Revised: October 11, 1993

ENVIRONMENTAL REPORT

CHURCHROCK IN-SITU LEACH PROJECT

1.0 INTRODUCTION

1.0 Proposed Activities

Hydro Resources, Inc., (HRI)* a wholly-owned indirect subsidiary of Uranium Resources, Inc. (URI) proposes to develop an in-situ uranium leach operation in McKinley County, New Mexico. The proposed project is located six (6) air miles northeast of Churchrock, off of County Highway 566.

Mining will be located on lands owned or leased to HRI on Section 8 and 17, T16N, R16W as described below:

Section 8

SE/4 - 174.546 ac. Patent Mining Claims

Section 17

200.0 acres being NE/4 and the SE/4 NW/4 - Mining lease with Cerrillos Land Company

Cerrillos has a Surface Use Agreement with the Navajos on Section 17, also, BLM administers the land.

An anticipated 800,000-1,000,000 pounds of U_3O_8 will be produced per year by solution mining with a dilute solution of natural ground water, sodium bicarbonate and oxygen. U_3O_8 will be extracted from the ground water lixiviant using ion exchange (IX) technology. Ion exchange resin or yellowcake slurry will be transported in top-loading, #316 stainless steel slurry trailers for transport to the Crownpoint facility where it would be processed for yellowcake production. If resin is hauled, it will be returned to the Churchrock IX system for further use after it has been stripped of uranium at the Crownpoint facility.

All solid waste generated by the project will be disposed of at a licensed disposal site. Liquid wastes will be disposed of by either surface irrigation, surface discharge, or evaporation.

The anticipated life of the project, including final restoration activities, is ten (10) years. This life span could be increased by ten (10) years with the discovery of additional reserves.

Ground water restoration will be ongoing throughout the project life and will be centered upon lixiviant control. Oxygen will be shut off to a wellfield after uranium concentrations are no longer economic and uranium will be reduced by circulation through the plant. TDS will be reduced to previous use levels by ground water sweep and reverse osmosis treatment. Following ground water restoration all surface facilities, roads and contaminated soil will be removed. Also, all wells will be plugged with cement and their casing cut below plow depth.

HRI will provide financial security for mine closure by obtaining a plugging bond, payable to the State of New Mexico. In addition, for surface and subsurface restoration and reclamation, HRI will submit a surety bond for the ongoing liability for reclamation activities.

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* Hydro Resources, Inc. is a Delaware Corporation licensed to do business in New Mexico. Because the name "Hydro Resources" was not available, the company operates as HRI, Inc. (also referred to as HRI). All references to Hydro Resources, Inc. and HRI should be considered interchangeable for the purposes of this report.

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2.0 SITE CHARACTERISTICS

2.1 Site Location and Layout

The proposed facility will be located on Section 8, Township 16N, Range 16W, of McKinley County, New Mexico. The location of the proposed site with respect to state, county, and other political subdivisions, such as farms, railroads, and highways is presented in Figure 2.1-1. The location of the plant perimeter and exclusion area boundaries with elevation contours is presented in Figure 2.1-2.

Hydro Resources Inc., (HRI) mineral rights include 160 acres of patented mining claims and 200 acres of leases in the permit area. The process facility including all buildings, plant areas, parking areas, and ponds will occupy approximately 6 acres. Wellfields in the Section 8 and Section 17 properties will occupy approximately 100 acres.

2.2 Uses of Adjacent Lands and Waters.

McKinley County is a sparsely populated county. With a land area of 5,442 square miles and an estimated 1985 population of 62,800, the country has an average density of 11.5 people per square mile. Considering that well over one third of the county's population is concentrated in approximately 30 square miles of urban (Gallup) and other built-up areas (Crownpoint and Ft. Wingate, for example), the average population density throughout the county is closer to 5.5 people per square mile. As a comparison, the U.S. population density is approximately 62 persons per square mile.

Urban and built-up areas account for only 0.5% of the county's total area. Areas classified as being non-commercial timber and woodland, comprise the single largest land use category in McKinley County. Approximately 47% of the county's total land area is in this classification. Seven percent of the county's land area, however, has commercial grade timber resources.

Rangeland is the second largest land use category in McKinley County - almost 43% of the total land area is classified as being rangeland. The table below lists McKinley County's major land uses and provides an estimate of the percentage of land area devoted to each use.

2.6.2 MINE ZONE GEOLOGY

Numerous exploration holes have been drilled which delineate the geology within the project area. Figures 2.6-5 through 2.6-10 are detailed cross sections and index maps which illustrate the geologic features in the area. In addition, Appendix A contains cutting and geophysical logs of the recently drilled test wells.

The Churchrock project contains mineralization in the Westwater Canyon member of the Jurassic Morrison formation. This section of the Westwater has been arbitrarily designated the "A" sand in the project area. As described previously, the Westwater was deposited as a broad alluvial fan sequence with a preponderance of thick arkosic sandstone on the west side of the San Juan Basin shaling out to the east and northeast at the distal edge of the fan. At Churchrock, the "A" sand consists of a medium to coarse- grained, moderately sorted conglomeratic sandstone with numerous clay clasts intermixed throughout the section. Sieve analysis of well CR-3 is shown on Figure 2.6-11. Laboratory air permeability studies indicate permeability of 8.048 to 1.450 darcies, however, pump test results indicate lower permeability in the 850 millidarcy range. The "A" sand is approximately 200 feet thick in the area.

Uranium mineralization within the "A" sand occurs in individual roll fronts. The "A" sand contains 9 roll fronts in separate horizons. These nine horizons are shown on cross section C-C' (Figure 2.6-8) with their designations.

The roll fronts form elongate tabular deposits along the iron-redox interfaces. Mineralization varies in thickness, but averages nine feet in each zone, for a combined thickness at 80 feet for the Churchrock ore body. Fronts contain ore grade mineralization (mineralization above .05% U_3O_8) along a 5300 foot length. Each front has an average width between 80 and 200 feet. Due to the stacked nature of the rolls, the overall dimension of the ore body is 5300 feet long by 800 to 1000 feet wide.

The uranium ore occurs as coffinite and uraninite concentrated in interstitial matrix and occurs on grain margins and at grain contacts. Below the "A" sand is a sandstone unit which is designated the "AA" sand for the purpose of this project. The "AA" sand, which contains uranium mineralization, is the lower-most unit of the Westwater Member and lies on top at the Recapture shale. There is 150 feet of Recapture shale overlying the Cow Springs sandstone.

Above the "A" sand is the Brushy Basin Member of the Morrison Formation. It consists of upper and lower bentonitic shales sandwiching a sand horizon. These have been designated the "A" shale, for the lower shale horizon, "B" shale for the upper shale horizons and "B" sand for the sand unit.

Overlying the Brushy Basin member is the Dakota Formation composed of sandstone with interbedded shales and coal seams. The Dakota sands are the overlying monitor zone.

Exploration drilling has indicated the presence of uranium mineralization in the Dakota sand. If future drilling indicates a minable resource, this will be addressed by a future application. All necessary monitoring safeguards will be proposed.

From the top of the Dakota to the surface is the Cretaceous Mancos Shale.

Old Churchrock mine workings extensively cover the ore area in the NE 1/4 Section 17, T16N, R16W. Unmined ore extensions surround the old workings, as shown by Figure 2.6-12 and 2.6-13. HRI will solution-mine these extensions from the surface with injection and extraction wells being completed in these zones, as well as virgin ore in deeper horizons. HRI will approach the mining of this ore to gain maximum recovery with minimal dilution of uranium-bearing flow streams by placing extraction wells adjacent to the workings and injection wells in the ore further away from the workings. It is anticipated that lixiviant will enter the workings during the operation. Any affected water in the adits will be restored concurrently with the normal restoration of surrounding ore horizons to level consistent to baseline.

The maps of underground workings demonstrate the prior underground mining was conducted in upper portions of the "A" sand of the Westwater Member. Also, an ore trend in the "B" sand of the Brushy Basin member, which lies above the "A"" sand contains some workings. Figure 2.6-13 shows the stratigraphy of the mine site and the mine workings. The "B" sand is overlain by the non-permeable "B" shale of the Brushy Basin Member. In the event that sloughing and/or fractures in the "B" shale allow conduits for solutions, the proposed fresh water protection will consist of the following elements:

A. The Dakota is over-pressured relative to the Westwater. This has been demonstrated by test wells completed within 1,000 feet of the mine workings, whereby the static water level in the Dakota was observed to be 184 feet higher than Westwater wells. This greater hydrostatic pressure will cause an inflow from the Dakota into the mine workings if connectivity is in fact the case.

B. The mining in the Westwater will be conducted with a 1% or greater negative bleed from the operating horizon, thereby depressuring the mine zone relative to the Dakota to an even greater extent.

C. In addition, the Dakota will contain monitor wells as required for the first overlying sandstone aquifer. Pump tests will be undertaken prior to mining to test the possibility of connectivity. Static water levels will be recorded, and during operations increases in water pressure that indicate a potential imbalance will be monitored.

D. If required by observed data, HRI will complete monitor wells adjacent to the workings in the Dakota to detect any lixiviant migration. Any contamination of the Dakota will be immediately considered as an excursion, and excursion amelioration procedures will be undertaken.

The geology of the mine site contains all the attributes favorable to in-situ leaching. The "A" sand has high transmisivity in the 1 darcy range, and is stratigraphically continuous through the mine area. This will allow for high flow and efficient uranium recovery and efficient monitoring of horizontal solution movement. Also, high flow rate is an important factor for restoration efficiency. The overlying and underlying sands are all separated by thick continuous bentonitic shale with wet laboratory permeabilities less than "A" sand, and the confining shales will enhance in-situ leaching because leach solutions will be contained and dilution will be minimal. Environmentally, the confining shales will preclude migration into overlying or underlying sands.

2.7 HYDROLOGY

2.7.1 Ground Water

2.7.1.1 Well Inventory

Water supply wells and mine shafts in the vicinity of the proposed mine site are identified on Figure 2.7-1. No water supply wells tap the Westwater Formation. There is no other water supply well within the permit area boundary or within one mile of the permit area boundary. Information on the chemical quality of water from some of the wells is present in Figures 2.7-2 through 2.7-4. Well 16.16.17 was not operating on numerous visits, therefore, water samples could not be collected.

2.7.1.2 Mine Area Ground Water Quality

Eight waterwells have been drilled and completed at the permit area which were used for hydrologic testing and to establish water quality characteristics. Four wells; CR-3, CR-5, CR-6 and CR-8 were completed in the "A" sand. CR-4 was plugged. One well was completed in each of the "AA", "B", and Dakota sands. The wells are located on Figure 2.7-5. These wells were sampled at least quarterly to determine seasonable or laboratory variability. Variability, or lack thereof, will be the basis for determining the frequency and number of samples for commercial baseline establishment.

Figures 2.7-6 through 2.7-12 show the water quality parameters for the CR wells. In most cases, water quality parameters meet New Mexico standards for human consumption. The primary cation present is sodium and the primary anion is bicarbonate. This will enhance the effectiveness of the bicarbonate leach solution.

2.7.1.3 REGIONAL HYDROLOGY

Alluvium

Water-bearing alluvium is present in the principal drainage of the basin of the North Fork of the Rio Puerco. The alluvium has been tapped by wells in a number of places primarily for small quantities of domestic and stock water, which are withdrawn by windmill or hand-operated pumps. Water quality is highly variable because recharge is derived from local storm flows in very small drainages, but is ordinarily good to fair with total dissolved solids ranging from less than 200 mg/liter to somewhat over 1000 mg/liter.

Gallup Sandstone

The Gallup sandstone forms the cliffs in the mine area. The sandstones comprising the Gallup sandstone aquifer have a net thickness of approximately 210 feet. The uppermost sandstone, approximately 35 feet thick, is referred to as the Gallegos Member. It is separated from the next major sandstone by approximately 45 feet of sandy marine shale and interbedded thin sandstones. The second major sandstone, also approximately 45 feet thick, is considered the lower part of the Gallegos Member. The first Gallup Sandstone rests upon approximately 130 feet of sandy marine shale and thin lenticular sandstones assigned to the Mancos Shale which, in turn, rests upon the "second Gallup." The second Gallup is correlative with the "massive Gallup" that can be traced over a large area in the Southern San Juan Basin.

All of these sandstones are considered part of the "Gallup aquifer." The sandstones are assumed to be hydraulically connected, at least in some areas toward the southwest where the intervening marine shale tongues pinch out and the transgressive and regressive sandstones merge.

The upper sandstones described above are variable in thickness, generally becoming thinner toward the northeast. The two lowest beds, referred to as the first Gallup and second Gallup, are the most perisitent, but only the lower second Gallup continues as a massive sandstone into the central part of the San Juan Basin. The upper sandstones of the Gallup aquifer are of irregular lithology and generally are composed of light-gray to buff, or pink, fine-to-medium-grained sandstone sometimes with coarser grained channel fillings. The upper units also contain a number of thin shale beds. The two lower sandstone beds are generally buff to light gray, fine-grained and silty, and the lowest, second Gallup, becomes gradually finer-grained towards the base, merging with the rather thick transition zone which comprises the upper 100 feet of the underlying Mancos Shale.

Although the Gallup is the principal aquifer in a number of wells near the city of Gallup, including four supply wells at Window Rock Junction, the Gallup aquifer has not been extensively utilized in the area of the mine. Records show only two wells completed in the Gallup near the mine. These are well 17.16.32.112, approximately 6.5 miles north-northeast of the mine, and well 17.15.30.341, approximately 5.5 miles northeast of the mine in the valley of Pipeline Canyon. Neither of these wells penetrates more than a small part of the Gallup aquifer. Specific capacities of these two wells are 0.15 and 0.46 (gal/min)/ft, respectively. Water quality is only fair, with total dissolved solids being 1390 and 2450 mg/liter. Water from both wells is high in sulfate concentration.

Dakota Sandstone

The top of the Dakota Sandstone aquifer is approximately 310 feet below the surface in the mine area. Regionally, the Dakota is separated from the Gallup Sandstone by approximately 500 feet of Mancos Shale, which is composed primarily of dark gray and greenish-gray shales with thin interbedded sandstones. The Mancos has very low relative permeability and is considered an aquiclude.

The upper member of the Dakota Sandstone, termed the Two Wells Member, is approximately 61 feet thick. It is composed of an upper massive sandstone unit approximately 47 feet thick, a lower, fairly massive sandstone about 8 feet thick, and an intermediate shale zone. The massive sandstone units are highly resistive and "clean" and can be assumed to contain relatively high quality water.

Below the Two Wells Member lies the Whitewater Arroyo Shale, which is approximately 56 feet thick and is generally similar to the main body of the Mancos Shale. The Whitewater Arroyo Shale, atongue of the Mancos Shale, merges with the main body north- eastward in the San Juan Basin. Like the main body of the Mancos Shale, the Whitewater Arroyo Shale has very low permeability. Beneath the Whitewater Arroyo Shale is an unnamed member of the Dakota, approximately 66 feet thick, made up of six ledges of clean, resistive sandstone separated by marine shale. The net thickness of resistive sandstone in this lower unit is approximately 38 feet.

Four wells in the vicinity of Applicant's mine draw water from the Dakota aquifer. These wells are designated 16.15.17.141, 16.15.20.121, 16.16.1.112, and 17.16.35.414. The first well mentioned is located about 1.5 miles north of Pinedale Trading Post, 5-3/4 miles southeast of the Applicant's mine, and is equipped with a windmill and pump jack. The well is used for domestic and stock water supplies. The second well mentioned is at the Pinedale Chapter House, 6 miles southeast of the Applicant's mine, and is equipped with a submersible pump. The well is used primarily as a domestic water supply. The third well is about 4.5 miles east-northeast of Applicant's mine and is equipped with a windmill. This well is also used for domestic and stock water supplies. The last mentioned, located 3-1/2 miles is northeast, is United Nuclear's water well which draws water from both the Dakota and, below it, the Westwater Canyon Sandstone Member of the Morrison Formation.

