Solitude Tailings Landform: An Integrated Buttress and Landform Design for a Closed Tailings Facility

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March 1, 2023

SME MINEXCHANGE 2023 SME ANNUAL CONFERENCE & EXPO
CMA 125th National Western Mining Conference
BHP srk consulting The University of Arizona

Acknowledgements

Dr. Jon Pelletier: Technical Lead – Erosion Science and Modeling

Nathan Abramson

The University of Arizona

Department of Geosciences

Satya Chataut: Principal Study Engineer

Sriram Ananthanarayan: Principal Study Engineer

BHP Copper Inc.

Technical Centre of Excellence and Legacy Assets

Solitude Tailings Project Setting

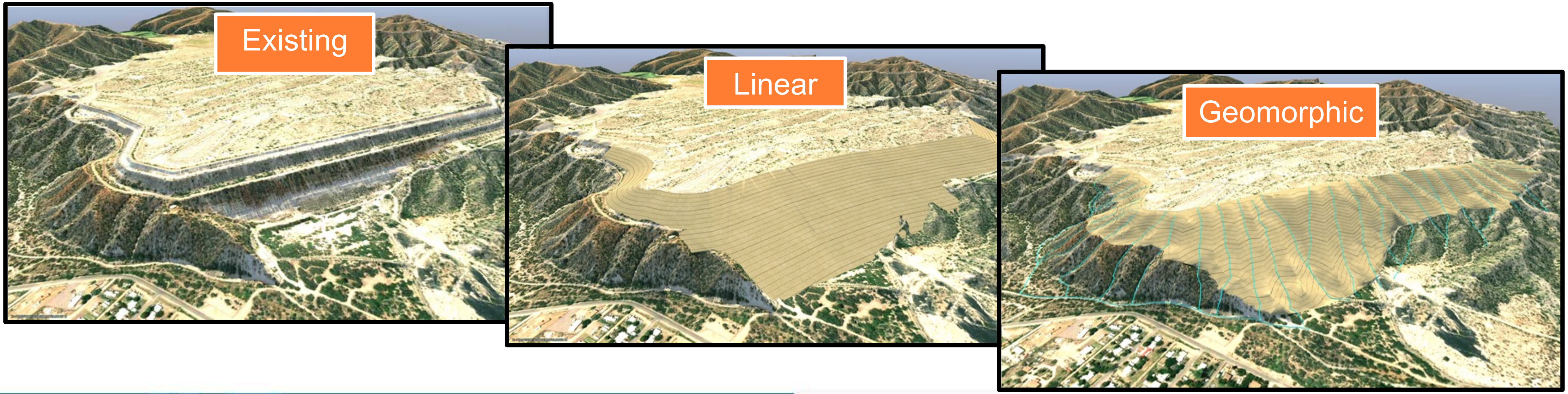
- Southern Arizona
- Starter berm + upstream raise
- 230-ft height
- First large-scale block cave

Project Drivers

- BHP review and prioritization of tailings risk mitigation
- Buttress required for final closure
- Closure Physical Stability (GT+Erosion)
- Highly Erosive Environment
  - Protect buttress structure & tailings
  - Post-closure maintenance cost

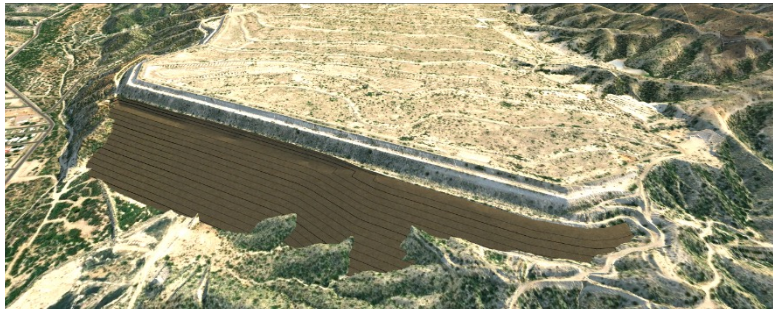
“Landform”…. What?

- Term “landform” implies “natural landform”
- Attempt to mimic stable natural hillslopes

