Budget-Friendly Boulders: Developing a Methodology for Evaluation of Rock within Spoil Piles for Reuse in Natural Landform Design

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Key Points

- Development of a methodology for evaluating rock within spoil piles for reuse in natural landform design.
- Integration of field testing, material mapping, and management planning to streamline decision-making processes.
- Utilisation of geospatial technology and historical data to optimize the selection, treatment, and transport of rock materials.
- Potential for cost-effective and sustainable utilisation of locally available rock resources in landform design projects.

Abstract

This paper presents a methodology for evaluating the quality and quantity of rock within spoil piles, aimed at facilitating cost-effective and sustainable reuse in natural landform design projects. The methodology integrates field testing, material mapping, and management planning to streamline decision-making processes and optimize the utilisation of rock materials. By harnessing geospatial technology and leveraging historical data, this approach offers a practical solution for maximizing the benefits of locally available rock in landform design projects.

Keywords

Rock Evaluation, Spoil Piles, Natural Landform Design, Material Mapping, Management Planning, Geospatial Technology, Sustainable Utilisation, Cost-effective Solutions.

Introduction

Natural landform design projects in the mine closure and remediation space increasingly rely on locally available materials, such as rock contained within old spoil piles, highlighting the need for effective methodologies for evaluating and utilising these resources, rather than importing suitable quality material at an unfeasibly high cost. This paper addresses the challenge of assessing rock within large spoil piles for reuse in landform design, proposing a systematic approach that integrates field testing, material mapping, and management planning. To align with the objectives of a typical mining client, this methodology aims to streamline decision-making processes by providing the client with simple yet adequate tools and to reduce the sample size wherever possible to save time and cost.

Study Area

The study area encompasses spoil piles that have been dumped cost effectively near mining pits >10m tall, sitting in the weather for 5-20+ years, with a 20-100+ ha footprint, which are to be used as a borrow source for rock (seen in Figure 1). The study area also includes the mining pits that are being rehabilitated, and that rely on the rock from the borrow source for final use in chute drains (example in Figure 2), unlicenced diversion drains, rock mulch (example in Figure 3) and capping material.

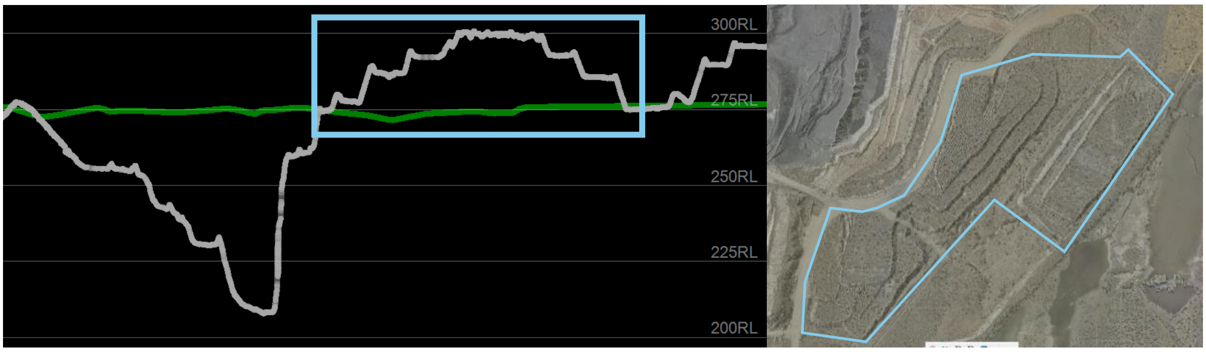

Figure 1: Highwall dump (blue box) of mining pit (grey) on natural pre-mining surface (green). 60 ha spoil pile on mining pit highwall to be used as borrow source for rock, sitting 25m above natural surface.

Note: Vertically exaggerated Z-Axis x 5

Figure 2: Small chute drain using rock from borrow source after processing (design life – 10 years).

