Headquarters U.S. Air Force

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OU5 (Sites SS083 and FT082) Hydrus Model Development Process

Former George Air Force Base
September 2017
Sacramento, CA

ED_003054_00003449-00001

Overview

- OU5—Chlorinated hydrocarbons; TCE primary COC
  - Vadose soil zone contamination managed in SS083 and FT082
  - Groundwater managed in OT069e (OU3) and CG070 (OU1)
- 3D data analysis and modeling process (SS083 example)
- SS083 and FT082 water level and TCE concentration time-series data analysis
- Hydrus flow and transport models
  - Objective: Establish soil clean-up goals for the OU5 sites
  - FT082 model
  - SS083 model

TCE Vapor Concentration in Equilibrium with Groundwater at 5 µg/L

- **Objective—Assuming equilibrium partitioning, determine vapor concentration that will result in groundwater concentrations >= 5 µg/L**

?? ppbv

5 µg/L

$$TCE_{GW} = 5\frac{\mu g}{L_w}$$

$$TCE_{Vapor} = 5\frac{\mu g}{L_w} * 0.42 = 2.1\ \mu g/L_{vapor}$$

$$TCE_{Vapor} = \frac{2.1\ \mu g}{L_{vapor}} * \frac{1\ ppbv}{0.0055\frac{\mu g}{L_{vapor}}} = 381\ ppbv$$

$$Round\ down\ to\ 350\ ppv\ for\ modeling$$

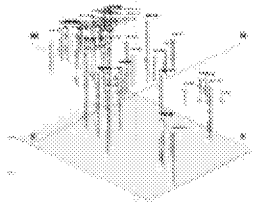
where

- 0.42 = unitless Henry's constant
- 0.0055 vapor conversion from ug/L_v to ppbv

3D Data Modeling Process

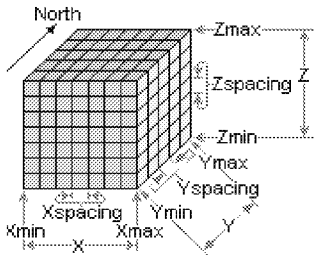
Compile data into 3D database

- Boring logs, analytical data, etc.



Construct 3D volumetric "cube"

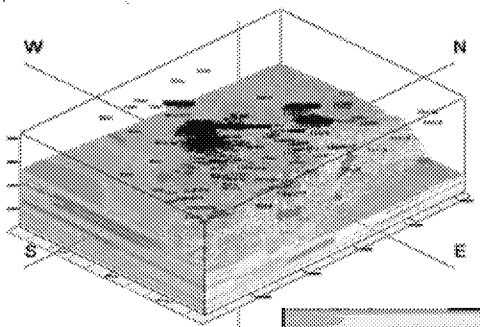
- 3D data gridding (various methods)



Integrate existing surfaces

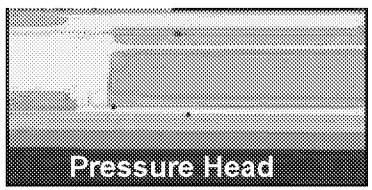
- Topography, water level elevations, structural surfaces, etc.

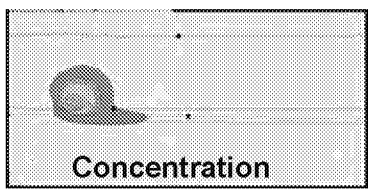
Final 3D "cubes"



Generate maps and cross-sections

HYDRUS 2D Model

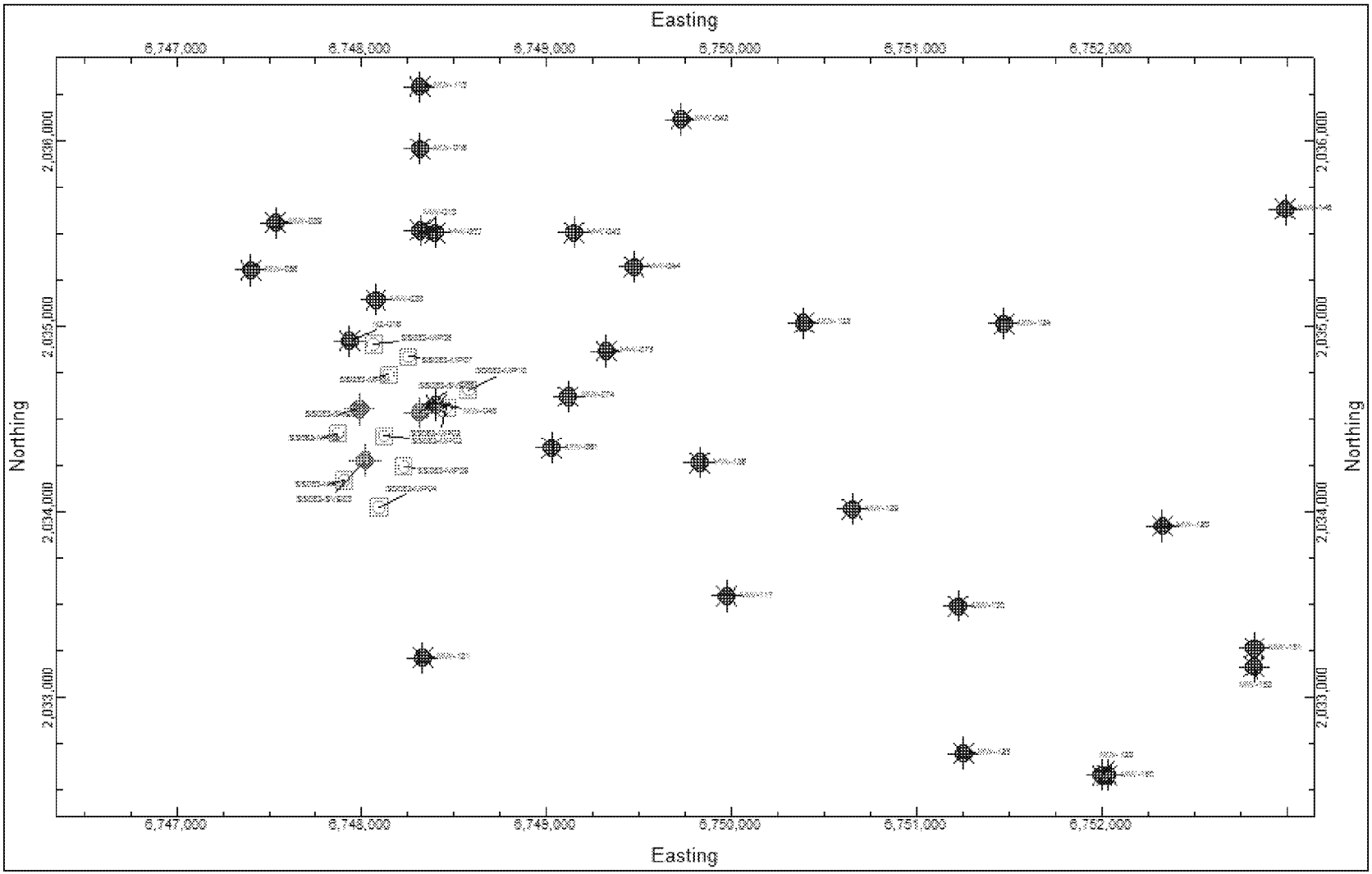




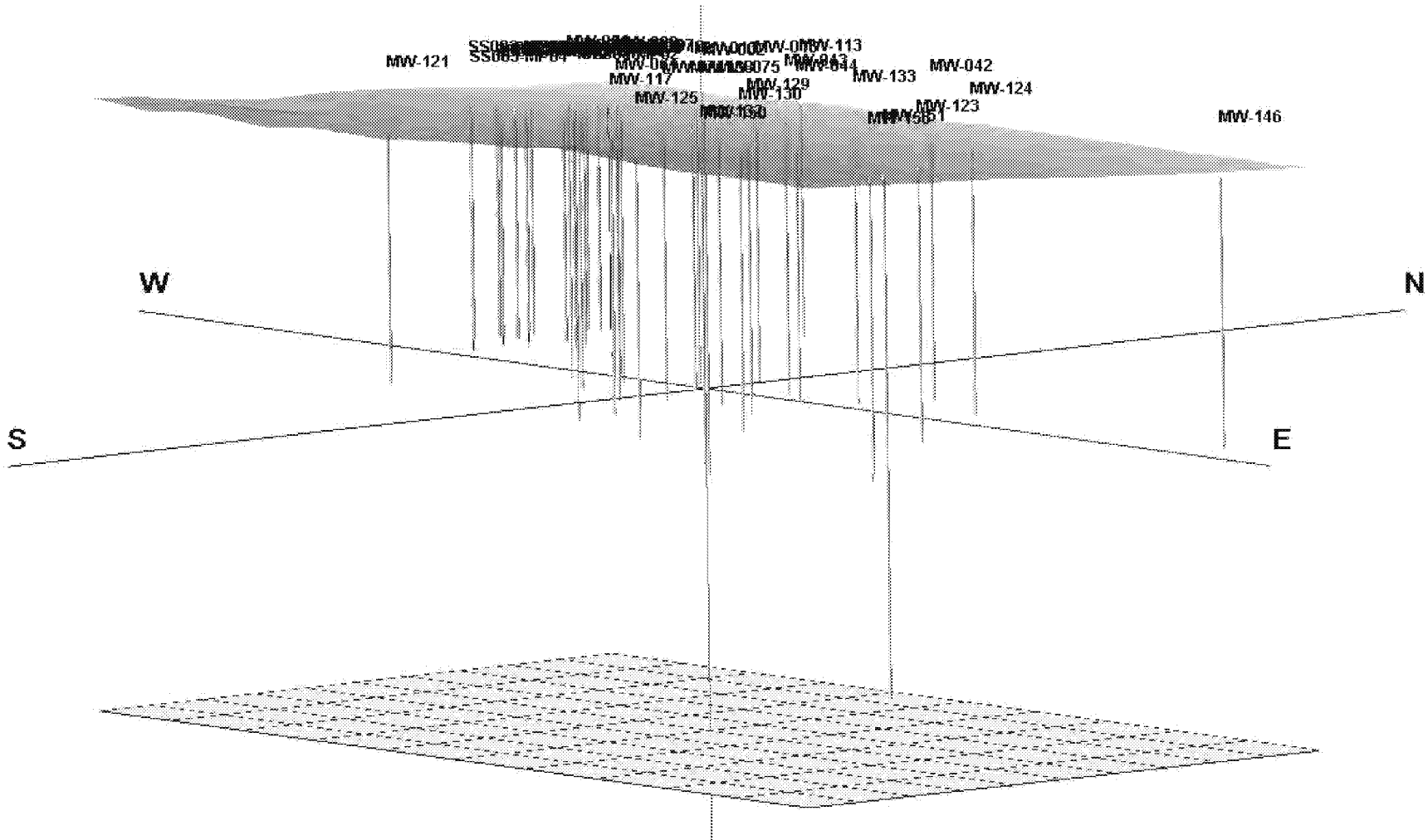
3D Data Modeling and Checking

- Define the model area
- Develop local lithology data model
  - Finer grid spacing than site-wide lithology model
  - Typical 25’ x 25’ x 2’ (XYZ) for local model vs 50’ x 50’ x 5’ for site-wide model
- Extract Upper and Lower Aquifer water level surfaces from annual GIS maps
- Prepare model area groundwater and vapor concentration data for selected time period(s)
- Develop 3D vapor and groundwater concentration data models
  - Visualize data in 3D, check, and correct input data
  - 3D gridding—Typically use inverse-distance-weighting of log-transformed concentrations with weighting exponents of 2 horizontal and 4 to 6 vertical
  - Adjust model gridding parameters based on results
  - Add perimeter control points to remove 3D grid artifacts and add aquifer boundaries (e.g. bluff area)

Step 1a—Select Model Area and Wells (SS083)



Step 1b—3D Review of Wells



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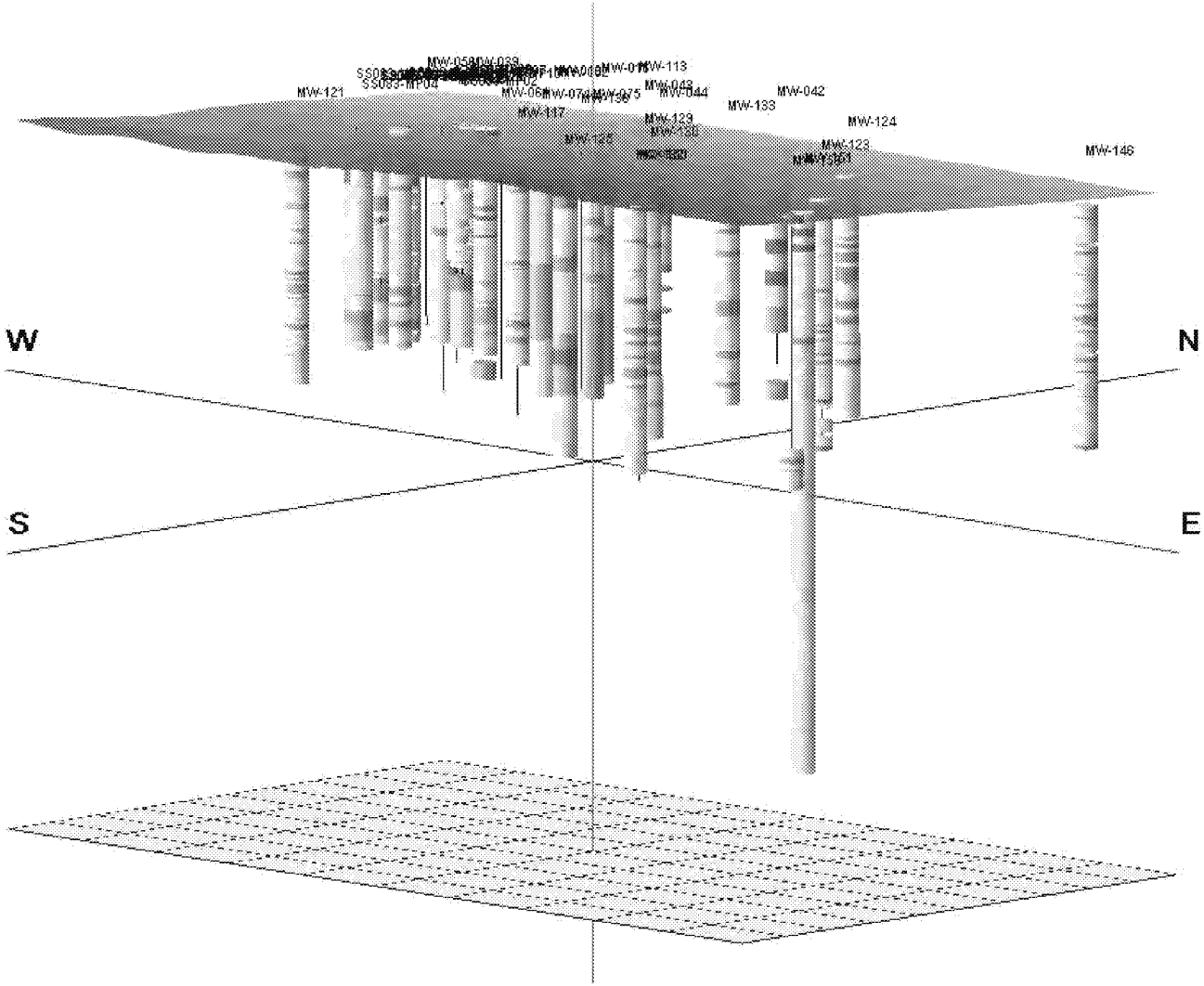
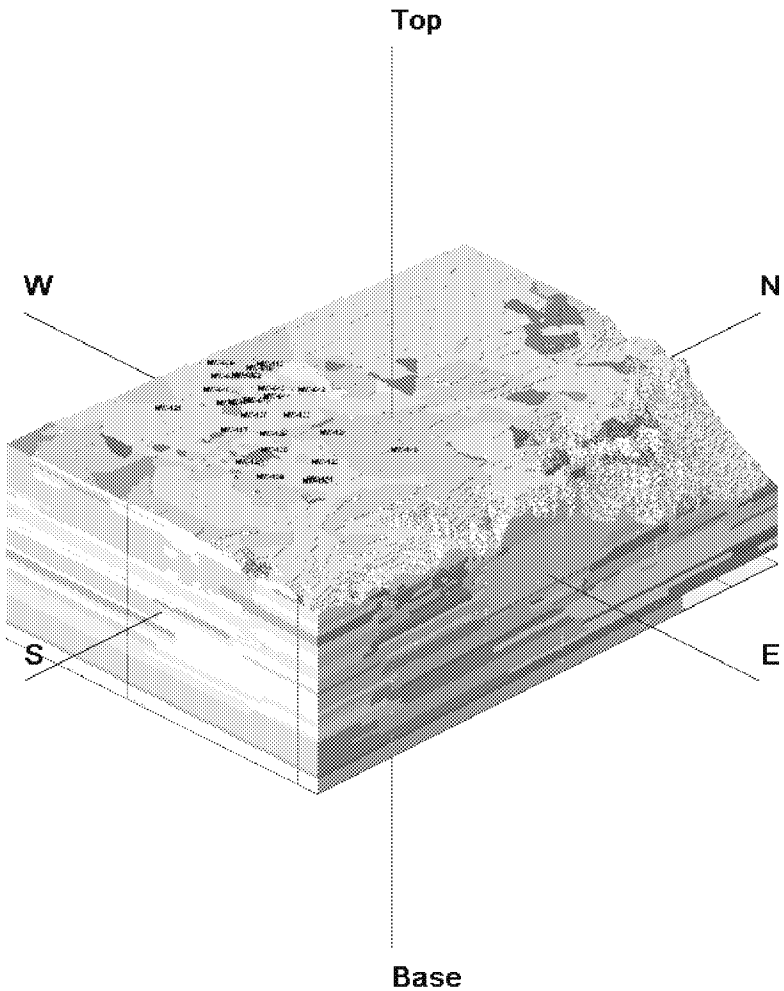
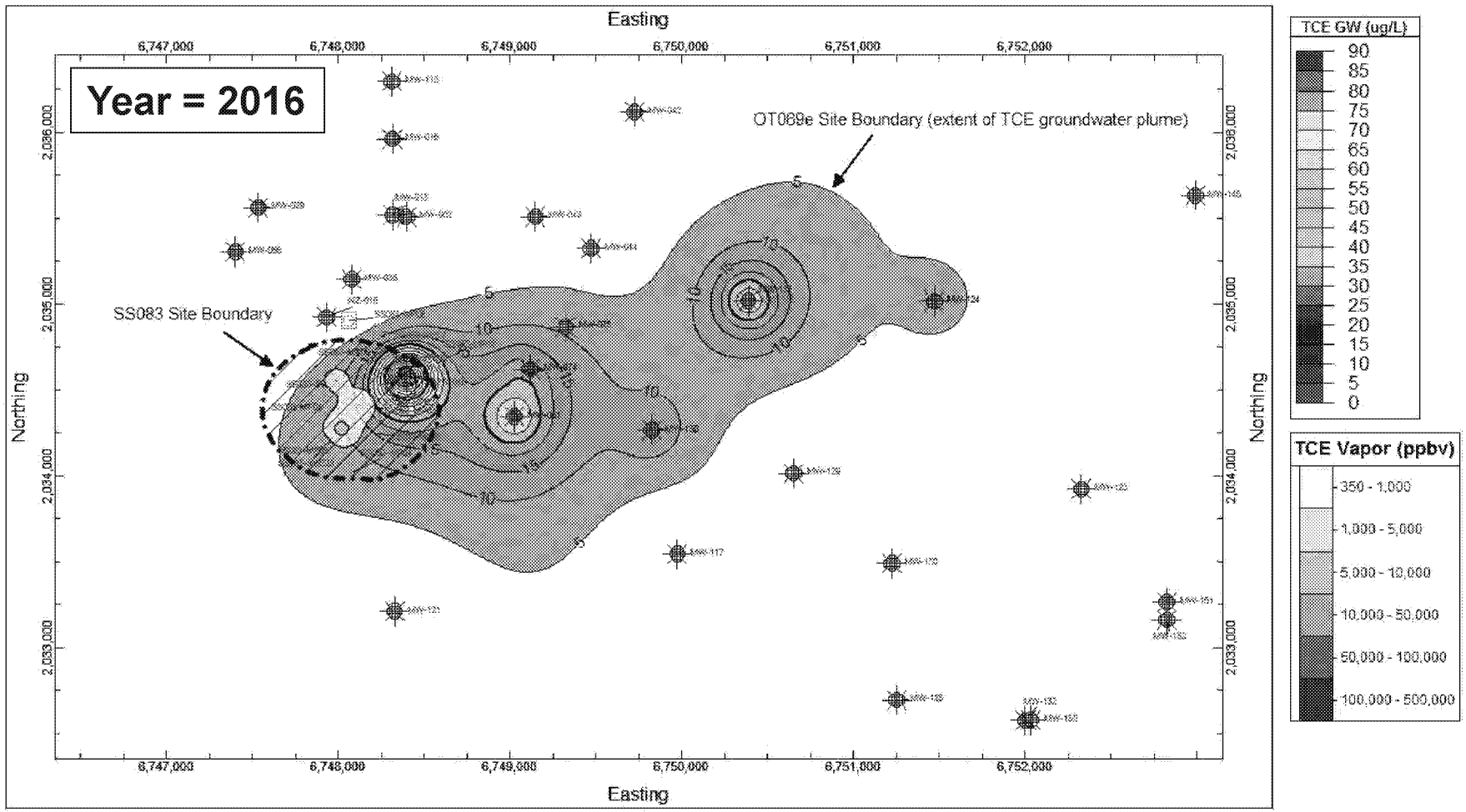
Step 2—Develop Local Lithology Model



