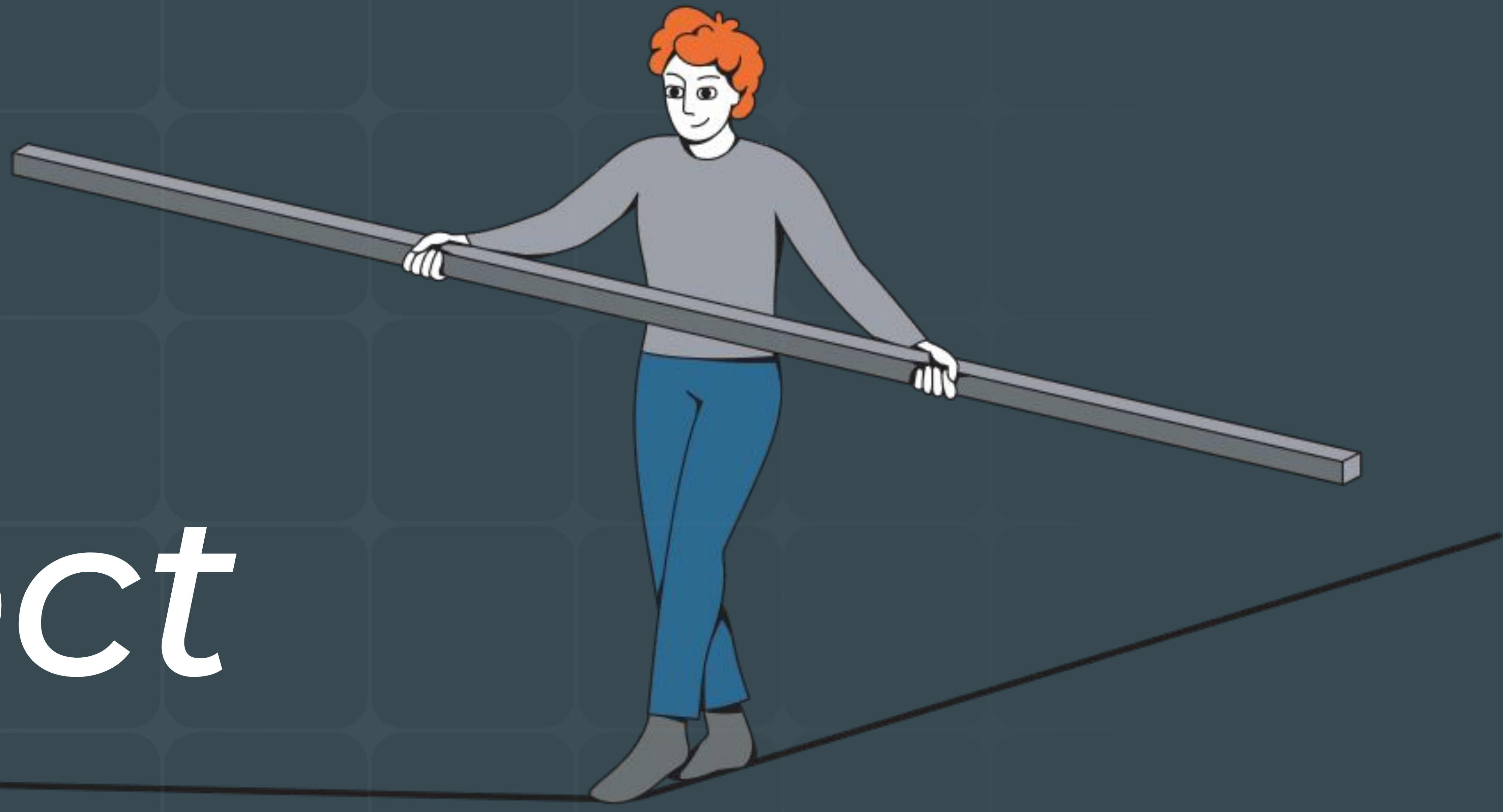
PVFARM

Piles for Miles

Optimizing Pile Design for Efficient Solar PV Projects

PVFARM

The Piles *that* *Hold the Project*



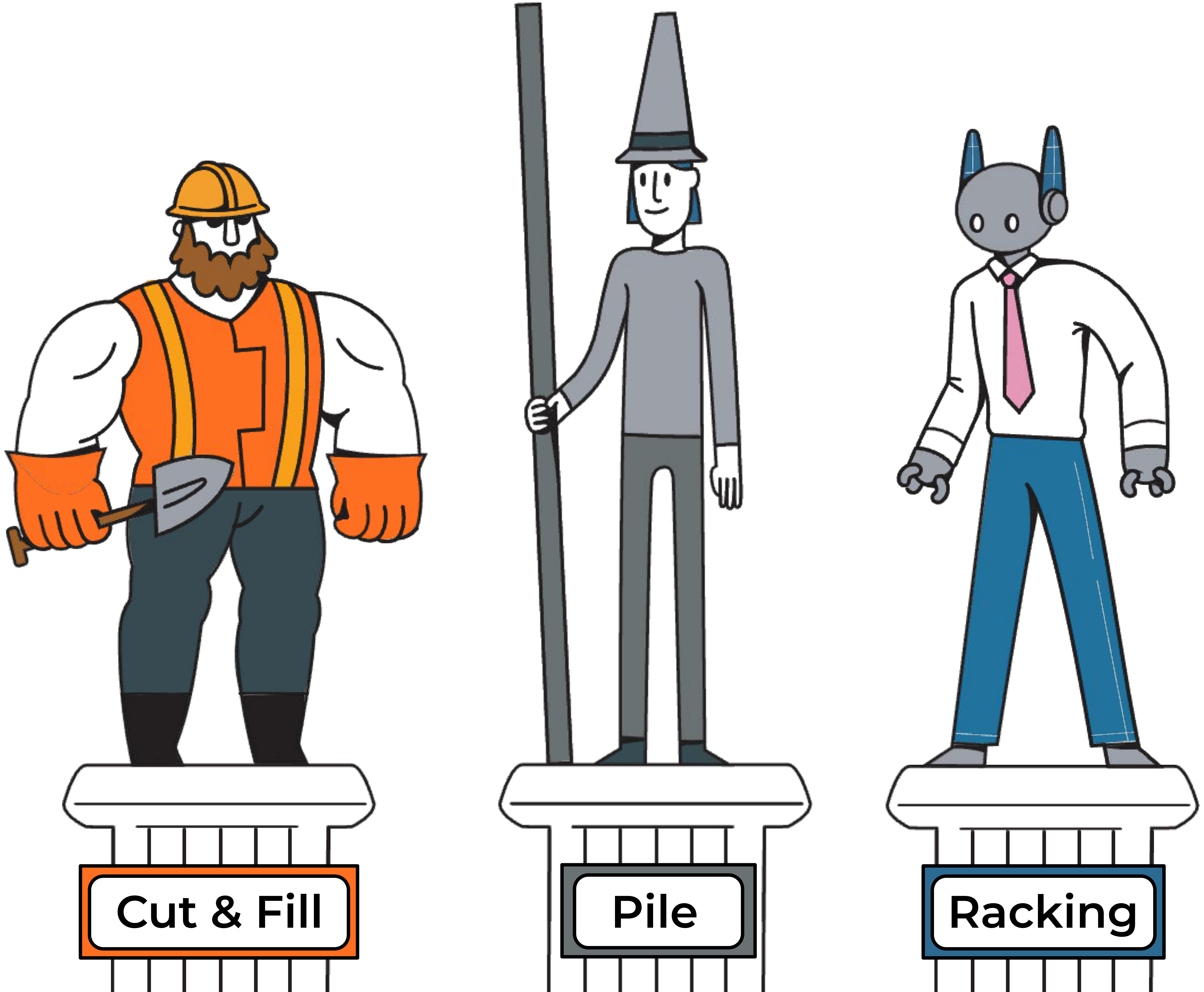
Understanding their importance reveals opportunities to optimize design and manage risks

The Role of Piles in the Solar PV System

The three pillars or three foundations of solar PV projects capital cost

Piles, Earthwork & Racking. Interdependencies

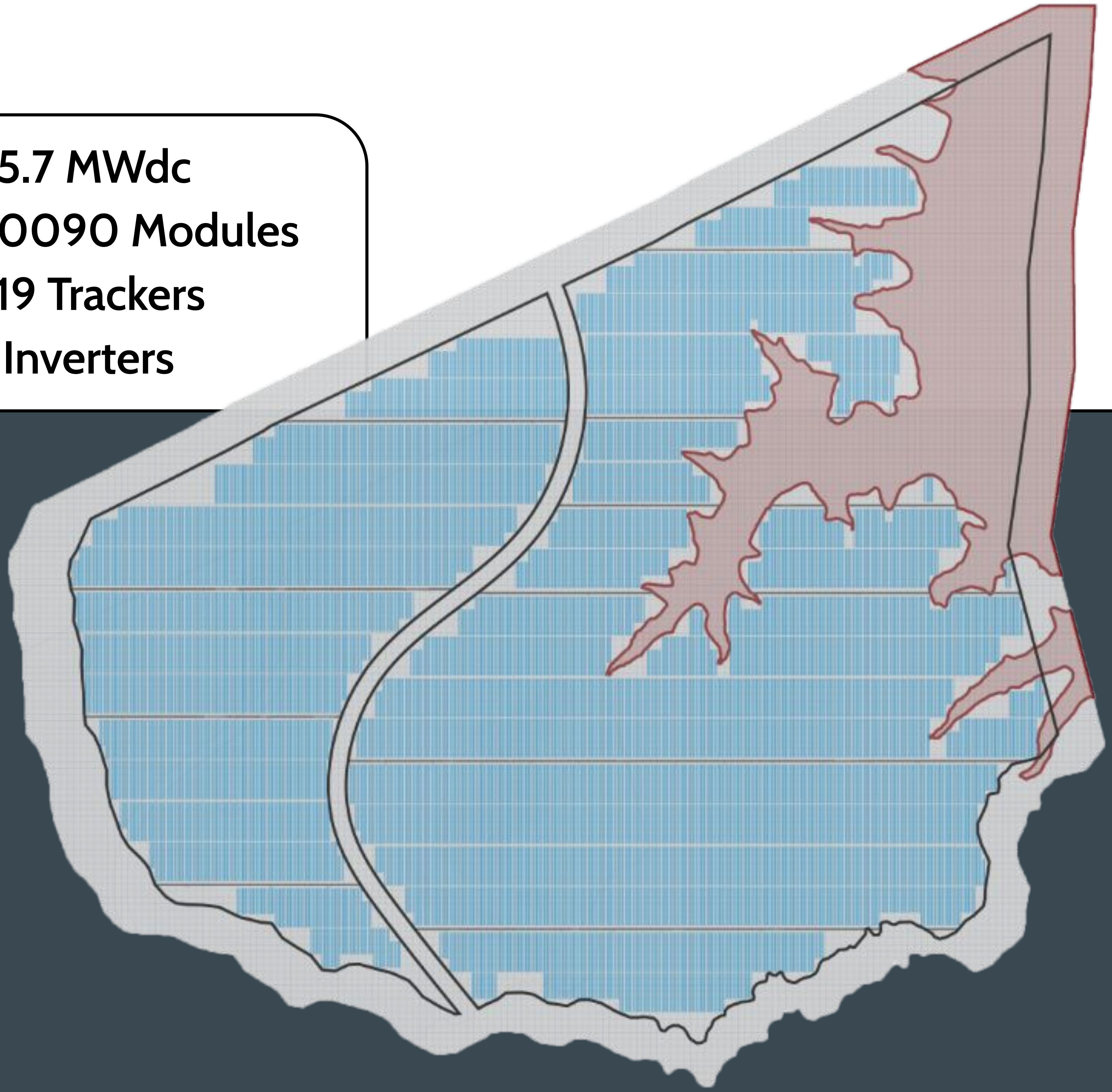
You can opt for cheaper grading with more expensive piles or vice versa. The key is finding the right balance



Hidden Costs in the Solar PV System

Spot 5 differences during bidding phase

245.7 MWdc
540090 Modules
6219 Trackers
57 Inverters



VS

245.7 MWdc
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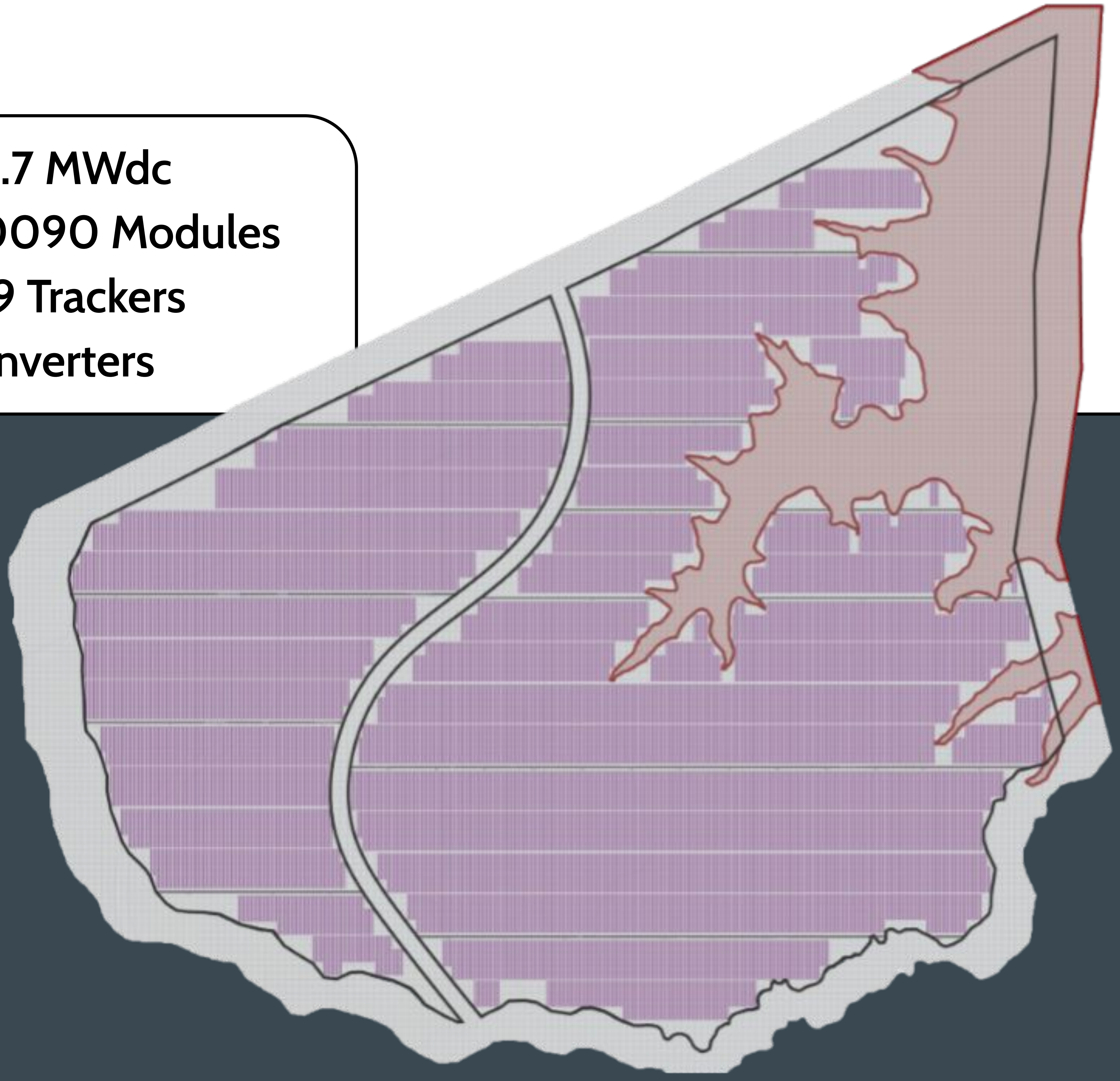
57 Inverters



Hidden Costs in the Solar PV System

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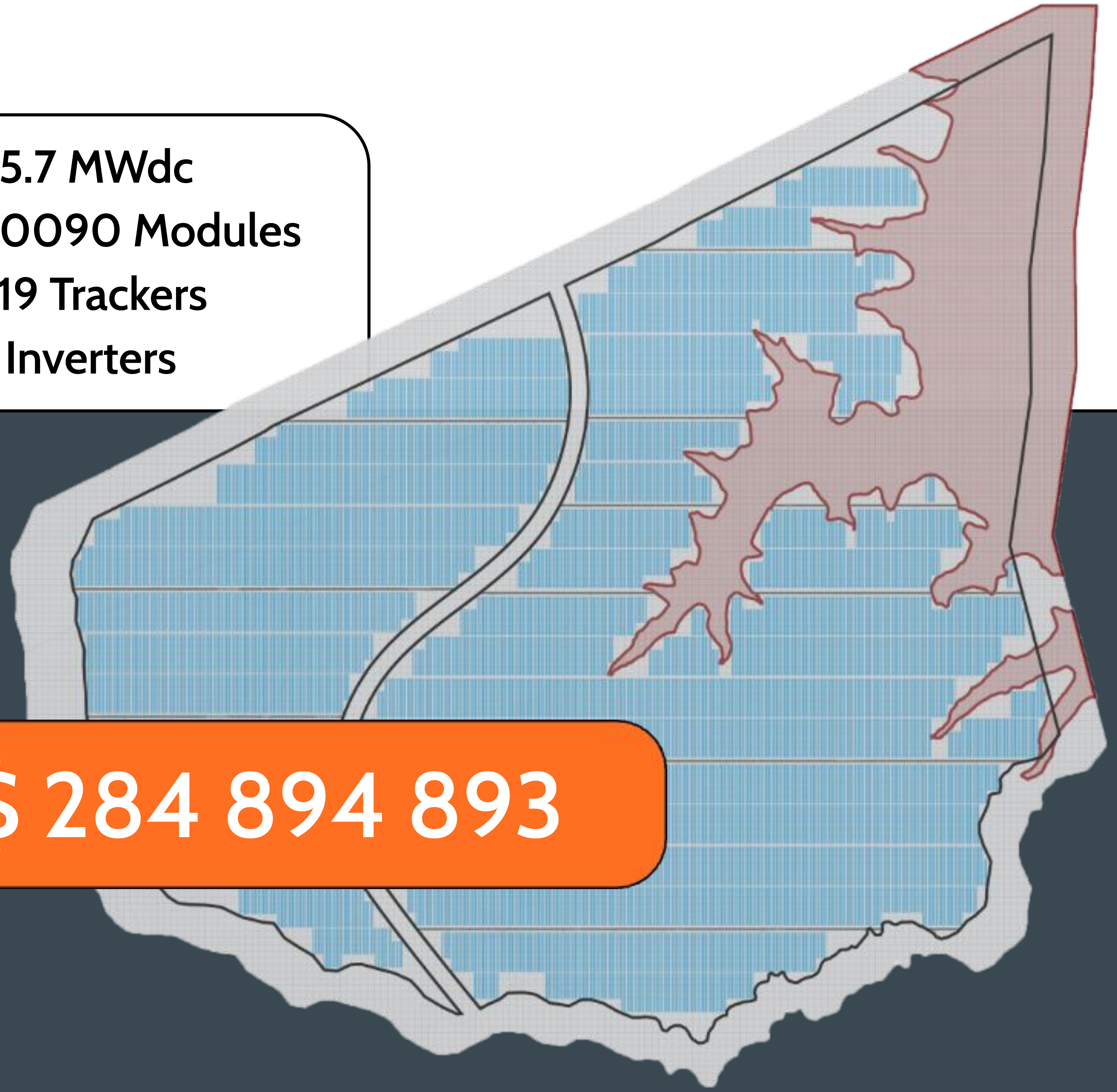

$ 284 894 893

VS

245.7 MWdc
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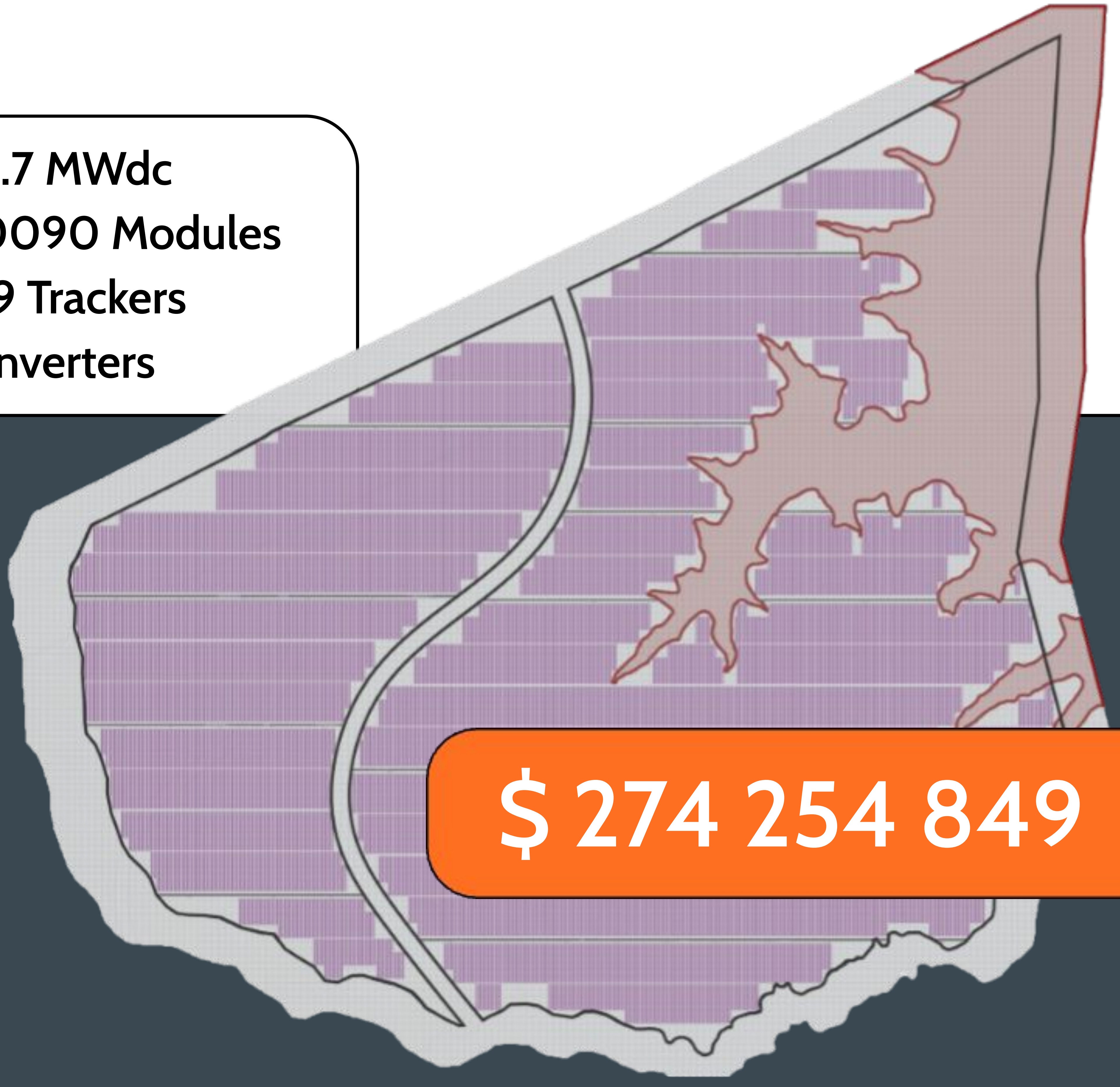


$ 274 254 849

Cost Difference at a Glance

Let's compare final costs

1.