Figure 3: Spoil pile has been rock-mulched in situ (deep ripped by a dozer).

Methods

The methodology involves a progressive testing regime to assess the quality of rock layers within spoil piles, including visual assessment, geotechnical field assessment, and laboratory testing (outlined in Figure 4).

Geospatial technology, such as high-definition drone imagery, is utilised to map the distribution of rock materials across the site. Material management plans are developed to guide the processing and movement of rock resources, ensuring efficient utilisation in landform design projects.

The below testing procedure has been designed to allow a rapid testing regime for significant size spoil piles. A simpler version of the below testing regime may be suitable for testing of smaller and more shallow spoil piles, which should be decided upon risk analysis from the mine managers.

Testing of rock on site is progressive (done layer by layer) due to the significant height of spoil piles, and follows the process outlined below in Figure 4**Error! Reference source not found.**.

The general idea of the below procedure is to:

- Narrow down the area you want to target for testing and apply more testing in areas of interest.
- Test the first 3m layer and decide upon quality.
- Create a haul plan to transport good material to the next stages in processing/ use and transport bad material to a waste dump.
- Track and transport material.
- Final check of rock in drains.

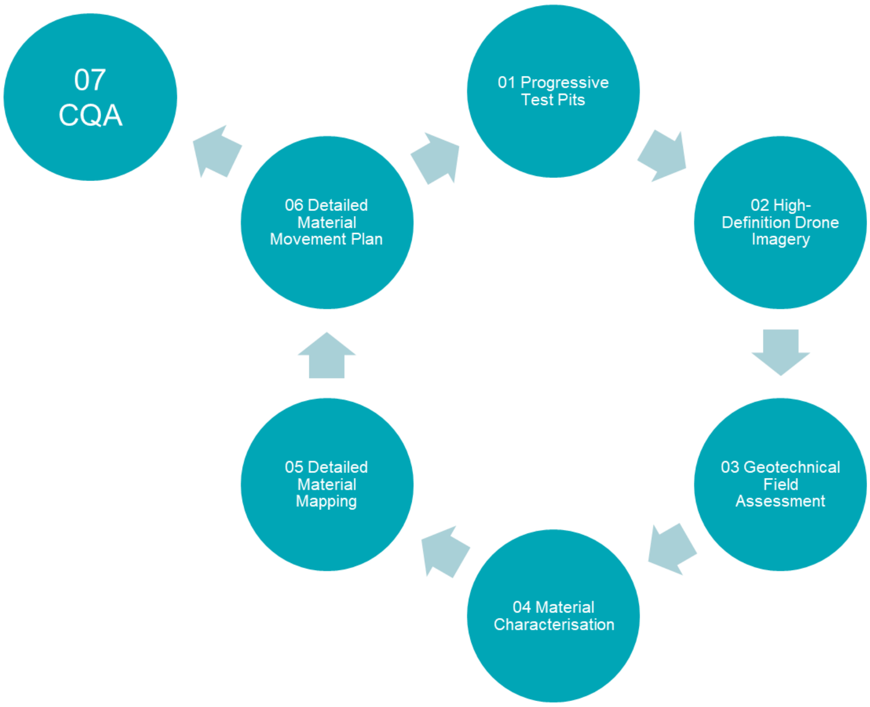

Figure 4: NOC Rehabilitation Rock Testing Procedure

Step 01a: Development Of a Test Pit Investigation Brief

The goal of this step is to develop a targeted investigation brief for the first layer of a spoil pile, based on a visual aerial assessment – applying more testing where there is uncertainty.

A procedure has been developed to assess the surface of the stockpile below the vegetation to enable the development of a targeted geotechnical investigation brief. It should be noted that steps 1 and 2 can be skipped for subsequent layers if done before vegetation growth. The procedure is as follows:

1. Map out 10x10m squares separated by a spacing of a 100x100m grid (Figure 5).

   Note step 1 can be altered based on feedback from site and engineers.

