Paleochannels, Lithology, and Aquifer Interaction Characterized using Surface Geophysical Methods at the Standard Chlorine of Delaware, Inc. Superfund Site, Delaware City, Delaware

Maryland Groundwater Symposium
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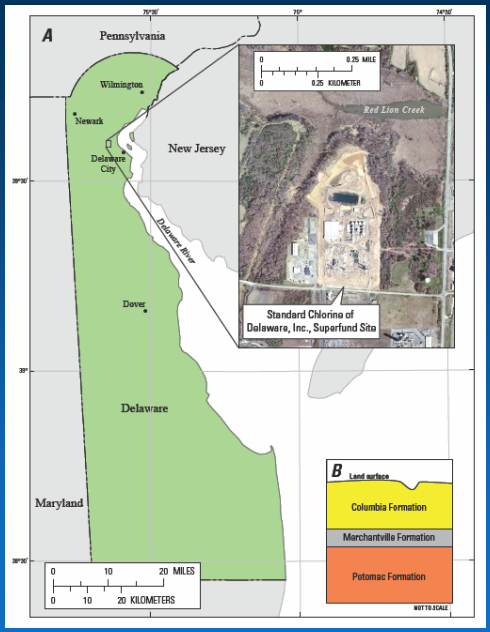
MD/DE/DC Water Science Center

U.S. Department of the Interior
U.S. Geological Survey

Standard Chlorine of Delaware, Inc. USEPA Superfund Site

Site History:
1965 Standard Chlorine of Delaware (SCD) chemical plant built
1981 Railroad taker spill; listing on EPA National Priorities List
1986 Tank rupture and spill of 569,000 gallons of mixed VOCs
2002 SCD abruptly closed, abandoned the plant, and declared bankruptcy
2002 U.S. taxpayers assume full liability; EPA takes full control of the site

Chlorobenzenes have been found in groundwater, soil, creek sediments, surface water, and nearby wetlands



http://www.epa.gov/reg3hwmd/npl/DED041212473.htm

Acknowledgements:

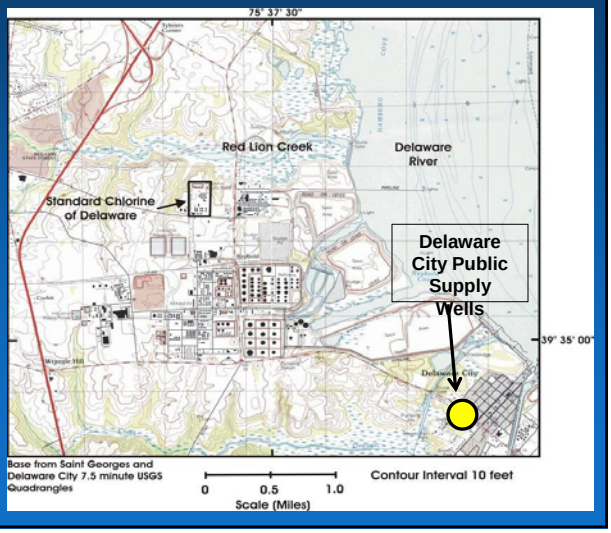
- James R. Degnan, Hydrogeologist
  - USGS NH/VT Water Science Center
- Cooperators:
  - EPA Region 3
  - DNREC (Delaware Department of Natural Resources and Environmental Control)
  - HydroGeologic (consulting firm)
- Delaware Geological Survey
- MD/DE/DC Water Science Center personnel
- USGS Branch of Geophysics, Storres, CT
- USGS Field Office, San Angelo, TX

The Problem:

Does contamination in the uppermost sand layer of the Potomac aquifer at Standard Chlorine pose a threat to public water supply?

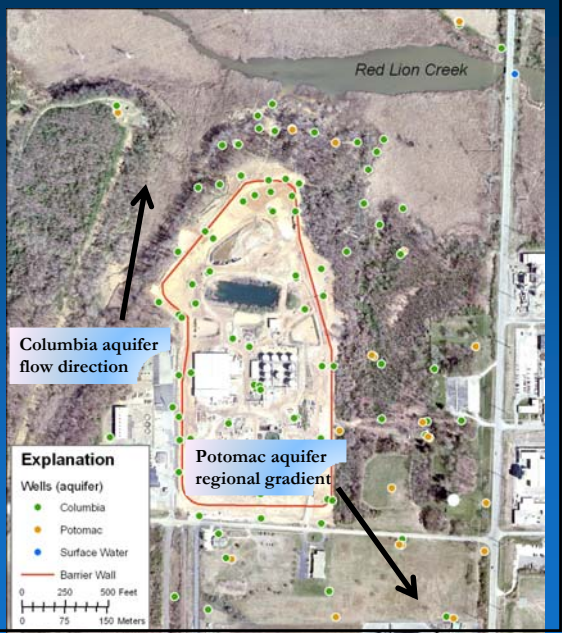
Potomac Aquifer Study Objectives:

- Determine direction and rate of ground-water flow in the Potomac Aquifer (vertical & horizontal)
- Determine rate of contaminant flux into the Potomac aquifer from the Columbia aquifer
- Identify potential receptors of contaminated ground water



Site Hydrology

- Local flow in the Columbia (water table) aquifer is generally south to north, discharging to Red Lion Creek
- Regional flow gradients in the Potomac aquifer are from northwest to southeast
- Stage changes in Red Lion Creek can affect water levels in the Potomac aquifer
- Regional industrial pumping of the middle Potomac aquifer (~300 feet below land surface) affects water levels in the upper Potomac
- Continuous water-level monitoring has shown that Potomac sands are connected



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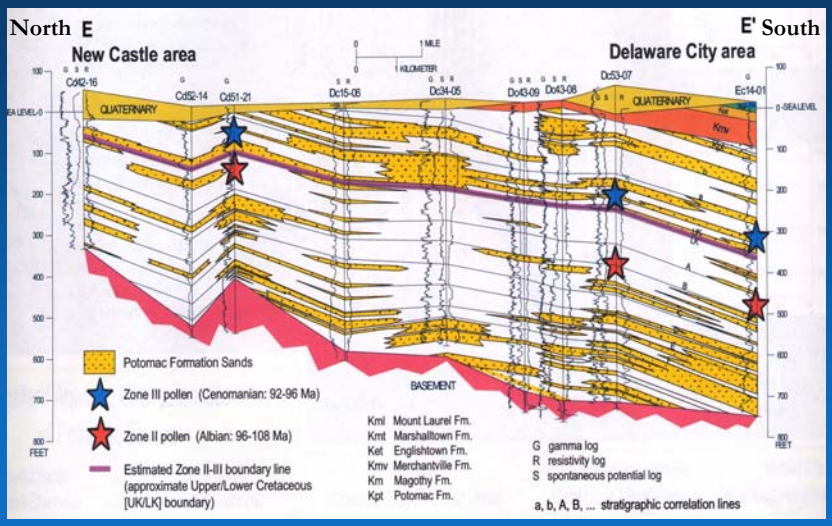
Geologic Setting

