	Ohio Department of Transportation **Division of Production Management** **Office of Geotechnical Engineering** **Geotechnical Bulletin**	**GB 3**

ROCK CUT SLOPE & CATCHMENT DESIGN

January 15, 2016

Geotechnical Bulletin GB3 was developed by the Office of Geotechnical Engineering. The first edition of GB3 was dated January 13, 2006. This edition supersedes all previous editions.

This Geotechnical Bulletin is intended to provide guidance on the design of rock cut slopes, rockfall catchment, and rockfall controls. Recommendations presented in this manual are based on research presented in Shakoor and Admassu (2010) entitled "Rock Slope Design Criteria" (State Job Number 134325), previous FHWA co-sponsored research, and the experience of the Office of Geotechnical Engineering (OGE). These guidelines should be viewed as the presentation of the philosophy of the OGE regarding rock cut slope and catchment design. It is not possible to provide design guidance for all potential scenarios. If a scenario is encountered that falls outside those described in this Bulletin, the design is recommended to be done in consultation with the OGE or District Geotechnical Engineer (DGE).

The Designer is responsible for preparing a design that is based on a site-specific geotechnical exploration and achieves the optimal balance of safety, construction costs, and future maintenance costs. The use of "template" designs shall be avoided. Instead, the designer shall use appropriate information regarding the site geology, slope of the natural hillside, and the condition of cut slopes in similar geology within proximity to the project to determine the appropriate slope configuration. The designed configuration will be influenced by lithology, rock properties, and bedrock structure. Research and experience has shown that a consistent design methodology can be formulated by using properties such as intact rock strength, rock durability, fracture frequency, regional joint characteristics, and other common rock properties.

The design approach first satisfies the overall global stability of the rock cut. It is recognized that in nearly all cases typical geologic and geometric conditions exist throughout Ohio, namely nearly horizontally bedded sedimentary rock strata with a range of lithologies that include limestone, dolomite, sandstone, siltstone, shale, claystone and coal. In this Bulletin, those strata defined as shale in the ODOT Construction and Material Specifications (C&MS) Item 203.02.P are considered a rock type and are included in this manual. Based on practice, OGE experience, and results of research (Woodard, 2004; Shakoor and Admassu, 2010), it is recognized that the primary cause of degradation and failure of rock cuts in Ohio are the differences in durability of rock units and intersecting discontinuities found throughout Ohio. The design approach presented in this manual accounts for these differences in durability of geologic units as well as anticipated geologic structure encountered in most rock cuts in Ohio.

The typical geologic structure present in Ohio makes the necessity for rigorous rock mechanics structural analysis (kinematic analysis) rare for cut slope designs in Ohio. If the designer believes a detailed kinematic analysis is necessary, contact the DGE or OGE, as the design may be beyond the bounds of these guidelines.

The Designer should note that the guidelines presented in this document may result in a designed slope with varying slope angles and benches where the excavation quantities and/or costs are similar to simply creating a continuous 1.5H: 1V cut slope, for example. The use of a continuous slope through varied geologic formations, while possibly simplifying construction, may not effectively address long-term conditions with respect to weathering. Therefore, replacing the designed rock slope with a constant slope is generally not recommended.

OGE recognizes that rockfall poses a serious geologic hazard and the selection of appropriate slope configurations, as well as rockfall catchment controls, will minimize this hazard. This manual presents guidelines to be used as a basis to provide adequate rockfall catchment and controls based on OGE experience and FHWA co-sponsored research.

Expanded discussion of the items in this document can be found in the ODOT Rock Slope Design Guide, which along with this Bulletin and other information may be obtained from the Office of Geotechnical Engineering's web site (http://www.dot.state.oh.us/Divisions/Engineering/Geotechnical/Pages/default.aspx). This web site contains other ODOT geotechnical documents and bulletins, including an online copy of the Geotechnical Engineering Design Checklists and Specifications for Geotechnical Explorations (SGE), which are referenced in this document.

A. Definitions

Lithologic Unit: A body of rock comprised of a similar mineral composition, grain size, and engineering characteristics.

