Project 86-060-24
December 1990

Canonie Environmental



Volume I - Text, Tables, Figures

# Response to Comments and Proposed Reclamation Plan Modifications

Church Rock Site
Gallup, New Mexico

Prepared For:

United Nuclear Corporation
Gallup, New Mexico

# Canonie Environmental

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November 21, 1990

86-060-24

Mr. Juan R. Velasquez
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Transmittal
Final Draft of
Responses to Comments and Proposed Reclamation Plan
Modification
Church Rock Mill Site
Gallup, New Mexico

Dear Juan:

Enclosed is one copy of the final draft of the subject document. Copies of this document have also been sent to Mr. Paul McClain, Mr. Richard Lange, Mr. Steve Barringer, and Mr. Ed Morales.

We look forward to receiving your comments at your earliest convenience. Please call us if you have any questions.

Very truly yours,

Michael J. Timmer
Project Supervisor

MT/ps

Enclosure

cc: Mr. Steve Barringer
Mr. Richard Lange
Mr. Paul McClain
Mr. Edward Morales

*Fill Interim Soil cover only.*

# TABLE 4

## BRANCH SWALE CHARACTERISTICS

| XSECT | Swale Designation | Length (ft) | Slope (ft/ft) | Bottom Width (ft) | Peak Discharge (cfs) | Depth of Flow (ft) | Minimum Swale Depth (ft) | Riprap $D_{50}$ (in) | Riprap Thickness (in) | VOL $FT^3$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | A | 2,600 | 0.0038 | 10 | 40 | 0.98 | 2.0 | 1.5 | 3.0 | 0 |
| 0 | B | 3,600 | 0.0083 | 20 | 97 | 0.97 | 2.0 | 1.5 | 3.0 | 0 |
| 28'× 1' | C | 3,400 | 0.0050 | 10 | 75 | 1.38 | 2.0 | 1.5 | 3.0 | 95200 |
| 28×1 | D | 3,200 | 0.0028 | 10 | 68 | 1.43 | 2.0 | 1.5 | 3.0 | 89600 |
| 31×1 | E | 1,350 | 0.0037 | 10 | 85 | 1.53 | 2.5 | 1.5 | 3.0 | 41850 |
| 31×1 | F | 1,600 | 0.0031 | 10 | 126 | 2.00 | 2.5 | 1.5 | 3.0 | 49600 |
| 31×1 | G | 1,400 | 0.0021 | 10 | 99 | 1.88 | 2.5 | 1.5 | 3.0 | 43400 |
| 44×1 | H | 2,550 | 0.0085 | 20 | 284 | 1.90 | 2.5 | 3.0 | 6.0 | 112200 |
| 50×1 | I | 550 | 0.0040 | 20 | 385 | 2.65 | 3.5 | 3.0 | 6.0 | 27500 |
| 31×1 | J | 1,900 | 0.0047 | 10 | 101 | 1.66 | 2.5 | 1.5 | 3.0 | 58900 |
| | | | | | | | | | | 518,250 |

= 19194.44 BCY

= 19200 BCY

Note: See Figures 2-2 and 2-3 for swale locations.

2-15-91

cut

TABLE 4

BRANCH SWALE CHARACTERISTICS

| X SECT | Swale Designation | Length (ft) | Slope (ft/ft) | Bottom Width (ft) | Peak Discharge (cfs) | Depth of Flow (ft) | Minimum Swale Depth (ft) | Riprap $D_{50}$ (in) | Riprap Thickness (in) | VOL $F^3$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 3'×19' | A | 2,600 | 0.0038 | 10 | 40 | 0.98 | 2.0 | 1.5 | 3.0 | 148200 |
| 3'×29' | B | 3,600 | 0.0083 | 20 | 97 | 0.97 | 2.0 | 1.5 | 3.0 | 313200 |
| 3'×19 | C | 3,400 | 0.0050 | 10 | 75 | 1.38 | 2.0 | 1.5 | 3.0 | 193800 |
| 3'×19 | D | 3,200 | 0.0028 | 10 | 68 | 1.43 | 2.0 | 1.5 | 3.0 | 182400 |
| 3.5×20.5 | E | 1,350 | 0.0037 | 10 | 85 | 1.53 | 2.5 | 1.5 | 3.0 | 96862.5 |
| 3.5×20.5 | F | 1,600 | 0.0031 | 10 | 126 | 2.00 | 2.5 | 1.5 | 3.0 | 114800 |
| 3.5×20.5 | G | 1,400 | 0.0021 | 10 | 99 | 1.88 | 2.5 | 1.5 | 3.0 | 100450 |
| 4×32 | H | 2,550 | 0.0085 | 20 | 284 | 1.90 | 2.5 | 3.0 | 6.0 | 326400 |
| 5×35 | I | 550 | 0.0040 | 20 | 385 | 2.65 | 3.5 | 3.0 | 6.0 | 96250 |
| 3.5×20.5 | J | 1,900 | 0.0047 | 10 | 101 | 1.66 | 2.5 | 1.5 | 3.0 | 136325 |
| | | | | | | | | | | 1,708,687.5 |

= 63284.72 BC,

63300 BCY

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Note: See Figures 2-2 and 2-3 for swale locations.

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Canonie Environmental

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RESPONSES TO COMMENTS
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RECLAMATION PLAN MODIFICATIONS

# 1.0 INTRODUCTION

This document provides responses to Nuclear Regulatory Commission (NRC) comments regarding United Nuclear Corporation's (United Nuclear) reclamation plan for the Church Rock uranium mill tailings disposal site in Gallup, New Mexico. The comments addressed herein were presented by the NRC in letters of June 29 and August 16, 1990 and in meetings held on July 27 and October 12, 1990. Many of these comments were addressed in the September 17, 1990 response to comments. The comments remaining to be addressed primarily concern erosion protection of the tailings cover and tailings embankment sideslope, the long-term stability of Pipeline Arroyo and the North and South Diversion ditches, and specifications for the soil cover material and riprap materials as presented in the original plan.

This response proposes certain modifications to the original reclamation plan design submitted to the NRC in an effort to alleviate the NRC's concerns. This response also provides substantiation that demonstrates that United Nuclear's original tailings reclamation plan fully complies with the standards set forth in 10 Code of Federal Regulations (CFR) 40, Appendix A.

In addition, this response demonstrates that either of these alternatives achieves the level of stabilization and a level of protection for the public health and safety and the environment equivalent to the extent practicable that would allow the NRC to make a finding in accordance with Section 84(c), 42 United States Code (USC) 2114, of the Atomic Energy Act. Finally, this response requests that such a finding be made by the NRC. This request is based on Canonie Environmental Services Corp.'s (Canonie) and United Nuclear's belief that, the NRC concerns notwithstanding, the reclamation plan as originally submitted and the proposed modifications to the plan submitted in this document adequately protect tailings from release for the minimum 200-year design period. In addition, it provides reasonable assurances that tailings would not be released to the environment for 1,000 years to the extent practicable.

## 1.1 General Comments

In June 1987, as required by the NRC, United Nuclear submitted a reclamation plan for the Church Rock site. It was subsequently modified in responses to the NRC's comments dated May 23, 1988, August 31, 1988, February 23, 1989, and September 12, 1990. Reclamation activity was initiated in 1988 at the direction of the NRC. United Nuclear reluctantly initiated reclamation only after the NRC threatened to serve an Administrative Order requiring United Nuclear to commence construction of the tailings cover if the company would not agree to such action voluntarily and issued a unilateral license amendment requiring United Nuclear to do so.

Implementation of these interim activities, including construction of the evaporation ponds, regrading of the North and Central cells of the tailings impoundment, and installing the interim soil cover over these cells, were required by the NRC as a license amendment. These activities, performed in 1988, 1989, and 1990, represent the first three years of an eight-year phased program for final reclamation.

As of September 30, 1990, United Nuclear has completed placement of the first foot of soil cover over tailings on the North and Central cells of the impoundment, providing interim stabilization for 73 acres of tailings. United Nuclear has also constructed two lined 5-acre evaporation ponds and an enhanced spray evaporation system and has installed and is currently operating 20 seepage collection wells.

United Nuclear's intent has always been to implement an integrated plan that addresses not only tailings stabilization but also ground water protection. This has been a consistent theme with regard to all of its tailings reclamation and seepage remediation planning. United Nuclear's reluctance to initiate reclamation activities in 1988 was because of the interrelationship of the various components of the plan. United Nuclear expressed significant concern that subsequent changes to the plan could negatively impact the reclamation activities, thereby creating duplicate work, wasted effort, and the waste of money. Only after being threatened with the Administrative Order and being assured by the former director of the NRC and his staff that any future design changes would be in the manner of "fine tuning" and would not significantly impact reclamation did United Nuclear agree to commence reclamation. The NRC viewed the plan presented to it at the time as "over 90 percent approved," as represented by the director and his staff. United Nuclear was told that there remained only technical details to be finalized in review but that only the ground water issue remained unresolved because of the Environmental Protection Agency's ongoing Remedial Investigation and Feasibility Study. At no time did the NRC represent that the surface water issues were of significant concern.

Significantly, the changes proposed by the NRC in its comments are not based on the lack of performance by United Nuclear or the design as implemented to date, but rather the NRC's desire to achieve a more conservative measure of comfort. The NRC's proposed changes, however, are very costly. The total estimated additional cost for the NRC's proposed changes is approximately $11.9 million almost doubling the cost of the original reclamation plan. The concomitant benefits to public health and the environment, however, are clearly not doubled. The risks associated with following the NRC's proposals versus United Nuclear's original plan are very small. In fact, because United Nuclear's reclamation plan addresses interrelated impacts, such as surface water erosion versus ground water impacts, its plan has fewer risks associated with it. The NRC's proposal is more likely to result in larger potential impact to ground water while attempting to address surface water erosion considerations because it does not attempt to balance risks.

The design originally submitted was prepared using prudent engineering judgment and accepted analytical methods and criteria commonly used by the engineering community and many other governmental agencies. The quality control monitoring conducted to date in the field during interim reclamation activities confirms that the original plan does in fact exceed prescribed requirements. There is no reason to believe that the construction yet to be conducted in final reclamation will not also exceed the NRC's requirements.

The original design provides permanent isolation of the tailings pursuant to 10 CFR 40 Appendix A by minimizing disturbance and dispersion by natural forces without ongoing maintenance. It also successfully meets the stated goal of isolating tailings from possible release to the environment for 1,000 years to the extent practicable and for 200 years at a minimum. The design also provides for protection of ground water, another primary objective of 10 CFR 40, by alleviating conditions that lead to excessive seepage from the tailings impoundment. The primary source of such potential seepage following reclamation is the infiltration of precipitation through the tailings impoundment. Minimizing infiltration was and continues to be a primary design goal in the original reclamation plan.

This year, as United Nuclear entered the third season of work at the site, the NRC asked for major amendments to the plan to satisfy the new NRC technical guidance. The requested changes, in many cases, are inconsistent with the previously approved plan, requiring that major new elements be added or that expensive measures already completed or underway be redone.

## 1.2 NRC Comments

In June 1990 through October 12, 1990, well into the third season of construction, the NRC provided United Nuclear with additional comments on the reclamation plan. Despite the commitment by the NRC not to require major changes, the NRC, citing a new Staff Technical Position (STP), indicated for the first time that major changes in the plan were necessary. The NRC's comments indicate that the original reclamation design would have to be significantly revised to meet the guidelines in the STP. Originally, the NRC enumerated 13 comments concerning these topics. All but four of the comments were addressed in the September 12, 1990 responses to comments.

The remaining comments to be addressed herein include the following points in response to NRC comment Nos. 7 and 8 of the NRC's June 29, 1990 letter and comment Nos. 9b and 9c of the NRC's August 16, 1990 letter:

1. That vegetation could not be taken into account for the control of erosion on tailings covers in arid areas;

2. That the Maximum Permissible Velocity (MPV) of 3 feet per second (fps) is no longer appropriate for erosion protection due to shallow overland flow;

3. That the runoff interception ditches on the embankment sideslopes will not be stable; and

4. That the reconfigured channel design for Pipeline Arroyo will not provide long-term stability.

The four points criticize the original design as it relates to the tailings cover, the tailings embankment, and the reconfigured Pipeline Arroyo. These criticisms result in three significant changes proposed by the NRC to the original plan:

1. Place a 6-inch rock mulch layer on the entire impoundment cover or, alternatively, reconfigure the cover design to much flatter slopes;

2. Place a 6-inch rock mulch on the embankment sideslopes or, alternatively, significantly flatten the sideslopes; and

3. Provide riprap rock armor on the reconfigured excavated Pipeline Arroyo and a 6-inch rock mulch layer over the sacrificial areas between the arroyo and the toe of the embankment.

In preparing the responses to these comments as contained herein, Canonie reaffirms that the original design is appropriate to meet the requirements of 10 CFR 40, Appendix A.

## 1.3 Proposed Modifications to Reclamation Plan

The NRC proposes changes in the reclamation plan design, prompted in part by the final NRC STP concerning the design of erosion protection covers for stabilization of uranium mill tailings sites (US NRC, 1990) and in part by a significant change in the NRC's position regarding the appropriate plan for Pipeline Arroyo. The NRC's STP incorporates some new methodologies and criteria for surface water control and erosion protection designs and reinterprets others originally endorsed by the NRC and used by United Nuclear and its design engineers for the original design plan.

Extensive changes to the original reclamation plan cover design would be required to rigorously adhere to recent changes in the NRC's prescribed analytical methodologies particularly because it has been three years since submittal and implementation of the plan per license requirement. Such changes will cause the reclamation work completed to date to be wasted at a cost of several million dollars as the STP requires that flat "table-top" slopes (stable slopes) be constructed to reduce tractive forces to acceptable levels. In addition, strict adherence to the NRC's methodologies with regard to grading design to minimize erosion increases the potential for infiltration into the tailings, which could have a detrimental impact on United Nuclear's ground water remediation program.

There are, of course, a number of engineering approaches that can be taken to design a reclamation plan that meets the specified criteria. Each has its attendant costs. Some are very conservative and attempt to eliminate all risk to human health and the environment, while others attempt to balance the relative risks against cost considerations. While United Nuclear and Canonie believe that the original design appropriately balances those factors and provided a plan which meets the criteria, the proposed modifications described above equally succeed in achieving these goals. They also address the recent changes in analytical protocol recommended by the NRC without discounting or otherwise negating the work already performed. In addition, the proposed modifications integrate the need to protect ground water by eliminating infiltration concerns.

While United Nuclear and Canonie believe that the original reclamation plan fully complies with 10 CFR 40, Appendix A, the following proposed modifications to the original reclamation plan are submitted for NRC's consideration to address the NRC concerns. These proposed modifications are designed within the context of reclamation work already performed and are offered without prejudice to United Nuclear's position that they are not necessary. Rather they are offered as an accommodation to the NRC to settle and resolve the NRC's outstanding comments set forth above.

The components of the proposed modified design include the following:

1. Installation of a buried jetty across the Pipeline Arroyo valley to reinforce the nickpoint, but to otherwise leave the present channel configuration unchanged;

2. Addition of a rock mulch protective cover over the tailings embankment slopes in conjunction with construction of a protective bench between the toe of the embankment and the Pipeline Arroyo channel; and

3. Construction of a tailings cover consisting of a 1.5-foot-thick soil cover to control radon emanation to prescribed levels and a six-inch-thick soil/rock matrix (erosion protection layer) over the radon attenuation soil cover on the tailings to provide long-term stability similar to that recently approved by the NRC at another site.

Section 2.0 provides a detailed discussion of the proposed design modification.

The proposed modified design meets the requirements of 10 CFR 40, Appendix A, by using the methods and criteria set forth in the STP and other applicable scientific guidelines. Also, it can be implemented within the framework of reclamation activities already performed on site.

Installation of rock mulch on the tailings embankment and soil/rock material on the tailings soil cover provide long-term stability to these areas without relying on vegetation. By leaving the present Pipeline Arroyo channel unchanged, the potential for future changes to the present geomorphic conditions is minimized. Furthermore, the buried jetty ensures that the stable conditions that currently exist upstream of the nickpoint remain for a 1,000-year period. The result of the proposed modified design is long-term stability with no maintenance requirements.

United Nuclear proposes to reduce the radon attenuation soil cover by incorporating the data gathered during the interim reclamation activities. The reduction in radon cover requirements for the Church Rock site is consistent with the original reclamation plan design submitted to the NRC. The plan recognized that the soil characteristics used in the RADON computer model to design the 3.4-foot radon attenuation soil cover were very conservative. It contemplated that those parameters would be checked by field data as they became available during construction of the interim cover in anticipation of providing justification for the reduction of the cover design by use of actual numbers obtained in the field rather than estimates. These new data confirm that estimates used in the original submittal are excessively conservative. The field data provide justification for the reduced soil cover thickness of 1.5 feet to meet the radon emanation standard.

