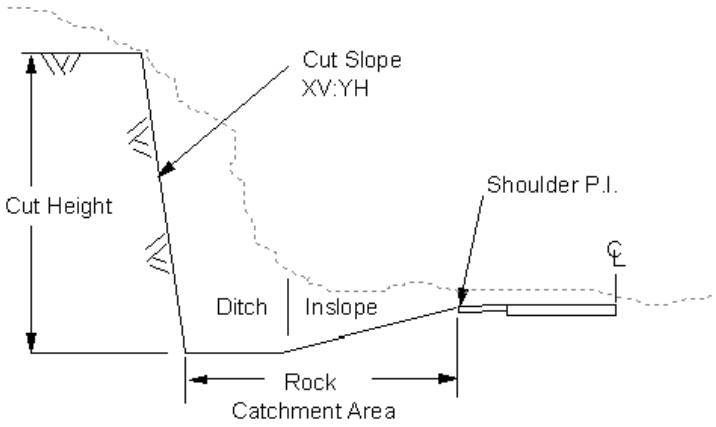
Rock Slopes

The Geotechnical Section provides rock slope recommendations for new and existing sites where construction requires removal of bedrock in the back slope. Rock slope recommendations are provided for new and existing rock cuts to accommodate new road alignments, widening of roadways, or for stabilizing existing rock slopes or providing improved rock catchment. Rock slope recommendations are based on many different factors, including:

Rock type
Discontinuity (bedding, joints, fractures) orientation and frequency
Cut Height
Weathering
Presence of erodible material
Highway orientation
Right-of-way
Aesthetics

Figure 1: rock cut slope diagram



An optimum rock slope design minimizes risk to the public and also minimizes the amount of excavation and stabilization required. Proper design includes selection of an optimum “safe” cut slope angle together with an appropriate rock fall catchment area. Figure 1 illustrates the terms used in a Rock Slope design. The **cut slope** is often referred to as a “cut slope angle”, but at MnDOT it is expressed as a slope, vertical to horizontal (for example 2V:1H). The **rock catchment area** includes the flat ditch area plus the inslope that ends at the shoulder. The inslope normally varies between 1V:6H and 1V:4H.

Cut slope angles are typically derived from an evaluation of **rock mass characteristics**, which can be attained from a combination of measurement made of

exposed bedrock faces and an assessment of rock cores taken by the Foundations Unit. Additional factors that may bear on cut slope selection include site conditions (groundwater, roadway orientation, and others) and experience.

In reality the design process is a tradeoff between stability and economics. Steep slopes and narrow ditches are usually less expensive to construct than the safer and more stable flatter slopes and wider ditches. To a lesser extent, aesthetics may play a role in rock cut designs and can enhance engineering designs. They should not, however, be allowed to dictate the design. In most cases agreeable compromises are possible between aesthetics and safety.

Since the geologic structure and type of rock vary considerably at each individual rock cut (often within the same project), it is difficult to provide general guidelines for design recommendations that fit all circumstances. The following guidelines are created to fit typical conditions common to Minnesota. The Geology Unit should be contacted for site-specific designs. The examples below will consider two general categories of rock based on their ease of excavation. **Soft rocks**, which include principally shale and sandstone, can be excavated without blasting. **Hard rocks**, which require blasting to excavate, include igneous, metamorphic rocks and carbonates.

Low rock cuts (<6 ft in height) can be treated as rock slopes or soil slopes by the designer. Softer rock slopes may be laid back to match existing soil slopes and covered with topsoil and vegetation. In hard rock, blasting of the slope will likely be required. MnDOT specification 2105.3C requires presplitting of hard rock types for any cut slope steeper than 1H:1V. Presplitting of these low cut faces is not necessary from a rockfall standpoint, but will result in a clean, durable rock face that does not deviate significantly from the planned excavation line. Aesthetic considerations such as excavating back to natural discontinuities in the rock face rather than presplitting are allowed, but special provision language will need to be included that excludes presplitting.

Intermediate rock cuts (6 ft to 30 ft in height) should closely follow the design guidelines in the Road Design Manual, Figure 4-6.02, Typical Rock Section, or may employ an alternate design approved by the Geotechnical Engineering Section. Soft rock slopes can be treated as soil slopes with standard ditch sections, in which case they should be covered with topsoil and vegetation. Often, sandstone is exposed in high bluffs where it would be impractical to cut it to a soil slope. In this case it is often desirable to cut the sandstone to a steep slope, such as 4V:1H, and direct runoff away from the face to the extent possible. In hard rock types, controlled blasting techniques are required for final shaping of the cut face. The standard ditch width should be 12 feet, with a depth of 4 feet. Using a standard inslope of 1V:6H or 1V:4H, the resultant rock catchment area (ditch width + inslope) would be 36 feet or 28 feet, respectively. Composite slopes, consisting of both soft and hard rock types (particularly with hard overlying soft) are susceptible to differential erosion and require careful consideration. Typically, the hard rock layer will be set back 10 feet from the face of the underlying soft rock, with an impermeable bench constructed on top of the soft rock layer.

High rock cuts (>30 ft in height) should be investigated and designed by appropriate units of the Geotechnical Engineering Section. Investigation of rock quality and rock mass properties (such as joint orientation and frequency) should be conducted on rock outcrops and rock core samples to design appropriate cut slopes and ditch catchment areas. High rock cuts require controlled blasting techniques to limit rockfall during construction and after completion of the project. For preliminary planning purposes, you may estimate the necessary rock removal/right-of-way by assuming a rock slope of 2V:1H (63°) and a rock catchment area of 35 feet. These will yield conservative values in most cases and should be refined prior to finalizing the design.

Transitions into and out of bedrock, both transverse and longitudinal, should be provided in the design to minimize differential settlement. Provide a minimum of 1:20 taper in the longitudinal and 1:10 taper in the transverse directions. The District Soils Engineer or the Geology Unit can provide recommendations for specific projects.