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August 1991

Canonie Environmental

Volume I - Text

Tailings Reclamation Plan
As Approved by NRC March 1, 1991
License No. SUA - 1475

Church Rock Site
Gallup, New Mexico

Prepared For:

United Nuclear Corporation
Gallup, New Mexico

(Public)

UNITED NUCLEAR CORPORATION

UNC

1700 Louisiana N.E.
Suite 230

Albuquerque, New Mexico 87110
Telephone 505/262-1800
FAX 262-1809

August 30, 1991
UNC/ASHQ-91-484M

Mr. Ramon Hall, Director
U. S. Nuclear Regulatory Commission
Uranium Recovery Field Office
730 Simms St., Suite 100
Golden, CO 80401

RE: NRC License SUA-1475
Submittal of Tailings Reclamation Plan

Dear Mr. Hall:

United Nuclear Corporation hereby submits the enclosed document titled "Tailings Reclamation Plan As Approved by NRC March 1, 1991, License No. SUA-1475". This document represents the single comprehensive document describing the approved composite reclamation plan including specifications and updated cost estimates based on the composite plan, as required in license condition 34. The updated cost estimate was submitted to you on June 6, 1991 and is provided herein as well as an appendix in Volume III.

If you have any questions or require additional information please do not hesitate to call.

Sincerely yours,

Juan R. Velasquez
President

JRV:jkt

cc: Ed Morales

bcc: Paul X. McLain
Ridgway Hall, Crowell & Mooring
R. Bruce Andrews, w/o attachments
Richard Lange, w/o attachments

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LIST OF APPENDICES

EXECUTIVE SUMMARY

United Nuclear Corporation (United Nuclear) operated the Church Rock uranium mill facility located in northwestern New Mexico from 1977 to mid-1982. United Nuclear is submitting this reclamation plan for the Church Rock facility, as approved by the Nuclear Regulatory Commission (NRC) March 1, 1991, that protects health and the environment consistent with the criteria set forth in the NRC regulations in Appendix A of 10 CFR 40.

Canonie Environmental Services Corp. (Canonie) was engaged by United Nuclear to develop the Church Rock reclamation plan. Canonie conducted extensive field investigations and reviewed and utilized the substantial existing data base generated by United Nuclear, the Environmental Protection Agency (EPA), and others, to develop a comprehensive and accurate depiction of site conditions. The proposed reclamation plan was originally submitted in June 1987.

The plan was approved in March 1991 with several significant technical changes from the original plan submitted. Since United Nuclear submitted the proposed Reclamation Plan on June 1, 1987, the Reclamation Plan has undergone review with subsequent revisions over a period of nearly four years. In the meantime, United Nuclear has implemented several components of the plan in accordance with the proposed plan as directed by the NRC. Specifically, United Nuclear has implemented the following actions:

1. Interim stabilization of tailings, control of blowing tailings, and cleanup of wind-blown tailings in accordance with License Conditions 16 and 33,

2. Decommissioning of the mill in accordance with License Conditions 26 and 33,

3. Collection of tailings seepage in accordance with License Condition 30, and

4. Construction of an enhanced evaporation system in accordance with License Condition 32.

This document presents the Reclamation Plan, as approved by NRC, for United Nuclear's Church Rock uranium mill and tailings disposal facility near Gallup, New Mexico as required under License Condition 34 of License No. SUA-1475. The original plan has been amended on several occasions in various documents submitted to the NRC. The surface reclamation component of the plan was approved in March 1991. The seepage component of the plan, also included, was approved before March 1, 1991 by the NRC as the Corrective Action Program (CAP) and by the EPA as the Remedial Design.

In accordance with License Condition 34, this plan represents a single, comprehensive document that describes the approved composite Reclamation Plan, including specifications and updated cost estimates based on the composite plan. This plan describes the existing site conditions and identifies in detail the appropriate mitigation measures being taken to reclaim the Church Rock site. Following is a summary of the Reclamation Plan which includes:

Section 1.0 Site Description
Section 2.0 Radiological Survey
Section 3.0 Geotechnical Investigation
Section 4.0 Interim Stabilization Plan
Section 5.0 Final Reclamation Plan
Section 6.0 Corrective Action Program
Section 7.0 Mill Decommissioning Plan

Site Description

United Nuclear's Church Rock mill processed ore from its Northeast Church Rock (NECR) and Old Church Rock (OCR) mines, as well as some ore produced from Quivira Mining Company's (Quivira) Church Rock mine. The mill was operated from 1977 to mid-1982. Tailings disposal also occurred from 1977 to late-1982, the latter disposal associated with cleaning of the mill circuits upon mill closure.

The Church Rock mill is located approximately 17 miles northeast of Gallup, New Mexico in McKinley County, approximately one mile south of the Navajo Indian Reservation, in Section 2, Township 16 North, Range 16 West. United Nuclear owns the surface of Section 2 and Section 36 immediately to the north.

The entire region is sparsely populated. The city of Gallup, 17 miles southwest of the site, is the largest population center in the county. The nearest residence to the site is located approximately one mile northwest of the site. The nearest point of ground water use is located 1.7 miles northeast of the perimeter of the site.

The mill facility and associated tailings disposal area cover approximately 125 acres. The site is situated in an alluvial valley known as Pipeline Arroyo Canyon. Pipeline Arroyo is an ephemeral channel that traverses the site to a point southwest where it joins the Rio Puerco, a larger ephemeral drainage.

The site is located in an arid region typical of the southwestern United States, where evaporation significantly exceeds precipitation. The annual average rainfall in this area is approximately 12 to 14 inches per year. The average net-pan evaporation rate is approximately 60 inches per year.

Geological Setting - The tailings disposal site is located in the Pipeline Canyon, an alluvial valley drained by the Pipeline Arroyo. The site is situated on alluvial valley fill and sandstones and shales of Cretaceous age. The stratigraphic units identified in the site area, in descending order, include:

1. Alluvium (sand, silts, clays and gravels)

2. Dilco Coal Member of the Crevasse Canyon Formation (Dilco)

3. Upper Gallup Sandstone, divided into:

    - Zone 3, upper sandstone
    - Zone 2, shale and coal
    - Zone 1, lower sandstone

4. Upper D-Cross Tongue Member of the Mancos Shale (Mancos)

The alluvium and, to a limited extent, Zone 3 and Zone 1 of the Gallup Sandstone are in direct contact with the tailings and show evidence of limited tailings seepage. The Dilco, Zone 2 of the Gallup Sandstone, and the Mancos are not affected by tailings seepage because the permeability of these units is too low to allow seepage to migrate into or through their layers. These units are considered to be aquitards in this vicinity.

Structural features within the site were identified on cross sections developed from geophysical and lithological logs of wells drilled on site. Preparation of the cross sections identified several areas of flexure with associated fracturing and/or faulting in Zone 3 and Zone 1 of the Upper Gallup Sandstone. The fracturing was evident in three areas along the east and north sides of the borrow pits and two areas north and east of North Cell. Fracture zones influence the direction of flow because they generally have higher permeability than the surrounding rock matrix. However, the data indicate that these fractures do not affect the rate of flow.

Hydrological Setting - Site hydrogeologic conditions were determined from the significant volume of data and reports compiled for this site since the time the original Environmental Report, which accompanied the license application for the site, was prepared. The majority of the geohydrologic data has been synthesized in the Geohydrologic Report (GHR) prepared by Canonie in 1987 (Canonie, 1987a). Since that time, additional monitoring data have been gathered and Canonie has continued to update its understanding of the geohydrologic conditions at the site. This plan cites the pertinent data sources used where appropriate.

Prior to mining and milling activities, no contiguous ground water system was known to exist in the near-surface geologic units, including alluvium and Zone 3 and Zone 1 of the Gallup Sandstone, in the general area of the tailings disposal (Canonie, 1987a). Water was first introduced to formations underlying the site by the discharge of mine water into Pipeline Arroyo, and later by seepage of tailings liquids from the tailings impoundment and Borrow Pit No. 2.

Mine water was discharged to Pipeline Arroyo for a period of approximately 17 years. The mine water partially saturated the alluvium and Zone 3 and Zone 1, creating a temporary artificial ground water system. Since discharge of the mine water ceased, the artificial system has been dissipating and returning to the natural unsaturated conditions. Declines in water levels and flow rates since cessation of mine water discharge are evidence of the dissipation of the artificial system (Canonie, 1987a).

Hydrogeochemistry - The geochemistry of the of the water present in the formations of concern has been evaluated and the results were presented in several previous reports including the "Geochemical Background Investigation" by Billings (1986) and the "Evolution of Ground Water Chemistry" by Canonie (1988a). These studies indicate that the geochemistry of the artificial system evolved as the mine water migrated first through the alluvium and then into the underlying Zone 3 and Zone 1. As the mine water percolated through the alluvium, it reacted with the soil materials, dissolved various soluble constituents, and evolved into the water chemistry present today in areas outside the influence of tailings seepage. As the water migrated into the Upper Gallup Sandstone, the chemistry did not change because these strata are essentially chemically inert.

Seepage from tailings has altered the chemistry of the artificial system created by mine water discharge. Seepage effects on the artificial system have varied depending on whether seepage migrated through the alluvium, which has favorable geochemical properties, or through the geochemically inert Upper Gallup Sandstone, i.e., Zone 3 or Zone 1, without passing through the alluvium. Analyses of samples from the alluvium identified the presence of calcium carbonate, iron hydroxide, natural organic carbon, and clay material with significant cation-exchange capacity (Canonie; 1987a, 1988). These properties give the alluvium the ability to neutralize acidic seepage and to precipitate or reduce concentrations of metals and radionuclides in the seepage.

Conversely, Zone 3 and Zone 1 lack the favorable geochemical properties necessary to neutralize the acidic seepage. Therefore, the primary mechanism for neutralizing the seepage in Zone 3 and Zone 1 is its dilution by the mine discharge water which saturated Zone 3 and Zone 1 prior to deposition of tailings. Seepage migrating directly into the Gallup Sandstone created a plume evident in Zone 3 north and east of the North Cell where tailings were placed directly on Zone 3 outcrops. The plume is also evident in Zone 1 east of Borrow Pit No. 2 which was excavated into Zone 1 sub-crop.

Radiological Survey

A survey of the site was conducted to assess the radiological characteristics of the site. Background values were established by surveying areas unaffected by facility operations to determine action levels for possible remediation. In accordance with the guidelines of Appendix A of 10 CFR 40, remediation of soil is required in areas where the Ra-226 activity concentrations due to by-product (i.e., tailings material) are observed to be greater than specified levels above background Ra-226 concentrations.

Several areas were identified as requiring remedial action resulting from the deposition, transport or release of such materials. Specifically identified areas included:

1. The mill site,

2. Limited wind-blown tailings areas to the northeast of the tailings disposal area,

3. Catch basins and drainage areas, and

4. Several areas of tailings deposition adjacent to the tailings disposal area.

Geotechnical Investigation

A geotechnical investigation was conducted to provide the data needed to develop the specifications for the planned remedial actions, including regrading and tailings disposal area soil cover design, borrow and riprap source delineation, and geomorphologic considerations related to the Pipeline Arroyo and control of the Probable Maximum Flood (PMF). A number of borings were drilled and test pits excavated to provide data for the reclamation design. Laboratory testing performed in developing the plan included testing of soil to determine physical properties used in the cover design. The geotechnical investigation indicated that sufficient borrow material exists on-site to provide adequate cover for the tailings disposal area to provide long-term protection from radon emissions and to ensure the protection of the tailings facility for the 1,000-year design period to the extent reasonably achievable.

Investigations were also conducted to identify potential sources of suitable riprap material for erosion protection. Local sources of riprap of adequate quality are available within reasonable transport distances from the site. Sources of riprap with even greater quality are available at a much greater distance from the site.

Interim Stabilization Plan

United Nuclear has implemented the interim stabilization portion of the plan designed to minimize the potential for release of contaminants to the environment. The interim stabilization plan focuses on the elimination of significant pathways for potential release, such as the seepage routes and the air route via wind-blown tailings and radon emanation. Interim stabilization was initiated in 1989 in accordance with NRC directives. The interim reclamation concept has provided an opportunity for monitoring the success of the program and allows for necessary adjustments prior to initiation of final reclamation. Indeed, using data gathered during implementation of interim stabilization in the North and Central Cells of the tailings disposal area, the radon attenuation soil cover layer design was reduced from 3.6 feet, originally proposed in 1987, to the 1.5 feet, approved in March 1991.

Interim stabilization minimizes infiltration from precipitation by regrading and recontouring the tailings disposal area. Conduits of potential seepage migration have been eliminated by plugging selected wells. Interim stabilization consists of placing an interim soil cover and revegetation in some areas to eliminate wind-blown tailings, to reduce infiltration of precipitation, and to reduce radon flux from the tailings. This interim cover makes up the first 1.0 foot of the 1.5 feet of radon attenuation soil cover called for in final reclamation. The following actions have been accomplished during the first three years of implementation of interim stabilization:

1. Disposed of the neutralized water stored in Borrow Pit No. 2 by using it on tailings to assist in control of wind-blown tailings. During interim stabilization, United Nuclear dewatered Borrow Pit No. 2.

2. Regraded and recontoured the tailings materials to provide drainages to allow the North and Central Cells of the tailings disposal area to shed precipitation, reduce recharge, and eliminate ponding. Recontouring was designed to place coarse tailings over fine tailings to reduce radon flux from the tailings disposal area.

3. Collected wind-blown tailings north and east of the tailings disposal area, on Section 36, Township 17N, Range 16W, and Section 1, Township 16N, Range 16W property immediately adjacent to the tailings disposal area and placed the affected soils in the tailings disposal area.

4. Placed the 1.0-foot interim soil cover over the North and Central Cells of the tailings disposal area to stabilize the site during the interim period and reduce erosion and further minimize radon releases. The South Cell will be regraded and covered in 1991.

5. Plugged selected wells.

6. Initiated the CAP approved by the NRC and the RD approved by the EPA, which included the installation of extraction wells and construction of

evaporation ponds and an enhanced evaporation system to dispose of collected seepage.

7. Initiated mill decommissioning.

Final Reclamation Plan

United Nuclear plans to conduct final reclamation activities commencing at the satisfactory completion of the seepage collection program. The primary tasks to be accomplished in final reclamation include:

1. Completing backfilling and grading Borrow Pit No. 2,

2. Regrading and covering the evaporation ponds,

3. Placing the final radon attenuation soil cover and the soil/rock matrix erosion protection cover,

4. Constructing surface water control channels, diversion ditches, drainage swales, Pipeline Arroyo low flow channel, and the buried jetty, and

5. Revegetating disturbed areas and securing reclaimed areas.

The final reclamation actions will be implemented in compliance with Appendix A of 10 CFR 40. The plan meets the objectives of Appendix A of 10 CFR 40, to the extent practicable by minimizing final slopes, containing and controlling major flood events, minimizing radon emanation from the tailings disposal area, and maximizing the long-term stability of the reclaimed site.

The final tailings area radon attenuation soil cover has been designed to provide reasonable assurance that control of radiological hazards will be effective for 1,000 years and that releases of Rn-222 to the atmosphere will not exceed an average release rate of 20 picoCuries per square meter per second, to the extent practicable, throughout the design life of the cover. Soil used for the final cover that meets the gradation requirements specified in the design model, will be obtained from borrow areas adjacent to the tailings disposal area. A radon attenuation soil cover having a total thickness of 1.5 feet (1.0 foot during interim stabilization, 0.5 foot during final reclamation) will be placed over the tailings to provide the required reduction in release rates specified by NRC.

Final reclamation activities will include various actions to protect the tailings disposal area from the effects of storm and flood events. The Probable Maximum Precipitation (PMP) and the Probable Maximum Flood (PMF) were selected as the precipitation and flood events used for hydraulic designs to control surface water in the reclamation plan.

Following placement of the radon attenuation soil cover, a soil/rock matrix layer will be placed over the tailings cover to protect it from water and wind erosion. Rock riprap will also be placed in certain critical areas, such as in diversion ditches, drainage swales, and in construction of the buried jetty. The soil/rock matrix layer, the rock mulch, and rock riprap have been designed to protect the tailings disposal area and drainage channels from damage from the PMF and lesser storm events. Runoff control and diversion ditches at the tailings disposal area will be constructed and modified to ensure long-term protection of the tailings disposal area from the PMF and lesser storm events.

The Pipeline Arroyo, the principal surface water drainage on the property, will be modified to ensure that the PMF will pass without damage to the tailings disposal area. The low-flow channel in the modified arroyo will also protect against the long-term geomorphic changes resulting from storms having less intensity than the design events.

Areas outside the tailings disposal area disturbed by grading activities will be revegetated with natural species. Existing fencing will be used to control access into the majority of the reclaimed areas. Additional fencing will be installed around the area to be deeded to the U.S. Department of Energy prior to transfer of the property.

Corrective Action Program

United Nuclear was required to implement active seepage remediation at the Church Rock site because constituent concentrations in the ground water exceeded:

1. Ground water protection standards established by the NRC and documented in Condition 30 of United Nuclear's Source Materials License, and

2. Applicable or Relevant and Appropriate Requirements (ARARs) established by the EPA and documented in the Record of Decision (ROD) dated September 30, 1988.

This seepage remediation program, referred to here as the CAP, evolved over 2 years from 1987 through 1989, and was based on requirements established by the NRC and later, the EPA. The NRC's involvement with the site began in 1986 when licensing authority was transferred from the State of New Mexico to the NRC. The EPA initially became involved when the site was placed on the National Priorities List in 1981 and later took a more active role when it conducted a remedial investigation/feasibility study of the site and published its ROD pursuant to Comprehensive Environmental Response, Compensation and Liability Act.

NRC and EPA signed a Memorandum of Understanding (MOU) to delineate the responsibilities of the two agencies for administering the remedial action at the site. The

MOU was signed in August, 1988 and established the agencies responsibilities as follows:

1. NRC - source control and on-site surface reclamation pursuant to the License,

2. EPA - off-site ground water remediation pursuant to the ROD, and

3. NRC and EPA - integration of ground water remediation pursuant to the NRC License and EPA's ROD.

The CAP for collection of tailings seepage was developed in response to the NRC license condition No. 30 of Amendment No. 4 to the Source Material License SUA-1475 issued on January 3, 1989, and the EPA ROD for the United Nuclear Church Rock site issued September 30, 1988 (EPA, 1988a). The CAP presents the technical basis for the detailed design of the tailings seepage active remedial action to be taken.

The CAP was presented to the NRC and EPA in April 1989 in the document entitled "Remedial Design Report" (RD) prepared by Canonie (1989). The program was initiated in May 1989 and has been operating for almost two years. This plan incorporates the RD describing the CAP, because it has been implemented with changes implemented as a result of annual performance evaluations and agency comments.

Corrective Action Description and Design - Seepage corrective action at the Church Rock site consists of extraction of tailings seepage from Zone 3, Zone 1, and the Southwest Alluvium and dewatering of Borrow Pit No. 2 to remove the source of tailings seepage to Zone 1. The collected tailings seepage is disposed of by evaporation.

1. Zone 3 - Remedial action in Zone 3 consists of pumping 23 extraction wells to create a hydraulic barrier against further migration of the plume and to

dewater the target area and Point of Compliance (POC). The extractable volume of the target area in Zone 3 is estimated to be 200 million gallons or less, based on a target area of 100 acres, an observed average saturated thickness of 60 feet, and an extractable porosity of 10 percent. However, monitoring of hydrogeologic conditions during remediation will determine the duration and magnitude of pumping actually required.

2. Zone 1 - The remedial action for Zone 1 consists of dewatering Borrow Pit No. 2 and continued pumping from several extraction wells. Originally, the extraction wells were to be decommissioned after dewatering the borrow pit was complete because additional pumping in Zone 1 was considered impracticable and unnecessary due to the low permeability of the formation within the target area. However, due to NRC and EPA requirements, the Zone 1 extraction wells are still in operation.

3. Southwest Alluvium - Remedial action for the Southwest Alluvium consists of pumping four wells for the purpose of creating a barrier against further seepage migration and extracting seepage from the Southwest Alluvium. The system is located downgrade of the southern edge of the South Cell of the tailings impoundment and upgrade of the POC wells identified by the NRC in the Southwest Alluvium.

4. Disposal of Extracted Tailings Seepage - Seepage collected by the extraction wells is disposed of by evaporation. The evaporation disposal system consists of two, five-acre, lined evaporation ponds equipped with an enhanced evaporation mist system and a separate mist or spray evaporation system installed on the surface of the tailings. The evaporation disposal system is installed and is operating entirely within the tailings disposal area.

Performance Criteria - Ideally, the objective of the remedial action is to clean up the target areas and POCs to the ground water protection standards established by the NRC in the License and the ARARs designated by the EPA. However, the following factors will influence the degree to which the remedial action is successful in meeting these standards:

1. Background values established by the NRC and the EPA may not reflect site conditions because adequate consideration may not have been given to the fact that "background" (i.e., pre-tailings water quality) resulted primarily from the evolution of the mine water chemistry as it percolated through previously dry sediments. Therefore, in many instances, background levels exceed the water quality standards established by the NRC and the EPA.

2. With time, dewatering may preclude operation of individual wells.

3. Performance monitoring may demonstrate that it is technically impractical to meet the regulatory standards, despite a reasonable expenditure of time and efforts. For example, it is possible that portions of the system may always be capable of sustaining limited pumping without realizing cleanup benefits.

Water Quality Standards - The NRC ground water protection standards established for this site are either Maximum Contaminant Levels designated in Table 5C of title 10 Code of Federal Regulations (CFR) 40 Appendix A, or background values, whichever are greater.

The EPA determined the contaminant-specific ARARs for the site by reviewing pertinent federal, state, and health based standards and background levels for the constituents of concern. The background levels established for constituents by the EPA were set as the ARARs if such levels were deemed by the EPA to be at higher concentrations than federal, or state, or health-based standards for that constituent. The federal, state, or health-based standard was set as the ARAR when the EPA determined that background was below the standard for the constituent.

Ideally, the objective is to clean up to those levels. However, achievement of the NRC's ground water protection standards and the EPA's ARARs may not be attainable due to the unrealistically low background levels which were established. In recognition of this problem, the NRC states in Appendix A of 10 CFR 40 that it may be necessary to set Alternate Concentration Limits (ACLs) for the NRC ground water protection standards identified at this site.

Similarly, the EPA stated in its ROD that should additional information become available that would significantly alter estimation of background levels, such information would be evaluated in terms of its impact on remedial action in each formation of concern. The EPA has further determined in its ROD that operational results may demonstrate that it is technically impractical to achieve all cleanup levels (ARARs). Consequently, waivers to meet certain contaminant-specific ARARs may require reevaluation (EPA, 1988a).

<u>Operational Limitations</u> - The EPA has determined that the probability of significant reductions in the saturated thickness of these formations at the site must be considered during performance evaluations since much of the water underlying the tailings disposal area is the result of mine water and tailings discharge, both of which no longer occur. It has also recognized that in the event that saturated thicknesses cease to support pumping, remedial action would be discontinued or adjusted to appropriate levels (EPA, 1988a). Performance monitoring may demonstrate significant declines in pumping rates, with time, due to insufficient natural recharge of the Southwest Alluvium. As a result, individual wells may be

decommissioned after obtaining the necessary approvals because they can no longer sustain pumping while others will be decommissioned based on criteria as described later herein.

Performance Monitoring - A program of performance monitoring is used to evaluate the success of the remedial action in meeting design expectations. Performance monitoring may indicate that the objectives have been met and the remedy is complete. The results of the monitoring may also indicate that it is technically impractical to achieve all cleanup levels in a reasonable time period and that it may be necessary to set ACLs and waive the requirements to meet certain contaminant-specific ARARs.

The objective of the monitoring program is to provide statistically valid water level and water quality data, which can be used to evaluate the performance of the extraction system in meeting regulatory criteria. Water chemistry analysis for the monitoring program is conducted for the chemical constituents including all constituents which are in exceedance of ground water protection standards and ARARs at the site. Water chemistry data are used 1) to monitor compliance with License Condition 30, Part B criteria at POC wells, 2) to monitor and assess trends in water quality which may develop in response to pumping, 3) to evaluate the effectiveness of cleanup within the target area, 4) to provide an adequate database for development of ACLs (NRC) and waivers to ARARs (EPA), if necessary, and 5) to supplement the existing database. In addition, background water quality plays a very important role in setting both the NRC's ground water protection standards and the EPA's ARARs. Therefore, the monitoring program is also designed to further aid in establishing background water quality conditions.

Water-level data are used to determine the effects of the system on geohydrological conditions including creation and performance of the hydraulic barriers and to monitor the decreases in saturation which will occur as pre-mining natural conditions are re-established.

System Decommissioning - The CAP sets forth conditions by which the system would be decommissioned. While these conditions set forth physical parameters used to define when systems or components thereof become candidates for decommissioning, in accordance with NRC License Condition 30C, no program component meeting the decommissioning criteria will be decommissioned without prior approval from NRC.

The objectives of the extraction system in Zone 3 and the Southwest Alluvium are to create a hydraulic barrier to prevent further migration of tailings seepage and concurrently, dewater the identified target area in Zone 3. Additionally, operation of the system may provide an opportunity to clean up water quality in strata subject to remedial action to the NRC ground water protection standards and the ARAR levels established by the EPA in the ROD. However, both agencies have recognized that modifications may have to be made to these standards. The NRC regulatory mandate recognizes the possibility of not achieving the cleanup standards by providing in Appendix A, 10 CFR 40 the option of establishing ACLs. Further, the EPA also provides an alternative approach of establishing waivers to the ARARs as stated in Appendix A to the ROD (EPA, 1988a).

The systems in Zone 3, Zone 1, and the Southwest Alluvium are performance based, i.e., their success will be measured against their ability to produce compliance with agency water quality standards, or in the case of Zone 3, dewater the target area. Achievement of either condition will merit considering the system as a candidate for decommissioning. Additionally, the inability of the systems to meet the above performance criteria would indicate the need to evaluate an application for ACLs (NRC) and ARAR waivers (EPA).

Implementation - Implementation of the CAP has progressed as scheduled and the remedial action systems are all performing as designed. In accordance with the requirements of the License and the ROD, implementation and evaluation of the performance of the CAP are documented annually in a report submitted to the EPA and NRC. To date, two reports, the 1989 and 1990 Annual Review (Canonie; 1989c, 1990a) have been submitted to the agencies.

1. Zone 3 - The Zone 3 system has been operating since August 1989 and is successfully dewatering the target area and providing a hydraulic barrier to further migration of seepage. As of fourth quarter 1990, the saturated thickness in the eastern margins of the target area was near zero and the area of intense dewatering delineated by the 10-foot contour of reduced saturated thickness covered 60 percent of the Zone 3 target area. Also, the areal extent of the plume has remained at its reduced configuration since the extraction wells were turned on in 1989. By October, 1990, a total of approximately 27.3 million gallons had been extracted from Zone 3.

2. Zone 1 - The Zone 1 remediation was scheduled to be completed at the end of April 1989 when Borrow Pit No. 2 was dewatered. However, the NRC and EPA have required that United Nuclear continue to operate the Zone 1 pump-back wells. The Zone 1 wells have continued to pump at low rates, typically at rates of less than 1.0 gpm, with no benefit in terms of accelerating the rate of dissipation of the seepage mound or reduction in contaminant concentrations. Rather, the mound has been dissipating naturally at the rate predicted based on the performance monitoring data. Programs are presently in place to develop data to be used in preparing a request for the setting of ACLs and a waiver of the ARARs for Zone 1.

3. Southwest Alluvium - The Southwest Alluvium system has been operating since October, 1989 and is successful in creating a barrier to prevent further migration of seepage and extracting seepage. The extent of the plume has remained stable confirming that the wells are controlling migration of seepage. Between October 1989 and October 1990 a total of approximately 7.4 million gallons had been extracted from the Southwest Alluvium.

4. Evaporation Disposal System - The evaporation disposal system has operated since January, 1989, when extracted seepage from the then existing pump-back wells and Borrow Pit No. 2 began to be discharged to the evaporation ponds. The system has operated as designed with some adjustments to account for actual operational inflows and outflows. The primary adjustment occurred in 1991, between January and April, when pumping rates in the extraction wells were reduced and some extracted seepage was discharged to Borrow Pit No. 2 for temporary storage. These adjustments allowed for continued operation of the extraction wells and at the same time prevented exceeding the maximum safe operating capacity of the evaporation ponds. The seepage temporarily stored in Borrow Pit No. 2 was removed by the end of May, 1991 and disposed of through the spray evaporation system.

Mill Decommissioning

United Nuclear initiated mill decommissioning in 1991 and will complete mill decommissioning by the end of 1992 in accordance with NRC License requirements.

Upon placing the mill facility on standby in 1982, the entire mill was flushed and cleaned of process material following a logical sequence through the processing circuits. Pipelines and equipment were rinsed and emptied to ensure that closed circuits were clean. All instrumentation and equipment was cleaned and lubricated. This cleaning process has made the job of mill decommissioning much less onerous. United Nuclear has been actively salvaging and selling selected mill equipment since 1985. Any equipment remaining on-site will be decontaminated and sold, if possible, or crushed and disposed of in Borrow Pit No. 2.

During mill decommissioning, United Nuclear will:

1. Dismantle the portions of the mill that will not be salvaged,

2. Clean and decontaminate foundations that are to remain in the mill area,

3. Excavate foundations that cannot be decontaminated, and

4. Dispose of mill debris and contaminated foundation material in Borrow Pit No. 2.

In conducting these activities, United Nuclear will continue to implement a comprehensive radiation safety program including monitoring, record-keeping, and reporting requirements. In addition, United Nuclear will continue to provide security in the mill area during decommissioning to prevent unauthorized access.

The portion of the mill complex that is decommissioned will be backfilled, graded, and revegetated during final reclamation.

1.0

TAILINGS RECLAMATION PLAN
AS APPROVED BY NUCLEAR REGULATORY COMMISSION
MARCH 1, 1991
LICENSE NO. SUA - 1475

1.0 SITE DESCRIPTION AND OPERATIONS

1.1 Introduction

This document presents the Reclamation Plan as approved by the Nuclear Regulatory Commission (NRC) for United Nuclear's Church Rock uranium mill and tailings disposal facility near Gallup, New Mexico. This Reclamation Plan represents the single, comprehensive document that incorporates the changes made to the plan since the original submittal. This plan supersedes the proposed Reclamation Plan originally submitted to the NRC in June 1987. This Reclamation Plan is submitted as required under license condition No. 34 of License No. SUA-1475, which requires that a single, comprehensive document be submitted. This document contains a description of the approved Reclamation Plan in Volume I, and the specifications and updated cost estimate, based on the composite plan, in Volume III in Appendices B and F, respectively. The original plan has been amended in various documents, which were submitted to the NRC on the following dates:

1. January 20, 1988
2. May 23, 1988
3. June 29, 1988
4. July 26, 1988
5. August 31, 1988
6. February 23, 1989
7. September 12, 1990
8. December 4, 1990
9. February 13, 1991
10. March 4, 1991

The plan was approved in March 1991 with several significant technical changes from the original plan submitted. Since United Nuclear submitted the proposed Reclamation Plan on June 1, 1987, the Reclamation Plan has undergone review with subsequent revisions. In the intervening period, United Nuclear has implemented several components of the plan, in accordance with the proposed plan as directed by the NRC via various amendments contained in the NRC License. These components are integral to the successful completion of the tailings reclamation plan. The details of these activities are discussed later in this document and in other documents incorporated into this plan by reference. These components are integral to the successful completion of the tailings reclamation plan. The details of these activities are discussed later in this document and in other documents incorporated into this plan by reference. Specifically, United Nuclear has implemented the following actions:

1. Interim stabilization of tailings, control of blowing tailings, and cleanup of wind-blown tailings in accordance with License Conditions 16 and 33;

2. Decommissioning of the mill in accordance with License Conditions 26 and 33;

3. Collection of tailings seepage in accordance with License Condition 30; and

4. Construction of an enhanced evaporation system in accordance with License Condition 32.

1.2 Site Characteristics

UNC Mining and Milling, a division of United Nuclear Corporation (United Nuclear) operated the Church Rock uranium mill and adjacent tailings disposal area (the Church Rock facility or site) near the western border of New Mexico. Uranium ore from two proximate mine sites, identified here as the Old Church Rock (OCR) and Northeast Church Rock (NECR) mines, was processed at the mill site and discharged to the tailings disposal area from 1977 to 1982.

The United Nuclear mill and tailings disposal site is located about 20 miles northeast of Gallup, New Mexico, in McKinley County, shown on Figure 1-1. The mill is accessed via State Highway 566 from its intersection with Interstate 40 about 10.5 miles to the south of the mill. Figure 1-1 also shows the mill site location in relation to county boundaries, nearby communities, and highway systems.

The mill and tailings disposal areas are located in Section 2 of Township 16 North, Range 16 West, as illustrated on Figure 1-2. The NECR mine site is located at the northern termination of Highway 566 in Section 35, Township 17 North, Range 16 West, south of the Navajo Indian Reservation. The OCR mine site is located adjacent to Highway 566 about three miles south of the mill in Section 17, Township 16 North, Range 16 West.

United Nuclear owns the surface of Section 2, Township 16 North, Range 16 West, and Section 36, Township 17 North, Range 16 West, which adjoins Section 2 to the north. Figure 1-2 illustrates the land surface ownership status. As shown on this figure, Quivira Mining Company (Quivira) has surface facilities (vacant offices and storage) occupying an area of approximately three acres to the north of United Nuclear's land in the east half of Section 36. Quivira also has inactive mining facilities on the Navajo Indian Reservation north of the United Nuclear site.

United Nuclear's tailings disposal area occupies approximately 100 acres, and the mill facilities area occupies approximately 25 acres, as shown on Figure 1-3. The conditions depicted on Figure 1-3 are the conditions present in 1987 before implementing any reclamation activities. Since 1987, significant work has been completed, as described in this plan. The site conditions present in the Spring of 1991 are presented on Figure 1-4. In this plan, many of the drawings are presented with the 1987 site base map, or with the conditions present before reclamation to give the reader an understanding of the scope of changes involved in the total reclamation of the site, and the progress that has been achieved in the seepage collection program. Drawings that show the conditions present in late 1990 and early 1991 are provided where appropriate to show the significant progress at the site. Attempts have been made to clearly identify the point in time depicted on the drawings. However, the reader is advised to review the drawings with caution and note what date of conditions is being depicted.

The tailings disposal area was subdivided during operations by cross-dikes into cells identified as the South Cell, Central Cell, and North Cell areas. In addition, two soil borrow pits (Pits No. 1 and No. 2) were located in the Central Cell area. Borrow Pit No. 1 was filled with tailings and has been regraded and covered. Borrow Pit No. 2 was used for storage of recovered, neutralized water extracted by the three pumping well systems (Northeast, East, and North Cross-Dike Seepage Control Systems) that operated at the locations shown on Figure 1-3.

As shown on Figure 1-4, by the Spring of 1991, the North and Central Cells of the tailings disposal area were regraded and covered, Borrow Pit No. 2 was drained, additional extraction well systems were installed, and evaporation ponds and spray evaporation systems were constructed to evaporate tailings seepage water produced by the extraction well systems. Also shown is the area where wind-blown tailings have been removed.

The United Nuclear mill and tailings disposal facilities are situated on an alluvial plain in the Pipeline Canyon at an average elevation of 7,000 feet. An ephemeral drainage channel, referred to as the Pipeline Arroyo, is situated between Highway 566 and the tailings disposal area. El Paso Natural Gas Company has a pipeline right-of-way adjacent to the channel between the highway and Pipeline Arroyo. The Pipeline Arroyo traverses the site to a point 2.5 miles southwest of the mill site where it joins the Rio Puerco, a larger ephemeral drainage. The surrounding terrain is varied, consisting of narrow canyons, arroyos, steep cliffs, and mesas. Vegetation in the lowland area is sagebrush/grassland with transition to pinyon/juniper in the upland areas.

1.3 Climate

The United Nuclear site is situated in an arid to semi-arid continental climate with sunshine more than 50 percent of the time throughout the year. Climatological data from the site indicate that winds are generally moderate, originating from the west and southwest, parallel to the trend of Pipeline Canyon, shown on Figure 1-3. Wind frequency and velocity are usually highest during the spring. Temperatures during the year average approximately 50 degrees Fahrenheit with a maximum daily average of 68 degrees (in July) and minimum daily average of 31 degrees (in January). The annual average precipitation for the area is approximately 14 inches. The majority of the precipitation occurs during the summer. Net pan evaporation averages approximately 54 inches per year and exceeds net precipitation. A summary of the precipitation-evaporation data for the Church Rock site is presented in Table 1.1.

1.4 Mining and Milling Operations

United Nuclear began uranium milling operations in May 1977. Ore for processing was primarily obtained from two proximate underground mines, the NECR and OCR mines, owned and operated by United Nuclear. Ore from other sources, including Quivira's mine, was also processed at the mill (United Nuclear, 1987). Primary ore feed was obtained from the NECR mine from the Westwater Canyon member of the Jurassic Morrison Formation. Average ore grade of the mill feed was about 0.12 percent U_3O_8.

The United Nuclear mill employed a conventional acid leach, solvent extraction process to produce yellowcake. The mill was designed to operate with a throughput of 4,000 tons per day (tpd). During its operation (1977 to 1982), the mill processed approximately 3.8 million tons of ore (United Nuclear, 1987). Figure 1-3 shows the general mill facilities configuration used during operations.

Approximately 3.8 million tons of uranium tailings were generated from milling operations. United Nuclear constructed a tailings disposal area as shown on Figure 1-3 to accommodate the coarse and fine fractions of the tailings. Borrow Pits No. 1 and No. 2 were excavated to provide additional tailings storage and construction materials for the tailings retention embankment. Material removed from the borrow pits not ultimately used for embankment construction was stored, and remains on the eastern side of the tailings disposal area (Figure 1-3). This material is available for use as cover material during reclamation, as described in detail later.

Ore was milled from 1977 until July 1979, when a breach in the tailings disposal area occurred in the southern retention embankment. United Nuclear cleaned the spill to the satisfaction of all regulatory agencies and recommenced milling operations in the fall of 1979. The milling operations continued until May 1982, when the mill was placed on standby due to a depressed uranium market.

After recommencing operations in 1979, tailings seepage was suspected at the north side of the tailings disposal area. United Nuclear has installed numerous wells since then, to address this issue. Many of these wells are currently in use as monitor wells and for pumping to intercept seepage from the tailings disposal area, as discussed in Section 6.0 of this plan.

1.5 Population

The city of Gallup, approximately 20 miles southwest of the site, is the largest population center within McKinley County. The county is sparsely populated with a 1990 census population density of 11.2 people per square mile as compared to 12.5 people per square mile in the state and 68.6 people per square mile in the United States.

The county is culturally diverse. In 1990, 72 percent of the population was American Indian including Navajo, Zuni, and Hopi, and 16 percent was Anglo-American, including 13 percent of Spanish origin.

A steady increase in population occurred in Gallup, New Mexico, and McKinley County from 1950 to 1990. Substantial growth occurred between 1970 and 1980 due to mining activities such as United Nuclear's Church Rock operation. A decline in mining activities and the closure of several uranium mining and milling operations has increased unemployment and resulted in a slowing of the population growth trend since 1980.

The Church Rock facility is located in a sparsely populated area of McKinley County. The nearest residence is situated approximately one mile northwest from the center of the tailings disposal area. The nearest point of ground water use is located 1.7 miles northeast of the perimeter of the tailings disposal area.

The demography has changed modestly since the proposed plan was submitted in 1987, as indicated in the annual descriptions of demographic changes provided to the NRC by United Nuclear in accordance with License Condition 31. The changes in local population do not have an impact on the radiological analyses completed in 1986 as part of this plan.

1.6 Geology

The United Nuclear mine and mill facilities are located in the Colorado Plateau physiographic province. The Cretaceous and Mesozoic sediments, which crop out in the area, dip two degrees to four degrees to the north-northwest into the San Juan Basin and emerge south of the San Juan Mountains in the Farmington, New Mexico area.

Erosion during the Pleistocene epoch carved valleys into the Cretaceous sediments. These valleys have since been filled with alluvium. Bedrock subcrops are in contact with this alluvium in the Pipeline Arroyo and across the tailings disposal area. The thickness of the alluvium on-site varies up to 150 feet thick.

The bedrock units of interest at the United Nuclear site are, in descending order, the Dilco Coal Member (Dilco), the Upper Gallup Sandstone, and the Upper D-Cross Tongue of Mancos Shale (Mancos). The Dilco is a sequence of alternating sandy siltstones, sandstones, coals, and carbonaceous shales. The mill facilities are located on the Dilco Coal Member. The thickness of this unit varies from 0 to 300 feet in the site area.

Underlying the Dilco, is the Upper Gallup Sandstone. The Upper Gallup Sandstone has been subdivided into three units in the site area: Zone 3, an upper sandstone; Zone 2, a shale and coal parting member; and Zone 1, a lower sandstone unit. The sandstone units generally subcrop beneath alluvium throughout the tailings disposal area, but crop out in a limited area.

The Mancos underlies the Upper Gallup Sandstone throughout the tailings disposal area and subcrops under the alluvium at the south end of the tailings disposal area.

1.7 Hydrogeology

The hydrogeology of the United Nuclear site is best described in two phases. The first phase represents natural or background site conditions prior to the onset of mining and milling activities. This pre-mining phase is characterized by the lack of a continuous ground water system in all near-surface geologic formations in the site vicinity. The second phase represents site conditions as they existed after the changes that occurred as a result of the mining and milling activities. The following provides a summary of the pre- and post-mining and milling phases of the hydrogeologic site conditions. A detailed discussion of the hydrogeology of the site and the Corrective Action Program (CAP) is presented in Section 6.0 of this plan. Detailed discussions have also been included in numerous documents submitted since 1987, including the Geohydrologic Report (GHR) (Canonie, 1987a), in the Amendments I and II to the proposed reclamation plan submitted in 1987 (Canonie, 1988b and 1989a) approved by the NRC, and in the Remedial Design Report (RD) (Canonie, 1989d) approved by the NRC and EPA. As described in Section 6.0, United Nuclear has been implementing control of tailings seepage, indicated in the CAP and RD in accordance with License Condition 30 and the EPA's Record of Decision.

Pre-Mining and Milling - Prior to mining and milling activities, the near-surface bedrock units and the alluvium in the vicinity of the tailings disposal area were unsaturated. The alluvium and exposures of the Upper Gallup Sandstone received minor amounts of water from direct precipitation. The exposures of the Upper Gallup Sandstone in the site area serve as a part of the recharge area for the Upper Gallup Sandstone aquifer to the north in the San Juan Basin. However, the recharge from precipitation did not result in saturated conditions at the site. Evidence of unsaturated conditions in these geologic formations comes from the construction log for United Nuclear's NECR mine shaft constructed at the beginning of 1968, and from the absence of water in geotechnical borings in the tailings disposal area drilled before tailings disposal. Both the construction log and the boring logs show saturated conditions did not exist in the tailings disposal area above the Mancos. Therefore, both the alluvium and the Upper Gallup Sandstone in the vicinity of the United Nuclear facility were essentially unsaturated prior to mining activities at the site.

Post-Mining and Milling - Conditions at the site began to change in 1968, as a result of discharge of mine water into the arroyo. Artificial recharge from the arroyo to the alluvium occurred via discharge of mine water from both the United Nuclear and Quivira mines. This discharge saturated portions of the alluvium and Zone 3 and Zone 1 of the Upper Gallup Sandstone, creating a transient, temporary, artificial ground water system.

Tailings Seepage - Milling operations began in May 1977, and continued through May 1982. Disposal of tailings into the tailings disposal area continued through October 1982 while the mill circuits were being cleaned. The seepage from the tailings created a localized mound on top of the artificial system.

Both the artificial system and the seepage mound represent transient hydrogeologic conditions at the site. Since the original sources of water (i.e., mine water discharge and later seepage from tailings disposal) have been removed, eventually the system will return to the unsaturated condition that existed prior to mining and milling activities at the site.

1.8 Surface Water Hydrology

The United Nuclear Church Rock site is located west of the Continental Divide in the Rio Puerco Basin on the Colorado Plateau. This region is characterized by numerous mesas, buttes and plateaus, interspersed with steep gullies and arroyos. The smaller drainages flow only as a result of intense rainfall events. Only the larger drainage basins have either intermittent or perennial flow.

The United Nuclear site is located in the Pipeline Arroyo drainage basin, which drains into the North Fork of the Rio Puerco drainage. The Pipeline Arroyo Basin above the United Nuclear site has a drainage area of 18.2 square miles. The North Fork of the Rio Puerco drainage basin drains 280 square miles above the confluence of Pipeline Arroyo. The Pipeline Arroyo Basin above the United Nuclear boundary has a maximum relief of about 800 feet. Upland areas consist of relatively flat mesas with extremely steep sideslopes. Channel slopes vary considerably (0.0054 to 0.0347 feet per feet) and are dependent on local bedrock controls.

There are no surface water bodies, diversions, or control structures below the mill site within Pipeline Arroyo. Above the mill site is one impoundment capable of storing approximately ten acre-feet of runoff for livestock watering.

Diversion ditches, constructed while the facility was operating, intercept runoff from the small drainage basins to the east of the tailings disposal area and route the runoff around the tailings disposal area to Pipeline Arroyo.

A bedrock outcrop within Pipeline Arroyo, designated the "nickpoint," provides a local base control for the arroyo channel (Figure 1-3). Channel gradients above the nickpoint are quite shallow, and the channel is wide and shallow. Below the nickpoint channel, gradients are steep, and the channel is narrow and deep.

