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SOHIO WESTERN MINING COMPANY

P.O. BOX 25201, ALBUQUERQUE, NEW MEXICO 87125

TELEPHONE (505) 242-2762

URANIUM OPERATIONS

December 4, 1980

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RADIATION PROTECTION SECTION

Mr. Steve E. Reynolds
State of New Mexico
State Engineer's Office
Bataan Memorial Building
Santa Fe, New Mexico 87503

Dear Mr. Reynolds:

Enclosed is A. K. Kuhn's fourth quarter report detailing his November 10, 1980 inspection of SOHIO's L-Bar Uranium tailings dam and impoundment area. Mr. Kuhn did not note any significant changes in the dam or impoundment since the last inspection done by Mr. Frank Holliday, Woodward-Clyde.

The 1½:1 slope on the tailings dam was reestablished above the starter dam in October.

As requested in your November 5, 1980 letter, a stability analysis for the L-Bar tailings dam is included. D'Appolonia has run static, pseudo-static, and static with 100% pore-pressure build up cases. These analysis indicated that potential instability lies in liquc.action susceptibility of the saturated tailings, not in static or pseudo-static loading conditions alone.

Work on the remedial action program for the tailings dam is continuing on schedule. We will present our final plans to you on the 15th of December as agreed.

If you have any questions or comments, please call me or Alan Kuhn.

Sincerely,

S. Shaw, III
Vice-President, Operations

JJO/bm

Attachments

cc: J. Bazemore
E. Maurer
A. Kuhn w/o attachments
J. Oliver
G. Stewart, EID

D'APPOLONIA
CONSULTING ENGINEERS, INC.

December 4, 1980

Alan K. Kuhn, Ph.D., P.E.
PROJECT SUPERVISOR

Project No. NM80-740

Sohio Western Mining Company
P.O. Box 25201
Albuquerque, NM 87125
Attention: Mr. Jerry Oliver

<u>1980 Fourth Quarter Inspection Report</u>
<u>Tailings Dam</u>
<u>L-Bar Uranium Operations</u>
<u>Seboyeta, New Mexico</u>

Gentlemen:

The Fourth Quarter, 1980, Inspection of the tailings dam at the L-Bar Uranium Operations has been completed and the results of the inspection are presented below. In accordance with the first provision of the New Mexico State Engineer's letter of November 14, 1980, the inspection consisted of a visual inspection and a stability analysis of the impoundment structure.

The visual inspection indicated that conditions of the tailings dam, pond, and saddle dam have not changed noticeably in this quarter. The seepage face at some locations in the downstream slope of the first tailings raise is the only observable phenomenon which indicates a need for corrective action (remedial measures are being developed at this time). Under conditions existing at the time of the field inspection, the seepage through the first raise was not having detrimental effects (i.e., piping, sloughing, liquefaction, or surface erosion). However, increase in pond elevation or dynamic (earthquake) loading could induce one or more of these detrimental effects.

The stability analyses showed that the tailings dam has an adequate factor of safety under both static and pseudo-static (static load plus earthquake load) conditions. However, with the present phreatic level in the dam, the tailings below the phreatic surface would probably liquefy under the maximum earthquake acceleration of 0.1g, resulting in failure due to liquefaction. Our analyses of slope stability differs from that performed previously by Woodward-Clyde in that they included liquefaction by allowing for strain softening of the tailings during the earthquake and by performing static analysis with strain softened soil properties. No "pseudo-static" earthquake loading was applied in their analyses.

FIELD INSPECTION

On November 10, 1980, the undersigned performed the 1980 Fourth Quarter Inspection of the tailings dam at Sohio's L-Bar Uranium Operations. I was accompained on this inspection by Mr. Parrish and Mr. Bazemore of

2340 ALAMO, S.E., SUITE NO. 306, ALBUQUERQUE, NM 87106 TELEPHONE: 505/842-0835
BECKLEY, WV CHESTERTON, IN DENVER, CO HOUSTON, TX LAGUNA NIGUEL, CA
PITTSBURGH, PA WILMINGTON, NC BRUSSELS, BELGIUM SEOUL, KOREA

Sohio. This inspection was performed in accordance with USNRC Regulatory Guide 3.11.1 to examine and assess observable features influencing the stability and performance of the impoundment system.