## 1.4 Request for NRC Finding

The proposed design modifications described above represent a reasonable approach that will allow the NRC to approve United Nuclear's reclamation plan. Alternatively, the NRC could approve the originally submitted design as being equally protective of human health and the environment. The original design provides a practicable design for protection of the public health and safety and the environment. The cost of implementing the NRC's proposed fixes to meet the technical guidance is inordinately high and provides only minimal additional protection to human health and the environment. The additional cost of meeting the NRC's technical guidance to mitigate the NRC's concerns regarding the potential impacts of surface water erosion by implementing the proposals contained in the NRC's comments would approach $11.9 million as compared to the original implementation cost of $12.4 million. For the reasons discussed in more detail later in this document, the added benefit of implementing the NRC's proposals to meet the technical guidance is minimal when compared to the extraordinary costs that would be incurred and cannot be justified.

United Nuclear requests that the NRC approve either the proposed modified design contained in this document or the reclamation plan design as originally submitted by United Nuclear, pursuant to Section 84(c), 42 USC 2114, of the Atomic Energy Act, wherein the commission may find that the proposed alternatives meet the commission's requirements if the alternatives "achieve the level of stabilization and containment...and a level of protection of public health, safety, and the environment from radiological and nonradiological hazards associated with the [Church Rock] site which is equivalent to the extent practicable to the level which would be achieved by the standards of...[10 CFR 40, Appendix A and the standards promulgated by the Environmental Protection Agency in 40 CFR 192, Subparts D and E]." In particular, criterion 6 of Appendix A requires that the tailings disposal design provide reasonable assurance of control of radiological hazards to be effective for 1,000 years to the extent reasonably achievable and, in any case, for at least 200 years.

United Nuclear and Canonie believe that the design as originally submitted meets the 1,000-year design criteria to the extent reasonably achievable as defined in the Uranium Mill Tailings Radiation Control Act and the NRC's regulations. It also meets the design criteria of 200 years. It is designed to protect tailings from release to the environment in a manner protective of human health and the environment. It considers the site-specific constraints unique to Church Rock and provides mechanisms to accommodate them. It considers the state of technology by providing feasible solutions that will work as designed. In addition, and importantly, it considers the economics of alternative solutions in relation to benefits to the public health and safety and other societal and socioeconomic considerations.

The NRC should approve either the proposed modified design or the original reclamation plan design because they take into account the risk to the public health and safety and the environment with due consideration to the economic costs involved. These two designs balance all of the competing needs of the criteria contained in 10 CFR 40 Appendix A, in particular the concerns regarding the effects of surface water erosion and the concerns of protecting ground water. United Nuclear and Canonie believe that adequate demonstration has been made that either design is approvable under the authority described in Section 84(c) of the Atomic Energy Act. If the NRC cannot make such a finding, then United Nuclear requests a hearing before the commission to further substantiate its position.

## 2.0 DETAILED RESPONSE TO COMMENTS AND PROPOSED DESIGN MODIFICATIONS

This section provides details of the proposed design modifications to the tailings cover, tailings embankment, and Pipeline Arroyo. The proposed design modifications described herein have been prepared to address the NRC's concerns as presented in their comments. Submission of these proposals should not be construed by the NRC to mean that United Nuclear and Canonie believe that the original design is inadequate.

Section 2.1 provides the proposed design modifications for the tailings cover, including the technical discussion and basis for the stability of the erosion protection cover and the radon attenuation soil cover. Sections 2.2 and 2.3 provide the proposed design changes for the tailings embankment and Pipeline Arroyo, respectively. Section 2.4 provides responses to other NRC comments regarding the stability of the North and South Diversion ditches.

### 2.1 Tailings Cover - Comment Number 7 (June 29, 1990)

NRC comments regarding the tailings cover design state that:

1. Vegetative cover over the reclaimed tailings cannot be taken into account for control of erosion in arid areas; and

2. The MPV of 3 FPS is not appropriate for shallow overland flow.

NRC requests that United Nuclear either add an appropriate riprap layer on top of the originally designed soil cover or, alternatively, redesign the tailings soil cover to meet the STP tractive force criteria.

As discussed in Section 3.1, Canonie believes that the original design for controlling erosion on the regraded tailings impoundment remains valid. However, the NRC's STP has changed the criteria for evaluation of the erosional stability of the tailings cover.

In order to meet the STP's requirements, either the entire surface of the regraded tailings cover would have to be covered with riprap or the design would have to be changed to flatten the tailings cover. Placement of riprap over the entire regraded surface of 120 acres would be prohibitively expensive and cannot be justified in relation to the benefits obtained.

Table 2.1 provides a summary of the costs attendant to construction of the various alternatives proposed by the NRC in its comments. The cost of placing a 6-inch rock mulch layer over the entire regraded tailings cover is estimated to be $2.4 million. This estimate is based on placing 96,700 cubic yards (cy) of rock mulch at a unit cost of $25 per cy of placed material. The rock mulch must be transported 42 miles to the site.

Designing the cover to meet the tractive force requirements of the STP will require that the cover be regraded to be nearly as flat as a table top at 0.002 feet per foot (ft/ft). Such a configuration would also be prohibitively expensive. Table 2.1 indicates that the construction of a reconfigured "flat table top" design is estimated to cost $4.0 million. This estimate is based on the movement of approximately 776,500 cy of additional soil material at a unit cost of $3/cy and placement of 31,300 cy of riprap on the downslopes from the table top and in runoff collection ditches at a unit cost of $54/cy of placed material. The riprap is more expensive than the rock mulch described above because it is much larger, making it more difficult to produce, transport, and place. Implementation of such a design would require that all of the previous reclamation work conducted to date be negated at a cost loss of approximately $3.5 million.

In addition, as a practical matter, it would be impossible to construct a cover which meets the 0.002 ft/ft slope criteria to keep tractive forces to below levels of concern. The closest even the best field equipment could manage would be approximately 0.005 ft/ft and would require extraordinary quality control. Therefore, the desire to meet the NRC's STP criteria for tractive forces is confounded by the practical limitations that render the criteria difficult if not useless.

Finally, either of the two approaches described above would increase infiltration into the tailings due to decreased runoff velocities. Therefore, the NRC's STP criteria for regrading which uses tractive forces as a means of surface water erosion protection is in direct conflict with Criterion 5 of the NRC's regulations which requires protection of ground water. It is critical that any approvable reclamation plan integrate and balance these kinds of competing factors. Reduction of infiltration through the tailings is an important component of the ground water remediation program at the site.

Similarly, approvable plans must also balance the cost against the associated benefits. The NRC's proposed methodologies to mitigate its concerns regarding the erosion on the tailings cover design would add from $2.4 to $4.0 million to the present plan even without accounting for the cost losses for work already performed. It is difficult to ascertain that there is any significant associated benefit to the NRC's proposal. Even if the design were to apply the flat table top concept, the resultant construction limitations would be such that the criteria would not be met. As stated earlier, either design would exacerbate the ground water protection criteria. Therefore there appears to be no associated incremental benefit to a proposed cost addition of $2.4 to $4.0 million.

### 2.1.1 Proposed Design Modification

A balanced alternative proposed approach to design of the tailings cover that incorporates the original grading design and a 6-inch-thick soil/rock matrix erosion protection layer has been developed. This soil/rock matrix will be constructed by placing a 3-inch-thick rock mulch layer over the tailings cover, then placing a 4- to 6-inch layer of random soil material over the rock mulch. The passage of construction equipment over the soil will force it into the rock mulch voids. This modified design meets the NRC's 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.

The proposed soil/rock matrix will be installed over a 1.5 foot radon attenuation soil cover designed to control radon emanation to below 20 picoCuries per meter squared per second (pCi/$m^2$/sec). This represents a reduction in radon soil cover requirement of 1.9 feet from the original design requirement of 3.4 feet. As described in greater detail herein, the reduction is justified by the use of data collected during the first two years of construction of the first foot of soil cover. Extensive testing demonstrates that the soil characteristics of the material used for construction is such that the reduction in radon attenuation soil cover is warranted. The resulting total thickness of the soil cover over the tailings including the soil/rock matrix is 2.0 feet.

2.1.1.1 Erosional Stability Analysis

Figures 2-2 and 2-3 depict the proposed modified tailings impoundment configuration and grades at final reclamation. This configuration has been changed from that of the original reclamation plan (see Figure 1 of the August 31, 1988 responses to comments and Figure 3 of the September 12, 1990 response to comments) in three aspects. First, the surface contour elevations have been reduced 2 feet to reflect the resulting reduced tailings cover thickness. Second, additional swales have been added to the South Cell to collect surface water runoff. Third, the tailing's 2-foot soil cover will incorporate a 6-inch-thick soil/rock matrix to protect the cover from erosion. These proposed design modifications promote surface water drainage while maintaining the erosional stability of the tailings soil cover.

Hydraulic Analyses

The proposed swales have been located 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 soil cover from erosion. The swales would consist of shallow, trapezoidal ditches with 3H:1V sideslopes. The bottom and sideslopes of the swales will be protected with riprap. Table 2.2 provides a summary of the swale bottom widths and depths.

Hydraulic analyses of the flows to be generated within the swales was performed to determine the minimum depth of the swales. The peak discharge of the runoff generated by the PMP event on the impoundments was calculated using the SCS TR-55 method. The depth of these peak discharges in the swales was calculated using Manning's equation. A freeboard of at least one-half foot was added to the depth of flow in the swales to determine the minimum depth of the swales. This design approach follows the guidelines set forth in the NRC STP and provides for erosionally stable water conveyance structures that will promote drainage and reduce infiltration into the tailings. Table 2.2 provides a summary of the hydraulic analyses for the swales. Appendix A provides the detailed calculations used to perform the hydraulic analyses.

Long-term Stability

Swales - The Safety Factors method of the proposed riprap design was used to size the riprap that would be installed in the swales. Table 2.2 provides a summary of the riprap sizes for the swales. In many cases, the same rock proposed for use for the soil/rock matrix is adequate for the swales. Table 2.3 provides filter and riprap material grading requirements. Appendix A provides the detailed calculations used to determine the riprap sizes.

The riprap sizes shown in Table 2.2 are nominal sizes and have not been oversized to account for weathering. Due to economic considerations, the exact source and, thus, quality of the rock is not yet known. However, the rock used as riprap and rock mulch for reclamation will have a minimum rock quality rating of 50 and will be oversized in accordance with the procedures provided in Appendix D of the STP.

Soil/Rock Matrix - The CSU method described in NUREG 4651 (NRC, 1987) was used to size rock protection for the top surface of the tailings soil cover. Based on flow depths and velocities computed by the unit-width method described in NUREG 4620 (NRC, 1986), a $D_{50}$ of 1.5 inches for the riprap has been determined to provide erosion protection. This form of protection was recently approved by the NRC for use under similar conditions at Anaconda's Bluewater tailings disposal facility in New Mexico.

The erosion protection layer would consist of a 3-inch layer of rock overlain by a 3-inch layer of soil compacted into the rock. A 4- to 6-inch-thick soil lift would be placed over the rock to maintain an approximate thickness of 3 inches above the rock layer. This overall 6-inch-thick soil/rock matrix would provide long-term erosional protection. Compaction of the soil would densify the rock layer by tightly wedging the stones. The soil would fill the void spaces, stabilizing the rock from movement, and decrease the effective evaporative zone depth, thereby providing for 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 gradation of the soil/rock matrix is sufficiently fine-grained so as to not require filter material. The soil/rock matrix would also protect the soil cover from wind erosion. A detail of the soil/rock matrix is shown on Figure 2-1. Appendix A provides the detailed calculations used to size the soil/rock matrix.

2.1.1.2 Proposed Radon Attenuation Soil Cover Reduction

United Nuclear's Reclamation Plan as originally submitted contained a proposed tailings soil cover 4 feet thick to be placed over regraded tailings, 3.4 feet of which was for radon attenuation and 0.6 feet of which was for erosion protection. United Nuclear proposes a reduction and redesign of this cover as follows.

The radon attenuation soil cover portion of the tailings soil cover has been reduced to a total thickness of 1.5 feet to be constructed over regraded tailings. This would be then be overlain by the 6-inch-thick soil/rock matrix. This layer would aid in further reducing radon emanation but has not been included in the analyses. Figure 2-1 illustrates the soil cover profile. Based on recent results obtained from the RADON computer model, the reduced radon attenuation soil cover of 1.5 feet will limit radon emissions from the reclaimed tailings impoundment to the required 20 $pCi/m^2/sec$. A detailed discussion follows.

Radon Attenuation Parameters

The proposed reduced radon attenuation soil cover thickness of 1.5 feet is based on revised physical and radon attenuating properties derived from more extensive evaluation of proposed soil borrow and results from QA/QC testing performed during construction of the interim soil cover. The following sections discuss the soil cover parameters and values that were used in the RADON model. Appendix B provides a summary of the soil borrow geotechnical properties and the RADON model calculations.

Diffusion Coefficient - The soil cover property that has the greatest impact on reducing the cover thickness is the diffusion coefficient. A revised diffusion coefficient was calculated based on higher in-place densities (derived from actual interim cover QA/QC testing as presented in Appendix B) and lower porosities as compared to more conservative parameters that were estimated for the original design. The original estimated in-place density and porosity were 99.0 pounds per cubic foot (pcf) and 0.39, respectively. The revised in-place density and porosity are 108.3 pcf and 0.33, respectively. This translates to a revised lower diffusion coefficient of 0.0029 square centimeters per second ($cm^2$/sec) as compared to an original diffusion coefficient of 0.0093 $cm^2$/sec. These values are summarized in Table 2.4. 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.

Long-Term Moisture - An additional soil cover property, which has a very important effect on the diffusion coefficient and, thus, the soil cover thickness, is the long-term moisture content of the soil cover materials. The long-term moisture (i.e., the wilting point moisture content) used in this analysis is 13.4 percent, the same as that used in the original design.

The long-term moisture content was derived based on an average of in-situ moistures for site soils (see June 29, 1988 Response to NRC Comments) and long-term moisture laboratory measurements [American Society for Testing and Materials (ASTM) D-3152)]. These two approaches yielded long-term moistures of 13.4 and 13.6 percent, respectively. In addition, the long-term moisture content was calculated in accordance with Regulatory Guide 3.64 (Equation 5). The empirical equation is based on the percent of fines (-200 sieve-size material) and percent of organic material in the soil cover material. It was conservatively assumed that the organic content was zero. The fines content specified for the soil cover ranges from 40 to 85 percent. Incorporating these fines contents into the above-referenced equation yields long-term moisture contents ranging from 22.6 to 45.1 percent. The lowest long-term moisture content value of 13.4 percent was used in the radon calculations to provide the most conservative soil cover thickness. Appendix B presents the results of the long-term moisture determinations.

Soil Cover Materials - The NRC has requested that procedures be presented for determining the acceptability of borrow material used as soil cover should different borrow sources be used other than those identified in the Response to Comments dated September 12, 1990. It is not expected that other sources of borrow material will be required in excess to those identified in the Response to Comments. If other borrow sources are required, then gradation and classification tests will be performed to ensure that these materials meet project specifications. Testing will be performed at the frequency of one gradation and Atterberg limits test per 6,500 cubic yards of proposed imported fill material. Samples will be obtained by means of borehole drilling and sampling or 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 prior to placement of imported fill as soil cover material.

In informal discussions, the NRC has expressed concern that a thinner soil cover design would be more sensitive to material gradation fluctuations and resultant radon attenuating characteristics. To address this concern, the gradation and Atterberg testing frequency will be increased to an average of one test per 1,500 cubic yards of soil cover material placed for the project. Testing on the soil cover to date has been at the lower frequency of one test per 6,500 cy as specified in the original Reclamation Plan. It will be possible to attain the higher testing frequency of one test per

1,500 cy based on an average of all tests taken for the project. This will be accomplished when the interim soil cover is conditioned (i.e., moisture adjusted and compacted) immediately prior to placement of the final soil cover. Additional in-place density tests and gradation/Atterberg tests will be performed at this time to meet required project frequencies. This will provide assurance that the material placed meets the requirements of that modeled in the design.

As described in the September 12, 1990 responses to comments, the acceptable soil types for use in the soil cover construction will classify as clay (Cl), silt (ML), silty sand (SM), or clayey sand (SC) soils in accordance with the Unified Soil Classification System. The gradation limits will be specified as follows:

| Sieve Size | Maximum Percent Passing |
|---|---|
| 3/4 inch | 95 - 100 |
| No. 4 | 90 - 100 |
| No. 10 | 85 - 100 |
| No. 40 | 65 - 100 |
| No. 100 | 50 - 100 |
| No. 200 | 40 - 85 |

The above gradation limits provide a tabular representation of the graphical grain size envelope presented as Figure 2 in the September 12, 1990 submittal.

Nuclear Densimeter Correlation - The NRC has requested that a method be outlined for establishing a correlation between sand cone and nuclear densimeter methods during in-situ density testing of the soil cover materials. Based on performance to date for interim construction activities, it has been determined that test results obtained by the nuclear densimeter are erratic. The as-built report North Cell Interim Reclamation Activities documents the erratic nature of the nuclear densimeter test. 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.

