HIGHWALL SAFETY PROJECT

Geotechnical Center of Excellence | University of Arizona

Rockfall Test Data Collection

Complete Field Guide

Protocol for testing, data collection, and spreadsheet field guide for contributing sites.

In collaboration with the National Institute for Occupational Safety and Health (NIOSH)

Version History		
v0.0	April 2026	Initial draft sent to GCE member companies
v1.0	June 2026	Previous version; Incorporates GCE member feedback and minor edits
v1.1	August 2026	Incorporates new feedback and minor edits
V1.2	September 2026	Current version; incorporates lessons learned from field campaign, adds pre-visit logistics guidance and toe-zone clearance guidance, adds Appendix D field reference photos.

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The GCE team is happy to discuss testing approaches, data formats, or partial contributions in advance.

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1. Purpose and Background

The Geotechnical Center of Excellence (GCE) at the University of Arizona, is collecting rockfall testing data from operating open pit mines to improve the technical basis for catch bench design and evaluate proposed updates to the Modified Ritchie Criterion (MRC). This is a collaborative effort with partners including operations, consultants, and the National Institute for Occupational Safety and Health (NIOSH).

For participating operations, this effort provides a structured framework to evaluate rockfall behavior under their own geological, geometric, and operational conditions. The data collected can be used to better understand bench performance at site and to inform more appropriate, evidence-based catch bench width design.

This document serves as a complete field guide for participating sites. It includes background context, a step-by-step testing protocol, and detailed instructions for each field in the data collection spreadsheet, ensuring consistency and usability of the data both at the site level and across the broader project.

1.1 What Is Being Requested

Participating mines are asked to contribute raw field data from single-bench, double-bench, or multi-bench rockfall tests. Key data elements include:

- **Slope geometry:** design and as-built bench height, catch bench width, bench face angle
- **Test rock information:** lithology, dimensions, shape, weight
- **Release method documentation:** equipment used, release type, sequence
- **Rockfall trajectory and termination data:** release and resting locations, video.

Rockfall testing under this program generally takes one of two forms:

- **Roll-out distance testing (single-bench).** A rock is released from a single bench crest and its travel distance is measured, most importantly, the distance from the toe of the bench face to its final resting position (Sheet 5: Release & Results, "Distance from Toe"). This isolates how far a given rock size, shape, and release condition will travel on one bench, without the influence of upper benches.
- **Multi-bench (full highwall) testing.** Rocks are released from the top of a multi-bench slope and their progress is tracked bench-by-bench down the full highwall. This measures overall catch bench system performance, whether each rock is retained by the catch bench system (Sheet 5: Release & Results, "Retained by Catch Bench?") and how many rocks are retained at each bench level (Sheet 6, Catch Bench Performance) — rather than the travel distance of any single release.

Partial datasets are welcome and valuable. GCE can extract geometry and trajectories on behalf of contributors when underlying data such as Digital Terrain Models (DTMs), video, or photographs are provided.

Contributors are asked to provide raw field data, not interpretations or design conclusions. The Highwall Safety Project team handles all post-processing, trajectory analysis, and evaluation. Contributors may choose their level of involvement throughout the project, from data sharing only to active participation in technical discussions. Contributors receive regular project updates and early access to analyses, findings, and project deliverables derived from the shared data.

2. How to use this guide

This guide comes with an accompanying spreadsheet (*RockFall_Test_Guidelines_Spreadsheet.xlsx*) for data entry. Together, they provide everything a contributing site needs to conduct a rockfall test and submit useful data to the Highwall Safety Project.

The guide is organized as follows:

Section 3 details recommended collection methods for supporting information, including photogrammetry, video, and rock photography that are not captured directly in the spreadsheet but are critical for maximizing the value of your rockfall test data.

Section 4 provides a suggested step-by-step workflow for test day, from pre-test preparation and camera setup through rock documentation, release, post-release recording, and post-test wrap-up. It is intended as a practical checklist that can be adapted to site-specific conditions and safety requirements.

Appendix A provides a detailed guide to every sheet, column, and entry in the spreadsheet. The spreadsheet contains six tabs: Instructions, Test Information, Slope Geometry, Rock Descriptions, Release & Results, and Catch Bench Performance. This section walks through each one in order.

Appendix B is a Rock Shape Classification Field Reference.

3. Recommended Data Collection Methods

This is information not captured in the spreadsheet, but useful for getting the most out of your rockfall test.

3.1 Photogrammetry

Photogrammetry surveys (pre- and post-test) are strongly encouraged for generating DTMs and extracting geometry, release points, and resting positions. When photogrammetry is provided, GCE can extract most geometric data directly, reducing the field data entry burden on contributors.

i TIP: If you are providing pre- and post-test DTMs, the As-built Slope Geometry portion of the Slope Geometry sheet can be left blank. GCE will extract bench geometry from the DTM.

3.2 Video

Standard RGB videos from fixed ground-based cameras or drones are recommended for trajectory capture. Camera stability and an unobstructed view of the slope matter more than resolution. Thermal video is ideal but not required.

Blast videos as supplementary data: If the site conducts blasting adjacent to the test area, pre- and post-blast videos can provide valuable supplementary rockfall data at low additional cost. These videos capture natural spalling and rockfall behavior triggered by blasting and can show how far material travels onto the catch bench under real conditions. Contributors are encouraged to share any available blast footage alongside formal test data.

3.3 Rock Photography

Photographing test rocks with a scale reference (tape measure, hard hat, etc.) prior to release is strongly encouraged. This is one of the most valuable things contributors can do for data quality. It allows independent verification of rock dimensions and shape.

i TIP: Spray-painting rocks with an ID number prior to photographing will make it easier to later reference a photo to a test case.

4. Pre-Test and Test Day Protocol

This section provides a step-by-step workflow for conducting a rockfall test event. Adapt as needed for site-specific conditions and safety requirements. All testing must be coordinated with mine operations and safety personnel.

