Handbook of Geologic and Hydrologic Data Requirements

For Preparation of the Probable Hydrologic Consequences
of Proposed Coal Mining and Reclamation Operations
in Louisiana

Louisiana Department of Natural Resources
Office of Conservation
Injection & Mining Division
Surface Mining Section

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Preface

The Louisiana Department of Natural Resources, Office of Conservation (LOC) has developed this guidebook to meet the needs of consistent data collection and analysis of information in order to comply with Louisiana law and LOC rules regulating the mining of coal.

The format and contents of this guidebook are intended to help address the geologic and hydrologic information requirements of the Louisiana Surface Mining Regulations (LSMR) §§2507-2513 in such a manner that a prediction of Probable Hydrologic Consequences (PHC) of coal mining and reclamation activities can be made as required in LSMR §2523. This handbook will also be useful in determining water monitoring needs during both mining and reclamation.

The first part of the handbook contains procedures for collecting and analyzing site-specific geologic data. The second part contains procedures for collecting and analyzing site-specific hydrologic data. The data will be used in predicting and evaluating the probable hydrologic consequences of proposed mining and reclamation operations. LOC will use the PHC as presented in the permit application, as well as other data, in the Cumulative Hydrologic Impact Assessment (CHIA) which is used in part to determine whether to issue or deny a permit application.

In developing this guidebook, LOC sought comments from the U.S. Department of the Interior, Office of Surface Mining Reclamation and Enforcement (OSMRE), Louisiana State University Agronomy Department, and the Louisiana coal industry.

Additional copies of this document may be obtained by contacting the Louisiana Department of Natural Resources, Office of Conservation, P.O. Box 94275, Baton Rouge, Louisiana, 70804.

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Introduction

The Louisiana Department of Natural Resources, Office of Conservation (LOC) recognizes a responsibility to provide guidance to a prospective permit applicant prior to the development of a surface coal mining application. It is assumed that a good deal of exploration will take place during this period. This guidance will allow for more cost-effective and accurate data collection. Clarifying the data requirements prior to collection will allow both the applicant and LOC to better study the area in question.

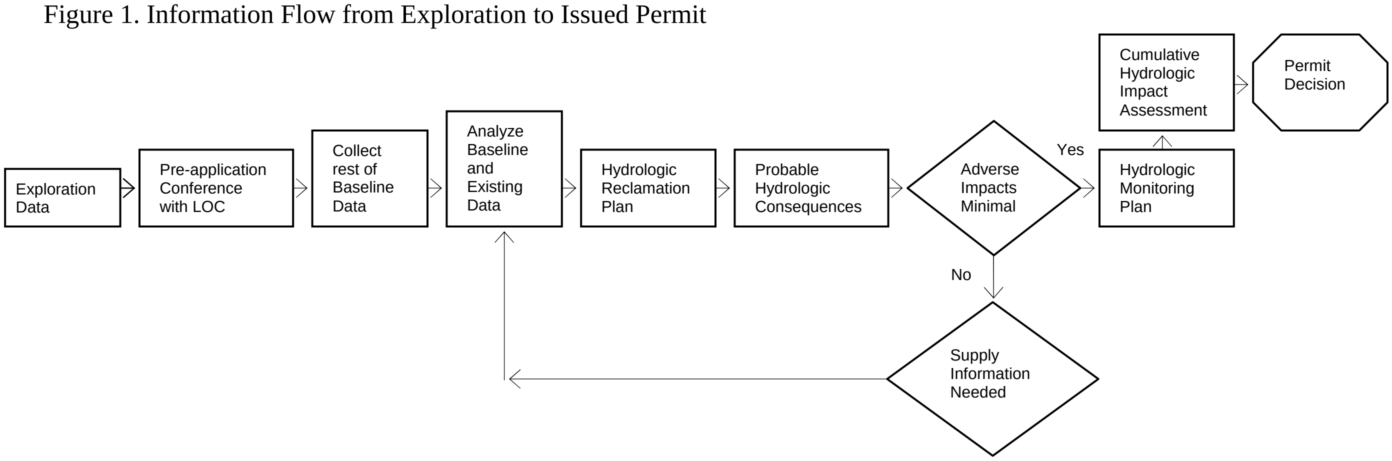
LOC will provide an opportunity for a pre-application conference to work with the applicant in selecting criteria deemed important in the development of the PHC determination. The applicant should bring exploration information and a map of the area (7.5 minute USGS quad sheets) to the conference. LOC has existing hydrologic, geologic and topographic information which will be used together with that which the applicant provides. A flow chart accompanying this introduction illustrates the process from exploration data to permit issuance.

The applicant must have identified the proposed disturbed area, the proposed permit area, the adjacent area, and have an understanding of the geology and hydrology of these areas.

The information used in the pre-application conference will not become public until application for the permit is actually made.

This guidebook is intended to assist a prospective mine operator in the preparation of a permit application. Adherence to the processes contained in this guidebook should provide a basis for making the probable hydrologic consequence determination. The permit application will be evaluated in accordance with the Louisiana Surface Mining and Reclamation Act (R.S. 30:901-932) and the Louisiana Surface Mining Regulations (LSMR), Statewide Order 29-0-1.

Figure 1. Information Flow from Exploration to Issued Permit



Study Area

For premining (baseline) hydrology definition and for water monitoring during both mining and reclamation the study area must include the permit area and the adjacent area. The adjacent area, by definition, is the area within which surface water and ground water may be adversely impacted by surface coal mining and reclamation operations.

