CHAPTER II
BASELINE INFORMATION

A. Determining the Ground-water and Surface-water Baseline Collection Area

Baseline hydrologic data must be collected for both the permit and adjacent area. Many states have a set distance that is used in all cases to define the area outside of the permit area for which baseline data must be collected (e.g., one-half mile, 1,000 feet). Care must be used in determining and applying a set distance for all operations although it may be important to routinely require inventories of structures such as cisterns, wells and other water systems within one-half mile of the permit area for surface operations at which blasting will take place. A water system inventory is necessary because of the applicant's requirement to conduct pre-blast surveys at the request of any resident or property owner located within one-half mile of the permit area.

OSM believes that in some cases it may be more important to determine this distance on a case-by-case basis than to use a prescribed distance to assure that all pertinent information is obtained. This would usually involve a consultation between the RA and the applicant to discuss areas to sample based on several considerations related to the site and proposed mining. The advantage to this is that the applicant has a better chance of meeting the baseline requirements when the permit is eventually submitted. This should also enable the applicant to avoid sampling areas that are not hydrologically connected (and therefore no hydrologic impacts are anticipated) or duplicating data in areas where sampling has already been done by other entities. Some preliminary hydrologic information may need to be collected prior to the consultation. However, in practice, OSM realizes that a pre-baseline collection consultation will not always be possible.

The goal in baseline collection is to characterize the hydrology, hydrologic balance, and identify any water resource or water use that could be affected by the proposed operation. In this regard, it is important to review permit data from similar adjacent operations. Such operations will have actual data on the type and extent of impacts that can be used to determine the baseline collection area for the proposed mine. Information received from prior citizen complaints, aquatic surveys, and other sources also can be of assistance.

In some instances, it may also be appropriate to identify and characterize potential hydrologic impacts from non-mining sources that could occur in the permit and adjacent areas. These sources may include, for example, coal-bed methane development, timber harvesting, or large public or commercial water users. It may be advantageous to know about these non-mining sources to distinguish between coal mining impacts and non-mining impacts after the permit is issued.

1. Considerations for Delineating the Area for Ground-water Baseline Data Collection

For defining the area for collecting ground-water baseline data, a primary consideration would be the type of mining and associated types and degree of impacts to be expected. In this context, the extent of water level drawdown expected by the mining operation would be a major factor. Baseline data should be collected for the areas where this drawdown is expected over the life of the operation. Usually, disturbance to a shallow unconfined aquifer will have a smaller area of drawdown than a confined aquifer. This area can be estimated by using analytical drawdown calculations involving the depth and area of mining and the estimated hydraulic conductivity of the water- bearing strata. The distance to known or expected ground-water recharge or discharge areas is also important as is the identification/location of any boundaries such as outcrops, streams or faults that may effect ground-water recharge or discharge.

A ground-water use inventory should be conducted within and beyond the estimated mine drawdown area. This inventory may be used to determine whether the estimated mine drawdown area intercepts the recharge area of adjacent ground-water users. An inventory of springs and seeps is also an important consideration as these features reflect the locations of natural sources of ground-water discharge. The inventory area may extend a short or long distance from the mine drawdown area. Distance depends on the aquifer characteristics and magnitude of current and anticipated ground-water pumping in the area. Aquifers and other water-bearing strata which are located above or below the proposed surface or underground operation and which may be hydrologically connected to the coal or overburden/underburden to be disturbed need to be considered for baseline characterization.

Another major consideration is the proposed mining effects on ground-water quality. Estimates should be made of the type and concentration of pollutants expected from the proposed operation and the direction and magnitude of ground-water movement during and after mining. For example, if sulfate or TDS are expected to significantly increase, the ground-water user inventory and baseline data collection may need to extend to the closest public or domestic wells downgradient from the mine. If significant increases in trace metal concentrations are expected, the baseline data collection may need to extend to the nearest ground-water discharge area such as a stream or lake.

Fractures should also be considered in defining the limits of the baseline collection area. In areas where ground-water movement is controlled by fractures, the fracture zone(s) may limit the spread of the cone of depression. However fracture zones can also carry pollutants significant distances if the fractures are interconnected and the zone is highly transmissive. For stress relief fracture areas in steep valleys, the baseline area may only need to extend to the lateral boundaries of the fracture zone. It is often difficult to get complete baseline information for these areas because most wells, even observation wells, may only intercept a portion of the fracture system. In addition, it is important to choose the appropriate analytical tools to determine well yield and, as needed, hydraulic properties of bedrock aquifers where storage and movement are controlled by fractures because many of the common techniques for quantifying aquifer properties have limitations when applied to fractured bedrock systems. If the mine is large and impacts are expected to be significant, the water use inventory area may need to extend through the valley bottom to the downstream point where the fracture system discharges.

2. Considerations for Delineating the Area for Surface-water Baseline Data Collection

Determining the surface-water baseline data collection area is usually done after the ground-water baseline area has been determined. This sequence often eliminates the need to sample some streams that may be close to the proposed mining operation but which are not hydrologically connected to the mine (i.e., not reasonably expected to be impacted by virtue of the pre-application ground-water assumptions and estimates).

A first step is to look at a map with the location of all streams, water bodies, conveyance structures and possible surface-water users in the region including withdrawals from alluvial aquifers that can induce surface water flow to the well. This "region" should include and extend past the ground-water baseline collection area and include streams that are one or two stream orders higher than the receiving stream within the proposed permit and adjacent area. It may be advisable to have a map showing the location of the nearest major water user such as a public water system in case a catastrophic, unanticipated event were to occur during the operation. This information should be readily available from existing published maps or GIS databases.

Once a regional map has been obtained, the RA and applicant should try to establish those surface-water systems hydrologically connected to the ground-water baseline area and surface water runoff watershed. This is done by considering the ground-water recharge and discharge areas, direction and magnitude of ground water movement, and location of discharge structures, etc. Once surface-water systems that could be affected by mining are identified, the next task is to determine how far downstream the baseline area needs to extend.

Since hydrologic systems are often very complex and mining impacts difficult to predict with total precision, the inventory should err on the conservative side. The applicant may need to inventory all water users included in the next higher order drainage or even higher depending on circumstances. In this regard, it would be important to review existing information on threatened and endangered fish and associated aquatic species and their critical habitat because of their sensitivity to changes in surface-water quality or seasonal flow patterns.

The baseline collection area commonly becomes some subset of the larger surface-water inventory area based on simple mass balance (dilution) calculations estimated for a worst case discharge rate, worst-case mine water quality, and typical ambient water quality and quantity of the receiving stream. Calculations may need to be conducted for both high and low flows. Downstream baseline sampling should extend to a point where the estimated stream quality and quantity would be diluted by other streams to ambient conditions. If this distance is too large and impractical, it may be reduced by fine tuning of mass balance calculations based on more refined assumptions.

The estimated stream water quality should also be compared with water-use standards (e.g. domestic, irrigation, livestock) and receiving stream standards as set by the appropriate state or Federal Clean Water Act authority. The baseline collection area should include all downstream segments of the receiving stream to the point where the potential impact would not result in exceeding these governing water quality standards.

B. Baseline Information for PHC

Baseline information describes site-specific conditions prior to mining and is the foundation on which permitting decisions are based. It provides a starting point from which to make predictions required in the PHC determination, and from which to compare potential hydrologic changes caused by mining. The Federal regulations require the applicant to obtain sufficient baseline surface-water, ground-water, geologic and overburden information to make a PHC determination, and to develop a hydrologic reclamation plan and surface- and ground-water monitoring plans for their proposed mining operation. In turn, the RA uses the PHC information to prepare the CHIA for the designated cumulative impact area (CIA). The regulations outline specific requirements for each of these determinations, assessments and plans in order to address a wide range of hydrologic concerns, including:

- Flooding and streamflow changes.
- Seasonal variation in flow and quality.
- Sediment yield and drainage control.
- Total suspended solids.
- Total dissolved solids.
- Toxic and acid drainage.
- Water availability and water use.
- Restoration of recharge capacity
- Disturbance to the hydrologic balance.
- Material damage prevention.
- Compliance with federal and state water-quality laws.

Specific hydrologic issues and concerns for individual permitting situations will vary. These issues and concerns need to be identified early in the permitting process in order to ensure sufficient baseline data are collected to characterize, evaluate and remediate them in the PHC. There are many activities that affect the hydrologic balance not related to coal. Some of these activities may produce significant impacts. In some cases a coal mining operation may be proposed in an area where the effects of mining will overlap those of non-SMCRA regulated activities. For example logging, coal-bed methane extraction, in-situ mine, municipal or other large water users, and agricultural activities may have significant hydrologic impacts on surface and ground water. Therefore, it may be necessary to collect information in order to evaluate the effect of these non-SMCRA activities when characterizing the ambient hydrologic condition and when projecting the effects and relative contribution of these activities when evaluating the hydrologic impacts of the proposed operation. In these situations, we encourage coordination and cooperation in data collection with agencies having interests or responsibilities in these non-SMCRA activities.

The number of sites, the frequency of sampling, and the parameters analysed will also vary for different mining scenarios. For example, a tipple or haulroad permit will generally require less intensive sampling than a mountaintop operation or a large area mine.

The gathering of baseline data to describe ambient conditions prior to mining is different from hydrologic monitoring data required during the mining operation and reclamation activities. The two hydrologic data activities are linked to different regulatory requirements, although the baseline data sites may also serve as monitoring sites for evaluating surface and ground-water impacts. Thus, some or all of the baseline sites will very likely be included as part of the ground- and surface-water monitoring plans.

Baseline information is needed to describe the hydrology, geology and overburden characteristics of the proposed permit and adjacent areas. Information is also needed on the chemical and other properties of any potentially acid-forming or toxic materials that will be imported or disposed of within the permit are, such as, coal combustion by-products (CCBs), and coal slurry or refuse.

Assembly of the necessary baseline information for the PHC determination by the applicant should be approached as a two-step process. First, existing information should be assembled and evaluated for usefulness and adequacy. The accuracy of the information and its applicability to the sites should also be assessed. On the basis of this initial evaluation, a plan should be developed for filling any additional data needs. This typically involves field sampling and analysis by the applicant.

This chapter discusses baseline information for the PHCs and CHIAs. Examples of baseline study plans for mining environments in the eastern, midwestern and western U.S. have been provided. It is important to note that the geographic setting, hydrologic concerns and size of coal mines vary. Also, many states have specific baseline data requirements and/or hydrologic resource protection obligations. Consequently, baseline data needs will differ and each permitting situation must be evaluated accordingly.