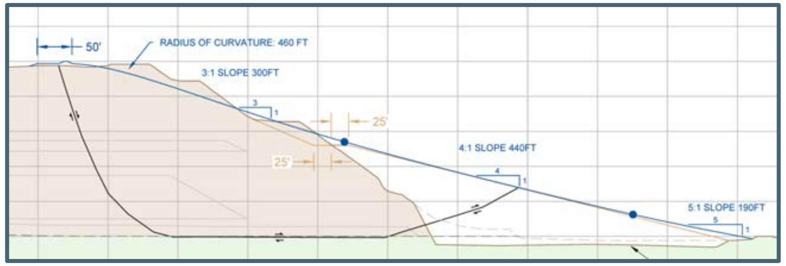


Buttress + Landform Concept

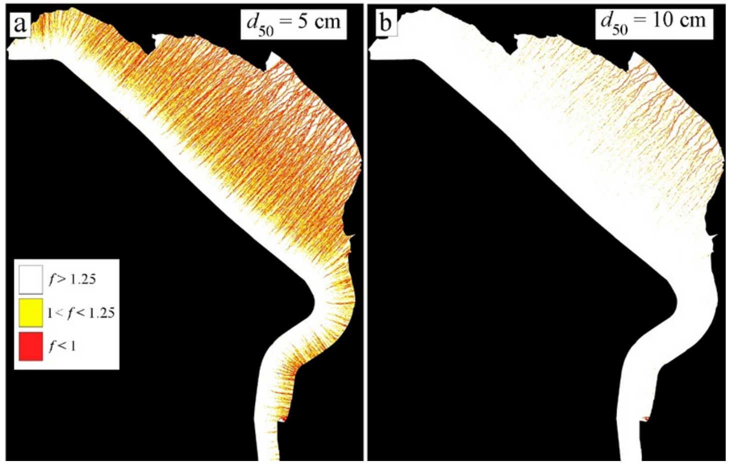
Step 1: Define geotech stability buttress (EOR)



Step 2: 2D Landform Modeling & Optimization



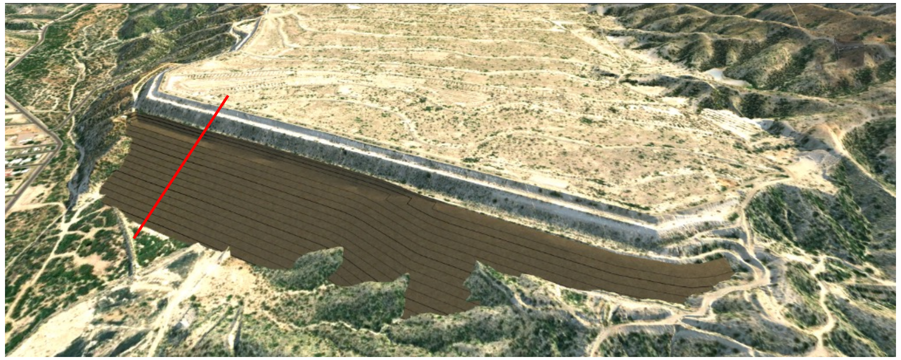
Step 3: 3D Landform Design, Modeling & Benchmarking

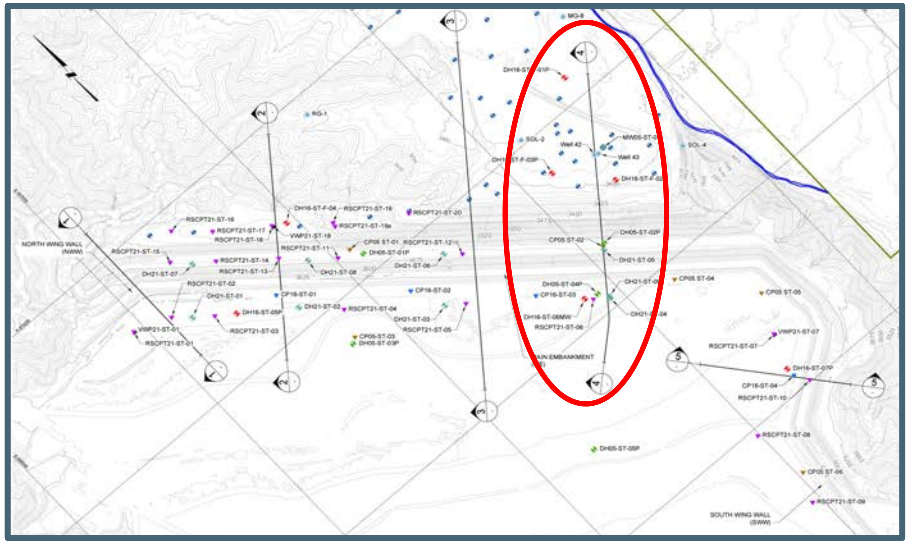


Step 1: Geotechnical Buttress Requirements

Critical Buttress Sections Defined

- EOR (KCB) defined sections
- 2D Optimization performed on longest section: **Main Embankment**
- Stability verified after landform completed



