitoring wells. Most of the contaminants from the A/M Area are found in the uppermost aquifer. While the uppermost aquifer is not a source of on-site drinking water, it is used off-site for domestic purposes. The uppermost aquifer is separated from the principle confined aquifer and subsequent deeper aquifers by a thick and continuous confining layer. This limits the migration of contamination from the uppermost aquifer into the deepest aquifer that is used for drinking water and process water at SRS. Contamination has spread from the uppermost aquifer into the principle confined aquifer at levels varying from less than one part per billion of TCE to 1000 ppb of TCE. Based on the 2005 environmental report, levels of TCE and PCE in the aquifers underlying A/M Area are on the order of 30,000 ppb of TCE and 130,000 ppb of PCE where the MCL for each is 5 ppb (EPA 1992b).

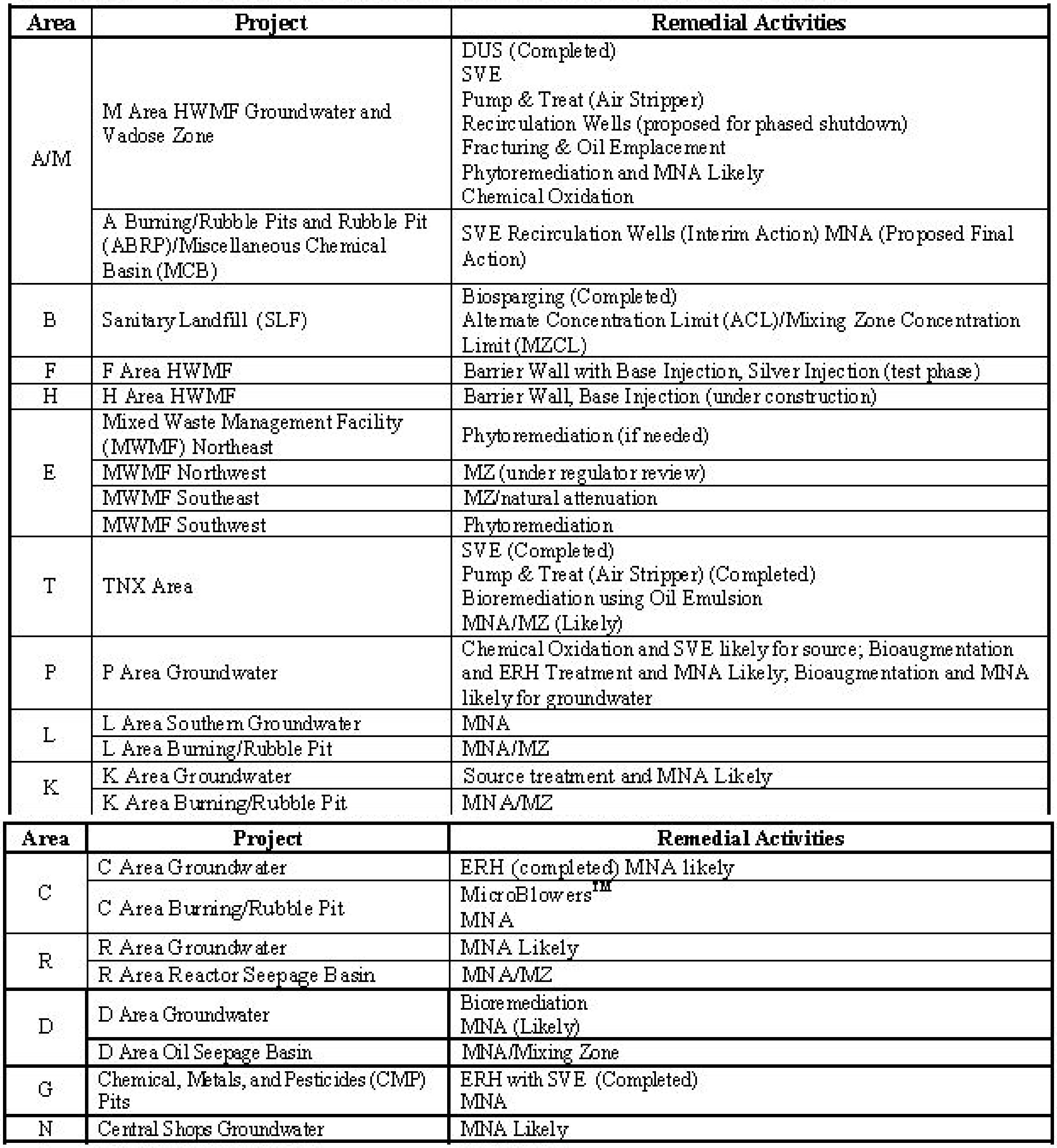
Clean-up levels and Removal Processes

In response to detection of VOCs in the groundwater, SRS undertook a voluntary groundwater cleanup program in 1981. In 1983, in agreement with the South Carolina Department of Health and Environmental Control, SRS began an experimental groundwater treatment program. One recovery well and a 20 gallon per minute air stripper was installed first. By early 1984, two more recovery wells and a larger, 70 gpm, air stripper were installed. In 1985, eight additional extraction wells were installed and all eleven wells were connected to a 400 gpm air stripper. In 1990, the air stripper flow rate was increased to 500 gpm. In 1992, one of the small, experimental air strippers was moved to a different part of A-Area to treat water from one extraction well. The air strippers remove organics to below drinking water standards; the treated water is then discharged in accordance with the NPDES permit for the A-014 Outfall. Since air stripping solvents from water works by volatilizing those solvents, the site must comply with air quality standards in addition to water quality standards. By the date of the ROD published in 1992 (EPA 1992a), over 250,000 pounds of solvents had been removed from the subsurface. The groundwater treatment program complies with ARARs including South Carolina Primary Drinking Water Regulations (R.61-58) Maximum Contaminant Levels or the Federal Safe Drinking Water Ace (40 CFR 141) promulgated MCLs. An air emissions permit is required for air stripping operations. Air quality must comply with the Federal Clean Air Act and the South Carolina Air Pollution Control Regulations (R.61-62), specifically the South Carolina Ambient Air Quality Standards (R.61-62.5). Discharge of treated groundwater must comply with the NPDES permitting system under the Clean Water Act and the South Carolina NPDES Permit Regulations (R.61-9). While the system is permitted through the South Carolina Air Quality Control Program and the Clean Water Act, the treatment system should also be consistent with the RCRA Subpart AA “Air Emission Standards for Process Vents” to satisfy EPA Region IV.

The strategy to manage groundwater contamination at SRS is to mitigate the source of the contamination and limit its migration. Table A5.1 shows the SRS groundwater corrective actions. In order to reduce the number of wells used to remediate the A/M groundwater plume, the site transitioned to using monitored natural attenuation (MNA) and phytoremediation for the distal portion of the plume. Phytoremediation is used at the Mixed Waste Facility Southwest to capture tritium from collected water used to irrigate 44 acres of pine trees (EPA 2011a).

Beyond Areas A/M, SRS has unique waste management strategies of interest to PORTS. The Defense Waste Processing Facility sorts both low level and high level waste. The low level waste is separated from tanks as a radioactive salt solution and disposed in the Saltstone Disposal Facility. This allows the high level waste to be separated, bonded to a borosilicate glass for stable storage (Savannah River Nuclear Solutions 2011).

Table A5.1 Groundwater Cleanup at SRS (EPA 2011a)



Area	Project	Remedial Activities
A/M	M Area HWMF Groundwater and Vadose Zone	DUS (Completed) SVE Pump & Treat (Air Stripper) Recirculation Wells (proposed for phased shutdown) Fracturing & Oil Emplacement Phytoremediation and MNA Likely Chemical Oxidation
	A Burning/Rubble Pits and Rubble Pit (ABRP)/Miscellaneous Chemical Basin (MCB)	SVE Recirculation Wells (Interim Action) MNA (Proposed Final Action)
B	Sanitary Landfill (SLF)	Biosparging (Completed) Alternate Concentration Limit (ACL)/Mixing Zone Concentration Limit (MZCL)
F	F Area HWMF	Barrier Wall with Base Injection, Silver Injection (test phase)
H	H Area HWMF	Barrier Wall, Base Injection (under construction)
E	Mixed Waste Management Facility (MWMF) Northeast	Phytoremediation (if needed)
	MWMF Northwest	MZ (under regulator review)
	MWMF Southeast	MZ/natural attenuation
	MWMF Southwest	Phytoremediation
T	TNX Area	SVE (Completed) Pump & Treat (Air Stripper) (Completed) Bioremediation using Oil Emulsion MNA/MZ (Likely)
P	P Area Groundwater	Chemical Oxidation and SVE likely for source; Bioaugmentation and ERH Treatment and MNA Likely; Bioaugmentation and MNA likely for groundwater
L	L Area Southern Groundwater	MNA
	L Area Burning/Rubble Pit	MNA/MZ
K	K Area Groundwater	Source treatment and MNA Likely
	K Area Burning/Rubble Pit	MNA/MZ
C	C Area Groundwater	ERH (completed) MNA likely
	C Area Burning/Rubble Pit	MicroBlowers™ MNA
R	R Area Groundwater	MNA Likely
	R Area Reactor Seepage Basin	MNA/MZ
D	D Area Groundwater	Bioremediation MNA (Likely)
	D Area Oil Seepage Basin	MNA/Mixing Zone
G	Chemical, Metals, and Pesticides (CMP) Pits	ERH with SVE (Completed) MNA
N	Central Shops Groundwater	MNA Likely

A6. Ashtabula Closure Project – Fields Brook

Ashtabula Closure – Fields Brook Site (Site), located 55 miles east of Cleveland in the city and county of Ashtabula, Ohio, is a six square-mile watershed where up to 20 separate facilities have operated since 1940. Activities range from chemicals production to metals-fabrication. Fields Brook flows into the Ashtabula River, which drains into Lake Erie approximately 1.5 miles downstream of the site. Soil and sediment in the Fields Brook floodplain, and surrounding wetlands area, are contaminated with a wide variety of pollutants including polychlorinated biphenyls (PCBs), metals and chlorinated solvents. The Site was placed on the National Priorities list for hazardous waste sites on September 8, 1983 (EPA 1997c).

In general, the subsurface geology of the Fields Brook watershed consists of three geologic formations. In descending order, these formations are: glacial-lacustrine, glacial till, and shale bedrock (EPA 1997c). Additionally, several feet of miscellaneous soil fill materials were encountered, distributed sporadically, as the result of several years of industrial activities.

Arsenic is present in the watershed as a natural constituent of the local geology at levels at which exposure risks approximate those found in background areas. Since the U.S. EPA generally does not require cleanup of contaminants below background levels at sites, the arsenic cleanup goal for the floodplain/wetlands area (FWA) is set at the background level, 27 ppm.

Upper reaches of Fields Brook flow through heavily industrialized areas; although access to the brook in these areas is not completely restricted, public use is generally not found due to the industrial nature of the area. Lower reaches of the brook flow through residential neighborhoods before emptying into the Ashtabula River. Approximately 23,000 people live within one mile of the site. The City of Ashtabula provides drinking water to all residents in Ashtabula with water taken directly from Lake Erie, and this water is tested regularly and has not shown any exceedences of drinking water standards (EPA 1997c).

Groundwater Contamination

Decades of manufacturing activity and waste management practices at industrial facilities (Detrex, RMI extrusion, RMI metals, ACME, Millenium $TiCl_4$, and Conrail) (Figure A6.1) resulted in the discharge or release of a variety of organic and heavy metal pollutants to Fields Brook and its watershed, including the FWA. Sediments at the Site were contaminated with PCBs, volatile organic compounds (VOCs), polycyclic aromatic hydrocarbons, heavy metals, phthalates, and low-level radionuclides. VOCs and heavy metals including mercury, lead, zinc, and cadmium were detected in surface water from Fields Brook, threatening drinking water intakes in Lake Erie. Contaminants detected in fish included PCBs and VOCs.

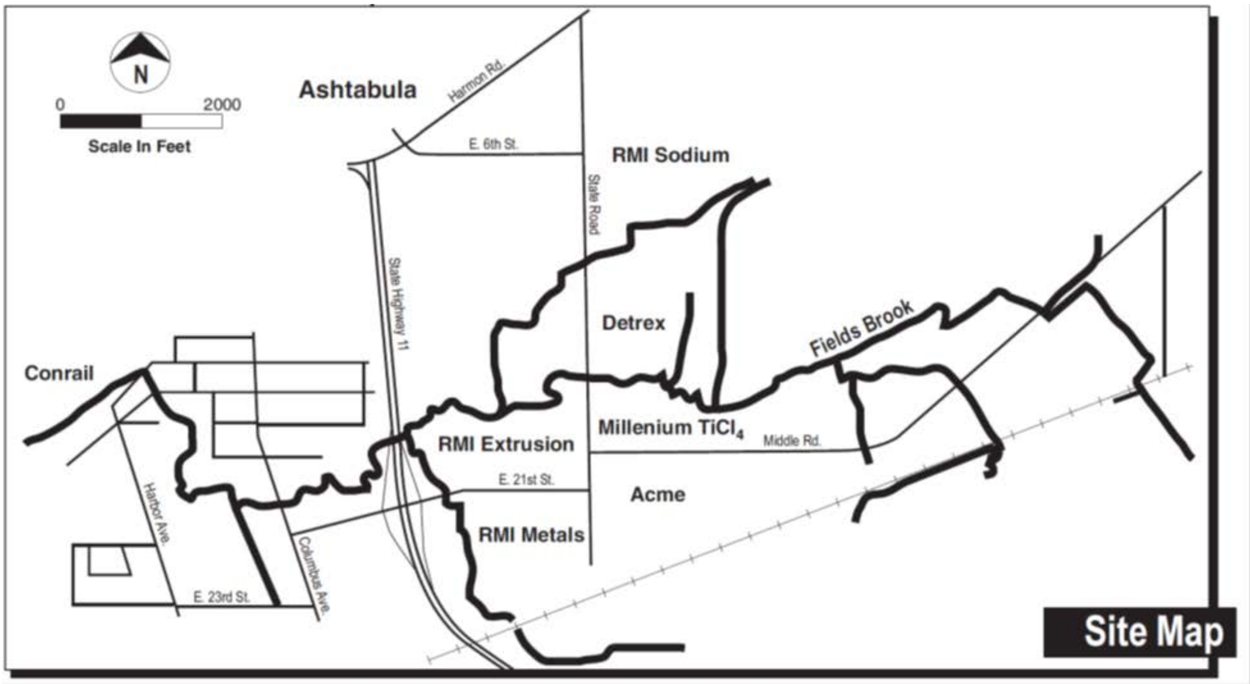


Figure A6.1. Industrial facilities in the Fields Brook area (USEPA 1999)

Clean-up and Removal Processes

Beginning in 2000, contaminated soils and sediments in the floodplain and surround wetlands area which exceed cleanup action levels have been excavated or covered followed by backfill with hydric-compatible soils. Contaminated sediments underwent thermal treatment at an off-Site facility; in addition, an on-Site landfill was constructed to contain site soils at the Millennium landfill and RMI Sodium property (Map 1). For sediment with background levels of radionuclides, off-site thermal treatment would proceed as planned. For sediment with levels of radionuclides above background, the sediment would be chemically stabilized prior to disposal in the on-site landfill. Trees within the excavation areas and all trees below 12” diameter at basal height, considered contaminated were removed. Native vegetation and erosion mats were used to revegetate all backfill and cover areas.

Monitoring wells around the landfill were routinely sampled to detect for radionuclides. Air monitoring was performed at the landfill to ensure that levels of radon gas emanating from the landfill did not present any risk to human health.

In one of the 6 sub-locations of Fields Brook (Detrex Corporation), a DNAPL plume has been identified, migrating toward the northwest, consistent with groundwater flow and the structure of the top of the underlying till layer. One remediation alternative (alternative IV) proposed the construction of a partial slurry wall to contain the plume; extracted DNAPL will be treated and recycled off-site.

Chemical specific ARARs were to be included in Tables 4-1 and 4-2 of the 1986 ROD; however, these tables were omitted from the report. However, Table A6.1 summarizes clean-up levels from the 5-year review report (EPA 2004a).

Table A6.1. Clean-up levels as indicated in the EPA 2004 5-year review report (EPA 2004a)

Parameter	Level
Radium 226 & 228 (residential areas)	5 pCi/g
Radium 226 & 228 (industrial areas)	10 pCi/g
U-238 (residential & industrial)	30 pCi/g
PCB (residential; industrial)	6; 50 ppm
Hexachlorobenzene (res; indust)	80; 200 ppm
Barium	2000 ug/L
Lead	15 ug/L

A7. Mound Plant Site

The Mound Plant Site is located within the city limits of Miamisburg, in Southern Montgomery County, Ohio. The Site is approximately 10 miles south of Dayton and 45 miles north of Cincinnati. The Mound site facility supported the early atomic weapons programs in 1946 and was situated on 306 acres (DOE 2001). Operable Unit 1 (OU 1) includes a historic landfill site that was used by the Mound Plant from 1948 to 1974. Plant waste materials that were disposed of in OU 1 included general trash and liquid waste. There are known releases of VOCs from OU 1 into the adjacent Great Miami Buried Valley Aquifer (BVA). In addition, tritium has been detected in water samples taken from wells in OU 1, although the concentration was below the drinking water maximum contaminant level 20 nCi/L (EPA 1995c, EPA 2004b). Miamisburg is predominantly a residential community with some supportive commercial facilities and limited industrial development. Much of the residential, commercial, and industrial development within a 5-mile radius of the Site is concentrated on the Great Miami River floodplain (EPA 1995c). The river valley is highly industrialized while the surrounding region is mixed farmland, residential, and small communities. According to the 2010 Census within a 10-mile radius of the Site there are 336,956 residents and within a 50-mile radius there are 3,183,953 residents (DOE 2011).

The Great Miami Buried Valley Aquifer (BVA) is a USEPA designated sole-source aquifer and serves as a drinking water source for over a million people in southwestern Ohio. The first commercial public water supply down gradient from the Mound Plant occurs approximately two river miles downstream of the canal and supports approximately 219 service connections (EPA 2004b). There are two hydro-geologic regimes at Mound Plant: flow through the bedrock and flow within the unconsolidated glacial deposits and alluvium associated with the BVA in the Great Miami River Valley. Water-lain deposits consist of outwash composed of well-sorted sand and gravel. The bedrock system, an interbedded sequence of shale and limestone, is dominated by fracture flow especially in the upper portions of the bedrock. Groundwater flow from Mound Plant is generally to the west and southwest toward the BVA of the Great Miami River Valley (EPA 1999b).

Groundwater Contamination

The Mound Plant was placed on the National Priorities List (NPL) on November 21, 1989 as a result of the Site groundwater contamination and its proximity to a sole source aquifer. DOE signed a CERCLA Section 120 Federal Facility Agreement (FFA) with US EPA, effective October 1990. In 1995, after initiating remedial investigations for several operable units (OU), DOE and its regulators realized during a strategic review the OU approach was inefficient. DOE and its regulators agreed that it would be more appropriate to evaluate each building separately, use removal action authority to remediate them as needed, and establish a goal for no additional remediation other than institutional controls for the final remedy. This process was named the Mound 2000 Process (EPA 1999b, 1999c). The Sites numerous “Release Blocks” and parcels were evaluated through the Mound Process 2000 and remediated though institutional controls. Some of the restrictions included: maintenance of industrial/commercial land use, prohibition against residential use, and prohibition against the use of groundwater. Deeds were filed with

Montgomery County and blocks and parcels were deleted from the NPL from 1999 to 2002 (DOE 2011).

Of principal threat is the contaminated groundwater in OU 1 because of the possible offsite migration of VOC-contaminated plume and the potential for direct ingestion of contaminants through drinking water wells. The soil contaminants in OU 1 are restricted to the area of past disposal activity with no discernible source detected. Five VOCs at levels above proposed or established regulatory limits (40 CFR 141) in the groundwater beneath OU 1. These VOCs are vinyl chloride (chloroethene), trichloromethane (chloroform), 1,2-cis-dichloroethene (DCE), TCE, and tetrachloroethene (PCE). From the 1995 ROD values of vinyl chloride and TCE were 17 and 160 ug/l, respectively, while estimated levels of trichloromethane, DCE and PCE were 130, 640, and 290 ug/l, respectively (EPA 1995c).

