



The Colorado Geological Survey (CGS) worked with Jefferson County planners to develop a Geographical Information System (GIS) coverage for potential rockfall hazard areas in 2004. The scope of the project was to map potentially hazardous rockfall areas within the Evergreen Community Plan area in Jefferson County and provide these mapped zones in digital GIS format to the Jefferson County Planning Department. This publication includes a map of the GIS data and a description explaining the hazard, mapping methodology, and implications to development in the area. The project was funded by the Colorado Department of Emergency Management, Jefferson County, and CGS.

### Overview

Poorly planned growth in Colorado's natural hazard areas can impact communities with declining property values, public safety concerns, and high reconstruction costs. Communities, such as the Evergreen area, face the need to accommodate growth in difficult terrain while trying to protect community character and foster a wise use of limited natural and financial resources.

Rockfall is considered a geologic hazard in the Colorado Revised Statutes (C.R.S. § 24-65.104), and local communities are encouraged to identify rockfall hazards and adopt land-use policies to regulate development in prone areas. This publication identifies these areas and describes the methods used to determine rockfall susceptibility within the Evergreen Community Plan area boundary.

### Background

Rockfall is the falling of a detached mass of rock from a cliff or down a steep slope. Rocks in a rockfall event vary greatly in size (from golfball to house sized), and roll, bounce, or slide rapidly downslope under the force of gravity. Rockfall can be a continuous process over a considerable period of time, a single event, or series of single intermittent events. A rockfall event can involve a single rock or large volumes of broken rock material.

Rockfall, a type of landslide, is common near cliffs of massive broken, faulted, or jointed bedrock, or where steep bedrock ledges are undercut by natural processes or human activities. A major natural cause of rockfall is repeated freeze-thaw of water within rock crevices: freezing water expands, weakening and wedging apart blocks of rock.

Rockfall occurrences are difficult to predict, and can range from a single rock falling or rolling to large-scale catastrophic events. The size of the falling rock depends on the source area geology (bedding thickness, bedding dip and dip direction, hardness, jointing/fracturing orientation), weathering, and position. Rolling or sliding rocks occur on steep slopes where loose rocks may mobilize due to gravity (slope creep) or hillside development activity. This may occur in areas where loose rocks are located on steep slopes, regardless of the presence of an outcrop.

Water erosion from rain or melting snow and decomposition of rock from chemical weathering can remove the underlying support for blocks of rock and trigger downslope movement. Root growth, water pressure, wildlife, and ground shaking can also cause rockfall.

Rockfall events can quickly demolish structures and can injure or kill people. Rocks falling on highways may strike vehicles, block traffic, or cause accidents and road damage. However, most areas susceptible to rockfall can be identified and steps can be taken to avoid, reduce, or mitigate rockfall risk.

### Previous Rockfall Hazard Mapping

In 1974, passage of House Bill 1041 (C.R.S. § 24-65.1-101 through 204) provided funding to map geologic hazards; the resulting maps are commonly called "HB 1041" maps. Rockfall and other geologic hazards near and surrounding Evergreen were mapped in the late 1960s and early 1970s. Some of this information is included in the 1974 Jefferson County Mountain Area Research Project, put together by the University of Colorado at Denver and Jefferson County Planning (Schalman and Blackburn, 1974).

The maps concentrated primarily on identification of a few rockfall source areas and did not fully identify runoff areas that may be subject to the impacts of rolling, bouncing or sliding rock fragments. Many of the geologic hazards mapped during the 1970s are included in the Jefferson County Geologic Hazard Overlay District.

Additionally, the HB 1041 maps were mapped at a scale of 1:24,000 or 1 inch = 2,000 feet (Schmidt, 1972). The mapping scale made it difficult to identify historic rockfall events and fully evaluate potential hazards. Current high-resolution aerial photography, GIS, and other digital data allow improved susceptibility mapping at a scale more appropriate for community planning (i.e., 1:6,000 or 1 inch = 500 feet).

### Methodology

In order to map the rockfall susceptibility boundaries, existing digital data were compiled in a geodatabase using ArcMap GIS version 9. The data included aerial photography from the Jefferson County Planning Department and scanned geologic data from USGS mapping in the area (Reed et al, 1973; Sheridan et al, 1972). Additionally, existing paper maps of the area were evaluated for information relating to rockfall potential (Schmidt, 1972 and 1976).

