

TRANSPORTATION RESEARCH  
**CIRCULAR**

Number E-C260

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# Managing Highway Rock Slope Scaling

*Design and Construction  
State of the Practice:  
Presentations from the  
97th Annual Meeting of the  
Transportation Research Board*

January 7, 2018  
Washington, D.C.

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TRANSPORTATION RESEARCH CIRCULAR E-C260

# **Managing Highway Rock Slope Scaling**

## *Design and Construction State of the Practice*

Presentations from the 97th Annual Meeting of the  
Transportation Research Board  
January 7, 2018  
Washington, D.C.

Transportation Research Board  
500 Fifth Street, NW  
Washington, D.C.  
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## Introduction

This Transportation Research E-Circular includes a synopsis of 11 presentations from the workshop “Managing Highway Rock Slope Scaling: Design and Construction State of the Practice” held at the 97th Annual Meeting of the Transportation Research Board. This workshop was sponsored by the Standing Committee on Engineering Geology, the Subcommittee on Rockfall Management, and the Standing Committee on Geotechnical Site Characterization.

The publication of this e-circular is timely and will serve as a valuable reference for agencies, designers, researchers, and professionals that design, estimate, inspect, and administer slope-scaling projects for transportation corridors.

## BACKGROUND

Scaling loose rocks from slopes adjacent to highways is a simple and effective measure for temporarily reducing the risk of rockfall potential on naturally occurring bedrock outcrops and highway rock–soil cuts. As defined in *Rockfall: Characterization and Control* (TRB 2012), “scaling is a form of excavation used principally to remove individual loose or unstable rock blocks from a slope face.” Removal typically is done by hand using pry bars or with mechanical assistance such as jacks, hydraulic splitters, air pillows, or heavy machinery (e.g., excavators, backhoes, cranes dragging heavy objects on the slope). In some cases, trim blasting techniques are considered part of a scaling program. Slope access is generally achieved by personnel on foot and by rope access; however, telescopic boom-lifts and crane baskets also are used.

Many owners and transportation agencies conduct scaling work on a reactionary basis because of continued or prolonged rockfall activity. With the aging of Interstate highways and the overall transportation infrastructure, there is an increasing need to address long-term weathering of constructed and natural slopes along their corridors, rock scaling has become a maintenance measure implemented with greater frequency by transportation, land management agencies, and railway companies. The required frequency of scaling takes into account the slope characteristics, geology, rock structure, local climate, performance expectations, consequences of rockfall impacts, and budget availability.

The current practice in estimating scope of work and contracting rock scaling projects are inconsistent from agency to agency. Unlike other highway construction projects, where a cubic yard of building material is independent of the contractor, scaling units of measure for a bid, often on an hourly, unit weight, or volume basis, are not independent of contractor’s ability or

### PUBLISHER’S NOTE

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experience. Hidden geologic characteristics and actual required scaling effort to remove loose rock are difficult to foresee and predict until on-slope work begins. Scaling measures based on unit weight or volume may incentivize over-excavation when the ideal course of action might be to stabilize blocks in place.

In scaling, efforts and costs often escalate without a clear, satisfactory completion target being achieved. This can leave contract administrators and construction engineers without a resolution when the bid quantities are exhausted and scaling work is incomplete. Clear guidance are warranted to assist owners to better judge when overruns are warranted due to geologic conditions, rather than from low contractor production rates or over-excavation from easy and unneeded scaling efforts.

Some beneficial shifts in practice may be difficult to implement due to the lack of published information regarding best practices, guidelines, or a general lack of institutional experience.

The intent of this workshop was to discuss best practices in the industry that include safe construction methods that add value through a reduction in construction delays and life-cycle costs, and preservation rather than replacement of existing rock and soil slopes. To assist with these efforts, a first-of-its-kind nationwide survey was distributed to agency owners and designers, consultant engineers and geologists, and specialty rockfall contractors. Survey results contained herein inform others on the state of the practice for the industry.

The workshop discussed information to improve methods for developing engineering cost estimates, contract development, and administration, and covered select case histories that covered both successful and unsuccessful project outcomes. A cross-section of transportation and federal land management agencies, consultant specialists, and rockfall specialty contractors participated in the workshop as attendees, presenters, and panel members. Their annotated presentations are shared in the remainder of this e-circular.

## **WORKSHOP INFORMATION**

This e-circular is based on Session 170, a workshop of the 97th Annual Meeting of the Transportation Research Board, held January 7–11, 2018, in Washington, D.C.

### **Session 170**

#### **Managing Highway Rock Slope Scaling: Design and Construction State of the Practice**

(<https://annualmeeting.mytrb.org/interactiveprogram/Details/7631>)

Darren Beckstrand, Landslide Technology; Ben Arndt, RJ Engineering and Consulting; Lucas (Ty) Ortiz, Colorado Department of Transportation, presiding. Sponsored by Standing Committee on Engineering Geology (AFP10), Subcommittee on Rockfall Management (AFP10(1)), and Standing Committee on Geotechnical Site Characterization (AFP20).

*Speakers:*

#### **Scaling Basics: What It Is, How It Is Done, and What It Accomplishes (P18-20247)**

Darren Beckstrand, Landslide Technology; Ben Arndt, RJ Engineering and Consulting; Black, Landslide Technology.

**Questionnaire Results (P18-20248)**

Ben Arndt, RJ Engineering and Consulting

**Case Histories of Scaling: Successes and Improvement (P18-20249)**

Brent Black, Landslide Technology, Peter Ingraham, Golder Associates Inc., Lucas (Ty) Ortiz, Colorado Department of Transportation, Darren Beckstrand, Landslide Technology, Krystle Pelham, New Hampshire Department of Transportation

**Designer, Owner (Geotech and Resident Engineer), and Contractor Perspectives (P18-20250)**

Douglas Anderson, Federal Highway Administration (FHWA) (presented by Brian Collins, Federal Highway Administration (FHWA)), Todd Reccord, Ameritech Slope Constructors, Peter Ingraham, Golder Associates Inc.

**Plans and Specification Examples (P18-20251)**

Brent Black, Landslide Technology

**Needed Areas of Improvement; Research Needs (P18-20252)**

Lucas (Ty) Ortiz, Colorado Department of Transportation, and Daniel Journeaux, GeoStabilization International

**Wrap-Up (P18-20253)**

Darren Beckstrand, Landslide Technology

# Scaling Basics

**BRENT BLACK**  
*Landslide Technology*

Scaling is considered a stabilization measure; however, hazard reduction is realized by the removal of loose or unstable rock from the slope face via hand tools and/or mechanical means. It is a type of rock removal along with blast scaling, trim blasting, and re-sloping. Quotes regarding scaling are taken from Turner and Schuster (2012).

## SCALING: What is it, how is it done, and what does it accomplish?

Managing Highway Rock Slope Scaling:  
Design and Construction State of the  
Practice

TRB 97<sup>th</sup> Annual Meeting  
AFP10 Session # 170

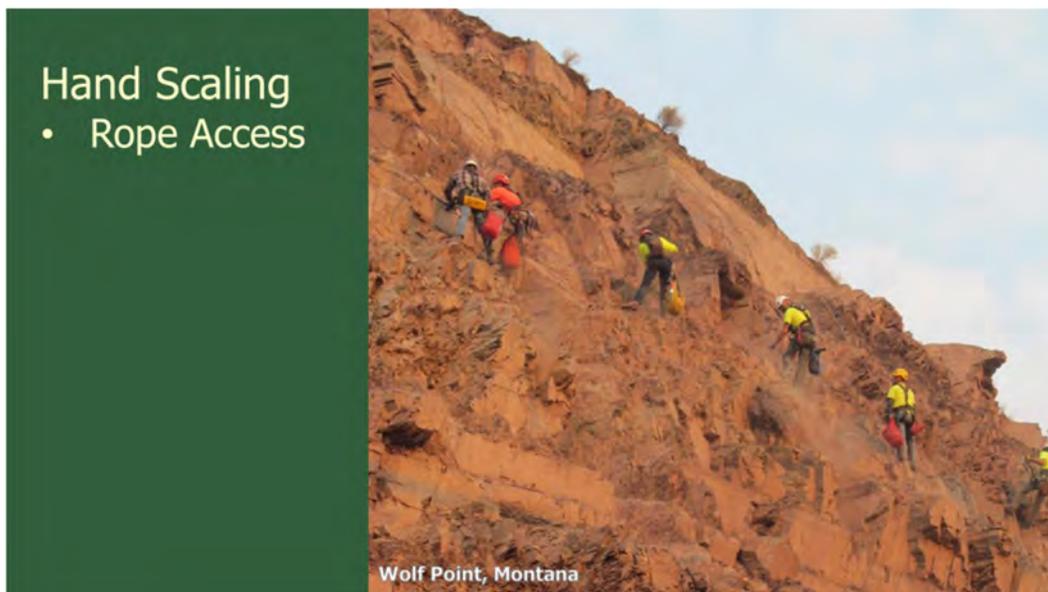


- **ROCKFALL: CHARACTERIZATION AND CONTROL (TRB 2012)**
  - STABILIZATION MEASURE
  - ROCK REMOVAL
  - SCALING
    - “Process of removing loose or unstable rock from a slope face by means of hand tools and/or mechanical equipment.”
    - “It is effective in the short term but less so in the long term.”
    - “Commonly used with other rockfall mitigation design elements.”





Generally, traditional hand scaling or “high scaling” consists of scalers on ropes with scaling bars, removing loose rock.



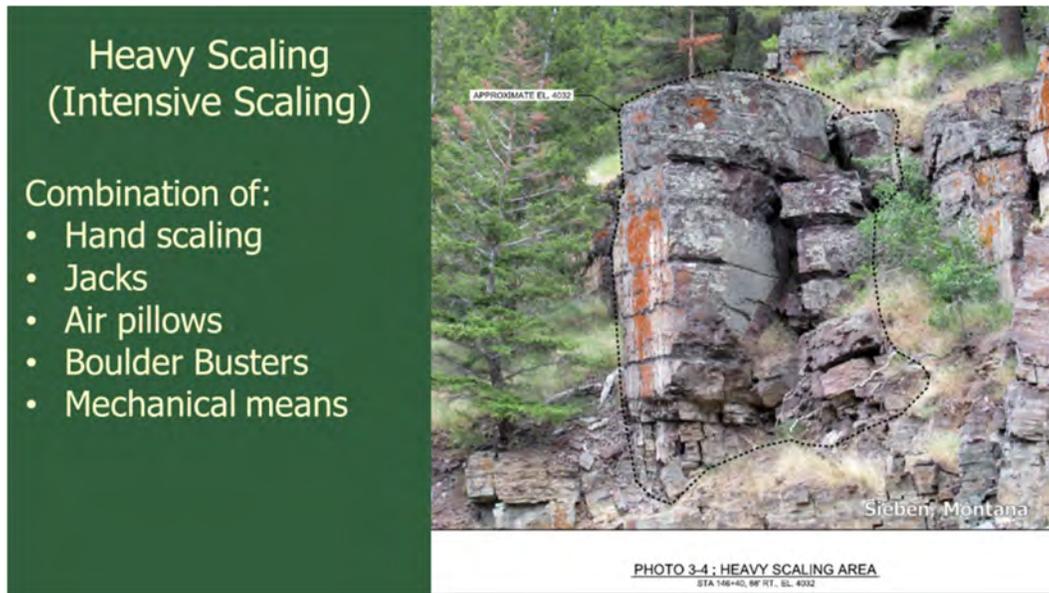
Typically, a crew of scalers using rope access techniques work in a straight line from the top down, removing loose rock in a controlled manner that could potentially otherwise fall on the roadway.



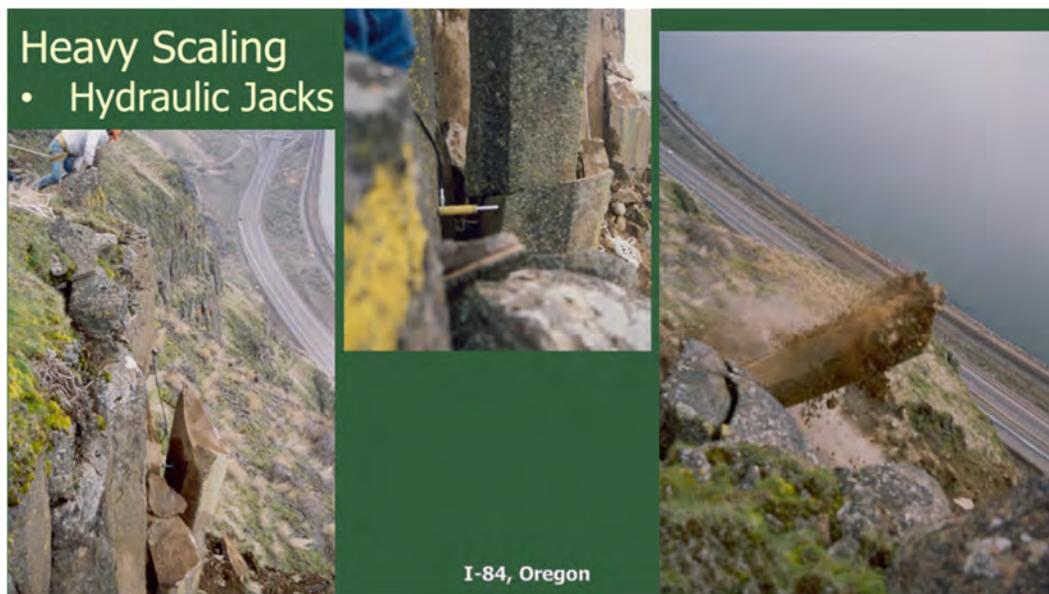
Scaling from lifts can be highly effective and productive, if they can reach high enough and there is enough room for equipment (road is usually closed). Scalers working from lifts usually use a slightly different scaling bar, typically longer and made of aluminum with steel tips.



Hand scaling from a crane supported platform is general slow and expensive, usually utilized if the crane is already on site for other purposes.



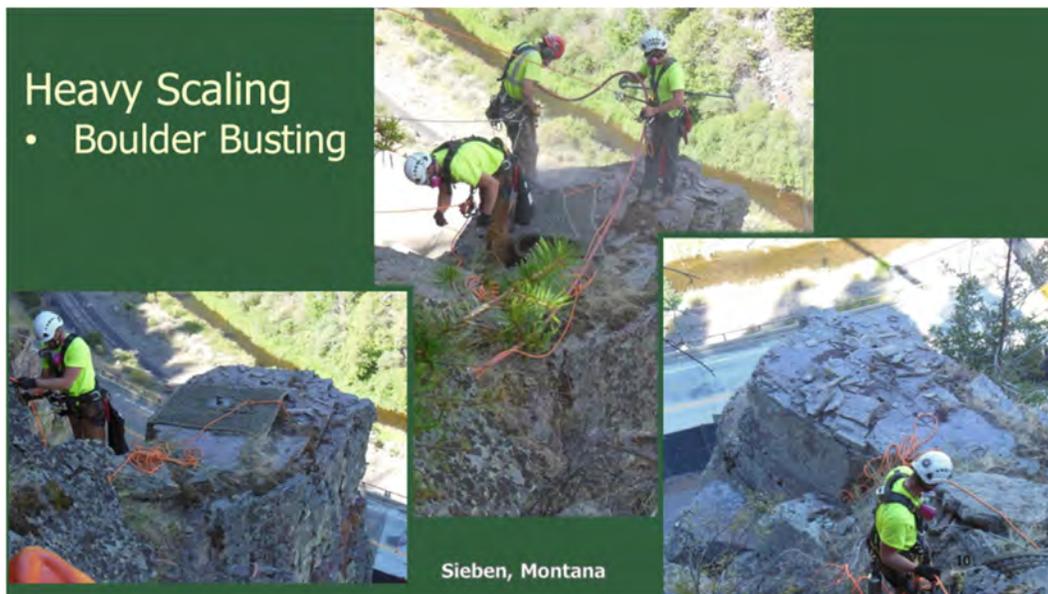
Heavy or intensive scaling usually implies the removal, or near removal of the identified rock mass hazard.



Heavy scaling tools include hydraulic jacks. This method is commonly being replaced by air pillows.



Air pillows are a very effective means of mechanical scaling.



Another heavy scaling technique is boulder busting. Boulder busting uses hydrostatic pressure waves to fracture rock. Usually explosives are used only in heavy scaling.



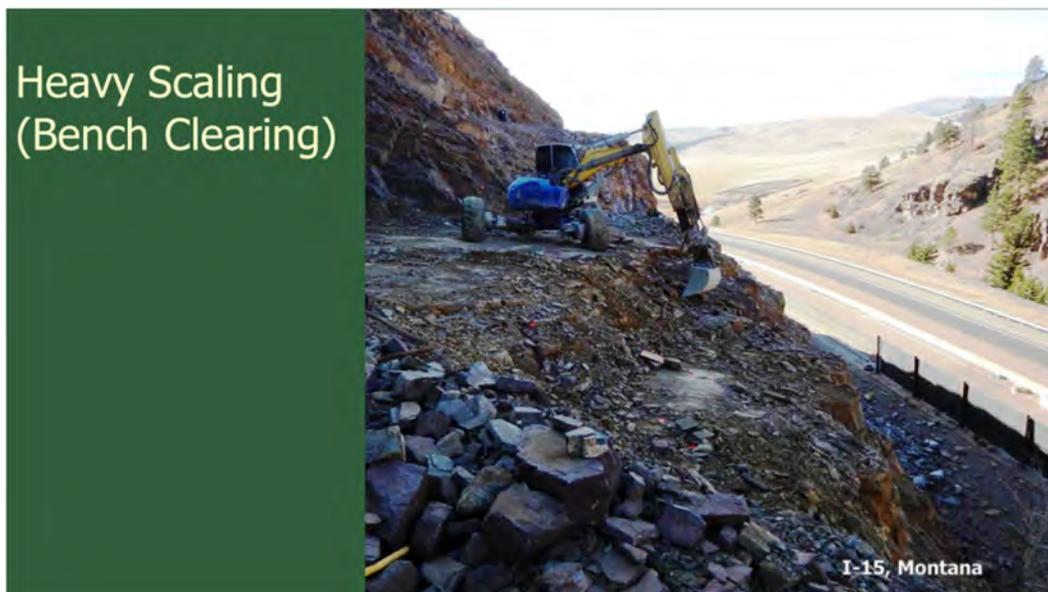
Mechanical scaling is limited by the reach of the equipment. Care must be taken not to over excavate or undermine sections of the slope.



Long-reach excavators can extend the limits of mechanical scaling. The insert on the left is a modified I-beam used by a track-excavator that could reach 70 ft above the ground.



This is an example of unconventional crane assisted mechanical scaling. This technique is slower, less effective, and generally more expensive than the other traditional scaling methods.



