830 Power Building

TENNESSEE VALLEY AUTHORITY

CHATTANOOGA, TENNESSEE 37401

MAR 15 1977

Mr. Norman C. Moseley, Director
Office of Inspection and Enforcement
U.S. Nuclear Regulatory Commission
Region II - Suite 818
230 Peachtree Street, NW.
Atlanta, Georgia 30303

Dear Mr. Moseley:

WATTS BAR NUCLEAR PLANT UNITS 1 AND 2 - REPORTABLE DEFICIENCY - UNEXPECTED SOIL CONDITIONS ENCOUNTERED DURING EXCAVATION OF INTAKE CHANNEL

The subject deficiency was initially reported to NRC-OIE Region II office, Inspector V. L. Brownlee, on October 15, 1976, in accordance with 10 CFR 50.55(e). Our first interim report was submitted on November 16, 1976. Enclosed is our final report concerning this deficiency.

Very truly yours,

J. E. Gilleland
Assistant Manager of Power

Enclosure
CC: Dr. Ernst Volgenau, Director (Enclosure)
Office of Inspection and Enforcement
U.S. Nuclear Regulatory Commission
Washington, DC 20555

7 0204

390
MAI

GD

WATTS BAR NUCLEAR PLANT UNITS 1 AND 2

REPORTABLE DEFICIENCY

UNEXPECTED CONDITIONS ENCOUNTERED DURING EXCAVATION

OF THE INTAKE CHANNEL

FINAL REPORT

Description of the Deficiency

The original soils exploration program in the intake channel area defined the general soil profile as a 15-foot layer of lean clay material from elevation 695 to 680, a 15-foot layer of silty sand from elevation 680 to 665, and a 15-foot layer of firm basal gravel from elevation 665 to 650 (top of rock). The layer of silty sand was judged to have a potential for liquefaction during a seismic event, and therefore the design of the intake channel involved removal of this material down to top of firm gravel (elevation 665). A typical cross section of the intake channel with the profile discussed above is shown in figure 1.

During the excavation of the channel, unexpected soil conditions were encountered in the layer of firm gravel. Therefore, test trenches and pits were excavated into the firm gravel to better define the soil conditions. On the upstream side of the channel, conditions were as expected except from the pumping station to about halfway to the river, top of rock was determined to be at about elevation 663. Therefore, excavation in this area was made to top of rock, and about 18 inches of granular fill compacted to 85-percent maximum relative density was placed to provide a dry working base for placement of the compacted fill. The strength characteristics of the granular fill are better than the basal gravel and the compacted earthfill, and no additional design and analysis was required.

On the downstream side of the channel, layers of sand and one layer of clay were found to exist in the firm gravel. From the pumping station to about halfway to the river, top of rock was found to be at about elevation 656. It was decided to excavate down to rock in this area and place the layer of granular fill (if needed to obtain a dry base) and then compacted earthfill as originally planned. Additional stability analyses have been made to verify the limits of excavation. In the remainder of the downstream side, difficulties were encountered in excavating the trenches and test pits to top of rock due to the water table.

Samples of the sand and clay material in this area were collected by TVA's Singleton Materials Laboratory for evaluation. Preliminary examination of the sandy material by the soils laboratory and comparison of its characteristics with the empirical rules concerning evaluation of liquefaction potential outlined in section 2.5.4.8 of the Watts Bar FSAR indicated a possibility for liquefaction during a seismic event.

Accordingly, a program of additional soils borings was formulated to determine the lateral and vertical extent of the sand and clay layers and to better define top of rock. Figure 2 is a plan view of the channel which shows the locations of the additional soils borings. The exploration program determined that the lowest bedrock elevation occurred near the mouth of the channel at elevation 650. In addition, a program of cyclic testing of the sandy material and static testing of the clay material, under R conditions in both cases, was instituted. The results of the exploration and testing program were evaluated to determine the need for additional analysis. These results indicated a probable liquefaction of the sand layer during a seismic event. In addition, the strength properties of the clay layer were too low to stabilize overlying slopes. Additional analyses have been made to determine new limits of excavation to top of rock for the downstream side of the channel extending from the reservoir to approximately halfway to the pumping station.

Additional Analyses

As outlined above, additional stability analyses were made for those portions of the downstream side of the channel with bedrock elevations ranging from 656 (approximately halfway to the reservoir) to 650 at the reservoir end of the channel. The analyses assumed that the excavated material would be compacted and placed as fill in the same manner as that used in other areas of the intake channel. The strength properties of the remolded material are $\emptyset=15^{o}$ and c=1200 psf, the same values used in the original analysis, as determined by tests on the remolded soil. The liquefiable material adjoining the remolded slopes is assumed to have no strength. Section 2.5.5 (Stability of Slopes) of the Watts Bar FSAR, the most critical design case for the intake channel is for sudden drawdown plus the occurrence of an SSE. The minimum factor of safety for this case is 1.0.