The study area includes (approximately) the part of Jefferson County east of the Clear Creek County Line, west of R70W, north of N. Turkey Creek and south of Genesee Park. The study area boundary was estimated using large-scale maps of the Evergreen Community Plan Boundary.

Areas identified on maps and air photos as potentially having geologic and topographic conditions that might produce a rockfall event were field checked during winter and spring 2004 - 2005. Field observations were made regarding the source area, extent of the historic runoff area, volume of material, size of the blocks that could fall, and topographic features that could affect rockfall. Field observations were recorded by GIS points and used to refine the preliminary boundaries mapped in GIS. This digital data was then placed on a topographic basemap for easier referencing.

### Mapping Results

The rockfall susceptibility map was developed at a scale of 1 inch = 500 feet (1:6,000) to discern rockfall areas identified during this study. Much of the mapped Zone B rockfall hazard area roughly correlates with the high risk areas shown on the existing Geohazards map for the study area (Jefferson County Planning and Zoning, 2004).

Two rockfall susceptibility categories were mapped: Zone A (worst-case rockfall) includes areas where rockfall may occur under changed conditions (adverse grading, earthquake, fire, catastrophic event, etc.), and Zone B (existing rockfall) depicts areas where rockfall may be present or occur under current ground conditions. The mapped zone boundaries include potential source areas and runoff areas where bouncing or rolling material may extend, based on field observation.

### Development Considerations and Mitigation

Human activities can create rockfall hazards or cause rocks to fall sooner than they would naturally. Vibration from trains or blasting can trigger rockfall, as can development related changes in surface and ground water conditions.

Excavations, such as road cuts, often remove support for overlying or overhanging rock and create rockfall risks. Talus (loose rock fragments) on steep slopes is often the result of numerous small rockfall events. Construction on talus slopes can increase rockfall risks to areas above and below construction by increasing or renewing movement of talus. Over-steepened cuts and other excavations can increase the danger and frequency of rockfall or sliding rocks.

Hazard avoidance is by far the simplest, most effective, and least costly approach to mitigation. However, other forms of mitigation can reduce, but not eliminate, rockfall risk. Some typical types of mitigation include

- stabilization of rocks by removal of unstable rocks (scaling), rock bolting, or installation of retaining walls;
- capturing, slowing, or diverting moving rocks with rock fences, screens, berms or ditches;
- concrete barriers or covered galleries placed around vulnerable structures and facilities.

All of these measures are expensive, require regular maintenance, and do not eliminate the risk of rockfall. For example, complete removal of all potentially unstable rocks is often not possible; berms, ditches, and fences fill with fallen rock and must be cleaned out; and concrete barriers and galleries deteriorate, due to weather and rock damage, and require replacement.

An important factor to keep in mind is that although the place of potential rockfall is to some degree predictable, the time of failure is not. Hence, complete avoidance of areas of potential rockfall is the most sensible mitigation measure where lives or property values are at stake.

### Map Usage and Limitations

The mapped rockfall susceptibility areas in the Evergreen Community Plan boundary were mapped on a 1 inch = 500 feet (1:6,000) scale. Inclusion of properties within a rockfall susceptibility zone does not imply that rockfall events will impact a property at any given time; it means that the property has a higher risk compared to areas not within a mapped area, based on geologic and topographic conditions. Conversely, areas not identified as being susceptible to rockfall could become susceptible due to blasting, grading, excavation, or a change in natural conditions. Additionally, isolated outcrops that were not observed on air photos or through field visitations may be present and may include rockfall risk not shown on the map.

The potential rockfall susceptibility areas shown in the geodatabase were constructed qualitatively using available geologic, topographic, and field evidence. No levels of risk assessment (high vs. low risk) were made within each zone. This map is intended for general purposes and does not replace the need for detailed site-specific studies.

Prior to any development, a qualified geotechnical engineer or engineering geologist should further evaluate potential hazard areas. These investigations should include consideration of current and future geologic conditions, and how the proposed development might impact adjacent properties. Mitigation measures may be required in order to reduce potential rockfall risks.

### References

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