Design and Construction Guidance Document for Precious Metals Heap Leach Extraction Facilities

prepared by

JBR Environmental Consultants

for

the Utah Department of Environmental Quality

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DESIGN AND CONSTRUCTION GUIDANCE DOCUMENT FOR PRECIOUS METALS HEAP LEACH EXTRACTION FACILITIES

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JBR ENVIRONMENTAL CONSULTANTS, INC.

for

THE UTAH DEPARTMENT OF ENVIRONMENTAL QUALITY

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1 INTRODUCTION/PROJECT OBJECTIVE

The Utah Division of Water Quality (the Division) has desired for a number of years that a guidance document for design and construction of cyanide heap leach facilities be developed that would be useful to both permit applicants and Division staff who review heap leach permit applications. This guidance document has been prepared for the purpose of serving these needs. In preparing this document, consideration has been given to design and construction guidelines for cyanide heap leach pads, ponds, and solution conveyances that are adequate for protection of human health and environmental values while considering economics of facilities construction. The Division's experience with cyanide heap leach operations permitted in the past, as well as the framework of regulations in existence in other western states, were considered in preparation of these guidelines.

The Division intends that these guidelines be applied flexibly, both by Division staff and the precious metals industry. These guidelines present technologies, not necessarily a set of minimum standards which have been acceptable to the Division in previous instances. The Division will consider alternatives to the design criteria presented in this document if such alternatives are demonstrated, to the satisfaction of the Division, to adequately protect ground water resources and meet the appropriate standards for best available technology [BAT]. These guidelines may be used by applicants in preparing designs and may be expected to result in design approval by the Division if the scope of issues discussed in the guidelines including future changes in technology and available materials are adequately addressed by applicants and site specific conditions are adequately taken into consideration so that best available technology is achieved.

2 ESTABLISHMENT OF BENCHMARKS FOR VARIOUS DESIGN CRITERIA

Utah's regulatory agencies, chiefly the Divisions of Water Quality and Oil Gas and Mining, began regulating cyanide heap leach operations in the late 1980s when a number of applications for construction permits were received from various mining companies. Since that time, facilities that began production in the late 1980s have expanded. Through the application review process, on-going interaction with mining companies and/or their consultants, interaction with other Western States' regulatory agencies, and formalized staff training, the Divisions of Water Quality and Oil, Gas and Mining have developed a knowledge base of applicable science for design and construction criteria for cyanide heap leach facilities. The Division of Water Quality considered promulgating regulations for the design and construction of heap leach facilities; however, the Division recognized that specific, detailed regulations could unnecessarily inhibit or constrain facility designs and restrict consideration of site-specific conditions or new technologies.

These guidelines reflect the Division of Water Quality's experience and current understanding with regard to design and construction of cyanide heap leach facilities and have been assembled with the intent of providing guidance to potential applicants for a precious metals heap leach extraction facility.

Geologic, hydrologic, climatological, and terrain conditions are unique to each potential mining and heap leach site; therefore, the Division cannot approve a permit application unless these key factors are addressed in the design of heap leach pads and ponds. On a larger scale, these factors result in physiographic settings that define the unique diversity of each state. Just as some of these physiographic settings are shared between or among states, some heap leach design guidance criteria are also appropriately shared.

Utah regulates facilities that may discharge to ground water under its Ground Water Quality Protection Rules (R317-6, *Utah Administrative Code*) establish ground water quality standards (generally the same as federal maximum contaminant levels for drinking water) from which, after consideration of site-specific background ground water quality data, site-specific ground water protection levels are established. These protection levels represent levels which may not be exceeded at compliance monitoring points (usually monitor wells) and they are most often well below the ground water quality standard and slightly above background. Utah has a policy of *anti-degradation* of ground water and this policy is reflected by these rather stringent protection levels. In the event that an exceedence of the protection levels occurs, the Ground Water Quality Protection Regulations, R317-6, *Utah Administrative Code,* require corrective action.

In order to maximize success in the design and operation of a heap leach facility in Utah, the general design principles summarized in Table 2-1 should be carefully considered. The design features described in Table 2-1 will fulfill the requirements for best available technology for the types of facilities and different settings, but applicants may propose alternate designs which meet the requirement to protect ground water.

Table 2-1 General Heap Leach Facility Design Principles		
Potentially Impacted Resource	**Potential Source of Impact**	**Preventive Design Benchmark**
Surface Water	Solution Pond Release	• Appropriate Storm Events Considered in Pond Sizing • Adequate Solution Pumping/Recirculating Capacity • Adequate Primary and Back-up Power Supply • On-site Treatment Capability, if Necessary
	Leach Pad Release	• Adequate Diversion of Run-on from Areas Adjacent to Pad • Adequate Storm Event Design Considered in Solution Collection System Sizing • Adequate Barren and Pregnant Solution Pipe Leak Detection or Containment
Ground Water Quality	Solution Pond Release	• Adequate Foundation Design • Adequate Liner, and Leak Detection System Design if necessary • Appropriate Foundation and Liner Construction QA/QC Plan • Adequate Response/Repair Plan When Leaks Detected • Adequate Ground Water Monitor Well Array if necessary

Table 2-1 General Heap Leach Facility Design Principles		
Potentially Impacted Resource	Potential Source of Impact	Preventive Design Benchmark
Ground Water Quality	Heap Leach Pad Release	• Adequate Foundation Design • Adequate Liner System Design • Adequate Leak Detection System Design or Enhanced Liner System Design • Adequate Solution Collection and Conveyance System Design • Appropriate QA/QC Plans for all Above Components • Appropriate Response/Repair Plan if Leaks are Detected

3 SUMMARY OF HEAP LEACH PERMITTING REQUIREMENTS

3.1 Utah Permit Requirements Overview

The Division of Water Quality typically issues Construction Permits and Ground Water Discharge Permits for heap leach facilities, as described more fully in Section 3.2. The Division of Oil, Gas and Mining (DOGM) issues approvals of Notices of Intent and Reclamation Contracts for large and small Mining Operations based upon mining and reclamation plans submitted by the applicant with the Notice of Intent. Small mining Operations are defined as those disturbing less than five acres. Most heap leach operations would, with the associated mines and ancillary facilities, disturb more than five acres and fall into the category of large mine operations. Mining and reclamation plans for large mines must comprehensively address all aspects of facility operations and reclamation including surface and ground water protection, topsoil preservation and re-application, reclamation regrading, restoration of native vegetation, and restoration of natural surface drainage systems. The Division of Water Quality has primacy over all matters pertaining to protection of surface and ground water quality.

The Division of Air Quality issues Approval Orders for mining and heap leach operations covering emissions from stationary sources, mobile sources, and fugitive, and area sources. The Division of Solid and Hazardous Waste issue permits for any non-mining solid waste disposal that may occur on a mine site. Other permitting or notification programs managed by the Divisions of Environmental Response and Remediation (underground tanks), Drinking Water (public water supplies), and Water Rights may also apply.

Local governments may have special use permit requirements. Federal land management agencies, namely the Bureau of Land Management and the Forest Service have permitting and environmental approval requirements for all mining operations on public land.

3.2 Division of Water Quality Permit Requirements

Construction and/or ground water discharge permits, as required in R317-1 and R317-6, *Utah Administrative Code*, respectively, must be obtained from the Executive Secretary of the Water Quality Board before beginning the construction of the leach pad, process water pond, and tailings depositories. Permits will be required for heap leach pads and ponds and may be required for: ore and waste rock stockpiles, process liquid conveyance components, chemical holding facilities and other areas which may cause a discharge to surface or ground water. Planning for the heap leach operations should be preceded by a Pre-design Conference attended by appropriate staff from the Division of Water Quality, the Division of Oil Gas and Mining, as well as other regulatory agencies. Supplemental dialogue, including informal telephone discussions and meetings, during the design process is encouraged. Through its experience in approving a number of currently operating gold heap leach operations, as well as its ordinary program for permitting of pollution prevention and waste water treatment facilities, the Division of Water Quality has determined that permit applications should consist of an engineering report, construction plans and technical specifications for construction of the pertinent components of the project. The appropriate permits will be issued when the applicant has demonstrated to the satisfaction of the Division of Water Quality that plans submitted are complete, that selected designs and technologies are appropriate for the project setting, and that the facilities as designed would, under the operating conditions described in the application, meet the rules. Construction and ground water discharge permits are generally issued concurrently, and application for same should be made at least 180 days before desired approval.