Well 16.15.17.141 is open to only 10 feet of the aquifer and has a specific capacity of 0.03 (gal-min)/ft. Water quality is fair with a conductance of 160 umhos. Well 16.15.20.121 is open to approximately 90 feet of the Dakota Sandstone aquifer, 55 feet of which is in the Two Wells Member and approximately 35 feet of which is in the lower, unnamed member of the Dakota. This well has a specific capacity of 0.07 (gal/min)/ft. Water quality is relatively poor, having a conductance of 1600 umhos. This poor water quality is probably due to completion of the well in both the upper and lower zones. The "shaliness" of the lower zone can cause a high dissolved solids content. Well 16.16.1.112 is open to only 7 feet of the aquifer, probably in the Two Wells Member, and has a specific capacity of only 0.01 (gal/min)/ft. Specific conductance of the water is 1060 umhos.

Westwater Canyon Sandstone

The Westwater Canyon Member of the Morrison Formation is the most significant aquifer in the mine area and the mineral-bearing zone. This sandstone lies at a depth of 575 feet below the surface in the mine area and is separated from the base of the Dakota Sandstone by approximately 50-75 feet of green shale interbedded with sandstone. The Westwater Canyon Member includes approximately 135 feet of what appears to be relatively resistive sandstone with a total thickness of 280 feet. The sandstone is typically light gray to pale yellowish-brown with minor breaks of greenish-gray shale. The sandstone is generally poorly sorted, ranging from fine- to coarse-grained, and often contains channel fillings, coarse-grained sand, and conglomerate.

The coefficient of transmissivity for the Westwater Canyon Member generally falls in the range of 1000 to 2500 (gal/day)/ft. for wells in the Crownpoint and Borrego Pass area east of Applicant's mine. Wells west of the mine indicate poorer transmissivity for the Westwater Canyon Member. Aquifer tests of the City of Gallup's Monoz-1A well indicate that neither the Westwater Canyon Member nor the Dakota contribute a significant amount of water to that well. However, toward the center of the San Juan Basin, the Morrison is a potentially important aquifer. Strong water flows attributed to the Westwater Canyon Member have been noted during uranium test drilling in a band from Coyote Canyon through Standing Rock and at a point a few miles north of Crownpoint.

Another well in the Westwater Canyon Member has been recently completed in T.23 N., R.14 W. Municipal water supplies are also drawn from the Westwater Canyon at Crownpoint. The quality of water within the Westwater Canyon Member is typified by that pumped from the monitor wells. Quality is generally good with conductance less than 700 umhos and total dissolved solids not much more than 400 mg/liter.

<u>Deeper Aquifers</u>

Several stratigraphic units which yield water in other areas are present below the Westwater Canyon Member at the proposed mine site. However, little is known about the aquifers' water- bearing characteristics. These units include, in descending order, the Cow Springs Sandstone, the Summerville Formation, the Todilto Limestone, the Entrada Sandstone, all of Jurassic age; the Wingate Sandstone and several sandstone units in the Chinle Formation, all of Triassic age; the San Andres Limestone and the Glorieta Sandstone, both of Permian age. None of these units are tapped for water near the proposed mine site because adequate supplies have been available from more shallow formation. The uppermost unit (Cow Springs) is separated from the westwater by approximately 150 feet of Jurassic Morrison Formation Recapture shale which contains low permability.

2.7.2.6 Confining Clays and Leakage Potential

Test analysis of the regional pump test shows excellent confining shales for the Westwater Canyon aquifer. This was evidenced by the lack of drawdown in the over and underlying observation wells while pumping of CR-3 and by the excellent match of the data from the Westwater monitor wells using the non-leaky Theis curve.

In addition, core analysis was performed on cores retrieved from the "AA Clay" separating the Westwater Canyon Member from the underlying AA in well CR-7. Three samples were examined by Core Laboratories, resulting in an average permeability of 4.1×10^{-6} millidarcies (5.5×10^{-6} md, 5.6×10^{-6} md, and 1.3×10^{-6}). This is 72 million times less than the 298 md average calculated using the Theis curve fit.

Both the hydrologic test and the core information make it apparent that the potential of our leachate migrating to zones outside our production horizon is very low.

2.7.3 Exploration Boreholes

In Churchrock, many exploration holes were drilled during the 1950's, (see listing in Appendix G) before plugging regulations were in place and the natural drill mud must be relied upon as an adequate plugging medium, additional actions will be undertaken before beginning wellfield construction to verify the adequacy of the natural mud. To state the case, natural drill mud plugging of the drill holes has been demonstrated to be sufficient to prevent hydraulic connectivity in pump tests conducted by HRI. Also, prior to operations and after completion of injection, extraction and monitor wells, additional pump tests will be undertaken. In Churchrock, since hole locations are documented, an additional extra step of coring the abandonment mud in selected holes to evaluate the gel strength of the drill hole across the confining clays will be undertaken. The gel strength is a measure of the shearing stress required to overcome the tendency of the wellbore fluid to remain static. This stress can be converted to pressure, in psi, estimated for a certain depth from the following equation:

Pressure, psi = .003 X GS X H/D

Where GS = gel strength (lb/100 sq. ft.)

F = depth (ft.)

D = wellbore diameter (in.)

This equation is taken from the paper "Factors Affecting the Area of Review for Hazardous Waste Disposal Wells", presented by Ken E. Davis & Associates. The presentation was made at the March, 1986 proceedings of the International Symposium on Subsurface Injection of Liquefied Wastes.

Once the above mentioned coring is completed, computer simulation runs will calculate the pressures exerted by the mining operations at these unplugged locations. This information will be used to evaluate the advisability of drilling out and plugging these abandoned locations before mining.

2.7.5 Differential Pressures Between Zones

The fluid pressure within the Westwater Canyon Sandstone in the Old Churchrock area is considerably lower than that in either the first overlying sand (The Poison Canyon) or the second overlying sand (the Dakota) as evidenced by fluid levels measured in observation wells in Section 8, just to the north of the Old Churchrock mine workings. This will cause water movement out of these overlying sands and into the Westwater Canyon, if a hydraulic connection exists between the zones. The fluid levels in the Section 8 observation wells have been recorded periodically since early 1988, and show that presently (January,1993) the pressure in the Poison Canyon sand is 30.7 feet (of water) higher than that in the Westwater Canyon, while that in the Dakota sand is 58.9 feet greater than in the Westwater. These piezometric pressures have been adjusted for elevation.

The differences in pressure potential between these three zones was probably caused by dewatering of the aquifers at differing flowrates for underground mining. The dewatering in the area stopped about January, 1986. Although the water levels have been recovering since then, this pressure recovery has slowed considerably with time, which is normal. The difference in piezometric levels between the Poison Canyon and the Westwater Canyon sands had an average change, month-to-month, from January, 1992 through January, 1993 of 0.046 feet or 0.55 feet calculated on a yearly basis. Thus, the differential pressure with the Dakota and the Poison Canyon greater than the Westwater would extend decades into the future (30.7 feet/0.55 feet/year) before equilibrium is accomplished, even discounted that the changes would naturally become smaller with time, increasing the time to equivalence significantly.

Presently, these differential pressures would cause a substantial recharge of the Westwater Canyon with water from the overlying aquifers, if any of the mine workings at the Old Churchrock site extend up and into the Poison Canyon, and then into the Dakota sand. This natural migration of water into the Westwater would take considerably pressure to reverse at the Old Churchrock site, and such a reversal would not be expected during the normal ISL operations surrounding the site.

2.7.6 Water Level Rebound

Since HRI began measuring water levels in the Churchrock area in 1988, the water levels have increased significantly (Figure 2.7-17). This rebound is the result of the cessation of mine watering as discussed in 2.7-5.

3.1.2 Well Construction

Details of well specifications are shown on Table 3.1-1 and Figures 3.1-1, 3.1-2 and 3.1-3 and 3.1-4, and described below.

All holes will be rotary-drilled with water well-type drill rigs, which are capable of circulating drilling fluids to the surface. The drill holes will be straight-drilled or directionally drilled depending upon the surface locations of obstacles such as cliffs or roads. Casings of injection, production and monitor wells will be either of fiberglass or PVC, and perforated, underreamed or screened. A combination of fiberglass in the lower section of the hole and PVC in the upper hole is also an option that may be used.

As mentioned above, the production, injection, and monitor wells will be cased using various casing types and techniques which are dependent on the site characteristics of the particular wellfield and completion horizon. One of three possible casing techniques will be used.

- Single string of casing through the completion interval
- Dual size casing to accommodate large submersible pumps to pumping depth and smaller diameter casing through the completion interval.
- Single string of casing to top of completion interval with a cement basket and integral screen below the basket through the completion zone.

The casing will be constructed of either threaded fiberglass casing or solvent-welded PVC casing. Fiberglass casing is preferred when differential drawdowns are expected to exceed 400 feet, fiberglass casing is capable of sustaining 1,400 feet of differential collapse pressure for 4" casing with a wall thickness of .150 inch. Besides its high resistance to collapse, fiberglass casing is acceptable for perforation since it will not shatter from the shock of perforation. Fiberglass and PVC casings are resistant to the oxidized conditions that are inherent in in-situ uranium mining.

PVC casing is by far a more economical alternative to fiberglass casing. PVC casing can sustain collapse pressures of over 400 feet for 6 inch SDR 17 casing. PVC is used widely in the in-situ uranium mining business for its relatively good strength, low cost, availability and resistance to the oxidized environment inherent in the leaching solutions. PVC casing is not as good for perforated completions because of its tendency to shatter, but techniques have been developed by HRI to use PVC casing and crossover to fiberglass casing to take full advantage of the properties of both casing types.

Steel casing does provide an alternative to PVC and fiberglass casing by demonstrating a significantly higher resistance to burst and collapse pressures. When considering the application of steel casing to in-situ leach mining operations, further attention must be made to the lixiviant chemistry and the resistance to corrosion provided by the casing material. Steel casing is very vulnerable to corrosion resulting from contact with the lixiviant which over time could significantly reduce the mechanical integrity of the casing. Therefore, steel casing remains not as attractive as the non-metallic alternatives considering the precautions required to protect the casing from corrosion.

Table 3.1-1

WELL CASING SPECIFICATIONS FOR THE CHURCHROCK PROJECT

Casing Type	4" PVC Sch 40	5" PVC SDR 17	6" PVC SDR 17	4" FRP DHC175	6" FRP DHC250	4" Steel H-40	6" Steel H-40
O. D. (inches)	4.500	5.563	6.625	4.680	6.900	4.500	6.625
I. D. (inches)	4.026	4.909	5.845	4.330	6.400	4.090	5.924
Wall Thickness (inches)	0.237	0.327	0.390	0.175	0.250	0.205	0.351
Casing Weight (lbs/foot)	2.030	3.450	4.890	2.100	4.750	9.500	20.00
Joint Length (feet)	21	21	21	30	30	20	20
Burst Strength (psig)	175	250	250	700	800	3,190	3,040
Collapse Strength (psig)	150	212	212	400	200	2,770	2,520
Material Specification	ASTM D-1785	ASTM D-2241	ASTM D-2241	API 15 HR	API 15 HR	API Bul. 5C2	API Bul. 5C2
Test Temperature (°F)	73.5	73.5	73.5	150	150	200	200
Resistance to Lixiviant	Yes	Yes	Yes	Yes	Yes	No	No

a. ASTM D-1785: ASTM F480 Specifications for PVC schedule 40, 80, and 120 pressures
b. ASTM D-2241: ASTM F480 Specifications for PVC SDR rated pipe
c. API Bulletin 5C2: Bulletin on Performance Properties of Casing and Tubing

Operating Characteristics

Injection Wells

Expected Injection Wellhead Pressure:	125 psig
Differential Injection Head inside Casing:	161 psig
Total Injection Pressure inside Casing:	286 psig
Burst Resistance Pressure of Casing with Cement:	2,840 psig
Safety Factor:	8.94

Production Wells

Expected Well Drawdown:	173 psig
Collapse Resistance Pressure of Casing with Cement:	1,420 psig[d]
Safety Factor:	8.21

d. Denotes that the collapse pressure represents 50% of the total compressive strength of the cement sheath. This pressure includes a 100% safety factor to account for annular inconsistencies which may occur during cementing.

When considering the relative strength of casing materials with respect to operating conditions, one also needs to consider the additional strength provided by the cement sheath that exists in the annulus of the wellbore. This cement protects the casing by providing additional burst and collapse pressure resistance resulting from the relatively high compressive strength of the cement. This compressive strength increases the burst and collapse strength of the casing to approximately that of the cement. The physical properties of the cement to be used are listed below:

Type:	ASTM Class I
	API Class A
Density:	13.5 ppg
Additives:	2% bentonite gel
Compressive	2840 psig @ 80° F. & 72 hours
Strength:	3350 psig @ 100° F. & 72 hours

(Source: Halliburton Cementing Tables)

When the casing is run into the hole it will include centralizers with each being spaced between 150 to 200 feet along the total casing length. The casing that is to be used for perforated, and underreaming will include a cap at the bottom. This casing includes a weephole to allow the cement to flow below and around the casing back to the surface in the annular volume of the hole. In this case, the casing is run through the completion interval to a casing depth set by the geophysical log.

The casing that will be used for integral screen completion will include the screen attached to the bottom of the casing, and between the casing and screen, a cement basket. The cement basket packs off the annular space between the casing and wellbore wall to isolate the screen from the cement, and it includes a plug inside the basket to seal off the casing inside from the screen. The cement is allowed to flow through weepholes above the plug, which then flows out to fill up the basket and return to the surface. When the well is completed, the plug is drilled out to reveal a clean open screen to the casing.

Once the casing is run into a well, it is cemented from bottom to top. The cement will consist of a slurry of Class A cement, approximately 2% bentonite gel, and water with a weight of approximately 13.5 ppg. The cement is pumped through the casing, through the weepholes in the cap or basket, and up the annular volume between the casing and borehole to the surface. The slurry volume will be sufficient to fill the annular volume, a portion of the lower casing volume, and to provide enough excess volume to fill any potential washouts with returns to the surface. After the entire slurry volume is pumped down the well, it is displaced in the casing with water to a depth considered sufficient to ensure that enough cement remains in the casing to properly seal the bottom weepholes. The well is sealed with the displacement fluid in the casing to prevent backflow and is allowed to set for 48 hours to cure the cement.

There are three principal completion techniques utilized by HRI:

- Perforated Casing completion.
- Underreamed Casing completion.
- Integral Screen completion.

The method of which completion will be used is determined by such factors as the casing method used, depth of the well, and the nature of the completion horizon.

The integral screen completion has been discussed previously in the casing methods. This completion is typically used for shallower wells with very long completion intervals and satisfactory vertical isolation. The cement basket is set in a confining shale above the completion interval and the screen is suspended below the basket.

Perforated and underreamed casing completion are both used to open wells with casing placed across the target interval. The perforated casing completion utilizes hollow charge shots to punch holes through the casing, cement, and into the formation. The underreamed casing completion uses a mechanical downhole tool to cut away the casing, cement, and the filter cake on the sandface. Both techniques are very effective ways to open the well to the completion horizon. These completions provide very good vertical isolation of the interval due to cement remaining above and below the opening to seal the annulus of the casing from leach solution migration.

The advantage of perforations is derived from the ability to operate them with a wireline unit at any depth. Perforations are a proven means of opening a well, and HRI has a great deal of experience perforating wells.

The advantage of underreaming casing is that it allows the removal of the casing, cement and filter cake from the completion interval. This creates a large diameter hole which allows for a very large surface area in the formation to be open to the wellbore. Historically, wells completed by underreaming have demonstrated higher volumetric flow rates over those observed in perforated wells. The major disadvantage in underreaming results from the limitations of the rotary rig and underreaming tool. As the depths increase, the amount of weight resulting from the drill-string increases proportionally downhole on the blades of the cutter. HRI has a great deal of experience using underreamers in deep wells, and with careful management of string weight and torque, the underreaming will be completed without major problems.

After the well is completed, a set of cased hole geophysical logs are run through the open interval and length of the casing. The single point resistivity and gamma ray logs are run for this survey. The open interval and any potential casing leaks will be detected by the logs.

After logging the well and opening the ore interval, the mechanical integrity of the casing and cement is tested. An inflatable packer is run into the well to a depth directly above the open interval. The packer is inflated, and the casing is filled with water. The well is sealed, filled with water and pressured up with air to a pressure approximately 125 psi or 25% above the expected operating pressures, whichever is greater. Operating pressure will vary with the depth of the well and will be less than formation fracture pressure with a significant safety margin. After the test pressure is reached, the well is sealed to hold pressure and allow to stand for one hour. After one hour, the well is passed if less than 10% of the starting pressure is lost over the course of the test. If the test is failed, then corrective action is taken to ensure that the mechanical integrity test can be passed, and if passage of the test is unattainable, the well is not considered operational.