Dam and Pond Elevations

The tailings dam has been constructed through the first raise and the initial lift of the second raise. Due to the suspension of further dam construction imposed by the State Engineer, no construction above the initial lift of the second raise has been done. Sohio's records indicate that the dam crest low point elevation was 6200.73 and the pond elevation was 6193.87 on October 20, 1980. From visual observations on November 10, 1980, it was evident that the freeboard was at least five feet and the sand beach was at least 200 feet wide (upstream crest of tailings dam to water surface). Sohio's pond level records show that the freeboard was 6.11 feet on November 17.

Embankment Conditions

A visual inspection of the starter dam, tailings raises, and saddle dam was made. No visible evidence of settlement, cracking, or piping was seen. At station 6+25 on the first raise a shallow (approximately 6 inches deep) slough, about five feet wide, has developed about midheight on the downsteam slope. This feature is purely surficial and does not affect stability.

The drainage system in the starter dam appears to be functioning effectively. All finger drains are functioning. Seepage from these drains is clear and totals about 10-20 gpm for the entire system. The toe drainage ditches are unobstructed and drain freely to the collection sump. The booster pump at the sump is operative.

The starter dam appears to be in good condition with no signs of distress. The crest is dry, and the slopes are apparently stable. Shallow rills, up to six inches deep, have been eroded into the downstream slope but they cause no stability problem. No rodent burrows were observed in the starter dam.

The first raise above the starter dam appears to be stable under existing conditions. Other than the surface slough noted above, no deformations were observed. The lower portion of the downstream slope, from the crest of the starter dam to 2-4 feet above that level is a weeping surface from about station 18+00 on the north to about station 13+00 on the south and from station 20+00 to 20+50. The tailings below the surface are saturated. Apparently, evaporation and drainage downward to the chimney drain of the starter dam are sufficient to keep pace with seepage through the first raise, because no running or ponded water has developed at the toe of that slope. From station 9+50 to the south along the left abutment dike raise, a similar weep occurs up to 3.0 feet above the toe of the slope, but the tailings are only moist, not saturated, at the surface.

The saddle dam has no visible signs of distress. The downstream slope is dry. No seeps or wet spots were observed.

It should be noted here that the stationing referred to above is the stationing presently posted along the dam. This stationing is different from that used on the design drawings of the dam. Sohio is in the progress of changing the posted stationing to be the same as the design stationing.

Instrumentation

Movement points and piezometers were noted but not measured by the undersigned during this inspection. Records of readings taken on the movement points on October 20, 1980, were examined. The recorded movements are all in the range of hundredths of feet, which we considered to be insignificant and within the expectable range of measurement error. Piezometer levels for the period since the last quarterly inspection show no significant change. The drop in PZ-5 has continued and the level is about one foot lower than the August, 1980, level. All other piezometer readings show changes which are within the expectable range of error in measurement.

Conclusions and Recommendations

This field inspection has determined that no apparent significant change has occurred in the tailings dam since the last inspection. Under present conditions the dam appears to be stable. Sohio's inspection program is adequate, and the responsible personnel are keeping good records of the critical observations. The seepage occurring in the slope of the first raise must be observed closely, as it has been in the past.

The following actions are recommended to enhance the stability and performance of the tailings dam:

1. Piezometers should be periodically tested (once each quarter) for sensitivity and function. The test consists of pouring water into the piezometer pipe until the water level is several feet above the level read before the test. The drop in water level should be measured at intervals of several hours to ascertain that the level in each piezometer has returned to the pretest point. If the latter has not been reached within 24 hours, the piezometer should be flushed to restore function. The undersigned will advise Sohio on the flushing procedure, if required.

   While the dam is stable under present conditions, better control of seepage and lowering of the phreatic surface in the embankment is clearly needed. The studies and plans currently in progress to control seepage and lower the phreatic surface through the tailings raise and enhance stability should be completed as soon as possible.