4.1 Pre-Test Preparation (Days/Weeks Before)

1. **Coordinate with GCE.** Notify the GCE team of your planned test date and proposed approach (we are here to help!). GCE can provide guidance on testing objectives and data collection priorities and, where feasible, may arrange to have personnel participate on-site or remotely. GCE will also provide a folder for data upload and support contributors throughout the testing and analysis process.
2. **Select the test site.** Prioritize areas with reasonably uniform bench geometry and safe access. Document the rationale for site selection in the Site Selection Notes field. Where possible select benches that are clean of talus accumulation, or plan to clear talus before testing, so that both the effective (as-mined) and remaining (usable) catch bench widths can be measured and compared. If talus is present, please be sure to record that in the As-built Slope Geometry section of the Slope Geometry tab.
3. **Complete a pre-test photogrammetry survey.** If possible, acquire a drone-based photogrammetry survey of the test area as close to the test date as practical, ideally within a few days of testing. The survey should capture the full slope, catch benches, and surrounding terrain and be of sufficient quality to generate a digital terrain model (DTM) and orthomosaic. Whenever possible, avoid significant mining activity, blasting, scaling, or clean-up activities between the survey and the test, as these activities can alter bench conditions and talus accumulation. If such activities occur, document them in the Site Selection Notes field.
4. **Organize and schedule test.** Confirm test dates and obtain any necessary permits and approvals.
5. **Prepare test rocks.** Identify and stage natural and/or synthetic rocks near the release point. Select rocks spanning a range of sizes and shapes representative of typical rockfall material at the site. When using synthetic rocks, include a subset of natural rocks for

calibration and select synthetic rock sizes that are representative of the site's expected rockfall conditions.

6. **Plan camera positions.** Identify fixed ground-based camera locations or drone flight plans that provide an unobstructed view of the full slope from crest to catch bench. Scout for stable, safe positions.
7. **Document site preparation and blasting context.** Before testing, gather available information about the site's wall preparation and blasting practices. Relevant context includes: whether walls are scaled or washed after blasting; blasting design parameters (hole diameter, burden, spacing, powder factor); whether pre-split or trim blasting is used; and who reviews and approves blasting adjacent to highwalls. This background helps GCE interpret bench surface conditions and understand factors that may have pre-conditioned the slope. Record what is available in the Site Selection Notes and Additional Notes fields.
8. **Confirm telehandler and pallet compatibility.** Verify the telehandler make/model, fork dimensions, and compatible pallet sizes. Confirm pallets are in suitable condition for the anticipated loads. An equipment mismatch discovered on site can cost a full day of setup.
9. **Plan specimen transportation and staging logistics.** For synthetic rocks where practical, use a flatbed truck or other vehicle capable of moving a larger number of specimens directly to the test location in fewer trips. Ensure the bench crest is fully prepared and inspected before specimens arrive on site.
10. **Coordinate with the telehandler operator in advance.** Review staging, positioning, and release procedures with the operator and field crew before testing begins. Using the same operator throughout the campaign improves consistency and efficiency.
11. **Build weather contingency into the schedule.** Include at least one contingency day where feasible, and consider seasonal weather patterns (e.g., monsoon season) when selecting the testing window.
12. S**eparate setup/mobilization time from active testing time.** Build the field schedule around realistic mobilization and staging time, distinct from time actually spent releasing rocks.
13. **Bring printed copies of field procedures and this guide.** Printed materials are more practical for active field use than relying only on digital versions. If tablets or laptops will be used, plan for a canopy or shaded work area.

4.2 Test Day Setup

14. **Establish exclusion zones.** Work with site safety personnel to define and enforce exclusion zones around the slope toe and any area within the potential rockfall path. Post observers and use radios as needed.

15. **Define the toe clearance zone.** Maintain a clear zone along the toe of the slope at least double the bench height (e.g., an 80-ft cleared zone for a 40-ft bench), free of personnel, equipment, and loose debris prior to each release. Verify and mark this distance during setup.
16. **Set up video cameras.** Position cameras on stable mounts (tripod, vehicle, fixed structure). If possible, ensure the full test slope is in frame with no obstructions. Start a test recording to verify framing and focus.
17. **Complete the 'Test Information' sheet in the 'Rockfall Test Data Collection' spreadsheet.** Fill in mine / location name, date, location, bench configuration, weather, and recording details. If you are recording, please provide camera specs, type of video, and coordinates of the camera.

4.3 Rock Documentation (Before Each Release)

18. **Assign a Rock ID.** Use the pre-filled IDs (R-001, R-002, etc.) from the spreadsheet. Write or paint the ID on the rock if practical.
19. **Photograph the rock with a scale reference.** Place a tape measure, hard hat, or other known-dimension object next to the rock. Take photos from multiple angles.
20. **Measure or estimate dimensions.** Record the long axis, short axis, and estimated weight. Practical field estimates are acceptable; laboratory precision is not required.
21. **Record the shape.** Use the standard shape categories: blocky, tabular/flat, spherical/rounded, elongated, angular, or irregular. See *Appendix B: Rock Shape Classification Reference* for visual examples.
22. **Record lithology and geological unit.** Identify the rock type (e.g., granodiorite, sandstone) and geological unit (e.g., Pinal Schist) if known.
23. **Fill in the Rock Descriptions sheet.** Enter all pre-release data for this rock.

4.4 Rock Release

24. **Confirm the exclusion zone is clear.** Radio or visual confirmation from all observers before each release.
25. **Start video recording.** Ensure cameras are rolling before each release.
26. **Release the rock(s).** The goal is to replicate natural rockfall initiation as closely as possible by introducing minimal energy beyond gravity. Releasing multiple rocks within the same size class (e.g., <6 in [15 cm]) during a single test can improve efficiency, simplify video recording, and support post-processing analysis of trajectories and final rest locations.
27. **Use a recommended release method.** Three release methods are illustrated in Appendix C: Scraping Method + Anchoring to Ground, Scraping Method + Anchoring to Telehandler, and the Tilt Method. Refer to Appendix C for step-by-step diagrams and guidance on choosing between them.

28. **Record the release method and type.** Note the equipment used and whether the rock was pushed, dropped, or rolled. Record release height above bench if applicable.
29. **Observe and note trajectory.** Watch for unusual bounces, fragmentation, near-misses with berms, or other notable behavior. Note these in the spreadsheet after the test.

4.5 Post-Release Documentation (After Each Rock, or group of rocks)

30. **Mark the resting position (where feasible).** If safe access is available, mark the final resting location of the rock with spray paint, a flag, GPS point, or other field marker. This is strongly recommended when post-test photogrammetry will be conducted, as it allows the resting position to be identified and extracted accurately from the resulting model. If the resting location cannot be safely accessed, or if photogrammetry is not planned, proceed directly to *Record resting location* and document the location using visual observations.
31. **Record resting location.** At a minimum, record the bench on which the rock came to rest. If the resting location is not marked and will not be captured through photogrammetry, also record as much detail as practical: approximate position on the bench, distance from the toe, coordinates (Easting/Northing in the site's local mine grid or UTM), and any identifiable landmarks visible in photographs or video.
32. **Record outcome.** State whether the catch bench system retained the rock, or whether it reached the toe of the slope or traveled beyond the catch bench system.
33. **Check for fragmentation.** If the rock broke apart, note approximately where on the slope breakage occurred, how many major pieces resulted, and whether the largest fragment was tracked.
34. **Repeat.** Return to Step 4.3 for the next rock. Note the test sequence number (1st, 2nd, 3rd, etc.).