Long-Term Stability of Radon Attenuating Soil Cover - The radon attenuation soil cover would be protected from wind and water erosion by the proposed soil/rock matrix erosion protection cover. This layer would also provide for a higher and more stable long-term moisture as compared to a vegetated cover. 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 over-land flow velocity of runoff as compared to a cover consisting of compacted soil only. By decreasing evaporation, the soil and rock cover reduces the gradient which would draw moisture from the soil cover to the atmosphere. Thus, through time, annual precipitation at the site will provide for a long-term moisture content closer to the higher field capacity moisture content rather than the wilting point moisture content, due to minimal moisture gradients through the soil cover.

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 to the frost line, close enough to supply capillary water from a saturated soil layer. The potential for capillary action is dependent 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, which indicate that 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, the susceptibility of the soil cover to frost heave is low.

Shrinkage and its potential effect on radon attenuation is also governed by the presence of 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.

Radon Source Parameters

The radon source parameters used in this evaluation are more conservative than the average values used in the original design. It is still United Nuclear's belief that average radiological source values are valid for determining the soil cover thickness. Regulatory Guide 3.64 states that the radon flux standard is based on average annual radon emission from the entire site; therefore, average radiological source values are appropriate. Using average soil cover attenuation and average radiological source values in the RADON model result in a required radon attenuation soil cover that is 1.2 feet thick. The results of this RADON model evaluation were presented in the September 12, 1990 (Canonie, 1990) submittal.

The NRC has expressed its concern that more conservative radiological source values, such as the upper 95 percent confidence intervals, be used to design the soil cover. Therefore, in response to this concern, the proposed radon attenuation soil cover thickness has been designed using the upper 95 percent confidence interval values for both coarse- and fine-grained tailings source parameters. Table 2.4 summarizes the values used as input into the RADON model. Use of these conservative values indicates that a 1.5-foot-thick soil cover is required to attenuate radon emissions from the regraded tailings impoundment to within the prescribed limits of 20 $pCi/m^2/sec$. Appendix B presents the data used in the model and the source of the data.

Source Term - The most critical source parameters that influence the thickness of the soil cover are 1) the source term which is calculated from the radium content and 2) the emanation coefficient. These values were measured in the laboratory. Tables 2.5 and 2.6 summarize the test results of measured radon source parameters for both coarse-grained tailings and fine-grained tailings, respectively. These same tables were presented in the original reclamation plan (Canonie, 1987).

As illustrated in these tables, the upper 95 percent confidence interval values represent very conservative RADON model input values. As shown in Table 2.5, there are only two radium content values and one emanation coefficient value that are higher than the upper 95 percent confidence interval value used in the RADON model for the coarse-grained tailings. Likewise, for the fine-grained tailings (see Table 2.6), there is only one radium content value and one emanation coefficient value higher than the upper 95 percent confidence interval value used in the RADON model. Therefore, use of upper 95 percent confidence interval values in the RADON model represents very conservative conditions for estimation of the source term.

Long-Term Moisture and Diffusion Coefficient - The long-term moisture content and diffusion coefficient values used in the RADON model for the coarse-grained tailings also represent very conservative conditions. As shown in Table 2.5, there are two values lower than the moisture content of 10.4 percent used in the RADON model for coarse tailings. The diffusion coefficient was calculated in accordance with Regulatory Guide 3.64, using the average physical properties for dry density and porosity shown in Table 2.5 and the long-term moisture content of 10.4 percent. As shown in Table 2.5, there are no diffusion coefficient values that are lower than the 0.047 $cm^2$/sec used in the RADON model.

The long-term moisture content and diffusion coefficient values used in the RADON model for the fine-grained tailings represent the 95 percent confidence interval for these parameters. As shown in Table 2.5, there are only two values lower than the moisture content of 29.7 percent used in the RADON model for fine-grained tailings. The value of 29.7 percent is based on in-situ moisture contents measured in the tailings material. This value is typical of laboratory determined and calculated long-term moisture contents for fine-grained tailings at other sites and for fine-grained soils and is substantially lower than the 42.6 percent moisture content calculated using Equation 5 presented in Regulatory Guide 3.64 (assuming 80 percent -200 material). The diffusion coefficient of 0.0053 $cm^2$/sec is higher than all but two of the measured diffusion coefficients presented in Table 2.6 and represents a conservative value for input into the RADON model.

Additional Design Considerations

It should be noted that 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 prior to placement of the soil cover. This 7-foot layer essentially attenuates 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 over the fine-grained tailings provides an approach to the design that enables a thinner single radon attenuating soil layer to be designed as opposed to having two thickness of soil cover, 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 coarse-grained tailings placed over the fine-grained tailings will in actuality consist of a combination of coarse-grained tailings overlain by clean borrow soil. This has been the case in regrading of the North and Central cells conducted in the last two years. Typically clean borrow soil has been required in excess of the regraded coarse tailings to attain the specified grades. This provides for additional conservatism in 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.

Therefore, as discussed above, the soil cover has been designed incorporating as-built interim cover and borrow area radon attenuation properties and conservative radon source parameter values. Use of interim soil cover radon attenuation properties, which is more effective at attenuating radon than those conservatively assumed in the original design and conservative upper 95 percent confidence limit radon source values in the RADON model, results in a soil cover design thickness of 1.5 feet, which is 1.9 feet thinner than the original design. 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 10 CFR 40, Appendix A.

## 2.2 Tailings Embankment - Comment Number 8 (June 29, 1990)

The NRC is concerned that the runoff interception ditches on the embankment sideslopes may not be stable due to the possibility of flows overtopping the ditches, siltation within the ditches, and gullying on the ditch out-slopes. As discussed in more detail in Section 3.2, the original design consisting of runoff interception ditches and an armored central collection channel provides adequate erosion protection for the embankment slopes.

The NRC requests that either an appropriate riprap layer be placed on the sideslopes or, alternatively, that the sideslopes be flattened sufficiently to mitigate NRC concerns regarding surface water erosion.

In order to comply with the requirements of the STP, the embankment side-slopes would have to be flattened or armored. Flattening the sideslopes as suggested by the NRC would require that the embankment toe be extended out into the arroyo and would expose the tailings embankment to the full erosive forces of runoff within the Pipeline Arroyo. As such, flattening the slopes is not considered a practical solution.

Armoring the entire tailings embankment face as proposed by the NRC is estimated to cost approximately $0.25 million. This estimate is based on a volume of 10,400 cy of rock for a 6-inch-thick layer at a unit cost of $25/cy. While this cost is not exorbitant by itself, certain additional proposed design modifications incorporated into the overall design would result in reducing this cost while mitigating the NRC's concern. These proposed design modifications are discussed herein in more detail.

### 2.2.1 Proposed Design Modifications

A modified design is proposed for the tailings embankment slopes that incorporates rock mulch armor for erosion protection of the upper portion of the embankment and the construction of a protective bench at the toe of the tailings embankment to provide a buffer between probable maximum flood (PMF) flows in Pipeline Arroyo and the toe of the tailings embankment. Figures 2-2 and 2-3 show the configuration of the proposed tailings embankment at final reclamation. The sideslopes would remain at 5H:1V as provided in the original design and would terminate at the runoff control ditch located at the top of the protective bench to collect runoff from the embankment. The embankment sideslopes would be protected from erosion by a 3-inch-thick rock mulch layer, which extends from to the top of the tailings embankment to the runoff control ditch. The rock mulch would be designed to withstand the runoff generated by the probable maximum precipitation (PMP) event as discussed in more detail herein.

The runoff control ditch, located on the protective bench, would also be located between the embankment toe and the Pipeline Arroyo channel. The top of the protective bench would be 40 feet wide and up to 20 feet higher than the Pipeline Arroyo channel bank. Figure 2-4 shows the profiles of the bench toe, bench top, and embankment top. Figures 2-5 and 2-6 provide several cross sections that illustrate the spatial relationship between these features as well as the Pipeline Arroyo channel. Figure 2-6 provides a detail of the runoff control ditch.

#### 2.2.1.1 Stability Analysis

The Corps of Engineers' program HEC-2 was used to simulate the passage of the PMF through Pipeline Arroyo as configured in accordance with the proposed design modifications discussed herein. Appendix C provides the results of the simulations.

#### Hydraulic Analysis

Figure 2-4 shows that the PMF water surface elevation is less than that of the top of the proposed protective bench. Thus, the bench would protect the embankment toe and would keep the runoff control ditch above the PMF level. The average velocities and depths of the PMF within Pipeline Arroyo along the 5H:1V sideslopes 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 |

While the sideslope of the protective bench would be contacted by water produced during the passage of the PMF, the low flow velocities along the sideslopes indicate that little scouring would take place during this one-time event. Evaluation of the amount of scour was performed using the methods described in the Bureau of Reclamation's Technical Guideline for Computing Degradation and Local Scour (Pemberton and Lara, 1984). Appendix D provides the detailed scour calculations.

The evaluation indicated that the maximum lateral bank scour to be expected during the passage of the PMF was 4.9 feet. As shown on Figure 2-6 the runoff control ditch would be located 14 feet from the protective bench edge, and the tailings embankment toe is 40 feet from the protective bench. Thus, the PMF would not contact either the runoff control ditch or the tailings embankment toe.

Long-term Stability

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

<u>Rock Mulch Design</u> - The CSU method (NUREG 4651, 1989) was used to size the rock mulch for protection of the embankment sideslopes from the erosional forces of runoff generated by the PMP. The resulting $D_{50}$ of 1.5 inches and thickness of 3.0 inches for this rock mulch match is similar to that of the proposed tailings cover design so that the same rock material could be used for both areas. Table 2.3 provides the gradation for this rock mulch.

<u>Runoff Control Ditch</u> - The runoff control ditch would have a 10-foot bottom width and 3H:1V sideslope on the left bank and the same 5H:1V sideslope as the tailings embankment slope on the right bank. The minimum depth would be 2 feet. The channel slopes would vary from 0.007 to 0.022 ft/ft.

The riprap that would be used to protect the ditch during the PMF event was sized using the Safety Factors method. The resulting $D_{50}$ was 1.5 inches for the upper section and 3.0 inches for the lower section. The riprap layer thickness would be 6 inches. The gradation for this riprap is provided in Table 2.3.

## <u>2.3 Pipeline Arroyo Channel - Comment Number 9B and 9C (August 16, 1990)</u>

The NRC comments indicate a concern that the reconfigured channel design for Pipeline Arroyo would not provide long-term stability. This opinion is based on the concept that the nickpoint incision and channel reconfiguration proposed in the original design will lead to a geomorphic imbalance, eventual erosion of the tailings embankment, and unacceptable risk of potential release of tailings.

The NRC requests United Nuclear to install sufficient riprap in the reconfigured Pipeline Arroyo and place an appropriate rock mulch layer in the area between the toe of the embankment and Pipeline Arroyo.

As discussed in Section 3.3, the original design provides for the erosional stability of Pipeline Arroyo to meet the NRC's regulatory criteria. While the NRC's proposal to riprap the reconfigured Pipeline Arroyo may add an additional measure of comfort as to the long-term stability of the Arroyo, the original design submitted contains sufficient conservatism to protect the tailings from the potential for release of tailings to the environment for 1,000 years to the extent practicable.

As indicated in Table 2.1, the NRC's proposal would cost an additional $7.6 million. This estimate is based on the production, transport, and installation of 132,000 cy of riprap in the reconfigured Pipeline Arroyo at a unit cost of $54/cy, as well as placing 18,500 cy of rock mulch to cover the 23 acres of sacrificial area with a 6-inch-thick layer. The rock mulch would be purchased, transported, and placed at a unit cost of $25/cy. This high cost is affected significantly by the fact that very large rock (i.e., $D_{50}$ of 39 inches) is required to meet the STP. Such rock is not locally available and would have to be imported from 42 miles away.

The original plan submitted by United Nuclear took these high costs into consideration. It was concluded that while the use of riprap theoretically is a viable alternative, the costs are simply prohibitive in relation to the benefits received. It was further concluded that a design could be prepared so as to provide reasonable assurances that tailings would not be released to the environment within the 1,000-year design period.

### 2.3.1 Proposed Modification

In response to the NRC's comments that the original design is not adequate, Canonie has developed an equally protective proposed design modification, which takes into account the NRC's concerns. This proposal utilizes a "buried jetty" in conjunction with the protective bench discussed in Section 2.2 to protect tailings from being released. The buried jetty, constructed about 150 feet upstream from the nickpoint, will serve to maintain the long-term geomorphic stability of Pipeline Arroyo and deflect flows within the arroyo away from the tailings embankment, thus protecting the tailings embankment toe from erosion.

Figures 2-2 and 2-3 provide a plan view of the revised Pipeline Arroyo channel configuration at final reclamation. The channel 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 configuration will include the following:

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

2. Filling in the depressions that presently exist in the area between Pipeline Arroyo and the tailings embankment;

3. Constructing a protective bench along the tailings embankment toe to contain the runoff control ditch and protect the tailings embankment toe from the PMF within Pipeline Arroyo;

4. Constructing a buried jetty from the nickpoint east across the Pipeline Arroyo floodplain to the runoff control ditch to augment the geomorphic control provided by nickpoint; and

5. Filling in the areas that previously had been headcut along the eastern side of Pipeline Arroyo within the sacrificial area.

Figure 2-4 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 from the nickpoint and the spatial relationship of these features.

Figures 2-5 and 2-6 provide several cross sections across Pipeline Arroyo to the reclaimed tailings embankment top. These cross sections also illustrate the spatial relationships between the channel, bench, and embankment.

## 2.3.1.1 Stability Analysis

### Hydraulic Analysis

The Corps of Engineers' program HEC-2 was used to simulate the passage of the PMF of 26,300 cfs through the Pipeline Arroyo channel. The simulation for reaches 1 and 2 (station 0+00 to station 61+40) was performed for the subcritical flow conditions that would occur in these reaches, while that for reach 3 (station 61+40 to station 82+90) was performed to simulate the supercritical flow conditions that would occur in this reach. Appendix C provides the input data and results for this simulation.

Figures 2-2 and 2-3 show the extent of the PMF floodplain, while Figure 2-4 shows the profile of the PMF maximum WSEL. The PMF fills most of the wide valley north of the tailings impoundments. The WSEL of the PMF stays below the top of the protective bench from station 35+00 to station 80+10. 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.

An evaluation of the flow capacity of the low-flow channel, i.e., the portion of the low-flow channel that is protected from erosion by the rock of the nickpoint, was performed. At Station 59+50 the low-flow channel bottom and west bank will be protected by the rock of the nickpoint while the east bank will be protected by the buried jetty. The low-flow channel will have a bottom width of 30 feet, 3H:1V sideslopes, and a depth of 4.0 feet. HEC-2 simulations were used to determine that 2,250 cfs would 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.

### Long-term Stability

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

<u>Channel Erosion</u> - The proposed modified design of the Pipeline Arroyo effects little change to the existing erosional and geomorphic conditions within the valley. The channel slopes would 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 would be minimized. The steeply sloped area within the nickpoint would be protected from erosion by the rock of the nickpoint. 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 to occur 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) so as to minimize this erosion. In addition, the vast volume of material existing in the sacrificial 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.

As a result of the proposed design modifications proposed above, the riprap in the North Diversion Ditch downdrain and in the lower reach of the South Cell Drainage Channel as contained in the original design would be unnecessary. Pipeline Arroyo channel bottom would not be incised in Reach 1 so that the North Diversion Ditch could enter the Pipeline Arroyo with the same channel bottom elevation. 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 would not be able to affect the reaches upstream from the rock cuts. Thus, the rock cuts provide long-term stability for these channels.

<u>Meander Growth</u> - An evaluation of potential meander growth along Pipeline Arroyo was performed to assess the likelihood of the release of tailings due to this geomorphic phenomenon. The evaluation was performed by first characterizing existing meander patterns of the Pipeline Arroyo and a nearby similar arroyo. These characteristics were then applied to the

proposed channel configuration and location and the potential impact identified.

Figure 2-7 shows the channel reaches and watersheds that were 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 that drain 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) that have resulted in the formation of large alluvial-fill valleys upgradient of the nickpoint. The channels upgradient of the nickpoint have shallow slopes.

Table 2.7 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 that meander growth will not cause the release of tailings. As shown on Figures 2-2 and 2-3, the distance between the channel and the tailings ranges from 335 feet at station 36+50 to 680 feet at station 76+00. Figures 2-5 and 2-6 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 tailings, there is little likelihood of meander growth causing the release of tailings.

Nickpoint Reinforcement - Reinforcement of the nickpoint would be accomplished by constructing a buried jetty consisting of a stone-filled trench that would extend across the valley from the nickpoint to the top of the protective bench along the tailings embankment toe at station 59+50. The proposed jetty would ensure that flows continue to pass over the nickpoint and would provide vertical control of the Pipeline Arroyo channel bottom. Vertical control would maintain the shallow slopes for the channel reach upstream from the nickpoint and thus would maintain the long-term geomorphic stability of Pipeline Arroyo. The proposed 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 2-2 shows the location of the proposed jetty, while Figure 2-8 provides the jetty details. The jetty would 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 at the time of construction. For the present design, the low-flow channel was considered to be 30 feet wide and located at the west terminus of the jetty. The low-flow channel may be wider, depending on the nickpoint configuration.

The sizing of the stone (riprap) to be used in the proposed jetty 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 proposed jetty is 6 inches.

