# RemTech 2011

# *IN-SITU* BIOREMEDIATION OF CHLORINATED SOLVENTS

## - A CASE STUDY -

**Presented by: René Filion, Eng.**

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# PRESENTATION OVERVIEW

- Site history
- Environmental Site Assessment process
- Soil and groundwater remedial actions
- Remediation results
- Current status
- Q&A period

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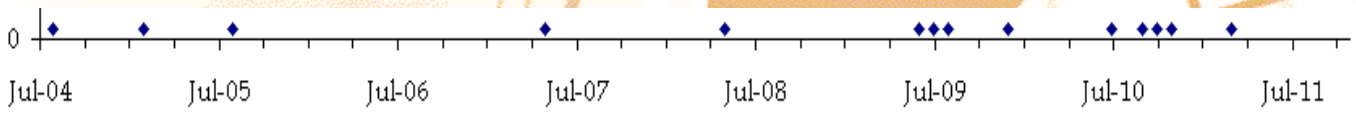
# SITE HISTORY

- Industrial Park located within Québec City urban area
- Site development in 1930s
- Electric/electronic device manufacturing 1947 through 2004
- Site closure notice December 31, 2004

# ENVIRONMENTAL SITE ASSESSMENTS

## Timeline

- Phase I – August 2004
- Phase II Site characterization - 2005
- Screening Level Assessment (SLA) on Building components/materials
- Supplemental Phase II Site characterization - 2007
- Remedial Action Plan (RAP) - May 2008
- Pre-implementation Delineation - Summer 2009
- RAP Addendum - December 2009
- RAP Approval - July 2010
- Excavations – September through November 2010
- Amendment injections - March 2011

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# OBSERVATIONS – Soil impacts

**Courtyard**

(TPH, metals, PCBs – surface, TPH and PCBs to 2.4 m BGS)

RAP: Excavation

**Plating Room**

(metals)

RAP: Risk Assessment

**Degreaser Area**

(TCE)

RAP: Excavation of vadose zone & *in-situ* bio-remediation for saturated zone

**Al-Ni Magnet Mfg Area**

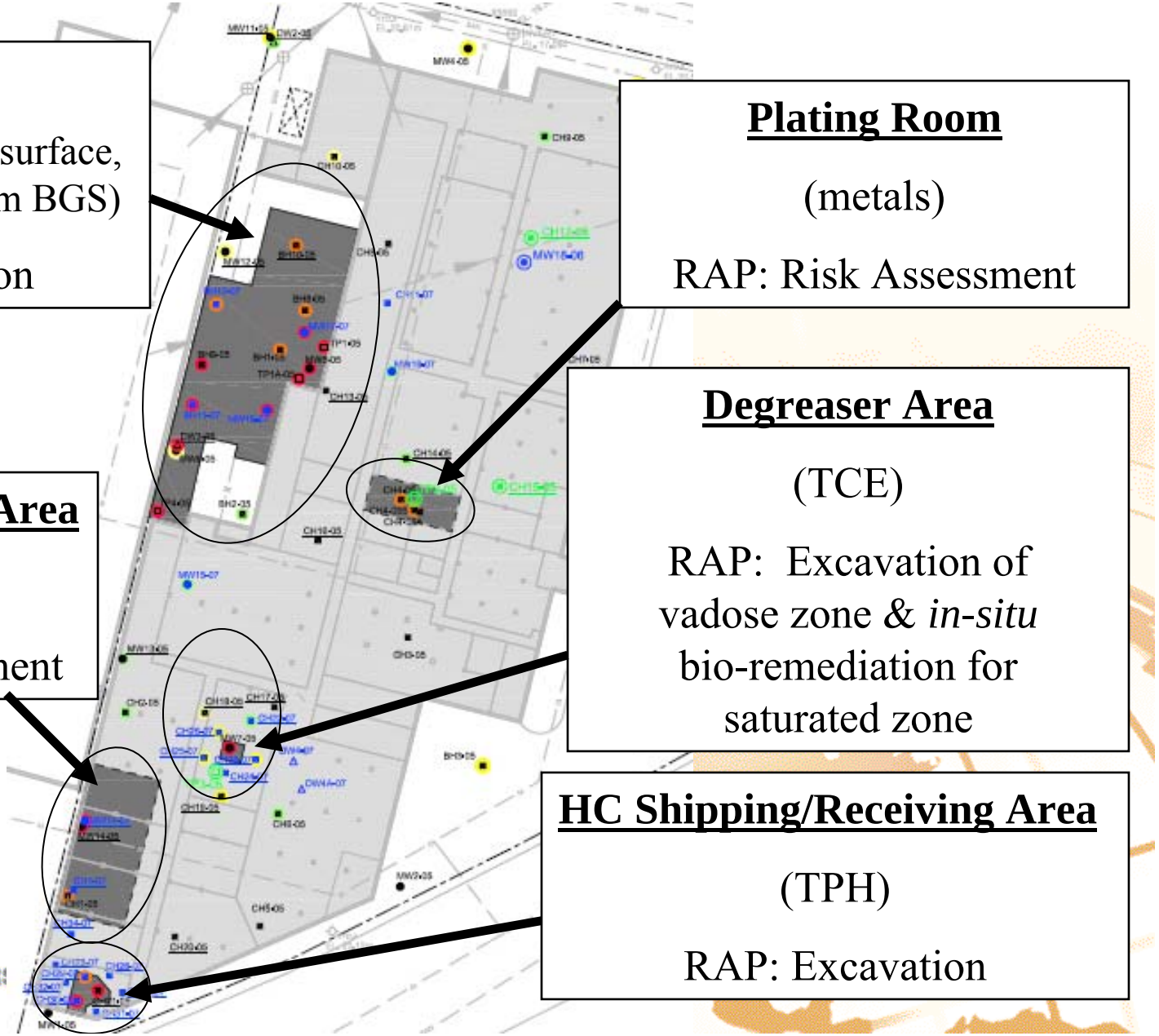
(metals)

RAP: Risk Assessment

**HC Shipping/Receiving Area**

(TPH)

RAP: Excavation



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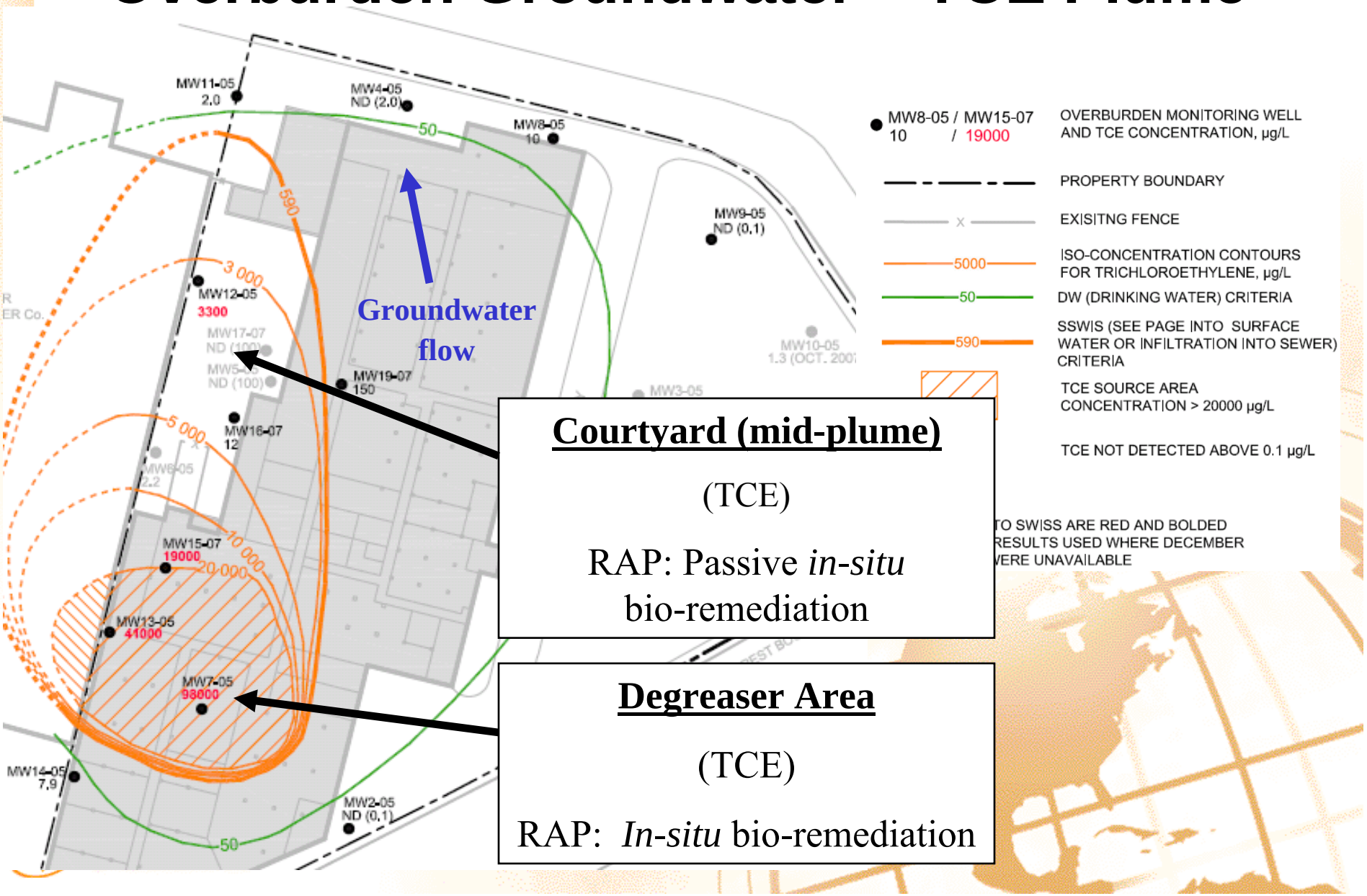
# OBSERVATIONS

## Overburden Groundwater – TCE Plume




**Courtyard (mid-plume)**

(TCE)

RAP: Passive *in-situ* bio-remediation

**Degreaser Area**

(TCE)

RAP: *In-situ* bio-remediation

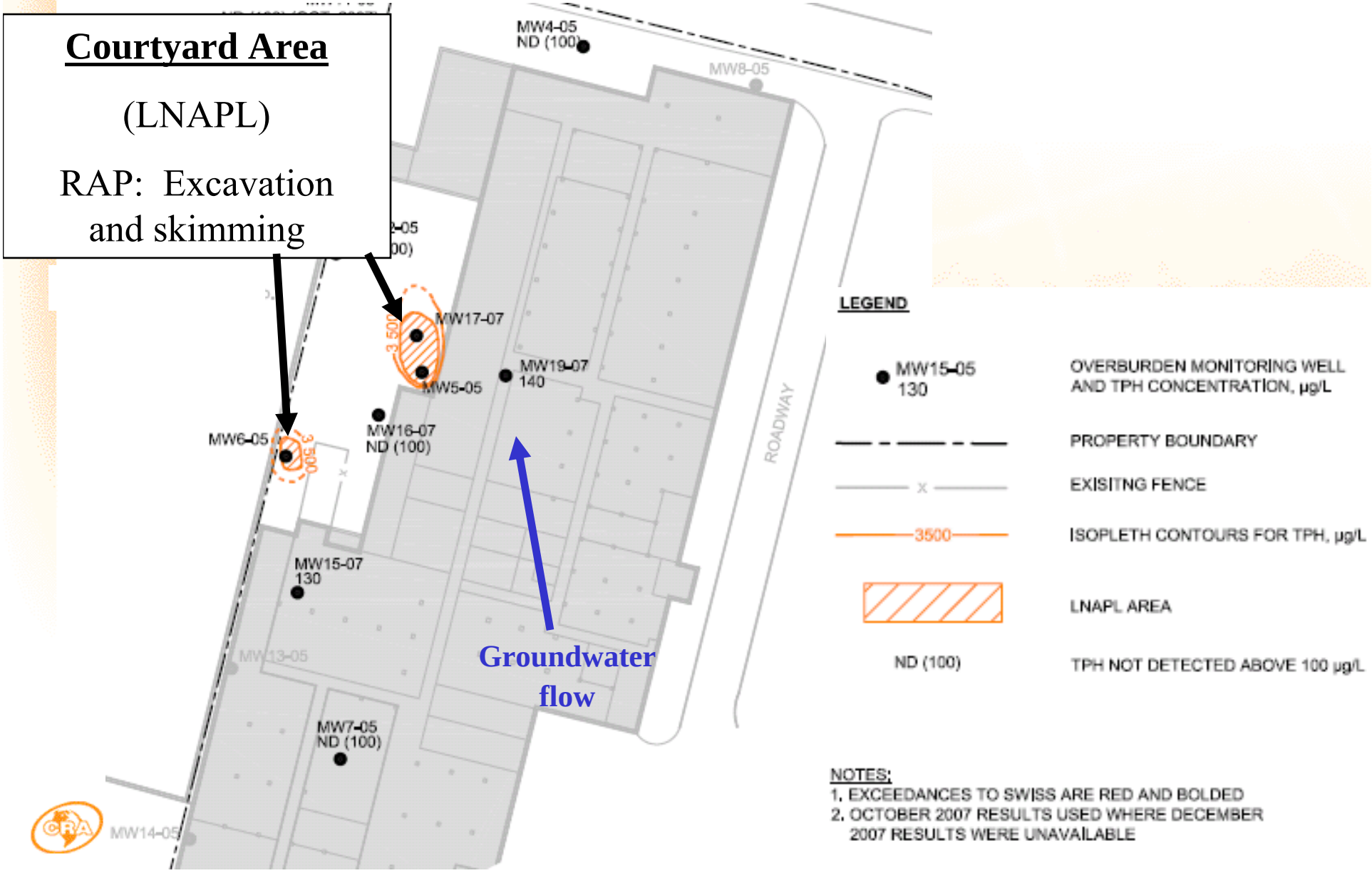
# OBSERVATIONS

## Overburden Groundwater – LNAPL

**Courtyard Area**

(LNAPL)

RAP: Excavation and skimming




NOTES:
1. EXCEEDANCES TO SWISS ARE RED AND BOLDED
2. OCTOBER 2007 RESULTS USED WHERE DECEMBER 2007 RESULTS WERE UNAVAILABLE