1.9 Site Activities 1987 to 1990

United Nuclear has pursued an aggressive plan of remedial action since the proposed plan was submitted in June 1987. All of these actions were taken pursuant to various NRC license amendments and EPA seepage remedial action approvals. Figure 1-4 shows the site as it existed in the Spring 1991. Comparison of Figures 1-4 and 1-3 (which depicts 1987 conditions) provides a measure of the significant work completed to date, even absent an approved remediation plan.

1.9.1 Seepage Collection Activities

Beginning in 1988, United Nuclear initiated construction of the seepage CAP approved by NRC and EPA. Two 5-acre hypalon-lined evaporation ponds were constructed to dispose of collected seepage as shown on Figure 1-4. United Nuclear also constructed 15 new seepage collection wells, 12 in Zone 3 and three in the southwest alluvium. The location of these wells is shown on Figure 1-4. These wells began operation in 1989 in conjunction with pre-existing seepage collection wells, described to the NRC in the June 1987 plan and shown on Figure 1-3. An additional eight new extraction wells have recently been constructed, seven in Zone 3 (Phase II) and 1 in the southwest alluvium, and are expected to be operating by the end of the Third Quarter 1991. Between August 7, 1989 and July 26, 1991, approximately 59 million gallons of water have been collected by the systems.

To enhance evaporation, United Nuclear installed a series of spray mister nozzles on the evaporation pond embankments. It has also installed 26 impact spray guns over the reclaimed Central Cell, as shown on Figure 1-4. United Nuclear has submitted annual reports to the NRC and EPA evaluating progress made by operation of the seepage collection system pursuant to NRC License Condition 30 and the EPA Administrative Order.

1.9.2 Tailings Reclamation

Beginning in 1989, United Nuclear initiated an interim tailings reclamation program in conformance with NRC license requirements. United Nuclear cleaned up and revegetated over 60 acres of land containing wind-blown contaminated tailings. The cleaned area is outlined in Figure 1-4. This area was identified in the Wind-blown Tailings Cleanup Verification Reports for Sections 1, 2, and 36 (United Nuclear, 1989 and 1990), submitted to the NRC in accordance with License Condition 33. United Nuclear has recontoured and covered the North and Central Cells of the tailings disposal area with a minimum of one foot of radon attenuating soil cover, as shown on Figure 1-4. All of this work was performed in accordance with license requirements and was completed using the technical specifications, described in the June 1987 proposed reclamation plan and modified as a result of comments by the NRC.

1.9.3 Mill Decommissioning

The proposed reclamation plan submitted in June 1987 included a Mill Decommissioning Plan. After initial review and comment, NRC decided it needed to amend United Nuclear's license, to require submittal of a more detailed Mill Decommissioning Plan by the end of 1990. United Nuclear submitted a detailed Mill Decommissioning Plan for the Church Rock mill to the NRC on December 22, 1990. Supplemental information was submitted to NRC on April 10, 1990 in response to NRC review comments. The Mill Decommissioning Plan was approved by the NRC in January 1991, and United Nuclear began decommissioning in 1991.

The Mill Decommissioning Plan is presented in Section 7.0 and includes a description of:

1. Dismantling procedures for the portions of the mill that will not be salvaged,

2. Cleaning and decontaminating procedures for foundations that are to remain in the mill area,

3. Procedures for excavating foundations which cannot be decontaminated,

4. Disposal procedures for of mill debris and contaminated foundation material in Borrow Pit No. 2,

5. The radiation safety program to be followed during mill decommissioning,

6. The monitoring to be conducted,

7. The records and reports to be generated and maintained, and

8. Security.

The plan also incorporates an equipment salvage and sales program designed to help defray the cost of reclamation. Certain pieces of equipment have been removed and decontaminated for sale. Others have been sold and removed from the facility.

2.0

2.0 SITE RADIOLOGICAL SURVEY

A radiological survey of the Church Rock facility was conducted for the purpose of assessing the radiological characteristics of the site and to form a basis for reclamation planning, in accordance with NRC regulations (Appendix A of 10 CFR 40). These standards stipulate that remediation is generally required when the Radium-226 (Ra-226) concentration, averaged over areas of 100 square meters, exceeds the background level by 5 picoCuries per gram (pCi/g) in the first 15 centimeters (cm) of soil or 15 pCi/g in any 15 cm layer of soil below the first 15 cm.

The survey primarily consisted of 1) determination of soil radium concentrations and gamma ray exposure rate background values, 2) a gamma ray exposure rate survey of the mill and tailings disposal area, 3) borehole logging for subsurface characterization of Ra-226 levels, and 4) soil sample collection and analysis to determine the soil Ra-226 activity concentration.

Radiological surveying was performed by Western Radiation Consultants, Inc. (Fort Collins, Colorado) under subcontract to Canonie Environmental Services Corp. (Canonie) for Canonie's use in determining the type and extent of reclamation required on the site. Details of the radiological survey are described in the following sections.

The survey was conducted using the following systematic steps:

1. Determine natural (i.e., background) Ra-226 concentrations in site soils through sampling and laboratory analyses of soils taken from areas unaffected by uranium processing activities.

2. Determine background gamma ray exposure rates in areas unaffected by uranium processing activities.

3. Conduct a systematic gamma ray exposure survey of the site.

4. Collect soil samples for laboratory determination of Ra-226 concentrations where gamma ray exposure rates were observed to exceed 4 microroentgens per hour (μR/hr) above background, as described in NUREG-2954 (NRC, 1983a), and in other areas of concern.

5. Correlate laboratory-determined concentrations of Ra-226 with gamma ray exposure readings.

6. Drill boreholes in areas where surface gamma ray exposure readings were greater than 4 μR/hr above background, and in other areas of concern, to estimate Ra-226 concentrations in layers of soil below the first 15 cm.

7. Delineate areas to which Appendix A of 10 CFR 40 criteria may apply by comparison of observed or estimated by-product Ra-226 concentrations at the site to the background Ra-226 concentration.

The areas surveyed in accordance with this approach as part of this program are shown on Figures 2-1 through 2-5 and include:

1. Three background areas to determine natural concentrations of Ra-226 at the site and background gamma ray exposure rates.

2. A radial grid centered on and extending from the approximate center of the tailings disposal area.

3. Areas proximate to the tailings disposal site to identify areas affected by tailings.

4. The mill site and facilities area, excluding actual structures.

2.1 Survey Methods and Procedures

Consistent with regulatory guidance, a practical methodology using correlations between gamma ray exposure rates and Ra-226 concentrations was employed to identify areas of high Ra-226 levels, and is described in NUREG/CR-2954 (NRC, 1983a). These relationships indicate that Ra-226 concentrations greater than 5 pCi/g above background due to residual radioactivity are almost never present in soils at locations having gamma ray exposure rates of less than 4 μR/hr above background levels.

The areas surveyed include three background areas to estimate preoperational radiological characteristics of the site, the mill site itself (in the northeast quadrant of Section 2), the area surrounding the tailings impoundment (Section 2), and areas of potential wind-blown tailings activity (Sections 2 and 36). All areas are shown on Figure 2-1.

Ra-226 concentrations in soils were estimated by 1) a gamma ray exposure survey for near surface soils, 2) a borehole logging survey for subsurface characterization of soils, and 3) soil sample collection and laboratory analyses to determine Ra-226 concentrations. All three types of surveys were conducted in the background areas to determine baseline comparison values.

Delineation of areas planned for remediation, as shown on Figure 2-4, was accomplished by visual interpolation of gamma ray activity data points. Identification of these areas does not necessarily indicate the existence of areas exceeding the by-product action level criteria because the technique of averaging Ra-226 concentrations over a 100-square-meter area was not used.

2.1.1 Gamma Ray Exposure Survey

The gamma ray exposure surveys were performed using a Precision 111B scintillometer calibrated against a Pressurized Ion Chamber (PIC). All measurements were made at approximately one meter above the surface. For areas where the unshielded instrument recorded a value greater than 4 μR/hr above background, a measurement was also made with the detector shielded with an annulus of lead approximately 1.5 cm (0.6 inches) thick. Shielded and unshielded Precision 111B measurements were correlated with measured surface soil Ra-226 concentrations.

2.1.2 Borehole Measurements

Boreholes were drilled in areas selected on the basis of surface gamma ray exposure survey readings greater than 23 μR/hr to obtain gamma ray exposure readings below the ground surface. This gamma ray action level was developed using the correlation between Ra-226 and gamma ray exposure rates as discussed in NUREG/CR-2954 (NRC, 1983a). In areas accessible to a truck-mounted auger, holes were drilled to a depth of approximately three meters (10.0 feet). In other areas, where possible, holes were dug using a hand-operated gas-powered auger or a simple hand auger. The locations of the boreholes were dictated by accessibility and soil conditions.

The borehole logger used was a Victoreen Thyac III Model 490 survey meter and a Model 489-55 NaI probe with a 3.5-meter (11.5-foot) cable. The barrel of the probe was encased in a layer of thinsulite foam [approximately 1.0 cm (0.4 inch)] and a plastic bag to protect it from shock, sudden temperature changes and moisture. All cable connections were wrapped with electrical tape to reduce stress on the connections when the probe was suspended.

The borehole logger cable was marked at 15-cm (0.5-foot) intervals. Readings were generally made in the boreholes drilled at the surface and in the center of each subsequent 15-cm (0.5-foot) interval to a depth of two to three meters (6.5 to 10 feet). In some cases, where exposure rates were changing rapidly with depth, 5.0-cm (0.2-foot) intervals were used. However, graphs of exposure rate versus depth were nearly identical for both interval readings.

2.1.3 Soil Sample Collection and Analyses

Cuttings were collected from boreholes at 15-cm (0.5-foot), 30-cm (1.0-foot), 1.0 meter (3.3 feet), 2.0 meters (6.6 feet), and 3.0 meters (10.0 feet) depths for radiological analyses in the laboratory. The samples were placed in one-gallon plastic bags and labeled with borehole identification and depth.

Samples were also collected from drill holes at 0 to 15 cm (0 to 0.5 feet), 15 to 30 cm (0.5 to 1.0 feet), and in some cases, 30 to 45 cm (1 to 1.5 feet). All soil samples were placed in one-gallon plastic bags, marked with the location, depth, and date of collection. Samples were stored in an on-site storage room. Selected soil samples were sent to Colorado State University (CSU) for analysis.

Soil samples were dried, pulverized, and packed into one-quart (946 milliliter) steel cans. The can lid was fitted securely and sealed with silicone sealant. A Ra-226 in-growth period of at least 20 days was allowed before counting.

The sample cans were counted by a shielded Ge(Li) high resolution gamma ray spectrometry system. Ra-226 activity concentrations was calculated from the net spectral area under either the 0.60932 megaelectron volts (MeV) peak or the 1.7645 MeV peak, due to the gamma rays of Bi-214. Uranium-238 (U-238) concentration was calculated from the net spectral area under the gamma rays of Pa-234 at 0.0947 MeV and 0.984 MeV. Secular equilibrium with the parent U-238 was assumed.

A representative fraction of the soil samples obtained in areas around the tailings disposal area was analyzed by the CSU gamma ray spectroscopy laboratory for Ra-226 and U-238. These analyses were performed to obtain actual Ra-226 activity concentrations and to establish the equilibrium relationship between the two radionuclides.

2.2 Background Determination

Three background areas, illustrated on Figure 2-1, were surveyed to estimate pre-operational radiological conditions at the mill and tailings disposal areas as a basis for ascertaining the radiological impact of site operations. The background areas were selected on the basis of distance and direction from the tailings and their locations opposing the predominant wind direction. Plot No. 1 is located in the southeast corner of Section 3 on both the east and west sides of Highway 566. Plot No. 2 is located in the southwest area of Section 35, west of the water towers. Plot No. 3 is located in the southeast corner of Section 2.

2.2.1 Radium in Background Soils

Table 2.1 presents results of laboratory analyses for Ra-226 concentrations in composite soil samples obtained from the three background test plots illustrated on Figure 2-1. The weighted overall mean of the measurements was 0.78 pCi/g Ra-226 with a standard deviation of $\pm$0.53 pCi/g. The value of 1 pCi/g Ra-226 was selected as the background concentration for the site, based on the upper 95 percent confidence interval of the mean as shown in Table 2.1. On this basis, the remediation criteria identified in Appendix A of 10 CFR 40 indicate that 6 pCi/g Ra-226 (5 pCi/g plus background) is the target acceptable limit for surface Ra-226 activity and 16 pCi/g Ra-226 activity is the target acceptable limit for depths greater than 15 cm.

2.2.2 Gamma Survey

Fifty gamma ray exposure rate measurements were made at each background area. Table 2.2 summarizes results of unshielded gamma ray exposure readings measured on the background plots. These readings were obtained as a baseline for comparison to areas affected by tailings. As indicated in Table 2.2, the mean (corrected) background external gamma ray exposure rate is 15 μR/hr with a standard deviation of 12 percent. Statistically, the probability of observing a background gamma ray exposure rate of between 11.5 and 18.5 μR/hr is 95 percent. The probability of observing a gamma ray exposure rate greater than 18.5 μR/hr, which is due only to background, is 2.5 percent.

The mean background gamma ray exposure rate (15 μR/hr) was first used as the basis for identifying areas around the tailings disposal area and mill facilities area that required more extensive evaluation. Areas showing gamma ray exposure rates of 4 μR/hr or greater above background (i.e., $\geq$19 μR/hr) were subjected to further assessment (shielded readings, borehole logging, and/or soil sampling/analyses).

Table 2.3 presents the correlations between Ra-226 soil activity concentrations versus measured gamma exposure rates as determined using simple linear regression analysis. The 6 pCi/g Ra-226 correlates to a gamma ray exposure rate of 23 μR/hr. This value was used as the action level for determining Ra-226 at the surface in lieu of soils laboratory analyses.

2.2.3 Borehole Logging

Gamma spectroscopy measurements were made and drillholes advanced with a gas auger at 10 to 13 locations in each plot. The drillholes were logged with the downhole gamma ray logger, and soil samples were collected for determination of radium concentrations, as previously described. Borehole logger readings were obtained in these two background plots to assist in calibrating the borehole logger for correlation of readings to Ra-226 concentrations below the first 15 cm soil thickness. Table 2.4 presents results of those readings for background Plots No. 1 and No. 3. Due to the shallow bedrock surface and rocky nature of background Plot No. 2, no drillholes could be advanced in that area. All drill hole measurements are reported as dimensionless values since actual meter readings are meaningless, except as indirect relative measurements between borehole Ra-226 concentrations. As shown in Table 2.4, the mean background borehole logger (BHL) reading was 1.7.

Correlations between Ra-226 activity concentrations and borehole logger readings were developed for holes drilled by truck-mounted rig (boreholes) and drilled by hand auger methods (drillholes) to develop action levels for subsurface soils.

These correlations were also developed using simple linear regression analysis. The derived values differ for truck-mounted auger boreholes and hand auger drillholes because of the difference in diameters between the boreholes and drillholes. The derived correlations for the boreholes and drillholes are presented in Tables 2.5 and 2.6, respectively.

The estimated mean borehole logger reading for a Ra-226 activity concentration of 6 pCi/g is 5.6 (dimensionless) for truck-mounted auger boreholes. A Ra-226 activity concentration of 16 pCi/g for truck-mounted auger boreholes corresponds to an estimated mean borehole logger reading of 12.8 (dimensionless).

Similarly, the estimated mean borehole logger reading for a Ra-226 activity concentration of 6 pCi/g is 3.9 (dimensionless) for hand auger drillholes. A Ra-226 activity concentration of 16 pCi/g for hand auger drillholes corresponds to an estimated mean borehole logger reading of 10.1 (dimensionless).

These values were used as action levels in assisting in a determination of areas that may require reclamation.

2.3 Site Survey Results

2.3.1 Areas Adjacent to the Tailings Disposal Area

Areas adjacent to the tailings disposal area were surveyed by all three methods described previously, including gamma ray exposure rate measurements, BHL, and soil sampling with laboratory analysis for Ra-226.

Gamma Ray Exposure Rate Survey

The gamma ray exposure rate survey of the tailings disposal area was conducted along a radial grid as illustrated on Figure 2-1. The center point of the grid was chosen as the approximate center of the entire tailings disposal area. Eighteen radial lines were set with stakes at 50-meter intervals, and readings were taken at each point. The starting point for each radial line was the outside edge of the tailings embankment. The radials in the direction of the prevailing wind were set at angles of separation of 11.5 degrees. In other directions, the radials were set at 30-degree angles of separation. Radials were not set to the east because of inaccessibility to the area.

At locations where an unshielded measurement was greater than 4 μR/hr above background, indicating the possibility of elevated Ra-226 concentrations, a measurement was also made with a 1.5-cm lead annulus shielding the detector. The results of the gamma radiation survey in the tailings disposal area vicinity and Pipeline Arroyo area are shown on Figures 2-1 through 2-3.

More extensive gamma ray exposure rate measurements were made and boreholes were drilled in areas that had unshielded gamma exposure rates greater than 4 μR/hr above background, based on the radial survey. Four such areas were identified: the area between Highway 566 and the tailings disposal areas, the area to the northeast of the tailings in the predominant wind direction, the topographically elevated area directly west of the east boundary line for Section 2, and an area along Radial "N." The results of these measurements are shown on Figures 2-1 through 2-3 and indicate the extent of wind-blown tailings is limited primarily to the northeast corner and a short distance northeast from the corner of the tailings disposal area, as shown on Figure 2-4.

Borehole Logging

Boreholes were drilled in areas accessible to the truck-mounted auger at the locations identified on Figures 2-1 through 2-3. Measurements were made in these holes using the downhole logger as described in Section 2.1. Drillholes were advanced with either a gas-powered auger or a hand auger in locations inaccessible to the truck-mounted auger. The locations of these drillholes are also shown on Figures 2-1 through 2-3.

A representative number of soil samples was selected for Ra-226 analysis to confirm the borehole logging results. The results are shown in Tables 2.7A through 2.7E. The borehole logging results indicate two limited deposits of tailings outside of the tailings embankment. One is located along radial "N" southwest of the South Cell as shown on Figure 2-1. The other area is located in the south half of the west side of the embankment. These two areas were apparently created when a two-foot thick blanket of coarse tailings sands was placed as a drain for future expansion of the south half of the tailings embankment. The blanket was covered to varying depths with compacted soil, which formed the base of the expanded embankment. The bottom of this drain blanket was encountered at depths ranging from 1.0 meter (3.3 feet) to over 2.3 meters (7.5 feet). Table 2.8 summarizes the depths at which the 16 pCi/g level for Ra-226 activity concentration was observed during borehole logging at the locations shown on Figure 2-1. Table 2.9F presents the analysis results for soil samples collected in the vicinity of the sand blanket material along radial "N."

Tables 2.9A through 2.9G identify Ra-226 concentrations in soil samples obtained at various locations shown on Figures 2-1 through 2-5. These tables also present U-238/Ra-226 ratios of the samples as a relative indication of whether the soil has been affected by ore or by-product materials. A ratio greater than one has a higher probability of being ore-related rather than tailings (i.e, by-product) material waste.

2.3.2 Mill Site

The mill area was similarly surveyed by gamma ray exposure rate measurement, borehole logging, and soil sampling and laboratory analyses for Ra-226. No survey of structures was conducted as part of this work since it is planned that the majority of building debris and equipment will be disposed of in the tailings disposal area as part of final reclamation.

Gamma Ray Exposure Rate Survey

A gamma ray exposure rate survey of the mill site was conducted on an approximate 10-meter (33-foot) grid, as shown on Figure 2-5. The grid spacing was plotted on a site plan and paced off in the field using landmarks from the site plan. The results of the survey are also shown on Figure 2-5.

A portion of the mill area was paved with asphalt after mill startup. Surface presence of by-products, which occurred after the placement of asphalt pavement, was revealed by the gamma ray exposure rate survey. However, determining if these radiological elements were present before paving is not possible with this method.

Elevated gamma ray exposure rates were noted in the vicinity of the ore storage pad, mill building, clariflocculator (CCD) tank, and sewage treatment plant. The overall gamma ray exposure rates on the site were slightly elevated above background, probably due to the proximity to the ore storage pad.

Borehole Logging

Boreholes were drilled on the mill site by the truck-mounted auger wherever possible in areas of elevated gamma ray exposure rates. The borehole locations are shown on Figure 2-5. The choice of borehole locations was limited by the presence of utility lines and other obstructions on the site.

The borehole logging results are shown in Table 2.10, and the Ra-226 analyses of soil samples are shown in Table 2.11. Some of the boreholes in the vicinity of the ore storage pad and the mill building showed elevated readings immediately beneath the asphalt.

Boreholes in the ore storage area were logged using the borehole logger. The depth to 16 pCi/g for most holes was less than 50 cm (1.6 feet), but ranged as high as 120 cm (4 feet). The results of the borehole logging on the ore storage pad are shown in Table 2.12.

Surface soil samples were taken in two areas near the northeast corner of the mill area (Figure 2-5). Elevated gamma ray exposure readings in the area are likely due to the ore storage pad. The samples had Ra-226 activity concentrations of 24 pCi/g and 89 pCi/g with U-238/Ra-226 ratios of 1.7 and 0.92. The ratio of 1.7 clearly indicates the presence of ore; however, the ratio of 0.92 is inconclusive.

Based on the radiological survey, Ra-226 concentrations due to the presence of by-product materials in the mill area appear limited and, where detected, are located near the ground surface.

2.3.3 Catch Basins and Drainage Areas

The area west of the Pipeline Arroyo contains two catch basins as shown on Figure 2-4 that received drainage from the mill site. Catch Basin No. 1 received drainage from the paved area of the mill site, while Catch Basin No. 2 received drainage from the ore storage area. The catch basins were also designed to act as secondary containment in the event of failures in the tailings discharge pipeline where it crosses Pipeline Arroyo. The survey indicated the presence of elevated radiological readings in these catch basins. The results of the gamma ray surveys are shown on Figures 2-2 and 2-3. The results of the borehole logging are presented in Table 2.7D.

The depth of elevated activity in Catch Basin No. 1 is approximately 0.9 meters (3 feet) based on borehole logging results and about 1.5 meters (4.9 feet) in Catch Basin No. 2. Based on the U-238/Ra-226 ratios from gamma ray spectroscopy, Ra-226 concentration activity within Catch Basin No. 2 appears to be from ore. The results of analyses for radium in the soils for Catch Basin No. 2 are presented in Table 2.9G.

2.3.4 Wind-blown Tailings Disposal Areas

The predominant wind direction is from the southwest to the northeast as shown on Figure 2-4. The radiological survey results were evaluated to identify areas that may require cleanup due to wind-blown tailings migration. Limited areas northeast of the tailings exhibited evidence of elevated radioactivity from wind-blown tailings, as illustrated on Figure 2-4. Affected areas were evaluated on the basis of acceptable levels of Ra-226 concentrations compared to background levels, which were determined by the gamma ray exposure rate measurements, borehole logging results, and soils analyses, discussed in previous sections of this plan.

Analyses of samples from within the defined wind-blown area revealed below-background activity levels at shallow depths. Soils below 15 cm were typically found to have Ra-226 concentrations below both the 16 pCi/g limit and the 6 pCi/g surface soil limit.

Tables 2.9A through 2.9E contain the soils analyses for data points in the wind-blown tailings disposal area as shown on Figure 2-4. Wind-blown tailings also affected an area immediately north of the North Cell embankment, as indicated by soil analyses presented in Table 2.8 for Boreholes R-12 through R-17.

Figure 2-4 has been revised since the proposed plan was submitted in 1987 to include an area in Section 1 where wind-blown tailings had impacted the soil. When the plan was proposed in 1987, United Nuclear did not have permission to access Section 1 to radiologically survey the area. Accordingly, this area was not included in the discussion. When the Navajo tribe allowed access to the land, United Nuclear conducted the necessary radiological surveys. Figure 2-4 was revised to show approximately six acres in Section 1, which exhibited evidence of contamination by wind-blown tailings. As described in Section 4.0 below, United Nuclear cleaned the area impacted by wind-blown tailings from Sections 2 and 36 in 1989 and Section 1 in 1990. The results of this cleanup program are contained in reports submitted to the NRC (United Nuclear, 1989 and 1990).

2.3.5 Diversion Ditch

A gamma ray exposure rate survey of the south drainage diversion ditch, located along the east edge of the tailings disposal area (Figures 1-3 and 2-1), indicated no significant elevated readings beyond approximately 350 meters south of the northeast corner of Section 2 as illustrated on Figure 2-1. These areas within the ditch exhibiting gamma ray activity greater than 23 μR/hr (representative of a Ra-226 concentration of 6 pCi/g) were located in the northeast corner of the site and had probably been affected by wind-blown tailings.

3.0

3.0 GEOTECHNICAL INVESTIGATION

Geotechnical investigations have been performed to obtain data required for reclamation plan preparation (e.g., channel and cover designs), and to supplement extensive engineering investigations conducted previously at the site. The reclamation plan investigation was conducted before the proposed reclamation plan submittal in June 1987. Additional data were generated from sampling conducted during the interim stabilization activities in the North and Central Cells. These data were used to develop responses to NRC reclamation plan review comments. The investigations consisted of drilling test borings, excavating test pits, and conducting geotechnical laboratory tests to characterize the site soils. Soil samples obtained during the investigations were also selectively used to obtain radiological design parameters for the final reclamation soil cover, described in Section 5.0.

3.1 Field Exploration

Canonie performed geotechnical field explorations at the Church Rock facility as part of the reclamation plan investigation completed prior to the June 1987 submittal. Primary objectives of the investigation included:

1. Determining potential sources for soil cover borrow areas,
2. Characterizing bedrock conditions in the Pipeline Arroyo for surface water control evaluations,
3. Characterizing the mill site area for regrading design purposes, and
4. Evaluating potential rock riprap sources.

Borings were also selectively used for radiological field survey purposes as previously described in Section 2.0.

In response to NRC review comments, the data provided from previous investigations at the site and from the reclamation plan investigation were reevaluated. This review resulted in a decision to use only soil data for samples likely to be included in actual borrow areas to develop the radon attenuation soil cover. In addition, data, collected from testing the soil cover placed during interim stabilization of the North and Central Cells, and soil from the soil stockpile were also used to refine the design of the radon attenuation soil cover. The locations of samples for which data was used in the radon attenuation soil cover design are shown on Figure 3-1. Testing during interim stabilization of the North and Central Cells consisted of both in-place moisture-density tests and laboratory tests including moisture-density relationship, gradation characteristics, and Atterberg limits. The methods of data evaluation were refined in responses to NRC comments in September 1990, and the final radon attenuation soil cover evaluation, as approved by the NRC, was presented in the March 1991 response to NRC comments. These requirements for soil cover material are included in the Construction/Technical Specifications provided in Appendix B.

3.1.1 Borings

Geotechnical test borings were drilled to depths of up to 80 feet below the existing ground surface to define subsurface materials and conditions around the tailings disposal and mill tailings areas. The locations of the test borings for which data was used in the radon attenuation soil cover evaluation are illustrated on Figure 3-1. Logs of these borings drilled as part of the reclamation plan exploration program are provided in Appendix A. Drilling was conducted using a Central Mining Equipment (CME) 55 drill rig with hollow stem auger, split spoon and tube sampling, and rock coring (rotary water) methods.

As indicated in the boring logs in Appendix A, the alluvial materials are predominantly silts intermixed with varying quantities of sands and clays, ranging in depth to over 80 feet in the boreholes drilled as part of this program. Sandstones present in the vicinity of the Pipeline Arroyo nickpoint are lightly to moderately cemented. Because sufficient deposits of alluvial soils and sediments exist in the soil stockpile, the areas around the tailings, and the Pipeline Arroyo can be used as soil borrow for a tailings cover.

3.1.2 Test Pits

Test pits were excavated to refusal or depths of approximately 12 feet at the locations shown on Figure 3-1. Logs of the test pits are presented in Appendix A. The test pits were excavated using a Case 580C backhoe. The purpose of the test pits was to obtain bulk soil samples for laboratory testing of representative materials.

The soils in the north alluvial plain were excavated with relative ease and generally consisted of either a brown, clean to silty sand, or a dark brown silt with clay fractions varying from zero to 50 percent and little sand. These two types of soils are distributed in shallow zones that could be easily excavated and placed during reclamation operations to produce a homogeneous soil cover. The results of testing on the actual soil cover placed during interim stabilization of the North and Central Cells confirm the homogeneity and adequacy of the soil cover.

3.2 Laboratory Testing Program

Laboratory testing was performed on samples obtained in the field to identify the characteristics of soils and rock. Soil tests provided data necessary for the evaluation of soil erodibility, natural moisture content, specific gravity, grain size distribution, compaction, and other physical characteristics for design of the cover thickness necessary to attenuate radon flux. Rock test results allowed the evaluation of the suitability of rock material as riprap and provided an indication of the degree of difficulty that would be encountered during rock excavation. These test results were used, along with data from previous geotechnical investigations (Sergent, Hauskins, and Beckwith, 1979), to select and check parameters for reclamation soil cover design as well as data collected during placement of the interim stabilization soil cover (i.e., North and Central Cells).

3.2.1 Soils/Testing

Soil samples obtained from the borings and test pits were subjected to the following geotechnical testing:

1. Natural moisture contents
2. Specific gravity
3. Grain size distribution
4. Compaction (moisture-density relationship)

A summary of the relevant geotechnical test results for acceptable soil cover materials based on the NRC's Staff Technical Position (STP), used in developing the radon attenuation soil cover design, is provided in Tables 3.1 to 3.3. Particle size gradation curves as determined by sieve analyses for samples tested are provided in Appendix A. These data sheets also provide the soil sample description and moisture content. Moisture-density relationships as determined by the Standard Proctor method of compaction (ASTM D 698) are provided in Appendix A.

3.2.1.1 Natural Moisture Content

The natural moisture content of the soil samples was evaluated using laboratory-derived long-term moisture contents and in-situ moisture contents. Laboratory testing (Method

ASTM-D3152) of a representative soil sample to determine the long-term moisture content of the soil cover produced a value of 13.6 percent by weight. Laboratory test data are contained in Appendix C. The sample tested had a fines fraction of 65 percent. A more detailed discussion of the moisture contents used in developing the radon attenuation soil cover is presented in Section 5.0.

Evaluation of in-situ moisture content measurements from 119 representative borrow soil samples identified a long-term moisture content of 13.4 percent by weight. This value is the average moisture content of the samples tested as provided in Appendix D. Samples were obtained from available borrow soils within Pipeline Arroyo, the tailings embankment, and the soil stockpile located east of the tailings impoundment.

NRC review questioned the representativeness of these soils and indicated only samples meeting the acceptable soil cover grain-size envelope and obtained from a depth of between 120 centimeters (cm) and 500 cm should be employed in evaluating long-term moisture, based on observed moisture contents. Therefore, refined evaluation of in-situ moisture content measurements was conducted to include only the data meeting those criteria. Forty-seven soil samples were identified as meeting the gradation and depth requirements and are located in potential borrow areas. The average in-situ moisture content of these samples was determined to be 12.9 percent. This calculation is presented in Appendix D. This value of 12.9 percent was used in design of the radon barrier as described in detail in Section 5.0.

3.2.1.2 Specific Gravity

The specific gravity results indicated a range of values between 2.57 and 2.63, typical of these types of soil materials (Appendix D). A value of 2.6 was used for the specific gravity of the soil in the design of the radon attenuation soil cover as described in Section 5.0.

3.2.1.3 Particle Size Analyses

Particle size analyses were performed for soil classification purposes and to obtain data for establishing a representative site soil gradation for cover design purposes. Particle size distribution curves are provided in Appendix A. Tables 3.1 through 3.3 contain results for over 50 grain size distribution and Atterberg limits analyses for soils from the proposed borrow sources.

The data in Tables 3.1 to 3.3 were used to develop a range of soil material types with characteristics acceptable to meet the design criteria for radon attenuation. The actual soil cover material placed in the field during reclamation will be a blend of various soil types, the result of excavation and placement of the soil during construction. To address NRC review comments regarding soil uniformity, a range of allowable soil types for the soil cover was developed. The graphic envelope, shown on Figure 3-2, provides an expedient method to evaluate gradation results for soil-cover soils. Use of this envelope will ensure consistency with the soil types modeled in the soil-cover design. The radiological soil cover modeling is described in Section 5.0.

The results of grain size analyses indicate, in general, that the proposed borrow soils to be used in construction of the radon attenuation soil cover can be characterized as clay with varying fractions of silt and sand. Figure 3-2 illustrates the average soil gradation of the materials to be used in the soil cover.

The envelope of allowable soil mixtures for the soil cover (Figure 3-2), accounting for blending of all soil types as a result of excavation and placement during construction, will produce a soil cover consistent with that modeled in the design. That design and the allowable grain size distribution envelope include all blended soil types (Unified Soil Classification System) that are expected to be encountered during construction of the soil cover. The gradation curves of soil used to construct the soil cover will fall within the envelope and will classify as silty clay (CL), clayey sand (SC), silt (ML), or silty sand (SM). No individual soil type, particularly sand (SP), is represented to be suitable alone for use as the soil cover. Only those soils falling within the soil cover gradation limits shown on Figure 3-2 will be used for soil cover construction.

The data compiled for the borrow sources is adequate for the soil cover design described in Section 5.0. However, in addition to the borrow sources data described above, data have also been collected for the soil cover material placed during interim stabilization activities in the North and Central Cells. This actual field data was used in the radon attenuation soil cover design as described in Section 5.0 and provides soil data representing a significant portion of the soil cover.

Compaction

In the proposed plan submitted in June 1987, moisture-density relationships of soils within the north alluvial plain and within the arroyo were determined using the Standard Proctor method of compaction (ASTM D 698). The clayey soils most prevalent as borrow material exhibited a representative maximum dry density of about 104 pounds per cubic feet (pcf). The sands exhibited a maximum dry density of about 111 pcf. Moisture-density relationships of soil samples compacted as part of this program are illustrated in Appendix A.

The data used to determine the moisture-density relationship of soil for the radon attenuation soil cover were refined to address NRC concerns about using soil sample data from areas that may not actually be used as borrow sources for the soil cover. Only soil materials that satisfy the requirements in the specifications were used. Figure 3-2 shows the acceptable gradation envelope for soil cover material as approved by NRC. Additionally, the bulk dry density used in determining the required thickness of the final soil cover was determined using soil samples obtained from the interim stabilization cover placed in the North and Central Cells. Maximum bulk dry densities for the soil samples ranged from 109.0 pcf to 121.0 pcf (Appendix A). As presented in the soil cover evaluation in Appendix C, average values were determined for different soil types within the acceptable gradation envelope and a weighted-average value of 113.7 pcf for maximum bulk dry density of soil material was determined using the proportion of borrow soil anticipated for these soil types. A density of 108.0 pcf corresponding to a compaction of 95 percent of maximum dry density was used in the radon attenuation soil cover design.

3.2.2 Testing of Potential Riprap Sources

As part of the reclamation investigation, in preparation for submittal of the 1987 proposed reclamation plan, borings were drilled into four outcrops on or near United Nuclear's property at locations considered to be both representative and reasonably accessible for development of a quarry for riprap. The purpose of the investigation was to determine the availability of on-site sources of rock for riprap. These borings include:

1. Boring No. RR-1 drilled in the southwest quarter of Section 2 just south of the main tailings embankment,

2. Boring No. RR-2 drilled in the northwest quarter of Section 36 east of NECR,

3. Boring No. RR-3 drilled in the northeast quarter of Section 8 northeast of OCR, and

4. Boring No. RR-4 drilled in the southeast quarter of Section 34 southwest of NECR.

The logs for these borings are included in Appendix A. The potential riprap borrow sources investigated were each comprised of sandstone. The sandstone units that were cored included the Upper and Lower Dalton, Zone 1 of the Upper Gallup Sandstone, and the Lower Gallup Sandstone. Each unit was easily cored. Visual inspection of the cores indicated that none of the units would be suitable for use as a source of riprap although testing of rock samples was still performed to verify this conclusion.

Rock samples of on-site sandstone units were prepared for slake durability testing to evaluate their suitability for use as a riprap borrow source. However, due to the poor quality of the sandstone units found on-site, none of the core samples remained intact during simple preparation of the samples. Accordingly, none of the on-site rock sources can be considered satisfactory for use as riprap borrow.

In response to NRC review comments regarding adequate rock for riprap material, United Nuclear investigated other off-site sources of rock. Three potential off-site riprap sources were identified. Samples from two limestone quarries and one basalt quarry have been obtained and tested. Laboratory testing of the limestone indicated a range of rock quality characteristics. Consequently, the NRC requested that additional rock sources be investigated to determine the cost-effectiveness of providing higher quality riprap. Testing of the basalt, from a commercial source in Grants, New Mexico, results in higher rock quality ratings compared to the limestone.

Limestone rock samples were obtained from two quarries that mine rock from the Todilto Limestone formation. The Todilto Limestone formation crops out in north-dipping exposures from the Cebolleta Mesa near Grants, New Mexico, to just east of Gallup, New Mexico. This limestone is a laminated to thickly bedded, finely crystalline limestone. A site inspection of the potential limestone borrow revealed that the laminated bedding planes within the limestone have good cohesion. Therefore, it appears that riprap of 30-inch diameter or greater will be available for use during reclamation.

The most commonly selected reference for evaluating the suitability of riprap materials is NUREG/CR-4620, "Methodologies for Evaluating Long-Term Stabilization Designs of Uranium Mill Tailings Impoundments," (NRC, 1986). This document cites the U.S. Bureau of Reclamation (USBR) durability standards as appropriate for use in stabilizing impoundments.

Samples of the limestone, and later the basalt, were tested for four of the five USBR durability properties. The tests samples included the following:

1. Specific gravity analysis
2. Absorption
3. Sodium and magnesium sulfate soundness
4. L.A. Abrasion

Test results and rock quality rating calculations for the limestone (best and worst cases) and basalt are provided in Tables 3.4 and 3.5, respectively. The rock quality ratings for limestone samples ranged from 57.3 using worst-case results for each individual test to 67.0 using best-case results for each test. The rock quality rating for the basalt sample was 93.2.

A petrographic evaluation of the limestone was also conducted (NRC, 1986). The limestone samples may be classified as a Group 3 rock (carbonate), fresh to slightly weathered, with no clays.

4.0

4.0 INTERIM STABILIZATION

As originally proposed in the 1987 Reclamation Plan, and initiated in 1989 in conformance with NRC license requirements, interim stabilization focuses on minimizing the potential for pathway releases while placing the first one foot of the radon attenuation soil cover. The interim stabilization concept has provided an opportunity for monitoring success of the program before initiating final reclamation. It has also provided, and will continue to provide, the opportunity to generate data that are useful in confirming or modifying final design parameters.

Activities associated with interim stabilization were selected and designed to mitigate releases in the near term that may affect health and the environment. Interim actions ameliorate current effects while assisting in preparing the site for final stabilization. Accordingly, a number of specific actions were and continue to be undertaken to address potential exposure pathways including emissions to the air via wind-blown tailings and radon gas, and tailings seepage.

Interim reclamation addresses existing and potential sources that may contribute to release pathways, and serves to prepare the site for final reclamation. Wind-blown tailings were minimized or eliminated by protecting the tailings from transport mechanisms using covers or otherwise preventing tailings from dispersal by erosion forces, i.e., wind and water erosion.

Regarding the seepage pathway, sources have been eliminated and future contributions will be prevented. United Nuclear has conducted extensive hydrologic investigation programs in response to NRC and EPA regulatory programs to determine the appropriate means for eliminating sources and mitigating the seepage pathways. These investigations have resulted in a number of significant findings that form the underlying basis for the seepage collection remedial action measures implemented as part of the interim stabilization and final reclamation plans.

Fundamental components needed for mitigating seepage pathways include:

1. Removing sources of continuing seepage,

2. Minimizing precipitation recharge,

3. Eliminating potential pathways of seepage migration through wells constructed before the plan, and

4. Providing active remediation of seepage.

The following actions have been accomplished during the first three years of implementation of interim stabilization, each of which is discussed in more detail in this section or Section 6.0:

1. Dewatered Borrow Pit No. 2 by spraying neutralized water on tailings to assist in controlling wind-blown tailings, using a spray mister system constructed over the tailings.

2. Collected wind-blown tailings north and east of the tailings disposal area in Sections 1 and 2, Township 16N, Range 16W, and Section 36, Township 17N, Range 16W property immediately adjacent to the tailings disposal area (Figure 1-4), and placed those affected soils in the tailings disposal area.

3. Regraded and recontoured the tailings materials in the North and Central Cells of the tailings disposal area to shed precipitation, reduce recharge, and

eliminate ponding. Recontouring was designed to place coarse tailings and other fill materials over fine tailings to reduce radon flux from the tailings disposal area.

4. Placed a 1-foot-thick radon attenuation soil cover over the regraded North and Central Cells of the tailings disposal area to stabilize the site during the interim period, reduce erosion, and further minimize radon releases. The South Cell will be regraded and covered in 1991.

5. Plugged selected wells to prevent them from becoming conduits for seepage migrations.

6. Initiated the Corrective Action Program (CAP) approved by the NRC and the Remedial Design (RD) approved by the EPA, which includes installation of extraction wells, and construction of evaporation ponds and an enhanced evaporation system to dispose of collected seepage.

7. Initiated mill decommissioning.

4.1 Dewatering of Borrow Pit No. 2

Borrow Pit No. 2 was dewatered to eliminate it as a potential source of continuing seepage. Dewatering the borrow pit removed the driving head that caused water recharge into Zone 1 of the Upper Gallup Sandstone (Canonie, 1987a). Borrow Pit No. 2 contained approximately 10 million gallons of neutralized water originating from the pumping well systems, which had been in operation since at least 1983. The water in Borrow Pit No. 2 had been treated to a neutral to basic pH of about 7.5 to 8.5 as part of on-going operations to eliminate acidity and to remove heavy metals and radionuclides. United Nuclear pumped water from the borrow pit and directed it through a spray system onto the tailings sands. This eliminated the pit water by enhanced evaporation and assisted in the suppression of dust during dry periods of the year. It also mitigated radon gas emanation by keeping the surface of the tailings moist.

The spray system was operated under NRC License approval to evaporate the maximum amount of water possible during the dry season while minimizing potential infiltration, which could result if the system was operated at excessive rates of spray during periods when conditions were not conducive to evaporation. The spray nozzles utilized by the system were selected to produce finely atomized droplets, enhancing the evaporation rate. The spacing of the nozzles was selected to provide maximum evaporative area without overlapping.

United Nuclear originally estimated that it would take a minimum of two evaporation seasons to complete dewatering of the borrow pit. United Nuclear successfully dewatered Borrow Pit No. 2 in 1989. It was necessary to temporarily store some water in the borrow pit during the winter of 1990-1991. Details on the progress of dewatering were included in annual progress reports to the NRC and EPA. The borrow pit was dewatered for the final time in early 1991, and is currently being backfilled with debris from the mill decommissioning.

4.2 Regrading and Recontouring Tailings

The interim stabilization plan involving regrading and recontouring of the tailings disposal area is shown in Figures 4-1 and 4-2 with a base map showing conditions prior to the reclamation activities. The North and Central Cells of the tailings disposal area have been regraded and recontoured in conformance with NRC License requirements as part of initial interim stabilization activities in 1989 and 1990, as shown on Figures 4-3 and 4-4, to prevent ponding of precipitation and provide positive drainage. The South Cell is currently being regraded and covered and will be completed by year-end 1991.

The resultant reconfiguration of tailings will provide a minimum seven-foot thickness of coarse tailings sands and/or clean fill material over fine-grained tailings and, once covered with soils, establish relatively flat slopes to prevent erosion.

Regrading and contouring the site produces several beneficial results. Radon gas emanation is reduced as a result of placement of coarse tailings sands, which have a lower radium content, over fine-grained tailings, which have a relatively higher radium content. Placement will reduce the radiological source term significantly. In addition, a more stable working surface is provided over the soft, fine-grained tailings. Most importantly, positive drainage of precipitation off of the North and Central Cells eliminates ponded water and minimize infiltration. As a result of NRC review comments on the proposed plan, the South Cell will be graded, covered, and will remain in the impounded configuration until final reclamation. In the proposed plan, the South Cell was to be graded to allow drainage of surface water. In deference to the NRC's desire and in conformance with NRC License requirements, the South Cell will remain impounded to provide secondary containment for the evaporation ponds.

The total area of tailings to be regraded is approximately 100 acres. Approximately 490,000 cubic yards (cy) of tailings will have been moved during this reconfiguration. Estimated earthwork quantities for interim stabilization activities are listed in Table 4.1.

Details of the tailings regrading program are provided in the Construction/Technical Specifications in Appendix B. Placement of coarse tailings sands over wet fine-grained tailings areas is accomplished by pushing the coarse material over the fine-grained tailings using a low-ground pressure bulldozer until a sufficient thickness of sands is established. The top one-foot-thick layer of the sands is compacted to 90 percent of the maximum dry density as determined using the Standard Proctor method (ASTM D 698) to provide a firm surface for placement of the interim soil cover. In areas where the surface of the fine-grained tailings is especially soft, it may be necessary to place geotextile fabric over the fine-grained tailings before placing the initial layer of coarse sands. The geotextile is used only to provide sufficient support for the tailings sands to allow the movement of construction equipment when moving tailings sand over the slimes. The geotextile fabric allows pore water to transfer from the moist slimes into the drier sands as it is loaded over the slimes, while keeping the materials segregated. This process results in partial dewatering and associated consolidation of the slimes over a relatively short time, while the geotextile is still competent. In the long term, when the geotextile begins to degrade, the pore water pressures in the slime materials will have equilibrated with the pore water pressure in the overlying sands. Because of this equilibration, no long-term detriment to the cover's stability will result.