4.6 Post-Test Wrap-Up

35. **Conduct post-test photogrammetry survey.** Fly or walk the same area after all rocks have been released. Capture any marked rock resting locations, slope changes, and catch bench conditions. Use the same coordinate system and survey control as the pre-test survey whenever possible to facilitate comparison.
36. **Stop video recording.** Secure all video files and photographs. Label files with the test date, site, and camera location or identifier.
37. **Complete the Catch Bench Performance sheet.** Record the number of rocks observed reaching and coming to rest on each catch bench, along with any notable observations regarding rock retention, bypass, fragmentation, or bench performance. Final performance metrics may be refined during post-processing and analysis.
38. **Review and finalize the spreadsheet.** Transfer any field notes to the digital spreadsheet. Verify that Rock IDs match the Rock Descriptions and Release & Results sheets. Confirm

that all photographs, videos, survey files, and supporting documentation have been uploaded to the project folder.

TIP: Earlier rock releases may alter bench conditions (debris accumulation, surface damage) for later rocks. The Test Sequence Number field captures this ordering so GCE can account for it in analysis.

Appendix A: Spreadsheet Field Guide

This section explains every sheet, column, and field in the companion spreadsheet (RockFall_Test_Guidelines_Spreadsheet.xlsx). The spreadsheet has six tabs. This guide walks through each one in order.

ℹ TIP: Partial data is acceptable and valuable. Fill in what you can; leave fields blank if data is not available.

Sheet 1: Instructions

This is the first tab in the spreadsheet. It provides an overview of the workbook and brief descriptions of each sheet. No data entry is required here. Use it as a quick reference while working in the other tabs.

Sheet 2: Test Information

This sheet captures general information about each test event, the site, and data collection methods. Complete it once per test event. Each field occupies one row with a Value cell to fill in.

ℹ TIP: Video is strongly encouraged. Camera stability and an unobstructed view of the slope matter more than resolution.

Field	Format	Required?	What to Enter
Mine / Operation Name	Text	Yes	The name of the mine or operation where testing took place.
Test Date	YYYY-MM-DD	Yes	Date the test was conducted. Use ISO format (e.g., 2025-06-15).
Test Location Description	Text	Yes	Brief description of the area within the mine where testing occurred (e.g., “North wall, Pit 3, Phase 2”).
Bench Configuration	Single / Double / Multi	Yes	Whether the test slope had a single bench, double bench, or multiple benches.
Number of Benches Tested	Integer	Yes	Total number of benches in the test area. This defines the height of the test slope.
Site Selection Notes	Text	Recommended	Describe bench uniformity, condition, access, and why this site was chosen.
GCE Personnel Present?	Yes / No	Yes	Whether GCE staff were on-site during testing.
Weather Conditions	Text	Recommended	Conditions at the time of testing (e.g., Clear, Windy, Light Rain).
Photogrammetry Performed?	Yes / No	Yes	Whether photogrammetry was conducted. Note if pre-test, post-test, or both.

Survey Method Used	Text	Yes	How geometry was measured (e.g., photogrammetry, total station, GPS, design drawings).
Video Recorded?	Yes / No	Yes	Whether video was captured during testing.
Video Type	RGB / Thermal / Both	If video = Yes	Type of video camera used.
Camera Setup	Text	If video = Yes	Camera configuration (e.g., fixed ground-based, drone, handheld).
Total Rocks Tested	Integer	Yes	Total number of rocks released during this test event.
Blasting Context / Site Preparation	Text	Recommended	Describe site wall preparation and blasting practices relevant to bench conditions: e.g., whether walls are scaled or washed after blasting; blasting design parameters (hole diameter, burden, spacing, powder factor); use of pre-split or trim blasting; who reviews and approves blasting adjacent to highwalls.
Blast Video Available?	Yes / No	Optional	Whether pre- and/or post-blast videos are available for this area. If Yes, note what they cover and provide filenames or links. Blast videos can provide supplementary rockfall behavior data at low additional cost.
Additional Notes	Text	Optional	Any other relevant site-specific conditions, hazards, or observations.

Sheet 3: Slope Geometry

This sheet records bench-by-bench geometry measurements. Enter one row per bench level, numbered from the top (release point) downward. The spreadsheet provides rows for up to 20 benches.

ℹ TIP: This sheet can be left blank if photogrammetry or other DTM data is provided. DTM data collection is strongly recommended. Pre- and post-test surveys allow GCE to extract geometry, release locations, resting positions, and rockfall paths directly from the DTM.

Design Slope Geometry

Complete once per slope area or design segment. This table records the planned or design geometry of the test slope, providing context for how as-built conditions compare to design intent.

Column	Units	What to Enter
Slope Area / Design Segment	—	Name or identifier for the slope area or design segment being tested (e.g., North Wall Phase 2, Pit 3 East).
Design Bench Height (m)	meters	The design or target bench height for this area.
Design Catch Bench Width (m)	meters	The design or target catch bench width for this area.
Target Bench Face Angle (°)	degrees	The design or target bench face angle for this area.
Single Bench / Multi Bench	—	Whether the design for this area is a single-bench or multi-bench configuration.
Notes	Text	Describe any slope design changes within the testing area (e.g., by level/elevation range or other geometry grouping). Note relevant design features such as berms, ramp locations, or localized geometry changes.

As-built Slope Geometry Table

Enter one row per bench level, numbered from the top (release point) downward. The spreadsheet provides rows for up to 20 benches. Include the measurement method for each parameter.

Column	Units	What to Enter
Bench Number (top = 1)	—	Sequential bench number starting at 1 for the topmost bench (where rocks are released). Number increases going downslope.
Level / Elevation (masl)	masl	Elevation of the bench crest in meters above sea level (masl), if known. Useful for referencing bench geometry to mine survey data.
Bench Height (m)	meters	Vertical height of each bench face, measured from the toe of the face to the crest.
Effective (as-mined) Catch Bench Width (m)	meters	Total horizontal width of the catch bench below the bench face, measured from the toe of the upper face to the crest of the next lower face. This is the as-mined or design width (E in the E/T/R diagram).
Remaining (useable) Catch Bench Width (m)	meters	Flat, useable width of the catch bench after accounting for any talus accumulation at the toe of the bench face (R in the E/T/R diagram). Measured from the top of the talus pile (or toe of the face if clean) to the crest of the next lower face.