Competent Unit: A lithologic unit described as a limestone, sandstone, or siltstone and based on the following guidelines:

- Any limestone or sandstone visually described as moderately strong or stronger based on SGE 605.5
- Any limestone or sandstone visually described as very weak, weak, or slightly strong based on SGE 605.5; have a unit weight of 140 pcf or greater; or a unit weight less than 140 pcf with a second cycle (Id_2) SDI value of 85 percent or greater as based on ASTM D 4644
- Any siltstone with a second cycle (Id_2) SDI greater than 85 percent as based on ASTM D 4644.

Incompetent Unit: A lithologic unit described as shale or claystone, or a competent lithologic unit described as slightly strong, weak, or very weak based on SGE 605.5, with a unit weight less than 140 pcf and an Id_2 value less than 85 percent.

Design Unit: A portion of a slope, or the entire slope, that can be cut at a consistent angle. A design unit may be comprised of single or multiple lithologic unit(s). A design unit can be selected on the basis of characteristic lithology and the anticipated slope failure(s). The thickness of a design unit can range from a relatively short thickness (minimum 10 feet) to the height of the entire cut slope. Three (3) design units are considered in this Bulletin, defined as follows:

1. Competent Design Unit: Consists of greater than 90 percent competent units. The failures anticipated to occur in this design unit are those controlled by unfavorable orientation of discontinuities (plane, wedge, or toppling failures).

2. Incompetent Design Unit: Consists of greater than 90 percent incompetent units. The failures anticipated in this design unit include raveling, mudflows and rotational slides.

3. Interlayered Design Unit: Consists of interlayered competent and incompetent units, each ranging in proportion from more than 10 percent to 90 percent. Undercutting-induced failures (rockfalls) and mudflows are the anticipated primary failures in this design unit. However, raveling and rotational slides are possible.

B. Subsurface Exploration

Exploration for a rock cut slope, which includes geologic explorations, data collection, and presentation of information, are vital to the design and construction of rock cut slopes. Each specific project involves unique situations and the explorations should be planned accordingly.

When designing the rock cut slope configuration, evaluations of the current conditions of existing cuts or nearby exposures of the same material should be performed, if available, and used to confirm the appropriateness of a design slope angle. For example, if a slope appears to be stable at a 1:1, then a new slope cut at 1:1 should also be anticipated to be stable. Additionally, the County Manager, or an individual knowledgeable with the cut, should be contacted to determine the past maintenance and performance of an existing cut slope, or nearby cut slopes. Periodic maintenance can mask the true performance of a slope.

New rock cuts excavated in areas where there typically are limited (if any) rock exposures, will require a detailed subsurface exploration. Existing rock cuts that are located near a new cut area and are located within a similar geology are helpful in assessing the performance of particular rock units.

Planning of the subsurface exploration should follow the guidelines presented in the SGE Section 303. The subsurface exploration program (e.g. borings) should be tailored to the site specific conditions determined after the site reconnaissance has been performed. It should be noted that variations can occur even in similar geology, both vertically and horizontally. Occasionally these variations may occur rapidly over just a few feet.

Existing rock cut slopes that are to be rehabilitated afford rock exposure that can be studied as part of the exploration efforts. Therefore, depending on the amount of information available and the scope of the remediation, subsurface explorations (e.g. borings) may be limited, or may not be required. The need for subsurface explorations should be assessed after a site reconnaissance is performed and should be tailored on a project specific basis.

As an example, a rehabilitation project that is being completed as part of widening of an existing cut that is performing well may not have the need for a detailed exploration. Evaluation of archival subsurface data, as well as geotechnical and geological characterization of the existing cut may be sufficient.

Information regarding sampling and testing, including bedrock description and unconfined compression strength testing, is located in Sections 400 and 600 of the ODOT SGE. In addition to the aforementioned specifications, the following requirements should be followed:

1. Perform a representative number of Unconfined Compression Strength Tests (ASTM D 7012) to define conditions for the following lithologic units.

   If a limestone or sandstone is described using field parameters as slightly strong, weak, or very weak (less than 3,600 psi for unconfined compressive strength) based on SGE 605.5, Unconfined Compression Strength testing is required.

   The program should include at least one test for each unit listed above. The presentation of the test results should also include the unit weight of the design unit.

2. If there are insufficient sized samples for Unconfined Compression Strength Tests, the Point Load Test should be used. ODOT research (Shakoor and Admassu, 2010) has found that a correlation factor of 24 for competent units or a factor of 12 for incompetent units can be used to correlate Point Load Test Results to Unconfined Compressive Strength Test Results.