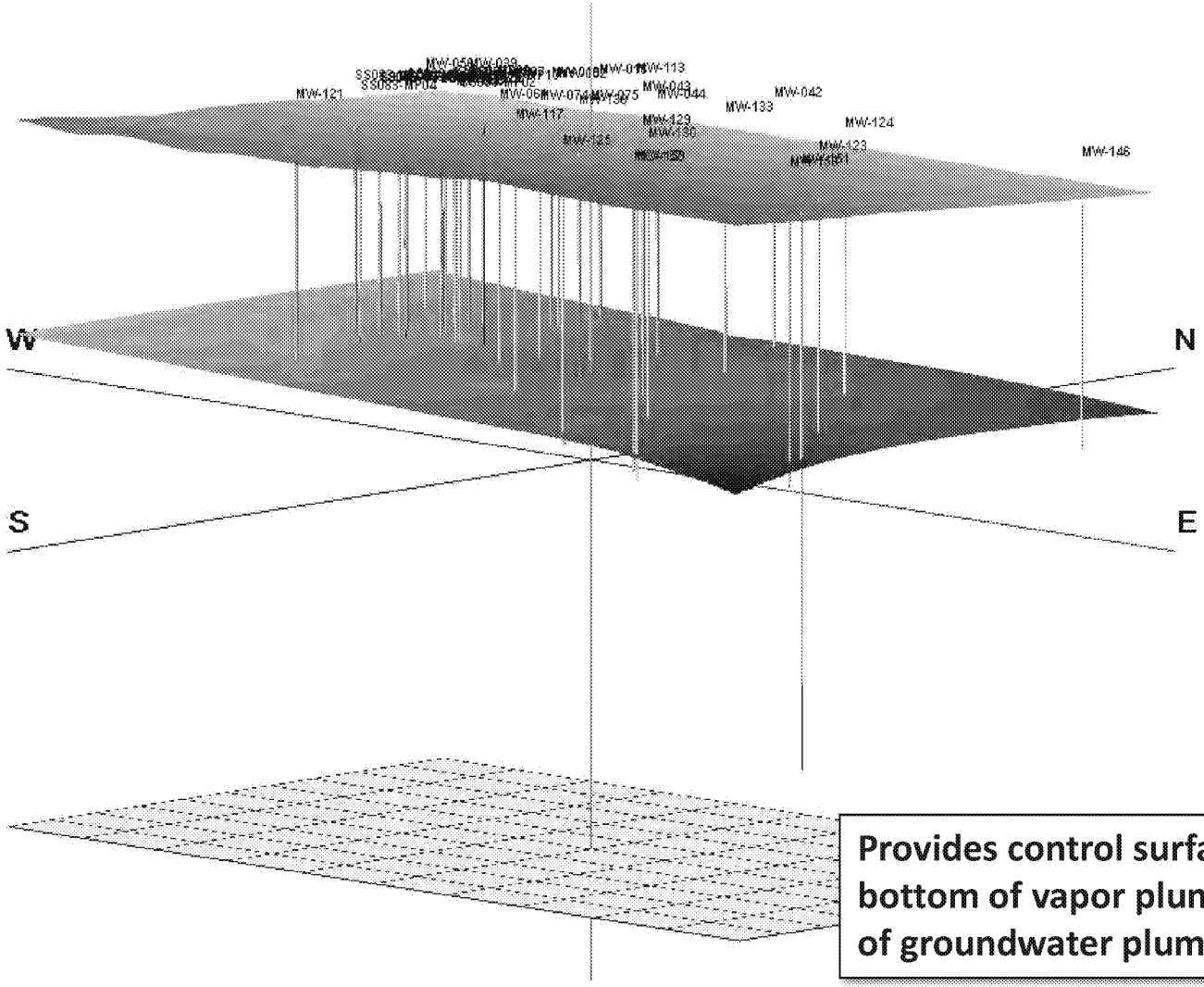
Example Local Lithology Model



Step 3—Evaluate Vapor and Groundwater Plumes

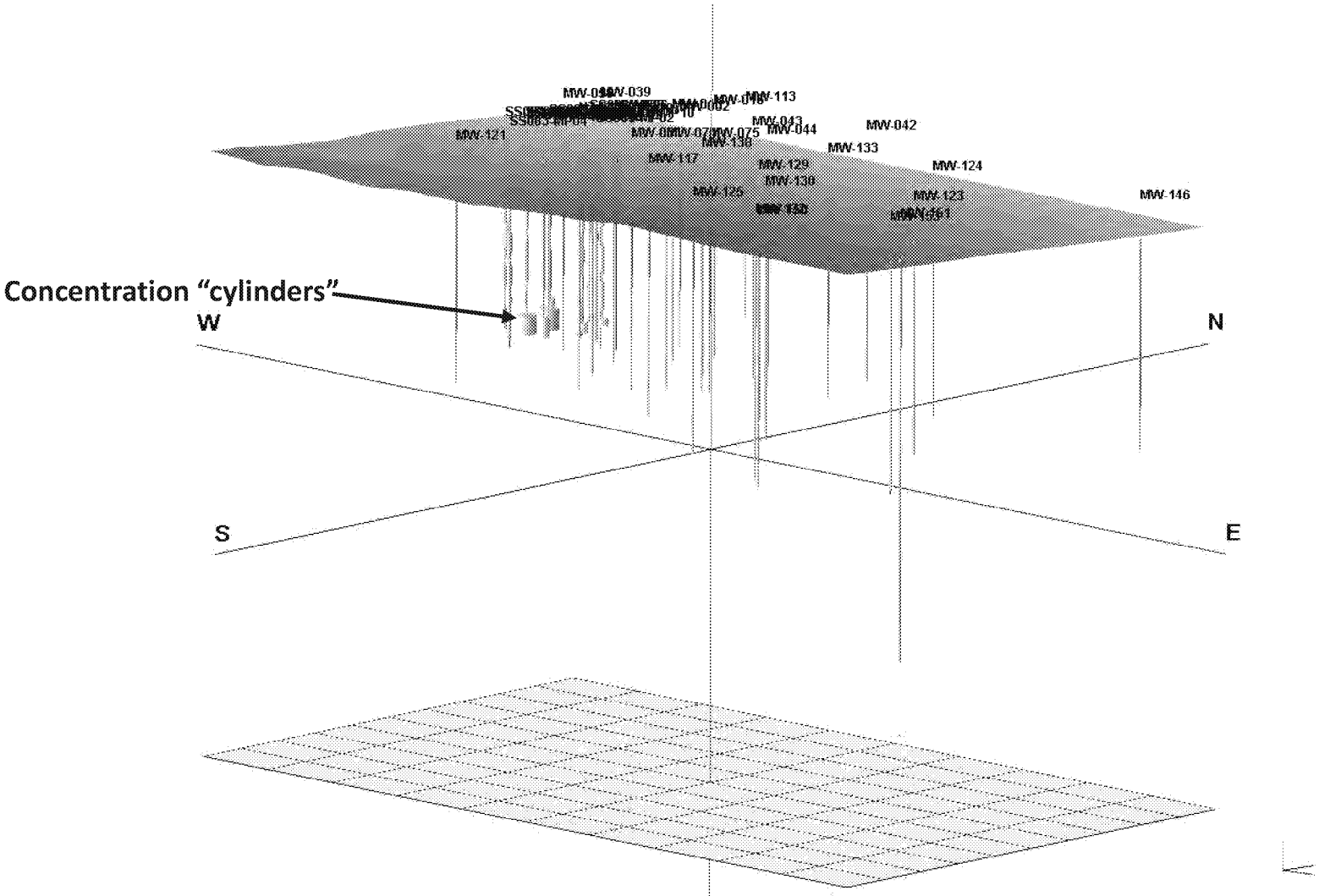


Step 4—Import Upper Aquifer Water Table Map

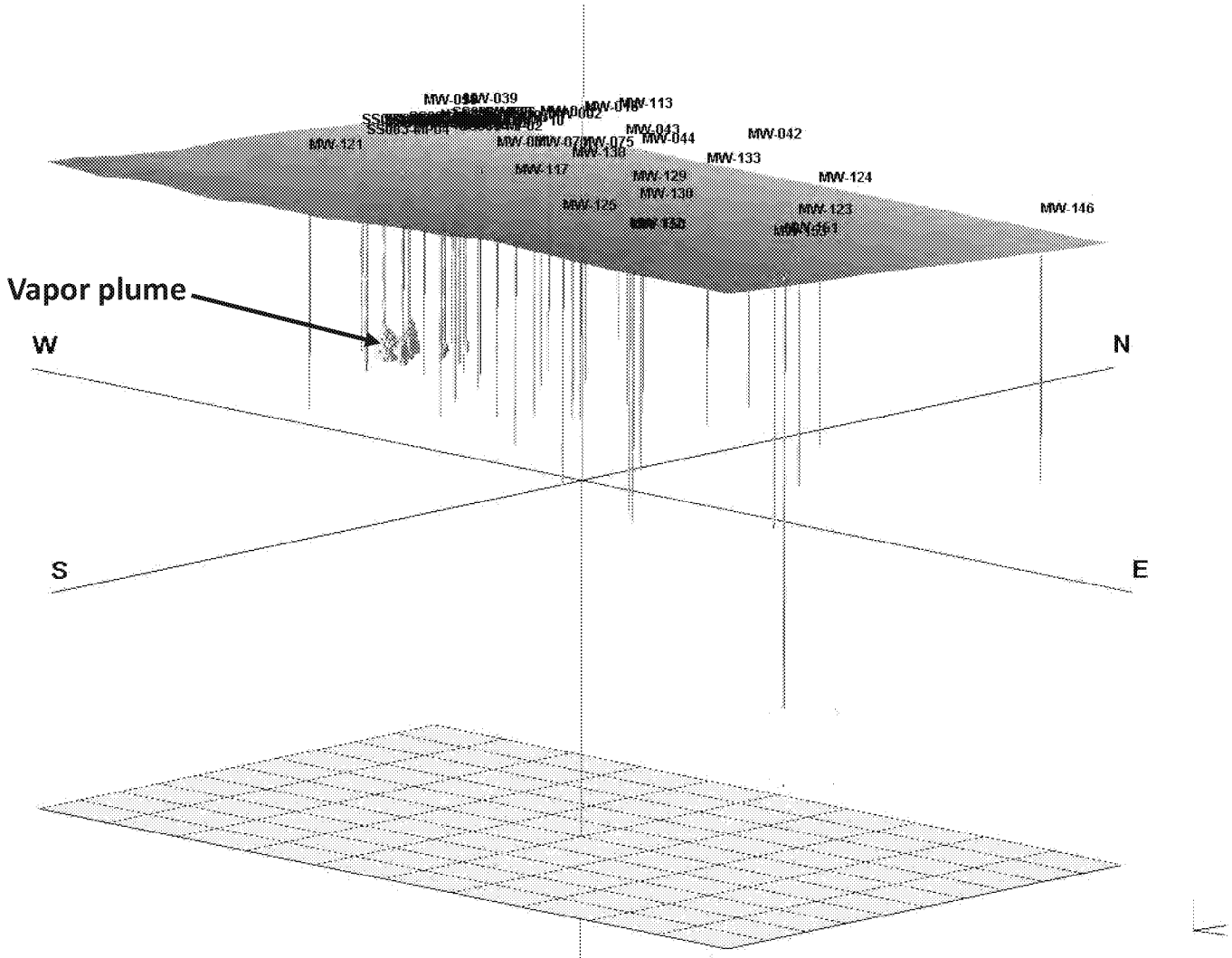


Provides control surface for bottom of vapor plume and top of groundwater plume.

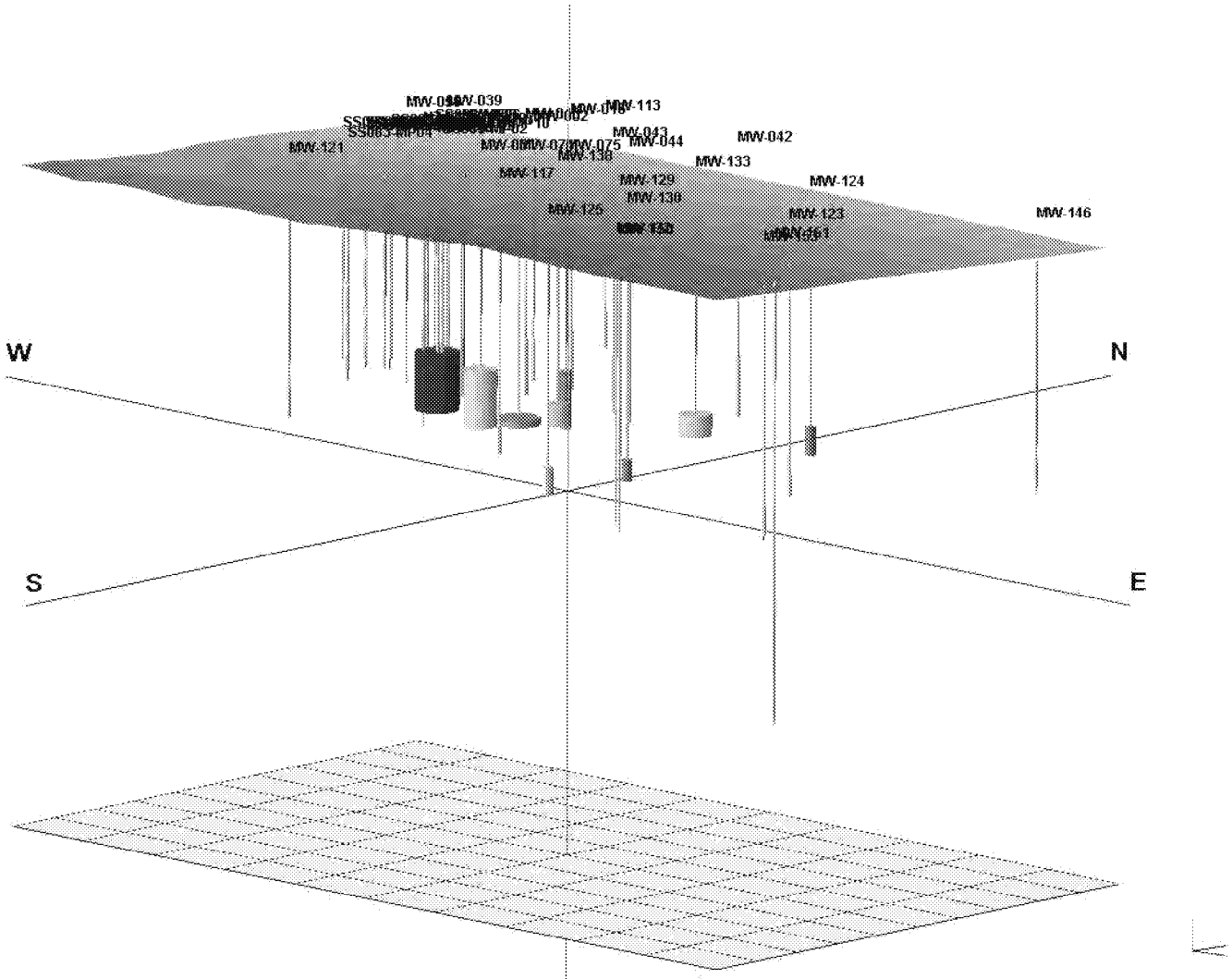
Step 5—Evaluate Vapor Data and Develop 3D Vapor Model