Records of mechanical integrity tests and construction details will be recorded on the well completion report, such as illustrated in Figure 3.1-5.

3.1.3 Wellfield Operations

Mining will proceed with fortified ground water lixiviant (Table 3.1-2) being circulated through the uranium ore by injection and extraction wells as follows.

The lixiviant solution will be composed of a bicarbonate ion complexing agent and dissolved oxygen gas in ground water. Uranium in the ore will react with the lixiviant to form either a soluble uranyl tricarbonate complex by reaction (2a), or a bicarbonate complex by reaction (2b):

$$2UO_2 + O_2 \text{-----------------------} 2\,UO_3 \qquad (1)$$

$$UO_3 + Na_2CO_3 + 2NaHCO_3 \text{--------------------} Na_4UO_2(CO_3)_3 + H_2O \qquad (2a)$$

$$UO_3 + 2NaHCO_3 \text{----------------------------} Na_2UO_2(CO_3)_2 + H_2O \qquad (2b)$$

The uranium-enriched pregnant lixiviant solution will be pumped from the bottom of production wells to the process plant for uranium extraction by ion exchange. The resulting uranium-depleted (barren) lixiviant will then be refortified with chemicals and reinjected into the wellfield to repeat the leaching cycle.

The anticipated lixiviant circulation rate at Churchrock will average approximately 2,500 gpm. The injection pressure at the well head will not exceed 125 psi. During normal operations, the lixiviant injection and production rates in a producing region will be regulated to recover about 1 percent more fluids than injected. The resulting hydraulic pressure sink will cause native groundwater outside of the ore zone to migrate into the wellfield. This excess quantity of fluid, called the process bleed (or purge stream) after uranium recovery, will form the primary liquid waste stream from the wellfield.

Baseline and restoration values will be established by sampling each production zone monitor well, non-production zone monitor well and baseline wells. All samples shall be collected, preserved and analyzed as follows:

- o Two casing volumes of water will be evacuated from a well prior to sampling. A casing volume will be defined as follows:

$$(TD - FL) \times \frac{\pi D^2}{4} \times 7.48$$

Where	TD	-	Well depth
	FL	-	Fluid level from surface
	D	-	Well diameter

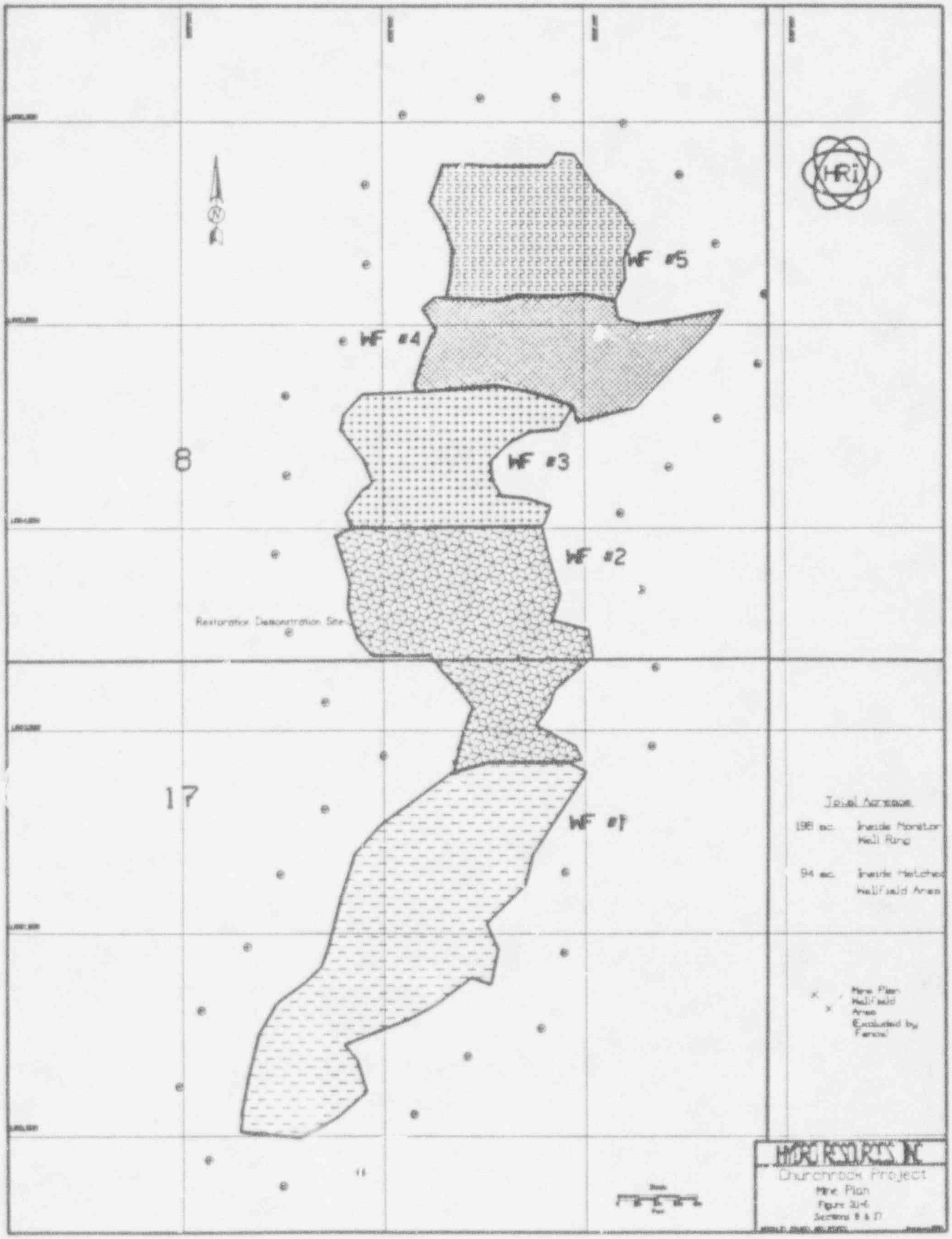
Water samples will be obtained after conductivity and pH are stable for three consecutive samples. Sample preservation and analysis and analytical quality control will be as defined in the current issues of Methods for Chemical Analysis of Water and Wastes, (EPA Technology Transfer).

These samples will be analyzed for the parameters listed in Table 6.4-2, and the results for each summarized and submitted to the NMED and NRC as follows:

- **Mine area baseline** - The averages and ranges of the parameter values determined for the designated production zone monitor wells;

3.1.4 Mine Timetable

The proposed mining plan at Churchrock is summarized in Table 3.1-3 and shown on Figure 3.1-6. Production will proceed sequentially from one end of the wellfield to the other, with production in one end being initiated as a simultaneous restoration is being conducted in the other end of the wellfield. Within the wellfield, individual wells will be shut down when they cease to be economically productive. When an entire segment of a wellfield has been depleted of uranium, restoration will be started via ground water mixing and reverse osmosis treatment and brine concentration. The estimated productive/restoration life of the wellfields at Churchrock is about 5-7 years, which corresponds to the duration of the NRC license cycle. HRI proposes to post financial security for this period of mining.

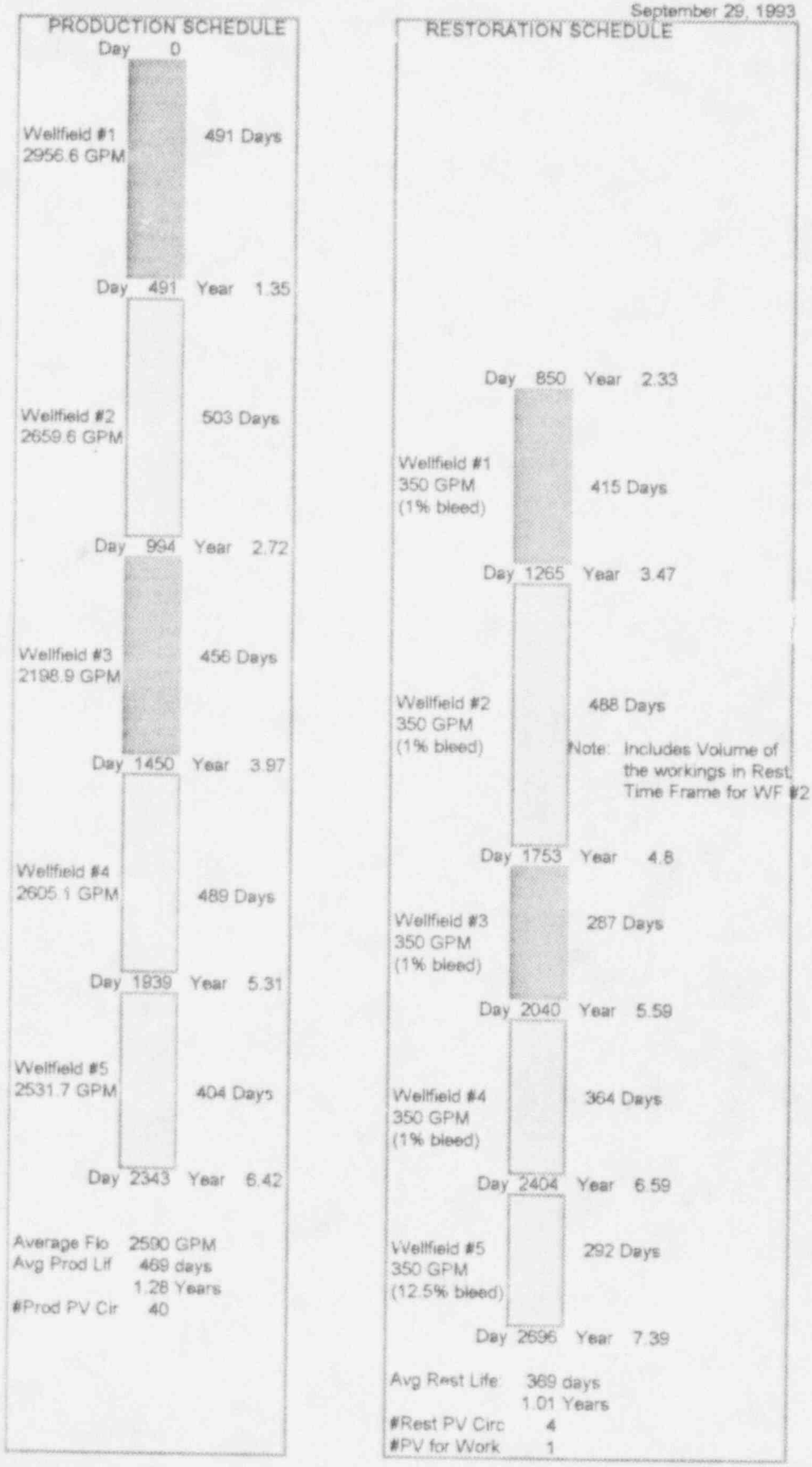


HRI
WF #5
WF #4
WF #3
WF #2
WF #1
8
17
Restoration Demonstration Site
Total Acreage
198 ac. Inside Monitor Well Ring
94 ac. Inside Hatched Wellfield Area
Mine Plan Wellfield Area Excluded by Fence
HYDRO RESOURCES, INC.
Churchrock Project
Mine Plan
Figure 3.1-6
Sections 8 & 17

Table 3.1-3

PRODUCTION & RESTORATION SCHEDULE
FOR THE CHURCHROCK WELLFIELDS

Revision #5 by WPG
September 29, 1993



3.2 Recovery Plant Equipment

The location of the process plant is shown in Figure 3.2-1, and a plot plan is shown in Figure 3.2-2. Major structures to be provided initially include (1) process pad, on which uranium extraction and precipitation equipment will be located; (2) waste retention ponds; (3) tankage; and (4) office and service buildings (laboratory, control room, workshops, etc.). Liquid oxygen tanks will be located in the well fields. Other chemicals will be stored in tankage on the concrete pad near the waste retention pond (Figure 3.2-3).

3.2.1 Process Pad

The process pad will be made of concrete and provided with a sump and a 6-inch high curb at the periphery. The curb will be designed to confine and hold chemical spills and potentially contaminated runoff from the process equipment area. The pad will have a total area of 7,813 $ft.^2$, with 258 $ft.^2$ occupied by process vessels and tanks. The total fluid retention capacity of the pad and sump will be 28,257 gallons, which is adequate to retain the fluid contents of the largest tank on the pad.

3.2.2 Ponds

Two or more waste retention ponds will be provided. The ponds, which will be constructed such that all retained fluid is below ground level, thereby eliminating the potential for embankment failure and the need for NRC Regulatory Guide 3.11 Embankment Requirements. With either location, ponds will be added as needed to accomodate the fluid handling requirements of the operation.

The ponds will have two membrane liners: an inner 36 mil Hypalon liner (or equivilant), and an outer liner 30 mils thick made of chlorinated PVC or an equivalent (1 mil = 0.001 inch). A space 4 to 5 inches thick between the two liners will contain sand or some other granular medium or geonet, and a network of open piping, forming an underdrain leak detection system. The outer liner will provide secondary containment for any leakage that may occur, thereby minimizing the potential for subsurface contamination. The ponds will be inspected daily for leakage except on weekends and holidays. Fluid of any quantity found in the leak detection system will be cause for immediate corrective action, including immediate notification of NRC by telephone.

3.2.3 Tankage

Fiberglass Vessels

Standards utilized in the fabrication of fiberglass reinforced tanks conforms to Voluntary Product Standard PS 15-69. This voluntary standard, initiated by the Society of the Plastics Industry, Inc., has been developed under the *Procedures for the Development of Voluntary Product Standards*, published by the Department of Commerce. The purpose of this Product Standard is to establish a national basis for standard sizes, dimensions, and significant quality requirements for commercially available glass-fiber-reinforced-chemicl resistant process equipment. Standards adopted include: American Society for Testing and Materials (ASTM) Designation D883-69, *Standard Nomenclature Relating to Plastics*.

The design of vessel wall thickness is predicted on using a safety factor of 10 to 1 using mechanical property data for Glass Content, Tensile Strength, Flexural Strength, Flexural Modulus, and Hardness utilizing a liquid of specific gravity of 1.2 and temperatures to 180 degrees F.

Glass Content - Glass content shall be determined in accordance of ASTM Designation D2584-67T, *Tentative Method of Test for Ignition Loss of Cured Reinforced Resins.*

Tensile Strength - Tensile strength shall be determined in accordance with ASTM Designation D638-67T, *Standard Method of Test for Tensile Properties of Plastics.*

Flexural Strength - Flexural strength shall be determined in accordance with Procedure A and table 1 of ASTM Designation D790-66, *Standard Method of Test for Flexural Properties of Plastics.*

Flexural Modulus - The tangent modulus of elasticity in flexure shall be determined by ASTM Method D790-66

Hardness - The hardness shall be determined in accordance with ASTM Designation D2583-67, *Standard Methods of Test for Indentation Hardness of Plastics by Means of a Barcol Impressor.*

When bidding fiberglass vessels to commercial fabricators, HRI always requests conformity to Voluntary Product Standard PS 15-69. This standard addresses the criteria used in manufacturing fiberglass flanges, vents, elbows, tees, crosses, eccentric reducers, etc. Finally, the resin of choice for most applications within the recovery operation is one that can stand up to acids and bases over a broad pH spectrum.

Steel Vessels

Sand filters and downflow ion exchange vessels will be fabricated from steel. Companies whose business is the commercial fabrication of steel pressure vessels use the American Society of Metallurgical Engineers (ASME) guide of Section VIII, Division 1 for the design and fabrication of pressure vessels. This design incorporates a safety factor of 4 times the design pressure at conditions specified by the end user. Pressure testing for at least one hour at 1.5 times maximum operating pressures is required to obtain ASME coding. HRI specifies all of its steel pressure vessels to be built to these standards.

Piping

Process piping within the plant facility will be made of steel and polyvinyl chloride (PVC) of varying diameters and wall thicknesses. Wherever applicable, the use of PVC piping will be utilized because of its superior rating for chemical resistivity.