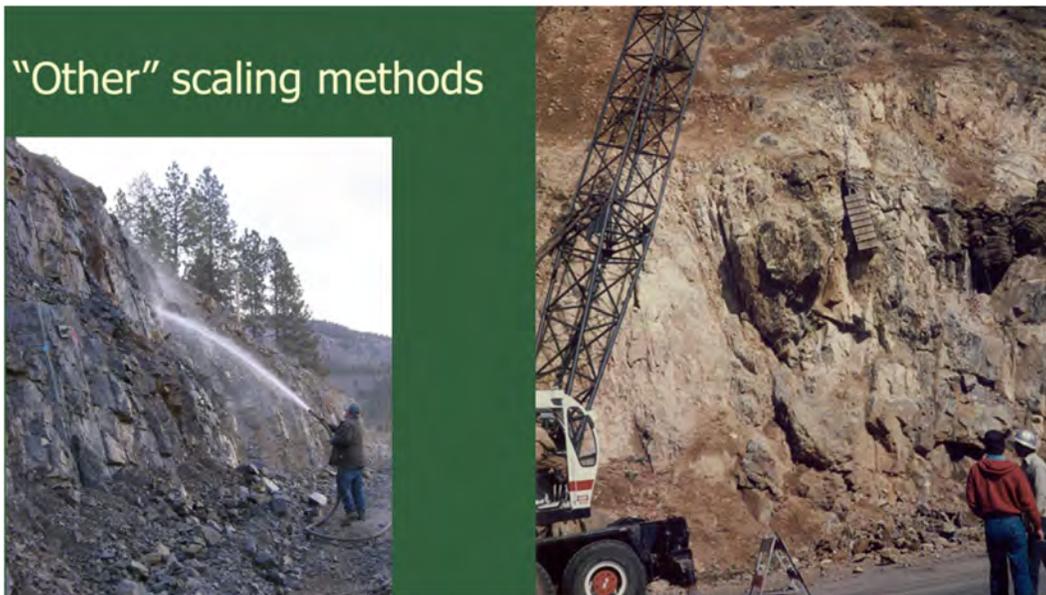
Another form of scaling is bench clearing or bench cleaning. If there is access, a conventional excavator can be used to clean the bench. A spider hoe may be useful for locations difficult to access.



Another heavy scaling technique is “yard scaling.” A steel bar behind, or lasso around the rock, is used to pry or pull the block with a large piece of equipment. The removal of individual large blocks using this method can be more difficult to control.



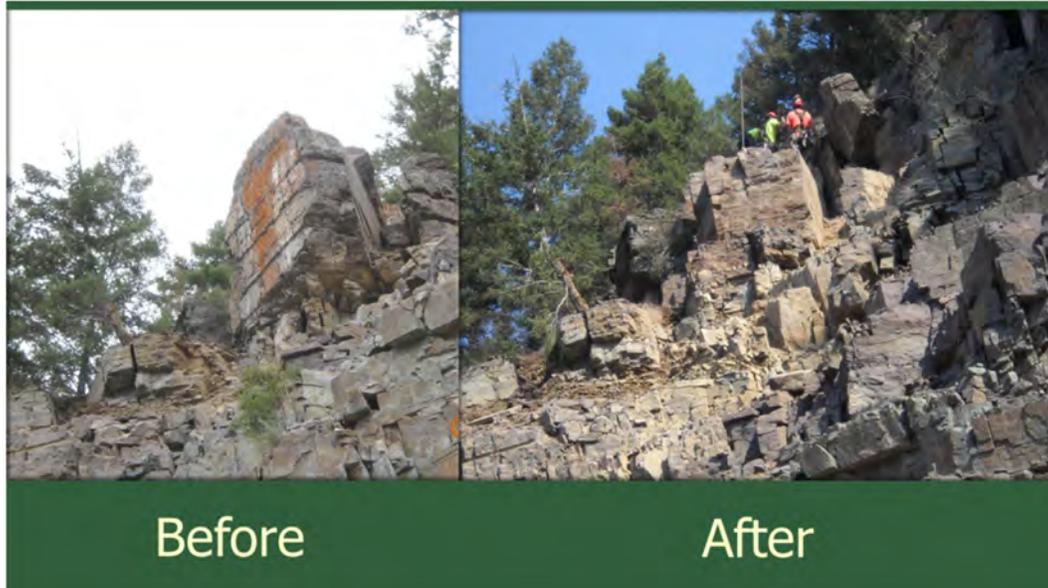
This was a video in the presentation that shows a rock being dropped using the “yarding” method. The block did not go in the direction that it was being pulled, but it was stopped by a high-capacity flexible rockfall barrier (FRB).



These are a couple of scaling methods (“hydro” scaling and cat-track dragging) that were often employed in the past that were generally less effective when compared to qualified scalars working from ropes or lifts.



Scalars on ropes, using just pry bars, can be highly effective removing loose rock that has the potential to reach your roadways.



This is what heavy scaling can do.



This constructed bench near the top of the rock cut had never been cleaned and accumulated a significant amount of talus that was launching rockfall on to the road below. This 400-ft long bench was cleaned by a Spyder hoe (75 machine hours).

## What does scaling accomplish?

- Hazardous rocks removed from slope in controlled manner – Safer roads, safer maintenance
- 'Resets' rockfall activity – Keeps slopes in Good Condition
- Reduces state-funded maintenance costs
- Always first step in rockfall mitigation projects
- Often last step in rock excavation

## Why This Workshop Was Convened

- No 'Standards' exist
  - Design, inspection, quantities, payment, work acceptance, etc.
- Difficult to measure performance, work completion for Resident Engineer
- Difficult for inexperienced contractors to perform well
- Difficult to design/specify/exhibit satisfactory completion to ensure positive outcome
- Mitigate risk for all stakeholders

## Why This Workshop Convened

- Identify opportunities for improvement and where research needs exist
- Progress toward documenting common practice

### *Scaling Survey - Results*

# Questionnaire Results

**BEN ARNDT**

*RJ Engineering and Consulting*

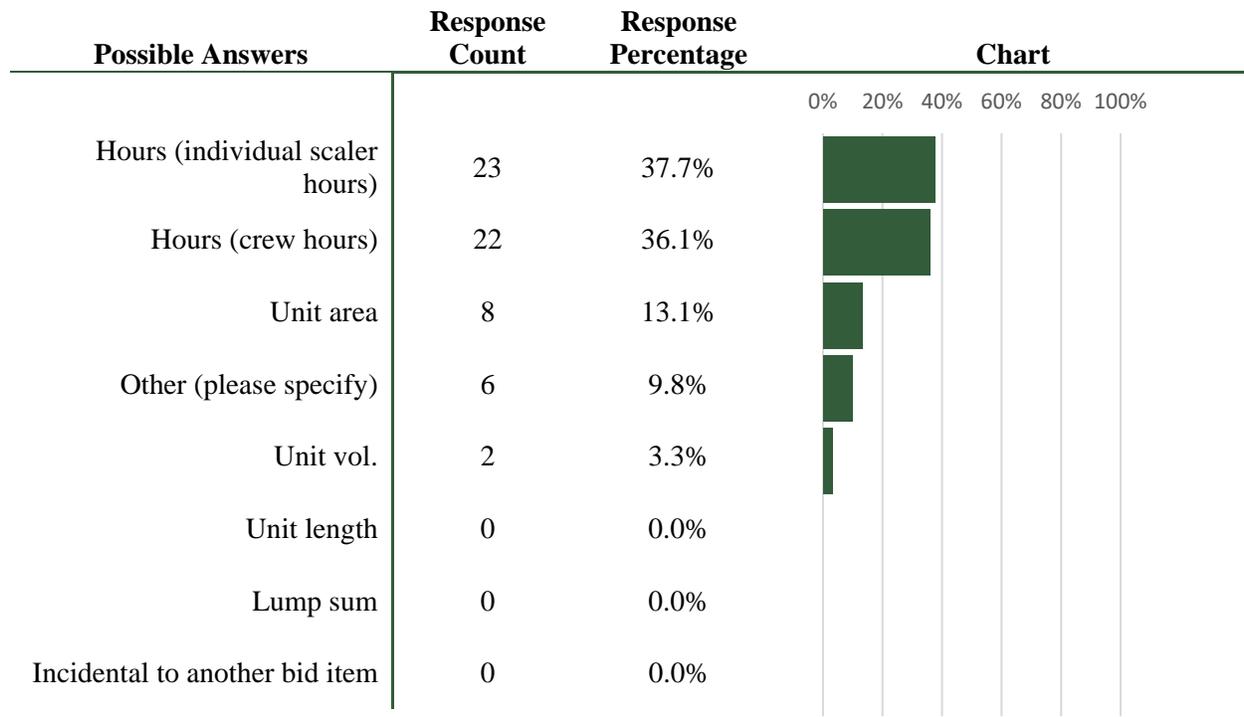
## INTRODUCTION

To clarify, understand, and better evaluate the current state of practice for rock scaling on transportation projects, a rock scaling questionnaire was sent out to obtain input from agencies, designers, and contractors. The survey consisted of 22 questions regarding various aspects of rock scaling in a project delivery framework. Based on the survey, a total of 61 responses were received and are summarized in this paper. The questionnaire attempted to capture many factors in the project delivery realm including: common bid items, methods of measurement and payment, qualification requirements of the contractors, acceptance of scaled slopes, safety versus programmed scaling, to name a few.

It appears from the responses received there is no well-defined process or delivery method that encompass all phases of a rock-scaling project. Many questionnaire responses suggest that scaling projects are a case-by-case process that may have many different objectives and desired outcomes. For instance, the responses to the questionnaire suggested that one aspect that could be addressed in future work is whether scaling is considered a maintenance–management activity or a programmed–designed process? Depending on the scaling project, the objectives and outcomes can be completely different. Overall the questionnaire responses illustrate the need for further discussions and definitions of what the current state of practice is for rock scaling and how to better evaluate objectives and performance criteria when undertaking a scaling project.

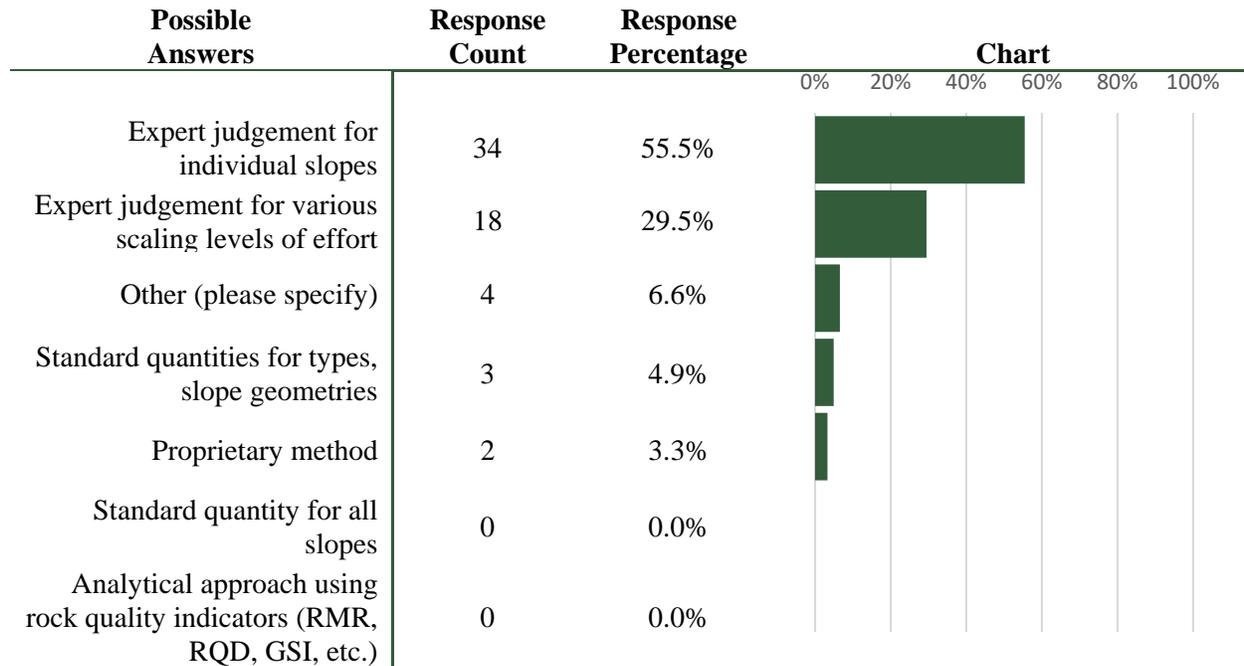
## QUESTIONS AND RESPONSES

### Question 1: What units do you use to measure scaling quantities?



“Other” responses:

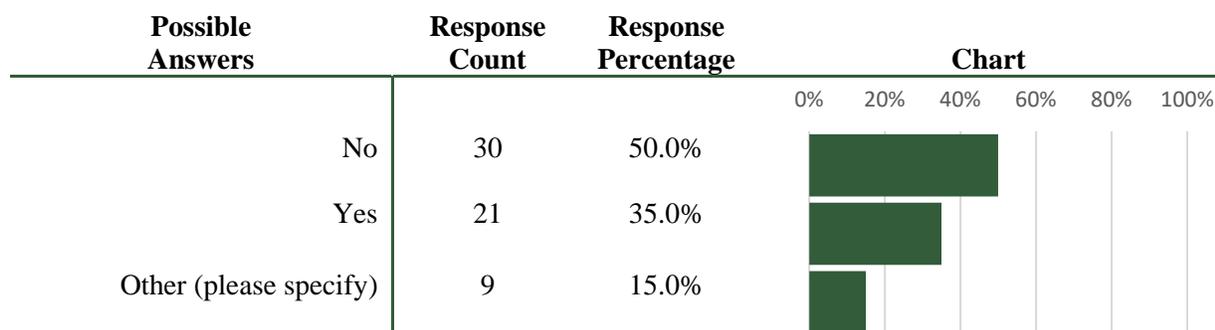
1. Pay with loader and trucking hours to haul off.
2. Crew hours, assuming crews of three.
3. Crew hours are the most common but I have seen lump sum attempted by some owners.
4. I have used all of the above.
5. Hours or incidental (for post-blast scaling).
6. Usually volume but have used crew hours for special projects.

**Question 2: How do you estimate scaling quantities?**

“Other” responses:

1. Estimate volume of scaled material.
2. Area (m<sup>2</sup>) of slope face to be scaled, measured by ground length and hand tool survey or from digital terrain model. Don't estimate based on volume of loose rock expected to be produced.
3. Since it is an area estimate we provide a rough approximation of the location to be scaled.
4. Get base hours by dividing the slope area by number of rope sets (width) and rate of decent. Modify accordingly with expert judgement of geology and slope conditions.

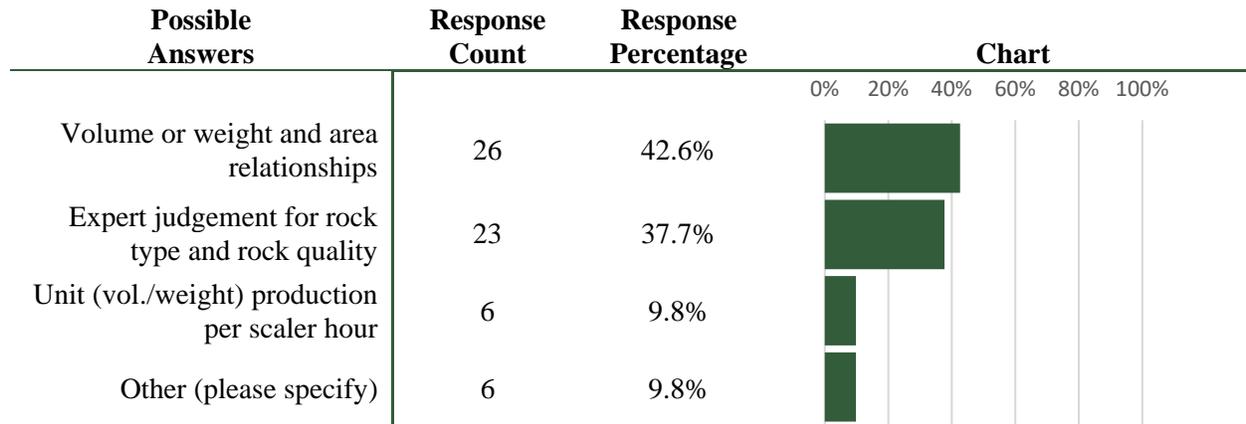
**Question 3: Do you use separate bid items for different scaling techniques? (hand scaling from ropes, hand scaling from lifts, mechanical or equipment-assisted, air-pillows, heavy scaling, etc.)**



“Other” responses:

1. Estimate a quantity of “safety scaling” if tied to another operation, and then required scaling. No difference in prices for the technique.
2. Where possible.
3. We break out hand scaling (which includes air bags–splitters) from mechanical (machine scaling).
4. Depends on project. Use both approaches.
5. We recently modified our scaling into light and heavy-duty scaling.
6. Generally, mechanical scaling and manual scaling are bid separately.
7. Different item for mechanical (excavator with breaker) and hand scaling.
8. Typically scaling is by hand with the use of various tools and access equipment (and paid by the crew hour, or per person hour, with the crew size stipulated). On occasion mechanical scaling with heavy equipment is called for, in which case payment is done by cubic yard.
9. Typically general and heavy scaling.

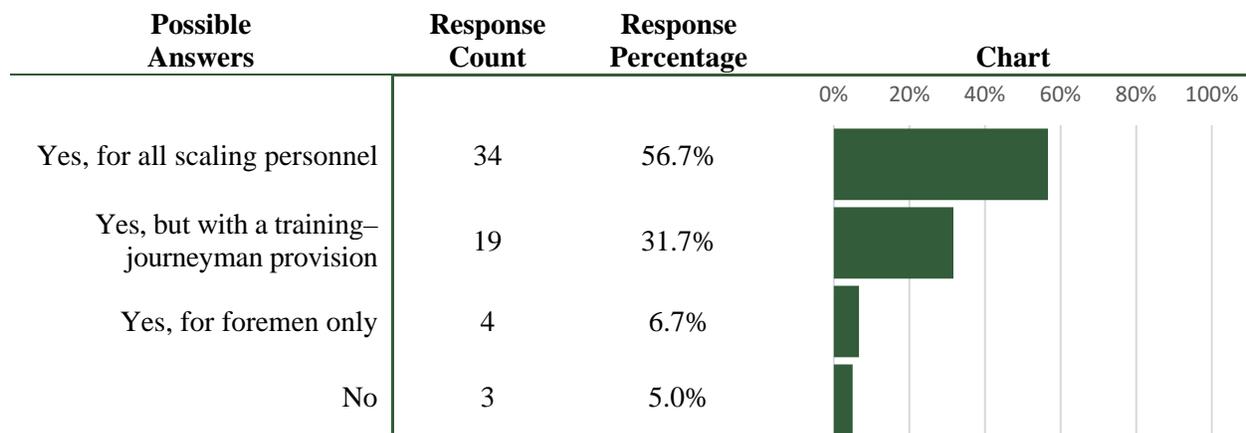
**Question 4: How do you estimate the volume of scaling debris for removal and haul?**



“Other” responses:

1. Quantities and pay items are in square yard.
2. I don't. Area (m<sup>2</sup>) unit rate includes disposal. May specify disposal site (location from work site).
3. Generally roll scaling operations into larger project. Hauling of debris paid separately from scaling specification and is estimated based on judgement.
4. Hauling is incidental to our specification.
5. No estimate, debris removal incidental.
6. Always assume it is incidental to scaling. Difficult to estimate and have seen claims regarding this.

