ATTACHMENT 2

REVISED PAGES OF WBN CALC. WCG-1-547
INTAKE CHANNEL SLOPE STABILITY ANALYSIS

APPENDIX B

PARAMETRIC STUDY

THIS SHEET ADDED BY REV 1

WCG-1-547

SHEET B1 OF
WATTS BAR NUCLEAR PLANT

PARAMETRIC STUDY OF SLOPE STABILITY
INTAKE CHANNEL AT IPS

COMPUTED HRT DATE 4/26/91
CHECKED ICL DATE 4/26/91

PURPOSE:

To modify the critical section of this analysis, see sheet 8, to more closely reflect actual field conditions. To make a parametric study of the modified critical section, by varying the soil strengths of the potentially liquefiable silty-sand layer, to evaluate the conservatism in the critical section of the existing analysis.

BACKGROUND:

During the NRC audit in April, 1991, the NRC reviewer expressed concern about how reasonable the reduction in strengths of the silty sand was with respect to the marginal factor of safety for the critical section (FS = 1.038). Although this was above the required factor of safety of 1.0, he indicated concern that a slightly larger reduction would possibly yield a FS < 1.0.

In discussions with the reviewer about this concern, it was identified that there were several conservatisms used in the development of the critical section that would if included in the model increase the resultant factor of safety. These conservatisms included;

1. The depth of silty sand between the intake channel fill and the fill for the underground barrier was deeper than actual field conditions.

2. The assumption of using clay fill properties for the granular fill properties in the south end of the underground barrier.

3. The assumption of a higher ground water level in the fill slope than required by the design criteria.

4. Use of a 4:1 slope for the intake channel embankment rather than an actually flatter slope due to the curve of the section being evaluated.

5. Lack of consideration of information about the excavation of the intake channel and the intake pump station that would show a reduced area of potentially liquefiable silty-sand material.

6. Lack of consideration of soil boring information that would show the existence of alluvial basal gravel in the area rather than just the potentially liquefiable silty-sand material.

The reviewer requested a revision of this calculation to include a reassessment of the critical section and a parametric study of the strength of the silty-sand in the modified critical section to evaluate the conservatism of the existing analysis.

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PARAMETRIC STUDY OF SLOPE STABILITY
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APPROACH:

1. Gather available information that would provide information about the excavation around the IPS, the excavation and backfilling of the intake channel, and for the excavation and backfilling of the underground barrier - trench B.

2. Compile soils information obtained in borings made in the area of the IPS and intake channel.

3. Reassess the critical section using the above information in conjunction with the information used to develop the critical section.

4. Develop appropriate soil properties for each material.

5. Do a parametric study, using the same computer program (REAME), of the revised section by varying the soil properties (ϕ and c) between a reasonable upper and lower bound properties.

6. Summarize the parametric study and compare the result of the existing analysis with the result of the parametric study.

7. Develop a conclusion about the parametric study.

REFERENCES:

1.0 TVA Drawings
- 1.1 "Excavation & Gantry Crane Layout Intake Pumping Station," 601N10131 (R1).
- 1.2 "Grading Plan Intake Channel," 10N215 (R9).
- 1.3 "Underground Barriers for Potential Soil Liquefaction," 10N213-1 (R1).
- 1.4 "Underground Barriers for Potential Soil Liquefaction," 10N213-2 (R6).

2.0 TVA Documents
- 2.1 "Watts Bar Nuclear Plant Site Investigation and Laboratory Testing," Report No. 9-2014, (CSB771006050).

3.0 Design Criteria
- 3.1 "Intake Pumping Station Concrete Structure, Intake Channel, and Retaining Walls," WB-DC-20-19 (R8).

4.0 Design Guides and Standards (None)

5.0 Codes and Standards (None)

6.0 TVA Calculations
- 6.1 "Analysis of As-Built Conditions for Remedial Treatment for Liquefaction Potential for ERCW Pipeline," WCG-1-737 (R1).
- 6.2 "Seismic Analysis of WBN Intake Channel," (CEB801114079).

7.0 Others

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7.1 Seed, H. Bolton, Tokimatsu, K., Harder, L. F., and Chung, Riley M., "The Influence of SPT Procedures in Soil Liquefaction Resistance Evaluations," EERC-84-15, Oct. '84.

ASSUMPTIONS: None

ANALYSIS:

Compile Information of Excavation

The excavation of the IPS is detailed on drawing 601N10131 (ref 1.1). This drawing was produced by the Div. of Const. to detail the excavation of the IPS. Reference 6.2 provides information on the excavation of the channel in the area of the critical section. This information detailed a silty-sand layer that extended to ~~for~~ a deeper depth to the weathered shale. This material was excavated and replaced with granular material which was stronger than the basal gravel. Several photographs of the excavation of the area around the IPS were also reviewed during this parametric study. HRT 4-26-91

The details of the excavation of the intake channel is shown on reference 1.2 which provides design information of how the excavation was to take place.

The details of the excavation of the underground barrier are shown on references 1.3 and 1.4. As-built cross-sections of the underground barrier are shown in reference 6.1. A profile along the east and west sides of the underground barrier prepared by Const. shows details about the end configuration of trench B.