The slope stability of the Sohio tailings embankment must meet the safety factor criteria adopted by the State Engineer, which specify that the embankment must have a minimum safety factor of 1.5 against slope failure under static loadings at maximum operating pool elevation and minimum safety factor of 1.0 against slope stability failure under earthquake loading from a maximum earthquake acceleration of 0.1g.

STABILITY ANALYSIS

The D'Appolonia analysis of the Sohio tailings embankment examined three slope stability cases:

1) Static loading under maximum operating pool conditions.

2) "Pseudo-static" earthquake loading, corresponding to the loading condition at the beginning of the earthquake before any appreciable strain softening or pore pressure build-up has occurred.

3) Static loading with 100% pore pressure build-up in the saturated tailings soil and no pseudo-static forces. This condition would occur immediately after the end of the earthquake when the pore pressure has not had adequate time to dissipate.

The strain softening of the starter dam and native stiff clays was not considered to be large enough to appreciably effect the slope stability under a 0.1g earthquake. In addition, these soils are not susceptible to liquefaction. Therefore, strain softening of the starter dam and native clays was disregarded in these analyses.

A strong motion earthquake with a long duration of strong motion produces two potential failure modes in an embankment.

1. Pseudo-static--If the static slope stability of the embankment is very low or the earthquake magnitude is very high, slope failure may be initiated by the force of the earthquake alone. This mode of failure may be investigated by applying "pseudo-static" forces that represent the strong motion forces generated by the earthquake. Generally, a failure under pseudo-static forces alone occurs only in embankments which already have very low static slope stability safety factors, or in the case of very severe earthquakes.

2. Liquefaction--An embankment which has a high static slope stability safety factor may be subject to slope failure during an earthquake as a result of strain softening of the embankment material. The amount of strain softening is related to the number of equivalent strong motion cycles in the earthquake. The softening effect is non-linear with the earlier earthquake cycles producing less strain softening than the latter cycles. In the case of a saturated uniform loose cohesionless soil the strain softening is accompanied by an increase in the pore pressure. If enough strong earthquake cycles occur, this pore pressure may become equal to the total stress of the overlying overburden. This condition is termed "liquefaction" and is responsible for many flow slide embankment failures. Loose saturated mining tailings placed by hydraulic techniques are very susceptible to this mode of failure during an earthquake.

Liquefaction Potential

An assessment of liquefaction potential was made using the data reported in Woodward-Clyde, 1980. This report presents penetration resistance data from both Standard Split Spoon (SPT) blowcounts and Cone Penetration Resistance (CPT). The tailings sand classification is showned in Appendix A of Woodward-Clyde, 1980, as mainly SM (Unified Soil Classification System). The grain-size curves indicate a very uniform material with the major portion of the distribution between a No. 50 and No. 200 sieve, classified as a uniform fine sand. This type of material in a loose condition is highly susceptible to liquefaction.

The SPT penetration resistance data was summarized and found to have a range of 0 to 4 blows per foot in the tailings. CPT penetration resistance as presented in Appendix B of Woodward-Clyde, 1980, were converted to SPT blowcounts using a conversion factor of 4. The converted CPT resistances produced SPT blowcount equivalents ranging from 0 to 4 blows per foot in the tailings. The high CPT penetration resistances noted in the top few feet of the tailings were disregarded when making this summation.

The SPT blowcount ranges were compared to two correlations between SPT blowcount and cyclic stress ratio. These correlations, presented by Seed (1976) and Castro (1975) are based on the known response of sands during earthquakes. The cyclic stress ratio from the 0.1g maximum acceleration earthquake was evaluated by the simplified shear column approach (Seed and Idriss, 1971). The stress ratio necessary to cause liquefaction was determined to be 0.07 at the top of the saturated tailings and 0.11 at the bottom of the saturated tailings. With the SPT blowcount range of 0 to 4 blows per foot and the above stress ratios, both the Seed and Castro liquefaction correlations indicated a high potential for liquefaction (safety factor against liquefaction less than 1.0). Therefore, the liquefaction of saturated tailings sands was considered in the ensuing slope stability assessment by reducing the strength of the saturated sands to near zero (see Table 1). This condition corresponds to a time immediately after the strong motion shaking from the earthquake has ceased.

