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AMERICAN SOCIETY • SURFACE MINING and RECLAMATION •

APPLYING GEOMORPHOLOGIC PRINCIPLES TO RESTORE STREAMS IMPACTED BY SURFACE MINING[1]

by

Michael S. Ellison[2]

ABSTRACT. The combination of geomorphic principles and native material restoration techniques provides a viable alternative to traditional engineering approaches to restore rivers and streams affected by surface mining. Channels can be designed to reflect ranges of stability known to occur in natural streams for measurable parameters such as bankfull width, depth, gradient, meander radius, sinuosity and entrenchment. Stable channel geometry reduces stresses on the stream bed and banks and eliminates the need for channel lining. Methods to utilize native materials have been developed and refined to stabilize stream channels constructed to appropriate dimensions until planted riparian vegetation develops mature root systems. These native materials include root wads, willow bundles, and boulders. These methods result in improved wildlife habitat in and around channels that maintain equilibria between sediment supply and sediment transport, and between erosional and depositional rates and patterns. Two streams in Baltimore County, Maryland were disturbed during mining operations and are being restored using this approach. Goodwin Run had been channelized to allow quarrying of the Cockeysville Marble. Approximately 1100 feet of stream were restored in the fall of 1992. White Marsh Run has been channelized and relocated several times to facilitate sand and gravel mining between an urbanized area and sensitive habitats of the Chesapeake Bay. The design of the White Marsh Run Restoration Project incorporated refinements to techniques used at Goodwin Run, and entails the restoration of over 5000 feet of stream and adjacent wetland habitat.

Additional Key Words: Stream Classification, Channel Geometry, Native Materials.

Introduction

Stream channel morphology is a sum of function and process that reflects the influence of physical laws. The organized nature of stream morphology is expressed by natural stream channels, and the consistent relationships among measurable variables allow streams to be classified based on delineative criteria. The classification system developed by Rosgen (1994) allows predictions of a river's response to changes in its watershed that may result from surface mining.

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Prior to passage of the Surface Mining and Reclamation Control Act of 1977 (SMCRA), rivers were frequently relocated to acquire access to mineral deposits. While the current regulatory climate discourages this practice, streams continue to be impacted by surface mining operations. The cumulative effects of increased runoff, decreased infiltration, and increased sediment load, disturb the dynamic equilibrium of stable streams, resulting in adjustments of channel geometry and pattern.

Recognition of the potential effects to streams from increased discharge and sediment load requires an understanding of the normal characteristics of channels, fluvial processes, and probable reactions to imposed changes (Dunne and Leopold, 1978). Given such an understanding, measures can be prescribed to restore river function and process. By applying proven geomorphologic principles, the river environment can be returned to a more natural state.

English units of measure are used herein for two reasons. First, all of the river measurements published by the U.S. Geological Survey, and therefore the vast majority of the literature, are published in English units. Second, as a result, most of the hydrologists involved in stream restoration are more accustomed to this system.

The Nature of Streams

A river or stream functions as a conveyance system for water and sediment. The system is powered by the process of energy transformation in which the potential energy of elevation is transformed into the kinetic energy of flowing water and sediment. In a natural state, a condition of dynamic equilibrium exists in which the sediment supplied by the watershed is efficiently carried by the stream, and erosion rates within the active channel are balanced by approximately equal rates of deposition. Owing to the universality of physics, channel morphology is highly organized and similar for streams of the same size in comparable climates (Dunne and Leopold, 1978).

Bankfull flow corresponds to the stage that shapes and maintains channels, and has been shown to have a recurrence interval of 1.5 years (Leopold et al, 1964). It is the most effective discharge in that it transports the largest amount of sediment. Larger flood events may move more material, but they occur so infrequently that, over time, they do not accomplish as much as bankfull flows (Leopold, 1994). It is the bankfull flow that is most responsible for forming or removing bars, forming or changing bends and meanders, and generally doing the work that results in the average morphologic characteristics of rivers (Dunne and Leopold, 1978). These average morphologic features, which can be identified and measured, are the manifestations of the physical processes which must be understood in order to understand of a given reach of stream.

Channel geometry describes the physical size, shape, and characteristics in relation to the hydraulic factors of velocity, roughness, slope, and flow frequency (Dunne and Leopold, 1978).

Shear stress is the eroding force per unit area exerted by streamflow. The form assumed by a stable channel is such that shear stress at every point on the wetted perimeter is approximately balanced by the resisting forces of the stream bed or bank (Leopold, 1994).

Stream pattern morphology refers to the form taken by a river in its valley and is directly influenced by eight variables: channel width,

depth, velocity, discharge, slope, roughness of channel materials, sediment load, and sediment size. The independent variables are discharge and sediment load. A change in any one of these variables sets up a series of channel adjustments which lead to a change in the others, and the result is an alteration in stream pattern morphology (Rosgen, 1994). The response among the dependent variables to changes in discharge or load is highly consistent from one location to another in a given river system, and from one river to another, and are all factors related to the dissipation or conservation of energy, and to the distribution of energy expenditure (Leopold, 1994).

One of the most obvious morphological features is the stream meander, and the lateral migration of stream meanders is a very important and readily observed process. Meandering represents the condition that channels approach as erosion and deposition proceed. Stable channels maintain a constant cross section as lateral migration occurs, with the quantity of material eroded from the cut bank being approximately equal to the amount of deposition on the next point bar downstream on the same side of the channel (Leopold, 1994).

Meanders are a good example of the predictability of river behavior that is so important in the restoration of disturbed systems. The relation of bankfull width and radius of curvature to meander wavelength is linear through five orders of magnitude (Leopold, 1994). Rosgen (1993) has demonstrated that the meander radius of stable streams is 2.2 to 2.8 times the bankfull width. Leopold (1994) states that the meander radius of 2.3 times the bankfull width is the ratio of least friction loss, and manifests the conservation of energy or tendency toward minimum work. Having once established a meandering pattern, a stream will not change to a straight pattern as long as the climate does not change (Dunne and Leopold, 1978). Therefore, the relationships between bankfull width and meander radius and wavelength must be maintained or re-established for effective restoration.

Stream Classification

Scientists have long sought to define a categorical order for streams, and a multitude of descriptive and theoretical schemes are documented in the literature. One of the more recent classification systems is that of David Rosgen, who analyzed data from over 450 rivers in the United States, Canada, and New Zealand and developed a methodology based on the concept that current channel morphology is governed by the laws of physics through observable stream channel features and related fluvial processes (Rosgen, 1994). Because Rosgen brought together quantitative relationships into a readily understood, meaningful framework, his system has gained rapid acceptance across a variety of disciplines. The Rosgen Classification System is now the most widely accepted manner of describing a channel (Leopold, 1994).

Rosgen provides a staged classification scheme with four levels of detail that can be applied commensurately with the objectives and skills of the user. The system organizes data from measurable stream features into combinations of delineative criteria (Figure 1), while at the same time recognizing a continuum within and between the various stream types. The end result is 42 major stream types determined by (in order) entrenchment ratio, width/depth ratio, sinuosity, slope range and channel material particle size (Figure 2).

The entrenchment ratio provides a quantitative means of describing the interrelationship of a stream to its

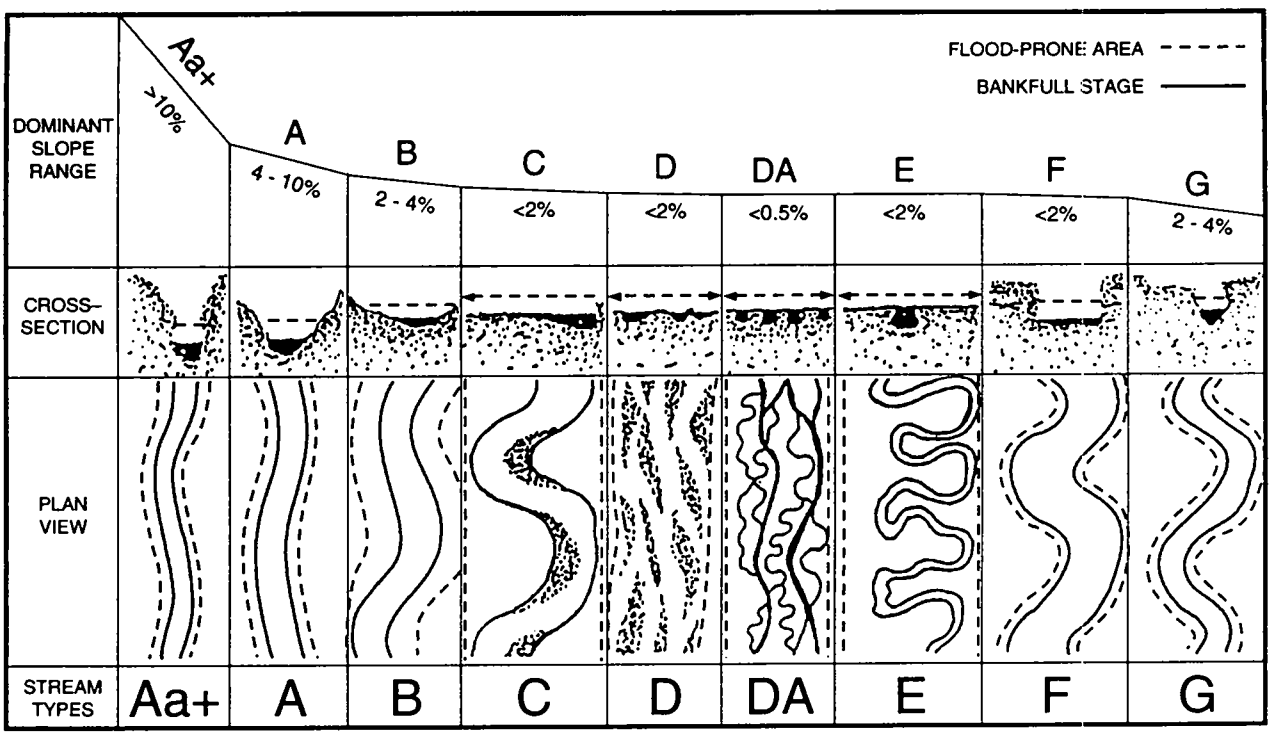
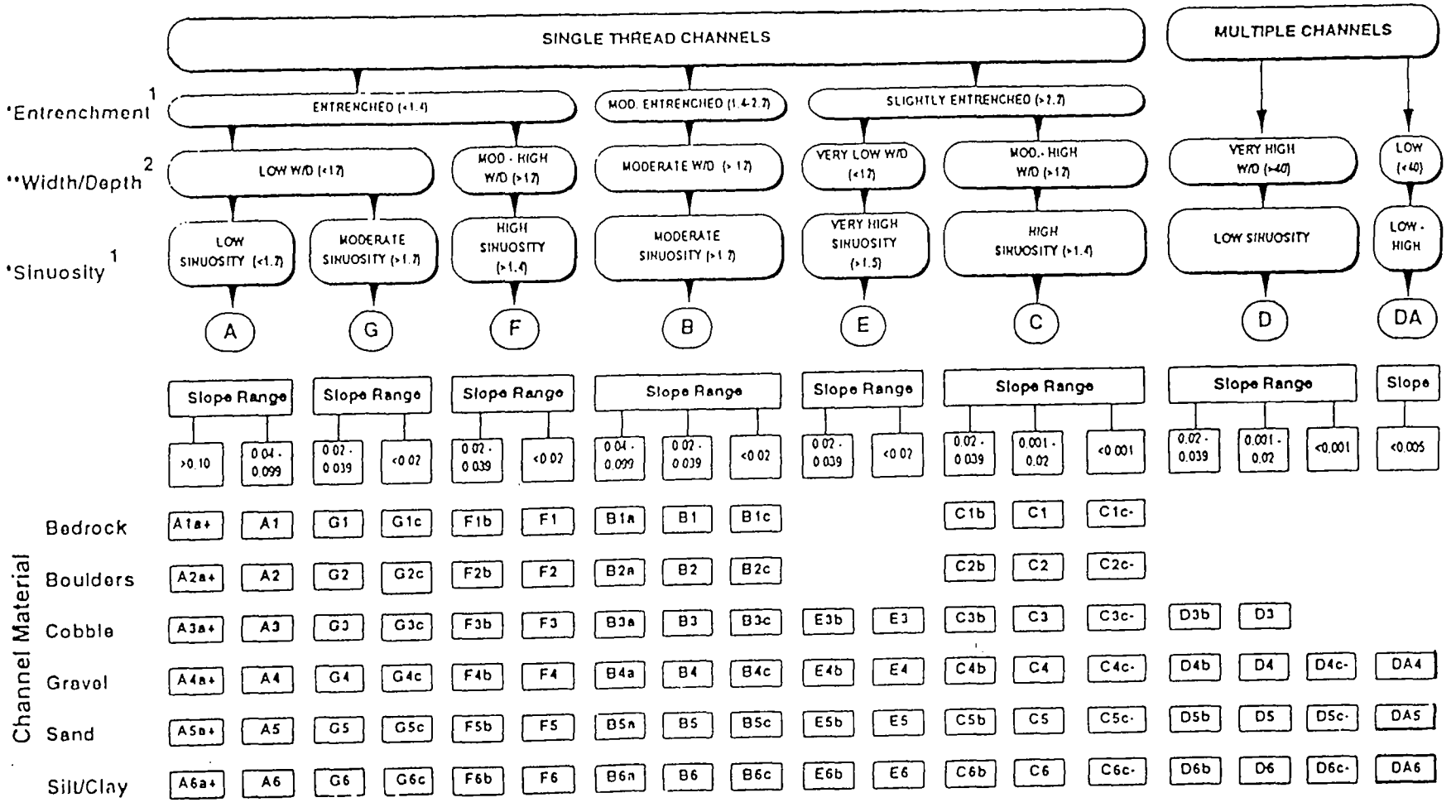


Figure 1. Longitudinal, cross-sectional, and plan views of major stream types (from Rosgen, 1994).

valley and/or adjacent landforms. It is the ratio of the width of the floodprone area to the bankfull width of the channel (Rosgen, 1994). Rosgen defines the floodprone area as the width measured at an elevation which is determined at twice the maximum bankfull depth (Figure 3). This is a relatively frequent flood elevation (50 year return period or less) and helps distinguish whether the flat adjacent to a channel is active floodplain, terrace, or outside a floodprone area.