Actual experience during interim stabilization of the North Cell indicated that only a very small area required the use of geotextile fabric. In the Central Cell, geotextile fabric was not required, and it is not anticipated that any will be required in the South Cell.

The recontoured configuration creates slopes in the tailings ranging from approximately 10:1 (horizontal:vertical) to as little as 120:1, or about 10 percent to 1 percent slopes, as shown on Figures 4-3 and 4-4. The reclamation plan calls for the earth embankment along the west and south sides of the tailings disposal area to be regraded from an exterior slope of about 3:1 to a flatter configuration of 5:1 or less. Drainage of precipitation across these slopes will be slow and controlled, minimizing infiltration and erosion. Excess soil generated by this earthwork is used as part of the interim stabilization soil cover. The exposed tailings surface is covered with an interim soil cover as soon as practicable to further limit erosion, reduce radon emanation, and reduce recharge.

Regrading operations also included the construction of evaporation ponds as illustrated on Figure 4-3 and described in more detail in Amendment I to the proposed plan on July 26, 1988 and subsequently approved by the NRC (See Section 6.0). As discussed above, the drainage channel for the South Cell will not be constructed until the evaporation ponds are no longer needed and are closed. When the channel is constructed, part of the channel will be excavated into the bedrock to maximize its stability and longevity.

The soil regrading during interim stabilization includes construction of haul roads and access to the tailings disposal area as shown on Figures 4-1 and 4-2. During regrading, the external slopes of the existing compacted soil embankment on the west and south sides of the tailings disposal area are graded to a slope of five horizontal to one vertical (5H:1V) or less. For example, at the north end of the tailings disposal area, one section of the embankment has been regraded to a slope of ten horizontal to one vertical (10H:1V) (Figure 4-3).

4.3 Removal of Soils Affected by Wind-blown Tailings

The prevailing wind direction and direction of highest wind intensity is from the southwest to the northeast. Limited amounts of tailings were transported to the northeast of the tailings disposal area, as identified by the radiological investigation described in Section 2.0 of this report. The area influenced by the wind-blown tailings is outlined on Figures 4-1 and 4-2. Soil within this area was stripped and placed in the North Cell and Borrow Pit No. 2.

United Nuclear completed and submitted Wind-blown Tailings Cleanup Verification Reports in December 1989 and November 1990, pursuant to NRC License Condition 33. As described in the verification reports, United Nuclear conducted additional radiological surveys, soil sampling and analyses in 1988 and 1989 to refine the areas potentially impacted by wind-blown tailings. The boundaries of the areas to be cleaned were staked by survey. Trees and large shrubs within these areas were removed and burned. Subsequently, at least six inches of soil was removed from the areas in

Sections 2 and 36 and placed in the North Cell as fill material during regrading. Soil, from the areas requiring additional excavation from Sections 2 and 36 as a result of verification surveys, and soil removed from Section 1 in 1990 was placed into the southwest corner of Borrow Pit No. 2 and sprayed with a polymer binding agent to prevent wind dispersal. Placement of soil into the borrow pit was required because the North Cell had been filled to design grade at the time the additional soil was excavated. Verification surveys were conducted after excavation of soil in the delineated areas to confirm removal of soil potentially impacted by wind-blown tailings. Wind-blown Tailings Cleanup Verification Reports were submitted to the NRC on December 21, 1989 and November 21, 1990 (United Nuclear, 1989 and 1990, respectively). After completing the verification survey, the excavated areas were fertilized with nitrogen and phosphate and revegetated with the native seed mixture provided in Table 4.2. The areas, from where soil potentially impacted by wind-blown tailings was removed, are outlined on Figures 4-1 and 4-2. The stippled areas shown on Figures 4-1 and 4-2, representing areas impacted by wind-blown tailings, are larger than the areas identified in the wind-blown cleanup reports. The areas outside those shown in the cleanup reports were excavated as part of regrading the tailings.

4.4 Placement of Interim Stabilization Soil Cover

During interim stabilization, a soil cover with a minimum thickness of 12 inches was to be placed over the reconfigured tailings disposal area. This cover prevents wind-blown migration of tailings, reduces erosion of tailings, lowers radon gas emanation, and reduces infiltration due to precipitation. It also represents the first 1.0 foot of radon attenuation soil cover to be placed over tailings. During interim stabilization of the North and Central Cells, a soil cover more than 12-inches thick was placed in many areas in order to reach the grades shown on Figures 4-1 and 4-2. Consequently, the final soil cover may be also thicker than required.

The soil cover to be is constructed of soil obtained in part from regrading of areas adjacent to the arroyo as shown on Figures 4-1 and 4-2. Other areas where soil cover material is to be obtained, include the excavation of surface water control channels and the soil stockpile. A detail of the interim soil cover design is shown on Figure 4-5. The total volume of soil needed for this cover is estimated to be approximately 161,000 cubic yards. The interim soil cover placed in 1989 and 1990 represents approximately 125,000 cy or 43 percent of the total soil cover. The remainder of the interim soil cover to be placed over the South Cell in 1991 will contribute approximately 36,000 cy or 12 percent of the total soil cover.

The soil cover is to be placed at or near its optimum moisture content and compacted with mechanical rollers. Details on the placement of soil cover materials are discussed further in Section 5.0.

4.4.1 North and Central Cell Interim Cover Soils

As previously discussed, interim soil cover was placed over the North and Central Cells in 1989 and 1990, respectively. During construction of the interim cover over the North Cell, several small volume borrow sources were utilized, including the northernmost portion of the west embankment of the tailings retention dam and the North Cross Dike, which separated the North Cell from the Central Cell. Both of these structures were made of soils that meet the soil cover envelope criteria previously discussed and depicted on Figure 3-2. A portion of the North Diversion Ditch extension was also excavated to provide additional soil material. The Central Cell soil-cover borrow was also obtained from the west embankment, as well as from the stockpile south of Borrow Pit No. 2. Excavation in these areas provided the 125,000 cy of material needed for interim cover construction in these cells. Figures 4-1 and 4-2 show the construction of the North and Central Cell interim soil covers.

Numerous geotechnical tests were performed on the actual interim soil cover materials to verify their suitability for soil cover material. Test results are summarized in Table 3.3. The location of the tests are shown on Figure 3-1. These data are representative of as-built soil cover conditions. The results of this testing indicate that the majority of the material placed to date classifies as silt or clay material, well suited, as anticipated, for use as a soil cover.

As shown on Figure 3-2, the average gradation of the North and Central Cell interim soil cover material falls well within the limits of the specified "allowable" soil cover gradation envelope. This graphic presentation of allowable soil-cover soil types provides a reliable method to evaluate gradation results before soil is placed in the soil cover. This method ensures the soil placed in the soil cover is consistent with the soil types modeled in the soil-cover design. The gradation envelope was developed in response to NRC review comments.

Atterberg limits and gradation analyses indicate that clays are the most common soil type used in the interim cover constructed to date. As shown on Figure 3-2 and summarized in Table 3.3, the average percent passing the No. 200 sieve is 56 percent, indicating the soils' fine-grained characteristics and suitability for the soil cover. Table 3.3 summarizes the results of the sampling and testing of the interim cover material. Appendix A contains the geotechnical laboratory reports. Thus, laboratory testing performed to date substantiates the suitability of these materials for soil cover. Additionally, these data were used to adjust the final soil cover design presented in Section 5.0.

Interim stabilization has provided the opportunity to develop data regarding the applicability of the reclamation design in the following areas:

1. Constructibility and the successful use of planned construction techniques,

2. Tailings consolidation and the attainment of 90 percent consolidation, and

3. Soil characteristics and the refinement of radon attenuation soil cover design.

The interim stabilization activities conducted in the North and Central Cells have essentially been a large field-scale test of the design. The experience gained in constructing the North and Central Cells, and the data collected during interim stabilization have met or exceeded the conditions anticipated in the design. The refined soil characteristics were used to refine the soil-cover design and gain approval of the design by the NRC.

4.4.2 Interim Stabilization Revegetation

After placement of the interim soil cover, the soil cover and disturbed areas proximate to the North and Central Cells were revegetated. A total area of up to approximately 75 acres was revegetated as part of interim stabilization activities. Approximately 28 acres in the North Cell and areas where wind-blown tailings were removed were revegetated with the seed mixture of native plant species, as identified in Table 4.2. Approximately 45 acres of the interim stabilization cover in the Central Cell was revegetated with the relatively temporary mixture of rye grasses presented in Table 4.3.

Areas that have been heavily compacted by equipment operation were first scarified and/or disked as necessary to provide a suitable planting medium. Areas where wind-blown tailings were removed were ripped with a bulldozer or equivalent equipment with ripper shanks to create parallel cuts along the contours. The area was disked to provide a suitable surface for drill or broadcast seeding.

Drill seeding and broadcast seeding methods were both employed during revegetation. When the drill seeding process was used, the seeding was conducted along the contour or at a right angle to the prevailing wind. When broadcast seeding was used, seeding was accomplished using a cyclone-type broadcaster. After seeding, the area was conditioned by raking and harrowing to ensure proper coverage of the seed with soil. Revegetation of the interim stabilization cover in the South Cell is not planned. Since the cover surface will be sloped only very slightly, no drainage from the South Cell will occur until final reclamation.

4.5 Well Plugging

Recontouring and regrading has occurred over areas where several monitoring and pumping wells were located. These wells were sealed or plugged prior to performance of the earthwork. Some wells along the North Cross Dike and within soil stripping areas required plugging. In addition, United Nuclear plugged selected unneeded wells. All wells were plugged in conformance with approvals received from NRC. Plugging procedures were conducted in compliance with New Mexico State Engineers Office (NMSEO) regulations.

4.6 Seepage Remediation

During the initial interim stabilization activities, United Nuclear initiated the CAP approved by the NRC and the RD approved by the EPA. The actions included the installation of additional extraction wells and construction of evaporation ponds and an enhanced evaporation system to dispose of collected seepage as shown on Figure 1-4. The seepage cleanup activities are described in detail in Section 6.0.

4.7 Mill Decommissioning

In the proposed reclamation plan of 1987, the mill was scheduled to be decommissioned by the end of 1997. Subsequently, the NRC required that decommissioning of the mill be complete by the end of 1992 in License Condition 26. United Nuclear submitted a Mill Decommissioning Plan in December 1988 and subsequently received approval from the NRC, pursuant to License Condition 26, to decommission the mill (United Nuclear, 1988). This plan was initiated in 1991 and will be completed during the interim stabilization period, in accordance with the schedule in NRC License Condition 33.

The mill area at United Nuclear's Church Rock facility will be decommissioned by demolishing the facilities (with the exception of the administration building, warehouse, lube storage area, tire storage shed, and guard/change house building), disposing of the debris in Borrow Pit No. 2, and regrading and revegetating the mill area. The Mill Decommissioning Plan is described in detail in Section 7.0.

4.8 Interim Stabilization Monitoring

As part of interim stabilization, monitoring will be conducted to evaluate the benefits derived from the tailings regrading and soil cover placement. In addition, United Nuclear will continue its current monitoring programs as required by its source materials license. These programs are expected to provide further data to supplement the interim stabilization monitoring program described here.

Settlement of the tailings, and thus the overlying soil cover, can occur by three different methods, which can each apply added weight to the tailings and cause them to consolidate. They are:

1. Natural draining of the hydraulically placed tailings,

2. Placement of additional tailings and other fill materials during regrading operations, and

3. Placement of the interim and final soil covers.

Since tailings disposal was terminated in 1982, much of the settlement from natural draining of the hydraulically placed tailings has already occurred and will continue to occur at an ever-decreasing rate. Placement of coarse tailings and other fill materials over slimes during regrading will be accomplished before final soil-cover placement. Accordingly, the majority of settlement which may influence the integrity of the final soil cover will be due to the weight of the soil cover itself.

Two procedures will be implemented to ensure that future anticipated settlements will not adversely affect the performance of the radon barrier. These procedures relate to the soil placement techniques to be used and concurrent settlement monitoring.

Construction of the first 12-inch-thick lift (interim cover) has commenced in stages across the site commencing from north to south as required by the NRC in License Condition 16. This phased construction will aid the settlement process by slow application of loading on the underlying tailings. United Nuclear has already placed the interim soil cover over the North and Central Cells of the tailings impoundment. United Nuclear will place an interim soil cover layer over a regraded South Cell in 1991. Settlement monitoring will be performed to verify that 90 percent of primary consolidation has occurred before placement of the remaining radon barrier and erosion protection layers during final reclamation.

Figure 4-6 shows the type of survey monument used to monitor settlement. The monuments are used to monitor actual settlement occurring due to regrading of the tailings materials and placement of the interim soil cover. In addition, the monument allows settlement monitoring for a period of time after placement of the interim cover, depending on the observed rate of settlement. The locations for the settlement monuments were originally identified in the proposed plan in 1987 and were revised on June 29, 1988 in response to NRC comments. The approximate locations of the settlement monuments are shown on Figures 4-1 and 4-2. The monuments are placed at locations of expected maximum settlement and at locations that can monitor the areal extent of settlement. They were installed before tailings regrading. Settlement monuments SM-3 and SM-4 will be installed when the evaporation ponds are regraded and closed.

Monitoring settlement monuments has been, and will be, performed daily during the first week following tailings regrading. Monitoring frequency will change after the first week to a minimum monthly schedule, until approximately 90 percent of the tailings consolidation has occurred, as determined using semilogarithmic plots of settlement versus time, or until sufficient documentation exists to demonstrate that no adverse effects are occurring to the cover from settlement. In the event that settlement does occur, additional soil-cover material will be placed and compacted in low areas to maintain the grades shown on Figures 4-1 and 4-2. This process will be repeated until 90 percent consolidation has occurred and low areas of the interim soil-cover surface have been filled to the design grades.

These procedures have been followed in placing the interim cover over the North and Central Cells. NRC staff has inspected the monitoring data generated to-date during their site inspections. At present, the monitoring data indicate that 90 percent consolidations have occurred in the North and Central Cells. Data generated in the future will also be made available.

5.0

5.0 FINAL RECLAMATION PLAN

Final reclamation activities will be initiated after completing interim stabilization measures and interim stabilization monitoring. Final reclamation of the South Cell will not be conducted until the NRC CAP and the EPA remedial actions, described in Section 6.0 of this report, have been completed. The site configuration following completion of final reclamation activities will be as shown on Figures 5-1 and 5-2.

Final reclamation activities will include the following:

1. Complete backfilling and grading Borrow Pit No. 2 to final contours,

2. Regrade and place the radon attenuation soil cover over the evaporation ponds,

3. Place the final 6 inches of radon attenuation soil cover and the soil/rock matrix erosion protection cover,

4. Construct surface water control channels, diversion ditches, drainage swales, Pipeline Arroyo low-flow channel, and the buried jetty, including placing riprap,

5. Revegetate disturbed areas and secure reclaimed areas.

This section of the reclamation plan describes work performed as part of final reclamation activities. It provides the technical basis for designing those activities, particularly with respect to compliance with 10 CFR 40, Appendix A. The plan meets the objectives of 10 CFR 40, Appendix A, to the extent practicable, by minimizing final slopes, containing and controlling major flood events, minimizing radon emanation from the tailings disposal area, and maximizing stability of the reclamation for the long-term.

5.1 Completion of Backfilling and Grading Borrow Pit No. 2

After dewatering in 1991, backfilling of Borrow Pit No. 2, shown on Figure 5-1, began with mill demolition debris, ore and tailings from within mill area drainages, excess material from the ore storage pad, and alternating layers of backfill soil from the site. During final reclamation, additional backfill will be placed and compacted in the borrow pit to meet the contours shown on Figure 5-1. Soil from the adjacent clean-soil stockpile will be used as required. An estimated 155,000 cy of additional fill will be required to bring Borrow Pit No. 2's surface up to the planned final grade.

5.2 Regrading Evaporation Ponds

At the completion of the seepage remediation program, described in Section 6.0 of this report, the evaporation ponds constructed in the South Cell (Figure 4-3) will be closed to allow placement of the final reclamation cover. Closure of the evaporation ponds will include the following tasks:

1. Grading the pond embankments into the ponds by spreading the embankment material in lifts and compacting the material with mechanical equipment.

2. Covering the compacted materials with 1.5 feet of radon attenuation soil cover. This soil cover will be placed using the same technical specifications used in placing the soil cover over tailings. The 6-inch soil/rock matrix will be placed over the ponds when it is placed on the remainder of the South Cell.

The hypalon liners will be buried in-place in the pond backfill. The closed ponds will be graded to provide a uniform surface that conforms to the rest of the regraded tailings cells, shown on Figure 5-1.

5.3 Final Tailings Cover Design

The final radon attenuation soil cover incorporates the previously constructed interim cover by adding 6 inches of radon attenuation soil cover to the 12 inches of cover placed during the interim stabilization phase (Figure 5-3). In addition, a 6-inch-thick soil/rock matrix erosion protection layer will be constructed using on-site soils from various net excavation areas (drainage channels) and the existing soil stockpile. Rock used in the soil/rock matrix will be derived from off-site quarries. This erosion protection layer will be installed over the 1.5-foot radon attenuation soil cover, in accordance with the Construction/Technical Specifications provided in Appendix B, and integrated as part of the final soil cover. The resulting 2-foot-thick cover meets the design requirements stipulated by 10 CFR 40, Appendix A, in that the first 1.5 feet of radon attenuation soil cover provides reasonable assurance for effectively controlling radiological hazards for 1,000 years, and that releases of Rn-222 to the atmosphere will not exceed an average release rate of 20 picoCuries per square meter per second ($pCi/m^2/sec$) throughout the effective design life of the cover. Also, the 6-inch soil/rock matrix is designed to protect the radon attenuation layer for 1,000 years.

The design procedure employed for the final reclamation cover consisted of the following basic steps, using the RADON computer model:

1. Determining the characteristics of coarse and fine tailings to identify the source term used in the RADON computer model for radon flux calculations from the tailings.

2. Determining the characteristics of soil borrow materials to calculate the bulk radon diffusion coefficient for the soil cover.

3. Identifying the required thickness of the soil cover to limit radon flux to 20 pCi/m^2/sec in excess of that emitted by the cover soils.

4. Calculating the total cover thickness to account for long-term performance, infiltration, dispersion and frost heave.

The proposed design, submitted to the NRC in 1987, used soil characteristics determined from the field explorations conducted during the reclamation investigation and previous site investigations. Subsequently, the design was modified using actual field construction data obtained during the two years of interim cover placement over the North and Central Cells.

5.3.1 Tailings Characteristics

Based on characterization of ore during mill design (Kaiser, 1976), mineral composition of the ore host rocks consists of 78-79 percent quartz, 2-3 percent calcite, and 18-20 percent kaolinite and feldspars. Accordingly, the tailings are expected to approximately reflect these coarse-to-fine ratios of about 80 percent coarse tailings and 20 percent fine tailings.

The coarse tailings typically exhibit lower radon flux than the fine-grained fraction. Regrading the tailings as part of interim stabilization activities was designed to cover the limited fine-grained tailings deposits with a minimum seven-foot thickness of coarse tailings and/or other fill materials, minimizing radon flux from the tailings and reducing the ultimate required soil-cover thickness.

In the first two years of tailings regrading, the quantity of coarse tailings available in the work area was insufficient to cover the fines with seven feet of coarse tailings. Consequently other fill materials, including wind-blown tailings, affected soils, and clean soil were used to provide the additional fill necessary. The interim stabilization soil cover was placed over this fill material. The imported fill materials have much lower radium contents and lower diffusion coefficients than those modeled in the soil cover design which assumed a coarse tailings layer of seven feet thickness over the fine tailings. Use of fill material to augment the coarse tailings in the minimum 7-feet-thick layer of material over the fine tailings resulted in a layer with greater radon-attenuation properties than properties of the coarse tailings materials used for design purposes.

5.3.1.1 Coarse Tailings

A laboratory testing program was conducted to evaluate various geotechnical and radiological parameters of the coarse tailings, which affect cover design. Table 5.1 presents the results of these tests.

The long-term moisture content of the coarse tailings can be expected to approach that of natural near-surface soils with a similar particle size gradation. The long-term moisture content of the coarse tailings was determined based on NRC acceptable methodology, as described in Regulatory Guide 3.64 or equivalent.

NRC guidance (Regulatory Guide 3.64) describes three acceptable methodologies for evaluating long-term moisture contents:

1. In-situ moisture content
2. The Rawls equation
3. Laboratory testing

The use of the laboratory test methodology was discounted in conducting the evaluation as a result of the NRC's review comments regarding its representativeness.

In-situ moisture contents of 79 samples of native sandy soils on-site were compiled to estimate the long-term moisture content of the coarse tailings, as shown in Appendix D. The moisture contents of these soil samples are representative of long-term moisture contents of coarse-grained tailings. (These soils were chosen for use in establishing an average value because their texture and gradation were similar to that of the coarse tailings.) The average in-situ moisture content was found to be 10.1 percent by weight. This value was used for the long-term moisture of the coarse-grained tailings in the June 1987 proposed plan. In reviewing that design, the NRC questioned whether the value was truly representative of long-term conditions.

To address NRC's review comments, another acceptable method of evaluating long-term moisture was implemented. The Rawl's empirical equation was then used to compute the long-term moisture content of the coarse-grained tailings, conservatively assuming only a 15 percent, minus 200 fraction. The resultant long-term moisture content was determined to be 6.5 percent by weight. This value is close to the NRC default value of 6 percent. The default value of 6 percent was used to evaluate the radon barrier. The diffusion coefficient was also calculated using this more conservative long-term moisture content.

Test results presented in Table 5.1 provide dry-bulk densities obtained from in-situ coarse tailings samples during investigation activities. As indicated in the Construction/Technical Specifications (Appendix B), the surface of the graded coarse tailings are to be compacted to a minimum 95 percent of the maximum dry density, as determined by the Standard Proctor compaction method (ASTM D 698). The dry-bulk density of coarse tailings used for the cover design was 97.5 pcf, and can be obtained by track-mounted dozers and other construction equipment. This density is consistent with observed in-place densities of the coarse tailings as identified in Table 5.1.

Given the dry density and the moisture content, various other physical parameters were calculated for the coarse tailings as follows:

Dry Bulk Density at 95 Percent Compaction:	97.5 pcf, (1.56 g/cm^3)
Long-term Moisture Content (NRC default value):	6 percent
Void Ratio:	0.79
Porosity:	47 percent

The porosity value of 47 percent and the resulting void ratio of 0.79 are the upper-bound 95 percent confidence interval values. Using these parameters, a radon diffusion coefficient was computed for the coarse tailings using guideline procedures stipulated in NUREG/CR-3533 (NRC, 1984b) for radon attenuation cover design. The radon diffusion coefficient of .0360 cm^2/sec for the coarse tailings was computed using the RADON computer model. This value was used for cover design purposes and is higher (i.e., more conservative) than the majority of actual values measured in the laboratory (see Table 5.1). Use of this value produces a thicker soil cover than if the measured laboratory values were used. However, the values measured in the laboratory were typically tested at higher moisture contents than the default value of 6 percent or the calculated value of 6.5 percent. As discussed previously, the representativeness of values measured in the laboratory had been questioned by NRC. Nonetheless, the measured bulk diffusion coefficient of 0.023 cm^2/sec for the coarse tailings at a moisture content of 10.5 percent is lower than the 0.036 cm^2/sec used for cover design purposes, demonstrating that the cover design values for diffusion coefficient and moisture content are conservative.

The radium content and radon emanation coefficient were determined in the laboratory by Rodgers and Associates, Salt Lake City, Utah (United Nuclear Corporation, HSA, 1985) for the coarse tailings. These values were used in the RADON computer code to determine radon flux through the soil cover. The tested coarse tailings have an average radium content of 154 pCi/g, and a radon emanation coefficient of 0.26. This value represents the average of nine samples, as shown in Table 5.1.

5.3.1.2 Fine-Grained Tailings

The same three methods used to determine long-term moisture content for coarse-grained tailings were also used for fine-grained tailings. The use of this approach is also the result of NRC review of the design proposed in 1987. These methods included use of Equation 5 from NRC Regulatory Guide 3.64 (Rawl's equation), in-situ moisture content measurements, and laboratory testing to determine the wilting-point moisture content. Comparison of these methods substantiates the long-term moisture content selected for input to the RADON model as representative of long-term conditions. The following discussion provides the result of the comparison and identifies the parameters used to design the soil cover.

Table 5.2 and Appendix D present the in-situ moisture content of fine-grained tailings samples. The average in-situ moisture content was 38.7 percent with a 95 percent confidence interval of 29.7 percent to 47.7 percent. A value of 29.7 percent was used for comparison to the calculated long-term moisture content.

Using the empirical Rawl's equation for comparison, the volumetric long-term moisture content of the fines fraction for the fine-grained tailings was calculated at 32.6 percent. Converting this volumetric moisture content to a long-term weight-ratio moisture content yields a moisture content of 23.6 percent by weight. Appendix C presents this calculation. This value is comparable to a long-term, weight-ratio moisture content of 29.7 percent derived from in-situ data for the fine-grained tailings.

On further review, the NRC commented that although the fine-grained tailings classify as a clay, the total fines fraction is not appropriate for use in the Rawl's equation. Further, only the clay portion of the fines fraction [0.002 millimeter (mm) or less in size] should be used and, therefore, the value of 23.6 percent is not appropriate. Since the samples used in calculating long-term moisture content were not all clay-size, the use of a lower moisture content (i.e., the default value) was considered more appropriate by NRC. Therefore, the cover was designed using the NRC's 6 percent default value. The diffusion coefficient for the fine tailings was also calculated using the 6 percent long-term moisture content.

Table 5.2 also presents additional fine-grained tailings characteristics used to select parameters for cover design. The average dry-bulk density for the selected samples was found to be 86 pcf. A review of available data indicates that the dry bulk density typically ranges from as low as 74 pcf to as high as 97 pcf (Appendix C). Although the design cover thickness is not highly sensitive to the dry bulk density of the fine-grained tailings, the value of the average dry-bulk density was increased 5 percent (i.e., to 90 pcf) when used for design purposes to account for consolidation. The 48 percent porosity of fine-grained tailings was calculated using the calculated bulk density and the average specific gravity.

Geotechnical parameters of fine-grained tailings for calculating an associated bulk diffusion coefficient using the RADON computer model are summarized as follows, based on data presented in Table 5.2, and the previously described selection criteria:

Maximum Bulk Dry Density Plus 5 percent:	90 pcf (1.45 g/cm^3)
Weight Percent Moisture (NRC default value):	6 percent
Porosity:	48 percent

The bulk radon diffusion coefficient was calculated using the RADON computer model with the default value for the moisture content and calculated porosity. The diffusion coefficient was calculated to be 0.0400 cm^2/sec, which is much higher (i.e., more conservative) than the actual measured value.

The radium content and radon emanation coefficient were determined in the laboratory by Rodgers & Associates, Inc., Salt Lake City, Utah, for United Nuclear (United Nuclear Corporation, 1985) on the fine-grained tailings. These values are used in the RADON computer model to determine radon flux through the soil cover.

The fine-grained tailings were tested and found to have an average radium content of 547 pCi/g, and a radon emanation coefficient of 0.26. These values represent the average of seven samples, as shown in Table 5.2.

5.3.2 Radon Attenuation Soil Cover Characteristics

Soils used for the radon attenuation layer (i.e., 1.5 feet) of the reclamation cover will be obtained from the north area flood plain, excavation of several surface water channels, the tailings embankment and the existing soil stockpile. The geotechnical characteristics of these soils for use in cover design were defined by a field investigation program, as documented in Appendix A, a laboratory testing program, and a literature review of previous geotechnical engineering reports (Sergent, Hauskins, and Beckwith, 1979).

As described in Section 3.0 and indicated by the laboratory data in Appendix A, representative borrow soils contain approximately 40 percent sand and 60 percent silts and clays. Representative soils with this approximate gradation were tested to identify anticipated properties of the soil cover summarized as follows:

Maximum Bulk Dry Density (Average value):	113.7 pcf
Bulk Dry Density at 95 percent Compaction:	108.0 pcf (1.73 g/cm^3)
Natural Moisture Content:	13.4 percent
Void Ratio:	0.65
Long-term Moisture Content:	12.9 percent
Porosity:	33.0 percent
Specific Gravity:	2.63
Degree of Saturation:	54.0 percent

The cover soil bulk dry density was determined by considering only test results from materials that satisfy the specification's requirements. Figure 3-2 shows acceptable gradation ranges for the soil cover material as approved by NRC. Appendix C presents the calculation of dry-bulk density.

5.3.2.1 Diffusion Coefficient

The diffusion coefficient has the greatest impact on the cover thickness. In refinements to the soil-cover design since submitting the proposed plan in 1987, the diffusion coefficient was calculated using higher in-place densities derived from actual interim cover testing (Appendix C), and lower porosities compared to the more conservative parameters estimated in the original design. The original estimated in-place density and porosity were 99.0 pcf and 0.39, respectively. The revised in-place density and porosity using actual soil data from the interim stabilization cover already placed are 108.0 (95 percent of maximum dry density) and 0.33, respectively. This revision results in a revised, lower diffusion coefficient of 0.0036 cm^2/sec compared to an original diffusion coefficient of 0.0093 cm^2/sec (Appendix C). Table 5.3 summarizes the values used in the final soil-cover design as approved by NRC. The lower diffusion coefficient reduces the amount of radon that can emanate through the soil, which significantly decreases the thickness of the soil cover needed.

5.3.2.2 Soil Cover Long-Term Moisture

The long-term moisture content of the soil-cover material was evaluated using three of the NRC-accepted methodologies presented in NRC Regulatory Guide 3.64 (i.e., the Rawl's equation, in-situ moisture contents, and laboratory-derived, long-term moisture contents). Use of the Rawl's empirical equation produces a long-term, weight-ratio moisture content of 17.9 percent when the average fines fraction from the acceptable soil-cover grain-size envelope is used (Figure 3-2). NRC comments in reviewing the proposed plan indicated that, even though the soil-cover material generally classifies as a clay, the total fines fraction is not appropriate for input into the Rawl's equation. Accordingly, only the clay portion of the fines fraction (0.002 mm or less in size) should be used and, therefore, the value of 17.9 percent was not considered appropriate by the NRC.

Laboratory testing (Method ASTM-D3152) of a representative soil sample to determine the long-term moisture content of the soil cover produced a value of 13.6 percent by weight. Appendix C provides the laboratory test data. The tested sample had a fines fraction of 65 percent. Compared to the allowable soil-cover gradation presented on Figure 3-2, the particle-size distribution of this sample indicates it is acceptable for use in the soil cover. In subsequent review, the NRC commented on the representativeness of the tested soil sample due to the 65 percent fines content, which is near the upper 95 percent confidence limit of fines in the acceptable soil-cover grain-size envelope. Only one long-term moisture content, as determined by laboratory procedures, was available and the NRC questioned its representativeness. In addition, the NRC commented that the Rawl's equation using the fines fraction as input calculates an inappropriate long-term moisture content value. NRC further indicated that this value is not acceptable alone for input to the RADON model.

Evaluation of in-situ moisture content measurements from 119 representative borrow soil samples identified a long-term moisture content of 13.4 percent by weight. This value is the average moisture content of the samples tested, as provided in Appendix D. Samples were obtained from available borrow soils within Pipeline Arroyo, the tailings embankment and the soil stockpile located east of the tailings impoundment.

NRC commented on the representativeness of these soils, and indicated that only samples meeting the acceptable soil cover grain-size envelope and obtained from a depth between 120 centimeters (cm) and 500 cm should be used to evaluate long-term moisture based on observed moisture contents. Evaluation of in-situ moisture content measurements was refined to include only the data meeting these criteria. Forty-seven soil samples were identified as meeting the gradation and depth requirements, and are located in potential borrow areas. The average in-situ moisture content of these samples was 12.9 percent. Appendix D presents this calculation.

The 12.9 percent value was used in designing the radon attenuation layer, and was obtained from the average of the above-mentioned 47 samples for which in-situ moisture data are available. This value was derived using an NRC-accepted methodology, and NRC approved its use as the long-term moisture content. The soil-cover diffusion coefficient was also calculated using this 12.9 percent long-term moisture.

5.3.3 Radon Attenuation Soil Cover Calculation

The required soil-cover thickness for the radon attenuation layer was determined using the RADON computer model for the tailings regrading plan, and tailings and soils characteristics described previously. The radon attenuation layer of the final soil cover, illustrated on Figure 5-3, was designed to limit the long-term radon flux to 20.0 pCi/m^2/sec. Table 5.3 lists the input parameters used for the RADON computation. The radon attenuation soil cover portion of the tailings cover has been reduced to a total thickness of 1.5 feet to be constructed over regraded tailings (Appendix C) as approved by NRC. The radon attenuation layer will be overlain by a 6-inch soil/rock matrix, which will serve as an erosion control layer, as described below. The soil/rock matrix will aid in further reducing radon emanation, but has not been included in the analyses.

The areas within the tailings disposal area with the highest radon source (i.e., the fine-grained tailings areas) will be covered with a minimum of 7 feet of coarse-grained tailings, or other fill material, before placing the soil cover. This layer essentially attenuates all the radon emanating from the fine-grained tailings. The soil cover will, therefore, only be required to attenuate radon emanating for the lower radon source coarse-grained tailings. Placing a minimum 7-foot-thick coarse-grained tailings layer, or other fill material, over the fine-grained tailings enables a thinner, single, radon-attenuating soil layer to be designed, instead of having two soil-cover thicknesses (i.e., one for attenuating radon from coarse-grained tailings and one for the higher radon source, fine-grained tailings).

In addition, the minimum 7-foot-thick layer of material placed over the fine-grained tailings will in actuality consist of a combination of coarse-grained tailings overlain by clean borrow soil. This was the case when regrading the North and Central cells during the initial phases of interim stabilization. Typically, clean borrow soil has been required in excess of the regraded coarse tailings to attain the specified design grades. This excess adds additional conservatism to the cover design, in that the thickness of clean soils over the regraded tailings is typically thicker than the design thickness of 1.5 feet. This conservatism has not been accounted for in the RADON model.

In summary, the final radon attenuation soil cover has been designed using:

1. Conservative radon-source parameter values for the fine- and coarse-grained tailings.

2. A minimum 7-foot-thick layer of coarse-grained tailings over the fine-grained tailings. In many areas, however, this layer will actually consist of a combination of coarse-grained tailings and other fill material. As such, radon source parameter values will be significantly less than has been assumed for the design purposes.

3. Actual soil-cover radon attenuation properties achieved during placement of the interim stabilization cover in the North and Central Cells.

Use of interim soil-cover radon attenuation properties, which is more effective at attenuating radon than those conservatively assumed in the original design, results in a soil cover design thickness of 1.5 feet (Appendix C). This soil cover, along with the soil/rock matrix for erosion protection, will provide a final soil cover that meets the requirements set forth in Appendix A of 10 CFR 40 (Figure 5-3).

The acceptable soil types for use in the soil-cover construction will classify as silty clay (CL), clayey sand (SC), silt (ML), or silty sand (SM), in accordance with the Unified Soil Classification System (USCS). Figure 3-2 shows the gradation limits of the mixed soil to be placed in the soil cover, as approved by the NRC.

5.3.4 Soil Cover Quality Control Program

The quality control program originally outlined in the specifications for the 1987 proposed plan represented the design engineer's minimum acceptable program to confirm that the construction meets the design intent. United Nuclear has been conducting interim reclamation of the tailings impoundment and performing quality control monitoring, at the direction of the NRC, since 1989. A minimum of one foot of radon attenuation soil cover has been placed over regraded tailings in the North and Central Cells. In placing that cover, United Nuclear has conducted a quality control program that exceeds the minimum acceptable program stipulated by the original design specifications, and more closely complies with the guidance provided by NRC's Staff Technical Position Paper (STP) on Testing and Inspection Plans.

The NRC has inspected this work on two occasions and has found the field quality control program to be in compliance with the NRC requirements. However, NRC indicated greater quality control monitoring in the field than that proposed in 1987 would be required for the approved, thinner soil cover. United Nuclear has agreed to an expanded quality assurance/quality control (QA/QC) program for reclamation activities conducted after March 1, 1991. The QA/QC program has been revised to reflect NRC guidance in the STP Testing guidance.

Table 5.4 summarizes the required testing frequencies in the Field Testing and Inspection Plan (FTIP) for the soil cover. United Nuclear may petition the NRC for a license amendment for reducing required QA/QC activities to those originally proposed, if testing and inspection activities consistently meet QA/QC criteria during reclamation.

Accordingly, the quality control program described in more detail here, reflects the quality control procedures implemented in the field beginning 1991. With the exception of field moisture/density testing, the quality control program described below is consistent with the program that has been conducted to-date in the field, and that was approved during the NRC's inspections. The tests presented here will be implemented for all future reclamation activities, and will be used to verify the criteria used in the design of the radon barrier. The quality control data are expected to be adequate to meet this verification requirement.

5.3.4.1 Soil Cover Materials

In reviewing the proposed design, NRC requested procedures for determining acceptability of borrow material used as soil cover, should borrow sources differ from those identified in this plan. It is not expected that other sources of borrow material will be required other than those identified in this plan. However, if other borrow sources are required, gradation and classification tests will be performed to ensure that these materials meet project specifications. Samples will be obtained by means of borehole drilling and sampling, or by test pit excavation, and sampling and analyses for gradation and classification. The on-site quality assurance engineer will review and accept or reject the test results before placement of imported fill as soil cover material. In addition, to address NRC review comments, a graphic presentation of allowable soil-cover soil types provides a reliable method to evaluate gradation results before soil is placed in the soil cover. This method ensures the soil placed in the soil cover is consistent with the soil-cover design (Figure 3-2).

5.3.4.2 Standard Proctor Compaction Testing (ASTM D 698)

The frequency of Standard Proctor laboratory tests to confirm the moisture versus density relationship of the soil, will be a minimum of one compaction test for every 15 field moisture/density (i.e., compaction verification) tests performed as recommended by NRC's Testing STP. NRC's Testing STP frequency is one Standard Proctor test for every 10 to 15 field moisture/density tests performed.

The actual frequency for Standard Proctor compaction tests, during the 1989 and 1990 interim stabilization activities at the Church Rock site was one test for every four field moisture/density tests performed, exceeding NRC's Testing STP guidance. Fifteen tests were conducted during the placement of approximately 125,000 cy of soil cover, or one standard Proctor compaction test for every 8,000 cy of material placed. The actual compaction testing frequencies during initial interim stabilization activities satisfied the NRC during their inspections.

5.3.4.3 One-Point Proctor Testing

NRC's Testing STP specifies that a one-point Proctor test be performed for every five field moisture/density tests. The Standard Proctor testing frequency employed by United Nuclear in 1989 and 1990 of one full Standard Proctor test for every four field moisture/density tests exceeds the total recommended frequency of testing for both one-point and Standard Proctor compaction tests. One-point tests will be conducted at the minimum frequency of one test for every five field moisture/density tests conducted during future reclamation activities.

5.3.4.4 Field Moisture/Density Verification Test

NRC's Testing STP recommends that one moisture/density (compaction verification) test be completed for every 500 cy of fill placed, and that a minimum of two moisture/density tests be conducted each day. United Nuclear has been conducting field moisture/density testing at the frequency of one test for every 2,000 cy of fill placed and performing at least two tests daily. This frequency exceeds the design engineer's minimum specification requirements included in the 1987 proposed plan and is in accordance with Bureau of Reclamation (BUREC) dam construction standards.

Use of the BUREC standard for tailings cover material is appropriate at the Church Rock site because the relative risks posed by failure of a soil cover, compared to the risks associated with dam failure, are much smaller. That is, construction specifications accepted for structures used to impound water are considered sufficiently conservative for use in the constructing covers for tailings sands.

Additional support for use of this BUREC standard arises from the FTIPs for constructing the original embankments used to retain the tailings. Tailings retention embankment construction standards for many tailings disposal sites, including Church Rock, employed testing frequencies similar to the BUREC standard, rather than NRC's Testing STP guidance. These tailings embankments will remain part of the impoundment reclamation, having a 1,000-year design life. Therefore, United Nuclear did not consider it necessary to use more conservative testing frequencies for the reclamation cover than those used for constructing the original retention embankments.

Thus, this field moisture/density testing frequency to confirm that soil for earthen embankments has been sufficiently compacted will also be used at the Church Rock site, as approved by NRC. This standard is one test for each 2,000 cy of fill or a minimum of two tests for each day of fill placed in excess of 150 cy. At this frequency, over 300 field density and moisture verification tests would be completed once the final soil cover is in place.

Due to NRC's review comments regarding the thinner soil cover as described above, the field moisture/density testing frequency will be increased to an average of one test per 500 cy of soil cover placed for the project. During initial interim stabilization activities, a total of 62 moisture/density tests were taken in the interim cover for 125,000 cy of soil cover material placed, which is equivalent to a testing frequency of one test per 2,000 cy, which meets the BUREC frequency. It will be possible to attain the higher testing frequency of one test per 500 cy, based on an average of all tests taken for the project. The higher frequency will be accomplished when the interim soil cover is conditioned (i.e., moisture-adjusted and compacted) immediately before placement of the final soil cover. Additional in-place density tests will be completed at this time to meet required project frequencies, ensuring the material placed meets the requirements modeled in the design.

5.3.4.5 Nuclear Density Gauge Correlation

As stipulated in NRC's Testing STP, moisture/density compaction verification testing performed by nuclear density gauge methods was correlated to one in-situ field density Sand Cone test (ASTM D 1556) and one oven-dry moisture test for every 10 nuclear density gauge tests performed. During initial interim stabilization activities, 20 Sand Cone tests were conducted on the interim soil cover in the North and Central Cells. Sand Cone tests were used exclusively to verify moisture/density compaction of the North Cell interim cover, when a good correlation between the nuclear gauge and Sand Cone tests could not be obtained. Future moisture/density verification testing will meet the frequency requirement of NRC's Testing STP.

Based on performance to-date for interim construction activities, test results obtained by the nuclear densimeter are erratic. The as-built report for the North Cell Interim Reclamation Activities documented the erratic nature of the nuclear densimeter testing. Therefore, only the Sand Cone method of in-place density determinations was used in the 1990 construction activities, and will be used in all future construction.

5.3.4.6 Gradation and Soil Classification

As described previously in Section 3.0, a detailed evaluation of expected soil types and gradations was performed as part of the original design. This evaluation was based on over 50 gradation analyses obtained from test pits and borings installed within the proposed borrow areas shown on Figure 3-1. The test data, summarized in Tables 3.1 through 3.3 and Figure 3-2, demonstrate the relative uniformity of grain size distribution of these soil samples. In addition, further uniformity of the soil cover will be achieved by the mixing of soils as the material is removed from the proposed borrow areas, spread, and compacted as the soil cover. Therefore, the soil-cover characteristics should be relatively uniform.

The expected uniformity has been confirmed by a total of 19 particle-size gradation and soil classification tests completed as part of interim reclamation quality control on borrow soils placed in the soil cover during interim stabilization activities. The tests represent a testing frequency of one test per 6,500 cy of soil placed. The actual field test results show that both geotechnical exploration data and initial soil-cover field testing demonstrate consistent soil grain-size distribution and soil-cover characteristics (as expected during design). As shown in Tables 3.1 through 3.3 and illustrated on Figure 3-2, the gradations of the material placed in the North and Central Cells for interim soil-cover construction are uniform and very similar to those samples in the proposed borrow areas. Due to this low variability in grain-size distribution and soil classifications during initial cover placement, a higher testing frequency is not necessarily warranted.

However, in review, the NRC expressed concern that a thinner soil-cover design would be more sensitive to material gradation fluctuations and the resultant radon attenuating characteristics. To address this comment, the gradation and Atterberg testing frequency will be increased to an average of one test per 1,000 cy of soil-cover material placed for the project. Soil-cover testing before 1991 was at the lower frequency of one test per 6,500 cy as specified in the 1987 proposed plan. It will be possible to attain the higher testing frequency of one test per 1,000 cy, based on an average of all tests taken for the project, and will be accomplished when the interim soil cover is conditioned (i.e., moisture adjusted and compacted) immediately before final soil-cover placement. At the same time, additional gradation and Atterberg tests, as well as in-place density tests as identified above, will be conducted to meet required project frequencies, which will ensure that the material placed meets the requirements of that modeled in the design.

5.3.4.7 Interim Stabilization QA/QC Summary

As a part of construction QA/QC during interim stabilization soil-cover construction in the North and Central Cells, representative tests of actual soil parameters were taken, including 15 standard Proctor compaction tests, 28 one-point Proctor tests, 62 field moisture/density tests, 19 grain-size distribution analyses, and 7 permeability tests. As described above, the representative in-situ soil cover properties were then used to calculate radon attenuation parameters (i.e., porosity and diffusion coefficient) for the average soil-cover material. The final reclamation soil-cover design has been adjusted on the basis of these actual soil parameters.

5.4 Long-Term Stability of the Radon Attenuation Soil Cover

The radon attenuation soil cover is designed to reduce radon emissions from the tailings to less than 20 pCi/m^2/sec, in accordance with NRC requirements. To provide long-term stability of the radon attenuation soil cover for the 1,000-year design period, several measures have been included in this plan, which incorporates the following features:

1. The grading plan was developed with the surface having nominal slopes to provide runoff yet minimize erosional forces.

2. A soil/rock matrix layer was designed to further minimize erosion of the cover.

3. The final cover was also designed to manage surface water runoff using surface water control channels, including branch swales, drainage channels and diversion ditches.