# OBSERVATIONS

## Bedrock Groundwater

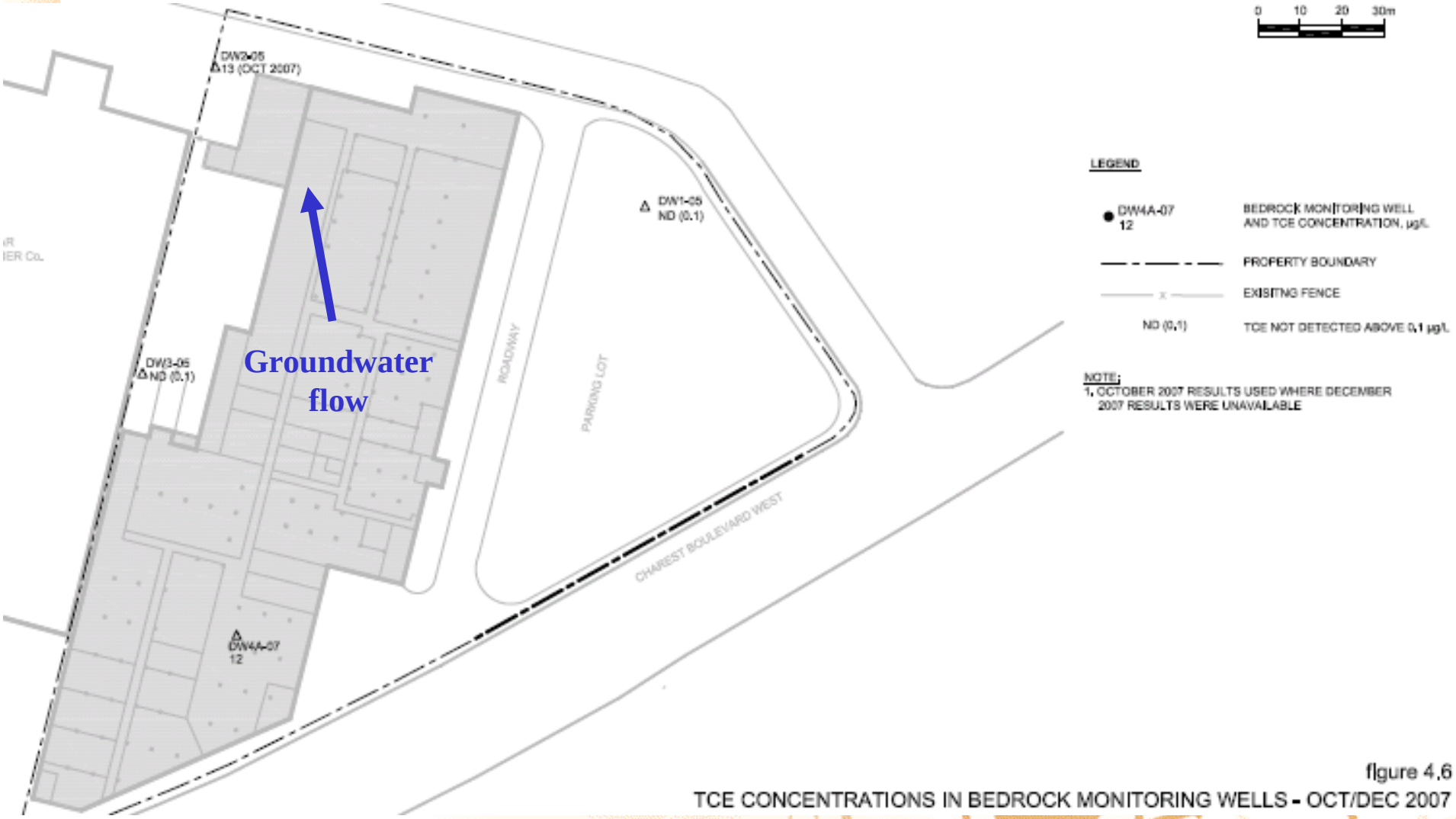



figure 4.6

TCE CONCENTRATIONS IN BEDROCK MONITORING WELLS - OCT/DEC 2007

# RAP IMPLEMENTATION
## Courtyard Area

- **Excavation of sub-surface soil impacts (PCBs, TPH)**

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# RAP IMPLEMENTATION

## Courtyard Area

- **TCE mid-plume treatment strategy – chitin top of saturated zone**


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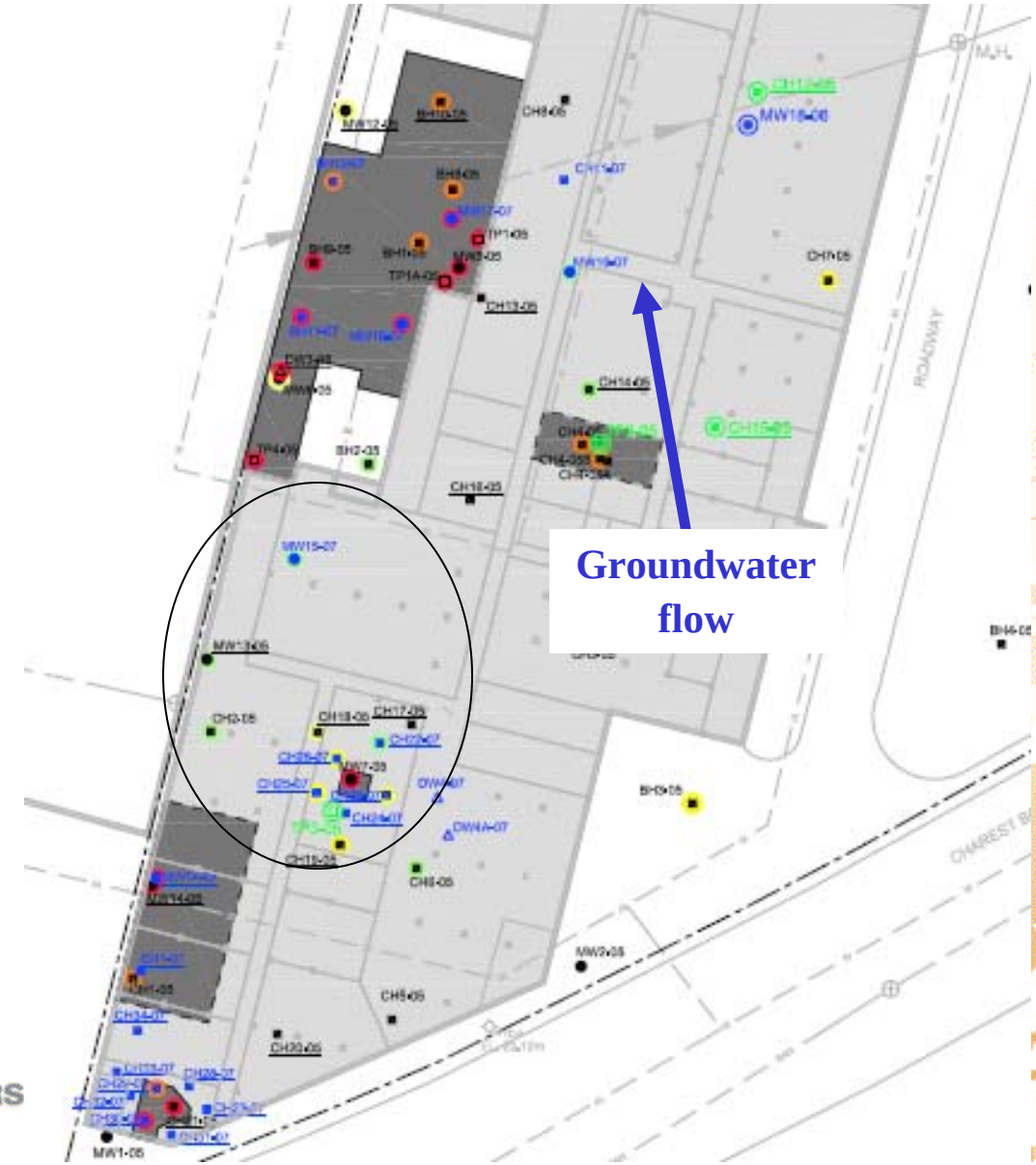
# TCE SOURCE AREA REMEDY

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# TREATABILITY STUDY

**Purpose:**

- Stimulate reductive dechlorination in the TCE source area at the Quebec City Site

**Reductive Dechlorination Process:**

- TCE → cis-1,2 DCE → VC → ethene

**Objectives:**

- Evaluate if chitin, sodium lactate or EVO can stimulate reductive dechlorination of TCE to ethene;
- Determine if supplemental nutrients (nitrogen, phosphate, and trace minerals) would be necessary or beneficial to the dechlorination process;
- Determine if bioaugmentation would be necessary or beneficial to the same process; and
- Evaluate the relationship between TCE concentration and dechlorination.

# TREATABILITY STUDY

- 50 g soil + 75 ml groundwater from Site
- Study Variables:
  - High (~150 µg/L) and Low (~10 µg/L) TCE Concentrations
  - Three electron donors: sodium lactate, chitin, emulsified vegetable oil
  - With and without nutrients & bioaugmentation

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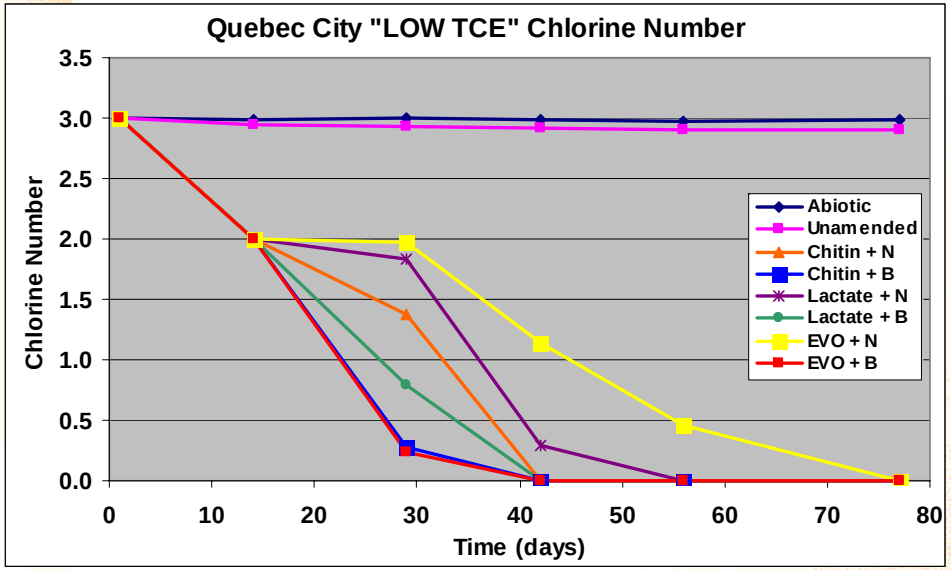
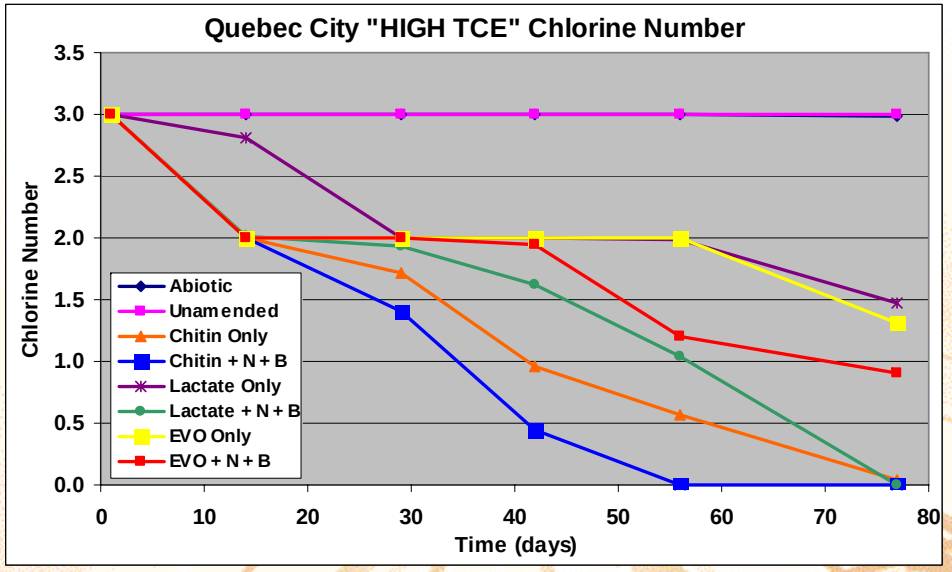
# TREATABILITY STUDY FINDINGS

## Low TCE Concentration




## High TCE Concentration




**Complete dechlorination of TCE to ethene is indicated by a decrease in chlorine number from 3 to 0**

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# TREATABILITY STUDY FINDINGS

- All treatments supported TCE dechlorination to daughter products
- Chitin was most effective amendment; nutrients and bioaugmentation were also beneficial
- Confirmed presence of native microbial communities (likely including *Dehalococcoides spp*.) capable of dechlorinating TCE completely to ethene
- pH shift was observed
- All three donors proposed in Site remedy
- Defined data gaps

# Evaluation of Data Gaps & Define TCE Source Area

- Vadose zone soil sampling
- Estimated volume increased from 10 m³ to 195 m³ (20x increase)
- Stratified groundwater sampling program
- TCE concentrations [shallow], rock interface
- Possible line source


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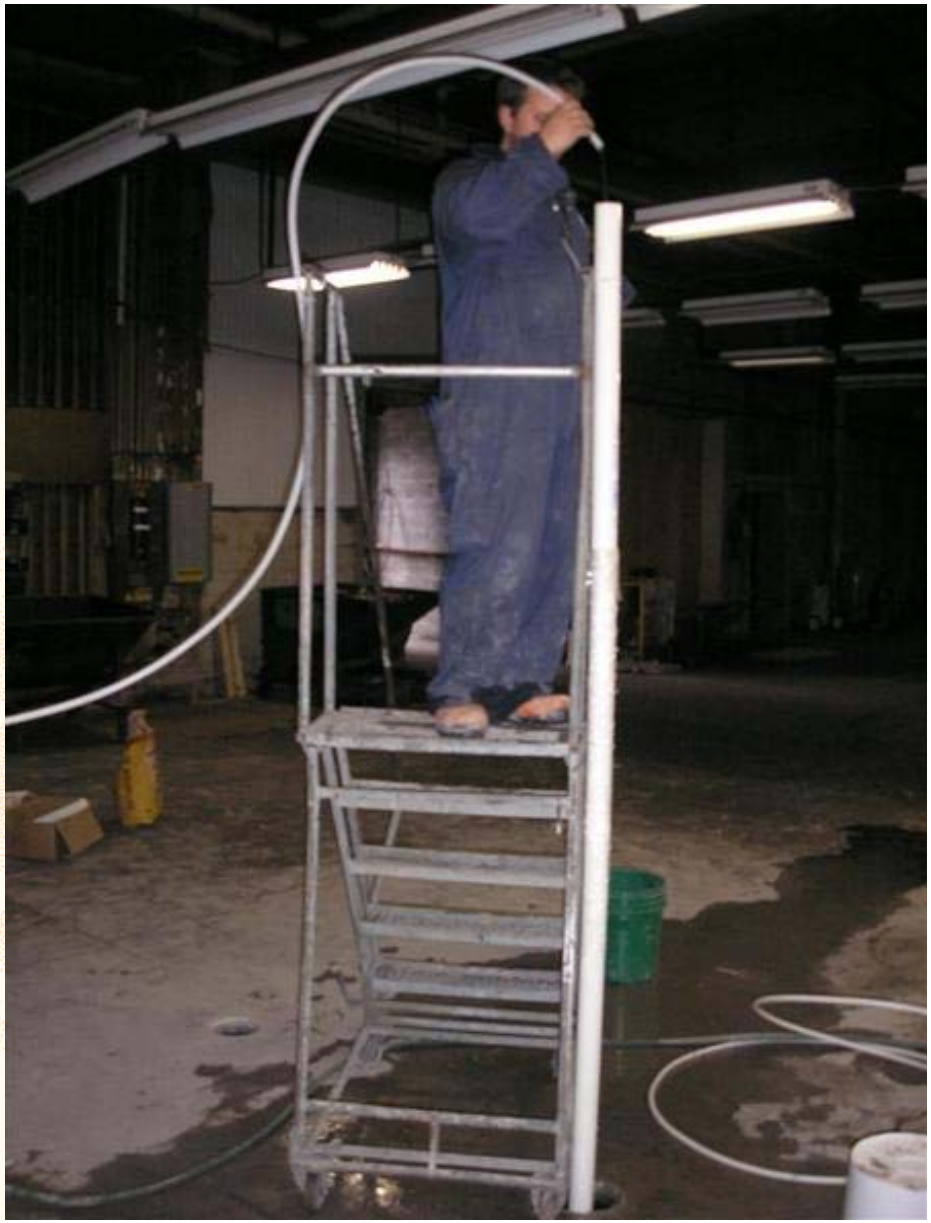
# Evaluation of data gaps & Define TCE Source Area

## Treatment system design parameters

- Aquifer testing (porosity, permeability, injection rate, hydraulic conductivity)
- System parameter testing (oil retention testing, tracer testing)



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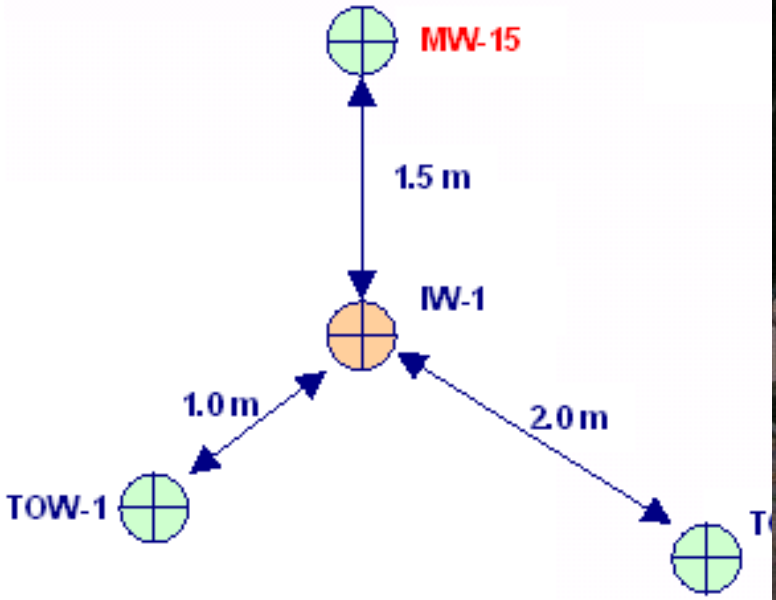
# PILOT SCALE TESTING

