DRILLING

Section Editor: Mickey Steward

Handbook of Western Reclamation Techniques

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SECTION 7: DRILLING PROGRAM

A. INTRODUCTION

Section editor: D.G. Steward

The purpose of this section is to provide a framework for identifying and conducting the activities associated with a drilling program. Drilling is done for a variety of reasons at coal mines. While the section does not address drilling in the pit for blasting, it does address the many other reasons drilling is conducted.

Overburden chemistry can be sampled as part of the drilling program. From this information, estimates of the volume and location of materials requiring special handling in the reclaimed area backfill can be made. Special handling of certain materials is often required by the state program permit for the mine operation. Documentation of the backfill geochemistry and the proper placement of specially handled materials may be required by the permit, and can be used to support bond release requests. This documentation is provided through the drilling program.

Wells can be installed as part of the drilling program. Monitoring wells in native and reclaimed lands may be required by permit and regulation, dewatering wells may be used to facilitate pit advance, and production wells provide water for the mine facilities and support operations.

Drilling is used to obtain information on coal quality, quantity, structure, and location. This information is used to maximize efficient coal extraction and comply with customer contract specifications. Drilling also provides geotechnical information that aids in pit configuration, and helps to identify mining limits by providing data for cropline and slope stability analysis.

Finally, drilling is used for miscellaneous projects that cannot always be specified beforehand. Three examples are: installation of ground wires for electrical substations, assessing the extent of soil or groundwater contamination, and obtaining geotechnical data to facilitate design for structure foundations, reservoir embankments, and slope and highwall stability.

Much of the drilling that is conducted for one purpose can also be used for another. For example, sampling of overburden during the installation of dewatering wells adds to the data base for overburden quality. It is important, therefore, to view the drilling program as an integrated program and plan for the maximization of results from every hole drilled.

Drilling is heavily regulated by state and federal agencies. These operating techniques have been developed to aid in the execution of a drilling program, and to help ensure that all elements of the program are addressed. While some of these elements are not uniformly applicable to all types of drilling, each element is presented in order to fully identify all aspects of the program that require decisions and/or action.

Weather, equipment, personnel, regulatory constraints, mine plan changes, changes in management, and management emphasis can alter the best planned program. Flexibility is essential. A problem anticipated and planned for is no problem. In addition to listing the necessary elements for the various types of drilling, this section provides a basis for early anticipation and avoidance of potential problems. Good planning will lead to a timely and efficient program. The

foremost ingredient in a successful program is a timetable of the necessary elements, which assures timely availability of results.

TIMETABLE FOR ANNUAL DRILLING PROGRAM PLANNING

ITEM	DATE	REASON
Communicate with mine personnel and budget drilling program for the upcoming year	September	Typical time for submitting budget
Prepare and circulate request for contractor bids	January	Best prices
Choose successful bidder	February	Facilitate optimum scheduling
Schedule driller	February	Facilitate optimum scheduling
Execute the program	July-September	Good weather
Collect and review analytical data	October	Prompt analysis of samples collected
Submit logs and required reports	November-December	Prompt closure of field season

NOTE: Regulatory requirements for drilling can change rapidly. State and Federal regulatory agencies should be contacted prior to the planning phase of any drilling program to ensure current standards and requirements are met. It may also be necessary to comply with State Engineer and Oil and Gas programmatic requirements in your state. Failure to meet regulatory requirements can have severe consequences so this effort must be pursued assiduously.

Acknowledgements
The assistance of Mike Nicholson, Bob Stowe, Robin Kerschner, and Marlys Hansen in completing this drilling program is greatly appreciated.

B. PRE-DRILLING REQUIREMENTS

1. Identifying Drilling Needs

Section editor: D.G. Steward *Subsection authors: Robert Cowan/D.G. Steward*

Applicability

The first step in the planning of any drilling program is to identify the mine's requirements for the upcoming year. Permitting and regulatory requirements must be considered throughout the planning process.

Special Considerations

While planning for a drilling program must be fairly exact, a certain amount of flexibility is necessary, in the budget as well as the program itself. This allows for changes and additions that may become necessary during execution of the program.

Techniques

a. Meetings

Hold meetings, at least annually, with mine personnel to discuss the drilling schedule, and receive input on the drilling requirements for all departments. Drilling may be required for operations, permitting, or special projects. Be sure to receive input on possible conflicts that may affect the efficient completion of the drilling project. Locations of any buried pipelines, cables, and other utilities should be identified and staked to prevent hazardous situations and/or interruption of services.

b. Operations Requirements

Coal quality exploration drilling provides the necessary information to allow planning for efficient removal of overburden, and extraction of coal of the requisite quality to meet contract requirements. Coal structure exploration is necessary for coal seam location and correlation. Drilling of dewatering wells allows for more efficient mining operations. Production wells provide water for the mining facility and support operations.

c. Mining Permit and Regulatory Drilling Requirements

Mining operations are required by law to provide a certain amount of geologic and hydrologic information. Specific regulatory requirements or guidelines for each state may differ and should be investigated.

Mine permits typically present information collected as part of the permit application process. Mine permits also specify what sampling and monitoring programs will be conducted both during and after mining. The extent of the program is set by regulation and negotiation. The current mine permit should be consulted for program specifics.

(1) Baseline Inventory

Regulations may require drilling to establish a premining baseline inventory of subsurface conditions.

(2) Overburden Suitability

A mining permit often requires that overburden suitability be established. The need for special handling of materials during backfill, if any, is established by

drilling and sampling. Postmining backfill suitability and groundwater monitoring are also required to comply with mining regulations.

(3) Ground Water Monitoring

The ground water monitoring program is typically specified in the mine permit. Monitoring of both quality and quantity is the norm. Monitoring is conducted before, during, and after mining. Special drilling may be necessary in the development of monitoring wells to prevent inadvertent contamination of the well or samples. For example, sampling criteria for the collection of samples for selenium analysis can be restrictive and time consuming.

(4) Bureau of Land Management (BLM) Requirements

For lease coal, the BLM requires information regarding coal quantity and quality, and overburden thickness. Baseline information for economic and environmental evaluation is also needed.

d. Special Projects

Drilling is occasionally required to obtain data for structural design of foundations for new construction or for slope stability analysis. Drilled holes may also be required for installation or removal of ground wires for electrical substations.

Backhoe pits may be needed for various reasons, such as soil description. The same general requirements for reclamation that cover drilling operations will often apply to backhoe pits.