The width/depth ratio is simply the bankfull width divided by the average bankfull depth, and is usually calculated from field measurements. Sinuosity is the quotient of channel length divided by valley length. Slope refers to the water surface slope in the center of the channel at the bankfull stage, and should be measured over a length of at least twenty channel widths. Channel material particle size is the median intermediate diameter of particles in the bed and banks of the active



1 Values can vary by ± 0.2 units as a function of the continuum of physical variables within stream reaches.
2 Values can vary by ± 2.0 units as a function of the continuum of physical variables within stream reaches.

Figure 2. Streamtype delineation key (from Rosgen, 1994).

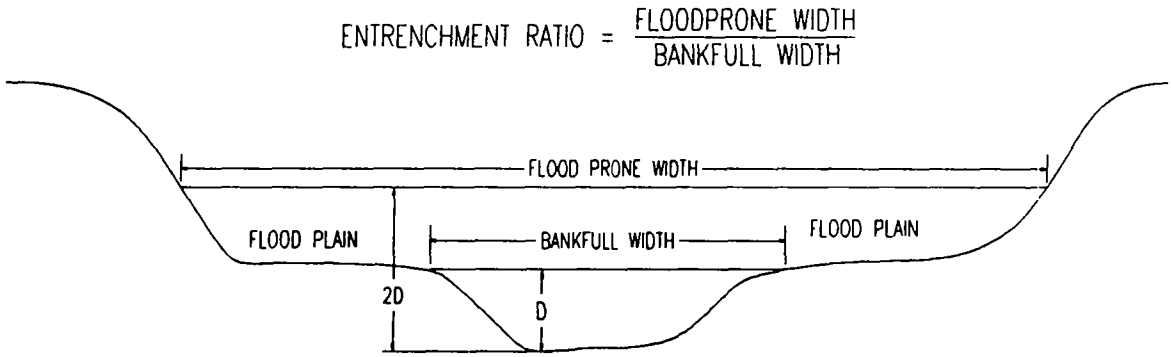


Figure 3. Determination of Entrenchment Ratio.

channel.

One of the primary objectives of this classification system was to be able to predict a river's behavior from its appearance, with a major application being the restoration of disturbed streams (Rosgen, 1994). The system was designed to allow interpretations regarding modes of adjustment-- either vertical, lateral, or both-- and energy distribution to be inferred through stream types (Rosgen, 1994). Rosgen and others have used this system to evaluate changes in channel geometry that have resulted, or would most probably result, from hydrologic and sediment load changes within watersheds.

Since its adoption by the USDA Forest Service, U.S. Fish and Wildlife Service, and many state and local government agencies, the Rosgen system has been successfully applied to many hundreds of streams across North America and found equally valuable for the evaluation of ephemeral, intermittent and perennial streams. Rosgen's system is a Classification of *Natural* Rivers (emphasis added) intended for use on individual reaches rather than entire stream systems or watersheds. Under natural conditions a given stream may vary in character, and therefore class, even through short distances downstream, as a result of passage from one lithologic type to another, tributary entrance, or change in landscape character (Leopold, 1994).

Stream Disturbance from Surface Mining

The overwhelming consensus in the literature is that surface mining increases the runoff and sediment supply to receiving streams, which, as discussed above, will initiate alterations in channel pattern. Changes in vegetative cover are a primary cause of the changes in hydrologic and sediment regimes that destabilize streams. In addition, alterations to soils, geology, and topography all contribute to erosion and affect the amount, timing and location of water reaching streams. Channel relocations to facilitate mining operations are another major cause of river instability, and will be discussed in a subsequent section.

Clearing vegetation increases runoff volume and decreases lag time, thereby increasing peak flows from a given storm event (Dunne and Leopold, 1978). Drainage diversions around active mine sites can result in the premature channelization of runoff from upslope undisturbed areas, increasing times of concentration. Toy and Hadley (1987) describe higher peak flows in mined watersheds compared to unmined watersheds, and discuss increases in volume, depth, and velocity of runoff, as well as increased rates of delivery to receiving streams as a result of reduced soil infiltration capacity.

Elliott (1990) and others have correlated increased bulk densities in reclaimed soils with reduced infiltration rates. Toy and Hadley also provide a good synopsis of several studies that compared erosion rates and sediment yield from surface mined lands to natural sites.

Elliott (1990) studied areas reclaimed under current SMCRA regulations that were still affected by relatively rapid erosion rates several years after conclusion of reclamation activities. He found erosion rates can remain high after establishment of vegetation due to steep slopes or narrow valley floors. Elliott identified two geomorphologically distinct areas of erosion: rills with occasional gullies on hillslopes, and gullies/unstable stream channels on valley floors. While both conditions can provide excess sediment to streams, gullies on reclaimed valley-floors have the potential to rapidly mobilize substantial volumes of soil and spoil, thereby inducing channel instability downstream. In addition, local base-level lowering can propagate headcuts upstream and into nearby tributaries (Elliott, 1990).

Surface mining also tends to remove lithologic and structural controls on the drainage network as consolidated lithologic units are fragmented, removed, and replaced when operations proceed across valleys (Elliott, 1990). The destruction of bedrock also results in decreased material strength and resistance to erosion and mass wasting (Toy and Hadley, 1987). Because geomorphic process rates are accelerated during and for some time after mining operations, valley geometry and hillslope stability become important factors in long term stream stability.

In evaluating stream impacts from mining, the elements of proximity and direction need consideration. Due to the interconnected nature of drainage networks, many effects may not be fully observed for some great distance from where change occurred (Dunne and Leopold, 1978). Different stream types adjust to stress in different ways, and some, such as most "A" type and some "B" type channels, are more forgiving of hydrologic changes, and significant channel disturbance may not be manifest until there occurs a change in stream type down valley. Additionally, the concept of headward erosion implies that all impacts may not be downstream of the mine site.

Traditional Remedies: The Engineering Approach

Historically, streams destabilized as a result of mining operations have been neglected. Dredging often occurs when mass wasting or excessive sedimentation cause flooding problems, and various methods of armoring have been applied to protect bridges or other structures threatened by erosion, but, in general, the restoration of river function and habitat is a relatively new concept. This is probably due, at least in part, to the lack of understanding of fluvial processes and the downstream ramifications of disturbance in the watershed.

In addition, the physical relocation of rivers has typically resulted in straight ditches designed for maximum efficiency of water movement and covering the shortest distance possible (Thompson, 1985). This practice, generally referred to as channelization, usually raises the severity of erosion and deposition problems. Without the appropriate channel geometry, a river will not remain passively in its newly assigned place, but will instead respond immediately with alterations among hydraulic variables to return to its pre-disturbed pattern (Dunne and Leopold, 1978).

In addition to the instability

caused by adjustment to imposed conditions, channelization typically has downstream effects, especially increased bank erosion and aggradation or degradation of the bed (Dunne and Leopold, 1978). One example, though unrelated to mining, frequently mentioned in the literature (Dunne and Leopold, 1978; Toy and Hadley, 1987; Leopold, 1994) is the Blackwater River in Missouri. The river was shortened by the elimination of meanders, which increased the slope of the channel and has caused over 60 years of continuous downcutting.

Artificial channels are often sized to contain flood events well in excess of the bankfull flow, and are typically designed to have a wide, relatively flat cross section. These conditions typically cause aggradation because the increase in width/depth ratio reduces the shear stress and entrainment capacity of the stream at any flow (National Research Council, 1992). In addition, the bed and banks are routinely stabilized with rip-rap, gabion baskets, or concrete, which limit the development of aquatic and riparian habitats and are devoid of aesthetic value.

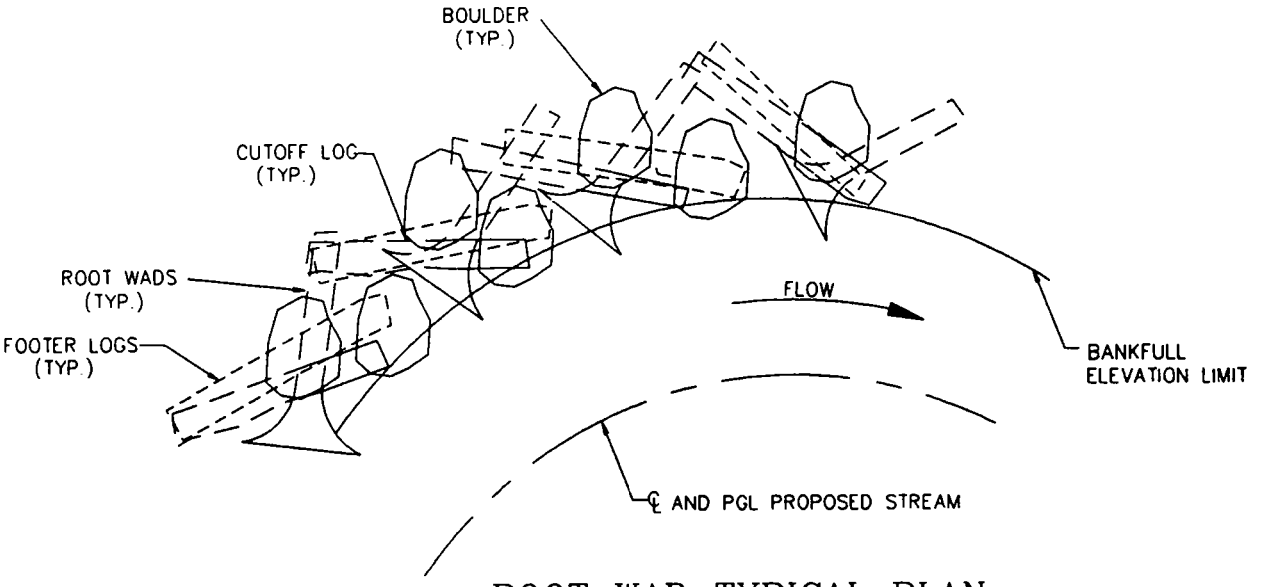
Geomorphology and Native Materials: An Alternative Approach

The objective of stream restoration is to restore the dynamic equilibrium of the physical system, which will establish and support the biological components (National Research Council, 1992). This is accomplished by establishing the channel geometry and pattern that are appropriate for the bankfull discharge and sediment load, and consistent with the morphological features of the valley.

The Rosgen classification system provides a framework for determining the most probable form of a stream. The delineative criteria reflect ranges of stability that can be used to calculate design channel dimensions based on streamtype. The morphology of the valley is the primary determinant of the appropriate streamtype because of the empirical relationships between a stream and its valley. Narrow valleys will dictate moderate to high entrenchment, while broader valleys allow greater sinuosity and a more developed floodplain. In addition, the valley slope divided by sinuosity equals the channel slope, which allows the integration of potential vertical and lateral constraints in the restoration design.

Other relationships between the valley-floor width, valley slope and drainage area are described by Elliott (1990). Elliott suggests that stream channel stability can be significantly improved if these parameters are replaced to appropriate values during the reclamation process.

If the channel geometry of a river is restored to a stable form, shear stress will be minimized and excessive armoring of bed and banks is unnecessary. This eliminates the expense of importing large quantities of rock or concrete. Instead, stream banks can be effectively stabilized using native material revetments such as rootwads and willow bundles (Figures 4 and 5, respectively), which can often be salvaged close to the site. These materials allow the construction of vertical banks on the concave side of meander bends, unlike rip-rap, which must be placed at slopes of 1:1 or less. In addition, they provide organic matter for benthic organisms and can be installed to provide cover for fish. Willow cuttings are typically planted in and around rootwads to provide permanent bank stabilization after the rootwads decay. Native materials facilitate this establishment of riparian habitat to the edge of the active channel, with the end result being a more natural stream in terms of aesthetics and function.



ROOT WAD TYPICAL PLAN

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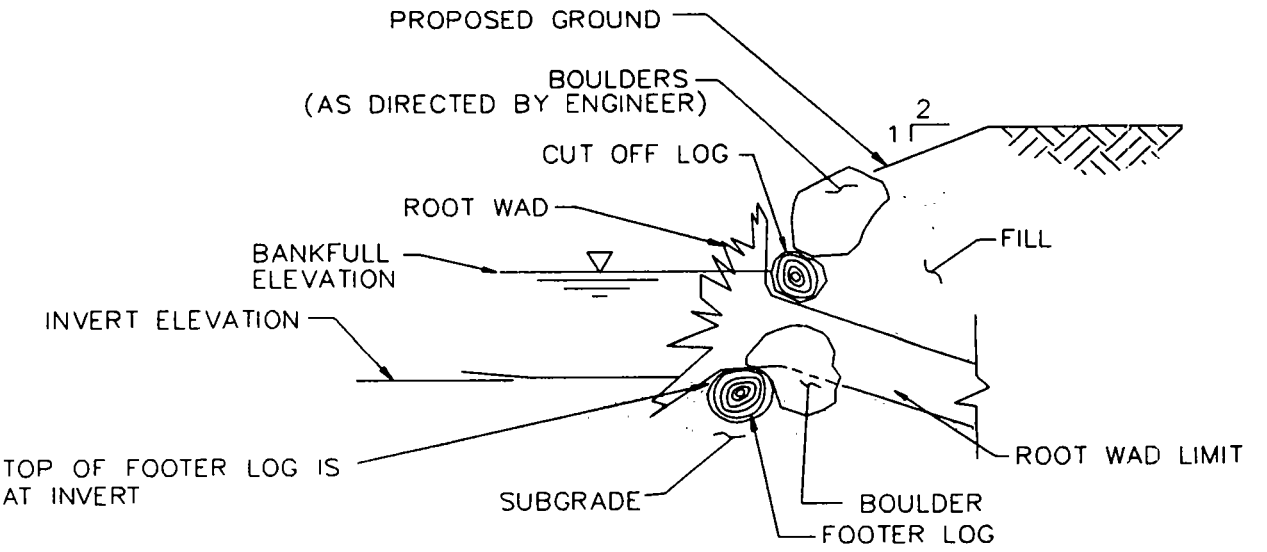

ROOT WAD REVETMENT TYPICAL SECTION

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Figure 4. Root wad revetment for concave side of restored meander.