Available Soils Information

Section 3 of reference 2.1 provides details of soil borings made in the area of the critical section. This report shows 3 soil borings were made in the vicinity of the area in question. Borings SS-20, SS-25 and SS-37 show data that would be useful in establishing the soil profile for the stability section.

Reassessment of the Critical Section

Figure 2 (sheet 26) shows the critical section that was analyzed in this calculation. Figure B1 (sheet B78) shows the revised section that is being evaluated in this parametric study. There are several notable changes which are detailed as follows with an explanation for the change.

1. The basis for the parametric study is to analyze a section cut along the inside curve of the construction road on the SW side of the IPS shown on reference 1.1. The section being evaluated for the parametric study appears to line up reasonably well with the critical section used in the existing calculation.

2. The contact between the clay fill making up the intake channel and the underlying base (ie. rock) is set at

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Elevation 665. This was done because a review of the existing analysis will show that this area is not critical to the stability of the channel. It is not critical for the stability of the section whether rock or crushed stone is shown at the interface.

3. The contact between the backfill in the underground barrier and the base (ie. rock) is based on the as-built cross-sections of the underground barrier (see ref. 6.1).

4. The backfill in the underground barrier that was conservatively taken in the existing analysis as clay backfill is replaced with granular fill properties based on the as-built cross-sections of the underground barrier (see ref. 6.1).

5. The excavation line of the underground barrier is taken from the profiles that construction prepared on the east and west sides of the underground barrier.

6. The depth of the silty-sand layer is established at the interface with the underground barrier based on the depth of sand shown on the cross-section for Station 0+31. The sand is shown to be 6 feet deep on the west side of the section. The depth of sand at the interface of the sand layer with the backfill of the intake channel fill is estimated based on interpolation of data from borings SS-25 and SS-37 (see ref 2.1).

7. The layer of basal gravel is included based on interpolation of data from borings SS-25 and SS-37 (see ref 2.1). The cross-sections of the underground barrier do not show any basal gravel, but all three of the soil borings in the area do show a layer of basal gravel. The properties of the basal gravel are based on those properties used in the analysis calculation of the intake channel (see ref 6.2).

8. The ground water table was lowered slightly to reflect the water levels given in the design criteria (ref 3.1), from that used in the existing analysis. In addition, the water level was adjusted upward in the area within the underground barrier to reflect the design groundwater levels used in the underground barrier calculation (see ref 6.1).

9. The slope of the section for the intake channel fill reflects the actual slope considering the curvature of the section rather than the maximum slope of 4H:1V for the intake channel fill.

Soil Properties

The soil properties used in this parametric study are the same as the existing analysis, except for the addition of the basal gravel and backfill (ie. granular fill and earthfill) for the underground barrier. As noted earlier, the properties for the basal gravel are

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based on the properties used in the intake channel analysis (see ref 6.2). The properties used for the backfill in the underground barrier are based on the properties used in the analysis of the underground barrier (see ref 6.1). The design properties of the earthfill in the underground barrier are used instead of the "as-built" results from the shear strength testing of the block samples taken during the construction of the underground barrier. The use of the design properties in lieu of the "as-built" properties is an additional conservatism in this analysis.

Since the concern is with the strength loss of the silty-sand, a parametric study will be performed varing the cohesion (c) and angle of internal friction (ϕ) properties of the potentially liquefiable silty-sand layer. The design soil parameters of the silty-sand is a cohesion of 600 lb/ft^2, and an angle of internal friction of 20^0 (see ref 3.1). The variation used in the existing calculation (ie. cohesion reduced by 50% and ϕ reduced by 30%) will be enveloped in the study. Additional justification for the reduction in the existing calculation is as follows:

1. The average number of cycles (N = 16) that it took, in the cyclic triaxial tests on silty-sand samples from the intake channel (see ref 2.1), to reach 100% pore pressure (ie. initial liquefaction) exceeds the average number of cycles (N = 5 to 6) to obtain initial liquefaction for a magnitude 5.8 earthquake (see ref 7.1). The minimum number of cycles from the cyclic testing was 4, however this test was on a sample with SPT blow counts of 1 or 0. The average SPT blow count for silty-sand material from nearby borings to the analysis section was N = 10±, thus the low cycles in the cyclic triaxial are not representative tests.

2. The extensive construction activities, including vibration from heavy equipment and the dewatering activities for the intake channel and the underground barrier, around the zone of material left in place would be conducive to densification the layer and further reducing the potential for the layer to liquefy.

Parametric Study

The parametric study will be made on the modified profile for the intake channel adjacent to the IPS (see Figure B1 - sheet 78). The parametric analysis will be done using the same program (REAME) used in the existing analysis.

Sheets B7 to B72, are the analysis output files for the parametric study. The analysis input data is echoed in the initial portion of the output. The results of the analysis for each trial are summarized in the output, with the critical circle (center and radii) and factor of safety summarized at the end of each run.