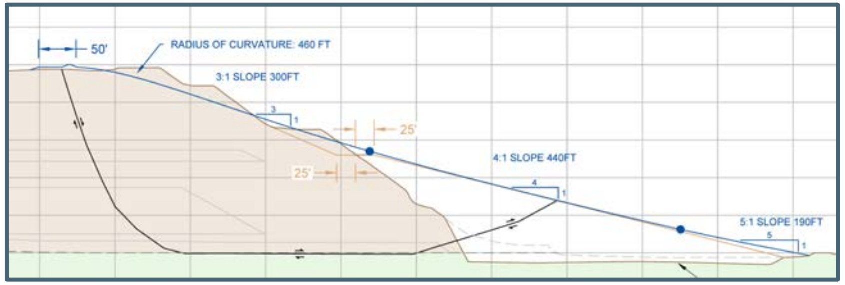


Source: KCB

Step 2: 2D Landform Design & Optimization

- Landform overlays buttress
- Optimize Landform section w/U of A
- Evaluate 2D: Shape + Cover
- U of A model shape and cover in WEPP

Landform Overlying Buttress



WEPP Modeling (U of A)

Rock Armor Cover + Shape

- **US Department of Agriculture:** Developed in 80's & 90's
- **WEPP** = Limitations on steep/long slopes
- **Screening tool**
  - Can suggest "bad", tough to differentiate between closely performing options
- **Cover:** Using a rock armor D_{50} of 4-in provided substantial reduction in erosion

Rock D50 = **2 in**
~60m of stability at 3H:1V slope

Rock D50 = **4 in**
~60m of stability at 3H:1V slope

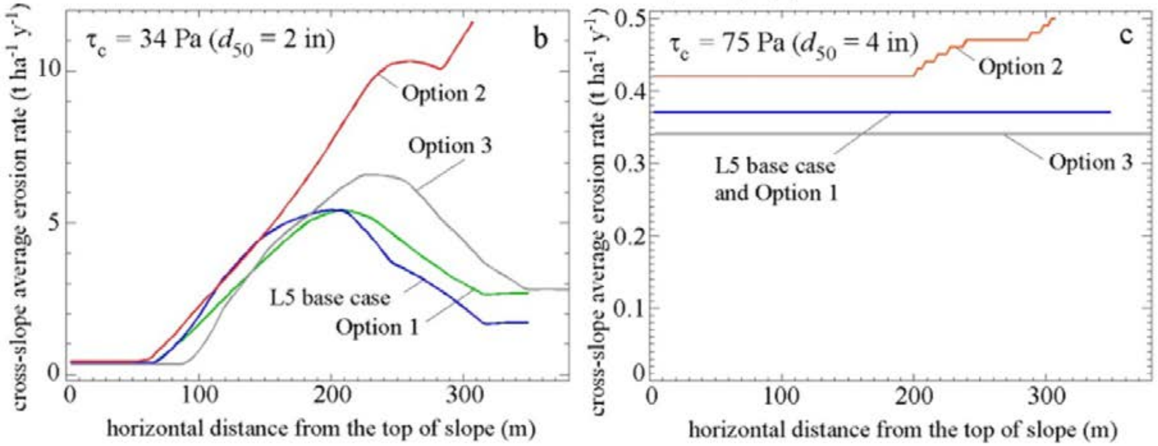


Figure 2. Plots of elevation and cross-slope average erosion rates versus horizontal distance for the L5 landform and the three alternative options using (b) reference-case parameters and (c) a higher critical shear stress for rill initiation.

Source: Pelletier, 2022

WEPP Results

Outputs & Predictions

- Erosion: tonnes/hectare/year
  - Results range ~0.5 to 50 t/ha/yr
- Localized gullies more critical than average annual erosion rate

