Degradation of Explosives at Cornhusker Army Ammunition Plant using a Zero-Valent Iron Permeable Reactive Barrier

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Outline

- Background
- PRB Construction
- Groundwater Monitoring Results
- Conclusions

Background

- TNT and RDX impacted groundwater at many DoD and related contractor site
- Common practice involves P&T with GAC or UV and significant O&M
- Lab studies show ZVI promotes rapid degradation of TNT & RDX
- Degradation products of ZVI are more amenable to biodegradation

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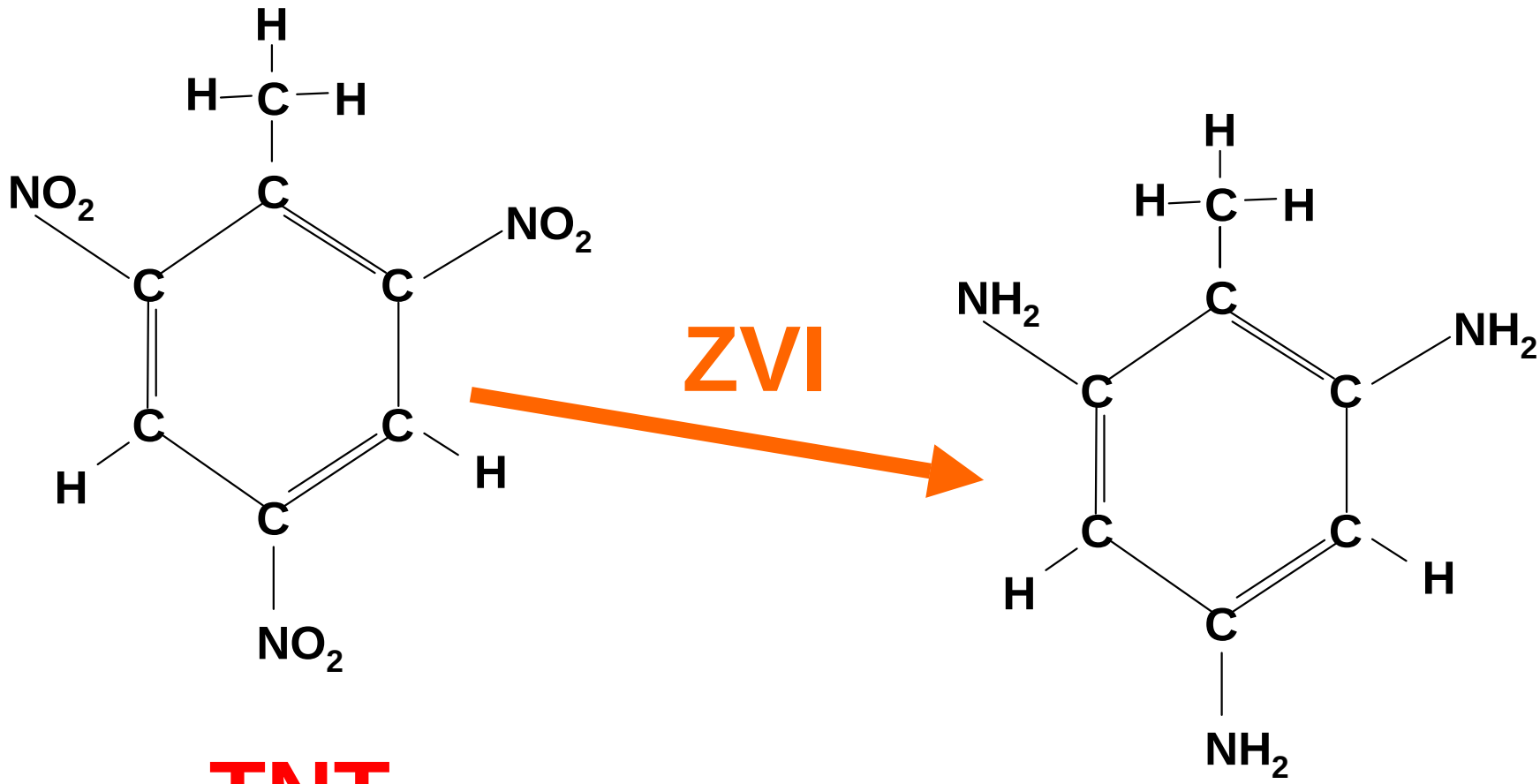
TNT Degradation with ZVI



TNT

trinitrotoluene

TAT

triaminotoluene

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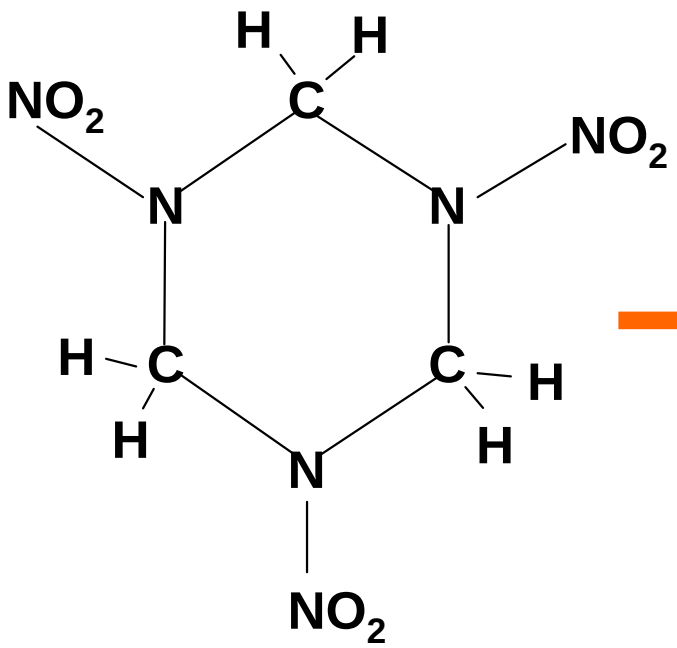
RDX Degradation with ZVI



ZVI

Various less toxic degradation products

RDX

hexahydro-1,3,5-trinitro-1,3,5-triazine

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ZVI PRB Construction

- Cornhusker Army Ammunitions Plant (CHAAP), Grand Island, Nebraska
- Former manufacturing of munitions
- Significant plume of TNT and RDX
- ZVI PRB install in Nov 2003
- 50 ft long, 17 ft saturated thickness

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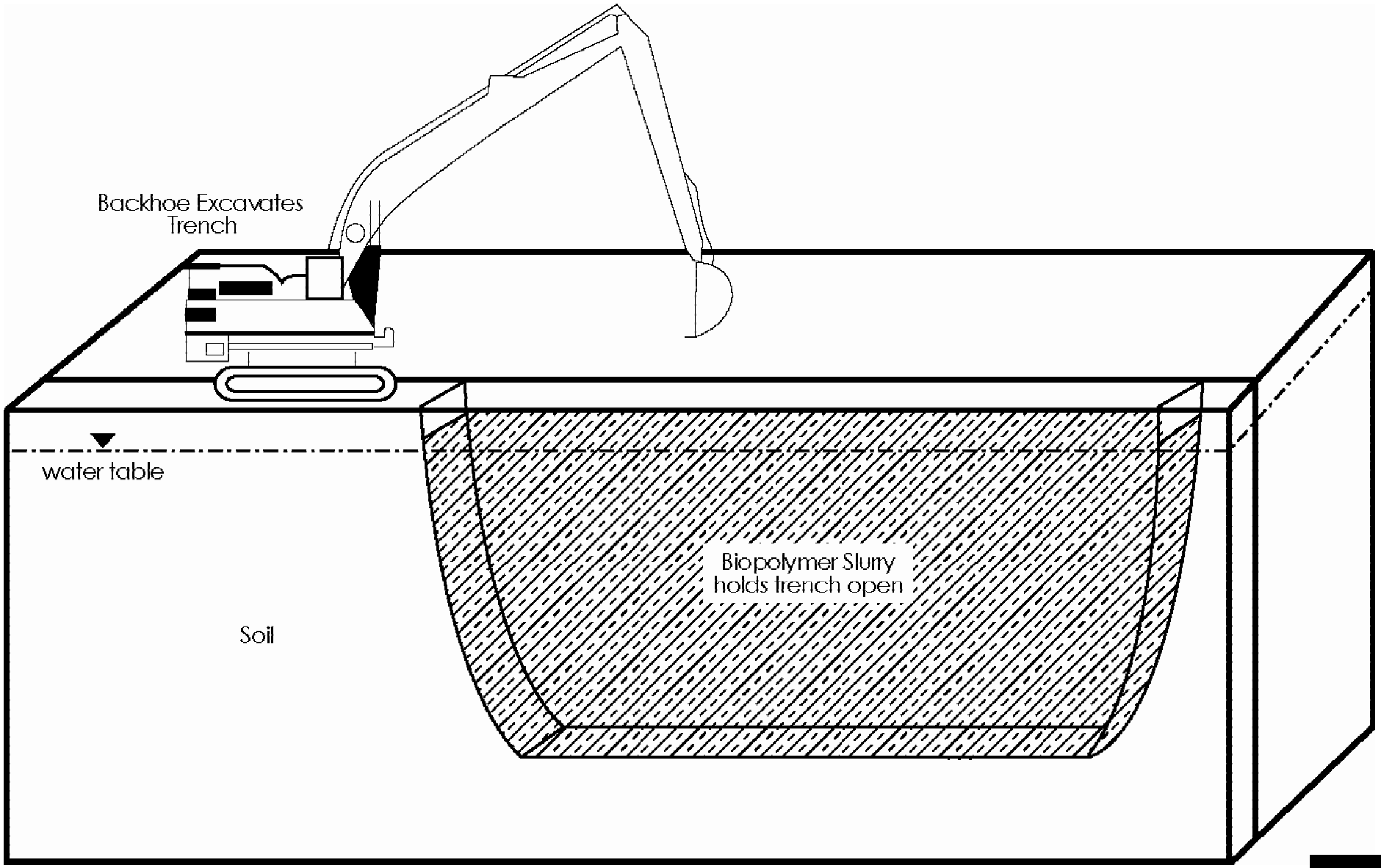
PRB - Excavation