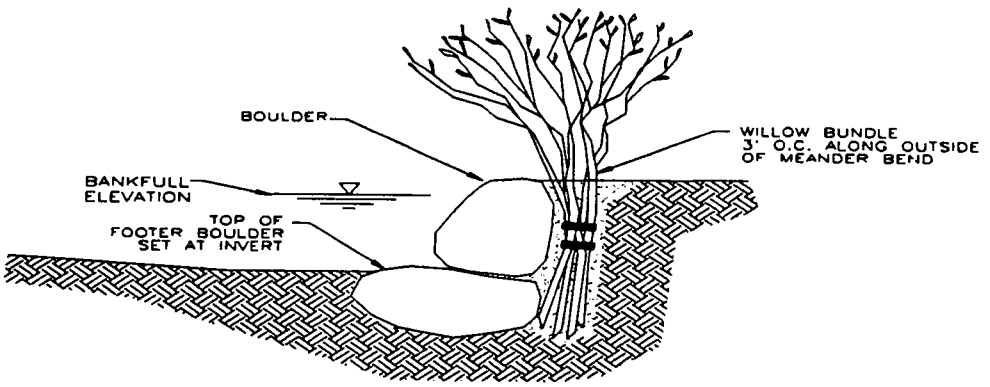


Figure 5. Willow Bundle revetment for concave side of restored meander.

Vortex rock weir structures (Figure 6) were developed and refined by David Rosgen to provide habitat enhancement and grade control without inducing backwater conditions. In addition, the upstream pointing "V" configuration directs flow into the thalweg, thereby reducing stresses on the near bank regions. Footer rocks are set at the channel invert elevation behind the vortex rocks to break the hydraulic jump of flow over the vortex rocks. These structures are typically placed at intervals of about every two to three channel widths, and at the points of curvature in and out of meander bends.

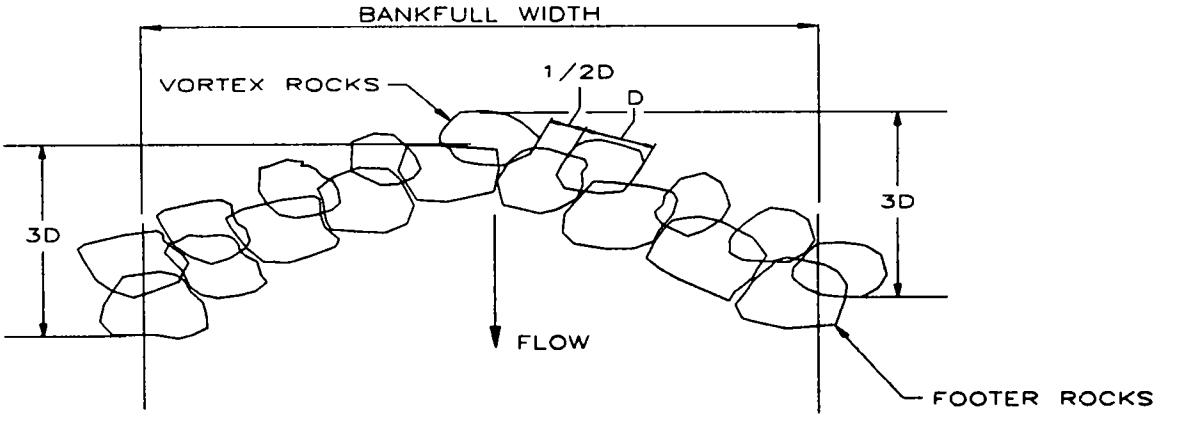
Examples

Goodwin Run

Goodwin Run is a second order tributary to Beaverdam Run, a significant trout fishery in the Piedmont physiographic province of north-central Baltimore County, Maryland. Near the confluence of its two headwater tributaries, Goodwin Run flows through a large quarrying operation where the Cockeysville marble has been extracted for decades. Despite several channel relocations over the years, one of the tributaries sustains a good brook trout population, and brown trout have been known to inhabit the main stem. The stream had been targetted for restoration as part of a county-wide stream improvement program, and funding was aquired when the Maryland State Highway Administration required compensatory mitigation for stream and wetland impacts related to a road project that would cross the stream.

Prior to restoration, the channelized stream was classified using the Rosgen system as predominantly a "G" type channel with some reaches of the "F" streamtype (Gracie, 1995). In addition, some sections of the stream had been lined with rip-rap. Severely eroding banks were providing excess sediment to downstream reaches and to Beaverdam Run, with substantial aggradation occurring near a railroad crossing just upstream of the confluence. The objectives of the restoration effort were to arrest the bank erosion problems by installing natural channel geometry, and to improve fish habitat by using native material revetments.

Measurements of existing conditions were collected to allow determination of the bankfull discharge and other design criteria. The design of the new stream was based on a C4 stream type in the Rosgen classification system (McGill and



VORTEX ROCK WEIR (PLAN)

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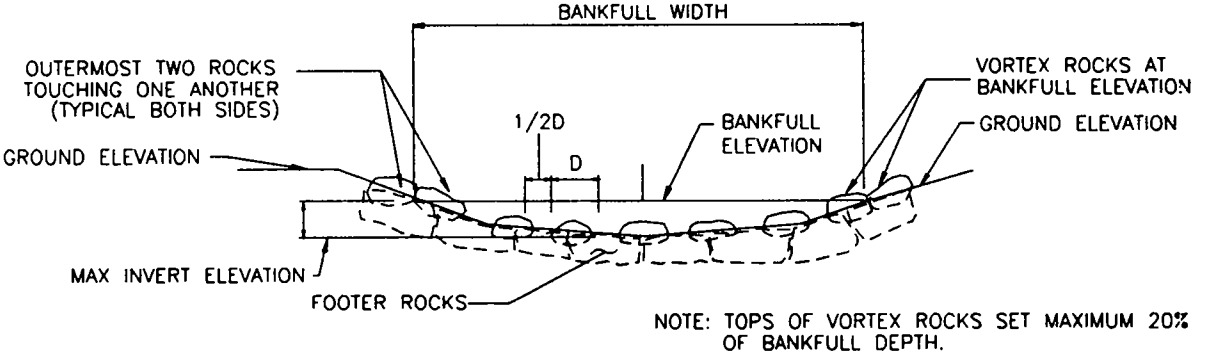

VORTEX ROCK WEIR (CROSS SECTION)

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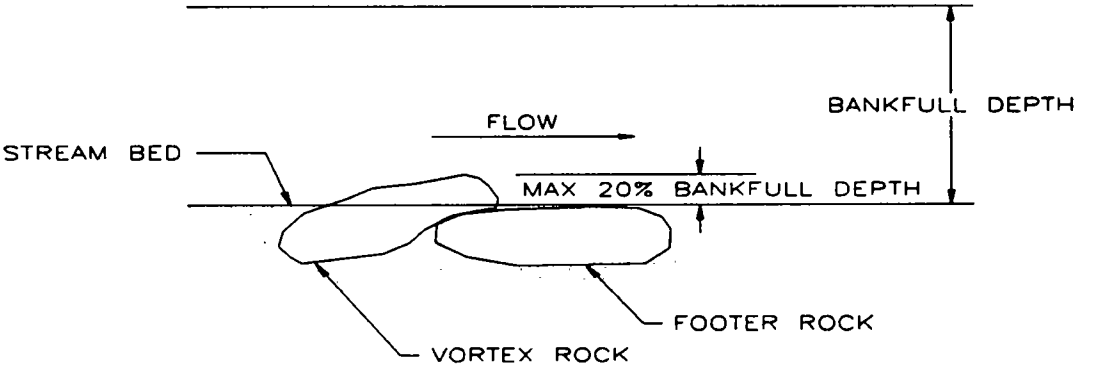

VORTEX ROCK WEIR (PROFILE)

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Figure 6. Vortex Rock Weir structure for grade control and habitat enhancement.

Gracie, 1993). The design bankfull width was 28 feet and the average bankfull depth was 2 feet. The maximum depth in pools was 3.6 feet. Rootwads were used to reinforce meander bends and vortex rock weirs to provide grade control and direct flow into the center of the channel. Approximately 1100 feet of river were restored.

Construction was completed in September of 1992, and within a week a tropical storm caused flows to exceed the bankfull stage. The stream has since received several bankfull events and has generally held up well. Monumented cross sections allow consistency in annual monitoring of channel geometry, and sample data are provided in Figure 7.

Since construction, there have been some minor adjustments in the stream that are instructive. First, there has been some erosion of point bars on the inside of meander bends. The primary cause of this was a directive from a regultory authority that required the application of a stabilization seed mix on the point bars within the the limits of the active channel. After the grass was established, channel capacity was reduced and roughness was increased. The river adjusted by eroding enough material from unvegetated portions of the point bars to regain its capacity. The stream was designed to have a width/depth ratio of 14. If a width/depth ratio at the higher end of the stable range for this streamtype had been used, the amount of this erosion would most likely have been less.

Another problem has been aggradation in and around the rock weirs. There probably was not enough displacement to the apex of the weirs; in other words, the distance in the center of the channel from the wide end of the `V' to the upstream-most rock at the point was insufficient. Design modifications by Rosgen now indicate that this displacement should be 2.5 to 3 times the average intermediate diameter of the boulders. In addition, the vortex rocks supplied by the contractor were too big. Although correctly installed with a 0.3 to 0.5 diameter space between rocks, the large gap appears to have inhibited proper functioning of these devices.

The last problem was with the rootwad revetments. Rootwads are installed such that the bole of the tree is oriented parallel with the incoming flow, which usually sets the root fan normal to flow (Figure 4). The cut-off log is placed on top of the bole and oriented downstream and out toward the next rootwad. The cutoff log is secured with a single boulder and backfill material. The purpose of the cutoff log is to break up eddy currents that can develop when bankfull flows come around the meander. To function effectively, it is critical that the elevation of the tops of the cutoff logs be above the bankfull elevation. At Goodwin Run, most of the cutoff logs were only about twelve feet long. The result was that some of the logs were not long enough to be adequately buried in the bank. Of over 100 cutoff logs installed, 3 have been torn out and 4 or 5 others show evidence of buoyancy during high flows.

<u>White Marsh Run</u>

White Marsh Run has been channelized and relocated several times to facilitate extensive sand and gravel mining between a heavily urbanized area and sensitive habitats of the Chesapeake Bay. Due to the mitigation requirements of another highway project, approximately forty acres of wetlands will be created and over 5000 feet of stream will be restored. The existing stream is an F4 streamtype that is fully entrenched by steep banks.

The discharges used for the

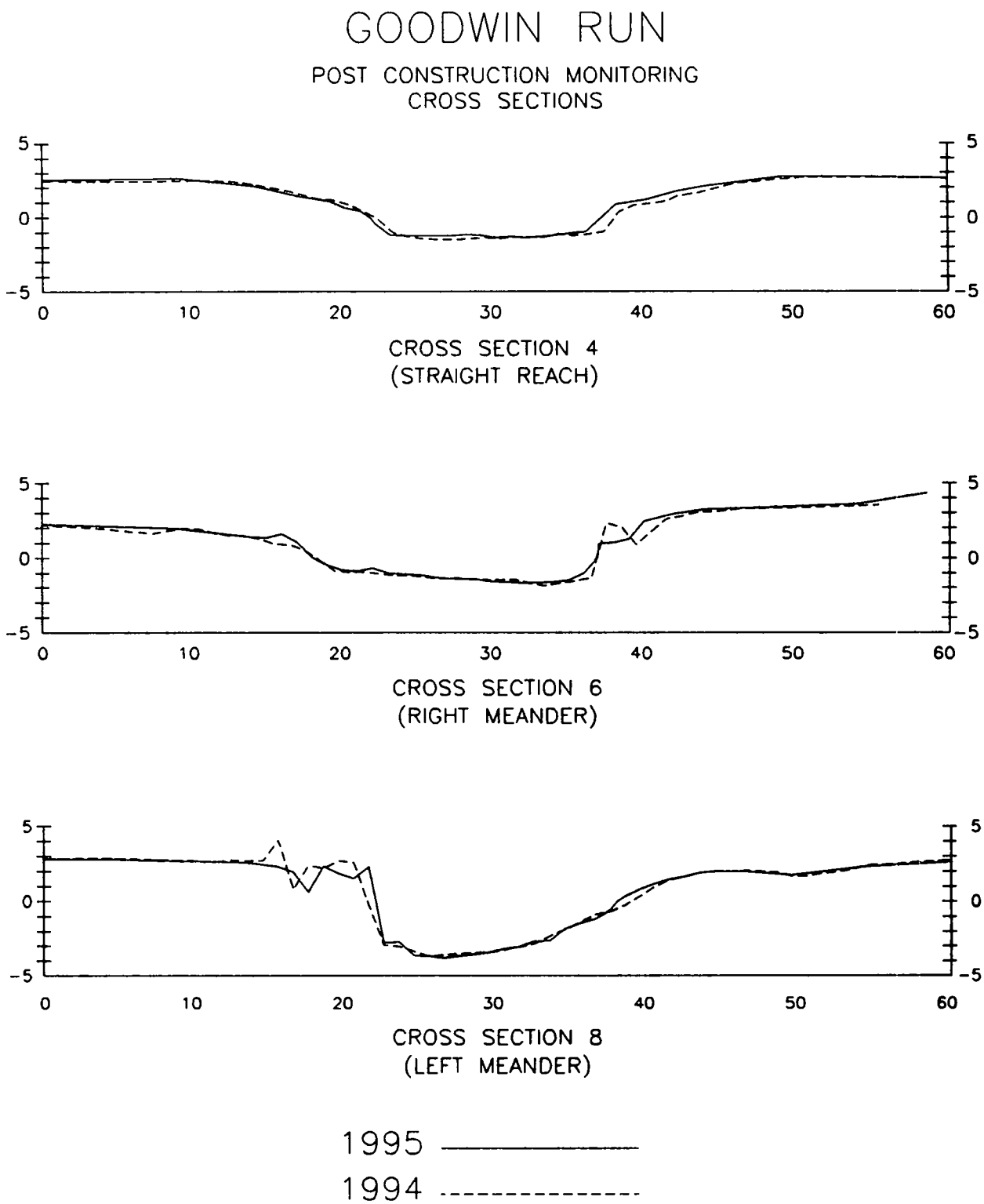

Figure 7. Goodwin Run sample cross section monitoring data.

restoration design were determined from field measurements and checked by stage discharge relations from gage station data. The upstream portion of the project was designed for a bankfull flow of 250 ft^3/second, with 300 ft/second used for the downstream section due to tributary entrance and increased drainage area. The restoration plans again call for a C4 streamtype with rootwad revetments on meander bends. The width/depth ratio will be 22. The cutoff logs are specified to have a minimum length of 16 feet. The plans also include the revised vortex rock weir design shown in Figure 6. Construction was started in March of 1996 and is expected to take 6 months to complete.