1. Geology

Conducting a thorough baseline geologic investigation requires several key steps to adequately describe local conditions. Available information must be reviewed, sampling sites must be appropriately located, and sufficient samples and data collected in order to define the local geologic conditions and characterize the overburden.

a. Regulatory Requirements

Permanent program requirements governing geologic information are summarized below. The Federal regulatory citation is included in parentheses.

(1) Geologic Information (30 CFR 780.22)

Each application shall include geological information in sufficient detail to assist in determining:

- The probable hydrologic consequences of the operation upon the quality and quantity of surface and ground water in the permit and adjacent areas, including the extent to which surface- and ground-water monitoring is necessary.

- All potentially acid- or toxic-forming strata down to and including the stratum immediately below the lowest coal seam to be mined.

- Whether reclamation can be accomplished and whether the proposed operation has been designed to prevent material damage to the hydrologic balance outside the permit area.

Geologic information shall include, at a minimum, the following:

- A description of the geology of the proposed permit and adjacent areas down to and including the deeper of either the stratum immediately below the lowest coal seam to be mined or any aquifer below the lowest coal seam to be mined which may be adversely impacted by mining.

- Analyses of samples collected from test borings; drill cores; or fresh unweathered, uncontaminated samples from rock outcrops from the permit area. The analyses of the geologic core samples will result in the following:

    - Logs showing the lithologic characteristics, including the physical properties and thickness of each stratum.

    - Chemical analyses to identify those strata that may contain acid- or toxic forming or alkalinity- producing materials and to determine their content.

- Chemical analyses of the coal seam for acid- or toxic-forming materials, including sulfur and pyritic sulfur.

(2) Definition of Acid-forming Materials (30 CFR 701.5)

Acid-forming materials are those earthen materials that contain sulfide minerals or other materials which, if exposed to air, water, or weathering processes, form acids that may create acid drainage.

(3) Definition of Toxic-forming Materials (30 CFR 701.5)

Toxic-forming materials are those earth materials or wastes which, if acted upon by air, water, weathering, or microbiological processes, are likely to produce chemical or physical conditions in soils or water that are detrimental to biota or uses of water. The OSM definition differs from the definition used by the Environmental Protection Agency (EPA).

(4) Cross sections, maps, and plans (30 CFR 779.25)

This regulation identifies specific geologic information required in cross sections, maps, and plans that are included in the permit application. The required information is outlined in the section on maps and cross sections of this chapter.

(5) Hydrologic-balance protection (30 CFR 816.41)

Surface- and ground water shall be protected by handling earth material in a manner that minimizes the formation of acidic or toxic drainage by identifying and burying and/or treating, when necessary, materials which may adversely affect water quality.

(6) Backfilling and Grading: General Requirements (30 CFR 816.102 (f))

Acid- and toxic-forming materials exposed, used, or produced during mining shall be adequately covered with nontoxic material, or treated, to control the impact on surface and ground water.

b. Existing Information and Resource Inventories

An evaluation of existing geologic data in the permit and adjacent areas may provide an applicant all or part of the information necessary to meet the regulatory requirements for geology and overburden. The information may be available from the following sources:

- Geologic maps published by state Geological Surveys or organizational units.

- Geologic maps published by the U.S. Geological Survey (USGS).

- Soil survey information published by the U.S. Natural Resources Conservation Service (NRCS).

- Logs of exploratory holes maintained by state RAs or other state agencies.

- Published geologic literature.

- Orphan highwalls and active mining operations in the same geologic formations within one-half mile for detailed data or two miles for generalized statements. Observations and data from such areas will also lend credence to the interpretation of areal geology.

- Data bases such as the National Coal Resources Data System of the USGS, the Pennsylvania State Coal Database and other state data bases.

- Monitoring data from active mines in the area.

Data bases and web sites that provide information which may be useful in preparing geologic descriptions for permit applications are identified in Appendices A and B.

c. Geologic Description and Information

Certain geologic information is required as part of the permit application in order to adequately characterize the mine site and adjacent area. Due to local variations in the chemical and physical makeup of rocks, a geologic description must be provided which is site-specific and representative of the permit and adjacent areas. In addition, a generalized regional geologic description is necessary to adequately describe the geologic setting of the adjacent area. The geologic description must include the areal and structural geology of the area. It must also include a description of the lithology and stratigraphy commonly obtained from test borings, drill cores, or fresh, unweathered, uncontaminated samples from rock outcrops. Chemical analyses of overburden and coal strata are also required as part of the drilling program. Geologic information on lithology, stratigraphy and structure is depicted on maps and cross-sections.

Geologic data is closely inter-related to hydrologic baseline data. Structural data will help determine how the mining operation may affect the local ground- and surface-water systems and where to place water monitoring points. Overburden data will give an indication of potential postmining water quality in addition to determining what special handling techniques may be necessary in the mining plan.

d. Geologic Setting, Mineralogy and Weathering Processes

When exposed to near-surface conditions, spoils derived from deeply buried strata may undergo significant changes that affect their suitability for reclamation applications. The changes associated with spoil weathering that may negatively affect the exposed overburden include the oxidation of pyrite to create acid conditions that result in AMD and the release of salts that may accumulate in high concentrations hazardous to biota.

Geologic factors play a major role in the kind of water produced by a surface coal mine The two most important groups of minerals, in terms of postmining water quality impacts, are carbonates and sulfides. Weathering of carbonates produces alkalinity, and weathering of sulfides produces acidity. Major ions produced by these reactions are calcium, sulfate, and iron. The leaching of other ions also contributes to the composition of mine drainage, especially under low pH conditions. Some of these ions include manganese, magnesium and aluminum. The presence and predominance of sulfide minerals versus carbonate minerals in the rocks are based on the depositional environment. Rocks formed from the deposition of sediments in a marine environment frequently contain high-sulfur zones or layers– but they can also have calcareous zones. Rocks formed in brackish environments tend to have high sulfur and lack calcareous minerals. Rocks formed in marginally brackish (paralic) environments frequently have less sulfur than their marine and brackish counterparts. Truly freshwater sediments tend to have calcareous minerals.

Coal mine drainage can be acidic or alkaline and, depending on concentration, may seriously degrade the aquatic habitat and the quality of water supplies because of toxicity, corrosion, and incrustation. Acidic mine drainage, in which mineral acidity exceeds alkalinity, typically contains elevated concentrations of sulfate (SO_4), iron (Fe), manganese (Mn), aluminum (Al) and other ions. AMD results from the interactions of certain sulfide minerals with oxygen, water, and bacteria. The iron disulfide minerals pyrite (FeS_2) and, less commonly, marcasite (FeS_2), are the principal sulfur-bearing minerals in bituminous coal. Pyrrhotite (FeS), arsenopyrite (FeAsS), chalcopyrite ($CuFeS_2$) and other sulfide minerals containing Fe, copper (Cu), arsenic (As), antimony (Sb), bismuth (Bi), selenium (Se) and molybdenum (Mo) also can produce acidic solutions upon oxidation, but these minerals are uncommon in coal beds. Because of its wide distribution in coal and overburden rocks, especially in shales of marine and brackish water origin, pyrite is recognized as the major source of acidic drainage in the eastern U.S. Pyrite oxidation can be rapid upon exposure of freshly broken rock that is exposed by mining to humid air or aerated water, particularly above the water table. The following equation represents the oxidation of pyrite:

$$FeS_2(s) + 7/2\ O_2 + H_2O = Fe^{+2} + 2\ SO_4^{-2} + 2\ H^+$$

The pyrite or marcasite is oxidized releasing ferrous iron, sulfate and hydrogen ions. (Hydrogen ions cause low pH /acid conditions.) Ferrous iron can in turn be oxidized to ferric iron. The ferric iron can be hydrolyzed to form ferric hydroxide and more hydrogen ions (and a lower pH) as shown below:

$Fe^{+3} + 3\ H_2O = Fe(OH)_3 + 3\ H^+$ or,

the ferric iron can directly attack the pyrite and marcasite and act as a catalyst in generating greater amounts of ferrous iron, sulfate and considerable hydrogen ions (acidity) as shown in the following equation:

$$FeS_2(s) + 14\ Fe^{+3} + 14\ H_2O = 15\ Fe^{+2} + 2\ SO_4^{-2} + 16\ H^+$$

In contrast, neutral or alkaline mine drainage has alkalinity that equals or exceeds acidity but can still have elevated concentrations of SO_4, Fe, Mn and other solutes. Neutral or alkaline mine drainage can originate as AMD that has been neutralized by reaction with carbonate minerals, such as calcite and dolomite, or can form from rock that contains little pyrite. Dissolution of carbonate minerals produces alkalinity, which promotes the removal of Fe, Al and other metal ions from solution, and neutralizes acidity. However, neutralization of AMD does not usually affect concentrations of SO_4.

AMD is not a major consideration in the reclamation of the surface-mined lands in the semi-arid and arid parts of western states, although acid-forming materials have been encountered at a few sites. Most economic western coal deposits are non-marine in origin and therefore, low-sulfur. Also, the geochemistry and climate of the region tend to mitigate acidity because the arid conditions lead to accumulations of alkaline materials. The acidic solution produced by pyrite weathering is readily neutralized by reacting with calcite and dolomite, releasing calcium (Ca^{2+}), magnesium (Mg^{2+}), and bicarbonate (HCO_3^-) ions. The divalent cations released by these reactions may be carried upwards through capillary action and deposited near the surface as sulfate or carbonate minerals or they may displace sodium from the exchange sites of sodium-saturated shrink/swell clays as the solutions move downward through the spoil material. The sodium released through the exchange reactions may be leached into the ground-water system during periods of excess moisture. Sodium sulfate ground water with high pH is a serious problem in the semiarid environments of the Northern Great Plains (Senkayi and Dixon, 1988). Weathering of materials in arid environments can also lead to the formation of sodium bicarbonates and calcium sulfates that can affect ground water throughout the western region.

During the process of chemical weathering, which involves hydrolysis, hydration, solution, oxidation, and carbonation, salts are gradually released. Soluble salts that occur in soils and spoils consist primarily of the cations calcium, magnesium, and sodium and the anions chloride and sulfate. Potassium, carbonate, bicarbonates, nitrate and borate are found in smaller quantities (Willliams and Schuman, 1987). In humid environments, weathering of the newly exposed overburden material is accelerated, but salts are readily leached and carried away in solution, and thus do not accumulate. In arid climates, where annual evapotranspiration greatly exceeds annual rainfall, very little water percolates through the spoil under normal conditions. The result is that, although the lack of water reduces the intensity of spoil mineral weathering, the products of weathering (i.e., salts) tend to accumulate in the spoil. A major influx of water will, however, flush many of these salts out of the spoils and they may enter the ground or surface water systems.