PVC Piping - ASTM standards for PVC pipe and fittings are divided among five groups. These groups are: Group A, Plastic Pipe Specifications: Group B, Plastic Pipe Fittings Specifications; Group C, Plastic Piping Solvents, Cements and Joints; Group D, Methods of Test; Group E, Recommended Practices. In addition, Product Standards have been established for each grouping. Type I and II PVC are defined by manufacturer's recommended standards. These standards originating from Product and ASTM Standards.

Processing solutions normally transferred under load pressures (<150 psig) within the plant facility. According to PS 21-70 and ASTM 1785, the maximum working pressure at 73.4 degrees F. for 8-inch, schedule 40 PVC is 160 psig. Most PVC piping within the extraction facility will range below 6 inches in diameter. Maximum working pressure for 6-inch diameter PVC is 180 psig. Schedule 80 PVC, which has a wall thickness slightly larger than schedule 40, can sustain maximum operating pressures at higher levels. For example, 6-inch diameter schedule 80 PVC pipe has a maximum operating pressure of 280 psig.

All process piping will be designed in accordance with generally accepted engineering standards according to the flowrate, required pressure and the medium being processed. Process pumps will also be sized to minimize required discharge pressures to achieve transfer requirements as specified:

Steel Piping - The use of steel piping will be minimized within the water treatment facility. However, if steel pipe is specified for a particular application, then the rated operating pressure for that pipe will be used in the design specifications. The construction of line steel pipe conforms to ASME A53 for standard plain end pipe. For example, Grade A pipe of dimensions 8 inches, 10 inches and 12 inches have maximum operating pressures of 1,300, 1,200, and 1,400 psig respectively. These safe operating pressures far exceed any that will be employed at either the Churchrock or Crownpoint projects.

¤ **Conclusion**

HRI will employ all safety and design features that have been successfully employed at its twin operations in Texas. The use of generally accepted engineering design will be utilized in the specification and selection of piping and tankage.

3.2.4 Process Description

The general flow scheme for the uranium recovery process, including well field leaching, is shown in Figures 3.2-5 and 3.2-6.

The pregnant lixiviant stream containing the uranyl carbonate complex will be received at the process plant through a network of wellfield piping, collection headers, and trunk pipelines, and will be pumped through four ion exchange columns, operated in series in a downflow mode. The entire system will be pressurized precluding the elevation of gasses, including radon, to the process building. Uranium will be exchanged on the reacting sites of the resin for chloride ion (if the resin is in chloride form) according to either of the following reactions:

$$Na_4UO_2(CO_3)_3 + 4RCl \text{ --------------------> } R_4UO_2(CO_3)_3 + 4NaCl \quad (3a)$$

$$2Na_2UO_2(CO_3)_2 + 2RC1 \text{ -------->} R_{42}2[UO_2(CO_3)_3] + 4NaCl \quad (3b)$$

Where R is a reacting site of the ion exchange resin. It may be noted that the uranium-loading capacity of the ion exchange resin (i.e., number of the uranium molecules held per reacting site) with the uranyl tricarbonate complex (equation 3a) is one-half that obtained with the bicarbonate complex (equation 3b), thus making the latter route economically more attractive.

The uranium-depleted (barren) lixiviant obtained from the ion exchange column train two surge tanks, pumped through three sand filters to remove any particulates, refortified with requisite chemicals, and piped back to the well fields for reinjection.

When the ion exchange resin in a column has captured uranium to its optimum loading capacity, uranium breakthrough will occur. That is, uranium concentration in the barren lixiviant exiting the column will begin to rise. At this point, the column will be taken off the operating circuit, and another column with fresh ion exchange resin will be taken on line as the last of the two, three or four- stage series.

The loaded resin from the isolated column will be stripped of its uranium with brine, either in place at the Churchrock facility, or will be transported to Crownpoint, by a two-step elution process based on the following reaction:

$$R_4UO_2(CO_3)_3 + 4NaCl \text{ ------------> } Na_4\ UO_2\ (CO_3)_3 + 4RCl \quad (4a)$$

A total of seven ion exchange columns will be available with any six operating at one time in the extraction/uranium-loading circuit, and the remaining one operating in the stripping/elution circuit.

In the first elution step, partially enriched eluant (from the second elution step) will be sent through the fully loaded ion exchange bed to yield a uranium-rich (pregnant) eluate, which will be stored in a tank. In the second step, barren eluant will be passed through the partially denuded resin bed to remove all residual uranium present on the resin. The resulting partially enriched eluant will be stored in a recycle tank and used as the stripping solution at the first step.

The pregnant eluate batch will then be acidified with hydrochloric acid (HCl) to a pH of less than 4 in an vented agitated tank to yield uranyl chloride in a solution (equations 5(a) or 5(b)), which will then be treated with hydrogen peroxide to precipitate uranyl peroxide hydrate or yellowcake (equation 6):

$$Na_4UO_2(CO_3)_3 + 6HCl \longrightarrow UO_2Cl_2 + 4NaCl + 3CO_2 + 3H_2O \quad (5a)$$

$$Na_2UO_2(CO_3)_2 + 4HCl \longrightarrow UO_2Cl_2 + 2\,NaCl + 2CO_2 + 2H_2O \quad (5b)$$

$$UO_2CL_2 + H_2O_2 + x\,H_2O \longrightarrow UO_4\,X\,H_2O + 2HCl \quad (6)$$

Carbon dioxide gas (CO_2) generated during acidification will be vented into the atmosphere. The precipitate will be allowed to settle. The supernatant liquid (barren eluant) will be decanted and stored in two storage tanks, reconcentrated with salt (NaCl), and reused in the uranium stripping circuit (elution step 2). A part of this stream will be discarded periodically to keep accumulated impurities within limits.

A thickened yellowcake slurry will be filtered in two batch filter presses, washed, and stored in a tank for drying.

Yellowcake slurry will be dried using a batch-type rotary vacuum dryer system at the Crownpoint facility.

Polyethylene pipe is highly chemically resistant, being impervious to solutions of inorganic salts, alkaline fluids, non-oxidizing acids, and low concentrations of oxidizing acids (i.e., these solutions utilize the same design service factor as water).

Polyethylene pipe is applicable for pressures up to 265 psi and temperatures from below freezing to 180° F. Temperature design factors are based on the expected temperature of the pipe itself, which on a sunny day can be as much as 20-30° F. above ambient temperature. The expected lower temperatures in New Mexico dictate a lower design temperature of -20° F., although the actual pipeline temperature will never reach this lower limit during operation. At this extreme low temperature, polyethylene pipe's burst strength actually increases. The pipe will still be ductile at this temperature, but fittings such as concentric reducers and tees will be slightly (on the order of 10%) more susceptible to bending moments. The pipeline will be installed such that bending moments will be minimized or eliminated with sufficient additional pipe length to account for the maximum contraction and expansion movements between the expected temperature extremes (-20° F and 120° F.) to which the pipeline will be subject during operation. Special care will be taken during operations to ensure that flanged connections are tightened during colder weather to account for internal contraction of the pipe fitting. These are normal design concerns for any pipeline material subjected to extremes in temperature and do not represent departures from normal prudent operations.

Wellfield Piping and Fittings

Wellfield piping will utilize a combination of polyethylene pipe and schedule 40 PVC pipe (polyvinyl chloride pipe), Class 12454-B (formerly designated Type I, Grade I). Approximately 90% of the surface piping will be polyethylene pipe with the remainder to be primarily PVC pipe fittings. PVC pipe is characterized by high physical properties and resistance to corrosion `that would damage other piping systems. The maximum service temperature is 146° F and PVC has a design stress of 2000 psi. PVC has the highest long-term hydrostatic strength at 73° F of any of the major thermoplastics being used for piping systems. The wellfield PVC pipe will be joined by solvent cementing, threading, or flanging.

The physical properties of PVC pipe area as follows:

ASTM Test Method	**Property Tested**	**Result of Test**
D-792	Specific gravity	1.38
D-638	Tensile strength psi @ 73° F	0.05
D-638	Modulus of elasticity in tension, psi at 73°F. x 10^5	4.2
D-790	Flexural strength, psi	14,500
D-256	Izod impact strength @ 73°F (notched)	0.65
D-696	Coefficient of thermal expansion, inch/inch° F. x 10^{-6} inch/inch/°F x 10^{-5}	3.0
D-648	Heat distortion temperature, °F @ 264° F	160

The pressure ratings of 1/2" through 6" PVC pipe are no less than 160 psi at 73°F (the pressure rating for 6" PVC pipe). All PVC pipe to be used in the wellfield will be manufactured to the specifications and quality outlined in ASTM Standards D-1785 and F-441. We have used this material in HRI/URI's south Texas mining operations with excellent success.

Pipeline Design and Flow Design Considerations

The plant-wellfield pipeline will lay on the surface except where the pipeline crosses roadways, at which points the pipeline will be encased in culverts of an internal diameter of at least 3" greater than the external diameter of the pipeline. Burial of the pipeline beneath the surface is undesirable as the pipelines are inspected daily, and burial would hinder the inspection process. Constant physical inspection of the pipelines is required, as normal remote electronic pressure loss sensing devices are unreliable due to the surging nature of extraction pipelines being fed by multiple wellfield downhole pumps. Insulation of the large main trunk pipelines is not normally required due to the constant rapid flow of large volumes of warm fluids in the temperature range of 70-90° F and the absorption of sunlight by the black surface of the pipe itself (subsurface temperature of the black pipe is normally 20-30° F. higher than the ambient temperature). All small gathering lines from individual wells to the metering containment building will be buried no less than 20" beneath the surface with all metering equipment to be housed in containment buildings for protection from the weather. Furthermore, all wellheads will be insulated from the point the piping from the containment building leaves the ground to the point the well casing contacts the ground.

Fluid flow through the main pipeline will be metered by a flux flowmeter located at the plant end of the pipeline. Fluid flow into the pipeline is determined by the flow of individual wells which is adjusted constantly by the wellfield operators through the 24 hour period of each day. The flow from each individual well is metered by individual flowmeters at each well. All flow data is fed into a computer daily, and the information is used to maintain a balanced flow within the wellfield between the individual injection and extraction wells. To further enhance response time, verbal communication via handheld radios is maintained between the plant operators, the wellfield operators, and the plant and wellfield foremen to enable quick response times in the event an adjustment of flow is required either at the plant injection pumps or within the wellfield itself.

Pipe and Pipe Fittings Pressure Testing

All piping, including fittings, will be static pressure tested to 100% of its designed working pressure for one hour. The pressure testing method will consist of filling the piping to be tested with water, pressured by an external pressure source, to the designed working pressure. The piping to be tested will then be isolated from the external pressure source with positive shut-off valves, under pressure, and held under pressure for one hour. Piping that retains 90% of the original shut-in pressure after one hour will be considered to be competent, and pressure leakage in excess of 10% will constitute a failure of test. The 10% leakage factor is to allow for material expansion under pressure with time and thermal expansion, if applicable. Any visible leakage of fluids within the test section of piping will constitute a failure of the pressure test. Any pipe that fails its pressure test will be replaced or repaired and retested.

The exception to this test procedure will be polyethylene piping and other piping that has excessively flexible walls under pressure to distort the pressure test results. Due to the ductile nature of polyethylene pipe walls, a shut-in pressure test is inconclusive due to pipe expansion under pressure and concurrent loss in internal pressure (without leakage). The polyethylene piping will be dynamically tested by applying a constant pressure to the pipe without isolation from the external pressure source. Visible leakage during the one hour of applied pressure or structural failure of the piping itself will constitute failure of the test.

4.3 Waste Disposal Options

There are several viable options which can be used for waste disposal at the Churchrock facilities, which option or combination of options would be limited by a number of variables including:

- Economics
- Regulatory Constraints
- Availability of Land
- Available of Water Rights

The following discussion includes all potential waste disposal options which HRI considers feasible for use in the proposed operation.

4.3.1 Surface discharge of restoration fluids

In order to acquiring an EPA permit to surface discharge waste water a company must first be able to demonstrate that waste quality including Total Dissolved Solids (TDS) and radionuclides (uranium and radium) will comply with established NPDES standards.

At URI's Benavides and Bruni mines in south Texas, each project was permitted to surface discharge restoration fluids. The treatment of solutions to meet discharged standards for radionuclides were strictly followed.

Irrigation

Irrigation can be accomplished if radium and uranium are selectively removed prior to direct application, and can be definitely considered for restoration type waters. Mining process bleed may still require some other form of disposal because of NRC and EPA legal definition.

The water which will be used for irrigation is derived from the plant bleed and restoration stream. It is anticipated from core leaching experiments that two contaminants, RA-226 and Uranium need to be removed from these solutions to avoid accumulation within topsoil. Other potential contaminant concentrations will be determined during operations by monthly sampling of the parameters listed in Table 6.4-1. If a parameter is elevated above NMED irrigation levels, it will be treated to reduce the contaminant below the standard, or as required by the NMED. The purpose of this section will be to discuss these treatment objectives.

Once the waste stream is pumped to surface, the first step in treatment will be uranium removal. The uranium had been complexed and solubilized underground during the mining phase utilizing oxygen and sodium bicarbonate as follows:

$$UO_2 + O_2 = 2UO_3$$

$$UO_3 + Na_2CO_3 + 2NaHCO_3 \text{ ----------------> } Na_4\,UO_2(CO_3)_3 + H_2O$$

The remnant uranyl tricarbonate complex will be removed from the waste stream by pumping the solution through two 12' diameter, downflow ion-exchange columns placed in series. Each column will contain approximately 400 cubic feet of Dow 21K resin or equivalent. In the column the uranyl tricarbonate anion complex is exchanged onto positively charged resins by displacement of chloride ions through the following reaction:

$$4RC1 + Na_4UO_2(CO_3)_3 = R_4UO_2(CO_3)_3 + NaCl$$

The now barren waste stream passes from the first ion exchange column to the second and from the second to the radium removal system detailed below.

Once the first column overflow exceeds 2 ppm U_3O_8 it is removed from the stream for elution. The resin is stripped of uranium by filling the column with an eluant consisting of 8-10 percent NaCl and 2 percent Na_2CO_3. The solution is agitated in the column removing the uranyl complex from the resin and regenerating the resin with chloride ions.

Following elution the eluant may be refortified with NaCl and $NaCO_3$ for reuse, or may be disposed of by evaporation. The resin column is rinsed with clear water and placed in service as the second column in the ion-exchange train. Following treatment for uranium removal, the solution will then be processed for the removal of RA-226.

Radium will be removed from discharge streams at the project by barium chloride precipitation. Currently accepted technology for radium reduction of mine waste streams involves the addition of 0.1 - 0.2 pounds of barium chloride per 1000 gallons of water. The barium chloride will form barium sulfate which in time will co-precipitate with soluble radium. Flocculants may be added to enhance precipitation. Results of tests conducted with local mine wastes, are within Table 4.3-1. These tests indicate that small additions of barium chloride will effectively reduce mine waste stream radium levels below EPA NPDES discharge specifications.

Solutions of waste stream water were treated with varied concentrations of barium chloride, allowed to settle for 24 hours, decanted and analyzed for soluble radium. Flocculant was not added.

During the period of surface irrigation following the uranium removal state, waste streams would be pumped to a settling pond capable of 40 hour retention. Prior to entering the pond, a slurry of barium chloride and flocculant, if needed, would be injected into the waste stream. The stream would then pass through a static mixer and enter the settling pond. discharge from the settling pond would be gravity bled to a second settling pond, also capable of 40 hour retention, and then to surface irrigation. Figure 4.3-1 illustrates this process flow.

Sampling of each pond outlet would be done on a daily basis, aggregated monthly and analyzed for parameters listed in Table 6.4-2. Adjustments to water treatment would be implemented as needed depending upon the sampling results.

Solid waste generated during restoration would be collected in barrels or as bulk slurry and transported to a licensed byproduct disposal facility.

The limiting factor which would prevent continuous treatment of uranium is break-through due to all sites being filled on the ion exchange resin. If this were the case and only a single column used, the system would have to be shut down while the resin is being eluted. To provide for continuous treatment, HRI will first introduce the fluids to a primary column. Effluent from the primary column will thereafter be introduced to a second stripper column. Whenever the uranium levels in the primary column exceed 4 ppm, the primary column will be taken out of service, and the stripper column will be employed as the primary column. After being eluted, the primary column which was taken out of service will become the stripper column.

