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16. Abstract (Limit: 200 words)

This report provides the program plan, costs and schedule, and engineering design specifications for an in situ copper leaching field experiment at the ASARCO-Freeport McMoran Joint Venture Santa Cruz Site in Casa Grande, Arizona. The field experiment is based on a unit cell concept of direct scale-up to a commercial scale design which was developed for this site using the algorithms and computer program contained in the Draft Generic In Situ Copper Mine Design Manual. The field experiment unit cell design includes integrated testing of two 5-spots and an SX-EW plant with supporting environmental permitting activities. The field experiment has a maximum capacity of 50 gpm and 1,095 tons per year copper production. The unit cell consists of: a plan of 160 feet by 320 feet; 160 feet producer-to-producer spacing; well depth of 2,220 feet; leach interval of 322 feet averaging 0.70% copper. The time frame of the field experiment is 44½ months at a cost of $15,939,616.

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ABSTRACT

This report provides the program plan, costs and schedule, and engineering design specifications for an in situ copper leaching field experiment at the ASARCO-Freeport McMoran Joint Venture Santa Cruz Site in Casa Grande, Arizona. The field experiment is based on a unit cell concept of direct scale-up to a commercial scale design which was developed for this site using the algorithms and computer program contained in the Draft Generic In Situ Copper Mine Design Manual. The field experiment unit cell design includes integrated testing of two 5-spots and an SX/EW plant with supporting environmental permitting activities. The field experiment has a maximum capacity of 50 gpm and 1095 tons per year copper production. The unit cell consists of: a plan area of 160 feet by 320 feet; 160 feet producer to producer spacing; well depth of 2,220 feet; leach interval of 322 feet averaging 0.7 % copper. The time frame of the field experiment is 44 1/2 months at a cost of $15,939,346.

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

Page

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

EXECUTIVE SUMMARY

1.1 GOALS AND OBJECTIVES

It is the intent of the U.S. Bureau of Mines (USBM) to promote the development of "true" in situ copper mining technology as quickly as possible within the U.S. mining industry. A key factor in this process is providing industry with an operating data base to be used with scale-up procedures for commercial facility design. This data base does not currently exist. The USBM has selected a site in Casa Grande, Arizona (ASARCO-Freeport McMoran Joint Venture Santa Cruz Deposit), as a candidate deposit to acquire this data base through operation of a field experiment. This report provides the program plan and design specifications, schedules, and costs for a field experiment at the Santa Cruz Site.

The estimated duration and cost of the field experiment is 44 1/2 months and $15.7 million. The facility is designed for a maximum production of 1095 tons per year cathode copper (4.6% of commercial scale design capacity), and 1.5 years steady-state operation (50% of commercial scale well life). At 70¢/lb copper price, sale of the cathode copper could recover up to $2.3 million of the project cost.

The test program is based on a unit cell concept of direct scale-up to a commercial design (Chapter 5) which was a developed for this site using the algorithms and computer program in the Draft Generic In Situ Copper Mine Design Manual. A commercial ore block has been identified: 97 million tons of ore; averaging 0.72% acid soluble copper; average depth below the surface of the bottom of the ore zone 2,136 feet; average ore thickness of 345 feet. Based on a discounted cash flow rate of return (DCF/ROR) cash flow economic analysis the best commercial mining scenario is associated with drilling vertical wells from the surface at producer to producer 5-spot pattern spacing of 160 feet, using a short radius hydrofracturing matrix modification procedure.

The unit cell is designed to correspond as closely as possible to a commercial operation. The goal of the test program is to demonstrate over a sustained period of operation attainment of projected operating costs, copper production, system and equipment operability, and hydrologic isolation of the ore zone.

Specific test program objectives to meet this goal are:

- o Obtain rock and fluid data to assess well pattern changes over a sustained period of operation
- o Assure that suitable well installation procedures can be achieved
- o Demonstrate that production size equipment can readily be obtained and maintained
- o Verify attainment of projected capital and operating costs
- o Develop reliable copper recovery prediction capability
- o Evaluate effectiveness of solvent extraction/electrowinning (SX/EW) process using true in situ production fluids
- o Identify problems not currently anticipated with the system and develop solutions to these problems
- o Demonstrate that the in situ process can be permitted in a timely fashion and operated as permitted.

1.2 DESCRIPTION OF PROGRAM ACTIVITIES

1.2.1 Design Basis

To achieve the program objectives and maintain a field experiment operation the following design criteria are used: the well spacing and flow rates per well module are to have the same values as in a commercial operation; that the unit cell be a module of a commercial wellfield; that the unit cell be operated for a sufficient period of time to demonstrate the expected copper recovery curve; that pregnant copper solutions be stripped of copper and the raffinate recycled after acid makeup; and that the surface facility have the same capacity as the wellfield module. The rationale for each is discussed below.

- o By maintaining well spacings and the flow rate per well module equal to a commercial operation the following will be accomplished.
  - + At equal well spacings the circulating wellfield lixiviant "sees" a representative geologic environment that is the same as in a commercial scale operation. In addition, it encompasses sufficient copper mineralization to enable a determination to be made as to whether it is possible to achieve the copper recovery factors and average copper loadings required for a commercial wellfield design.

+ By using the same flow rate per module the residence times associated with a commercial operation can be evaluated with respect to concentrating pregnant solution to the desired level. In addition working pressures will be of the same level as in a commercial operation.

o By using commercial scale wellfield modules in the field experiment, it can be determined whether this module can be constructed at anticipated costs, and will provide the anticipated flow rate and flow control between wells. Disadvantages of using one module are twofold:

  + Since it is one module, dilution of pregnant copper liquor will be more than in a commercial operation. This can be accounted for in the analysis of system performance by using a chemical tracer to measure dilution.

  + The ratio of injection to production wells is not the same as in a commercial wellfield. This does not pose an operational problem. However, the well costs for the unit cell cannot be scaled-up directly for the commercial operation. To minimize dilution effects and to provide for an assessment of deposit variability two adjacent 5-spot patterns will be used.

o By providing for sustained operation (24 hour per day/7 days per week) over an 18 month period, sufficient time is allocated to encounter any major operating and maintenance problems and determine whether copper loadings can be maintained at a constant level over a significant fraction of a commercial well pattern life.

o By designing the surface plant to have the same flow capacity as the wellfield, the field experiment can be operated in a recycle mode to assess the impacts of recycle solution composition (sulfate and gangue metal concentration build-up) on in situ permeability, net acid consumption, and copper extraction rate. The design basis for the surface plant includes:

  + Utilization of unit operations and hardware associated with a commercial operation.

  + Capability to operate over a system flow rate range of 10 gpm to 50 gpm. This range corresponds to the minimum flow rate that can be used with commercial size equipment and the maximum flow rate that is expected per well.

  + A minimum EW capacity of 750 lb/day of cathode production, which is the minimum required to produce commercial size cathode.

  + A maximum copper loading in the SX circuit of 12 grams per liter (gpl). This corresponds to 10 gpl pick-up in the well pattern and 84% recovery efficiency in the surface plant. The 10 gpl pick-up provides for surface plant capability to process higher pregnant liquor concentrations than are obtained from heap or dump leaching.

+ Build-up of aluminum, magnesium, and iron compositions in the pregnant liquor are based on gangue consumption of 3 1/2 pounds acid per unit copper production, and Al to Fe and Al to Mg ratios of 1.5 to 1. The former is based on ASARCO data obtained on acid leaching of crushed core from Santa Cruz, the latter on contractor experience with previous in situ leaching of copper oxides.

+ Build-up of chloride concentrations in the pregnant liquor are based on an average atacamite content in the ore of 20%.

+ Design specifications for construction of facilities associated with climate, codes, seismic activity, and soil bearing capacity are based on construction at San Manuel, where Davy McKee corporation has current construction experience and data.

+ Specifications pertaining to roads, electricity, and grading based on site specific data for the Santa Cruz Site.

1.2.2 Program Activities

To meet the goals and objectives of the test program described in Section 1.1, six operational activities were defined for the purpose of developing design specifications, schedules, costs, and manpower requirements for the program plan.

These activies are:

o Assess Test Ore Block Flow Characteristics

  Tests will be conducted using one (1) test hole to measure the flow capacity, porosity, and uniformity of these parameters in the section of the ore block selected for the field experiment. The test hole will be drilled 10 inches diameter from the surface to the top of the ore interval and cased and cemented to surface. A 7 5/8 inch diameter hole will be drilled through the ore interval and cased and cemented. Prior to casing and cementing in the ore interval the following activities will be carried out, at specified sections: core will be obtained; water injection permeability tests will be conducted; and geophysical logs and flow profile tests will be conducted.

o Assess Well Pattern Flow Control

  Two additional test holes will be drilled, and in conjunction with the first test hole, a determination of the orientation of natural and induced fractures will be made to ascertain how to orient the operating wells to maximize fluid control in the well pattern. Hole drilling sizes and casing and cementing procedures are the same as in the first activity. A nominal well spacing of 50 feet is specified. The two additional wells will be oriented relative to the first well parallel to and perpendicular to the direction of natural fracture orientation. Prior to casing and cementing the ore interval the following tests will be conducted: water injection permeability and inter-well pressure interference tests; geophysical logging; flow profile testing. Following casing and cementing of the ore interval specific intervals will be selected in each well and the following tests conducted: pressure interference and chemical tracer testing; short radius hydrofracturing and propellant fracturing; and large radius hydrofracturing. The propellant fracturing is also referred to as high energy gas fracturing (H.E.G.F.).

o Well System Construction

This activity involves the drilling and completion of seven (7) additional wells, which in conjunction with one of the two wells from the second activity form two (2) contiguous 5-spot patterns. Hole sizes, permeability and geophysical logging of the ore interval prior to completion, and casing and cementing of the well are the same as in the previous activities. Producer-to-producer spacings are 160 feet. Following casing and cementing of the ore interval the leach interval will be perforated, and well logs and pressure transient and interference tests conducted to calibrate the well pattern flow system prior to matrix modification and leaching. All wells will then be subjected to a short radius hydrofracture over an 8 foot radius, and interference testing repeated. All well production and injection equipment will be installed and tested prior to initiation of long term operation.

o Surface Facility Construction

This activity pertains to site preparation and construction and installation of facilities and equipment for processing solutions for acid make-up and injection, and handling enriched copper solutions for separation of copper and cathode production. Costs and construction and installation schedules are based on design criteria and specifications.

Process design criteria include: description of the process, capacity, site conditions, battery limits and tie-in requirements, analysis of solutions, flowrates, specific process details, operating schedule unit rates of specific equipment, retention time of tanks and ponds, and utility requirements.

Design specifications include:

+ Pumps - including number, capacity, type, total dynamic head hp and materials of construction

+ Mixer/settlers - including dimensions, materials of construction description of internal components, mixer/agitator number, type and horsepower

+ Tanks - capacity, materials of construction, special features

+ Ponds - capacity, liner material, inflow and outflow requirements

+ Electrowinning cells - outline of the basic cell design including description of all components, operating current, and voltage

+ Anodes - size, number, materials of construction, and fabrication requirements

+ Cathodes or starter sheets - site, number, materials of construction and fabrication requirements

+ Transformer/rectifiers -including general description capacity, input and output requirements, duty

+ Major electrical equipment - listing of items, general descriptions with size, quantity, duty power requirements (size)

+ Materials of construction - listing of acceptable materials of construction by area and chemical environment

+ Pipes and valves - listing with rating, material, use, type, method of connection

+ Safety systems - classification of hazardous areas with equipment and firm protection system requirements.

The layout and interfacing of equipment are described by:

+ Flow sheet and mass balance - drawings showing each of the components and the interconnecting flows, listing with rates (tpy, gpm) for inflows and outflows

+ General arrangement drawings - showing the placement of equipment and critical elevations

+ Piping and instrumentation drawing - schematic diagrams showing equipment and the interconnecting piping with pipe, class, size, and instrumentation noted

+ Electrical one-line drawing of schematic diagrams - showing electrical equipment, distribution, and loads

o Well System Operation

This activity addresses all phases of the operations of the two 5-spot patterns which include startup, long-term leaching, well pattern shutdown and temporary well abandonment.

Test startup involves: gradually increasing water injection flowrates to the limiting pressure or rate; recovery pump startup and adjustment to attain maximum drawdown; initiation of sampling and data collection procedures; and initiation of acid injection.

Long-term leaching is designed for an 21 month time frame to provide performance and cost data that is representative of a commercial operation. A 24-hour per day and 7 day per week operation is provided for along with scheduled maintenace functions. Following termination of leaching and fluid circulation in the well pattern, fluid level changes will be recorded in all wells until static levels are achieved. This is followed by removal of well equipment.

The shutdown phase involves measuring permeability, porosity, and flow profiles in each well and drilling two core holes, one per 5-spot pattern, to assess changes in rock fluid flow and mineral properties that occurred during leaching.

To prevent contamination of groundwater outside the ore zone temporary well abandonment procedures are provided that meet the requirements of the ADWR.

- o Surface Facility Operation

  The activity addresses all functions associated with the operation and maintenance of all surface facilities for a 24-hour per day/7 day per week operation. This includes: manpower and staffing levels and costs; unit rates and costs for consumables and utilities; operating and safety procedures; and maintenance requirements and costs.

1.2.3 Environmental Permitting Process

The environmental permitting process addresses each of the six field activities described in Section 1.2.2 with regard to the following:

- o Identifying the site specific environmental impacts which could result.
- o Identifying the environmental permits which could be required to construct and operate the field experiment, and the nature of the individual permit application procedures.
- o Defining the monitoring, contingency planning, remedial action program, closure, and post-closure plans and restoration requirements for each site.
- o Design and development of specifications, guidelines, schedules and costs for the permit application procedures, monitoring systems and restoration plans for each site.

1.3 PROGRAM SCHEDULE AND COSTS

1.3.1 Overall Program Schedule

The overall program schedule consists of four phases of work listed below. This is derived from individual work schedules for the Well System, Surface Facility, and Environmental Pemitting. Key factors used to integrate these schedules are listed in Table 1-1. The time frame of work activities within each Phase is listed in Table 1-2.

- o Phase I - Procurement Preparation
  - + The time frame is from day 0 to day 140
  - + The work involves: developing design specifications into procurement documents; obtaining bids and making awards for purchase of equipment and well services; and obtaining permits for drilling and hydrologic testing wells.
- o Phase II - Facility Construction and Installation
  - + The time frame is from day 141 to 540
  - + The work involves: construction, installation, and testing of all facilities and equipment; obtaining the permit to leach; and staff training for facility operation.
- o Phase III - Facility Operation and Closure
  - + The time frame is from day 541 to 1,236
  - + The work involves: start-up, steady state operation, and shut-down of leaching operations.
- o Phase IV - Demobilization of Facilities
  - + The time frame is from day 1,237 to 1,356
  - + The work involves dismantling of all surface plant equipment and shipment off site, and preparation of the final report.

1.3.2 Overall Program Costs

The total field experiment cost is $15,939,616. Table 1-3 lists total costs by; operating costs, well system costs, surface plant costs, environmental costs. Table 1-4 summarizes cost expenditures by year for each of the cost categories.

TABLE 1-1. FACTORS USED TO INTEGRATE INDIVIDUAL WORK SCHEDULES

- o Minimize total project time
- o Maintain staff continuity
- o Environmental constraint
  - + Require 400 days from permit initiation to approval to leach
- o Well system constraints
  - + Require 326 days to install and test one core hole and 10 test wells
  - + Require 696 days from initiating leaching to temporary well abandonment
- o Surface Facility Constraints
  - + Require 180 days from initiation of construction and installation to completion
  - + Longest lead time for procurement is 365 days for transformer/rectifier. Latest time for installation is 125 days prior to completion. This requires procurement 310 days prior to initiation of construction.
- o Staffing Levels
  - + Project Staff
    - - Level P1, Day 0 to 466, Day 1,237 to 1,356
    - - Level P2, Day 467 to 1,236
  - + Surface Facility Operator Contractor
    - - Level S1, Day 140 to 466, Day 1,237 to 1,356
    - - Level S2, Day 467 to 1,236.
- o Consumables and Power Costs applied from Day 467 to 1,179
  - - Consumables at $772/day
  - - Power at $660/day

TABLE 1-2. PROJECT SCHEDULE SUMMARY

- Phase I - Day 0 to 140
  - Well system - Day 0 to 140
  - Surface Facility - Day 0 to 140
  - Environmental - Day 0 to 140
- Phase II - Day 141 to 540
  - Well system
    - Day 141 to 466, installation/testing all wells
    - Day 467 to 540, operational training
  - Surface Facility
    - Day 141 to 365, follow-up engineering
    - Day 141 to 505, follow-up with procurement
    - Day 360 to 540, construction and installation
    - Day 467 to 540, operational training
  - Environmental
    - Day 141 to 540, permit application process for leaching
- Phase III - Day 541 to 1,236
  - Start-up, steady state, shut-down leach operations, temporary well abandonment
- Phase IV - Day 1,237 to 1,356
  - Demobilization of the Surface Plant
  - Final Report

TABLE 1-3. SUMMARY OF COSTS BY COST CATEGORY

o Operating Costs		
+ Labor		
- Project staff	-	$3,449,548
- Surface facility operating Contractor	-	$2,888,960
+ Consumables	-	$550,350
+ Power	-	$470,541
	Total	$7,359,399
o Well system costs		
+ Rental	-	$35,982
+ Equipment and materials	-	$1,584,881
+ Hydrofracturing	-	$97,804
+ Explosive Fracturing	-	$41,050
+ Well Services	-	$2,431,376
	Total	$4,191,093
o Surface plant costs		
+ Wellfield	-	$443,300
+ SX	-	$461,000
+ EW	-	$1,237,500
+ Tank Farm	-	$225,300
+ General Engineering	-	$667,600
+ Demobilization	-	$671,160
	Total	$3,706,860
o Environmental permitting costs		
+ Fees	-	$20,090
+ Hydrogeologic characterization	-	$133,190
+ Corrective action	-	$270,460
+ Monitoring well system	-	$239,924
+ Baseline water quality	-	$10,000
+ Operational monitoring	-	$8,600
	Total	$682,264

TABLE 1-4. SUMMARY OF COSTS BY YEAR

o Year 1		
+ Project staff	-	$807,380
+ Surface facility operator contractor	-	$306,000
+ Well system	-	$3,690,548
+ Surface plant	-	$3,035,700
+ Environmental	-	$673,664
	Total	$8,513,292
o Year 2		
+ Project staff	-	$962,458
+ Surface facility operator contractor	-	$922,000
+ Well system	-	$86,712
+ Consumables	-	$203,776
+ Power	-	$174,240
+ Environmental	-	$2,150
	Total	$2,351,226
o Year 3		
+ Project staff	-	$1,020,175
+ Surface facility operator contractor	-	$1,080,400
+ Well system	-	$166,578
+ Consumables	-	$281,736
+ Power	-	$240,900
+ Environmental	-	$4,300
	Total	$2,794,089
o Year 4		
+ Project staff	-	$659,535
+ Surface facility operator contractor	-	$580,560
+ Well system	-	$247,255
+ Surface facility	-	$671,160
+ Consumables	-	$64,838
+ Power	-	$55,401
+ Environmental	-	$2,150
	Total	$2,280,899

1.4 STAFFING REQUIREMENTS

1.4.1 Definition of Program Staffing

It is assumed that all personnel requirements pertaining to the procurement and installation of equipment and the operation and maintenance of the field equipment are provided by Project Staff and a Surface Facility Operator Contractor. The Project Staff manages the financial and technical activities of the field experiment. The Surface Facility Operator Contractor provides those support activities to the Project Staff required to install, operate, and maintain the field experiment. Sections 1.4.2 and 1.4.3 define the staff mix and list job descriptions and costs for each staff position. Section 1.4.4 specifies the staffing levels and costs over the time frame of the field experiment.

1.4.2 Project Staff

- Project Manager
  - Job Description: Overall management of the project; accountable for cost, schedule, and technical performance; develops work plans and provides overall technical direction; approves all procurements; responsible for all personnel matters; and prepares all project technical and cost reports.
  - Annual salary: $65,000
- Administrative Assistant
  - Job Description: Procurement of equipment, materials, and subcontracts; equipment and materials inventory control; project cost and inventory control; payroll administration. Reports to Project Manager.
  - Annual salary: $45,000
- Clerical Support
  - Job Description: General secretarial and clerical support. Reports to Project Manager.
  - Annual salary: $25,000

- o Subsurface Manager

    + Job Description: Plan and design downhole well operations; develop work plans and schedules; develop specifications for procurement of equipment, materials, and subcontracts; supervise installation, operation, and maintenance of equipment; supervise personnel; and coordinates work activities with Surface Manager. Reports to Project Manager.

    + Annual salary: $45,000

- o Surface Manager

    + Job Description: Plan and design surface operations; develop work plans and schedules; develop specifications for procurement of equipment, materials, and subcontracts; supervise installation, operation, and maintenance of equipment; supervise project staff. reports to Project Manager.

    + Annual salary: $45,000

- o Downhole Engineer

    + Job Description: Supervise and assist with planning daily well operations; supverise subcontractor personnel in equipment installation, maintenance, and daily operation; supervise data collection and prepare daily reports; reduce and analyze data. Reports to Subsurface Manager.

    + Annual salary: $35,000

- o Surface Process Engineer

    + Job Description: Supervise and assist with planning daily operation of surface facilities; supervise subcontractor personnel in equipment installation, maintenance, and daily operation; supervise data collection and prepare daily reports; reduce and analyze data. Reports to Surface Manager.

    + Annual salary: $35,000

- o Environmental Engineer

    + Job Description: Support site operator with permit application process and assure conformance to all permit stipulations; develop specifications for procurement of equipment, materials, and subcontracts to support environmental permit application process; supervise data and sample collection and analysis and assure strict conformance to QA/QC procedures established for water quality sampling and testing program; supervise installation, operation, and maintenance of monitoring system; and supevise any subcontractor activities. Reports to Project Manager.

    + Annual salary: $38,000

- Technicians
  - Job Description: Collect field data and samples; arrange for sample analysis; drafting; computer data entry; data reduction; quick response chemical analysis.
  - Annual salary: $25,000

1.4.3 Surface Facility Operator Contractor

- Foreman
  - Job Description: Provides and supervises personnel required for installation, operation, and maintenance of field experiment. Takes direction from Surface Manager.
  - Daily cost: $35/hour x 8 hours = $280/day
- Mechanic/Pipefitter
  - Job Description: Provide mechanical support for installation and maintenance of equipment. Reports to Foreman.
  - Daily cost: $30/hour x 8 hours = $240/day
- Electrician
  - Job Description: Provide electrical support for installation and maintenance of equipment. Reports to Foreman.
  - Daily cost: $30/hour x 8 hours = $240/day
- Operators
  - Job Description: Operate all equipment. Reports to Foreman.
  - Daily cost: $25/hour x 8 hour = $200/day

1.4.4 Staffing Levels and Daily Costs

1.4.4.1 Prior to Well System and Surface Plant Operation

- Project Staff - Level P1
  - Staffing Levels

- (1) ea. Project Manager	-	$65,000/yr
- (1) ea. Administrative Assistant	-	$45,000/yr
- (1) ea. Secretary	-	$25,000/yr
- (1) ea. Surface Manager	-	$45,000/yr

- (1) ea. Sub-surface Manager - $45,000/yr
- (1) ea. Downhole Engineer - $35,000/yr
- (1) ea. Environmental Engineer - $38,000/yr
- (1) ea. Technician - $25,000/yr

Total $323,000/yr

+ Daily costs
  - $885/day for salaries
  - $2,212/day burdened costs

o Surface Facility Operation Contractor - Level S1

+ Staffing Levels

- (1) ea. Foreman	-	$280/day
- (1) ea. Mechanic/Pipefitter	-	$480/day
- (1) ea. Operators	-	$600/day
	Total	$1,360/day

+ Daily cost
  - $1,360/day burdened cost

1.4.4.2 Well System and Surface Plant Operation

o Project Staff - Level P2

+ Staffing Levels

- (1) ea. Project Manager	-	$65,000/yr
- (1) ea. Administrative Assistant	-	$45,000/yr
- (1) ea. Secretary	-	$25,000/yr
- (1) ea. Surface Manager	-	$45,000/yr
- (1) ea. Sub-Surface Manager	-	$45,000/yr
- (1) ea. Process Engineer	-	$35,000/yr
- (1) ea. Downhole Engineer	-	$35,000/yr
- (1) ea. Environmental Engineer	-	$38,000/yr
- (1) ea. Technicians	-	$75,000/yr
	Total	$408,000/yr

+ Daily Costs
  - $1,118/day for salaries
  - $2,795/day burdened costs

- o Surface Facility Operator Contractor - Level S2
  - + Staffing Levels

- (1) ea. Foreman	-	\$280/day
- (1) ea. Mechanic/Pipefitter	-	\$240/day
- (1) ea. Electrician	-	\$240/day
- (6) ea. SX/Wellfield Operators	-	\$1,200/day
- (5) ea. EW Operators	-	\$1,000/day
	Total	\$2,960/day

  - + Daily Cost
    - - \$2,960/day burdened cost

1.5 ENVIRONMENTAL PERMIT REQUIREMENTS AND SCHEDULES

The site owner, ASARCO-Freeport McMoran (ASARCO), has assumed the role of permittee for the application and approval of all environmental permits. As the permittee, ASARCSO has established an approach to the issues of hydrogeologic isolation and monitoring of the alluvial groundwater system which overlies the Santa Cruz ore body. The following are the key factors in the ASARCO permitting approach to be followed in applying for an Aquifer Protection Permit issued by the Arizona Department of Environmenal Quality (ADEQ).

- o The bedrock regime, which contains the Santa Cruz ore body, is not presently considered to be an aquifer due to its probable limited water-bearing capability, poor water quality and/or excessive depth and remoteness from potential usage.

- o The point of compliance for the ADEQ permit is established as the lower portion of the alluvial aquifer which overlies the ore body and is separated from the test leach interval by a thickness of approximately 1,100 feet of low permeability crystalline bedrock and indurated conglomerates. The overlying alluvial aquifer is presently estimated to extend to a depth of about 700 feet, with groundwater in an unconfined condition occurring at a depth of 550 feet.

- o The water quality of the alluvial aquifer will be monitored at the point of compliancae by using three monitoring wells, one 450 feet upgradient and two 450 feet downgradient of the test area. These wells will be screened over 145 feet of the alluvial aquifer.

- o The intervening bedrock and conglomerate between the shallow alluvial aquifer and the test leach interval is considered as a confining zone capable of preventing any water quality impacts on the shallow groundwater.

- Assuming total hydrologic isolation, no restoration will be necessary. The residual process fluids left in the ore body will be subject to an undetermined amount of natural buffering, ultimately increasing the pH and immobilizing many of the dissolved constituents.

Table 1-5 summarizes the permitting process, and Figures 1-1 and 1-2 summarize the permitting schedules.

1.6 SUMMARY EQUIPMENT AND MATERIALS REQUIREMENTS

- Well System

Table 1-6 summarizes the sequence of activities, time increments, contracting services, and costs for mud rotary drilling. Table 1-7 summarizes the same data for air hammer drilling, which results in a 34 day reduction in field testing and $320,041 reduction in cost.

Table 1-8 lists the distribution of costs for each activity by well services (drilling, coring, servicing, logging, casing, cementing), hydrofracing, explosive fracing, equipment rentals, and equipment and materials purchases.

Table 1-9 provides a list of all materials and equipment requirements for each activity.

Table 1-10 provides a list of all well service equipment requirements and performance specifications for each activity.

- Surface Facility

A listing of equipment of all the components required for the surface plant is provided in Table 1-11. The equipment list shows the pertinent information for the principle items that are in the surface facilities. Each item is assigned an equipment number. The first two numbers denote the general area of the facility, 20 - Well Field, 30 - Solvent Extraction, 40 - Tank Farm, 50 - Electrowinning, 90 - Ancillary Facilities. The second set of numbers denote the general equipment class, or specification. The third group of numbers is a sequential number, when combined with the previous groups gives each item a unique number for identification.

TABLE 1-5. ENVIRONMENTAL PERMITS AND RELATED REGULATORY APPROVALS REQUIRED

Permit Name and/or Description	Issuing Agency With Name & Address and Agency Contact(s) With Telephone No.	Approximate Timetable to Receive Approval	Legal Citation(s)	General Remarks
o Aquifer Protection Permit	Arizona Dept. of Environmental Quality 2005 North Central Avenue Phoenix, Arizona 85004 Mr. Roger W. Kennett Ms. Debra L. Daniel (602) 257-2270	13 months to complete from proposal through final approval; allowing 3 months to develop and present hydrogeologic and corrective action data.	Arizona revised statutes sections 36-3501 through 36-3624 and Sections 49-101 through 49-105.	Analysis of regulatory requirements partially based upon draft regulations which are subject to change.
o Underground Injection Control Program (UIC) Class V Authorization	U.S. Environmental Protection Agency Region 9 215 Fremont Street San Francisco, California Mr. William M. Bohrer (415) 974-0807	6 months from initial notification to EPA authorization letter.	40 CFR Chapter 1, Parts 144 through 146.	Due to experimental nature of proposed action, EPA should authorize activity by rule, with only basic inventory requirements reported.
o Right to Withdraw Groundwater	Arizona Dept. of Water Resources Pinal Active Management Area 901 E. Cottonwood Lane, Suite B Casa Grande, Arizona 85222 Mr. Tom Carr (602) 836-4857	Notify only.	Arizona Revised Statutes Sections 45-401 through 45-637.	Due to grandfathered groundwater rights held by ASARCO, no permit process is required if withdrawals do not exceed yearly allotment.
o Conformance to Well Construction Standards and Use of Certified Driller	Arizona Dept. of Water Resources 99 East Virginia Avenue Phoenix, Arizona 85004 Mr. Richard A. Gessner Mr. Robert Fayfield (602) 255-1533	15 days from notice of intent to drill.	Arizona Administrative Rules and Regulations; Title 12, Chapter 15.	Notice of intent to drill must include name and certification no. of driller. Driller must submit well log and completion record within 30 days of well completion.

TABLE 1-5. ENVIRONMENTAL PERMITS AND RELATED REGULATORY APPROVALS REQUIRED (Continued)

Permit Name and/or Description	Issuing Agency With Name & Address and Agency Contact(s) With Telephone No.	Approximate Timetable to Receive Approval	Legal Citation(s)	General Remarks
o Air Quality Installation Permit	Pinal-Gila Counties Air Quality Control District P.O. Box 1076 Florence, Arizona 85232 Mrs. Dorothy M. Rankin (602) 868-5801	6 to 12 months to complete; partially dependent upon whether preoperational monitoring will be required.	Amended Rules and Regulations prepared by Air Quality Control District Staff, Sections 7-1-2 through 7-3.	Process involves interaction with Pinal-Gila Air Quality Board.
o Building Permit	Pinal County Planning & Zoning Dept. P.O. Box D Florence, Arizona 85232 Mr. Gary Beck (602) 868-5801	6 weeks to complete.		Requires submission of final plans.
o Permit for Septic Disposal	Pinal County Health Dept. P.O. Box 807 Florence, Arizona 85232 Mr. Reg Glos (602) 868-5801	4 weeks to complete.		On-site percolation testing required.
o Notification of Commencement (Worker Safety)	ARizona State Mine Inspector 1624 West Adams Street, Room No. 208 Phoenix, Arizona 85007 Mr. James Mott (602) 255-5971	Notify only.	Arizona Administrative Rules and Regulations; Title 27, Chapter 1, Article 2.	
o Notification of Commencement of Operation	Mine Safety & Health Administration 3221 North 16th Street, Suite 300 Phoenix, Arizona 85016 Mr. Gary Day (602) 241-2030	Notify only.	30 CFR, Chapter 1, Part 56.	Worker safety training program involved.

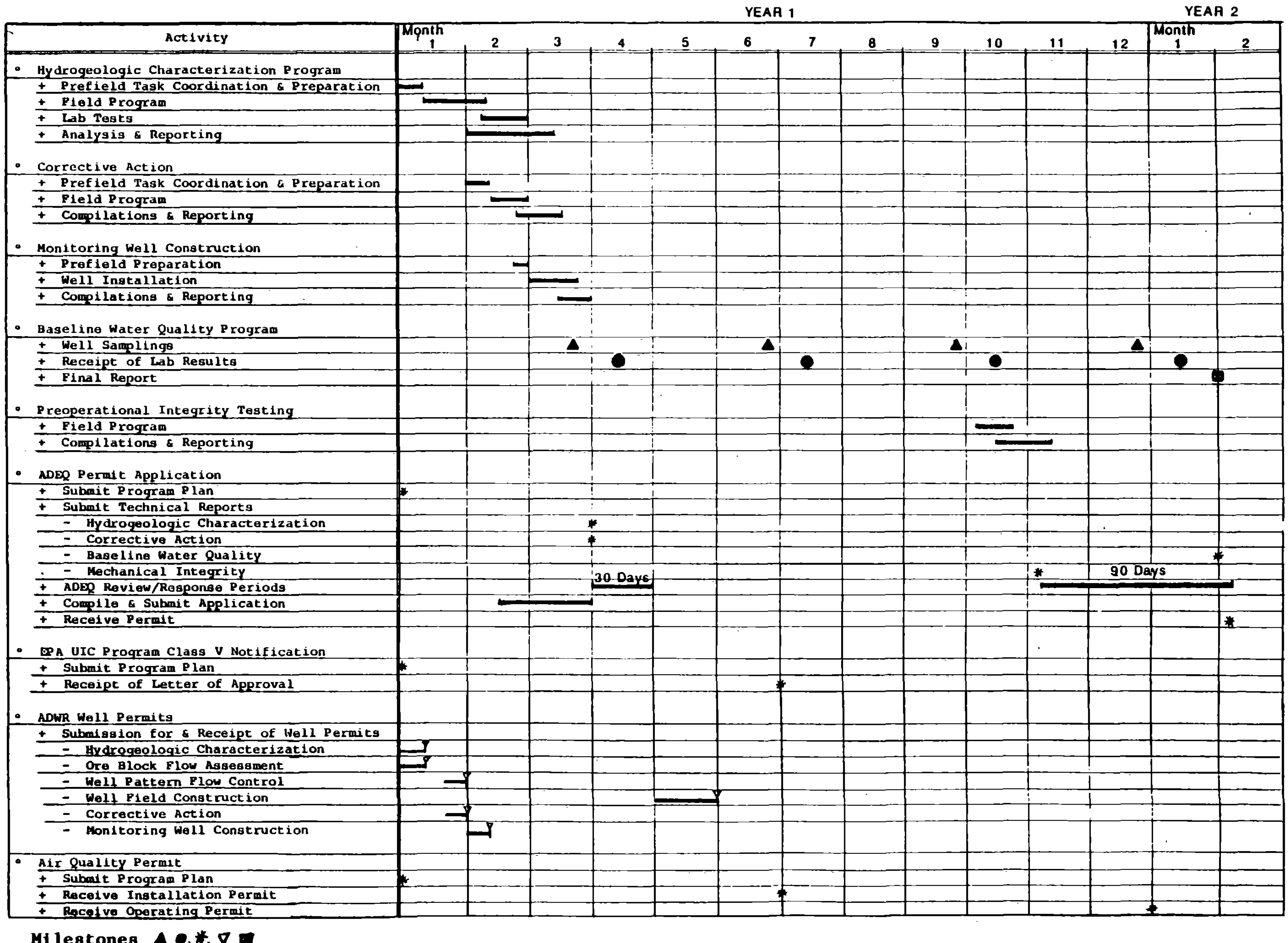


Figure 1-1. Schedule of Environmental Activities and Permitting Prior to Receipt of ADEQ Aquifer Protection Permit

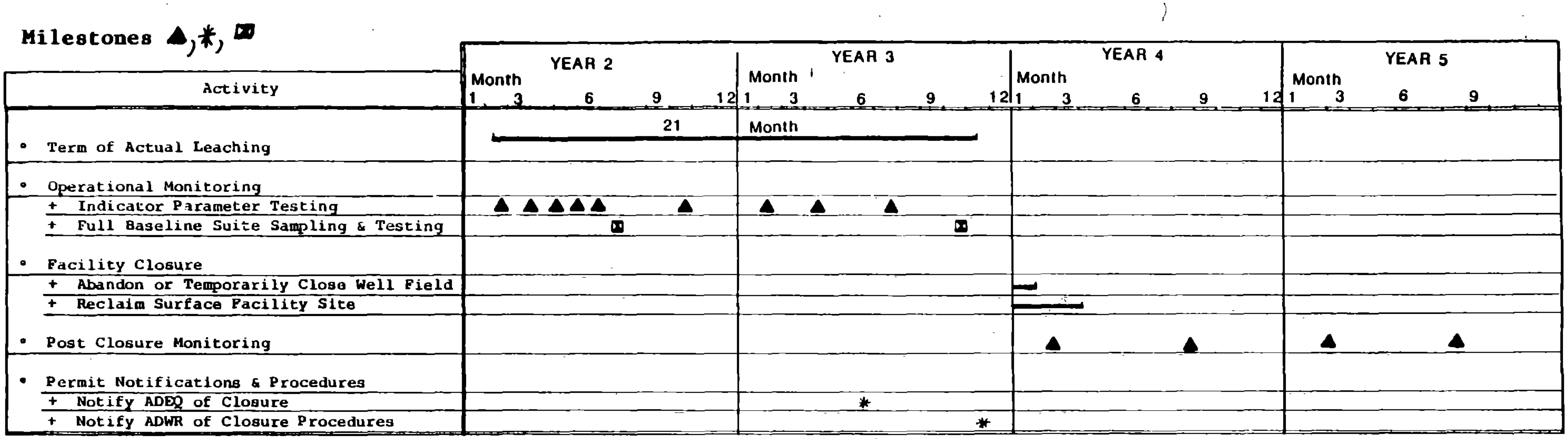


Figure 1-2. Schedule of Operational, Closure, and Post-Closure Environmental Activities and Permit Actions

TABLE 1-6. SUMMARY WELL SYSTEM REQUIREMENTS MUD ROTARY DRILLING

Section	Days Per Item	Total Days From Project Start	Field Service Contracting	$ Equipment and Services
2.1 ORE BLOCK FLOW ASSESSMENT				
2.1.1 Drill Core Hole C1	14	154	Drill/Core/Cement	46,340
2.1.2 Install Well T1 Through Sediments	5	159	Drill/Log/Cement/Casing	79,482
2.1.3 Install Well T1 Through ore zone	11	170	Drill/Log/Cement/Case Directional Drill/Oriented Core	147,992
2.1.4 Open Hole Testing T1	4	174	Drill/Log	36,525
2.1.5 Wireline Log T1	1	175	Drill/Log	14,900
	35			325,239
2.2 WELL PATTERN FLOW CONTROL				
2.2.1 Site Wells T2 and T3	1	176	----	---
2.2.2 Install Wells T2 and T3	31	207	Same as 2.1.2 and 2.1.3	425,248
2.2.3 Open Hole Tests T2 and T3	8	215	Same as 2.1.4	47,050
2.2.4 Wireline Log T2 and T3	1	216	Same as 2.1.5	29,800
2.2.5 Cased Hole Tests T1,T2,T3	49	265	Drilling/Log	110,340
2.2.6 Stimulation T1,T2,T3	6	271	Drill/Hydrofrac/Explosive Frac	97,350
2.2.7 Large Radius Hydro Frac	5	276	Drill/Oriented Core/ Hydrofrac/Seismic/Log	271,132
	101			980,920

TABLE 1-6. SUMMARY WELL SYSTEM REQUIREMENTS MUD ROTARY DRILLING (continued)

Section	Days Per Item	Total Days From Project Start	Field Service Contracting	$ Equipment and Services
2.3 WELL SYSTEM CONSTRUCTION				
2.3.1 Wellfield Design Review	14	290	Computer Simulator	20,000
2.3.2 Well Site Selection T4 Through T10	1	291	---	---
2.3.3 5-Spot Installations	49	340	Same as 2.1.2 and 2.1.3	1,521,900
2.3.4 Wireline Log T4 Through T10	7	347	Drill/Log	104,300
2.3.5 Cased Hole Tests T4 Through T10	8	355	Drill/Log	39,150
2.3.6 Pre/Post Stimulation Log T4 Through T10	4	359	Drill/Log	55,860
2.3.7 5-Spot Tracer Tests	90	449	Drill/Log	76,010
2.3.8 Stimulate 5-Spot	10	459	Drill/Hydrofrac	127,064
2.3.9 Equip 5-Spot	7	466	Drill	440,105
	190			$2,384,389
Operational Training	74	540	---	---
2.4 WELL SYSTEM OPERATION				
2.4.1 5-Spot Leaching	639	1,179	Chemical assay spray lab	191,625
2.4.2 5-Spot Maintenance	---	---	Drill/Log	100,000
2.4.3 Post Leach 5-Spot Tests	15	1,194	Drill/Log	101,000
2.4.4 Post Leach Core Drilling C2 and C3	28	1,222	Same as 2.1.1	92,680
2.4.5 Temporary Wellfield Abandonment	14	1,236	Same as 2.3.9	15,240
	696			500,545
TOTAL ALL SECTIONS	1,096	1,236		$4,191,093

TABLE 1-7. SUMMARY WELL SYSTEM REQUIREMENTS AIR HAMMER DRILLING

Section	Days Per Item	Total Days From Project Start	Field Service Contracting	$ Equipment and Services
2.1 ORE BLOCK FLOW ASSESSMENT				
2.1.1 Drill Core Hole C1	13	153	Drill/Core/Cement	42,460
2.1.2 Install Well T1 Through Sediments	4	157	Drill/Log/Cement/Casing	69,357
2.1.3 Install Well T1 Through Ore Zone	8	165	Drill/Log/Cement/Case Directional Drill/Oriented Core	129,167
2.1.4 Open Hole Testing T1	4	169	Drill/Log	36,525
2.1.5 Wireline Log T1	1	170	Drill/Log	14,900
	30			292,409
2.2 WELL PATTERN FLOW CONTROL				
2.2.1 Site Wells T2 and T3	1	171	----	---
2.2.2 Install Wells T2 and T3	16	187	Same as 2.1.2 and 2.1.3	366,258
2.2.3 Open Hole Tests T2 and T3	8	195	Same as 2.1.4	47,050
2.2.4 Wireline Log T2 and T3	1	196	Same as 2.1.5	29,800
2.2.5 Cased Hole Tests T1,T2,T3	49	245	Drilling/Log	110,340
2.2.6 Stimulation T1,T2,T3	6	251	Drill/Hydrofrac/Explosive Frac	97,350
2.2.7 Large Radius Hydro Frac	5	256	Drill/Oriented Core/ Hydrofrac/Seismic/Log	271,132
	86			921,930

TABLE 1-7. SUMMARY WELL SYSTEM REQUIREMENTS AIR HAMMER DRILLING (continued)

Section	Days Per Item	Total Days From Project Start	Field Service Contracting	$ Equipment and Services
2.3 WELL SYSTEM CONSTRUCTION				
2.3.1 Wellfield Design Review	14	270	Computer Simulator	20,000
2.3.2 Well Site Selection T4 Through T10	1	271	---	---
2.3.3 5-Spot Installations	38	309	Same as 2.1.2 and 2.1.3	1,303,435
2.3.4 Wireline Log T4 Through T10	7	316	Drill/Log	104,300
2.3.5 Cased Hole Tests T4 Through T10	8	324	Drill/Log	39,150
2.3.6 Pre/Post Stimulation Log T4 Through T10	4	328	Drill/Log	55,860
2.3.7 5-Spot Tracer Tests	90	418	Drill/Log	76,010
2.3.8 Stimulate 5-Spot	10	428	Drill/Hydrofrac	127,064
2.3.9 Equip 5-Spot	7	435	Drill	440,105
	179			2,165,924
Operational Training	74	509	---	---
2.4 WELL SYSTEM OPERATION				
2.4.1 5-Spot Leaching	639	1,148	Chemical assay lab	191,625
2.4.2 5-Spot Maintenance	---	---	Drill/Log	100,000
2.4.3 Post Leach 5-Spot Tests	15	1,163	Drill/Log	101,000
2.4.4 Post Leach Core Drilling C2 and C3	25	1,188	Same as 2.1.1	84,920
2.4.5 Temporary Wellfield Abandonment	14	1,202	Same as 2.3.9	15,240
	693			492,785
TOTAL ALL SECTIONS	1,062	1,202		3,873,048

TABLE 1-8. DISTRIBUTION OF WELL SYSTEM COSTS
MUD ROTARY DRILLING

Section	$ Well Services	$ Hydro Frac	$ Explosive Frac	$ Rental	$ Purchase
2.1.1	40,365	--	--	--	5,975
2.1.2	56,548	--	--	--	22,934
2.1.3	65,747	--	--	--	82,245
2.1.4	23,025	--	--	1,000	12,500
2.1.5	14,900	--	--	--	--
2.2.1	--	--	--	--	--
2.2.2	249,782	--	--	--	175,466
2.2.3	47,050	--	--	--	--
2.2.4	29,800	--	--	--	--
2.2.5	94,190	--	--	9,000	7,150
2.2.6	32,300	17,100	41,050	6,000	900
2.2.7	241,350	20,440	--	8,982	360
2.3.1	--	--	--	--	20,000
2.3.2	--	--	--	--	--
2.3.3	907,769	--	--	--	614,131
2.3.4	104,300	--	--	--	--
2.3.5	31,150	--	--	8,000	--
2.3.6	55,860	--	--	--	--
2.3.7	48,310	--	--	--	27,700
2.3.8	66,800	60,264	--	--	--
2.3.9	28,400	--	--	--	411,705
2.4.1	--	--	--	--	191,625
2.4.2	100,000	--	--	--	--
2.4.3	98,000	--	--	3,000	--
2.4.4	80,730	--	--	--	11,950
2.4.5	15,000	--	--	--	240
	2,431,376	97,804	41,050	35,982	1,584,881

TABLE 1-9. WELL SYSTEM MATERIALS AND EQUIPMENT

Section	Materials and Equipment
2.1.1	Drilling mud and additives for rotary and coring 4 1/2 inch o.d. steel casing, 950 feet HQ core boxes and blocks Core photography equipment, film and procesing
2.1.2	Drilling mud and additives, rotary drilling (970 feet of 14 inch hold) 16 inch o.d. surface casing (40 feet) 10 3/4 inch o.d. intermediate casing (950 feet) Casing cementing equipment (centralizers, float equip., cement baskets) Cement and additives (530 sacks, 14.7 lb./gal. slurry)
2.1.3	Steel "work string" tubing (2 7/8 in., 2500 feet) F.R.P. well casing, 7 inch o.d., 2230 ft./well Cement, lightweight "microsphere" type and additives.
2.1.4	Water tank, 10,000 gal., corrosion resistant Water truck (rental) Packer, inflatable, 6 inch i.d. casing. 1000 psi Packer inflation tubing and equipment
2.1.5	No purchases required
2.2.1	No purchases required
2.2.2	Same as subactiviaty 2.1.2 and 2.1.3, for two wells (omit "work string" tubing purchase)
2.2.3	No purchase required
2.2.4	No purchase required
2.2.5	Quartz pressure guage rental (if not supplied by logger) Tracer chemical (NaCl salt) 43 tons Assaying services Sample containers
2.2.6	Packer, inflatable (rental), carbon stel, 6 inch i.d. casing, 3000 + psi differential press. rated Packer, mechanical (purchase), carbon steel, as above
2.2.7	Packer, inflatable (see subactivity 2.2.6) Bridge plug, retrievable (rental), 6 inch i.d. casing

TABLE 1-9. WELL SYSTEM MATERIALS AND EQUIPMENT
(continued)

Section	Materials and Equipment
2.3.1	No purchases required
2.3.2	No purchases required
2.3.3	Same as subactivities 2.1.2 and 2.1.3, for 7 wells
2.3.4	No purchases required
2.3.5	Quartz pressure guage (if not supplied by loggers)
2.3.6	No purchases required
2.3.7	Tracer chemical (NaCl salt), 354 tons Assaying services Sample containers
2.3.8	Packer, inflatable (rental)-same as subactivity 2.2.6
2.3.9	Tubing: F.R.P., 2 3/8 inch o.d. Stainless steel, high alloy, 2 3/8 inch o.d. F.R.P. couplings for s.s. tubing Thread adapters, corrosion resistant, as req'd.
	Packers, tube-inflatable, 6 inch i.d. casing, 2000 psi differential rated, high alloy s.s. and suitable elastomers. Packer inflation tube, elastomer, corrosion resistant, less than 1 inch o.d., 200 psi rated.
	Strapping, corrosion resistant, for holding equipment to well tubing
	Wellhead equipment: Wellhead (carbon steel, 7 inch casing) Tubing landing nipples, high alloy s.s., 2 3/8 o.d. Valves (as described in text) Pressure guages (as described in text) Pipe fittings, high alloy s.s., (as required)
	Recovery Pumps:
	Electric submersible - 316 s.s. alloy, 8.3 gpm from 1890 feet depth, with suitable cable, splices and controls

TABLE 1-9. WELL SYSTEM MATERIALS AND EQUIPMENT (continued)

Section	Materials and Equipment
	Progressing cavity - 316 s.s. and high alloy s.s., 8.3 gpm from 200 ft. depth, suitable drive rods (5/8 A.P.I. sucker rods of 316 s.s. construction, or equivalent), rod guides (coorosion resistant), pump drive head, packing gland (corrosion resistant), and motor.
	Spare parts inventory, as described in text
2.4.1	Assaying services Sample containers
2.4.2	No purchases required
2.4.3	Quartz pressure guage rental (if not available from loggers)
2.4.4	Same as subactivity 2.1.1
2.4.5	Well Closure cap materials (10 wells) Large diameter steel casing Steel plate Locks and hardware

TABLE 1-10. WELL SERVICE EQUIPMENT REQUIREMENTS

Section	Well Service Equipment Requirements
2.1.1.	Drilling:
	6 inch rotary to 970 ft.
	HQ core, 970 to 2,220 ft.
	Pull casing, bentonite-fill hole
2.1.2.	Drilling:
	Surface hole - 19 in. to 40 ft.
	Set & cement surf. casing
	Intermediate hole - 14 in. to 970 ft., mud rotary
	Set 10 3/4 in. casing & equip. to 970 ft.
	Rotate & reciprocate casing during cementing
	Furnish drilling data recorder
	Logging:
	Caliper, temperature & cement bond
	Cementing:
	Cement full length with 14.7 lb./gal. slurry
2.1.3.	Drilling:
	Drill out intermediate casing cement & equip.
	Production hole - 10 in. to 2,250 ft.
	Operate drilling data recorder
	Oriented core - 4 in., 10 ft., specified depth
	Condition hole for casing & cementing
	Assist with logging & casing
	Rotate & reciprocate casing during cementing
	Logging:
	Open hole logs as specified
	Cement bond & temprature logs
	Perforate bottom 200 ft. of asing, 4 j.s.p.f.
	Casing (contract crew):
	Install 7 in. F.R.P. casing & equip. to 2,230 ft.
	Cementing:
	Cement full length with 9.5 lb./gal. slurry
2.1.4.	Drilling:
	Install & remove injection equipment
	Provide mast & assistance to loggers
	Logging:
	Flow profile & temperature logs
2.1.5.	Logging:
	Run open and cased hole logs as required, including:
	Spontaneous potential
	Resistivity or induction
	Compensated density
	Compensated neutron
	Gamma ray
	Conpensated sonic

TABLE 1-10. WELL SERVICE EQUIPMENT REQUIREMENTS (Continued)

Section	Well Service Equipment Requirements
2.1.5.	Temperature & differential temp. Caliper (4 arm oriented & multi-arm casing) Spinner Directional survey Cement bond Additional work specified for various subactivities includes: Perforations (6 in. size casing gun, premium jets) Pressure monitoring with quartz type press. gauge Drilling: Provide mast & assistance to loggers
2.2.1.	No contract services required
2.2.2.	Same as subactivities 2.1.2. and 2.1.3., for 2 wells
2.2.3.	Same as subactivity 2.1.4., for 2 wells
2.2.4.	Same as subactivity 2.1.5., for 2 wells
2.2.5.	Drilling: Provide mase & assistance to loggers Install & remove well equipment (including tubing, packers, pumps & fluid level monitoring equip.) Logging: Spinner and/or differential temp. logs Gamma ray log Multi-arm casing caliper Pressure monitoring with quartz gauge
2.2.6.	Drilling: Install & remove tubing & packer equip. Provide mast & assistance to loggers Circulate wells clean after stimulation Possible fishing work Hydraulic Fracturing: Assist with stimulation design Provide equipment, materials & instrumentation (for multiple short-radius propped hydrofractures) Utilize mini-frac to modify design Install propped fractures in 2 wells H.E.G.F.: Assist with stimulation design Provide equipment, materials & instruments (for 200 ft. interval, 2,000 ft. depth, F.R.P. csg.) Install H.E.G.F. stimulation in 1 well Logging: Post-stimulation cement bond & casing caliper logs

TABLE 1-10. WELL SERVICE EQUIPMENT REQUIREMENTS (Continued)

Section	Well Service Equipment Requirements

2.2.7.	Drilling:
	    Install & remove well equipment
	    Install & rotate abrasive jet tool (two times)
	    Plug 1 well bottom and sand & cal-seal
	    Install & remove mechanical bridge plug (1 well)
	Logging:
	    Temp., casing caliper, cement bond & gamma ray logs
	    Assist with log analysis
	    Provide/apply R/A tracer fluid to hydrofrac fluid
	Hydraulic fracturing:
	    Assist with stimulation designs (2 depths, 1 well)
	    Provide equipment, materials & instrumentation
	    Utilize mini-frac to modify design
	    Install 2 propped, 60 ft. radius ractures
	Downhole seismic:
	    Assist in program design and data interpretation
	    Provide equipment materials & instrumentation
	    Install equipment, with site contractor assistance
	    Operate equipment (2 uses)
	    Provide a formal report
	Surface seismic:
	    Same as Downhole seismic
	Core Analysis:
	    Assist in program design
	    Provide personnel, equipment & materials
	    Transport core as required
	    Provide core analysis & formal report (3 cores)

2.3.1.	No services required
2.3.2.	No services required

2.3.3.	Same as subactivities 2.1.2. and 2.1.3., for 7 wells, except:
	    Omit open-hole testing
	    Drilling:
	        Omit oriented coring
	        Directional drilling may be required
	        Install & remove well equipment
	        Two rigs will be required
	    Logging:
	        Perforate bottom 322 ft. of casing (7 wells)
	        Perforate 122 ft. of csg. in 1 existing well

2.3.4.	Drilling:
	    Provide mast & assistance to loggers
	Logging:
	    Same as subactivity 2.1.5.

TABLE 1-10. WELL SERVICE EQUIPMENT REQUIREMENTS (Continued)

Section	Well Service Equipment Requirements
2.3.5.	Drilling: Install & remove well equipment (8 wells) Logging: Flow profile & temp. logs (2 wells) Monitor pressure (two logging units & 2 quartz gauges required)
2.3.6.	Drilling: Install & remove well equipment (8 wells) Provide mast & assistance to loggers Logging: Flow profile & temp. logs (8 wells) Cement bond & casing caliper logs (post stim.)
2.3.7.	Drilling: Same as subactivity 2.2.5. Possibly demob./re-mobilization Logging: Same as subactivity 2.2.5. Possibly demob./re-mobilization
2.3.8.	Drilling: Same as subactivity 2.2.6, for 7 wells Omit water-filling wells for stimulation Install & remove a sand & cal-seal well plug Hydraulic fracturing: Same as subactivity 2.2.6., for 7 wells Stimulate a 122 ft. interval in 1 existing well
2.3.9.	Drilling: Install leaching equipment in 8 wells Assist in testing equipment Assist surface contractor with well equipment
2.4.1.	No services required
2.4.2.	Drilling: Mob. & demob. as required (well maintenance) Install & remove well equipment Possible fishing & well repair work
2.4.3.	Same as subactivity 2.3.5.
2.4.4.	Same as subactivity 2.1.1.
2.4.5.	Drilling: Remove well equipment Assist surf. contractor in well closures

TABLE 1-11. SURFACE PLANT EQUIPMENT LIST

EQUIP. NO.	QTY	DESCRIPTION	hp
20-3-100	1	Salt Mixing Tank 12 ft dia x 20 ft fiberglass tank w/cover 15,000 gal capacity	
20-1-105	1	Recirculation Pump 50 gpm, complete with motor, coupling, base and guard CPVC wetted parts	0.75
20-0-200	1	Well Field Pipe - Low Pressure Distribution and return lines HDPE butt welded pipe	
20-0-210	1	Well Field Pipe - High Pressure 1,500 psi rated, 904L stainless steel, flanged or welded	
20-0-240	8	Well Pads 20 ft x 10 ft concrete pad w/coarse fill sub-base, HDPE barrier and drain to dry sump	
20-3-250	1	Injection Pump Head Tank 4 ft dia x 6.5 ft Elevated HDPE tank with cover 500 gal active volumn	
20-0-275	3	Injection Pump (2+1) Progressive cavity, positive displacement pump, 50 gpm each w/motor, coupling, base	40
20-0-285	3	Injection Pump Spares Stator and rotor	
20-0-290	1	AC Variable Frequency Control Speed control for injection pumps, eq. nos. 20-3-275/276	
20-0-500	1	Production Well Pipe Polypropolene lined steel or HDPE pipe, collects solution from wells, feeds PLS pond	
20-0-910	1	Well Field Water Distribution	

TABLE 1-11. SURFACE PLANT EQUIPMENT LIST (Continued)

EQUIP. NO.	QTY	DESCRIPTION	hp
20-0-917	1	Well Field Power/Distribution 480 V, medium tension 120 V, lighting	
20-0-920	1	Misc. Well Field Pipe/Valves	
20-0-930	1	Electrical	
20-0-950	1	Instrumentation	
30-4-050	1	PLS Pond 50 ft x 50 ft x 6 ft double lined HDPE with dry sump	
30-1-060	1	SX Feed Pump 50 gpm, complete with motor, coupling, base & guard CPVC wetted parts	0.75
30-2-100	3	Extraction Pump/Mixer Box 180 gal active capacity fiberglass construction with agitator bridge	
30-2-105	12	Extraction P/M Inserts (*) Active capacities of: 36, 60, 90 120 gal	
30-2-110	3	Extraction P/M Agitator Complete with motor, shaft, impellor, gear box and variable speed drive	1.5
30-2-115	3	Extraction P/M Agitator (*) Complete with motor, shaft, impellor, gear box and variable speed drive	0.5
30-2-120	32	Impellors (*) Various sizes for different mixer inserts	
30-2-130	3	Extraction Mixer Box 180 gal active capacity fiberglass construction with agitator bridge	

TABLE 1-11. SURFACE PLANT EQUIPMENT LIST (Continued)

EQUIP. NO.	QTY	DESCRIPTION	hp
30-2-135	12	Extraction Mixer Insert (*) Active capacities of: 36, 60, 90, 120 gal	
30-2-140	3	Extraction Mixer Agitator Complete with motor, shaft, impellor, gear box and variable speed drive	0.75
30-2-145	3	Extraction Mixer Agitator (*) Complete with motor, shaft, impellor gear box and variable speed drive	0.25
30-2-150	3	Extraction Settler 180 sq ft active area 12 ft x 22.3 ft x 3 ft concrete, HDPE lined, covered	
30-2-400	2	Strip Pump/Mixer Box 180 gal active capacity fiberglass construction with agitator bridge	
30-2-405	2	Strip Pump/Mixer Insert (*) Active capacities of: 36, 60, 90, 120 gal	
30-2-410	2	Strip P/M Agitator Complete with motor, shaft, impellor, gear box and variable speed drive	1.5
30-2-415	2	Strip P/M Agitator (*) Complete with motor, shaft, impellor, gear box and variable speed drive	0.5
30-2-450	2	Strip Settler 180 sq ft active area 12 ft x 22.3 ft x 3 ft concrete, HDPE lined, covered	
30-4-700	1	Raffinate Pond 50 ft x 50 ft x 6 ft Double HDPE liner with dry sump	

TABLE 1-11. SURFACE PLANT EQUIPMENT LIST (Continued)

EQUIP. NO.	QTY	DESCRIPTION	hp
30-1-705	1	Raffinate Pond Pump 50 gpm, complete with motor, coupling, base and guard CPVC wet'd parts, neg. suction	
30-0-710	1	Static Mixer 20 Alloy mixing zone with stainless steel cooling zone Protected from direct sunlight	
30-3-715	1	Raffinate Check TAnk 4 ft dia x 6.5 ft fiberglass tank w/covered top 500 gal active volumn	
30-1-720	1	Raffinate Filter Feed Pump 50 gpm, complete with motor, coupling, base & guard CPVC wetted parts	0.75
30-0-725	2	Raffinate Filter (1+1) Wound fiber/activated carbon cartridge filter, with 1 micron filtrate limit	
30-0-730	1	Pond Skimmer Floating skimmer to reclaim organic collecting on the surface of the pond	0.5
30-0-750	1	pH controller Automatic acid control for the leach injection solution	
30-4-780	1	Evaporation Pond 100 ft x 100 ft x 6 ft double HDPE liner with dry sump	
30-0-930	1	Electrical	
30-0-940	1	Piping	
30-0-950	1	Instrumentation	

TABLE 1-11. SURFACE PLANT EQUIPMENT LIST (Continued)

EQUIP. NO.	QTY	DESCRIPTION	hp
30-0-999	3	Portable Crud Pump (1+1) Pneumatic, diaphragm pump 20 gal capacity with PVDF wetted parts	
40-3-250	1	Loaded Organic Tank 11.5 ft dia x 7 ft fiberglass tank w/covered top 5,000 gal nominal capacity	
40-1-255	2	Loaded Organic Pump (1+1) 70 gpm, complete with motor, coupling, base & guard CPVC wetted parts	0.75
40-3-260	1	Strip Extract Storage Tank 11.5 ft dia x 7 ft fiberglass tank w/covered top 5,000 gals nominal capacity	
40-1-280	1	Filter Feed Pumps 35 gpm, complete with motor, coupling base & guard CPVC wetted parts	0.75
40-0-285	2	Electrolyte Filter (1+1) Wound fiber/activated carbon cartridge filter	
40-3-300	1	Strong Electrolyte Tank 11.5 ft dia x 7 ft fiberglass tank w/covered top 5,000 gal nominal capacity	
40-1-305	2	Strong Electrolyte Pumps (1+1) 35 gpm, complete with motor, coupling, base & guard CPCV wetted parts	0.75
40-0-500	1	Crud Collection System	
40-0-510	1	SX Drain Sump 4500 gal nominal capacity tank seamless HDPE design w/cover 12 ft dia x 5.6 ft	

TABLE 1-11. SURFACE PLANT EQUIPMENT LIST (Continued)

EQUIP. NO.	QTY	DESCRIPTION	hp
40-1-515	1	SX Drain Sump Pump Vertical, immersible, self-priming pump with direct drive motor and coupling	0.33
40-3-525	1	Centrifuge Feed Tank 3.5 ft dia x 4.5 ft fiberglass with covered top	
40-1-530	1	Centrifuge Feed Pump complete with motor base, coupling & guard	
40-0-550	1	Centrifuge Vertical, desludging type 316L/CF-3M wetted parts w/motor & coupling	
40-3-565	1	Recovered Organic Tank 3.5 ft dia x 4.5 ft fiberglass tank w/covered top 250 gal nominal capacity	
40-3-600	1	Sulfuric Acid Tank 12 ft dia x 20 ft carbon steel tank with top 15,000 gal capacity	
40-1-610	1	Sump Pump 5 gpm, vertical centrifugal w/ motor, coupling, base & guard self priming, CPVC wet. parts	0.5
40-1-615	5	Barrel Pumps 25 gpm at 10 TDH, complete with pneumatic motor, 316 tube set with seal	
40-0-620	1	Sulfuric Acid Mettering Pump 10 gpm, complete with motor base, coupling & guard hi-silicon iron wetted parts	0.5
40-99-700	1	Reagent Storage Bldg. 25 ft x 40 open sided structure w/roof, chain-link fence sides	

TABLE 1-11. SURFACE PLANT EQUIPMENT LIST (Continued)

EQUIP. NO.	QTY	DESCRIPTION	hp
40-0-930	1	Electrical	
40-0-940	1	Piping	
40-0-950	1	Instrumentation	
50-0-100	1	Heat Exchanger Plate and frame type	
50-3-110	1	Circulation Tank 12 ft dia x 4 ft w/cover 2,500 gal nominal capacity PVC/316L construction	
50-1-115	2	Circulation Pumps 180 gpm, complete with motor, coupling, base & guard CPVC wetted parts	5
50-1-125	1	Spent Electrolyte Pumps 35 gpm, complete with motor, coupling, base & guard CPVC wetted parts	0.75
50-5-225	6	Electrolytic Cells 19.5 ft x 3.7 ft x 4.7 ft (d) nominal size, actual based on final electrode selection	
50-5-235	7	Cell Liners (6+1) Seamless plasticized PVC Paraline or equal	
50-6-250	400	Anodes (342 + 58) Ca,Sn lead, solid blade, steerhorn suspension bar with copper insert	
50-7-260	400	Cathodes (336 + 64) Mt Isa type stainless steel blade and suspension bar	
50-5-265	1,500	Anode Guides PVC hairpin insulators	
50-5-270	800	Cell Top Insulators fiber filled, polycarbonate, interlocking modules	

TABLE 1-11. SURFACE PLANT EQUIPMENT LIST (Continued)

EQUIP. NO.	QTY	DESCRIPTION	hp
50-5-340	7	Intercell Bus Bars (5+2) Walker double triangle 110 ETP copper	
50-5-345	2	Apron Bus Vertical wrap over end bus w/Walker triangle, 100 ETP copper, 25.2 kA rated	
50-5-350	1	Main Bus 25.2 kA rated insulated cable	
50-8-400	1	Transformer/Rectifier 25.2 kA, 15 V dc output 6 pulse, thyristor type	
50-0-450	1	Over Head Crane 10 t underhung, single beam, pendant with stepless control 37.5 ft span, 25 ft lift	7.5
50-0-455	2	Crane Lifting Bales Anode bale w/57 hooks, Cathode bale w/28 hooks	
50-0-460	1	Cathode Washing Station Stainless steel spay and dip tank, 20 ft x 4 ft x 5 ft	
50-0-470	1	Cathode Stripping Station Two parallel bars to receive cathodes for stripping and reloading	
50-0-475	1	Cathode Wax Tank 20 ft x 4 ft x 1 ft tank with cathode guides	
50-0-500	1	Cathode Scale 20,000 lb capacity, 5 x 7 ft platform, low profile - weigh plate type w/load cell design	
50-0-520	1	Anode Storage Racks 3 layer, full bale storage mild steel, painted	

TABLE 1-11. SURFACE PLANT EQUIPMENT LIST (Continued)

EQUIP. NO.	QTY	DESCRIPTION	hp
50-0-530	1	Cathode Storage Racks 3 layer, full bale storage, painted mild steel	
50-1-610	1	Sump Pump 5 gpm, vercial centrifugal w/ motor, coupling, base & guard self priming, CPVC wet. parts	0.5
50-0-725	4	Reagent Feeders (2+2) For CoSO4 and HCl PVC wetted parts	0.1
50-3-730	1	Reagent Solution Tank - CoSO4 65 gal nominal capacity with agitator support and cover	
50-3-735	1	Reagent Solution Tatnk - HCl 65 gal nominal capacity PVC tank with covered top	
50-2-740	2	Solution Tank Agitator (1+1) Direct drive with motor, 316 shift and impellor. duty: mix CoSO4	0.33
50-0-750	1	In-line Process Water Heater Propane fired	
50-0-800	1	Forklift 4t capacity, propane fueled, with penumatic tires	
50-99-900	1	Electrowinning Building 40 ft x 100 ft x 24 ft height open portal, structural steel structure	
50-99-925	1	Control Room/Electrical Bldg. With the electrowinning bldg, HVAC system for personnel and electrical equipment	
50-0-930	1	Electrical	
50-0-940	1	Piping	

TABLE 1-11. SURFACE PLANT EQUIPMENT LIST (Continued)

EQUIP. NO.	QTY	DESCRIPTION	hp
50-0-950	1	Instrumentation	
90-0-010	1	Transformer 13.8 kV - 480 500/560 KVA, 3 PH	
90-0-011	1	Main Disconnect Switch	
90-0-015	1	Motor Control Center Units complete with enclosures switches, magnetic contractors, relays, fuses, etc...	
90-3-100	1	Potable Water/Firewater Tank 12 ft dia x 20 ft Mild steel with closed top dedicated vol. for emergency	
90-1-110	1	Potable Water Pumps 100 gpm, complete with motor, coupling, base & guard bronze case and impellor	15
90-99-120	1	Fire Pump Building 20 ft x 30 ft x 12 ft Houses firewater pump, AFFF system and ancillary equipment	
90-0-125	1	Firewater Pump 250 gpm, complete with diesel motor drive, controller fuel tank and jocky pump	7.5
90-0-135	1	Automatic AFFF System Provide foam to tanks, vessels and fire water system, complete w/control system	
90-99-200	1	Administration Building 2,500 sq ft, full HVAC, toilets offices and laboratory, temporary building or trailers	
90-99-300	1	Maintenance Building 1,000 sq ft floor space, 3 vehicle bays, maintenance and warehouse areas	

TABLE 1-11. SURFACE PLANT EQUIPMENT LIST (Continued)

EQUIP. NO.	QTY	DESCRIPTION	hp
90-0-310	1	Plant Air Compressor Oil-less type complete package unit with motor and receiver 100 std cu ft/min @ 100 psi	40
90-0-315	1	Instrument Air Dryer Heatless - desiccant type with prefilter and afterfilter	
90-0-400	1	Propane Tank	
90-0-500	1	Sanitary Sewer System	
90-0-930	1	Electrical	
90-0-940	1	Piping	
90-0-950	1	Instrumentation	

Table 1-12 summarizes total cost estimates for equipment and installation by area. An itemized list of equipment by area is provided in Table B-1 in Appendix B.

o Environmental

A listing of all equipment and well service pertaining to environmental permitting is provided in Table 1-13.

1.7 COMPARISON OF FIELD TEST DATA WITH DESIGN PARAMETERS

Data obtained from the field tests at the Santa Cruz site and the core leach tests at TCRC were evaluated to determine whether the design specifications selected for the commercial and field experiment designs at Santa Cruz should be modified, and if so make the appropriate changes to each design. Based on this evaluation no modifications are recommended. The rationale for this conclusion is reviewed below.

- The best mining scenario for the commercial design assumed a 2 md permeability. As reported in Volume V, permeabilities measured in the new SC-46 and SC-19 core holes are 1 and 4 md respectively. These are thought to be minimum values due to mud interference. Measurements made in the old SC-19 core hole indicate a 5 fold increase in permeability can be expected without mud interference. Therefore, the assumption of 2 md permeability for the best mining scenario is valid.

- The definition of the size and geometry of the commercial ore body was derived from ore reserve data provided by ASARCO. The core obtained from SC-46 and SC-19 in the field test did not differ significantly from previous core obtained in these holes, nor represented a sufficient re-sampling of the ore body to enable an adjustment in the reserve to be made.

- Based on the geometry of the commercial ore body (average well depth of 2,137 feet and ore thickness of 345 feet), 2 md permeability, and 3-to-1 stimulation by small radius hydrofracing, an injection flow rate of 42 gpm was projected for the commercial operation. The field experiment was designed to accommodate an SX/EW flow rate range of 10-to-50 gpm. The upper limit corresponds to the maximum flow rate anticipated for a single well, the lower limit corresponds to a flow rate required to use commercial size process equipment. The field test injectivity data for SC-46 indicate that a minimum injection rate of 5 gpm would be expected when mud damage is eliminated. This is sufficient to achieve the 10 gpm required for the SX/EW since the field experiment utilizes two 5-spots. It is expected that the 5 gpm rate can be increased by 15 gpm by application of small radius hydrofracturing.

TABLE 1-12. SURFACE PLANT EQUIPMENT COSTS BY AREA

AREA	PROCESS EQUIPMENT COST $\$ \times 10^3$	MATERIALS COST $\$ \times 10^3$	LABOR COST TO INSTALL $\$ \times 10^3$	COMMON DISTRI-BUDABLES $\$ \times 10^3$	TOTAL $\$ \times 10^3$
20 Wellfield	155.2	132.9	96.2	59.0	443.3
30 Solvent Extraction	86.4	153.4	160.2	67.0	461.0
40 Tank Farm	47.3	85.5	62.5	30.0	225.3
50 Electro-winning	712.0	192.5	168.0	165.0	1,237.5
90 General	84.3	364.3	130.0	89.0	667.6
TOTAL	1,085.2	928.6	616.9	405.0	3,035.7

TABLE 1-13. ENVIRONMENTAL EQUIPMENT AND WELL SERVICE REQUIREMENTS

	Purchases	Unit Cost	Quantity	Estimated Cost
1.	Permits			
	Fees for ADWR Well Permits		20 wells	$ 200
	Fee for ADEQ Permit			1,000
2.	Hydrogeologic Characterization Program			
	Grout	$50/yd^3	40 yd^3	2,000
	Coreboxes, Hand Tools, Shipping			800
	Bit Use			1,800
	Casing	$12/ft	800 ft	9,600
3.	Corrective Action Program			
	Grout	$50/yd^3	220 yd^3	11,000
	Bit Use			1,800
4.	Monitoring Well Installation			
	Surface Casing 16" steel	$11/ft	60 ft	660
	Wellhead Assembly	$150/ea	3 units	450
	Grout	$50/yd^3	40 yd^3	2,000
	Gravel	$100/yd^3	10 yd^3	1,000
	6" I.D. FRP Casing	$15/ft	1,800 ft	27,000
	6" I.D. FRP Well Screen	$35/ft	300 ft	10,500
	6" I.D. FRP Caps	$25	6 caps	150
	FRP Casing Centralizers	$25	30 units	750
	Submersible Pumps	$2,000 ea	3 pumps	6,000
	Risers, Elec. Conduit, Tubing			1,900
	Bit Use			1,800

TABLE 1-13. ENVIRONMENTAL EQUIPMENT AND WELL SERVICE REQUIREMENTS (Continued)

	Purchases	Unit Cost	Quantity	Estimated Cost
5.	Baseline Water Quality Program			
	pH Meter	$300	1	300
	Conduct/Temp Meter	$500	1	500
	Water Leel Sounder	$400	1	400
	Peristaltic Pump	$300	1	300
	Filter System	$300	1	300
	Preservatives, Filter Paper, Distilled Water			200
6.	Operational Water Quality Monitoring Program			
	Preservatives, Filter Paper, Distilled Water			200

7. Dual-tube Reverse Circulation

To maximize the return of geologic information when drilling in alluvial materials, the dual tube reverse circulation method will be used for advancing four boreholes. Three of the holes will be completed as monitor wells. The fourth hole is part of the Hydrogeologic Characterization Program. The three monitor wells will be drilled at 6 3/4-inch diameters to depths of 700 feet. the test hole well be drilled at 6 3/4-inch diameter to 800 feet, then cased with 4 1/2-inch I.D. flush jointed pipe, from the surface to total depth. Casing will be securely grouted in throughout the entire length.

The drill unit will be a reverse circulation system for drilling with dual tube drill pipe and a hydraulically controlled water injection system. The drill unit will have a depth capability of 1,000 feet. Drill bit subs and adapters for tricone and/or down-the-hole hammer will be capable of drilling up to a maximum hole diameter of 6 3/4 inches. The derrick will be capable of changing a 20-foot section of drill pipe.

The drill unit will be truck mounted for ease in mobility. The unit will be equipped with air compressors capable of delivering 750 cfm free air at 250 psi. Additional boosters delivering 1,000 cfm free air at 250 psi will be available upon request.

TABLE 1-13. ENVIRONMENTAL EQUIPMENT AND WELL SERVICE REQUIREMENTS (Continued)

Additional equipment will include a three-tiered Jones-type splitter, cyclone assembly complete with discharge hose, and a combination pipe, service and water truck.

8. Rotary

A rotary unit will be required on-site at two separate times for two different functions. The first function comprises part of the Corrective Action Program. The rotary unit will be used to clean out the total of seven, NX to HQ sized exploratory drill holes to 1,800-foot depths. The holes will be grouted through drill pipe from 1,800 feet to the bottom of 3 1/2-inch I.D. casing (approximately 900 feet below surface), then the casing will be ripped and space behind casing will be pressure grouted; all boreholes will be grouted to the surface. Drill will follow 2,000 feet of existing borehole through casing and bedrock without deviating or creating a new hole. The rotary unit will be capable of drilling to 2,000 feet. Mud or air rotary method will be used. Mud tanks or air supplies, and a combination pipe, service and water truck will be supplied by the Drilling Contractor. Grout will consist of a low permeability, corrosion and shrinkage resistant, sodium bentonite-based mixture.

The second function of a rotary unit will be to ream the three 700-foot boreholes to 10-inch diameters and complete the borings as monitor wells. Details on monitor well installation requirements are found in Chapter 4, Section 4.6.

9. Wireline Coring

The wireline coring unit will continuously core in the borehole designed for hydrogeologic characterization. The first 800 feet of the borehole will have been drilled by the dual tube reverse circulation method and will be cased to 800 feet with 4 1/2-inch I.D. flush jointed pipe casing. A HQ sized hole will be cored for 1,000 feet to a total depth of 1,800 feet. If necessary and approved by the Field Experiment Operator, the coring size may be reduced to NQ. Within this 1,000-foot interval, the wireline operators will carry out 20 packer tests at 50-foot intervals.

The drill unit will have a depth capability of 2,000 feet. Water will be the only drilling fluid permitted; mud polymers will be used only with the permission of the Owner's Hydrogeologic Representative. No use of lubricants or heavy grease that could possibly seal off formations will be allowed. Core barrel length will be 10 feet. Wireline drill rod size will be HQ. NW casing and NQ rods will be available on-site if additional casing is required.

All packer equipment will be provided by the drilling contractor. Packers must be able to seal off 10 to 50-foot intervals subject to flow rates of up to 40 gpm. Other equipment to be provided will include a pipe, service, and water truck.

- o The recommended location of the field experiment is in the vicinity of SC-35. It was selected because it best approximates the average properties of the commercial ore block pertaining to % copper grade, well depth, and ore thickness. This location also contains porphyry type host rock, as does the test interval in SC-46. Although measurements in SC-19 are higher than SC-46 and the host rock type in SC-19 is granite it is not recommended that the location of the proposed field experiment be changed since adequate flow rates are projected for the SC-35 area and it is most representative of the average commercial ore block propeties.

- o Porosity measurements obtained in SC-46 average 8%. The average porosity used in the commercial and field experiment designs is 5%. Impacts on each of the designs are discussed below.

  - + The higher porosity increases wellfield start-up time in a commercial operation. The generic design manual computer program was used to assess the impact of well spacing on selling price at 8% porosity. The shape of the sensitivity response of selling price versus well spacing parallels that at 5% porosity. Therefore, the optimum spacing of 160 feet is retained. The higher porosity adds 2¢/lb to the selling price of copper.

  - + The only impact of the higher porosity on the field experiment design occurs in Section 2.2.5.4 which pertains to tracer testing in the three-hole pattern. This activity requires a four pore volume displacement to measure the tracer breakthrough curve. An additional 3% porosity would increase the testing time by 19 days and salt and field service costs by $18,000. Since this cost impact is insignificant in relation to the total project cost, it is not recommended that the field experiment design be modified.

  - + All of the other test activities for the field experiment involve testing times that are much larger than transient times that are porosity dependent. Porosity variations do not impact the work schedule for these activities.

- o Core testing conducted to date at TCRC demonstrates that copper loadings of the order of 10 gpl were obtained with acid concentrations of 40 to 50 gpl at acid consumption levels less than 3 1/2 lb acid per lb copper. Based on these data, no modification to the field experiment design is recommended at this time.

- o No modification to the environmental permitting process for the field experiment is required since the location and size of the field experiment does not require modification.