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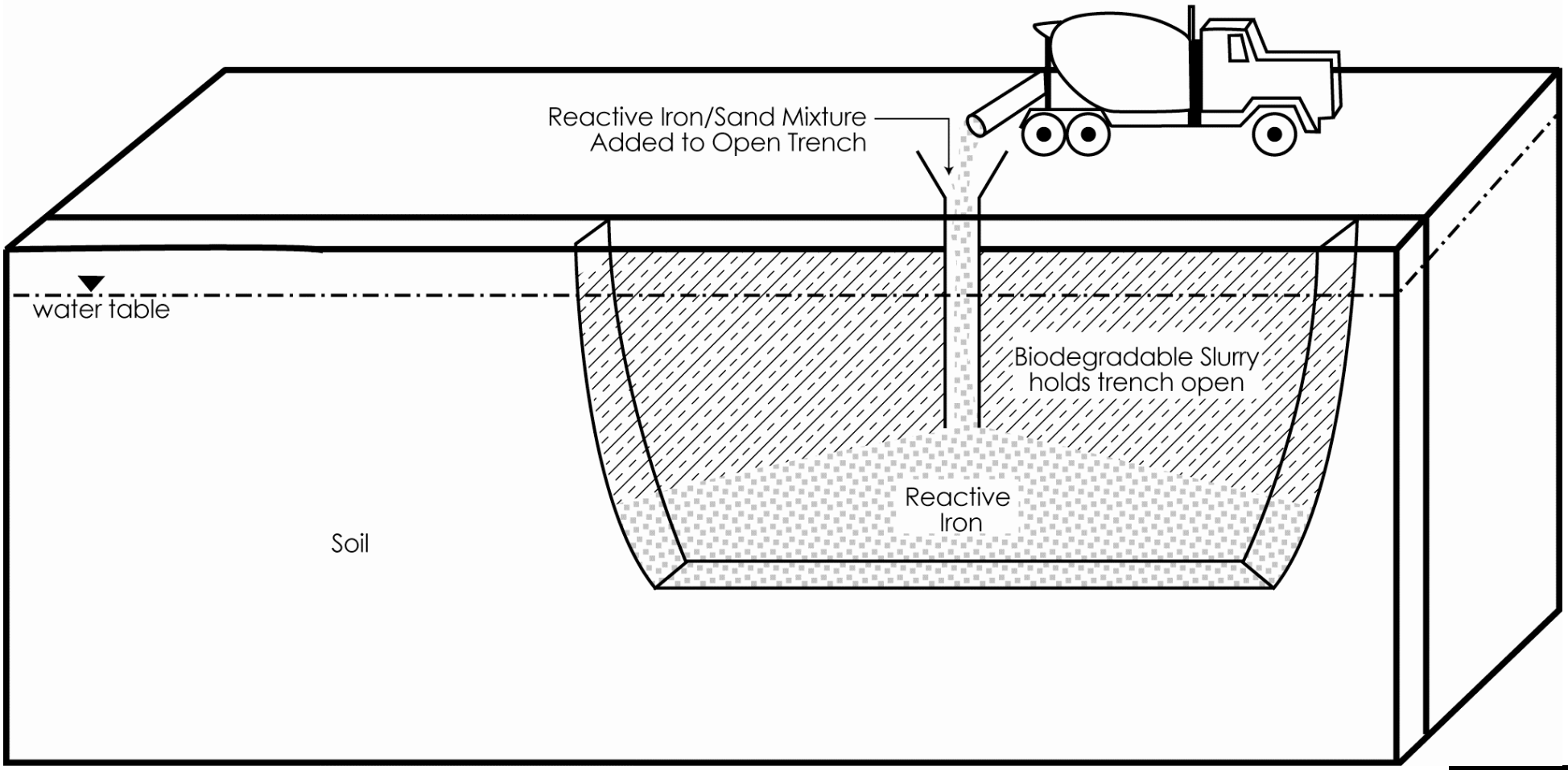
PRB - Backfilling

Backfill



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Site Preparation

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Trench Excavation

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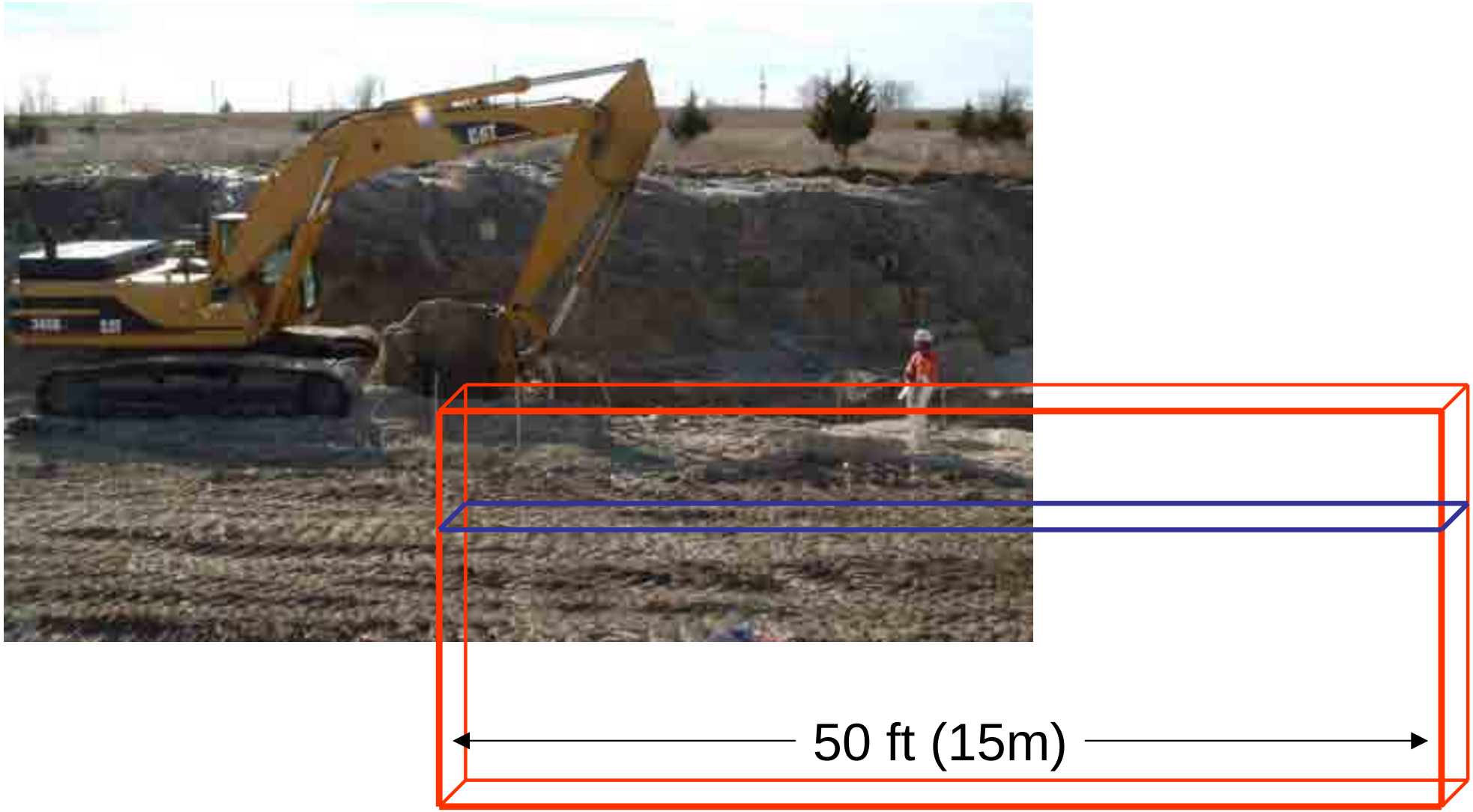
Cross Section of Excavation



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Excavation Complete

Positioning of Tremie Pipe

Development Wells In Place

Loading Iron Into Mixing Truck

Backfilling Iron in Trench

Backfilling Iron in Trench

Backfilling Complete

Geotextile placed in the top of trench prior to clay addition

Backfilling above the PRB

Backfilling above the PRB. The white pipes are 3-inch access tubes for coring

Monitoring Well Network

View looking SE (cross-gradient) along the line of the PRB. Dashed red line is the approximate footprint of the PRB.

