Overview

- Use
- Methodology
- Critical Components
- Scenarios
Their Use
Two Big Reasons

Understand the Past
- What did we do?
- How did we do?

Estimate the Future
- What do we have?
- Where is it at?
- For how long?

• The need and use varies:
  • By Client
  • By State
  • By Consultant
Example Uses

**Estimate the Future**
- Airspace available
- Soil available
- Construction phasing and timing
- Permitting
- Regulatory compliance
- Planning (e.g. site, state)
- Lifespan estimate
- Asset evaluation
- Operations

**Understand the Past**
- Airspace used
- Soil used
- Operational performance metrics (density)
Can help answer questions

- How much capacity does my landfill have?
- How much airspace have I used?
- How long until the landfill fills up?
- How much material did we take in today?
- How well are we utilizing airspace?
- When will we run out of airspace in this cell?
- Where can I put waste when it rains?
- How long until we need to construct the next cell?
- How much dirt do I need to cover that area?
- How much dirt will I get if I excavate that area?
- How many trucks will I need to haul that dirt?
- How big does my berm need to be to water?
- Can my pond handle the storm?
- How much is my landfill worth?

...and the list goes on.
...but to answer questions (correctly)

• Must know the end use of volume calculations.
  • Guides assumptions during the calculation phase.
Methodology
Volume

• Volumes are:
  • Comprised of three dimensions
  • Measured in cubic units

• Calculate by hand
  • Formulas for different shapes

• Computer Aided Drafting
  • CAD
  • Compare two 3D surfaces

Typical Units:
• Cubic meters (m$^3$)
• Cubic feet (ft$^3$)
• Cubic yards (yd$^3$ or cy)
  • 1 cy = 27 ft$^3$
The Inputs

Surface Grades
- Topography (existing)
- Permitted (base, cover, and slopes)
- Operational (intermediate and existing waste slopes)

Boundary
- Edge of waste
- Active/primary fill area
- Permitted
- Constructed
- Borrow source
The Output

Volumes

- Density
- Fill Rates
- Estimated Life
Density / Specific Weight

- Density is:
  - Mass divided by volume
  - **Weight divided by volume (specific weight)**
  - Measured in:
    - Pounds per cubic foot (lb/ft$^3$)
    - Pounds per cubic yard (lb/yd$^3$)
    - Tons per cubic yard (ton/yd$^3$)

- Can include:
  - Waste
  - Soil
  - Waste and soil

Technically we use specific weight but loosely call it density
Fill Rates

• Weight per time
  • Tons per day (tons/day, tpd)

• Volume per time
  • Cubic yards per day (cy/day)
  • Cubic yards per month (cy/mo)
  • Cubic yards per year (cy/yr)

• Density allows you to move between the two
  • Consider the density type
    • Waste, soil, or waste and soil
Remaining Life Estimates

• Projection of how long landfill will last
  • Different methodologies
    • Based on inputs and assumptions

• Always need:
  • Volume airspace remaining

• May need:
  • Density (projected, varies)
  • Volume to be consumed (projected, varies)
  • Tonnage (historical)

Sensitive to inputs with future predictions
Other Considerations

- Compaction methods
- Settlement and compression
- Waste type and composition
  - Compressible
  - Degradable
- Liquids addition or removal
  - Bioreactor
  - Leachate recirculation
- Soil
  - Waste to soil ratio
  - Soil types
  - Soil removal
  - Alternative daily cover
- Survey accuracy and precision, type
- Site facilities, roads, stockpiles, slope repair
The Fun Examples
And a little math.
Example General Info

• Focus on CAD
  • (not hand calculations)

• Utilized AutoCAD Civil 3D software

• CAD Volume Surface
  • Surface 1 = the bottom surface
  • Surface 2 = the comparison surface
The Site (a landfill)

Permitted Landfill Waste Boundary
The Site (cross section)
Landfill’s Constructed Area

Constructed Landfill Cells
(22.6 acres)
Cross section with constructed area
Cross section waste in place

- Future Waste Placement Areas
- Waste In Place
- Constructed Landfill Cells
Site Information

- MSW Landfill
  - 41.5 acres permitted
  - 22.6 acres constructed

- Permitted capacity
  - 3,240,000 cy

- Remaining permitted capacity (2017)
  - 2,233,000 cy

- Remaining constructed capacity (2017)
  - 597,900 cy

- Old survey completed in 2017 (ground survey)
- New survey completed in 2018 (drone survey)
Some Typical Questions

• How much airspace consumed between surveys?
• What is the density of the material in place (lb/cy)
• How long will landfill last?
• Survey impacts?
## Airspace Consumed between Survey Dates

<table>
<thead>
<tr>
<th></th>
<th>Scenario 1</th>
<th>Scenario 2</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface 1</td>
<td>2017 Survey</td>
<td>2017 Survey</td>
<td></td>
</tr>
<tr>
<td>Surface 2</td>
<td>2018 Survey</td>
<td>2018 Survey</td>
<td></td>
</tr>
<tr>
<td>Boundary</td>
<td>Constructed Footprint</td>
<td>Primary Filling Area</td>
<td>Variable</td>
</tr>
<tr>
<td>Airspace Consumed</td>
<td>73,000 cy</td>
<td>62,000 cy</td>
<td>11,000 cy</td>
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<tr>
<td>Tonnage</td>
<td>33,569 tons</td>
<td>33,569 tons</td>
<td></td>
</tr>
<tr>
<td>Density</td>
<td>920 lb/cy</td>
<td>1,083 lb/cy</td>
<td>163 lb/cy</td>
</tr>
</tbody>
</table>

What does this tell you? How would you use each?
Active landfill areas

- Primary Filling Areas
- Constructed Landfill Cells
Cross section with active filling area
Things to consider:

• Constructed landfill footprint boundary
  • Accounts for landfill as a whole
  • Includes some settlement outside areas where no change occurred (not quantifiable)

• Primary filling area boundary
  • Better gauge of operational metrics
    • How are we filling?
    • How well are we utilizing soil?
    • Etc.

