Embankment Criteria
And Performance Report

Cave Run Lake
Licking River Basin
Kentucky

April 1986
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The embankment criteria and performance report provides a summary record of significant design data, design assumptions, design computations, specification requirements, construction equipment, construction procedures, construction experience, field control and record control test data and embankment performance as monitored by instrumentation during construction and during initial lake filling.
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APPENDIX

A

Photographs
CAVE RUN LAKE
LICKING RIVER BASIN
EMBANKMENT CRITERIA AND PERFORMANCE REPORT

PERTINENT DATA


2. Purpose of Project. To furnish flood protection in the valley of the Licking River Basin. The reservoir project is a unit in the general comprehensive plan for flood control and allied purposes in the Ohio River Basin. A secondary purpose of the project is to provide storage for water supply and a pool for recreation and fish and wildlife activities.

3. Location of Project. The project is located in east-central Kentucky, approximately 84 air miles southeast from Cincinnati, Ohio, and about 118 air miles east from Louisville, Kentucky. The damsite is on Licking River, 173.6 miles above its junction with the Ohio River and four miles upstream from Farmers, Kentucky.

4. Drainage Area at Damsite. 826 square miles.

5. Reservoir.

<table>
<thead>
<tr>
<th>Item</th>
<th>Elevation (feet msl)</th>
<th>Area (acres)</th>
<th>Storage</th>
<th>Inches</th>
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<tr>
<td>Minimum Pool</td>
<td>720</td>
<td>6,790</td>
<td>147,300</td>
<td>3.34</td>
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<tr>
<td>Water Quality Pool</td>
<td>724</td>
<td>7,390</td>
<td>175,600</td>
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<tr>
<td>Seasonal Pool</td>
<td>730</td>
<td>8,270</td>
<td>222,600</td>
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<td>Flood Pool</td>
<td>765</td>
<td>14,870</td>
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<td>-</td>
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<td>9.95</td>
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<td>391,500</td>
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6. Dam.

a. Embankment

<table>
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<th>Type</th>
<th>Earth and rockfill</th>
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<tr>
<td>Top Elevation (msl)</td>
<td>788</td>
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<tr>
<td>Maximum Height, feet</td>
<td>148</td>
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<td>Length, feet</td>
<td>2,700</td>
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<td>Top Width, feet</td>
<td>30</td>
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Side Slopes - Upstream

1V on 2.5H down to elev. 765
1V on 3H down to elev. 737
1V on 30H down to elev. 732
1V on 3.5H remainder

- Downstream

1V on 2.5H down to elev. 765
1V on 3H remainder

b. Spillway

Type

Open cut through divide ridge near left abutment

Crest Elevation (msl) 765
Bottom Width, feet 650
Side Slopes

1V on 3H in overburden
(10-foot berm)
4V on 1H in rock

c. Outlet Works

Conduit Type
Circular, concrete

Conduit diameter, feet 15

Control Gates, number 2

Size of Gates, feet 6.75 x 15

Discharge capacity with:
Minimum Pool, elev. 720, cfs 7,500
Water Quality Pool, elev. 724, cfs 7,800
Seasonal Pool, elev. 730, cfs 8,200
Flood Pool, elev. 765, cfs 10,300

Invert Elevation (msl) 656

7. Land Acquisition

Fee, acres 8,270

8. Relocations

a. State Highways

Kentucky 801 10.5 miles
Kentucky 1274 24.5 miles
Kentucky 519 14.9 miles
Kentucky 1240 6.1 miles
Kentucky 985 7.3 miles
Kentucky 976 7.0 miles
Kentucky 7 1.5 miles
Kentucky 1161 3.1 miles

b. County Roads

Morgan County 17.3 miles
Rowan County 3.6 miles
Menifee County 20.8 miles
c. **Forest Service Roads**

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<th>Road</th>
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<tr>
<td>FSR 16</td>
<td>5.8 miles</td>
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<td>FSR 129</td>
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d. **Public Utilities**

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<td>Abandonment</td>
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<td>Electric (Kentucky Power Co.)</td>
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<td>Abandonment</td>
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<td>Gas (United Fuel Gas Co.)</td>
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<td>Telephone (Mountain RECC)</td>
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<tr>
<td></td>
<td>Relocation</td>
<td>3.6 miles</td>
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9. **Hydroelectric Power.** None

10. **Construction Time.** 5 years.
CAVE RUN LAKE
LICKING RIVER BASIN
EMBANKMENT CRITERIA AND PERFORMANCE REPORT

1. General.
   a. Authority. Authority for preparation of the Embankment Criteria and Performance Report for Cave Run Dam is contained in ER 1110-2-1901, dated 1 August 1972.

   b. Project Purpose. To furnish flood protection in the valley of the Licking River Basin. The reservoir project is a unit in the general comprehensive plan for flood control and allied purposes in the Ohio River Basin. A secondary purpose of the project is to provide storage for water supply and a pool for recreation and fish and wildlife activities.

   c. Project Location. The project is located on Licking River, 173 miles above its junction with the Ohio River and 4 miles upstream from Farmers, Kentucky. It is located about 84 miles southeast of Cincinnati, Ohio, and 118 miles east of Louisville, Kentucky. The reservoir area is shown on Plate 1. The general plan is shown on Plate 2.


   Significant Contract Dates

   15 September 1969    Started clearing outlet channel and damsite.
   16 April 1970        Began excavating the cutoff trench on the left bank and finished stripping right abutment to rock.
   4 May 1970           Started placing fill in the temporary dike and the left portion of the dam embankment.
   10 April 1971        Started installing vertical sand drains.
   23 May 1971          Temporary dike was finished.
   24 November 1971     The embankment reached elevation 721.
27 October 1972  The embankment reached elevation 740 right of the conduit.

16 July 1973  A rise in piezometer levels with visual and actual recorded movements noted necessitated the halting of the fill placement. An emergency berm was constructed to elevation 737.

15 September 1973  Dam embankment completed.

2. **Geology.**

   a. **Project Area.** The project area is located along the border of the Blue Grass and Eastern Kentucky Coal Field regions of Kentucky. The topography is characterized by dendritic drainage developed on steep hillside slopes. Relief in the area is approximately 700 feet. The Licking River has developed a broad flood plain below and above the damsite. The flood plain varies from one to two miles wide downstream from the dam to 1/2 mile to 1 mile upstream to the junction of Bath, Menifee and Rowan Counties. This flood plain has been developed on the Ohio Black Shale. Above the junction of the three counties, the flood plain narrows to 400 to 600 feet in width. The narrow flood plain has developed in the New Providence sandstone and shales. Structurally, the area is located on the east flank of the Cincinnati Arch. The geologic formations encountered are the New Providence, Sunbury, and Bedford formations of the lower Mississippian and Ohio Black Shale of Devonian Age. The regional dip is 30 feet per mile to the southeast. Dominant joint patterns recorded are N85W, N30W, N10E and N45E. The site is considered quiescent and no earthquake shocks are known to have occurred which would have caused an intensity greater than VII (modified Mercalli scale) at the damsite. The maximum intensity was associated with 1811-1812 earthquakes near New Madrid, Missouri.

   b. **Damsite.** There is considerable lithologic variation in the bedrock strata at the damsite. A general description of the rock in this area is given below in descending order.

   (1) **Lower New Providence Formation.** This formation caps the hills in the immediate damsite area. Lithologically, the formation consists of gray soft silty shale; interbedded sandstone and shale; gray fine grained fairly well cemented sandstone with thin interbedded gray shale; and gray medium hard sandy shale at the base.

   (2) **Sunbury Shale.** A black, fissile, hard carbonaceous shale which is very similar to the Ohio Black Shale which is described below. This shale is usually fairly highly-jointed and varies in thickness from 14 to 16 feet.
(3) **Bedford Shale.** A light gray to gray medium hard shale with white calcareous sandy seams and laminae which separates the Sunbury and Ohio Black Shale and has a thickness of approximately 26 feet.

(4) **Ohio Black Shale.** A black, hard, fissile, carbonaceous shale with some pyrite nodules and thin limestone seams.

The geologic profile of the dam axis is shown on Plates 8 and 9. For reference, boring location plans are presented on Plates 5 through 7.

c. **Abutments.** The dam abutments are composed of the lower New Providence formation, Sunbury Shale, Bedford Shale, and upper Ohio Black Shale. There is approximately 0 to 8 feet of clay on the side slopes overlying sandstone and weathered shale. At the toe of the right abutment is 28 feet of colluvium (clay with soft weathered shale and sandstone fragments and boulders). The left abutment has overburden varying from 3 feet of residual clay overlying the New Providence formation to 12 feet of weathered sandstone boulders and clay rubble. When not protected by the overlying formations, the Bedford Shale is highly weathered and soft.

d. **Spillway.** The spillway cut is in the lower portion of the New Providence formation. The crest is in a medium-hard to hard, fine grained, fairly well cemented sandstone with 1.0' - 2.0' bedding. Overburden which is basically a clayey sand and the top 6 feet of rock which is a highly weathered, soft shale, is cut on 3 horizontal to 1 vertical slopes. There is a 10-foot berm at the base of highly weathered shale below which the rock is cut on 1 horizontal on 4 vertical slopes.

3. **Foundation and Abutment Treatment.**

a. **Right Abutment.** The entire right abutment was stripped to rock from station 5+30 to the end of the embankment to remove colluvial material. A special treatment area 30 feet wide was hand cleaned before placement of the embankment materials.

b. **Flood Plain.** A cutoff trench was excavated to unweathered rock from station 5+30, which was roughly the right bank of the original river channel, to station 28+00. The cutoff trench had a bottom width of 50 feet, 1V on 2H side slopes, and averaged 30 feet in depth. The trench was backfilled with impervious material to provide a positive cutoff in the pervious foundation layers. The remainder of the foundation was stripped of topsoil.

c. **Left Abutment.** An inspection trench with a bottom width of 10 feet and 1V on 1H side slopes was excavated 6 feet deep from dam station 28+00 to the end of the embankment. The remainder of the foundation was stripped of topsoil.
d. Grout Curtain. A single line grout curtain extended from station 2+63 to 30+00. These holes were drilled a maximum depth of 55 feet into the foundation rock and were initially located 20 feet apart. The holes were split spaced as close as 2.5 feet on centers as required to assure a tight foundation. It was thought that only the top 10 to 20 feet would be jointed and therefore take any grout. In practice, it was found that the upper zone was relatively tight and that the lower zone experienced some large grout take from station 14+00 to 21+00. The total amount of grout hole drilling was 16,658 linear feet. The total amount of grout used was 4,290 cubic feet. The grouting plan and profile are shown on Plate 11. A more detailed description of the grouting is contained in the Foundation Report.

4. Embankment.

a. General. The embankment section utilized the suitable required excavation from construction and borrow from the designated areas. The embankment was constructed to elevation 788 for a maximum height of 140 feet above the streambed. Crest width is 30 feet. The length of the dam is 2,700 feet at the crown.

The embankment is constructed of compacted impervious fill with 1V on 3.5H slopes. The inclined drain of crushed limestone is 5 feet in width and extends from natural ground to elevation 765 on a 1 on 1 slope. The inclined drain connects to a horizontal drain 25 feet in length and 3 feet in thickness that connects to 3-foot thick finger drains which are 10 feet in width and spaced on 50-foot centers extending to the downstream toe of dam. The finger drains are located from station 6+00 to 25+00 and were installed under a contract modification to reduce the quantity of drain material. The right abutment to station 6+00 has a continuous horizontal blanket drain. Rock excavation from the spillway was placed downstream of the inclined drain to the downstream toe of dam. The random rock was placed to elevation 700± except in the river channel area which was filled to approximately elevation 735. Vertical sand drains 12 inches in diameter and spaced on 12-foot equilateral triangle pattern were installed from station 10+30 to 23+00 starting 75 feet upstream of centerline to a minimum of 20 feet from the upstream toe of dam.

A compacted impervious core with 2V on 1H slopes was constructed to elevation 740. The embankment upstream and downstream of the core is compacted random earth fill. Above elevation 740± compacted impervious fill extends to elevation 785 with a 20-foot top width and 9V on 1H slope upstream and downstream. The remainder of the embankment is constructed of compacted random earth fill. A 50-foot bottom width cutoff trench was provided from station 5+40 to 28+00. An inspection trench 6 feet in depth and 10-foot bottom width was excavated from station 28+00 to the end of dam.

The upstream slope is protected by 180-pound maximum size stone on a 9-inch bedding from elevation 715 to 732 and elevation 737 to top of dam. The top of berm from elevation 737 to 737 is protected by a 2-foot thickness of shale.
A toe drain was installed at the downstream toe of the dam from station 5+50 to 15+00 and station 18+00 to 23+00. Horizontal drains with 1-1/2-inch diameter screens were installed in the upstream embankment on 25-foot centers from station 4+23 to 23+00 with additional drains installed at 12.5-foot centers in the vicinity of stations 6+50, 11+00 and 16+25. The typical dam sections are shown on Plate 13. Details of the drainage system for the horizontal drains are shown on Plate 12.

b. Material Sources. Approximately 4,100,000 cubic yards of impervious earth, random earth and random rock drainage and transition material, and protection stone were required in the dam section. The material used to construct the primary embankment zones is presented below.

<table>
<thead>
<tr>
<th>Material</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Impervious earth</td>
<td>Borrow areas</td>
</tr>
<tr>
<td>Random earth</td>
<td>Borrow areas</td>
</tr>
<tr>
<td>Random rock</td>
<td>Spillway</td>
</tr>
<tr>
<td>Stability berm</td>
<td>Borrow areas</td>
</tr>
<tr>
<td>Filter sand</td>
<td>Borrow areas</td>
</tr>
<tr>
<td>Graded aggregate</td>
<td>Commercial</td>
</tr>
<tr>
<td>Bedding</td>
<td>Commercial</td>
</tr>
<tr>
<td>Riprap</td>
<td>Commercial</td>
</tr>
</tbody>
</table>

The Materials Usage Charts are shown on Plates 81 and 82.

c. Compaction Equipment. The following rollers were used in compacting the embankment materials:

Tamping Rollers:
Ferguson SP-120D

(1) Drum
   a. Number - 2
   b. Diameter - 60 in.
   c. Length - 60 in.

(2) Tamping Foot
   a. Base Area - 11.5 in. ²
   b. Length - 7 in.
   c. Number/wheel - 120
   d. Shape - rectangular

(3) Roller Weight
   a. Empty - 32,920 lbs.
   b. As used - 44,500 lbs.

(4) Foot Pressure
   a. Empty - 295 psi
   b. As used - 393 psi
Ferguson SP-120B

(1) Drum
   a. Number - 2
   b. Diameter - 60 in.
   c. Length - 60 in.

(2) Tamping Foot
   a. Base area - 9.5 in.
   b. Length - 9 in.
   c. Number/wheel - 120
   d. Shape - Circular

(3) Roller Weight
   a. Empty - 28,170 lbs.
   b. As used - 38,370 lbs.

(4) Foot Pressure
   a. Empty - 168 psi
   b. As used - 228 psi

Vibratory Rollers:
   Hyster C250A

(1) Drum
   a. Number - 1
   b. Diameter - 60 in.
   c. Length - 68 in.

(2) Static roller weight - 21,500 lbs.
(3) Dynamic pressure - 49,000 lbs.
(4) Vibrating frequency - 1,200 vpm

Pneumatic-Tired Rollers:

(1) Tires
   a. Number - 4
   b. Size - 18.00 x 25
   c. Ply rating - 24
   d. Spacing - 28 in.

(2) Roller width, weight and tire pressure
   a. Width - 108 in.
   b. Weight - 50 tons
   c. Tire pressure - 45 to 85 psi

(3) Contact pressure - 125 psi

Materials Placement:

(1) Impervious Zone. This material was spread in 6-inch loose lifts and compacted by 6 complete passes with either a Ferguson SP-120D or Ferguson SP-120B tamping roller. The moisture content permitted by the specifications was between plus or minus 2 percentage points of optimum.
(2) Random Earth. This material was spread in 6-inch loose lifts and compacted by 6 complete passes with either Ferguson SP-120B or Ferguson SP-120D tamping roller. The moisture content permitted by the specifications was between plus or minus 2 percentage points of optimum. The W. E. Grace Model W18R 50 ton rubber-tired roller was used on some of the more granular random earth materials.

(3) Random Rock. This material was spread in 24-inch loose lifts and compacted by 4 complete passes with a W. E. Grace Model W18R 50-ton rubber-tired roller.

(4) Filter Sand. This material was spread in 12-inch loose lifts and compacted by 4 completed passes with a Hyster C250A vibratory roller. No moisture control was required on these zones.