**Question 5: Do you require scaler experience qualifications in your scaling specification?**



**Question 6: If yes to Question 5, what are the qualifications? (select all that apply):**

Possible Answers	Response Count	Response Percentage	Chart
Years of experience	33	56.9%	
Hours of experience	25	43.1%	
Rope access training certification	24	41.4%	
Other (please specify)	8	13.8%	

“Other” responses:

1. Experience falls under requirements for general specialty geotechnical work.
2. Training by a scaling supervisor or equivalent.
3. Number of projects. Ropes don’t have to be a certification, but some documentation of training.
4. Years of experience for foremen, months of experience or training program for scalers under supervision of foreman, first aid training for foreman.
5. Combination of all above.
6. Hours on similar access projects within a time limit of the last 5 years.
7. Require the company to be prequalified through an evaluation process.
8. Both years and hours of experience

**Question 7: Do you require a prequalified specialty contractor to perform scaling work?**

Possible Answers	Response Count	Response Percentage	Chart
Yes	34	55.7%	
No	21	34.4%	
Other (please specify)	6	9.8%	

“Other” responses:

1. No, our DOT contract folks do not like a prequalified contractor.
2. Not an owner.
3. Prime contractors must be prequalified but not subcontractors.

4. Prefer a prequalified contractor.
5. May vary by project.
6. May vary by project.

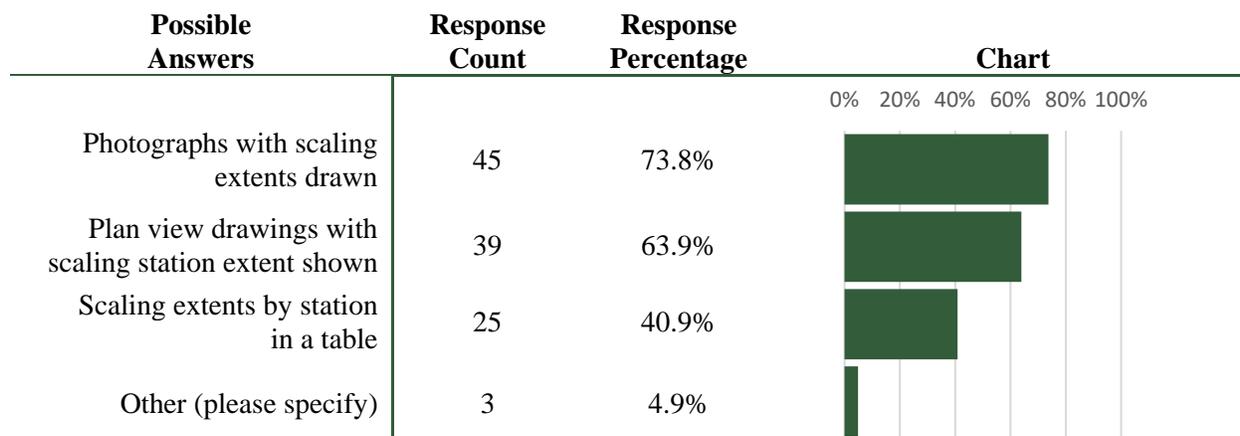
**Question 8: Do you specify scaling acceptance or performance criteria to judge when scaling is complete?**

Possible Answers	Response Count	Response Percentage	Chart
Yes	25	41.0%	
No	23	37.7%	
Other (please specify)	13	21.3%	

“Other” responses:

1. The slope must be accepted by the engineer.
2. We state that all loose rock shall be removed, and the final slope shall be accepted by visual inspection by the engineer.
3. To the satisfaction of the engineer (contracting officer). For this reason, we ask for unit prices.
4. Acceptance from the geotechnical office is required.
5. Scaling is “as directed” work under expert observation, direction.
6. Per the direction of the engineer.
7. Visual evaluation by onsite engineering geologist (working for owner).
8. At the inspection of the geotechnical specialist and to the satisfaction of the project manager.
9. A departmental geologist oversees scaling operations.
10. Based on judgement of the designer.
11. Visual inspection.
12. Scaling must be approved by construction project engineer.
13. Must be approved by construction engineer.

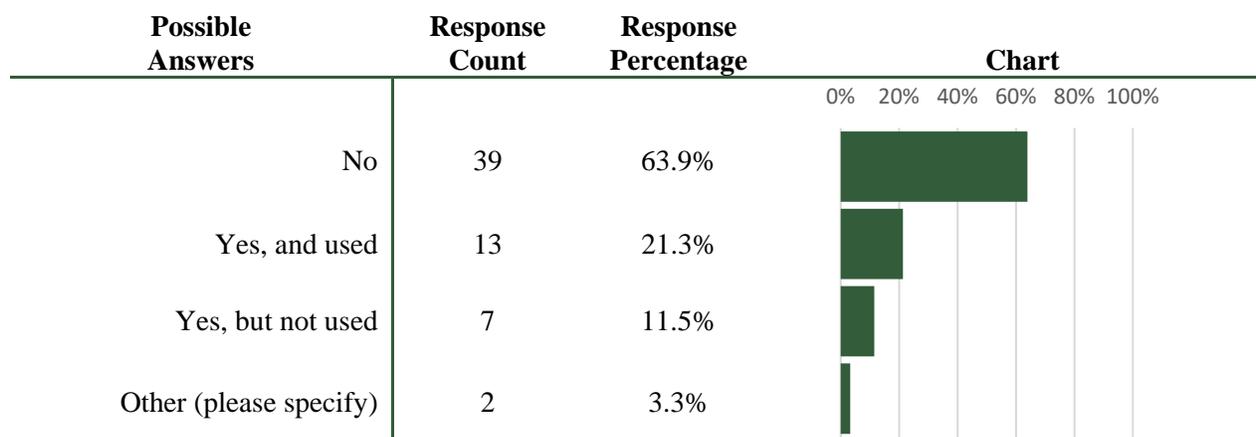
**Question 9: How do you delineate scaling extents in the plan drawings? (Select all that apply.)**



“Other” responses:

1. We use a combination of the photographs and also tables with station ranges. The photos work very well.
2. We have evolved to using the best method for the slope conditions, not just one method.
3. All of the first three.

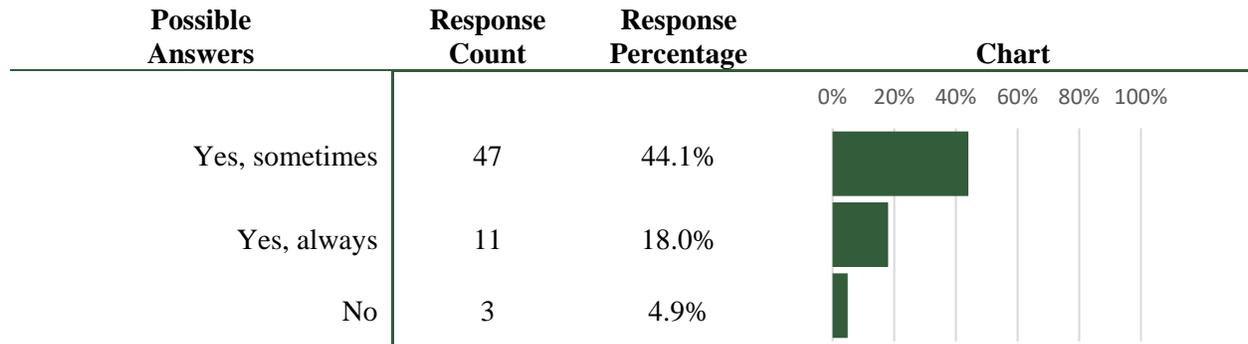
**Question 10: Have liquidated damages or incentives/disincentives been part of your scaling or rockfall mitigation-specific project specifications?**



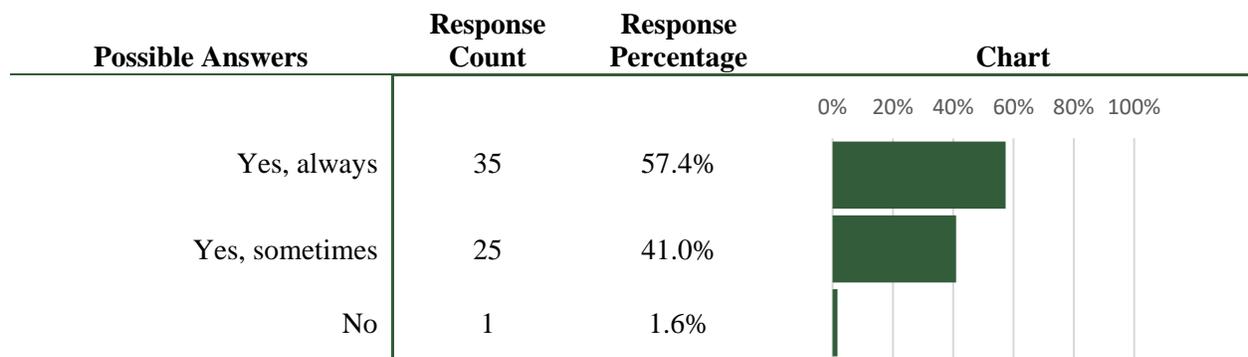
“Other” responses:

1. Not common; actually rare.
2. We include them, I am not sure if they have ever been used.

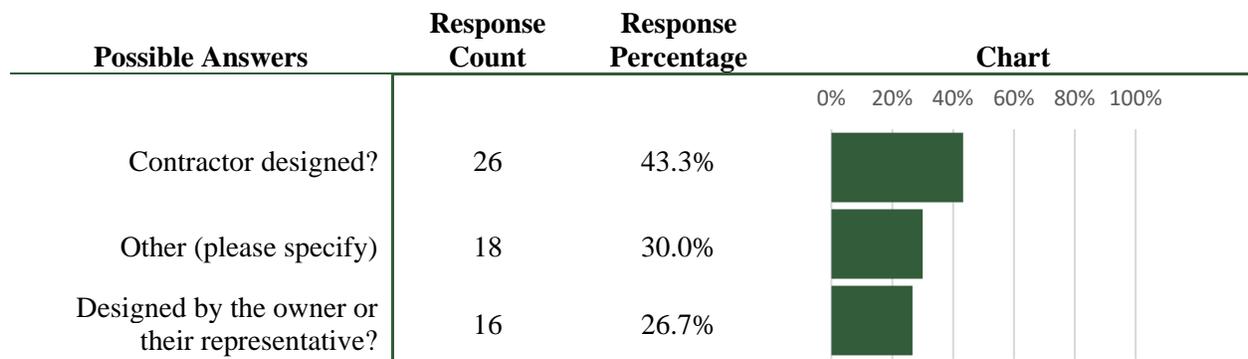
**Question 11: Do you require temporary pavement protection?**



**Question 12: Do you require temporary traffic protection?**



**Question 13: If yes for Question 11 or Question 12, is it**



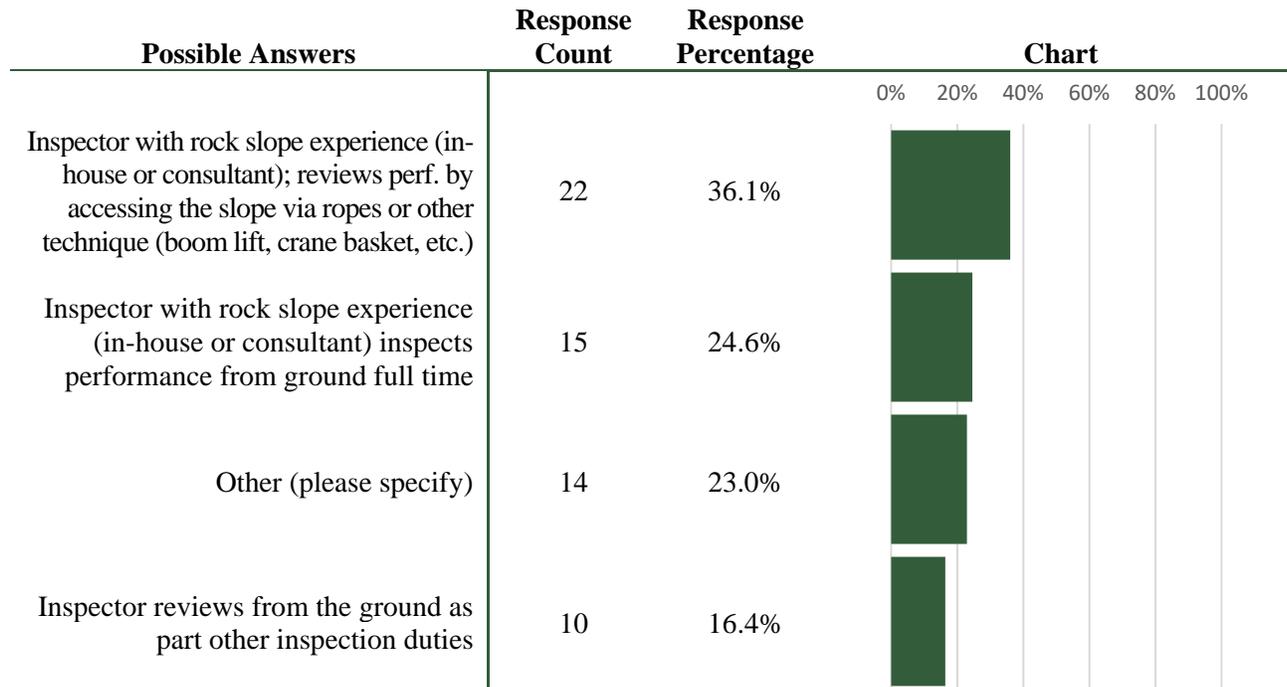
“Other” responses:

1. Traffic control specified by client. Pavement protection contractor–designer is held responsible for damage.
2. Have had both internal and contractor designed–provided.
3. Can be either.
4. Minimum height and length specified with the details to be designed by the contractor.

- 5. If it is traffic control it is designed by owner but for temporary protection it is generally designed by the contractor.
- 6. We have used both owner-designed and consultant-designed systems.
- 7. Contractor designed. Owner and project designer review and approval required.
- 8. Both contractor and owner designs have been allowed for different projects.
- 9. Contractor designed, but approved as part of a work plan submittal.
- 10. Owner–representative–designed when road is not closed.
- 11. Both, depending on the complexity and the risks associated with the temporary protection.
- 12. Have gone both ways on this.
- 13. We have used both owner designed and contractor designed, usually it is contractor designed.
- 14. Depends on the scale of the job.
- 15. We’ve done both. (Our agency owns a temporary rockfall barrier).
- 16. Both methods are used.
- 17. Contractor designed, but must be accepted by construction project engineer.
- 18. Contractor designed. Must be approved by project engineer.

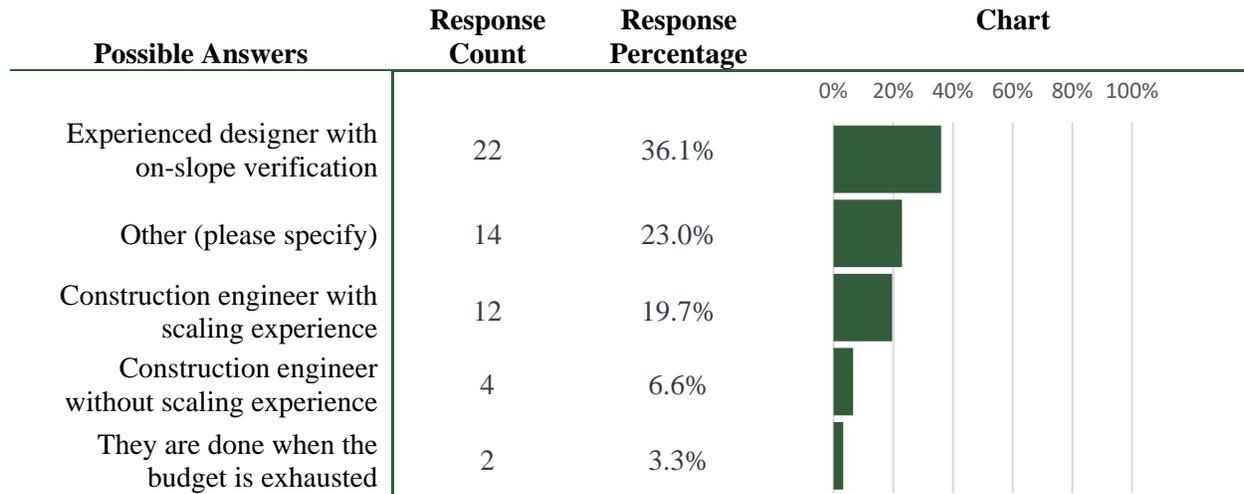
**Question 14: Do you temporarily hold traffic during scaling?**

Possible Answers	Response Count	Response Percentage	Chart
Yes, sometimes	34	55.7%	
Yes, always	27	44.3%	
No	0	0.0%	

**Question 15: How do you inspect scaling activities?**

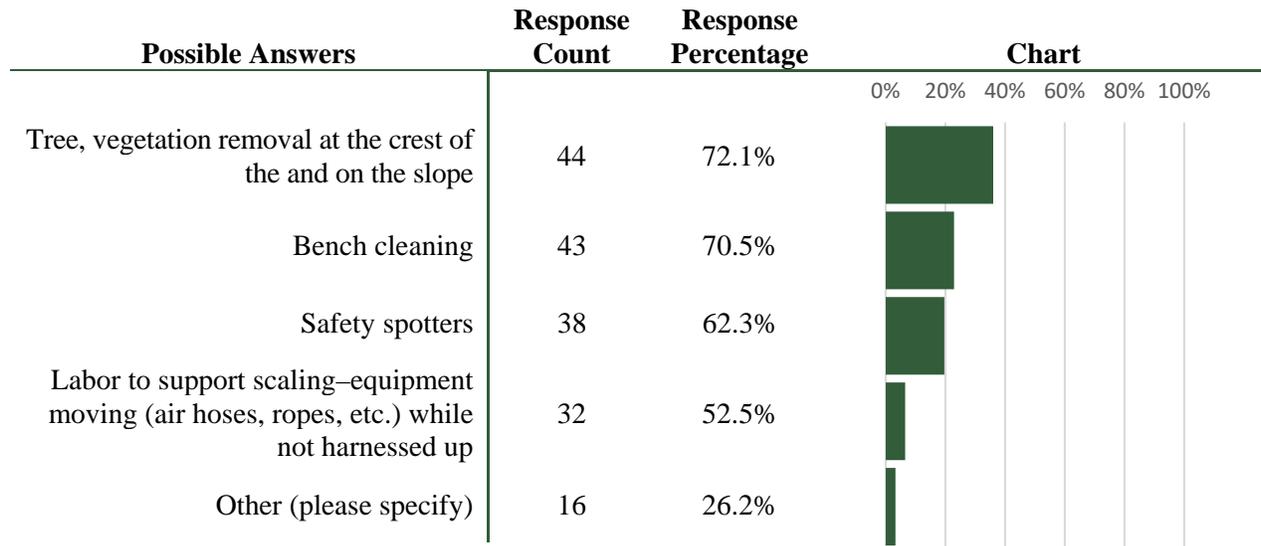
“Other” responses:

1. Combination. General inspector keeps up with hours after scope of duties is established. Final and period inspection by geotechnical staff.
2. Part-time inspector with rock slope experience.
3. All the above plus taking the contractors word that they sufficiently scaled the slope.
4. Both from ground or from slope by inspector with rock slope experience.
5. Inspected by person with extensive rock slope experience. Method based on their judgement of what is needed.
6. We have used all of the above at some point on different projects.
7. All of the above, depending on the project; most projects have inspection by an experienced geotech at some point during the work.
8. All of the above except depending upon situation.
9. Inspector with rock slope experience (consultant) inspects performance from the ground periodically and at the end of scaling. Inspection from boom lift or rope access if deemed necessary.
10. Combination of all three, dependent on the complexity and/or level of comfort of inspectors and the work being performed.
11. District geologist is on site.
12. Varies across the three options provided.
13. All of the above, depends on scale of job.
14. All of the above, depending on the specific project.