The adjacent area on the upstream side should start at the watershed boundary or one mile upstream from the permit boundary, whichever is closer. On the downstream side, the adjacent area should extend to the point of confluence of the affected stream with the stream of next higher order or to a point one mile downstream from the permit boundary, whichever is closer. If an affected stream skirts the permit area, the extent of the adjacent area should be up to the watershed boundary of the stream or one mile, whichever is closer.

For surface-water hydrology, the study area should consist of the permit and adjacent areas as defined above for all streams passing through or skirting the affected area. Generally, ground water follows topography and, therefore, the study area for ground water would be the same as that for surface water. However, if the continuity of ground water is established beyond the surface-water study area by drilling records or otherwise, the ground-water study area should be determined on the basis of continuity of the ground water.

The study area should be delineated with premining as well as post-mining drainage configurations on one map. All wells and surface-water monitoring stations should also be shown on the same map.

Maps

Maps should illustrate information obtained during a field reconnaissance of the permit and adjacent areas. All "point" locations, such as drill holes, are to be located by surveyor's coordinates (i.e., a distance north and a distance east of a particular point to the southwest of the area) and shown on a 1:4800 scale, or other approved scale, map. Information presented on these maps must include:

1. Delineation of the permit and adjacent areas.
2. Location and names of streams classified as to streamflow characteristics (ephemeral, intermittent or perennial) within the permit and adjacent areas.
3. Elevations and locations of streamflow gauging sites used to gather data on surface-water quantity and quality.
4. Elevations and locations of test borings and core samplings.
5. Elevations and locations of water wells and springs used to gather data on ground-water quantity and quality.
6. Elevations, locations, and depth of water wells in the permit and adjacent areas.
7. Location and extent of ground water within the permit and adjacent areas; at a minimum, this should include hydraulic gradient and flow direction for each identified water-bearing stratum, including water table and perched water zones.
8. Locations of surface-water bodies or features within the permit and adjacent areas that constitute a water resource which may be impacted, such as lakes, ponds, springs, constructed or natural drains, irrigation ditches, water supply intakes, wetlands and swamps; and features which may cause an impact, such as known or anticipated point-source discharges, and other sources of pollution to streams.
9. Location and extent of existing or previously mined areas within the permit area.
10. Location and scaled outlines of existing areas of spoil, coal waste and non-coal waste disposal, dams, embankments, other impoundments, and water treatment facilities within the permit area.

Part One

Procedures for Collecting and Analyzing Overburden Data and Evaluating Geologic Information

A statement detailing the results of test borings or core samplings is required as part of the operator's permit application, LSMR §2509.B.2. Data and other information that comprise this statement apply to the permit area and involve a description of specific physical and chemical properties of the overburden strata, coal to be mined, and the stratum immediately below the lowest coal seam to be mined. The Louisiana Office of Conservation (LOC) may require that test borings or core samplings be collected and analyzed to greater depths within the proposed permit area or in areas outside the proposed permit area that would be impacted by mining. These provisions may be waived on a specific application by written determination by LOC that such requirements are unnecessary because equivalent data are accessible to LOC as prescribed by LSMR §2509.D. The primary purpose for collecting the data is to provide information about potentially acid- or toxic-forming or alkalinity-producing materials which could adversely affect the hydrologic balance and the potential for successful revegetation. With this information, appropriate procedures can be developed to mitigate environmental consequences during and after coal mining and reclamation operations.

This section describes approaches and procedures for providing information to enable the applicant to plan both mining and reclamation in an optimum manner and to enable LOC to properly evaluate the potential impacts of mining and reclamation operations on the hydrologic balance.

The data gathering process should be completed as the first step in providing the premining hydrology and geology information required in the permit application. The extent of the ground-water baseline data collection program (location, number of sites, and sampling frequency) in many areas can be based upon geologic/hydrologic conditions encountered during this phase of the work.

A. Geologic Description

LSMR §§100.5(6,7,34) define three areas required to be described to obtain a permit to mine coal. These areal definitions are as follows:

Adjacent area. Land located outside the affected area, permit area, or mine plan area, depending on the context in which "adjacent area" is used, where air, surface water or ground water, fish, wildlife, vegetation, or resources protected by the Act may be adversely impacted by surface coal mining and reclamation operations.

Affected area. Any land or water surface which is used to facilitate, or is physically altered by, surface coal mining and reclamation operations. The affected area includes: the disturbed area; any area upon which surface coal mining and reclamation operations are conducted; any adjacent lands the use of which is incidental to surface coal mining and reclamation operations; all areas covered by new or existing roads used to gain access to, or for hauling coal to or from, surface coal mining and reclamation operations; any area covered by surface excavations, workings, impoundments, dams, ventilation shafts, entryways, refuse banks, dumps, stockpiles, overburden piles, spoil banks, culm banks, tailings, holes or depressions, repair areas, storage areas, or shipping areas; any areas upon which are sited structures, facilities, or other property material on the surface resulting from, or incident to, surface coal mining and reclamation operations; and the area located above underground workings.

Cumulative impact area. The area, including the permit area, within which impacts resulting from the proposed operation may interact with the impacts of all anticipated mining on surface- and ground-water systems. Anticipated mining shall include, at a minimum, the entire projected lives through bond release of: (a) the proposed operation, (b) all existing operations, (c) any operation for which a permit application has been submitted to LOC, and (d) all operations required to meet diligent development requirements for leased federal coal for which there is actual mine development information available.

