DETERMINATION OF APPROXIMATE ORIGINAL CONTOUR[1]

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Abstract.--Quantitative geomorphic methods are proposed for comparing premine and postmine topography to determine compliance with approximate original contour regrading requirements. The methods proposed include grid-sampling of slope gradient, hypsometric analysis, and measurement of drainage density in premining, postmining and surrounding areas. The morphology of specific hillslope and channel components of the postmining topography should be based on stability criteria rather than similarity to premining topography.

INTRODUCTION

The Surface Mining Control and Reclamation Act (Public Law 95-87) passed in 1977 requires that surface mining operators regrade disturbed areas to the approximate original contour of the premine topography. Section 701.5 of the Permanent Regulatory Program defines approximate original contour as:

> ...that surface configuration achieved by backfilling and grading of the mined area so that the reclaimed area, including any terracing or access roads, closely resembles the general surface configuration of the land prior to mining and blends into and complements the drainage pattern of the surrounding terrain, with all highwalls, spoil piles, and coal refuse piles eliminated. Permanent water impoundments may be permitted...

Both State and Federal regulations are vague in that they do not provide clear direction for satisfying the AOC requirements. For example, the phrases "closely resembles", and "blends into and compliment" all require subjective intrepretation of their meaning. Likewise, a review of the legislative history indicates that Congress had difficulty in defining a concise approach to this issue. For example, refer to Congressional Deliberations of 1971 and 1973. In attempting to derive a functional regulation a number of exemptions and variances are provided which further confuses the issue.

Review of the regulations and their history shows that there is one central theme, and that is the concern for the postmined land use. Therefore, application of AOC requirements, as currently practiced, may leave the surface that is not conducive to the post mining land use or to geomorphic stability.

Problem

In a mining and reclamation permit application the applicant must demonstrate that the postmining topography of the mined area meets the approximate original contour requirements of the applicable Federal or State regulations. The task is to present a quantitative method for determining compliance with these requirements.

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Objectives

Three quantitative measures of landscape characteristics are employed to compare the premining topography with the proposed postmining topography. Documented geomorphic procedures are used to develop quantitative measures of drainage basin topographic characteristics. Statistical techniques are used in some cases to determine the significance of differences between premining and postmining topography, and therefore, whether AOC has been achieved.

The following three quantitative morphometric properties are used to compare premining and postmining topography.

1) grid sampling of ground slope.
2) hypsometric or area-elevation curves.
3) drainage density (miles of stream channel per square mile of drainage area).

These techniques provide a quantitative chacterization of the landscape that can be used to objectively compare two topographic surfaces.

GEOMORPHIC ANALYSIS

The use of wording such as "general nature" or "closely resembles" in the definition and regulations in regard to AOC suggests the use of quantitative geomorphic analysis in the comparison of reclaimed (postmining) and original premining topography. Methods first proposed by Horton (1945) and extended by Strahler (summarized 1964) provide a means of quantifying topographic characteristics. Strahler (1950) employed statistical techniques to draw conclusions about landscape character from a large sampling of slope measurements. The statistical approach is necessary to reveal similarities and differences between landscape characteristics due to the high variability inherent to the landscape.

Drainage basin measurements can be made from topographic maps depicting pre- and postmining topography. Measurements of hillslope and channel gradient, drainage area, and channel profiles can be taken from these maps. A set of aerial photographs can aid in delineation of the drainage network. Drainage areas can be measured with a planimeter and channel distances can be measured with a chartometer (map wheel). Hillslope and channel gradient can be measured by scaling the distance between adjacent contours along a line perpendicular to the contours.

Slope Gradient

A sampling of topographic gradient throughout the mine area can provide an objective comparison of pre- and postmining topography. Slopes can be measured using a grid system to define slope gradient. The grid size should be determined on a site specific basis. Significance of difference between pre-and postmining average slope gradients can be determined with a statistical t-test at a 95 percent level of confidence. Frequency distributions of the premining and postmining slopes can be plotted to compare a visual representation of the slope sample. In the example (Fig. 1), the frequency distributions of pre- and postmining topography are similar.