**Question 16: Do you temporarily hold traffic during scaling?**

“Other” responses:

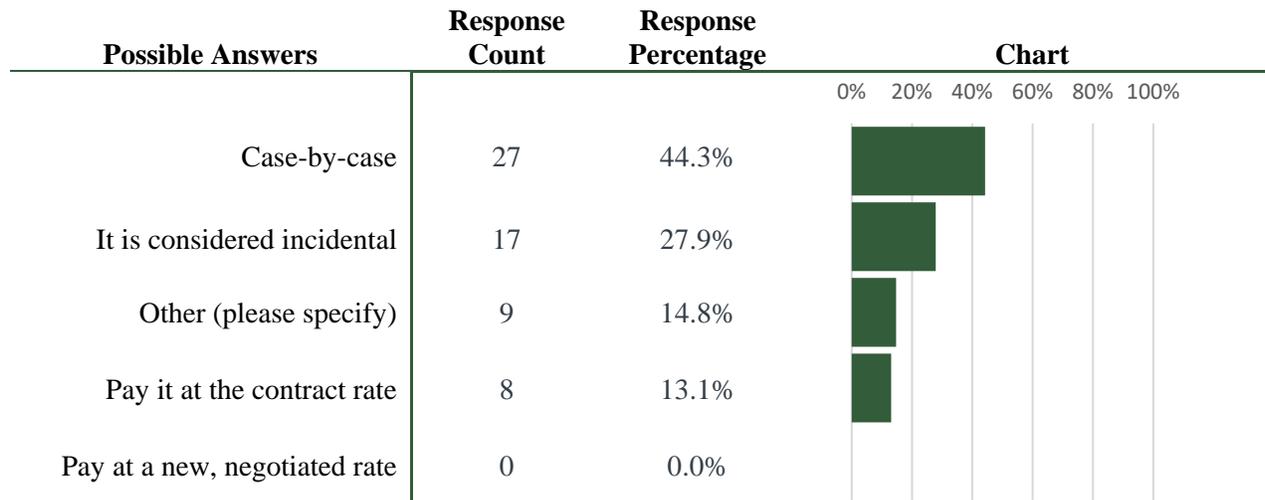
1. The construction engineer with recommendations from geotechnical office.
2. Construction engineer with experience with input from engineering geologist.
3. Department’s project manager.
4. Experienced rock engineer with methods determined by them.
5. All of the above.
6. Experienced designer w/on-slope verification; with concurrence of experienced department engineering geologists.
7. The construction engineer is ultimately responsible for acceptance, with input from geotech.
8. The construction PM accepts the work on the recommendation of the experienced designer.
9. Combination of project manager, geotech, or consultant with scaling experience.
10. In-house geotech–geologist at various stages of each slope.
11. In-house geologist.
12. Our construction guys accept it, but they usually call us (geotechnical) personnel to help them and provide guidance.
13. District geologist when available.
14. Usually the on-site inspector, experience level varies greatly.
15. Departmental geologist.
16. A, B, and C, again depends on the scope–scale.
17. Engineering project manager in consultation with the geotechnical section or our designee.
18. Construction engineer with geotechnical staff.
19. Experienced designer with man lift verification and/or ground verification.
20. Construction project engineer based on expert consultant.
21. Construction engineer based on recommendations of expert consultant.

**Question 17: What tasks are measured and paid as “scaling?” (Select all that apply.)**

“Other” responses:

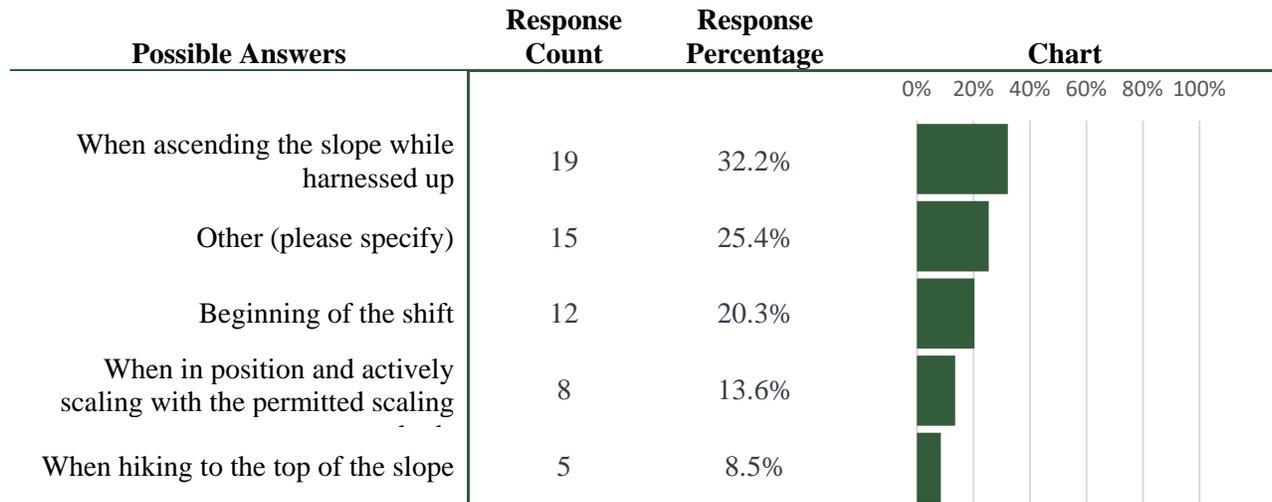
1. Soil removal too using blow pipe or manual methods.
2. All the above depending upon how the construction engineer want to administer the contract.
3. Checked above are incidental to the scaling rate. Veg removal may be a separate pay item. Colluvial scaling (e.g., sloping back soil at the slope crest) may be a separate pay item from rock scaling.
4. Difficult to understand what this question is asking.
5. All of the above.
6. Support work (handling hoses, air bags, rope) while on rope but not necessarily removing rock.
7. All incidental tasks incurred during scaling except vegetation removal and MPT.
8. Installing anchor points for scaling ropes.
9. Minor mesh repairs incidental to the scaling work.
10. All of the above.
11. All of the above have been argued into payment by contractor to at different times to different owners.
12. Include a foreman (spotter, scaler) on the ground for safety and to communicate with department geologist.
13. Installing mesh.
14. Anytime debris–vegetation is being removed from the slope. Paid during installation of scaling anchors when trees or other tie-off points are not available.
15. Removal and haul of scaled debris.

**Question 18: How do you handle “safety scaling” requested by the contractor not required in the plans?**



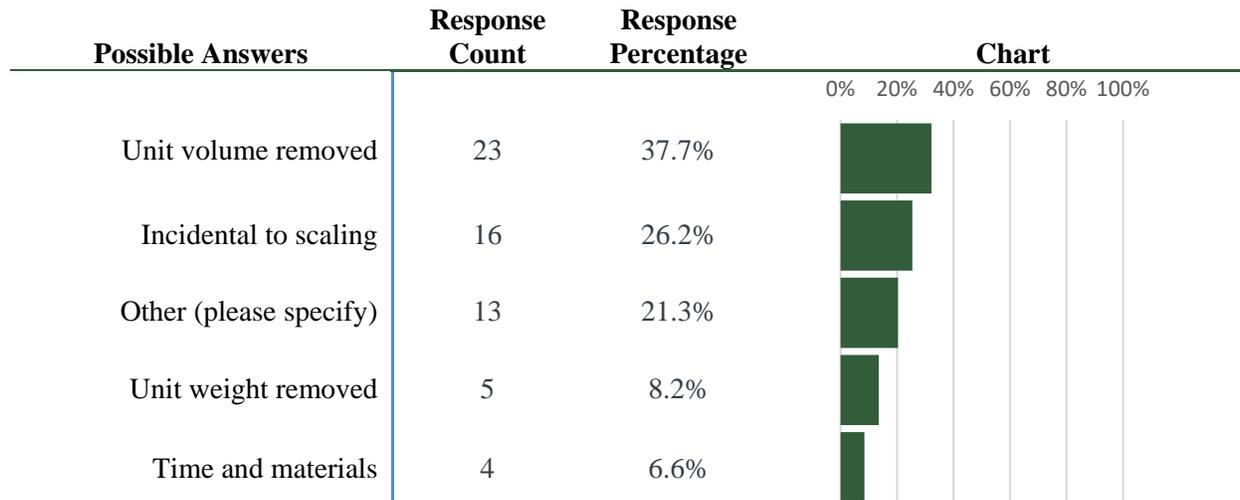
“Other” responses:

1. Pay at the contract rate, geotech staff and contractor agree on general realistic quantity.
2. It is usually paid at the contract price, as long as there is a bid item for it. If not, the construction engineer negotiates a price under force account.
3. All my work involves scaling by rope access. This means that the scalers have to be comfortable working below everything. This means they will have to scale anything that is above them. As a result, I always include scaling up to the crest as part of the work.
4. Not applicable to date.
5. One of the first two. An area should be checked for safety prior to crews working under a rock slope.
6. All of the above, depending on project.
7. Generally incidental, but can be case-by-case as needed.
8. Paid at contract price if work is approved by construction project engineer.
9. Pay at contract price if work is approved by construction engineer.

**Question 19: If paying by the hour, when does the measurement ‘start’?**

“Other” responses:

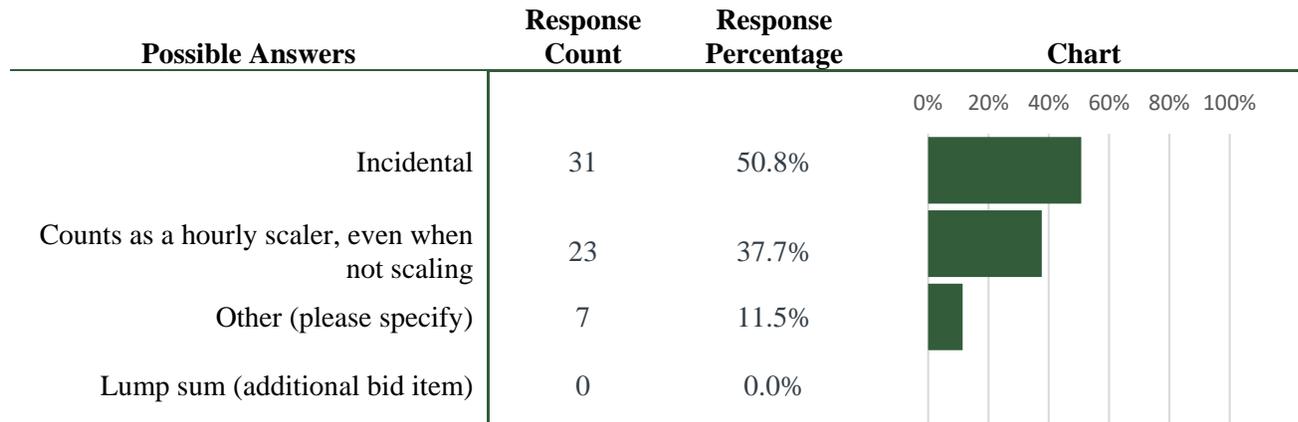
1. Not sure.
2. All the above are possible in addition to letting the traffic pass while scalers remain on the slope not scaling. It depends upon how the construction engineer wants to interpret the contract.
3. Do not pay by the hour.
4. Not applicable to date.
5. Beginning of a shift. Safety briefings (tailgates) are part of the project.
6. All of the above.
7. When in position and actively scaling or waiting on traffic holds but not when ascending or descending slope for the day.
8. Not paid by hour.
9. Varies by construction engineer.
10. When rope rigging for scalers starts.
11. Case-by-case depending on what contractor can convince owner to pay, regardless of specifications used.
12. Variable, but should be at beginning of the shift as long as the crew is actively preparing to begin work.
13. When scaler is equipped and starts to climb the slope.
14. When scaler is equipped and begins to climb the slope.

**Question 20: How do you measure and pay for removal of scaling debris?**

“Other” responses:

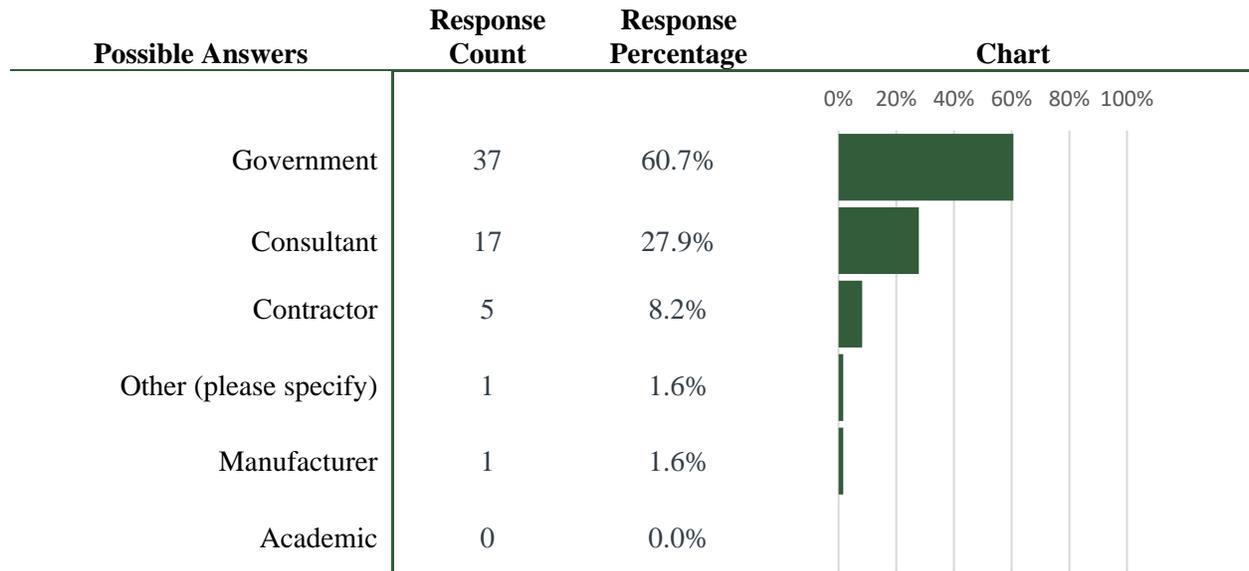
1. All scaling has been done under prime grading contractor or removed by in-house maintenance. Prime typically paid by volume.
2. Scaling typically part of larger project. Debris removed by GC, paid by CY.
3. Both incidental and volume depending on owner–client.
4. All of the above.
5. Unit volume removed or equipment hours (time and materials) depending on the project.
6. Either unit weight or volume, specified as volume in plans.
7. Project specific.
8. Incidental, unit volume, or time and materials, depending upon situation.
9. Depends on contract. Unit weight or T&M are most common.
10. Incidental or by volume/weight.
11. Unit volume when contracted, mostly with department maintenance equipment and personnel.
12. Been done by multiple means depending on the slope.
13. Weigh material and convert to volume for payment.

**Question 21: How do you pay for the foreman coordinating scaling activities?**



“Other” responses:

1. The foreman is part of the scaling crew that is paid by the hour.
2. They are a vital part of the crew. Not paying for them is like asking a consulting company to have a design only done by their lowest level engineers and not paying for senior review.
3. All of the above.
4. Hourly as long as foreman is acting as spotter or other task directly related to scaling.
5. Paid for separately by the hour.
6. Paid as part of the specified crew, usually two on the slope, one (foreman) on the ground.
7. Hourly, but as safety spotter too.