The geologic information should include 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. Aquifer is defined as a zone, stratum, or group of strata that can store and transmit water in sufficient quantities for a specific use. This definition has been interpreted by the courts to mean any legitimate use. It has no volume or dimension as a lower limit, but is defined solely on use. This information will usually be available through referenced material. Also the results of test borings or core samples, information obtained during installation of any observation wells, and information from existing geologic maps may be used to provide this geologic description. Information to be provided on maps, and in narrative form, includes a description of overburden lithology, thickness, lateral variation and local geologic structure. In addition, at least two geologic cross-sections, preferably taken at right angles to each other, should be provided and their locations shown on a map. If the coal to be mined outcrops in the permit or adjacent areas, the outcrop should be shown in plan view on an appropriate base map. Aquifers within the permit and adjacent areas, or potential aquifers identified by the ground-water investigation during this study, should be described in terms of depth below the land surface and horizontal extent within the permit and adjacent areas.

B. Collection and Analysis of Overburden Data

1. Pre-Application Conference

A pre-application conference between the applicant and LOC is strongly suggested for the purpose of deciding upon such matters as the appropriate number and location of drill holes, substitution of drill cuttings or highwall sampling for continuous coring (where justified), possible locations for water monitoring wells, possible acid- or toxic-forming materials, etc. The applicant should make arrangements for this conference as early in the development of an application as is practical, possibly even before the exploration drilling is completed. LOC may require additional sample holes or monitoring wells.

2. Number of Test Boreholes and Locations

Concurrence from LOC is needed as to the borehole locations for the purpose of characterizing the site geology. Boreholes should be taken at a minimum of 1,000 ft. centers down the long axis of the mining block. Additional boreholes may be required when evaluating permit areas where the existing data indicate that a high variability in the lithology or structure exists or where acid- or toxic-forming materials are present or suspected. Knowledge of existing conditions and the field log of the first test boring should be used by applicants in consultation with LOC in determining the number and locations of additional boreholes.

It may be possible to complete boreholes or coreholes of adequate diameter for use as ground-water observation wells if site selection is carefully done to accomplish both purposes.

Although core drilling is the recommended procedure, this requirement may be waived by LOC, with respect to a specific application, by a written determination that this requirement is unnecessary because equivalent data are available to LOC. Also, at the discretion of LOC, the requirement for continuous core drilling may be satisfied by the inclusion of such data as are available from coal exploration cores, drill cuttings, highwall sampling, or hollow stem auger drilling with soil sampling.

Coal exploration cores, if obtained within the permit area, may be substituted for the required drilling, if the following information and materials are available: (1) location of drill site, (2) elevation of ground surface at drill site, (3) depth of any ground water encountered, and (4) a continuous core from the surface down to and including the first stratum beneath the coal to be mined.

Drill cuttings from test borings may be substituted for the preferred core samples. A minimum of one sample should be taken from each major lithologic unit from the base of topsoil to a depth of one foot below the lowest coal seam to be mined. Any layer thinner than five inches need not be separately sampled. The samples collected from each stratum should be a composite sample representing an interval not to exceed ten feet in length. Any individual stratum greater than five inches in thickness and less than ten feet in thickness should have one composite sample taken. (Note: If drill cuttings are allowed to be substituted for core samples, extreme care must be used in collecting and evaluating the stratigraphic information based on the cuttings.)

3. Data Collection

a. Geologic information

The drilling site must be shown on the required 1:4800 scale topographic map and located with respect to its section, township, and range, and elevation above mean sea level. This will allow cross reference to maps developed for the PHC determination. The elevation should be determined by altitude survey described to mean sea level or, if approved by LOC, from an existing topographic map that has a contour interval of no greater than 5 feet.

A geologist or other qualified professional specialist experienced in preparing field logs of test drilling operations should perform the sampling. Information should be provided for each stratum down to and including the first stratum beneath the coal to be mined. Stratum is defined as a section of the geologic formation that consists of an essentially homogeneous sedimentary material of any thickness, which is usually separated from the other upper or lower layers by a discrete visual change in the character of the material.

Geologic logs should be provided for each sample hole. The geohydrologic descriptions should include such details as (1) depth intervals, (2) rock type, (3) grain size, (4) color, (5) accessory minerals, (6) water-bearing zones, and (7) permeability and porosity. The characteristics of any water expelled from the test hole, e.g., color and odor, should be noted.

In addition, horizons that are observed in the field to contain pyrite or marcasite, gypsum or anhydrite, calcite, or potentially toxic material should be identified and described.

b. Sampling intervals

Major lithologic units should be sampled in about 5-foot intervals and composited into about 10-foot increments. All major lithologic units less than 10 feet in thickness should be sampled and not composited further. Sampling should be initiated at the surface and continue downward to include the next stratum below the coal to be mined, not to exceed 10 feet below the base of the coal to be mined.

c. Compositing samples for laboratory analysis

Samples should be composited to adequately represent each of the strata encountered within each drillhole. This process should not involve composites prepared from increments greater than 10 feet in length. When more than one hole is sampled, there must not be compositing of cores between holes.

d. Laboratory samples

i Physical properties. A specific test for texture analysis should be made on each stratum of the overburden.

ii. Chemical properties. Determination of chemical properties of both the overburden materials and of the coal, to identify materials which are potentially acidic or toxic to the environment, are required by state rules.

Certain analyses, as identified below, are required from each stratum of the overburden, including coal rider seams too thin to mine and the stratum immediately beneath the coal to be mined.

(a) Routine analyses (overburden)

(i) Sample preparation: Samples should be prepared so as to obtain as homogeneous a state as possible in that interval; the preparation should include selection of a representative portion of a given stratum, (see previous discussion regarding sampling intervals and compositing of samples).

Coal operators are strongly advised to require the analytical laboratory selected to retain sample splits. Thus, if for any reason the analyses are unsatisfactory, retention of sample splits will allow an operator to avoid the delay and expense of redrilling.