Analysis of Safety Implications

Cooling water for both normal operating and safe shutdown conditions comes from the ERCW intake pumping station which communicates with the river through the intake channel. If the site experienced a severe seismic event, earth slippage might occur, with the most probable result being a partial blockage of the intake channel. The plant could have been brought to a safe shutdown condition and could have been maintained there indefinitely. In the unlikely event of a complete blockage of the intake channel isolating the ERCW pumping station from the river, the plant could be maintained in a safe condition for a limited time; but eventual loss of ERCW would have resulted in loss of the emergency diesel generator and core cooling capability. During this limited period the plant staff could take action to restore the source of water or take other action (such as elimination of nonessential loads) to extend the cooling capability. If these measures failed and core cooling was lost, the health and safety of the public could be endangered.

Corrective Action Taken

For bedrock elevation from 660 to 656 the limits of excavation will be as shown in figure 3. The factor of safety for a wedge failure along a plane at 656 is 1.12. The slope is therefore stable against failure by sliding.

Figure 4 shows the limits of excavation for a section with a bedrock elevation of 650. The factor of safety for a wedge failure along a plane at elevation 650 is 1.0. This factor of safety is considered adequate since it was computed with the use of extremely conservative assumptions. As shown on figure 4, the factor of safety was computed assuming that the entire zone of sandy material extending from elevation 680 to 650 liquefies completely during a seismic event. This is a very conservative assumption. Furthermore, the assumption has been made that no shear strength exists along the failure plane where it passes through the sandy zone; again, this is a very conservative assumption. Even a small amount of shear strength in the liquefiable zone along the failure plane would make the safety factor greater than 1.0.

A dike was constructed at the reservoir end of the intake channel and left in place so that excavation and replacement could be accomplished in the dry. When the dike is removed to complete the mouth of the channel, the side slopes will be constructed of rockfill placed underwater. The strength of the rockfill is $\phi=45^{o}$, $c=0$. On the upstream side of the mouth of the intake channel the firm gravel layer will be left in place and rockfill placed on top of it from elevation 665 to 695. On the downstream side the rockfill will be placed on bedrock down to elevation 650.

Figure 5 shows a typical cross section of the rockfill slopes on the upstream side of the channel. The factor of safety against sliding along a plane at elevation 665 is 1.5.

The downstream side of the channel with rockfill placed on a bedrock elevation of 650 is shown in figure 6. The factor of safety for a wedge failure at 650 is 1.30, and the slope is therefore stable.

Summary

The effect of these unexpected soil conditions on the stability of the intake channel side slopes has been determined through additional analyses. Limits of excavation of sufficient extent to ensure slope stability have been computed and transmitted to TVA construction forces. Construction is underway at the plant site using these revised limits of excavation. Appropriate sections of the Watts Bar FSAR will be revised to incorporate the material presented in this report.