$ 284 894 893

$ 1.1593 (per DC Watt)

Racking — $ 51.45 M

Cut & Fill — $ 28.33 M

Piles — $ 17.03 M

$ 274 254 849

$ 1.1160 (per DC Watt)

Racking — $ 51.45 M

Cut & Fill — $ 17.03 M

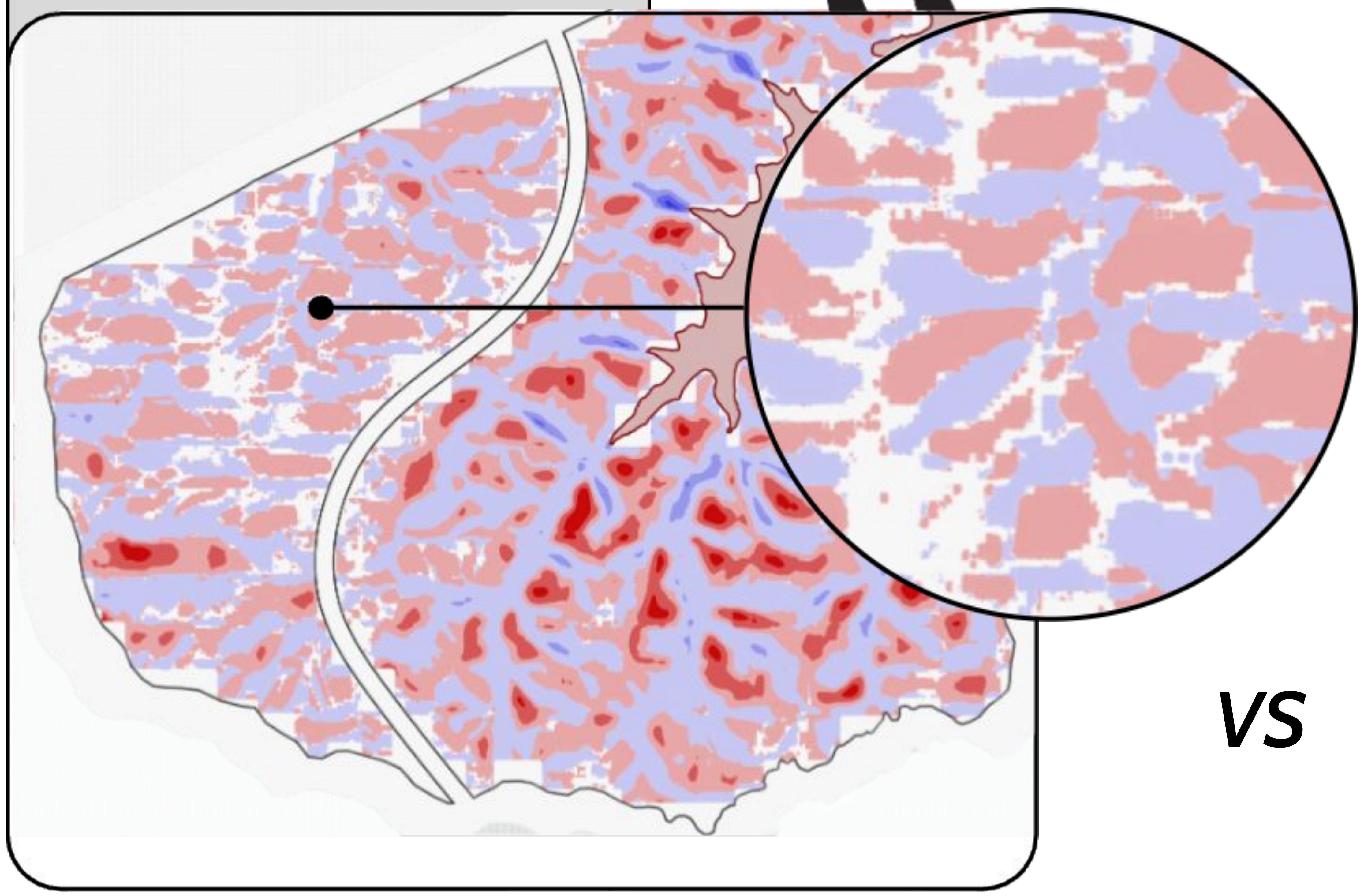
Piles — $ 17.98 M

Fill | Cut | No Grading

Cost Difference in Depth

2.5M CY cut and fill

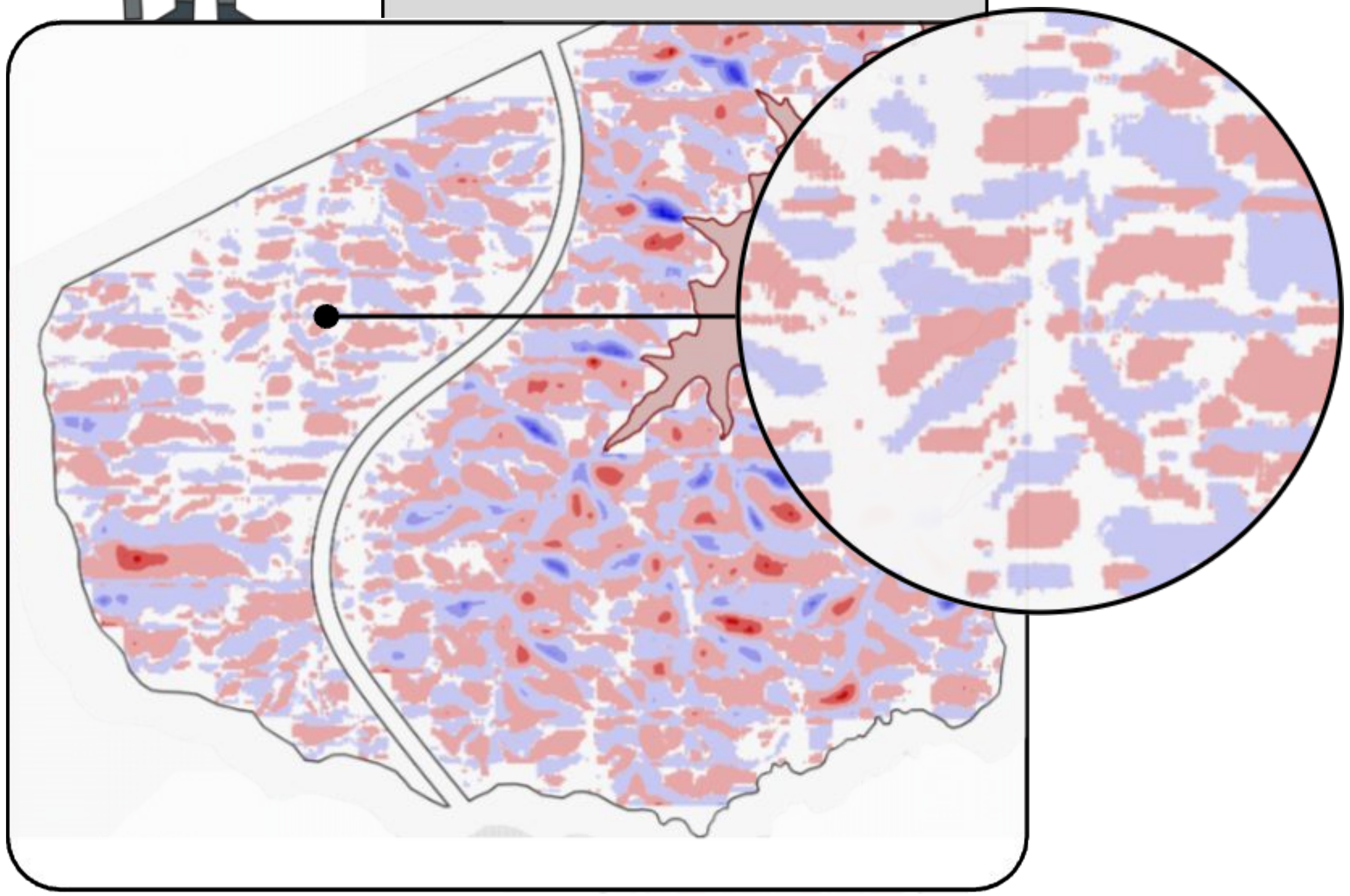
7.5M lbs steel



VS

1.5M CY cut and fill

7.8M lbs steel



Why Are Piles Overlooked Early in Project Planning?

A “known unknown” in early planning — recognized as essential but deferred due to limited data and tools

How to Reveal Hidden Factors Sooner?

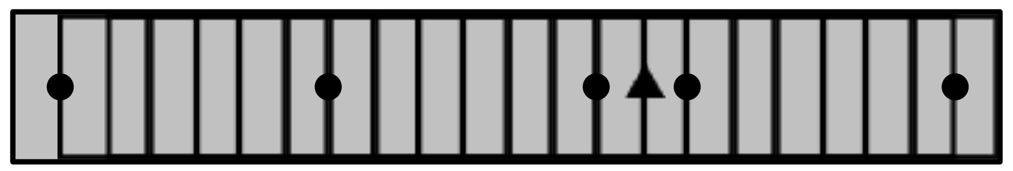
Recognizing piles as a predictable yet often hidden cost allows us to address them proactively, minimizing unexpected expenses down the line. By prioritizing early data gathering and applying tools that highlight these known unknowns, we can surface hidden factors sooner, aligning project expectations with real-world conditions and avoiding costly surprises.

! Imagine accessing procurement-level details early - a future insight or past experience to guide better decisions today

Electrical representation: module count, strings, and approximate tracker length.

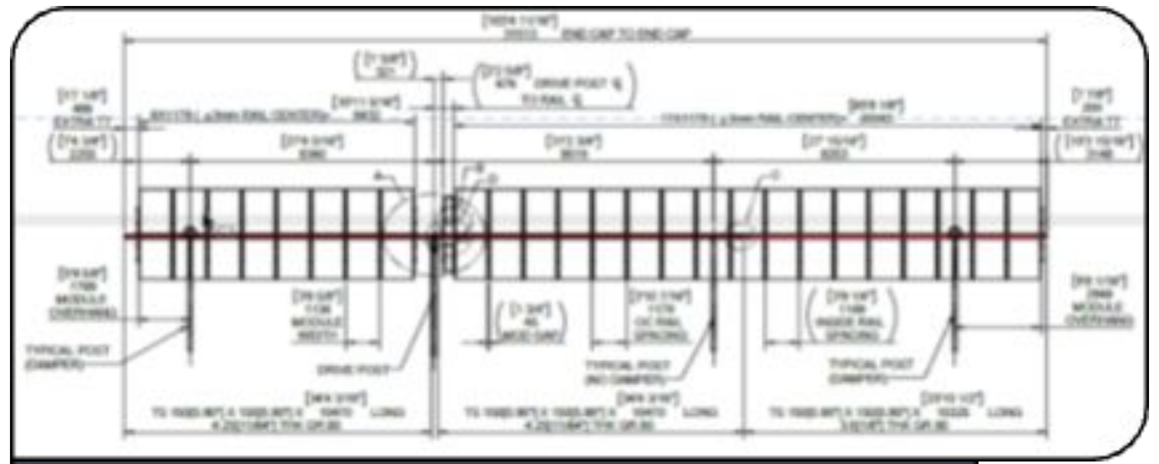
1. DEVELOPMENT

Mechanical and structural details: gaps, motor placement, and piles, and exact tracker length.



2. ENGINEERING

Finalizes pile lengths and cross-sections for construction and tracker costs for contracts.