Summary

Geomorphologic principles can be applied to streams disturbed by surface mining to restore channel geometry to a stable form. By integrating knowledge of fluvial process, stream pattern morphology, channel and meander geometry, and the natural tendencies of adjustment toward stability, the most effective design for long-term stability and function can be predicted. The Rosgen Classification System provides a methodology for the determination of the design parameters needed for a natural channel design. By defining design parameters within the ranges of stability for natural streams, and by respecting the relationships between the eight variables, streams be returned to a self-maintaining condition of dynamic equilibrium.

By restoring this stable condition, a stream will tend toward uniformity in the rate of energy expenditure and minimum work, therefore exerting the least stress on channel bed and banks. The minimization of stress allows native materials to support and complete restoration to a natural condition.

Literature Cited

Dunne, T. and L. Leopold, 1978. Water in Environmental Planning. W. H. Freeman and Company, San Francisco.

Elliott, J.G., 1990. Geomorphic Evaluation of Erosional Stability at Reclaimed Surface Mines in Northwestern Colorado. U.S. Geological Survey, Water-Resources Investigation Report 90-4132, Denver, Colorado.

Gracie, J.W., 1995. Personal Communication.

Leopold, L.B., 1994. A View of the River. Harvard University Press, Cambridge, Massachusetts.

Leopold, L.B., Wolman, M.G., and Miller, J.P., 1964. Fluvial Processes in Geomorphology. W.H. Freeman and Co., San Francisco, 522 pp.

McGill, S. and Gracie, J., 1993. Restoration of a stream channel using native materials. Land and Water, Fort Dodge, Iowa.

National Research Council, 1992. Restoration of Aquatic Ecosystems: Science, Technology, and Public Policy. National Academy Press, Washington, D.C.

Rosgen, D.L., 1994. A classification of natural rivers. In: Catena, 22:169-199.

Rosgen, D.L., 1993. Short course in applied fluvial geomorphology. Wildland Hydrology. Pagosa Springs, Colorado.

Thompson, C.S., 1985. Stream relocation on surface mined land. In: Starnes, L.B. (Editor), Fish and Wildlife Relationships to Mining, Sympos-

ium Proceedings, 113th Annual Meeting of American Fisheries Society, Milwaukee, Wisconsin.

Toy, T.J. and Hadley, R.F., 1987. Geomorphology and Reclamation of Disturbed Lands. Academic Press, Inc., Orlando, Florida.

REINTERPRETING SMCRA: "PERMITTING" PHASED POSTMINING LAND USE

by

Zina R. Merkin and Thomas J. Nieman

Abstract: The coal producing area of Appalachian Kentucky has a shortage of developable land. The majority of mined land in this region has been reclaimed to pastureland or hayland, while narrow interpretation of the Surface Mining Control and Reclamation Act of 1977 (SMCRA) and regulations, especially regarding bond release, has limited alternative postmining land uses which could support economic development. A study of Federal and State of Kentucky laws and regulations shows that postmining land use regulations and their implementation have focussed on preventing and minimizing environmental damage. Land use and land use planning concepts are not well understood, thus permit applications inadequately address land use needs and the "highest and best use" of a site. Required information about pre-mining conditions is not collected and analyzed in a way useful for determining appropriate postmining land use. More comprehensive, higher quality land use information, with information about regional factors such as transportation, utilities, labor market, etc., should be included in the permit application to identify sites with strong development potential. This, combined with a broader interpretation of the law recognizing the validity of a phased implementation of postmined land use, would continue environmental protection while preparing reclaimed land to meet potential future land use needs. The mining plan can be designed so that appropriate areas are prepared and laid out for future buildings or roads, yet are conducive to interim use for pasture, wildlife or recreation. Reclamation to the interim use, sufficient to protect the public and allow bond release, maintains the potential for later development. Land later can be made available in response to development demands, contributing to a more diversified economy.

Additional Key Words: Surface Coal Mining, Regional Planning, Mining Regulation

Introduction

The Surface Mining Control and Reclamation Act of 1977 (SMCRA) was enacted both to protect the public from the negative impacts of coal mining and to assure the continuation of an industry seen as vital to the nation's interest. The law and regulations as finally promulgated reflect a contentious history, and are ambiguous, confusing, and sometimes unrealistic. Overall the effect of the law has been positive; it is responsible for improvements in reclamation and a significant reduction in the most notorious negative impacts of mining including acid mine drainage, erosion, landslides, and damage to both surface and groundwater. It is a big step, however, between mitigating these negative impacts and returning the land to its "highest and best use."

In Appalachian Kentucky, past farming, logging, and mining practices have left scars on the land. (Caudill 1963) The land's productive capacity is diminished throughout much of the region. The economy has followed the boom and

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[3] Publication in this proceedings does not prevent authors form publishing their manuscripts, whole or in part, in other publication outlets.

bust cycles of extractive industries, and other industries are needed badly. The rugged topography has few relatively level areas which are not in the floodplain, and these tend to be just a few acres in size. (Nieman, and others 1989) Land suitable for commercial, industrial or even residential development is in short supply, a major obstacle to encouraging new industries or businesses in Appalachia. Scarcity is evident by the price that developable acreage commands.[4] Kentucky's strategy for economic development includes better utilization of reclaimed surface mined land to meet the need for commercial or industrial sites. (Kentucky Cabinet for Economic Development 1994) However, current interpretation and implementation of the mining law and regulations appear to be constraining designation of commercial and industrial postmining uses. Lack of clarity in the land use regulations is exacerbated by the lack of planning support or guidance from local or state agencies. The current interpretation of the regulations requires establishing a commercial/ industrial postmining use within a tightly specific time frame. Financing, politics, and other complexities of commercial/industrial development, combined with the logistics involved in mining, especially with large permit areas, make it infeasible for a mining company to commit to such timing. A mechanism for considering reclamation and land capability over a longer term, beyond bond release, and reclaiming to provide an immediate use with a potential for a later, more intensive use, can bridge this feasibility gap.

In searching for this mechanism within a reinterpretation of the law, the questions to be asked are 1) is it the intent of SMCRA to support reclamation for industrial, residential and commercial uses; 2) do the regulations promulgated to implement SMCRA support these postmining land uses, in theory and in practice; and 3) what are the obstacles to more productive postmining land use and how can they be overcome? The implementation of the law occurs largely through the permitting and bonding processes, which set the enforcement framework. A brief analysis of law and regulations introduces a more detailed discussion of the treatment of land use issues in the permit application. An analysis of the State of Kentucky permit application process, including examples from permit files, illustrates how a lack of understanding of land use principles has made the permitting process less effective than it could be in supporting a variety of productive land uses. The concept of phased postmining land use is examined as a solution to aspects of the permitting process which do not fulfill the intent of the law, and in fact work against productive postmining land use.

The Surface Mining and Reclamation Act of 1977

Background

The passage of SMCRA in 1977 created the Office of Surface Mining Reclamation and Enforcement (OSMRE) to promulgate and enforce regulations to control surface mining and reclamation operations. The law requires surface mining operations to follow a complicated process of permit application, bonding to cover expected reclamation costs, ongoing inspection, compliance with performance standards, and an extended period of liability during which reclamation efforts must be proved successful before bond monies are released. The complicated process, its focus on lengthy and detailed engineering specifications, and the lack of clarity with which land use issues are addressed, have restricted the perception of what reclamation can accomplish and inhibited consideration or adoption of reclamation approaches which might better fulfill the intent of the law. (Desai 1993) (figure 1)

[4]Whayne Supply paid approximately $600,000 for 5 acres in Hazard in 1991.

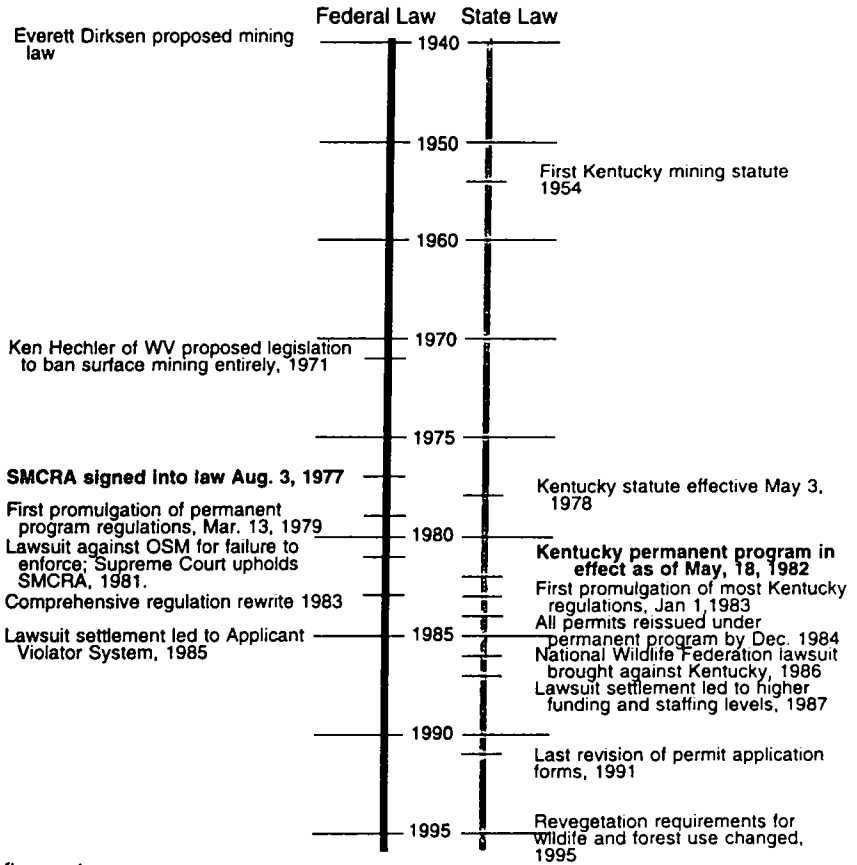


figure 1
Mining Law Timeline

The Act provides the legislative authority and intent upon which the regulations are based. Regulations are subject to challenge and judicial review with regard to whether they actually carry out the intent of a law. (Beck 1993) Within federal law alone there is ambiguity and inherent conflict of purpose. (McElfish and Beier 1990) The intent is laid out in Section 102, Statement of Purpose, to "assure that the coal supply essential to the Nation's ...economic and social well-being is provided and strike a balance between protection of the environment and agricultural productivity and the Nation's need for coal as an essential source of energy...." The relative success with which the regulations have been developed is a function of the degree to which ambiguities in the act are a result of the "political impossibility of developing a consensus" or a lack of understanding of the issues involved. (Miller 1993) The law was enacted on a nationwide basis to set a minimum level of public protection and prevent states from competing with one another on the basis of lesser environmental safeguards. (PL 95-87 §101(g); Scicchitano,and others 1993) The statute does allow states to establish 'primacy' and respond appropriately to local conditions in the design of their regulations. The often tenuous relationship between state and federal agencies has contributed to confusion in implementation of the mining law (Conrad 1993; Miller 1993), at times making compliance difficult for operators who may get conflicting direction from regulators. Similarly, enforcement has been delayed or avoided in some cases. While discretion is built into the law and regulations[5], the exercise of that

[5] For example: 405 KAR 16:020 Section 2. The approved backfilling and grading plan may specify time and distance criteria less restrictive than those set forth in this regulation when the permittee has demonstrated..., and *the cabinet has determined* that use of such criteria will not likely cause adverse environmental impacts. (emphasis added)

discretion is accompanied by uncertainty, political pressure, and litigation. (Morris 1993, Scheberle 1993)

The Intent of SMCRA in Regard to Postmining Land Use

In the Statement of Findings, SMCRA addresses the negative impact pre-law and irresponsible mining has had on the natural environment, public safety, and public welfare through

> disturbances of surface areas that burden and adversely affect commerce and the public welfare by destroying or diminishing the utility of land for commercial, industrial, residential, recreational, agricultural, and forestry purposes, by causing erosion and landslides, by contributing to floods, by polluting the water, by destroying fish and wildlife habitats, by impairing natural beauty, by damaging the property of citizens, by creating hazards dangerous to life and property, by degrading the quality of life in local communities, and by counteracting governmental programs and efforts to conserve soil, water, and other natural resources.(PL 95-87 Title I:§101(c))

The Act thus recognizes a broad standard of utility for land, and also requires that a permit application describe

> the use which is proposed to be made of the land following reclamation, including a discussion of the utility and capacity of the reclaimed land to support a variety of alternative uses, and the relationship of such use to existing land use policies and plans... (PL 95-87 §508(a)(3))

While naively assuming that land use policies and plans exist, this passage illustrates an intent for proposed uses to be examined in a context of surrounding land uses, needs, and markets. The environmental protection performance standards stipulate that land must be returned "to a condition capable of supporting the uses which it was capable of supporting prior to any mining, or higher or better uses of which there is reasonable likelihood....[not] deemed to be impractical or unreasonable, inconsistent with applicable land use policies and plans, [nor involve] unreasonable delay in implementation.. "(PL 95-87 §515(b)(2)) The ambiguity of many undefined terms, e.g., "reasonable likelihood" or "impractical," by default leaves interpretation of the standards to the regulations by which the law is implemented, and to the regulators in the field who are ultimately responsible.