Slope Stability Assessment

The stability analyses were performed using the STABL computer program for limiting equilibrium slope stability analysis. This program was developed at Purdue University in 1975 for the Indiana State Highway Commission and has been verified and updated by the D'Appolonia Quality Assurance Group. STABL has been used previously on stability analyses of other uranium tailings dams, and the results of these analyses have been accepted by the NRC.

The STABL program requires input of soil properties. The soil strength properties for the starter dam and native soils were taken from Woodward-Clevenger and Associates, 1974. The soil strength properties for the tailings were estimated based on the SPT blowcount range of 0 to 4 blows per foot. Again the stiffer tailings layer indicated at the surface by the CPT resistances was disregarded when assessing the strength properties of the tailings. The soil strength properties used in the analysis are listed in Table 1.

The slope stability was investigated on the maximum height section, Section E-E' (Woodward-Clyde, 1980) for five selected failure modes. The first mode is a wedge type block failure with sliding through the native soil under the starter dam and exit near the top of present embankment. The second mode is a wedge type block failure with sliding through the native soil under the starter dam and an exit point on the beach area. The third mode is a circular failure arc under the starter dam with an exit point on the beach area. The fourth mode is a shallow circular arc totally within the tailings at the top of the embankment. The fifth mode, used only for the liquefaction case, is a wedge type sliding failure totally within the saturated tailings. These failure modes are illustrated in Figure 1, 2, and 3.

Each mode was analyzed using the generalized procedure of slices (Janbu method). The calculations were performed by computer with 100 potential failure surfaces analyzed for each mode. The results of analyses are presented on Figures 1, 2, and 3. Figure 1 shows the most critical static loading failure surface for each of the first four modes. Mode 1 has the lowest safety factor, 2.07 under static loading. Figure 2 shows the most critical failure surface for each of the first four modes under pseudo-static earthquake loading (0.1g maximum horizontal acceleration). Mode 4 has the lowest pseudo-static safety factor, 1.49. Figure 3 shows the most critical failure surfaces under static loading with liquefaction. In this case mode 5 is most critical with a safety factor of 0.25, although mode 4 also indicates failure with a safety factor of only 0.73.

In addition, Section A-A' (Woodward-Clyde, 1980) was investigated for stability under liquefaction conditions. Three modes of failure where investigated. The first was a circular arc in the tailings, the second was a wedge analysis of a sliding block through the native soil, and the third was a wedge analysis of a sliding block within the saturated tailings with an exit near the upstream crest. The third mode had the lowest factor of safety, 0.87, and was the only mode which failed under liquefaction conditions. Figure 4 shows the locations of the critical failure surfaces for all three modes.

The present tailings dam configuration with the high phreatic surface in the tailings is very susceptible to liquefaction-induced failure. The full extent of the flow produced by liquefaction is not quantitatively assessible.

Conclusions on Stability Analysis

Although the visual inspection of the tailings dam revealed no evidence of instability under present conditions, the need for controlling seepage through the embankment, noted during the field inspection, is supported by the stability analyses. These analyses indicate that potential instability lies in the liquefaction susceptibility of the saturated tailings, not in static or pseudo-static loading conditions alone. The most effective method of reducing liquefaction potential is to reduce the thickness of saturated tailings, i.e., to lower the phreatic surface. Additional analyses, now in progress, will show that lowering the phreatic surface significantly below the present level should produce adequate stability against a liquefaction-induced failure.

If I can be of further assistance, or if you have any question on this report, please contact me.

Yours very truly,

Alan K. Kuhn

Alan K. Kuhn
Project Supervisor
N.M. PE No. 6798

AKK:tac

TABLE 1

Soil Strength Properties

Slope Stability Analysis

Soil	Total Unit Weight (PCF)	Moist Unit Weight (PCF)	Friction Angle, ϕ	Cohesion, (PSF)
Native Soil	129	--	10°	1000
Starter Dam				
Saturated	122	--	10°	700
Unsaturated	--	100	10°	3900
Tailings	118	100	25°	--
Liquefied Tailings	118	--	1°	--

REFERENCES

Castro, G., 1975, "Liquefaction and Cyclic Mobility of Saturated Sands," Journal of the Geotechnical Engineering Division, ASCE, Vol. 101, No. GT6.