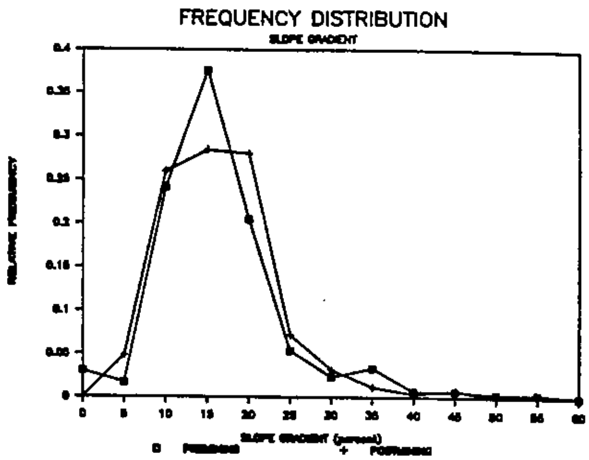

Figure 1. Frequency distribution of slope gradient sampled at a 500 foot grid spacing over the entire mine.

Hypsometric Curves

Hypsometric analysis is a means of determining the distribution of mass within a watershed (Strahler, 1952). A planimeter can be used to measure the area of the watershed above a given contour on a topographic map. Elevation of each contour measured is plotted against area above the contour for first order basins both pre- and postmining topographic maps.

Comparison of first-order drainage basins in the hypsometric analysis is based upon belief by many that the drainage basin represents the smallest fundamental hydrologic or geomorphic unit. For instance, Gregory and Walling (1973, preface) state that the drainage basin "...is visualized increasingly as the fundamental unit of study in fluvial geomorphology..." Ritter (1978, p. 169) introduces a chapter on drainage basins by describing basins as "...excellent fundamental units of geomorphic systems." Chorley et al. (1984, p. 316) point out that the drainage basin "...has been recognized as a viable process-response unit since the beginning of the last century." It is concluded then, that comparison of mine areas smaller than a first order basin is inappropriate because it is a comparison of only a portion of the basic geomorphic system unit.

For example, hypsometric curve pairs (Fig. 2) can indicate that the topography has not been significantly modified by mining and reclamation. The areas beneath the two curves (hypsometric integrals) differ by less than two percent. Strahler (1952) found that integrals in natural areas of similar relief, lithology, and climate vary by 10 to 11 percent suggesting that in our example topographic variation due to mining and reclamation is within natural limits. Overall the curves are very similar suggesting that postmining topography is geomorphically similar to premining topography.

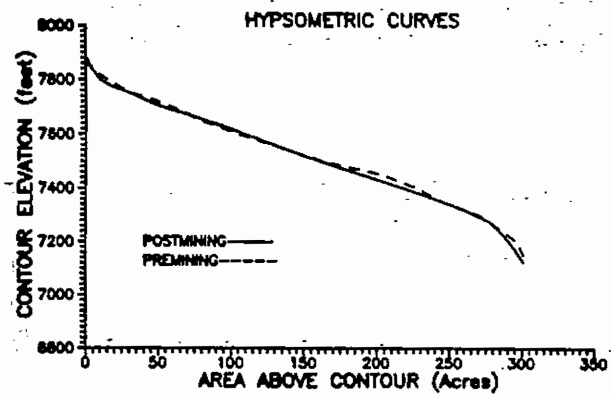

Figure 2. Hypsometric curves for a representative area of the mine.

Drainage Density

Drainage density was defined by Horton (1945) as the sum of all channel lengths within a basin divided by the basin area. It is a measure of the efficiency with which water is removed from a basin by the drainage network. Measurement of drainage density on premining, postmining, and adjacent topography provides an objective insight into whether reclamation has changed drainage density and whether the change, if any, is significant. A significant change of drainage density occurs if the postmining drainage density lies outside the range of values for surrounding topography of similar lithology and relief.