2. Identifying Logging and Sampling Requirements

Section editor: D.G. Steward *Subsection authors: Robert Cowan/D.G. Steward*

Applicability

This subsection is intended to outline any logging, sampling, analysis, or special equipment that may be required for a drilling program. These requirements will vary depending on the individual mine's needs for that year, as discussed in the subsection entitled "Identifying Drilling Needs".

Special Considerations

Once requirements for individual drilling programs have been identified, they should be specified in "Request for Quotation" and "Scope of Work" documents. More information on these documents can be found in the subsection entitled "Contracting the Drilling Program".

Techniques

a. Specify the Descriptive Requirements

More detail on logging can be found in the subsection entitled "Logging". However, the program administrator must decide if both lithologic and electric logs are needed for the project, or if lithologic logs alone will suffice.

(1) Lithologic Logs

Lithologic logs are prepared by the geologist, geotechnical consultant, and/or driller. They consist of descriptions of the materials encountered as drilling

progresses. These logs note the depths at which soil/rock type changes or water is encountered, as well as depths and types of samples obtained.

(2) Electric (geophysical) Logs

Geophysical logs are made after completion of drilling by lowering electronic remote sensing equipment down the hole and recording digitally and/or on strip charts. Downhole logging of changes in density, moisture, resistivity, and caliper may be required for exploration holes. Geophysical logging is often performed by contractors.

b. Specify the Sampling Requirements

(1) Type of Samples Required

Chip sampling of coal and overburden is the most cost effective sampling method and may be used where practical. When continuous coring is required, three-inch diameter cores are standard, and have been found to provide adequate sample volume for analysis. If at least 90% of the coal and 75% of the overburden is not recovered in each run of the coring tool, that part of the profile must be re-cored.

If re-coring is unsuccessful, or, if in the judgment of the driller, recovery is highly unlikely because the material is too loose and soft to be retained in the core barrel, it is permissible to catch cuttings at the surface in a bucket placed near the discharge pipe of the drill. The cuttings are then bagged for each interval in which the unrecoverable material was drilled.

Special sample equipment may be required for geotechnical samples. The drilling contractor must know in advance any equipment he is to provide, potential materials to be encountered, and frequency of sampling that will be expected.

(2) Analysis Required

The analysis required to be performed on samples will govern the type of laboratory equipment and procedures necessary. Laboratories bidding to perform the work must have complete information on required analysis and time constraints for reporting of results. The mine permit will usually provide specific information on the analysis that must be performed on overburden and water samples.

Coal analysis requirements are usually dictated by the information necessary for the sale of coal. Normally, coal analysis can be broken down into the following groups: proximate, ultimate, ash mineral, fusion, and grindability. Federal regulations for coal analysis requirements of leased federal coal prior to the commencement of mining operations can be found in Section 43 CFR 3482.1 (c)(3)(i) of the Code of Federal Regulations (CFR, 1993). Meet with mine personnel to achieve consensus on the amount of data necessary for the purposes set forth.

(3) Special Equipment Required

If the need for specialized or unusual equipment is anticipated, extra lead time and expense should also be anticipated. For example, if undisturbed samples are required from unconsolidated backfill, a Pitcher sampler may provide better recovery than standard core samples. Special preparations may be required, however, to obtain the sampler and manage the samples.

(4) Sample Identification

Any special sample identification procedures that will be required must be identified and contractors advised before bidding.

3. Identifying Number, Size, Location, and Depth of Drill Holes

Section editor: D.G. Steward *Subsection authors: Robert Cowan/D.G. Steward*

Applicability

This subsection is intended to assist in planning the actual holes to be drilled in a mine's drilling program. These requirements will vary depending on the individual mine's needs for that year, as discussed in the subsection entitled "Identifying Drilling Needs".

Special Considerations

Once requirements for individual drilling programs have been identified, they must be specified in "Request for Quotation" and "Scope of Work" documents. More information on these documents can be found in the subsection entitled "Contracting the Drilling Program".

Techniques

a. Identify Grid Spacing and Number of Holes to be Drilled

The number and spacing of drill holes will depend on the purpose of the drilling. The mine permit requirements, and state guidelines, dictate the minimum number and spacing of drill holes.

Delineate coal and overburden quality sufficiently to prevent basing too large a portion of the near and intermediate term mine plan on interpolated data, especially if important parameters exhibit large variability over the areas sampled. Have a good picture for the next three to five years to allow flexibility of planning. Meet with mine personnel to verify hole spacing for the project.

Spacing and depth of geotechnical holes should be selected by the geotechnical consultant performing the analysis. When spacing drill holes for exploration, take into account the variability of data already in hand and the timeframe during which the area will be mined. Based on the grid spacing selected, and the area to be drilled, estimate the total number and size of holes to be drilled. Where possible, based on prior information, provide the total depth to which the holes will be drilled.

b. Choose the Drilling Method

Several factors affect the choice of drilling methods and the equipment required to perform the work. These factors include the type of material to be drilled, the water table, and possible monitoring.

(1) Anticipated Material to be Drilled

The types of materials anticipated to be drilled, and the water table levels expected, if known, can help predict the need to drill with air or with drilling mud, and whether or not surface casing must be provided to keep the hole open in saturated sands or gravels.

(a) Drilling with Air

Drilling with air is desirable to facilitate identification of materials drilled, and is preferable for collection of chip samples from specific sample intervals. Air drilling can also facilitate identification of water tables during drilling. Materials such as wet clays, however, will not clean well when drilled with air. If porous formations such as scoria (fused shale) are encountered, air circulation will be lost. Injection of water, and occasionally foam, while drilling with air prevents dust and facilitates cleaning the hole. Mine Safety and Health Administration (MSHA) requires that dust be controlled during drilling.

(b) Drilling with Mud

Drilling mud facilitates drilling in wet clays and scoria, but is time consuming and in some cases makes sampling and logging more difficult. Drilling with mud often has a greater environmental impact than air drilling. Drillers should be prepared to drill with air or mud as required.

(c) Using Surface Casing

When drilling near creeks or other locations where saturated sands and gravels may collapse into the hole, surface casing may be required to allow drilling and sampling. Anticipating these conditions can save time if the driller provides casing materials at the site before drilling begins.