The Potomac formation was formed in a complex fluvial depositional environment
Inter-bedded sands and clays are common



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(Delaware Geological Survey)

Seeing Deeper into the Potomac Aquifer

- How continuous are the Merchantville and Potomac clay layers?
- How thick are these layers?
- What have we learned from sonic drilling?
  - Merchantville is eroded in many places
  - Upper Potomac clay is absent at north end of the site

Merchantville Clay (0-20 feet thick)

Potomac Clay (0-30 feet thick in upper Potomac formation)

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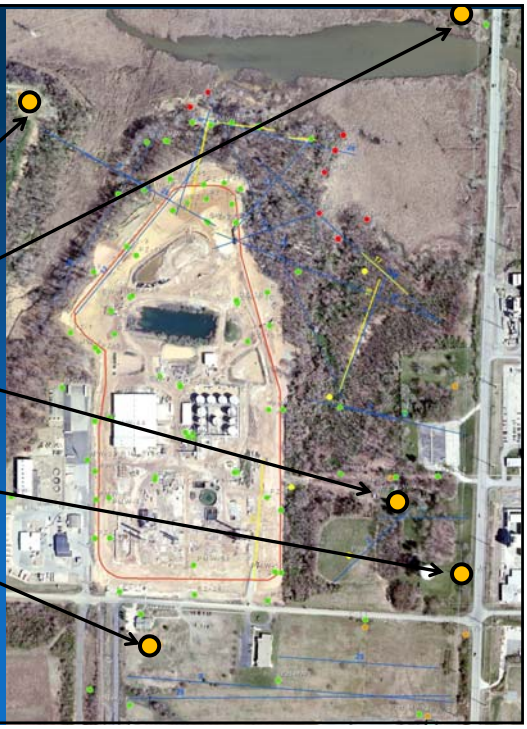
2007 Potomac Drilling Summary

- **PW-6** (2 wells) Vertically profiled to 180 feet; no contamination encountered
- **PW-5** (2 wells) Vertically profiled to 110 feet; no contamination encountered
- **PW-4** (3 wells) Vertically profiled to 150 feet; Contamination encountered, only at 150 feet; lateral transport likely
- **PW-8** (1 well) Vertically profiled to 200 feet; no contamination
- **PW-7** (1 well) Well screened in sand seam below Merchantville, but above Potomac clay; no contamination encountered



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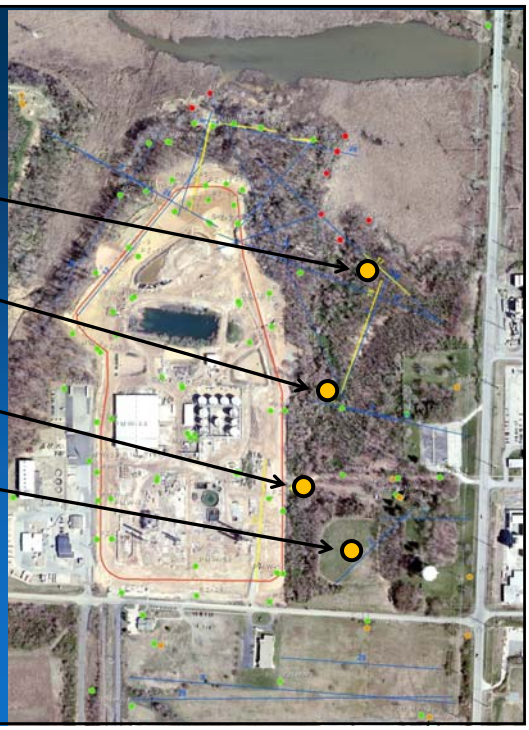
2009 Potomac Drilling Summary

- **PW-11** – (3 wells) Vertically profiled to 255 feet; no contamination encountered
- **PW-10** (2 wells) Vertically profiled to 250 feet; no contamination encountered
- **PW-12** – (1 well) Vertically profiled to 130 feet; Contamination encountered, only at 130 feet; lateral transport likely
- **PW-9** (1 well) Vertically profiled to 148 feet; Contamination encountered, only at 148 feet; lateral transport likely



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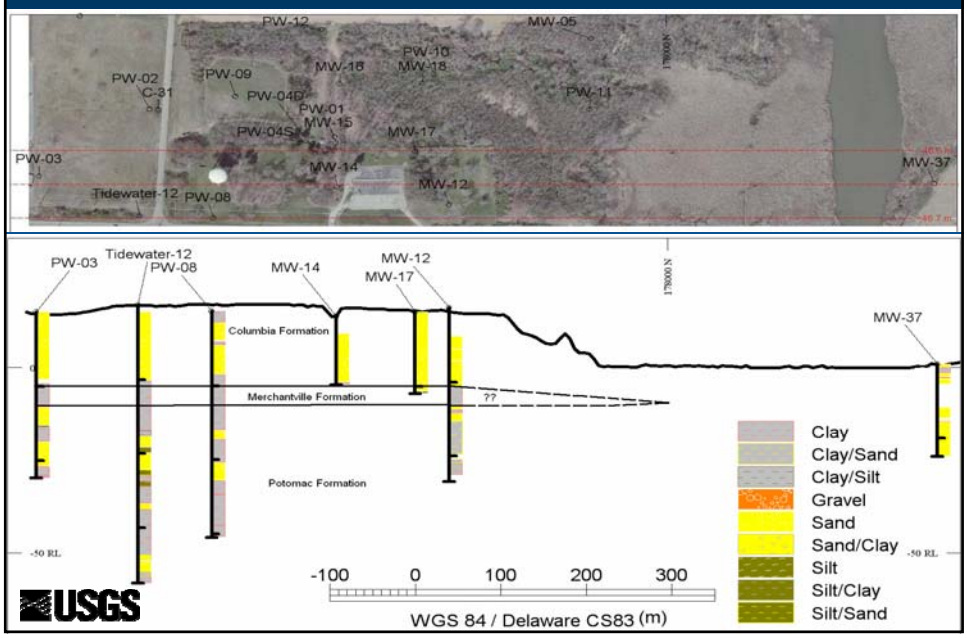
Geologic Cross Section