<u>Stability of the Proposed Jetty and Reach 3</u>

Some potential exists for headcuts to form at the Pipeline Arroyo channel banks downstream of the proposed 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 that are 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 would capture these flows allowing the potential formation of headcuts that could migrate towards the proposed jetty. The location of the headcuts would 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. This relationship indicates that in a given year the probability of occurrence of a flood event greater than 2,250 cfs is less than 1 percent and that flows would remain within the low-flow channel in more than 99 percent of the years.

As shown on Section B-B′ of Figure 2-8, any potential headcuts would have to start at least 150 feet downstream from the proposed jetty at the beginning of Reach 3. The low-flow channel remains stable for this distance at a constant low slope on the rock of the nickpoint. Thus, the propensity for creating headcuts would not exist in the first 150 feet below the jetty because any flows in the overbank area would be traveling parallel to the channel banks.

The channel slope begins to increase at the distance of 150 feet from the jetty. Thus, at this point, the channel would be capable of carrying more flow and would capture any overbank flow. As this overbank flow entered the channel, it could potentially induce the formation of headcuts beginning at this location. Any headcuts formed at this point would be shallow headcuts because the channel depth is shallow.

Headcuts that could affect the toe of the proposed jetty would have to start at least 308 feet downstream from the proposed jetty. As shown on Section C-C′ of Figure 2-8, the toe of the jetty would 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 would have to form at or below Station 62+78 where the Pipeline Arroyo channel bottom is at elevation 6,920 feet to be able to be below elevation 6,923 feet at the toe of the proposed jetty. The distance this potential headcut would have to migrate is about 308 feet from Station 62+78 to Station 59+70.

Only the large, more infrequent flood events would be capable of remaining in the overbank area 308 feet downstream from the jetty. Thus, their likelihood of occurrence is extremely small. For example, the PMF is fully contained within the Arroyo at a distance 420 feet downstream of the jetty.

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

Finally, even should the unlikely event occur that a potential headcut were to breach 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 would not intercept the tailings embankment. In addition, the runoff control ditch on the proposed protective bench would intercept runoff from the tailings embankment ensuring that potential tributary headcuts do not form on or towards the embankment.

Therefore, in consideration of the many reasons provided above, headcut formation is extremely unlikely to breach the proposed 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.

## 2.4 North and South Diversion Ditches

This section addresses two additional comments regarding the North and South Diversion ditches in response to concerns raised by NRC personnel during the meeting on October 12, 1990 as summarized below:

1. The stability of the two diversion ditches at the confluences of the tributaries to the ditches; and

2. The potential effects of the bedding planes and unconformities of the Dilco Coal Member in the steep rock cut through which the North Diversion Ditch passes.

2.4.1 Confluence Stability

The stability of the confluences of tributaries to the North and South Diversion ditches was evaluated to determine whether inflow from the tributaries may damage the diversion ditch banks and allow flows to pass over the reclaimed tailing impoundments. Such an occurrence could potentially allow a release of tailings. 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 would 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 evaluation of stability was performed 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 would have to be scoured to allow the flows to pass over the diversion ditch channel bank.

Three critical locations are shown on Figure 2-2. 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. None of the tributaries to the South Diversion Ditch provide a large proportion of flow to the ditch.

Figure 2-9 provides a schematic of the tributaries and related cross sections on the North Diversion Ditch. Table 2.8 provides a summary of PMF flow characteristics for each of these locations. The PMF peak discharges were determined using the SCS TR55 method. Manning's equation was used to determine the flow depth and discharge in the North Diversion Ditch and in the tributaries. Appendix F provides the calculations.

Table 2.8 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.

Confluence Geometry

The geometry of the three confluences was evaluated to identify the confluence angle and the amount of material existing in the far ditch bank. Figure 2-2 shows that Tributaries A2 and B enter the 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 North Diversion Ditch at about a 90-degree angle. This angle indicates that tributary flows would cause more turbulence at the confluence than would be caused by a shallower angle.

Figure 2-9 provides 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 Tributary B. These distances are all sufficiently large such that channel scour would 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 would become wider and thus protect itself from future scour.

Conclusion

At confluence A1, the total head of the tributary flow is considerably less than that of flow in the ditch. Furthermore, channel scour would 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 would 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 would not impinge directly upon the diversion ditch bank. Furthermore, about 150 feet of material would have to be scoured before flows could pass over the tailings.

The above evaluation indicates that while scour and erosion would 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.

### 2.4.2 North Diversion Ditch Slope Stability

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 stable from a geologic point of view.

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

Discontinuities and saturation of the formation could potentially lead to a reduction in shear resistance and 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 due to 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, which makes 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.

# 3.0 SUBSTANTIATION OF ORIGINAL DESIGN

This section provides substantiation that the original reclamation plan design submitted to the NRC, and subsequently modified in previous responses to the NRC comments, meets the requirements of 10 CFR 40 Appendix A, particularly as it relates to the recent criticisms as contained in the NRC's comments. The original design provides an integrated approach that appropriately balances all needs of the criteria to meet the requirements as set forth in the regulations at reasonable cost.

The NRC criticizes the original design as not being sufficient to meet the NRC's criteria as it relates to long-term stability via the surface water erosion mechanism. The NRC's concerns are based on the premise that the original design does not meet the NRC's STP and, therefore, does not sufficiently protect against the release of tailings to the environment. Specifically, the NRC is concerned that:

1. The proposed tailings cover is not designed so as to adequately control erosion;

2. The embankment slopes are not adequately protected to control erosion; and

3. The Pipeline Arroyo is not adequately armored to control erosion.

As discussed in this section, United Nuclear will demonstrate that its original design provides erosion control of the tailings soil cover, the embankment slopes, and the Pipeline Arroyo. The design is based on extensive geomorphologic evaluations, surface water hydrology analyses, and numerical engineering calculations.

## 3.1 Tailings Soil Cover

The present erosion protection design for the tailings soil cover includes regrading of the impoundment to fill in low spots, covering the fine-grained tailings with coarse-grained tailings, and providing gentle top slopes. As more fully described in Section 7.5 of the original Reclamation Plan, the slopes of the cover will average approximately 2 percent. The plan also includes the construction of seven swales to collect surface water runoff and to route the runoff to riprapped drainage channels. The swales were designed to ensure that overland flow velocities and channel flow velocities would not exceed the MPV at which erosion may occur of 3 fps. In addition, the tailings cover will be revegetated.

The soil cover design was prepared on the basis that it had to meet Criterion 4 and Criterion 6 of the 10 CFR 40 Appendix A criteria related to surface water erosion considerations. In addition, the design took into consideration Criterion 5, regarding the need to protect ground water, as well as paragraph 5 of the Introduction to Appendix A that requires that all licensing decisions based on the criteria take public health and safety and the environment in due consideration to the costs involved and other factors as appropriate.

Criterion 4(d)

This criterion requires that a self-sustaining vegetative cover must be established or rock employed to reduce water erosion. It considers that a rock cover must be employed when conditions are such that a vegetative cover is unlikely to be sustained. It also considers that the rock cover requirement will be relaxed for extremely gentle slopes, such as those that may exist on the top of the pile.

Canonie was counseled by the NRC during preparation of the design that the NRC considered gentle slopes to mean those slopes that kept surface water flows to less than 3 fps. This MPV, endorsed by the NRC and the NRC's consultant, is described in a reference by Barfield et al., (1985). The NRC further encouraged United Nuclear to vegetate the soil cover and take credit for same in calculating the MPV.

Criterion 6

This criterion requires that the tailings disposal area be closed in accordance with a design that provides reasonable assurance of control of radiological hazards to be effective for 1,000 years to the extent reasonably achievable and, in any event, for at least 200 years. Those assurances are to be based, in part, on the adequacy of erosion protection of the soil cover.

The terms "reasonably achievable" and "practicable" are equivalent words as defined in the regulations. Appendix A requires that decisions involving these terms take into account the state of technology and the economics of improvements in relation to benefits to public health and safety and the environment.

Canonie demonstrated in submittals dated May 23, 1988 and August 31, 1988 that constructing gentle slopes, keeping the MPV to less than 3 fps, providing runoff collection swales, and vegetating the soil cover prevented the soil cover from eroding, thus protecting tailings from releases for the prescribed 200 and 1,000 year periods.

Criterion 5

This criterion requires that ground water be protected.

Canonie designed the soil cover to achieve a balance between the need to keep the slopes as gentle as possible to control surface erosion and at the same time contour and swale the cover so that water would be allowed to run off the cover, thus minimizing the opportunity for infiltration of water. This was a critical consideration for United Nuclear because of the EPA's activity at the site relative to CERCLA. During preparation of the design, the NRC concurred that this was an important consideration and endorsed this approach to balancing these potentially conflicting criteria.

Introduction to Appendix A, 10 CFR 40, Paragraph 5

The introduction to Appendix A, 10 CFR 40, requires that licensing decisions made by the commission be based on risks to public health and safety and the environment with due consideration to cost and other factors.

As part of preparing its design, Canonie conducted an assessment of various alternative approaches to tailings stabilization. The alternative of providing a rock cover as well as the alternative of constructing the soil cover using flat "table-top" slopes (stable slopes) were evaluated along with other scenarios. This exercise was conducted in the normal course of decision making to identify cost-effective approaches that provided solutions to regulatory requirements. As such, these evaluations were never formalized into reports. Nonetheless, as a prudent businesslike measure, the costs and benefits of various alternatives were assessed, and it was concluded that the alternative whose cost, as related to the benefit to public health and safety and the environment, was most balanced was the design proposed in June 1987.

In preparing its response to the NRC's most recent comment, as contained herein, Canonie revisited the costs of the NRC's proposed rock mulch and flat, stable slopes alternatives. As discussed in Section 2.1, the costs for these alternatives are \$2.4 and \$4.0 million, respectively, higher than the proposed design. While these cost estimates are reflective of costs that would be incurred today, not those at the time the design was submitted, they clearly demonstrate the point because the relative costs remain the same. In fact, the earlier cost estimates would have been higher because a potential rock source closer to the site has been identified since 1987 and earth moving estimates today are more accurate.

The fact that no suitable rock of the quality and size required is locally available significantly increases the cost of the rock cover because of the need to import the rock from an off-site source. The significant amount of earth work required to reconfigure the top of the tailings to a more stable slope, together with the requirement for rock to stabilize the downslopes, increased the cost of the flat "table-top" slope design.

Conclusion

The NRC has criticized the original design of the soil cover. It has used as its fundamental argument the fact that the design fails to meet the tractive force criteria contained in its STP, concluding that because the design does not meet the STP, it does not meet the regulatory criteria of Appendix A.

Canonie believes that the NRC's conclusion is in error. The STP is not the controlling document. The regulation is. Staff technical positions can and do change without being subject to the same rule-making process as proposed regulatory changes. As demonstrated by the NRC's most recent comments, in the space of three years the NRC's STP (or its interpretation of its STP) has changed such that it no longer accepts the premise that a vegetative cover can be self-sustaining at the Church Rock site, that an MPV of less than 3 fps is no longer sufficient to protect the cover, as designed, from erosional forces, and the slopes that average 2.0 percent are not sufficiently gentle to protect the cover, as designed, from erosional forces.

Without producing any substantiating technical evidence, the NRC now concludes that the more conservative approach of requiring either a rock mulch addition to the cover design or reconfiguring the design in favor of "flat" slopes is adequate.

Canonie submits that, contrary to the NRC's representation that its proposals should be implemented because they meet the regulatory criteria, the NRC's proposed approach significantly violates its own regulations. The NRC's proposals are in conflict with Criterion 5 of Appendix A, whereby the flat slopes are not protective of ground water impacts. In addition, while "flat slope" designs are theoretically possible, a slope of 0.002 ft/ft must be obtained with the soil available at the site for use as cover material in order to meet the NRC's STP tractive force requirement.

However, it is physically impractical to obtain sufficient field control of construction materials to ensure that slopes at or less than 0.002 ft/ft are in fact being constructed. The very best that might be expected would be 0.005 ft/ft and even accomplishing such a feat in the field is highly unlikely. Additionally, a slope of 0.005 ft/ft will not allow the STP tractive force requirement to be met, creating, as a practical matter, the same concern that the NRC seeks to obviate.

The introduction to Appendix A clearly identifies that alternatives must be technologically and economically practicable. As demonstrated earlier, both of the NRC's proposals are unjustifiable on the basis that no significant incremental benefit to public health, safety, and the environment are realized relative to the increased cost.

For the reasons as stated above, the original cover design as proposed meets the criteria as set forth in 10 CFR 40, Appendix A, and should be approved.

## 3.2 Tailings Embankment

As described in more detail in the response to comments dated August 31, 1988, the present erosion protection design for the 5H:1V tailings embankment sideslopes includes a series of runoff interception ditches to route runoff to a central collection channel. The interception ditches are spaced at 40-foot intervals to prevent the formation of gullies. The response indicated that this 40-foot spacing was calculated using Horton's method for determining the belt of no erosion. The collection channel is lined with riprap designed for the PMF. The flow velocities in the interception ditches will be below the MPV of 3 fps. The basis used for this design of the tailings embankment protection was the same as that described in Section 3.1 for the tailings cover.

The NRC criticized United Nuclear's design based on the potential for siltation, for the potential for flow to overtop the outer bank, and for potential for progressive erosion of the ditch outbank resulting in gullying.

The NRC's concerns are not well founded with regard to the potential for siltation. An analysis of the potential flow velocities in the interception ditches was made to determine the likelihood of siltation (deposition), transport, or erosion of the soil used in the embankment and ditch design. This soil has an average grain-size diameter of 0.05 millimeters (mm). Figure 6-7 of Ritter (1978) shows that flow velocities above about 0.013 fps will transport sediment of this grainsize while flow velocities below this value will allow siltation of this sediment. This is an extremely low-flow velocity, yet still manages to transport the sediment. Sediment with a diameter of 1 mm (20 times larger than the average) will be transported by a flow velocity of about 0.3 fps. This flow velocity corresponds roughly to a discharge of 0.006 cfs at a depth of 0.08 feet in the interception ditches.

Thus, siltation of even large sediment will not occur in the interception ditches. Appendix G provides the detailed calculations used for this analysis.

With regard for the potential for overtopping, Canonie has overdesigned the ditches so that overtopping would not occur. The design accounts for the total head (velocity head plus elevation head) of incoming flow as compared to the elevation head at the ditch bank crest. Determination of the overland flow down the 5H:1V embankment and 3H:1V interceptor ditch sideslopes was performed by the methods prescribed in NUREG-4620. This method allowed the calculation of the velocity and depth of overland flow at the bottom of the interceptor ditch generated by the PMP. Bernoulli's equation was used to determine the amount of energy, or head, necessary for the overland flow to overtop the interceptor ditch bank. The total head at the bottom of the ditch was found to be 0.25 feet while the total head necessary to overtop the interceptor ditch was 2.5 feet. Therefore, no flow would overtop the ditch bank. Appendix G gives the appropriate calculations for both the overland flow and Bernoulli's equation.

With regard to the potential for progressive erosion of the outbanks, the following evaluation demonstrates that gullying will not cause the interception ditch outbanks to cause the release of tailings. The crest of the ditch outbank provides a watershed divide. The 3H:1V sideslopes of the ditch outbanks intersect the 5H:1V embankment sideslopes approximately 23 feet downhill from this crest. The methods prescribed in the STP were used to estimate the maximum depth of gullying ($D_{max}$) and the distance from the crest at which the $D_{max}$ would occur. $D_{max}$ was found to be 0.31 feet and would occur 1.1 feet from the intersection of the 3H:1V slopes and the 5H:1V slopes. The gully would not reach the crest of the ditch bank.

The sediment produced by this gullying would be deposited on the 5H:1V sideslopes as the flow velocities decreased. Thus, this minor amount of gullying would not affect the interception ditch, nor cause the release of tailings. Appendix G provides the detailed calculations used for this evaluation.

Therefore, United Nuclear's design for protection of the embankment slopes meets 10 CFR 40 Appendix A criteria and should be approved.

### 3.3 Pipeline Arroyo

Canonie expended a significant effort in designing and subsequently addressing a large number of NRC comments regarding this design and submitted responses to comments dated August 31, 1988, February 23, 1989, and September 12, 1990 to the NRC specifically on the subject of the stability of the Pipeline Arroyo design. The NRC and its consultants have spent many hours evaluating the proposed design.

The details of the design will not be restated in this document as they are readily available in the above-referenced documents. Briefly, however, the original design for Pipeline Arroyo provides a reconfigured channel to be incised approximately 20 feet into the sandstone outcrop known as the nickpoint. The incision prevents the channel from migrating off of the nickpoint and into the tailings. The reconfigured channel above the nickpoint would have a slope of about 0.008 ft/ft, which is slightly steeper than the existing channel slope of 0.003 ft/ft. Below the nickpoint, the channel slope would vary but would be approximately the same as the existing slope. Riprap would be installed at the nickpoint to protect any channel banks that would be contacted by the PMF.

This design fully contains the PMF within the reconfigured channel; thus, no flow will contact the tailings embankment. Furthermore, the solid rock of the nickpoint provides horizontal and vertical control of the channel, thus ensuring that the channel remains as far as possible from the tailings impoundment.