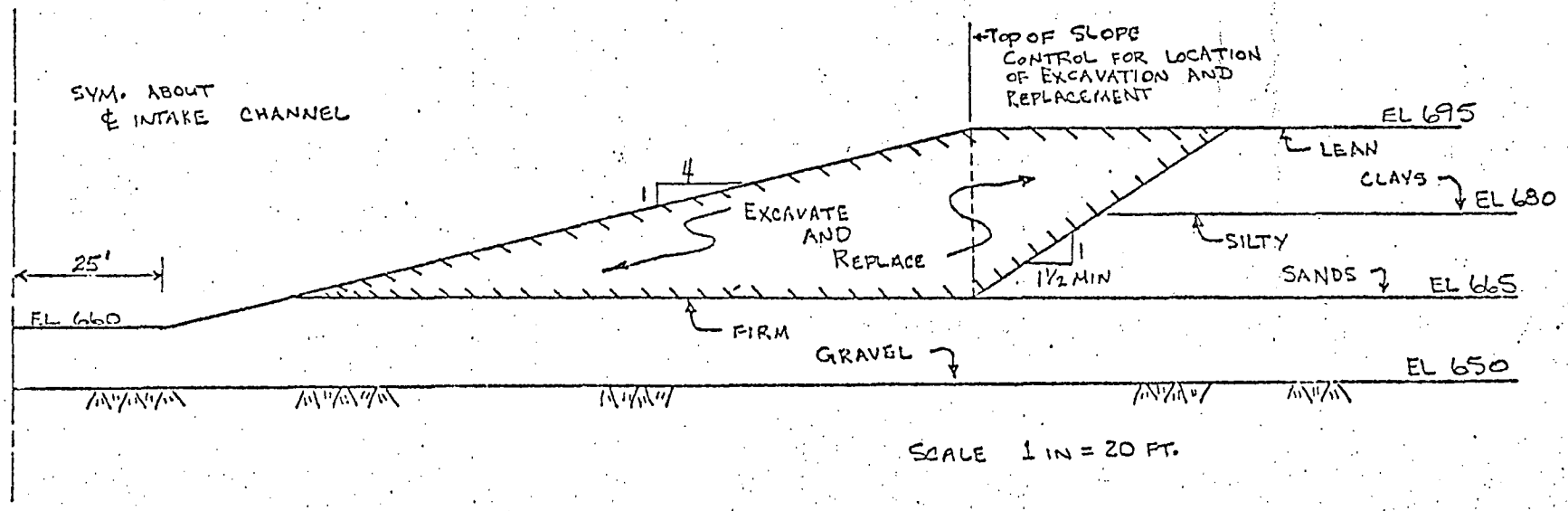
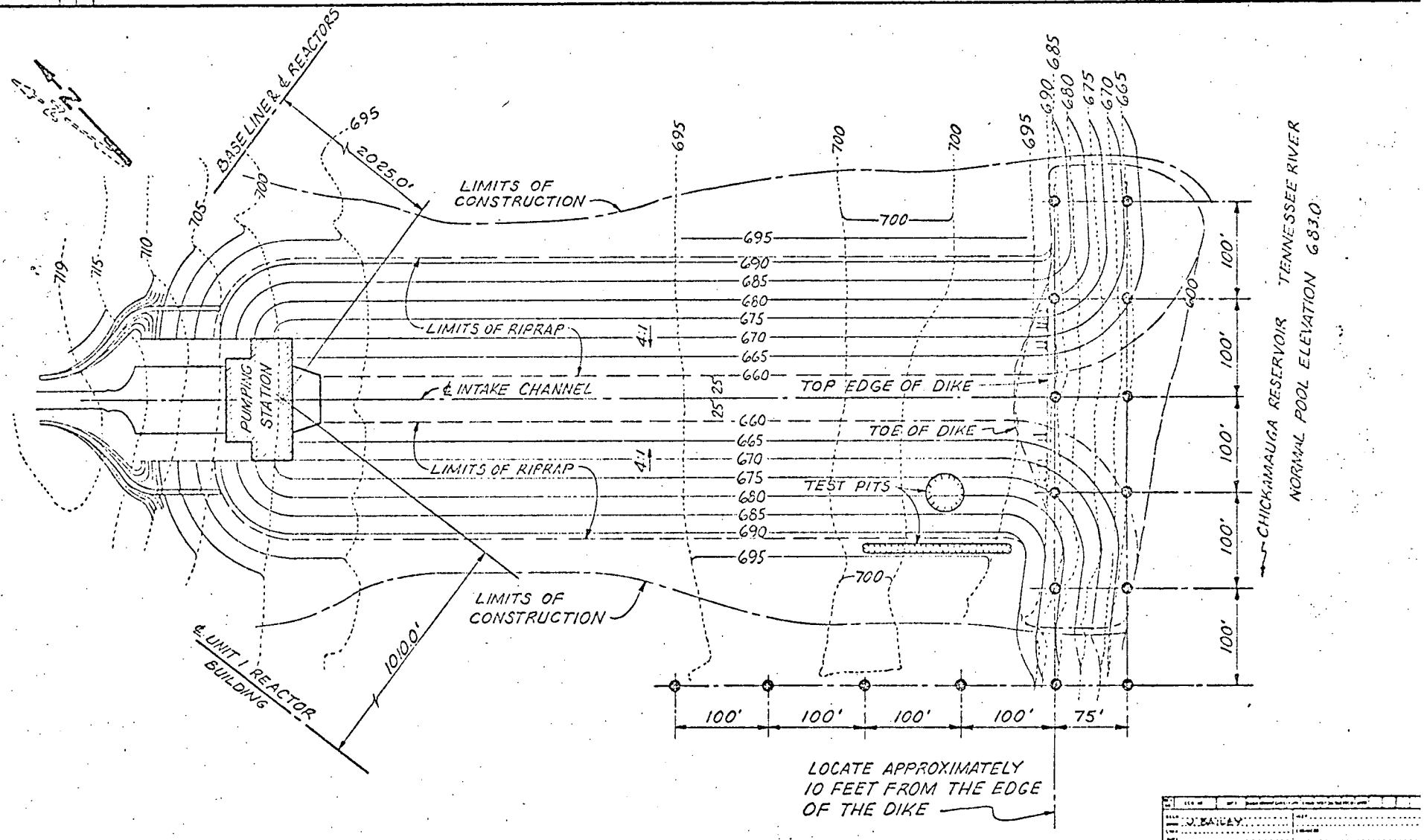