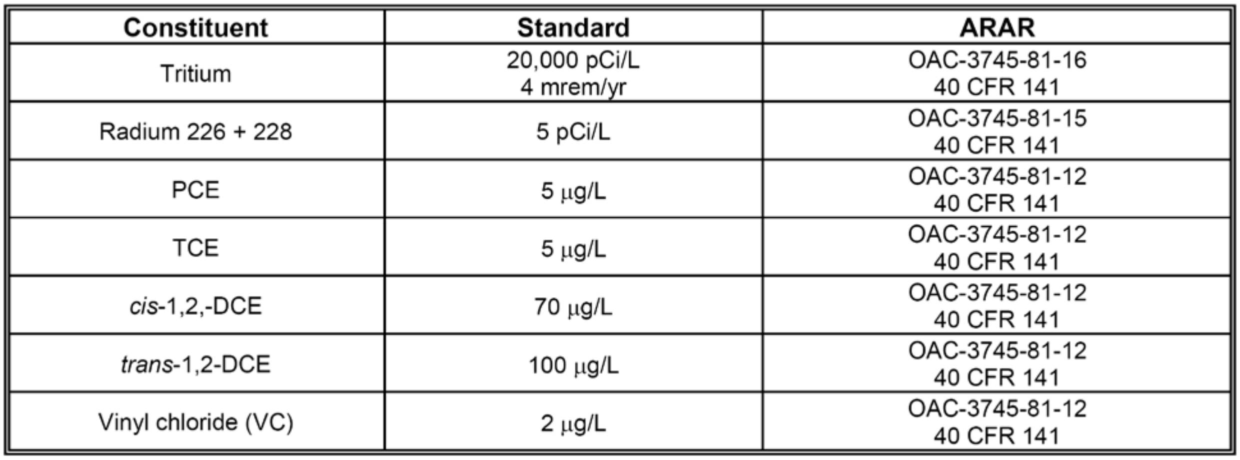
Clean-up levels and Removal Processes

The selected remedy is protective of human health and the environment. It complies with federal and state requirements that are legally applicable or relevant and appropriate to the remedial action and is cost effective. To protect human health, the remedial action objective will be to prevent ingestion of water with contaminant concentrations in excess of remediation goals (1x10-4 aggregate cancer risk for chemical risk and radiological risk combined). To protect environmental health, the objective will be to control or reduce (to remediation goals) the contaminant concentrations in the aquifer adjacent to OU 1. This will prevent contaminant movement into the BVA and ensure that the BVA remains a safe drinking water source (EPA 1995c).

The selected remedy is to collect and treat the contaminated groundwater and dispose of treated water. All extracted groundwater will be treated to levels that comply with the requirements of the Mound Plant National Pollutants Discharge Elimination System (NPDES) Permit. The major components of the selected remedy include two groundwater extraction wells within OU 1, treating the extracted groundwater to remove VOCs and other constituents, as required, using cascade aeration, UV oxidation, conventional air stripping, and discharging the treated groundwater to the Great Miami River trough an NPDES outfall (EPA 1995c). Long-term groundwater monitoring is conducted in the bedrock system to verify TCE is decreasing due to natural attenuation and is not impacting the BVA (DOE 2011). The Mound Plant will remain in industrial use into the future. This future use has been determined based upon agreement among DOE, US EPA, OEPA, and interested stakeholders (EPA 1999b).

The chemical-specific ARARs identified in the 1995 ROD for OU 1 at the site are maximum contaminant level (MCL) specified in the Safe Drinking Water Act and MCLs identified in State of Ohio regulations (OAC-3745-81-11, -12, -13, -15, and -16). Numerical standards for the primary constituents of concern at the site are listed in Table A7.1 (DOE 2011).

Table A7.1. Applicable Groundwater Standards for the Mound Site (DOE 2011)



Constituent	Standard	ARAR
Tritium	20,000 pCi/L 4 mrem/yr	OAC-3745-81-16 40 CFR 141
Radium 226 + 228	5 pCi/L	OAC-3745-81-15 40 CFR 141
PCE	5 μg/L	OAC-3745-81-12 40 CFR 141
TCE	5 μg/L	OAC-3745-81-12 40 CFR 141
cis-1,2,-DCE	70 μg/L	OAC-3745-81-12 40 CFR 141
trans-1,2-DCE	100 μg/L	OAC-3745-81-12 40 CFR 141
Vinyl chloride (VC)	2 μg/L	OAC-3745-81-12 40 CFR 141

A8. Big D Campground

Big D Campground is located in Ashtabla County, Ohio. This site consists of a 1.2 acre landfill created out of a former sand and gravel quarry. From 1964 to 1976 the site owner accepted approximately 28,000 cubic yards of hazardous materials for disposal. The contaminated media was groundwater and soil. In 1986 remedial investigation identified the landfill as the primary source of contamination in soil outside of the landfill and groundwater underlying the landfill. Groundwater contamination is a significant concern because it is migrating towards the drinking water supply wells of nearby residences and Conneaut Creek which is adjacent to and south of the site. The primary contaminants of concern affecting the soil and groundwater are VOC's including TCE and PCE and other organics, and metals including chromium and lead. The lower two miles of the Ashtabula River and its outer harbor were designated an Area of Concern due to severe pollution problems by the U.S. EPA in 1988 (EPA 1989a).

Five hydrogeologic units are identified at the site; three aquifers and two aquitards. The units present at the upper portion of the site are the water table aquifer (uppermost), the silt-clay aquitard, the hard grey clay till aquitard, and the bedrock aquifer. The units present at the lower portion of the site are the alluvial aquifer and the bedrock aquifer (EPA 1989a).

Groundwater Contamination:

Trichlorothene (TCE) contamination levels identified in groundwater were up to 1500 times in excess of federal standards for drinking water. Also shallow wells on site and near the creak showed concentrations of inorganic contaminants above background levels. Deep wells on site and near the creek showed concentrations of some inorganic constituents above background levels as well. The indicator chemicals in the shallow well sites detected include Chlorobenzene, 1,2- and 1,4-Dichlorobenzene, Trans-1,2-Dichlorobenzene, Diaminotoluene, Tetrachlorethene, Trichloroethene, and Vinyl Chloride. The maximum amount of Trichloroethene detected was 7500 ug/L, and the MCL established by ARAR is 5ug/L. Ingestion of groundwater identified total cancer risks as high as $1X10^{-2}$ under worse case condition from all three aquifers in the area. The contaminants associated with these risks are; Diaminotoluene, Tetrachlorethene, Trichloroethene, and Vinyl Chloride. TCE levels in the groundwater were up to 1500 times in excess of federal standards for drinkning water (EPA 1989a).

Clean-up Levels and Removal Processes:

The selected remedy includes a ground water collection system which will collect ground water in the water table aquifer with two interceptor trenches one at the down gradient edge of the plume and one at the north end of the source area. Ground water in the alluvial and semi-confined bedrock and confined bedrock aquifers will be collected with 30 extraction wells. A collection time of 20 to 60 years will be required to reach ground water cleanup levels in the water table aquifer. This estimate is based upon the amount of time necessary to remove contaminants from the saturated portion of the aquifer immediately below the source area and all contamination which has already migrated from the source area.

The remedial action risk objectives for the site are based on reducing health risks posed by contamination in the ground water to a cumulative hazard index of 1.0 or less and a cumulative carcinogenic risk of 10^{-6} or less. The following chemical specific ARARs will be met by the selected remedy (Table A8.1) (EPA 1989a):

Table A8.1: ARARs that will be met by the selected remedy (after EPA 1989a)

Chemical	**MCL (ug/L)**
BARIUM	**1,000**
1,4-DICHLOROBENZENE	**75**
CHROMIUM	**50**
TRICHLOROETHENE	**5**
VINYL CHLORIDE	**2**

A9. Bowers Landfill

Bowers Landfill, in Pickaway County, Ohio, is a twelve acre site that operated as a pit for gravel excavation from 1958. The owners subsequently converted the quarry to a landfill and, from 1958 to 1968, accepted domestic refuse, grain elevator and industrial wastes. Bowers Landfill is located in Pickaway County, Ohio. During this time, at least 7,500 tons of chemical waste were deposited on site, often only covered by soil and sometime incinerated. Landfill operations ended in 1968. In 1980 the USEPA found that pollutants had migrated from the landfill into nearby monitoring wells; contamination included volatile organic compounds. The groundwater contamination had the potential to impact the 60 residents that live within one half mile of the site (EPA 1989b).

Geologic conditions in the site area can be divided into two categories: unconsolidated glacial and alluvial (stream) deposits, and underlying consolidated rock strata. Potable water in the area is limited to the unconsolidated deposits; naturally occurring salts and sulfides present in bedrock water sources produce poor water quality. The primary sources of recharge are from infiltration of precipitation and from underground movement of ground water from aquifers in the adjacent upland area (Dames & Moore 1988). Ground water levels in the area generally reflect topographic conditions. Ground water movement is toward the Scioto River unless locally reversed by pumping from large nearby well fields. There are no known water wells within a mile of the landfill in a downgradient direction, as all wells appear to be located across the Scioto River or on topographically higher (upgradient) areas (Dames & Moore 1988).

Groundwater Contamination:

Monitoring of onsite groundwater wells found elevated heavy metals, VOCs, including acetone, methylene chloride, tetrachloroethene and benzene, and phthalates. The contamination caused unacceptable risk for individuals who drank or came in contact with the groundwater, inhaled contaminated soil or sediment particles or ate small animals, birds, fish or plants contaminated by the chemicals released from site. The risk of contamination is increased due to the biannual floods between the site area and the Scioto River (EPA 1989b).

Clean-up and Removal Processes:

Based on USEPA investigations carried out between 1983 and 1989, the selected remedy for the site was to reduce infiltration through contaminated soils, restrict water use downgradient from the site and to monitor groundwater wells for any increase in contamination (EPA 1989b).

The cleanup alternative selected did allow for hazardous wastes to remain in place with a low permeability (maximum permeability of 10^{-7} cm/s). Additionally, groundwater monitoring on and off site will be used to ensure that groundwater standards are met at the 'Point of Compliance'. While MCL's are meant to apply to drinking water systems serving greater than 25 people, they are still the statutory requirement applied to the contaminated groundwater at Bowers Landfill. In addition to two known wells that exceed MCL's for volatile organic compounds (VOCs), discharges from the aquifer into the Scioto River are also closely monitored to ensure no VOC's are released (EPA 1989b).

A10. Buckeye Reclamation Landfill

The Buckeye Reclamation Landfill (BRL) site is located in Belmont County, Ohio. It occupies about 100 acres of the nearly 660 acres site owned by the Ohio Resources Corporation. The site is long and narrow, extending 3,700 feet in the north-south direction and only 500 to 1000 feet in the east-west direction. In 1971, the Belmont County Health Department licensed BRL for municipal solid waste and it operated until 1991. During the period from 1976 to 1979 the BRL received industrial sludge and liquids which were mostly deposited at the north end of the landfill (EPA 1991a).

Several water bearing bedrock aquifers positioned below the unconsolidated surface material are composed of the Wegee limestone, Waynesberg coal, Uniontown sandstone, and Benwood limestone. The Redstone limestone aquifer underlies the entire site. All the bedrock formations show no indications of any substantial primary porosity or permeability. Groundwater yields are the result of secondary porosity and permeability at joint faces, coal cleats, and among bedding planes. In general, most groundwater emanating from beneath the BRL Site is discharged laterally to surface water before leaving the site. Groundwater and surface water is not used as a source of drinking water (EPA 2009a).

Groundwater Contamination:

The primary source of groundwater contamination is from the landfill. During the 'Remedial Investigation', twelve contaminants were identified as indicator chemicals in the waste pit, soils, leachate, groundwater and surface water. These indicator chemicals include arsenic, beryllium, lead, cadmium, chromium, nickel, benzene, trichloroethene, carbon tetrachloride, 1 1-dichloroethene, and carcinogenic polyaromatic hydrocarbons (PAHs). These twelve contaminants are responsible for the majority of the human health risk (EPA 1991a).

On site monitoring wells frequently exceed secondary water quality standards for total dissolved solids, iron, manganese and sulfur, whereas, fewer wells exceed the MCL for contaminants including benzene and arsenic. A total of 19 volatile organic compounds have been measured.

Clean-up and Removal Processes:

To address the groundwater contamination, a collection system for both landfill leachate and contaminated groundwater was installed. The collected water is then treated to MCL to prevent release of contamination from the site. Additionally, the cleanup included capping of both waste and up-gradient areas that acted as recharge zones to the groundwater. Additionally, a groundwater monitoring system will ensure that no contaminants leave site (EPA 1991a).

A11. Coshocton Landfill

The Coshocton Landfill in Coshocton County, Ohio was used for strip mining operation for much of the mid-1900's Coshocton Landfill. Drummed liquid wastes including alcohols, acetone, resins, xylene, perchloroethylene, mineral spirits, plasticizees and neoprene were landfilled on site. Leaking drums in the landfill contaminated groundwater, surface water and soils, although the city water supply for the city of Coshocton (population approximately 13,400) is not threatened by the landfill (EPA 1988a).

Site geology generally consists of a series of related strata (Pennsylvanian Allegheny series) with the uppermost member being sandstone followed by coal (middle Kittanning coal or no. 6), clay, shale, coal, and clay. The nominal bottom of the Coshocton landfill waste mass in the mine fill areas, is at the bottom of the no. 6 coal (EPA 1988a).

Groundwater Contamination:

The Coshocton Landfill released contaminants to both surface and groundwater. Indicator chemicals in the groundwater were identified as 2-butanone (methyl ethyl ketone), carbon disulfide, 1,1-dichloroethane, polynuclear aromatic hydrocarbons (pah), 1,1,1-trichloroethane, pentachlorophenol, heptachlor and heptachlor epoxide, phthalates, toluene, vinyl chloride, xylene, copper, nickel, and zinc. Unacceptable incremental carcinogenic risks were found due to arsenic and bis(2ethylhexyl)phthalate in the upper aquifer (EPA 1988a).

Clean-up and Removal Processes:

The Record of Decision was signed in 1988 to control contamination from the landfill. The decision called for capping the landfill and monitoring the groundwater to ensure that no contamination left site. Low levels of contamination have been detected off site, although no current potable water sources are threatened, any future use of groundwater down-gradient of the landfill would cause unacceptable carcinogenic risk. The discharge from site must meet both federal and state water quality regulations (MCL). In 1998, the remedy was found to be effective enough to remove the site from the National Priorities List.

A12. Miami County Incinerator

The Miami County Incinerator in Miami County, Ohio is a series of landfills and an incinerator. They opened in 1968 and processed both municipal and industrial wastes. Wastes were either buried or incinerated, including oils and solvents. Cleanup efforts were completed in the mid 1990's (EPA 1989c).

The local geology is a complex interstratification of glacial outwash, glacial till and recent fluvial deposits. These deposits form two separate aquifers in the immediate vicinity of the site. The upper aquifer is unconfined and is separated from the lower aquifer by a glacial till unit of variable thickness and continuity. The lower aquifer is generally under confined conditions except in areas where the intervening confining unit is absent. In those locations, both aquifers behave as a single aquifer and are under water table conditions. The general direction of groundwater flow is to the east towards the Great Miami River. Available data indicate that groundwater migrating from the site (in both aquifers) discharges to the river within 3/4 of a mile of the southern property boundary of the site (EPA 1989c). The aquifer in this area (the Great Miami Valley fill aquifer) has been designated a sole-source aquifer under the Safe Drinking Water Act by the U.S. EPA (EPA 1989d).

Groundwater Contamination:

Groundwater contamination was first detected in an on-site well in 1973; this prompted groundwater sampling on and off-site that revealed contamination that had migrated off-site in an east-southeasterly direction. The plume flowed from the liquid disposal area into the Great Miami River Aquifer and contaminated many residential wells. Unacceptable carcinogenic risk due to the contaminated groundwater was found for both ingestion and inhalation of on-site and off-site groundwater in both the upper and lower aquifers. The key chemicals contributing to the unacceptable health risk are Vinyl Chloride, Trichloroethene, Methylene Chloride and Tetrachloroethene (EPA 1989c).

Clean-up and Removal Processes:

In order to protect human health, first the groundwater users with contaminated wells were connected to the City of Troy water supply and contaminated wells were closed. The source area was treated using vapor extraction and the contaminated groundwater was pumped and treated. Both the north and south landfills and the liquid disposal cell were capped to reduce further infiltration. These actions all serve to prevent discharge of contaminated water into the Great Miami River. All cleanup levels have been chosen to meet human health targets and require use of best available technology economically available before surface discharge (EPA 1989c), in practice, this usually means treating the water to MCL (J.D. Chiou, personal communication 2011).

A13. Pristine Inc.

Pristine Inc. is located in Hamilton County. During its life from 1974 to 1981, it operated as both a liquid waste disposal facility and a waste incinerator. Before becoming a disposal facility, the site was used to manufacture sulfuric acid. The site was closed by the OEPA in 1981 due to permit violations. At that time, over 10,000 drums plus several hundred thousand gallons of bulk liquids and sludges were on site. These liquid and sludge wastes included acids, pesticides, PCBs, VOCs, semi-VOCs and cyanide (EPA 1988b).

The Site is underlain by the Mill Creek bedrock valley. Mill Creek discharges into Ohio River. The lower outwash aquifer above this bedrock valley was formerly the primary source of water supply for the area, including the water supply for the City of Reading (EPA2006).

There is a separate upper aquifer in some parts of the bedrock valley, but below the Site, groundwater is present only in a number of interconnected lenses above the lower outwash aquifer. Mill Creek flows from north to south approximately 600 feet west of the Site. Mill Creek is not used for drinking or recreation other than for occasional fishing (EPA 2006).

Groundwater Contamination:

Groundwater contamination was detected in the City of Reading’s wellfield near the site. Concentrations of benzene, DCE and TCE had exceeded MCL in some wells; the concentrations of some other chemicals led to unacceptable lifetime cancer risk for residents using the water. The predicted TCE concentration at the site boundary was 430 ug/L. In March 1994, the City of Reading abandoned its wellfield near the site (EPA 1988b).

Clean up and Removal Processes:

Under a Consent Order with the Ohio EPA, in 1983, most of the drummed material was removed from site. Additionally, a 150 gpm pump and treat groundwater treatment system will remove contamination to MCL for at least 30 years and a soil vapor extraction system will operate for at least 10 years to remove liquid waste in the soil and prevent further groundwater contamination (EPA 1990a).

A14. Rickenbacker Air National Guard

Rickenbacker Air National Guard Base (USAF) is located in Franklin County, Ohio. Construction began on site in 1942 and until its closure in 1980, the site was under the Air Force's control. At closure, the over 4,000 acre site was transferred to the Ohio Air National Guard. In 1982, the Base began being distributed and by 2003, less than 50 acres of land were still under the control of the Air Force. While the site has been divided up, the contamination on site is similar to the contamination found at a large airport and is being treated overall under regulations for a 'Formerly Used Defense Site' (EPA 2000).

Groundwater Contamination:

At Rickenbacker Air National Guard Base, there has been considerable contamination from leaking underground fuel tanks and lines. Additional chemicals were released into the soil at various locations on site. TCE and its products have been detected in the groundwater; given the many re-use plans on site, cleanup is a priority (EPA 2000).

Clean up and Removal Processes:

For cleanup, the site was divided into several Installation Restoration Program areas which became the focus of the cleanup. All fuel spills were treated based on Ohio regulations for underground storage tanks. The drum disposal area was a key source of contamination and was a focus during cleanup. Cleanup actions included removal of drummed waste, particularly chlorinated solvents, removal of oil-water separators at two sites, installation of a groundwater cutoff trench and a treatment wall to treat contaminated groundwater and a monitoring program to assess the natural attenuation of VOCs on site. By 2005, the groundwater reached MCLs. Due to the intended future uses (airport), health-based criteria were not the driver for this cleanup since no residential scenario was necessary (EPA 2000).

A15. Sanitary Landfill

Sanitary Landfill Co. is a 36 acre site located in Montgomery County, Ohio. Initially a sand and gravel quarry, from 1971 to 1980, the site accepted both domestic and industrial wastes including solvents. The site was capped with soil when operations ended in 1980 (EPA 1993a).

The site is located at the top of a kame terrace in the Great Miami River valley buried aquifer system, which has been designated by the U.S. EPA as a sole-source aquifer. Glacial materials deposited in the valley system, which are the primary source of ground water, can range from 100 to 300 feet in thickness. The property surrounding the Site is zoned commercial, light industrial and residential. A single occupied residence abuts the site on the extreme northeastern perimeter of the Site. All residents in the area near the site are provided with municipal drinking water (EPA 1993a).

Groundwater Contamination:

A 1987 Remedial Investigation found both organic and inorganic contaminants of concern in the soil, sediments, surface water and landfill gas. Contaminants of concern included VOCs, including TCE and benzene, semi-VOCs and metals, including arsenic, chromium and lead (EPA 1993a).

While most organic compounds were found at low concentrations in most monitoring wells, VOCs were found in excess of MCLs in a cluster of wells at the southern boundary of the site in multiple rounds of sampling. Eight organic compounds were found in nearby production wells for drinking water leading to undue carcinogenic risk across the site (EPA 1993a).

Clean up and Removal Processes:

The components of the remedy included a solid waste landfill cap, onsite subsurface gas controls, surface run-off controls, long-term monitoring, institutional controls, and a supplemental site investigation to determine if a ground water extraction/treatment system was necessary. The remedy is intended to restore the Great Miami River Buried Valley Aquifer system to a drinking water source. In order to restore this use, water will be treated to MCLs and meet all water quality standards before discharge or reinjection (EPA 1993a).

A16. Wright Patterson Air Force Base

Wright- Patterson Air Force Base (WPAFB) is a 4,900 acres site located in Greene and Montgomery County, Ohio. Patterson Field contains the active runway, warehouses and offices and industrial facilities. The Air Force Base overlies the Mad River Buried Valley Aquifer which provides drinking water for about 500,000 people. In total, on-site, 65 sites are source areas for contamination. These include chemical burn sites, underground storage tanks, landfills and spill sites (EPA 1999a).

