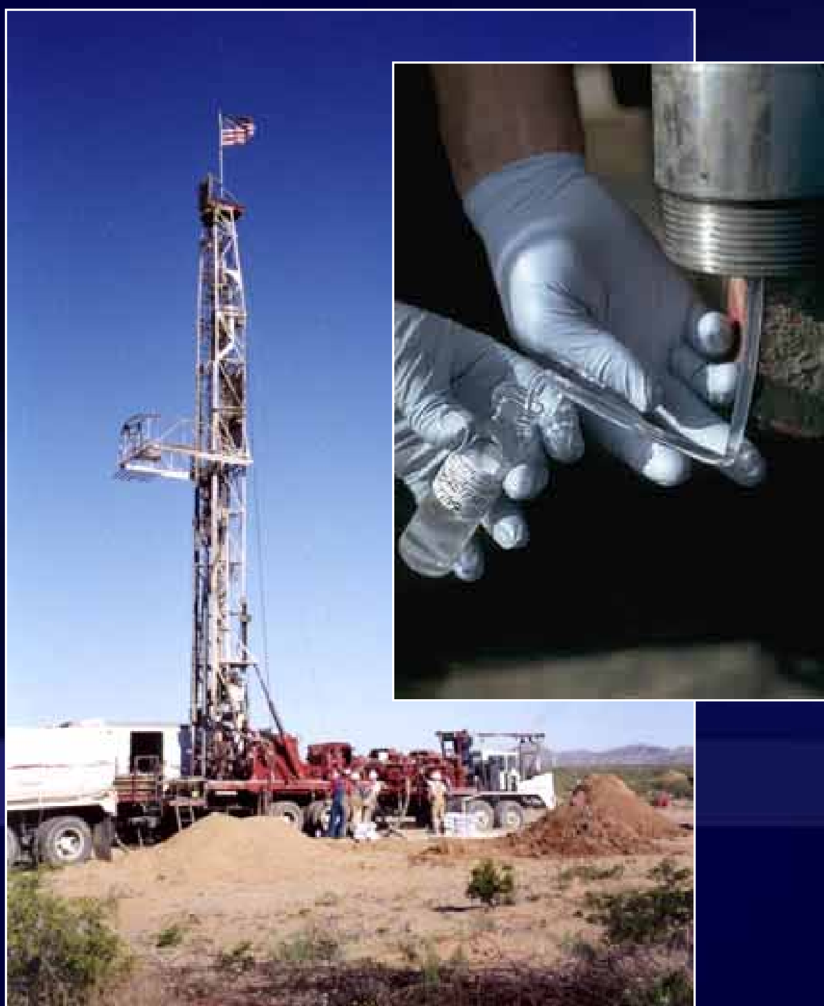
Optimization of a Long-Term Monitoring Program at an Arizona Superfund Site