(d) Drilling with Auger Rigs

Auger rigs with continuous flights and hollow stem augers are useful for sampling backfill and soils, or for shallow geotechnical sampling (usually less than 100 feet). Auger rigs are also employed to install shallow monitoring wells. These rigs are usually smaller, more maneuverable, and less expensive than rotary drilling rigs.

(2) Water Table if Known

Advance knowledge of water tables will allow drillers to anticipate possible drilling or sampling problems.

(3) Atmospheric or Soil Monitoring Required

Monitoring of gases such as hydrogen sulfide (H_2S) and methane (CH_4) that may be encountered while drilling may be required. The contractor's Scope of Work should specify what monitoring will be required, who will provide the equipment, who will perform the monitoring, and what records are to be kept. If hazardous materials are anticipated, the safety procedures and personal

protective equipment to be employed should be specified, as well as any special waste disposal and decontamination measures required.

c. Name the Holes and Map the Hole Locations

There are many ways to name and identify holes. Typically a combination of letters and numbers are used. The letters generally designate the property or mine on which the drilling occurs, while the numbers give the hole a unique designation. For example, CB-0101 would designate Caballo hole number one hundred and one (101), where the holes are numbered sequentially over the life of the mine. Alternately, BT-9501 would designate Black Thunder, hole one (1), drilled in 1995. Or JRM-10-C-01 would designate Jacobs Ranch Mine's hole one (1) in coal in Section 10.Another way to identify holes is to use a six digit abbreviated form of the northing and easting, or other appropriate survey coordinate base, written in that order, and formed by extracting the fifth through third digits left of the decimal point rounded to the nearest one hundred feet. For example: If the location of a hole is given by northing 1,354,281.070 and easting 416,359.730, then the hole identification number on the hole marker would be 543164. Be aware that, when using this method, the hole name may change if its location changes during field operations. To avoid the confusion this would cause, proposed holes may be given a temporary numeric hole name at the outset of the program.

Hole identification conventions other than that suggested here may be developed which obviate renaming holes and which better suit the needs of the specific property. After naming the holes, place the proposed drill holes on a map. Show associated terrain features and access routes on the map.

4. Pre-field Permitting and Reclamation Planning

Section editor: D.G. Steward *Subsection authors: Robert Cowan/D.G. Steward*

Applicability

There are paperwork requirements that must be met before the actual drilling can begin in any drilling program. All paperwork should be documented in drilling correspondence files organized by year and hole type. Reclamation plans must also be made and outlined in the "Scope of Work" document.

Special Considerations

Regulatory requirements regarding permitting, reclamation, and bonding may differ from state to state. Planning should be done according to applicable regulations. Once these requirements have been identified, they must be specified in "Request for Quotation" and "Scope of Work" documents. More information on these documents can be found in the subsection entitled "Contracting the Drilling Program."

Techniques

a. Permitting and Notification for Drilling and Access

(1) Obtain Permission

Permission to perform any drilling in the permit area must be obtained from the state regulatory authority. If access to the drilling area requires crossing

lands for which the mine has no control or existing right-of-way agreement, permission to cross must be negotiated.

(2) Obtain Permits

Written permits must be applied for in advance, allowing sufficient time for processing. The following figures give paperwork flow charts for BLM, Wyoming Department of Environmental Quality, Land Quality Division (WDEQ-LQD), and Wyoming State Engineer's Office (SEO) documentation and permitting requirements.

Federal regulatory requirements can be found in 30 CFR 772.11, 772.12, 772.15, 780.22(b)(2), 815.13; 43 CFR 3410, 3482, 3484.1(a)(4), and 3485.1(a),(b),(c) (CFR, 1993). There are significantly different requirements for drilling unleased, as opposed to leased, coal. Read applicable regulations carefully and contact the BLM. State regulatory requirements may differ from state to state and should be investigated.

(3) Give Public Notice when Required

Public notice may be required for some drilling activities. Be sure to retain records of the publication.

(4) Review Permits

Meet with mine personnel and property owners or other concerned parties to verify that all permitting and notification are complete. It may be appropriate to obtain legal advice, or consult with regulatory agencies, to confirm that all issues have been adequately addressed.

b. Reporting Requirements

Documentation and reporting of all drilling activities are required by Federal regulation. These regulations can be found in 30 CFR 772.11(b)(5); 43 CFR 3410.2-2(b), 3482.1(a)(3)(v), and 3485.1(b)(8) (CFR, 1993). These requirements are often addressed in the mine permit. In Wyoming, drill holes in which artesian water flow is encountered at the surface must be reported within 60 days to the Wyoming State Engineer's Office and the Administrator of the WDEQ-LQD. Regulations may differ for other states, and should be investigated. A drilling correspondence file should be developed to document all reporting activities.

