The primary concern during construction is to be sure that the materials and practices employed in each phase of construction are capable of producing a finished product that will meet the appropriate strength and performance criteria.

It is important that the inspector know the characteristics of the materials being used, appropriate construction practices for those materials, and appropriate equipment for those practices. The inspector must be on the site during critical periods of construction. To do that, the inspector must be aware of the sequence and timing of operations.

When the Permit Application Package calls for construction of an impervious clay core for a dike or dam, or a clay wall to isolate toxic spoil, the clay will not likely perform its task if it is not of the proper type and purity, is used in scant quantity, or is in the wrong position.

When compaction is specified at 95% Proctor, the use of uncalibrated materials, or of calibrated materials that are excessively moist or dry, is unlikely to yield a finished product that meets the stated requirements. Likewise, to bed an uncoated metal pipe, a concrete culvert, or a metal culvert in pyritic materials or where acid water is likely to be encountered is unwise and, in many situations, unacceptable.

To produce a finished structure of the proper strength and performance requires that appropriate equipment be used in the proper manner. Compaction equipment should be matched by both type and weight to the materials receiving the compactive effect. Sheepsfoot rollers are for cohesive materials—the clay core of a dam—but rubber-tired rollers are for sandy, noncohesive materials such as might be used in the outer portions of the dam embankment.

Five passes with a 4-ton roller will not necessarily produce the same compaction as one pass with a 20-ton roller, and vice-versa. Layer placement and compaction does not mean to place all the layers and then compact, but to apply compactive effort *uniformly* over the *entire* surface of *each* individual layer after it is placed.

And "walking-in" culvert bedding and cover materials with dozer tracks does not accomplish the same consistent compaction as compacting thin layers with a hand-guided mechanical tamper. To allow installation of any pipe or culvert that has anti-seep collars without using a mechanical tamper to achieve proper compaction is asking for trouble.

The key points in construction are that the materials be of the proper kind, that they be correctly positioned, that the equipment be matched by size and type to the material, and that the equipment be used in an appropriate manner, to a sufficient extent, and at the proper time during each stage of construction. These points apply whether the structure is a diversion ditch, an embankment to detain runoff or trap sediment, a haul road, or a massive head-of-hollow or valley fill.

On-Site Indicators of Hydrologic Problems

The following indicate conditions with a potential to adversely affect local surface and groundwater:

- Spoil and geologic debris placed where surface drainage may exit beyond control structures. Examples are: clearing the mine site or removing overburden before installing drainage controls, and development roads or clearing operations that extend beyond contour trenches currently in place.
- Encroachment by spoil or geologic debris—whether deliberately placed, or the result of slope failure—upon Permit Application Package-designated zones of non-disturbance parallel to stream courses.
- Mass slope movements on reclaimed surfaces indicate the slope is too steep. The development of tension cracks indicates movement has occurred and that additional movement is likely.
- Rill development on finish-graded surfaces. Channels or gullies at the midpoint or toe of slopes and deposits of eroded materials whether on the graded surface or at the toes of slopes.
- Deposits of eroded material at locations or in volumes that may disrupt planned drainage patterns and defeat control structures. Excess deposits may block road culverts, fill diversion ditches, overload contour trenches and sediment catchment structures, and fan out on "flat" portions of the reconstructed topography to cover newly seeded areas.
- Evidence that waters are moving from subsurface to surface flow conditions. Some indicators are active seeps and a marshy, spongy surface, or marsh grass on finished slopes. Slumps and hummocky terrain on slopes indicate that the waters have already contributed to mass failure.
- Evidence that improper methods or materials, or both, were used in construction of durable rock fills. Some indicators are trucks being loaded with, hauling, or dumping materials that are too small or are not durable —shales, claystones, or finely stratified material of any rock type, and the lack of increasing particle size from top to bottom in the constructed face.
- Improper construction sequence, such as mine site clearing before construction of drainage and sediment control structures, or drilling and blasting before removal and disposition of topsoil.
- Drainage or sediment control structures not located or not sized in accord with Permit Application Package.
- Improper provision for, or improper handling of active drainage. Some indicators are: improper direction of flow or standing water in ditch lines, equipment for pit drainage at locations where drainage is not allowable, evidence of concentrated overland flows—rills, gullies, alluvial deposits—but no evidence of the flow source.
- Evidence of flow into or out of underground working or auger holes, or conditions that could allow such flow at locations or times not approved in the

Permit Application Package. Indicators are: active flow, patterns upon the soil made by prior flows, and the lack of physical barriers (i.e., dams or seals) where they are called for by the approved Permit Application Package.

