Groundwater Plume Analytics® Services

GRA Remediation Conference:
Optimization of Remediation Systems and Long-Term Monitoring

November 14, 2019
The material contained in this presentation, including text, graphic representations and the oral description thereof, is the sole and exclusive property of EarthCon Consultants, Inc. and is considered Proprietary and Confidential. This material, or any copy, facsimile, photograph or other reproduction of whatever kind, may not be disseminated to any third party without the express written consent of EarthCon Consultants, Inc.
Analytics is the discovery and communication of meaningful patterns in data. Especially valuable in areas rich with recorded information, analytics relies on the simultaneous application of statistics, computer programming and operations research to quantify performance. Analytics often favors data visualization to communicate insight.

- From Wikipedia, the free encyclopedia
Benefits of Groundwater Plume Analytics®

- Enhance project management and strategic planning
- Basis for termination of remediation systems
- Basis for Monitored Natural Attenuation (MNA)
- Monitor progress of remediation systems
- Foundation for groundwater monitoring optimization
Groundwater Plume Analytics® Tools

- Ricker Method® Plume Stability Analysis
- Spatial Change Indicator™ Analysis
- Well Sufficiency Analysis™

California Example Site

- Petroleum bulk terminal in northern California
Ricker Method® Plume Stability Analysis
Phenol
Upper Sand
Sep-1984

Concentration (mg/L)

0 2 5 10 20 30 50 100 150

Plume Characteristics
Plume Area: 12.4 hectares
Plume Average Concentration: 33.8 mg/L
Plume Mass Indicator: 8,771 kgs

This analysis requires fixed data points within a fixed area for the purposes of assessing relative changes of area, average concentration, and mass indicator over time. Therefore, any created isopleth maps are not intended to be a depiction or model of the actual plume but rather is meant to show conceptual behavior of the aforementioned metrics over time.

© EarthCon 2019

Legend:
- Monitoring Well
- Hanging Well
- Concentration (mg/L)
- Well Not Sampled (Assigned Value Shown)
- Plume Center of Mass
- General Groundwater Flow
- Approx. Property Boundary
This analysis requires fixed data points within a fixed area for the purposes of assessing relative changes of area, averaged concentration, and mass indicator over time. Therefore, any created isopleth maps are not intended to be a depiction or model of the actual plume but rather is meant to show conceptual behavior of the aforementioned metrics over time.

© EarthCon 2019
Phenolics Plume Spread
(Upper Sand Unit)

- Capping of North Pond
- South Pond Remediation Completed
- Seasonal Operation of Recovery Wells
- System Shutdown

**Sep-1984 to Sep-2014**
- Decreasing Trend
- Mann-Kendall: >99% Confidence
- Regression: >99% Confidence

**Sep-2014 to Oct-2018**
- No Trend
- Mann-Kendall: 62% Confidence
- Regression: 37% Confidence
Spatial Change Indicator™ Analysis
**Petrachlorophenol Plume Area**

- **Area (acres):**
  - 1998: 8
  - 1999: 8
  - 2000: 8
  - 2001: 8
  - 2002: 8
  - 2003: 8
  - 2004: 8
  - 2005: 8
  - 2006: 8
  - 2007: 8
  - 2008: 8

**Jan-1998 to Jan-2008**
- Decreasing Trend
- Mann-Kendall: >99% Confidence
- Regression: >99% Confidence

**WA Guidance for Plume Status**
Plume Characteristics

Plume Area: 4% Decrease
Plume Average Concentration: 24% Decrease
Plume Mass Indicator: 28% Decrease
Mass Increase: 0.33 lbs Increase
Mass Decrease: 7.07 lbs Decrease

Legend:
- M200: Monitoring Well
- Plume Center of Mass
- 1998 Plume Boundary
- 1999 Plume Boundary

Spatial Change Indicator™

This analysis requires fixed data points within a fixed area for the purposes of assessing relative changes of area, average concentration, and mass indicator over time. Therefore, any created isopleth maps are not intended to be a depiction or model of the actual plume but rather a need to show conceptual changes of the aforementioned metrics over time.