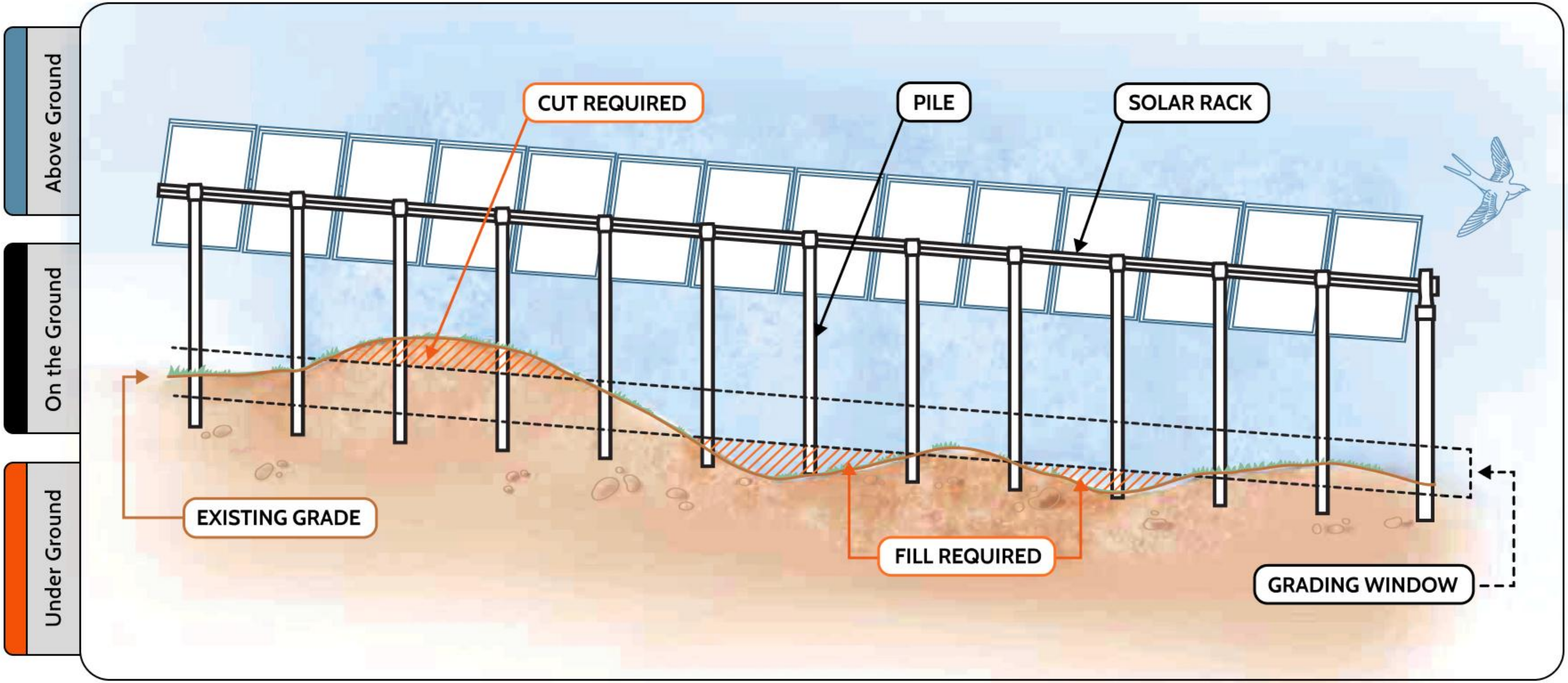
3. PROCUREMENT

CONSTRUCTION

Factors that Shaping Piles

A breakdown of the key drivers shaping pile design decisions

Factors Influencing Pile Design



Piles and Grading Window

A. Maximum Flood Depth

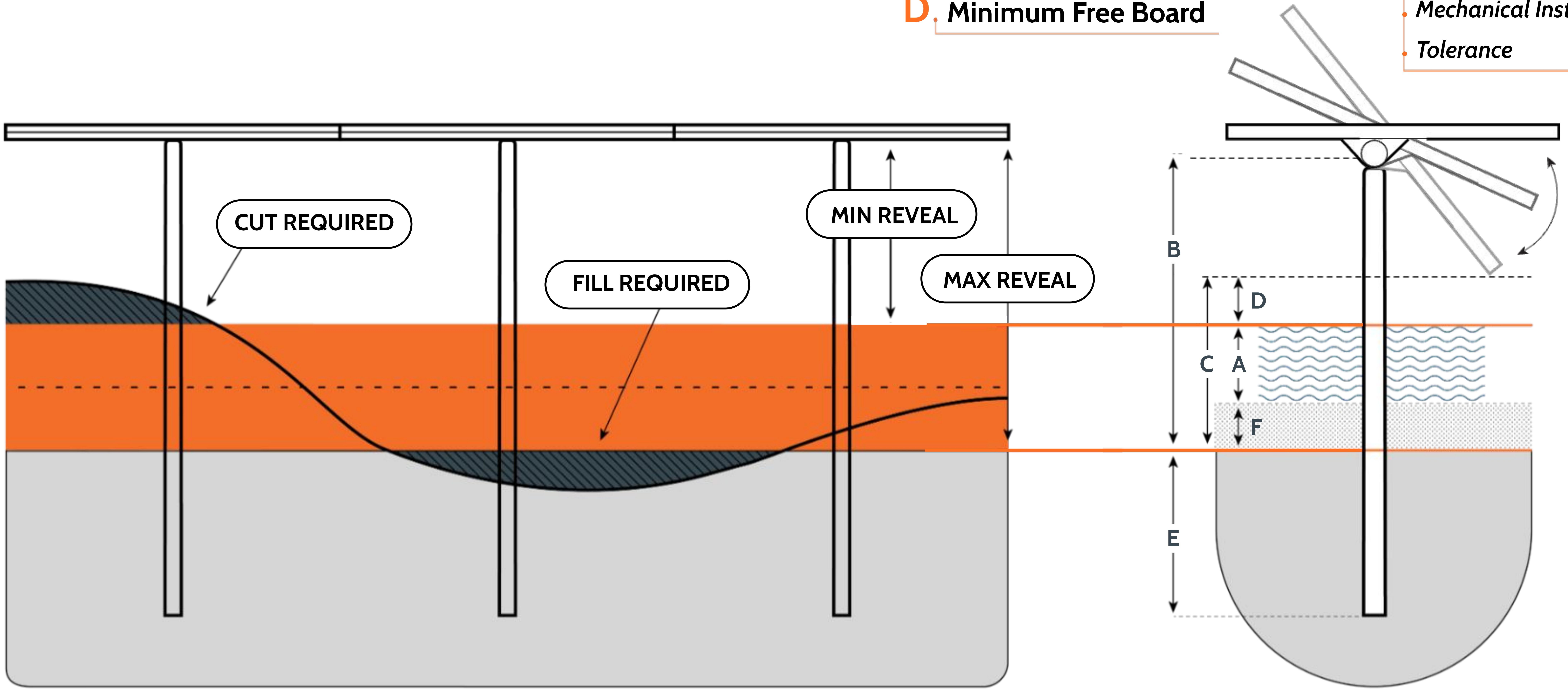
B. Pile Reveal

C. Minimum Ground Clearance

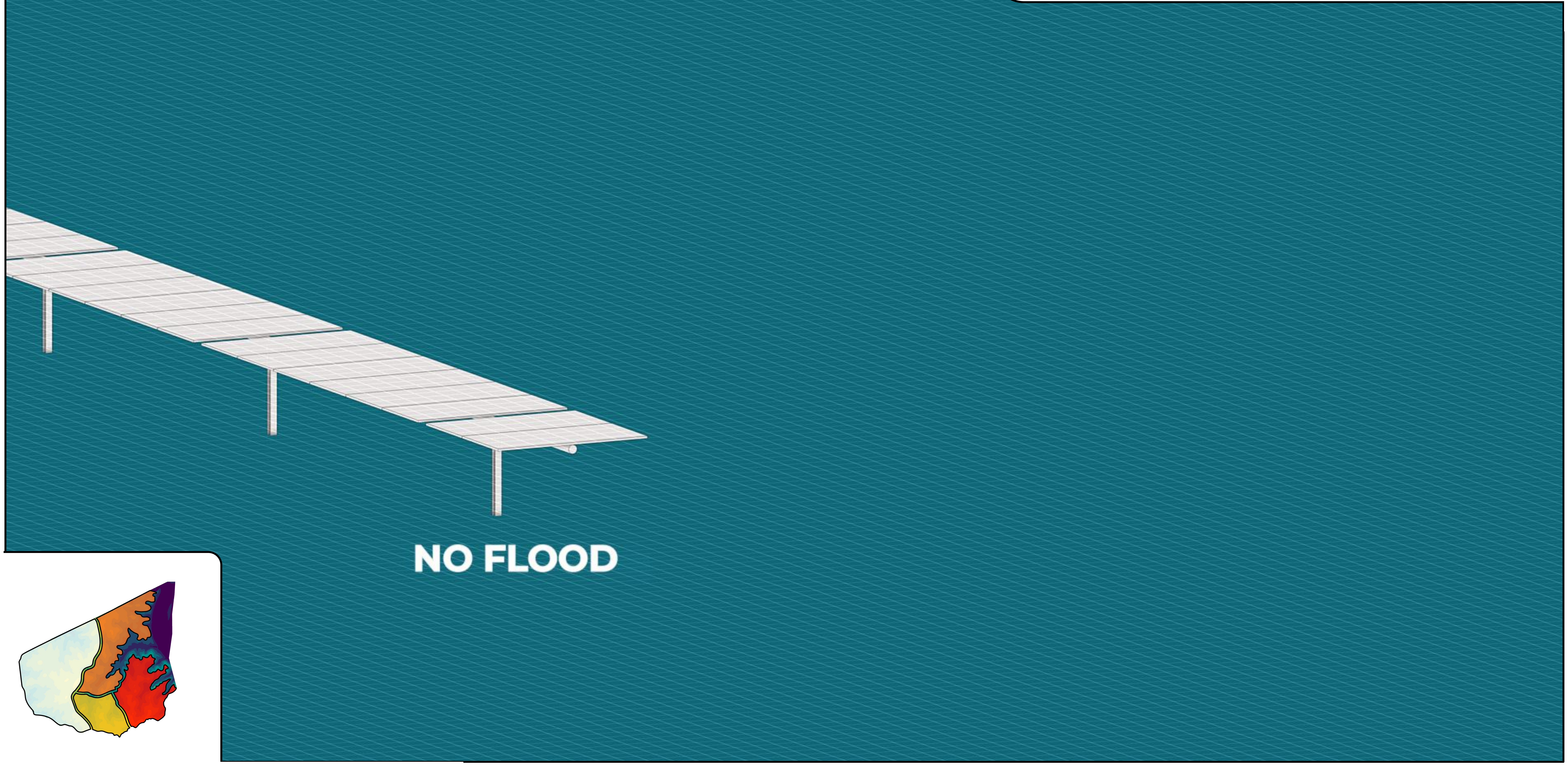
D. Minimum Free Board

E. Pile Embedment

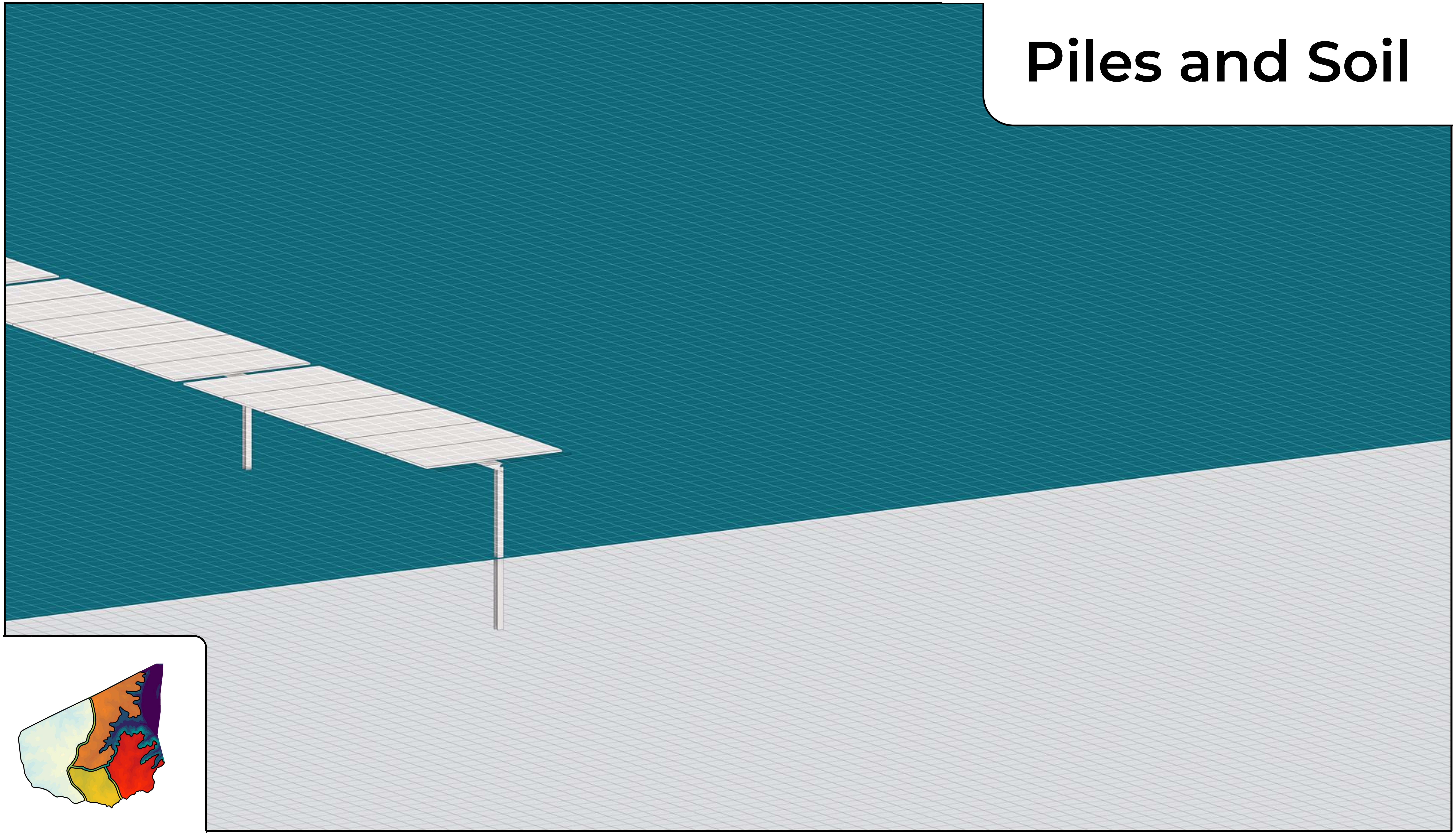
F.
- *Subcontractor Tolerance*
- *Scour Depth*
- *Topo Accuracy Tolerance*
- *Mechanical Installation*
- *Tolerance*