FIGURE 1 Intake Channel - Lateral Excavation and Replacement
Typical cross-section based on original soils exploration



APPROXIMATE SCALE 1"=50'

● - SOIL BORING

FIGURE 2

Additional Soils Exploration Program

SITE STUDY

INTAKE CHANNEL SOILS INVESTIGATION

WATTS BAR NUCLEAR PLANT
TENNESSEE VALLEY AUTHORITY

INSPECTED AND APPROVED FOR ISSUE

KNOXVILLE

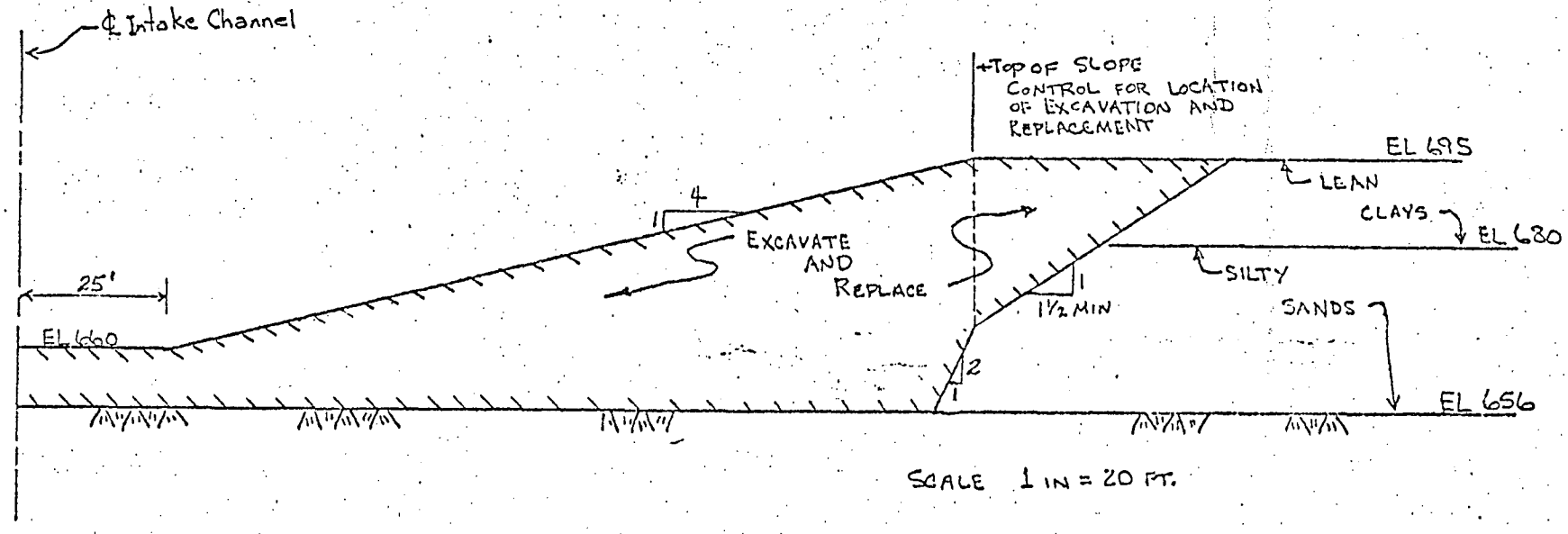


FIGURE 3 Intake Channel - Lateral Excavation and Replacement
Downstream side of intake channel with bedrock at 656

