Example analogy calculation:

- **Calculate planar area and average height of a conical shaped pile of soil.**

- **Planar area;** 
  \[ A = \pi r^2 = \pi (3)^2 = 9\pi \text{ ft}^2 \]

- **Volume;** 
  \[ V = \frac{1}{3} \pi r^2 h = \frac{1}{3} \pi (3)^2 \times 6 = 18\pi \text{ ft}^3 \]

- **Average height (i.e., level) =** 
  \[ V/A = 2 \text{ feet} \]
Same analogy calculation using Surfer:

- Grid representation of soil pile
- Plan view contour map of soil pile

Calculated volume of grid = 56.55 ft$^3$
Calculated Planar Area = 28.27 ft$^2$

Average Height = 56.55 ft$^3$ / 28.27 ft$^2$ = 2.0 ft.
Ricker Plume Stability Analysis Method

- Same analogy applied to contaminant isopleth map:

**Naphthalene Data for 2005**

<table>
<thead>
<tr>
<th>Well</th>
<th>X Coord.</th>
<th>Y Coord.</th>
<th>2005</th>
</tr>
</thead>
<tbody>
<tr>
<td>DB-15</td>
<td>499296</td>
<td>99655</td>
<td>NS</td>
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<td>DB-18</td>
<td>499191</td>
<td>99566</td>
<td>9,400</td>
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<td>99426</td>
<td>560</td>
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<td>DB-22</td>
<td>498916</td>
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<td>DB-29</td>
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<td>DB-33</td>
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<td>98384</td>
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<td>DB-34</td>
<td>497931</td>
<td>99369</td>
<td>NS</td>
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<td>DB-35</td>
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<td>DB-43</td>
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<tr>
<td>DB-44</td>
<td>498022</td>
<td>100539</td>
<td>ND</td>
</tr>
</tbody>
</table>

Calculated volume of grid = $1.35 \times 10^9 \text{ ft}^2 \cdot \mu g/l$

Calculated Planar Area = 1,269,220 ft$^2$

Average Height (Concentration) = $1.35 \times 10^9 \text{ ft}^2 \cdot \mu g/l / 1,269,220 \text{ ft}^2 = 1,062 \mu g/l$
Calculation of Plume Center of Mass

- Grid File Containing 40,000 Nodes

<table>
<thead>
<tr>
<th>Node</th>
<th>X</th>
<th>Y</th>
<th>Z</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>498046</td>
<td>98387</td>
<td>10.422</td>
</tr>
<tr>
<td>2</td>
<td>498065</td>
<td>98387</td>
<td>10.770</td>
</tr>
<tr>
<td>3</td>
<td>498084</td>
<td>98387</td>
<td>10.740</td>
</tr>
<tr>
<td></td>
<td>40,000</td>
<td>500530</td>
<td>100713</td>
</tr>
</tbody>
</table>

- Centroid of Grid = Moment around Grid Origin (i.e., concentration weighted average coordinate)

- Center of Mass X Coordinate = $\frac{\sum_{n=1}^{40,000} X \times Z}{\sum_{n=1}^{40,000} Z}$

- Center of Mass Y Coordinate = $\frac{\sum_{n=1}^{40,000} Y \times Z}{\sum_{n=1}^{40,000} Z}$
**Center of Mass Calculated Using Spreadsheet**

<table>
<thead>
<tr>
<th>Node</th>
<th>X</th>
<th>Y</th>
<th>Z</th>
<th>XZ</th>
<th>YZ</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>498046</td>
<td>98387</td>
<td>10.42</td>
<td>5190766</td>
<td>1025413</td>
</tr>
<tr>
<td>2</td>
<td>498065</td>
<td>98387</td>
<td>10.77</td>
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<td>1059597</td>
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<td>3</td>
<td>498084</td>
<td>98387</td>
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<td>1056699</td>
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<tr>
<td>40,000</td>
<td>500530</td>
<td>100713</td>
<td>0.003</td>
<td>1574</td>
<td>317</td>
</tr>
</tbody>
</table>

\[
\text{Total:} \quad 4.07 \times 10^6 \quad 2.03 \times 10^{12} \quad 4.05 \times 10^{11}
\]

- **Center of Mass X Coordinate**

\[
\frac{\sum_{i=1}^{40,000} X \cdot Z}{\sum_{i=1}^{40,000} Z} = \frac{2.03 \times 10^6 + 12}{4.07 \times 10^6} = 498867
\]