The phrase "higher or better use," however, is from real estate law, referring to the most intensive land use allowed or available, generally one which offers a higher return on investment. Therefore, while public safety is a main focus of the law, there is also a clear commitment to economic productivity, not only by facilitating coal extraction, but also through protecting and restoring the productive capacity and usefulness of the land resource. Confirming this as central to the law is the variance on returning the land to approximate original contour (AOC), allowed for steep slope and mountaintop removal mining. The House Interior and Insular Affairs Committee, which initially considered SMCRA in 1977, determined productive postmining land use to be an adequate reason for an exception to the performance standards of the law.

> The bill is built upon the Committee's finding that in the vast majority of cases, certain reclamation goals must be achieved if the term "reclamation" is to have any real meaning. Nevertheless, the committee has approved exceptions to these requirements to achieve flexibility and avoid arbitrary constraints. For example, the elimination of highwalls, return of the land to approximate original contour, and establishment of viable vegetative cover are among the standards critical to the elimination of the worst effects of coal surface mining and yet these standards are

> either subject to exception, framed in variable terms or both. Rather than weakening the effectiveness of these standards, such treatment is viewed by the Committee as justified and desirable. Workable Federal Requirements must be appropriate to the mining setting and such standards should not preclude practices which are beneficial from a planning viewpoint. (1977 U.S. Code Cong. and Adm. News, p 621-622, quoted in correspondence,permit file #098-0136)

The variance on returning the land to Approximate Original Contour (AOC) applies to steep slope and mountaintop removal mining, in "cases where an industrial, commercial, agricultural, residential or public facility (including recreational facilities) use is proposed...where after consultation with the appropriate land use planning agencies, if any, the proposed [use] is deemed to constitute an equal or better economic or public use of the affected land, as compared with premining use."(PL 95-87 §515(c)(3)) Congress had the vision that with proper planning, reclamation could create economic development possibilities, but recognized that some assurance of support for such development was necessary.

> Surface mining also presents possible land planning benefits as such mining involves the opportunity to reshape the land surface to a form and condition more suitable to man's use. In such instances, the overburden and spoil become a resource to achieve desired configurations rather than a waste material to be disposed of or handled by the most economic means. The performance standards recognize that return to approximate pre-mining conditions may not always be the most desirable goal of reclamation and thus appropriate exceptions to the general requirements are provided. As the realization of such alternative post-mining land uses as industrial, commercial or residential development will often depend on the commitments or assurances that necessary services will be available, evidence of such availability prior to mining is a necessary part of the permit approval process. (H.R. Rep. No.95-218, 95th Cong., 1st Sess., 94 (April 22, 1977), quoted in correspondence, permit file #098-0136)

There is a process written into the performance standards by which "equal or better" use is to be approved. Specific plans for the land use are to be presented, and the permittee must demonstrate its compatibility with adjacent uses, a need or market for the use, and the financial capability to complete the proposed project. Also required is the assurance of "investment in necessary public facilities," and a schedule "integrat[ing] the mining operation and reclamation with the postmining land use."(PL 95-87 §515(c)(3)(B)(iii),(vi)) The exact criteria by which to demonstrate compatibility, financial capability, or market demand are unspecified, however, and are left to the discretion of the regulators. Given the lack of understanding of land use planning, regulators have tended to steer away from built uses. In any case these criteria are generally absent in evaluating potential land use (McElfish and Beier 1990), and the default measure of a reclamation plan is public health and safety coupled with erosion control.

The Influence of the Bonding Process

Reclamation choices have been shaped in large part through the implementation of the bonding mechanism written into law with SMCRA. A percentage of the bond is released upon completion of each of three phases of reclamation but at all times the balance must be sufficient to cover any work remaining. Phase III completion entails the continued success of site vegetation through the liability period in which no appreciable fertilization, mulching or replanting is necessary. The land must also be "capable of supporting the approved postmining land use." In practice, this requires meeting performance standards for the various designated uses, e.g., pasture, prime farmland,

fish and wildlife, or commercial. In Kentucky, Technical Reclamation Memoranda (TRMs) supplement the regulations, guiding coal operators through the standards. Until recently, in steep sloped Eastern Kentucky the major post mining land use designated was pastureland or hayland. Most of the premining land use was either unmanaged forest, primarily third growth, or undeveloped, i.e., derelict land from pre-law mining. There is no prime farmland in the region which must be restored, and any "alternative" postmining land use has been considered a "higher use." Coal operators therefore have chosen to implement the land use with standards they could attain most cost effectively and reliably, usually pasture. Reclamation research on the Illinois basin region suggests that

> reclamation has been guided by two objectives: minimizing economic cost of reclamation, and mitigating physical and aesthetic effects of mining. The result has been widespread planting of simple, homogeneous grassland communities that seem to have limited agricultural and conservation value and may be ecologically unstable. (Brothers 1990)

Kentucky, recognizing that such so-called pasture is not truly a higher use, recently has made regulatory changes.(KDFWR, and others 1995)

> In the mountainous eastern region, the recent trend is toward either fish and wildlife land use or unmanaged forest. Recent regulation changes lowering the stocking rate of trees and shrubs for these uses have prompted permittees to abandon the previously predominant hayland/pastureland postmining land use. Approximately 50% of the areas being mined are returning to forestland or fish and wildlife land uses. Approximately 30% are still being utilized for hayland/pastureland uses, mainly in the areas of more level terrain on the fringes of the eastern coal field. (Smith)

While regulators influenced postmining land use by trading a lower stem count for greater species diversity, making reclaimed areas healthier and more attractive to wildlife while reducing the cost to operators, they have yet to address performance standards and bond release requirements for residential, commercial or industrial use in terms of making reclamation to these uses more attractive or feasible for mining companies.

The Regulations -- Federal and State

Many sections of the federal regulations refer to land use, particularly those outlining the permit application and the environmental performance standards. 30 CFR Section 508 details all the information required on the surface mining permit application. This information, in theory, allows the regulatory authority to determine the probable environmental impacts of a particular operation and the adequacy of the reclamation plan. The performance standards (30 CFR Chapter VII, K, §816) state technical requirements for erosion control, backfilling and grading, disposal of excess spoil, revegetation, and postmining land use. These basic standards primarily consist of engineering specifications deemed sufficient to prevent the major negative impacts of mining. There are additional standards for special categories of mining, including steep slope and mountaintop removal mining in which variances may be granted in lieu of returning the land to AOC. The information required in the permit application is closely related to the performance standards, especially since the application requires submittal of the reclamation plan. This plan, which includes postmining land use, must be able to produce results which fulfill the performance standards.

Performance standards for postmining land use capability require that, before final bond release, "affected areas shall be restored in a timely manner," to conditions capable of supporting prior uses or approved alternative uses. "Higher or better alternative uses may be approved if :

(1) There is a reasonable likelihood that the land use will be achieved

(2) The use will not be

impractical or unreasonable

(3) The landowner or land management agency having jurisdiction over the lands has been consulted, and the proposed alternative postmining land use is consistent with applicable land use policies and plans;

(4) The proposed use will not present an actual or probable hazard to public health or safety or threat of water pollution or diminution of water availability

(5) The proposed use will not involve unreasonable delays in implementation

(6) the proposed use will not cause or contribute to violation of federal, state, or local law."(405 KAR 16:210)

These and other land use requirements are vaguely stated, and do not give regulators much guidance. One intent behind items 1, 2, and 5 is to ensure that reclamation does, in fact, take place, acknowledging that the sooner this happens, the less negative environmental impact will occur. Items 2, 3 and 4 are to protect the landowner and the community. Item 4 is the only one which explicitly deals with the postmining land use capability, the other standards relate to financial feasibility and legality. However, they do not define how to evaluate practical or reasonable, and the meaning in the field has come about by trial and error, negotiation, compromise, and political pressure.

Performance standards for revegetation (405 KAR 16:200) include coverage standards for grasses and legumes, numbers of plants (stem counts) for trees and shrubs, and diversity measures. Pasture and cropland uses must meet specific productivity, or yield, standards based on local conditions. Performance standards for commercial or industrial postmining uses are not clear or specific, however, and this has implications for bond release. As an illustration, ten years after passage of SMCRA, this 1987 memo was sent from the Kentucky Natural Resources and Environmental Protection Cabinet to the Lexington OSM office:

Dear Mr. Tipton,

Attached is a letter from J.R. Harris granting OSMRE approval of an interim program experimental practice permit for commercial development as the primary post mining land use.

As the approved permit contains no information relating to criteria for establishing the commercial development, it is unclear when the permit becomes eligible for a complete bond release.

Since approval of the complete release will require involvement of the OSMRE, I would appreciate your review of the permit and receipt of your understanding of the work to be completed by the permittee to receive the release. (Permit #098-0067)

Potential retention of bond monies, if regulators determine that a postmining land use is not, in fact, established, is a powerful disincentive for coal companies to attempt alternative land uses. Timing is a key element in this determination. The permit application requires a "discussion of how the proposed postmining land use(s) will be achieved within a reasonable time frame." (MPA-03, 21.12(c)) The concern with achieving the land use derives partly from the goal of minimizing erosion by reclaiming as quickly as possible, and partly in response to irresponsible operators. Many had defaulted on their reclamation plans, or, in order to avoid backfilling and returning to AOC, designated commercial uses for benches without ever building anything there (Rothman) Therefore, in practice, the regulatory requirements of "reasonable likelihood" for achievement and no "unreasonable delays"(405 KAR 16:210 §4(1),(5)) have been taken to mean a tangible commitment to development. At the permit application stage this might be proof of a bank's commitment to financing, in addition to the specific plans for development required by the regulations. For final bond release the regulatory

agency wants to see the initial stages of construction. Unfortunately, the realities of the construction and development process require the flexibility to respond to market fluctuations. The likelihood of the timing of reclamation coinciding with an advantageous development window is not high. Coal companies are resistant to the possibility of 1) delaying final bond release and 2) having to hold onto the land, and the liability which that entails, until development becomes practical. As one coal executive noted, they [coal operators] do not want to be in the land business, and are certainly not land use planners. (Geiger) These factors inhibit designation of the more intensive postmining land uses in original permit applications.

Designation of postmining land use can be changed through a major permit revision process, which requires public notice. This is the way most industrial and commercial land use designations have been handled. Operators will weigh the time and cost for the revision against any possible cost savings involved in changing the use. If it involves less reclamation cost and quicker bond release, the company goes through with the revision. As an example, landowners are "quick to take advantage of any level areas adjacent to roads for residential use or commercial/industrial if offices or shop buildings are left in place by the coal company. Final bond releases are relatively easy to obtain if the land is being totally utilized by home construction or occupation of existing buildings by a new business."(Smith) One problem with this approach is that it precludes any long range planning for development, and makes it difficult to coordinate reclamation and development of any particular site with regional trends so as to make infrastructure investment more efficient. A paradox is created, as well. Surface owners of land do have the right to make use of their land, and one often finds that they have initiated projects before bond release, which can be problematic for operators. Even when the surface owner is a subsidiary of the coal company, since proof of the use is required to get approval and bond release, one finds construction beginning on alternative postmining land uses before they are actually approved. This acts to subvert the intent of the public notice provision of the law. In one case in Eastern Kentucky the land holding corporation related to the mining company deeded the surface to the city, which sold it to a private company to build a prison. The construction of the prison created a highwall and expanded a hollow fill, all of it before final bond release and without supervision from the regulatory authority. After the facility was in operation, the mining company filed a major revision requesting approval of a land use change from forest to industrial/commercial. The "walk sheet" inspection for proposed major revision #2, stated, "Company is requesting to change Post Mining Land Use to Industrial Commercial so that a Phase III bond release can be obtained. Otter Creek Correctional Facility has been constructed on the permit."(permit #836-0120)

The Permit Application

Surface coal mining and reclamation regulations are implemented through the permit application and approval process, as well as through enforcement. (figure 2) Kentucky permit application requirements evolved quite a bit through the period between the pre-SMCRA state program and primacy, although the land use regulations remained vague. Submittals improved as engineering firms and regulators grew more familiar with the scope of work required to get permit approval. The areas in the law and regulations where ambiguities existed became more obvious, and in many instances conflicts arose which had to be settled in court. A default, working, interpretation of the regulations developed, as certain disputes were resolved verbally with no written record in the file of the rationale behind final permit conditions, perpetuating misunderstanding of the intent and purpose of the law in regard to land use issues.