**Question 22: Please identify your affiliation.**

“Other” response:

1. Now consultant. Previously owner equivalent to government.

## Case Histories of Scaling

### *Successes and Improvement Opportunities*

#### **LIBBY, MONTANA, AND MDT DISTRICT 3 INTERSTATE 15 ROCKFALL MITIGATION**

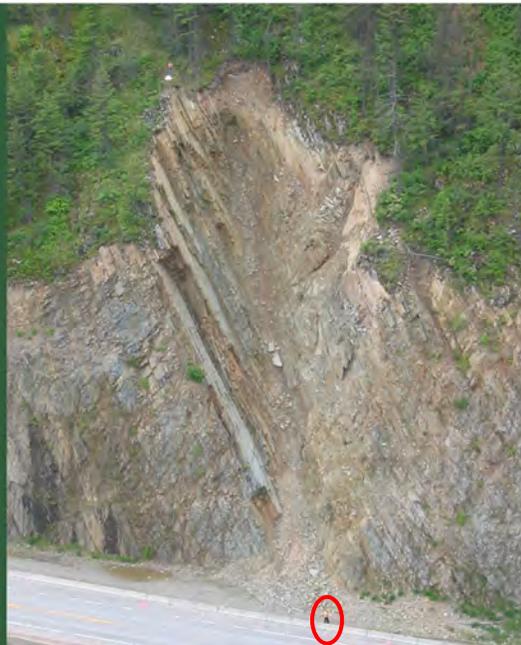
**Brent Black**

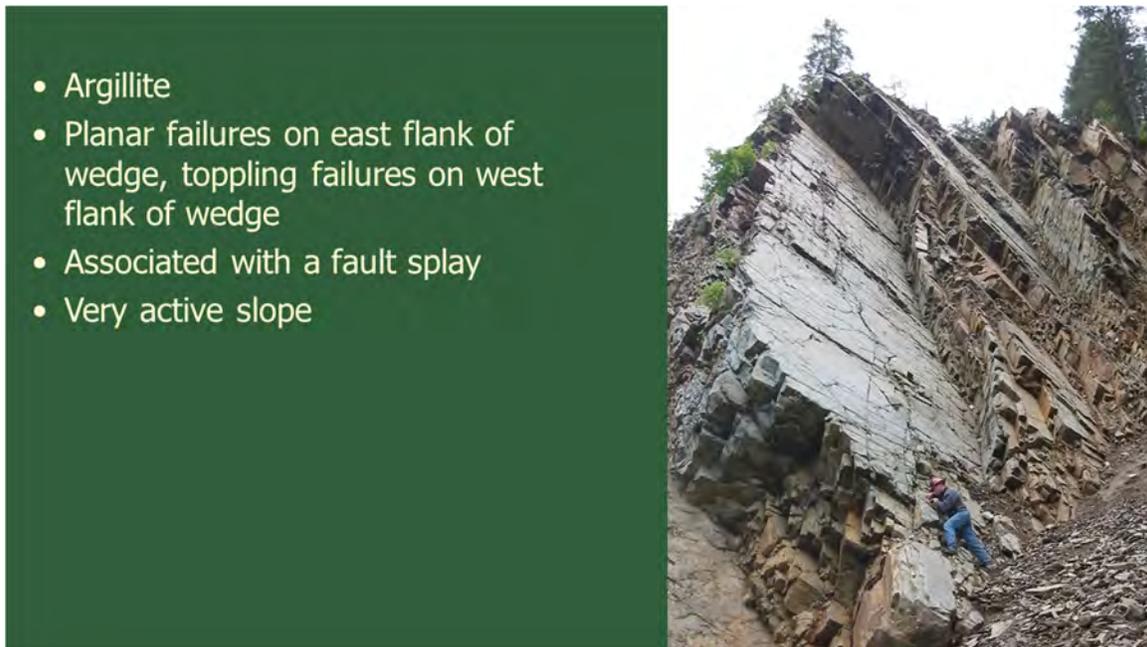
*Landslide Technology*

The original cut slope was 125 ft tall. The failure had retrogressed 130 ft into the slope and the height of the slope at the back of the wedge was nearly 200 ft. To give a sense of scale, there is a person at the bottom right-hand side of the failure.

#### U.S. Hwy. 2 – West of Libby, MT

- Original cut 1992 (125 ft. tall)
- Wedge failure retrogressed beyond the crest (130 ft. into the slope) by 2002
- Back of wedge ~ 200 ft. above road grade
- Scaling performed in conjunction with other rockfall mitigation measures





Description of the site geology and slide mechanisms. View looking at planar failures causing rockfall along the left flank of the larger wedge failure.



This project called for significant scaling effort. Limitations included 20-min road closures. The queue typically cleared in 10 to 15 min, but regardless, would hold traffic after 20 min. Even though there was a sizeable ditch (30 ft), the contractor brought an MRB (moveable rockfall barrier) to help minimize rock cleanup in the road before traffic was let. This MRB was loosely based on an old Washington DOT design (FRB mounted to steel plates).

- Significant amount of rockfall debris was scaled from slope



There was a significant amount of rockfall debris generated during scaling. The MRB was effective but not tall enough to keep all of the scaled debris off of the road. It also had to be repaired numerous times during the scaling effort.

- MRB extended 8 ft. using gabion mesh and geotextile was added to control rock splatter



Quickly, the contractor realized he needed to improve his temporary rockfall protection (TRP) and added an 8-ft extension with gabion mesh and geotextile to help control splatter.



Scaling at the crest of the slope.

- 383 Scaling Crew Hours (3 scalers and a working foreman)
- 3.5 cubic yard per scaling hour
- Amount of material removed from scaling
  - Approx. 5,000 cubic yards

Production of over 3 yd<sup>3</sup> per scaler per hour is quite high. This depends on the geology and rock mass characteristics found at the site, but the scalers on this project knew what they were doing as well.

### I-15 between Helena and Great Falls, MT

- Six sites between 100 to 400 ft. tall, 400 to 1,400 ft. long
- Argillites (bedding daylights towards roadway)
- Scaling performed in conjunction with other rockfall mitigation measures



### Traffic Control/Temporary Rockfall Protection

- These items go hand-in-hand!
- Limit Periodic Road Closures
- Let traffic pass during scaling.
- Incentives/Disincentives
- Traffic Control and Temporary Rockfall Protection Work Plan



One of the directives received from the state was to limit road closures (closure of two lanes with crossovers was acceptable). The vast majority of scaling occurred while traffic was running, but traffic was periodically held while scaling was performed high on the slopes when the chance of rockfall reaching the traffic lanes was possible. An incentive–disincentive was added to the contract regarding the number of days that periodic road closures could occur. Rockfall potential from the slopes above where cars were stopped in the queue had to be considered during the design phase.

## Moveable Rockfall Barriers (MRBs) and Rock Containment Nets (RCNs)

- Perform all on-slope work with a MRB in-place.
- On-slope work other than scaling conducted less than 50 vertical feet above roadway without MRB if demonstrated not to represent a hazard to traffic.
- Allow traffic to pass when scaling less than 150 feet vertically above the roadway if MRB and RCNs in-place.
- Stop traffic in both directions for up to 20 minutes for all scaling conducted more than 150 feet vertically above the roadway (this is where the incentives/disincentives came into play).



For this I-15 MT project, the TRP was specified. A MRB is a flexible rockfall barrier mounted on steel plates that can be dragged by a loader (moved along, parallel to the slope to keep it between the active work zone and roadway). RCNs (rock containment nets) are 50 ft wide with 100-ft-long cable nets suspended from large cranes. They are held in front of the MRBs to knock down high-flying rockfall.

## Scaling

- General
- Heavy
- Bench cleaning
- ~4,000 Scaler-hours
- Used ~75% of the hours allocated



The contractor did not get close to using all of the allocated scaling hours, a rarity in our experience. It is possible that the road closure incentives–disincentives may have played a role in this.



This I-15 MT project was unique. Due to the directive to limit road closures, and knowing that most of these slopes were draped with either high-tensile strength mesh or even higher strength attenuator fences, the scalers were ask not to worry about small rockfall and concentrate on larger blocks that had the potential to damage the draped mesh systems. They also had to scale rocks that represented a hazard to themselves when they were scaling. These condition also factored into why only 75% of the scaling hours were utilized. However, the additional time to scale the entire slope, if required, needs to be accounted for in the quantities.

### Heavy Scaling

- The other 30% of the scaling.
- Potential for major damage if not removed.

Combination Of:

- Hand scaling
- Air pillows
- Boulder Busters
- Mechanical

PHOTO 3-4 : HEAVY SCALING AREA  
STA 146+40, 98 FT. EL. 4032

Over 1,000 h of the allotted scaling hours were for heavy or intensive scaling on the I-15 MT project. These hours were for the removal of bigger, more hazardous rock blocks that had

the potential to damage the draped mesh systems to be installed. This particular block was also located above a bridge.



Heavy scaling generally means the rock is removed. Mechanical scaling techniques included air pillows and boulder busting techniques. This particular rock mass took approximately 200 h to scale. It is necessary to account for such focused significant efforts in estimated quantities.

- 1 cubic yard per scaling hour
- Amount of Material Removed From Scaling
  - Over 5000 tons
  - Approx. 3,000 cubic yards

Overall, averaged 1 yd<sup>3</sup> per scaler per hour. This varies depending on geology, site conditions, and contractor's abilities.

## NEW YORK THRUWAY AND TENNESSEE PROJECT

**Pete Ingraham**

*Golder Associates*

Two projects are discussed where inappropriate measures or a lack of oversight impeded projects. The first project was on the thruway that involved machine scaling with an excavator that was completed unsupervised. The results led to over-excavation and destabilization of a slope. To restabilize the slope was costly and unnecessary if the scaling had been done correctly.

NY Thruway Rock Slope above Yonkers Toll Plaza

- Machine scaling
- Operator arrived one hour before Thruway Geologist
- Aggressively mined weak rock formation destabilizing the slope
- Repairs added \$800k to the work.



The limits of the project had to be extended a couple hundred feet because of the damage to the slope by the machinery—the cost overrun was approximately \$800,000.

Today the slope looks relatively unremarkable, but its stability and unremarkable appearance came at a high cost. The takeaway is that experienced scaling contractors are the best bet, and pre-qualifying and holding a kick-off meeting is essential.



As noted early on in this e-circular, the most common and preferred type of scaling is “hand scaling” that is done by trained technicians using rope access. Many heavy construction and earthmoving contractors lean toward machines to “bludgeon” the slopes and knock loose rocks off. In many cases they knock rocks off but leave a damaged slope behind that will shed rocks for a long time as the slope goes through storms and freeze–thaw events.

Bludgeoning Methods.....slopes will lose rocks for years to come.....



- Using crane and steel beam/old blasting mat



In some cases contractors try to work from the crest of a slope reaching over the top with an excavator or dragging a chain, surplus dozer tread or other heavy object across the slope face to loosen and remove rocks. In the case of excavators reaching down from the crest, if a large

mass of rock comes off the slope face and pulls sharply on the bucket, the excavator can tip forward or tip over.

### Working blind – not a thorough job



- Using excavators and old tractor tread or old chain



### Ocoee Gorge Tennessee – Slopes repaired by a Paving Contractor



In 2009, a major slide occurred on Route 64 in Ocoee, Tennessee. A paving contractor was retained to complete slope repairs. The contractor had experience with landslide repair, but felt that a large crane was the best equipment to use for the construction of repairs.

### Ocoee Gorge Tennessee – Slopes repaired by a Paving Contractor

- High Scalers using “fall protection”
- Safety rope held by supervisors hand....



The contractor’s laborers were not trained in rope access although DOT and engineering staff were all on rope rappel. In one case the rope tie-off for the contractor’s laborers was to a supervisor’s hand, who held the fall protection lanyard. This approach is not recommended.

### Ocoee Gorge Tennessee – Slopes repaired by a Paving Contractor

- Poor safety measures
- Improper tools (pinch point bars)
- Untrained personnel



Scaling personnel were using hand shovels and pinch point bars weighing much more than a mine scaling bar, decreasing production rates by using nonstandard and less-effective tools.

Improvised barriers and nonstandard equipment were used throughout the work.



The contractor relied almost entirely on a large crane for slope access, limiting the amount of work that could be done at any given time to the number of people and pieces of equipment that could be hoisted on a platform by the crane. Only one operation at a time could be completed and the schedule dragged out as a consequence. Other concerns were for the safety of personnel below, including the crane operator as the site was scaled.

#### Ocoee Gorge Tennessee – Slopes repaired by a Paving Contractor

- 180-Ton Crane for access.
- Intended use also for scaling
- Reach limitations – in the line of fire for falling rocks



The contractor tried bludgeoning methods with a crawler tread, but found the usual tools were not efficient with a 180-ton crane and the large rock blocks found on site.

Ocoee Gorge Tennessee – Slopes repaired by a Paving Contractor

- The crawler tread was too small.....



A nonstandard scaling method used was a yard cable using a deadman's block at the toe of slope and a cable pulled by a caterpillar 960 loader. This was used until the cable broke. Reportedly a similar cable break led to a fatality on a similar project a few years earlier.



The contractor planned on using this lightened bucket to rake the slope; however, Tennessee DOT realized the unsafe potential for a large rock to fall into the bucket that would overload the crane jib that could result in the crane collapsing. Tennessee DOT did not allow this technique to be used.

#### Ocoee Gorge Tennessee – Slopes repaired by a Paving Contractor

- You must be kidding.....
- Danger of large block falling into bucket suddenly loading the crane – cannot calculate load ahead of time – potential crane collapse
- Crane must work in danger zone to avoid over-reaching.



Another high-scaling technique used on this job with the crane involved a small excavator with a hoe ram suspended on a platform against the rock face. The platform was stabilized with tag lines held by workers standing at the toe, near to where falling rocks were landing in the roadway (as shown below).



As noted, the crane operator, machine operators and laborers holding tag lines for the crane platform are typically in the “line of fire” or in other words, unsafe, in jeopardy of being hit by falling rock, as shown in the image below (note red arrow pointing to falling rock).

Ocoee Gorge Tennessee – Slopes repaired by a Paving Contractor



Beyond the production bottleneck caused by reliance on a single crane for many activities on a project (e.g., scaling, blasthole drilling, loading and shooting, and rock bolting in sequence), operating from a platform can be dangerous. Rockfall into a scaling bucket—or the fall of a block being drilled transferring its weight to the drill mast—can suddenly and catastrophically load the crane with potentially fatal results.

The bullet points in the following slide are the key considerations learned on this project.

Ocoee Gorge Tennessee – Slopes repaired by a Paving Contractor

- Drilling/blasting done from a platform/lift,
- Consider detonators and charges in a lift basket together....
- Consider a block failing during drilling—suddenly loading the drill mast/platform/crane with several tons of rock.....
- Specialty contractors with on-slope drills and methods a better choice.
- Project probably took longer than needed due to methods used.

## **GLITTER GULCH, PARKS HIGHWAY, ALASKA**

**Darren Beckstrand**

*Landslide Technology*



Rockfall Case History: Parks Highway, between Anchorage and Fairbanks, Alaska. Slopes are in Nenana Canyon, between the entrance to Denali National Park and Healy, where seasonal workers reside between shifts.

### **Specifics**

- Scaling was result of a 'different site condition' on a paving contract
  - Changed condition was documentation of potential slope hazards
- Construction engineering personnel had limited experience with scaling
- Owner does not perform many rockfall mitigation projects

When the issue first appeared, the Alaska Department of Transportation and Public Facilities (DOT&PF) and the contractor were engaged to resolve the problem to finish the contract. A formal claim did not develop.

Worker safety was a concern during paving, DOT&PF requested assistance from federal technical resources. The resulting trip report and documentation was deemed to constitute the different site condition, triggering rockfall mitigation work consisting mainly of scaling loose rock and overhangs.

## Specifics

- State's design, through consultant designer, was fast tracked after unsuccessful contractor/contractor's engineer submittal.
- Commercially sensitive location between Denali Nat'l Park entrance and location of seasonal staff housing required night scaling and minimal closures
- Scaler qualification requirements not enforced, rather most were apprentices

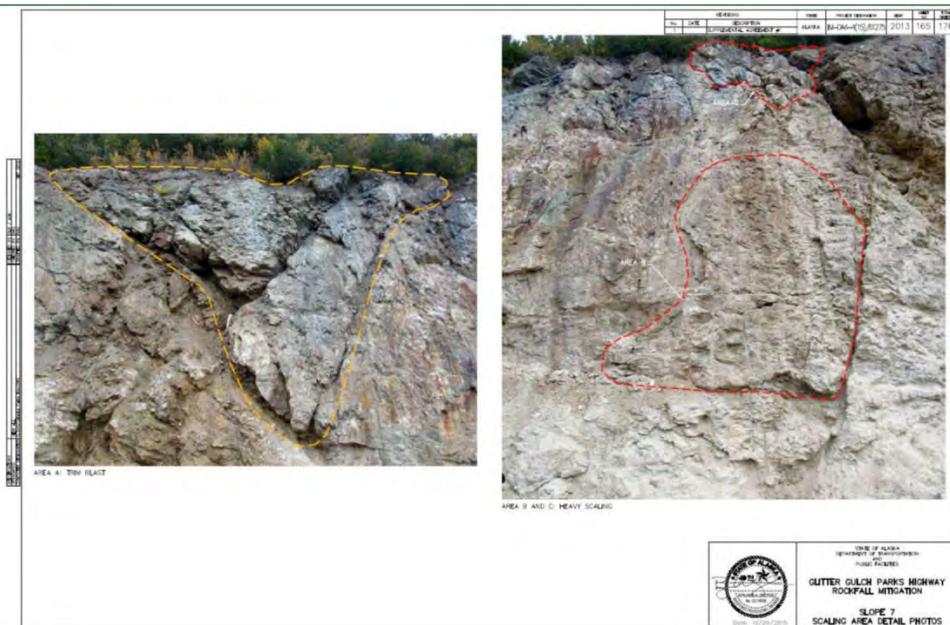
Assistance with design, plans, and specifications was requested. Rapid turnaround time of about 2 weeks from field work was desired.



This is one of four slopes that was worked on, out of five that were originally scheduled for mitigation work. Work on one of the slopes was eliminated after additional modeling. Ditch cleanout work reduced the safety risk, while slow production rates and high unit costs reduced the value of performing the work.



Sample plan sheets to illustrate scaling extent are shown. The black line indicates general scaling area, red dashed lines indicates heavy scaling area, orange indicates trim blast–blast scale areas.



Detail sheets for trim blasting (left) and heavy scaling (right) shown above. Note the poor rock quality and major features that have eroded at different rates, leading to overhangs and potential instability of larger areas.



Heavy scaling area shown in image above.



Trim blast area (left) and heavy scaling of tension cracks (right).



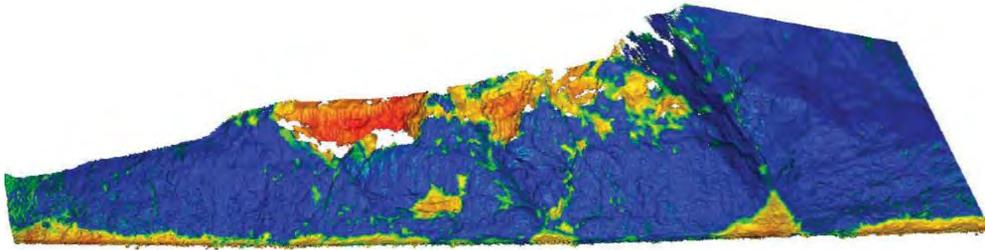
Scaling occurred on 24-h basis, using long days during summer with supporting light plants, and intermittent breaks during traffic. Nearly all work occurred from ropes (as shown in the above photos). Alternative methods (crane, lift, etc.) were suggested, but rejected by the contractor.



Connex boxes with ballast and concrete barrier backing served as protection to keep majority of rock off the road. Traffic was halted during active scaling.



Trim blast results at the slope crest.



Point cloud surface model difference exhibiting (in red) where most rock had been scaled or blasted off.