Bench Face Angle (°)	degrees	Angle of the bench face from horizontal. Typically 60–90° for hard rock mines.
Berm Present	Yes / No	Whether a berm is present on this bench.
Bench Toe Condition	Text	Condition at the toe of the bench face. Describe whether the toe is clean (no talus), partially talus-filled, or entirely talus-filled. Note approximate depth or width of any talus accumulation.
Bench Face Condition	Text	General shape/condition of the bench face profile. Describe as smooth, convex, concave, or irregular. Note any significant undercutting or overhanging sections.
Measurement Method	Text	How this bench geometry was obtained: photogrammetry, total station, GPS, tape measure, design drawings, estimate, etc.
Notes	Text	Any additional observations about this bench (e.g., significant backbreak, unusual conditions).

Note: *The distinction between Effective and Remaining catch bench width is illustrated in the diagram below (E=Effective as mined width; T = Talus accumulation; R = Remaining useable width). Both measurements are requested because talus infilling may significantly influence catch bench performance, and collecting both allows GCE to evaluate performance against each metric.*

Sheet 4: Rock Descriptions

This sheet records pre-test information about each rock before it is released. Enter one row per test rock. The spreadsheet provides rows for up to 50 rocks (R-001 through R-050).

ℹ TIP: Photograph every rock before release with a scale reference (tape measure, hard hat, etc.). This is one of the most valuable things you can do for data quality.

Column	Format	What to Enter
Rock ID	R-001, R-002, etc.	Unique identifier for each rock. Pre-filled in the spreadsheet. These IDs must match those used in the Release & Results sheet.
Type (Natural / Synthetic)	Text	Whether the rock is a natural rock from the mine or a synthetic/manufactured test rock.
Lithology / Geological Unit	Text	Rock type or geological unit (e.g., granite, sandstone, ore zone). Can be approximated. Mainly relevant for natural rocks.

L Axis	meters	Longest dimension of the rock. Practical field measurements are acceptable; laboratory precision is not required.
W Axis	meters	Intermediate dimension of the rock.
H Axis	meters	Shortest dimension of the rock.
Estimated Weight	kilograms	Estimated or measured weight. An approximation is fine if exact measurement is not feasible.
Shape Description	Text	General shape of the rock (e.g., blocky, rounded, flat/tabular, angular, irregular).
Fragmented During Test?	Yes / No	Whether the rock broke apart during the test. Fill this in after the test is complete.
Fragmentation Notes	Text	If fragmented: describe approximately where on the slope breakage occurred, how many major pieces resulted, and whether the largest fragment was tracked.
Pre-Test Photo Taken?	Yes / No	Whether a photograph of the rock was taken before release. Photos with a scale object are strongly encouraged.
Notes	Text	Any other relevant observations (e.g., visible discontinuities, unusual shape features, weathering).

Sheet 5: Release & Results

This is the core data sheet. It records the release method, coordinates, resting location, and outcome for every test rock. Enter one row per rock. Rock IDs must match the Rock Descriptions sheet.

Release Information Columns

Column	Format	What to Enter
Rock ID	R-001, etc.	Must match the ID used in the Rock Descriptions sheet.
Release Method	Text	Equipment or technique used to release the rock (e.g., excavator, loader, manual placement, dozer).
Pushed / Dropped / Rolled	Text	How the rock was released: pushed off the edge, dropped from height, or rolled. Describes the initial motion.
Release Height Above Bench (m)	meters	If the rock was dropped or lifted, the approximate height above the bench surface at the moment of release. Enter 0 if placed and gently released at surface level.

Location Columns

ℹ TIP: If coordinates are not available, clearly mark final resting positions in the field before post-test photogrammetry so GCE can extract locations from the DTM.

Column	Format	What to Enter
Release Easting	Coordinate	Easting coordinate of the release point. Use the site's local mine grid or UTM.
Release Northing	Coordinate	Northing coordinates the release point.
Resting Easting	Coordinate	Easting coordinate of where the rock came to rest.
Resting Northing	Coordinate	Northing coordinate of where the rock came to rest.
Resting Bench Number	Integer	Which bench the rock stopped on, using the same numbering as the Slope Geometry sheet (1 = top).
Distance from Toe (m)	meters	Straight-line distance from the toe of the bench face to the final outer edge of the rock's resting position, measured along the slope surface — not to the rock's center or centroid. This is the distance directly comparable to the Modified Ritchie Criterion (MRC) catch bench width.

Outcome & Observation Columns

ℹ TIP: Release energy matters. Where feasible, release rocks gently to approximate natural detachment. Avoid throwing, pushing hard, or dropping from significant height, as this adds energy beyond gravity.

Column	Format	What to Enter
Retained by Catch Bench?	Yes / No	Whether the rock was successfully caught and retained by the catch bench. This is the primary pass/fail outcome.
Trajectory Captured on Video?	Yes / No	Whether this specific rock's trajectory was recorded on video.
Test Sequence Number	Integer	Order in which this rock was released during the test event (1st, 2nd, 3rd, etc.). Earlier tests may alter bench conditions for later rocks.
Notes / Observations	Text	Any notable behavior: unusual bounces, fragmentation, near-misses, interactions with berms, or anything that affected the outcome.

Sheet 6: Catch Bench Performance

This summary sheet evaluates how well each bench retained rocks. It provides one row per bench. The "% Retained" column auto-calculates from your input, so you only need to fill in the count columns.

Column	Format	What to Enter
Bench Number	Integer	Bench number matching the Slope Geometry sheet numbering (1 = top).
Total Rocks Reaching Bench	Integer	How many rocks arrived at or passed through this bench level during the test.
Rocks Retained on Bench	Integer	How many of those rocks came to rest on this bench (were caught).
% Retained on Bench	Auto-calculated	Do not enter – this field calculates automatically as Rocks Retained / Total Rocks Reaching Bench.
Cumulative % Retained	Auto-calculated	Do not enter – running cumulative retention rate across all benches.
Notes	Text	Observations about bench performance: was there a berm, was the bench wider/narrower than others, signs of prior rockfall activity, etc.

General Field Tips

Consistency of Rock IDs: The Rock ID (R-001, R-002, etc.) is the key that links the Rock Descriptions sheet to the Release & Results sheet. Always use the same ID for the same rock across both sheets.

Bench Numbering: Always number benches from the top down, with Bench 1 being the topmost bench at the release point. This must be consistent across Slope Geometry, Release & Results, and Catch Bench Performance.

Units: All distances and dimensions are in meters. All angles are in degrees. All weights are in kilograms. Coordinates should use the site's local mine grid or UTM.

Partial Data: Partial datasets are valuable. If you cannot fill every column, fill in what you can. A test with basic geometry and outcomes is still useful even without coordinates or video.

