RECONNAISSANCE
HYDROLOGIC & ENGINEERING INVESTIGATIONS

FOR

ENGLEWOOD DAM

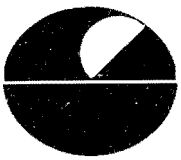
Arapahoe County, Colorado

FOR

URBAN DRAINAGE & FLOOD CONTROL DISTRICT

BY

WOODWARD—CLEVENGER & ASSOCIATES, INC.
Consulting Engineers & Geologists
2909 West Seventh Avenue
Denver, Colorado 80204



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Woodward-Clyde Consultants

RECONNAISSANCE HYDROLOGIC & ENGINEERING INVESTIGATIONS FOR ENGLEWOOD DAM ARAPAHOE COUNTY, COLORADO

Prepared for

URBAN DRAINAGE & FLOOD CONTROL DISTRICT
181 East 56th Avenue
Denver, Colorado 80216

Attention: Mr. L. Scott Tucker
Executive Director

Job No. 16849-7715

May 17, 1973

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INTRODUCTION

This report presents results of our Phase I engineering and geologic investigations for Englewood Dam, located on Willow Creek, a tributary of Little Dry Creek. The study is an initial phase of an overall study of the Little Dry Creek Basin intended to define and evaluate drainage problems associated with urbanization of the basin.

The objectives of our study were: (1) to determine whether the dam and its appurtenant facilities could safely retain flood flows associated with the 100-year average frequency recurrence storm, (2) to determine whether the dam and its appurtenant facilities could safely pass flood flows associated with the probable maximum precipitation (PMP) storm, and (3) to formulate preliminary opinions and criteria necessary to prepare feasibility-grade cost estimates for renovation of the dam if necessary to permit it to pass the PMP storm. All evaluations of runoff are based on assumed residential and commercial development of the area.

Data from our investigations are summarized on Figures 1 through 20, and Tables I, II, and III.

CONCLUSIONS

(1) Our preliminary opinion indicates the existing Englewood Dam is probably adequate to safely pass only the approximate 100-year average frequency recurrence flood. Some rehabilitation work will be necessary at the discharge end of the ungated concrete pipe outlet.

(2) We believe either the proposed raising of Englewood Dam by either 5 feet and construction of a spillway having a weir length of 460 feet; or raising of the dam by 10 feet and construction of a spillway having a weir length of 200 feet, as discussed in our report, are feasible from the soils, geologic and hydrologic standpoints. Preliminary study indicates raising of the dam by 10 feet would be the cheaper of the alternatives.

(3) Table III is a summary of hydrologic and reconnaissance-grade cost data relating to possible rehabilitation of Englewood Dam to the extent necessary to permit it to pass the maximum probable flood occurrence.

(4) Maintenance costs for a rehabilitated Englewood Dam designed to safely pass the probable maximum flood occurrence should be relatively minor.

PROJECT DESCRIPTION

Englewood Dam is an earthfill structure having a capacity of about 1200 acre-feet which was built during the mid-1930's to partially control flood flows of Little Dry Creek. It is located on Willow Creek in Section 29, Township 5 South, Range 67 West, a short distance upstream of its confluence with Little Dry Creek, as shown on Figure 1. Willow Creek and Little Dry Creek are typically dry.

The approximate 9 1/2 square mile watershed contributing to Englewood Reservoir is gently rolling and is presently covered with

grass and weeds. Only a few improvements have been constructed in the area, although it must be assumed that much of the area will ultimately be developed for residential and commercial purposes.

Englewood Dam is an earthfill structure about 50± feet high and 1700± feet long. It has a crest width of about 20 feet. The upstream slope of the dam is about 2½:1 and the downstream slope is about 2:1. The principal water outlet from the dam is an ungated 36-inch diameter concrete pipe having a maximum capacity of about 200 cubic feet per second with water level at the crest of the dam. The outlet is located near the toe of the dam in the natural stream channel. In addition to the ungated outlet the dam is equipped with two unlined emergency spillways. Elevations and dimensions of principal features of the dam are as follows:

Elevation of top of dam		-	5606 feet.
Elevation of spillway crest		-	5600 feet.
Elevation of ungated outlet		-	5574 feet.
Spillway widths:	Left	-	100 feet.
	Right	-	70 feet.

INVESTIGATIONS

Soils and geologic investigations for this report were initiated and substantially completed by March 1973. The investigations included the drilling of 20 test holes in the dam area and 6 test holes in the reservoir area, as located on Figure 2. The holes in the dam area included 5 along the axis of the dam, 3 along the downstream toe of the dam, three 100± feet downstream of the

downstream toe of the dam, 3 along the alignment of each unlined spillway on the left and right abutments, 2 along the alignment of each spillway discharge channel, and 1 near the present outlet works. Penetration tests were made in these test holes to aid in identifying the underground materials and to provide data on in-place firmness of the soil and hardness of the rock. "Undisturbed" Shelby tube "push" samples were also taken from test holes drilled along the crest of the existing dam to obtain samples of the dam and the underlying natural soils. Gravity permeability tests were also performed in selected test holes in the dam and downstream of the dam to help evaluate the permeability characteristics of the dam and the underlying natural materials.

Laboratory testing included visual classification of samples, moisture content determination, dry density determination, gradation analyses, Atterberg limits, standard compaction, unconfined compression and triaxial compression tests.