Mining and heap leach operations are subject to storm water pollution prevention plan requirements under the Utah Pollutant Discharge Elimination System (UPDES), R317-8. These facilities may also be subject to permitting of point source discharges. Heap leach facilities are universally designed as zero-discharge facilities. Those technologies that are reviewed and approved as a part of the permits approval process are considered best available technology for that project. Discharge to surface waters from heap leach facilities would only be allowed following treatment of effluent to demonstrate that all Federal New Source Performance Standards, all water quality standards applied at the discretion of the Executive Secretary of the Board of Water Quality, and applicable water quality standards for the receiving stream under R317-2, *Utah Administrative Code*, would be met.

3.2.1 Engineering Report

An engineering report should be submitted which contains sufficient information to establish the scope, basis of design and feasibility of the project. It is recommended that the report be submitted before preparation of final plans and specifications for approval by the Executive Secretary. Engineering and design aspects of the report should be prepared under the direction of a registered professional engineer licensed to practice in the State of Utah. It should provide basic project information, criteria and assumptions, evaluation of alternate designs, if desired, preliminary plan layouts, architectural, structural, mechanical sketches, brief process description which details all waste streams, assessments of all environmental factors, conclusions and recommendations with a proposed design for consideration; and a proposed construction and operations schedule for the project.

In addition to the requirements shown above, the report should contain applicable information, including the following items:

- Name of the applicant, legal status of the organization - i.e. corporation, partnership, etc., an authorized and designated representative or agent, responsible corporate officers, mailing address, and telephone number.
- Land ownership status of the facility - i.e., federal, state, private or public.
- A topographic map showing the location and extent of the following within two-mile radius of the site:
    - complete information regarding the local hydrologic regime including such features as: wells, springs, wetlands, flood plains, surface waters, irrigation ditches, all surrounding uses of ground and surface waters, process water supply sources, public and private drinking water supply sources, stock and irrigation wells;
    - site access information regarding service roads, public roads and other means of access;
    - all existing and proposed buildings, structures and other site improvements;
    - components of the facility intended to contain, treat, or dispose of process water or water contaminated with process chemicals;
    - property boundaries and land use and ownership information;
    - area disturbances including area to be mined, ore stockpiles, waste rock disposal areas, topsoil stockpiles, and erosion control structures, including diversions and sediment basins.
- Information on subsurface geology, ground water conditions and ground water quality, beneath the site and within a one-mile radius of the site
- Schematic drawings showing, locations of process ponds, leach pads and extraction plant with all utilities and process piping.
- Materials required for construction of various components of the facility and schematic details showing

proposed types of sealing systems and foundation construction for process pons and leach pads.

- Construction or installation quality assurance, testing, and certification procedures for all components of leach pads, solution ponds, solution collection systems, and any necessary secondary containments in the facility, i.e. liner systems, foundations, etc.

- Chemical quality and material safety data sheets on the leaching agents.

- Potential project impacts on the local surface and ground waters.

- Climatological data for the area needed to develop a hydrologic mass balance diagram to be used for sizing of the process ponds. Information should include precipitation and evaporation data, and local topographical run-off characteristics.

- Calculations to determine sizing for all process and hydraulic containment and conveyance structures.

Description of adequate domestic wastewater facilities during construction and during the life of the project. The requirements of *R317-5*, and *R317-501* through *R317-515, Utah Administrative Code,* should be reviewed in consultation with the local health department.

3.2.2 Construction Plans for Leach Pads, Solution Ponds, Solution Collection Systems, and Secondary Containments

A complete set of construction drawings must be submitted for review by the Division of Water Quality. All waste water treatment facilities are required to submit such plans (R317-3, *Utah Administrative Code*) Plans should show a project title, name of sponsoring entity, current revision date, and name, registration number, seal and signature of engineer designing the project.

The construction plans should include:

- Vicinity and Location Plans
  - A large scale vicinity map should be provided for a suitable geographical location reference to the project. This map should also indicate all access routes to the project and outline the drainage area that could impact the heap leach facilities due to the generation of runoff from storm water or snowmelt.

- General Site Work Plans
  - The plans should show the locations of pertinent facilities and improvements, all natural and artificial streams and water impoundments, the complete storm water management scheme, the direction of flow and water surfaces, with elevations, should be clearly shown. A flow routing plan should be prepared that shows leachate collection, interconnecting pond spillways, and plumbing and pump lines to and from the ponds and process area. All

topographic information should be shown with contours drawn at the smallest reasonable contour interval to adequately depict necessary construction details, but to also enable the contours to be clearly discernable. In general for detailed plans, contour intervals should range from one to ten feet, depending on the steepness of the terrain depicted. In areas depicting steep terrain, the contour interval should be reduced locally to present a clear drawing unobscured by excessively dense contour lines. For general plans, contour intervals of from 10 to 40 feet are usually adequate. The scale for general site work plans is typically 1 inch = 200 feet; however, an alternate scale, so long as it adequately depicts all necessary information, is acceptable.

- Detailed Plans

  - Detailed plans of ponds, pads, chemical holding facilities, process fluid conveyance facilities and other places where spills of process fluids may occur must be submitted for review.

- Specifications

  - Complete technical specifications for the construction of leach pads, process ponds, storm water and process liquid conveyances, structural fill or foundations, ore depositories, chemical holding facilities, and other areas which may cause a discharge to surface or ground water should accompany the plans. The specifications accompanying the plans should include all construction information not shown on the drawings, which is necessary to inform the builder, in detail, of the design requirements for the quality of materials, workmanship and fabrication of the project. The specifications should include all Quality Assurance/Quality Control procedures and standards required to properly implement the construction.

- Revisions to Approved Plans and Specifications

  - Any changes, such as addenda, change orders, field changes etc., to the approved plans or specifications affecting capacity, flow, operation of units, or point or quality of discharge should be submitted for review and approval before any such change is made in either contract documents or construction. Plans or specifications proposed to be so revised should, therefore, be submitted at least 30 days in advance of any construction work which will be affected by such changes to permit sufficient time for review and approval. Field changes that require immediate approval should be reviewed orally with the executive secretary or his/her designated staff prior to their implementation. They may then be approved verbally, and then should be submitted to the executive secretary in writing within seven days of the change.

- The applicant should include copies of information prepared for other state and federal agencies for review and approval, as a part of the design package. The available information on spill prevention, and control, operations during emergency conditions, contingency plans, etc. will facilitate the review of the project.

4 DESIGN AND CONSTRUCTION GUIDANCE

4.1 Heap Leach Pads

4.1.1 Pad Foundations

Leach pad foundations should be designed and constructed so that the liner is not subjected to any movements which would jeopardize the integrity and function of the liner system or any under-pad leak detection system which may be included in the overall facility design. The slope of the leach pad and the stability of the foundation materials are key factors in designing and constructing an effective leach pad foundation.

Consideration during design should be given to stability of the foundation under both static and dynamic conditions. If the foundation of the leach pad liner system is to be natural materials (soils, unconsolidated sediments, or bedrock), the structural properties of the natural foundation should be documented through appropriate field and laboratory testing. If the leach pad systems are to be constructed on fill materials, the material selected for foundation construction should be appropriately tested and characterized.

A geotechnical site investigation of the proposed leach pad site prior to layout and final design should be conducted. The investigation is conducted in order to obtain information relating to foundation conditions beneath the proposed heap leach pads, ponds and any associated structures, where construction will change the stress in the existing subsoils and rock. A minimum of one backhoe trench or soil boring per acre of heap leach pad area is recommended, to provide a reasonable estimate of subsurface conditions that may be encountered, and to provide the necessary data for design rule of thumb of one test pit or boring per acre should be considered a guideline by applicants. If soil or bedrock conditions at a site are variable, increased sampling may be necessary to ensure that the foundation materials are adequately characterized. Fewer borings may be necessary if soil conditions are generally uniform. Strength values for the foundation materials such as: natural soils, unconsolidated sediments and imported fill material are best determined through testing of the specific materials by direct or triaxial shear laboratory testing. The strengths of competent foundation materials such as bedrock are typically estimated based on information in published documents.

Prior to construction, the complete technical design for the foundation along with the construction and material specifications that meet the established design criteria should be reviewed and approved by the Division. The construction specifications should also include the quality assurance and quality control [QA/QC] procedures to be used to monitor the construction of the foundation. An example table of contents for a technical design report, technical specifications and QA/QC procedures is found in Appendix A. In considering design of the foundation the following elements should be considered:

- Local topography has a bearing on depth of required fill and cuts, has important implications for the placement and type of required fill material, and the slope of leach pad.
- The makeup of the foundation materials and their physical parameters.
- The static and dynamic loading conditions to be applied to the foundation.

Key criteria for acceptability of the foundation design are:

- The integrity and function of the liner system or any under-pad leak detection system which would be included in the overall facility design will not be compromised by the result on any movement or failure to the foundation.
- The foundation should withstand the projected static and dynamic loading and the projected differential stress.
- A foundation surface slope of between four and six percent is generally accepted by the Division; however, steeper slopes would generally require additional design and failure analysis.