The company's records of water sampling and testing may show unusual similarities or differences in test results—results that would not be expected because of the time, the concurrent conditions of the contributing drainage surfaces, or concurrent test results from other locations. Some examples are:

- An unlikely relationship between flow stage, water chemistry, suspended solids, and precipitation may, in the absence of unusual climatic or mining events, indicate errors in discharge measurement, sample collection, or analysis. On most watersheds, these parameters follow a fairly consistent annual cycle. Normally floods and high water stages are associated with increases in suspended solids and, because of dilution, decreases in dissolved constituents. Runoff from frozen ground surfaces, flushouts of acid following a drought, or a change in the mix or sources of waters being sampled can produce an extreme change in water quality without there having been an error in sampling or analysis. Normally suspended solids and turbidity increase and decrease together. Measurable alkalinity cannot exist in water with a pH less than 4.6 and if such is reported, one value must be wrong.
- Water quality values outside the limits permitted by the approved Permit Application Package.
- A series of samples with nearly identical chemical characteristics. This could occur because the samples were (1) collected at the same place and same time but assigned different dates, or (2) improperly analyzed in the lab; however, they could be perfectly in order. The inspector may need to take independent samples more frequently until convinced that the operator is demonstrating compliance with the permit.
- Indications of improper or inadequate sampling methodologies, such as soiled sample containers, containers made of products other than glass or plastic, absence of preservatives when such are required, or use of a pH probe in laboratory samples in a manner that may add electrolyte to the sample.
- Discovery of a cache of accumulated samples may indicate that samples were not being promptly submitted for analysis.

Detecting violations or potential problems is an essential function of field inspection and requires continual skill refinement. Because mining areas and operations are so diverse, the inspector will need to consider site-specific conditions and concerns on which to focus field review. Some of the following observation techniques may prove helpful in detecting problems regarding the surface water and groundwater aspects of the permit.

The inspector should look for evidence of water movement at locations where no movement—flow, seepage, etc.—is to be expected:

- On outslope faces of dams or sediment control structures, look for:
  - Active flow—surface or seepage
  - Rills or erosion patterns whose upper ends begin at an elevation at or below the elevation of impounded water
  - Toxic streaks—slick zones or zones barren of vegetation
  - Dispersion streaks—deposits of ultra fine-grained sediment
  - Marsh or wetland plants such as sedges, horsetail, rushes, cattails
  - Mass slope movement—hummocky terrain
  - Water flow in the channel immediately below a structure when there is no flow through the spillway
- In principal or secondary spillways, as specified on the plans, look for:
  - Outflow at other than spillway locations
  - Seepage around pipe or culvert spillways
  - Progressive removal of culvert backfill materials at the outlet end
  - Deterioration of riprap-paved structures in the form of
    - Displacement of individual stones
    - Disaggregation of the stones themselves
    - Erosion of channel bottoms and sides—usually first noticed at locations at or near the downstream extremity
  - Conditions indicative of spillway entrance malfunction, for example:
    - Trash accumulations or brush racks clogged with debris
    - Erosion patterns indicating flows at other than spillway locations
    - Insufficient freeboard
  - Evidence of structure settlement or consolidation, such as:
    - Inconsistent flowline gradient
    - Vertical or lateral shift in portions of spillway — nonalignment of flow structure
  - Flow path (route) located in or upon fill material that might:
    - Be conducive to excessive erosion
    - Allow extensive infiltration where it may not be desirable or environmentally sound
    - Promote slope saturation and mass failure
- On ditches and surface flow control and routing structures be alert for:
  - Debris deposits in the channel resulting from:
    - Cut bank failure and slippage
    - Improper or incomplete road maintenance
    - Sediment and alluvium deposits in culvert inlet basins and culverts resulting from:
      - Angle between ditch and culvert flow lines being less than 90 degrees
      - Ditch gradient being too slight
      - Culvert gradient being less than ditch gradient
    - Collapse, consolidation, or compaction under traffic of fills associated with culverts
  - Surface flow escape from ditches through or across berms or structure embankments
    - Erosion down the roadway wheel tracks—particularly in the track nearest the roadside ditches
    - Erosion across road—rills, gulleys

- Rills or deposition beyond berm crests
- Recently patched or reshaped sections of berms
- Subsurface flow escape from ditches and berms
- Mass slope failure or hummocky terrain and seepage downslope from berms or on the outer slopes of road fills
- Unexplained local patterns in vegetation
- Lack of vegetation
- Patterned deposition of dispersed soils below berms, at culvert outlets, or on road fill slopes
- Outflow around rather than through culverts.