Fragmentation: When a rock breaks apart, record the pre-fragmentation dimensions in Rock Descriptions. Track the largest fragment as the primary data point for resting location. Record smaller fragment locations if possible.

Photos: Photographing rocks before testing (with a scale reference) is one of the most impactful things contributors can do. It allows independent verification of rock dimensions and shape.

Appendix B: Rock Shape Classification Field Reference

Use these standard categories when filling in the **Shape Description** column in the Rock Descriptions sheet of the data collection spreadsheet.

Axis definitions: L = longest dimension · W = intermediate dimension · H = shortest dimension

Shape category	Axis ratio	Description	Typical trajectory behavior
Blocky / Cuboid 	L ≈ W ≈ H	Roughly equal dimensions in all three axes. Cube-like mass with flat faces.	Moderate bounce height. Tends to tumble rather than roll. Moderate distance from toe.
Tabular / Flat / Slab 	L ≈ W >> H	Disc or slab-like shape. Two long axes, one much shorter. Flat profile.	Low bounce. Slides and skids along the surface. Often stays close to the toe of the bench face.
Spherical / Rounded 	L ≈ W ≈ H (smooth)	Rounded, smooth surfaces with near-equal axes. No sharp edges or flat faces.	Highest rolling potential. Travels farthest on the catch bench. Many bounces, high energy retention.
Elongated / Columnar 	L >> W ≈ H	Rod or column-like shape. One axis much longer than the other two.	End-over-end tumbling. Unpredictable bounce direction. May roll sideways if oriented along slope.
Angular 	Variable (sharp edges)	Sharp, freshly broken edges. Flat faces from joints, fractures, or blasting. Recently broken rock.	High bounce potential on impact. Energy may be dissipated by fragmentation during fall.

Appendix C: Recommended Release Methods

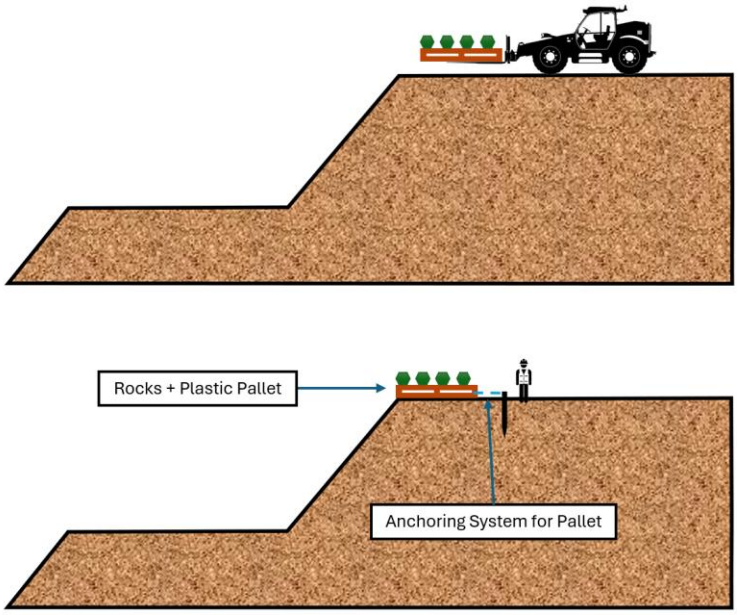
Use these methods when releasing rocks with a telehandler and pallet setup. Each is designed to release rocks with minimal added energy, approximating natural detachment as closely as possible.

ℹ TIP: Regardless of method, always confirm the exclusion zone is clear and video is recording before initiating release (see Section 4.4).

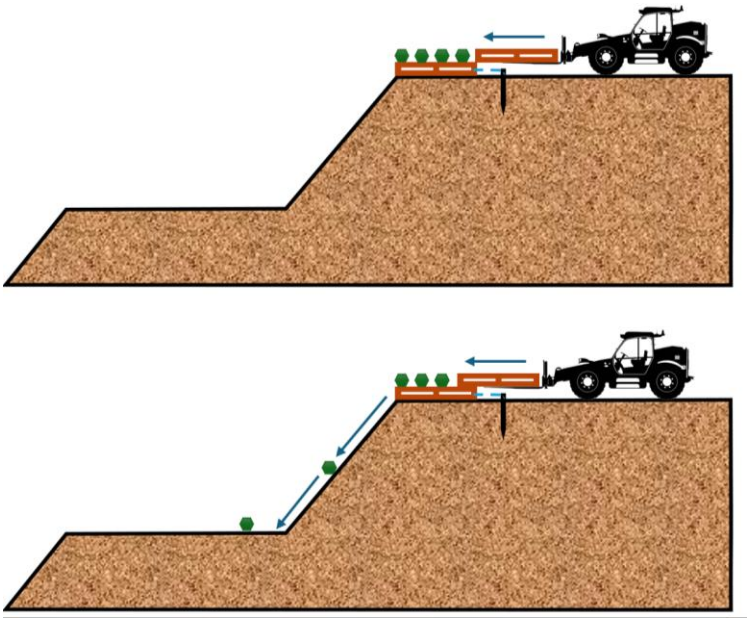
C.1 Scraping Method + Anchoring to Ground

This method anchors the rock-loaded pallet directly to the ground at the crest, then uses a second pallet to scrape the rocks off. It is well suited to sites where a stable anchor point can be established at the crest edge.

Step 1: Grab a pallet loaded with rocks and place it on the crest edge using the telehandler. Secure the pallet to the ground using the anchoring system.



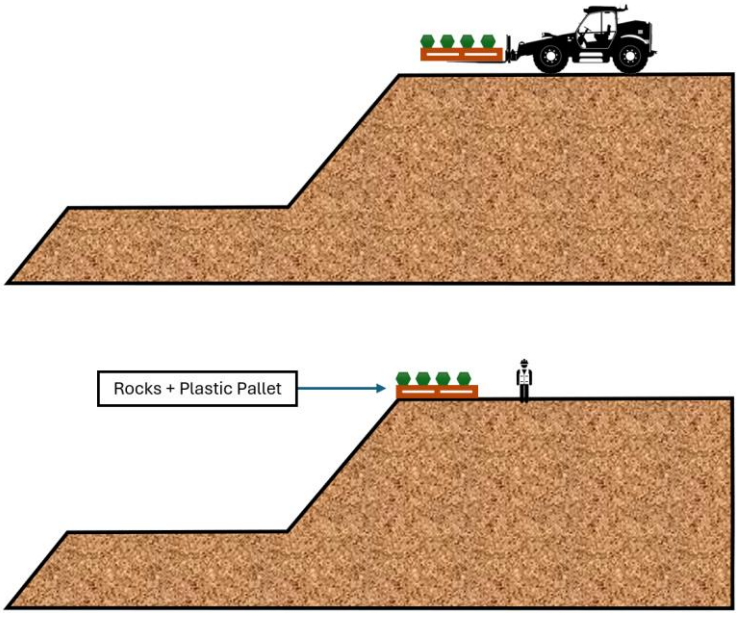
Step 2: Grab a second pallet and slowly approach the anchored pallet. Use it to gently push or scrape the rocks off the anchored pallet and over the edge.