© EarthCon 2018

Environmental Challenges
BUSINESS SOLUTIONS
Well Sufficiency Analysis™
Constituent A
Reduced Network 1
Dec-2013

Reduced Network 1
MW01W
MW04
MW05
MW27
MW60

Plume Characteristics
Plume Area: 55.7 acres
Plume Average Concentration: 235 µg/L
Plume Mass Indicator: 213 lbs
Constituent A Plume Area

Original Network Trends
Mann-Kendall: No Trend 45% Confidence
Regression: No Trend 8% Confidence

Constituent A Plume Average Concentration

Original Network Trends
Mann-Kendall: No Trend 86% Confidence
Regression: No Trend 88% Confidence

Constituent A Plume Mass

Original Network Trends
Mann-Kendall: Decreasing Trend 91% Confidence
Regression: No Trend 86% Confidence
Constituent A
Reduced Network 2
Dec-2013

Reduced Network 2
MW01W
MW04
MW05
MW27
MW60
MW03R
MW41
MW43
MW45
MW47
MW49
MW62

Plume Characteristics
Plume Area: 56.1 acres
Plume Average Concentration: 233 μg/L
Plume Mass Indicator: 213 lbs

LEGEND
MW16R
Monitoring Well
MW05
Removed Well
→ General Groundwater Flow
+ Plume Center of Mass

Concentration (μg/L)

0 0.035 1 5 10 50 100 500 2,500 10,000 50,000

0 ft 500 ft 1000 ft
Constituent A Plume Area

Original Network Trends
Mann-Kendall: No Trend 45% Confidence
Regression: No Trend 6% Confidence

Reduced Network Trends
Mann-Kendall: Decreasing Trend 91% Confidence
Regression: No Trend 84% Confidence

Average RPD: 4.29%
Correlation: 0.80

Constituent A Plume Average Concentration

Original Network Trends
Mann-Kendall: No Trend 86% Confidence
Regression: No Trend 88% Confidence

Reduced Network Trends
Mann-Kendall: No Trend 55% Confidence
Regression: No Trend 43% Confidence

Average RPD: 4.37%
Correlation: 0.89

Constituent A Plume Mass

Original Network Trends
Mann-Kendall: Decreasing Trend 91% Confidence
Regression: No Trend 86% Confidence

Reduced Network Trends
Mann-Kendall: Decreasing Trend 91% Confidence
Regression: No Trend 85% Confidence

Average RPD: 0.35%
Correlation: 1.00
## Well Sufficiency Analysis Argument

<table>
<thead>
<tr>
<th>Strength of Argument</th>
<th>Primary Line of Evidence</th>
<th>Secondary Line of Evidence</th>
<th>Correlation Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Trend via Mann-Kendall</td>
<td>Trend via Linear Regression</td>
<td>Relative Percent Difference</td>
</tr>
<tr>
<td>Very Strong</td>
<td>Same</td>
<td>Same</td>
<td>&lt;10%</td>
</tr>
<tr>
<td>Strong</td>
<td>Same</td>
<td>Same</td>
<td>&lt;20%</td>
</tr>
<tr>
<td>Marginal</td>
<td>Increasing/Stable or Decreasing/Stable</td>
<td>Increasing/Stable or Decreasing/Stable</td>
<td>&lt;30%</td>
</tr>
<tr>
<td>Poor</td>
<td>Increasing/Decreasing</td>
<td>Increasing/Decreasing</td>
<td>&gt;30%</td>
</tr>
<tr>
<td>Original Program</td>
<td>Optimized Program</td>
<td></td>
<td></td>
</tr>
<tr>
<td>------------------</td>
<td>-------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Cr(^{+6}): 65 wells</td>
<td>• Cr(^{+6}): 42 wells (35% reduction)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Other metals: 84 wells</td>
<td>• Ni: 65 wells (24% reduction)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• VOCs: 84 wells</td>
<td>• Metals: 42 wells (50% reduction)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Quarterly monitoring</td>
<td>• VOCs: 37 wells (56% reduction)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Quarterly reporting</td>
<td>• Every 3(^{rd}) qtr monitoring</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Annual Cost: $144,784</td>
<td>• Annual Cost: $29,190</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Petroleum Bulk Terminal – Northern California
Plume Characteristics
Plume Area: **34.6 acres**
Plume Average Concentration: **1,317 µg/L**
Plume Mass Indicator: **1,115 lbs**

Benzene A-Zone
Jan-1994

Concentration (µg/L)

LEGEND

MW-01T  FTT Groundwater Monitoring Well
MW-01A  Groundwater Monitoring Well
P-1     FTT Piezometer
MW-1    Groundwater Monitoring Well
PT      Hanging Well
△       Sparge Well
●       U-Shaped Oxygen Well
□       Vapor Extraction Well
□       Dual Phase Extraction Well
□       Groundwater Extraction Well
+       Plume Center of Mass