- **Center of Mass Y Coordinate**

\[
\frac{\sum_{i=1}^{40,000} Y \cdot Z}{\sum_{i=1}^{40,000} Z} = \frac{4.05 \times 10^6 + 11}{4.07 \times 10^6} = 99429
\]
Ricker Plume Stability Analysis Method

- Evaluate temporal trends in plume characteristics using statistical methods

**Methodology**

- **Plume Mass Trend**
  - R² = 0.3717

- **Plume Area Trend**
  - R² = 0.3717

- **Plume Average Concentration Trend**
  - R² = 0.5001

**Mann-Kendall Trend Analysis Summary**

<table>
<thead>
<tr>
<th>Parameter</th>
<th># of samples, n</th>
<th>S Statistic</th>
<th>Confidence Factor</th>
<th>Coeff of Variation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plume Area</td>
<td>12</td>
<td>-34</td>
<td>99.7%</td>
<td>0.10</td>
</tr>
<tr>
<td>Plume Average Concentration</td>
<td>12</td>
<td>-38</td>
<td>99.4%</td>
<td>0.43</td>
</tr>
<tr>
<td>Plume Mass</td>
<td>12</td>
<td>-452</td>
<td>97.9%</td>
<td>0.44</td>
</tr>
</tbody>
</table>

**Linear Regression Trend Analysis Summary**

<table>
<thead>
<tr>
<th>Parameter</th>
<th># of samples, n</th>
<th>Slope (yr⁻¹)</th>
<th>R²</th>
<th>Confidence Factor</th>
<th>Coeff of Variation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plume Area</td>
<td>12</td>
<td>-2.56</td>
<td>0.37</td>
<td>96.5%</td>
<td>0.10</td>
</tr>
<tr>
<td>Plume Average Concentration</td>
<td>12</td>
<td>-452</td>
<td>0.43</td>
<td>97.9%</td>
<td>0.43</td>
</tr>
<tr>
<td>Plume Mass</td>
<td>12</td>
<td>-3,211</td>
<td>0.56</td>
<td>99.5%</td>
<td>0.44</td>
</tr>
</tbody>
</table>

**Conclusion**

- Decreasing Trend
- Decreasing Trend
- Decreasing Trend
Ricker Plume Stability Analysis Method

- **Methodology**
  - Evaluate temporal trends in plume characteristics using statistical methods

- **Mann-Kendall Trend Analysis**
  - \( n = 12 \)
  - \( S \) Statistic = -36
  - Confidence Factor = 99.2%
  - Coeff. of Variation = 0.08
  - Conclusion: Decreasing Trend

- **Linear Regression Trend Analysis**
  - \( n = 12 \)
  - Slope = -17.3
  - \( R^2 = 0.46 \)
  - Confidence Factor = 98.4%
  - Coeff. of Variation = 0.08
  - Conclusion: Decreasing Trend

- **Shallow Zone COM Trend**
  - Year: 1998 to 2009
  - Graph showing decreasing trend with correlation coefficient \( R = 0.4565 \)
Plume Stability Analysis - Example Site 1

- Wood Treating Site in South Mississippi
- Naphthalene Plume
- GW P&T system Operation Through 2002
- Plume Stability Analysis was Basis for Termination of P&T System
Naphthalene Time Series

1992

Property Boundary

Church House Branch
Closed Cell on, Penta, and Creosote Recovery Ponds
1992

Naphthalene Time Series
Naphthalene Time Series

1994
Naphthalene Time Series

1997

Property Boundary

Church House Branch
Closed Cello n, Penta and Creosote Recovery Po nds

1997 Naphthalene Time Series
Naphthalene Time Series

1998
Naphthalene Time Series

2000

Property Boundary

Church House Branch
Closed Cello n, Penta and Creosote Recovery Pond

Naphthalene Time Series
Naphthalene Time Series

2001
Naphthalene Time Series

Property Boundary

Church House Branch
Closed Cello n, Penta and Creosote Recovery Po nds
2002

Naphthalene Time Series
Naphthalene Time Series

2003
Naphthalene Time Series

2004

Property Boundary

Church House Branch
Closed Cell on Penta and Creosote Recovery Ponds

2004 Naphthalene Time Series
Naphthalene Time Series

Property Boundary

2005
Naphthalene Time Series

2007

Property Boundary

Church House Branch

Closed Cell, Pentachloro- and Creosote Recovery Ponds