3. Perform at least one Slake Durability Test (ASTM D4644) per lithologic unit for the following units:

   - Competent Design Units: If a limestone or sandstone is described as slightly strong, weak, or very weak (less than 3,600 psi for unconfined compressive strength) based on SGE 605.5 and a unit weight less than 140 pcf then SDI testing is required. For a siltstone, SDI testing is required.

   - Incompetent Design Units: SDI testing is required.

   - Interlayered Design Units: SDI testing is required (incompetent lithology only).

If the Designer believes additional test procedures are warranted for a specific project, the DGE or OGE should be contacted. Possible tests include, but not limited to, those to determine shear strength, Young's Modulus, Poisson's ratio, tensile strength, hydraulic conductivity (falling/constant head or in-situ packer).

Additional discussion of explorations can be found in Section 200 of the ODOT Rock Slope Design Manual.

C. Rock Cut Slope Configuration (Determination of Slope Angle)

The design of rock cut slopes is a staged process, with the number of steps dependent on the size of the project. A major project will likely have a preliminary stage consisting of a limited drilling and testing program resulting in preliminary design(s) leading to the final program consisting of the same components on a larger scale. The remainder of the testing program is then conducted on the final boring program, influenced by the preliminary design, to refine the final design. For a small project, the preliminary stage will be very limited, or not performed at all. Only final borings and the final design are completed.

The rock cut slope configuration is influenced by a number of factors (lithology, strength, weathering resistance, bedding characteristics, joint inclination, and discontinuities). Three design units (competent, incompetent, and interlayered) have been identified as representing the conditions typically encountered in Ohio. The following sections outline the guidelines for each of the Design Units.

1. Competent Design Units

Once it is established that the rock slope will be comprised of competent design units, the cut slope inclination may be determined based on Rock Quality Designation (RQD) as follows in GB3 Table 1:

GB3 Table 1 - Cut Slope Angle: Competent Design Units

RQD (%)	Recommendations
0-50	Cut slope to 1H:1V or consult with the DGE
51-75	Review global stability and design based on engineering judgment or consult with the DGE
76-100	Slope grade of 0.5H:1V, or 0.25:1V for thickly bedded units

2. Incompetent Design Units

The design of the slope angle for incompetent design units is based on the average second-cycle SDI (Id_2). The following design guidelines (GB 3 Table 2) should be used:

GB 3 Table 2 - Cut Slope Angle: Incompetent Design Units	
SDI (Id_2) (%)	**Recommendations**
< 20	2H: 1V or flatter -Special design; contact the DGE
20-60	2H: 1V
60-85	1.5H: 1V
85-95	1H: 1V
95-100	1H: 1V or steeper – contact the DGE

For incompetent design units that have SDI less than 20 percent, the design should be based on engineering judgment and consultation with the DGE. For slopes steeper than 1H:1V, use engineering judgment and consult with the DGE.

3. Interlayered Design Units

Interlayered units exhibit significant stratigraphic variations. Cut slope design recommendations for these units need to take into account these variations. Four stratigraphic configurations, designated as Type A through Type D, are recognized and defined in GB3 Table 3 below:

GB 3 Table 3- Definitions of Interlayered design unit types	
Type	**Description**
Type A	Very thick (>3 ft) competent units underlain by incompetent units
Type B	Medium to thick bedded (10 inches to 3 ft) ***sandstone and siltstone*** units interbedded or interlayered with incompetent units in variable proportions
Type C	Medium to thick bedded (10 inches to 3 ft) ***limestone*** units interbedded or interlayered with incompetent units in variable proportions
Type D	Thin bedded (2 to 10 inches) limestone units interbedded with incompetent units in variable proportions

a. Recommended Cut Slope Design for Type A Stratigraphy

Type A stratigraphy, consisting of competent units underlain by incompetent units. Slope instability typically results in topples of flat or cubical rockfalls due to undercutting. Type A stratigraphy may also be interpreted as an incompetent design unit overlain by a competent design unit. For either scenario, design should focus on reducing toppling failures within the competent unit and minimizing excessive weathering of the incompetent unit which causes undercutting of the overlying unit. The cut slope should follow the contour of the contact. Provide adequate catchment area (Section E) and drainage. The following slope design options are recommended for Type A stratigraphy:

- Cut the competent rock at 0.5H:1V to avoid toppling failures. If the incompetent unit is of significant thickness (10 feet thick or greater), cut the incompetent unit at an angle as specified in GB3 Table 2.
- If the incompetent unit is 3 feet to 10 feet thick, cut at 1H:1V. If the incompetent unit is less than 3 feet thick, cut at the same angle as the competent rock.
- If the incompetent unit is 3 feet or greater, provide a geotechnical bench following guidelines in Section D at the contact between units.
- When the competent unit consists only of very thickly to massive bedded sandstone, slopes may be cut at 0.25H:1V. Use of this steeper cut slope angle may result in the need for localized or patterned stabilization using rock bolts. The decision to use the steeper cut angle should be based on engineering judgment in consultation with the DGE.

b. Recommended Slope Design for Type B Stratigraphy

Type B stratigraphy consists of medium to thickly bedded sandstone and siltstone units interbedded or interlayered with incompetent units, which typically results in flat or cubical rockfall debris. The design approach for this type of stratigraphy should be to either cut the slope at a uniform gentle angle to reduce undercutting or cut at a steep slope (0.25H:1V) angle and provide an effective catchment ditch. Due to the thickness of the sandstone units, treating each sandstone unit as a separate design unit and using multiple benches will be impractical in this situation. Two cases are considered.

Case 1: Competent lithology comprises 50 percent or greater of unit

- Cut the slope at a uniform angle of 1.5H:1V. Provide adequate catchment area (Section E) and drainage.
- Cut the slope at 0.25H:1V and evaluate if stabilization of the sandstone/siltstone units in the cut slope is needed. A higher frequency of maintenance should be anticipated.

Case 2: Incompetent lithology comprises greater than 50 percent of unit

- Cut the slope at 1.5H:1V. Provide adequate catchment area (Section E) and drainage.

c. <u>Recommended Slope Design for Type C Stratigraphy</u>

Type C stratigraphy, consisting of medium to thick bedded limestone units interbedded or interlayered with incompetent units. These slopes typically produce cubical rockfall debris. Two cases are considered below.

Case 1: Competent lithology comprises 50 percent or greater of unit

- Cut the design unit at 0.25H:1V for heights of design units not exceeding 25 ft. For design units in excess of 25 feet in height cut at 0.5H:1V.

  In this case, the incompetent units are too thin to be independently designed. The appropriate design approach should be cutting slopes at steep angles and providing adequate catchment areas. Stabilizing limestone units in the upper portions of the slope, which have a greater potential to release rockfalls, may be justified using engineering judgment with consultation of the DGE. Coal seams are common within this stratigraphy and should be protected from weathering. Placing benches on top of coal seams might not necessarily prevent undercutting.

Case 2: Incompetent lithology comprises greater than 50 percent of unit

In this case, the incompetent units are usually in red bed claystone units. The design approach should focus on reducing the degradation of the thick incompetent units and retaining the weathered material on the slope face by constructing a serrated slope (a series of small, 3-4' wide benches), especially in zones containing limestone units. The design should be based on the incompetent rock unit and follow procedures in GB3 Table 2. If the slope contains significant thicknesses of red beds, refer to the Special Care Formations sub-section. Provide adequate catchment area (Section E) and drainage.

d. Recommended Slope Design for Type D Stratigraphy

Type D stratigraphy consists of thinly bedded limestone units inter-layered with incompetent units in variable proportions. This type of stratigraphy is especially prone to releasing flat-shaped rockfalls that can have long trajectories in the presence of steep slopes. Thinly bedded limestone units are most commonly associated with marine limestones that can be identified as fossiliferous (typically found in Southwestern Ohio). Field observations show that where limestone proportion is high (competent/incompetent ratio greater than 0.5) toppling and other types of undercutting-induced failures can occur.

Cut slope at 1H:1V or flatter based on engineering judgment. Provide adequate catchment (Section E) and drainage.

Special Care Formations

These geologic formations identified below are potentially prone to:

1. Rapid weathering because of low durability
2. Gradual change in shear strength caused by weathering
3. Landsliding where over-steepened

Special care should be taken when these units are encountered. Design for these units should be based on engineering judgment and consultation with the DGE.