Seed, H. B., 1976, "Evaluation of Soil Liquefaction Effects of Level Ground During Earthquake," Proceedings of the Symposium on Soil Liquefaction, ASCE National Convention, Philadelphia.

Seed, H. B., and I. M. Idriss, 1971, "Simplified Procedure for Evaluating Soil Liquefaction Potential," Journal of the Soil Mechanics and Foundations Division, ASCE, Vol. 101, No. GT9.

Woodward-Clyde, 1980, "Geotechnical Evaluation Tailing Storage Area Sohio L-Bar Uranium Project," prepared for Sohio Westerm Mining Company and Reserve Oil and Minerals Corporation.

Woodward-Clevenger and Associates, 1974, "Engineering and Geologic Investigations and Consultation for Tailing Dam Sohio L-Bar Uranium Project," prepared for Fluor-Utah, Incorporated.

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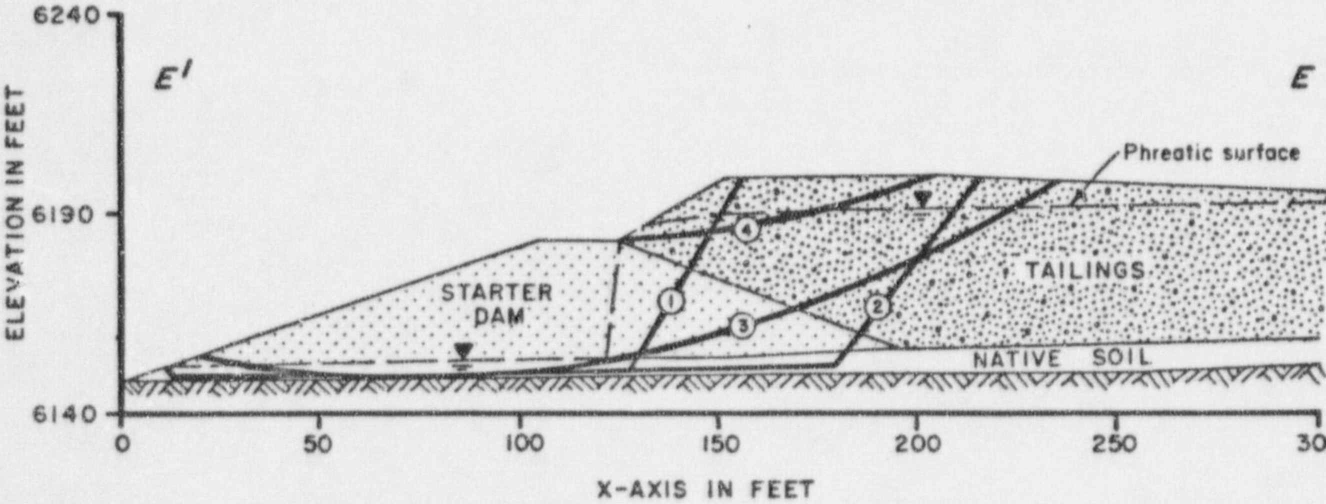