Analysis of the long-term stability of the reconfigured channel using Yang's unit stream power equation indicated that the channel would not cause the release of tailings in a 1,000-year period. This period includes multiple occurrences of the 2-year through 100-year flood events as well as the PMF. Thus, the reconfigured channel will not cause the release of tailings within a 1,000-year period and permanent isolation of tailings is maintained.

Canonie prepared this design for the Pipeline Arroyo reconfiguration on the basis of meeting Criterion 6 of Appendix A, which requires that the disposal area be closed in accordance with a design that provides reasonable assurance of control of radiological hazards to be effective for 1,000 years to the extent reasonably achievable and, in any event, at least 200 years.

As was the case with the tailings cover design, Canonie evaluated a number of alternative designs to meet this criterion before concluding that the most appropriate design would require that the nickpoint be incised to allow the PMF to flow as quickly past the site as possible while taking into consideration other factors that could affect meeting the criterion. It was also determined that the design should incorporate an incision in the nickpoint because of the importance this structure plays in the long-term geomorphic stability of the arroyo in the area of the site.

Much careful calculation, each compounded with its own inherent conservatism, was used in the design to account for passage of the PMF and the full range of lesser flood events with the potential for release of tailings during the design period, i.e., 1,000 years. For example, detailed analyses identified above and incorporated herein by reference indicate that, even after the full range of lesser flood events have been factored into the equation, there will still remain over 170 feet of soil that would have to be eroded away from the location closest to the tailings embankment before tailings could possibly be released. Additionally, in calculating the effects of erosion in the arroyo, no credit was taken for the occurrence of vertical (downward) erosion. All erosion was assumed to occur laterally. Also, no credit was taken for the deposition of materials from upgradient as a result of previous storm events. There are many other examples contained in the references. Nonetheless, the NRC is not comfortable with the analysis.

Canonie evaluated the costs attendant to a variety of alternative Pipeline Arroyo designs to determine which offered the best balance of achieving the criteria against the cost. Included in this analysis was the cost of providing riprap sufficient to armor the reconfigured arroyo. A recent reevaluation of the costs indicate that it would cost an additional $7.1 million to riprap the reconfigured arroyo in the original design. This added cost alone would increase the estimated cost of tailings reclamation approximately 55 percent. The cost of placing a 6-inch rock mulch layer between the arroyo and the toe of the embankment would add another $0.5 million.

Canonie also evaluated alternative excavated channel configurations, including shallower and wider channels and steeper sideslopes. This analysis was limited to some extent by physical constraints present at the site, not the least of which is the presence of a liquified natural gas pipeline and a state highway, both running parallel to the Pipeline Arroyo. The analysis indicated that 3H:1V sideslopes were the best configuration to balance the desire to maximize stability, keep the arroyo center line as far away from the tailings as possible, and provide the borrow material needed to construct the tailings cover.

Canonie conducted extensive analyses of the long-term stability of the reconfigured Pipeline Arroyo as designed, as contained in the response to comments dated February 23, 1989. This document clearly demonstrates that there is sufficient conservatism included in the design to accommodate the relatively small risk associated with not riprapping the arroyo channel. The highest risk associated with the possible occurrence of erosion in the reconfigured arroyo is for the arroyo to meander sufficiently towards the tailings, causing release of tailings. Canonie analyzed the potential of such an occurrence by evaluating the meander characteristics of Hard Ground Canyon and Pipeline Arroyo, as described above, and demonstrated that it was unlikely. The average meander amplitude was found to be 155 feet, while the closest distance to the tailings was 355 feet.

Conclusion

The NRC criticizes the original design in its August 16, 1990 comments as not being adequate to meet the criteria of 10 CFR 40, Appendix A, because in its view United Nuclear has not provided sufficient evidence to ensure that the reconfigured channel is stable enough to withstand surface water erosion forces for the long term, i.e., 1,000 years. Additionally, the NRC criticizes the design for not sufficiently protecting the area between the arroyo and the toe of the embankment sideslope.

In a subsequent meeting, the NRC's geomorphic expert revealed that his true concern was that he believed that the nickpoint should never have been proposed to be incised. He further stated that he believed that incising the nickpoint as proposed in the original design was "inherently fatally flawed" because such an action would cause a serious geomorphic imbalance of the arroyo. The NRC's expert offered the observation that in his view Canonie had inappropriately recommended an engineering solution to a geomorphic problem. They had, in his opinion, attempted to solve the problem by focusing entirely on the passage of the PMF through the site as quickly as possible, using engineering techniques that were to the detriment of geomorphic stability. No substantiating technical evidence was offered to support this position.

Canonie believes that the NRC's conclusions are in error. The NRC has presented no technical evidence to support its claim that the original design as originally submitted fails to meet the criteria. A statement of fear that headcuts and meanders "could be created' such that they "would threaten" release of tailings is hardly sufficient justification to require expenditure of $7.1 million.

The NRC's comments notwithstanding, Canonie designed a solution that meets Criterion 6 of providing "reasonable assurances of control of radiological hazards to be effective for 1,000 years to the extent reasonably achievable." Canonie evaluated the various alternative technical approaches and appropriately balanced them against the attendant costs and also took into account site-specific constraints to the extent that they affected the design. The incremental benefits of placing riprap in the arroyo when compared to the additional costs clearly cannot be justified. Finally, contrary to the NRC's belief, Canonie thoroughly evaluated and understood both the engineering and geomorphic stability implications of this design and appropriately balanced them in determining the most reasonable technical solution.

Therefore, for the reasons stated above, United Nuclear's Pipeline Arroyo reconfiguration design as proposed meets the criteria as set forth in 10 CFR 40, Appendix A, and should be approved.

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# REFERENCES

## REFERENCES


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# TABLES

TABLES

TABLE 2.1

SUMMARY OF RECLAMATION PLAN ALTERNATIVES AND ADDITIONAL COSTS

| | Pipeline Arroyo | Sacrifical Area | Embankment Sideslopes | Tailings Soil Cover | Total Additions Cost |
|---|---|---|---|---|---|
| United Nuclear Original Design Submittal | Incise nickpoint, reconfigured arroyo, add riprap at selected locations. | Regrade to eliminate depressions. | Construct and rip-rap runoff control ditch. Install interception ditches. | Regrade tailings to shed water. Install 4-foot soil cover vegetation. | |
| Additional Cost | $0 | $0 | $0 | $0 | $0 |
| NRC Proposed Changes | Install riprap on entire length of reconfigured channel. | Provide a 6-inch-thick rock mulch layer. | Provide a 6-inch-thick Rock mulch layer. | Provide a 6-inch-thick rock mulch layer. | |
| | $7,100,000 | $501,000 | $251,000 | $2,417,500 | $10,269,500 |
| | | | | OR | OR |
| | | | | Regrade top to stable slopes (benches). Install riprap swales, no vegetation. | |
| | | | | $4,020,000 | $11,872,000 |
| United Nuclear Proposed Design Modifications | Do not incise nick-point; install a low-flow channel, buried jetty. | Regrade to eliminate depressions. | Provide 3-inch-thick rock mulch layer and protective bench. | Provide soil/rock matrix over soil cover, riprap swales, no vegetation. | |
| Additional Cost | ($492,000) | $0 | $95,000 | $1,380,000 | $983,000 |

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TABLE 2.2

IMPOUNDMENT TOP DRAINAGE SWALE CHARACTERISTICS

| Swale Designation | Length (ft) | Slope (ft/ft) | Bottom Width (ft) | Peak Discharge (cfs) | Depth of Flow (ft) | Minimum Swale Depth (ft) | Riprap $D_{50}$ (in) |
|---|---|---|---|---|---|---|---|
| A | 2,600 | 0.0038 | 10 | 40 | 0.98 | 2.0 | 1.5 |
| B | 3,600 | 0.0083 | 20 | 97 | 0.97 | 2.0 | 1.5 |
| C | 3,400 | 0.0050 | 10 | 75 | 1.38 | 2.0 | 1.5 |
| D | 3,200 | 0.0028 | 10 | 68 | 1.43 | 2.0 | 1.5 |
| E | 1,350 | 0.0037 | 10 | 85 | 1.53 | 2.5 | 1.5 |
| F | 1,600 | 0.0031 | 10 | 126 | 2.00 | 2.5 | 1.5 |
| G | 1,400 | 0.0021 | 10 | 99 | 1.88 | 2.5 | 1.5 |
| H | 2,550 | 0.0085 | 20 | 284 | 1.90 | 2.5 | 3.0 |
| I | 550 | 0.0040 | 20 | 385 | 2.65 | 3.5 | 3.0 |
| J | 1,900 | 0.0047 | 10 | 101 | 1.66 | 2.5 | 1.5 |

Note: See Figures 2-2 and 2-3 for swale locations.

TABLE 2.3

RIPRAP AND FILTER MATERIAL GRADATION REQUIREMENTS (a)

| Location | D 50 (b) | Sieve Size: | 30 Inch | 25 Inch | 20 Inch | 15 Inch | 10 Inch | 5 Inch | 4 Inch | 3 Inch | 1 Inch | No. 4 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Percent Passing by Weight | | | | | | | | | |
| Upper Section South Cell Drainage Channel | 23 Inches (c) | | 100 | | 35-45 | | 12-32 | 5-22 | | 0-17 | | |
| Upper Section North Cell Drainage Channel | 14 Inches (c) | | | 100 | | 40-50 | | 10-33 | | 0-27 | | |
| Lower Section North Cell Drainage Channel | 11 Inches (c) | | | | | 100 | | 17-30 | | 10-24 | 0-12 | |
| North Diversion Ditch, Buried Jetty | 6.0 Inches | | | | | | 100 | | 30-40 | | 7-20 | 0-3 |
| Swales H and I, Lower Reach of Runoff Control Ditch | 3.0 Inches | | | | | | | 100 | | 40-47 | 15-32 | 0-16 |
| Soil/Rock Matrix, Swales, Upper Reach of Runoff Control Ditch | 1.5 Inches | | | | | | | | | 100 | 25-37 | 0-17 |
| | | Sieve Size: | No. 200 | No. 40 | No. 10 | No. 4 | 3/4 Inch | 3 Inch | +3 Inch | | | |
| | Filter Layer | | 0-30 | 23-70 | 47-94 | 65-100 | 85-100 | 100 | -- | | | |

(a) The rock quality will be determined in accordance with Appendix D of the NRC's Staff Technical Position (STP) on "Design of Erosion Protection Covers" dated August 1990. Rock used for channels, swales, and the tailings cover soil/rock matrix shall be considered "noncritical" and have a minimum rock quality rating of 50.

(b) Rock sizes shown will be oversized based on their rock quality rating by the methods provided in Appendix D of the NRC's STP.

(c) Rock sizes have been based on Maynord's 1987 method. United Nuclear reserves the right to modify the above gradations using Maynord's 1978 method as an alternative method if justifiable.

TABLE 2.4

SUMMARY OF RADON MODEL INPUT PARAMETERS

| General Description | Specific Gravity | Dry Bulk Density (pcf) | Porosity | Moisture Content (percent) | Radium Content (pCi/g) | Diffusion Coefficient (cm2/sec) | Emanation Coefficient |
|---|---|---|---|---|---|---|---|
| Radon Source Parameters: | | | | | | | |
| Fine Tailings | | | | | | | |
| Average | 2.78 | 86 | 0.53 | 38.7 | 547 | 0.00176 | 0.26 |
| 95 Percent Confidence Interval | 2.73 to 2.83 * | | 0.50 to 0.56 * | 29.7 * to 47.7 | 296 to 798 * | 0.00022 to 0.0053 * | 0.20 to 0.32 * |
| Coarse Tailings | | | | | | | |
| Average | 2.81 | 97.5 | 0.45 | 10.4 * | 154 | 0.029 | 0.26 |
| 95 Percent Confidence Interval | 2.77 to 2.84 * | | 0.43 to 0.47 * | | 125.0 to 183.0 * | 0.018 to 0.047 * | 0.25 to 0.27 * |
| Radon Attenuation Parameters: | | | | | | | |
| Soil Cover | 2.6 * | 108.3 * | 0.33 * | 13.4 * | -- | 0.0029 * | -- |

Notes:

1. * indicates parameters that were used in the RADON model.

2. Radon attenuation parameters for the soil cover materials were calculated from measured geotechnical parameters.

TABLE 2.5

COARSE TAILINGS LABORATORY TEST DATA

| General Description | Boring Number | Depth (feet) | Specific Gravity | Dry Bulk Density (pcf) | Porosity | Moisture Content (percent) (a) | Radium Content (pCi/g) | Diffusion Coefficient (cm2/sec) (b) | Emanation Coefficient |
|---|---|---|---|---|---|---|---|---|---|
| Tailings Sands | 658 | 15 | NT | 105 | 0.40 | NT | NT | NT | NT |
| | 658 | 20 | 2.83 | 104 | 0.41 | 23.5 | 160 | 0.0000053 | 0.32 |
| | 658 | 30 | 2.81 | 98 | 0.44 | 23.4 | 141 | 0.000019 | 0.27 |
| | 658 | 40 | 2.89 | 92 | 0.49 | 31.2 | 212 | 0.000002 | 0.25 |
| | 659 | 10 | 2.84 | 95 | 0.46 | 6.1 | 125 | 0.037 | 0.18 |
| | 659 | 20 | 2.83 | 94 | 0.47 | 10.5 | 227 | 0.023 | 0.21 |
| | 659 | 30 | 2.74 | 97 | 0.43 | 13.1 | 132 | 0.016 | 0.20 |
| | 659 | 32.5 | NT | 106 | 0.47 | 8.1 | 115 | 0.042 | 0.27 |
| | 662 | 20 | NT | 97 | 0.49 | 34.1 | NT | NT | NT |
| | 662 | 25 | 2.78 | 96 | 0.36 | 25.1 | 108 | 0.0000025 | 0.33 |
| | 662 | 30 | 2.79 | 94 | 0.46 | 29.6 | 177 | 0.0000013 | 0.28 |
| Supplemental (c) | | | | | | | 143.1 | | |
| Average | | | 2.81 | 97.5 | 0.45 | 20.47 | 154 | NA | 0.26 |
| 95 Percent Confidence Interval | | | 2.77 to 2.84 | NA | 0.43 to 0.47 | NA | 125.0 to 183.0 | NA | 0.25 to 0.27 |

NT = Not tested

(a) Moisture contents are not indicative of long-term values, which will typically be lower; therefore, soils test data have been averaged and a value of 10.4 percent obtained.

(b) Diffusion coefficients are typically low due to the high moisture content values; therefore, calculated values will be used.

(c) Value for radium content from Environmental Report on Uranium Mill Tailings Backfill presented in April 8, 1981 letter from United Nuclear to the New Mexico Environmental Improvement Division.