The Special Care Formations identified in Ohio include:

- Conemaugh formation: red beds–Round Knob Shale (below the Ames Limestone), Clarksburg Red Shale (below the Connellville Sandstone)
- Monongahela formation: few red beds–Upper Uniontown Shale, Tyler Shale
- Washington formation: red beds–Creston Red Shales
- Fairview/Kope formation: highly weatherable shale in Cincinnati Area
- Miamitown formation: weatherable shale in Cincinnati Area
- Friable Sandstones: e.g. Sharon and Blackhand formations

D. Rock Cut Slope Benches

The purposes of a bench include:

- Providing erosion provisions of a less durable rock underlying a more durable rock where weathering may result in undercutting

- Allowing for overall steeper angles of a slope where weaker lithologies are present

- Providing stages of construction

- Providing transition areas

Even though rock slope benches provide some degree of protection against rockfall, this is considered a secondary attribute of benches. Benches should be located to account for construction access and global or localized slope failures and not as a means of rockfall protection.

Benches constructed with the specific intent of catchment should be avoided. FHWA discourages mid-slope benches because they are rarely cleaned and could become launching features for rocks (FHWA, 1998). In general, mid-slope benches are not effective for rockfall control unless they are directly beneath a near vertical slope (0.25:1 or steeper). Design of slopes that include a maintained bench will require the inclusion of access points to all maintained benches as well as a sufficient width (accounting for weathering) for equipment access.

Types of benches include overburden benches, geotechnical (lithologic) benches, and construction benches.

1. <u>Overburden Benches</u>

The purpose of the soil overburden bench is to create an area where adjustments can be made during construction (due to unexpected variations in the soil-rock interface elevation) without requiring a change to cut slope design angles and limits.

At the interface between soil overburden and bedrock, a minimum 10-foot wide bench should be provided.

Slopes in the soil overburden zone (where the soil is over 10 feet thick) should typically have a slope of 2H:1V. Stability analysis for an overburden zone thicker than 10 feet may be necessary in certain situations to confirm the appropriateness of a 2H:1V slope. If a 2H:1V slope does not daylight over a reasonable distance, steeper slopes may be required to minimize right-of-way and excavation. On occasion, the overburden zone may include or be comprised entirely of severely weathered rock. For the use of overburden zone slopes steeper than 2H:1V, contact the DGE. If the overburden zone is less than 10 feet thick or the natural slope is 1H:1V or steeper, rounding of the top of the cut to blend into the natural slope is permissible.

Design of these benches should include an evaluation of drainage, especially in the vicinity of large recharge areas.

2. <u>Geotechnical (Lithologic) Benches</u>

A geotechnical (lithologic) bench is a bench placed at the top of a less durable design unit (e.g. shale or claystone) that underlies a more durable design unit (e.g. sandstone or limestone). The purpose of a geotechnical bench is to provide protection against undercutting of the more durable design unit as the less durable design unit weathers and erodes. Benches should be placed at locations where warranted. Guidance on design of geotechnical benches is provided below.

a. For incompetent design units 10 feet thick or less, the benches should be 10 feet wide.

b. For incompetent design units thicker than 10 feet, the benches should be made wider as necessary based on specific conditions. The designer should use engineering judgment to determine the site-specific minimum thickness of a weatherable bed that will require benching. Conditions to consider are the rate of weathering and the ultimate angle of repose of the weathered incompetent material. For instance, if a material weathers back to 2H: 1V, this should be considered in design to prevent undercutting.

c. For interlayered design units, provide a minimum 10-foot bench at the contact between different design units. The designer should use engineering judgment to determine the site-specific bench size required.

d. Where permeable formations overlie impermeable ones (including areas of fractured flow), which may indicate potential aquifer zones, the configuration of benches must consider drainage issues.

e. For coal, clay, or mineral seams of mineable thickness, or in the case of known or suspected underground mines that will be located within the cut slopes, a 20-foot wide bench should be inserted. Bench locations should be below suspected mine voids and above un-mined seams.

f. The slope of benches longitudinally should follow the base of the competent rock with the outslope having positive drainage typically at a grade of 10%, with a minimum grade of 3%. Special consideration should be given to drainage in vicinity of coal seams. Bench grades are extremely hard to control when rock is blasted.

g. Where there are competent/incompetent unit interfaces near the termination of the slope at the catchment ditch, a 10-foot wide bench should be inserted below road grade to prevent undercutting of the cut slope during maintenance procedures.

h. Where the above guidelines would result in different types of benches in the vicinity of each other (e.g. a construction bench and a geotechnical bench within a few feet vertically), the designer must use engineering judgment to produce a practical design, and combine benches.

i. Access roads to benches will most likely require additional right of way. Sufficient width for equipment access on maintained benches will also be necessary.

j. Bench widths may need to be modified in order to maintain a temporary working bench during construction. These geometric benches should accommodate relief in the existing slope face. The cut line needs to consider all relief as well as the burden thickness.

k. Geotechnical benching must be field adjusted during construction to follow any changes in the bedding surface.

l. Install a bench drain along the contact between competent-incompetent rock units where groundwater is encountered or anticipated to collect seeping water, and a backslope drain behind the slope crest to reduce runoff on slope face.