Catherine Schladweiler
Malcolm Pirnie

June 15, 2004

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Case Study

Tucson International Airport Area (TIAA) Superfund Site

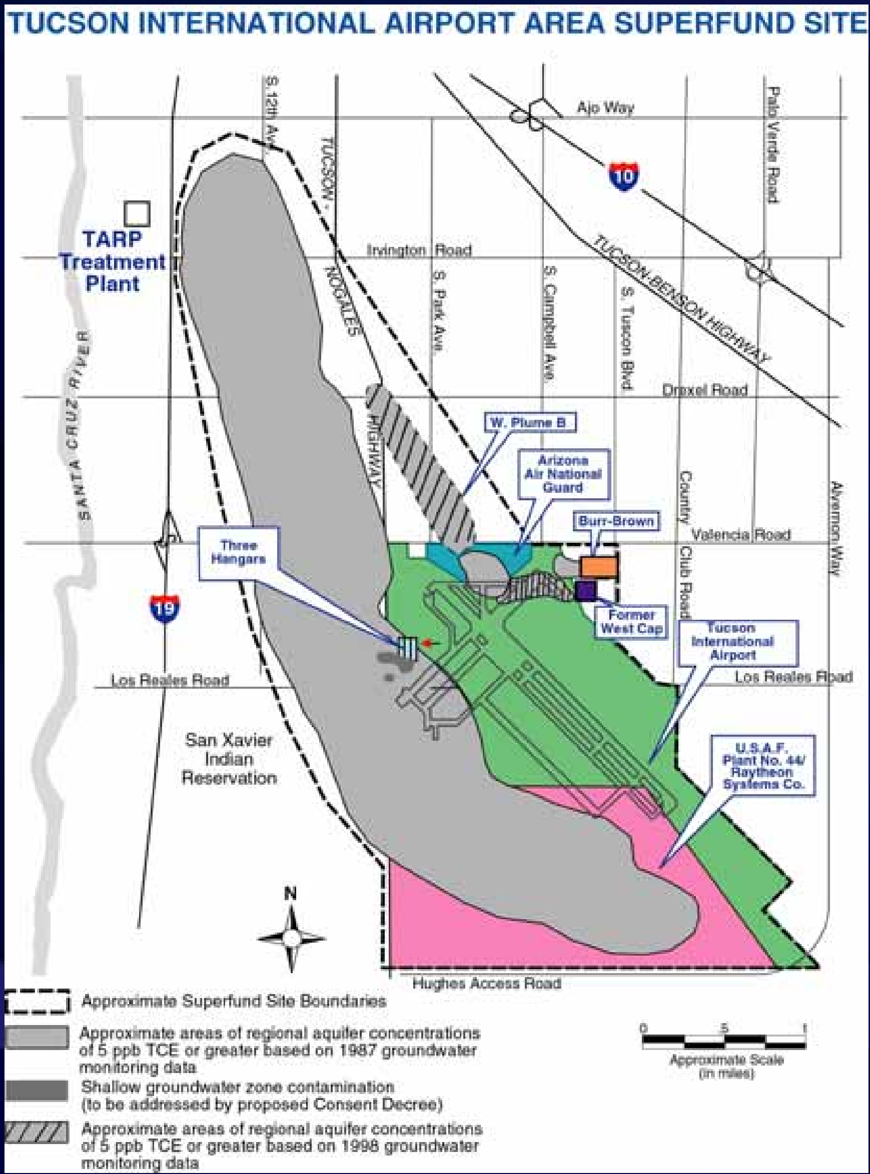

Figure provided by Tucson Airport Authority

- TARP
- AF Plant 44
- Airport Property
- AZ Air National Guard
- Burr-Brown (now TI)
- West Cap
- West Plume B

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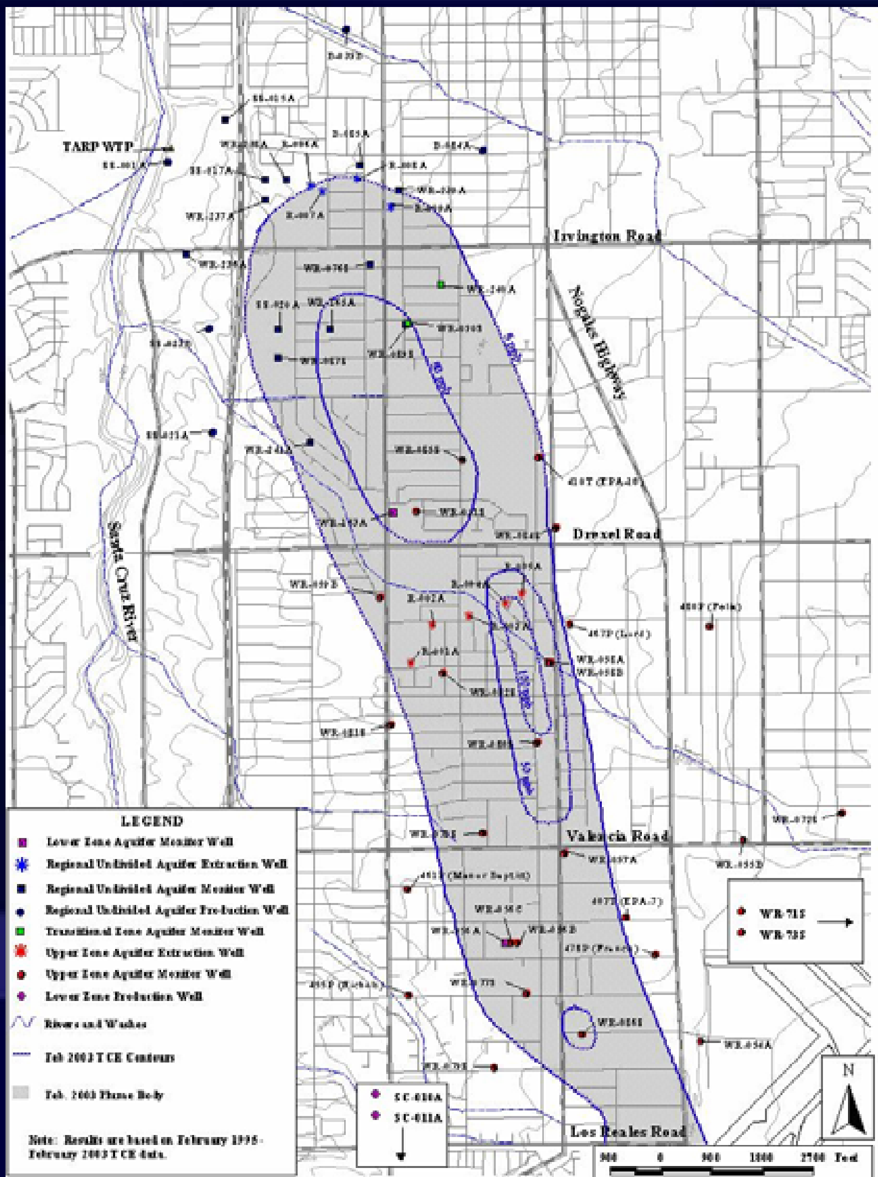
Current Monitoring Network



- TCE primary contaminant of concern
- 61 Wells:
  - 7 Production
  - 5 Private
  - 9 Extraction
  - 40 Monitoring

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Assess Optimization Potential

- Goal of monitoring program per Consent Decree

  “Evaluate the capture and restoration of the VOC contaminated groundwater plume”

Elements of Optimization

- **Monitoring Frequency**
- **Monitoring Points**
- **Monitoring Parameters**
- **Sampling Procedures**
- **Evaluation and Reporting**