(5) Graded Aggregate. This material was spread in 12-inch loose lifts and compacted by 4 complete passes with a Hyster C250A vibratory roller. No moisture control was required on these zones.

A summary of field compaction control test data and design placement requirements for the dam is shown on Plate 83. Field Compaction Control Test Data Sheets are shown on Plates 84 through 128.

e. Seepage Control. To insure watertightness in the foundation, a single line grout curtain was constructed along the centerline of the dam. This grout curtain was 55 feet in depth and penetrated into sound rock. In addition, a cutoff trench to rock was also provided. The cutoff trench was backfilled with impervious material. A strip of sand was placed on the side slopes of the cutoff trench between the foundation and the impervious material to both control seepage in the trench during construction and prevent the possibility of piping. Design seepage computations through the impervious zone were based upon a permeability coefficient of $0.0013 \times 10^{-4}$ feet per minute based upon a test of composite samples from the borrow areas. The site plans for the borrow areas are shown on Plates 3 and 4. Based on the design and the low permeability of the soil, seepage through the dam is not considered a problem. Any seepage through the dam will be intercepted by the inclined drain, finger drains, and right abutment blanket drain. A perforated pipe drain is installed along the downstream toe of the dam to collect seepage from the finger drains and intercept seepage from the foundation. Details of the internal drainage system for the embankment are shown on Plates 14 and 15.

f. Shear Strengths. Laboratory soil test data was studied to select shear test values which most nearly approximated the prototype conditions which were expected to exist at various stages of the project construction. Data was grouped by depth, location, classification and usage. The valley foundation was divided into two primary classifications: plastic and nonplastic. The embankment was treated as a homogenous material. Adopted soil design values are presented in Table 1. The laboratory and adopted design strength envelopes are shown on Plates 16 through 26.
<table>
<thead>
<tr>
<th>Material</th>
<th>$\gamma_m$</th>
<th>$\gamma_{sat}$</th>
<th>$\gamma_{sub}$</th>
<th>Test</th>
<th>$\tan \phi$</th>
<th>$c$</th>
<th>Tons/ft</th>
</tr>
</thead>
<tbody>
<tr>
<td>Embankment (Impervious)</td>
<td>127.8</td>
<td>130.4</td>
<td>68.0</td>
<td>Q</td>
<td>0.00</td>
<td></td>
<td>1.10</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>R</td>
<td>0.51</td>
<td></td>
<td>0.40</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>S</td>
<td>0.57</td>
<td></td>
<td>0.00</td>
</tr>
<tr>
<td>Foundation (Valley Clay</td>
<td>124.4</td>
<td>127.4</td>
<td>65.0</td>
<td>Q (Upper)</td>
<td>0.00</td>
<td></td>
<td>0.80</td>
</tr>
<tr>
<td>Rt. of Conduit)</td>
<td></td>
<td></td>
<td></td>
<td>Q (Lower)</td>
<td>0.05</td>
<td></td>
<td>1.05</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>R</td>
<td>0.42</td>
<td></td>
<td>0.20</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>S</td>
<td>0.50</td>
<td></td>
<td>0.00</td>
</tr>
<tr>
<td>Foundation (Valley Clay</td>
<td>124.4</td>
<td>127.4</td>
<td>65.0</td>
<td>Q</td>
<td>0.00</td>
<td></td>
<td>0.80</td>
</tr>
<tr>
<td>Lt. of Conduit)</td>
<td></td>
<td></td>
<td></td>
<td>R</td>
<td>0.42</td>
<td></td>
<td>0.20</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>S</td>
<td>0.50</td>
<td></td>
<td>0.00</td>
</tr>
<tr>
<td>Foundation (Weak stratum of</td>
<td>139.4</td>
<td>122.4</td>
<td>60.0</td>
<td>Q</td>
<td>0.04</td>
<td></td>
<td>0.40</td>
</tr>
<tr>
<td>silty sand &amp; sandy silt)</td>
<td></td>
<td></td>
<td></td>
<td>R</td>
<td>0.50</td>
<td></td>
<td>0.20</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>S</td>
<td>0.60</td>
<td></td>
<td>0.00</td>
</tr>
<tr>
<td>Foundation (Shale)</td>
<td>147.1</td>
<td>148.4</td>
<td>86.0</td>
<td>Q</td>
<td>0.60</td>
<td></td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>R</td>
<td>0.24</td>
<td></td>
<td>0.43</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>S</td>
<td>0.60</td>
<td></td>
<td>0.00</td>
</tr>
</tbody>
</table>
(1) Plastic Foundation. The clays over the nonplastic foundation contain varied amounts of silt and sand. Because of the difference in Q strength for the material from the right abutment to station 14+00, the clay was considered as two strata. The Q strength values for the upper stratum (silty clay) compare well with the plastic foundation (sandy clay) from station 14+00 to the left abutment. The Q shear strength for the lower stratum, consisting of lean clays and silty clays, was considerably higher. Q strength values for the lower stratum were derived from tests on materials below 8 feet in depth. The R strength values for all the materials compared reasonably well. The minimum Tan θ value for all materials was selected on the basis of a pure numerical average of the five available tests, since all tests were similar.

(2) Nonplastic Foundation. The Q strength for the weak stratum was determined from the five low test values. The adopted Q value for the stronger material was selected from available tests. The adopted R and S values were selected on the basis of a numerical average of all tests available.

(3) Embankment. The R and S strengths were selected by taking a pure numerical average of the available test results. The Q strength is based on a composite of samples at optimum plus 2 percent which is considered a realistic average placement moisture content.

g. Initial Design Stability Analyses. The embankment section at station 16+00 has been subjected to analysis by the circular arc and sliding wedge and block methods. The adopted shear test values were used in the analysis. The methods used in the analysis follow the procedures outlined in Appendix IV, EM 1110-2-1902, published 27 Dec 1960. The slopes were analyzed for end of construction, steady seepage, partial pool and sudden drawdown. Since the damsite is not located in an area of seismic activity, no earthquake analysis was considered. A summary of safety factors is presented below in Table 2.

<table>
<thead>
<tr>
<th>Case</th>
<th>Slope</th>
<th>Minimum Safety Factor</th>
<th>Required Safety Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>End of Construction</td>
<td>D.S.</td>
<td>1.31</td>
<td>1.30</td>
</tr>
<tr>
<td>Sudden Drawdown</td>
<td>U.S.</td>
<td>1.51</td>
<td>1.20</td>
</tr>
<tr>
<td>Partial Pool</td>
<td>U.S.</td>
<td>1.74</td>
<td>1.50</td>
</tr>
<tr>
<td>Steady Seepage</td>
<td>D.S.</td>
<td>1.69</td>
<td>1.50</td>
</tr>
</tbody>
</table>
End of Construction. Q shear strengths are applicable for this case. A minimum factor of safety of 1.31 was obtained for this case.

Sudden Drawdown. R shear strengths are applicable for this case. The upstream slope was analyzed for drawdown from spillway crest to a minimum pool for a maximum drawdown of 45 feet. Full uplift was assumed with saturated weights utilized below the saturation line. A drawdown flow net was not assumed. A minimum factor of safety of 1.51 was obtained.

Partial Pool. R shear strengths are applicable for this case. The pool elevations considered were spillway crest elevation, seasonal pool elevation and minimum pool elevation. Full uplift was utilized with horizontal saturation lines. A minimum factor of safety of 1.74 was obtained.

Steady Seepage. R and S strengths are applicable for this case. The internal drainage system was considered operative. The embankment was considered to be saturated to spillway crest upstream of the incline drain. No tailwater was considered. A minimum average factor of safety of 1.69 was obtained.

The stability analyses for the above-described conditions are presented on Plates 33 through 36.

h. Supplemental Design Stability Analyses. During the course of review of the Design Memorandum for the Dam and Spillway, it was pointed out by the Ohio River Division Office that the dam should also be analyzed between stations 5+50 and 6+50 because of the height of the embankment in this area. The stabilities were done and the stability analyses summaries are presented on Plates 37 and 38. A summary of the safety factors is presented in Table 3.

<table>
<thead>
<tr>
<th>Case</th>
<th>Slope</th>
<th>Minimum Safety Factor</th>
<th>Required Safety Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>End of Construction</td>
<td>U.S.</td>
<td>1.32</td>
<td>1.30</td>
</tr>
<tr>
<td>End of Construction</td>
<td>D.S.</td>
<td>1.76</td>
<td>1.30</td>
</tr>
<tr>
<td>Sudden Drawdown</td>
<td>U.S.</td>
<td>1.71</td>
<td>1.20</td>
</tr>
<tr>
<td>Partial Pool</td>
<td>U.S.</td>
<td>1.93</td>
<td>1.50</td>
</tr>
<tr>
<td>Steady Seepage</td>
<td>D.S.</td>
<td>1.69</td>
<td>1.50</td>
</tr>
</tbody>
</table>

It was also recommended by the Ohio River Division Office that the End of Construction Case at station 16+00 be analyzed again using R strengths in the pervious strata with Q strengths for embankment and foundation clays. The stability was done and the neutral block was founded in the pervious strata. The analysis is presented on Plate 39. A minimum safety factor of 1.41 was obtained for this condition. Another End of Construction Analysis was made assuming the pervious
layer to consolidate instantaneously and the neutral block was through the weaker clay strata. The analysis is presented on Plate 40. A minimum safety factor of 1.11 was obtained for this case. However, since it would take two seasons to construct the embankment, it was concluded that the clay would consolidate sufficiently to produce the required safety factor of 1.3 for End of Construction.

1. Construction Stability Analyses. During an inspection of embankment placement on 26 October 1970 by personnel from ORD, ORLCD-L, and ORLED-G, it was observed that loaded scrapers caused excessive rutting in the upstream section of the embankment between stations 12+00 and 14+00. Therefore, numerous borings were made and cube samples were also taken to determine shear strength values for the embankment. (A detailed description of this work is contained in "Report on Cave Run Embankment" dated July 1971.) The laboratory shear strength test parameters on the embankment record samples are shown on Plates 27 through 32. The laboratory test results for the cube samples are as follows:

### TABLE 4

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Sample Elev.</th>
<th>Cohesion (T.S.F.)</th>
<th>Tan $\phi$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>683.5 - 682.5</td>
<td>1.33</td>
<td>0.134</td>
</tr>
<tr>
<td>2</td>
<td>682.5 - 681.5</td>
<td>0.58</td>
<td>0.034</td>
</tr>
<tr>
<td>3</td>
<td>681.5 - 680.5</td>
<td>0.60</td>
<td>0.088</td>
</tr>
<tr>
<td>4</td>
<td>680.5 - 679.5</td>
<td>0.71</td>
<td>0.098</td>
</tr>
<tr>
<td>5</td>
<td>679.5 - 678.5</td>
<td>0.84</td>
<td>0.000</td>
</tr>
</tbody>
</table>

Stability analyses were performed using the above values for calculating forces acting on the central block, and test values from the Feature Design Memorandum were used for calculating the forces acting on the active wedge. The elevation at the base of the central block is the same as the elevation of the cube sample. The results of the stability analyses using peak strengths are given below for the End of Construction Case.

### TABLE 5

<table>
<thead>
<tr>
<th>Elev. of Base Central Block</th>
<th>Slope</th>
<th>Cube No.</th>
<th>Cohesion (T.S.F.)</th>
<th>Tan $\phi$ Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>682</td>
<td>U.S.</td>
<td>2</td>
<td>0.58</td>
<td>0.034</td>
</tr>
<tr>
<td>681</td>
<td>U.S.</td>
<td>3</td>
<td>0.60</td>
<td>0.088</td>
</tr>
<tr>
<td>680</td>
<td>U.S.</td>
<td>4</td>
<td>0.71</td>
<td>0.098</td>
</tr>
<tr>
<td>679</td>
<td>U.S.</td>
<td>5</td>
<td>0.84</td>
<td>0.000</td>
</tr>
<tr>
<td>* 681</td>
<td>D.S.</td>
<td>3</td>
<td>0.60</td>
<td>0.088</td>
</tr>
</tbody>
</table>

11
The critical stability is presented on Plate 41.

*The stability for the downstream section was performed using conservative values on the theory that possibly a weak layer existed in the impervious embankment below the random rock fill. Borings along the downstream toe indicate that the embankment is properly compacted and no weak zone exists; therefore, the stability is over-conservative.

The shear values presented in Table 4 were based on peak strengths and OCE felt that ultimate strengths may be more applicable. The cube sample test results were reanalyzed and the stress-strain curves projected to develop ultimate strengths. These strengths were used along the base of the central block and the same embankment values as presented in the Feature Design Memorandum were used to recalculate the upstream stabilities. The results of the stability analyses for the End of Construction Case using ultimate strength were as follows:

<table>
<thead>
<tr>
<th>Elev. of Base</th>
<th>Slope</th>
<th>Cube No.</th>
<th>Cohesion (T.S.F.)</th>
<th>Tan $\phi$</th>
<th>Safety Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>682 US</td>
<td>2</td>
<td></td>
<td>0.50</td>
<td>0.035</td>
<td>1.21</td>
</tr>
<tr>
<td>681 US</td>
<td>3</td>
<td></td>
<td>0.45</td>
<td>0.089</td>
<td>1.31</td>
</tr>
<tr>
<td>680 US</td>
<td>4</td>
<td></td>
<td>0.65</td>
<td>0.043</td>
<td>1.36</td>
</tr>
<tr>
<td>679 US</td>
<td>5</td>
<td></td>
<td>0.65</td>
<td>0.000</td>
<td>1.36</td>
</tr>
</tbody>
</table>

The critical stability is presented on Plate 42.

OCE felt that the test results obtained from the cube samples were not representative of the actual strength due to the high pore pressures indicated by the piezometers. OCE felt that the effective stress was somewhere between 0.14 TSF and 0.32 TSF and recommended a value of 0.25 TSF be used for the weak material to compute stabilities for discussion. Using this value along the base of the central block, a 625-foot long berm to elevation 740 would be required for a factor of safety of 1.30. By removing waste material upstream of the embankment toe and using the combination of 0.25 TSF and 0.80 TSF along the base of the central block, the berm length is reduced to 260 feet. These two stability analyses are presented on Plates 43 and 44. The stability of the embankment section was analyzed by excavating the weak material from the upstream toe toward the centerline. Using the wedge method of analysis, removal of material for 165 feet from the upstream toe toward the centerline was required for a safety factor of 1.30. Calculating the lateral earth pressure for full embankment height and using an at-rest pressure coefficient of 0.5 required the removal of material for 171 feet from the upstream toe for a safety factor of 1.30. The depth of excavation was assumed to be in the order of 17-20 feet. The preceding stabilities are presented on Plates 45 and 46.
The main area of concern was upstream of the centerline on each side of the conduit. The area downstream of the centerline was considered adequate due to the finger drains and random rock fill. Three solutions were possible for increasing the stability of the embankment:

1. Construct a 260-foot long berm to elevation 740. This would require removal of approximately 50,000 cubic yards of waste, additional borrow, and construction of an outlet works entrance channel through the berm. The cost was estimated at $493,000.

2. Remove the weak material from the upstream toe toward the centerline for a minimum depth of 17-20 feet. Removal and replacement of material would require additional borrow and delay the contract. The cost was estimated at $393,000.

3. Install vertical sand drains in the upstream section of the embankment. This plan would minimize the delay on the contract and would not influence the schedule for closure. The cost estimate was $198,000 for 12-inch diameter drains on 12-foot centers.

The following remedial measures were derived from meetings which analyzed fill investigations, test data, stability analyses, and piezometer observations.

1. Obtain the remainder of the borrow from the high borrow areas in the abutments to avoid moisture problems.

2. Install vertical sand drains 12 inches in diameter on 12-foot centers in an equilateral triangle pattern on the upstream side of dam from station 9+00 to 23+00. Bottom the drains out in the sand and silty sand of the foundation. Have a horizontal sand drain 24 inches in width and depth, connect the top of each vertical drain in line, and discharge toward the upstream embankment slope. Place additional Casagrande type piezometers at the center of the equilateral triangle formed by 3 vertical sand drains to check the effects on pore pressures as the embankment construction proceeds. Sand drain details and piezometer locations are shown on Plate 14.

3. Place additional movement markers, two lines on the upstream slope and two lines on the downstream slope of the embankment, to check horizontal and vertical movement of fill during and after construction. The locations of all movement markers are shown on Plate 49.

4. Reduce the impervious core slopes to 1 horizontal to 2 vertical to better utilize material as it comes from the borrow areas.