4.1.2 Pad Loading and Solution Collection

The pad liner surface should be protected from damage by rock, whether it be run-of-mine or crushed rock, during loading. This is most commonly accomplished by installing a granular cushion layer over the primary leach pad liner. This layer may also be referred to as an over-liner or a drainage blanket. Such a layer commonly serves the dual purpose of providing a medium for transport of leach solutions along the base of the heap to the pad margins as well as a protective layer for the liner. In the design of this layer, the following should be considered:

- the size of ore to be placed on the heap;
- the method of pad loading;
- the rate of solution application and the design storm event to be conducted through the solution collection layer;
- the pad slope and configuration.

All of these factors should be considered when determining the thickness and material specifications of the over liner material.

Key criteria for acceptability of the over liner design are:

- over liner thickness and functionality as a protective blanket; and,

- the maximum hydraulic head on the primary liner taking into account the thickness and hydraulic properties of the over liner blanket and of the overlying ore.

Unless otherwise justified based upon site specific criteria and other heap leach pad design components, the system should be designed with a hydraulic head of no more than 12 inches. In addition, the design should ensure that the pad liner will not be damaged by loaded ore or the ore loading equipment. In the Division of Water Quality's experience; an over liner thickness of no less than two feet is desirable. The size and shape of the particles that comprise the over liner should be based upon field conditions and should meet the specifications called out by the manufacturer of the synthetic liner when the maximum thickness of ore to be placed on the leach pad and proposed ore loading methods are taken into consideration. In the event that compatibility with these specifications cannot be demonstrated, consideration should be given to modifying the over liner materials or increasing the thickness of the synthetic liner.

4.1.3 Pad Liner Systems

The pad liner system should consist of a composite liner comprised of a geomembrane placed on top of and in direct contact with a soil or soil-amended liner which exhibits low hydraulic conductivity. The overall pad liner design must be demonstrated to provide sufficient protection of ground water that site-specific ground water protection levels are met.

Geomembrane liners are manufactured from synthetic materials which can be polyvinyl chloride (PVC), hypalon, high density polyethylene (HDPE), very low density polyethylene (VLDPE), polypropylene (PPE), Derry Oil Company's Membrane 6, and chlorinated polyethylene (CPE). All of these liner materials are compatible with typical cyanide heap leach solutions. To ensure compatibility with the lixiviant to be used, applicants should consult manufacturers' specifications when considering options for synthetic liner materials,

Soil liners can be produced from on-site or nearby borrow materials or mixtures of both, while soil amended liners use bentonite or other soil additives along with the local soils. Soil liners that are produced from native borrow materials are typically high in clay content and are typically referred to as clay liners.

Geomembranes are manufactured in a number of different thicknesses. Important factors to be considered during the design and selection of the type of the geomembrane liner include:

material type, including factors such as: thickness, strength, durability and cost

static and impact loading that may be imposed during construction and operation,

slopes on which the liner will be placed,

hydraulic head expected on the liner,

interface strengths along the geomembrane, bedding and ore contacts

potential for exposure of the geomembrane to sun wind and temperature variations, the availability and quality of the bedding and cover material either on-site or from nearby local sources,

and construction and installation methods to be used and time of year of the proposed construction.

The selection of a liner system and its materials of construction should be based on site specific conditions and is generally specified by the applicant. The strength of the geomembrane selected for the pad liner is important since this membrane is subjected to stresses from the weight of the heaped ore as well as local concentrated stresses caused earth moving, pad loading, and possible irregularities in the foundation. It has been the Division's experience that HDPE is the most widely used geomembrane in liner systems, and that the minimum thickness of HDPE which should normally be considered for pad liners is 60-mil.

The soil liner should be a minimum of 12 inches thick and should have a maximum permeability of 1×10^{-7} centimeter per second. The maximum recommended lift thickness for the soil liner is six inches. The soil liner materials should be compatible with the process solutions and those process solutions should not cause an increase in hydraulic conductivity of the liner. The soil liner construction and QA/QC should be certified by a registered professional engineer. The operator should verify that the construction design and specifications have been completed according to the approved plans prior to loading the pad. Important factors to be considered during the design of the soil liner are:

Availability and quality of the on-site or local soil materials;

Soil material characteristics and composition including: permeability, chemical compatibility with leachate, and plasticity;

Soil material characteristics related to constructibility including: work ability, preparation and mixing requirements, and compaction;

Laboratory testing procedures of the soil liner materials typically involve the determination of the following material properties: gradation, plasticity, moisture content, unit weight, specific gravity, hydraulic conductivity, strength (determined by; unconfined compressive tests, direct shear and or triaxial), and compaction (determined by standard or modified proctor)

Heap leach pads currently permitted in Utah have full under-pad blanket leak detection/collection systems. These permitted systems leak detection systems have included: a demonstration that soil will not migrate into the leak detection medium; a seepage detection media (typically an aggregate material with hydraulic conductivity of no less than 1×10^{-2} centimeter per second.); a seepage collection and conveyance system which consists of perforated pipes placed at the bottom of the leak detection layer (each of these pipes discharges into an individual contained discharge point which can be visually monitored); and, a seepage detection system seal or clay liner located beneath the seepage collection and conveyance pipe. These leak detection systems have typically been installed directly over the pad foundation. The upper 12 inches of the foundation serves as a barrier to vertical fluid flow and cause leaked fluids to be trapped and laterally transported. The Division's most recent experience suggests that the upper 12 inches of the foundation should have a permeability of 1×10^{-6} centimeter per second. or less. The leak detection pipe should be perforated (except on the bottom) to collect fluids and transport the fluids to detection/collection ports.

The Division believes that leak detection should be considered as part of the pad liner design. Figure 1 depicts several examples of liner systems with leak detection systems. The extent and nature of the leak detection system under the pad should be sufficient to demonstrate that the liner system will protect ground water quality at the site.

In order to approve any leak detection system, the Division would require that the design be supported by calculations that demonstrate that the system would actually perform in the proposed manner.

Large leach pads should be constructed to allow for the segregation of ore into a number of cells. These cells are created by building small internal berms during foundation and underliner construction. These berms are then covered by the synthetic liner. During operation of the heap these cells can be operated as if they are independent heaps, with dedicated solution collection and leak detection systems. The leak detection system should also be segregated by the berms, so that if a leak in excess of the permitted quantity is detected, the cell from which the leak is originating can be determined. This segregation of solution should allow the operator to continue operations on other cells of the heap while the liner system of the cell reporting the leak is repaired or decommissioned.

The Division views an under-pad leak detection system as an early warning system in the event of a release of solutions through the composite liner. The Division considers the leak detection system as a no-flow boundary. Any detectable leakage is considered a best available technology failure, but, it is not necessarily deemed to be a violation of the ground water permit. The operator or the permit holder may present an affirmative defense concerning the leakage. Such a system may enable the operator to isolate the leak, control solution application to the leaking pad cell, and more cost effectively direct any necessary repairs before ground water is contaminated. If the design includes a geomembrane underlying the leak detection zone, then an allowable leakage rate will be set for the design. If ground water contamination in excess of the established site-specific protection levels is detected in a monitor well(s), immediate action to eliminate the source of contamination may be required. In addition, an investigation of the extent of ground water contamination and development and implementation of a corrective action plan may also be required.

An engineering As-Built and Quality Assurance (QA) report should be prepared by a licensed professional engineer, prior to pad use, certifying that the materials as placed, and workmanship during construction of the liner system were in substantial conformance with the technical specifications and accepted construction practices. Any significant changes, to the previously approved design, to be made during construction should be approved by the Division prior to construction. The As-Built/QA report, should include: the daily quality assurance field reports, field and laboratory testing reports for the earthwork involved in the placement of the soil liner, and detailed information about the geomembrane and its installation such as: material quality control certificates from the manufacturer, seaming schedules, geomembrane panel location as built drawings, destructive seam testing and water tightness testing and inspection. The report should also contain as built drawings of the liner system. An example table of contents for an As Built/QA report is found in Appendix B.

Key criteria for acceptability of the pad liner system design are:

- The liner system for a heap leach pad should function under a variety of physical and chemical conditions to which it is exposed during construction, operation and throughout the reclamation and closure phases of the project. In addition the liner system should maximize leachate collection and minimize leakage to the environment.

- A demonstration that the liner system has, with an acceptable safety factor, the ability to prevent leak from within the engineering composite liner.

- Demonstration that an effective under-pad leak detection system, designed to detect leaks form from the composite liner system, or an acceptable alternative, has been included in the overall leach pad design.