Sheets B73 to B77 represent a run made with the modified profile, but with a 50% reduction in cohesion and an 30% reduction in ϕ, to provide a comparison with the existing analysis. The resultant factor of

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safety was 1.160. Figure B2 (sheet B79) shows the critical arc for this analysis.

Summary

The following table summarizes the results (Factor of Safety) of the various runs made in the parametric study.

CRITICAL FACTOR OF SAFETY

RUN #	LAYER 2 *		FACTOR OF SAFETY	REFERENCE SHEET
	COHESION (lb/ft^2)	ϕ		
1	600	20^0	1.398	B7-B12
2	450	20^0	1.330	B13-B17
3	300	20^0	1.260	B18-B22
4	150	20^0	1.186	B23-B27
5	600	15^0	1.322	B28-B32
6	450	15^0	1.251	B33-B37
7	300	15^0	1.176	B38-B42
8	150	15^0	1.098	B43-B47
9	300	14^0	1.160	B73-B77
10	600	10^0	1.245	B48-B52
11	450	10^0	1.170	B53-B57
12	300	10^0	1.092	B58-B62
13	600	5^0	1.165	B63-B67
14	450	5^0	1.061	B68-B72

* Potentially liquefiable silty-sand layer

The use of actual field conditions in the existing analysis allowed an approximately 12% increase in the Factor of Safety for the slope.

$$\frac{1.160 - 1.038}{1.038}(100) = 11.7\%$$

CONCLUSION:

The above parametric study has shown that the existing analysis, when actual field conditions are used in the model, has an adequate margin of safety when using reasonable reductions (50% of cohesion and 30% of ϕ) in strengths of the potentially liquefiable silty-sand layer for the "during the earthquake" case.

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ATTACHMENT 3

PREVIOUS RESPONSE PROVIDED AND REVIEWED BY THE STAFF
INTAKE CHANNEL SLOPE STABILITY ANALYSIS

Question 4 In the description of the analyses provided, the vertical earthquake coefficient is not included in determining effective loads and strengths. Simultaneous application of both the horizontal and vertical earthquake loads is typically included in these stability calculations.

Response: Investigation of seismic stability of embankments and slopes against earthquake forces using pseudo-static analyses has been described in detail by Seed and Martin (reference 1). In this approach the stability of a potential sliding mass is evaluated in a similar manner as for static loading conditions, with the effects of earthquake loading taken into account by including an equivalent horizontal seismic force in the computations. The horizontal seismic force is expressed as the product of the weight of the sliding mass under consideration and a seismic coefficient. If the product of the seismic coefficient and the weight of the potential sliding mass represents the maximum inertia force developed on the mass during the design earthquake, then the application of this force, which would act for only an instant of time, as a static force would result in a very conservative assessment of effects due to earthquake loading (reference 1).

TVA evaluated the necessity of including a vertical seismic coefficient by several methods:

a. TVA studied 40 strong motion (actual) earthquake accelerograms (Reference 2 and 3). There were only two instances where the peak horizontal and vertical acceleration components occurred in the same time frame. It is unrealistic to automatically assume these components simultaneously occur in the direction of least stability.

b. The Corps of Engineers (reference 4) account for only an additional horizontal force in a pseudo-static stability analysis.

c. Sarma (reference 5) showed that consideration of some angle of incidence of an earthquake acceleration (to create both horizontal and vertical inertial forces) with the base of an embankment would not provide much difference in resultant factors-of-safety, and concluded that use of only horizontal acceleration could be adopted for stability analysis calculations.

d. In addition supporting this position, the seismic pseudo-static stability analyses performed on the safety related intake channel slopes at Watts Bar considered only a horizontal seismic coefficient. Section 2.5.5 of the NRC's Safety Evaluation Report (NUREG-0847), June 1982 concludes.... slopes have been analyzed by the applicant in a reasonable manner.... and are acceptable.

Therefore, in summary vertical seismic coefficients need not be used in the pseudo-static slope stability analysis to calculate forces due to earthquake loading for the following reasons: (a) use of a peak horizontal seismic coefficient to compute the equivalent horizontal force and apply it as a static force is very conservative; (b) it would be extremely unlikely that the peak horizontal and vertical inertia forces would occur both at the same instant of time and in the most adverse directions; and (c) the use of a pseudo-static slope stability analysis technique considering only the horizontal component was an accepted practice at the time of the analysis.

References

1. Seed, H. B., and Martin, G. R. (1966) "The Seismic Coefficient in Earth Dam Design", JSMFD, ASCE, Volume 92, Number SM3, May, pp 25-58.

2. "Strong Motion Earthquake Accelerograms", Cal. Inst. of Tech. EERL 71-50, Sept. 1971, Pasadena, California.

3. "Strong Motion Earthquake Accelerograms", Cal. Inst. of Tech., EERL 72-50, Feb. 1973, Pasadena, California.

4. "Engineering and Design Stability of Earth and Rock-Fill Dams", EM 1110-2-1902, April, 1970.

5. Sarma, S. K. (1975) "Seismic Stability of Earth Dams and Embankments", Geotechnique 25, Number 4, pages 743-761.