2. Remove / Scrape vegetation for initial layer.

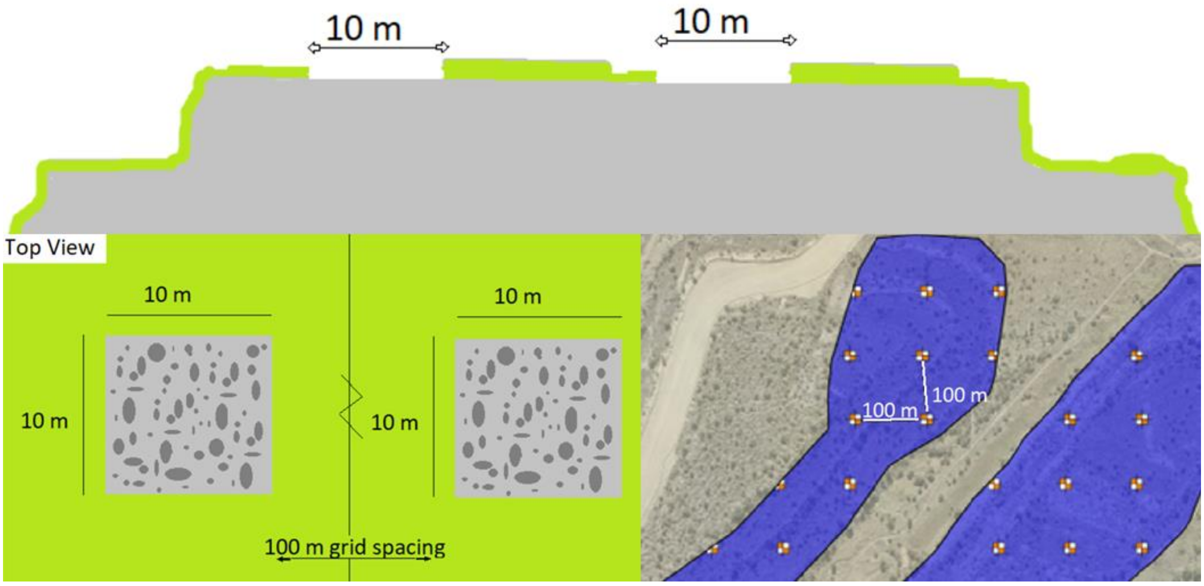

Figure 5: Topsoil Scraping

3. Utilise site drone to conduct fly over scraped areas to visually assess colour, size, consistency etc.
4. Develop Targeted Investigation Brief where good quality material was identified from visual assessment.

Step 01b: Progressive Test Pit Investigation Works

The goal of this step is to take targeted physical samples from the stockpile in safe manner.

The below procedure has been developed for the physical investigation process for each 3m deep section of the spoil pile as depicted in Figure 6.

1. Dig test pits to a depth of 3m at the testing locations (Figure 7) from the investigation brief produced in step 1a.
2. Place the material from the test pits in the ordered manner shown below in
3.
4.
5. Figure 8**Error! Reference source not found.**.
   a. Dump on eastern side of hole.
   b. 1st to 3rd meter placed north to south.
   c. Each new meter as a new row dumped west to east.
   d. Total depth of rows to be no more than 3 rocks deep (if rock present).
6. Excavated rock to be spread into thin layers (2-3 rocks deep) – placed on eastern side of hole, layered from North to South (for future assessment) as shown in Figure 8.