- One injection well (IW); three observation wells (OW)
- 21-hour injection test (over 3 day period)
- 200 gallons of groundwater containing 12.5% by volume emulsified vegetable oil (EVO) and 200 mg/L of sodium bromide tracer
- 434 gallons of municipal water to flush the oil/tracer through the subsurface

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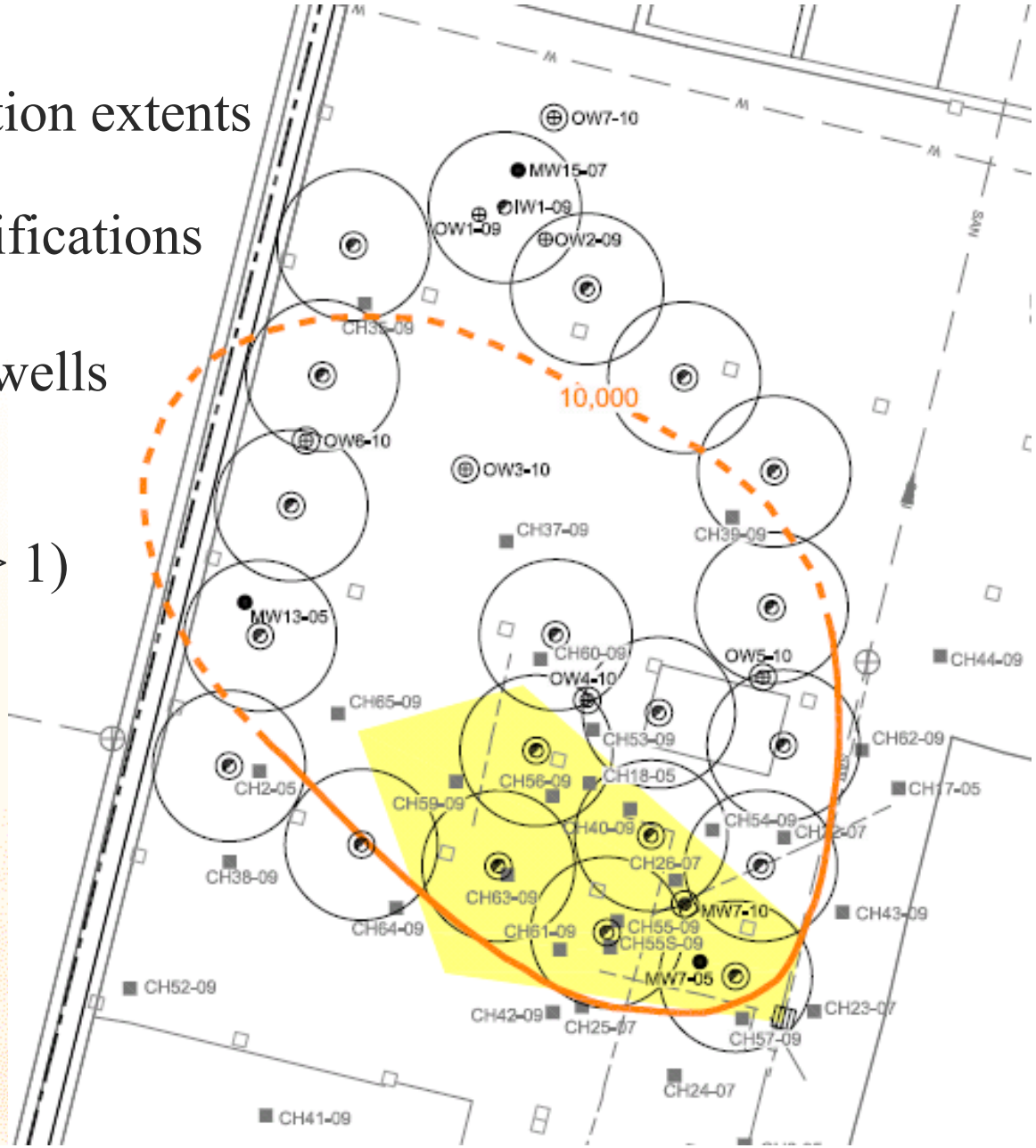
# REMEDY DESIGN

Defined vadose zone excavation extents (chitin backfill)

Injection system design specifications

- 20 injection wells
- 5 additional observation wells
- EVO as principal electron donor
- Sodium lactate (density > 1) to reach fractured bedrock layer

Submitted December 2009

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# TCE Source Area Excavation

**Excavate by sector for column stability**

**Engineered excavation techniques around columns – sloped for soil stability**

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# TCE Source Area Excavation

- Excavated volume 238 $m^3$ vs. 320 $m^3$ anticipated (26% reduction)
- Backfill with chitin at groundwater interface

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# SUBSTRATE INJECTION PROGRAM

- Injection well and observation well installation December 2010
- Injection of amendments in March 2011

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# SUBSTRATE INJECTION PROGRAM

- Ferrous oxide on tubing from monitoring well
- 2 days setup & 13 days injection
- Constant monitoring during operation


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# SUBSTRATE INJECTION PROGRAM

- **Total solution injected: 54,833 gallons**
  - EVO: 7,732 kg (35 drums) + activator: 190 kg + vitamin B-12: 16kg
  - Sodium lactate 60% solution: 2,750 kg (10 drums) + accelerite: 45kg
  - Sodium bicarbonate: 1,067 kg
- **Surfacing observed at two wells (repaired and reused)**

# PERFORMANCE MONITORING

- **Groundwater monitoring program**
- **Air sampling program**
- **<u>Preliminary</u> groundwater results MW13 & OW3**


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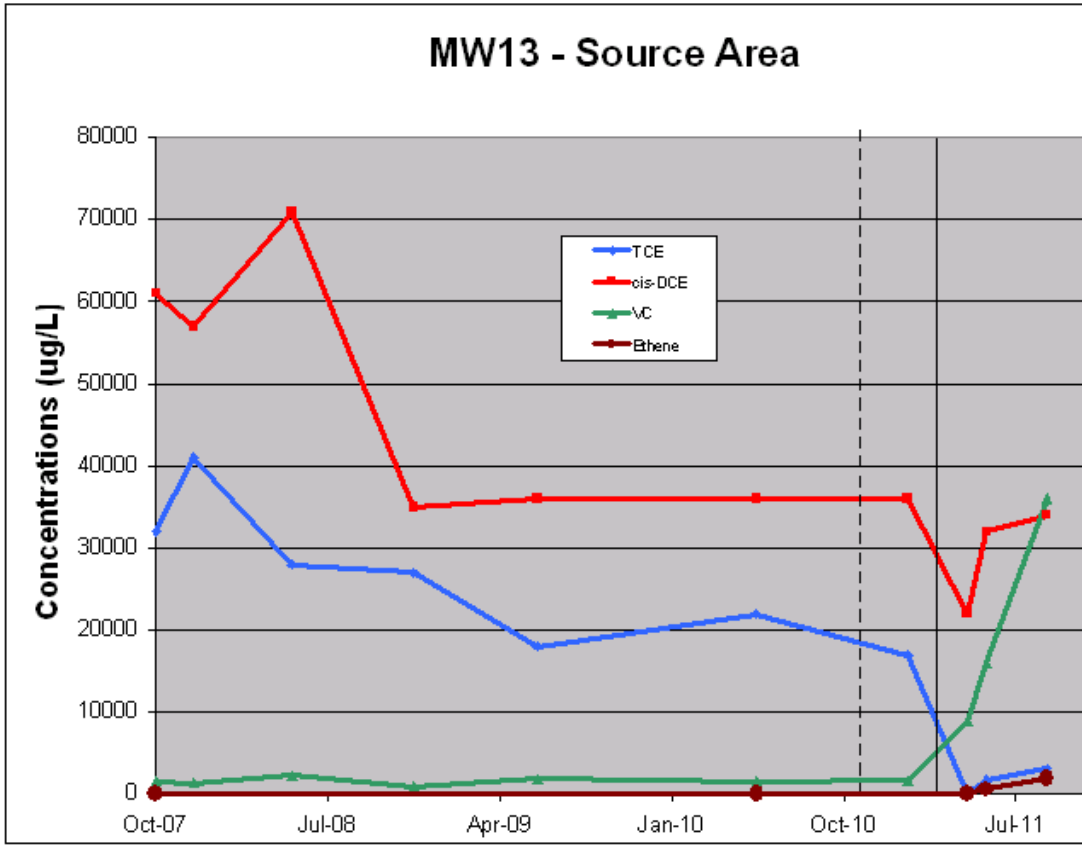
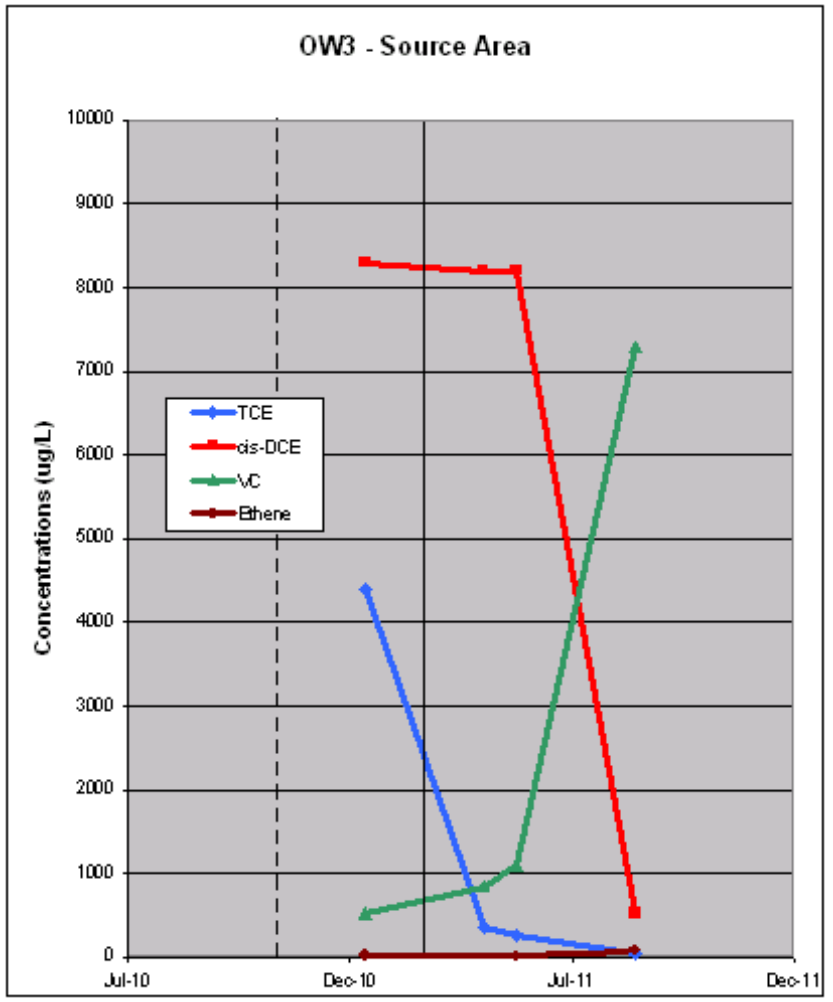
# PERFORMANCE MONITORING

- **Reductive dechlorination process**
  TCE → cis-1,2 DCE → VC → ethene




——— Chitin backfill (11/1/2010) ——— EVO injection (3/1/2011)

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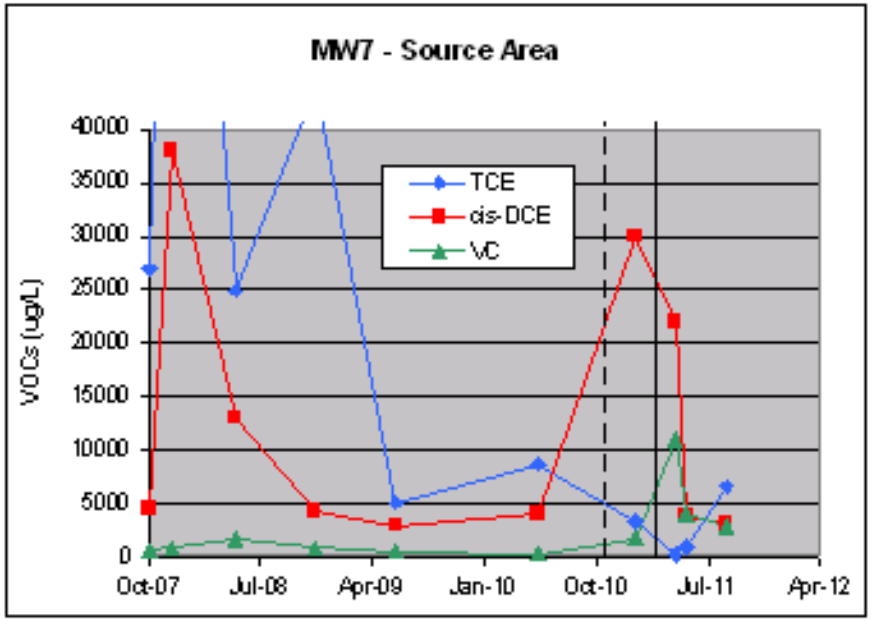
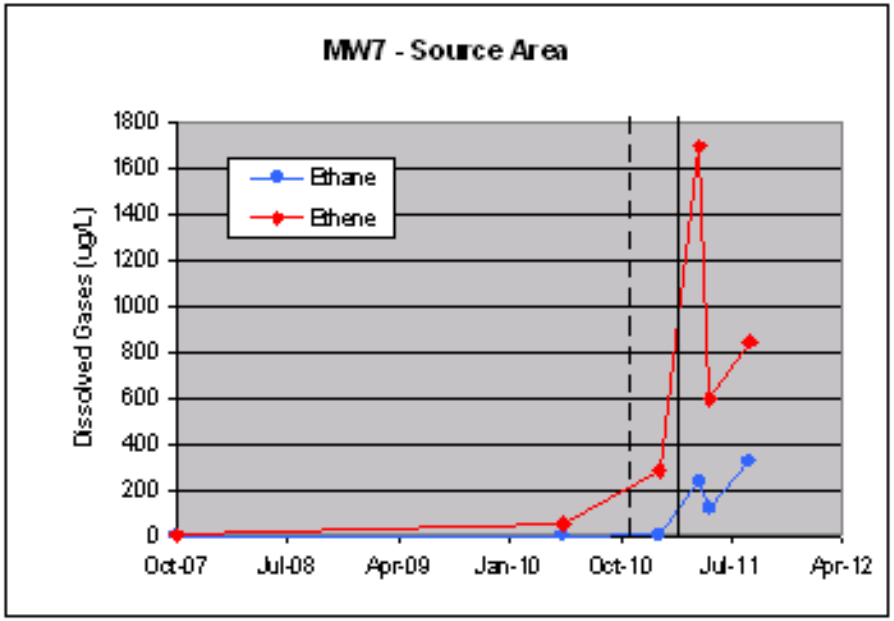
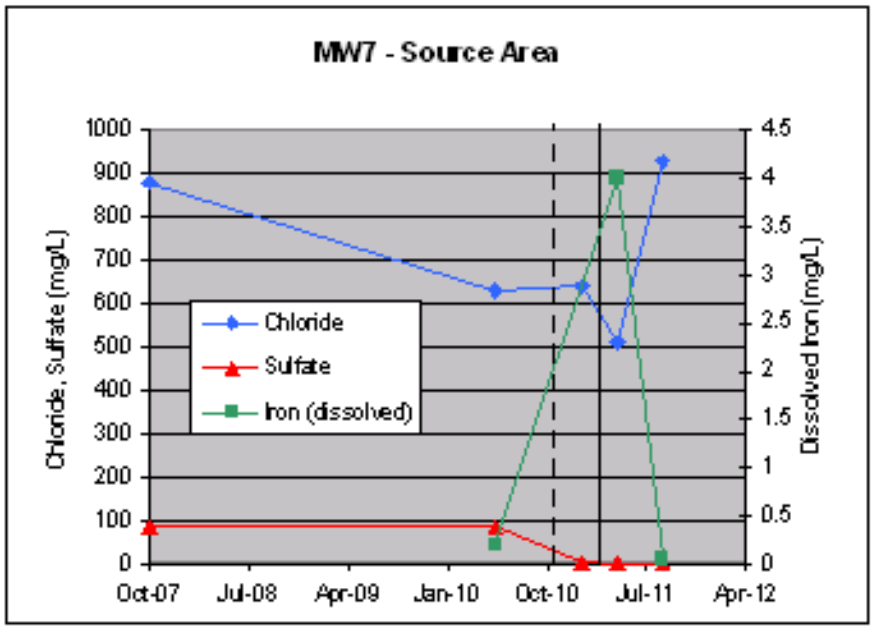
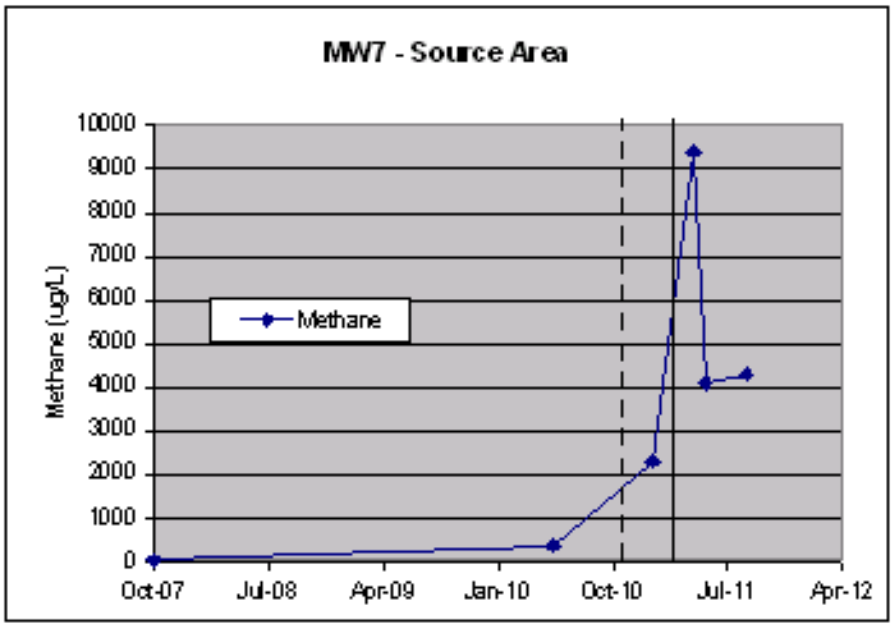
# PERFORMANCE MONITORING