After installation of the vertical sand drains within the embankment in the spring of 1971, the stability of the embankment was continually evaluated until completion of the project. Stability analyses for the end of construction case were performed using unit shearing strengths developed from the effective normal stress within the embankment and an angle of internal friction based on recommended values from the design.
memorandum along with results from test on undisturbed samples obtained from the embankment during November 1970. See paragraph 6d for more discussion on the stability berm.

The location and size of the upstream stability berm was determined by running the set of stability analyses presented on Plate 47. After completion of the embankment pore pressures dissipated.

5. **Construction Sequence.**

   a. **First Construction Year** (1969). A late award date of 29 August 1969 permitted only stripping of the dam foundation on the left riverbank and part of Borrow Area 2. Excavation for the cutoff trench or the temporary dike for flood protection was not accomplished this year.

   b. **Second Construction Year** (1970). The cutoff trench on the left bank was completed and graded to approximate dam station 8+40 and the right abutment was stripped to rock. Early in the spring, the temporary dike was constructed to elevation 680 and embankment placement was started left of the outlet works contract had dried out and collapsed in the impervious core section due to lack of support. This material was removed and replaced as the impervious fill section of the embankment was raised. A portion of the intake and retreat channels was excavated and part of the riprap and bedding materials upstream of station 31+00 was placed in the dry, but not completed. The specified minimum fill height of elevation 705 was not attained across the entire embankment due to embankment material problems, late start due to delays in the cutoff trench work, and adverse weather conditions. The minimum elevation right of the conduit was approximately 690. The shore arms of the diversion dam were not constructed. However, a portion of the temporary dike was raised and was later incorporated into the diversion dam, left bank shore arm.

   c. **Third Construction Year** (1971). During the winter close-down period, December 1970 through March 1971, the embankment placed during construction year 1970 was investigated using ORLED-G drill rigs. In April 1971, the contractor by contract modification began installing vertical sand drains in the embankment and foundation. This work was completed on 10 June 1971. Excavation of the retreat channel and placement of slope protection in the dry to station 31+00 was essentially complete by June 1971. The contract specifications stipulated that the stream portion of the barrier dam not be started prior to 1 June 1971, and then only when weather and river conditions were favorable. Specifications permitted placing the channel portion of the diversion dam without dewatering, but the construction of the closure section was accomplished in the dry in lieu of the wet condition; thereby, permitting better cleaning of the foundation and a more stable embankment. The river was diverted on 24 May 1971 and construction of a low water crossing approximately 350 feet upstream of the barrier dam. After this crossing was made, a concentrated effort was made to strip the required area at the right abutment and construct the right bank shore arm. The diversion dam was constructed in the dry. Weather and wet conditions...
continued to plague the operations, including excavating and grouting
the remaining portion of the cutoff trench, river channel, and right
abutment. With the cutoff trench excavation and backfill operations
delayed, the required embankment height of elevation 721 was not reached
across the entire embankment, but rather a berm was constructed along
the upstream slope. Winter close-down occurred on 24 November 1971 with
the lowest point of the embankment crest at elevation 721.

d. Fourth Construction Year (1972). The construction schedule
was to complete the embankment to full height, section and length not
later than 1 November 1972. Again, weather and embankment conditions
were not conducive to completing the embankment as required. The borrow
source was changed from the low borrow to high borrow for more suitable
moisture. Early winter halted embankment operations on 27 October 1972
with an average elevation of 740 right of the conduit.

e. Fifth Construction Year (1973). Borrow operations were
shifted to Borrow Area 3 and the embankment was completed on
15 September 1973.

The sequence of construction procedures is shown on Plate 10.

6. Changes in Design and Modifications.

a. Borrow-Source Changes.

(1) During initial embankment construction materials were
taken from Borrow Area 2 on the Licking River flood plain, as required
by the contract specifications. During the late summer of 1970 it was
recognized that the Borrow Area 2 materials had a high silt content and
high in situ moistures. This material was very sensitive to moisture
and lacked sufficient shear strength to hold up the hauling equipment at
the top of the specified moisture range. It was determined that better
material was available on the abutments, so borrow operations were moved
to Borrow Areas 1 and 4 on the left abutment.

(2) By late 1972 the available impervious material in Borrow
Areas 1 and 4 was exhausted. A haul road was cut into the right abut-
ment area and Borrow Area 3 was opened. The embankment was completed
with materials from Borrow Area 3.

b. Rezoning of Embankment Materials.

(1) The move from Borrow Area 2 to the upland borrow area
restricted the quantity of impervious material available. To conserve
impervious material, the embankment above that placed during the 1970
season was rezoned. The impervious zone was cut down to a central core
30 feet wide at the top with 1 horizontal to 2 vertical slopes. The
outer shell was constructed of random earth materials. A further change
in late 1971 allowed the contractor to place more pervious, sandy
materials in the upstream random section and the downstream random
section outside of the inclined drain, so long as the downstream random
section outside of the inclined drain, so long as the upstream and
downstream slopes were faced with a more plastic, erosion-resistant material.

(2) After borrow Areas 1 and 4 were exhausted in 1972, investigations indicated that Borrow Area 3 had somewhat less good impervious material than had been anticipated, but contained a large quantity of borderline impervious-random material. To ensure an intact impervious core and better utilize the available material, the embankment was rezoned again for the start of the 1973 construction season. The impervious core was rezoned to a 20-foot top width with 1 horizontal to 9 vertical slopes, using the most select impervious material available. The rest of the embankment section, except for the inclined drain and a small random rock section, was constructed of random earth. The last usable random rock from the spillway excavation was placed in a 20-foot wide zone on the upstream slope under the riprap. The bedding layer was deleted where the riprap was backed up by random rock.

c. Installation of Vertical Sand Drains and Excessive Water Problems. During construction, moisture control was a constant problem on the embankment. Pumping, rutting, and heaving were often evident at moisture near the top of the allowable upper limits. During late 1970 and early 1971 it was determined that moisture contents in the upstream portion of the embankment from station 10+50 to approximately station 23+00 were high enough to develop excessive pore pressures. A system of vertical French drains was drilled into the underlying alluvial overburden and were connected by a series of sand laterals at the existing top of the embankment. During the 1971 season when the embankment was extended across the river to the right abutment after several feet of fill was placed, high moisture contents were detected in the impervious material in the cutoff trench. Investigation indicated the water was coming from the sand and gravel deposits overlying the foundation rock. The material was removed and the reach from station 8+75 to station 5+50 was regrutted. The water in the excavation was controlled by sandbagging and using sumps. The embankment material was then replaced. During the latter portion of the 1972 season, pumping and heaving was noticed in the impervious zone from about station 15+00 to the left abutment. Investigations indicated that an intermittent 2-foot zone of wet material had been placed in the impervious section about 5 to 7 feet below the existing surface. This material was removed and replaced. At the same time, free water was found to be ponded in the pervious, sandy random section. This problem appeared to be more prominent in the downstream random section. Several gravel-filled windows were cut through the impervious, erosion-resistant face along the base of the pervious, sandy zone on the downstream slope of the dam. During the 1973 season, free water was found in the upstream sandy pervious section. An extensive system of low angle, PVC screened drain holes were drilled into this section to drain off free water.

d. Upstream Stability Berm. In July 1973, when the embankment had been completed to approximate elevation 760 (top of dam elevation 785), certain piezometric levels changed rapidly. An inspection of the upstream face of the dam uncovered a developing shear over-thrust surface at about elevation 705 between stations 5+00 and 11+00 with an
apparent movement of about 0.3 foot. The upstream movements of monu-
ments on a line 230 feet upstream from the centerline indicated hori-
zontal movements of 1.08 feet. A 150-foot wide emergency berm was
constructed to elevation 737 sloping to elevation 732 with a system of
horizontal 1-1/4-inch diameter PVC drains to drain the pervious random
fill placed upstream of the impervious core in a zone varying between
elevations 720± and 704±. The extent of the failure was not determined.
No positive shear plane could be defined on top. Another line of monu-
ments was established 140 feet upstream from the centerline of the dam.
Construction of the embankment was resumed and in an effort to level the
top of the embankment some areas were built up quite rapidly to approxi-
mately elevation 775. Increased pore pressures resulted particularly in
the previously delineated failure area and the monuments 140 feet
upstream indicated general upstream movement of 0.65 foot maximum.
After investigation revealed no surface failure, placement was resumed
at a rate not to exceed 2 feet per day. The embankment was completed
without further incident.

7. Major Construction Difficulties. Most of the major construction
difficulties have already been discussed in previous paragraphs.
However, the problem that has not been covered yet was the flooding
threat. In July 1971 after the river had been diverted and the barrier
dam completed, a severe flooding situation developed when 7 inches of
rain fell in the drainage basin. The barrier dam was temporarily raised
to elevation 696.5 under emergency conditions and overtopping was
prevented. The construction schedule was altered to provide a high
enough diversion dam to resist overtopping until the embankment could be
raised to sufficient height.

8. Instrumentation.

a. General. The embankment and foundation are monitored by
piezometers, settlement plates, and movement markers. Instrumentation,
plans, details and sections are shown on Plates 48 and 49.

b. Piezometers. Initially plans called for installing 11
Casagrande type and 29 air-actuated piezometers with 16 piezometers
located in the embankment and 24 piezometers placed in the foundation.
During construction, with the development of high pore pressures within
the embankment, 23 additional Casagrande type and 31 wellpoint piezo-
meters were installed in the embankment. Two additional Casagrande type
and 1 wellpoint piezometers were installed in the foundation. Hall
gas-actuated piezometers were installed in lieu of air-actuated piezo-
meters as indicated in the contract plans.

Pressures read higher than the embankment in the core area during part
of the construction. These excessive pressures were the reason that
first, vertical sand drains were installed and later it was necessary to
add a stability berm. These excessive pressures dissipated with time.

Piezometers located in the foundation and embankment section upstream of
the core now react and read slightly below the pool. Piezometers within
the core read slightly higher than the pool upstream of centerline with
a significant drop downstream of centerline. Piezometers located down-
stream of the core are dry or have low readings which reflect the
effectiveness of the impervious core cutoff, internal drainage system
and free draining random rock toe. The piezometer plots are shown on
Plates 50 through 62. All of the readings are within the range of
pressures expected.

c. Movement Monuments. Eight rows of movement monuments are
installed on the embankment at the following locations:

<table>
<thead>
<tr>
<th>Row Number</th>
<th>Distance from Centerline (ft.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>235 upstream</td>
</tr>
<tr>
<td>1A</td>
<td>145 upstream</td>
</tr>
<tr>
<td>2</td>
<td>85 upstream</td>
</tr>
<tr>
<td>3</td>
<td>15 downstream</td>
</tr>
<tr>
<td>4</td>
<td>150 downstream</td>
</tr>
<tr>
<td>5</td>
<td>270 downstream</td>
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<tr>
<td>6</td>
<td>330-390 downstream</td>
</tr>
<tr>
<td>7</td>
<td>280 upstream</td>
</tr>
</tbody>
</table>

Initially the contract plans required a row of movement monuments
located at the downstream crest, upstream toe, and downstream toe of
dam. As a result of high pore pressures within the embankment, five
additional rows of movement monuments were installed. Progressive
horizontal movement of monuments in row number 1 resulted in the instal-
lation of the upstream stability berm. All movement monuments in row
number 1 were covered by the stability berm which was completed in
August 1973. Recent readings indicate that along the crest and upstream
slope of the embankment very minor horizontal and vertical movement is
still occurring. The downstream portion of the embankment has moved
slightly. Row 1A located 145 feet upstream of centerline has recorded
the maximum horizontal movement of 0.82 foot upstream, and row 2 located
85 feet upstream of centerline has recorded the maximum vertical move-
ment of 0.68 foot. The row 1A movement monuments located 145 feet
upstream of centerline are underwater. The horizontal and vertical
movement plots are shown on Plates 63 through 76. All of the movements
are within the range of movement expected.

d. Settlement Gages. Four settlement gages were installed in the
foundation prior to placing fill for the embankment. The locations are
as follows:

<table>
<thead>
<tr>
<th>Gage Number</th>
<th>Station</th>
<th>Distance from Centerline (ft.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>11+00</td>
<td>100 upstream</td>
</tr>
<tr>
<td>2</td>
<td>11+00</td>
<td>100 downstream</td>
</tr>
<tr>
<td>3</td>
<td>18+00</td>
<td>100 upstream</td>
</tr>
<tr>
<td>4</td>
<td>18+00</td>
<td>100 downstream</td>
</tr>
</tbody>
</table>

The maximum settlement to date of the foundation has been 1.18 feet.
The settlement gage plots are shown on Plates 77 through 80. All of the
settlements are within the range of movement expected. All settlement
has essentially stopped.
PLATES
NOTES:
1. RESTORATION OF BORROW AREA URED ABOVE EL. 358 SHALL BE IN ACCORDANCE WITH NOTE ON SHEET 17.
2. THE CONSTRUCTION NOTE ON SHEET 18.
The maximum settlement to date of the foundation has been 1.18 feet. The settlement gage plots are shown on Plates 77 through 80. All of the settlements are within the range of movement expected. All settlement has essentially stopped.
U.S. ARMY ENGINEER DISTRICT LOUISVILLE

CAVE RUN RESERVOIR
LOUISIANA RIVER, KENTUCKY

TYPICAL DAM SECTIONS

PLATE 18
### Adopted Values

**Upper Clay**
- $\tan \phi = 0.00$
- $c = 0.80 \, \text{ft}^2/\text{ft}$

**Lower Clay**
- $\tan \phi = 0.05$
- $c = 1.05 \, \text{ft}^2/\text{ft}$

### Shearing Stress vs. Stress

<table>
<thead>
<tr>
<th>HOLE NO.</th>
<th>SAMPLE NO.</th>
<th>CLASS</th>
<th>LL</th>
<th>PL</th>
<th>$\tan \phi$</th>
<th>T/C</th>
<th>Classification &amp; Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>U-128</td>
<td>3</td>
<td>CL</td>
<td>44.8</td>
<td>26.7</td>
<td>0.000</td>
<td>1.10</td>
<td>Silty Clay (50-25) Upper Clay</td>
</tr>
<tr>
<td>U-130</td>
<td>3</td>
<td>CL:M</td>
<td>46.1</td>
<td>28.4</td>
<td>0.109</td>
<td>0.78</td>
<td>Silty Clay (50-75) Clay</td>
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<tr>
<td>UK-104</td>
<td>4</td>
<td>CL</td>
<td>22.4</td>
<td>14.5</td>
<td>0.132</td>
<td>1.05</td>
<td>Lean Clay (8.7-10.5)</td>
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<tr>
<td></td>
<td>6</td>
<td>CL</td>
<td>22.4</td>
<td>14.5</td>
<td>0.062</td>
<td>1.60</td>
<td>Sandy Silty Clay (13.7-15%) Lower Clay</td>
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<tr>
<td>U-128</td>
<td>5</td>
<td>CL</td>
<td>43.1</td>
<td>25.6</td>
<td>0.026</td>
<td>1.20</td>
<td>Silty Clay (10.0-12.5) Clay</td>
</tr>
<tr>
<td>U-130</td>
<td>5</td>
<td>CL</td>
<td>38.2</td>
<td>25.6</td>
<td>0.000</td>
<td>1.71</td>
<td>Silty Clay (10.0-12.5)</td>
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</table>

**PLATE 16**
<table>
<thead>
<tr>
<th>HOLE NO.</th>
<th>SAMPLE NO.</th>
<th>CLASS.</th>
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<th>C</th>
<th>T/FT²</th>
<th>Classification &amp; Depth</th>
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<td>UC-105</td>
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<td>CL</td>
<td>33.5</td>
<td>17.2</td>
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<td>0.60</td>
<td>Sandy Clay (6.2-6.0)</td>
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<tr>
<td>UC-106</td>
<td>2</td>
<td>CL</td>
<td>24.2</td>
<td>14.0</td>
<td>0.068</td>
<td>0.00</td>
<td>Sandy Clay (8.7-5.0)</td>
<td></td>
</tr>
<tr>
<td>UC-120</td>
<td>2</td>
<td>CL</td>
<td>43.0</td>
<td>23.5</td>
<td>0.000</td>
<td>0.88</td>
<td>Lean Clay (4.2-5.0)</td>
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</tr>
<tr>
<td>U-132</td>
<td>5</td>
<td>CL</td>
<td>32.6</td>
<td>20.6</td>
<td>0.000</td>
<td>1.25</td>
<td>Sandy Clay (9.1-11.6)</td>
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<td></td>
<td>6</td>
<td>CL</td>
<td>32.5</td>
<td>19.3</td>
<td>0.000</td>
<td>0.88</td>
<td>Sandy Clay (11.6-14.1)</td>
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</table>