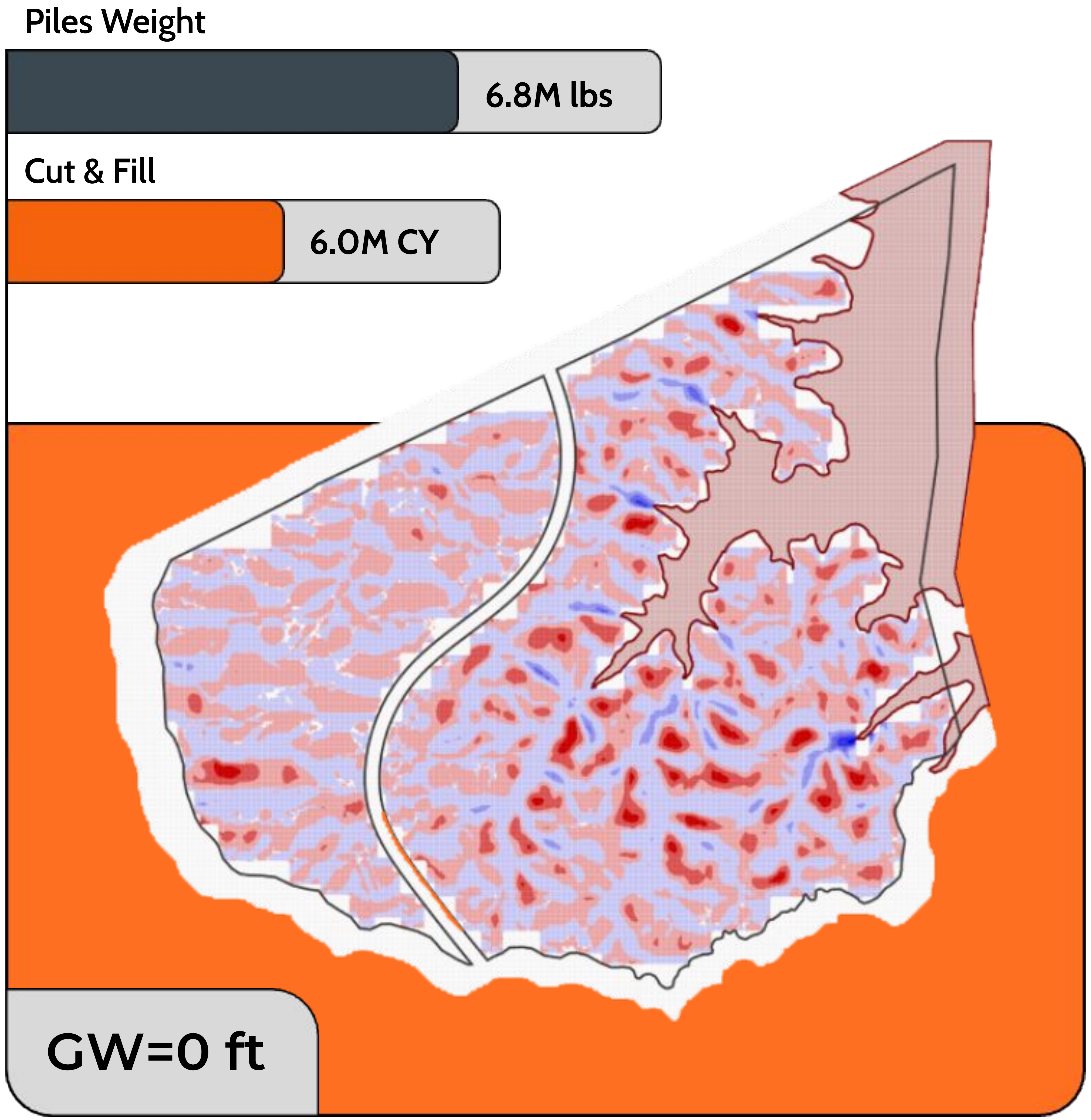
Piles and Water



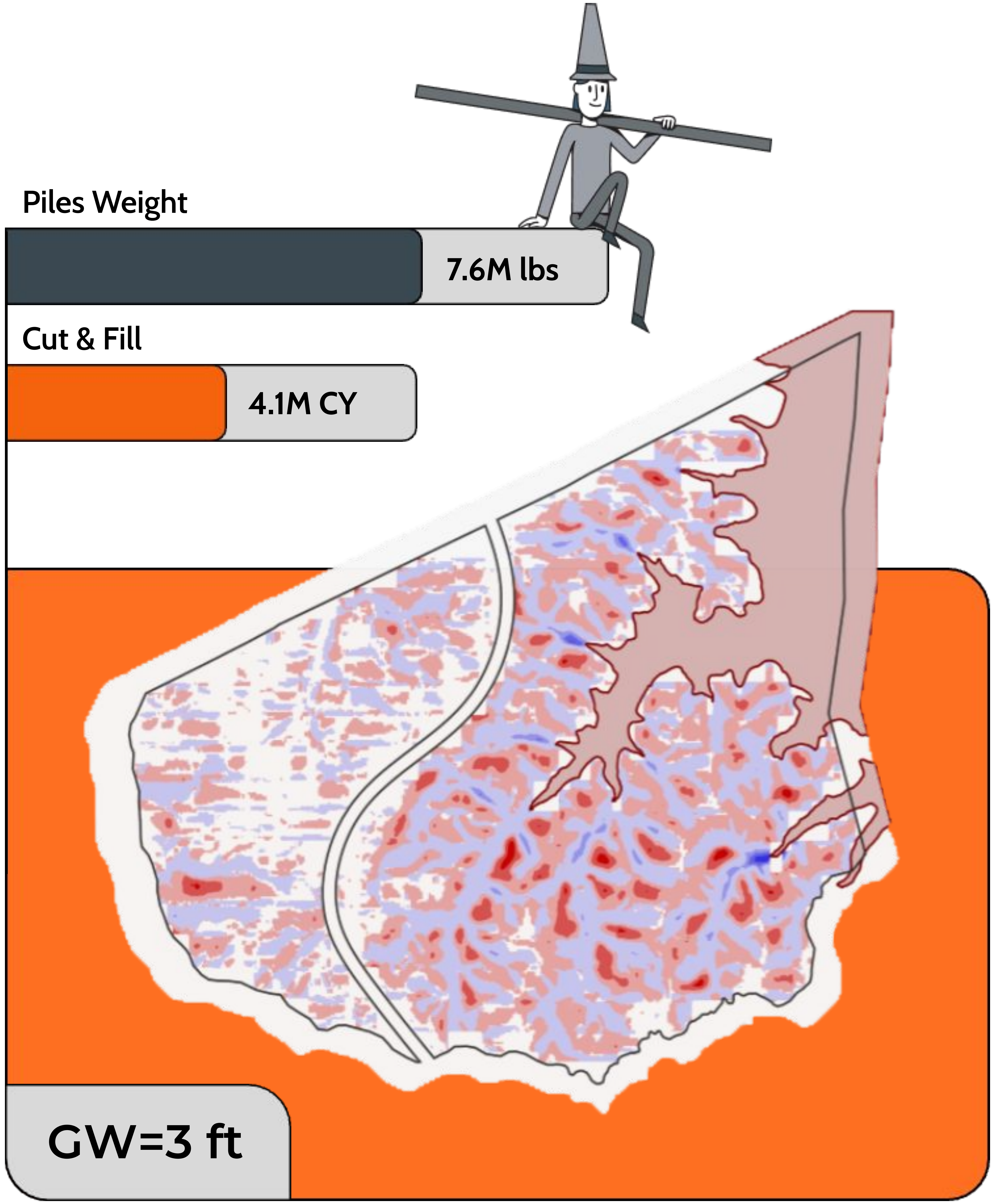
Piles and Soil



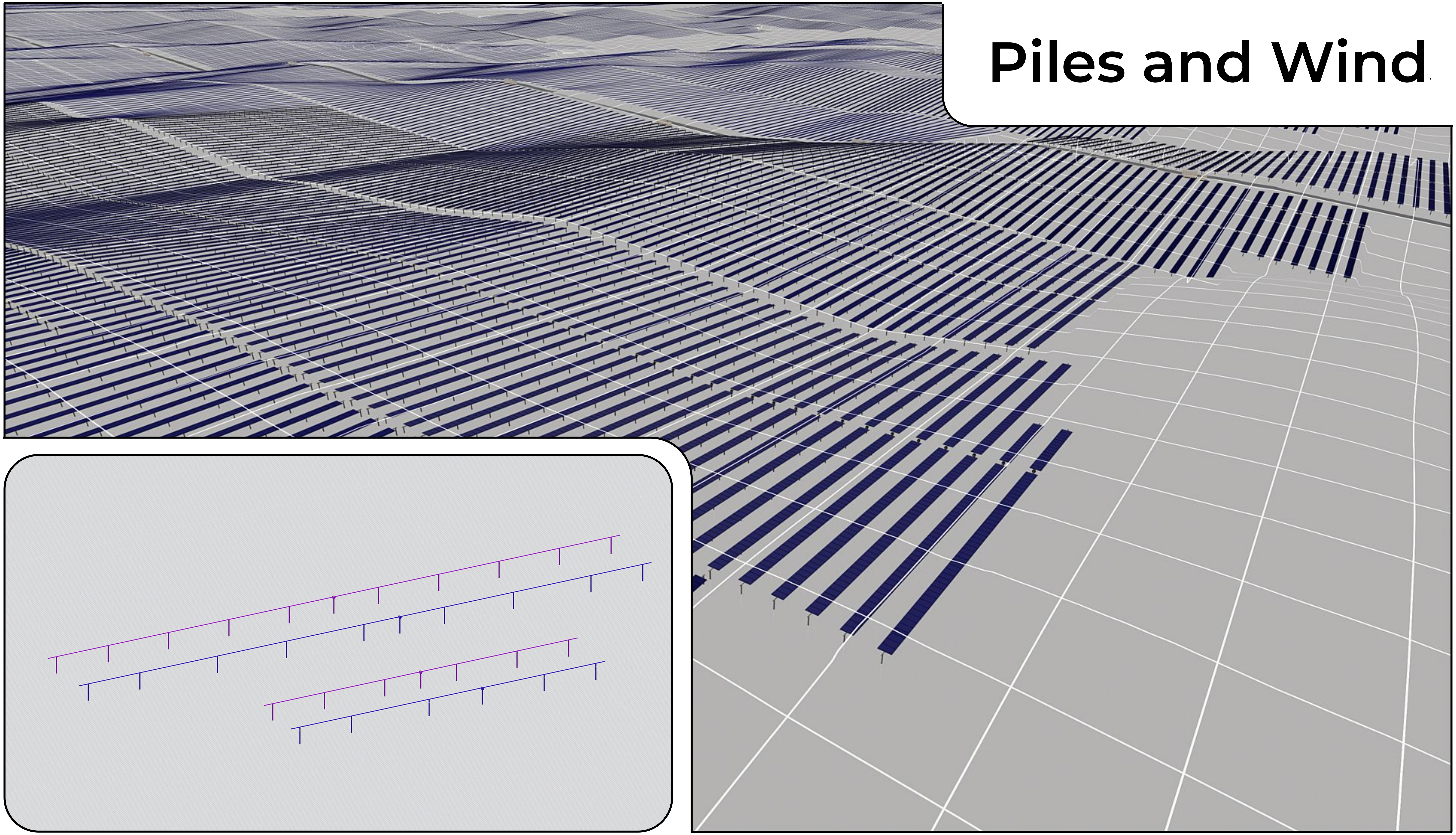
Piles and Grading



VS

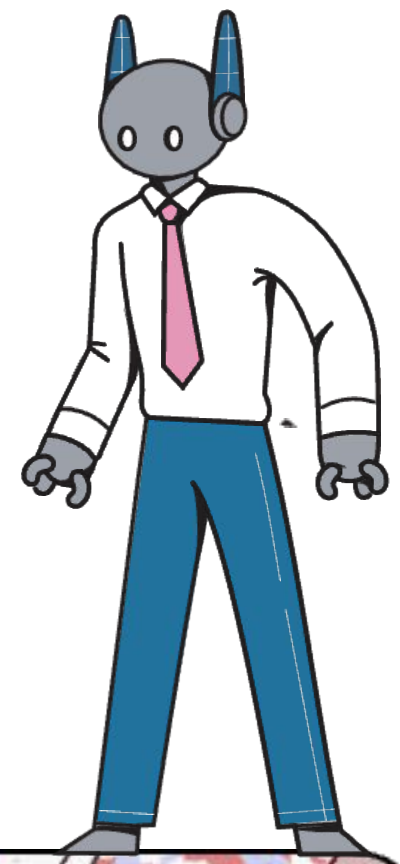


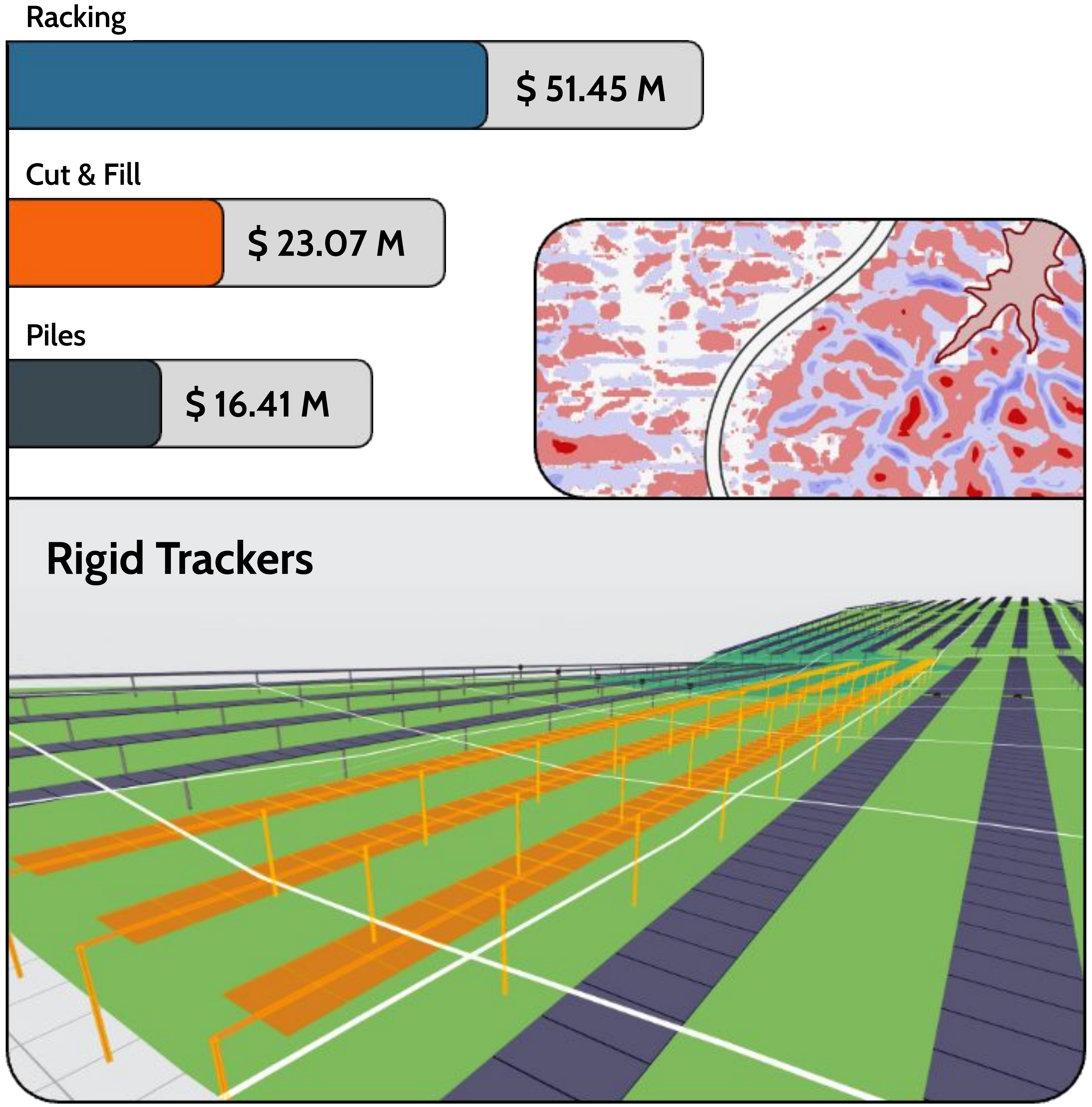
Piles and Wind



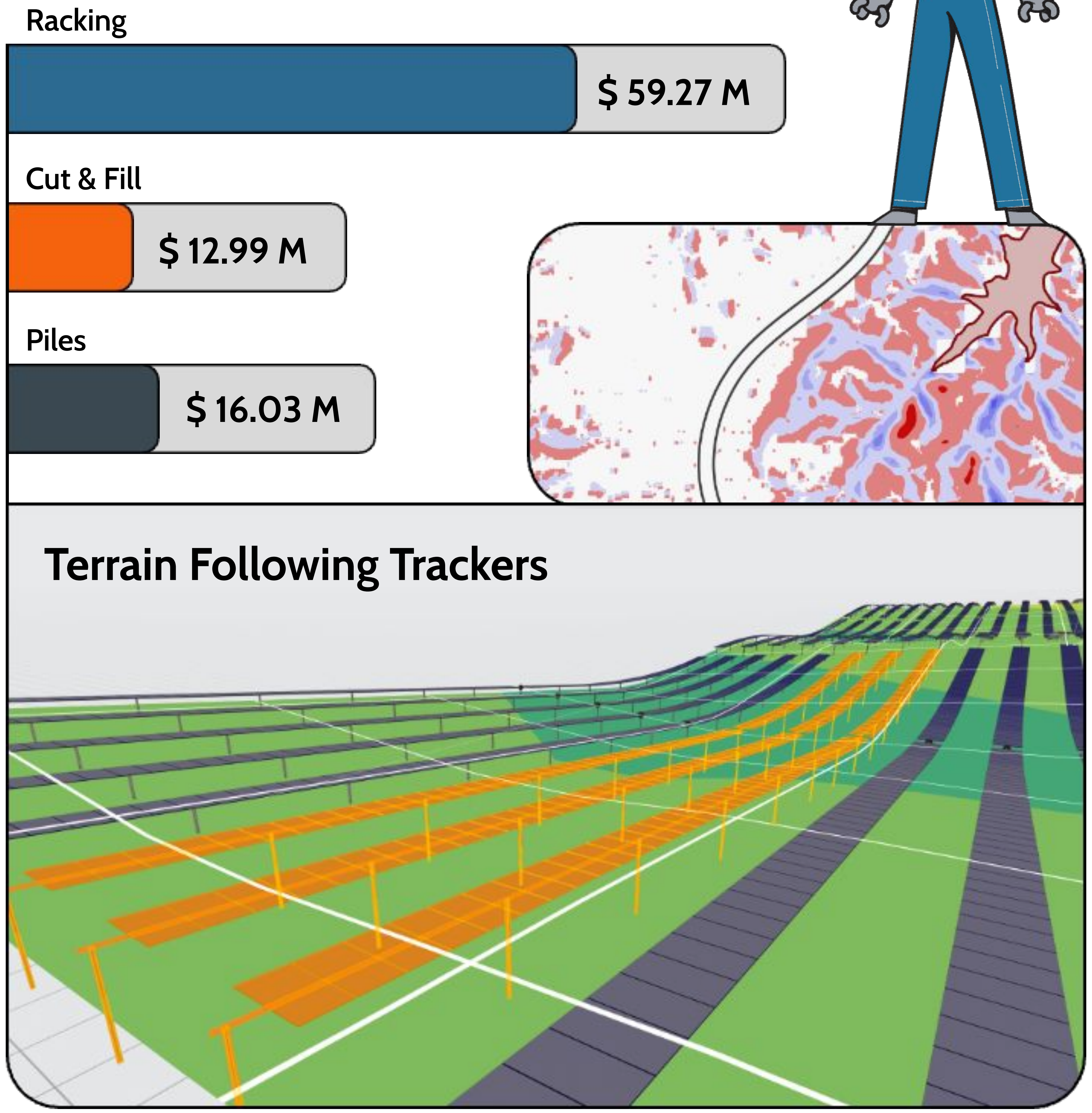
Piles and Racking

Rigid vs Terrain following



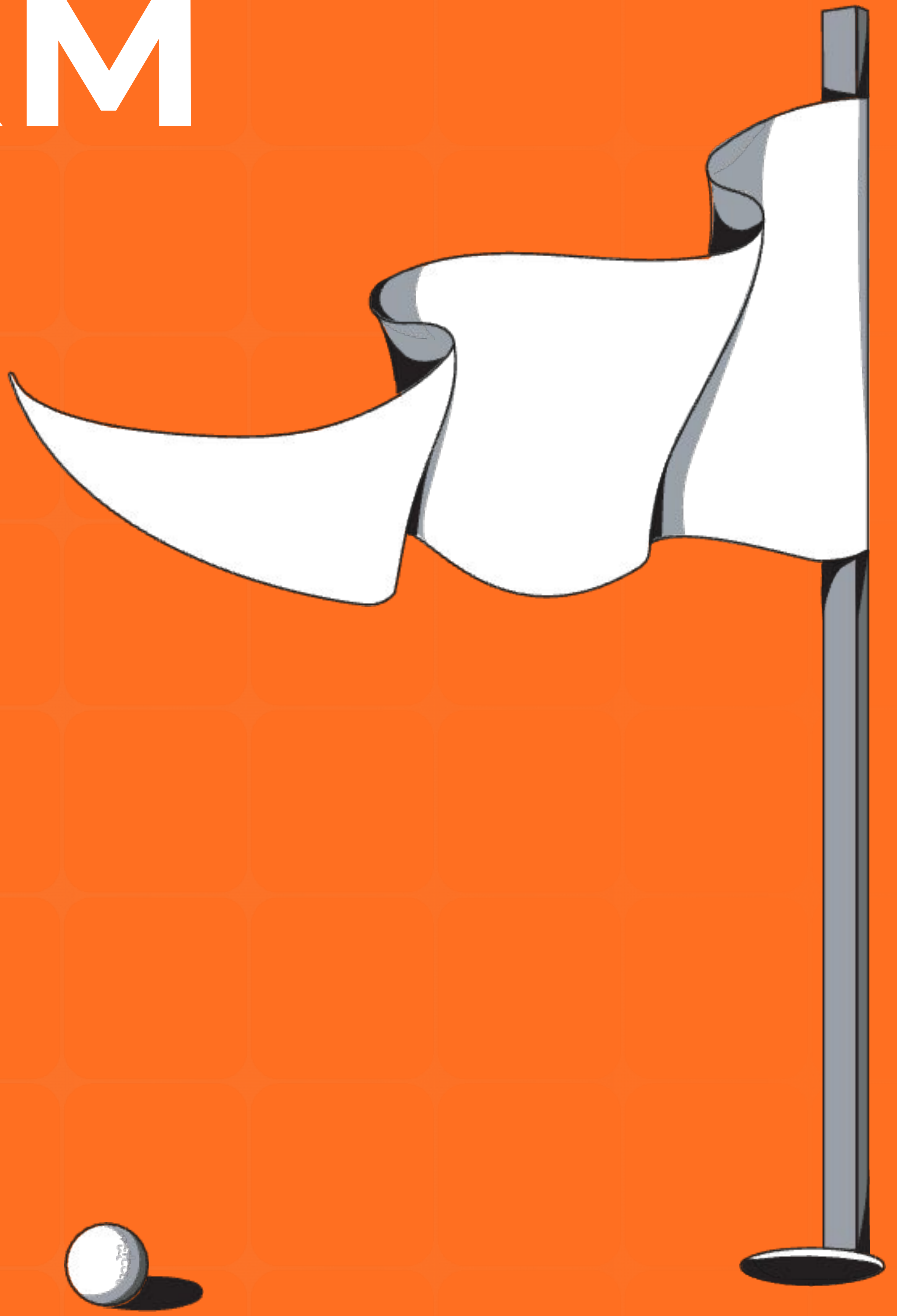


VS



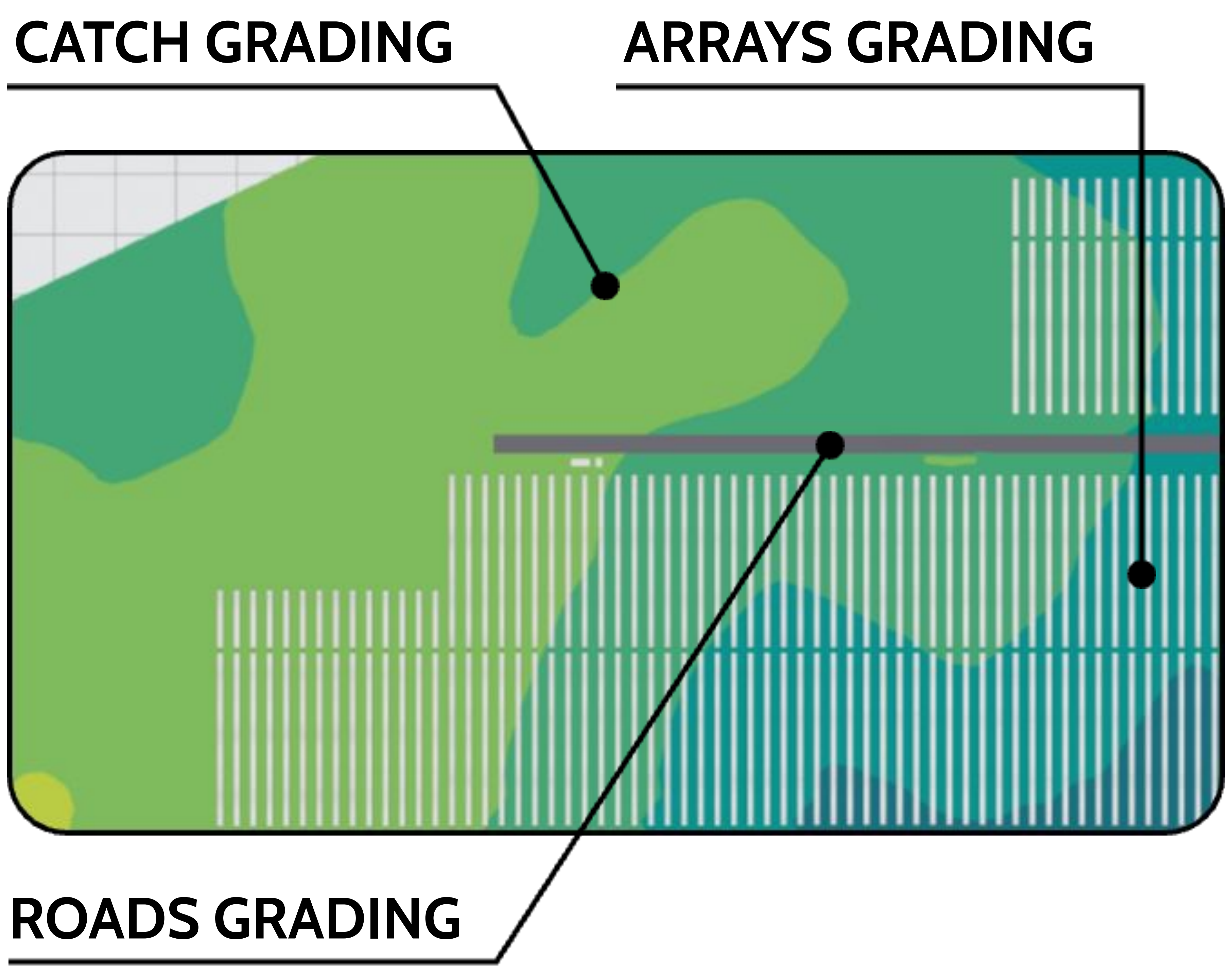
Piles in PVFARM

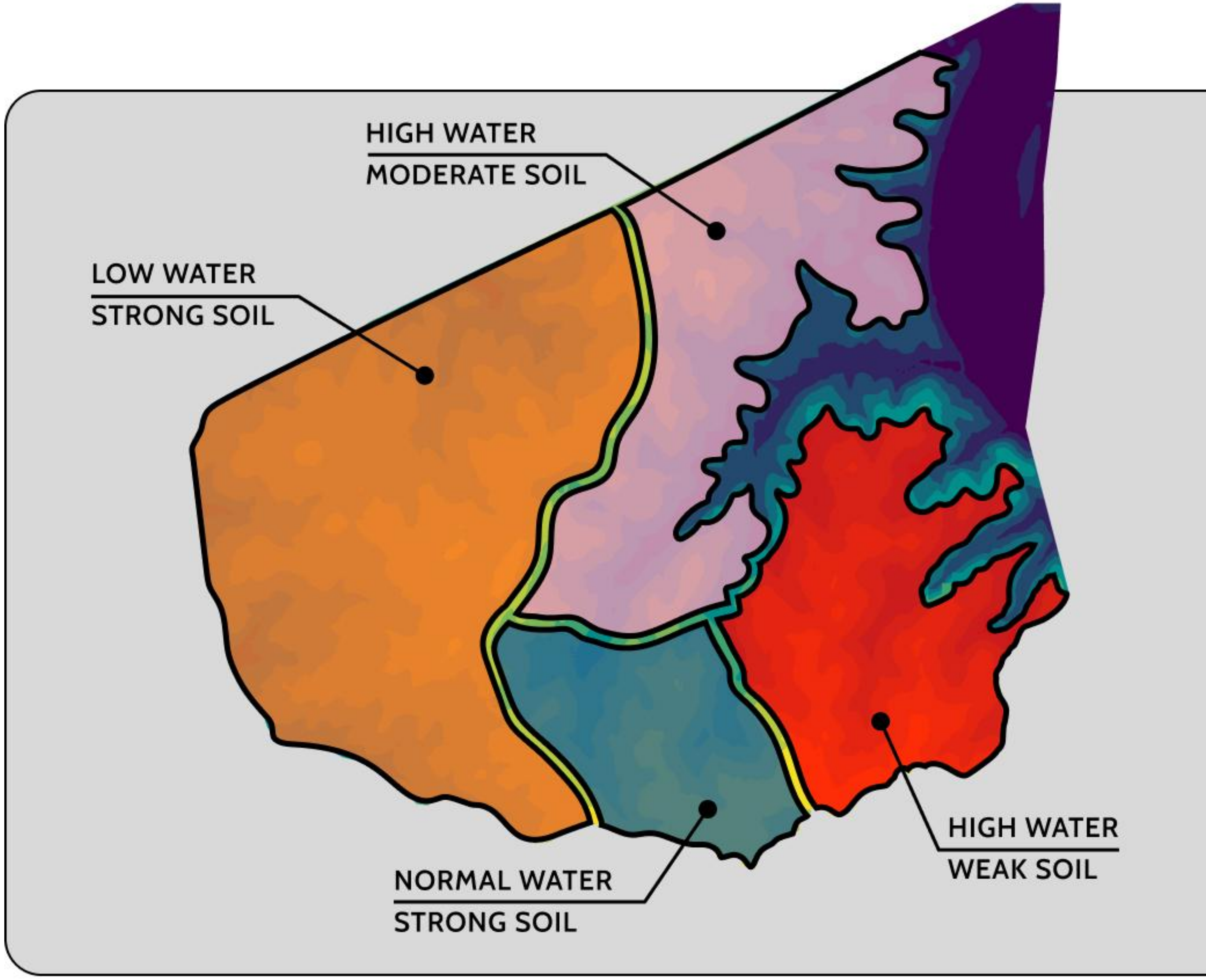
How we embedded piles into layout design



Cumulative Optimization

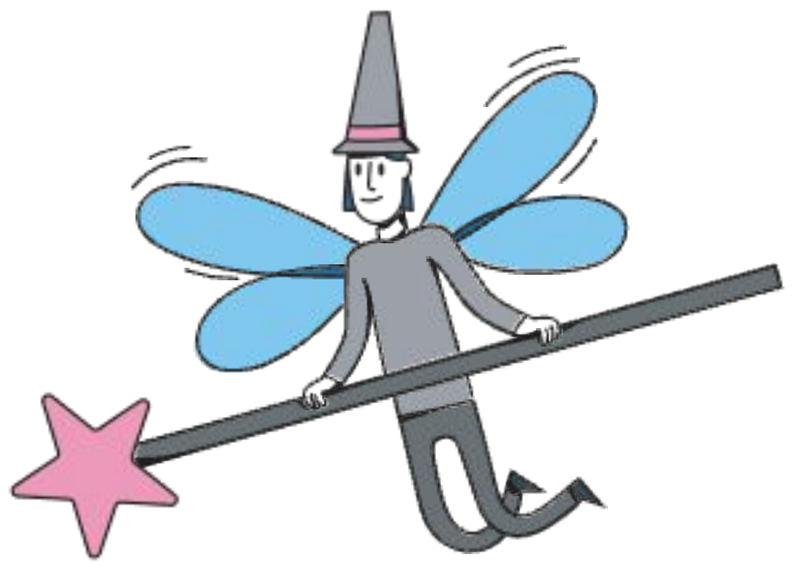
Perform multiple runs on a single surface using different grading strategies to **mimic real-world scenarios**

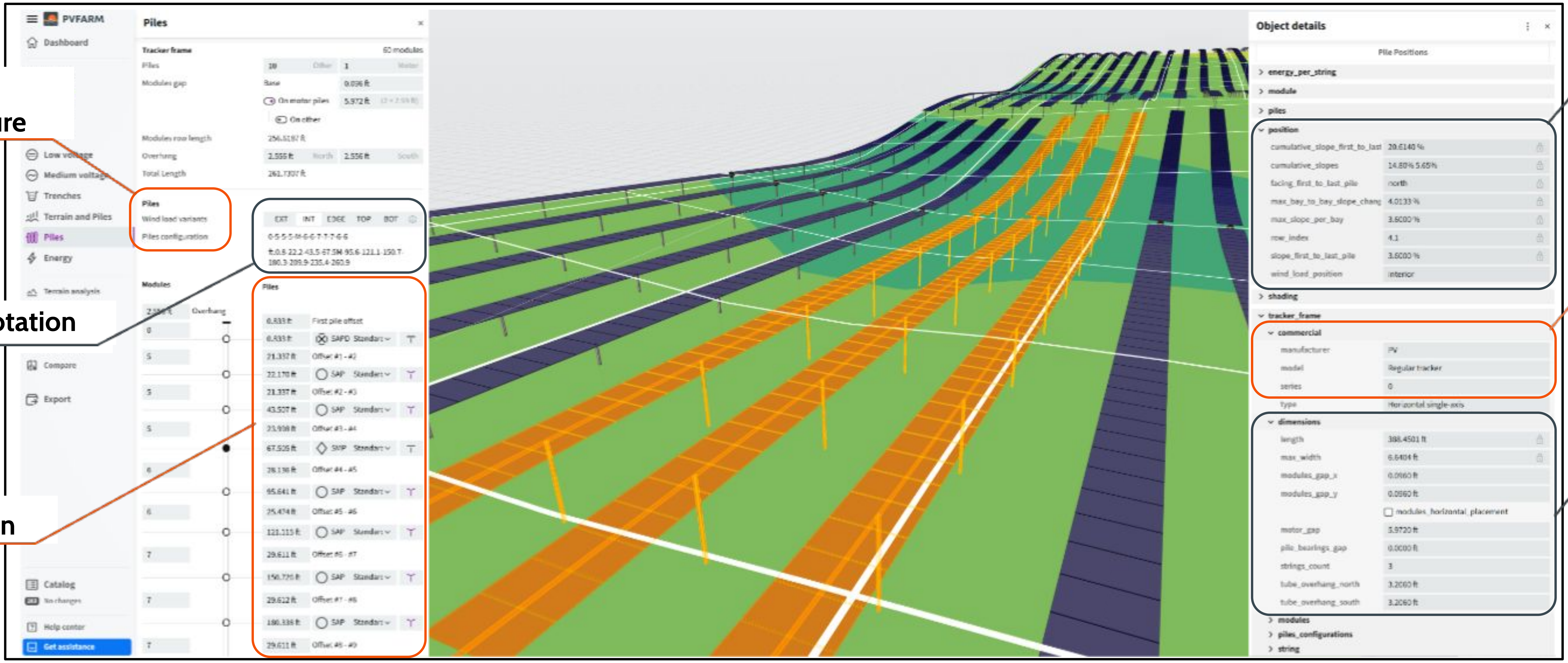




The Right Detail at the Right Moment

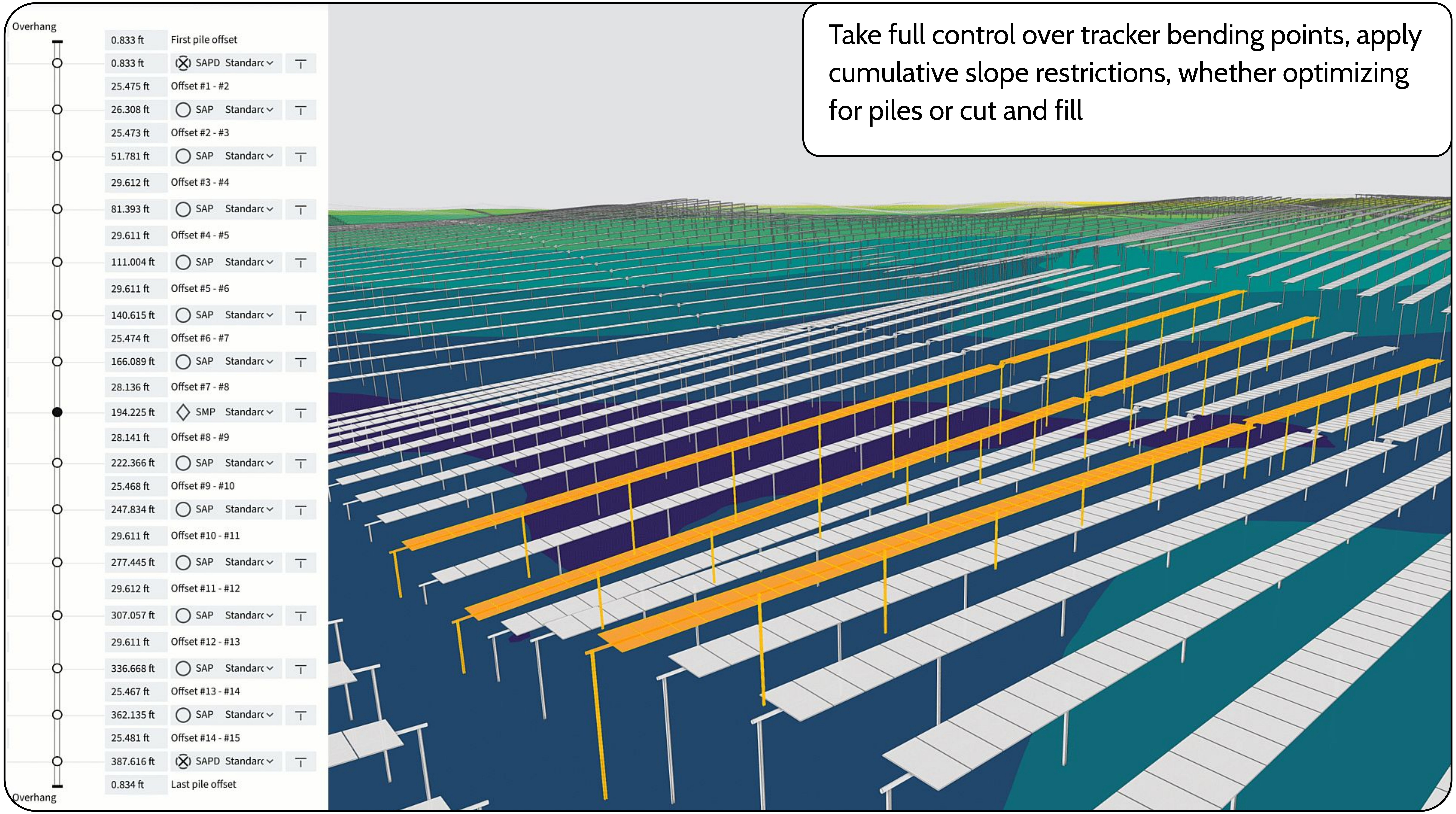
Electrical, mechanical and structural configurations are all available when needed