- o Modifications to the SX/EW facility design for the field experiment may be required at a future date with regard to chloride build-up resulting from atacamite dissolution. The current design is based on assumptions of 20% of the copper being initially present as atacamite and equal dissolution rates of all copper minerals. No additional data are available at this time to justify a design change. The chloride build-up in the field experiment can be estimated when the following data are obtained.

+ A correlation between chloride to copper ratios in core leach effluent and the assay ratio of atacamite copper to total copper.

+ The average ratio of atacamite copper to total copper determined by analysis of core obtained from the core hole to be drilled at the start of the field experiment.

Sufficient time exist after drilling the first field experiment core hole to modify the SX/EW design to handle chloride levels that based on the above measurements would be calculated to exceed the levels associated with 20% of the copper originating in atacamite.

o Davy McKee Corporation has identified several modifications to the field experiment SX/EW design that could be evaluated to handle chloride levels in excess of the 5 gpl concentration on which the current design is based. These are discussed below.

+ The solvent extraction plant has been designed with 5 mixer/settlers and is expected to operate with 3 in extraction and two in strip. The SX plant has the option of operating with 3-mixer/settlers, 2 in extraction and 1 in strip. This combination would have the same volumetric capacity but have lower recovery. The two unused mixer/settlers could be used for removal of undesirable chloride ion that may build up beyond the assumed concentration limit. A candidate chemical process for use in this equipment could be the chloride removal by solvent extraction process identified in the December 1977 Hazen Research report to the Casa Grande West Copper Company. As reported in the SAIC report to USBM of 9/30/87, Generic In Situ Copper Mine Design Manual Review of CGW Data, the first step should be obtaining laboratory data on chloride extraction efficiency and then testing in a complete SW/EX circuit.

+ A cupric chloride precipitation process could be used. This was utilized at Chuquicamata many years ago. Copper oxide powder is mixed with the raffinate to precipitate cupric chloride. This would require design and purchase of a mixing tank, agitator, and a solid/liquid separation unit.

CHAPTER 2

WELL SYSTEM DESIGN

This chapter describes the four activities pertaining to the design and operation of the well system; Ore Block Flow Assessment; Well Pattern Flow Control; Well System Construction; and Well System Operation. For each activity the major sub-activities are listed, and within each sub-activity the following information is provided:

- A description of all work
- A summary of the design and specifications for conducting the work
- The time required to conduct the work
- All labor costs associated with drilling, installing, logging, and equiping the wells. These are categorized as well system contractor costs. All costs associated with operation, maintenance, and supervision are listed in Section 1.3 under Project Staff and Surface Facility Operating Contractor Costs. All costs for consumables and power are contained in Chapter 3.
- The type of contractors required to conduct the work.

2.1 ORE BLOCK FLOW ASSESSMENT

2.1.1 DRILL CORE HOLE AT TEST SITE - C1

Description:

Wireline core will be obtained from the ore test zone within the pilot test area (approximately 100 ft. south of existing core hole S.C. 35) to verify geologic conditions including mineralization, host rock type and ore grade. It will also provide information on geologic structure, assist with data projections from existing core holes S.C. 35 and 46, and provide limited information on drilling conditions at the site.

Drilling of the overlying sediments will be attempted by means of air hammer, in order to provide a basis for deciding on air hammer or mud rotary drilling of the larger test holes. If air hammer drilling becomes impractical due to water inflow rates and/or hole stability problems, the hole will have to be completed by mud rotary methods. Due to the uncertainty of predicting this operation, costs and work schedules are provided for both mud rotary and air hammer drilling.

Geologic information gained during core drilling can be used to modify other aspects of the test design if the test site geology is found to be signficantly different than that indicated by existing core hole S.C. 35.

Design Summary:

Core hole drilling procedure:

- o Obtain drilling permit.
- o Drill surface hole, set and cement suitable surface casing (6" i.d., 20 ft. deep).
- o Drill 6" hole to about 950 ft. (bottom of sediments).
- o Set suitable casing through sediments (4" i.d.).
- o Core HQ through oxide ore zone, to at least 2220 ft. deep.
- o Photo, log, box & store core for future reference.
- o Abandon core hole as required (Section 2.4.5.):
  - + cement or bentonite fill core hole
  - + pull casing, if possible
  - + cement or bentonite fill hole through sediments

Equipment Specifications:

- o Standard air hammer and mud rotary drilling equipment for 950 feet depth.
- o Standard HQ wireline coring equipment from 950 to 2220 feet.

Schedule:

- o Mud rotary drill sediments, mud coring: 14 days
- o Air hammer drill sediments, mud coring: 12.5 days

Well Costs:

- o Mud rotary drill sediments, mud coring: $ 46,340.
- o Air hammer drill sediments, mud coring: $ 42,460.

Contractor Requirements:

- o Well System Contractors
  - + Drilling contractor. Provide all manpower requirements to drill and core the hole.
- o Project Staff - observe drilling conditions, make decisions regarding air or mud drilling, calculate well deviation, modify test designs as appropriate, and log, photograph and store core. One engineer will be required, 1 shift/day.

2.1.2. INSTALL FIRST TEST WELL THROUGH SEDIMENTS - T1

Description:

Drill, case and cement full length through approximately 900 ft. of sediments, to isolate fluids within the sediments, allow drilling and open-hole testing of the underlying ore zone and provide drilling information for subsequent well installations. Drilling and casing sizes specified are based upon well equipment requirements for leach test wells, since at least one of the initial 3 test wells is to be used in the field experiment as a leach well. (See the detailed well design, Appendix A.1.1). Suitable equipment for recording drilling data such as weight on bit, bit rpm, circulating fluid flowrate, pressure and penetration rate will be required.

Utilize air hammer drilling of the sediments if previous sediment drilling (associated with coring) was successful. Be prepared to convert to mud rotary drilling if necessary. If air hammer drilling is successful and the resulting hole is suitably stable, consider modifying the well design to eliminate the intermediate casing string through the sediments. Hole deviation should be maintained less than 2 degrees from vertical; downhole directional surveys should be taken during drilling at appropriate intervals, and a survey map maintained.

Design Summary: (See also Figure 2-1)

Operations sequence for air hammer drilling:

1. Select first test well site, based on information from first core hole.
2. Mobilize and rig up drilling equipment.
3. Drill, set and cement the 15.37" i.d. surface casing to 40 ft. (Follow the procedure outlined in Appendix A section A.1.1 to assure good vertical alignment.)
4. Drill 14" to a point about 70 ft. below the bottom of sediments (about 970 ft.).

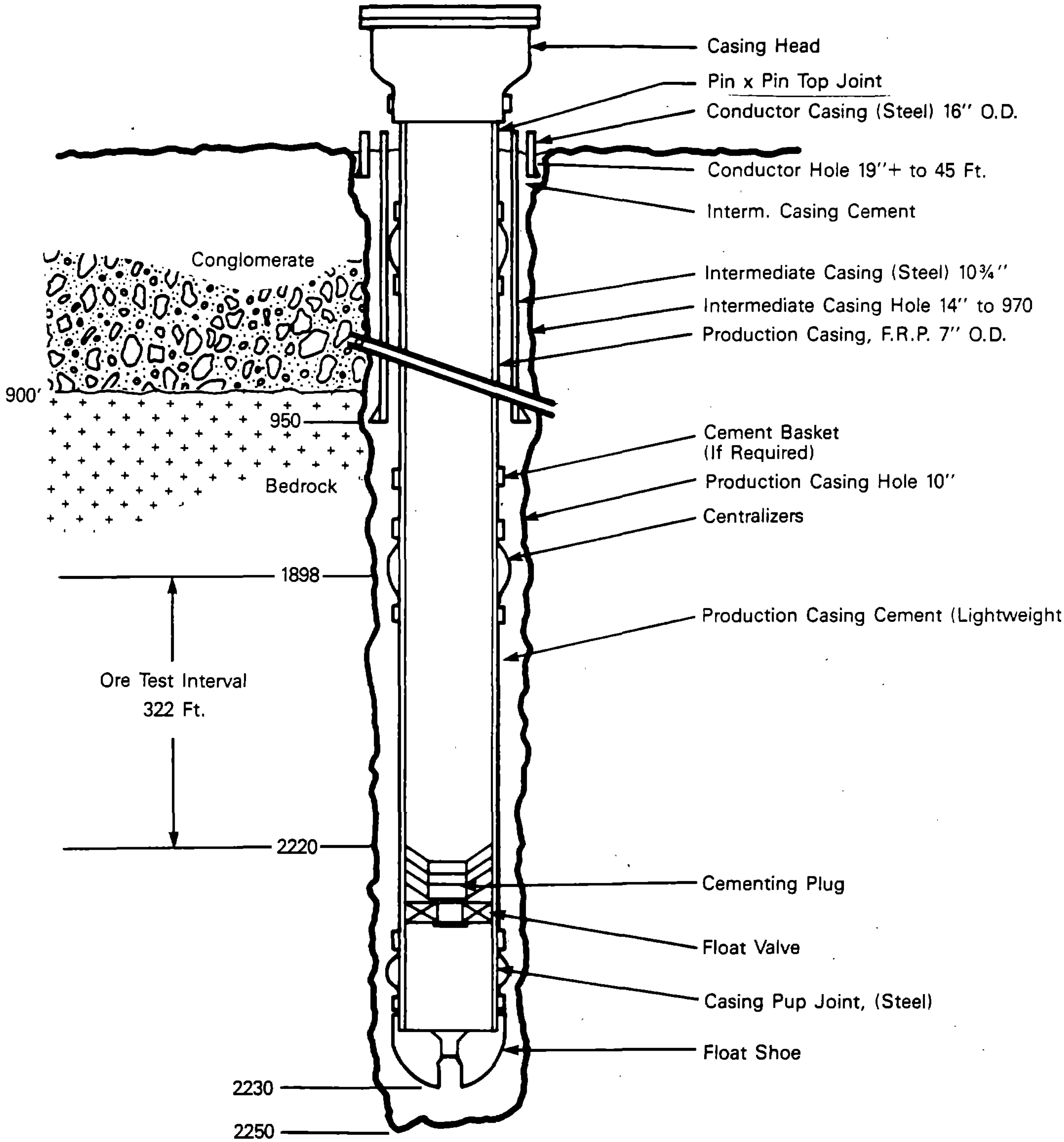


Figure 2-1. Santa Cruz Site Test Well Design

5. Remove drilling equipment from the hole and run a temperature and caliper survey. Run in drilling tools and condition the hole for casing if logs indicate substantial fill in the hole.

6. Set 10.75" o.d. (10.192" i.d.) casing to about 50 ft. below the sediment bottom (approximately 950 ft.). Install cementing equipment on the casing, as specified in the detailed design, Appendix A.1.1.)

7. Cement the casing full length, using a cementing service contractor and appropriate equipment. The cementing contractor will provide the detailed cementing design, including material and equipment specifications. Portland type II or A.P.I. class A or B neat cement slurry will be assumed for this test plan. Use caliper log to calculate cement volume; add 50% excess. If air drilling is utilized and the cement is displaced by water, the cement density must be kept below 14.5 lb./gallon to avoid casing buoyancy. (standard 15.7 lb./gallon cement density is suitable if displaced by normal 9.7 lb./gallon drilling mud.) Casing collapse is not a problem at these depths with this casing. Casing rotation and reciprocation should be utilized during cementing if possible, especially if mud rotary drilling had been utilized. Wait-on-cement time will be specified by the detailed cementing design; about 12 hours is proposed at this time. Retain all cementing records for data base and environmental use.

8. Run sonic bond log and temperature logs to evaluate quality of the cement job. Plan and execute remedial work if necessary. Fill the casing to surface with water and monitor fluid level for 6 hours.

Operations sequence for mud rotary drilling:

Operations change from those above only in cementing design (addition of a suitable mud breaker and displacement fluid), drilling tools and equipment, mud costs, drilling rates and hole conditioning preceeding casing operations. All well specifications remain unchanged regardless of drilling method.

Equipment Specifications:

Drilling:
Drill string and equipment, circulating equipment data gathering equipment, hoisting capacity and crew experience adequate to air hammer or mud rotary drill 14 inch diameter to 970 ft., set casing and assist cementing and rotate and reciprocate casing during cementing.

Wire logging:
Caliper, temperature and differential temperature log capability suitable for 14 inch open hole use.

Casing and Equipment:
See detailed well design, "casing" section, Appendix A.1.1. Well is planned based on 10.75 inch o.d., 10.192 inch i.d., A.P.I. F-25 threaded and coupled 32.8 lb./ft. steel well casing. Centralizers,

cement baskets, float shoe and float valve equipment, are specified in the detailed design.

Cementing:
Detailed design, personnel and equipment suitable for cementing the 10.75 inch casing full length to 950 ft. depth. Assuming approximately 50% excess cement to account for unknown fluid loss or other conditions, the job will require about 530 sacks of cement at 1.18 cubic ft. per sack yield.

<u>Schedule</u>:

- o Air Hammer Drilling: 4 days
- o Mud Rotary Drilling: 5 days

<u>Well Costs</u>:

- o Air Hammer Drilling: $67,357
- o Mud Rotary Drilling: $79,482

<u>Contractor Requirements</u>:

- o Well System Contractors
  - + Drilling contractor - manpower for drilling and casing and service operations and support of logging and cementing
  - + Logging contractor
  - + Cementing contractor
- o Project staff-supervision for 24 hours/day, 7 days/week.

<u>Other Support Services</u>:

- o Drilling fluid supplier should provide mud engineer for quality control.

2.1.3. INSTALL FIRST TEST WELL THROUGH ORE ZONE - T1

<u>Description</u>:

Utilizing the previously drilled and cased hole through overlying sediments, drill 10 inch hole approximately 1250 ft. through the igneous ore host rock, from 970 ft. to about 2220 ft. (during which time a large-diameter oriented spot core will be obtained). After performance of open-hole tests (see open-hole test plan, A.1.2) and conduct of caliper and temperature logs, drill to 2250 ft., condition hole, set and cement 7 inch o.d. F.R.P. casing through ore zone, run a temperature and bond log and fill the casing with water and monitor the fluid level for 6 hours, to evaluate casing integrity. Perforate the bottom 200 ft. of the ore test zone. Suitable drilling data recording equipment (as specified for the previous sediment drilling operation) should be provided. The hole will be directionally surveyed, and should be maintained within 1.5 degrees of deviation from vertical. If deviation is excessive (or inconsistent between this and subsequently drilled test holes), it may be necessary to directionally drill portions of the hole to bring bottom hole locations within specifications suitable for multiwell tests.

Air hammer drilling will be utilized when possible, in order to minimize near wellbore permeability impairment associated with bentonite mud systems; if air drilling is not possible, mud rotary drilling will be used, employing a polymeric mud system.

Core drilling will employee conventional coring equipment, capable of obtaining approximately 10 ft. of 4" diameter oriented core in one run. Oriented core will be utilized for laboratory leach testing and stress field determinations. The core will be photographed, and packaged in suitable containers for shipping.

Service work performed during open hole testing will consist of setting and removing inflatable packer equipment, assisting with wireline logging operations and possibly performing fishing operations. The rig will be on standby during performance of open hole tests. Power tongs suitable for handling 2 3/8 inch and 2 7/8 inch o.d. tubing should be provided; rig mast height capable of pulling and standing doubles (based on 30 ft. random joint lengths) is desired.

Casing operations will utilize a casing running crew to assure proper and efficient handling of the F.R.P. casing.

Cementing operations and detailed design will be performed by a cementing service contractor. The low density of F.R.P. casing will require use of low density cement, to prevent undesirable buoyancy during cementing operations. Cement density must be maintained below about 9.5 lb./gallon, if water is used to displace cement from the casing. Use of cement additives employing hollow microspheres is recommended to achieve this low density, while maintaining suitable strength and low cement permeability. Monitor the water level in the casing to evaluate casing integrity.

Perforating the casing will be done by means of shaped charge "jet" type perforators, fired from a hollow carrier casing gun. Perforating equipment and services will be supplied by the wireline logging contractor. Perforations will consist of 4 holes per foot, phased at 90 degrees, unless otherwise indicated by the detailed stimulation design. (Which will be performed by the well stimulation contractor.)

Design Specifications:

Sequence of operations for air hammer drilling:

1. Drill out intermediate casing string cement and equipment (starting about 940 ft.), 10 inch diameter, through igneous ore host rock to the oriented core interval at about 1089 ft. An attempt will be made to get core at approximately 1100 ft in one hole, and 1900 to 2200 ft in two other holes. Record all pertinent drilling data, and directionally survey hole at 100 ft. intervals, initially.

2. Remove drilling tools from hole, run in large diameter (approximately 4") coring tools with appropriate orientation equipment. Drill 10 ft. of core, utilizing water circulation if possible, and polymer mud otherwise. (Drill without circulation returns if necessary and prudent.) Obtain about 10 ft. of oriented core and remove coring equipment from hole.

3. Run in drill string, ream cored interval to size and drill through the test interval. (To about 2220 ft. depth.)

4. Remove drilling tools, rig up wireline contractor, and run wireline logs (as specified in the logging section), including 4-arm oriented caliper for "wellbore breakout" fracture attitude analysis caliper and temperature logs.

5. Run in open hole test equipment, as specified in the openhole test section A.1.2. Assist with packer setting and related test operations, including repositioning of well equipment, as required. Maintain rig on standby status as required during tests.

6. Remove test equipment following openhole testing.

7. Run in drill string, drill additional 30 ft. of "rat hole," from about 2220 to 2250 ft.; condition hole for casing.

8. Set 7 inch o.d., 1250 psi F.R.P. integral joint casing and associated equipment (see well design, Appendix A.1.1.), to about 10 ft. below the test interval bottom, at about 2230 ft. Fill the casing with water as required to prevent floating. Utilize services of a casing crew.

9. Cement the casing full length with a suitably designed lightweight, acid resistant cement. Cementing contractor will provide detailed cementing program design, equipment and operations. Rotate and reciprocate the casing during cementing if possible. (This is particularly important when utilizing lightweight cement, which is frequently too viscous to be displaced in turbulent flow at acceptable pressures and consequently may tend to "channel.") Record cement density, flowrate, pressure and volume data and collect samples of cement and returns at intervals throughout the job. Check for flowback after bumping the plug; release casing pressure. Wait for the cement to set to an acceptable strength. (Assume 12 hours, for planning.)

10. Run cement bond and temperature logs, examine and save cement samples and cementing records; fill casing with water and monitor fluid level for 6 hours; evaluate cement job performance. Recommend remedial procedures if indicated.

11. Rig up wireline contractor and perforate the bottom 200 ft. of the well, using a hollow carrier casing gun, 4 j.s.p.f., phased at 90 degrees. (Unless otherwise indicated in the detailed stimulation design.)

Sequence of Operations for Mud Rotary Drilling:

Operations change from those above only in cementing design (addition of a suitable mud breaker and displacement fluid), drilling tools and equipment, mud costs, drilling rates and hole conditioning preceeding casing operations. All well specifications remain unchanged regardless of drilling method.

Equipment Specifications:

- o Drilling:
  Drill string and equipment, circulating equipment, data gathering equipment, hoisting capacity and crew experience adequate to air hammer or mud rotary drill 10 inch diameter to 2250 ft., drill large diameter oriented core, set and assist cementing F.R.P. casing, rotate and reciprocate casing during cementing, perform directional drilling and perform service operations as described.

- Oriented Core:
  Equipment compatible with the specified drill rig, capable of obtaining about 10 ft. of oriented core of 4" nominal diameter.

- Wireline logging:
  Caliper, temperature and differential temperature log capability suitable for 10 inch open hole use. (In addition to capabilities required for open hole logging and testing, as described in the appropriate design sections.)

- Casing and Equipment:
  See detailed well design, "casing" section, Appendix A.1.1. This well is designed based on 7.2 inch o.d., 6.004 inch i.d., 1250 psi rated, integral joint, 7.65 lb./ft. F.R.P. well casing. Centralizers, cement baskets, float shoe and float valve equipment, thread adapters, pup joints and wellhead equipment are as specified in the detailed design.

- Cementing:
  Detailed design, personnel and equipment suitable for cementing the 7 inch F.R.P. casing full length to 2230 ft. depth with lightweight, acid resistant cement. Assuming approximately 50% excess cement to account for unknown fluid loss or other conditions, the job will require about 263 sacks of cement at 3.3 cubic ft. per sack yield. Contractor experience with "microsphere" type lightweight cement additive is required.

- Perforating:
  Personnel, equipment and materials suitable for installing 200 ft. of jet perforations, as specified.

<u>Schedule</u>:

- Air Hammer Drilling:

Drilling, Coring and Service	7.15 days
Casing, Cementing, Logging	0.75
Total	7.9 days per well

- Mud Rotary Drilling:

Drilling, Coring and Service	9.75 days
Casing, Cementing, Logging	0.75
Total	10.5 days per well

<u>Well Costs</u>:

- Air Hammer Drilling:

+ Work String Purchase	$ 14,000
+ Drilling, Casing and Service	38,445
+ Casing and Equipment	48,474
+ Cementing	21,898
+ Logging and Perforating	5,350
Total	$129,167

o Mud Rotary Drilling:

+ Work String Purchase	$ 15,000
+ Drilling, Casing and Service	57,270
+ Casing and Equipment	48,474
+ Cementing	21,898
+ Logging and Perforating	5,350
Total	$147,992

Contractor Requirements:

o Well System Contractors:

+ Drilling contractor
+ Drilling fluids supplier
+ Logging contractor
+ Cementing contractor
+ Directional drilling contractor
+ Core orientation contractor
+ Casing crew

o Project staff: Supervision/engineering - 3 shifts/day

2.1.4 OPEN HOLE TESTING - T1

Description:

The open hole test work consists of spinner logging the entire ore interval and injection testing smaller sections of the ore interval. The general pupose of the work is to determine permeability and its variation in the vertical ore interval. This is called "flow profile logging".

Spinner logging will consist of water injection into the entire ore column with simultaneous spinner logging. The ore interval is planned to be the bottom 322 ft of the hole. Low permeability rock is expected so that the injection flow rate is predicted to be small. Because of this, the spinner tool must be able to accurately measure fluid velocity of 1 ft. per minute minimum. In order to maximize injection flowrate, drilling techniques will be used to prevent or minimize the formation of a positive skin on the wellbore. Calculations and a further discussion of spinner logging are given in Appendix A.1.2. Spinner logs are used to determine an injection profile over the ore interval. Permeability is proportional to the loss of injected fluid over a given interval. Using essentially the same system for injection, injection tests are planned for selected short sections of the ore interval.

Design Summary:

For injection over the entire ore interval, a single packer may be used above the interval. However, for permeability testing several smaller intervals, straddle packers are used to isolate sections while injection occurs. Three, 20 ft intervals are planned at present for these tests. The intervals are chosen to provide good isolation (good packer seal) and be representative of the ore interval geology. Three permeability tests are planned for the ore interval, and a time of 24 hours is planned for each test. Injection continues until the well has reached steady-state condition. The permeability can then be calculated from the pressure and the injection flowrate.

For both spinner logging and injection testing, an injection system is required for pumping and metering fresh water into the well. Materials and equipment required are:

1. Water Tank

   Purpose: To provide storage capacity for fresh water (and in subsequent tests more corrosive fluid) so that injection of fluid can proceed on a continuous basis.

   Description: The tank capacity should be 10,000 gal minimum, vertical tank preferred. Construction should be of FRP or plastic that is non-corrosive in acidic leach solutions and chloride containing liquors. Tank will be provided by contractor building the SX/EW plant.

2. Lubricator for Wireline

   Purpose: To allow movement of the logging contractor's wireline tools while concomitant injection takes place down the tubing.

   Description: The lubricator is a fitting that attaches to the top of the wellhead. It contains a "packing gland" that seals against the wireline, even while the wireline is in motion. This special fitting will be supplied by the wireline service company. A tee fitting below the lubricator allows fluid injection into the tubing.

3. Injection Pump

   A moyno pump is planned for injection. This pump will be capable of 1000 psi, and should deliver up to 50 gpm. A variable speed drive is also planned. The pump will be supplied by the contractor responsible for surface facilities construction. If the surface injection facilities have not been completed prior to the open hole testing a leased or purchased pump (perhaps a plunger pump) will be used for the injection. The leased or purhcased pump cost is included in costs for this activity.

4. Meters, Piping and Fittings

Purpose: To control the delivery of fluid to the injection well.

Description: For a general sketch of the injection system, see Figure 2-2. A pressure relief valve will be needed on the discharge of the high pressure pump. This valve should be the same size as the pump discharge and set for release at 500 psig. Three meter runs are planned to accurately measured injection flowrate. The meters are of the turbine design, sized to the expected range of flow. Accuracy of these meters should be 1% or less error. Pressure gauges rated at 1% or less error are also planned for installation on the injection piping and the wellhead. Miscellaneous pipe, valves and fittings are needed to deliver the fluid to the well. All fittings and pipe must be capable of 500 psig working pressure (minimum). The surface facilities design provides further description of the injection equipment, and also a description of water and power sources used for injection. The open hole testing is planned for early in the test program. Because some of the surface injection equipment may not be on hand, some temporary equipment that is not corrosion resistant may be used for the injection of fresh water. This equipment will be purchased or rented during the early test work. Specifically, the injection pump and the meters may be leased or purchased. These costs are included in estimates for this section.

5. Packer and Tubing

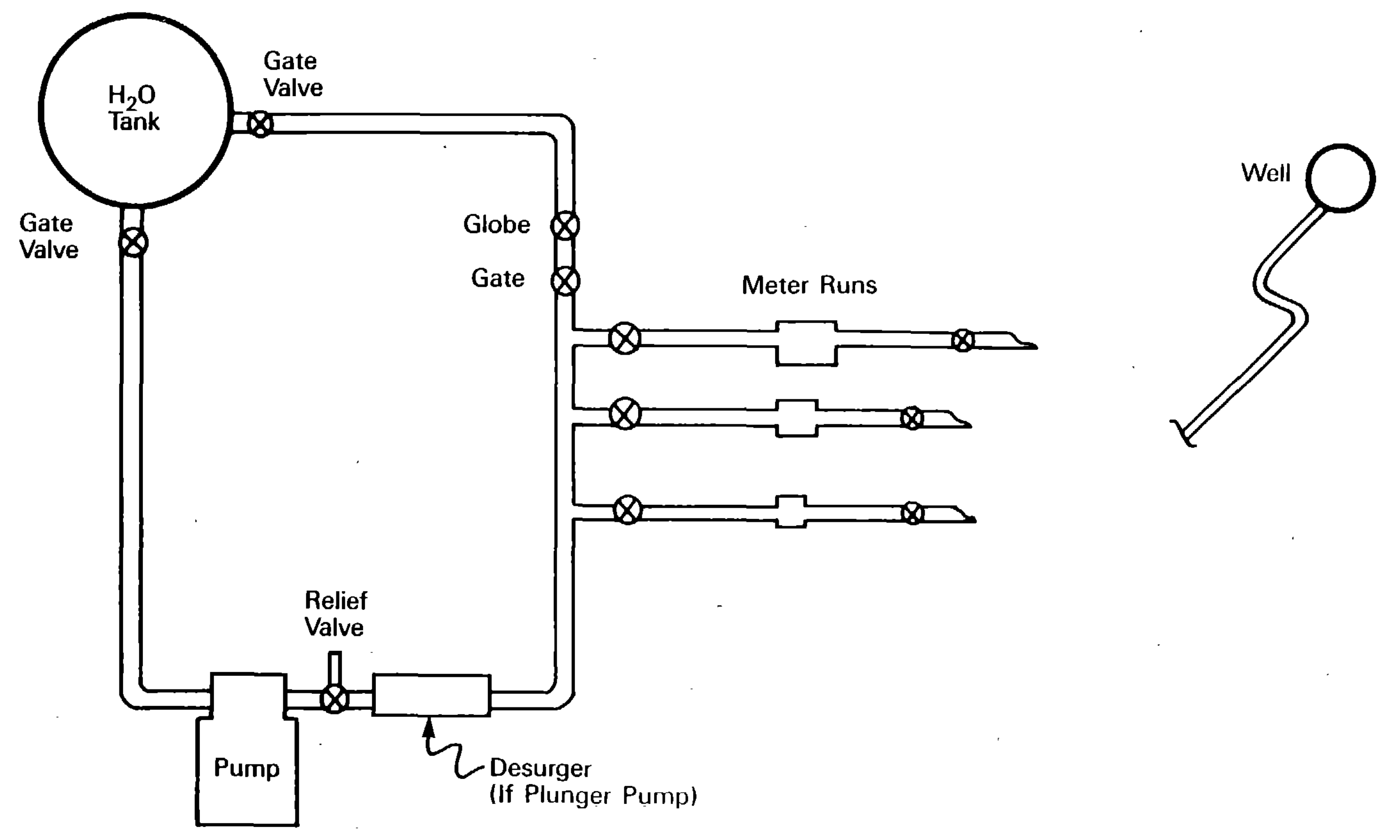
The tubing planned for running the packer will be 2-7/8" steel API work string. This tubing is costed in section 2.1.3, and utilized for various other operations. An inflatable packer is also planned for a nominal 10" hole. The packer will have an element size of 6" x 40". A sliding end type is recommended. Inflation tubing, nitrogen bottle and pressure regulators will also be required, capable of delivering 2000 psig. For testing of short intervals, a straddle packer arrangement will be required, so that an additional packer, a perforated tubing joint, and associated equipment will be needed.

6. Wireline Logging

The logging contractor will be needed to run the spinner and temperature logs.

Schedule:

The total time required for the tests is estimated at 4 days. One day is required for the spinner tests and 3 additional days are required to injection test the three zones in the ore interval.



Notes:

1. Pump can be plunger or moyno, capable of multiple rates and 1,000 PSI
2. Meter ranges from 1 to 50 GPM

Figure 2-2. Injection System for Testing (Fresh Water)

Well Costs:

Costs for the open hole testing in this first hole are summarized:

o Logging contractor	
+ 1 day active logging	$ 1,500
+ 3 days standby	2,550
o Drilling contractor	
+ 29 hours run packers @ $250/hr	7,250
+ standby w/crew @ 175/hr, 67 hrs	11,725
o Injection equipment - lease and purchase	6,000
o Packers, inflation system (tubing costs in sec. 2.1.3)	6,500
o Water truck (for injection water)	1,000
Total	$36,525

Contractor Requirements:

- o Well system contractors:
  - + Drilling
  - + Logging
- o Surface Facility Operation Contractor
  - + To operate injection equipment and collect data, 2 per shift, 3 shifts per day
  - + 3 per day shift for construction and maintenance
- o Project Staff
  - + Supervision of field work, 3/day

2.1.5 WIRELINE LOGGING WELL-T1

Description:

Two discrete logging activities will be required for all installed wells. Subsequent to drilling through the overburden and prior to installing an intermediate casing string a caliper and temperature log will be run. Because these logs will be run in a 14-in diameter hole the operator will assure that suitable-size tools are supplied by the contractor. These logs will be run to total depth (TD) from surface. The temperature log will provide background data whereas the results of the caliper log will be used in the cement program design. Subsequent to running and cementing the intermediate casing string a cement bond log from surface to TD will be run. This will permit evaluation of the cementing job effectiveness.

After the hole has been drilled through the ore zone another suite of open-hole logs will be run. The purpose of this operation is to obtain data on rock properties, hole size variation, hole direction variation, zones of fluid exit and background temperature and radiation. Tools will be selected which will be suitable for logging in a 10-inch diameter hole.

The wireline logging contractor will participate in other tests (and possibly well diagnostic work) as described in other sections of this report, in addition to these logging functions.

Design Summary:

Driller will condition hole and pull out the drill string. Loggers will rig up and run temeprature and caliper logs.

Subsequent to running and cementing the intermediate casing string the logger will run sonic bond log.

Subsequent to drilling to total depth, the driller will condition hole and pull out drill string.

The following logs will be obtained (See Appendix A.1.3. for details):

- Spontaneous Potential
- Resistivity or Induction
- Compensated Density
- Compensated Neutron
- Gamma Ray
- Compensated Sonic
- Temperature
- Caliper

- o Spinner, Radiotracer or Differential Temperature (performed with activities described in section 2.1.4)(and not performed in every well)
- o Direction Survey

After the casing is set and cemented, the logger will run Sonic Bond.

Schedule:

Intermittantly this activity will require approximately 24 hours total time.

Well Costs:

o Logging	$10,700
o Drilling Contractor $175/hr for 24 hr	4,200
Total	$14,900

Contractor Requirements:

- o Well System Contractors
  - + Drilling
  - + Logging
- o Project Staff superivison of work, 1/shift, 3 shifts/day

2.2 WELL PATTERN FLOW CONTROL

2.2.1 SITE SECOND AND THIRD TEST WELLS - T2 AND T3

Description

Locate second and third test wells, relative to the first test well, in order to install the wells in a 3-well pattern for performing flow control tests. The present plan is to space these wells 50 ft. from the first well, with the wells oriented to form a 90 degreee angle. This spacing should provide acceptable flow testing times for an appropriate volume of rock and enable determination of large radius hydrofrac properties. Bottom hole locations will be held within specifications by use of directional drilling. Test interval depth is planned to be the same as the first well, from 2020 ft. to 2220 ft.

The purpose of the three-well tests is to evaluate deposit directional permeability, verify previous test results regarding test interval permeability and flow profile, determine effects of well stimulation treatments and fluid sweep efficiency and large-radius hydrofracture properties, and collect additional drilling and well completion data.

Design Summary:

The present spacing and orientation of wells is based upon assumptions defined in the testing section. If some or all of these assumptions change (based on open-hole test results), these parameters may require adjustment. At the Santa Cruz site, topography should not be a significant restraint on well location. Drilling accuracy may impose constraints upon achieving predictable bottom hole locations closer than 50 ft., and keeping the test intervals of the wells spaced within the desired 10 ft. horizontal distance from top to bottom.

Schedule:

This work will be done concurrently with open hole testing. Approximately 16 man hours of project staff time will be required for well siting.

Well Costs:

Project staff only.

Contractor Requirements:

Project staff personnel only.

2.2.2. INSTALL SECOND AND THIRD TEST WELLS - T2 AND T3

Description

Install two additional test wells at the specified sites to conduct open-hole testing and interwell flow testing. Well stimulation, including short-radius hydrofractures and H.E.G.F. ("explosive") methods, will be evaluated. Large-radius hydrofracture properties will be evaluated, to determine if axial-flow leaching is appropriate at the Santa Cruz site. These wells will be installed and completed identically to the first test well T-1, unless experience installing the first test well dictates otherwise for technical or economic reasons. Drilling methods, the need for intermediate casing, and well completion techniques will be re-evaluated prior to drilling these wells. During installation, additional well completion information will be gathered, adding to the data base. The wells will be drilled and tested sequentially, so no additional drilling equipment is required. Testing methods are described in Section 2.1.4.

Design Summary:

Operating Sequence:

- o Drilling, open hole testing, logging, cementing, casing and perforating are presently planned to remain the same as for the first test well, subject to modifications based on experience.
- o Following well casing perforation, a sequence of tests will be run in the cased well. These tests include wireline logging, pressure transient, interference and tracer tests. The sequence of operations for these tests is described in Section 2.2.5.; well service work similar to that required for open-hole testing will be performed.

Well Bottom-hole locations:

- o In order to obtain useable flow test results, the test well bottom-hole locations should be no closer than 30 ft. and no further apart than 70 ft. Additionally, within the 200 ft. vertical test interval immediately above the well bottom, planned well spacings should not vary more than 10 ft.
- o Depending upon drilling characteristics at the site, achieving the degree of accuracy specified for bottom-hole locations is likely to require some directional drilling. The wells can be kept parallel within the specified 10 ft. tolerance by maintaining about 1.4 degrees or less vertical deviation. If all the wells deviate in a similar direction (a common occurrence), directional drilling may be minimized or unnecessary.

Equipment and contractor specifications:

Same as specifications for the first test well T1

Schedule:

- o Air hammer drilling (excluding testing): 25 days
- o Mud rotary drilling (excluding testing): 31 days

Well Costs:

- o Air hammer drilling: $366,258
- o Mud Rotary drilling: $425,248

Contractor Requirements:

- o Well System Contractors
  - + Drilling contractor
  - + Drilling fluids supplier
  - + Logging contractor
  - + Cementing contractor
- o Project Staff provides supervision/engineering - 3 shifts/day

2.2.3 OPEN HOLE TESTS - T2 AND T3

The description and design summary for this activity is the same as described in Section 2.1.4 of this document. Again the purpose is to measure permeability and its variation in the ore interval. Because permeability can vary significantly from place to place, the second and third wells are tested to provide more data.

Schedule:

A total of 8 days are planned for testing both wells.

Well Costs:

Costs for the open hole testing in both of the holes are summarized:

- o Logging contractor:

+ 2 day active logging	$ 3,000
+ 6 days standby	$ 6,100
Total	$ 9,100

- o Drilling contractor:

+ 58 hours run packers @ $250/hr	$14,500
+ standby w/crew @ 175/hr, 134 hrs	$23,450
Total	$47,050

The same injection equipment used for testing the first drill hole will also be used for the above activity. Since costs are included for the injection equipment under Section 2.1.4, no costs are included here.

Contractor Requirements:

- o Well System Contractors
  - + Drilling contractor
  - + Logging contractor
- o Surface Facility Contractor to operate and maintain injection equipment and collect data, 3/shift, 3 shifts/day
- o Project staff to supervise all work.

2.2.4 WIRELINE LOGGING - T2 AND T3

Description:

Two discrete logging activities will be required for each of these two wells. Subsequent to drilling through the overburden and prior to installing an intermediate casing string a caliper and temperature log will be run. Because these logs will be run in a 14-in diameter hole the operator will assure that suitable-size tools are supplied by the contractor. These logs will be run to total depth (TD) from surface. The temperature log will provide background data whereas the results of the caliper log will be used in the cement program design. Subsequent to running and cementing the intermediate casing string a cement bond log from surface to TD will be run. This will permit evaluation of the cementing job effectiveness.

After the hole has been drilled through the ore zone another suite of open-hole logs will be run. The purpose of this operation is to obtain data on rock properties, hole size variation, hole direction variation, zones of fluid exit and background temperature and radiation. Tools will be selected which will be suitable for logging in a 10-inch diameter hole. Although the same program is recommended for thes second and third wells as for the first, logging results from the first may indicate modifications to the logging program such as duplication, elimination, and/or additions.

Design Summary:

Driller will condition hole and pull out the drill string. Loggers will rig up and run temperature and caliper logs.

Subsequent to running and cementing the intermediate casing string the logger will run sonic bond log.

Subsequent to drilling to total depth, the driller will condition hole and pull out drill string.

The following logs will be obtained (See Appendix A.1.3 for details):

- Spontaneous Potential
- Resistivity or Induction
- Compensated Density
- Compensated Neutron
- Gamma Ray
- Compensated Sonic
- Temperature
- Caliper
- Spinner, Radiotracer or Differential Temperature (see Section 2.1.4)
- Directional Survey

After the casing is set and cemented, the logger will run Sonic Bond logs; perforations will be installed in the well casings, as described and costed in Section 2.2.2.

Schedule:

Intermittantly this activity will require approximately 24 hours total time for each of the two wells.

Well Costs:

o Logging	$ 21,400
o Drilling contractor (standy-by)	8,400
Total	$ 29,800

Contractor Requirements:

- Well System Contractors
  - Drilling contractor
  - Logging contractor

- o Project staff supervision, 1/shift, 3 shifts/day, 2 wells

2.2.5 CASED HOLE TESTS - T1, T2, T3

2.2.5.1 Logging

Description:

Prior and subsequent to stimulation of each of the three test wells, data must be gathered by the operator. In one well an H.E.G.F. ("explosive") stimulation will be conducted. In each of two wells, short radii hydraulic fractures will be installed. And a total of two large radius fractures (LRF) will be installed. One LRF will be in the deeper part of the orebody and the other in the shallower part of the orebody.

Prior and subsequent to H.E.G.F. and short radius fracturing, a spinner or differential temperature log will be run to determine flow profile in the vertical ore column. The time required could be as little as 4 hours to conduct the spinner log and as much as 12 hours to complete the differential temperature log. The spinner log is preferred because it provides semi-quantitative data and requires less time to run compared to the differential temperature log.

Design Summary:

The following activities are to be carried out.

- o After perforating casing and checking total depth, equip well for injection; logger will rig up spinner or differential temperature log and rig down.
- o Driller will condition hole and install equipment if any for H.E.G.F. stimulation. (see Section 2.3.6)
- o After H.E.G.F. stimulation driller will condition hole and rig up for injection. Inflatable packer set on 2-7/8" tubing, to about 2000′ above perforations). Injection equipment rigged up.
- o Logger will repeat either the spinner or the differential temperature log.

- The system will be rigged down, well equipment removed.

After two of the test wells have been perforated for installation of short radii hydraulic fractures the logger will rig up to run either the spinner log or differential temperature log.

The drilling contractor will equip the well with tubing and packer to about 2000 ft. and the surface contractor will rig up the water injection system. Subsequent to obtaining the log the logger will rig down and the injection system will be rigged down. The driller will remove well equipment.

The drilling contractor will install equipment to stimulate the well (see Section 2.3.6). After stimulation the drilling contractor will remove the well equipment which had been used for stimulation and rig up for repeat water injection and logging. The logging contractor will repeat either the spinner log or differential temperature log.

Prior and subsequent to installation of LRF a gamma ray and temperature log will be run in each well. These will be conducted over the entire ore interval. Before and after gamma ray and temperature logs will be compared to attempt to determine the attitude of the induced frature. A caliper log will be run in the hole before fracturing to locate and obtain measurements on the slot through which the LRF will be induced. Radioactive material will be introduced with the fracturing fluid and it will be measured by the gamma ray log. A change in temperature of the rock by the injected fracturing fluid will be detected by the temperature log.

<u>Schedule</u>:

Time required for logging each of the wells is as follows:

o Before H.E.G.F.	12 hours
o After H.E.G.F.	12 hours
o Before short-radii fractures	24 hours
o After short-radii fractures	24 hours
o Before each large radius fracture	3 hours
o After each large radius fracture	3 hours
Total	78 hours

Total time for this activity is 234 hours

Well Costs:

o Drilling Contractor	$13,650
o Logging Contractor	20,440
Total	$34,090

Contractor Requirements:

- o Well System Contractors
  - + Drilling contractor
  - + Logging contractor
- o Surface Facility Contractor-operate injection equipment
- o Project staff supervision-1/shift, 3 shifts, 2 wells

2.2.5.2 Transient Testing

Description:

After the three initial wells are cased and before any stimulation technique is used, transient injection tests are planned. These tests will consist of constant rate injection and the monitoring of the resulting pressure in the well bore. The tests are used to mainly determine permeability and wellbore condition (skin).

Design Summary:

A 200 ft vertical interval in the ore zone will be used for testing. Calculations shown in Appendix A.1.2 suggest that with 2 md rock the injection flowrate will be approximately 15 gpm.

The surface injection equipment must be capable of handling at least this rate. The maximum flowrate range is 50 gpm.

A downhole shut-in tool is planned for installation and operation during the test. This tool prevents significant flow between the formation and the wellbore which can influence early-time pressure/time data, and thus prolong the time (and cost) of the test.

Materials and equipment used for transient testing are essentially the same as in all injection tests (see Section 2.1.4). The only addition to the required equipment is a downhole pressure transducer with a surface readout, such as a quartz Hewlett-Packard gauge. The quartz gauge will be operated by the wireline logging contractor.

Pressure vs time data are collected. The data are analyzed for several flow regimes, namely spherical, radial and linear. Experience running similar tests suggests that an injection period of 4 to 8 hours will be required, followed by 16 to 20 hours during which the pressure decline is observed.

Schedule:

For each test, 1 day will be required to set packers and prepare for injection. An additional day is required to inject fluid and obtain pressure response data. The total time required for three holes is 6 days.

Well Costs:

o Drilling contractor (run tubing and packer in and out)	
48 hours at $250/hour	$12,000
Standby while injecting 3 days @ 175/hour	$ 4,200
o Logging contractor 3 days active logging	$ 4,500
Standby 36 hours	$ 1,275
o Quartz gauge rental (may not be required)	$ 6,000
Total	$27,975

Contractor Requirements

- o Well System Contractors
  - \+ Drilling contractor
  - \+ Logging contractor
- o Surface Facility Contractor-1/shift, 3 shifts
- o Project Staff-test supervision 3/day

Other Supplies and Services Requried:

Water will be obtained from the surface piping facilities, scheduled for completion before this test.

2.2.5.3 Interference testing

Description:

After the initial three holes have been completed and perforated, an injection test can be performed by injecting in one hole and observing the response in the other two. With proper analysis of the data, information on permeability, directional permeability, and porosity-compressibility can be obtained.

Design Summary:

It is planned that the interference test will follow the three transient tests described above. A waiting period of 24 hours between tests is used so that the transient introduced in previous work can dissipate.

A quartz gauge is needed on the observation well. For the injector, a mechanical wellhead pressure gauge should be adequate. Calculations shown in Appendix A.1.2, based on 2md rock suggest that the pressure response is large enough to measure by gas tubes or wire depth probes. In the event that prior work indicates lower permeability, the quartz gauge can be used on one observation well, and the other observation well monitored by wire depth probe or gas tube. The quartz gauge will be used on the well with the lowest expected response, because of its high resolution.

The basic procedure for running the test is as follows:

- Install tubing and packer in injection well (packer installed above perfs)
- Set up injection equipment on surface
- Equip observation wells with pressure gauges (Set gas tubes to known depth, or find fluid level with wireline probe)
- Inject water and monitor response
- Remove well equipment

Schedule:

A time period of 12 hours appears adequate to obtain a pressure response for the interference tests. Thus, including the standby time waiting on dissipation of the previous transient, the total time is 36 hours for the interference test.

Well Costs:

o Drilling contractor (run tubing and packer in and out)	
16 hours at $250/hour	$ 4,000
Standby while injecting 1 day @ 175/hour	$ 4,200
o Logging contractor 1 day active logging	$ 1,500
Standby 12 hours	$ 425
o Quartz gauge rental (may not be required)	$ 3,000
Total	$13,125

Contractor Requirements:

- o Well System Contractors
  - + Drilling contractor
  - + Logging contractor
- o Surface Facility Contractor 1/shift, 1 shift
- o Project Staff-supervision 1/shift, 3 shifts

Other Supplies and Services:

Water will be obtained from the surface piping system, scheduled for completion before this test.

2.2.5.4 Tracer Test

Description:

Tracer tests are planned using radial flow in the first three cased holes. The main purpose of the test is to provide information on reservoir anisotropy (variation in permeability) and sweep efficiency.

The test is performed by injecting a relatively inert chemical at a constant rate and concentration while pumping from the recovery wells at constant rate. The arrival concentration in the production wells is monitored with time.

Design Summary:

Sodium chloride is planned as the first chemical tracer used. Chloride is a tracer that is easy to assay, inexpensive, inert to the formation and is of non-toxic. The chloride should be introduced at about 10 times the background chloride level in the reservoir fluid. Calculations show (see Appendix A.2.1) a total salt requirement of 43 tons for this test, based on an assumption of a background chloride level of 0.5 gpl. A tank and pump system are planned as part of the surface facilities for mixing salt and water, and for delivering the tracer mixture to the injection pumps. Produced fluid should be delivered to the evaporation pond.

It is suggested that produced and injected fluids be sampled at frequent intervals until the nature of the tracer breakthrough is established. Hourly sampling is suggested at first. A library of samples can be maintained and assays only performed on a portion of the samples as required. See Appendix A.2.1 for more information on sampling.

Pumps will be installed in the two production wells (T1 and T2), with hole T3 as the injector. Hole layout is shown in Figure 2-3. Gas tubes will be required for fluid level monitoring in the production wells. Tubing and packer must be installed in the injector.

Schedule:

The time for the tracer test is planned to be 32 days. Variation in porosity, permeability and other factors will affect the tracer arrival in this test, so the time for adequate data collection can vary. 32 days is used as the maximum allowable time.

Well Costs:

- o Drill rig standby without crew @ $500/day — $16,000
- o Drill rig install and remove well equip. 48 hours total at $250/hr — $12,000

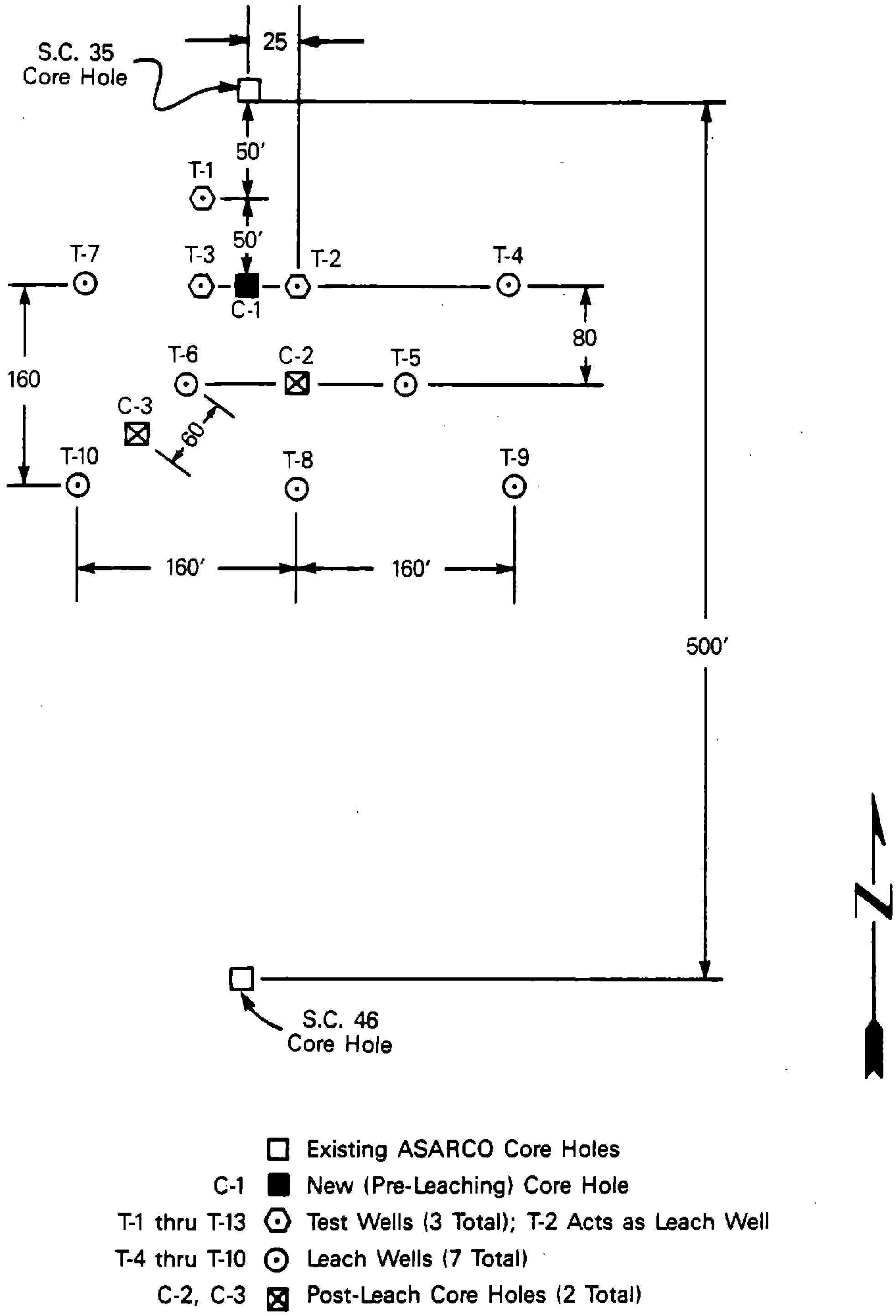


Figure 2-3 Proposed I.S.L. Wellfield (Santa Cruz Site)

o Salt	43 tons @ \$50/ton	\$ 2,150
o Assaying	1000 samples X \$5/sample	\$ 5,000
	Total	\$35,150

Contractor Requirements:

- o Well System Contractors
  - + Drilling contractor
- o Surface Facility Operator Contractor-operate test equipment
- o Project Staff-supervise work

Other Support Services:

A commercial assay laboratory must be chosen for analysis of samples.

2.2.6 STIMULATION - T1, T2, T3

Description:

The three test wells will be stimulated in the perforated 200 ft. interval immediately above the ore test interval bottom. The objective of these stimulations is to achieve a 3:1 flow increase over unstimulated conditions, evaluate stimulation effectiveness, and build a data base for subsequent stimulation of leaching wells.

Two of the wells will be stimulated by means of short-radius induced hydrofractures. High energy gas fracturing (H.E.G.F.) will be used to stimulate the remaining well. This technique induces fractures by controlled gas release by burning a propellant.

Analysis of stimulation effectiveness will include comparison of pre- and post-stimulation flow test results. Cost effectiveness for commercial leaching operations will be evaluated.

Design Summary:

Operation Sequence, Short-Radius Hydrofractures:

- o Stimulate the end wells of the three-well pattern with short-radius hydrofractures. (Wells T-1 and T-2, Figure 2-3.)
- o The selected hydrofracturing contractor will provide the detailed fracturing program design. Present cost estimates are based on 8 ft. radius fractures installed at 5 ft. vertical intervals.
- o Install 2 7/8 inch tubing and inflatable packer at approximately 2000 ft. depth, above perforated interval. Have a slip-type mechanical tension set packer available, in case slippage of the inflatable packer is experienced during hydrofracturing.
- o Rig up hydrofrac contractor, move materials to site, test all equipment.
- o Stimulate perforated interval according to the detailed hydrofrac design. Collect pressure, flowrate and injected volume data during the procedure.
- o Remove equipment from well, run cement bond and multiple arm caliper logs to evaluate casing and cement integrity. Install test equipment required for post-stimulation tests and move to the next well. Install fracturing equipment (as above), and repeat procedure.

Equipment and Materials specifications, Short-Radius Hydrofractures:

- o Well service rig - Equipped to install/remove well equipment.
- o Hydrofracture materials & equipment - Specified in detailed hydrofrac design; includes fracture fluid, water requirements, tankage, proppant, diverting meterials, pumping and blending equipment, data recording instrumentation, piping, fittings and personnel.

Operation Sequence, H.E.G.F. Stimulation:

- o Use the remaining (center) well for H.E.G.F. stimulation. (Well T-3, Figure 2-3)
- o The selected contractor will provide the detailed design. Secifications for the design include the perforated interval depth (2020 to 2220 ft., well completion details (casing size & type, cement, perforation details), and if available, drill core and information on Young's modulus & Poisson's ratio for the host rock. At present, the latter information is not available.
- o The contractor will provide a propellant charge (12 ft. length) to design specs, install it in the well with a pressure transducer instrument package, fill the well with water to a specified level (to confine any generated gas to the desired interval), and ignite the charge.

- Pressure and time data from the transducer is utilized to optimize subsequent charges; to determine if the process is working correctly, several instrument runs may be required. This process is expected to require approximately 2 days to stimmulate a 200 ft. interval.

Materials and equipment specifications:

- Well Service Rig - minimal involvement; primarily provide a derrick for wireline operations and assist surface operations as required. Fishing may be necessary.

- Stimulation contractor - Provide tools, instruments, equipment and personnel sufficient to carry out the detailed design, including wireline equipment, charges, instruments & data recording equipment.

Schedule:

- Short-radius hydrofractures = 3.5 days

- H.E.G.F. = 2 days
  Field work = 2 days; design (staff) time = 1 day.

- Total field time = 5.5 days.

Well Cost:

o Short-radius hydrofractures:		
Drilling contractor		$ 18,200.
Hydrofracturing contractor		$ 17,100.
Logging contractor		$ 2,500.
Equipment		$ 6,900.
	Total, 2 wells	$ 44,700.
o H.E.G.F.:		
Drilling contractor		$ 9,100.
Logging contractor		$ 2,500
H.E.G.F. contractor		$ 41,050.
	Total, 1 well	$ 52,650.
o Total		$ 97,350.

Contractor Requirements:

- Well System Contractors
  + Drilling contractor
  + Hydrofracturing contractor
  + Explosive Fracturing contractor

- Project staff-supervise all field work, review and approve designs

2.2.7 DETERMINE LARGE RADIUS HYDROFRACTURE PROPERTIES - WELL T2

Description:

Two large-radius (approximately 50 ft. radius) propped hydraulic fractures will be installed for the purpose of determining fracture plane attitude (orientation in space), pressure gradients associated with hydrofracturing, and injectivity increases resulting from hydrofracturing. This information will be used to evaluate whether axial flow leaching methods can be used at the Santa Cruz site.

One hydrofracture of approximately 50 ft. radius will be installed immediately above the existing test well perforations, to determine hydrofracture properties associated with the deepest portion of the deposit accessable by these wells (approximately 2000 ft.); the other hydrofracture will be installed at a depth associated with shallower ore known to exist within the deposit (approximately 1100 ft.). The rationale for testing at two depths is based on hydrofracturing theory which indicates that fracture plane attitudes may change from horizontal to vertical within the depth range from 1000 ft. to 3000 ft., depending on the local in-situ stress field. In order to consider axial flow leaching designs, the attitude of induced hydrofractures must be known and predictable. Both hydrofractures should be installed in the center test well T1, to aid in detection of fracture intersection by use of the surrounding wells. Work will include the following: plug the existing perforated interval; install a slot in the casing (using an abrasive jet tool); run wireline background logs in adjacent wells; rig up surface and downhole geophysical instrumentation; rig up the hydrofracturing contractor; install a "minifrac"; modify the hydrofrac design if necessary (based on the minifrac results); install the hydrofrac; collect geophysical and fracturing data; evaluate post-frac casing and cement integrity; and analyze the data and determine the hydrofrac attitude (and, if possible, its size).

Determination of the hydrofracture attitude will be done by means of a variety of geophysical measurements during and following hydrofracture installation; core tests (anelastic strain recovery and differential strain curve analysis) on the large diameter core will be considered, and examination of the oriented four-arm, open hole caliper measurements will be performed to analyze for indications of in-situ stress represented by "wellbore breakout."

Following is a list of geophysical methods used for, and literature references describing, hydrofracture attitude determination. These methods are listed in their approximate order of reliability for igneous rock environments.

- o Methods:
  - + Temperature and gamma ray logs.
  - + Triaxial borehole seismic methods.
  - + Tiltmeter survey.
  - + Surface microseismic measurements.
  - + Wellbore breakout analysis.
  - + Core tests to determine in-situ stress conditions.
- o Literature references:
  - + Teufel, et. al., "Determination of Hydraulic Fracture Azimuth by Geophysical, Geological and oriented Core Methods at the Multiwell Experiment Site, Rifle, Colorado," S.P.E. Professional Paper No. 13226, presented at the 59th Annual Technical Conference, Houston,, Texas, Sept. 16 - 19, 1984.
  - + Lacy, L.L., "Comparison of Hydraulic Fracture Orientation Techniques," S.P.E. Professional Paper No. 13225, presented at the 59th Annual Technical Conference, Houston, Texas, Sept. 16 - 19, 1984.
  - + Fitz-Patrick, R.P. et. al., "A Comprehensive Fracture Diagnostics Experiment: Part 1 - Overview," S.P.E. Production Engineering Magazine, Nov. 1986, p.p. 411-422.
  - + Smith, M.B., et. al., "A Comprehensive Fracture Diagnostics Experiment: Part 2 - Comparison of Fracture Azimuth Measuing Procedures," S.P.E. Production Engineering Magazine, Nov. 1986, p.p. 423-432.
  - + Sorrells, G.G., et. al., "Advances in the microseismic Method of hydraulic Fracture Azimuth Estimation," S.P.E. Professional Paper No. 15216, presented at the Unconventional Gas Technology Symposium of the S.P.E., Louisville, Ky., May 18-21, 1986.

Determination of in-situ stress conditions by core analysis may not be possible if the core contains numerous small fractures or displays a strong anisotropic rock "fabric."

Techniques for defining fracture attitude which depend upon access to an open hole (such as borehole televiewers and impression packers), are not applicable to this task.

Design Summary:

Operating Sequence, Lower Test Interval:

- Select large-radius frac test well; the center test well T1 is proposed at this time.

- Design the frac program for a 50 ft. radius propped hydrofracture in the lower test interval, located at approximately 1990 ft. This program will include installation of a slot in the casing (to provide fluid access to the rock), fracturing materials, pressures, volumes, flowrates and procedures required for frac installation. Data collection will be specified. Use of radioactive tracer in the frac fluid & proppant, and operating procedures designed to optimize geophysical data collection during the fracturing operation, will be specified.

- Prepare adjacent wells for detection of the intersecting hydrofracture. This includes running temperature and gamma logs to determine background conditions, installing the triaxial borehole seismic tool in one adjacent well and calibrating it (involving three small dynamite charges located about 1000 ft. from the well).

- Install and calibrate surface geophysics, including microseismic and tiltmeter instrumentation.

- Recomplete the well for fracturing. This will consist of installing sand fill through the perforated interval, to a depth of about 2020 ft. (through tubing), and placing a Cal-Seal plug above the sand (by dump bailer), to a depth of about 2010 ft. Allow plug to set and verify plug-top depth with either tubing or wireline.

- Run in work string tubing with abrasive jet tool to 1990 ft. (fracture depth), rig up fracturing contractor, establish circulation and tubing rotation, install the slot, circulate the well clean and remove tools. Run caliper log over slot interval to verify slot location and size.

- Run in packer and work string tubing to approximately 1980 ft. Initially, use an inflatable packer, to avoid casing damage from mechanical packer slips. After setting the tubing in wellhead slips, fill the annulus with water and chain the tubing to the wellhead as a precaution in case of packer slippage during fracturing. (If the packer does slip, remove it and set a mechanical packer. Previous experience with mechanical packers indicates that they are suitable for hydrofracturing in F.R.P. casing, with a tolerabale amount of casing damage.)

- Rig up the fracturing contractor, mix frac fluids and test the equipment and lines. Perform a "minifrac" to use for field modification of the large-radius frac design. Modify the design as indicated (pumping rates & pressures), and install the large-radius hydrofrac. Record fracturing data. Including pressures, flowrates, volumes & time. Record I.S.I.P. after terminating pumping; allow sufficient time for pressure bleed-off. Record real-time geophysical data.

- o Monitor post-frac seismic and tiltmeter responses; log the unused well with temperature and gamma ray tools, and the fractured well with cement bond and multi-arm caliper tools. Remove downhole seismic tools and fracturing equipment from the other wells and repeat these logs as soon as possible. (This will depend on the time required for downhole seismic monitoring to be completed.) Each geophysical contractor should independently analyze their own data. Following these independent analyses the results should be correlated (by a geophysical consultant, if necessary), and a conclusion reached regarding the fracture attitude, size, and data reliability.

- o Equip the well with tubing and packer and perform injectivity tests, as described elsewhere, to determine the injectivity increase associated with the fracture.

Operating Sequence, Upper Test Interval:

- o Use the same well used for the first large-radius hydrofracturing test, if possible.

- o Design the fracturing program as before, assuming the fracture will be installed at about 1100 ft. depth.

- o Recomplete the test well by installing a retrievable bridge plug at about 1150 ft. depth, and covering it with about 10 ft. of sand. Verify depth to top of sand by tubing or wireline.

- o Prepare adjacent wells for data collection, as before.

- o Install and calibrate surface geophysics, as before.

- o Run in work string tubing with abrasive jet tool to 1100 ft., and install the casing slot as before. Verify slot depth and height by caliper log.

- o Equip the well with tubing and packer as before, set to about 1090 ft.

- o Rig up the hydrofracturing contractor, mix fluids and repeat the previous hydrofracturing procedure, including the "minifrac" and frac design modificaiton, if indicated.

- o Collect data during and following the fracturing process and analyze the data as before. Run cement and multi-arm caliper logs in the fractured well, to evaluate casing and cement integrity.

- o Equip the well and perform injectivity tests, as before. Remove tubing and packer equipment, retrieve the rental bridge plug and return it to the owner.

- o Determine the fracture attitude, size, and degree of certainty of these parameters for the upper test interval, as before.

Contractor and Materials Specifications:

- o Drilling - Perform service operations, assist as required with associated operations.

- o Logging - Run temperature, multi-arm and 4 arm oriented caliper and gamma ray and cement bond logs. Assist with data analysis, as required.

- o Hydrofracturing - Provide detailed hydrofrac designs for lower and upper test zones. Provide personnel and equipment adequate for operations outlined above. Supply tankage, materials and transportation for the above fracture-related operations.

- o Downhole Seismic - Provide personnel & equipment associated with setting and operating the tool, interpreting the data and analyzing for frac attitude and size. Assistance in detailed planning, and a formal final report will be required.

- o Surface Seismic and tiltmeter - provide personnel & equipment associated with setting, calibrating & operating the equipment, interpreting the data and analyzing for frac attitude (and size, if possible). Assistance in planning and a formal final report will be required.

- o Core analysis - Provide personnel to observe oriented core upon removal from hole, to render an opinion on suitability of proposed methods of determining in-situ stress conditions and to observe caliper logs for evidence of wellbore breakouts related to in-situ stress conditions. If these methods are deemed suitable, personnel will package and tansport core to the lab facility. A formal report will be required if this work is done.

- o Equipment - Steel work string tubing (previously purchased for openhole testing), rental of an inflatable packer suitable for fracturing operations and rental of a suitable mechanical bridge plug. (A suitable mechanical packer was previously purchased in Section 2.2.6).

<u>Schedule</u>:

Total field time = 5 days (Data analysis, reporting and related activities will not delay field operations.)

<u>Well Cost</u>:

o	Drilling contractor	= $ 22,350
o	Hydrofrac Contractor	= $ 20,440
o	Materials	= $ 9,342
o	Downhole Seismic	= $ 54,000
o	Surface Seismic	= $ 65,000
o	Tiltmeter	= $ 40,000
o	Logging	= $ 10,000
o	Core Analysis	= $ 40,000
o	Consultant (Geophys)	= $ 10,000
	Total	$271,132

Other Support Services:

Geophysical consultant(s), if additional analysis of contractor reports or fracture attitudes is required.

2.3 WELL SYSTEM CONSTRUCTION

2.3.1 Wellfield Design Review - T4, T5, T6, T7, T8,, T9, T10

Description:

The purpose of the wellfield design review is to select a well pattern and spacing that will provide maximum copper production at the lowest cost. In this particular case, the wellfield is to be a "unit cell" of a commercial wellfield. That is, the patterns chosen will be the same as envisioned in a commercial operation. The principal advantage of this "unit cell" concept is to provide similitude so that the result of pilot operations will better represent the actual commercial results and economics.

The 5-spot radial flow pattern has been selected as an initial design for the program plan. The purpose of this activity is to review data obtained in Sections 2.1 and 2.2 to determine whether modifications to the baseline radial design should be considered.

Design Summary:

Use of the Generic Design Manual has shown favorable economics based on a 160 ft. well spacing. Calculations have been made (see Appendix A.2.2) which show that an acceptable flow rate can be expected using stimuated wells in radial flow in 2+ md rock. Based on the flowrate and the expectation of 10 gpl pregnant liquor loading, the pattern should have an expected life of approximately 3 years. Basic assumptions include 50% copper recovery and a 322 ft. test interval opened for radial flow, 8.3 gpm radial flowrate per producer, and 25 gpm flowrate (radial) per injector.

This design may be modified as field data become available. Such information as permeability, permeability anisotropy, and fracturing will be reviewed to determine whether major design modifications for the well pattern are warranted.

Schedule:

Two weeks of project engineering effort will be required.

Well Cost:

Computer services for data analysis and well pattern design	$20,000

Contractor Requirements:

- o Well system contractors-none
- o Computer simulation contractor
- o Project staff-conduct data review and design analysis

Other Support Services:

A reservoir simulator will be needed for wellfield design. The simulator should be capable of modeling unconfined fractured reservoirs.

2.3.2 WELL SITE SELECTION AND PREPARATION - T4 THROUGH T10

Description:

Location of the proposed field experiment wells is shown in Figure 2-3; test and leach well spacings specified in the open-hole test and wellfield design sections of this document are shown on the figure.

The exact location of the test and leach wells is arbitrary at this time, and may be changed as site-specific experience is gained; only well spacings are presently defined by design. Siting of the first core hole (C1, Figure 2-3, specified for the purpose of defining test site geology), is discussed in a previous section. Locations of the two post-leaching core holes C2 and C3, specified for the purpose of measuring changes in each well pattern resulting from leaching are also arbitrary at present.

No specific site preparation in excess of drilling contractor requirements is planned prior to drilling the test wells. Following well installation, the well sites will be graded to drain toward the well, a drainage piping system and an impermeable barrier will be installed. The area immediately surrounding the well will be elevated 1 or 2 ft. above the existing grade with granular fill and a concrete pad will be emplaced. These will provide for isolation and drainage of well fluid spills to a central collection point, protection of the wellhead from flooding, and provision of a good surface for well service and test related work and equipment. This construction will be performed by the surface facility operations contractor.

Design Summary:

Spacing between test and leaching wells is fixed by test design. Location of these well groups relative to one another is presently constrained only by the requirement to use one of the test wells (well T-2, in the well pattern configuration shown in Figure 2-3) as a leach well during operation. Location of test and leach wells relatively close to the existing S.C. 35 core hole is based on the ore test interval selected from logs of that core hole. Geologic uncertainty implicit in the wide spacing of the existing core holes therefore dictates test hole locations be near this core hole.

Topography, drainage, vegetation, cultural features and soil conditions do not appear to impose constraints upon well locations at the Santa Cruz site. Therefore, a great deal of latitude is available for modifications of the well locations as dictated by well pattern flow assessment test results.

Schedule:

Project staff time required will be approximately 1 day.

Well Cost:

Construction of well pads is included with surface facilities installation and is described here for information purposes only.

Contractor Requirements:

o Project staff only-for well siting.

2.3.3 5-Spot Well Installation - T4 Through T10

Description:

Seven additional wells, in the form of two adjacent 5-spot well patterns, will be installed. These wells will be positioned as described in

Section 2.3.2. and shown in Figure 2-3, so as to incorporate one of the previously installed test wells into one of these well patterns. These wells will be used for field experiment copper leaching, to be conducted over a period of about 18 months.

Well design for these new wells is identical to the test well design for T1, T2, T3, as described previously. (See also Appendix A.1.1 and Figure A-1.)

Well installation procedures are the same as those described in sections 2.1.2. and 2.1.3, with the following exceptions.

- Do not perform any large-diameter coring operations.
- Do not perform open-hole tests.
- Perforate the entire ore test interval, which is planned to be 322 ft., between depths of 1898 and 2220 ft.
- In order to represent a commercial leaching well pattern and to obtain useable test results, the well bottom locations must be within about 30% of their planned spacings. Assuming the presently planned 160 ft. like-well spacings, and the worst case well deviation (in which wells deviate in opposite directions), a vertical well deviation tolerance of about 0.6 degree overall would be required at these depths. This tolerance exceeds the limits attainable by good drilling practices, and will therefore probably require directional drilling. If wells all deviate in a similar direction, (a common occurrence) directional drilling costs will be minimized.
- Perforate the remaining 122 ft. of ore test interval in the test well selected for use as a leach well (T2).
- To minimize well installation time, two drill rigs will be scheduled for simultaneous operations.

<u>Design Summary</u>:

Operation Sequence:

- Rig up first drill on T6 (the wellsite closest to the new core hole), and commence drilling operations. Selection of this site will provide a greater degree of certainty about the well site geology than a site more distant from the core hole. Sample drilling cuttings on about 10 ft. intervals; these cuttings will be logged by site operator personnel to verify geology. The sequence of drilling for this rig after T6 is T5, T8.

- o Mobilize second drill rig to the adjacent wellsite T7 and commence drilling, as above. The sequence for this rig after T7 is T4, T9, T10.

- o Install seven new wells using the design in Appendix A.1.1, as described in Sections 2.1.2 and 2.1.3, excepting operations noted above.

- o Perforate all test wells through the 322 ft. test interval from 1898 to 2220 ft. depth, using the same methods and equipment as for previous perforation operations. Also perforate the remaining 122 ft. above existing perforations in test well T2, selected for use as a leaching well.

- o Afer perforating each well, the following tests are run which require the indicated equipment:

  + Cased-hole logs - no equipment required
  + Transient tests - tubing, packer & shut-in tool

- o Following installation of the well patterns, interference tests are run sequentially in each pattern and require the following equipment to be installed:

  + Injection well - tubing & packer
  + Production wells - recovery pump, tubing & fluid level monitoring equipment.

- o Following the above test, all equipment will be removed from the well in preparation for stimulation, the well pads and drainage system will be installed and the second drill rig will be released.

Schedule

- o Assuming mud rotary drilling: 49 days
- o Assuming air hammer drilling: 38 days

Well Cost:

- o Assuming mud rotary drilling: $1,521,900.
- o Assuming air hammer drilling: $1,303,435.

Contractor Requirements:

o Well System Contractors:

Same as Sections 2.1.2 and 2.1.3, without the oriented core contractor.

Project staff:

+ For air hammer drilling: 3 shifts, 38 days
+ For mud rotary drilling: 3 shifts, 49 days

2.3.4 Wireline Logging - T4 Through T10

Description:

Two discrete logging activities will be required for the seven newly installed leach wells. Subsequent to drilling through the overburden and prior to installing an intermediate casing string a caliper and temperature log will be run. Because these logs will be run in a 14-in diameter hole the operator will assure that suitable-size tools are supplied by the contractor. These logs will be run to total depth (TD) from surface. The temperature log will provide background data whereas the results of the caliper log will be used in the cement program design. Subsequent to running and cementing the intermediate casing string a cement bond log from surface to TD will be run. This will permit evaluation of the cementing job effectiveness.

After the hole has been drilled through the ore zone another suite of open-hole logs will be run. The purposes of this operation is to obtain data on rock properties, hole size variation, hole direction variation, zones of fluid exit and background temperature and radiation. Tools will be selected which will be suitable for logging in a 10-inch diameter hole. Some changes may result as logs obtained in Sections 2.1.5 and 2.2.4 are evaluated.

Design Summary:

Driller will condition hole and pull out the drill string. Loggers will rig up and run temperature and caliper logs.

Subsequent to running and cementing the intermediate casing string the logger will run sonic bond log.

Subsequent to drilling to total depth, the driller will condition hole and pull out drill string.

The following logs will be obtained (See Appendix A.1.3 for details):

- o Spontaneous Potential
- o Resistivity or Induction
- o Compensated Density

- o Compensated Neutron
- o Gamma Ray
- o Temperature
- o Caliper
- o Directional Survey
- o Compensated Sonic

After the casing is set and cemented, the logger will run Sonic Bond.

Schedule:

This activity will require approximately 24 hours total time for each of the seven wells. Total time is seven days.

Well Cost:

o Logging	$ 74,900
o Drilling Contractor (Stand by)	$ 29,400
Total	$104,300

Contractor Requirements:

- o Well System Contractors
  - + Drilling contractor
  - + Logging contractor

- o Project staff-supervision, 1/shift, 3 shifts, each well.

2.3.5 Cased Hole Tests - T4 Through T10

Description:

Interference testing is planned using the perforated leach wells prior to stimulation. Generally the purpose and procedure is the same as described in Section 2.2.5. For this work, two separate tests are planned, one test in each of the five spot patterns. Water injection is planned for the center well, and the fluid level rise in the surrounding wells will be observed. Because of the larger well spacing than that used in the previous 3-well testing, pressure response in the observation wells will not be as large.

Design Summary:

Following the method of calculating pressure response as shown in Appendix A.1.2, a pressure response of approximately 10 psi may be expected. Depending on actual reservoir properties, such as low permeability rock, less than a 10 psi repsonse is possible. If perliminary work shows that reservoir conditions will result in a small pressure response, quartz pressure transducers should be used instead of wireline probes or gas tubes for measuring fluid level.

The equipment required for these tests is essentially the same as described in Section 2.1.4. Additional fluid level monitoring equipment will be required, because of the larger number of wells involved in this test. Two wireline logging units will be needed to operate two quartz pressure gauges.

The sequence of events necessary for execution is as follows:

- Run in packer and tubing into injection well to just above perforations.
- Equip two observation wells with wireline quartz pressure transducers. Equip two additional holes with wireline electric depth probes or gas tubes.
- After all pressures have stabilized, inject at constant rate.
- Observe and record pressure responses with time on observation wells and injector. Record injection rate.
- After sufficient data have been obtained, stop injection, bleed off pressure, and remove packer.
- Run packer in second injector, wait for fluid levels (pressure to stabilize), and repeat test.
- Remove all well equipment, and demobilize extra wireline logging unit.

Schedule:

The time allocated for each test is 2 days. A waiting period of 4 days is included to provide for decay of the first pressure transient prior to starting the second test. Thus, a total time of 8 days is projeted for this work.

Well Costs:

o Drilling contractor (run tubing packer in and out twice) 32 hours at $250/hour		$8,000
o Standby while injecting: 2 days at $175/hr		$8,400
o Standby without crew: 5.5 days at $500/d		$2,750
o Quartz gauge rental (may not be required, but includes other depth probe cost)		$8,000
o Logging contractor, 8 days active logging (required if quartz gages used)		$12,000
	Total	$39,150

Contractor Requirements:

- o Well System Contractors
  - + Drilling contractor
  - + Logging contractor
- o Surface Facility Operations Contractor-operate injection equipment and truck water
- o Project staff for test supervision

2.3.6 Pre- and Post-Stimulation Logging - T4 Through T10

Description:

All seven leach wells will be stimulated with short-radii fractures. This stimulation procedure is known to be achievable and the costs can be estimated. This activity is described in Section 2.3.8. (Stimulation technique may change after work on the three test wells discussed in Section 2.1 and 2.2 above have been completed.) Logs will be obtained to help evaluate the utility of short-radii fractures. The logging program will consist of either a spinner log or differential temperature log. Either of these two logs will be run before and after the stimulation treatment to evaluate any changes in flow profile resulting from the stimulation treatment.

Design Summary:

After the seven wells have been perforated, the logging contractor will rig up to run either spinner log or differential temperature log.

The drilling contractor will rig up the water injection system. Subsequent to obtaining the log the logger will rig down and the injection system will be rigged down.

The drilling contractor will install equipment to stimulate the well. After stimulation the drilling contractor will remove the well equipment which had been used for stimulation and rig up for repeat water injection and logging. The logging contractor will repeat either the spinner log or the differential temperature log.

Schedule:

The time required is assumed to be 12 hours per well. Total time of 3 1/2 days.

Well Costs:

- Logging $41,160
- Drilling Contractor (Stand-by) $14,700
- Total $55,860

Contractor Requirements:

- Well Systems Contractor
  - Drilling contractor
  - Logging contractor
- Project staff-1/shift, 3 shifts, each well

2.3.7 Tracer Tests in 5-Spot Patterns

Description:

After stimulation using short radius fractures in the 5-spot patterns, tracer tests are planned. The tests will be executed and run as described in Section 2.2.5, and as in Appendix A.2.1. As previously discussed, the main purpose of the tracer testing is to provide information on sweep efficiency and dilution. The test is conducted by injecting tracer (chloride) at constant concentration and flowrate and producing from recovery wells at a total flowrate equal to the injection rate. Produced fluids are assayed for chloride. Equipping the wells is the same procedure as described in Section 2.3.9.

Design Summary:

The tracer tests will be run in both five spots simultaneously. The expected time for one pore volume injection using a 160 ft. well spacing is 53 days. A total time of 90 days is planned for the tracer test.

If chloride is used as a tracer, calculations show that 177 tons of salt will be required when the level of chloride used is 5 gpl.

The test will be executed by first installing tubing and packer in the injectors, followed by installing pumps in the producers. Salt and water are mixed using the surface facilities to a concentration of 5 gpl, or 10 times background. Fluid injection and production is started and maintained continuously with the total production rate equal to the injection rate. Samples and flowrate measurements are taken every few hours from each production well and the injectors. A library of fluid samples is maintained and samples are sent out for assay periodically.

After completion of the test, all well equipment is removed from the wells.

Schedule:

A total of 90 days are planned for this test.