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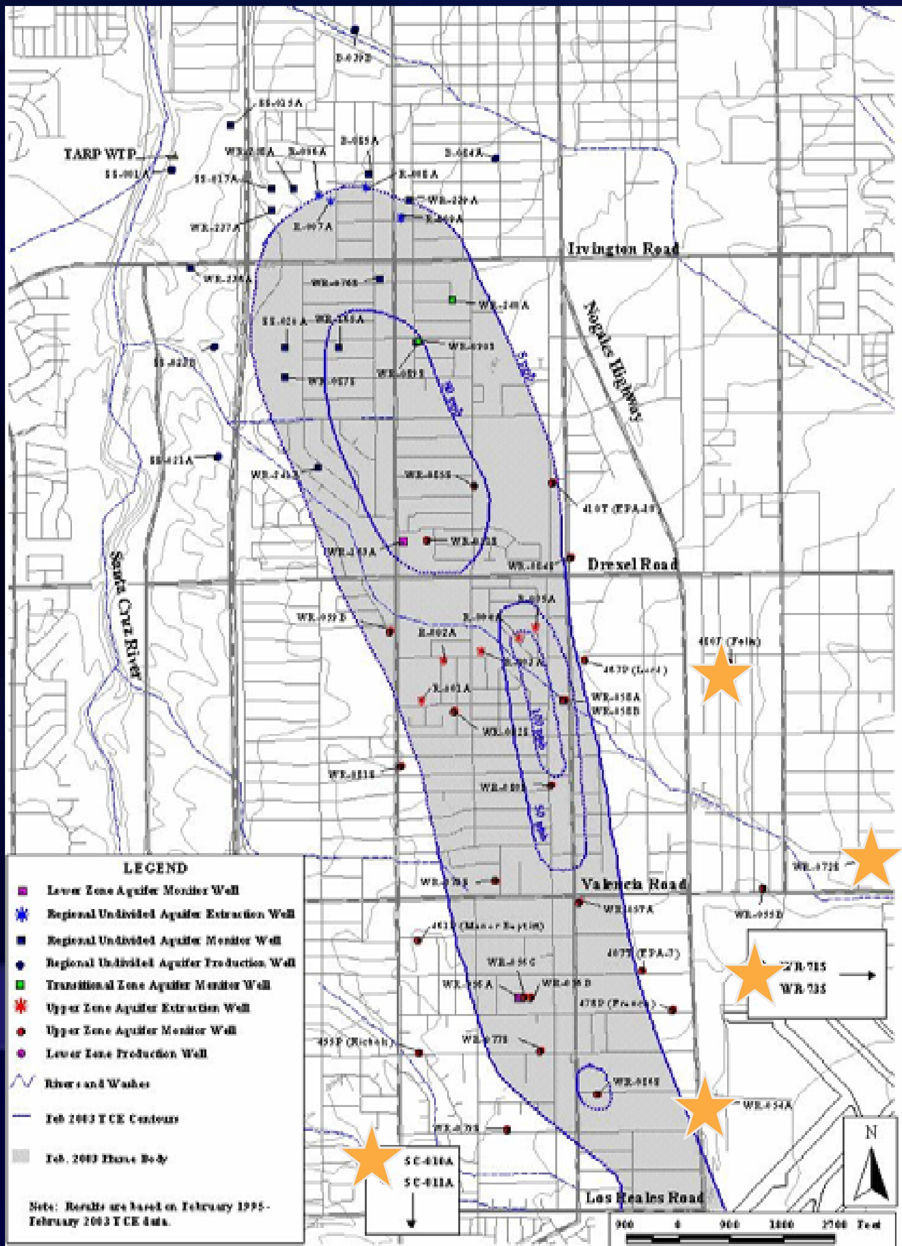
General Data Review



- Seven "Outliers" Identified
  - Out-of-plume
  - Inappropriate Screened Interval

Case Study

Optimization Scope

- Goal of the Optimization Study

Determine the most efficient frequency and distribution of sampling points that will allow evaluation of the extraction and containment system

TARP Optimization Evaluation

- Temporal Analysis
  - *Trend Analysis*
  - *Autocorrelation Function*
- Spatial Analysis
  - *General Data Review*
  - *Geostatistics*
- Site Specific Considerations
  - *Decision Tree Criteria*

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Case Study

Temporal Analyses

- Trend Analyses
  - Mann-Kendall Test for Trend
    - **Calculate the sign of all possible differences (where $x_2 - x_1$, $x_3 - x_1$, $x_n - x_1$)**
    - **Calculate the Mann-Kendall statistic, S (# of positives minus # of negatives)**
    - **S < 0 indicates a downward trend**
    - **S > 0 indicates an upward trend**
    - **S = 0 indicates no trend**
  - Example:

Date	3-1-95	3-5-96	3-19-97	3-3-98	n = 4
Conc. (ppb)	2.3	0.8	1.8	0.5	Sum
		-1	-1	-1	-3
			1	-1	0
				-1	-1
					S = -4

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Temporal Analyses

- Sens's Slope Estimator Method (to verify Mann-Kendall)
  - **Calculate the slope estimate, Q between each time interval**
    - **If N' is odd** $Q_{[(N'+1)/2]}$
    - **If N' is even** $Q_{[N'/2]} + Q_{[(N'+2)/2]}$
  - Given Q, determine the Sen's Estimator (or median slope)
  - Example:

Date	3-1-95	3-5-96	3-19-97	3-3-98
Time Period	1	2	3	4
Conc. (ppb)	2.3	0.8	1.8	0.5
		-1.5	-0.25	-0.933
			1.0	-0.65
				-2.3
N' = 6		1	2	3