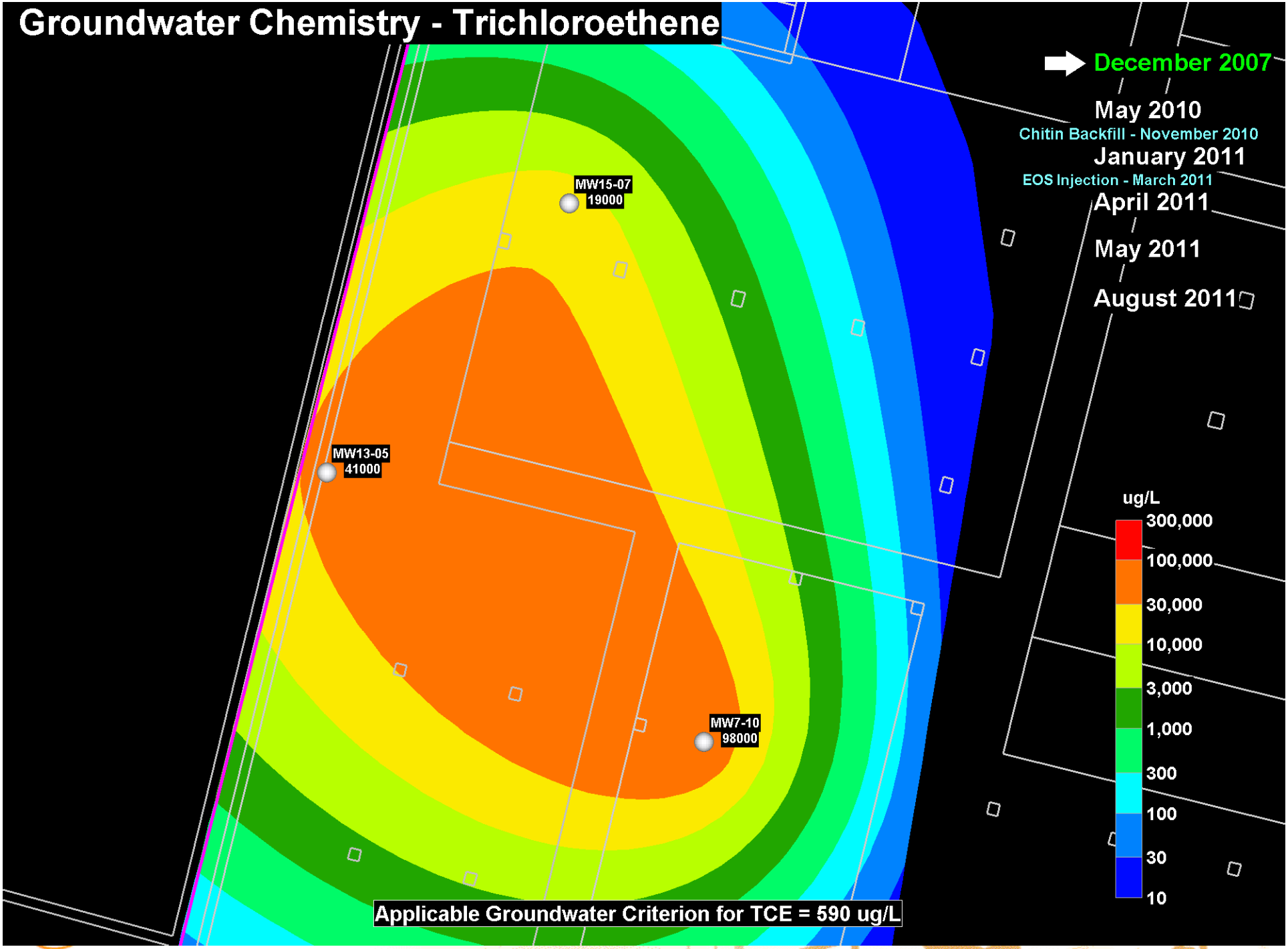


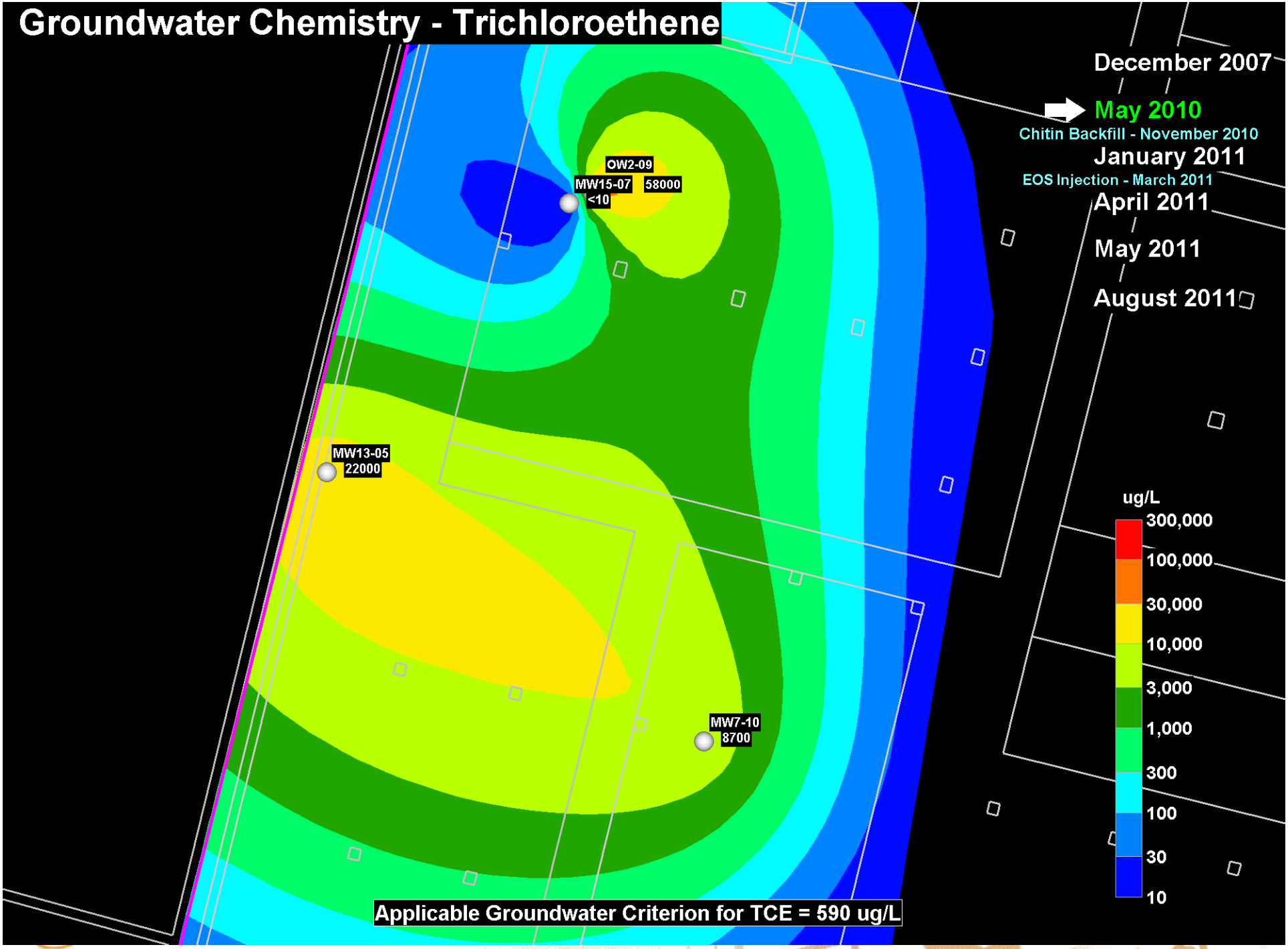




——— Chitin backfill (11/1/2010) ——— EVO injection (3/1/2011)


Groundwater Chemistry - Trichloroethene
December 2007
May 2010
Chitin Backfill - November 2010
January 2011
EOS Injection - March 2011
April 2011
May 2011
August 2011
MW15-07
19000
MW13-05
41000
MW7-10
98000
ug/L
300,000
100,000
30,000
10,000
3,000
1,000
300
100
30
10
Applicable Groundwater Criterion for TCE = 590 ug/L


Groundwater Chemistry - Trichloroethene
December 2007
May 2010
Chitin Backfill - November 2010
January 2011
EOS Injection - March 2011
April 2011
May 2011
August 2011
OW2-09
MW15-07
58000
<10
MW13-05
22000
MW7-10
8700
ug/L
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100,000
30,000
10,000
3,000
1,000
300
100
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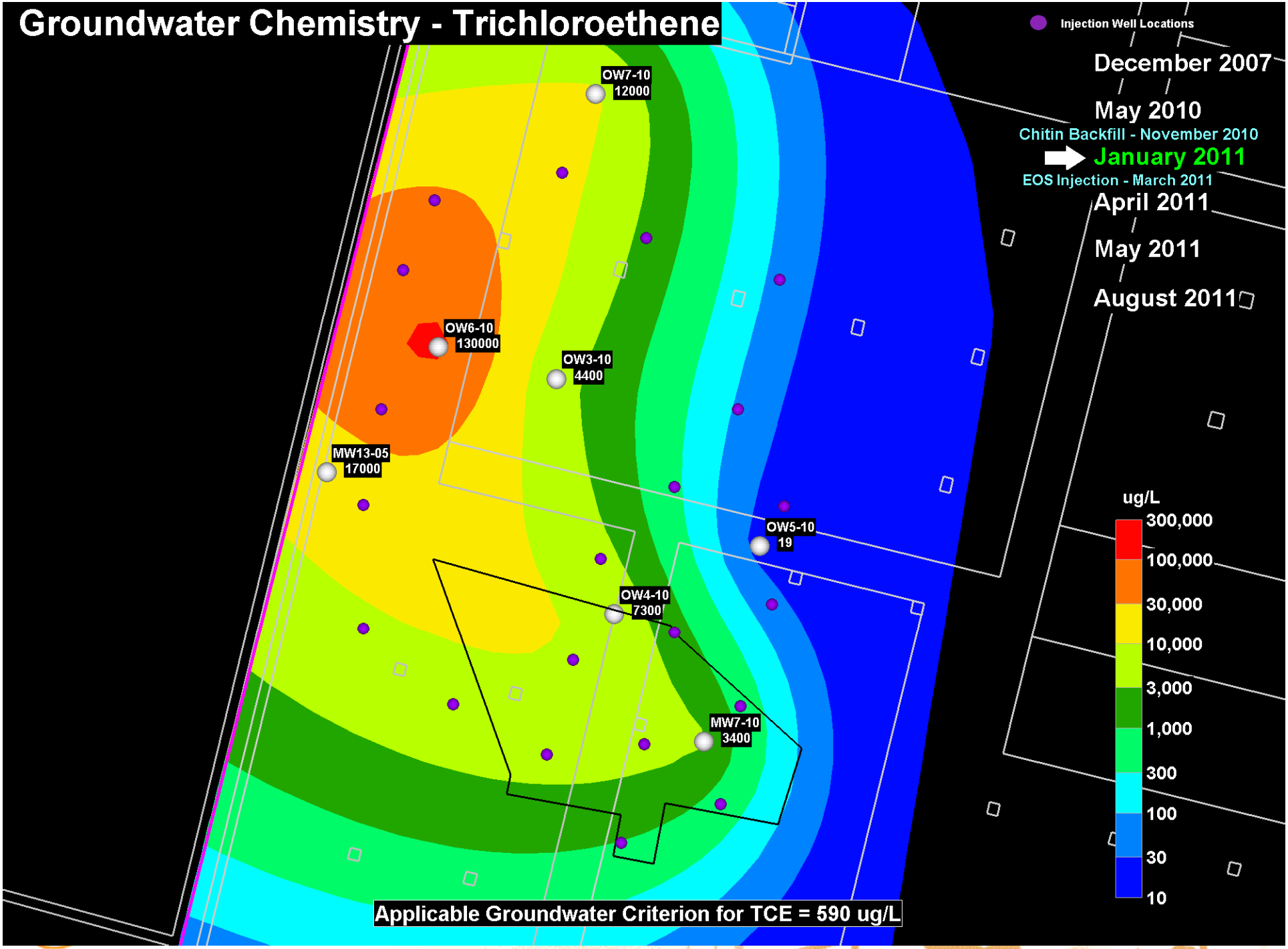
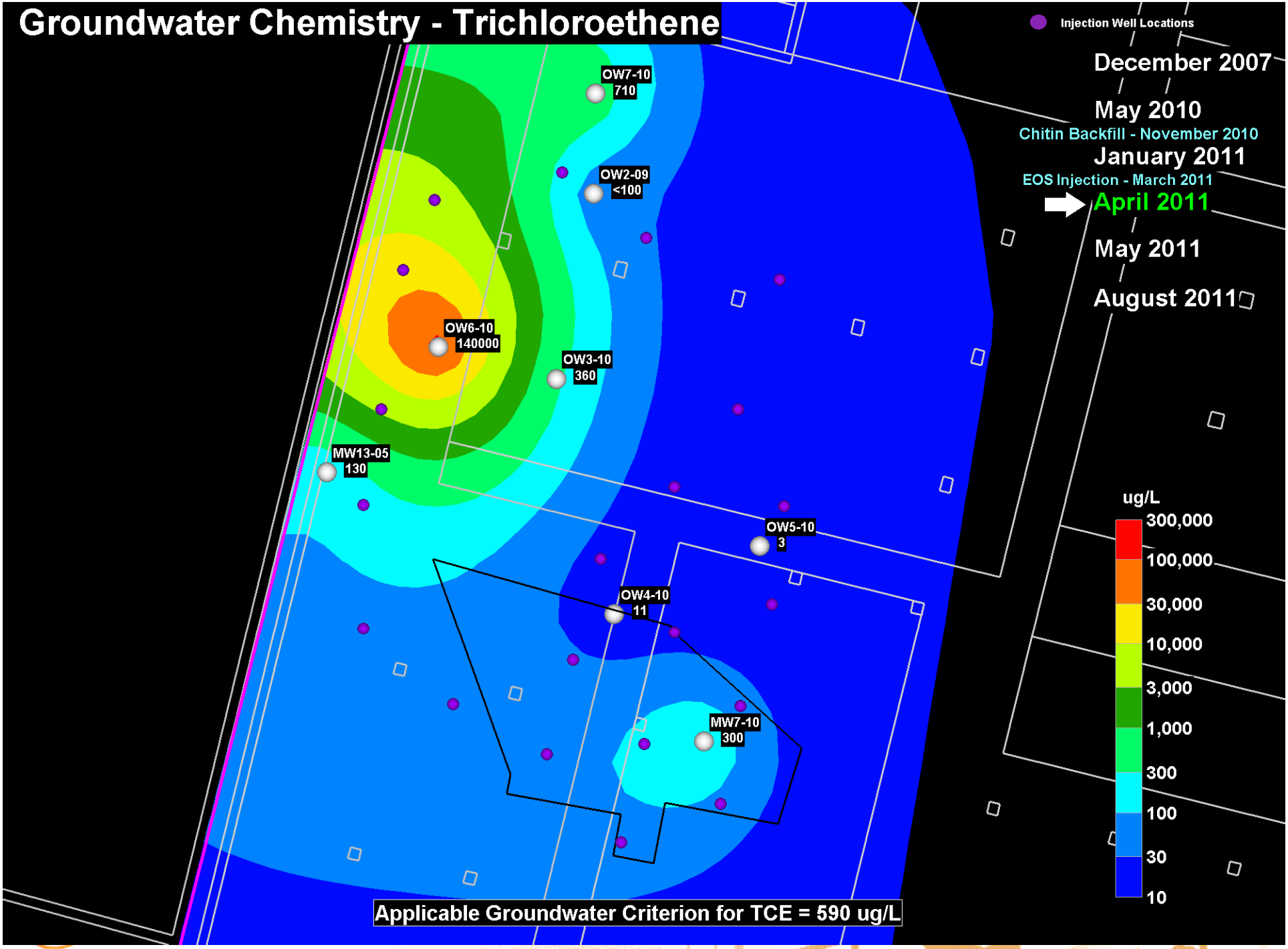
10
Applicable Groundwater Criterion for TCE = 590 ug/L