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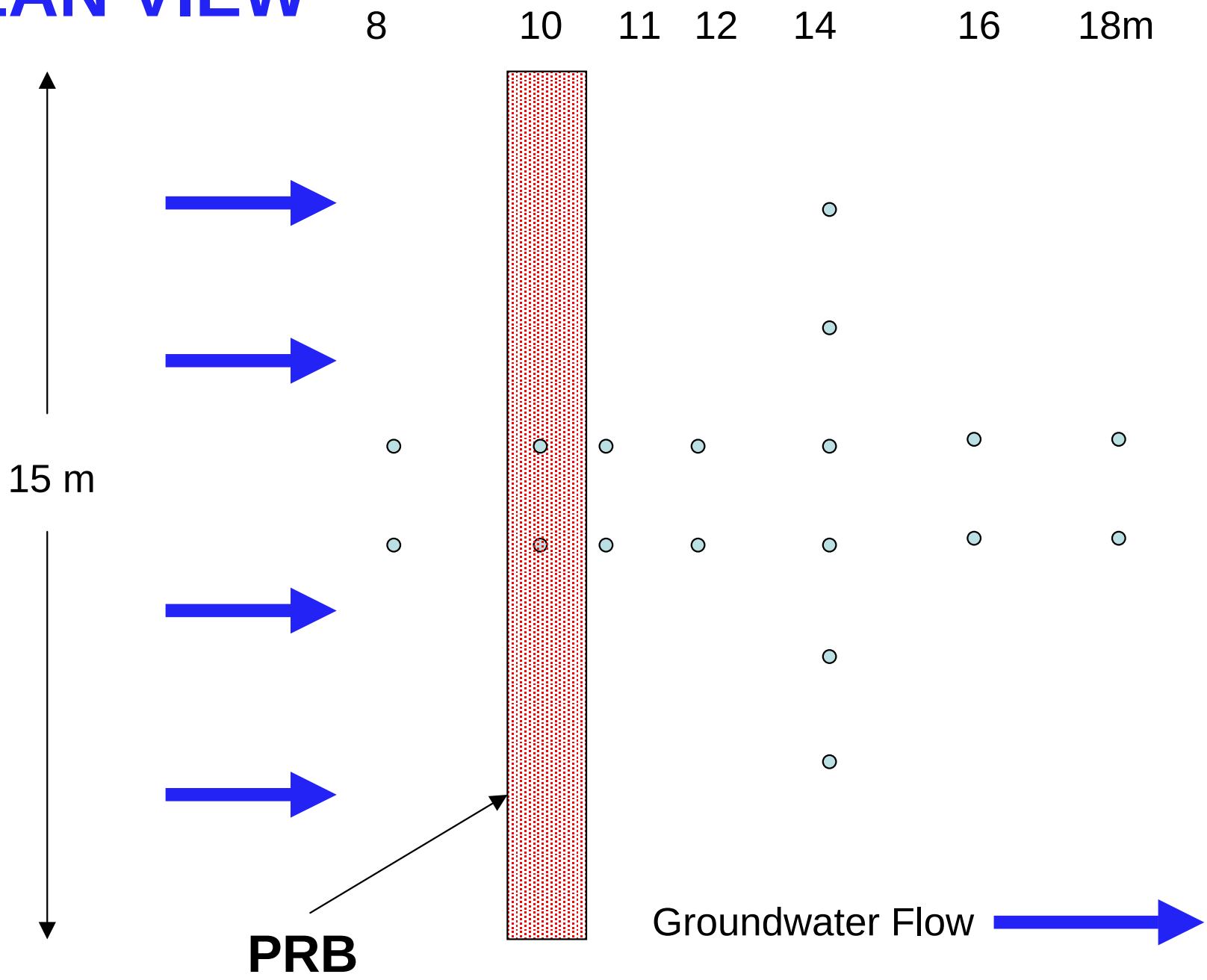
PLAN VIEW



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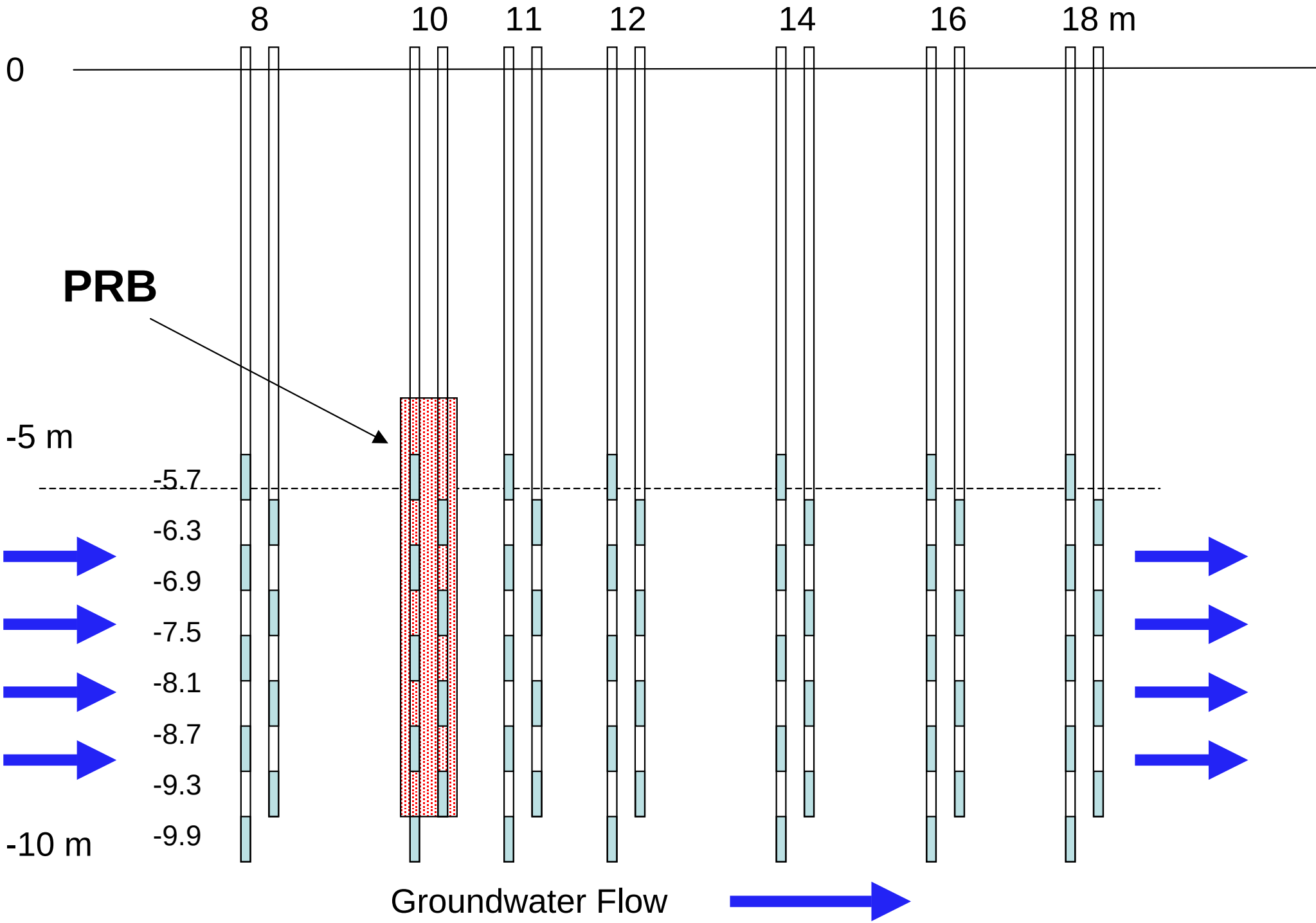
SECTION VIEW



TNT

December 2003

TNT (ug/L) DEPTH (M)	DISTANCE (M) 8	10	11	12	14
-5.7	21	0	0	46	63
-6.3	199	0	0	145	149
-6.9	119	0	0	0	15
-7.5	108	0	0	0	27
-8.1	84	0	0	0	1
-8.7	18	0	0	0	1
-9.3	29	0	0	2	2
-9.9	39	0	0	0	33

February 2004

	8	10	11	12	14
-5.7	165	0	0	0	18
-6.3	113	0	0	0	4
-6.9	102	0	0	0	0
-7.5	106	0	0	0	0
-8.1	23	0	0	0	0
-8.7	49	0	0	0	0
-9.3	28	0	0	0	0
-9.9	33	0	0	0	17

Yellow indicates concentrations below background

March 2004

TNT (ug/L)

	8	10	11	12	14	16	18
-5.7	136	0	0	0	0	0	0
-6.3	120	0	0	0	0	0	0
-6.9	91	0	0	0	0	0	0
-7.5	88	0	0	0	0	0	0
-8.1	25	0	0	0	0	0	0
-8.7	51	0	0	0	1	0	0
-9.3	20	0	0	0	0	0	0
-9.9	37	0	0	0	11	0	0

2ADNT

December 2003

2ADNT (ug/L)	DISTANCE (M)				
DEPTH (M)	8	10	11	12	14
-5.7	31	0	0	17	18
-6.3	29	0	0	25	25
-6.9	34	0	0	0	15
-7.5	51	0	0	0	62
-8.1	76	0	0	0	40
-8.7	56	0	0	0	0
-9.3	44	0	0	0	0
-9.9	17	0	0	0	14

February 2004

	8	10	11	12	14
-5.7	31	0	0	0	20
-6.3	45	0	0	0	11
-6.9	71	0	0	0	0
-7.5	54	0	0	0	0
-8.1	84	0	0	0	0
-8.7	61	0	0	0	0
-9.3	69	0	0	0	0
-9.9	20	0	0	0	17

Yellow indicates concentrations below background

March 2004

	8	10	11	12	14	16	18
-5.7	18	0	0	0	0	0	0
-6.3	28	0	0	0	0	0	0
-6.9	46	0	0	0	0	0	0
-7.5	33	0	0	0	0	0	0
-8.1	81	0	0	0	0	0	0
-8.7	53	0	0	0	9	0	0
-9.3	31	0	0	0	0	0	0
-9.9	11	0	0	0	18	0	0