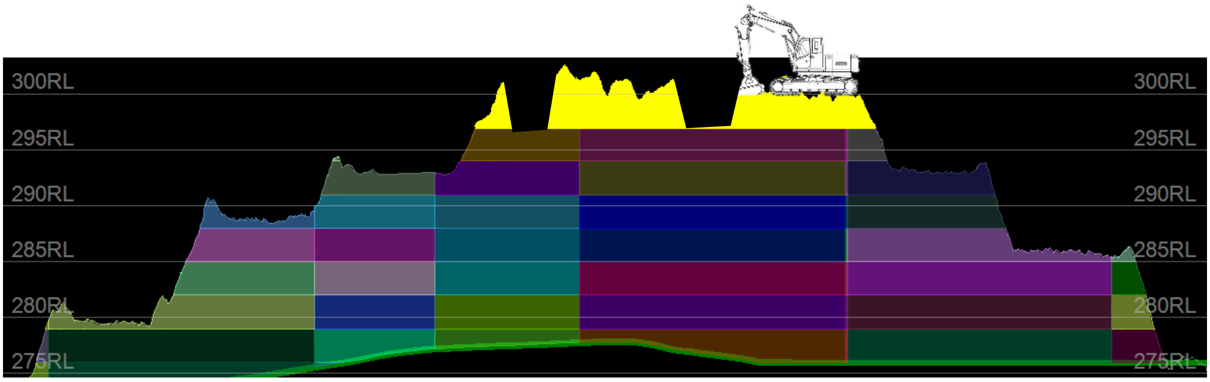

Figure 6: Testing and Depletion of initial 3m

Fast-forwarding through the entire process… Complete step 2 to 6 (outlined below) to determine material quality and material movement plan to deplete layer. For example, if the total volume of layer is 52,000 bcm, step 2 to 4 indicates that:

- 20,000 bcm is high-quality rock to be processed and transported to permanent drainage infrastructure.
- 10,000 bcm is moderate-quality rock to be processed and transported to temporary drainage infrastructure.
- 22,000 bcm is unsuitable material and is discarded into the mining pit.

… The layer is depleted and the process restarts as shown in Figure 7.