The portions of the preceding discussion pertaining to acid mine drainage were taken from Chapter 1, Geochemistry of Coal Mine Drainage. (Link to: http://www.dep.state.pa.us/dep/deputate/minres/districts/cmdp/chap01.html) and

Chapter 8, Influence of Geology on Postmining Water Quality: Northern Appalachian Basin (Link to: http://www.dep.state.pa.us/dep/deputate/minres/districts/cmdp/Chap08-1.html)
of the Handbook on Coal Mine Drainage Prediction and Pollution Prevention in Pennsylvania (October, 1998).

[NOTE– ***Links to the technical reference: Coal Mine Drainage Prediction and Pollution Prevention in Pennsylvania are provided throughout this section. We found it to be a relevant and comprehensive synthesis of ideas, concepts, and research on the topics of overburden analysis, coal-mine drainage prediction, and related topics. At the same time, the user should be aware that the Pennsylvania document may have limitations when applied to other areas. In this context, we encourage use of this technical reference, where applicable.*****]**

e. Acid Drainage Technology Initiative

We also note the work products of the Acid Drainage Technology Initiative (ADTI), (Link to: http://www.nrcce.wvu.edu/nmlrc) ADTI is a partnership-based joint venture in which OSM has joined with industry, the states, academia, other government agencies and groups to identify science-based solutions to AMD problems. The ADTI operations committee initially set up two Workgroups on AMD Avoidance/Remediation and on AMD Prediction to address these issues for coal mining in the Eastern U.S. (A new metal mining section was added in 1999 to address the same two issues for hard rock mining in the Western U.S.)

The initial work product of the Avoidance/Remediation Workgroup is a user manual/handbook on AMD remediation methods, including historical case studies of previously conducted AMD remediation technology experiments, data and information. This handbook was published in June, 1998. (Acid Drainage Technology Initiative, 1998)
(Link to: http://www.nrcce.wvu.edu/nmlrc)

The handbook covers four main areas of AMD remediation technology - Alkaline Addition and Overburden/Refuse Reclamation; Engineered Structural Techniques; Active Treatment Technologies; and Passive Systems Technologies. The Handbook is a technical resource designed to aid the user in obtaining information on the best technology that is suited to a particular situation that is economically feasible. The handbook aids in determining research needs and cost effectiveness for various options. The Workgroup plans to update the handbook periodically to add new information obtained from additional case studies and research.

The AMD Prediction Workgroup effort focused on technical guidelines on the best science and technology to predict AMD potential in the Appalachian coal fields of the Eastern U.S. The Workgroup has completed a technical manual, “Prediction of Water Quality At Surface Coal

Mines" which is available in print (Acid Drainage Technology Initiative, 2000) and on the website below.
(Link to: http://www.nrcce.wvu.edu/nmlrc)

f. Structural Geology

Structural geology may have a major influence on the occurrence and movement of surface and ground water. A description of the structural geology should include both local and regional features that might affect the local and regional hydrologic balance. The description of structural geology includes the structural features of rocks as well as their distribution and includes the general disposition, attitude, arrangement, or relative positions of the rock masses. It also includes deformational processes, such as faulting and folding. Structural features should be discussed with particular reference to the control of, or effect on, surface and ground water resources.

While not strictly structural geology, it may also be appropriate to discuss fluvial features in this section, such as the occurrence of significant colluvial or alluvial deposits. Such discussion may be needed to understand the occurrence and significance of alluvial valley floors (AVFs) in the western U.S. or the occurrence of alluvial aquifers along streams. AVFs are a special concern in the arid and semiarid regions located west of the one hundredth meridian west longitude. AVFs are unconsolidated stream-laid deposits containing streams with water availability sufficient for subirrigation or flood irrigation agricultural activities such as farming or pasturing or grazing of livestock. Whether AVFs can be mined depends on their significance to farming and impacts to the quality and quantity of the surface- and ground-water systems. Federal regulations at 30 CFR Part 822 describe additional requirements for surface coal mining operations on or affecting AVFs.

(1) Structural Descriptions Such As Strike and Dip

The structural description should include both the strike and dip of major geologic units such as sandstones or other aquifers as well as the coal seam or underclay. The description should include an area large enough to evaluate the effects of the structure on both the local and regional surface and ground-water movement. A regional dip in one direction does not preclude local ground-water flow in another direction. It is easy to overlook structural features that affect the movement of ground water locally.

While the dip of strata can affect ground-water movement, particularly in unconfined conditions, it does not always dictate the direction of ground-water flow. For example, a surface operation may mine downdip; then upon reclamation the spoils will saturate and ground water will flow in a downdip direction. However, water may eventually move along the strike of the strata at the buried highwall face. This is due to the relative permeabilities of the spoils and the undisturbed strata. The presence of semi-confining units or discontinuous permeable zones may also result in ground-water movement contrary to geologic structure of the area. For confined and unconfined water-bearing units, water moves from areas of high hydraulic head (recharge zones) to areas of lower hydraulic head (discharge zones) regardless of the strike and dip of the strata.

For these reasons, the ground-water divide does not necessarily coincide with the surface-water divide. For unconfined aquifers, the ground-water divide often coincides with the local topographic divide. For unconfined alluvial and confined aquifers the ground-water divide is independent of the local topographic divide.

(2) Structural Features From Deformational Processes

Structural features resulting from deformation can have major effects on ground-water flow by increasing bedrock permeability and controlling direction of flow. This is known as secondary permeability. The geology section should include a discussion and/or maps of features such as joints, fractures, lineaments, and faults. The geologic description should discuss the degree, spacing, and orientation of joint (fracture) patterns and faults.

Fractures can have a direct influence on ground-water flow rate due to the generally lower frictional resistance to ground-water flow within fractures versus intergranular pores and through the fractures' role in lessening flow system tortuosity. Fracture features and their degree of interconnection are important in controlling ground-water flow in bedrock aquifers. The following is a list of secondary permeability features which can impart significant local and/or regional controls on flow systems:

- <u>Joints</u> - A joint is a rock fracture along which displacement has not occurred. The joint pattern is cumulative and represents a record of all stress events sufficient to induce fractures. Systematic joints are planar joints in shales and sandstones and the face cleats in coal. Nonsystematic joints are curved joints in shales and sandstones and butt cleats in coal. Spacing suggests the number of joints available for ground-water pathways. The width indicates the ability of the joints to transmit water. Systematic joints tend to be more important to ground-water flow since they are often continuous and can transmit water longer distances, more rapidly, than non-continuous, non-systematic joints.

- <u>Stress-relief fractures</u> - Stress-relief fractures are a fracture network unrelated in age and orientation to tectonic stresses, and are often associated with stream downcutting and deglaciation. They include vertical fractures parallel to valley walls and horizontal bedding plane separation in valley bottoms. Studies of stress-relief fractures typically describe a highly permeable, valley-related, shallow flow system which consists of interconnected valley-wall and valley-floor fracture sets, and which are often the most transmissive part of an aquifer. Sections of the valley-floor portion of the subsystem can become artesian due to the presence of alluvial clay which generally occurs mid-valley and can serve as a confining layer. See Wyrick and Borchers (1981) for discussion of stress relief fractures.

- <u>Zones of fracture concentration</u> **-** Fracture zones are relatively restricted areas where numerous fractures dissect the rock mass. They are commonly identified through fracture traces and lineaments shown on a geologic map. The degree of interconnectedness varies. The hydrologic impacts of a fracture zone can be profound. Fracture zones are often valley-related phenomena where they can become integrated with valley stress-relief fracture systems. These features can, and do, serve as major conduits for ground-water occurrence and flow. In zones of relatively intense fracturing, hydraulic conductivities are often several orders of magnitude higher than in unfractured rocks, resulting in fracture-dominated flow.

- Bedding-plane partings - Inherent weaknesses in rock arising from thin bedding (laminations), fissility and/or lithologic contacts often are zones which will provide avenues for ground-water migration. Sometimes the contact between geologic strata can provide more ground-water flow than the unit itself. It is not uncommon to see water seeping from the top of a sandstone at a bedding-plane.

- Faults - A fault is a fracture or fracture set along which there has been displacement. Faults can be important conveyers of ground water relative to the surrounding unbroken rock mass.

The preceding discussion on secondary permeability features is taken from Chapter 2, Groundwater Flow on the Appalachian Plateau of Pennsylvania, of the Handbook on Coal Mine Drainage Prediction and Pollution Prevention in Pennsylvania (October 1998) (Link to: http://www.dep.state.pa.us/dep/deputate/minres/Districts/CMDP/chap02.html).

g. Lithology and Stratigraphy

Lithology pertains to the physical and chemical description of a series of rocks. All changes in lithologic character in a local section reflect changes in the conditions of deposition of the rocks in the section. These lithologic differences are the result of shifts in paleoclimate, paleodepositional environment, and recent surface weathering. These changes in environmental conditions have a direct influence on the rock chemistry in the section.

Stratigraphy pertains to the formation, composition, sequence, and correlation of stratified rocks. The stratigraphic description is a generalized, composite description of the stratigraphy of a mine area as determined by measuring and describing the sequence of strata at several locations. Stratigraphy data can be graphically reported as a stratigraphic column. The description should represent the entire area to be affected and identify significant facies changes laterally across the site. This information is important for identifying discrete zones of acid- or toxic-producing overburden for special handling considerations. Site-specific lithology and stratigraphy information is primarily derived from drill hole data. This information is reported or displayed on drill logs, cross-sections, and structural maps.

Lithologic and stratigraphic data are obtained from visual observations, microscopic examination, and physical and chemical analyses of the strata. Descriptions may include data such as:

- Color.

- Grain size.
- Fossils.
- Mineral composition.
- Bedding character.
- Relative hardness/induration.
- Field fizz test.
- Stratum thickness.

Using this information and physical testing of core samples, characteristics like porosity, permeability, resistance to physical weathering, rippability, and others may be estimated. The location and thickness of water bearing zones in the geologic section should be identified.