TNT - August 2004

Longitudinal Distance (m)

TNT (ug/L)	8	10	11	12	14	16	18
Elevation (m bgs) -5.7	112	0	0	0	0	0	0
-6.3	109	0	0	0	0	0	0
-6.9	58	0	0	0	0	0	0
-7.5	97	0	0	0	0	0	0
-8.1	12	0	0	0	0	0	0
-8.7	65	0	0	0	0	0	0
-9.3	27	0	0	0	0	0	0
-9.9	20	0	0	0	12	7	4

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Sulfate - August 2004

Longitudinal Distance (m)

Sulfate (mg/L) Elevation (m bgs)	8	10	11	12	14	16	18
-5.7	170	0	2	3	1	1	1
-6.3	160	1	2	4	3	5	4
-6.9	217	25	0	3	2	23	17
-7.5	200	1	0	2	9	6	32
-8.1	258	9	2	38	36	206	182
-8.7	220	5	4	40	242	287	273
-9.3	328	46	44	246	356	356	386
-9.9	380	215	227	176	374	380	295

SECTION VIEW

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Conductance - August 2004

Longitudinal Distance (m)

Elevation (m bgs)	cond	8	10	11	12	14	16	18
-5.7	786	350	358	426	319	345	505	
-6.3	830	371	373	247	280	1205	308	
-6.9	840	370	420	286	250	247	261	
-7.5	850	379	377	390	1259	1202	841	
-8.1	862	357	365	587	606	842	887	
-8.7	872	376	337	796	885	990	1008	
-9.3	1017	436	622	968	1074	1094	1077	
-9.9	1117	1016	1034	1076	1076	1270	1088	

SECTION VIEW

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Alkalinity - August 2004

alk (mg/L)		Longitudinal Distance (m)					
Elevation (m bgs)	8	10	11	12	14	16	18
-5.7	270	125	135	170	140	165	325
-6.3	270	110	115	80	90	125	130
-6.9	305	150	130	105	140	85	150
-7.5	270	150	155	160	690	675	535
-8.1	265	125	115	170	210	485	400
-8.7	260	105	130	265	260	350	400
-9.3	320	115	260	320	350	345	385
-9.9	270	290	245	295	370	405	385

SECTION VIEW

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ORP - August 2004

Longitudinal Distance (m)

Eh (mv)		8	10	11	12	14	16	18
Elevation (m bgs)								
-5.7	-55		-360	-319	-191	-172	-138	-124
-6.3	-60		-339	-302	-150	-123	-136	-108
-6.9	-68		-359	-301	-252	-238	-154	-148
-7.5	-67		-318	-289	-110	-76	-102	-88
-8.1	-66		-404	-323	-87	-91	-91	-97
-8.7	-68		-338	-296	-109	-97	-118	-92
-9.3	-57		-345	-150	-104	-98	-84	-97
-9.9	-68		-146	-99	-105	-88	-91	-88

SECTION VIEW

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Ferrous Iron - August 2004

Longitudinal Distance (m)

Fe2+ (mg/L)	8	10	11	12	14	16	18
Elevation (m bgs) -5.7	0	0	0	0.78	0.45	0.81	0.97
-6.3	0	0	0	0.4	0.12	0.32	0.25
-6.9	0	0	0	0	0.05	0.22	0.03
-7.5	0	0	0.06	1	0.86	0.85	0.35
-8.1	0.06	0	0	0.9	0.28	1.03	0.29
-8.7	0.03	0	0.03	1.13	1.1	0.71	0.49
-9.3	0.13	0	0.02	0.1	0.26	0.97	0.85
-9.9	0	0.52	0.1	0.18	0.32	0.41	0.14

SECTION VIEW

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pH - August 2004

Longitudinal Distance (m)

pH	8	10	11	12	14	16	18
Elevation (m bgs)							
-5.7	7.1	9.7	9.8	7.9	7.8	7.2	7.2
-6.3	7.1	9.7	9.7	7.4	7.1	6.8	7
-6.9	7.1	9.7	9.6	8.2	8	7.2	7.4
-7.5	7.1	9.3	9.6	7.1	6.7	6.4	6.7
-8.1	7.1	9.5	9.3	6.9	7.1	7	6.8
-8.7	7.1	8.9	9	7.2	7	7	7.1
-9.3	7.1	9.4	8.3	7.2	7.1	7.4	7.1
-9.9	7.1	7.6	7.3	7.2	7.1	7.2	7.1

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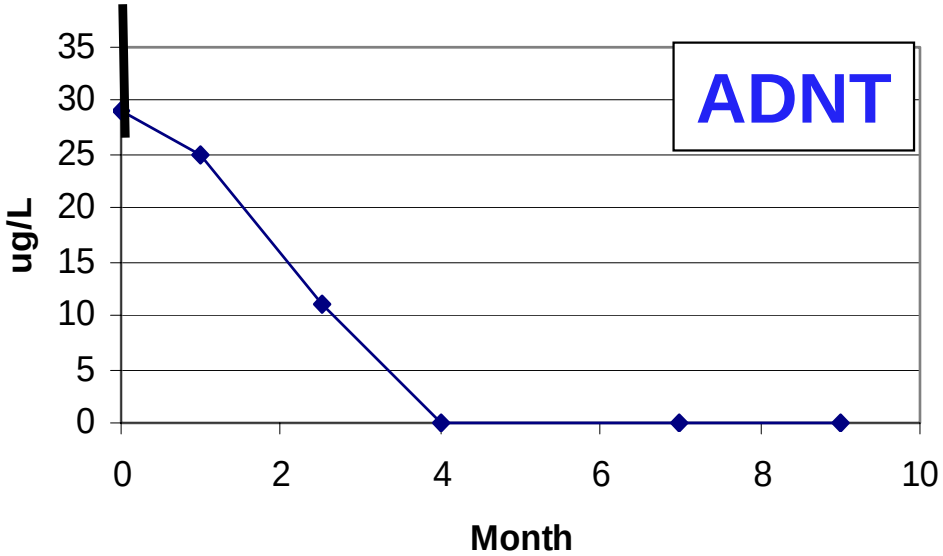
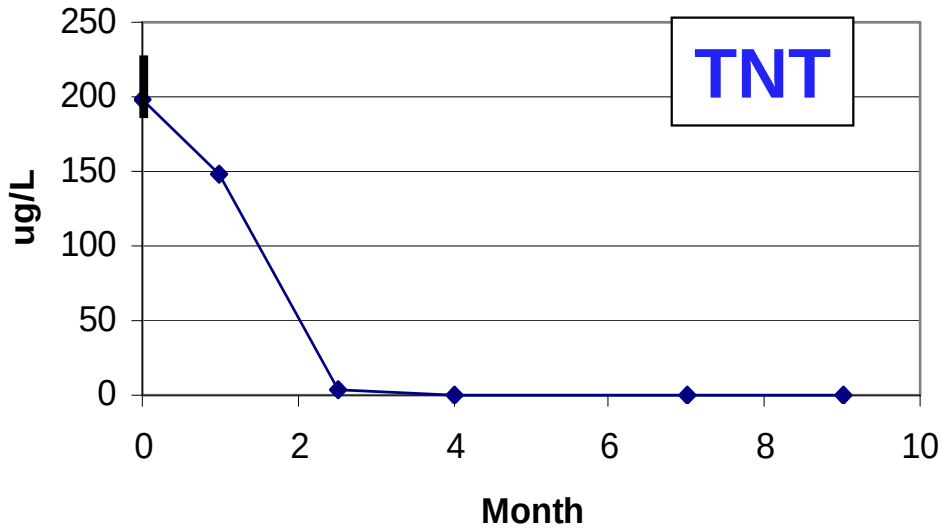
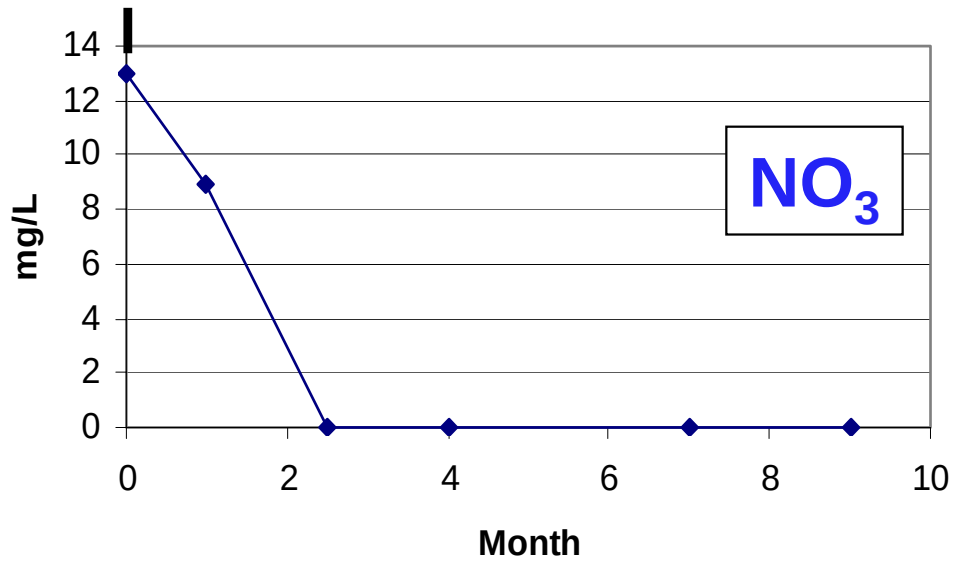
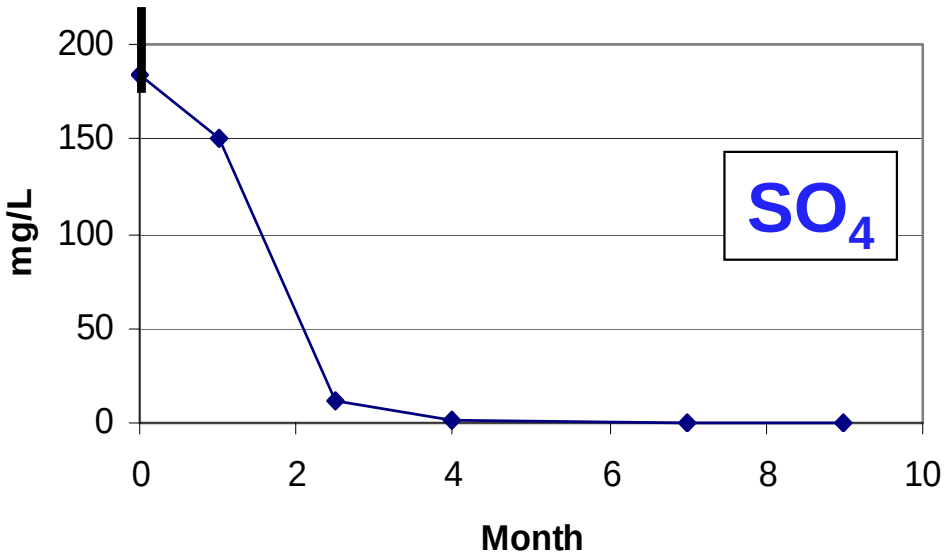
Time Series Data - 4 m downgradient, 6.3 m bgs