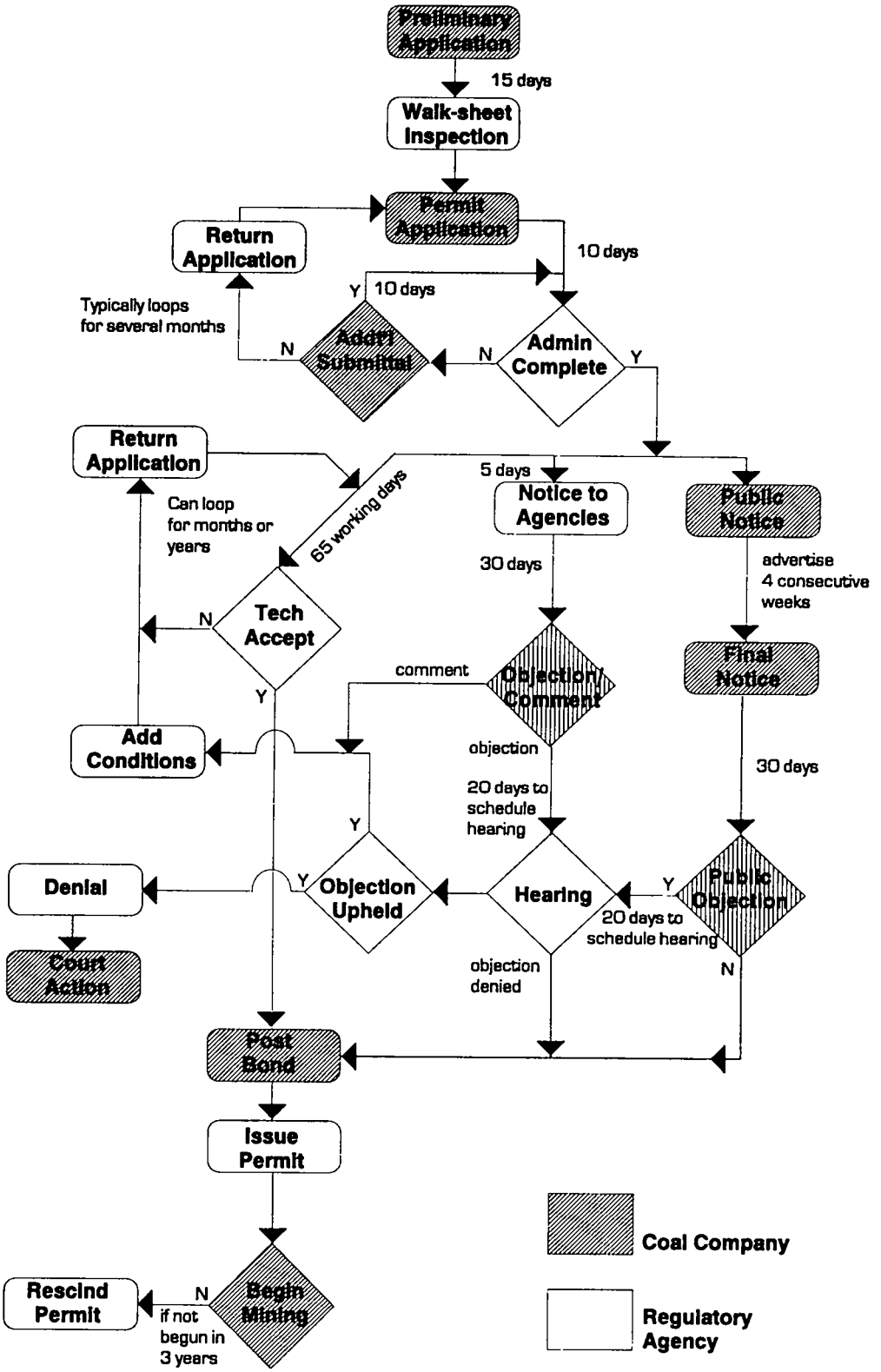


figure 2
Generalized Coal Mining Permit Process

The quality of information submitted with permit applications still varies greatly, depending on the experience and expertise of the applicant and the reviewer. (McElfish and Beier 1990) Based on the information in the application, permits for mining and reclamation are issued with various conditions which the mining operators must follow.(figure 2) In many sections of the application, submittals consist of restating the performance standards. In other words, omitting site specific details, coal operators are in effect complying by stating they will comply. For certain precise technical specifications such as slope, or cross-drain intervals, this provides sufficient and measurable grounds for evaluation and enforcement. But because the land use criteria are vague to begin with, restating them does not give regulators an adequate means of assessing performance.

The major deficiencies in permit applications, associated with land use issues, are poor quality maps, inconsistent responses to the land use questions, an agronomic bias to land use information, and confusion in regard to the difference between reclamation and land use. Item 21.12 of the application requires a discussion of the "feasibility, i.e. suitability, capability, cost effectiveness of the proposed postmining land use(s)...[and] how the proposed postmining land use(s) will be achieved within a reasonable time frame" if the postmining land use is to be different than the existing or pre-mining use. The permit actually requires less explanation than called for in the regulations, dropping discussion of the "utility" of the reclaimed land or capacity to support a "variety of alternative uses." There appears to be no attempt to discern the best use of the land or to place it in context within the local region. A typical submittal to 21.12 follows:

Attachment 21.12 (A,B,C & D)

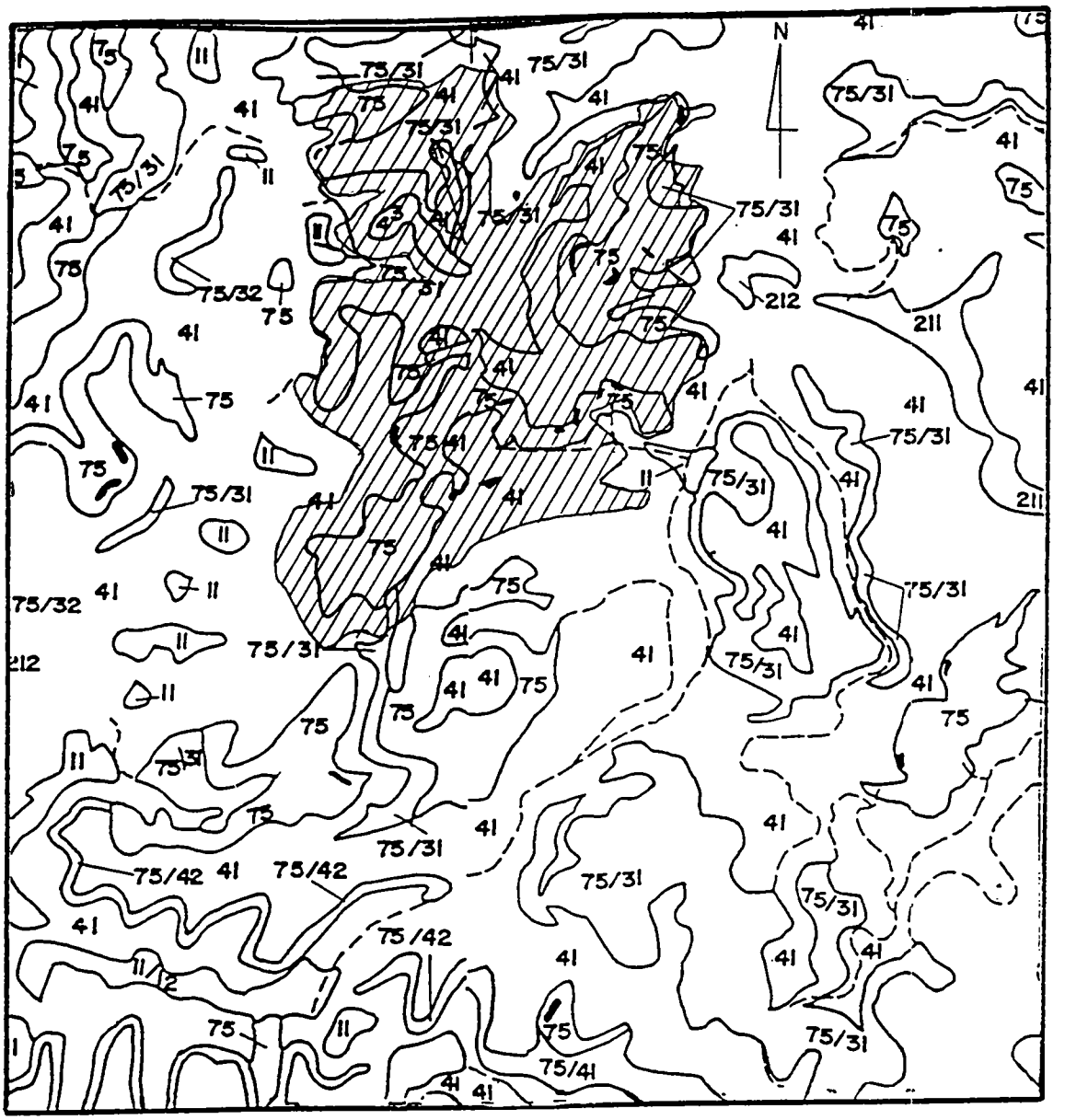
A) The proposed post-mining land use is compatible with adjacent land uses in this part of County. A land use change for fish and wildlife habitat with permanent roads has been demonstrated to be feasible in this part of Eastern Kentucky. This land use has been demonstrated to be expediately [sic] achieved. This is due to planting of quick cover crops such as annual rye and winter wheat.

B) Upon completion of the mining activity, the revegetation plan will immediately be put into place. The post-mining land use will be obtained when the vegetation plan for the area has been successful.

C) The post-mining land use will be achieved as quickly as natural conditions will allow. This will be done by the immediate execution of the revegetation plan. Hand-seeding will be employed if areas of poor vegetation are found. (permit #867-0355)

This submittal does not specify why the land use is compatible with surrounding uses or how it will be feasible. The entry also confuses achievement of revegetation with achievement of the land use.

Engineers, agronomists, and biologists are some of the specialists involved in the permitting process, and their professional bias is evident. Land use analysis is derived primarily from soil survey data and vegetation associations, e.g., upland forest. Granted, much mining occurs in remote areas where the human influence is small, but roads and infrastructure are important facets of land use and must be addressed. In addition, there is little consideration of future land use potential or need. The map in figure 3, which does not show highway 15 at all, as well as omitting parts of the legend, e.g. land use 11 (residential), is typical of how whole categories of land use are ignored.



RIVER COAL CO., INC.
EXISTING LAND USE MAP

LEGEND

31 HERBACEOUS RANGE

41 DECIDUOUS FOREST

43 MIXED FOREST

75 EXTRACTION: ACTIVE OR INACTIVE MINES, QUARRIES OR PITS

APPLICATION NO. 497-0073: AMEND. 2

PERMIT AREA

SCALE: 1" = 2000'

ATTACHMENT NO. 20.7.B

figure 3
Typical Land Use Map (reduced)

Other examples from this and a more recent permit file illustrate that land use and planning are misunderstood and land use issues are inadequately analyzed in permit applications. The first file involves a large site whose permits have continued through the interim, transition and permanent program years (permits #097-0073 and #497-0073). The initial job was a mountaintop removal, and paperwork in 1981 listed both premining and postmining land use as forest. Much of the site had been disturbed in the previous 20 years; the transition application more accurately listed pre-mining land use as "undeveloped." The transition was begun in July 1982, and a permit issued in September of 1984. Much of the original acreage was fully mined by this point, though bond was not released, and Item 31.3 of the application stated

> The proposed post mining land use for this area will be mostly Commercial. A small part of the area which is not directly related to the commercial use will be developed as pasture land. The commercial use intended will be for air traffic. Already, a 3,200 ft. runway has been constructed and used privately. When the mining process allows another strip in excess of 6,000 ft. is to be constructed which will be able to accomadate [sic] larger aircraft. The 3,200 ft. runway already in use is paved and a terminal building is at present (10-13-83) under construction.

No major revision for land use change occurred -- the change was handled *during and after construction* through the transition program permit application.

Amendment 1 to the transition permit proposed to finish a point removal and leave a surface configuration to match the adjacent area on which the airport had been built, stating "The commercial land use option is proposed to allow expansion of the small airport that is presently operating on the interim portion of the permit" (Attachment 20.9.A). Yet the application fails to mention the airport as an existing land use in Attachment 20.7.A, nor shows it on the Environmental Resources Map or Existing Land Use Map.

Entries to Section 20.12 show other weaknesses in analysis of land use issues.

> Attachment 20.12(a):Feasibility of Post-Mine Land Use
> The post-mining land use of hayland/pasture is a feasible alternative to the original usage of forest. The pre-mine forest land occurring on undisturbed and previously mined areas was basically unmanaged. The diversification of habitats through differing land uses are also desirable to wildlife. An "edge" effect will be created, thereby improving wildlife distribution....
> The cost effectiveness of planting pasture as opposed to forest makes it a practical land use alternative. The cost is already reduced by not having to plant developed seedlings into an already established herbaceous cover....
> The commercial land use is proposed to allow expansions of the ...Airport operating on the interim portion of the permit area. This airport is a public facility that benefits the local economy in income and needed air transportation.
> In summary, the post-mine usage of hayland/pasture and commercial instead of forest is a viable alternative. The selected land use will provide erosion control, diversify habitats, be a less expensive alternative to forest, and serve the good of the community.

This entry describes encouraging wildlife. Not only is this not compatible with the adjacent land use of airport (one does not want deer wandering the runways), but also, habitat distribution must be considered within a larger region than investigated in this application. (Nieman and Merkin 1995) Regardless, the proposed interim use actually was for pasture, not

wildlife, and there is no mention of cattle nor a market demand for hay. As for cost effectiveness, this describes the cost effectiveness of the reclamation, not the land use, a very common mistake. Lastly, the value to the community of an expanded airport is only hinted at through the acknowledgment of the value of the existing airport, yet this should be a very strong argument for allowing the land use change.

