

Volume Calculations

More than Just Math

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Overview

Use

Methodology

Critical Components

Scenarios

An abstract graphic consisting of several horizontal layers of color. From top to bottom: a thin olive green band, a light olive green band, a medium olive green band, a light teal band, and a large teal band. A white, curved swoosh shape starts near the top left and curves downwards and to the right, crossing through the olive green and light teal bands.

Their Use

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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

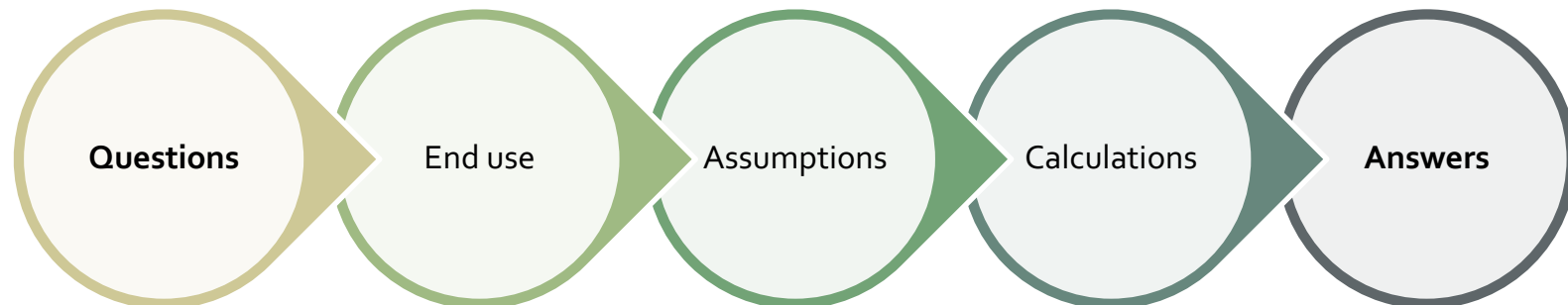
- How much capacity does my landfill have?
- How much airspace have I used?
- How long until the landfill fills up?
- How much material did we take in today?
- How well are we utilizing airspace?
- When will we run out of airspace in this cell?
- Where can I put waste when it rains?
- How long until 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.



The graphic features a layered design. At the top is a solid olive green bar. Below it is a light green area with a white, curved swoosh that tapers from left to right. Underneath is a medium green section, and the bottom half of the graphic is a large, solid teal block. The word 'Methodology' is centered in the teal section in a white, sans-serif font.

Methodology

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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)
 - $1\ cy = 27\ ft^3$