Samples will be taken from the overflow of both columns on a regular basis, aggregated into a daily sample and analyzed. Additionally, a "spot" sample will be taken and analyzed form each column early each shift.

4.3.2 Radium Removal

As discussed in Section 4.3.1, radium has long been removed from process waters by taking advantage of barium sulfate's low solubility in water and its inherent ability to coprecipitate radium.

A dilute barium chloride salt solution is added to the waste stream which contains sufficient sulfate level to achieve complete precipitation. Occasionally, sulfate levels are too dilute, which then necessitates the addition of supplemental sulfate in the form of bulk sodium sulfate solids. The precipitate formed can either be filtered or directed to lined lagoons for gravity separation.

4.3.3 Reverse Osmosis

Reverse osmosis is a water treatment process whereby the a majority of dissolved "ions" are filtered from the waste water and concentrated into a smaller concentrated brine volume. The resulting product water typically meets or exceeds drinking water standards and, during restoration activities, is reinjected back into the wellfield further diluting the underground mining solutions toward baseline quality. The concentrated brine stream, representing 25 - 35% of the feed volume, must be disposal either by deep well disposed, surface evaporation, or brine concentration (a form of distillation).

4.3.4 Deep Well Disposal

Injection of waste water and brines into deep geologic formation is common place at URI's mining facilities in south Texas, and is the preferred means where technically feasible. Preferred geologic formations are repositories containing total dissolved solids (TDS) in excess of 10,000 ppm. Additionally, we must demonstrate confinement from overlying fresh water aquifers.

Wastes must be relatively neutral in the acid-base spectrum before being deep well injected. Calcium and iron scaling inhibitor are added prior to injection which is continuously monitored for pressures, flowrates, and temperatures.

Mobil/TVA drilled a test well at Crownpoint to establish the availability of deep seated confined aquifers containing water in excess of 10,000 ppm TDS, which also met the confinement criteria. Two zones meeting these criteria were determined, the Abo and Yeso Formations. If HRI plans to use deep well injection, it will require a permit from the New Mexico Environmental Department of Environment (NMED).

4.3.5 Brine Concentrator

Before a brine concentration is employed, water is first pretreated by multistage downflow ion exchange for uranium removal. The effluent is then processed by reverse osmosis to produce a product water that can be reinjected in a Class V well outside the monitor well ring while the brine stream is treated with $BaCl_2$ to coprecipitate radium. The reinjection of product water enhances hydrologic control of the mining process within the wellfield. The small volume of coprecipitated solids formed are removed by filtration leaving a brine solution free of radionuclides. The brine can now be discharged to double-lined ponds for evaporation or distilled to deionize water inside a brine concentrator.

Brine concentration is a process that can literally process a waste stream into deionized water and a solids slurry. Many electrical utilities and paper and pulp companies have employed this technology for decades to handle their waste streams. The principle behind the process is based on the ideal Carnot cycle. More simply explained, an initial fixed volume of concentrated brine is heated to boiling. The steam vapor created is mechanically compressed resulting in a secondary steam vapor whose temperature is elevated (15-20 degrees) by the work consumed during compression. Distilled water is condensed from the secondary steam vapor onto internal heat exchangers. The heat loss during condensation is transferred to the circulating brine on the opposite side of the heat exchanger. The brine's temperature is raised maintaining the internal boiling environment. This source of heat sustains the creation of primary steam used to feed the compressor. This cycle is continuous so long as energy is added at the compressor stage. The electrical power consumed in compressing and elevating the temperature of the primary steam vapor produces a distilled product water. The resultant hyper-concentrated brine precipitates solids in the form of commons salts in order to comply with the solution's limits for solubility. Systematic blowdown of the solid slurry is directed to a waste disposal pond. Typically, for each 100 gallons of waste brine treated, 99 gallons of distilled water and 1 gallon of slurry solids are formed.

This proposal provides a system which utilizes no more than 1-5 gallons per minute of ground water during mining and restoration, and generates two solid waste streams. The largest solid waste stream could be characterized as non-hazardous, and accordingly, either contained on-site or haul and disposed in any municipal landfill. The second, but smaller solid waste stream would take the form of radium precipitated sludge which would be e disposed as 11-E-2 byproduct material.

4.3.6 Evaporation Ponds

This system is similar to brine concentration in that solar evaporation ponds are installed in sufficient area to allow evaporation of reverse osmosis (RO) generated brine. Since the vapor pressures of high TDS solutions are low resulting from the additional attractive ionic forces available, the evaporation rates would be lower than ordinary fresh water (3.5 gpm per acre).

1. Approximately 100 acres of double-lined ponds would be required.

2. If a spraying system were installed in the ponds, the areal evaporative extent required is estimated at 45 acres.

3. At the conclusion of mining and restoration, the evaporative solids formed and those solids blown into the ponds from the surrounding land will have to be disposed of as appropriate.

Sampling of each pond outlet would be done on a daily basis, aggregated weekly and analyzed. Barium chloride and/or flocculant would be adjusted as needed. Solid waste generated during restoration would be collected in barrels or as bulk slurry and transported to a licensed LSA disposal facility.

A limited factor which would preclude continuous treatment of RA-226 is, breakthrough. The RA-226 will pass through both a primary and stripper pond, just as is the case with uranium removal. Samples will be collected daily from outlets of both columns, aggregated weekly, and analyzed. Elution of the primary column will proceed if outlet of that column exceeds 10 pci/liter.

4.4 Environmental Monitoring

Environmental monitoring will be performed during the operational life of the facility as outlined below (Table 4.4-1). Additionally, samples will be collected from each location and media listed below, for three consecutive samples at monthly intervals to establish baseline before operations commence.

4.5 Contaminated Equipment

All contaminated equipment will be surveyed before the determination of its final disposition.

The record of the survey will be completed on a form such as Figure 4.5-1.

All equipment that does not meet the maximum requirements of 5,000 cpm/100 cm^2 removable contamination will be cleansed and resurveyed, or be disposed of only in a NRC-licensed disposal facility, such as a licensed tailings impoundment.

4.6 Excursions

If routine monitoring as described in Section #3 of this report indicates that a UCL has been exceeded, a verifying analysis of the monitor well(s) verifying analysis of the monitor well(s) will be obtained within 24 hours. If the verifying analysis indicates that mining solutions are present in a designated monitor well, HRI will take the following actions:

1. Notification - Notify the NRC/ED offices by the next working day by telephone and by letter postmarked within 48 hours identifying the affecting monitor well and submitting the control parameter concentrations.

2. Analysis - Complete a ground water analysis report for each affected well for the parameter listed on Tale 6.4-2.

- Clean-up - Clean up all designated monitor wells, all zones outside of the production zone, and the production zone outside of the mine area that contain mining solution. HRI will use any method necessary and prudent to define the extent of the mining solutions and to effect this clean-up in an expeditious and practical manner. Well clean-up will be deemed to be accomplished when the water quality in the affected monitor well(s) has been restored to values consistent with current local baseline water quality as confirmed by three consecutive daily samples for the Control Parameters.

- It may be determined that cleanup is not necessary if HRI can demonstrate that the change in water quality is not due to the presence of mining solutions or fluids from other mining activities.

To achieve osmotic purification, the pretreated solution is pressurized to approximately 235 pounds per square inch (psi) by a centrifugal pump. The pressurized solution is directed to the first step of a two-stage reverse process. Approximately 50 percent of the total feed volume will be converted to product water in the first stage. The balance of the water which yields a overall product to brine ratio of 2:1. The quality of the product water will be vastly superior to that of the Westwater Formation. The brine generated will be disposed of by evaporation and or brine concentration and evaporation. It is expected that the product water will be mixed with post-mining fluids before reinjection so that the water/mineral formation is not "shocked" chemically.

HRI selected the Churchrock properties in part because of low quantities of complexing organics which may hamper restoration and especially stability. In fact, organic reductants may actually enhance stability by rendering oxidation sensitive species insoluble.

Stability will be determined by three sample sets taken at two-month intervals from the original baseline wells, and analyzed for the parameters in Table 6.4-1 and any other parameters required by the NMED or NRC. Providing no significant differences exist between the first two analyses, the third sample set will be analyzed for the minor and trace constituents as shown in (Table 6.4-2). If the major and minor constituents reported for all three sample sets are within the restoration limit, restoration is complete, and no further subsurface restoration is required.

TABLE 6.4-2 - Water Quality Parameters (Long list)

CALCIUM	TDS(180)	MERCURY
MAGNESIUM	EC(25C)	MOLY.
SODIUM	ALK	NICKEL
POTASSIUM	PH	SELENIUM
CARBONATE	ARSENIC	SILVER
BICARBONATE	BARIUM	URANIUM
SULFATE	CADMIUM	VANADIUM
CHLORIDE	CHROM.	ZINC
NITRATE	COPPER	BORON
FLUORIDE	IRON	AMMONIA
SILICA	LEAD	RA-226
	MANGANESE	

When the values of the parameters describing water quality have stabilized for a period of 90 days, and the ground water would be suitable for any use to which it was reasonably suited prior to mining, if restoration is complete.

6.5 Irrigation/Land Application

6.5.1 Irrigation Site Location and Characteristic

During operations, water will be delivered to a 70 acre piece of land which is located southeast of the process facility (Figure 6.5-1). Approximately 54 acres of the 70 acre tract will be used in the irrigation plan discussed in this report. The remaining 16 acres will provide room for future expansion, if necessary. Water will be pumped to the irrigation field through PVC lines which will pass under State Road 566.

The site chosen for irrigation is particularly well suited for this purpose because of its gentle slopes and its soil characteristics. According to a survey conducted by a soils scientist (a consultant retained by HRI), the soil in the irrigation area is El Rancho sandy loam, and according to Soil Conservation Service (SCS) information, it is usually found on slopes ranging from 0 to 5 percent at elevations ranging from 5000 to 7000 feet. The soil is further characterized as being deep (40+ inches), well drained, and moderately alkaline (pH 7.4 to 7.8). Soil permeability is 0.60 to 2.00 inches per hour, and available water capacity (i.e., its capacity to hold water for plant use) is in the moderate range of 6 to 9 inches (water) in a 60 inch (soil) zone, or approximately 0.15 inches of water per inch of soil.

Soil samples were collected from the irrigation area for classification purposes. Soils were taken from four different depth increments and analyzed for sand, silt, clay content, and reactivity (pH). The results of the analysis are given as follows:

Soil Depth	Sand %	Silt %	Clay %	pH	Soil Type
0-6 inches	59.2	22.0	18.8	7.9	Sandy Loam
6-16 inches	53.2	24.0	22.8	7.5	Sandy Clay Loam
16-32 inches	59.2	20.0	20.8	7.9	Sandy Clay Loam
32-45 inches	40.8	29.6	29.6	7.9	Clay Loam

In addition to considering soil texture, depth, drainage, permeability, reactivity, slope, and water holding capacity, soils were also evaluated for major available, soluble and exchangeable cations, as well as conductivity and sodium absorption ratio (SAR). Table 6.5-1 summarizes this information and also shows concentrations of several other elements of importance, namely arsenic, selenium, copper, molybdenum, RA-226 and uranium.

The major cations and SAR levels are of interest in that they provide additional information on which to base an assessment of a soil's suitability for irrigation, especially with respect to sodium loading. The metals shown on Table 6.5-1 are often found in association with uranium processing and therefore are included in the evaluation.

The amount of sodium in soil as well as its occurrence in proportion to soluble calcium, magnesium, and potassium has a significant influence on the health of plants. The manner in which this occurs is a two-fold process: (1) salts govern the amount of soil water available to plants and (2) salts affect plants directly according to their individual sensitivity to these elements. As salt concentration increase, the osmotic pressure gradient between plant root hairs and soil changes to restrict the flow of soil water and essential dissolved nutrients. With the addition of more salts, the osmotic pressure in the soil becomes greater and less water and nutrients are available for plant use - plants then become stressed through nutrient deprivation, reduced evaporative capacity, and depending on their salt tolerance, further stress may occur. An over abundance of sodium can also negatively affect plants by changing soil structure and permeability. With increasing sodium concentration, for example, soils become more dispersed and permeability is reduced. For these reasons, the cation exchange capacity of the soil and presence of salts in the irrigation water are of primary importance.

A review of Table 6.5-1 shows that the soil in the irrigation area has a very low SAR (0.12), and as noted earlier, the soil is deep and moderately permeable - this is one of the most desirable types of soil for irrigation with ground water. Other constituents reported in Table 6.5-1 (arsenic, copper, molybdenum, selenium, uranium, and RA-226) are in the normal range of concentration for this area.

6.5.2 Climatic Elements Affecting Irrigation

A full description of the area's climatic and meteorological characteristics is given in earlier sections of the environmental report; however, several aspects of the climate must be examined here because of their effect on irrigation. The elements of importance are: annual average precipitation, mean annual evaporation rate, and maximum rainfall event information.

Annual average precipitation for this area is 10.7 inches. Approximately 43% of this total occurs in the months of July, August and September. Monthly means for these months are 1.74 inches, 1.81 inches, and 1.05 inches, respectively. Monthly precipitation during the rest of the year is evenly distributed with each month receiving between .51 and .78 inches.

The reported maximum 24 hour rainfall event for Gallup was 1.90 inches which occurred in July 1954. The maximum 10-year 24-hour rainfall event for this region of New Mexico is 2.5 inches and the 100-year 24-hour event is 3.5 inches.

The mean annual pan evaporation rate for the Gallup area is fairly high at 75 inches per year. Approximately 72% of this evaporation occurs between the months of May and October.

The high evaporation rate and low annual precipitation are the two strongest factors affecting the types of crops grown in the area and their productivity. The availability of irrigation water, therefore, would certainly benefit crop production.

6.5.3 Irrigation Plan

During restoration, up to 300 gpm of water will be available for irrigation. During mining, 25 gpm will be available. For a significant portion of the restoration period, the general characteristics of this water will not be too unlike that of the native ground water levels shown in Table 6.5-2. Several of the elements shown in the table will be temporarily elevated as a result of mining operations. At the start of restoration, for example, sodium levels could increase to approximately 245 ppm, bicarbonate to 740 ppm, sulfate to 300 ppm, and magnesium to 1.2 ppm. But according to past restoration experience, levels begin to move toward baseline conditions quickly as water in the mine zone is displaced by native ground water. Since the bulk of water delivered to the irrigation field will have concentrations well below those at the start of restoration, but higher than baseline, estimated mid-range values were chosen for calculational purposes. Mid-range values are estimated concentrations between baseline values and start-of-restoration concentrations.

To estimate potential impacts on soils and to evaluate the suitability of this water for irrigation, mid-range values were assumed throughout the restoration period - <u>no allowance</u> was made for the improving water quality that will occur during the final months of restoration.

An elevation in the metals can also be expected, but the increase (with the exception of RA-226 and uranium) will not result in significantly higher concentrations. Although radium and uranium levels will increase significantly, this will not affect irrigation in that these elements will, for the most part, be removed from the water prior to irrigation.

The water used for irrigation will be treated to remove RA-226 and uranium. Based on experience from other operations, the removal of these elements can be accomplished with a high degree of efficiency. RA-226 will be precipitated from the water with barium chloride and residual uranium will be recovered through the use of a uranium ion exchange column. With the use of this technology, RA-226 and uranium concentrations in the irrigation water will be very low. The average RA-226 concentrations in the irrigation water will be very low. The average RA-226 concentration will be approximately 1 pCi/l and uranium will be about 0.3 ppm. At these levels, significant problems are not expected to arise.

6.5.5 Monitoring Program

The suggested monitoring protocol outlined in this report is based on past experience with other in-situ uranium irrigation projects and on site specific characteristics of HRI's operation. The key elements to be monitored will include irrigation water, soils and vegetation. A description of the sample frequency and parameters to be analyzed is summarized below.