5.4.1 Soil/Rock Matrix Design

The radon attenuation soil cover will be protected from wind and water erosion by the soil/rock matrix erosion-protection cover shown on Figure 4-6. This layer will also allow a higher and more stable long-term moisture content, compared to a vegetated cover. This design meets the requirements for erosion protection of the tailings cover while maintaining adequate slopes to promote surface water runoff and reduce infiltration into the tailings. A similar soil/rock matrix design was approved by the NRC for use at Anaconda's Bluewater facility in New Mexico.

Previous studies of tailings impoundments (Mayer et al., 1981) indicate that rock covers increase the soil moisture content below the rock cover by decreasing the effective evaporative zone and reducing the overland flow velocity of runoff, compared to a cover consisting of compacted soil only. By decreasing evaporation, the soil and rock cover reduces the gradient that draws moisture from the soil cover to the atmosphere. Thus, through time, annual precipitation at the site will provide a long-term moisture content closer to the higher field-capacity moisture content rather than the wilting-point moisture content.

The CSU method described in NUREG 4651 (NRC, 1987) was used to size the rock in the soil/rock matrix. Based on flow depths and velocities computed using the unit-width method described in NUREG 4620 (NRC, 1986), a D_{50} of 1.5 inches for the rock mulch provides erosion protection.

The soil/rock matrix will be constructed by placing a 3-inch-thick rock mulch layer over the completed radon attenuation soil cover, then placing a 4- to 6-inch layer of random soil material over the rock mulch. The soil will be forced into the rock mulch voids by driving construction equipment over the soil. The 4- to 6-inch-thick soil lift will be placed over the rock to maintain an approximate thickness of three inches above the rock layer. This overall 6-inch-thick soil/rock matrix will provide long-term erosion protection. Soil compaction will densify the rock layer by tightly wedging the stones. The soil will fill the void spaces, stabilizing the rock, and decreasing the effective evaporative zone depth, which provides more stable and higher long-term moisture content of the radon barrier. The use of soil compacted into rock has been shown to increase the stability of rock protection (NUREG 4651). The soil/rock matrix is sufficiently fine-grained that is does not require filter material. The soil/rock matrix will also protect the soil cover from wind erosion. Appendix E provides the calculations used to size the soil/rock matrix.

Frost heave and the potential effect of decreasing radon attenuation of the soil cover were also considered. For a material to be frost susceptible, there must be a source of water, close enough to the frost line to supply capillary water from a saturated soil layer. The potential for capillary action depends on the effective pore diameter. The coarse tailings located below the cover classify as poorly graded sands and are considered relatively free draining. These characteristics are indicative of relatively large pore diameters, indicating these materials have a low potential for capillary action. Since this material below the cover material will not support capillary action, the ability to transport water to the frost line by capillary action does not exist. Therefore, soil cover susceptibility to frost heave is low.

Shrinkage and its potential effect on radon attenuation is also governed by capillary action. When a saturated soil dries, a meniscus develops in each void at the soil surface. Tension develops in the soil water and a matching compression develops within the soil. Since the long-term moisture of the soil cover will remain fairly stable and the material below the cover soil will not support capillary action, shrinkage effects on the cover soil will not be significant.

5.4.2 Soil/Rock Matrix Quality Control Program

The construction of the soil/rock matrix cover will be verified by construction control, staking, and probing, as described in the specifications (Appendix B). A standard procedure will be used to verify the thickness of rock mulch placed, by measuring the rock at locations on a rectangular grid intersecting at 100-foot intervals across the tailings cover. The soil will be placed over the rock mulch only after the rock mulch thickness has been tested and documented as acceptable. The maximum and minimum thickness, and adequacy of soil intrusion into the rock mulch will be verified using the same procedure identified for measuring the rock mulch layer. The extent soil is present throughout the rock mulch layer will also be measured. The measurement procedures are described in detail in the specifications (Appendix B).

5.4.3 Tailings Cover Branch Swales

Branch swales have been added to the tailings cover design to collect surface water runoff while minimizing erosion (Figures 5-1 and 5-2). The location of the swales was chosen to provide the optimal combination of hydraulic characteristics (overland slope and slope length) that allow the use of a soil/rock matrix cover to protect the radon attenuation soil cover from erosion. The swales will consist of shallow, trapezoidal ditches with 3H:1V sideslopes (Figure 5-3). The bottom and sideslopes of the swales will be protected with riprap. Table 5.5 summarizes the design characteristics of the swales.

Hydraulic analyses of the flows generated within the swales was conducted to determine the minimum swales depth. The peak discharge of the runoff generated by the

Probable Maximum Precipitation (PMP) event on the impoundments was calculated using the Soil Conservation Service (SCS) Technical Release No. 55 (TR-55) method. The depth of these peak discharges in the swales was calculated using Manning's equation. A freeboard of at least .5 foot was added to the flow depth in the swales to determine the minimum swales depth. This design approach follows the guidelines set forth in the NRC's August 1990 Staff Technical Position (STP), "Design of Erosion Protection Covers for Stabilization of Uranium Mill Tailings Sites" and provides for stable water conveyance structures that will promote drainage and reduce infiltration into the tailings. Table 5.5 summarizes the hydraulic analyses for the swales. Appendix E details the calculations used to complete the hydraulic analyses.

The Safety Factors method of riprap design was used to size the riprap that will be installed in the swales. Table 5.5 summarizes the riprap sizes for the swales. In many cases, the same rock used for the soil/rock matrix is adequate for the swales. Appendix E shows the detailed calculations used to determine the riprap sizes.

The minimum riprap layer thickness is two times the D_{50} size. The D_{50} of the riprap in Branch Swales H and I is 3.0 inches. The D_{50} of the remaining Branch Swales is 1.5 inches. A 6-inch-thick bedding layer will be placed under the riprap layer in Branch Swales H and I. The D_{50} of the lower 3 inches of this material in Branch Swales H and I is 0.02 inch. The D_{50} of the upper 3 inches of this layer is 0.35 inch. The remaining Branch Swales will require a single 3-inch-thick bedding layer with a D_{50} of 0.02 inch. Tables 5.6 and 5.7 provide the gradation limits of the riprap and bedding layer materials for the Branch Swales, respectively.

5.4.4 South Cell Drainage Channel

The South Cell Drainage Channel, shown on Figure 5-1, is designed to remove runoff from the South Cell tailings area to enhance the long-term stability of the tailings cover.

The South Cell Drainage Channel will be excavated into bedrock along part of the upper section from approximately Station 4+50 to Station 9+00, as shown on Figure 5-1. Figure 5-4 shows typical sections. Riprap will be placed within the upper reach at all locations not protected by competent bedrock (i.e., from Station 0+00 to approximately Station 4+50). It will not be necessary to riprap the lower reach, from Station 9+00 to the confluence with Pipeline Arroyo, because this reach is isolated from the tailings by the 450-foot-wide bedrock section.

The South Cell Drainage Channel is trapezoidal in shape with a 10-foot bottom width and 3 horizontal to 1 vertical (3H:1V) side slopes. Approximately 450 feet from the beginning of the channel, it will bend to the west. At this bend, the side slope will gradually change to a 2H:1V slope as bedrock is encountered. The channel in this upper reach will have a gradient of 0.0244 foot per foot (ft/ft).

In determining the flow rate and riprap requirements used in the hydraulic design for the South Cell Drainage Channel, the following values of design parameters were used:

1. A runoff curve number of 80 was used for the soil/rock matrix, which will be placed on the catchment area draining to the channel.

2. The Probable Maximum Precipitation (PMP) amount of 8.43 inches was determined from Hydrometeorologic Report No. 29.

3. The Probable Maximum Flood (PMF) hydrograph was determined using the tabular method of hydrograph generation described in SCS TR-55.

4. The size of riprap to be placed was determined using the Safety Factors method as described in NUREG/CR-4651.

5. The material size and gradation of the bedding layer under the riprap were determined by the methods provided in NUREG/CR-4620.

The calculated PMF for the South Cell Drainage Channel has a peak discharge of 694 cubic feet per second (cfs). This peak discharge produces a peak flow depth of 3.5 feet in the upper reach.

The riprap for the unprotected portions of the upper reach will have a D_{50} of 15 inches, a D_{50} of 19 inches, and a minimum thickness of 23 inches. A 6-inch-thick bedding layer will be placed under all riprapped sections of the upper reach. The 6-inch bedding layer will consist of a lower 3-inch sand layer with a D_{50} of 0.02 inch and an upper 3-inch-thick gravel layer with a D_{50} of 0.35 inch. Tables 5.6 and 5.7 provide the gradation limits for the riprap and the bedding layer materials for this channel, respectively.

5.4.5 North Cell Drainage Channel

The North Cell Drainage Channel, shown on Figure 5-2, will remove runoff from the North Cell tailings area to enhance the long-term stability of the soil cover by collecting flows from Branch Swales B through G. The North Cell Drainage Channel will intercept the North Diversion Ditch extension at a location north of the tailings disposal area as shown on Figure 5-2. The North Diversion Ditch extension transports the runoff into Pipeline Arroyo.

The upper reach of the North Cell Drainage Channel will be trapezoidal in shape with a 10-foot bottom width and 3H:1V side slopes (Figure 5-3). This reach will have a channel gradient of 0.020 ft/ft.

The lower reach of the channel will also be trapezoidal in shape with a 10-foot bottom width and 3H:1V side slopes. The lower reach will have a channel gradient of 0.0126 ft/ft.

The same methods of PMF hydrograph determination and riprap and bedding layer design were used for this channel as were used for the South Cell Drainage Channel. The parameters included a PMP of 8.43 inches and a runoff curve number of 80.

The PMF for the upper reach of the North Cell Drainage Channel has a peak discharge of 359 cfs. The peak discharge produces a peak flow depth of 2.5 feet in the upper reach. This depth is sufficiently lower than the 3.5-foot channel depth allowing PMF flows to pass safely.

The riprap for the upper reach will have a D_{50} of 9 inches, a D_{50} of 15 inches, and a minimum thickness of 15 inches. The 6 inches of bedding layer material will consist of a lower 3-inch sand layer with a D_{50} of 0.02 inch and an upper 3-inch-thick gravel layer with a D_{50} of 0.35 inch. Tables 5.6 and 5.7 provide the gradation limits for the riprap and the bedding layer material, respectively.

The PMF for the lower reach of the North Cell Drainage Channel has a peak discharge of 562 cfs. The peak discharge produces a peak flow depth of 3.5 feet in this reach. This depth is sufficiently lower than the 4.0-foot depth of the channel allowing PMF flows to pass without overflowing the channel bank.

The calculations for riprap size for the lower reach indicate a D_{50} of 8 inches is appropriate. Since this size is close to the size needed for the upper reach, the riprap and bedding layer design for the upper reach will also be used for the lower reach. Tables 5.6 and 5.7 provide the gradation limits for the riprap and the bedding layer material for the North Cell Drainage Channel, respectively.

5.5 Diversion Ditches

Figures 5-1 and 5-2 depict the South and North Diversion Ditches that intercept precipitation runoff from the drainage basins to the south, east, and north of the tailings disposal area. These ditches were constructed by United Nuclear during facility operation. They continue to be useful in reclamation because they enhance the long-term stability of the tailings disposal area by preventing runoff from flowing onto the tailings disposal area. Minor modifications to the North Diversion Ditch are planned during reclamation, as addressed below.

The ability of these ditches to convey the PMF from the contributing drainage basins without over-topping the banks was investigated as part of the reclamation design. The investigation determined the PMP amounts for each drainage basin, calculated the peak discharge of the PMF hydrograph, and evaluated the ditches' characteristics (cross-sectional shapes, channel gradient, and roughness coefficient). The flow depth of the PMF peak discharge was determined at several cross sections to evaluate the ability of the ditches to convey the PMF.

The one-hour PMP amount from a thunderstorm event was determined using Hydrometeorologic Report 49 (NOAA, 1984). The PMF hydrograph and peak flow rate was estimated using the SCS Triangular Unit Hydrograph Method (Bureau of Reclamation, 1977). Appendix E provides the work sheets for these calculations. The cross sections and channel slopes were determined from 1985 topographic mapping at a scale of 1:2400. A roughness coefficient of 0.025 was chosen for these earth channels. Manning's equation was used to calculate the normal flow depth at the various sections.

5.5.1 South Diversion Ditch

The South Diversion Ditch intercepts runoff from Drainage Basin C, delineated on Figure 5-5, and routes the runoff to a natural ephemeral drainage that discharges into Pipeline Arroyo approximately 3,000 feet downstream from the nickpoint. The South Diversion Ditch is generally trapezoidal in shape with a 15-foot bottom width and 2H:1V side slopes. It is generally 8-feet deep and has an average gradient of 0.003 ft/ft.

The PMF for Drainage Basin C has a peak discharge of 1,370 cfs. This peak discharge produces a peak flow depth of 4.85 feet in most sections of the channel. This depth is considerably lower than the 8-foot channel depth.

Previous evaluations (Science Applications, Inc., 1981) identified two limiting sections (Sections R-R' and S-S') on the South Diversion Ditch. Figure 5-1 shows the locations of these sections, and Figure 5-6 shows their shapes. The channel gradient at these sections is 0.002 ft/ft. Although the locations are upgradient from much of the inflow to the South Diversion Ditch, they are able to pass the full PMF peak discharge. The peak flow depth at Section R-R' is 6.4 feet and 4.25 feet at Section S-S'. At Section R-R', a freeboard of 1.1 feet exists above the peak-flow height, while freeboard at Section S-S' is 1.5 feet. Thus, the South Diversion Ditch is fully able to convey the PMF with no additional channel modification.

5.5.1.1 South Diversion Ditch Confluence Stability

In reviewing the proposed plan, the NRC expressed concern that inflow from the tributaries to the North and South Diversion Ditches may damage the diversion ditch banks at the tributary confluence with the ditch, and allow flows to pass over the bank to the reclaimed tailing impoundments. NRC commented that an occurrence could potentially allow a release of tailings. To respond to this comment, the stability of the confluences of tributaries and the South Diversion Ditch was evaluated. The evaluation indicated none of the tributaries to the South Diversion Ditch provide a large proportion of flow to the ditch. Therefore, overtopping at the confluence of a tributary and the ditch is not a concern.

5.5.2 North Diversion Ditch

The North Diversion Ditch intercepts runoff from drainage basins A1, A2, and B, delineated on Figure 5-5, and routes this runoff to the alluvial floodplain north of the tailings disposal area.

The North Diversion Ditch does not have a consistent cross-section configuration. Five channel sections (T-T, U-U, V-V, W-W, and X-X) are illustrated on Figure 5-6. Side slopes range from 1.1 to 7.6H:1V, bottom widths range from 12 to 22 feet, and channel depths range from 7 to 35 feet. The channel gradient is relatively uniform at approximately 0.0075 ft/ft.

The PMF peak discharge in the North Diversion Ditch is 1,081 cfs, with the additional contribution of Drainage Basin A2, it is 2,265 cfs, and with the additional contribution of Drainage Basin B, it is 5,850 cfs. Table 5.8 lists the contributing drainage areas and peak discharges at each section. The table also identifies characteristics for these sections of the North Diversion Ditch including the average side slope, the bottom width, channel slope, normal depth of the peak flow, and the average velocity of this flow.

Figure 5-6 shows the PMF peak discharge is contained within the North Diversion Ditch at all five sections. While some channel and bank erosion, and local scour will occur as a result of the high PMF flow velocities, the distance between the diversion ditch and the tailings disposal area is a minimum of 200 feet. Therefore, it is unlikely the potential for scour would be large enough to result in the release of tailings. However, in response to NRC comments, riprap will be installed on the two inside curves of the North Diversion Ditch, as described below.

During review and comment, the NRC expressed the concern that two sharp curves on the North Diversion Ditch may show increased amounts of erosion that could allow flood flows to pass onto the tailings area (Figure 5-1). Accordingly, cross sections were developed, hydraulic calculations were completed, and riprap was designed for these two curves. Cross Sections AA-AA' and BB-BB' on Figure 5-3 show these curves in the existing North Diversion Ditch will contain the PMF without over-topping the embankment. In addition, the calculated flow velocities were moderate and the flow was subcritical at both locations (Froude number less than 1.0). Thus, the hydraulic calculations indicate a minimal potential for the existing North Diversion Ditch to migrate into the tailings pile. Therefore, it will not be necessary to place riprap into other existing portions of the North Diversion Ditch.

Riprap was sized for the curved channel locations at sections AA-AA' and BB-BB' using criteria provided in NUREG-4620 and by the 1987 Maynard method. The riprap sized for the curve at AA-AA' will be used at BB-BB' as well, because its larger size meets more stringent flow criteria, providing a greater safety factor. The riprap will have a D_{50} of 6 inches and a thickness of 10 inches. The riprap layer will be underlain by a 6-inch-thick filter blanket. Tables 5.6 and 5.7 present the gradation requirements for the riprap and bedding material, respectively. Appendix E shows the calculations for the riprap sizing. Requirements for the rock used in riprap are discussed in more detail in Section 5.6.

5.5.2.1 North Diversion Ditch Confluence Stability

In reviewing the proposed plan, the NRC also expressed concern that inflow from the tributaries to the North and South Diversion Ditches may damage the diversion ditch banks at the tributary confluence with the ditch, and allow flows to pass over the bank to the reclaimed tailing impoundments. NRC's concern was that this occurrence could potentially allow a release of tailings. Therefore, the stability of the confluences of tributaries and the existing North Diversion Ditch was evaluated. Damage to the ditch banks could potentially occur when the flows from the tributary are generally perpendicular to the ditch bank and impinge directly on the far bank. Such flows could potentially scour the far bank of the ditch by removing bank material. The tributary flows will have to be relatively large or relatively fast compared to the flows in the diversion ditch to have sufficient energy to damage the ditch bank.

The stability evaluation was conducted by first comparing total head (velocity head plus elevation head) of the PMF in the diversion ditch and in the tributary at three critical confluences. The second part of the evaluation considered the geometry of the confluences with respect to the confluence angle and extent of material that will have to be scoured to allow the flows to pass over the diversion ditch channel bank.

Three critical locations are shown on Figure 5-1. These three confluences (A1, A2, and B) involve tributaries to the North Diversion Ditch that provide a large proportion of the total flow of the diversion ditches at discrete locations.

Figure 5-7 provides a schematic of the tributaries and related cross sections on the existing North Diversion Ditch. Table 5.9 summarizes of PMF flow characteristics for each of these locations. The PMF peak discharges were determined using the SCS TR-55 method. Manning's equation was used to determine the flow depth and discharge in the existing North Diversion Ditch and in the tributaries. Appendix E provides these calculations.

Table 5.9 also provides a comparison of total head at all the locations. The total head for the flows in tributaries A1, A2, and B are all less than those of the North Diversion

Ditch cross sections (K, L, and M), located immediately upstream of the confluences. Thus, while the tributary flow will cause turbulence at the confluence, the flow will not be able to impinge directly on the ditch banks.

The geometry of the three confluences was evaluated to identify the confluence angle and the amount of material in the far ditch bank. Figure 5-1 shows Tributaries A2 and B entering the existing North Diversion Ditch at shallow confluence angles of approximately 45 degrees. Thus, their flows will not impinge directly on the far ditch bank. Tributary A1 enters the existing North Diversion Ditch at about a 90-degree angle. This angle of tributary flow will cause more turbulence at the confluence than that caused by a shallower angle.

Figure 5-7 shows cross sections of the North Diversion Ditch at the confluences. The cross sections show the extent of material that would have to be scoured before flows left the diversion ditch and passed across the tailings. These scour distances are 90 feet at confluence A1, 170 feet at confluence A2, and 150 feet at confluence B. These distances are all sufficiently large that channel scour will not allow flows to pass over the tailings. In addition, as channel scour removes material from the far bank during a particular flow event, the channel will become wider, protecting itself from future scour. Finally, the tailings at these locations are at least 500 feet away from the locations of these confluences and the regraded surface of the tailings cover is sloped down towards the ditch making the potential release of tailings unlikely.

At confluence A1, the total head of the tributary flow is considerably less than that of the ditch flow. Furthermore, channel scour will have to remove 90 feet of material before flows could pass onto the tailings. At confluence A2, the total head of the tributary flow is less than that of the diversion ditch and the confluence angle is about 45 degrees. Thus, the tributary flows will not impinge directly on the ditch bank. Furthermore, about 170 feet of material will have to be scoured before flows could pass over the tailings.

At tributary B, the total head of the tributary flow is also less than that of the ditch and the confluence angle is about 45 degrees. Thus, the tributary flows will not impinge directly on the diversion ditch bank. Furthermore, about 150 feet of material will have to be scoured before flows could pass over the tailings.

The above evaluation indicates that, while scour and erosion will occur at the confluences, the total head differential, confluence angles, and amount of ditch material to be removed will not allow the release of tailings.

5.5.2.2 North Diversion Ditch Outlet

The outlet of the existing North Diversion Ditch will be extended during final reclamation to intersect with the North Cell Drainage Channel and on to intersect with the Pipeline Arroyo, as shown on Figure 5-2. The new ditch extension will consist of a short section cut into the underlying rock with a steep gradient. The ditch will then be continued to the Pipeline Arroyo in a curved and then straight section with a shallow gradient (Figure 5-2).

The extension of the north diversion ditch will contain the PMF, except for that portion of the ditch constructed within the floodplain north of the North Cell tailings disposal area. This section is designed to contain the 100-year flood. Designing the lower section of the ditch to contain the PMF is impractical because, as shown on Figure 5-2, the PMF boundary for the Pipeline Arroyo extends to the eastern edge of the floodplain. Therefore, if a PMF event occurred, water in the Pipeline Arroyo floodplain will inundate the area and the North Diversion Ditch extension.

5.5.2.3 North Diversion Ditch Slope Stability

When reviewing the proposed plan, NRC expressed concern that the steep slope of the North Diversion Ditch bank between Stations 41+00 and 50+00 (Figures 5-1 and 5-2) may not be stable. To address NRC comments, an evaluation of this bank was conducted. Based on a review of data contained in "Geology of the Church Rock Area," Science Applications, Inc., and visual observation of the cut-face of the North Diversion Ditch in the northeast portion of the site (Station 41+00 to Station 50+00), the excavation is geologically stable.

The channel cut is through the Dilco Coal member of the Crevasse Canyon formation. Typically, the bedding planes of the Dilco member in this channel excavation area trend from southeast to northwest and dip to the northeast at relatively small 3 to 5 degree angles. Visual observations of the channel excavation verify these conclusions. This small 3 to 5 degree angle is significantly lower than the internal angle of friction of 45 degrees (Perloff and Baron, 1976) for this material. Therefore, little probability of bedding planes slippage due to shear failure exists.

Discontinuities and saturation of the formation could potentially reduce shear resistance and cause failure. The only observable discontinuities in the Dilco Coal member typically consist of lower-strength materials (i.e., shale and siltstone) interbedded with higher strength materials (sandstone). These discontinuities alone are not likely to lead to instability because of the high cohesion and friction angles between these layers. Saturation of these layers and resultant strength losses are also highly unlikely. The water table is approximately 140 feet below the excavation, making saturation from this source unlikely. The low precipitation (12-14 inches/year), small infiltration area uphill of the excavation (4.9 acres), and impermeable nature of the member make infiltration and percolation through the bedding planes unlikely. Therefore, shear strength losses due to saturation of the interbedded layers are essentially nonexistent.

Based on the observed and predicted stability of the Dilco Coal member exposed in the North Diversion channel excavation from stations 41+00 to 50+00, the cut slopes will remain stable throughout the 1,000-year design life of the reclaimed site. No modifications to stabilize the channel cut slopes are necessary or required.

5.6 Pipeline Arroyo and Embankment Stability

In addition to the tailings cover, the long-term stability of the tailings embankment is necessary to prevent the release of tailings. The primary surface water drainage on the United Nuclear property is the Pipeline Arroyo, an ephemeral channel that flows to the southwest parallel to the west tailings embankment. Consistent with the objective (10 CFR 40, Appendix A) of maximizing reclamation design longevity to 1,000 years (to the extent reasonably possible) the Pipeline Arroyo channel and the tailings embankment were investigated, and hydrologic analyses and designs were developed to minimize channel erosion and meandering, and to ensure protection of the reclaimed tailings disposal area. This section of the reclamation plan describes the channel and embankment evaluations, provides results of hydrologic analyses, and presents planned channel modifications and embankment protection measures to satisfy these objectives.

5.6.1 Existing Pipeline Arroyo Channel Description

The United Nuclear mill site and tailings disposal area are adjacent to Pipeline Arroyo, an ephemeral channel draining approximately 18.2 square miles of upland areas. These upland areas consist of relatively flat mesas with steep side slopes, as shown on Figure 5-5. The channel slopes of the arroyo vary considerably (0.0018 to 0.053 ft/ft) from its headwaters to its confluence with the North Fork Rio Puerco ephemeral drainage. These channel slopes depend on local bedrock control, such as the nickpoint located near United Nuclear's facilities, shown on the channel profile (Figure 5-8. The nickpoint is a steep head-cut into Zones 1, 2, and 3 of the Upper Gallup Sandstone.

The channel above the nickpoint is relatively wide and has a braided stream pattern due to the nickpoint, which provides a channel base-control section. The channel slope above the nickpoint is as low as 0.0018 ft/ft. The sediment capacity of the channel immediately upstream of the nickpoint is less than that of locations farther upstream. When sediment-laden runoff reaches the area above the nickpoint, the sediment is deposited in bars, and the braided pattern forms.

Below the nickpoint, the channel slope steepens to as high as 0.053 ft/ft. The channel cross section in this area is narrow and deeply incised into the previously deposited alluvial sediment. Incision occurs because the flow increases its sediment capacity when it enters the steeper channel slopes downstream of the nickpoint. The flow gains this additional sediment capacity by causing channel and bank erosion. The channel maintains the meandering pattern established before the nickpoint provided local control.

The channel bottom near the United Nuclear facilities lies above the expected base level of the channel because of the local base control provided by the nickpoint. Figure 5-8 illustrates the actual channel base and its expected base, if the controlling nickpoint did not exist. The expected base level is the level to which the channel will attempt to reach over a long period of time, if the nickpoint were not providing base control.

If the channel moved off the nickpoint, the channel will downcut into the alluvium. Head-cuts would form and migrate upstream. The increased sediment load induced by this action would cause aggradation (deposition of sediment) at the location of the decrease in channel slope near its exit from the United Nuclear property as shown on Figure 5-8. This aggradation might raise the actual base level in this area as the channel reaches its new state of dynamic equilibrium. However, the location of the expected base level shown on Figure 5-8 provides a more conservative level for reclamation design purposes. Thus, one of the final reclamation design objectives was to fix the nickpoint as a more stable control point and to maintain the base level of the channel as described later.

Information gathered during geotechnical and geological field investigations include subsurface information in the area adjacent to and upstream of the nickpoint. Section 3.0 and Appendix A summarize the field investigation results. The alluvial soils in this area of the channel consist primarily of silts intermixed with varying quantities of sand and clay. Grain-size analyses of the soil samples indicated an average gradation of 40 percent sand and 60 percent fine-grained material (i.e., silts and clays). The average D_{50} size is 0.07 millimeters (mm). These particles have been lightly cemented by calcium carbonate throughout the alluvial zone.

The depth of the alluvium ranges from 0 feet at the edges of the valley and at the nickpoint outcrop to more than 150 feet at near the southwest corner of Section 36 (Figure 5-2). The alluvium at the greater depth indicates the filling of a paleochannel (Canonie, 1987a).

Several auger holes in alluvium were extended into the underlying rock formations with a coring bit. The channel cross section (Figure 5-9) illustrates subsurface conditions extending across the channel 100 feet northeast of the nickpoint, using auger hole and rock coring data. This cross section shows that the nickpoint is formed by an outcrop of Zone 3 of the Upper Gallup Sandstone. This outcrop was not continuous across the arroyo, but ends abruptly under the alluvium near the present channel.

The surface of the rock underlying the alluvium is moderately-to-highly weathered. Beneath the weathered zone, the sandstone varies from soft to hard. Within the nickpoint, the sandstone of Zone 3 appears massive with few fractures.

The shales of Zone 2 (beneath Zone 3) are softer and less competent than the Zone 3 sandstone. The fissile nature of the Zone 2 shales make this material less competent and more erodible than the sandstones above (Zone 3) and below (Zone 1). Zone 2 is exposed only as a thin layer (less than 5 vertical feet) within the nickpoint.

The sandstone of Zone 1 is similar in appearance to that of Zone 3 sandstone. It is exposed only at the bottom of the nickpoint for about 10 vertical feet, and forms a relatively stable base.

The channel cross section on Figure 5-9 shows that the existing channel walls within the nickpoint are higher on the west side than on the east side. The maximum height of the west rock wall is approximately 10 feet, while on the east side it is approximately 4 feet high.

5.6.2 Historical Analysis of Pipeline Arroyo Channel Morphology

The channel characteristics of sinuosity, meander wave length, amplitude, and channel width/depth ratio were determined for the channel reaches above and below the nickpoint on Pipeline Arroyo and below the confluence between Pipeline Arroyo and the North Fork Rio Puerco drainage. These characteristics were identified from aerial photographs taken over a 33-year period in 1952, 1983, and 1985, and are summarized in Table 5.10.

Although a 33-year time span is minimal on the geologic scale, several changes occurred in the channel's morphology. The nickpoint adjacent to the mill is evident in the 1952 aerial photograph, although its effect on channel morphology is not as pronounced as in the later photographs. The morphological effects of the nickpoint were probably enhanced by the large mine water drainage discharges from both the Quivira and United Nuclear mines beginning in 1968. These discharges were relatively free of sediment and, thus, had large sediment capacities to fulfill. The mine water discharges were continuous from 1968 to 1986. Accordingly, their slow but continual ability to downcut the channel became apparent after several years of operation.

The width/depth ratio of Pipeline Arroyo below the nickpoint decreased between 1952 and 1983. This decrease was caused by the downcutting of the channel, primarily due to increased flow velocities at and below the nickpoint, which increased the flow's sediment capacity. This capacity resulted in further channel erosion. The moderate cementation of the silty alluvial soils resulted in steep channel banks.

The channel reach above the nickpoint evolved from a meandering pattern to a braided pattern and its width/depth ratio increased, by the sediment deposition above the nickpoint. The changes from a meandering pattern to a braided pattern reflect the stream's attempt to carry as much sediment as possible.

The North Fork Rio Puerco drainage below the confluence with Pipeline Arroyo showed an increase in the width/depth ratio from aggradation in this reach. The aggradation was caused by a decrease of the channel gradient, an increased sediment load from Pipeline Arroyo and the subsequent sediment deposition. The zone showing aggradation is relatively short and does not extend far downstream. The sinuosity of the channel in this reach decreased from 1952 to 1985 as several meanders were cut off and a straighter channel developed.

5.6.3 Pipeline Arroyo Drainage Basin Description

The Pipeline Canyon drainage basin has been thoroughly described in previous license applications, renewal applications and reports (United Nuclear Corporation, 1981; Faith Engineering, 1981). The drainage basin shown on Figure 5-5 was delineated as the appropriate contributing basin for calculating flood events. The outlet of this basin is adjacent to the north end of the tailings disposal area. The drainage areas to the east of the tailings disposal area are intercepted by diversion ditches that either route the flows to the arroyo channel below the United Nuclear facilities, or pass the peak flows from these areas before the flood peak on the main channel arrives at their confluence.

The Pipeline Arroyo basin consists of an area of 18.2 square miles, has a total relief of 819 feet, and has a longest drainage path of 6.2 miles (Table 5.11). The basin is elliptical in shape and has a circularity ratio of 0.74. These data were determined from 7.5-minute USGS maps as illustrated on Figure 5-5. A Soil Conservation Service (SCS) curve number of 79 was selected for use based on the hydrologic characteristics of the soil and vegetation conditions of this basin (Faith Engineering, 1981). This number was confirmed by Canonie in 1987.

5.6.4 Pipeline Arroyo Design Flood Calculations

The PMF was used as the design flood event for evaluating the long-term hydraulic stability of the Pipeline Arroyo. To minimize erosion and prevent the release of tailings, the potential impacts of large flood events (e.g., the PMF) must be evaluated and protection against erosion provided. Use of the PMF is consistent with the guidelines set forth by the Nuclear Regulatory Commission NUREG/CR-3397 (NRC, 1983b). However, during review of the proposed plan, NRC expressed additional concern that, over time, the arroyo meandering would result in channel migration significant enough to impact the tailings impoundment. Consequently, the geomorphology of Pipeline Arroyo and the potential for channel meandering to adversely affect the tailings impoundment was evaluated as described in Section 5.6.6.7 below.

The peak-flow rate of the PMF originating from the Pipeline Arroyo drainage basin was estimated by the SCS Synthetic Triangular Unit Hydrograph Method (Bureau of Reclamation, 1977). The one-hour PMP from a thunderstorm event was determined using Hydrometeorological Report 49 (NOAA, 1984). Appendix E provides the work sheet for the calculation of the PMP. The resulting PMP amount for the drainage area of 18.2 square miles, and a mean basin elevation of 7,275 feet was 6.2 inches.

Appendix E also provides the PMF hydrograph generation by the SCS method. This method uses basin geometry such as the maximum relief and the longest drainage path to calculate a synthetic triangular unit hydrograph. The PMP rainfall is divided into quarter-hour segments, which amounts are reordered to simulate an actual thunderstorm. The amount of runoff produced by these rainfall amounts is determined by applying the appropriate curve number. The runoff amounts are applied to the unit hydrograph to produce intermediate hydrographs for each quarter-hour segments. These intermediate hydrographs are then combined to produce the composite hydrograph for channel-design purposes.

The peak-flow rate of the composite PMF hydrograph was calculated to be 26,300 cubic feet per second (cfs). This peak occurs approximately 1.7 hours from the beginning of the PMP.

5.6.5 PMF Routing - Existing Pipeline Arroyo Channel

Hydrologic modeling of existing channel conditions was conducted to determine if modifications of Pipeline Arroyo would be necessary as part of reclamation. The PMF of 26,300 cfs was routed through the existing Pipeline Arroyo channel and valley adjacent to the United Nuclear facilities by using the COE's HEC-2 water surface profiles model (Corps of Engineers, 1977). Eight channel cross sections were developed from 1985 topographic mapping and four additional channel cross sections were field surveyed. The HEC-2 program was used to separately develop the water surface profiles of the subcritical flow expected above the nickpoint, and the supercritical flow expected below the nickpoint.

For the existing unmodified channel, the flood waters of the PMF would contact the full extent of the main earth embankment of the North and Central Cells, but would not overtop the crest of the embankment in any location. The average flow velocities above the channel and against the embankment (i.e., HEC-2 right overbank area) in the sections where the flood waters would contact the embankment range from 2.7 to 7.9 feet per second (fps), and would generally increase in the downstream direction. These velocities would be sufficient to cause minor erosion of the main embankment and indicate that some modifications to the channel and embankment protection are required as part of final reclamation.

For the existing unmodified channel downstream of the nickpoint, the flood waters would be contained primarily in the existing, deeply-incised channel. The PMF flow velocities within the channel would be extremely high and range from 27.2 to 37.3 fps. These velocities would cause a large amount of bank and channel erosion, and local scour. However, the channel in this location would not be expected to migrate to the tailings disposal area during a PMF flood event, based on volumetric determinations of scour compared to the amount of available material between the channel and tailings disposal area.

The channel and overbank flow velocities in the nickpoint area would be high enough (12.5 to 17.2 fps) to also cause bank erosion and local scour of both the alluvial channel and the overbank area. Avulsion (large movement) of the existing channel off the nickpoint and into the alluvium southeast of the nickpoint would be likely. Such channel movement would allow rapid downcutting or further channel migration during the PMF or subsequent flood events. Thus, without protection of the alluvium east of the nickpoint to reduce the potential channel movement, the channel might migrate over a long period of time as far as the tailings disposal area embankment.

Previous studies of the flood stability of Pipeline Arroyo have also indicated the probability of existing channel migration, large-scale scouring and avulsion of the existing channel during large-scale flooding events (Simons, Li & Associates, 1980; Faith Engineering, 1982). Based on this hydrologic modeling of existing conditions, the plan proposed in 1987 called for the Pipeline Arroyo channel and embankments to be excavated, reconfigured and protected to stabilize the channel and provide protection of the tailings disposal area for a 1,000-year period, to the extent practicable.

The design approach to provide arroyo stability was changed in response to NRC comments. The new approach approved by NRC in this plan involves artificially extending the nickpoint across the alluvial plain to the tailings embankment by construction of a buried rock "jetty." The design approved by NRC will allow the arroyo channel to meander naturally in a low-flow channel upgradient from the nickpoint, as described below.

5.6.6 Arroyo Channel and Tailings Embankment Modifications

The design objectives for the channel and embankment modifications were as follows:

1. Pass the PMF in the modified channel without encroachment on the tailings cover,

2. Prevent lateral migration of the channel into the tailings disposal area,

3. Provide a geomorphologically stable channel configuration, and

4. Prevent gully formation on the tailings soil cover.

Alternatives considered in the preliminary evaluations included widening and/or deepening the channel, increasing the channel slope, incising the channel into the nickpoint, relocating the channel, and/or providing an artificial base-control section. The ability of each of these design alternatives to fulfill the design objectives was qualitatively evaluated. The combination of alternatives best fulfilling the objectives was then selected for quantitative analyses. The June 1987 proposed plan submitted to NRC contained a design that depended significantly on channel excavation and reconfiguration. Based on NRC review comments, the design was subsequently modified to focus on controlling the nickpoint and protecting the tailings embankment without extensive channel excavation.

Figures 5-1 and 5-2 show a plan view of the Pipeline Arroyo and tailings embankment at final reclamation. The channel itself will be modified only slightly from its present configuration to enhance its flow capacity, while maintaining its present shallow channel bottom slopes. The modifications to the present channel and embankment configuration will include the following:

1. Constructing a protective bench at the toe of the tailings embankment that will contain the runoff control ditch, which will collect surface drainage off the embankment face. The bench will also protect the tailings embankment toe from the PMF within Pipeline Arroyo.

2. Constructing a buried jetty from the nickpoint outcrop east across the Pipeline Arroyo floodplain to the runoff control ditch. This jetty will augment the geomorphic control provided by nickpoint.

3. Enhancing the low-flow capabilities of the present channel by constructing a 30-foot-wide, low-flow channel within the reach upstream of the nickpoint from station 0+00 to station 61+40.

4. Filling in the depressions and headcuts that presently exist in the area between Pipeline Arroyo and the tailings embankment.

Figure 5-10 provides profiles of the channel bottom, PMF water surface elevation (WSEL), protective bench toe, protective bench top, and tailings embankment top from station 0+00 to station 82+90. The profile shows the shallow slopes of the Pipeline Arroyo channel bottom upstream of the nickpoint, and the spatial relationship of these features.

5.6.6.1 Tailings Embankment

The tailings embankment will be modified to protect the embankment from erosion. These modifications include the use of a protective rock mulch, as well as construction of a protective bench and riprapped runoff control ditch. The tailings embankment slope design incorporates rock mulch armor for erosion protection of the upper portion of the embankment, installation of a runoff control ditch to channel runoff from the slope, and the construction of a protective bench at the toe of the tailings embankment to provide a buffer between PMF flows in Pipeline Arroyo and the toe of the tailings embankment.

The long-term stability of the tailings embankment depends on the rock mulch on the embankment side slope and the runoff control ditch. The following discussion describes the design considerations used to develop and provide long-term stability of these features. Appendix E provides the detailed calculations for the long-term stability evaluations of the tailings embankment.

Figures 5-1 and 5-2 show the configuration of the tailings embankment at final reclamation. The side slopes will remain at 5H:1V as provided in the original design and will terminate at the runoff control ditch, located at the top of the protective bench to collect runoff from the embankment. The embankment side slopes will be protected from erosion by a 3-inch-thick rock mulch layer, which extends from the top of the tailings embankment to the runoff control ditch. The rock mulch for protecting the embankment side slopes from the erosional forces of runoff generated by the PMP was designed using the CSU method (NUREG 4651, 1989). The resulting D_{50} of 1.5 inches and thickness of 3.0 inches for this rock mulch is similar to that of the rock mulch used in the soil/rock matrix in the tailings-cover design, so that the same rock material could be used for both areas. Table 5.6 provides the gradation for this rock mulch.

A theoretical slope stability analysis was also conducted to confirm the structural stability of the regraded tailings retention embankment. A critical section, illustrated on Figure 5-11, was selected for the analyses. Analyses were performed for both static and earthquake (pseudostatic) loadings to determine the factor of safety against a slope failure that could cause the release of tailings. The factor of safety against slope failure for static conditions was 2.7, and for earthquake conditions was 1.6, representative of a highly stable configuration. The slope stability calculation is provided in Appendix E.

5.6.6.2 Protective Bench

A protective bench, adjacent to the runoff control ditch at the base of the tailings embankment, will be located between the embankment toe and the Pipeline Arroyo channel. The protective bench will be 40-feet wide and up to 20-feet higher than the Pipeline Arroyo channel bank. Figure 5-10 shows the profiles of the bench toe, bench top and embankment top. Figures 5-12 and 5-13 show several cross sections illustrating the spatial relationship among these features, as well as the Pipeline Arroyo channel. Figure 5-13 provides a detail of the protective bench and the runoff control ditch.

5.6.6.3 Runoff Control Ditch

The runoff control ditch, shown on Figures 5-1 and 5-2, will intercept runoff from the western side slope of the tailings cover, located between the protective bench and the embankment toe (Figures 5-1 and 5-13). Interception of runoff will preclude the formation of gullies at the Pipeline Arroyo channel, which could otherwise eventually intrude upon the tailings disposal area. The runoff control ditch will transport the collected runoff to a downdrain, to the south cell drainage channel, then to the Pipeline Arroyo (Figure 5-4).

Calculation of the PMP amount and the PMF hydrograph were conducted using the methods described in Section 5.5.4. Appendix E includes the work sheets for these calculations. The cross sections and channel slopes were determined from Figures 5-1 and 5-2. Maynard's method was used to calculate the normal flow depth and the riprap sizes.

The runoff control ditch was designed as a trapezoidal channel with a 10-foot bottom width (Figure 5-13). The side slope on the bank of the protective bench, which makes up the outer bank of the runoff control ditch, will be 3H:1V. The side slope of the protective bench will be the same as the tailings embankment slope (5H:1V) on the east bank. The minimum depth will be 2 feet. The channel slope will vary from 0.003 to 0.019 ft/ft. Figure 5-13 shows a typical channel section.

The PMF for the runoff control ditch has a peak discharge of 52 cfs. This peak discharge produces a peak flow depth of 1.26 feet in the channel sections, sufficiently lower than the 3-foot depth of the ditch, allowing the PMF flow to pass.

The riprap that will be used to protect the ditch during a PMF event was sized using the Safety Factors method. This resulted in a D_{50} size of 1.5 inches in the upper reach and a D_{50} size of 3 inches in the lower reach of the runoff control ditch. The riprap layer will be 6 inches. A 6-inch-thick filter layer will underlie the riprap in the lower reach of the runoff control ditch only (Figure 5-13). Due to the low flow velocity in the upper reach, the smaller riprap (D_{50} of 1.5 inches) does not require a bedding layer. Tables 5.6 and 5.7 show gradation sizing of the riprap and bedding material (for the lower reach), respectively. Section 5.6 describes requirements for the rock riprap.

5.6.6.4 Buried Jetty

The nickpoint must be stabilized to maintain the geomorphic stability of Pipeline Arroyo, which will be accomplished by constructing a buried jetty, a stone-filled trench, that will extend across the valley approximately 150 feet north of the nickpoint outcrop. The jetty will extend from the Gallup Sandstone subcrop in the arroyo's west bank to the top of the protective bench along the tailings embankment toe at station 59+50. The jetty will ensure flows continue to pass over the nickpoint, and will provide vertical control of the Pipeline Arroyo channel bottom. Vertical control will maintain the shallow slopes for the channel reach upstream from the nickpoint and thus, will maintain the long-term geomorphic stability of Pipeline Arroyo. The jetty has been designed to withstand the effects of the PMF passing over it. In addition, the low-flow channel will contain smaller, but more frequent, flood events and direct these flows over the nickpoint.

Figure 5-1 shows the location of the jetty, while Figure 5-9 provides the jetty details. The jetty will be keyed into the nickpoint at its furthest extent to maximize the flow capacity within the nickpoint. The exact configuration of the eastern edge of the nickpoint will be determined in the field during construction. The low-flow channel is designed to be 30 feet wide and located at the jetty's west terminus. The low-flow channel width constructed at the nickpoint may change, depending on the nickpoint configuration determined in the field.

The sizing of the jetty stone (riprap) was calculated using the Safety Factors method. The maximum depth of the PMF at this station (8.0 feet), as determined by the HEC-2 simulation and the actual channel-bottom slope, was used in these calculations. Appendix E provides the detailed calculations. The resulting D_{50} rock size of the jetty is 6 inches.

5.6.6.5 Flood Routing - Modified Pipeline Arroyo Channel

The PMF was routed through the Pipeline Arroyo channel as configured in this plan to evaluate the effectiveness of the planned channel and embankment modifications. The COE's program HEC-2 was used to simulate the passage of the PMF of 26,300 cfs through the modified arroyo channel. Appendix E includes the simulations. The simulation for reaches 1 and 2 (station 0+00 to station 61+40) was conducted for the subcritical flow conditions that will occur in these reaches, while the simulation for reach 3 (station 61+40 to station 82+90) was performed to model the supercritical flow conditions occurring in this reach.