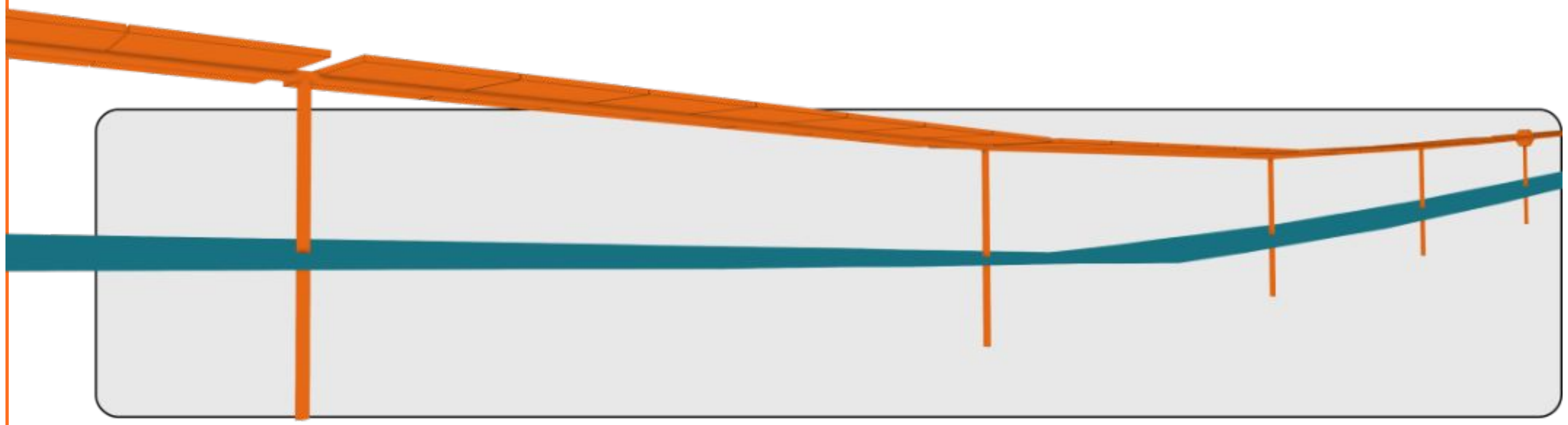
Advanced Configurability

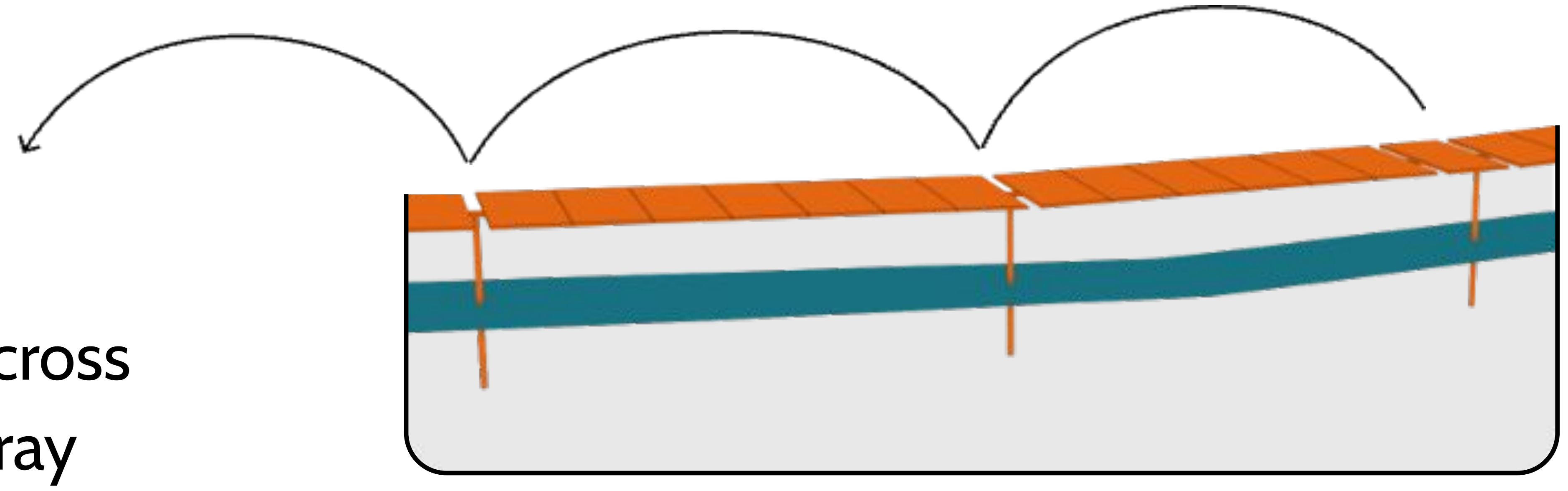
Take full control over tracker bending points, apply cumulative slope restrictions, whether optimizing for piles or cut and fill



Terrain Following First Optimization

If you can optimize for terrain-following trackers, optimizing rigid ones is simply a matter of adding additional constraints





Cumulative Slope
This is the total slope across the wing of the solar array

We describe the problem as a list of assertions.

1. Ω is the site.
2. $z^0(x, y)$ is the initial ground height at a point $(x, y) \in \Omega$.
3. $c(x, y) \geq 0$ is the cut value at a point $(x, y) \in \Omega$.
4. $f(x, y) \geq 0$ is the fill value at a point $(x, y) \in \Omega$.
5. $z(x, y) = z^0(x, y) - c(x, y) + f(x, y)$ is the final ground height at a point $(x, y) \in \Omega$.
6. $\left|\frac{\partial z(x, y)}{\partial x}\right| \leq \text{tan\_x}$, $(x, y) \in \Omega$.
7. $\text{min\_tan\_y} \leq \frac{\partial z(x, y)}{\partial y} \leq \text{max\_tan\_y}$, $(x, y) \in \Omega$.
8. $\int_\Omega (f(x, y) - c(x, y))\mathrm{d}s = \text{net\_balance}$.
9. The objective is $\int_\Omega (c(x, y) + f(x, y))\mathrm{d}s \to \min$.

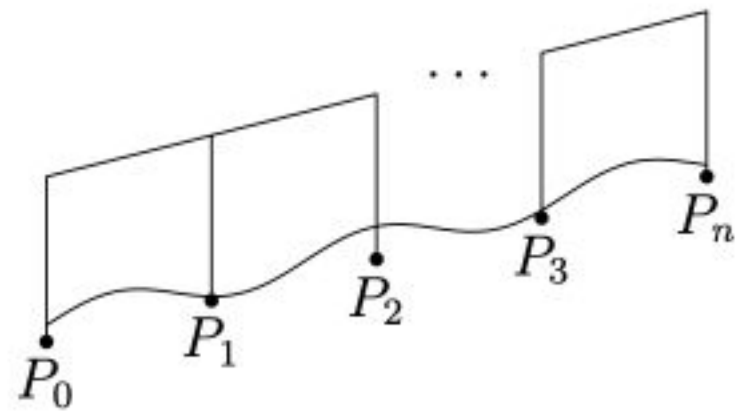
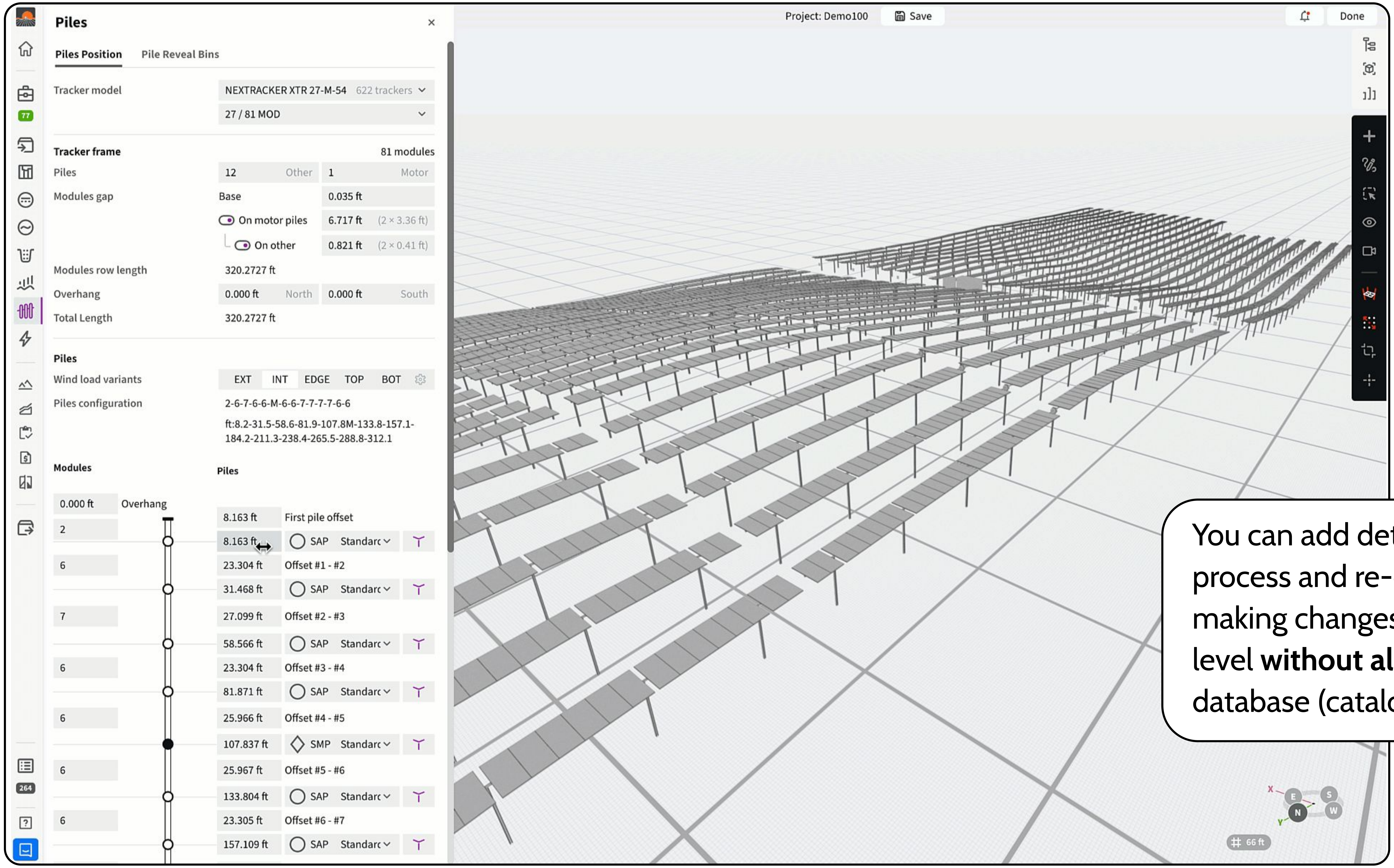


Figure 1: Tracker

10. $P_k = (x_k, y_k, z_k) \in \Omega$ is the base point of a pile, $0 \leq k \leq n$.
11. The points $P_0, P_1, \ldots, P_n$ are collinear (lie on the same line).
12. $|z_k - z(x_k, y_k)| \leq \text{tolerance}$, $0 \leq k \leq n$.
13. The angle between the line P_0P_n and the plane Oxy is not greater than max_angle.

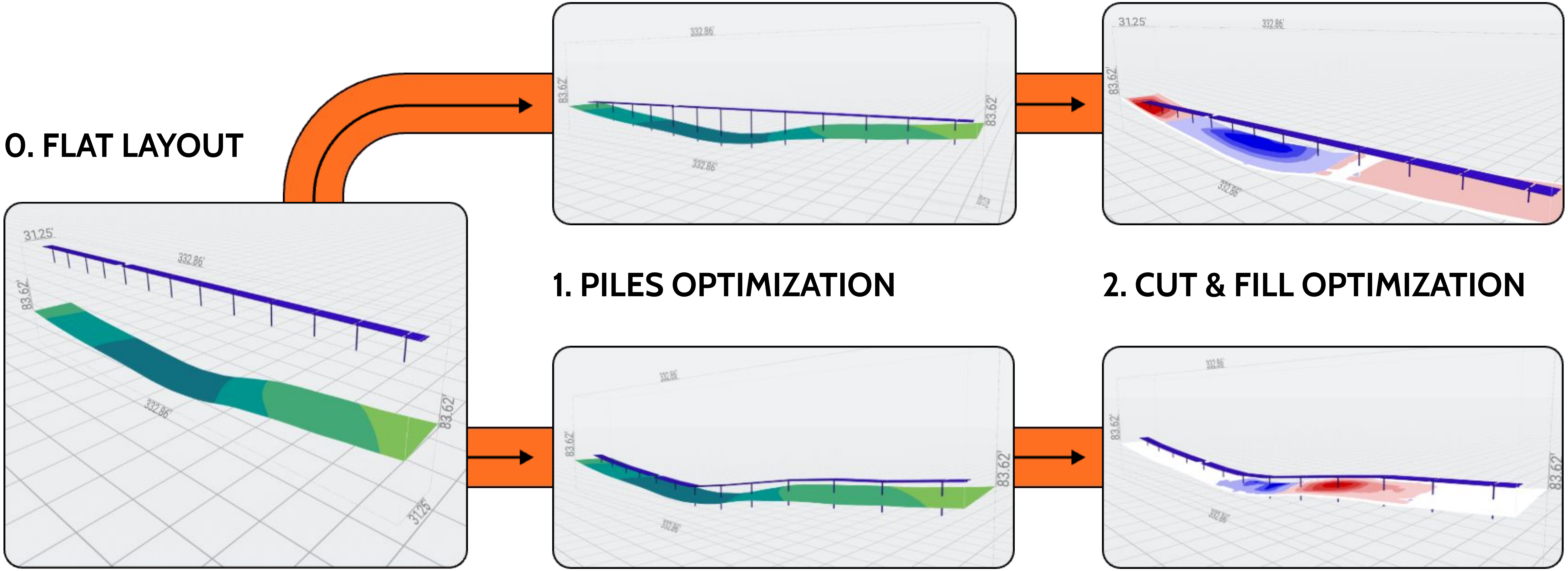
Non-Destructive Flow



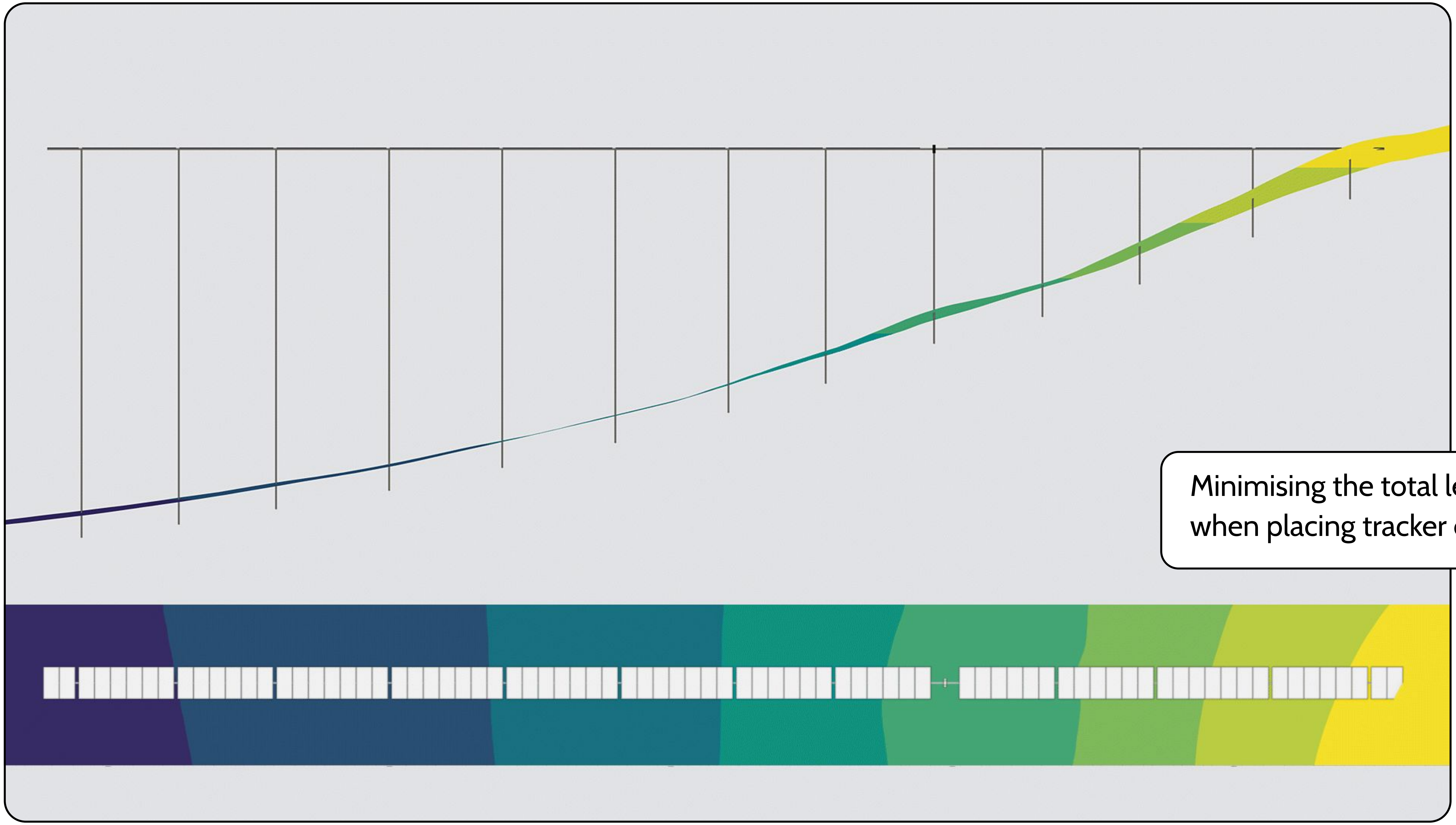
You can add details later in the process and re-optimize grading, making changes at the project level **without altering** the global database (catalog)

Two-Step Optimization

Optimizing for piles and optimizing for cut & fill are separate optimizations that can be run independently or sequentially



Piles Optimisation



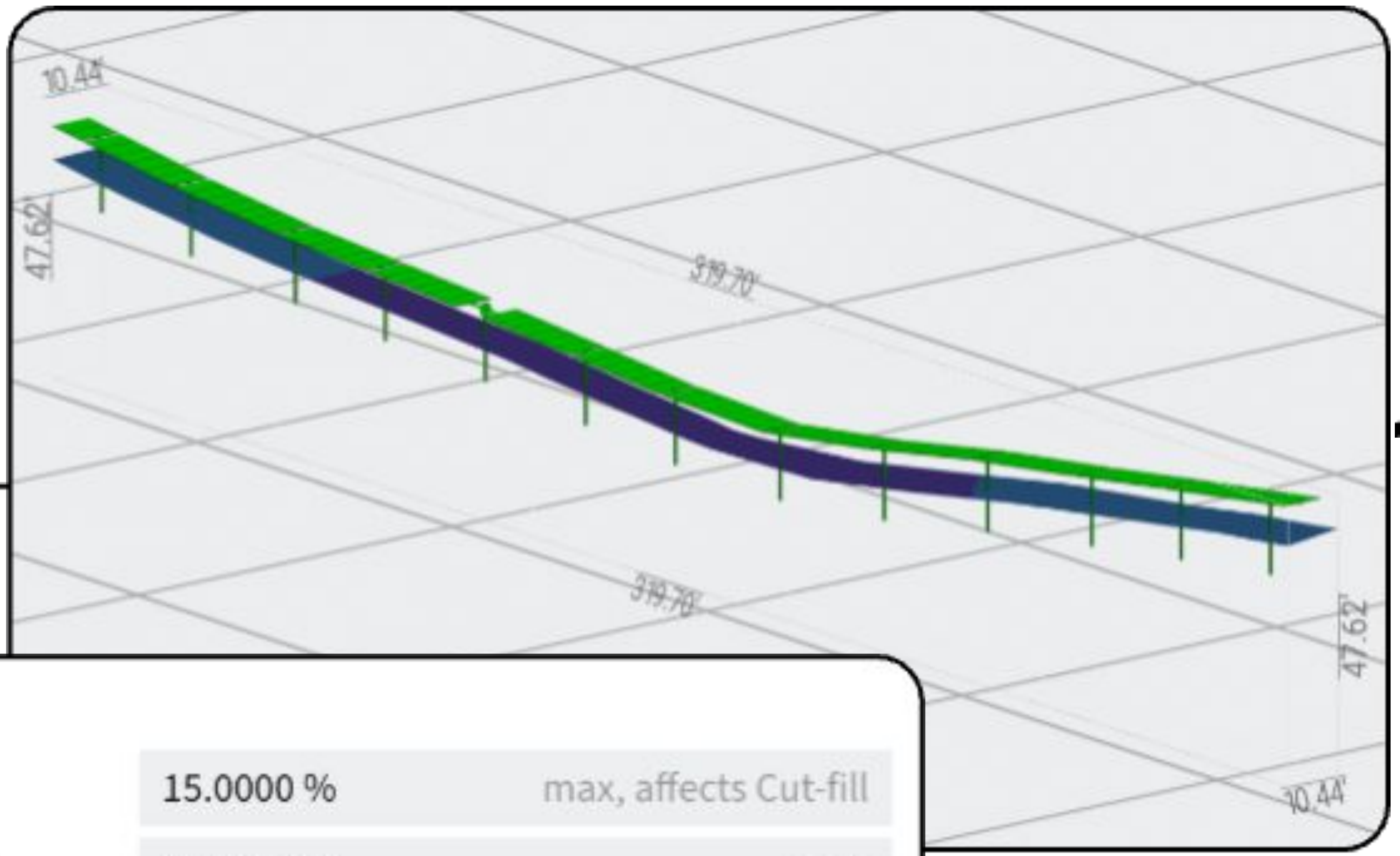
Minimising the total length of piles when placing tracker on the terrain

Procurement-Design Feedback Loop

Apply your binning analysis back to design and enjoy updated BIM model with all necessary data

1

DESIGN



Solar Arrays limits

Slope along axis	15.0000 %	max, affects Cut-fill
Slope change, Bay to bay	15.0000 %	max
Cumulative	100.0000 %	max