c. Reclaiming and Abandoning Drill Holes

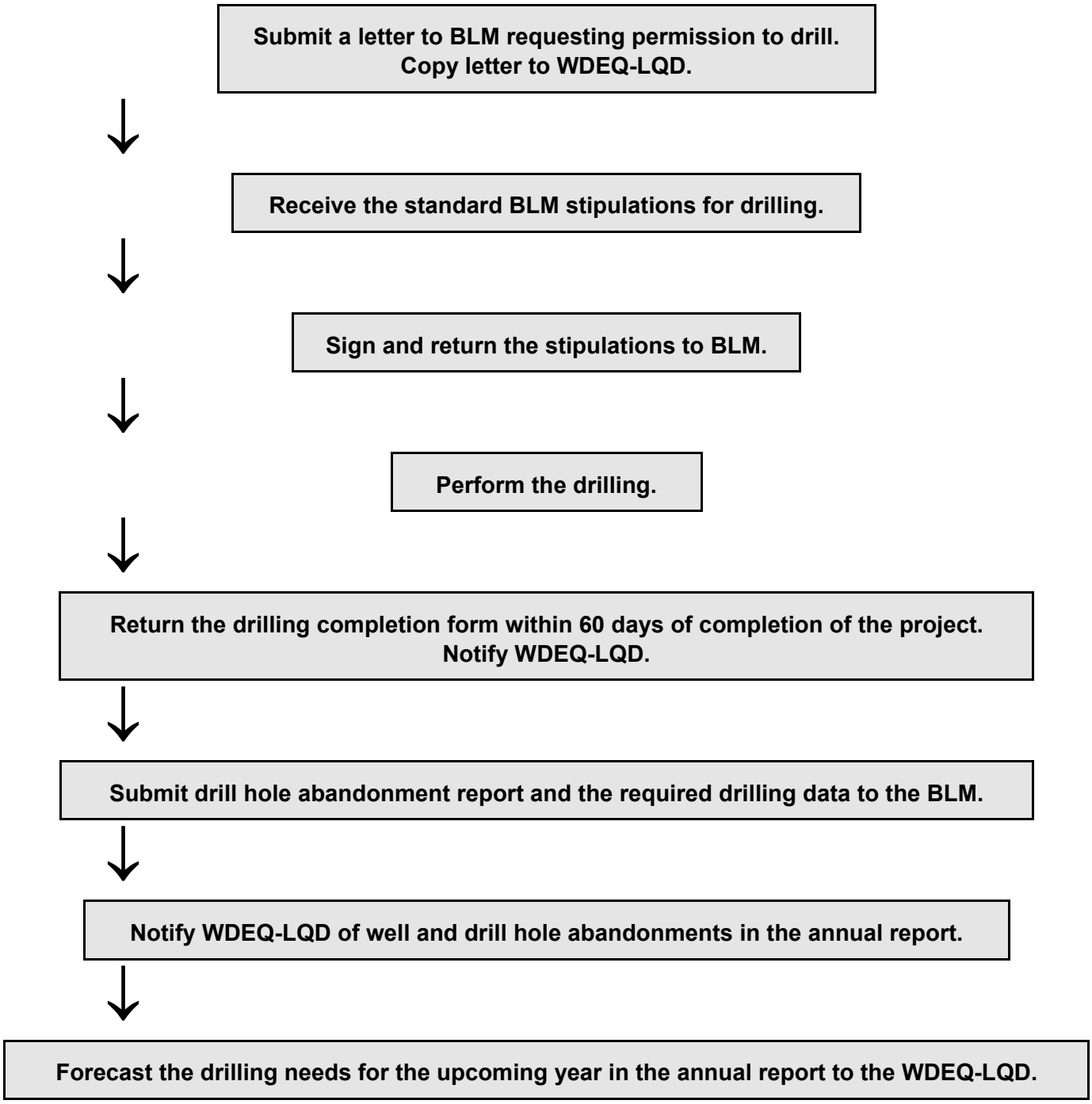
Reclamation and abandonment procedures are usually described in the mine permit. Federal regulations regarding these procedures can be found in 30 CFR 815.15, 816.13, 816.14, 816.15, 816.101, 816.102; 43 CFR 3484.1(a), and 3484.2(a) (CFR, 1993). State regulations should be investigated. In Wyoming, developmental drill holes to be mined through within one year should be made surface safe, but need not be permanently reclaimed.

The Scope of Work must specify what measures are to be employed and which holes are to be reclaimed. More detail on drill hole reclamation is provided in the subsection entitled "Drill Hole Reclamation".

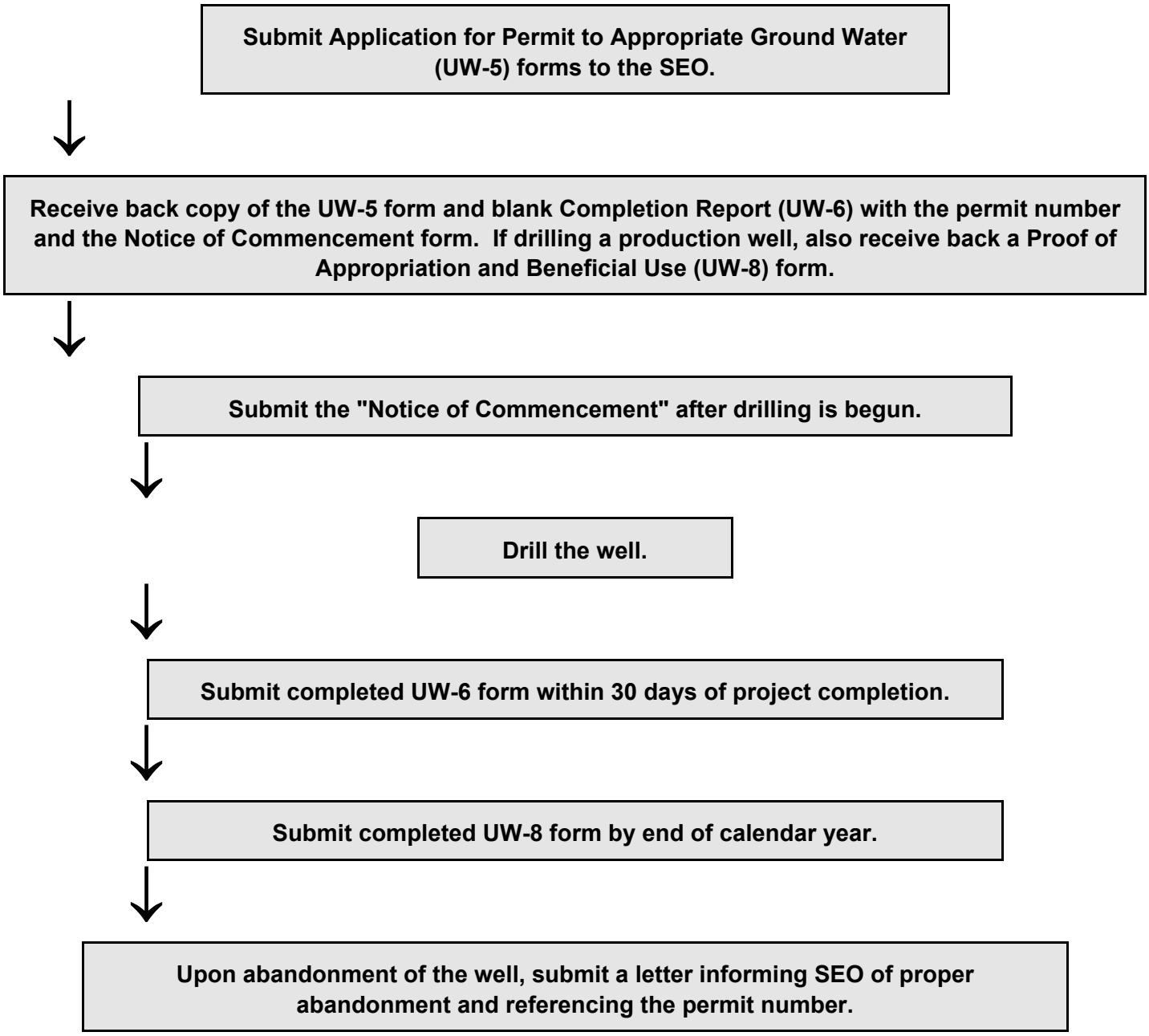
d. Bonding

Where drilling is proposed off lease on federal coal, or on lease, a bond is required. Bonding for exploration and monitoring is set in the annual report in which the drilling for the year is forecast, and is based on the estimated cost to reclaim drill holes and sites.