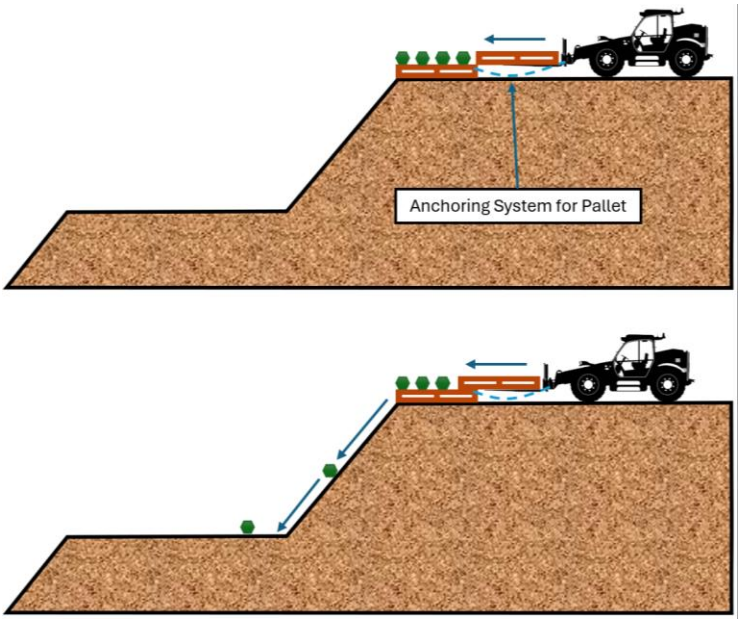
C.2 Scraping Method + Anchoring to Telehandler

This variant follows the same scraping approach, but anchors the rock pallet to the telehandler itself rather than the ground. This is useful when ground anchoring isn't practical or when a faster setup is preferred. A tow strap is a common anchoring tool for this method.

Step 1: Grab a pallet loaded with rocks and place it on the crest edge using the telehandler. Secure the pallet to the telehandler with the anchoring system.



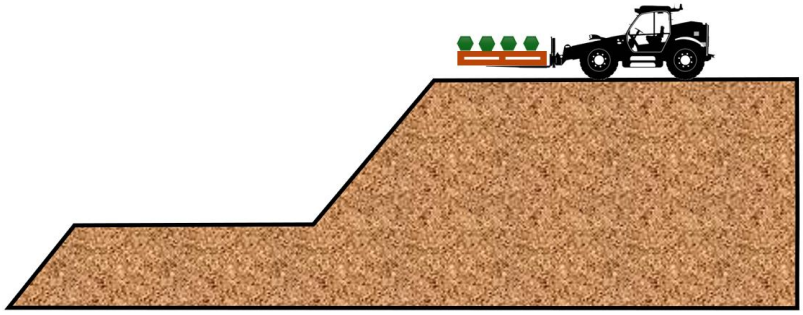
Step 2: Grab a second pallet with the telehandler and approach the rock pallet closely. Use the second pallet to gently push or scrape the rocks off and over the edge.



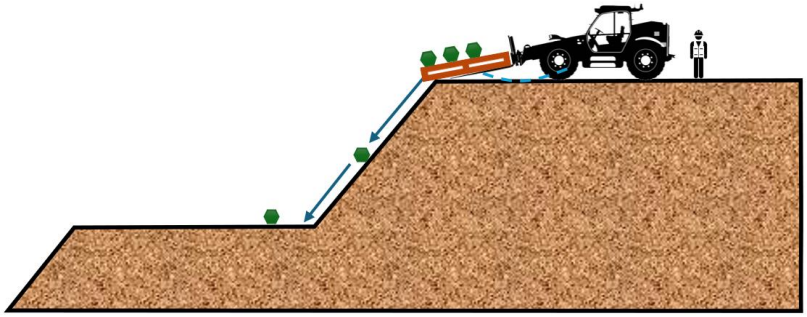
C.3 Tilt Method

The tilt method releases rocks by tilting the telehandler forks rather than scraping with a second pallet. It requires fewer pallets but relies on controlled fork movement to avoid adding excess release energy.

Step 1: Grab a pallet loaded with rocks and safely approach the crest edge with the telehandler. Position the pallet so it is touching or nearly touching the ground.



Step 2: Once in place, gently tilt the forks until all rocks have slid off the pallet. Ensure the pallet remains anchored to the telehandler throughout.



ℹ TIP: Choice of method may depend on site conditions, available anchoring equipment, and crest access. Document which method was used in the Release Method field of the Release & Results sheet (Sheet 5).

ℹ Field Tips:

- **Photograph every rock** before release with a scale reference (hard hat, tape measure). This is the single most valuable action for data quality.
- **If unsure between two categories,** pick the closest one and describe the specific features in the Notes column of the spreadsheet.
- **For fragmented rocks,** record the pre-fragmentation shape. Note post-fragmentation shapes in Fragmentation Notes if the fragments are significantly different from the original.
- **Shape strongly affects trajectory** — rounded rocks roll much farther than tabular ones. Accurate shape description directly improves rockfall model calibration and catch bench design validation.