Piles

Embedment	7.0000 ft	min
Reveal	5.00 ft min / 6.00 ft	max

Update Piles, Cut-Fill

2

BINNING PROCUREMENT

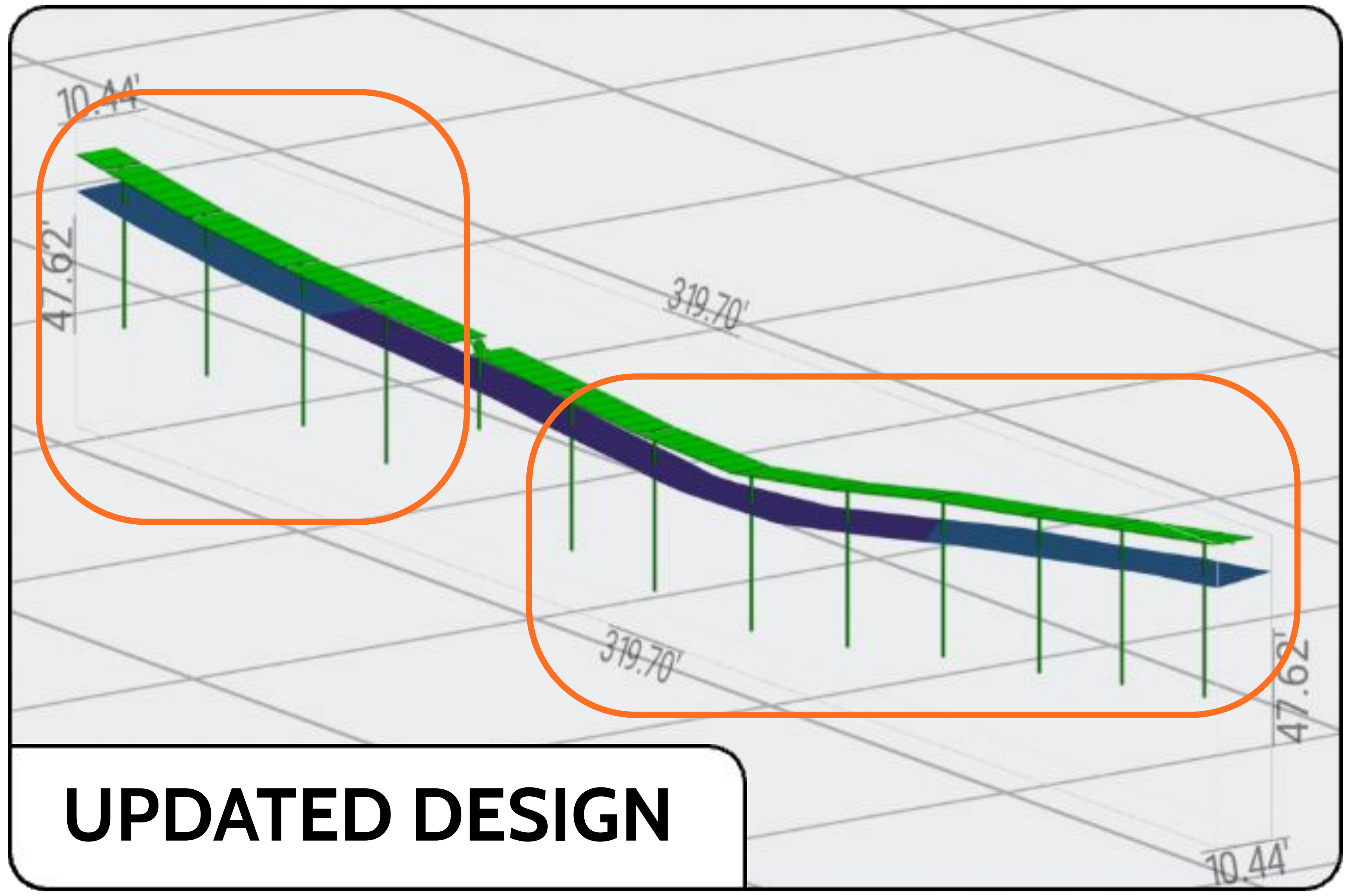
14 Piles types

Piles bin 1 — 6.000 ft max reveal

× 8079, 99.91%		Pile profile	Length, ft	Profile (scene)	Reveal, ft	Embedment, ft
× 6168	SAP	W6x7	× 25.00	W6x7	5.00 - 6.00	19.00 - 20.00
× 906	SAE	W6x7.75	× 13.00	W6x7	5.00 - 5.99	7.01 - 8.00
× 590	SMP	W6x10.5	× 13.00	W6x10.5	5.00 - 5.98	7.02 - 8.00
× 319	HAP	W6x9	× 13.00	W6x7	5.00 - 5.98	7.02 - 8.00
× 64	HAE	W6x9	× 13.00	W6x7	5.00 - 5.77	7.23 - 8.00
× 32	HMP	W6x15	× 13.00	W6x10.5	5.00 - 5.80	7.20 - 8.00

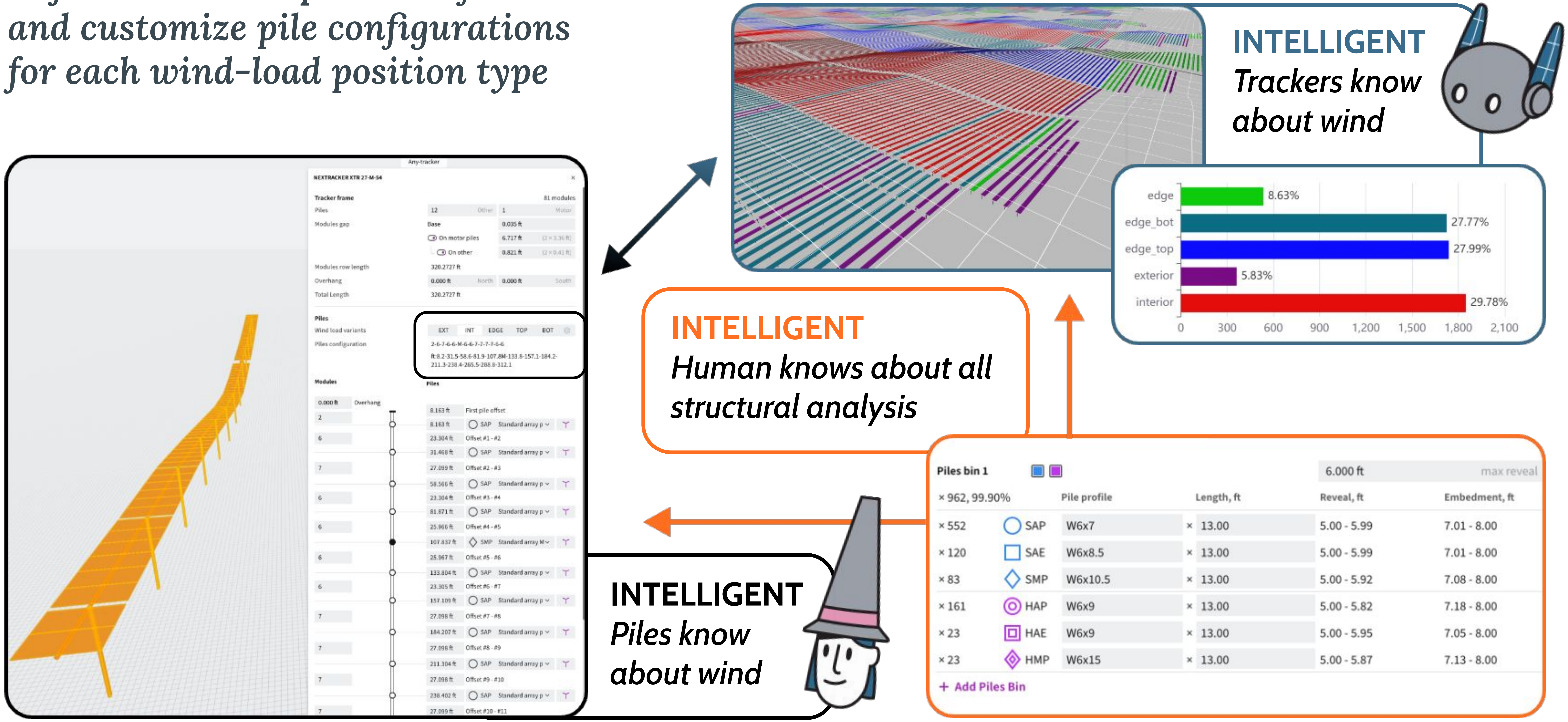
3

UPDATED DESIGN

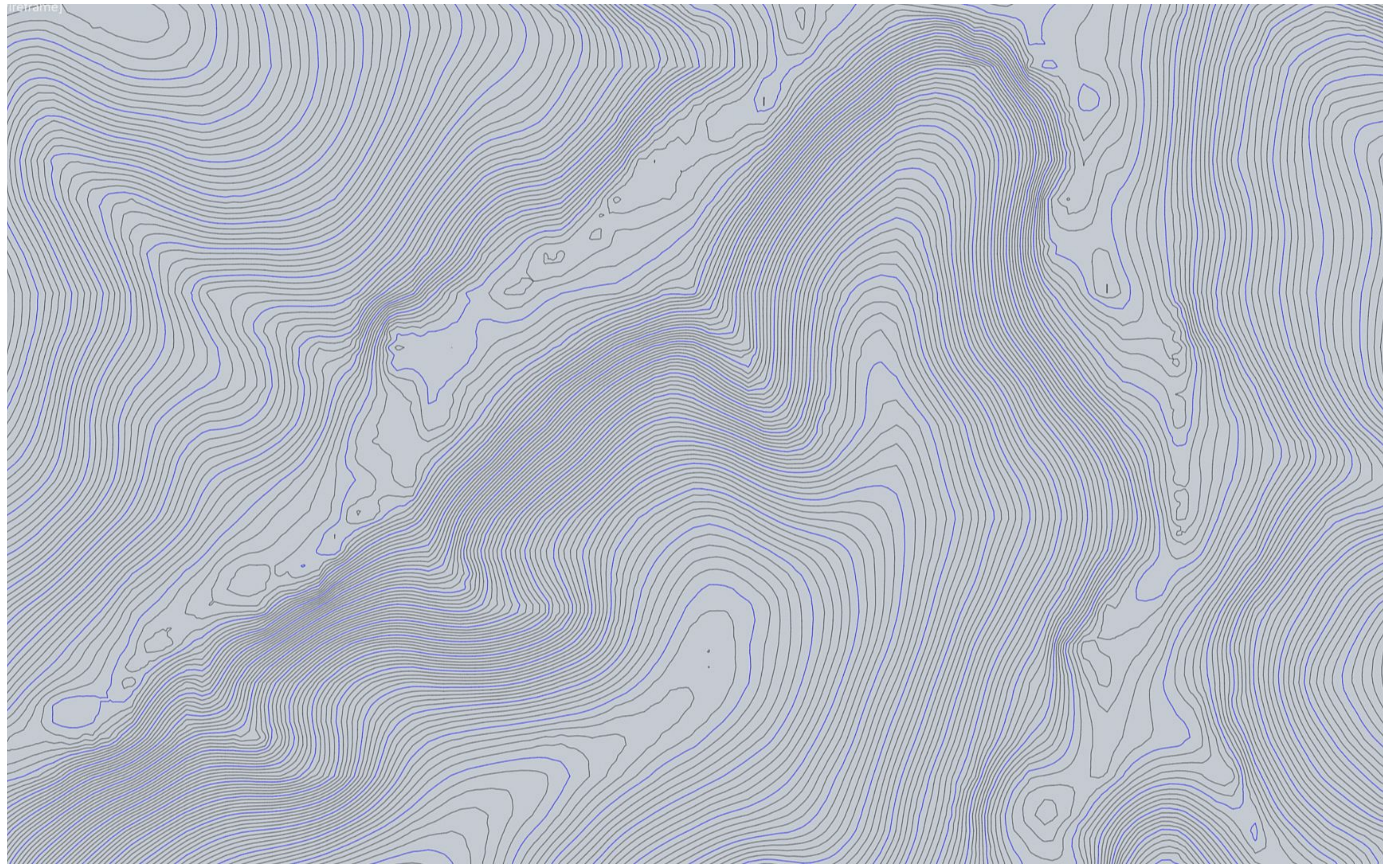


Wind Load Exposure Analysis

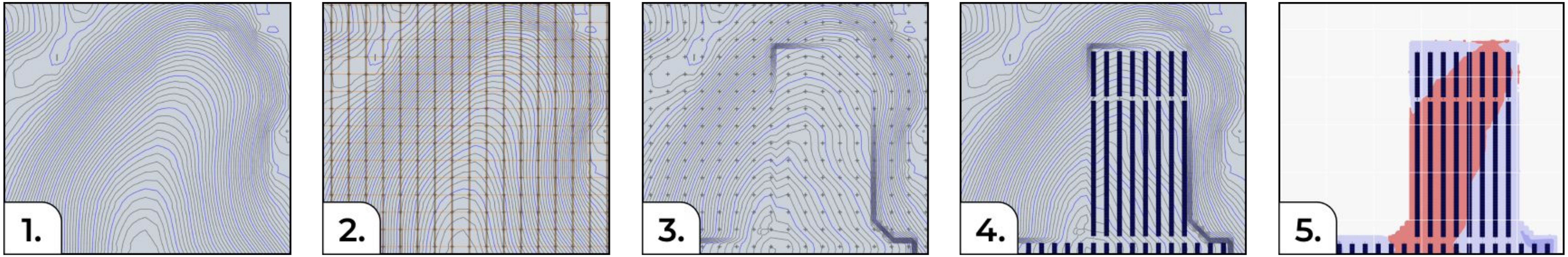
Define wind load positions for trackers and customize pile configurations for each wind-load position type

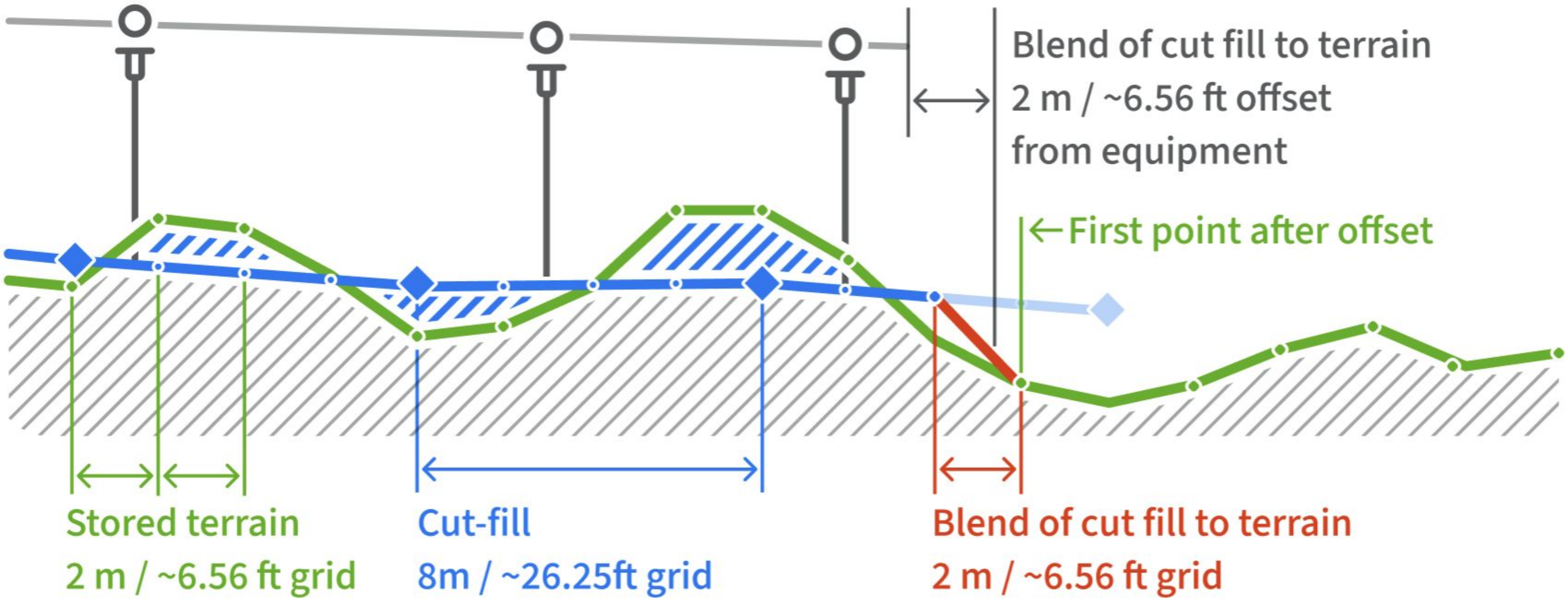


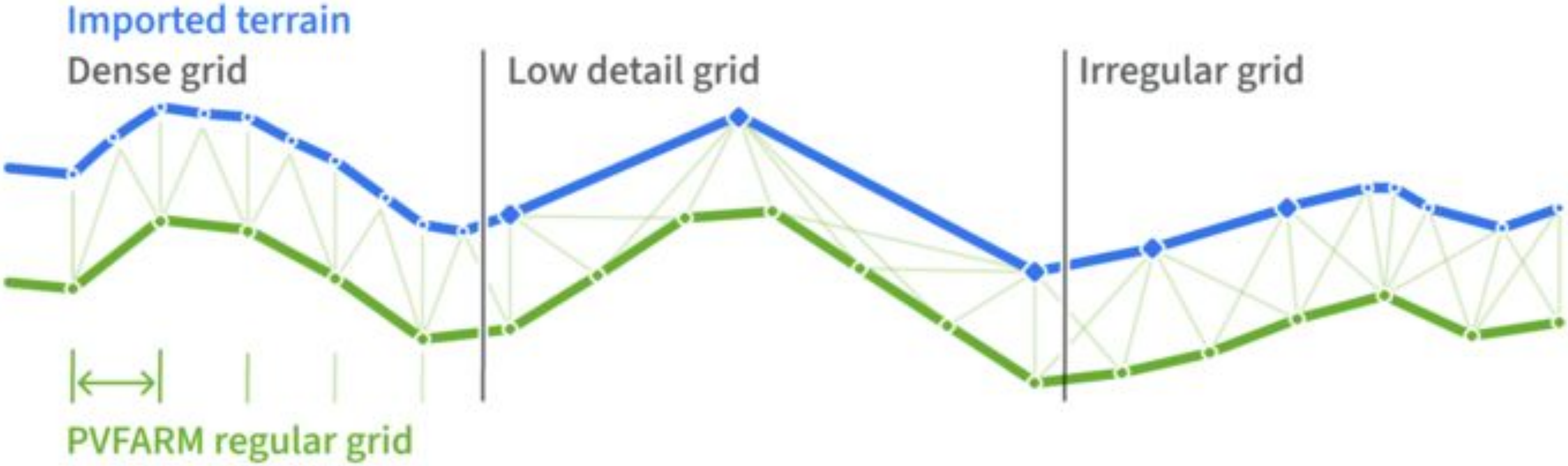
Meaningful Optimization



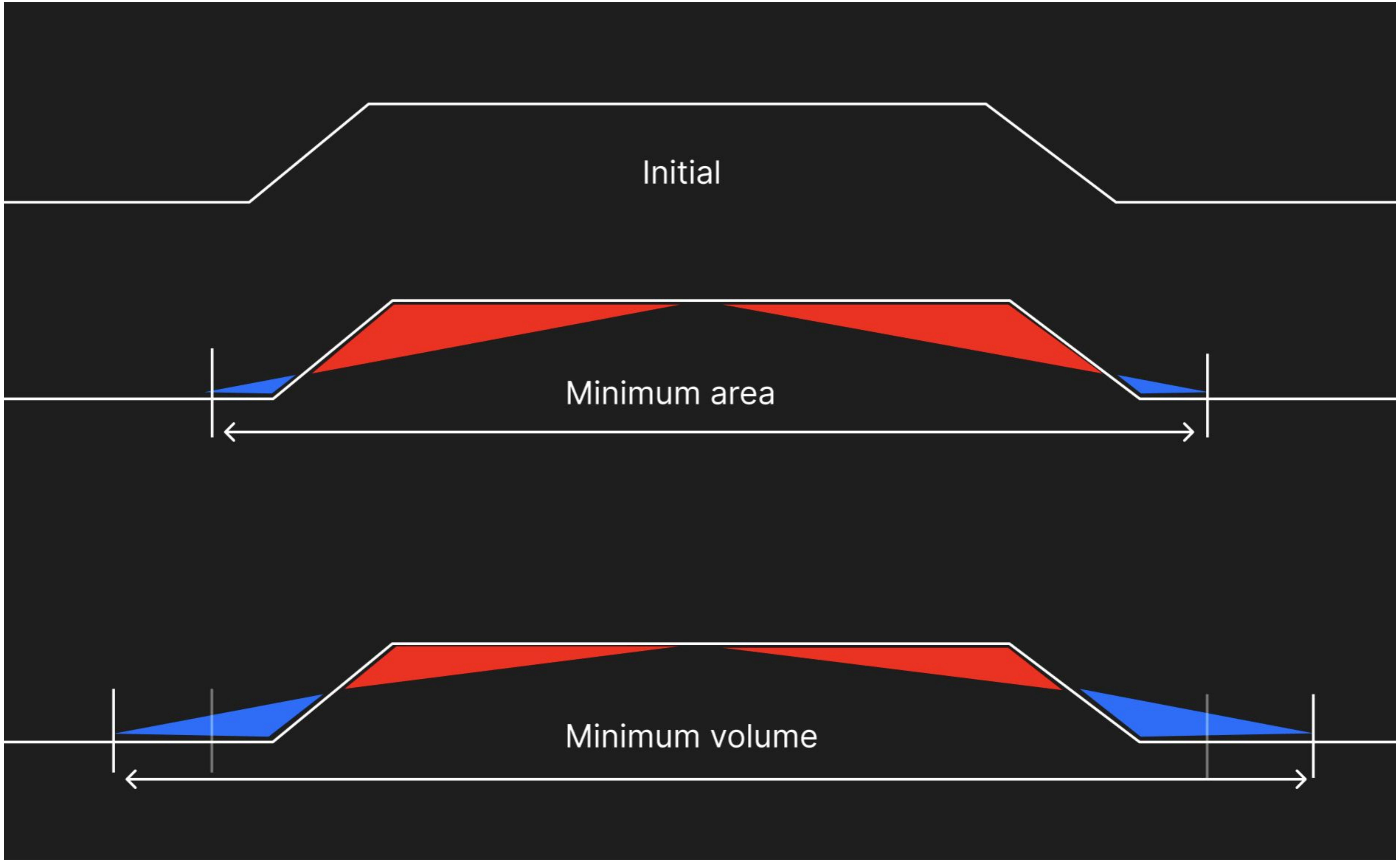
Focused on achieving practical, real-world results