Critical
Components

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The Inputs

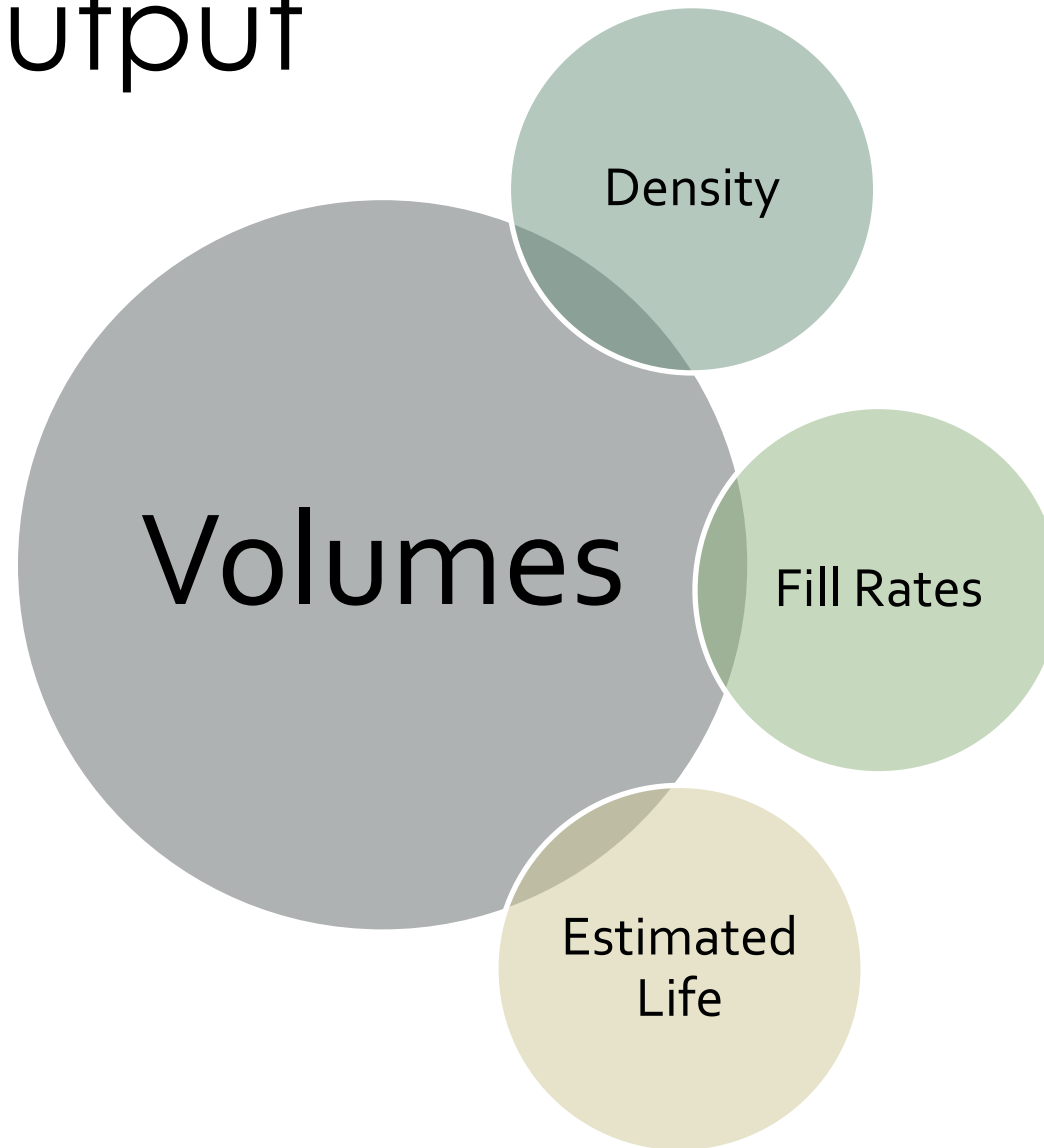
Surface Grades

- 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



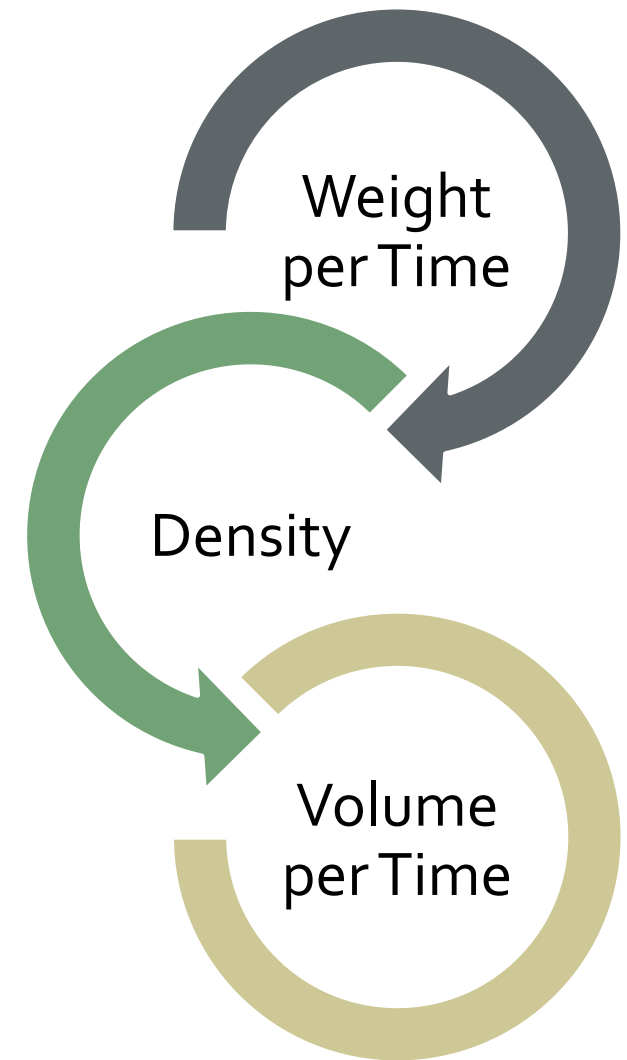
Density / Specific Weight

- Density is:
 - Mass divided by volume
 - **Weight divided by volume (specific weight)**
 - Measured in:
 - **Pounds per cubic foot (lb/ft³)**
 - Pounds per cubic yard (lb/yd³)
 - Tons per cubic yard (ton/yd³)
- 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

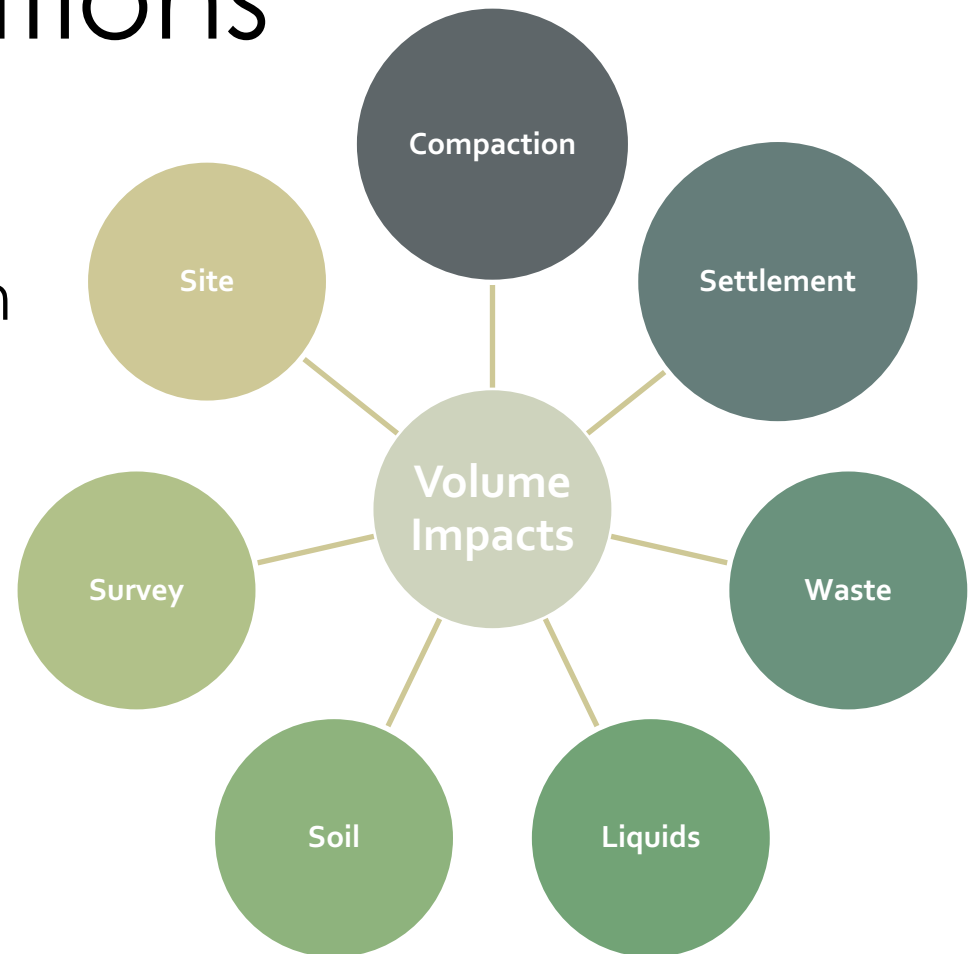
- Projection of how long landfill will last
- Different methodologies
 - Based on inputs and assumptions
- Always need:
 - Volume airspace remaining
- May need:
 - Density (projected, varies)
 - Volume to be consumed (projected, varies)
 - Tonnage (historical)



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.