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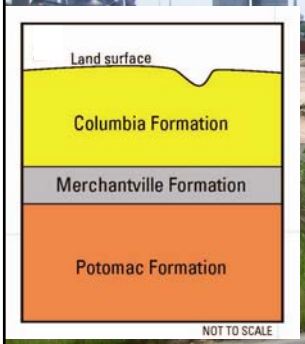
Geophysical Investigations

Objectives:

- Map confining clay and locate holes without (expensive!) drilling
- Locate groundwater with elevated specific conductance
- Measure the trend, extent and connectivity of paleochannels



Geophysical methods at site:

- Borehole gamma logging
- Multi-channel analysis of surface waves
- Direct current resistivity
  - Test box
  - Two dimensional
  - Square array

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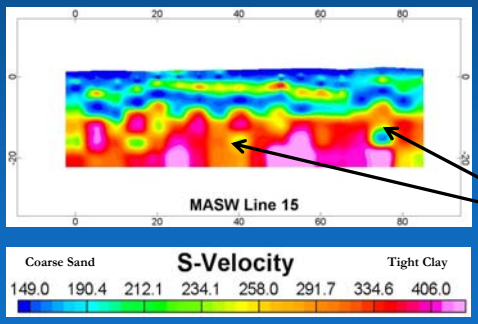
Multi-Channel Analysis of Surface Waves

Skid mounted geophones (24) are dragged behind a vehicle equipped with a 40kg propelled weight drop for continuous seismic profiling

- MASW is not affected by water surface or changes in water quality



More permeable zones (holes) through the clay

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Two Dimensional Resistivity

Approach:

- Does the method work at this site? (Yes)
- Is there enough contrast in geologic material? (Yes)
- How deep to you want to "see"? (95 meters)
  - Depth of penetration is 20% of total line length
  - Level of detail is a function of electrode spacing
- Sting and Iris systems both used successfully at the site, including a survey floating across shallow water

Field considerations:

- Cultural features present? (buried utilities, construction debris, fences, etc.)
- How much open space to you have?
- Is site clearing necessary?
- Water level measurements to distinguish saturated sediments
- Pore water fluid resistivity very important; Measurements needed in nearby wells and surface water

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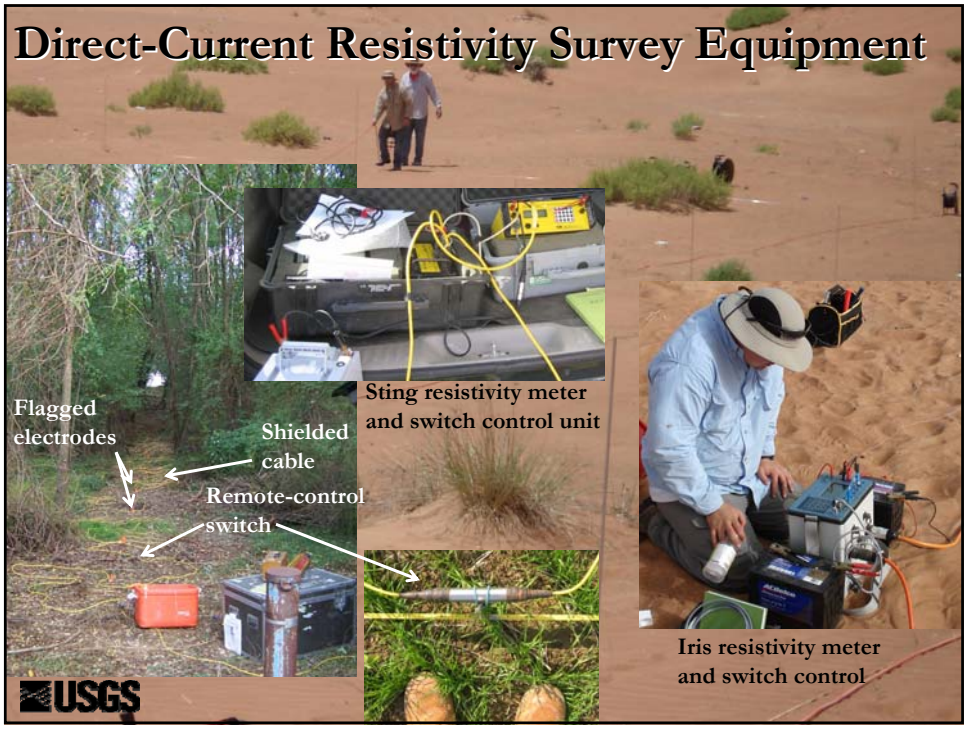
Direct-Current Resistivity Survey Equipment