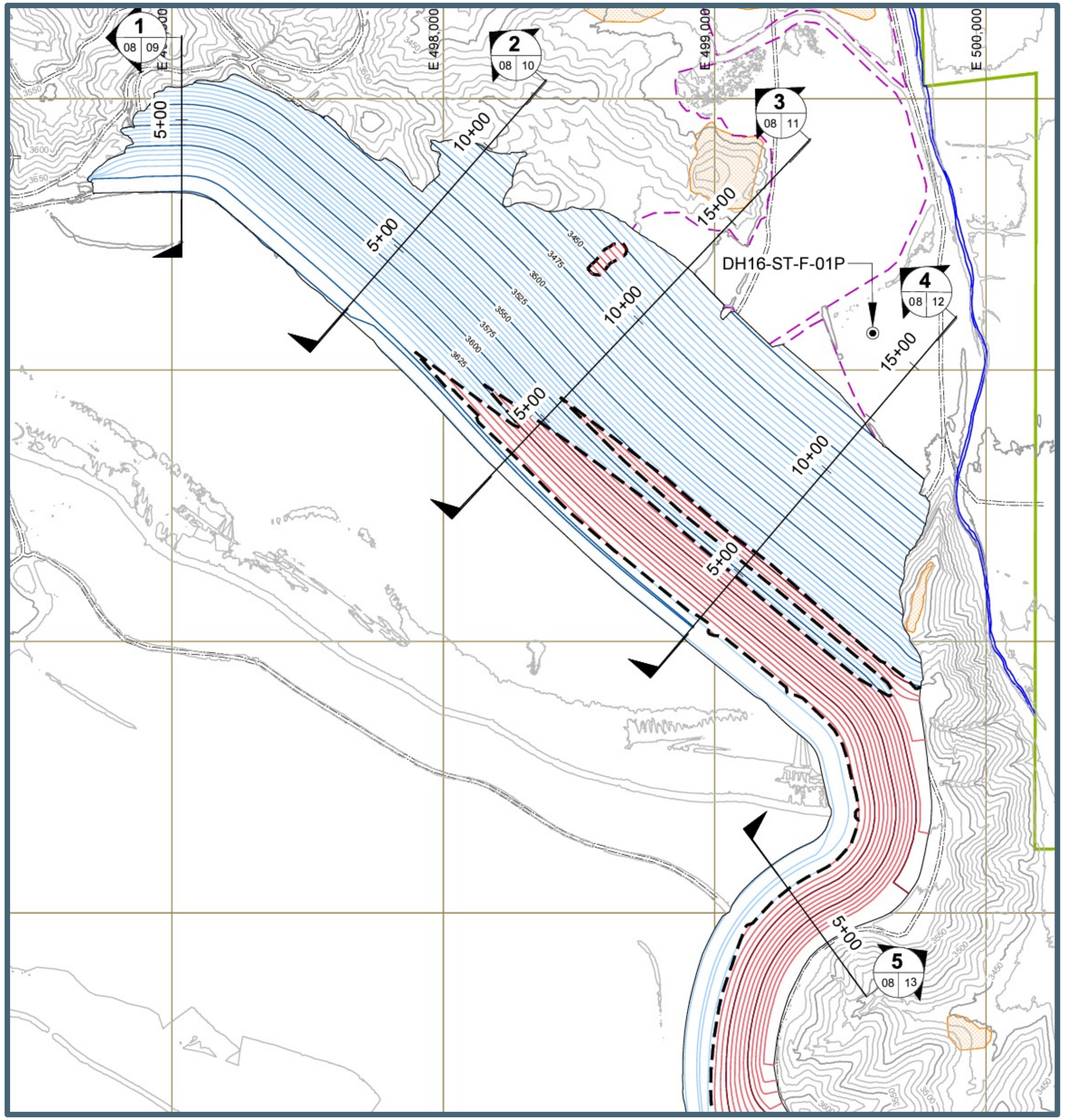
Annual erosion rate alone doesn't capture what matters!

Step 3: 3D Landform Design, Modeling, & Benchmarking

- 2D section into 3D grading
- 3D surface modeled in Rillgen2D (U of A)
- Benchmarking: Sanity Check

2D Section to 3D Grading

1. 2D section into 3D grading
2. Compare to min buttress dimensions
3. Proceed to 3D modeling (U of A)



3D Modeling: Rillgen2D

2D in plan. 3D input!

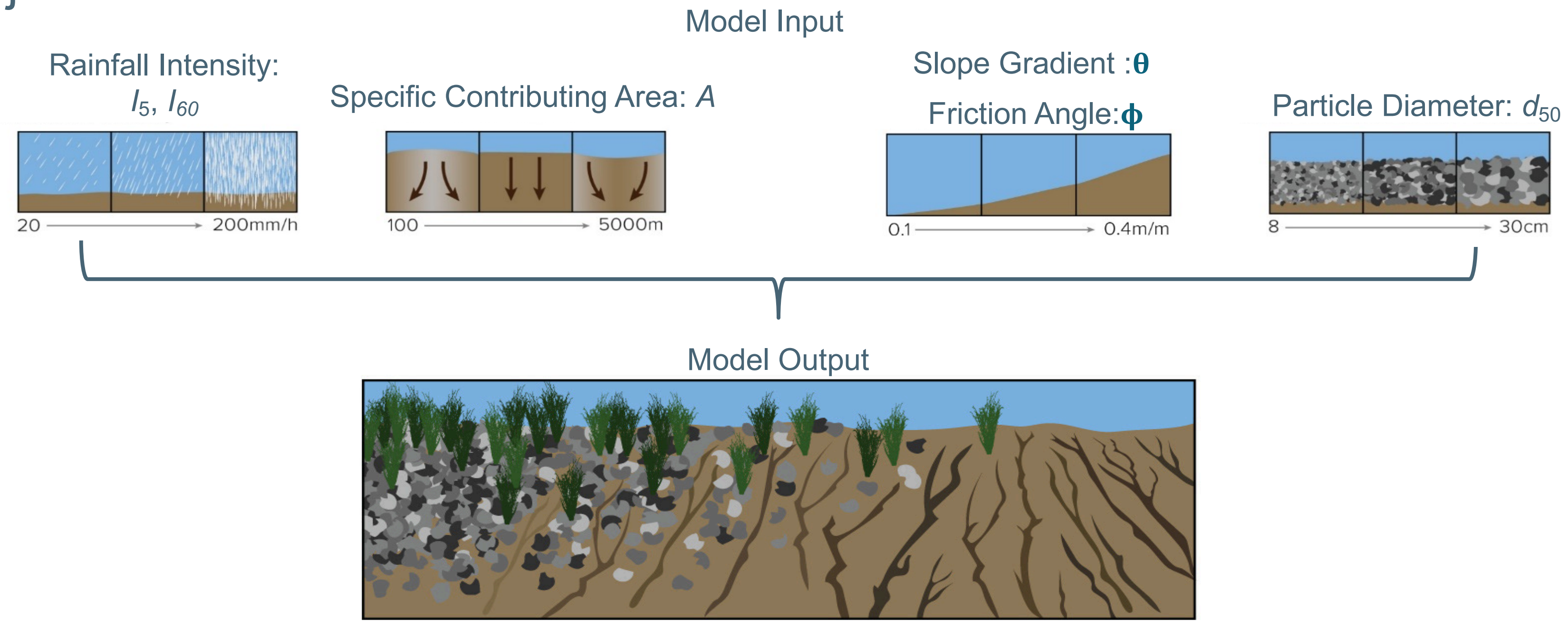
Note on other erosion/landform evolution models:

CL: LEM ≠ Design Tool

SIBERIA: UA rewiring to RITCH (Abramson, et al., 2022)

L5 Landform “3D” Modeling

- Rillgen2D is a model developed by UA (Pelletier, et al., 2022) in response to the BHP led erosion research project:



Rillgen2D Modeling

Landform Section Shape

- Predicted rilling over 100-yr time series
- **Slope Length:** Diminishing returns by increasing slope length

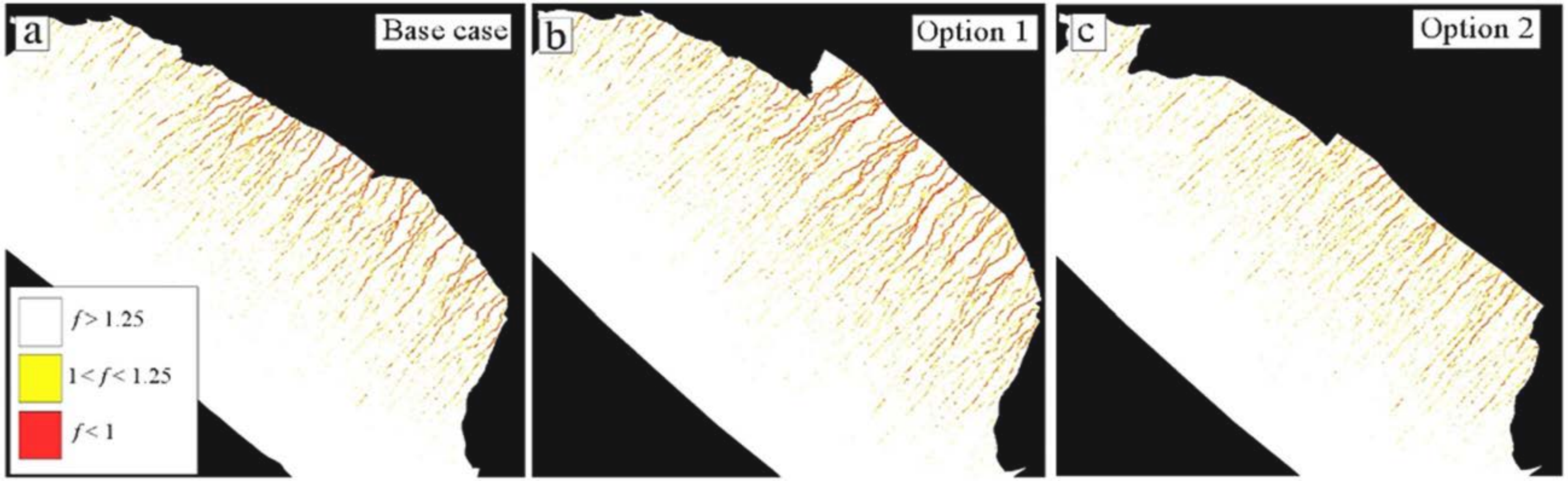


Figure 15. Color maps of predicted rilling (in red) for the main slope portion of the (a) L5 base case, (b) Option 1, and (c) Option 2 landforms over the next century for the scenario with ± 40 cm microtopography.