This analysis requires field data points within a fixed area for the purposes of assessing relative changes of area, average concentration, and mass indicator over time. Therefore, any created contour maps are not intended to be a depiction or model of the actual plume but rather is meant to show conceptual behavior of the aforementioned metrics over time.
Benzene Plume Area (A-Zone)

Oct-2001 to Jan-2019
Decreasing Trend
Mann-Kendall: >99% Confidence
Regression: >99% Confidence

Benzene Plume Average Concentration (A-Zone)

Oct-2001 to Jan-2019
Decreasing Trend
Mann-Kendall: >99% Confidence
Regression: >99% Confidence

Benzene Plume Mass Indicator (A-Zone)

Oct-2001 to Jan-2019
Decreasing Trend
Mann-Kendall: >99% Confidence
Regression: >99% Confidence
**Plume Characteristics**

- **Area:** 19% Decrease
- **Average Concentration:** 15% Decrease
- **Mass Indicator:** 31% Decrease
- **Mass Increase:** 19.3 lbs Increase
- **Mass Decrease:** 597 lbs Decrease
Bulk Terminal Site Well Sufficiency Analysis™
Plume Characteristics

Plume Area: **34.6 acres**
Plume Average Concentration: **1,317 µg/L**
Plume Mass Indicator: **1,115 lbs**
Original Network Trends
MK: Decreasing Trend >99% Confidence
R: Decreasing Trend >99% Confidence

Original Network Trends
MK: Decreasing Trend >99% Confidence
R: Decreasing Trend >99% Confidence

Original Network Trends
MK: Decreasing Trend >99% Confidence
R: Decreasing Trend >99% Confidence
Plume Characteristics

Plume Area: **34.6 acres**
Plume Average Concentration: **1,317 μg/L**
Plume Mass Indicator: **1,115 lbs**
27 wells removed

**Plume Characteristics**
- Plume Area: **17.2 acres**
- Plume Average Concentration: **180 µg/L**
- Plume Mass Indicator: **75.5 lbs**

**Benzene A-Zone Jan-2013**

**Concentration (µg/L)**
- 5,000
- 2,500
- 1,500
- 1,000
- 1,000
- 500
- 100
- 50
- 10
- 1

**LEGEND**
- MW-01T: FTT Groundwater Monitoring Well
- P-1: FTT Piezometer
- MW-01A: Groundwater Monitoring Well
- MW-01: Groundwater Monitoring Well
- Hanging Well
- Sparge Well
- U-Shaped Oxygen Well
- Vapor Extraction Well
- Dual Phase Extraction Well
- Groundwater Extraction Well
- Plume Center of Mass

This analysis requires fixed data points within a fixed area for the purposes of assessing relative changes of area, average concentration, and mass indicator over time. Therefore, any created output or model of the actual plume is not intended to be a depiction or model of the actual plume but rather is meant to show conceptual behavior of the aforementioned metrics over time.
Wells Removed:
MW-1
MW-01A
MW-2
MW-04A
MW-11A
MW-12
MW-15A
MW-16A
MW-17
MW-17A
MW-18
MW-18A
MW-18R
MW-19A
MW-20A
MW-21A
MW-22A
MW-23A
MW-24A
MW-40T
MW-41T
MW-46T
MW-4R
RW-03T
RW-08T
RW-10T
RW-13T

**27 of 68 Wells Removed**
40% Reduction

Original Network Trends
MK: Increasing Trend 92% Confidence
R: Increasing Trend 91% Confidence

Reduced Network Trends
MK: Increasing Trend 98% Confidence
R: Increasing Trend 94% Confidence

Average RPD: 5.7%
Correlation: 0.75

**27 of 68 Wells Removed**
40% Reduction

Original Network Trends
MK: No Trend 75% Confidence
R: No Trend 51% Confidence

Reduced Network Trends
MK: No Trend 88% Confidence
R: No Trend 61% Confidence

Average RPD: 19.2%
Correlation: 0.84

**27 of 68 Wells Removed**
40% Reduction

Original Network Trends
MK: No Trend 52% Confidence
R: No Trend 34% Confidence

Reduced Network Trends
MK: Increasing Trend 94% Confidence
R: No Trend 74% Confidence

Average RPD: 19.4%
Correlation: 0.88
Thank you for the opportunity to present this information to you!

Joe A. Ricker, P.E.

jricker@earthcon.com

901-337-1010

www.earthcon.com