The Richmond Group of Ordovician Age is the bedrock unit underlying most of WPAFB. The Richmond Group consists of up to 265 feet of interbedded shales and limestones that crop out in portions of eastern Montgomery and Western Greene Counties. Unconsolidated materials of the Pleistocene Age overlie bedrock and are represented in the area by glacial till and outwash deposits. These deposits, interbedded with water-bearing sand and gravel zones, locally may form confining aquifers or may limit recharge to underlying unconsolidated aquifers. Outwash deposits attain a maximum thickness of 250 feet at Dayton and usually overlie till deposits. Outwash deposits form the most prolific aquifer of the Ohio region (EPA 1993b). At WPAFB, the hydraulic conductivity of the outwash ranges from 1,000 to 3,000 gallons per day per square foot (gpd/ft2). The buried valley aquifer, a Federally designated Sole Source Aquifer, is used by WPAFB for water supply and is also the primary unit from which municipal supplies are drawn at the nearby Dayton Municipal Wellfield (EPA 1993b). Total depth of the sole source aquifer varies between approximately 50-250 feet depending on position within the buried valley and also depending on water producing horizons within that range (EPA 1994).

Groundwater Contamination:

The primary contaminants of concern in soils and groundwater are PCE, TCE and benzene. Modeling was completed to explore the possibilities for natural attenuation over a 90 year period. The modeling effort shows that for most contaminants, levels would be less than 1 ug/L after 30 years and for TCE after 65 years (EPA 1999a).

Clean up and Removal Processes:

Multiple RODs have been signed for the site that dictated cleanup. The cleanup actions included landfill capping, leachate collection and treatment, gas collection and treatment and controls on public water supply. Previous cleanup efforts included drum and tank removal, free product recovery systems and groundwater treatment by air stripping. All surface and groundwater must be treated to MCLs to meet standards for drinking water supplies (EPA 1999a).

A17. Distler Farm

The Distler Farm is located in Jefferson County, Kentucky. This site is approximately 3 acres, part of a 27 acre property. Before it was discovered by the EPA in 1977, the site was used for unauthorized chemical waste disposal and storage. The EPA personnel on site found 600 drums of waste on the ground; an additional 800 drums were found after a flood of the Ohio River in 1978. The site is adjacent to the Distler Brickyard Superfund Site (EPA 1989e).

The area supports select agricultural activities, primarily small farming and grazing. Only a few residential and industrial buildings are located close to the site. The property is underlain by Quaternary-age alluvium and glacial outwash deposits of the Ohio Valley Alluvium. The later is made up of two hydrosratigraphic units, the Fine Grained Alluvium (FGA) and the Coarse Grained Alluvium (CGA). The CGA is directly below the FGA and is a laterally continuous, gravel-sand unit with a minor distribution of silt and clay. In the region as a whole, the CGA is highly saturated with water and forms a reliable source of private well water. Near the site, several residences obtained their drinking water from the CGA in the past. Most of the private wells in the area have been shut down recently due to mechanical problems and/or availability of public water supply (EPA 2003).

The aquifer underlying the site could be classified as Class I, which would indicate that it could be a sole source of drinking and domestic water supplies for downgradient communities(EPA 1986a).

Groundwater Contamination:

By 1984, site investigation was completed and showed that no contamination had migrated off-site from either the soil or groundwater. While no contamination was shown off-site, groundwater is the most probable pathway. The shallow groundwater on site moves in a southeast direction towards Stump Gap Creek. The deep aquifer on site is directly connected hydraulically to the Ohio River. The contaminants of concern identified in the shallow aquifer included chromium, lead, TCA, toluene, TCE, vinyl chloride and naphthalene (EPA 1986). Groundwater contamination has been detected beneath the site in a localized "pool". This "pool" of contamination has been contained on site by virtue of topography, groundwater flow, and soil characteristics. However, the potential for leakage into a deeper aquifer does exist and could provide a possible migration pathway for contaminants to move offsite. The rate at which contaminants could migrate would probably be impeded because of "barrier effects" in that aquifer (i.e. the effect of the Ohio River) (EPA 1986a).

Clean-up and Removal Processes:

Cleanup on site will follow the regulatory guidance of RCRA and the Clean Water Act, but is driven by the Groundwater Protection Strategy. The cleanup levels are based on health of a future groundwater user and are at or below MCLs due to the health scenarios used (EPA 1989e).

A18. National Coil Co.

The National Electric Coil Co. is located in Harlan County, Kentucky. Past degreasing at the site used TCE-based solvents which caused on and off-site contamination. Liquid solvents, waste sludges and PCB-laden oils were allowed to flow overland and through a drainage pipe to the Cumberland River. These practices continued into the mid-1980s and resulted in VOC contamination of groundwater drinking water supply near site (EPA 1992c).

The Site is underlain by two significant water-bearing units. The uppermost, alluvial deposits consisting of well to poorly sorted accumulations of sand, silt, and clay occur at ground surface. The alluvial deposits are twenty-five to thirty feet thick in the vicinity of the Site. They generally contain ground water under unconfined conditions, at depths averaging twenty feet below existing land surface (EPA 1992c).

The alluvium is underlain at a depth of thirty feet by consolidated sedimentary bedrock. Ground water occurs under generally confined conditions within the bedrock’s secondary fractures and faults; the bedrock unit is reported to be a reliable source of drinking water. Because the alluvial water table is higher in elevation than the potentiometric surface of the bedrock unit, recharge from the overlying unit into the bedrock is likely (EPA 1992c).

The bedrock aquifer is no longer used as a primary source of drinking water (since the impacted area provided connection to municipal water services in 1989) so it is not considered to pose a current risk to residents or workers. (EPA 1996a).

Groundwater Contamination

Contamination of the site’s drainage channels, river embankment property and grounds and drinking water supply for the Holiday Mobile Home park with VOCs were found by early 1989. Twelve of fifty wells sampled showed the presence of VOCs. To mitigate the health effect, the residents were given first bottled water, then temporary surface tanked water, then were finally connected to a municipal water supply (EPA 1992c). In 1992, the deep aquifer had levels of vinyl chloride as high as 350 ug/L and DCE levels as high as 905 ug/L in off-site private wells. In the shallow aquifer, contamination levels were even higher; DCE concentrations reached 3,700 ug/L, TCE as high as 17,000 ug/L, vinyl chloride concentrations of 77 ug/L and benzene concentrations of 19,000 ug/L. Additionally, elevated levels of lead and chromium were found in the deep aquifer (EPA 1992c).

Clean-up and Removal Processes

To comply with cleanup actions, an air stripper tower is used for groundwater treatment. The extraction well and air stripper system reduces toxicity, mobility and volume of VOC contaminants. The treated groundwater is discharged to the Cumberland River in compliance with KPDES permitting limits (EPA 1996a).

A19. Tri City Disposal

From 1964 to 1967, the Tri-City Disposal Company operated a 57-acre landfill at this 349-acre property in Shepherdsville, Bullitt County, Kentucky. The landfill accepted highly volatile liquid wastes, lumber scraps and fiberglass insulation from Louisville area industries. By 1968, several hundred drums were buried on site and some were stored above ground. In 1987, the State found contaminated soils and groundwater on site (EPA 1996b).

Geology at the Site consists of thin (10-50 ft), unconfined, limestone aquifer composed of the Salem Limestone and Harrodsburg Limestone. Hydraulic communication between overburden and the Salem/Harrodsburg Limestone aquifer is evident; water or contaminants percolating through the overburden could enter the Salem/Harrodsburg Limestone Aquifer at the contact between the overburden and the partially weathered rock to contaminate the aquifer (EPA 1996c). Although the groundwater / spring water is not currently being used as a drinking water source, EPA and the Commonwealth of Kentucky have classified the aquifer as a Class 11-B Aquifer, a resource which should be maintained at drinking water quality (EPA 1991c).

Groundwater Contamination

VOCs from the Tri-City site contaminated two springs that were used for drinking water. Additionally, a tributary to Brushy Fork Creek was contaminated with heavy metals from the site. Soil contamination on-site includes PCB, heavy metals and organic compounds. Contamination from the site could impact the 1,600 people that obtain drinking water from springs and wells within three miles of site. All surface drainage on site flows south into Brushy Fork Creek which supports agriculture (including livestock) and recreation. The key pathway of concern is groundwater because it is readily used as a potable drinking water source.

Clean-up and Removal Processes

Since the aquifer and its springs are used as potable water, the contaminated groundwater must be cleaned up to MCLs under requirements for a class IIB aquifer (drinking water quality, but not currently used for drinking water—USEPA Groundwater Classification Guidelines 1986). Any surface discharge is regulated under NPDES permits established by the Clean Water Act and regulated by the commonwealth of Kentucky. To manage the risk caused by this site, restrictions on potable use of groundwater have been enforced including provision of potable water to residents who have previously used contaminated water for drinking. The groundwater on and off-site will be monitored for 30 years. In 1996, the affected springs were sampled and deemed to no longer impact human health, although the use restrictions remain (EPA 1996b).

Appendix B – Off-site Groundwater Quality Data Plots

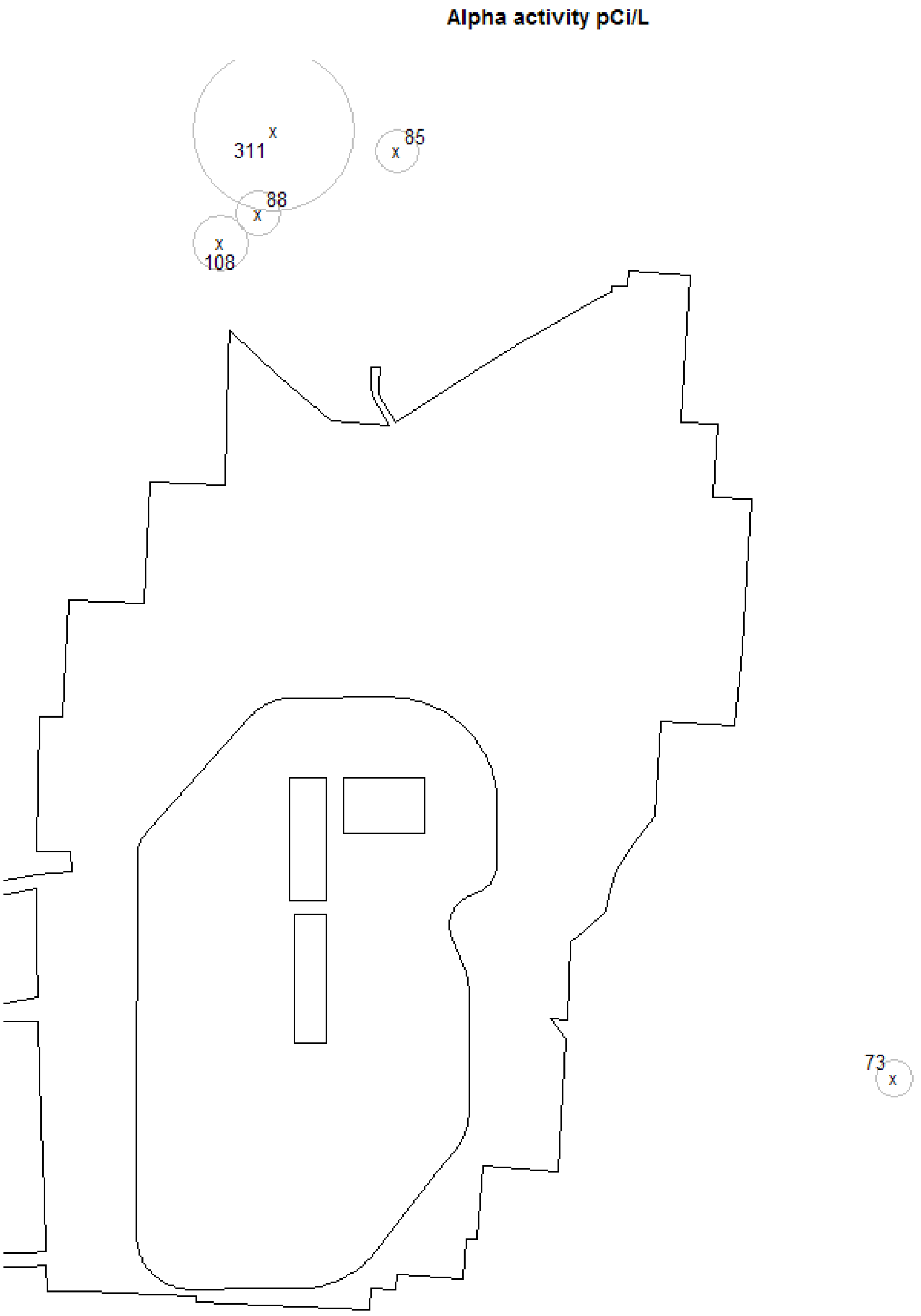


Figure Ba. Alpha activity in off-site wells (pCi/L).

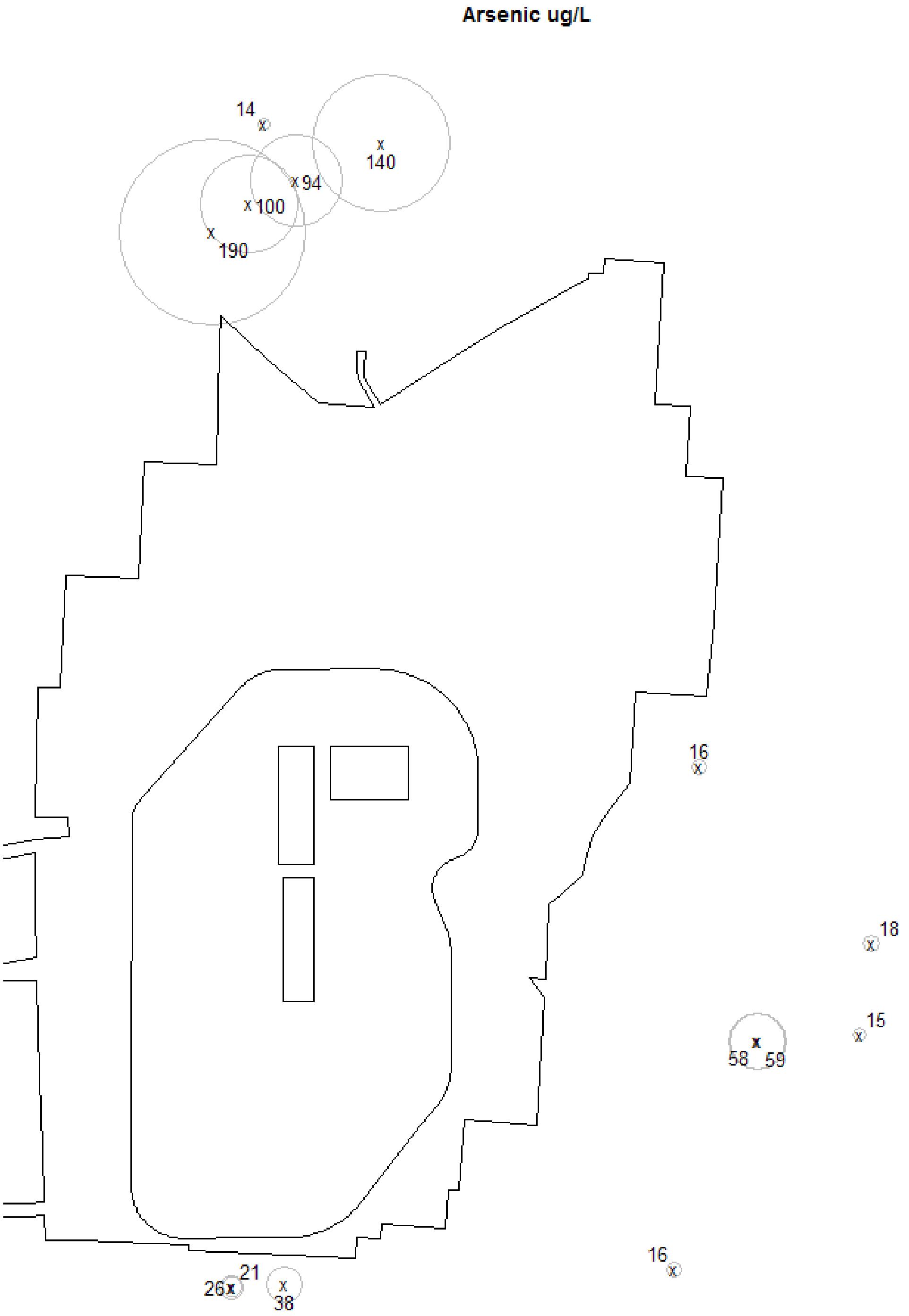


Figure Bb. Arsenic concentration in off-site wells (µg/L).

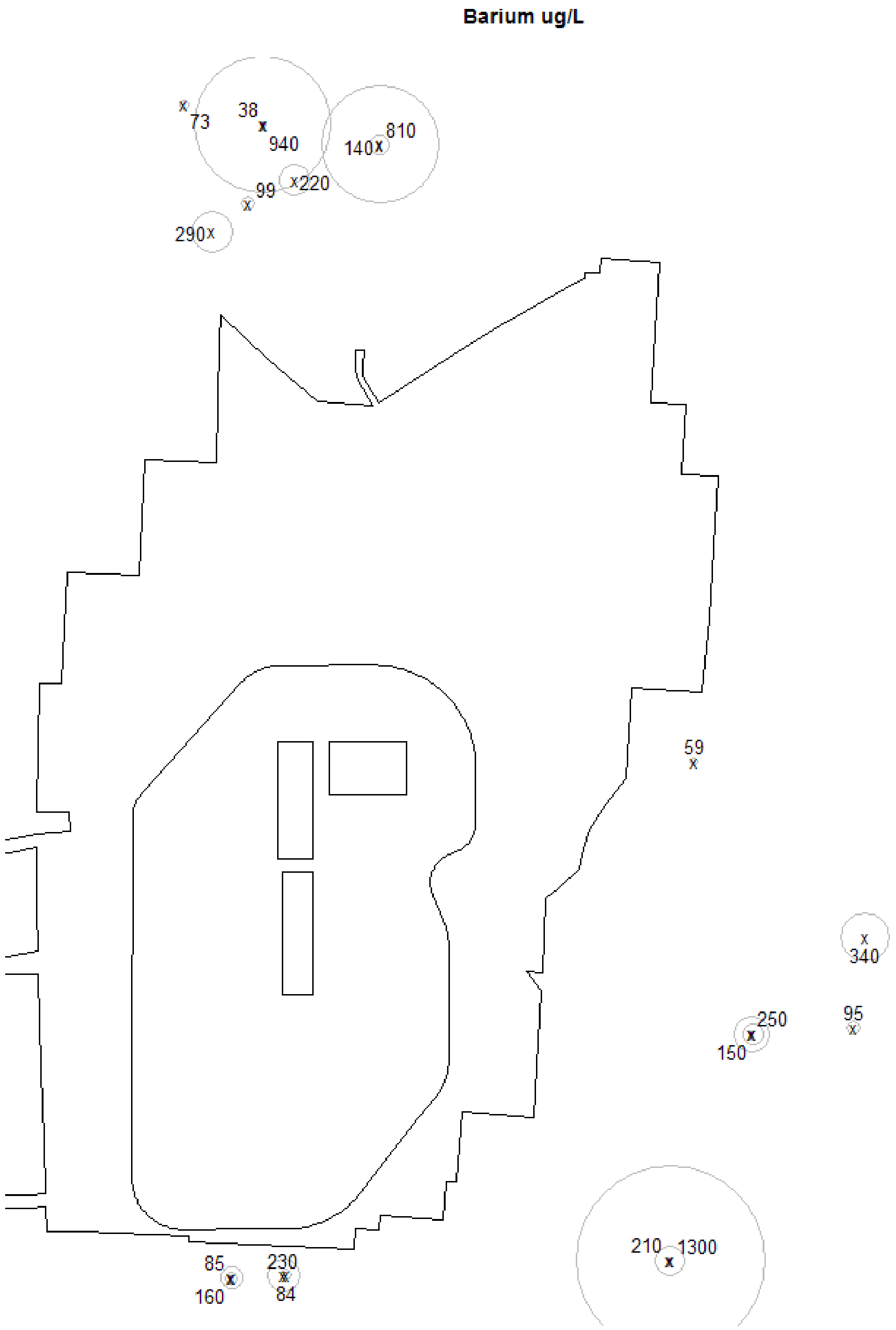


Figure Bc. Barium concentration in off-site wells (µg/L).

