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.

Channel Erosion - 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.

Meander Growth - 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.

<u>Nickpoint Reinforcement</u> - 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.

Stability of the Proposed Jetty and Reach 3

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 ϕ 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.