Techniques and Devices Used to Control Drainage and Erosion

In the following paragraphs an attempt is made to identify in a general way several methods, techniques, and devices, commonly used in mine site reclamation, that relate to hydrology. Their effects are important to the post-mining hydrology and they impose design and functional constraints upon structures built to control surface and subsurface flows onto, through, and from disturbed areas.

For convenience the methods and techniques are grouped into three use categories, ranging from areawide to site-specific. A fourth category covers remedial techniques and maintenance measures. This category includes methods and measures that are often applicable when maintenance is required, where previously constructed facilities are deteriorating, or where remedial reclamation measures are needed before a bond is released.

Category 1. Measures applied broadly to parts of the disturbed land:

A. Topographic reconstruction allows the mine operator to exert various degrees of control over post-mining slope length, steepness, and direction. Topographic elements can be managed to influence the:
   - Balance between surface and subsurface flows from the treated area;
   - Stream flow hydrograph—both base flow and stormflow;
   - On-site storage of both groundwater and surface water;
   - Erosion forces active on the area; and
   - Extent to which toxic spoils are in contact with water flowing from or to the surface.

B. Mechanical measures applied to the surface of a rebuilt, regraded topography include any activity that modifies the microtopography of that surface. Activities such as compaction or use of a bulldozer to "track" a slope will decrease roughness, while activities such as disking, scarifying, plowing, or ripping will increase roughness. Such mechanical treatments may be used to:
   - Modify infiltration rates and soil/water storage capacities;
   - Forestall erosion;
   - Eradicate slight erosional effects that already exist;
   - Strengthen the mechanical bond at the spoil-topsoil interface; or
   - Increase permeability and capillary flow through the spoil-topsoil interface.

   Of course, mechanical treatments may also change those physical characteristics of the surface that influence its serviceability as a seedbed and plant growth medium.

C. Materials applied to or spread upon the reconstructed topographic surface may include mulches, topsoil, or preselected spoils that have superior growth medium characteristics. The direct hydrologic influences expected from placement of superior spoil or topsoil are similar to those listed in the previous paragraph. The effects can be enhanced or weakened by superimposing mechanical treatment. However, mulches will exert other influences upon elements of the hydrologic cycle and site hydrology such as: reduce evaporation, increase resistance to erosion, and stabilize conditions conducive to infiltration.

Category 2. Measures applied to distinct zones or portions of the disturbed area

Quite often, because of their size, location, and the time in the sequence of operations when they were installed, or because the need for them decreased with progressively improving vegetative cover, the structures included in this category may be classed as temporary. Modifications to the basic reconstructed topography allow a greater degree of control over specific segments of the hydrologic cycle and their effects, and allow that control to be exerted at locations and positions when or where it is needed most. Measures include contour furrows, lister pits, diversions and ditches, and devices for dissipating flow energy or spreading flow.

A. Furrows and pits momentarily detain water at or near the raindrop impact point. This serves to:
   - Increase temporary on-site storage of surface water;
   - Promote infiltration;
   - Decrease the incidence of concentrated surface flow and forestall initiation of erosion;
   - Reduce the volume of surface flow from the treated area; and
   - Increase the duration of both surface and subsurface flow from the treated area.

B. Diversions and ditches provide prepared pathways for movement of surface flow from one area to another. They facilitate:
   - Drainage of low areas;
   - Rapid removal of waters from zones where infiltration might be undesirable;
   - Rapid movement of water to zones where infiltration is thought to be desirable — or at least not detrimental; and
   - Erosion control on long slopes, by removing water before highly erosive flow volumes and velocities can build up. (Used as an alternative to furrows and pits.)

C. Flow-energy dissipators serve to decrease the erosive power of flowing water by slowing it down or spreading it out. They can take many forms, may be constructed of a variety of materials, and are useful in many situations. Their end result is to disperse concentrated flows of surface water in much the same fashion as contour furrows and lister pits control the smaller concentrations of water in their smaller zones of influence.

   They may take the form of a permeable wall or sill of rock, brush or straw; a bed or pile of durable stones, a small check dam, or a fence of any of the above materials; or a check structure of posts, hog wire, and cables. They may simply be small topographic depressions which serve as stilling basins from which the outflow may be either surface or subsurface flow.