Rock characteristics help to define hydrologic conditions. For example, a sandstone overburden may result in greater infiltration rates than an overburden that is primarily shale and siltstone. A more permeable strata such as some sandstones can also lead to greater leakage through the pit floor than a clay strata. Additionally, the higher weathering rates of shales, as opposed to sandstones, can cause problems in backfill stabilization. Finally, typically the smaller the overall grain size, the faster the chemical reactions, such as AMD generation, within the backfill. However, the potential for AMD generation in a sandstone and shale with equal sulfur contents may be greater in the sandstone due to greater permeability.

h. Maps and Cross Sections

Geologic information must include cross sections and maps.

Information that should be placed on maps includes:

- Elevations and locations of test borings and core samplings.
- All crop lines and the strike and dip of the coal to be mined and other important strata within the proposed permit and adjacent areas.
- Bedrock geology, major surficial deposits, and structural features such as faulting and folding.

- Location and extent of known workings of active, inactive, or abandoned underground mines, including mine openings to the surface within the proposed permit and adjacent areas.

- Location and extent of subsurface water, if encountered, within the proposed permit or adjacent areas.

- Location and extent of existing or previously surface-mined areas within the proposed permit and adjacent areas.

- Location, and depth if available, of gas and oil wells within the proposed permit area and water wells in the permit area and adjacent area.

A geologic cross section is a diagram or drawing portraying a vertical section of the earth with a certain depth and height. Each geologic cross section should depict the overburden or other material from the upper limit of disturbance down to, and including, the deeper of either the stratum immediately below the lowest coal seam to be mined or any aquifer below the lowest coal seam to be mined that may be adversely impacted by mining. A cross section should be drawn from a minimum of two data points, such as core hole/drill hole sites and/or highwall/face up observation points. However, the more real data that can be projected onto the cross section, the more accurate the spatial representation. Single-point data presentation does not meet the requirements for, or definition of, a geologic cross section. Usually, at least one cross section should be drawn as nearly parallel to the strata dip as possible, but primary consideration should always be given to an accurate portrayal of the permit and adjacent areas. The number of cross sections needed to depict an area may vary, depending upon the geology of the area and the size and type of mining operation. At least one cross section should be drawn for each area of surface disturbance associated with surface or with underground mining operations. For underground mines, it is recommended that at least one cross section be drawn to represent the areas of the projected underground workings. For area type surface mines, cross sections should depict both the length and width of the proposed site, and at least one cross section should intercept any pronounced structural feature such as a fault. A legend and both horizontal and vertical scales should be indicated on the drawing, with any scale exaggerations noted.

Each geologic cross section should portray the nature, depth, and thickness of all strata including coal or rider seams, using standard geologic terminology and symbols matching those used on the stratigraphic column. The “nature” of each stratum identifies the type of material and its lithologic characteristics. An elevation scale should be included on the drawing to allow calculations of the depth and thickness of each stratum.

A common graphical technique to display geologic information from more than two stratigraphic sections (e.g., drill holes) is a fence diagram. This aids in the presentation and interpretation of geologic data in a horizontal as well as vertical direction.

2. Overburden Analysis

a. Purpose of Overburden Analysis

The purpose of any overburden analysis program is to:

- Provide data to prepare a PHC and demonstrate that the proposed mining can be accomplished without causing AMD or toxic discharges.

- Assess the probable cumulative impacts of mining on the hydrologic balance.

- Aid in the design of the mining and reclamation plan to minimize damage to the hydrologic balance within the permit and adjacent areas and prevent material damage outside the proposed permit area.

Through the overburden analysis it is possible to:

- Identify the vertical and horizontal distribution of acid and toxic forming materials.

- Identify alkaline zones which can be incorporated into a mining plan to prevent acidic drainage.

- Determine the distribution of pyritic zones which may require special handling or avoidance.

- Calculate alkaline addition rates.

- Determine reclamation feasibility by identifying volumes of suitable and unsuitable material.

- Determine mining feasibility, including potential environmental impacts, before investing a large amount of money in leasing (advance royalties) and permit application preparation.

    - Identify topsoil substitutes and supplements.

b. Considerations for A Successful Sampling Program

The obvious and most frequently asked questions that operators and permit consultants have when preparing an overburden analysis proposal are:

- Should holes be drilled for overburden analysis?

- How many overburden analysis holes are needed?

- Where should they be drilled?

Answers to these types of questions depend on many factors such as available data and site-specific conditions. A perspective based on regional issues is provided by summaries of actual permitting scenarios described later in this document. Many states have developed their own procedures and guidelines for overburden sampling.

The site-specific mining information needed to properly plan an overburden analysis include:

  - Mining limits.
  - Boundaries of the proposed area to be affected by coal removal.
  - Proposed maximum highwall heights.
  - Type of mining - for example, contour/block cut or hill top removal.
  - Accessibility to the site.
  - Geologic considerations, such as coal seam identification, depth of weathering, and stratigraphic variation.
  - Information that is available in the permit files of the regulatory authority, such as water-quality data from previous permits or applications covering the same or adjacent areas.
  - Overburden analysis from the same or adjacent areas.
  - Other considerations in developing an overburden analysis drilling plan include:
    - Exploration equipment. It is important to understand the limitations that are likely with different types of drilling equipment. These differences will have an impact on the ability to obtain unbiased representative samples. The choice of exploration equipment is also important in establishing costs.
    - Type of overburden analysis to be performed. This is important in knowing how much sample is required for the specific type of testing to be employed, and the time needed to analyze the samples.

c. Representative Samples

Any overburden drilling program must be designed to collect samples that accurately represent the affected strata of the area. Most overburden holes will be located within the limits of the proposed mining area. Ideally, some holes must be located at maximum highwall conditions, and the holes must represent all of the strata to be encountered by mining. Other holes should be located under low and average cover conditions to provide representative sampling of the overburden where zones may be missing or which may have been altered due to surface weathering. It is important to provide enough drill holes to adequately represent the geology of the site, including any spatial lithologic variation.

Adequate exploratory drilling is essential to the development of a sampling plan that will accurately reflect the range of overburden characteristics. Sulfur is not uniformly distributed in a homogeneous fashion. Because of this, accurately determining the mean percent total sulfur of a particular stratum may be difficult, which could in turn lead to faulty predictions of the potential to produce AMD. The concentration of total sulfur at a mine site may not be the critical factor of whether or not AMD will be produced.

d. Sample Collection

Overburden sampling is accomplished by drilling or direct collection of the sample from an open source such as a highwall. Primary drilling methods that are generally used to obtain overburden samples include:

- Diamond coring
- Air rotary rig: normal circulation
- Reverse circulation rotary rig

Other types of sampling approaches for overburden include augering and highwall sampling.

- Augering - Auger drilling is not recommended for general overburden sampling. It is typically used for unconsolidated or highly weathered materials. The auger lifts the materials on the auger screw. They are in constant contact with the overlying stratum, thus providing for intermixing. However, augering can be successfully used in homogeneous materials such as glacial till and/or old mine spoil.
- Highwall Sampling - Direct collection of samples from an open source, such as a highwall within or near a proposed permit area, can be used for overburden analysis, provided several caveats are understood. First, samples may be weathered to such a degree that they do not represent the strata to be mined. Second, highwall sampling is limited by the availability and accessibility of highwalls. Therefore, care should be taken to collect only unweathered samples from the highwalls in close proximity to and representative of the proposed mining. It is recommended that open source (outcrop, highwall, etc.) samples be used primarily as a supplement to drilled samples.

The above discussion pertaining to overburden was taken from Chapter 5 (Link at: http://www.dep.state.pa.us/dep/deputate/minres/Districts/CMDP/chap05.htm) of the Handbook on Coal Mine Drainage Prediction and Pollution Prevention in Pennsylvania (October, 1998).

For one example of acceptable techniques for sample collection, compositing, and laboratory preparation see OSM Document "Overburden Sampling and Analytical Quality Assurance and Quality Control (QA/QC) Requirements for Soils, Overburden and Regraded Spoil Characterization and Monitoring Programs for Federal Lands in the southwestern U.S. at (Link at: http://www.osmre.gov/pdf/osmswguide.pdf)."

e. Analytical Parameters

Geochemical parameters to be analyzed, methods of analysis, and suitability criteria vary by region based on environmental conditions and concerns. The potential impacts of surface mining operations on the surface and subsurface water quality depend on several factors, including the physical and mineralogical characteristics of the overburden, the degree of infiltration, the extent of spoils weathering and oxygen availability. All these factors must be considered in predicting impacts and in evaluating the parameters which may control these impacts.

The regulatory authority should be consulted for specific analytical requirements. The parameters that may be a concern in overburden quality, and that could subsequently affect water quality, are outlined below.

(1) Acid Base Accounting (ABA)

ABA is based on the premise that the propensity for a site to produce acid mine drainage can be predicted by quantitatively determining the total amount of acidity and alkalinity the strata on a site can potentially produce. The values of maximum potential acidity (MPA) (expressed as a negative) and total potential alkalinity, termed neutralization potential (NP), are summed. When ABA was first used, if the result was positive, the site should have produced alkaline water; if it was negative, the site should have produced acidic water. Early landmark studies originally defined any strata with a net potential deficiency of 5 tons per 1,000 tons or greater as being a potential acid-producer for the use of mine soil prediction. (See Sobek and Others, 1978). This threshold limit is no longer universally accepted for predicting AMD. The MPA is stoichiometrically calculated from the percent sulfur in the overburden. However, the appropriate calculation factor is somewhat controversial. Early researchers noted that 3.125 g of $CaCO_3$ is theoretically capable of neutralizing the acid produced from 1 g of S (in the form of FeS_2), suggesting that the amount of potential acidity (PA) in 1,000 tons of overburden could be calculated by multiplying the percent S times 31.25. This factor is derived from the stoichiometric relationships and carries the assumption that the CO_2 dissipates as a gas:

$$FeS_2 + 2\ CaCO_3 + 3.75\ O_2 + 1.5\ H_2O \dashrightarrow Fe(OH)_3 + 2\ SO_4^{-2} + 2\ Ca^{+2} + 2CO_2\ (g).$$

Recent research has suggested that in backfills where CO_2 cannot readily dissipate into the atmosphere, some dissolves and reacts with water to form carbonic acid. If all the CO_2 dissolves in the water, then the MPA, in 1,000 tons of overburden, should be derived by multiplying the percent S times 62.50. (See discussion by Cravotta and others, 1990). In most cases, the 31.25 value is used because of a lack of specific information on the amount of CO_2 gas that ends up as carbonic acid.