Soil

Prior to the start of irrigation, a set of samples will be collected to establish a uniform baseline condition of the soils. Since the site has only one soil type (El Rancho sandy loam) and since the ground surface does not have any significant relief features, three surface samples taken from 0-6 inches in depth would provide adequate coverage at ground level. As noted earlier, soil texture changes with depth from sandy loam to sandy clay loam, and then to clay loam. To develop a profile of how the salts and other constituents in the irrigation water will be distributed, and to demonstrate how ground water will not be negatively impacted by the operation, it is important to establish a baseline for these subsoils. Therefore, prior to irrigation, it is suggested that three samples be taken from the sandy clay loam layer at 6-12 inches and three samples from the clay loam layer at 32-36 inches.

Samples will be composited by depth increment. That is, the three soil samples from the 0-6 inch zone should be composited and analyzed as one sample, and the same should be done with the other zones. Samples should be collected with a soil auger and weight at least 2 kg. The samples should then be analyzed for total RA-226, natural uranium, barium, vanadium, electrical conductivity, SAR, and pH.

Soil samples will be taken at the end of each irrigation year and analyzed for the constituents named above.

Vegetation

Vegetation samples will be collected at the time of harvest and analyzed for total RA-226, natural uranium, vanadium, arsenic, copper, selenium, and molybdenum.

Irrigation Water

Irrigation water will be sampled on a regular basis under the plant operational monitoring schedule to demonstrate the effectiveness of the RA-226 and uranium treatment system. Irrigation water will also be analyzed, the constituents shown in Table 6.5-1.

Daily Management

Day to day management of the irrigation project will be the responsibility of mine operators who will be supervised by HRI management. HRI management will ensure that monthly inspection of the crops, equipment, and soils is carried out by a person qualified in this area.

Anticipated Impacts

Based on the average constituents in the restoration water, the application rate, the relatively short irrigation period (six years), the quality of the soil, and the management plan, no significant negative impacts are expected. However, the use of HRI's water for irrigating agriculture is a beneficial use of the resource. In the past in-situ mining operations would dispose of water (usually by deep well injection) thus precluding a secondary and beneficial use. Although restoration water does not qualify as drinking water, it does in many cases meet irrigation standards. Since restoration water from HRI's operation can be productively used for agriculture without harming soils or degrading the state's ground water resources, this aspect of the operation is beneficial.

Finally, upon completion of restoration, a summary report will be prepared describing the condition of the soil in the irrigation area - soil analyses collected at the end of the final irrigation year will serve as the basis for describing soil conditions.

6.6 Restoration Demonstration

6.6.1 Purpose and Scope

Leach studies were conducted on core material which was taken from the ore horizon at the Churchrock property. The purpose of these studies was to demonstrate the leachability of the uranium, determine what the expected leach chemistry would be and finally demonstrate that the ground water could be restored to premining conditions.

Tests were conducted on core material from wells CR-3, CR-4, CR-5 and CR-6. These wells are situated at extreme positions within the orebody, thereby assuring representative leach/restoration characteristics for the entire orebody. Batch tests were conducted for all wells to predict which ions and trace metals would be elevated as a result of leach solution contact, for different points in the ore body. Two column leach studies were conducted on CR-3 core; one at a rate that simulated actual leach solution flowrate in the field (Core Study #1), and one accelerated leach study (Core Study #2).

6.6.2 Core Handling

All core material was sampled in one foot sections (Figure 6.6-1), and analyzed for uranium and TOC. The uranium determination was used to select the interval(s) to be used in the leach study. TOC was used internally to predict oxygen consumption during the study.

Based on the information gleaned from the well logs and laboratory analysis, the appropriate sections of core were selected from CR-3. The core material was ground and a sample sent to Hazen Research for mineralogical analysis. The result of the core analysis is presented as Figure 6.6-2. Specific information on the core material is within Table 6.6-1. The material was then packed into two, three-inch diameter columns and sealed. The cores were then set up as shown in Figure 6.6-3 for the leach study.

6.6.3 Fast Leach

6.6.3.1 Leaching Phase

Leach solution was prepared using water from the Westwater Formation at the UNC mill site, and fortifying it with sodium bicarbonate to 800 mg/l. Baseline water quality is shown on Figure 6.6-4. This solution was forced through the column under pressure of 125 psi. Initially, pressure was provided by bottled nitrogen in order to extract the preoxidized uranium. Oxadant was introduced to the system at pore volume 6.3 through two sources, bottled O_2 at 125 psi and 118 ppm hydrogen peroxide in the barren lixiviant.

The core was leached at approximately one pore volume per day. Pregnant lixiviant was removed from the collection column daily and analyzed daily for pH, conductivity and uranium. Results of these analysis are shown on Table 6.6-2. The daily samples were composited into approximately weekly samples which were analyzed for pH, conductivity, Table 6.6-3 shows the results of the composites.

To simulate plant operations, the pregnant leach solution composites were circulated through small ion exchange columns. The barren lixiviant was analyzed, fortified with sodium bicarbonate -if needed- and recirculated throughout the core.

The leach test was conducted for approximately two months with 49.8 pore volumes circulated. This is roughly the number of pore volumes which will be circulated during commercial operations. Total uranium recovery was 72.1 percent. At the termination of the leaching phase, uranium was still high (46.7 ppm), however, to expedite the study, the restoration phase began.

Before restoration began, a complete suite of analysis was performed on the pregnant lixiviant as shown on Figure 6.6-5.

6.6.3.2 Restoration Phase

At the end of the leach phase, the restoration phase was initiated. Baseline quality water was mixed with distilled water to obtain conductivity of 80% of the baseline conductivity. This is the quality of water which would be expected from the product side of the R.O. unit during commercial operations. The simulated R.O. water was pumped through the core, the effluent taken daily and analyzed for pH, conductivity, uranium, chloride, bicarbonate and sulfate. The daily analysis is within Table 6.6.4. At the termination of the restoration study, a composite sample was sent to Jordan Lab for complete analysis. This analysis is within Figure 6.6-6.

6.6.3.3 Core Results

Baseline water quality used in the leach study has similar chemistry to water obtained in wells CR-3, CR-5, and CR-6. TDS was 289 mg/l, well below New Mexico drinking water standards. In fact, there were no parameters above the drinking standards.

During the leach phase, TDS was elevated to 970 mg/l, which is still below New Mexico drinking water standards. The three primary ions which were elevated were; Sodium (341 mg/l), Bicarbonate (573 mg/l) and Chloride (232 mg/l) which were still below New Mexico drinking water standards.

Trace metals which were noticeably elevated include; arsenic (.084 mg/l), barium (.59 mg/l), uranium (40.9 mg/l) and vanadium (2.4 mg/l). Arsenic and barium were below New Mexico drinking water standards, vanadium does not have a health standard and uranium is misleadingly high because the leaching phase was terminated early to accelerate this application.

Radioactivity, as RA-226 was elevated to 665 pCi/l during the leach phase as would be expected in a uranium mineralized formation.

Past experience has been that metals are less elevated during actual leaching operations because the ore material does not experience the crushing and grinding which is necessary to pack the core.

One interesting result which was apparent in this study is the lack of the sulfate ion. Normally, elevated sulfate is experienced in core leach studies and leach operations because of the oxidation of sulfides within the orebody. This often becomes the primary restoration parameter. As shown in Figure 6.6-2, sulfides concentrations in the ore material was less than .01 percent which apparently precluded sulfate buildup in the leach solution.

Restoration resulted in reducing the TDS to baseline concentrations in essentially 4.15 pore volumes. This was also the case for Sodium, Bicarbonate and Chloride.

Arsenic and Barium were slightly above baseline following restoration, but well below New Mexico drinking standards. Uranium was reduced to 10.6 mg/l from 40.9 mg/l. This value is above the New Mexico drinking standards. However, concentration is deceiving because of the partial depletion of the uranium and the fact that restoration began with uranium so high. HRI usually depletes uranium to the 10 mg/l level before beginning restoration simply because of the economic value of uranium concentrations above 10 mg/l. Therefore, with proportional restoration efforts and results, starting at 10 mg/l, the final restored concentration would be about 2.5 mg/l, well below the New Mexico drinking water standard. Vanadium did not show any apparent response to restoration; however, it does not affect the water's use as drinking water in the post-restoration concentrations.

Radioactivity as RA-226 was reduced to 231 pCi/l. This concentration is above baseline, but consistent with the background radium concentrations commonly found in uranium orebodies and what will likely be found at the project during commercial wellfield development.

To conclude, the post-core leach study results indicate that the uranium at the Churchrock project was amenable to in situ leach using a mild, neutral bicarbonate solution and oxygen. Restoration could be accomplished using R.O. which returned the ground water to its premining conditions.

6.6.4 Slow Core Leach

6.6.4.1 Leach Phase

During the Slow Core Leach, a total of 54 pore volumes were circulated through the core, which is similar to the amount of circulation in commercial conditions. The ground water was fortified with bicarbonate as sodium bicarbonate to bring the concentrations to levels which HRI has historically used in commercial leach solutions.

Additionally, the resin used to strip uranium from the solution was eluted with sodium bicarbonate/chloride eluate, thereby elevating chloride and sodium as is experienced commercially. As shown in Figure 6.6-7, TDS in the leach solution was 1,520. There were also trace amounts of arsenic, barium and vanadium in the leach solution. Uranium was elevated in the leach solution which demonstrates that the ore is amenable to in-situ leaching. Finally, radium was increased in the leach solution. We feel that these levels of radium are more of a result of core preparation, i.e., crushing of the rock matrix to pack the core, rather than a chemical reaction with the leach solution.

6.6.4.2 Restoration Phase

Restoration was accomplished by flushing the core with baseline water diluted with distilled water to 80% of baseline conductivity to simulate R.O. product water. Restoration progress is shown on Table 6.6-5 and graphically on Figures 6.6-8 to 6.6-14. Common ions such as HCO_3, Cl and Ca and conductivity became asymptotic and were restored to baseline and/or drinking standards in 3 pore volumes. Bicarbonate continued to decline through pore volume 8. However, this decline had minimal affect on water quality since bicarbonate as an ion is inconsequential.

Uranium remained above the drinking standard for most of the study after becoming asymptotic after 3 pore volumes, as shown in Figure 6.6-14. These uranium values can be attributed to the fact that the uranium in the core material was not depleted at the onset of restoration, as can be shown on Table 6.6-5, where initial uranium was 32.1 ppm. Under commercial conditions, uranium in these concentrations would be economic, and would continue to be recovered down to the 10 ppm level at which time restoration would begin. Uranium restoration has not been a problem in the solution mining business because the same geochemical environment that was present which caused deposition of the orebody is reinstated after oxygen is shut off in the wellfield and residual uranium becomes insoluble.

HRI attempted to artificially create a reduced environment beginning at pore volume 5-1/2 to 20 by adding 10 to 100 ppm of sodium bisulfite to the solution. The results of the addition of sulfite is shown on Figure 6.6-12, where sulfate concentrations increased to 57 ppm indicating continued oxidizing conditions. The addition of sulfate was not sufficient to duplicate the pre-mining reduced environment in the core and uranium values did not respond. Additional core flushing for radium reduction, as will be discussed below did reduce uranium to 2.38 ppm which is below the drinking water level.

Figure 6.6-15 is a complete ground water analysis of the leach solution following restoration. Common ions were reduced to levels consistent to levels found in Table 6.6-5. Silica was elevated to 93 mg/l, however, it has no effect on water quality. With the exception of uranium, iron was the only parameter above drinking water standards. HRI found the iron value suspect since it was never present during the leaching stage. The sample was re-tested and as expected, the 10 ppm value was a laboratory error, and iron concentrations were actually .04 mg/l. Vanadium was in the 1 ppm range following restoration, however, vanadium in this concentration has no effect on drinking water.

Following the initial phase of restoration, it became apparent that further work would have to be performed to reduce RA-226. The core was flushed with 6.95 pore volumes of native ground water and again sampled. Radium at this point was significantly reduced, as shown on Figure 6.6-19.

Another test HRI conducted was to make the radium insoluble by flushing 4.86 pore volumes of the native ground water with 10 ppm barium chloride and 200 ppm sulfate. Radium analysis during flush is shown on Figure 6.6-16. Following the flushing, the core was allowed to sit so the barium chloride sulfate could reside in the core and react. The sample analysis following co-precipitation is shown as Figure 6.6-17, where radium was reduced to levels constant with baseline. Note the reduction in sulfate values, presumably as a result of the $RaSO_4$ co-precipitation. Under commercial conditions, if warranted, BaCL and Sulfate could be introduced at the beginning of restoration to reduce radium concentration early in the process. As previously discussed, we do not anticipate radium levels in the commercial wellfield to be of these levels, because the formation will not be physically disturbed.

6.6.4.3 Conclusions

The "slow" core leach and restoration study demonstrated that the ore at the Churchrock project was amenable to in-situ leaching, and that restoration was achievable to return the ground water to previous use conditions. Comparisons of water quality on a parameter-by-parameter basis before, during and after the test, are shown on Figure 6.6-18 through 6.6-29. Uranium remained slightly above drinking water initially because it was never depleted in the core as will be accomplished during commercial mining. In the end, uranium was reduced to below drinking water standards. Iron was above drinking water standards in one sample analysis; however, this turned out to be laboratory error. RA-226 was shown to be elevated, however, responded favorable to barium chloride/sulfate treatment, and was reduced to Churchrock baseline levels. The ore zone will not be subjected to the crushing and grinding that the core was, and therefore, the radium will not be released from the rock matrix, and not present in the commercial leach solution to the extent it was during the core leach.

6.6.5 Batch Test Results

Batch tests were conducted on core material from CR-3, CR-4, CR-5, and CR-6 to demonstrate if any of the leach solutions were of similar character throughout the orebody (making restoration properties similar). The batch test of CR-3 was to determine the similarities of batch leach solution, and column leach solution.

For each test, two hundred grams of core material were placed in 3,000 m/l of leach solution consisting of 800 mg/l $NaCO_3$ and 1,200 mg/l. The mixture was then agitated for four days, the solution decanted and analyzed. The results of these analyses are within Figures 6.6-30 through 6.6-33.

The four batch tests resulted in leacheate chemistry which was similar to the fast column leach. The major ions which were elevated were sodium and bicarbonate. Sulfate remained unchanged. TDS was elevated. None of the ions or TDS were elevated above New Mexico Drinking Water Standards.

Trace metal concentrations were similar to the column leach. Arsenic and Barium were elevated slightly, but were well below New Mexico Drinking Water Standards. Uranium increased in response to contact with the leach solution, but had no affect on the usefulness of the water. Radium increased to similar levels found in the core.

The batch tests demonstrate that similar leaching characteristics should be expected in various areas within the Section 8 orebody. Given the fact that there are no noticeable changes in geology or geochemistry, the restoration of leach solution should respond similarly simply because the same parameters will have to be restored.