• Volume notably impacts density numbers
Airspace Remaining in Constructed Landfill Cells

<table>
<thead>
<tr>
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<th>Scenario 1</th>
<th>Scenario 2</th>
<th>Scenario 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface 1</td>
<td>2018 Survey</td>
<td>2018 Survey</td>
<td>2018 Survey</td>
</tr>
<tr>
<td>Surface 2</td>
<td>Final grades</td>
<td>Intermediate grades</td>
<td>Intermediate grades, revised</td>
</tr>
<tr>
<td>Boundary</td>
<td>Constructed Footprint</td>
<td>Constructed footprint</td>
<td>Constructed footprint, revised</td>
</tr>
<tr>
<td>Airspace Remaining</td>
<td><strong>548,000 cy</strong></td>
<td><strong>527,000 cy</strong></td>
<td><strong>515,000 cy</strong></td>
</tr>
</tbody>
</table>

What does this tell you?
Cross section waste in place with potential intermediate waste grades.
Scenario 1

Airspace Remaining
Scenario 2

Airspace Remaining
Impacts of slopes
Scenario 3

What to do with this airspace?
Things to consider:

• Know how using this number

• Use correct type of surface for data want to know
  • Operational use/metrics
  • Big picture planning
  • Intermediate slopes are important

• Ultimately impacts next step in calculations
  • Variable can be skewed up or down based on assumptions.
## Fill Rates and Remaining Life

<table>
<thead>
<tr>
<th></th>
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<th>Scenario 2</th>
<th>Scenario 3</th>
<th>Scenario 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remaining Airspace</td>
<td>527,000 cy</td>
<td>527,000 cy</td>
<td>527,000 cy</td>
<td>527,000 cy</td>
</tr>
<tr>
<td>Annual Tonnage</td>
<td>33,000 tons</td>
<td>33,000 tons</td>
<td><strong>40,000 tons</strong></td>
<td><strong>40,000 tons</strong></td>
</tr>
<tr>
<td>Density *</td>
<td>920 lb/cy</td>
<td><strong>1,080 lb/cy</strong></td>
<td>920 lb/cy</td>
<td><strong>1,080 lb/cy</strong></td>
</tr>
<tr>
<td>Fill Rate</td>
<td>72,000 cy/yr</td>
<td>61,000 cy/yr</td>
<td>87,000 cy/yr</td>
<td>74,000 cy/yr</td>
</tr>
<tr>
<td>Remaining Life</td>
<td>7.3 years</td>
<td>8.7 years</td>
<td>6.0 years</td>
<td>7.1 years</td>
</tr>
</tbody>
</table>

*Density includes waste and soil

**What does this tell you?**
Things to consider:

• Can vary:
  • Fill rate (cy/mo)
  • Waste acceptance (ton/yr) and density (lb/cy)
  • Less varying inputs, the better

• Cannot account for all variables

• Calculations are subjective

• Sensitive to assumptions
  • More critical closer to cell completion
# Survey Impacts

<table>
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<tbody>
<tr>
<td><strong>Surface 1</strong></td>
<td>2018 Survey</td>
<td>2018 Survey</td>
<td>2018 Survey</td>
</tr>
<tr>
<td><strong>Boundary</strong></td>
<td>Constructed Footprint</td>
<td>Constructed footprint</td>
<td>Constructed footprint</td>
</tr>
<tr>
<td><strong>Area</strong></td>
<td>22.6 acres</td>
<td>22.6 acres</td>
<td>22.6 acres</td>
</tr>
<tr>
<td><strong>Tolerance</strong></td>
<td>0’</td>
<td>+0.5’ (high)</td>
<td>-.25’ (low)</td>
</tr>
<tr>
<td><strong>Tolerance Volume</strong></td>
<td>0 cy</td>
<td>+18,230 cy</td>
<td>-9,115 cy</td>
</tr>
</tbody>
</table>

What does this tell you?
Things to consider:

• Survey is valid
• Survey type and equipment
• Tolerances can add up over larger areas
• These impact the numbers
• Often not discussed

• Other similar types of limitations.
Conclusions
Volume Calculations are:

• Useful tool for numerous applications
  • Looking forward
  • Checking the past
  • Know how to use them

• Limited by
  • Inputs and outputs provided
  • Considerations of software
  • Feasibility of data collection

• Not able to predict the future
  • But can help see where came from and where going

• Subject to interpretations
Important to Know

• Volumes can change
• Volume changes impact density
• Consistency in assumptions is valuable
• Remaining life sensitive to change
  • (depending on the methodology)
• Ask questions and understand end use
Questions?

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