4.1.4 Solution Conveyance and Collection

Solutions transported through the drainage blanket or over liner are conveyed over slightly sloping pad surfaces to solution conveyance pipes or channels. In the Division's experience, leach pads should be divided into individual cells from which solutions are collected in pipes located at the down gradient margins of the cells. Additional piping may be necessary for solution head control (discussed below) or other operational reasons. The use of cells is desirable as a means of controlling solution application both for metal recovery purposes and to isolate leakage within a cell in the event that a leak is detected (Section 4.1.3). Figure 2 shows two general solution collection arrangements: one for external solution collection where solutions flow to channels at pad margins; and, one for interior solution collection where solutions flow to an interior solution collection channel. Interior solution collection is common in other states; however, with the exception of valley fill heap leach facilities (section 4.1.5), such are not currently in operation in Utah.

Solution collection channels then convey solution to one or more collection points, generally a sump, from which solutions are carried by pipeline or ditch to process ponds. Within the limits of the leach pads themselves, solution conveyance channels would represent those parts of the pad with the greatest exposure to large quantities of solution. In addition, for well designed heaps, solution heads would ordinarily be greatest in these channels.

In considering the sizing, location, liner, and leak detection needs of solution collection channels, the following should be considered:

- the volume of solution to be transported in the channels under normal and storm-loaded circumstances;

- the probable need to perform routine maintenance in open channels, resulting from rockfall or erosion of stacked ore from the flanks of the heap;

- the increased potential for liner leakage due to exposure to large quantities of fluids (relative to the remainder of the liner), solution head, and increased likelihood of liner damage due to maintenance-related activities;
- the need to repair liner leaks above the design leak threshold that are detected by the solution collection system leak detectors.

Key criteria for acceptability of the solution collection system design will be:

- the design precipitation event that is selected for sizing the solution collection channels;
- the liner system and leak detection system designs;
- the proposed maintenance and repair response procedures to respond to and repair damaged or leaking liners, obstructed channels, etc.;

A reasonably conservative design storm event is a storm with a predicted frequency of 100 years. The duration of the event (for example, 6 hours, 24 hours,,etc.) should be selected in order to assess the greatest potential for runoff depth and/or accumulation based on the individual site conditions. The SCS (Soil Conservation Service, or the US Natural Resource Conservation Service) Curve Number Method and the Type II storm distribution, as described in the *National Engineering Handbook, Section 4, Hydrology*, is an acceptable methodology in preparing appropriate runoff and fluid accumulation calculations. The NOAA [The National Oceanic and Atmospheric Administration, US Department of Commerce] Atlas 2, Precipitation-Frequency of the Western U.S., Volume VI-Utah or an alternative source approvable by the Division, should be used to obtain information on storm duration and frequency. In some cases where site-specific conditions may suggest that the storm events predicted in published sources may be understated, then use of a greater storm induced runoff concentration in planning channels sizes may be advisable. Meteorological baseline data should be considered if available; however, the limitations of the accuracy of short-duration precipitation data to predict long-term precipitation patterns should be recognized.

Adequate leak prevention and leak detection is considered critical beneath solution conveyance components of heap leach pads. These components typically have the greatest solution heads and are thus more susceptible to significant solution release via small leaks. In addition, significant tears, holes or seam separations can result in large quantities of solution release in areas of high solution flow volume if separations of the primary synthetic liner from the underlying liner occurs. This is most likely to occur at pad margin solution collection channels where the weight of overlying ore is not present to hold the liner closely to the underlying secondary liner.

A program of regular and frequent inspection and maintenance of exposed solution collection channels is also essential to allow for identification and repair of liner damage, evidence of possible unstable conditions in clay secondary liners or pad margin foundation conditions (soft spots, channel flow irregularities, etc.), or blocked channels resulting from rockfall or channel deposition resulting from excessive erosion of ore stored on the pad.

The Division recommends that the exposed portions of the liner around the periphery of the pad, which are not covered by the ore heap or granular cushion layer to a depth of more than ten feet, including the process fluid collection catchments, be overlain with an additional impermeable protective layer.

A geogrid or other hydraulically conductive material is also suggested for installation between the protective over-liner and the primary liner in the solution collection channel to direct any leaks to collection points. The solution transmittal layer should be designed to isolate leakage along the collecting ditch at reasonable intervals (a suggested interval is approximately 200 feet). Ports for monitoring the presence of solutions in this layer should be considered at the low end of each section. These ports should be equipped to allow monitoring of solution volumes reporting to them and removal of collected fluids to the main solution collection system. This system, is intended to monitor seepage through exposed areas of the top geomembrane in this peripheral area.

In the event that leaks are detected in a pad margin solution transmittal layer, the leak should be identified and repaired as soon as possible. A schedule for leak responses and repair based upon a pre-established leak release rate should be proposed in the design report. A low leak release rate is recommended, since repairs in pad margin leak detection systems can be readily affected. Typically leak release rates are represented as volume per unit area of liner surface area per day. A leak rate of no greater than 200 gallons per acre per day is accepted as a leakage rate threshold value.

In other states, solution collection channels have also been located beneath the pad (refer to Figure 2). Because leaks cannot be readily repaired when the solution collection system is entirely under the leach pad, a secondary solution collection system with a leak detection system should be considered in the design. In such instances, leak detection systems installed beneath the solution collection channels or pipes should have the capability to detect leaks with approximately the same efficiency and with the same confidence in isolating the leak as is the case for pads with exterior solution collection. Since detection of a leak would result in the need to repair the leak and cease some or all leach pad operations temporarily or permanently (depending on the leak location and the cost to repair it), applicants should give careful consideration to the impact of such repairs or shutdowns, as well as he potential costs for ground water corrective action, on the project economics before selecting this method of solution collection placement of solution collection channels beneath heaps.

Solution channels typically flow to collection sumps at leach pad margins. These sumps typically serve the purpose of collecting the water from the pad and transferring it solution conveyance channels or pipes that conduct the solutions to process ponds. Sumps are generally constructed of geomembrane, concrete or both and should be designed and constructed with at least double liners and leak detection systems. Due to the high solution flow rate through sumps, repairs should be made to leaks as soon as possible after their identification.

Solution conveyances through which solutions are transferred either directly or indirectly to process solution ponds are typically open channels, pipes or both. Such solutions conveyances should be designed with secondary containment and some means of leak detection. For example, if an open channel is used, a liner/leak detection system like that described above for pad margin solution collection channels would be necessary. If a pipeline in a lined open channel is used, visual leak detection in the channels may be adequate, depending upon the pipe and liner materials used and the condition of the channel and visibility of the pipe. If buried pipelines are used for transfer of any process solution, the pipes should be double-piped and monitored for leaks.

4.1.5 Valley Fill Heap Leach Facilities

The Division of Water Quality's experience with valley fill heap leach facilities is limited in comparison to its experience with permitting conventional heap leach pads and ponds. Valley fill leach facilities typically have high hydraulic heads, steeper slopes that serve as liner foundations, and very high loads on these steep slopes. These conditions can make design of a heap leach system with an acceptably low risk of leakage difficult.

The Division has not developed extensive guidance specifically for design and construction of valley fill heap leach facilities. The design considerations described above for pad foundations (Section 4.1.1), pad loading and solution collection (Section 4.1.2), and pad liner systems (Section 4.1.3) for heap leach pads also apply in large part to valley fill heap leach facilities. Additional comments regarding design considerations are presented below.

- Foundations for valley fill leach facilities are typically comprised of native soil or bedrock beneath much of the heaps themselves. The key to good foundation strength in most valley fill heaps is the retaining structure located at the down-valley terminus of the heap. A thorough and complete foundation investigation and a containment structure design that demonstrates stability under both static and dynamic conditions is essential. The geotechnical stability of the valley floor soils or bedrock beneath the fill should also be demonstrated.

- Pad loading for valley fill heaps requires special consideration of the ore itself, which must be durable and have inherent strength sufficient to provide a foundation for successive ore lifts under saturated conditions. A demonstration that the protective blanket over the liner can protect the liner during ore placement should be provided. Control of solution heads on the liner system is required; however, the Division recognizes that valley fill heaps are designed to store solutions. Therefore, it is essential that the liner system and any leak recovery or detection system be designed in response to predicted hydrostatic heads.

- A composite pad liner either as a primary or secondary liner is also considered advisable for valley fill heaps by the Division. In addition, a leak detection system beneath those parts of the fill where significant hydrostatic heads is considered by the Division to be an essential design element.