Groundwater Chemistry - Trichloroethene
Injection Well Locations
December 2007
May 2010
Chitin Backfill - November 2010
January 2011
EOS Injection - March 2011
April 2011
May 2011
August 2011
OW7-10
12000
OW6-10
130000
OW3-10
4400
MW13-05
17000
OW5-10
19
OW4-10
7300
MW7-10
3400
ug/L
300,000
100,000
30,000
10,000
3,000
1,000
300
100
30
10
Applicable Groundwater Criterion for TCE = 590 ug/L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OW7-10
710
OW2-09
<100
OW6-10
140000
OW3-10
360
MW13-05
130
OW5-10
3
OW4-10
11
MW7-10
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ug/L
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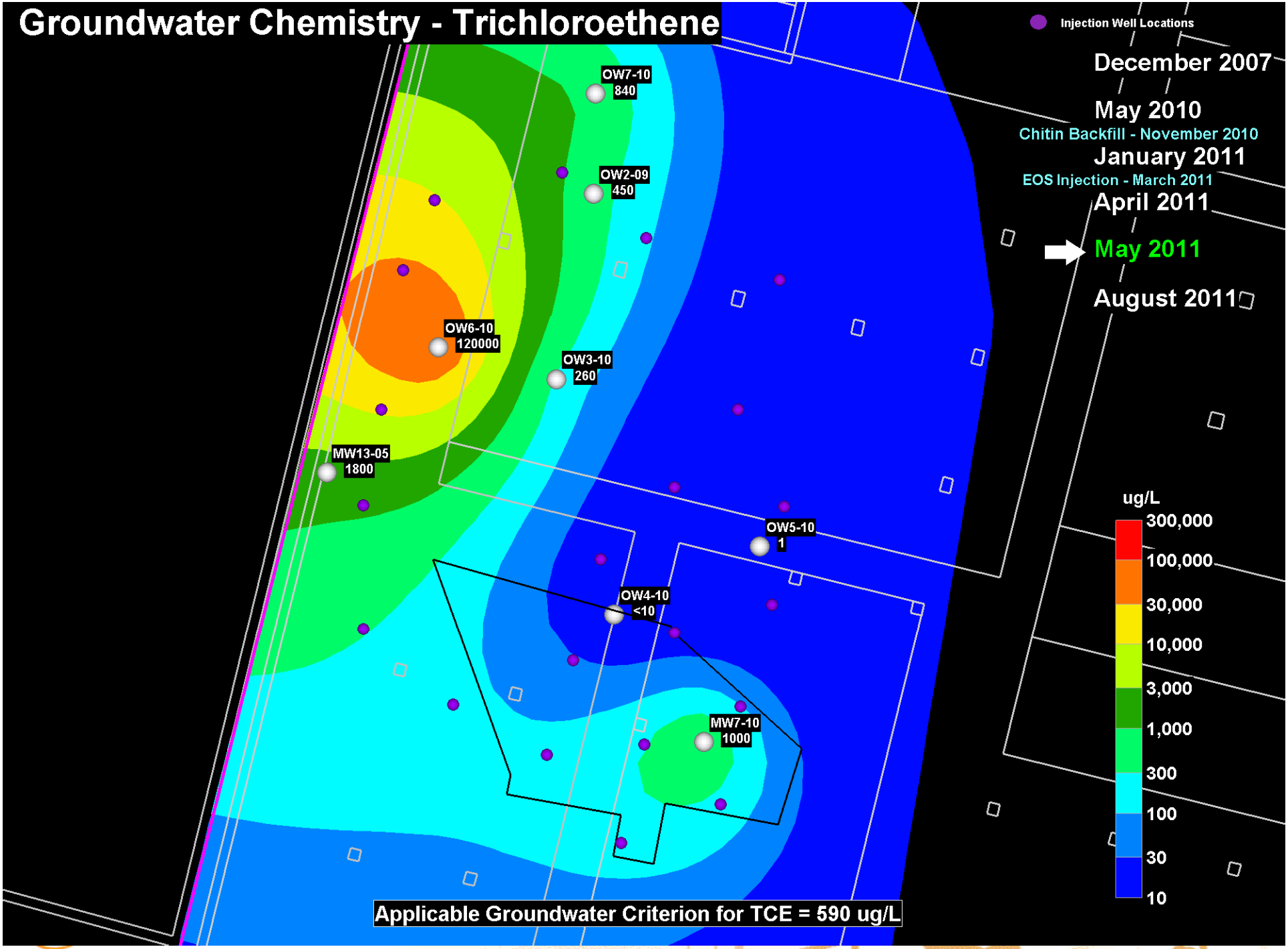
Applicable Groundwater Criterion for TCE = 590 ug/L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December 2007
May 2010
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January 2011
EOS Injection - March 2011
April 2011
May 2011
August 2011
OW7-10
840
OW2-09
450
OW6-10
120000
OW3-10
260
MW13-05
1800
OW5-10
1
OW4-10
<10
MW7-10
1000
ug/L
300,000
100,000
30,000
10,000
3,000
1,000
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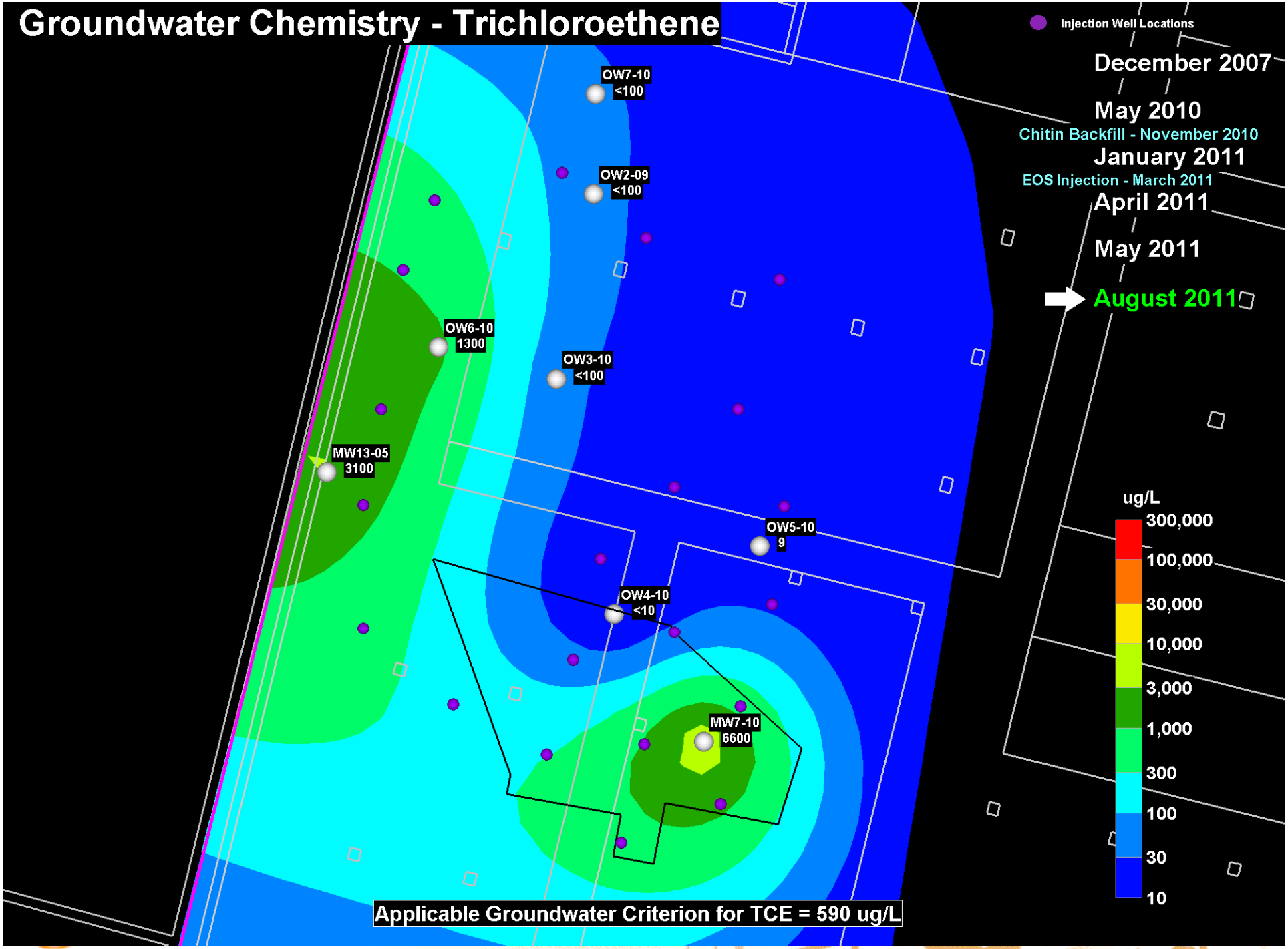
Applicable Groundwater Criterion for TCE = 590 ug/L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<100