Figures 5-1 and 5-2 show the extent of the PMF floodplain, while Figure 5-10 shows the profile of the PMF maximum WSEL. The PMF fills most of the wide valley north of the tailings impoundment. The WSEL of the PMF stays below the top of the protective bench from station 35+00 to station 80+10 (Figure 5-10). Thus, the bench will protect the embankment toe, and will keep the runoff control ditch above the PMF level. The average velocities and depths of the PMF within Pipeline Arroyo along the 5H:1V side slopes of the protective bench were determined by the HEC-2 program and are summarized below:

Station No.	Average Velocity (fps)	Depth (feet)
82+90	0	0
80+10	0	0
73+80	0	0
63+80	0	0
62+30	0	0
61+40	2.79	1.0
60+40	5.92	3.5
57+75	6.40	4.6
50+00	3.82	4.0
41+95	3.91	3.0
35+00	0.97	0.5

Downstream of station 63+90, the PMF is contained within the Pipeline Arroyo channel and does not reach the overbank area or the protective bench.

While some portions of the side slope of the protective bench will be contacted by water produced during the PMF passage, the low-flow velocities along the side slopes indicate that little scouring will occur during this one-time event. Evaluation of the scour amount was completed using the methods described in the Bureau of Reclamation's Technical Guideline for Computing Degradation and Local Scour (Pemberton and Lara, 1984). Appendix E provides the detailed scour calculations.

The evaluation indicated the maximum expected lateral bank scour during the PMF passage was 4.9 feet. As shown on Figures 5-12 and 5-13, the runoff control ditch will be located 14 feet from the protective bench edge, and the tailings embankment toe is 40 feet from the protective bench. Thus, the PMF will not contact either the runoff control ditch or the tailings embankment toe.

The flow capacity was evaluated for the portion of the low-flow channel protected from erosion by the nickpoint rock to determine what flow rate would be required to exceed the low-flow channel. At Station 59+50, the low-flow channel bottom and west bank will be protected by the nickpoint rock, while the east bank will be protected by the buried jetty. The low-flow channel in this area will have a bottom width of 30 feet, 3H:1V side slopes, and a depth of 4.0 feet. HEC-2 simulations were used to determine that 2,250 cfs will be contained within this low-flow channel. This flow is slightly greater than the peak discharge of the 100-year flood of 2,100 cfs for Pipeline Arroyo. Thus, the low-flow channel is capable of containing all low flows up to, and including, the 100-year flood.

5.6.6.6 Stability of the Jetty and Pipeline Arroyo Below Jetty

Some potential exists for headcuts to form at the Pipeline Arroyo channel banks downstream of the buried jetty, when flows are greater than those that could be contained in the low-flow channel, i.e., flows greater than 2,250 cfs. These flows would pass across areas not protected by riprap and into the channel below the nickpoint. The increasing depth from the channel bank to the channel bottom, within the nickpoint, will capture these flows and allow potential headcut formation that could migrate towards the jetty. The location of the headcuts will depend upon the water-surface elevation of the flows.

Flows greater than 2,250 cfs have a recurrence interval greater than approximately 110 years. Therefore, in a 1,000-year period, flood events with peak discharges greater than 2,250 cfs should occur, on the average, only nine times. Consequently, in a given year, the probability of occurrence of a flood event greater than 2,250 cfs is less than 1 percent and flows will remain within the low-flow channel more than 99 percent of the years.

As shown on Section B-B' of Figure 5-9, any potential headcuts will have to start at least 150 feet downstream from the jetty, at the beginning of Reach 3. The low-flow channel remains stable for this distance at a constant small slope on the nickpoint rock. Thus, the propensity for creating headcuts will not exist in the first 150 feet below the jetty because any flows in the overbank area will be traveling parallel to the channel banks.

The channel slope begins to increase 150 feet from the jetty. At this point, the channel will be able to carry more flow and will capture any overbank flow. As this overbank flow enters the channel, it could induce headcut formation beginning at this location. Any headcuts formed at this point will be shallow headcuts because the channel depth is shallow.

Headcuts that could affect the toe of the jetty will have to start at least 308 feet downstream from the buried jetty. As shown on Section C-C' of Figure 5-9, the toe of the jetty will extend downward to an elevation of 6,923 feet at Station 59+70. Assuming a headcut channel slope of 0.01 ft/ft, a potential headcut will have to form at or below Station 62+78, where the Pipeline Arroyo channel bottom is at elevation 6,920 feet, to be below elevation 6,923 feet at the toe of the jetty. This potential headcut could migrate only about 308 feet from Station 62+78 to Station 59+70.

Only the large, more infrequent flood events will be able to remain in the overbank area 308 feet downstream from the jetty. Thus, the likelihood of a large flood event is extremely small. For example, the PMF is fully contained within the Arroyo 420 feet downstream of the jetty.

Given the unlikely scenario that a potential headcut migrated from below Station 62+78 to the jetty by the occurrence of nine or less flood events, additional flood events with recurrence intervals greater than 110 years will be required to breach the jetty and migrate upstream from the jetty, further reducing the likelihood of a potential headcut breaching the jetty within a 1,000 year period.

Finally, even in the unlikely event of a potential headcut breaching the jetty, the headcut would then migrate directly upstream parallel to Pipeline Arroyo, and thus parallel to the protective bench at the toe of the tailings embankment. Therefore, a potential headcut will not intercept the tailings embankment. In addition, the runoff control ditch on the protective bench will intercept runoff from the tailings embankment, ensuring that potential tributary headcuts do not form on or towards the embankment.

Therefore, considering the many reasons provided above, headcut formation is extremely unlikely to breach the jetty and create conditions that could cause the release of tailings in a 1,000-year period. It follows logically that such an occurrence in a 200-year period is infinitely smaller.

5.6.6.7 Geomorphic Effects - Modified Pipeline Arroyo Channel

The long-term stability of the Pipeline Arroyo channel was evaluated in terms of the potential channel bank erosion, the potential for meander formation, the effects of the nickpoint and jetty reinforcement of the nickpoint by the buried jetty, on channel geomorphology.

Channel Erosion - The design of the reconfigured Pipeline Arroyo creates little change to the existing erosional and geomorphic conditions within the valley. The channel slopes will remain extremely flat (0.003 ft/ft) in reaches 1 and 2 (Station 0+00 to Station 61+90). Thus, the erosional capacity of all flows in these reaches will be minimized. The steeply sloped area within the nickpoint will be protected from erosion by the nickpoint rock. The jetty will also ensure that flows remain on the nickpoint at a location as far as possible from the tailings embankment. Some erosion is expected in reach

3, below the nickpoint, but the channel slopes in this reach will remain at their existing values (0.0118 to 0.0220 ft/ft) to minimize this erosion. In addition, the vast volume of material in the area between the Pipeline Arroyo and the tailings embankment effectively prevents the release of tailings due to channel erosion, within a 1,000-year period.

The North Diversion Ditch and South Cell Drainage Channel enter the Pipeline Arroyo with the same channel-bottom elevation as the arroyo in the respective locations (Figures 5-1 and 5-2). Also, both the North Diversion Ditch and the South Cell Drainage Channel are separated from the tailings by a reach cut through rock. Erosion in the reaches downstream from the rock cuts will not be able to affect the reaches upstream from the rock cuts. Thus, the rock cuts provide long-term stability for these channels.

Meander Growth - An evaluation of potential meander growth along Pipeline Arroyo was conducted to assess the likelihood of the release of tailings due to this geomorphic phenomenon. The evaluation first characterized existing meander patterns of the Pipeline Arroyo and a nearby similar arroyo. These characteristics were then applied to the modified-channel configuration and location, and the potential impact was identified.

Figure 5-14 shows the channel reaches and watersheds, characterized in the watershed known as Hard Ground Canyon, which is about 5 miles northwest of Pipeline Arroyo. The two watersheds are similar in size, soil and vegetation characteristics. The channels draining these watersheds are also similar, in that their lower reaches are deeply incised, probably by headcutting that has migrated from downstream areas. The headcuts have been terminated by sandstone outcrops (nickpoints), resulting in the formation of large alluvial-fill valleys upgradient of the nickpoint. The channels upgradient of the nickpoints have shallow slopes.

Table 5.12 provides the meander characteristics for the two channels. As can be seen, a wide range in channel slopes exists. However, the range of meander amplitudes (lateral distance from meander trough to meander peak) is quite small. Thus, channel slope does not have a strong influence on meander amplitude for these channels. The average meander amplitude for the two channels is 155 feet with a maximum amplitude of 570 feet within Pipeline Arroyo and 350 feet in Hard Ground Canyon. These maximum values may have been influenced by rock outcrops or variations in soil characteristics.

Comparison of the distances between the Pipeline Arroyo channel and the tailings with the 155-foot average meander amplitude indicates meander growth will not cause the release of tailings. As shown on Figures 5-1 and 5-2, the distance between the channel and the tailings ranges from 335 feet at station 36+50 to 680 feet at station 76+00. Figures 5-12 and 5-13 illustrate this relationship at stations 41+95, 60+40 and 73+80. These distances are all greater than the 155-foot average meander amplitude and approach the maximum amplitudes noted for the two channels. Thus, even if all the meander growth were in the direction of the tailings impoundment, the meander will still be greater than 180 feet from the tailings embankment and will not result in the release of tailings.

5.7 Rock Riprap and Bedding Material

Rock riprap and bedding material layers have been designed for many surface water control swales, channels and ditches to provide long-term stability for the tailings impoundment and radon attenuation soil cover. Tables 5.5, 5.6 and 5.7 summarize the gradation requirements for the riprap and bedding materials. Appendix E includes the calculations for these designs.

5.7.1 Bedding Material Requirements

Rock riprap is designed to provide erosion protection for the PMF events in each channel. As shown in Table 5.7, a filter-blanket, bedding layer is planned under many of the riprap layers. A filter layer prevents the migration of underlying finer-grained soil into the riprap layer to maintain riprap stability during large, high-velocity flow events. Loss of fine-grained soil from the foundation layer, due to migration, can create voids in the foundation material, and lead to riprap failure from loss of support. Accordingly, filter layers have been designed to prevent the migration of fine-grained soil and the riprap failure. In some areas, the riprap is sufficiently fine that filter layer is not required.

Filter layers have been designed, based on criteria presented in NUREG/CR-4480. Two filter layers are required in all locations where bedding material is used. The primary filter will consist of a well-graded mixture with a D_{50} of 0.02 inches (Table 5.7), which will prevent upward migration of the fine-grained soils (silts and clays) in the foundation material. The secondary filter/bedding layer will prevent migration of the fine fraction from the primary bedding layer. The secondary filter/bedding layer will consist of a well-graded material with a D_{50} of 0.35 inches (Table 5.7). Table 5.7 presents more complete gradation requirements.

The primary and secondary filters/bedding layers will have a minimum thickness of 3 inches. Filter material will consist of hard durable material meeting the same durability requirements as the riprap. Filter material used on-site will be tested for the same parameters, and at the same frequency as riprap material.

5.7.2 Rock Riprap Selection

The rock riprap at the United Nuclear site will be subjected to "occasionally" to "seldom" saturated conditions (NRC, 1986). Therefore, freeze-thaw resistance, abrasion and chemical weathering are less important. The intermediate and poor ratings of the limestone samples (Section 3.0) for absorption and abrasion criteria are also less critical than they might be for frequently saturated areas.

NRC guidelines identified in Appendix D, August 1990 Staff Technical Position (STP), "Design of Erosion Protection Covers for Stabilization of Uranium Mill Tailings Sites" suggest that, to be suitable for use as riprap in occasionally-to-seldom saturated areas, rock should have quality scores from 50 to 65. A minimum score of 65 is necessary for rock riprap placed in critical areas. Alternatively, a lower score of at least 50 may be acceptable, if it can be demonstrated that the cost of obtaining adequate rock is excessive.

Testing the limestone rock source considered for use as riprap in critical areas produces a range of rock quality ratings from 57 using all worst-case test results to 67 using all best-case test results. Table 3.4 provides the test results and rating calculations. Thus, the rock-quality rating of this rock may at times be less than 65. In License Condition 34, the NRC requested the rock source for riprap to be placed in critical areas have a quality score of at least 65. Alternatively, a lower score of at least 50 is acceptable, if it can be demonstrated that the cost of obtaining adequate rock meeting the criterion is excessive, compared to the benefit of using better rock. The cost of obtaining, transporting and placing limestone rock is estimated at $54 per cubic yard for rock larger than 12 inches in diameter and $25 per cubic yard for rock less than 12 inches in diameter.

The commercial source of basalt rock investigated, from the Grants, New Mexico area--approximately 80 miles from the site, has rock up to 30 inches in diameter with a rock quality rating of 93. Table 3.5 provides the test results and rock quality rating calculation for this rock. The cost for obtaining and placing this rock is generally the same as for the limestone. However, transportation of the rock will add approximately

TABLE 2

SCORING CRITERIA FOR DETERMINING ROCK QUALITY

Laboratory Test	Weighting Factor			Score										
	Limestone	Sandstone	Igneous	10	9	8	7	6	5	4	3	2	1	0
					Good			Fair			Poor			
Sp. Gravity	12	6	9	2.75	2.70	2.65	2.60	2.55	2.50	2.45	2.40	2.35	2.40	2.25
Absorption, %	13	5	2	.1	.3	.5	.67	.83	1.0	1.5	2.0	2.5	3.0	3.5
Sodium Sulfate, %	4	3	11	1.0	3.0	5.0	6.7	8.3	10.0	12.5	15.0	20.0	25.0	30.0
L/A Abrasion (100 revs), %	1	8	1	1.0	3.0	5.0	6.7	8.3	10.0	12.5	15.0	20.0	25.0	30.0
Schmidt Hammer	11	13	3	70.0	65.0	60.0	54.0	47.0	40.0	32.0	24.0	16.0	8.0	0.0
Tensile Strength, psi	6	4	10	1400	1200	1000	833	666	500	400	300	200	100	0

LIMESTONE ROCK QUALITY RATINGS

Lab Test	Result	Score	Weight	Score x Weight	Maximum Score
Specific Gravity	2.61	7	6	42	60
Absorption, %	1.22	4	5	20	50
Sodium Sulfate, %	6.90	6	3	18	30
L/A Abrasion, %	8.70	5	8	40	80
Schmidt Hammer	51	6	13	78	130
Tensile Strength, psi	670	6	4	24	40
Totals				222	390

Rating: 222/390x100% = 57

TABLE 1

SAND, ROCK, RIPRAP GRADATION REQUIREMENTS

Percent Passing by Weight

D^{50} (inches) — Sieve Size:	20 inch	15 inch	12 inch	10 inch	6 inch	5 inch	4 inch	3 inch	1 inch	3/4 inch	No. 4	No. 10	No. 40	No. 200
.02								100		85-100	65-100	47-94	23-70	15-30
.35								65-100		43-80	22-60	15-38	5-12	0-10
1.5								100	8-37		0-8			
3.0					100		45-67		0-22					
6.0				100	28-51		13-36		0-9					
9.0		100		45-58		10-33		0-23						
15.0	100		28-40		8-21		2-14	0-10						

$17 per cubic yard to the emplaced cost. This represents a 61 percent increase in the cost of the smaller rock and a 31 percent increase in the cost of the larger rock.

The total volume of rock needed in the critical areas for both riprap and bedding material is estimated at 33,500 cy. Thus, the additional cost of transporting the rock from the Grants source is approximately $569,500. United Nuclear deems this amount excessive.

All other sources of rock identified to-date are either more distant than the basalt source, or consist of rock with a minimum rating of less than 65. As a result of NRC review comments, United Nuclear has agreed to provide riprap with a minimum rating of 65 for all critical areas (i.e., Buried Jetty, Runoff Control Ditch, North and South Cell Drainage Channels, and existing North Diversion Ditch). United Nuclear also agreed to further investigate and test other rock sources to identify rock meeting this criterion. Based on the test results, United Nuclear will either propose procedures for meeting this criterion, or propose and justify the use of the best quality rock available near the Church Rock facility. United Nuclear will also investigate alternative testing techniques to identify acceptable test techniques more applicable to limestone materials than testing performed to-date.

5.7.3 Rock Riprap Requirements

The exact rock sources to be used for erosion protection in final reclamation have not been identified. However, based on the rock selection considerations in the previous section, the following requirements have been developed for rock material quality used as riprap.

Rock used as riprap will be tested to determine rock durability for the following criteria: specific gravity, absorption, soundness and the L.A. abrasion test. The rock will be sampled and the tests performed consistent with the NRC's August 1990 STP. The source for material used for riprap and rock mulch shall be dense limestone and shall meet the following minimum criteria:

1.	Specific Gravity	2.6 or greater
2.	Absorption	1.8 percent or less
3.	Sodium Sulfate Loss	10 percent or less

Alternatively, the rock source shall have a minimum score of 50 using the scoring criteria shown on Table D1 of the August 1990 STP and will be oversized, if needed, in accordance with the procedures in Appendix D of the August 1990 STP.

5.8 Revegetating Disturbed Areas and Securing Reclaimed Areas

At the completion of final reclamation, disturbed areas will be revegetated, and the reclaimed areas secured to prevent unauthorized access.

5.8.1 Revegetation Considerations

The areas revegetated in final reclamation will consist of areas disturbed by reclamation construction activity, but not covered with the soil/rock matrix. Revegetation requirements have been developed based on species currently on-site, discussion with local SCS representatives, and adaptability of species to the site. Sod and bunchgrass species have been selected to provide soil stability and to minimize erosion. The native-seed mixture for permanent revegetation, presented in Table 4.2, will be planted between mid-June and mid-September to allow for favorable moisture and temperature conditions.

During final reclamation, the following areas will be revegetated with the permanent seed mixture shown in Table 4.2. Approximately 40 acres will require revegetation, including Catch Basins Nos. 1 and 2, and the regraded area between the embankment and the Pipeline Arroyo. These recontoured areas are shown on Figures 5-1 and 5-2.

The areas to be revegetated will be prepared in the following manner:

1. The area will be recontoured using construction equipment and prepared for seeding by disking or harrowing along the contours.

2. Soil samples will be taken from the areas prepared for seeding to determine soil fertility. Analyses will assess the amount of nitrate-nitrogen, phosphorus, organic matter, and potassium contained in the areas to be revegetated.

3. The permanent seed mixture (Table 4.2) will be planted using one of two seeding methods, including drill or broadcast seeding. The primary seeding method will be drill seeding. Drill seeding offers uniform placement of seeds, requires fewer seeds per acres planted, and can be drilled directly into a preparatory crop stubble, providing a uniform stand of seeded plants. Broadcast seeding is not considered as effective as drill seeding due to uneven seed distribution and, if seeds are not properly covered with soil, seed desiccation can occur. If broadcast seeding methods are used, the application rate in Table 4.2 will be doubled.

4. Mulch will be applied to all seeded areas planted with the permanent seed mixture to conserve soil moisture and to protect the bare soil from water- and wind-induced erosion. Mulch will be applied immediately after seeding and fertilization. If a stubble stand has been developed through the use of a preparatory crop, mulching may not be required. This point will be decided

at the time of seeding. No slopes will be greater than 5H:1V. Accordingly, no special mulch, such as jute netting, cellulose fiber, exclusion mat, etc., will be required.

5.8.2 Maintenance and Revegetation

The success of the revegetation will be evaluated yearly with respect to desired germination levels. If the desired results have not been achieved, the area(s) requiring reseeding will be seeded with permanent seed mixture.

5.8.3 Secure Fencing

Existing barbed-wire fencing will be used to control access into the majority of the reclaimed areas. The fencing will prevent livestock grazing and will remain in place as long as United Nuclear is responsible for maintaining the areas. Permanent fencing will be installed at the time of license termination to separate areas to be deeded to the U.S. Department of Energy.

5.9 Materials Balance

To understand the material balance during final reclamation, this section summarizes where various materials will be obtained and placed. Excavation and grading operations during final reclamation are planned, as shown on Figures 5-1 and 5-2, to provide materials handling flexibility and an approximate balance between cut and fill quantities. Estimated areas and volumes for each major materials handling activity are presented in Table 5.13 and discussed briefly below.

Borrow Pit No. 2 - Borrow Pit No. 2 will have been backfilled with mill demolition debris and excavated ore-pad materials during interim stabilization. During final reclamation, approximately 155,000 cy of material, including catch-basin materials, unsuitable soil-cover materials, and other soil as necessary, will be required to bring the surface of the borrow pit to the final grades shown on Figures 5-1 and 5-2.

Pipeline Arroyo - The Pipeline Arroyo, will be modified to have a consistent 30-foot-wide low-flow channel, and the protective bench between the arroyo and the runoff control ditch. This modification will occur during final reclamation over about 27 acres, and will require the excavation of approximately 36,000 cy and placement of approximately 103,000 cy of soil. This results in a net fill requirement of 67,000 cy. The extra soil required for the fill sections will be taken from the South Cell Drainage Channel excavation.

South Cell Drainage Channel - The South Cell Drainage Channel will be extended to the Pipeline Arroyo (Figure 5-1) to allow PMF passage. This channel excavation will provide approximately 84,000 cy of soil, expected to be used in fill sections near the Pipeline Arroyo.

Soil Stockpile - The existing soil stockpile will be used as a source for cover materials, evaporation pond backfill and Borrow Pit No. 2 backfill as needed. It is estimated the existing stockpile contains approximately 325,000 cy of material. An additional 135,000 cy is available from excavating existing soils beneath the pile if necessary. An anticipated 352,600 cy of material from the stockpile will be used in the radon attenuation layer of the soil cover, the soil/rock matrix, and for backfill in the evaporation ponds and the borrow pit.

6.0

6.0 CORRECTIVE ACTION PROGRAM

6.1 Introduction

United Nuclear was required to implement active seepage remediation at the Church Rock site because constituent concentrations in ground water exceeded the:

1. Ground water protection standards established by the NRC and documented in Condition 30 of United Nuclear's Source Materials License, and

2. Applicable or Relevant and Appropriate Requirements (ARARs) established by the EPA and documented in the Record of Decision (ROD) dated September 30, 1988.

This active seepage remediation program, referred to here as the CAP, evolved over two years, from 1987 through 1989, and was based on requirements established by the NRC and later, the EPA. License Condition 30B identified the ground water protection standards for the site and License Condition 30C required that a CAP be implemented because the standards were exceeded at the designated Point of Compliance (POC) wells.

The EPA initially became involved when the site was placed on the National Priorities List in 1981. EPA conducted a remedial investigation and feasibility study (RI/FS) for the site beginning in 1984, and completed it in 1988. The results of the RI/FS were used to develop ARARs and remedial action alternatives for areas impacted by tailings seepage. EPA prepared a ROD, documenting the selected remedial actions for the site, and listing the selected ARARs. Under an Administrative Order issued in mid-1989, EPA required that United Nuclear prepare a remedial action plan (RAP) and an RD.

NRC and EPA have entered into a Memorandum of Understanding (MOU), which delineates each agency's responsibilities for administering the remedial action at the site, which follow:

1. NRC - source control and on-site surface reclamation pursuant to the License,

2. EPA - off-site ground water remediation pursuant to the ROD, and

3. NRC and EPA - integration of ground water remediation pursuant to the NRC License and EPA's ROD.

6.1.1 Purpose

The CAP report provides the design detail of the corrective action, including the following components:

1. Delineation of the target areas, taking into consideration the hydrogeologic database, the NRC's ground water protection standards, and the EPA ARARs,

2. Detailed design of the remedial action systems, including design basis, engineering methods, and design specifications for the Zone 3 and Southwest Alluvium seepage extraction systems, limited remedial action in Zone 1, and the spray/evaporation system, including the water balance,

3. Performance monitoring program,

4. Criteria for decommissioning,

5. Remedial action schedule.

6.1.2 Objectives of the CAP

The objective of the CAP is to return the concentrations of the constituents identified in United Nuclear's NRC License to the ground water protection limits set forth in the License. Table 6.1 presents the ground water protection standards to be met at the POCs for Zone 3, Zone 1, and the Southwest Alluvium. This table also displays the exceedances of ground water protection standards identified by the NRC in Amendment 4 of United Nuclear's License, at certain locations in the formations of concern.

The objective of the CAP, consistent with the objective stated by the EPA in Appendix A to the ROD (EPA, 1988a), is also to capture seepage that has migrated from the tailings impoundment, and to abate future seepage migration so ground water outside the tailings impoundment is protected, to the maximum extent practicable and necessary, to protect public health and the environment. Performance of the remedial action will be measured against ARARs established by the EPA in its ROD. Table 6.2 contains the ARARs established for the Church Rock site. This table also displays the EPA-identified ARARs exceedances at certain locations in each of the formations of concern, and the constituents of primary concern to the EPA.

6.1.3 Summary of Corrective Action Program

This CAP for collecting tailings seepage was developed in response to the NRC License Condition No. 30, Amendment No. 4 to the Source Material License SUA-1475 issued on January 3, 1989, and to the EPA ROD for the United Nuclear Church Rock site, issued September 30, 1988 (EPA, 1988a). The CAP presents the technical basis for the detailed design of the tailings seepage active remedial action.

The CAP was presented to the NRC and EPA in April 1989 in the document titled "Remedial Design Report" (RD), prepared by Canonie (1989). The program was initiated in May 1989 and has been operating for almost two years. This section incorporates the RD, describing the CAP implemented, together with changes implemented as a result of annual performance reports and agency comments.

Throughout the remainder of Section 6.0, the terms "corrective action "and "remedial action" are used interchangeably. Typically, corrective action is a term used by the NRC and remedial action is a term used by the EPA. The RD (the basis for Section 6.0), while prepared specifically for the EPA under the Administrative Order, describes the components of the Zone 3, Zone 1 and Southwest Alluvium seepage cleanup program submitted to and approved by the NRC as the CAP.

Corrective action has been implemented for the geologic formations of concern identified as Zone 3 and Zone 1 of the upper Gallup Sandstone and the Southwest Alluvium in the GHR (Canonie, 1987a), the EPA's Feasibility Study (FS) (EPA, 1988b) and the EPA's Remedial Investigation (RI) (EPA, 1988c). Figure 6-1 is a site-orientation map providing an overview of the site and the areas where remedial action is occurring.

As stated in the RD (Canonie 1989d), United Nuclear proposed seepage remedial actions to the NRC as part of Amendment I to this Reclamation Plan (July 1988), consisting of the expansion of its then existing, seepage-extraction system in Zone 3, and continued operation of its then existing, seepage-extraction system in Zone 1, until the source of seepage to Zone 1 (i.e., Borrow Pit No. 2) was dewatered. It proposed natural attenuation processes in the alluvium i.e., natural pH buffering capacity, made it unnecessary to capture seepage from the South Alluvium. The remedial actions for Zone 3 and Zone 1 were approved by the NRC, and found by the EPA to be "at least consistent with" its ROD in September 1988. The ROD, however, indicates a seepage-extraction system should also be installed in the Southwest Alluvium. A similar requirement was subsequently prescribed by the NRC in License Amendment No. 4. United Nuclear proceeded with its design to accommodate these requirements.

In March 1989, United Nuclear submitted Amendment II to the Reclamation Plan for the NRC's consideration (at the same time it submitted the RD to EPA). This amendment proposed the desired seepage extraction system in the Southwest Alluvium. This CAP integrates remedial measures for Zone 3, Zone 1 and the Southwest Alluvium.

In the CAP, United Nuclear considers the hydrogeological properties of the formations, subject to remedial action in designing the methods to meet the NRC ground water protection standards and the EPA's ARARs established for this site. The CAP identifies target areas and POC within those target areas, for which remedial action will be implemented. It also provides details of remedial-action-design-performance monitoring program to observe and evaluate system performance, and identifies decommissioning criteria. The corrective action is designed to be performance-based and as such, is designed for flexibility to accommodate variability in conditions encountered and saturation changes occurring during system operation.

Seepage remedial action at the Church Rock site consists of extraction of tailings seepage from Zone 3 and the Southwest Alluvium, and limited seepage extraction from Zone 1 until dewatering of Borrow Pit No. 2, to remove the source of tailings seepage to Zone 1, is completed. The collected tailings seepage will be disposed of by evaporation. Figure 6-1 shows the location of the remedial activities. A summary of the remedial action for the three strata is presented below.

6.1.3.1 Zone 3

Tailings seepage in this stratum originated in the North Cell of the tailings impoundment and migrated to the northeast. Geohydrologic conditions and ARAR exceedances have been used to aid in identifying the Zone 3 target area and POCs. However, since Zone 3 has no acid-buffering capacity, acidic pH measurements provide the most reliable information about the extent of the target area in this formation.

Remedial action in Zone 3 consists of pumping 19 new wells in conjunction with the Zone 3 seepage-extraction wells, which have been in existence since 1983, to create a hydraulic barrier against further plume migration and to dewater the target area. The extractable volume of the target area in Zone 3 is estimated to be 200 million gallons or less, based on a target area of 100 acres, an observed average saturated thickness of 60 feet, and an extractable porosity of 10 percent. Monitoring hydrogeologic conditions during remediation will determine the duration and magnitude of pumping actually required.

6.1.3.2 Zone 1

Tailings seepage in Zone 1 originates from its subcrop in Borrow Pit No. 2. Since Zone 1 also has no acidic buffering capacity, the extent of the target area is also best defined on the basis of acidic pH. The remedial action for Zone 1 consists of dewatering Borrow Pit No. 2 and continuation of pumping from the existing north cross-dike and east pump-back wells. Pumping in Zone 1 after Borrow Pit No. 2 had been dewatered was considered impracticable and unnecessary because of the low transmissivity of the formation within the target area, as documented in the GHR and the ROD (Canonie, 1987a; EPA, 1988b). However, NRC and EPA have required the continued well operation, as discussed in more detail later.

6.1.3.3 Southwest Alluvium

The source of tailings seepage in the Southwest Alluvium is the South Cell of the tailings impoundment. Tailings seepage migrated to the southwest following the topographic dip of the site. The remedial action target area and POCs for the Southwest Alluvium are defined by the use of plume travel-time calculations together with chloride concentrations.

Remedial action for the Southwest Alluvium consists of a barrier/collection system of pumping wells completed in the target area. The system, which originally consisted of three wells and has since been expanded to include a fourth, is located downgradient of the southern edge of the South Cell of the tailings impoundment, and upgradient of the POC wells identified by the NRC in the Southwest Alluvium. The location, spacing and pumping rates for the wells were designed so an effective hydraulic barrier to further seepage migration through the alluvium could be established.

6.1.3.4 Disposal of Extracted Tailings Seepage

Seepage collected by the extraction wells is disposed of by evaporation. The system consists of two, 5-acre lined evaporation ponds equipped with an enhanced evaporation mist system and a separate mist or spray evaporation system installed on the tailings surface. The evaporation disposal system has been installed and is operated entirely within the tailings disposal area.

6.1.4 Performance Monitoring

A program of performance monitoring is used to evaluate the success of the remedial action in meeting design expectations. Performance monitoring may indicate the objectives have been met and the remedy is complete. The monitoring results may also indicate it is technically impractical to achieve all cleanup levels in a reasonable time period, and that it may be necessary to set ACLs and waive the requirements to meet certain contaminant-specific ARARs.

The objective of the monitoring program is to provide statistically valid water level and water quality data that can be used to evaluate the performance of the extraction system in meeting regulatory criteria. Water chemistry analysis for the monitoring program is conducted for the chemical constituents displayed in Table 6.3, including all constituents in exceedance of ground water protection standards and ARARs at the site. Water chemistry data are used 1) to monitor compliance with License Condition 30, Part B criteria at POC wells, 2) to monitor and assess trends in water quality that may develop in response to pumping, 3) to evaluate the effectiveness of cleanup within the target area, 4) to provide an adequate database for development of ACLs (NRC) and waivers to ARARs (EPA) if necessary, and 5) to supplement the existing database. In addition, background water quality plays a very important role in setting both the NRC's ground water protection standards and the EPA's ARARs. Therefore, the monitoring program is also designed to further aid in establishing background water quality conditions.

Water level data are used to determine the effects of the system on geohydrological conditions, including creation and performance of the hydraulic barriers and to monitor the decreases in saturation that will occur as pre-mining natural conditions are re-established.

6.1.5 System Decommissioning

The CAP presented in the RD and described in Section 6.2 of this plan sets forth conditions by which the system would be decommissioned. While these conditions set forth physical parameters used to define when systems become candidates for decommissioning, in accordance with NRC License Condition 30C, no program component meeting the decommissioning criteria will be decommissioned without prior approval from NRC.

The objectives of the extraction systems in Zone 3 and the Southwest Alluvium are to create a hydraulic barrier to further migration of tailings seepage, and also concurrently to dewater the identified target area in Zone 3. In addition, system operations may provide an opportunity to clean up water quality in strata, subject to remedial action to the NRC ground water protection standards and the ARAR levels established by the EPA in the ROD. However, both agencies have recognized that modifications may have to be made to these standards. The NRC regulatory mandate recognizes the possibility of not achieving the cleanup standards by providing, in Appendix A, 10 CFR 40, the option of establishing ACLs. Further, the EPA also provides an alternative approach of establishing waivers to the ARARs, stated in Appendix A to the ROD (EPA, 1988a).

The systems in Zone 3, Zone 1 and the Southwest Alluvium are performance-based, i.e., their success will be measured against their ability to produce compliance with agency water quality standards, or in the case of Zone 3, dewater the target area. Achievement of either condition will merit decommissioning the system. In addition, the inability of the systems to meet the above performance criteria would necessitate the issuance of ACLs (NRC) and ARAR waivers (EPA).

6.1.6 Summary of CAP Implementation

Table 6.4 summarizes the CAP implementation from 1989 through July 1991. In accordance with the requirements of the License and the ROD, implementation and evaluation of the CAP performance are documented annually in a report submitted to the EPA and NRC. To date, two reports, the 1989 and 1990 Annual Review (Canonie; 1989c, 1990a), have been submitted to the agencies. The summary presented here is based on the information in these reports. For ease of discussion, the implementation is presented on a yearly basis covering the period from January 1989 through July 1991 and includes the field activities completed in 1991. These field activities will be presented in the 1991 Annual Review to be submitted December 31, 1991.

6.1.6.1 CAP Activities - 1989

The 1989 CAP activity included operation of the evaporation disposal system, dewatering of Borrow Pit No. 2, and the installation and operation of the new extraction wells for Zone 3 and the Southwest Alluvium. These activities were conducted in accordance with the design presented in Amendment I (Canonie, 1988b) and Amendment II (Canonie, 1989a) to the 1987 Reclamation Plan (Canonie, 1987a) and the RD (Canonie, 1989d).

The evaporation disposal system began operation in January 1989, when seepage from Borrow Pit No. 2 and the existing pump-back wells was directed into the lined ponds, which were constructed during the Fall and Winter 1988. From that time, with the exception of a period between January and April 1991, all extracted seepage has been disposed of through the evaporation disposal system.

Borrow Pit No. 2 was dewatered by the end of April 1989, completing the Zone 1 active remediation presented in the RD (Canonie, 1989d). As shown in Table 6.4, the dewatering was completed approximately six months earlier than anticipated. United Nuclear continued to operate the Zone 1 pump-back wells through the end of the year.

The new extraction wells for both Zone 3 and the Southwest Alluvium were installed and began operating in 1989. Table 6.4 shows that the Zone 3 wells began operating at the beginning of August, while the Southwest Alluvium wells began operating in the middle of October.

The 1989 Annual Review (Canonie, 1989c) was submitted at the end of December, as required by the NRC License and the EPA Administrative Order. The report described the 1989 CAP implementation and an evaluation of the performance of the remediation systems. The evaluation results indicated that the remedial action systems in all three formations were performing as designed.

6.1.6.2 CAP Activity - 1990

CAP activity in 1990 consisted of continued operation of the systems operating in 1989, with some revisions to monitoring in Zone 3 and to the pump-back system well configuration for Zone 1. These revisions were implemented in response to NRC and EPA comments to the 1989 Annual Review (Canonie, 1989c).

As shown in Table 6.4, Well 126 was added to the Zone 3 monitoring program to provide water level data to further aid in the evaluation of the extraction well performance. The Zone 3 extraction wells continued to pump throughout 1990 in accordance with the schedule established in the RD (Canonie, 1989d).

As required by NRC and EPA, United Nuclear continued to operate the Zone 1 pump-back wells, although the monitoring data demonstrated that continued well operation would have no effect in accelerating the dissipation of the seepage mound and reducing contaminant concentrations. The agencies, in their comments to the annual review, required United Nuclear continue operating the Zone 1 wells under a modified program. United Nuclear proposed and implemented the modified program in September 1990. As shown in Table 6.4, the modified program consisted of pumping the revised east pump-back system, which consists of wells located further to the east within the remedial action target area, where water quality monitoring had shown the highest concentration of constituents of concern.

The 1990 Annual Review (Canonie, 1990a) was submitted in December. The report indicated all three remedial action systems operated as designed. The Zone 3 wells continued to dewater the target area and control plume migration. The Southwest

Alluvium wells had created a barrier approximately 90 percent effective in preventing further seepage migration. Monitoring data from Zone 1 provided a further demonstration that active remediation in this formation is not feasible.

6.1.6.3 CAP Activity - 1991

CAP activity, as of July 1991, consisted of operation of the seepage cleanup wells, adjustment to the operation of evaporation disposal system, installation of Stage II of the remaining Zone 3 extraction wells, installation of a new Southwest Alluvium extraction well, and implementation of an as low as reasonably achievable (ALARA) demonstration program for Zone 1. This information will be presented formally in the 1991 Annual Review to be submitted in December 1991.

The well system continues to operate in 1991. Some adjustments to pumping rates were made during the winter to reduce inflow to the evaporation disposal system for the period between January and April 1991. Reductions in pumping rates were necessary because the water level in the evaporation ponds had reached the maximum safe operating level. During this period, the northeast pump-back wells were turned off, and the Zone 3 extraction wells were reduced to approximately half their normal rate. The Southwest Alluvium and Zone 1 revised east pump-back wells continued to pump at their 1990 rates.

In addition, beginning at the end of January 1991, extracted seepage was discharged to Borrow Pit No. 2 for temporary storage. Discharge to the borrow pit was necessary to allow continued operation of the extraction wells and, at the same time, prevent exceeding the capacity of the evaporation ponds. A total of approximately 2.8 million gallons was discharged to the borrow pit for temporary storage, until April when the spray evaporation system began operating. The stored seepage was removed from the borrow pit by the end of May 1991 and disposed of through the spray evaporation system.

The Stage II, Zone 3 wells and the new Southwest Alluvium well were installed in May and June. The Stage II, Zone 3 wells were installed as described in the CAP and RD. The Southwest Alluvium well was installed as a result of comments from NRC and EPA upon review of the 1990 Annual Review (Canonie, 1990a). The additional well was required to complete the creation of a hydraulic barrier against further seepage migration. The Southwest Alluvium well began operating June 26 and the Zone 3 wells in August 1991.

United Nuclear also proposed and implemented a program to provide an ALARA demonstration for Zone 1. The program is based on discussions with the NRC and EPA about their review comments to the 1990 Annual Review (Canonie, 1990a). The demonstration program consists of pumping four Zone 1 wells known to be the most prolific Zone 1 water producers and monitoring the quantity and quality of water extracted. The wells will be operated for a period of five months. The purpose of the program is to provide a final demonstration that ALARA concentrations of chemical constituents in the Zone 1 target area have been achieved. The data collected during the performance monitoring of this system will be used to support an application for ACLs and a waiver to ARARs.

6.2 Corrective Action Program Details

This section presents a detailed description of the final CAP design as presented in the RD (Canonie, 1989d), as well as a description of the implementation and the status of the CAP through time. To date, the CAP status since implementation has been documented in two reports, the 1989 and 1990 Annual Reviews prepared by Canonie in accordance with the requirements of License Condition 30 and the ROD.

The original design of the remedial action systems presented in this section was based on data collected before implementing the CAP. Data collected since the CAP implementation have refined the understanding of site conditions and, at the same time, have validated the data on which the design was based. Continued monitoring of the performance of the systems will allow adjustments to system design, as necessary.

6.2.1 Zone 3 - Corrective Action Program

This section presents the technical basis for the design for the Zone 3 corrective action as originally presented in the RD (Canonie, 1989d), as well as the conditions that exist as of July 1991, approximately three years after implementation of the remedial action. Sections 6.2.1.1 through 6.2.1.6 incorporate much of the text, tables, and figures that were provided in the RD. Section 6.2.1.7 discusses system operation and performance, using the information presented in the 1989 Annual Review (Canonie, 1989c) and the 1990 Annual Review (Canonie, 1990a). This section also describes the installation of Stage II Zone 3 extraction wells completed in May 1991, in accordance with the schedule in the RD and the 1987 Reclamation Plan submitted in July 1987.

As described in the RD, the Zone 3 remedial action system was designed to create a hydrologic barrier against further tailings seepage migration and to dewater the target area. This design criterion was originally presented in Amendment I of United Nuclear's Reclamation Plan approved by the NRC. The EPA accepted this design as documented in the ROD.

6.2.1.1 Hydrogeology of Zone 3

The GHR (Canonie, 1987a) contains substantial detail about site hydrogeology and was the basis for design of the Zone 3 corrective action. As discussed in the GHR, Zone 3 was unsaturated in the target area before the onset of the mine dewatering in 1968.

Evidence for this condition is provided by the construction log for the northeast Church Rock mine shaft, water level data for the Indian Well located approximately 1.7 miles northeast of the site, and drilling logs for two deep geotechnical boreholes drilled in the tailings area. Figure 6-2 provides the locations of the mine shaft, well and boreholes.

Water levels reported in the mine shaft and Indian Well were projected into the tailings area to estimate the pre-mining and pre-milling water level. Figure 6-3 presents the results of this projection. The projection shown on Section A-A' indicates Zone 3 was unsaturated near the North Cell of the tailings impoundment.

The two deep geotechnical boreholes (HL-5 and SHB76-2W), drilled within the tailings area, support the conclusion that the near-surface geologic formations were unsaturated prior to mining and milling activities. Figure 6-2 shows the locations of Borehole HL-5, drilled in 1968 before mine dewatering and Borehole SHB76-2W, drilled in 1976 before tailings discharge. Both boreholes were drilled to an elevation of almost 6,800 feet, below the base of Zone 3, and both boreholes were reported dry when drilled. For more detailed discussion of these conditions, refer to the GHR (Canonie, 1987a).

After mining began in 1968, water discharged into Pipeline Arroyo percolated through the alluvium and into Zone 3, resulting in partial saturation and an attendant water quality (i.e., background). Tailings seepage then migrated into Zone 3 from the North Cell and, to a lesser extent, Borrow Pit Nos. 1 and 2, creating a ground water mound on top of the artificial system. Background water quality in the Zone 3 target area was then altered as seepage from the tailings impoundment commingled with the "background" water in the target area.

As identified by the EPA in the RI (EPA, 1988c), water migrated to the east-northeast at the northeast corner of the site. With increasing distance from the tailings site along this east-northeasterly flow path, Zone 3 approaches unsaturated flow conditions. This unsaturated condition is particularly evident in the vicinity of Well Nos. EPA-17 and EPA-1 where, in 1989 at the time the RD was prepared, less then 10 percent of the vertical section of Zone 3 was saturated. Well No. EPA-17 was reported dry when drilled (locations of these wells are shown on Figure 6-2). Zone 3 is dry in the area east of Borrow Pit No. 2.

Confirmation of the unsaturated condition is provided in the 1989 and 1990 Annual Reviews (Canonie; 1989c,1990a) which show that Zone 3 has already been dewatered near wells EPA-17 and EPA-18, in response to the pumping from the remedial action wells. Section 6.2.1.7 presents further discussion of dewatering Zone 3.

6.2.1.1.1 Physical Characteristics of Zone 3

Zone 3 consists of fine- to coarse-grained, quartzose sandstone with a thin coal and shale seam along its base. The thickness of this unit at the site ranges from 70 to 90 feet. Zone 3 dips at approximately 2 degrees to the northeast, and subcrops in the north end of Borrow Pit No. 2 and in the northeast corner of the North Cell. Evaluation of hydrologic testing by Billings and Associates, Inc. (1982, 1983, 1984, 1985a, 1985b) and CH2M Hill (1985) showed that Zone 3 has an average permeability of 10^{-3} centimeters per second (cm/sec) with an average transmissivity of 1,000 gallon(s) per day (gpd) per foot. In addition, pumping test data indicate saturation in Zone 3 exists in an unconfined condition and the unit storativity is 0.05 (Canonie, 1987a).

These geologic and hydrologic properties were verified when drilling and testing the Stage I wells (Wells 701 through 713). The 1989 Annual Review also discusses these properties (Canonie, 1989c).

Structural features, particularly the fracture zones identified on the cross sections presented in the GHR, appear to influence the direction of the flow in areas where the fractures are present. The effect of fracture-influenced flow is illustrated on the pH isoconcentration map in the GHR (Canonie, 1987a; Figure 3-1). As shown on the figure, plume migration from the North Cell is concentrated to the northeast and east along these predicted fracture zones. The fluid movement in Zone 3 is thought, however, to be dominated by porous flow because the distance of tailings seepage migration predicted on the basis of porous flow coincides with the plume's observed migration distance. Thus, fractures appear to control direction of flow, but do not significantly affect the fluid transport rate.

Aquifer testing of Zone 3 during installation of the Stage I wells in May/June 1989 confirmed the conclusion that porous flow dominates the fluid movement in Zone 3. The results of the testing were presented in the 1989 Annual Review (Canonie, 1989c).