4.1.6 Heap Leach Pad Closure

Heap leach operators are required to submit a conceptual closure plan with their ground water permit application and a comprehensive final closure plan near the end of the operational term of the heap leach. The plans should address neutralization of heap materials, identification of persistent contaminants, final grading and cover, and long term management of heap leach solutions. The Best Available Technology standard of the Ground Water Quality Protection Regulations applies to each of these closure aspects.

The Division of Water Quality has not developed specific numerical chemical standards for leach pad rinsate. The Division does require the application of Best Available Technology with the goal of achieving heap rinsate concentrations of 0.2 milligrams per liter Weak Acid Dissociable (WAD)-cyanide, a neutral pH and the Ground Water Quality Standards for dissolved metals, nitrates and other contaminants. Neutralization could utilize the appropriate combination of rinsing, recirculation, water treatment and chemical addition in an attempt to meet these goals prior to regrading and placement of cover material. The Division recognizes that in most cases one or more contaminants will persist in concentrations above these goals. Column neutralization studies are generally performed to aid in assessment of the effectiveness of the rinse media (e.g. fresh water, recirculated rinsate, or chemically amended rinse water), rinse media volume requirements, and duration of rinsing.

Based on the type and concentration of the persistent contaminants in the heap leach rinsate, the site specific vulnerability of ground water and the performance of the heap pad liner during facility operation, an appropriate cover is designed. Best available technology in terms of heap leach pad cover is defined as cover that insures that protection levels at individual monitoring points are met both at the time of closure and into the foreseeable future. Minimum cover design includes sufficient soil for the establishment of vegetative cover, the establishment of vegetation in accordance with DOGM standards and the grading of side slopes sufficient to prevent erosion of the cover. More extensive cover design may be required for facilities in recharge areas, sites with high annual precipitation or heap leaches that leaked extensively during operation.

Post closure management of heap leach drain down and infiltration fluids is required. Surface discharge of heap leach solutions is normally impracticable due to the high cost of water treatment. Management strategies that may be acceptable under site specific conditions are the evapotranspiration of drain down solutions by reapplying rinsate to the heap leaches, construction of passive bio-treatment systems prior to discharge in infiltration galleries or even direct infiltration when expected water volumes and pollutant concentrations are low enough that site-specific ground water protection levels would not be impacted.

Applicants should be aware that the Utah Ground Water Quality Protection Rules have corrective action provisions which may require that corrective action (consisting of a contamination investigation and preparation and implementation of a corrective action plan) be taken in the event that aquifer contamination occurs as the results of a release of contaminants to ground water. Closed facilities can be considered subject to the corrective action regulations if the closure plan provisions regarding ground water protection are not met and an adverse impact to ground water quality is demonstrated.

4.2 Heap Leach Ponds

Solutions collected in leach pad solution conveyance collection systems are typically conveyed to open solution ponds. These solutions, known as pregnant solutions in the extractive minerals mining industry, are typically delivered by open channel or pipeline to the pregnant solution pond. Other solution ponds typically found at heap leach operations are barren solution ponds (ponds for storage of and preparation of leach application solutions) and make-up water or fresh water ponds. Solution ponds commonly store or have the potential to store large quantities of solutions under conditions of high hydraulic head. Those solution ponds which store or may store process solutions (such as barren or pregnant solution ponds) are the subject of this guidance.

Determination of the capacity, foundation design, liner design, and leak detection designs for solutions ponds should consider the following:

- storage volume requirements based upon normal and precipitation induced flows from the leach pads;
- the affect of local topography on cuts and fills and foundation materials characteristics;
- the static and dynamic loading conditions to be applied to the foundation;
- appropriate liner selection criteria (see Section 4.1.3);
- the need for rapid detection of and response to leaks; and,
- maintenance access requirements to the liner and leak detection system.

Key criteria for the acceptability of the solution pond design will be:

- the liner system and leak detection system designs;
- the proposed maintenance and repair response procedures to respond to and repair damaged or leaking liners;
- "ordinary" solution storage requirements based upon consideration of solution inventory, pumping capacity (including back-up pump and power supply capacity), and other appropriate considerations; and,
- the design precipitations event and precipitation impact considerations that are selected for sizing the solutions ponds.

It has been the Division's experience that a solution pond liner/leak detection system consisting of the following principal components can provide an adequate liner/leak detection design:

- a primary geomembrane liner of 60 mils in thickness or greater over a high permeability leak detections layer consisting of geonet or granular media; and
- a secondary liner immediately beneath the leak detection layer that consists of a composite liner like that described in Section 4.1.3 for leach pad primary liners

The guidance for design and installation (including QA/QC) of foundations, geomembrane liners, and soil liners provided for leach pads in section 4.1.3 should be followed for design and construction of these components of solution ponds. Leak detection thresholds related to increased monitoring and repair should also be established. The Division has typically approved a leakage rate of 200 gallons per acre per day in solution pond leak detection systems.

Solution containment capacities should include the capacity to contain ordinary process solution inventories, the solution volume that would return to the ponds as the result of pump failure for an established time period, the increased solution volumes derived from design precipitation events and the contribution of snowfall, if appropriate. Until recently, a rule of thumb guideline in Utah and elsewhere for the design storm event has been the 100-year, 24-hour storm. In general, the Division considers this design storm event to be a minimum storm event for sizing of solution ponds. In some cases, however, the Division's experience indicates that additional allowances for storm retention capacity may be required to accommodate the influence of successive closely spaced precipitation events. The influence of precipitation-derived solutions due to ordinary seasonal precipitation can exceed the volume from a single low-probability design storm event. At locations where, for example, heavy snowfall, winter rainfall, heavy spring rainfall or a combination of these conditions occur such that precipitation-induced solutions accumulate well in excess of the evaporation rate, the cumulative solution volume derived from such precipitation events could exceed the volume of solution derived from a single design storm. For this reason, solution storage volume at a heap leach facility may need to include capacity for more precipitation-induced solution than would result from a single low-probability storm event.

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APPENDIX A

COMPARISON OF
HEAP LEACH DESIGN AND
CONSTRUCTION REQUIREMENTS OF
SELECTED WESTERN STATES

Construction Requirements of Selected Western States

Western states have taken varying approaches to regulation and guidance for heap leach facility construction and operation. Relevant regulations and guidance documents have been examined from the following states: Colorado, Idaho, Montana, Nevada, New Mexico, and South Dakota. Regulation of heap leach facilities by these states ranges from regulation under general water quality protection rules, without either regulations or guidance documents specific to heap leach facilities, to specific regulatory requirements for liners and other components, to relatively non-specific regulations with supporting detailed guidance documents.

Table A-1 presents a summary of regulatory requirements of guidance for selected heap leach facility components.

Colorado

Cyanide leaching operations regulation in the State of Colorado is administered through the Department of Natural Resources, Division of Minerals and Geology. Specifically, the regulations are promulgated by the Colorado Mined Land Reclamation Board in a document entitled *Mineral Rules and Regulations*. The Mined Land Reclamation Division is the technical arm of the Colorado Mined Land Reclamation Board, and is responsible for the implementation of board policies. Colorado has no explicit regulatory requirements for design and construction of heap leach facilities. The Mined Land Reclamation Division has published a guidance document entitled *Guidelines for Cyanide Leaching Projects*, in which technical specifications for cyanide leaching operations are set forth. These guidelines are meant to be used for reference purposes only, and do not carry the weight of regulation. Actual permitting of cyanide leaching projects is accomplished on a case-by-case basis, by the authority granted to the Colorado Mined Land Reclamation Board in the *Colorado Mined Land Reclamation Act, of 1973*. The guideline specifications for some of the components of a heap leach operation, as set forth by the Mined Land Reclamation Division, are listed below.

Heap Leach Pad Liners

All leach pads must be double lined. According to Colorado's guidance document, the four liner systems used predominantly in Colorado are: 1) two layers of synthetic material separated by a leak-detection layer of sand or geonet fabric; 2) a lower layer of clay or clay-amended soil overlaid by a leak-detection layer of sand and capped by an upper synthetic layer; 3) a composite liner comprised of a synthetic layer immediately overlying a clay or clay-amended soil layer; or, 4) a reusable pad. In no case should the synthetic liner be thinner than 40 mil. The type of liner system is proposed by the applicant based upon site conditions.

Soil-liner thickness guidelines are variable depending on site and installation factors. Topsoil must be salvaged for reclamation purposes and may not be used for liner construction. A minimum thickness of one-foot is called for with a standard placement of two-feet recommended. The actual thickness is determined based upon "the resistance of the materials to solution it will come in contact with", the degree of "care" taken in placement of the soil (careful placement justifies a thinner liner), and "the amount of traffic expected on the liner." The permeability of the soil liner should be a "maximum of 1×10^{-6} centimeter per second in order to qualify as an impermeable liner." A demonstration that the integrity of the soil liner material will not be adversely affected due to a reduction in permeability caused by contact with the proposed leach solution should also be made.