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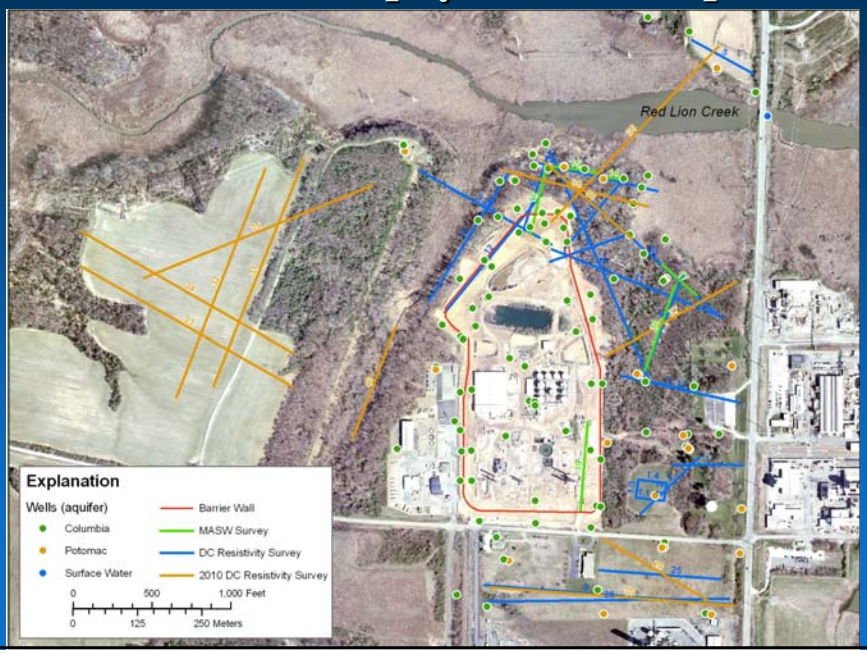
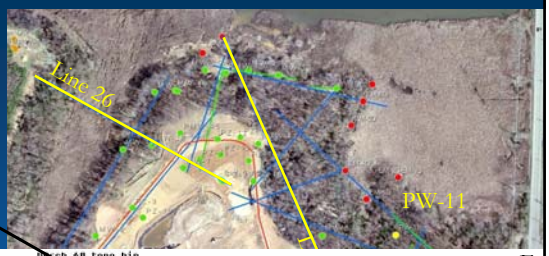
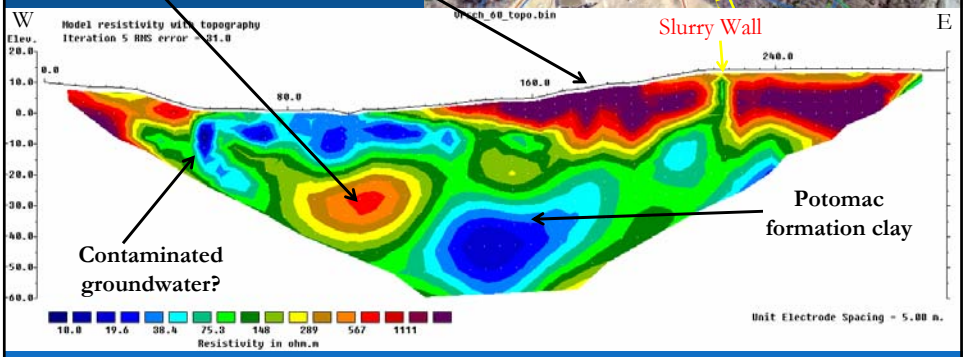
Surface Geophysics Site Map



Direct Current Resistivity, Line 26

Elevation corrected DC resistivity cross section which passes through a marsh and crosses the slurry wall