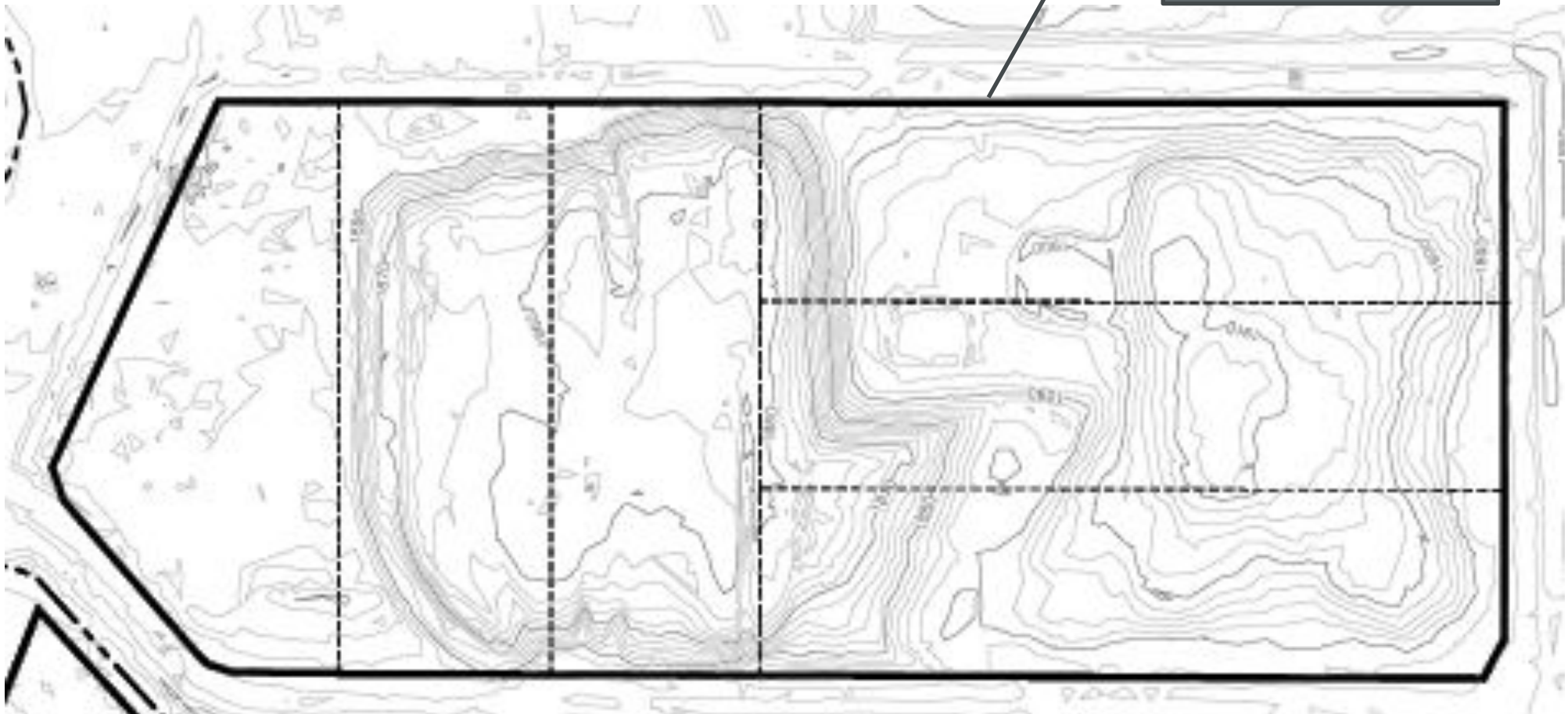
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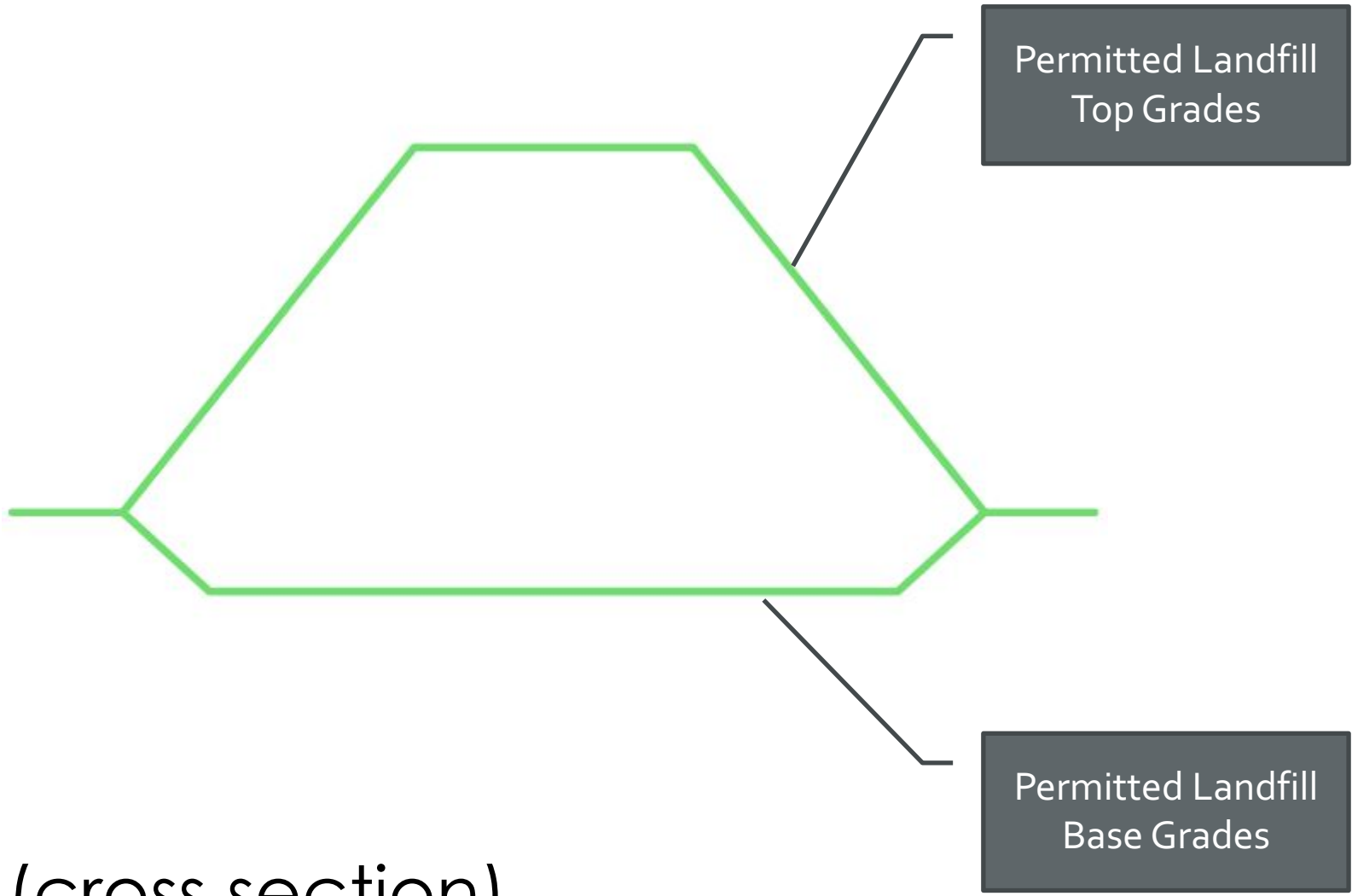
Example General Info

- Focus on CAD
 - (not hand calculations)
- Utilized AutoCAD Civil 3D software
- CAD Volume Surface
 - Surface 1 = the bottom surface
 - Surface 2 = the comparison surface

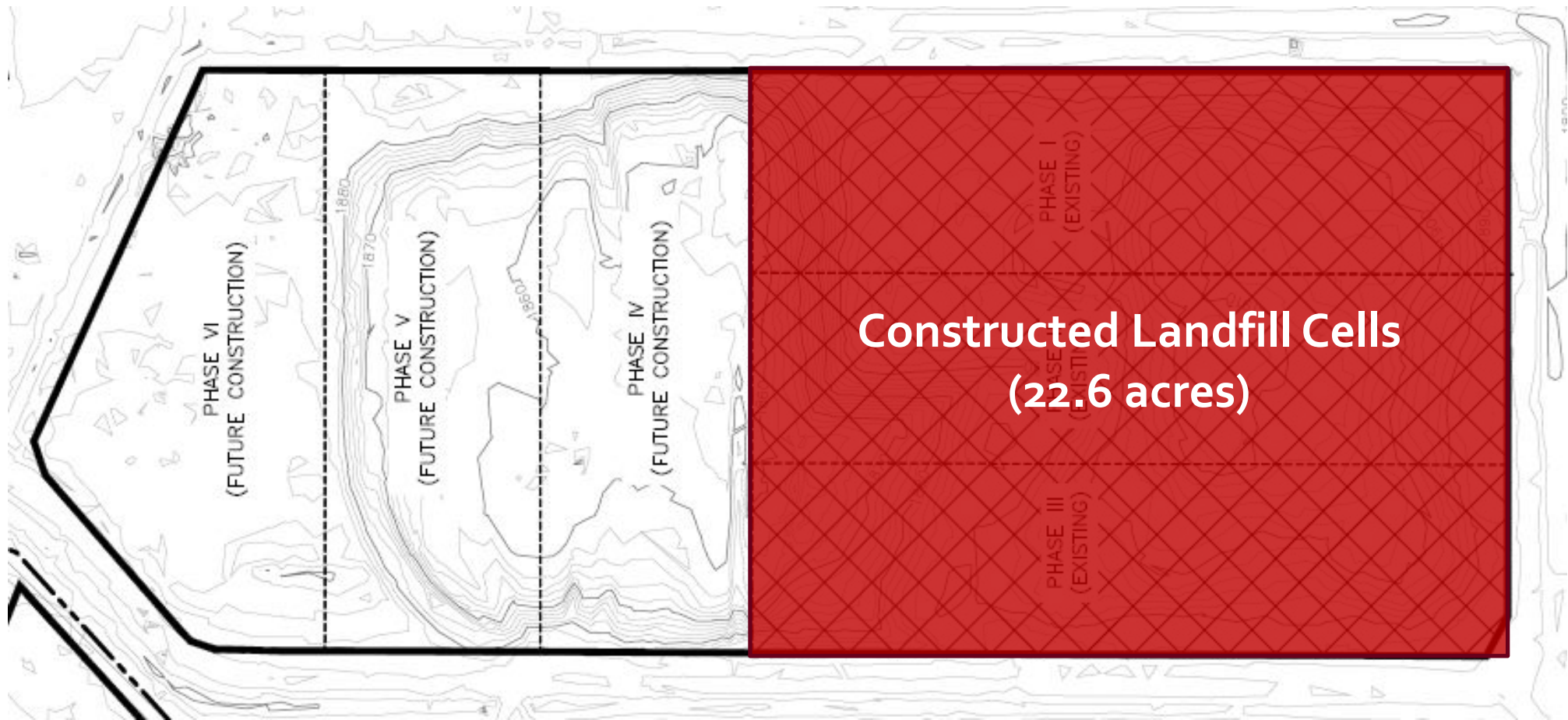
The Site (a landfill)