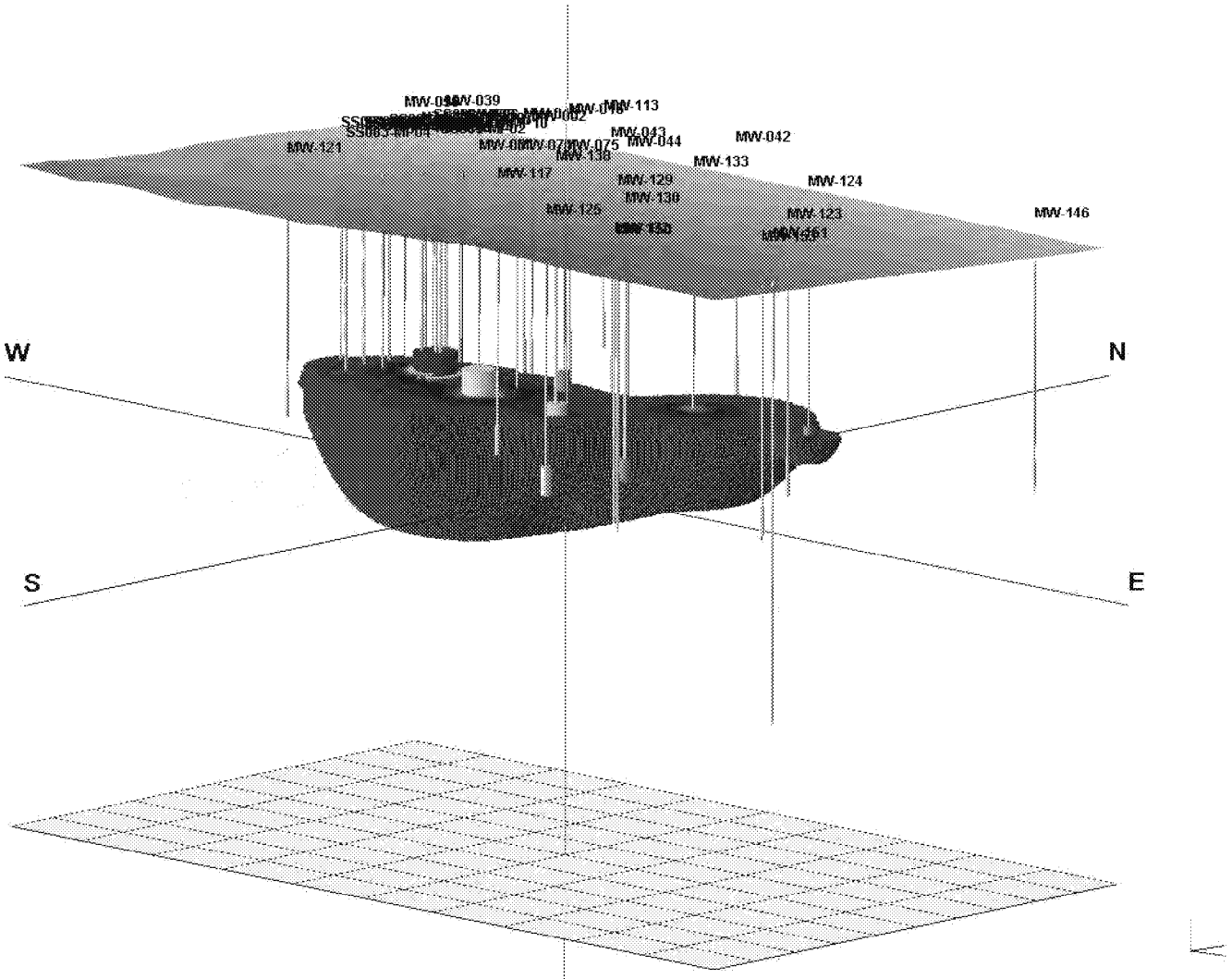
SS083 TCE Vapor Model (Conc. > 350 ppbv)



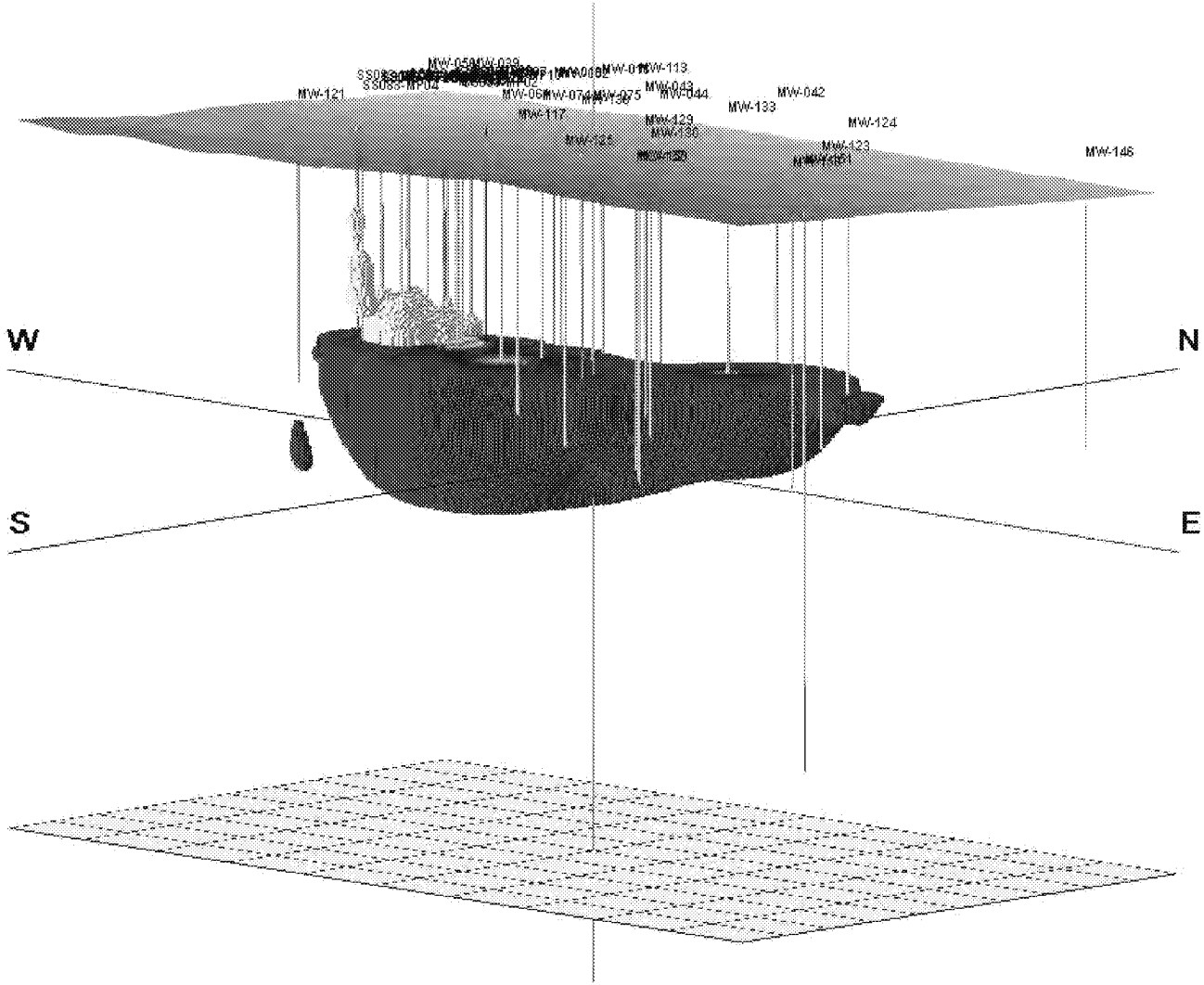
Step 6—Evaluate Data and Develop 3D Groundwater Plume



SS083 TCE Groundwater Plume (Conc. > 5 µg/L)



Step 7—Composite Multiple Features into 3D Data Model



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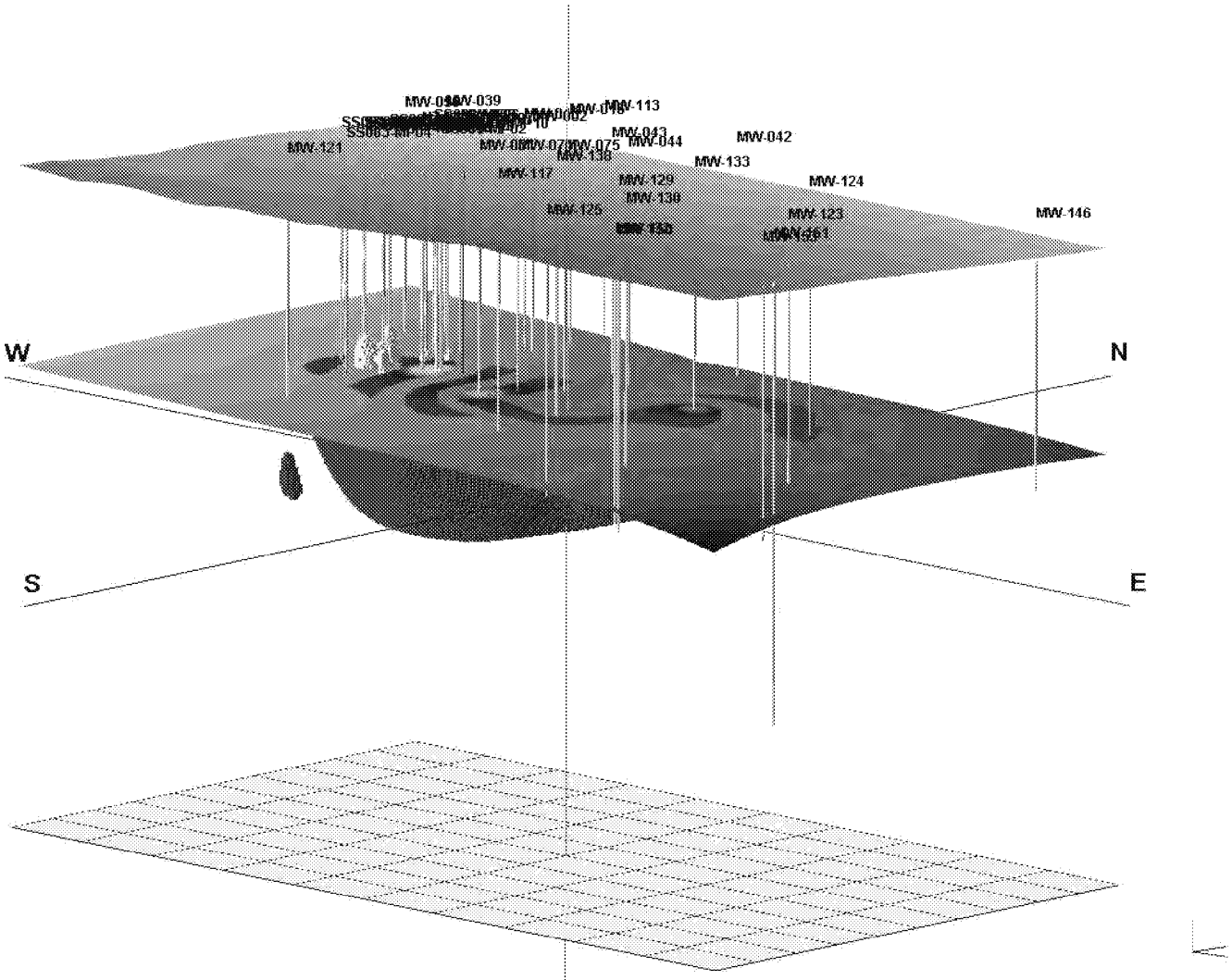
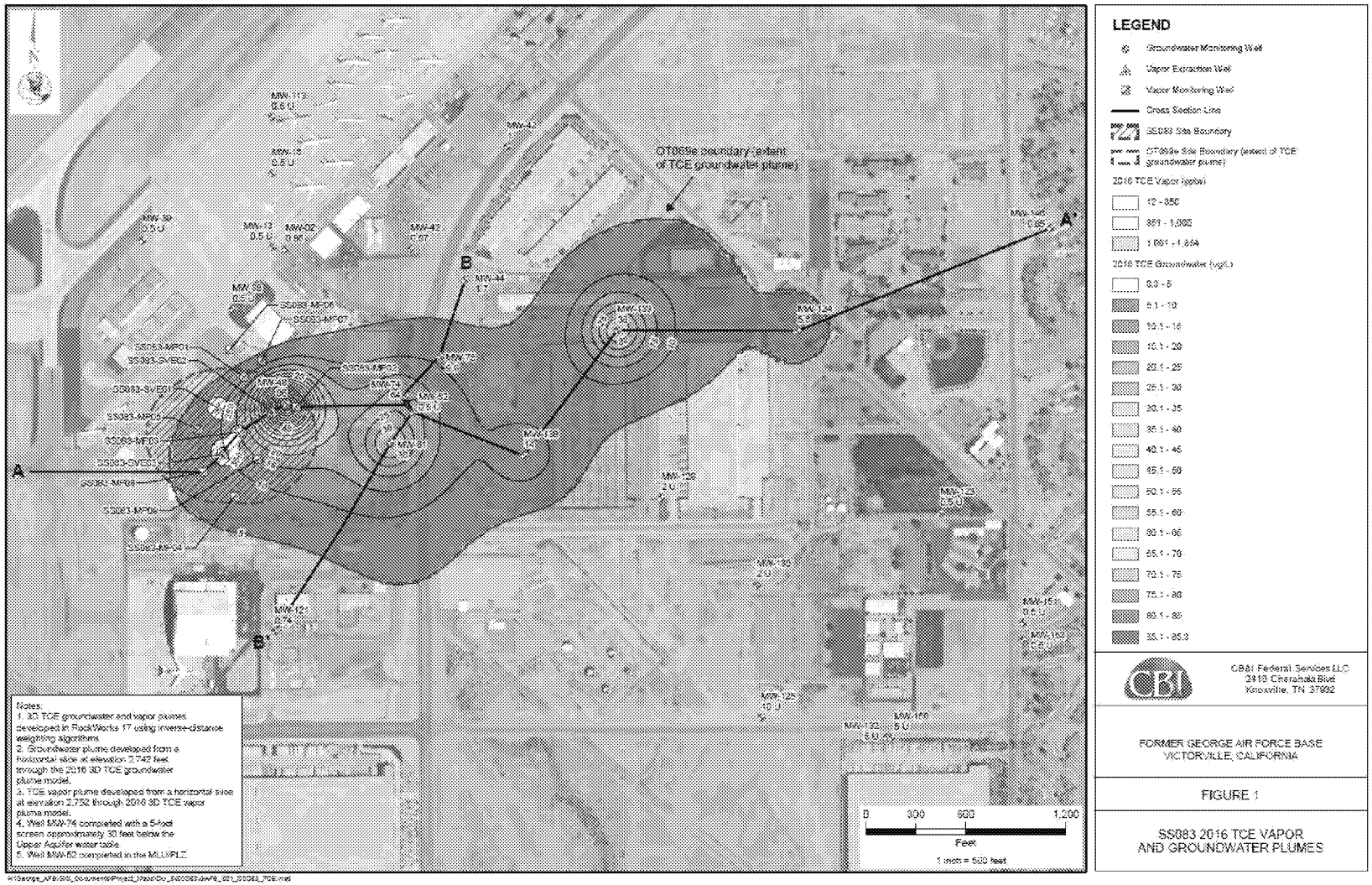


Plan Plume Maps—Horizontal Slice



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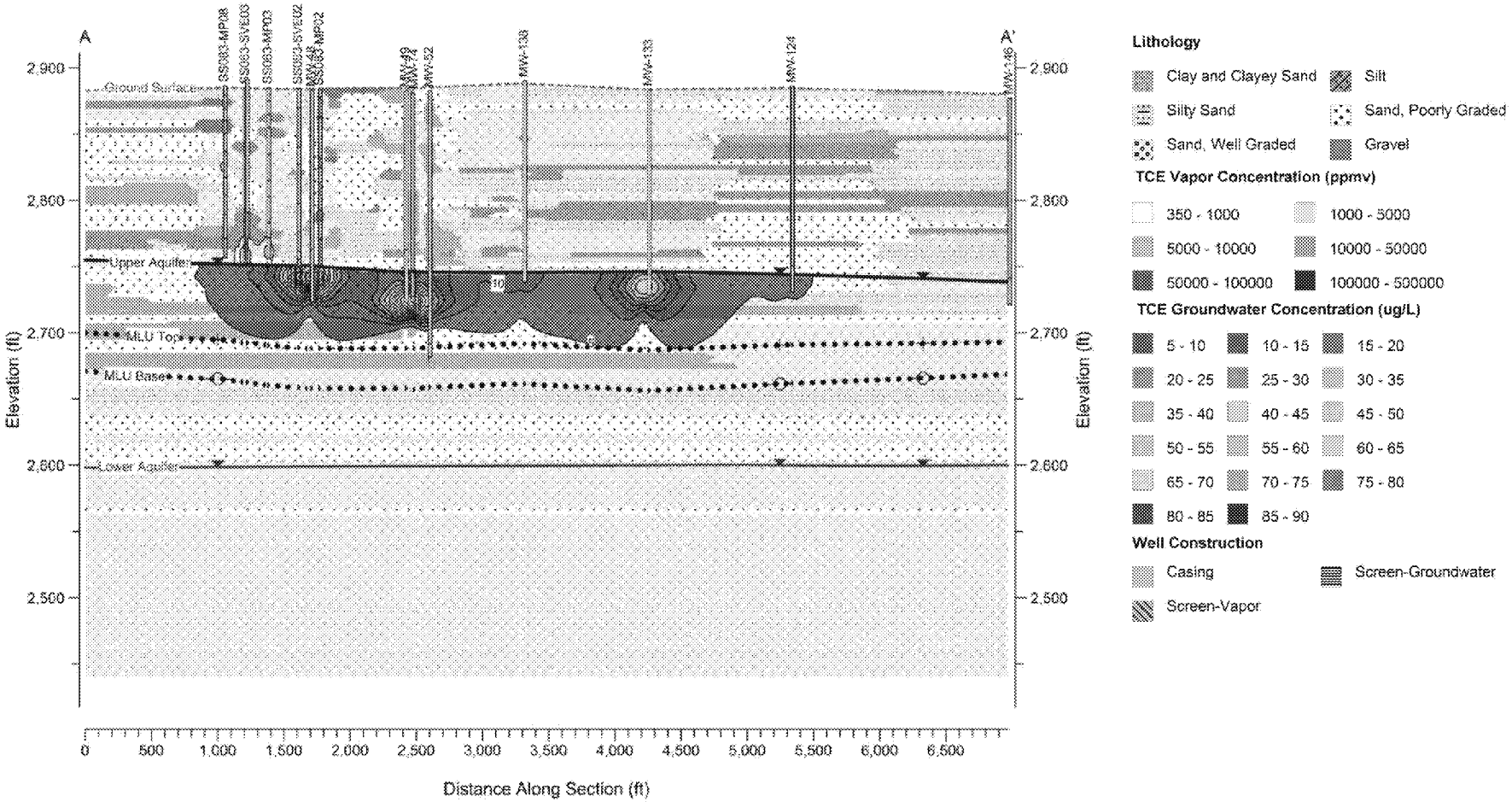
Plume Cross-Sections—Vertical Slice