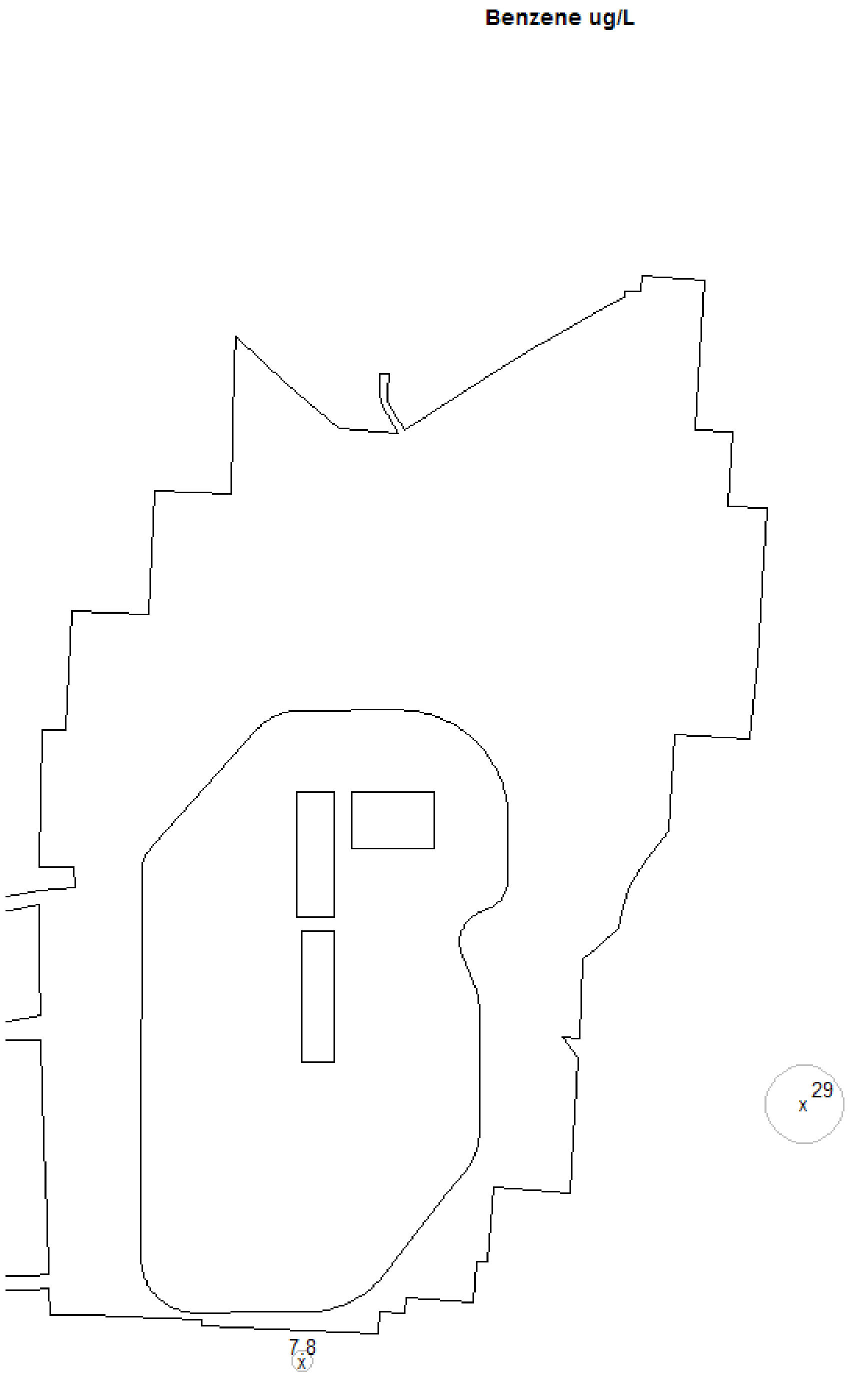


Figure Bd. Benzene concentration in off-site wells (µg/L).

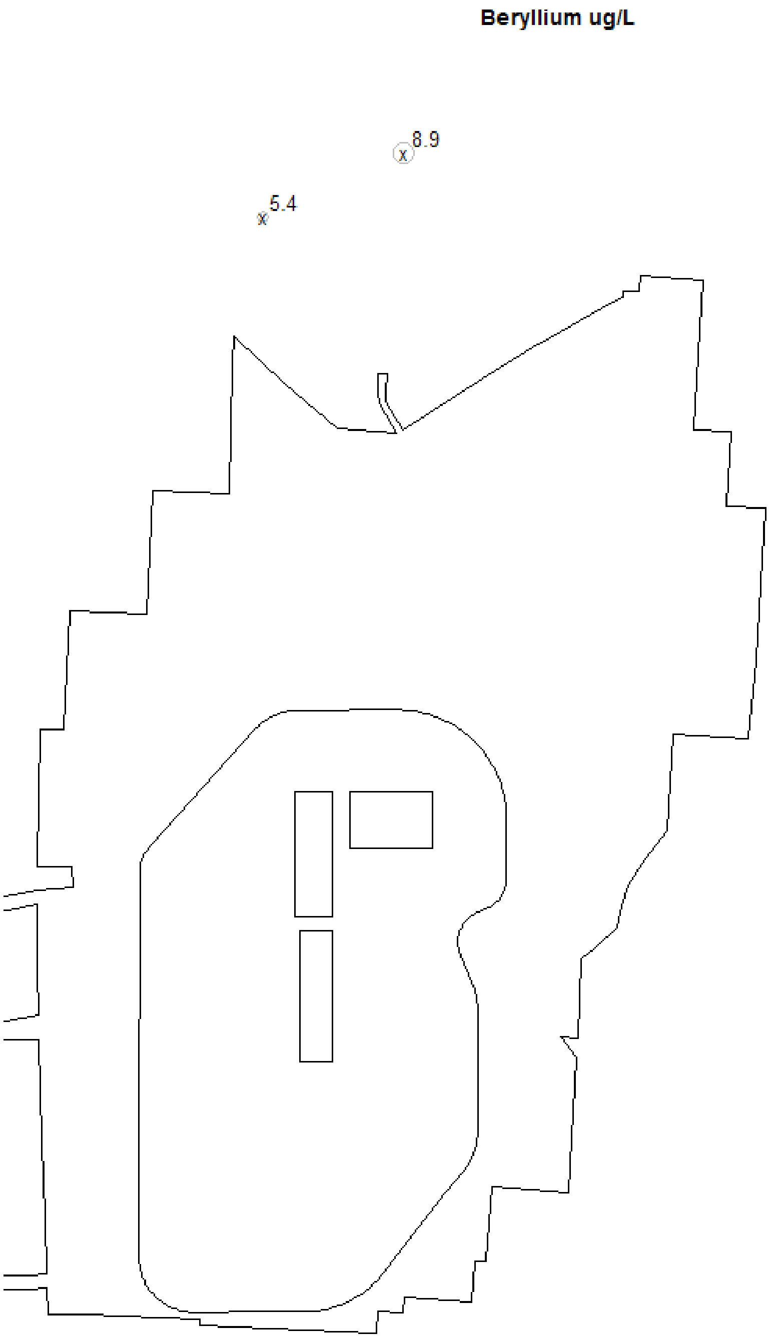


Figure Be. Beryllium concentration in off-site wells (µg/L).

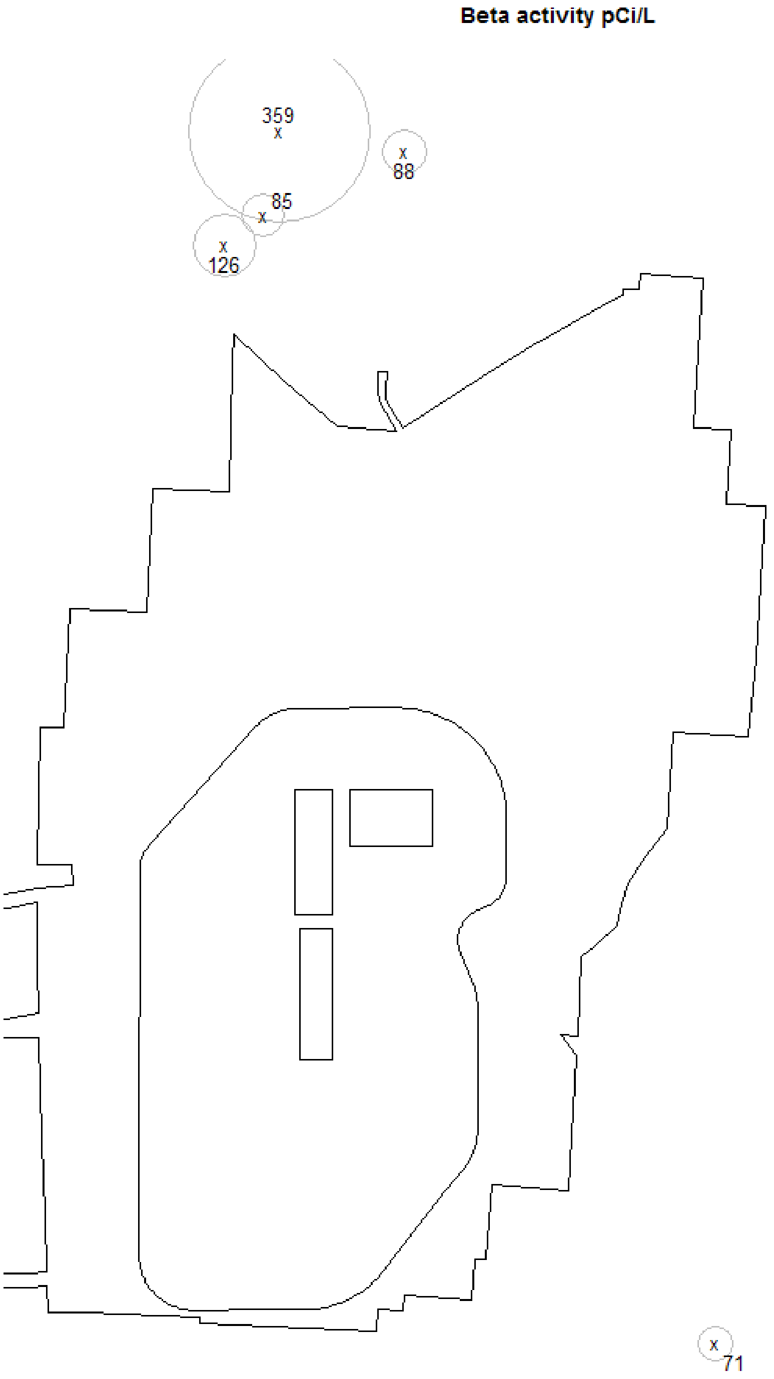


Figure Bf. Beta activity in off-site wells (pCi/L).

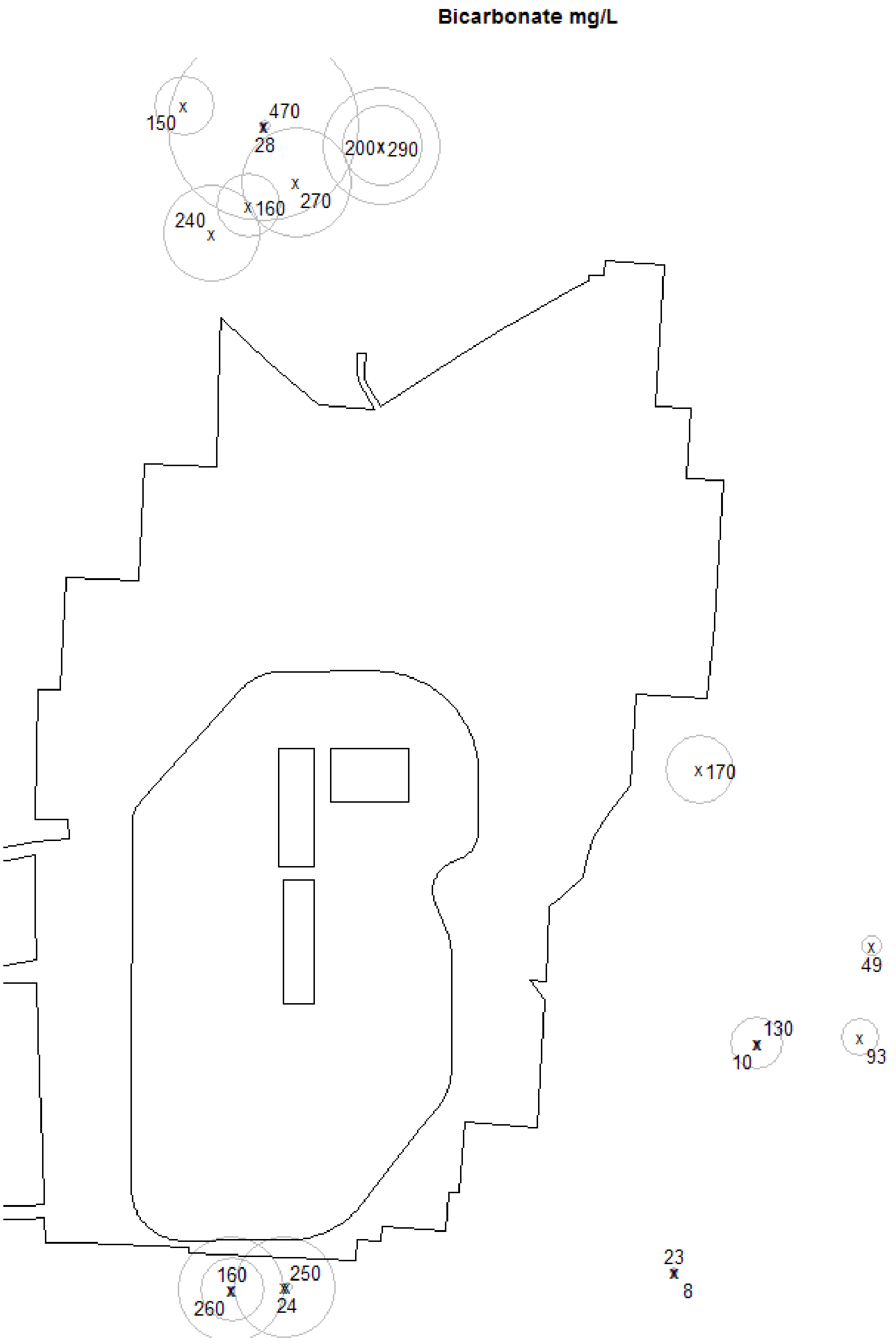


Figure Bg. Bicarbonate concentration in off-site wells (mg/L).

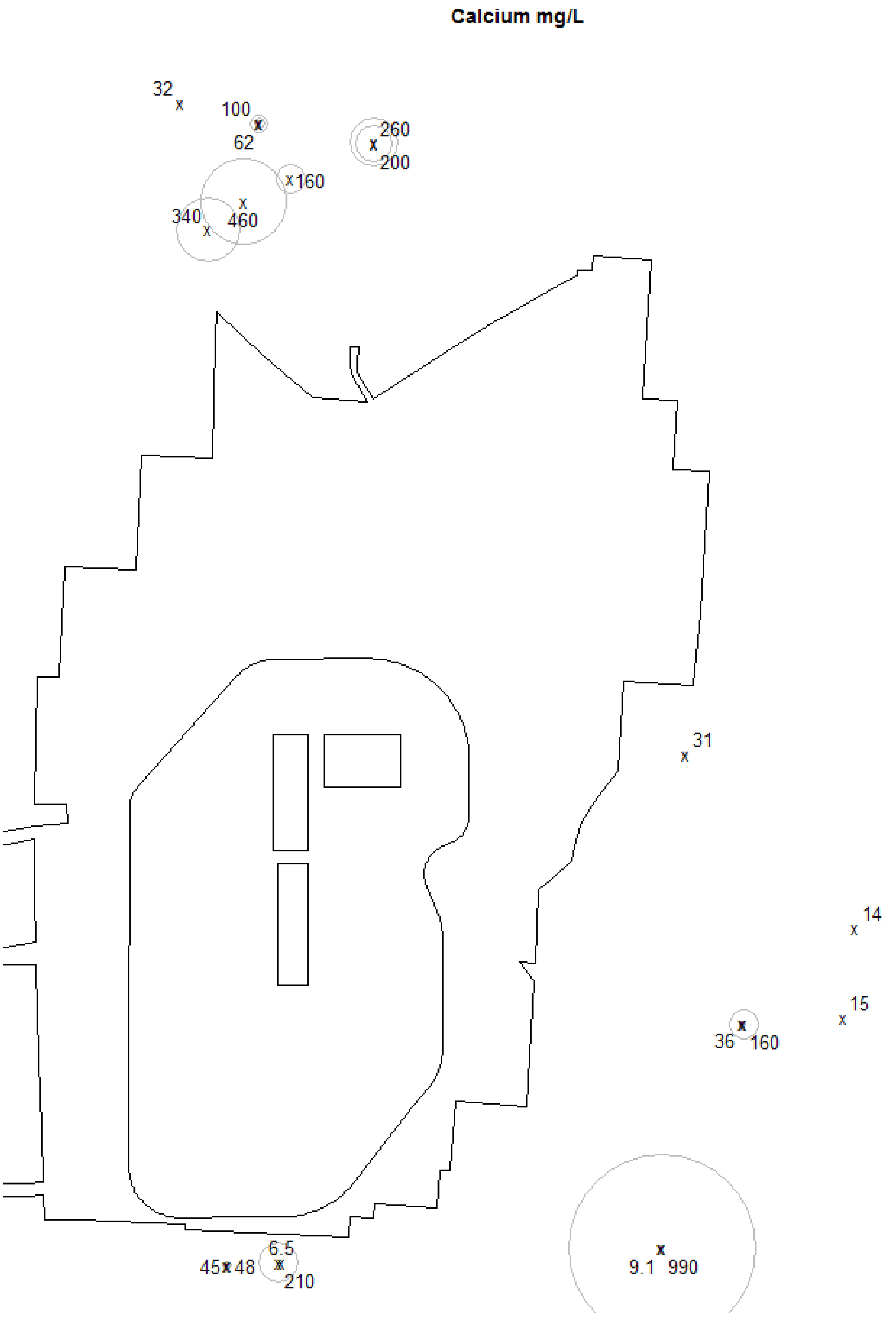


Figure Bh. Calcium concentration in off-site wells (mg/L).

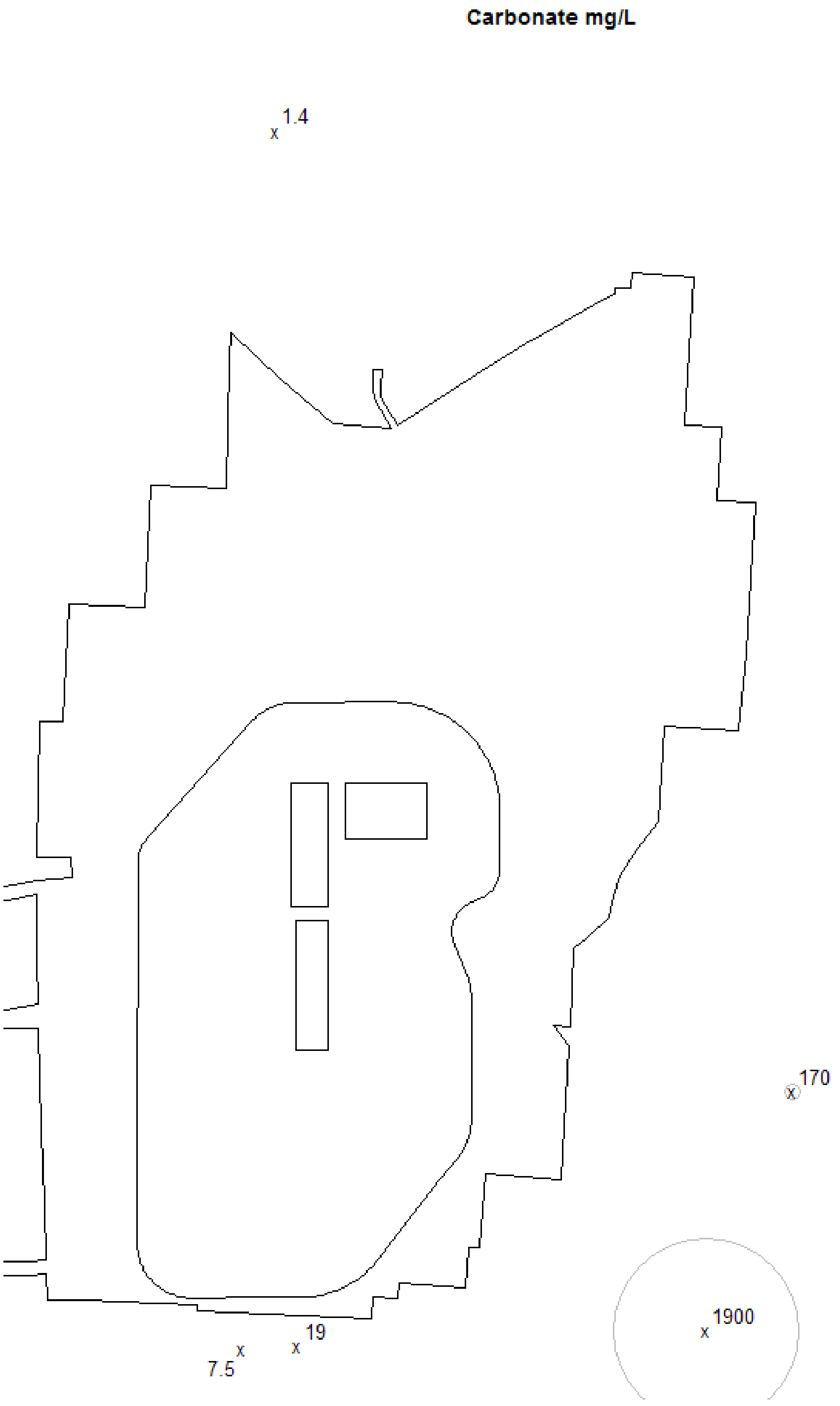


Figure Bi. Carbonate concentration in off-site wells (mg/L).