Cost:

o Salt 354 tons @ $50/ton	$ 17,700
o Assaying	$ 10,000
o Well equipment installation removal	$ 32,000
o Well repair and maintenance for two wells	$ 7,000
o Logging relative to repair and maintenance	$ 7,310
o Drilling contractor demobilization	$ 2,000
Total	$ 76,010

Contractor Requirements:

- o Well system contractor

  Because of the long duration of this test, it is planned that the drilling and logging contractor be demobilized during test operations.

- o Surface Facility Operator Contractor-will be needed to perform construction, collect data, operate the injection equipment and perform maintenance and repair. From time to time, some contractor efforts will be required to maintain the wellfield.

- o Project staff-supervise all work.

Other Support Services:

Well logging or well servicing may be required in the event of equipment or well failure; to account for this the following contractor costs have been included:

- o Drilling Contractor for maintenance:

+ 2 mobilizations to site (service rig)	$ 2,000
+ Round-trip 2 wells for repair/maint.	$ 5,000

- o Logging Contractor

+ Mobilize to site once	$ 3,560
+ Production logs (estimate 2 days)	$ 3,750

2.3.8 Stimulate 5-Spot Pattern - T2, T4 Through T10

Description:

All eight wells will be stimulated using existing perforations by installation of multiple short-radius hydrofractures, with the objective of providing a flow increase of about 3:1 over unstimulated conditions. Post-stimulation tests will be run for the purpose of evaluating the effect of the stimulations, as the stimulations are performed. Test equipment will be removed and equipment required for leaching subsequently installed in the wells.

Design Summary:

Operating Sequence:

- Obtain a detailed stimulation design from the selected stimulation contractor based on 8 ft. radius propped hydrofractures installed approximately every 5 vertical feet, over the 322 ft. test interval from 1898 to 2220 ft. depth.

- Recomplete test well T2 (selected for use as a leach well), to enable similar stimulation of the perforated, unstimulated 122 ft. test interval. This 122 ft. interval overlies the existing stimulated, 200 ft. test interval. This requires plugging the existing stimulated interval with sand from 2,220 ft. to about 2,020 ft.; following stimulation (and prior to testing), this interval will be circulated clean.

- Mobilize and rig up the stimulation contractor. Move materials to the site, test the equipment and prepare fracturing fluids.

- Install the stimulation treatment for each well, according to the detailed design. Collect pressure, flowrate, volume and time data. Allow time for pressure bleed-off after the treatment.

- Remove well equipment, clean out the well. Run cement and multi-arm caliper logs to evaluate casing and cement integrity. Reinstall tubing and packer equipment. Perform transient and flow profile tests, as described elsewhere. Remove well equipment, and move to next well.

- Repeat the stimulation, logging, transient test and logging procedures until all wells have been stimulated and tested.

Equipment and Materials Specifications:

Same as for stimulation of test wells, described in Section 2.2.6.

Schedule:

Stimulation of the eight wells will require 10 days.

Well Cost:

- o Drilling Contractor = $ 46,800
- o Logging Contractor = $ 20,000
- o Hydrofracturing contractor = $ 60,264
- o Total = $127,064

Contractor Requirements:

- o Well system contractors
  - + Drilling: same as Section 2.2.6
  - + Logging: same as Section 2.2.6
  - + Hydrofracturing: same as Section 2.2.6
- o Project staff supervision of all work, 1/shift, 3 shifts.

2.3.9 Equip 5-Spot Wells for Leach Test - T2, T4 Through T10

Description:

The corrosion resistant equipment will be installed in all eight test wells in preparation for leach testing. Two wells will be equipped for fluid injection, using inflatable packers and F.R.P. tubing. Four of the remaining six recovery wells will be equipped with electric submersible pumps, F.R.P. tubing, fluid level detection tubing and electric cable. Two remaining wells will be equipped with downhole progressing cavity pumps, metallic or F.R.P. tubing, fluid level detection equipment, drive rods and drive heads.

Wellhead equipment will be connected to surface flow lines and power sources by the surface contractor, with assistance from drilling contractor personnel.

All installed equipment will be tested both during and following installation.

Design Summary:

Operating Sequence:

- Rig up on an injection well. Run in and set the inflatable packer to about 1,880 ft. depth, on 2 3/8 inch o.d., 1,500 psi, F.R.P. tubing. Run packer inflation tubing with the injection tubing, fastening as required. Inflate the packer with high pressure gas. Fill the tubing-casing annulus with water; observe fluid level stability and gas bubble occurrance.

- Rig up injection wellhead as shown in Figure 2-4; connect injection flow line (flexible hose) to the injection wellhead piping. Initiate water injection, gradually increasing pressure and flowrate to leach test levels; inject for sufficient time (about 1/2 hour) to verify proper operation. Move rig to other injection well.

- Repeat the above steps. Move rig to a recovery well and rig up.

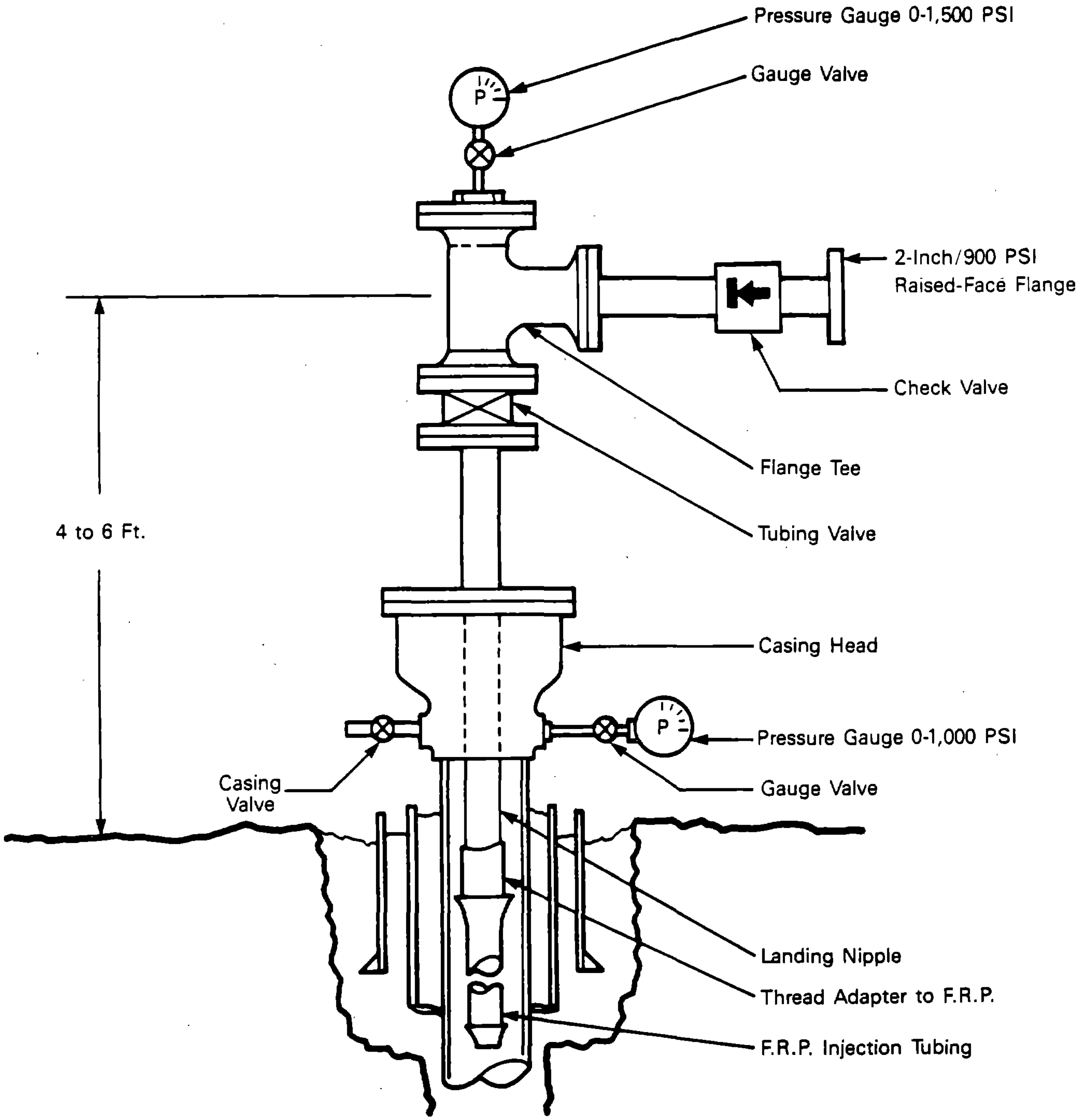
- Set the submersible pump and drain valve at about 1,890 ft., just above the perforated casing interval, on the same type of F.R.P. tubing used in the injection well. Fasten the electric cable and fluid level monitoring tube to the recovery tubing as required. Test the pump electric cable for resistance (megohm check) periodically during installation.

- Rig up recovery wellhead as shown in Figure 2-5; connect recovery flowline (flexible hose) to the wellhead piping and hook up the fluid level monitoring equipment. Test operation of the fluid level monitoring equipment. If fluid level is sufficient to provide the required N.P.S.H. for the pump, run the pump, to verify correct operation. (Do not allow the well fluid level to fall below that which provides the minimum required N.P.S.H.) Shut pump off and move rig to another recovery well.

- Repeat the above steps for three more recovery wells; move rig to one of the two remaining recovery wells.

- Set a progressing cavity pump stator at 2,200 ft. (within the perforated test interval), on 2 3/8 inch o.d. tubing, see Figure 2-6. (Both alloy 904 or equivalent metallic tubing and F.R.P. tubing will be used in this application, to determine suitability.) Connect the fluid level measuring tubing and equipment, as before. Install the pump rotor, drive rods and rod guides, spacing the rotor as specified by the manufacturer. Install the packing gland and drive head, and connect the electric power and flowlines. Test the fluid level monitoring equipment as before, and verify a minimum of 10 ft. N.P.S.H. exists, prior to pump operation. Run the pump to verify correct operation. Move the rig to the remaining recovery well.

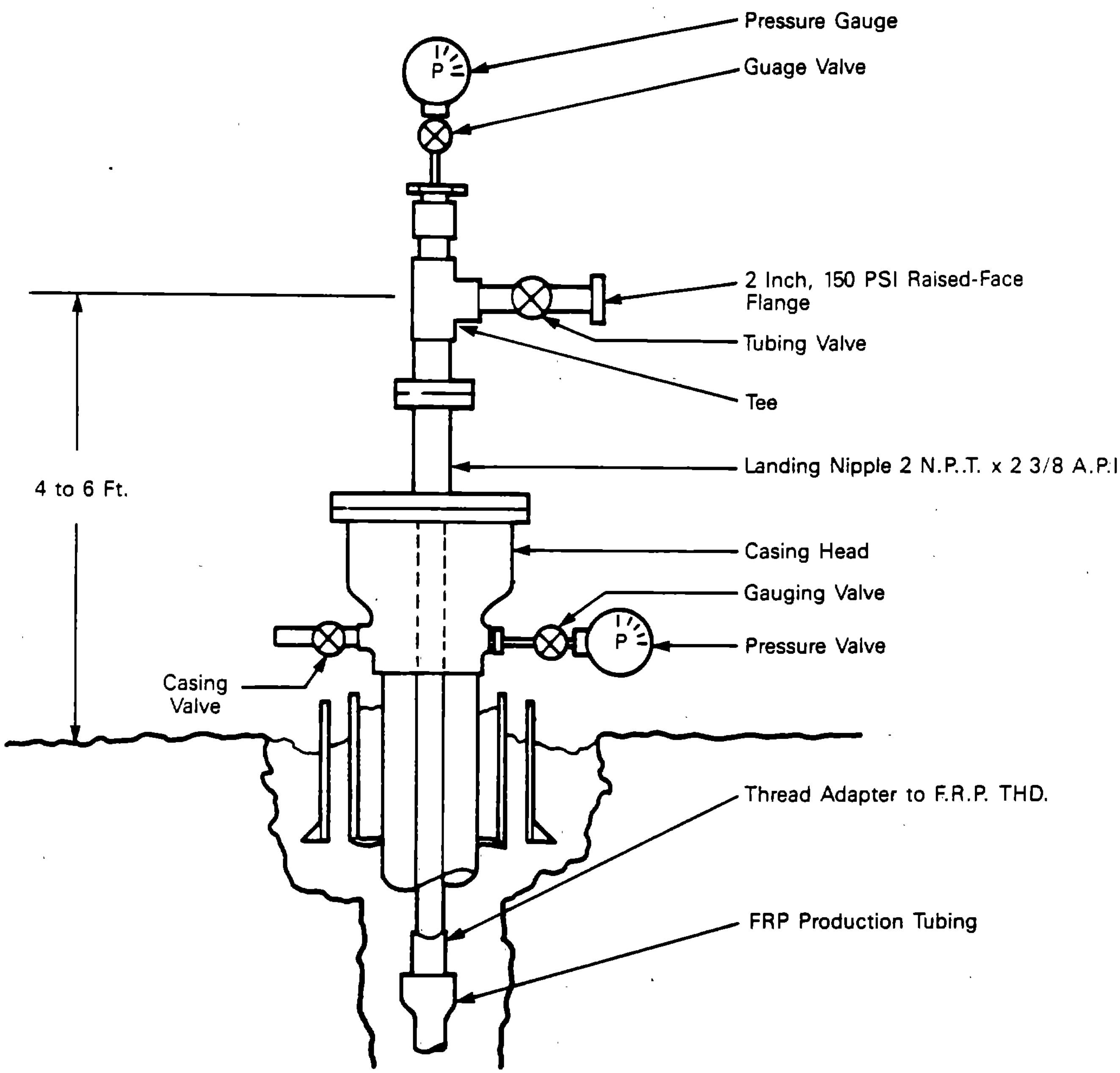
- Repeat the installation steps described above. This well will use the type of pump tubing (metallic or F.R.P.) which was not used on the above well.



Notes:

- Metallurgy—904L or Higher Alloy
- Working Pressure—1000 PSI
- Size—2 Inch I.D.

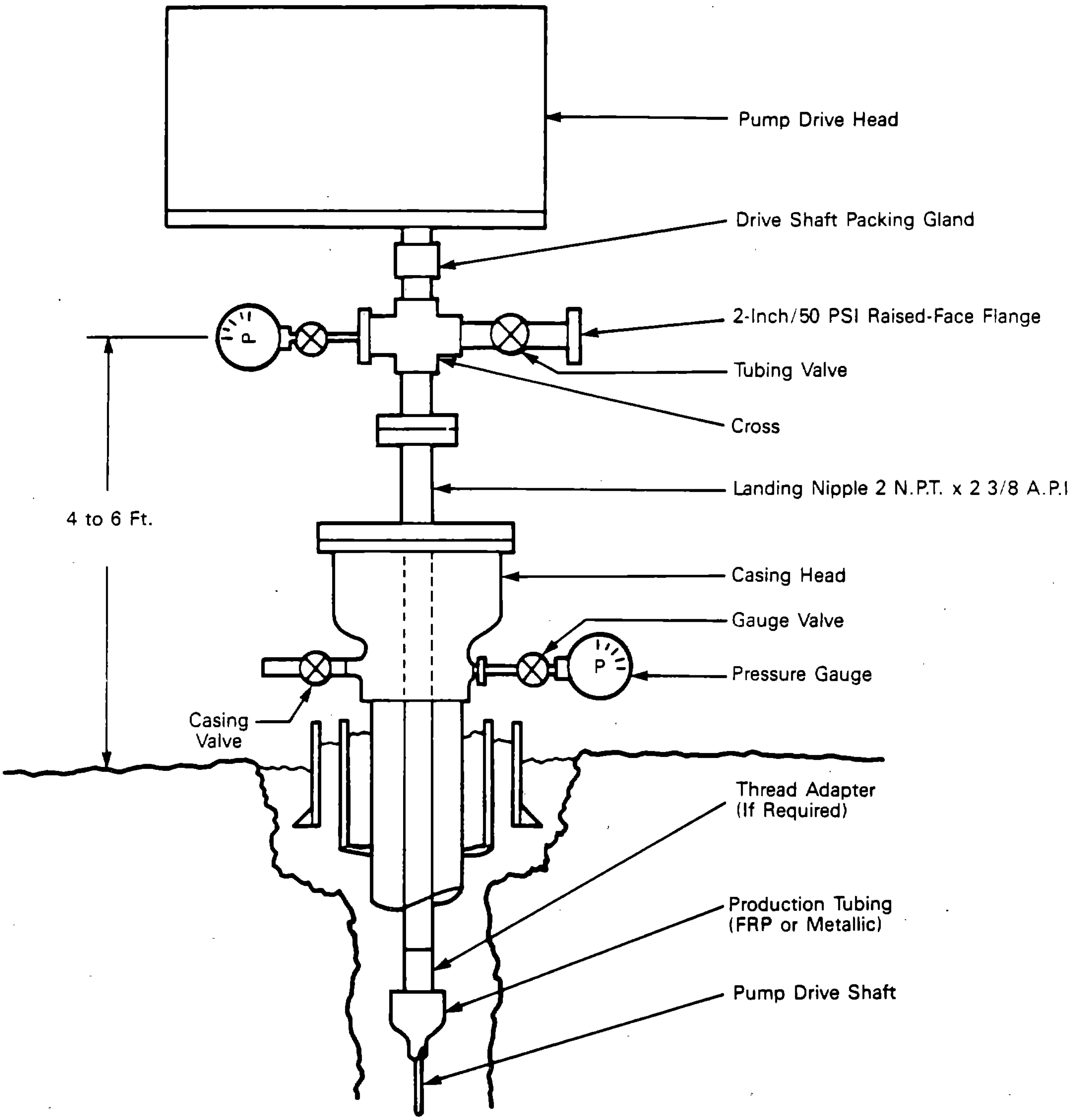
Figure 2-4. ISL Injection Wellhead Equipment



Notes:

- Metallurgy—904L or Higher Alloy
- Working Pressure—1000PSI
- Size—2 Inch I.D.

Figure 2-5. ISL Recovery Wellhead (Electric Submersible Pump)



Notes:
- Metallurgy—904L or Higher Alloy
- Working Pressure—1000 PSI
- Size—2 Inch I.D.

Figure 2-6. ISL Recovery Wellhead (Progressing Cavity Pump)

Equipment Specifications: (See also Appendix A.1.1.)

- o Injection Wells:
  - + Tubing:
    - Purpose: to conduct injection flow and suspend well equipment.
    - Specifications: 2 3/8 inch o.d., 1,500 psi rated F.R.P., integral joint tubing. Box o.d. dimension must be less than about 4.3 inches, to provide clearance for other well equipment. Will include thread adapters if necessary. Spare parts inventory will include a 2,200 ft. long spare tubing string.
  - + Packer:
    - Purpose: to isolate injection fluid pressure and flow to desired interval of the well casing.
    - Specifications: tube-inflatable type, capable of withstanding about 2,000 psi differential pressure, constructed of 904L or higher alloy and suitable elastomers, such as E.P.D.M. rubber. The spare parts inventory will include 2 complete packers.
  - + Packer inflation tubing:
    - Purpose: to conduct high pressure gas from the surface to the packer, to inflate the packer element. A gas must be used instead of a fluid, to allow proper packer deflation at these depths.
    - Specifications: suitable metallic or elastomeric tubing, capable of withstanding approximately 2,000 psi pressure and resistant to well fluid corrosives. This tubing must be about 1 inch or less o.d., to assure adequate clearance with other well equipment. Spare parts inventory will include extra fittings and 1,000 ft. of tube.
  - + Strapping:
    - Purpose: to fasten tubes and electrical cable to the well tubing.
    - Specifications: suitable metallic or plastic material to withstand forces associated with this application, and resistant to well fluid corrosives. (Nylon is not suitable)
  - + Wellhead:
    - Purpose: holds well tubing and provides a means of isolating and controlling annulus pressure and flow.
    - Specifications: flange-type, 1,500 psi rated, standard steel construction, epoxy painted.

+ Landing Nipple:

  - Purpose: to hold the F.R.P. well tubing in the wellhead slips without damaging it.

  - Specifications: 2 3/8 inch o.d., alloy 904L or higher tubing capable of operation at 1,000 psi or more, A.P.I. threads on one end and a 2 inch raised-face flange welded on the other end.

+ Thread adapters:

  - Purpose: to adapt the well tubing thread form to associated equipment in cases where both threads are not the same.

  - Specifications: proper thread forms, pressure capability of at least 1,000 psi and construction of F.R.P. or alloy 904L or equivalent.

+ Casing Valve:

  - Purpose: to control pressure and flow from the casing annulus, through the wellhead.

  - Specifications: 2 inch alloy 904 ball valve, rated 1,000 psi.

+ Tubing Valve:

  - Purpose: to control pressure and flow from the injection tubing and to allow passage of wireline logging and other tools through it, down the tubing.

  - Specifications: 2 inch, full-opening gate valve, rated at 1,000 psi, constructed of alloy 904 or equivalent.

+ Injection Tee:

  - Purpose: to conduct injection flow into the tubing, allow wireline tools access to the tubing and provide a pressure gauge location.

  - Specifications: 2 inch flanged connections, 1,000 psi rating, 904L or equivalent construction.

+ Check Valve:

  - Purpose: to prevent backflow from the well, into the injection lines and equipment.

  - Specifications: swing-check type, 1,000 psi rated, 904 or equivalent construction.

+ Injection Flange:

  - Purpose: to connect the injection wellhead piping to the injection flowline.

- Specifications: 2 inch raised-face, 900 lb. rated (Rated to 1,500 psi at 200 degrees F.) flange, of 904L construction, or equivalent.

+ Pressure Gauges:

  - Purpose: monitor pressure within the well tubing and tubing-casing annulus.

  - Specifications: Tubing gauge: 0 to 1,500 psi range, 1% accuracy, 904 or equivalent construction; Wellhead gauge: same as above.

+ Gauge valves:

  - Purpose: to turn on or off the above valves; can also be used to attenuate fluid pulsations to the gauge.

  - Specifications: 1/4 inch, 1,000 psi rated, 904 or equivalent construction, ball valves.

o Recovery Wells equipped with electric submersible pumps:

+ Tubing: Same as injection well.
+ Strapping Material: Same as injection well.
+ Wellhead: Same as injection well.
+ Landing Nipple: Same as injection well.
+ Thread Adapters: Same as injection well.
+ Pressure tubing:

  - Purpose: to conduct high pressure gas to a depth near the recovery pump, in order to measure gas pressure, which is converted to well fluid level depth.

  - Specifications: small-diameter high pressure elastomeric tubing rated to approximately 1,500 psi, of suitable corrosion resistant construction. Spare parts inventory will include extra fittings and 1,000 ft. of tubing.

+ Fluid level measurement surface equipment:

  - Purpose: (refer to Figure 2-7; high pressure gas source (usually 2,000 psi nitrogen) and related piping, valves, regulators and gauges. Purpose is to supply sufficient gas pressure to the downhole fluid level monitor tube, in order to displace well fluid from the tube. Measurement of gas pressure at the surface indicates the well fluid level above the tube end, which is then converted to depth to the fluid level from the surface.

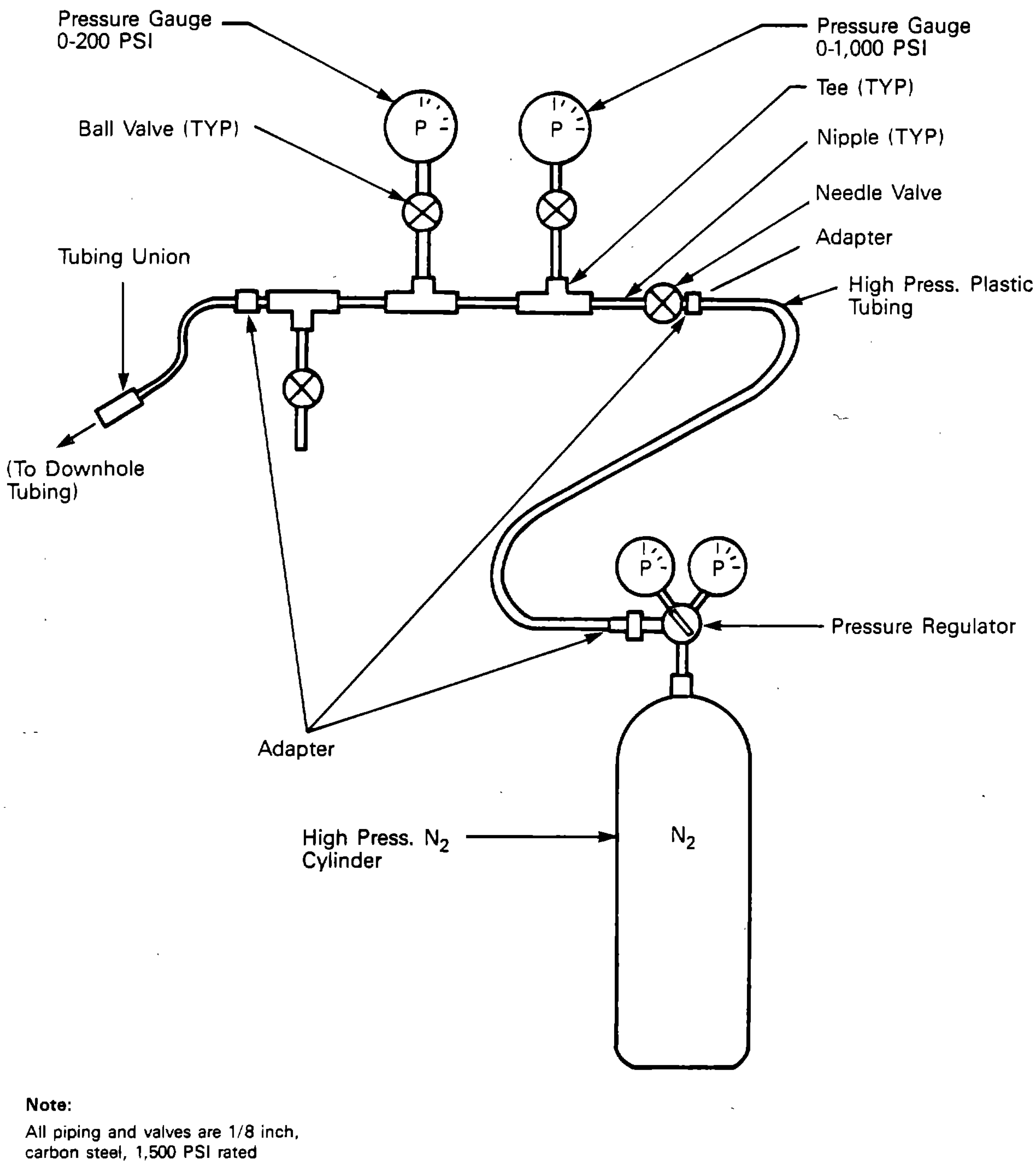


Figure 2-7. Flow Level Monitoring Surface Equipment

- Specifications: carbon steel or plastic construction (this equipment is not in a corrosive environment), 1/8 tubing, valve and fitting size is adequate. Pressure rating of at least 1,500 psi; low pressure gauge should be 0 to 200 psi; high pressure gauge should be 0 to 1,000 psi; both should be 1% accuracy. High pressure tank must be located in noncorrosive environment, or adequately protected from corrosion, as a safety precaution. The spare parts inventory will include a complete set of surface equipment and 2 spare gas bottles; about 6 gas bottle refills per well will be required during the course of the test.

+ Recovery Pump:

  - Purpose: to lift well fluids to the surface and maximize well fluid drawdown.

  - Specifications: electrical submersible pump; 480 volts, three phase power, capable of producing at least 8.3 gpm from 1,890 ft. depth, with sufficient pressure for surface flow requirements (about 30 psi) and includes a check valve; if 904 or equivalent construction is unavailable, 316 alloy construction, with sufficient spare parts inventory, is acceptable. (Assume 316 alloy pump failures on 4 month intervals through the leaching operation.) The spare parts inventory will include 12 complete pump and motor units.

+ Pump Cable:

  - Purpose: conduct electrical power to the recovery pump.

  - Specifications: sufficient size and number of conductors for the specified recovery pump horsepower, and pump depth. Insulating materials must be resistant to well corrosives and normal abrasion experienced during pump setting operations. Adequate cable splicing methods and materials are required. The spare parts inventory will include 5,000 ft. of cable and 50 splice kits.

+ Drain Sub:

  - Purpose: to allow the tubing string to drain as it is removed from the well. (To avoid "wet pulls" with the tubing full of corrosive fluid.) After removing the well pump a "sinker bar" is lowered on a wireline, to break the hollow drain sub pin, allowing fluid inside the tubing to flow into the well.

  - Specifications: 904L or equivalent construction, A.P.I. threaded ends, large supply of expendable valve pins (about 20 per drain sub), 2 inch i.d., 2 3/8 o.d., rated at 1,000 psi.

+ Recovery Tee:

  - Purpose: allow wireline tool access to the drain sub, provide fluid access to the recovery flowlines and provide a tubing pressure gauge location.

- Specifications: 904L or equivalent construction, N.P.T. threads, 150 psi rating, 2 inch i.d.

+ Tubing Valve:

  - Purpose: to provide tubing flow control and allow tubing pressure to be used to slightly restrict pump flow, if desired.

  - Specifications: 2 inch ball valve, 904 or equivalent construction, 150 psi rated.

+ Recovery Well Flange:

  - Purpose: same as injection well.

  - Specifications: 150 lb. rated, 2 inch raised-face flange, 904L or equivalent construction.

+ Tubing Gauge:

  - Purpose: indicate pump operating pressure at the wellhead, for keeping the pump within its specified operating pressure range during flow adjustments.

  - Specifications: 0 to 200 psi, 1% accuracy, 904 or equivalent construction.

+ Wellhead Gauge: same as injection well.

+ Gauge Valves: same as injection well.

+ Casing Valve: same as injection well.

o Recovery wells equipped with progressing cavity pumps:

  + Tubing:

    - Purpose: to suspend the recovery pump and fluid level measurement tubing, conduct fluid to the surface, and contain the pump drive rods.

    - Specifications (metallic tubing): 2 3/8 inch o.d., 0.190 inch wall thickness, A.P.I. 8-round external upset end thread form, about 30 ft. long joints, alloy 904 or equivalent. Couplings are 2,000 psi rated F.R.P. type, using same thread form. Use of F.R.P. couplings considerably reduces the cost of the tubing, and obviates thread galling problems. Tubing pup joints in 2, 4, 6, 8 and 10 ft. lengths are required. Spare parts inventory will include 5 full-length joints and 10 F.R.P. couplings.

    - Specifications (F.R.P. tubing): same as injection well, without additional spare tubing.

+ Strapping material: same as injection well.

+ Wellhead: same as injection well.

+ Landing nipple: same as injection well.

+ Thread adapters: same as injection well.

+ Fluid level monitoring equipment: same as previous recovery well.

+ Recovery pump:

  - Purpose: same as previous recovery well.

  - Specifications: downhole progressing cavity, positive displacement pump, powered by a surface-mounted drive head, through rotating drive rods. Capable of lifting 8.3 gpm of fluid from 2,300 ft. depth, and supplying about 30 psi pressure for surface flow. In order to test two types of metallurgy, two types of pumps are specified. One will have alloy 904 or equivalent rotor and stator; the other type will be alloy 316 or equivalent. Spare parts inventory for the 904 alloy pump will be 2 spare rotors and stators; the 316 alloy pump will have 4 spare stators and rotors, since it is likely to corrode more quickly.

+ Pump drive head:

  - Purpose: to provide power transmitted through the drive rods, to the pump rotor. Varying the rotational speed of the drive rods varies the pumping rate. A brake on the drive head prevents backwards rotation of the pump (and possible overspeed damage), following pump shutoff. The drive head contains an integral packing gland, to isolate fluid within the tubing and prevent contamination of drive head bearings and parts. A separate packing gland, made of alloy 904 or equivalent, will be placed below the drive head, to prevent corrosion of the carbon steel drive head.

  - Specifications: adequate to supply sufficient horsepower (approximately 16 hp.), support the 2,200 ft. long string of drive rods, vary pump rotation speed from about 100 to about 500 rpm and supply sufficient torque (about 1,750 inch pounds). Carbon steel materials of construction are suitable; it is doubtful that drive heads are commercially available in alloys adequate for this service, so a separate packing gland will be utilized. This packing gland will connect to the drive head and the wellhead piping, be constructed of alloy 904 or equivalent, have suitable corrosion-resistant packing material, and fit the selected drive rod size. Spare parts inventory will include 2 spare packing glands and 1 spare electric motor.

+ Drive shaft:

  - Purpose: to transmit rotation and power to the pump rotor and to suspend the rotor from the wellhead.

  - Specifications: alloy 316 A.P.I. sucker rods of suitable diameter for the torque requirements of the pump. Alloy 316 is thought adequate since limited pitting corrosion can be tolerated in this application. Crevice corrosion in the rod connections will be avoided by use of a suitable anaerobic thread compound applied to the joints during installation. Suitable lengths of "pony" rods will be required in order to properly space the pump rotor, during installation. Spare parts inventory will include 10 drive rods.

+ Rod guides

  - Purpose: to prevent harmonic vibrations in the drive rods (induced by the eccentric rotation of the pump rotor), from causing rod motion which may result in abrasive damage to the pump tubing. In the case of F.R.P. tubing, the rod gudes will be designed to provide a bearing surface for the rods, to prevent abrasive tubing wear resulting from rotation of rods or guides. Since it is not presently known which type of rod guides (or "paraffin scrapers") will perform best, a variety of different types will be tested. Performance will be evaluated when well equipment is removed.

  - Specifications: each drive rod will be equipped with one rod guide constructed of suitably abrasion and corrosion resistant materials. (High density polyethylene or polyurethane, for example.) Rod guides for use in the F.R.P. tubing will be constructed so as to allow the rod to rotate freely within the guide; guides for use in the metallic tubing may clamp onto the rods in conventional manner, allowing the guide to rotate against the metallic tubing wall. Spare parts inventory will include 1 complete set of rod guides.

+ Recovery tee:

  - Purpose: same as previous recovery well; access to a drain sub is not applicable in this case. Since the drive head is located where the tubing pressure gauge was on previous recovery wells, a pipe "cross" is used to provide the gauge outlet. (See Figure 2-6.)

  - Specifications - 2 inch pipe "cross," 904L or equivalent construction, N.P.T. threads, 150 psi rating.

+ Tubing valve: same as previous recovery well.

+ Recovery well flange: same as previous recovery well.

+ Pressure gauges: same as previous recovery well.

+ Casing valve: same as previous recovery well.

- Contractor Specifications:

  + Drilling Contractor: Provide a suitable rig for performing the well service operations described. The rig equipment should include a weight indicator, a wireline winch with about 2,500 ft. of cable, tubing tongs equipped for use with F.R.P. tubing and a mast height sufficient to stand double tubing lengths (about 60 plus ft.).

  + Surface Contractor: Assist as required with operations described above which involve surface equipment or connections, equipment handling, etc.

Schedule:

Equipment installation and testing: 7 days

Well Cost:

o Drilling contractor:	$ 28,400.
o Equipment and spare parts:	$411,705.
o Total	$440,105.

Contractor Requirements:

- Well systems contractors same as Section 2.2.6.
- Surface Facility Operator Contractor - assist with installation and testing 3/shift, 6 shifts.
- Project staff - provide supervision, quality control, approval of work.

Other Support Services:

Factory representative to assist first installation of progressing cavity pump.

2.4 WELL SYSTEM OPERATION

2.4.1 5-Spot Leaching

Description:

The leaching test will utilize two contiguous 5-spot well patterns. As shown in calculations (Appendix A.2.2), the maximum expected flowrate is aproximately 40 gpm per injector. The surface plant has a maximum flowrate of 50 gpm, which is sufficient to handle 25 gpm per injector. The extra injection capacity is needed since fluid losses may occur in the ground. The injection flowrates is based on an assumption of 2 md permeability, which is not known at the present time.

The main purpose of the leaching test is to demonstrate the rate of copper production (flow rate x concentration) and to allow prediction of the percent recovery of copper from the orebody. The field experiment may not operate for a time period that is long enough to leach all of the recoverable copper. However, the time should be long enough to allow a projection of total copper recovery that is reasonably accurate. Other objectives of the leaching tests are to evaluate equipment performance, investigate the extraction of copper from pregnant liquor, investigate corrosion, scaling, changes in rock properties, and net acid consumption by the gangue.

Design Summary:

A startup period of 2 months is anticipated during which flowrate equiilibrium is established, solutions approach steady state concentrations, and equipment problems are identified and resolved. After this period leaching is planned for 18 months.

To begin the leach test, all production pumps will be started and the total production rate under semi-steady state condition will be determined after 24 hour production. The wells will be pumped off (maximum drawdown used). Injection will then be started, using dilute sulfuric acid, at a rate equal to the total production. Injection pressure should be maintained at less than fracture pressure, 500 psi surface pressure at a frac gradient of 0.7 psi per foot at the top of the leach interval. Produced fluids will be reinjected (after acid makeup) until the copper content of the solution reaches a level which can be treated by the SX plant. After SX treatment the raffinate will be reinjected.

During the startup period, a close watch should be maintained on all operating equipment. For example, all motors should be checked for high temperature operation. The tubing-casing annulus should be examined for pressure which may indicate leakage past the packer or a leak in the injection tubing string. The start-up period will also be used to adjust injection well flowrates and the distribution of flow from the production wells to maximize the production of copper and the pregnant liquor concentration of the flow stream being delivered to the SX/EW plant.

After the startup period, leaching is planned for 18 months. During this time the leach test will simulate actual mining operations. Injection and production would continue under steady-state operation. Fluid flow rates would be recorded from each well and samples of fluid taken from time to time from each well. The data would be used to estimate total well production and production rate from the patterns. Ultimately the data would be used to project total copper recovery from the patterns.

Specific operational characteristics and potential problems that will be closely monitored for are discussed below:

- Copper loadings are expected to decline from the production wells as the pattern becomes depleted in copper. It is also possible in this case that too much acid breakthrough occurs at the production well, which would interfere with solvent extraction. Options in this case include reducing the acid concentration injected or cutting back the production flowrate from the well.

- Another possibility is short circuiting of fluid, or "channelizing". This condition exists when the lixiviant passes through a very short path directly to the produciton well. A short circuit results in low copper loadings and high acid strength in the produced fluid. Remedial action might employ polymers for profile modification or to plug a short circuit. The decision to use such methods would have to be made after observing well conditions.

- Another potential operational problem is the reduction of permeability near the production wellbore because of precipitation of minerals such as gypsum. If this occurs, the use of scale inhibitors may be considered and implemented.

During the leaching test, solution samples of the injected lixiviant and produced solutions from each production well will be collected. All samples should be of about 1 liter in size. Lixiviant samples will be required at approximately 4 hour intervals. These can be taken from the piping leading to the injection pumps. also, production well samples will be needed at about hour intervals from each well. The samples should be stored in a library. Daily, composite samples can be made for each production well, and for lixiviant. It is planned that one composite sample will be sent for assay daily for each well and for the lixiviant acid strength. Approximately once each month samples (composites) from the individual produciton wells should be sent for complete analysis. After assay results are received, and checked, solution samples can be thrown away, and the sample bottles reused.

A shut down period of up to one month is planned following completion of the steady-state portion of the leach test. Water would be injected to flush strong acid from the injection system (pumps, piping, and wells). This would be followed by a gradual reduction of surface pressure and production pumping, during which time a minimum quantity of produced fluids would be circulated through the 5-spot patterns to minimize disturbance to the downhole environment prior to post leach coring. Production pumps and injection tubing with packers would then be removed from the holes in preparation for temporary well abandonment, which is described in Section 2.4.5.

Schedule:

This activity consists of three phases; start-up of 2 months, steady-state operating 18 months, and shut-down of 1 month. Total time is 21 months.

Well Costs:

- o No additional well costs. Maintenance costs are given in Section 2.4.2. Spare parts were included with well installation costs.
- o Chemical analysis costs of $191,625 based on $150/sample and 2 samples per day.

Contractor Requirements:

- o Well systems contractors - none.
- o Surface Facility Operator Contractor - operate and maintain all surface facilities, and provide labor for the collection of data, solution samples, etc. Labor schedule is:
  - + 3/day shift, maintenance, repair, construction required for 7 days a week

  + 2 per swing and graveyard shifts for operation of plant and data collection, 7 days per week

- o Project Staff - supervision, planning, evaluation of all operations.

2.4.2 Maintenance of 5-Spot Operations

Description:

The well system and equipment will be maintained during the leach test. This includes: start-up, steady state operation, schedule and unscheduled maintenance, and shut-down of operation.

Test operations consists of injection into two wells, fluid recovery from six wells, monitoring of the tubing-casing annulus fluid level (to verify injection equipment integrity and assure adequate N.P.S.H. for recovery pumps), adjustment of recovery pump rates to match well production capability, and maintaining records of equipment performance. Maintenance functions are required to ensure that test operations proceed as scheduled.

Scheduled maintenance includes inspection or replacement of both downhole and surface well equipment at prescribed intervals, and development of equipment performance records.

Unscheduled maintenance includes unpredicted events such as well equipment failures, well damage, recompletions and fishing. In addition, changes in the test plan may be required due to unknown geological conditions, well damage or may be indicated by interim test results. Examples of test plan changes would be to change the injection/recovery function of several wells, or to recomplete or re-stimulate well intervals. These functions are considered unscheduled maintenance

Design Summary:

Scheduled maintenance of downhole equipment involves only operations where moving parts are involved. These are associated with the production wells. Specific activities of inspection are listed below. Surface well equipment will be inspected on a daily basis and repaired as necessary. Equipment found defective will be replaced from the spare parts inventory.

o Service progressing cavity pump drive heads	By manufacturers specs
o Inspect electrical submersible pumps	4 months
o Inspect progressing cavity pumps (alloy 316)	4 months
o Inspect progressing cavity pumps (alloy 904)	6 months
o F.R.P. tubing, drive rods and rod guides	as related to pump

Prior experience with in situ copper leach field tests indicates that unscheduled maintenance may involve up to 50% of the scheduled maintenance.

Schedule:

- o Scheduled maintenance of 27 days
- o Unscheduled maintenance of 13 1/2 days

Well Costs:

o Drill Rig	=	\$ 80,000
o Logging	=	\$ 20,000
Total		\$100,000

Contractor Requirements:

- o Well System Contractors
  - + Drilling Contractor -
- o Surface Facility Operator Contractor - Labor for scheduled and unscheduled maintenance
- o Project Staff - plan and supervise all operations, and evaluate and report all data.

2.4.3 Post Leach 5-Spot Tests

Description:

After leach tests have been performed, flow profile logging and interference tests are planned. These tests are the same as described in Sections 2.2.5 and 2.3.5. The purpose of repeating these tests is to evaluate changes in permeability which may result from leaching. The dissolution of gangue and copper minerals may result in a permeability increase, whereas precipitation inthe rock may reduce permeability. It is also possible that leaching may change the flow profile by altering the permeability in a non-uniform manner.

Design Summary:

Flow profile logging using differential temperature and spinner logs would first be run in the 5-spot injectors. These wells would be equipped wtih tubing and packer at the end of the leach testing. The surface plant would set up for water injection, and the logs run. While logging is performed in the injectors, the pumps could be removed from the producing wells.

After the injectors are logged, tubing and packer are run in the production holes, and logging is repeated. Each of athe six production wells would be logged in this manner.

After the logging, tubing and packer would be installed in one center injection well. One production well would be equipped with the wireless operated quartz pressure transducer and all other wells (the surrounding 3 others) would be equipped with wireline depth probes or gas tube level monitors. Interference testing would then be conducted as described in Section 2.3.5.

Schedule:

- o Logging 11 days
- o Interference testing 4 days
- o Total 15 days

Well Costs:

o Drilling contractor (RI/PO packer & tubing) 184 hours at $250/hour	$46,000
o Drilling contractor on standby 176 hours at $175/hour	$30,800
o Logging contractor 13 days active logging at $1,500/day	$19,500
2 days standby at 850/day	$1,700
o Pressure gauge rental 3 days at $1,000/day	$3,000
Total	$101,000

Contractor Requirements:

- Well System Contractors
  - Drilling contractors
  - Logging contractors
- Surface Facility Operator Contractor - Labor for rigging surface injection facilities and for operation and maintenance
- Project Staff - supervision and data evaluation

2.4.4 Post-Leach Core Drilling - C2 and C3

Description:

Following the leach test, two core holes will be drilled in the test area for the purpose of defining fluid flow paths and mineral recovery, by examining changes in rock properties resulting from the leaching. Proposed locations of the wells are shown in Figure 2-3; these locations are arbitrary, and may be changed later with no schedule or cost consequence. The drilling and coring procedures will be identical to those used in the first core hole, described in Section 2.1.1. The holes will be cored in sequence, requiring only one core rig; it may be advantageous to schedule drilling and casing of the sediments prior to leach test completion, in order to save time. The cores will be logged, boxed, shipped, and stored by the USBM.

Design Summary:

Same as Section 2.1.1.

Schedule:

- o Mud rotary drill sediments; mud coring: 28 days
- o Air hammer drill sediments; mud coring: 25 days

Well Cost:

- o Mud rotary drill sediments; mud coring = $ 92,680.
- o Air hammer drill sediments; mud coring = $ 84,920.

Contractor Requirements:

Same as Section 2.1.1.

Other Support Services:

Same as Section 2.1.1.

2.4.5 Temporary Wellfield Abandonment - T1 Through T10 and Core Holes C1 Through C3

Description:

Following the leach test, all wells (core hole C1 will have previously been abandoned according to these procedures) will be abandoned in accordance with the Arizona Department of Water Resources (ADWR) Rules and Regulation R-12-15-817 environmental regulatory requirements. The procedure described here will prevent vandalism to the wells, protect against fluid contamination from or to the wells, allow future access to them for fluid level monitoring and sampling. This abandonment procedure includes removal of all well equipment, sealing the wellhead, and installing a protective locking cap over the wellhead.

Design Summary:

Operating sequence:

- o Remove all wellhead piping, fluid level monitoring, drive head and surface well equipment. Store or dispose of the equipment as specified by the USBM.
- o Remove all downhole well equipment from the wells, inspect and photograph where appropriate for the well files. Store or dispose of equipment as above.

- o Equip the wellheads with blank steel plates in the seal ring locations. Use rubber seal rings to effect a fluid seal. Remove annulus valves and gauge equipment and replace with suitable plugs. This effectively seals the well from external fluid contamination.

- o Fabricate and install steel locking covers over the wellheads, sufficient to prevent well access without unlocking the cover. (Suggest using a short section of well casing large enough to cover the entire wellhead, with a steel plate welded over one end. A slot in this plate would allow locking to a short projection welded onto the wellhead seal plate.)

- o Well pads are recommended to be left as is, at this time.

Schedule:

A total of 2 weeks will be required for this work.

Well Cost:

o Drilling contractor	=	$ 15,000.
o Materials	=	$ 240.
o Total	=	$ 15,240.

Contractor Requirements:

- o Well System Contractors - Same as Section 2.3.9.

- o Surface Facility Contractor - 3/shift, 3 shifts, 14 days.

- o Project staff: supervise contractors.

CHAPTER 3

SURFACE FACILITY

The design/engineering study for the in situ field experiment's solvent extraction plant is presented in the following chapter. The solvent extraction plant includes SX/EW and ancillary facilities which have been designed for the Santa Cruz site. The field experiment's suface facility is a complete processing system for the incoming pregnant leach solution and rejuvenating the lixiviant for reinjection into the well field. The design of the solvent extraction makes extensive use of plastics to accomodate the high anticipated chloride levels in the pregnant leach solution. The facility has been designed for an expected life of two years. At the end of the field experiment the facility will be dismantled and the site cleared.

3.1 SURFACE FACILITY CONSTRUCTION

Surface facilitiy construction is defined as those steps necessary to place a fully operational surface facility at the Santa Cruz site. The facility will be designed as described in the design specification and susequent criteria, flowsheets, specifications, and drawings. The installation of the facility will be implemented as described schedule. The installed cost has been estimated and included.

3.1.1 Description of Facilities

The Santa Cruz Field Experiment includes surface facilities for the recovery of copper, handling of well field solution and provides for ancillary services. The specific facilities are:

Well field (Area 20) equipment up to the well heads of the injection and production wells are part of the surface facility. This includes the pipe lines to and from the well field, injection pump, distribution manifold, tank and instrumentation. Each well has a 10-foot by 20-foot concrete pad for the drill rig. Electrical power and water are available at the well field.

Solvent extraction plant (Area 30) which recovers copper from well field solution, provides electrolyte for electrowinning and reconditions the leach solution before reinjection. The solvent extraction plant is composed of five mixer settlers, three for extraction and two for strip. The mixers are constructed of fiberglas and have agitators with variable speed drives. The basic design has two mixers for each extraction stage and a single mixer for each strip stage. Several sets of mixer inserts and agitators are included to change the retention time of the mixers to match the 10 to 50 gpm range in design flowrate. The settlers are HDPE lined concrete and fiberglas with a distribution launder and picket fence to evenly disperse the mixed solution and internal weirs for the collection of the organic and aqueous phases. The mixer-settlers are placed on an elevated bench to allow gravity flow of loaded organic and strong electrolyte. A drain and curb system contains any spills and directs the solutions to the SX drain sump. The area within the curb is asphalt paved.

The tank farm area (Area 40) provides bulk storage and surge capacity for process liquids. The area includes the SX drain sump, loaded organic tank, salt mixing tank, sulfuric acid tank and all associated pumps. The area is asphalt paved and curbed. Equipment for preparing the lixiviant; acid metering pump, static mixer, filter and the pump to transfer the lixiviant to the well field are located in the area.

The electrowinning area (Area 50) produces copper cathode. Included in the area are: a pre-engineered building, 40-feet by 100-feet, housing the electrowinning cells and work stations, an attached concrete block building, 40-feet by 20-feet for electrical equipment and the operating control room. Electrolyte tanks for strip extract, strong electrolyte, circulating electrolyte and associated equipment are adjancent to the building in a curbed and asphalt paved area. Electrolyte filter and heat exchanger are located in this area.

Three ponds, two 50-feet by 50-feet and one 100-feet by 100-feet, are located adjacent to the solvent extraction and tank farm areas. The two smaller ponds are used to contain pregnant leach solution from the well field and raffinate solution prior to being mixed with sulfuric acid and reinjected. The large pond is used for evaporation of various plant solution selected for disposal or to control solution volume. The ponds are designed to be constructed above ground with earthern berms. The ponds are double lined with a bottom layer of PVC, a HDPE flow net separating a top layer of HDPE.

The ancillary facilities (Area 90) include fire protection, maintenance and administration.

Fire protection is provided with a diesel motor driven fire water pump and AFFF foam system, located in the the fire pump building. The solvent extraction area is protected with an automatic sprinkler system. The plant water tank has a dedicated volume for fire protection.

A pre-engineered building 25-feet by 40-feet with three truck bays is provided for maintenance and warehouse storage.

Administrative offices are housed in a pre-engineered building or trailers as determined at the time of purchase. The facility planned to be 40-feet by 64-feet. The facility is complete with interior walls, electrical wiring and plumbing.

3.1.1.1 Equipment List

An equipment list with a brief description, quantity and connected horse-power of components that comprise the surface facility is presented in Table 3-1. Each item in the list is given a number for identification. The first number denotes the area where the item is located. The second number denotes the specification that describes the item. The last number is a sequential number used to make the number unique to that item. This equipment number is used in the flowsheets and capital cost estimate to identify the component.

```
                                      XX - X - XXX

            AREA NUMBER           -------+
            SPECIFICATION NUMBER  -----------+
            SEQUENTIAL NUMBER     ----------------+
```

FIGURE 3-1. EQUIPMENT NUMBER

An asterisk (*) in the equipment description identifies items used when operating below maximum design capacity.

TABLE 3-1. SURFACE PLANT EQUIPMENT LIST

EQUIP. NO.	QTY	DESCRIPTION	hp
20-3-100	1	Salt Mixing Tank 12 ft dia x 20 ft fiberglass tank w/cover 15,000 gal capacity	
20-1-105	1	Recirculation Pump 50 gpm, complete with motor, coupling, base and guard CPVC wetted parts	0.75
20-0-200	1	Well Field Pipe - Low Pressure Distribution and return lines HDPE butt welded pipe	
20-0-210	1	Well Field Pipe - High Pressure 1,500 psi rated, 904L stainless steel, flanged or welded	
20-0-240	8	Well Pads 20 ft x 10 ft concrete pad w/coarse fill sub-base, HDPE barrier and drain to dry sump	
20-3-250	1	Injection Pump Head Tank 4 ft dia x 6.5 ft Elevated HDPE tank with cover 500 gal active volumn	
20-0-275	3	Injection Pump (2+1) Progressive cavity, positive displacement pump, 50 gpm each w/motor, coupling, base	40
20-0-285	3	Injection Pump Spares Stator and rotor	
20-0-290	1	AC Variable Frequency Control Speed control for injection pumps, eq. nos. 20-3-275/276	
20-0-500	1	Production Well Pipe Polypropolene lined steel or HDPE pipe, collects solution from wells, feeds PLS pond	
20-0-910	1	Well Field Water Distribution	

TABLE 3-1. SURFACE PLANT EQUIPMENT LIST (Continued)

EQUIP. NO.	QTY	DESCRIPTION		hp
20-0-917	1	Well Field Power/Distribution 480 V, medium tension 120 V, lighting		
20-0-920	1	Misc. Well Field Pipe/Valves		
20-0-930	1	Electrical		
20-0-950	1	Instrumentation		
30-4-050	1	PLS Pond 50 ft x 50 ft x 6 ft double lined HDPE with dry sump		
30-1-060	1	SX Feed Pump 50 gpm, complete with motor, coupling, base & guard CPVC wetted parts		0.75
30-2-100	3	Extraction Pump/Mixer Box 180 gal active capacity fiberglass construction with agitator bridge		
30-2-105	12	Extraction P/M Inserts Active capacities of: 36, 60, 90 120 gal	(*)	
30-2-110	3	Extraction P/M Agitator Complete with motor, shaft, impellor, gear box and variable speed drive		1.5
30-2-115	3	Extraction P/M Agitator Complete with motor, shaft, impellor, gear box and variable speed drive	(*)	0.5
30-2-120	32	Impellors Various sizes for different mixer inserts	(*)	
30-2-130	3	Extraction Mixer Box 180 gal active capacity fiberglass construction with agitator bridge		

TABLE 3-1. SURFACE PLANT EQUIPMENT LIST (Continued)

EQUIP. NO.	QTY	DESCRIPTION	hp
30-2-135	12	Extraction Mixer Insert (*) Active capacities of: 36, 60, 90, 120 gal	
30-2-140	3	Extraction Mixer Agitator Complete with motor, shaft, impellor, gear box and variable speed drive	0.75
30-2-145	3	Extraction Mixer Agitator (*) Complete with motor, shaft, impellor gear box and variable speed drive	0.25
30-2-150	3	Extraction Settler 180 sq ft active area 12 ft x 22.3 ft x 3 ft concrete, HDPE lined, covered	
30-2-400	2	Strip Pump/Mixer Box 180 gal active capacity fiberglass construction with agitator bridge	
30-2-405	2	Strip Pump/Mixer Insert (*) Active capacities of: 36, 60, 90, 120 gal	
30-2-410	2	Strip P/M Agitator Complete with motor, shaft, impellor, gear box and variable speed drive	1.5
30-2-415	2	Strip P/M Agitator (*) Complete with motor, shaft, impellor, gear box and variable speed drive	0.5
30-2-450	2	Strip Settler 180 sq ft active area 12 ft x 22.3 ft x 3 ft concrete, HDPE lined, covered	
30-4-700	1	Raffinate Pond 50 ft x 50 ft x 6 ft Double HDPE liner with dry sump	

TABLE 3-1. SURFACE PLANT EQUIPMENT LIST (Continued)

EQUIP. NO.	QTY	DESCRIPTION	hp
30-1-705	1	Raffinate Pond Pump 50 gpm, complete with motor, coupling, base and guard CPVC wet'd parts, neg. suction	
30-0-710	1	Static Mixer 20 Alloy mixing zone with stainless steel cooling zone Protected from direct sunlight	
30-3-715	1	Raffinate Check TAnk 4 ft dia x 6.5 ft fiberglass tank w/covered top 500 gal active volumn	
30-1-720	1	Raffinate Filter Feed Pump 50 gpm, complete with motor, coupling, base & guard CPVC wetted parts	0.75
30-0-725	2	Raffinate Filter (1+1) Wound fiber/activated carbon cartridge filter, with 1 micron filtrate limit	
30-0-730	1	Pond Skimmer Floating skimmer to reclaim organic collecting on the surface of the pond	0.5
30-0-750	1	pH controller Automatic acid control for the leach injection solution	
30-4-780	1	Evaporation Pond 100 ft x 100 ft x 6 ft double HDPE liner with dry sump	
30-0-930	1	Electrical	
30-0-940	1	Piping	
30-0-950	1	Instrumentation	

TABLE 3-1. SURFACE PLANT EQUIPMENT LIST (Continued)

EQUIP. NO.	QTY	DESCRIPTION	hp
30-0-999	3	Portable Crud Pump (1+1) Pneumatic, diaphragm pump 20 gal capacity with PVDF wetted parts	
40-3-250	1	Loaded Organic Tank 11.5 ft dia x 7 ft fiberglass tank w/covered top 5,000 gal nominal capacity	
40-1-255	2	Loaded Organic Pump (1+1) 70 gpm, complete with motor, coupling, base & guard CPVC wetted parts	0.75
40-3-260	1	Strip Extract Storage Tank 11.5 ft dia x 7 ft fiberglass tank w/covered top 5,000 gals nominal capacity	
40-1-280	1	Filter Feed Pumps 35 gpm, complete with motor, coupling base & guard CPVC wetted parts	0.75
40-0-285	2	Electrolyte Filter (1+1) Wound fiber/activated carbon cartridge filter	
40-3-300	1	Strong Electrolyte Tank 11.5 ft dia x 7 ft fiberglass tank w/covered top 5,000 gal nominal capacity	
40-1-305	2	Strong Electrolyte Pumps (1+1) 35 gpm, complete with motor, coupling, base & guard CPCV wetted parts	0.75
40-0-500	1	Crud Collection System	
40-0-510	1	SX Drain Sump 4500 gal nominal capacity tank seamless HDPE design w/cover 12 ft dia x 5.6 ft	

TABLE 3-1. SURFACE PLANT EQUIPMENT LIST (Continued)

EQUIP. NO.	QTY	DESCRIPTION	hp
40-1-515	1	SX Drain Sump Pump Vertical, immersible, self-priming pump with direct drive motor and coupling	0.33
40-3-525	1	Centrifuge Feed Tank 3.5 ft dia x 4.5 ft fiberglass with covered top	
40-1-530	1	Centrifuge Feed Pump complete with motor base, coupling & guard	
40-0-550	1	Centrifuge Vertical, desludging type 316L/CF-3M wetted parts w/motor & coupling	
40-3-565	1	Recovered Organic Tank 3.5 ft dia x 4.5 ft fiberglass tank w/covered top 250 gal nominal capacity	
40-3-600	1	Sulfuric Acid Tank 12 ft dia x 20 ft carbon steel tank with top 15,000 gal capacity	
40-1-610	1	Sump Pump 5 gpm, vertical centrifugal w/ motor, coupling, base & guard self priming, CPVC wet. parts	0.5
40-1-615	5	Barrel Pumps 25 gpm at 10 TDH, complete with pneumatic motor, 316 tube set with seal	
40-0-620	1	Sulfuric Acid Mettering Pump 10 gpm, complete with motor base, coupling & guard hi-silicon iron wetted parts	0.5
40-99-700	1	Reagent Storage Bldg. 25 ft x 40 open sided structure w/roof, chain-link fence sides	

TABLE 3-1. SURFACE PLANT EQUIPMENT LIST (Continued)

EQUIP. NO.	QTY	DESCRIPTION	hp
40-0-930	1	Electrical	
40-0-940	1	Piping	
40-0-950	1	Instrumentation	
50-0-100	1	Heat Exchanger Plate and frame type	
50-3-110	1	Circulation Tank 12 ft dia x 4 ft w/cover 2,500 gal nominal capacity PVC/316L construction	
50-1-115	2	Circulation Pumps 180 gpm, complete with motor, coupling, base & guard CPVC wetted parts	5
50-1-125	1	Spent Electrolyte Pumps 35 gpm, complete with motor, coupling, base & guard CPVC wetted parts	0.75
50-5-225	6	Electrolytic Cells 19.5 ft x 3.7 ft x 4.7 ft (d) nominal size, actual based on final electrode selection	
50-5-235	7	Cell Liners (6+1) Seamless plasticized PVC Paraline or equal	
50-6-250	400	Anodes (342 + 58) Ca,Sn lead, solid blade, steerhorn suspension bar with copper insert	
50-7-260	400	Cathodes (336 + 64) Mt Isa type stainless steel blade and suspension bar	
50-5-265	1,500	Anode Guides PVC hairpin insulators	
50-5-270	800	Cell Top Insulators fiber filled, polycarbonate, interlocking modules	

TABLE 3-1. SURFACE PLANT EQUIPMENT LIST (Continued)

EQUIP. NO.	QTY	DESCRIPTION	hp
50-5-340	7	Intercell Bus Bars (5+2) Walker double triangle 110 ETP copper	
50-5-345	2	Apron Bus Vertical wrap over end bus w/Walker triangle, 100 ETP copper, 25.2 kA rated	
50-5-350	1	Main Bus 25.2 kA rated insulated cable	
50-8-400	1	Transformer/Rectifier 25.2 kA, 15 V dc output 6 pulse, thyristor type	
50-0-450	1	Over Head Crane 10 t underhung, single beam, pendant with stepless control 37.5 ft span, 25 ft lift	7.5
50-0-455	2	Crane Lifting Bales Anode bale w/57 hooks, Cathode bale w/28 hooks	
50-0-460	1	Cathode Washing Station Stainless steel spay and dip tank, 20 ft x 4 ft x 5 ft	
50-0-470	1	Cathode Stripping Station Two parallel bars to receive cathodes for stripping and reloading	
50-0-475	1	Cathode Wax Tank 20 ft x 4 ft x 1 ft tank with cathode guides	
50-0-500	1	Cathode Scale 20,000 lb capacity, 5 x 7 ft platform, low profile - weigh plate type w/load cell design	
50-0-520	1	Anode Storage Racks 3 layer, full bale storage mild steel, painted	

TABLE 3-1. SURFACE PLANT EQUIPMENT LIST (Continued)

EQUIP. NO.	QTY	DESCRIPTION	hp
50-0-530	1	Cathode Storage Racks 3 layer, full bale storage, painted mild steel	
50-1-610	1	Sump Pump 5 gpm, vercial centrifugal w/ motor, coupling, base & guard self priming, CPVC wet. parts	0.5
50-0-725	4	Reagent Feeders (2+2) For CoSO4 and HCl PVC wetted parts	0.1
50-3-730	1	Reagent Solution Tank - CoSO4 65 gal nominal capacity with agitator support and cover	
50-3-735	1	Reagent Solution Tatnk - HCl 65 gal nominal capacity PVC tank with covered top	
50-2-740	2	Solution Tank Agitator (1+1) Direct drive with motor, 316 shift and impellor. duty: mix CoSO4	0.33
50-0-750	1	In-line Process Water Heater Propane Fired	
50-0-800	1	Forklift 4t capacity, propane fueled, with penumatic tires	
50-99-900	1	Electrowinning Building 40 ft x 100 ft x 24 ft height open portal, structural steel structure	
50-99-925	1	Control Room/Electrical Bldg. With the electrowinning bldg, HVAC system for personnel and electrical equipment	
50-0-930	1	Electrical	
50-0-940	1	Piping	

TABLE 3-1. SURFACE PLANT EQUIPMENT LIST (Continued)

EQUIP. NO.	QTY	DESCRIPTION	hp
50-0-950	1	Installation	
90-0-010	1	Transformer 13.8 kV - 480 500/560 KVA, 3 PH	
90-0-011	1	Main Disconnect Switch	
90-0-015	1	Motor Control Center Units complete with enclosures switches, magnetic contractors, relays, fuses, etc...	
90-3-100	1	Potable Water/Firewater Tank 12 ft dia x 20 ft Mild steel with closed top dedicated vol. for emergency	
90-1-110	1	Potable Water Pumps 100 gpm, complete with motor, coupling, base & guard bronze case and impellor	15
90-99-120	1	Fire Pump Building 20 ft x 30 ft x 12 ft Houses firewater pump, AFFF system and ancillary equipment	
90-0-125	1	Firewater Pump 250 gpm, complete with diesel motor drive, controller fuel tank and jocky pump	7.5
90-0-135	1	Automatic AFFF System Provide foam to tanks, vessels and fire water system, complete w/control system	
90-99-200	1	Administration Building 2,500 sq ft, full HVAC, toilets offices and laboratory, temporary building or trailers	
90-99-300	1	Maintenance Building 1,000 sq ft floor space, 3 vehicle bays maintenance and warehouse areas	

TABLE 3-1. SURFACE PLANT EQUIPMENT LIST (Continued)

EQUIP. NO.	QTY	DESCRIPTION	hp
90-0-310	1	Plant Air Compressor Oil-less type complete package unit with motor and receiver 100 std cu ft/min @ 100 psi	40
90-0-315	1	Instrument Air Dryer Heatless - desiccant type with prefilter and afterfilter	
90-0-400	1	Propane Tank	
90-0-500	1	Sanitary Sewer System	
90-0-930	1	Electrical	
90-0-940	1	Piping	
90-0-950	1	Instrumentation	

3.1.1.2 General Data

SITE:

Santa Cruz Site

- o Name of Owner: Asarco Freeport McMoRan
- o Head Office Address: 180 Maiden Lane, New York, NY 10038
- o Site Office Address:
  - + Contact: Verle Martz - Sacaton-Asarco
  - + Position: Geologist
- o Company Ownership and Affiliations: Santa Cruz is a joint venture between Asarco and Freeport McMoRan

SITE CONDITIONS:

- o Quality of road access: gravel, one mile from state maintained paved highway
- o Nearest highway: one mile
- o Site elevation: 1310 ft
  - + Earthquake zone: UCB Zone 2*
  - + Weather hazards: thunder storms
- o Soils Data:
  - + Bearing pressure: 5,000 lb/sq ft*
- o Site area available:
- o Type of site: Greenfield - Yes, no other installations and service present flat, low site, some flooding during heavy rains

UTILITIES:

- o Power available: yes
- o Power company: Arizona Power Company
- o Location of power lines: 100 feet from plant site
  - + Site Incoming Power:
  - + High Tension: 12.5 kV* 3 Phase 60 Hz
  - + Plant Distribution: (Proposed)

+ High Tension:	4160 V	3 Phase	60 Hz
+ Low Tension:	480 V	3 Phase	60 Hz
+ Control Circuits:	120 V	1 Phase	60 Hz
+ Fractional hp motors	120 V	1 Phase	60 Hz
+ From 1/2 hp to 150 hp	460 V	3 Phase	60 Hz
+ From 200 hp	4160 V	3 Phase	60 Hz

- o Reliability: Commercial power
- o Frequency and duration of outages in local main power supplies:
  - + Complete failure of system: not known
  - + Voltage drop due to external cause: not known

<u>TYPES OF WATER AVAILABLE</u>: Well water

- o QUALITY

+ pH	TBD
+ Total Hardness	TBD
+ Temporary Hardness	TBD
+ Total Solids	TBD
+ Soluble Salts	TBD
+ Analysis	TBD
+ Chloride	TBD

<u>CLIMATIC DATA</u>:

o Rainfall:	8.4 ins
o Maximum rate and duration:	4.5 ins (24 hrs)
o Snow cover:	trace
o Temperature:	65° Mean
o Maximum:	122°
o Minimum:	17°
o Design:	Full range
o Relative Humidity:	20-55%
o Wind velocities and direction:	to be determined
o Design wind velocity:	TBD

Water type and storage for fire fighting: None

LEACHATE DATA:

o Solution feed rate:	Maximum:	50 gpm
	Minimum:	10 gpm
o Solution temperature:	Maximum:	TBD
	Minimum:	TBD
o Solution analysis: (to be determined by the USBM)	H_2SO_4:	
	Cu:	
	Fe total:	
	Fe (ic):	
	Co:	
	Ni:	
	Al:	
	SiO_2:	
	Mg:	
	NH_3:	
	Cl:	
	Solids:	
	Others:	
	pH:	

*Data to be confirmed at initiation of field experiment project.

3.1.2 Design Specifications

A design specification has been developed for the solvent extraction and electrowinning plant and is presented in this section. The design specification contains the following:

- Process Criteria, a listing of all critical design parameters.
- Flowsheets showing major process equipment components and the material flow between the components. These are:
  - Figure 3-2. Well Field Flowsheet
  - Figure 3-3. Solvent Extraction Flowsheet
  - Figure 3-4. Electrowinning Flowsheet
- Equipment and material specification, a general description of the duty requirements of selected equipment and materials. These include:
  - Pumps
  - Mixer/Settlers
  - Tanks
  - Ponds

+ Electrowinning components
+ Electrical equipment including electrowinning transformer/rectifier
+ Piping materials
+ SX/EW Safety Systems

o Facility drawings includung general arrangement drawing and section, Piping diagrams and electrical one line diagram. These are:

+ Figure 3-5.	Plot Plan
+ Figure 3-6.	Plant Profile
+ Figure 3-7.	Electrowinning Building, Plan & Section
+ Figure 3-8.	Solvent Extraction P&ID
+ Figure 3-9.	Electrowinning P&ID
+ Figure 3-10.	Well Field P&ID
+ Figure 3-11.	SX-EW Facilities Single Line Diagram

3.1.2.1 Process Design Criteria

SOLVENT EXTRACTION:

o OPERATIONS

+ Operating schedule, overall	continuous 365 days/year 24 hours/year
+ Annual overall availability	95 %

o PREGNANT LEACH SOLUTION (PLS)

+ Pregnant leach solution is the product of the in situ leaching well field.

+ Flowrate, (gal/min)	10 - 50 (maximum)
+ Analysis, (g/1):	
Cu	11.8 design maximum
H_2SO_4	2
Fe	13
Al	20
Mg	13
Cl	5 1/2
pH	2
+ Temperature, (°F)	100 (maximun)

o RAFFINATE

+ Flowrate, (gal/min)	10.2 - 51

+ Analysis, (g/1):

Cu	1.8 (based on 85% extraction)
H_2SO_4	20.7

ORGANIC PHASE:

o Extractant

+ Name	Acorga M 5397 Henkel LIX 984
+ Generic description	Salicylaldoxime with modifiers
+ Specific gravity	0.92
+ Volume, (V/V%)	25 for M 5397 33 for LIX 984

o Diluent

+ Name	Escail 100 Kermac 470B
+ Generic description	high flash point kerosene
+ Flash Point, (°C) at 101.3 kPa Pensky Martens method ASTM D-93	78

o Organic

+ Stripped organic loading, (gpl)	4.5
+ Loaded organic loading, (gpl)	13.5
+ Copper/Iron transfer ratio	300 : 1
+ Organic entrainment, (ppm)	500
+ Crud removal method	suction pump
+ Crud treatment	centrifuge

o Strip solution

+ Spent electrolyte, (g/l)

Cu	30
H_2SO_4	150 - 170
Fe (max.)	2.5

+ Strong electrolyte, (g/l)

Cu	45
H_2SO_4	127 - TBD
Fe (max.)	2.5

<u>SOLVENT EXTRACTION PLANT CONFIGURATION:</u>

o Phase continuity	Aqueous or organic continuous in all stages
o O/A ratio	
+ extraction	1.0 - 1.4 : 1
+ strip	1.5 - 2.0 : 1
o Stage efficiency, (%)	
+ extraction	90
+ strip	95
o Overall per cent extraction	85
o Number of stages	
+ extraction	3
+ strip	2
o Mixer boxes per stage	
+ extraction	2
+ strip	1
o Impeller	
+ primary	pump/mixer
+ secondary	variable chord hydrofoil
o Aqueous recycle, per cent of organic design flow	
+ extraction	100
+ strip	100
o Mixer retention, (sec)	
+ extraction, each mixer	180
+ strip	90
o Unit settling rate, (gal/min sq ft)	
+ extraction	1.5
+ strip	1.5
o Fire protection	AFFF foam
o Fire protection class	Class I, Div. 1 - Class 1 Div. 2 per NFPA publication 30 Chapter VIII, & Article 500 of the National Electrical Code (1984)

- o Electrolyte filter

+ Type	wound fiber/activated carbon cartridge
+ Rating	3000-4600 gph

- o POND & TANK RETENTION TIME, h

+ PLS pond	24 hrs
+ Raffinate pond	24 hrs
+ Evaporation pond	-
+ Loaded organic tank	1 hr
+ Strong electrolyte tank	2 hrs
+ Strip Extract tank	2 hrs
+ Diluent storage	60 days
+ Sulfuric acid storage tank	60 days (electrowinning only)
+ Reagent storage	60 - 90 days

POND DESIGN:

Double lined HDPE earthen ponds with dry well

TANK DESIGN:

Fiberglass, HDPE or steel with containment berm, flame arrestor on organic tanks

PUMP PHILOSOPHY:

Installed spares for critical applications only

ELECTROWINNING:

o Plant capacity, (t/d)	3
(t/y)	1,000
o Operating schedule, overall	continuous 24 hours/day 365 days/year
o Annual plant availability, %	95
o Cathode pulling schedule days per week	5

- o CELL AND ELECTRODE DATA
  - + Electrowinning deposition onto permanent cathodes
  - + Current density, (A/m2)

Operating	180
Design	220

+ Transformer - Rectifier capacity	
V dc	15
kA	25.2
+ Bus bar and rectifier rating	
kA	25.2
+ Current efficiency, %	85 (design)
+ Cell availability, %	95
+ Cell voltage, (V/cell)	2.5 (design)
+ Cell construction	concrete box
+ Cell size, (ft x ft)	19.5 x 3.7
+ Number of cells	6
+ Arrangement	single row of six cells
+ Cell liner	PVC, Paraliner
+ Cathode spacing, (in)	4
+ Cathode size, (in)	TBD
+ Deposition area, (m2)	1.0
+ Cathode cycle	7 day depostion cycle
+ Cathode	
type	stainless steel
design	Mt. Isa, I.M.I. Australia
+ Cathode weigh, (lb)	128 plus blank 195 maximum deposite
+ Cathodes per cell	56
+ Cathode handling	Hook bale and overhead crane
+ Anode type	solid blade, flat surface with "steerhorn" suspenbar, rolled or cast manufacture
+ Anode alloy, % (hot rolled)	
Ca	0.06 - 0.07
Sn	1.25 - 1.5
Al	0.005 - 0.02
Pb	balance

+ Anode thickness, (in)	0.35
+ Anode suspension bar	steerhorn with solid copper bar
+ Anodes per cell	57

MECHANICAL HANDLING:

o Crane	overhead bridge crane with pendant control
o Capacity, (tons)	10
o Crane speed, (ft/min)	
+ hoist	14
+ trolley	60
+ bridge	120
o Control system	stepless
+ Cathode stripping	manual stripping station
+ Cathode washing	spray tank

ELECTROLYTE, (g/l):

o H_2SO_4	127 - 150
o Cu	30 - 45
o Fe	2.5 maximum controlled by bleed
o Co, (ppm)	60
o Cl, (ppm)	50 maximum

Electrolyte circulation tank:

o capacity, (gal)	-
o material of construction	316L stainless steel
o Pipe material	PVC, CPVC, stainless steel
o Circulation system	direct to cells
o Cell flowrate, (l/min) (unit rate per sq. meter of deposition area)	1
o Cell flowrate, (gpm)	30 (per cell)
o Maximum cell temperature, (C)	45
o Cell flow control	individual cell valves

o Pumps	horizontal centrifugal 316L/CF-3M or CPVC wetted parts

ELECTRICAL:

o Transformer/rectifier	
+ input, (V ac)	12.5 or 13.8 kV
+ output, (V dc) (kA)	15 25.2
o Rectifier type	thyrister
o Bus bar current rating, A/mm2	1
o Maximum bus temperature, (C)	90
o Bus bar type	
+ trunk	multiple leaf, welded or multiple strand electrical cable
+ intercell	double triangle, Walker type
o Bus bar material	copper (100% IACS min.)
o Cell electrical bypassing	shorting switches
o Short detection	IR camera, Gaussmeter
o Bus circuit design	floating ground

BUILDING DESIGN:

o Floor protection	multi-layer vinyl ester and silica sand coating
o Steel protection	epoxy primer with vinyl top coat
o Building ventilation	induced draft
o Lighting, (lux)	
+ work areas	500
+ cell area	300

o Building will be an open portal structural steel frame structure.

3.1.2.2 Flowsheets

Refer to Figures listed below:

o Figure 3-2.	Well Field Flowsheet
o Figure 3-3.	Solvent Extraction Flowsheet
o Figure 3-4.	Electrowinning Flowsheet

3.1.2.3 Equipment and Material Specifications

- o Solvent Extraction Electrowinning Pumps
- o Mixer/Settlers
- o SX/EW Tanks
- o SX/EW Ponds
- o Electrowinning Components
- o Piping Materials - Pipes and Valves
- o Solvent Extraction/Electrowinning Safety Systems
- o Electrical Equipment
- o Electrowinning Transformer and Rectifier

SPECIFICATION FOR SX/EW PUMPS:

o SCOPE

This specification establishes the minimum requirements for the design, manufacture and supply of centrifugal pumps for a solvent extraction and electrowinning plant. The equipment shall be designed for installation outdoors, fully exposed to the weather; in continuous full load service, operating 24 hours per day, 365 days per year.

o CODES AND STANDARDS

Conformance with the following codes will be considered a minimum requirement:

ANSI	American National Standards Institute
ASTM	American Society for Testing and Materials
HI	Hydraulic Institute
NEMA	National Electrical Manufactures Association

o EQUIPMENT DESCRIPTION

Horizontal and Vertical Centrifugal Pumps:

Pumps shall be complete with motor, common base plate for motor and pump, coupling, and guards covering all exposed, rotating parts.