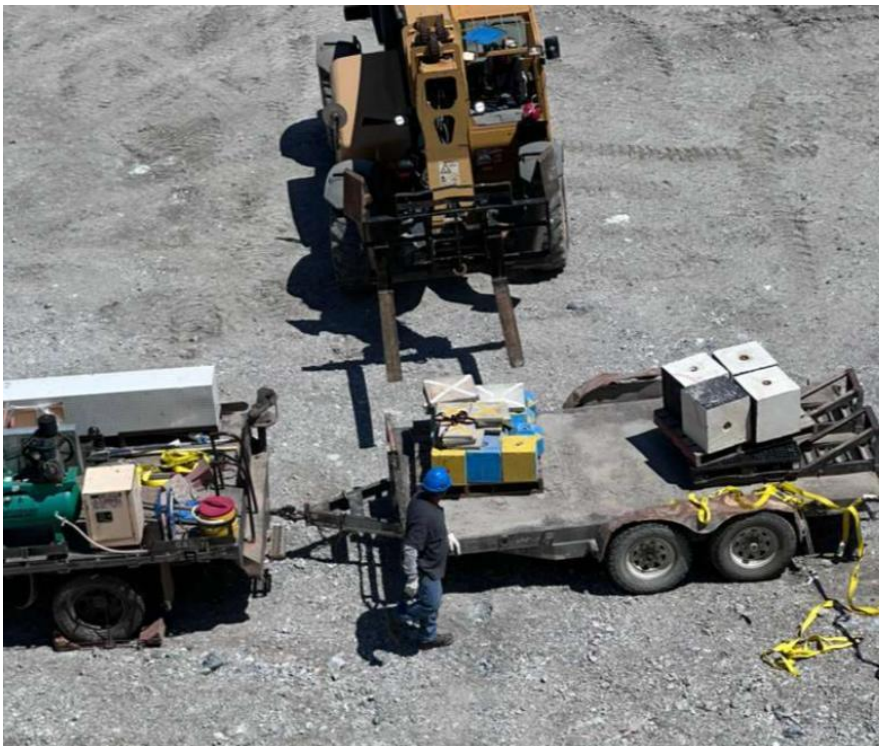
Appendix D: Field Reference Photos

The photos in this appendix are drawn from GCE/NIOSH Highwall Safety Project rockfall testing and are provided as real-world reference for the procedures and equipment described in Section 3 – 4 and Appendix C. Actual configurations will vary by site, geology, and equipment availability.

D.1 ASARCO Mission Mine, Arizona (August 31–September 3, 2026)



Metal-sheet pallet coated with lubricant to reduce scraping friction during release. This configuration — a standard pallet fitted with a metal sheet — worked well for the scraping method (Appendix C.1–C.2)



Equipment staging: support trailer, telehandler, and other field equipment organized at the test location (Section 4.1). A dedicated support vehicle and clear staging area reduced setup



Thermal and visual camera station positioned to give a clear, unobstructed view of the bench, with a support truck staged nearby (Section 4.2, Set up video cameras).



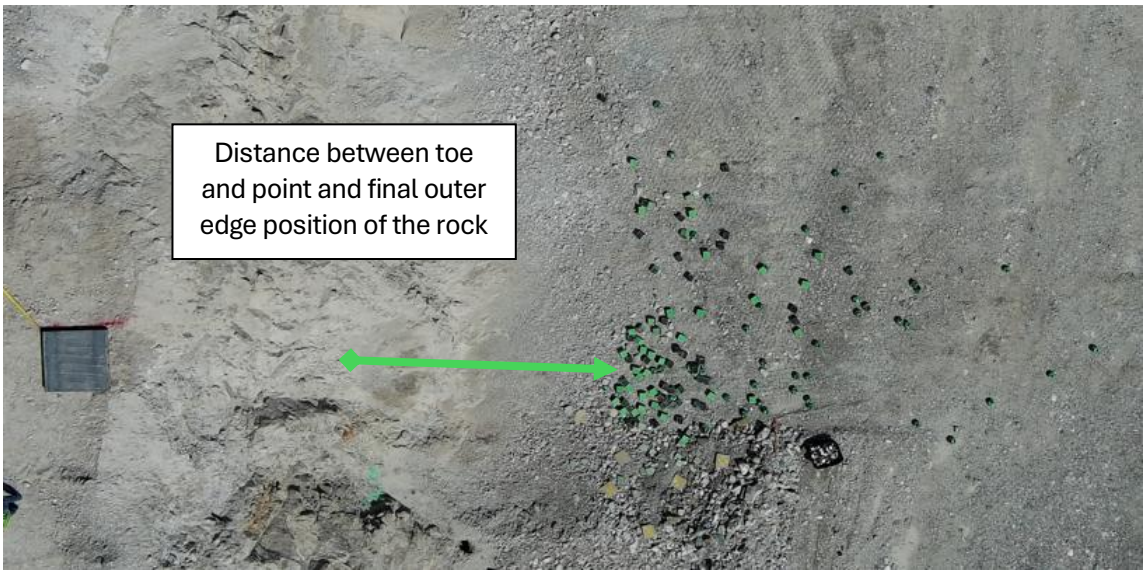
Crest-side release operations: the field crew positions the scraping pallet ahead of a controlled release (Appendix C.1–C.2, Scraping Method).



Synthetic rock specimens staged on pallet at the single-bench test location, one shape per test (Section 4.3, Rock Documentation).



Synthetic rock specimens being push with the scraping method (Appendix C.1–C.2)



Rock resting position recorded following release (Section 4.5, Post-Release Documentation). The green arrow shows distance from toe — measured from the toe of the bench face to the final outer edge of the rock, not its center. This is the value directly comparable to the Modified Ritchie Criterion (MRC) catch bench width.



Roll-out distances and resting positions recorded from the crest.



Natural rock specimens selected by size, painted for photogrammetric identification, measured, and tagged prior to release using the tilt method (Appendix C.3, Tilt Method).

D.2 Bald Mountain Mine, Nevada (2022–2023)

Single-bench rockfall testing conducted by NIOSH at Bald Mountain Mine (Kinross Gold Corporation), reported in Warren et al., “Revisiting Rockfall Catch Bench Design Guidelines: Test Results from Bald Mountain Mine, NV, USA,” Slope Stability 2024, Belo Horizonte, Brazil.



Natural rock specimens sorted and spray-painted by color prior to release, so each can be identified in post-test photos and photogrammetry (Section 4.3, Rock Documentation).



Data acquisition station (left) with tripod-mounted still/video cameras under a shade canopy, and a drone-acquired 3D point cloud (right) marked with the drop point and runout area — an example of photogrammetry used to measure distance from the toe (Section 3.1).