FAILURE MODE	SAFETY FACTOR
①	2.07
②	2.19
③	2.24
④	2.09

FIGURE 1

TAILINGS DAM SECTION E-E'
L-BAR URANIUM OPERATIONS
STATIC SLOPE STABILITY
CRITICAL FAILURE MODES

PREPARED FOR

SOHIO WESTERN MINING COMPANY
SEBOYETA, NEW MEXICO

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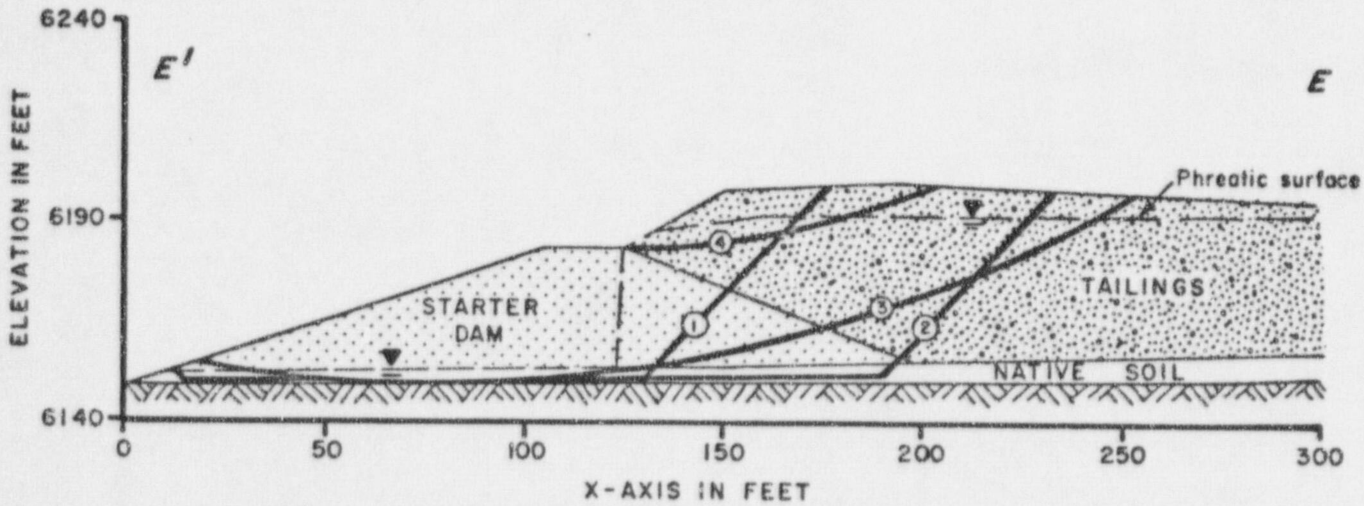

FAILURE MODE	SAFETY FACTOR
①	1.56
②	1.67
③	1.65
④	1.49

FIGURE 2

TAILINGS DAM SECTION E-E'
L-BAR URANIUM OPERATIONS
PSEUDO-STATIC SLOPE STABILITY
CRITICAL FAILURE MODES

PREPARED FOR

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19 1253 HERCULENE. A&B SMITH CO., PGH., PA LT1530.1079

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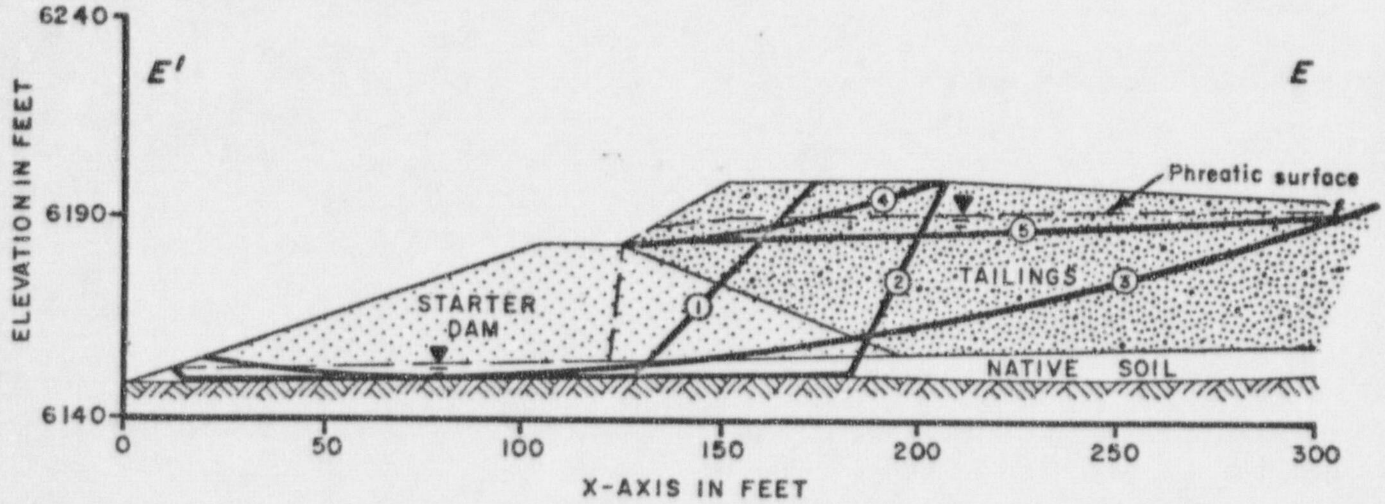