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Temporal Analyses

Q	Slope
1	-2.3
2	-1.5
3	-0.933
4	-0.65
5	-0.25
6	1.0

N’ = 6 (even)

$Q_{[N'/2]} + Q_{[(N'+2)/2]}$

$Q_3 + Q_4 = Q_{3.5}$

(-0.933 + -0.65)/2 = **-0.792**

Negative slope = downward trend

-> Sampling can be reduced

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Temporal Analyses

- Used ChemStat 4.1 Software to evaluate 39 wells
- Results:
  - *Mann-Kendall*
    - *22 wells indicated a decreasing trend in data*
  - *Sen's*
    - *20 wells indicated a decreasing trend in data*

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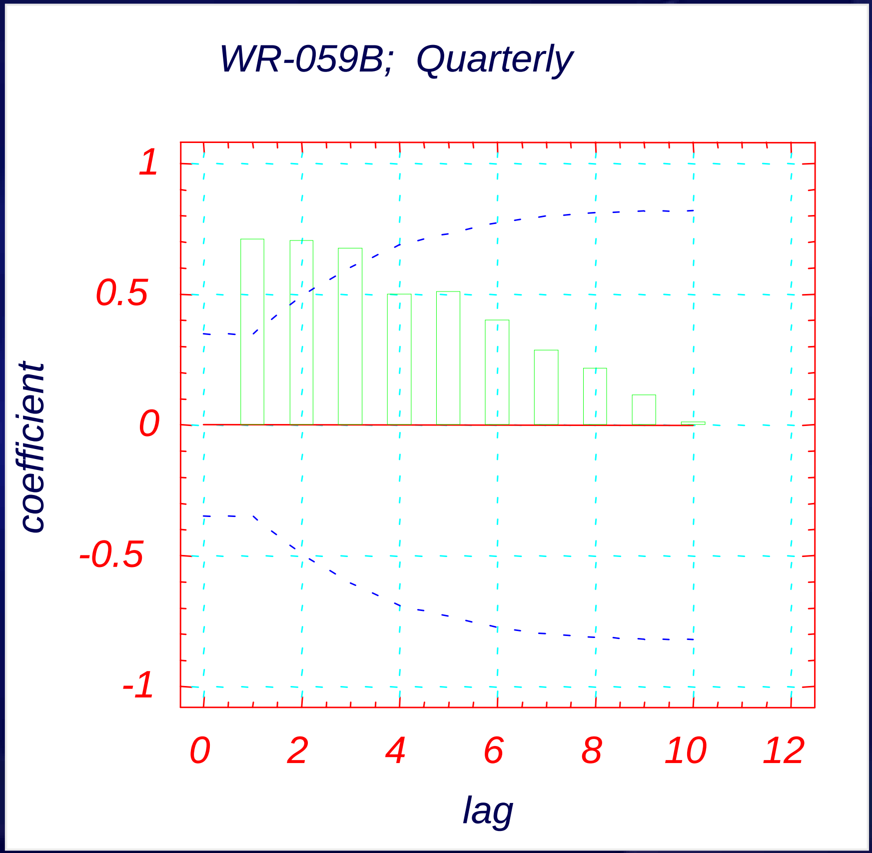
Temporal Analyses

- Autocorrelation Function
  - Indicates the “memory” of a well by tests for patterns in time series data
  - Statgraphics Plus program was used to perform this analysis
  - Example:
    - **50 wells analyzed (includes ND wells)**
    - **45 wells have enough “memory” to reduce sampling frequencies**
    - **Autocorrelation indicates appropriate sampling frequency**



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Case Study

Spatial Analyses - Variograms

- Determine Plume Stability
- Variogram Analysis
  - Evaluates spatial correlation of data in the direction of groundwater flow