SS083
3D Plume Animation

Review Results in 3D to Understand Hydrogeology and Select Hydrus Line

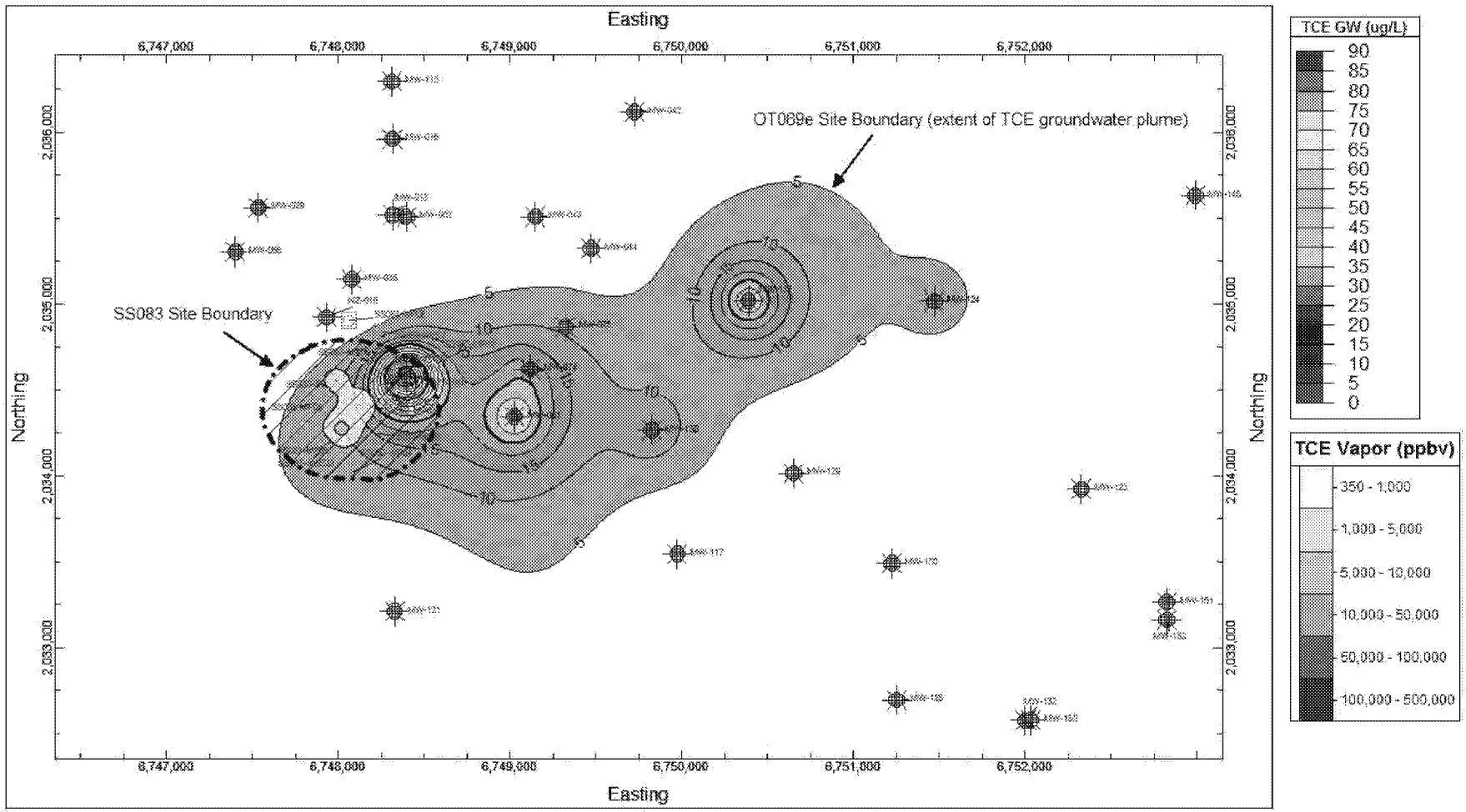
FT082
3D Plume Animation

Review Results in 3D to Understand Hydrogeology and Select Hydrus Line

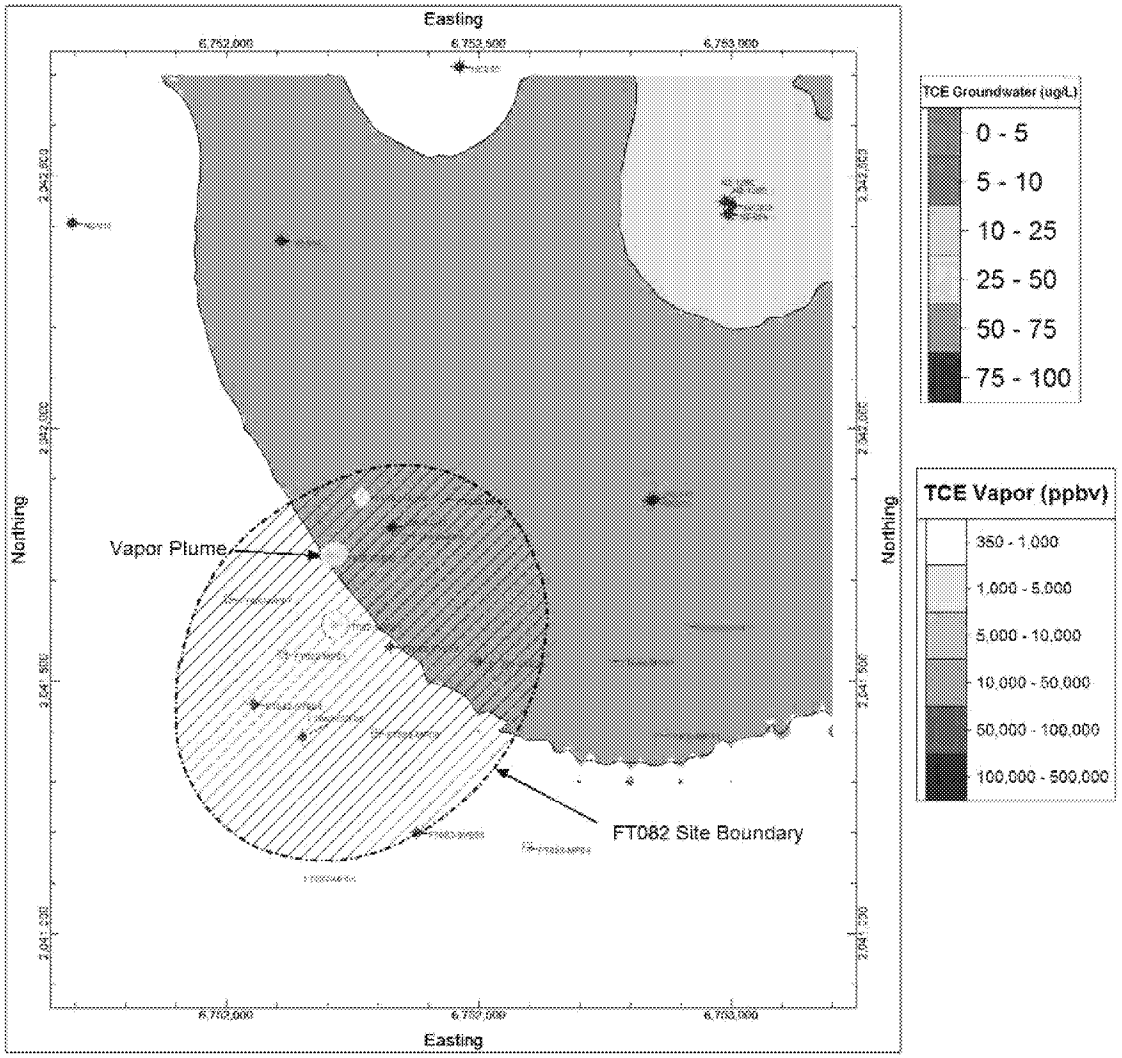
2016 FT082 and SS083 Vapor Concentrations

- SVE removed majority of vadose zone contaminant mass
- Most vapor concentrations less than 350 ppbv (water concentrations = 5 μg/L)
- Vapor plumes have small footprint

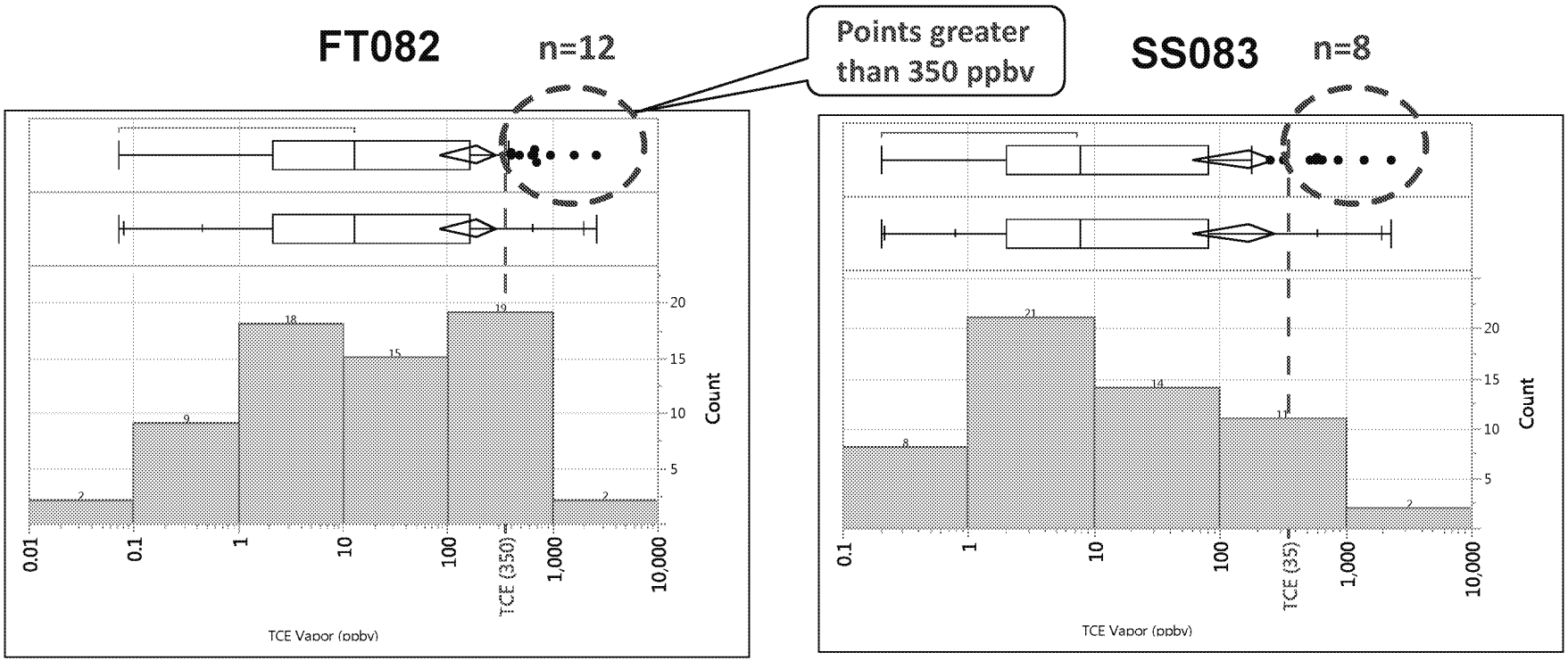
SS083 2016 TCE Vapor and Groundwater Plumes



FT082 2016 TCE Vapor and Groundwater Plumes



Histograms—2016 Vapor Concentrations

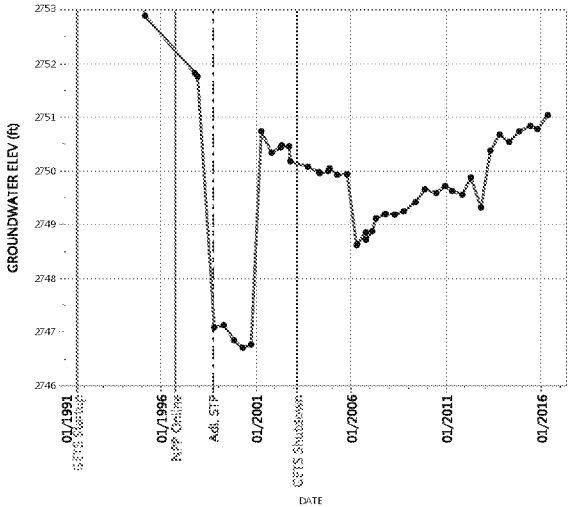


Summary Statistics—2016 Vapor Concentrations

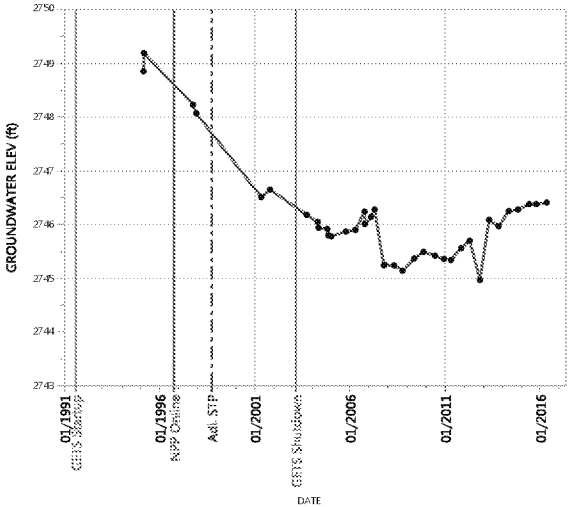
Statistic	FT082	SS083
Mean	186.1	166.4
Std Dev	413.9	393.6
Std Err Mean	51.3	52.6
Upper 95% Mean	288.7	271.8
Lower 95% Mean	83.6	61.0
N	65	56
Minimum	0.07	0.2
Maximum	2,600	2,300
Median	13.0	7.7
Geometric Mean	17.4	14.9
Range	2,600	2,300
Interquartile Range	157.8	80.0

SS083 Vapor and Groundwater Time-Series Analysis

SS083 Hydrographs



MW-48



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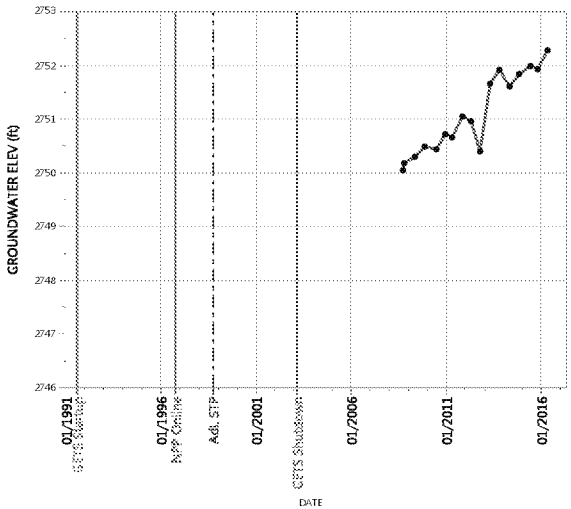

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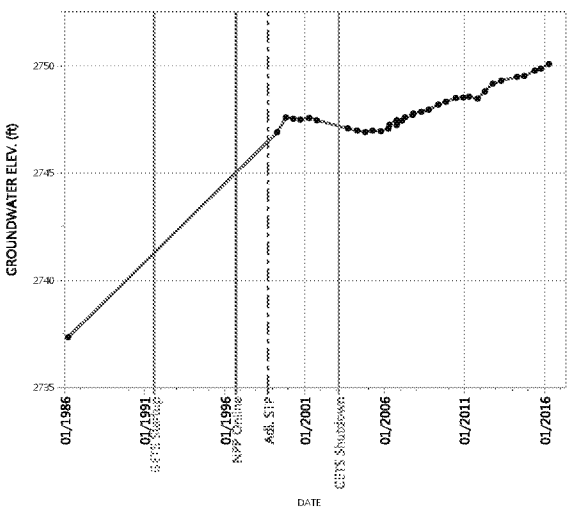
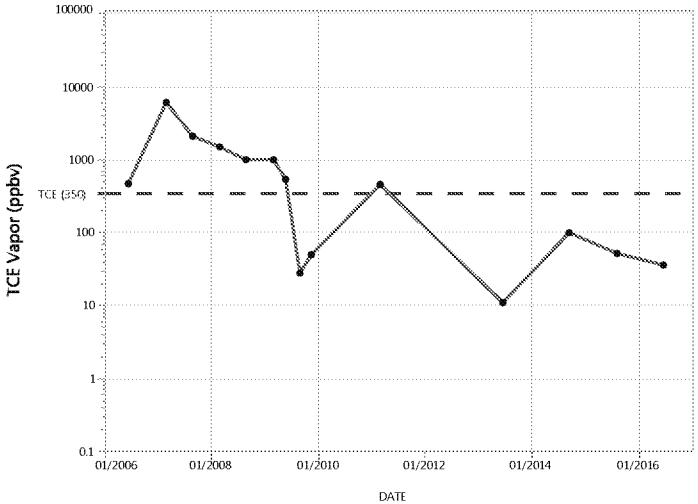
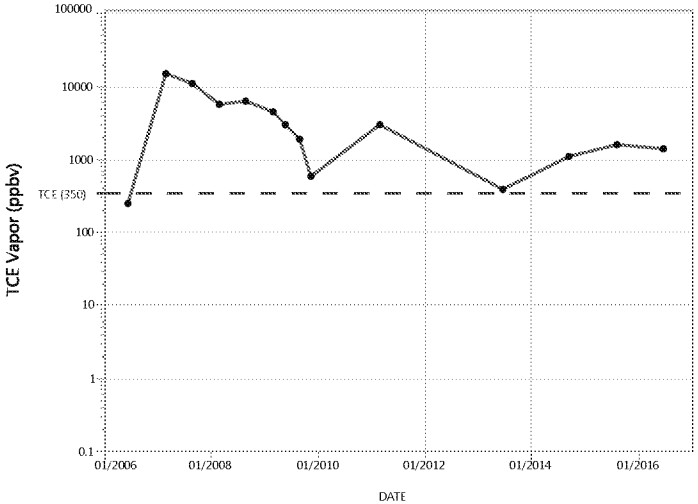