Permitted Landfill
Waste Boundary





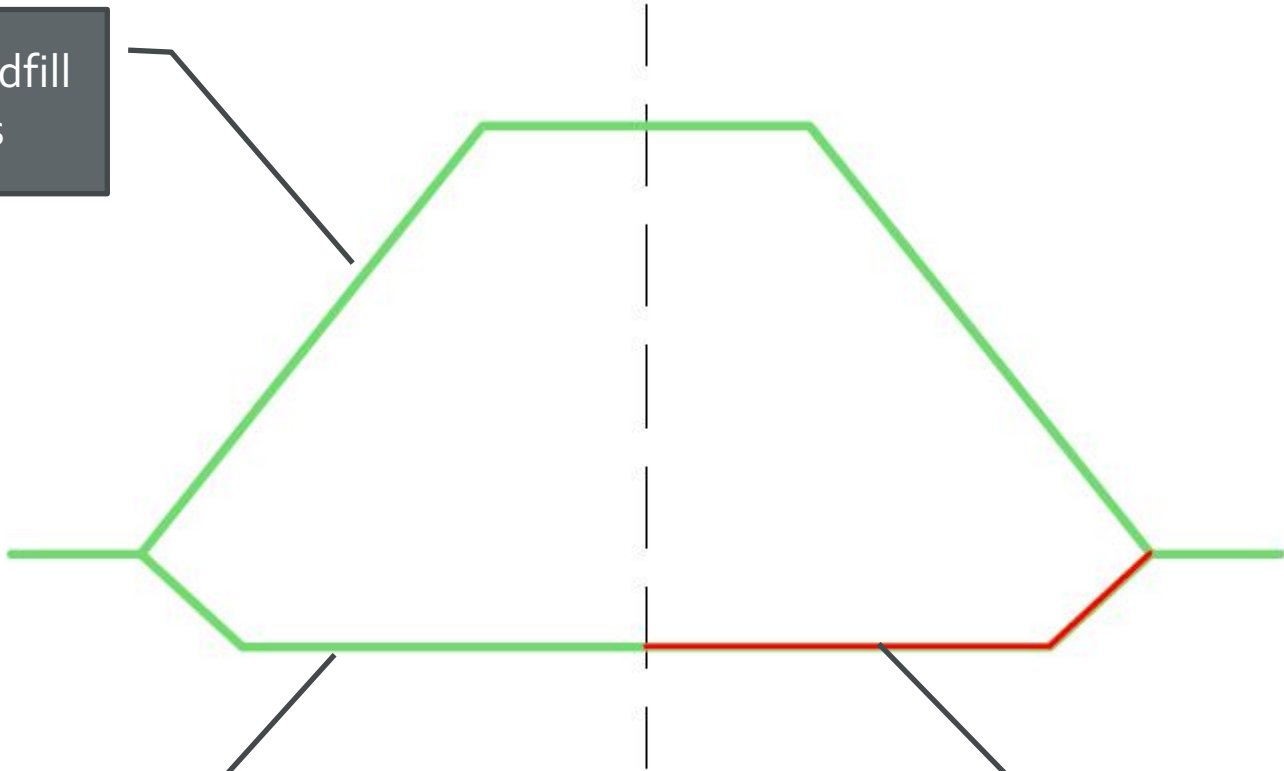
The Site (cross section)