## Results

- Hazard was reduced to satisfaction
- Some heavy scaling areas low on the slope eliminated
- Jersey rail added as ditch effectiveness improvement
- 1,349 scaling hours at this one site
- Production rate of ~3.8 sq ft per hour

## Questions

- How could cost overrun risk be limited in this situation for Owner?
- Could have publications exhibiting historic production rates demonstrated exceptionally slow performance?
- Can/should slope access method (cranes, lifts, etc.) be directed when production is unsatisfactory and access is cited as a cause?

Persistent questions that challenge owners are highlighted by this project.

## NEW HAMPSHIRE CASE HISTORIES

**Krystle Pelham**

*New Hampshire Department of Transportation*

### NH Case Histories

- NH approach is to rock slope remediation is reactionary
  - Lack of programmatic funding
  - HSIP/Betterment/maintenance (rental agreements)
- “Proactive” work is completed in conjunction with pavement rehabilitation projects
  - Hand scaling/machine scaling
- Assess service life of resin grouted rock reinforcements



Rock slope remediation contracted by the New Hampshire DOT tends to be on a reactionary basis due to the lack of programmatic funding. Relative to this workshop, hand scaling and machine scaling have been part of the department’s contracts for almost the past 20 years. (Note: HSIP = highway safety improvement programs.)

### Experience in three Categories

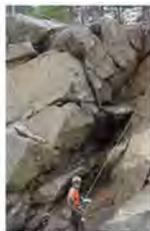
- Safety/qualifications
- Performance
- Cost



The departments approach on specifying this work has evolved over time to begin to address safety, the qualification of the subcontractor performing the work, performance, and the cost of the work.

### Safety/Qualifications

- Method of rope access is not specified or certification/training program
- Years of experience per individual is required
- Contact hours can be inconsistent due to personnel having a change in careers
- Inconsistent tracking of personnel experience – can be a challenge to validate or ensure they are qualified



The method of rope access is not specified in our contracts nor is the specific certification training program. New Hampshire DOT has evaluated these criteria but because there are no specific rope access training for the industry, the Department has elected not to use this as a qualification requirement. Often New Hampshire DOT believes that rope access is less invasive and will minimize the permits required compared to using heavy equipment, and work is approached more cautiously and avoids destabilizing an entire slope. Historically, years of experience is the method of measuring experience requirements in the specifications. Requiring minimum years of experience can be inconsistent as personnel may have a change in careers resulting in a break of time that may or may not be duly documented. Various methods of tracking personnel experience make it difficult to validate that the experience requirements in the contract documents are met.

### Performance

- Variability (production rates)
- Safety scale vs. service life
- When to stop how much to remove
- Machine scaling – General (paving) contractors typically do not have expertise or experienced operators for this workers or understand the intent



Relative to performance, work completed under the scaling specification has been quite variable. To execute the intent of the contract it is critical to have experienced geotechnical staff on the construction site to have the conversation with the contractor to reach a mutual understanding of expectations. Inevitably the conversation of when to stop and how much to remove occurs on any given job. Additionally, there are many interpretations of the scaling requirements, and intent is important, whether scaling is performed to ensure a safe work environment for the installation of rock reinforcement or other instrumentation, or if it is to obtain the expected service life from a hand-scaled slope.



Machine scaling frequently used in contracts with slopes with significantly lower heights is often completed by the general contractor and by their everyday machine operator who are not specialists in rock slope remediation. They may not understand the intent of the work and may require significant input by the geotechnical expert to successfully complete the work.

### Cost

- Per man hour (4 man crew – each with years experience)
- Crew hour (specifying 4 man crew)
- One contract back in 2009 language adjusted : Prime contractor shall perform work amounting to no less than 35% of the total bid amount (lowered from 50%)
  - Resulted in unbalanced bid with hand scaling at \$1,000+/-/man hr



Bid prices for scaling work can vary when the general contractors lack an understanding of the scaling work required. At the time of bidding, they may not know who the specialty contractors are that meet the requirements. Varying the method of measurement used to request the different type of work in the contract may achieve the desired outcome and result in more consistent bids and estimates.

### Summary

- Hourly rate works well
- Investigate adding provision for apprentice
  - Experience requirements do not guarantee adequate performance/production
- Involvement from design through construction into maintenance proves greatly beneficial
- Scaling and installation of rock reinforcement should be done by the same contractor
- Clearly define limits and expectations followed by inspection of ongoing work



In summary, rock slope remediation work, specifically scaling has worked well in New Hampshire when paid by an hourly rate with specific experience requirements for the individuals or contractor. Modifying the requirements to allow new personnel to enter into the industry and perform work on DOT contracts is advantageous to the industry. Based on the contracts New Hampshire DOT has completed, it is important that all the rock slope remediation work within a given project be completed by the same specialty contractor. The idea of a safe work zone may not be the same or consistent between two different entities. This could result in an unanticipated increase in cost or items required on a given DOT contract due to a different interpretation by construction personnel. The limits of scaling work expected, at least a description of the anticipated results, in conjunction with inspection of the work by qualified, experienced geotechnical staff is required to achieve proper execution.

## Designer, Owner (Geotech and Resident Engineer), and Contractor Perspectives

### DESIGNER PERSPECTIVES

**Pete Ingraham**

*Golder Associates*



A recent project involving a large scaling project above a sensitive structure included scaling loose materials by hand, and some machine scaling with a slusher—a small dragline-type apparatus that rakes and plucks loose rocks from a slope. The project afforded an opportunity to assess the amount of minor rockfalls that occur after hand scaling and machine scaling. The slope was roughly 1,200 ft long and 325 ft high, and had been blasted from an old coal mine highwall. At the slope toe is a leachate lagoon that is lined and armored with fabric and grout called “fabri-form.”



At the slope toe is a perimeter ditch and the drape was installed to address safety concerns for employees that have to clear debris in the ditch as well as maintain the lined leachate pond during the life cycle of the facility.



The owner selected a wire mesh solution for the project to protect site workers. Large blocks that could damage the mesh were bolted and dental shotcrete (small amounts to fill voids) and structural shotcrete buttresses (shotcrete that stabilizes rock blocks, as opposed to cosmetic shotcrete applied for aesthetics) were constructed to help keep large blocks in place. During

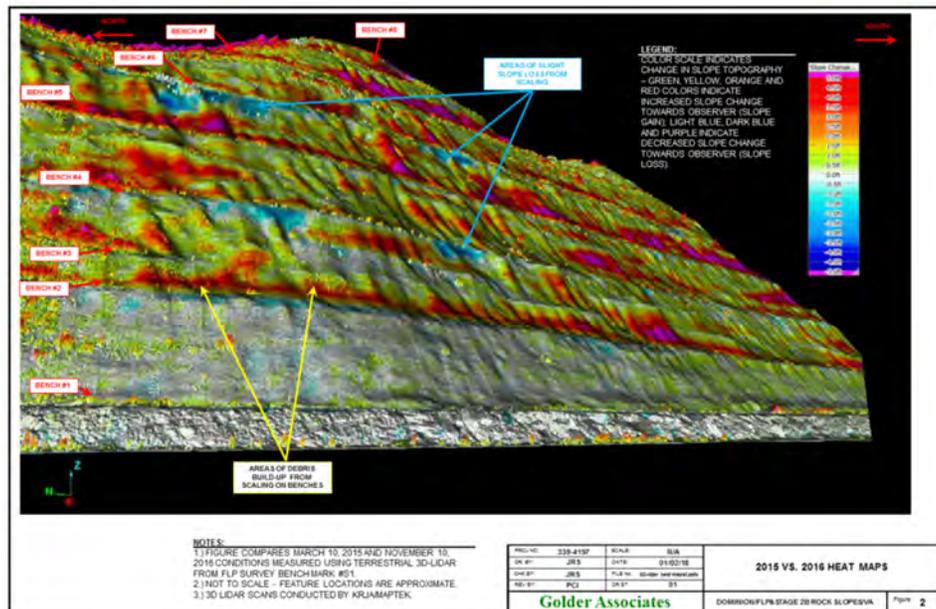
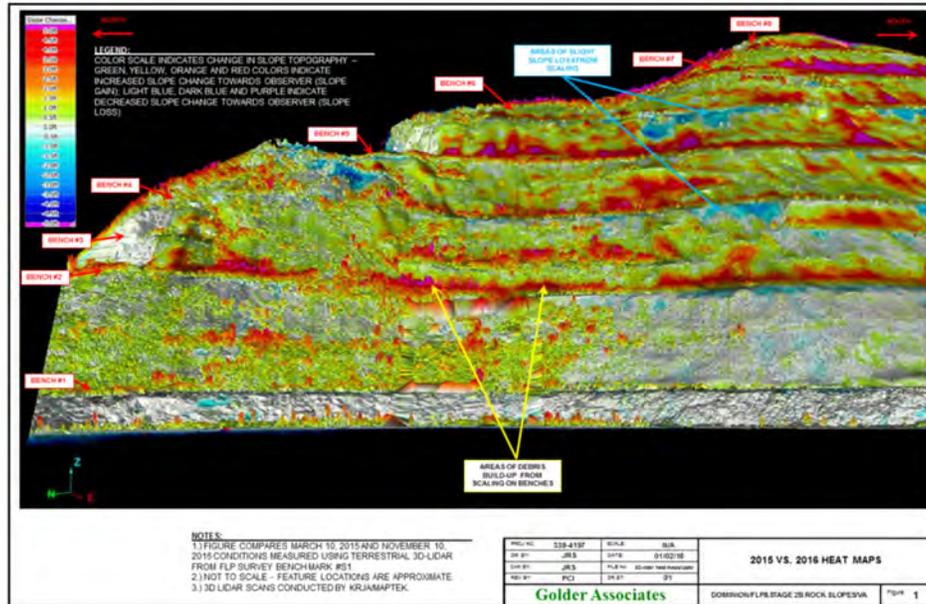
scaling, a temporary barrier was installed to protect the leachate pond lining, and blasting mats were placed over the concrete bottom of the perimeter ditch to protect the concrete from damage.

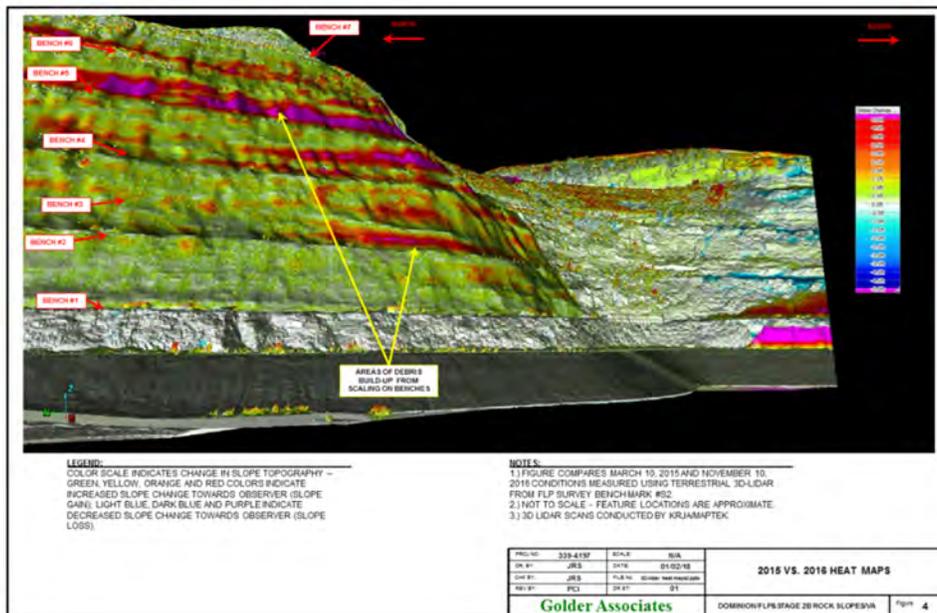
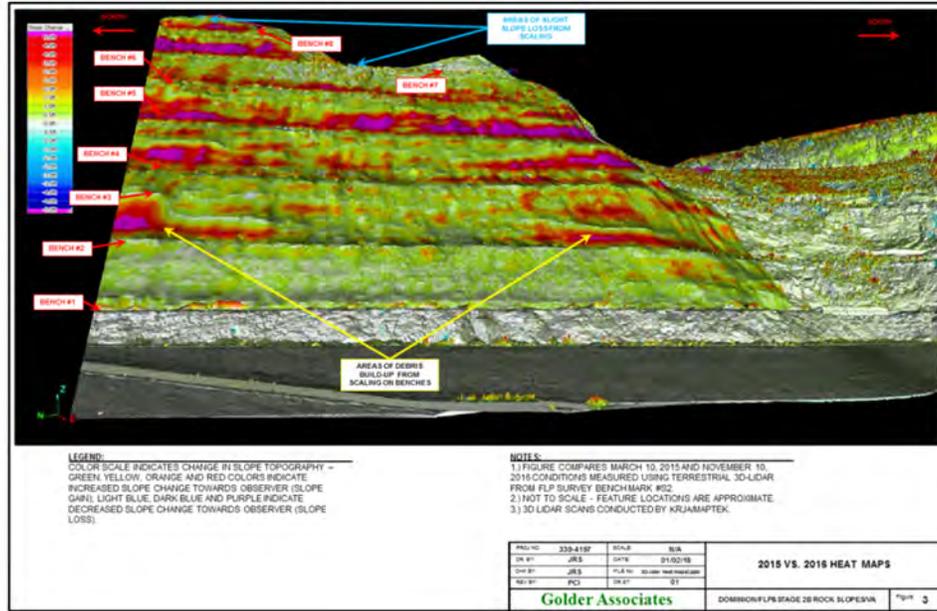


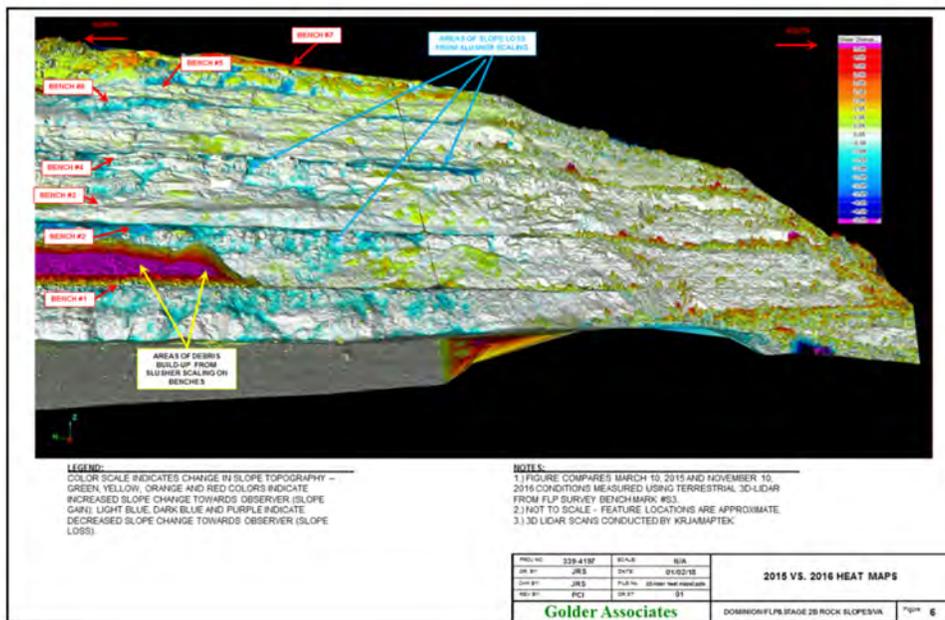
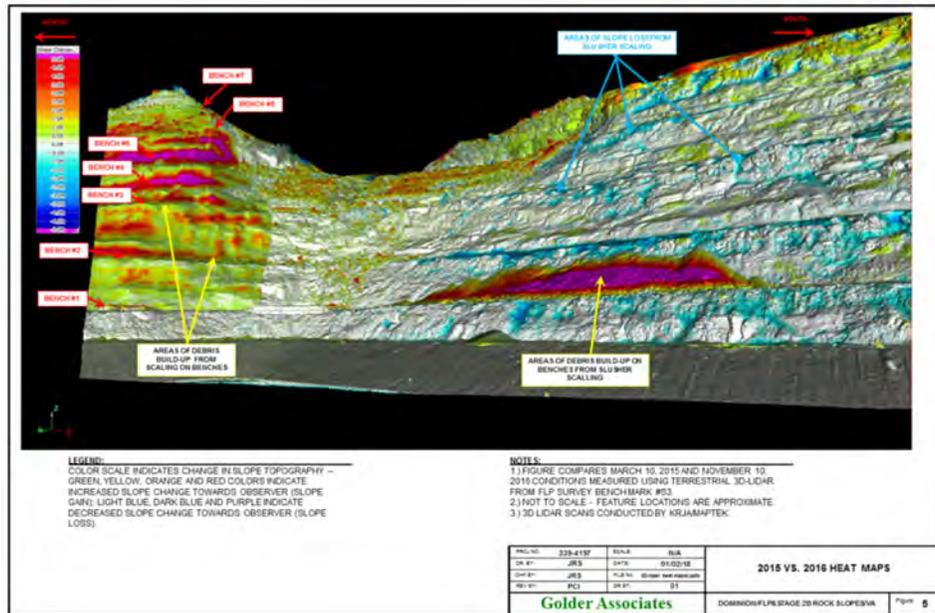
The completed drape has an area of 372,000 square feet and is checked every year for movement and changes in the slope using lidar.

The following pages show lidar scans of the slopes that compare changes in the rock slope from during scaling, to after drape installation. Some ongoing raveling was expected from weak shale strata. Blue areas show slope loss and red areas show zones of accumulation. The

images show the change of the slope surface from beforehand scaling to after scaling. Some scaled material was allowed to accumulate on benches, provided the benches remained clear of debris at least 5 ft behind the brow, because a drape was being installed.







An adjacent slope that did not receive a drape was scaled using mechanical methods (slusher). The two figures below show in blue the loss of material that occurred following scaling using a slusher. The purple area shows that the slusher was able to concentrate scaled material in a large area. Machine scaling is tough on the slope and some slightly loosened blocks are likely to remain on the slope after the slope face is raked-over by such scaling. Those loosened blocks will be the first pieces of rock to fall from a slope as it ages following scaling.

The following three slides illustrate that the results draped portion of the slope was also scanned a year after hand scaling and did not exhibit the same degree of slope raveling as the machine scaled segment of slope.





## SCALING FROM AN OWNER'S PERSPECTIVE

**Douglas A. Anderson and Brian Collins**

*FHWA, Western Federal Lands Highway Division*

**Scaling from an Owner's Perspective**

Western Federal Lands

Transportation Research Board 97<sup>th</sup> Annual Meeting – January 2018

Brian Collins, P.E.  
Doug Anderson, L.E.G.  
FHWA Western Federal Lands Highway Division

FHWA – FLHD  
WSDOT  
ODOT  
ITD  
MDT  
ADOT&PF

U.S. Department of Transportation  
Federal Highway Administration

Western Federal Lands Highway Division (WFLHD) serves a similar role as a state DOT, except we are not actually “owners.” Collins and Anderson design and deliver projects on Federal and Tribal Lands and other Federal Land Management Agencies and Tribes (e.g., National Park Service, U.S. Forestry Service, Navajo Nation). They also carry out projects on roads that access federal lands that sometimes include state highway projects.