(ii) Determination of pH: Using a representative subsample of the sieved (No.60 mesh) material, prepare a paste sample using distilled water. The resulting saturated paste should stand at least 1 hour before the hydrogen ion activity (pH) is measured, in accordance with standard methodology, e.g., U.S.D.A Agriculture Handbook 60, 1954, Method 21, pp.84 and 102.

(iii) Acid-base accounting: Acid-base accounting, a procedure by which acid-forming materials can be evaluated, consists of three measurements, these being (1) pyritic sulphur, (2) exchangeable acidity, and (3) neutralization potential. Thus the accounting method balances the maximum potential acidity against total neutralizers present in the overburden.

Calculations of both the potential acidity (1 plus 2 above) and neutralization are evaluated so as to equate the three measurements on a common comparative basis. Thus, the resulting values, expressed as calcium carbonate equivalent, (Appendix A), are compared so as to compute a net acid-producing (calcium carbonate deficiency) or neutralizing (calcium carbonate surplus) potential.

Generally, the total amount of pyritic sulphur is converted to tons of calcium carbonate equivalent per 1000 tons of material by multiplying the percent of sulphur by a factor of 31.25. Thus, a concentration of 0.1% sulphur (all assumed present as pyritic sulphur), yields an amount of sulphuric acid that would require 3.125 tons of calcium carbonate to neutralize 1000 tons (acre-furrow slice) of material.

From the acid-base accounting results, potentially toxic materials are defined as any material that has a net potential deficiency of 5 tons or more of calcium carbonate equivalent per 1000 tons of material.

Regardless of the acid-base accounting results, materials which have pH values of less than 4.0 are defined as acid/toxic.

Pyritic sulphur (acid potential). Several methods are available for the analysis of pyrite, with two of the more commonly used procedures being (1) determination of total sulphur content using the LECO sulphur analyzer, or (2) determination of potential acidity, based upon an estimation of total pyritic iron. See Sobek, et al., (1978).

Using a representative subsample of the sieved (No.60 mesh) material, the acid potential may be determined using one of the methods described above.

Neutralization potential. Several methods are available for determining the quantity of bases present in overburden materials which would serve to neutralize sulphuric acid formed by the oxidation of pyrite. The most widely used is the HCl titration outlined by Sobek, et al., (1978).

This analysis should be performed on a representative subsample of the sieved (No.60 mesh) material.

Exchangeable acidity: The suggested method is the 1N KCl extraction outlined by Thomas (1982), method 9-4.2.

(iv) Elemental analyses: Concurrence of LOC is necessary early in the permit application preparation process regarding the elements which will be required for analysis. LOC, in conference with the applicant, will determine these elements based upon existing data.

The solubility and potential movement of elements in overburden and soils is strongly dependent upon pH. At acidic pH values of about 5.5 or lower, many trace elements such as aluminum, copper, manganese, zinc, and lead become soluble, and in turn, mobile. Thus, these elements could be released into surface-water or ground-water systems, and if present within a given root zone, could be absorbed and translocated by plant species. Conversely, at strongly alkaline pH levels of 8.5 or higher, other elements, such as molybdenum, could be solubilized. Also, under these alkaline conditions, excessive concentrations of sodium, selenium, boron, etc. may be present and released from overburden materials.

If the paste pH of a sample of a given overburden stratum is 5.5 or lower, then the water extract, filtered from the saturated paste, should be analyzed for iron and aluminum. Either Atomic Absorption or Inductively Coupled Argon Plasma (ICP) spectrophotometry could be used for all of the above metals.

Should the pH values for the various strata analyzed be greater than 5.5, the strata with the **lowest** pH value should be analyzed as follows: (1) prepare a saturated paste of each of the stratum using distilled water, maintained at a pH of 5.0 with acetic acid; (2) allow the saturated paste to stand at least 1 hour; and (3) filter and analyze the extract for iron, aluminum, manganese, sulfate and lead as described previously. This procedure is recommended so that adequate site-specific elemental baseline data are collected. This procedure should be continued until adequate data are available (as determined by LOC) to describe the potential presence of various elements in the overburden.

In the event that alkaline conditions (pH of 8.5 or greater) are found from analyzing any of the strata, the analytical scheme should include sodium, calcium, boron, molybdenum, selenium and magnesium, together with a calculated sodium adsorption ratio (SAR) value.

(b) Coal analyses

Sobek, et al., (1978) should be followed to determine total sulphur and pyritic sulphur content (include combined sulfides of pyrite and marcasite).

C. Written Justification for Waiver of Statement of Analysis of Test Borings or Core Samplings.

The preceding requirements will not be waived unless LOC determines that other equivalent data are available. Equivalent data may include physical and chemical analyses (conducted with acceptable methods) on the same stratigraphic sequence at a site within the adjacent area. However, the waiver will not be granted unless equivalent information is sufficient to determine if adequate reclamation is attainable to protect the hydrologic balance of the permit and adjacent areas.

Part Two

Procedures for Collecting and Analyzing Site-Specific Hydrologic Data

This portion of the guidebook provides clarification of the requirements necessary for the permit application to provide a thorough description of potential impacts on the hydrologic system. Although only the hydrologic data needed for the permit application are addressed, these premining (baseline) data provide the basis for other hydrologic requirements, including the requirement that hydrologic monitoring be conducted both during and after the mining and reclamation operations. Methods and techniques that may be used to collect, analyze, and interpret hydrologic data include not only those discussed in this handbook, but also any other comparable methods approved in advance by LOC.