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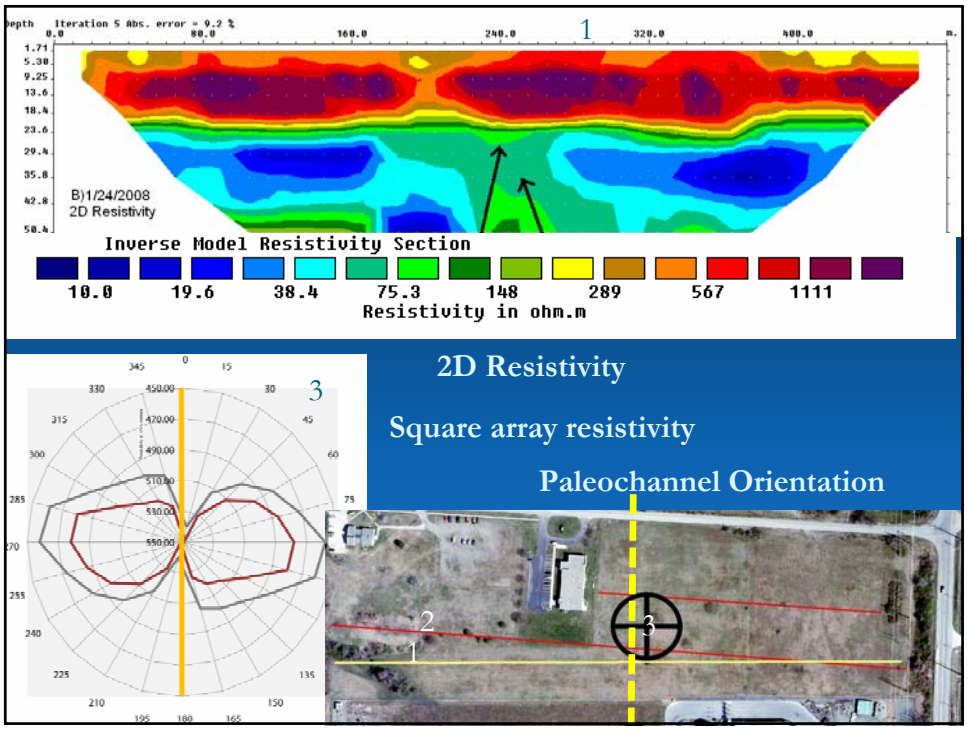
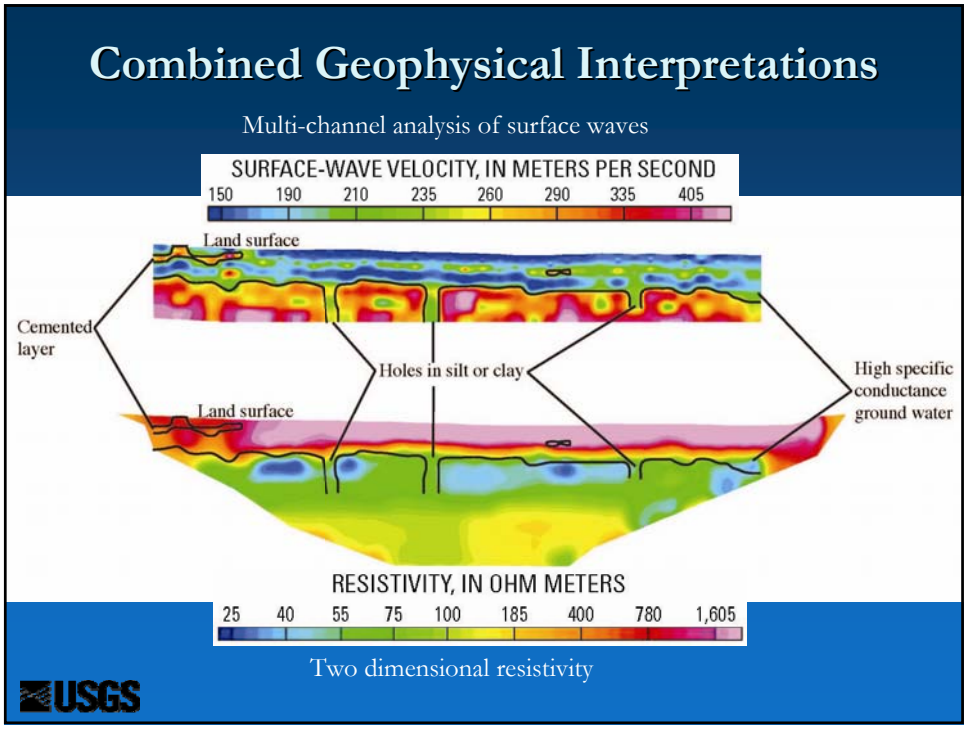
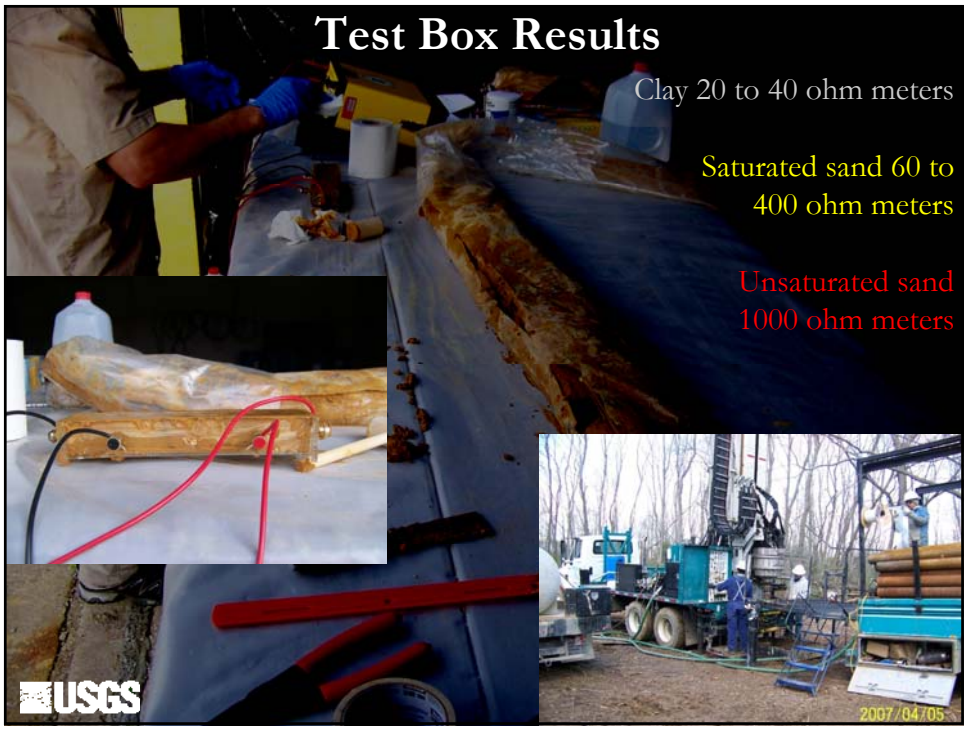
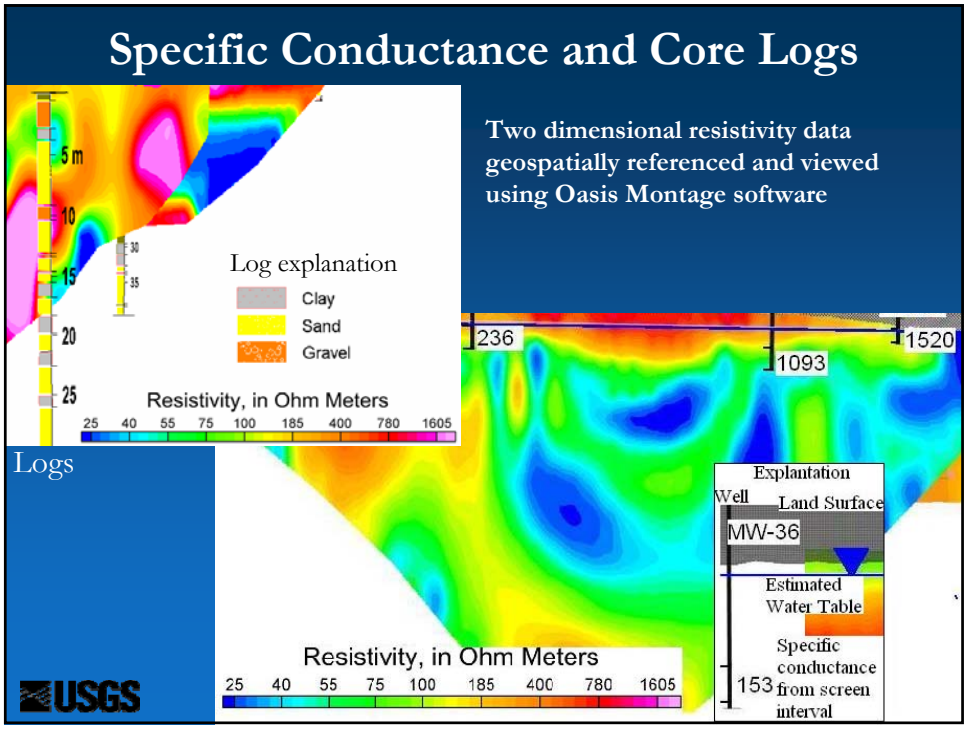

1
B)1/24/2008
2D Resistivity
Inverse Model Resistivity Section
10.0
19.6
38.4
75.3
148
289
567
1111
Resistivity in ohm.m
3
2D Resistivity
Square array resistivity
Paleochannel Orientation
2
1
3


Combined Geophysical Interpretations
Multi-channel analysis of surface waves
SURFACE-WAVE VELOCITY, IN METERS PER SECOND
150 190 210 235 260 290 335 405
Land surface
Cemented layer
Holes in silt or clay
High specific conductance ground water
Land surface
RESISTIVITY, IN OHM METERS
25 40 55 75 100 185 400 780 1,605
Two dimensional resistivity
USGS


Test Box Results
Clay 20 to 40 ohm meters
Saturated sand 60 to 400 ohm meters
Unsaturated sand 1000 ohm meters
USGS
2007/04/05