<u>6.2.1.1.2 Flow in Zone 3</u>

The hydrologic regime in Zone 3 created by the mine water discharge and tailings disposal is transient. The tailings seepage mound has been dissipating since tailings discharge ceased in 1982. Evidence for dissipation was presented in the GHR and documents a decline in Zone 3 hydraulic gradients of 0.001 to 0.003 feet/feet per year (Canonie, 1987a). Since contribution to the recharge to Zone 3 no longer exists because mine dewatering has ceased, mound dissipation will continue at ever-decreasing rates. This process would occur even if no remedial action were implemented. Also, because the sources of recharge and the potential for future recharge when the tailings are reclaimed will no longer exist, a finite volume of water is present in Zone 3 of the target area. Remedial action in Zone 3 is based on removing that finite volume.

Remedial action in Zone 3 has accelerated the mound dissipation as indicated by the increased rate of decline in water levels and dewatering certain areas, such as the vicinity of EPA-17 and EPA-18. The effect of the remedial action in Zone 3 is documented in the 1989 and 1990 Annual Reviews (Canonie; 1989c, 1990a), and is discussed in Section 6.2.1.7 of this plan.

6.2.1.2 Zone 3 Target Area Delineation

In the ROD, the EPA identified the remedial action target area for Zone 3 be delineated as follows:

> "Active remediation of Zone 3 outside the tailings disposal site will be performed in areas contaminated by tailings seepage . . . The full extent of the tailings seepage plume will be determined . . . on the basis of ground water flow directions in the aquifer in conjunction with identification of the margin or amount by which standards are exceeded for hazardous constituents in ground water." (EPA, 1988a, page 3).

The chemistry of Zone 3 water is derived from two sources: the geochemical interaction of mine water discharged to the arroyo as it percolated through the alluvium and into Zone 3, and the tailings seepage. Despite the different origins of the saturation, water from both sources contains many of the same chemical constituents. Although tailings seepage is clearly much poorer quality than the water derived from mine discharge in Zone 3, the concentrations distinguishing the two water types is not always clear or consistent. For this reason, the Zone 3 target area, defined by the EPA's ROD based on ARAR exceedances, includes large areas saturated by mine water discharge, but not affected by tailings seepage. These areas represent background water quality.

Therefore, to ensure remedial action is completed in areas contaminated by tailings seepage, a water quality parameter must be used to define the tailings seepage plume, definitive in distinguishing between waters from the two sources. Since Zone 3 has no acid-buffering capacity, and the tailings seepage source is acidic in nature (Canonie, 1988a), pH measurements can be used to aid in defining the extent of the tailings seepage plume in that formation.

The Zone 3 target area can be further defined by considering travel distance and rate of seepage flow. The distance that particles of tailings seepage could travel northeastward from the tailings impoundment into Zone 3 was determined by the following calculation:

$$V = \frac{Ki}{n_e}$$

where:

V = velocity [length per time (L/T)]

K = permeability (L/T)

i = gradient (dimensionless)

n_e = effective porosity (dimensionless)

This calculation assumes porous media transport, rather than fracture flow conditions. As presented in the GHR (Canonie, 1987a), fracture flow does not significantly control the rate of fluid movement in Zone 3, although it may influence the direction of plume movement. This is substantiated by the calculations, as described below, because the distance calculated for plume migration based on porous flow coincides well with the observed migration distance. Aquifer test results reported in the 1989 Annual Review (Canonie 1989c) also substantiated this finding, as did water quality data collected since the RD was submitted in April 1989. Refer to Section 6.2.1.7 of this plan for a further discussion of the test results and water quality data.

The calculation is based on the permeability of Zone 3 (1.0×10^{-3} cm/sec) (Canonie, 1987a; Table 2.2), the average gradient in Zone 3 (0.03) (Canonie, 1987a, Figure 3-2), and the porosity of a sandstone (such as Zone 3) of 0.10 (Freeze and Cherry 1979, page 37). Considering that effective porosity may be 10 to 30 percent lower than the total porosity value (0.10), the formula produces values of velocity ranging from 345 feet/year to 444 feet/year. Tailings were first disposed of in the North Cell in 1980. Based on the six-year period available for plume migration, these velocities translate into plume travel distances of 2,000 feet to 2,500 feet. As shown on Figure 6-4, these calculated distances are consistent with the observed travel distance of 2,200 feet to the leading edge of the pH plume.

The target area determined from pH and seepage travel time, and shown on Figure 6-4, lies entirely within the more conservative target area determined by the EPA for Zone 3. The remedial action for this refined target area in Zone 3 is designed to extract and dispose of tailings seepage delineated in this manner.

6.2.1.3 Zone 3 System Design

As described in the RD, the remedial design for Zone 3 consisted of as many as 20 wells, installed in two stages. The first stage consisted of 12 new wells (originally 13) installed in 1989. The first five wells (708 through 712) were installed at the locations shown on Figure 6-5, and were tested to verify system performance as designed and the total number of new wells needed for this stage. As discussed in the 1989 Annual Review (Canonie, 1989c), the test results indicated one of the proposed wells (Well 704) should be eliminated from the system. The remaining seven wells (701 through 713, excluding 704) of the initial stage were installed at the locations shown on Figure 6-5.

As illustrated on Figure 6-5, the second stage consists of seven wells, installed in 1991. The well locations (Figure 6-5) are a refinement of those presented in Amendment I, based on the performance simulation presented here.

6.2.1.3.1 Zone 3 Design Criteria

In the ROD, the EPA identified in the ROD the criteria for design of a remedial action program for Zone 3 as follows:

> "Seepage collection in Zone 3 will be designed to create a hydraulic barrier to further migration of contamination. Final well locations will be guided by observed saturated thicknesses in Zone 3, and the extent of the tailings seepage plume as defined above. Data obtained during performance monitoring of the extraction system should be used to determine the optimum rate of pumping, and extent and duration of pumping actually required." (EPA, 1988a, page 3).

Therefore, the extraction system design was based on the following four criteria:

1. Capture and extract seepage in the target area, and create a hydraulic barrier against further migration of tailings seepage.

2. Locate wells in areas of maximum saturated thickness to ensure efficiency of extraction.

3. Space wells adequately to ensure efficient extraction rates and capture of the target zone.

4. Verify that predicted pumping rates for the system will dewater the target area within the reclamation period (by 1996).

6.2.1.3.2 Zone 3 Design Methods

The conceptual well layout was presented in Amendment 1 to the 1987 site Reclamation Plan (Canonie, 1988b), as approved by the NRC, using a well spacing of 150 to 200 feet. This configuration focused on surrounding the target area and the POCs, while maintaining most well locations north of the plume, to create a hydraulic barrier against the northeastern movement of tailings seepage. The well spacing was based on an initial calculation of required well distance to produce overlapping depression cones by two pumping wells, pumping at a rate of 5 gallons per minute (gpm). (5 gpm is known to be a feasible pumping rate in Zone 3, based on field observation.) The location and spacing of the wells was refined as a result of the performance simulation conducted for the RD, which identified inadequacies of the conceptual design presented in Amendment I (Canonie, 1988b).

Detailed design proceeded using the target area displayed on Figure 6-4. An isopach map of saturated thickness was constructed using water levels from October 1987. Data developed by United Nuclear when preparing the RD was used to adjust the 1987 data where necessary. Table 6.5 lists the water level data used to construct the isopach map. As shown on Figure 6-6, at the time the design was developed, the area of saturated thickness was greatest directly north of the North Cell, in areas that had become saturated by mine water discharge. The complex distribution of saturation shown on Figure 6-6 is a result of the intermittent and transient sources of recharge to the formation, the northeastern dip of the strata which is of unequal thickness, and the effects of the northeast pump-back system near the North Cell. Figure 6-6 also illustrates that Zone 3 saturation is reduced to the northeast, in the direction of flow.

As discussed in the 1989 Annual Review (Canonie 1989c), the saturated thicknesses used to design the system were confirmed by further field observations during installation of the Stage I wells. Initial saturated thickness conditions determined from field data before the start of pumping, matched closely with those presented in the RD and on Figure 6-6.

A complex response of Zone 3 to pumping-well extraction was anticipated, due to the variability of the saturated thickness and the irregular northeasterly directed gradient.

To account for the complexity, a computer model was used to simulate the initial response to pumping by the extraction system. The objective of the computer simulation was to demonstrate hydraulic control of the plume target area during the initial years of system operation, and to refine the system's well spacing and pumping rates.

The model used to simulate system performance was the Prickett and Lonnquist finite difference model (Illinois State Water Survey, 1971). The version used simulates non-steady flow in a two-dimensional aquifer, where transmissivity changes as a function of aquifer thickness. The Fortran code used is contained in Appendix A of the RD (Canonie, 1989d).

The model simulation assumed the following aquifer parameters for Zone 3:

Hydraulic Conductivity: 1.0×10^{-3} cm/sec (Canonie, 1987a, Table 2.2)

Storativity: 0.05 (Canonie, 1987a, Table 2.2)

Figure 6-6 displays the boundary conditions of the model and the initial conditions of saturated thickness. No-flow boundaries were placed in areas to the south and east of the model to simulate the limit of Zone 3 saturation. A no-flow boundary was also placed on the western edge of the model, limiting the investigation to the area of concern, namely, the tailings seepage target area, including the POCs. Given the overall northward direction of flow in this formation, the boundary approximates the orientation of a flow line in the system and, therefore, flow will occur parallel to this boundary and not across it. As a result, the boundary approximates an area where neither recharge or discharge from the modeled area will occur, and its no-flow designation is appropriate. A constant head boundary was placed at the northeastern end of the model where the saturated thickness decreases and where flow to the northeast is directed. The constant head boundary acts to simulate the constant, northeasterly directed flow of water.

The initial saturation conditions shown on Figure 6-6 were based on the site-specific data presented in Table 6.5. For the purposes of model input, water levels and basement elevations were contoured and the resulting values were assigned to each model node.

6.2.1.3.3 Zone 3 System Performance Simulation

The first well configuration tested consisted of 20 wells, including the 14 wells presented in Amendment I, together with the current drawdown effects of the existing Zone 3 extraction wells. These wells were pumped at 5 gpm during the computer simulation. The results of this initial run demonstrated that the wells to the south became unpumpable during the first year and significant quantities of water remained in the southern portion of the target area.

The model was then refined in two ways. First, the pumping rates were varied to simulate a decline in pumping rates for each well due to losses in efficiency. Table 6.6 shows the revised pumping schedule. Second, well locations were changed to those shown on Figure 6-6 to focus more of the extraction in areas of greater saturated thickness. Thirteen wells were pumped during the first two years of simulation. The remaining seven wells were used beginning in the third simulation year. This configuration allowed the southern wells, which are essential to dewatering the southeastern portion of the target area, to continue operating.

The results of the refined well configuration are displayed on Figure 6-7. This figure illustrates that significant dewatering of the target area was predicted to occur during the first 2.5 years of simulated operation (i.e., two years with 13 wells operating, and one-half year with 20 wells operating). Comparison of Figure 6-6, depicting initial conditions, and 6-7 shows that much of the target area was predicted to be dewatered to less than 10 feet of saturation in the first 2.5 years of operation.

The simulation indicated the system would not only dewater the target area and the POCs, but would also create a barrier against further migration of tailings seepage. Figure 6-8 displays the capture zone of the well system after 2.5 years of modeled operation. This figure shows that the capture zone of the system will encompass the entire target area, preventing the northeastern migration of tailings seepage until target area dewatering is completed.

The results of the modeling effort indicated several refinements of the conceptual system design described in Amendment I:

1. The entire system would be pumped at a uniform 5 gpm rate. A variable pumping schedule, similar to that shown in Table 6.6, based on conditions of saturation and permeability encountered at each well location, would be used.

2. Figure 6-8 demonstrates that, if the system modeled were to be pumped at the rates prescribed in Table 6.6, the capture of water in the target area would be successful. In addition, over the course of the reclamation period, the system would extract approximately 200 million gallons, the estimated volume of the target area, as presented in Amendment I (Canonie, 1988b). The system would also capture Zone 3 seepage to a significant distance (800 feet) north of the defined target area, as shown on Figure 6-8, providing an additional margin of cleanup benefits.

3. The seven northern-most wells (714 through 720) would not be necessary during the initial extraction phases. However, as extraction proceeds, wells

to the south would successively become unpumpable due to a loss of saturated thickness. The seven northern wells would become necessary in later stages of the extraction process to complete target area dewatering.

4. To verify design adequacy, the initial 13 wells would be installed in stages. The first five wells installed, (708 through 712), would be tested for individual capacity and well interference. The testing procedure, contained in Appendix B of the RD (Canonie, 1989d), would allow verification of predicted pumping rates and adequate well spacing. Modifications to the design would be considered, based on the results of the test. Potential modifications would include adjustments in well spacing, or the operation of existing Wells, such as 608 and 672, in place of modeled Wells 703 and 704.

   As discussed in the 1989 Annual Review (Canonie, 1989c), testing of the first five wells resulted in deletion of Well 704 from the system. Also, pumping rates in the individual wells are different than predicted because of variability of the physical properties of Zone 3.

5. The previously existing northeast Zone 3 pump-back Wells (608, 610, 613, 672) would be operated and decommissioned in conjunction with the new system.

Evaluation of the system performance presented in the 1989 and 1990 Annual Reviews (Canonie; 1989c, 1990a) demonstrated that the computer simulation was representative of conditions in Zone 3 and that predictions of the response to pumping were reliable. Section 6.2.1.7 of this plan discusses the comparison of the computer model predictions with the performance monitoring data.

6.2.1.4 Zone 3 Well Design and System Construction

Appendix C of the RD presented the technical specifications for the Zone 3 extraction well design, construction and pumps (Canonie, 1989d). The design was based on the predicted maximum aggregate pumping rate of 65 gpm. The as-built construction of the Stage I wells was presented in the 1989 Annual Review (Canonie 1989c) and the as-built for the Stage II wells will be presented in the 1991 Annual Review, to be submitted to the agencies by December 31, 1991.

The possibility of placing a sump below the screen and extending beneath the contact of Zone 3 and Zone 2, was considered as a design option. However, calculations showed that a 50 percent efficient well would drop in production to 1 gpm with 5 feet of remaining saturated thickness (assuming an initial thickness of 40 feet). The decline in the pumping rate would occur from a loss of both efficiency and the decrease in saturated thickness with attendant reductions in the well's specific capacity. Neither of these two factors are altered or enhanced by sump installation. Therefore, the use of sumps below the screen was not incorporated in the Zone 3 well design.

6.2.1.5 Zone 3 Performance Monitoring Program

Table 6.7 and Figure 6-9 display the wells used for monitoring the performance of the system. The wells listed in Table 6.7 are of two types: 1) wells currently monitored in Zone 3 as required by the NRC in License Condition 30, Parts A and B; and 2) system extraction wells that monitor the dewatering performance of the pumping system. Table 6.3 displays the list of chemical constituents that are utilized in the monitoring program.

Only water levels are monitored in the 19 system extraction wells (701 through 720). These water levels, together with the water levels from the 20 other monitoring wells listed in Table 6.7, are used to verify the creation of a hydraulic barrier to future migration of the tailings seepage plume contained by the target area. These wells provide the water level data necessary to confirm successful dewatering of the target area and the eventual decommissioning of the system.

As of the Third Quarter 1991 sampling event, several changes had been made to the list of wells included for performance monitoring of Zone 3. First, as shown in Table 6.9, Well 704 was deleted because it was not installed. Aquifer testing during installation of the Stage I wells indicated that inclusion of this well would detract from the performance of the system. Second, Well TWQ 126 was added to the program in April 1990 at the request of the NRC and EPA in their comments to the 1989 Annual Review (Canonie, 1989c). This well is used to monitor water levels only. Finally, Well EPA 11 was deleted from the list because, as of second quarter 1990, Well EPA 11 could no longer be sampled. The water level near the well has declined in response to pumping the Zone 3 extraction wells and, as a result, the water level is below the pump intake. After contacting the NRC and EPA, United Nuclear attempted to lower the pump in the well. This attempt was unsuccessful and NRC and EPA agreed via telephone conversations in July 1990, to exclude this well from further monitoring.

Monitoring for all chemical constituents selected for the performance monitoring program is conducted quarterly, consistent with United Nuclear NRC License. Results are reported semiannually and the monitoring program is re-evaluated annually in conjunction with the system performance evaluation required by the NRC and the EPA. The annual evaluation also allows determinations to be made regarding the efficacy of reducing the sampling frequency of the monitoring program.

Annual system performance evaluations have been completed and submitted to the NRC and EPA, in accordance with the requirements of the License and the ROD. These evaluations have been submitted as the 1989 and 1990 Annual Reviews prepared by Canonie (1989c and 1990a).

6.2.1.6 Zone 3 System Decommissioning

The objective of the Zone 3 extraction system is, as stated previously, to create a hydraulic barrier against further migration of tailings seepage, and to concurrently dewater the identified target area. In addition, the operation of the system may provide an opportunity to clean up water quality in Zone 3 to the NRC ground water protection standards and the ARAR levels established by the EPA in the ROD. However, both agencies recognize modifications may have to be made to these standards. The NRC regulatory mandate recognizes the possibility of not achieving the cleanup standards by providing (in Appendix A, 10 CFR 40) the option of establishing ACLs. Further, the EPA also provides an alternative approach of establishing waivers to the ARARs as stated in Appendix A to the ROD (EPA, 1988a).

This system is performance-based, i.e., its success is measured against its ability to 1) produce compliance with agency water quality standards, or 2) dewater the target area. Achievement of either condition will merit decommissioning the system. In addition, the inability of the system to meet the above performance criteria would necessitate the issuance of ACLs (NRC) and ARAR waivers (EPA). While these conditions set forth physical parameters used to define when the system becomes a candidate for decommissioning, in accordance with NRC License Condition 30C, no program component meeting the decommissioning criteria will be decommissioned without prior approval from NRC.

The three conditions for which the system, or parts thereof, become candidates for decommissioning are discussed in further detail as follow:

Decommissioning - Condition 1

In the event that system operation results in meeting the NRC ground water protection standards at the POCs, as set forth in the License, and cleaning up to the EPA's ARARs as set forth in the ROD in the Zone 3 target area identified here, the system will become a candidate for decommissioning.

Decommissioning - Condition 2

Individual wells may become candidates for decommissioning because of the lack of available saturated thickness in the formation. The system may become a candidate for decommissioning based on the successful dewatering of the target area. The saturated thickness is predicted to decline steadily in response to pumping because the primary source of recharge to Zone 3 no longer exists. Water level data collected for performance monitoring will be used to determine when the saturated thickness declines to a level where an individual well or the system can no longer operate.

Once a well begins to lose its ability to pump efficiently, it will be evaluated for stimulation to improve productivity or, if its productivity declines to or below 1 gpm for a period of one month, possible replacement. The well will be stimulated and cleaned, then turned off and allowed to recover, to determine whether the formation can produce sufficient water to merit well replacement. If the water level recovers sufficiently to produce 1 gpm but the well efficiency does not allow production of 1 gpm or more, the well will be replaced. If the water level in the well does not recover sufficiently to allow production of water in amounts greater than 1 gpm, the well will be considered for decommissioning.

The 1 gpm criteria accounts for yearly declines of 20 percent pumping rate, based on long-term pumping records for existing Zone 3 wells. The target area is expected to be dewatered i.e., approximately 200 million gallons extracted, over the 6-1/2-year remedial action period. Over this 6-1/2-year period, the annual 20 percent production loss will reduce pumping rates at individual wells to approximately 1 gpm. As of July 1991, approximately 37 million gallons have been extracted from Zone 3. While this volume is approximately 30 percent less than predicted, the system is performing as predicted during the remedial design.

Decommissioning - Condition 3

The system may also become a candidate for decommissioning because of its inability to reduce constituent concentrations to the NRC ground water protection standards and the EPA ARAR levels. As discussed in Section 6.2.1.2, the standards set for the site are below background concentrations and may not be representative of the actual site conditions. If system operation does not result in successful dewatering of the target area, or in a statistically valid trend towards water quality improvement cannot be established, the system will be considered for decommissioning and the need for ACLs and Waivers to ARARs will be evaluated.

6.2.1.7 Implementation of Zone 3 Corrective Action Program

This section discusses the implementation of the Zone 3 corrective action program through July 1991. This information was presented in the 1989 and 1990 Annual Reviews (Canonie; 1989c, 1990a) and responses to NRC and EPA comments on the two annual review reports. Table 6.8 provides a list of the activities and dates associated with implementing this program. For ease of discussion, the implementation is presented on a yearly basis covering the period from May 1989 through July 1991, and includes a summary of the performance monitoring results presented in the two annual reviews, as well as a description of field activities completed in 1991. These field activities will be presented formally in the 1991 Annual Review to be submitted by December 31, 1991, as required by the NRC License.

6.2.1.7.1 Zone 3 CAP Activity - 1989

As shown in Table 6.8, the Stage I wells were installed, tested and began operation in 1989. Installation commenced in May and was completed by the end of June. Figure 6-5 shows the well locations. Well 704 was excluded from the system based on the results of the aquifer test conducted in the first five wells installed, Wells 708 through 712.

The distribution lines connecting the extraction wells with the evaporation disposal system were installed during July. The wells began operation on August 7 and 8, 1989. As discussed in the 1989 Annual Review, operational pumping rates averaged 43 gallons per minute (gpm) during the three months, compared to 60 gpm assumed for the system design in the RD. The operational pumping rates are lower because the hydraulic properties of the formation limit the productivity of the wells. Table 6.9 presents the operational data for the Zone 3 Stage I wells.

The system performance was evaluated for the 1989 Annual Review (Canonie, 1989c) based on three months of water level data and two quarters of water quality data. The third quarter data represented initial conditions before starting operation and the fourth quarter data represented conditions after almost three months of operation. The evaluation indicated that the extraction wells were performing as designed and were successful in :

1. Capturing and extracting seepage in the remedial action target area, and

2. Creating a hydraulic barrier against further migration of seepage.

Figures 6-10, 6-11, and 6-12, originally presented in the 1989 Annual Review (Canonie, 1989c), illustrate the effect of the wells in capturing seepage and creating a hydraulic barrier against further migration. For example, Figure 6-10 shows the change in saturated thickness between third and fourth quarter 1989. In the area, drawdown (decrease in saturated thickness equaled or exceeded 10 feet) was approximately 52 acres which incorporates 90 percent of the Zone 3 target area.

Comparison of actual field conditions and conditions predicted by the computer simulation provide additional confirmation of the well system performance. As discussed in the 1989 Annual Review (Canonie, 1989c), the location and configuration of the contours of saturated thickness, based on the fourth quarter 1989 water level data, are similar to those generated by the computer simulation. The similarity of the contour plots indicates the system was operating as predicted in the RD (Canonie, 1989d).

Finally, the pH data presented on Figures 6-11 and 6-12, confirm the wells are extracting seepage. Comparison of the data from the third quarter (Figure 6-11) and fourth quarter (Figure 6-12) sampling events indicates that the areal extent of tailings seepage represented by acidic pH was reduced by half, from approximately 72 acres to 34 acres, during the first three months of operation.

6.2.1.7.2 Zone 3 CAP Activity - 1990

CAP Activity during 1990 consisted of operation and monitoring the performance of the Stage I wells. The operation and performance of the system was presented in the 1990 Annual Review (Canonie, 1990a) and is summarized here.

The wells pumped continuously through 1990 with some adjustments to the flow rates. Table 6.10 summarizes the operational data for the Zone 3 Stage I wells during 1990.

As shown, between October 1989 and October 1990, the wells pumped at an average cumulative rate of 30 gpm with a total of 15.3 million gallons extracted. This operational rate was less than the predicted design rate of 34 gpm. The total volume of water extracted from Zone 3 by the new and existing wells during the 1990 reporting period was 22.1 million gallons. This volume represents almost 10 percent of the 200 million gallons predicted to be removed for the RD.

A comparison of Tables 6.10 (1990 data) and 6.9 (1989 data) indicates the effects of dewatering on system operation. The dewatering effects are indicated by the lower operational pumping rate (i.e., 30 gpm versus 43 gpm) and the fact that five additional wells (701, 703, 705, 709, and 710) required installation of automatic controllers. These controls automatically turn off the pumps for a preset time period when the water level in the wells declines to the level of the pump intake. Initially, only low-yield wells 702, 712, and 713 were equipped with the controls. Due to declines in water level, the five additional wells were equipped with the controls during 1990.

The system continued to perform as designed throughout the 1990 reporting period. As discussed in the 1990 Annual Review (Canonie, 1990a), water levels continued to decline, dewatering of Zone 3 progressed to the point that several areas are dry, and the acidic plume was maintained at the areal extent shown in the 1989 Annual Review (Canonie, 1989c) and shown on Figure 6-12.

For example, as discussed in the 1990 Annual Review, a distinctive cone of depression had developed along the entire northern boundary of the target area. Furthermore, between October 1989 and October 1990, the cone of depression had expanded by as much as 400 feet to the northeast. Since ground water flow within the cone of depression was toward the pumping wells, seepage within the target area was captured and extracted by the wells.

The effect of dewatering is illustrated by the change in saturated thickness between October 1989 and October 1990. As shown on Figure 6-13, the area of Zone 3 dewatered by the extraction wells, represented by the contour of 10 feet reduction in saturated thickness, had expanded by an area of approximately 13 acres during 1990. The total area of intense dewatering was delineated by the 10-foot contour of reduced saturated thickness and incorporated approximately 60 percent of the remedial action target area, compared to 47 percent in October 1989.

Figure 6-14 further illustrates the effect of the extraction wells in dewatering the remedial action target area. Wells EPA 17, EPA 18, EPA 3, and 106 D, which penetrate Zone 3 to its bottom, were dry or had less than 5 feet of water as of fourth quarter 1990, proving that the aquifer in these areas has been nearly dewatered. Also, although Wells EPA 3 and 106 D still had up to 5 feet of water, projection of the trend of declining water levels indicates that Zone 3 may be dewatered near these wells by the end of 1991.

As in 1989, comparison of actual field conditions and conditions predicted by the computer simulation provide additional confirmation of the well system performance. As discussed in the 1990 Annual Review (Canonie, 1990a), the location and configuration of the contours of saturated thickness, based on the fourth quarter 1990 water level data, are similar to those generated by the computer simulation. The similarity of the contour plots indicates the system was operating as predicted in the RD (Canonie, 1989d).

Finally, as discussed in the 1990 Annual Review (Canonie, 1990a), comparison of figures presenting isoconcentrations of pH indicates that the area of tailings seepage represented by acidic pH in fourth quarter 1990 was similar in both shape and extent to that shown for 1989. The fact that the extent of the acidic plume is not expanding indicates the extraction wells are performing as designed and creating a barrier against further migration of tailings seepage.

6.2.1.7.3 Zone 3 CAP Activity - 1991

CAP activity as of July 1991 consisted of installing and testing the Stage II wells designed in the RD. Figure 6-5 shows the locations of the wells. These locations are the same as the design locations presented in the RD. Revision of the locations was considered unnecessary because the system has been performing as predicted.

As shown in Table 6.8, installation was started in mid-May and completed in mid-June. The wells will begin operation in August 1991. Details of the operation and performance of these wells and the existing wells will be presented in the 1991 Annual Review, which will be submitted at the end of December, 1991.

6.2.2 Zone 1 - Remedial Action Program

This section presents the technical basis for the design for the Zone 1 remedial action as originally presented in the RD (Canonie 1989d), as well as the conditions that exist as of July 1991, after approximately three years implementing the remedial action. Sections 6.2.2.1 through 6.2.2.6 incorporate much of the original text, tables, and figures provided in the RD. Section 6.2.2.7 discusses the system operation and performance using the information presented in the 1989 Annual Review (Canonie 1989c) and the 1990 Annual Review (Canonie 1990a). This section also includes a description of the revisions made to the Zone 1 pump-back well configuration in response to NRC and EPA comments on the two annual reviews (Canonie; 1989c, 1990a), including those implemented in June 1991 as part of United Nuclear's program for an ALARA demonstration in Zone 1.

As described in the RD, remedial action in Zone 1 consists of eliminating the source of seepage to Zone 1 by dewatering Borrow Pit No. 2, and continuing seepage extraction from the then existing east and north cross-dike pump-back wells. Their location is shown on Figure 6-1. The EPA's FS (EPA, 1988b) determined that the alternative of pumping Zone 1 "... does not provide a substantial reduction in contaminant concentrations... as compared to institutional controls and natural flushing" (page 8-24). This finding is in accordance with the remedial action for Zone 1 approved by the NRC and the EPA.

Additional seepage extraction in Zone 1 was considered to be impractical and unnecessary because of the low permeability of the formation. Also, after Borrow Pit No. 2 was dewatered, no additional recharge from the pit to Zone 1 was expected to take place, eliminating the need for pumping. Water level data collected in February 1989 from the alluvium adjacent to the pit indicated that pit dewatering should be permanent as discussed in Section 6.2.2.4. Water levels had declined below the bottom of the pit, so that inflow after dewatering was not anticipated.

Performance monitoring data, collected from when Borrow Pit No. 2 was dewatered in April 1989 until the present time, confirm the design considerations presented in the RD (Canonie 1989d). As anticipated, the seepage mound has been dissipating over time at the rates calculated based on the measured changes in Zone 1 water levels. Also, United Nuclear has continued to pump the Zone 1 wells as required by the NRC and EPA. As expected, the performance monitoring data indicate operating the wells has no effect on the rate of dissipation or the quality of the seepage mound. Therefore, United Nuclear has implemented a program, approved in NRC Amendment 12 to License Condition 30, of pumping and sampling to provide a demonstration that active seepage remediation is not feasible and that ALARA water quality criteria have been met.

6.2.2.1 Hydrogeology of Zone 1

The GHR (Canonie, 1987a) contains a detailed discussion of the hydrogeology of Zone 1 and was the basis for the design of the Zone 1 corrective action. A summary is presented here. The remedial action program focuses on the hydrogeologic conditions of Zone 1 in the area east of Borrow Pit No. 2, i.e., the identified target area and POCs shown on Figure 6-15.

Tailings seepage was introduced directly to Zone 1 in the target area through its subcrop in Borrow Pit No. 2. As discussed in the GHR, the subcrop in Borrow Pit No. 2 is the only location in the tailings disposal area where Zone 1 is in hydraulic contact with acidic tailings liquid. In the remaining areas, Zone 1 is separated from this liquid either geochemically by alluvium buffering the seepage, or hydraulically by Zone 2 which is impermeable.

Tailings liquid stored in Borrow Pit No. 2 seeped to the east in Zone 1. However, the low permeability of Zone 1 limited the extent of seepage migration. The permeability of Zone 1 is an order of magnitude lower than the permeability of Zone 3. Despite the steep gradient created by the 30 feet to 40 feet of water stored in Borrow Pit No. 2, which drove seepage into the subcrop of Zone 1, by 1986 the seepage had migrated only approximately 700 feet from the pit.

Also, fractures influence flow rates and direction in Zone 1 east of Borrow Pit No. 2. The GHR identified two fracture zones along the east side of the pit. These fractures provide a more permeable flow path for the liquids migrating from Borrow Pit No. 2. The water level contours presented in the GHR (Canonie, 1987a, Figure 3-3) are distorted near these fracture zones, causing flow directions to be directed to the east-southeast across the dip of the strata, rather than to the northeast and down the dip, as is the condition in the remaining saturated parts of Zone 1. The influence of the fracturing is also evident on the pH contour map of Zone 1 presented in the GHR (Canonie, 1987a, Figure 4-9), and also depicted on Figure 6-15 of this plan. The shape of the plume appears to follow the preferential flow path created by the fracturing.

6.2.2.2 Zone 1 Target Area Delineation

The Zone 1 target area was defined for the RD in 1989 based on the travel distance and rate of seepage flow from Borrow Pit No. 2, assuming that porous media flow conditions exist. The distance that tailings seepage could migrate to the east from Borrow Pit No. 2 was estimated by the following calculation:

$$V = \frac{Ki}{n_e}$$

where:

- V = velocity (L/T)
- K = permeability (L/T)
- i = gradient (dimensionless)
- n_e = effective porosity (dimensionless)

The calculation was based on the permeability of Zone 1 (1.0×10^{-4} cm/sec) (Canonie, 1987a, Table 2.3), the average gradient in Zone 3 to the east from Borrow Pit No. 2 (0.10) (Canonie, 1987a, Figure 3-3), and the porosity of a sandstone, such as Zone 1, of 0.10 (Freeze and Cherry, 1979, page 37). Considering that effective porosity may be 10 to 30 percent lower than the total porosity value of 0.10, the equation produces a velocity ranging from 115 feet/year to 148 feet/year. Since tailings liquids were first discharged to Borrow Pit No. 2 in 1980, these velocities translate into a plume travel distance of 690 feet to 890 feet for the 6-year period available for plume migration. Review of Figure 6-15 indicates that these calculated travel distances coincide with the

700 foot distance to the leading edge of the tailings seepage plume defined by acidic pH.

The travel distance calculations have been confirmed by performance monitoring data collected since 1989. The water level data indicate that the mound is dissipating at or below the rates anticipated given the hydraulic properties of the formation. Also, water quality data indicate that the downgradient boundary of the target area has migrated at a rate three times less than those discussed above.

The Zone 1 target area was also delineated by acidic seepage as presented in the GHR (Canonie, 1987a). Figure 6-15 presents the target area and POCs defined on this basis and represents a refinement of the target area presented by the EPA in its FS (EPA, 1988b). The EPA's target area was based on ARAR exceedances. However, as discussed in previous reports (Canonie, 1987a; Canonie, 1988a), acidic pH can be tied directly to the tailings seepage because of the lack of buffering capacity in Zone 1.

The smaller size of the refined target area in Zone 1, compared with the area delineated in Zone 3 is due to several factors. These factors include the operational history of Borrow Pit No. 2, the low permeability of Zone 1 and the limited area of Zone 1 exposed to tailings liquids. As stated in the GHR, acidic discharges to Borrow Pit No. 2 occurred only during the period from 1980 to about mid-1982. After mid-1982, all water was neutralized before discharge to the borrow pit so that by 1983, the pH of Borrow Pit No. 2 was neutral. Since only neutralized water was recharging Zone 1, the acidic water that had previously migrated into Zone 1 was apparently diluted and neutralized (Canonie, 1987a, page 35).

6.2.2.3 Zone 1 System Design

The remedial action program for Zone 1 is based on the program presented in Amendment I to the Reclamation Plan (Canonie, 1988b), submitted to the NRC in July 1988, and approved by the NRC in September 1988. The EPA has determined that Amendment I is "at least consistent with" the requirements contained in the ROD. The program consists of dewatering of Borrow Pit No. 2, and continued pumping from the existing pump-back wells until the pit is dewatered.

The low productivity of Zone 1 is the controlling factor that defines the remedial actions technically feasible for this formation. The low productivity of the formation was addressed in the GHR (Canonie, 1987a) and confirmed by the EPA in their FS when it states that ". . . the limited hydraulic conductivity of Zone 1 is prohibitive to pumping large quantities of water" (EPA, 1988b, page 8-3).

The east pump-back wells, pumping from Zone 1 before 1987 and adjacent to Borrow Pit No. 2, demonstrate the very low productivity of this formation. These 12 pump-back wells were pumping at a total rate of less than 5 gpm with the maximum rate of 0.7 gpm in Well 620 in 1986. The maximum total flow from all wells measured in the east system was 14 gpm in 1984 when the wells first operated.

The low-flow rates have been confirmed during continued operation of the Zone 1 pump-back wells since 1989. The operational performance of the wells was discussed in the 1989 and 1990 Annual Reviews (Canonie, 1989c, 1990a), and is discussed in Section 6.2.2.7 of this plan.

6.2.2.4 Dewatering Borrow Pit No. 2

The remedial action for Zone 1 consists of dewatering of Borrow Pit No. 2 in conjunction with continued seepage extraction from the seepage-extraction wells. Tailings seepage, collected from wells operated by United Nuclear before implementation of the CAP, stored in the pit was removed by the end of April 1989.

Dewatering Borrow Pit No. 2 served two purposes. First, the tailings liquid was removed and disposed of via evaporation. Second, the hydraulic head (i.e., height of the water in the pit above the Zone 1 subcrop), which was driving the seepage into Zone 1, was eliminated. As a result, the tailings seepage mound began to decline and the plume is dissipating naturally as the flow system in Zone 1 returns to the unsaturated conditions believed to exist before mining and milling operations.

Additional inflow to the pit from surrounding formations once the pit was dewatered was not expected and did not occur. Water level data collected in February 1989 from Wells B-3 and B-4 adjacent to the west side of Borrow Pit No. 2 (Figure 6-15) indicate the alluvium was unsaturated to a depth below the bottom of the pit (personal communication, United Nuclear Management 1989a).

As discussed in the 1989 Annual Review (Canonie, 1989c) Borrow Pit No. 2 was dewatered by the end of April 1989, approximately six months earlier than anticipated. Seepage into the pit from surrounding formations after dewatering was not observed. Also, water levels in the monitoring wells located adjacent to the pit began to decline in response to dewatering. A more detailed discussion of the system performance is presented in Section 6.2.2.7.

In the winter of 1990-1991, as provided for as a contingency in the plan, Borrow Pit No. 2 was utilized to temporarily store seepage from the extraction wells. The seepage was discharged to the borrow pit beginning the end of January 1991 until April, when it was diverted to the spray evaporation system for disposal. During this period, a total of approximately 2.8 million gallons was discharged to the borrow pit. All the seepage temporarily stored in the borrow pit had been removed by the end of May 1991.

This interim use of Borrow Pit No. 2 was required because the water levels in the evaporation ponds had reached the maximum safe operating elevations. The volume stored, however, did not create enough hydraulic head to drive the seepage into Zone 1. A discussion of the use of Borrow Pit No. 2 is presented in Section 6.2.4 of this plan and will be presented in the 1991 Annual Review to be submitted to the NRC and EPA at the end of December, 1991.

6.2.2.5 Zone 1 Performance Criteria

The remedial action program for Zone 1 was designed to remove the source of seepage to the target area by dewatering Borrow Pit No. 2. Therefore, the performance monitoring of the remedial action program is focused on the dissipation of the mound in Zone 1 in response to dewatering of Borrow Pit No. 2. These performance criteria are consistent with the findings in the FS (EPA, 1988b) as previously stated.

6.2.2.6 Zone 1 Monitoring Program

The monitoring program focuses primarily on water level monitoring in wells located to the east of Borrow Pit No. 2. The objective of the program originally was to monitor and evaluate the effect of dewatering the borrow pit. This objective was later modified to monitor and evaluate the effects of continued operation of certain east system wells as required by NRC and EPA after review of the 1989 Annual Review (Canonie, 1989c). Water quality monitoring required by the NRC was also incorporated into this program to provide a database for application for ACLs and waivers, should they become necessary.

Table 6.11 and Figure 6-9 present the wells used for the monitoring program. Water quality monitoring is conducted for all the chemical constituents designated by the NRC for monitoring in United Nuclear's license and all constituents designated by the EPA for ARAR exceedances in Zone 1. Table 6.3 lists the constituents included in the monitoring program for Zone 1.

Water level data from the wells located along the east side of Borrow Pit No. 2 (Wells 515A, 516A, 604, 614, 619, EPA-5, and EPA-7) are used to evaluate the mound dissipation in Zone 1 in response to dewatering the pit. Since September 1990, EPA-7 is also used as a pumping well.

Following review by NRC and EPA of the 1989 Annual Review (Canonie, 1989c), both agencies required that United Nuclear continue to operate the east and north cross-dike pump-back wells to further demonstrate active remediation in Zone 1 was not feasible. The demonstration was required even though the performance monitoring data showed the seepage mound was dissipating as predicted and the pump-back wells were having no effect in accelerating the rate of dissipation or improving the quality of the water in the mound.

Several Zone 1 wells continue to pump as of July 1991 and are expected to continue operation at least until the end of December 1991. Also, the configuration of the pump-back wells has been revised twice (September 1990 and June 1991) in response comments from the NRC and EPA to the 1989 and 1990 Annual Reviews (Canonie; 1989c, 1990a). A discussion of the operation of the Zone 1 wells was presented in the two annual reviews and is presented in Section 6.2.2.7.

Monitoring for all chemical constituents selected for the performance monitoring program is conducted quarterly, consistent with United Nuclear's NRC license. Results are reported semiannually and the monitoring program is re-evaluated annually in conjunction with the system performance evaluation required by the NRC and the EPA. The annual evaluation also allows determinations to be made regarding the efficacy of reducing the sampling frequency of the monitoring program. Annual evaluations of the system performance have been completed and submitted to the NRC and EPA in accordance with the requirements of the License and the ROD. These evaluations have been submitted as the 1989 and 1990 Annual Reviews prepared by Canonie (1989c, 1990a).

6.2.2.7 Implementation of Zone 1 Corrective Action Program

This section discusses the implementating the Zone 1 corrective action program through July 1991. This information was presented in the 1989 and 1990 Annual Reviews (Canonie; 1989c, 1990a) and responses to NRC and EPA comments on the two annual review reports. Table 6.12 provides a list of the activities and dates associated with implementation of this program. For ease of discussion, the implementation is presented on a yearly basis covering the period from May 1989 through July 1991, and includes a summary of the results of the performance monitoring presented in the two annual reviews as well as a description of field activities completed in 1991. These field activities will be presented formally in the 1991 Annual Review to be submitted by December 31, 1991.

6.2.2.7.1 Zone 1 CAP Activity - 1989

CAP activity in 1989 consisted of dewatering Borrow Pit No. 2, continued operation of the then existing east and north cross-dike pump-back wells, and performance monitoring. As shown in Table 6.12, Borrow Pit No. 2 was completely dewatered by the end of April 1989, approximately six months earlier than predicted. The time required to dewater was accelerated mainly because the actual volume of water remaining in the pit was much less than predicted. Increased evaporation in 1989 as a result of drier than usual climatological conditions was also a factor.

Additional pit inflow did not occur because, as discussed in the 1989 Annual Review (Canonie, 1989c), the water level measured in wells located adjacent to the pit on the west and north sides was at or near the original bottom of the pit. Borrow Pit No. 2 remained dry until January 1991, when extracted seepage was temporarily discharged to Borrow Pit No. 2. Since the stored seepage was removed by the end of May 1991 no inflow from surrounding formations has been observed.

The then existing east and north cross-dike wells operated continuously throughout 1989. Figure 6-1 shows the general location of these wells. The east pump-back wells are the most important from the standpoint of evaluating plume migration because they are located adjacent to and downgradient from Borrow Pit No. 2. Because Zone 1 has very low permeability, the wells pumped at very low rates. Their effectiveness in removing seepage was negligible. As discussed in the 1989 Annual Review (Canonie, 1989c), the pumping rate of the wells as of October 1989 ranged from 0.16 gpm to 2.3 gpm with a combined average of 4.1 gpm for the 12 operating wells.

The system performance was evaluated for the 1989 Annual Review (Canonie, 1989c) based on three quarters (second, third, and fourth) of water level and water quality data. The second quarter data approximated initial conditions since Borrow Pit No. 2 was dewatered at the end of April, shortly after the second quarter monitoring data were collected. The evaluation indicated that, because of the low permeability of the formation, the response of the system to dewatering was small. Any impacts would not be observed until at least the end of 1989, after the fourth quarter measurements were taken.

For example, review of the water level data presented in Table 6.13 shows that, between second quarter and fourth quarter 1989, changes in water level ranged from 0.2 feet to 1.2 feet. Also, the only wells that exhibited declining water levels were Wells 516A, 604 and 614 which, as shown on Figure 6-9, are located closest to the borrow pit. The rising water levels in the remaining wells indicated these locations were still exhibiting a delayed response to the water in the borrow pit.

Documentation of the delayed response was presented in United Nuclear's responses to the NRC and EPA comments to the 1989 Annual Review and in the 1990 Annual Review (Canonie, 1990a). Canonie estimated the time for response in each of the monitoring wells, based on a comparison of water levels in each of the wells with water levels in Borrow Pit No. 2. Table 6.14 presents the results of the calculations, indicating most of the wells would not exhibit declining water levels in response to dewatering the borrow pit until the end of 1989. In fact, wells such as EPA 2 and EPA 8 are not expected to show a response to dewatering until 1993 or later.

Evaluation of the water quality data showed conditions remained stable for the six month period following dewatering of Borrow Pit No. 2. Figure 6-16 presents the isoconcentrations of pH for fourth quarter 1989. The plume, represented by acidic pH, had migrated approximately 150 feet downgradient from the extent of the remedial design target area shown on Figure 6-15. Based on a Zone 1 flow velocity of 115 feet per year to 148 feet per year calculated in the RD (Canonie, 1989d), the extent of the plume in 1989 would be expected to be 345 feet to 444 feet further downgradient from the target area, which was delineated based on 1986 data. The shorter travel distance is probably due to dewatering the borrow pit, which reduced the gradient in Zone 1. The pH values reported in 1989 were similar to those reported in 1986, as would be expected given the fact that the dissipation mound is very slow.

6.2.2.7.2 Zone 1 CAP Activity - 1990

CAP activity in 1990 consisted of continued operation of the pump-back wells and performance monitoring. The system operation and performance was presented in the 1990 Annual Review (Canonie, 1990a) and is summarized below.

Water levels in the monitoring wells continued to decline naturally with no apparent effect (i.e., increased magnitude of decline) related to the pumping. The data confirmed the existence of the delayed response to dewatering Borrow Pit No. 2. The data also confirmed predictions made in the Response to Comments (United Nuclear, 1990) that, because of the delayed response, dissipation of the seepage mound would not be observed until at least the beginning of 1990. As shown in Table 6.14, only five wells (604, 515 A, 516 A, 619, and 614) were expected to show a response to dewatering the borrow pit by the end of the 1990 reporting period.