*Material to be stripped*
Adopted

Weak Strata

\[
\tan \theta = 0.04 \\
C = 0.40 \frac{\text{ft}}{\text{ft}^2}
\]

\[\text{PLATE~IA} \]

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<th>HOLE NO.</th>
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<th>LL</th>
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<th>Classification &amp; Depth</th>
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<td>0.240</td>
<td>0.70</td>
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<td>ML</td>
<td>N-P</td>
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<td>0.123</td>
<td>0.85</td>
<td>Sandy Silt (19.1-20.0)</td>
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<tr>
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<td>N-P</td>
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<td>Silty Sand (23.2-25.0)</td>
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<td>0.055</td>
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<td>CL</td>
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<td>0.075</td>
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weak strata
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<th>PI</th>
<th>TAN ( \beta )</th>
<th>SATURATION</th>
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<td>0.498</td>
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<td></td>
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<td>CL</td>
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<td>14.5</td>
<td>0.617</td>
<td>99.9</td>
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<td>CL</td>
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<td>0.420</td>
<td>95.3</td>
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<tr>
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<td>CL</td>
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<td>0.482</td>
<td>95.0</td>
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</tbody>
</table>
**Adopted**

**Clay**
\[
\text{Tan } \theta = 0.50 \\
C = 0.00 \text{ t/ft}^2
\]

**Sand and Silt**
\[
\text{Tan } \theta = 0.60 \\
C = 0.00 \text{ t/ft}^2
\]

---

**Material to be stripped**

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<th>SAMPLE NO.</th>
<th>CLASS.</th>
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<th>PL</th>
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**Note:**
- Plate 21
- Subject: Cave Run Reservoir, KY
- Sheet No. 1 of 2
- Foundation Testing Summary
- Jon No.
*Materials to be removed*

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<th>HOLE NO.</th>
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**Embankment Materials**

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<tr>
<th>HOLE NO.</th>
<th>SAMPLE NO.</th>
<th>CLASS</th>
<th>LL (%)</th>
<th>PL (%)</th>
<th>TAN ϕ</th>
<th>C T/FT²</th>
<th>SATURATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Comp A</td>
<td>CL</td>
<td>30.8</td>
<td>17.7</td>
<td>0.093</td>
<td>1.50</td>
<td>0.053</td>
<td>0.80  2.2% WET</td>
</tr>
<tr>
<td>Comp B</td>
<td>SM</td>
<td>N.P.</td>
<td></td>
<td>0.460</td>
<td>1.00</td>
<td>0.500</td>
<td>0.67  12% WET</td>
</tr>
<tr>
<td>Comp C</td>
<td>CL</td>
<td>28.0</td>
<td>16.5</td>
<td>0.061</td>
<td>1.28</td>
<td>0.335</td>
<td>0.60  2.4% WET</td>
</tr>
</tbody>
</table>

Adopted

\[
\tan \varphi = 0.00 \quad (C = 1:10)
\]

Diagram showing shearing stress vs. applied stress for different compactions (A, B, C).
**Adopted**

\[ \tan \phi = 0.51 \]
\[ C = 0.40 ft \]

### Table

<table>
<thead>
<tr>
<th>HOLE No.</th>
<th>SAMPLE No.</th>
<th>CLASS.</th>
<th>LL %</th>
<th>PL %</th>
<th>TAN ( \phi )</th>
<th>C Tifs</th>
<th>SATURATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Comp &quot;A&quot;</td>
<td>CL</td>
<td>30.8</td>
<td>17.7</td>
<td></td>
<td>0.700</td>
<td>0.10</td>
<td>100</td>
</tr>
<tr>
<td>Comp &quot;B&quot;</td>
<td>SM</td>
<td>NP</td>
<td></td>
<td></td>
<td>0.674</td>
<td>0.40</td>
<td>88.9</td>
</tr>
<tr>
<td>Comp &quot;C&quot;</td>
<td>CL</td>
<td>28.0</td>
<td>16.5</td>
<td></td>
<td>0.510</td>
<td>0.60</td>
<td>85.6</td>
</tr>
<tr>
<td>Comp &quot;D&quot;</td>
<td>CL</td>
<td>41.7</td>
<td>21.0</td>
<td></td>
<td>0.329</td>
<td>0.47</td>
<td>100</td>
</tr>
<tr>
<td>Comp &quot;E&quot;</td>
<td>SC</td>
<td>25.4</td>
<td>17.5</td>
<td></td>
<td>0.623</td>
<td>0.40</td>
<td>99.4</td>
</tr>
</tbody>
</table>

---

**Date:**

Adopted Cave Run Reservoir

**Job No.:**

Date:

Semi-Circular Test Data

**Plate 25**
<table>
<thead>
<tr>
<th>HOLE NO.</th>
<th>SAMPLE NO.</th>
<th>CLASS.</th>
<th>LL %</th>
<th>PL %</th>
<th>TAN $\phi$</th>
<th>C' (T/ft²)</th>
<th>SATURATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Comp A</td>
<td>419-1</td>
<td>CL</td>
<td>39.8</td>
<td>17.7</td>
<td>0.632</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td>Comp A</td>
<td>419-2</td>
<td>SM</td>
<td>N.P.</td>
<td></td>
<td>0.662</td>
<td>0.00</td>
<td>Do Not Average</td>
</tr>
<tr>
<td>(212-1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Comp B</td>
<td>422-1</td>
<td>CL</td>
<td>28.0</td>
<td>16.5</td>
<td>0.598</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td>(422-2)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Comp D</td>
<td>488</td>
<td>CL</td>
<td>41.7</td>
<td>21.0</td>
<td>0.492</td>
<td>0.00</td>
<td></td>
</tr>
</tbody>
</table>

Adopted

Tan $\phi = 0.57$

C = 0.00

Caved Run Reservoir

Embankment Material
### Shear Strength Parameters

- Normal Stress, \( \sigma_1, \text{T/sq ft} \)
- Shear Stress, \( \tau, \text{T/sq ft} \)

### Water Content

<table>
<thead>
<tr>
<th>Test No.</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water content ( w )</td>
<td>21.0%</td>
<td>20.9%</td>
<td>21.8%</td>
<td>22.7%</td>
</tr>
<tr>
<td>Void ratio ( e_0 )</td>
<td>0.652</td>
<td>0.641</td>
<td>0.659</td>
<td>0.688</td>
</tr>
<tr>
<td>Saturation ( S_0 )</td>
<td>89.1%</td>
<td>90.2%</td>
<td>91.6%</td>
<td>91.4%</td>
</tr>
<tr>
<td>Dry density, ( \gamma_d )</td>
<td>104.6</td>
<td>105.3</td>
<td>104.2</td>
<td>102.4</td>
</tr>
</tbody>
</table>

### Void Ratio

<table>
<thead>
<tr>
<th>Test No.</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Void ratio ( e_0 )</td>
<td>0.652</td>
<td>0.641</td>
<td>0.659</td>
<td>0.688</td>
</tr>
</tbody>
</table>

### Saturation

<table>
<thead>
<tr>
<th>Test No.</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saturation ( S_0 )</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Water Content

<table>
<thead>
<tr>
<th>Test No.</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water content ( w_f )</td>
<td>21.0%</td>
<td>20.9%</td>
<td>21.8%</td>
<td>22.7%</td>
</tr>
<tr>
<td>Void ratio ( e_r )</td>
<td>0.652</td>
<td>0.641</td>
<td>0.659</td>
<td>0.688</td>
</tr>
<tr>
<td>Minor principal stress, ( \sigma_3 )</td>
<td>1.08</td>
<td>2.16</td>
<td>2.88</td>
<td>3.60</td>
</tr>
<tr>
<td>Max deviator stress, ( (\sigma_1-\sigma_3)_{\text{max}} )</td>
<td>3.38</td>
<td>3.33</td>
<td>3.95</td>
<td>4.15</td>
</tr>
<tr>
<td>Time to failure, ( t_f )</td>
<td>8.9</td>
<td>9.1</td>
<td>8.3</td>
<td>12.4</td>
</tr>
<tr>
<td>Rate of strain, ( % \text{/min} )</td>
<td>0.79</td>
<td>0.78</td>
<td>0.76</td>
<td>0.79</td>
</tr>
</tbody>
</table>

### Controlled Stress

- Initial diameter, in. \( D_0 \) | 1.313 | 1.313 | 1.313 | 1.313 |
- Initial height, in. \( H_0 \) | 2.813 | 2.813 | 2.813 | 2.813 |

### Type of Test

- Q

### Type of Specimen

- UD-From Compacted Fill

### Classification

- LL 44.0
- PL 22.9

### Remarks

- Test Pit for Cubes 1 thru 5 located 150 feet upstream from Station 12+50

### Project

- CAVE RUN RESERVOIR
- Record Samples
- EMBANKMENT
- Boring No. Test Pit
- Sample No. Cube 1
- Depth 2.5'-3.5'
- Date November 1970

### TRIAXIAL COMPRESSION TEST REPORT

- ORDL
- TRANSLUCENT

---

**PLATE 27**
Shear Strength Parameters

\[ \tan \phi = 0.034 \]
\[ c = 0.58 \text{ kPa} \]

Method of saturation

- Controlled stress
- Controlled strain

Water content

<table>
<thead>
<tr>
<th>Test No.</th>
<th>Water content ( w_0 )</th>
<th>Void ratio ( e_0 )</th>
<th>Saturation ( S_0 )</th>
<th>Dry density ( \gamma_d )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>18.6 %</td>
<td>0.560</td>
<td>88.7 %</td>
<td>106.8</td>
</tr>
<tr>
<td>2</td>
<td>18.9 %</td>
<td>0.566</td>
<td>89.2 %</td>
<td>106.4</td>
</tr>
<tr>
<td>3</td>
<td>17.9 %</td>
<td>0.541</td>
<td>88.3 %</td>
<td>108.1</td>
</tr>
</tbody>
</table>

Initial

- Final back pressure \( w_f \)
- Void ratio \( e_f \)
- Minor principal stress \( \sigma_3 \)
- Major deviator stress \( (\sigma_1-\sigma_3)_{max} \)
- Time to failure \( t_f \)
- Rate of strain \( \delta \%

Ult deviator stress \( (\sigma_1-\sigma_3)_{ult} \)

Initial diameter, in. \( D_0 \)

Initial height, in. \( h_0 \)

Type of test: Q

Type of specimen: UD-From Compacted Fill

Classification

- LL 28.3
- PL 17.2
- PI 11.1
- \( G_s 2.67 \)

Remarks

- Project: CAVE RUN RESERVOIR
- RECORD SAMPLES
- Area: EMBANKMENT
- Boring No. Test Pit
- Sample No. CUBE 2
- Depth: 3.5-4.5
- Date: November 1970

Sheet 1 of 2
### Test Results

<table>
<thead>
<tr>
<th>Test No.</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water content, %</td>
<td>18.1</td>
<td>17.5</td>
<td>17.9</td>
</tr>
<tr>
<td>Void ratio</td>
<td>0.572</td>
<td>0.538</td>
<td>0.536</td>
</tr>
<tr>
<td>Saturation</td>
<td>84.5</td>
<td>86.8</td>
<td>89.2</td>
</tr>
<tr>
<td>Dry density, lb/cu ft</td>
<td>106.0</td>
<td>108.3</td>
<td>108.5</td>
</tr>
<tr>
<td>Water content</td>
<td>18.1</td>
<td>17.5</td>
<td>17.9</td>
</tr>
<tr>
<td>Void ratio</td>
<td>0.572</td>
<td>0.538</td>
<td>0.536</td>
</tr>
<tr>
<td>Saturation</td>
<td>84.5</td>
<td>86.8</td>
<td>89.2</td>
</tr>
<tr>
<td>Final back pressure, lb/sq ft</td>
<td>12.2</td>
<td>11.8</td>
<td>10.7</td>
</tr>
<tr>
<td>Rate of strain, percent/min</td>
<td>0.90</td>
<td>0.93</td>
<td>0.90</td>
</tr>
</tbody>
</table>

### Shear Strength Parameters

- **Axial Strain, %**
- **Shear Strain Parameters**
  - $\phi = \theta$
  - $\tan \phi = \frac{c}{\sigma}$
  - $c = \text{effective stress, lb/sq ft}$

### Method of Saturation

- Controlled stress
- Controlled strain

### Type of Test Q

- **Type of specimen UD-From Compacted Fill**

### Classification

- LL 28.3
- FL 17.2
- P.I 11.1
- O.C. 2.67

### Remarks

- Project: CAVE RUN RESERVOIR
- RECORD SAMPLES
- Area: EMBANKMENT
- Boring No. TEST PIT: Sample No. CUBE 2
- Depth: 3.5-4.5
- Date: November 1970

---

**Note:** The image contains a table and a diagram related to soil testing and classification, with detailed data and parameters for each test condition.
<table>
<thead>
<tr>
<th>Test No.</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water content</td>
<td>( w_0 )</td>
<td>18.7%</td>
<td>18.4%</td>
</tr>
<tr>
<td>Void ratio</td>
<td>( e_0 )</td>
<td>0.582</td>
<td>0.575</td>
</tr>
<tr>
<td>Saturation</td>
<td>( S_0 )</td>
<td>87.1%</td>
<td>86.8%</td>
</tr>
<tr>
<td>Dry density, ( \text{lb}/\text{cu ft} )</td>
<td>( d )</td>
<td>106.9</td>
<td>107.4</td>
</tr>
<tr>
<td>Water content</td>
<td>( w_c )</td>
<td>-----</td>
<td>-----</td>
</tr>
<tr>
<td>Void ratio</td>
<td>( e_c )</td>
<td>-----</td>
<td>-----</td>
</tr>
<tr>
<td>Saturation</td>
<td>( S_c )</td>
<td>-----</td>
<td>-----</td>
</tr>
<tr>
<td>Final back pressure, ( \text{lb}/\text{sq ft} )</td>
<td>( u_f )</td>
<td>-----</td>
<td>-----</td>
</tr>
<tr>
<td>Water content</td>
<td>( w_r )</td>
<td>18.7%</td>
<td>18.4%</td>
</tr>
<tr>
<td>Void ratio</td>
<td>( e_r )</td>
<td>0.582</td>
<td>0.575</td>
</tr>
<tr>
<td>Minor principal stress, ( \text{lb}/\text{sq ft} )</td>
<td>( c_3 )</td>
<td>1.08</td>
<td>2.16</td>
</tr>
<tr>
<td>Max deviator stress, ( \text{lb}/\text{sq ft} )</td>
<td>( (\sigma_1-\sigma_3)_{\text{max}} )</td>
<td>1.59</td>
<td>1.74</td>
</tr>
<tr>
<td>Time to failure, min</td>
<td>( t_r )</td>
<td>15.8</td>
<td>13.7</td>
</tr>
<tr>
<td>Rate of strain, percent/min</td>
<td></td>
<td>0.94</td>
<td>0.91</td>
</tr>
</tbody>
</table>

Shear Strength Parameters

\[ \tan \theta = 0.088 \]

\[ c = 0.60 \, \text{lb}/\text{sq ft} \]

Method of saturation

- [ ] Controlled stress
- [X] Controlled strain

<table>
<thead>
<tr>
<th>Type of test</th>
<th>Type of specimen</th>
</tr>
</thead>
<tbody>
<tr>
<td>D</td>
<td>From Compacted Fill</td>
</tr>
</tbody>
</table>

Classification

<table>
<thead>
<tr>
<th>LL</th>
<th>FL</th>
<th>PI</th>
<th>PI</th>
<th>( q_a )</th>
</tr>
</thead>
<tbody>
<tr>
<td>28.8</td>
<td>17.2</td>
<td>11.6</td>
<td>11.6</td>
<td>2.71</td>
</tr>
</tbody>
</table>