Heap Leach Pad Leak Detection

Leak detection is required for all four liner system types mentioned above and the system should be designed for "quick detection and recovery of any leaked solutions." The leak detection system "should be placed below the upper liner." Interlayered liners (types 1) and 2) described above)
should have a high permeability layer ("on the order of 1×10^{-2}centimeter per second) between the primary and secondary liners. No specific leak detection medium is required; however, either sand, finegravel, or geonet are listed as the "major materials" used in construction of leak detection layers.

For composite liners, the Colorado guidance document states that "solution may tend to flow along the interface between the two (2) liner layers" and that "solution can be captured at intervals along the hydraulic gradient." The following are listed as possible components of a leak detection system in a composite liner: a grid of perforated pipe embedded in the lower clay/soil component of the composite liner; a grid of synthetic material below the upper liner that will "wick moisture"; "strict quality control/certification on liner construction"; and, downgradient monitor wells.

Solution Pond Liners

All process ponds which normally contain cyanide solutions should be double lined. Two layers of geosynthetic material are recommended. If a soil liner is proposed for a lower liner, a maximum permeability of 1×10^{-7} centimeter per second is required. A collection sump is recommended. At least one interior side should be designed at 3h:1v to allow escape of persons who may have fallen into the pond.

Solution Pond Leak Detection

Leak detection systems are required for all process ponds which normally contain cyanide and should consist of sand or geonet on pond bottoms and geonet on side slopes where sand cannot be placed. The leak detection layer should be hydraulically connected to a solution collection sump. This sump should be accessible by a pipe of sufficient diameter to allow insertion of a submersible pump to remove solution.

Solution Conveyance

Double-lining is required for all solution conveyance ditches. Suggested configurations are dual synthetic liners or, if pipes are used, placement of pipes in lined ditches so that any leaks are readily detectable. The guidelines state that "[n]o leak detection layers are required in the solution conveyance structures. Instead, only visual inspection is called for. Buried pipelines which would carry cyanide-bearing solutions should be pressured-tested regularly to ensure their integrity and consideration should be given to using double pipe when pipelines are buried.

Table A-1 Comparison of Selected Heap Leach Design Criteria for Some Western States

State	Design Criteria							
	Leach Pad Liner	Solution Pond Liner	Pad & Pond Leak Detection	Solution Conveyance	Solution Containment	Foundations	Construction QA/QC	Spent Ore Detoxification
Colorado	-double lined, min. one synthetic liners -soil liner max. $K = 1 \times 10^{-6}$ cm/sec	-two FML req'd. -soil liner, if used, max. $K=1 \times 10^{-7}$ cm/sec	-required for leach pads and ponds	-double line all ditches -only visual leak detection required	-normal op. vol. -100-yr ,24-hr. -draindown -consider snowmelt	careful foundation prep. encouraged	recom-mended for soil liners	developed individually for each facility
Idaho	-continuous liner; natural or man-made; -soil liner max. $K= 1 \times 10^{-7}$ cm/sec, min. thk.=-12"	same as for pads	-required for ponds -site-dependent for pads	-not addressed in regs.	-max. op. water balance -100-yr ,24-hr. event -consider snow	-withstand static/dyna-mic loads & differential settlement	required for liners	- site-specific stds. for WAD CN & other contaminants, and - effluent pH between 6.5 & 9.0
Montana	All criteria are determined individually for each site & operation based on review of detailed designs and operations plans provided by the applicant, by DSL.							
Nevada	-composite liner or equivalent -soil liner on native soil max. $K=1 \times 10^{-7}$ cm/sec, min. 12" thick	-double liner; primary FML, secondary = reqs. for pad liner	-l.d. layer that will minimize head on secondary liner required for ponds	-not specifically addressed in regs.	-all process fluids + 25 yr, 24-hr event, -100-yr ,24-hr. event	-consider static/ dyna-mic loads & differential movement or shifting	-plan required for liners -summary required w/ as-builts	-rinse until WAD CN <0.2mg/l - pH 6.0 to 9.0 -other contaminants levels will not degrade waters of State -variances can be granted
New Mexico	All criteria are determined individually for each site & operation based on review of detailed designs and operations plans provided by the applicant, by DEQ.							
South Dakota	All criteria are determined individually for each site & operation based on review of detailed designs and operations plans provided by the applicant, by DENR.							

NOTES. The following abbreviations are used in this table FML — flexible membrane liner, K — permeability, l.d. — leak detection, op. — operating, min. — minimum,prep. — preparation, regs. = regulations; req'd. = required; stds. = standards, thk.= thickness; WAD CN = weak acid dissociable cyanide

Solution Containment

Solution storage requirements should at a minimum contain the normal operating storage volume, the solution volume induced by a 100-year, 24-hour precipitation event, the volume of water expected from heap "desaturation" (draindown), and one foot of freeboard. Consideration should also be given to the impact of snow melt. Containment of anticipated snowmelt volumes in solution ponds is preferable to snow removal as a means of control of snow melt impacts to solution containment systems.

Heap Leach pad and Pond Foundations

No specific requirements are listed in the guidance document, but reference is made to the importance of placement of liners on a "smooth" foundation and the need for careful foundation preparation to "ensure the long-term performance of the pad."

Construction QA/QC

Construction QA/QC is not discussed as a separate subject in the guidelines proper; however, an Appendix dedicated to Geotechnical Testing is included. This appendix states that "it is recommended that gradation testing, permeability, and proctor testing be performed at least once per week during construction of a soil liner." Although Geotechnical testing of "foundation soil" and "leach material" is suggested for design development and material selection, no Geotechnical testing of constructed foundation materials is called out. The appendix also states that "[a]dditional testing may be necessary on a site-specific basis."

Water Quality Monitoring

Water quality monitoring should occur throughout the life of the project both during the active operations and during the reclamation of the site. Monitoring of surface and groundwater should occur three to four times a year, more frequently if warranted by site conditions.

Neutralization/Detoxification of Spent Ore

The Colorado guidance document mentions several methods of heap detoxification; however, no specific method is mandated. Cyanide detoxification standards are developed individually by the MLRD in consultation with the applicant. Factors considered in developing these standards include baseline surface and ground water quality, nearby uses of water surface and ground water, expected effluent characteristics. In addition to cyanide detoxification standards, standards for metals in heap effluent may be established if geochemical testing of the ores indicates that elevated metals levels may occur. At the time the guidelines were written, no consideration had been given to establishment of standards for heap solids which may have increased metals content due to metals precipitation.

IDAHO

In Idaho, regulation of cyanide leaching operations is administered through the Idaho Department of Health and Welfare. Permits for cyanide operations are granted by the Director of the Idaho Department of Health and Welfare. Authority is granted to the Director in Title 39, Chapter 1, of the Idaho Code. The regulations under which the Director acts are known as the Idaho Department of Health and Welfare Rules and Regulations, Title 1, Chapter 13, ***Rules and Regulations for Ore Processing by Cyanidation***. Details regarding technical specifications of this type of operation are limited in the rules and regulations, however, all design and processing details are subject to the approval of the Director. Information submitted to the Director in pursuit of an operating permit must be of sufficient detail to allow the Director to make necessary factual determinations concerning design competence and environmental protection. The submitted facility design shall be certified by a registered professional engineer. The specifications listed in the rules and regulations for some heap leaching operation components are listed below.

Heap Leach Pad and Pond Liners

Idaho regulations call for a "[c]ontinuous layer of natural or man-made materials beneath and, if applicable, on the sides of a surface impoundment or leach pad which restricts the downward and lateral escape of liquids." Leach pad and pond liners should be designed for a maximum coefficient of permeability of 1×10^{-7} centimeter per second; a clay liner should also have a minimum thickness of twelve-inches. In addition, liner materials must be chemically compatible with materials contacting them and, when appropriate, minimal hydraulic head on the liner should be ensured.

Heap Leach Pad and Pond Leak Detection

Idaho regulations do not specifically require leak detection systems for leach pads; however, leach pad leak detection may be required depending on site-specific factors. Impoundments, including solution ponds, must "be designed for efficient leak detection and provide for adequate leak recovery."

Solution Conveyance

Solution conveyance is not specifically addressed in the Idaho regulations.

Solution Containment

Facility solution containment is required to accommodate "the maximum expected operating water balance" plus water resulting from the 100-year, 24-hour storm event. In addition, snowmelt events must also be "considered in determining containment capacity."

Heap leach Pad and Pond Foundations

Leach pads and impoundments should have a competent foundation designed to withstand the projected static and dynamic loading and projected differential settlement.