Drainage basins can be delineated on premining and postmining maps of appropriate scale (for instance, 1 inch equals 500 feet). In addition, basins outside the mine area on similar lithology and topography can be delineated on 1:24000 scale USGS quadrangles or other appropriate topographic maps. The drainage networks on the maps can be delineated by following contour crenulations up the basin until they were no longer visible. Aerial photographs can be used to aid in delineation of drainage basins.

In an example data set, drainage density of the premining topography is 3.3 miles per square mile and for postmining topography it is 4.0 miles per square mile. Reclamation has produced an increase in drainage density of 0.7 mi./sq. mi. However, drainage density of adjacent areas ranges from 2.7 mi./sq. mi. to 8.2 mi./sq. mi. Premining and postmining drainage densities lie within this natural background range and, in addition, these values lie within one standard deviation (± 1.7 mi./sq. mi.) of the average (5.1 mi./sq. mi.) adjacent-area drainage density. In this example, reclamation has not resulted in a geomorphically significant change in drainage density.

DISCUSSION

Analysis of slopes, hypsometric curves and drainage density can indicate that the postmining topography has morphometric properties that are not significantly different from those of the premining topography. In the above example, objective criteria (Figs. 1 and 2) indicate that approximate original contour has been re-established.

In applying the above techniques to determining AOC the statistical nature of the techniques must be understood. For instance, the grid sampling of slope gradient does not measure all possible gradients because observations are obtained at a finite number of points. Hypsometric analysis considers only the area above discrete contours and the shape of the area is not taken into account. Therefore, the proposed techniques for evaluating AOC reflect average values and trends within random samples of morphometric data. Statistical techniques, such as these, are valuable tools for drawing conclusions about the morphology of the landscape.

It will be important for a permit applicant to recognize the impact of variable slope gradient on the success of reclamation and to plan accordingly. However, careful evaluation of the pre- and postmining topography should overcome these shortcomings. For example, portions of a reclaimed watershed could be rejuvenated if channel gradients are not designed correctly. Therefore, prudent engineering practices should be employed to design a stable channel. Likewise, geomorphic stability criteria can be used to design a stable channel.

These methods can be used in lieu of AOC criteria. This point is underscored by the fact that regulatory programs mandate the restoration of stable stream channels.

A Geomorphic Perspective

The concept of restoring the original contour may not always be appropriate given the changes that will occur due to disturbance of the surface materials by mining. For example, this is demonstrated by relationships between the morphology of a drainage basin and the infiltration capacity of the surficial materials (Haoley and Schumm, 1961). Specifically, drainage density was found to be inversely proportional to infiltration capacity (Fig. 3). Using data from Hadley and Schumm's study (1961) Ritter (1978) plotted a relationship between sediment yield and infiltration capacity (Fig. 4) which is, in turn, a function of the lithology underlying the basin. Eccker (1984) found that drainage basin morphology on the Mesa Verde Sandstone in northwestern Colorado is significantly different from basin morphology on the Mancos Shale and Browns Park Sandstone. The differences in morphology are attributed to differences in permeability and erosion resistance of the surface materials.

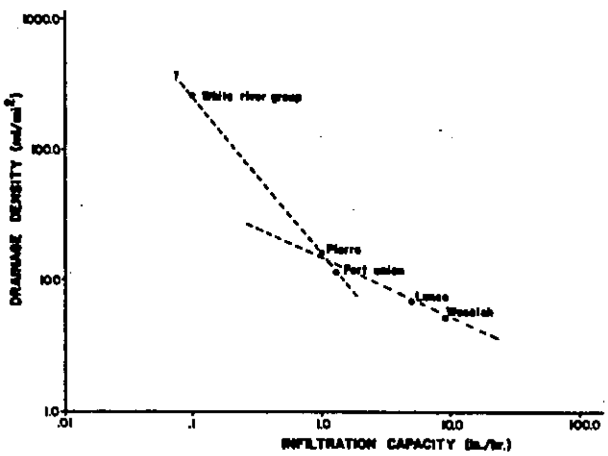

Figure 3. Drainage density versus infiltration capacity for geologic formations in the Cheyenne River Basin (data from Hadley and Schumm, 1961).