Source: Pelletier, et al, 2022

Rillgen2D Modeling

Microtopography

- **Spatial Variation on Surface:** Microtopography simulates as-built conditions:
  - Construction imperfections
  - Settlement
- **Planar vs Micro Topo:** zero erosion or widespread rilling!
- **Take-Away:** Using CAD leads us to design planar surfaces, this can lead to overly optimistic predictions

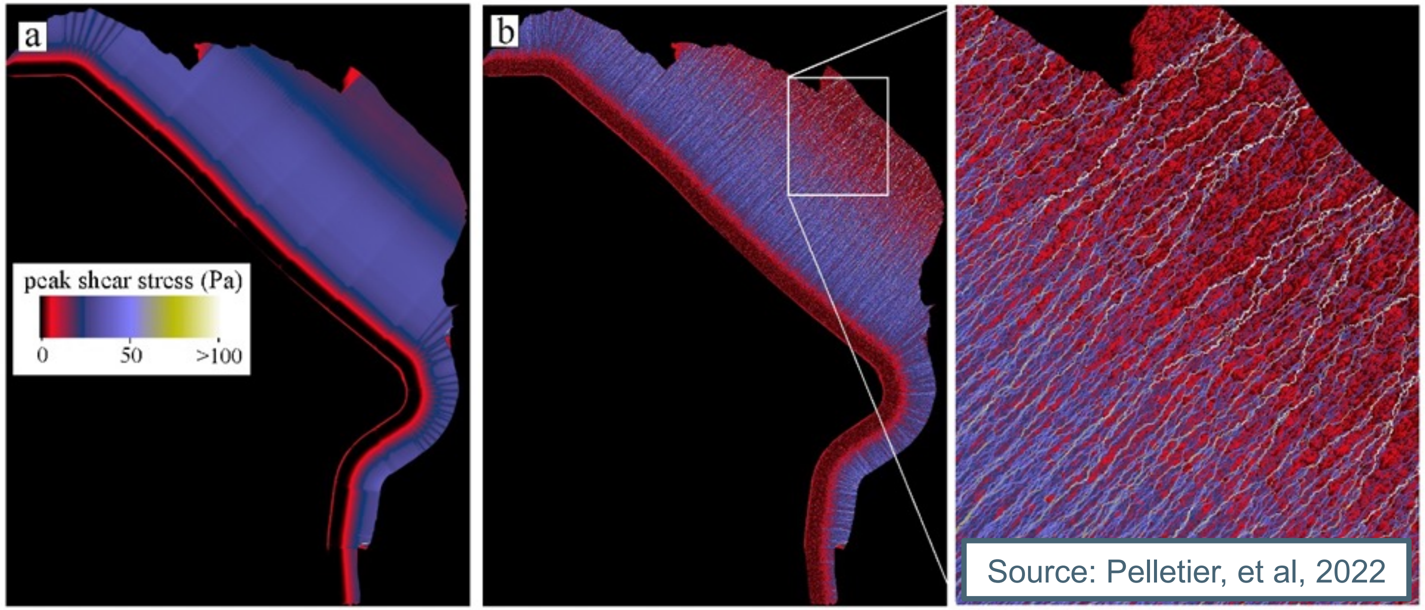


Figure 13. Maps of peak shear stress (a) without and (b) with microtopography for the Option 1 landform.

Rillgen2D Modeling

Rock Armor Cover

- **Impact of Rock Size:** Predicted rilling over 100-yr time series for 2in (5cm) and 4in (10cm) D_{50} rock armor
- Model predicts significant reduction in erosion using the larger material