The determination of the probable hydrologic consequences (PHC) of proposed coal surface mining and reclamation operations is required to be a part of the permit application in accordance with LSMR §2523. The PHC determination applies to the hydrology of the permit and adjacent areas during both the mining and the reclamation phases of the operation. The determination includes estimation of the dissolved (chemical) as well as the suspended solids (sediment) characteristics of surface- and groundwater systems under seasonal flow conditions. The components of the PHC determination include: (1) a description of baseline hydrologic conditions, and (2) a prediction of the effects on these baseline conditions in the permit and adjacent areas resulting from the proposed surface mining and reclamation operations.

The purpose of the PHC determination is to insure that the mining and reclamation plan is developed to minimize impacts to the hydrologic balance. Thus, site-specific geologic and hydrologic data, obtained within the permit and adjacent areas, are needed in order to establish a baseline upon which to evaluate adverse impacts to the hydrologic system as a result of the proposed operation. Also, by monitoring selected surface- and ground-water parameters during both the mining and reclamation phases, and using the same procedures and analytical methodologies as used for the baseline work, an operator and/or LOC can then evaluate changes that are occurring as a result of the operation. The actual and predicted changes can then be compared and the validity of the PHC determination evaluated for inclusion in future permit applications proposed in the same geologic and hydrologic setting (Figure 1). In addition, the PHC determination, together with appropriate data from the cumulative impact area, is necessary to enable LOC to make a Cumulative Hydrologic Impact Assessment (CHIA) of all anticipated mining in the cumulative impact area, particularly on water availability (LSMR §2525).

Figure 1 illustrates the relationship of the PHC determination to other elements of the permitting process. The CHIA would enter into individual PHC determinations only if the CHIA identified material damage within the cumulative impact area (CIA) necessitating modifications in mining and reclamation activities within that area. LOC would deny a permit on the basis of the CHIA only if the amount of damage exceeded material damage criteria within the CIA as established by LOC.

This handbook is intended as a general description of approaches and procedures for collecting and analyzing data needed for the PHC determination. In practice, data collection and analysis should be tailored to reflect the characteristics bf the particular permit area, adjacent area, and the data that are currently available. More intensive monitoring may be needed where water resource problems could be critical. The objectives of the hydrologic analysis presented in this handbook are twofold: (1) define the existing hydrologic system in the permit and surrounding areas through a minimum of 12 consecutive months of hydrologic data collection, and (2) estimate, quantitatively and qualitatively, the changes in the hydrologic system that can be expected as a result of the mining and reclamation operations.

A. Baseline Hydrologic Data and Duration of Data Collection

Baseline data for specific sites are necessary to describe seasonal surface- and ground-water variability and also to establish the basis for the hydrologic predictions. The baseline data are also required to identify site conditions that may necessitate special mitigative measures to be taken during the mining and reclamation process. After reclamation, the baseline data can be compared with post-mining data to demonstrate the effectiveness of reclamation measures and to help evaluate the prediction of probable hydrologic consequences (PHC). The amount of the new data that must be collected depends upon the reliability and applicability of existing data. Use should be made of existing data supplemented with the necessary new data. The minimum duration of basic data collection for specific parameters listed in this handbook is 12 consecutive months.

B. Surface Water

1. Baseline Data

a. Surface-water inventory

Water availability must be determined and assessed. An inventory of surface-water use in the permit and adjacent areas should be conducted by contacting local property owners and state or federal agencies. This inventory must include ponds, their source of water, location, size, and elevation.

b. Streamflow gauging

Measurements of surface-water quantity and quality must be made on selected streams in the permit and adjacent areas as identified during the pre-application conference. Because water quality varies significantly with discharge, discharge must be measured (gauged) concurrently with all water-quality sampling so that these variations can be defined.

i. Streamflow gauging site network. Streamflow gauging sites should be established on the selected streams, both upstream and downstream of the proposed areas to be disturbed within the permit area. In general, downstream gauging sites should be located as close as possible to proposed areas of disturbance while at the same time being far enough downstream to include all disturbed areas within the basin. Gauging larger streams which only skirt the permit area should be avoided. Such streams will very likely be affected by other activities within their basins such as other mining, farming, etc. As a result, streamflow information collected on such streams probably will not reflect site-specific hydrologic conditions.

ii. Streamflow measurements. A streamflow gauge is an installation on a stream with a defined relationship between stage (water level) and discharge and, as such, provides estimates of discharge via stage readings. Streamflow gauges must be established at all surface-water measurement sites to collect seasonal water quantity and quality information. In practice, this means installation of weirs or measuring flumes on small streams, or definition of the critical stage-discharge relations (via instrument surveys of channel geometry, or concurrent stage and current meter discharge measurements of stable channel sections) on larger streams.

c. Surface-water sampling

Streamflow quality parameters should be measured over the range of discharges experienced at the streamflow gauging sites to evaluate seasonal variations in the surface-water regime. Peak or flood flow, low flow, and median or average flow conditions for the period of record should be measured and described at each streamflow gauging site. Concurrently with discharge determinations, water quality sampling should be done to evaluate not only seasonal water quality variations, but also to define variations in water quality with discharge. Sampling of impounded water in selected ponds and lakes within the permit and adjacent areas should also be done, as determined during the pre-application conference.

i. Seasonal flows. Seasonal flows are characterized by site-specific peak flow, average flow, and low flow data collected during the study.

(a) Peak or flood flows. The effect of mining may alter peak flows. Increased peak flows can pose hazards to property and human life. In addition, changes in peak flow characteristics can affect downstream channel morphology, water quality, and aquatic life. Peak flows in Louisiana usually occur during the spring.

Peak flows for at least two storms during this period should be determined at each streamflow gauging site. These flows may be determined by staff gauge readings if the peaks do not exceed measuring device (flume or weir) capacity. Otherwise, peak flows may be determined by indirect methods such as slope area, culvert computation, contracted opening, or other appropriate method.