FLOW CHART FOR BLM AND WDEQ-LQD PAPERWORK



WYOMING STATE ENGINEER'S OFFICE PAPERWORK AND ACTIONS



5. Contracting the Drilling Program

Section editor: D.G. Steward *Subsection authors: Robert Cowan/D.G. Steward*

Applicability

This subsection outlines the steps necessary for obtaining a contractor that will fill the needs of a specific drilling program. Requirements and responsibilities for all contractors must be clearly documented.

Special Considerations

The contractor requirements for a drilling program should be specified in "Request for Quotation" and "Scope of Work" documents. These needs will depend upon decisions already made regarding drilling, logging, and sampling requirements. Exact responsibilities of each contractor should be clearly specified. It is desirable to allow for some contractor flexibility in execution of the program, while clearly stating requirements that *must* be met.

Techniques

a. Prepare the Written Scope of Work

Include every aspect of the project as it pertains to the various contractors who may bid on all or part of the project. Use a checklist similar to the following for preparing a Scope of Work.

1. Determine the purpose of the drilling.
2. Gather all pertinent documents that control the type of drilling proposed.
3. If geotechnical or other consultants are required to participate, obtain their input on special requirements for drilling, sampling, or analysis.
4. Define the sampling program for the project.
5. Determine the number, location, and depth of drill holes and list what types of drilling and sampling equipment are to be provided by the drilling contractor. Identify who is responsible for any equipment, such as probes, that may be lost down drill holes.
6. Note anticipated materials that may be encountered during drilling, and any atmospheric or soil monitoring required.
7. Provide a map of the drill hole locations showing associated terrain features, access routes, any restricted areas, and pertinent geologic and hydrologic data that are available.
8. If appropriate, list the types of laboratory analysis required and the time frame in which the results will be needed. The analysis of the samples may be bid separately from the drilling.
9. List the type of logs that need to be prepared during drilling, and who will prepare them.
10. If wells are to be developed, list the materials to be used and provide a drawing of the completed well.
11. Determine what reclamation and abandonment procedures are applicable to the project and list specific materials to be used.
12. Determine who will provide well and/or reclamation materials.

13. Determine the time frame during which the project will be completed and any unusual working schedules necessary to meet the deadlines which may be set.
14. Prepare a "Scope of Work" or "Request for Quotation" for each contractor to include all of the foregoing information.

b. Identify Contractors

Prospective contractors bidding on the work should provide current statements of qualifications, current licenses, references from previous clients, and a history of work performed. The driller, the geologist, the logger, and the laboratory may be bid together as a package or separately.

(1) Driller

(a) Safety Record, MSHA Training

Investigate for any history of safety violations or accidents that may have occurred, and determine if remedial steps were taken. Determine if the contractor provides a safety training program for his employees, and whether or not MSHA training has been completed if required.

(b) Suitable Equipment

Determine if the prospective contractor's equipment is appropriate to the job and in good operating condition.

(c) Past Experience

If the prospective contractor has performed work for the mine previously, information may be available from records or personnel about the quality of work performance that can be expected.

(d) References

Obtain a list of references of previous clients from prospective contractors about whom additional information is desired. Consult these clients concerning past job performance.

(2) Geologist/Geotechnical Consultant

The geologist can be sub-contracted through the driller, requiring the driller to coordinate all applicable activities, or vice-versa. The same information regarding safety, equipment, experience, and references that are required for the driller should also be obtained for the geologist/geotechnical consultant.

(3) Laboratories (Chemical/Geotechnical)

The same information regarding equipment, experience, and references that are required for the driller should also be obtained for the laboratory. In addition to this, it is necessary to ascertain if prospective laboratories have met standards of government or industry sponsored certifying agencies for the types of analysis required.

Establish what timeframe is required to receive laboratory results and evaluate the prospective lab's ability to meet requirements with respect to equipment, personnel, and workload.

Laboratories must demonstrate that they can consistently achieve accurate analytical results. In some cases it may be desirable to submit duplicate samples or "spiked" samples to check lab performance. Selection of reputable, certified labs and submission of duplicate samples to different labs can help minimize variability of results caused by lab operations.

(4) Downhole Logger

The logger can be sub-contracted through the driller, requiring the driller to coordinate all applicable activities. The same information regarding safety, equipment, experience, and references that are required for the driller should also be obtained for the downhole logger.

Check equipment calibration records to verify timely regular performance checks of logging equipment. Identify the digital data capacity of the logger. In addition to strip charts or other visual representations of data, it may be desirable to have geophysical data provided in a digital form compatible with available computer systems.

c. Contact Prospective Bidders

Contact prospective contractors to determine their availability to perform the work during the proposed project timeframe.

d. Pre-bid Meeting

Meet with prospective contractors to discuss and clarify the Scope of Work prior to accepting bids.

e. Receive and Analyze Bids

Once bids have been received, prepare a master spreadsheet that allows a direct comparison of both line item and overall bid costs. Discuss this comparison with purchasing, accounting, and engineering personnel. Remember, the low bidder may not be the best buy. Finally, select the contractor.

f. Schedule the Contractors

Prepare contract documents which establish a timeframe for beginning and completing work and give contractors notice to proceed. If desired, establish the normal working hours expected.

6. Sample Storage

Section editor: D.G. Steward *Subsection authors: Robert Cowan/D.G. Steward*

Applicability

Planning for the handling and storage of drilling samples will expedite these activities when field work is actually being done. Storage facilities should be identified before they are needed.

Special Considerations

Capacity, accessibility, and necessary climate control must be considered in the choosing of a storage facility for drill samples.

Techniques

a. Capacity and Accessibility

The sample storage facility must be large enough to allow samples to be easily identified and sorted by hole number and depth interval. Use hole number, diameter, and depth to estimate the total storage volume required. Loading and unloading of samples should be as convenient as possible. Provide keys to the locked storage facility to authorized persons only.

b. Temperature and Humidity

Ensure that climate control in the storage facility is adequate to preclude extremes of temperature or humidity. Samples must not dry out, or lose volatile constituents during storage.

c. Time Constraints

Transfer samples expeditiously to the analytical laboratory in accordance with good practice for the types of analysis required. Determine how long it will be necessary to use the storage location before samples are shipped.