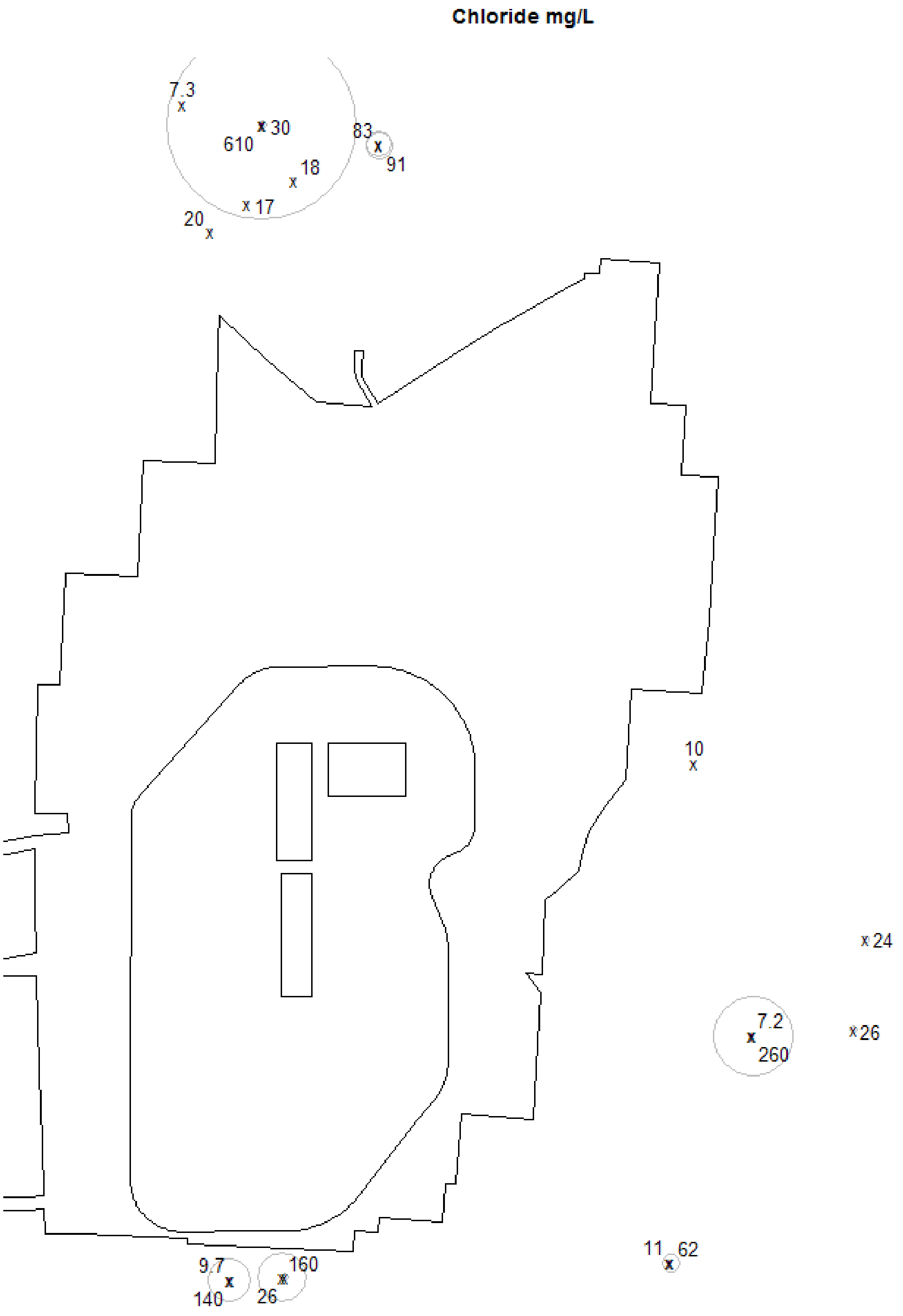


Figure Bj. Chloride concentration in off-site wells (mg/L).

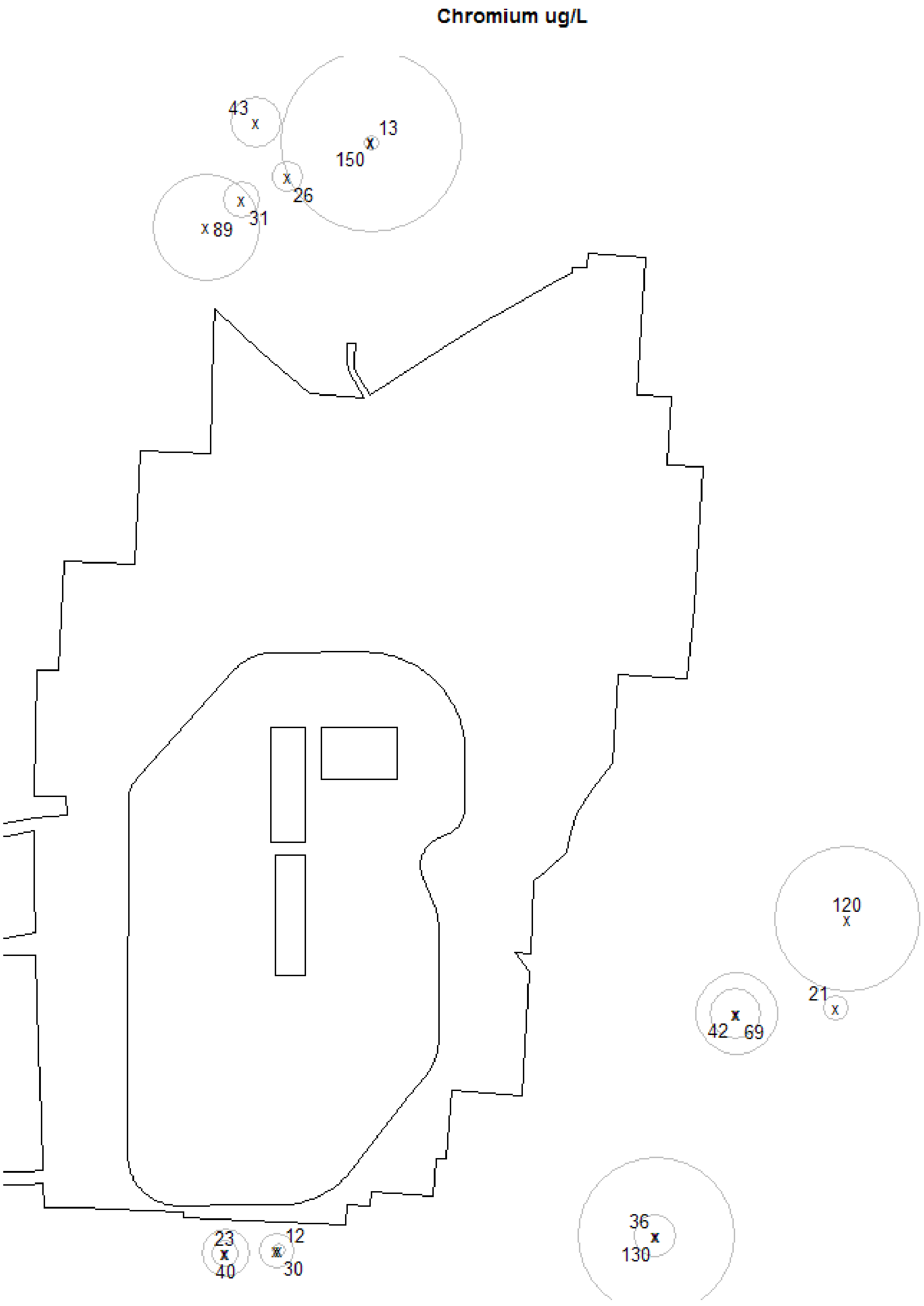


Figure Bk. Chromium concentration in off-site wells (µg/L).

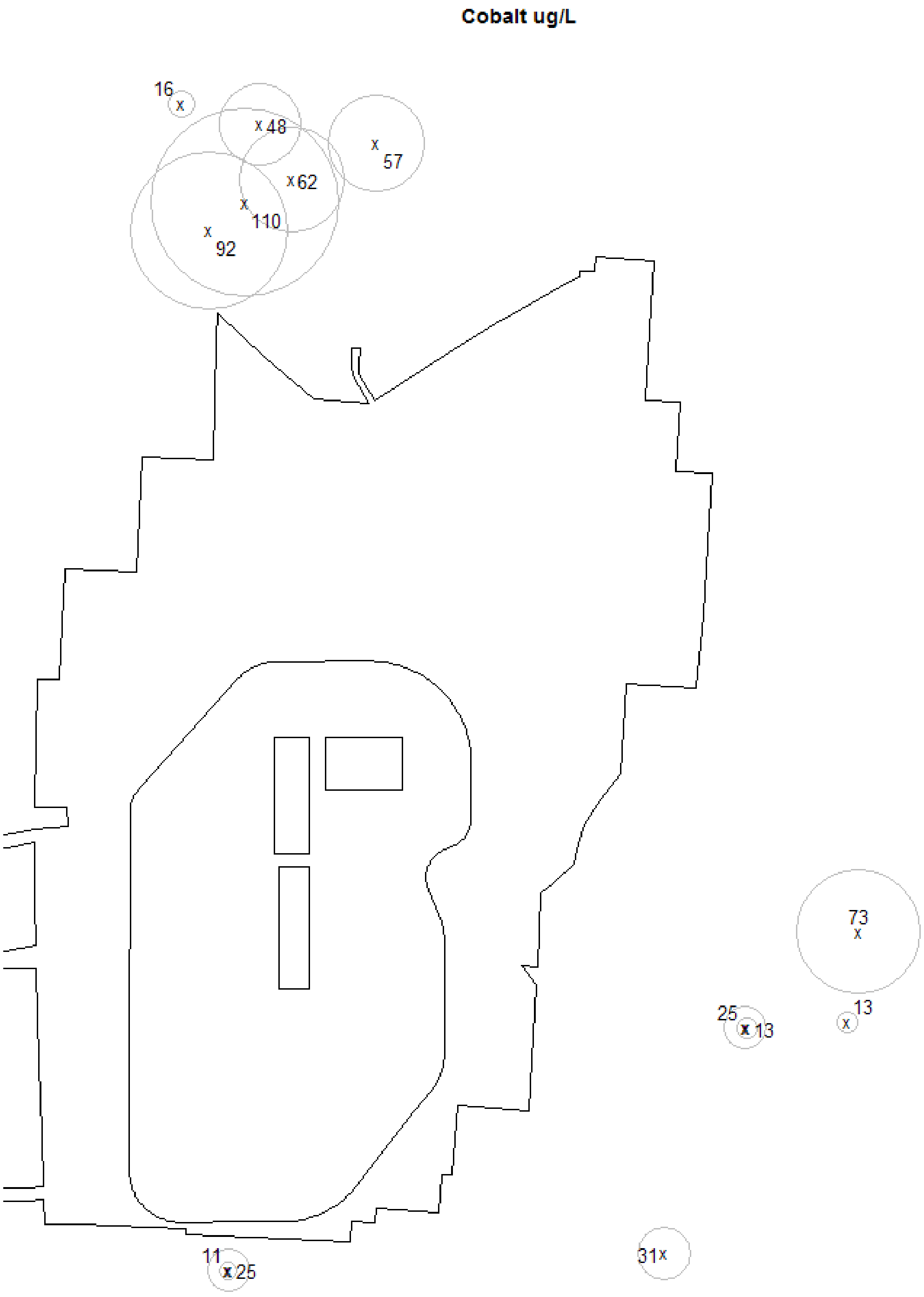


Figure Bl. Cobalt concentration in off-site wells (μg/L).

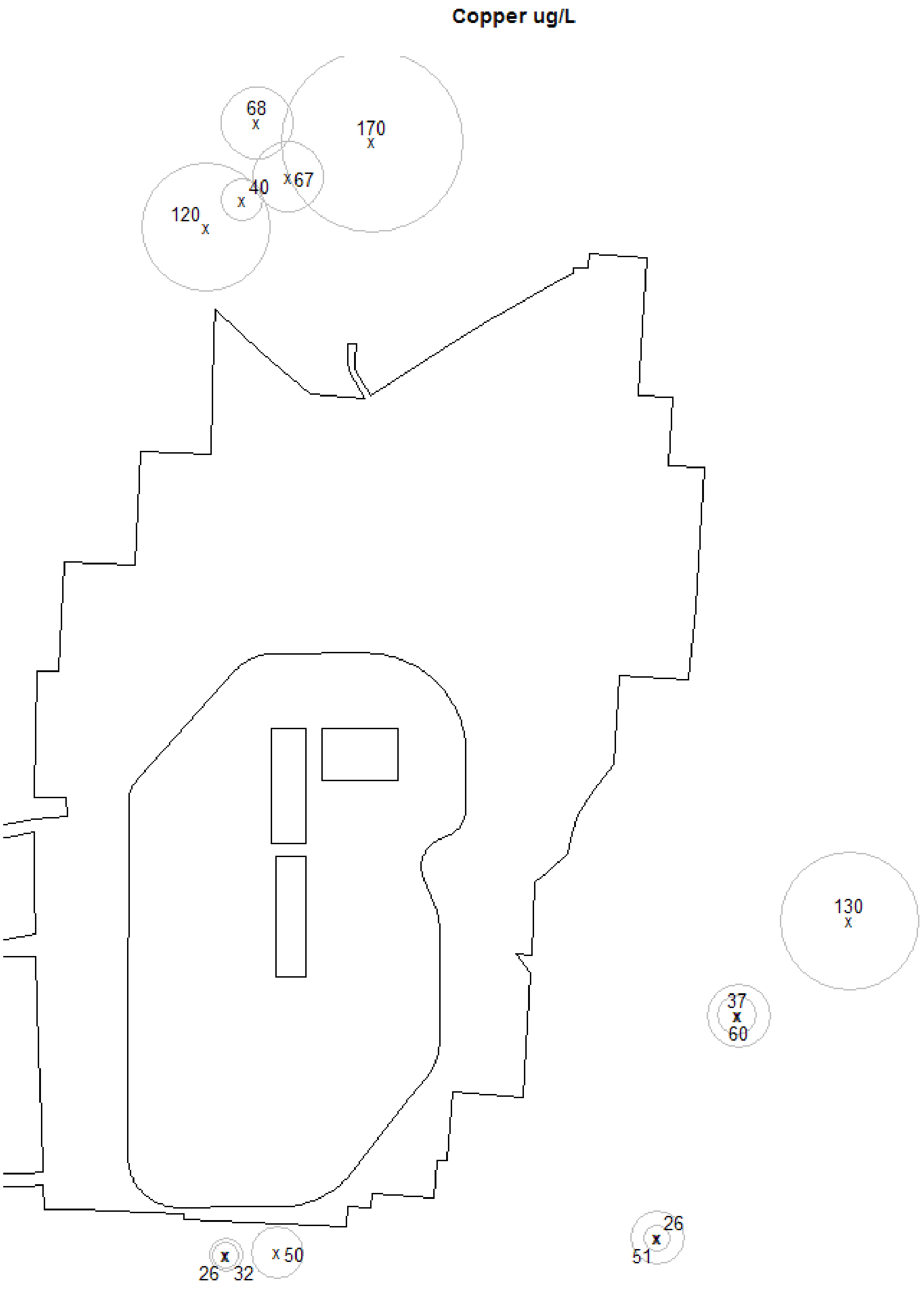


Figure Bm. Copper concentration in off-site wells (µg/L).

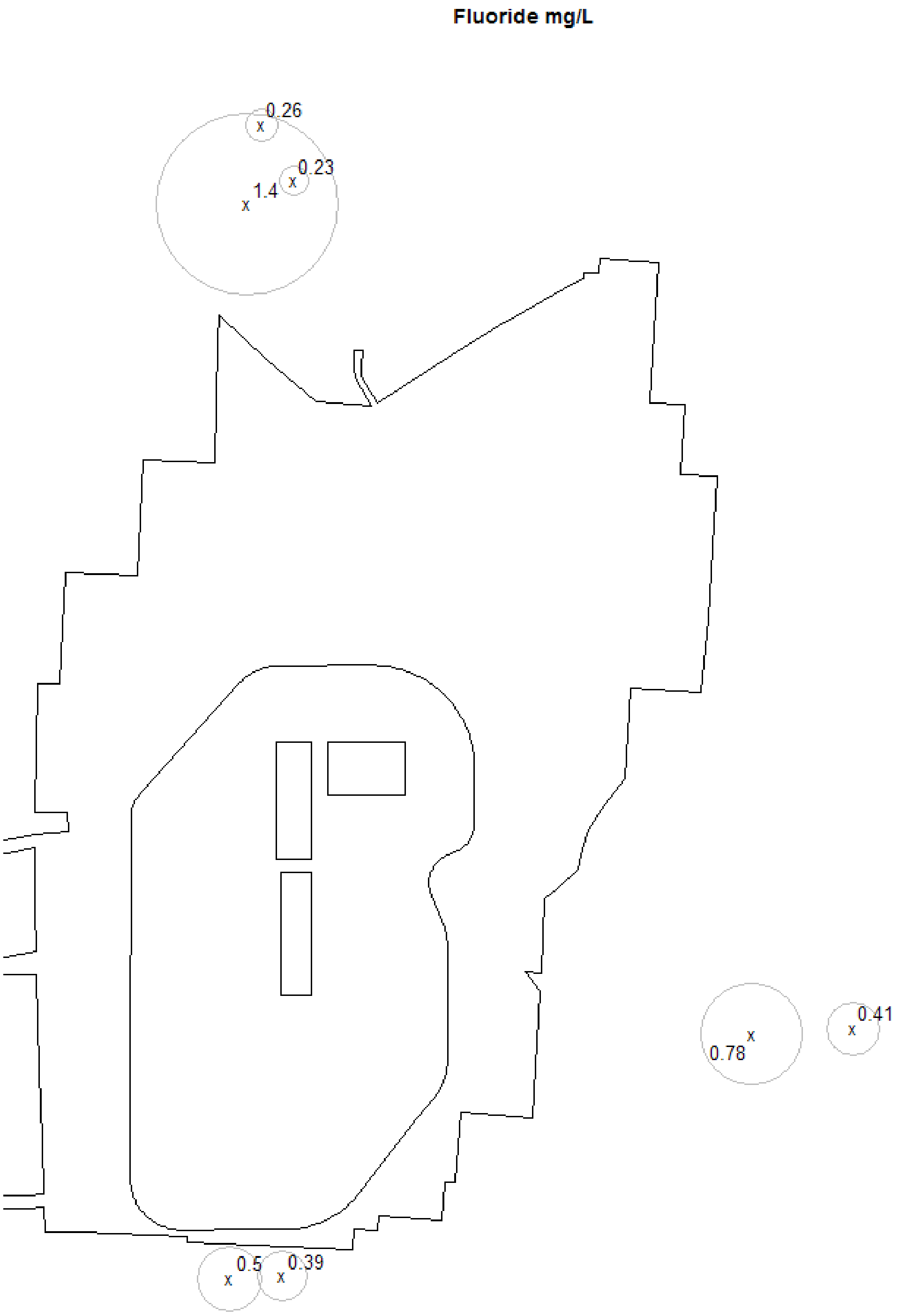


Figure Bn. Fluoride concentration in off-site wells (mg/L).

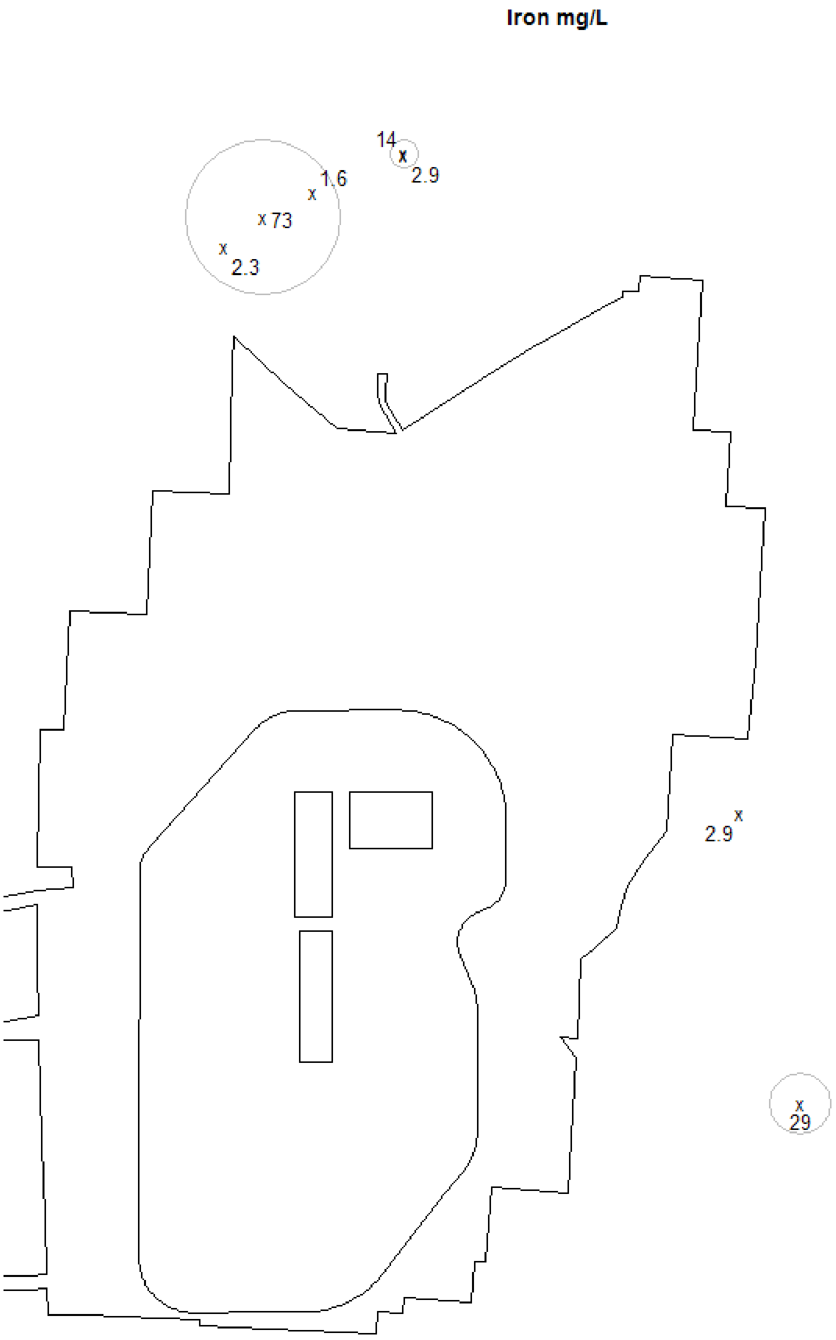


Figure Bo. Iron concentration in off-site wells (mg/L).