**Constructed Landfill Cells
(22.6 acres)**

Landfill's Constructed Area

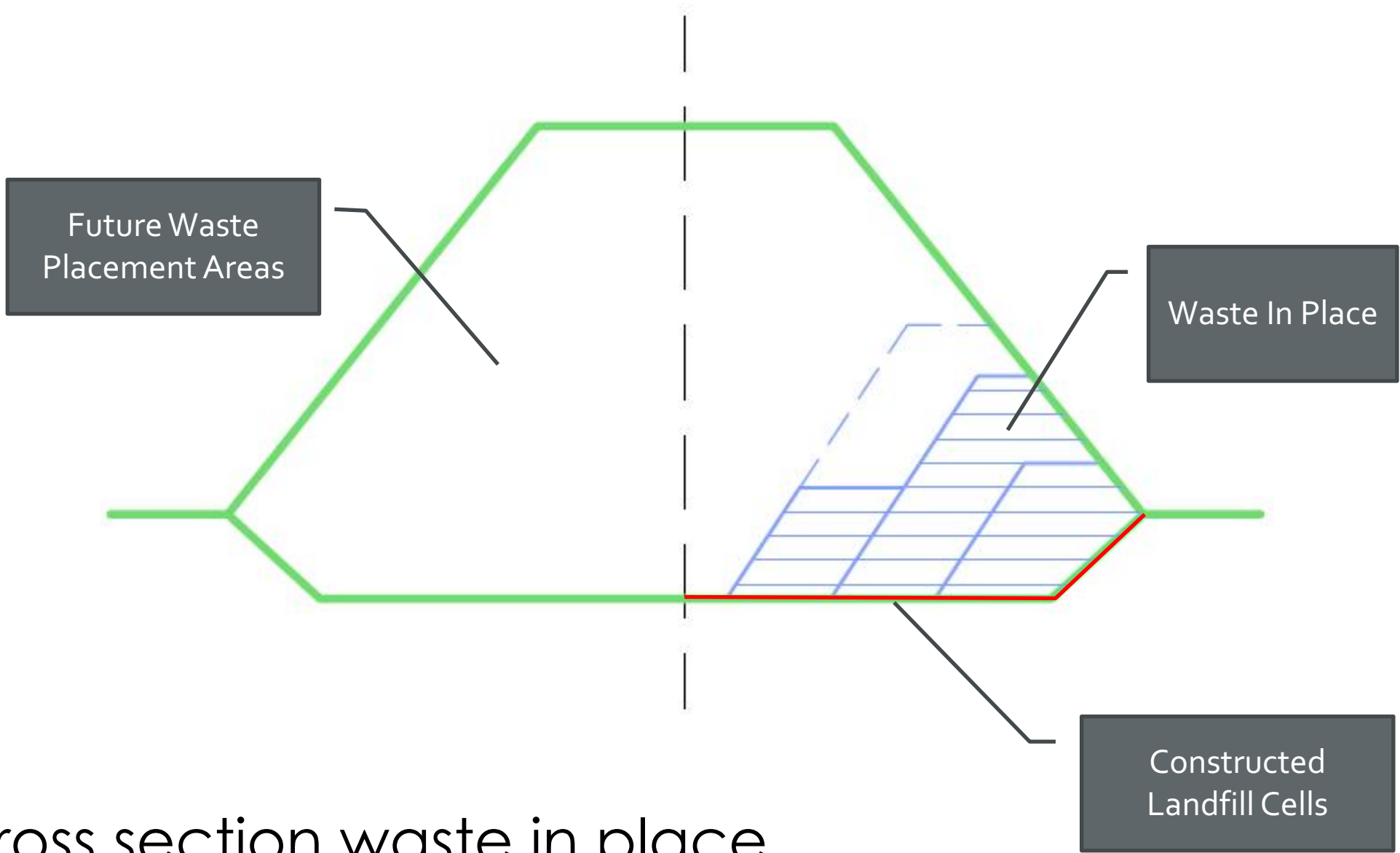
Permitted Landfill
Top Grades



Permitted Landfill
Base Grades

Constructed
Landfill Cells

Cross section with constructed area



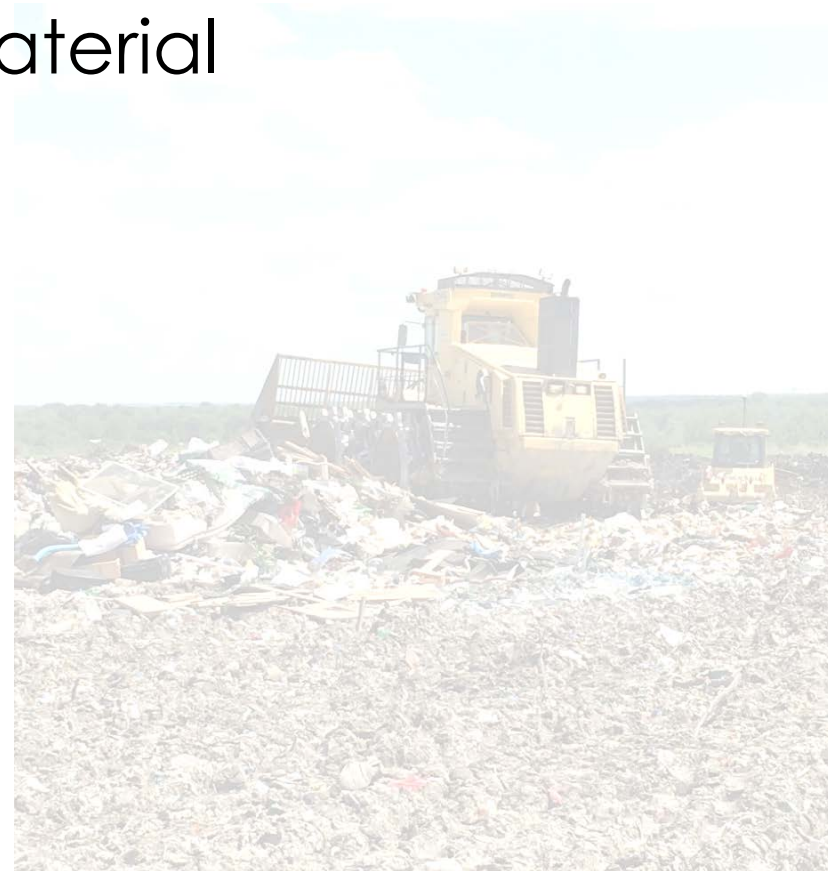
Cross section waste in place

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

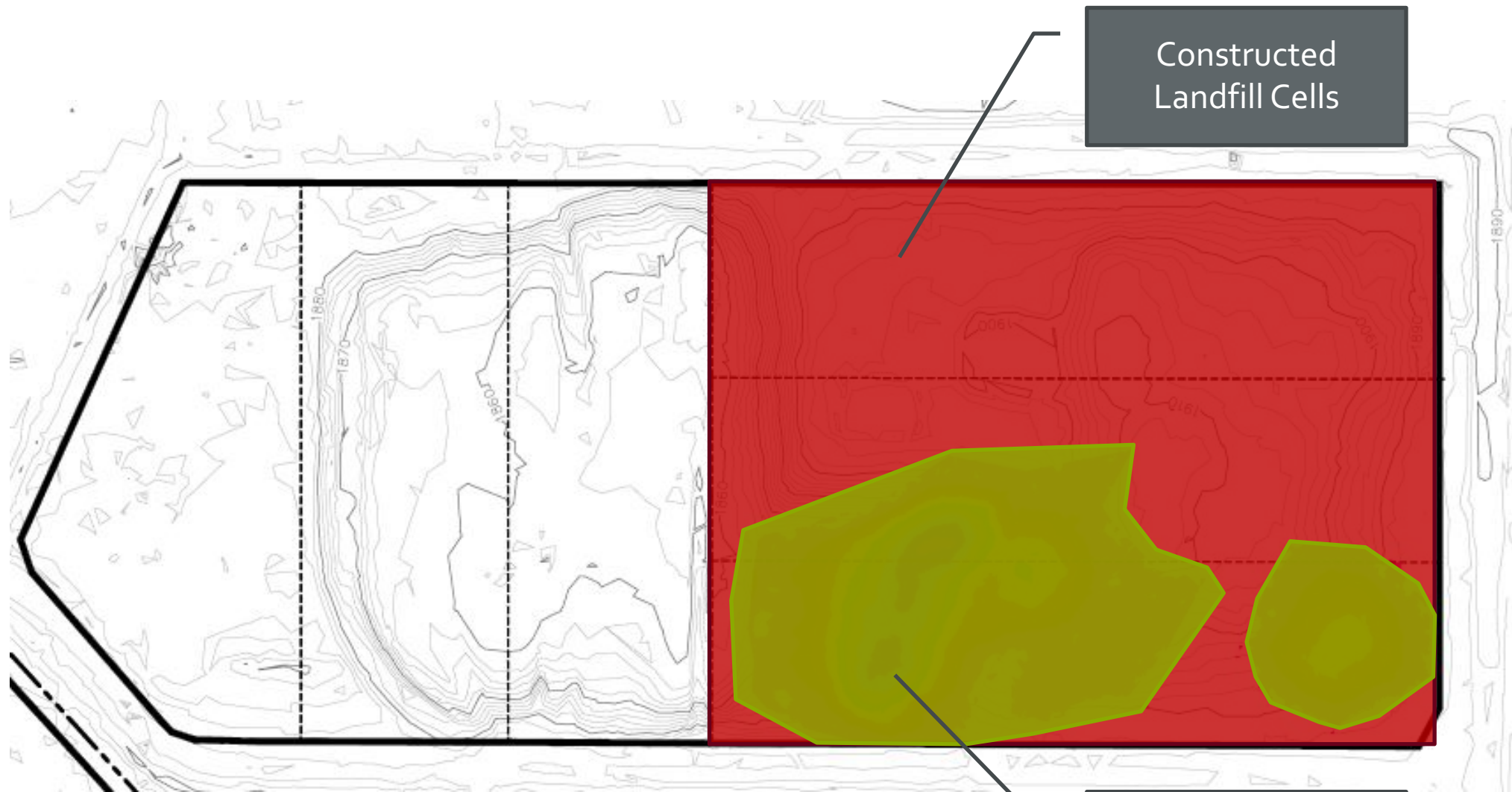
- How much airspace consumed between surveys?
- What is the density of the material in place (lb/cy)
- How long will landfill last?
- Survey impacts?