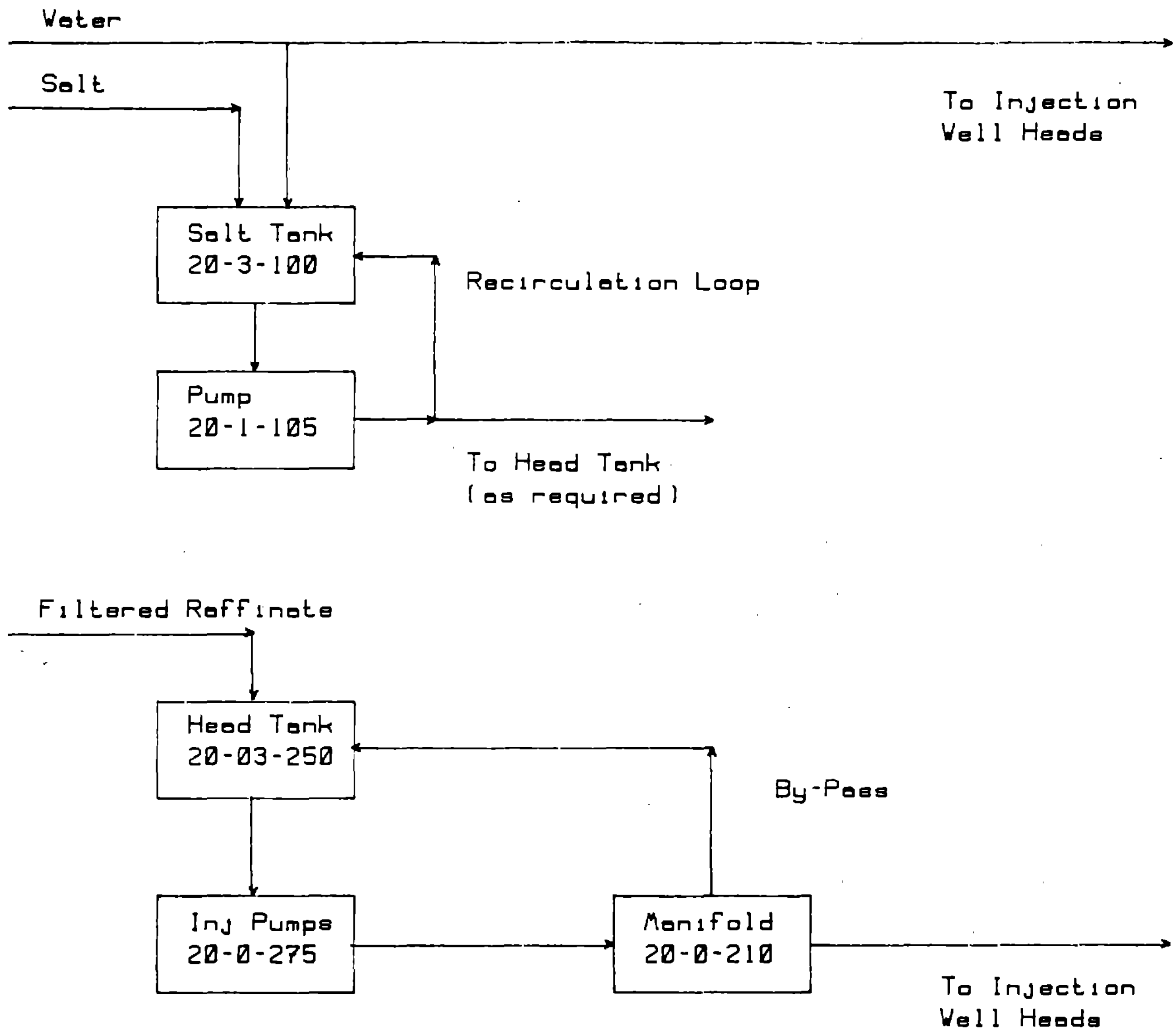


FIGURE 3-2 . WELL FIELD FLOWSHEET

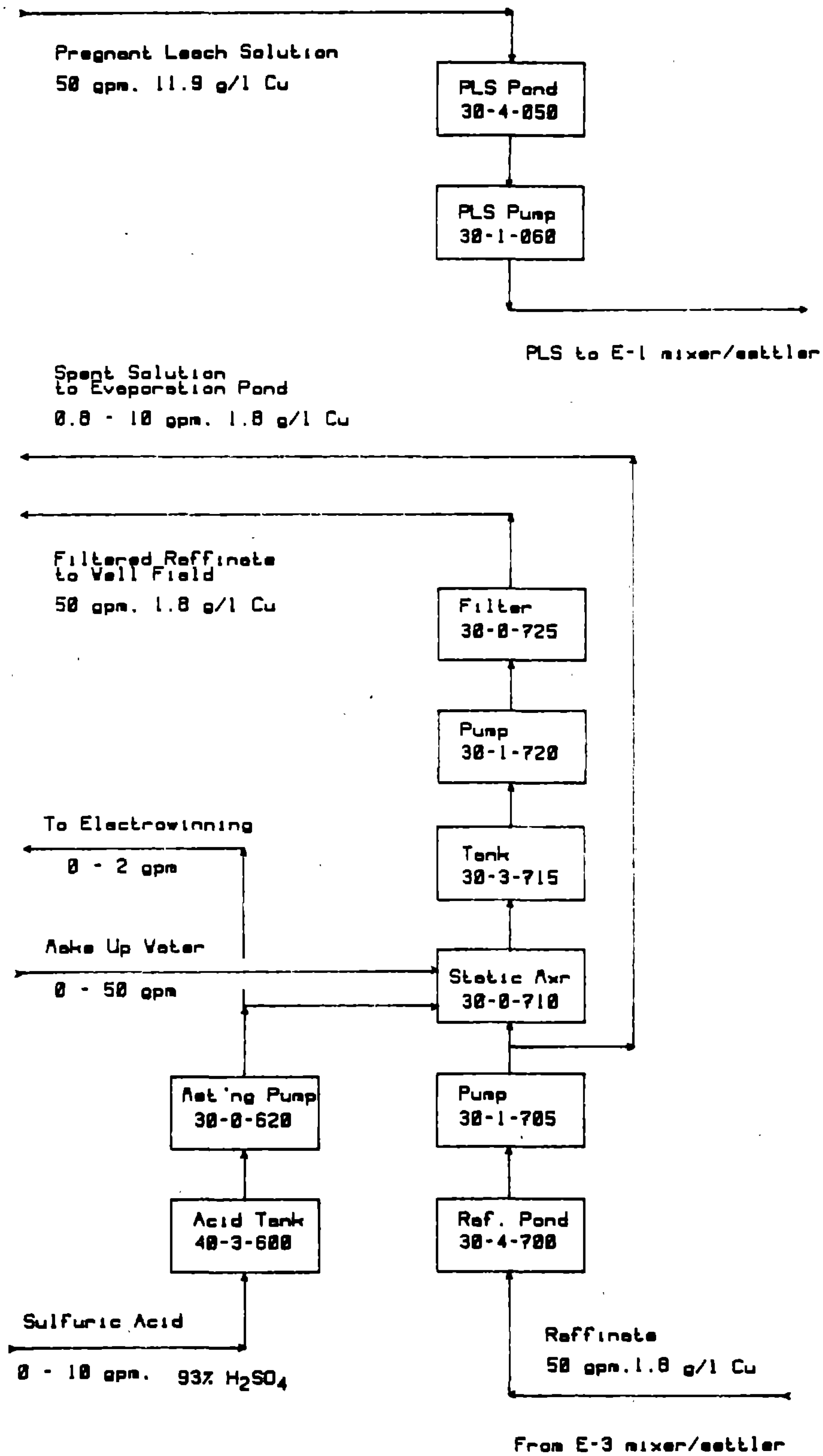


FIGURE 3-3. SOLVENT EXTRACTION FLOWSHEET

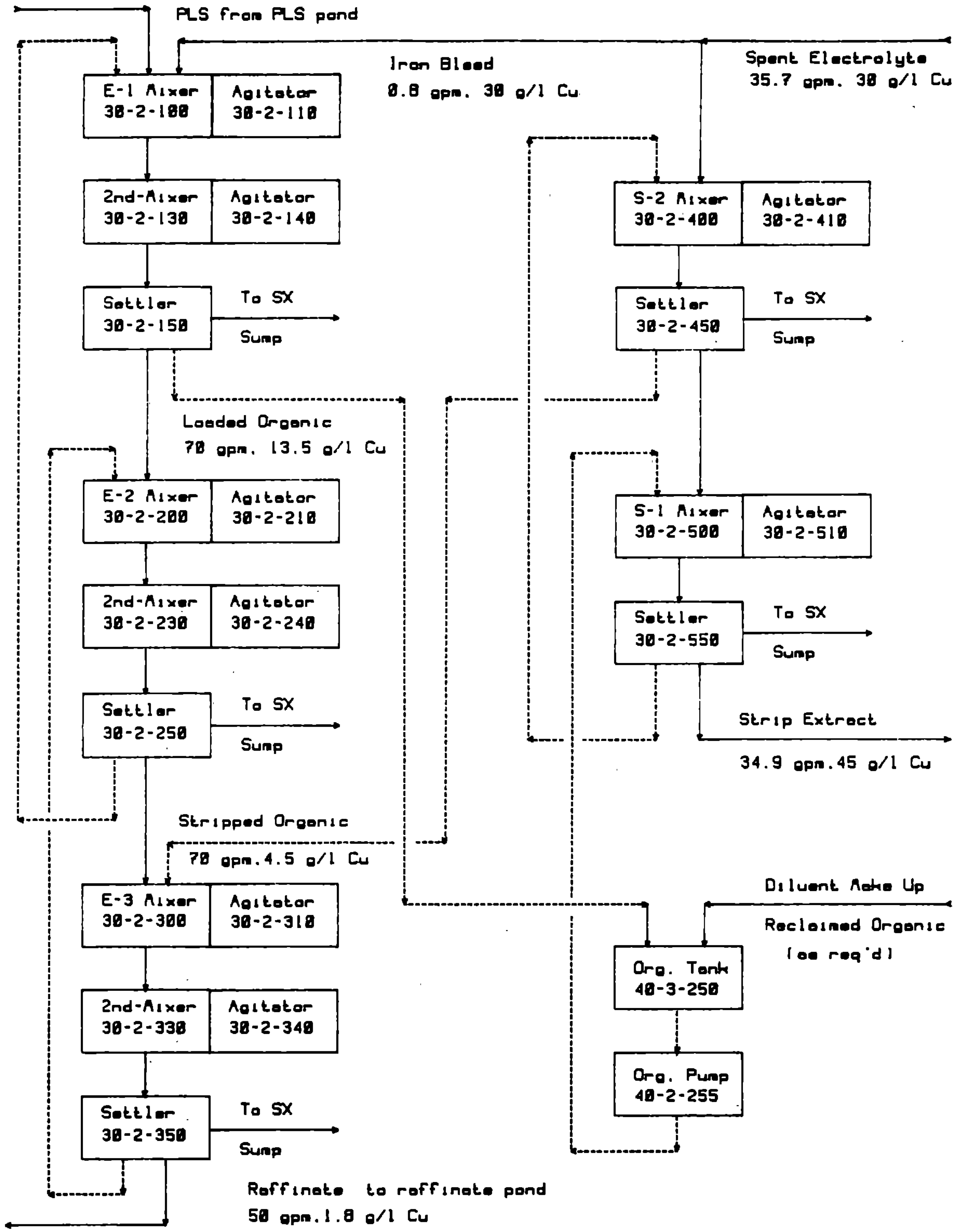


FIGURE 3-3. SOLVENT EXTRACTION FLOWSHEET
(CONTINUED)

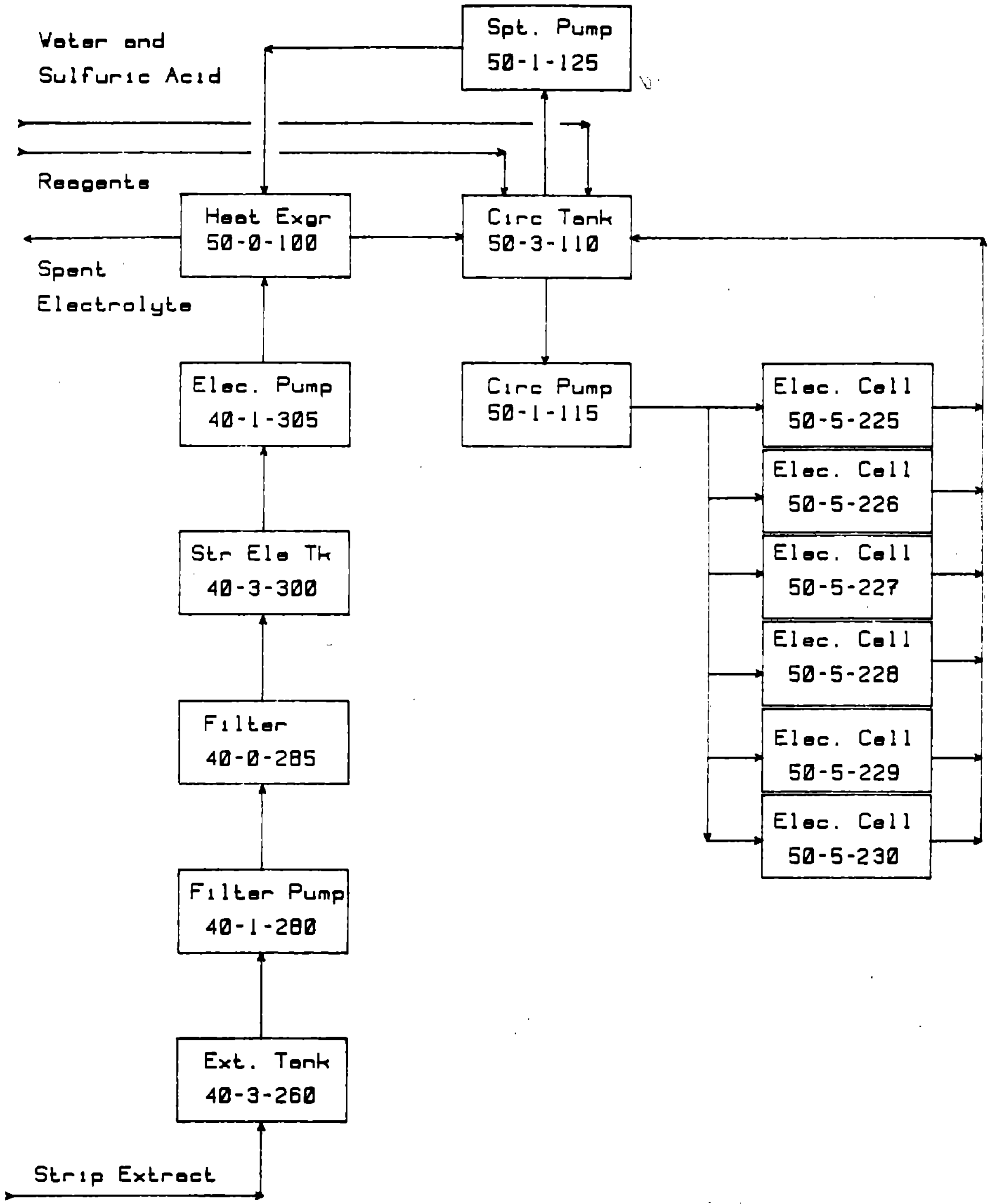


FIGURE 3-4. ELECTROWINNING FLOWSHEET - ELECTROLYTE CIRCUIT

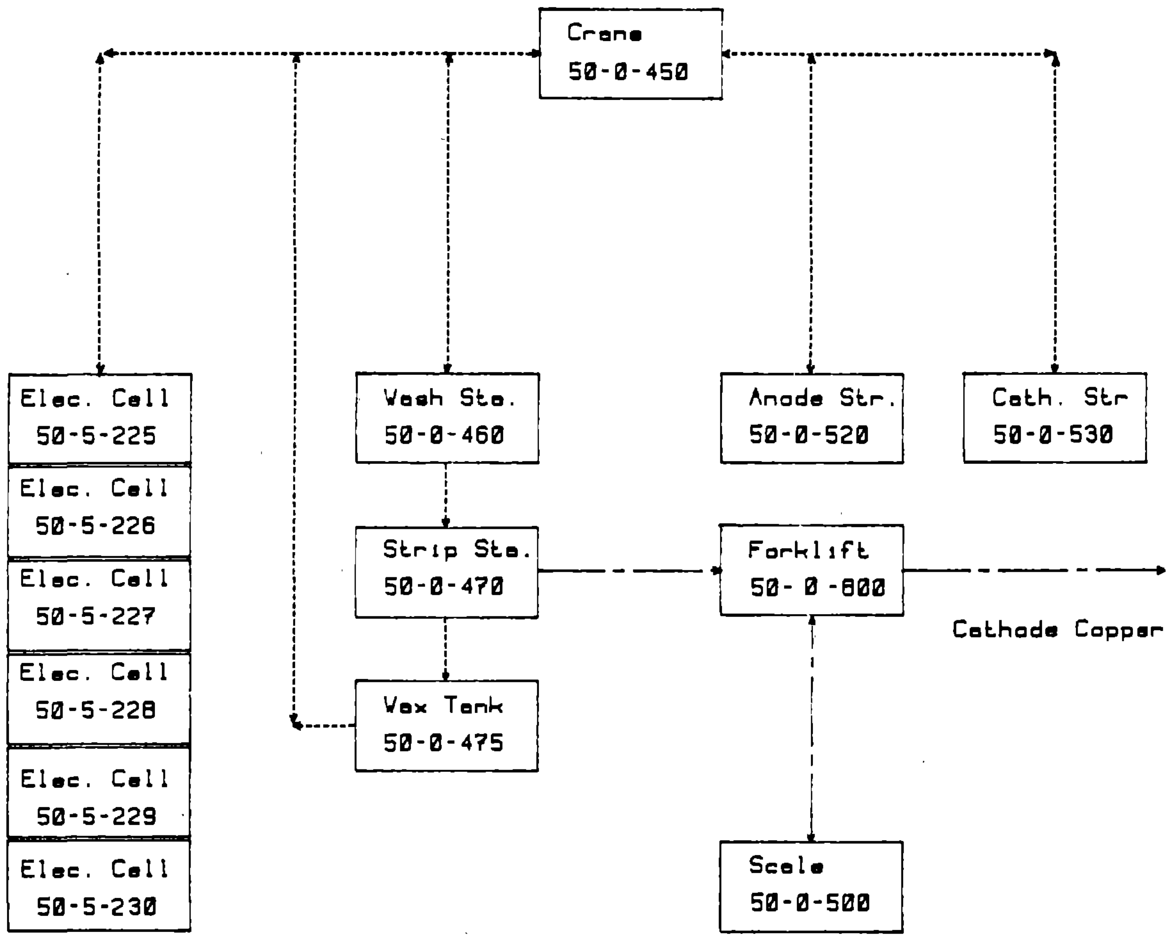


FIGURE 3-4. ELECTROWINNING FLOWSHEET (CONTINUED)
MATERIAL HANDLING

Centrifugal pumps shall be designed to ANSI standards. All pumps shall be direct drive with standard TEFC motors, double mechanical seals with water flush. Mechanical seals shall be replaceable. All wetted parts shall be CPVC.

Pumps to be furnished with performance curves noting capacity efficiency NPSH, impeller diameter and power requirement.

Vertical pumps shall include an extended suction pipe.

Individual equipment description are stated in the equipment list.

SPECIFICATION FOR MIXER/SETTLER:

- SCOPE

This specification establishes the minimum requirements for the design and installation of mixer/settlers for a solvent extraction plant. The equipment shall be designed for installation outdoors, fully exposed to the weather; in continuous full load service, operating 24 hours per day, 365 days per year.

- EQUIPMENT DESCRIPTION

Mixer/settlers shall be complete with:

Primary Mixer	Fiberglas tank with aqueous and organic bottom/side inlets, top side discharge flanged for connection to settler inlet weir or secondary mixer. A separate agitator bridge designed to allow various mixer boxes to be inserted to change retention time. Mixer to have provisions for full solution recycle from the discharge weirs in the settler.
Secondary Mixer	Fiberglas tank, similar to primary with single bottom/side inlet
Primary Agitator	Complete with explosion proof motor, gear box, mechanical variable speed drive, shaft and impeller, All wetted parts rated for corrosive service. Impeller to be a pump-mixer design.
Secondary Agitator	Similar design to the primary agitator with an axial flow, hydrofoil turbine agitator, with graduated pitch angle and cord.
Settler	Concrete basin lined with high density polyethylene (HDPE) complete with inlet distribution launder, picket fence, aqueous and organic discharge weirs. Each settler to be

covered with a translucent self supporting fiberglas cover with ventilation louvers. Adjustable dams within the settlers to change the settler area to maintain a constant unit settling area as solution flow rates change.

SPECIFICATION FOR SX/EW TANKS:

o SCOPE

This specification establishes the minimum requirements for the design, manufacture and supply of tanks for a solvent extraction and electrowinning plant. The equipment shall be designed for installation outdoors, fully exposed to the weather; in continuous full load service, operating 24 hours per day, 365 days per year.

o EQUIPMENT DESCRIPTION

Fiberglas Tanks

Tanks shall be constructed of fiberglas and shall meet the requirements of ASTM D-3299 for filament wound tanks and ASTM 4097. Fire retardancy is defined in ASTM E-84. Tanks shall be constructed with an inner corrosion barrier and a structural wall with a fire retadency raring of Class 1 per ASTM E-84.

Tanks shall be provided with lifting lugs and tie-down lugs.

Resin for corrosion barrier shall be:

Atlac 4010

Hetron 197-3

Derakane 510-A40

Resin for outer, structural wall shall be:

Atlac 711-050A, with 3.7 Nyacol APE-1540

Hetron 197 AT, with 3.75% Nyacol APE-1540

Derakane XP71730, with 7.5% Nyacol APE-1540

Steel Tanks

Steel tanks shall be of welded or bolted steel construction designed in accordance with :

American Petroleum Institute Standard 650
American Water Works Association Standard
ASTM A-182, A-312, A-53, A-181, A-240, and A-283 C

SPECIFICATION FOR SX/EW PONDS:

o SCOPE

This specification establishes the minimum requirements for the design and supply of material for ponds for a solvent extraction and electrowinning plant. The equipment shall be designed for installation outdoors, fully exposed to the weather; in continuous full load service, operating 24 hours per day, 365 days per year.

o EQUIPMENT DESCRIPTION

+ Ponds

Ponds shall be double, high density polyethlene lined earthern structures with dry well. Ponds shall be constructed above grade with berms. A layer of HDPE flownet shall be placed between the linings to allow flow of seepage between the linings. The pond bottom shall be sloped toward one corner to channel seepage to the dry well for detection.

Description	Size
Pregnant Leach Storage	50 ft x 50 ft x 6 ft
Raffinate	50 ft x 50 ft x 6 ft
Evaporation	100 ft x 100 ft x 6 ft

Top layer of lining material shall be high density polyethylene (HDPE) with a resin formulation equivalent to the following:

Phillips Drisco 8600

Marlex M 8000

Vestolen A 3512

All joining of pieces shall be by full fusion/ extrusion welding with 100% test of seams.

+ Flownet — Gundle or equal

+ Bottom layer — PVC geotextitle grade material can be substituted for HDPE

SPECIFICATION FOR ELECTROWINNING CELLS AND COMPONENTS

o SCOPE

This specification establishes the minimum requirements for the design, manufacture and supply of electrowinning cells and components for a electrowinning plant. The equipment shall be designed for installation indoors, in continuous full load service, operating 24 hours per day, 365 days per year.

- EQUIPMENT DESCRIPTION

Cells	Six (6) concrete boxes, 19-ft. 6-in. x 3-ft. 8-in. x 4-ft. 8-in., with 4-in. walls. Provisions for over flow box and drain holes for leak detection. Concrete to have a smooth finish and radiused corners.
Cell Liners	Seven (7) one piece seamless plasticized PVC lining with integral inlet box, adjustable overflow weir and cell discharge box, side and bottom buffer sheets.
Capboards	800 units, insulating and spacing modules. Injected molded, interlocking every second space and laterally spacing the electrode suspension bars on 4-inch centers. Modules rest on top or the intercell bus bars. Material, fiber filled polycarbonate, Lexan or equal.
Anode Guides	1500 units, PVC "hairpin" type insulators, two per anode. Units clip over the anode suspension bar and extend down each face of the anode blade. Tops of the insulators formed to guide cathodes and maintain cathode alingment.
Intercell Bus	Seven (7), Walker double triangle design. Extruded from 100 ETP copper, Rockwell hardness: B38-57. Buses to have provisions for attaching multiple high amphere cables.
Apron Bus	Two (2), Vertical wrap over copper busbar with matching triangle contact bar. Both to be fabricated from 100ETP copper, Rockwell hardness: B 38-57. Buses to have provisions for attaching multiple high amphere cables from the main bus.
Anodes	400 anodes with rectangular solid blade, copper "steerhorn type" suspension bar. Anode to be hot rolled from a calcium, tin, aluminum alloy with proven electrowinning service.
Cathodes	400 cathodes with rectangular solid stainless blade, welded suspension bar. Blade to have a 2B mill finish and accommodate edge strips. Design to be ISA type or equal.

<u>SPECIFICATION FOR SX/EW PIPES AND VALVES:</u>

- POTABLE WATER, INSTRUMENT AIR

Primary rating	125 class ANSI B16.1
Maximum temperature	250°F @ 150 psi
Corrosion allowance	none

Pipe and fittings

Pipe	seamless carbon steel per ASTM A53 Gr B
- 2"	Sch 40 grooved ends
3 - 6"	Sch 40 beveled ends

o FIRE PROTECTTON (ABOVE GROUND)

Primary rating	125 class ANSI B16.1
Maximum temperature	150°F
Corrosion allowance	0.0625

Pipe and fittings

Pipe	seamless carbon steel per ASTM A53 Gr B
- 2"	Sch 80 threaded & coupled
3 - 6"	Sch 40 beveled ends

o LEACH SOLUTIONS, ORGANIC

Primary rating	150 class ANSI B16.1
Maximum temperature	140°F @ 50 psi
Corrosion allowance	none

Pipe and fittings

Pipe	HDPE, high density polyethylene, PE 3408, type III, category 5, class C, grade P34. Cell classification PE 355434 C per ASTM D-3350, ASTM D-1248
- 2"	SDR 9.33 plain end

o ELECTROLYTE

Primary rating	150 class ANST B16.1
Maximum temperature	140°F @ 50 psi
Corrosion allowance	none

Pipe and fittings (exterior use)

Pipe	HDPE SDR 9.33 plain end

Pipe and fittings (interior use)

Pipe	Chlorinated polyvinyl chloride, CPVC, per ASTM D 1784, type 4, grade 1. Cell classification 23477-BK and ASTM F441

- SULFURIC ACID

Primary rating	150 class ANSI B16.1
Maximum temperature	200 psi @ 100°F
Corrosion allowance	0.0125

Pipe and fittings

Pipe	seamless carbon steel per ASTM A53 Gr B
- 2"	Sch 80 plain ends, socket welded fittings per ASTM A105 Gr B

- SANITARY SEWER

Pipe and fittings (exterior use)

Pipe	Polyvinyl chloride, PVC, plastic sewer pipe per ASTM D3034 for SDR 35, bell and spigot ends with rubber rings.

<u>SPECIFICATION FOR SX/EW SAFETY SYSTEMS:</u>

The following systems are considered for the solvent extraction and electrowinning areas :

Fire Protection

Dry pipe, closed head system with AFFF foam injection. Water source from a dedicated volume in the plant/fire water tank.

System includes:

Automatic AFFF foam system for mixer settlers, SX sump, and tanks containing organic solutions and/or mixtures. System includes AFFF concentrate diaphram tank, detection system, and control panel.

Manually operated monitors and fire hydrants, connected to AFFF system in SX area.

Fire water hoses in tank house area.

Portable, 10 liter, AFFF extinguishers in SX-area.

Portable dry chemical extinguishers and hose reels in Electrowinning building.

Potable Halon extinguishers for control and electrical rooms.

Diesel motor driven firewater pump with cast iron pump housing, separate jockey pump with direct drive electric motor, dual battery ignition system with automatic charger, local fuel tank with 8 hour capacity, local control panel, full UL rating on all components. Pump capacity: 250 gpm at 185 ft TDH

Electrical — All electrical equipment in the solvent extraction area shall conform with Class I, Division I and Class I, Division II, per National Fire Protection Association's publication 30, chapter VIII and Article 500 of the National Electrical Code (1984).

Electrowinning electrical circuit design includes a floating ground to prevent accidental shorting to ground.

SPECIFICATION FOR ELECTROWINNING TRANSFORMER AND RECTIFIER:

- SCOPE

  This specification establishes the minimum requirements for the design, manufacturing and testing of the transformer/rectifier.

- CODES AND STANDARDS

  The equipment shall be designed, assembled and tested in accordance with the applicable standards of ANST, IEEE, NEMA and NEC, including the following standards and codes:

  + National Electrical Manufacturer's Association Electrochemical Processing Semiconductor Rectifier Equipment, Pub. No. RI-6-1959 and revisions.

  + National Electrical Manufacturer's Association Pub. PV-3 Safety Code for Semiconductor Power Converters.

  + ANSI C34.2-1968 Practices and Requirements for Semiconductor Power Rectifiers.

- EQUIPMENT DESCRIPTION

  + General

    Each of the transformer/rectifiers will receive A-C power supply from a 13.8, 3 phase, 60 Hz. resistance grounded system.

    The output of rectifier units shall be as follows:

Maximum D-C current	25.2 kA
Maximum voltage	15 Vdc

  + Transformer - General

    Rectifier/transformers will be outdoor type, OA, (oil over air), and arranged for close coupling to the rectifier. Rectifier transformer will carry its rated maximum load continuously without exceeding 55°C temperature rise above 40°C ambient.

The transformer primary connection will be made with 15 kV, 500 MCM shielded cables. Secondaries shall be shielded bus of either aluminum or copper. Output bus shall be suitable for connection to copper bars which are used for feeding the electrowinning cell circuits.

Provision will be made for insulating the rectifier transformer and the attached rectifier components from ground and from other structures. Grounding will be accomplished by a single grounding cable with current sensing transformers within the rectifier compartment, arranged to sense flow of either A-C or D-C case ground current.

+ Rectifier

The rectification shall be by means of parallel thyristor groups. Each group shall be impedance matched and contain circuitry for balanced load sharing.

The rectifier shall be rated to carry maximum current continuously with one thyristor per leg out of service. Peak reverse voltage (PRV) shall be coordinated with the system design and with adequate margin.

Surge protection systems shall be provided to prevent thyristor damage due to voltage transients and excessive voltage rate-of-rise.

Each thyristor shall be protected by a fuse which shall give indication of failure at the annunciator and at the thyristor failure monitor. Fuses in an unfaulted leg must be capable of riding through a fault without melting or degradation.

+ D-C Control Range

The range of control shall be from essentially zero to 100% rated current and voltage.

+ Control Panel

Panel shall be free standing, NEMA type 1A semi dust tight enclosure, with gasketed rear doors. All wires shall terminate on medium duty type terminal blocks and marked with the same wiring numbers used on the drawing.

Panel shall include but not necessarily be limited to the following:

- D-C rectifier output current
- H.V. A-C current
- D-C rectifier output voltage

- H.V. A-C voltage
- Power factor
- A-C watts
- D-C watts
- D-C kWh
- Integrating D-C ammetter

SPECIFICATION FOR ELECTRICAL EQUIPMENT:

o SCOPE

This specification establishes the requirements and standards for the design of all electrical facilities and control system.

o CODES AND REGULATIONS

Conformance with the following codes will be considered a minimum requirement. In the event of different requirements between codes and/or rules, the most stringent code or rule shall apply:

+ National Electrical Code (NEC)
+ National Electrical Manufacturer's Assoc. (NEMA)
+ Underwriter's Laboratory (UL)
+ National Board of Fire Underwriters (NBFU)
+ National Electrical Safety Code (NESC)
+ Institute of Electrical and Electronic Engineers (IEEE)
+ American Society for Testing Materials (ASTM)
+ American National Standards Institute (ANSI)
+ Insulated Cable Engineers Assoc. (ICEA)
+ Illuminating Engineering Society (TES)
+ Instrument Society of America (ISA)
+ Arizona State and Local Codes
+ Occupational Safety and Health Administration (OSHA)
+ Factory Mutual Engineering Assoc. (FMEA)

o VOLTAGE LEVELS

Primary Distribution: 12.5 or 13.8 kV, 3-phase, 60 Hz, solidly grounded wye from the Arizona Public Service.

Secondary Distribution: 480 volts, 3-phase, 60 Hz, solidly grounded wye.

o Motor Control

120 volts, single phase, 60 Hz, for circuit runs under 400 feet.

o Lighting

120 V, 60 Hz, for high pressure sodium, incandescent and fluorescent local lighting.

- Variable Speed

  480 volts, 3-phase, 60 Hz, input to variable frequency speed controllers.

- POWER TRANSFORMERS

  Power distribution transformer will be two winding, 3-phase, 60 Hz.

  12.5 kV - 480 V transformers will have a delta primary and a solidly grounded wye secondary.

  The transformer design shall be suitable for connection to the specified system and distribution voltages. Provision shall be made for addition of cooling fans for outdoor installations.

  Oil cooling shall be specified for large outdoor transformers with ratings of 500 kVA and above. Transformers shall be sealed tank type with pressure relief protection and high temperature alarm contacts. The transformer neutral connections shall be fully insulated up to the point of grounding.

  Every transformer shall be provided with two 2-1/2 percent taps above and two 2 1/2 percent taps below rated primary voltage.

  The transformers shall have an integrally mounted, two position, manually operated, air-insulated, primary fused disconnect switch (including fuses). In order to prevent interruption of load current, each switch shall be keyinterlocked with the secondary main breaker.

- SECONDARY POWER DISTRIBUTION

  Except for certain isolated equipment, electrical switchgear and control hardware shall be installed in air conditioned rooms. The supply air shall be filtered and the room air pressure shall be maintained at plus 1/2 in. water column static pressure to hold dust entry to a minimum.

  The 480 volt switchgear shall be metal enclosed air-break type and shall include a main circuit breaker. All breakers shall be draw-out type with solid state overcurrent trip units incorporating integral ground fault protection.

  The main circuit breaker shall be key interlocked with the transformer primary disconnect switch.

- MOTOR CONTROL CENTERS

  All 460 volt motors shall be fed from motor control centers. Motor control centers shall be modular type consisting of vertical sections with modular, "plug-in" starter units.

  Thermal-magnetic type, molded case circuit breakers shall be provided for power feeders from the motor control center.

The starter units shall be combination "motor circuit protector/ starter" type with three phase, ambient compensated overload protection. Ground fault protection shall also be provided.

- ELECTRICAL CONTROLS

All motors shall have a local "Start-Stop" push button station provided with a lockable attachment for "Stop" position. This station shall be located within 25 feet of the motor and the motor shall be visible from the station. The control stations shall be mounted in heavy-duty, NEMA 4X, water and dust tight enclosures.

- WIRE AND CABLE

15 kV and 5 kV cables shall be 3 conductor, cross-linked polyethylene (90°C), 133% insulation level with aluminum sheath and PVC jacketed, sunlight resistant, suitable for cable tray or direct burial.

600 volt power cables shall be 3 conductor with ground wire, type XHHW with aluminum sheath and PVC jacketed, sunlight resistant, suitable for cable tray or direct burial, minimum size #12 AWG.

Control cable shall be multi-conductor stranded copper type, constructed similar to 600 V power cables but without ground wire.

- CABLE TRAYS AND CONDUITS

Cable trays shall be the ladder type, constructed of galvanized steel with adequate strength for the load. Power and control cables may be run in a common tray provided the cable insulation voltage rating is identical. Separate trays shall be provided for high voltage cables.

Conduit for power, control and lighting circuits, for corrosive atmosphere applications shall be rigid galvanized steel conduit with a 40 mil PVC coating. This requirement also includes threaded fittings.

- GROUNDING

Equipment such as transformers, switchgear, motor control centers, control panels, lighting panels, etc., shall be individually grounded directly to two main grid by bare copper conductors in a manner to provide a minimum of two paths to ground.

All 460 volt motors shall be grounded through a green insulated conductor in the motor feeder cable to the ground bus in the motor control center.

Cable trays shall be grounded to the main grid system through a copper conductor at the beginning and end of the tray run.

3.1.2.4 Facility Drawings

This section contains the following facility drawings:

3.1.3 Work Schedule and Costs

This section presents the schedule and cost to fully implement the surface facility for the field experiment. The schedule and capital cost estimate have been specifically prepared for the Casa Grade site.

3.1.3.1 Project Schedule

The implementation of the surface facility portion of the field experiment has been divided into three sections, pre-construction engineering, procurement and construction. A project schedule showing the relative durations of the principle activities is shown in Figure 3-12.

Pre-construction is divided into two activities, equipment selection and detail engineering. Detail engineering is engineering that requires knowledge of the specific equipment that will be used in the project.

Procurement is the time from the placement of the purchase order to the arrival of the equipment at the site. This activity includes expediting and traffic services. The schedule indicates that several equipment items have long lead delivery times. These items are:

EW Transformer and rectifier	12 months
Crane	9 months
Injection Pump	6 months
Anodes and cathodes	6 months

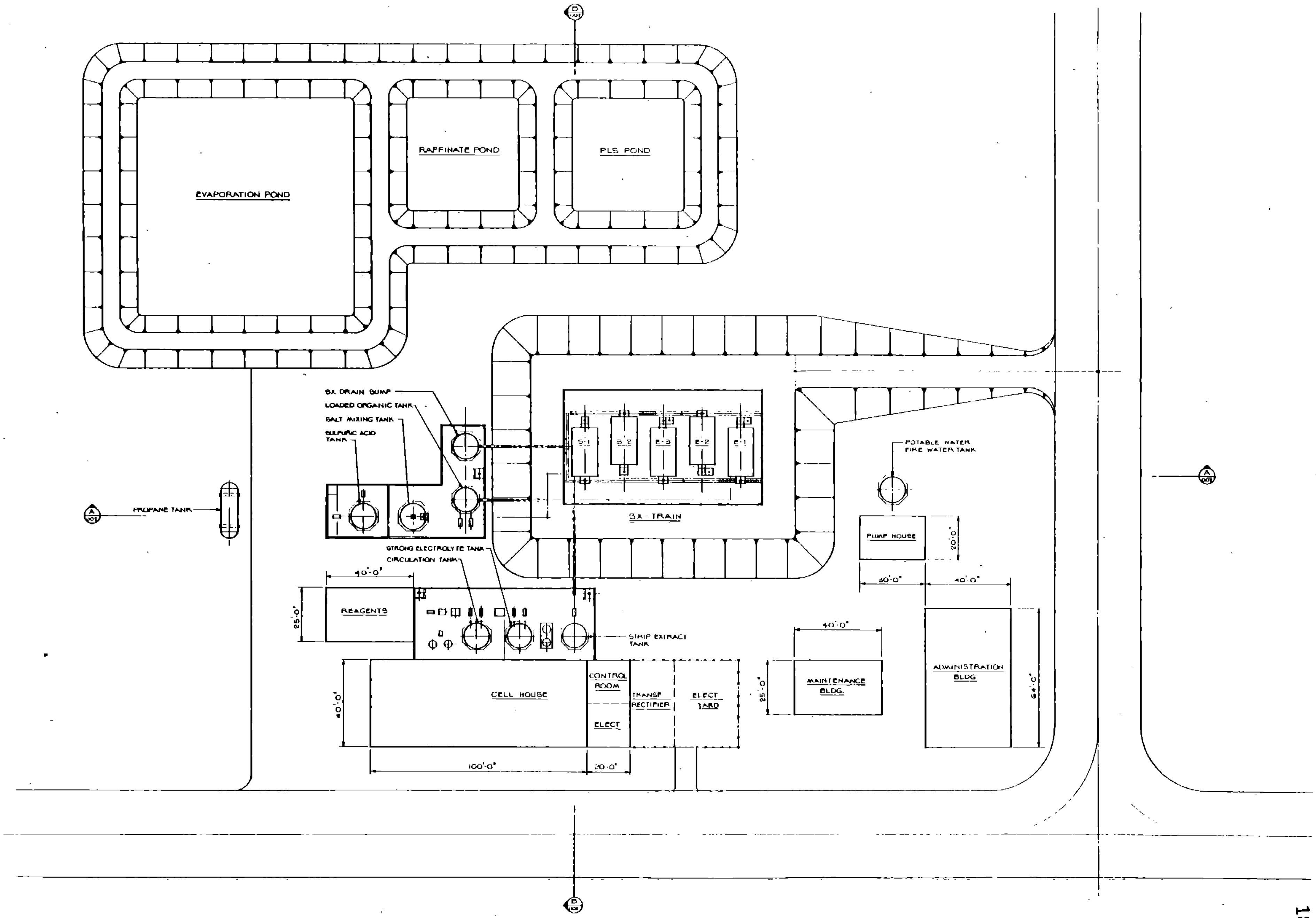


Figure 3-5 Plot Plan

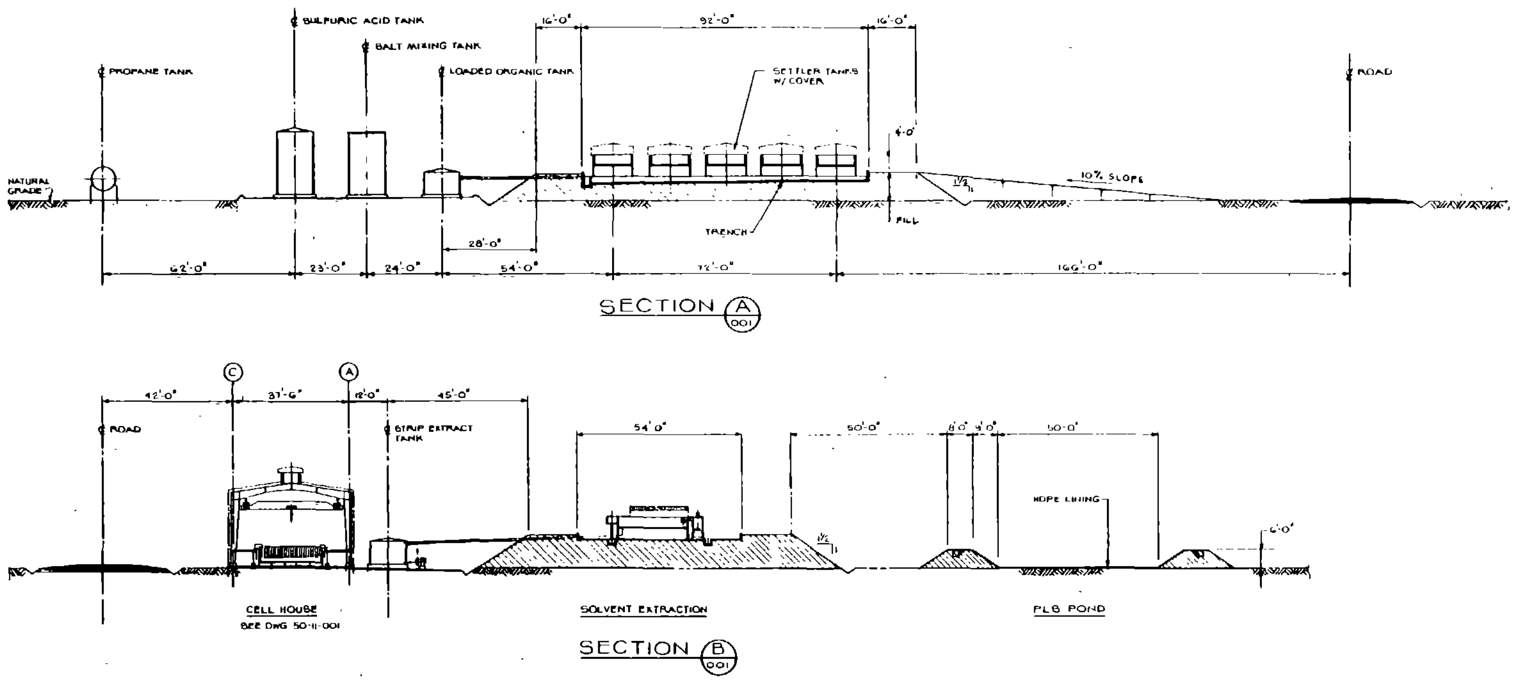


Figure 3-6 Plant Profile

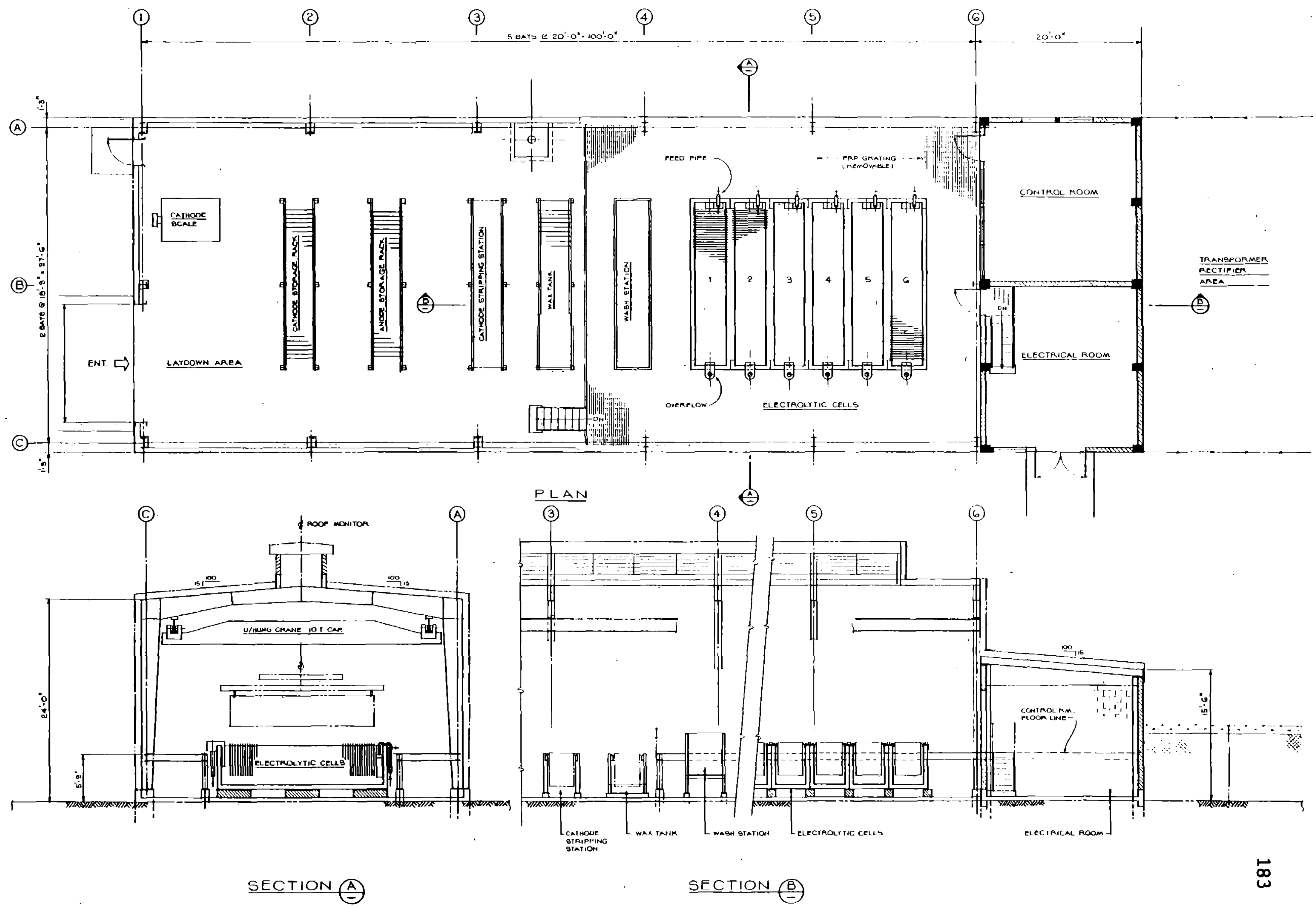


Figure 3-7 Electrowinning Building, Plan & Section

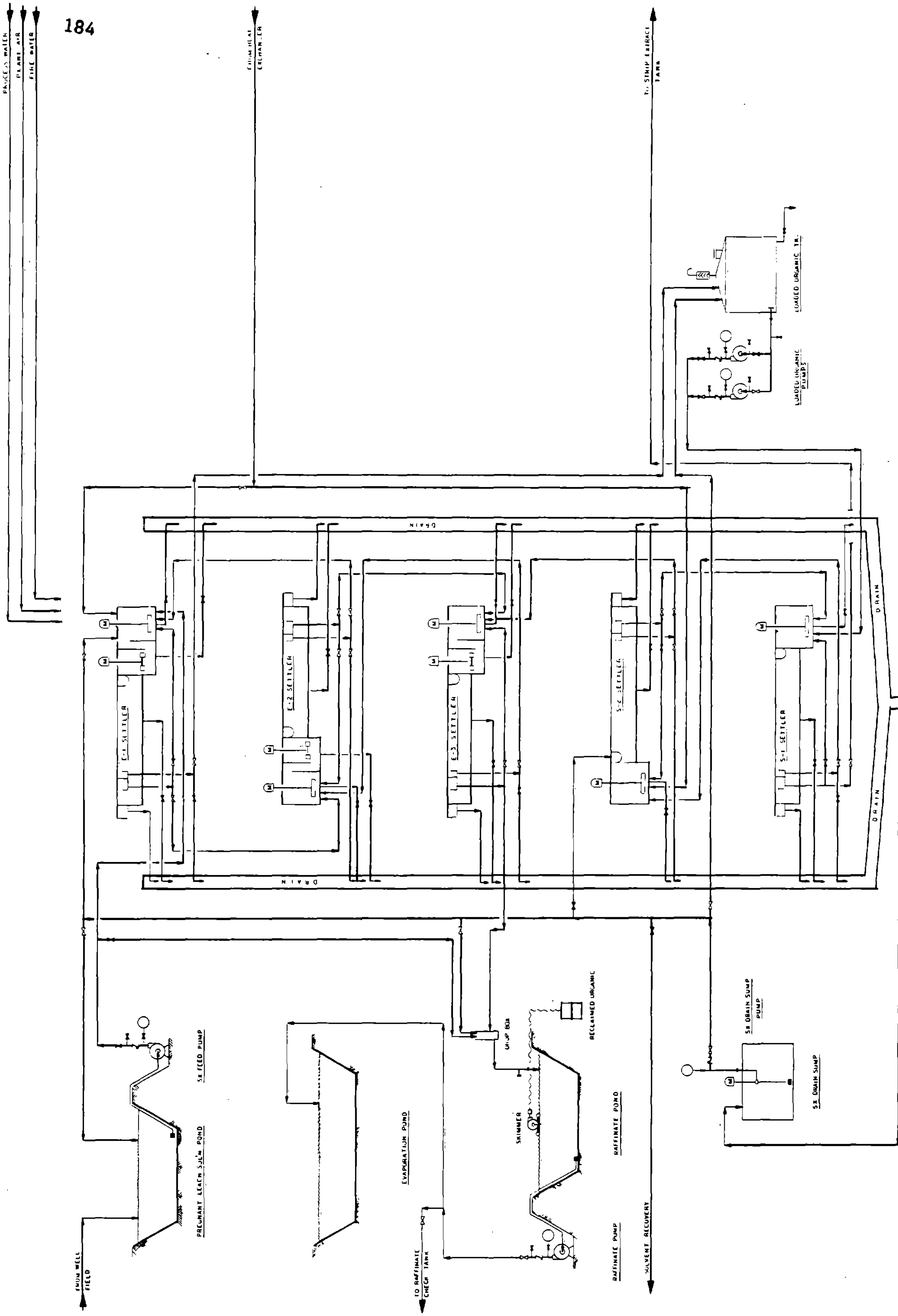


Figure 3-8 Solvent Extraction P & ID

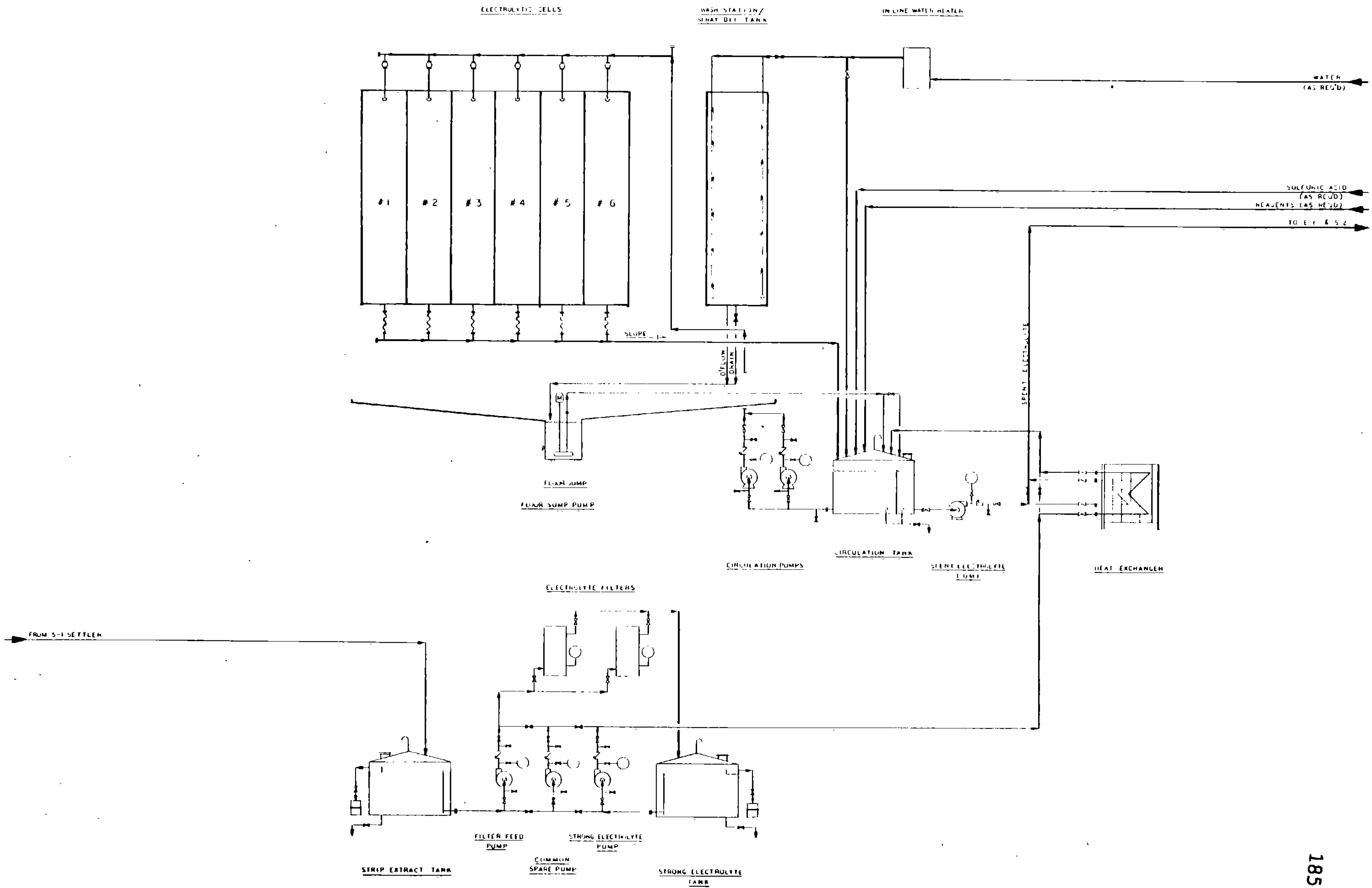


Figure 3-9 Electrowinning P & ID

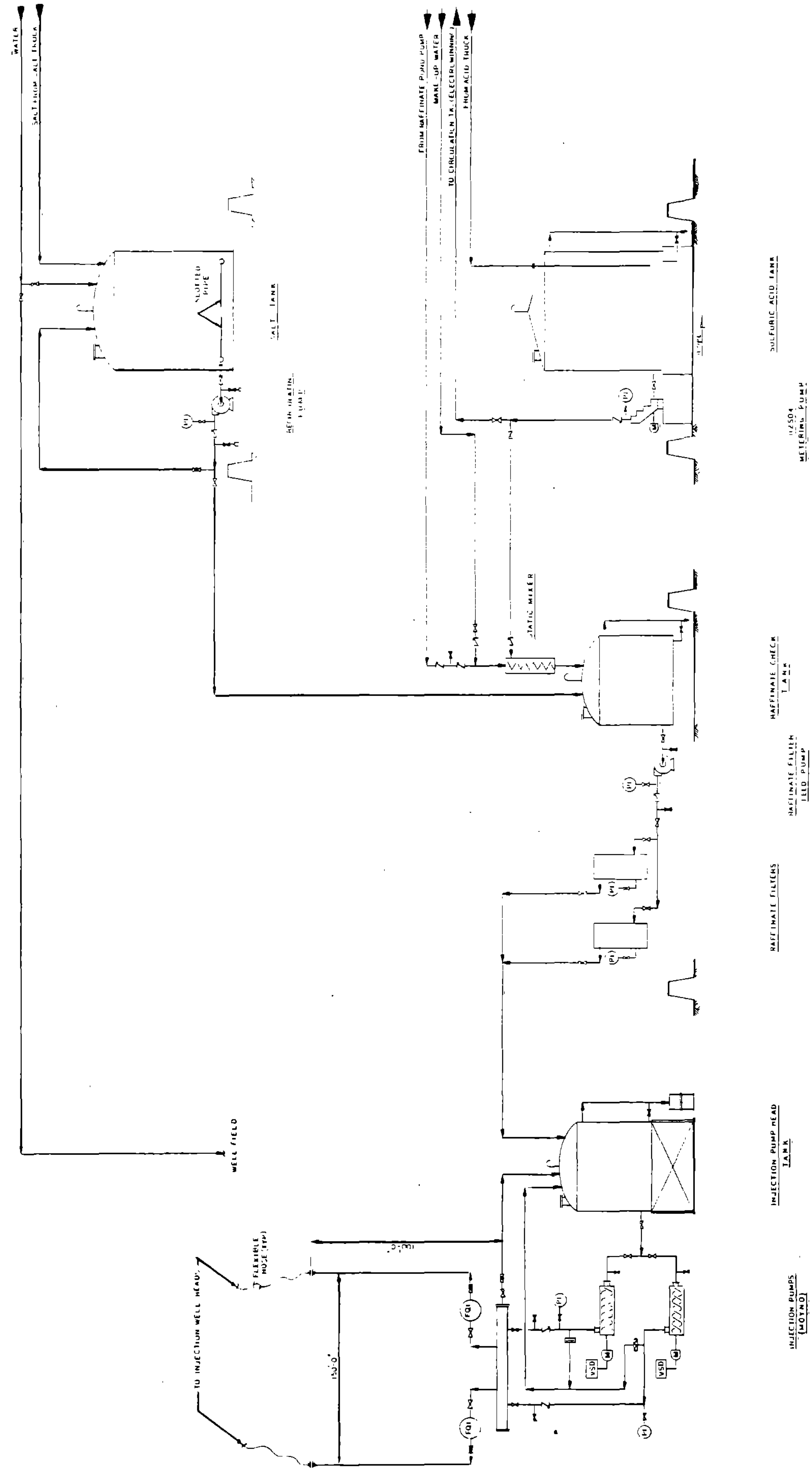


Figure 3-10 Well Field P & ID

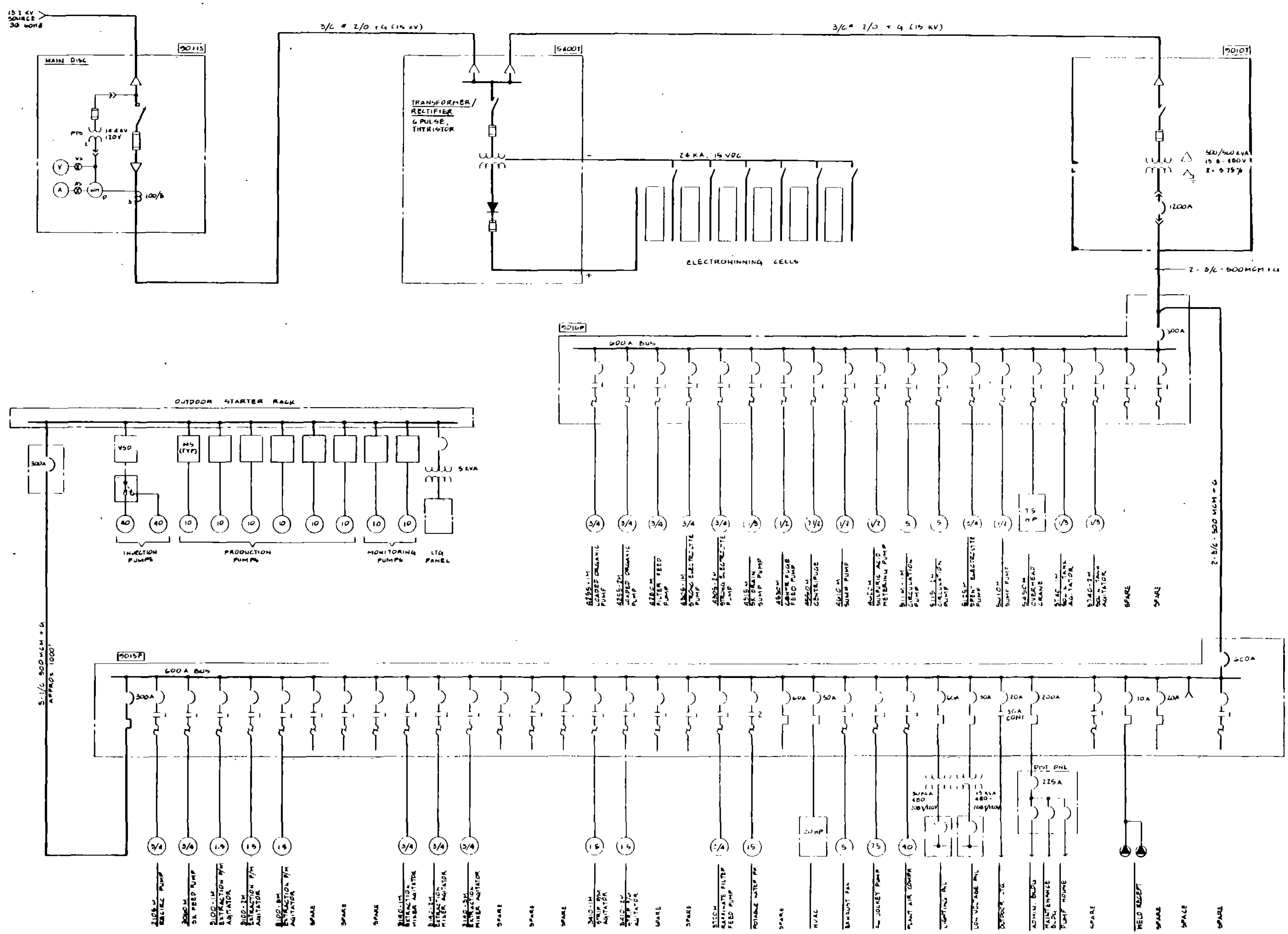


Figure 3-11 SX-EW Facilities Single Line Diagram

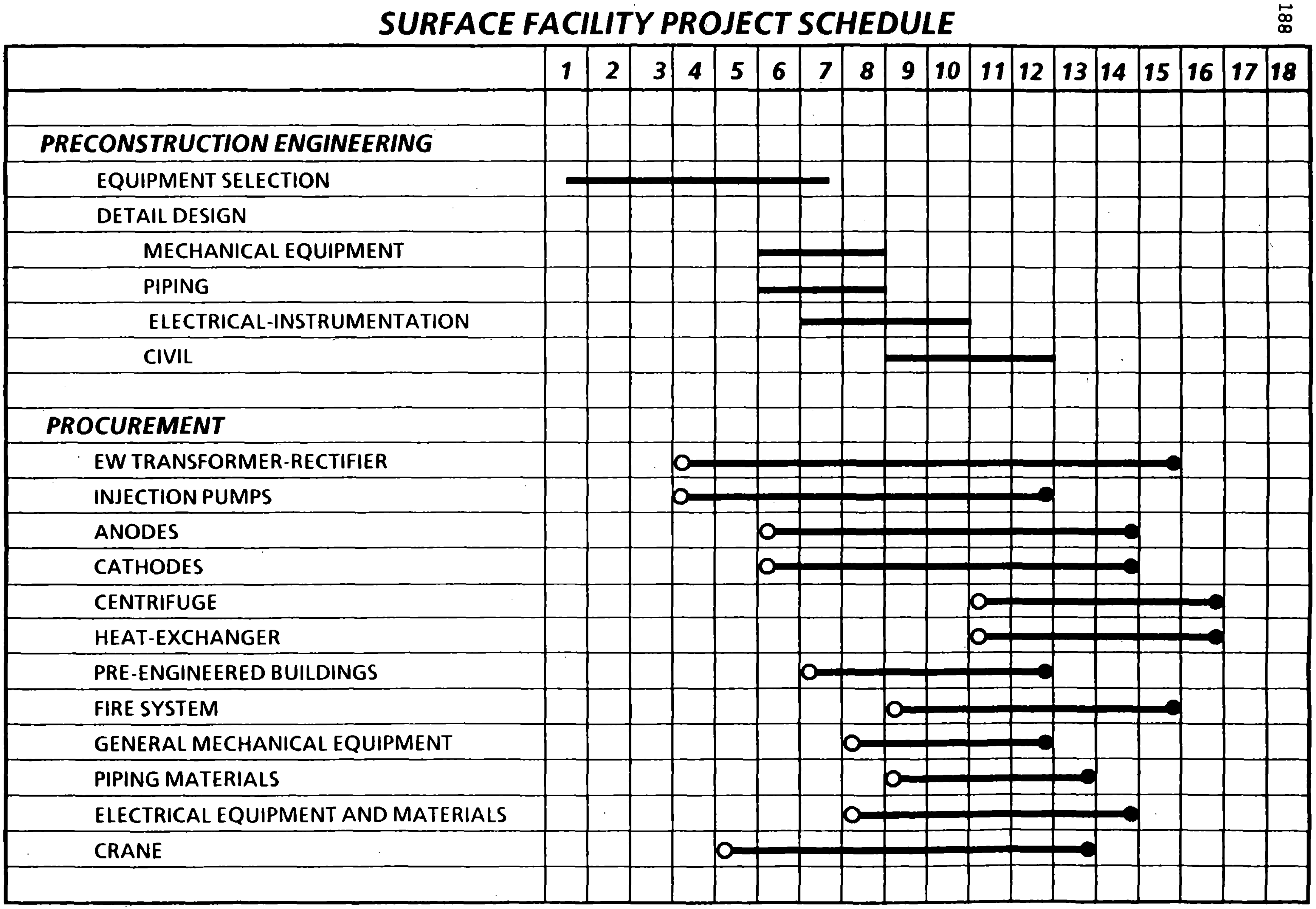


Figure 3-12. Project Schedule

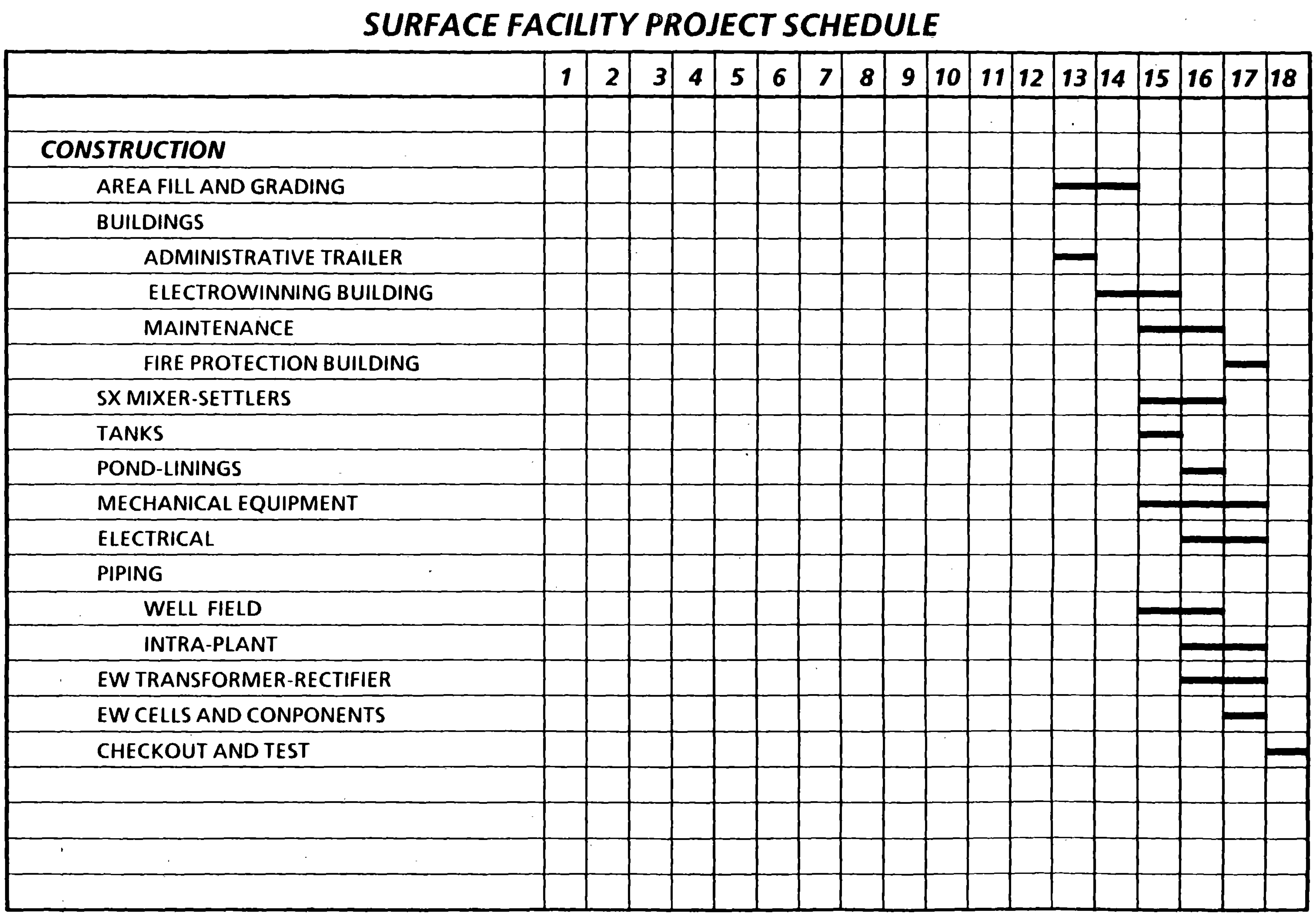


Figure 3-12. Project Schedule (continued)

Crane	9 months
Pre-engineered buildings	4 months
Centrifuge and heat exchanger	4 months
Fire protection system	4 months

Construction starts 12 months after the start of engineering. The critical path is controlled by the delivery o the transformer and rectifier. Construction activities are scheduled around this constraint.

3.1.3.2 Capital Cost Estimate

The capital cost estimate for the surface facility includes those costs to engineer, procure equipment and material, and construct a solvent extraction and electrowinning plant. Included with the cost are the ancillary facilities for maintenance, administration and the above surface equipment and materials for the well field. Costs are given in Table 3-2 for the installed

TABLE 3-2. CAPITAL COST ESTIMATE SUMMARY

($ X 1,000)

AREA & DESCRIPTION	EQUIPMENT	MATERIALS	LABOR	COMMON DISTRIB'S	TOTAL
20 WELL FIELD	155.2	132.9	96.2	59.0	443.3
30 SOLVENT EXTRACTION	86.4	153.4	160.2	62.0	462.0
40 TANK FARM	47.3	85.5	62.5	30.0	225.3
50 ELECTROWINNING	712.0	192.5	168.0	165.0	1,237.5
90 GENERAL	84.3	364.3	130.0	89.0	667.6
TOTAL	1,085.2	928.6	616.9	405.0	3,035.7

costs of those items that comprise the surface areas of the well field, solvent extraction, tank farm, electrowinning, and general facilities. General facilities are defined as items required to support other areas. The costs are summarized as follows:

- Equipment - Costs of those items listed in the equipment list. Costs of major equipment items were based on prices obtained from vendor's quotes and inhouse data. Prices include an allowance for freight to Casa Grande.

- Materials - Cost of materials for site, earthwork and concrete were based on quantities obtained from conceptual takeoffs from engineering drawings. Electrical, instrumentation and piping costs were factored based on Davy McKee's experience with solvent extraction and electrowinning plants. Pre-engineered building costs were based on in-house data. Unit material costs were based on a current project located in central Arizona.

- Labor - Labor rates and productivity factors were based on a current project. Rates used were inclusive of fringe benefits, subsistence, payroll taxes, and contractor's administrative exprience, overhead and profit. Rates are based on a 40 hour per work week during construction.

- Common Distributables - This cost includes a factored costs field construction management, field engineering and an allowance of 5% for variations in quantities, estimating errors and omissions. The allowance accounts for variations resulting from assumptions that are clarified as engineering progresses.

The capital cost estimate does not consider the following:

- Taxes except payroll taxes, sales tax, gross receipts tax, transportation tax are not included.
- Cost for initial charges and inventory.
- Land costs and right of ways.
- Permits, licenses, fees.
- All risk insurance.
- Cost for vendor representatives.
- Start-up.

The estimate is based on a two year plant life. The costs are mid 1987 costs and no escalation is included.

3.2 SURFACE FACILITY OPERATION

3.2.1 Description of Operations

3.2.1.1 Solvent Extraction

The feed solution of pregnant leach solution (PLS) is pumped from the well field pumps into the SX feed pond. The pond provides solution storage capacity and is sized with 24 hours of retention time at 50 gpm. Solids contained in the SX feed solution tend to settle to the bottom of the pond, from where they are periodically removed. Copper is extracted from the SX feed solution by counter current contacting with the organic extractant diluted with kerosene in the SX mixer-settlers.

The feed solution is pumped from the feed pond to the E-1 (first extraction stage) mixer-settler in which it is contacted with organic flowing from the second stage. Part of the copper is extracted, then the aqueous solution passes on to E-2, and then on to E-3, where it is contacted with freshly stripped organic to complete the recovery of copper. The barren aqueous solution (raffinate), flows by gravity from the third extraction stage to the raffinate pond for return to the well field. The organic is periodically removed from the surface of the pond using a floating skimmer which delivers it into drums. The contents of the drums are tested to determine whether the organic is suitable for re-use.

Organic loaded with copper flows by gravity from the first extraction stage into the loaded organic tank. It is then pumped to the first of two strip mixer-settlers where copper is stripped by contact with spent electrolyte returning from electrowinning. The stripped organic discharging from the stripping stage S-2 flows back to the third extraction stage E-3 to pick up more copper. A stream of electrolyte is continuously recycled from the discharge weirbox of the stripping settlers to the primary mixing box to maintain an organic/aqueous ratio of 1:1.

Copper enriched, strong electrolyte flows from the stripping stage S-1 to the strong electrolyte tank, from where it is pumped to the electrolyte filters for removal of entrained organic. The clarified strong electrolyte flows on to the strong electrolyte surge tank as feed for the electrowinning tankhouse.

Spent electrolyte from electrowinning is drawn from the electrolyte circulation tank and pumped to the stripping stage S-2. A small continuous bleed stream is diverted to the first extraction stage to limit the accumulation of impurities such as iron and chloride in the electrolyte.

Overflows and leakages in the SX area are collected in the SX sump. The sump overflow is designed to preferentially retain organic. Sump contents are normally returned to the circuit using the SX sump pump.

Reagent and diluent make-up is added to the loaded organic tank using the barrel pump.

PUMP MIXERS:

The whole performance of the solvent extraction plant depends on the correct operation of the pump-mixers. The units provide the head for interstage transfer of the organic and aqueous solutions as well as the mixing action in the mixing boxes. Both of these functions are favored by increasing the speed of the impellers. However, as the tip speed of the impellers increases, the increased shearing action will tend to increase the amount of entrainment in the solutions discharging from the settlers. This is particularly undesirable in the E-3 mixer-settler and the S-1 mixer-settler where any organic entrained in the aqueous phase leaves the system and must be recovered. In the other stages any aqueous leachate entrained in the organic phase contaminates the electrolyte feed to the tankhouse with impurities such as iron and so result in higher flows of tankhouse bleed.

The ratio of the organic solution flow (volumetric) to the aqueous solution flow to any mixer settler is known as the O/A ratio. For the two phases at the mixing box it is the Mix O/A and overall for the mixer settler the Advance O/A. The O/A ratio affects the mixing efficiency and entrainment losses. For copper extraction plants employing currently used reagents in mixer settlers, the optimum Mix O/A ratio has been found to be close to 1/1.

Operation should normally be maintained as close to 1/1 as possible but within the range 1.5/1 to 1/1.5 to achieve stable phase continuity conditions in the mixing boxes. In all mixer settlers the desired O/A ratio is obtained by recycling aqueous from the aqueous weirbox back to the mixing box. In the extraction stages this is not normally necessary when the plant is operating close to design.

If any changes are made to the main plant flow streams, simultaneous adjustments must be made to the recycle rates to maintain correct operating conditions. Non-optimal recycle flows cause lower extraction and stripping efficiencies and produce increased entrainment. Changes in any of the plant flow rates without compensating changes in recycle flows to maintain the correct O/A ratio can cause undesirable "flip overs" of the phase continuities in the mixing boxes.

Extraction Circuit:

The extraction circuit is designed to operate at a 1.0 - 1.4:1 ratio, which is achieved by making the organic flow rate the same as the leach solution feed rate. However, in practice, it may be necessary to operate with a slight excess of organic in order to maintain stable organic continuous conditions in the second extraction stage mixing box. To accommodate this, two methods are available for adjusting the extraction mixing O/A ratio. The most direct is to use the aqueous recycles to vary the amount of aqueous entering the mixer.

An aqueous recycle line is provided for the extraction stages. This is not normally used and is intended only for occasional use for achieving aqueous continuous conditions in the mixing box or for condition of varying feed flow.

Stripping Circuit:

Experience in the industry has shown that it is more difficult to maintain stable organic continuous conditions (required in the first stripping stage) in the stripping circuit than in the extraction circuit, especially at low temperature. The recommended aqueous recycle flows be set for O/A ratio of 1.5-2 : 1.

ELECTROLYTE FILTRATION:

Copper enriched, strong electrolyte gravity flows from the stripping stage S-1 to the strong electrolyte tank, from where it is pumped to the electrolyte filters for removal of entrained organic. The clarified strong electrolyte flows on to the strong electrolyte tank as feed for the electrowinning tankhouse.

Pressure, cartridge typefilters are used for the removal of solids and organic entrainment that may be present in the SX plant solutions. The filter cartridges are replaced with the filter experiences high back-pressure.

TEMPERATURE:

Heat is generated from:

- Heat of reaction during leaching
- Contact with subsurface rock at elevated temperatures
- Heat generated during electrowinning.

In addition, hot water from the cathode wash system is added to the electrolyte circuits.

During winter operation it is most important that the temperature of the solutions in the mixer-settlers is checked frequently. The rate of phase disengagement is extremely sensitive to change in temperature. A drop of 1 or 2 degrees C. will significantly slow down the phase disengagement and could bring the plant close to the flooding point. Local temperature indicators enable the operator to keep a close watch on the leachate and returned spent electrolyte temperatures.

If operating conditions in the leaching or electrowinning sections result in the temperature falling close to the 12 degrees C. design minimum, a close watch should be kept on the temperature of mixer settlers and on the width of the dispersion bands. The temperature must be checked in each overflow box with a thermometer.

PHASE CONTINUITY:

The term "phase continuity" refers to the nature of the emulsion in the mixers. The emulsion may be a mixture of tiny organic droplets in a continuous matrix of an aqueous solution (aqueous continuous mode), or it may be a mixture of tiny aqueous droplets in a continuous organic matrix (organic continuous mode). It is important that the correct phase continuity be achieved and maintained in each mixing box. Failure to do so can lead to increased entrainment in the phase leaving the system from the settler.

The choice of phase continuity has a dramatic effect on secondary entrainment and phase break, i.e. the time required to settle the mixer emulsion. Organic continuous operation tends to produce low organic entrainment in the aqueous, higher aqueous entrainment in organic, and slower phase break times. Aqueous continuous operation is the opposite, with higher organic entrainment in the product aqueous stream, lower aqueous entrainment in the organic stream and rapid phase break.

Under ideal, warm solution conditions, the following configuration is chosen:

o First Extraction Stage (E-1)	Aqueous Continuous
o Second Extraction Stage (E-2)	Aqueous Continuous
o Third Extraction Stage (E-3)	Organic Continuous
o First Strip Stage (S-1)	Organic Continuous
o Second Strip Stage (S-2)	Aqueous Continuous

Under these conditions, there is considerable entrainment in organic and aqueous solutions that advance between E-2 and E-3 and between S-1 and S-2. Such entrainment is of little consequence, however, because the entrainment is retrieved in the emulsion of the mixer as it enters.

This plant has been designed with the expectation that incoming solutions may occasionally be too cold to permit organic continuous operation in E-3 and S-1. At colder temperatures the organic continuous phase break time can increase to the point that the mixer emulsion will not separate completely in the settler. This would lead to considerable flooding of organic through the aqueous outlet, an intolerable operating condition. For this reason, the plant is equipped with several features such as skimmers, filters, large surge tanks and ponds to recover the entrained organic when operating E-3 and S-1 in the aqueous continuous mode. Under very cold conditions the plant flows may have to be reduced.