(b) Low flows. Low flow is normally coincident with base flow which derives primarily from ground-water discharge to streams. Low flows generally have higher concentrations of dissolved solids due to limited dilution from better quality surface-water runoff. Lowest flows in Louisiana usually occur during late summer and fall. Low flow information should be collected monthly at streamflow gauging sites; documentation should be included for no-flow situations. An appropriate method of measuring discharge during very low flow conditions involves measuring the time necessary for a container of known volume to fill. Such measurements can be used to verify the stage-discharge rating at a gauge. Low flow measurements should be made during dry weather.

(c) Average flows. Moderate or average flows should be measured and sampled at each site. Moderate flows in Louisiana usually occur during the winter.

ii. Chemical water quality. Base or low flow periods are generally times of highest dissolved solids concentrations, whereas high or flood flow periods are generally times of highest suspended solids concentrations. Potential changes in water quality during all such seasonal flow conditions are important considerations in assessing the suitability of a mining and reclamation plan. The variation in water quality should be measured over the entire range of discharges experienced at each streamflow gauging site. In practice this means that water quality measurements should be made concurrently with all discharge measurements.

The pre-application conference will allow the applicant to seek approval from LOC to narrow the chemical constituents to be monitored (*Appendix A - Monthly Surface Water Test Report*). The applicant should be able to justify with available data why certain chemical constituents need not be monitored.

iii. Onsite erosion and sediment Two approaches for erosion and sediment prediction and measurement may be used. One prediction method will allow an estimate of the average annual onsite erosion rate, and the other prediction method will allow an estimate of the stream sediment loads resulting from a selected individual storm. These two evaluations use the prediction equations described later in this Section. It is permissible to use the Universal Soil Loss Equation (USLE).

Onsite erosion before mining should be evaluated for two storm events. These two storms should be the same two storms during which the peak flows are determined. Suspended solid samples should also be collected for these storms at the surface-water monitoring sites. Runoff volume, discharge peaks, and sediment loads should all be estimated for each of the two storms. Onsite erosion rates can be predicted for the two storms using the modified Universal Soil Loss Equation (USLE). The equation's LS factor for the watershed should be determined using the referenced technique. The K and T factors are described by the Soil Conservation Service. These values can be obtained from the parish field office of NRCS.

After the onsite erosion is determined, it should be compared with the suspended solids data to see whether a relationship can be demonstrated and the USLE parameter values validated. Data for the average annual erosion rate should then be developed for the same site for which the individual storm erosion estimates were made. There are several approaches to predicting average annual on-site erosion. The USLE procedures were originally developed for agricultural use. A modification of the USLE has been developed for nonagricultural land use. Additional coefficient modifications for forest land management use were made by the U.S. Forest Service. Before these modified equations are used, the appropriate State or Federal forestry agency should be contacted to obtain a copy of the appropriate guidelines.

An alternative approach to evaluating average annual onsite erosion that utilizes the USLE, but without the complex measurements, is described by the NRCS. Once the estimates of the parameters in the USLE have been validated for the premining conditions, certain of these parameters can be estimated for future conditions, and predictions can be made. If these results are to be translated to other locations, a sediment delivery ratio will have to be considered. This approach to sediment delivery must be used with caution because adjustments must be made for different stream locations, changes in terrain due to mining, and the destruction of ground cover between the minesite and the stream.

When other state-of-the-art techniques for estimating erosion and sedimentation become more generally accepted, their use should be considered.

2. Prediction of Probable Hydrologic Consequences

The probable hydrologic consequences (PHC) of mining, as pertaining to the permit and adjacent areas, must be estimated and submitted with the application for a mining permit. The applicant should predict and substantiate his predictions of the consequences of both the mining and reclamation phases of the operation on the existing flow regime, including stream channel stability and, in particular, the peak flow, low flow, sediment, and chemical quality characteristics of affected streams.

LOC will provide reference sources of available data which may be used at the office in conjunction with site-specific data collected by the applicant during the baseline hydrology study in making the PHC determination. Narrative descriptions of the anticipated effects of mining on surface-water quantity and quality must be provided including quantified estimates of these effects.

In addition to the regulated parameters (iron and manganese), emphasis should be given to the indicator parameter aluminum, as well as any other critical parameters identified during the pre-application conference or through monitoring. Water quality constituents identified as having unusually high concentrations should be explained in the determination.

Quantitative estimates of the effects of mining and reclamation on seasonal discharge characteristics (high, median, and low flows) should be made for each streamflow gauging site. These estimates should be based on factors such as the amount of disturbance proposed in each basin in relation to total basin area, changes in runoff resulting from mining disturbances (generally increases), interception of flows by diversions and ponds (generally decreases), and altered basin runoff characteristics once reclamation is completed.

For instance, sedimentation ponds are to be designed to contain or treat the 10-year, 24-hour storm runoff. Therefore, during mining, runoff and sediment at basin outfalls (streamflow gauging sites) would be reduced in proportion to the percentage of the basin up-gradient from ponds for the 10-year recurrence interval and smaller storms. For reclamation, proposed post-mining basin runoff characteristics (vegetative cover, slopes, infiltration rates, etc.) should be compared to runoff characteristics of the undisturbed premining basin to estimate changes in seasonal discharge quality and sediment characteristics at basin outfalls.

Using the data collected during the 12-month baseline hydrologic study in conjunction with information on relative parameter concentrations upstream and downstream from mining, the permit applicant should make quantitative estimates of changes to be expected in parameter concentrations resulting from proposed mining and reclamation operations.