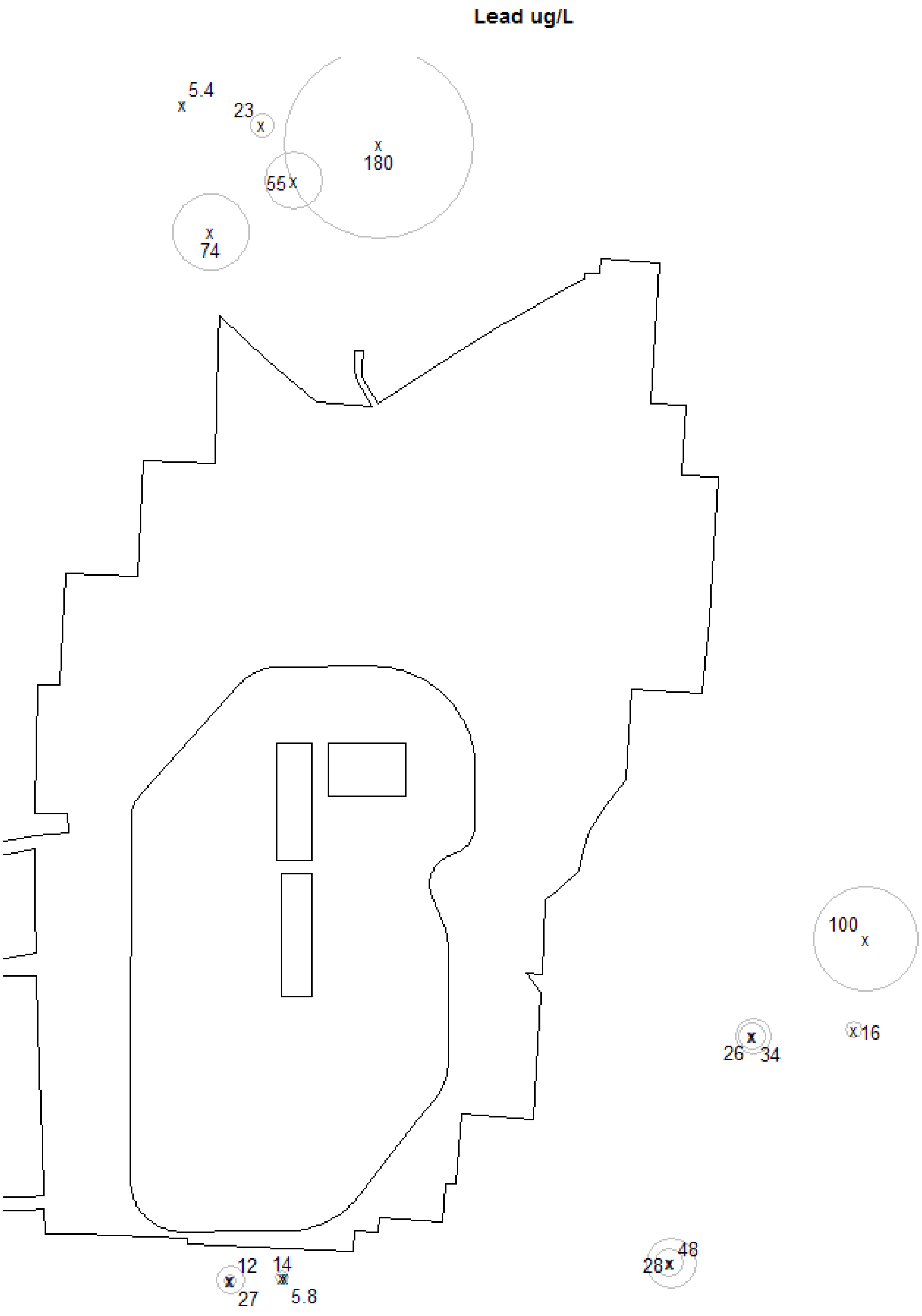


Figure Bp. Lead concentration in off-site wells (μg/L).

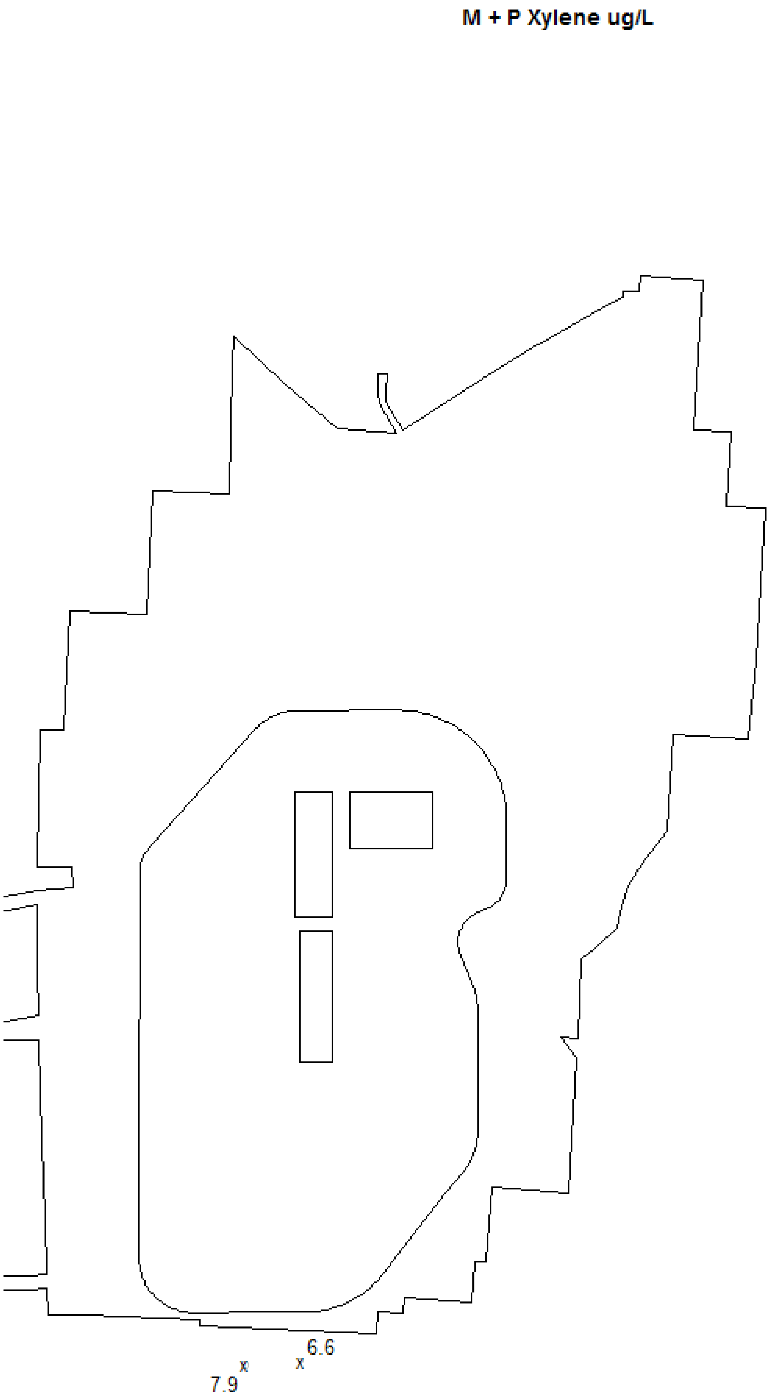


Figure Bq. M+P Xylene concentration in off-site wells (µg/L).

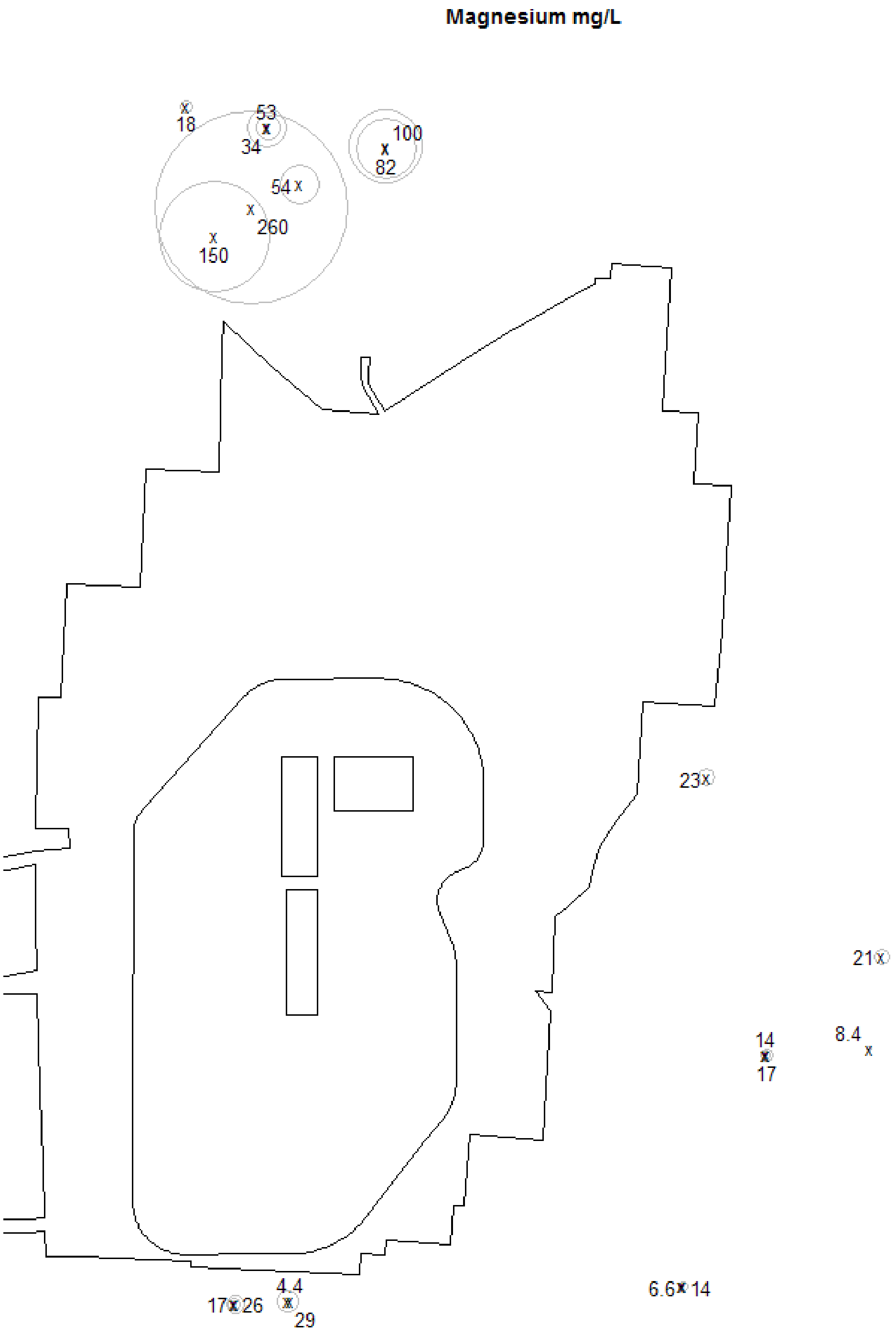


Figure Br. Magnesium concentration in off-site wells (mg/L).

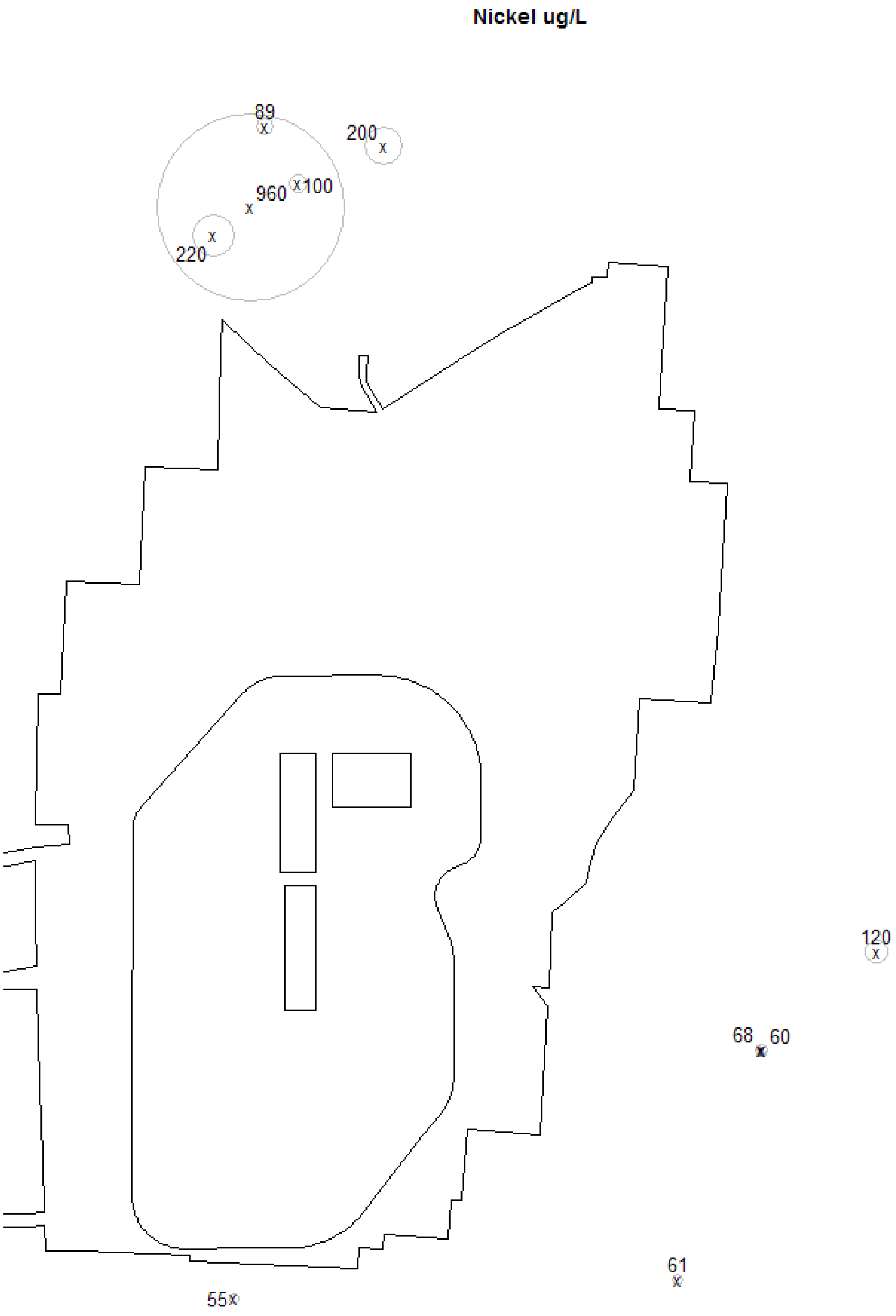


Figure Bs. Nickel concentration in off-site wells (µg/L).

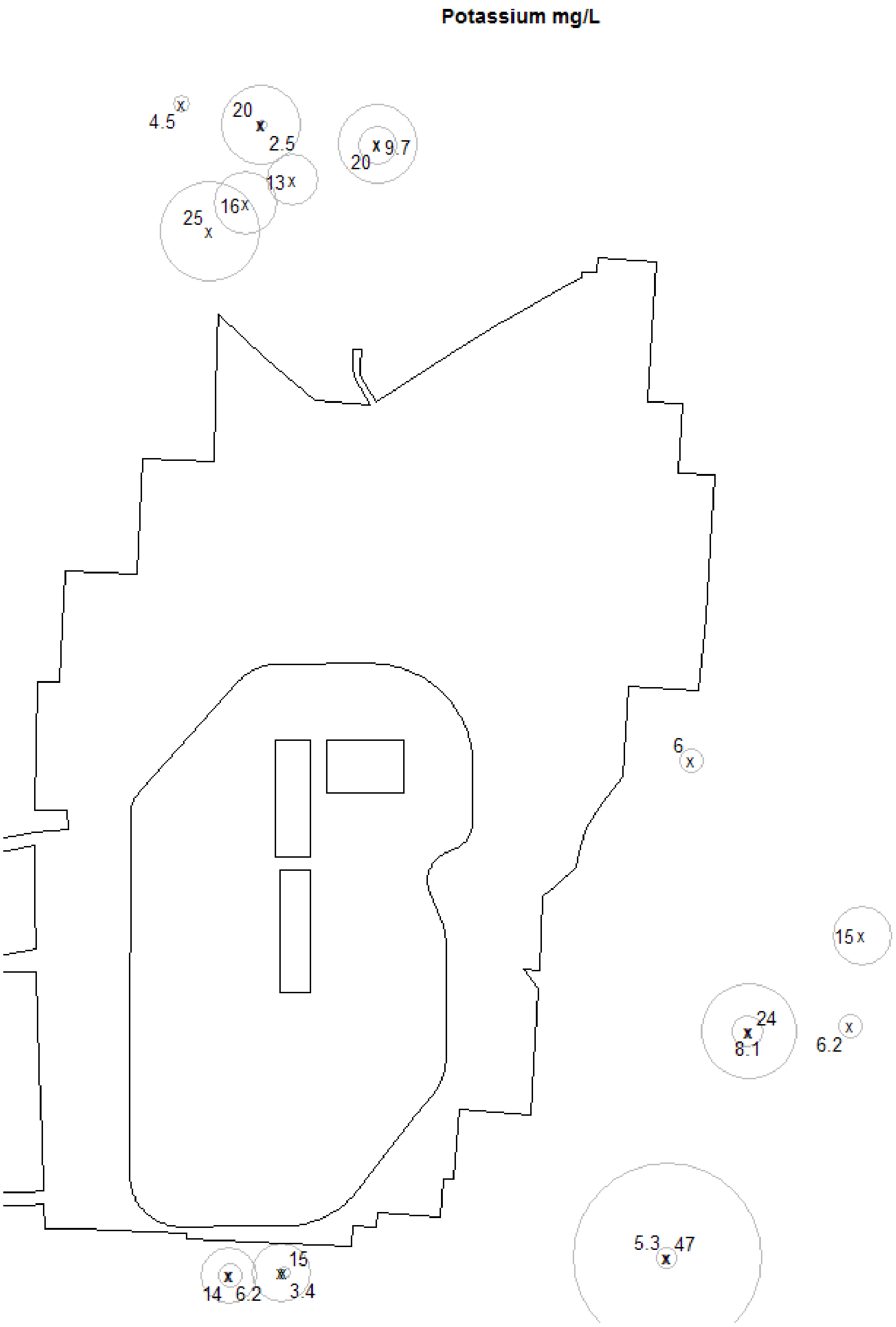


Figure Bt. Potassium concentration in off-site wells (mg/L).

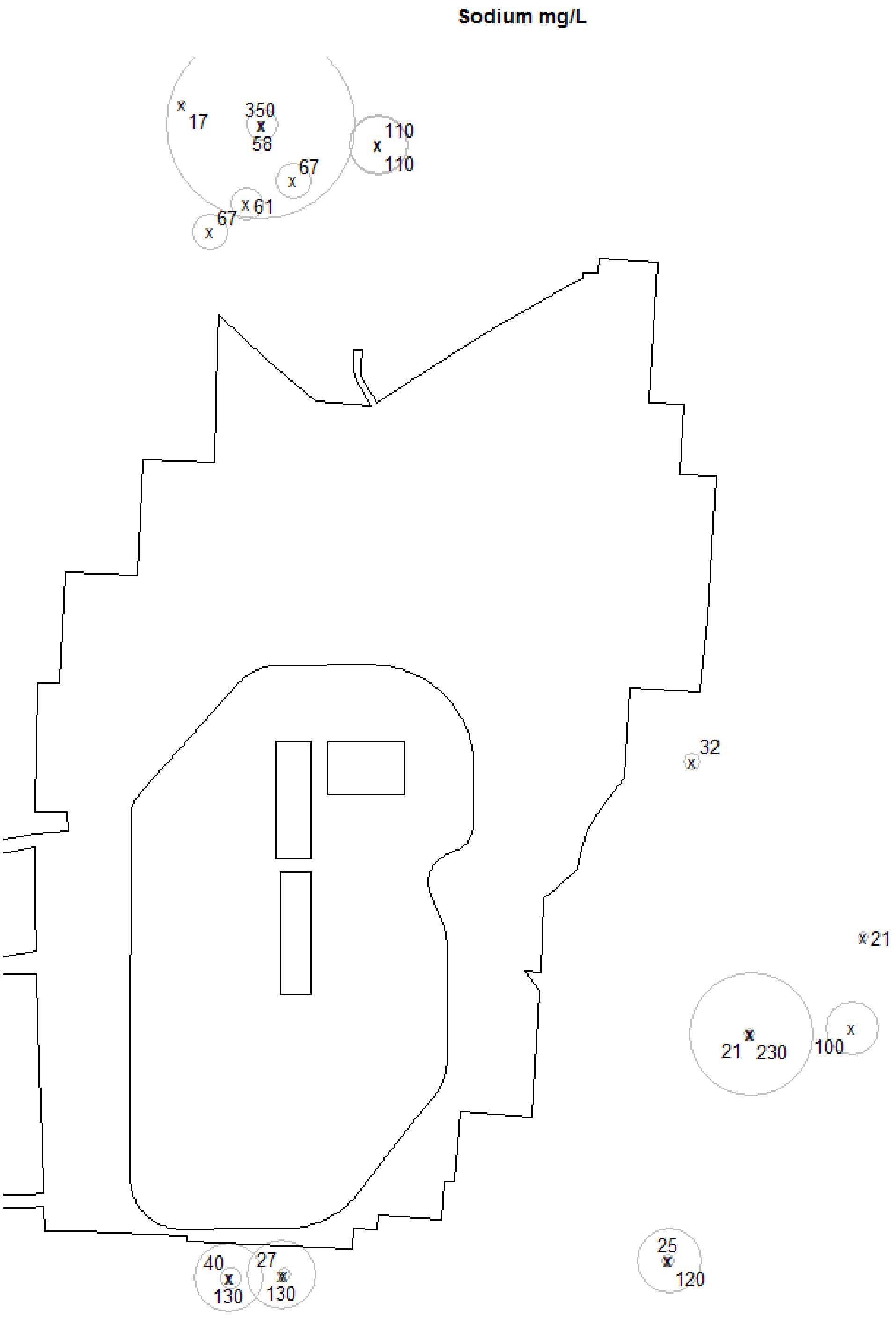


Figure Bu. Sodium concentration in off-site wells (mg/L).