Specific Conductance and Core Logs
Two dimensional resistivity data geospatially referenced and viewed using Oasis Montage software
5 m
10
15
20
25
30
35
Log explanation
Clay
Sand
Gravel
Resistivity, in Ohm Meters
25 40 55 75 100 185 400 780 1605
236
1093
1520
Logs
Explantation
Well
Land Surface
MW-36
Estimated Water Table
Specific conductance from screen interval
153
Resistivity, in Ohm Meters
25 40 55 75 100 185 400 780 1605
USGS

2010 Potomac Drilling Summary

- **PW-14** (1 well) Vertically profiled to 69 feet; Contamination encountered, multiple depths
- **PW-17** (1 well) Vertically profiled to 105 feet; Contamination encountered, multiple depths
- **PW-13** – (1 well) Vertically profiled to 170 feet; Contamination encountered at 165 feet
- **PW-2D** (1 well) Vertically profiled to 250 feet; No contamination encountered
- **PW-16** (1 well)Vertically profiled to 250 feet; No contamination encountered

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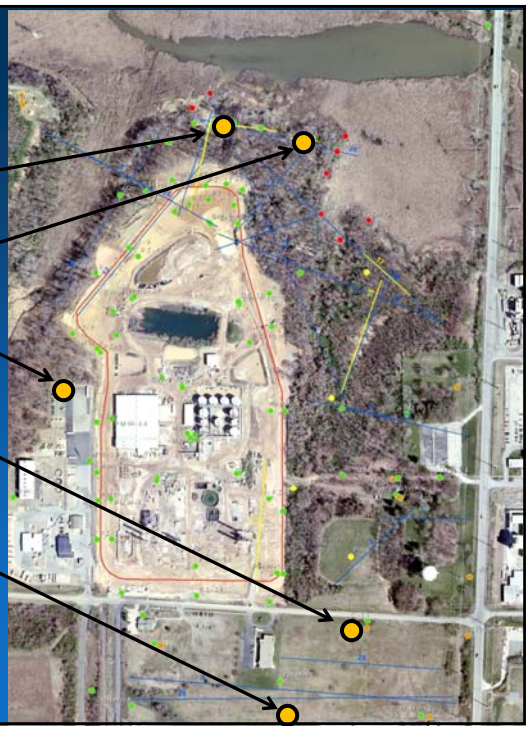

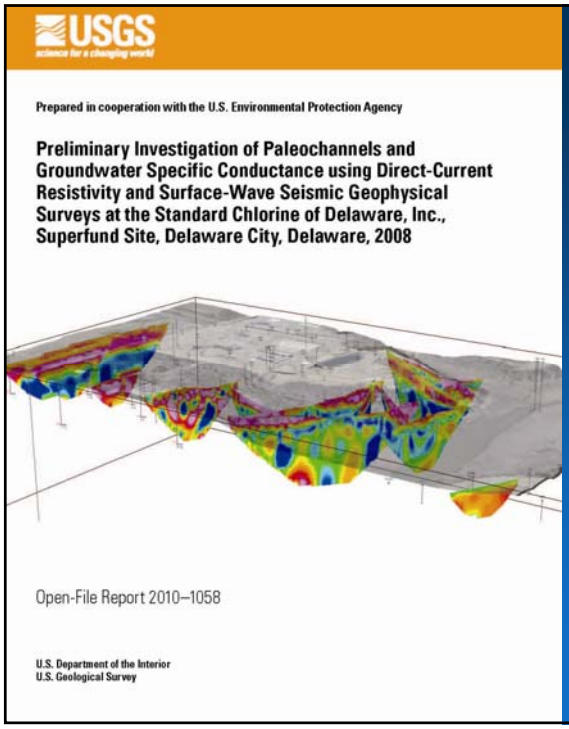

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Prepared in cooperation with the U.S. Environmental Protection Agency

Preliminary Investigation of Paleochannels and Groundwater Specific Conductance using Direct-Current Resistivity and Surface-Wave Seismic Geophysical Surveys at the Standard Chlorine of Delaware, Inc., Superfund Site, Delaware City, Delaware, 2008

Open-File Report 2010–1058

U.S. Department of the Interior
U.S. Geological Survey

Future Publications:

Hydrologic and Geochemical Characterization of Aquifer Interactions at the Standard Chlorine of Delaware, Inc. Superfund Site, 2005-2009

Surface Geophysical Investigations –Part 2

Upper Potomac Formation Multiple-Well Aquifer Test at the Standard Chlorine of Delaware, Inc. Superfund Site, August 2010

Continued Surface Geophysical Work

- Collect 2D resistivity surveys, targeting areas where clay may be absent
- Experiment with more advanced surveys (complex geometry)
- Process previously collected data using 3D composite of data
- Additional test box measurements on recently recovered core material

Related Ongoing Site Investigations

- Semi-annual VOC/SVOC monitoring of Columbia aquifer (water table) and Potomac aquifer (semi-confined) wells
- Evaluation of natural attenuation and potential for enhanced biodegradation in adjacent wetlands
- Continuous water-level monitoring of multiple aquifers
- Evaluation of regional pumping effects on local flow-systems

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Questions?

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Water-Level Network

- Currently USGS is measuring 42 sites for water levels
  - 18 Potomac wells
  - 1 Red Lion Creek stage
  - 8 Drivepoints in east marsh
  - 7 Columbia wells
  - 2 Barrier wall Columbia wells (replicate with HGL)
  - 1 Deep Potomac well (Tidewater 12, Dc53-07)
  - 5 Tybouts Potomac wells (occasionally)
- Monthly levels coordinated with HGL (Columbia wells)
- Currently have 14 sites with continuous recorders, including stage recorder at Red Lion Creek
- Barrier wall instrumented (10 wells w/HGL)