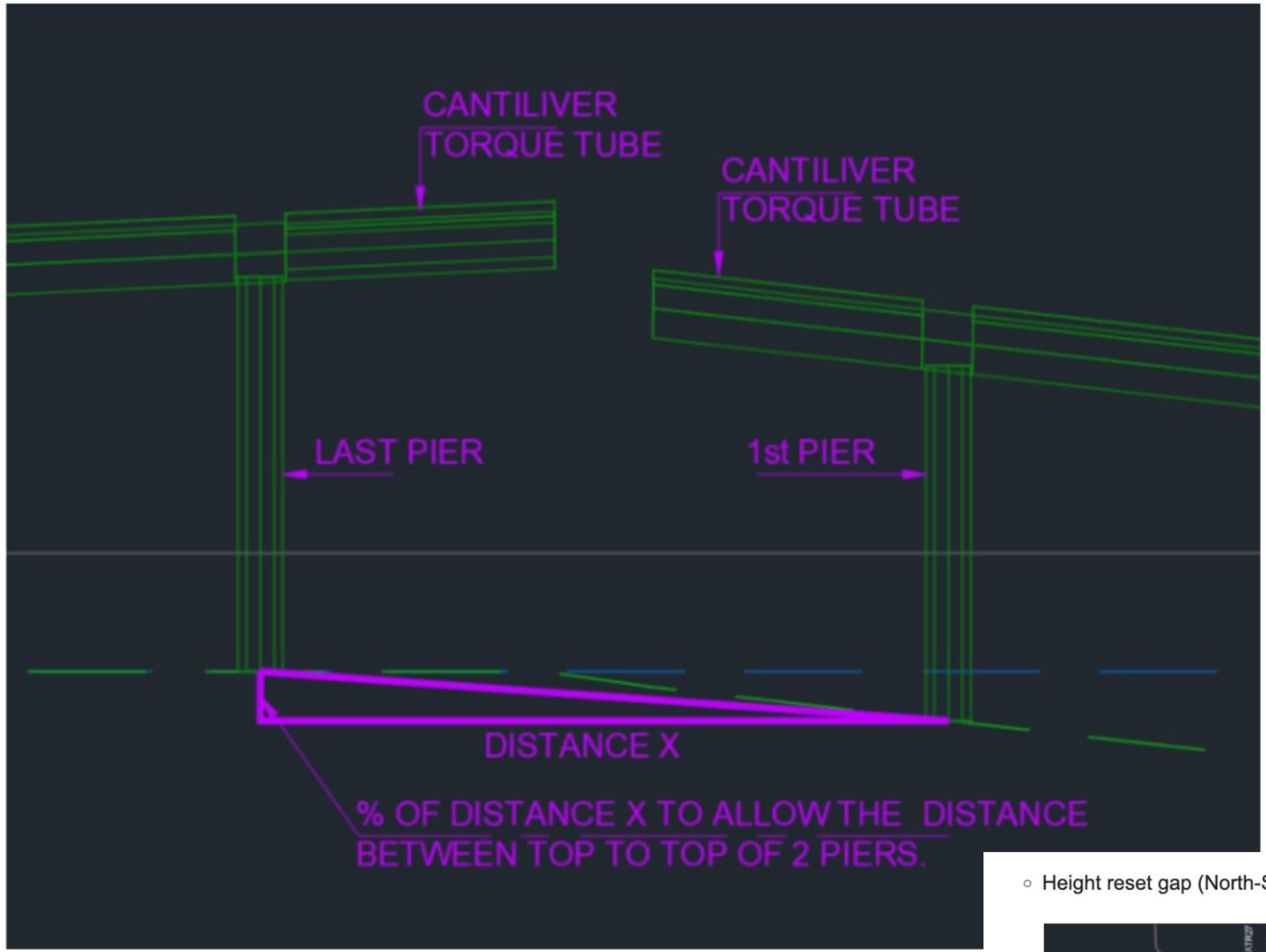

Blend of cut fill to terrain
2 m / ~6.56 ft offset
from equipment
←First point after offset
Stored terrain
2 m / ~6.56 ft grid
Cut-fill
8m / ~26.25ft grid
Blend of cut fill to terrain
2 m / ~6.56 ft grid



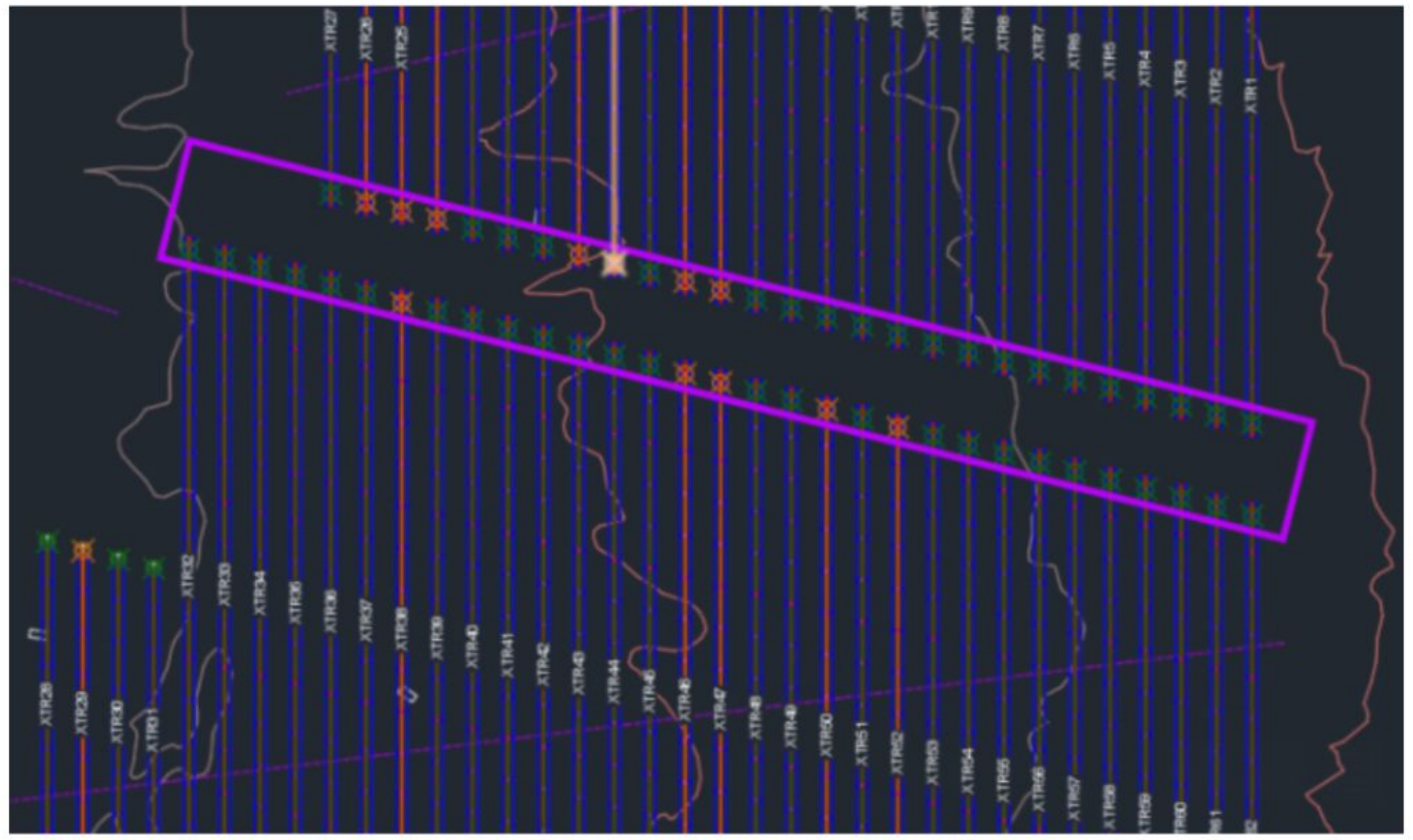
PVFARM converts any imported terrain to a regular grid. Only the converted terrain is included when exporting it. File with original data is not stored.


Initial
Minimum area
Minimum volume

- Adjacent Tracker slope N-S Direction = 20% - *This is the % of distance between last pier of 1st tracker to 1st pier of Nextracker. If the distance between 2 piers is "X" and if we put this values as 100% then the tool will allow the pier adjustments in vertical directions up to X only. For example if we set this value as 1000% then it will allow up to 10X distance. This vertical distances place an important role when Robotic requirement is there or we need proper alignment of the trackers.*

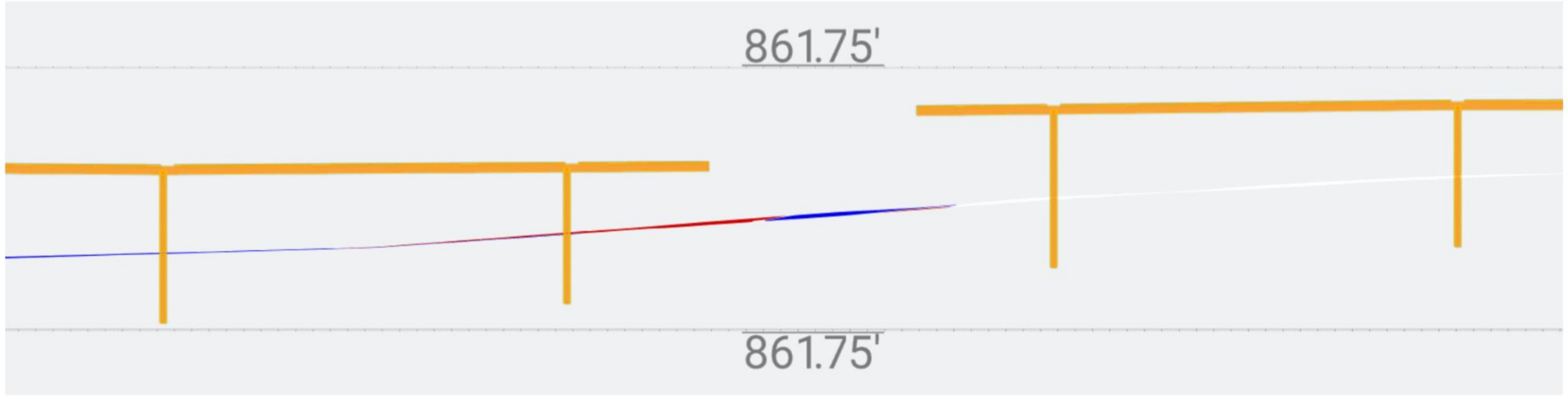


- Height reset gap (North-South) = 10 feet - *This is the road distance between 2 trackers or the distance between 2 trackers for which we don't need an alignment so can ignore the above point.*