NZ-16

SS083 Vapor TCE Time-Series Data



SS083-MP03-102



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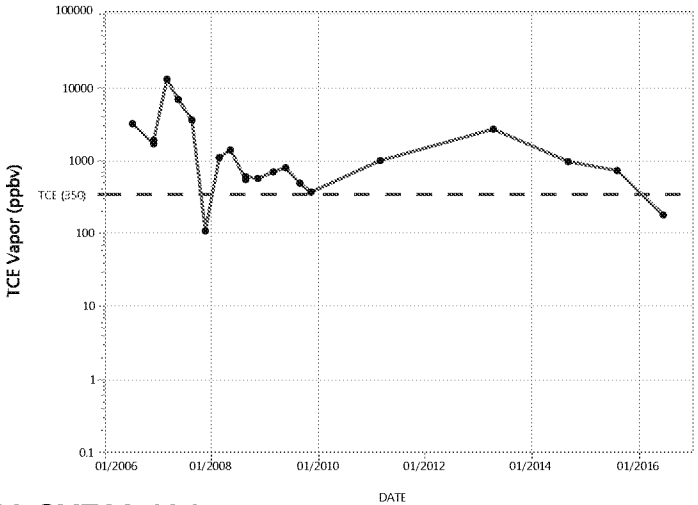

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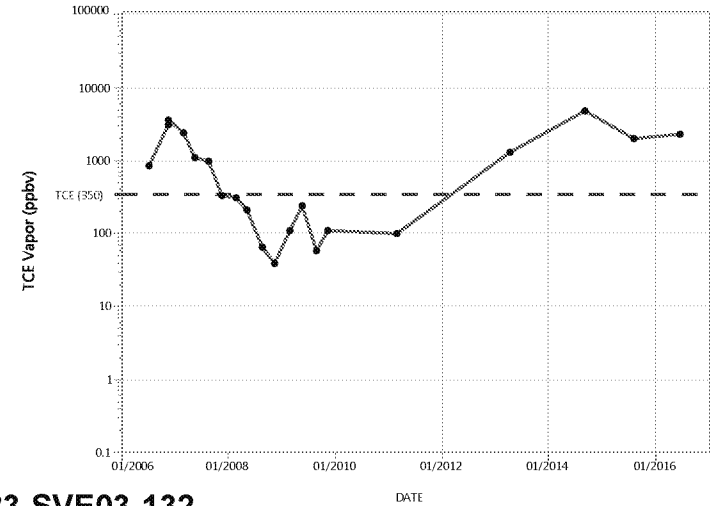
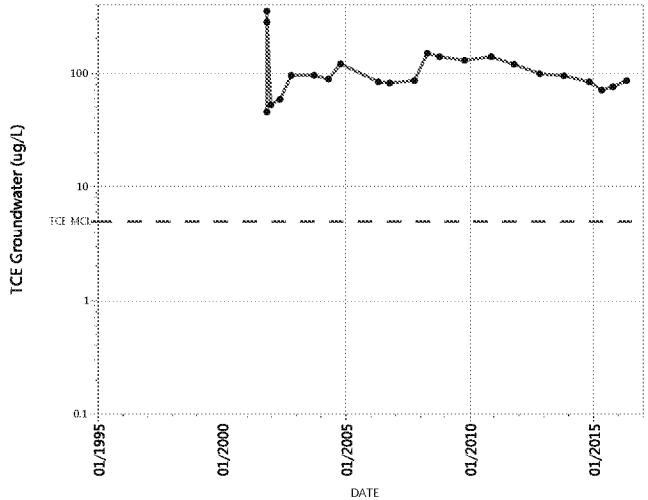


SS083-SVE03-132

SS083 Groundwater TCE Time-Series Data



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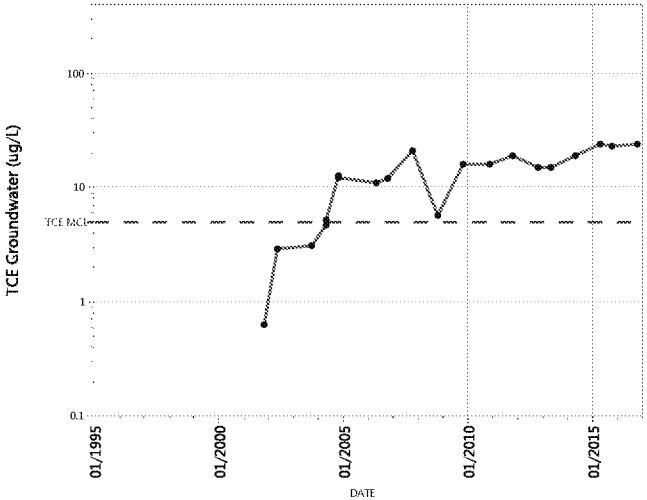

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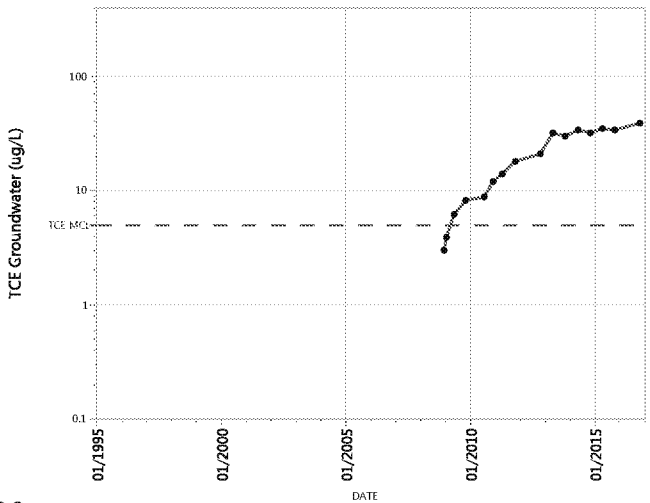

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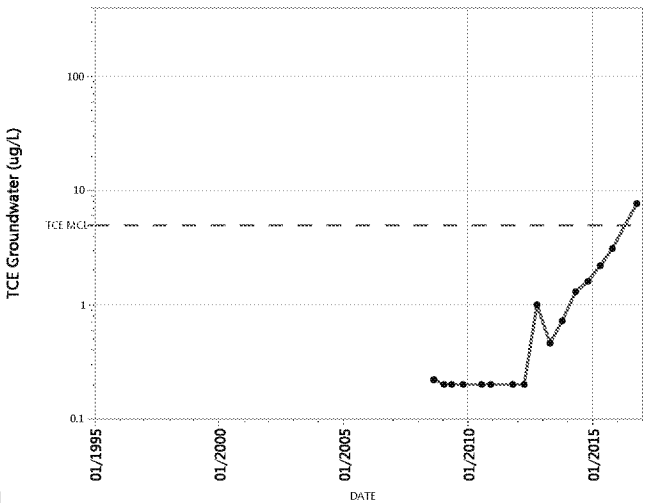
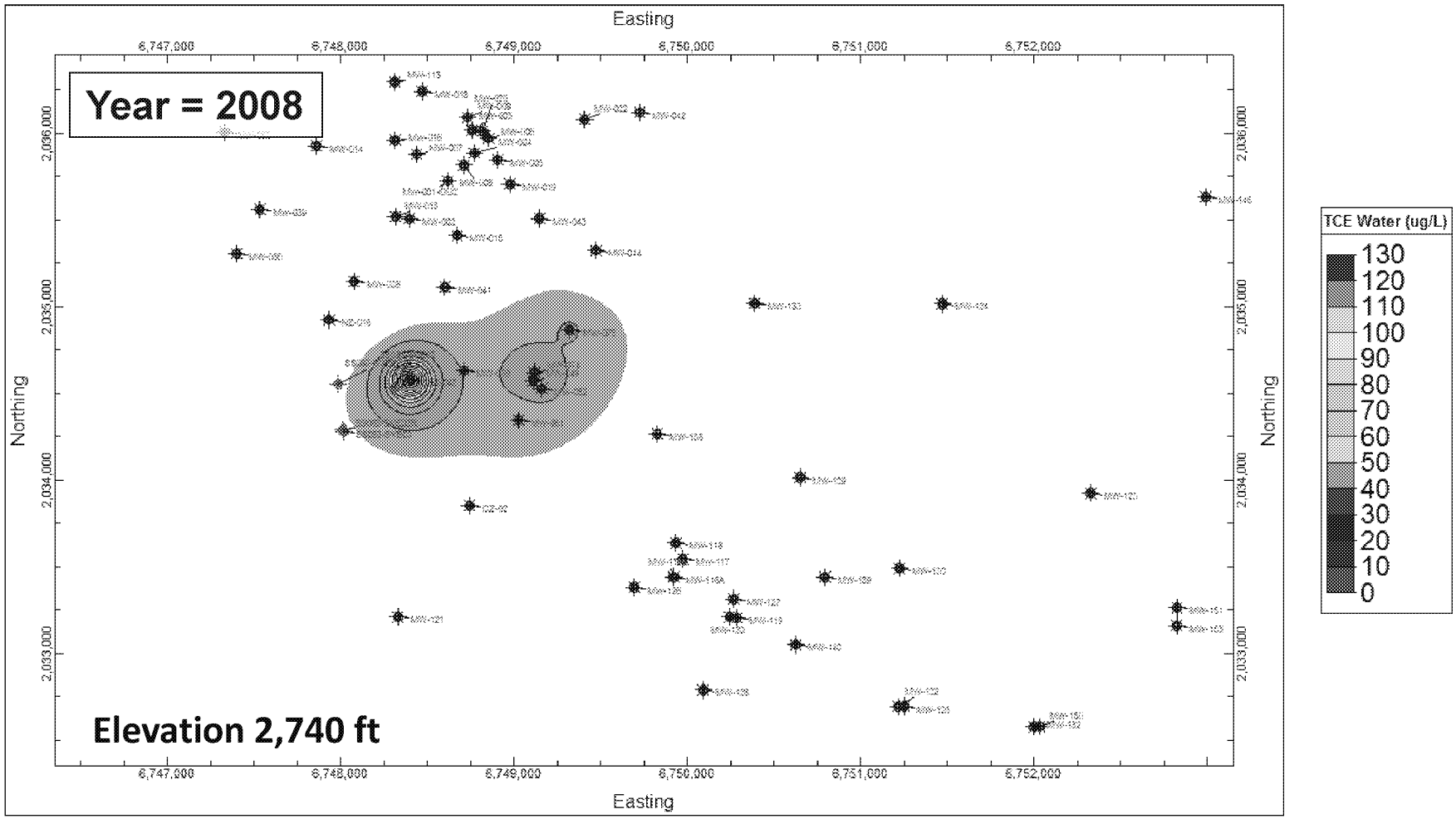
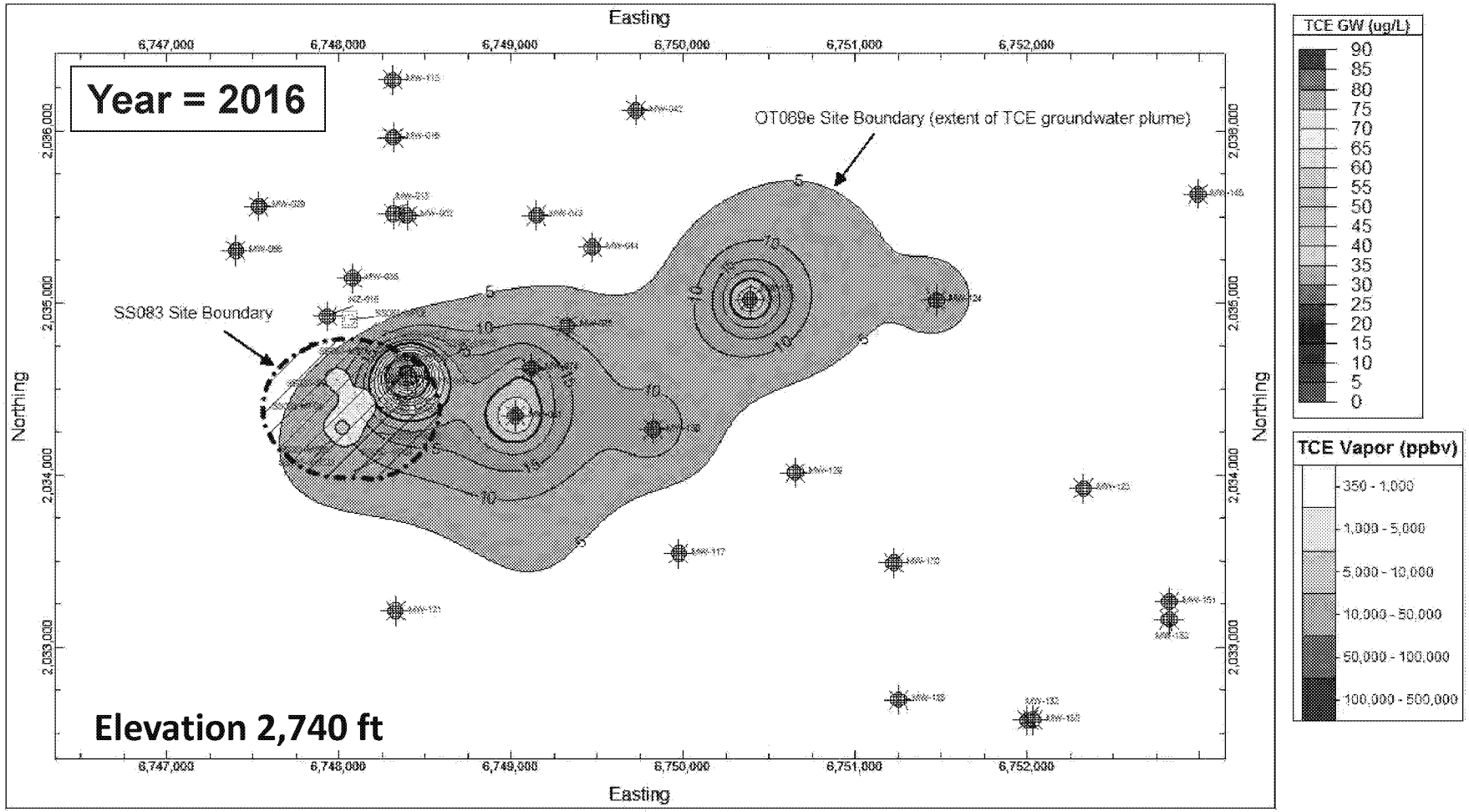


MW-124

2008 SS083 Groundwater Plume Footprint



2016 SS083 Groundwater Plume Footprint

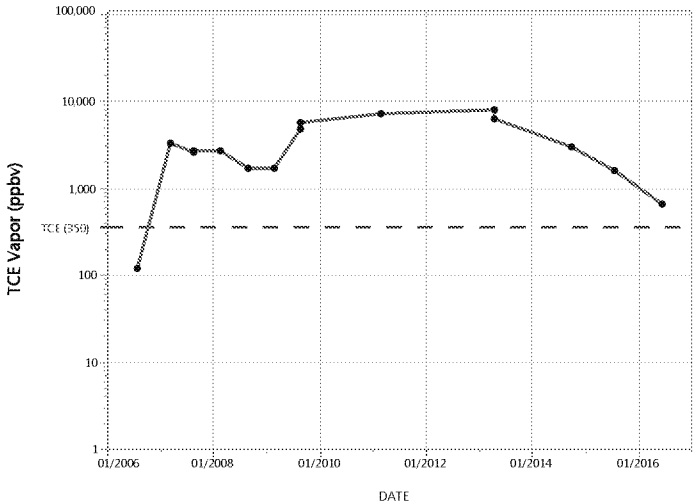


SS083 Vapor and Groundwater Data Analysis

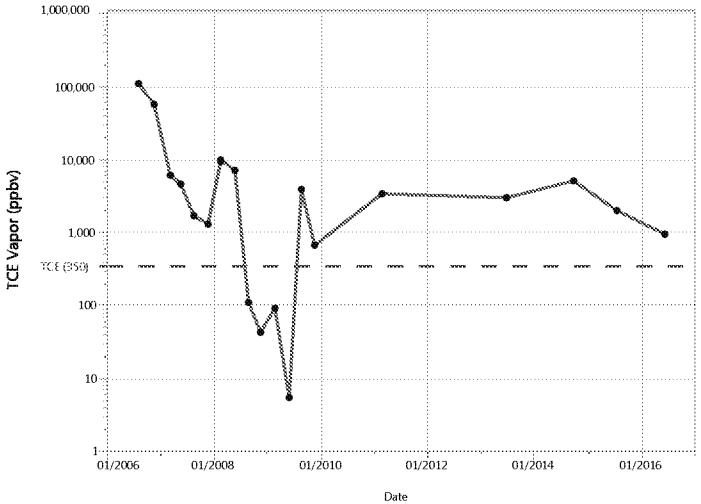
- Groundwater levels
  - Decline from mid-1990's to 2006/2007; cause unknown
  - Water level rise on west side of site from 2006/2007 to present likely attributed to the Adelanto STP infiltration system
  - Gradient increase from 2006/2007 to present with east flow direction
- Vapor plume
  - SVE removed 254 lbs (21 gal) TCE thru 2016
  - Most wells have declined to less than 350 ppbv (equilibrium vapor concentration for water at 5 μg/L)
    - Maximum 2016 concentration 2,300 ppbv
    - Geometric mean 2016 concentration 15 ppbv
    - Median 2016 concentration 7.7 ppbv
- TCE plume migrated from MW-61/MW-74 to MW-124 (r=2,500 ft) in 12 years (2004 to 2016)