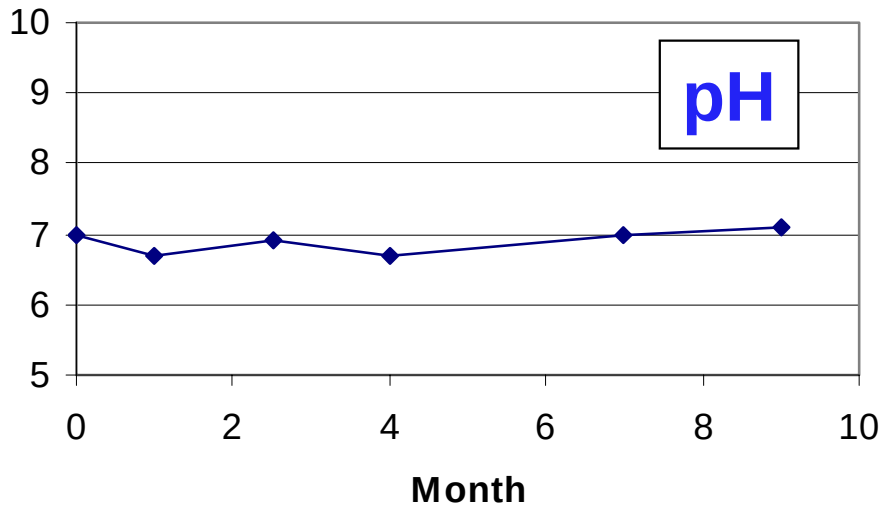


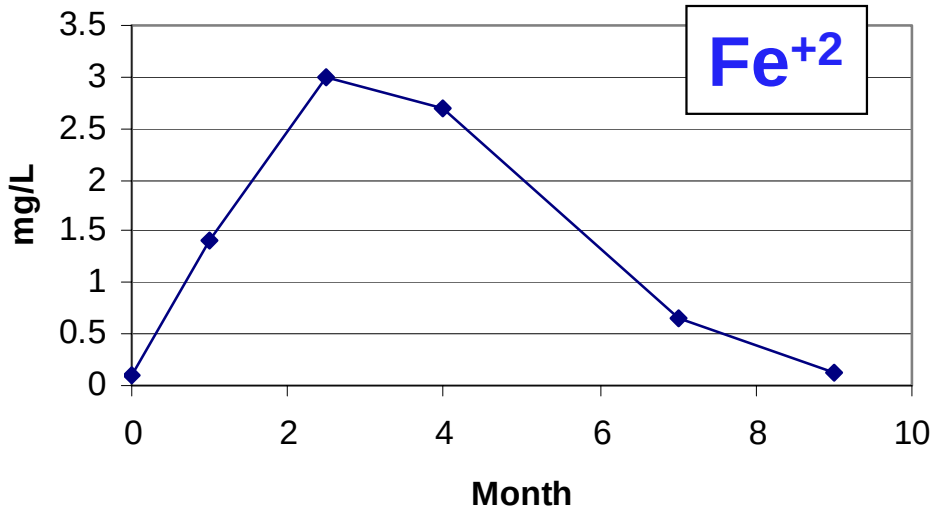


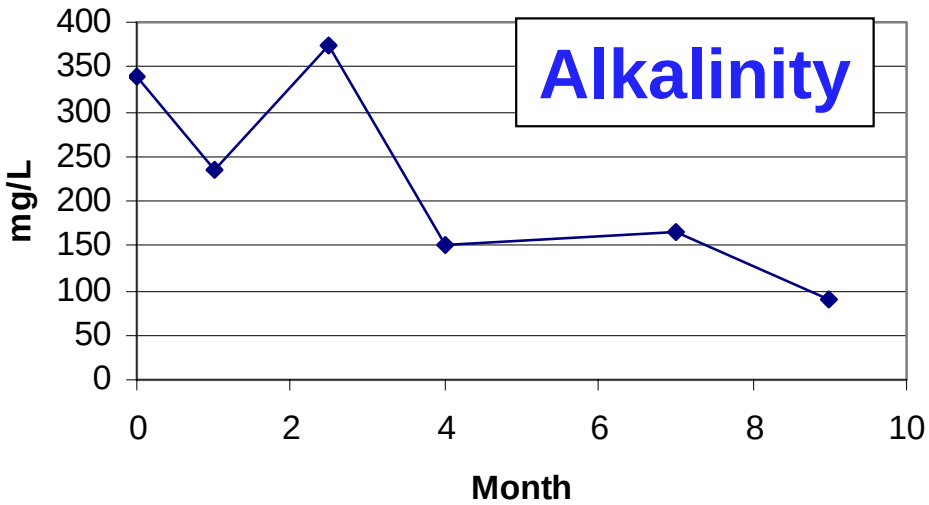


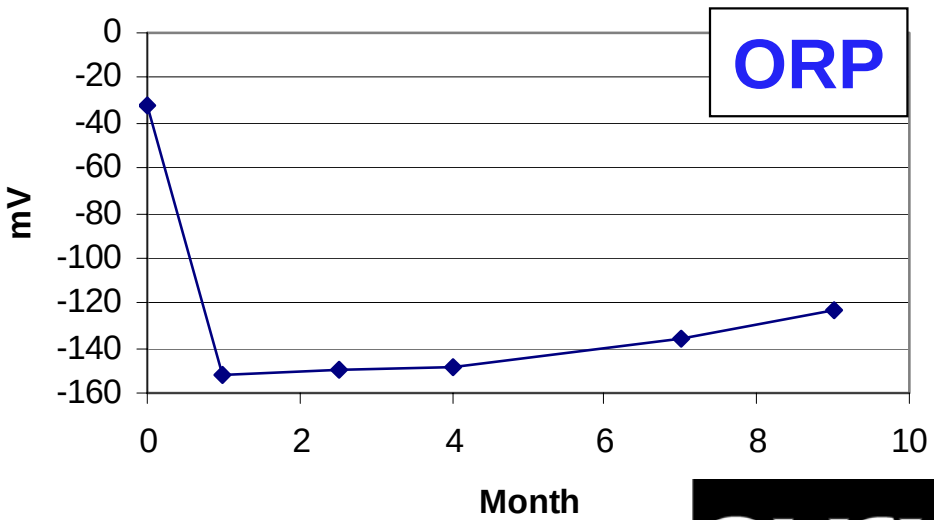
Month 0 data estimated from up-gradient and pre-installation data