Remarks

Project: CAVE RUN RESERVOIR

RECORD SAMPLES

Area: EMBANKMENT

Boring No.: TEST PIT   Sample No.: CUBE 3

Depth: 4.5-5.5   Date: November 1970

TRIAXIAL COMPRESSION TEST REPORT ORDL

PLATE 30
Normal Stress, \( c \), T/sq ft

<table>
<thead>
<tr>
<th>Test No.</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water content ( w_0 )</td>
<td>19.2%</td>
<td>18.2%</td>
<td>18.8%</td>
<td>16.9%</td>
</tr>
<tr>
<td>Void ratio ( e_0 )</td>
<td>0.601</td>
<td>0.574</td>
<td>0.607</td>
<td>0.554</td>
</tr>
<tr>
<td>Saturation ( S_a )</td>
<td>87.2%</td>
<td>86.5%</td>
<td>84.5%</td>
<td>83.2%</td>
</tr>
<tr>
<td>Saturated dry density, ( \bar{d} ) lb/cu ft</td>
<td>106.4</td>
<td>108.2</td>
<td>106.0</td>
<td>109.6</td>
</tr>
<tr>
<td>Water content ( w_c )</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>Void ratio ( e_c )</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>Saturation ( S_c )</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>Initial back pressure, ( p_0 ) T/sq ft</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>Water content ( w_f )</td>
<td>19.2%</td>
<td>18.2%</td>
<td>18.8%</td>
<td>16.9%</td>
</tr>
<tr>
<td>Void ratio ( e_f )</td>
<td>0.601</td>
<td>0.574</td>
<td>0.607</td>
<td>0.554</td>
</tr>
<tr>
<td>Minor principal stress, ( \sigma_3 ) T/sq ft</td>
<td>1.08</td>
<td>2.16</td>
<td>2.88</td>
<td>3.60</td>
</tr>
<tr>
<td>Max deviator stress, ( (\sigma_1-\sigma_3)_{max} )</td>
<td>1.67</td>
<td>1.75</td>
<td>1.67</td>
<td>3.90</td>
</tr>
<tr>
<td>Time to failure, ( t_f ) min</td>
<td>10.0</td>
<td>10.3</td>
<td>11.9</td>
<td>16.3</td>
</tr>
<tr>
<td>Rate of strain, ( \dot{e} ) percent/min</td>
<td>0.96</td>
<td>0.94</td>
<td>0.93</td>
<td>0.90</td>
</tr>
<tr>
<td>Ult deviator stress, ( (\sigma_1-\sigma_3)_{ult} ) T/sq ft</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>Initial diameter, in. ( D_0 )</td>
<td>1.313</td>
<td>1.313</td>
<td>1.313</td>
<td>1.313</td>
</tr>
<tr>
<td>Initial height, in. ( H_0 )</td>
<td>2.813</td>
<td>2.813</td>
<td>2.813</td>
<td>2.813</td>
</tr>
</tbody>
</table>

Type of test: Q
Type of specimen: UD-From Compacted Fill

Classification

| LL | 35.1 | PL | 18.1 | FT | 7.0 | \( a_s \) | 2.73 |

Remarks

Project: CAVE RUN RESERVOIR

RECORD SAMPLES

Area: EMBANKMENT

Boring No. TEST PIT | Sample No. | CUBE 5 | Depth | 6.5-7.5 | Date November 1970

TRIAXIAL COMPRESSION TEST REPORT ORDL
ADOPTED DESIGN VALUES

<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>VERTICAL SRT</th>
<th>PERCENT VERTICAL SRT</th>
<th>HORIZONTAL SRT</th>
<th>PERCENT HORIZONTAL SRT</th>
<th>0° STRENGTH</th>
<th>TAN 0°</th>
<th>25° STRENGTH</th>
<th>TAN 25°</th>
</tr>
</thead>
<tbody>
<tr>
<td>EMBANKMENT</td>
<td>137.0</td>
<td>100.0</td>
<td>0.0°</td>
<td>0.00</td>
<td>1.00</td>
<td>25°</td>
<td>0.51</td>
<td>0.65</td>
</tr>
<tr>
<td>FOUNDATION CLAY (SPT)</td>
<td>124.0</td>
<td>100.0</td>
<td>0.0°</td>
<td>0.00</td>
<td>0.86</td>
<td>25°</td>
<td>0.48</td>
<td>0.65</td>
</tr>
<tr>
<td>FOUNDATION SILT</td>
<td>29.0</td>
<td>100.0</td>
<td>0.0°</td>
<td>0.00</td>
<td>0.86</td>
<td>25°</td>
<td>0.48</td>
<td>0.65</td>
</tr>
<tr>
<td>FOUNDATION SAND</td>
<td>8.0</td>
<td>100.0</td>
<td>0.0°</td>
<td>0.00</td>
<td>0.86</td>
<td>25°</td>
<td>0.48</td>
<td>0.65</td>
</tr>
</tbody>
</table>

NOTES:
1. "0°" SHEAR STRENGTHS USE FOR EMBANKMENT AND FOUNDATION CLAY
2. "0°" SHEAR STRENGTHS USE FOR FOUNDATION SILT
3. SUNKED WEIGHTS USE SELF-PRIV SUNKEN SURFACE
4. PS = 28.0 kPa
5. CS = 0.00
6. COMPUTATIONS PRESENTED PER PLAN

ASSUMED TAN θ = 0

CA = 1.0 \( \frac{P}{A} \)

NEUTRAL BLOCK

\[ \tan \theta = \frac{P}{A} \]

PASSIVE WEDGE

\[ \tan \theta = \frac{P}{A} \]

\[ \frac{P}{A} = \frac{1}{2} \frac{P}{A} \]

WEIGHTED COHESION = 1.0 \( \frac{A}{A} \)

WEIGHTED CEMENT = 0.5 \( \frac{A}{A} \)

A = \( \frac{A}{A} \)

ACTIVE WEDGE

\[ \tan \theta = \frac{P}{A} \]

\[ \frac{P}{A} = \frac{1}{2} \frac{P}{A} \]

\[ \frac{P}{A} = \frac{1}{2} \frac{P}{A} \]

\[ \frac{P}{A} = \frac{1}{2} \frac{P}{A} \]

\[ \frac{P}{A} = \frac{1}{2} \frac{P}{A} \]

\[ \frac{P}{A} = \frac{1}{2} \frac{P}{A} \]
ADOPTED DESIGN VALUES

<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>E [ksi]</th>
<th>K</th>
<th>T</th>
<th>D [ft]</th>
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</table>

**ACTIVE WEDGE**

\[
\begin{align*}
\tan \beta &= 0.0 \\
W_b &= \frac{H_b(1 + 0.008)}{0.008} \\
&= \frac{H_b}{0.008} \left( 1 + \frac{1}{100} \right) \\
W_a &= 125.0 \\
\theta_a &= 12\left(\frac{D}{h}\right) = 120^\circ
\end{align*}
\]

**NEUTRAL BLOCK**

\[
\begin{align*}
\tan \beta &= 0.0 \\
W_b &= \frac{H_b(1 + 0.008)}{0.008} \\
&= \frac{H_b}{0.008} \left( 1 + \frac{1}{100} \right) \\
W_a &= 125.0 \\
\theta_a &= 12\left(\frac{D}{h}\right) = 120^\circ
\end{align*}
\]

**PASSIVE WEDGE**

\[
\begin{align*}
\tan \beta &= 0.0 \\
W_b &= \frac{H_b(1 + 0.008)}{0.008} \\
&= \frac{H_b}{0.008} \left( 1 + \frac{1}{100} \right) \\
W_a &= 125.0 \\
\theta_a &= 12\left(\frac{D}{h}\right) = 120^\circ
\end{align*}
\]

**NOTES:**
1. W shear strengths used
2. Submerged weights used below ground surface
3. K = Tan \( \beta \), \( F_k = K \)
4. Computations presented for plane 100° downstream
5. \( H = 60^\circ \) and trial \( \phi = 1.3 \)
Slope stability computations were made with an IBM 360 electronic computer. The stability of the critical wedge was checked manually as shown.

2. The computations presented are for a failure plane 40° U.S. from the C of dam with $B = 47°$ and a trial F.S. = 1.29.

3. Test values used for central block are from shear tests on cube samples from test pit located 200 ft. U.S., Sta. 12+50.

**Active Wedge**

$W_a = 0.05,000$

$C_a = 1.29$

$C_4 = 277 K$

$\phi_a = 0°$

**Central Block**

$W_{cb} = 178.03$

$C_{cb} = 1.29 \times 100$

$C_{cb} = 277 K$

$\tan \phi_a = 0.034 \times 0.026$

$\phi_a = 1.5°$

**Top of Spillway Crest EL 71**

DAM SECTION

SCALE: 1" = 50'

$C_{cb}$

$F_{cb}$

$\phi_f = 2.0°$

$F_{cb}$
VECTOR DIAGRAMS

ANGLE OF INCLINATION

\[ \frac{17.5^\circ}{16.6^\circ} = \frac{\alpha}{\theta}, \quad \alpha = 2.6^\circ \]

ACTIVE WEDGE

SCALE: 1" = 200K

FOR EQUILIBRIUM \( E_a = E_{cb} \)

\[ 330^\circ = 330K \]

\[ F.S. = 1.29 \]

CENTRAL BLOCK

SCALE: 1" = 400K

CAVE RUN LAKE
STABILITY ANALYSIS
WEDGE METHOD
END OF CONSTRUCTION

EXHIBIT 5  PLATE 41
Notes:

1. Slope stability computations were made with an IBM 360 electronic computer. The stability of the critical wedge was checked manually as shown.

2. The computations presented are for a failure plane 40' U.S. from the toe of dam with $\beta = 47^\circ$ and a trial F.S. = 1.21.

3. Stability computed using assumed ultimate strength as indicated.

Active Wedge

$W_a = 610.5 \text{ K}$
$C_a = 8.2 \text{ kips} (127)$
$C_a = 231 \text{ kips}$
$\phi_d = 0^\circ$

Central Block

$W_{cb} = 1702.1 \text{ kips}$
$C_{cb} = 1.21 \text{ (308)}$
$C_{cb} = 2.54 \text{ kips}$
$\tan \phi_d = \frac{0.053}{1.21} \cdot 0.029$
$\phi_d = 1.7^\circ$

Dam Section

Scale: 1" = 50'

Top

Spillway Crest E

EL 735

CENTRAL BLOCK

$V_m = 127$
$C = 0.5$
$\phi = 2.6$
Vector Diagrams

Active Wedge
SCALE: 1"=200K

For Equilibrium $E_a = E_c b$
300K$=310K$

CENTRAL BLOCK
SCALE: 1"=200K

TOP OF DAM EL.788

REST EL.765

CAVE RUN LAKE
STABILITY ANALYSIS
WEDGE METHOD
END OF CONSTRUCTION

SAB
30 MAR, 71

EXHIBIT 5
PLATE 12
Length of berm required to obtain a F.S. = 1.3 when \( C = 0.25 \) TSF along entire length of failure plane.

\[
F.S. = \frac{C \times L}{E_A}
\]

\[
1.3 = \frac{(0.25)(L)}{362}
\]

\[
L = \frac{(1.3)(362)}{0.5}
\]

\[ L = 940' \]

.: Berm length = 940' - 315' = 625'

Conclusion: A berm 625' to obtain a F.S. = 1.3 when \( C = 0.25 \) TSF along entire length of failure plane.

Vol. of sa
A berm 625' long x 60' high is required to obtain a Factor of Safety = 1.3 when C=0.25 TSF along entire length of failure plane.

Vol. of said berm = 688 CY/ft. of width.
Factor of Safety with No Berm

\[ F.S. = \frac{CL}{Ea} \]
\[ F.S. = \frac{0.25T \times \frac{3.15'}{362K} \times \frac{2K}{T}}{F_s} \]
\[ F.S. = 0.435 \]

Determination of Necessary Berm to Obtain F.S. ≥ 1.3

1. Assume berm height = 30'
2. \[ E_p = 2HCd \frac{N \phi}{2} + \frac{KN^2}{2} \]
3. \[ E_p = (2 \times 30')(\frac{2.2K}{362})(1) + \frac{(127)(30)^2}{2} (1) \]
4. \[ E_p = \frac{132}{F.S.} + 57 \]
5. \[ CL = (1.6)(220) = 110 \]
6. \[ F.S. = \frac{E_p + CL}{Ea} = \frac{(132 + 57) + 110}{362} \]
7. \[ F.S. = \frac{167 + 167 + 110}{362} \]
8. \[ F.S. = 0.88 \]

Determination of Berm Length Necessary to Obtain F.S. ≥ 1.3

\[ C = 0.875 \text{ TSF on berm failure plane} \]
\[ C = 0.25 \text{ TSF on central block failure plane} \]
\[ F.S. = \frac{CL + CL_{\text{berm}}}{Ea} \]
\[ 1.3 = \frac{(1.5)(108) + 1.6)(L)}{362} \]
\[ L = 260' \]

Conclusion: A

\[ \text{TOP OF DAM} \]

<table>
<thead>
<tr>
<th>SPILLWAY CREST EL 748</th>
</tr>
</thead>
<tbody>
<tr>
<td>EL 740</td>
</tr>
<tr>
<td>3.0</td>
</tr>
<tr>
<td>3.5</td>
</tr>
</tbody>
</table>

\[ C = 0.8 \text{ TSF} \]
\[ \phi = 0' \]
\[ f_m = 127.3 \text{ PCF} \]
Necessary Berm Height

1. $h = 30'$

2. Assume berm height = 50'

$$E_p = (2)(50)(\frac{2.2}{F_3}) + 1.27(50)^2(1.5)$$

$$E_p = \frac{220}{F_3} + 159$$

$$C_L = (5)(138) = 69$$

$$F.S. = \frac{220}{E_p} + 228$$

$$F.S. = \frac{228}{V(220)(138)(50)}$$

$$F.S. = 1.15$$

3. Assume berm height = 55'

$$E_p = (2)(55)(\frac{2.2}{F_3}) + 1.27(55)^2(1.5)$$

$$E_p = \frac{242}{F_3} + 192$$

$$C_L = 61$$

$$F.S. = \frac{242}{E_p} + 253$$

$$F.S. = 1.24$$

4. Assume berm height = 60'

$$E_p = (2)(60)(\frac{2.2}{F_3}) + 1.27(60)^2(1.5)$$

$$E_p = \frac{264}{F_3} + 228$$

$$C_L = 54$$

$$F.S. = \frac{264}{E_p} + 282$$

$$F.S. = 1.33$$

Conclusion: A berm 260' long x 60' high is required to obtain a Factor of Safety = 1.3 when $C = 0.8$ TSP along the berm failure plane. Vol. of berm = 275 CY/ft. of width.

CAVE RUN LAKE
STABILITY ANALYSIS
WITH ADDITION OF BERM
SHEET 2 OF 2

EXHIBIT 5  PLATE 44
NOTES:

1. Embankment values are from feature design memorandum.

2. Foundation values were recommended by OCE.

3. The depth of excavation was assumed to be in the order of 17-20 feet.

**ACTIVE WEDGE**

WA = 617 K

Trial S.F. = 1.0

CA = \( \frac{22}{1.0} \) (127) = 280 K

Trial S.F. = 1.5

CA = \( \frac{22}{1.5} \) (127) = 187 K

Trial S.F. = 2.0

CA = \( \frac{22}{2.0} \) (127) = 140 K

**CENTRAL BLOCK**

Assume Ec = 2

Begin excavating 100 ' U.S. C

Trial S.F. = 1.0

Ec = 60 \( \left( \frac{18}{7.5} \right) \) + 240 \( \left( \frac{8.8}{1.0} \right) \) = 562 k

Trial S.F. = 1.8

Ec = 60 \( \left( \frac{18}{7.5} \right) \) + 240 \( \left( \frac{8.8}{1.8} \right) \) = 416 k

Trial S.F. = 2.0

Ec = 60 \( \left( \frac{18}{7.5} \right) \) + 240 \( \left( \frac{8.8}{2.0} \right) \) = 289 k

Begin excavating 150 ' U.S. C

Trial S.F. = 1.0

Ec = 110 \( \left( \frac{18}{7.5} \right) \) + 198 \( \left( \frac{8.8}{1.8} \right) \) = 549 k

Trial S.F. = 1.8

Ec = 110 \( \left( \frac{18}{7.5} \right) \) + 198 \( \left( \frac{8.8}{2.0} \right) \) = 435 k

Trial S.F. = 2.0

Ec = 110 \( \left( \frac{18}{7.5} \right) \) + 198 \( \left( \frac{8.8}{2.0} \right) \) = 245 k

TOP OF O

**VECTOR DIAGRAM**

ACTIVE WEDGE

SCALE: 1" = 200 K

**SPILLWAY CREST EL 765**

EL 735

\( \phi = 12.7 \)

C = 1.10

\( \psi = 0^\circ \)

**FAILURE PLANE**

EXCAVATE AND BACKFILL CCB

\( \phi = 12.7 \)

C = 0.1

\( \psi = 0^\circ \)
Assume $E_{cb} = C_{cb}$ since $tan \theta = 0$

Begin excavating 200' U.S. G

Trial S.F. = 1.0

$E_{cb} = 160(\frac{88}{100}) + 140(\frac{4}{100}) = 406^k$

Trial S.F. = 3

$E_{cb} = 160(\frac{115}{100}) + 140(\frac{4}{100}) = 230^k$

Trial S.F. = 2

$E_{cb} = 160(\frac{4}{100}) + 140(\frac{4}{100}) = 203^k$

150' U.S. G

$B(\frac{4}{100}) = 491^k$

$B(\frac{115}{100}) = 327^k$

$B(\frac{4}{100}) = 245^k$

DAM SECTION

SCALE: 1" = 80'

TOP OF DAM EL. 768

EST EL. 765

ACTIVE WEDGE

EL. 765

-800

0

2.5

-750

W

-700

-650

EL. 682

$\gamma = 127.3 \text{pcf}$

$C = 0.25 \text{ T.S.F.}$

$\phi = 0^\circ$

CAVE RUN LAKE

EXCAVATING FOUNDATION FOR STABILITY ANALYSIS BY WEDGE METHOD

D.L.T. 7 APR 71

EXHIBIT 5 PLATE 45
NOTES:

1. The computations presented are for the lateral earth pressure for full embankment height using an at-rest pressure coefficient of 0.5.