CRUD REMOVAL AND TREATMENT:

"Crud" is the term used to describe material which collects at the interface between the organic and aqueous phases. It is also referred to as "grungies" or "gunk". Crud can be caused by:

- Solid material which has entered the solvent extraction circuit
- Solid material which has been precipitated in the mixer settler
- The formation of a gelatinous organic/aqueous material.

It is often found to be a net of bacterial growth commonly occurring at kerosene/water interfaces, which collects precipitated siliceous or calcareous solids.

Crud is processed through the centrifuge for the recovery of contained organic and aqueous solutions. The centrifuge feed pump sends each accumulated batch of crud to the vertical stacked disc desludging centrifuge. Most of the organic is recovered by the centrifuge and collected to facilitate the checking of its phase disengagement characteristics prior to pumping to the E-1 mixer. Should the characteristics be unacceptable, the organic is discarded.

The recovered aqueous is pumped to the first extraction stage. The solids in the crud are ejected intermittently from the centrifuge as a slurry. Water is added as required to the crud disposal sump to assist pumping.

ORGANIC MAKE-UP:

Loss of organic from the circuit is due to a number of factors, including entrainment in the raffinate and strip extract solutions, evaporation, leakages, spills, and entrainment in the crud. Organic losses must be made-up in order to maintain the correct plant inventory. Reagent and diluent are transferred in correct ratio directly to the loaded organic tank and mixed bv circulation through the SX circuit. The barrel pump is an air driven pump, suitable for pumping reagent or diluent directly from the drums. A diluent hose connection is provided for flushing out the reagent drums to ensure complete emptying.

SULFURIC ACID ADDITION:

Sulfuric acid is added to the raffinate to replace acid consumed by gangue minerals. A metering pump measures the sulfuric acid blended, in a static mixer, with raffinate and water as required. An automatic pH control circuit maintains a constant acid concentration at the discharge of the static mixer. The acid enriched raffinate or lixiviant is pumped through a cartridge type, presure filter to remove particulates as the last process step prior tp reinjection. The filter cartridges are replaced when the filter experiences high back pressure.

FIRE PROTECTION:

The diluent used in the SX process is a potential fire hazard. To minimize the fire risk, a special type of kerosene with a flash point of at least 78 degrees C. is used in the plant. In addition, the plant is equipped with a very effective fire protection system. Although these precautions do provide a high degree of safety, it is imperative that operations and maintenance staff adopt safe practices when in the plant area. In particular, the no smoking regulations must be strictly observed in the designated areas, and welding should only be carried out with the prior permission of the plant superintendent and plant safety officer. At such times special vigilance on the part of plant operators is required.

Apart from spillage, from whatever cause, it is considered that the greatest hazard lies in the enclosed space of mixer settlers, SX drain sump and surge/storage tanks, where relatively high sun temperatures and the absence of ventilation may give rise to the generation of explosive mixtures at temperatures approaching the flash point.

Once a fire has started on the surface of the kerosene in a tank, the bulk temperature will rise very quickly. Unless the fire is contained rapidly, it is expected the product would be unusable afterwards. When the fire has been extinguished, re-ignition could occur unless the bulk liquid temperature is reduced.

PLANT SAFETY FEATURES:

The features listed below have been incorporated in the design for the purpose of promoting safety and to avoid potential fire risks:

- Liquid spillage is to be contained by slope of grade with curbs diverting to drain trenches and interceptors
- Fitting of flame arrestors on tank vents
- Proper specification of the piping system components to obviate leakage and ensure as far as possible a liquor-tight piping system
- Incorporation of temperature alarms to provide notice of high product temperatures
- An audible fire alarm system to alert all plant personnel plus others in adjacent areas, that a fire or fire risk exists
- The incorporation of a fire water ring main, having hydrants and hoses located at strategic points, and which would allow potential fire hazards to be countered before a fire develops
- A fixed piping system using AFFF foam, fed from the fire water main to arrangement of spray nozzles inside settlers and sump as a "front line" measure in the event of an internal fire.

The automatic pre-action water spray/AFFF system serves all mixer-settlers and the SX sump. Each mixer-settler has a distribution pipe network located below the cover to provide protection to mixing boxes, the main settler, and the organic discharge weir box. The network is fitted with closed spray heads with fusible links. Spray heads are also provided to cover the walkways between the mixer-settlers.

The SX sump is equipped with a similar system including distribution piping, closed head fusible link spray heads, supply header, sensors and activation system.

- o The loaded organic, strong electrolyte and diluent storage tanks are designed for surface application in accordance with NFPA 11B manually operated by push buttons in the control room. Each tank has a separate supply header, capable of individual operation.
- o The reagent storage area is equipped with water/foam sprays manually activated.
- o The fire water pump house has a wet sprinkler system with fusible heads using water only.
- o The monitors are combined monitor/hydrants equipped with variable flow fog nozzles.

The entire fire water/foam system is designed for 250 gpm maximum flow. A concentrate diaphragm tank is located in the fire pump house, close to the fire water pumps. The tank is sized to provide sufficient foam for the maximum system flow. The minimum duration of foam application is 10 minutes for the mixer settlers and SX drain sump, and 30 minutes for the surge/storage tanks.

A fire occurring in a mixer-settler, the diluent tank, the loaded organic tank, or either of the two main pipe trenches will be detected and alarmed automatically, and AFFF solution will be applied automatically.

PRECAUTIONS AGAINST FIRE:

The institution of routine safety precaution and the strict enforcement of fire protection regulations greatly reduce fire risk. The matter is an important one and merits close and careful consideration. The following suggestions are, therefore, made with a view of assisting in the formulation of a safety code for the whole of the process area:

- o Plant to be surrounded by security fence with adequate de-matching and no-smoking regulations.
- o Safe working procedures to be instituted and rigidly followed.

- Strict control over all construction work taking place adjacent to operating plant. Welding permits must be required and tools should be nonsparking and preferably air driven.
- No naked lights to be permitted.
- Maintenance of high standard of cleanliness to ensure that plant areas are free from rubbish and other potential fire raising products.
- A high standard of plant maintenance thereby ensuring absence of product leaks. Establishment of safe working procedures regarding entry to tanks containing vapors and other explosive or flammable products.
- Training procedures for all plant personnel in isolating items of plant and in fire protection techniques.
- Proper use and regard for fire protection equipment e.g. hoses well maintained, used for emergency only, not for plant washdown and similar routine operations.
- Maintenance and cleanliness of fire fighting equipment.
- The appointment of a qualified Fire Officer who will arrange procedures and drills to ensure that the foregoing are understood and properly implemented.

3.2.1.2 Electrowinning Plant

Strong electrolyte from the SX plant is held as surge in the strong electrolyte tank and dosed there with chloride ion. The solution is pumped to the tankhouse circulation circuits. To stabilize the tankhouse operating temperature, heat is exchanged in the electrolyte interchangers with outgoing warmer spent electrolyte to preheat the strong electrolyte prior to receipt in the electrolyte circulation tank. In this tank the strong electrolyte is mixed with spent electrolyte returned from the electrowinning cells which underflows a weir from an adjacent compartment in the tank. Make-up cobalt sulphate, sulphuric acid, and water are added to the circuit in this part of the tank. The mixture (cell circulation feed electrolyte) is pumped to the cell reticulation piping and delivered from the cell risers into each individual cell.

The spent electrolyte solution, leaving the cells after electrolysis, returns by gravity to the spent electrolyte compartment of the electrolyte circulation tank. From this compartment the spent electrolyte overflows a weir into a pump box from which it is pumped, via the electrolyte interchangers to preheat the incoming strong electrolyte, to the stripping stage of the solvent extraction plant.

During the process the electrolyte is depleted of copper and enriched in sulphuric acid, with water being consumed and oxygen liberated at the anode. Copper deposits on the cathodes and, after a given period in the cell (7 days), these cathodes are removed by the tankhouse crane. The cathodes from the cells are washed free of electrolyte with hot water under pressure. The product cathodes are transported to storage.

CATHODE PULLING:

The electrowinning cells are pulled "live" with the current remaining at full amperage. To do this, every second cathode is removed at any one pull from the cell. The higher current density appearing on the remaining cathodes for the cell pull period is then an increase of 100 percent. This normally is only for a short period and has little effect on the cathode.

Steerhorn format bars are used on the anodes, which allow maximum access for a crane bale with fixed hooks. Restraining hooks are used on the crane bale to prevent premature dislodging of electrodes.

CATHODE WASHING AND STRIPPING:

The crane, with a bale of full deposit cathodes, stops at the cathode wash station. The crane lowers the bale and cathodes into the wash station where high pressure water sprays clean the cathode surface. After washing, the cathodes are moved to the stripping station. Cathodes are individually stripped by hand. The stripped cathodes, or blanks, are moved, first to the wax station where a narrow band of wax is placed on the lower edge, then returned to the cells. The copper sheets removed from the cathode blanks are stacked, weighted and stored.

TANKHOUSE VENTILATION AND ACID MIST:

Anodically generated oxygen in the electrowinning cells carries up into the tankhouse atmosphere fine droplets of electrolyte. The acid content of this material produces levels of acid in the tankhouse atmosphere, particularly above the cells, may exceed acceptable working levels. Mist production in the electrowinning tankhouse is reduced by a combination of ball blankets and an appropriate ventilation system.

Ventilation is induced draft using corrosion resistant roof fans. These induce flow through side wall louvers and air filters with sufficient momentum to carry across the tankhouse and then drawn up to the fan intake.

SLUDGE REMOVAL:

A slow build-up of sludge occurs in the electrowinning cells due largely to flaking of lead oxides from the anode surface. With the type of lead alloy anodes used, the amount of lead sludges which accumulate in the bottom of the cells is minimal. Cell cleanout frequency is 6 months to 1 year. A pneumatic diaphragm pump is provided to pump the sludge from the bottom of the cell. The sludge would be sent to a refinery to recover its metal values.

RECTIFIER DESIGN:

The cells are designed to operate at a current density of 180 amperes per square foot during normal operation. Rectifier current settings are varied to maintain constant copper concentration in the spent electrolyte. Thyristor type rectifiers are used to supply direct current for the cells. These units offer high reliability since there are no tap changers which can wear, a voltage / current range spanning substantially from zero to full value, and improved conversion efficiency since the regulating transformer losses are eliminated.

Since the thyristor rectifier uses phase control to achieve voltage control, its operating power factor at normal operation current will be less than a silicon diode type rectifier. The thyristor power factor is raised to or above that of diodes by using a manual tap changer to be set for normal operating values and power factor correction capacitors. Thyristor cooling systems are a combination of closed air and liquid systems with air cooled heat exchangers. Rectifier units are 6 pulse units without harmonic filters.

3.2.2 Operating Schedule

The surface facility will operate 24-hours per day, 7-days per week for the 21-month life of the field experiment. The well field, solvent extraction and electrowinning operations will be attended by two people at al times, the well field/SX operator and the electrowinning operator. The plant area will be relatively small and the two operators, while responsible for their own areas would provide off shift back up for each other. The 21-shift coverage would accomplished with rotating shifts of 4.2 employees per position. The fractional employee would be a helper-operator on move up to cover the 21-shift. Day shift, Monday through Friday would be fully staffed with maintenance, supervision and helpers.

The operating staff would be present at the site prior to the start of operations for operator training and start-up. The staff would remain at the site after the conclusion of the field experiment to assist in the demolition and demobilization of the surface facilities.

3.2.3 Staffing

The operating staff will be responsible for the daily operation and maintenance of the well field and solvent extraction/electrowinning facilities. The complete facility will be attended 3-shifts, 24-hours per day, 7-days per week. Maintenance and supervisory staff will be present on day shift, Monday through Friday.

The operating and maintenance staff will be composed of:

Foremen	1
Mechanic/Pipefitter	1
Electrician/Instrument Tech	1
SX - Well Field Operators	6
Electrowinning Operators	5

3.2.4 Operating Cost Estimate

This chapter presents the major operating cost for the solvent extraction and electrowinning facility excluding manpower. The costs of man power are detailed in the section on staffing. All costs assume full capacity operation and full time, continuous operation.

ELECTRICAL POWER COSTS:

The electrowinning plant is scheduled to operate 24 hours per day and 365 days per year. The power cost is based on full production of 3 tons per day at 0.9 pounds per kilowatt-hour and 9 cents per kilowatt-hour.

1095 ton/year x $0.09/kWh x 2,000 lb/ton / 0.9 lb/kWh = $ 219,000

Non-electrowinning power costs are estimated to be 10% of the electrowinning power costs.

$ 219,000 x 0.10 = $ 22,000

MAINTENANCE MATERIALS AND SUPPLIES:

The annual cost of maintenance materials and supplies are estimated to be 5% of facility capital cost.

$ 3,000,000 x 0.05 = $ 150,000

SOLVENT EXTRACTION REAGENTS:

The cost to replace lost reagents is based on the raffinate containing less than 50 parts per million of organic entrainment. This is achievable in a well operated plant. Minimizing organic entrainment in the raffinate is important for both costs and good well field operations.

Extractant Make-up Costs

0.015 m^3/gpm-y x 50 gpm x $ 1,000/m^3 = $ 7,500

Diluent Make-up Costs

0.085 m^3/gpm-y x 50 gpm x $ 300/m^3 = $ 1,300

ELECTROWINNlNG REAGENTS:

The costs of cobalt sulfate, hydrochloric acid and mist suppression agents are estimated to be less than $1,000 per year. For the purpose of this estimate they are considered as part of miscellaneous supplies.

ANODE AND CATHODE REPLACEMENT COSTS:

The expected lives of the lead anodes and stainless steel cathodes are greater than the scheduled life of the field test. Spare anodes and cathodes have been included with the purchase of capital items. No operating cost is allowed for these items.

SULFURIC ACID COSTS:

Electrowinning requires sulfuric acid make-up to replace the sulfate lost in the iron bleed used to control impurities. Thls is make-up rate has been calculated to 0.238 lb/lb. Acid make-up for gangue is also required.

+ 0.238 t(H2S04)/t(Cu) x 3 t(Cu)pd x 365 d/y x $ 30/t(H2S04) = $ 8,000
+ 3 1/2 t(H2S04)/t(Cu) x 3 t(Cu)pd x 365 d/y x $ 30/t(H2S04) = $114,975

TABLE 3-3. SUMMARY OF OPERATING COSTS

($ x 1,000)

COST ITEM	ANNUAL COST
Electrical power	
electrowinning	$ 219.0
non-electrowinning	22.0
Maintenance Materials and Supplies	150.0
Extractant	7.5
Diluent	1.3
Sulfuric acid	123.0
Annual Operating Costs SX/EW facility	$ 522.8
Operating costs for the 21 month life of the field experiment	$ 914.9

3.3 DEMOBILIZATION

The design of the solvent extraction and electrowinning facilities considered the short duration of the field experiment and the requirement to return the site to its earlier condition. The request to provide a fully skid mounted plant is impractical because of the size of the components required to process the 50 gpm flow rate. Where ever possible equipment items have been held to a 12-foot maximum dimension to allow highway transport. Over sized items will be erected at the site.

At the completion of the field experiment all process solutions and inventory will be disposed. The process solutions, pregnant leach solution, raffinate, organic, and electrolyte have some value and it has been assumed that these solutions will be accepted by a local, commercial solvent extraction and electrowinning operation. The inventory of extractant, diluent and sulfuric acid would be minimized during the final period of operation. Remaining inventory would be returned to suppliers for credit or disposal as per the process solutions.

All mechanical and electrical equipment will be disconnected and removed for disposition by others off site. Electrical wiring, conduit, instrumentation and pipe would be removed. Equipment foundations would remain. Pre-engineered buildings and trailer would be dismantled and prepared for disposal by others off site. Foundations and sewer system would remain. Tanks would be disconnected from pumps, pipes and foundations. Tanks would be removed for use by others. Ponds would be used for solution containment and evaporation during undergound restoration. Once no longer needed the pond liners would be removed and the containment berms leveled.

The site after disposal of buildings, equipment and materials would have remaining; concrete foundations, curbed and asphalt areas, fill material and septic system.

Costs associated with demobilization are estimated as: labor costs equal to those for construction ($616,900 Table 3-2); and shipping costs or 5% of the process equipment cost ($54,260 = 5% of $1,085,000 from Table 3-2). The total demobilization cost is $671,160.

CHAPTER 4

ENVIRONMENTAL PERMITTING

4.1 DESCRIPTION OF ACTIVITIES

This chapter presents the environmental permitting aspects related to the construction, operation and closure of the field experiment program at the ASARCO Santa Cruz property. These discussions include the delineation of the environmental permits and the regulatory structure under which the project will operate, coupled with the associated designs of a preoperational hydrogeologic investigation, corrective action program, monitoring system, contingency plans, and closure/post-closure procedures. The environmental permtting activities have been subsequently scheduled and costed.

As discussed in detail in Section 4.1.1 which follows, the proposed field experiment will include the completion of ten boreholes to depths of 2,220 feet. As depicted on Figures 4-1 and 4-2, the field experiment will be located in T6S, R4E, Section 13. Of the ten holes, eight will form two 5-spot injection/ recovery arrays which will be used to acid leach a small fraction of the Santa Cruz ore body for 21 months. The leach interval spans 322 feet, beginning at a depth of 1898 and extending to 2220 feet below the surface. The entire test leach field and the two adjacent test holes will encompass an area of approximately 160 by 320 feet in plan dimension. The exact orientation of the leaching array will be determined subsequent to the initial well pattern flow control testing using the first three borings. The maximum combined rate of acid inflow into the two test injection wells will be 50 gallons per minute (gpm). The cumulative rate of recovery in the six surrounding pumpback wells will exceed the rate of injection by about 5 percent.

Central to the environmental requirements for the subject experiment is the permit structure of the Arizona Department of Environmental Quality (ADEQ). The Aquifer Protection Permit issued by the ADEQ involves the most comprehensive permitting process required for the Santa Cruz experimental program. The details of the ADEQ permit application and its impact on project

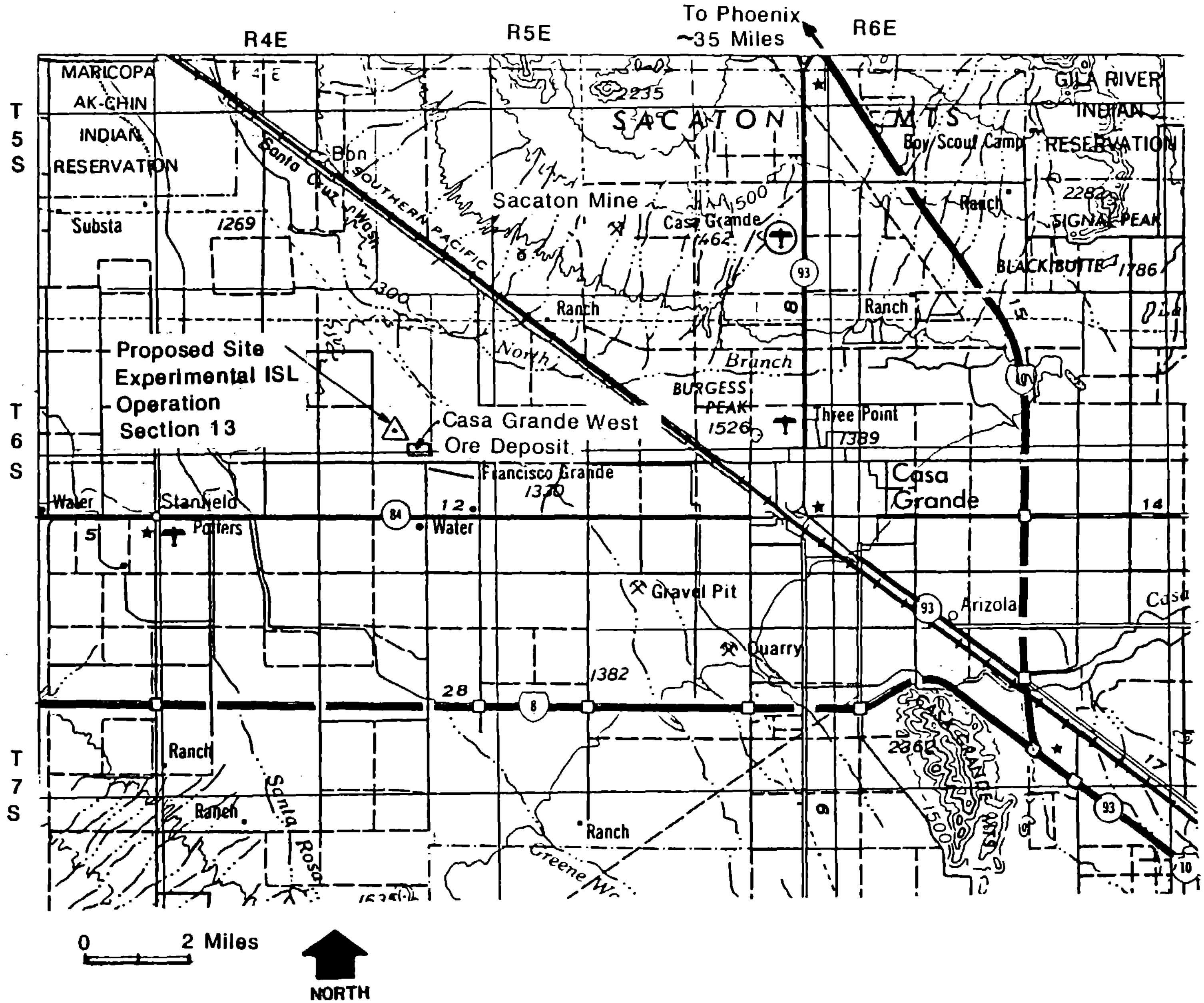
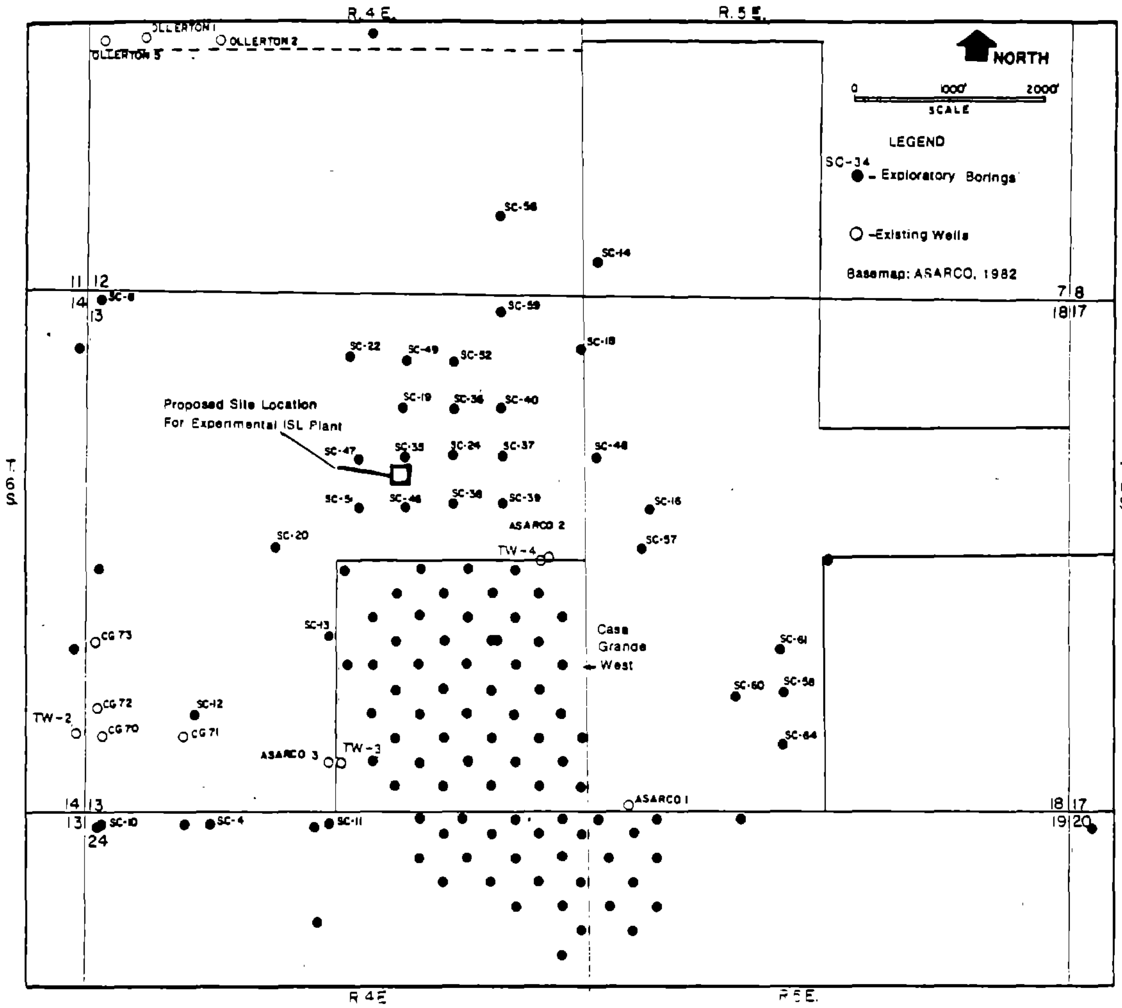
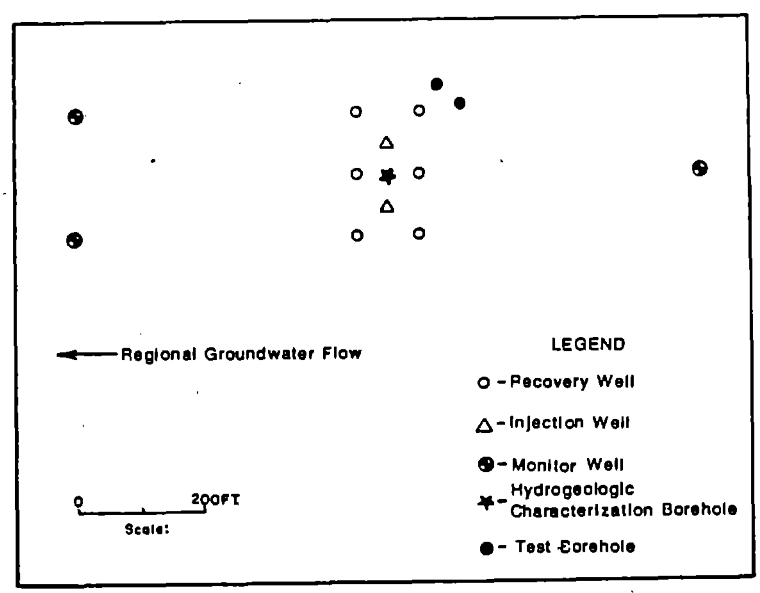


FIGURE 4-1. Map Of Casa Grande Area Showing General Location Of Experimental ISL Operation, Pinal County, Arizona



Proposed Field Experiment Site



Wellfield Configuration

FIGURE 4-2. Location And Configuration Of Experimental ISL Operation

schedule and cost are presented in Sections 4.2, 4.14 and 4.15, respectively. In addition, the initial discussions of permit requirements include the acquisition of Class V Underground Injection Control (UIC) Program authorization from the U.S. Environmental Protection Agency (EPA), air quality permits, and other miscellaneous permits or approvals.

With the full approval of the U.S. Bureau of Mines (USBM), the site owner, ASARCO/Freeport-McMoran (ASARCO), has assumed the role of permittee for the application and approval of all environmental permits. As the permittee, ASARCO has established an approach to the issues of hydrogeologic isolation and monitoring of the alluvial groundwater system which overlies the Santa Cruz ore body. The following are the key factors in the ASARCO permitting approach:

- The bedrock regime, which contains the Santa Cruz ore body, is not presently considered to be an aquifer due to its probable limited water-bearing capability, poor water quality and/or excessive depth and remoteness from potential usage.
- The point of compliance for the ADEQ permit is established as the lower portion of the alluvial aquifer which overlies the ore body and is separated from the test leach interval by a thickness of approximately 1,100 feet of low permeability crystalline bedrock and indurated conglomerates. The overlying alluvial aquifer is presently estimated to extend to a depth of about 700 feet, with groundwater in an unconfined condition occurring at a depth of 550 feet.
- The water quality of the alluvial aquifer will be monitored at the point of compliance by using three monitoring wells, one 450 feet upgradient and two 450 feet downgradient of the test area. These wells will be screened over 145 feet of the alluvial aquifer.
- The intervening bedrock and conglomerate between the shallow alluvial aquifer and the test leach interval is considered as a confining zone capable of preventing any water quality impacts on the shallow groundwater.
- Assuming total hydrologic isolation, no restoration will be necessary. The residual process fluids left in the ore body will be subject to an undetermined amount of natural buffering, ultimately increasing the pH and immobilizing many of the dissolved constituents.

The ultimate regulatory approval of the field experiment under the permitting approach initially established by ASARCO is dependent upon a comprehensive demonstration of hydrogeologic isolation of the test leaching activity from the overlying aquifer. An aquifer protection permit will not be issued by the ADEQ until a full demonstration of hydrologic isolation is completed and presented for agency review and subsequent approval. The elements of the environmental permitting designs and procedure described herein which are tailored to demonstrate hydrogeologic isolation are as follows:

- A preoperational hydrogeologic field investigation which includes the drilling and hydrologic testing of a boring designed specifically to obtain data on the geologic properties of the intervening formations which comprise the confining zone.
- Completion and baseline water quality testing of the three monitoring and four selected outlying wells to enable the system to recognize the ambient quality of the local groundwater and detect changes during initial testing and leach operation.
- Monitoring of head distribution and water quality in the overlying aquifer during initial test procedures in the first three borings.
- Corrective action program to seal all boreholes potentially capable of transmitting process fluids upward to the alluvial aquifer.
- Mechanical integrity testing of all injection/recovery wells to eliminate possibility of an excursion caused by insufficient cementing or breach in casing string.
- Preleach verification of well integrity by utilizing annular pressure measurements between casing and injection string in the two injection wells.

4.1.1 Scope of Field Experiment Operational Plan

Details of the field experiment operational plan were obtained from a review of project technical memoranda, hydrogeologic information provided by ASARCO, and existing geologic mapping and literature. Operational procedures as assumed during development of the environmental monitoring program are summarized in the following discussions.

4.1.1.1 Ore Block Flow Assessment

This task consists of the following activities:

- Drilling of a nominal 10-inch borehole to the top of the ore zone using air hammer methods, installation of 7 5/8-inch O.D. steel casing, cementing the casing in over the full length, running cement bond logs and pressure testing to verify integrity of the well head and casing. The requirements of the Arizona Department of Water Resources (ADWR) for installation and grouting of surface casing will be strictly complied with. Regulation R12-15-811 specifies that an annular space of minimum 1 1/2 inches surrounding the surface casing to a minimum depth of 20 feet shall be grouted to the surface to ensure isolation of the well from potential surface contamination.

- Drilling of a 7 5/8-inch borehole through the ore zone and obtaining oriented spot cores at selected intervals near the top, middle and bottom for determination of lithology and structure, orientation and spacing of fractures, copper mineralization locations and in situ stress conditions.

- Performance of open-hole flow tests at three intervals intermittently during drilling to determine flow profiles and permeabilities. Temperature and caliper logs will be run through each selected interval to aid in data interpretation.

- Wireline geophysical logging of the borehole through the entire length of the ore zone. The following logs will be run:

  - Temperature and differential temperature.
  - Caliper.
  - Spontaneous potential.
  - Resistivity.
  - Three-dimensional sonic velocity.
  - Natural gamma.
  - Gamma density.
  - Thermal neutron.

- Casing with 4.5-inch O.D. F.R.P. casing, cementing in the full length, and running of cement-bond logs and pressure testing to verify integrity of the well head and casing.

4.1.1.2 Well Pattern Flow Control

- The second and third wells will be sited at approximately 50-foot spacing adjacent to the first well. The three wells will form an approximate 90 degree angle.

- Drilling procedures, open-hole flow tests, wireline logging, casing and cementing will be performed according to the specifications outlined above in Section 4.1.1.1 for the first hole.

- Perforation of the lower 200 feet of the ore zone in each of the three wells will be performed using a hollow carrier gun and jet perforators.

- o Performance of cased hole testing in each of the three wells prior to well stimulation will consist of the following:
  - + Temperature logs.
  - + Permeability testing and determination of flow profiles.
  - + Interference and tracer tests performed simultaneously, utilizing the three wells, for approximately 24 days (unstimulated condition).
- o Well stimulation will include the following procedures:
  - + Installation of short-radius hydrofractures in two of the three wells and performance of permeability testing for determination of flow profiles.
  - + Installation of "explosive" stimulation in the remaining well and performance of permeability testing for determination of flow profiles.
  - + Running of cement bond logs on each well to define the effects of stimulation on cement.
  - + Performance of interference and tracer tests, using the three wells, for a duration of approximately eight days (stimulated condition). A chloride tracer will be used from a sodium or calcium chloride mixture with water, to a concentration of approximately ten times the level found in the formation water.
  - + Design of the hydraulic fracture program.
  - + Determination of large-radius hydrofracturing properties in the lower and upper portions of the ore zone, successively.

4.1.1.3 Well System Construction

The well system will consist of two adjacent five-spot arrays containing a total of eight wells (two injection and six recovery). The following lists the design elements and construction activities related to the well system installation:

- o The wellfield design will utilize at least one of the existing wells drilled for ore block flow assessment and well pattern flow control, ss outlined above in Sections 4.1.1.1 and 4.1.1.2. Spacing of production and injection wells is assumed to be about 100 feet.
- o Two contiguous five-spot well patterns will be installed, requiring the drilling of seven new wells (five production wells and two injection wells).

- o Two drill rigs will operate continuously, using air hammer methods, to advance seven 7-inch diameter boreholes to the required total depths.

- o Wireline geophysical logging will be performed in each new well as outlined above in Section 4.1.1.1, and 4 1/2-inch O.D. F.R.P. casing will be installed from top to bottom; cement of suitable composition will be installed over the full length of each casing, and cement bond logs and pressure tests will be run to verify the integrity of the well head and casing.

- o Approximately the lower 320 feet of the ore zone in each of the seven new wells will be perforated, using a hollow carrier gun and jet perforators.

- o Prestimulation flow tests, stimulation and poststimulation flow tests will be performed following specifications as outlined above for the initial three wells. Duration of prestimulation flow tests will be approximately seven days; interference tests approximately six days.

- o Installation of equipment for long-term acid leach tests.

Environmental permitting activities slated for completion prior to the installation of the well field are as follows:

- o Hydrogeologic characterization program presented in Section 4.4, with the field program completed in concurrence with ore block flow assessment discussed in Section 4.1.1.1.

- o Completion of corrective action programs (see Section 4.5).

- o Construction of monitoring wells (see Section 4.6).

- o Initiation and continuation of baseline water quality monitoring program (see Section 4.8).

4.1.1.4 Well System Operation

- o Leaching and an initial tracer test will be initiated following the installation of all necessary equipment as outlined above in Section 4.1.1.3.

- o The acid leach system will operate continuously with the ongoing collection of data and system maintenance for an assumed duration of 21 months.

- o The acid leach and final tracer tests will be terminated after approximately 21 months of steady-state operation.

- o Post-leach flow tests.

+ Interference testing (recording of fluid level drop will be performed in all wells for six days).

+ Permeability testing will be performed in selected wells following procedures outlined above for determination of flow profiles.

o Post-leach core drilling.

+ A total of two coreholes will be drilled (one per five-spot well pattern), following termination of the 21-month acid leach test. These will utilize rotary or hammer methods through the overburden and wireline core methods through the ore zone.

+ All core obtained will be logged, photographed, packaged and stored.

o All wells will be properly abandoned after termination of the acid leach test, and post-leach flow tests and core drilling.

Environmental monitoring activities will be performed throughout the course of well system operation as discussed below in Section 4.10. These activities will include the following:

o Mechanical integrity testing (initial test performed prior to acid injection).

o Injection flow rate and injection pressure monitoring. o Water quality monitoring.

o Air quality monitoring.

4.1.1.5 Surface Facility Construction and Operation

Surface processing facilities will consist of a solvent extraction, electrowinning (SX-EW) plant and support facilities. The SX-EW plant facilities include:

o Double-lined ponds for leach solution storage and pumps for both production well solution (pregnant leach solution) and well field solution (raffinate solution).

o Solvent extraction facilities designed for two extraction and two stripping stages.

o Solution storage, handling and pumping equipment for organic and aqueous solutions.

Prior to initiating construction of the SX-EW facility, ASARCO will obtain the required permits for installation (see Section 4.2). Before operations begin, mechanical integrity testing will be performed to verify proper performance of all components and to assure protection of the surface environment. During operations, surface facility monitoring will include:

- o Testing lined ponds for leakage.
- o Visual inspection of all tanks and pipelines for leakage.
- o Inspection to assure proper containment of stored reagents:
  - + Sulphuric acid.
  - + High-flash point kerosene.
  - + Copper-specific reagents used for extraction.

4.2 ENVIRONMENTAL PERMIT REQUIREMENTS

4.2.1 Water Quality and Usage

In the categories of water quality and nsage, the Santa Cruz experimental program will be subject to the regulatory scrutiny and environmental permit requirements of three agencies, the ADWR, the ADEQ and the EPA. The regulatory authority of the ADWR generally resides with issues of water usage and conservation, with the exception of their administration of a well construction standards and well driller certification program. The major focus of the regulatory structure of the ADEQ and EPA is the protection of groundwater quality. Due to the experimental nature of the proposed program, the EPA will classify the project as a Class V operation, with a limited and very reduced regulatory interaction required as compared to the permit requirements of a commercial-scale operation. The most comprehensive body of environmental law and regulations applicable to the experimental program is the aquifer protection permit structure of the ADEQ. As will be discussed in detail later in this report section, the ADEQ permitting involves a lengthy and involved process of snbmitting supporting documentation which presents the concepts and designs of the proposed project, characterizes the hydrogeologic setting and provides contingency, closure and post closure plans.

TABLE 4-1. ENVIRONMENTAL PERMITS AND RELATED REGULATORY APPROVALS REQUIRED

Permit Name and/or Description	Issuing Agency With Name & Address and Agency Contact(s) With Telephone No.	Approximate Timetable to Receive Approval	Legal Citation(s)	General Remarks
o Aquifer Protection Permit	Arizona Dept. of Environmental Quality 2005 North Central Avenue Phoenix, Arizona 85004 Mr. Roger W. Kennett Ms. Debra L. Daniel (602) 257-2270	13 months to complete from proposal through final approval; allowing 3 months to develop and present hydrogeologic and corrective action data.	Arizona revised statutes sections 36-3501 through 36-3624 and Sections 49-101 through 49-105.	Analysis of regulatory requirements partially based upon draft regulations which are subject to change.
o Underground Injection Control Program (UIC) Class V Authorization	U.S. Environmental Protection Agency Region 9 215 Fremont Street San Francisco, California Mr. William M. Bohrer (415) 974-0807	6 months from initial notification to EPA authorization letter.	40 CFR Chapter 1, Parts 144 through 146.	Due to experimental nature of proposed action, EPA should authorize activity by rule, with only basic inventory requirements reported.
o Right to Withdraw Groundwater	Arizona Dept. of Water Resources Pinal Active Management Area 901 E. Cottonwood Lane, Suite B Casa Grande, Arizona 85222 Mr. Tom Carr (602) 836-4857	Notify only.	Arizona Revised Statutes Sections 45-401 through 45-637.	Due to grandfathered groundwater rights held by ASARCO, no permit process is required if withdrawals do not exceed yearly allotment.
o Conformance to Well Construction Standards and Use of Certified Driller	Arizona Dept. of Water Resources 99 East Virginia Avenue Phoenix, Arizona 85004 Mr. Richard A. Gessner Mr. Robert Fayfield (602) 255-1533	15 days from notice of intent to drill.	Arizona Administrative Rules and Regulations; Title 12, Chapter 15.	Notice of intent to drill must include name and certification no. of driller. Driller must submit well log and completion record within 30 days of well completion.

TABLE 4-1. ENVIRONMENTAL PERMITS AND RELATED REGULATORY APPROVALS REQUIRED (Continued)

Permit Name and/or Description	Issuing Agency With Name & Address and Agency Contact(s) With Telephone No.	Approximate Timetable to Receive Approval	Legal Citation(s)	General Remarks
o Air Quality Installation Permit	Pinal-Gila Counties Air Quality Control District P.O. Box 1076 Florence, Arizona 85232 Mrs. Dorothy M. Rankin (602) 868-5801	6 to 12 months to complete; partially dependent upon whether preoperational monitoring will be required.	Amended Rules and Regulations prepared by Air Quality Control District Staff, Sections 7-1-2 through 7-3.	Process involves interaction with Pinal-Gila Air Quality Board.
o Building Permit	Pinal County Planning & Zoning Dept. P.O. Box D Florence, Arizona 85232 Mr. Gary Beck (602) 868-5801	6 weeks to complete.		Requires submission of final plans.
o Permit for Septic Disposal	Pinal County Health Dept. P.O. Box 807 Florence, Arizona 85232 Mr. Reg Glos (602) 868-5801	4 weeks to complete.		On-site percolation testing required.
o Notification of Commencement (Worker Safety)	ARizona State Mine Inspector 1624 West Adams Street, Room No. 208 Phoenix, Arizona 85007 Mr. James Mott (602) 255-5971	Notify only.	Arizona Administrative Rules and Regulations; Title 27, Chapter 1, Article 2.	
o Notification of Commencement of Operation	Mine Safety & Health Administration 3221 North 16th Street, Suite 300 Phoenix, Arizona 85016 Mr. Gary Day (602) 241-2030	Notify only.	30 CFR, Chapter 1, Part 56.	Worker safety training program involved.

As an overview to the environmental permits and related approvals required for the Santa Cruz experimental program, Table 4.1 is provided. This table lists the various permits and approvals required, identifies the issuing agencies, provides a tentative timetable for permit approval and presents the agency personnel contacts for each regulatory activity as they were established during the course of this study.

The current ADEQ aquifer protection permit program is the result of enabling legislation in 1986. The Arizona Environmental Quality Act (EQA) established the new ADEQ and delineated the permitting structure. The ADEQ has compiled draft regulations which further define the requirements of the permit 4-12 program. These regulations are currently being reviewed by the Governor"s Regulatory Review Council and other interested parties. Public hearings on the regulations are scheduled for October of 1987.

As defined by the language of the EQA and the draft regulation for aquifer protection permits, ASARCO will be required to submit a permit application for the Santa Cruz experimental program no later than 180 days prior to the date on which acid leaching commences. As outlined in Section 4.14 of this document, the overall permitting process is estimated to encompass a 13-month time frame, with specific submittals and review/comment periods integrated into the overall construction and preoperational activities.

The following is a listing of the regulatory factors and specific requirements of the ADEQ aquifer protection permitting structure:

o The ADEQ will adopt, by rule, specific water quality standards for the alluvial aquifer which overlies the Santa Cruz ore body (ARS 36-3521 and 49-223). These standards will be established with the consideration of the protection of the public health and environment, existing and projected water use, and any unique physical, biological or chemical properties of the aquifer. It is probable that these standards will be numerical, with the concentrations of specific dissolved constituents delineated. The underlying purpose of these standards is to provide a basis for alert levels, defined as elevated concentrations of a suspected pollutant at the point of compliance which may require the activation of the project's contingency plan.

- o The ADEQ will require the application of the best available demonstrated control technology (BADCT) to achieve the greatest degree of discharge reduction (ARS 36-3543). A BADCT determination is specific to each project, with the following as general guidelines to evaluate the proposed technologies and operating methods.

  - + Site characteristics such as proximity to other discharging facilities, distances to drinking water wells and residential populations, topography waste stream characteristics and general geologic setting.

  - + Geohydrologic factors such as permeability, depth to groundwater, water quality, and groundwater gradient.

  - + Achieving the highest practical degree of water conservation.

  - + Consideration for the capital, operating and maintenance costs for the use of alternative treatment or containment technologies.

  - + The ADEQ will require that the applicant submit a description of alternative discharge control measures considered and a technical justification for the selection of the preferred alternative. All of the factors discussed above need to be addressed in presenting a project-specific approach to the BADCT concept.

- o To a large degree, the content of this document meets a variety of specific requirements of the ADEQ permit application procedure. As indicated in the EQA (ARS 36-3543) and the revised draft regulations (AARR 18-9-104), the following information will be required during the application process:

  - + A written statement of project purpose.

  - + Design of the facility.

  - + Description of how the facility will be operated.

  - + Proposed pollutant control measures.

  - + Characteristics of the potential pollutants.

  - + Description of the surface and subsurface geology.

  - + Regional and site specific description of surface water and groundwater conditions.

  - + Discharge impact assessment.

  - + Site maps showing property lines, structnres, borings, wells, topography, land ownership, proposed locations of point-of-compliance.

  - + Contingency plan.

+ Monitoring plan.

+ Post closure plan.

+ Closure cost estimate.

+ Present water usage.

+ Existing water quality.

The permit requirements of the EPA are delineated in the regulations of the Underground Injection Control (UIC) program as presented in 40 CFR parts 144 through 146. The regulatory program and the specific requirements which relate to the Santa Cruz field experiment are interpreted to fall under the Class V category, a miscellaneous classification under which injection is authorized by rule, not permit. The EPA has classified injection wells under five categories, with specific reference to wells used in experimental technologies as Class V wells (40 CFR 146.5).

The Class V regulatory requirements will obligate ASARCO to submit the following inventory information (40 CFR 144.26):

- Facility name and location.
- Name and address of legal contact.
- Ownership of facility.
- Nature and type of injection wells.
- Operating status of injection wells.
- Location of each well by Township Range, Section and Quarter-Section, or by latitude and longitude to the nearest second.
- Date of completion of each well.
- Identification and depth of the formation(s) into which each well is injecting.
- Total depth of each well.
- Casing and cementing record, tubing size, and depth of packer.
- Nature of injected fluids.
- Average and maximum injection pressure at the well head.

- o Average and maximum injection rate.
- o Dated last mechanical integrity test.

The EPA has not authorized Arizona to administer its own State UIC Program. As a result, the UIC program authority still lies with the EPA. Due to this fact, the EPA has the authority to request additional information from the operator of injection wells (40 CFR 144.27). This information may include the following:

- o Performance of groundwater monitoring and the periodic submission of monitoring reports.
- o Analyses of injected fluids and periodic submission of such analyses.
- o Description of the geologic strata through and into which injection is taking place.

Although the EPA authorization by rule for Class V wells does not include a preoperational approval period, it is recommended that available inventory details be submitted to EPA approximately six months before startup of the leaching operation. By submitting this information prior to startup, ASARCO can have a clear indication as to EPA"s data collection requirements during the operation, and thereby respond to these requirements in a timely mnnner.

The remaining permit/approvals relating to water quality and usage listed on Table 4.1 which merits additional discussion is the ADWR requirements pertaining to well construction standards, use of a certified well driller, and rights to withdraw groundwater.

In Arizona, the management of surface water and groundwater resources is administered by the ADWR. Due to a long-term overdraft problem in some of Arizona"s large alluvial groundwater basins in the central and southern portions of the state, a comprehensive groundwater management act was passed by the Arizona legislature in 1980 (The Groundwater Code). The Code established four active management areas (AMAs) and two nonexpansion areas. The Santa Cruz ore body lies within the Pinal AMA.

Generally, the use of groundwater in the AMAs is more strictly regulated, with explicit mandatory conservation measures required. The Code basically restricts the withdrawal of groundwater to those with groundwater rights or permits, and institutes a 45-year management and conservation program.

In an effort to conserve the groundwater resources within the Pinal AMA, a management plan has been established which requires the use of conservation measures for metal mining facilities. These requirements will obligate ASARCO to apply the latest commercially available conservation technology which is consistent with a reasonable economic return. Although the specifics of the Pinal AMA management plan deals with water consumption in the tailings disposal operation, the field experiment will be scrutinized to evaluate its consumptive use and methods to conserve the resource.

In its designated role in water resosrce management, the ADWR also regulates the construction of wells and licensing of well drillers, as specified in the rules and regulations of Title 12, Chapter 15, Article 8 (AARR 12-15-801 through 821) and the Arizona Revised Statutes, Title 45, Chapter 2, Article 10 (45-591 through 604). In brief, the ADWR sets quality standards for the 4-19 rehabilitation, deepening, replacement, completion and abandonment of wells, and administers the testing and licensing of well drillers.

ASARCO holds a Type 2 Non-Irrigation grandfathered groundwater right (GFR) for the Santa Cruz property (Mr. Bill Kurtz, ASARCO, personal communication, March 1987). With this GFR, each monitoring, injection and recovery well completed for the ISL experiment will necessitate the filing of an Intention to Drill. This Intention to Drill specifies the construction details of the well, the owner and the certified well driller who will perform the work. All work must be performed by a duly licensed well driller who is required to file a completion report for each well drilled within 30 days of completion.

4.2.2 Air Quality

Prior to initiating construction of the experimental facility, ASARCO must apply for an air quality installation permit from the Pinal County Air

Quality Control District Office in Florence, Arizona. Information from the applications will be used by the District to determine permit conditions in accordance with Regulation 7-1-2.1 of Amended Rules and Regulations prepared by the Air Quality Control District staff. A separate application is required for each functional unit of operation, process, or activity involving basic equipment, and each unit or system of air pollution control equipment requiring a permit.

An installation permit remains in effect until an operating permit is granted or denied or the application is cancelled. The installation permit expires two years from the date of issue. No installation permit will be granted unless ASARCO can demonstrate to the satisfaction of the control officer that the proposed source will neither prevent nor interfere with the attainment nor maintenance of ambient air standards or will exceed the allowable emission standards (AARR 7-1-2.1 D).

Three potential sources of air pollutants involved in the SX-EW operations are dust from access and maintenance roads, sulfuric acid mist, and vapor from the storage of kerosene. Proposed controls, safety procedures, and other pertinent information related to these three sources will accompany the application. Specific information requested by the Air Quality Control Board includes site information, plans, descriptions, specifications and drawings showing the designs of the sources, the nature and amounts of emissions, and the manner in which they will be operated and controlled.

A brief summary of regulations specific to the three possible pollutants follows:

- Emission Standards for Particulates - (AARR 7-3-1)
  - <u>Fugitive dust</u> - (AARR 7-3-1.2)
    Dust on roadways or in construction areas must be kept to a minimum by such measures as wetting down, or by other reasonable means.
  - <u>Process Industries</u> - (AARR 7-3-1.8)
    Discharge of particulate matter (sulfuric acid mist) into the atmosphere in any hour from any existing process source in total quantities in excess of calculated amounts determined by process weight rates is not allowed. Tables of the allowable rates of emission are presented in the Amended Rules and Regulations.

- o Emission AARR Standards - Organic Compounds from Stationary Sources - (AARR 7-3-3).

  - + Storage of Volatile Organic Compounds - (AARR 7-3-3.1) A container of more than 40,000 gallon capacity for the storage of any petroleum distillate having a vapor pressure of 1.5 pounds per square inch, absolute or greater at loading pressure, must be a pressure tank maintaining working pressures sufficient to prevent hydrocarbon vapor or gas loss to the atmosphere, or must be equipped with a floating roof or vapor recovery system or other vapor emission control device.

  - + Loading of Volatile Organic Compounds - (AARR 7-3-3.2) Dock loading of petroleum products having a vapor pressure of 1.5 pounds per square inch, absolute or greater at loading pressure, must provide for submerged filling or acceptable equivalent for control of hydrocarbon emissions.

Requirements for air quality monitoring during operations will be determined by the Air Quality Control Board. It is assumed for costing and scheduling purposes that no preoperational monitoring will be required for the Santa Cruz experimental facility.

4.3 HYDROGEOLOGIC SETTING

The following discussion is based on geologic and hydrologic information, from the area of the experimental ISL operation, provided by ASARCO. These data give both a historical overview of changing groundwater conditions in the project area and a basic understanding of the hydrogeologic setting.

The Santa Cruz deposit is located in the Lower Santa Cruz Basin, within the Basin and Range physiographic province of Arizona (Figure 4-1). The site area lies within an intermontane valley of low relief. The Sacaton Mountsins are 6 miles northeast of the site and the northern end of the Casa Grande mountain range is about 3 miles to the southeast. Two major drainages, the north branch of Santa Cruz Wash and Santa Cruz Wash, merge northwest of the site area, flowing toward the Santa Cruz Wash-Gila River confluence southwest of Phoenix.

The Santa Cruz Basin is one of the most highly developed agricultural areas in Arizona, with groundwater as the principal source of irrigation water. High demands for water have caused a dramatic decline in the groundwater level over the past 60 years (Halpenny and Greene, 1972). In this arid environment, the low rainfall and high rate of evaporation result in very little groundwater recharge. The amount of stored groundwater in the Casa Grande area was declared critical in 1951 and irrigation was restricted to lands under cultivation at that time. However, groundwater levels continue to decline as agricultural pumpage exceeds groundwater recharge.

4.3.1 General Geology

Geology of the project area consists of igneous and metamorphic basement rocks, overlain by Tertiary-aged conglomerate and unconsolidated alluvium of Quaternary age (Figure 4-3). During the Late Cretaceous-Tertiary Laramide Orogeny the basement rocks were intruded by porphyritic stocks. The hydrothermal activity associated with the emplacement of these stocks is believed to be related to the sulfide mineralization found in the area (Cummlngs, 1982). Subsequent faulting, uplift, and erosion altered the tops of mineralized areas, forming copper rich zones of chalcocite. Subsidence of the area in mid-Tertiary time was followed by deposition of conglomeratic units of middle to late Tertiary age and unconsolidated alluvium of Quaternary age.

The structural setting for the area is complex, with a history of several periods of deformation. Late Basin and Range faulting was responsible for the present configuration of structural blocks with complex geometries and large-scale offsets. Cummings (1982) reports that the neighboring Sacaton ore body lies within an allochthonous block resting on a low-angle structure. Northwesterly trending normal faults divide the allochthonous rocks into several horst and graben units. Two preferred orientations of fractures are present at Sacaton: the first set trending N50E to east-west, dipping 70 degrees in either direction; the second set trending north-south to N20W, with a near vertical dip. In the subsurface, above the Sacaton deposit, the conglomerate rests on a sheared and brecciated basement fault.

Three major structures have been recognized in the area of the Casa Grande West ore body, located along the southeast edge of Section 13 (White, 1981). The east side of the ore body borders a zone of complex faulting that

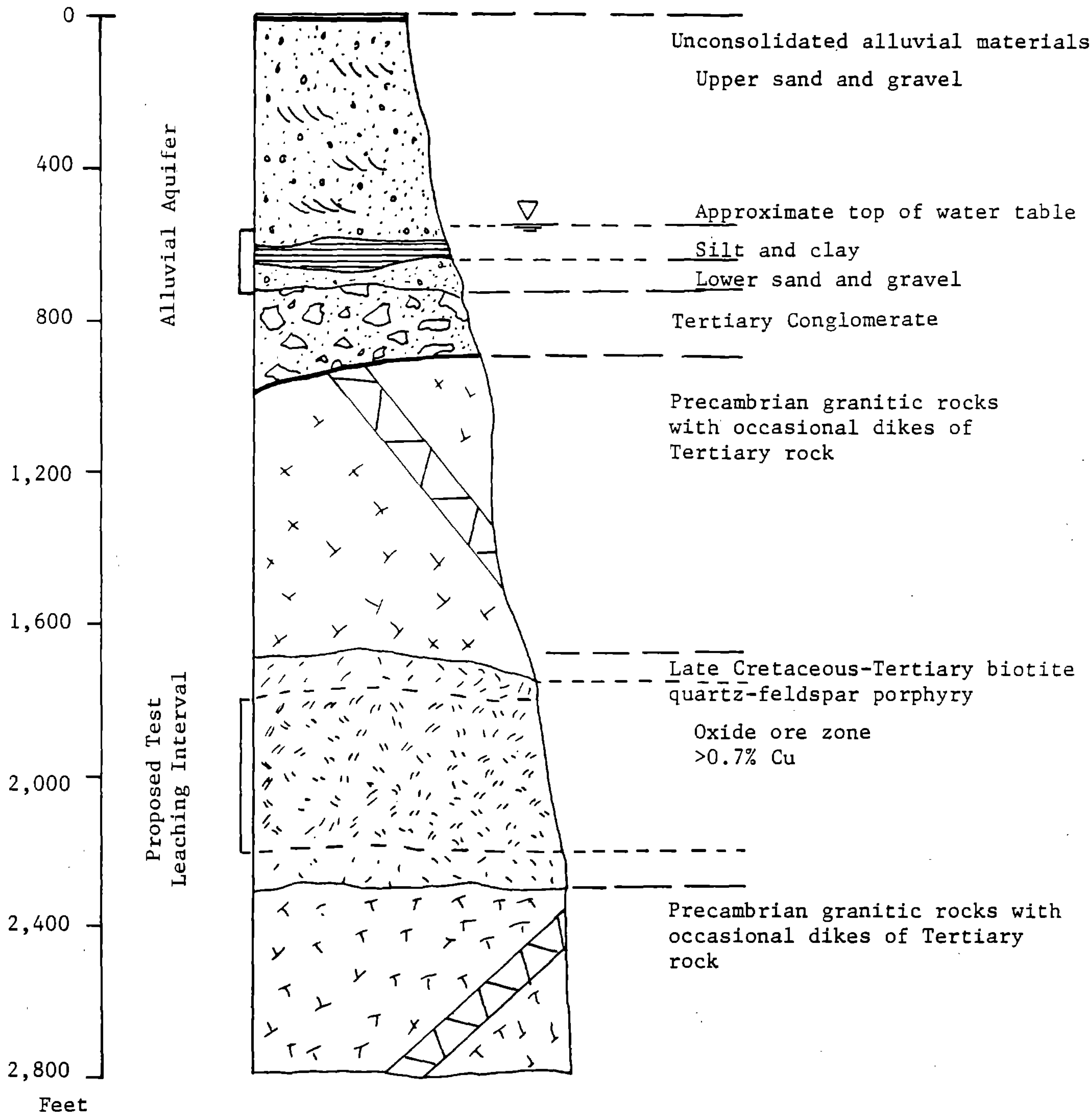


FIGURE 4-3. Schematic Stratigraphic Column Based On Drillhole Data From SC-35

is bounded by a pair of normal faults striking NNW and dipping 35 to 55 degrees to the east. The southeastern end of the bedrock is truncated by a WSW striking fault that dips 50 degrees to the southeast. A north-south striking fault, dipping to the west at 20 to 30 degrees, defines the lower limit of the ore body. White (1981) reports that these three structures affect the indurated sediments but do not appear to extend into the overlying alluvial section.

Details concerning the local structural setting are not available. However, the variable thicknesses of the units suggest the presence of concealed faults. Within Section 13, top of bedrock elevations vary by more than 1,000 feet. The thickness of the conglomerate is also extremely variable, ranging from 250 feet near a bedrock high to greater than 1,000 feet in a distance of 1/2 mile (Halpenny and Greene, 1972). The alluvium ranges from 400 to 800 feet in thickness. The topology of the top of bedrock surface shows two deep depressions along the eastern edge of the area, which may be indicative of downdropped blocks, possibly cut by east-west trending faults. The steep rise in elevation from east to west may be due to a northeast trending fault, downthrown to the southeast (Figure 4-4).

4.3.2 Hydrogeology

General descriptions of the water producing zones overlying the ore deposits are presented in Hardt and Cattany (1965). The following summary of their report is accompanied by details of unit thicknesses and permeabilites provided by Casa Grande West (1987).

The primary aquifer in the area is the unconsolidated alluvial materials which yield relatively large quantities of groundwater which is used extensively for irrigation. By comparison, the underlying Tertiary conglomerate is considered to be relatively impermeable, although in some localities the conglomerate yields snfficient quantities of water for domestic or stock wells. The crystalline basement rocks and minor sedimentary rocks are reported to be essentially non-water-bearing.

- Unconsolidated Alluvial Materials. The unconsolidated alluvium in Western Pinal County is divided into three units. These units

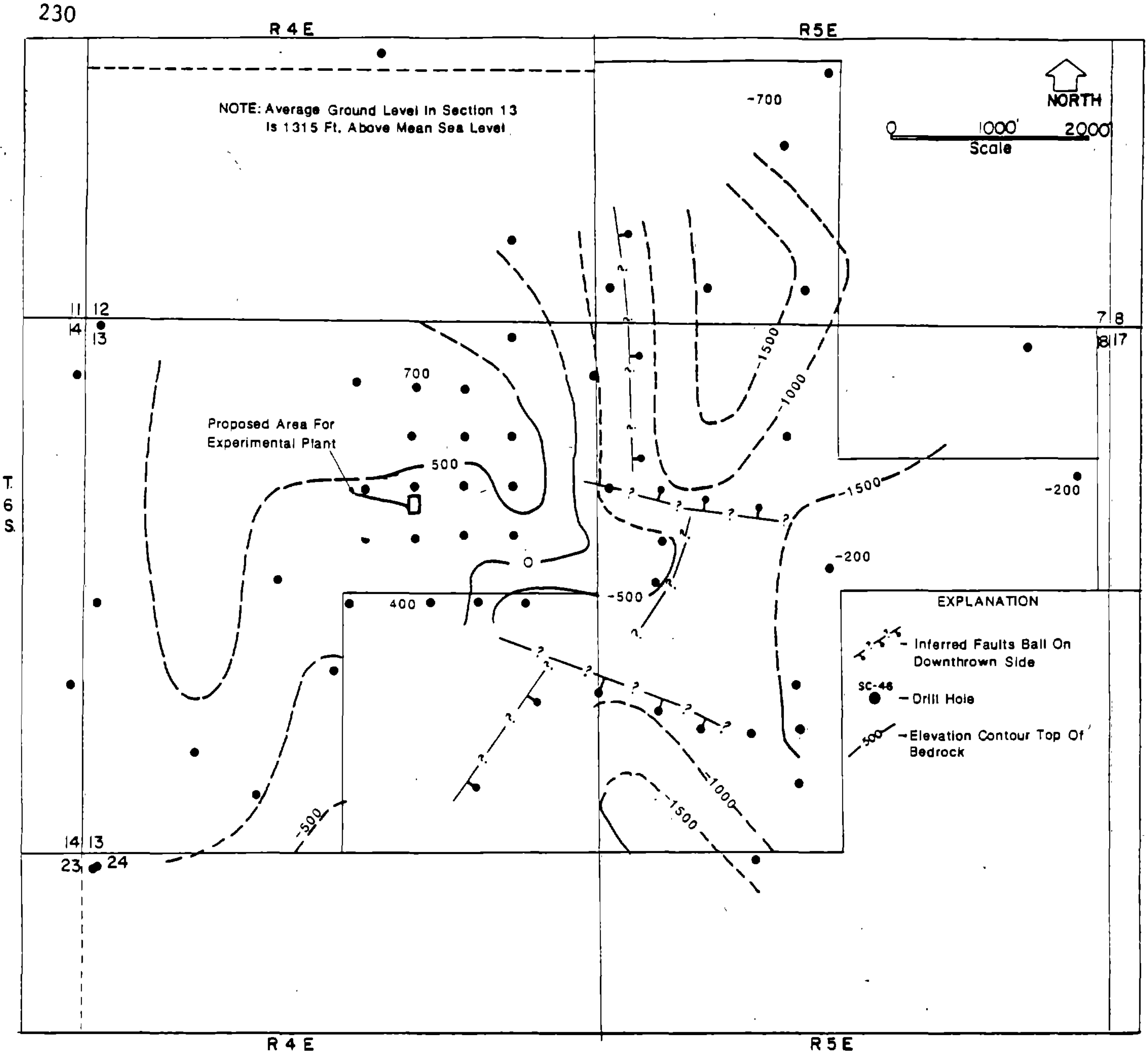


FIGURE 4-4. Contours Of Top Of Bedrock Elevations Showing Inferred Faults (Basemap From ASARCO, 1982)

include: lower sand and gravel, silt and clay, and upper sand and gravel.

The lower sand and gravel is a heterogeneous mlxture of sand, gravel and clay, generally about 100 to 250 feet thick. This unit ranges in depth from 300 to 1,100 feet below land surface. Where the lower sand and gravel unit is overlain by the silt and clay unit, it generally contains water under artesian conditions. At Casa Grande West, the thickness of this unit is 0 to 200 feet with reported permeability values between 18.6 and 41.2 millidarcys (md).

The silt and clay unit, composed of fine sand, silt and clay, generally ranges from 200 to 800 feet in thickness. The top of the unit varies from 200 to 400 feet below land surface. This unit is the least productive of the allnvial units, however, strings and lenses of highly permeable sand and gravel yield moderate amounts of water. At Casa Grande West, this unit is estimated to be 200 to 500 feet thick with a reported permeability value of 2.4 md.

The upper sand and gravel unit is similar in lithology to the lower sand and gravel unit, but it is not as firmly cemented and areally is more extensive. This unit has the highest average permeability of the unconsolidated alluvial units, and high well yields. Permeability varies vertically and laterally, resulting in a wide range of well yields. This unit begins at land surface and is generally 300 to 400 feet thick. A 600-foot thick section is found at Casa Grande West with a reported value of 24,400 md permeability.

Hydrological data for the alluvial aquifer include water level measurements and results of pumping tests with calculations of transmissivity and storativity (Cooper, 1983; Hargis and Montgomery, Inc., 1981 and 1983). The most current water level measurements provided for this report were taken in 1983. Present water levels are estimated to be deeper than 550 feet below land surface. Values for transmissivities range from 50,000 to 90,000 gpd/ft and storativity values are reported at 0.1 (Casa Grande West, 1987).

- Conglomerate. The conglomerate contains 40 to 60 percent clasts in a silty to gritty, moderately well indurated matrix, partially cemented with calcareous cement (Cummings, 1982). Because the material is tight and partially cemented, the rate of yield to wells is low (Halpenny, 1970). Casa Grande West reports 10.1 to 16.1 md permeability for the indurated conglomerate. Laboratory tests of permeability and porosity provide a range of values from 74 to 360 md for permeability and 6.0 to 24.9 percent porosity (Halpenny, 1970). From the laboratory results, transmissivities were calculated to be 10,000 to 20,000 gpd/ft. Storage coefficient was estimated to be about 5 percent by volume.

- Crystalline Basement Rocks. The crystalline basement rocks consist of different rock types, all of which have very low permeabilities; permeabilities are reported to be 0.2 md in the leached capping and 0.8 md in the oxide ore zone at Casa Grande West. No other data were available on the hydrologic properties of this unit.

Prior to large-scale pumping for irrigation purposes, the depth to groundwater was about 85 feet below the land surface and flow was in a northwesterly direction, with a gradient of 10 feet per mile. The Casa Grande Ridge, a bnried bedrock basement high east of the site between Burgess Peak and Casa Grande Peak, caused a slight steepening of the gradient. Today, deep depressions in the water table are present as a result of pumpage. Groundwater levels near the site area dropped approximately 415 feet in 57 years, from about 85 feet in 1923 to about 500 feet in 1980 (Halpenny and Greene, 1972; Hargis and Montgomery, Inc., 1980). Groundwater levels declined another 40 feet by 1983, measuring 540 feet below the surface (Hargis and Montgomery, Inc., 1983). Recently, groundwater levels have fluctuated owing to reduced pumpage and periods of no pumpage when fields lie fallow during cycles of crop rotation.

Groundwater quality has become progressively poorer with increased drswdown. Groundwater analyses from the USGS in 1941 show an anomalous zone with high TDS near the Casa Grande Ridge. This high migrated westward, closer to the site area, as drawdown increased. Water analyses from 1972 (Halpenny and Greene, 1972) show high TDS (547 to 1,028 mg/1) and high specific conductance (883 to 1,420 micromhos) in two wells neighboring the site. High fluoride concentration (2.0 mg/1) was measured in one of the two wells. Water quality data from Hargis and Montgomery, Inc. (1983) show that in 1980 TDS content increased to a high of 2,000 mg/1. Subsequent analyses taken from 1980 to 1982 indicate a decreasing trend in TDS content, lower by 16 percent. Continuing trends in enrichment of nitrate concentration are reported.

4.4 HYDROGEOLOGIC CHARACTERIZATION PROGRAM

The major assumption fundamental to the environmental integrity of the experimental program at Santa Cruz is the hydrologic isolation of the alluvial aquifer from the leach zone by intervening rock units of very low permeability. Verification of this isolation is essential to assuring that no water quality degradation will occur in the overlying alluvial aquifer.

The following descriptions are based on information from borehole SC-35, which was used to define preliminary ore block characteristics. Top of the ore zone is defined by a cut-off grade of 0.7 percent Cn, placing it at 1898 feet below ground surface. The bottom of the conglomerate is 900 feet below ground surface. The alluvium is estimated to be about 700 feet thick, which places the bottom of the alluvium at least 1,100 feet above the ore zone. This 1,100-foot interval is probably comprised of about 200 feet of conglomerate, 800 feet of granite, and 100 feet of biotite-quartz-feldspar porphyry (Figure 4-3).

The depth to groundwater may be as much as 550 feet, making the thickness of saturated alluvium about 150 feet. However, the total thickness of the aquifer is uncertain since the upper portion of the underlying conglomerates may be permeable (Halpenny, 1970). The conglomerate is expected to become more indurated and less permeable with depth, but little hydrologic data are available and the local saturated thickness is unknown.

In order to demonstrate the lack of hydrologic connection between the ore zone and the alluvial aquifer, a more comprehensive definition of the geologic and hydrologic characteristics of this interval is required. To obtain this information a borehole will be drilled within a 100-foot radius of the hole used to define ore-block flow characteristics (see Section 4.1.2). The borehole will be placed within the boundary of the field test plant (Figure 4-2).

Procedures to be carried out during drilling include: logging, sampling, coring, geophysical logging, and hydrologic testing. Because many of these tests will be dependent on borehole stability and integrity of rock formations, scheduling will be based on a series of contingencies. Attempts at coring will be made in more indurated rock; rocks are expected to become more coherent in the lower parts of the conglomeratic unit. Hydrologic tests will require hole stability. Geophysical logs will be run in open hole.

All requirements of the ADWR for well construction, licensing of well drillers, and permitting of wells will be fulfilled during drilling and well installation (see Section 4.6 for details).

Although many decisions will need to be made on-site as drilling is in progress, the following plan is presented for costing purposes:

- A 6-inch borehole will be drilled to a depth of 800 feet (100 feet above the bedrock/conglomerate contact) using a dual-tube, reverse circulation method.
- Continuous logging of drill cuttings, water recovery, and drilling rate will be performed during the drilling program by trained personnel.
- Drill cuttings will be retained at 5 or 10-foot intervals for additional geologic examination. Sample collection, labelling, recording, storage and handling will follow procedures detailed in Section 4.6.
- Borehole will be drilled with fluids capable of stabilizing the borings. Use of bentonic muds will be avoided if possible. Polymer-based drilling muds are preferred.
- Temporary casing of 4-inch i.d. flush steel will be set from surface to 800 feet depth.
- Continuous wireline coring (size HQ) will proceed from 800 feet to a total depth of 1,800 feet. Cores will be logged and retained for laboratory tests. Twenty laboratory determinations of both permeability and porosity will be completed.
- During coring, 20 packer tests will be performed over 50-foot intervals from 800 to 1800 feet. A single packer, constant head test with variable inflow rates will be run for 1 1/2 hours per test or until inflow rates stabilize.
- Temporary casing will be removed.
- Geophysical logging of the hole will include:
  + Temperature.
  + Spontaneous potential.
  + Resistivity.

+ Natural gamma.
+ Gammn gamma.
+ Neutron.
+ Caliper.
+ Spinner.

- o Hole will be abandoned by grouting with cement/bentonite mixture from total depth to 20 feet below the surface. The remaining portion of the boring will be backfilled with cement-grout.

These tests are designed to aid in verifying hydrologic isolation of the alluvial aquifer by providing hydrogeologic parameters of the underlying units.

- o The cores will allow observation of the competence of the rocks and presence and degree of fracturing to distinguish depth intervals of rock units that may have increased permeability along faults or breccia zones.
- o Laboratory tests on the core will provide permeability and porosity measurements.
- o In-situ determinations of permeability will be derived from the packer tests.
- o Geophysical logging will aid in characterizing stratigraphic units, and their corresponding porosities and zones of increased permeability.

4.5 CORRECTIVE ACTION

As defined by the regulations of the EPA UIC Program (40 CFR 144.55), corrective action is that activity implemented prior to injection which will prevent the migration of injected fluids to an underground source of drinking water through improperly sealed, completed or abandoned wells. These regulations apply specifically to Class I through III well permits and, therefore, are not directly applicable to the Santa Cruz field experiment. However, the regulations of the ADWR (ARS 12-15-816) concerning well abandonment could be interpreted to apply in the case of the Santa Cruz activity. The bulk of these regulations apply to boreholes permanently abandoned and not temporarily capped wells designed for reentry, as is the case with the exploratory borings which penetrate the Santa Cruz ore body.

Considering the nature of the proposed injection/recovery system and the distribution of the monitoring wells slated for installation, it appears that six exploratory borings will require proper and permanent abandonment. The location of the field experiment lies between Borings SC-35 and SC-46. With the current uncertainty concerning the exact orientation of the two 5-spot well array, six borings may lie within a 500 to 600-foot radius of the experimental operation. Therefore, the following exploratory borings are slated for complete abandonment at this time: SC-19, SC-24, SC-38, SC-46, SC-47 and SC-51 (See Figure 4-2).

To prevent the uncontrolled migration of process fluids from the zone of injection to the overlying alluvial aquifer, the following will be completed:

- In cased holes, it will be necessary to perforate existing casing prior to grouting. This procedure will allow grout to enter the annular space between casing and borehole.

- Borings will be properly conditioned prior to grouting in order to ensure a good bond between the grout and casing, and grout and the formation. Conditions that could cause poor grouting include high mnd strength, high viscosity or density of fluids in the well, and excessive chemical content of borehole fluids (Smith, 1976).

- Grout all borings with a low permeability, corrosion and shrinkage resistant, sodium bentonite-based grout.

- Grouting will be performed utilizing the tremie pipe positive displacement method of placement. This method involves placing a tremie pipe to the bottom of the drill hole and pumping a desired quantity of grout slurry through the pipe. The amount to be pumped will be the quantity calculated to fill approximately 40 feet of the boring. After pumping this amount, the tremie is pulled up 40 feet, and a quantity of grout calculated to fill an additional 40 feet of the hole is pumped through the tremie. This procedure is continued until the entire length of the boring has been grouted.

If comprehensive drill logs and completion records are not available for a particular boring, it will be necessary to perform caliper and TV logging to determine downhole conditions prior to grouting.

If it is determined that the borehole has caved, or casing has collapsed to the point where grouting tools cannot be placed, it will be necessary to redrill the hole to the original total depth, or 1,800 feet, whichever is less, prior to grouting.

For costing purposes, several assumptions have been made concerning the conditions of the borings to be grouted.

- o All six borings will require redrilling prior to grouting.
- o Available information concerning the number of exploratory holes to be grouted and the condition of those wells is correct.
- o All borings have been cased through the alluvium and the conglomerate with mild steel pipe, and that there is no grout behind the casing. Wells are uncased below the conglomerate.

4.6 MONITORING WELL DESIGN AND CONSTRUCTION

The monitoring scheme consists of three wells designed to monitor piezometric head levels and water quality in the alluvial aquifer. The purpose of these wells is to confirm hydrologic isolation of the leaching test zone from the overlying source of drinking water and to detect possible excursions of lixiviants from the well head, other surface facilities, or the casing string. The locations of these monitoring wells relative to the experimental well field are shown in Figure 4-2.

The monitoring well design is illustrated in Figure 4-5. It is assumed for design purposes that the monitoring wells will extend to total depths of 700 feet each (the probable base of water-bearing strata). The water table is assumed to occur at a depth of 550 feet. Piezometric head measurements and

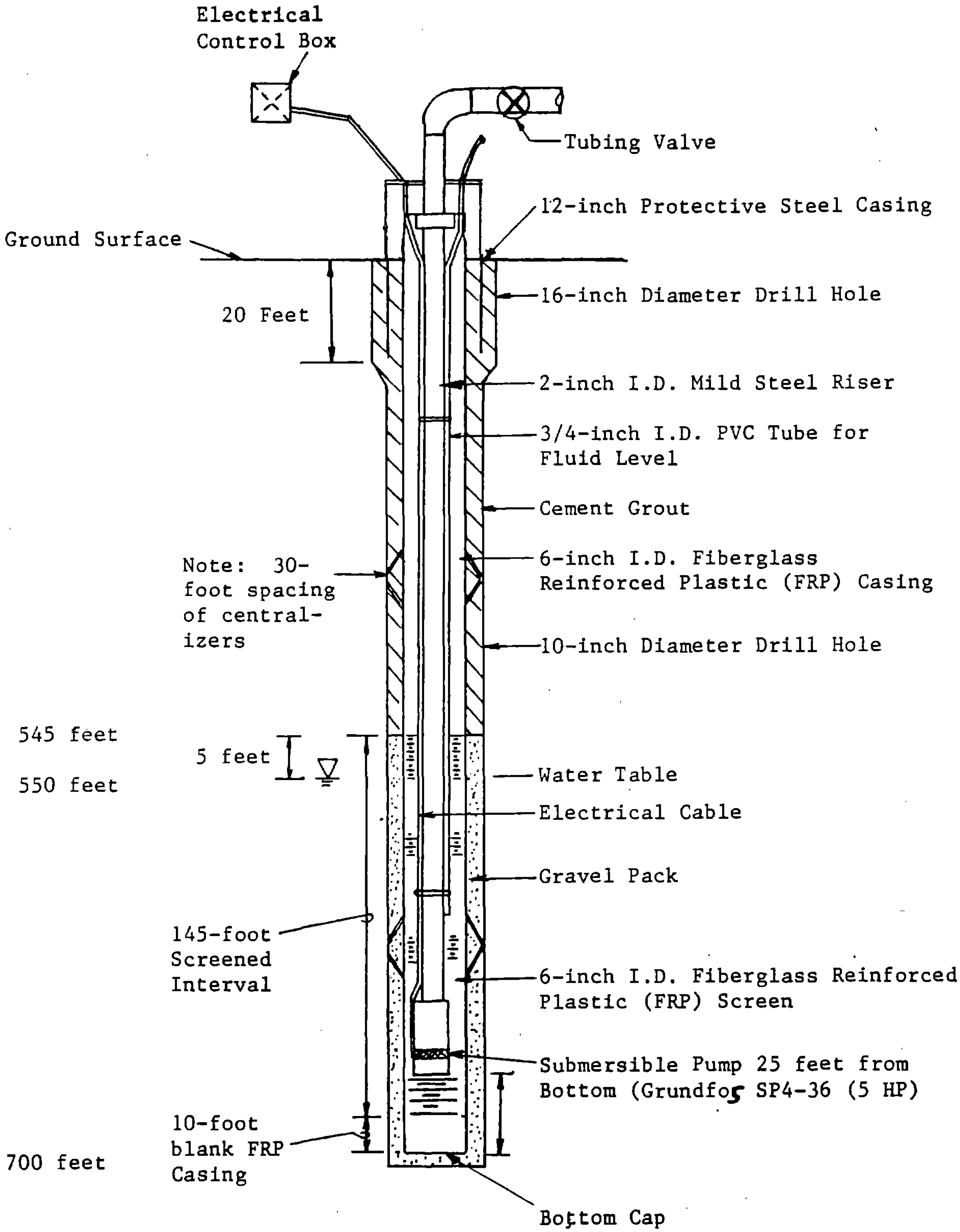


FIGURE 4-5. Monitor Well Design

water samples will be obtained from a screened interval in the lowermost 145 feet of each well.

The location and spacing of wells and design of individual wells may be slightly adjusted following completion of the proposed hydrogeologic characterization to provide the best possible coverage. Construction details of the individual monitoring wells may also be further adjusted after borehole drilling, logging, sampling and testing to isolate particular water-bearing zones.