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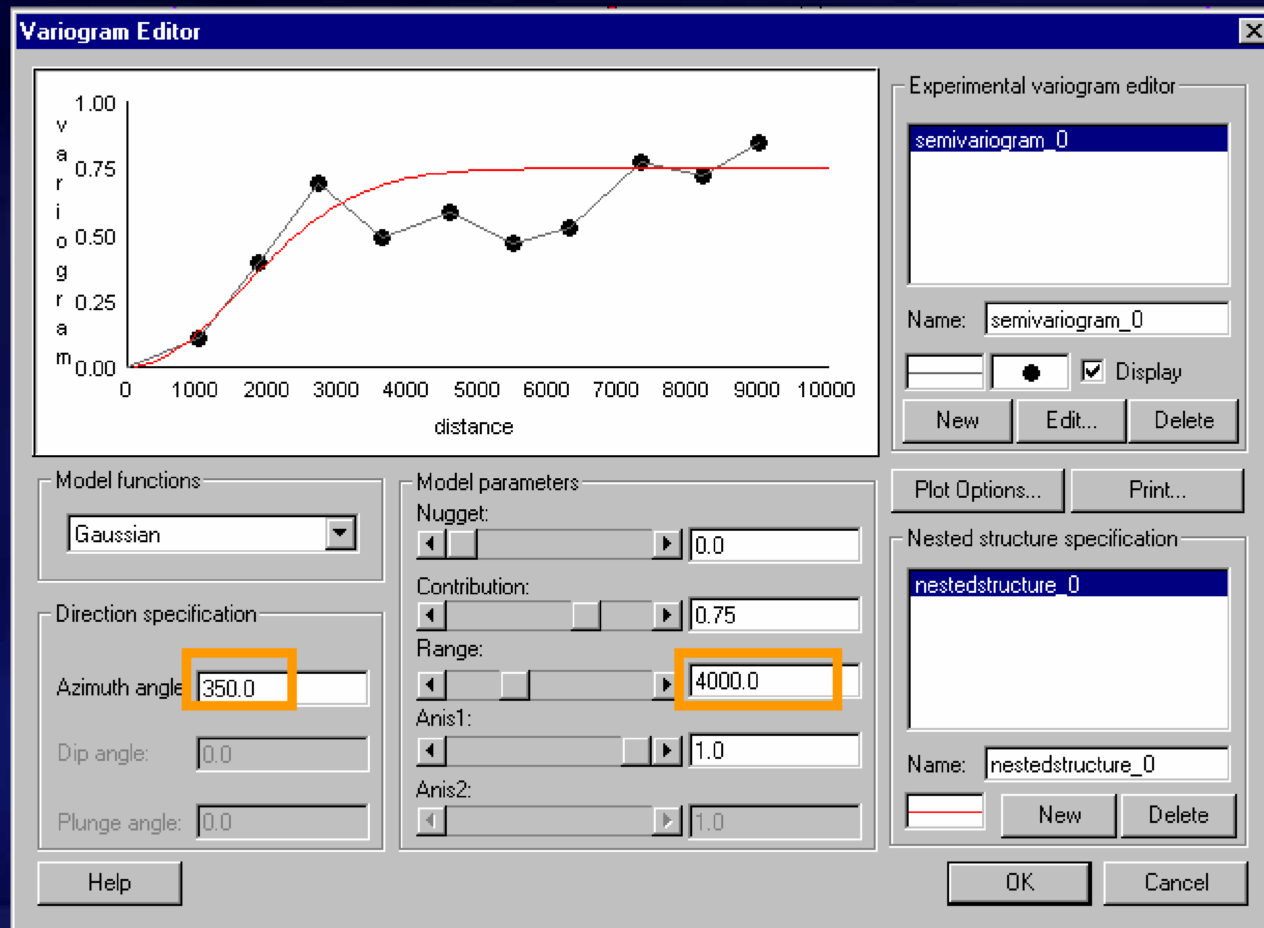
Spatial Analyses - Variograms

Best correlation was:

- **350º (10º west of north – corresponds to gw flow)**
- **20º window**
- **Range (distance with which the data are spatially correlated = approximately 4,000 ft**



*GMS 3.1 Variogram Editor

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Spatial Analyses - Variograms