2. Embankment values are from feature design memorandum.

3. Foundation values were recommended by OCE.

4. The depth of excavation was assumed to be in the order of 17-20 feet.

DRIVING FORCE

\[ E_A = \frac{1}{2} K_0 \gamma m H^2 \quad \text{where} \quad E_A = \frac{1}{2} (5)(127)(106)^2 \]
\[ E_A = 358 \text{ k} \]

RESISTING FORCE

Assume \( E_{CB} = C_{CB} \) since

Begin excavating 100' U.S. G.
\[ E_{CB} = 248(2.2) + 100(0.5) \]
\[ E_{CB} = 595 \text{ k} \]

\[ S.F. = \frac{E_C}{E_A} = \frac{595}{358} = 1.66 \]

Begin excavating 100' U.S. G.
\[ E_{CB} = 165(2.2) + 100(0.5) \]
\[ E_{CB} = 455 \text{ k} \]

\[ S.F. = \frac{E_C}{E_A} = \frac{455}{358} = 1.27 \]

TOP OF DAM

DAM SECTION

SCALE: 1" = 50'

SPILLWAY CREST EL. 765

\[ \gamma m = 127.8 \text{ k} \]
\[ C = 1.10 \text{ ft} \]
\[ \phi = 0^\circ \]

EXCAVATE AND BACKFILL

\[ \gamma m = 127.3 \text{ k} \]
\[ C = 0.25 \text{ ft} \]
\[ \phi = 0^\circ \]
WHERE:  
\[ \begin{align*} 
E_a &= \text{lateral earth pressure} \\
K_o &= \text{at-rest pressure coefficient} \\
\delta_m &= \text{moist unit weight emb} \\
H &= \text{embankment height} \\
\end{align*} \]

\[ g \text{ (106)}^2 \]

\[ \tan \theta = 0 \]

\[ \theta = 100' \text{ U.S.} \to 100' (0.5) \]

\[ \frac{595}{358} = 1.66 \]

\[ g \text{ (183') U.S.} \to 183' (0.5) \]

\[ \frac{455}{358} = 1.27 \]

\[ 30' \]

\[ \begin{align*} 
\delta_m &= 127.8 \text{ PCF} \\
C &= 1.10 \text{ T.S.F.} \\
\theta &= 0^\circ \\
\end{align*} \]

Cave Run Lake

Excavating Foundation for Stability Analysis Using Lateral Earth Pressure

Exhibit 5 Plate 46
NOTES: READINGS TAKEN FROM LEFT ABUTMENT TO RIGHT

MONUMENTS COVERED BY STABILITY PERM SINCE AUGUST 1973

CAVE RUN LAKE
MOVEMENT MONUMENTS
235' UPSTREAM & ROW 1
HORIZONTAL MOVEMENT

PLATE 63
NOTE
1. MONUMENTS COVERED BY STABILITY BERM SINCE AUGUST 1973

CAVE RUN LAKE MOVEMENT MONUMENTS 235' UPSTREAM & ROW I VERTICAL MOVEMENT

PLATE 64
ALL MEASUREMENTS TAKEN FROM LEFT TO RIGHT ABUTMENT

CABE RUN LAKE
MOVEMENT MONUMENTS
85 UPSTREAM & ROW 2
HORIZONTAL MOVEMENT

APENDIX V PLATE 65
INITIAL READING

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STATION

14 KID | 16 KID | 18 KID | 20 KID | 22 KID | 24 KID

17 JAN 74
8 MAR 74
3 MAY 74

MONUMENTS

24 JULY 74
3 OCT 74
15 FEB 75
3 OCT 75
30 OCT 75
28 APR 76
11 AUG 76
12 DEC 75
2 APR 74
10 MAY 78

WAVE RUN LAKE

MOVEMENT MONUMENTS
AS UNIT PVT 1 
RUN 2

VERTICAL MOVEMENT

APR 21

PLATE 66
NOTE: INITIAL READINGS TAKEN 25 JULY 74

CAVE RUN LAKE
MOVEMENT MONUMENTS
15' D/S & ROW 3
VERTICAL MOVEMENT
NOTE: READINGS TAKEN FROM LEFT ABUTMENT TO RIGHT EXCEPT ON 30 OCT 75

EXHIBIT 69
INITIAL READING

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<tr>
<td>57</td>
<td>699.54</td>
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</tbody>
</table>

CAVE KUN LAKE
MOVEMENT MONUMENTS
270 DOWN TOTAL &
ROW 5
VERTICAL MOVEMENT

EXHIBIT 72
VERTICAL CUMULATIVE MOVEMENT
(HUNDREDS OF A FOOT)
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<tr>
<td>63</td>
<td>690.16</td>
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</table>

INITIAL READING

Cave Run Lake Movement Monuments
340' - 390' Downstream L
Row 6 Vertical Movement

Exhibit 74
NOTE: READINGS TAKEN FROM ABUTMENT TO RIGHT
READINGS TAKEN FROM LEFT ABUTMENT TO RIGHT

CAVE RUN LAKE MOVEMENT MONUMENTS 280° UPSTREAM Q R&W 7 HORIZONTAL MOVEMENT

- 16
- 18
- 20
- 22
- 24
- 26
- 28
- 30
- 32
- 34
- 36
Riser height = 72.21'
Riser height: 81.52

CAVE RUN LAKE
SETTLEMENT GAGE #4
100' D.S. STA 18+00


APPENDIX V PLATE 80
CAVE RUN LAKE

MATERIALS USAGE CHART
EXCAVATION

<table>
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<th>Item</th>
<th>Excavated Quantity CY</th>
<th>Total Quantity CY</th>
<th>Disposition</th>
<th>Disposition Quantity CY</th>
<th>Balance Factor</th>
<th>Embankment Quantity CY</th>
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<td>67,000</td>
<td>Waste Area</td>
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<tr>
<td>Spillway</td>
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<td>Earth Excavation</td>
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<tr>
<td>Dam Foundation</td>
<td>205,500</td>
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<td>Borrow Areas</td>
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<td></td>
</tr>
<tr>
<td>Spillway Area</td>
<td>132,500</td>
<td>132,500</td>
<td>Random Fill</td>
<td>132,500</td>
<td>1.20</td>
<td>159,000</td>
</tr>
<tr>
<td>Item</td>
<td>Quantity</td>
<td>Source</td>
<td>Total</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>------------------------------</td>
<td>-----------</td>
<td>-------------------</td>
<td>-----------</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Impervious Fill</td>
<td>1,245,000</td>
<td>Borrow Areas</td>
<td>1,245,000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Random Earth Fill</td>
<td>1,807,150</td>
<td>Borrow Areas</td>
<td>1,807,150</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Random Rock Fill</td>
<td>159,000</td>
<td>Spillway</td>
<td>159,000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Graded Aggregate</td>
<td>13,000</td>
<td>Commercial</td>
<td>13,000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inclined Drain and Horizontal Drain</td>
<td>80,000</td>
<td>Commercial and Borrow Areas</td>
<td>80,000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stone Protection</td>
<td>54,000</td>
<td>Commercial</td>
<td>54,000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stability Berm</td>
<td>750,000</td>
<td>Borrow Areas</td>
<td>750,000</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Plate 82
<table>
<thead>
<tr>
<th>MATERIAL (ZONE)</th>
<th>NUMBER OF TESTS</th>
<th>DRY DENSITY</th>
<th>PERCENT COMPACTION</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>HIGH</td>
<td>LOW</td>
</tr>
<tr>
<td>IMPERVIOUS</td>
<td>795 *</td>
<td>127.6</td>
<td>95.3</td>
</tr>
<tr>
<td>RANDOM</td>
<td>893 **</td>
<td>142.6</td>
<td>98.3</td>
</tr>
<tr>
<td>PERVIOUS</td>
<td>208 ***</td>
<td>120.8</td>
<td>96.2</td>
</tr>
</tbody>
</table>

* OF THE 795 TESTS RUN ON THE IMPERVIOUS MATERIAL, 46 TESTS FAILED OPTIMUM, 1 TEST INDICATED THE MATERIAL WAS TOO DRY (OF OPTIMUM COMPACTION DESIRED) AND 8 TESTS INDICATED THE MATERIAL WAS TOO WET (OF OPTIMUM COMPACTION DESIRED). ALL OF THE TEST SECTIONS THAT FAILED WERE RETESTED AND ALL THESE TESTS WERE ACCEPTABLE.

** OF THE 893 TESTS RUN ON THE RANDOM MATERIAL, 68 TESTS FAILED OPTIMUM, 2 TESTS INDICATED THE MATERIAL WAS TOO DRY (OF OPTIMUM COMPACTION DESIRED) AND 18 TESTS INDICATED THE MATERIAL WAS TOO WET (OF OPTIMUM COMPACTION DESIRED). ALL OF THE TEST SECTIONS THAT FAILED WERE RETESTED AND ALL THESE TESTS WERE ACCEPTABLE.

*** OF THE 208 TESTS RUN ON THE PERVIOUS MATERIAL, 13 TESTS FAILED OPTIMUM, 2 TESTS INDICATED THE MATERIAL WAS TOO DRY (OF OPTIMUM COMPACTION DESIRED) AND THE TESTS WERE ACCEPTABLE.

---

1. STANDARD PROCTOR TEST USED ON THE IMPERVIOUS AND RANDOM MATERIAL
2. NOT APPLICABLE - NO MOISTURE CONTROL SPECIFIED
3. INDICATE RESULTS OF ALL TESTS FOR HIGH AND LOW VALUES AND INDICATE
<table>
<thead>
<tr>
<th>VESOE DO</th>
<th>Low</th>
<th>AVERAGE</th>
<th>DESIGN</th>
<th>HIGH</th>
<th>LOW</th>
<th>AVERAGE</th>
<th>SPECIFIED</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.8</td>
<td>23.7</td>
<td>10.5</td>
<td>11.4</td>
<td>10.1</td>
<td>15.6</td>
<td>-3.3</td>
<td>+1.0</td>
</tr>
<tr>
<td>0.7</td>
<td>22.4</td>
<td>5.5</td>
<td>15.2</td>
<td>10.1</td>
<td>15.1</td>
<td>-3.7</td>
<td>+1.0</td>
</tr>
<tr>
<td>0.6</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Tests failed (8 tests indicated the material was too wet of y of optimum, 29 tests indicated the material was below material was both too wet of optimum and below the filled were reworked. There were 25 areas that were tests failed (8 tests indicated the material was too wet of dry of optimum, 40 tests indicated the material was below material was both too wet of optimum and below the filled were reworked. There were 37 areas that were tests failed (all of the tests indicated the material was sections that failed were reworked. All areas were.

Red material, relative density test used on the pervious material indicate results of acceptable tests and retests for average values.
SPECIFIED RANGE OF WATER CONTENT

| Fill Percent Compaction | 115 | 114 | 113 | 112 | 111 | 110 | 109 | 108 | 107 | 106 | 105 | 104 | 103 | 102 | 101 | 100 | 99 | 98 | 97 | 96 | 95 | 94 | 93 | 92 | 91 | 90 | 89 | 88 | 87 | 86 | 87 | 88 | 89 | 90 | 91 | 92 | 93 | 94 | 95 | 96 | 97 | 98 | 99 | 100 | 101 | 102 | 103 | 104 | 105 | 106 | 107 | 108 | 109 | 110 | 111 | 112 | 113 | 114 | 115 |
|-------------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|

CUMULATIVE TO THIS REPORT

<table>
<thead>
<tr>
<th>TOTAL NO. OF TESTS</th>
<th>6</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO. OUTSIDE LIMITS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>V</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>DENSITY</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>V &amp; DENSITY</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>NO. REWORKED</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>NO. RETESTED AFTER REWORKING</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

LEGEND:
- • WITHIN ACCEPTABLE LIMITS
- X OUTSIDE ACCEPTABLE LIMITS
- Xₐ LATER REWORKED ONLY (NO RETEST)
- X₂ LATER REWORKED AND RETESTED
- ø RETEST RESULT OF RETEST AFTER REWORKING
- A₀ A₀ INITIAL TEST (USE ONLY w/CHECK TEST)
- A₂ A₂ CHECK TEST

NOTE: USE SAME NUMBER FOR LATER REWORKED AND RETESTED AND RESULT OF RETEST AND FOR INITIAL AND CHECK TEST.

Stationing of Areas Tested

<table>
<thead>
<tr>
<th>16+75 to 22+30</th>
</tr>
</thead>
</table>

Elevation of Areas Tested

| 662.5 to 686.5 |
SPECIFIED RANGE OF WATER CONTENT

Cave Run Reservoir
PROJECT: Const. of Dam & Spillway
DISTRICT: Louisville
REPORT PERIOD: 6/1/70 to 6/30/70
REPORT NO.: 2
TYPE OF MATERIAL: Impervious Fill

TOTAL NO. OF TESTS
NO. OUTSIDE LIMITS:

TOTAL

w

DENSITY

w & DENSITY

NO. REWORKED

NO. RETESTED

AFTER REWORKING

LEGEND:

• WITHIN ACCEPTABLE LIMITS

x OUTSIDE ACCEPTABLE LIMITS

x, x, x LATER REWORKED ONLY (NO RETEST)

x, x, x LATER REWORKED AND RETESTED

0, 0, 0 RESULT OF RETEST AFTER REWORKING

Δ, Δ INITIAL TEST (USE ONLY w/ CHECK TEST)

Δ, Δ CHECK TEST

NOTE: USE SAME NUMBER FOR LATER REWORKED AND RETESTED AND RESULT OF RETEST AND FOR INITIAL AND CHECK TEST.

EMG Form 4287A
JUN 69

VARIATION OF FILL w FROM LAB OPTIMUM w,
PERCENTAGE POINTS

<table>
<thead>
<tr>
<th>Stationing of Areas Tested</th>
<th>Sta 11+20 to Sta 23+30 U/S</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sta 12+80 to Sta 14+00 D/S</td>
<td>Sta 11+20 to Sta 23+30 U/S</td>
</tr>
</tbody>
</table>

Elevation of Areas Tested

684.0 to 698.8 U/S & 672.5 to 675.8 D/S
**SPECIFIED RANGE OF WATER CONTENT**

**PROJECT:** Cave Run Reservoir  
**DISTRICT:** Louisville  
**REPORT PERIOD:** 8-1-70 thru 8-31-70  
**REPORT NO.:** 4  
**TYPE OF MATERIAL:** Impervious

<table>
<thead>
<tr>
<th>CUMULATIVE TO THIS REPORT</th>
<th>THIS REPORT</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOTAL NO. OF TESTS</td>
<td>108</td>
</tr>
<tr>
<td>NO. OUTSIDE LIMITS:</td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td>9</td>
</tr>
<tr>
<td>W</td>
<td>1</td>
</tr>
<tr>
<td>DENSITY</td>
<td>8</td>
</tr>
<tr>
<td>W &amp; DENSITY</td>
<td>0</td>
</tr>
<tr>
<td>NO. REWORKED</td>
<td>9</td>
</tr>
<tr>
<td>NO. RETESTED AFTER REWORKING</td>
<td>2</td>
</tr>
</tbody>
</table>

**LEGEND:**  
- • WITHIN ACCEPTABLE LIMITS  
- X OUTSIDE ACCEPTABLE LIMITS  
- X_r LATER REWORKED ONLY (NO RETEST)  
- X_r, X_s LATER REWORKED AND RETESTED  
- O_r, O_s RESULT OF RETEST AFTER REWORKING  
- A_r, A_s INITIAL TEST (USE ONLY W/CHECK TEST)  
- A_r, A_s CHECK TEST

**NOTE:** USE SAME NUMBER FOR LATER REWORKED AND RETESTED AND RESULT OF RETEST AND FOR INITIAL AND CHECK TEST.

<table>
<thead>
<tr>
<th>Stationing of Areas Tested</th>
<th>15+00 to 24+70</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elevation of Areas Tested</td>
<td>666.0 to 709.0</td>
</tr>
</tbody>
</table>
Cave Run Lake
PROJECT: Construction of Dam and Spillway
DISTRICT: Louisville
REPORT PERIOD: 10 Oct., 70 thru 31 Oct., 70
REPORT NO.: 6
TYPE OF MATERIAL: Impervious

TOTAL NO. OF TESTS
213
63

NO. OUTSIDE LIMITS:
TOTAL
12
2

v
2
1

DENSITY
10
1

v & DENSITY
0
0

NO. REWORKED
12
2

NO. RETESTED
2
0

LEGEND:
● WITHIN ACCEPTABLE LIMITS
x OUTSIDE ACCEPTABLE LIMITS
X LATER REWORKED ONLY (NO RETEST)
X1, X2 LATER REWORKED AND RETESTED
●, ○ RESULT OF RETEST AFTER REWORKING
Δ, Δ INITIAL TEST (USE ONLY v/Check Test)
Δ1, Δ2 CHECK TEST

NOTE: USE SAME NUMBER FOR LATER REWORKED
AND RETESTED AND RESULT OF RETEST
AND FOR INITIAL AND CHECK TEST.