Time Series Data - 4 m downgradient, 6.3 m bgs









Month 0 data estimated from up-gradient and pre-installation data

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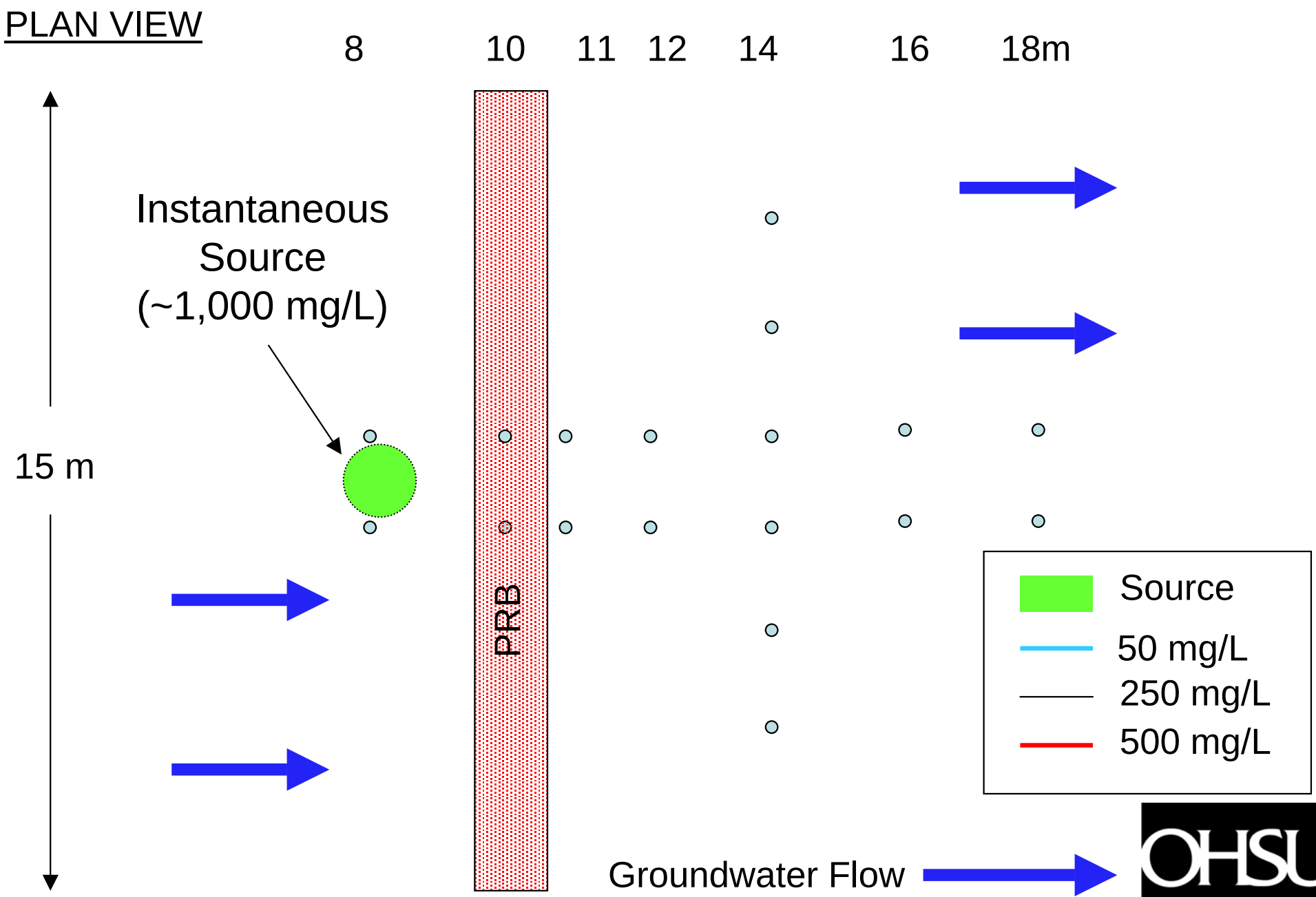
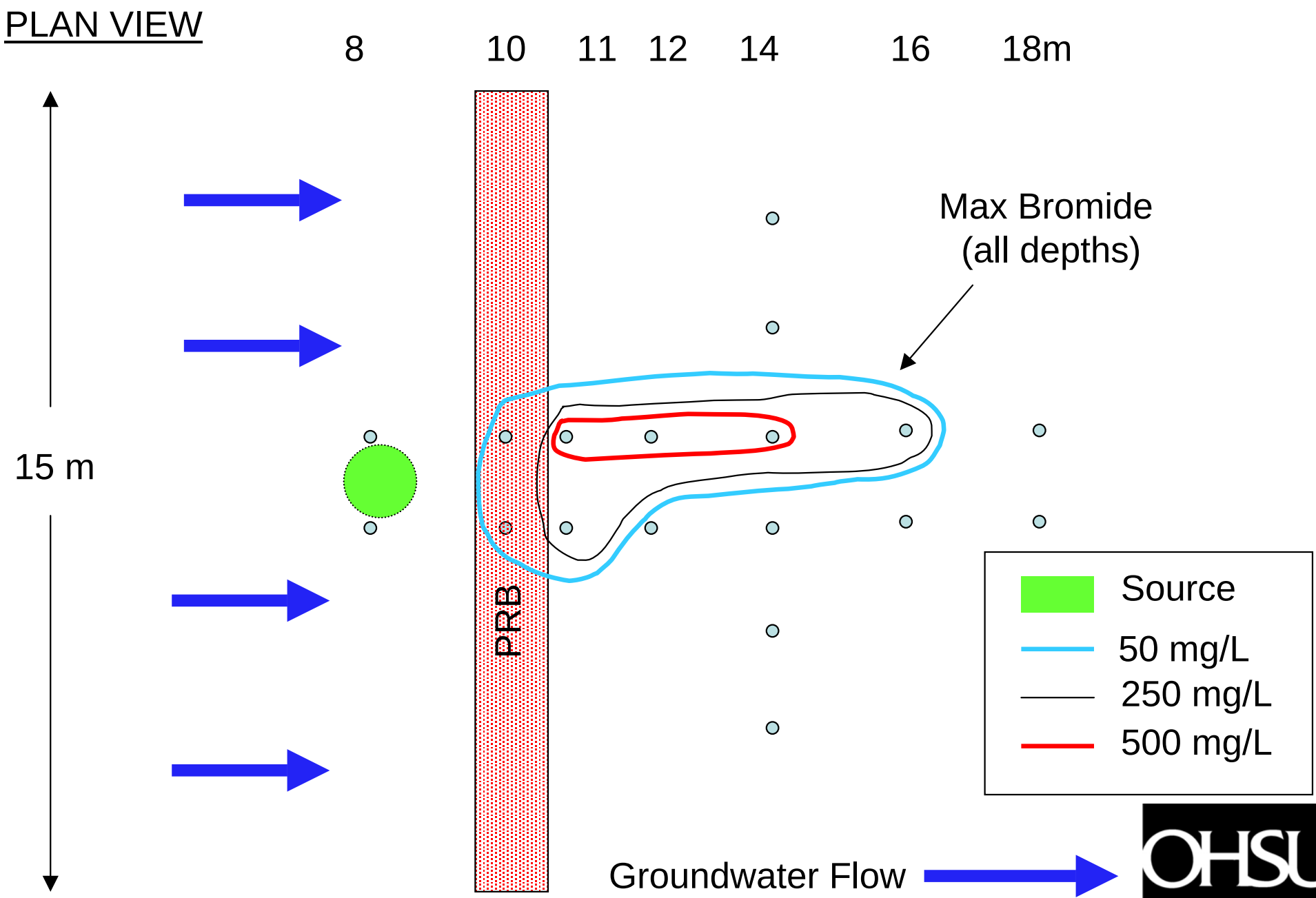
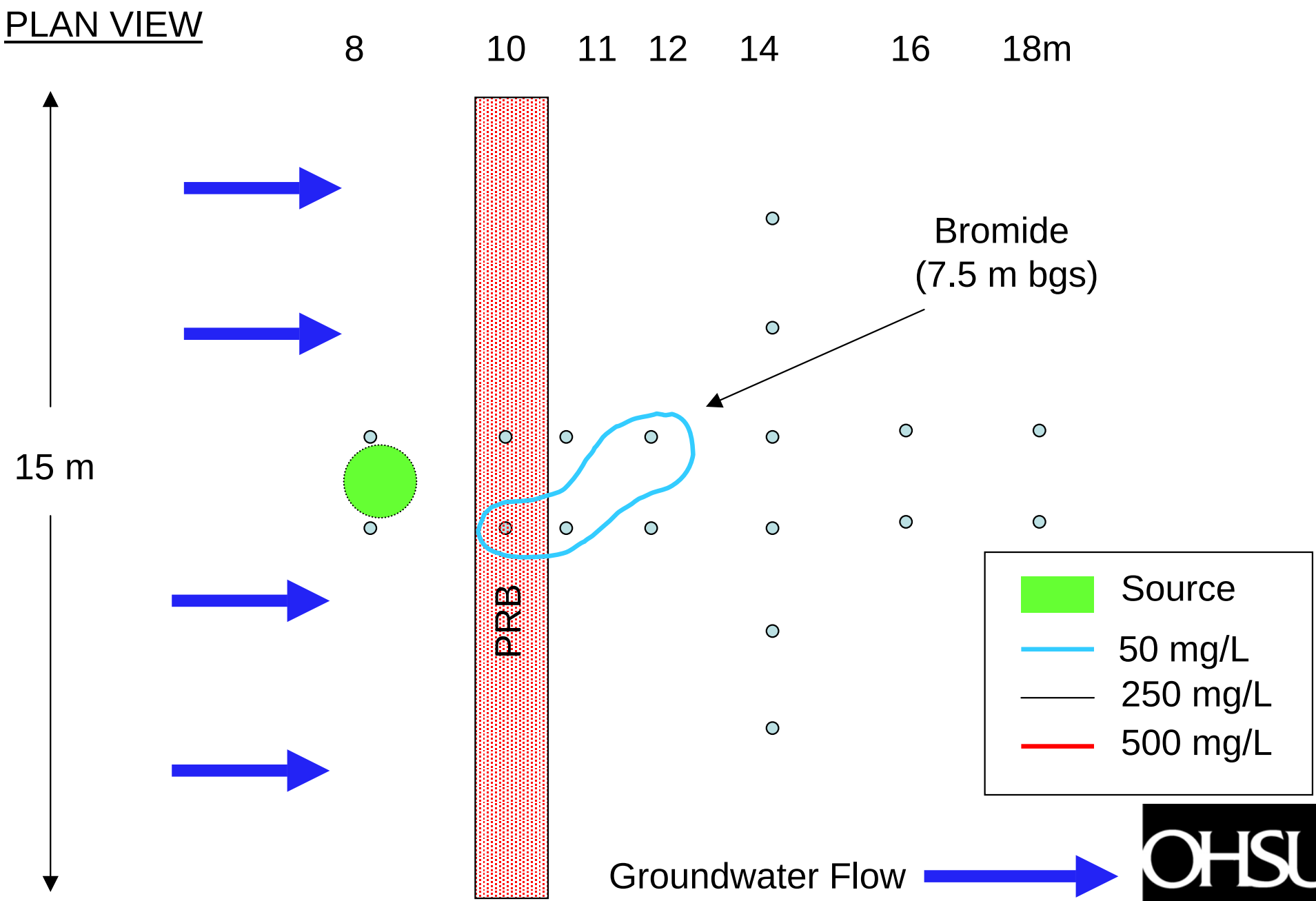
Bromide Tracer Test