This permit indicates that the timing of development needs to be addressed in a more flexible manner. Permit file records indicated that in this case, the issue of timing, or implementation, of the land use was debated at length, but finally settled informally. The permittee in essence suggested a phased land use, first of pasture, then commercial use when the airport was actually expanded. Item 20.8 lists the acreage twice, once for each proposed land use, pasture and commercial. A review letter stated, "List the acreage to be used as pasture and acreage for commercial. You cannot propose optional land use change." The permittee replied, "The hayland/ pasture use is requested to be used contemporaneously with the commercial usage. As stated in the application, the rate of expansion of the airport is unknown; therefore, a land use is specified for the interim. Since this is an approved method in the original permit, the same uses can apply to the amendment." The permit authority responded, "An optional landuse can not be proposed," however the application entries stand, but on the permit face condition 10 states, "Approval is granted for the alternate postmining land use of hayland/pastureland as described in the permit application." There existed sufficient proof that the airport would expand, and the land use was productive, feasible and would be established, but it was not presented properly. Neither the permittee nor regulators understood how to document or prove support for this land use, and much time was wasted before the issue was finally let drop in the permit approval process.

In a related case of regulatory dislike for a contingent land use, a much more recent job has a strong potential for development of commercial or residential uses. It is close to a developed area, has utility infrastructure available, has a major highway nearby, and is a large enough site to warrant development. (permit #867-0355) Because the timing both of the actual mining and certain improvements in the area is subject to change, the development time frame is uncertain. In this case, the permittee initially attempted to declare an industrial postmining land use, but the only evidence of this is in correspondence related to the permit review. A deficiency letter stated, "... Item 21.10: What does <u>and Industrial</u> mean? Please remove this." The reply notes, "Industrial has been deleted as a description of the post-mining land use." A fish and wildlife postmining land use has been declared instead, though a careful look at the reclamation plan makes it clear that the site is being handled in such a way as to suit the more intensive use as well. The backfill on the ridge area is being placed only twenty feet deep, as opposed to a potential depth of over a hundred feet. Therefore foundation engineering on this site will be fairly straightforward, conventional in both design and cost. This site will be none the less useful for a fish and wildlife use, but prepared for an eventual residential or commercial use. This is forward thinking; it is unfortunate that discussion of the land use potential and designation of future, more intensive land use, must be skirted to remain within the interpretation of the law.

Conclusion

Given the process of development of the law and regulations, and the nature of the types of problems SMCRA was intended to solve, the problems still remaining are not surprising. The technical answers to issues such as acid mine drainage, erosion control, and stable and safe sediment ponds and fills, have come from engineers who are specialists in their particular fields. The personnel who develop permits and those who review them also are engineers, often come from the mining industry, and are habituated to looking at things a

certain way. They are not land use planners, landscape architects, economic geographers, or from some other discipline which considers land use issues within a broad framework. As one permit reviewer noted, if the technical problems weren't taken care of, the land use designation wouldn't matter because the land would not be useful for anything. But solving the technical problems, while necessary, is little assurance of a wise use of the land.

An important step is to recognize that land use occurs in a regional context. The utility of a particular use is related to the need for that use now and in the future, and whether other land is available to fulfill that need. Universally accepted planning principles recognize that land use needs change over time, as does the availability of the factors which support particular land uses. Time constraints for reclamation should be applied, based on their original intent of protecting the public and environment from negative impacts of mining, to quick achievement of an acceptable interim use, such as pasture or wildlife, which is consistent with future, more intensive development. The permit application should answer questions critical to more intensive land uses such as the relative location and quality of roads and other transportation networks, availability and cost of utilities and telecommunications, nearness to population centers, and capacity of the workforce, as well as general costs of construction based on engineering and location factors. There is a broad spectrum of factors which must be examined and used to justify particular land uses. A clear justification for expecting a site to have high potential for future residential or commercial development must be accepted as fulfilling SMCRA requirements for feasibility, capability, compatibility, etc., and allow designation of a contingent use. In addition, consideration of phased land use more closely follows the regulatory requirement to discuss "the utility and capacity of the reclaimed land to support a variety of alternative uses." There is nothing in the law or regulations to prohibit a phased or contingent land use. This has derived from practice, and this interpretation can and should be changed.

Literature Cited

Brothers, Timothy S. 1990. "Surface-Mine Grasslands." *The Geographical Review* Volume 80(3): 213-225.

Caudill, Harry M. 1963. *Night Comes to the Cumberlands*. Boston: Little, Brown and Company.

Conrad, Gregory E. 1993. "Federal-State Relations." Chapter 6, in: Uday Desai, ed. *Moving the Earth: Cooperative Federalism and Implementation of the Surface Mining Act*. Westport, CT: Greenwood Press.

Desai, Uday, ed. 1993. *Moving the Earth: Cooperative Federalism and Implementation of the Surface Mining Act*. Westport, CT: Greenwood Press. 256p.

Geiger, Daniel. James River Coal Service Company. Personal communication.

Kentucky Cabinet for Economic Development. 1994. *Kentucky Strategic Plan for Economic Development: a closer look*. Frankfort, KY: Commonwealth of Kentucky

[KDFWR] Kentucky Department of Fish and Wildlife Resources, Kentucky Department of Natural Resources - Division of Foresty, and Kentucky Department for Surface Mining Reclamation and Enforcement. 1995. *Plant Species, Distribution Patterns, Seeding Rates, and Planting Arrangements for Revegetation of Mined Lands: [TRM] Technical Reclamation Memorandum #21*. Frankfort, KY: Commonwealth of Kentucky

[KDSMRE] Kentucky Department for Surface Mining Reclamation and Enforcement. 405 KAR Chapters 7 through 24.

KDSMRE Permit # 097-0073 and 497-0073

KDSMRE Permit # 098-0067

KDSMRE Permit # 298-0001

KDSMRE Permit # 836-0120 and 836-0238

KDSMRE Permit # 867-0355

McElfish, James M., Jr. and Ann E. Beier. 1990. *Environmental Regulation of Coal Mining: SMCRA's Second Decade*. Washington, DC.: Environmental Law Institute.

Miller, Richard O. 1993. "The Surface Mining Control and Reclamation Act: Policy Structure, Policy Choices, and the Legacy of Legislation." Chapter 2 in: Uday Desai, ed. *Moving the Earth: Cooperative Federalism and Implementation of the Surface Mining Act*. Westport, CT: Greenwood Press.

Morris, Lisa J. 1993. "The Impact of Court Decisions on the Implementation of a State Regulatory Program." Chapter 8 in: Desai, Uday, ed. *Moving the Earth: Cooperative Federalism and Implementation of the Surface Mining Act*. Westport, CT: Greenwood Press.

Nieman, Thomas J. and Zina R. Merkin. 1995. "Wildlife Management, Surface Mining, and Regional Planning." *Growth and Change*. Volume 26(3): 405-424.

Nieman, Thomas J., Diane Meshako and Barbara Rackers. 1989. "Star Fire -- Needs Assessment and Preliminary Development Report."

Rothman, Paul. KDSMRE. Personal communication.

Scheberle, Denise. 1993. "State and Federal Perceptions about the Surface Mining Control and Reclamation Act." Chapter 12 in: Uday Desai, ed. *Moving the Earth: Cooperative Federalism and Implementation of the Surface Mining Act*. Westport, CT: Greenwood Press.

Scicchitano, Michael J., David Hedge, and Patricia Metz. 1993. "State Performance under the Surface Mining Control and Reclamation Act." Chapter 11 in: Uday Desai, ed. *Moving the Earth: Cooperative Federalism and Implementation of the Surface Mining Act*. Westport, CT: Greenwood Press.

Shover, Neal, Donald A. Clelland, and John Lynxwiler. 1986. *Enforcement or Negotiation: Constructing a Regulatory Bureaucracy*. Albany, NY: State University of New York Press.

Smith, Keith. KDSMRE, Field Services. 1995. Personal Communication.

Additional References

United States, Congress, House Committee on Interior and Insular Affairs, Subcommittee on Mining and Natural Resources. *Implementation of SMCRA: Oversight Hearing before the Subcommittee on Mining and Natural Resources*. Serial No. 102-73, February 20, 1992. Washington, DC: GPO.

THE PROSPECT OF GULLY GRAVURE ON RECLAIMED HILLSLOPES

by

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Abstract. Hillslope development and evolution are the products of process-sequences. One such sequence is gully gravure, a mode of development requiring coarse-textured material overlying fine-textured material. Rill or gully processes erode through the coarse material into the fine material. The coarse material falls into and accumulates in the channel entrapping fine material. The permeability and porosity of the channel-fill is reduced, and runoff is deflected toward the periphery of the deposit. Thus, the loci of erosion shifts laterally along the hillsides. The sequence is completed by channel-filling with additional coarse material from the channel sides. A new surface of coarse material is created at a lower elevation as a result of lateral planation. Field studies near Tucson, Arizona and Denver, Colorado, indicate that gully gravure may occur on reclaimed hillslopes. Previous research suggests that gully gravure results in landscape stability, maintenance of adjusted hillslope angles, and low rates of denudation and sediment delivery, which are fundamental objectives of reclamation.

Additional Key Words: Hillslope Erosion, Hillslope Evolution, Rock Fragment Surface Cover

Introduction

Both natural and reclaimed hillslopes are subject to various geomorphic processes, such as geochemical and pedochemical weathering, mass-movement, erosion, and deposition. The assemblage of processes in a particular environmental setting controls hillslope development and evolution. Each process has been examined in detail by earth scientists in order to understand its mechanics and rates of operation. Infrequently, however, do we consider sequences of processes that may be collectively responsible for hillslope characteristics. Through sequencing, one process prepares the surface for the next process and usually contributes certain attributes to the final form. It is the purpose of this report to describe the process-sequence known as " gully gravure" and suggest, based upon field examples, that this process-sequence may be occurring on reclaimed hillslopes.

The Gully Gravure Process-Sequence

Gully gravure is the term used by Bryan (1940) to describe the process-sequence depicted in the idealized diagram of Figure 1. In profile, the initial stage (A) consists of a nearly planar surface of coarse-textured, erosion-resistant geologic material overlying a fine-textured, less-resistant material. During the second stage (B), the surface is incised by rill or gully processes. In stage (C), coarse material falls by simple gravity processes and accumulates in the channels because flow energies are insufficient to transport it downslope. Weathering processes influence the rate of material

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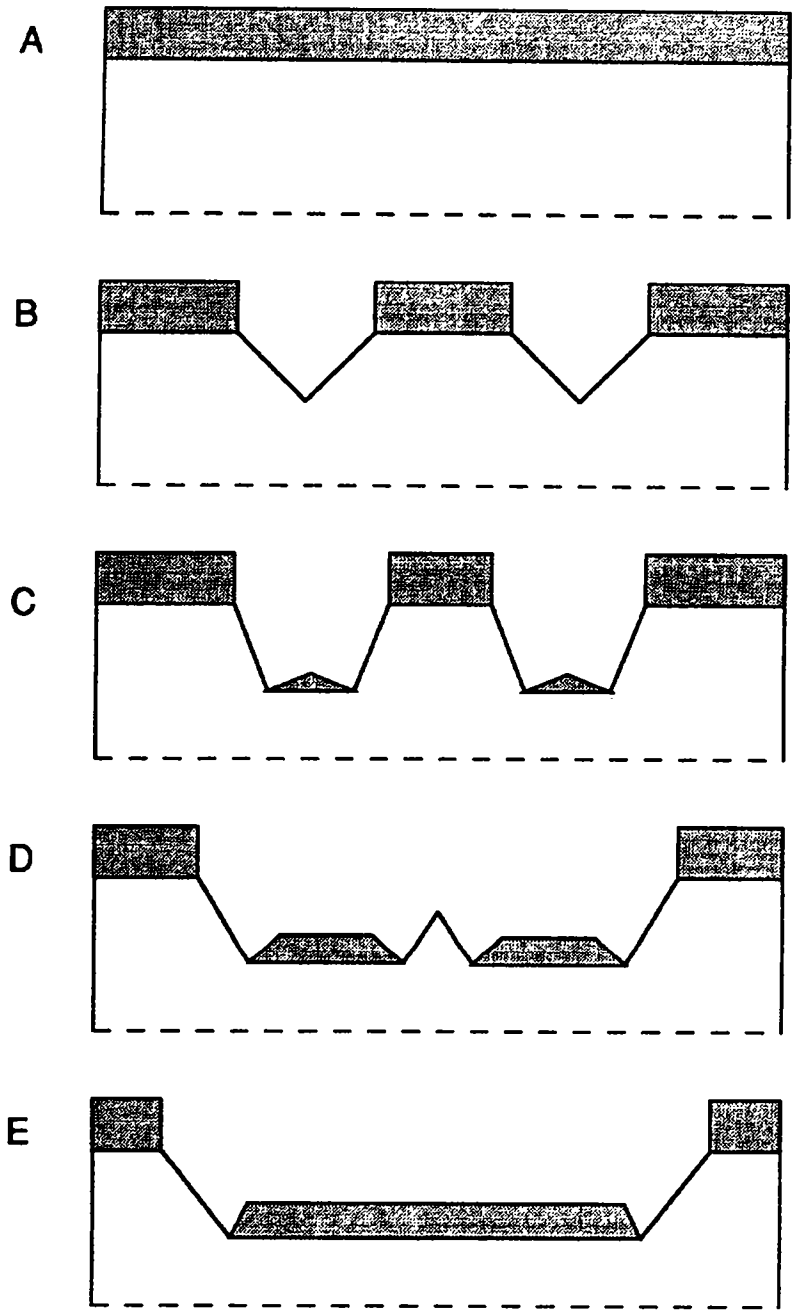

Figure 1: The sequence of gully gravure processes; (A) initial stage of coarse material overlying finer material; (B) incisement of surface by rills and gullys; (C) accumulation of coarse material from above in the incisement; (D) lateral shifting of rills and gullys and continued accumulation of coarse material; (E) lateral planation and formation of a new surface veneered by coarse material.

released from the overlying cap and hence the rate of accumulation in the channels. The coarse channel-fill entraps interstitial fine-textured materials produced by weathering, or wind and water erosion. The permeability and porosity of the channel-fill are reduced, and runoff is deflected toward the periphery of the deposit. As suggested in stage (D), the loci of erosion shift laterally along the hillslope, exploiting the weakness of the fine material. The sequence is completed by the filling of the newly enlarged channel with additional coarse material from the sides of the channel. A new surface of coarse material is created at a lower elevation as a result of lateral planation on the hillside, as shown in stage (E).