**Goals from the Owner's Perspective**

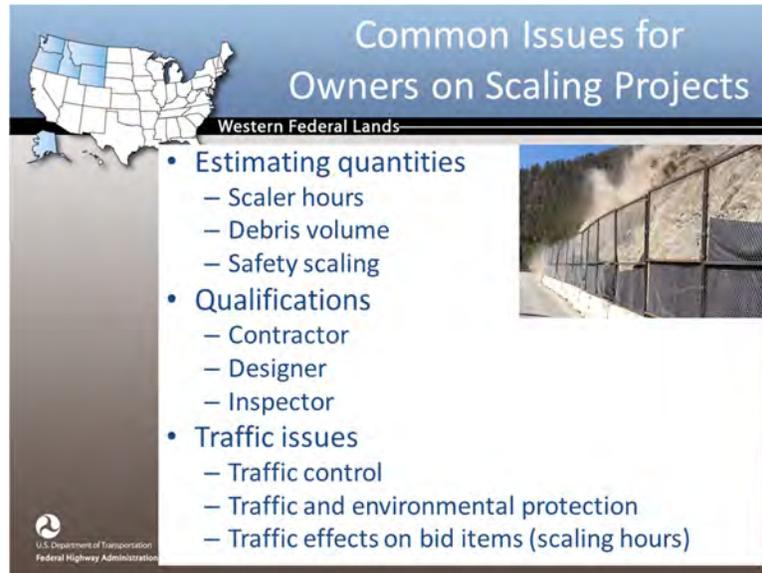
Western Federal Lands

- Reduce rockfall risk to the traveling public
- Minimizing maintenance expenditures and limiting damage to the roadway surface, guardrail, etc.
- Stay within budget
- Stay on schedule

U.S. Department of Transportation  
Federal Highway Administration

For the owners, risk reduction is most important. The intent of scaling projects is to improve safety to the traveling public and reduce overall maintenance requirements and

expenditures as funding has decreased maintenance and operations (M&O) preservation budgets. Major goals on any project are to stay within budget and on schedule. It is not realistic to put all the risk on the contractor, especially to meet the budget and schedule objectives. The best method to reduce budget and schedule risks is to ensure that the plans and specifications clearly communicate the scope and pay items for the work.



The following are the major issues and thoughts compiled from Federal Lands and other partner agencies:

- Reliable estimates of quantities are difficult to develop and may vary based on rock type, structure, and contractor's abilities.
- Safety scaling is difficult to estimate and a sensitive issue because it relates to the perceived safety of the personnel performing the work, and this varies from one contractor to the next.
- Qualifications of all those involved in the project influences the outcome.
- An experienced designer is necessary to develop reliable estimates and clear contract documents.
- The contractor performing the work must have sufficient experience to stay on schedule, within budget and protect their personnel and the traveling public.
- The inspector must be qualified to discern proper scaling techniques and safe practices and know when the scaling effort has adequately reduced the rockfall risk, while making sure the slope is not over scaled.
- Traffic issues are a major aspect on any scaling project and a lack of thorough consideration will result in major cost and schedule overruns.

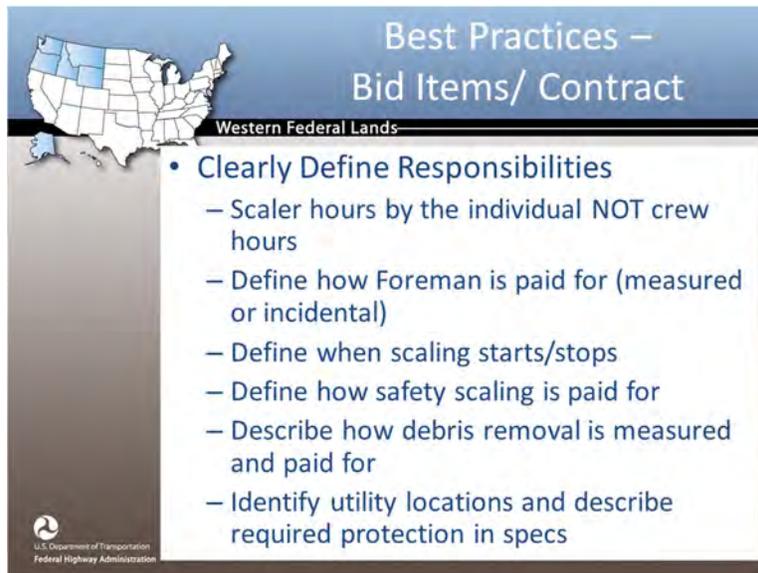
Significant questions to consider:

1. What will the traffic flow be during scaling operations and is a full roadway closure possible? We normally work on rural roads without adequate detour routes and therefore must

maintain traffic during construction. Even short closure periods (e.g., 2 h) during shoulder seasons, typically between snow-covered ground and Memorial Day in the spring and after Labor Day until construction is too difficult to continue during the rainy or snowy conditions in late fall, can greatly improve scaling production and limit disruption to high tourist destinations. The plans and specifications should be laid out around the traffic control plan and clearly communicate requirements to the contractor. Focus on performance requirements rather than method specifications.

2. How will traffic and the environment be protected? Can a temporary rockfall catchment system that will allow vehicles to pass during active scaling be provided? What type of system will the contractor be required to provide to protect traffic, pavement, utilities, and natural resources?

3. Remember to consider how the traffic control plan will affect your bid items. For example, if scalers were paid from when they start to ascend until they return to the road, it is important to keep in mind that when estimating quantities, they are paid while on hold for traffic cues to clear.



**Best Practices – Bid Items/ Contract**

Western Federal Lands

- **Clearly Define Responsibilities**
  - Scaler hours by the individual NOT crew hours
  - Define how Foreman is paid for (measured or incidental)
  - Define when scaling starts/stops
  - Define how safety scaling is paid for
  - Describe how debris removal is measured and paid for
  - Identify utility locations and describe required protection in specs

U.S. Department of Transportation  
Federal Highway Administration

The following slide is a list of suggested best practices based on lessons learned and those shared by WFLHD's partner DOTs regarding the bid items and contract preparation considerations.

### Best Practices – Photo Plans



Western Federal Lands

- Use drone or helicopter photos to communicate scaling area/conditions
- Contractor can clearly see areas to be scaled and areas requiring “intense/heavy scaling”



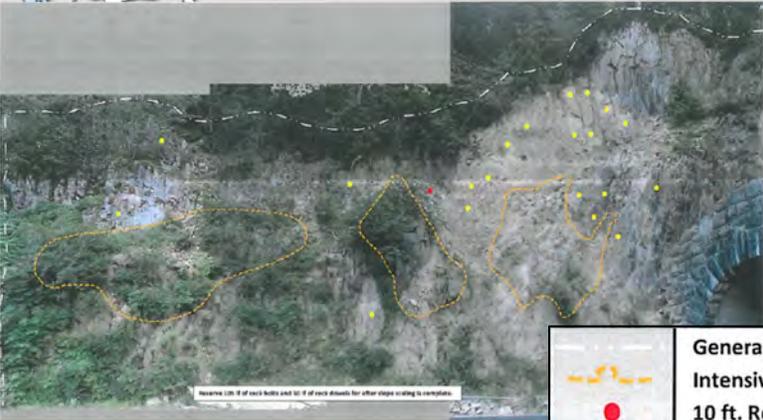
U.S. Department of Transportation  
Federal Highway Administration

These suggested best practices are based on lessons learned and those shared with WFLHD’s partner DOTs regarding clearly communicating the site conditions and scope of work.

### Typical Plan Sheet



Western Federal Lands



**General Slope Scaling Limits**

**Intensive Slope Scaling Areas**

10 ft. Rock Dowel (minimum length)

15 ft. Rock Bolt (minimum length)

Requires 100 ft. of each bolts and 50 ft. of each dowels for other slope scaling to complete.

Above is an example of a typical plan sheet for rock slope risk reduction stabilization work. The plan sheet legend has been enlarged to aid the reader.

**Best Practices – Traffic Control Plan**

Western Federal Lands

- Clearly define traffic limitations in contract and account for all delays when calculating quantities
- Contractor designed traffic protection allows ingenuity; NEPA may require this to be designed and accepted prior to construction

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Federal Highway Administration

Above is a list of suggested best practices based on our lessons learned and those shared with WFLHD’s by partner DOTs regarding traffic control and protection. Environmental permitting in sensitive cultural and environmental areas may require design and approval before bidding.

**Best Practices – Communication**

Western Federal Lands

- Contractor Work Plan submittal – opportunity to identify any misunderstandings in the contract and to make sure the contractor personnel is qualified and is equipped to perform the specified work
- Pre-bid and/or pre-construction meetings
- Frequent on-site reviews during the work
- FaceTime or Skype between office Geologists/Engineers and Field Inspectors

U.S. Department of Transportation  
Federal Highway Administration

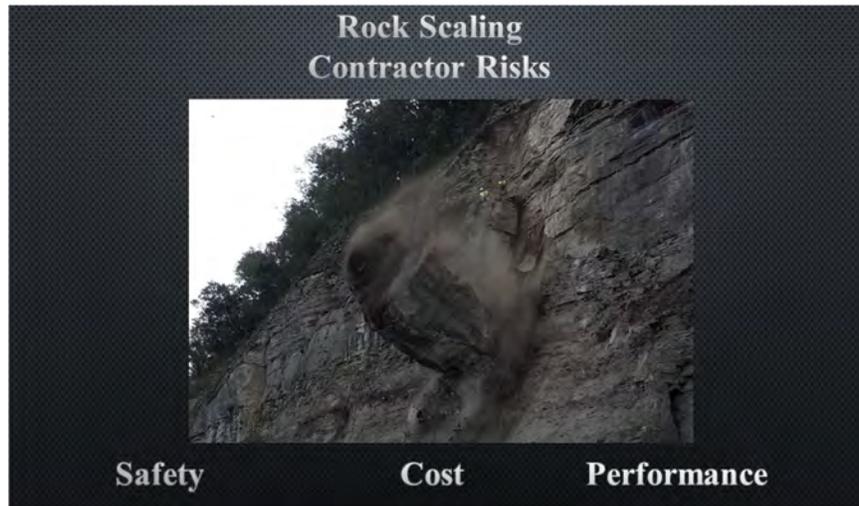
Above is a list of suggested best practices based on WFLHD’s lessons learned and those shared by its partner DOTs regarding communication.

## ROCK SCALING CONTRACTOR'S RISK

**Todd Reccord**

*Ameritech Slope Constructors, Inc.*

These slides provide an overview of what contractors experience in terms of risk, specifically, safety, cost, and performance risks.



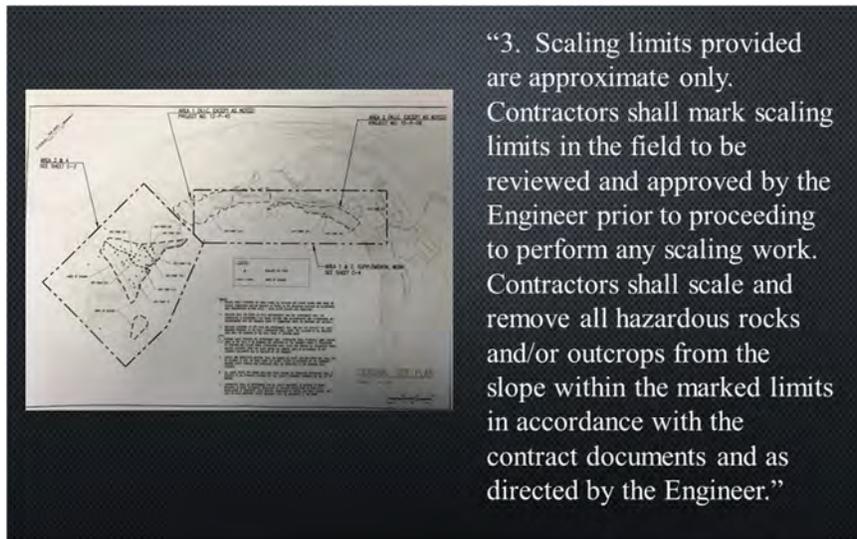
Taking unstable rock masses off a slope is dangerous and extreme caution must be used but this is not the only risk faced. Note the picture above is a rock scaled with a 70-ton air bag and an estimated weight of 240 tons. It took “a minimal effort” to dislodge this piece that was sitting right above a road with a 2-ft shoulder. There was a complete road closure for the entire project so traffic control was a nonissue. Although this is an inconvenience to the traveling public it allowed the scaling activities to accelerate and the project to be completed more quickly than if the public were allowed to travel on the road.

<b>Contractor Risks on Rockfall Projects</b>		
<b>Performance Risks:</b>	<b>Cost Risks:</b>	<b>Safety Risks:</b>
<ul style="list-style-type: none"> <li>• Established Timeframe</li> <li>• Means &amp; Methods Restrictions</li> <li>• Traffic Control</li> <li>• Work Crew Experience Requirements</li> <li>• Experienced Geotech on Site</li> <li>• Weather</li> </ul>	<ul style="list-style-type: none"> <li>• Liquidated Damages</li> <li>• Incidental Items</li> <li>• Units of Measure</li> <li>• Unforeseen Conditions</li> </ul>	<ul style="list-style-type: none"> <li>• Public Safety</li> <li>• Rockfall Protection Plan</li> <li>• Rope Access Methods</li> <li>• Slope Condition</li> <li>• Environmental Hazard Exposure</li> </ul>

Above are bullet points of the types of risk to deal with on rock fall projects.

There are a number of issues to be considered when addressing cost risk. Contractors are always reviewing plans and specifications to develop bid prices. The risk is minimized when the specs clearly define the crew size and the bid is by the crew–man hour. It is good from a client’s perspective to compare “apples to apples” when reviewing submitted bid numbers.

Risk becomes elevated when bidding rock work scaling as a “lump sum.” Normally, when developing estimates, it is not possible to “access” the slope, which means getting on the slope using rope access methods to examine the slope. In many cases, the slope is completely covered with vegetation and it becomes necessary to use best judgement but from a distance.



The above image is an example of a project where all the scaling bid is lump sum. There is a lot of vegetation on the slope so some of the rock masses are obscured. The owner did a good job getting pictures of everything that needs to be removed, and adding this information to the specifications and contract documents. Also, all rock masses to be removed had GPS coordinates attached to them so they are easy to locate. It is possible to upload all the coordinates into GPS devices to find the rocks, and safely remove them. As the project limits and scaling limits have been identified, the risk seems minimal. However consider the following language in the specifications:

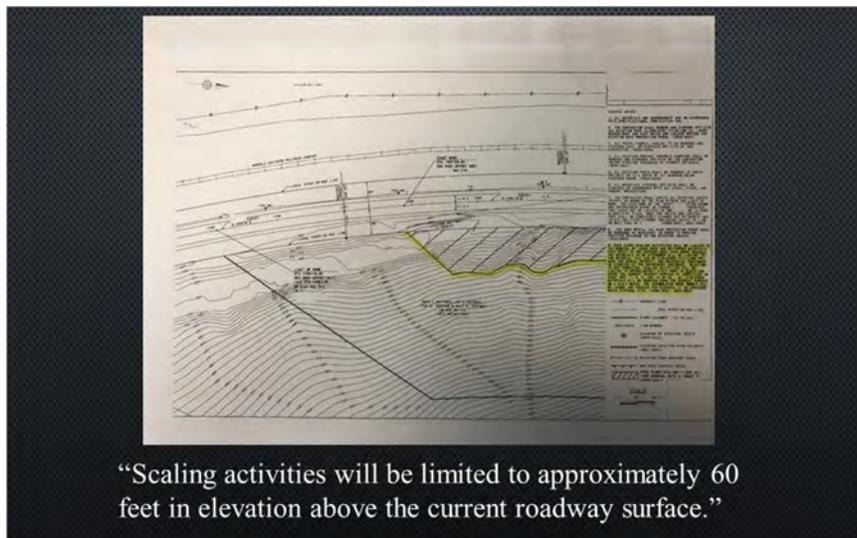
“Rock slope scaling operations shall include removal of loose or unstable rocks, soil, and debris from the slope face or ground surface utilizing hand scaling bars and non-destructive methods within the scaling limits and/or areas provided and as directed by the engineer in the field, including those boulder locations specifically identified on the contract documents, which meet the criteria for scaling even if shown outside the said limits.”

Including this language elevated the risk for contractors who now may be directed to remove additional rocks, soil, and debris without additional compensation. It is impossible to accurately predict what additional work will be requested and then factor the possibility of the work into a lump sum price. If the contract bid was by the man hour or crew hour, the contractor would be covered. As contractors have different thresholds of acceptable risk, those thresholds

can be seen in the bid results. The low bidder was at \$1.9 million, the second bidder was around \$2 million, the third contractor was \$3.3 million and the fourth contractor was over \$4 million.



Safety of the people doing the work is of the utmost importance. In the image above, this slope is approximately 500 ft in height. The contractor's task was to drape the slope, but to safely do that, it was necessary to scale as much of the loose rock off as possible. (No scaling has been done in the photo above.) At the base of the slope is a concrete liner that was protected by installing a temporary movable rockfall barrier. Standard industry practice for scaling is to start at the top of the slope and work down. Before going lower on the slope, it is important to ensure that all loose rock above the working area is removed.



Plans and specifications will dictate scaling conditions and the work requirements to which the scaling activities must adhere, including traffic control, types of protection, and public

safety. In the plan sheet shown above the highlighted statement reads “scaling activities will be limited to approximately 60 ft in elevation above the current roadway surface...” In the slide above, the slope is shown to be approximately 235 ft before the contour lines are cut off, yet the slope was over 300 ft in height. To take this job on and limit scaling to 60 ft above the current roadway would put scaling workers at an unacceptable risk. For comparison, look at the 500-ft tall slope in the previous image. A similar request would be to require scaling only the area below the red line, yet there is plenty of loose rock above the red line that could easily fall on workers as they scale below the red line. If the lower 60 ft of a slope has unstable rock on it, there likely is unstable rock above. Not only are the workers at risk but the travelling public is as well. A scaling contractor would not want to work on this project. The rock slope is what it is and easements should not override a safety concerns.



Rocks falling down a slope are unpredictable and erratic. In the picture shown above, scaling was occurring under “stop and go” traffic. As shown, much of the rock was landing inside the concrete barriers, except for one rock took an erratic bounce and ended up in the middle of the roadway. The contractor recognized that the temporary rockfall barrier at the bottom would likely not contained all rock so was prepared to mitigate danger and minimize disruption to the public, by having two machines staged ready to move the rock out of the way.