If possible, site-specific regression equations relating critical parameter concentrations to discharge, and/or specific conductance, should be developed for each streamflow gauging site. These equations will help describe variations in baseline hydrology and, hence, should aid in quantifying projections of changes to be expected with mining and reclamation.

In summary, the objective of the surface water part of the PHC determination is to quantify the projected effects of mining and reclamation on both surface-water quantity and quality. Available information and references should be used in conjunction with site-specific information from the 12-month baseline hydrologic study and simple mathematical models (e.g., linear regression equations), to develop a sufficient understanding and description of existing permit and adjacent area hydrology so that reliable estimates of the changes in surface-water quantity and quality resulting from mining and reclamation can be made.

The results of the PHC determination should be used in reevaluating the adequacy of the proposed mining and reclamation plan. Modification of the plan may be necessary to mitigate potentially adverse impacts identified in the initial PHC determination. The final PHC determination would reflect reduced impacts resulting from the modified mining and reclamation plan, thus minimizing the impact of the proposed mining operation on the area's hydrologic balance.

C. Ground Water

1. Baseline Data

a. Ground-water inventory

An inventory of ground-water wells, springs, and their usage must be made for the permit and adjacent area by contacting the appropriate local, state, or federal agencies and local residents within the permit and adjacent areas unless it can be shown that they are hydrologically isolated from the area to be affected by mining. This can be discussed at the pre-application conference. During a ground-water inventory, as much of the following information as is possible should be collected from each well: (a) depth of well; (b) diameter of well; (c) depth of casing, and location of perforated or screened intervals; (d) date drilled; (e) use of water; (f) static water level; (g) yield of well; (h) formation name or rock type of the aquifer; (i) location of water yielding zones; j) land surface elevation referenced to mean sea level at well site; (k) water quality; (1) type of water treatment, if applicable; (m) estimated daily amount of water used; and (n) permission to use the well for monitoring purposes or to test for hydraulic characteristics.

b. Ground-water information sites

Ground-water information or monitoring sites may consist of a combination of observation wells (appropriate existing wells or wells drilled to monitor ground-water conditions) and existing springs. Monitoring sites must be located in the permit area as well as up-gradient and down-gradient in the adjacent area. A sufficient number of ground-water monitoring sites must be specified by the applicant for monitoring of quality and water levels, based upon the site-specific conditions. It may be necessary to complete and maintain observation wells in coal seams where these seams are known to bear water.

The purpose of ground-water monitoring in a permit area is two-fold: (1) to determine the quantity and quality of ground water flowing into the disturbed mine plan area and, (2) to determine the quantity and quality of the ground water flowing out of the disturbed mine plan area.

The ground-water monitoring network must accomplish these objectives. If field review of a permit application shows that a particular well does not or cannot, due to errors of placement, perform this function, LOC will, during its review, inform the applicant that his program is deficient for lack of ground-water monitoring, and that review has been suspended until the problem is resolved.

Ground-water monitoring may not be required by LOC if the substantiation of all of the following can be provided to the satisfaction of LOC staff: (a) the ground water is not withdrawn for use; (b) previous mining in the vicinity has not caused discernible impact to the ground-water quality or supplies; (c) the ground water is not an important resource and is not an important part of the hydrologic system; and (d) no hydraulic connection exists between the proposed disturbed area and underlying aquifers.

Wells must be completed in only one aquifer. However, this does not preclude the use of nested piezometers. A diagram showing actual well completion for each well should be provided. When possible, the wells should be located so that they can be used both for mining and post-mining monitoring.

When observation wells are installed, geohydrologic logs should be made by a professional experienced in geohydrologic work. The logs should identify the lithology and the water bearing zones, and provide the information described earlier under "Ground-water Inventory" and "Geologic Description". This information will be useful in providing a description of the general geology of the site.

References contain regional ground-water information.

c. Ground-water parameters and sampling frequency.

i. Water level elevations. Water levels should be measured in all observation wells at least once each month. Measurements should be made using standard techniques. Results should be reported to the nearest tenth of a foot and related to mean sea level.

ii. Field water quality. During the 12-month baseline data collection period, samples of ground water should be collected and analyzed for those quality and quantity parameters described below. Observation wells should be pumped or bailed until two or three casing volumes of water have been removed so that a representative sample of aquifer water can be obtained. If the well does not recharge rapidly, the well should be allowed to recharge and a water sample should be taken as soon as possible and so noted on the report form.

The following parameters should be determined in the field: (a) temperature, in degrees Celsius; (b) pH, in standard units; (c) specific electrical conductance, in micromhos per centimeter at 25^0C.

iii. Laboratory determination of water quality.

(a) Monthly samples should be collected for laboratory analysis of those parameters contained in the Monthly Ground Water Test Report, (Appendix B). The results should be expressed in milligrams per liter.

(b) The water quality samples should be analyzed in the laboratory for the major inorganic constituents identified during the pre-application conference. If any water quality constituents meet or exceed federal or state water quality limits when first sampled, then a sample should be collected for laboratory analysis for that constituent on a monthly basis through the sampling period. Results should be expressed as milligrams per liter (mg/L).

(c) Further, if it is suspected that mining will occur in close proximity to active domestic wells, LOC may require analyses of water samples from these wells, with the owner's approval.

iv. Aquifer characteristics. Aquifer testing should consist of a standard pump test, slug test, bailer test, or any other method approved by LOC. The water level data should be analyzed according to standard techniques to yield values of transmissivity and hydraulic conductivity for permeability determinations, and pump test for determination of storage coefficients.

v. Analysis of observed data. The observed data are to be tabulated and described. Aquifers should be classified according to the presence of unconfined (water table) or confined (artesian) conditions or perched conditions.