The neutralization potential (NP) is determined by digesting a portion of the prepared sample in hot acid, and then by titrating with a base to determine how much of the acid the sample consumed. NP represents carbonates and other acid neutralizers and is commonly expressed in terms of tons $CaCO_3$ per 1,000 tons of overburden. Negative NP values are possible, and are sometimes derived from samples of weathered rock that contain residual weathering products which produce acidity upon dissolution.

Interpretation of ABA data involves the application of numerous assumptions; some of the more significant assumptions often used are:

- All sulfur in a sample will react to form acid.
- All material in the sample which consumes acid during digestion in the lab will generate alkalinity in the field.
- The reaction rate for the sulfur will be the same as the dissolution rate for the neutralizing material.
- NP and percent sulfur values below certain threshold levels do not influence water quality.

As these assumptions imply, interpretation of ABA data is far more complicated than simply summing the MPA and NP values. The assumptions are discussed un more detail in Chapter 11 entitled "Interpretation of Acid-Base Accounting Data" (Link to: http://www.dep.state.pa.us/dep/deputate/minres/Districts/CMDP/chap11.html) of the Handbook on Coal Mine Drainage Prediction and Pollution Prevention in Pennsylvania (October, 1998).

In addition to the percent sulfur and NP determinations, two other measured parameters in an ABA overburden analysis are paste pH and fizz. Other derived values typically include calculations of MPA, tons of neutralization potential, tons of PA, and tons net neutralization potential for each sample, as well as for the entire bore hole. Since acid mine drainage results from accelerated weathering of sulfide minerals, the amount of sulfur in a sample, or in an overburden column, is obviously an important component of ABA. As noted above, ABA uses the percent sulfur to predict the MPA that a particular overburden sample or column could produce if all the sulfur reacts.

Sulfur determinations for ABA are often performed for total sulfur only; however, determinations for forms of sulfur are sometimes included. Sulfur generally occurs in one of three forms in the rock strata associated with coals: sulfide sulfur, organic sulfur, and sulfate sulfur. Sulfide sulfur is the form which reacts with oxygen and water to form acid mine drainage. The sulfide minerals most commonly associated with coals are pyrite and marcasite, both of which are FeS_2, chemically. Other sulfide minerals such as chalcopyrite ($CuFeS_2$) and arsenopyrite (FeAsS) may also be present in small amounts. Organic sulfur is that sulfur which occurs in carbon-based molecules in coal and other rocks with significant carbon content; since organic sulfur is tied up in compounds that are stable under surface conditions, it is not considered a contributor to acid mine drainage. Organic sulfur can represent a significant fraction of the total sulfur found in coal seams.

Sulfate sulfur often occurs in partially weathered materials as reaction by-products of sulfide mineral oxidation. Common hydrous iron sulfates such as melanterite, rozenite, copiapite and coquimbite represent "stored acidity." The stored acidity can be released when these secondary minerals dissolve and Fe^{+3} undergoes hydrolysis. This process can significantly affect water quality and generate AMD well after pyrite oxidation has been curtailed. However, sulfate sulfur may or may not produce acid. Alkaline earth sulfate minerals such as gypsum ($CaCO_3 \cdot 2H_2O$) contribute to the sulfate sulfur fraction, but unlike some iron sulfate phases, the alkaline earth sulfate minerals do not produce acid. Nevertheless, when dissolved, these weathering by-products are a source of sulfate ion that is a contaminant found in AMD. Secondary sulfate minerals tend to be highly soluble and may be leached from the upper portion of spoil during the wetter times of the year. For a more complete discussion of secondary mineral formation, see Chapter 1, Geochemistry of Coal Mine Drainage. (Link to: http://www.dep.state.pa.us/dep/deputate/minres/Districts/CMDP/chap01.html) of the Handbook on Coal Mine Drainage Prediction and Pollution Prevention in Pennsylvania (October, 1998).

Commonly used methods of the American Society for Testing and Materials (ASTM) for performing total sulfur determinations include: high temperature combustion methods (ASTM D4239), the Eschka Method (ASTM D3177) and the Bomb Washing Method (ASTM D3177). Of these methods, the high temperature combustion methods are the simplest and most frequently used and provide accurate, reproducible results. A common method used for determining forms of sulfur is ASTM D2492. Research has shown that modifications of these methods are required for accurate and reproducible results. When properly analyzed, total sulfur determinations are typically simple to do, are reproducible, and can be calibrated and verified using available standards. Complete discussion of the modified methods can be found in Chapter 6, Laboratory Methods for Acid-Base Accounting: an Update, (Link to: http://www.dep.state.pa.us/dep/deputate/minres/Districts/CMDP/chap06.html) of the Handbook on Coal Mine Drainage Prediction and Pollution Prevention in Pennsylvania (October, 1998) and Hossner (Texas Mine Land Reclamation Monitoring Program Issues, A report of the Soils Working Group October 1998). (Link to: http://www.osmre.gov/pdf/TXMONITORING.pdf).

Pyritic sulfur determinations are done using a variety of methods (sometimes not standardized, and at least one of which is considered inappropriate for rock samples), produce results which are often not reproducible between laboratories, and cannot be calibrated and verified using available standards. Given these considerations, and that pyritic sulfur is the most abundant form in coal overburden (but not necessarily in the coal), total sulfur determinations currently provide the best basis for calculating MPA.

- <u>Fizz Test</u>

The fizz test is frequently presented as a minor part of the NP test; however, the fizz test can have a large impact on the reliability and reproducibility of NP data, so it is discussed separately here. The fizz test is a measure of the reactivity of alkaline materials in a sample after adding a small amount of dilute hydrochloric acid. The fizz test results are a matter of human judgement and, therefore, somewhat subjective. The greater the reactivity, the higher the fizz test.

The fizz test can be used as a check on the NP determination, since there should be a qualitative correlation between the two. More importantly, however, the fizz test determines the volume and the strength of the acid which is used to digest the prepared sample, which in turn can affect the NP determination results. The NP result is then somewhat dependent on the fizz test results.

Given the difficulties which the current fizz test system introduces into NP determinations, a reproducible, objective carbonate-rating test could significantly improve the reproducibility of NP data. Until such a test is refined, individuals who generate and interpret ABA data need to be much more aware of the influence of the fizz test values on the NP determinations. Where fizz test results and NP values seem to be at odds, further testing would be prudent. When a carbonate rating system other than the familiar four-tiered fizz test is used, data interpretation will have to be adjusted and interpretive rationales will have to be "recalibrated."

- <u>Neutralization Potential (NP)</u>

Carbonate minerals, such as calcite and dolomite, are known to be the major contributors to ground-water alkalinity in the coal regions. The acid-digestion step of the NP test is suspected of dissolving various silicate minerals when excess acid is used as a result of the fizz test. This results in an NP determination that overstates the amount of carbonate minerals in a sample.

Siderite ($FeCO_3$) is common in coal overburden and has long been suspected of interfering with the accuracy of NP determinations and of complicating the interpretation of the data. If iron in solution from the siderite is not completely oxidized when the titration is terminated, then the calculated NP value will be high, since complete oxidation of the iron would produce additional acidity. An unstable titration end point can obviously affect the reproducibility of the NP results.

Several researchers have proposed adding a hydrogen peroxide step to the NP determination procedures to eliminate the problems with the method caused by siderite. (See Skousen and others, 1997). If the hydrogen peroxide step performs according to its intent, it should generally decrease the NPs of strata with a significant siderite content, but should not appreciably affect the NP values of strata that do not include significant amounts of siderite. It should also lead to better reproducibility of NP data between laboratories, especially for samples with significant siderite content.

- Other Methods of Determining Carbonate Content

The NP test has been adapted and widely used to approximate the carbonate content of mine overburdens largely because it is relatively quick, inexpensive, and easy to perform. However, as noted, it may not always provide results which are accurate and reproducible. Ongoing research may result in a test that is more reliable and reproducible.

In summary:

1. The MPA (i.e., total sulfur) component of the ABA analytical technique should be used to avoid problems in:

- Determining forms of sulfur
- Underestimating acid contributions from all forms of sulfur

2. The NP test should include the hydrogen peroxide step to account for the presence of siderite.

The above discussion pertaining to acid base accounting was taken from Chapter 6, Laboratory Methods for Acid-Base Accounting: an Update, (Link to: http://www.dep.state.pa.us/dep/deputate/minres/Districts/CMDP/chap06.html) of the Handbook on Coal Mine Drainage Prediction and Pollution Prevention in Pennsylvania (October, 1998).

(2) Kinetic Tests

Kinetic tests can supplement ABA analyses or simulate the products of weathering in the backfill material. Kinetic tests include both field and laboratory tests to simulate the physical, chemical, and biological processes that affect the chemistry of water as it migrates through rock. These tests try to address the unique mechanisms and chemical reaction rates that occur when rock is mined and subjected to the environment. Factors such as weathering, adsorption/desorption, biological decay, and rainfall/recharge are often simulated or measured directly in kinetic tests. Column leach tests, soxhlet reactors, lysimeter test plots, and humidity cells are just some of the common test methods that have been used on coal spoil.

While much attention has been given to kinetic tests for acid mine drainage prediction, other non-AMD impacts such as prediction of salt loading or nutrient leaching better lend themselves to kinetic tests. The rates of reactions can also be simulated, such as a leach test to determine how quickly the alkalinity component of spoil leaches out in comparison to the acidity component. For example, in one case, a major sandstone tested out as alkaline in an acid-base accounting test. However, a leach test later determined that the sandstone did not weather quickly enough for the alkalinity to be released and contribute to neutralizing the acidity of adjacent strata. After mining, field evidence confirmed that the sandstone did not release alkalinity.

There have been many reports in the literature on the success and failures of kinetic tests. Some of the major problems of kinetic tests include: simulating grain size, simulating freeze/thaw action, finding a representative sample, simulating rainfall/recharge, controlling ground-water contact with the rock, controlling biological conditions, and simulating pore gas composition. For this reason, it is recommended that kinetic tests be used as a supplement to static testing such as ABA or other methods, such as sampling spoil water from adjacent mined areas. Like any predictive technique, kinetic tests are just one tool available for making overall predictions. For more information on kinetic tests see Chapter 7, Kinetic (Leaching) Tests for the Prediction of Mine Drainage Quality (Link to: http://www.dep.state.pa.us/dep/deputate/minres/Districts/CMDP/chap07.html) of the Handbook on Coal Mine Drainage Prediction and Pollution Prevention in Pennsylvania (October, 1998).