FT082 Vapor and Groundwater Time-Series Analysis

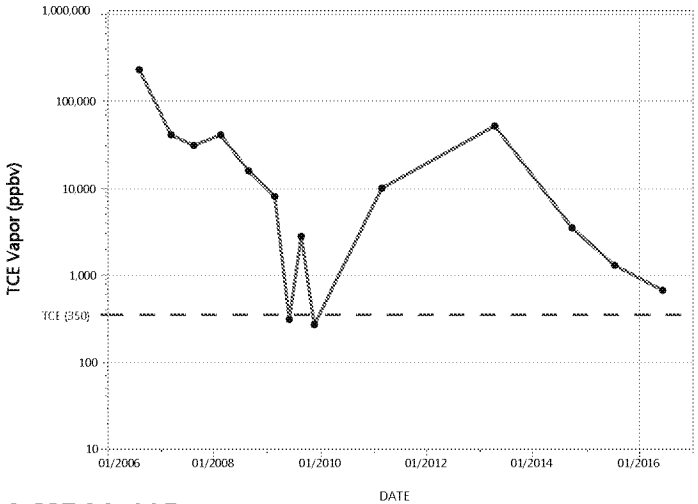
FT082 Vapor TCE Time-Series Data



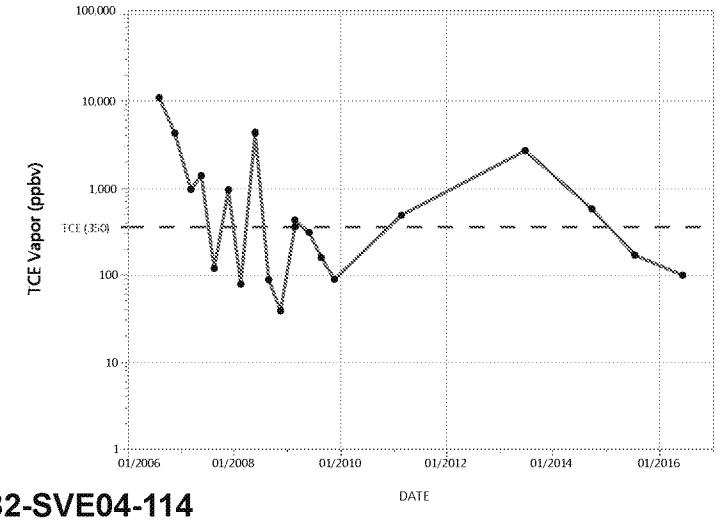
FT082-MP01-113



FT082-SVE01-114

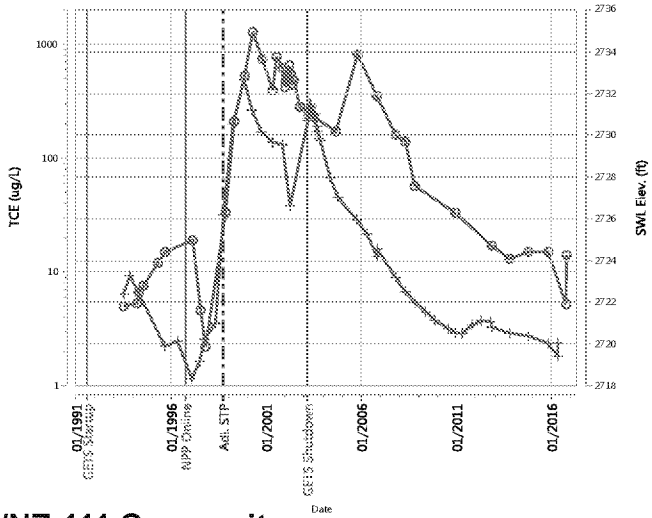


FT082-MP06-115

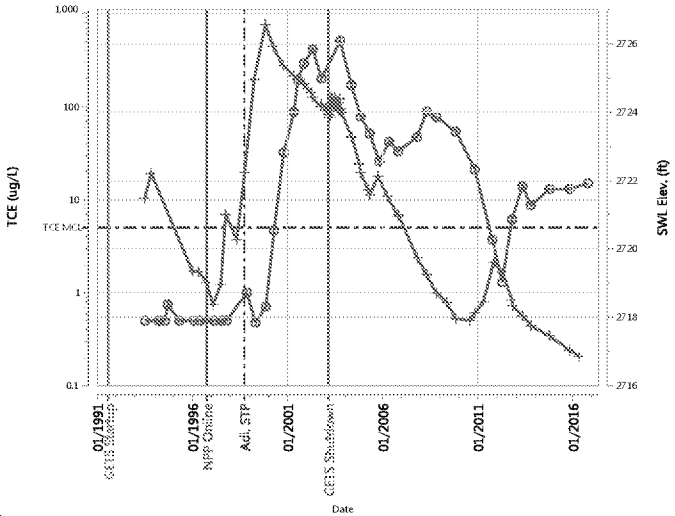


FT082-SVE04-114

FT082 Water Level/TCE Groundwater Plots



NZ-55/NZ-111 Composite



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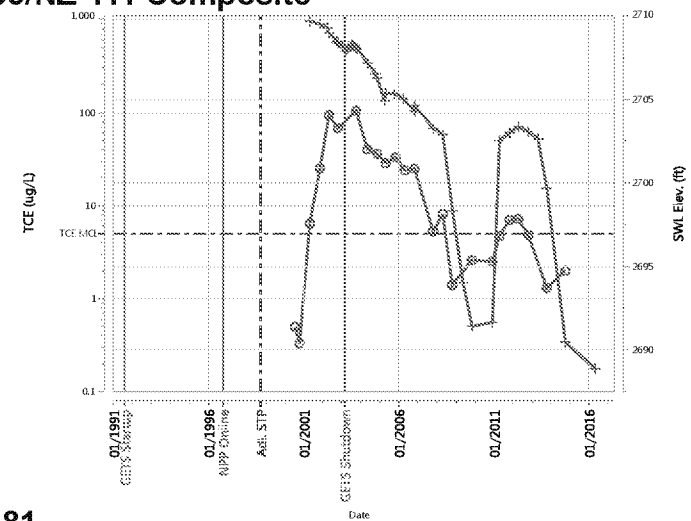
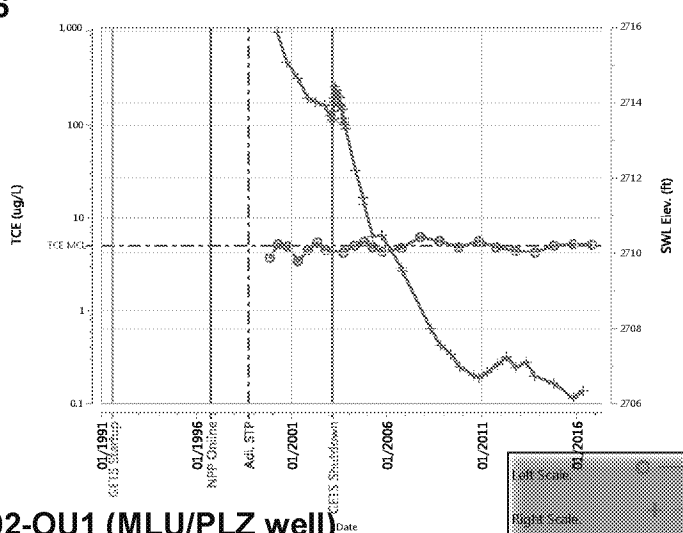


MW-81



MW-102-OU1 (MLU/PLZ well)

FT082 Vapor and Groundwater Data Analysis

- Groundwater levels and concentrations
  - Major water level rise (20+ ft) starting in 1996 related to NPP infiltration
  - Entrained TCE mass from vadose zone
  - Plume migrated into Upper and Lower Aquifers
- Vapor plume
  - SVE removed 607 lbs (50 gal) TCE thru 2016
  - Most wells have declined to less than 350 ppbv (equilibrium vapor concentration for water at 5 μg/L)
    - Maximum 2016 concentration 2,500 ppbv
    - Geometric mean 2016 concentration 17 ppbv
    - Median 2016 concentration 13 ppbv
  - 2016 vapor plume has small footprint

SS083 Hydrus Model Setup and Calibration

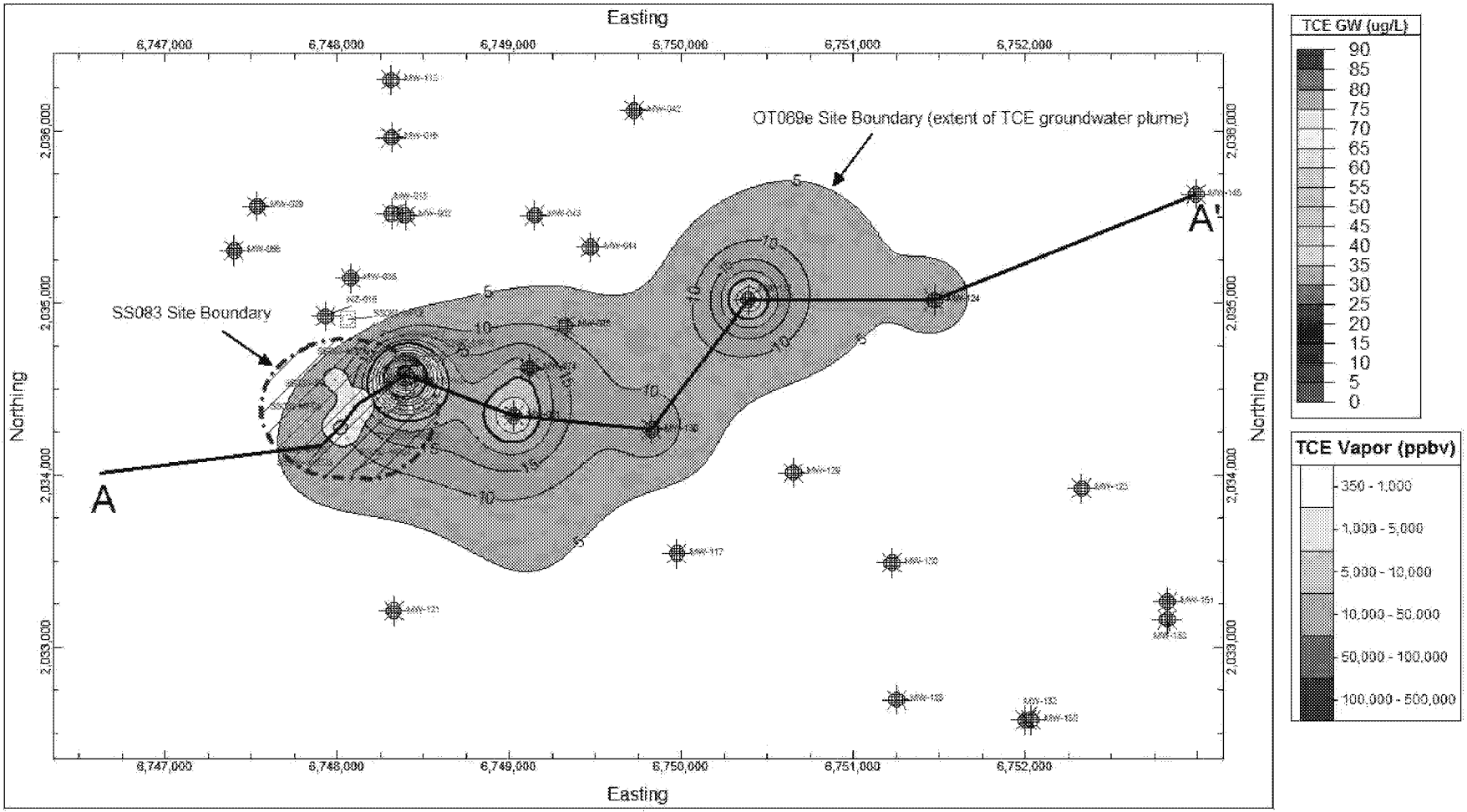
SS083 TCE Plume

- Atmospheric recharge is insufficient to get TCE dissolved in water from ground surface to Upper Aquifer in 40 years
- Enhanced recharge needed to generate observed TCE vadose zone and groundwater plume
- Most logical source is leaking drains and sewers: ~ 5 gal/year/ft drain
- Assume TCE first entered subsurface in 1960's
- Assume drains contained TCE from 1965 until 1995 (30 years)
- After 1994, assumed drains leaked water but no TCE
- Need to have zone of high hydraulic conductivity in Upper Aquifer to calibrate to observed SS083 TCE groundwater plume

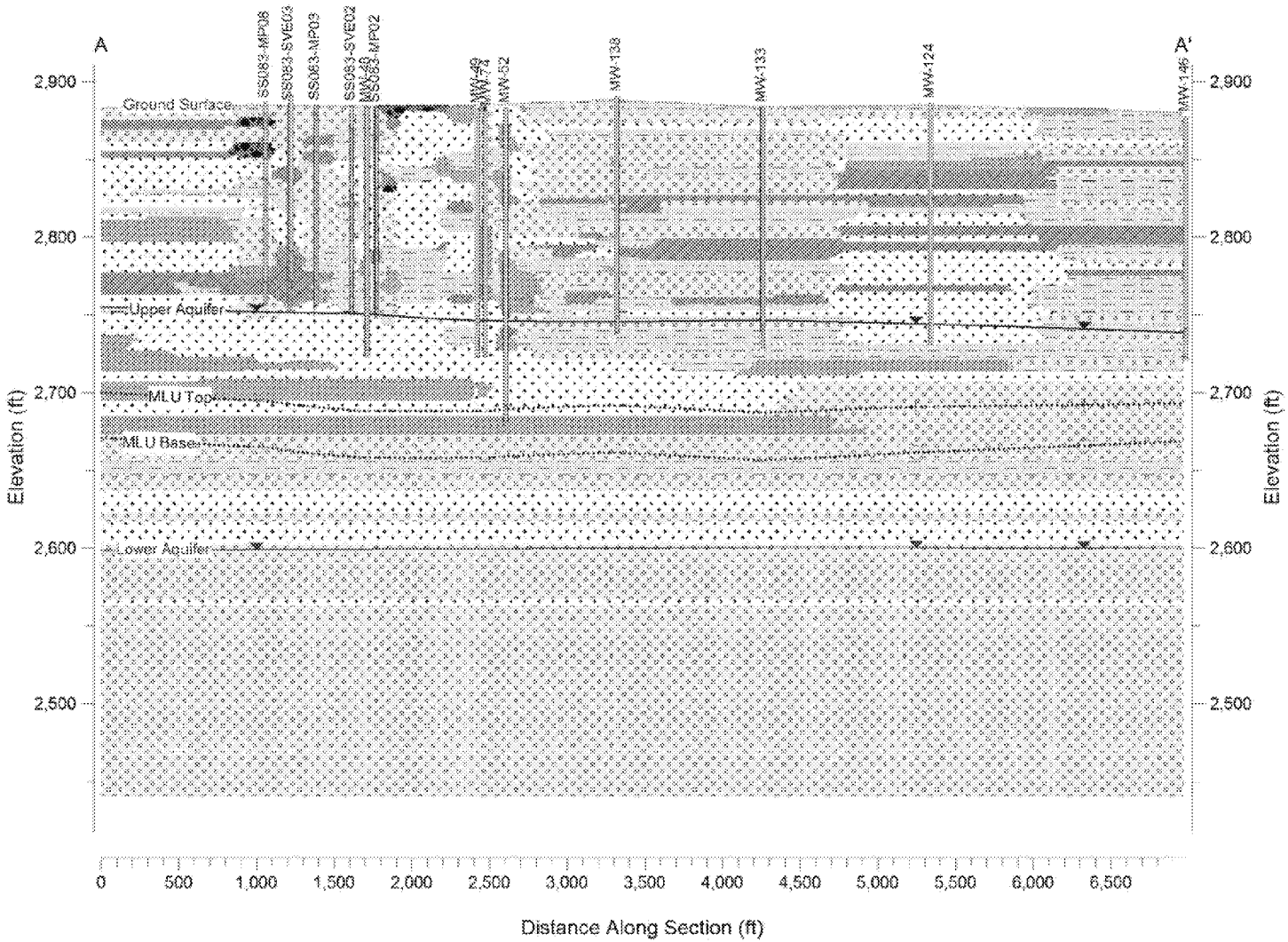
Objective and Approach to SS083 Hydrus Modeling

- **Objective: Use calibrated SS083 2D profile model to develop maximum vadose zone soil concentrations at various depths that will not adversely affect groundwater in OT069e.**
- **Approach**
  1. **Setup and calibrate Hydrus model to TCE plume. Calibration will include development of TCE groundwater plume over time.**
  2. **Discuss model with regulatory agencies (this presentation).**
  3. **Assuming OT069e TCE plume doesn't exist, insert various vapor concentrations in model at different depths and see how concentrations affect OT069e groundwater concentrations.**
  4. **Initial concentrations will be based on 2016 vapor concentrations. Soil concentrations can be calculated from vapor concentrations, assuming equilibrium partitioning.**
  5. **Remedial goals will be based on vapor concentrations.**