OW2-09
<100
OW6-10
1300
OW3-10
<100
MW13-05
3100
OW5-10
9
OW4-10
<10
MW7-10
6600
ug/L
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10
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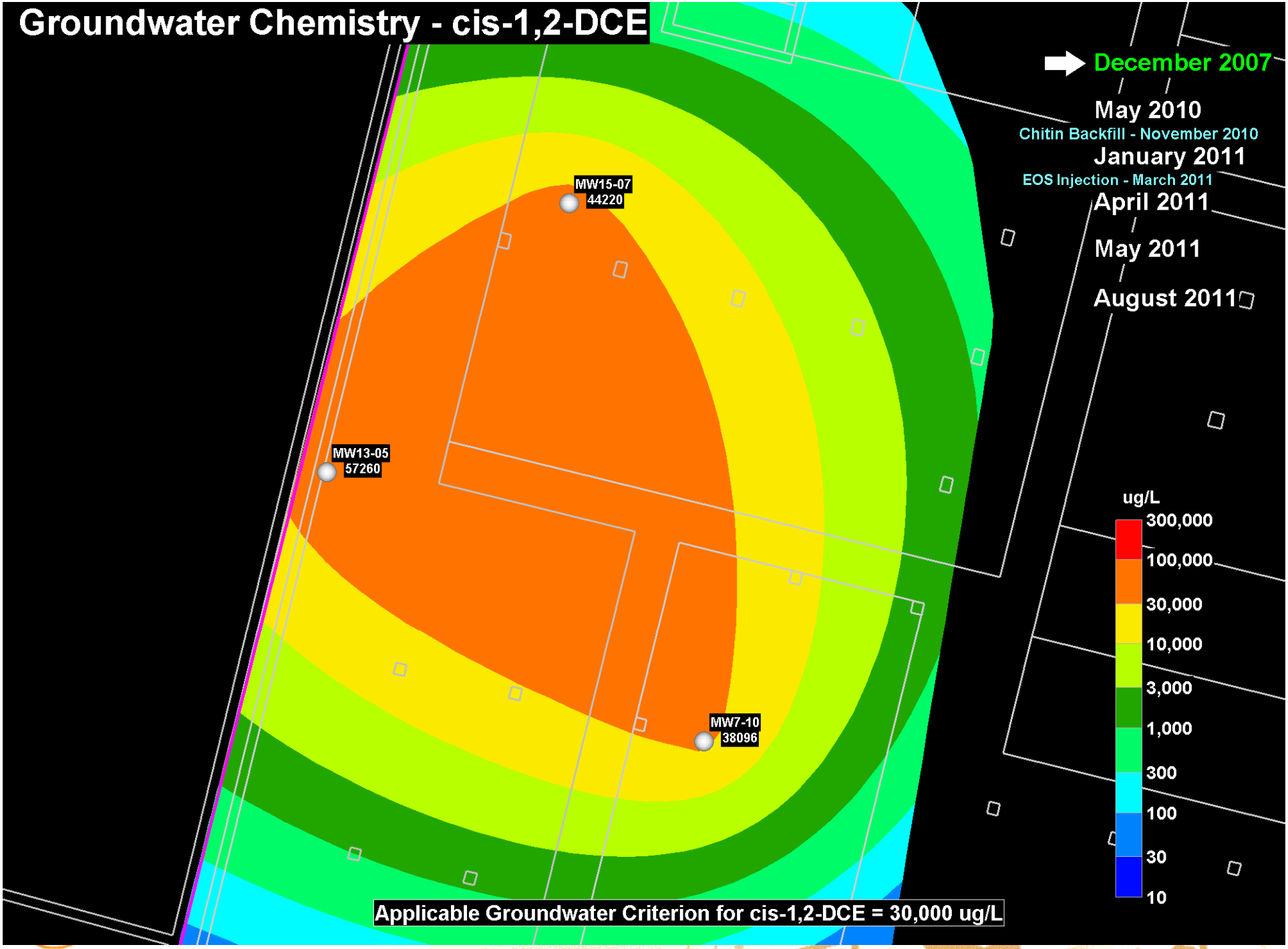
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December 2007
May 2010
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January 2011
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April 2011
May 2011
August 2011
MW15-07
44220
MW13-05
57260
MW7-10
38096
ug/L
300,000
100,000
30,000
10,000
3,000
1,000
300
100
30
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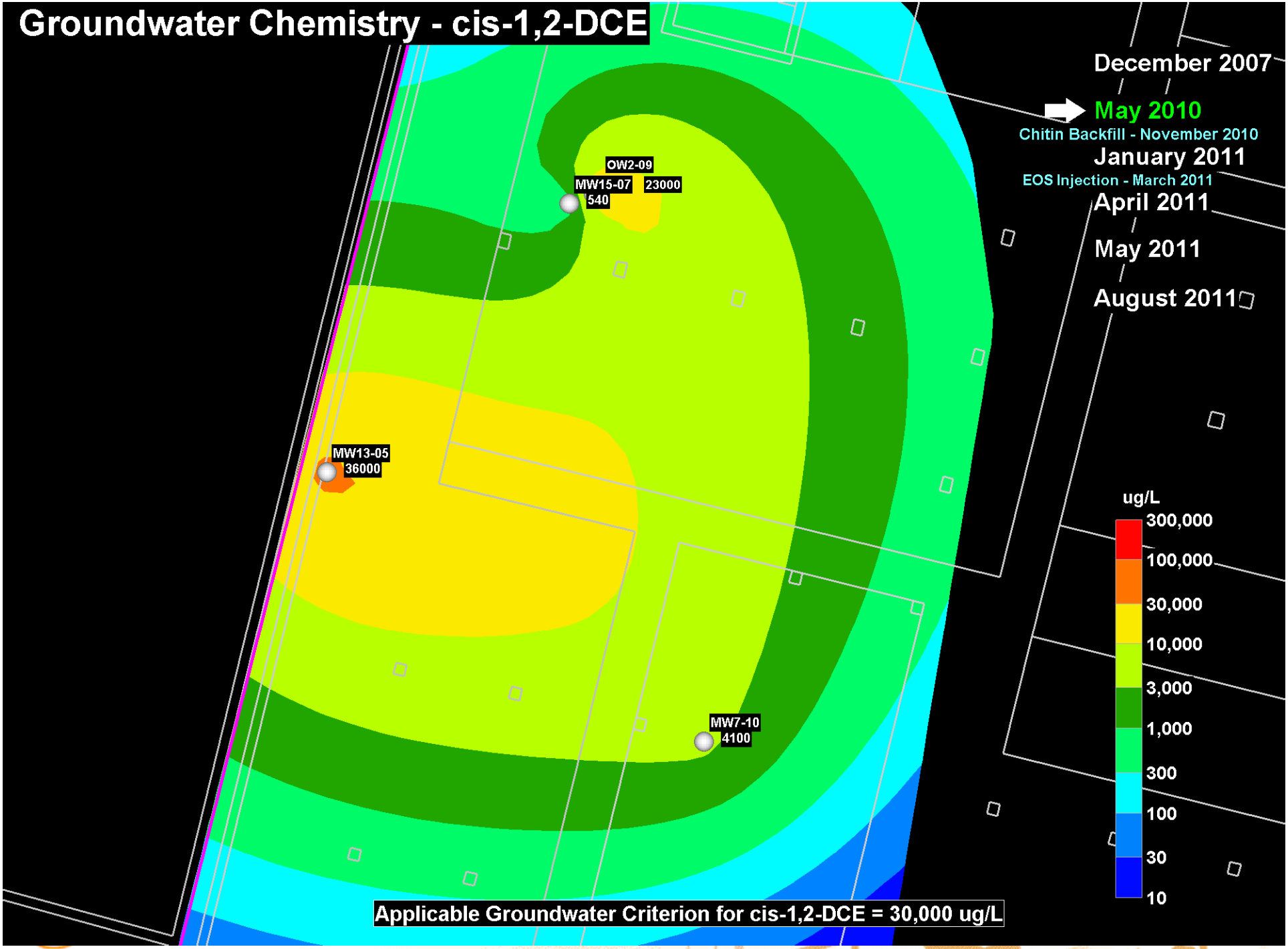
Applicable Groundwater Criterion for cis-1,2-DCE = 30,000 ug/L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April 2011
May 2011
August 2011
OW2-09
MW15-07
23000
540
MW13-05
36000
MW7-10
4100
ug/L
300,000
100,000
30,000
10,000
3,000
1,000
300
100
30
10
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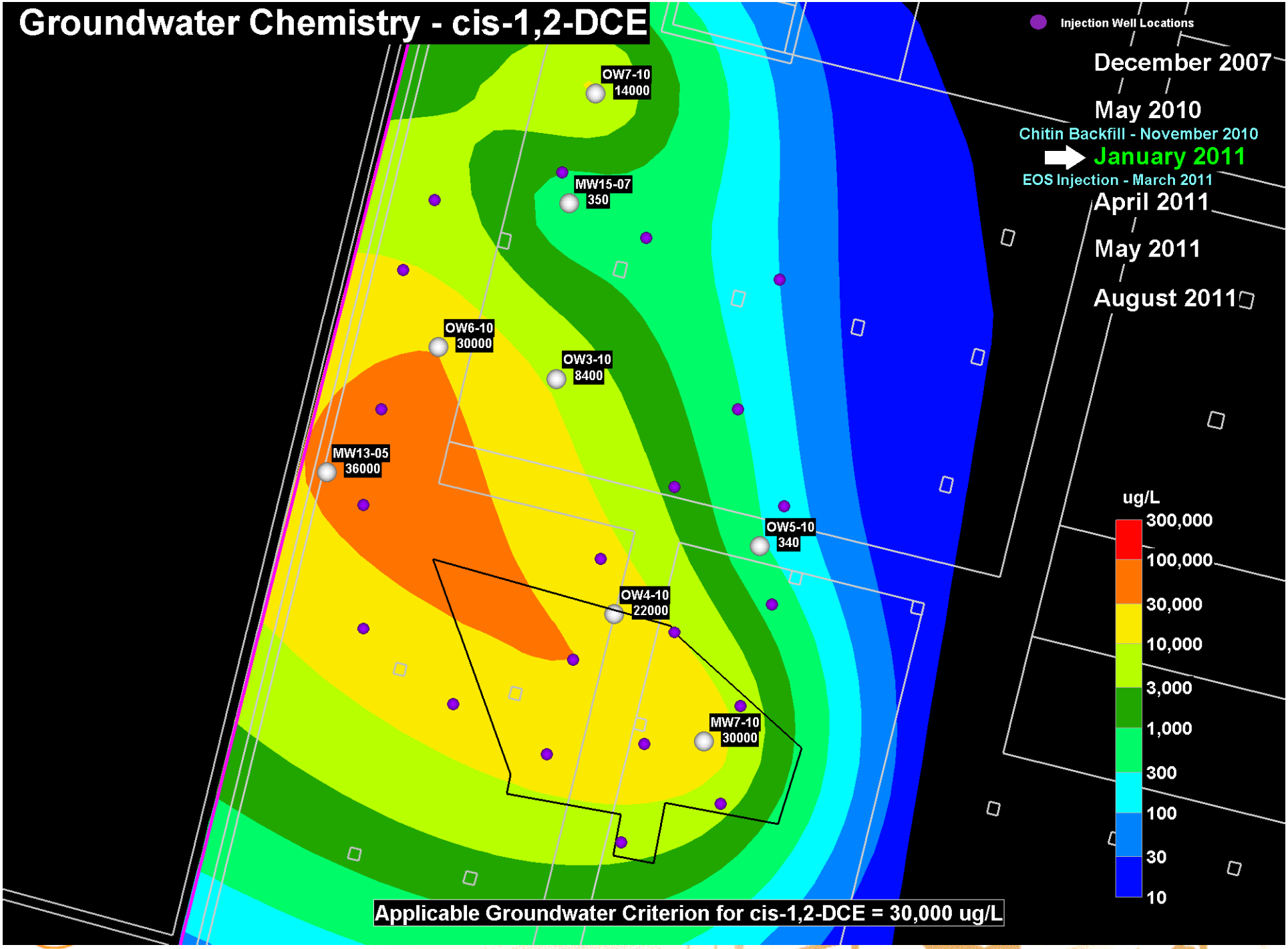
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14000
MW15-07
350
OW6-10
30000
OW3-10
8400
MW13-05
36000
OW5-10
340
OW4-10
22000
MW7-10
30000
ug/L
300,000
100,000
30,000