(3) pH

The pH is a measure of the acidity or alkalinity of the overburden. A low pH is an indicator of acid toxicity and a high pH generally indicates extremely sodic conditions. The pH affects the availability of chemical elements, thereby controlling the level of nutrients and toxic elements in overburden and water. The activity of microorganisms also responds to pH levels. Generally, a moderate pH - not extremely acid or alkaline - provides the most adequate biological conditions.

(4) Electrical conductivity (EC)

The EC is a measure of the soluble salts present in the overburden. It includes chlorides and sulfates of potassium, sodium, calcium and magnesium. These salts are easily leached from exposed soil or overburden material. Excess salinity can increase osmotic pressure in the root zone, resulting in less water uptake by the plants. Salinity can also impact the suitability of water for irrigation and livestock. Landscape position and precipitation will have an effect on salinity levels. Salts are transported with water over the landscape and will therefore move down slope and collect at the bottom of slopes and in depressions. Salts may also be brought toward the surface by upward movement of water. Presence of salts is influenced by season and rainfall patterns. Salinity hazard is assessed by measuring the EC of an aqueous extract of the overburden. Many states have suitability criteria for electrical conductivity. High levels of soluble salts in overburden are generally associated with arid climates where evapotranspiration exceeds rainfall. The products of weathering are not leached downward, but eventually accumulate at or near the surface. However, salts released from spoil can pose problems in humid regions as well, where they may deter seedling establishment before being flushed from the rooting zone.

(5) Sodium Adsorption Ratio (SAR)

Sodium (Na) is a common constituent in unleached overburden. It can be present in the form of salts in solution, or adsorbed onto clays. Sodium is highly mobile and is readily released from exposed spoil. Once mobilized it can migrate upward from the spoil into the root zone in arid regions such as the western U.S.. The primary concern with sodium is physical degradation of soil structure due to dispersion and swelling of clay. Dispersion causes blocked pores and swelling causes smaller pores. Water infiltration and hydraulic conductivity are reduced, which limits the amount of available water for plants and decreases the leaching of salts, which can accumulate to hazardous levels. Dispersion and swelling may also cause surface crusting, which reduces aeration, inhibits germinating seedling emergence, and increases runoff and erosion. The suitability of water supplies for irrigation and livestock can also be affected by high levels of sodium.

SAR is the standard measure of sodicity. SAR is a comparison of the concentrations of extractable Na, Ca, and Mg and takes into account the moderating effects of calcium and magnesium ions on sodium hazards.

$$SAR = Na^{+} / [(Ca^{+2} + Mg^{+2}) / 2]^{1/2}$$

In laboratory analysis, it may not be appropriate to base dilutions for all analytes on the highest concentration analytes such as Na, which can cause inaccurate readings for Ca and Mg and will have a large effect on overall results.

Other factors influence the effects of sodium, and SAR criteria may be modified based on local environmental conditions. Parameters considered in determining the degree to which sodium may be detrimental include salinity, soil texture, and clay mineralogy.

- <u>Salinity</u>- The tendency of clay particles to disperse in sodic soils decreases with increasing electrolyte concentration up to certain levels.

- <u>Soil texture</u>- Textural analysis determines the amount of clay available for dispersion/swelling. Fine-textured soils are affected to a greater degree than coarse textured soils. Most western states modify SAR suitability criteria based on texture.

- <u>Clay mineralogy</u> - Material with a high fraction of smectitic minerals (2:1 clays, such as montmorillonite) are susceptible to swelling, and therefore generally more affected by high levels of sodium that lead to reductions in hydraulic conductivity than are clays with other mineralogy. Saturation percent provides an indirect measure of shrink/swell clays.

(6) Saturation percent

Saturation percent is a measure of soil water-holding capacity. It is correlated with soil texture and swelling tendency. High saturation percent tends to be associated with high clay content soils that are dominated by smectitic clay mineralogies. Materials with high proportions of swelling clays have reduced infiltration and available water.

Most regulatory authorities, particularly in the arid West, have minimum saturation percent criteria of 25, as an indicator of low water-holding capacities (e.g., sands), and maximum saturation percent criteria of 80-85, as an indicator of the presence of swelling clays that may restrict water movement and exacerbate sodium problems at locations with high SARs.

(7) Texture

Textural analysis to determine the proportion of sand, silt, and clay in the overburden material is important in determining the infiltration, hydraulic conductivity and water holding capacity of the material as well as assessing erosivity. Fine-textured materials limit water movement. Small pores allow less air and water to move into and through the overburden which increases runoff and erosion. Also, due to the high surface area in clay, water adheres tightly to clay particles and becomes less available to plants. Clays are also more susceptible to compaction from heavy equipment. Raindrop splash can lead to crust formation in finer materials, as particles are washed into surface pores. This inhibits seedling emergence and again contributes to runoff and erosion. Coarse-textured materials, on the other hand, have high permeabilities and low water-holding capacity which can also limit the availability of water for plants.

(8) Selenium

Selenium (Se) is a common trace element that is commonly associated with pyrite and has similar geochemistry to sulfur. Soluble forms tend to concentrate in sedimentary materials, especially dark shales, coal stringers and carbonaceous shales. High concentrations are commonly restricted to the arid West and some areas of the Midwest. Solubility of Se is controlled by its oxidation state, which is governed by redox potential and pH. The most soluble forms of selenium occur in alkaline and oxidizing environments. Soluble selenates and organic selenium are forms most readily available to plants.

Although selenium is an essential nutrient, it can also be extremely toxic to animals. Selenosis (selenium toxicity) is a hazard to livestock when excess selenium accumulates in either water or plants. Care must be taken not to place selenium overburden material in the recharge zone where it could contaminate underlying aquifers.

The RA may require analysis of both total and soluble selenium in overburden. Analysis for total selenium provides the long-term potential of available Se. Soluble selenium tests measure the readily available Se in the overburden. Se fractionation can be used to determine forms and stability of Se in soil medium, a technique that is generally not required but gives the best indication of a selenium hazard in the area.

(9) Boron

Boron (B) is a widely distributed trace element in many rock types, especially in coal and carbonaceous shales, and has a tendency to concentrate in arid soils. Boron is more mobile in alkaline environments than acidic environments. Increased mobility enhances the potential for increased bioavailability. The range for boron toxicity and deficiency to plants in soils is narrow. Boron concentrations of irrigation waters in the arid west, are particularly important because many crops are susceptible to even extremely low concentrations of this element. Coal combustion by-products can contain elevated levels of boron.

(10) Trace metals

Trace metals, such as arsenic and molybdenum, may require analysis.

See Appendix D, Baseline Information, for a sample outline for collecting and organizing PHC baseline data.

3. Ground Water

Conducting a thorough baseline ground-water investigation requires following several key steps in order to collect the data needed to adequately describe the local ground-water hydrology. Available ground-water information must be reviewed, existing ground-water resources must be inventoried, baseline sampling sites must be appropriately located, wells must be properly constructed and sufficient data collected to define the ground-water system and to determine baseline quantity and quality under seasonal conditions.

a. Regulatory Requirements

Minimum ground-water information requirements for surface and underground mining permit applications are stated in the regulations at 780.21(b) and 784.14(b). This information includes:

- Location and ownership of existing wells, springs and other ground-water resources such as seeps for both the proposed permit area and adjacent areas
- Seasonal quality of ground water
- Seasonal quantity of ground water
- Ground-water use

These are only minimum requirements. Additional information may be required depending upon the complexity of the hydrologic system and the concerns of the RA.

b. Resource Inventories and Available Information

Before any baseline ground-water sampling and analysis can be done, the location of all ground-water sources should be identified. Both a field inventory and a literature review to collect the ground-water inventory information should be conducted. There are many different types of hydrologic information sources and data bases available (See Appendix A and B). Although use of existing information is important, a field examination is also necessary for verification.

Minimum baseline ground-water information requires an inventory of wells and springs near the permit area, including location, ownership (including any information regarding ground-water rights), quantity, seasonal usage rates, spring discharge rates, depth to water and specified measurements of quality. Water use inventory information will be used to determine whether mining has adversely impacted individual water supplies. In addition, any adjudicated or otherwise vested water rights should be identified.

Providing information about existing wells may be necessary. This information could include:

- Well driller's log
- Location of well (e.g., latitude-longitude, UTM)
- Elevation and description of measuring point (e.g., surface and top of casing)
- Depth and diameter of wells
- Position of screens or uncased (open) hole
- Position of pump, indicated in the well driller's logs
- Geophysical logs
- Aquifer characteristics (e.g., transmissivity, storativity and specific capacity)
- Sampling protocol for consistent water quality and level measurements
- Periodic measurements of static water level
- Pumping water level
- Well yield
- Water quality

c. Site Selection

Properly planned selection of ground-water evaluation sites is important in order to collect the data necessary to accurately determine baseline conditions. The number of ground-water sites selected for documenting baseline quality and quantity conditions should be sufficient to generally reflect the geographic variability of quality and quantity values. Baseline sites should be distributed on and around the proposed operation and located both up gradient and down gradient from the area to be disturbed. Baseline information collected should be adequate to characterize conditions throughout the portions of the aquifer that may be impacted later by the proposed operation.

The use of observation wells is preferred in most cases to characterize the aquifer. However, it may be acceptable to use information from existing wells that were identified in the water-use inventory. An existing well in use generally describes the ambient condition of the developed portion of the aquifer unaffected by the proposed mine. An existing well in use should not be used to describe the undeveloped portion of the aquifer. Older wells may be in poor condition or lack completion and other information to describe baseline conditions. Therefore, observation wells may have to be drilled in order to get sufficient site-specific information.

Two observation sites (e.g., springs, wells) from each aquifer identified, one located up gradient and the other down gradient from the permit area, will usually provide adequate coverage to characterize water quality. Three observation sites are needed to describe the ground-water potentiometric surface and flow direction. As the system complexity increases, more sites may be necessary.