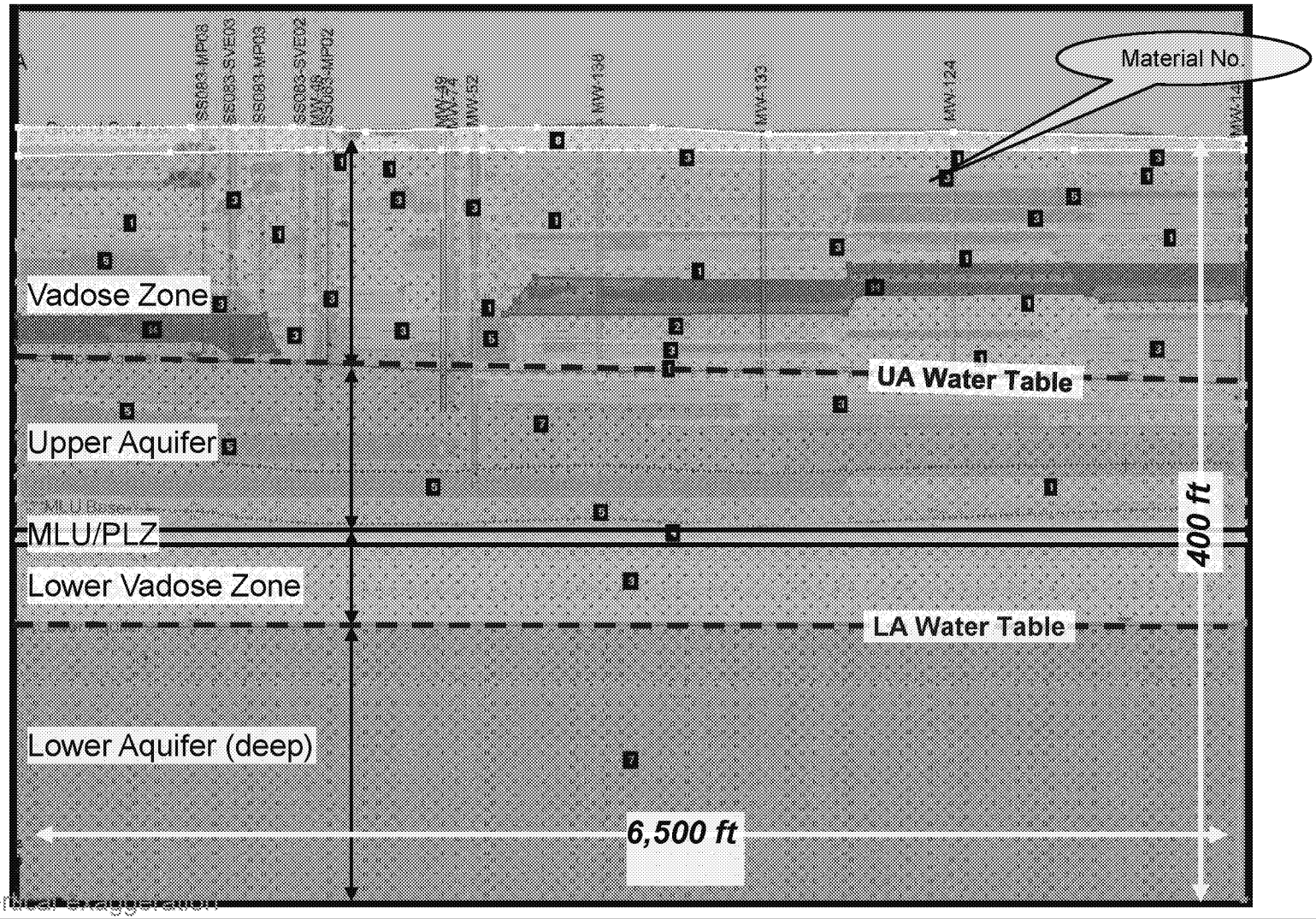
SS083 Hydrus Section Line



Lithology Cross-Section



Hydrus Lithology Setup



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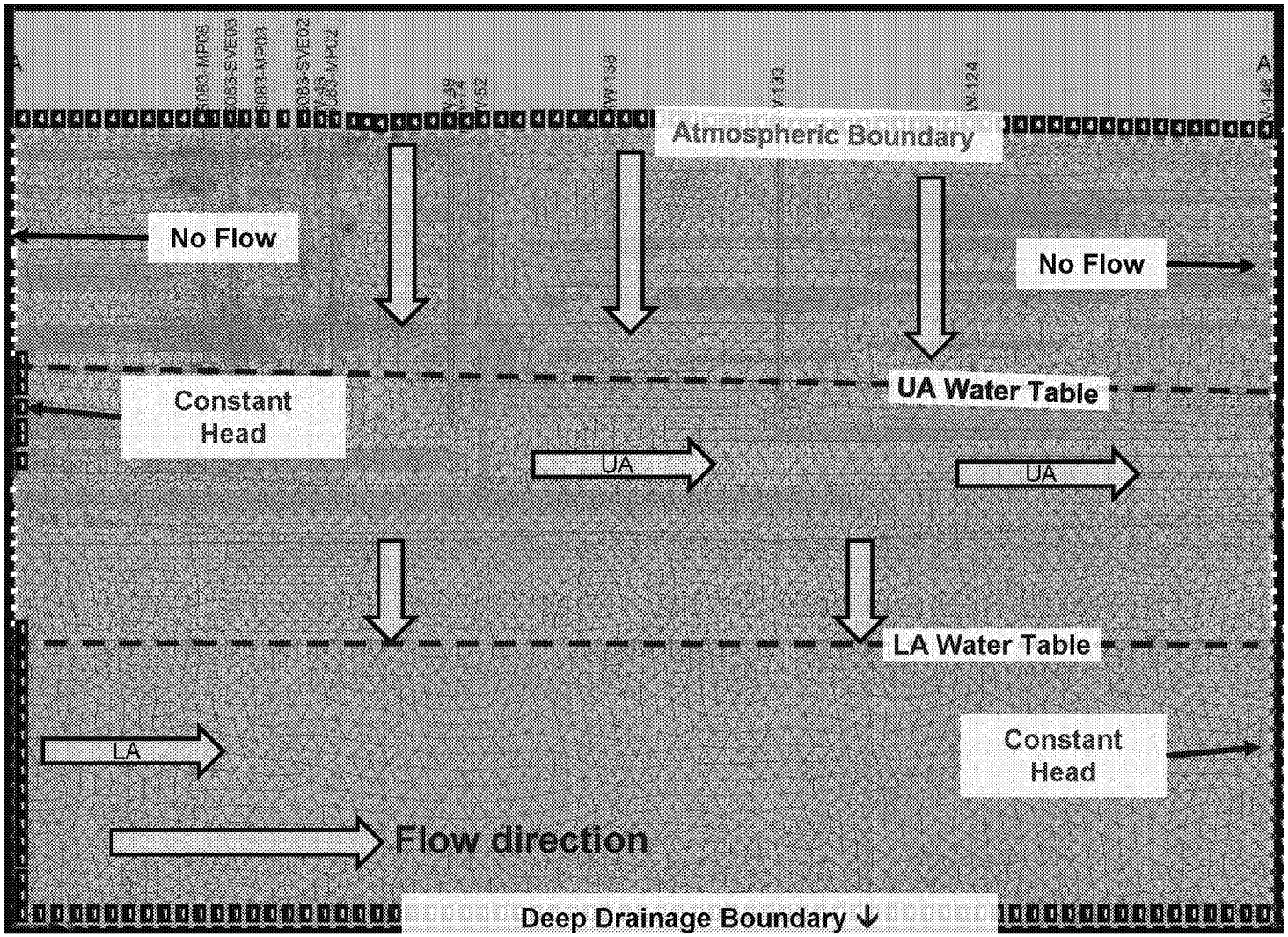
Boundary Conditions



10x vertical exaggeration

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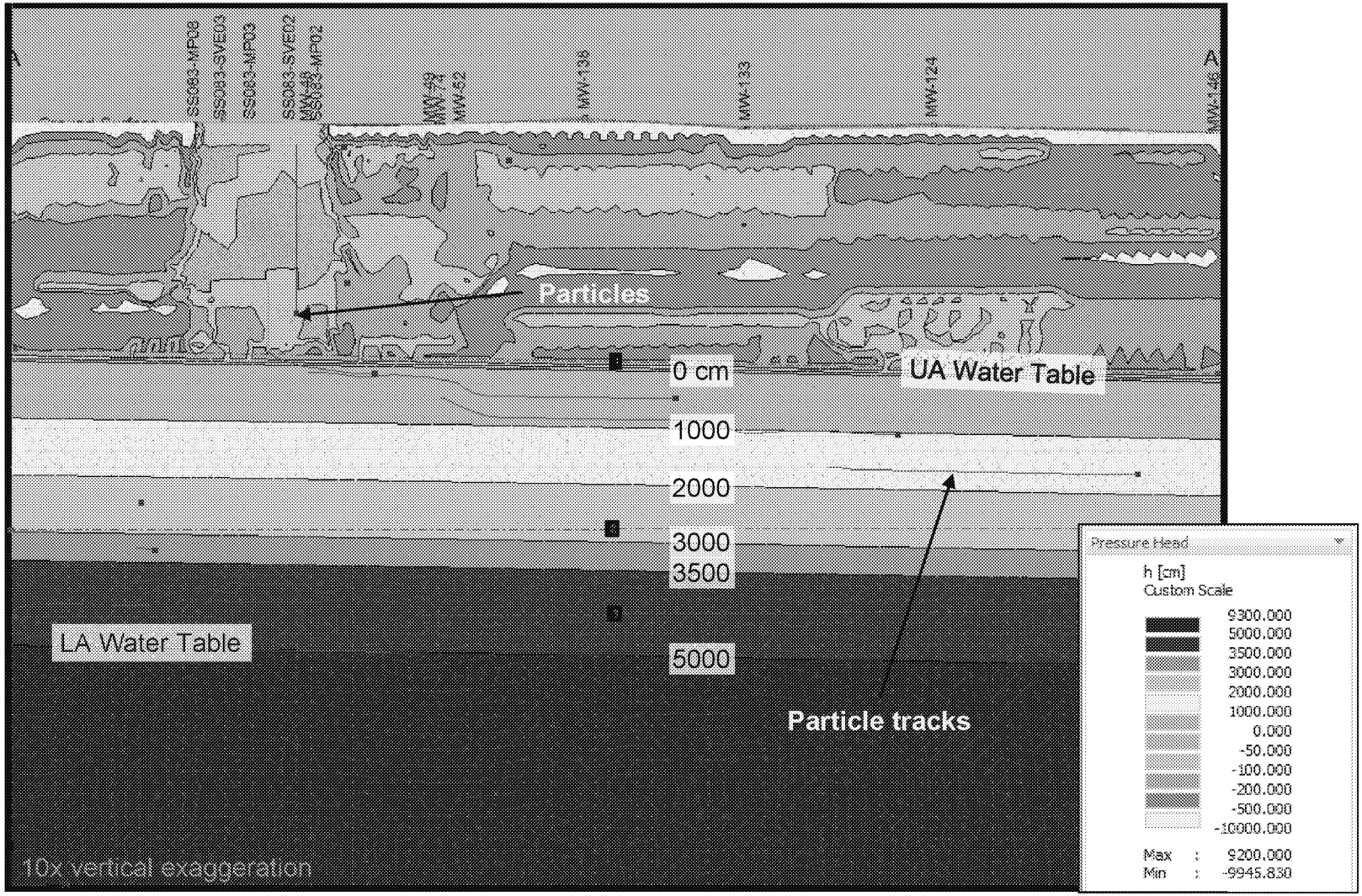
Pressure Head Results



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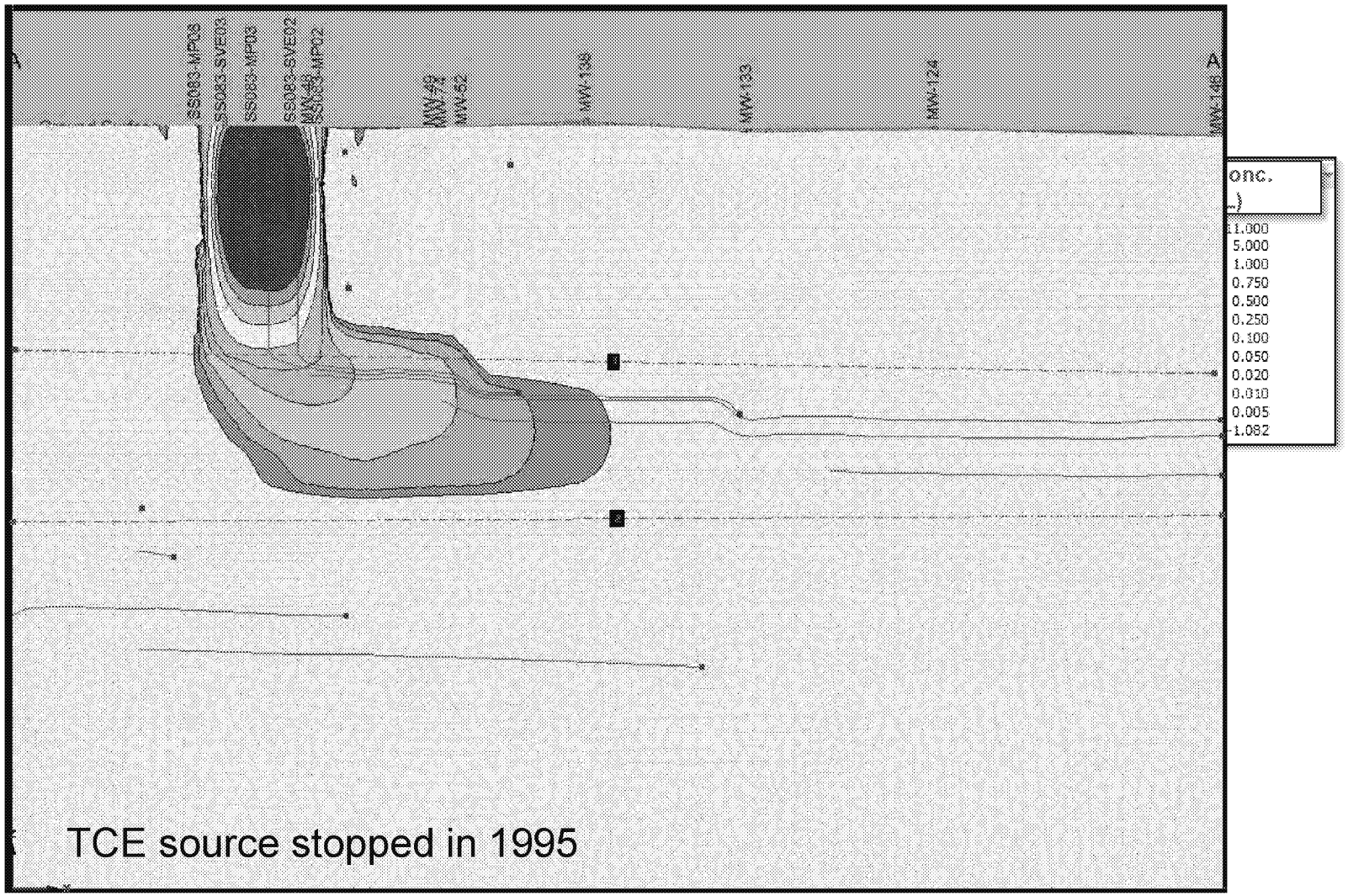
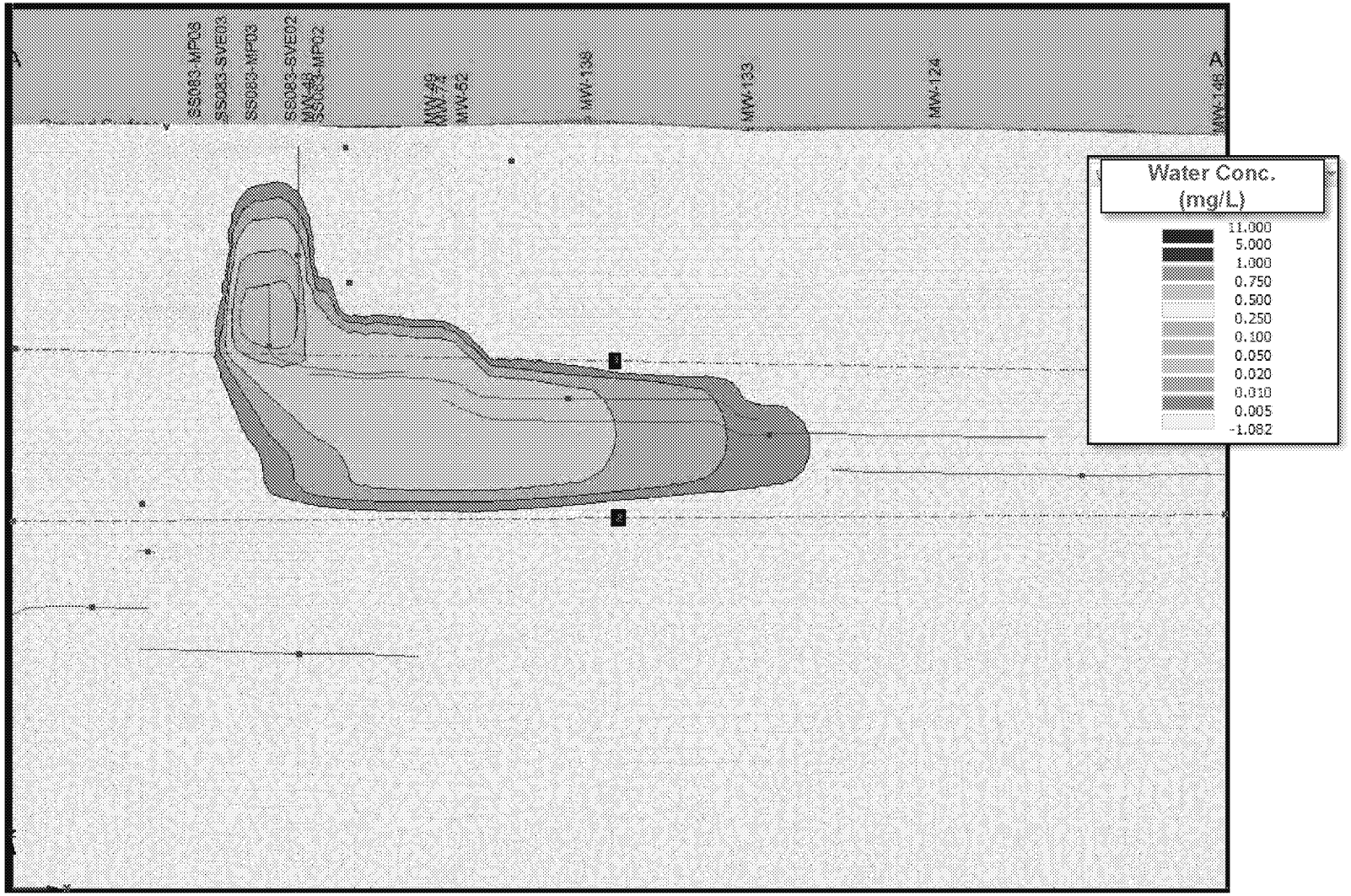
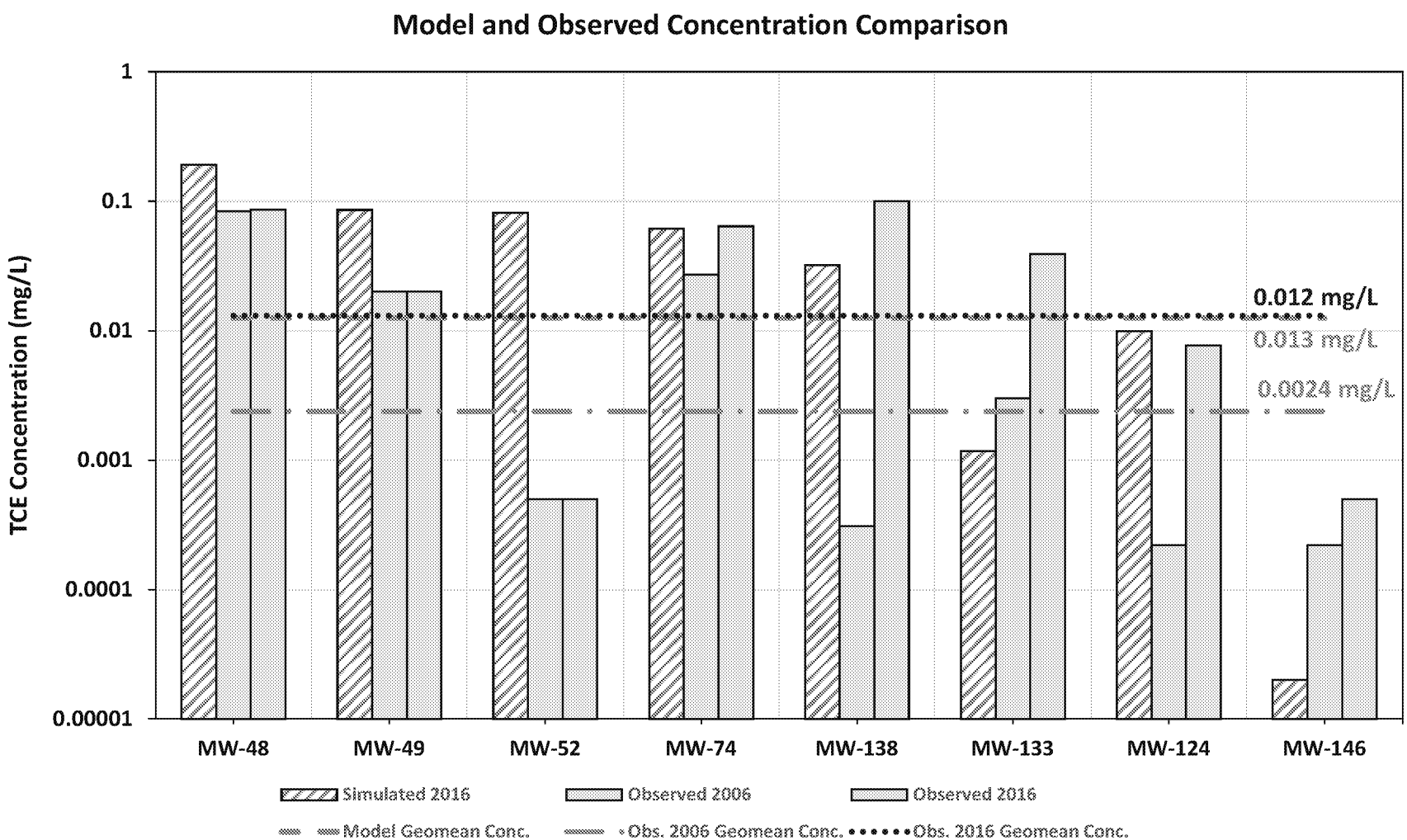
40-Year TCE Simulation Results (1965-2005)