3. Construction Benches

A construction bench is a five (5)-foot bench that is used to accommodate construction practices. For design purposes, where design unit thicknesses or sections of slope designs are greater than 30 feet, blasting must proceed in stages. These benches are provided to account for the required 2-foot offset between lifts during pre-splitting due to constructability issues as well as for the tool variances that occur in drilling (such as tool wander). Without accounting for necessary construction offsets with construction benches, the as-built cut line will either be moved back at the top, impacting project right-of-way, or be made steeper, to maintain the plan offset at the toe of cut.

For slopes steeper than 1:1, or where pre-splitting is specified for a 1:1 slope, 5-foot wide horizontal construction benches should be placed at a maximum of 30-foot vertical intervals of a rock cut slope where no geotechnical benches are required. Variations of plan and actual construction bench width are expected and in fact these benches may, and should if possible, be eliminated during construction.

E. Rockfall Catchment Design

Adequate rockfall catchment must be included in the design of rock cut slopes. The Office of Geotechnical Engineering views catchment ditches as the primary rockfall control method along new slopes. Barriers and other similar controls are viewed as being solutions to rockfall problems on existing slopes. These items should be used in combination or independently only in special circumstances as part of a new slope design (for example to satisfy roadside grading criteria as discussed in the ODOT Location and Design Manual, Vol. 1, Section 307.2.1, to address right-of-way concerns, to address changing slope condition of bedrock quality, or where the cut is very high).

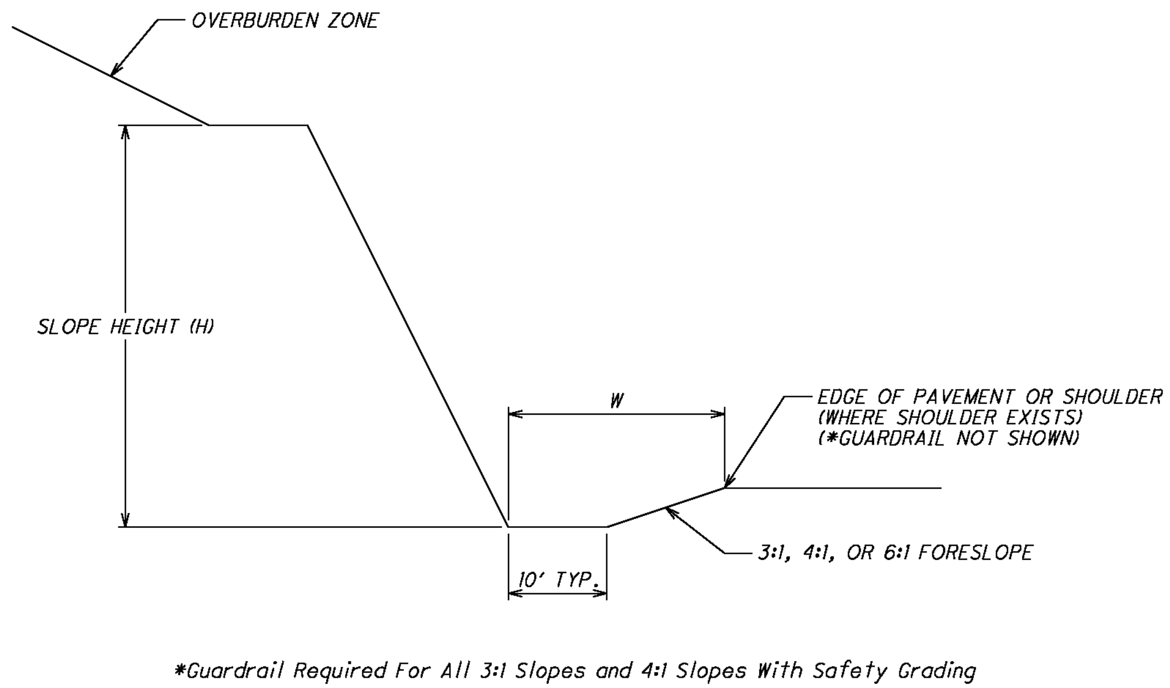
OGE has established a rockfall catchment design criteria of 95% rockfall catchment at the edge of pavement or shoulder (where shoulder exists). An effective method of minimizing the hazard of rockfalls is to control the distance and direction in which they travel. The recommended and most frequently used method to control rockfall in Ohio is the appropriate sizing of a catchment area. Other rockfall control and protection methods beyond catchment ditches include barriers, wire mesh fences, and mesh slope drapes (Refer to ODOT Rock Slope Design Guide Section 504 for further information). A common feature of all these protection methods is their energy-absorbing characteristics in which the rockfall is either stopped over some distance, or is deflected away from the roadway.