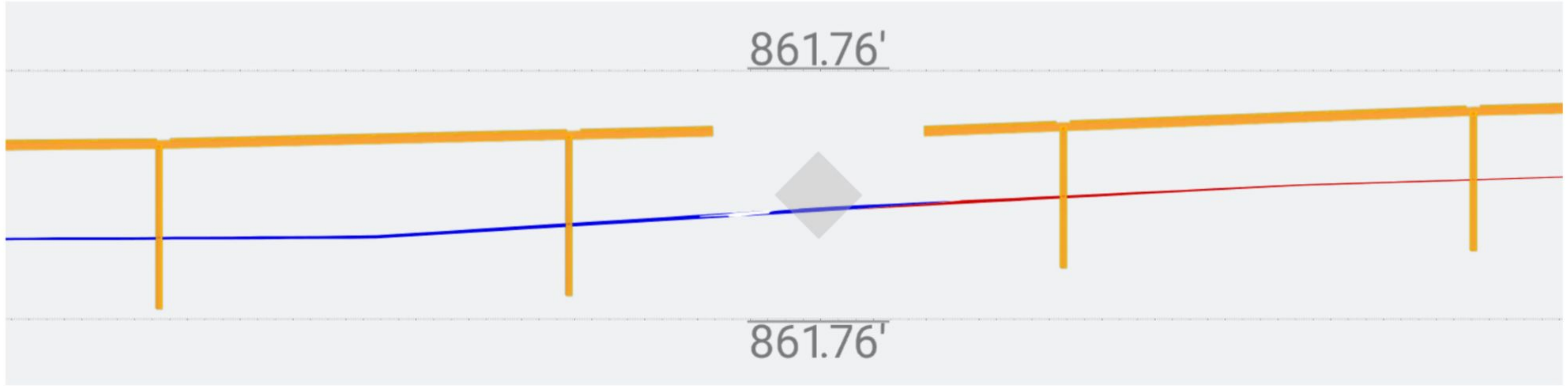


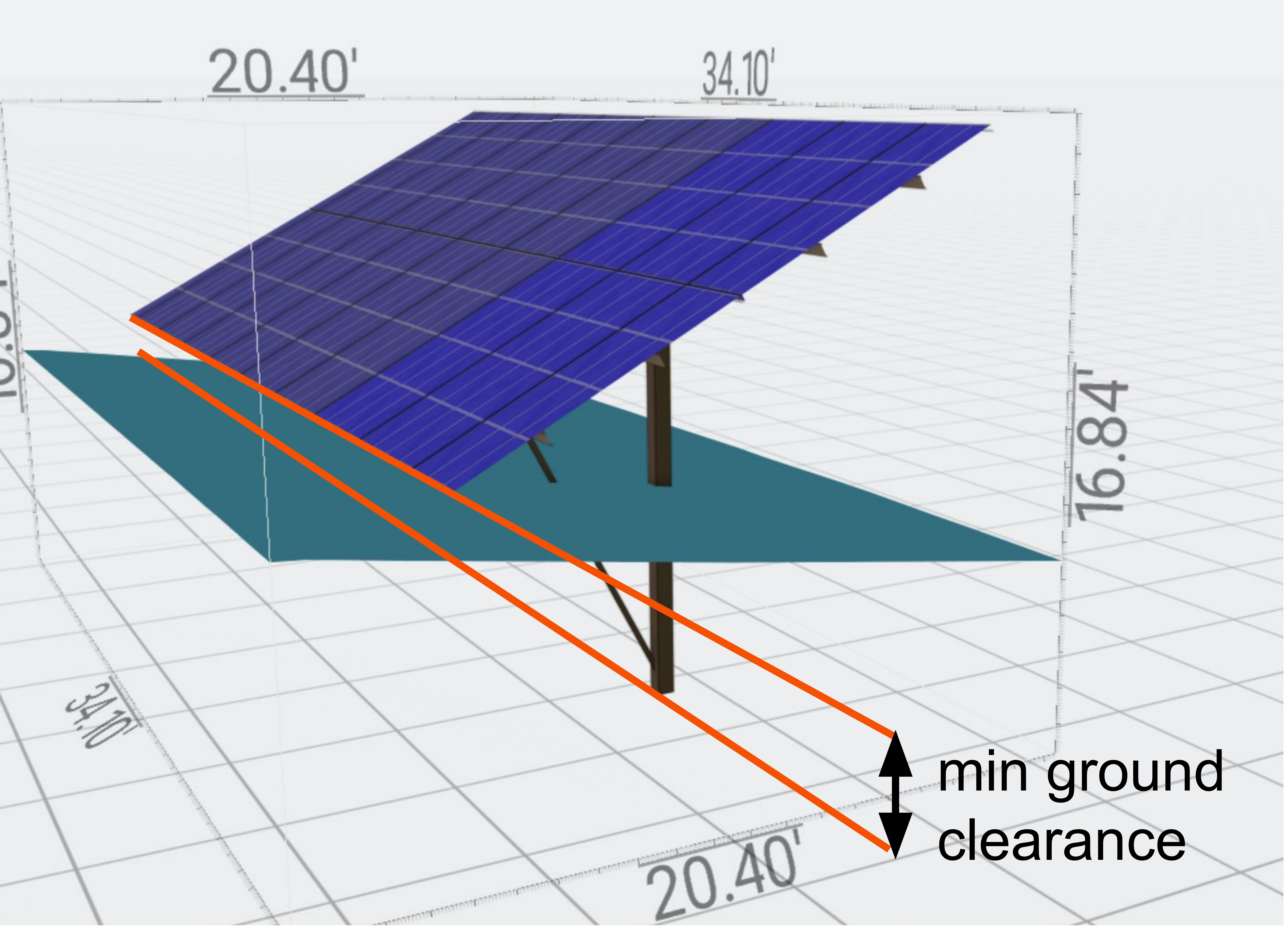
End-to-end vertical exposure

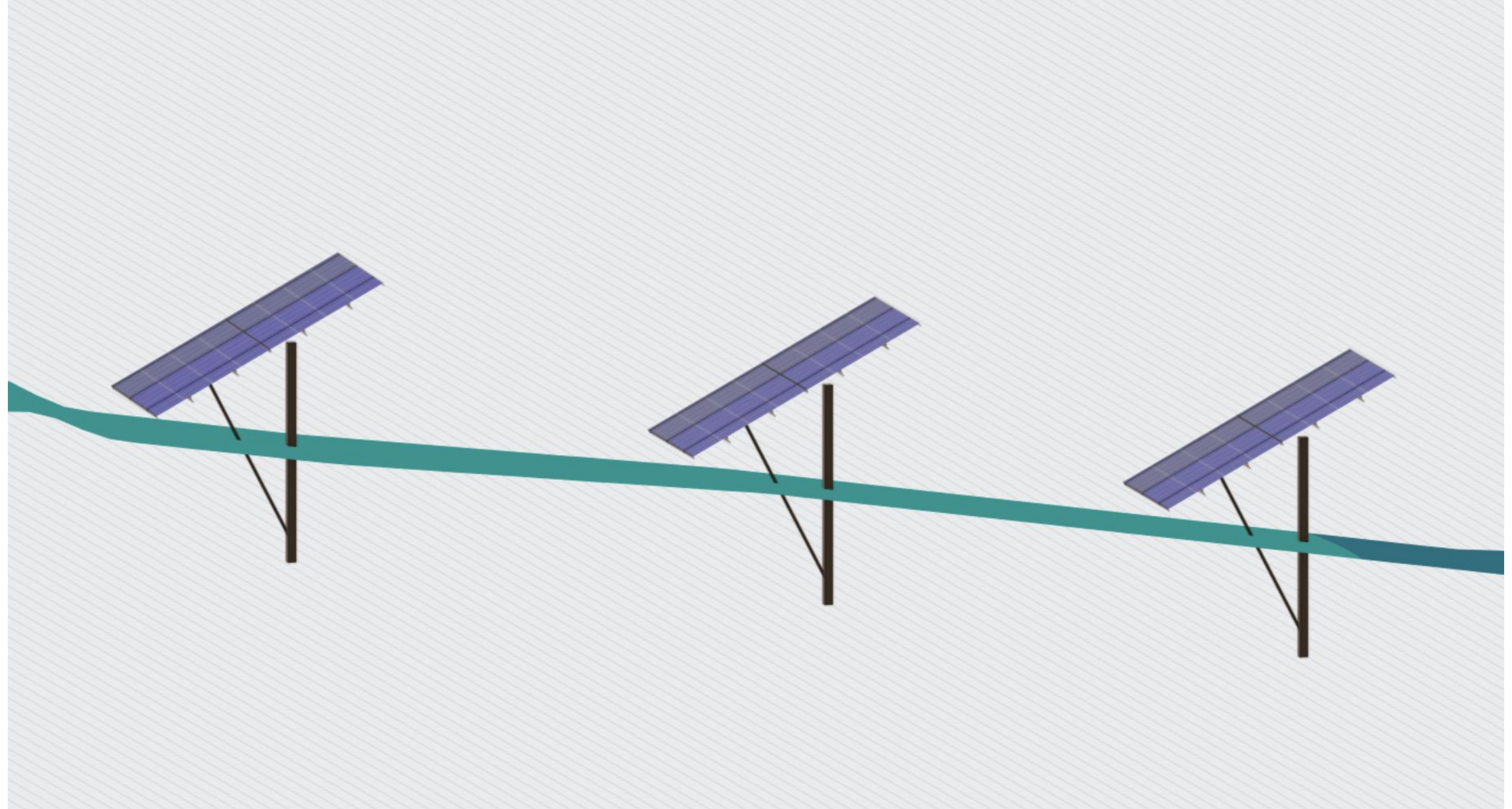
BEFORE

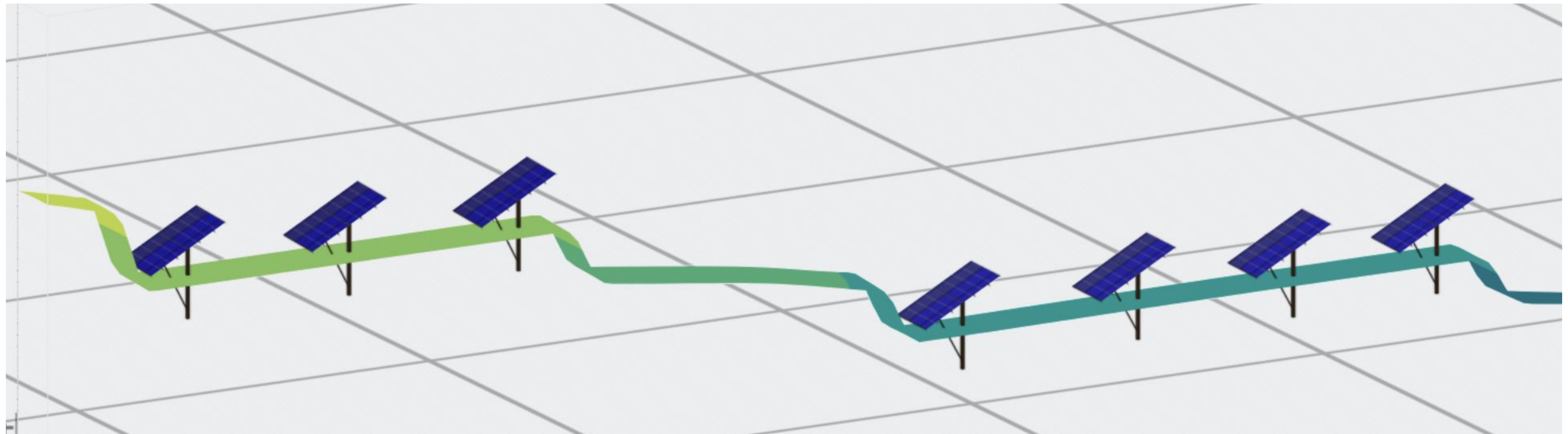


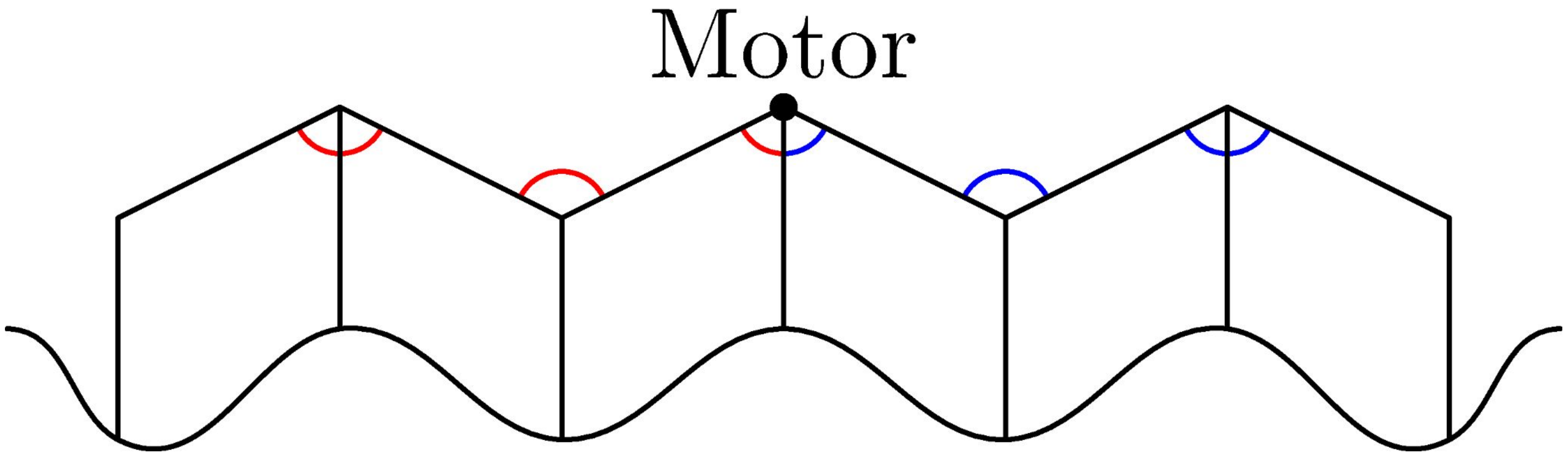
AFTER



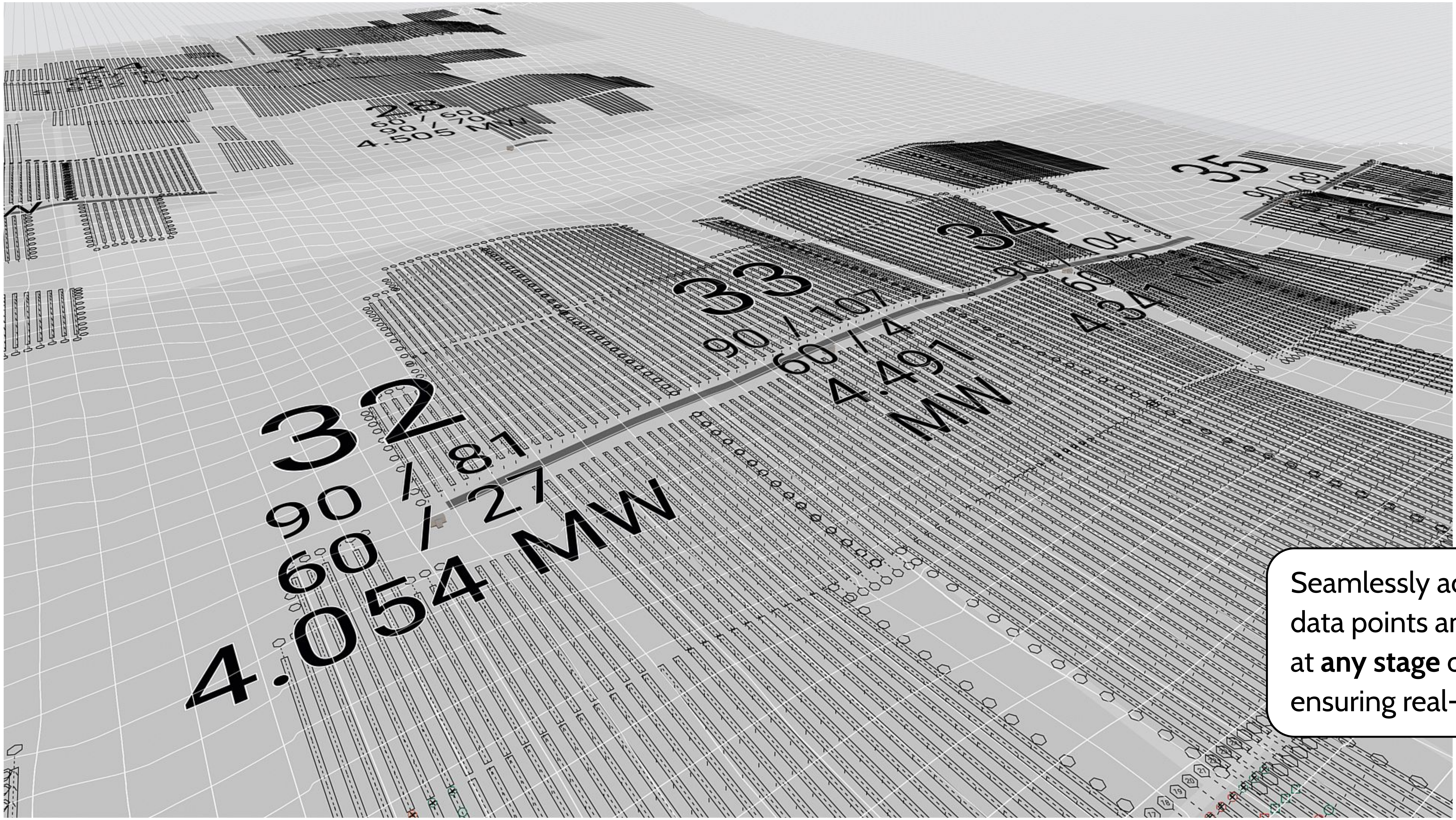

20.40'
34.10'
16.84'
34.10'
20.40'
min ground
clearance





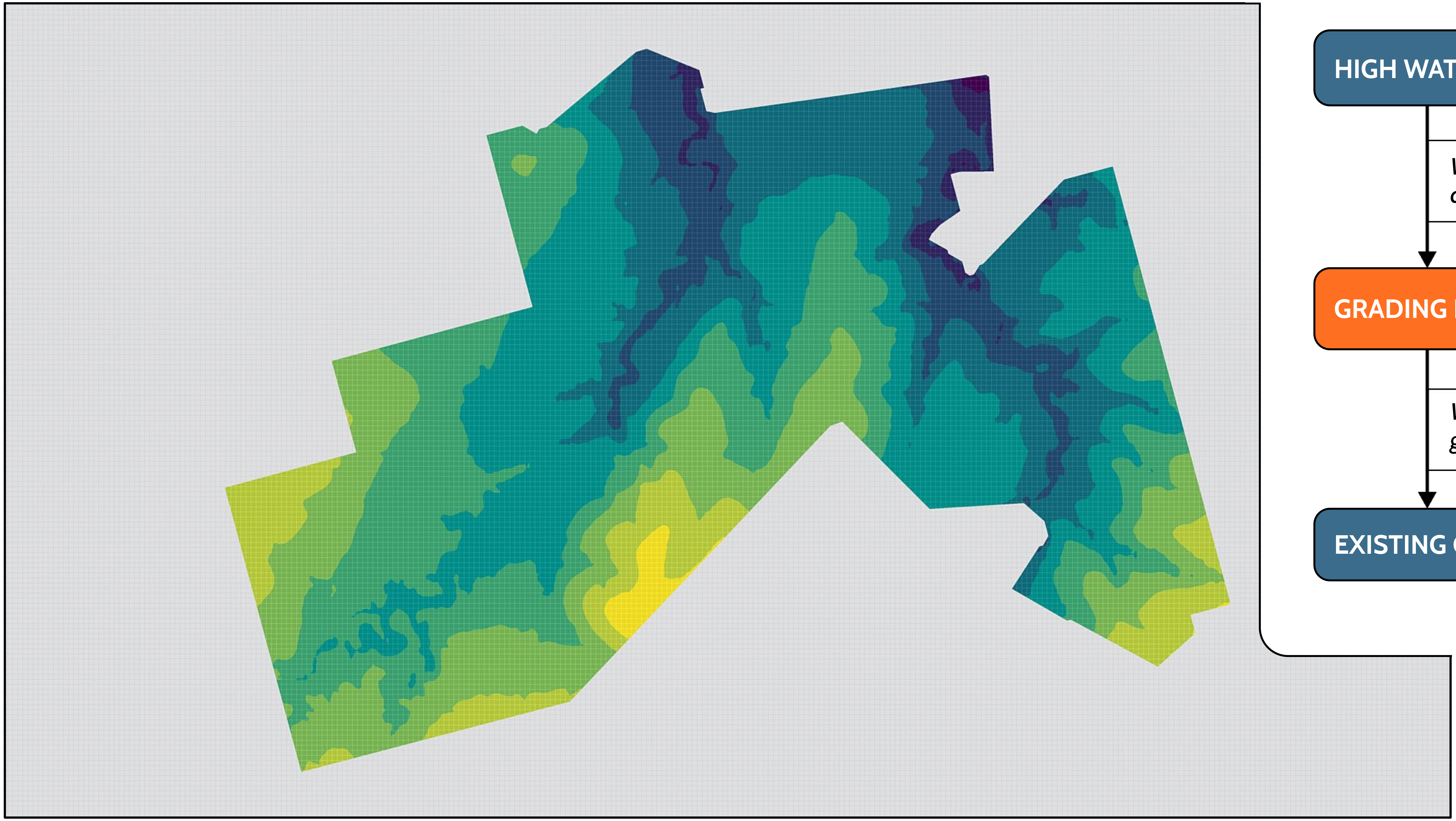

Motor

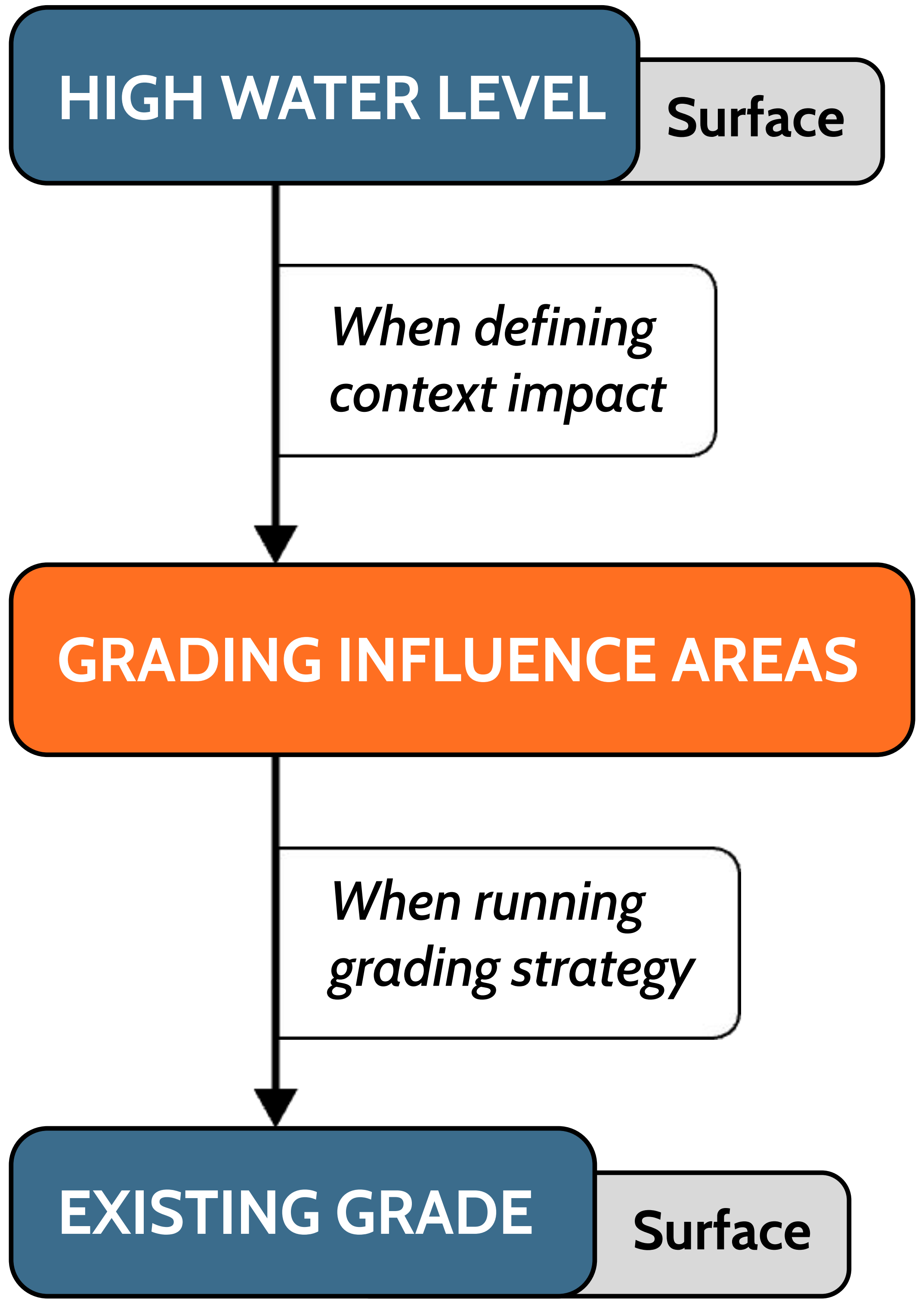
Model-Linked Datapoints



Seamlessly access linked data points and deliverables at **any stage** of the process, ensuring real-time visibility

Multi-Surface Support

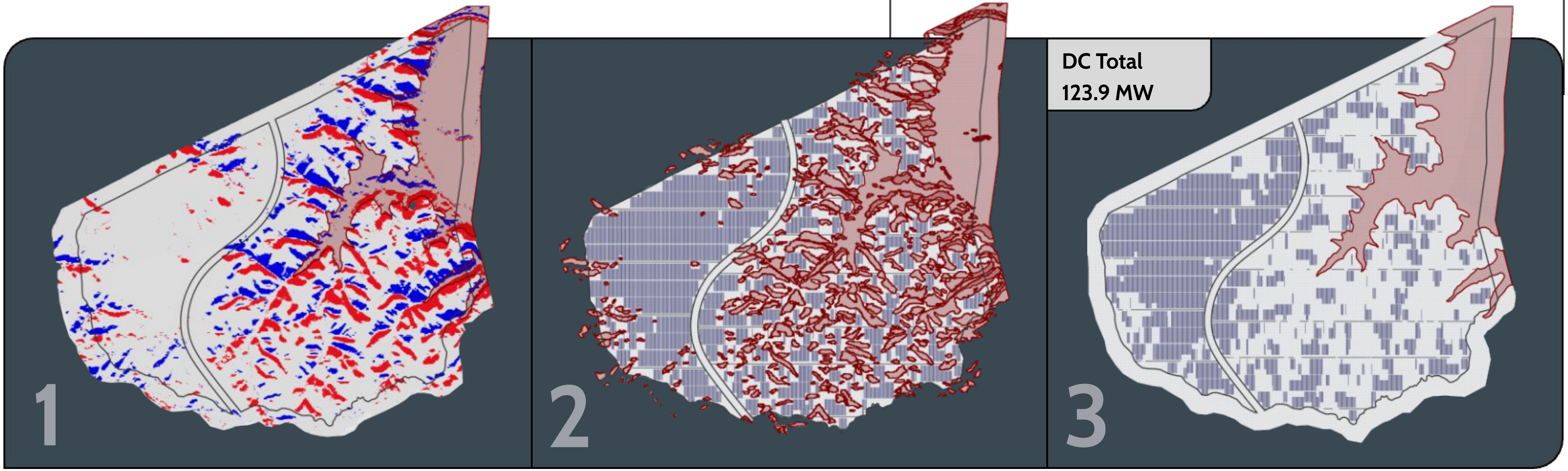




Evaluating EG by Slopes

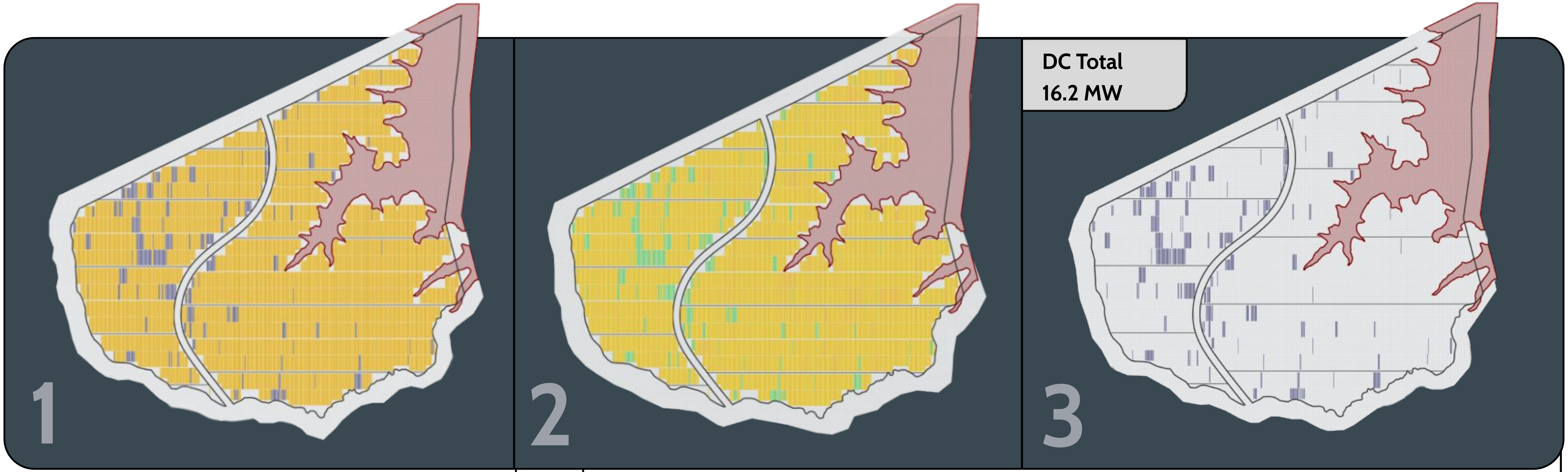
Avoiding areas with high slopes

Min Slope	Max Slope	Area	Share
- 372.0 %	- 10.0 %	158.2018 ac	9.3169 %
- 10.0 %	10 %	1338.3566 ac	78.8194 %
10.0 %	372.0 %	201.4446 ac	11.8636 %



Evaluating EG by Piles

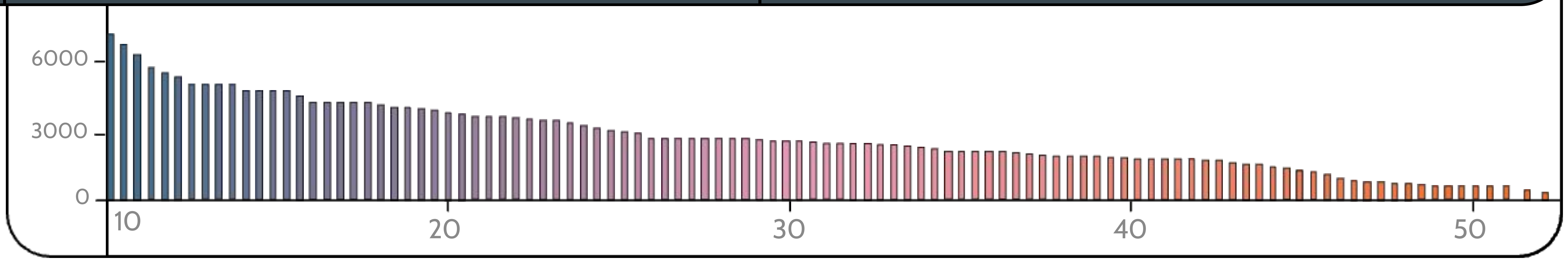
Avoiding trackers that have at least one pile with reveal longer than expected



PILES LENGTHS

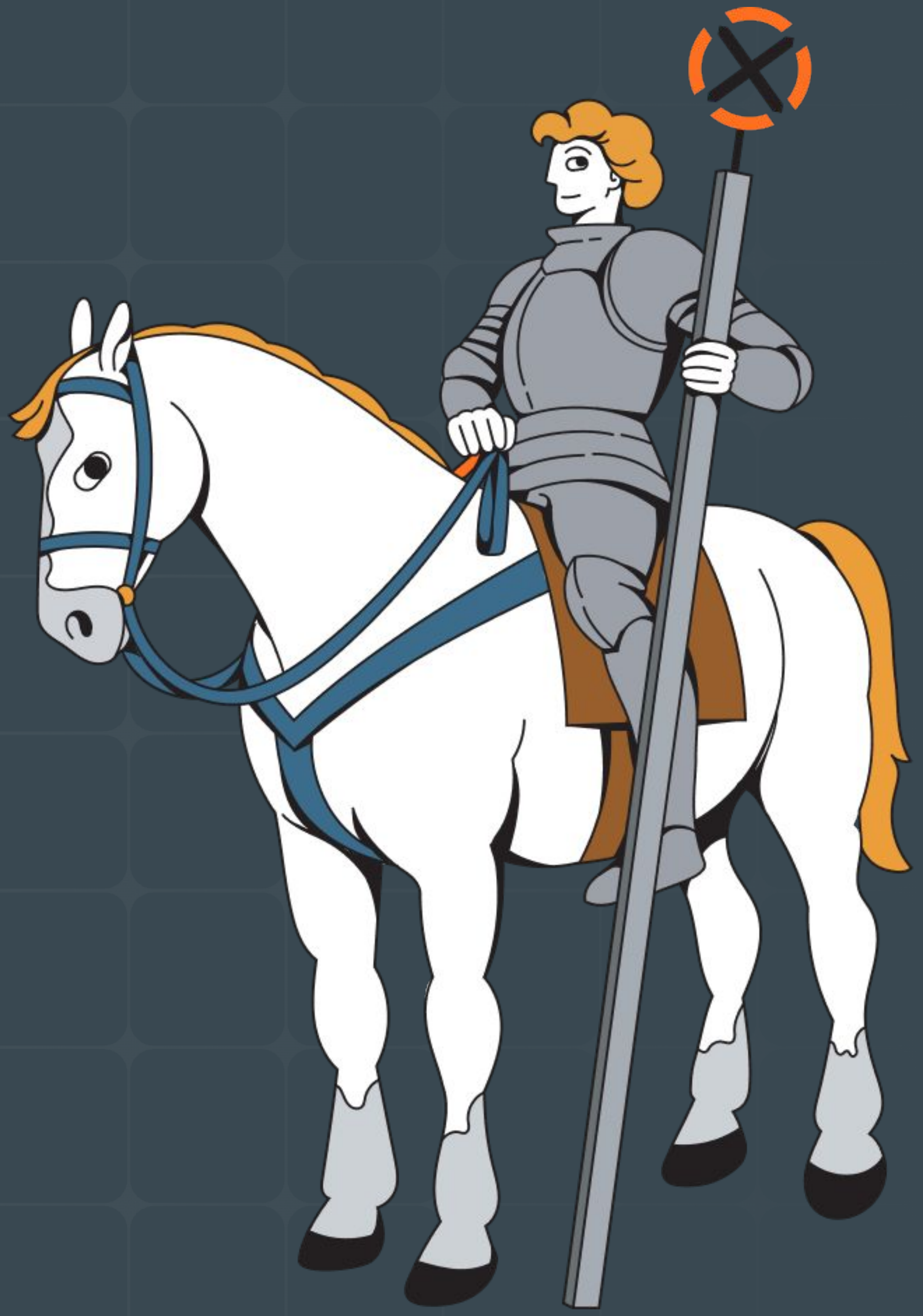
Range: 10 to **54.843 ft**

Average: 13.525 ft of **92295** objects



Piles Journey

From the beginning of the design to the end, when we get all the things we need



Let's flow

1. Configure trackers with smart defaults for piles based on manufacturer specifications (e.g., Nextracker vs. ATI)
2. Create a flat layout and run wind-load analysis to position placeholder piles with assumed reveal/embedment depths and default cross-sections
3. Load terrain data and evaluate it based on pile placement
4. Optimize cut-and-fill operations versus pile positioning, balancing costs to determine the most efficient solution
5. Account for hydrology and soil conditions, adjusting pile reveal/embedment depths in affected areas
6. Refine tracker details by specifying exact piles and types, ensuring these adjustments are project-specific and maintaining the cost balance
7. Implement pile binning strategies based on reveal and length, exploring multiple binning
8. approaches for efficiency
9. Update pile cross-sections based on embedment depth and length to match structural needs
10. Generate deliverables, analyze them (e.g., DXFs, PDFs), and demonstrate how SAPPP integrates with the model

Thank you!

Any questions?

PVFARM