Upper Zone vs. Regional Undivided Aquifers

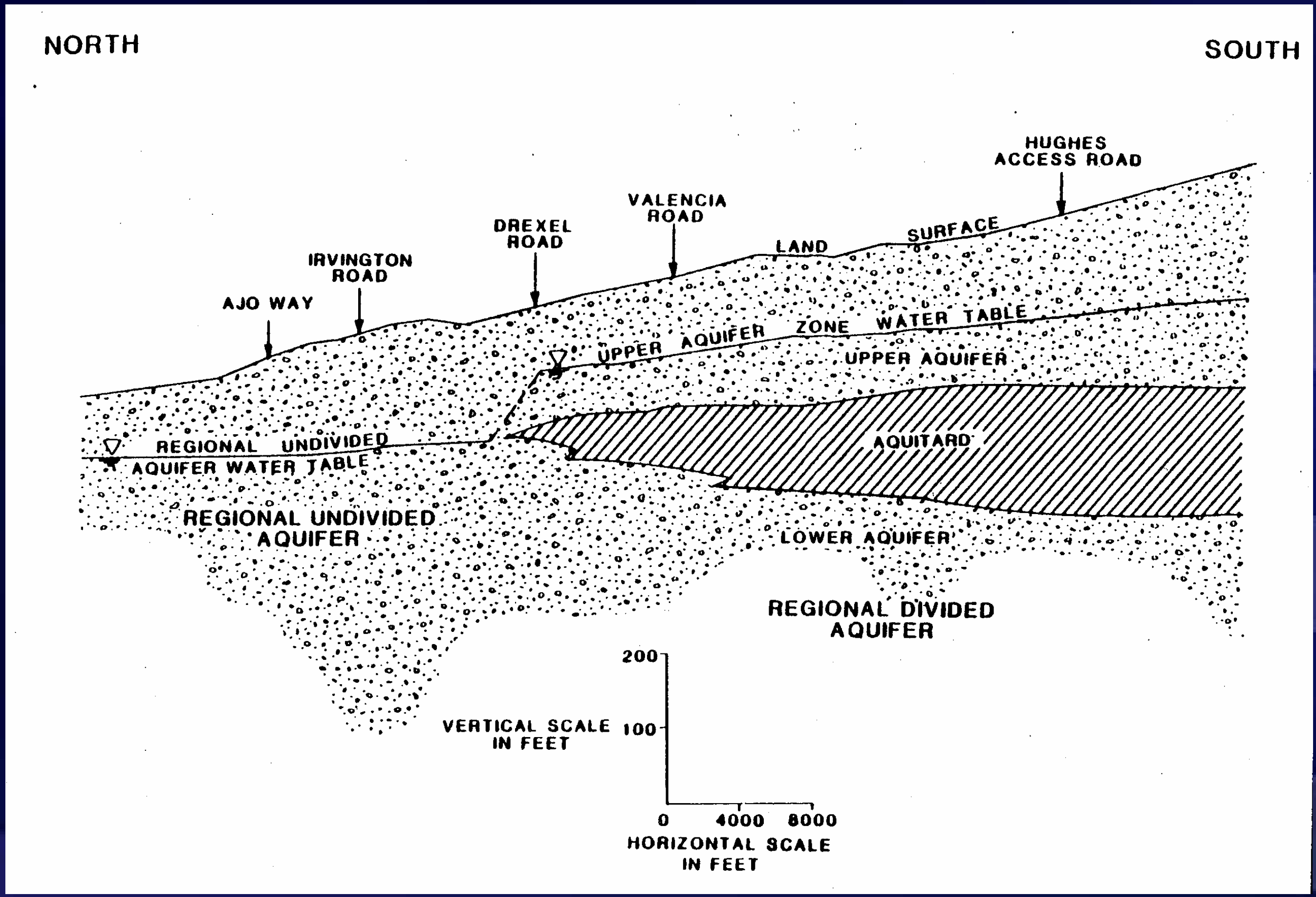

Figure from TIAA Record of Decision

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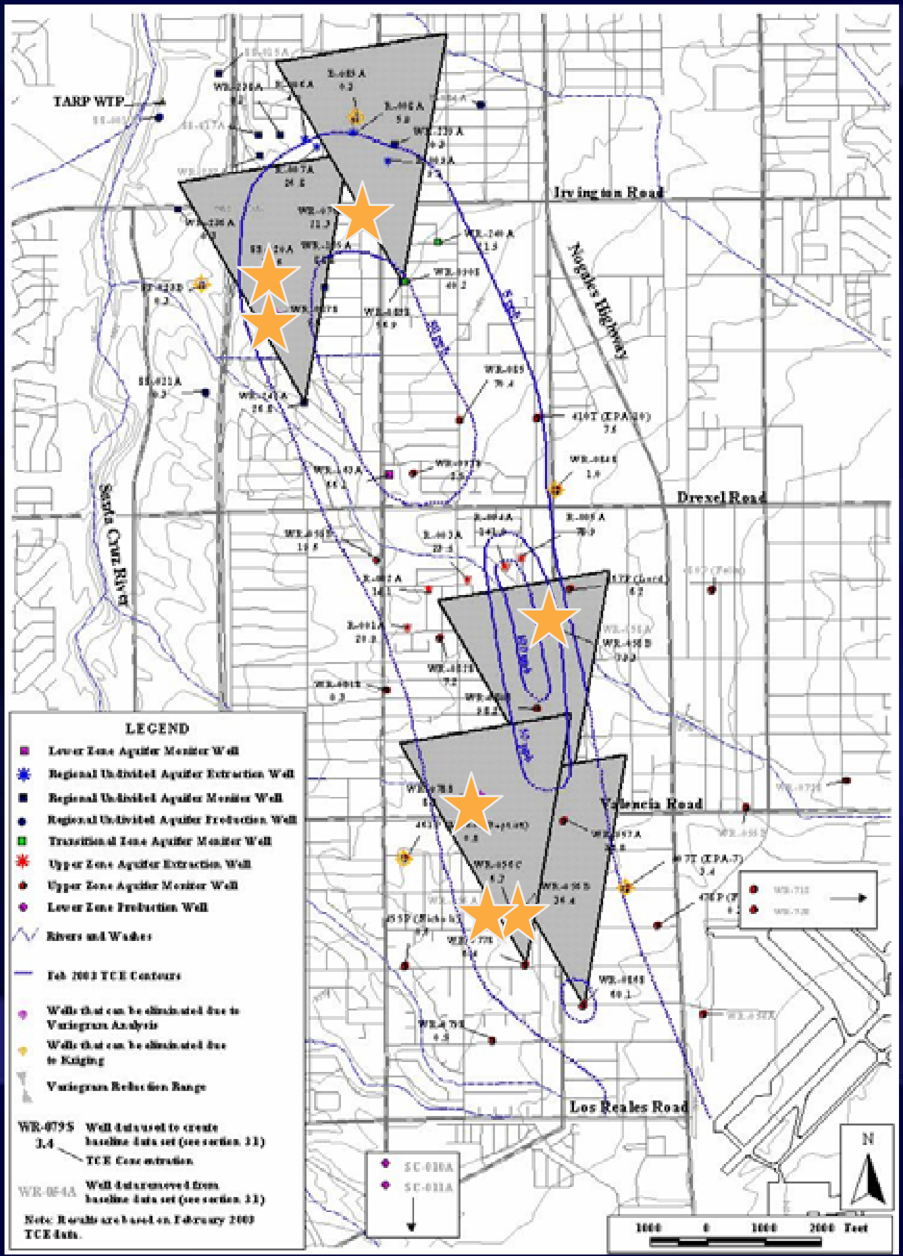
Case Study

Spatial Analyses



- Correlation range of approximately 4,000 feet in the direction of groundwater flow
- Seven wells could be eliminated based on this information

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Spatial Analyses – Kriging

- Kriging
  - ◆ Evaluates wells outside the areas of directional correlation
    - Step 1: Thin the data set by removing the data for the selected well
    - Step 2: Using the model variogram created from the variogram analysis, interpolate TCE concentrations in selected area
    - Step 3: Compare the interpolated value with the original TCE concentration; if the difference was minimal (less than 10 ppb, the point could be removed).