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3,000
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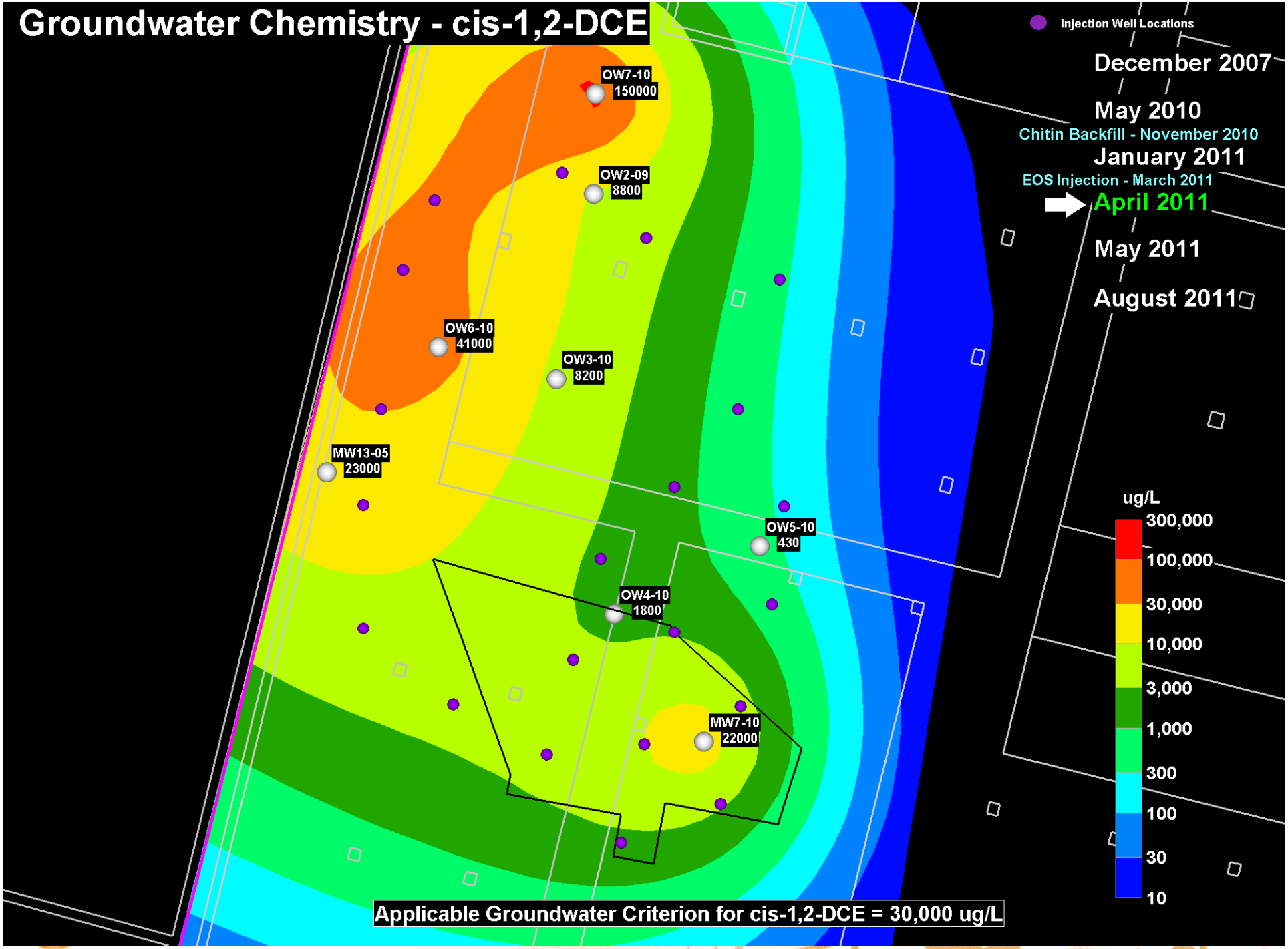
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150000
OW2-09
8800
OW6-10
41000
OW3-10
8200
MW13-05
23000
OW5-10
430
OW4-10
1800
MW7-10
22000
ug/L
300,000
100,000
30,000
10,000
3,000
1,000
300
100
30
10
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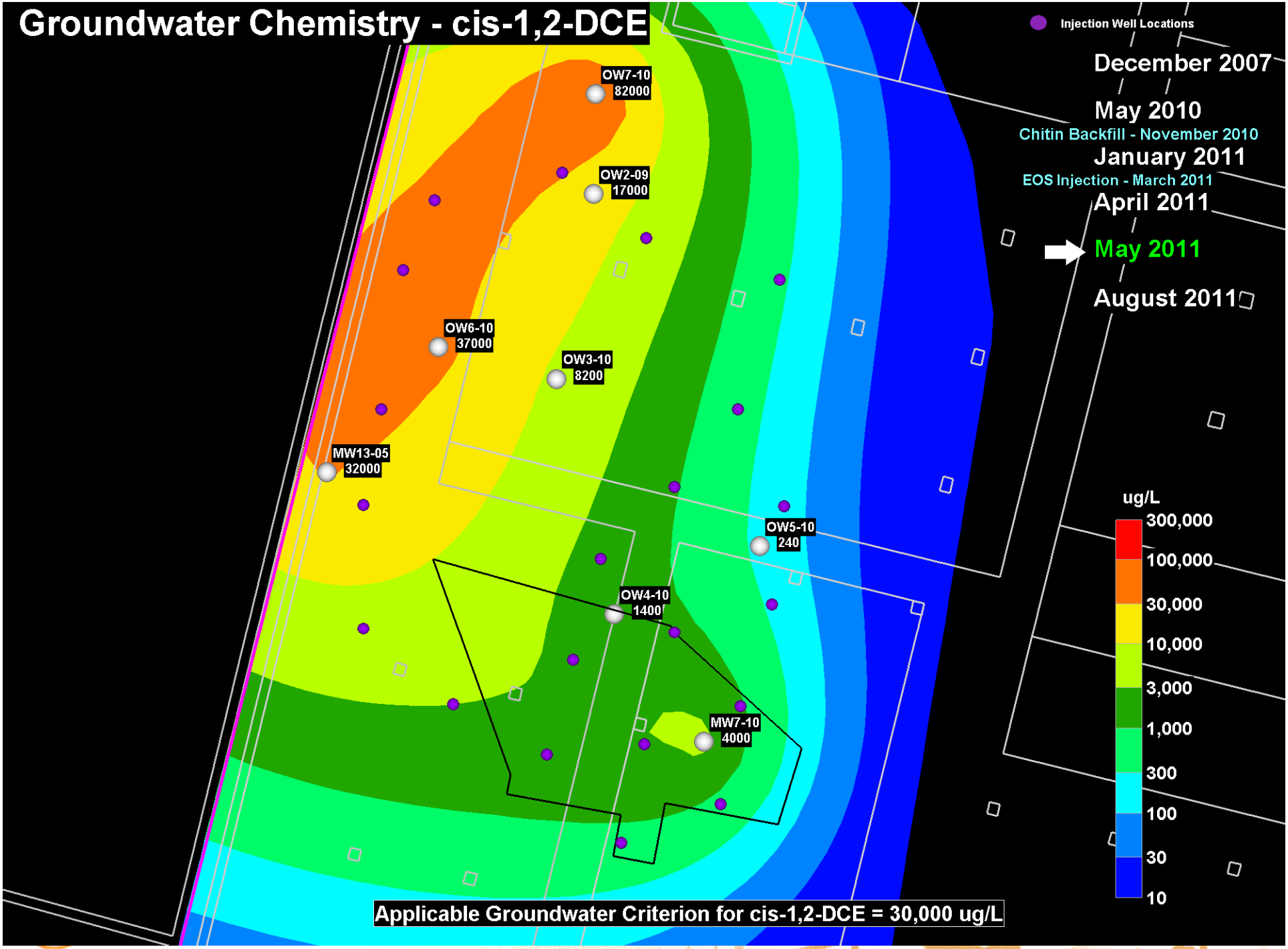
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82000
OW2-09
17000
OW6-10
37000
OW3-10
8200
MW13-05
32000
OW5-10
240
OW4-10
1400
MW7-10
4000
ug/L
300,000
100,000
30,000
10,000
3,000
1,000
300
100
30
10
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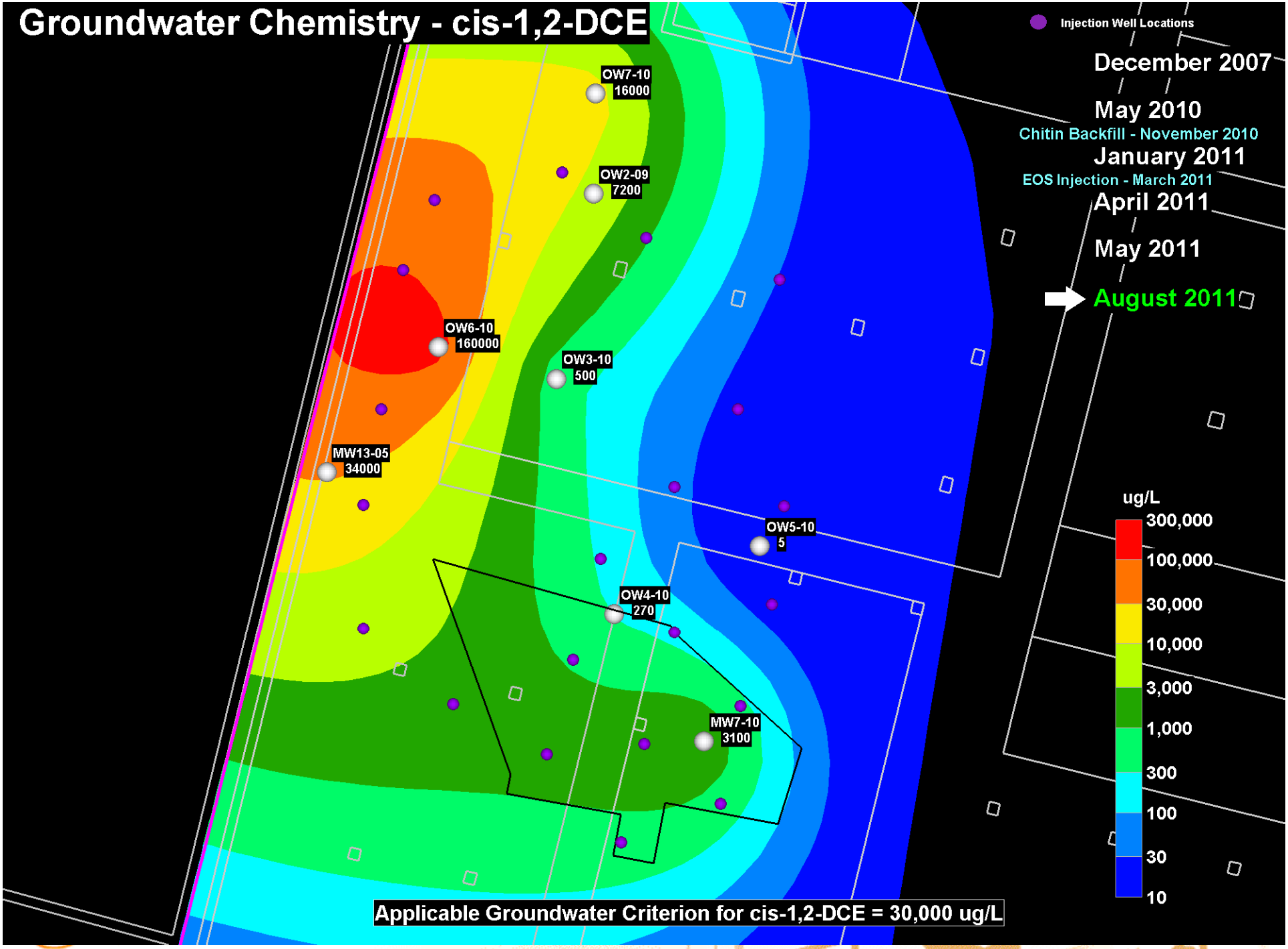
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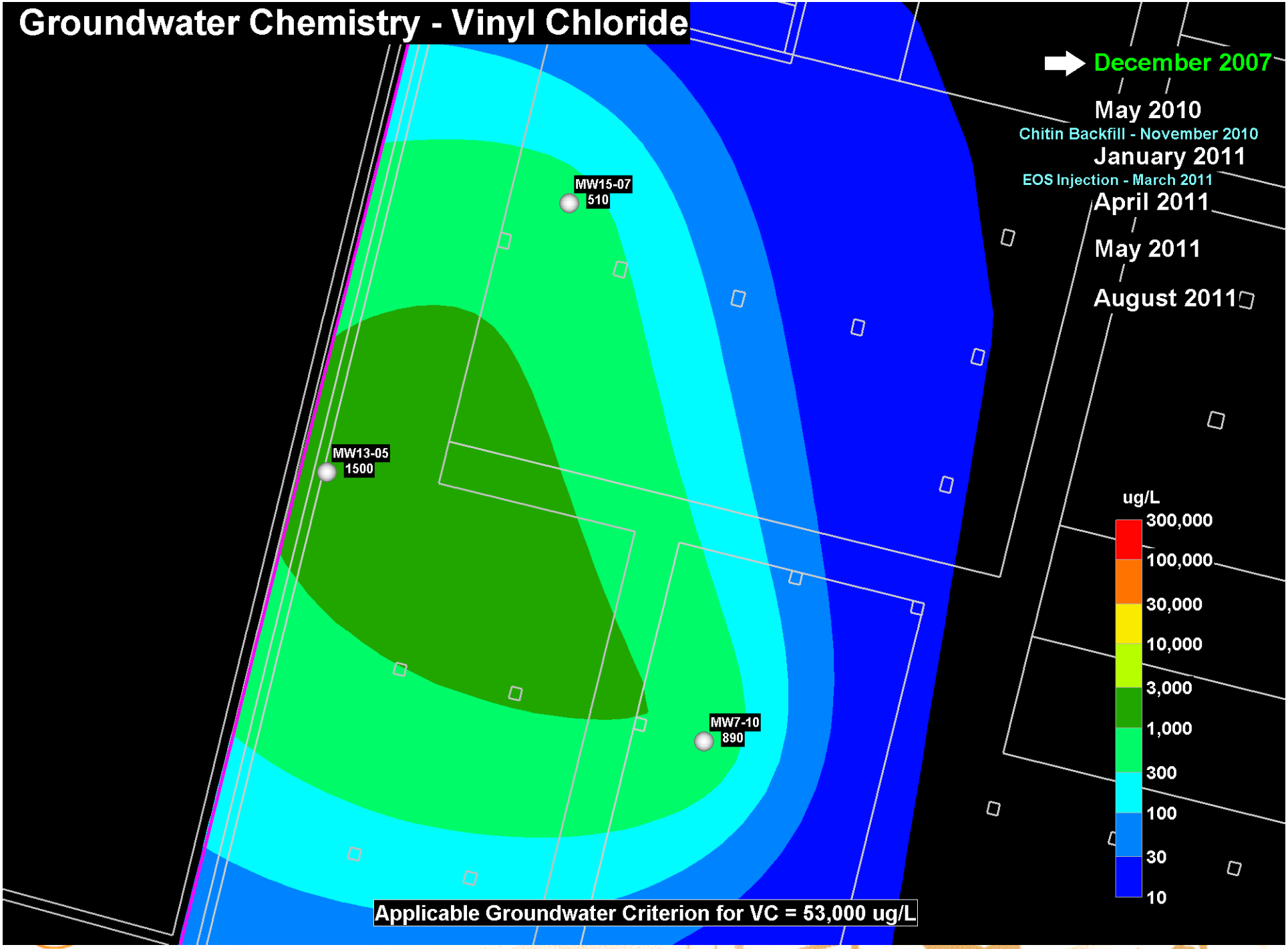
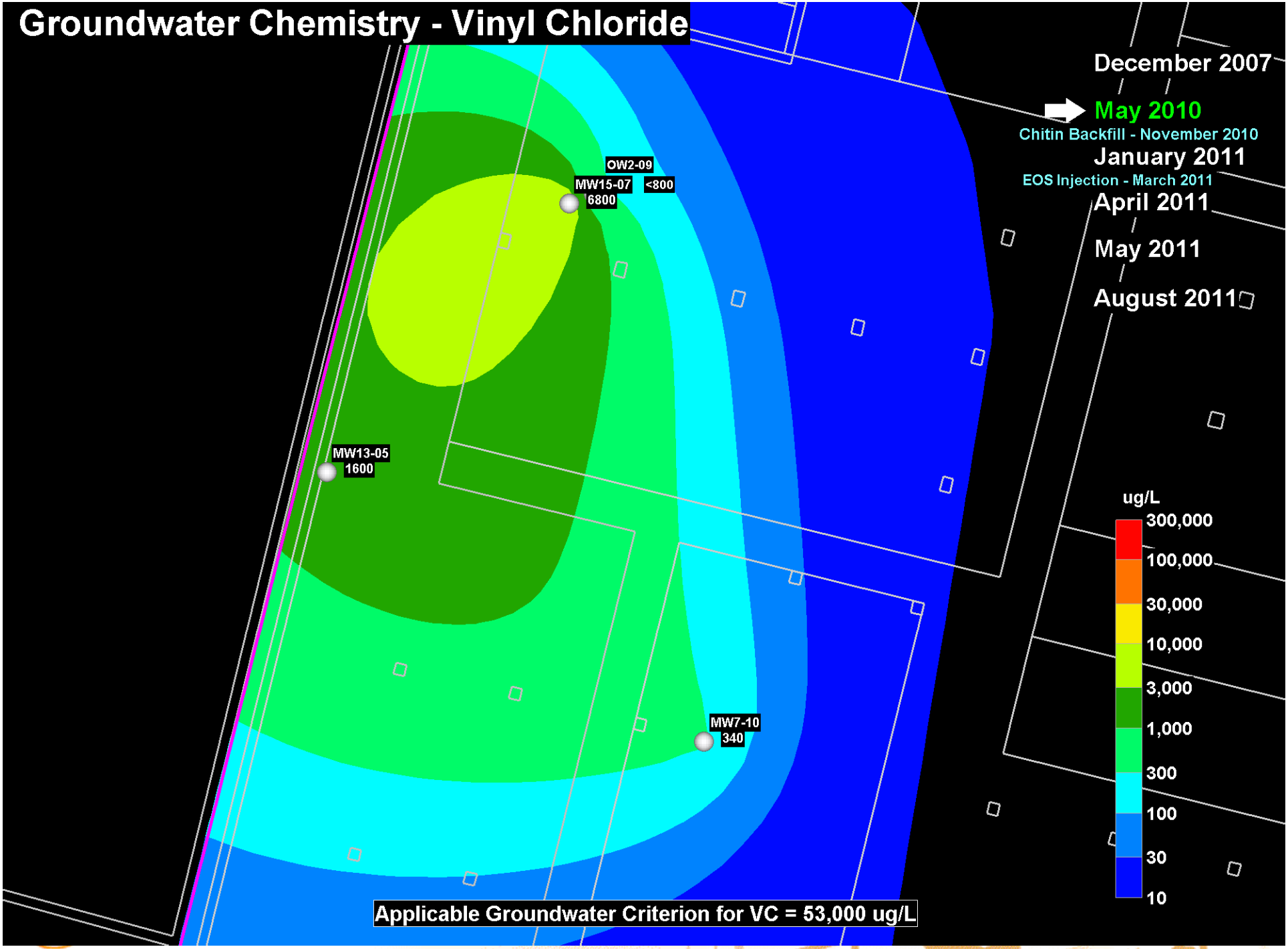
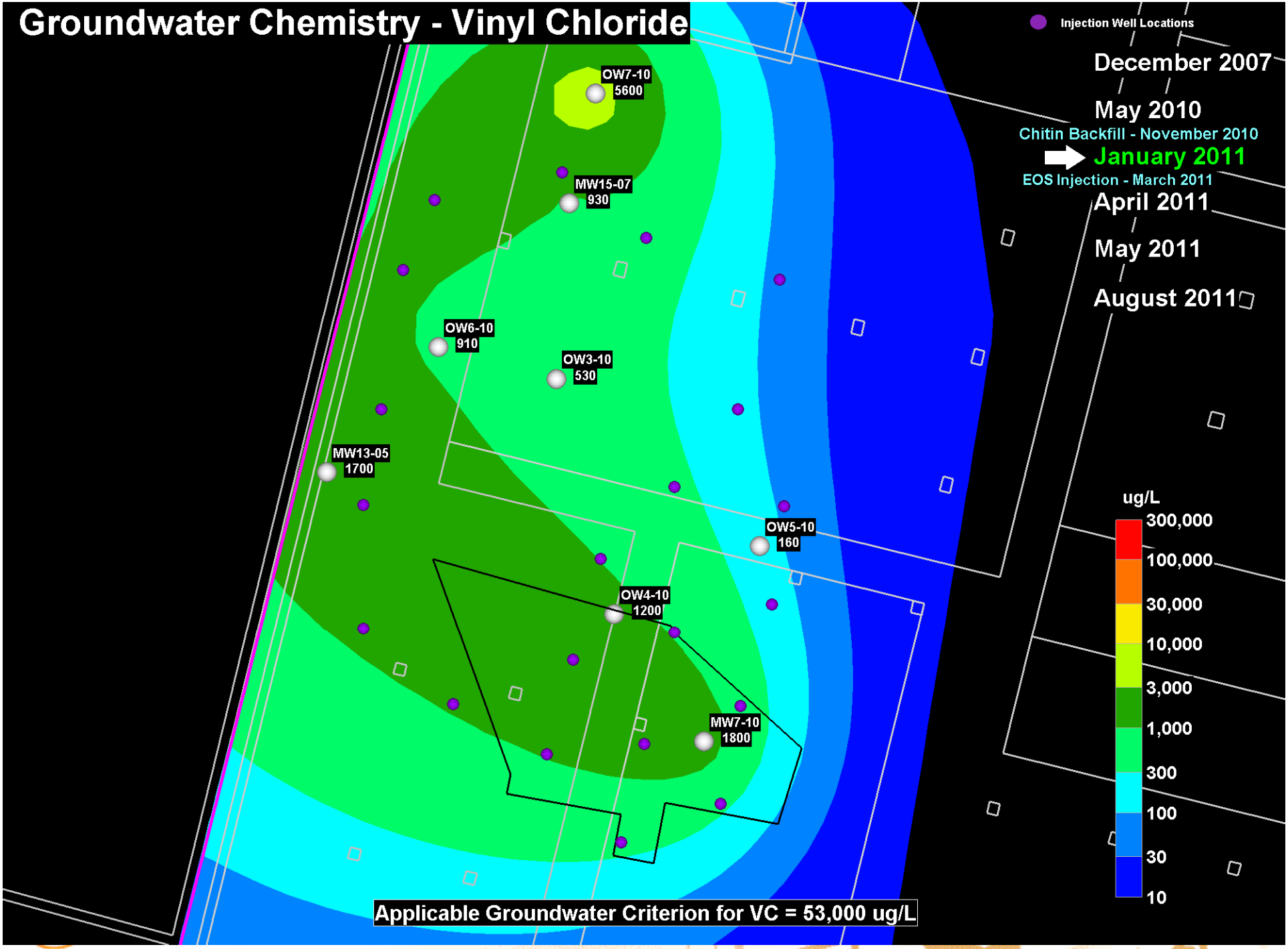
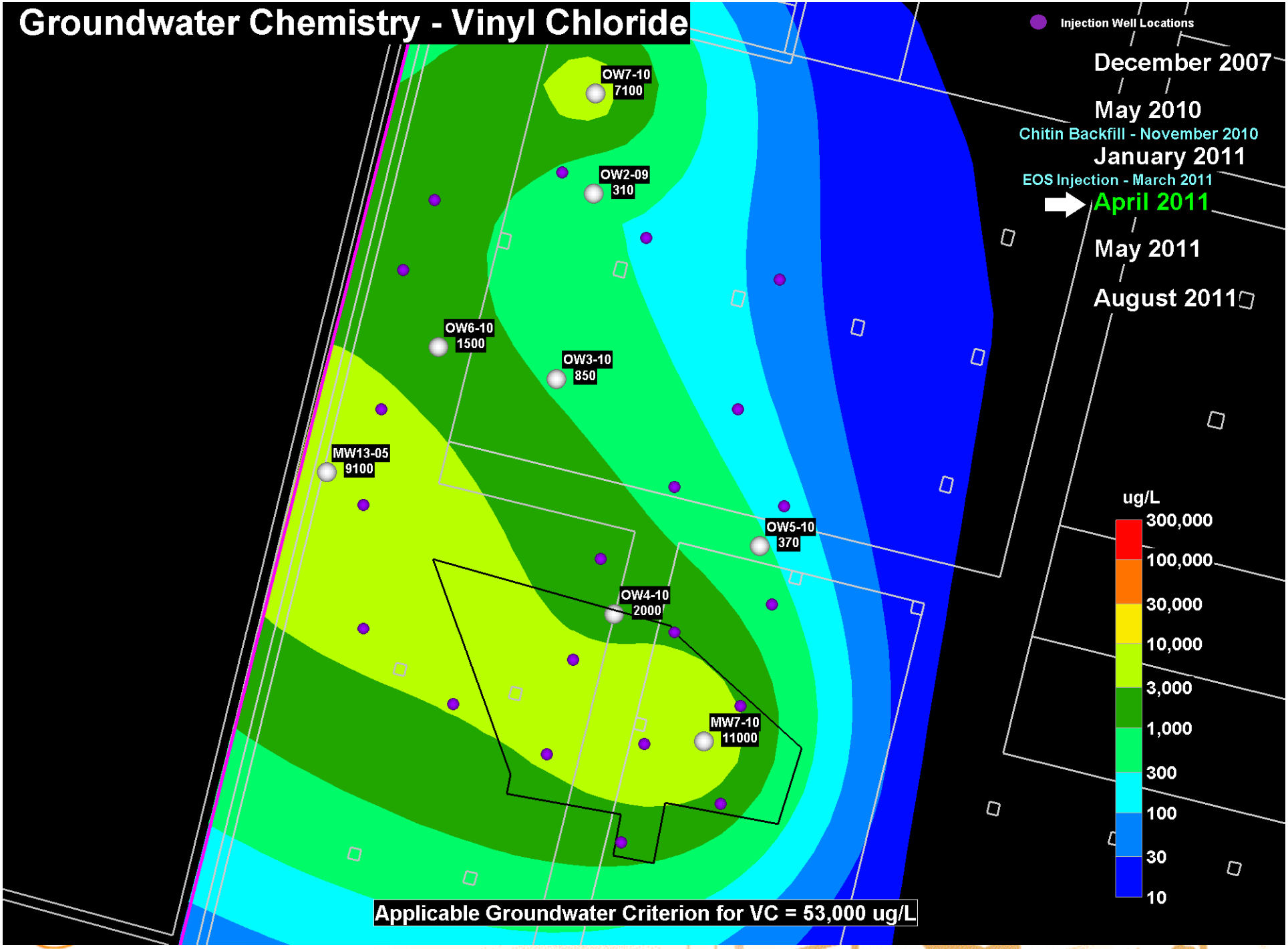
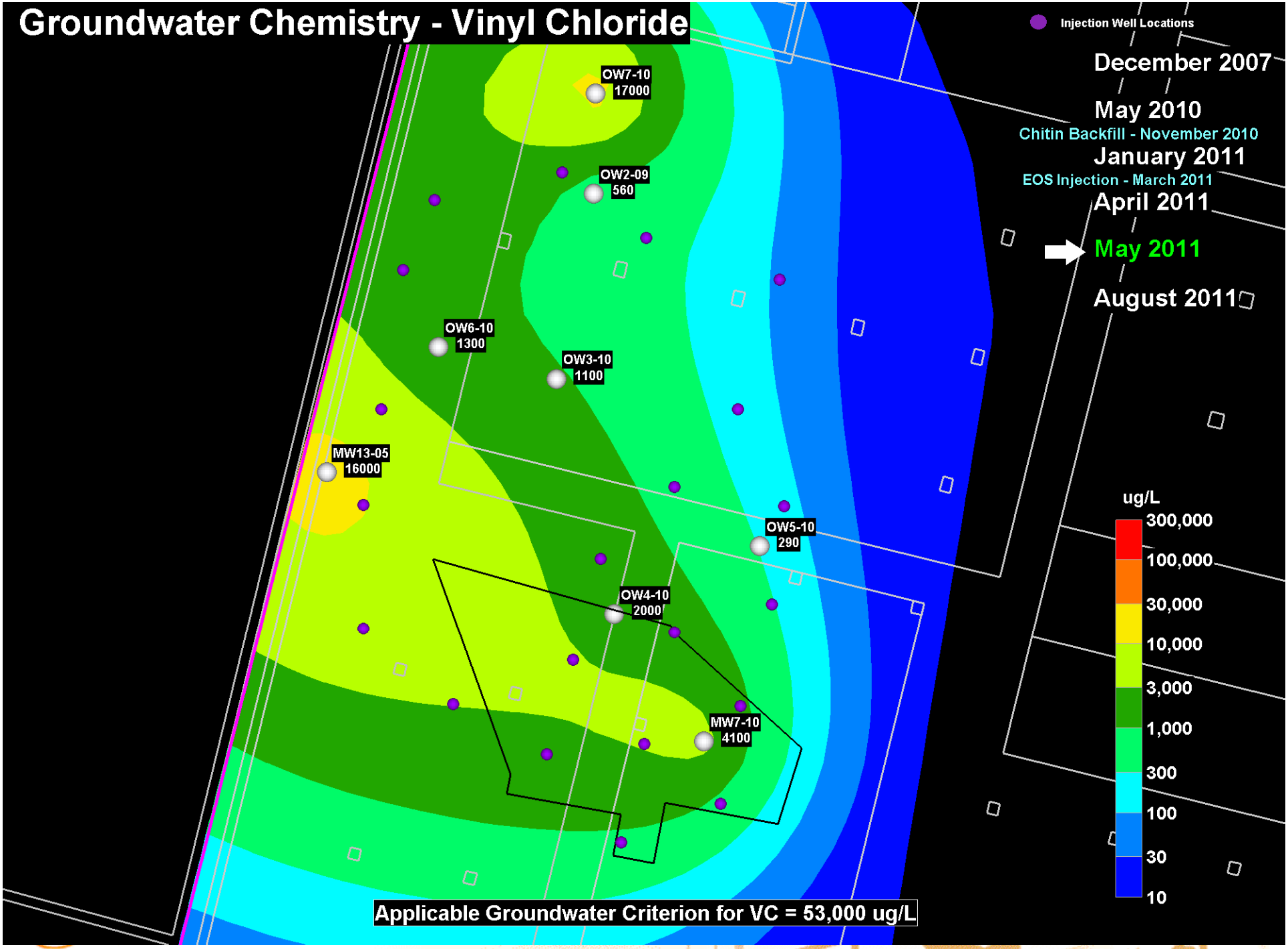
August 2011
OW7-10
16000
OW2-09
7200
OW6-10
160000
OW3-10
500
MW13-05
34000
OW5-10
5
OW4-10
270
MW7-10
3100
ug/L
300,000
100,000
30,000
10,000
3,000
1,000
300
100
30
10
Applicable Groundwater Criterion for cis-1,2-DCE = 30,000 ug/L