<table>
<thead>
<tr>
<th>Stationing of Areas Tested</th>
<th>9+20 to 24+50</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elevation of Areas Tested</td>
<td>670.0 to 703.0</td>
</tr>
</tbody>
</table>
SPECIFIED RANGE OF WATER CONTENT

CUMULATIVE
REPORT
TO THIS
REPORT
TOTAL NO. OF TESTS
TOTAL
W
DENSITY
W & DENSITY
No. REWORKED
NO. RETESTED AFTER REWORKING
LEGEND:

- WITHIN ACCEPTABLE LIMITS
- OUTSIDE ACCEPTABLE LIMITS
- LATER REWORKED ONLY (NO RETEST)
- LATER REWORKED AND RETESTED
- RESULT OF RETEST AFTER REWORKING
- INITIAL TEST (USE ONLY W/CHECK TEST)
- CHECK TEST

NOTE: USE SAME NUMBER FOR LATER REWORKED AND RETESTED AND RESULT OF RETEST AND FOR INITIAL AND CHECK TEST.

Stationing of Areas Tested
11400 to 24420

Elevation of Areas Tested
681.0 to 706.5
PROJECT: Cave Run Lake
DISTRICT: LOUISVILLE
REPORT PERIOD: 1 June - 30 June 1971
REPORT NO.: 11
TYPE OF MATERIAL: Impervious & Random Earth

CUMULATIVE TO THIS REPORT
REPORT
TOTAL NO. OF TESTS
494 92
NO. OUTSIDE LIMITS:

<table>
<thead>
<tr>
<th></th>
<th>THIS REPORT</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOTAL</td>
<td>28</td>
</tr>
<tr>
<td>W</td>
<td>9</td>
</tr>
<tr>
<td>DENSITY</td>
<td>20</td>
</tr>
<tr>
<td>W &amp; DENSITY</td>
<td>0</td>
</tr>
<tr>
<td>NO. REWORKED</td>
<td>25</td>
</tr>
<tr>
<td>NO. RETESTED AFTER REWORKING</td>
<td>6</td>
</tr>
</tbody>
</table>

LEGEND:

- WITHIN ACCEPTABLE LIMITS
- OUTSIDE ACCEPTABLE LIMITS
- LATER REWORKED ONLY (NO RETEST)
- LATER REWORKED AND RETESTED
- RESULT OF RETEST AFTER REWORKING
- INITIAL TEST (USE ONLY w/CHECK TEST)
- CHECK TEST

NOTE: USE SAME NUMBER FOR LATER REWORKED AND RETESTED AND RESULT OF RETEST AND FOR INITIAL AND CHECK TEST.

Stationing of Areas Tested
2+85 to 25+55

Elevation of Areas Tested
648.0 to 720.0
SPECIFIED RANGE OF WATER CONTENT

PROJECT: Cave Run Lake
DISTRICT: Louisville
REPORT PERIOD: 1 Oct. to 31 Oct 1971
REPORT NO.: 15
TYPE OF MATERIAL: Impervious & Random Earth

PLATE 1

TOTAL NO. OF TESTS

NO. OUTSIDE LIMITS:
TOTAL
60 22
w
2 9
density
8 9
w & density
5 4

NO. RETESTED

NO. RETESTED AFTER REWORKING
5 2

LEGEND:
• WITHIN ACCEPTABLE LIMITS
• OUTSIDE ACCEPTABLE LIMITS
• LIMIT REWORKED ONLY (NO RETEST)
• LIMIT REWORKED AND RETESTED
• RESULT OF RETEST AFTER REWORKING
• INITIAL TEST (USE ONLY w/CHECK TEST)
• CHECK TEST

NOTE: USE SAME NUMBER FOR LATER REWORKED AND RETESTED AND RESULT OF RETEST AND FOR INITIAL AND CHECK TEST.

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JUN 69

VARIATION OF FILL w FROM LAB OPTIMUM w, PERCENTAGE POINTS

Stationing of Areas Tested
2+65 to 19+95
Elevation of Areas Tested
643.0 to 719.0
PROJECT: Cave Run Lake
DISTRICT: Louisville
REPORT PERIOD: Nov. 1971 to 30 Nov 1971
REPORT NO.: 16
TYPE OF MATERIAL: Impervious & Random Earth

CUMULATIVE TO THIS REPORT
TOTAL NO. OF TESTS 984
NO. OUTSIDE LIMITS:
TOTAL 62
w 20
DENSITY 39
w & DENSITY 5
NO. Reworked 58
NO. RETESTED AFTER REWORKING 21

LEGEND:
- WITHIN ACCEPTABLE LIMITS
X OUTSIDE ACCEPTABLE LIMITS
X_r LATER REWORKED ONLY (NO RETEST)
X_1, X_2 LATER REWORKED AND RETESTED
O_r O RESULT OF RETEST AFTER REWORKING
A_1, A_2 INITIAL TEST (USE ONLY w/ CHECK TEST)
A_1, A_2 CHECK TEST

NOTE: USE SAME NUMBER FOR LATER REWORKED AND RETESTED AND RESULT OF RETEST AND FOR INITIAL AND CHECK TEST.

Stationing of Areas Tested 4+00 to 11+00
Elevation of Areas Tested 669.0 to 704.5
PROJECT: Cave Run Lake
DISTRICT: Louisville
REPORT PERIOD: 5-1 thru 5-31-72
REPORT NO.: 18
TYPE OF MATERIAL: Impervious & Random Earth

SPECIFIED RANGE OF WATER CONTENT

<table>
<thead>
<tr>
<th>CUMULATIVE TO THIS REPORT</th>
<th>THIS REPORT</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOTAL NO. OF TESTS</td>
<td>1113</td>
</tr>
<tr>
<td>NO. OUTSIDE LIMITS:</td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td>67</td>
</tr>
<tr>
<td>DENSITY</td>
<td>22</td>
</tr>
<tr>
<td>v &amp; DENSITY</td>
<td>42</td>
</tr>
<tr>
<td>NO. RETESTED AFTER REWORKING</td>
<td>63</td>
</tr>
</tbody>
</table>

LEGEND:

- • WITHIN ACCEPTABLE LIMITS
- X OUTSIDE ACCEPTABLE LIMITS
- Xr LATER REWORKED ONLY (NO RETEST)
- X1, X2 LATER REWORKED AND RETESTED
- ○, ○1 RESULT OF RETEST AFTER REWORKING
- A1, A2 INITIAL TEST (USE ONLY w/ CHECK TEST)
- A1, A2 CHECK TEST

NOTE: USE SAME NUMBER FOR LATER REWORKED AND RETESTED AND RESULT OF RETEST AND FOR INITIAL AND CHECK TEST.

Stationing of Areas Tested | 3+25 to 27+45
Elevation of Areas Tested  | 700.0 to 728.5
PROJECT: Cave Run Lake
DISTRICT: Louisville
REPORT PERIOD: 6/1/72 to 6/30/72
REPORT NO.: 15
TYPE OF MATERIAL: Impermeable, Random Earth, Sandy Random, Residual Shale

CUMULATIVE TO THIS
REPORT

TOTAL NO. OF TESTS 1200 87
NO. OUTSIDE LIMITS:
TOTAL 68 1
\( w \) 22 0
DENSITY 44 1
\( w \) & DENSITY 6 0

NO. REWORKED 64 1
NO. RETESTED 24 0
AFTER REWORKING

LEGEND:
- \( \bullet \) WITHIN ACCEPTABLE LIMITS
- \( \times \) OUTSIDE ACCEPTABLE LIMITS
- \( x_r \) LATER REWORKED ONLY (NO RETEST)
- \( x_2 \) LATER REWORKED AND RETESTED
- \( o_1 \) RESULT OF RETEST AFTER REWORKING
- \( a_1, a_2 \) INITIAL TEST (USE ONLY \( w \)/CHECK TEST)
- \( a_1, a_2 \) CHECK TEST

NOTE: USE SAME NUMBER FOR LATER REWORKED AND RETESTED AND RESULT OF RETEST AND FOR INITIAL AND CHECK TEST.

<table>
<thead>
<tr>
<th>Stationing of Areas Tested</th>
<th>3+45 to 27+25</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elevation of Areas Tested</td>
<td>713.0 to 735.0</td>
</tr>
</tbody>
</table>
**PROJECT:** Cave Run Lake  
**DISTRICT:** Louisville  
**REPORT PERIOD:** 1 July - 31 July 1972  
**REPORT NO.:** 20  
**TYPE OF MATERIAL:** Impervious, Random Earth  

<table>
<thead>
<tr>
<th>CUMULATIVE TOTAL NO. OF TESTS</th>
<th>THIS REPORT</th>
</tr>
</thead>
<tbody>
<tr>
<td>TO THIS REPORT</td>
<td>1296</td>
</tr>
<tr>
<td>THIS REPORT</td>
<td>96</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>NO. OUTSIDE LIMITS:</th>
<th>TOTAL</th>
<th>w</th>
<th>DENSITY</th>
<th>w &amp; DENSITY</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>77</td>
<td>24</td>
<td>51</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td></td>
<td>2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>NO. REWORKED</th>
<th>72</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO. RETESTED</td>
<td>32</td>
<td>9</td>
</tr>
</tbody>
</table>

**LEGEND:**  
- O WITHIN ACCEPTABLE LIMITS  
- X OUTSIDE ACCEPTABLE LIMITS  
- Xn LATER REWORKED ONLY (NO RETEST)  
- Xp Xn LATER REWORKED AND RETESTED  
- O RETEST AFTER REWORKING  
- Ap Xn INITIAL TEST (USE ONLY w/CHECK TEST)  
- A0 CHECK TEST  

**NOTE:** USE SAME NUMBER FOR LATER REWORKED AND RETESTED AND RESULT OF RETEST AND FOR INITIAL AND CHECK TEST.

<table>
<thead>
<tr>
<th>Stationing of Areas Tested</th>
<th>5.00 to 26.95</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elevation of Areas Tested</td>
<td>715.5 to 744.5</td>
</tr>
</tbody>
</table>
PROJECT: Cave Run Lake
DISTRICT: Louisville
REPORT PERIOD: 8-1-72 to 8-31-72
REPORT NO.: 21
TYPE OF MATERIAL: Sandy Random

CUMULATIVE TO THIS THIS
REPORT REPORT
TOTAL NO. OF TESTS 1418 122
NO. OUTSIDE LIMITS:
TOTAL 99 22
v 29 5
DENSITY 63 12
v & DENSITY 13 5
NO. REWORKED 89 17
NO. RETESTED AFTER REWORKING 38 6

LEGEND:
○ WITHIN ACCEPTABLE LIMITS
× OUTSIDE ACCEPTABLE LIMITS
×× LATER REWORKED ONLY (NO RETEST)
××× LATER REWORKED AND RETESTED
⊙⊙⊙ RESULT OF RETEST AFTER REWORKING
ΔΔ ΔΔ INITIAL TEST (USE ONLY w/CHECK TEST)
ΔΔ ΔΔ CHECK TEST

NOTE: USE SAME NUMBER FOR LATER REWORKED AND RETESTED AND RESULT OF RETEST AND FOR INITIAL AND CHECK TEST.

Stationing of Areas Tested
5+25 to 27+20

Elevation of Areas Tested
717.0 to 792.4
SPECIFIED RANGE OF WATER CONTENT

PROJECT: Cave Run Lake
DISTRICT: LOUISVILLE
REPORT PERIOD: 1-30 Sept 72
REPORT NO.: 22
TYPE OF MATERIAL: Impervious, random earth

CUMULATIVE TO THIS REPORT
TOTAL NO. OF TESTS 1511
NO. OUTSIDE LIMITS:
   TOTAL 103 4
   w 29 0
   DENSITY 67 4
   w & DENSITY 13 0
NO. REWORKED 93 4
NO. RETESTED AFTER REWORKING 40 2

LEGEND:
- WITHIN ACCEPTABLE LIMITS
X OUTSIDE ACCEPTABLE LIMITS
Xn LATER REWORKED ONLY (NO RETEST)
Xt Xn LATER REWORKED AND RETESTED
© X © RESULT OF RETEST AFTER REWORKING
Δt Δn INITIAL TEST (USE ONLY w/CHECK TEST)
Δt Δn CHECK TEST

NOTE: USE SAME NUMBER FOR LATER REWORKED AND RETESTED AND RESULT OF RETEST AND FOR INITIAL AND CHECK TEST.

Stationing of Areas Tested  4+05 to 26+10
Elevation of Areas Tested  722.5 to 751.0
PROJECT: Cave Run Lake
DISTRICT: LOUISVILLE
REPORT PERIOD: 1 Oct - 31 Oct 72
REPORT NO.: 29
TYPE OF MATERIAL: Impervious, Filled Earth

CUMULATIVE TO THIS REPORT

<table>
<thead>
<tr>
<th>TOTAL NO. OF TESTS</th>
<th>THIS REPORT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1533</td>
<td>22</td>
</tr>
</tbody>
</table>

NO. OUTSIDE LIMITS:

<table>
<thead>
<tr>
<th>TOTAL</th>
<th>106</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>V</td>
<td>30</td>
<td>1</td>
</tr>
<tr>
<td>DENSITY</td>
<td>70</td>
<td>3</td>
</tr>
<tr>
<td>V &amp; DENSITY</td>
<td>14</td>
<td>1</td>
</tr>
</tbody>
</table>

NOTE: USE SAME NUMBER FOR LATER REWORKED AND RETESTED AND RESULT OF RETEST AFTER RETEST AND FOR INITIAL AND CHECK TEST.

Stationing of Areas Tested 6+10 to 25+00

Elevation of Areas Tested 725.5 to 752.5
PROJECT: Cave Run Lake
DISTRICT: Louisville
REPORT PERIOD: 4-1-73 thru 4-30-73
REPORT NO.: 25
TYPE OF MATERIAL: Random

CUMULATIVE TO THIS REPORT
TOTAL NO. OF TESTS
NO. OUTSIDE LIMITS:
  TOTAL
  w
  DENSITY
  w & DENSITY
NO. REWORKED
NO. RETESTED
AFTER REWORKING

LEGEND:
- WITHIN ACCEPTABLE LIMITS
X OUTSIDE ACCEPTABLE LIMITS
X LATER REWORKED ONLY (NO RETEST)
X, X LATER REWORKED AND RETESTED
O, O RESULT OF RETEST AFTER REWORKING
A, A INITIAL TEST (USE ONLY w/CHECK TEST)
A, A CHECK TEST

NOTE: USE SAME NUMBER FOR LATER REWORKED
AND RETESTED AND RESULT OF RETEST
AND FOR INITIAL AND CHECK TEST.

Stationing of Areas Tested 4+75 to 14+90
Elevation of Areas Tested 729.0 to 136.1
Project: Cave Run Reservoir
District: Louisville
Report period: 7-1-70 thru 7-31-70
Report No.: 1
Type of material: Filter Sand

Cumulative

To this

This

report

report

Total no. of tests
9  9
No. below minimum
0  0
No. reworked
0  0
No. retested after reworking
0  0

Legend:
- * ABOVE ACCEPTABLE MIN
- x BELOW ACCEPTABLE MIN
- x_r LATER REWORKED ONLY (NO RETEST)
- x_u, x_z LATER REWORKED & RETESTED
- o, o_z RESULT OF RETEST AFTER REWORKING
- α_u, α_z INITIAL TEST (USE ONLY w/CHECK TEST)
- α, α_2 CHECK TEST

Note: Use same number for later reworked and retested and result of retest and for initial and check test.