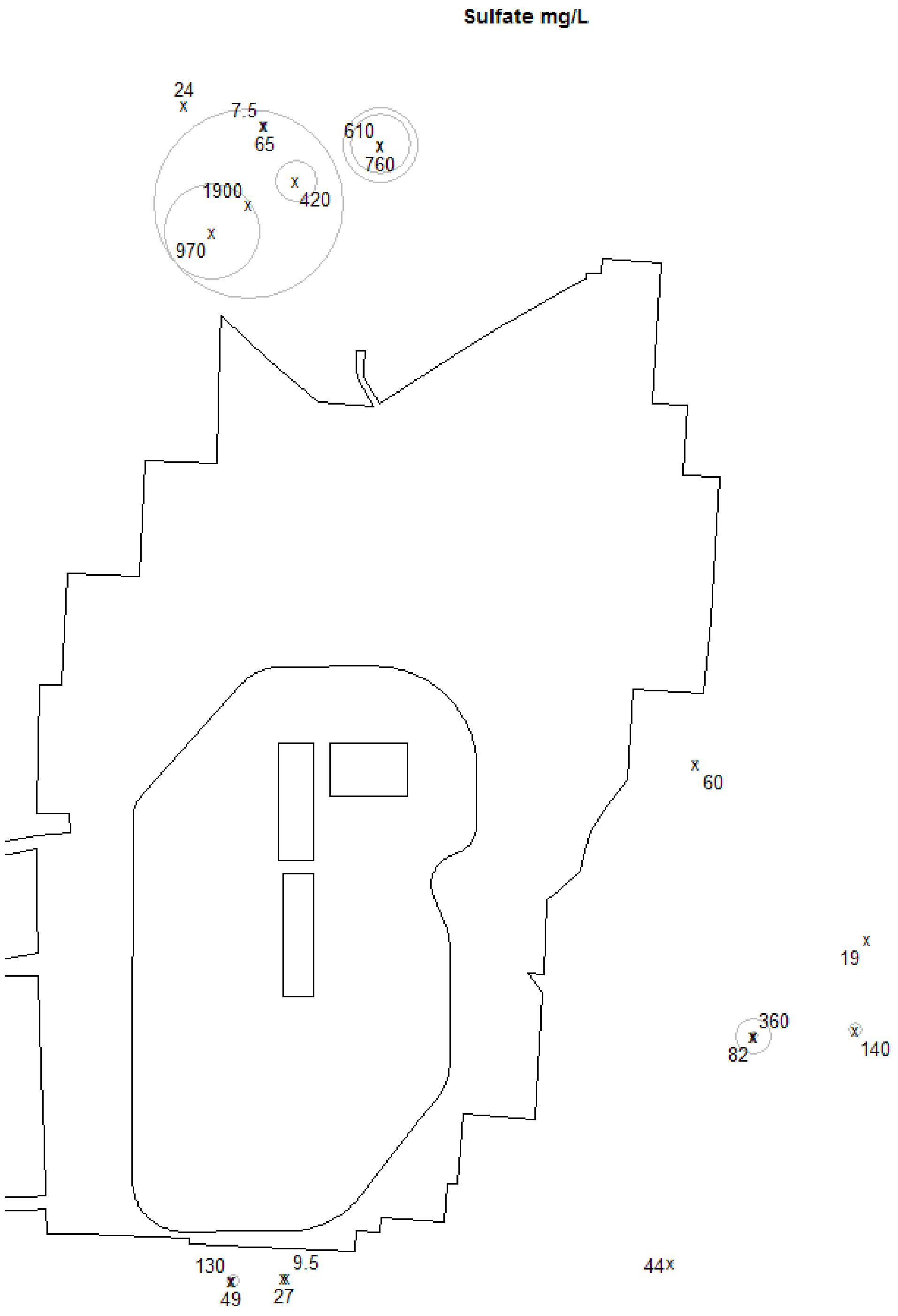


Figure Bv. Sulfate concentration in off-site wells (mg/L).

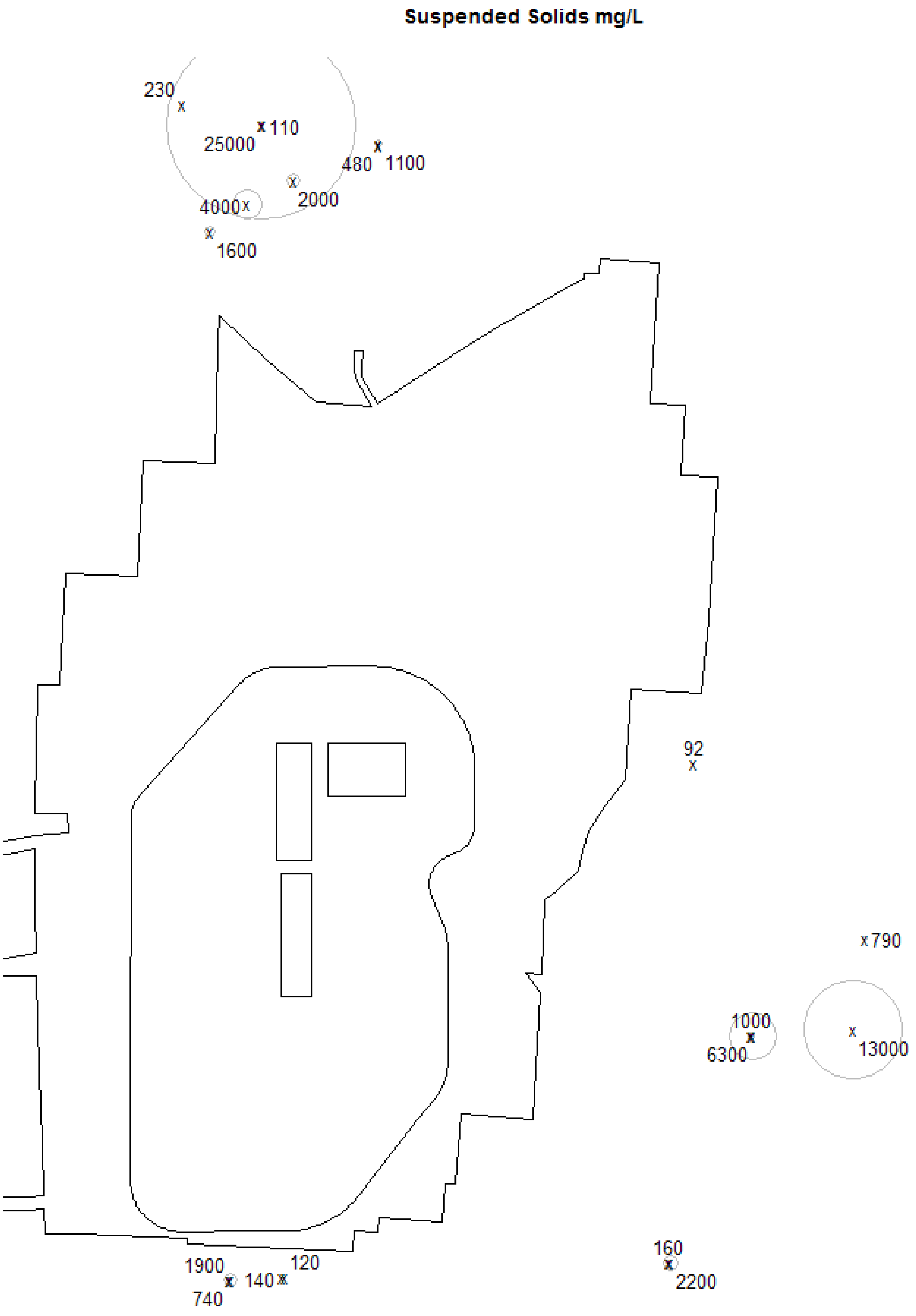


Figure Bw. Suspended solids concentration in off-site wells (mg/L).

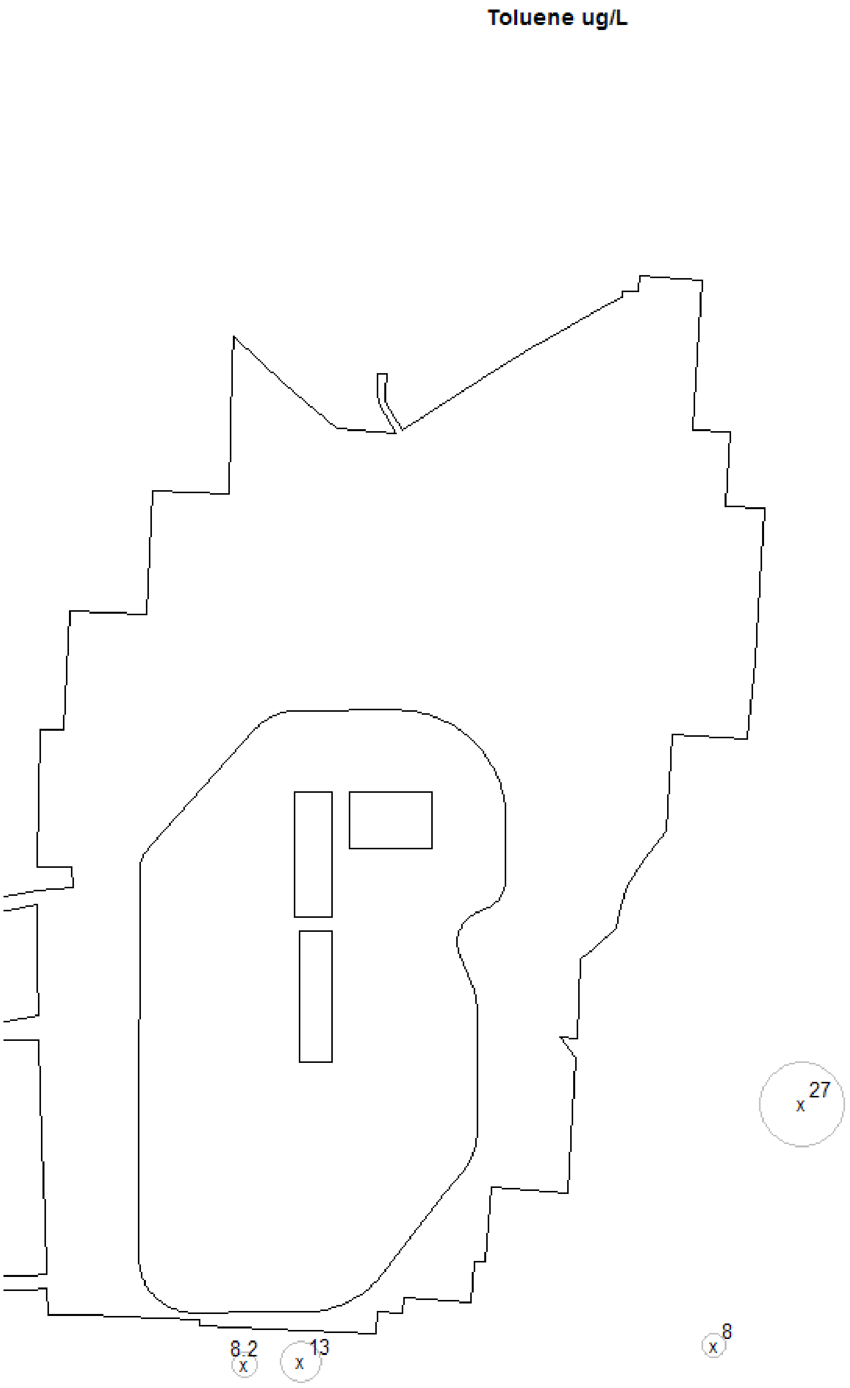


Figure Bx. Toluene concentration in off-site wells (µg/L).

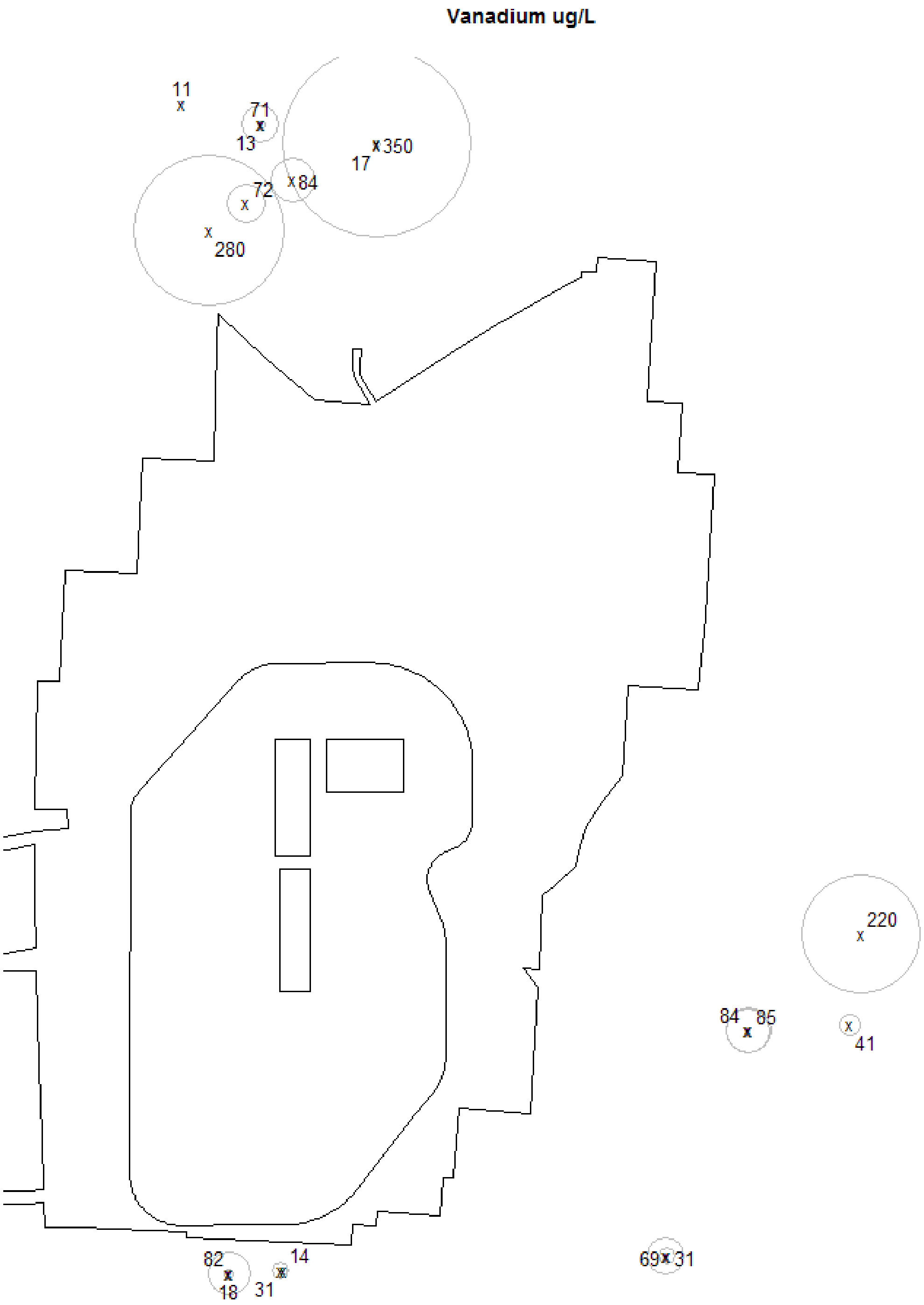


Figure By. Vanadium concentration in off-site wells (μg/L).

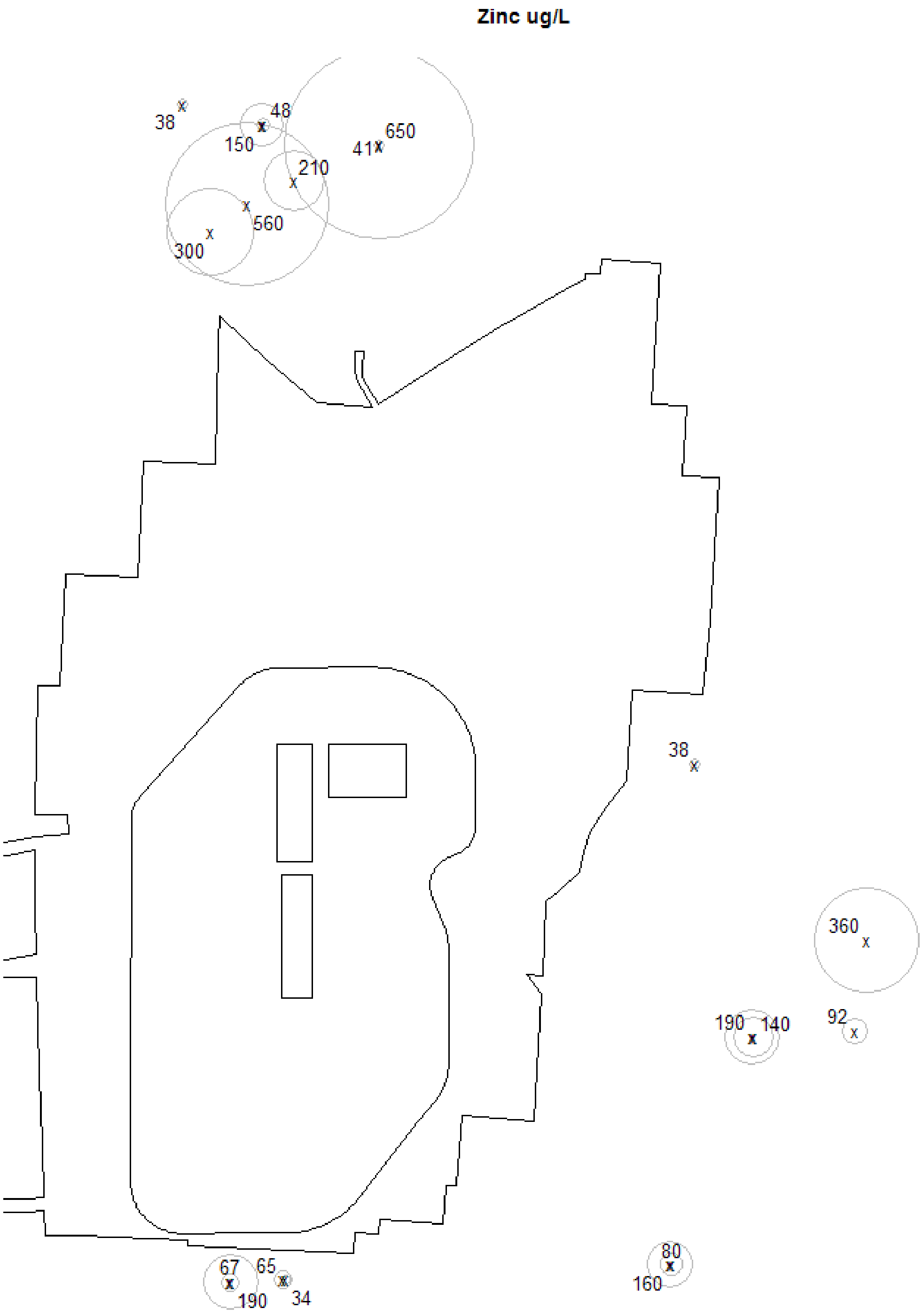


Figure Bz. Zinc concentration in off-site wells (µg/L).