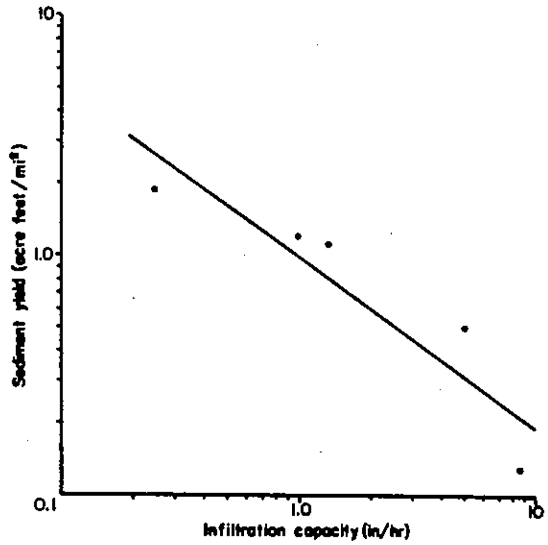

Figure 4. Relation between infiltration capacity and sediment yield, indicating lithologic influence (after Ritter, 1978; data from Hadley and Schumm, 1961).

In some cases relief may be substantially changed by surface mining and reclamation. Basin morphology and process is related to relief. For instance, Hadley and Schumm (1961) plot sediment yield as a function of relief ratio (basin slope) (Fig. 5), and Gregory et al. (1985) found that drainage density is directly related to relief ratio (Fig. 6) for several areas in western New Mexico. Therefore, it is likely that changes in premine drainage basin morphology can be expected due to the changes in relief and surface materials brought about by mining and reclamation.

The morphology of postmining topography should be determined by its erosional stability rather than by its similarity to original contour. Reclaiming to premine topography may produce a landscape in disequilibrium with existing erosional forces. An erosionally stable landform, although different from premining topography, can be in compliance with AOC. The proposed techniques for evaluating AOC provide the necessary flexibility that will allow mine operators to construct an erosionally stable landform which also meets the intent of the law and regulations.

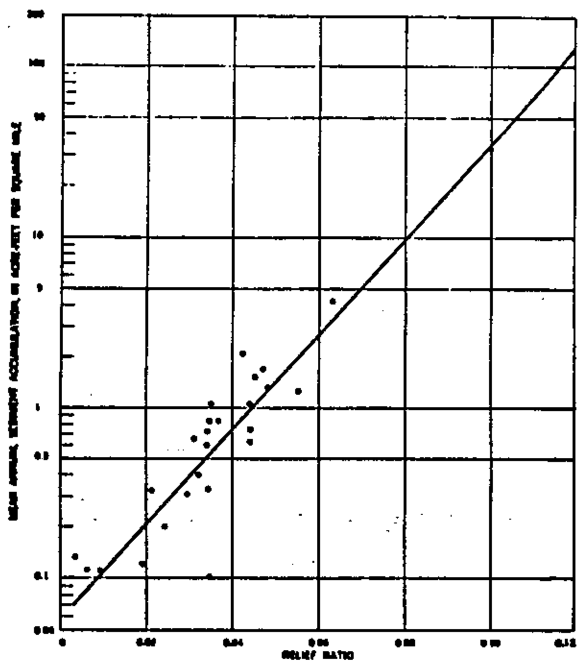

Figure 5. Relation between mean annual sediment accumulation and relief ratio for basins on Fort Union formation (from Hadley and Schumm, 1961).