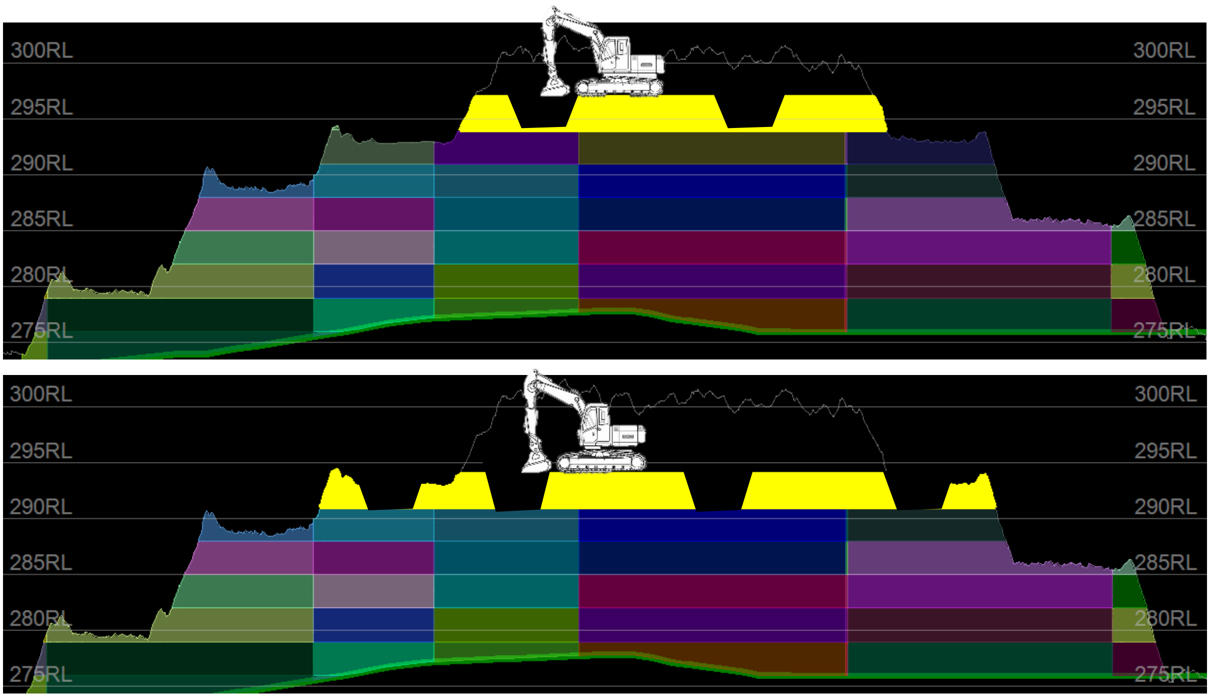

Figure 7: Testing and Depletion of subsequent layers

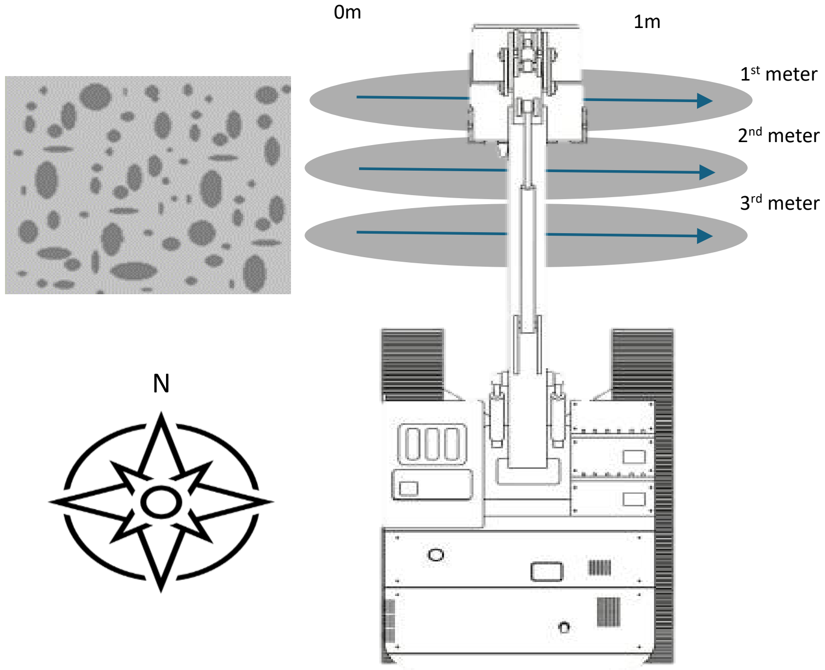

Figure 8: Dumping Configuration of Material from Test Pits to Enable Drone Assessment.

Step 02: High-Definition Drone Imagery

The goals of this exercise are to:

1. Evaluate uniformity in upper 3m of stockpile layer to reduce field testing requirements.
2. Capture imagery of piles to enable future sizing assessment- using WipFrag software.
3. Allow correlation of tested sections to non-tested sections (**Error! Reference source not found.**) (no testing, only removed vegetation) based on visual properties such as:
    a. Colour
    b. Texture
    c. Size

Note: It may be required for additional areas to be scraped of vegetation before imagery is taken.

Step 03: Geotechnical Field Assessment

Goal: Physically test material stockpiled during the test pitting program with site equipment where possible.

Representative samples taken from each test pit should follow the following life cycle:

1. Field notes on rock types, weathering grades and how they change with depth/spatially.
2. Onsite testing: Point load machine, scribe (for weathering), slake durability test, jar slake.
3. Lab testing: As per AS1726 (on unique materials identified in Onsite Testing)

4. Obtain high quality photos of individual rocks with standard background for size and colour matching, for future use as anecdotal evidence (Figure 9)

Figure 9: Example of high-quality photo, with rock placed on whiteboard (point 4 above)

Step 04: Material Characterisation

Goal: Assess the results obtained in the above section and provide an overall quality, which can be used in the material mapping and movement plans.