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TABLE 2.6

FINE TAILINGS LABORATORY TEST DATA

| General Description | Boring Number | Depth (feet) | Specific Gravity | Dry Bulk Density (pcf) | Porosity | Moisture Content (percent) | Radium Content (pCi/g) | Diffusion Coefficient (cm2/sec) | Emanation Coefficient |
|---|---|---|---|---|---|---|---|---|---|
| Fine-Grained Tailings Slimes | 659 | 37.5 | 2.72 | 78 | 0.54 | 29.6 | 602 | 0.0056 | 0.16 |
| | 660 | 8.0 | 2.81 | 74 | 0.58 | 44.27 | 341 | 0.0000011 | 0.37 |
| | 660 | 15.0 | 2.84 | 94 | 0.47 | 60.0 | 1099 | 0.0000016 | 0.31 |
| | 660 | 27.5 | 2.75 | 89 | 0.48 | 32.2 | 285 | 0.0000016 | 0.26 |
| | 660 | 37.5 | 2.84 | 79 | 0.56 | 41.4 | 526 | 0.0000027 | 0.28 |
| | 662 | 40.0 | 2.72 | 84 | 0.51 | 36.4 | 574 | 0.0000062 | 0.21 |
| | 662 | 42.5 | NT | 89 | 0.55 | 43.8 | NT | NT | NT |
| | 658 | 10.0 | 2.81 | 88 | 0.50 | 17.4 | 402 | 0.0067 | 0.22 |
| | 658 | 32.5 | NT | 97 | 0.55 | 43.6 | NT | NT | NT |
| Average | | | 2.78 | 86 | 0.53 | 38.7 | 547 | 0.00076 | 0.26 |
| 95 Percent Confidence Interval | | | 2.73 to 2.83 | NA | 0.50 to 0.56 | 29.7 to 47.7 | 296 to 798 | 0.00022 to 0.0053 | 0.20 to 0.32 |

----------

NT = Not tested

## TABLE 2.7

## SUMMARY OF MEANDER PATTERNS

### PIPELINE ARROYO

| Elevation Contour | Channel Distance (ft) | Slope (ft/ft) | Valley Distance (ft) | Sinuosity (ft/ft) | Average Meander Amplitude (ft) | Average Meander Wave Length (ft) |
|---|---|---|---|---|---|---|
| 6840 | | | | | | |
| 6880 | 3800 | 0.011 | 3375 | 1.126 | 200 | 1150 |
| 6920 | 5200 | 0.008 | 5025 | 1.035 | 150 | 1250 |
| 6960 | 7000 | 0.006 | 6500 | 1.077 | 100 | 2275 |
| 7000 | 2000 | 0.020 | 1675 | 1.194 | 100 | 2000 |
| 7040 | 7200 | 0.006 | 6025 | 1.195 | 100 | 1750 |
| 7080 | 3600 | 0.011 | 3225 | 1.116 | 200 | 750 |

Watershed Area = 20.12 square miles
Maximum Amplitude = 570 feet

### HARD GROUND CANYON

| Elevation Contour | Channel Distance (ft) | Slope (ft/ft) | Valley Distance (ft) | Sinuosity (ft/ft) | Average Meander Amplitude (ft) | Average Meander Wave Length (ft) |
|---|---|---|---|---|---|---|
| 6800 | 0 | | | | | |
| 6840 | 5600 | 0.007 | 5300 | 1.057 | 150 | 1050 |
| 6880 | 3400 | 0.012 | 3300 | 1.030 | 150 | 675 |
| 6920 | 7000 | 0.006 | 6800 | 1.029 | 200 | 1800 |
| 6960 | 3300 | 0.012 | 2500 | 1.320 | 350 | 1000 |
| 7000 | 7900 | 0.005 | 7500 | 1.053 | 150 | 1780 |
| 7040 | 2800 | 0.014 | 2600 | 1.077 | 100 | 1400 |
| 7080 | 2300 | 0.017 | 2150 | 1.070 | 75 | 2000 |

Watershed Area = 14.11 square miles
Maximum Amplitude = 350 feet

TABLE 2.8

TOTAL HEAD COMPARISONS AT CONFLUENCES

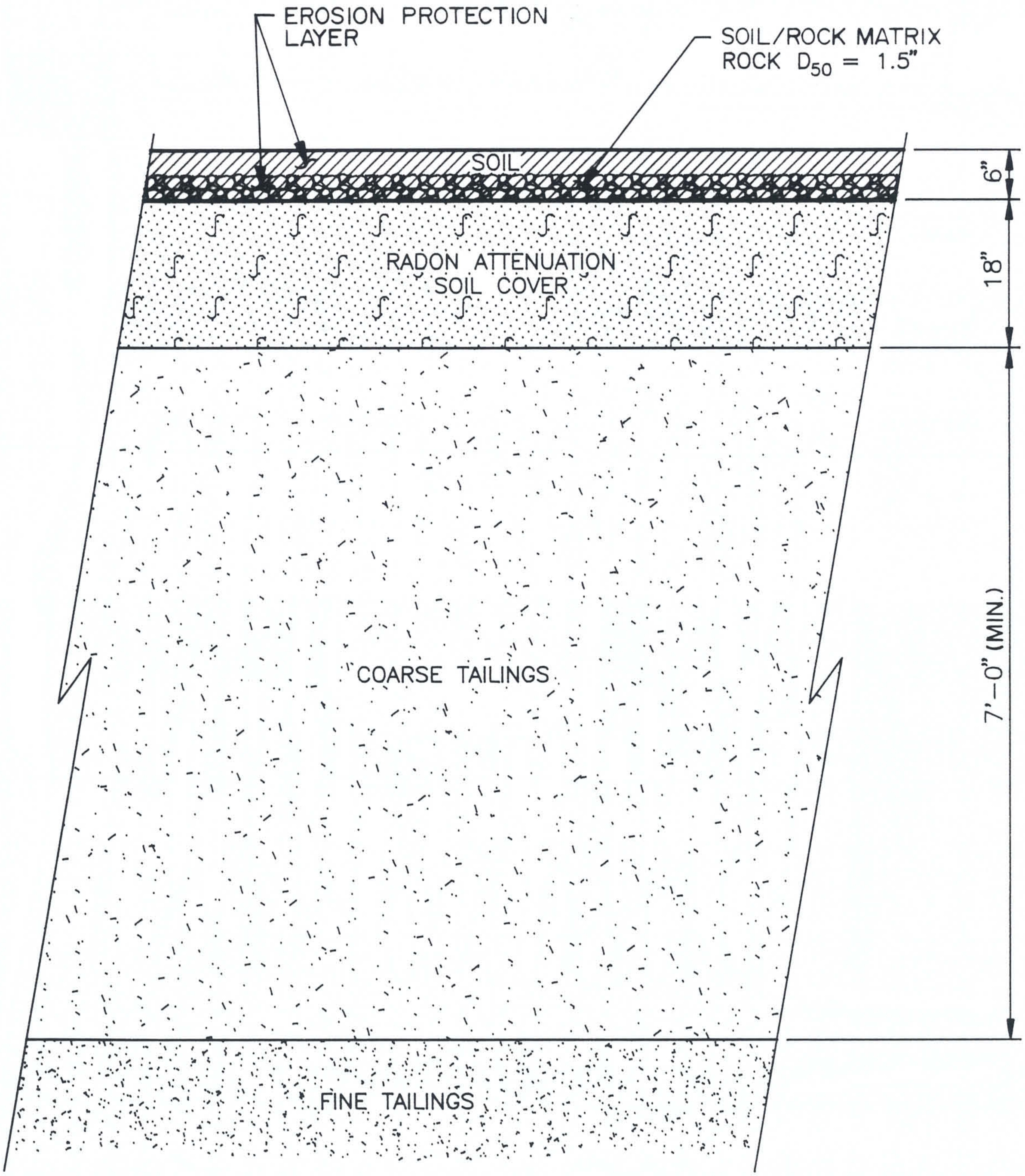
| Cross Section Location | Peak Discharge (cfs) | Channel Slope (ft/ft) | Depth of Flow (ft) | Flow Velocity (fps) | Velocity Head (ft) | Total Head (ft) |
|---|---|---|---|---|---|---|
| K | 1081 | 0.0054 | 4.22 | 9.0 | 1.26 | 5.48 |
| A1 | 383 | 0.044 | 0.88 | 11.2 | 1.95 | 2.93 |
| L | 2265 | 0.0071 | 5.69 | 12.5 | 2.43 | 8.12 |
| A2 | 765 | 0.020 | 1.81 | 10.8 | 1.82 | 3.63 |
| M | 2265 | 0.0074 | 4.34 | 9.8 | 1.49 | 5.83 |
| B | 2046 | 0.019 | 2.48 | 13.2 | 2.17 | 5.19 |
| N | 5850 | 0.0074 | 8.02 | 15.1 | 3.54 | 11.56 |

Note: Figure 2-8 provides the cross section locations.

FIGURES

FIGURES

DRAWING NUMBER 86-060-A426




**NOTE:**

1. THIS DRAWING IS NOT TO SCALE.

SOIL COVER PROFILE

PREPARED FOR

UNC MINING AND MILLING
GALLUP, NEW MEXICO

Canonie Environmental

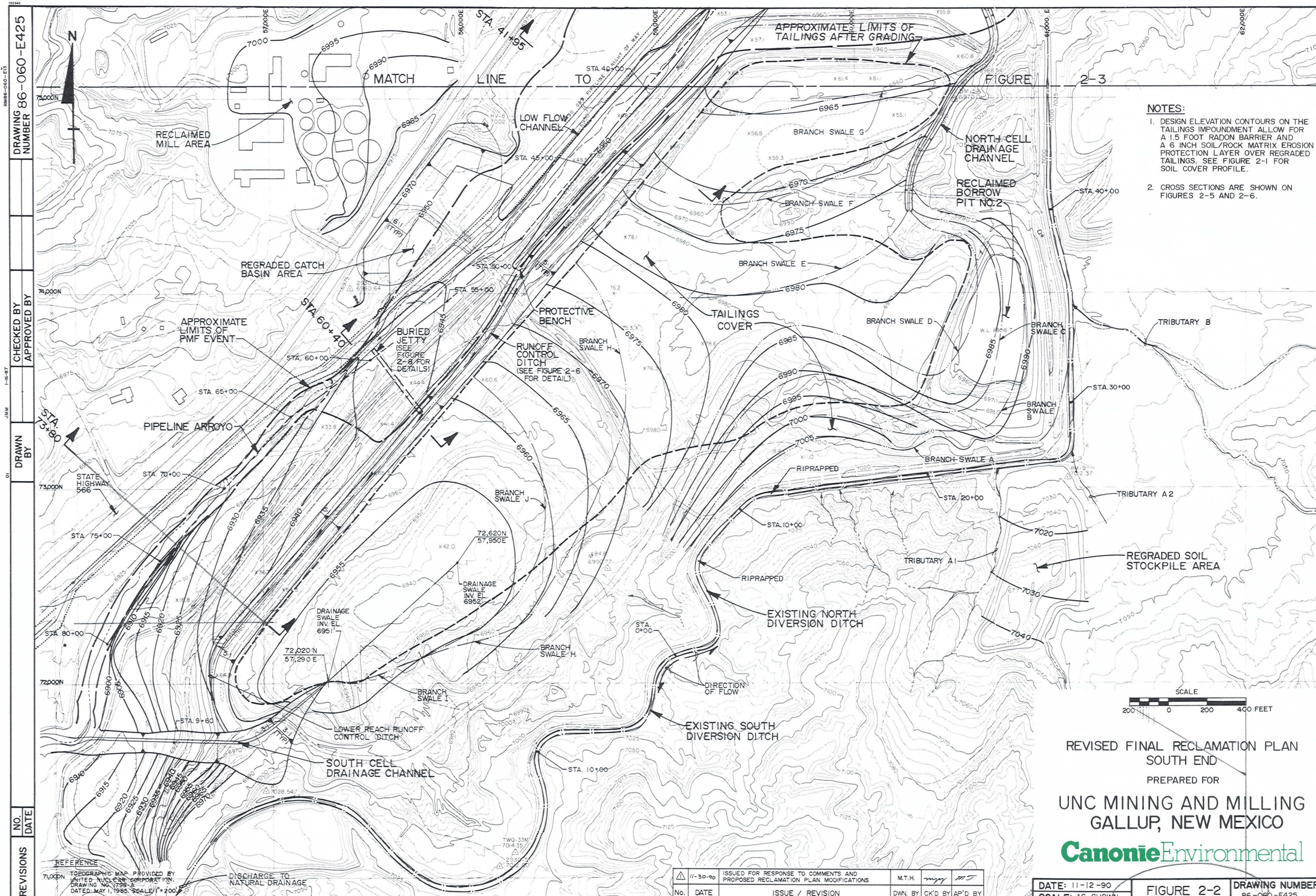
| No. | DATE | ISSUE / REVISION | DWN. BY | CK'D BY | AP'D BY |
|---|---|---|---|---|---|
| 1 (triangle) | 12-4-90 | ISSUED FOR RESPONSE TO COMMENTS AND PROPOSED RECLAMATION PLAN MODIFICATIONS | P.M.W. | mjy | DHG |

DATE: 11–12–90
SCALE: N.T.S.

FIGURE 2-1

DRAWING NUMBER 86–060–A426

1 (triangle)


MATCH LINE TO FIGURE 2-3
APPROXIMATE LIMITS OF TAILINGS AFTER GRADING
RECLAIMED MILL AREA
LOW FLOW CHANNEL
NORTH CELL DRAINAGE CHANNEL
RECLAIMED BORROW PIT NO.2
BRANCH SWALE G
BRANCH SWALE F
BRANCH SWALE E
BRANCH SWALE D
BRANCH SWALE C
BRANCH SWALE B
BRANCH SWALE A
BRANCH SWALE H
BRANCH SWALE J
BRANCH SWALE I
REGRADED CATCH BASIN AREA
PROTECTIVE BENCH
TAILINGS COVER
APPROXIMATE LIMITS OF PMF EVENT
BURIED JETTY (SEE FIGURE 2-8 FOR DETAILS)
RUNOFF CONTROL DITCH (SEE FIGURE 2-6 FOR DETAIL)
PIPELINE ARROYO
STATE HIGHWAY 566
TRIBUTARY B
TRIBUTARY A 2
TRIBUTARY A I
RIPRAPPED
REGRADED SOIL STOCKPILE AREA
EXISTING NORTH DIVERSION DITCH
EXISTING SOUTH DIVERSION DITCH
DIRECTION OF FLOW
DRAINAGE SWALE INV. EL. 6952
DRAINAGE SWALE INV. EL. 6951
72,620N 57,950E
72,020 N 57,290 E
LOWER REACH RUNOFF CONTROL DITCH
SOUTH CELL DRAINAGE CHANNEL
DISCHARGE TO NATURAL DRAINAGE
STA. 41+95
STA. 60+40
STA. 73+80
REFERENCE
TOPOGRAPHIC MAP PROVIDED BY UNITED NUCLEAR CORPORATION. DRAWING NO. 1798-A DATED MAY 1, 1985. SCALE 1"=200'
NOTES:
1. DESIGN ELEVATION CONTOURS ON THE TAILINGS IMPOUNDMENT ALLOW FOR A 1.5 FOOT RADON BARRIER AND A 6 INCH SOIL/ROCK MATRIX EROSION PROTECTION LAYER OVER REGRADED TAILINGS. SEE FIGURE 2-1 FOR SOIL COVER PROFILE.
2. CROSS SECTIONS ARE SHOWN ON FIGURES 2-5 AND 2-6.
SCALE
200 0 200 400 FEET
REVISED FINAL RECLAMATION PLAN SOUTH END
PREPARED FOR
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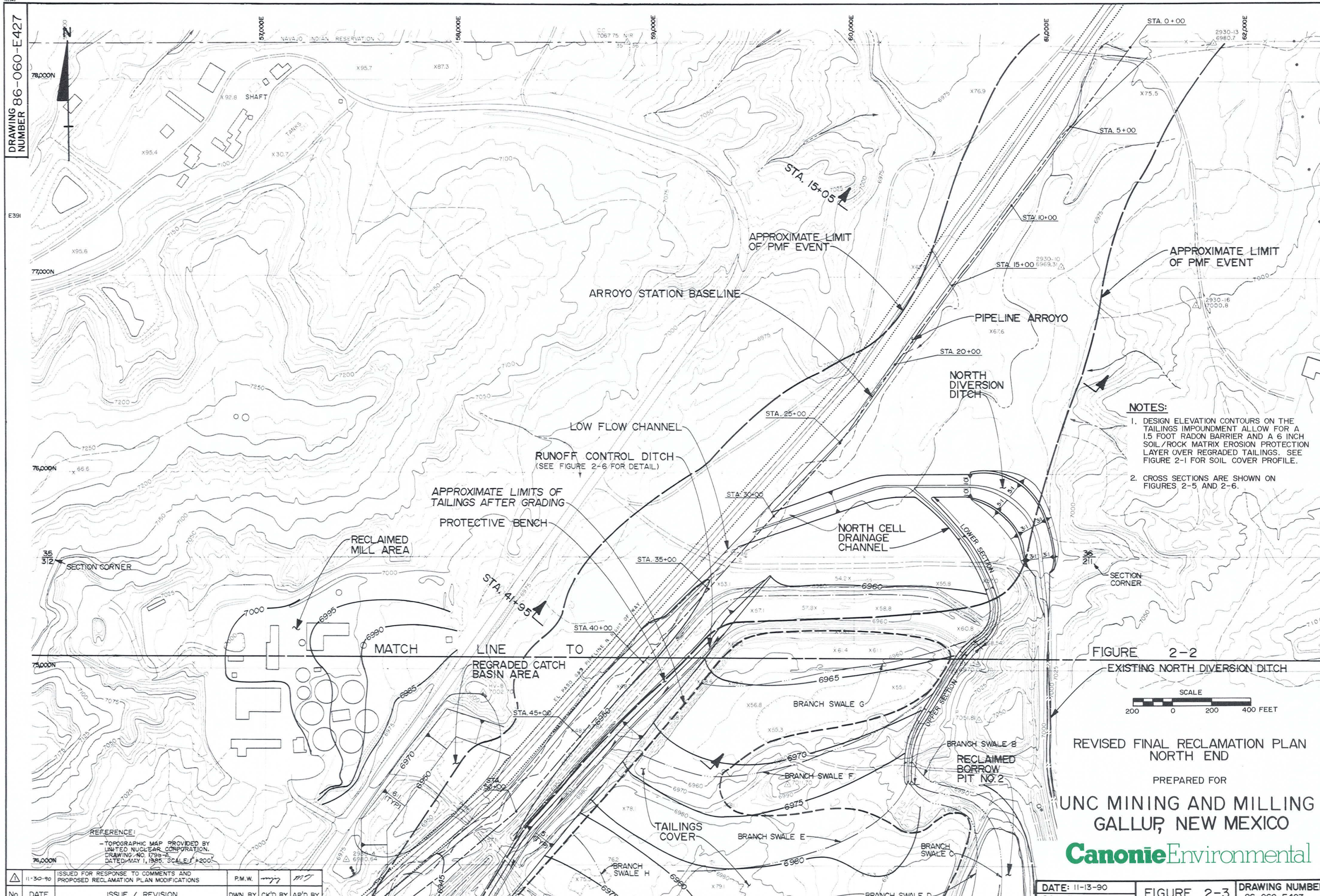
11-30-90 ISSUED FOR RESPONSE TO COMMENTS AND PROPOSED RECLAMATION PLAN MODIFICATIONS M.T.H.
No. DATE ISSUE / REVISION DWN. BY CK'D BY AP'D BY
DATE: 11-12-90
SCALE: AS SHOWN
FIGURE 2-2
DRAWING NUMBER 86-060-E425
REVISIONS NO. DATE DRAWN BY CHECKED BY APPROVED BY DRAWING NUMBER 86-060-E425