C. FIELD WORK

1. Field Activities

Section editor: D.G. Steward *Subsection authors: Robert Cowan/D.G. Steward*

Applicability

This subsection is intended to outline the steps needed for actual field work required in a drilling program, and to ensure that all elements of the program are addressed.

Special Considerations

In any drilling program, supervision will be required regarding location, access, and drilling of holes, as well as safety and environmental control considerations.

Techniques

a. Locate and Identify Drill Holes

(1) Select Accessible Drilling Sites and Drillable Hole Locations

Locations of holes may have to be adjusted to avoid obstacles to accessibility, such as swamps, ravines, steep slopes, and rock outcrops.

(2) Survey the Holes

Mark holes with a lath and flag or other suitable means. The following information may be helpful if placed on the lath:

(a) Northing and easting or UTM coordinates.

(b) Elevation at the surface.

(c) The estimated depth to coal, and coal thickness (optional).

(d) Type of hole (label the holes as monitoring, dewatering, exploration, etc. on the marker).

(e) If GPS (Global Positioning System, based on satellite transmissions) is available, this method may be used to locate drill holes.

b. Access the Drill Site

(1) Roadways

Special precautions may be necessary when permits or special permission have been obtained. If special permission has been received to cross lands not controlled by the mine, care must be taken to assure that all contractors are specifically advised of routes to be followed and restrictions to be observed.

Use existing roads and trails whenever possible. Limit vehicular traffic to drill sites to the minimum necessary. When wet conditions prevail, avoid areas where rutting and vegetation damage will cause undue reclamation effort.

(2) Hours

Drilling operations are normally scheduled during daylight hours for safety. If night drilling is anticipated, ensure that adequate lighting is provided.

(3) Restrictions

Drilling operations may involve movement of equipment in pit traffic areas, and, if so, may have to be restricted to certain times or routes. Drilling may have to be suspended and equipment moved during blasting operations.

c. Drill the Hole

(1) Special Sampling Considerations

Begin all drilling operations with clean equipment. Make sure any water, lubricants, pipe dope, or similar items used during drilling do not contain materials that will be analyzed in the samples, or that may interfere with analytical results. Obtain Material Safety Data Sheets (MSDS) to verify the contents. For example, if samples are to be analyzed for molybdenum, then drill pipe grease containing molybdenum should not be used while drilling and sampling.

(2) Environmental Considerations

(a) Safety (including monitoring for gases such as H_2S and CH_4)

Hydrogen sulfide and methane gases are routinely encountered when drilling in coal and overburden. Other toxic or flammable vapors may be found, especially when drilling in the vicinity of underground storage tanks. Have monitoring devices for hazardous gases available to ascertain if explosive, fire, or toxic exposure conditions exist. If toxic concentrations exceed the threshold limit value or flammable gas concentrations exceed 10% of the

lower explosive limit in the work area, mitigating procedures must be taken and personnel and equipment protected from hazards.

(b) Housekeeping

Require contractors to maintain a clean and orderly work place, and to contain and dispose of waste materials in an approved manner. Unused equipment, well supplies, and reclaiming materials should be stockpiled to avoid damage or loss, and to present no hazard to drilling or mine operations.

(c) Environmental Control

Excavate and backfill mud pits used to contain drilling fluid and cuttings in accordance with the mine permit. Take any precautions that may be necessary to protect people, livestock, and wildlife from open holes or other hazards.

Require contractors to prevent uncontrolled release of excess drilling fluids that may contaminate surface water or damage vegetation. Have the contractor provide MSDS for all material to be used during the drilling program.

d. Monitor Groundwater Levels

This is always done for geotechnical drilling, and may be appropriate for other types of holes. Instructions for monitoring are given in "Standard Method for Determining Subsurface Liquid Levels in a Borehole or Monitoring Well (Observation Well)" (ASTM, 1994).

2. Sample Collection

Section editor: D.G. Steward *Subsection authors: Robert Cowan/D.G. Steward*

Applicability

Sample collection is an important part of the drilling program. This subsection is intended to cover various aspects to be considered for all associated sampling. Sample requirements can be very site specific; the information provided herein is intended for use as a guide only.

Special Considerations

Methods used for collecting, bagging, and handling of samples will vary from mine to mine, depending on permit and regulatory requirements, as well as the information that is to be collected.

Techniques

a. Coal

There is usually no special cleaning required for coal sampling. Continuous coring through coal, with at least 90% recovery, is usually required. The structural tops and bottoms of the coal seams should coincide with sample interval starts and endings.

Sample collection can be made in a variety of ways. Composite coal samples can be taken and submitted for analysis for each seam encountered. Samples can be taken at two-foot intervals in the top and bottom six feet of coal, and at five to ten foot intervals between. The company representative in charge of geology should be consulted on sample intervals. Geophysical logs can be used to identify tops and bottoms of

structures. If the parting is identified, sampling is optional, but if sampling is required, separate bagging for the parting is required.

b. Overburden

Holes are drilled and cored or chipped. The interval at which chip samples are collected is set by the program administrator, and may depend upon bench height.

Subtract the estimated topsoil break and do not include as part of the overburden sample. This may be as much as five feet. Cores can be bagged in two-foot intervals, then combined for eight-foot intervals. When placing cores in boxes, orient the interval marking with the actual orientation of the cores as they were removed from the ground. Select sampling intervals consistent with the mine permit.

Selenium sampling may require special cleaning of samplers and equipment. Some operators collect samples for selenium analysis in accordance with "Standard Operating Procedures for the Sampling and Analysis of Selenium in Soil and Overburden/Spoil Material" (Carroll, et al., 1994).

c. Backfill

Backfill monitoring and sampling requirements are usually specified in the mine permit. In general, backfill sampling is required to demonstrate compliance with the mine permit.

d. Geotechnical

Normally, no special cleaning is required for geotechnical sampling. Types and locations of samples to be taken are specified by the program administrator or a geotechnical consultant. General requirements are outlined in the "Standard Guide for Investigating and Sampling Soil and Rock" (ASTM, 1994).