Table 1 below provides bounds of test results, which have been developed as a rapid testing regime to categorise rock quality.

Table 1: Test results and quality indicators

Testing Criteria	Sampling Size Requirements	High Quality Rock i.e. Design Life >50 years	Moderate Quality Rock i.e. Design Life >10 years	Poor Quality Rock i.e. Design Life <10 years
Description		Hard durable rock. Shall NOT include: • Mudstone • Sandstone • Volcanic Breccia • Shale • Highly weathered or altered rocks	Moderately durable rock. May include well cemented sandstone / sedimentary rock sources.	
Point Load Index (Is50)	1 x 1kg Piece Cylinder shape (length greater than 1 diameter)	<3.0 MPa	1.0 Mpa > 3.0 MPa	>1.0 Mpa
Slake Durability Index (Id2)	10 Pieces, each 40g to 60g (i.e. size of two thumbs)	>85% after 2nd cycle	60% > 85% after 2nd cycle	<60% after 2nd cycle
Slaking Swelling Dispersion OR	50 Gram sample	A11 after 24 hours	B22 after 24 hours	C22 after 24 hours
Jar Slake Test	50 Gram sample	≥5	4 > 5	<4

Step 05: Material Mapping

Aim: to take the testing data captured and store it in a format that can be used to produce a map for site as well as material movement plans. The output of this step is like that of a geological model, except it will go down to a depth of 3m for each iteration of the progressive testing regime.

Data input:

1. Geographic point for each rock sample at every metre tested (i.e., 3 in total per test pit) with attributes on:

- Testing results, description, photo of rock.
- Depth of test
- ID of the area
- Summary of rock durability based on test results.
- Summary of available rock use cases based on rock durability and size.
- Size data for metre 2 and 3. This is a manual input using the WipFrag results on the dumped 2nd and 3rd metres (see Step 01b above for context).

2. Polygons from WipFrag analysis to represent the 1st metre of rock sizing containing attributes on:

- Rock size cleaned up using a polygon dissolve by attribute tool.
- Depth = 1m
- ID of the area

Data processing:

1. Turn the above rock quality points into polygons through use of Voronoi polygons. This should be done by grouping the points based on first the quality data, then the Size data.
    - In total, there should be 3 sets of polygons derived from quality data and 2 sets of polygons derived from size data. The third set of polygons for size data will be taken from the cleaned WipFrag polygons (no need to guess the extents of the size changes when its on the top layer).
2. In total there will be 6 polygons, 3 grouped by quality and 3 grouped by size (1 for each metre depth). Run a Boolean function on the quality and size polygons for each metre to make polygons that describe both quality and size for each of the 3 metres.
3. Use the final polygons to create 3d solids using the depth attributes mentioned above.
4. Final output should be solids with attributes that can be used for material movement planning purposes.

Step 06: Material Movement Plan

Material Movement Plans can be produced using the DESWIK software to take advantage of the Material Distribution and Landform & Haulage tools.

Results and Discussion

Preliminary results demonstrate the effectiveness of the methodology in rapidly evaluating the quality and quantity of rock within spoil piles. Integration of field-testing data with historical insights enables informed decision-making regarding the selection, treatment, and transport of rock materials. Visual representations, such as rock mapping figures and spoil characterization diagrams, provide valuable tools for project planning and design optimization.

Conclusion

The development of a systematic methodology for evaluating rock within spoil piles represents a significant advancement in the field of natural landform design. By leveraging existing data and implementing standardized testing procedures, this approach offers a cost-effective and sustainable solution for maximizing the reuse of locally available rock materials. Future research should focus on refining and validating the methodology across diverse project contexts, with the goal of enhancing the resilience and functionality of landform designs.

Acknowledgements

The authors would like to acknowledge their clients for their support and collaboration in the development of this methodology.

References

Standards Australia. (2017). *AS 1726: Geotechnical Site Investigations*. Sydney: Standards Australia.