   Energy dissipators promote infiltration at the outfall of diversion ditches, road culverts, contour trenches and flows from terraced face slopes of valley fills, etc. They also forestall initiation of the erosion process at outfall locations and physically terminate ongoing or incipient erosion processes.

Category 3. Measures, devices and structures used at specific, well-defined locations within the permit area

Several treatments and structures included in this category have counterparts in Category 2 B and C. There, however, the devices are generally small, built to deal temporarily with relatively small, ephemeral flows, and may be "situation-specific" rather than "site-specific." Category 2 measures are installed on the disturbed area itself, whereas Category 3 measures are usually installed at the boundary between disturbed and undisturbed areas or entirely upon otherwise undisturbed land. Scaled and dimensioned drawings and construction details for Category 3 structures may be required.

The primary responsibility for the inspection of these devices during their construction generally lies with a professional engineer. The reclamation inspector assures that the plans have been certified by an RPE and are constructed in accord with plans. But after construction, all subsequent inspections and evaluations of functionability and safety may fall to the reclamation inspector.

Some of the most commonly used structures and measures are:

A. Interception ditches — Large ditches or channels that collect water from lands that will not be disturbed by the mining and route it around the zone of planned disturbance to a point below the downstream-most control structure. Flow gradients usually will be designed on the order of 1 to 3 percent unless measures are taken to prevent channel scour and bank erosion.
B. Terraces — Those portions of a fill face slope that are nearly level or slightly backsloped in cross section and slightly graded (1 to 3 percent in profile) and serve to move water from the fill slope face to protected drainways. (See Flume/chutes below)
C. Flumes/chutes — Those portions or sections of prepared channels, diversions, terraces, etc. that because of topographic constraints must have gradients steep enough to need protection from erosion. Normally, the protection is provided by stone riprap or masonry work, but metal culverts, plastic pipes, plastic sheeting, concrete or metal channel linings, or log structures can serve.
D. Debris/sediment and runoff-detention basins — These structures are installed in natural drainage channels or where artificial channels divert the flow. Their primary purpose is to detain water long enough for suspended solids to settle. Sometimes the waters thus detained are chemically treated before being released into the natural drainage system. Detention also tends to lessen stormflow peaks. Usually these structures are required to have both a primary and an emergency spillway.
E. Contour trenches — Small ponds, usually long in proportion to their width and depth, constructed at and along the contour at the lower boundary between disturbed and undisturbed areas on a mining operation. A single long trench may be divided into cells by check dams or dikes; or shorter individual trenches may be placed to allow a gradual step-up or step-down effect. Flow may be routed from cell to cell with a single outfall to serve several cells, or the convention of one outfall for each cell may be used.
F. Mine access and haulage roads — On many mining operations the haul road is the single most important drainage control structure. On some operations it is the only on-site structure that provides drainage and erosion control. Structural elements important to the drainage control function are roadside ditches, ditch relief culverts, energy dissipation at ditch and culvert outfalls, stilling basins at culvert entrances, road profile gradients, and road cross-section shape and gradient.

   Road location is important: distance from live streams, the relation of ditch relief structures to natural cross drains, and the steepness of the terrain between the route and any natural drainway below it. It is important that maintenance be performed correctly and at the proper time.

Category 4. Remedial measures, treatments, maintenance, and repairs

To a large extent the principles that govern repairs and maintenance are the same ones on which the treatment methods and structures already identified and discussed under Categories 1, 2, and 3 are based. However, the scale of application, and the techniques, equipment, and materials appropriate to maintenance and repair work can differ greatly from those used in the original construction.

If inspections have been thorough and timely, the period of deterioration has not been lengthy, and no catastrophic event has occurred, structures such as those discussed in Category 3 will seldom require replacement. For most structures, only occasional repair will be needed, but the drainage control elements of roads require continual maintenance.

The duties of an inspector in relation to repair and maintenance work are:

1. Recognizing situations and circumstances that call for repair or maintenance;
2. Evaluating each situation or circumstance with respect to the:
   a. Degree of imminent danger to life and property;
   b. Probability of increased danger to life and property;
   c. Time frame within which that probability is set;
   d. Remedial measures that are reasonable to apply under the circumstances;
   e. Extent or degree to which the measure would have to be applied in order to be effective;
   f. Time frame within which remedial actions can reasonably be initiated and completed;
   g. Disturbance to other areas or structures which likely would result from the remedial work;
   h. Chances of problem recurring after bond release.