All information related to well construction and well development should be included as part of the baseline data collection plan. Any existing well used for baseline data collection and analysis must be:

- Completed properly in the aquifer to be characterized
- Located to reflect conditions in the permit and adjacent areas
- Constructed with non-reactive casing material which will not alter the chemical quality of the water
- Accessible for water-level measurements and sampling

d. Defining Quantity

Baseline water-quantity descriptions should include approximate rates of discharge or usage and depth to water in the coal seam and each aquifer above and potentially impacted stratum below the coal seam. In addition, an understanding of the regional hydrologeologic setting and ground-water system, including rate, direction and overall pattern of ground-water movement is essential for predicting impacts to ground-water quantity. Both surface and underground mining have the potential to disrupt and permanently alter the physical characteristics of the ground-water system through the following:

- Reduction of ground-water availability through the removal of aquifers in the overburden or removal of the coal seam itself
- Changes in ground-water storage as measured by water-level declines
- Alterations of stream baseflow conditions
- Increases in ground-water recharge, storage and transmissivity by spoil aquifers

The characterization of the ground-water system should include:

- A description of hydrologic characteristics of geologic units within the aquifer and overburden systems
- The rate and direction of water movement as defined by the water table or potentiometric surface
- The rate and direction of water movement between aquifer units or between the aquifer and associated streams
- The location and rate of recharge or discharge

Characterization commonly requires the measurement and testing at selected sites for specific aquifer properties such as:

- Porosity (percentage of void space)
- Permeability (measure of interconnected void space)
- Hydraulic conductivity (measure of the ability of rock to transmit water)
- Transmissivity (measure of the ability of an aquifer to transmit water)
- Storage coefficient (measure of the amount of water an aquifer releases from or takes into storage)
- Specific yield (measure of storage coefficient for an unconfined aquifer)

The aquifer properties listed above represent various ways of defining hydraulic characteristics of geologic strata. Heath (1983) presents a clear and concise discussion of these basic aquifer properties. Information on aquifer properties is determined mainly through aquifer tests (pump or slug tests) conducted in the field. Richards (1985) provides a detailed discussion on the collection and evaluation of ground-water quantitative information for coal mine permit applications. Subjects covered include well drilling completion and development information, aquifer characterization and aquifer testing, relationship between ground and surface water, and fractured rock hydrology. Richards (1987) provides eleven case histories of ground-water studies in the different coal-producing areas of the U.S. It is important to select appropriate analytical tools to determine well yield and, as needed, hydraulic properties of fractured bedrock aquifers because many of the common techniques for quantifying aquifer properties have limitations when applied to fractured bedrock aquifers.

e. Defining Quality

At a minimum, the regulations require a description of total dissolved solids or specific conductance corrected to 25º C, pH, total iron and total manganese must be included in the baseline data collection. However, it is important to stress that these are the minimum regulatory data requirements and will not adequately characterize the overall baseline water quality. In order to determine impacts or potential for acid/toxic drainage, a thorough understanding of the premine water quality is necessary. Therefore, baseline water-quality data collection should include the parameters (see below) necessary to determine premining quality and water type and to evaluate analytical accuracy (e.g., cation/anion balance or TDS ratio).

Suggested Parameters for a Standard Chemical Analysis:

pH	Chloride
Acidity (hot)	Bicarbonate/Carbonate
Alkalinity	Nitrate/Nitrite
Specific Conductance	Sulfate
Total Dissolved Solids (TDS)	Sodium
Aluminum (total and dissolved)	Calcium
Iron (total and dissolved)	Magnesium
Manganese (total and dissolved)	Potassium

Ground-water quality is locally variable, resulting from chemical reactions with the minerals in the soil and the unsaturated and saturated zones. A comprehensive overview on the study and interpretation of the chemical characteristics of natural water can be found in Hem (1985). Ground-water quality impacts resulting from mining activities usually involve changes in the concentration of dissolved constituents rather than addition of new contaminants. Therefore, a well planned and comprehensive overburden/geology study plan is necessary in order to determine which chemical constituents could create problems either during mining or after mining is completed. This may require the analysis for additional parameters. For example, in the semiarid coal-producing regions of the western U.S. baseline water-quality parameter sets also include boron and selenium. In areas where AMD is a problem copper, nickel, zinc, cadmium, forms of dissolved iron and other trace metals may need to be analyzed. If CCBs are to be placed on the mine site, additional parameters related to the CCB chemistry may be needed.

f. Seasonal Characterization

The regulations require documentation of ground-water quality and quantity under seasonal flow conditions. The quality and quantity, or yield from wells and springs vary directly with the precipitation, infiltration and recharge to the water-bearing strata. Because seasonal phenomena are cyclic, one sample from a given site is not adequate for accurately describing complete seasonal flow conditions. The seasonal requirement may be satisfied by quality and quantity values from samples collected during actual calendar seasons (spring, summer, fall and winter). Another acceptable approach would be to collect data during times of seasonal recharge/discharge conditions – high, low and moderate water-table conditions associated with seasonal flow trends rather than arbitrary events. The intent of the regulation is to document a hydrologically-sound seasonal database to be used to establish the baseline and to be used for future comparisons for the PHC and for CHIA development.

Under certain conditions, historical hydrologic information to document seasonal variation may also be used. However, the representativeness of historical information should be judged on the basis of environmental changes that have occurred after the collection of the original data. For example, significant changes such as other mining activities, logging or highway construction might preclude the use of this data. If historical data are used extensively, a statement should be provided in the application that demonstrates why the information is still valid.

See Appendix D, Baseline Information, for a sample outline for collecting and organizing PHC baseline data.

4. Surface Water

Conducting a thorough baseline surface-water investigation requires following several key steps in order to collect the data needed to adequately describe the local surface-water hydrology. Available surface-water information must be reviewed, existing surface-water resources must be inventoried, baseline sampling sites must be appropriately located, and sufficient data collected to define the surface-water system and to determine baseline quantity and quality under seasonal conditions.

a. Regulatory Requirements

Minimum surface-water information requirements for surface and underground mining permit applications are stated in the regulations at 30 CFR 780.21(b) and 784.14(b). This information includes:

- Name, location, ownership, and description of all surface water bodies
- Location of any discharge into any surface water body in the proposed permit and adjacent areas
- Seasonal quality of surface water
- Seasonal quantity of surface water
- Surface-water usage

These are only minimum requirements. Additional information may be required depending upon the complexity of the hydrologic system and the concerns of the RA.

b. Resource Inventories and Available Information

Before any baseline surface-water sampling and analysis can be done, the location of all surface-water resources should be identified. Both a field inventory and a literature review to collect the surface-water information should be conducted. There are many different types of hydrologic information sources and data bases available. Although use of existing information is important, a field examination is also necessary for verification.

Minimum baseline surface-water information requires an inventory all water bodies, discharges, and withdrawals near the permit and adjacent areas, including location, ownership, quantity, seasonal usage rates, discharge rates, and specified measurements of quality (Curtis, undated). In addition, all registered water rights should be listed.

c. Site Selection

Properly planned selection of surface-water evaluation sites is important in order to collect the data necessary to accurately determine baseline conditions. Baseline sites should be distributed on and around the proposed operation and located both upstream and downstream from the proposed disturbed area. The upstream site should be located above the area of influence of the operation.

The number of surface-water sites selected for documenting baseline information should be related to the number of streams or impoundments which will receive point-source discharges from the proposed operation. Generally, all intermittent and perennial streams that are proposed to receive a discharge from the proposed operation should be included in the baseline sampling program. In the case of more than one proposed point-source discharge to a receiving stream, baseline sampling points should be established upstream and downstream from the uppermost and lowermost discharge points, respectively. The downstream site should be far enough downstream to yield a well-mixed sample of the different discharges but should not reflect the influence of any other mining operation. Consideration should be given to how the data will be used. For example, if one needs to know the quality of underground mine water, then a sample should be taken at the portal. However, if one needs to know how the underground mine affects the nearby stream, then a sample may be needed upstream and downstream of where the mine discharge enters the stream.

The applicant may select a baseline intermittent or ephemeral stream location. In these cases, baseline data collection may not be possible at all times because of no-flow conditions. Information for ephemeral streams, though possibly difficult to interpret, may still provide a source of data useful for estimating impacts on the streams.

d. Defining Quantity

At a minimum, baseline water-quantity descriptions should include seasonal flow rates. There are a number of techniques to measure stream flow. These techniques are described in a publication by the USGS (1982). There are regional differences in flow conditions. It is important to understand the factors contributing to these regional differences in order to describe surface-water quantity. Both surface and underground mining have the potential to disrupt and permanently alter the flow characteristics of the surface-water system by:

- Pumping and discharging to adjacent watersheds
- Increasing or decreasing storm hydrograph peaks
- Changing runoff characteristics due to groundcover changes
- Altering drainage patterns and drainage area size
- Changing stream baseflow conditions
- Collecting and storing water in temporary ponds or permanent impoundments

The description of the surface-water system should include:

- The drainage patterns and stream channel slopes
- Location and storage for impoundments and lakes
- The location and amount of water discharged to or withdrawn from any stream

Information on peak flows is a necessary component of baseflow information. The duration and frequency of sampling for all the baseline sites must be sufficient to demonstrate the seasonal variability of measured parameters. Additional information may be required, depending on the complexity of the hydrologic system related to other mining or impacts from other land uses and RA concerns.

Streamflow characterizations require several years of record to develop. Detailed USGS gauging station data are available from many locations. If a gauging station is not located in the proposed permit and adjacent areas, a set of instantaneous flow data may be correlated with coincident data from the nearest USGS station to interpolate and extrapolate on the limited baseline record. Regionalization techniques are discussed in Riggs (1973) and Searcy and Hardison (1960). Thus adequate baseline, peak and other discharges may be estimated from records at gauging stations or intermittent surface-water record stations located close to mining areas. Parameters like peak flow and baseflow are used to characterize seasonal baseline watershed and flow conditions. Seasonal water quality conditions also need to be determined.

f. Defining Quality

At a minimum, a description of total suspended solids, total dissolved solids or specific conductance corrected to 25° C, pH, total iron and total manganese must be included in the baseline data collection. However, it is important to stress that these are the minimum data requirements. In order to determine impacts or acid/toxic drainage, a thorough understanding of the premine water quality is necessary. Therefore, baseline water-quality data collection should include the parameters (See below) necessary to determine premine quality and water type and to evaluate analytical accuracy (i.e., cation/anion balance or TDS ratio).

Suggested Parameters for a Standard Chemical Analysis:

pH	Chloride
Acidity (hot)	Bicarbonate/Carbonate
Alkalinity	Nitrate/Nitrite
Specific Conductance	Sulfate
Total Dissolved Solids (TDS)	Calcium
Total Suspended Solids (TSS)	Sodium
Aluminum (total and dissolved)	Magnesium
Iron (total and dissolved)	Potassium
Manganese (total and dissolved)	

A comprehensive overview on the study and interpretation of the chemical characteristics of natural water can be found in Hem (1985). Surface-water quality impacts resulting from mining activities usually involve increases in the concentration of dissolved constituents rather than addition of new contaminants. This occurs primarily because of greater reactive surface areas in spoil material derived from the broken up overburden. When this ground water discharges to the surface through springs or seeps, it impacts the surface-water system. Therefore, the interconnection between the ground-water system and the surface-water system needs to be evaluated.