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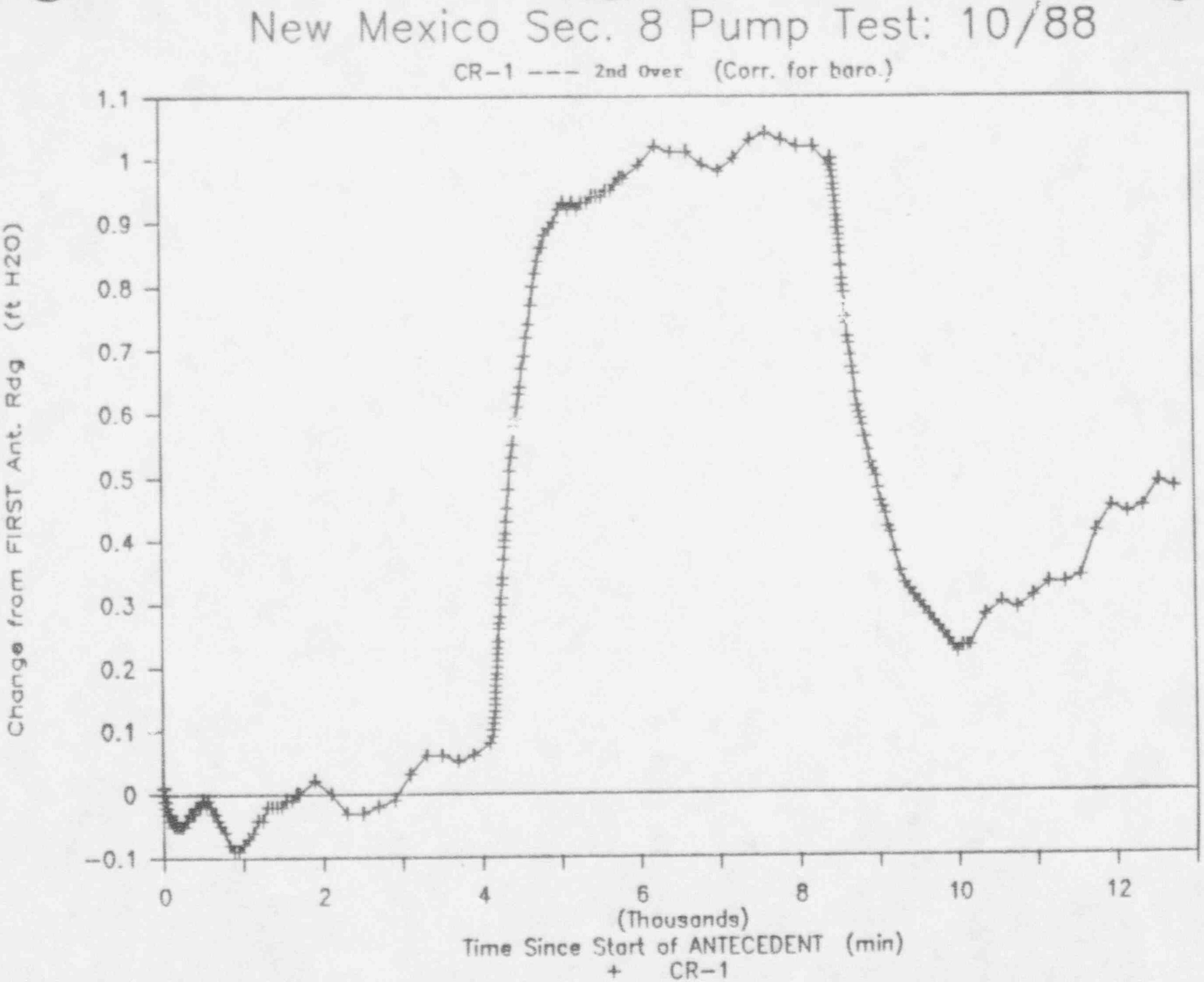
APPENDIX E

REPLACEMENTS

FIGURE B.1A

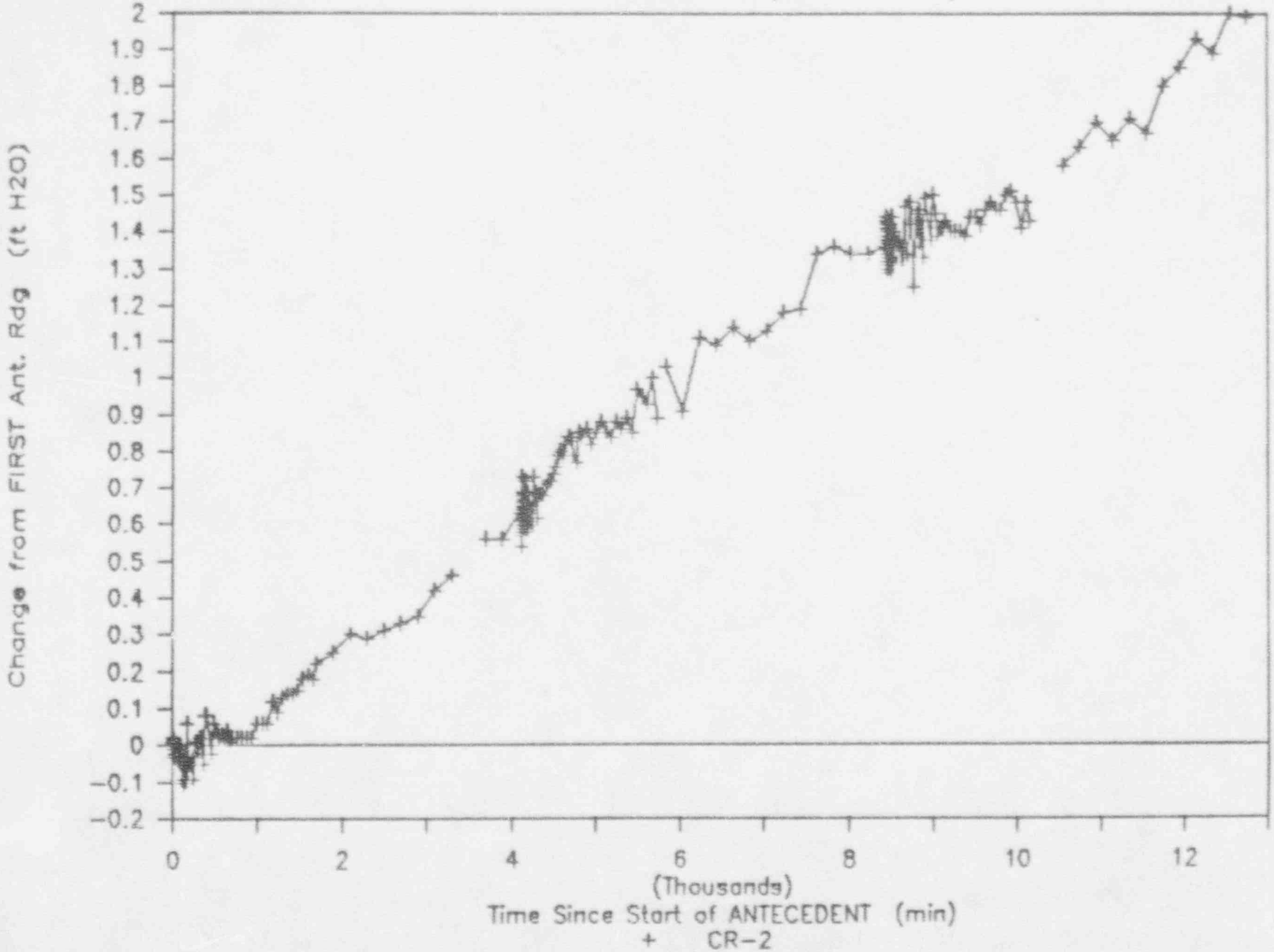


New Mexico Sec. 8 Pump Test: 10/88
CR-1 --- 2nd Over (Corr. for baro.)
Change from FIRST Ant. Rdg (ft H2O)
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
0
2
4
6
8
10
12
(Thousands)
Time Since Start of ANTECEDENT (min)
+ CR-1

FIG[illegible] B.2A

New Mexico Sec. 8 Pump Test: 10/88

CR-2 --- 1st Over (Corr. for baro.)



APPENDIX G

EXPLORATION BORE HOLE LISTING

CHURCHROCK
SECTIONS 8 & 17
ARTIFICIAL PENETRATIONS

Hole Number	Date Drilled	Depth Logged	
Sect 8			
8-CR-1	9-30-87	652	Yes
8-CR-2	10-8-87	681	Yes
8-CR-3	11-6-87	914	Yes
8-CR-4	11-22-87	932	Yes
8-CR-5	12-3-87	910	Yes
8-CR-6	12-1-87	797	Yes
8-CR-7	8-11-88	770	Yes
8-3	6-22-57	1100	Yes
8-4	6-24-57	1101	Yes
8-5	6-22-57	998	Yes
8-6	8-8-58	965	Yes
8-7	6-20-57	915	Yes
8-8	9-20-57	931	Yes
8-9	6-27-58	900	Yes
8-13A	10-6-57	1521	Yes
8-14	9-23-57	1120	Yes
8-15	7-18-57	975	Yes
8-16	6-27-57	1001	Yes
8-16A	2-24-58	950	Yes
8-17	7-9-58	920	Yes
8-18	6-25-57	814	Yes
8-21	10-15-57	1527	Yes
8-24	9-12-57	1545	Yes
8-26	6-27-57	978	Yes
8-27	6-24-57	895	Yes
8-37	7-12-58	1013	Yes
SP 8-1	4-23-62	818	Yes
SP 8-2	4-24-62	820	Yes
SP 8-3	4-25-62	860	Yes
SP 8-4	4-26-62	882	Yes
SP 8-5	7-29-64	1002	Yes
SP 8-6	6-25-65	985	Yes
SP 8-6C	8-9-77	1050	Yes
SP 8-7	11-30-65	1000	Yes
8-1-24	8-16-89	799	Yes
8-1-31	11-3-77	846	Yes
8-1-33	9-13-77	911	Yes
8-1-37	9-13-77	910	Yes
8-1-38	4-28-58	834	Yes
8-1-40	4-27-58	824	Yes
8-1-42	4-24-58	830	Yes
8-2-34	7-1-58	830	Yes
8-2-37	9-10-77	911	Yes
8-2-38	6-26-58	837	Yes
8-2-40	6-27-58	837	Yes
8-2-42	6-27-58	840	Yes
8-2.8/17.7	8-26-76	1130	Yes
8-2.8/32.5	10-31-58	863	Yes
8-2.8/40.9	11-13-58	810	Yes
8-3-39	6-30-67	1035	Yes
8-4-32	7-1-58	900	Yes
8-4-34	6-30-58	882	Yes
8-4-36	6-29-58	864	Yes
8-4-38	6-29-58	866	Yes
8-4-40	6-28-58	836	Yes
8-4-41	8-30 77	949	Yes

CHURCHROCK
SECTIONS 8 & 17
ARTIFICIAL PENETRATIONS

Hole Number	Date Drilled	Depth	Logged
8-4-42	6-27-58	854	Yes
8-4-51	2-8-78	916	Yes
8-5-41	8-31-77	951	Yes
8-6/30.5	11-2-77	876	Yes
8-6-32	7-10-58	900	Yes
8-6-34	7-2-58	940	Yes
8-6-36	11-20-57	875	Yes
8-6-38	6-30-58	862	Yes
8-6-40	12-3-57	836	Yes
8-6-42	12-14-57	866	Yes
8-7.4/18.9	8-27-76	1112	Yes
8-8-32	7-11-58	845	Yes
8-8-34	7-10-58	1045	Yes
8-8-35	9-9-77	950	Yes
8-8-36	7-9-58	940	Yes
8-8-38	11-18-57	889	Yes
8-8-40	12-12-57	878	Yes
8-8-47	2-1-78	982	Yes
8-8.2/32.9	11-26-58	977	Yes
8-8.2/41.3	12-15-58	858	Yes
8-10-34	7-15-58	1025	Yes
8-10-36	7-12-58	930	Yes
8-10-38	7-11-58	940	Yes
8-10-40	11-22-57	910	Yes
8-11-38	9-8-77	946	Yes
8-12-34	11-29-57	1008	Yes
8-12-36	7-11-58	1000	Yes
8-12-37	2-3-60	897	Yes
8-12-38	9-30-57	952	Yes
8-12-39	9-7-77	931	Yes
8-12-40	7-9-58	950	Yes
8-12-42	2-14-78	975	Yes
8-12/45.5	9-22-77	954	Yes
8-13-32	8-24-58	934	Yes
8-13-34	7-13-58	875	Yes
8-13-35	10-1-57	1013	Yes
8-13-36	6-13-60	850	Yes
8-13-37	2-11-58	966	Yes
8-13-38	6-9-60	908	Yes
8-14-36	7-14-58	1030	Yes
8-14-38	7-13-58	970	Yes
8-14-40	7-7-58	980	Yes
8-14-41	9-14-77	891	Yes
8-14-44	9-14-77	940	Yes
8-14.2/36	1-20-59	975	Yes
8-14.2/39.6	1-10-59	914	Yes
8-14.2/39.6C	8-16-77	949	Yes
8-14.5/43	[illegible]-3-78	1006	Yes
8-15-34	2-7-58	1118	Yes
8-15/35.5	8-28-59	980	Yes
8-15-36	7-29-58	1030	Yes
8-15-37	7-21-58	1017	Yes
8-15-38	5-18-60	860	Yes
8-15.8/21.1	10-21-76	1510	Yes
8-16-38	7-16-58	1000	Yes
8-16/39.5	5-12-60	830	Yes
8-16-40	7-15-58	984	Yes
8-16-41	6-3-60	835	Yes
8-16-42	11-26-57	956	Yes

CHURCHROCK
SECTIONS 8 & 17
ARTIFICIAL PENETRATIONS

Hole Number	Date Drilled	Depth	Logged
8-16-45	2-2-78	1029	Yes
8-16.5/37.5	8-13-59	955	Yes
8-16.5/40	6-1-60	845	Yes
8-16.5/43	6-7-60	830	Yes
8-17-36	8-26-59	984	Yes
8-17-39	2-5-58	938	Yes
8-17-41	9-30-59	853	Yes
8-17-42	9-25-59	840	Yes
8-18-36	12-5-57	1040	Yes
8-18-38	8-5-58	980	Yes
8-18/39.5	5-23-60	860	Yes
8-18-40	8-4-58	987	Yes
8-18-43	9-22-59	838	Yes
8-18-44	7-21-58	950	Yes
8-18.5/36.5	8-20-59	980	Yes
8-18.5/41	5-26-60	850	Yes
8-19/37.5	8-18-59	970	Yes
8-19/38.5	9-1-59	965	Yes
8-19-40	8-6-58	980	Yes
8-19/40A	1-25-58	939	Yes
8-19-42	5-27-60	850	Yes
8-19-43	9-1-77	1031	Yes
8-19.1/15.2	9-3-76	1467	Yes
8-19.5/41	6-30-60	870	Yes
8-20/34.5	2-16-78	979	Yes
8-20/36.5	9-15-77	1030	Yes
8-20-38	10-23-57	1014	Yes
8-20/39.5	9-4-59	970	Yes
8-20-40	8-9-58	1065	Yes
8-20/41.5	4-4-60	860	Yes
8-20-44	11-19-57	991	Yes
8-20-48	2-9-78	1020	Yes
8-20.2/43.6	3-6-59	948	Yes
8-20.2/39	4-23-59	979	Yes
8-20.5/13.5	11-13-77	1585	Yes
8-21/39.5	3-23-60	930	Yes
8-21-40	4-12-60	910	Yes
8-21/41.5	3-31-60	867	Yes
8-21.5/38.5	9-21-77	910	Yes
8-22-36	2-14-78	1077	Yes
8-22-38	12-18-57	1026	Yes
8-22/39.5	3-3-60	940	Yes
8-22-40	10-25-57	1102	Yes
8-22/40A	1-3-58	1082	Yes
8-22/41.5	2-23-60	913	Yes
8-22-42	10-20-57	1050	Yes
8-22/44.5	9-16-77	1051	Yes
8-22/45.5	8-13-69	1021	Yes
8-22/47.5	2-10-78	1027	Yes
8-22.5/41	6-28-60	930	Yes
8-23/40.5	2-12-60	935	Yes
8-23-43	9-17-77	1030	Yes
8-24-38	7-10-68	1128	Yes
8-24-40	12-21-57	1049	Yes
8-24-42	8-11-58	981	Yes
8-24-44	11-5-77	1070	Yes
8-24-48	2-11-78	1034	Yes
8-25-13	11-15-77	1674	Yes
8-25/15.2	9-15-76	1630	Yes

CHURCHROCK
SECTIONS 8 & 17
ARTIFICIAL PENETRATIONS

Hole Number	Date Drilled	Depth Logged	
8-25/37.5	7-11-68	1067	Yes
8-26-42	8-11-58	1094	Yes
8-26-2/40.9	2-5-59	1049	Yes
8-27/15.2	11-17-77	1673	Yes
8-27/37.5	8-12-69	1123	Yes
8-27/42.5	9-18-77	1031	Yes
8-27/44.5	9-20-77	1050	Yes
8-27.5/21	11-21-77	1675	Yes
8-27.5/27.5	11-25-77	1604	Yes
8-29.8/44.5	8-9-81	1090	Yes
8-30-44	7-30-88	1100	Yes
8-30.2/48.6	7-11-80	1100	Yes
8-31.5/29.5	12-1-77	1612	Yes
8-31.7/17.9	9-12-76	1568	Yes
8-31.8/43.8	8-30-76	1180	Yes
8-31.9/31.4	10-19-76	1558	Yes
8-33.5/40	7-29-90	1198	Yes
8-33.7/17.9	12-5-77	1632	Yes
8-35.9/46.6	8-22-76	1121	Yes
8 [illegible]7.3/26.8	10-8-76	1529	Yes
8-[illegible]8/4[illegible].5	9-15-78	1235	Yes
8-38.5/16.5	12-7-77	1871	Yes
8-39.5/46.5	8-21-76	1065	Yes