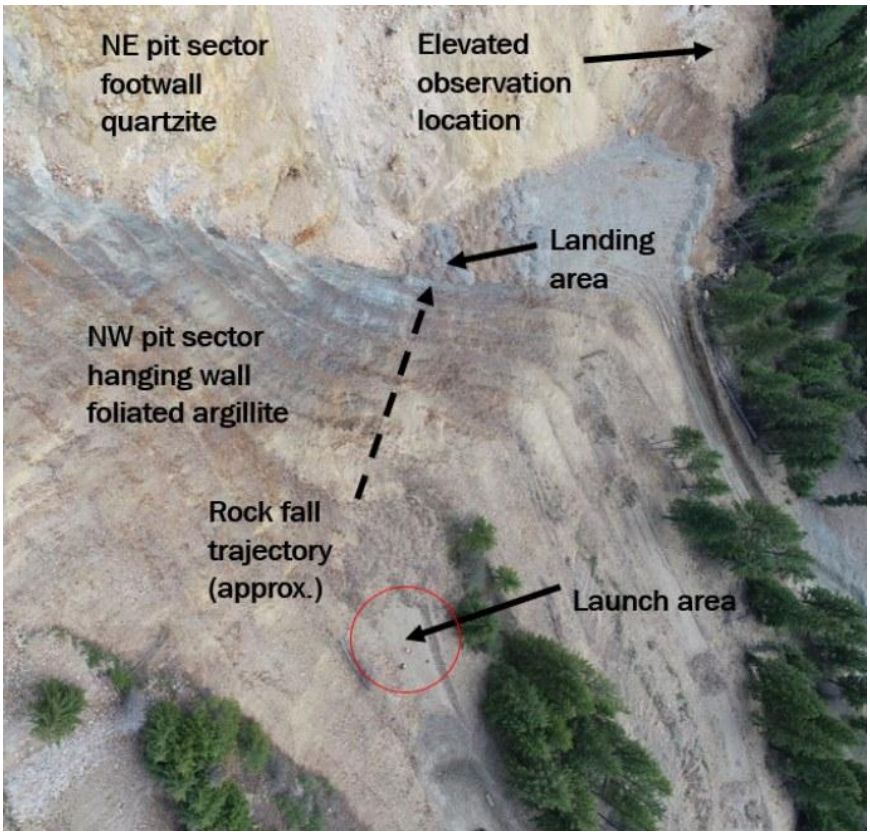
A single bench with talus accumulated at the toe (left), and the same toe being cleared prior to testing (right). Talus buildup at the toe reduces catch bench performance, which is why the guide asks contributors to record and, where practical, clear the toe zone before testing (Section 4.2, Define the toe clearance zone).



The same 40-ft bench height tested in two different lithologies — shale (left) and limestone (right) — illustrating how bench face condition and geology are documented alongside geometry (Sheet 3, Slope Geometry).

D.3 Golden Chest Mine, Idaho (May 2022)

Full highwall (multi-bench) rockfall testing conducted by NIOSH at the Golden Chest Mine (Idaho Strategic Resources), reported in Warren et al., "Revisiting Rockfall Catch Bench Design Criteria: Initial Rockfall Testing Results from the Golden Chest Mine, ID," Slope Stability 2022, Tucson, Arizona.



Annotated aerial photo of a test site, marking the launch area, approximate rockfall trajectory, landing area, and elevated observation location — the kind of site plan developed during pre-test scouting (Section 4.1, Select the test site).



An excavator (CAT 336) releasing synthetic rock specimens from a bucket at the crest (left) — an alternative to the telehandler-and-pallet methods in Appendix C. The view (right) shows a full highwall test with benches numbered from the drop point down to the pit bottom, illustrating the bench-numbering convention in Section 4.1 and the General Field Tips ("Bench Numbering").

D.4 Program-Wide Reference Photos (NIOSH Highwall Safety Project)

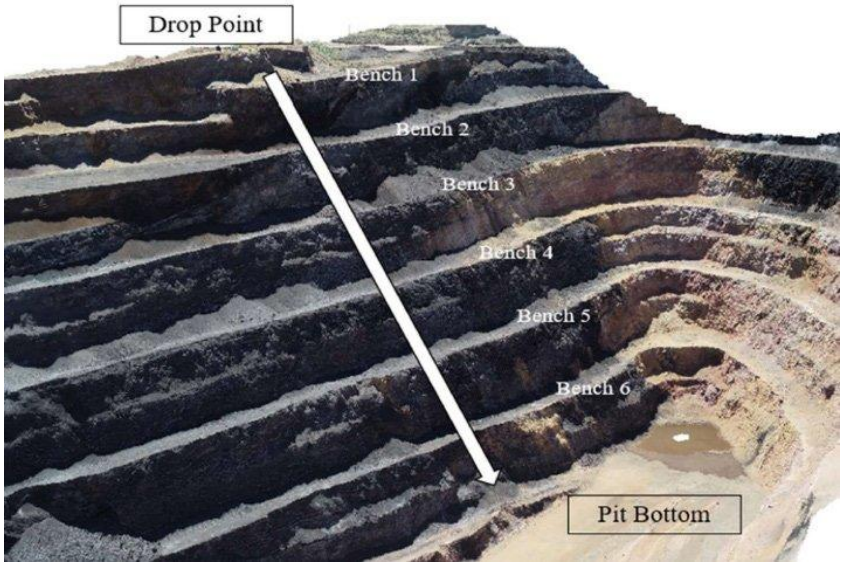
The following photos illustrate practices used consistently across NIOSH Highwall Safety Project testing sites, reported in Bourgeois and Warren, “Designing a Rockfall Testing Program for Open-Pit Mines to Investigate Runout and Bench Catchment,” NIOSH/CDC.



Synthetic rock specimens (3–18 in diameter; cube, ETAG 27, and flat/plate shapes), colored to distinguish size and shape, used across multiple sites to allow direct comparison of runout and catchment performance between mines (Sheet 4, Rock Descriptions).



Local rocks collected from a test site and spray-painted by size category (small, medium, large) prior to testing, so each size class can be tracked separately in post-test photos (Section 4.3, Rock Documentation).



Photogrammetry model of a multi-bench highwall test showing the drop point, benches numbered 1–6 from the crest down, and the pit bottom — an example of the bench-numbering convention described in the General Field Tips section.

References

Bourgeois, J., and Warren, S. N. "Designing a Rockfall Testing Program for Open-Pit Mines to Investigate Runout and Bench Catchment." Report 24-024, National Institute for Occupational Safety and Health (NIOSH)/CDC, Spokane Mining Research Division, Spokane, WA.

GCE/NIOSH Highwall Safety Project. *ASARCO Mission Mine Rockfall Testing Campaign Report* (v2). Geotechnical Center of Excellence, University of Arizona, September 2026. Internal field campaign report.

Warren, S. N., Bourgeois, J., Sbai, S., and Lasich, T. (2024). "Revisiting Rockfall Catch Bench Design Guidelines: Test Results from Bald Mountain Mine, NV, USA." *Slope Stability 2024*, Belo Horizonte, Brazil, April 14–19, 2024.

Warren, S., Bourgeois, J., Sweet, D., Sbai, S., Brackebusch, A., Stopka, C., and Armstrong, J. (2022). "Revisiting Rockfall Catch Bench Design Criteria: Initial Rockfall Testing Results from the Golden Chest Mine, ID." *Slope Stability 2022*, Tucson, AZ.