Geotechnical samples are to be transported to laboratories in accordance with "Practices for Preserving and Transporting Soil Samples" (ASTM, 1994).

e. Special Considerations

Begin all drilling operations with clean equipment. The type of sample dictates the procedure required for cleaning equipment. For example, when sampling for selenium (if following Carroll, et al., 1994), samplers, drill pipe, etc., must be washed with Alconox and rinsed three times with distilled water between samples.

Make sure water, lubricants, pipe dope, and similar materials used during drilling operations do not contain materials that will be analyzed in samples or that will interfere with analytical results. Obtain MSDS to verify the contents. For example, if samples are to be analyzed for molybdenum content, then drill pipe grease containing molybdenum should not be used while drilling and sampling.

f. Handling

(1) Packaging

Core and chip samples should be placed in double plastic bags, to provide additional resistance to damage and extra moisture protection. Seal both bags separately with tape to assure no loss of moisture. 6-mil polyethylene bags are adequate. All samples may then be placed in water resistant boxes for transport. If core boxes are used, double bagging may not be necessary.

(2) Labeling

Color code or label clearly for coal, overburden, and backfill samples as necessary to prevent confusion when handling samples. Mark the hole number and sample interval on the outside of the bags, and also on a tag placed between the two sample bags. Do not place sample tags inside the sample bag, as they will become unreadable.

(3) Cataloging/inventory by Geologist or Driller

Any data collected that may eventually be computerized should be in a format that reflects that eventuality. A copy of the lithologic log, which lists samples by number and depth, may be included with samples submitted to the lab, and with a chain of custody sheet, which should also accompany the samples.

3. Well Drilling

Section editor: D.G. Steward *Subsection authors: Robert Cowan/D.G. Steward*

Applicability

This subsection outlines requirements that may be necessary in contracting the drilling of water wells.

Special Considerations

Physical requirements of each well will differ greatly. Specifications for casing size and depth, placing of well screens, and any other requirements must be clearly designated to the contractor. Overburden sampling when drilling dewatering wells may be desired to add to the overburden quality or coal database.

Techniques

Wells to be developed as production or monitoring wells do not need to have earthen samples collected, although they may have. These wells must be cased with screen placed at the water-bearing levels to be monitored or pumped.

All casing must be sealed to prevent contamination from surface or other undesired water sources. Excess drill cuttings must be spread to one-quarter inch thickness, or disposed of in the pit or other disposal area to prevent any chemical hazard. Wells can be protected from unauthorized access, and are preferably maintained under lock and key.

In addition to the casing required to facilitate drilling and sampling, casing must be provided for the development of monitoring or production wells. Specify the inside diameter of the casing, the schedule of pipe to be used, the screen opening width, where the screen is to be placed, and the type of any security device to be installed. Specify the particle size range of sand to be placed around the well screen in wells. Wells are to be sealed from surface contamination or from communication with aquifers that are not desired to be sampled or pumped. Identify any preferences regarding brand names or sources of materials.

4. Logging

Section editor: D.G. Steward *Subsection authors: Robert Cowan/D.G. Steward*

Applicability

This subsection is intended to give a brief summary of the various types of downhole logging that may be used in a drilling program.

Special Considerations

The readouts from these logs may be used by one or more parties. There is often only one print-out of each log, and it is difficult to copy. Obtain digital data in addition to hard copies when possible. Information obtained from each log will differ, and can be compared with other logs for confirmation of results.

Techniques

a. Electrical Logs

Caliper, resistivity, and nuclear logs are the electrical logs normally obtained. The logs are obtained by lowering a logging device down the hole. Data from electrical logging are recorded digitally, and can be printed immediately in the field. The data are also usually recorded as computer data files. To the extent drilling has been completed, logging should also be completed by the end of each day.

(1) Caliper

The caliper log measures the hole diameter, and can be used in conjunction with other logs to confirm readouts.

(2) Resistivity

The resistivity log measures changes in the resistance of materials to electric current, and is especially useful in identifying water levels, logging changes from overburden to coal, and indicating fresh versus saline water.

(3) Nuclear

(a) Natural Gamma

Natural gamma radiation is emitted from downhole materials used to delineate lithologies.

(b) Gamma (density)

Gamma radiation is attenuated in proportion to density of materials, and is used to log changes in density in the profile.

(c) Neutron (porosity)

High speed neutrons are scattered by hydrogen-bearing materials such as hydrocarbons or water, hence can be used to infer porosity in the profile.

b. Descriptive Logs

Descriptive logs include lithologic and core logs. These are prepared by the driller or the geologist as material is removed from the hole. Drill logs should be received and reviewed daily for completeness and accuracy.

(1) Lithologic Log

The lithologic log identifies depths and thicknesses of general geologic rock types. This log is completed, for both chip and core drilling, by the driller or geologist. Guidelines for lithologic logs are given in "Standard Guide for Field Logging of Subsurface Explorations of Soil and Rock" (ASTM, 1994). Other logging formats can be used as determined by the operator.

(2) Core Log

The core log, which is generated by the geologist, is a description of specific lithologic and environmental characteristics of the core as it is removed from the hole.

D. POST-DRILLING REQUIREMENTS

1. Drill Hole Reclamation

Section editor: D.G. Steward *Subsection authors: Robert Cowan/D.G. Steward*

Applicability

Proper reclamation and abandonment of all drill holes and disturbed areas are necessary as part of the drilling program. Procedures must be planned for and outlined in the "Scope of Work". More information on the Scope of Work document can be found in the subsection entitled "Contracting the Drilling Program".

Special Considerations

Permit requirements and appropriate regulations must be considered in planning proper abandonment and reclamation of drill holes.

Techniques

a. Documentation and Reporting

Documentation and reporting of all drilling activities are required. For more details on reporting requirements, see the subsection entitled "Pre-field Permitting and Reclamation Planning."

b. Reclamation Procedures

Reclamation and abandonment procedures are usually described in the mine permit. Federal regulations regarding these procedures are listed in part c. or the subsection entitled "Pre-field Permitting and Reclamation Planning". State regulations may differ from state to state and should be investigated. Monitoring wells must be reclaimed in accordance with appropriate regulations when the period of monitoring is complete.

Holes in the area to be mined in the next year should be made surface safe, but need not be permanently reclaimed. Exploratory holes that will not be mined in the next year must be permanently reclaimed. These holes are normally filled to the top of coal with bentonite and above the coal with a mixture of bentonite and overburden chips. If the top of the hole is within the projected topsoil stripping depth, do not cap it. If the top of

the hole is not within this depth, cap it with concrete from two to seven feet. Cover the cap with topsoil after inspection.