DRAWING NUMBER 86-060-E427
NAVAJO INDIAN RESERVATION
SHAFT
TANKS
STA. 0+00
STA. 5+00
STA. 10+00
STA. 15+00
STA. 15+05
STA. 20+00
STA. 25+00
STA. 30+00
STA. 35+00
STA. 40+00
STA. 41+95
STA. 45+00
APPROXIMATE LIMIT OF PMF EVENT
ARROYO STATION BASELINE
PIPELINE ARROYO
NORTH DIVERSION DITCH
LOW FLOW CHANNEL
RUNOFF CONTROL DITCH (SEE FIGURE 2-6 FOR DETAIL)
APPROXIMATE LIMITS OF TAILINGS AFTER GRADING
PROTECTIVE BENCH
RECLAIMED MILL AREA
NORTH CELL DRAINAGE CHANNEL
LOWER SECTION
UPPER SECTION
SECTION CORNER
MATCH LINE TO FIGURE 2-2
EXISTING NORTH DIVERSION DITCH
REGRADED CATCH BASIN AREA
BRANCH SWALE G
BRANCH SWALE B
BRANCH SWALE F
BRANCH SWALE E
BRANCH SWALE H
BRANCH SWALE C
BRANCH SWALE D
RECLAIMED BORROW PIT NO. 2
TAILINGS COVER
NOTES:
1. DESIGN ELEVATION CONTOURS ON THE TAILINGS IMPOUNDMENT ALLOW FOR A 1.5 FOOT RADON BARRIER AND A 6 INCH SOIL/ROCK MATRIX EROSION PROTECTION LAYER OVER REGRADED TAILINGS. SEE FIGURE 2-1 FOR SOIL COVER PROFILE.
2. CROSS SECTIONS ARE SHOWN ON FIGURES 2-5 AND 2-6.
SCALE
200 0 200 400 FEET
REFERENCE:
- TOPOGRAPHIC MAP PROVIDED BY UNITED NUCLEAR CORPORATION. DRAWING NO. 1795-A DATED MAY 1, 1985. SCALE 1"=200'
REVISED FINAL RECLAMATION PLAN NORTH END
PREPARED FOR
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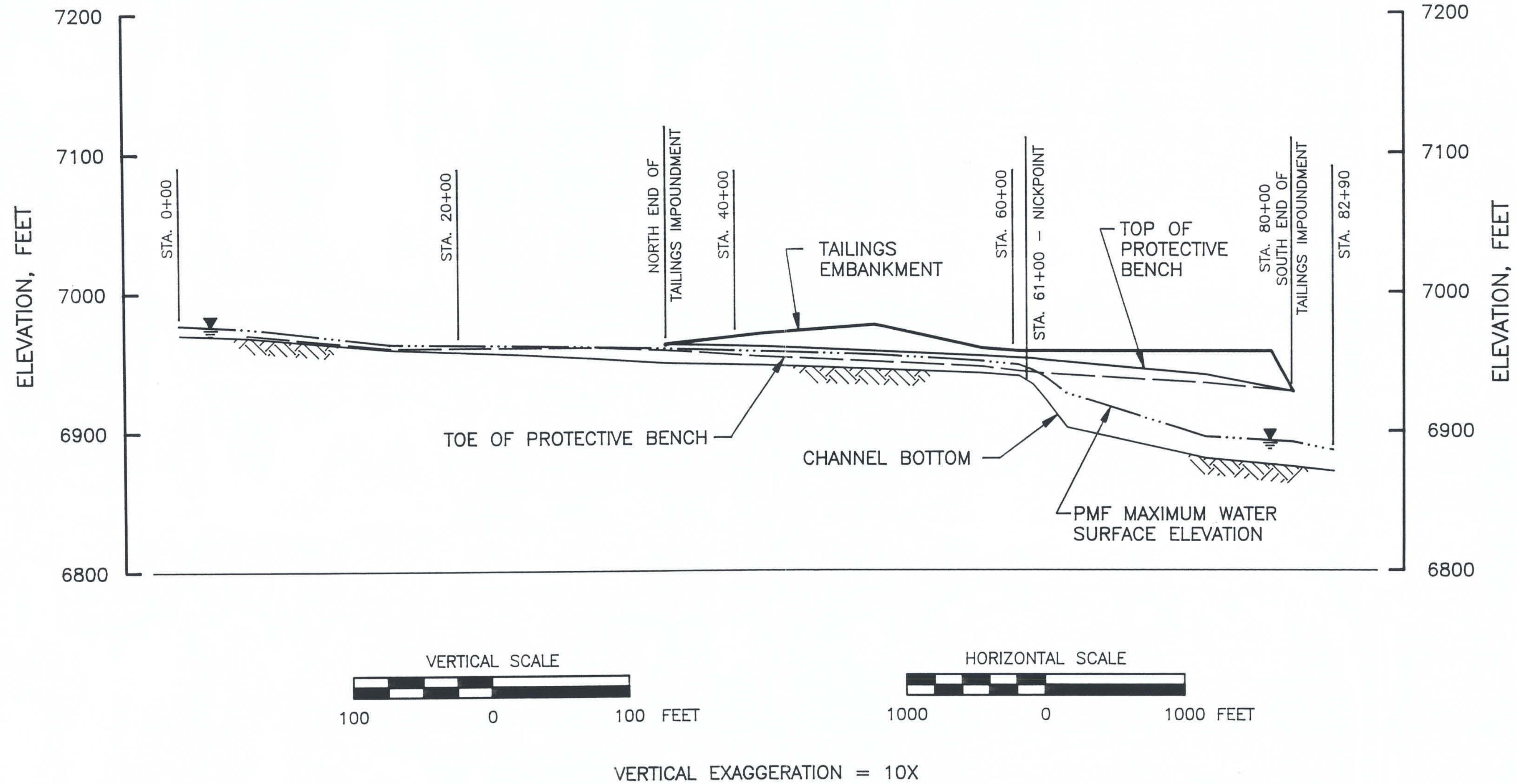
DATE: 11-13-90
SCALE: AS SHOWN
FIGURE 2-3
DRAWING NUMBER 86-060-E427
1 11-30-90 ISSUED FOR RESPONSE TO COMMENTS AND PROPOSED RECLAMATION PLAN MODIFICATIONS P.M.W.
No. DATE ISSUE / REVISION DWN. BY CK'D BY AP'D BY

DRAWING NUMBER 86-060-B420




**NOTE:**

1. ALIGNMENT OF PIPELINE ARROYO IS SHOWN ON FIGURES 2-2 AND 2-3.

PIPELINE ARROYO PROFILE

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| DATE: 11-9-90 | FIGURE 2-4 | DRAWING NUMBER 86-060-B420 |
|---|---|---|
| SCALE: AS SHOWN | | |

| No. | DATE | ISSUE / REVISION | DWN. BY | CK'D BY | AP'D BY |
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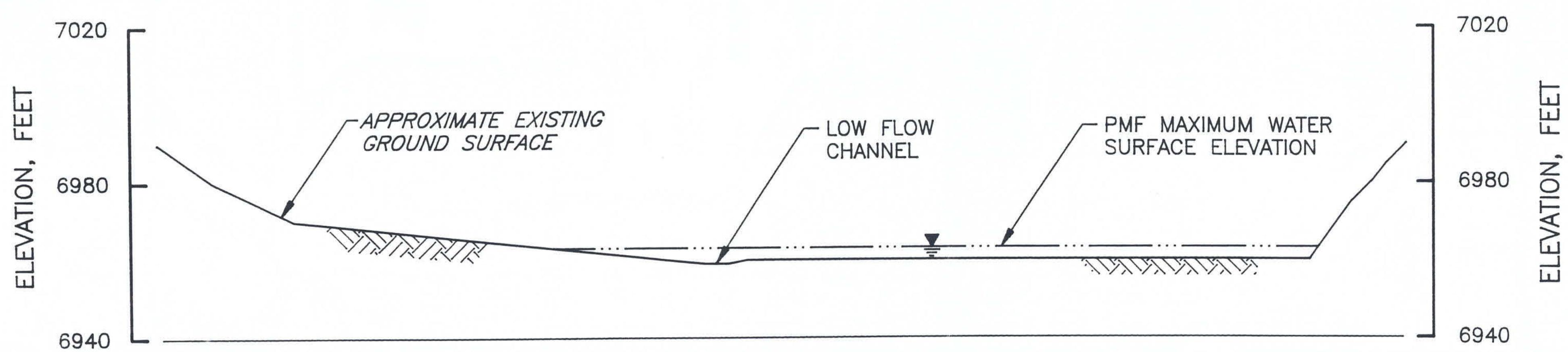
1

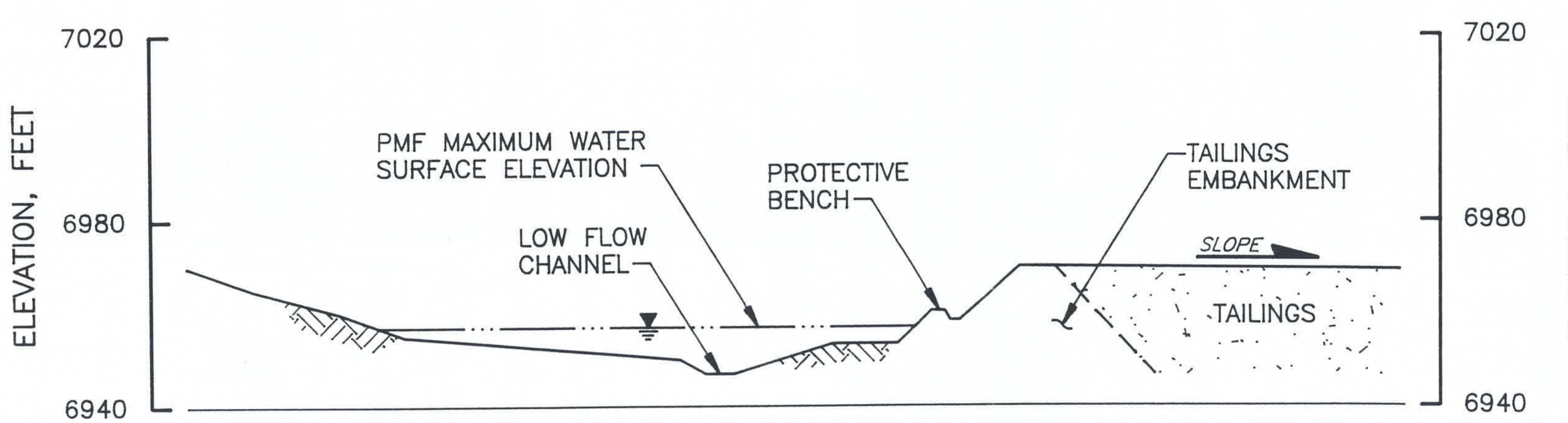
DRAWING NUMBER 86-060-B424




## PIPELINE ARROYO CROSS SECTION

STATION 15+05

(LOOKING NORTH)



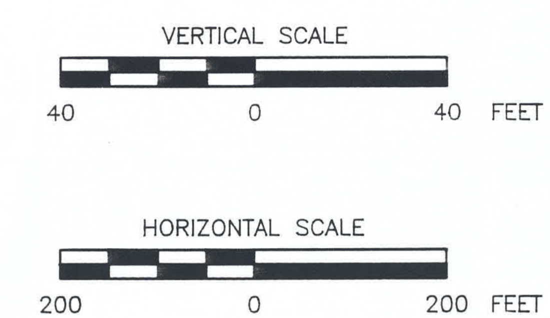

## PIPELINE ARROYO CROSS SECTION

STATION 41+95

(LOOKING NORTH)

**NOTE:**

1. CROSS SECTION LOCATIONS ARE SHOWN ON FIGURES 2-2 AND 2-3.




VERTICAL EXAGGERATION = 5X

PIPELINE ARROYO CROSS SECTIONS

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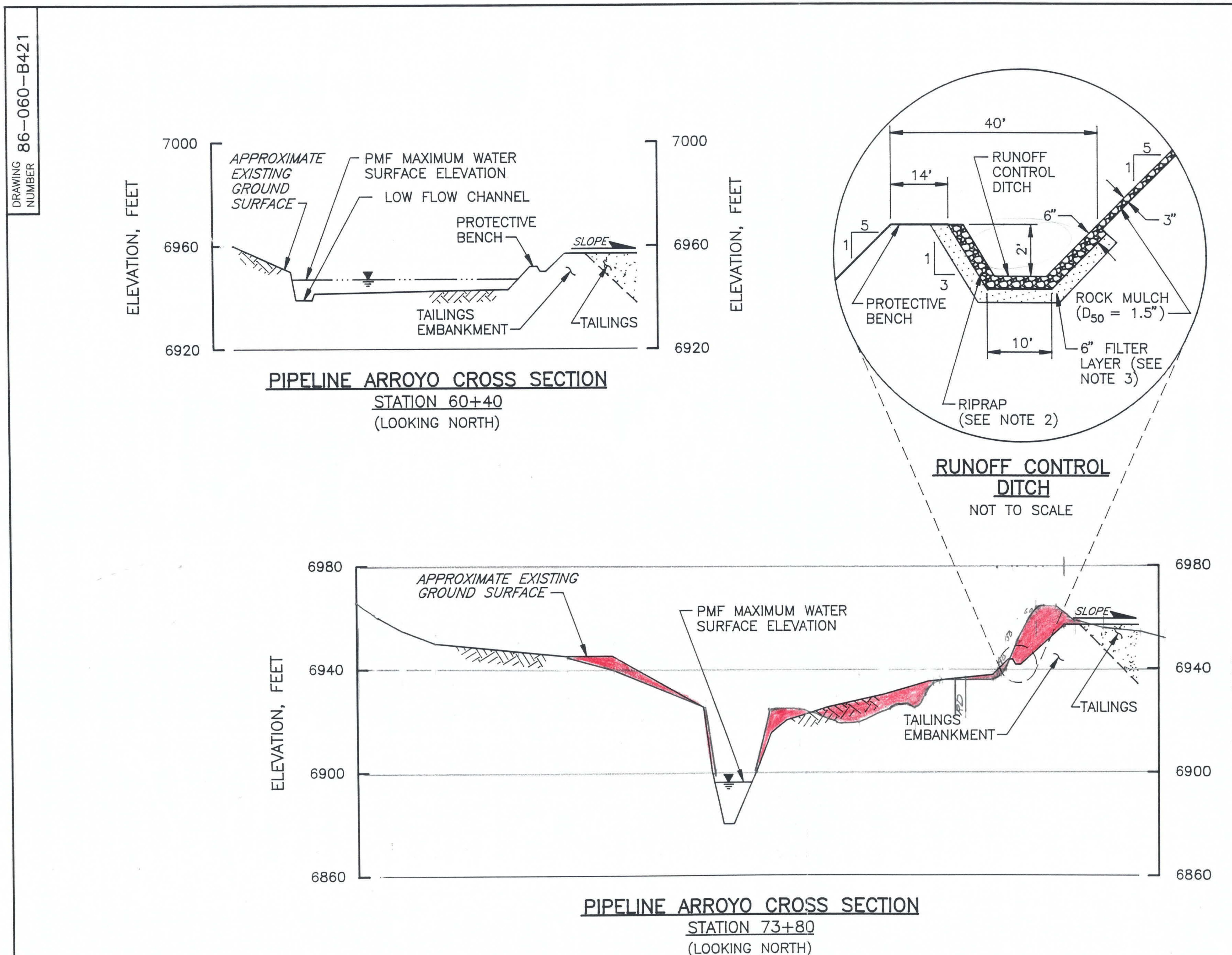
| DATE: 11-12-90 SCALE: AS SHOWN | FIGURE 2-5 | DRAWING NUMBER 86-060-B424 |
|---|---|---|

1




## NOTE:

1. CROSS SECTION LOCATIONS ARE SHOWN ON FIGURES 2-2 AND 2-3.
2. RIPRAP $D_{50}$ = 1.5" IN UPPER REACH OF RUNOFF CONTROL DITCH. $D_{50}$ = 3.0" IN LOWER REACH OF RUNOFF CONTROL DITCH.
3. FILTER LAYER REQUIRED ONLY FOR LOWER REACH OF RUNOFF CONTROL DITCH.