Airspace Consumed between Survey Dates

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

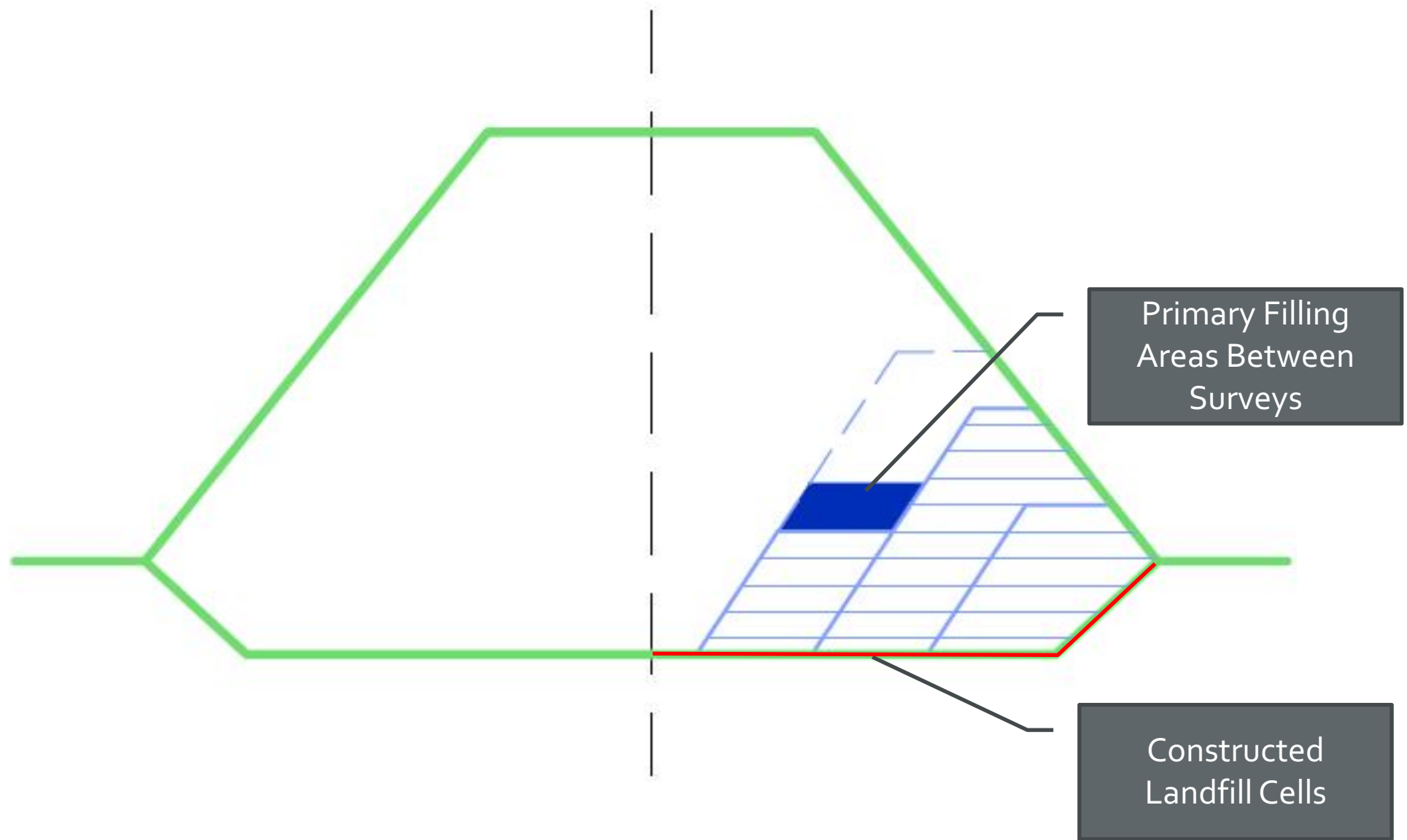
What does this tell you?
How would you use each?



Constructed
Landfill Cells

Primary Filling
Areas

Active landfill areas



Cross section with active filling area

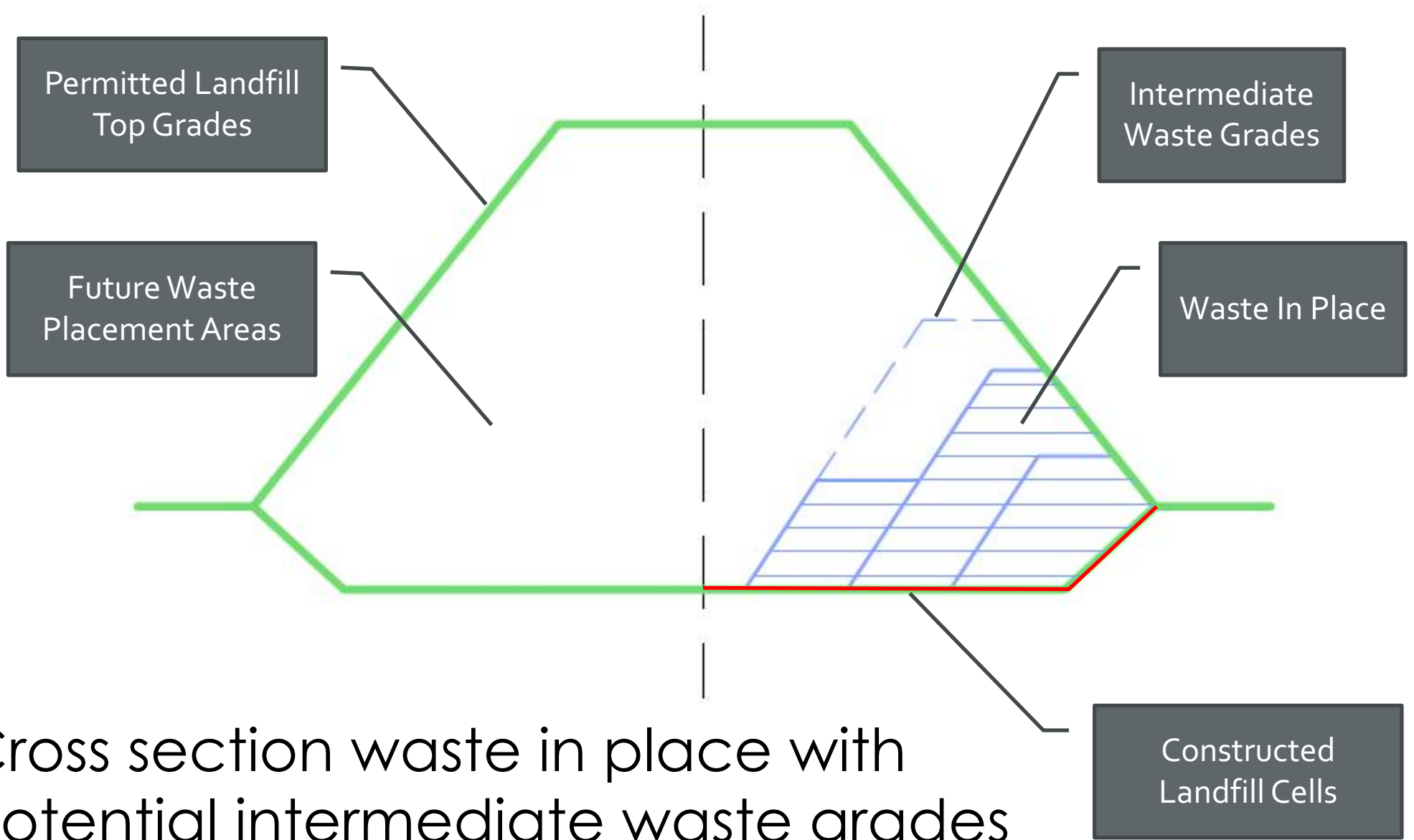
Things to consider:

- 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**

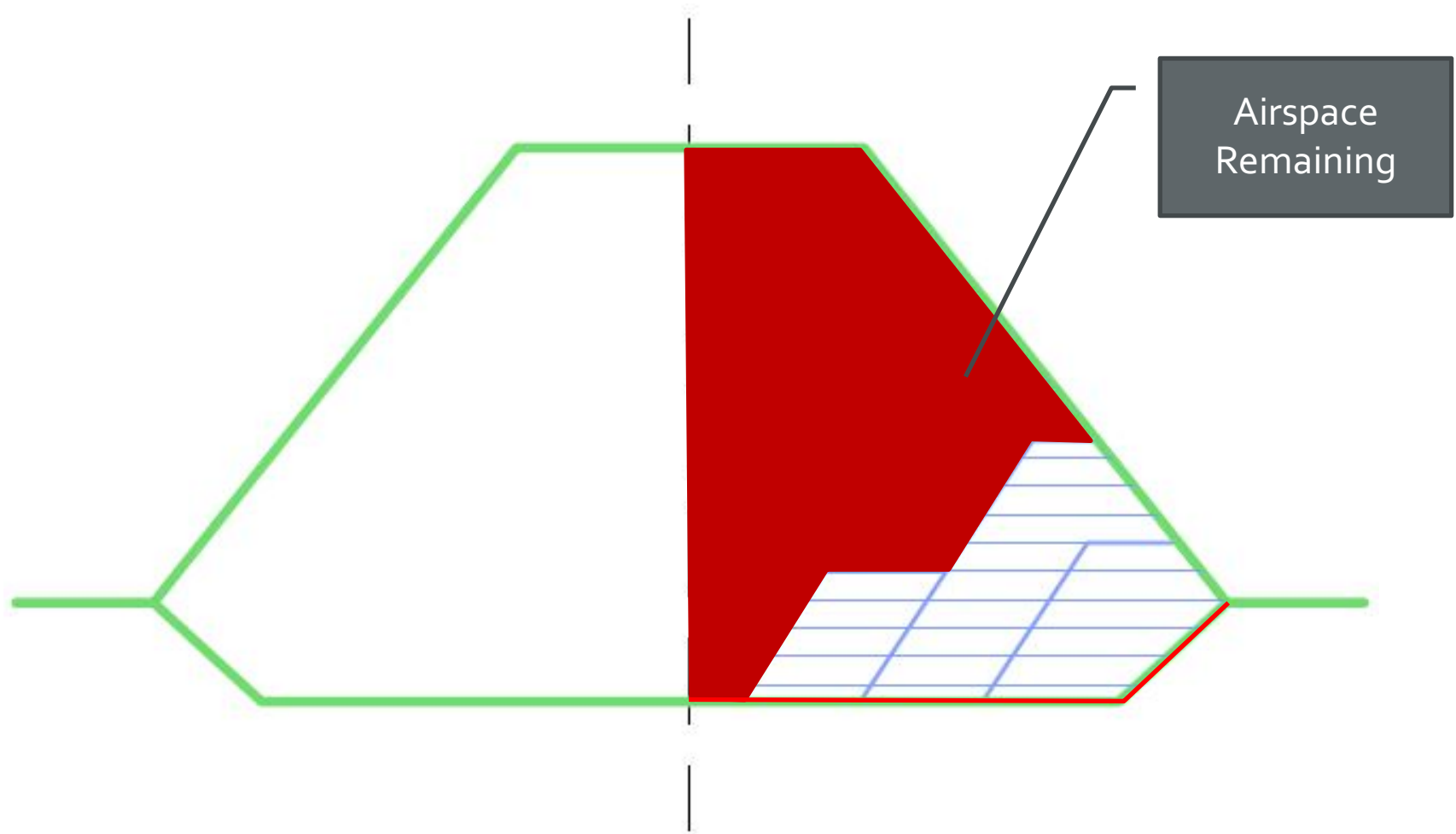
Airspace Remaining in Constructed Landfill Cells

	Scenario 1	Scenario 2	Scenario 3
Surface 1	2018 Survey	2018 Survey	2018 Survey
Surface 2	<i>Final grades</i>	<i>Intermediate grades</i>	<i>Intermediate grades, revised</i>
Boundary	Constructed Footprint	Constructed footprint	Constructed footprint, revised
Airspace Remaining	548,000 cy	527,000 cy	515,000 cy

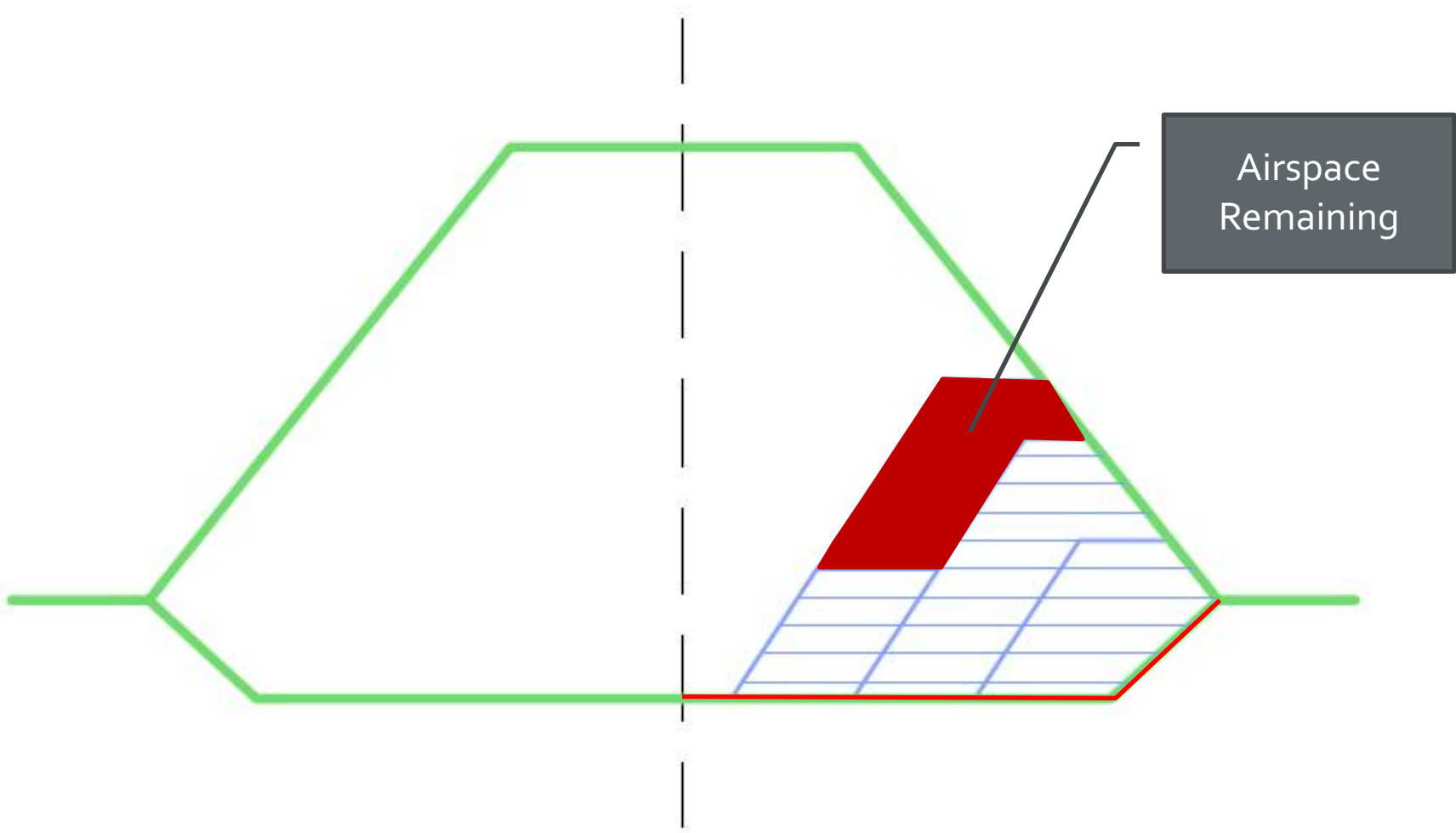
What does this tell you?