Construction QA/QC

Applicants must provide "[c]onstruction and material specifications that meet design criteria" with the application package. These specifications must include "major construction requirements related to materials of construction", necessary manufacturer certifications", "quality assurance procedure(s) for liner installation", and "a procedure for leak testing impoundments."

Water Quality Monitoring

A surface water and/or groundwater monitoring program is required. The parameters of the monitoring program are dependant on location, design, and operation of the cyanide leaching facility.

Detoxification/Neutralization of Spent Ore

With regard to chemical standards for heap closure, the regulations state that "disposal or abandonment of leached ore shall ensure that [t]he concentration of weak acid dissociable cyanide or free cyanide and other pollutants associated with Cyanidation in process-contaminated water draining from the leached ore is reduced to a level that is based on the disposal method, location and the potential for ground water and surface water contamination, or the pH of the process-contaminated water draining from the leach ore is stabilized to a pH between 6.5 to 9.0." In addition, the spent ore pile must be demonstrated to be stable following abandonment of the heap and surface and ground water monitoring to "verify that beneficial uses are maintained" is required following closure.

MONTANA

Operating permits for cyanide leaching facilities in Montana are issued under the authority of the Board of Land Commissioners, which consists of the Governor, Secretary of State, Attorney General, State Auditor, and Superintendent of Public Instruction. Actual issuance of permits is through the Department of State Lands, according to the provisions of the Montana Metal Mine Reclamation Act. Permits are issued on case-by-case basis. Few, if any, technical design requirements are published in the Montana Metal Mine Reclamation Act, however, the permit applicant is required to submit an in-depth plan of operations for departmental review and approval.

NEVADA

Cyanide leaching operations in Nevada are permitted through the Department of Conservation and Natural Resources, Division of Environmental Protection (NDEP). Heap leach facilities designs are regulated by the criteria in the document entitled "Regulations Governing Design, Construction, Operation and Closure of Mining Operations" (NAC 445). Nevada has the largest number of cyanide heap leach facilities in the United States; however, its regulations apply to all heap leaching activities including acid leach technologies for base metals. Its regulations describe general design requirements, requirements for liners, leach pads and "other non-impounding surfaces designed to contain and promote horizontal flow of process fluids", solution ponds, and other requirements. Nevada's regulations establish "minimum contaminant control technologies and define site and operating conditions which must be evaluated." Nevada's regulation allow for the application of best engineering judgement and consideration of site-specific conditions by NDEP in assessing whether "more or less protection through engineered containment" than specifically called for in the regulations will be required for each proposed facility.

Heap Leach Pads

Heap leach pads are required to be designed to maintain minimal solution head on the liner.
Leach pad liner systems must have containment capability equal to or greater than that of a composite liner consisting of a synthetic liner over one foot of compacted soil at a permeability of 1×10^{-6} centimeter per second or 1×10^{-5} centimeter per second if a leak detection system is used beneath portions of the liner with the greatest potential for leakage. In addition, specific minimum requirements for soil liners placed on "native materials" and synthetic liners used

for any purpose except lining of tailings impoundments are mandated. Soil liners placed on native materials must be compacted in lifts of not more than 6 inches, be at least 12 inches in thickness, and have a permeability of less than or equal to 1×10^{-7} centimeter per second. Synthetic liners must be rated as having resistance to fluid passage equal to a permeability of less than or equal to 1×10^{-11} centimeter per second.

The higher permeability standard for soil liners other than those placed directly on native materials reflects Nevada's recognition that soil liners placed on fill materials may be effectively enhanced by the underlying fill materials.

Solution Ponds

Nevada regulations require a primary synthetic liner and a secondary liner that meet the above-described liner specifications. The synthetic liners must be separated by a fluid transmission layer which is capable of transmitting leaked fluids at a rate that will ensure that excessive head will not develop on the secondary liner.

Solution Management and Containment

Process components must be demonstrated to have the capacity to "withstand" the runoff from a 100-year, 24-hour precipitation event. In addition, facility fluid management systems must demonstrate the capability of remaining "fully functional and fully contain all process fluids including all accumulation resulting from a 25-year, 24-hour precipitation event. The foregoing standards are minimal and additional containment capacity may be required if surface water bodies or human populations are in close proximity to the facility, or if ground water is shallow.

Construction QA/QC

Nevada regulations require that each applicant develop and carry out a quality assurance and quality control program for liner construction. A summary of the QA/QC program must be submitted to the NDEP with as-built drawings after construction has been completed.

Shallow Ground Water

Nevada regulations allow NDEP to require more stringent design requirements than those described above if the potential for contamination of ground water is significant. The criteria for assessing whether such a potential exists are one or more of the following: shallow ground water depth (less than 100 feet) with the permeability of the upper 100 feet of the "existing formation" greater than 1×10^{-5} centimeter per second; open fractures or faults beneath the proposed facilities; or the inability to demonstrated that drill holes beneath the facility have not been adequately plugged.

Neutralization/Detoxification of Spent Ore

Spent ore, whether it is to be left on pads or removed from a pad, "must be rinsed until" concentrations of WAD cyanide levels in the rinse water effluent are less than 0.2 mg/l, the rinse effluent pH is between 6.0 and 9.0, and concentrations of other "contaminants" in any effluent from the spent ore that "would result from meteoric waters" are sufficiently low that they will not degrade waters of the state. If these requirements cannot be achieved, the NDEP will grant a variance from the standards if it can be demonstrated that either:

> "[t]he remaining solid material, when representatively sampled, does not contain levels of

contaminants that are likely to become mobile and degrade the waters of the state under the conditions that will exist at the site, or

[t]he spent ore is stabilized in such a fashion as to inhibit meteoric waters from migrating through the material and transporting contaminants that have the potential to degrade the waters of the state."

NEW MEXICO

Cyanide heap leaching operations in New Mexico are regulated by the New Mexico Department of Environment, Water Quality Control Commission. The commission consists of eleven members: The Secretary of Environment; The Director of the Department of Game and Fish; The State Engineer; The Chairman of the Oil Conservation Commission; The Director of the State Park and Recreation Division; The Director of the Department of Agriculture; The Chairman of the Soil and Water Conservation Commission; The Director of the Bureau of Mines and Mineral Resources; and, Three representatives of the public, appointed by the Governor. The standards for the regulations are as provided under the authority of Section 74-6-4, NMSA 1978 (The New Mexico Water Quality Act, Chapter 326, Laws of 1973, as amended). Additional standards and regulations are provided by the New Mexico Mining Commission under authority of the New Mexico Mining Act NMSA 1978, Section 69-36-1 et. seq. [2-15-96]. Specific design criteria are not included in the Water Quality Control Commission Regulations or in the New Mexico Mining Act Rules. Applications for heap leach operations are considered on a case-by-case basis. It is incumbent on the applicant to provide the necessary design specifications, presumably based on industry and manufacturer standards, for Commission review. In the New Mexico Mining Act Rules (19 NMAC 10.2 Subpart 6 603.A) it is stated "The mining operation and reclamation plan shall be designed and operated using the most appropriate technology and the best management practices." Standards for design and construction are considered on a site-specific basis.

SOUTH DAKOTA

In South Dakota, permits for heap leaching operations are issued by the South Dakota Board of Minerals and Environment. This board is a lay committee of nine members, appointed by the Governor. Authority is granted to the Board by the Mined Land Reclamation Act, and permits are issued according to the provisions of the Mined Land Reclamation Regulations. No specific design criteria are included in the Act or the Regulations. Permits are issued on a case-by-case basis using information provided by the applicant and site specific conditions. Permit applications are reviewed by the Department of Environment and Natural Resources and are forwarded to the Board with a recommendation for or against the issuance of a permit.