The monitoring well system will be constructed by contractors selected by ASARCO or by the Field Experiment Operator subject to ASARCO"s approval. Overall supervision of monitoring well construction will be the responsibility of the Owner's Hydrogeological Representative (HR). The HR should be a geotechnical engineering or hydrogeological firm with experience in groundwater-related environmental engineering projects similar to the proposed work. This firm will be selected on the basis of a demonstrated capability to direct the drilling, installation and testing procedures outlined herein. The HR will direct and supervise the work of the Drilling Contractor and the Geophysical Contractor, who will also be selected by ASARCO or by the Field Experiment Operator subject to ASARCO's approval. The Drilling Contractor will be responsible for drilling the monitoring wells, and installation of monitoring equipment (pumps and ancillary equipment). Geophysical logging of boreholes will be performed by the Geophysical Contractor.

4.6.1 Fees, Permits & Licenses

All requirements of the ADWR concerning well construction standards, licensing of well drillers, and permitting of wells will be fulfilled prior to and during drilling and installation of monitoring wells. In addition, drilling will be performed by a Drilling Contractor with demonstrated capabilities to perform the work according to the specifications outlined herein.

In conformance with the regulation of the ADWR (AARR 12-15-804), the Drilling Contractor or his authorized representative will be a licensed water well driller in the State of Arizona. The Drilling Contractor will also be registered with the Arizona State Contractors Board as a licensed water well driller. The Drilling Contractor will be responsible for conforming to all current well drilling regulations enforced by the State of Arizona and Pinal County.

ASARCO will submit an Intention to Drill card to the ADWR prior to drilling, and a well log will be submitted by the Drilling Contractor to the ADWR within 30 days of completing each well. The Drilling Contractor will provide a copy of these documents to the Field Experiment Operator.

4.6.2 Inspection of Materials

All materials and equipment provided by the Drilling Contractor will be inspected and approved by the HR. The HR reserves the right to reject any equipment, material or workmanship that, in his judgment, is not acceptable and not in keeping with the provisions and intent of these specifications and drawings.

4.6.3 Drilling Supervision

The HR will be responsible for overall supervision of drilling and well installation. The HR will communicate directly with the Drilling Contractor during all phases of drilling, testing, and installation of monitoring equipment.

4.6.4 Drilling

A total of three boreholes are to be advanced to depths of about 700 feet each. These boreholes will be advanced by reverse circulation methods with sir or air-water mixtures using dual wall pipe to make 5 1/2 inch diameter holes. Boreholes will be reamed to 10 inches in diameter using a mud rotary drilling method. The Drilling Contractor shall dispose of drilling fluid, cuttings and discharged water in a manner approved by the HR so as not to create damage to public or private property.

4.6.5 Well Measurement

All measurements for well depths will be taken from the ground surface adjacent to the well. The Drilling Contractor will verify all hole or depth measurements.

4.6.6 Logging & Sampling

Continuous logging of all test borings will be performed during the drilling program by the HR. The Drilling Contractor will assist the HR in the performance of all logging and sampling activities. All soils encountered are to be classified by the Unified Soil Classification System (ASTM D2487). Samples of drill cuttings will be retained at 5 or 10-foot intervals for additional geologic examination. The samples will be secured, enclosed and plainly labeled in containers.

4.6.7 Surface Casing

The initial 20 feet of hole will be drilled to a diameter of 16 inches to accommodate a 12-inch diameter surface casing. Casing will extend a minimum of 20 feet below ground surface and a minimum of 1 foot above ground surface. The surface casing will be cemented in-place its entire length by a tremie pipe method until return occurs at the ground surface. The cement seal will be a neat cement or a sand-cement mixture, approved by the HR. The surface casing will be new steel conductor pipe, with a 1/4-inch or greater wall thickness.

4.6.8 Use of Drilling Muds

The three boreholes will be drilled with fluids capable of stabilizing the boring wall. Drilling fluids will be provided by the Drilling Contractor and will be approved before use by the HR. Use of bentonitic muds will be avoided if possible, but may be permitted by the HR, if necessary, to allow drilling to proceed. Polymer-based drilling muds are preferred. The Drilling Contractor will maintain a drilling fluid log showing date, time, depth, Marsh Funnel Viscosity, drilling fluid weight, and pH, and shall record any drilling fluid additives used, including time of introduction, as well as any other pertinent information.

4.6.9 Alignment

The Drilling Contractor will be required to drill the borehole and install the casing straight, plumb and concentric in accordance with AWWA standards A100-84, Section C.1 (AWWA, 1984). It is the Drilling Contractor's responsibility to demonstrate that the hole meets the above requirements. If the work performed fails to meet the alignment requirements, a new well shall be constructed by the Drilling Contractor at his own expense, at a location designated by the HR.

4.6.10 Geophysical Logging

Immediately following the completion of borehole drilling, a suite of geophysical logs will be run in each borehole by the Geophysical Contractor. This work will be performed in open, uncased boreholes, following withdrawal of the drill bit, if possible. The following suite of geophysical logs will be run through the entire depth interval of each borehole:

- Temperature and differential temperature.
- Caliper.
- Spontaneous potential.
- Resistivity.
- Three-dimensional sonic velocity.
- Natural gamma.
- Gamma density.
- Thermal neutron.

The Geophysical Contractor will confer with the HR and the Drilling Contractor in coordinating and scheduling the geophysical logging program.

In the event that the borehole will not remain open after withdrawal of the drill bit and any temporary casing, geophysical logging will be performed from inside the casing. Only gamma ray and neutron logs will be performed through cased sections of the boreholes.

4.6.11 Value Engineering and As-Builts

Following the completion of drilling, sampling and logging of each borehole, the HR, in collaboration with the Drilling Contractor, may adjust details of the design specified herein to respond to the hydrogeologic conditions encountered in each boring, and to provide the highest quality of information for long-term monitoring purposes. Detailed records of all final dimensions, materials and installation methods will be developed by the HR and submitted to ASARCO and the Field Experiment Operator.

4.6.12 Installation of Well Screen, Casing, and Filter Pack

The well screen casing and filter pack will be installed in each borehole following the completion of all geophysical surveys. Installation will be performed by the Drilling Contractor, under the direct supervision of the HR.

Well screen and casing, as shown in Figure 4-5, will be installed through any temporary drill casing, or in an open borehole after removal of drill casing, depending on the stability of the borehole.

Six-inch I.D. Fiberglass Reinforced Plastic (FRP) casing and screen will be installed in each borehole by the Drilling Contractor under the supervision of the HR.

The screen will be installed over the interval from a total depth of 545 to 690 feet, as shown in Figure 4-5. A 10-foot section of blank casing with a threaded bottom cap will be placed in the lowermost 10 feet (from total depth 690 to 700 feet) to act as a sediment trap. The screen slot size will be 0.040 inches, or selected on the basis of a geologic examination and/or mechanical size analysis of the natural water-bearing sediments and the artificially introduced gravel pack material. The screen will be factory-slotted to provide maximum inlet area consistent with strength requirements producing inlet slots with sharp outer edges, widening inwardly to mnimize clogging. Intermediate screen sections will be joined by threaded and coupled connections.

Blank casing will be installed over the interval from the wellhead to a depth of 545 feet. The blank casing will be joined to the screen, and intermediate sections will be joined by threaded and coupled connections.

The placement depths specified above may vary upon completion of drilling, logging, sampling and testing each individual borehole.

The position of the casing and screen in the center of the borehole will be maintained by placement of casing centralizers at 30-foot intervals. The centralizers will be aligned uniformly on the casing and screen during installation to avoid blockage of the casing/borehole annulus which could result from random placement and which could prevent placement of tremle pipes for proper installation of filter pack and grout.

A filter pack surrounding the screened interval will be placed by the tremie pipe method from the bottom of the hole to roughly 10 feet above the top of the screened interval. The Drilling Contractor will retain an accurate log of the volume of filter pack material placed in the borehole and the depth interval covered. The filter pack will consist of clean, uniform, well rounded silica sand with less than 1 percent calcareous material. Ninety-eight to 100 percent of this material will pass through a No. 6 sieve, while 98 to 100 percent shall be retained on a No. 16 sieve. Alternatively, the filter pack grain size may be designed on the basis of a mechanical size analysis of the waterbearing sediments encountered in the boreholes or may conform to changes in the slot size specified above for the well screen.

4.6.13 Well Development

Following installation of the well screen and casing in each borehole, the residual drilling fluids will be purged from the well by the Drilling Contractor. The well will then be developed by use of a jetting tool to force a clear water/air mix through the screen into the filter pack. Well development will continue until the discharged water is free of sediment, as determined by the HR.

4.6.14 Grouting

Following well development, the Drilling Contractor will seal the annular space between the blank casing and the borehole wall over the entire interval from the top of the filter pack to the ground surface with a low permeability, corrosion and shrinkage resistant, sodium bentonite-based grout. Prior to grout installation, the HR may require the Drilling Contractor to flush the annular space with clean water.

Grouting will be performed utilizing the tremie pipe positive displacement method of placement, which was previously described (Section 4.5).

4.6.15 Installation of Dedicated Pumps

After well development and grout placement have been completed, the Drilling Contractor will install a permanently dedicated submersible pump in each well. The pumps shall be placed 25 feet above the bottom of the casing string. This placement is designed to prevent the entry of blank casing from the sediment trap below the screened interval into the pump. The Drilling Contractor will provide and install the pump, discharge riser and electrical wiring as directed by the HR, and shown on Figure 4-5. The pump will be a 5 HP, 4-inch diameter Grundfos SP4-36 stainless steel pump or an equivalent unit that is approved by the HR. All pumps will be installed in accordance with the written instructions of the manufacturer. Pumplift requirements are greater than 550 feet, with discharge capabilities of 15 to 25 gpm. Installation will include discharge riser pipe, electrical wiring and 1/4-inch plastic airline tubing from the pump to the ground surface.

In addition, the Drilling Contractor will install a 1-inch PVC pipe extending from 2 feet above the ground surface to roughly 10 feet above the depth of placement of the pump. This pipe will be open-ended and will serve as a conduit for insertion of probes into the well for piezometric head measurements.

After installation of the pumps and ancillary equipment has been completed, operating tests will be carried out to assure that the pumping installation works properly. The pump shall be given a running field test in the presence of the HR for a minimum of two hours. The pump shall be operated at its rated capacity or such other point on its head-capacity curve selected by the HR. The Drilling Contractor shall provide an accurate and acceptable method of measuring the discharge flow. An insulation resistance test of the cable and the motor shall be conducted prior to installation of the pump, during installation of the pump, and after installation is complete. The resistance readings shall not be less than 10 megohms.

Tests shall assure that the units and ancillary equipment have been installed correctly, that there is not objectionable heating, vibration, or noise from any parts, and that all manual and automatic controls function properly. If any deficiencies are revealed during testing, such deficiencies shall be corrected and the tests shall be reconducted.

4.6.16 Protection & Capping

During the progress of the work, the Drilling Contractor will use all reasonable measures to prevent either tampering with the well or entrance of foreign material. The Drilling Contractor will be responsible for any objectionable material that may enter the well and its consequences until completion and acceptance by ASARCO and the HR. Upon completion of the well, the Drilling Contractor will furnish and install a welded cap and discharge outlet pipe on the well to prevent any pollution from entering the well and to allow normal operation of the pump. The cap will consist of 1/4-inch steel plate cut to the outside diameter of the casing and tack-welded to cover the top of the well. The cap shall have holes of suitable diameters to allow for placement of the discharge riser pipe, electrical wiring and the 1-inch PVC pipe used for measurement of piezometric head levels.

4.6.17 Sanitation and Cleanup

As a reasonable standard, the Drilling Contractor will adopt by reference and agree to comply with all State of Arizona and Pinal County laws, general rules, and regulations for sanitary conditions on the work site or adjacent thereto. There will be no pollution of streams, lakes, or water supply on or near the work site.

Upon completion of the work, the Drilling Contractor will remove from the vicinity of the work all equipment, buildings, rubbish, unused materials and other material belonging to them or used under their direction during construction. Drilling mud and cuttings will be disposed of on-site and in a manner selected by the Field Experiment Operator. Any excavations constructed by the Drilling Contractor, such as mud pits, will be graded and conform to the natural appearance of the landscape.

4.7 PREOPERATIONAL MECHANICAL INTEGRITY PROCEDURES

The EPA UIC Program regulations (40 CFR 146.8) state that an injection well has mechanical integrity if:

- There is no significant leak in the casing, tubing, or packer.
- There is no significant fluid movement into an underground source of drinking water through vertical channels adjacent to the injection well bore.

These regulations further define several methods to demonstrate both the integrity of the casing, tubing or packer, and the lack of significant fluid movement through vertical channels adjacent to the well bore. These regulatory stipulations are not specifically referenced to the Class V well, and are discussed above to appropriately define the terminology and delineate two circumstances which could produce an environmental consequence.

A program of preoperational mechanical integrity tests are specified herein for the Santa Cruz field experiment. With the exception of annulus pressure determinations, these tests will be performed on the entire ten-well configuration, which includes the following:

- Three test wells completed during the ore block flow assessment and well pattern flow control field programs (one of these wells will be incorporated into the two 5-spot leach field array as a recovery well).
- Five additional recovery wells.
- Two injection wells.

As presented in detail in Chapter 2 of this document, the test leach wellfield will consist of both recovery and injection wells, with some variation between the two well constructions. The injection well will be fitted with injection tubing which will pass the leach solution to the deep ore interval. This tubing will be fitted with a deep packer which will isolate the solutions from the upper annulus between the tubing proper and the well casing. In contrast, the recovery well contains no packer, only production tubing to contain the pregnant solution as it passes from the pump bowls to the surface. The well casings of both types of wells will be fully cemented.

All preoperational mechanical integrity tests will be performed during the flow block assessment, well pattern flow control or wellfield construction phases. Several of the tests discussed below are an integral part of the overall program plan. These activities are discussed in this section of the document because such actions demonstrate mechanical integrity. These tests are part of the program plan previously presented in Chapter 2, no costs are provided in this chapter.

In their approximate order of completion, the following actions will be incorporated into the Santa Cruz experimental program development to verify the mechanical integrity of the two test, six recovery and two injection wells:

- o Cementing records will be kept to demonstrate the presence of adequate cement filling the annulus between the borehole wall and the well casing.
- o Each borehole will be pressure tested subsequent to casing installation and cementing. The pressure testing will consist of prior to perforating, filling the borehole with clear water, and observing and measuring the amount of inflow while exerting a slight ambient pressure at the well head for 6 hours.
- o Temperature logs will be completed to document the top of the cemented interval.
- o Cement bond logs will be completed both before and after stimulation.
- o Multi-armed caliper logs will be performed in the upper 1,000 feet of any hole subjected to stimulation.

- o Following the equipping of all wells in the leaching array with the proper injection and recovery equipment, perform 48 hours of testing of the injection/recovery well system will be performed. Testing will consist of continuous monitoring of annulus pressure of the injection wells while injecting native water, and measurement of injection pressure and flow rate. For recovery wells, native water will be pumped while continuously monitoring well head pressure, flow rate and dynamic pumping levels.

4.8 BASELINE WATER QUALITY PROGRAM

In order to establish groundwater conditions that presently exist in the area surrounding the site, baseline data will be collected. An inventory of wells to be used in the baseline program will be completed. Well information to be inventoried includes:

- o Location, total depth, diameter and owners of wells.
- o Well yield, water quality and local usage.
- o Casing depth, type of casing, perforated interval(s) and monitoring zones.
- o Elevation of well and static water level.
- o Past well problems, historic water level and water quality fluctuation records, and permission to use the well for monitoring purposes.
- o Formation name(s) and rock type(s), and lithologic properties of aquifer(s).
- o Geophysical and driller logs.

The specific wells included in the baseline sampling and testing program are listed below and are shown on Figure 4-2.

- o The three monitor wells slated for completion in this program plan.
- o Wells TW-2, TW-3 and TW-4 completed by Casa Grande West, and located east, south and southwest of the test facility.
- o Ollerton Farm Well No. 2 (OW-2) located northwest of the test facility.

The three monitor wells will be constructed with 6-inch FRP casing that will be slotted from a depth of 545 to 690 feet. These wells will be properly developed prior to beginning the sampling program.

The TW series wells were constructed as part of a test pumping evaluation completed by Casa Grande West.

- TW-2 has 20-inch casing to a depth of 790 feet, and 16-inch casing from 790 feet to 1,200 feet below land surface. The casing is perforated from a depth of 400 to 1,190 feet.
- TW-3 has 20-inch casing from the surface to 500 feet, and machine-slotted 20-inch casing from 500 to 1,220 feet.
- TW-4 is cased with 20-inch blank steel casing from the surface to 500 feet and with machine-slotted 20-inch casing from 500 to 1,200 feet below surface.

Water quality data from the TW wells are available from 1978, 1980, and 1981 through 1983. More recent data may be available from Casa Grande West.

No data were provided on the Ollerton Farm well; however, the well is expected to have at least a 12-inch casing diameter with a slotted interval at significant depths above and below the present water table.

The TW series wells and the Ollerton well are assumed to be operable, and able to provide water at the well head for sampling purposes.

Methods of sampling and testing that will be followed during the baseline monitoring program are described in detail in the Quality Assurance/Quality Control (QA/QC) Program included in Appendix C of this document. Included in the QA/QC program are specific requirements regarding the preparation for sampling, the sequencing of sampling procedures, sample collection and preservation, sample labeling, chain-of-custody requirements, sample shipment and record keeping. These procedures will be followed throughout the baseline monitoring program to ensure that representative, accurate samples are collected and analyzed.

The baseline groundwater monitoring program will commence nine months prior to the startup of the acid leaching operation. This will necessitate the completion of the three monitor wells to be installed under this program plan at least nine months prior to the completion of the test facility.

All wells included in the baseline program will be sampled at three-month intervals beginning nine months before startup. This will result in a total of four samples from each well. A total of 28 samples will be tested, plus four duplicate and two blank samples during each sampling period.

The parameters to be tested during the baseline program will include both field and laboratory analyses. These parameters are presented in Table 4-2.

4.9 SURFACE FACILITY CONSTRUCTION

Protection of the environment is an inherent design parameter of the SX-EW facility. The design provides for full containment of process solutions with no discharge of pollutants on to the ground surface or into the vadose zone. The following features are present in the design:

- Stored reagents will be contained in an environmentally safe manner with berms constructed around the perimeter of each containment in case of leakage. Processing chemicals will be stored within a containment area, apart from one another and clearly labeled.
- Protection of the surface will be provided in areas surrounding well bores so that uncontrolled discharge would be collected and drained to an appropriate containment.
- Containment of ore solutions (pregnant leach and raffinate solutions) will be designed in such a manner as to prevent any solutions containing pollutants from reaching the vadose zone. The containment

TABLE 4-2 BASELINE WATER QUALITY PARAMETERS FOR FIELD AND LABORATORY ANALYSIS OF WATER QUALITY

Field Measurements

* Water Levels or Flow
* pH
* Specific Conductivity (umhos/cm)
* Temperature (C°)

Laboratory Measurements (mg/l)

* Total Dissolved Solids
  Total Hardness (as $CaCO_3$)
  Aluminum (Al)
  Arsenic (As)
  Barium (Ba)
  Boron (B)
* Carbonate (CO_3^{-2})
* Bicarbonate (HCO_3^-)
  Cadmium (Cd)
* Calcium (Ca)
* Chloride (CL^-)
  Chromium (Cr)
* Copper (Cu)
* Fluoride (F^-)
* Iron (Fe)
  Lead (Pb)
* Magnesium (Mg)
  Manganese (Mn)
  Mercury (Hg)
  Molybdenum (Mo)
  Nickel (Ni)
  Nitrogen: Ammonia (NH_3)
  Nitrite (NO_2)
* Nitrate (NO_3^-)
* Potassium (K)
  Phosphate (PO_4^{-3})
  Selenium (Se)
* Sodium (Na)
* Sulfate (SO_4^{-2})
  Sulfide (S^-)
  Zinc (Zn)
* Kerosene

* Constituents selected as indicator parameter for use in operational and post closure monitoring.

ponds will be nnderlain by a double lining of high density polyethylene (HDPE). The following guidelines for construction quality control of lined ponds will be adhered to:

+ The subgrade in contact with the liner will be a continuous, relatively smooth surface free of protrusions from rocks or other irregularities.

+ Liner material will be tested in the laboratory prior to delivery on site and shall meet or exceed National Sanitation Foundation's mlnimum materials properties (NSF, 1983).

+ Seams will be welded and each seam will be visibly inspected after welding operations. Destructive shear and peel tests will be performed on field seams.

o To ensure that there is no significant leakage, a leak detection system will be installed in each pond.

Testing of the surface facility will be performed to assure proper performance of the system prior to operation. This system wide check will verify that all facilities function as designed and there is no leakage.

During operation, daily visual monitoring of all above ground systems will be performed.

4.10 OPERATIONAL MONITORING PROGRAMS

4.10.1 Well Field Monitoring

The annulus pressure of the tamping fluid above the packer, injection pressure and injection flow rate will be monitored to detect any changes which could indicate leakage through the injection tubing, the well casing or around the injection tube packer. The annular tamping fluid will be clear water maintained at standing hydrostatic pressure. The annulus will be fitted at the well head with a fluid reservoir, access to the system to measure pressure, a pressure sensor and a continnous strip recorder. Injection pressure will be measured mannally with a standard pressure gauge at the well head, and a combined flow rate will be measured immediately upstream of the manifold between the two injection wells.

The injection pressures and flow rate will be measured and recorded once a day throughont the entire test period. The annulus pressure strip recorder will be reloaded weekly and observed daily.

An alarm and shutdown device will be installed so that if annulus pressure drops below or exceeds a preset amount, the operation will automatically shut down until the cause of failure is located. The shutdown pressure variations will be determined during preoperational testing and may change over the course of operation to take into account variations in injection pressure and injected fluid temperatures, which may cause significant changes in annslar pressures.

Contingency plans will be put into effect whenever an unusual change occurs in the relationship between pressure and flow over a short period of time. The magnitnde of change in a given period of time that constitutes an alert level will be determined during preoperational testing and may change over the course of the operation.

Each of the six recovery wells will be fitted with well head pressure gauges, flow meters and a downhole airline to allow for the measurement of dynamic pumping head in the well bore. Measurement of dynamic head distribution, recovery flow rate and line pressure will be performed daily.

The remaining two test wells adjacent to the two 5-spot arrays will be fitted with well bore airlines to allow for head measurements. The static head in each well will be measured weekly.

4.10.2 Water Quality

Water quality determinations will be performed during the field experiment operational phase from water derived from the three project monitoring wells, with supplemental baseline confirmed on the four outlying irrigation or test wells designated in the baseline program (TW-1, TW-2, TW-3 and OW-2). The operational program could involve fluids collected in the leak detection systems of the process and evaporation ponds.

All sampling and testing will be performed in compliance with the procedures outlined in the QA/QC manual (Appendix C). A record of all activities related to groundwater monitoring will be maintained for each monitoring point. Data to be included on these records are discussed in the QA/QC manual. Reporting of the results of the groundwater quality monitoring program will be made to ADEQ on a quarterly basis.

As delineated on Table 4-2, a set of indicator parameters have been selected from the more comprehensive baseline suite. Testing of these indicator parameters will be performed monthly on water collected from the three project monitoring wells for the first five months of in situ leaching. On the sixth month of operation, the baseline suite will be run on all designated wells in the operational monitoring system. After the comprehensive testing of all wells on the sixth month, the three project monitoring wells will be tested for indicator parameters quarterly for the remaining year of operation. At the cessation of leaching, all wells in the system will be tested for all baseline parameters.

The monitoring systems of the process and evaporation ponds will be checked on a weekly basis. Each sump access port will be probed to determine whether fluid has collected in the sump. If no fluid is found, a record of this lack of seepage will be made. If excessive fluid is present in any of the pond sumps, then a sample of the seepage will be collected and analyzed for the indicator parameters listed on Table 4-2. Excessive fluid is defined by an inflow rate to the sump in excess of 1.0 gpm. Fluid inflowing at a lower rate will be pumped from the sump into the pond on a daily basis.

4.11 CONTINGENCY PLAN

4.11.1 Alert Levels

Alert levels are changes in natural or operating system parameters which exceed the normal ranges of variation and which indicate uncontrolled excursions of lixiviants to the overlying alluvial aquifer. These fall into two general categories:

a) Variations in natural parameters such as groundwater chemistry and piezometric head distributions.

b) Variations in operational parameters of the injection/recovery/process system such as flow rates snd operating pressures.

If flows into any pond sump in excess of 1.0 gpm (1,440 gallons per day) persist for two weeks, an investigation of possible sources of the seepage will be initiated. The investigation will include reducing the fluid level in the pond to allow inspection of the liner and all seams, and installation of angled drill holes at the perimeter of the pond for monitoring moisture profiles. Based on the results of the investigation, a remedial action plan will be developed and submitted to ADEQ for its approval. The approved plan would be implemented within one week of ADEQ approval.

Additional specific values of alert levels for the Santa Cruz field experiment will be established after completion of the hydrogeologic characterization efforts and preoperational systems tests. These will be used to establish the normal fluctuations of various natural parameters and the operating ranges of the injection/recovery/process system.

Once these parameters have been defined, they will be monitored by the Field Experiment Operator or ASARCO throughout the period of operation, closure and post closure monitoring.

The list of critical parameters include the following:

- Piezometric head distributions in monitor wells and vicinity wells.
- Chemistry of groundwater.
- Annulus pressure.
- Injection and recovery flow rates.
- Percentage of return of lixiviants.
- Ore zone transmissivity and storativity.

4.11.2 Action Guidelines

Action guidelines are detailed, specified procedures which are to be followed by the Field Experiment Operator and ASARCO if and when variations in critical monitoring parameters exceed the established alert levels. The guidelines are as follows:

- Remeasurement & Reevaluation of Data
  Remeasurement of the parameter(s) of interest is performed immediately under carefully controlled conditions to verify the initial readings. If remeasurement results in a verification of the alert level condition, the data are critically reevaluated in light of current conditions such as weather, operation of nearby wells and other factors which may have led to the observed changes in monitoring parameters. Remeasurement of all other monitoring parameters is performed to aid in this evaluation. The alert levels themsclves are critically reevaluated in light of the new data.

- Complete or Partial Shutdown of the Injection Process
  In cases where a significant excursion of lixiviants is clearly indicated by the existing data, a complete or partial shutdown of injection operation will be performed immediately. If remeasurement and reevaluation of the data do not clearly point to a measurement error or some other factor not related to the injection/recovery/ process system as the cause of the alert level within ten working days, the injection operation will then be termlnated. Pumping of recovery wells will generally be continued, and pumping rates may be adjusted to inhibit or reverse the flow of contaminated groundwater. The injection system will not be restarted until the system failure has been located and repaired.

- Communication with ADEQ
  In the event that a shutdown of the injection system has to be performed based on the guidelines outlined above, the ADEQ will be notified verbally within 72 honrs. A brief letter report will be submitted to ADEQ within five days outlining the nature of the problem and the procedures being followed. At the present time there are no established forms issued by the State for this purpose (Fifield, 1987; Russell, 1987). The agency will then be consulted and kept well informed about the course of follow-up investigations, remedial action planning and plans to restart the injection system.

- Additional Investigations Using the Existing Facilities
  During the initial stage of follow-up investigations, the existing facilities are utilized to target the source and determine the extent of the problem. The investigation program would be determined by the nature of the problem itself, but could include some or all of the following procedures:

  + Mechanical integrity testing of well head, surface facilities, casing string, etc.

  + Geophysical logging, such as cement bond and caliper logs.

  + Borehole TV inspections.

  + Additional sampling and chemical testing of the groundwater.

  + Pump tests using selected wells to determine hydraulic connections.

- Additional Investigations Utilizing Construction of New Facilities
  When significant excursions are targeted, or in cases where the initial investigations do not clearly locate the source of the problem, further investigations utilizing new monitor well installations may be required. Locations of new wells will be determined by the currently available data. New wells can serve as additional monitoring wells to provide chemical quality data on affected groundwater and to provide piezometric head levels in zones of interest within the groundwater system.

- Remedial Action
  A remedial action plan would be instituted as a result of the investigations detailed above, if needed. The advice and consent of the ADEQ would be obtained in the design of a Remedial Action Plan. The exact nature of any program would be determined on the basis of current information, but could include some or all of the following:

  + Adjusted pumping sequences in existing wells.

  + Installation of new monitoring wells or pumping wells.

+ Neutralization or dilution of lixiviants by injection of fresh water or water containing appropriate chemical agents.

+ Repair of liners, casings, surface facilities, etc.

+ Adjustment of operating procedures such as reagent handling.

4.12 CLOSURE PLAN

4.12.1 Wellfield

As a key assumption to the closure of the wellfield, the U.S. Bureau of Mines has specified that a temporary closure be used, as additional use of the existing 5-spots may be considered at a future date. Therefore, the closure is deemed temporary and must provide for easy reentry into all wells. The cost for completing the temporary closure procedure will be assimilated by the site operator, ASARCO. The costs summaries presented in Appendix C, therefore, do not include any costs for the actions discussed below.

Adequate procedures established herein to temporarily secure the ten wells of the experimental system assume the previous removal of all pumps, injection and production tubing, packers and ancillary downhole and well head equipment. The well heads would then be fitted with a locking steel cap to prevent unauthorized access to the well bore. This approach to temporarily securing the wells is in conformance with ADWR requirements for securing exploratory wells left open for reentry (AARR 12-15-817). Within 30 days of project completion, a report will be submitted to ADWR which details the number of wells drilled, depth to water, and construction details related to providing an opportunity to reenter.

The three monitoring wells which only penetrate the overlying alluvial aquifer will be used for post closure monitoring, and are, therefore, not slated for abandonment upon closure of the well field.

As previously stated, closure of the experimental well field does not include any removal or treatment of process fluids left in the leached interval of the Santa Cruz ore body. The current perception that the intervening low permeability bedrock and conglomerate is capable of preventing water quality impacts in the alluvial aquifer precludes the need for ore body restoration. The closure approach assumes that natural buffering will eventually reduce the acidity of the abandoned process fluids and, thereby, immobilize many of the detrimental, previously dissolved constituents. The no-restoration approach is additionally supported by the post closure monitoring designed to confirm the long-term lack of water quality impacts in the overlying aquifer.

4.12.2 Surface Facility

Closure of the SX-EW facility will basically involve the removal of all equipment, buildings and related containment structures. Chapter 3 contains the details and costs associated with surface facility closure. The following summaries the various closure procedures for the experimental surface facility.

- All processing equipment and support buildings will be dismantled and removed from the site.
- All solid residues and sludges will be properly contained and subsequently removed from the site. A proper off-site disposal site will be selected.
- The solution storage and evaporation ponds will be decommissioned and reclaimed. The solutions will be either evaporated or trucked off-site. The pond liners will be removed and properly disposed of off-site. The pond dikes will be leveled.
- All unused reagents, including kerosene and sulfuric acid, will be removed from the site, possibly returned to the vendors, and all empty containers will be returned to the suppliers or disposed of at an appropriate off-site location.

4.13 POST CLOSURE MONITORING

Monitoring of water quality in the three project monitoring wells will continue after closure of the experimental well field and surface facility. This monitoring will be conducted for a two-year period following the 21-month operational phase. The three wells will be sampled and tested three times for the indicator parameters delineated on Table 4-2 at six-month intervals. The three monitoring wells will be permanently abandoned utilizing the procedures discussed in Section 4.12.1 following the post closure monitoring period.

A water quality data report will be compiled and submitted within six weeks of each post closure sampling and forwarded to the ADEQ. Should any water quality determinations indicate a possible migration of abandoned process fluids into the alluvial aquifer, appropriate portions of the contingency action discussed in Section 4.11 will be implemented.

It is assumed that ASARCO will assimilate all costs associated with post closure monitoring. Therefore, Appendix C contains no cost estimates for post closure activities.

4.14 SCHEDULING OF ENVIRONMENTAL ACTIVITIES AND PERMITS

The schedules developed for the work tasks described in this chapter were developed by incorporating both the permit timetable discussed in Section 4.2 and the sequencing of other interdependent construction and operational activities. Figures 4-6 and 4-7 depict the time lines and milestones associated with the environmental activities and acquisition of the appropriate permits.

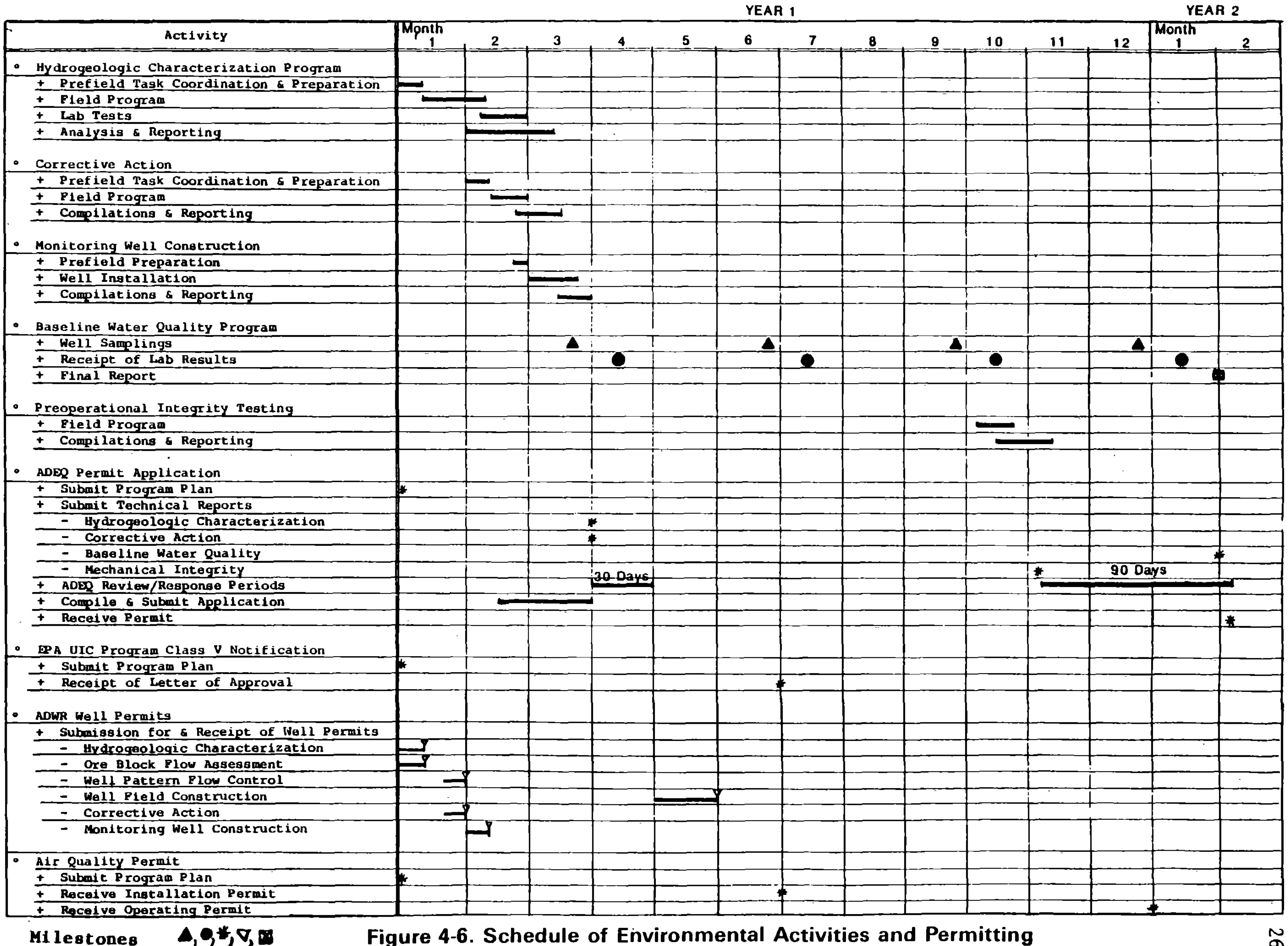


Figure 4-6. Schedule of Environmental Activities and Permitting Prior to Receipt of ADEQ Aquifer Protection Permit

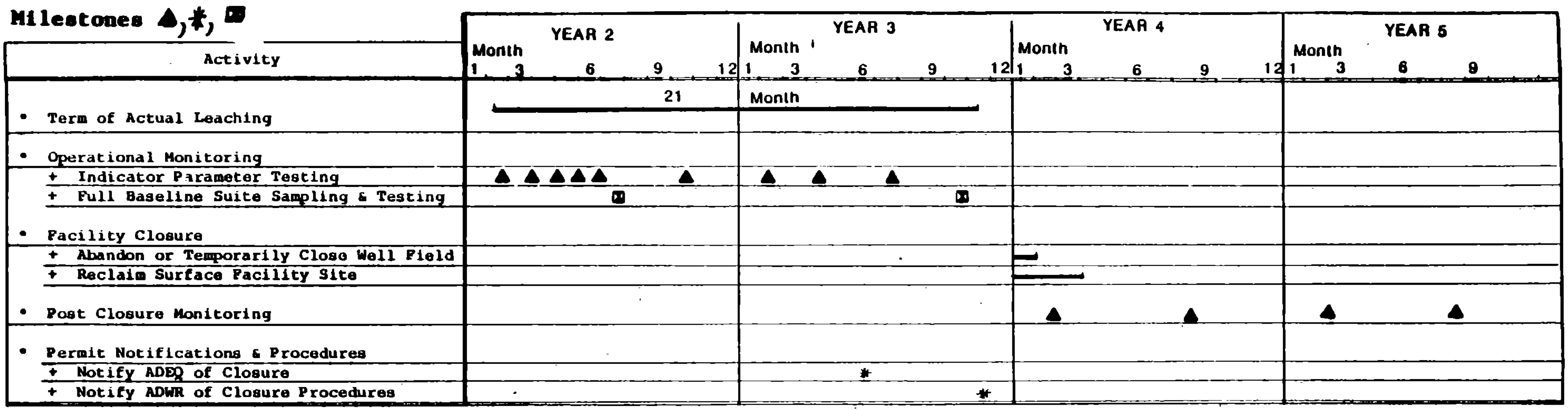


Figure 4-7. Schedule of Operational, Closure, and Post-Closure Environmental Activities and Permit Actions

4.15 COSTS FOR ENVIRONMENTAL ACTIVITIES

A cost analysis has been performed on the environmental activities and is presented in detail on nine tables included in Appendix C. A summary of this analysis is presented herein on Table 4-3.

Several factors influence the cost estimates developed for the environmental activity. These factors are as follows:

- The environmental program will be supported, in part, by the project staff, with the primary input provided by a senior, full-time environmental engineer. A description of this position is provided in Appendix C.
- The project staff will assume all monitoring and other environmental responsibilities after receipt of the ADEQ permit. No technical service contractor will be required during or after operation.
- All equipment and other costs associated with the preoperational and operational mechanical integrity testing are incorporated into the well costs proper and are not costed in the environmental program.
- ASARCO will assume all costs for closure and post closure activities.

Table 4-3 SUMMARY OF COST ESTIMATES FOR ENVIRONMENTAL ACTIVITIES

Activity	Estimated Cost
o Permit Fees & Technical Services to Acquire Permits	$ 20,090
o Hydrogeologic Characterization Program	$133,190
o Corrective Action Program	$270,460
o Monitoring Well Installations	$239,924
o Baseline Water Quality Program	$ 10,000
o Operational Monitoring Program	$ 8,600
TOTAL	$682,264

*See tables in Appendix C for detailed accounting of estimate above.

4.16 REFERENCES

1. American Society for Testing and Materials, Water, Part 31, 1982.

2. American Water Works Association, AWWA Standard for Water Wells, AWWA A100-84, 1984.

3. Arizona Department of Environmental Quality, Environmental Quality Act of 1986, Title 36, Chapter 35, Articles 1-5, and Title 49, Chapter 1, Article 1.

4. ______________________, Draft Regulations, Title 18, Chapter 9, Article 1, 1986-1987.

5. Arizona Department of Water Resources, Well Construction and Licensing of Well Drillers, Arizona Administrative Rules and Regulations, Title 12, Chapter 15, Article 8.

6. ______________________, Arizona Revised Statutes, Title 45, Chapter 2, Article 10.

7. ______________________, Groundwater Code, Arizona Revised Statutes, Sections 45-401 through 45-637, 1980.

8. ______________________, Management Plan, First Management Period 1980-1990, Pinal Active Management Area.

9. Arizona State Mine Inspector, Arizona State Mining Code, Arizona Revised Statutes, Title 27, Chapter 1, Article 2, and Title 27, Chapter 3, Articles 1-7.

10. ASARCO, Top of Bedrock Contour Map, Santa Cruz Project, Pinal County, Arizona, Unpublished Map, Scale 1:12,000, 1982.

11. ______________________, personal communication - Bill Kurtz with Ralph Weeks, March 1987.

12. Casa Grande West, Cross Section Listing Hydrologic Characteristics of Rock Units, Attachment to a Memorandum from Don Davidson, Science Applications International Corporation to Ralph E. Weeks, Sergent, Hauskins & Beckwith Geotechnical Engineers, Inc., July 21, 1987.

13. Cooper, A., Letter to Bob Crist with Water Well Data, January 10, 1983.

14. Cummings, R.B., Geology of the Sacaton Porphyry Copper Deposit, Pinal County, Arizona, in Titley, S.R., ed., Advances in Geology of the Porphyry Copper Deposits, Southwestern North America, Tucson, University of Arizona Press, Chapter 25, 1982.

15. Fifield, R.K., Personal Communication from R.K. Fifield, Arizona Department of Water Resources, to Paul V. Smith, Sergent, Hauskins & Beckwith Geotechnical Engineers, Inc., 1987.

16. Halpenny, L.C., Thickness and Hydrologic Character of Saturated Sediments in Vicinity of Sec. 13, T.6 S., R. 4 E., Pinal County, Arizona: Water Development Corporation, 1970, 24pp.

17. Halpenny, L.C., and D.K. Greene, History of Gronndwater Development in Casa Grande Area and Effect of Proposed Sacaton Project Upon Hydrology of Surrounding Region: Water Development Corporation, Tucson, Arizona, 1972, 36 pp.

18. Hardt, W.F., and Cattany, Description and Analysis of the Geohydrologic System in Western Pinal County, Arizona, U.S. Geological Survey, Open File Report, August, 1965.

19. Hargls and Montgomery, Inc., Summary of Hydrologic Monitoring Program, Casa Grande West, Pinal County, Arizona, Interim Report Prepared for Casa Grande Copper Company, May 30, 1980.

20. ____________________________, Analysis of Long-Term Aquifer Test TW-4, Casa Grande West, Pinal County, Arizona, Memorandum Report Prepared for Casa Grande Copper Company, January 14, 1981.

21. ____________________________, Summary of Hydrologic Monitoring Program, Casa Grande West, Pinal County, Arizona, Summary Report, July 1, 1983.

22. NSF (National Sanitation Foundation), NSF Standard 54 for Flexible Membrane Liners, National Sanitation Foundation, Ann Arbor, Michigan, 1983.

23. Pinal - Gila Counties Air Quality Control District, Amended Rules and Regulations, Prepared by Air Quality Control District Staff, Amended June 22, 1987, 34 p.

24. Russell, C., Personal Communication from C. Russell, Arizona Department of Environmental Quality to Paul V. Smith, Sergent, Hauskins & Beckwith Geotechnical Engineers, Inc., 1987.

25. Science Applications International Corporation, Written Communication, Santa Cruz Pilot Test Site Location (Phase II, Task D), File SAICPH2D.9.

26. Smith, D.K., Cementing, Monograph Volume 4, Henry L. Doherty Series, Society of Petroleum Engineers of AIME, 1976.

27. U.S. Environmental Protection Agency, Underground Injection Control Program, Code of Federal Regulations, Title 40, Chapter 1, Parts 144-146, 1986.

28. U.S. Geological Snrvey, National Handbook or Recommended Methods for Water-Data Acquisition, Chapter 5, Chemlcal and Physical Quality of Water and Sediment, 1984.

29. U.S. Environmental Protection Agency, Protection of Environment, Code of Federal Regulations, Title 40, Chapter 1, Parts 100-149, 1986.

30. White, D.H., Rock Mass Characterization and Preliminary Mine Design Estimates, Casa Grande West Deposit: Casa Grande Copper Company, February, 1981.

CHAPTER 5

DESIGNING COMMERICAL SCALE OPERATION FOR THE ASARCO-FREEPORT McMORAN JOINT VENTURE SANTA CRUZ SITE

5.1 INTRODUCTION

The method used to develop a design for a commerical scale operation involved defining a commercial scale operation and ore block, and then applying the algorithms provided in the generic design manual to identify a mining scenario that maximizes DCF/ROR for that ore block.

5.2 DEFINITION OF COMMERCIAL OPERATION

The information required to define a commercial operation for which design specifications and costs can be developed are: the total tonnage of recoverable copper; the time period over which copper is to be mined; the average depths below the surface of the bottom and top of the ore zone; the average grade of copper in the ore zone; the minimum DCF/ROR; and the selling price of copper.

On May 22, 1987 the contractor team met with ASARCO staff at the ASARCO Tucson, Arizona office. During this meeting data were obtained for use in defining a commerical operation. These data fall into the two categories listed below:

- o Business Decision Data
    - + Acceptable mine life: 15 to 20 years
    - + Minimum copper production rate: Corresponds to recovery of the ore reserve in 15 to 20 year time frame
    - + Copper selling price: current comex price (66 1/2¢/lb on 5/22/87)
    - + Minimum DCF-ROI: 20%
- o Deposit Data
    - + Chart of Copper Oxide Assays (mn 5294)
    - + ASARCO-Freeport Copper Reserve (mn 5421)

+ Copper Oxide Mineralization in SC-19 Area (mn 5407, CG-7 deleted)

+ A core hole location map, (Figure 5-1) showing an inventory of core holes and two geological reserve areas. This includes surveyed section lines of Section 13 and coordinates of drill holes.

+ Geological cross-section showing all core holes (except S.C.-51) used for commercial ore block definition. These sections include copper mineralogy designations; grade and thickness intervals based on the operator's ore cutoff criteria of 0.2% total copper; and at least 100 feet-%. These cross sections included holes S.C.- 19, 24, 35, 36, 38, 39, 46, 52, 58, 59, 60, 61 & 64.

+ Detailed core hole logs for 9 core holes within the two geological reserve areas. (Holes S.C.- 19, 35, 46, 52, 58, 59, 60, 61, 64.)

+ Verbal information on depth intervals and oxide grades in core hole S.C.-51. See Tables 5-1 and 5-3.

+ Memorandum of December 11, 1979 on acid leach tests by T.D. Henderson.

+ Data pertaining to the relative abundance of copper mineralization:

Northwest Reserve	Southeast Reserve
55% chrysocolla	45% chrysocolla
30% atacamite	45% atacamite
15% chalcocite & other	10% chalcocite & other

+ In addition to the ASARCO data, the USBM provided an interpretation of the site geology and mineralogy. Data from one of the USBM cross sections was used to determine oxide mineralization for core hole S.C.-39, in absence of detailed core log for the hole. ASARCO's cross section included chalcocite mineralization, but did not provide sufficient information to seperately define the oxides.

The following method was used to eliminate chalcocite from the reserve estimates.

o In holes with detailed drill logs. (S.C.- 19, 35, 46, 52, 58, 59, 60, 61, 64).

  + Assay intervals composed entirely of oxides, which met or exceeded ore cutoff criteria, were included.

  + Assay intervals consisting entirely of sulfides were omitted.

  + Assay intervals consisting of both oxides and sulfides: only the fraction representing oxide copper and meeting or exceeding cutoff criteria was included.

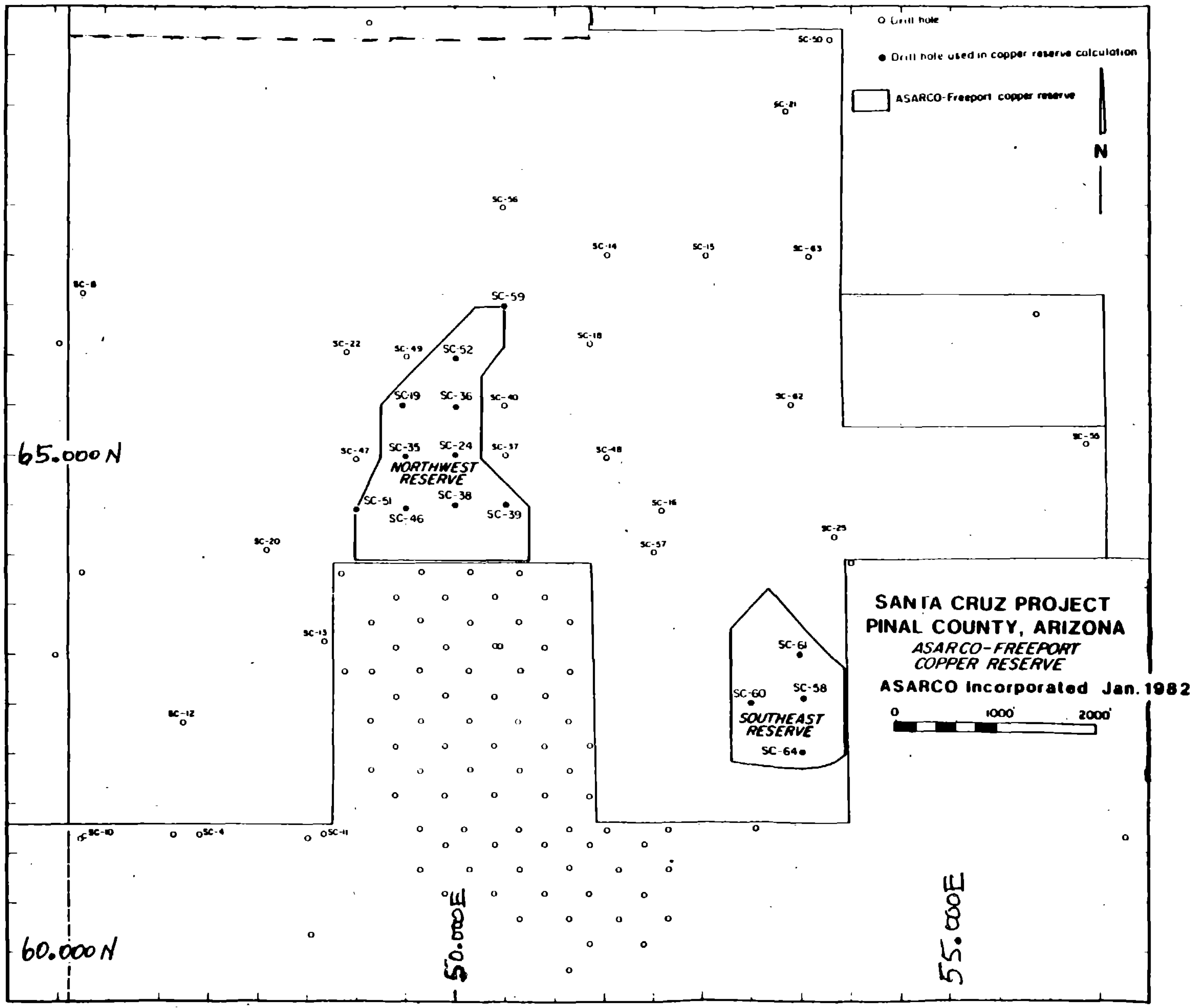


Figure 5-1. Core Hole Locations Santa Cruz Site

- o In holes with cross-sections, but no drill logs. (S.C.-24,36,38,39)

  - + Inspection of cross sections for S.C. -24 and 38 was adequate to define oxide ore intervals at both the 20 ft.-% and 100 ft.-% cutoff criteria.

  - + In hole S.C.-36, one interval was mixed oxide/chalcocite (1918'-2022'). The USBM data of 104 ft. at 0.89% copper was used for this interval. ASARCO figures were used for the other oxide ore interval (1269'-1355')

  - + In hole S.C.-39, several intervals of chalcocite were intermixed with oxides; USBM data were used exclusively for this hole.

The following procedure describes how the average deposit depth and ore thickness for a commerical ore block of oxide ore were determined. The ASARCO reserve data included chalcocite ore, which was not included in the determination of the commercial ore block ecause it is not considered to be oxide mineralization. In addition, the ASARCO ore reserve is based on 100ft-% grade-thickness criteria. This eliminates some intervals of ore which based on the contractor's experience are likely to be economically recovered by in situ mining. Therefore, two commerical ore blocks were identified, one at 20ft-% and 0.2% cutoff, and one at 100ft-% and 0.2% cutoff. See Tables 5-1, 5-2, 5-3, and 5-4.

- o Horizontal ore limits were determined by assigning a 500 foot square area of influence to each core hole used, based on the 500 foot core drill spacing at the site. All core holes used were located within two ASARCO defined reserve areas. Ore volume was calculated based on this assigned area of influence for each drill hole, and converted to tonnage by use of the assumed density factor of 12.5 cubic feet per ton (specific gravity equals 2.56).

- o The method used to determine vertical ore limits is described below. Supporting data are listed in Tables 5-1 and 5-3.

  - + Ore top and bottom depths were tabulated for any interval meeting or exceeding the ore cutoff criteria, in each core hole.

  - + Thickness and ft. times % product were determined and tabulated for each ore interval in each hole.

  - + Average grade for each hole was determined by summing the products for each interval and dividing by the sum of ore interval thicknesses for the hole.

TABLE 5-1. Oxide Ore Intervals Meeting Criteria

CRITERIA

- o Oxide Mineralization
- o % Cu >0.2%
- o % Cu x Interval > 20 ft-%

Core Hole	Depth-feet ORE Top	Depth-feet ORE Bottom	Length feet	Avg Cu %	ftx% Cu	Comments
S.C. 19	1193	1470	277	0.62	171.7	
	1620	1770	150	2.98	447.0	
	2160	2220	60	0.72	43.2	
			487		661.9	487 ft of 1.36 % Oxide
S.C. 24	1180	1280	100	0.51	51.0	
	1550	1820	270	0.69	186.3	(No logs)
			370		237.3	370 ft. @ 0.64% Oxide
S.C. 35	1595	1725	130	0.57	74.1	
	1898	2220	322	0.70	225.4	(No logs)
			452		299.5	452 ft. @ 0.66% Oxide
S.C. 36	1269	1355	86	0.39	33.5	
	1918	2022	104	0.89	92.5	(No logs)
			190		126.0	190 ft. @ 0.66% Oxide
S.C. 38	1150	1318	168	0.29	48.7	
	1823	1920	97	1.82	176.5	
	2180	2221	41	0.63	25.8	(No logs)
			306		251.0	306 ft. @ 0.82% Oxide
S.C. 39	1325	1354	29	.77	22.3	
	1440	1542	102	.81	82.6	S. Cook (USBM) Intervals
	1775	2019	244	.42	102.4	(≥.25 % Cu)
			375		207.4	375 ft @ 0.55% Oxide <No logs>
S.C. 46	1506	1716	210	0.91	191.1	
	1725	1800	75	0.89	66.8	
	1830	1870	40	0.55	22.0	
			325		279.9	325 ft. @ 0.86% oxide
S.C. 52	1031	1073	42	1.19	50.0	
	1520	1547	27	1.44	38.9	
	1779	1815	36	0.89	32.0	
	1870	2030	160	0.53	84.8	
	2060	2204	144	0.52	74.9	
			409		280.6	409 ft @ 0.69% Oxide
S.C. 51	1622	1764	142	0.70	99.4	(Verbal, H. Kreis, 6-2-87)
	1943	2033	90	0.37	33.3	
			232		132.7	232 ft @ 0.57% Oxide

TABLE 5-1. Oxide Ore Intervals Meeting Criteria
(continued)

CRITERIA
o Oxide Mineralization
o % Cu >0.2%
o % Cu x Interval > 20 ft-%

Core Hole	Depth-feet ORE Top	ORE Bottom	Length feet	Avg Cu %	ft x %	Comments
S.C. 58	1800	1900	100	0.26	26.0	
	2021	2614	593	0.65	385.5	
			693		411.5	693 ft. @ 0.59 % Oxide
S.C. 59	1456	1672	216	0.61	131.8	216 ft @ 0.61 Oxide
S.C. 60	2018	2162	144	0.52	74.9	
	2205	2303	98	0.38	37.2	
	2353	2515	162	0.29	46.9	
			404		159.0	404 ft @ 0.39% Oxide
S.C. 61	1817	1870	53	0.45	23.8	
	1964	2199	235	0.87	204.5	
			288		228.3	288 ft @ 0.79% Oxide
S.C. 64	2184	2273	89	0.90	80.3	89 ft @ 0.90% Oxide

TABLE 5-2. Summary of Oxide Ore Based on 20ft-% Criteria

Ore Block	Oxide Ore (ft) Thickness	Average % Cu (Oxides)	Tons of Ore x 10^6 (12.5 ft^3/ton)	Total Tons Contained Copper	Total Well Depth ft.	
Northwest Reserve:						
S.C. 19	487	1.36	9.740	132,464	2220	
S.C. 24	370	0.64	7.400	47,360	1820	
S.C. 35	452	0.66	9.040	59,664	2220	
S.C. 36	190	0.66	3.800	25,080	2022	
S.C. 38	306	0.82	6.120	50,184	2221	
S.C. 39	375	0.55	7.500	41,250	2019	
S.C. 51	232	0.57	4.640	26,448	2033	
S.C. 46	325	0.86	6.500	55,900	1870	
S.C. 59	216	0.61	4.320	26,352	1672	
S.C. 52	409	0.69	8.180	56,442	2204	N.W. RESERVE: 67.2 MM Tons
TOTAL	3362	--	67.240	521,144	20,301	@ 0.78% Cu.
AVG.	336	0.78	6.724	52,114	2030	Contains 521,144 Tons Cu
Southeast Reserve:						
S.C. 58	693	0.59	13.860	81,774	2614	
S.C. 60	404	0.39	8.080	31,512	2515	
S.C. 61	288	0.79	5.760	45,504	2199	
S.C. 64	89	0.90	1.780	16,020	2273	S.E. Reserve: 29.5 MM Tons
TOTAL	1474	--	29.480	174,810	9601	@ 0.59 % Cu.
AVG.	369	0.59	7.370	43,702	2400	Contains 174,810 Tons Cu

NOTE: Cutoff criteria Cu $\geq$0.2% Oxide Cu & $\geq$20 ft. - %
TOTAL RESERVE = 96.7 x 10^6 tons @ 0.72% Cu.
Contains 695,954 tons Cu
Avg. ore thickness = 345 ft.; Avg. Well Depth = 2136 ft.

TABLE 5-3. Oxide Ore Intervals Meeting Criteria

CRITERIA
- o Oxide Mineralization
- o % Cu>0.2%
- o % Cu x Interval >100 ft-%

Hole No.	Depth-ft. Ore Top	Ore Bottom	Length (ft)	Avg. % Cu	ft-%	Comments
S.C. 19	1193	1470	277	0.62	171.7	
	1620	1770	150	2.98	447.0	
			427		618.7	427 ft. @ 1.45%
S.C. 24	1550	1820	270	0.69	186.3	270 ft. @ 0.69%
S.C. 35	1898	2220	322	0.70	225.4	322 ft. @ 0.70%
S.C. 36	No Ore					
S.C. 38	1823	1920	97	1.82	176.5	97 ft. @ 1.82%
S.C. 39	1775	2019	244	0.42	102.4	244 ft. @ 0.42%
S.C. 46	1506	1716	210	0.91	191.9	210 ft. @ 0.91%
S.C. 51	No Ore					
S.C. 52	No Ore					
S.C. 58	2021	2614	593	0.65	385.5	593 ft. @ 0.65%
S.C. 59	1456	1672	216	0.61	131.8	216 ft. @ 0.61%
S.C. 60	No Ore					
S.C. 61	1964	2199	235	0.87	204.5	235 ft. @ 0.87%
S.C. 64	No Ore					

TABLE 5-4. Summary of Oxide Ore Based on 100ft-% Criteria

Ore Block	Oxide Ore Thickness (H), ft.	Avg. % Cu (Oxide Only)	Ore Tonnage $(x10^6)$	Total Tons Contained Copper	Total Well Depth (D) ft.	Comments
NORTHWEST RESERVE						
S.C. 19	427	1.45	8.540	123,830	1,770	
S.C. 24	270	0.69	5.400	37,260	1,820	
S.C. 35	322	0.70	6.440	45,080	2,220	
S.C. 36	No Ore			--		
S.C. 38	97	1.82	1.940	35,308	1,920	
S.C. 39	244	0.42	4.880	20,496	2,019	
S.C. 46	210	0.91	4.200	38,220	1,716	
S.C. 51	No Ore			--		
S.C. 52	No Ore					
S.C. 59	216	0.61	4.320	26.352	1,672	
Total	1,786		35.720	326,546	13,137	
Average	255	0.91	5.103	--	1,876	
SOUTHEAST RESERVE						
S.C. 58	593	0.65	11.860	77,090	2,614	
S.C. 60	No Ore					
S.C. 61	235	0.87	4.700	40,890	2,199	
S.C. 64	---	No Ore	--	--	--	
Total	828	--	16.560	117,980	4,813	
Average	414	0.71	8.280	58,990	2,406	
TOTAL DEPOSIT						
Total	--	--	52.280	444,526	--	
Average	290	0.85	5.809	--	1,994	

+ Ore interval thickness was taken as the sum of all ore intervals within the hole. Uncertainty in deposit structural features and geologic projections between the widely spaced core holes dictated this procedure. The bottom of the deepest ore interval in a core hole represents the maximum well depth required to mine the ore in that hole, so it is used as the definition of well depth for that hole. The top of the ore interval is found by subtracting ore thickness from well depth, for purposes of defining the average ore block.

o Average ore block characteristics were determined as below:

  + Ore volume for each hole = (ore thickness) x (area of influence, which is 250,000 square ft.)
  + (ore volume) / (12.5 cubic ft./ton) = (ore tonnage) for each hole.
  + (ore tonnage) x (ore grade) = (tons contained copper) for each hole.
  + (sum of all core hole ore tonnage) = (deposit ore tonnage)
  + (sum of all core hole contained copper) = (deposit contained copper)
  + (average deposit grade) = (deposit contined copper) / (deposit tonnage)
  + Deposit well depth and ore thickness are arithmetic averages of core hole well depths and ore thicknesses.

This procedure results in the definition of commerical ore blocks having the following average properties:

o Based on the 20ft-% and 0.2% cutoff criteria

+ Average ore grade	0.72% copper
+ Total ore tonnage	97 million tons
+ Average ore thickness	345 ft.
+ Average well depth	2136 ft.
+ Map-view ore area	3.5 million sq. ft.

  + Reserve corresponds to production rates of 23,200 tons per year for 15 years or 17,400 tons per year for 20 years at 50% recovery.

o Based on 100ft-% and 0.2% cutoff criteria:

+ Average ore grade	0.85% copper

+	Total ore tonnage	52 million tons
+	Average ore thickness	290 feet
+	Average well depth	1,994 feet
+	Map-view ore area	2.25 million sq. ft.

+ Reserves correspond to production rates of 14,800 tons per year for 15 years or 11,100 tons per year for 20 years at 50% recovery.

5.3 BEST MINING SCENARIO

An economic sensitivity analysis was conducted using the computer programm in the Draft Generic In Situ Copper Mine Design Manual to identify the best mining scenario for each of the two commerical ore blocks identified in section 5.2. For this analysis the best mining scenario is defined as that combination of deposit access and process input parameters that result in the least value of copper selling price at 20% return on investment.

Parameters selected for the base case mining scenario that are the same for the two defined commerical ore blocks are: surface drilling vertical wells; radial flow system; matrix modification of short radius hydro-fractures; 120 foot well spacing (producer to producer); 10 gpl effluent copper loadings; 2 md deposit permeability; 5% porosity; initial 100% water saturation; 3 1/2 lb acid/lb copper acid consumption by gangue minerals; and 50.6% copper recovery. Rationale for base case parameters are listed in Table 5-5.

For the commercial ore block derived from the 20 ft.-% criteria the base case parameters for production rate at 91.2% on stream time, mine life, ore grade, well depth, and ore thickness are; 23,600 tons per year, 15 years, 0.72%, 2,136 feet, 345 feet. For the commerical ore block based on 100ft.-% respective values of the base case parameters are; 16,200 tons per year, 15 years, 0.85%, 1,994 feet, and 290 feet.

Variations about each base case for which economic sensitivities were evaluated consist of:

o Method of Deposit Access

TABLE 5-5. RATIONALE FOR BASE CASE ASSUMPTIONS

- o Surface drilling vertical wells in 5-spot pattern with 120 foot spacing
  - \+ Contractor experience with installation and operation of situ copper mining.
- o Radial flow with short radius hydrofractures
  - \+ Site specific field data on the orientation of induced fractures (vertical versus horizontal) is not available to design well patterns using large radius induced fractures.
  - \+ Matrix modification usng short radius induced fractures does not impact well spacing design.
- o 2 md deposit permeability, 5% porosity, 100% water saturation.
  - \+ Contractor explerience with testing in copper oxide deposits
- o 10 gpl effluent copper loading
  - \+ Probability of achieving higher loadings than obtained by dump or heap leaching.
- o 3 1/2 lb acid consumption per lb copper for gangue consumption
  - \+ Assumed level based on contractor experience with oxide core leaching
- o 50% overall copper recovery
  - \+ Based on 75% sweep efficiency, 75% leach efficiency, 90% solution recovery efficiency. Site specific field data not available.

  + Underground drilling of fan wells with mine access development
  + Underground drilling of vertical wells with mine access development
- Matrix modification
  + None
  + Short radius fracturing with explosives
- Well spacings 100, 160, 200 feet
- Permeabilities of 0.5 and 5 md
- Copper loading of 6 gpl

Tables 5-6 and 5-7 list data pertaining to the mining scenario, economics, and well module life and flow rate for the 20 ft-% criteria, and data listed in Tables 5-8 and 5-9 for the 100ft-% criteria. Tables 5-10 and 5-11 summarize the economic sensitivity relataive to each base case. Based on this analysis the best mining scenario for each ft-% criteria is associated with vertical wells drilled from the surface at a producer-to-producer spacing of 160 feet using short radius hydrofracturing. The rationale for this selection is based on the following:

- The lowest value of selling price is obtained at both ft-% criteria with surface drilling and hydrofracturing (case 4).
- The optimum well spacing for the 20 ft-%, case is 200 feet. An increase in price of 2.2% results from a 40 foot reduction in well spacing to 160 feet (case 4 versus 3 Table 5-6). This also corresponds to a reduction in well life from 5 to 3 years (Table 5-7). Since no experience currently exists with regard to the long term continuous operataion of true in situ vertical wells, an increase in well life of 2 years to achieve a 2.2% reduction in selling price is not recommended.

It is noted that for both ft-% criteria that a 2 1/2-to-1 increase in permeability at fixed well spacing results in a 7.4% to 10% increase in selling price (Table 5-10 and 5-11). This apparent anamolous result is due to the reduction in well life from 2 to 1 year at fixed spacing associated with increased flow rates at higher permeability. This impacts selling price in a cash flow analysis to a greater extent by an increase in frequency of well pattern additions than by a reduction in cost associated with the number of operating wells at higher permeability.

TABLE 5-6. Selling Price vs. Mining Scenario (20ft-% Criteria)

Case	Deposit Access	Type of Pattern	Matrix MOD	Well Pattern Dimensions	Production Rate Tons/yr	Plant Life Years	Perm md	Copper Loading gpl	Annual Operating Cost ¢/lb	Selling Price ¢/lb	Total Initial Capital $ x 10^6
1	Surface	5-spot Radial	Short Hydro Frac	100′ P-P	23,600	15	2	10	25.1	60	26.9
2	Same	Same	Same	120′ P-P	23,600	15	2	10	25.5	56.4	29.2
3	Same	Same	Same	160′ P-P	23,600	15	2	10	25.2	50.9	27.9
4	Same	Same	Same	200′ P-P	23,600	15	2	10	25.4	50.1	28.8
2A	Same	Same	Same	120′ P-P	23,600	15	0.5	10	28.3	65.1	42.6
2B	Same	Same	Same	120′ P-P	23,600	15	5	10	25.1	60.6	27.1
10	Same	Same	Same	120′ P-P	23,600	15	2	6	27.1	58.8	34.8
12	Same	Same	None	120′ P-P	23,600	15	2	10	26.8	59.5	35.5
13	Same	Same	Short Exp Frac	120′ P-P	23,600	15	2	10	26.7	67.3	34.6
7	Under Grd Mine Dev	Same	Short Hydro Frac	120′ P-P	23,600	15	2	10	27.7	74	49.3
6	Under Grd Mine Dev	Fan Well	None	h = 83′ d = 50′	23,600	15	2	10	26.8	79.2	48.4
6A	Under Grd Mine Dev	Fan Well	None	h =166′ d = 50′	23,600	15	2	10	26	63.8	46

Average well depth = 2,137 feet
Average ore interval = 345 feet
Average grade = 0.72% copper
Average gradient = 0.7 psi/foot

TABLE 5-7. Well Pattern Life and Flow Rate and Plant Costs Versus Mining Scenario (20 ft-% Criteria)

Case	Well Module Life Years	GPM Per Well Module	Selling Price ¢/lb	Annual Operating Cost ¢/lb	Well Capital $ x 10^6	Wellfield Und Grd Capital $ x 10^6	Und Grd Dev Capital $ x 10^6	Plant Capital $ x 10^6	Total Initial Capital $/AT	Total Discounted Capital $/AT
1	1	48.9	60	25.1	5.7	0	0	21.2	1,140	1,730
2	2	34.7	56.4	25.5	7.7	0	0	21.5	1,237	1,480
3	3	41.4	50.9	25.2	6.4	0	0	21.5	1,182	1,180
4	5	38.4	50.1	25.4	7.1	0	0	21.7	1,220	1,086
2A	6	11.7	65.1	28.3	20.7	0	0	21.9	1,805	1,687
2B	1	71.7	60.6	25.1	5.9	0	0	21.2	1,148	1,762
10	3	39	58.8	27.1	11.2	0	0	23.6	1,475	1,583
12	4	17.6	59.5	26.8	13.8	0	0	21.7	1,504	1,529
13	2	34.7	67.3	26.7	13.1	0	0	21.5	1,466	2,009
7	2	34.7	74	27.7	5.0	5.7	14.2	21.5	1,966	2,314
6	1	9.7	79.2	26.8	2.0	5.6	19.5	21.4	2,055	2,695
6A	2	19.6	63.8	26	2.0	3.3	19.5	21.3	1,953	1,859

TABLE 5-8. Selling Price vs. Mining Scenario (100ft-% Criteria)

Case	Deposit Access	Type of Pattern	Matrix MOD	Well Pattern Dimensions	Production Rate Tons/yr	Plant Life Years	Perm md	Copper Loading gpl	Annual Operating Cost ¢/lb	Selling Price ¢/lb	Total Initial Capital $ x 10^6
1	Surface	5-spot Radial	Short Hydro Frac	100′ P-P	16,200	15	2	10	28.6	63.6	21.7
2	Same	Same	Same	120′ P-P	16,200	15	2	10	28.0	57.8	19.9
3	Same	Same	Same	160′ P-P	16,200	15	2	10	28.2	54.6	20.6
4	Same	Same	Same	200′ P-P	16,200	15	2	10	28.4	54.4	21.2
2A	Same	Same	Same	120′ P-P	16,200	15	0.5	10	31.3	68.8	30.8
2B	Same	Same	Same	120′ P-P	16,200	15	5	10	27.7	63.6	18.8
10	Same	Same	Same	120′ P-P	16,200	15	2	6	29.5	60.4	23.5
12	Same	Same	None	120′ P-P	16,200	15	2	10	30.5	65.4	28.2
13	Same	Same	Short Exp Frac	120′ P-P	16,200	15	2	10	30.0	67.1	22.9
7	Under Grd Mine Dev	Same	Short Hydro Frac	120′ P-P	16,200	15	2	10	30.5	79.7	37.9
6	Under Grd Mine Dev	Fan Well	None	h = 83′ d = 50′	16,200	15	2	10	29.3	83.1	37.3
6A	Under Grd Mine Dev	Fan Well	None	h =166′ d = 50′	16,200	15	2	10	28.6	69.0	33.0

Average well depth = 1,975 feet
Average ore interval = 290 feet
Average grade = 0.85% copper
Average gradient = 0.7 psi/foot

TABLE 5-9. Well Pattern Life and Flow Rate and Plant Costs Versus Mining Scenario (100 ft-% Criteria)

Case	Well Module Life Years	GPM Per Well Module	Selling Price ¢/lb	Annual Operating Cost ¢/lb	Well Capital $ x 10^6	Wellfield Und Grd Capital $ x 10^6	Und Grd Dev Capital $ x 10^6	Surface Plant Capital $ x 10^6	Total Initial Capital $/AT	Total Discontinued Capital $/AT
1	2	23.8	63.6	28.6	6.9	0	0	14.8	1,340	1.716
2	2	35.2	57.8	28.0	4.9	0	0	14.8	1,216	1,433
3	4	30.8	54.6	28.2	5.6	0	0	15.0	1,272	1,208
4	7	27.4	54.4	28.4	6.1	0	0	15.0	1,302	1,123
2A	7	9.8	68.8	31.3	15.5'0	0	0	15.3	1,901	1,719
2B	1	67.2	63.6	27.7	4.1	0	0	14.7	1,160	1,783
10	3	38.5	60.4	29.5	7.2	0	0	16.3	1,451	1,543
12	6	11.5	65.4	30.5	13.0	0	0	15.2	1,741	1,611
13	2	35.1	67.1	30.0	8.1	0	0	14.8	1,414	1,889
7	2	35.1	79.7	30.5	3.3	4.0	15.8	14.8	2,340	2,500
6	1	11.4	83.1	29.3	1.2	3.6	17.8	14.7	2,302	2,787
6A	2	23.1	69.0	28.6	1.2	2.1	15.0	14.7	2,037	2,020

TABLE 5-10. Sensitivity Analysis
20 ft-% Criteria

- o Reference data Tables 5-6 and 5-7
- o Use all default cost parameters in computer program except drift and crosscut costs at $600/foot, and fracture gradient of 0.7 psi/foot

Change in Mining Scenario	Change in Selling Price	Comment
17% reduction in well spacing	+6.4%	--
33% increase in well spacing	-9.2%	--
67% increase in well spacing	-11.1%	--
4-to-1 reduction in permeability	+15.4%	--
2 1/2-to-1 increase in permeability	+7.4%	Increase due to reduction in well life at fixed spacing, cash flow impact
40% reduction in copper loading	+4.3%	--
No matrix modification	+5.5%	--
Short radius explosive frac	+19.3%	--
Vertical wells with underground development	+31.3%	--
Fan wells with underground development wells 83 feet long	+40.4%	--
Fan wells underground development, fan wells 166 feet long	+13.1%	

TABLE 5-11. Sensitivity Analysis
100 ft-% Criteria

- o Reference data Tables 5-8 and 5-9
- o Use all default cost parameters in computer program except drift and crosscut costs at $600/foot, and fracture gradient of 0.7 psi/foot

Change in Mining Scenario	Change in Selling Price	Comment
17% reduction in well spacing	+10%	--
33% increase in well spacing	-5.5%	--
67% increase in well spacing	-5.9%	--
4-to-1 reduction in permeability	+19%	--
2 1/2-to-1 increase in permeability	+10%	At fixed well spacing 2 1/2-to-1 reduction in well life cost rise due to cash flow impact
40% reduction in copper loading	+4.5%	--
No matrix modification	+13.1%	--
Short radius explosive frac	+16.1%	--
Vertical wells with underground development	+37.9%	--
Fan wells and underground development	+43.8%	--
Fan wells, underground development, fan wells 166 feet long	+19.4%	--

In the optimum well spacing range 160 feet, case 3 Tables 5-6 and 5-8, the selling price variation is less than 7% (3¢/lb) when comparing a commercial ore body geometry and reserve based on either a 20ft-% or 100ft-% criteria. The ore body dimensions derived from the 20ft-% criteria are used in the field experiment design because contractor experience exists with previous field testing using this criterion.

Design parameters for the selected commercial scale operation are listed in Table 5-12, design specifications in Table 5-13, and annual cash flow in Table 5-14.