The need for additional parameters to adequately describe the surface water system should always be considered based on the types of users and resources present. For example, baseline data for areas where water is used for irrigation in the semiarid coal-producing regions of the Western U.S. would commonly include boron and selenium. Information on aquatic resources such as macroinvertebrates, benthics and fish may also need to be collected as part of the baseline.

g. Seasonal Characterization

The regulations require documentation of surface-water quality and quantity under seasonal flow conditions. Because seasonal phenomena are cyclic, one sample from a given site is not adequate for accurately describing complete seasonal flow conditions. The seasonal requirement may be satisfied by quality and quantity values from samples collected during actual calendar seasons (spring, summer, fall and winter). Another acceptable practice would be to collect during times of seasonal high and low flow conditions – high, low and moderate runoff and baseflow conditions associated with seasonal flow trends rather than arbitrary events. The intent of the regulation is to document a hydrologically sound seasonal database to be used to establish the baseline and to be used for future comparisons for the PHC and for CHIA development.

Under certain conditions, historical hydrologic information to document seasonal variation may also be used. However, the representativeness of baseline information should be judged on the basis of environmental changes that have occurred after the collection of the original data. For example, significant changes such as other mining activities, logging or highway construction might preclude the use of these data. If historical data are used extensively, a statement should be provided in the application that demonstrates why the information is still valid.

See Appendix D, Baseline Information, for a sample outline for collecting and organizing PHC baseline data.

C. Baseline Information For CHIA

Before a permit can be approved the RA must conduct an assessment of the cumulative hydrologic impacts (CHIA) of all anticipated mining on the hydrologic balance in the cumulative impact area (CIA) and must find that the proposed operation has been designed to prevent material damage to the hydrologic balance outside the permit area. CHIA preparation is an integrated process which embodies a specific application of hydrologic information management at each step of the process. A sample outline for the CHIA report is available in Appendix E. With proper enforcement of surface mining regulations, the hydrologic impacts of individual mining operations should be minimized. The hydrologic impacts that cannot be mitigated through implementation of the hydrologic reclamation plan may not be major when considered individually. However, when the impacts from existing mines, as well as from all anticipated mining within a specific area are considered, their additive effects may become major and create the potential for material damage to the hydrologic balance. The CHIA is intended to assure that such additive impacts will not be overlooked in the approval of individual permit applications.

Both the PHC and CHIA are predictive tools that evaluate the potential for adverse hydrologic impacts. The baseline data acquisition, as well as the subsequent operational monitoring, is largely aimed at providing information to accomplish these predictions.

Any major change in mining operations, such as the addition of a new area, a change in mining or reclamation methods, or the discovery of an unforeseen geologic or hydrologic condition necessitates a significant permit revision. This generally entails a reconfirmation of the accuracy of the PHC and CHIA findings, or a revision and updating of the findings.

At 30 CFR 780.21 (c) (1) the operator is required to identify and provide to the RA data for the CIA available from appropriate federal and state agencies. See Appendices A and B. Submission of these data are mandatory and will be used by the RA in preparing the CHIA.

In order to help expedite the permitting process, the operator may gather and submit the data not readily available from the federal and state agencies. Generally, it would be to the permit applicant's advantage, particularly with respect to time, to assist the RA by providing the necessary hydrologic and geologic information. However, it is the responsibility of the RA to verify the validity of these data.

To determine the type of hydrologic and geologic information needed for the CIA, the operator will have to work closely with the RA. The CIA, the anticipated mining, the information being submitted through other permits, and the type and amount of additional hydrologic and geologic information need to be determined. By working with the RA, the coal mine operator can facilitate and ensure the necessary hydrologic and geologic information is available.

The CHIA predicts the type and magnitude of impacts to the hydrologic system attributable to the proposed operation in conjunction with existing and anticipated mining. Thus, during the CHIA process the RA should:

- Define the area to be studied, the CIA
- Describe the baseline hydrologic system
- Identify hydrologic concerns

- Select material damage criteria
- Estimate the cumulative impacts of mining on the hydrologic balance
- Prepare a written material damage finding

This document on baseline data is concerned only with the first three items above. A sample outline for collecting and organizing CHIA baseline data is contained in Appendix E.

1. Delineating the CIA

The CIA is an area where impacts from the proposed operation, in combination with other anticipated operations may cause material damage. Anticipated mining includes, at a minimum, existing operations, proposed operations for which permit applications have been submitted to the RA, and operations required to meet diligent development requirements for leased Federal coal for which there is actual mine development information available.

When establishing a CIA, the RA should be aware that boundaries should be flexible and can be changed if analyses or new data reveal conditions or concerns not previously identified. In the interim, a "working" CIA may be delineated based on estimates or calculations of the down-gradient extent of measurable impacts to surface water or ground water. As the analysis progresses for the various parameters being evaluated, the need may arise for adjustment of the "working" CIA boundary. A sample procedure for delineating the CIA is provided in Appendix F.

The size and location of the CIA will depend on the surface- and ground-water system characteristics, the hydrologic resources of concern to the RA, and projected impacts from the operations included in the assessment. A ground-water CIA should extend from the up-gradient extent of impacts down-gradient to aquifer discharge points unless it can be demonstrated that measurable impacts do not extend that far. In some cases measurable ground-water impacts may extend down-gradient to surface-water bodies which receive ground water discharge.

Among other factors, two items generally of importance for ground-water CIAs are water-level drawdown areas and areas through which plumes of degraded water may migrate. Similarly, a surface-water CIA should extend from a downstream point at which all mining impacts can be cumulated, and upstream to either a watershed boundary or to a point at which upstream effects can be isolated from mining impacts, such as at a stream gauging station. This suggests that the CIA may require separate delineations for ground- and surface-water issues.

2. Define Baseline Hydrologic Conditions

The surface-water and ground-water systems should be described in sufficient detail to identify their significant characteristics and interactions. The description should focus on the hydrologic resources that may be affected by anticipated mining. This will enable the RA to focus the cumulative impact description and analysis on these same resources. Much of the data describing the hydrologic resources will be available in permit applications. However, areas outside permit boundaries may require additional data from other sources.

3. Identify Hydrologic Concerns

The RAs task in the CHIA is to estimate the magnitude and importance of changes to hydrologic resources as a result of mining. Lumb (1982) provides guidance and examples for determining the magnitude and significance of mining impacts. The hydrologic considerations differ greatly in the different coal regions of the U.S. primarily due to regional variations in rainfall, temperature, water use, topography, and geology. For example, typical hydrologic concerns in areas associated with the coal fields of the western U.S. may include:

- Reductions in the quantities of relatively scarce surface-water and ground-water resources which may be completely appropriated under state water rights laws. Available supplies may be reduced as a result of changes in surface runoff conditions or the lowering of ground-water levels. Beneficial changes can also occur, such as reduction of runoff peaks through increased infiltration, and increased stream baseflow through increased ground-water discharge.

- Increases in TDS or SAR in surface- or ground-water irrigation supplies which may cause critical crop production losses.

- Increases in the concentration of total suspended solids (TSS) which may cause destruction of aquatic habitat or the loss of reservoir storage capacity due to siltation.

- Changes in flow rates or suspended solids loads which can change the erosional balance of streams resulting in downcutting. In addition to increased sedimentation, erosional downcutting may lower adjacent water tables below plant-rooting depths.

- Changes in water quality which may critically affect some sites through increased concentrations of constituents such as boron, selenium, iron, or manganese.

Typical examples of hydrologic concerns in areas associated with coal mining in the eastern U.S. may include:

- Changes in the chemical composition of streamflow due to the addition of mine drainage (e.g., total iron, total manganese, sulfate, total dissolved solids and pH) that may cause adverse impacts to public supplies and aquatic organism populations

- Increases in the sediment load from the disturbed areas which may cause destruction of aquatic habitat in streams and ponds

- Changes affecting surface-water runoff which may add to the flood hazard of a watershed

- Disturbances of overburden due to mine excavation that may increase the availability of some chemical constituents that cause deleterious effects in water (e.g., total iron, manganese, aluminum, total dissolved solids, trace elements)

These are only typical hydrologic concerns and represent only a small number of possible impacts. At each site and within individual CIAs, the hydrologic considerations should be determined on the basis of water usage in the area, existing water-quality standards, and local hydrologic conditions.

Baseline information for the CIA may be required for identifying and describing all anticipated mining, ground-water and surface-water systems and for characterizing hydrologic concerns.

Geologic information of the following types could, in certain situations, be required for the CIA to help define potential impacts to ground-water systems off the permit area.

- Lineament maps prepared by an examination of aerial photographs– because of the significant effect of large-scale faults and fracture zones (reflected by lineaments) on local and regional ground water movement

- Mapping of alluvial stream deposits – because such deposits commonly contain significant quantities of ground water available for use and important also in maintaining the hydrologic balance of the area

- Structural geology – because the regional movement of ground water can be controlled by geologic structure including folding and fractures

Hydrologic baseline information of the following types could be required for the CIA.

- Streamflow information

- Water-quality information for ground and surface water

These types of information are commonly collected at USGS gauging and water-quality monitoring networks and are published in basic data and study area reports. In addition, basic data for individual stations is available at USGS web sites hot linked in Appendix A.

The examples cited above represent only a few of the possible types of geologic information that may be necessary for the CIA and how that information is useful.

D. Summary and Examples

The number of locations at which site-specific baseline data for geology, overburden, surface water and ground water needs to be collected depends on many variables. Rather than presenting and attempting to rationalize minimum or maximum numbers and locations for surface-water stations, boreholes for overburden data, ground-water observation wells and frequency and duration of water sampling, we have included summaries of baseline information for geology and hydrology as it exists in planned or actual permits. We refer to these summaries as regional examples of baseline data requirements. In this context, regional can refer to hydrologic issues as may exist in one region but not all regions of the country and for which precise kinds and amounts of data are needed to establish, for example, the potential for acid-mine drainage formation. Regional may also refer to differences in philosophy and technical approach to sampling and standards deemed acceptable for baseline geology and hydrology information from one state or region to another.

The three examples of baseline information collection from different regions of the country are presented in Appendices H, I, and J.