VERTICAL SCALE
40 0 40 FEET

HORIZONTAL SCALE
200 0 200 FEET

VERTICAL EXAGGERATION = 5X

PIPELINE ARROYO CROSS SECTIONS

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DATE: 11-12-90
SCALE: AS SHOWN

FIGURE 2-6

DRAWING NUMBER 86-060-B421


PIPELINE ARROYO AND HARD GROUND CANYON WATERSHEDS

PREPARED FOR

UNC MINING AND MILLING
GALLUP, NEW MEXICO

Canonie Environmental

REFERENCE:

COMPOSITE OF 7.5' USGS TOPOGRAPHIC QUADRANGLE MAPS OF HARD GROUND FLATS AND OAK SPRING, NEW MEXICO.
SCALE: 1" = 2000'. DATED: 1963. PHOTOREVISED: 1979.

| No. | DATE | ISSUE / REVISION | DWN. BY | CK'D BY | AP'D BY |
|---|---|---|---|---|---|
| 1 (△) | 12-3-90 | ISSUED FOR RESPONCE TO COMMENTS AND PROPOSED RECLAMATION PLAN MODIFICATIONS | M.T.H. | mjg | MT |

86-060-B428

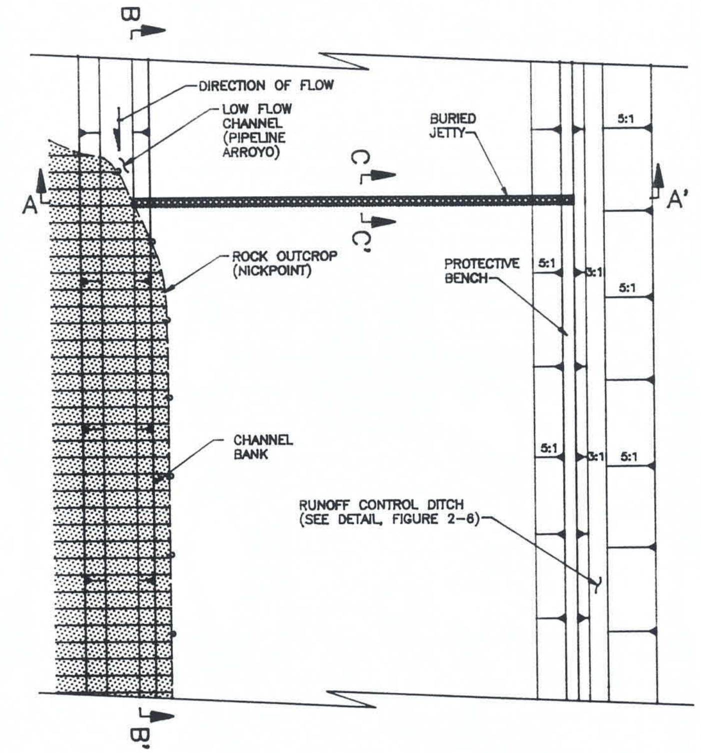
DATE: 11-14-90
SCALE: AS SHOWN

FIGURE 2-7

DRAWING NUMBER
86-060-B430
86-060-B429 △

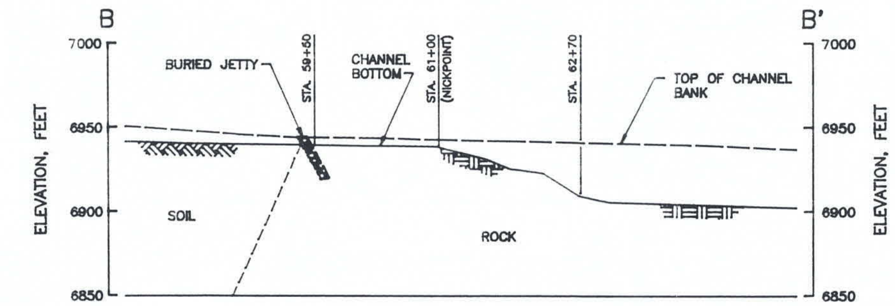
DRAWING NUMBER 86-060-B430
86-060-B428
86-060-B429
B428
B429

DRAWING NUMBER 86-060-E419




PLAN

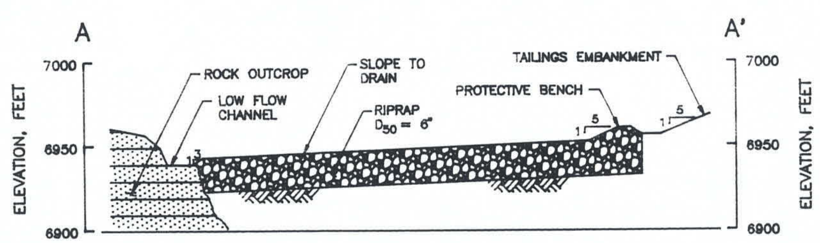
SCALE 100 0 100 FEET




SECTION B–B'
NICKPOINT REINFORCEMENT

VERTICAL SCALE 50 0 50 FEET — HORIZONTAL SCALE 100 0 100 FEET

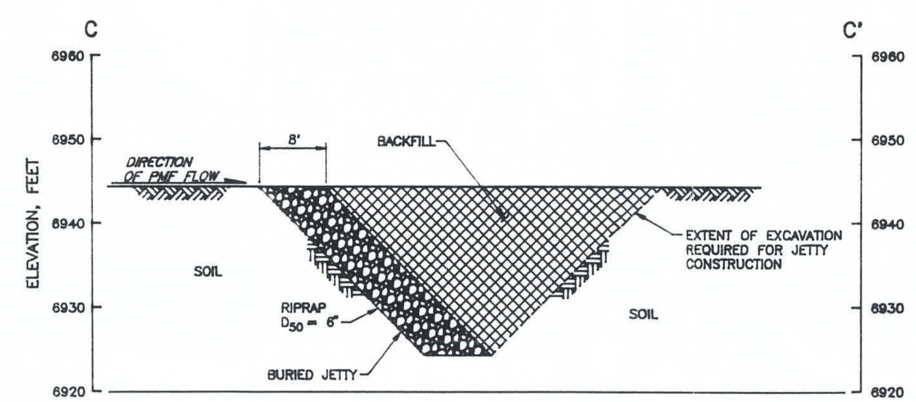
VERTICAL EXAGGERATION = 2X




SECTION A–A'

VERTICAL SCALE 50 0 50 FEET — HORIZONTAL SCALE 100 0 100 FEET

VERTICAL EXAGGERATION = 2X




SECTION C–C'

SCALE 10 0 10 FEET

BURIED JETTY DETAILS

PREPARED FOR

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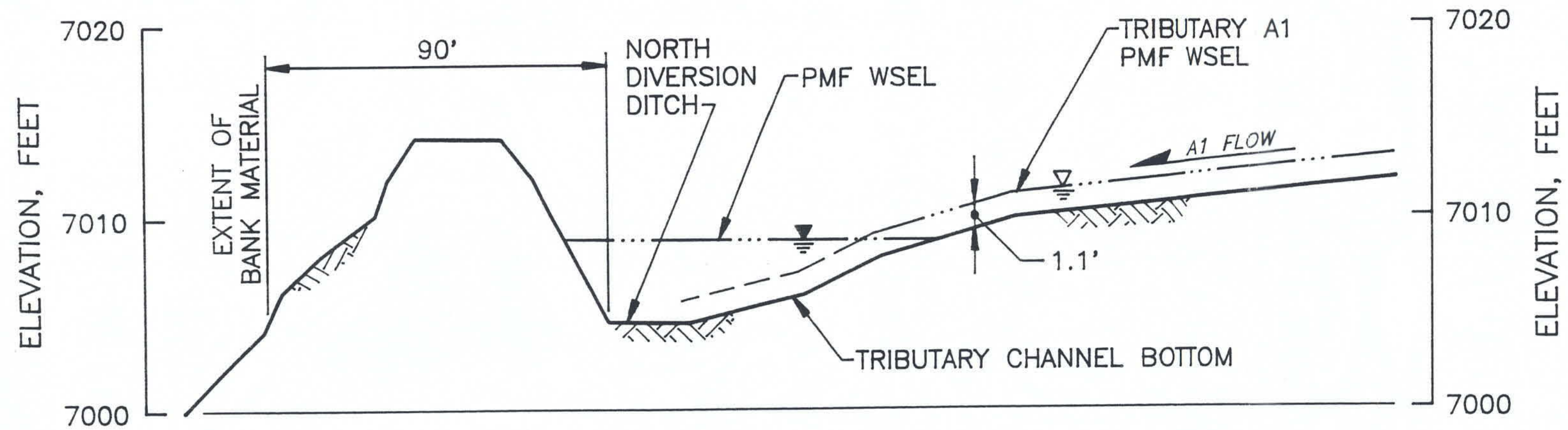
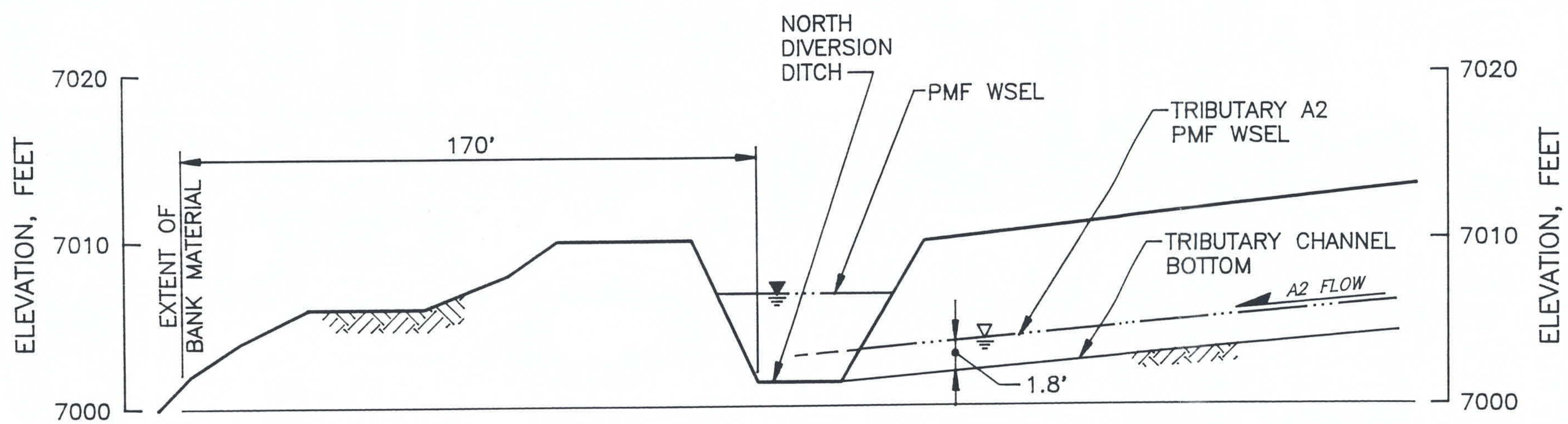
| --- | --- | --- | --- | --- | --- |
| 1 | 12/3/90 | ISSUED FOR RESPONSE TO COMMENTS AND PROPOSED RECLAMATION PLAN MODIFICATIONS | P.M.W. | mjg | MT |

| DATE: 11-15-90 | FIGURE 2-8 | DRAWING NUMBER 86-060-E419 |
| --- | --- | --- |
| SCALE: AS SHOWN | | |

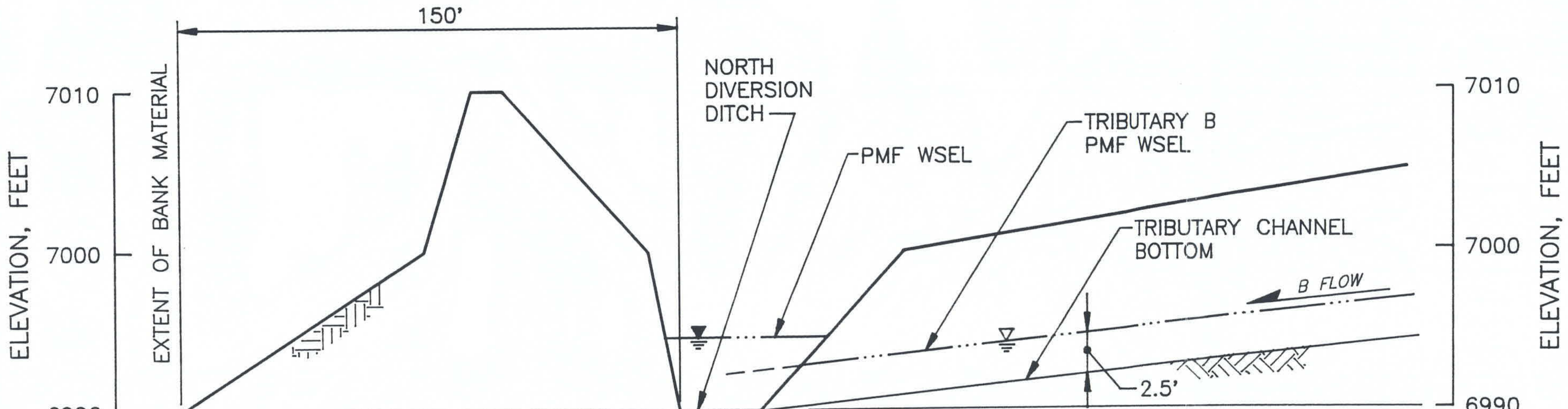
DRAWING NUMBER 86-060-B423



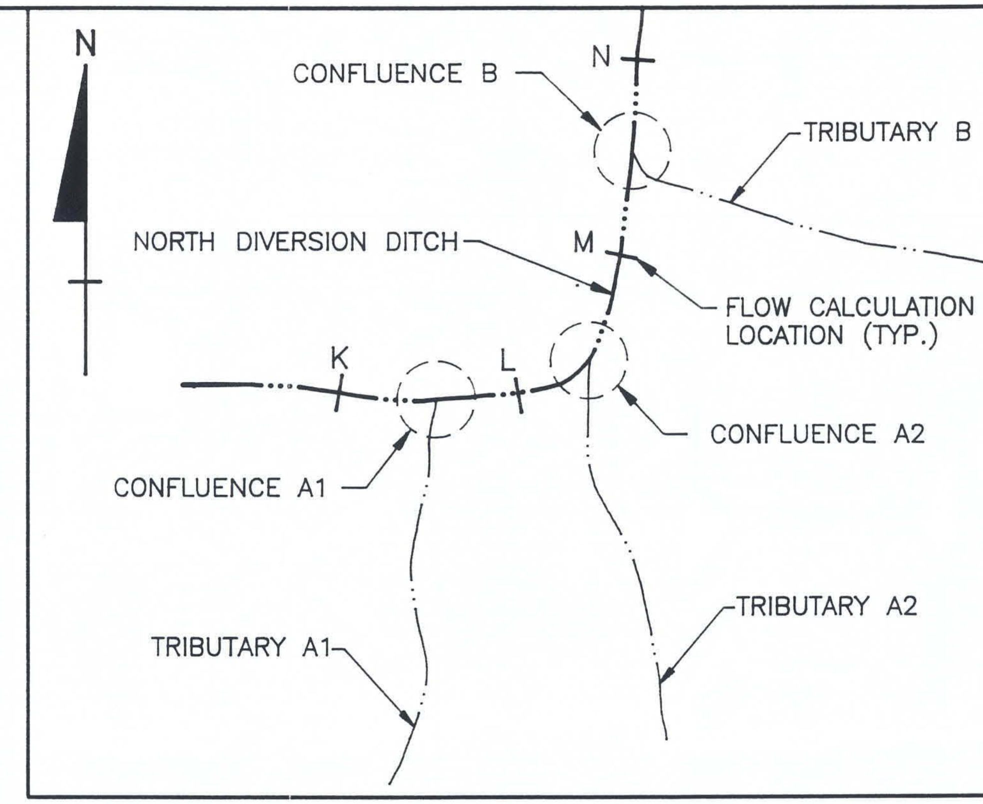

CONFLUENCE A1




CONFLUENCE A2




CONFLUENCE B




SCHEMATIC OF TRIBUTARY CONFLUENCES
(NOT TO SCALE)

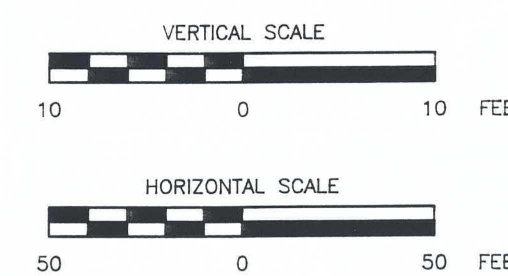
**LEGEND:**

PMF — PROBABLE MAXIMUM FLOOD

WSEL — WATER SURFACE ELEVATION

**NOTE:**

1. ACTUAL TRIBUTARY LOCATIONS ARE SHOWN ON FIGURE 2-2.




VERTICAL EXAGGERATION = 5x

NORTH DIVERSION DITCH CROSS SECTIONS

PREPARED FOR

UNC MINING AND MILLING
GALLUP, NEW MEXICO

Canonie Environmental

| No. | DATE | ISSUE / REVISION | DWN. BY | CK'D BY | AP'D BY |
|---|---|---|---|---|---|
| 1 | 12-4-90 | ISSUED FOR RESPONSE TO COMMENTS AND PROPOSED RECLAMATION PLAN MODIFICATIONS | P.M.W. | mjy | DHG |

| | | |
|---|---|---|
| DATE: 11-12-90<br>SCALE: AS SHOWN | FIGURE 2-9 | DRAWING NUMBER 86-060-B423 |

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