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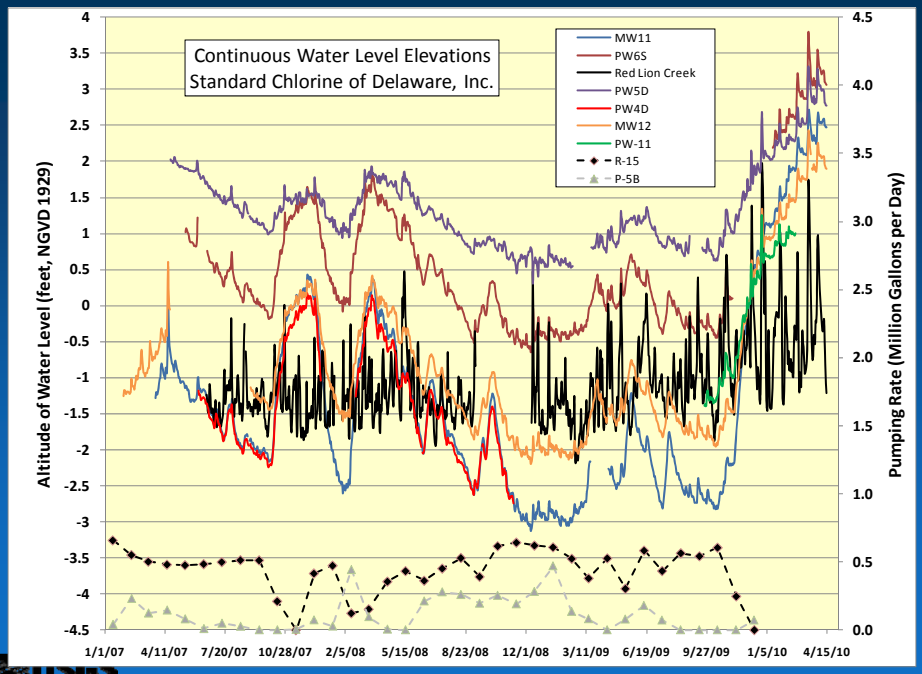

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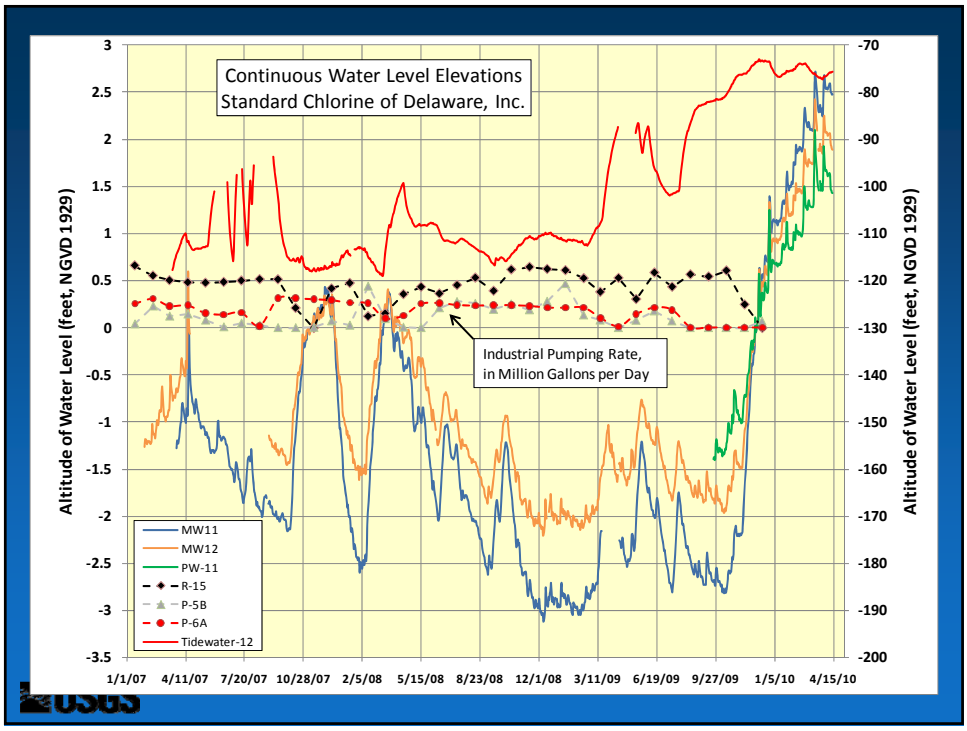
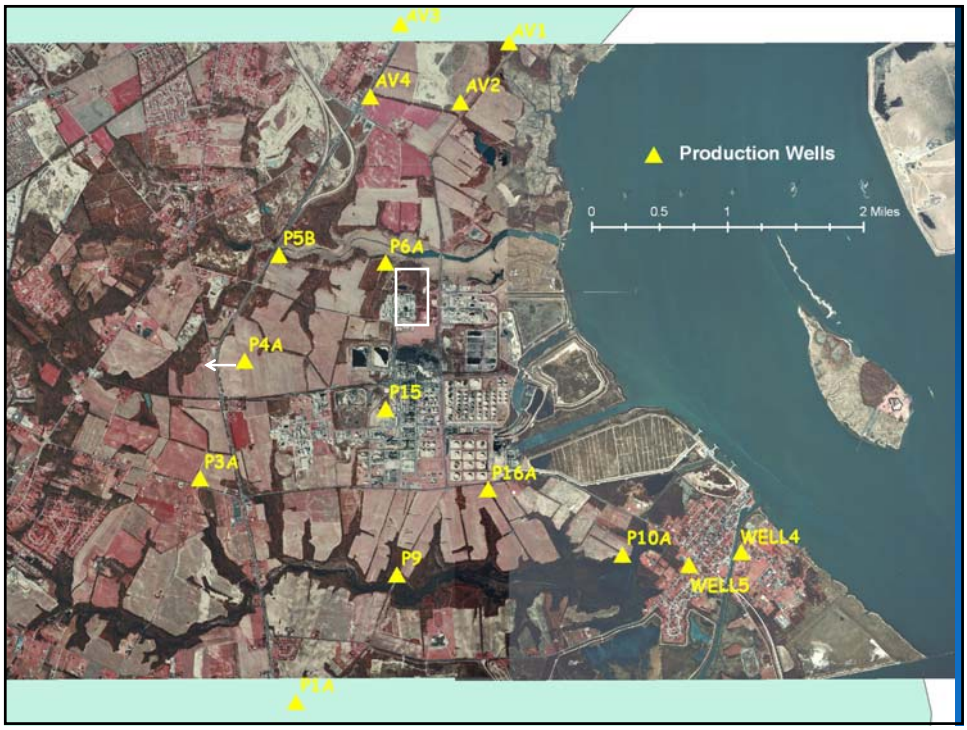