Well Name	Measured Conc (µg/L)	Interpolated Conc (µg/L)	Absolute Difference
407T	3.4	1.4	2.0
461P	0.8	0.6	0.2
SS-023B	ND < 0.5	0.9	0.4
WR-084A	1	9.1	8.1
B-085A	ND < 0.5	1.2	0.7

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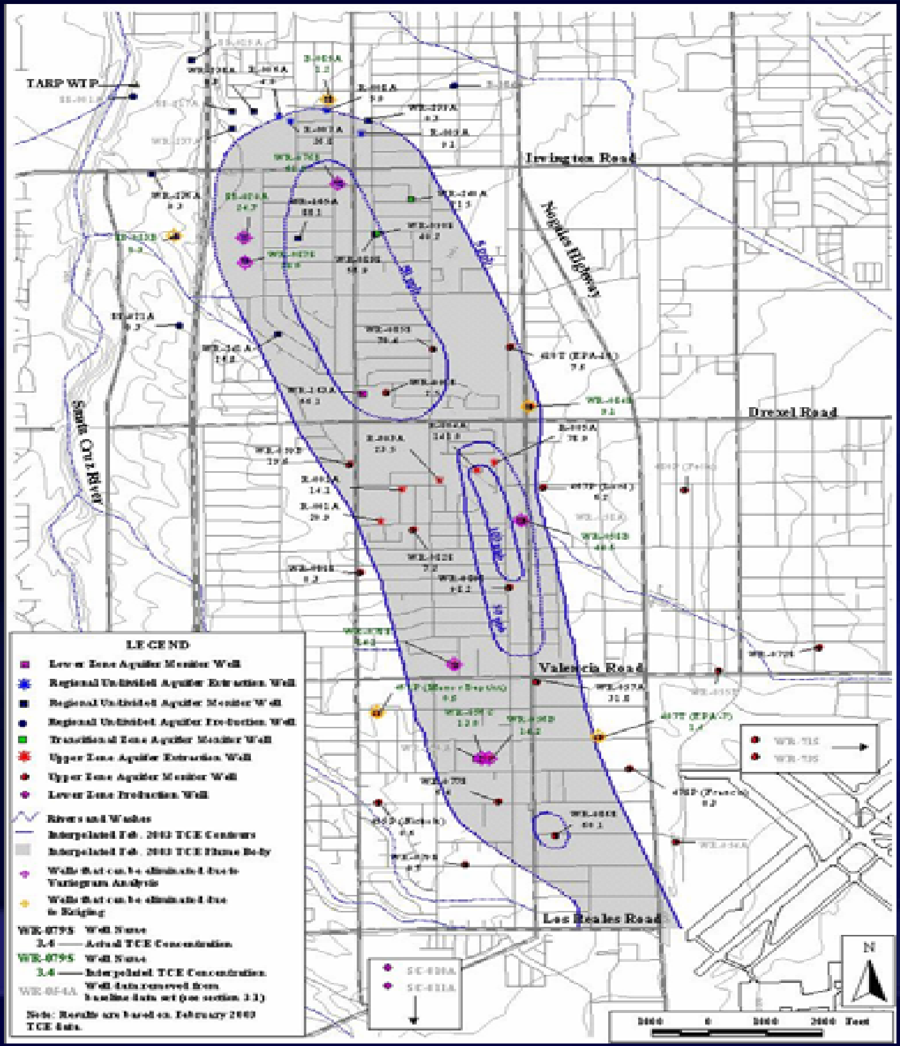
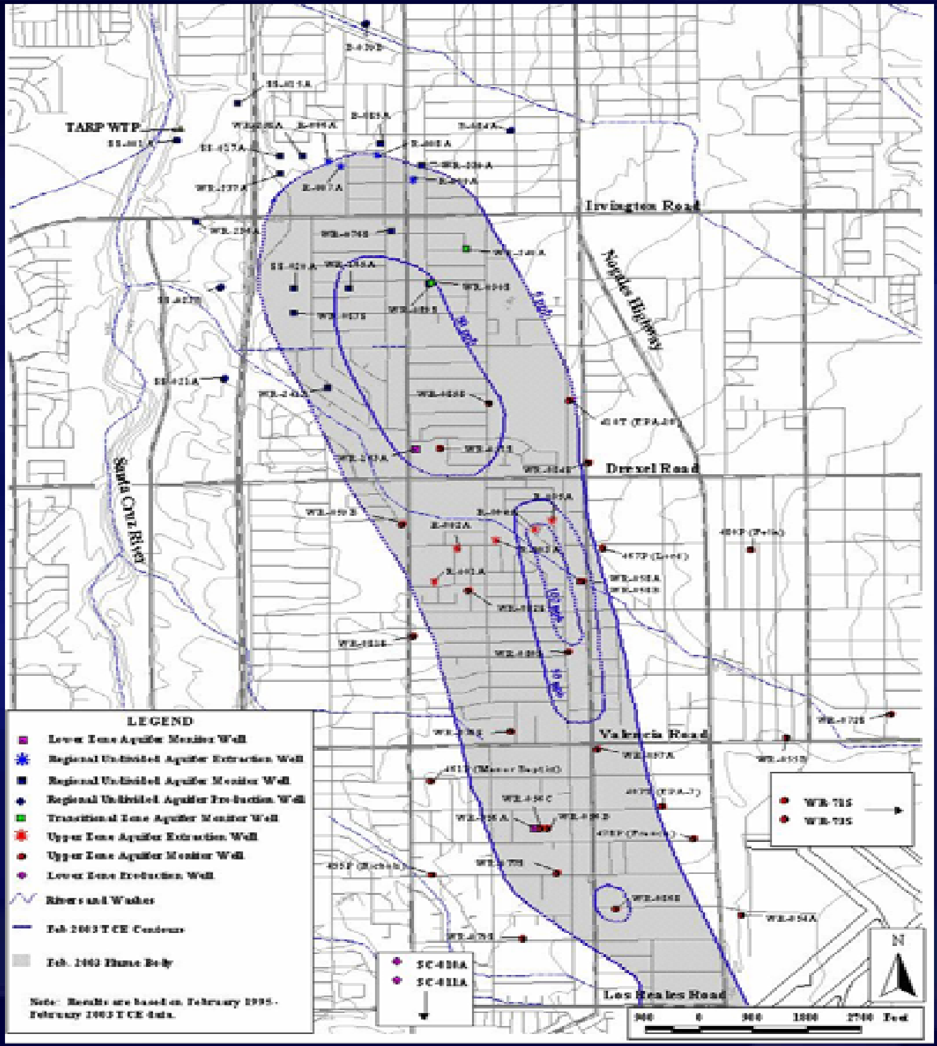
Spatial Analyses Check



