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# State of Utah
**DEPARTMENT OF NATURAL RESOURCES**
MICHAEL R. STYLER
*Executive Director*
**Utah Geological Survey**
RICHARD G. ALLIS
*State Geologist/Division Director*

November 16, 2015

Teri Paul
Park Manager
Edge of the Cedars State Park Museum
600 West 400 North
Blanding, Utah 84511

Subject: Potential rockfall boulder Emergency Response, Goosenecks State Park, San Juan County, Utah.

Dear Teri:

I enjoyed meeting you and Mark Bond on November 4, 2015, to discuss the potential rockfall boulder at Goosenecks State Park (figure 1). Your staff did a great job of recognizing movement, implementing monitoring, and seeking professional advice on this potential rockfall boulder. This letter is a summary of my observations and recommendations from my field visit.

The potential rockfall boulder is part of limestone cap rock at the top of a 33–38° slope above the San Juan River that lies 1000 feet below. The cap rock forms numerous rockfall boulders which are present on the slope below the cap rock. In the area of the potential rockfall boulder the limestone is massive and about 10–14 feet thick. The limestone is part of the Pennsylvanian Honaker Trail Formation that consists of interbedded limestone, sandstone, and siltstone (Stevenson, 2000). The limestone cap rock is underlain by a relatively easy weathering silty sandstone.

Rockfall is the result of natural weathering and erosion processes acting on the slope and cap rock in the park. Here, rockfall boulders develop along two prominent vertical rock joints or fractures in the limestone. The vertical fractures are oriented at 350° and at 80° at right angles to each other and produce large rectangular rockfall boulders. Differential erosion and weathering is the primary mechanism for generating rockfall in the park. Rockfall produced by differential erosion and weathering is a process in multilayered rock units where less resistant units erode at a faster rate and undermine more resistant units leaving the resistant unit unsupported, the unsupported resistant rock unit then detaches from the slope forming a rockfall (Higgins and Andrew, 2012). The underlying silty sandstone erodes faster than the overlying limestone cap rock and eventually generates rockfall. The cap rock exhibits different styles of rockfall, some rocks detach and come to rest at the top of the slope, some rocks travel downslope a short distance, and others likely roll downslope to the San Juan River.

The potential rockfall boulder is detached from the cap rock and has started tipping outward and possibly sliding onto the slope below. The monitoring point that Mark established documents the boulder movement relative to the adjacent cap

1594 West North Temple, Suite 3110, PO Box 146100, Salt Lake City, UT 84114-6100
telephone (801) 537-3300 • facsimile (801) 537-3400 • TTY (801) 538-7458 • *geology.utah.gov*

rock to the west. As we discussed, I recommend adding another monitoring point where the boulder is detaching from the cap rock and forming a vertical wedge shaped crack. This point would capture the maximum tipping movement of the boulder. All of the erosion and weathering processes acting on the boulder will eventually lead to failure when the boulder will fall, topple, or slide away from the cap rock onto the slope below. The timing of rockfall is difficult at best to predict and monitoring provides information on boulder movement and if the movement rate is increasing and leading to failure. Monitoring will also provide measured data to aid in making decisions regarding the rockfall hazard. However, the boulder may move and fall at any time.

The following are my recommendations for the potential rockfall boulder and other future potential rockfall boulders in the park.

- Continue movement monitoring on the potential rockfall boulder, particularly after precipitation events. If the movement continues or the movement rate increases, restrict access around the boulder to protect park visitors.
- Install warning signs that would notify park visitors of potential loose, unstable rocks.
- If the potential rockfall boulder presents an unacceptable risk, a rockfall mitigation company could stabilize the boulder (similar to rockfall along highways) to reduce the risk.
- Document rockfalls within the park as they occur to get an understanding rockfall frequency, location, and timing.
- Continue observations to check for future potential rockfall and monitor if needed. These observations will provide a method to anticipate and manage future potential rockfall within the park.
- Consider partnering with the Utah Geological Survey and adjacent land-management agencies in supporting the development of a geologic hazard maps to show where geologic hazards exist and their relative severity. Similar mapping is underway in Glen Canyon National Recreation Area to help future risk reduction efforts and visitor safety.