TCE Simulation Results (2005-2016)



SS083 TCE Plume Calibration



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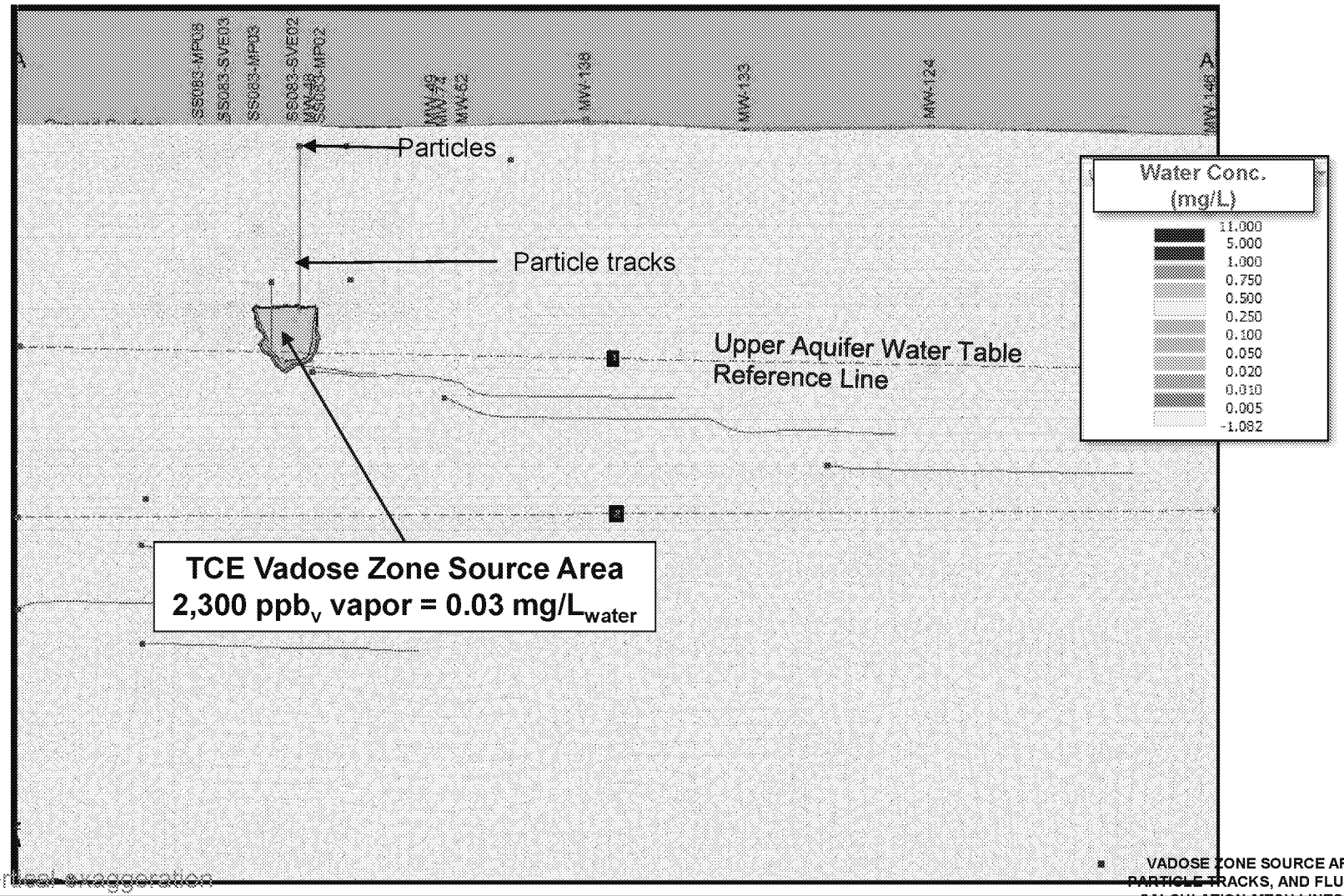
Vadose Zone Remediation Concentration Simulation

- Start with 2016 vapor concentrations—maximum concentration 2,300 ppbv (equivalent to 30 μg/L water)
- Highest vapor concentrations in silty sands, silts, and clays
- Run calibrated Hydrus model to determine groundwater plume extent over 20 years from just residual vadose zone contamination
- Evaluate groundwater plume extent

SS083 2016 Vadose Zone Vapor Source Area



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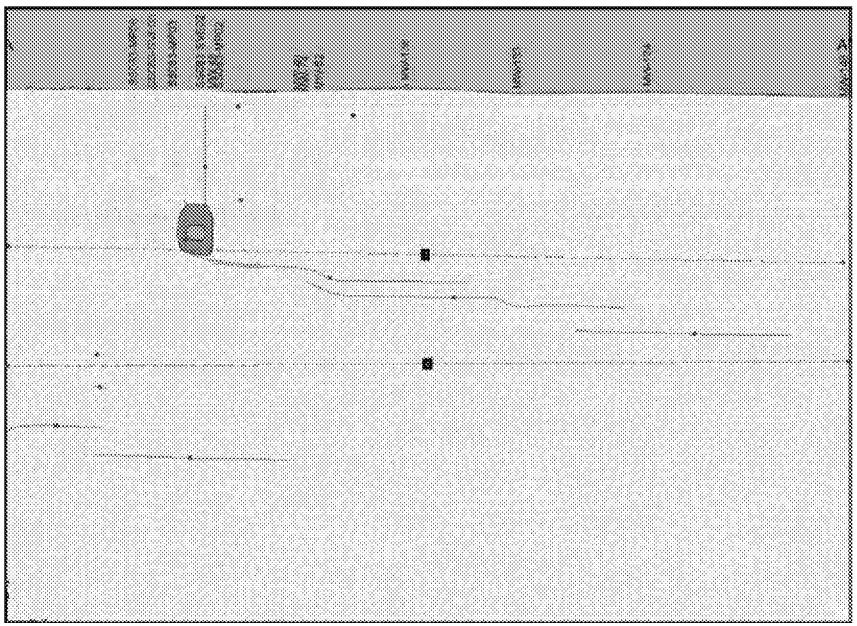
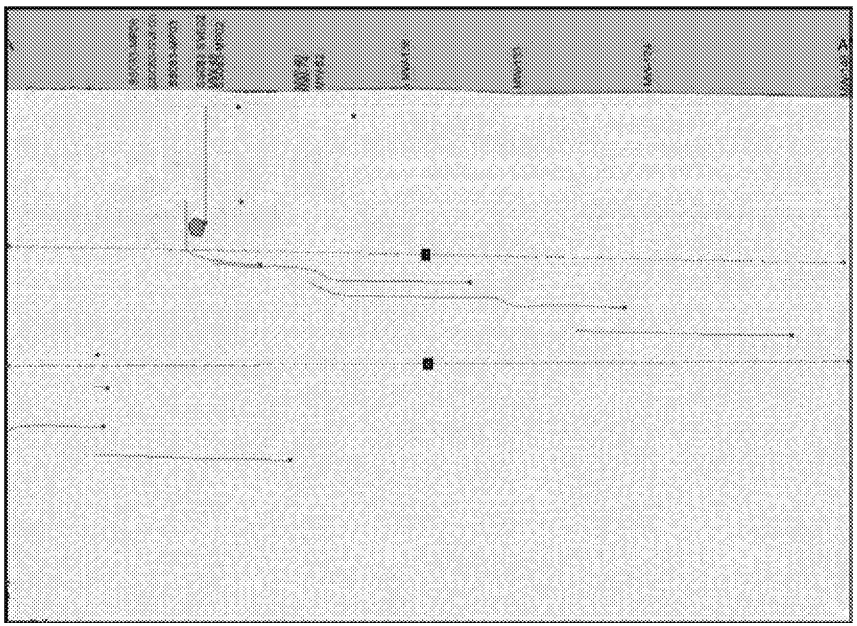
20 Year Hydrus Simulation

Year = 2026



Year = 2036



SS083 Hydrus Model Results

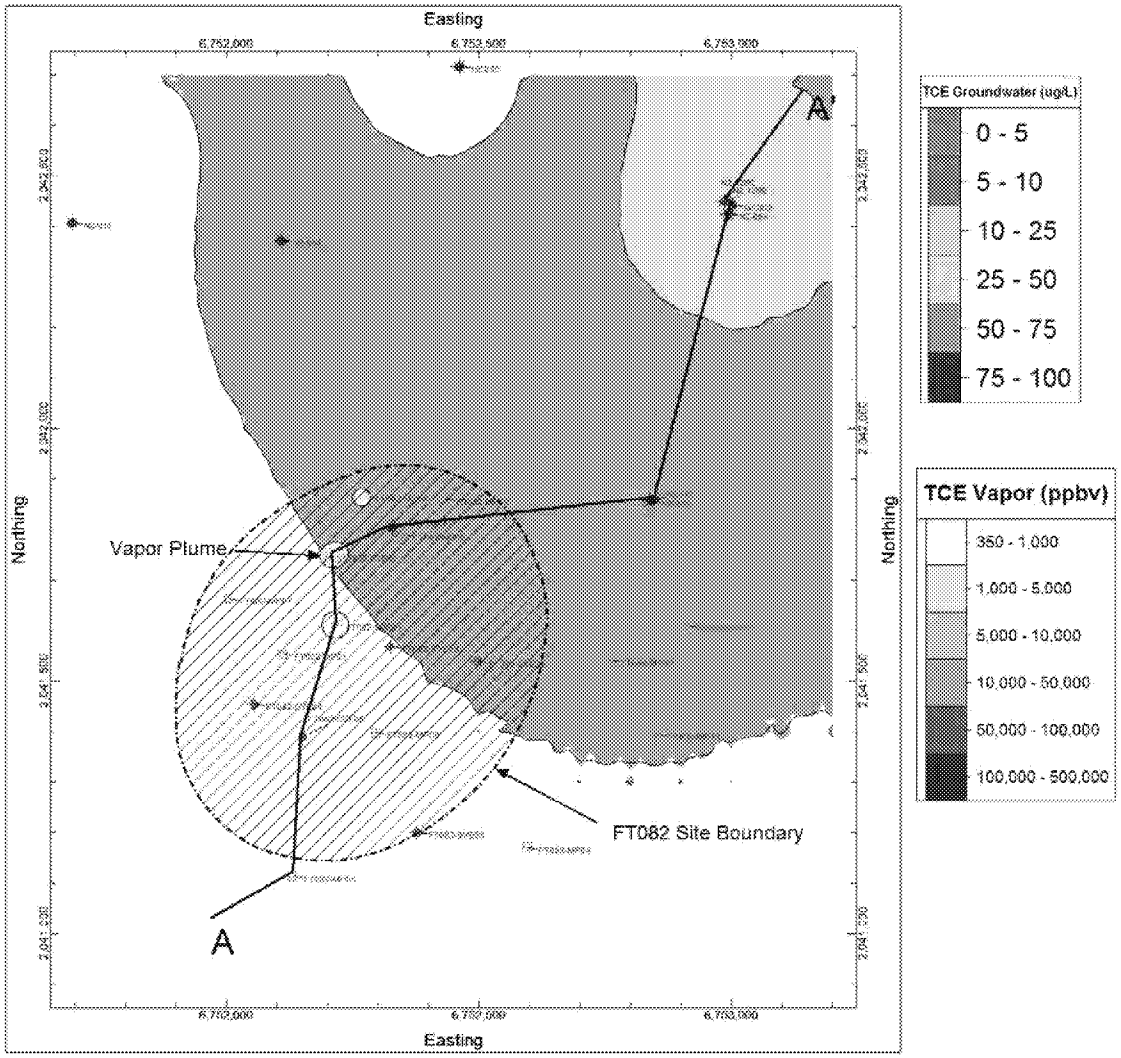
- Groundwater plume result of historical TCE contamination from source area through vadose zone into groundwater
- 2016 vadose zone contamination not contributing to existing groundwater plume
- Modeling shows that existing groundwater plume does not require ongoing migration from vadose zone into groundwater to explain plume migration—simply dissolved plume migration
- SVE mass removal had major impact on long-term groundwater plume prognosis

FT082 Hydrus Model

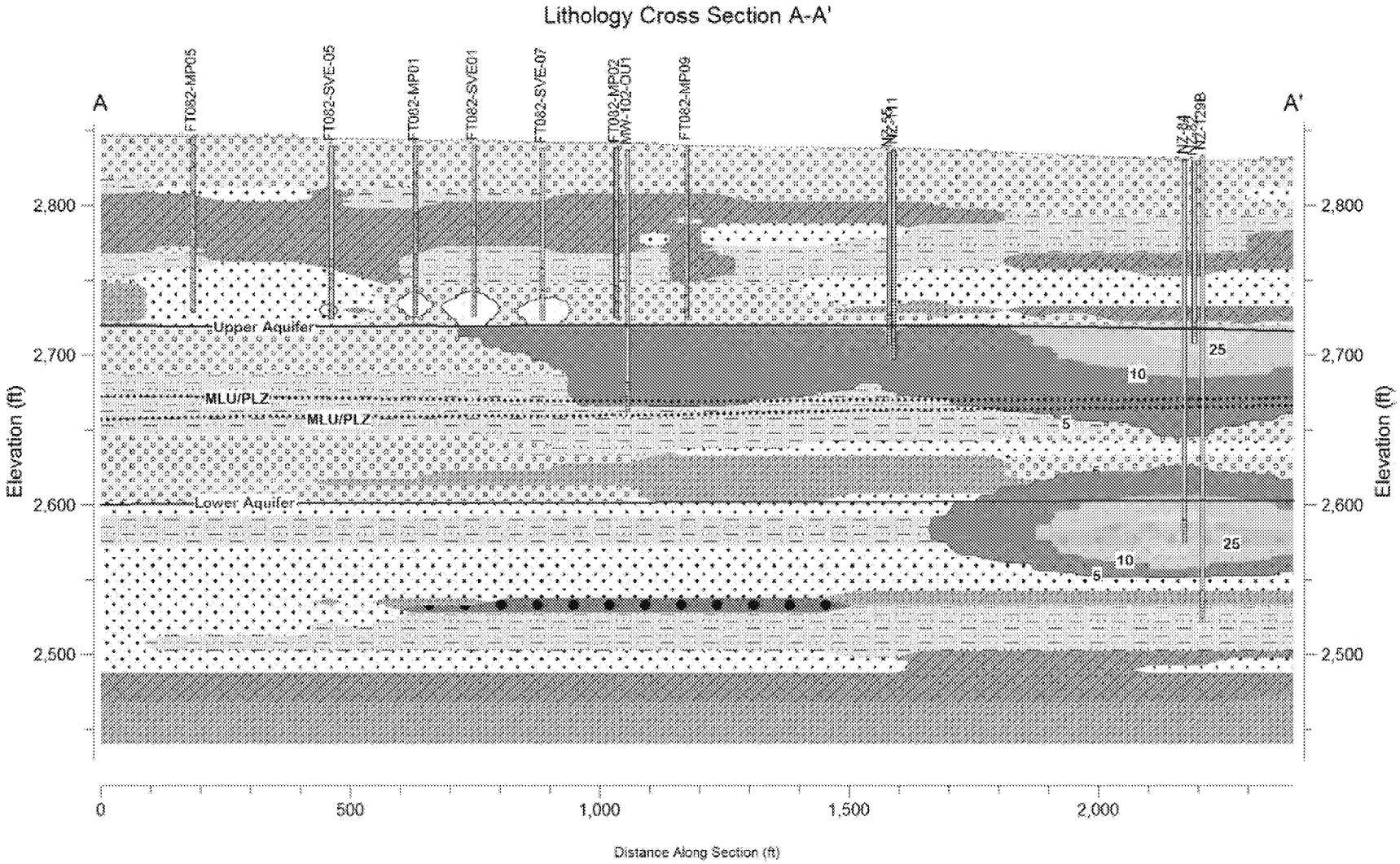
Objective and Approach to FT082 Hydrus Modeling

- **Objective: Use calibrated FT082 profile model to develop maximum vadose zone soil concentrations at various depths that will not adversely affect groundwater in OU1 (CG070).**
- **Approach**
  1. **Setup and calibrate Hydrus model to TCE plume. Calibration will include development of TCE groundwater plume over time.**
  2. **Discuss model with regulatory agencies (this presentation).**
  3. **Assuming OU1 TCE plume doesn't exist, insert various vapor concentrations in model at different depths and see how concentrations affect groundwater concentrations.**
  4. **Initial concentrations will be based on 2016 vapor concentrations. Soil concentrations can be calculated from vapor concentrations, assuming equilibrium partitioning.**
  5. **Remedial goals will be based on vapor concentrations.**

FT082 Hydrus Section Line



FT082 Plume Cross-Section



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FT082 Hydrus Model

- Will follow SS083 model setup and calibration
- Calibration will include 1996 to 2003 NPP recharge pulse and water level rise with accompanying increase in TCE concentrations
- Calibration will include transport from Upper to Lower Aquifer

Questions / Comments