APPENDIX B

SAMPLE TABLE OF CONTENTS
HEAP LEACH DESIGN REPORT

Design Report of the XYZ Heap Leach Operation

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APPENDIX C

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AS-BUILT / QA REPORT

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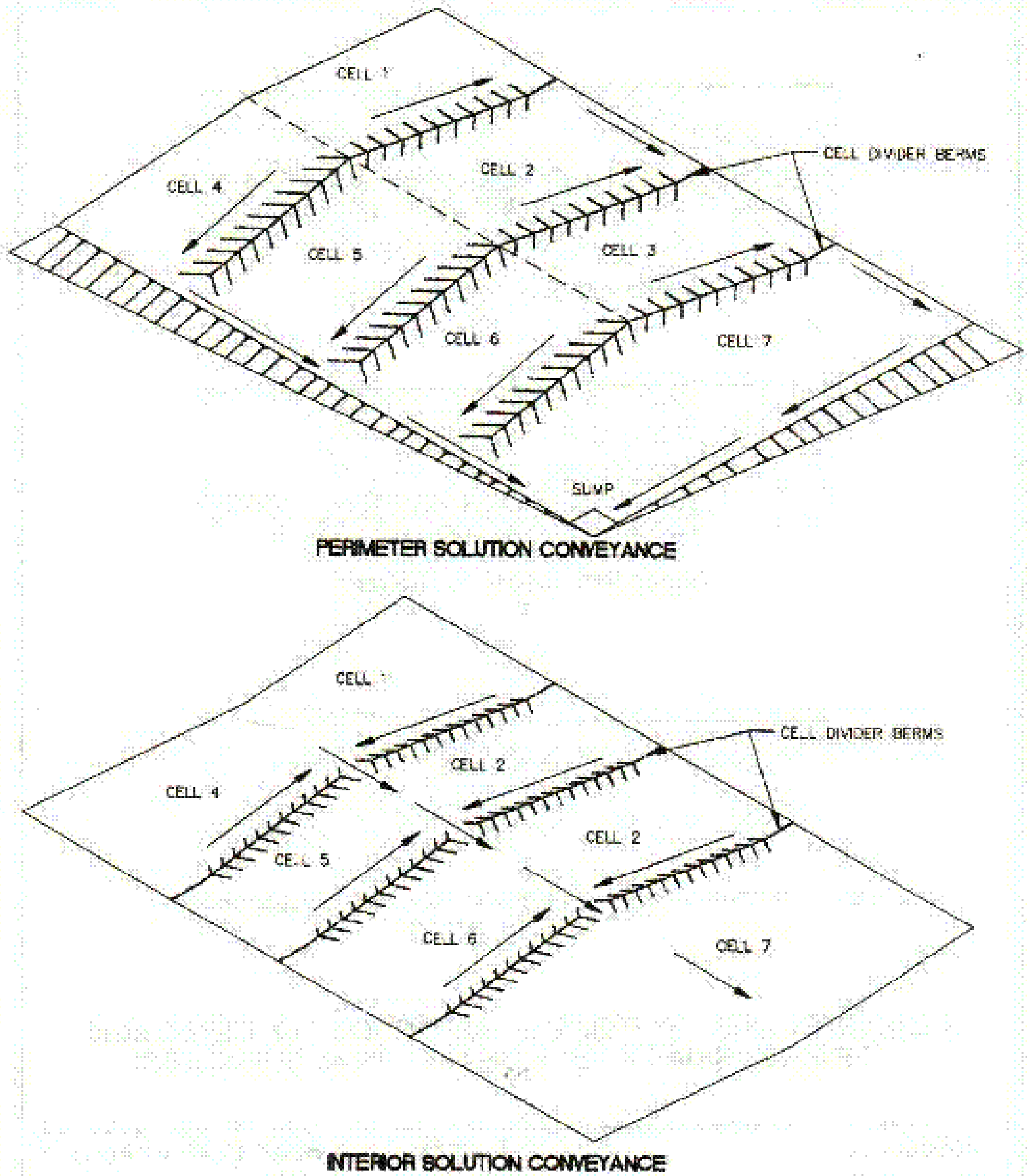
As-Built/QA Report

Appendices

FIGURES



EXPLANATION

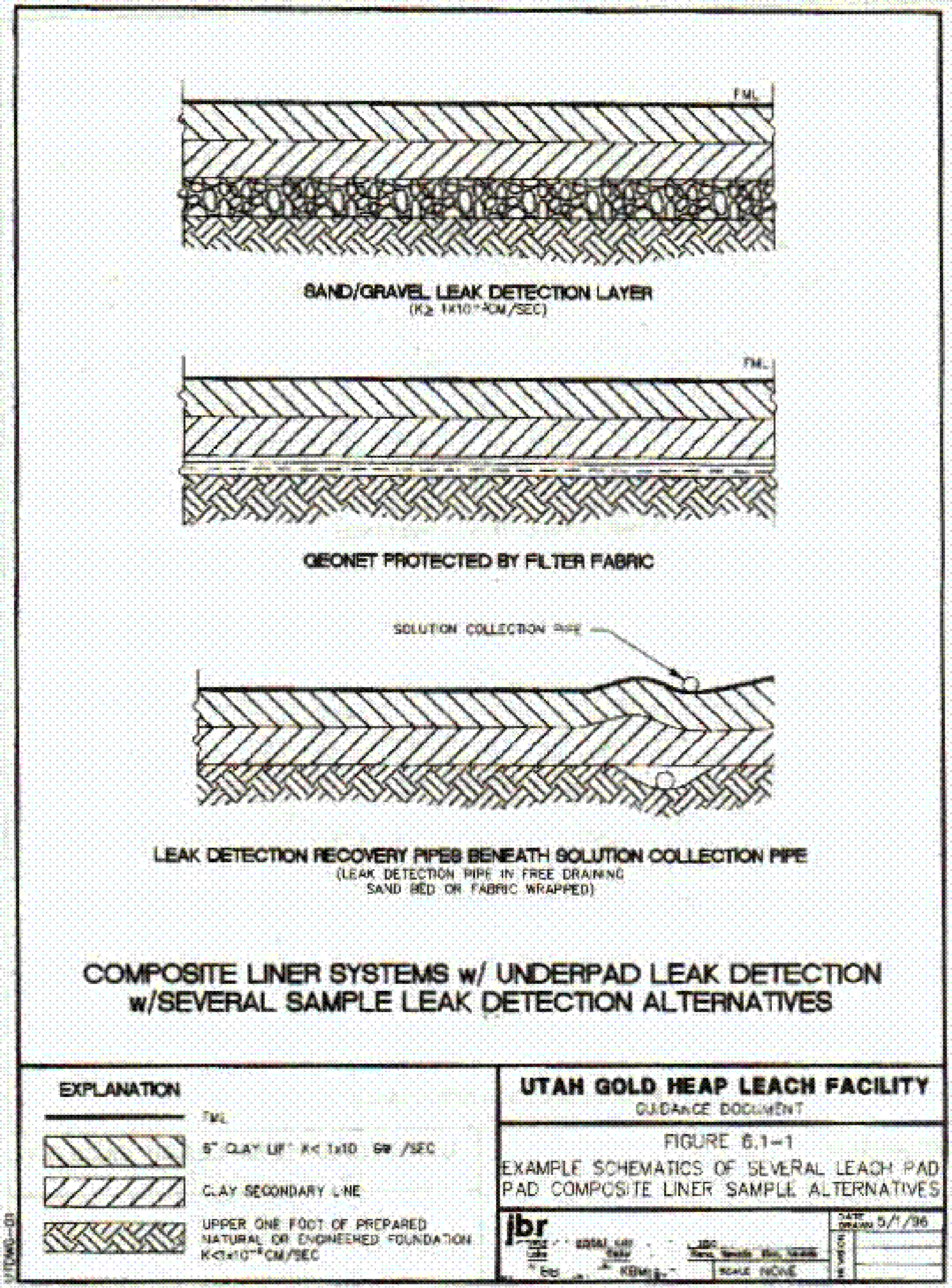
CELL DIVIDER BERM

NOTE
CELL DIMENSIONS SHOULD BE SIZED TO ENABLE CELLS TO BE TAKEN OUT OF SERVICE AS NECESSARY, IN THE EVENT OF LEAK

UTAH GOLD HEAP LEACH FACILITY
GUIDANCE DOCUMENT

FIGURE 5.1-1
SCHEMATIC PERSPECTIVE DIAGRAM
OF LEACH PAD CELLS

jbr
DATE DRAWN 5/1/96
BB KBM
SCALE NONE
REVISION



FML
SAND/GRAVEL LEAK DETECTION LAYER
FML
GEONET PROTECTED BY FILTER FABRIC
SOLUTION COLLECTION PIPE
LEAK DETECTION RECOVERY PIPES BENEATH SOLUTION COLLECTION PIPE
(LEAK DETECTION PIPE IN FREE DRAINING
SAND BED OR FABRIC WRAPPED)
COMPOSITE LINER SYSTEMS w/ UNDERPAD LEAK DETECTION
w/SEVERAL SAMPLE LEAK DETECTION ALTERNATIVES
EXPLANATION
FML
CLAY SECONDARY LINE
UPPER ONE FOOT OF PREPARED
NATURAL OR ENGINEERED FOUNDATION
UTAH GOLD HEAP LEACH FACILITY
GUIDANCE DOCUMENT
FIGURE 6.1-1
EXAMPLE SCHEMATICS OF SEVERAL LEACH PAD
PAD COMPOSITE LINER SAMPLE ALTERNATIVES
jbr
5/1/96
SCALE NONE