If you have any questions regarding the letter, please contact me.

Sincerely,


Richard E. Giraud, PhD
Senior Geologist
Geologic Hazards Program

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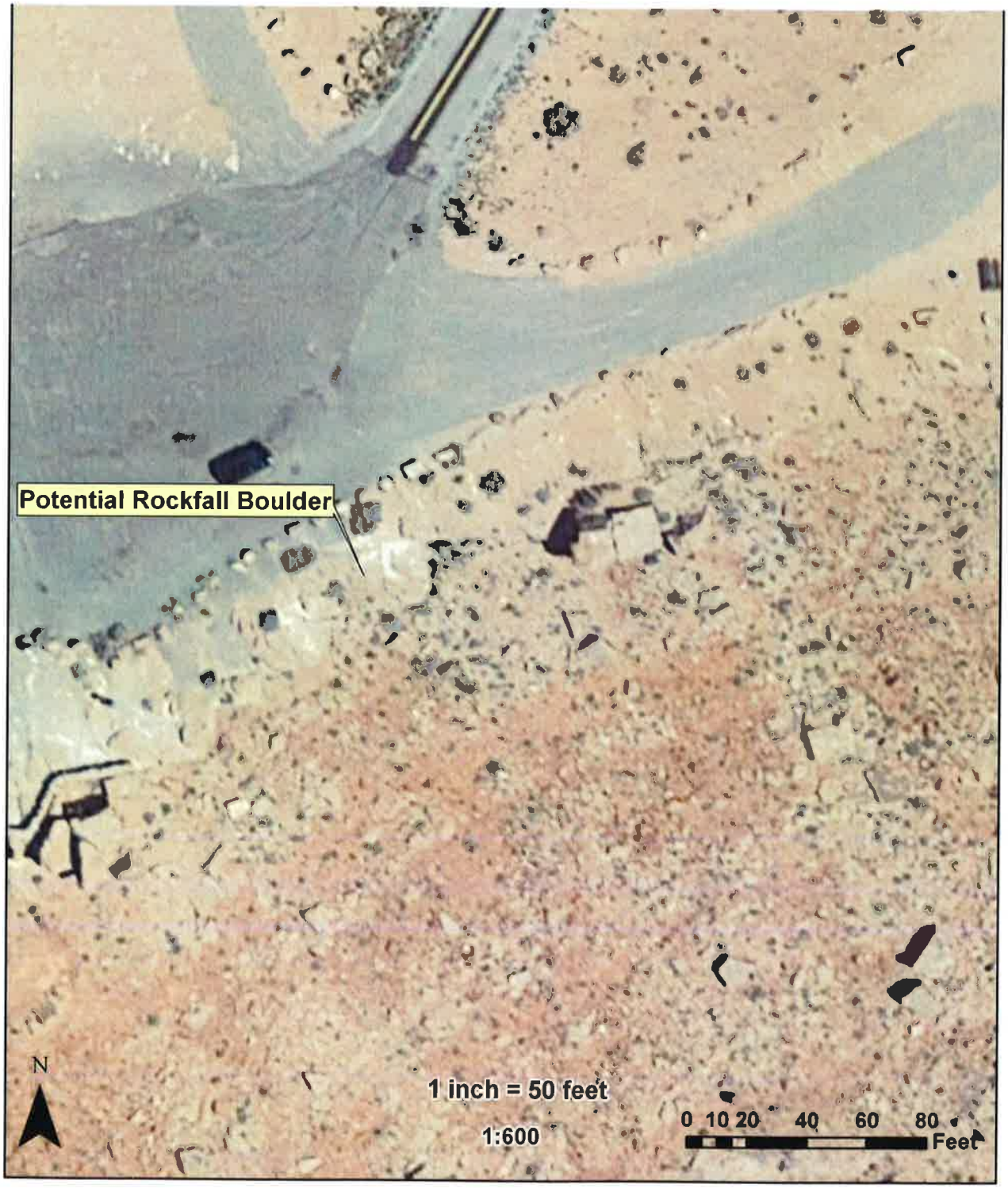


Figure 1. Location of potential rockfall boulder at Goosenecks State Park.

## REFERENCES

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