Potentiometric maps depicting ground-water levels should be prepared for the permit and adjacent areas. These maps should be prepared for each aquifer using observed water level information.

The maps will form the basis for describing the recharge and discharge areas for the aquifers. If more than one aquifer is present, ground-water level relationships and vertical movement between aquifers should be described. The observed water level data should be correlated (using statistical or graphical methods approved by LOC) with concurrent data from observation wells completed in the same aquifer in the general area so that long term water level fluctuations can be described. Also, a description of the potential use of any aquifer (if not presently being used) based on aquifer hydraulic characteristics and boundary conditions should be presented.

2. Prediction of Probable Hydrologic Consequences

The PHC determination is an estimate of the probable impacts of both mining and reclamation activities on the quality and quantity of ground water.

Mining operations will remove coal which may be serving as an aquifer and may change the aquifer properties of the overburden governing water quality, water levels, and ground-water movement in the permit and adjacent areas. Changes in ground-water quality and quantity should be predicted for post-mining periods. Generally, any approach or method used to predict post-mining ground-water availability or quality must account for changes in transmissivity, storage coefficient, and physical properties and mineralogical characteristics that affect the rate or amount of chemical solution in the reclaimed spoils. The values used for these parameters for post-mining reclamation predictions should be fully explained. Establishment of a monitoring well in the reclaimed affected area after mining will provide data to verity the prediction. The placement of the well should be discussed during the pre-application conference.

The results of the overburden analyses described in Part One of this guidebook should be utilized in predicting the post-mining ground-water quality. Estimation techniques, ranging from simple empirical equations to complex computer solutions, may be used for estimating impacts. If computer modeling is used, calibration is necessary with site-specific data. Model justification will be required.

The results of the PHC determination will be utilized in reevaluating the adequacy of the proposed mining and reclamation plans. Modification of the plans may be necessary to mitigate potentially adverse impacts, as identified in the PHC determination.

D. Climatological Data

Knowledge of the climatic factors in the permit and adjacent areas is necessary since these factors are important in determining the rainfall input, evaporation and transpiration relationships, soil moisture, ground-water recharge, and streamflow which are the basic components of the hydrologic balance. Records of daily precipitation should be presented for the 9-month duration of basic data collection. These data, collected at the proposed permit area, should be compared with data from National Weather Service stations in the vicinity, in order to estimate the required average seasonal precipitation variations.

References

Martien, Robert, F., 1978, Water-quality characteristics of the Red River in Louisiana: Louisiana Department of Transportation and Development and U.S. Geological Survey Water Resources Technical Report 16, 32 p., 17 figs.

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Snider, J.L., 1982, Premining hydrology of the lignite area in southeastern De Soto parish, Louisiana: Louisiana Department of Transportation and Development and U.S. Geological Survey Water Resources Technical Report 29, 40 p., 6 pls., 5 figs.

Snider,J.L., and Kenneth J. Covay, 1987, Premining hydrology of the Logansport lignite area, De Soto parish, Louisiana: Louisiana Department of Transportation and Development and U.S. Geological Survey Water Resources Technical Report 41, 65 p., 1 p1, 15 figs.

Sobek, AA, W.A Schuller, J.R. Freeman, and R.M. Smith, 1978, Field and laboratory methods applicable to overburden and minesoils, U.S. Environmental Protection Agency 600/2-78-054.

Thomas, G.W., 1982, Exchangeable cations In AL. Page (ed.) Methods of Soil Analysis, Part 2, Agron. No.9., Madison, WI. pp.159-166.

APPENDIX A

FORM SMD - 10

LOUISIANA DEPARTMENT OF NATURAL RESOURCES
OFFICE OF CONSERVATION
INJECTION & MINING DIVISION

Monthly Surface Water Test Report

Mine Name:_________________________________

Sample Date:________________________________

Sample Site or Location of Watercourse:____

Remarks:____

FIELD TESTS

Is water in test area flowing? [ ] Yes [ ] No Discharge:____________________

Conductivity: ________________________________ pH:________________________________

Investigator:_________________________________ Signature:___________________________

LABORATORY ANALYSES

Name of Lab:________________________________

Sample Analysis By:__________________________ Date:________________________________

Total Dissolved Solids __________________Mg/L

Total Suspended Solids __________________Mg/L

Total Iron __________________Mg/L

Total Manganese __________________Mg/L

Sulfate __________________Mg/L

Aluminum __________________Mg/L

Acidity __________________Mg/L

Alkalinity __________________Mg/L

Chloride __________________Mg/L

Specific Conductance __________________Mmhos/cm

Signature:___________________________________

APPENDIX B

FORM SMD - 11

LOUISIANA DEPARTMENT OF NATURAL RESOURCES
OFFICE OF CONSERVATION
INJECTION & MINING DIVISION

Monthly Ground-Water Test Report

Mine Name:________________________________

Sample Date:_______________________________

Well:_______________________________________ Depth of Sample:_____________________________

Remarks:____

FIELD TESTS

Conductivity: _______________________________ pH:____

Investigator:_______________________________ Signature:____________________________________

LABORATORY ANALYSES

Name of Lab:_______________________________

Sample Analysis By:__________________________ Date:____

Total Dissolved Solids	__________________	Mg/L
Total Iron	__________________	Mg/L
Total Manganese	__________________	Mg/L
Sulfate	__________________	Mg/L
Aluminum	__________________	Mg/L
Acidity	__________________	Mg/L
Alkalinity	__________________	Mg/L
Chloride	__________________	Mg/L
Specific Conductance	__________________	Mmhos/cm

Signature:____________________________________