TABLE 5-12. Design Parameters Santa Cruz Commercial Scale Operation

BUSINESS RELATED

INDC	100.00000 %	INDM	100.00000 %
ROI	20.00000 %	PRIC	0.00000 c/LB
SCM1	0.40000	SCM2	0.60000
SCM3	0.00000	SCM4	0.00000
SCM5	0.00000	SCP1	0.23000
SCP2	0.25000	SCP3	0.52000
SCP4	0.00000	SCP5	0.00000
SCW1	0.34000	SCW2	0.66000
SCW3	0.00000	SCW4	0.00000
SCW5	0.00000	TP	15.00000 YRS
Y	23600.00000 TPY		

Site Specific Orebody and Wellfield Characteristics

AF	0.70000 PSI/FT	D	2136.00000 FT
DRY	2.00000	GRDO	0.72000 %
H	345.00000 FT	H1	83.00000 FT
H2	50.00000 FT	MACE	1.00000
MINE	3.00000	PERM	2.00000 M.D.
PORO	5.00000 %	RA	8.00000 FT
RHOP	162.00000 LB/CU.FT	RW	8.00000 FT
S1	160.00000 FT	S2	160.00000 FT
SDA	0.00000 FT	SR	0.00010 FT
SS	0.00010 FT	STIM	2.00000
THTA	0.31500 RADIAN	WORK	1.00000
WS	100.00000 %	WD	500.00000 FT

Copper Leaching

CULD	10.00000 GRAM/L	EFFL	75.00000 %
EFFO	91.20000 %	EFFP	100.00000 %
EFFR	90.00000 %	EFFS	75.00000 %

TABLE 5-12. Design Parameters Santa Cruz Commercial Scale Operation (continued)

PLNT	2.00000	VISC	1.00000 CENTI P
W4	3.50000 T ACID/T	W7	1.54000 T ACID/T

Program Control

LOGICAL VARIABLES

LSTI	T
LSTA	T
LST	T

Well System Specification and Cost

AW	0.43000	PSI/FT	B1	0.56000	$/FT
B2	2045.00000	$/WELL	B3	1425.00000	$/WELL
B4	2500.00000	$/WELL	B5	14.00000	$/FT
B6	5000.00000	$/FRAC	B7	0.41000	$/SQ.FT.
B8	2800.00000	$/WELL	B9	235.00000	$/FT
B10	3135.00000	$/WELL	B11	2.70000	$/FT
B12	0.10000	$/FT	B13	92.00000	$/HP
B14	1811.00000	$/WELL	B15	5000.00000	$/WELL
B3U	5000.00000	$/WELL	B4U	5600.00000	$/WELL
B6U	10000.00000	$/FRAC	B8U	3600.00000	$/WELL
B10U	4702.50000	$/WELL	BA	2400.00000	$
BAU	5000.00000	$	BB	4.00000	$/CU.FT.
BG	15.00000	$/CU.FT.	BJ	1.50000	$/JET
BL	800.00000	$/WELL	BLU	1600.00000	$/WELL
BSI	2000.00000	$/WELL	BTI	1.00000	$/FT
BW	20.00000	$/FT	BW1	5.41000	$/FT
BW2	11.90000	$/FT	BW3	1.00000	$/FT
BW4	325.00000	$/HP	BW5	0.00000	$/WELL
BW6	1100.00000	$/HR	BW7	1240.00000	$/WELL
BW8	175.00000	$/HR	BW9	350.00000	$/HR
BW10	30.00000	FT/HR	BW11	15.00000	$/FT
BW12	33.00000	$/FT	BW13	7.00000	IN

TABLE 5-12. Design Parameters Santa Cruz Commercial Scale Operation (continued)

BW14	4.00000	IN	BW15	1.92000	IN
BW16	3000.00000	$/PACKER	BW17	7.35000	$/FT
BW18	16.17000	$/FT	BW19	3.00000	$/FT
BW20	70.00000	$/HP	BW21	500.00000	$/WELL
BW22	1350.00000	$/WELL	BW23	1240.00000	$/WELL
BW24	200.00000	$/HR	BW25	400.00000	$/HR
BW26	20.00000	FT/HR	BW27	26.00000	$/FT
BW28	57.20000	$/FT	BW29	10.00000	IN
BW30	6.00000	IN	BW31	2.42000	IN
BW32	5000.00000	$/PACKER	BW33	15.80000	$/FT
BW34	34.76000	$/FT	BW35	5.00000	$/FT
BW36	102.00000	$/HP	BW37	1000.00000	$/WELL
BW38	2500.00000	$/WELL	BW39	1718.00000	$/WELL
BW40	250.00000	$/HR	BW41	500.00000	$/HR
BW42	15.00000	FT/HR	BW43	35.00000	$/FT
BW44	77.00000	$/FT	BW45	12.00000	IN
BW46	8.00000	IN	BW47	4.04000	IN
BW48	7000.00000	$/PACKER	BWFI	30.00000	$/FT
BWFP	10.00000	$/FT	BX	600.00000	$/FT
CDA	600.00000	$/FT	CP	150.00000	$/HP
CPL	700.00000	KW	CR	1000.00000	$/FT
CS	3000.00000	$/FT	E	200000.00000	$
EM	2500000.00000	$	EV	120000.00000	4
FACJ	-0.61900		RC	130.00000	FT/HR

Surface Plant Specifications and Cost Default

BP1	2.00000	IN	BP1	12.50000	$/FT
BP3	3.00000	IN	BP4	18.75000	$/FT
BP5	4.00000	IN	BP6	25.00000	$/FT
BP7	6.00000	IN	BP8	37.50000	$/FT
BP9	8.00000	IN	BP10	50.00000	$/FT
BP11	10.00000	IN	BP12	62.50000	$/FT

TABLE 5-12. Design Parameters Santa Cruz Commercial Scale Operation (continued)

BP13	12.00000	IN	BP14	65.00000	$/FT
BP15	14.00000	IN	BP16	75.80000	$/FT
BP17	16.00000	IN	BP18	86.67000	$/FT
BP19	18.00000	IN	BP20	97.50000	$/FT
C1	10000.00000	$/CU.M.	C2	300.00000	$/CU.M.
C3	6.50000	$/KG	C4	30.00000	$/TON
C5	185.00000	$/TON	C6	50.00000	$/TON
C7	0.02000	$/GALLON	CE	650.00000	$/TPY
CL	20.00000	$/HR	CLPO	1746000.00000	$/YR
CLP1	1750000.00000	$/YR	CLP2	2625000.00000	$/YR
CLP3	3500000.00000	$/YR	CU	0.05000	$/KWHR
CX	2500.00000	$/GPM	ETA	0.70000	FRACTION
POPO	32.00000	MEN	POP1	40.00000	MEN
POP2	60.00000	MEN	POP3	80.00000	MEN
QSI	55.00000	GPM	QS2	150.00000	GPM
QS3	300.00000	GPM	QS4	800.00000	GPM
QS5	1600.00000	GPM	QS6	2900.00000	GPM
QS7	4500.00000	GPM	QS8	5700.00000	GPM
QS9	8000.00000	GPM	QS10	10600.00000	GPM
QW1	50.00000	GPM	QW2	100.00000	GPM
QW3	300.00000	GPM	RHOF	62.40000	LB/CU.FT
ST	6000.00000	FT	W1	0.01500	M^3/GPM/YR
W2	0.08500	M/GPM/YR	W3	0.26100	KG/TON
W5	0.06500	T ANOD/T	W8	0.20000	
W9	0.23100	T ACID/T	W12	0.57100	T CAO/T
W13	2.43000	SO4/LIME	W15	1.36000	FESO4/AC

Environment Cost Default

CMA	0.00014	$/SQFTFT	CMW	0.00018	$/SQFTFT
EP6	462500.00000	$	EPEM	80300.00000	$/YR
X1	5.00000	%			

TABLE 5-13. Design Specifications Santa Cruz Commercial Scale Operation

A	25600.00000	SQ.FT.	A SUB W	665600.00000	SQ.FT.
INJ PRES	1254.40002	PSI	Q	1076.16003	GPM
INJ FLOW	41.39077	GPM	# CELLS	26.00000	#
WEL LIFE	3.00000	YR	PRIM T	0.15106	YR
ACID C.	50.40000	GRAM/L	LIME CON	0.30777	TON/TON
ACID CON	4.03900	TON/TON	SULFATES	118547.17187	TON/YR
SULFATES	5.50788	TON/TON	G	532.32800	FT
RI	47.95126	FT	XI	16543.18359	FT^2
WEL MODS	26.00000	#	WELLS	63.00000	#
SOL. PIPE	20223.37305	FT	GUWGT	4893.28125	TON
RECOVERY	0.50625	FRAC.	MINE OPS	10.00000	#
CASING	4.00000	IN	HOLE DIA	7.00000	IN
INJ TUBE	1.92000	IN	PRD TUBE	1.92000	IN
INJ PUMP	437.30096	HP	PRD PUMP	696.44226	HP
WEL PIPE	4.00000	IN	TRS PIPE	8.00000	IN
PLNT OPS	89.76000	#			
SITE PRP	2400.00000	$/WELL	CASING	38173.44922	$/WELL
CEMENT	8733.03223	$/WELL	DRILLING	12465.83301	$/WELL
FAN WELL	0.00000	$/FAN	COMPLTON	10200.00000	$/WELL
LOGGING	8904.90039	$/WELL	INJ EQIP	17726.71875	$/WELL
PRD EQIP	23663.06641	$/WELL	UND.WORK	0.00000	$
CHEMICALS	3406751.25000	$/YR	LABOR	4273000.00000	$/YR
O & M	11907645.00000	$/YR	PLNT CAP	21497828.00000	$
SOL TRNS	871179.50000	$	UND.DEV.	0.00000	$
UTILITYS	2911826.00000	$/YR	WEL CAP.	6431692.00000	$
EIS &PER	462500.00000	$	MON WELS	1282059.00000	$
ENV.MON.	80300.00000	$/YR	RESTORE	89592.40625	$

TABLE 5-14. Annual Cash Flow Santa Cruz
Commercial Scale Operation

**** PRICE = 50.94 C/LB ****

DISCOUNTED INITIAL VALUE OF INVESTMENT = 1180.30 $/Annual Ton
Annual Operating Cost = 25.23 C/LB

CASH FLOWS IN $(000)

YEAR	PRODTN TPY	PLANT CAPITAL	WELL CAPITAL	UNDERGROUND CAPITAL	PLANT O & M	NET CASH FLOW	DISCOUNTED CASH FLOW
1	0.	4945.	0.	0.	0.	-4945.	-4945.
2	0.	5374.	2187.	0.	0.	-7561.	-6301.
3	0.	11179.	4245.	0.	0.	-15424.	-10711.
4	18.	0.	0.	0.	11908.	6378.	3691.
5	22.	0.	2217.	0.	11908.	7803.	3763.
6	22.	0.	4304.	0.	11908.	5716.	2297.
7	18.	0.	0.	0.	11908.	6378.	2136.
8	22.	0.	2217.	0.	11908.	7803.	2178.
9	22.	0.	4304.	0.	11908.	5716.	1329.
10	18.	0.	0.	0.	11908.	6378.	1236.
11	22.	0.	2217.	0.	11908.	7803.	1260.
12	22.	0.	4304.	0.	11908.	5716.	769.
13	18.	0.	0.	0.	11939.	6378.	715.
14	22.	0.	2217.	0.	11908.	7803.	729.
15	22.	0.	4304.	0.	11908.	5716.	445.
16	18.	0.	0.	0.	11908.	6378.	414.
17	22.	0.	0.	0.	11908.	10020.	542.
18	22.	0.	0.	0.	11908.	10020.	452.
						78074.	0.

CHAPTER 6

SELECTION OF FIELD EXPERIMENT SITE LOCATION

The primary criteria used to select the test site for the wellfield were matching ore grade, ore thickness, and depth to ore bottom with the corresponding average properties identified for the commercial ore block.

A comparison of ore intervals in several core holes at the site indicated those which best approximate the previously defined ore block characteristics exist primarily in hole S.C.-35 and secondarily in hole S.C.-46 (see Table 6-1). Therefore, the test site was located between these two holes, closer to S.C.-35. Details of the site location are shown in Figures 6-1 and 6-2. Average ore block characteristics (20 ft-% and 0.2% cutoff criteria) were defined as 345 feet ore thickness, 0.72% copper ore grade (oxides only), and ore bottom depth of 2,136 feet. As shown in the accompanying table, S.C.-35 has a total of 452 feet of oxide copper mineralization averaging 0.66% copper, with an ore bottom depth of 2,220 ft. Examination of S.C.-35 core logs and cross sections indicated a continuous interval of oxide ore 322 feet thick, averaging 0.70% copper, with a maximum depth of 2,220 ft. Since all of these values are within about 6% of the commercial ore block average values, this test interval was selected. Hole S.C.-46 is the second choice, containing an interval of oxide ore 324 feet thick, averaging 0.94% copper, with a depth of 1,800 feet.

Secondary considerations in site selection were host rock type, ore mineralization type, location relative to existing mine workings and operations, environmental considerations, and proximity to any core hole used to be obtain core and permeability data in prior field tests.

No mine workings or operations exist near the test site. The site is located approximately 1,000 ft. north of the property boundary indicating ownership by Coastal. The top of the test inteval ore is located at 1,898 feet depth; the core hole log indicates the bottom of conglomerate at 900 feet, underlain by granite.

TABLE 6-1. COMPARISON OF CORE HOLE AND AVERAGE COMMERCIAL ORE BODY PROPERTIES

	(All Ore Intervals) worksheet			(Continuous Ore Interval) logs and sections		
Hole No.	Grade, % Cu,	Thickness, feet,	Depth feet,	Grade, %Cu,	Thickness, feet,	Depth feet
S.C.-35	0.66	452	2,220	0.70	322	2,220
S.C.-46	0.86	325	1,870	0.91	210	1,785
S.C.-52	0.69	409	2,204	(numerous short intervals)		
S.C.-24	0.64	370	1,820	0.69	270	1,820
S.C.-61	0.79	288	2,199	0.87	235	2,199
S.C.-58	0.59	693	2,614	0.65	593	2,614

AVERAGE ORE BLOCK CHARACTERISTICS:
(Based on 20 ft-% and 0.2% cutoff criteria)

ore grade = 0.72%
ore thickness = 345 ft.
ore depth = 2,136 ft.
ore mineralogy:
chrysocolla = 53%
atacamite = 34%
chalcocite & misc. = 13%

AVERAGE TEST SITE CHARACTERISTICS:

ore grade =0.70%
ore thickness = 322 ft.
ore depth = 2,220 ft.
ore mineralogy:
relative percentages unknown
no chalcocite included

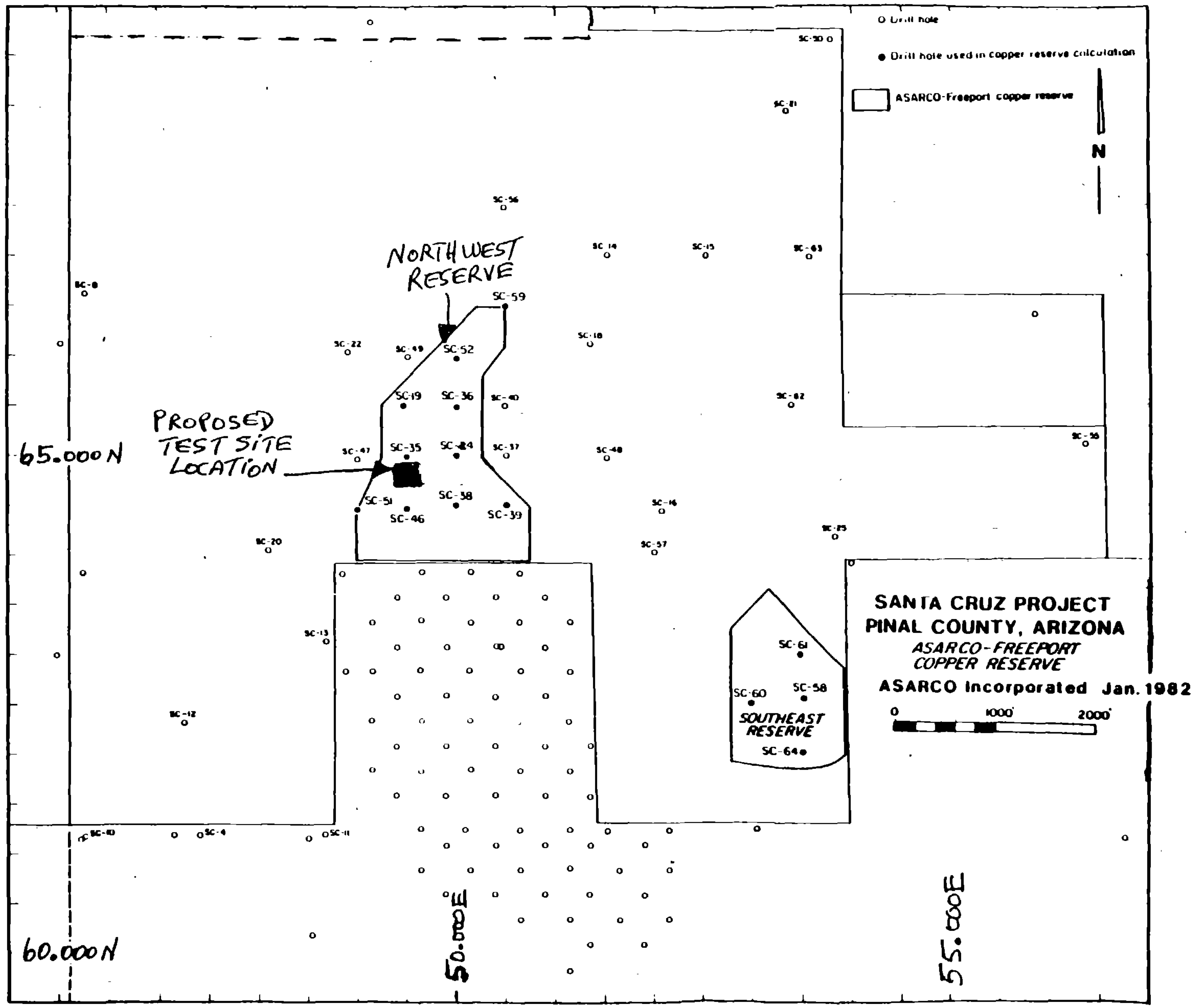


Figure 6-1. Plan Area of Site Location

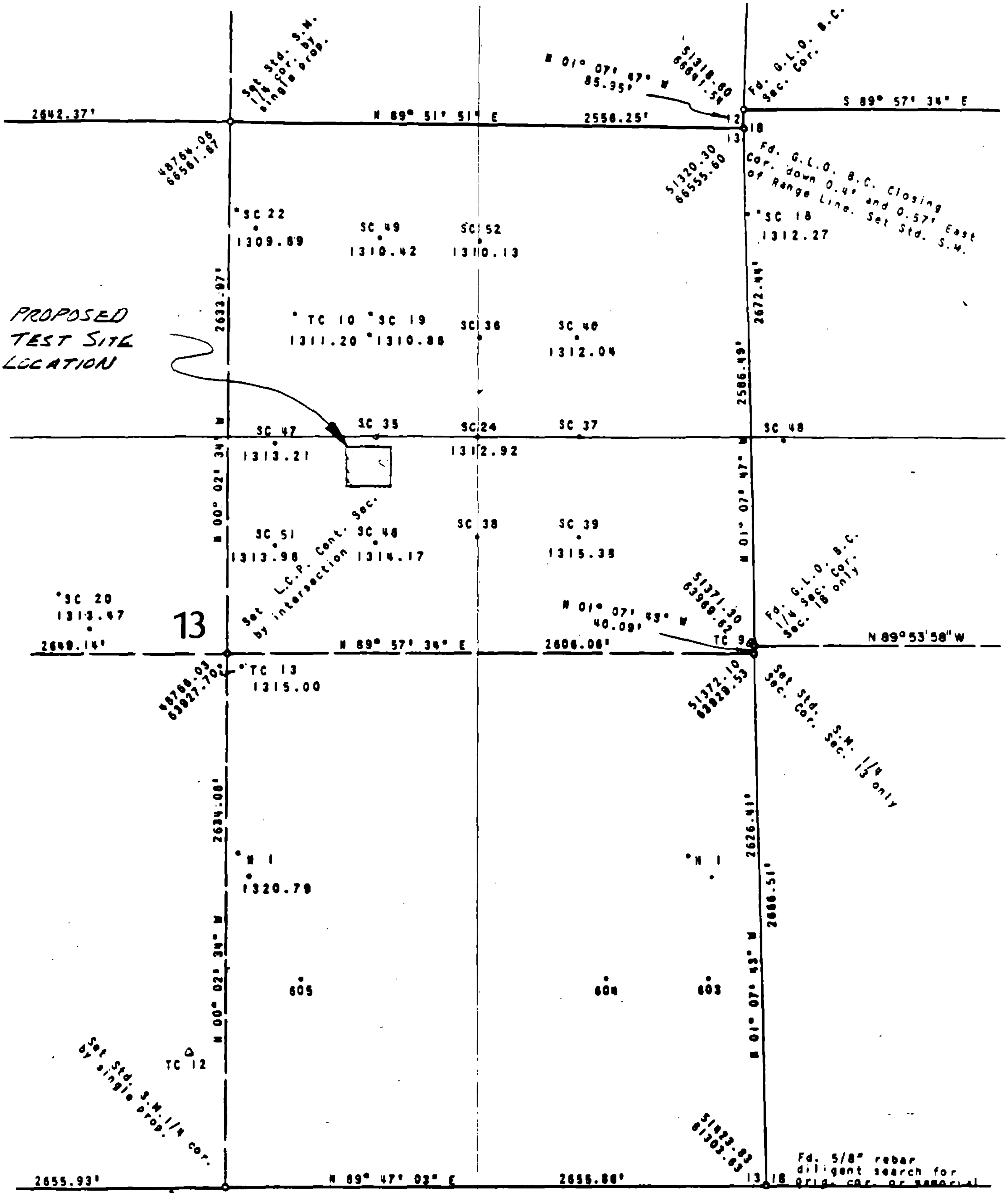


Figure 6-2. Coordinate Map of Site Area

Essentially all oxide ore within the selected intevals in both holes S.C.-35 and S.C.-46 occurs in porphyry type host rock; no significant granite host rock is present. Ore mineralogy in hole S.C.-35 is primarily chrysocola, occurring on fractures; in hole S.C.-46, the ore contains large amounts of brochantite/atacamite (probably containing at least 20% atacamite), also located primarily on fractures. With existing information (limited to 500 foot core hole spacings), it is not possible to accurately estimate the amount of atacamite within the selected test site ore interval before the test wells are drilled. The average proportion of atacamite in the entire deposit accounts for approximately 34% of the total oxide and chalcocite mineralization.

APPENDIX A

WELL SYSTEM DESIGN

A.1 ORE BLOCK FLOW ASSESSMENT

A.1.1 Well Design

- Introduction:

This Appendix describes the design of test wells for the Santa Cruz site field experiment. This well deisgn is used for all test wells in the ore block flow assessment and well pattern flow control tests, and the 5-spot leaching wells. See Figure 2-3 for locations of the proposed wells. This design enables one of the test wells used in the well pattern flow control tests to serve as a leach well, thereby saving the cost of an additional well.

- Summary:

The designed well utilizes a 7 inch o.d. (6 inch i.d.) F.R.P. production casing inside a 10 inch drilled hole, cemented through the ore zone full length from surface to about 2,220 feet depth, and a 10 3/4 inch o.d. steel intermediate casing inside a 14 inch drilled hole, cemented full length through the overlying sediments from surface to about 950 feet depth. (See Figure 2-1.)

This well design is based on: RHA experience in copper ISL wellfield installation and operations at other locations; geology of the test site; objectives and requirements of the test program; and discussions with drilling companies familiar with well installation near the site location. Well design and installation are dynamic procedures. During installation of the first few wells, site specific drilling data wil be obtained; hopefully, this will result in optimization of the well design and installation procedures. For this reason, it is recommended that comprehensive records of all aspects of well installation be maintained, with a view toward optimization.

- Design Sequence:

Condition of the proposed well site is a primary consideration in well design, in terms of determining the most cost effective methods to use. At the Santa Cruz site vertical drilling methods were selected because there are no apparent obstacles (such as terrain or site access) to this method.

Wells are designed from the inside to the outside. This process first considers the size and type of equipment to be placed inside the wells, and the type(s) of stimulation treatments to be utilized. These considerations determine the "production string" well casing size requirements. Well depth and operating conditions determine well casing strength requirements and material of construction. Casing size and cementing requirements, in turn determine the size of the production hole to be drilled. For the Santa Cruz site, geology and the proposed test program suggest that the sedimentary formation overlying the ore zone be separately cased. This "intermediate" casing string inside diameter is dictated by the size of the drill hole required for the production casing and cementing program; the intermediate casing size and cementing program in turn determines the diameter of hole to be drilled through the sediments.

o <u>Well Equipment:</u>

The following types of equipment are proposed for downhole use in the field experiment wells:

+ Leach test equipment:
  - Injection packers and packer inflation tubes
  - Recovery pumps:
    - Electric submersible type and electric cable
    - Progressing cavity type and drive rods and guides
  - Tubing:
    - F.R.P.
    - Metallic
  - Fluid level measurement tubing

+ Temporary equipment, for completion, stimulation and testing:
  - Inflatable Packer
  - Mechanical, tension-set packer (if inflatable is unsuitable)
  - Steel tubing, 2 7/8 inch o.d.
  - Wireline logging tools
  - Pressure sensors and shutoff valves (inside the tubing)
  - Fluid level sensing tube (attached outside the tubing)
  - Hollow carrier perforating gun
  - Dump bailer

All of the above equipment is commercially available in suitable materials of construction (the higher alloys as special order items), to fit inside 4 inch i.d. well casing, with the exception of the electric submersible pumps. Therefore, the recovery pumps are identified as the equipment which determines well casing size requirements. RHA's experience in ISL well operations indicates that electric subersible pumps can function in corrosive fluid environments if they are properly sized, operated and constructed. Operations in corrosive well fluids often considerably reduce the pump lifetime expected in non-corrosive service.

+ Recovery Pumps:

  The surface extraction plant to be used in the field experiments was designed for a maximum flowrate of 50 gpm. This flow must come from the proposed 6 recovery wells, at the proposed average flowrate of 8.3 gpm/well. The flow test interval is located between 2,000 and 2,220 feet depth; the leach test interval is located between 1,898 and 2,220 feet depth. The expected corrosivity of well fluids dictates that no steel materials of lower than 316 alloy should be used. If the fluid chloride content is sufficiently high, alloy 904L or equivalent may be required.

It is beyond the scope of this project to combine the electric motor and fluid ends from two different pump manufacturers in order to obtain an electric submersible pump which will operate satisfactorily inside a 4 inch casing at these depths and flowrates, in the proposed fluid environment.

The only commercially available electrical submersible pump unit marginally suitable for this application (the Grundfos model SP4-80DS), is constructed of 316 alloy; the pump size required for opeations at depths associated with the Santa Cruz site requires a 6 inch i.d. well casing. This pump is rated to produce 8.3 gpm from 1,900 feet, but that flow-depth combination is not in the center portion of the pump operating curve; this fact, combined with the pump's 316 alloy construction, is expected to seriously limit the pumps expected life, and require a substantial inventory of spare parts. The pump requires 10 hp., 480 v. 3-phase current, has a motor cooling shroud, and a pump diameter of 4.6 inches, and a motor diameter of 5.4. inches (with shroud).

Downhole progressing cavity pumps appear to provide a solution to the large well casing size requirements and other problems associated with electric submersible pumps, and are therefore recommended for evaluation in the field experiment. They have not, to the contractors knowledge, been previously used in the proposed fluid environment; therefore it is not considered appropriate to base the design of the field experiment wells entirely on this untested equipment. The pump specified for this operation (the Robbins Meyers 9 stage 5 model), will produce between 1.4 and 14.5 gpm within its rated rpm range, from about 2,000 feet depth. This allows a great deal of flexibility in matching pump capacity to well productivity.

The progressing cavity pump does not require motor cooling and will handle small amounts of particulates, so it can be set within the perforated well interval; this, combined with the low (10 feet) N.P.S.H. requirement allows a very low fluid level to be maintained in the well. These pumps are available (special order) in 316 and 904 or equivalent alloys, with E.P.D.M. elastromers. This pump has a calculated horsepower requirement of about 5 hp. at 8.3 gpm, and should be very efficient. It can be driven by a (surface mounted) motor utilizing the same power source as the electric submersible pumps described above. Power is transmitted from the surface mounted drive head through drive rods, downhole to the pump rotor. Use of drive rods within F.R.P. tubing is untested at ths time, so a string of suitable metallic tubing (described below) is also proposed for one of the two pump installations.

Sucker rod pumps are available in suitable materials of construction, but represent a substantial capital cost increase over the progressing cavity pumps (associated with the large surface drive unit), and do not allow the wide range of flowrates pemitted by the progressing cavity pumps; therefore they are not considered for this application.

Gas lift methods have been eliminated from consideration because they do not optimize well fluid drawdown, hence cannot optimize the wells productive capacity. Also, due to the high cost of compressing air, this method would not likely be selected for a commercial operation.

+ Pump and Injection Tubing:

Tubing for the use with electric submersible pumps, packers and one of the two proposed progressing cavity recovery pumps will be 2 3/8 inch o.d., 2,000 psi rated, F.R.P. type. This size is adequate for all proposed injection and recovery flowrates and pressures, wireline logging tools (specified for several flow tests), and provides adequate tensile strength. The tubing selected for this design (Centron 2/38 DH2000 model) incorporates an o-ring seal and a rounded thread form. Thread adapters will be required (and are available), for top and bottom connections. Maximum tubing o.d. (at the joint) is 3.45 inches, leaving adequate room inside the 6 inch i.d. casing for other required well equipment.

Tubing for use with one of the progressing cavity pumps will be constructed of alloy 904 stainless steel or equivalent, threaded to A.P.I specification, and will employ commercially available F.R.P. couplings, to prevent thread galling problems. This tubing (Cabval VS-28 alloy) will be 2 3/8 inch o.d., 0.190 inch wall thickness, with external upset ends. The purpose of using a metallic tubing string is to allow evaluation of one progressing cavity pump even if F.R.P. tubing proves unsuitable for use with the other.

+ Packer Equipment:

To isolate fluid pressure and flow to the desired portion of the injection well, and to minimize chances of damage to the F.R.P. well casing, inflatable type injection packers are proposed. The packer selected (Baski Water Instruments 40 inch, sliding end type), will withstand expected differential pressures, is available in alloy 316 and (special order) in alloy 904L or equivalent, with suitable elastomers, and can be set and released by means of an inflation tube, without removing the packer from the hole. The packer i.d. will allow necessary wireline tools to pass. The inflation tube will be attached outside the tubing, must be capable of about 2000 psi, and must be covered with or constructed of suitable corrosion resistant materials. The packer is inflated with gas pressure, supplied by a high pressure tank on the surface.

+ Other Well Equipment:

Other well and wellhead equipment such as electrical cable, pump drive rods, fluid level monitoring equipment, test equipment, etc. is described in section 2.3.9 of the text, and does not impact well design directly.

- <u>Site Geology and Conditions:</u>

  Geology at the test site consists of about 900 feet of unconsolidated or poorly consolidated alluvial gravels and valley fill overlaying the igneous (granite and quartz monzonite porphyry) ore host rock. It is believed that the sediments are water-saturated below some depth, and the formation has been used as an irrigation water source in the past. Topography of the test site is flat and unobstructed, having apparently been an agricultural field in the recent past. Site access does not appear to present an obstacle to a drilling program. Soil conditions appear amenable to formation of deep mud during rainy periods, which may be aggravated by the apparent poor drainage resulting from flat site topography.

- <u>Test Operating Conditions:</u>

  Several tests are proposed for these wells. The reader is referred to the text for a complete description of these tests; the following test requirements affect well design:

  + Pressure: Internal operating pressures are expected to reach gradients of about 0.7 psi/ft. during injection operations, and possibly 1.0 psi/ft. or more during fracturing operations. This translates to 1550 psi or more at the 2000 + ft. depths proposed. Casing collapse pressures are assumed to be related only to cementing operations (descibed later, and not to unknown geological conditions).

  + Chemical environmental: Preliminary tests will utilize only water injection and formation fluid recovery. Leaching tests will use dilute sulfuric acid injection, and copper sulfate recovery. The nataure of copper mineralization at the site (containing the mineral Atacamite), indicates that leaching and recycling of leach fluids may build up a considerable level of chlorides. Acidic chloride fluids can be very corrosive to some common types of stainless steel and non-metallic materials.

- <u>Well Casing and Drilling:</u>

  + Production Casing:

    In light of the proposed operating conditions, and based on RHA experience in previous ISL installations, F.R.P. production casing was selected. The selected casing (Centron DHC400 type) is rated at 1400 psi internal, 1200 psi collapse, tensile strength rating of 82,000 lbs., has a body outside diameter of 7.20 inches, an i.d. of 6.4 inches, box (maximum) outside diameter of 8.2 inches, weight of 7.65 lb./ft., and is suitable for the proposed chemical environment. Additionally, this type of casing has a special coarse, round thread form, which should alleviate many of the problems associated with making up large diameter F.R.P. threads of the A.P.I. form, during casing installation operations.

+ Production Hole Drilling:

Good cementing practice dictates a hole diameter about 3 inches greater than the casing outside diameter. This allows for good centralization of the casing and good wall cake removal before and during cementing operations. Since the casing o.d. is about 7 inches, a 10 inch hole is required. As described in the text, either air hammer drilling (perferred) or mud rotary drilling may be used. Air hammer drilling is preferred due to lower costs, less time and less invasion of drilling fluids into the rock. It is proposed to drill the well to a total depth of 2,250 feet, to allow some room below the proposed 2,230 feet casing point, for fill-in. The production hole must be within various straightness and total vertical angle specificaitons, depending upon the well's intended use, as described in the appropriate text sections. It is likely that directional drilling will be required in some if not all wells to maintain these specifications, especially if mud rotary drilling will be required, as described in the text. In holes scheduled for oriented spot coring and tests, drilling will be interrupted for these operations, as described in the text.

Air hammer drilling will use air or foam circulation. Circulation and drill string equipment must be capable of maintaining annular air velocities of about 4,500 feet per minute during operations at the 1,300 feet evaluation site, in 100 degree F. + temperatures. Chip samples will be taken on 10 feet intervals and stored.

Mud rotary drilling will use either water or polymeric mud for circulation. Circulation and drill string equipment must be capable of maintaining about 120 feet per minute mud velocities, taking chip samples as above, and adequately cleaning the mud. The drill string will be designed and stabilized to maintain a stiff drill string, with adequate drill collars above the bit to provide 5000 to 9000 lb. per inch of drill bit diameter. Approximately 20% of the collar weight will be in tension during drilling, to assist in drilling a vertical hole.

+ Intermediate Casing:

Test site geologic conditions and the sequence of planned test operations require use of an intermediate casing string through the sedimentary portion of the overburden, to enable open-hole flow testing to be performed in the ore zone below. If these sediments are found during drilling operations to be sufficiently stable to allow the tests to be conducted without the intermediate casing string, this casing string will not be utilized in subsequent well installations.

The sediments to be drilled and cased, exist from surface to about 900 ft. depth. This part of the hole will not be exposed to corrosive leach fluids, so steel casing is acceptable. Inside diameter must be larger than 10 inches, to pass production drilling equipment. A 10 3/4 inch o.d. A.P.I. grade F-25 threaded and coupled casing was selected. The i.d. is 10.192 inches. This casing has adequate tensile, burst and collapse strength for proposed cementing operations. This casing will be set to about 950 ft., to assure penetration of the sediment-bedrock interface.

+ Intermediate Hole Drilling:

As before, a drilled hole diameter about 3 inches larger than the casing o.d. will be required for cementing; the size selected is 14 inches, since that is a common drill bit size. In order to provide some room for fill-up, the hole will be drilled to about 970 feet depth. The proposed method of drilling is by mud rotary circulation, using either plain water or a bentonite mud system. Cost estimates are based on discussions with drilling companies which have operated near the test site. However, it is desired to evaluate air hammer drilling of the sediments, for cost savings and to acquire a data base. Therefore, it is proposed that drilling will begin by air hammer methods, using a 14 inch bit and air or foam circulation, at the discretion fo the drilling contractor. If, between the project staff and the drilling contractor, it is determined that air hammer drilling is unsatisfactory, mud rotary drilling will be used for remaining sediment drilling.

The same drill string, bit weight and circulation specifications indicated in the previous section on production hole drilling also apply here.

If drilling of the sediments by air hammer is possible, and indicates sufficient stability of the sediments to allow subsequent drilling and test work to be performed without an intermediate casing string, then the well design will be modified to exclude the intermediate casing string and 14 inch hole.

+ Surface Casing:

In order to prevent caving of surface materials during drilling of the intermediate hole, a surface casing will be installed to a depth of about 45 feet. In order to allow the 14 inch bit to pass, the proposed casing i.d. is 15.37 inches, and the o.d. is 16 inch; this is a standard A.P.I. casing size.

The hole for this casing is drilled with a 19 inch diameter or larger bit or "hole opener," usually using air circulation, which is adequate for the small depth involved.

It is important to cement this casing as nearly vertical as possible. This can be enhanced by running the drilling tools inside the casing to the bottom (in order to center the casing in the hole at the bottom), then raise the tools to the casing top, to center the casing at the top. The casing is then carefully wedged in place prior to cementing. Cementing is accomplished by pouring the cement slurry down the outside of the casing.

o Casing Equipment:

This section refers to equipment that is attached to the well casing during installation. This equipment is designed to promote a successful casing cement job, and is not required to withstand the corrosive evnironment after the cementing operation is completed. The following equipment is specified:

+ Centralizers: A total of 20 centralizers per well is specified for the production casing string, spaced as follows: 1 centralizer per 90 feet (each third casing joint) in the 970 feet to 2,220 feet interval; 1 centralize per 180 feet from surface to 970 feet depth (within the intermediate casing). These centralizers must fit on the nonstandard production casing o.d. of 7.2 inches. Purpose is to hold casing in the center of the hole during cementing operation, to assure a uniform surrounding cement sheath.

  Intermediate casing centralizers will be spaced every third joint, from surface to 950 feet. These centralizer must fit the standard casing o.d. of 10.75 inches. Purpose is same as above.

+ Production casing rough coating: The bottom 14 casing joints (about 420 feet) will be rough-coated on the exterior. Purpose is to promote cement adhesion to the casing exterior.

+ Thread adapters: Two adapters to change over the "Centron" brand round thread form to the standard A.P.I. casing thread form. One adapter will be used at the top of the casing string; the other will be used above the float valve. One should be constructed of 316 stainless steel or higher alloy.

+ Float shoe: Flapper or ball type, conventional drillable cement construction preferred, to fit A.P.I. threads of the thread adapters specified. Purpose is to prevent backflow of displaced cement into the casing, following cementing operations. This equipment is used on both the production and intermediate casing strings.

+ Insert float valve: Flaper or ball type, conventional aluminum construction. Purpose is redundancy for float shoe valve. This equipment is used on both the production and intermediate casing strings.

+ Pup joints: Lengths of 2, 4, 6, 8, and 10 ft. are required for spacing the production casing string; these joints will be of the same manufacture as the F.R.P. casing. A single 4 ft. long steel A.P.I. casing joint will be used to separate the float shoe from the float valve at the bottom of the casing, since corrosion resistance is not required at this point. The float equipment has the same A.P.I. threads as this casing joint. The purpose of this joint is to provide a small separation between the float valves. Lengths of 2, 4, 6, 8, and 10 ft. steel pup joints are required to space out the intermediate casing string. The joint between the float shoe and valve in this case may be 4 ft. as specified, or any similar short length. Pup joint used in the intrmediate string should be tack welded after assembly, to prevent them from unscrewing when the casing is drilled out following cementing.

+ Cement baskets: Two cement baskets are proposed for each production casing string. These must be special-ordered to fit the nonstandard 7.2 inch casing o.d. (Arrow Oil Tools is a source). The purpose of these is to minimize cement loss to weak or fractured portions of the formation. Geologic conditions determine necessity and placement of these.

o Casing Cementing

The purposes of cementing well casings is to provide mechanical casing support and prevent fluid movement in the casing-hole annulus. Well cementing procedure involves the following steps:

+ Prepare the well, cementing equipment and materials.

+ Mix the cement and pump it into the well.

+ Install the cementing plug in the casing.

+ Displace the cement out of the casing and into the well annulus by pumping it down the well with another fluid (usually water or drilling mud).

+ Release casing pressure to evaluate operation of the float valves and prevent microannulus formation.

+ Wait for cement to set (W.O.C.)

o Production Casing

Using F.R.P. production casing requires considertion of the effects of the low casing density and its very low compressive strength in cementing program design. It is necessary to prevent the casing from floating out of the well upon displacement of the cement by a low density fluid such as water. Two acceptable methods are available to accomplish this; one involves using equipment to anchor the casing at the bottom of the hole, and the other requires use of a lightweight cement slurry. Use of "microsphere" type lightweight additive is recommended, since it achieves acceptable compressive strength at these very low densities. Due to the low compressive strength of F.R.P. casing, restraining the casing at the top of the well is usually not acceptable. Casing anchors were not proposed due to the high calculated buoyant force and high equipment expense involved.

Assuming water is used as the displacement fluid, neutral casing buoyancy will be achieved by a cement density of 9.5 lb./gallon. Annulus volume is about 578 cubic ft.; using an excess cement volume of about 50%, and a cement yield of 3.3 cubic ft./sack, a total of 263 sacks of cement will be required (see attached calculations).

- Intermediate Casing

  Cementing the steel intermediate casing is by conventional methods, without consideration of compressive strength. If the cement is displaced with bentonite mud, slight negative buoyancy results. If the displacement fluid is water, buoyancy will result from cement densities higher than 14.5 lb./gallon; it is acceptable to restrain the casing at the surface, since steel casing possesses adequate compressive strength. Annulus volume in this case is about 417 cubic ft.; assuming 50% excess cement is used and the cement yields 1.18 cubic ft./sack, a total of 530 sacks will be required (see attached calculations).

- Well Completion and Stimulation

  Wells completed as described here are suitable for conventional completion and stimulation methods, including jet perforations, hydraulic fracturing, installation of casing slots by abrasive jet tools and acidizing. Use of high energy gas fracturing (H.E.G.F.) methods has not been tried at this time, but are believed to be suitable.

- Illustration of Calculation of Cement Density Requirement

  The following calculations illustrate cement density requirements for neutral buoyancy, assuming the following conditions:

  + Production casing specifications: weight = 7.65 lb./ft., o.d. = 7.2 inches, cap. = 1.471 gal/ft.

  + Well depth (production casing) = 2,220 ft. Water = 8.33 lb./gal., bentonite mud = 9.7 lb./gal.

  + Standard 4% bentonite neat cement slurry = 14.1 lb./gal.

  + Intermediate casing specifications: weight = 32.65 lb./ft., o.d. = 10.75 inches, cap. = 4.23 gal./ft.

  + Well depth (intermediate casing) = 950 ft.

  + ρ = cement density required for neutral buoyancy.

  + lightweight cement yield = 3.3 cubic ft./sack

  + standard (net) cement yield = 1.18 cubic ft./sack.

  Requirement for neutral buoyancy

  0 = (casing weight in air) + (casing equipment weight) + (fluid in casing) - (weight of displaced cement)

Production casing calculations

$$\text{Cement volume} = 1.5\ [(10/2)^2 - (7.2/2)^2]\ \Pi\ 2200/144/3.3$$

$$= 263 \text{ sacks}$$

$$\rho = \frac{7.65 + (500/2200) + (1.471 \times 8.33)}{(7.2/2)^2\ \Pi\ 7.48/144}$$

= 9.5 lb/gallon (assuming water used for displacement)

Intermediate casing calculations

$$\text{Cement volume} = 1.5\ [(14/2)^2 - (10.75/2)^2]\ \Pi\ 950/144/1.18$$

$$= 530 \text{ sacks}$$

$$\rho = \frac{32.65 + (300/950) + (4.23 \times 8.33)}{(10.75/2)\ \Pi\ 7.48/144}$$

= 14.47 lb./gallon

A.1.2 Reservoir Property Testing

Open Hole Flow Tests:

Permeability and its variation in the vertical column can be examined by the use of spinner and injection tests in the open (uncased) hole. Spinner testing consists of injecting water and measuring the velocity of fluid in the borehole over the injection interval. Changes in fluid velocity are proportional to the rate of loss to the formation and thus the volume rate of fluid injection can be recorded as a function of depth. The testing is normally conducted under steady state flow conditions so that flow rate variations in the vertical column are not a significant function of time.

A practical consideration in spinner testing is the velocity of fluid in the borehole. A practical limit of resolution for the spinner logging is a fluid velocity of approximately 1 foot/minute. The rate of fluid injection should be maximized by injecting at maximum pressure (without dilating the rock). Also, the wellbore should have no skin effect, which reduces the volume rate of injection. The fluid velocity can be estimated using assumptions of 2 md permeability, 0.7 psi/ft fracture gradient, an injection interval of 322 ft., and no skin effect. Calculating the flow rate:

$$q = \frac{(3.34 \times 10^{-5})\ k\Delta pG}{\mu} = 25.6 \text{ gpm} \equiv 3.42 \text{ ft}^3/\text{min} \qquad \text{(A-1)}$$

- o $G = \frac{2\Pi H}{7}$, radial flow without stimulation in unconfined flow geometry
- o k = 2 md, assume base case
- o H = 322 feet
- o D = 2220 feet
- o Δp = 0.7 (2220 - 322) = 1329 psi, 0.7 psi/ft fracturing gradient
- o μ = 1 centipoise

Calculating the velocity in a 6 inch diameter hole:

$$V = (3.42 \text{ ft}^3/\text{min})/\Pi(.25 \text{ feet})^2 = 17.4 \text{ ft/min}$$

It is apparent that a permeability significantly below 0.5 md will prevent accurate use of the spinner log. If the permeability is larger than 2 md, the injection equipment should be capable of greater flow rate to improve the accuracy of the logging.

Spinner testing will be conducted in the three uncased drill holes. Approximately 8 hours will be required to test a complete ore zone in one hole when the entire interval is logged at one time.

In addition to spinner logging, injection tests are also planned in the open hole. Three tests using straddle packers are planned for each hole. The packers must be set over intervals that permit a good seal between borehole and packer so that injected fluid is confined to the interval of interest.

Injection is planned at constant rate into intervals of approximately 20 ft. In order to prevent dilation of the fractures, the injection pressure is limited to 50% of the fracturing gradient (665 psi Δp). Pressure is recorded at the wellhead. Permeability is obtained by recording the pseudo steady-state injection pressure and flow rate. The flow rate can be estimated for radial flow without stimulation by proportioning the flow rate calculated for the entire interval at maximum pressure.

$$q = 25.6 \text{ gpm } (20/322)(665/1329) = 0.8 \text{ gpm} \quad \text{(A-2)}$$

Meters must be capable of accurately measuring the low rates. If a flow meter cannot be used, a constant pressure test could be performed instead of the constant rate test. The wellbore should not have a skin.

It is anticipated that the time required for each test will be 24 hours. This is the time until a near steady-state condition occurs. Three tests are planned in each of the three test holes.

A positive displacement pump (plunger, or Moyno) will be required for injecting the fluid. A desurger is required if a plunger pump is used. The maximum pump capacity should be 50 gpm at 1000 psi. Other equipment necessary for injection is:

- Water Tank (5000 gal min.)
- Lubricator for wireline
- Pressure relief valves
- Piping
- Flowmeters for 3 ranges of flow
- Miscellaneous piping
- Globe valves
- Gate or ball valves
- Water and power sources

All piping should be rated for 1500 psi working pressure. Clean water is required for injection; pipe and fittings can be of carbon steel. Figure 2-2 is a schematic of the surface injection equipment. Approximately 2 days will be required to assemble the injection equipment.

Cased Hole Tests (Transient Testing):

After completion of the initial three open hole tests, transient tests will be conducted. Transient testing is a procedure for determining formation characteristics such as permeability and wellbore flow condition. This procedure primarily provides data for calculation of permeability and skin factor. Skin factor is a number related to the flow capability of the rock in the immediate vicinity of the wellbore. A positive skin factor indicates reduced (or damaged) permeability. A positive skin factor can be caused by a number of factors including injection of dirty water, precipitation of minerals, inadequate perforations and damage resulting from drilling mud. A negative skin factor indicates an increase in permeability in the immediate vicinity of the wellbore and can be caused by induced fractures or dilation of flow channels, and also by acid dissolution of the rock.

Although not required, the test is normally conducted by injecting water at a constant rate for a sufficient period of time to create a pressure disturbance in the formation in the vicinity of the test well. After termination of water injection the pressure decline (or falloff) is measured. If the injection rate is not constant the data can be analyzed using a mathematical concept called the superposition principle. (While useful, the application of this procedure is tedious). Maintaining a constant injection rate permits the use of less complex data reduction methods.

There are several flow regimes which can occur in a formation. They are linear, radial, and spherical. A linear regime can occur if a natural or artificial high-permeability flow zone intersects the wellbore in the test interval. An artificial high-permeability flow zone would be an induced hydraulic fracture. The radial flow regime will almost always occur in a permeable formation that is bounded by low permeability or impermeable formations above and below. Spherical flow regime can occur when the test interval is small compared to the vertical extent of the formation. When analyzing test data the interpreter must consider the possibility of the various flow regimes. Often an understanding of the geology will alert the interpreter to expected flow regimes.

Mathematical equations have been developed to describe the flow rate and pressure relationship for transient tests for the various flow regimes (References A.1, A.2). Development of these equations is provided in the references along with the various assumptions. The working equation for radial flow is used here for design of transient testing.

The pressure difference is a linear function of the logarithm of time. When the pressure falloff is plotted against the log of time the straight line will have a slope of:

$$\Delta p = \left[\frac{162.6\ q\ u\ B}{kH}\right] \log \left[\frac{1.42 \times 10^{-2}\ k\ t}{u\ c_t\ r_w^{\ 2}}\right] \tag{A-3}$$

$$\Delta p = p_{wf} - p_o$$

where:

p_{wf} = injection pressure immediately before shut in, psi
p_o = initial formation pressure, psi
q = injection rates, barrels per day
u = viscosity of injected fluid, centipoise
B = reservoir formation volume factor, fraction
k = permeability, md
H = interval of formation intercepted, feet
ϕ = porosity, fraction
t = time, hours
c_t = compressibility of system, psi^{-1}
r_w = wellbore radius, feet

$$\text{slope} = \frac{162.6\ q\ u\ B}{kH} \tag{A-4}$$

Similar relationships exist in the linear and spherical regimes. However for the linear regime pressure difference (Δp) is linearly related to the square root of time ($\sqrt{t}$); whereas for the spherical regime (Δp) is linearly related to 1 ($\sqrt{t}$).

A practical problem which arises in the measurement of pressure falloff is wellbore storage. Wellbore storage affects the data when liquid, stored in the well after injection ceases, drains into the formation. This problem can be eliminated by the use of a downhole shut-in valve and by measuring the pressure falloff below this valve. The procedure to determine if wellbore storage effects are influencing early-time data and the duration of these effects is to plot log Δp versus log t. A straight line having a slope of 45° represents data which are influenced by wellbore storage.

To design a transient test, rock and fluid properties must be known or estimated. Often few data are available. The following are estimated values for fluid viscosity and rock compressibility. The combined rock and fluid compressibility is c_t.

$u = 1$ cp
$c_w = 3 \times 10^{-6}$, psi^{-1} (water compressibility)
$c_f = 6 \times 10^{-6}$, psi^{-1} (rock compressibility)
$c_t = c_w + c_f = 9 \times 10^{-6}$ psi^{-1}

A downhole shut-in valve (tool) is installed above the packer to isolate test interval fluid from the wellbore fluid above it. This minimizes pressure transients associated with wellbore fluid storage. The time frame of the transient associated with wellbore storage is estimated by using the following equation when the skin factor is zero, s = 0 (no impairment)

$$t_{ws} = \frac{170,000\ (C_1 + C_2)}{kH/\mu} \text{ hours} \tag{A-5}$$

C is the barrels per psi resulting from wellbore storage. The value of C to be used prior to the surface pressure becoming zero is C_1, and C_2 is the value during the time period when the wellbore fluid level is falling in the tubing string. The number 0.00404 is the barrels per foot of 2 inch ID tubing.

$$C_1 = 0.00404\ (D - H)C_w \tag{A-6}$$
$$C_2 = 0.00404\ (144/62.3) \tag{A-7}$$

For a depth of 2220 feet, a test interval of 200 feet, a permeability of 2 md, and a viscosity of 1 centipoise, C_1 equals 2.4×10^{-5} and C_2 equals 9.3×10^{-3} barrels/psi, and t_{ws} is calculated to be about 4 hours.

Previous tests in similar geologic environments suggest that the time for injection should be in the range of 4 to 8 hours. The time required for shut-in, i.e., the period during which pressure decline is recorded, should be in the range of 16 to 20 hours. The shut-in valve is required to avoid wellbore storage transients of the order of 4 hours from affecting data analysis during pressure transient testing.

A variation of the transient test referred to as an interference test will be conducted. This consists of injecting fluid into one well and monitoring the pressure as a function of time in surrounding wells. This pressure rise in the monitor well is measured using a downhole pressure sensor. Both quartz and pressured gas tube sensors have been used and have sufficient accuracy to measure the anticipated pressure changes. The quartz device is more accurate at lower permeabilities, where a lower pressure rise is obtained in the monitor well due to the higher pressure drop in the rock fractures. Quartz sensors are manufactured by Hewlett-Packard, Lynes, and Terra-Tek. The data obtained from these tests provide information on permeability, directional permeability, and the product of $[\phi \mu C_t]$.

For each test a time of 4 days is allocated. The first day is used to establish baseline transients and provide for decay of transients from any prior testing. Three days are planned for injection. This provides sufficient time to alter the continuous injection to a series of pulse injections which may be required when the permeability is low to distinguish pressure changes in the monitor well from background transients.

The pressure drop anticipated in this test is estimated by using the following relationships:

- $$\Delta p = \frac{141\ q\mu}{kH} (p_D), \text{ psi} \qquad \text{(A-8)}$$
- $$x = t_D / r_D^2 \qquad \text{(A-9)}$$

o $(p_D) = 0.5\ [\ln(x) + 0.809],\ 1/x < 5$ (A-10)

o $t_D = \dfrac{2.64 \times 10^{-4} kt}{\phi C_t r^2_w}$ (A-11)

o $r_D = r/r_w$

Previous tests in similar geologic environments indicate that pressure measurements should be made at the monitor well over a 16-to-20 hour time period to ensure that $1/x < 5$ is achieved.

Information to Be Documented:

For all tests proposed, the following information should be recorded:

- o Well completion data
  - + Casing, tubing, packer, etc.
  - + Test interval
    - - Depth to top and bottom
    - - How completed
  - + Stimulation
  - + A well diagram is quite useful
- o Activity at surrounding wells, if any
- o Injection or production rates prior to testing
- o Detailed rate and pressure data during injection
- o Characteristics of the injected fluid
- o Bottom-hole pressure measurements
  - + Pressure immediately before shut in
  - + Pressure for duration of test
- o Wellhead pressure
  - + On injection tubing
  - + On annulus

- o Other Data
  - \+ Diagram of surface flow equipment
  - \+ Chronology of how things happened during test

EQUIPMENT AND MATERIALS:

Equipment required to conduct the transient test include:

- o Pump can deliver up to 50 gpm at 1000 psi (surface pressure)
- o Flow rate meters
- o Downhole pressure sensing and recording
- o Downhole pressure sensing and surface indicating and recording
- o Lubricator
- o Downhole tubing, packer shut-in tool
- o Surface pressure gauges
- o Valves and piping

REFERENCES:

A-1. Culham, W.E., "Pressure Buildup Equations for Spherical Flow Regime Problems," Society of Petroleum Engineer's Journal, Dec., 1974, pg. 545.

A-2. Earlougher, Robert C. Jr., Advances in Well Test Analysis, Society of Petroleum Engineers, monograph, volume 5, 1977.

A.1.3 Geophysical Wireline Logging

The purpose of logging operations is to: provide information necessary for evaluation of test results; provide information about formation properties, for correlation with similar information obtained by different methods; and provide information to assist in well completion, operations and repairs, if required.

Since no experience with ISL copper exists at this location, it is important to use all reasonable and available means of data collection, including a variety of logs, in the initial information-gathering process. Correlation and comparison of logging data with other types of data are most important in this phase both as a cross-check of data and to evaluate usefulness of logs and test procedures. Also, since logs and well tests seldom measure the desired quantity directly, it is easy to misinterpret their results without comparison between two or more sources of similar information.

Those logs found to be useful and reliable will be proposed for future operations, and may eventually replace slower, more expensive information sources.

The following section describes the tools, procedures, operating principles, and applications of some logs which appear applicable to ISL investigations.

Descriptions of Logs:

Two main divisions of logging tools and procedures are:

- o Logs which provide information about formation properties.
- o Logs which provide information about fluid flow and pressure, or well mechanical condition.

Both types will be run in the "open" or uncased hole during testing; no "lithology" logs will be run in the cased hole. (Some logging tools serve both purposes, requiring different interpretations.)

"Formation" information requirements include the following: (Some types of information require a combination of logs and other tests.)

- o Permeability, variations, and boundaries.
- o Porosity.
- o Lithologic correlation, and variations within each rock type.
- o Fluid saturation, and formation water level.
- o Rock "elastic" or mechanical properties.
- o Formation thermal gradient.
- o Drilled hole size, shape, straightness, and deviation from vertical.

Other well information desired includes:

- o Evaluation of cased holed diameter and "regularity" (often related to casing damage).
- o Downhole pressure measurement; some tools provide continuous surface readout.
- o Flow profiles, showing fluid flow rates entering the formation over the measured depth interval. This usually requires pressurized fluid injection, and a suitable wellhead seal.
- o Evaluation of flow outside, and adjacent to the well casing, such as leakage flowing behind the casing, or a hydrofracture plane intersecting the casing.
- o Evaluation of quality of cement bond to the well casing and adjacent formation.
- o Installation of perforations in the well casing, to allow fluid entry or exit.

Proposed Tools and Operating Principles:

The following section discusses the types of logs and tools proposed for use in obtaining information and providing services required. These logs and tools fall into the following categories:

- o Electric Tools
- o Radioactivitiy Tools
- o Sonic or "Acoustic" Tools
- o Temperature Tools
- o Other Mechanical Tools, such as:
  - + Pressure measurement tools
  - + Size, or "caliper" tools
  - + Flowmeter tool
  - + Directional survey tool
  - + Perforating tool
  - + Wellhead "lubricator" seal

The following is a brief description of the processed tools, their operating principles and their applications. The tool names used here are those of one commercial company but most logging contractors have similar tools.

- Electric Tools

  + Spontaneous Potential (S.P.) log measures small voltages which result from differences in the drilling fluid and formation fluid. This log will not operate in dry portions of the hole. It is used primarily for lithology correlation, and may be a useful indicator of porosity variations.

  + Resistivity log measures the formation electrical resistance,which is primarily a function of pore fluid quantity and kind. "Short" and "long" electrode spacings "see" different distances away from the wellbore, indicating the extent of the zone invaded by drilling fluids. This log can be used for lithology correlation/variation, and, (combined with other tools), water saturation.

  + Induction log measure the formation conductivity, as a response to an induced electrical current. This log will operate best in dry hole, or holes with a high resistivity fluid. "Short" and "long" spacing between the transmitter and receiver coils measure different distances from the wellbore.

  + Laterolog is similar to the induction log, but indicates conductivity at the wellbore surface, in addition to two other "short" and "long" depths. This tool requires a conductive borehole fluid, and is particularly useful in defining thin lithologic "beds" or variations, and near-wellbore drilling fluid invasion.

- Radioactivity Tools

  + Compensated Density log measures gamma rays which have been emitted from a source in the tool and "scattered" by collisions with formation electrons. This measurement is correlated to formation density and is "compensated" for borehole irregularities by use of an integral caliper arm on the tool.

  + Compensated Neutron log measures the amount of slow or "thermal" neutron returned to the tool detector, after release of high energy neutrons and their collision with hydrogen nuclei in the formation. Since water is the major anticipated source of hydrogen, the log should indicate formation water, which is, in turn, an indicator of formation porosity. This log can be used in either open or cased, fluid filled holes.

  + Gamma Ray log measures natural gamma radiation. This is used primarily for background information and lithology correlation.

  + Radio-Tracer log measures the rate of fluid movement in a well, or behind well casing, by releasing a "slug" of radioactive fluid at a known time and depth, and detecting this "slug" at another time and depth. This log is most useful in diagnosing mechanical well problems; (such as fluid loss through damaged casing) but can also be used in flow profile determination in open or cased holes.

- Sonic or Acoustic Tools

  + Borehole Compensated Sonic log measures the travel time of sonic or pressure waves through the formation. This is analogous to seismic methods used at the surface. Interpretation can indicate rock mechanical properties related to "hardness" (such as density and Youngs modulus) in addition to an estimate of the degree of fracturing. These properties can be related to porosity. The log is compensted for borehole irregularities by transmitter and receiver locations.

  + Cement Bond log operates similarly to the borehole compensated sonic log in principle, but indicates the relative time and strength of the "first arrival" signal only. Since properly cement-bonded sections of the casing do not vibrate as easily as poorly bonded sections, the first return of the "casing signal" is much stronger in the poorly bonded intervals. This measure of cement bonding quality can indicate the degree of isolation of fluid flow outside the well casing, along the casing-hole annulus, and is therefore important to test result interpretation.

- Temperature Tools

  + Temperature log measures fluid temperature, and is usually run from top to bottom, in order to avoid disturbing the unmeasured fluid. This indicates the temperature gradient existing in the well, from top to bottom at that time. The "differential temperature" is a representation of the rate of change of this thermal gradient. It is produced by electronically comparing temperature readings as the tool moves along the hole, and serves to emphasize the otherwise subtle gradient change. Temperature logs are used in open and cased hole applications, and usually depend on comparison with "background" or previous temperature logs, for their interpretation.

- Other Tools

  + Caliper log measures the hole size; usually the tool indicates only the largest size sensed by the "arms." In the case of an "X-Y" caliper, the largest size in two perpendicular directions are plotted, to give an indication of hole shape. Several varieties of this tool are available, for cased and open holes. A multi-arm casing caliper is required for well integrity verification.

  + Pressure Measurement tools generally use a piezometric element, and furnish a continuous surface reading. Downhole pressure tools do not need correction for pipe friction, and do not require a full tubing string, as surface gauges do. They are therefore preferable for pressure transient testing. Pressures up to 2000 psi are anticipated; accuracy of 0.25% min. is required.

  + Directional Survey tool is a magnetically oriented inclinometer. Provides photos showing magnetic bearing and inclination at the depth where the tool is positioned. Nonmagnetic drill collar(s) are required for wireline operation.

+ Spinner tool measures the rotational speed of a flow sensing device. The rotation is proportional to flow rate past the tool. This tool can be used in a stationary location, or moved up or down the well. Flow rate is corrected for wireline velocity, when the tool is used in motion. Applications are primarily in determining the "profile" or fluid entering or exiting a well, or to detect fluid entry or exit locations.

+ Wireline "Lubricator" Seal allows the wireline to move up or down the well during pressure injection operation, without fluid leakage at the wellhead. This is required during pressure transient testing, flow profile logging and similar operations.

+ Perforating tool creates holes in the well casing, cement sheath and formation, to allow fluid flow between the formation and wellbore. Several types of perforators exist; for this work, a "hollow carrier" jet perforating gun is recommended. This tool optimizes the location, angle of incidence and penetration of the jet charges, while minimizing shock to the casing and amount of debris left in the hole. Various sizes of shaped-charge "jets" are available, and can be installed in a variety of spacings. These charges are placed inside the "gun," lowered to the desired depth in the well, and fired electrically. The "gun" is then retrieved by the wireline.

Discussion with the selected logging contractor may suggest use of additional logs; drilling procedures and circulation media chosen may eliminate some logs from consideration. Since each contractor's equipment differs, it is necessary to thoroughly investigate use of other equipment with the contractor (such as lubricator seals, downhole shutoff valves, pressure gauges or other logging tools).

All equipment proposed for pressure measurement, flow profiles and other "though tubing" operations must be small enough to pass through 2.00 inch I.D. tubing.

Logging Contractor Activities:

The following is a brief summary of logging activities:

o Downhole Pressure Measurement. In addition to the "pressure bomb" type recording pressure instrument, a surface-reading downhole pressure gauge is desirable. If available, the surface-reading gauge is preferred; the recording instrument could be used simultaneously, or as a standby unit. In this case, the logging contractor would also provide a compatible wireline "lubricator" type seal. This tool should also be compatible with a downhole shutoff tool.

Test procedure involves running the pressure gauge and shut-off tool through the lubricator, and tubing, to a point just above the packer. As water injection proceeds, pressure measurements are recorded. When injection ceases, the downhole shutoff valve is closed, and pressure falloff data are recorded. The shutoff tool eliminates the "wellbore storage" effects.

- <u>Caliper Logs</u> are run in the open hole intervals designated for packer setting locations, in order to help assure a good seal, prior to running pressure test. Usually the bottom hole depth is also checked, to determine the existence of fill, and a temperature log run, to record pre-injection temperature gradient. In addition this tool will be used to diagnose well problem, assist in interpretation of other logs and finalize cementing programs.

- <u>Flow Profile Logs</u> are run in both open and cased (perforated) hole intervals to indicate fluid exit zones and evaluate flow variations resulting from leaching.

- <u>Open Hole Lithology Logs</u> are run upon completion of drilling and open hole testing. The purpose of these logs is to define formation parameters such as porosity, fluid saturation, rock elastic properties, thermal gradient, hole size, shape, straightness and deviation. These logs provide a basis for comparison with other information, which will be used to assist in evaluating the log's usefulness.

- <u>Cement Bonding</u> between casing, cement, and formation, is evaluated by use of bond and temperature logs, run a few hours after well cementing. This log will indicate existence or absence of a good fluid seal along the casing, which is crucial to many of the proposed pressure and flow tests.

- <u>Caliper Logging of the Casing Slot</u>, to indicate its depth, and possible geometry is proposed. A suitable caliper tool should be specified.

- <u>Caliper Logging of the Casing Following Stimulation</u>, to verify integrity of casing above the stimulated interval is required by the permitting process. A suitable multiple-ARM casing caliper, capable of detecting casing damage, should be specified.

- <u>Location of the Injection Well Hydraulic Fracture Plane</u>, as its intersection with the recovery well, will be attempted. The proposed operation involves use of gamma ray and temperature logging in the recovery well, to indicate the depth at which a hydraulic fracture, induced in the injection well, intersects the recovery well. Detection will be assisted by use of a radioactive tracer in the initial hydrofracture fluid "pad" and sand proppant. If successful, results will greatly aid test planning and interpretation, in addition to learning the effect of fracture intersection upon well casing and cement.

- <u>Casing Perforations</u> are installed by use of the wireline perforating gun, to enable flow pressure and leaching test within the cased hole.

Tool Combinations:

In order to conserve time and minimize the number of tool "runs" required for a given job, several tools should be run together whenever possible. This should be discussed with the selected contractor, in advance. Recommended tools for the logging operations are:

- Downhole Pressure Measurement and Caliper Logs:
  - A three (or more) arm caliper tool, to define suitable packer seating locations, in the open hole.
  - A surface-reading downhole pressure gauge (preferred), compatible with the specified downhole shutoff tool, and a wireline "lubricator" seal, or a downhole pressure recording gauge.
- Flow Profile Logs, including:
  - Differential temperature tool
  - Flowmeter or "spinner" tool
  - Radioactive tracer tool
- Lithology Logs:
  - Spontaneous Potential
  - Resistivity or Induction; short and long spacings
  - Laterolog, if borehole conditions permit (conductive fluid)
  - Compensated Neutron
  - Gamma Ray
  - Borehole Compensated Sonic
  - Differential Temperature
  - Caliper (for evaluation of final hole condition and cement volume calculation).
  - Directional survey tool, to verify the hole direction and inclination.
- "Post-Completion" Logs
  - Cement Bond Log and Temperature Logs
  - Caliper log, to define size and shape of "slot" cut in casing.

+ Gamma-Ray log, run in recovery well, to located the fracture plane intersection.
+ Flow Profile and pressure measurement logs, as described above.

Log Analysis

A detailed description of log analysis is beyond the scope of this design. Three suggested approaches are:

- Inspection of the log and qualitative interpretation
- Correlation with other logs and available information
- Cross Plotting, which is useful primarily for lithology logs. Several techniques are used, the simplest being to compare various logs which measure a given formation property, by different methods.

Evaluation of Tools and Procedures

Evaluation of the value of each log (especially the lithology logs) should consider information gained, cost, time requirements, reliability or "repeatability," and necessity for further use of the log, in light of other methods of gaining the same information.

Logging procedures, related test procedures and all associated equipment should also be evaluated, especially after completion of the first well, so changes can be made in subsequent operations.

Cost and circumstances affecting logging costs should be recorded to aid in future planning.

A.2 WELL PATTERN FLOW CONTROL

A.2.1 Tracer Testing

Discussion

To perform the tracer tests, well patterns are placed in production with the production wells drawn down to the maximum level. This is approximately 20 feet over the pump intake for centrifugal pumps. Sucker rod and progressing cavity pumps do not require a significant level of head over the pump.

The injection rate is adjusted and maintained equal to the cumulative production rate. After equilibrium flow has been established, a tracer concentration is introduced into the injected well at a continuous, fixed level. Chloride is chosen as a tracer because it is relatively non-reactive, and solutions are conveniently assayed. After a period of time, the tracer breaks through to the production well. The concentration of tracer gradually increases in the production well with time, approaching the injection well concentration after a long time (more than one pore volume).

The tracer arrival is influenced by reservoir heterogeneity. Consider, for example the case of a set of high permeability fractures occurring between the injector and a production well. This could result in a short circuit, or very early tracer arrival in one or more of the production wells. The opposite problem could occur if an impermeable area exists between the holes. Calculations pertaining to tracer arrival are linearly dependent on porosity and flow rate and for this calculation are based on two dimensional flow. A tracer curve (plot of concentration vs. time) generated by computer for a homogeneous reservoir would be compared against the actual data. Various changes could be made in the computer model (by varying the input data) to learn what has occurred in the field. See section 7.3.1 Draft Generic In Situ Copper Design Manual.

The tracer test should provide information regarding:

- The degree of dilution in subsequent leaching tests
- Reservoir anisotropy, (variability in permeability (k) and porosity) and sweep efficiency by comparison with calculated dilution based on assumed uniform properties and two dimensional flow.

Tests in the Initial Three Hole Pattern

For the radial flow, based on the assumption of 2 md rock and a stimulated well condition, a flow rate of 26 gpm can be used for injection. Based on this rate, the time required to inject one pore volume (pv) has been calculated (see page A.2.1.3, following). The time for one pv is roughly equivalent to the tracer arrival time under ideal conditions (isotropy). With assumptions of 26 gpm injection rate and 5% porosity, 8.1 days are required for one pv. To maximize tracer arrival concentration 32 days are planned for testing, which is approximately 4 pv.

Water samples from the ore zone are used in the test work will be used to establish a background chloride level in the deposit water. An injection chloride concentration of 10 times background will be used. For the purposes of tracer concentration calculations, 5 gpl chloride is assumed. This is 8.3 gpl NaCl.

Both flow rate and solution injected are respectively proportional to permeability and porosity. The basic plan for execution of the tracer test must be modified when specific information is obtained from the ore zone with regard to these two parameters.

Tests in the Expanded 5-Spot Wellfield

Tracer testing is also planned in the 5-spot patterns used for leaching. The injected flow rate will be 33 gpm.

It is possible that chloride could be used as a tracer in the 5-spot patterns, if the injection during the 3-hole test work has not raised the background level significantly. In the event that the background level is too high, leaching could be started and the level of sulfate used in the lixiviant can be used as the tracer. Although some sulfate may be precipitated (for example as gypsum or jarosite), the amount precipitated should be very small compared to the large amount of sulfate injected. In leaching within the 5-spot pattern it is desirable to observe the chloride level obtained from the leaching of atacamite. If only sulfate is used as a tracer, no masking of the liberated chloride level will occur.

Calculations show that based on a 160 ft well spacing the time required to inject one pore volume is 64 days. This also provides a sufficient period of time at full pressure injection to demonstrate maintenance of hydrologic isolation prior to acid injection. It is planned that 90 days be used for a chloride tracer test, if tracer testing occurs as a separate test from leaching.

Salt Mixing

The surface facility must be capable of mixing salt or other tracer into the injected fluids. Calculations show that the quantity needed is about 126 tons of salt for the tracer work in the 5-spot patterns. For the 3-hole tests 43 tons would be required.

Sampling

It is recommended that samples be collected every hour until the nature of the tracer buildup has been established. It will not be necessary to analyze every sample for chloride. Every 6th sample should be assayed, for example, until breakthrough occurs. After breakthrough of 1/2 gpl above background, the frequency should be reduced to 1 sample every three hours. When observed chloride concentration change is less than 0.25 gpl, the spacing between assays can be increased.

It is suggested that all collected samples be maintained, so that repetition of assays can be made. In each tracer test, approximately 50 chloride assays should be sufficient to define the tracer curve.

Injection Flow Rates

Calculations provided in Section A.2.2 indicate an expected injection rate of 33 gpm for the 5-spot, and in Section A.1.2 26 gpm for the 3-spot.

Time for One Pore Volume Injection

- For radial flow in the 3-well test:

  Assume 5% effective porosity. P-I well spacing = 50 feet. Time is:

  $$\frac{322 \text{ ft. } (50 \text{ ft})^2 (0.05) \times 7.48 \text{ gal/ft}^3}{26 \text{ gpm } (1440 \text{ min/day})} = 8.1 \text{ days} \qquad \text{(A-13)}$$

  This time is for one pore volume, approximately breakthrough time.

- For radial flow in the 5-spot patterns. P-P well spacing = 160 feet. Time is:

  $$\frac{322 \text{ ft. } (160 \text{ ft})^2 (0.05) \times 7.48 \text{ gal/ft}^3}{33 \text{ gpm } (1440 \text{ min/day})} = 64 \text{ days} \qquad \text{(A-14)}$$

- o Sodium Chloride Requirements

  - + It is anticipated that the background concentration of chloride in the water is 0.5 gpl. Plan to use 5 gpl Cl or 10 times background. This is 8.3 gpl NaCl.

  - + For the 5 spot test requirement, let the total test time be 90 days or 1.7 pore volumes. The total volume of fluid is then:

    $$33 \text{ gpm} \times 1440 \text{ min/day} \times 90 \text{ days} = 4{,}276{,}800 \text{ gal} \qquad \text{(A-15)}$$

    Amount of salt required is:

    $$\frac{4.3 \times 10^6 \text{ gal} \times 3.78 \text{ l/gal} \times 8.2 \text{ g/l}}{454 \text{ g/lb} \times 2000 \text{ lb/ton}} = 126 \text{ tons} \qquad \text{(A-16)}$$

  - \- For the 3-well test with radial flow, 4 pore volumes are planned. The salt requirement is:

    $$\frac{32 \text{ days} \times 1440 \text{ min/day} \times 27 \text{ gpm} \times 3.78 \text{ l/gal} \times 8.3 \text{ gpl}}{453.6 \text{ g/lb} \times 2000 \text{ lb/ton}} = 43 \text{ tons} \qquad \text{(A-17)}$$

A.2.2 Wellfield Design Calculations

Flowrate can be estimated using the radial flow equation for a 5-spot pattern:

$$q = \frac{.0001035\ (k)\ (H)\ (\Delta P)}{u\ [\ln\ (d/r_w) - .619]} \qquad \text{(A-18)}$$

q = flow rate in gpm

d = injector/producer spacing in ft.

u = viscosity in cp

k = permeability in md

r_w = wellbore radius in ft.

Δp = applied pressure psi

H = vertical interval in ft.

To estimate the flowrate, assumptions made for the variables are as follows:

- o For d, a spacing corresponding to 160 ft producer-producer will be used. The 160 ft p-p spacing is obtained from computer runs using the

Generic Design Manual. The injector producer spacing for a square 5-spot geometry is:

$$d = 1/2 \sqrt{2(160)^2} = 113 \text{ ft} \qquad \text{(A-19)}$$

- For μ, mature recycled fluids are expected to be more viscous than plain water. The viscosity is assumed to be 1.3 centipoise.

- Permeability (k) is estimated at 2 md. The actual field value will be determined by field measurement.

- Wellbore radius r_w is taken as 0.25 ft. The effect of well stimulation techniques can be expressed by increasing the wellbore radius.

- The applied pressure drop (Δp) must be limited to a value less than fracture gradient (~1 psi/ft). For these estimates a value of 0.75 psi/ft will be used. Since the depth is 2,060 ft. the pressure is:

  $$\Delta p = (2{,}060\text{-}322 \text{ ft})(0.75 \text{ psi/ft}) = 1{,}304 \text{ psi} \qquad \text{(A-20)}$$

- The planned vertical interval is 322 ft. which is the ore thickness.

- Substituting these values into the 5-spot steady-state equation:

  $$q = \frac{.000103 \text{ (2md) (322 ft) (1,304 psi)}}{1.3 \text{ [ln } 113/0.25 - .619]} = 12.2 \text{ gpm} \qquad \text{(A-21)}$$

If well stimulation is employed, the expected flowrate will be increased. Assuming an increased radius of 8 ft. for r_w the flow rate is:

$$q = \frac{.0001035 \text{ (2)(322)(1,304)}}{1.3 \text{ [ln } 113/8 - .619]} = 33 \text{ gpm} \qquad \text{(A-22)}$$

<u>Well Pattern Life Estimate</u>

It is desirable from an economics viewpoint to mine a pattern in a three year period. The copper production possible at a flowrate of 39 gpm should be sufficient to mine the ore in three years. The following calculations calculate well pattern dimensions that could be mined in 3 years, assuming the pregnant liquor contains 10 gpl recoverable copper.

$$\text{Lbs cu} = \frac{33 \text{ gpm x 10 gpl x 3.785 l/gal x 1440 min/d x 365d x 3 yr}}{453.6 \text{ g/lb Cu}} \qquad \text{(A-23)}$$

$$= 4{,}341{,}936 \text{ lb Cu} \qquad \text{(A-24)}$$

4,341,936 lb of copper corresponds to 50% recovery, so contained copper is 8,683,871 lb. Taking the ore grade to be 0.70% or 14 lb cu/ton, so contained tons are:

$$\frac{8{,}683{,}871 \text{ lb}}{14 \text{ lb/ton}} = 620{,}277 \text{ tons} \quad \text{(A-25)}$$

Assuming that rock volume/ton is 12.5 ft^3/ton, then:

$$\text{Area} = \frac{620{,}277 \text{ tons} \times 12.5 \text{ ft}^3\text{/ton}}{322 \text{ ft}} = 24{,}079 \text{ ft}^2 \quad \text{(A-26)}$$

The pattern producer-producer spacing = $\sqrt{24{,}079 \text{ ft}^2}$ = 155′ thus, mining will require in excess of 3 years. The time will be:

$$\frac{(160 \text{ ft})^2}{(155 \text{ ft})^2} \times 3 \text{ years} = 3.2 \text{ years}$$

A.3 WELL SYSTEM COSTING

The following listing describe the costing of all well system items contained in each subactivity described in Chapter 2. Under cost type; S indicates a subcontractor cost, P a direct purchase of equipment or materials, and R a rental. The time represents the time required to complete a specific item.