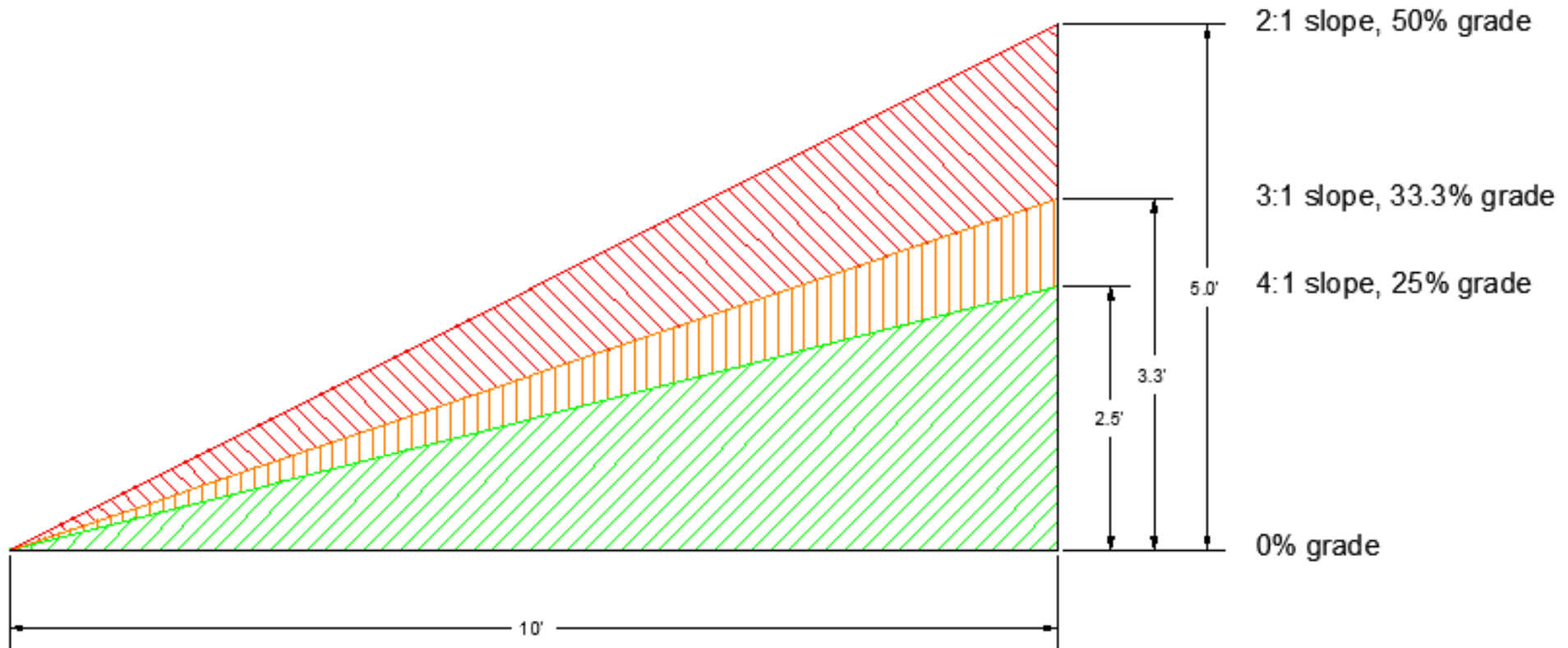
Cross section waste in place with potential intermediate waste grades



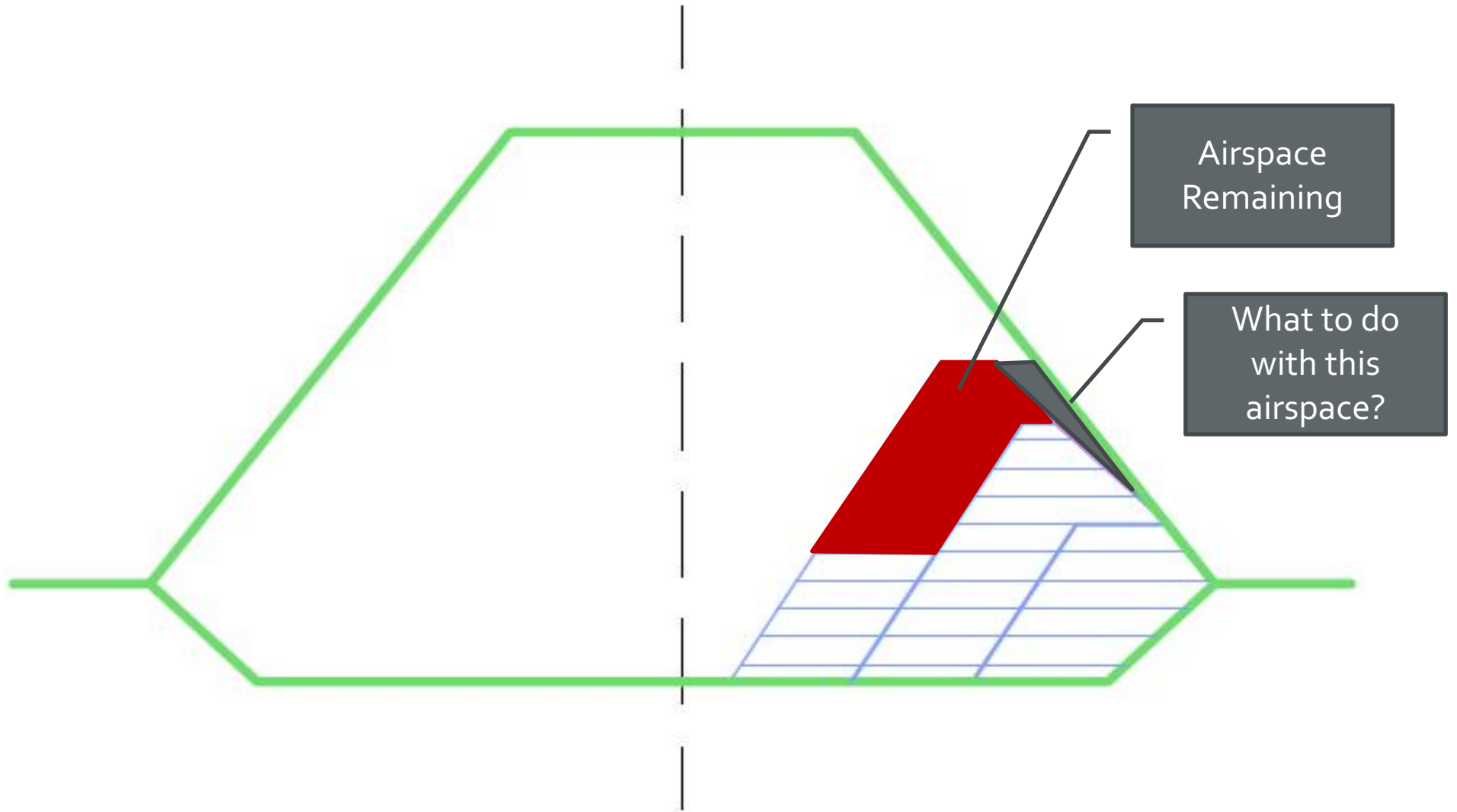
Scenario 1



Scenario 2



Impacts of slopes



Scenario 3

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

	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Remaining Airspace	527,000 cy	527,000 cy	527,000 cy	527,000 cy
Annual Tonnage	33,000 tons	33,000 tons	40,000 tons	40,000 tons
Density *	920 lb/cy	1,080 lb/cy	920 lb/cy	1,080 lb/cy
Fill Rate	72,000 cy/yr	61,000 cy/yr	87,000 cy/yr	74,000 cy/yr
Remaining Life	7.3 years	8.7 years	6.0 years	7.1 years

**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

	Scenario 1	Scenario 2	Scenario 3
Surface 1	2018 Survey	2018 Survey	2018 Survey
Boundary	Constructed Footprint	Constructed footprint	Constructed footprint
Area	22.6 acres	22.6 acres	22.6 acres
Tolerance	0'	+0.5' (high)	-.25' (low)
Tolerance Volume	0 cy	+18,230 cy	-9,115 cy

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

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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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