The use of design charts and rockfall computer simulation programs are necessary to select and design effective protection measures against rockfall. If design charts are used as the basis for design of catchment areas, representative critical sections along the rock cut slope should also be analyzed using a rockfall simulation program (Colorado Rockfall Simulation Program [CRSP] or equivalent software) to confirm the catchment ditch configuration is acceptable. The catchment area design should be the larger of the two designs; one based on GB 3 Table 4 and the other being the computer simulation models. GB3 Figures 1 and 2 should be referenced for rock slope terminology.

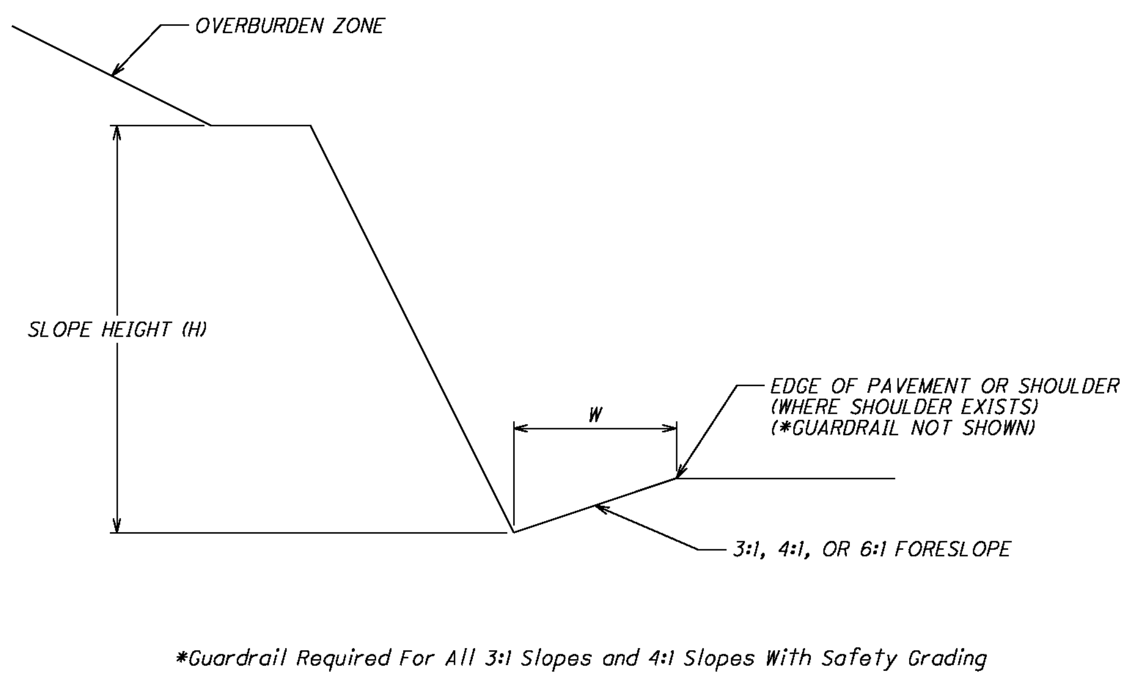
It should be noted that the mid-slope geotechnical (lithologic) bench is not to be designed as a rockfall mitigation measure. However, its ability to attenuate rockfall hazards should not be ignored. The effectiveness or contribution of benches at limiting rockfall hazards should be evaluated using rockfall simulation computer programs. This is accomplished by evaluating both end-of-construction as well as long term conditions.