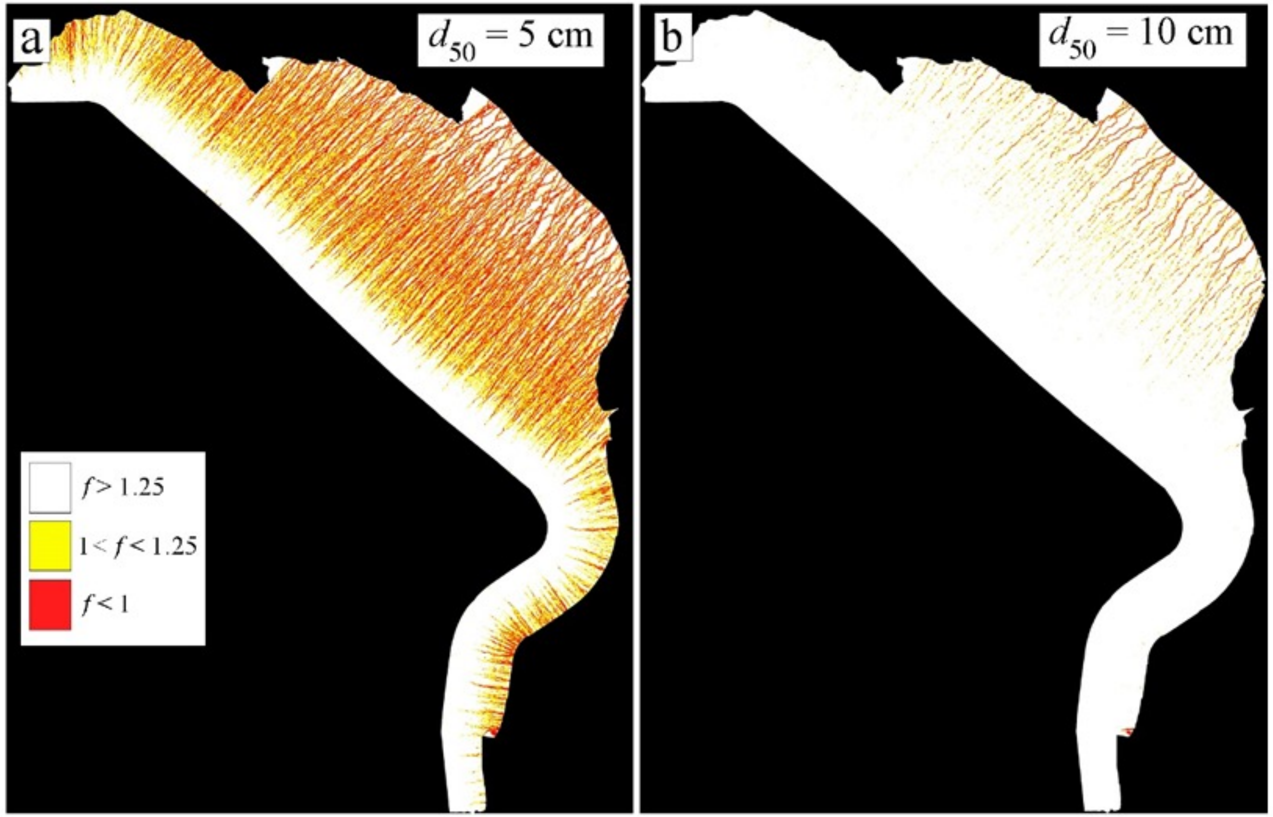


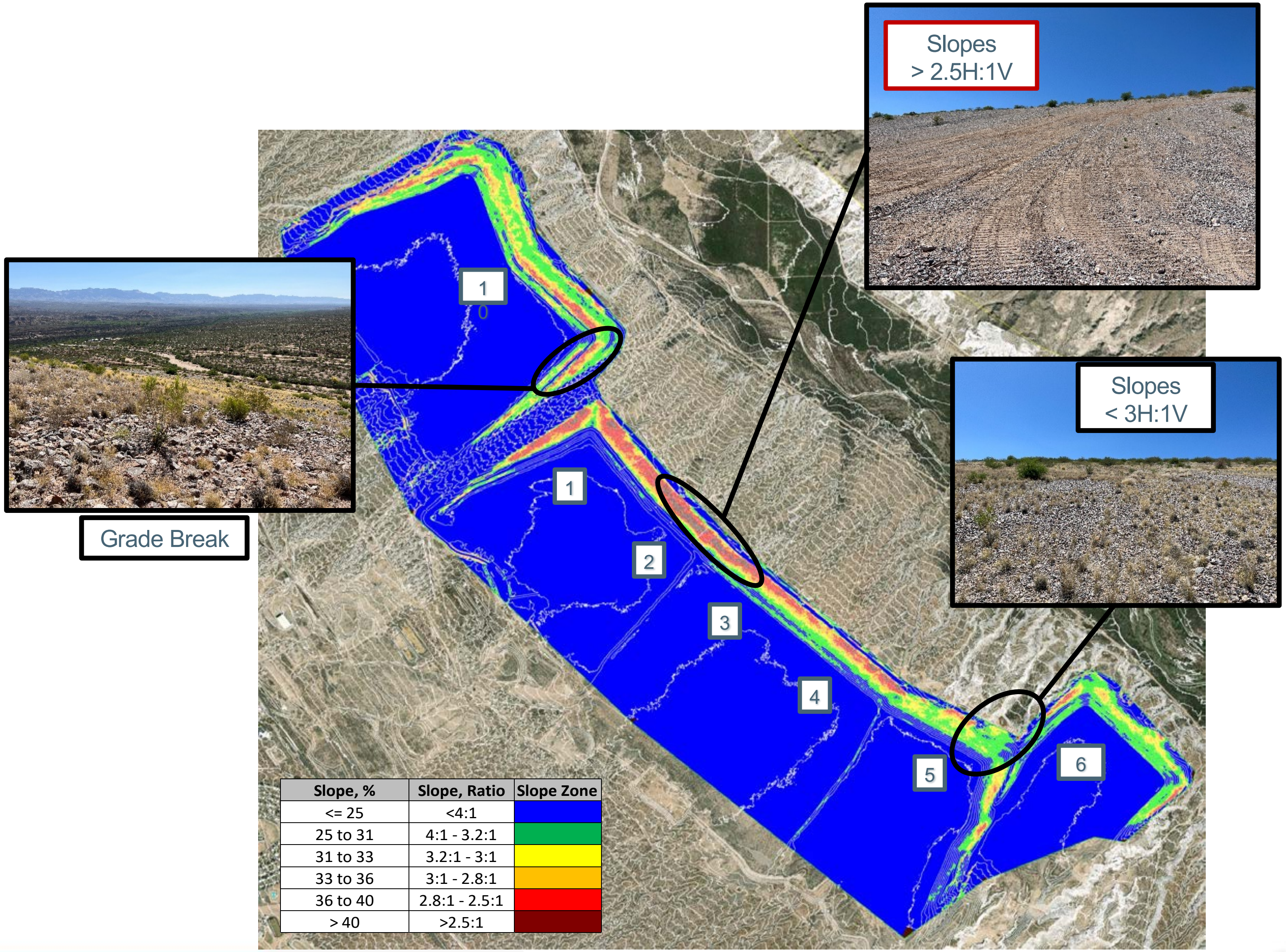
Figure 14. Color maps of predicted rilling (in red) for the Option 1 landform over the next century using rock armor with (a) d_{50} = 5 cm and (b) d_{50} = 10 cm.