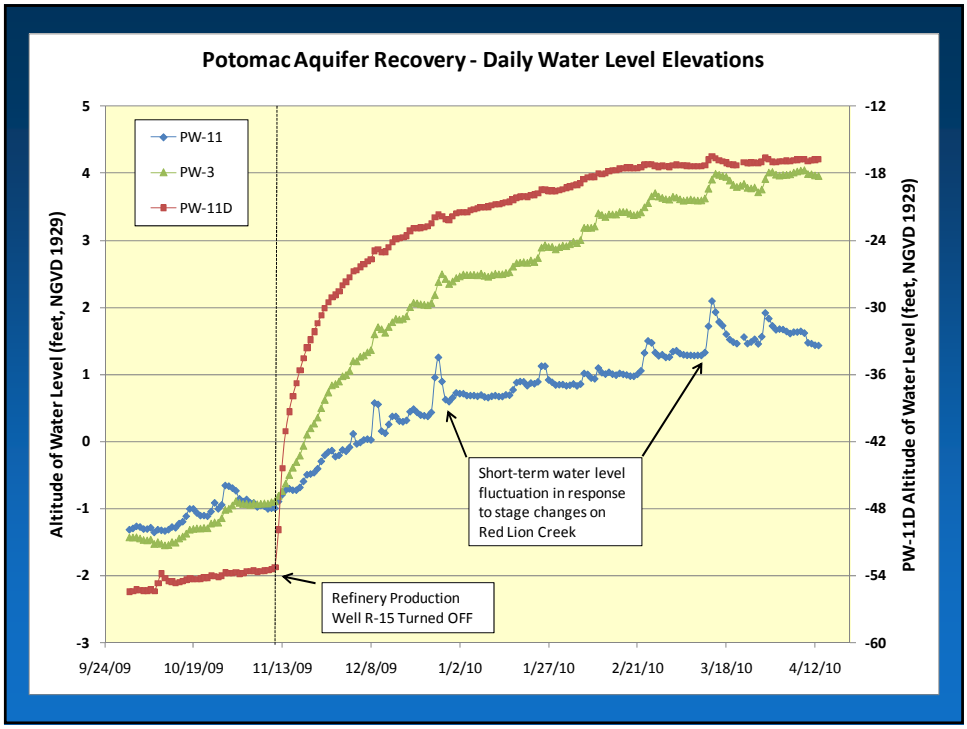
Water Use Wells near Standard Chlorine

Water Use Wells screened in Potomac Formation
Delaware City Industrial Area

Local Well Name	DNREC-ID	USGS-ID	DGS-ID	NAD-1983 Lat	NAD-1983 Long	Well Owner	Screen Interval (feet bls)
Artisan Village 4	177379	393720075382401		39 37 20	75 38 24	Artesian Water Co.	117-142
Artisan Village 2	43963	393714075374201	Dc33-08	39 37 18.02	75 37 39.34	Artesian Water Co.	125-225
Artisan Village 3	104641	393748075380901	Dc32-22	39 37 48	75 38 09	Artesian Water Co.	131-180
Artisan Village 1	43962	393741075371501	Dc33-07	39 37 41	75 37 15	Artesian Water Co.	155-215
P-1A	53065	393327075385801	Ec22-17	39 33 27.08	75 39 0.19	Motiva	237-280
R-15	10066	393522075381301	Dc52-24	39 35 20.42	75 38 16.77	Motiva	302-333
P-5B	72826		Dc41-57	39 36 19.39	75 39 9.47	Motiva	343-515
P-4A	54935	393542075394901	Dc51-15	39 35 38	75 39 26	Motiva	415-546
P-16A	91371	393456075373201	Ec13-21	39 34 49.79	75 37 25.05	Motiva	513-564
P-3A	49005	393456075401001	Eb15-16	39 34 53	75 39 48	Motiva	516-550
P-9	10058	393417075381001	Ec12-20	39 34 16.88	75 38 10.44	Motiva	525-558
P-10A	53066	393424075361801	Ec14-08	39 34 24.94	75 36 18.73	Motiva	630-714
P-6A	10057	393616075381601	Dc42-06	39 36 16.41	75 38 16.74	Motiva	668-698
WELL 4	36504	393425075351901		39 34 25	75 35 19	Delaware City	692-722
WELL 5	37981	393445075351001	Ec15-28	39 34 20.70	75 35 45.75	Delaware City	707-737

- What are the potential influences of industrial production wells on movement of water and contaminants at Standard Chlorine?


AV3
AV1
AV4
AV2
Production Wells
0
0.5
1
2 Miles
P5B
P6A
P4A
P15
P3A
P16A
P10A
WELL4
P9
WELL5
P1A


Potomac Aquifer Recovery - Daily Water Level Elevations
PW-11
PW-3
PW-11D
Altitude of Water Level (feet, NGVD 1929)
PW-11D Altitude of Water Level (feet, NGVD 1929)
5
4
3
2
1
0
-1
-2
-3
-12
-18
-24
-30
-36
-42
-48
-54
-60
9/24/09
10/19/09
11/13/09
12/8/09
1/2/10
1/27/10
2/21/10
3/18/10
4/12/10
Short-term water level fluctuation in response to stage changes on Red Lion Creek
Refinery Production Well R-15 Turned OFF

OR-6A Aquifer Tests

	Tybouts Corner Landfill	Standard Chlorine of Delaware, Inc.	Standard Chlorine of Delaware, Inc.
Date Test Began	March 19, 1985	October 1, 1990	August 28, 2010
Pump Rate	402 gpm	410 gpm	440 gpm
Duration	5.1 days (~122 hours)	74 hours	72 hours
Wells Monitored	12 wells in Potomac	37 wells total 34 in Columbia 3 in Potomac	Continuous: ~12 Columbia ~20 Potomac Full network discrete levels
Closest & Farthest Aquifer Well	TY-119A @ 2400 feet & TY-206 @ 4100 feet	MW-12 @ 2340 feet & MW-11 @ 2570 feet	PW-5D @ 2000 feet PW-03 @ 3500 feet MW-11 & MW-12
Summary Observations	Most wells showed drawdown effects in both sands; TY-119A showed 3.30 feet of drawdown and TY-206 showed 0.25 feet of drawdown	Drawdowns of: 7 feet @ MW-11 and 4 feet @ MW-12	Can 1990 drawdowns be replicated? Yes. Does the “bathtub” leak? No. Is there evidence of induced recharge from Red Lion Creek? Yes.
Test By	NUS Corporation	Roy F. Weston, Inc.	U.S. Geological Survey