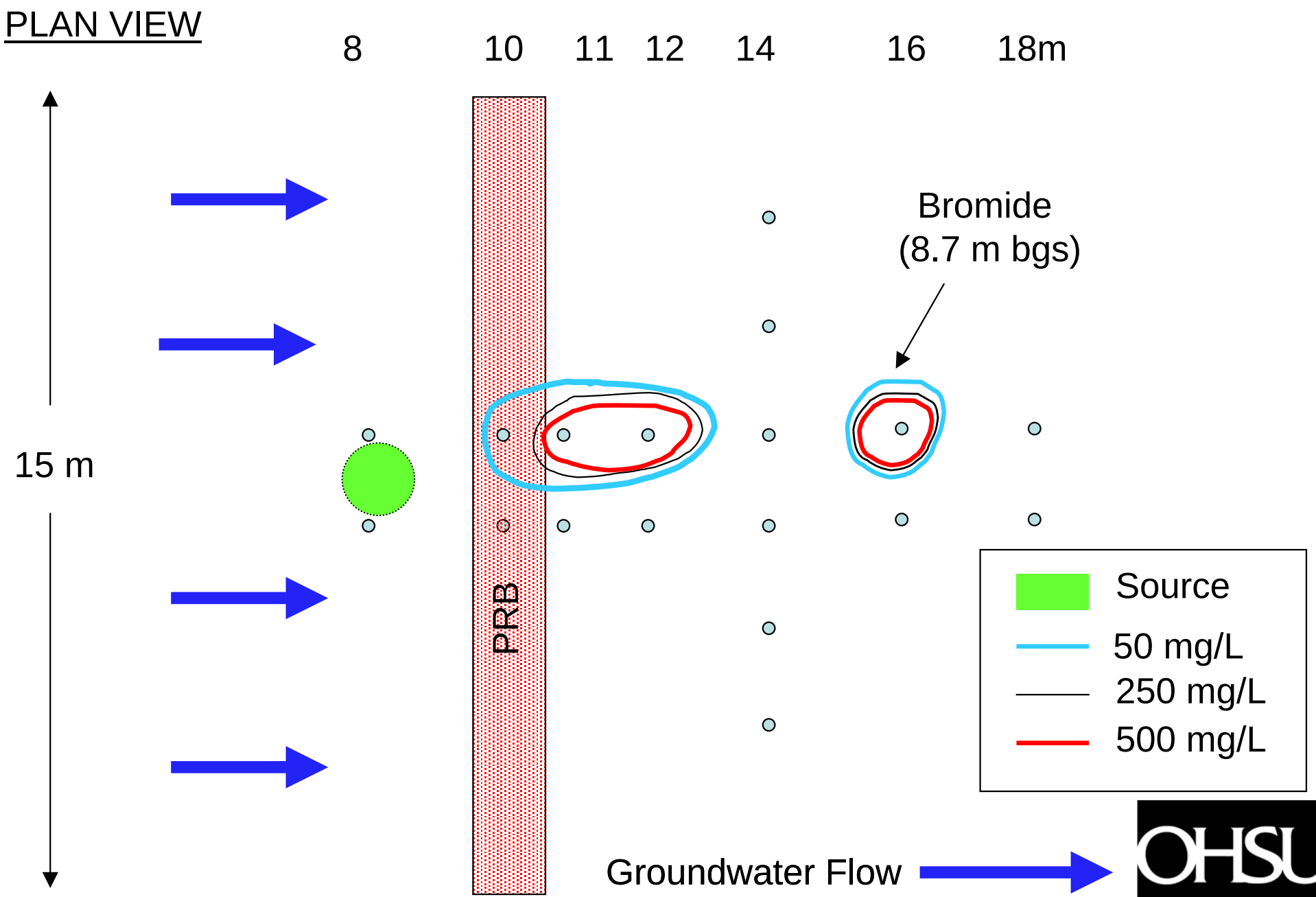
Bromide Tracer Test – Day 44



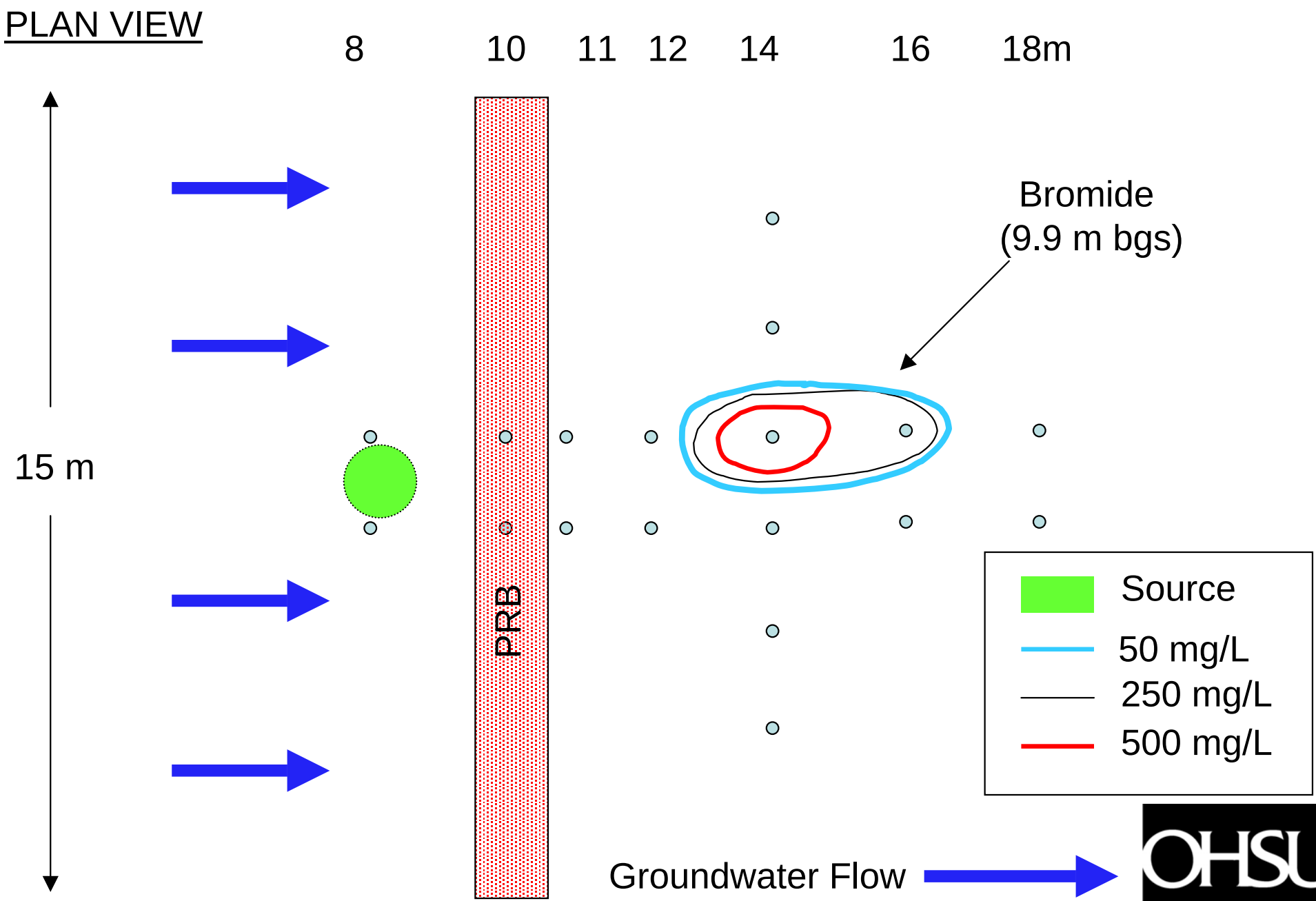
Bromide Tracer Test – Day 44



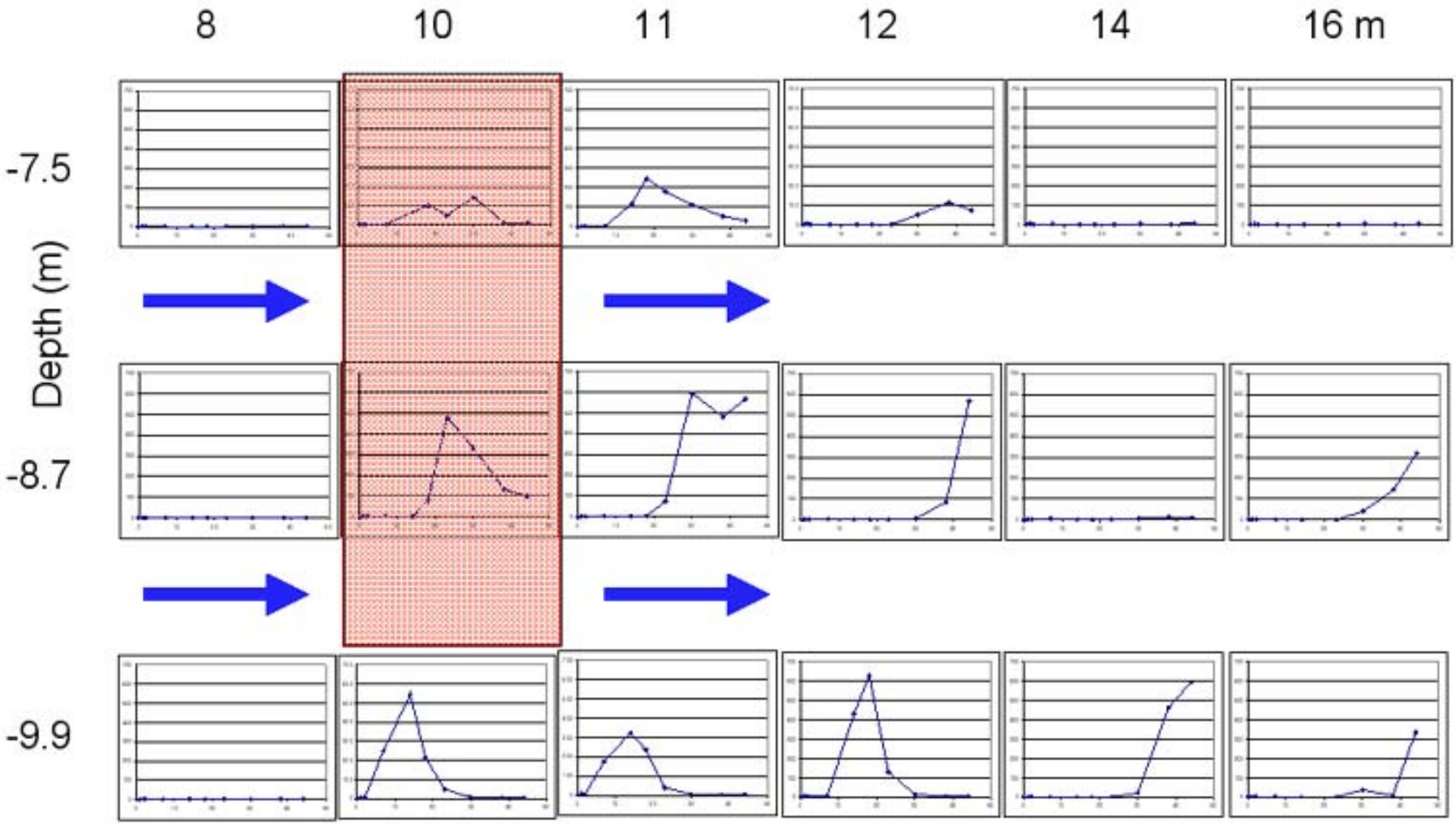
Bromide Tracer Test – Day 44



Bromide Tracer Test – Day 44



Bromide Tracer Test - Cross-Section



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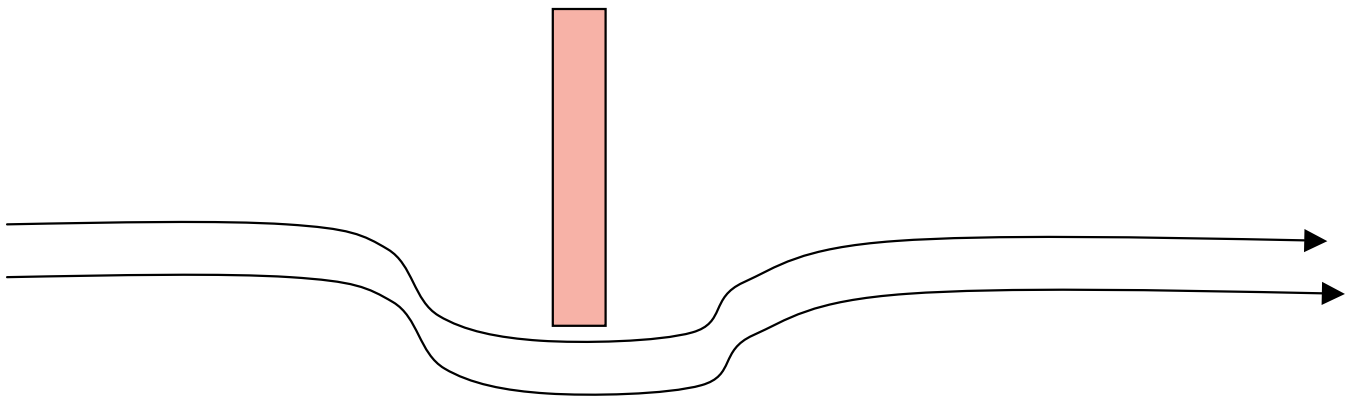
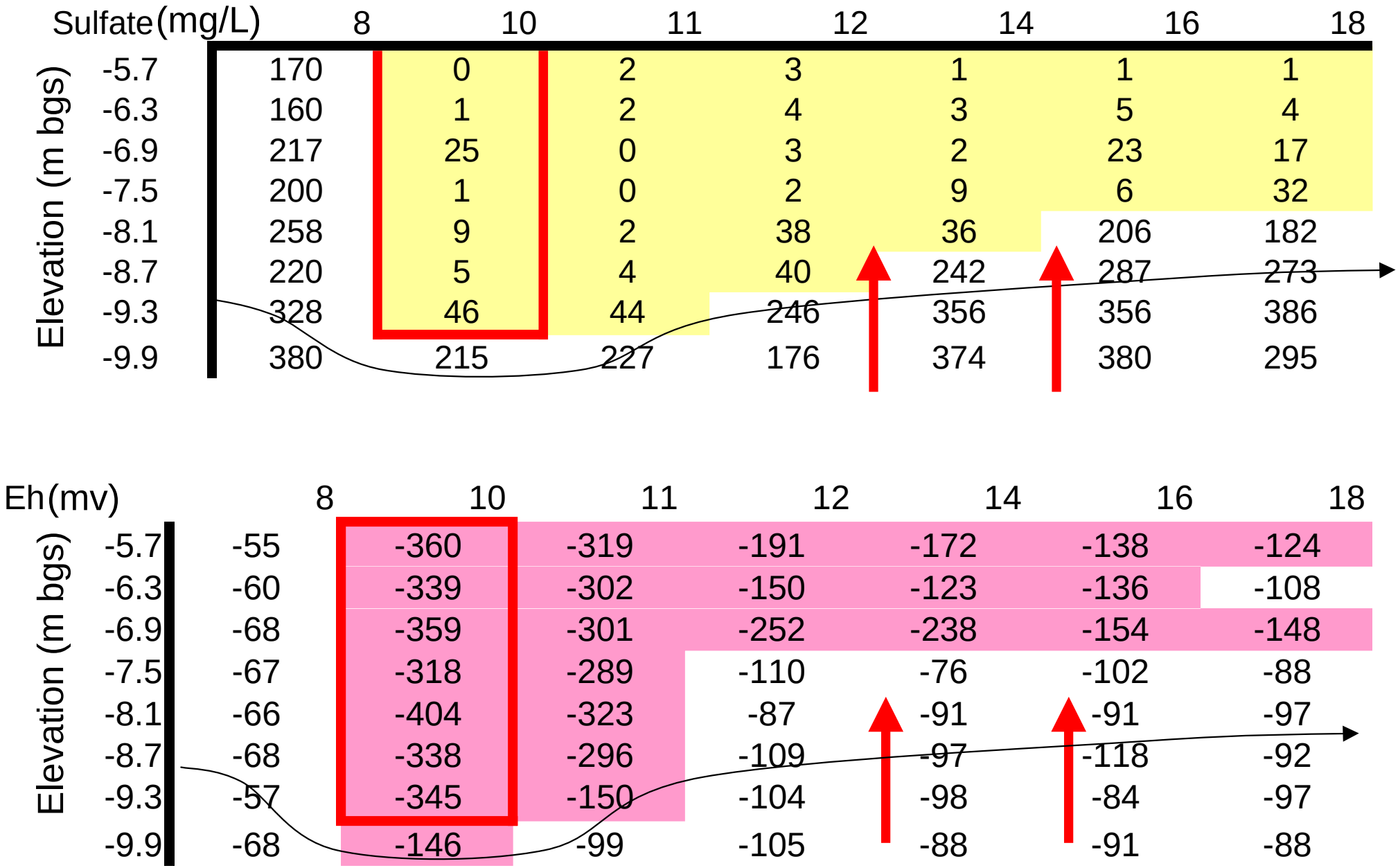
Groundwater Flow Evaluation

There is some evidence for some degree of underflow beneath the wall:

1. Geochemical conditions downgradient are shifting
2. Tracer data may suggest upward flow downgradient





The zone of higher sulfate and Eh downgradient of the wall are moving up over time, indicating a possible reduction in hydraulic conductivity of the wall

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Conclusions

1. After 9 months, PRB continues to be effective for TNT

2. Tracer test data from 9 months after installation indicate that water is still flowing through the PRB

3. Some evidence of porosity loss in PRB
   (evidence from geochemical and tracer data - hydraulic head differences are still too small to measure)

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