Cost Types: S = Subcontract P = Purchase R = Rental

	Cost Type	Time (Hrs)	Cost ($)
2.1.1 <u>Drilling Core Hole at Test Site</u>:			
Drilling contractor costs Ref. Longyear Co., Phone, 5-12-87			
o Mobilization, demob, rig up	S	8	1,000
o Core drilling, Hq wl size, 950 to 2,250 ft. deep [(1000-970)x20] + (500x22) + (500x24) + (20x26) = 24,120	S	181	24,120

o Drilling fluids Ref. Joy Equip. Co., Jim Koontz, Phone, 7/86 \$1.50/ft. x (2220′-970′) = 1,875	P	--	1,875
o Core boxes, film, core packaging matls. estimate total of 1.00/ft x 1,250 ft. = \$1,250	P	--	1,250
o Drilling through sediments, 0′ to 970,′ 6" diam.			
Air hammer drilling: 150 \$/hr x 970 ft ÷ 25 ft/hr =	S	39	5,820
Mud rotary drilling: \$150/hr x 970 ft ÷ 15 ft/hr = 9,700	S	65	9,700
o Well casing 4 1/2 o.d. A.P.I., T&C 0′-970′ \$3.00/ft x 970′ = 2,850	P	--	2,850
o Install casing: \$150.00/hr x 7 hours =	S	8	1,050
o Abandon core hole:			
- Mix and install cement in core hole: $(3.79 \div 2)^2 \pi \div 144 \times 1{,}250 \div 1.18$ x \$7.00/sack + (\$90.00/hr × 16 hr)	S	16	1,746
- wait on cement	S	8	--
- pull sediment casing (if possible) 10 hrs x \$90.00/hr	S	10	900
- mix and install cement in rotary hole:	S		
$(6 \div 2)^2 \pi \div 144 \div 1.18 \times 970$ x \$7.00/sack + (\$90/hr × 8 hr)	S	16	1,849
- wait on cement	S	8	--
o Total costs, excluding sediment drilling:			
Subcontract	S	263	30,665
Purchase	P	--	5,975
o Mud rotary drilling (sediments)	S	65	9,700
o Air hammer drilling (sediments)	S	39	5,820
o Total mud rotary drilling cost	-	329	46.340
o Total air hammer drilling cost	-	302	42,460

2.1.2 Install First Test Well Through Sediments

Drilling Contractor

o Mobilize/Demob./Rig Up Layne Western Co., Chandler, Ariz., R. Huskison, Phone 6/19/87	S	10	12,000

o Drill Surface Hole; Install Surf. Casing	S	12	2,000
o Drill Sediments to 970 ft.			
- Mud (water) Rotary: \$25/ft x 970 ft. = \$24,250, 65 hours			Mud ←
- Air Hammer: 970 ft x \$250/hr ÷ 20 ft/hr = \$12,125, 49 hours			
- Drilling Fluids: (estimate) \$1.50/ft x 970 ft. = 1,455 Air Drilling = \$13,580, 49 hrs			Air ←
o Casing Installation: \$250/ hr x 950 ft ÷ 130 ft/hr	S	7	1,826
o Wait on Cement: \$175/hr x 12 hr (incl. cementing time)	S	12	2,100
		====	======
MUD ROTARY SUBTOTAL =		106	42,176
AIR HAMMER SUBTOTAL =		90	31,506
Logging Contractor			
o Mobilization/Demob: (estimate) 900 mi x \$1.50/mi. x 2 ways	S	---	2,700
o Caliper Log: (estimate) \$350 setup + \$200/hr x 2 hr + \$700 (personnel)	S	6	1,250
o Standby 2 days x (500 + 200 + 150)	S	---	1,700
o Cement Bond Log (same as Caliper)	S	6	1,250
o Well Casing: Layne Western, \$15/ft x 950 ft	P	---	14,250
Cementing			
o Contractor Mobilization/Demob 500 mi. x \$2/mi x 2 units x 2 ways	S	---	4,000
o Cementing: 868 Ft^3 x \$4/Ft^3	S	4	3,472
o Materials: 970′ + 144 $(15 \div 2)^2$ $(10.75 \div 2)^2$ Π \$10/Ft^3 x 1.5xπ	P	---	8,684
		====	======
SUBTOTAL		16	37,306
MUD ROTARY TOTAL:			79,482
AIR HAMMER TOTAL:			68,812

2.1.3 <u>Install First Test Well Through Ore</u>
<Assuming Mud Rotary Drilling>

Drilling Contractor:

o Drilling $250/Hr ÷ 10 Ft/Hr x 1,250 Ft.	S	125	31,250
o Handling & Setting Equip. 3 R. Trips X 10 Hrs/R.T. x $250/Hr	S	30	2,500
o Drilling Fluids & Additives (estimates) $4/Ft. x 1,280′	P	---	5,120
o Oriented Core $100/Ft. x 10 Ft (Layne Western Estimate)	S	24	1,000
o Setting Casing 12 Hr x $250/Hr	S	12	3,000
o Cementing & W.O.C. (4 Hr x $250/Hr) + (12 Hr x $175)	S	16	3,100
o Directional Drilling (10 Hr x $250/Hr) + [14 Hr x $(250 + 200)] + $2,500	S	24	11,300
SUBTOTAL		231	57,270

Tubing for Flow Test:

o Work String Tubing, 2 7/8" A.P.I. (2,500 Ft x $6/Ft)	P	---	15,000

Casing Materials:

o Centralizers (Industrial Rubber Co.; Phone) 20 x $15 each	P	---	300
o Cement Baskets (Arrow Oil Tools; Phone I.D.) $128 x 2	P		256
o Pup Joints (Casing) $450 ea. avg. x 5	P		2,250
o Float Shoe & Value $250 + $100	P		350
o Thread Adapters (two, 316 s.s.)	P		1,100
o Casing Head (Hercules Co. Catalogs, HHS 7", equipped)	P		450
o Casing (Polymer Piping Co. Catalog, 1987, 7", 1,250 psi (2,230 Ft, $18.82/Ft)	P		41,968
Casing Running Crew: (3 men x $300/Day) + $600 Transp + $300 per diem	S	Above	1,800
CASING & SERVICE SUBTOTAL		---	48,474

Cementing:

o Materials (Lightweight, 50% excess) 867 FT^3 x $15/$FT^3$ Total	P	---	13,005
o Service (867 FT^3 x $4/$FT^3$ + 1,425) (ESTIMATE)	S	Above	4,893
o Mobilization/Demob. 500 mi x $2/mi. x 2 units x 2 ways	S	Above	4,000
CEMENTING SUBTOTAL			$21,898

Logging: (Associated only with drilling & cementing)

o Caliper $200/hr x 2 Hr + $350 setup + $700 personnel	S	6	1,250
o Cement Bond Same as Above	S	6	1,250
o Standby (1 day)	S	Above	850
o Perforations (200 Ft. x $6/Ft) + $800 (Generic Manual)	S	4	2,000
LOGGING SUBTOTAL		16	5,350
ACTIVITY TOTAL		247	136,383

2.1.3 Install First Well Through One <Assume Air Hammer Drilling>

Drilling Contractor:

o Drilling: ($250/hr x 1,250 ft + 20 ft/hr)	S	63	15,625
o Handling & Setting Test Equip. (3 R.Trips x 10 hr/R.T. x $250/hr)	S	30	2,500
o Drilling Fluids & Additives (1.50/ft x 1,280 Ft.)	P	---	1,920
o Oriented Core (Layne Western Est.) $100/Ft x 10 Ft	S	24	1,000
o Setting Casing (12 hrs x $250/hr)	S	12	3,000
o Cementing & W.O.C. (4 hrs x $250/hr) + (12 hrs x $175/hr)	S	16	3,100
o Directional Drilling (10 hr x $250/hr) + [14 hr x ($250/hr + $200/hr)] + 2,500	S	24	11,300
SUBTOTAL		169	38,445

Tubing for Flow Tests (2 7/8" A.P.I. "Work String") $6/Ft x 2,500 Ft	P	---	15,000
Casing & Service: (See "Mud Drilling" Section 2.1.3 estimate)	S	Above	1,800
Casing & Service: (See "Mud Drilling" Section 2.1.3 estimate)	P	---	46,674
SUBTOTAL			48,474
Cementing: (See "Mud Drilling") Section 2.1.3 estimate)	S	Above	8,983
	P	---	13,005
SUBTOTAL			21,988
Logging: (See "Mud Drilling" Section 2.1.3 estimate)	S	16	5,350
ACTIVITY TOTAL		185	117,558

2.2.2 Install Second and Third Wells
<Assume Mud Rotary Drilling>

Install Wells Though Sediments: (Section 2.1.2 estimates) $56,584/well x 2 wells = Less Mobilization (Rig & Logger) - Plus moving rig between holes +	$113,096 14,700 (contractor 15,000 estimate) $113,396	S	244	113,396
Purchased Equipment: $22,934/well x 2 wells		P	---	45,868
SUBTOTAL (sediments)			244	159,264
Install Wells Though Ore: (Section 2.1.3 estimates)				
$68,749/wells x 2 wells	= 136,386	S	486	136,386
Purchased Equipment: $64,799/well x 2 wells = 129,598		P	---	129,598
SUBTOTAL, (Ore)			486	265,984
TOTAL COST, ASSUMING MUD ROTARY DRILLING			730	425,248

Install Second and Third Wells				
<Assuming Air Hammer Drilling>				
Install Wells Through Sediments:				
(Section 2.1.2 Est.)				
$44,423/well x 2 wells	= 88,846			
Less mobilization (rig & loggers)	-14,700			
Plus onsite rig moves	+15,000			
Purchased Equipment:	89,146	S	212	89,146
$24,398/well x 2 wells		P	---	48,778
SUBTOTAL (sediments)			212	137,924
Install Wells Through Ore				
(Section 2.1.3 estimates)				
Subcontracted: $50,768/well x 2 wells		S	370	101,536
Purchased: $63,399/well x 2 wells		P	---	126,798
SUBTOTAL (ore)			370	228,334
TOTAL COST, ASSUMING AIR HAMMER DRILLING			582	366,258

2.2.6 Well Stimulation (First 3 Wells)

Drilling Contractor			
o Installing and removing well equipment 10 hrs x $250/hr	S	10	2,500
o Moving rig between wells 4 hrs x $250/hr	S	4	1,000
o Standby during stimulation operations 32 hours x $175/hr non-operating standby rate	S	Below	5,600
		-----	-----
DRILLING CONTR. SUBTOTAL <1-WELL>		14	9,100
Hydrofracturing <1 Well>			
o Mobilization/Demob/Rig Up (500 mi x $2/mi. x 2 units x 2 way + 2 well)	S	4	2,000
o Personnel and Expenses (2 days x 5 men x $75/day) + ($500/day engr x 1 day)	S	---	1,250
o Operations and materials (general manual) $14/ft x 200′ + $2,500	S	24	5,300
	S	Above	
HYDROFRC CONT'R. SUBTOTAL <1-WELL>		28	8,550

o Equipment <Assume 1-time charge>			
- Inflatable Packer & Equipment (Lynes Co.; 2 uses, $3,000/USE)	R	---	6,000
- Mechanical Packer (Arrow Oil Tools, Mr. Messenger, 7-8-87)	P		900
SUBTOTAL			6,900
H.E.G.F. Stimulation <1-well>			
o Design, Operation & Materials (S. Trost, Hi-Tech Nat'l Resources) 1-23-87; confirm 7-87) $2,000 + $800 + ($2,160 ÷ 12') x 200'	S	48	38,800
o Personnel & Expenses ($375/day x 2 days)		---	750
o Mobilization/Demob. (400 mi x $1/mi x 2 ways) + ($350/day x 2)			1,500
H.E.G.F. CONT'R. SUBTOTAL <1-WELL>		48	41,050
o Logging (Well integrity testing) (1-well)		---	2,500

Short-Radius Hydrofrac's.: <2-Wells>

Drilling Contractor	$18,200
Hydrofrac Contractor	17,100
Logging Contractor	2,500
Equipment	6,900
Total	$44,700

H.E.G.F. <1-Well>

Drilling Contractor	$ 9,100
Logging Contractor	2,500
H.E.G.F. Contractor	41,050
Total	$52,650

2.2.7 <u>Determine L.R. Hydrofrac Properties</u>

Drilling Contractor:

o Plug back lower well test intervals ($250/hr x 16 hr)	S	20	4,700
o Install casing slot ($250/hr x 12 hr)	S	12	3,000
o Install well equipment, hydrofracture ($250/hr x 12 hr) + (4 hrs x $175/hr standby)	S	16	3,700

o Plug lower well interval for top hydrofrac [$250/hr x (5 P.O.H. + 7 set plug)]	S	12	3,000
o Install upper casing slot ($250/hr x 12 hr)	S	12	3,000
o Install well equipment, hydrofracture, remove equipment [$250/hr x (12 equip x 5 P.O.H.) + $175/hr (4 standby)]	S	21	4,950
DRILLING CONT'R SUBTOTAL		93	22,350
Hydrofracturing Contractor: <per fracture>			
o Install Casing Slots (estimate)	S	Above	2,000
o Install mini-frac; analyze & modify frac design (estimates)	S	Above	2,000
o Install L.R. frac[2] (generic manual) $5,000 + $0.41/ft^2 x Π x (50)^2 x 2	S	Above	16,440
HYDROFRAC CONT'R. SUBTOTAL (1-FRAC)		16	20,440
Geophysical Consultants (est. 10 days x $1,000/day)	S	---	10,000
Materials:			
o Sand & Cal Seal for plugs (10 SK sand x $6/SK) + (6 SK Cal Seal x $50/SK)	P	---	360
o Retrievable Bridge Plug (Mtn St. Oil Tools, 7/8/87, Messenger)	R	---	2,982
o Infaltable Packer (estimate) 2 uses, $3,000 each	R	---	6,000
MATERIALS SUBTOTAL			9,342
Frac. Attitude Analysis:			
o Downhole Seismic (T.A.B.S.) (Phone, 2 wells, 2 days 7/87, G. Sorrells, Teledyne Geotech)	S	Above	54,000
o Logging Contractor (estimate) 4 logs @ $1,250/log x 2 wells, includes cost for well integrity testing	S	12	10,000
o Surface Seismic (Phone 10/86, L.W. Teufel, Sandia Labs, 2 Tests)	S	Above	65,000
o Tiltmeters (Above Ref., 2 tests)	S	Above	40,000

o Core analysis (Above Ref., 2 tests)	S	Above	40,000
SUBTOTAL <2-WELLS>		12	209,000
SECTION TOTAL		121	271,132

2.3.3 Leach Well Installation <Using MUD ROTARY Drilling>

o Drill & complete through sediments (subcontracted) <See subactivity 2.2.2 estimates, for 2 wells> \$113,396 ÷ 2 wells x 7 wells	S	427	396,886
o Mobilize second drill rig to site <See subactivity 2.1.1 estimate>	S	---	12,000
o Total Purchased Equipment <See subactivity 2.2.2 estimate> (\$45,868 ÷ 2 wells x 7 wells)	P	---	160,538
SUBTOTAL SEDIMENTS		427	569,424
o Drill and complete through ore (Subcontracted)	S	753	498,883

<Subactivity 2.2.2 estimate for 2 wells>	(Cost)	Time (Hr)
\$68,193/well x 7 wells	477,351	1,701
Less oriented Core = \$100/Ft x 10 Ft x 7 wells =	-7,000	-168
Less O.H. Testing (Service Rig Cost)	-17,500	-210
Plus perforate existing well	+1,532	+ 6
Plus test equip. Installation/removal:		
Transient tests	+20,000	+80
Tracer/interference test	+17,500	+70
Move rigs between holes	+ 7,000	+28
Subtotal	498,883	1,507

1507 Hours ÷ 2 rigs = 753 hours

o Purchased equipment total (See Subactivity 2.2.2 estimate) \$64,799/well x 7 wells			453,593
SUBTOTAL ORE		753	952,476
SUBACTIVITY TOTAL, MUD ROTARY DRILLING		1,180 (49 days)	1,521,900

2.3.3 Leach Well Installation <Air Hammer Drilling>

o Drill & complete through sediments <Subcontracted Costs> (see subactivity 2.2.2 under A.3) $89,146 ÷ 2 wells x 7 wells = 312,011	S	371	312,011
o Total purchased equipment <See Subactivity 2.2.2 estimate> $48,778 ÷ 2 wells x 7 wells = 170, 723	P	---	170,723
SUBTOTAL, SEDIMENTS		371	482,734
o Drill and complete through ore zone <See Subactivity 2.2.2 estimate>	S	550	376,908

$50,768/well x 7 wells =	$355,376	1,295 hrs
Less oriented core ($100/ft x 10 ft x 7 wells)	-7,000	-168
Less O.H. testing ($250/hr x 10hr well x 7 well)	-17,500	-210
Plus perforate existing well (122'x$6/ft.+$800)	+ 1,532	+ 6
Plus test equip. Install/remove: Transient tests ($250/hr x 10hr x 8 wells)	+20,000	+80
Tracer/interference tests (7 wells)	+17,500	+70
Move rig between holes ($250/hr x 4 x 7)	+ 7,000	+28
Subtotal	359,800	1,101

1101 Hrs ÷ 2 rigs = 550 hrs

o Purchased equipment total <See Subactivity 2.2.2 estimate> $63,399/well x 7 wells	P	---	443,793
SUBTOTAL, ORE ZONE		550	820,701
		====	=======
SUBACTIVITY TOTAL, AIR HAMMER DRILLING		921	1,303,435

2.3.8 Stimulate Leach Wells

o Drilling Contractor:

- Installing and removing equipment 10 hours x $250/hr x 8 well	S	80	20,000
- Recompleting well T-2 12 hours x $250/hr	S	12	3,000

- Moving between holes 4 hrs x 7 wells x $250/hr	S	28	7,000
- Standby during stimulations ($175/hr x 12 hrs/stim. x 8 stim)	S	Below	16,800
DRILLING CONT'R SUBTOTAL		120	46,800
o Hydrofracturing Contractor:			
- Mobilization/Demob. 500 mi x $2/mi x 2 units 2 ways	S	---	4,000
- Rig up and down; move between wells (cost incl. in frac. operations)		Above	-----
- Install short-radius hydrofracs (including matl's) (generic manual formula) 7 [2,500 + 14 (322)]+[2,500 + 14(122)]	S	64	53,264
- Personnel expenses 10 men, $75/day, (2-12 hr shifts) 4 days	S	---	3,000
- Standby - none		---	----
HYDROFRAC CONT'R SUBTOTAL		64	60,264
o Logging Contractor (well integrity testing) 8x($1,250/Log x 2)		48	20,000
o Equipment			
- Packers costed in Section 2.2.6			------
- Tubing costed in Section 2.1.3			------
SECTION 2.3.8 TOTAL		232	127,064

2.3.9 Equip. Leach Wells for Leach Test - T1

o Drilling Contractor:			
- Install equipment in each well 8 wells x 10 hours x $250/hour	S	80	20,000
- Move between wells 7 wells x 4 hrs x $250/hr	S	28	7,000
- Standby during equipment hook-up & testing 8 weeks x 1 hour x $175/hr	S	8	1,400
DRILLING CONT'R SUBTOTAL		116	28,400

o Equipment:

F.R.P. Tubing:

- :(Centron DH2000 2 3/8", catalog price): ($5.14/ft x 7 wells x 1900') + (2,200 (spare) x $5.14)	P	---	79,670
- Thread adapters; $130 ea x 2/well x [(8 wells) + (1 set spare)]	P	---	2,340
- Pup joints ($101 + 118 + 135 + 152 + 169) x 8 strings	P	---	5,400
- Thread lube (5-9 lb phils) x $82.50	P	---	412
Metallic Tubing: (For prog. cavity pump)			
- (Cabval, VS-28 Alloy, Mr. Geo. Peterson, Phone, 7/15/87)			
- 2 3/8" O.D. A.P.I. 8 RD E.U.E, 0.190" wall			
- [($19/Ft. x 30 Ft./Joint) + ($200/Joint (THDS)] (64 Joints/Well + 10 Spare Joints)	P	---	56,980
- 2 3/8" F.R.P. Couplings: [64 + 5 (pups) + 10 (spare)] $15.50 (Fiberglass Systems, 1984 Catalog Price)	P		1,224
- PUP. Joints $19 (2 + 4 + 6 + 8 + 10) + ($200 x 5)	P	---	1,570
o Thread Adapters (Fiberglass Systems Catalog)			
(2" 8RD x 2 1/2 8RD = $39.15 x 2 x 2 spare	P	---	157
WELL TUBING SUBTOTAL	P	---	147,753

Recovery Pumps:

o Electric submersibles (Grundfos SP 4-80 DS) Catalog Prices)			
- Pumps: $2915 ea x (4 wells + 12 spares)	P	---	46,640
- Motors: $1362 ea x (4 wells + 12 spares)	P	---	21,792
- Motor Control Panels $1072 ea x 4 wells	P	---	4,288
- Motor Leads: $45.00 ea x (4 + 12 spare)	P	---	720

o Electric cable (Generic Manual)			
- $3.00/ft (1900 ft x 4 wells + 5000 ft. spare)	P	---	37,800
- Cable splice kits $10.00 ea x 50 kits	P	---	500
SUBMERSIBLE PUMP TOTAL			111,740
o Progressing Cavity Pumps (Robbins-Myers 9 Stages) (Robbins Meyers, Tom Dollar Phone, 7/30/85) 316 S.S./Buna -N Construction			
Stator = 1697 ea x (1 well + 4 spares)	P	---	8,485
Rotor = 1356 ea x (1 well + 4 spares)	P	---	6,780
DH30 drive head, equipped (estimate)	P	---	3,500
o Factory eng., to assist w/1 installation est: $400 travel, $150 hotel/chk, $400.00/ day chg	S	---	950
904 Alloy or equivalent (scaled from above estimate)			
Stator ($5 x 1697) ea x (1 well + 2 spares)	P	---	25,455
Rotor ($5 x 1356) ea x (1 well + 2 spares)	P	---	20,340
DH30 drive head, equipped (estimate)	P	---	3,500
Spare electric motor (estimate) 460V 3ph, 10Hp	P	---	200
Drive Rods: 316 S.S., 5/8" A.P.I.			
Estimate [($3.00/ft x (2000 ft x 2 wells + 300 ft. spare)]	P	---	12,900
Pony rods (estimate) 2 sets ($500/set)	P	---	1,000
Thread sealent 4 gallons @ $80/gal.	P	---	320
o Rod guides: (Central Plastics Co.)			
Estimate ($3.00 each) [(2000 ft + 30 ft/ (2 wells + 1 spare)]	P	---	600
PROGRESSING CAVITY PUMP TOTAL			84,030
MISCELLANEOUS:			
o Tubing drain sub. - 904L, custom built			
Estimate $400 ea, x 4 wells	P	---	1,600
Spare breakoff pins 80 pins x $5 ea	P	---	400

o Recovery well tee (elec. sub. pumps) 904L, 150 PSI rated, 2" I.D. $30 ea x 4 wells + 2 spares	P	---	180
o Recovery tubing value, 150 psi, 904L Alloy, 2" Ball value $100 ea. x (6 wells + 2 spare)	P	---	800
o Recovery well flange 904L, 2", 150 PSI & nipple			
Est. $30 ea x 6 wells + 2 spares	P	---	240
o Recovery well press. gauges: 904 Alloy, 6", 1%			
Tubing gauge: 0-200 PSI, $150 ea x (4 wells + 2 spares)	P	---	1,200
Casing valves: 0-1500 PSI, $150 ea (4 wells + 2 spares)	P	---	1,200
Gauge valves & fittings 904 Alloy, 1/4" 150 PSI 2 valves/well x (4 wells + 1 spare) x ($40/valve + $10 fittings)	P	---	500
o Recovery Well Cross (P.C. pumps)			
904L, 2", 150 PSI N.P.T. $40 ea x (2 wells + 2 spares)	P	---	160
o Injection Packers: (BASKI/WATER/INST., 1984 Catalog & Phone) Alloy 904, 40" x 5 1/4" Sliding end = 1,280 x 5 x [2 + 2 (spare)]	P	---	25,600
o Packer Inflation Tube: (2000 PSI Minimum, Reinforced Elostomer) estimate (1.00/ft) [(1900 x 2 wells) + (1000 ft spare)] (includes couplings)	p	---	4,800
o Strapping: (Metallic or plastic strapping, tape or clamps) estimate $0.90/strap x (1900 ft ÷ 10 ft/strap) x 8 wells x 6 (replacements)	P	---	8,208
o Wellheads (Hercules 7" model HHS, equipped $450.00/wlhd x (7 + 1 (spare))	P	---	3600
o Landing nipples: Cabval V-20/alloy, flanged, threaded, 4′ long (2 wells + 1 spare) x [($19.00/ft x 4 ft) + ($100.00 thd) + ($50.00 fange)]	P	---	2,034

o Casing valves: (316 SS, 2", 2000 PSI ball valves $200.00/value x 8 wells + 1 spare	P	---	1,800
o Injection tubing value: Alloy 904, 2" full open gate, 1000 PSI estimate $400 ea x 2	P	---	800
o Injection tee: 904L, 1000 PSI, flanged tee estimate $150 ea x 2	P	---	300
o Injection check valve: 904L swing check, 1000 PSI, flanged est. 700 ea x 2	P	---	1,400
o Injection flange - 904L nipple & flange, 2" 900 lb., r.f. estimate $50.00 ea x 2	P	---	100
o Injection pressure and wellhead gauges: 904l, 6", 0-1500 PSI, 1% estimate $150.00 ea x (2/well) 2 wells + 1 spare	P	---	750
o Gauge valves & fittings: 904L, 1/4", 2000 PSI ball valves			
Valves: $40.00 ea x (2/well), 2 wells + 2 spare	P	---	240
Fittings: estimate $10.00/valve x 6 valves	P	---	60
o Recovery well fluid level monitoring equip. pressure tubing: 1/4" high press. tube 1500 PSI			
- ($0.50/ft (incl coupling) x 1900 ft x 6 wells + 1 well (spare)	P	---	6,550
- P gauges - 2/well x (6 wells + 1 spare) x $80.00 each	P	---	1,120
- Regulators - 1/well x (6 wells + 1 spare) $150.00 ea	P	---	1,050
- Valves & fittings est. $30.00/well x (6 + 1 spare)	P	---	210
- Pressure tanks (rental, refillable, 220 ft^3 size) ($50.0/bottle x 8 bottles) (6 refills/bottle x 8 bottles x $60.00/ fill)	R	---	3,280
	MISC. SUBTOTAL		68,182

A.4 WELLFIELD CHEMICAL CONCENTRATION BUILD-UP

The efficiency of copper extraction in the SX circuit can be affected by the composition and concentration of other ions in the pregnant leach solution. Al, Mg, and Fe are products of acid reaction with gangue, and Cl is a product of Atacamite dissolution. The concentration of these ions in the pregnant leach solution will increase with time, as acid spent wellfield production fluid is rejuvinated with acid and recycled through the wellfield numerous times. The build up in concentration of these ions is a function of: net acid consumption by gangue; the % of copper mineralization in the ore zone that is Atacamite; the number of times solution is recycled through the well pattern; and precipitation of ions in high pH zones of the wellfield or by gypsum precipitation. Since no true in situ recycle acid leach test has been operated to date, it is necessary to estimate the concentration build up of these ions in the pregnant leach solution.

- <u>Calculation of Number of Wellfield Circulations in Wellfield Life</u>

  + ϕ = % porosity
  + E_c = % copper recovery
  + F_c = % copper grade
  + Cu = gpl copper build up per pass through wellfield
  + N_T = Total number of wellfield circulation in wellfield life

$$N_T = 0.26 \left(\frac{100 - \phi}{\phi}\right) \left(\frac{E_c F_c}{Cu}\right) \qquad \text{(A-27)}$$

- <u>Calculation of Ion Build Up PER Wellfield Circulation</u>

  + Assumptions

    - Al, Mg, Fe principal gangue acid consumers
    - Al-to-Mg and Al-to-Fe ratio is 1.5-to-1
    - Cu-to-Cl ratio in Atacamite is 3.6-to-1

  + Nomenclature

    - Al = gpl aluminum concentration rise per pass
    - Mg = gpl magnesium concentration rise per pass
    - Fe = gpl iron concentration rise per pass
    - Cl = gpl chloride concentration rise per pass
    - Mg = lb H_2SO_4 reacted with gangue per lb copper produced
    - A_C = % copper grade as Atacamite
    - N_P = number of wellfield circulations

+ Calculation of concentration build up per pass

  - $Wg = \frac{5.44Al + 4.07Mg + 2.2Fe}{Cu}$ (A-28)
  - with Mg = Fe = Al/1.5:
  - $Wg = 9.62\ (Al/Cu)$ (A-29)
  - Solving for Al:
  - $Al = 0.104\ Wg\ Cu$ (A-30)
  - with Mg = Fe = Al/1.5:
  - $Mg = Fe = 0.0693\ Wg\ Cu$ (A-31)
  - $Cl = \frac{AcCu}{100 \times 3.6}$ (A-32)

+ The total concentration after N_p circulations is the product of N_p and the specific ion concentration. This assumes no precipitation in the wellfield or surface plant.

+ A total of 17 wellfield circulations (N_T) are calculated using the following set of solution and geologic parameters: 10 gpl effluent copper loading (Cu); 0.7% copper grade (F_c); 50% copper recovery (E_c); and 5% porosity (ϕ).

+ Based on a three year well life and an 18 month steady-state operation of the well pattern in the field experiment, 8 1/2 wellfield circulations (N_p) are calculated for the duration of the field experiment.

+ Assuming 20% of the copper is Atacamite, and the gangue acid consumption is 3 1/2 lb H_2SO_4 per lb copper (Wg), the calculated ion concentrations following 8 1/2 wellfield circulations are:

  - Al = 31 gpl
  - Mg = 21 gpl
  - Fe = 21 gpl
  - Cl = 5 1/2 gpl

+ It is likely that recycle may reduce the net acid consumption or that some fraction of the Al, Mg, and Fe may precipitate in situ. It is assumed that the maximum concentrations of Al, Mg, and Fe will be 20 gpl, 13 gpl, and 13 gpl respectively.

+ These Al, Mg, Fe, and Cl concentrations are listed in Section 3.1.2.1 under Analysis.

APPENDIX B

SURFACE FACILITIES DESIGN CALCULATIONS AND EQUIPMENT COSTS

B.1 DESIGN CALCULATIONS

(1)	Design Calculations for SX/EW			
(2)				
(3)				
(4)	Mass Balance Inputs:			NOTES:
(5)				
(6)	Copper loading	=	10.00 g/1	
(7)	Flow rate of PLS	=	11.36 m3/h	PLS - Plant Leach
(8)		=	50 gpm	Solution
(9)	% extraction	=	0.85	% of Cu in PLS
(10)	Cu:Fe	=	300	extraction ratio
(11)	Entrainment	=	500 ppm	organic carry over
(12)	Copper conc. in bleed	=	30.00 g/1	bleed - electrolyte
(13)	Iron conc. in PLS	=	12.00 g/1	returned to
			extraction	
(14)	Iron conc. in bleed	=	2.50 g/1	
(15)	Acid conc. in PLS	=	2.00 g/1	Acid = H2SO4
(16)	Acid conc. in bleed	=	150.00 g/1	
(17)				
(18)				
(19)	Mass Balance Report:			NOTES:
(20)				
(21)	O'all recovery	=	0.8440	0.84396 calc'd
(22)	Cathode	=	113.58 kg/h	calc. basis: Cu loading
(23)	Cathode	=	113.58 kg/h	calc. basis: mass balance
(24)				
(25)	[Cu](p)	=	11.85 g/1	conc. of Cu in PLS
(26)	Cu(p)	=	134.59 kg/h	mass rate of Cu in PLS
(27)				
(28)	[Cu](r)	=	1.82 g/1	conc. of Cu in Raf.
(29)	Q(r)	=	11.54 m3/h	flowrate of Raffinate
(30)	Cu(r)	=	21.00 kg/h	mass rate of Cu in Raf.
(31)	[H2SO4](r)	=	20.24 g/1	H2SO4 in Raffinate
(32)				
(33)	Daily production	=	2.73 mt/d	of Cu Cathode
(34)			3.01 st/d	
(35)				
(36)	General Mass Balance Equation about SX & EW:			
(37)				
(38)	[Cu](p) x Q(p) . [Cu](r) x Q(r) = Cathode + [Cu](b) x Q(b)			
(39)				
(40)	Mass Balance Equation with electrolyte bleed returned to extraction:			
(41)				

[Cu](p) x Q(p) - [Cu](r) x Q(r) + [Cu](b) x Q(b) =
Cathode + [Cu](b) x Q(b)

[Cu](p) x Q(p) - [Cu](r) x Q(r) - Cathode

[Cu](1) x Q(p) = Cathode   Note: [Cu](1): Cu loading
[Cu] Q
10.00 11.36
Cathode - 113.58 kg/h

[Cu](p) x Q(p) - (1-%) x ([Cu](p) x Q(p)) - Cathode
(%) x ([Cu](p) x Q(p)) - Cathode
% o'all Q Cathode   Note: " % " is the
0.84 - 11.36 113.58   % of Cu extraction
[Cu](p) = Cathode/ Q(p) x %
[Cu](p) = 11.85 g/1

Iron Balance

Fe by chemical transfer: Fe(1)

Cathode + [Cu](b) x Q(b) / Cu:Fe - Fe(1)   Note: Cu:Fe is the
Cathode [Cu] Q Cu:Fe   ratio of metals
113.58 30.00 0.1806 300 0.40   in extraction

Fe(1) = Cat/: + [Cu](b)/: x Q(b)   Note: " : " is the
Fe(1) = 0.37862 0.10000 x Q(b)   Cu:Fe ratio

Fe by entrainment transfer:

E > S (extraction to strip). Fe(2):

(Q(p) + Q(b)) x ppm x [Fe](p) = Fe(2)   Note: ppm is entrained
Qp Qb ppm [Fe]   aqueous in organic
11.36 0.18 500 12.00 0.06923   [Fe](p): Fe in
PLS
Fe(2) = Qp*ppm*F + ppm*F x Q(b)
Fe(2) = 0.07 0.0060 x Q(b)   Note: F = [Fe](p)

S > E (strip to extraction). Fe(3):

(Q(p) + Q(b)) x ppm x [Fe](b) = Fe(3)
Qp Qb ppm [Fe]
11.36 0.18 500 2.50 0.01442

Fe(3) = Qp*ppm*F + ppm*F x Q(b)   Note: F = [Fe](b)
Fe(3) = 0.0142 0.0013 x Q(b)

Fe in bleed. electrolyte returned to extraction. Fe(4):

```
[Fe](b) x Q(b)  -  Fe(4)
[Fe]        Qb
   2.50       0.18  0.4515
Fe(4) =    0.45149 kg/h

Fe(4) =  [Fe](b) x Q(b)
Fe(4) =    2.50 x Qb

Mass Balance of Fe about SX:

Fe(4) = Fe(1) + Fe(2) - Fe(3)
           0.43257  0.10475 x Q(b)
Q(b) =     0.18059

[Fe](4)   =  [Fe](1) + [Fe](2) . [Fe](3)
0.45           0.40  0.06923  0.01442
0.45        (check)

Copper in bleed

Cu(b)   =   [Cu](b) x Q(b)
            [Cu]    Q
               30.00  0.18059          Note:
Cu(b) =         5.42 kg/h              mass rate of Cu in bleed
[Cu](b) =      30.00 g/1               concentration of Cu in bleed
Q(b) =          0.18 m3/h              flow rate of bleed

Copper in PLS

Cu(p) -   [Cu](p) x Q(p)
              11.85      11.36         Note:
Cu(p) =   134.59 kg/h                  mass rate of Cu in PLS
[Cu](p) =  11.85 g/1                   concentration of Cu in PLS
Q(p) =     11.36 m3/h                  flow rate of PLS

Copper in raffinate

Cu(r)   = (1 . % extrac) x ( Cu(p) + Cu(b) )
            1-%      Cu(p)    Cu(b)
                0.15  134.59 5.4178    Note:
Cu(r) =        21.00 kg/h              mass rate of Cu in raffinate

[Cu](r)   =  Cu(r) / Q(r)
Q(r) = Q(p) + Q(b)
[Cu](r)   =  Cu(r) / Q(p)  +   Q(b)
             21.00     11.36     0.18  Note:
[Cu](r) =     1.82 g/1                 concentration of Cu in raffinate
Q(r) =       11.54 m3/h                flowrate of raffinate
```

```

CuSO4 + 2 HR  <=>  2 CuR + H2SO4      Note: SX chemical equation

Cu          =  (Cu(p) + Cu(b)) x % ext
Cu          = lCu(p) + ( [Cu](b) x Q(b) ) l x % ext
                Cu        Cu       Q      %
                  134.59    30.00   0.18        0.85

Cu          =   119.00 kg/h               Note: Cu is the mass rate of
                                                Cu entering extraction
Acid generated in extraction

H2SO4 = Cu x 98.08/63.54
          Cu          1.54359
            119.00   1.54359
H2SO4 =     184 kg/h                      Note: mass rate of acid
                                                generated in extraction
Acid in PLS solution

H2SO4 = [H2SO4](p) x Q(p)
          H+      Q
            2.00           11
H2SO4 -       23 kg/h                     Note: mass rate of acid in PLS

Acid in bleed

H2SO4 = [H2SO4](b) x Q(b)
          H+      Q
            150.00   0.1806
H2SO4 =         27 kg/h                   Note: mass rate of acid in bleed

Acid in raffinate

H2SO4   =  H+(b) + H+(p) + H+(ext)        Note: H+ = H2SO4
           H+      H+      H+                   ext - extraction
              27       23      184
H2SO4 =     233 kg/h                      Note: mass rate of acid in
                                                raffinate
[H2SO4](r)  =  H2SO4/Q(p) + Q(b)
           H+      Q       Q
              233   11.36  0.18059
[H2SO4](r)  =        20.24 g/1            Note: conc. of acid in raffinate

[Cu](p) x Q(p) - [Cu](r) x Q(r)  =  Cathode
[Cu](p)   Q(p)   [Cu](r)   Q(r)     Cathode
   11.85     11.36  1.82      11.54
Cathode =  113.58 kg/h                    Note: mass rate of cathode
                                                ie. cathode production
O'All recovery =  Cathode/[Cu](p) x Q(p)
                  Cat      Cu       Qp
```

```
(192)                          114      11.85        11
(193)  O'All recovery =  0.84396               Note: back calculated
(194)
(195)
(196)  Electrolytic Cell Criteria
(197)
(198)  Plating area              =  1.00 m2/side     m2
(199)  Current Density           =      180 A/m2        A/m2
(200)  Current efficiency        =       85 %        eff
(201)  EW availability           =       95 %        avail
(202)  Cathodes per cell         =       56             cath
(203)  Electro-chemical equiv. =  0.02845 kg/A d
(204)  Number of cells           =        6          # cell
(205)  Cell voltage              =     2.50 V dc/cell v/cell
(206)
(207)  Electrolytic Cell Production, (EPC):
(205)
(206)  EPC = m2 x 2 x A/m2 x eff x avail x 0.02845 x cathodes
(207)        1       180    0.85      0.95  0.02845     56
(208)
(209)  EPC =       463 kg/d per cell
(210)           1,021 lb/d per cell
(211)
(212)  Tankhouse capacity =    6,127 lb/d           0.01938
(213)  Cathode production =    6.011 lb/d
(214)
(215)
(216)  Current requirement = A/m2 x 2 x m2 x cathodes
(217)                         180       2      1     56
(218)
(219)  Current required =    20.2 kA
(220)
(221)  Voltage requirement = # cells x v/cell
(222)                         6.0       2.5
(223)
(224)  Voltage required -    15.0 V dc
(225)
(226)
(227)  Transformer/Rectifier output with 125 % capacity (228)
(229)  Current          =     25.2 kA   basis for design
(230)
(231)
(232)  Cathode Weight
(233)
(234)  Cathode wt. = m2 x 2 x A/m2 x eff x avail x 0.02845 x 2.205
(235)                1         180    0.85     0.95  0.02845
(236)
(237)  Cathode Wt.  =       18.2 lb/day, normal operating
(238)               =        128 lb, 7 day deposition peroid
(239)
```

```
Maximum Cathode Weight

Max wt. = m2 x 2 x A/m2 x eff x avail x 0.02845 x 2.205
                 1        220    1.00      1.00  0.02845

Max Wt.      =         27.6 lb/day. maximum weight
             =          193 lb, 7 day deposition peroid

Cathode deposition cycle  =    7 days
Pull cycle  =              5 days/wk.  Monday . Friday

Cathode/day  = (lb/day x day/wk) / (lb/cathode x day/wk)
               6,010.92         7   127.65        5
Cathode/day  =    66 average


Solvent Extraction Mixer/Settler Criteria

Aqueous flow rate        =  50.0 gal/min
Organic/Aqueous ratio    =   1.4 O/A, extraction
                             2.0 O/A. strip
Retention time           =   3.0 min., extraction
                             1.0 min., strip
Primary agitator kw      =  0.60 kw/m3
Secondary agitator kw    =  0.25 kw/m3
Settler length/width     =  1.50
Design factor            =  1.05
Unit settling rate       =  1.50 gal/min sq ft
Number of boxes          =     2 extraction
                               1 strip
Extraction mixer box size - full capacity

Active volume = total flow x retention time

Act vol -  Q(p) x [ 1 + O/A ] x t(min) / # units
            50.00    1.40      3.00          2.00
Act vol =  180.00 gal      Note: based on larger volume requirement
                                 of extraction

Extraction settler size - full capacity

Active area =  total flow x unit settling rate

Active area =  Q(p)[ 1 + O/A ] x unit settling rate
                  50.00   1.40        1.50
Active area =     180 sq ft

Width        =  [ area / L:W ]**.5 x design factor
                     180   1.50       1.05
```

Width = 11.5 ft

Length = [area x L:W]**.5 x design factor

	area	L:W	design factor
	180	1.50	1.05

Length = 17.3 ft

check 180

Mixer Active Volume Chart

min\Q(p)	50	25	10	
3	360	180	72]	mixer
1.5	180	90	36]	active
1	120	60	24]	volume

	360	2.00	180
=	180	1.00	180
	120	2.00	60
	90	0.50	180
	72	2.00	36
=	60	1.00	60
=	36	1.00	36
	24	0.66	36

Agitator Hp

primary = 0.60 kw/m3
secondary = 0.25 kw/m3
drive eff = 50 %
motor size = 90 % of load

Active Vol	Hp, prim.	Hp, sec.
180 gal	1.22	0.51
120	0.81	0.34
90	0.61	0.25
60	0.41	0.17
36	0.24	0.10
24	0.16	0.07

Copper Balance about cellhouse

Cu(str elec) - Cu(spt elec) = cathode + Cu(b)
[Cu](str) x Q(str) - [Cu](spt) x Q(spt) = Cathode + Cu(b)
[Cu](spt elec) = [Cu](b)
Q(str) = Q(spt) = Q(e)
Q(e) x ([Cu](str) - [Cu](spt)) - Cathode + Cu(b)
Q(e) - (Cathode + Cu(b))/([Cu](str) . [Cu](spt))

[Cu](str) = 45.00 g/1 Note: str = strong electrolyte
[Cu](spt) = 30.00 g/1 spt = spent electrolyte
Q(str) = m3/h e = electrolyte
Q(spt) = m3/h
Cathode = 113.58 kg/h
Cu(b) = 5.42 kg/h

Q(e) = (Cathode + Cu(b))/([Cu](str) - [Cu](spt))
113.58 5.42 45.00 30.00
Q(e) = 7.93 m3/h
Q(e) = 34.92 gpm Note: electrolyte flowrate

Organic Flow

O/A extraction = 1.40 Note: O/A organic to aqueous ratio
O/A strip = 2.00
Q(p) = 50 Q(p) = aqueous flowrate
Q(e) = 35

Organic flow rate in extraction, Q(o/e)

Q(o/e) = O/A(ex) x Q(p)
50 1.40
Q(o/e) = 70 gpm

Organic flow rate in strip, Q(o/s) (365)
Q(o/s) = O/A(stp) x Q(e)
35 2
Q(o/s) = 70 gpm

Tank	Q to tank gpm	retention time min	active vol gal	tank vol gal
loaded organic	70	60	4.191	5.029
strong electrolyte	35	120	4.191	5.029
strip extract	35	120	4.191	5.029

Circulation Pump Capacity (379)
Cell unit flowrate = 1.0 1/min m2
Deposition area/cathode = 2.0 m2/cathode
Cathode/cell = 56

Flowrate/cell = unit cell flowrate x cathodes x area/cathode
1 56 2
Flowrate/cell = 112.00 1/min
29.58 gpm

No. of cells = 6

Pump capacity = 177.49 gpm

Pump Hp = gpm x TDH x SpGr / 3960 x % eff (394)
TDH = 30.0 ft
SpGr = 1.2
% eff = 60.0

Pump BHp = gpm x TDH x SpGr / 3960 x % eff
177 30 1.2 3,960 0.60
Pump BHp = 2.68922
uses 5 Hp motor

Fire Pump Capacity (405)
monitor requirements = 250 gpm @ 100 psi
SX train area = 1,080 sq ft
AFFF flowrate = 0.16 gpm/sq ft
SX AFFF requirement = 173 gpm

Use 250 gpm

Reagent Consumption

Extractant	=	0.015 m3/gpm	0.75 m3/y
Kerosene	=	0.085 m3/gpm	4.25 m3/y
CoSO4	=	0.261 kg/tpy	13.05 kg/y
H2SO4	=	0.231 t/tpy	253.41 t/y
HCl	=		

gpm = 50
tpy = 1,097

Sulfuric Acid

Acid make-up = 20 % of flow (maximum condition)

gpm(H2SO4) = 10.16 gpm

Pump BHp = gpm x TDH x SpGr / 3960 x % eff
10 25 1.8 3.960 0.60
Pump BHp = 0.19241
Use a 1/3 Hp motor

```
Sulfuric Acid Storage Tank

Storage     =           1 days
usage       =       10.16 gpm

Volume  = # days x usage
                1.00   10.16         60.00         24.00
Volume  =  14,629 gal


Q = m3/h                flow rate
[  ] = g/1              concentration

Xxxx = Kg/h             mass rate
4.402 x m3/h = gpm

```

B.2 EQUIPMENT COSTS

Table B.1 lists the cost components for the surface plant.

TABLE B-1. SURFACE FACILITY ITEMIZED EQUIPMENT COSTS

Area	Equipment No.	Description	Qty/ Unit	Process Equipment Cost $\$ \times 10^3$	Materials Cost $\$ \times 10^3$	Labor Cost $\$ \times 10^3$	Common Distributables $\$ \times 10^3$	Total $\$ \times 10^3$
20 Wellfield	20-100	Salt Mixing Tank	1.0	0.000	17.430	5.540	3.530	26.500
	20-105	Recirculation Pump	1.0	0.700	0.030	0.380	.170	1.280
	20-200	Well Field Pipe Low Pressure	1.0	0.000	9.000	8.300	2.660	19.960
	20-210	Well Field Pipe High Pressure	1.0	0.000	25.000	6.910	4.900	36.810
	20-240	Well Pads, 20 ft. x 10 ft.	8.0	0.000	16.410	38.850	8.480	63.740
	20-250	Injection Pump Head Tank	1.0	0.000	0.780	0.140	140	1.060
	20-275	Injection Pump (2+1)	3.0	108.000	0.280	1.860	16.900	127.040
	20-285	Injection Pump Spares	3.0	46.500	0.000	0.000	7.140	53.640
	20-290	AC Variable Frequency Control	1.0	0.000	15.600	1.720	2.660	19.980
	20-500	Production Well Pipe	1.0	0.000	9.000	8.300	2.660	19.960
	20-910	Well Field Water Distribution	1.0	0.000	0.840	4.150	770	5.760
	20-917	Well Field Power/Distribution	1.0	0.000	20.000	4.980	3.830	28.810
	20-920	Misc. Well Field Pipe/Valves	1.0	0.000	12.000	8.640	3.170	23.810
	20-930	Electrical	1.0	0.000	5.000	4.810	1.510	11.320
	20-950	Instrumentation	1.0	0.000	1.500	1.660	480	3.640
	Subtotal			155.200	132.870	96.240	59.000	443.310

TABLE B-1. SURFACE FACILITY ITEMIZED EQUIPMENT COSTS (Continued)

Area	Equipment No.	Description	Qty/ Unit	Process Equipment Cost $\$ \times 10^3$	Materials Cost $\$ \times 10^3$	Labor Cost $\$ \times 10^3$	Common Distributables $\$ \times 10^3$	Total $\$ \times 10^3$
30 Solvent Extraction	30-050	PLS Pond 50′ x 50′ x 6′	1.0	0.000	9.720	11.800	3.340	24.860
	30-060	SX Feed Pump	1.0	0.700	0.030	0.380	.170	1.280
	30-100	Extraction Pump/Mixer Box	3.0	0.000	6.500	4.360	1.680	12.540
	30-105	Extraction P/M Inserts	12	0.000	9.600	0.120	1.510	11.230
	30-110	Extraction P/M Agitator	3.0	10.920	0.000	0.990	1.850	13.760
	30-115	Extraction P/M Agitator	3.0	9.360	0.000	0.990	1.600	11.950
	30-120	Impellors, Various Sizes	32	12.800	0.000	0.110	2.000	14.910
	30-130	Extraction Mixer Bos	3.0	0.000	3.000	0.200	500	3.700
	30-135	Extraction Mixer Insert	12	0.000	9.600	0.120	1.510	11.230
	30-140	Extraction Mixer Agitator	3.0	10.920	0.000	0.990	1.850	13.760
	30-145	Extraction Mixer Agitator	3.0	9.360	0.000	0.990	1.600	11.950
	30-150	Extraction Settler	3.0	3.000	26.340	47.580	11.920	88.840
	30-400	Strip Pump/Mixer Box	2.0	0.000	3.170	1.510	.730	5.410
	30-405	Strip Pump/Mixer Insert	2.0	0.000	6.400	0.080	1.000	7.480
	30-410	Strip P/M Agitator	2.0	7.280	0.000	0.660	1.230	9.170

TABLE B-1. SURFACE FACILITY ITEMIZED EQUIPMENT COSTS (Continued)

Area	Equipment No.	Description	Qty/ Unit	Process Equipment Cost $\$ \times 10^3$	Materials Cost $\$ \times 10^3$	Labor Cost $\$ \times 10^3$	Common Distributables $\$ \times 10^3$	Total $\$ \times 10^3$
	30-415	Strip P/M Agitator	2.0	6.240	0.000	0.660	1.070	7.970
	30-450	Strip Settler	2.0	2.000	10.320	17.270	4.590	34.180
	30-700	Raffinate Pond	1.0	0.000	9.720	11.800	3.340	24.860
	30-705	Raffinate Pond Pump	1.0	0.680	0.030	0.380	.170	1.260
	30-710	Static Mixer	1.0	0.800	0.000	0.330	.180	1.310
	30-715	Raffinate Check Tank	1.0	0.000	1.890	0.170	.320	2.380
	30-720	Raffinate Filter Feed Pump	1.0	0.680	0.030	0.380	.170	1.260
	30-725	Raffinate Filter (1+1)	2.0	7.600	0.070	0.780	1.310	9.760
	30-730	Pond Skimmer	1.0	0.300	0.000	0.030	.050	.380
	30-750	pH Controller	1.0	0.000	0.000	0.000	0.000	0.000
	30-780	Evaporation Pond	1.0	0.000	21.960	24.910	7.250	54.120
	30-930	Electrical	1.0	0.000	15.000	13.750	4.460	33.210
	30-940	Piping	1.0	0.000	10.000	12.100	3.430	25.530
	30-950	Instrumentation	1.0	0.000	10.000	6.660	2.580	19.240
	30-999	Portable Crud Pump	3.0	3.750	0.000	0.070	.590	4.410
	Subtotal			86.390	153.380	160.170	62.000	461.940

TABLE B-1. SURFACE FACILITY ITEMIZED EQUIPMENT COSTS (Continued)

Area	Equipment No.	Description	Qty/ Unit	Process Equipment Cost $\$ \times 10^3$	Materials Cost $\$ \times 10^3$	Labor Cost $\$ \times 10^3$	Common Distributables $\$ \times 10^3$	Total $\$ \times 10^3$
40 Tank Farm	40-250	Loaded Organic Tank	1.0	0.000	5.300	1.030	.970	7.300
	40-255	Loaded Organic Pump (1+1)	2.0	1.400	0.030	0.380	.280	2.090
	40-260	Strip Extract Storage Tank	1.0	0.000	5.300	1.030	.970	7.300
	40-280	Filter Feed Pumps	1.0	0.680	0.030	0.380	.170	1.260
	40-285	Electrolyte Filter (1+1)	2.0	7.600	0.070	0.780	1.300	9.750
	40-300	Strong Electrolyte Tank	1.0	0.000	5.300	1.030	.970	7.300
	40-305	Strong Electrolyte Pumps (1+1)	2.0	1.400	0.030	0.380	.280	2.090
	40-500	Crud Collection System	1.0	0.000	5.500	3.460	1.380	10.340
	40-510	SX Drain Sump	1.0	0.000	4.320	1.050	.820	6.180
	40-515	SX Drain Sump Pump	1.0	0.430	0.000	0.160	.090	.680
	40-525	Centrifuge Feed Tank	1.0	0.000	1.310	0.140	.220	1.670
	40-530	Centrifuge Feed Pump	1.0	1.000	0.030	0.380	.220	1.630
	40-550	Centrifuge	1.0	25.000	0.070	1.110	4.020	30.200
	40-565	Recovered Organic Tank	1.0	0.000	1.310	0.140	.220	1.670
	40-600	Sulfuric Acid Tank	1.0	0.000	11.420	6.070	2.690	20.180

TABLE B-1. SURFACE FACILITY ITEMIZED EQUIPMENT COSTS (Continued)

Area	Equipment No.	Description	Qty/ Unit	Process Equipment Cost $\$ \times 10^3$	Materials Cost $\$ \times 10^3$	Labor Cost $\$ \times 10^3$	Common Distributables $\$ \times 10^3$	Total $\$ \times 10^3$
	40-610	Sump Pump	1.0	0.530	0.640	1.440	.400	3.010
	40-615	Barrel Pumps	5.0	5.250	0.000	0.070	.820	6.140
	40-620	Sulfuric Acid Mettering Pump	1.0	4.000	0.030	0.380	.680	5.090
	40-700	Reagent Storage Building	1.0	0.000	11.830	10.480	3.430	25.740
	40-930	Electrical	1.0	0.000	8.000	6.870	2.280	17.150
	40-940	Piping	1.0	0.000	20.000	20.740	6.260	47.000
	40-950	Instrumentation	1.0	0.000	5.000	4.990	1.530	11.520
	Subtotal			47.290	85.510	62.490	30.000	225.290
Electro-winning	50-100	Heat Exchanger	1.0	15.500	0.070	0.610	2.490	18.670
	50-110	Circulation Tank	1.0	0.000	6.210	0.560	1.040	7.810
	50-115	Circulation Pumps	2.0	2.700	0.110	1.180	.610	4.600
	50-125	Spent Electrolyte Pumps	1.0	0.700	0.030	0.380	.170	1.280
	50-225	Electrolytic Cells	6.0	0.000	27.030	15.040	6.470	48.540
	50-235	Cell Liners (6+1)	7.0	20.300	0.000	0.990	3.280	24.570
	50-250	Anodes (342+58)	400	104.000	0.000	2.250	16.350	122.600

TABLE B-1. SURFACE FACILITY ITEMIZED EQUIPMENT COSTS (Continued)

Area	Equipment No.	Description	Qty/ Unit	Process Equipment Cost $\$ \times 10^3$	Materials Cost $\$ \times 10^3$	Labor Cost $\$ \times 10^3$	Common Distributables $\$ \times 10^3$	Total $\$ \times 10^3$
	50-260	Cathodes (336+64)	400	104.000	0.000	2.210	1.340	122.550
	50-265	Anode Guides	***	4.650	0.000	4.940	1.480	11.070
	50-270	Cell top Insulators	800	1.650	0.000	2.640	.660	4.950
	50-340	Intercell Bus Bars (5+2)	7.0	4.410	0.000	0.130	.700	5.240
	50-345	Apron Bus	2.0	14.800	0.000	0.660	2.380	17.840
	50-350	Main Bus	1.0	0.000	0.000	0.000	0.000	0.000
	50-400	Transformer/Rectifier	1.0	306.000	1.390	5.190	48.090	360.670
	50-450	Over Head Crane	1.0	63.000	5.000	8.550	11.780	88.330
	50-455	Crane Lifting Bales	2.0	5.300	0.000	0.130	.840	6.270
	50-460	Cathode Washing Station	1.0	12.000	0.000	1.320	2.050	15.370
	50-470	Cathode Stripping Station	1.0	4.000	0.000	1.320	.820	6.140
	50-475	Cathode Wax Tank	1.0	4.600	0.210	1.680	1.000	7.490
	50-500	Cathode Scale	1.0	15.000	0.000	0.330	2.360	17.690
	50-520	Anode Storage Racks	1.0	3.700	0.000	0.100	.580	4.380
	50-530	Cathode Storage Racks	1.0	3.700	0.000	0.100	.580	4.380

TABLE B-1. SURFACE FACILITY ITEMIZED EQUIPMENT COSTS (Continued)

Area	Equipment No.	Description	Qty/ Unit	Process Equipment Cost $\$ \times 10^3$	Materials Cost $\$ \times 10^3$	Labor Cost $\$ \times 10^3$	Common Distributables $\$ \times 10^3$	Total $\$ \times 10^3$
	50-610	Sump Pump	2.0	1.040	1.310	2.870	.800	6.020
	50-725	Reagent Feeders (2+2)	4.0	1.060	0.000	0.330	.210	1.600
	50-730	Reagent Solution Tank-CoS04	1.0	0.000	0.400	0.120	.080	.600
	50-735	Reagent Solution Tank-HCl	1.0	0.000	0.400	0.120	.080	.600
	50-740	Solution Tank Agitator (1+1)	2.0	0.840	0.000	0.070	.140	1.050
	50-750	In-Line Process Water Heater	1.0	1.000	0.070	0.450	.230	1.750
	50-800	Forklift	1.0	18.000	0.000	0.660	2.870	21.530
	50-900	Electrowinning Building	1.0	0.000	54.230	32.360	13.310	99.900
	50-925	Control Room/Electrical Bldg.	1.0	0.000	17.050	18.220	5.430	40.700
	50-930	Electrical	1.0	0.000	60.000	41.240	15.580	116.820
	50-940	Instrumentation	1.0	0.000	4.000	3.990	1.230	9.220
	Subtotal **			711.950	192.950	168.030	165.000	1,237.490
90 General Engineering	90-010	Transformer	1.0	0.000	21.140	1.640	3.500	26.280
	90-011	Main Disconnect Switch	1.0	0.000	7.900	1.370	1.430	10.700
	90-015	Motor Control Center	1.0	0.000	93.000	3.440	14.830	111.270

TABLE B-1. SURFACE FACILITY ITEMIZED EQUIPMENT COSTS (Continued)

Area	Equipment No.	Description	Qty/ Unit	Process Equipment Cost $\$ \times 10^3$	Materials Cost $\$ \times 10^3$	Labor Cost $\$ \times 10^3$	Common Distributables $\$ \times 10^3$	Total $\$ \times 10^3$
	90-100	Potable Water/Firewater Tank	1.0	0.000	9.930	4.260	2.180	16.370
	90-110	Potable Water Pumps	1.0	1.200	0.080	0.800	.320	2.400
	90-120	Fire Pump Building	1.0	0.000	8.250	3.390	1.790	13.430
	90-125	Firewater Pump	1.0	52.000	0.140	6.170	8.970	67.280
	90-135	Automatic AFFF System	1.0	0.000	50.000	13.830	9.820	73.650
	90-200	Administration Building	1.0	0.000	49.000	8.880	8.900	66.780
	90-300	Maintenance Building	1.0	0.000	20.760	9.090	4.590	34.440
	90-310	Plant Air Compressor	1.0	14.700	0.350	3.340	2.830	21.220
	90-315	Instrument Air Dryer	1.0	8.400	0.000	0.990	1.440	10.830
	90-400	Propane Tank	1.0	8.000	8.770	2.600	1.750	13.120
	90-500	Sanitary Sewer System	1.0	0.000	12.000	6.910	2.910	21.820
	90-930	Electrical	1.0	0.000	50.000	34.370	12.980	97.350
	90-940	Piping	1.0	0.000	40.000	27.660	10.400	78.060
	90-950	Instrumentation	1.0	0.000	1.000	1.330	.360	2.690
	Subtotal	—	—	84.300	364.320	130.070	89.000	667.690
Total All Areas	—	—	—	1,085.130	928.590	617.000	405.000	3,035.720

APPENDIX C

ENVIRONMENTAL PERMITTING

C.1 QUALITY ASSURANCE/QUALITY CONTROL PROGRAM FOR WATER QUALITY SAMPLING AND TESTING

To insure that valid water quality determinations are ascertained, the following procedures are presented. These procedures are based on guidelines established for the Environmental Protection Agency (EPA) in the Code of Federal Regulations (40 CFR 100-149), the U.S. Geological Survey (USGS, 1984) and the American Society for Testing & Materials (ASTM, 1982). All groundwater sample collection performed during this project for the analysis of water quality will follow these procedures.

C.1.1 Preparation for Sampling

The following steps will be taken no later than two weeks before sampling is to begin.

- o The testing laboratory will be contacted and advised of the upcoming sampling program. Details will include 1) the approximate number of samples they will be receiving, 2) when they will be receiving them, 3) the parameters to be tested, and 4) the number and types of sample bottles that the lab is to provide and preservatives that will be required.
- o All equipment will be inspected to confirm that all is in working order, and that the required amounts of reagents, solutions, filters, etc. are on hand. Equipment and supplies for this program are listed on Table C-1.

To reduce the potential for cross-contamination, all upgradient wells will be measured first, then downgradient wells, then on-site wells. All domestic wells will be sampled before sampling any on-site wells. Extra care will be taken in cleaning downhole sampling equipment before lowering mechanism into domestic wells.

C.1.2 Sample Collection

It is assumed that all wells involved in groundwater monitoring are or will be operable, and can provide water at the well head for discharge and collection. It is also assumed that these wells are capable of pumping water at a rate of at least 15 gallons per minute (gpm). Water from these wells will be sampled as close to the well head as is practicable. Samples will not be taken downstream of any device that alters water quality, such as a chlorinator or water softener.

Prior to collecting samples for analysis, static water level measurements will be taken. If pumps are running, sn attempt will be made to obtain a dynamic water level. A record of all data, including the status of pumping, will be compiled. All field measurements and comments will be recorded on the water quality field form (Table C-2).

Pumps will be started prior to sampling in order to evacuate stagnant water. First, field measurements of discharging water will be taken to determine when laboratory samples can be collected. Field measurements include water temperature, pH and electrical conductance (EC). Field measurements will be continued while pumping at least three well volumes. If measurements have stabilized after pumping three well volumes, then samples for laboratory analysis can be collected. If measurements have not stabilized, monitoring will continue while pumping up to 10 well volumes, or until readings stabilize. When making field measurements, a flow-through container will be used for temperature, pH and EC probes. The pumped water will enter the flow-through container before discharging. This procedure increases the accuracy and reproducibility of the field measurements.

To collect water samples for laboratory analysis, water is carefully added from the discharge point to the sample bottles. Bottles prerinsed in the field will not be used. The sample will not be allowed to overflow the bottle. Bottles from the laboratory will be precleaned and have had appropriate preservatives added.

Samples taken for the analysis of dissolved metals will be filtered with a 0.45 micron filter prior to placement in the sample bottle. To filter water, the use of a peristaltic pump and a 142 mm filter holder and filters is required. The filtering equipment will be set up to allow the peristaltic pump to withdraw water directly from the flow-through container and pump directly into the filter holder. Filtered water will be directed into the appropriate sample bottle. Procedures for filtering water are as follows:

- o Clean the outside of the filter apparatus and all tubing with distilled water.
- o Pump 1 to 2 liters of distilled water through all tubing involved in the sampling process.
- o Disassemble the filter apparatus and discard the old filter if one is present. Thoroughly rinse all serfaces with distilled water.
- o With clean hands, install a new filter, touching it only along its perimeter. Allow no dirt or dust to collect on the cleaned apparatus or filter. Reassemble the apparatus.
- o Before taking any samples, pump a few hundred milliliters of sample water through the filter. Fill the sample bottle. Allow no dirt or dust to enter the bottle or cap. Rinse cap with filtered water and screw onto bottle. Shake bottle to mix preservative.

During each sampling period, four duplicate samples will be taken and two blank samples will be prepared. Duplicate samples will be taken at the same time as the original sample, and will be filtered and preserved in the same manner as the original sample. The duplicate samples will be labeled the same as the original, except the sample identification number will be followed by the letter "D". Blank samples will be composed of deionized water added to a sample bottle under field conditions. Labeling of the blank samples will include a sample identification number "Blank 1" or "Blank 2". Field water sampling forms and a chain-of-custody record will be completed for each blank and duplicate sample, and shipment procedures will be the same as for the actual samples.

C.1.3 Labeling and Chain-of-Custody

All sample bottles will be labeled with the following information:

- o Well number or sample identification number.
- o Date and time.
- o Any preservative included in sample.
- o Filtered or unfiltered water.

- o Job number or name.
- o Name of sampler.

In addition to labeling the sample bottles, a chain-of-custody form will be completed for each sample. A sample of this form is presented as Table C-3. All samples will be accompanied by the chain-of-custody record. When transferring the possession of samples, the individuals relinquishing and receiving will sign, date and note the time on the record. The original record will accompany the samples to the testing laboratory, and a copy of the record will remain in the job file.

C.1.4 Sample Shipment

Samples will be shipped in insulated coolers with sufficient coolant to keep samples cool until they arrive at the testing laboratory. A self-contained coolant such as "Blue Ice" is the preferred choice of coolant. Coolers will be taped shut. Acidified samples will be shipped in sturdy boxes, otherwise the same procedures apply.

If possible, samples will be hand delivered to the testing laboratory. If samples need to be shipped, they will be packaged to arrive at the laboratory in good condition. Using tape, pertinent information will be fastened to the inside lid of the cooler. This information will include the name, address and telephone number of the testing laboratory, and the name of the person to contact at the lab. The original chain-of-custody record will also be included. This record will include the requested analyses for each sample included in the shipment.

If it is suspected that a sample may contain corrosive, toxic or hazardous materials, or an unusually high concentration of a particular constituent, a memo to this effect will be prepared. A copy of this memo will be included with the other information sent to the laboratory with the samples.

The sampling and shipments will be scheduled so that samples do not arrive at the laboratory after 4:00 PM on a Friday, or on weekends. Samples will be shipped so they arrive at the lab no later than 72 hours (48 preferably) after they were taken. The laboratory will be called to inform them when the samples will arrive.

C.1.5 Record Keeping

Proper record keeping is essential to the validity of the water quality sampling program. Records include the labeling of the sample bottles, completion of the chain-of-custody and field water sampling records, and all daily field reports (Table C-4). Upon the receipt of laboratory results, a data summary sheet will be developed for each monitoring point. This summary will include all field and laboratory testing results, listed chronologically. Summary sheets, original field forms and laboratory correspondence will be retained in a central file. These data will be accompanied by any pertinent details concerning well construction, such as geologic logs, well completion records, etc.

TABLE C-1. EQUIPMENT CHECKLIST

Fill out all blanks prior to leaving for field

pH Buffer	Yes	No	Comments
Sufficient volume 4	_____	_____	
Sufficient volume 7	_____	_____	
Sufficient volume 10	_____	_____	
Reagents & Bottles			
Litmus paper	_____	_____	
Nitric acid (pres.)	_____	_____	
Sulfuric acid (pres.)	_____	_____	
Not Required _____			
Other reagents*	_____	_____	
Not Required _____			
Required sample bottles:			
No. of Samples _____ x 1 TDS sample _____			
x 1 anion sample _____			
x 1 metal sample _____			
x 1 contingency _____			
TOTAL _____			
Sufficient bottles	_____	_____	
pH Meter			
Electrode good	_____	_____	
Meter calibrated	_____	_____	
Battery check	_____	_____	
S-C-T Meter			
50-foot probe	_____	_____	
10-foot probe	_____	_____	
Probes calibrated	_____	_____	
Meter calibrated	_____	_____	
Battery check	_____	_____	
Hand Held Thermometer			
Other Equipment			
Squeeze bottle	_____	_____	
Deionized water	_____	_____	
Number of gallons	_____	_____	

*If required, explain under Comments.

TABLE C-1. EQUIPMENT CHECKLIST (Cont'd.)

Fill out all blanks prior to leaving for field

Other Equipment (Cont'd.)
Flow-through container _____ _____
Water-level sounder _____ _____
battery check _____ _____
Paper towels _____ _____

Field Forms and Miscellaneous Equipment:

Expected No. of Samples _____ No. of Forms _____
Clipboard with cover _____ Sample Labels _____
Site Maps marked with Well Locations __________
Well Completion Information __________
Field Instruction Manual __________
Key(s) to Wells _____
To be picked up at ______________________________
WD-40 (for locks) _____ Transparent Tape _____
Marking Pens]_____ Strapping Tape _____
Coolers __________ Blue Ice __________
Buckets for Cleaning Equipment _____ Aquanox _____

Shipping Address of Lab(s):

____
____
____
____

Phone Numbers and Contact:

____
____
____

Peristaltic Pump
12 V. and 110 V. Power Cables ______________
Two Pump Heads __________
Clean ? Yes _____ No _____
Tubing _____ Length _____

Filter System
Is the System Clean ? Yes _____ No _____
Inspect Housing for cracks _______
Filter unit legs _______ Nipples _______
Filter size _______ Number of Filters _______
Bailer and Cable _______

TABLE C-2. FIELD WATER SAMPLING RECORD

Project Name ______________________ Date ______________________
SHB Job No. ______________________ Weather ______________________
Well No. ______________________ Temp. ______________________
Location ______________________ Field Obs. ______________________
Static Water Level ______________________ M.P. ______________________

Well Information

Total Depth ______________________ Screened Interval(s) ______________
Casing Size/Type ____
Well Development ____

Remarks ____

Field Measurements

Time	Temp. °C	Salinity ppt	pH	Alkalinity mg/1 CaCO3 at pH 4.8	Specific Conductance umhos		

Sample Collection

Method of Sampling ______________________ Sampling Depth ______________
Time of Sampling ______________________

Determination	Container Size/Type	Preservation	Filtered	Other

Lab Shipped to ______________________ Date Shipped ______________
Method of Shipment ____
Comments ____

TABLE C-3. CHAIN OF CUSTODY

DATE ______ PAGE ______ OF ______

PROJ. MGR. ______

COMPANY ______

ADDRESS ______

______

SAMPLERS (SIGNATURE) (PHONE NO.)

SAMPLE ID.	DATE	TIME	MATRIX	LAB ID.	ANALYSIS REQUEST																				NUMBER OF CONTAINERS

PROJECT INFORMATION	SAMPLE RECEIPT	
PROJECT:	TOTAL NO. OF CONTAINERS	
PO NO.	CHAIN OF CUSTODY SEALS	
	REC'D GOOD CONDITION/COLD	
SHIPPING ID. NO.	CONFORMS TO RECORD	
VIA:	LAB NO.	

SPECIAL INSTRUCTIONS/COMMENTS:

RELINQUISHED BY 1.		RELINQUISHED BY 2.		RELINQUISHED BY 3.	
(Signature)	(Time)	(Signature)	(Time)	(Signature)	(Time)
(Printed Name)	(Date)	(Printed Name)	(Date)	(Printed Name)	(Date)
(Company)		(Company)		(Company)	
RECEIVED BY 1.		**RECEIVED BY 2.**		**RECEIVED BY (LABORATORY) 3.**	
(Signature)	(Time)	(Signature)	(Time)	(Signature)	(Time)
(Printed Name)	(Date)	(Printed Name)	(Date)	(Printed Name)	
(Company)		(Company)			

TABLE C-4. DAILY FIELD REPORT & DRILLER'S LOG

Report by____________________**Project**________________________________**Report No.**______

Motel__________________________Job No._______________Day__________Date_________________

Telephone No.____________________

PERSONNEL TIME

Name	Class	Trvl	Field Work	Stdby	Lay	Rec	Test	Grt	Misc	Nbill	Total

Reasons for standby, repair, misc. and/or nonbillable time______________________________

____

____

____

DRILL RIG TIME

No.	Type	Trvl	Misc	HSA	CFA	Core	Gear	ODEX	Grout	Test	Repair	Total
			Footage:									

AUXILIARY EQUIPMENT

Type	Description	Miles/hrs.
Pickup		
Pickup		
1-Ton Truck		
Water Truck		
NQ Wireline		
Packer		
H_2O Samp. Eq.		
Backhoe		
Water Pump		
Seismograph		

SUPPLIES

Auger Teeth: No.
Gear Bit: Ser. No.
Core Bit: Ser. No.
Reaming Shell: Ser. No.
Lifter Shell: No.
Cement: Lbs.
Drill Add.: Type & Amt.
PVC Pipe: Size & Foot.
Sand/Grav.: Amt/$
Bentonite Pellets
Core Box
Rental Pickup:

Remarks: Discuss weather & site conditions; describe specific boreholes, etc., completed; difficult drilling conditions; state daily cost of any rented heavy equipment__________

____

____

____

____

____

____

____

____

____

Signatures: ______________________________

____

____

____

____

C.2 COST ESTIMATE

C.2.1 Cost Estimates for Permit Fees and Technical Services to Acquire Permits

Scope:

Fees to acquire ADEQ and ADWR permits, and estimate of hydrogeologic representative's contribution to preparing applications and comunicating with agencies.

Item Description	Unit Cost	Estimated Quantity	Estimated Total Cost
1. SUBCONTRACTED TECHNICAL SERVICES			
o Hydrologic Consultant			
+ Professional Geologists/ Engineers	$55/hr.	200 hrs.	$11,000
+ Staff Geologists/ Engineers	$47/hr.	150 hrs.	$ 7,050
+ Support Staff	21/hr.	0 hrs.	$ 840
		Subtotal	$18,890
2. SUBCONTRACTED FIELD SERVICES			
None			
3. PURCHASES			
+ Fees for ADWR Well Permits	$10/well	20 wells	$ 200
+ Fees for ADEQ Permit			$ 1,000
		Subtotal	$ 1,200
		TOTAL	$20,090

C.2.2 Cost Estimates for Hydrogeologic Characterization Program

Scope:

One boring, drilled to interim depth of 800 feet with 6-inch diameter rotary bit and dual-tube reverse circulation method; advanced to total depth of 1,800 feet with NQ coring; 20 single-packer inflow tests; 20 permeability/ porosity lab testing; eight-point geophysical logging; hole abandonment; data analysis, compilation and presentation.

Item Description	Unit Cost	Estimated Quantity	Estimated Total Cost
1. SUBCONTRACTED TECHNICAL SERVICES			
o Hydrologic Consultant			
+ Professional Geologists/ Engineers	$55/hr.	130 hrs.	$ 7,150
+ Staff Geologists/ Engineers	$47/hr.	340 hrs.	$15,980
+ Support Staff	$21/hr.	40 hrs.	$ 840
+ Miscellaneous Direct Costs	--	--	$ 2,200
o Laboratory Services			
+ 20 Permeability/ Porosity Tests	$750/test	20 tests	$15,000
		Subtotal	$41,170
2. SUBCONTRACTED FIELD SERVICES			
o Rotary Drilling Contractor			
+ Mobilization/ Demobilization	Lump Sum	2 round trips	$ 6,000
+ Drill 800 ft. of 7-inch diam. boring	$23/ft.	800 ft.	$18,400
+ Set Temporary Casing	$220/hr.	8 hrs.	$ 1,760
+ Abandon Boring - Grout In	$220/hr.	8 hrs.	$ 1,760
		Subtotal	$27,920
o Coring Contractor			
+ Mobilization/ Demobilization	Lump Sum	1 round trip	$ 3,000
+ HQ Coring	$30/ft.	1,000 ft.	$ 30,000
+ Packer Testing	$220/hr.	40 hrs.	$ 8,800
		Subtotal	$ 41,800

Item Description	Unit Cost	Estimated Quantity	Estimated Total Cost
2. SUBCONTRACTED FIELD SERVICES			
o Geophysical Contractor			
+ Mobilization/ Demobilization	Lump Sum	1 round trip	$ 1,000
+ Logging (6 logs)	$1,100/log	6 logs	$ 6,600
+ Report Preparation	$500	1 report	$ 500
		Subtotal	$ 8,100
3. MISCELLANEOUS PURCHASES			
o Grout	$50/yd^3	40	$ 2,000
o Bit Use			$ 1,800
o Casing	$12/ft	800	$ 9,600
o Coreboxes, Miscellaneous Expendable Field Equipment			$ 800
		Subtotal	$ 14,200
		TOTAL	$133,190

C.2.3 Cost Estimates for Corrective Action Program

Scope:

Review of available well data; abandon six existing exploratory boreholes; initial program of geophysical and TV logging, all six wells; assumption that all wells will require redrilling; consultant field supervision, data compilation and reporting.

Item Description	Unit Cost	Estimated Quantity	Estimated Total Cost
1. SUBCONTRACTED TECHNICAL SERVICES			
o Hydrologic Consultant			
+ Professional Geologists/ Engineers	$55/hr.	60 hrs.	$ 3,300
+ Staff Geologists/ Engineers	$47/hr.	460 hrs.	$ 21,620

Item Description	Unit Cost	Estimated Quantity	Estimated Total Cost
+ Support Staff	$21/hr.	40 hrs.	$ 840
+ Miscellaneous Direct Costs	--	--	$ 600
		Subtotal	$ 26,360
2. SUBCONTRACTED FIELD SERVICES			
o Rotary Drilling Contractor			
+ Mobilization/ Demobilization	Lump Sum	1 round trip	$ 3,000
+ Redrill 6 Borings	$18/ft.	10,800 ft.	$194,400
+ Hole Conditioning	$220/hr.	40 hrs.	$ 8,800
+ Perforate Casing	$220/hr.	40 hrs.	$ 8,800
		Subtotal	$215,000
o Geophysical Contractor			
+ Mobilization/ Demobilization	Lump Sum	1 round trip	$ 1,000
+ TV Logs	$1,100/well	6 wells	$ 6,600
+ Caliper Geophysical Logs	$450/well	6 wells	$ 2,700
		Subtotal	$ 10,300
o Grouting Contractor			
+ Mobilization/ Demobilization	Lump Sum	--	$ 1,000
+ Grout Holes	$100/hr.	50 hrs.	$ 5,000
		Subtotal	$ 6,000
3. MISCELLANEOUS PURCHASES			
o Grout	$50/yd^3	220 yd^3	$ 11,000
o Bit Use			$ 1,800
		Subtotal	$ 12,800
		TOTAL	$270,460

C.2.4 Cost Estimates For Monitoring Well Installation

Scope:

Three borings, drilled to 700 feet below surface with 5 1/2-inch diameter rotary bit and dual-tube reverse circulation method and reamed to 10 inches in diameter using a mud rotary system; upper 20 feet of hole drilled to 16-inch diameter; casing inserted with centralizers spaced every 30 feet; well bore packed with sand from 700 to 545 feet and grout from 545 feet to surface; steel casing set in upper 20 feet of borehole; dedicated pump set in well; construct wellhead assembly; consultant field assistance and reporting.

Item Description	Unit Cost	Estimated Quantity	Estimated Total Cost
1. SUBCONTRACTED TECHNICAL SERVICES			
o Hydrologic Consultant			
+ Professional Geologists/ Engineers	$55/hr.	100 hrs.	$ 5,500
+ Staff Geologists/ Engineers	$47/hr.	230 hrs.	$ 10,810
+ Support Staff	$21/hr.	24 hrs.	$ 504
+ Miscellaneous Direct Costs	--	--	$ 1,500
		Subtotal	$ 18,314
2. SUBCONTRACTED FIELD SERVICES			
o Drilling Contractor			
+ Mobilization/ Demobilization	Lump Sum	1 round trip	$ 3,000
+ Drill three 10-inch borings	$23/ft.	2,100 ft.	$ 48,300
+ Ream three borings to 10-inch diameter	$30/ft	2,100 ft.	$63,000
+ Install Wells & Set Pumps	$220/hr.	90 hrs.	$ 19,800
+ Standby During Geophysics	$220/hr.	20 hrs.	$ 4,400
		Subtotal	$138,500

Item Description	Unit Cost	Estimated Quantity	Estimated Total Cost
2. SUBCONTRACTED FIELD SERVICES			
o Geophysical Contractor			
+ Mobilization/ Demobilization	Lump Sum	3 round trips	$ 3,000
+ Logging (8 logs each well)	$1,100/log	24 logs	$ 26,400
+ Report Preparation	$500/report	3 reports	$ 1,500
		Subtotal	$ 30,900
3. MISCELLANEOUS PURCHASES			
o Surface Casing (16-inch black steel)	$11/ft.	60 ft.	$ 660
o Wellhead Assembly	$150/ea.	3 assemblies	$ 450
o Cement	$50/yd.^{3}	40 yd.^{3}	$ 2,000
o Gravel	$100/yd.^{3}	10 yd.^{3}	$ 1,000
o 6-inch I.D. FRP Casing	$15/ft.	1,800 ft.	$ 27,000
o 6-inch I.D. FRP Well Screen	$35/ft.	300 ft.	$ 10,500
o 6-inch I.D. FRP Caps	$25	6 caps	$ 150
o FRP Casing Centralizers	$25	30 centralizers	$ 750
o Submersible Pumps	$2,000 ea.	3 pumps	$ 6,000
o Bit Use	Lump Sum	--	$ 1,800
o Expendable Field Equipment	Lump Sum	--	$ 800
o Risers, Electrical Conduit, Airline Tubing	Lump Sum	--	$ 1,100
		Subtotal	$ 52,210
		TOTAL	$239,924

C.2.5 Cost Estimates for Baseline Water Quality Program

Scope:

Inventory all wells involved in the monitoring program. Comply with the established monitoring program of sampling, testing and reporting groundwater conditions in seven wells at three-month intervals for a nine-month period; a total of 28 samples will be collected; in addition, four QA/QC samples will be included in the testing; program performed by project staff without consultant retained.

Item Description	Unit Cost	Estimated Quantity	Estimated Total Cost
1. SUBCONTRACTED TECHNICAL SERVICES			
o Testing Laboratory			
+ Water Samples	$250	28	$ 7,000
+ QA/QC Sample Testing	$250	4	$ 1,000
		Subtotal	$ 8,000
2. SUBCONTRACTED FIELD SERVICES			
None			
3. MISCELLANEOUS PURCHASES			
o Sampling and Testing Supplies			
+ pH Meter	$300	1	$ 300
+ Conductivity/Temperature Meter	$500	1	$ 500
+ Water Level Sounder	$400	1	$ 400
+ Peristaltic Pump	$300	1	$ 300
+ Filter System	$300	1	$ 300
+ Miscellaneous Supplies	$200	1	$ 200
		Subtotal	$ 2,000
		TOTAL	$ 10,000

C.2.6 Cost Estimates For Operational Monitoring Program Water Quality Monitoring

Scope:

Sample, analyze and report results of monitoring of three on-site wells and four outlying wells. On-site wells will be tested monthly for selected parameters during the first five months of operation. At six months, all seven wells will be tested for the baseline suite. Following these tests, the three project monitor wells will be tested quarterly for the remaining year of operation. At the end of leaching, all seven wells will again be tested using the baseline suite. A total of fourteen samples tested for all baseline parameters, 24 samples to be tested for select parameters, and ten samples for QA/QC testing will be included in the laboratory analysis.

Item Description	Unit Cost	Estimated Quantity	Estimated Total Cost
1. SUBCONTRACTED TECHNICAL SERVICES			
o Testing Laboratory			
+ Baseline Parameter Testing	$250	14	$ 3,500
+ Selected Parameter Testing	$100	24	$ 2,400
+ QA/QC Sample Testing	$250	10	$ 2,500
		Subtotal	$ 8,400
2. SUBCONTRACTED FIELD SERVICES			
None			
3. MISCELLANEOUS PURCHASES			
o Miscellaneous Supplies	--	--	$ 200
		Subtotal	$ 200
		TOTAL	$ 8,600