Stationing of areas tested: 19485 to 23480
Elevation of areas tested: 666.0 to 687.5
PROJECT: CAVE RUN DAM
DISTRICT: LOUISVILLE
REPORT PERIOD: AUG. '70 TO JULY '71
REPORT NO. 2

TYPE OF MATERIAL: FILTER SAND

CUMULATIVE
TO THIS THIS REPORT REPORT
TOTAL NO. OF TESTS 30
NO. BELOW MINIMUM 0 0
NO. REWORKED 0 0
NO. RETESTED AFTER REWORKING 0 0

LEGEND:
• ABOVE ACCEPTABLE MIN
X BELOW ACCEPTABLE MIN
X₁ LATER REWORKED ONLY (NO RETEST)
X₂ LATER REWORKED & RETESTED
Θ₁, Θ₂ RESULT OF RETEST AFTER REWORKING
Δ₁, Δ₂ INITIAL TEST (USE ONLY W/CHECK TEST)
Δ₂ CHECK TEST

NOTE: USE SAME NUMBER FOR LATER REWORKED AND RETESTED AND RESULT OF RETEST AND FOR INITIAL AND CHECK TEST.

Stationing of Areas Tested | 15+70 to 24+85
Elevation of Areas Tested   | 682.0 to 706.0
Cave Run Lake
PROJECT: Construction of Dam and Spillway
DISTRICT: Louisville
REPORT NO. 4
TYPE OF MATERIAL: Filter Sand

CUMULATIVE TO THIS REPORT

<table>
<thead>
<tr>
<th>TOTAL NO. OF TESTS</th>
<th>THIS REPORT</th>
<th>REPORT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>60</td>
<td>28</td>
</tr>
</tbody>
</table>

NO. BELOW MINIMUM | 0 | 0 |
NO. REWORKED      | 0 | 0 |
NO. RETESTED AFTER REWORKING | 0 | 0 |

LEGEND:
○ ABOVE ACCEPTABLE MIN
X BELOW ACCEPTABLE MIN
Xn LATER REWORKED ONLY (NO RETEST)
Xm Xn LATER REWORKED & RETESTED
○n ○m RESULT OF RETEST AFTER REWORKING
A0, A1 INITIAL TEST (USE ONLY w/CHECK TEST)
A2, A3 CHECK TEST

NOTE: USE SAME NUMBER FOR LATER REWORKED AND RETESTED AND RESULT OF RETEST AND FOR INITIAL AND CHECK TEST.

Stationing of Areas Tested

<p>| |</p>
<table>
<thead>
<tr>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>10+30 to 23+00</td>
</tr>
</tbody>
</table>

Elevation of Areas Tested

<p>| |</p>
<table>
<thead>
<tr>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>676.0 to 701.5</td>
</tr>
</tbody>
</table>
Cave Run Lake
PROJECT: Construction of Dam & Spillway
DISTRICT: Louisville
REPORT PERIOD: 1 Nov to 30 Nov 1970
REPORT NO. 5
TYPE OF MATERIAL: Filter Sand

<table>
<thead>
<tr>
<th>CUMULATIVE TO THIS REPORT</th>
<th>THIS REPORT</th>
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</thead>
<tbody>
<tr>
<td>TOTAL NO. OF TESTS</td>
<td>76</td>
</tr>
<tr>
<td>NO. BELOW MINIMUM</td>
<td>0</td>
</tr>
<tr>
<td>NO. REWORKED</td>
<td>0</td>
</tr>
<tr>
<td>NO. RETESTED AFTER REWORKING</td>
<td>0</td>
</tr>
</tbody>
</table>

LEGEND:
- ● ABOVE ACCEPTABLE MIN
- X BELOW ACCEPTABLE MIN
- Xₖ LATER REWORKED ONLY (NO RETEST)
- Xₐ Xₕ LATER REWORKED & RETESTED
- Θ₀ Θₕ RESULT OF RETEST AFTER REWORKING
- Θₐ Θₖ INITIAL TEST (USE ONLY W/ CHECK TEST)
- Θₗ Θ₉ CHECK TEST

NOTE: USE SAME NUMBER FOR LATER REWORKED AND RETESTED AND RESULT OF RETEST AND FOR INITIAL AND CHECK TEST.

<table>
<thead>
<tr>
<th>Stationing of Areas Tested</th>
<th>Sta 22+00 to 11+30</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elevation of Areas Tested</td>
<td>699.0 to 677.0</td>
</tr>
</tbody>
</table>
PROJECT: Cave Run Lake
DISTRICT: Louisville
REPORT PERIOD: 1 Mar 71 to 30 April 71
REPORT NO. 7
TYPE OF MATERIAL: Filter Sand

CUMULATIVE TO THIS REPORT

| TOTAL NO. OF TESTS | 91 | 7
| NO. BELOW MINIMUM  | 0  | 0
| NO. REWORKED       | 0  | 0
| NO. RETESTED AFTER REWORKING | 0 | 0

LEGEND:
- ● ABOVE ACCEPTABLE MIN
- X BELOW ACCEPTABLE MIN
- Xr LATER REWORKED ONLY (NO RETEST)
- Xl Xs LATER REWORKED & RETESTED
- ● ● RESULT OF RETEST AFTER REWORKING
- Δl Δs INITIAL TEST (USE ONLY w/CHECK TEST)
- Δl Δs CHECK TEST

NOTE: USE SAME NUMBER FOR LATER REWORKED AND RETESTED AND RESULT OF RETEST AND FOR INITIAL AND CHECK TEST.

Stationing of Areas Tested
10+25 to 24+35

Elevation of Areas Tested
672.0 to 710.5
PROJECT: Cave Run Lake
DISTRICT: Louisville
REPORT PERIOD: May thru 31 May 1971
REPORT NO. 8
TYPE OF MATERIAL: Filter Sand

CUMULATIVE TO THIS REPORT
TOTAL NO. OF TESTS 97
NO. BELOW MINIMUM 0
NO. REWORKED 0
NO. RETESTED AFTER REWORKING 0

LEGEND:
- ABOVE ACCEPTABLE MIN
X BELOW ACCEPTABLE MIN
Xu LATER REWORKED ONLY (NO RETEST)
Xu Xu LATER REWORKED & RETESTED
o o RESULT OF RETEST AFTER REWORKING
A A INITIAL TEST (USE ONLY w/CHECK TEST)
A A CHECK TEST

NOTE: USE SAME NUMBER FOR LATER REWORKED AND RETESTED AND RESULT OF RETEST AND FOR INITIAL AND CHECK TEST.

<table>
<thead>
<tr>
<th>Stationing of Areas Tested</th>
<th>13+00 to 23+10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elevation of Areas Tested</td>
<td>672.0 to 710.5</td>
</tr>
</tbody>
</table>
**PROJECT:** Cave Run Lake

**DISTRICT:** Louisville

**REPORT PERIOD:** 5-1 to 5-31-72

**REPORT NO.:** 12

**TYPE OF MATERIAL:** Previous (Filter Sand)

<table>
<thead>
<tr>
<th>CUMULATIVE TO THIS REPORT</th>
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</tr>
</thead>
<tbody>
<tr>
<td>TOTAL NO. OF TESTS</td>
<td>148</td>
</tr>
<tr>
<td>NO. BELOW MINIMUM</td>
<td>7</td>
</tr>
<tr>
<td>NO. REWORKED</td>
<td>7</td>
</tr>
<tr>
<td>NO. RETESTED AFTER REWORKING</td>
<td>7</td>
</tr>
</tbody>
</table>

**LEGEND:**

- • ABOVE ACCEPTABLE MIN
- x BELOW ACCEPTABLE MIN
- x_r LATER REWORKED ONLY (NO RETEST)
- x_r x_l LATER REWORKED & RETESTED
- • • RESULT OF RETEST AFTER REWORKING
- A_u, A_r INITIAL TEST (USE ONLY w/ CHECK TEST)
- A_u, A_l CHECK TEST

**NOTE:** USE SAME NUMBER FOR LATER REWORKED AND RETESTED AND RESULT OF RETEST AND FOR INITIAL AND CHECK TEST.

**Stationing of Areas Tested:**

| 5+80 to 24+20 |

**Elevation of Areas Tested:**

| 668.4 to 719.5 |
**PROJECT:** Cave Run Lake  
**DISTRICT:** Louisville  
**REPORT PERIOD:** 1 June '72 to 30 June, 72  
**REPORT NO.:** 12  
**TYPE OF MATERIAL:** Filter Sand

<table>
<thead>
<tr>
<th>CUMULATIVE TO THIS REPORT</th>
<th>THIS REPORT</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOTAL NO. OF TESTS</td>
<td>153</td>
</tr>
<tr>
<td>NO. BELOW MINIMUM</td>
<td>8</td>
</tr>
<tr>
<td>NO. REWORKED</td>
<td>8</td>
</tr>
<tr>
<td>NO. RETESTED</td>
<td></td>
</tr>
<tr>
<td>AFTER REWORKING</td>
<td>8</td>
</tr>
</tbody>
</table>

**LEGEND:**  
- • ABOVE ACCEPTABLE MIN  
- X BELOW ACCEPTABLE MIN  
- X<sub>n</sub> LATER REWORKED ONLY (NO RETEST)  
- X<sub>n</sub> X<sub>2</sub> LATER REWORKED & RETESTED  
- 0, 0<sub>r</sub> RESULT OF RETEST AFTER REWORKING  
- A<sub>n</sub> A<sub>2</sub> INITIAL TEST (USE ONLY w/CHECK TEST)  
- A<sub>n</sub> A<sub>2</sub> CHECK TEST  

**NOTE:** USE SAME NUMBER FOR LATER REWORKED AND RETESTED AND RESULT OF RETEST AND FOR INITIAL AND CHECK TEST.

**Stationing of Areas Tested**  
8+55 to 21+00

**Elevation of Areas Tested**  
668.0 to 724.0
PROJECT: Cave Run Lake
DISTRICT: Louisville
REPORT PERIOD: 1 July - 31 July 1972
REPORT NO. 14
TYPE OF MATERIAL: Filter Sand (Pervious)

<table>
<thead>
<tr>
<th>CUMULATIVE TO THIS REPORT</th>
<th>THIS REPORT</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOTAL NO. OF TESTS</td>
<td>15</td>
</tr>
<tr>
<td>NO. BELOW MINIMUM</td>
<td>9</td>
</tr>
<tr>
<td>NO. REWORKED</td>
<td>9</td>
</tr>
<tr>
<td>NO. RETESTED AFTER REWORKING</td>
<td>9</td>
</tr>
</tbody>
</table>

LEGEND:
- • ABOVE ACCEPTABLE MIN
- X BELOW ACCEPTABLE MIN
- Xₐ LATER REWORKED ONLY (NO RETEST)
- Xₐ, X₂ LATER REWORKED & RETESTED
- o₂ RESULT OF RETEST AFTER REWORKING
- A₁, A₂ INITIAL TEST (USE ONLY w/CHECK TEST)
- Aₚ, Aₚ CHECK TEST

NOTE: USE SAME NUMBER FOR LATER REWORKED AND RETESTED AND RESULT OF RETEST AND FOR INITIAL AND CHECK TEST.

Stationing of Areas Tested | 1+90 - 25+00
Elevation of Areas Tested  | 668.0 - 734.0
Project: Cave Run Lake
District: Louisville
Report Period: 1-30 September 72
Report No.: 16
Type of Material: Filter Sand (Pervious)

Cumulative to This Report

<table>
<thead>
<tr>
<th>Total No. of Tests</th>
<th>This Report</th>
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</thead>
<tbody>
<tr>
<td>184</td>
<td>15</td>
</tr>
<tr>
<td>No. Below Minimum</td>
<td>14</td>
</tr>
<tr>
<td>No. Reworked</td>
<td>14</td>
</tr>
<tr>
<td>No. Retested After Reworking</td>
<td>14</td>
</tr>
</tbody>
</table>

Legend:
- O Above Acceptable Min
- X Below Acceptable Min
- X₁ Later Reworked Only (No Retest)
- X₂ Later Reworked & Retested
- O₁, O₂ Result of Retest After Reworking
- Δ₁, Δ₂ Initial Test (Use Only w/Check Test)
- Δ₃ Check Test

Note: Use same number for later reworked and retested and result of retest and for initial and check test.

Stationing of Areas Tested: 4+25 to 23+25
Elevation of Areas Tested: 718.4 to 747.5
PROJECT: Cave Run Lake
DISTRICT: LOUISVILLE
REPORT PERIOD: 4-1-75 THRU 4-30-75
REPORT NO. 18
TYPE OF MATERIAL: Filter Sand

<table>
<thead>
<tr>
<th>CUMULATIVE TO THIS</th>
<th>THIS REPORT</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOTAL NO. OF TESTS</td>
<td>192</td>
</tr>
<tr>
<td>NO. BELOW MINIMUM</td>
<td>15</td>
</tr>
<tr>
<td>NO. REWORKED</td>
<td>15</td>
</tr>
<tr>
<td>NO. RETESTED AFTER REWORKING</td>
<td>15</td>
</tr>
</tbody>
</table>

LEGEND:
- ○ ABOVE ACCEPTABLE MIN
- × BELOW ACCEPTABLE MIN
- Xₐ LATER REWORKED ONLY (NO RETEST)
- Xₐ Xₐ LATER REWORKED & RETESTED
- ○ₐ ○ₐ RESULT OF RETEST AFTER REWORKING
- Δₐ Δₐ INITIAL TEST (USE ONLY w/CHECK TEST)
- Δₐ Δₐ CHECK TEST

NOTE: USE SAME NUMBER FOR LATER REWORKED AND RETESTED AND RESULT OF RETEST AND FOR INITIAL AND CHECK TEST.

Stationing of Areas Tested: 6+50 to 12+65
Elevation of Areas Tested: 730.0 to 735.0
PROJECT: Cave Run Lake
DISTRICT: Louisville
REPORT PERIOD: 1 May 73 to 31 May 1973
REPORT NO. 10
TYPE OF
MATERIAL: Pervious (Filter Sand)

CUMULATIVE
TO THIS
THIS
REPORT
REPORT
TOTAL NO. OF TESTS 199 7
NO. BELOW MINIMUM 16 1
NO. REWORKED 16 1
NO. RETESTED AFTER REWORKING 16 1

LEGEND:
- ABOVE ACCEPTABLE MIN
- BELOW ACCEPTABLE MIN
- Xr LATER REWORKED ONLY (NO RETEST)
X LATER REWORKED & RETESTED
Xa, Xb RESULT OF RETEST AFTER REWORKING
- Xa, Xb INITIAL TEST (USE ONLY w/CHECK TEST)
- Xa, Xb CHECK TEST

NOTE: USE SAME NUMBER FOR LATER REWORKED AND RETESTED AND RESULT OF RETEST AND FOR INITIAL AND CHECK TEST.

Stationing of Areas Tested
10+67 to 26+00

Elevation of Areas Tested
739.0 to 751.0
PROJECT: Cave Run Lake
DISTRICT: Louisville
REPORT PERIOD: 1 June - 30 June 73
REPORT NO. 20
TYPE OF MATERIAL: Pervious (Filter Sand)

<table>
<thead>
<tr>
<th>CUMULATIVE TO THIS REPORT</th>
<th>THIS REPORT</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOTAL NO. OF TESTS</td>
<td>208</td>
</tr>
<tr>
<td>NO. BELOW MINIMUM</td>
<td>16</td>
</tr>
<tr>
<td>NO. REWORKED</td>
<td>16</td>
</tr>
<tr>
<td>NO. RETESTED AFT. REWORKING</td>
<td>16</td>
</tr>
</tbody>
</table>

LEGEND:
- • ABOVE ACCEPTABLE MIN
- X BELOW ACCEPTABLE MIN
- X₁ LATER REWORKED ONLY (NO RETEST)
- X₂ LATER REWORKED & RETESTED
- O₂ O₂ RESULT OF RETEST AFT. REWORKING
- A₁, A₂ INITIAL TEST (USE ONLY w/CHECK TEST)
- A₁, A₂ CHECK TEST

NOTE: USE SAME NUMBER FOR LATER REWORKED AND RETESTED AND RESULT OF RETEST AND FOR INITIAL AND CHECK TEST.

Stationing of Areas Tested | 4+30 to 16+10
Elevation of Areas Tested  | 739.2 to 752.0
APPENDIX A

PHOTOGRAPHS
(2) 20 July 1971
View of the barrier dam being raised to prevent overtopping.
(5) 20 July 1971

View from the right abutment area showing the barrier dam being raised to prevent overtopping.
19 September 1973

View of the upstream side of the dam showing the riprap being placed near the crest.