Appendix C – Water Quality Standards Developed in the Safe Drinking Water Act

National Primary Drinking Water Regulations

Contaminant		MCL or TT[1] (mg/L)[2]	Potential health effects from long-term[3] exposure above the MCL	Common sources of contaminant in drinking water	Public Health Goal (mg/L)[2]
OC	Acrylamide	TT[4]	Nervous system or blood problems; increased risk of cancer	Added to water during sewage/ wastewater treatment	zero
OC	Alachlor	0.002	Eye, liver, kidney or spleen problems; anemia; increased risk of cancer	Runoff from herbicide used on row crops	zero
R	Alpha/photon emitters	15 picocuries per Liter (pCi/L)	Increased risk of cancer	Erosion of natural deposits of certain minerals that are radioactive and may emit a form of radiation known as alpha radiation	zero
IOC	Antimony	0.006	Increase in blood cholesterol; decrease in blood sugar	Discharge from petroleum refineries; fire retardants; ceramics; electronics; solder	0.006
IOC	Arsenic	0.010	Skin damage or problems with circulatory systems, and may have increased risk of getting cancer	Erosion of natural deposits; runoff from orchards; runoff from glass & electronics production wastes	0
IOC	Asbestos (fibers >10 micrometers)	7 million fibers per Liter (MFL)	Increased risk of developing benign intestinal polyps	Decay of asbestos cement in water mains; erosion of natural deposits	7 MFL
OC	Atrazine	0.003	Cardiovascular system or reproductive problems	Runoff from herbicide used on row crops	0.003
IOC	Barium	2	Increase in blood pressure	Discharge of drilling wastes; discharge from metal refineries; erosion of natural deposits	2
OC	Benzene	0.005	Anemia; decrease in blood platelets; increased risk of cancer	Discharge from factories; leaching from gas storage tanks and landfills	zero
OC	Benzo(a)pyrene (PAHs)	0.0002	Reproductive difficulties; increased risk of cancer	Leaching from linings of water storage tanks and distribution lines	zero
IOC	Beryllium	0.004	Intestinal lesions	Discharge from metal refineries and coal-burning factories; discharge from electrical, aerospace, and defense industries	0.004
R	Beta photon emitters	4 millirems per year	Increased risk of cancer	Decay of natural and man-made deposits of certain minerals that are radioactive and may emit forms of radiation known as photons and beta radiation	zero
DBP	Bromate	0.010	Increased risk of cancer	Byproduct of drinking water disinfection	zero
IOC	Cadmium	0.005	Kidney damage	Corrosion of galvanized pipes; erosion of natural deposits; discharge from metal refineries; runoff from waste batteries and paints	0.005
OC	Carbofuran	0.04	Problems with blood, nervous system, or reproductive system	Leaching of soil fumigant used on rice and alfalfa	0.04
OC	Carbon tetrachloride	0.005	Liver problems; increased risk of cancer	Discharge from chemical plants and other industrial activities	zero
D	Chloramines (as Cl_2)	MRDL=4.0[1]	Eye/nose irritation; stomach discomfort; anemia	Water additive used to control microbes	MRDLG=4[1]
OC	Chlordane	0.002	Liver or nervous system problems; increased risk of cancer	Residue of banned termiticide	zero
D	Chlorine (as Cl_2)	MRDL=4.0[1]	Eye/nose irritation; stomach discomfort	Water additive used to control microbes	MRDLG=4[1]
D	Chlorine dioxide (as ClO_2)	MRDL=0.8[1]	Anemia; infants, young children, and fetuses of pregnant women: nervous system effects	Water additive used to control microbes	MRDLG=0.8[1]
DBP	Chlorite	1.0	Anemia; infants, young children, and fetuses of pregnant women: nervous system effects	Byproduct of drinking water disinfection	0.8
OC	Chlorobenzene	0.1	Liver or kidney problems	Discharge from chemical and agricultural chemical factories	0.1
IOC	Chromium (total)	0.1	Allergic dermatitis	Discharge from steel and pulp mills; erosion of natural deposits	0.1
IOC	Copper	TT[5]; Action Level = 1.3	Short-term exposure: Gastrointestinal distress. Long-term exposure: Liver or kidney damage. People with Wilson's Disease should consult their personal doctor if the amount of copper in their water exceeds the action level	Corrosion of household plumbing systems; erosion of natural deposits	1.3
M	*Cryptosporidium*	TT[7]	Short-term exposure: Gastrointestinal illness (e.g., diarrhea, vomiting, cramps)	Human and animal fecal waste	zero

LEGEND

D	**Disinfectant**	IOC	**Inorganic Chemical**	OC	**Organic Chemical**
DBP	**Disinfection Byproduct**	M	**Microorganism**	R	**Radionuclides**

Contaminant	MCL or TT[1] (mg/L)[2]	Potential health effects from long-term[3] exposure above the MCL	Common sources of contaminant in drinking water	Public Health Goal (mg/L)[2]
IOC Cyanide (as free cyanide)	0.2	Nerve damage or thyroid problems	Discharge from steel/metal factories; discharge from plastic and fertilizer factories	0.2
OC 2,4-D	0.07	Kidney, liver, or adrenal gland problems	Runoff from herbicide used on row crops	0.07
OC Dalapon	0.2	Minor kidney changes	Runoff from herbicide used on rights of way	0.2
OC 1,2-Dibromo-3-chloropropane (DBCP)	0.0002	Reproductive difficulties; increased risk of cancer	Runoff/leaching from soil fumigant used on soybeans, cotton, pineapples, and orchards	zero
OC o-Dichlorobenzene	0.6	Liver, kidney, or circulatory system problems	Discharge from industrial chemical factories	0.6
OC p-Dichlorobenzene	0.075	Anemia; liver, kidney or spleen damage; changes in blood	Discharge from industrial chemical factories	0.075
OC 1,2-Dichloroethane	0.005	Increased risk of cancer	Discharge from industrial chemical factories	zero
OC 1,1-Dichloroethylene	0.007	Liver problems	Discharge from industrial chemical factories	0.007
OC cis-1,2-Dichloroethylene	0.07	Liver problems	Discharge from industrial chemical factories	0.07
OC trans-1,2-Dichloroethylene	0.1	Liver problems	Discharge from industrial chemical factories	0.1
OC Dichloromethane	0.005	Liver problems; increased risk of cancer	Discharge from drug and chemical factories	zero
OC 1,2-Dichloropropane	0.005	Increased risk of cancer	Discharge from industrial chemical factories	zero
OC Di(2-ethylhexyl) adipate	0.4	Weight loss, liver problems, or possible reproductive difficulties	Discharge from chemical factories	0.4
OC Di(2-ethylhexyl) phthalate	0.006	Reproductive difficulties; liver problems; increased risk of cancer	Discharge from rubber and chemical factories	zero
OC Dinoseb	0.007	Reproductive difficulties	Runoff from herbicide used on soybeans and vegetables	0.007
OC Dioxin (2,3,7,8-TCDD)	0.00000003	Reproductive difficulties; increased risk of cancer	Emissions from waste incineration and other combustion; discharge from chemical factories	zero
OC Diquat	0.02	Cataracts	Runoff from herbicide use	0.02
OC Endothall	0.1	Stomach and intestinal problems	Runoff from herbicide use	0.1
OC Endrin	0.002	Liver problems	Residue of banned insecticide	0.002
OC Epichlorohydrin	TT[4]	Increased cancer risk; stomach problems	Discharge from industrial chemical factories; an impurity of some water treatment chemicals	zero
OC Ethylbenzene	0.7	Liver or kidney problems	Discharge from petroleum refineries	0.7
OC Ethylene dibromide	0.00005	Problems with liver, stomach, reproductive system, or kidneys; increased risk of cancer	Discharge from petroleum refineries	zero
M Fecal coliform and *E. coli*	MCL[6]	Fecal coliforms and *E. coli* are bacteria whose presence indicates that the water may be contaminated with human or animal wastes. Microbes in these wastes may cause short term effects, such as diarrhea, cramps, nausea, headaches, or other symptoms. They may pose a special health risk for infants, young children, and people with severely compromised immune systems.	Human and animal fecal waste	zero[6]
IOC Fluoride	4.0	Bone disease (pain and tenderness of the bones); children may get mottled teeth	Water additive which promotes strong teeth; erosion of natural deposits; discharge from fertilizer and aluminum factories	4.0
M *Giardia lamblia*	TT[7]	Short-term exposure: Gastrointestinal illness (e.g., diarrhea, vomiting, cramps)	Human and animal fecal waste	zero
OC Glyphosate	0.7	Kidney problems; reproductive difficulties	Runoff from herbicide use	0.7
DBP Haloacetic acids (HAA5)	0.060	Increased risk of cancer	Byproduct of drinking water disinfection	n/a[9]
OC Heptachlor	0.0004	Liver damage; increased risk of cancer	Residue of banned termiticide	zero
OC Heptachlor epoxide	0.0002	Liver damage; increased risk of cancer	Breakdown of heptachlor	zero
M Heterotrophic plate count (HPC)	TT[7]	HPC has no health effects; it is an analytic method used to measure the variety of bacteria that are common in water. The lower the concentration of bacteria in drinking water, the better maintained the water system is.	HPC measures a range of bacteria that are naturally present in the environment	n/a

LEGEND

D	**Disinfectant**	IOC	**Inorganic Chemical**	OC	**Organic Chemical**
DBP	**Disinfection Byproduct**	M	**Microorganism**	R	**Radionuclides**

Contaminant		MCL or TT[1] (mg/L)[2]	Potential health effects from long-term[3] exposure above the MCL	Common sources of contaminant in drinking water	Public Health Goal (mg/L)[2]
OC	Hexachlorobenzene	0.001	Liver or kidney problems; reproductive difficulties; increased risk of cancer	Discharge from metal refineries and agricultural chemical factories	zero
OC	Hexachlorocyclopentadiene	0.05	Kidney or stomach problems	Discharge from chemical factories	0.05
IOC	Lead	TT[5]; Action Level=0.015	Infants and children: Delays in physical or or mental development; children could show slight deficits in attention span and learning abilities; Adults: Kidney problems; high blood pressure	Corrosion of household plumbing systems; erosion of natural deposits	zero
M	*Legionella*	TT[7]	Legionnaire's Disease, a type of pneumonia	Found naturally in water; multiplies in heating systems	zero
OC	Lindane	0.0002	Liver or kidney problems	Runoff/leaching from insecticide used on cattle, lumber, gardens	0.0002
IOC	Mercury (inorganic)	0.002	Kidney damage	Erosion of natural deposits; discharge from refineries and factories; runoff from landfills and croplands	0.002
OC	Methoxychlor	0.04	Reproductive difficulties	Runoff/leaching from insecticide used on fruits, vegetables, alfalfa, livestock	0.04
IOC	Nitrate (measured as Nitrogen)	10	Infants below the age of six months who drink water containing nitrate in excess of the MCL could become seriously ill and, if untreated, may die. Symptoms include shortness of breath and blue-baby syndrome.	Runoff from fertilizer use; leaching from septic tanks, sewage; erosion of natural deposits	10
IOC	Nitrite (measured as Nitrogen)	1	Infants below the age of six months who drink water containing nitrite in excess of the MCL could become seriously ill and, if untreated, may die. Symptoms include shortness of breath and blue-baby syndrome.	Runoff from fertilizer use; leaching from septic tanks, sewage; erosion of natural deposits	1
OC	Oxamyl (Vydate)	0.2	Slight nervous system effects	Runoff/leaching from insecticide used on apples, potatoes, and tomatoes	0.2
OC	Pentachlorophenol	0.001	Liver or kidney problems; increased cancer risk	Discharge from wood-preserving factories	zero
OC	Picloram	0.5	Liver problems	Herbicide runoff	0.5
OC	Polychlorinated biphenyls (PCBs)	0.0005	Skin changes; thymus gland problems; immune deficiencies; reproductive or nervous system difficulties; increased risk of cancer	Runoff from landfills; discharge of waste chemicals	zero
R	Radium 226 and Radium 228 (combined)	5 pCi/L	Increased risk of cancer	Erosion of natural deposits	zero
IOC	Selenium	0.05	Hair or fingernail loss; numbness in fingers or toes; circulatory problems	Discharge from petroleum and metal refineries; erosion of natural deposits; discharge from mines	0.05
OC	Simazine	0.004	Problems with blood	Herbicide runoff	0.004
OC	Styrene	0.1	Liver, kidney, or circulatory system problems	Discharge from rubber and plastic factories; leaching from landfills	0.1
OC	Tetrachloroethylene	0.005	Liver problems; increased risk of cancer	Discharge from factories and dry cleaners	zero
IOC	Thallium	0.002	Hair loss; changes in blood; kidney, intestine, or liver problems	Leaching from ore-processing sites; discharge from electronics, glass, and drug factories	0.0005
OC	Toluene	1	Nervous system, kidney, or liver problems	Discharge from petroleum factories	1
M	Total Coliforms	5.0 percent[8]	Coliforms are bacteria that indicate that other, potentially harmful bacteria may be present. See fecal coliforms and *E. coli*	Naturally present in the environment	zero
DBP	Total Trihalomethanes (TTHMs)	0.080	Liver, kidney or central nervous system problems; increased risk of cancer	Byproduct of drinking water disinfection	n/a[9]
OC	Toxaphene	0.003	Kidney, liver, or thyroid problems; increased risk of cancer	Runoff/leaching from insecticide used on cotton and cattle	zero
OC	2,4,5-TP (Silvex)	0.05	Liver problems	Residue of banned herbicide	0.05
OC	1,2,4-Trichlorobenzene	0.07	Changes in adrenal glands	Discharge from textile finishing factories	0.07
OC	1,1,1-Trichloroethane	0.2	Liver, nervous system, or circulatory problems	Discharge from metal degreasing sites and other factories	0.2
OC	1,1,2-Trichloroethane	0.005	Liver, kidney, or immune system problems	Discharge from industrial chemical factories	0.003
OC	Trichloroethylene	0.005	Liver problems; increased risk of cancer	Discharge from metal degreasing sites and other factories	zero

LEGEND

D	**Disinfectant**	IOC	**Inorganic Chemical**	OC	**Organic Chemical**
DBP	**Disinfection Byproduct**	M	**Microorganism**	R	**Radionuclides**

Contaminant		MCL or TT[1] (mg/L)[2]	Potential health effects from long-term[3] exposure above the MCL	Common sources of contaminant in drinking water	Public Health Goal (mg/L)[2]
M	Turbidity	TT[7]	Turbidity is a measure of the cloudiness of water. It is used to indicate water quality and filtration effectiveness (e.g., whether disease-causing organisms are present). Higher turbidity levels are often associated with higher levels of disease-causing microorganisms such as viruses, parasites and some bacteria. These organisms can cause short term symptoms such as nausea, cramps, diarrhea, and associated headaches.	Soil runoff	n/a
R	Uranium	30μg/L	Increased risk of cancer, kidney toxicity	Erosion of natural deposits	zero
OC	Vinyl chloride	0.002	Increased risk of cancer	Leaching from PVC pipes; discharge from plastic factories	zero
M	Viruses (enteric)	TT[7]	Short-term exposure: Gastrointestinal illness (e.g., diarrhea, vomiting, cramps)	Human and animal fecal waste	zero
OC	Xylenes (total)	10	Nervous system damage	Discharge from petroleum factories; discharge from chemical factories	10

LEGEND

D	**Disinfectant**	IOC	**Inorganic Chemical**	OC	**Organic Chemical**
DBP	**Disinfection Byproduct**	M	**Microorganism**	R	**Radionuclides**

NOTES

1 Definitions

- Maximum Contaminant Level Goal (MCLG)—The level of a contaminant in drinking water below which there is no known or expected risk to health. MCLGs allow for a margin of safety and are non-enforceable public health goals.
- Maximum Contaminant Level (MCL)—The highest level of a contaminant that is allowed in drinking water. MCLs are set as close to MCLGs as feasible using the best available treatment technology and taking cost into consideration. MCLs are enforceable standards.
- Maximum Residual Disinfectant Level Goal (MRDLG)—The level of a drinking water disinfectant below which there is no known or expected risk to health. MRDLGs do not reflect the benefits of the use of disinfectants to control microbial contaminants.
- Maximum Residual Disinfectant Level (MRDL)—The highest level of a disinfectant allowed in drinking water. There is convincing evidence that addition of a disinfectant is necessary for control of microbial contaminants.
- Treatment Technique (TT)—A required process intended to reduce the level of a contaminant in drinking water.

2 Units are in milligrams per liter (mg/L) unless otherwise noted. Milligrams per liter are equivalent to parts per million (ppm).

3 Health effects are from long-term exposure unless specified as short-term exposure.

4 Each water system must certify annually, in writing, to the state (using third-party or manufacturers certification) that when it uses acrylamide and/or epichlorohydrin to treat water, the combination (or product) of dose and monomer level does not exceed the levels specified, as follows: Acrylamide = 0.05 percent dosed at 1 mg/L (or equivalent); Epichlorohydrin = 0.01 percent dosed at 20 mg/L (or equivalent).

5 Lead and copper are regulated by a Treatment Technique that requires systems to control the corrosiveness of their water. If more than 10 percent of tap water samples exceed the action level, water systems must take additional steps. For copper, the action level is 1.3 mg/L, and for lead is 0.015 mg/L.

6 A routine sample that is fecal coliform-positive or *E. coli*-positive triggers repeat samples--if any repeat sample is total coliform-positive, the system has an acute MCL violation. A routine sample that is total coliform-positive and fecal coliform-negative or *E. coli*-negative triggers repeat samples--if any repeat sample is fecal coliform-positive or *E. coli*-positive, the system has an acute MCL violation. See also Total Coliforms.

7 EPA's surface water treatment rules require systems using surface water or ground water under the direct influence of surface water to (1) disinfect their water, and (2) filter their water or meet criteria for avoiding filtration so that the following contaminants are controlled at the following levels:

- *Cryptosporidium*: 99 percent removal for systems that filter. Unfiltered systems are required to include Cryptosporidium in their existing watershed control provisions.
- Giardia lamblia: 99.9 percent removal/inactivation
- Viruses: 99.99 percent removal/inactivation
- *Legionella*: No limit, but EPA believes that if *Giardia* and viruses are removed/inactivated according to the treatment techniques in the surface water treatment rule, *Legionella* will also be controlled.
- Turbidity: For systems that use conventional or direct filtration, at no time can turbidity (cloudiness of water) go higher than 1 nephelolometric turbidity unit (NTU), and samples for turbidity must be less than or equal to 0.3 NTU in at least 95 percent of the samples in any month. Systems that use filtration other than conventional or direct filtration must follow state limits, which must include turbidity at no time exceeding 5 NTU.
- HPC: No more than 500 bacterial colonies per milliliter
- Long Term 1 Enhanced Surface Water Treatment; Surface water systems or ground water systems under the direct influence of surface water serving fewer than 10,000 people must comply with the applicable Long Term 1 Enhanced Surface Water Treatment Rule provisions (e.g. turbidity standards, individual filter monitoring, *Cryptosporidium* removal requirements, updated watershed control requirements for unfiltered systems).
- Long Term 2 Enhanced Surface Water Treatment; This rule applies to all surface water systems or ground water systems under the direct influence of surface water. The rule targets additional *Cryptosporidium* treatment requirements for higher risk systems and includes provisions to reduce risks from uncovered finished water storages facilities and to ensure that the systems maintain microbial protection as they take steps to reduce the formation of disinfection byproducts. (Monitoring start dates are staggered by system size. The largest systems (serving at least 100,000 people) will begin monitoring in October 2006 and the smallest systems (serving fewer than 10,000 people) will not begin monitoring until October 2008. After completing monitoring and determining their treatment bin, systems generally have three years to comply with any additional treatment requirements.)
- Filter Backwash Recycling: The Filter Backwash Recycling Rule requires systems that recycle to return specific recycle flows through all processes of the system's existing conventional or direct filtration system or at an alternate location approved by the state.

8 No more than 5.0 percent samples total coliform-positive in a month. (For water systems that collect fewer than 40 routine samples per month, no more than one sample can be total coliform-positive per month.) Every sample that has total coliform must be analyzed for either fecal coliforms or *E. coli*. If two consecutive TC-positive samples, and one is also positive for *E. coli* or fecal coliforms, system has an acute MCL violation.

9 Although there is no collective MCLG for this contaminant group, there are individual MCLGs for some of the individual contaminants:

- Haloacetic acids: dichloroacetic acid (zero); trichloroacetic acid (0.3 mg/L)
- Trihalomethanes: bromodichloromethane (zero); bromoform (zero); dibromochloromethane (0.06 mg/L)

National Secondary Drinking Water Regulation

National Secondary Drinking Water Regulations are non-enforceable guidelines regarding contaminants that may cause cosmetic effects (such as skin or tooth discoloration) or aesthetic effects (such as taste, odor, or color) in drinking water. EPA recommends secondary standards to water systems but does not require systems to comply. However, some states may choose to adopt them as enforceable standards.

Contaminant	Secondary Maximum Contaminant Level
Aluminum	0.05 to 0.2 mg/L
Chloride	250 mg/L
Color	15 (color units)
Copper	1.0 mg/L
Corrosivity	noncorrosive
Fluoride	2.0 mg/L
Foaming Agents	0.5 mg/L
Iron	0.3 mg/L
Manganese	0.05 mg/L
Odor	3 threshold odor number
pH	6.5-8.5
Silver	0.10 mg/L
Sulfate	250 mg/L
Total Dissolved Solids	500 mg/L
Zinc	5 mg/L

For More Information

EPA's Safe Drinking Water Web site:
http://www.epa.gov/safewater/

EPA's Safe Drinking Water Hotline:
(800) 426-4791

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