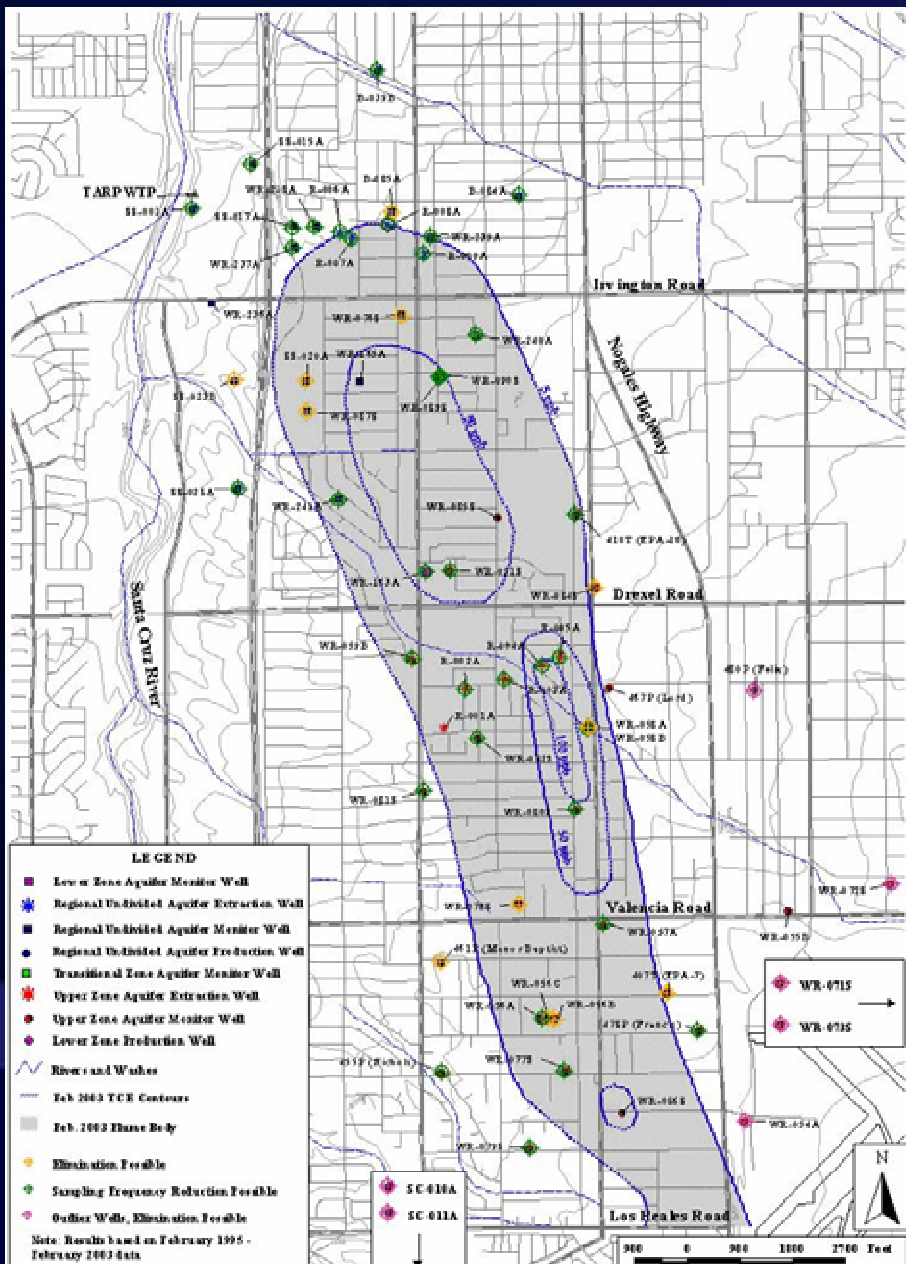
Interpolated Data Set



Original Data Set

Case Study

Statistical Results



- Of the original 61 wells:
  - 7 “outliers” were recommended for elimination
  - Sampling frequency reduction: 48 wells
  - Elimination: 12 wells

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