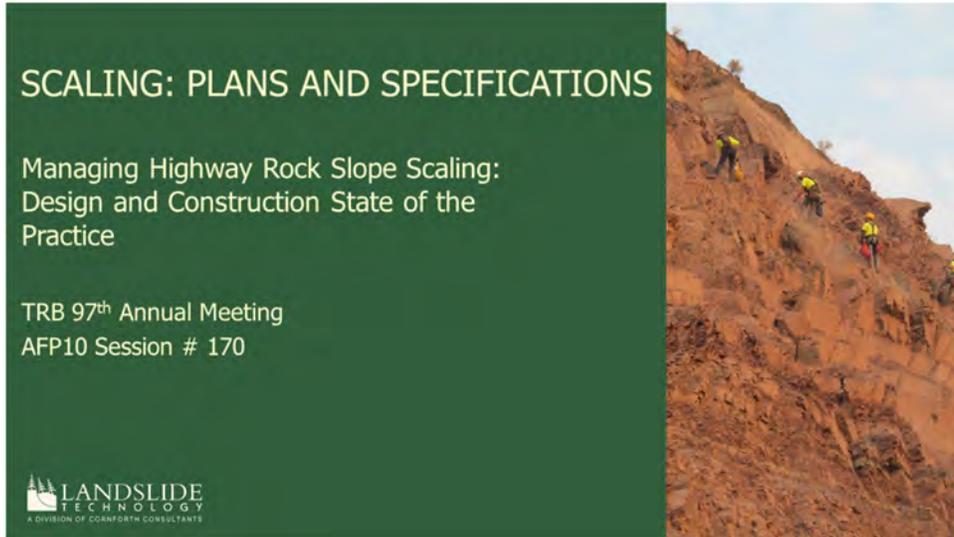
### **Contractor Risks on Rockfall Projects Summary:**

- Clearly defined language in plans and specifications.
- Experienced designers involved with the projects from design through construction
- Provision for apprentice scalers so a contractor can hire new staff to work into the industry and diversity their experience by exposure to a variety of projects

Contractors perspective on minimizing risks and maximizing potential for success of a rockfall project.

# Plans and Specification Examples

**BRENT BLACK**  
*Landslide Technology*



**SCALING: PLANS AND SPECIFICATIONS**

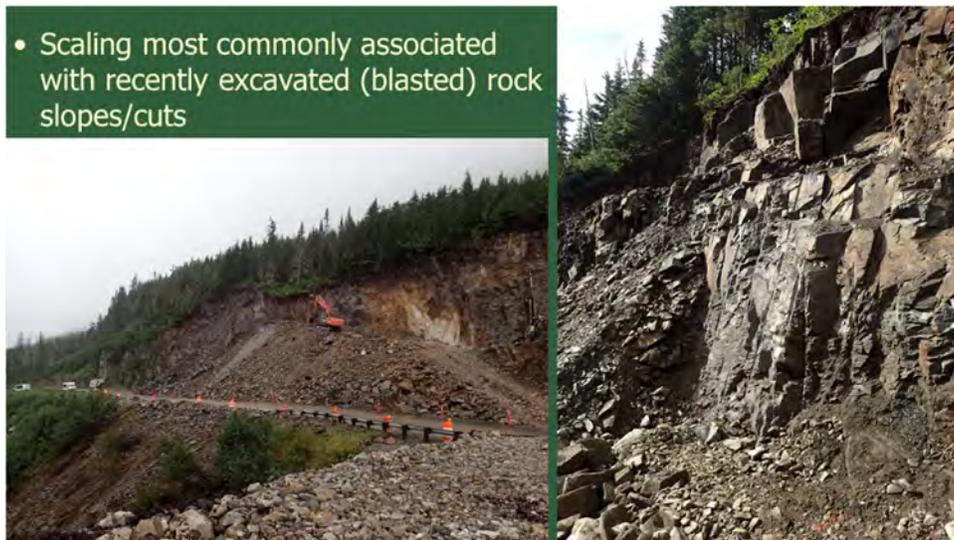
Managing Highway Rock Slope Scaling:  
Design and Construction State of the  
Practice

TRB 97<sup>th</sup> Annual Meeting  
AFP10 Session # 170

 **LANDSLIDE  
TECHNOLOGY**  
A DIVISION OF CORNFORTH CONSULTANTS

The slide features a green background with white text. On the right side, there is a photograph of a steep, reddish-brown rock slope. Several workers wearing yellow safety gear are visible on the slope, engaged in manual scaling work.

- Scaling most commonly associated with recently excavated (blasted) rock slopes/cuts



The block contains a green text box with a white bullet point. Below the text box are two photographs. The left photograph shows a wide view of a road cut through a forested hillside, with a large pile of excavated rock and debris at the base. The right photograph is a close-up of a steep, layered rock face, showing signs of weathering and potential scaling.

Typically, scaling is usually associated with recently excavated cut slopes. Typically, if scaling is found anywhere in most DOT standard specifications, it is under earthwork, and typically found under blasting. Usually an excavator does all of the scaling (mechanical scaling) when they are mucking out the shot lift. Sometimes this is adequate, but usually it is not as thorough a job as scaling by hand (and can sometimes be a bit heavy handed).

## SPECIAL PROVISIONS: SCALING

- Description
- Submittals
  - Qualifications
  - Work Plans
    - Scaling Work Plan
    - Temporary Rockfall Protection Plan
    - Traffic Control Plan during scaling
- Materials/Equipment
- Construction Requirements
- Measurement
- Payment



Typically, a special provision is written for scaling instead of a standard specification. For this presentation, approximately 25 different scaling special provisions were examined. Typically, a scaling special provision follows the standard specification format that has the following sections:

## SPECIAL PROVISIONS: SCALING

- Description:
  - Typically states: “work consists of scaling (removing) loose or detached blocks of rock and soil from the cut slopes and natural rock outcrops”
    - “soil”...?
    - What about trees and vegetation?
    - Is “Heavy or Intensive” scaling defined?
    - “natural rock outcrops”...?....Good Heavens!!!
  - Typically states: “within the areas shown on the plans”
    - Are vertical limits of scaling delineated on the Plans? If not, grab your wallet!
    - Does your Specials say “or as directed by the RE, CM, etc.” or “scaling outside the planned scaling limits will not be performed unless approved by the RE, CM, etc.”
    - How well does your Plans define your Scaling Limits?
    - What about “Safety Scaling”?



Sometimes projects have a separate tree clearing–falling special provision. If there are smaller trees and vegetation, it may be a good idea to include them in the scaling description. Sometimes heavy–intensive scaling was described. It is important to have vertical limits of scaling delineated in the plans. Also, whether “safety scaling” is addressed is the biggest issue regarding scaling, along with how to judge and control the quality of scaling.

## SPECIAL PROVISIONS: SCALING

### • Submittals:

#### – Qualifications

- Some DOTs require Prequalified Specialty Contractor Requirements
- AGHP, SPRAT, other requirement?
- Are the Experience Requirements of the Scaling Foremen and Scalers being met?...checked?
- What about "Apprentice Scalers"? Is there something in the Specials regarding "on-the-job-training"?

#### – Scaling Work Plan

- Who reviews it, CM or Geotechnical/Rockfall Mitigation Specialist?
- Is Temporary Rockfall Protection the responsibility of the Contractor or is it specified in the Contract Documents? Minimum Requirements outlined?
- Same with the Traffic Control Plan during scaling



Some DOTs require prequalified specialty contractor requirements.

## SPECIAL PROVISIONS: SCALING

### • Materials/Equipment:

- Do you specify Scalers working from ropes?
- Do you specify hand scaling using scaling bars?
- Commonly see: "scaling techniques using other measures such as hydraulic wedges, air pillow, or other mechanical means, may be used if demonstrated to be effective and approved in writing by the CM"
- Do you list what you don't want ("Hydro-scaling, "Yard-scaling, "Cat-track scaling", etc.)?



The following language has been included in many special provisions that have proven helpful: "scaling techniques using other measures such as hydraulic wedges, air pillow, or other mechanical means, may be used if demonstrated to be effective and approved in writing by the CM." In contrast, specific scaling techniques that are not acceptable may be noted, but if space for special provisions is limited, listing acceptable and unacceptable methods is not necessary.

## SPECIAL PROVISIONS: SCALING

### • Construction Requirements:

- Same as Materials/Equipment....Spell out what your requirements are (specify requirements).



Similarly, sequentially outline wants and construction requirements in this part of the special provisions.

## SPECIAL PROVISIONS: SCALING

### • Measurement/Payment:

- Scaler Hour?
- Scaling Crew Hour (define how many people constitutes a crew)?
- Area of Slope Face Scaled?
- Weight of debris removed?
- Volume of debris removed?
- Lump Sum?
- Different measurement and payment for "General vs. Heavy" scaling.
- When does scaling start (accessing slope, on ropes, waiting for TRP to be moved)?
- What's Incidental (TRP, TRP placement/movement, scaling foreman, vegetation/tree removal, **safety scaling, removal of scaled debris**, roadway repair, etc.)?



Measure and payment concepts are combined: As seen in the survey, about 70% of the respondents indicated they measure and pay by "hourly", either scaler hour or scaling crew hour. If using scaling crew hours, it is necessary to define what "a crew" is. Some find using scaler-hour is easier to track in the field. There was one special provision that payed by the slope area. Some options and variables to consider when putting the measurement/payment portion of the special provision together include:

- A few categorize measurement and payment (M&P) by weight, several use lump sum.
- M&P may a different unit rate for heavy scaling and often times for mechanical scaling as well (especially bench clearing or cleaning).
- When does scaling start should be clearly defined in the special provision?

- Defining what is incidental is important. Safety scaling and removal of scaled debris are the two issues that have resulted in the most change order claims.

### Key Considerations

- Require Prequalified Specialty Contractors
- Consider Incentives/Disincentives
- Have a say in the Traffic Control Special Provision.
- Don't have your traffic queue stopped below the 2<sup>nd</sup> most hazardous slope in your corridor.
- Require a mandatory pre-bid meeting.
- Review the Submittals and Work Plans.



These are some key considerations that have worked well in the past:

- Require prequalified specialty contractors.
- If prequalification is not required, write explicit special provision so as to have a qualified contractor for the project.
  - Strongly encourage a mandatory pre-bid meeting to ensure that the contractor has looked at the site

### Key Considerations

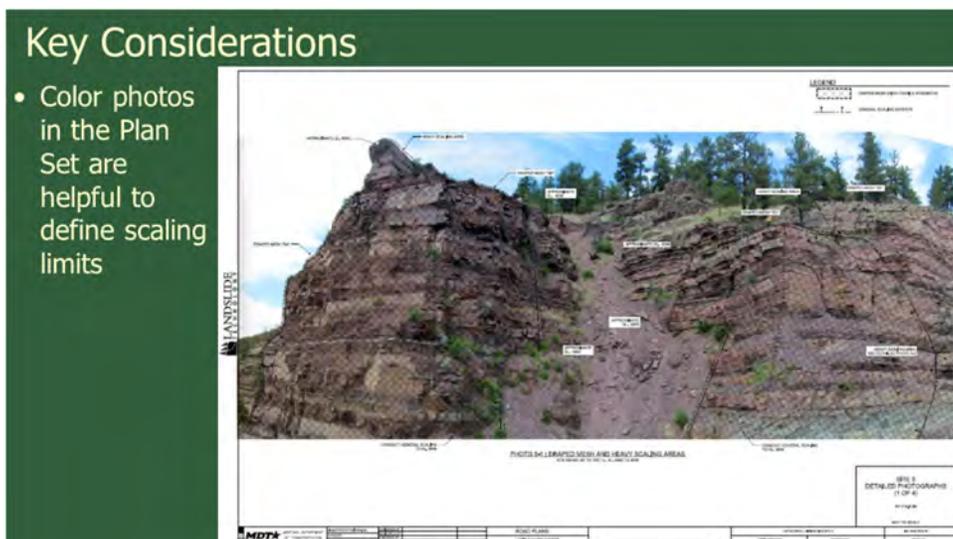
- Specify the Temporary Rockfall Protection Measures in the Special Provisions.
- Set a minimum standard?

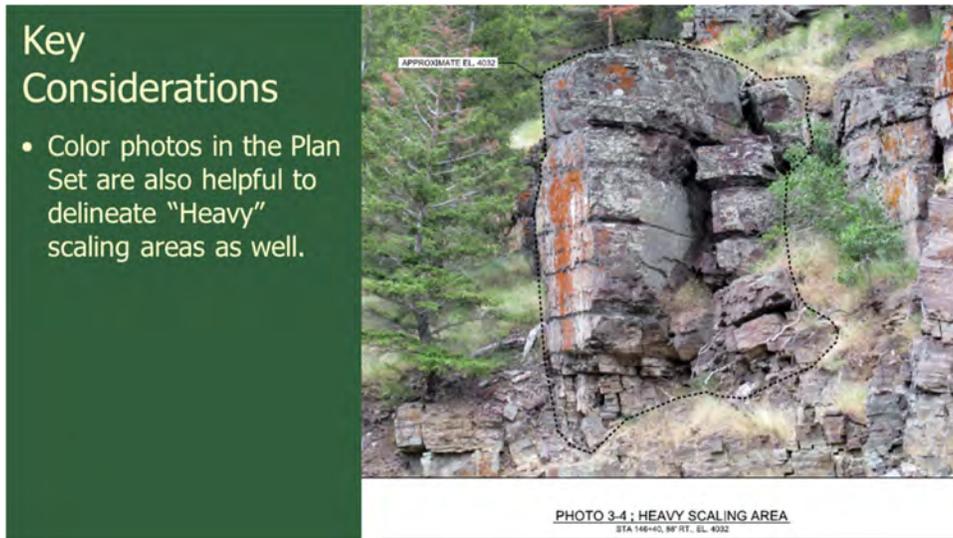


- I know this is a little controversial, but I like to specify the Temporary Rockfall Protection Measures in the Special Provisions, especially when doing scaling with active traffic being allowed to pass.
- MRBs and RCNs have worked for thousands of hours of scaling.
- Conex boxes are popular now and have performed adequately on other scaling projects.
- If allowing an approved alternative, it is important to set a minimum standard. From rockfall modeling, it will usually be possible to estimate rockfall bounce heights and energies.



It is best to not leave the temporary rockfall protection measures selection up to the contractor, or you may get something that is inadequate and does not provide the desired safety for workers or the public.





Color photos in the plan set are very helpful to define scaling limits and scaling types for rockfall mitigation projects.



Scaling is unique and a lot of CMs and construction inspectors generally do not have a lot of experience with this type of work. MDT had Landslide Technology (company) give a class to their construction staff to give them some idea of what field conditions and activities they could anticipate during the rock scaling portion of the project. It's best to have geotechnical/rockfall mitigation specialists with rope access capabilities to help with construction inspection.

## Key Considerations

- You can create a “bullet proof” set of Plans and Special Provisions, but it’s only as good as the Construction Management on-site.
- Geotechnical/Rockfall Mitigation Specialists need to have a major role during construction, not just during design.



It is necessary to communicate to construction management the importance of having experienced geotechnical–rockfall mitigation specialists onsite often, if not full time, not just at the end when the project is deemed “nearly complete”—at which point it’s often too late to correct deficiencies.

## **Panel Discussion and Needed Areas of Improvement** *Research Needs*

**TY ORTIZ**

*Colorado Department of Transportation*

**DANIEL JOURNEAUX**

*GeoStabilization International*

The panel discussion held at the conclusion of presentations revealed areas for further research. Workshop presenters made up the panel and included:

- Darren Beckstrand, Landslide Technology;
- Ben Arndt, RJ Engineering and Consulting;
- Ty Ortiz, Colorado Department of Transportation;
- Daniel Journeaux, Geostabilization International;
- Peter Ingraham, Golder Associates;
- Krystle Pelham, New Hampshire Department of Transportation;
- Brian Collins, Federal Highway Administration; and
- Brent Black, Landslide Technology.

The areas for future research revealed during the discussion include the following.

### **LIFE CYCLE (ROCK SLOPE DETERIORATION)**

The frequency of rock scaling needed depends on several factors that include geology, climate, and ditch effectiveness. Documentation on the time needed between scaling efforts is not readily available and often based on empirical observation. With few exceptions, where it does exist, data on rock scaling that could benefit life-cycle measurements is often kept with project records or is not formalized or readily available. An understanding of the deterioration rates associated with nature and disturbed slopes would benefit owners by increasing the confidence in decisions of when and where to perform rock scaling.

### **SPECIFICATIONS**

The workshop revealed a wide range of methods used to measure the amount of rock scaling needed on a project and the unit of measure used to pay for rock scaling. There is also inconsistency in the type of pay items used for rock scaling. In addition to the scaling defined in the plans and specifications, removal and disposal of scaled material is not consistently addressed. The development of consistent specifications will provide consistency for both contractors and field inspectors.

## **EXTENT AND DURATION**

The methods used to define the extent and duration to perform rock scaling is inconsistent. The industry has not consistently established how to determine the extent to which scaling is needed and which party is responsible for determining when to stop scaling efforts. It was the consensus of the audience that it is in both the owner and contractors best interest to have a rockfall specialist make these decisions.

## **SAFETY SCALING**

The discussion of safety scaling showed an inconsistency between contractors and owners on the need and extent of safety scaling. A definition of safety scaling needs to be developed.

## **DESIGN GUIDELINE**

The industry needs design guidelines for practitioners and owners. The guideline could define best practices for design, methods of measurement for quantities, payment methods, performance measurements and determining safety needs. The workshop panel and audience concluded that developing a design guideline would be the natural next step to address the concerns brought up during the panel discussion.

# *The National Academies of* **SCIENCES • ENGINEERING • MEDICINE**

The **National Academy of Sciences** was established in 1863 by an Act of Congress, signed by President Lincoln, as a private, non-governmental institution to advise the nation on issues related to science and technology. Members are elected by their peers for outstanding contributions to research. Dr. Marcia McNutt is president.

The **National Academy of Engineering** was established in 1964 under the charter of the National Academy of Sciences to bring the practices of engineering to advising the nation. Members are elected by their peers for extraordinary contributions to engineering. Dr. John L. Anderson is president.

The **National Academy of Medicine** (formerly the Institute of Medicine) was established in 1970 under the charter of the National Academy of Sciences to advise the nation on medical and health issues. Members are elected by their peers for distinguished contributions to medicine and health. Dr. Victor J. Dzau is president.

The three Academies work together as the **National Academies of Sciences, Engineering, and Medicine** to provide independent, objective analysis and advice to the nation and conduct other activities to solve complex problems and inform public policy decisions. The National Academies also encourage education and research, recognize outstanding contributions to knowledge, and increase public understanding in matters of science, engineering, and medicine.

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