Control of Water and Water Quality

Effects of Surface Mining

Water Flow

Whether water runs off or infiltrates during a rainstorm depends on slope, vegetative cover, soil conditions, and soil compaction. Infiltration will be increased by mining activities that produce cast spoil that is full of voids. This may also result in greater permeability and significant increases in water-holding capacity. But overburden moved by either scraper or truck will tend to be compacted and will likely have more runoff than the undisturbed site.

Surface mining may increase groundwater storage capacity. Any increase in capacity will depend on both the method of spoil placement and the character of the spoil itself. It is possible that "recharge zones" may be created by selecting those portions of the spoil that have the best infiltration characteristics and placing them where surface water can be diverted into them.

Increased infiltration usually means higher and longer baseflow of streams when the water eventually reappears in springs or seeps. Increased streamflow during dry weather and prolonged flow in streams that normally flow only intermittently are generally considered desirable. Studies have shown an increase in dry weather streamflow following surface mining. Other studies have shown that storm peak flows may be several times higher from mined watersheds than from unmined areas during and immediately after mining, but that after reclamation is complete, peak flows in mined areas can be significantly lower. The amount and velocity of runoff during storms will be a major factor in the amount of erosion and hence the amount of sedimentation.

Water Quality

Acid mine drainage (AMD), the detachment and transport of solid particles by flowing water, and the subsequent settling of those particles (sedimentation) are the major water quality problems caused by surface mining.

Sediment. Many experiments have quantified the sediment resulting from erosion on both active and abandoned surface mines. Current technology for control of erosion and sediment has evolved from experimental data as well as from field trials of a variety of sediment control features.

Preventing erosion and subsequent sedimentation is important to prevent:

- Sediment deposition in stream channels
- Continual exposure of toxic- or acid-forming spoil by erosion of unstable slopes
- Loss of soil needed to support a vigorous vegetative cover.

Acid Mine Drainage. When coal is mined, previously protected strata are exposed to oxygen, and in the case of surface mines, to direct weathering as well. When water and oxygen come into contact with iron disulfides (pyrite and marcasite), these minerals will oxidize and release sulfuric acid and ferrous sulfate. These oxidation products, together with an assortment of trace elements soluble in acid, are commonly called acid mine drainage (AMD). In most cases AMD will eventually find its way into streams and groundwater. The ferrous sulfate can oxidize further to produce an insoluble precipitate of ferric hydroxide and additional sulfuric acid. Iron disulfide that is under water or buried in impermeable materials will be effectively protected from oxygen, so no significant oxidation will take place. The only pyritic material in natural systems that can be oxidized at an environmentally significant rate is that which is exposed to atmospheric oxygen. The amount and rate of acid formation and the quality of water discharged are functions of the amount and type of pyrite in the overburden and coal, the duration of exposure to oxygen, the characteristics of the overburden, and the amount of water available.

If the overburden also contains alkaline material such as limestone, acid may be partially or entirely neutralized before it is discharged. However, discharges may be high in sulfate.

The pattern of acid discharge tends to be erratic. Streams may be damaged by continuous acid discharges that occur when streamflows are at low and moderate levels. However, the extremely high discharges when mines are dewatered can also be damaging. Likewise, "flushouts" of acids by the first storm following a drought can be devastating.

Acid Prevention. All techniques for preventing acid formation are based on the control of oxygen. There are two mechanisms by which oxygen can be transported to pyrite: convective transport and molecular diffusion.

The major energy source for convection transport is likely to be the heat generated by the oxidizing pyrite. As hot gases surrounding the pyrite rise, they are replaced by cool air containing oxygen. Changes in atmospheric pressure also induce exchanges between spoil gases and the atmosphere. Wind currents against steep slopes can drive oxygen deeper into the spoil mass. As pyrite is oxidized, oxygen is removed from the spoil atmosphere, thus creating a partial vacuum and drawing in still more outside air.

Molecular diffusion occurs whenever there is a gradient of oxygen concentration between two points, in this case, the spoil surface and some point within the spoil. Molecular diffusion is applicable to any fluid system, either gaseous or liquid. Oxygen will move from the air near the surface of the spoil, where the concentration is higher, into the gases or liquid-filled pores within the spoil, where the