The water level data confirm the predictions presented in Table 6.14. For example, the water level data presented in Table 6.13 show that the five wells located closest to Borrow Pit No. 2 exhibited water level declines of 1.0 to almost 4.0 feet between October 1989 and October 1990. In contrast, these same wells exhibited water level declines of less than 1.0 feet or, in the case of wells 515 A and 619, increases in water level between April 1989 (initial conditions) and October 1989. The reason for the contrast between the 1989 and 1990 data is that, because of the low permeability of the formation and the resulting slow seepage rates, the effect of dewatering of Borrow Pit No. 2 could not be observed in the wells until 1990.

As in 1989, the water quality in Zone 1 reported in 1990 remained unchanged from conditions reported in 1989. The shape and extent of the plume was similar to that presented on Figure 6-16 for the 1989 Annual Review (Canonie, 1989c).

The east and north cross-dike pump-back wells operated continuously until September 24, 1990. At that time, some of the wells were decommissioned and the revised east pump-back wells began operation. As shown in Table 6.12, United Nuclear requested in their response to NRC and EPA comments that these wells be turned off. This request was based on the performance monitoring data indicating water level declines were becoming evident in wells downgradient from Borrow Pit No. 2, and that continued pumping was having no effect on the natural dissipation of the seepage mound.

The NRC and EPA denied United Nuclear's request to turn off the pump-back wells and required pumping continue under a modified program. United Nuclear, in a letter dated June 1990, presented a proposed modified program. It was approved in July 1990 by NRC and EPA, and was included in Amendment 7 to the License.

The modified program consists of decommissioning the existing east and north cross-dike pump-back wells and pumping four other wells located east of Borrow Pit No. 2. Figure 6-17 shows the locations of these wells (615, 616, 617, and EPA 7), which are referred to as the revised east pump-back wells. The purpose of this program is to focus extraction from Zone 1 in the area of the greatest concentration of constituents of concern in an effort to further remove seepage emanating from Borrow Pit No. 2. The revised east pump-back system began operating on September 24, 1990.

Table 6.15 presents the operational data for the Zone 1 wells for the 1990 reporting period (October 1989 through October 1990). As shown, the 17 existing wells pumped at an average combined rate of only 8.2 gpm, and the four revised east pump-back wells pumped at a total combined rate of only 1.0 gpm. The total volume of water extracted by these wells between October 1989 and October 1990 was approximately 4 million gallons.

6.2.2.7.3 Zone 1 CAP Activity - 1991

Operation of the revised east pump-back wells continues in 1991. United Nuclear has also designed and implemented a demonstration program to conduct an ALARA demonstration. The program will support a future ACL application. This demonstration program was proposed by United Nuclear in June 1991, based on discussions with the NRC and EPA regarding their review comments to the 1990 Annual Review (Canonie, 1990a). NRC and EPA approved the program in July 1991.

The purpose of the program is to provide a demonstration that ALARA concentrations of chemical constituents in the Zone 1 target area have been achieved. The data collected during the performance monitoring of this system will be used to support an application for ACLs and a waiver to ARARs. The demonstration consists of operating four Zone 1 wells that have been shown to be the most prolific Zone 1 water producers. These wells are to be pumped for a period of approximately five months. During that time, water quality and quantity will be monitored to detect any changes. It is anticipated that none will occur.

Table 6.15 summarizes the activities for the ALARA demonstration program and Figure 6-18 shows the locations of the wells included in the demonstration. The demonstration will be conducted in three phases as shown in Table 6.15. The objective of the phased approach is to allow collection of data that can be used to compare the performance of the revised east pump-back wells (Phase I) with the performance of a different pumping scenario (Phase II), and to compare the performance of both of these scenarios with the original pump-back system that operated prior to September 1990.

Phase I was implemented at the beginning of July. All the samples for this phase were collected by August 8, 1991. Subsequently, Phase II was implemented and will continue through December, 1991 when the last sample will be collected. This demonstration program will be decommissioned in December after the final Phase II samples are collected.

6.2.3 Southwest Alluvium Remedial Action Program

This section presents the detailed technical design for the alluvial extraction system as originally presented in Amendment II (Canonie, 1989a) to the 1987 site Reclamation Plan and the RD (Canonie, 1989d), as well as the conditions that exist as of July 1991, after approximately three years of implementing the remedial action. Sections 6.2.2.1 through 6.2.3.6 incorporate much of the text, tables, and figures provided in the RD (Canonie, 1989d). The remaining Section 6.2.3.7 discusses system operation and performance using the information presented in the 1989 and 1990 Annual Reviews (Canonie; 1989c, 1990a). This section also includes a description of the installation of the new extraction well (Well 808) completed in June 1991, in accordance with Amendment 12 to the License.

As described in the RD (Canonie, 1989d), the design and configuration of the system complies with the objectives of both agencies, i.e., 1) operation will produce compliance with NRC License Condition 30, Part B criteria at the POC wells, and 2) the system will create a hydraulic barrier against further seepage migration, while the source is being remediated in accordance with the EPA's ROD.

6.2.3.1 Hydrogeology of the Southwest Alluvium

Figure 6-1 illustrates the area selected during the remedial design process for the location of the Southwest Alluvium extraction system. Before mining and milling activities, the alluvium in this area was largely unsaturated with only minor amounts of transient and perched ground water (Canonie, 1987a). Previously unsaturated conditions of the alluvium were evidenced by data from geotechnical borings indicating the alluvium was dry in the tailings area (Canonie, 1987a). After mining began in 1968, mine water was discharged to Pipeline Arroyo. Mine water percolated from the arroyo into the surrounding alluvium, resulting in its saturation and attendant water quality (i.e., background). Background water quality was then altered, beginning in 1977, by tailings liquid seepage.

Water in the alluvium flows to the southwest, adjacent to and beneath the South Cell of the tailings impoundment, and out of the site boundary into Section 3. During active site operations when mine water was discharged to Pipeline Arroyo, the flow rate in the alluvium was estimated to be several hundreds of gpm (Canonie, 1987a). As described in more detail later, water levels and gradients in the alluvium declined beginning in the early 1980s, in response to reductions in the rate of mine water discharge in March 1983 and cessation of the discharge in 1986. As a result, the flow rate in the alluvium has declined. Since recharge from mine water in the arroyo has been terminated permanently, this observed decline in alluvial flow rate is expected to continue in the future until pre-operational conditions are re-established.

Review of water level data collected since 1988 confirms the declining trend in water level and flow rate. Water levels have declined by 1.0 feet or more per year over the past three years, and several of the alluvial wells located closest to the mine water discharge point are dry (Well 645), or have little water (Well 643) as of July 1991.

6.2.3.1.1 Physical Characteristics of the Southwest Alluvium

The saturation conditions in the Southwest Alluvium, existing in 1988 when the remedial design was developed, presented a picture of variable saturated thickness, a sloping water table surface (unconfined), and a permeability typical of a silty sand.

Figure 6-19 displays the saturated thickness of alluvium in the Southwest Alluvium (as indicated by 1988 data) used for the remedial design in Amendment II (Canonie, 1989a) to the 1987 Reclamation Plan and in the RD (Canonie, 1989d). Table 6.17 presents the data used to determine the saturated thickness. These thicknesses are variable due to abrupt changes in topography on the surface of the underlying Mancos shale. A practical consideration in the extraction system design was locating wells in areas where the saturated thickness was sufficient to sustain pumping. Figure 6-19 was used as a basis for the system design.

Data collected during installation of the extraction and monitoring wells confirmed the 1988 data used to generate Figure 6-19. In most locations, the saturated thickness was within 5 to 10 feet of the thickness estimated based on Figure 6-19.

Figure 6-20 is a water-table elevation map of the Southwest Alluvium used for the remedial design. This figure illustrates that, based on the 1988 data used for the remedial design, ground water in the Southwest Alluvium exhibited a gradient of approximately 0.01 in a southwesterly direction. Figure 6-20 was also used as a basis for extraction system design in determining well capture zone size and orientation.

Water level data presented in the 1989 Annual Review (Canonie, 1989c) confirm the configuration of the gradient, based on 1988 data, used in the remedial design. The configuration of the gradient, based on the fourth quarter 1989 data, is similar to that presented on Figure 6-20.

As shown in Table 6.18, permeabilities in the alluvium determined from pumping test data collected before the remedial design varied from a maximum of 1.6×10^{-2} cm/sec to a minimum of 8.1×10^{-5} cm/sec. The system was designed using a permeability of 2.6×10^{-3} cm/sec, a mid-range value. This permeability was measured by the EPA at

Well EPA-28, the closest datum to the system, and was reported in the EPA's RI (EPA, 1988c). This permeability is typical of silty sand (U.S. Department of Interior, 1981).

The permeability of the alluvium near the extraction wells was determined from an aquifer test conducted in the remedial action extraction wells before operating the system. As discussed in the 1989 Annual Review (Canonie, 1989c), the permeability determined from the aquifer test was 2.0×10^{-2}, an order of magnitude higher than the value of 2.6×10^{-3} used for the system design. A discussion of the effect of the higher permeability on the system performance was presented in the 1989 Annual Review (Canonie, 1989c) and is summarized in Section 6.2.3.7.

6.2.3.1.2 Alluvial Flow Rate

Flow rates in the alluvium were evaluated during the remedial design to determine 1) whether sufficient flow was available for operation of pump-back wells, 2) the number of wells and pumping rate required to capture the flow, and 3) whether well design and design pumping rates must be adjusted over time to account for changing flow rates.

The flow rate in the alluvium, calculated near the proposed extraction system has declined steadily since the early 1980s as the rate of mine water discharge to the arroyo decreased and eventually ended in 1986. Figure 6-21 displays the calculated flow rates for the Southwest Alluvium. The pre-1988 flow rates, shown on Figure 6-21, document a decline in the alluvial flow, occurring from 1982 until the present time. This decline in flow occurred over the same period when the primary source of alluvial water (mine water discharge to the arroyo) decreased. Since this source has been permanently terminated, the flow rates will continue to decline until pre-operational conditions are re-established.

A comparison of the projected flow rate declines, shown on Figure 6-21 with the actual declines, is not feasible because the extraction wells are now affecting the cross-sectional area (described below) used to develop Figure 6-21. Also, Well 513 AD, which provided water level data, was plugged in 1988 in accordance with License requirements.

However, review of water level data from well EPA 23, located upgradient from the extraction wells, provides evidence that water level decline, and the associated flow rate decline, continue as predicted. For example, review of water level data for Well EPA 23 presented to the agencies between 1987 (when the water level was first measured) and 1990 shows the water level has declined from an elevation of 6900.3 feet in October, 1987 to 6894.5 feet in October 1990. The total in water level decline for this three-year period was almost 6 feet, a decline of approximately 2 feet per year.

Water level data from July 1991 confirm the declining trend continues. The water level in EPA 23 measured on July 9, 1991 was at an elevation of 6892.9 feet, again a decline of almost 2 feet over a nine-month period.

The estimates of flow rates were generated using Darcy's Law:

$$Q = KiA$$

where:

Q = discharge (L^3/T)

K = permeability (L/T)

i = gradient (dimensionless)

A = area (L^2)

Permeability - For the purpose of this calculation a range of 1 x 10^{-3} cm/sec to 1 x 10^{-2} cm/sec was used. The higher end of the range (1 x 10^{-2} cm/sec) was included to provide a more conservative estimate of potentially required pumping rates.

Gradient - The water-table gradient was estimated from water-level data for wells located in the Southwest Alluvium. Figure 6-22 presents the water levels measured in five representative monitoring wells for 1980 through 1988. As shown, the water levels have declined over this period.

The wells used to provide the water level data for Figure 6-22 have either been plugged, or are no longer included in the monitoring program. Therefore, the figure cannot be updated. However, as discussed previously, data for Well EPA 23 confirm water levels continue to decline as the alluvial system returns to pre-operational conditions.

Figure 6-23 displays the average annual discharge of mine water to the arroyo. This figure illustrates that the mine water source of alluvial water decreased in rate from 1979 until 1986. From 1986, when mine discharge was permanently terminated until the present, no source of recharge water has been available to the alluvium other than natural recharge.

Water-level gradients have decreased in response to the water level declines. Figure 6-24 illustrates the decline in water-table gradients in the Southwest Alluvium. The gradients were calculated from 38 well pairs in the Southwest Alluvium. Appendix D of the RD (Canonie, 1989d) documents the specific data used in preparating Figure 6-24. The gradient decline is expected to continue, since the source of water has been removed.

Future flow rates in alluvium were predicted by projecting the documented declines in gradients, using a linear regression. Figure 6-24 displays the best-fit line for data on gradients in the Southwest Alluvium. Extending this line into the future projected gradients based on the observed trend. The data points, marked on this projected gradient line, were used in the calculation of future flow rates in the Southwest Alluvium, and are displayed in Table 6.19.

Again, Figure 6-24 cannot be revised to account for actual conditions since 1988 when the remedial design was developed. Well 513 AD was plugged in 1988 and, as a result, no post-1988 data is available.

Cross Sectional Area - Computation of flow rates also required the use of a representative cross sectional area through which the flow occurs. Section A-A' (Figure 6-19) was selected for calculating the cross-sectional area. This section was chosen because it was close to the proposed pumping well locations. Also the lithological logs and water level data for Wells 511D and 513AD, which were located on each end of the cross section, provided reasonable certainty of the saturation limits.

Well 513AD was utilized to determine water-level elevation along the Section A-A'. Figure 6-25 displays the documented water levels in Well 513AD. The marked points on the projected trend, shown on Figure 6-25, were used to calculate the cross-sectional area for computation of flow rates for the time after 1988 (i.e., after Well 513AD was plugged). Table 6.19 lists the predicted future cross-sectional areas along cross section A-A'.

6.2.3.2 Southwest Alluvium Target Area Delineation

Tailings seepage water has a unique chemistry resulting largely from the milling process. Alluvial water derived from mine discharge, by contrast, reflects a chemistry resulting from mineral dissolution as it percolated through alluvium (Canonie, 1988a). Therefore, the area where ground water has the chemical characteristics originating from the tailings disposal area is defined as the Southwest Alluvium target area. Figure 6-26 depicts the target area and POCs location defined in this manner.

While tailings liquids contain a variety of chemical constituents, chloride was used as the chemical indicator to delineate the extent of the tailings seepage plume in the Southwest Alluvium because of its unique properties, which are clearly associated with tailings seepage. These properties include:

1. Chloride is a conservative species:

    "The chemical behavior of chloride in natural water is tame and subdued compared with the other major ions. Chloride ions do not significantly enter into oxidation or reduction reactions, form no important solute complexes with other ions unless the chloride concentrations is extremely high, do not form salts of low solubility, are not significantly adsorbed on mineral surfaces, and play few vital biochemical roles.

    The circulation of chloride ions in the hydrologic cycle is largely through physical processes. The lack of complications is illustrated by experiments with tracers in ground water described by Kaufman and Orlob (1956). These investigators found that chloride ions moved with the water through most soils tested with less retardation or loss than any of the other tracers tested - including tritium that had actually been incorporated into the water molecules." (United States Geological Survey Water Supply Paper No. 2254, p. 118).

    Therefore, chloride can be used as a reference for movement of the tailings seepage water (i.e., it will be transported at approximately the same rate as the plume).

2. Tailings fluids and tailings seepage contain very high chloride concentrations. Chloride concentrations of 608 parts per million (ppm) and 730 ppm were measured in the tailings liquid in January 1981 (Personal Communication,

United Nuclear Management, 1989b). In water samples taken at locations immediately adjacent to the tailings impoundment, chloride values are in the 200 ppm range. The high chloride character of the source is clearly distinguishable from the surrounding ground water derived from mine dewatering.

3. Billings (1986) identified pre-tailings disposal chloride values in the alluvial water, which had a peak value of 86 ppm. In addition, upgradient alluvial wells north of the site (i.e., Wells 644 and 645) demonstrated background chloride values of 100 ppm and 113 ppm, respectively. This information suggests that delineation of areas currently in exceedance of the range of 86 ppm to 100 ppm as being associated with the tailings seepage plume.

These characteristics (i.e., chemical conservatism, and the established peak value of background chloride before tailings disposal) aided in delineating the target zone in the Southwest Alluvium. The further downgradient from the tailings impoundment, the lower the chloride value becomes. Table 6.20 contains chloride analyses from the tailings and wells located progressively further to the southwest away from the tailings impoundment. Figure 6-26 displays the location of the wells identified in Table 6.20. The data indicate the gradual decrease of chloride until it reaches background conditions.

Data collected since 1988 confirm chloride concentrations decreased with increasing distance from the tailings disposal area. Table 6.20 has been revised to reflect the chloride data collected in 1989 and 1990 and reported in the 1989 and 1990 Annual Reviews (Canonie; 1989c, 1990a). As shown, chloride concentrations in water from the wells are similar for the period between 1988 and 1990. Also, the concentration decrease in Well EPA 28, which is located at the greatest distance downgradient. Data for Wells 513 AD and EPA 26 are not available after 1988 because Well 513 AD was plugged, and Well EPA 26 is no longer monitored.

The target area can also be defined by considering the travel distance and seepage flow rate in the Southwest Alluvium. The distance to which particles of tailings seepage could travel from the tailings impoundment into the Southwest Alluvium was determined by the following calculation:

$$V = \frac{Ki}{n_e}$$

where:

- V = velocity (L/T)
- K = permeability (L/T)
- i = gradient (dimensionless)
- n_e = effective porosity (dimensionless)

The calculation is based on the permeability of the alluvium (2.6×10^{-3} cm/sec), a value observed by the EPA in its pumping tests, the average gradient in the alluvium over the post tailings disposal period (0.018) (Figure 6-24), and the porosity of the alluvium (0.39) determined in the Reclamation Plan (Canonie, 1987b). Considering effective porosity may be 10 to 30 percent lower than the total porosity value (0.39), the formula produces values of velocity ranging from 138 feet/year to 179 feet/year. Tailings were first disposed of in the impoundment in 1977.

Based on the 11-year period for plume migration before implementation of seepage extraction, these velocities translate into plume travel distances of 1,520 feet to 1,970 feet. As shown on Figure 6-26, these calculated distances are consistent with the observed travel distance of 1,600 feet, defined by chloride concentrations in excess of 100 ppm. The target area determined from chloride concentrations and seepage travel time lies entirely within the more conservative target area as determined by the EPA for the Southwest Alluvium.

The EPA's target area is defined largely on the presence of ARAR exceedances at scattered locations, with no apparent relationship between the source and observed water quality. The Billings background study (1986) and Canonie Geochemistry Report (1988a) demonstrate that other natural sources exist that can and do cause ARAR and ground water protection standard exceedances.

6.2.3.3 Southwest Alluvium System Design

The detailed system design is based on three considerations. First, is the objective to meet License Condition 30, Part B criteria at POC wells. This criterion requires extraction wells be placed upgradient of POC Wells EPA-28, GW-1, GW-2, and 632, to intercept alluvial flow, which may be derived from tailings seepage before it can reach these wells. Second, the system must create a hydraulic barrier against further migration of tailings seepage as specified in the EPA's ROD (EPA, 1988a). Furthermore, in compliance with the ROD, the number and location of wells was determined from the observed saturated thickness and extent of tailings seepage, to the extent it could be defined (EPA, 1988a). Last, the system design balances the first two considerations within the constraints of practical and technical considerations imposed by the hydraulic properties of the saturated alluvium.

6.2.3.3.1 Southwest Alluvium Design Criteria

In accordance with the above stated considerations, the following technical criteria were used as a design basis:

1. Placement of extraction wells northeast (upgradient) of Wells GW-1, GW-2, EPA-28, and 632; and southwest (downgradient) of the South Cell, in areas suitable for drilling and construction activities.

2. Determination of sustainable pumping rates and practically acceptable water level drawdown for extraction wells, given the permeability and thickness of the saturated alluvium.

3. Determination of the number of wells required to adequately capture the alluvial flow and create a hydraulic barrier considering the gradient observed in the water table in 1988.

4. Selection of pumping well locations so the operational capture zones of adjacent wells overlap, creating an effective hydraulic barrier against further seepage migration.

5. Selection of a location that affords an opportunity for meeting the objective of returning the concentrations of the NRC identified hazardous constituents in the alluvium to the concentration limits specified in License Condition 30, Part B.

6.2.3.3.2 Southwest Alluvium Design Methods

Three analytical methods were employed in the system design:

1. Drawdown analysis using the Theis equation to determine optimum pumping rates for different saturated thicknesses and the corresponding water level drawdowns.

2. Generation of capture curves, using a dimensionless-type curve method presented in Javandel and Tsang (1986), which can be used to determine the number and location of wells required to create a hydraulic barrier.

3. Performance evaluation using a Theis well field simulator to predict the hydraulic effects of the entire system.

The first step in the drawdown analysis consisted of determining optimum achievable pumping rates for the range of possible initial saturated thicknesses. The analysis consisted of using the Theis non-equilibrium equation, in conjunction with a range of possible drawdowns, and compensating the transmissivity value for the reduced thicknesses, to produce values of corresponding discharge. Table 6.21 displays the derived values of peak discharge rates calculated for the range of possible initial saturated thicknesses, using this method.

Capture curves were constructed for the predicted peak pumping rates and their corresponding thicknesses (Table 6.21) using the dimensionless-type curve method from Javandel and Tsang (1986). The developed curves were then superimposed on the isopach map of saturated thickness (Figure 6-19) in the area downgradient of the South Cell tailings and upgradient of POC Wells GW-1, GW-2, EPA-28, and 632. The combination of wells was rearranged to minimize the number of wells, while producing overlapping capture zones that covered the portion of the valley east of the arroyo.

The result of this process was the determination that an effective hydraulic barrier could be produced by three extraction wells pumping at an aggregate rate of 17 gpm. Figure 6-27 displays the locations of the three wells, their respective pumping rates and the overlapping zones of capture. The operating performance of the entire system was then evaluated, as described below.

The design of the system was later modified to include an additional extraction well (Well 808), in accordance with NRC and EPA comments to the 1990 Annual Review (Canonie, 1990a). Well 808 was installed and began operating in June 1991. A description of the installation and operation of this well will be included in the 1991 Annual Review.

6.2.3.3.3 Southwest Alluvium System Performance Simulation

The performance of the pump-back wells was evaluated using a Theis well-field simulator and is described in Appendix E of the RD (Canonie, 1989d). The purpose of the simulation was to evaluate what the composite hydraulic effect of the system would be during the first year of operation, and to determine if the well interference effects of adjacent wells would render the proposed pumping rates infeasible.

The simulation results produced two conclusions verifying the feasibility of the design. First, the pumping rates will be sustainable. Appendix E of the RD (Canonie, 1989d) presents the projected operational drawdowns for each well after a year of operation. Second, the system produces an effective hydraulic barrier against further migration of seepage. Figure 6-27 displays the projected operational capture of the entire system, which was predicted to extend across the width of saturation in the southwest alluvial valley east of Pipeline Arroyo.

The actual system performance was initially evaluated immediately after installation and continues to be evaluated on an annual basis. The productivity of each well was tested after installation. The testing procedure was described in detail in Section 3.4, Appendix E, RD (Canonie, 1989a). The permeability of the alluvium and the operational performance of the entire system was also tested as part of the performance monitoring. The test results were presented in the 1989 Annual Review (Canonie, 1989c) and are discussed in Section 6.2.2.7 of this plan.

It was predicted that with continual operation of the system, the pumping rates required to maintain an effective hydraulic barrier would be reduced. While system monitoring has not indicated rates can be reduced, reduction in pumping rates is still anticipated due to the natural flow decline in the Southwest Alluvium, documented on Figure 6-21 and discussed in Section 6.2.3.1 of this report.

6.2.3.4 Southwest Alluvium Well Design and Construction

The technical specifications for extracting and monitoring well design and construction, pumps, and surface conveyance systems are presented in Appendix E of the RD (Canonie, 1989d). The design is based on the predicted aggregate pumping rate of 17 gpm (801:2 gpm; 802:5 gpm; 803:10 gpm). The as-built construction of the Southwest Alluvium Wells 801 through 807 was presented in the 1989 Annual Review (Canonie, 1989c) and the as-built for Well 808 will be presented in the 1991 Annual Review to be submitted to the agencies by December 31, 1991. The actual operational pumping rates have been presented in the two annual reviews. See Section 6.2.3.7 for presentation of the operational data.

6.2.3.5 Southwest Alluvium Monitoring Program

Table 6.22 and Figure 6-9 display the wells proposed and approved for monitoring system performance. Table 6.3 displays the list of chemical constituents utilized in the monitoring program. This list is inclusive of the NRC ground water protection standards and other required constituents contained in License Condition 30, Part A. The wells listed in Table 6.22 are divided into three groups: 1) wells monitored as required by the NRC in License Condition 30, Parts A and B; 2) wells that monitor the performance of the pumping system, and 3) wells that provide the data needed to complete the hydrogeologic evaluation. Note Table 6.22 has been revised to include extraction Well 808, which was added to the system in June, 1991.

The seven alluvial POC wells as identified by the NRC in License Condition 30, Part B, are used to monitor compliance with the NRC ground water protection standards. In conjunction with the water quality monitoring program, water level measurements are also taken in all wells identified in Table 6.22 before collecting the sample. Water levels are used to assess dewatering of the alluvium by monitoring the declines in saturated thickness.

Only water levels are monitored in the system monitoring wells (804, 805, 806, and 807). These water levels, together with the water level in 632, are used to verify the creation of a hydraulic barrier near the extraction wells. As shown on Figure 6-27, these wells are located between the extraction wells and along the capture zone boundary. Figure 6-28 shows water levels from these wells are used to define the gradients between the pumping wells, verifying that the water table slopes towards the pumping wells in these areas.

In addition to the wells required for compliance monitoring (NRC) and for monitoring system performance, six wells were selected to quantify the spatial variation of water quality in the alluvium. Data from these wells will be used in additional background studies. These are Wells 639, 642, 644, and 645 located north (upgradient) of the tailings impoundment; and Wells 627 and 624 located to the southwest of the target area.

6.2.3.6 Southwest Alluvium System Decommissioning

In accordance with NRC License Condition 30C, no program component meeting the decommissioning criteria will be decommissioned without prior approval from NRC. This section discusses the conditions presented in the RD (Canonie, 1989d) for determining when the system could be considered for decommissioning:

The objective of the system operation is to clean up to the ground water standards established by the NRC in License Condition 30, Part B and the ARARs established by the EPA in the ROD. However, both agencies recognize modifications may have to be made to these standards. The NRC, in Appendix A, 10 CFR 40 provides the option of establishing ACLs. The EPA recognizes the possibility of not achieving the cleanup standards by providing an alternative approach of establishing waivers to the ARARs in Appendix A to the ROD (EPA, 1988a).

This system is designed to be performance-based (i.e., its success is measured against its ability to meet agency standards). However, as discussed in the RD (Canonie, 1989d), the longest the system is anticipated to operate is the end of reclamation activities. The EPA established that: "seepage collection in the Southwest Alluvium will be designed to create a hydraulic barrier to further migration of contamination while the source is being remediated" (EPA, 1988a, page 3). The documented declines in flow rate, as described in Section 6.2.3.1.2 and illustrated on Figure 6-21, provide technical support demonstrating the system may not be capable of operating beyond the end of reclamation because the depleting available water may limit the feasibility of pumping the Southwest Alluvium by the mid-1990s. By that time, the source (i.e., the tailings) will be remediated by installation of a low permeability cover.

However, other aspects of system operation, as determined by actual performance, may allow it to be decommissioned earlier than the end of reclamation activities. For example, faster than predicted dewatering of the alluvium may occur. Also monitoring may determine that compliance with the NRC and the EPA standards has been attained. Alternatively, monitoring may determine that it is appropriate to waive ARAR requirements and set ACLs.

Decommissioning - Condition 1

In the event that system operation results in meeting the NRC ground water protection standards at the POCs and cleaning up to the EPA ARARs in the identified Southwest Alluvium target area, the system will be considered as a candidate for decommissioning.

Decommissioning - Condition 2

Individual wells and/or the system may be considered candidates for decommissioning before tailings reclamation because of the lack of available saturated thickness near the pump-back wells. The saturated thickness was predicted to decline steadily because the primary source of recharge to the alluvium (i.e., discharge of mine water), ceased in 1986. Water-level data collected for performance monitoring will be used to determine when the saturated thickness declines to a level where an individual well or the system can no longer operate. If the water level near a well(s) declines to a point where the well(s) can no longer produce water at rates greater than 1 gpm continuously, and this condition of low saturation persists for one month, the well and/or system of wells will be considered as candidates for decommissioning.

Decommissioning - Condition 3

The system may also become a candidate for decommissioning before tailings reclamation because of its lack of effectiveness in reducing constituent concentrations to the ground water protection standards established by the NRC and ARAR levels established by the EPA in the ROD. If system operation does not result in a statistically valid trend towards water quality improvement, the system may be considered for decommissioning and the need for ACLs and waivers to ARARs will be evaluated. The database for statistical evaluation will include the data collected for the performance monitoring program. Evaluation of the effectiveness of the system in reducing constituent concentrations is conducted on an annual basis together with evaluation of the compliance monitoring as mandated by the NRC in the License.

6.2.3.7 Implementation of Southwest Alluvium Remedial Action Program

This section discusses the implementation of the Southwest Alluvium corrective action program through July 1991. This information was presented in the 1989 and 1990 Annual Reviews (Canonie; 1989c, 1990a) and responses to NRC and EPA comments on the two annual review reports. Table 6.23 lists the activities and dates associated with implementing this program. For ease of discussion, the implementation is presented on a yearly basis covering the period from May 1989 through July 1991, and includes a summary of the results of the performance monitoring presented in the two annual reviews, as well as a description of field activities completed in 1991. These field activities will be presented formally in the 1991 Annual Review to be submitted by December 31, 1991.

6.2.3.7.1 Southwest Alluvium CAP Activity - 1989

As shown in Table 6.23 the extraction and monitoring wells were installed, tested, and began operation in 1989. Installation commenced and was completed in August. Figure 6-29 shows the well locations, which are similar to the proposed locations shown on Figure 6-27.

The aquifer test results showed the aquifer permeability is approximately 2 x 10^{-2} cm/sec. This value is an order of magnitude higher than the value of 2.6 x 10^{-3} cm/sec used to predict pumping rates for the system design. Normally, the higher permeability would mean higher pumping rates would be required to create the same drawdown as would be achieved with the lower permeability. However, as discussed in the 1989 Annual Review (Canonie, 1989c), a no-flow boundary was identified along the southeast edge of the alluvial valley. The boundary is expected to counteract the effect of the higher permeability by causing an increase in the water level declines in response to pumping, enhancing the effectiveness of the hydraulic barrier.

The distribution lines connecting the extraction wells with the evaporation disposal system were installed and tested during September and October, and the wells began operation on October 16, 1989. As discussed in the 1989 Annual Review (Canonie, 1989c), operational pumping rates averaged 19.7 gpm during the four-week period that data was collected, compared to 17 gpm assumed for the system design in Amendment II (Canonie, 1989a) and the RD (Canonie, 1989d). Table 6.24 (Table 2.10, 1989 Annual Review) presents the 1989 operational data the Southwest Alluvium extraction wells.

The system performance was evaluated for the 1989 Annual Review (Canonie, 1989c), based on approximately six weeks of water level data and one quarter of water quality data. The fourth quarter data represented initial conditions and data collected on December 4 represented conditions after six weeks of pumping.

The evaluation indicated the extraction wells were performing as designed and were beginning to create a hydraulic barrier to flow. Figures 6-30 and 6-31, which were originally presented in the 1989 Annual Review (Canonie, 1989c), illustrate the potentiometric surface of the alluvium for initial conditions (fourth quarter 1989) and after pumping for 1.5 months (October 16 through December 4, 1989), respectively. Comparison of the figures shows the extraction wells were causing a reversal in the slope of the water table near the system wells.

Chemical data reflecting conditions after pumping started was not available because the wells were turned on after collection of the fourth quarter water quality samples. However, initial conditions of chloride concentration were presented and are shown on Figure 6-32. As shown, the extent of the chloride plume in fourth quarter 1989, represented by concentrations of 100 mg/l, is the same as the extent of the remedial action target area (shown on Figure 6-26), which was based on fourth quarter 1988 data.

6.2.3.7.2 Southwest Alluvium CAP Activity - 1990

CAP activity during 1990 consisted of operation and monitoring of the performance of the extraction wells. The system operation and performance was presented in the 1990 Annual Review (Canonie, 1990a) and is summarized here.

The wells pumped continuously through 1990 with some adjustments to flow rates. Table 6.25 summarizes the operational data for the extraction wells during 1990. As shown, between October 1989 and October 1990, the wells pumped at an average rate of 14.3 gpm, with a total of 7.4 million gallons extracted. These pumping rates are similar to those predicted in Amendment II (Canonie, 1989a) and the RD (Canonie, 1989d).

Review of the water level data indicated the system was operating as designed and was creating a hydraulic barrier to flow. Comparison of Figure 6-33 (fourth quarter 1990), with initial conditions presented on Figure 6-30, illustrates the hydraulic barrier that had been created.

As discussed in the 1990 Annual Review (Canonie, 1990a), a hydraulic gradient towards the pumping wells existed through approximately 90 percent of the cross-sectional area of the barrier. Figures 6-33 and 6-34 present the water level data used to evaluate the effectiveness of the Southwest Alluvium extraction wells in creating a barrier. The plan view shown on Figure 6-33 indicates some of the water may have passed between pumping Wells 802 and 803 near Wells 805 and 806. Review of the cross section presented on Figure 6-34 indicates the hydraulic barrier gradient for approximately 10 percent of the cross-sectional area of the barrier may not have been directed toward the pumping wells. As a result of NRC and EPA review, the system was modified by adding Well 808, shown on Figure 6-34, to ensure that the hydraulic barrier is complete.

The 1990 water quality data indicated the configuration and extent of the seepage plume in 1990 was similar to the initial conditions in fourth quarter 1989 shown on Figure 6-32. Figure 6-35 presents the chloride concentrations reported for fourth quarter 1990. Comparison of Figure 6-32 and 6-35 illustrates the similarity of the plume configuration in 1989 and 1990.

The 1990 chloride data exhibited a small increase in concentration, typically less than 10 percent. The cause of the increase is believed to be natural conditions, especially considering that the increases were identified in both upgradient and downgradient wells. As shown on Figure 6-35, subtraction of the apparent effect of natural factors caused the extent of the 100 mg/l isoconcentration line to closely resemble that shown on Figure 6-32.

A statistical evaluation of the water quality data further demonstrated the primary exceedances of the EPA standards, nitrate, TDS and sulfate are due to the fact that the ARARs established for these constituents are inappropriate given the evolution of the alluvial water geochemistry. Previously, evidence for the appropriateness of higher background concentrations was presented in reports by Billings (1986) and Canonie (1988a).

As described in the 1990 Annual Review (Canonie, 1990a), the statistical evaluation used two different procedures ("t" test and analysis of variance) to test the data from wells located upgradient (Wells 639, 642, 644, and 645), wells located within the remedial action target area (Wells 801, 802, 803, 632, GW-1, GW-2, and GW-3), and wells located downgradient from the target area (Wells 624, 627, and EPA-25). Chemical data used for the evaluation were reported for the first quarter 1988 through fourth quarter 1990. The constituents included were chloride, nitrate, TDS and sulfate, which are the primary constituents reported in concentrations exceeding the ARARS in the Southwest Alluvium.

The results of both tests confirm that the 100 mg/l chloride concentration is an appropriate value for delineating the plume in the Southwest Alluvium. Both tests also confirmed that the elevated concentrations of nitrate, TDS, and sulfate are not indicative of seepage and are representative of background conditions. Refer to the 1990 Annual Review (Canonie, 1990a) for a discussion of the test procedures and more detail concerning the test results.

6.2.3.7.3 Southwest Alluvium CAP Activity - 1991

CAP activity as of July 1991 consists of operating the extraction wells and installing an additional extraction well (Well 808). NRC and EPA required installation of Well 808 in their responses to the 1990 Annual Review (Canonie, 1990a). The well is designed to enhance the effectiveness of the hydraulic barrier created by the existing extraction wells.

Figures 6-29 and 6-34 show the location of Well 808 with respect to the other extraction and monitoring wells. As shown, this well is located between Wells 802 and 803 and is designed to enhance the effectiveness of the hydraulic barrier near Monitoring Wells 805 and 806. A discussion of the installation, testing, and operation of this well will be included in the 1991 Annual Review, which will be submitted by December 31, 1991.

6.2.4 Evaporation Disposal System

This section discusses the evaporation disposal system designed and constructed to dispose of water collected from the seepage collection well systems in Zone 3, Zone 1 and the Southwest Alluvium, and from Borrow Pit No. 2. The system was originally described in Amendment I (Canonie, 1988b) and re-evaluated in Amendment II (Canonie, 1989a) to the 1987 Reclamation Plan (Canonie, 1987b). Construction began in the fall/winter of 1988, when the evaporation ponds were built. The ponds have been operating since January 5, 1989. The operational performance of the system has been presented in two reports, the 1989 Annual Review (Canonie, 1989c) and the 1990 Annual Review (Canonie, 1990a) submitted to the agencies.

Figures 6-36, 6-37, and 6-38 show the site conditions and the components of the evaporation disposal system. The components of the system include the following:

1. Two 5-acre, lined evaporation ponds equipped with misters located on the embankments of the ponds to enhance evaporation.

2. Mist evaporation system consisting of several lines of misters located in the Central Cell.

3. Spray evaporation system consisting of a series of spray guns also located on the Central Cell.

The mist evaporation system operated only before and during 1989. It was dismantled in Spring 1990 to allow construction of the interim reclamation cover in the Central Cell. The spray evaporation system, which replaced the mist evaporation system, was installed at the end of the 1990 construction season on top of the Central Cell interim reclamation cover. See Appendix G of the RD (Canonie, 1989d), Technical Specifications (Canonie, 1988c), and the Engineer's Report (Canonie, 1990b) for detailed drawings and specifications for these components.

The design of the evaporation disposal system is based on a water balance providing that all seepage collected from Zone 3, Zone 1, the Southwest Alluvium, and stored in Borrow Pit No. 2 would be evaporated between 1989 and 1996. The water balance accounted for the following inflows and outflows from:

1. Inflow

    - Pump-back and extraction wells
    - Borrow Pit No. 2
    - Precipitation

2. Outflow by evaporation from:

    - The surface of the evaporation ponds
    - The pond misters located on the evaporation pond embankments
    - The mist and spray evaporation systems

Table 6.26 presents the monthly net evaporation rates used to estimate the outflow from the system for the remedial design. Based on performance evaluations of the system, these rates provided a reasonable design guide.

Tables 6.27 and 6.28 present the predicted and actual values for the inflows and outflows of the water balance for the first three years of operation. The predicted values were used for the system design and were originally presented in the RD (Canonie, 1989d). The actual values were determined from performance monitoring of the system.

The water balance is based on the premise that maximum disposal occurs during the summer months when evaporation rates are highest. During the winter months, when evaporation rates are low, or there is net precipitation, the inflow must be regulated so the pond capacity is not exceeded. For example, as shown in Table 6.27, the total inflow volume for 1989 was predicted at 40.6 million gallons, while outflow was predicted at 33.3 million gallons. The difference of 7.3 million gallons represented the volume of water stored in the ponds during the non-evaporative months when outflow would be nearly zero.

6.2.4.1 Evaporation Ponds

Figure 6-36 shows the location and configuration of the evaporation pond system. As discussed in Amendment I of the Reclamation Plan, (Canonie, 1988b) the pond size was determined based on the volume required during non-evaporative months to store water pumped from the pump-back wells, Borrow Pit No. 2 and precipitation. The ponds were completed in January 1989. Details of the pond construction are presented in the As-Built Construction Report (Canonie, 1989b) and are included on the drawings in Appendix G of the RD (Canonie, 1989d).

Storage Capacity - The constructed storage capacity of the ponds is approximately 13.7 million gallons, assuming that under normal operating conditions the ponds are filled to a maximum depth of 4 feet. This depth allows for adequate freeboard to provide additional storm water capacity for as much as 3.6 million gallons per pond. The additional freeboard is adequate to store the probable maximum precipitation event of approximately 8.5 inches of rainfall or approximately 6.7 million gallons of water. Appendix G of the RD (Canonie, 1989d) provides the as-built area/capacity curves for each pond.

Evaporative Capacity - As discussed in Amendment I, evaporation from the surface of the ponds is estimated to be 9.2 million gallons per year. This evaporation volume is based on the net evaporation rates presented in Table 6.26 and conservatively assumes the surface area of the ponds is 10 acres. The actual surface area is slightly greater, approximately 11 acres, because as the ponds fill, the sloped sides create increased surface area and, therefore, increased evaporation capacity.

The evaporation pond system is equipped with two lines of atomizing mist nozzles. The specifications for the pond misters were presented in the Technical Specifications (Canonie, 1988c) and on the drawings included in Appendix G of the RD (Canonie, 1989d). However, the specified nozzle was not available. Therefore, United Nuclear elected to revise the design presented in the Technical Specifications to maintain system efficiency using replacement nozzles.

The misters are designed to operate at a maximum rate of approximately 350 gpm, at least 10 hours per day, 7 days per week during the evaporation season. For design purposes, the evaporative efficiency of the pond mist system was estimated at 35 percent, or 123 gpm, based on the observed efficiencies of similar systems operating at other sites. Evaporation from the misters was predicted to be 15 million gallons per year based on the design efficiency. However, as discussed in Section 6.2.4.3, field operation indicates evaporation efficiency is less than predicted.

The estimates of design efficiency accounted for the climatic conditions prevailing at the site and the evaporative capacity of the mister systems to be installed. Climatic information for the United Nuclear site was obtained from Climates of the States, Gale Research Company 1981, and from the Uranium Mill License Renewal Application (D'Appolonia, 1981).

The pond misters have been monitored during operation to evaluate system efficiency and to determine what adjustments can be made to improve efficiency. These adjustments may include charging the lines with compressed air, selecting a different nozzle, further elevation of the nozzles above the pond dike, or other operational adjustments.

6.2.4.2 Tailings Mist and Spray Evaporation Systems

Additional evaporative capacity was provided initially by the mist evaporation system, which was located on the tailings surface in the Central Cell of the tailings disposal area. This system consisted of several lines of mist nozzles, which sprayed water over tailings to control dust. The mist system was installed and operating at the time of the RD (Canonie, 1989d) and continued to operate until May 1990. At that time, the mist system was dismantled to make way for interim reclamation construction activities.

At the end of the 1990 construction season, a spray evaporation system was installed and began operating. This system consists of a series of 26 spray guns located in the Central Cell. A description of the operation of the two systems was provided in the 1989 and 1990 Annual Reviews (Canonie; 1989c, 1990a).

6.2.4.2.1 Tailings Mist System

In 1989, the mist evaporation system located in the Central Cell with a maximum capacity of 350 gpm (4.2 gpm per nozzle) was being used to evaporate water stored in Borrow Pit No. 2. Figure 6-36 shows the general location and configuration of this system. This system was approved for operation by the NRC and began operation in the 1988 evaporative season. The mist system operated until May 1990, when it was removed, so tailings grading and soil-cover placement for interim stabilization could commence in that area.

6.2.4.2.2 Spray Evaporation System

In accordance with Amendment I, a spray evaporation system replaced the mist evaporation system after interim stabilization grading and cover placement were completed in the Central Cell. The spray system is designed so no infiltration into the cover soils will occur. The system consists of a series of spray guns that can each wet an area of approximately 1 acre. Figures 6-37 and 6-38 show the system layout. Appendix G of the RD (Canonie, 1989d) presents a schematic of a typical spray gun.

Experience in designing similar systems indicates that, to achieve adequate spray coverage of the approximate 15 to 20 acres available at the Central Cell for system placement, 20 to 30 guns may be required. At present, the system consists of 26 guns. The spray guns are operated sequentially to balance application rates and evaporation rates. The maximum application rates vary depending on the month, and may approach up to 6,000 gpd per acre based on the evaporation rates listed in Table 6.26.

Specifications for the spray guns and piping were presented to NRC after the evaporation disposal system had operated and been monitored for performance efficiency. NRC approved the installation of the spray evaporation system in Amendment 7 to the License.

The spray system was selected to replace the mist system for this site because of greater flexibility of operation. The capacity of the spray system is greater than the anticipated volume of seepage predicted to be discharged to the system. Therefore, if the volume from the seepage collection system is greater than anticipated, the spray system will be able to accommodate the additional volume. Spray guns can also be added or subtracted from the system to adjust to changes in climatic conditions, such as dry or wet years, or to changes in volumes pumped from the seepage collection system.

Initially, 16 spray guns were installed in accordance with the design specifications presented in the "Enhanced Evaporation System Engineer's Report" (Canonie, 1990b). Figure 6-37 shows the initial layout of the system in 1990. Ten additional spray guns were added in the spring of 1991 to increase the system capacity. Figure 6-38 shows the system layout with the additional spray guns.

6.2.4.3 Operational Water Balance

This section discusses the predicted and actual operational water balance. The predicted water balance was presented in the RD (Canonie, 1989d) for the design of the evaporation disposal system. The water balance has been updated annually so the need for adjustments to system operation can be identified, and the adjustments can be implemented in a timely manner. The 1989 and 1990 Annual Reviews (Canonie, 1989c, 1990a) presented discussions of the actual operational water balances for those two years. A revised water balance was also presented in the ALARA demonstration proposal (United Nuclear, 1991) to account for the additional water from Zone 1 and the Southwest Alluvium. Tables 6.27 and 6.28 present the predicted and actual values for the water balance for 1989 through July 1991.