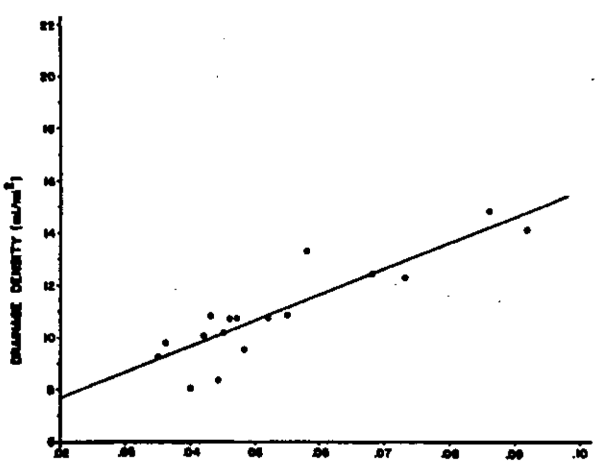

Figure 6. Drainage density versus relief ratio for basins in western New Mexico (from Gregory et al., 1985).

CONCLUSIONS

Geomorphic analysis of the landscape provides a means of drawing conclusions from large amounts of morphometric data obtained from maps, aerial photographs and field reconnaisance. The evaluation of AOC by geomorphic techniques is desirable for three reasons. First, the natural landscape, even within areas of similar climate, lithology and relief, displays a considerable amount of variability which is most consistently analyzed by statistical means. Second, interpretation of the AOC regulations are currently subjective and the application of the intrepretation may not produce a geomorphically stable landform because mining and reclamation may produce changes in surface materials that influence the postmine equilibrium morphology. Third, statistical and geomorphic analyses provide quantifiable description for wording that is incorporated into the definition of AOC as published by OSM. The proposed analysis can provide both mine permit applicants and regulatory agencies with a tool to use in assessing approximate original contour requirements.

LITERATURE CITED

Chorley, R.J., Schumm, S.A., and Sugden, D., 1984, Geomorphology, Methuen, London, 625 p.

Eccker, S.L., 1984, The effect of lithology and climate on the morphology of drainage basins in northwestern Colorado: Colorado Water Resources Res. Inst., Colorado State Univ., Completion Report 131, 124 p.

Gregory, K.J. and Walling, D.E., 1973, Drainage Basin Form and Process, a geomorphological approach: John Wiley and Sons, New York, 458 p.

Gregory, D.I., Schumm, S.A., and Watson, C.C., 1985, Determination of drainage density for surface mine reclamation in western U.S.: Final report to Office of Surface Mining, Denver, Colorado, Contract No. H5140136, 59 p.

Hadley, R.F., and Schumm, S.A., 1961, Sediment sources and drainage basin characteristics in Upper Cheyenne River Basin: U.S. Geol. Survey, Water Supply Paper 1531-B, p. 137-196.

Horton, R.E., 1945, Erosional development of streams and their drainage basins; hydrophysical approach to quantitative morphology: Geol. Soc. Am. Bull, v. 56, p. 275-370.

http://dx.doi.org/10.1130/0016-7606(1945)56[275:EDOSAT]2.0.CO;2

Ritter, D.F., 1978, Process Geomorphology: Wm. C. Brown, Dubuque, Iowa, 603 p.

Strahler, A.N., 1950, Equilibrium theory of erosional slopes approached by frequency distribution analysis: American Journal of Science, v. 248, pp. 673-696 and 800-814.

Strahler, A.N., 1952, Hypsometric (area-altitude) analysis of erosional topography: Geol. Soc. Am. Bull, v. 63, pp. 1117-1142. http://dx.doi.org/10.1130/0016-7606(1952)63[1117:HAAOET]2.0.CO;2

Strahler, A.N., 1964, Quantitative geomorphology of drainage basins and channel networks: in V.T. Chow (ed.) Handbook of Applied Hyorology, McGraw Hill Book Company, San Francisco, pp. 4-36 to 4-76.