Factors that bear on the evaluation process and govern the nature and extent of appropriate remedial work include:

- The gross location of the site where the damage is occurring:
  - Is it on or off the permit area?
  - Will it be necessary to get a right-of-way easement to access the work area?
- The physical, chemical, and vegetational characteristics of that area, zone, or structure identified as the source or cause of the damage:
  - What are its topographic and hydrologic parameters?
  - Is a selected or designated vegetation growth medium (topsoil or selected spoil) present?
  - What is the stage of vegetation establishment in and near the damage source area? (No vegetation planted; poor, good, nearly ready for bond release, etc.)
  - To what degree has the damaging circumstance or condition (rill or gully depth, acid water production, severity, or seepage flow quantity, exposure of toxic spoil, etc.) developed?
- The climate and season of the year as they pertain to precipitation patterns, potential for establishing temporary or permanent vegetation, freeze and thaw frequency, etc.
- The position of the damage source and the area where the damage is occurring with respect to its potential for becoming more serious.
  - Is there (little, moderate, great) potential for the present damage level to — intensify, extend?
    - Is the damage area on moderate or steep terrain?
    - Is it on the surface or below—in a stream, or aquifer?
    - Is it primarily a problem of size, of position, or of quality?
  - If the damage does grow what are the chances that it will pose a threat to property or life or permanent change in the character of downgradient ecosystems?
- The planned (as presented in the approved Permit Application Package) post-mining land use.
  - Will the remedial measures chosen (proposed by the operator) be compatible, have little impact, be detrimental, or improve, the implementation of the post-mining land use?
    - How soon can treatment be started? Completed?
    - Historically, has a problem of this type been amenable to treatment of the type proposed?
    - Are the equipment and materials required to implement the proposed measure available?
- The prospects for the problem to recur before or after bond release.
  - Is it appropriate to seek a "permanent" solution at this time?
  - Is the planned post-mining land use such that it would be reasonable to expect continued remedial treatment applications when such are needed in the future?
  - Is the nature of the problem and are its surroundings and contributing conditions such that it is reasonable to expect recurrence?
  - If the problem should recur after bond release is it likely to develop to the degree that life, property, and/or ecosystem values are threatened? Is it likely to be limited to levels such that its surroundings will buffer its effects and keep them within tolerable limits?

Sampling Site Selection and Sampling Frequency

Water-quality sampling sites for enforcement purposes should be selected so as to assess clearly the impact of mining activities on the water resource and to assure that comparisons can be made with subsequent samples. Because physical conditions at mining sites are continually changing, a sampling scheme must have enough flexibility to provide comparable data over a wide range of physical and hydrologic conditions. In addition, permitted point-source discharges from disturbed areas are always considered in sampling because of specific operator liabilities for discharge quality.

Effluent violations are most likely to occur during very low or very high flows. For surface water the common ions (calcium, magnesium, sodium, potassium, sulfate, chloride, and bicarbonate) and total dissolved solids are usually near their maximum when flows are very low. Suspended solids, on the other hand, are generally highest during high flows.

Inspection personnel are required to collect samples of surface water and groundwater from such diverse sources as: streams, impoundments, wells, mine openings, and springs and seeps.

Emphasis is placed on the need to obtain representative samples, properly collected and adequately documented in the field at the time of collection. The inspector should exercise proper care and custody of samples until they are delivered for appropriate analysis. The following pages present a general discussion of sample site selection and sampling frequency for the source mentioned above.

No one scheme can be considered the only correct approach to selecting water-quality sampling sites and establishing sampling frequency. One or a combination of schemes may be utilized by either the inspector or the operator to verify the extent to which requirements set forth in the Permit Application Package are being met.

Long-term monitoring sites may be needed for:

- stream quality during and after mining, to determine the success of reclamation or to provide information for bond-release analysis;
- well-water sampling during and after mining to determine off-site impact.

Short-term sampling sites can be established to collect data on:

- surface water or groundwater, to evaluate ambient conditions before mining
- stream discharge during high flow to evaluate the effectiveness of sediment-control measures.

Streams

The customary approach to determining the effects of mine drainage is to sample the receiving stream above and below inflow from the mine area. This scheme is useful