Utilizing a combination of sources, including other state DOT standards, FHWA cosponsored research, and ODOT research, GB3 Table 4 has been formulated for the various recommended cut slope angles (1.5H:1V or steeper). GB3 Table 4 is based on the OGE established 95% rockfall containment within the catchment area. In this table there are two general ditch configuration options presented, and these configurations are shown in GB3 Figures 1 and 2.

In the case of rock cut slopes with multiple slope angles (e.g. presence of benches), the governing cut slope angle that will be used to determine adequate catchment should be the angle of the portion of slope that intersects the ditch. Catchment width for an individual rock cut slope section should not vary in width throughout the section and should be based on the critical section of the slope design. The critical section is typically the maximum rock cut slope height. However, instances where larger block sizes are anticipated for section of shorter heights may be the critical section. The height of cut slope (H) should be defined as the vertical distance from overburden bench (or lowest 2H:1V or flatter slope of more than 10 feet in height) to the base of the slope. Modifications to the examples in GB3 Figures 1 and 2 may be made for site-specific hydraulic concerns. The catchment ditch width (W) may include the 10-foot wide maintenance bench discussed in Section D Item 2g, provided it is below the edge of pavement or shoulder (where shoulder exists) elevation.



GB3 Figure 1. Typical ditch configuration for a catchment area with a single angle foreslope. (Updated 1/16)



GB3 Figure 2. Typical ditch configuration for a catchment area with flat catchment area and angled foreslope. (Updated 1/16)

GB3 Table 4 - Recommended catchment widths for varying slope and catchment foreslope angles.*						
	Cut Slope Height, H (ft)					
	0-40	**50**	**60**	**70**	**80**	**>90*** **
Cut Slope Angle	**Catchment Ditch Width, W (ft)**					
3H:1V Catchment Foreslope Angle*						
0.25:1	10	15	15	15	20	25 min.
0.5:1	10	15	20	20	20	25 min.
1.0:1	15	20	20	20/25**	25	30 min.
1.5:1	15	20	20	20/25**	25	30 max.
4H:1V Catchment Foreslope Angle*						
0.25:1	10/15**	15	20	20	25	30 min.
0.5:1	15	15	20	20	25	30 min.
1.0:1	15/20**	20	20/25**	25/30**	30	35 min.
1.5:1	15/20**	20	20/25**	25/30**	30	35 max.
6H:1V Catchment Foreslope Angle*						
0.25:1	15	20	25	30	35	40 min.
0.5:1	20	20	25	30	35	40 min.
1.0:1	25/30**	25/30**	30	35	40	40 min.
1.5:1	25/30**	25/30**	30	35	40	40 max.

* For new slopes only, consult ODOT Location and Design Manual, Volume 1, Section 307.2.1 for guidance on catchment foreslope angles.
**Option 1 Catchment Ditch Width / Option 2 Catchment Ditch Width
*** Slopes with a height (H) greater than 90 feet and at an angle of 1H:1V or steeper should be designed with GB3 Table 4 width as minimum and adjusted according to specific site conditions

The designer should use engineering judgment and CRSP or equivalent software analysis to determine the appropriate catchment ditch width for a rock cut slope where the portion of the slope intersecting the ditch is flatter than 1.5H:1V.
Further guidance on CRSP can be found in Section 503.1 of the ODOT Rock Slope Design Guide.

F. Other Geotechnical Considerations

Refer to Section 600 of the ODOT Rock Slope Design Guide for the following topics:

- Mines and Mine Seals
- Groundwater
- Surface Water
- Transitions
- Karst

Refer to Section 700 of the ODOT Rock Slope Design Guide for discussion on construction considerations.

G. Plan Requirements and Deliverables

1. Overburden, geotechnical (stratigraphic), and construction benches must be shown on the cross-sections. The intent of a particular bench should be denoted on the cross-sections. A plan note or typical section is not acceptable except to further define the various benches.

2. Rockfall catchment software analysis output as well as input parameters should be presented as part of the geotechnical report.

3. Cost analysis comparing potential catchment configuration must be presented with catchment recommendations in the geotechnical report.

4. Present any testing results for bedrock samples as per the ODOT SGE Section 700.

H. References

Refer to Section 800 of the ODOT Rock Slope Design Guide.