6.2.4.3.1 Inflow

Inflow to the system consists of 1) water pumped from Zone 3, Zone 1 and the Southwest Alluvium seepage extraction systems, 2) water pumped from Borrow Pit No. 2, and 3) precipitation. The contribution from each of these components is described below.

Seepage Extraction System - Pumping volumes from the pump-back wells and extraction wells vary from year to year, depending on the number of wells operating and the anticipated decline in pumping rates due to well productivity. Table 6.27 presents the predicted and actual total volumes pumped each year from the wells and Borrow Pit No. 2, and Table 6.28 presents details of predicted and actual pumping rates and volumes from Zone 3, Zone 1 and the Southwest Alluvium.

Predicted pumping volumes from the new extraction wells were based on an expected initial total pumping rate of 60 gpm for the Zone 3 wells and 17 gpm for the Southwest Alluvium. Pumping rates for the northeast (Zone 3) and east and north cross-dike (Zone 1) pump-back wells were based on actual rates reported in 1988, and assuming these rates would decline over time. Also, the Zone 1 pump-back wells were expected to be decommissioned at the end of 1989.

The actual pumping rates have varied from the predicted rates. For example, as discussed in Section 6.2.1.7, many of the Zone 3 wells pump at lower rates than predicted because the physical conditions of the aquifer limit the well productivity. Also, the Zone 1 wells have continued to operate through 1990 and 1991, rather than being decommissioned at the end of 1989 as predicted for the remedial design water balance.

Tables 6.27 and 6.28 list the total volumes and the pumping rates for the wells. As shown, the Zone 3 and Zone 1 pump-back wells produced more water than predicted in 1989 and 1990.

The Zone 3 extraction wells have produced less than predicted, in part because of limited aquifer productivity. Another factor, which became evident in 1990, is the reduced saturated thickness near the extraction wells, which reduces well efficiency and lowers productivity. As shown in Table 6.27, the actual volume pumped from the Zone 3 extraction wells was approximately half the volume predicted. Table 6.28 shows that by the end of 1990, a total of approximately 46 million gallons of seepage was extracted from Zone 3, which is less than the 64 million gallons predicted. However, the system continues to operate as predicted in terms of dewatering the target area and capturing the plume.

The Southwest Alluvium wells have been pumping at rates similar to those predicted for 1989 and 1991. As a result, the actual volumes extracted, shown in Tables 6.27 and

6.28 approximate the predicted volumes. Also, since Well 808 was added to the system in 1991, the volumes pumped in future years are expected to exceed the predicted volumes.

Borrow Pit No. 2

The water stored in Borrow Pit No. 2 before implementing the CAP was discharged to the evaporation ponds, beginning January 1989. As discussed in Section 6.3, Borrow Pit No. 2 was dewatered by the end of April 1989, approximately six months earlier than anticipated. Table 6.27 shows that only 4 million gallons of seepage were removed, compared to the 12 million gallons predicted for the water balance.

Additional inflow to Borrow Pit No. 2 after the volume of stored seepage was removed came from precipitation only. Inflow from the surrounding alluvium did not occur. Water levels measured February 1989 in Wells B-3 and B-4 located on the west side of Borrow Pit No. 2, indicated the alluvium was unsaturated to a depth below the current bottom of the pit near the pit (Personal Communication, United Nuclear Management, 1989b).

During the winter months of 1990-1991, Borrow Pit No. 2 was used to temporarily store seepage from the extraction wells. As shown in Table 6.27, by the end of December 1990, the volume of water stored in the evaporation ponds was 12.2 million gallons. By the end of January, the maximum safe operating capacity of the ponds had been reached. Borrow Pit No. 2 was used for temporary storage so the extraction and pump-back wells could continue operating throughout the winter months. This interim use of the borrow pit to augment the available capacity of the evaporation ponds was addressed in Amendment I (Canonie, 1988b), the RAP (United Nuclear, 1989), and the RD (Canonie, 1989d) to allow for flexibility in the CAP operation.

As shown in Table 6.27, a total of approximately 2.8 million gallons was discharged to the borrow pit between January and April 1991. The seepage temporarily stored in Borrow Pit No. 2 was diverted to the evaporation disposal system beginning April 1991, when the spray evaporation system began operating. All stored seepage was removed by the end of May 1991.

Precipitation - Inflow to the evaporation pond from precipitation was estimated from the on-site average monthly net evaporation data presented in Table 6.26. Total inflow from precipitation is estimated to be 300,000 gallons per year for a 10-acre pond surface area.

The estimated precipitation volume has been reasonable for the actual operational water balance. The only exception was the snowfall occurring in December 1990. As shown in Table 6.27, this snowfall was estimated to contribute as much as 1.3 million gallons to the volume stored in the evaporation ponds.

6.2.4.3.2 Outflow

Outflow from the system includes evaporation from the evaporation pond surfaces, evaporation from the pond-mist system, and evaporation from the mist and spray evaporation systems located on tailings (depending on which system is in operation). The following describes each of these components.

Pond Surface - Evaporation from the pond surfaces was calculated from the average monthly net evaporation rates presented in Table 6.26 for a surface area of 10 acres. Table 6.27 shows that the water volume predicted to evaporate from the pond surface each year is 9.2 million gallons.

<u>Pond-Mist System</u> - The pond-mist system is designed to achieve an average evaporation rate of 123 gpm, assuming 35 percent efficiency. The estimated maximum volume disposed of through the pond-mist system is 15 million gallons per year.

The total volume predicted to evaporate from the pond surfaces and the pond misters is approximately 24.2 million gallons per year. As shown in Table 6.27, the actual amount evaporated in 1989 was estimated to be 7.3 million gallons, and in 1990 this volume was estimated to be 14.4 million gallons. The lower actual volume in 1989 occurred because for most of the evaporation season only one cell of the ponds contained water and the full evaporative capacity of neither the pond surface nor the pond misters was utilized. In 1990, the lower actual volume was attributed to actual operating efficiency of the pond misters, which was estimated to be 5 to 10 percent, compared to the 35 percent predicted for the design.

<u>Mist and Spray Evaporation Systems</u> - The volume of water discharged through the mist and spray evaporation systems varies depending on the evaporation requirements during the period considered. For the original design, these systems were estimated to discharge up to 20 million gallons. Also, the volumes discharged through the mist and spray evaporation systems were predicted to decline corresponding to the declining discharge rates from the seepage collection systems, including the alluvial extraction system.

Table 6.27 shows the predicted and actual volumes of seepage discharged through the mist and spray evaporation systems in 1989 and 1990. The mist evaporation system operated during the 1989 evaporation season and discharged approximately 9.4 million gallons of seepage over the tailings. The system was predicted to discharge up to 20 million gallons. However, this capacity was not utilized because of the reduced volume of water stored in Borrow Pit No. 2, and the lower than predicted volume of water from the pump-back and extraction wells.

In 1990, the mist evaporation system was scheduled to operate in April and May before initiating construction activities. The system was then to be dismantled and, after placement of the interim reclamation cover, the spray evaporation system was to be installed. The spray evaporation system was originally scheduled to start operation at the beginning of August and continue through October. As shown in Table 6.27, the two systems were predicted to discharge a combined total of 11.6 million gallons in 1990. However, the total volume discharged through the two systems was only 2.4 million gallons in 1990. This reduced volume occurred because of the following factors:

1. The mist evaporation system did not operate in 1990 because the construction schedule was revised to begin in March rather than June. As a result, the mist evaporation system was dismantled before the onset of the evaporation season.

2. The spray evaporation system began operation in mid-September rather than at the beginning of August. Therefore, more than a month of evaporation time was lost and evaporation rates were lower because the system operated after the peak of the evaporation season.

Table 6.27 shows the reduced outflow to the mist-spray evaporation systems was offset by the approximately 11.2 million gallons utilized for construction purposes.

The capacity of the spray evaporation system was expanded in 1991 with the installation of 10 additional spray guns. These guns were added to increase the capacity of the evaporation disposal system to handle the additional water from the continued pumping of the Zone 1 wells and Well 808. The operational capacity of the spray evaporation system will be evaluated in the 1991 Annual Review

6.2.5 Remedial Action Schedule

The schedule of the corrective action to be conducted at the Church Rock site was presented in the RD. The dates presented in this schedule are subject to change depending on the performance success of the remedial action plan. The schedule remains unchanged, with the exception of the schedule for decommissioning the Zone 1 wells and a few other minor modifications.

7.0 MILL DECOMMISSIONING

7.1 Introduction

This section describes the mill decommissioning activities as presented in the December 1988 Church Rock Mill Decommissioning Plan (MDP) (United Nuclear, 1988).

In June 1987, United Nuclear submitted the detailed proposed Reclamation Plan (Canonie, 1987b) to the NRC. The proposed Reclamation Plan was subsequently revised with the submittal of Amendment I in July 1988. Amendment I, approved by the NRC in September 1988, contained a detailed schedule of reclamation activities to be undertaken by United Nuclear, which included decommissioning of the mill facility in 1992. In addition, NRC License Condition 26, required United Nuclear to submit a detailed mill facility decommissioning plan by December 31, 1988. The MDP was originally submitted to the NRC on December 29, 1988. In response to NRC review comments of March 5, 1990, supplemental information for this plan was provided on April 10, 1990. Mill decommissioning began in 1991, following NRC approval in January 1991.

In addition to discussing the decommissioning activities, this section describes the United Nuclear radiation protection programs established to protect personnel from undue radiological exposures and keep radiological releases as low as reasonably achievable.

7.2 Decommissioning Action

United Nuclear's schedule for reclaiming the Church Rock uranium mill and tailings facility outlines various activities through 1997. The schedule for the mill decommissioning task depends on the success of certain preceding tasks. United

Nuclear proposed to decommission the mill in 1992, assuming that Borrow Pit No. 2 had been successfully dewatered, which occurred in early 1991. Borrow Pit No. 2, an excavated pit located at the eastern end of the property, was excavated during mill operation to provide additional holding capacity for tailings water recirculation.

United Nuclear determined in late 1984 that the Church Rock facility would be closed permanently. Since that time the company has actively pursued the salvage and sale of equipment and materials from the mill. To this end, much of the equipment at the mill has been decontaminated, sold and removed from the site. Other equipment has been dismantled, decontaminated and segregated into "clean" areas awaiting sale. All these areas are located outside the restricted area. Some equipment and material yet to be decontaminated for sale remain. The company continues to actively seek opportunities to sell its equipment and materials on the open market. While NRC or agreement-state licensees have purchased some equipment and material, non-licensees have bought most of the equipment. United Nuclear will continue its active sales program, until significant return can no longer be realized.

In addition, United Nuclear has identified several areas within the mill complex that will remain useful beyond the life of mill operations. These areas include the administration building, the shop/warehouse building and the guard/change house building. A radiological survey will be conducted in these facilities to allow their release for general unrestricted use after any necessary decontamination.

Finally, the remainder of the facility is being, and will continue to be, dismantled and disposed in Borrow Pit No. 2. United Nuclear is disposing of mill materials in lifts not exceeding five feet thick. Each lift of debris is covered with a minimum of one foot of compacted soil to provide a solid foundation for the next lift. United Nuclear compacts each one-foot soil lift to work the soil into existing void spaces. When Borrow Pit No. 2

(Figure 5-1) is filled completely, the radon attenuation soil-cover layer and soil/rock matrix erosion protection layer, described in Section 5.0, will be installed.

Following is a detailed discussion of the various activities anticipated in decommissioning the mill facility.

7.3 Equipment Salvage and Sale

As indicated above, United Nuclear has been actively salvaging and selling selected mill equipment since 1985. A list of equipment sold before December 1988 from the mill, or moved to the clean areas was provided in Appendix A of the MDP (United Nuclear, 1988). Appendix A of the MDP also contains the documentation of the radiological survey results conducted for each piece before its release for unrestricted use.

The Radiation Safety Officer (RSO) was, and continues to be, an integral component of the equipment sales program. He must be advised of all equipment sales so he can coordinate the surveying, decontamination (if required), preparation, loading and shipment of the materials leaving the site.

7.3.1 Salvage and Decontamination Procedure

When the mill facility was placed on standby in mid-1982, the entire circuit was flushed and cleaned of process material. Each circuit was emptied of process material in logical sequence from the front to the back of the process flow (i.e. from ore storage and conveying, through grinding, leaching, countercurrent decantation, filtering, solvent extraction and stripping and finally precipitation and packaging). All the process lines were flushed with water to remove residual process materials, and each piece of equipment was rinsed with water as it was emptied to ensure that each circuit was clean when shut down. All walls and floors were washed with water and, in some cases, scrubbed with acid. All control rooms and instrument panels were cleaned and mothballed. All equipment was lubricated and placed on standby. All wood stave tanks were filled with water to keep them swollen tight.

The precipitation and packaging circuits were the last to be shut down, and were used until February 1983 to process liquids received from the ion-exchange (IX) plants at the mines.

Upon placing the facility on standby, the source or by-product material remaining on-site consisted of:

1. A small amount of low grade ore and pond residue at the northeast corner of the ore pad,

2. Materials recovered from the precipitation circuit during cleanup,

3. Some organic solution from the solvent extraction circuit that contained uranium,

4. The yellowcake samples retained in the metallurgical and chemical laboratories, and

5. Resin from the ion-exchange columns.

These materials were temporarily stored in drums at the mill.

United Nuclear retains detailed records of the activities undertaken during the standby period in the offices of the RSO. These records are available for inspection on request.

The procedure followed during standby made the task of mill decommissioning much easier.

After deciding to close the facility, United Nuclear acted to dispose of the remaining materials in storage. The low-grade ore and pond residues were deposited in the tailings area. The material recovered from the yellowcake precipitation circuit and yellowcake samples were shipped to another mill in the area for processing. The organic solvent from the solvent extraction, and the resin from the IX plants were sold to other licensees. The water from the wood stave tanks was disposed in tailings and through evaporation.

United Nuclear initiated an equipment salvage and sales program designed to recoup some of the investment in the mill equipment. The above actions made it much easier to decontaminate the equipment at the time of sale. All potentially salable mill components were identified and surveys were conducted by the RSO to identify levels of contamination, as well as to establish decontamination protocol and ultimate segregation of contaminated and clean materials. The equipment was removed under the supervision of the RSO. All equipment was inventoried using a reference number as established from the original construction drawings and specifications for the mill.

The precipitation building was used as the cleaning area. The equipment was dismantled to its most basic parts, and if contaminated, the parts were steam cleaned. If needed, the parts were also washed with muratic acid, then steam cleaned again. Any equipment with a gamma reading of twice background or more than 300 counts per minute (cpm) Alpha, on the surface or from a swipe sample, was rewashed. A record was kept of all equipment cleaned this way, and is available for inspection on request.

As a matter of policy, all equipment sold was resurveyed before it left the site as a precautionary measure. No equipment has been allowed to leave the restricted area unless it has met the following criteria: gamma readings of less than twice background (approximately 40 μR/hr.) and less than 5,000 cpm Alpha as a surface reading, or less than 1,000 cpm on a swipe reading. This system was established to provide strict controls for ensuring all materials were adequately decontaminated before they were released for unrestricted use, and will be followed during any future equipment sales.

7.4 Mill Decommissioning Activities

This section describes how the major identifiable areas of the mill have been, and will continue to be, decommissioned. Figure 1-5 depicts the general mill facility layout and identifies the major processing components. The overall objective of decommissioning the facility is to remove all residual radioactive materials from the site so the whole physical plant area may be released for unrestricted use.

7.4.1 Truck Scale and Scale House

This portion of the facility contains remnants of ore residual, as it is where ore entered the restricted area. These facilities are not considered to be significantly contaminated (if at all) and are identified for sale. The truck scale and scale house are still being used, and will continue to be used until, they become an obstacle to the demolition activities. If a sale has not been effected by the time they become an obstacle to mill demolition activities, the truck scale and scale house will be surveyed and decontaminated, if necessary, using techniques consistent with those described in Section 7.3.1, and removed to one of the clean storage areas.

7.4.2 Ore Receiving Bin

This portion of the facility is not considered significantly contaminated, if at all. The bin consists of a surface-metal grizzly screen and hopper enclosed on three sides with concrete vault. The metal grizzly and hopper were removed and disposed of in Borrow Pit No. 2. The vault itself is a poured concrete, below-grade structure. The vault walls will be surveyed. If any contamination can be removed from the concrete, it will be cleaned with either an acid wash or scrabbled to remove surface contamination. If any contamination cannot be removed from the concrete, it will be excavated and disposed of in Borrow Pit No. 2. The remaining vault void or open excavation will be filled with soil and graded smooth at the surface.

7.4.3 Conveyor

The conveyor belt system feeding from the bottom of the ore hopper into the semi-autogenous grinding (SAG) mill has been removed. It was surveyed and decontaminated consistent with procedures described in Section 7.3.1, and was sold. The metal conveyor housing structure was also decontaminated and sold. The part of the above-ground concrete structure connected to the grizzly vault will be crushed and disposed in Borrow Pit No. 2.

7.4.4 Mill Building

The mill building contains several discrete processing areas, including the SAG mill, boiler room, motor control room, precipitation section, yellowcake drying and packaging, and a maintenance shop area. The mill building, SAG mill, the boilers and the sulfuric acid tank have been sold and were shipped from the site. Many processing pumps and related equipment from this area have also been decontaminated and sold, or stored in a clean area. The remainder of the former mill equipment, including a number of wooden and steel tanks, filters, pumps, and motors, were decontaminated and sold, or are in clean storage awaiting sale. The yellowcake dryer and packaging system and related equipment have been crushed and disposed in Borrow Pit No. 2.

Most of the equipment that could reasonably be decontaminated and salvaged has been removed, decontaminated and stored in clean storage area, if not already sold and shipped off-site. Some stainless steel pumps, which could not meet releasable standards, were sent to another licensee. All unsold equipment from this area has been cut, crushed or otherwise condensed to minimize void space, and disposed in Borrow Pit No. 2.

Some portions of the mill building structure itself, particularly those areas containing the ore grinding circuit, boiler, motor controls, and the maintenance shop, were only marginally contaminated, if at all. These portions of the mill building have been sold and removed. Dismantling the building was done in accordance with procedures developed by the RSO. The RSO developed all necessary Radiation Work Permits (RWPs) consistent with United Nuclear's license requirements, monitored all work, and implemented personnel and area monitoring as necessary. All dismantled materials removed off-site were surveyed and decontaminated consistent with the procedures described in Section 7.3.1.

7.4.5 CCD Thickeners and Associated Tanks and Buildings

This area consisted of six countercurrent decantation (CCD) thickener tanks, one enviroclear thickener tank, the CCD pump-house building and sumps, one raffinate tank, one clarifier-flocculator tank, one overflow surge tank and a sodium chlorate storage building.

The CCD tanks were constructed of wood with concrete flooring, and all six have been dismantled. The wood slats from five of the six CCD tanks are presently being decontaminated before sale. The wooden slats from the walls of Thickener No. 6 were dismantled and burned in Borrow Pit No. 2 due to poor quality for salvaging. A small amount of tailings residue remaining in the bottom of the tank was transported to the tailings pile for disposal. The enviroclear thickener has been decontaminated, sold and shipped off-site. Some walkways, rakes, pumps and motor drives were decontaminated and sold, or are in clean storage awaiting sale. Others were crushed and disposed in Borrow Pit No. 2. The mechanical drive motors, pumps and rakes were decontaminated and moved to clean storage.

The thickener area consists of the tank bottom concrete slabs, the CCD pump house building and the associated tanks, sumps and equipment. Some equipment was salvaged, decontaminated and has either been shipped off-site or is in clean storage. The building and any associated unsold equipment was dismantled, cut, crushed or otherwise condensed to minimize void spaces, and disposed of in Borrow Pit No. 2.

The concrete slabs will be surveyed to determine the extent of contamination. Depending on the extent of contamination, the slabs may either be acid-washed, scrabbled to remove surface contamination, or extracted and disposed in the Borrow Pit. These decisions will be made in the field during decommissioning. The basement sump area below the CCD tanks will be filled in with clean soil once equipment has been removed, the area decontaminated, and surveys conducted to confirm that it is clean.

The raffinate, clarifier-flocculator and overflow surge tanks were all constructed of wooden slats with concrete aprons. The wooden slats were dismantled in the same fashion as the CCD tanks and either salvaged or burned in Borrow Pit No. 2, if the quality was too poor for salvaging. The concrete aprons around these tanks will be crushed and buried in Borrow Pit No. 2.

The sodium chlorate building was dismantled and removed from the restricted area. This work was done under instructions from United Nuclear's RSO, using RWPs where necessary. The RSO monitored all work, and implemented personnel and area monitoring as necessary. The dismantled building was taken off-site after the appropriate surveys and decontamination procedures. The equipment previously contained in the building was decontaminated and sold or crushed and disposed in Borrow Pit No.2.

7.4.6 Solvent Extraction Area

The solvent extraction area consists of a series of concrete tanks poured in place, covered with steel walkways, railings and covers, and one steel tank. All the tanks are empty of process material as they have been since the facility was placed on standby, except for some rainwater. Rainwater will be pumped to the lined evaporation ponds for disposal. Some of the hand rails and piping have been dismantled, crushed, and disposed in Borrow Pit No. 2. The remaining handrails, piping, walkways and steel covers will be cut or crushed to minimize void spaces before disposal in Borrow Pit No. 2. All the tanks are assumed to be significantly contaminated. Therefore, these tanks will be rubblized, or cut into pieces for excavation, removal and disposal in Borrow Pit No. 2.

7.4.7 Administration, Guard/Change House and Warehouse Buildings

These three buildings, as indicated previously, will be surveyed, decontaminated (if necessary) and released for unrestricted use, as it is anticipated that these facilities will be useful beyond the life of the mill. Two associated facilities (i.e., the lube storage area and the tire storage shed) will also be cleaned and released for unrestricted use. Preliminary surveys were conducted of these facilities in 1987. A summary of these results is included in Appendix B, MDP (United Nuclear, 1988). The results indicated all these areas were clean. Additional surveys will be conducted of all these areas, as necessary, to ensure their cleanliness before release.

7.4.8 Miscellaneous Surface Facilities

The miscellaneous facilities include the emergency solvent dump pond, kerosene tank holding area, ammonia storage tank area, fuel-oil storage tank area, the storm drainage pond, the sewage treatment plant, and electrical sub-station. Most of these areas were not significantly contaminated, if at all. The emergency solvent dump pond was constructed for emergency use in the event of overflow, spill or break in the solvent extraction circuit. The pond is lined with gunite and sealed with a rubberized coating. This lining will be stripped from the surface and disposed of in the tailings pile. Because this pond may have received liquids from the solvent extraction circuit from time to time, particular attention to soil surveys will be paid to this area. After appropriate decontamination procedures have removed any contaminated soils, the pond depression will be filled with clean soil.

The kerosene tank has been surveyed, decontaminated and sold. The containment dikes are coated with gunite, which will be stripped off and disposed of in the tailings pile. The dikes will be collapsed into the emergency containment area to fill the depression, after verification surveys have been conducted. The same procedure will be used to reclaim the fuel-oil storage tank area and storm drainage pond. The ammonia storage tank was surveyed, decontaminated and sold. The lube storage building was sold.

The sewage treatment plant may be surveyed, decontaminated if necessary, and released for unrestricted use. During operation, the treatment plant was plumbed to discharge to the tailings area. However in 1985, a septic tank and leach field were installed outside the restricted area to which the sanitary sewer from the facilities now discharges. The piping from the plant to the tailings disposal area was dismantled, crushed and disposed in Borrow Pit No. 2. The leach field facility is a part of the administrative/guardhouse and warehouse complex, which United Nuclear will retain for unrestricted use.

The electrical sub-station, depicted on Figure 1-5, has been dismantled. Power is now supplied by a much smaller unit located at the shop/warehouse building. This unit will remain as part of the facilities described in Section 7.4.7.

7.4.9 Foundations, Floors and Supports

Insignificant contamination of concrete floors, supports and foundations is anticipated. Except for hot spots from spills or overflow, much of the foundations, supports and flooring should not be contaminated. Surveys will identify those concrete areas that might require decontamination or removal. Contaminated concrete structures will be evaluated to determine the feasibility of decontamination. Those structures that can be easily and economically decontaminated by processes such as acid-rinsing, sandblasting or scabbling will be treated as appropriate. It may be more efficient and economical to rubblize, cut, blast or otherwise remove contaminated concrete structures for disposal in Borrow Pit No. 2. These decisions will be made in the field as decommissioning progresses. The RSO will provide appropriate RWPs and attendant monitoring when necessary.

7.4.10 Buried Lines and Plumbing

Most of the process lines at this facility were located overhead. These pipes have been dismantled, crushed and disposed in Borrow Pit No. 2. However, a few buried lines exist at the process plant, one 4-inch and one 12-inch line connecting the solvent extraction circuit to the raffinate tank, the overflow lines from the solvent extraction circuit to the emergency pond, and the drains from laboratories to the CCD sump. These lines will be excavated to the extent practicable and disposed in Borrow Pit No.2. If excavation becomes impractical, the lines will be surveyed at their access points. If they indicate contamination, reasonable efforts will be made to excavate them. If deemed impractical, appropriate exception approvals will be sought from the NRC. On receipt of specific exception approvals from the NRC, the access points will be plugged with concrete and reburied. Drainage sumps will similarly be decommissioned. Buried utility lines such as electrical conduit, water lines, etc., will be abandoned in place. Where necessary, such lines will be cut off and plugged below the ground surface and reburied.

The tailings discharge lines, previously leaving the mill site at the southeast corner of the facility and crossing under the highway and over Pipeline Arroyo, were removed and disposed in Borrow Pit No. 2. The covered pipe trestle will be salvaged. Catch Basins No. 1 and No. 2, shown on Figures 2-2 and 2-3, will be excavated and placed in Borrow Pit No. 2.

7.4.11 Mill Facility Soils and Ore

Section 2.0 of this Reclamation Plan presents a detailed site radiological survey, which included three background areas, the soils around the tailings facility to determine the extent of wind-blown tailings, as well as the mill site and facilities area, excluding the actual structures. Details of the survey methods and procedures are contained in

Section 2.0, including the use of gamma ray exposure surveys, borehole logging surveys for sub-surface characterization and sample collection and sample analysis for Radium.

Section 2.3.2 of the Tailings Reclamation Plan discusses the results of the survey conducted at the mill. Figure 2-5 and Tables 2.10, 2.11 and 2.12 contain the survey results. Generally, these results indicate overall gamma exposure rates on-site were slightly elevated above background, probably due to the proximity to the ore storage pad. The Ra-226 concentrations from by-product material in the mill area appear limited and, where detected, are located near the ground surface. Therefore, decommissioning activities with regard to mill area soils will be limited to removing the asphalt surface in all areas (except around the administration building, warehouse, lube storage area, tire storage shed and guard/change house buildings) and scraping approximately six inches of soils beneath the asphalt to remove possible surface contamination. In addition, any ore materials remaining in the ore storage area will be removed and disposed in the tailings disposal area. Approximately six inches of surface material will then be scraped from the ore storage area to remove possible surface contamination.

Finally, a verification gamma survey will be conducted to identify any remaining hot spots. Hot spots identified will be dealt with on a case-by-case basis. For example, individual hot spots may be easily removable by additional removal of minor amounts of soil. It may be necessary in some cases to characterize the "hot" area further to determine its overall condition once an average over a grid section is identified. These decisions will be made in the field as decommissioning progresses.

7.4.12 Schedule For Mill Decommissioning

As indicated, certain mill buildings or portions of buildings were sold and removed before 1991. The main mill building structure (except the precipitation and packaging section, which were disposed in Borrow Pit No. 2), the sodium chlorate building and the sample preparation section of the scale house were sold and removed off-site. These facilities were dismantled, cleaned and removed under the supervision of the RSO, as described in Sections 7.3 and 7.5 of this plan.

It is anticipated the truck scale and the remaining portion of the scale house will also be sold before commencing further mill decommissioning activities in 1992. The CCD building structure, and the precipitation and packaging section of the mill building have been dismantled and disposed in Borrow Pit No. 2. All salable equipment will be removed to a clean area or sold by 1992. The following sequence of events occurred in 1991:

1. Dismantled all remaining wood stave tanks.

2. Removed equipment attached to the precipitation and CCD building frames.

3. Removed standing equipment within the floor space of the CCD and precipitation buildings that would impede disassembly of the structures.

4. Dismantled the CCD and precipitation building structures.

5. Removed any remaining equipment within the concrete foundations of these buildings.

6. Dismantled piping and structures in the SAG mill conveyor housing and the grizzly.

7. Removed and cut some steel storage tanks.

8. Removed the tailings discharge lines and the support structures over Pipeline Arroyo.

The cutting, crushing, or other size reduction of scrap equipment proceeded simultaneously with the above activities to minimize void space during burial.

The following sequence of events is anticipated for 1992:

1. Remove and cut any remaining steel storage tanks.

2. Remove the support structures over Pipeline Arroyo.

3. Remove the covers, walkways and platforms associated with the solvent extraction tanks.

4. Demolish the solvent extraction tank concrete.

5. Demolish other above-grade or on-grade concrete.

6. Decontaminate below-grade concrete, if feasible, followed by backfilling of void space with clean soil.

7. Rip and remove the asphalt paving and the solvent extraction dump pond.

8. Radiologically survey the exposed soil and buried piping.

9. Remove contaminated soil and seal buried pipe openings.

10. Remove radium-contaminated soils in and near the Catch Basins.

11. Remove the mill yard fencing.

12. Strip the surface of the ore storage area.

13. Final grade for drainage.

14. Revegetate the disturbed area.

7.5 Radiation Protection Program

This section describes the programs implemented by United Nuclear to ensure that personal exposures and releases to unrestricted areas are kept as low as reasonably achievable. This program includes radiation safety organization and responsibilities, internal and external exposure protection, radiation safety training, RWPs, controlled area designation, health physics monitoring and record keeping.

7.5.1 Radiation Safety Organization and Responsibilities

The General Manager (GM) of the Church Rock Operations is the senior manager responsible for all activities on-site. The RSO is also the GM and oversees all aspects of the Radiation Protection Program. The RSO has the responsibility and authority to ensure that all activities related to decommissioning activities are conducted to keep all personal exposures and releases to unrestricted areas as low as reasonably achievable.

All decontamination activity has been, and will continue to be, conducted by United Nuclear personnel or contractors to United Nuclear. United Nuclear personnel report directly to the RSO, effecting maximum control of decontamination activities. All decontamination contractors are managed by the RSO, again effecting maximum control of decontamination activities.

United Nuclear uses this reporting structure because the RSO has the technical experience and the educational background to undertake such a responsibility. The RSO was the mill superintendent of the operating mill, and supervised some of its construction. The RSO also placed the facility on standby and oversaw its eventual shutdown. Finally, the RSO has been a integral part of the equipment sales team and presently provides its direct supervision. The company's radiation protection responsibilities have been paramount during all of these activities and will continue through the decommissioning phase.

United Nuclear currently has one full-time radiation safety technician. One other technician has been trained to assist in additional decommissioning activities. Their training is discussed in Section 7.5. The RSO and his staff perform the following duties as part of the decommissioning plan:

1. Implement and oversee the Radiation Protection Program.

2. Establish a radiological monitoring program for each activity to provide data for calculating radiation exposures and keeping adequate records.

3. Review radiological monitoring data to evaluate exposures and ensure that the radiation exposures are as low as reasonably achievable.

4. Evaluate control measures to ensure that the potential for radiological exposures are kept as low as reasonably achievable.

5. Implement and maintain a dosimetry program, as necessary.

6. Advise, instruct, and train personnel in their radiation safety responsibilities.

7. Observe site activity to ensure compliance with the Radiation Protection Program and cease the work activity if a potential exists for inadvertent, excessive radiation exposure to personnel or the general public.

8. Maintain records of radiological monitoring and exposures, as necessary.

9. Provide radiation safety training to all individuals conducting decommissioning activities.

10. Implement and maintain an effective respiratory and bioassay program, as necessary.

11. Maintain all radiation survey instruments properly calibrated and certified.

12. Conduct a documented daily inspection of all work areas while dismantling and decommissioning the mill. This inspection will occur only during those times when work is actually being performed, as sometimes physical activity may not occur.

United Nuclear may contract all or part of the health physics monitoring and assistance in radiation protection to a qualified radiological service contractor for monitoring and surveys required by the license conditions and 10 CFR Part 20. Such a contractor may also provide a qualified health physicist to act as the RSO's designee, capable of assisting the implementation and supervision of the Radiation Protection Program, as well as contamination surveys for equipment released to the unrestricted area.

United Nuclear may hire contractors to conduct the dismantling, decommissioning activity. The RSO will supervise the work and will ensure that the contractors' employees receive adequate radiation training and protection. The contractor will ensure his personnel follow the Radiation Protection Program to keep personal exposures and releases to the unrestricted area as low as reasonably achievable, and to avoid inadvertent exposures to radiation. The contractor will also be responsible for knowing the radiation hazard conditions in the work place and the use of radiation protection equipment. Any violation of radiation safety procedures or presence of hazardous conditions reported to the contractor by his employees will be conveyed to the RSO as soon as practicable. The RSO will take appropriate steps to correct those violations. Each individual worker, whether a contractor or company personnel, will be responsible for understanding and adhering to the Radiation Protection Program. All workers will be required to understand the radiological conditions of the specific area to which they are assigned. Individuals will be instructed to stop work if problems arise that might increase radiation exposure, and they must notify their supervisors and the RSO, who will evaluate the situation. Each individual will be required to report any conditions that may lead to a violation of the Radiation Protection Program to their supervisor, health physicist or the RSO. Workers will be made aware of their rights of radiation protection under the law.

7.5.2 Exposure Controls and Monitoring

Decommissioning activity is likely to increase the potential for the release of airborne radioactive materials, thus increasing the potential for internal and external exposure. United Nuclear has developed the Radiation Protection Program to minimize potential exposures to personnel in the restricted area, as well as release and exposure in the unrestricted area. Regulations 10 CFR Part 20, specify the maximum permissible concentration (MPC) of radioactive materials for restricted-area occupational exposures, as well as releases to unrestricted areas and non-occupational exposures.

7.5.2.1 Restricted Area

Exposures to individuals in the restricted area has been, and will continue to be, kept within the limits set by NRC's regulations. The key to controlling exposures in the restricted area is a combination of adequate employee training so the worker knows the hazards and participates actively to protect himself; the use of effective engineering and work techniques to minimize the pathways of exposure; and adequate monitoring programs to aid in evaluating conditions. Section 7.5.3 discusses United Nuclear's Radiation Safety Training Program in detail. The techniques used to minimize the exposure pathways for external and internal doses, and the monitoring designed to evaluate working conditions are discussed in this section.

All personnel are instructed in procedures necessary to minimize internal exposures via ingestion. Eating and smoking are prohibited in restricted areas except in designated "clean" areas. Exposure controls will be achieved through use of radiation work permits, personal monitoring, evaluation of radiological status, posting areas and specific personal protective equipment, as well as the use of dust suppression techniques to minimize airborne contamination. Exposures are also controlled by utilizing engineering measures, such as ventilation and wetting down, and removing any loose contamination. Personal protective equipment is issued or required of contractors, as necessary to conduct specific tasks. The RSO determines the appropriate protective equipment. All employees are required to use the equipment issued as a condition of continued employment. When necessary, instructions and/or training in the use of the equipment is provided to the employee. Areas are posted to inform employees when entering a radiation area.

External exposures are also minimized and kept within applicable NRC regulations with the techniques described above.

Area air sampling is performed as necessary to monitor the concentrations of airborne radionuclides for evaluating the individual exposures in work areas. The RSO will evaluate the potential for elevated concentrations of airborne radioactive materials. Working area air sampling will be conducted to monitor the concentrations of airborne radionuclides, as well as for calculating exposure to individuals working in the area. An individual of the group in the work area will be equipped with a personal air sampler. Individual breathing zone sampling will be conducted as indicated on the RWP, based on the RSO's evaluation of the potential for significant exposure to airborne radioactive materials. A conservative air concentration measurement of either the personal air sample or general area sample will be used to determine exposure for the workers in that area. To assess the adequacy of radiation protection and air sampling, bioassay (urinalysis) will be performed biweekly on employees working in the yellowcake areas of the mill and monthly for other employees working on mill decommissioning. In addition, pre-employment and termination urinalysis will be run for all employees involved in mill decommissioning. A blank and spiked sample will be submitted for analysis with each set of urine samples for quality control. "Airborne Radioactivity Area" signs will be posted where monitoring shows airborne concentrations of radionuclides exceeding 25 percent of those specified in 10 CFR Part 20, Appendix B (Table I, Column I).

RWPs include a description of the monitoring activity conducted in performing the task. All personnel working in the restricted area will wear personnel thermoluminescent dosimeter (TLD) badges. The following is the procedure for the personal dosimetry program:

1. The personal TLD badge will be exchanged and analyzed quarterly.

2. The TLDs will be assigned at the beginning and returned at the end of the day shift at the access control point.

3. All TLDs will be worn as instructed by the RSO.

4. All exposures will be determined and recorded from the analyses of TLD badges. If an individual loses the TLD badge, the RSO will investigate the exposure conditions of the work area to estimate the external exposure for that period.

5. All personnel will notify their supervisor or RSO if they lose their TLD badges. A thorough search will be made to obtain true exposure. The individual will be assigned a new TLD badges, if the search fails.

Should exposure results approach the maximum limits of 10 CFR Part 20, an investigation will be conducted. This investigation will include a radiation survey of the area and immediate analysis of the TLD badge. Should an individual whose exposure is under investigation lose the TLD badge, this individual will be removed from the work area until the investigation is complete.

In keeping with the ALARA Policy and to prevent any inadvertent overexposure, United Nuclear's action limit for airborne radioactive materials is established at 25 percent of the MPC specified in 10 CFR Part 20. This control limit will be used as an action level to implement measures for reducing airborne concentrations. If such practical and reasonable engineering and administrative control measures are not feasible or effective, the acceptable respiratory protection program as defined in the NRC Regulatory Guide 8.15, will be implemented.

7.5.2.2 Unrestricted Area

United Nuclear will continue monitoring airborne concentrations of radioactive materials in the unrestricted area during decommissioning by operating its monitoring program, as specified in its NRC License No. SUA-1475. The limits for release of radioactive material in the air to the unrestricted area shall be those specified in 10 CFR Part 20, Appendix B (Table II, Column I).

7.5.3 Radiation Safety Training

United Nuclear considers the training aspect of radiation protection essential to the success of minimizing exposures. NRC regulations require all personnel working in or frequenting any portion of a restricted area be informed of the storage, transfer or use of radioactive materials or radiation in such portions of the restricted area. The regulations further require all personnel be instructed in the health protection problems associated with exposure to radioactive materials or radiation, in precautions or procedures that should be used to minimize exposure, and in the purposes and functions of protective devices employed. All personnel are to be instructed in, and to observe, the applicable regulations for protecting personnel from radiation or radioactive material exposures in such areas. Instruction will also include the responsibility to report promptly, to their supervisor, any condition that may lead to or cause a violation of the regulations or unnecessary radiation or radioactive material exposure; instruction in the appropriate response to warnings made for any unusual occurrence or malfunction involving exposure to radiation or radioactive material; and information about the radiation exposure reports, which they may request pursuant to the regulations.

7.5.3.1 Program Description

All personnel are trained according to their work assignments. The Radiation Safety Training Program includes the following topics:

1. Fundamentals of Health Protection

- Radiological and toxic hazards of exposures to uranium and its daughters
- Pathway of uranium and its daughters into the body
- ALARA Policy for exposure to uranium and its daughters

2. Radiation Protection and Personal Hygiene
   - Protective clothing
   - Proper use of respirators
   - Eating, drinking and smoking in designated areas only
   - Radiation Work Permit and access controls
   - Methods of personal decontamination

3. Health Physics Monitoring
   - Airborne radioactive material measurement
   - Bioassay
   - Material exposure rate survey and personal dosimetry

4. Radiation Monitoring
   - Operation of monitoring equipment
   - Function checking of equipment
   - Calibration of air sampling equipment
   - Maximum limits of exposure or contamination
   - Record keeping of monitoring data
   - Sampling and monitoring procedure
   - Monitoring requirements per License Conditions

To assess comprehension of the training, all personnel receiving radiation safety training are given a written test. The results of the test are reviewed with the employee. Employees receiving a non-passing score will be re-tested. Individuals sign an acknowledgement that they have received the radiation training and will comply with the Radiation Protection Program.

7.5.4 Radiation Work Permit

While much of the mill decommissioning work will be conducted as a matter of normal work-day activity, some specific tasks may have a potential for significant radiation exposure. Also, instances may occur where no standard operating procedure (SOP) exists for a task. Such work will be carried out under a RWP to ensure the task is conducted to minimize exposures and releases to the environment. The RWP will be used to control radiation exposure by implementing specific radiological protection and monitoring tailored for the task. The RSO will develop the RWP for the task. No work requiring a RWP will be carried out without an approved RWP. The personnel conducting the RWP work will be given specific instructions by the RSO for that task, so they are aware of the hazards and understand the use of special radiation protection equipment and/or procedures. The RWP will include location and description of work, names of all workers involved, radiological protection equipment to be used, special monitoring required, any special instructions given, date of issue and expiration if appropriate, the results of radiation surveys and RSO's approval. The RWP work area will be designated a controlled area and isolated from the restricted area. The access will be limited to trained individuals involved with the controlled area work, to minimize the spread of contamination and to control exposures.

7.5.5 Designated Controlled Areas

Each area of the mill site represents its own unique potential radiation hazard. Areas will be designated based on the nature and degree of potential for radiation exposure. The controlled areas will be established to limit radiation exposures to site workers, visitors and the general public. The designation of an area and associated posting, barriers and necessary precautions will be established, changed or removed only on RSO approval.

7.5.5.1 Restricted Area

The fenced part of the mill site, which contains the process buildings and tanks, support shops, and the warehouse on the west side of state highway 566, is designated the Restricted Area, for mill decommissioning. All entrances to the restricted area are posted with signs that indicate, "Any Area Within This Mill May Contain Radioactive Material". All personnel involved with mill decommissioning activities in the restricted area will be provided radiation safety training.

7.5.5.2 Radiation Areas

An area where a worker could receive a radiation dose of 5 mrem per hour or 100 mrem during five consecutive work days will be designated and posted as a "Radiation Area". The RSO will use radiological surveys to designate radiation areas. All personnel in the radiation area will wear a dosimetry badge and access will be limited to authorized personnel only.

7.5.5.3 Airborne Radioactivity Areas

A respiratory protection program is used to meet the requirements of 10 CFR 20.103(c). Any area where the airborne radioactive material concentrations exceeds 25 percent of the maximum permissible concentrations specified in 10 CFR Part 20, Appendix B (Table I, Column I), will be designated and posted as an "Airborne Radioactivity Area". Respiratory protection will be provided for all individuals in this area.

7.5.5.4 Clean Areas

Any area where the radioactivity is not high enough to require radiation protection is considered a "Clean Area." The clean area will not exceed the surface contamination levels of 5,000 cpm of alpha/100cm^2 average for one square meter, 15,000 cpm/100cm^2 maximum and 1,000 cpm/100cm^2 removable alpha contamination. All the areas of the mill site outside the restricted area and some within the restricted area may be designated clean areas. Eating, drinking and smoking will be permitted only in a designated clean area. Designated clean areas within the restricted area are surveyed weekly for total and removable surface contamination. Wash facilities are conveniently located near the designated clean areas. All personnel are required to wash before eating, drinking, or smoking.

7.5.6 Health Physics Monitoring Procedures and Calibration

All procedures used by the RSO for radiation surveys and health physics monitoring will meet the LLD requirements and quality assurance program as defined in the NRC Regulatory Guide 8.30, "Health Physics Surveys in Uranium Mills" and Regulatory Guide 4.15, "Quality Assurance for Radiological Monitoring". Radiological field and laboratory analyses equipment will be calibrated using National Bureau of Standards (NBS) traceable standards. Calibration frequency will be performed as defined in United Nuclear's equipment calibration procedures contained in its license. A background and function check will be made on each radiological instrument daily or before use.

7.5.7 Records and Reports

Records of radiological monitoring, surveys, exposures, calibrations, reports, inspections, training, investigations, corrective actions and submittal of reports will be maintained. The following lists the specific records and reports that will be monitored:

1.	10CFR 19.11	Posting of Notice
2.	10CFR 19.12	Instruction to Worker
3.	10CFR 19.13	Reports to Individuals
4.	10CFR 20.401	Records of Survey, Radiation Monitoring and Disposal
5.	10CFR 20.403	Notification of Incidents
6.	10CFR 20.405	Reports of Overexposure and Excessive Concentrations
7.	10CFR 20.407	Personnel Monitoring Reports
8.	10CFR 20.408	Reports of Personnel Monitoring Upon Termination of Employment
9.	10CFR 20.4095	Notification and Reports to Individuals

7.6 Security

United Nuclear will continue to provide security at the Church Rock Uranium Mill site throughout the facility's decommissioning. All gates and entrances to the restricted area are posted with signs that comply with the NRC Material License SUA-1475. The entry gates will be locked during non-working hours and access controlled during normal working hours. All site visitors will be required to log in before entering the restricted area and log out when leaving. All individuals, equipment and items leaving the site must comply with radiological requirements defined in the Radiation Protection Program. A daily record book will be maintained regarding the activities related to access, release and other security matters.

All employees entering the restricted area monitor themselves with an alpha survey meter before leaving the restricted area. If the alpha survey indicates contamination of 1000 cpm/100 cm^2, or if the individual is known to have been working in a yellowcake dust area, where the potential for exposure is significant, the individual will be required to shower and change clothing before leaving the restricted area. Documentation of all surveys and shower requirements will be maintained.

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