Specify in the Scope of Work the reclamation practices that are to be followed, and the estimated quantities of materials such as bentonite chips, concrete, or sand to be used.

c. Disposal of Drill Cuttings

Drill cuttings, especially carbonaceous, should be replaced in the hole or hauled to the coal mine prior to completing hole reclamation. Because monitoring and production wells must remain open and free of debris, drill cuttings from these holes should be spread around the hole to one-quarter inch thickness, or disposed of so as to prevent any chemical hazard.

2. Post-drilling Responsibilities

Section editor: D.G. Steward *Subsection authors: Robert Cowan/D.G. Steward*

Applicability

This subsection outlines the post-field activities that accompany a drilling program. These activities must be identified and assigned to responsible parties.

Special Considerations

The responsibilities listed in this subsection can be efficiently carried out by more than one party. For example, some of the work listed as the geologist's responsibility may be given to the geotechnical consultant, at the discretion of the geologist or program administrator.

Techniques

a. Geologist's Responsibilities

(1) Transporting Samples

Packaging and labeling of samples, and preparation of a list of samples collected, are supervised in the field by the geologist or geotechnical consultant. Especially during exploratory drilling and coring, a large number of heavy samples may be obtained in a day's work. Specify in the Scope of Work who will provide a truck or trailer of sufficient capacity, and labor for transporting samples to the storage facility each day. More information on the Scope of Work document can be found in the subsection entitled "Contracting the Drilling Program."

(2) Storing Samples

Store samples in the designated facility, but prevent excessively high temperatures. Organize samples by drill hole in the storage facility. Use the inventory sheet developed in the field for confirmation and tracking of samples. Overburden, coal, and backfill samples may be separated for ease of handling.

(3) Completion of Activities Report

Require the geologist to complete a form summarizing all drilling data needed to meet regulatory reporting requirements. Figure 1 gives a good example of a form that may be used.

(4) Processing Samples

(a) Sample Handling

Submit samples for analysis to an appropriate lab promptly. Minimize delays and environmental extremes in storage or transit. Geotechnical samples must always be protected from excessive temperatures or drying out, as their properties can be altered significantly by these processes. Ordinary air temperatures are usually not detrimental to coal and overburden samples, but direct sunlight may increase sample temperatures excessively.

Samples for chemical analysis are often sensitive to changes in temperature, humidity, or contact with the air or other substances. Time restrictions may apply, especially when analysis is to be performed for chemical properties which vary significantly with biological activity in the sample or which exhibit high volatility. Consult with the laboratory performing the analysis to determine if special handling or field procedures are required to assure valid results.

(b) Specifying Tests Required

Verify that all necessary testing has been included in the Scope of Work for the laboratory, and communicate with laboratory representatives for clarification.

Drilling Project Report Summarization

HOLE TYPE	HOLE NUMBER	LITHOLOGIC LOG	ELECTRIC LOG	DRILLERS LOG	COAL ANALYSIS	OVERBURDEN ANALYSIS	WATER ANALYSIS	RECLAMATION REPORT	COMPLETION REPORT	COMMENTS
BACKFILL										
DEWATERING										
EXPLORATION										
GEOTECHNICAL										
MONITORING										
PRODUCTION										

(c) Interpreting Results

Review the data and compare with previous data, noting significant changes in values or variability. Note values which appear anomalous, and evaluate possible causes.

b. Laboratory Responsibilities

In addition to hard copy, laboratories may also be able to provide data in digital format for ease of assimilation into computer programs currently used for statistical analysis, plotting, or drafting.

c. Program Administrator's Responsibilities

(1) Chain of Custody Forms

Review chain of custody forms that accompany samples to the lab, and document changes in custody as samples change hands during the process of analysis or transport. Look for completeness of the documentation and note discrepancies. Maintain a file of these forms for reference should problems be encountered.

(2) Processing the Data

Analyze the data, reducing it to a form appropriate for the context in which it is intended for use at the mine or by regulatory agencies.

(3) Presenting the Data in Usable Form

Computerize the data in a spreadsheet format such as Lotus. Data in this format can be sorted by hole number, location, depth, date drilled, hole type, etc. Disseminate this data to the users by appropriate means.

3. Reporting, Inspection, and Recordkeeping Requirements

Section editor: D.G. Steward *Subsection authors: Robert Cowan/D.G. Steward*

Applicability

Reporting and recordkeeping practices are vital to any successful drilling program. These needs must be identified and assigned to responsible parties.

Special Considerations

Some of the activities listed in this subsection may be efficiently carried out by more than one party and may be assigned at the discretion of the program administrator.

Techniques

a. Reporting

Reports, as described in the flowcharts in Figures 1 and 2 of the subsection entitled "Pre-field Permitting and Reclamation Planning", must be completed and documented. Drilling correspondence files should be developed and maintained by year and hole type to document all reporting activities. Include all items given in this flow chart in the documentation.

Documentation and reporting to the BLM should include geophysical and lithology reports, coal quality reports, and completion/abandonment forms. State Land Quality

annual reports should include information on holes drilled, reclamation of drill holes, and bonding. In Wyoming, remember to report to the State Engineer's Office any artesian well encountered during drilling.

b. Inspection

All holes should be inspected by the program administrator after drilling, installation (in the case of wells) and reclamation activities have been completed. A standard form may be useful in documenting that the holes are left in an acceptable condition. Reclaimed holes may be inspected by State or Federal regulatory authorities, at their discretion. It is best to conduct your inspection before such an inspection is conducted by an outside party.

c. Recordkeeping

Maintenance of drilling files usually falls to the person responsible for maintaining the geologic database. These files typically include computer files, hard copy files, and the all important correspondence file.

(1) Computer Files

Maintaining computer data files is an important part of the drilling program. Sample analysis data files should be kept together where they can be easily located. Backup diskettes may also be kept on file.

(2) Hard Copies

Hard copies of drilling information can be filed numerically by hole number. Each hard file should contain all information pertaining to that hole, including lithologic and geophysical logs, depth to water, and laboratory sample analysis data. It may be desirable to color code holes by type.

(3) Correspondence Notebook

Annual notebooks, subdivided by hole type, may be used to file copies of all correspondence.

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