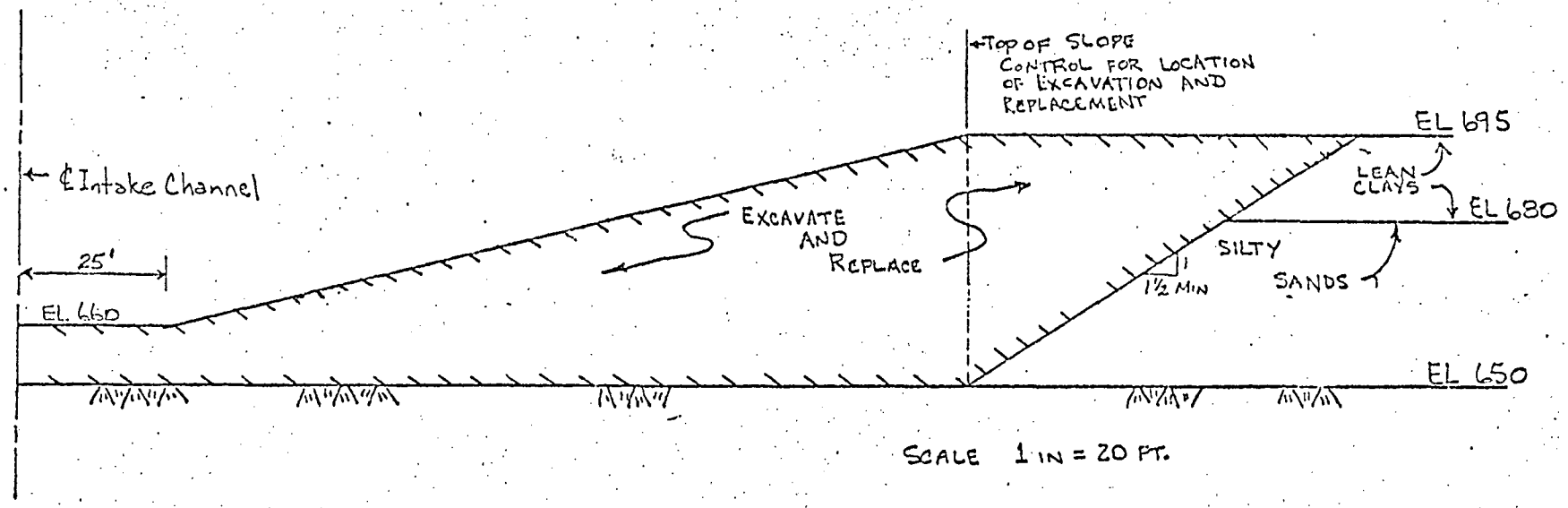


FIGURE 4 Intake Channel - Lateral Excavation and Replacement
Downstream side of intake channel with bedrock at 650

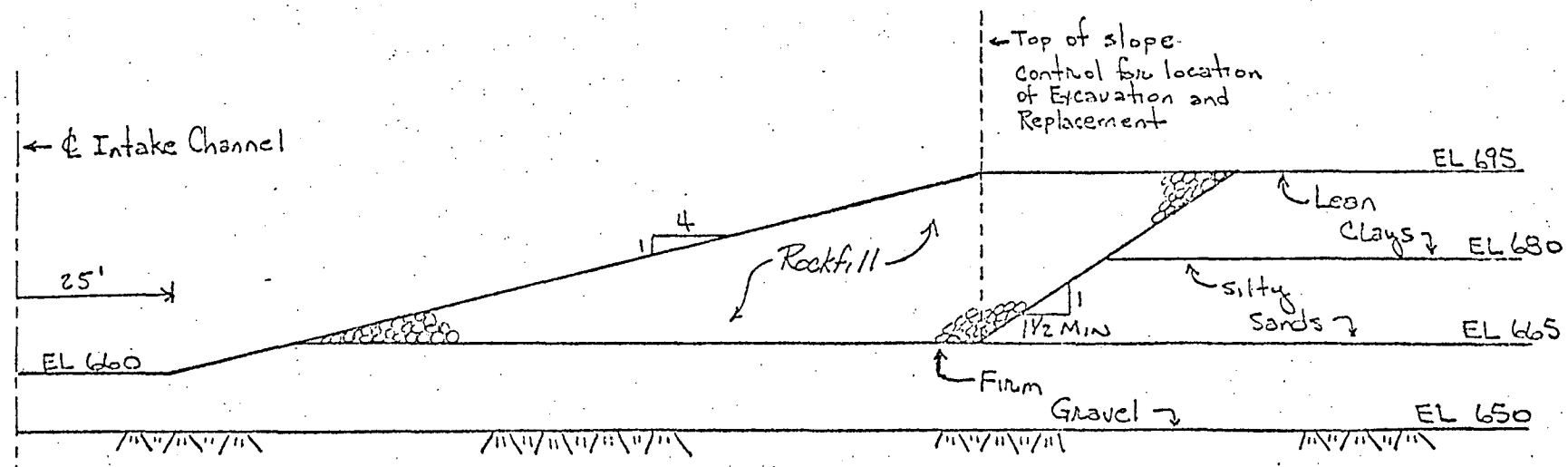


FIGURE 5 Intake Channel - Lateral Excavation and Replacement
Upstream reservoir end with rockfill placed at 665