Source: Pelletier, et al, 2022

Benchmarking

The Model is Not Our Master!

- Model results are one line of evidence to support design
- Erosion modeling still in experimental stage
- Good fortune of successful (and unsuccessful) reclamations in region
- Identified good performing long slopes and weighted that input in making a final design decision



Slope, %	Slope, Ratio	Slope Zone
<= 25	<4:1	
25 to 31	4:1 - 3.2:1	
31 to 33	3.2:1 - 3:1	
33 to 36	3:1 - 2.8:1	
36 to 40	2.8:1 - 2.5:1	
> 40	>2.5:1	

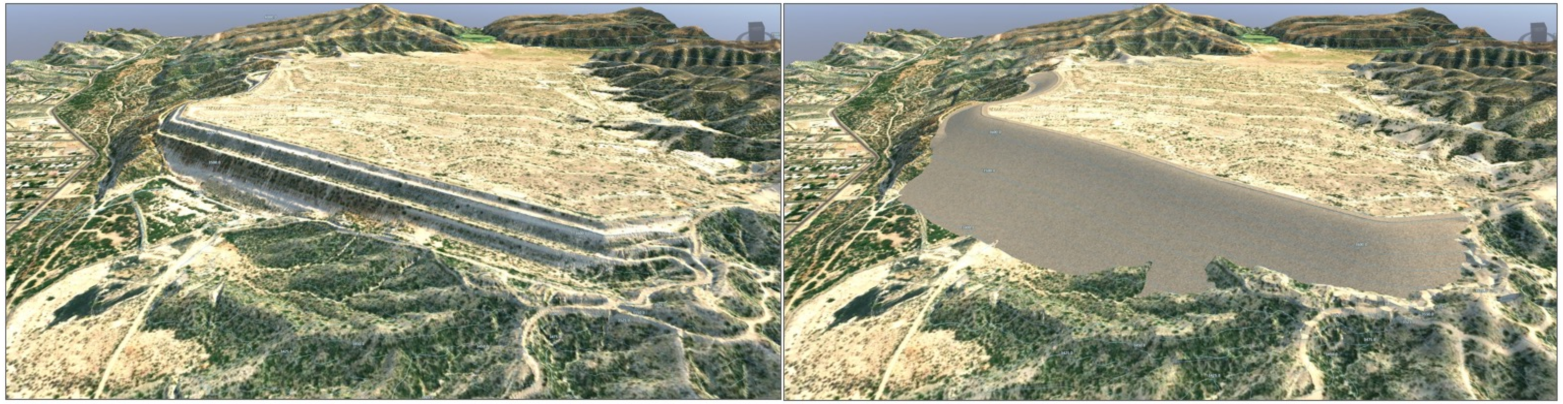
Outcome and Lessons Learned

– **Profile:** Catena profile best performing. Avoid straight lines, angled corners, look to surroundings for inspiration

– **Rock Armor:** Not all climates support vegetation. Rock required to stabilize slope, in this setting.

Figure 16: Isometric View – Present Day & Proposed Design Looking South-West

Figure 18: Isometric View – Present Day & Proposed Design Looking South



Questions?

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