FAILURE MODE	SAFETY FACTOR
①	1.77
②	1.95
③	2.16
④	0.73
⑤	0.25

FIGURE 3

TAILINGS DAM SECTION E-E'
L-BAR URANIUM OPERATIONS
STATIC SLOPE STABILITY WITH
LIQUEFIED TAILINGS
CRITICAL FAILURE MODES

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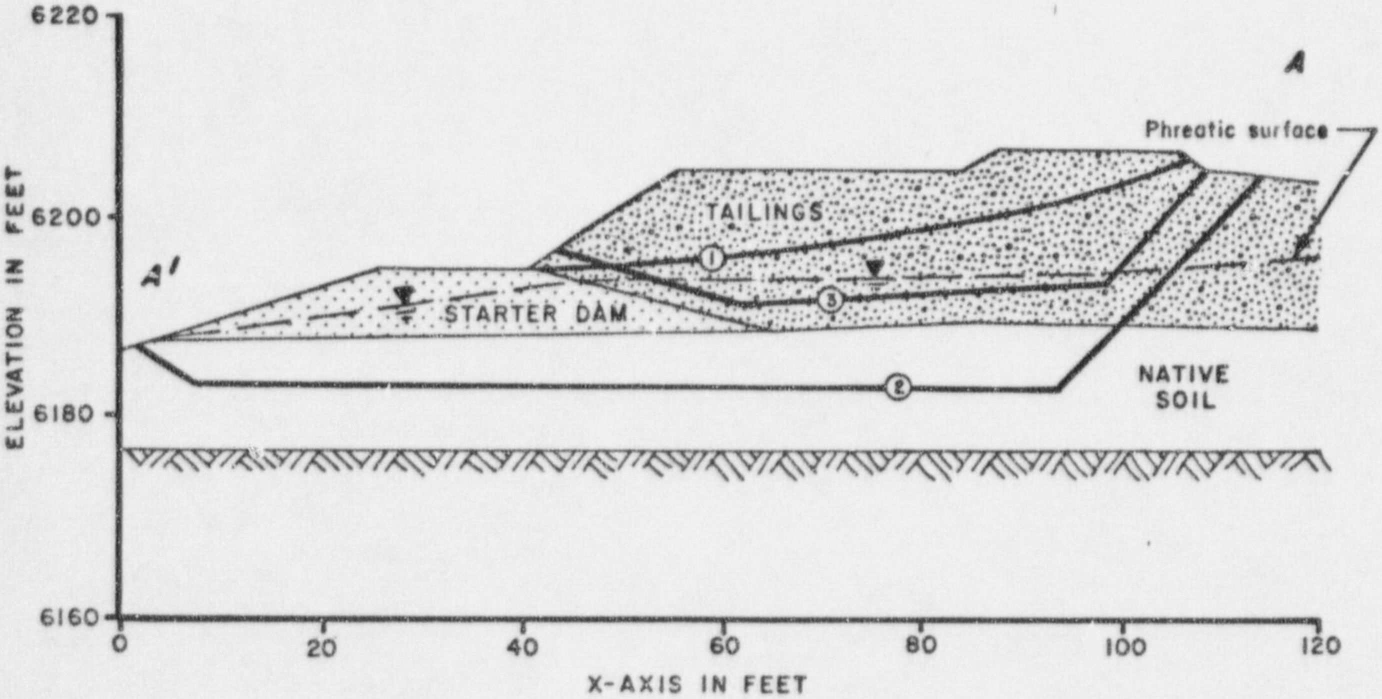

FAILURE MODE	SAFETY FACTOR
①	2.92
②	5.20
③	0.87

FIGURE 4

TAILINGS DAM SECTION A-A'
L-BAR URANIUM OPERATIONS
STATIC SLOPE STABILITY WITH
LIQUEFIED TAILINGS
CRITICAL FAILURE MODES
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