Case Study

Tucson International Airport Area (TIAA) Superfund Site

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

Figure provided by Tucson Airport Authority
Case Study

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
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*
**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:**

<table>
<thead>
<tr>
<th>Date</th>
<th>3-1-95</th>
<th>3-5-96</th>
<th>3-19-97</th>
<th>3-3-98</th>
<th>n = 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conc. (ppb)</td>
<td>2.3</td>
<td>0.8</td>
<td>1.8</td>
<td>0.5</td>
<td>Sum</td>
</tr>
<tr>
<td></td>
<td>-1</td>
<td>-1</td>
<td>-1</td>
<td>-3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>-1</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>-1</td>
<td>-1</td>
<td>S = -4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Case Study

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:

<table>
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<tr>
<th>Date</th>
<th>3-1-95</th>
<th>3-5-96</th>
<th>3-19-97</th>
<th>3-3-98</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time Period</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Conc. (ppb)</td>
<td>2.3</td>
<td>0.8</td>
<td>1.8</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td>-1.5</td>
<td>-0.25</td>
<td>-0.933</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.0</td>
<td>-0.65</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>-2.3</td>
<td></td>
</tr>
<tr>
<td>N’ = 6</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td></td>
</tr>
</tbody>
</table>
## Temporal Analyses

### Case Study

<table>
<thead>
<tr>
<th>Q</th>
<th>Slope</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-2.3</td>
</tr>
<tr>
<td>2</td>
<td>-1.5</td>
</tr>
<tr>
<td>3</td>
<td>-0.933</td>
</tr>
<tr>
<td>4</td>
<td>-0.65</td>
</tr>
<tr>
<td>5</td>
<td>-0.25</td>
</tr>
<tr>
<td>6</td>
<td>1.0</td>
</tr>
</tbody>
</table>

\[ N' = 6 \text{ (even)} \]

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

\[ Q_3 + Q_4 = Q_{3.5} \]

\[ (-0.933 + -0.65)/2 = -0.792 \]

Negative slope = downward trend

\[ \rightarrow \text{Sampling can be reduced} \]
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
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**

- WR-059B; Quarterly

![Autocorrelation Chart](chart.png)
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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:
- 350° (10° west of north - corresponds to gw flow)
- 20° window
- Range (distance with which the data are spatially correlated = approximately 4,000 ft

*GMS 3.1 Variogram Editor

MALCOLM PIRNIE
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Spatial Analyses - Variograms

Upper Zone vs. Regional Undivided Aquifers

Figure from TIAA Record of Decision
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Spatial Analyses

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

<table>
<thead>
<tr>
<th>Well Name</th>
<th>Measured Conc (µg/L)</th>
<th>Interpolated Conc (µg/L)</th>
<th>Absolute Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>407T</td>
<td>3.4</td>
<td>1.4</td>
<td>2.0</td>
</tr>
<tr>
<td>461P</td>
<td>0.8</td>
<td>0.6</td>
<td>0.2</td>
</tr>
<tr>
<td>SS-023B</td>
<td>ND &lt; 0.5</td>
<td>0.9</td>
<td>0.4</td>
</tr>
<tr>
<td>WR-084A</td>
<td>1</td>
<td>9.1</td>
<td>8.1</td>
</tr>
<tr>
<td>B-085A</td>
<td>ND &lt; 0.5</td>
<td>1.2</td>
<td>0.7</td>
</tr>
</tbody>
</table>
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Spatial Analyses Check

Interpolated Data Set

Original Data Set
Statistical Results

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