Section 17

Hole Number	Date Drilled	Depth Logged	
17-1	5-25-57	915	Yes
17-2	5-25-57	882	Yes
17-3	5-27-57	780	Yes
17-4	5-28-57	800	Yes
17-5	5-29-57	820	Yes
17-6	5-24-57	762	Yes
17-7	5-25-57	820	Yes
17-8	5-27-57	760	Yes
17-9	5-29-57	760	Yes
17-10	5-30-57	740	Yes
17-11	5-24-57	700	Yes
17-12	5-26-57	700	Yes
17-13	5-28-57	700	Yes
17-14	5-30-57	640	Yes
17-15	6-3-57	580	Yes
17-16	5-24-57	560	Yes
17-17	5-27-57	620	Yes
17-18	5-28-57	598	Yes
17-19	5-30-57	580	Yes
17-20	6-4-57	520	Yes
17-21	6-4-57	537	Yes
17-22	5-29-57	600	Yes
17-23	5-30-57	520	Yes

CHURCHROCK
SECTIONS 8 & 17
ARTIFICIAL PENETRATIONS

Hole Number	Date Drilled	Depth Logged	
17-24	6-3-57	520	Yes
17-2220	12-15-57	698	Yes
17-2418	12-12-57	698	Yes
17-2420	12-12-57	714	Yes
17-2422	12-17-57	676	Yes
17-2517	11-8-57	763	Yes
17-2551	2-23-69	628	Yes
17-2614	12-14-57	718	Yes
17-2616	11-12-57	740	Yes
17-2618	11-11-57	740	Yes
17-2620	11-15-57	737	Yes
17-2631	11-26-58	633	Yes
17-2633	11-25-58	640	Yes
17-2635	11-19-58	640	Yes
17-2637	11-16-58	641	Yes
17-2639	11-15-58	640	Yes
17-2814	17-7-57	718	Yes
17-2816	12-10-57	718	Yes
17-25-18	12-9-57	720	Yes
17-2820	11-18-57	722	Yes
17-2822	12-5-57	701	Yes
17-2826	11-20-57	678	Yes
17-2828	11-19-57	667	Yes
17-2830	11-30-58	643	Yes
17-2838	11-20-58	637	Yes
17-2930	11-1-77	756	Yes
17-3014	12-19-57	739	Yes
17-3016	12-18-57	738	Yes
17-3018	12-10-57	739	Yes
17-3020	11-29-57	758	Yes
17-3022	12-21-57	736	Yes
17-3024	1-30-78	753	Yes
17-3026	11-20-57	750	Yes
17-3028	11-19-57	803	Yes
17-3035	2-1-78	771	Yes
17-3042	2-16-78	760	Yes
17-3048	2-17-78	760	Yes
17-3051	2-23-69	605	Yes
17-3218	2-7-78	795	Yes
17-3228	11-22-57	740	Yes
17-3229	10-27-77	775	Yes
17-3231	12-2-58	723	Yes
17-3233	10-30-77	776	Yes
17-3235	1-27-78	770	Yes
17-3227	10-27-77	777	Yes
17-3335	1-27-78	778	Yes
17-3339	2-4-78	773	Yes
17-3430	10-28-77	836	Yes
17-3431	8-23-58	750	Yes
17-3432	8-26-58	711	Yes
17-3440	1-25-78	775	Yes
17-3444	6-13-58	696	Yes
17-3448	6-12-58	660	Yes
17-3451	2-28-69	706	Yes
17-34.5/27.5	11-11-77	773	Yes
17-3530	10-28-77	732	Yes
17-3531	8-25-58	717	Yes
17-3532	7-25-58	735	Yes
17-3533	8-13-58	719	Yes

CHURCHROCK
SECTIONS 8 & 17
ARTIFICIAL PENETRATIONS

Hole Number	Date Drilled	Depth Logged	
17-3534	8-12-58	721	Yes
17-3535	11-11-58	737	Yes
17-3550	2-28-69	723	Yes
17-3551	2-24-69	688	Yes
17-3552	3-3-69	709	Yes
17-35.5/33	11-10-58	740	Yes
17-36.5/27.5	10-29-77	775	Yes
17-3632	8-24-58	715	Yes
17-3633	7-27-58	735	Yes
17-36/33.5	7-24-59	700	Yes
17-3634	6-18-58	722	Yes
17-36/35.5	11-13-58	725	Yes
17-3642	1-25-78	766	Yes
17-3644	6-12-58	710	Yes
17-3646	10-30-57	696	Yes
17-3648	6-16-58	761	Yes
17-3651	2-27-69	710	Yes
17-36.5/24	2-5-78	776	Yes
17-36.5/31	11-4-58	740	Yes
17-36.5/32.5	10-31-58	743	Yes
17-3731	11-2-58	736	Yes
17-3732	10.29-58	742	Yes
17-37/32.5	7-16-59	580	Yes
17-3733	6-16-58	737	Yes
17-3434	6-15-58	734	Yes
17-3735	4-30-58	736	Yes
17-3736	6-14-58	724	Yes
17-37/45.5	3-23-69	768	Yes
17-3747	3-22-69	740	Yes
17-37.5/34	7-23-59	600	Yes
17-37.5/35	7-28-59	615	Yes
17-3826	12-6-81	816	Yes
17-37.5/51	2-27-69	752	Yes
17-37.5/51	2-27-69	752	Yes
17-3832	12-18-58	746	Yes
17-3833	12-17-58	738	Yes
17-3834	6-14-58	755	Yes
17-3835	5-3-58	730	Yes
17-3836	5-2-58	715	Yes
17-3837	4-30-58	733	Yes
17-3844-A	3-24-69	750	Yes
17-3844	10-26-57	716	Yes
17-3846	6-12-58	708	Yes
17-3848	6-12-58	712	Yes
17-38.5/33.5	7-27-59	710	Yes
17-38.5/34.5	7-9-59	712	Yes
17-38.5/35.5	7-22-59	710	Yes
17-38.5/35.5-C	8-26-77	809	Yes
17-3932	10-26-77	770	Yes
17-3933	7-6-59	732	Yes
17-3934	6-16-58	744	Yes
17-3935	6-15-58	745	Yes
17-3936	7-23-58	755	Yes
3937	9-3-58	745	Yes
-3939	1-24-78	813	Yes
3945	3-21-69	754	Yes
./-39/45.5	3-23-69	768	Yes
17-3946	1-22-78	756	Yes
17-3947	3-21-69	636	Yes

CHURCHROCK
SECTIONS 8 & 17
ARTIFICIAL PENETRATIONS

Hole Number	Date Drilled	Depth Logged	
17-3948	2-4-78	761	Yes
17-39/51.5	2-26-69	725	Yes
17-40/25.5	12-5-81	819	Yes
17-4026	12-4-81	817	Yes
17-4032	10-26-77	773	Yes
17-4033	1-8-59	733	Yes
17-4034	12-3-58	764	Yes
17-4035	9-16-58	758	Yes
17-40/35.5	7-22-59	600	Yes
17-4036	4-26-58	736	Yes
17-4037	9-4-58	742	Yes
17-4038	4-29-58	734	Yes
17-4043	1-24-78	799	Yes
17-4044	3-26-69	768	Yes
17-4050	2-26-69	736	Yes
17-4051	2-24-69	797	Yes
17-40.4/37.4	4-17-61	630	Yes
17-40.5/34	7-2-59	495	Yes
17-40.5/36.5	4-18-61	670	Yes
17-40.6/35.5	NO LOG		
17-40.9/40	9-19-61	658	Yes
17-4133	2-5-59	738	Yes
17-4134	2-7-59	750	Yes
17-4135	1-3-59	743	Yes
17-4136	9-8-58	800	Yes
17-4137	5-4-58	780	Yes
17-4138	8-3-59	620	Yes
17-4147	4-20-69	760	Yes
17-41/51.5	2-27-69	751	Yes
17-41.5/35.6	NO LOG		
17-41.5/36.5	6-30-59	658	Yes
17-41.7/37.4	4-20-61	640	Yes
17-4234	4-24-58	755	Yes
17-4235	7-1-59	505	Yes
17-4236	10-24-57	779	Yes
17-4237	9-10-58	842	Yes
17-4238	10-25-57	736	Yes
17-4240	10-2-57	741	Yes
17-4242	10-3-57	759	Yes
17-42.5/33	10-30-77	776	Yes
17-42.5/34	5-19-60	500	Yes
17-42.5/35	5-16-60	493	Yes
17-42.5/36	5-11-60	498	Yes
17-42.5/37.5	7-31-59	641	Yes
17-4335	11-26-58	743	Yes
17-4336	11-25-58	742	Yes
17-4337	5-3-58	753	Yes
17-4338	11-14-58	740	Yes
17-4339	11-17-58	745	Yes
17-4340	11-19-58	745	Yes
17-4341	11-20-58	740	Yes
17-43/48.5	9-21-60	735	Yes
17-43.5/36	5-9-60	500	Yes
17-43.8/39.3	9-22-61	670	Yes
17-43.9/37.4	10-20-58	721	Yes
17-4434	10-23-57	753	Yes
17-4435	1-10-59	757	Yes
17-4436	6-2-58	805	Yes
17-4438	6-2-58	796	Yes

CHURCHROCK
SECTIONS 8 & 17
ARTIFICIAL PENETRATIONS

Hole Number	Date Drilled	Depth	Logged
17-4439	11-30-58	739	Yes
17-44/39.5	9-3-60	470	Yes
17-4440	6-1-58	780	Yes
17-4441	12-2-58	740	Yes
17-4442	10-4-57	733	Yes
17-44/48.5	9-23-6+0	460	Yes
17-44.3/34.3	4-21-61	660	Yes
17-44.3/35.7	3-29-61	660	Yes
17-44.5/33.5	10-31-77	796	Yes
17-44.5/36.5	7-29-59	660	Yes
17-44.5/38	6-22-59	638	Yes
17-44.5/40	6-25-59	520	Yes
17-44.5/41.5	8-31-60	470	Yes
17-44.5/42	12-4-58	740	Yes
17-44.5/43	12-31-58	512	Yes
17-44.5/48	9-26-60	454	Yes
17-44.6/37.8	3-25-61	655	Yes
17-44.7/35.1	3.27-61	660	Yes
17-44.9/40	4-27-61	660	Yes
17-4535	4-28-58	776	Yes
17-4536	6-10-59	645	Yes
17-4537-C	3-9-58	735	Yes
17-6539-C	6-2-58	773	Yes
17-4541	6-25-59	510	Yes
17-4542	6-26-59	480	Yes
17-45/42.5	9-2-60	470	Yes
17-4543	12-9-58	730	Yes
17-4544	12-14-58	513	Yes
17-45/44.5	1-23-78	800	Yes
17-4548	9-19-60	745	Yes
17-45.1/36.3	3-31-61	655	Yes
17-45.2/37.9	3-2-61	657	Yes
17-45.2/39.7	3-19-61	660	Yes
17-45.5/37.2	3-4-61	691	Yes
17-45.5/38.5	6-24-59	642	Yes
17-45.5/43	12-11-58	738	Yes
17-45.5/44	12-15-58	501	Yes
0.17-45.5/44.5	9-6-60	475	Yes
17-45.5/46	2-5-78	816	Yes
17-45.5/48	9-27-60	459	Yes
17-45.6/39.3	2-25-61	654	Yes
17-4634	9-23-57	857	Yes
17-4636	6-16-59	650	Yes
17-4636	6-9-59	655	Yes
17-4637	6-19-59	645	Yes
17-4638	9-20-57	858	Yes
17-46/38.3	4-26-61	660	Yes
17-4639	1-12-59	744	Yes
17-46/39.8	3-20-61	658	Yes
17-4640	9-26-57	780	Yes
17-4642	10-7-57	739	Yes
17-46/47.5	9-22-60	453	Yes
17-46.2/37.1	4-24-61	660	Yes
17-46.4/37.6	3-1-61	670	Yes
17-46.4/40.3	4-28-61	660	Yes
17-46.5/36	3-23-61	659	Yes
17-46.5/37	3-6-61	740	Yes
17-46.5/38.4	2-27-61	675	Yes
17-46.5/39.2	2-23-61	662	Yes

CHURCHROCK
SECTIONS 8 & 17
ARTIFICIAL PENETRATIONS

Hole Number	Date Drilled	Depth Logged	
17-46.5/41	8-27-77	810	Yes
17-46.5/46.5	1-22-78	854	Yes
17-46.6/36.6	4-25-61	660	Yes
17-4737	6-11-59	653	Yes
17-47/36.3	3-8-61	657	Yes
17-4737	8-5-59	654	Yes
17-47/37.3	3-9-61	657	Yes
17-4738-C	12-19-57	759	Yes
17-4739	1-14-59	740	Yes
17-4746	9-7-60	475	Yes
17-47/47.5	9-8-60	460	Yes
17-47.3/37.8	3-10-61	658	Yes
17-47.3/38.4	3-14-61	659	Yes
17-47.4/36.6	3-22-61	665	Yes
17-47.5/31.5	8-13-59	780	Yes
17-47.5/36	4-19-80	860	Yes
17-47.5/49	9-8-60	470	Yes
17-47.6/38.8	3-31-61	658	Yes
17-47.7/37.2	5-1-61	665	Yes
17-47.9/36.6	4-22-80	850	Yes
17-47.9/37	3-15-61	665	Yes
17-47.9/37.7	3-1-61	665	Yes
17-4834	9-24-57	835	Yes
17-48/35.5	1-29-60	832	Yes
17-4836	9-20-57	811	Yes
17-4837	6-15-59	665	Yes
17-4838	10-9-57	759	Yes
17-4839	9-20-59	756	Yes
17-4840	10-8-57	740	Yes
17-4841	8-28-77	892	Yes
17-4842	11-14-57	803	Yes
17-4851	9-16-60	720	Yes
17-48.1/38.2	5-4-61	680	Yes
17-48.2/36.1	4-25-80	857	Yes
17-48.2/38.6	3-31-61	665	Yes
17-48.3/39.6	4-29-61	660	Yes
17-48.4/37.8	4-3-61	680	Yes
17-48.5/36	8-6-59	659	Yes
17-48.8/38.5	5-3-61	680	Yes
17-48.9/37.4	4-10-61	680	Yes
17-4938	6-18-59	660	Yes
17-4939-C	3-5-58	759	Yes
17-4940	8-10-59	660	Yes
17-4941	8-30-77	912	Yes
17-49/46.5	9-12-60	750	Yes
17-49.5/38.3	4-11-61	680	Yes
17-49.6/39	4-7-61	670	Yes
17-49.9/38.6	9-17-58	819	Yes
17-5038	10-17-57	839	Yes
17-5040	10-18-57	799	Yes
17-5041	8-28-77	908	Yes
17-5042	11-13-57	781	Yes
17-50.5/39.3	4-5-61	620	Yes
17-50.5/46	9-13-60	760	Yes
17-50.6/37.8	11-4-77	830	Yes
17-50.6/38.1	4-15-61	690	Yes
17-50.6/38.8	4-6-61	680	Yes
17-5128	2-7-78	895	Yes
17-5130	11-10-77	916	Yes

CHURCHROCK
SECTIONS 8 & 17
ARTIFICIAL PENETRATIONS

Hole Number	Date Drilled	Depth	Logged
17-5132	11-9-77	957	Yes
17-5134	1-27-78	900	Yes
17-5139	1-23-59	800	Yes
17-5140	3-13-59	759	Yes
17-51.3/38.6	4-14-61	690	Yes
17-51.6/39.3	4-13-61	693	Yes
17-5238	11-3-57	839	Yes
17-5239	1-25-59	800	Yes
17-5240	10-25-57	800	Yes
17-5241	8-28-77	911	Yes
17-5242	10-26-57	838	Yes
17-52.5/45.5	9-14-60	780	Yes
17-5332	11-2-77	836	Yes
17-5341	8-29-77	930	Yes
Shaft	1958	877 *	Yes
Vent 1	1958	620 *	Yes
Vent 2	1979	877 *	Yes
Gravel Hole	1981	620 *	Yes
Water Well	6-6-80	417	Yes

* (Reported)

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