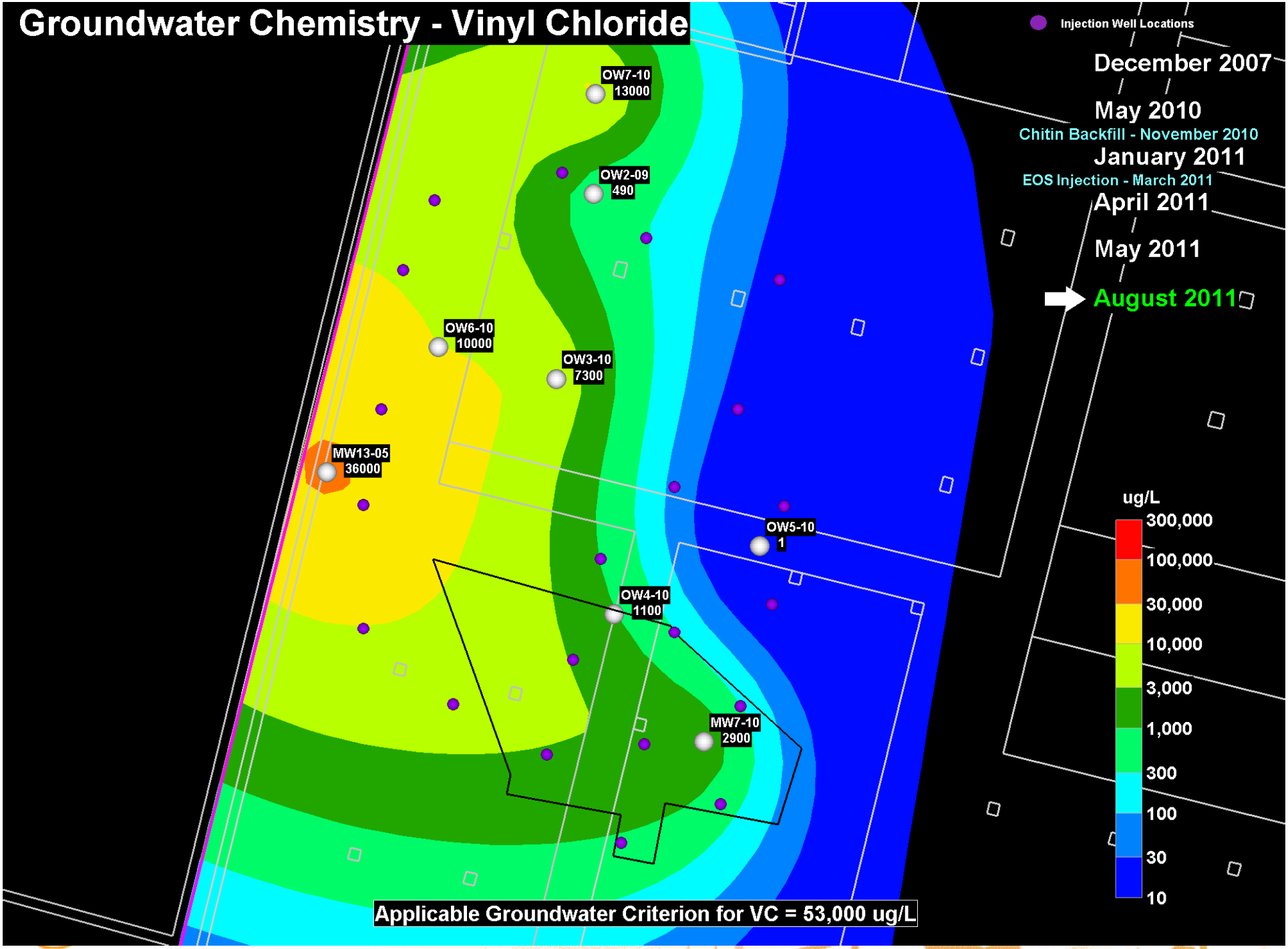

Groundwater Chemistry - Vinyl Chloride
December 2007
May 2010
Chitin Backfill - November 2010
January 2011
EOS Injection - March 2011
April 2011
May 2011
August 2011
MW15-07
510
MW13-05
1500
MW7-10
890
ug/L
300,000
100,000
30,000
10,000
3,000
1,000
300
100
30
10
Applicable Groundwater Criterion for VC = 53,000 ug/L


Groundwater Chemistry - Vinyl Chloride
December 2007
May 2010
Chitin Backfill - November 2010
January 2011
EOS Injection - March 2011
April 2011
May 2011
August 2011
OW2-09
MW15-07
6800
<800
MW13-05
1600
MW7-10
340
ug/L
300,000
100,000
30,000
10,000
3,000
1,000
300
100
30
10
Applicable Groundwater Criterion for VC = 53,000 ug/L


Groundwater Chemistry - Vinyl Chloride
Injection Well Locations
December 2007
May 2010
Chitin Backfill - November 2010
January 2011
EOS Injection - March 2011
April 2011
May 2011
August 2011
OW7-10
5600
MW15-07
930
OW6-10
910
OW3-10
530
MW13-05
1700
OW5-10
160
OW4-10
1200
MW7-10
1800
ug/L
300,000
100,000
30,000
10,000
3,000
1,000
300
100
30
10
Applicable Groundwater Criterion for VC = 53,000 ug/L


Groundwater Chemistry - Vinyl Chloride
Injection Well Locations
December 2007
May 2010
Chitin Backfill - November 2010
January 2011
EOS Injection - March 2011
April 2011
May 2011
August 2011
OW7-10
7100
OW2-09
310
OW6-10
1500
OW3-10
850
MW13-05
9100
OW5-10
370
OW4-10
2000
MW7-10
11000
ug/L
300,000
100,000
30,000
10,000
3,000
1,000
300
100
30
10
Applicable Groundwater Criterion for VC = 53,000 ug/L

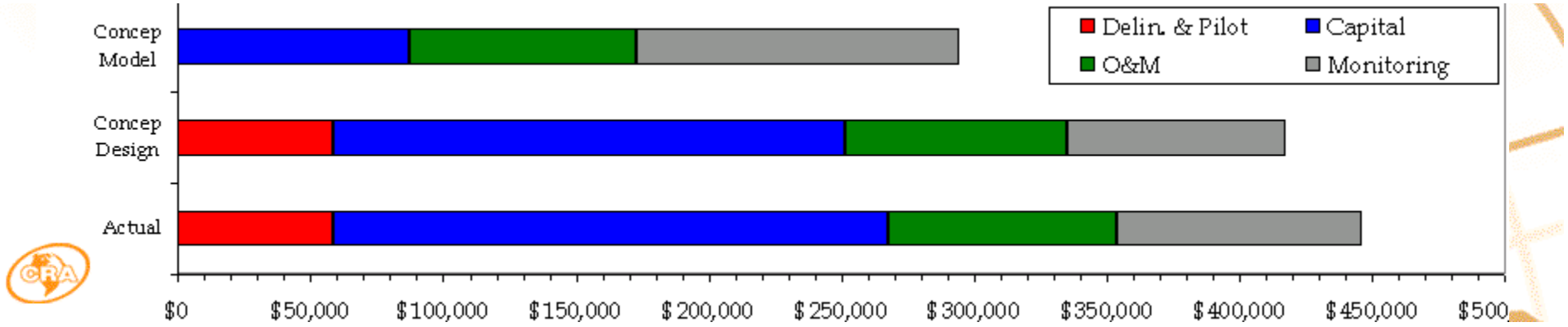

Groundwater Chemistry - Vinyl Chloride
Injection Well Locations
December 2007
May 2010
Chitin Backfill - November 2010
January 2011
EOS Injection - March 2011
April 2011
May 2011
August 2011
OW7-10
17000
OW2-09
560
OW6-10
1300
OW3-10
1100
MW13-05
16000
OW5-10
290
OW4-10
2000
MW7-10
4100
ug/L
300,000
100,000
30,000
10,000
3,000
1,000
300
100
30
10
Applicable Groundwater Criterion for VC = 53,000 ug/L


Groundwater Chemistry - Vinyl Chloride
Injection Well Locations
December 2007
May 2010
Chitin Backfill - November 2010
January 2011
EOS Injection - March 2011
April 2011
May 2011
August 2011
OW7-10
13000
OW2-09
490
OW6-10
10000
OW3-10
7300
MW13-05
36000
OW5-10
1
OW4-10
1100
MW7-10
2900
ug/L
300,000
100,000
30,000
10,000
3,000
1,000
300
100
30
10
Applicable Groundwater Criterion for VC = 53,000 ug/L

# TCE REMEDY COSTS RECAP

| Items (timelined events) | Date (mm/yyyy) | Cost Summary ($CAD, no taxes) | | | Total Costs $CAD (no taxes) | Comments (assumptions) |
|---|---|---|---|---|---|---|
| | | Capital | O&M | Monitoring | | |
| **Conceptual Model** | 01/2008 | $87,500 | $85,000 | $ 122,000 | **$294,500** | - 250m²<br>- 15 IWs<br>- 2-3 years O&M<br>- 3 MWs |
| Delineation Sampling & Pilot Test | 06-07/2009 | N/A | N/A | N/A | **$58,250** | - 17 sampling points<br>- 2 Ows & 1 IW<br>- 5 days testing/injection |
| **Conceptual Design** | 08/2009 | $193,000 | $84,000 | $ 82,000 | **$359,000** | - 730m²<br>- 20 IWs<br>- 3 years O&M<br>- 5 MWs |
| **Actual** | 04/2009 to 03/2011 | $209,300 | $86,150 | $ 92,300 | **$387,750** | - 730m²<br>- 20 IWs<br>- 3 years O&M<br>- 9 MWs |
| | | | ***(note 1)*** | | | |

***(note 1)*** - ***Second injection with same injection quantities & costs - if required***



# RemTech 2011

## *IN-SITU* BIOREMEDIATION OF CHLORINATED SOLVENTS

## - A CASE STUDY -

## Q & A

Thank you

**Presented by: René Filion, Eng.**

CONESTOGA-ROVERS & ASSOCIATES