A few characteristics of hillslopes experiencing gully gravure are especially noteworthy. First, there seems to be a limit to the depth of incision that can occur before sufficient coarse material accumulates to deflect the flow and erosion toward the periphery of the channel-fill. Second, a topographic inversion takes place between stages (B) and (C), wherein the former channel becomes elevated due to the accumulation of coarse material. Third, in map view, the surface may appear as alternating stripes of coarse and fine materials. Last, surfaces composed of coarse rock fragments, as found in many places, could be products of gully gravure.

Gully gravure has not been widely documented because many hillslopes do not possess the requisite geologic configuration and hillslope processes commonly operate at slow, nearly-imperceptible, rates. Nevertheless, in addition to Bryan (1940), Mills (1981), Twidale and Campbell (1986), possibly Whitney and Harrington (1993), and Osterkamp and Toy (1994) found evidence of gully gravure at various scales and in various environmental settings.

Field Evidence

Osterkamp and Toy (1994) examined hillslope development on two road cuts and one borrow pit southeast of Tucson, Arizona. At these sites sand, gravel, and cobbles cap mid-Pleistocene lacustrine beds. The hillslope surfaces are extensively rilled with coarse material accumulating in the channels. Excavation of cross-sections through the rills revealed sharp textural contrasts between the channel-fill and the lacustrine material adjacent to and beneath the channel. Especially interesting was the wide, roughly horizontal contact along the base of the channel fill, shown in Figure 2. This indicates lateral planation rather than further incision by erosion processes. In some places, topographic inversion appeared to be in progress. The field evidence was analogous to stages (C) and (D) of Figure 1.

Hillslope development at certain locations within the "mesa and butte" topography of the Colorado Piedmont south of Denver, Colorado, also suggests the operation of gully gravure. The hillslopes in this area are products of a complex geomorphic history as portrayed diagrammatically in Figure 3. In profile, the geology consists of horizontal strata of conglomerates or rhyolite overlying sandstones, siltstones, and shales, shown in stage (A) of Figure 3. Erosion by fluvial processes is primarily responsible for the characteristic flat-topped mesas and buttes with steep sideslopes. Colluvial deposits at various places on these sideslopes attest to debris flows following formation of the mesas and buttes, as indicated in stage B (fig. 3). These deposits were incised by fluvial erosion and probably debris avalanches during a high-intensity precipitation event of June 16, 1965, indicated by stage C (fig. 3). Gravitational processes caused both coarse- and fine-textured colluvium to fall into the channels. Fluvial processes since that time have evacuated much of the fine material leaving the very coarse material to accumulate in the channel. Some clasts of this channel-fill approach a mean diameter of 3 meters. This coarse debris deflects flow toward the periphery of the channel resulting in nearly-vertical channel banks in various places. The current cross-section topography is reminiscent of stage C in Figure 1. If this interpretation is correct, then stages D and E of Figure 1 may follow.

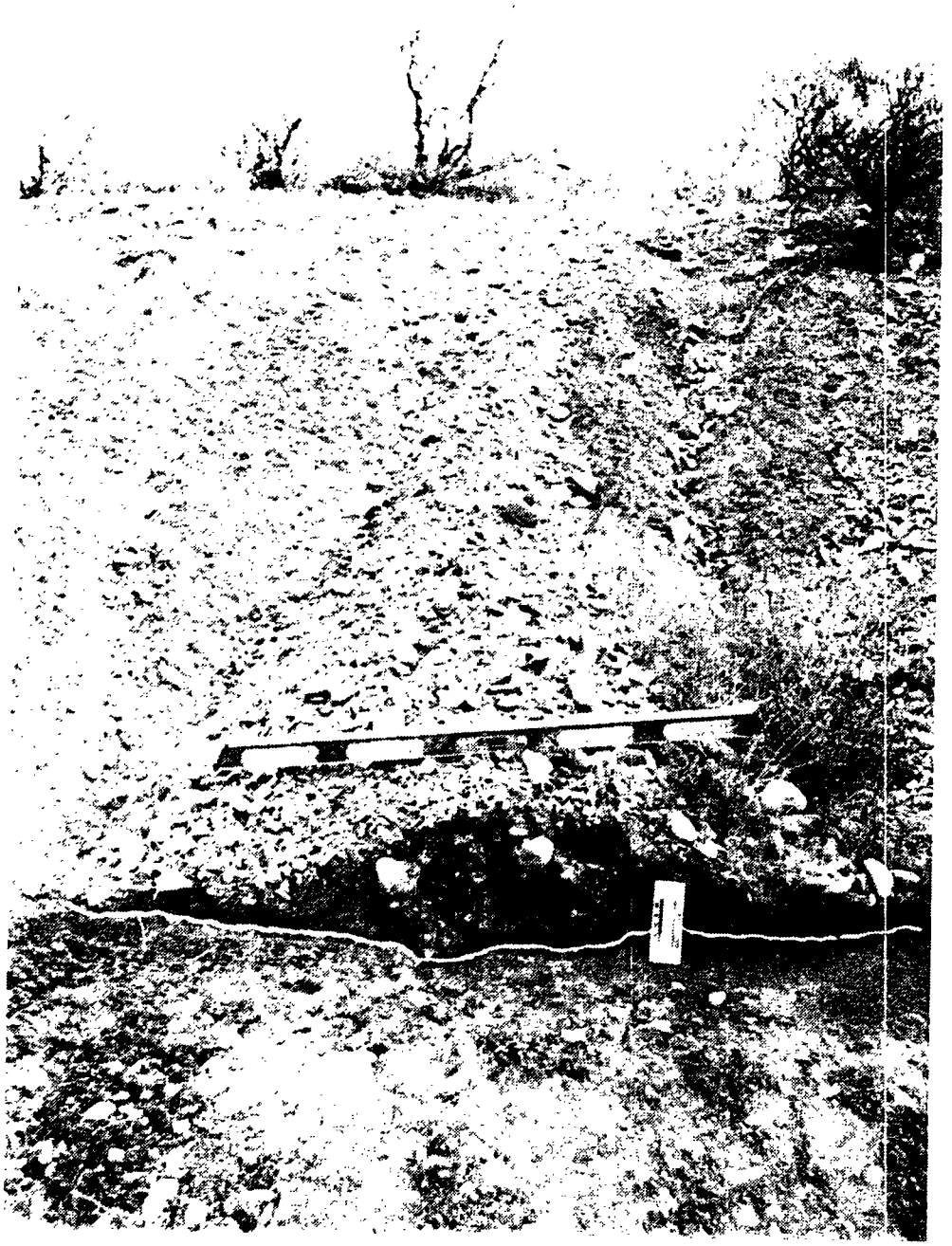

Figure 2: Photograph of rill partially filled with coarse material from above. The white line marks the contact between the coarse material and the underlying fine material. This field site, near Tucson, Arizona, is representative of stage D in Figure 1.

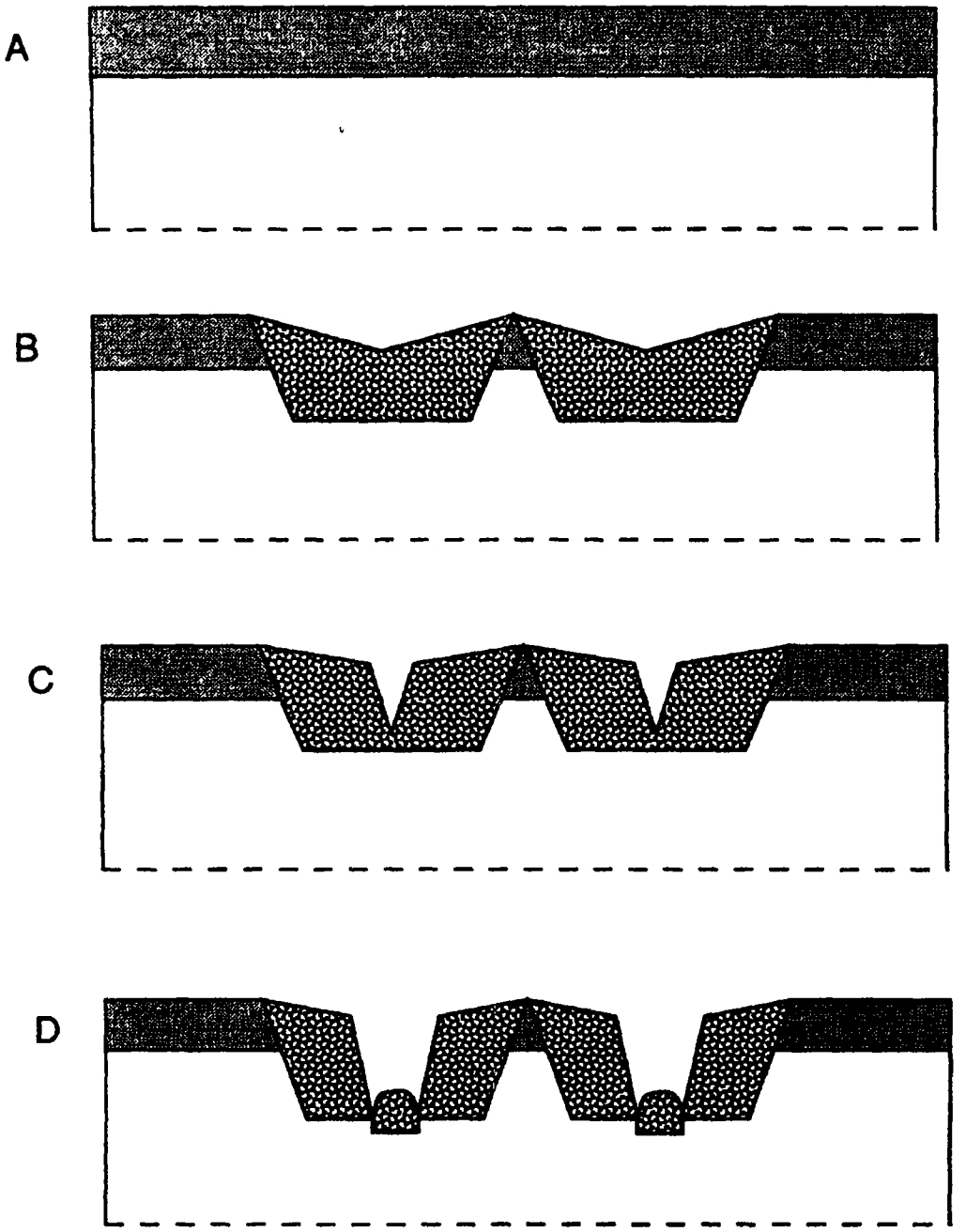

Figure 3: Diagram representing a sequence of hillslope-development processes near Denver, Colorado; (A) horizontal resistant rocks overlying less resistant rocks, forming a mesa-type topography; (B) erosion of sideslopes and filling of gullys with coarse colluvium; (C) fluvial incisement of colluvium; (D) fluvial sorting and additional accumulation of the coarse colluvium, thereby providing the potential for continuing gully-gravure processes.

An implication of this interpretation is that the source of channel-fill in gully gravure need not be a discrete capping layer of coarse materials envisioned by Bryan (1940) and others. A heterogeneous mixture of particle sizes, as occurs in a colluvial deposit or a waste-rock (spoil) disposal site, will suffice. Consequently, gully gravure on reclaimed hillslopes is a distinct possibility.

Conclusion

Osterkamp and Toy (1994) concluded that gully gravure yields general landscape stability, maintenance of adjusted hillslope angles, and low rates of denudation and sediment delivery. These conditions are fundamental objectives of hillslope reclamation. Such surfaces provide stable platforms for revegetation and support eventual land uses.

There is reason to suspect that gully gravure may be occurring on some reclaimed hillslopes. This would be fortuitous because the accumulation of coarse channel-fill limits the depth of incision by fluvial erosion and the development of a coarse surface veneer may reduce soil loss by as much as 99% (Osterkamp and Toy, 1994). Although it would not be prudent to rely upon gully gravure to produce stable hillslopes from waste rock disposal sites because specific geologic conditions and lengthy time periods are required, this process-sequence provides one mechanism that controls the extent of fluvial erosion and drives hillslope development toward stable configurations in many cases.

To be sure, gully gravure is only one mode of hillslope development and evolution. It is, however, a most interesting prospect within the context of disturbed-land reclamation and one deserving of careful scrutiny and verification. Toward this end, we solicit your assistance. If there is evidence of gully gravure on the reclaimed hillslopes with which you are familiar, please bring this to our attention.

Literature Cited

Bryan, K. 1940. Gully gravure, a method of slope retreat. Journal of Geomorphology 3:89-106.

Mills, H.H. 1981. Boulder deposits and the retreat of mountain slopes, or, "gully gravure" revisited. Journal of Geology 89:649-660.

Osterkamp, W.R. and T.J. Toy 1994. The healing of disturbed hillslopes by gully gravure. Bulletin, Geological Society of America 106:1233-1241.

Twidale, C.R. and E.M. Campbell 1986. Localized inversion on steep hillslopes: gully gravure in weak and in resistant rocks. Zeitschrift fur Geomorphologie 30:35-46.

Whitney, J.W. and C.D. Harrington 1993. Relict colluvial boulder deposits as paleoclimatic indicators in the Yucca Mountain region, southern Nevada. Bulletin, Geological Society of America 105:1008-1018.