Our hydrologic investigations included (1) theoretical determination of and routing of the 100-year and PMP floods through the reservoir to determine adequacy of the existing dam to pass these floods, (2) calculation of spillway weir lengths necessary to pass the PMP flood occurrence assuming the dam were to be raised by either 5 feet or 10 feet, and (3) calculation of the area inundated for each dam height increase. Included is a reconnaissance-grade

assessment of costs necessary to raise the dam for assumed conditions of 5 feet and 10 feet.

HYDROLOGY

The estimation of probable peak rates and volumes of flow for any given average frequency flood occurrence is typically based on an evaluation of available information, extrapolation of available information, and judgment by the hydrologist. We have based our calculations of flood magnitude for the 100-year average recurrence storm on a review and analyses of rainfall records in the general Denver area. Due to the extreme improbability of the maximum probable precipitational occurrence, we have relied on hydrometeorologic information prepared by the U. S. Weather Bureau as it relates to the maximum probable storm. In addition, we have assumed watershed runoff characteristics based on our field inspection of the area and calculated time of storm concentration. Items used in the calculation of the storm hydrographs and results are as follows:

100-year storm = 4.7 inches in 6 hours
PMP storm = 22 inches in 6 hours
Time of storm concentration = 1.5 hours
Runoff Factor = Curve No. of 80*
100-year storm peak = 4100 cubic feet per second (Figure 12)

*Based on procedures used by U. S. Bureau of Reclamation and Soil Conservation Service

100-year storm volume = 1300 acre-feet
PMP storm peak = 44,200 cubic feet per second (Figure 13)
PMP storm volume = 9700 acre-feet

Results of our analyses indicate the existing dam should contain the 100-year average frequency flood occurrence assuming operation of the ungated outlet. Although water level would be at emergency spillway crest elevation, as shown on Figure 15, the emergency spillways would not operate. We would expect less frequent storm occurrences to result in operation of the emergency spillways.

We were directed by Mr. Scott Tucker of the Urban Drainage and Control District to evaluate spillway size required to pass the maximum probable flood occurrences based on raising of the dam embankments by either 5 feet or 10 feet. Results of the study for raising the dam by 5 feet reveal a 460-foot wide spillway weir length would be required. A 200-foot spillway weir length would be required if the dam were raised by 10 feet. Both conditions assume 2 feet of freeboard above the probable maximum high water elevation. Inflow and outflow hydrographs and water elevations for the 5-foot dam raise are shown on Figures 2, 13 and 15; and hydrographs for the 10-foot raise are shown on Figures 2, 14 and 15.

GEOLOGY

The dam and reservoir is underlain by the Dawson-Arkose formation comprising interbedded sandstones, siltstones and claystones.

Bedrock is mantled throughout the reservoir area by slopewash and alluvial soils on the steeper slopes, and by recent alluvium in the valley bottom. The slopewash and residual soils comprise mainly sandy clay, while the alluvium comprises a combination of sand, silt, and clay. There is no evidence of slope instability in the dam and reservoir area, nor do we anticipate any induced slope instability problems. Leakage through the dam abutments and dam foundation should be minimal due to the clayey nature of the soils.

DAM.

Subsoils

Our test holes show that the existing dam is constructed primarily of stiff to very stiff clays, with occasional sandstone and claystone pieces, and is underlain by natural medium stiff to stiff clays, medium dense sands, and thence by claystone and sandstone bedrock. On a profile constructed along the centerline of the dam (see Figure 3) the claystone-sandstone bedrock was found at depths of up to 20 feet below natural ground. Laboratory test data from test holes drilled on the existing dam are shown on Figures 16 and 18 through 20.

The test holes drilled along the axis of the dam appeared to verify a cutoff trench as shown on the 1936 plans. Test holes drilled downstream of the dam show man-made fill in one test hole

and 10 to 28 feet of medium stiff clays and medium dense sands underlain by claystone and sandstone bedrock at depth of 10 to 30 feet. Four sections constructed through the dam, showing subsoils found in our test holes in the dam and downstream of the dam are shown on Figures 4 and 5. In our opinion, the natural soils and the soils in the downstream section of the present dam are adequate to support the larger, higher proposed dams.

Our test holes drilled in the vicinity of the existing left and right abutment areas show up to 9 feet of natural medium stiff clays and medium dense sands (see Figure 17) underlain by generally shallow and variably hard claystone and sandstone bedrock. Profiles constructed through the spillway locations under consideration for this investigation are shown on Figure 7. These profiles indicate that spillways at either proposed location would be founded on varying combinations of natural overburden and bedrock soils that should be capable of supporting conventionally designed spillways without abnormal movements.

Stability

Our investigations included theoretical stability analyses of the downstream slope performed on an embankment section constructed from cross section surveys by Merrick and Company. The results of this stability analyses are shown on Figure 11. This analysis was made to provide information to assist in judgment

decisions on proposed raising of the existing dam and use of the present dam. The assumptions made, although based upon data which is not of the highest order of accuracy, indicate the dam to be stable.

Borrow Material

Our test holes in the reservoir area upstream of the dam revealed that borrow soils from within the reservoir area would be predominately clays, as show on Figure 7. Bedrock was found at depths of about 5 feet in three of the six test holes drilled and in general should be at relatively shallow depth. In our opinion, any of the bedrock soils which would break down during excavation and/or in placement could also be used as a source of borrow material for proposed raises of the dam. However, we do not believe it would be necessary to excavate into bedrock and it seems probable that more detailed investigations would verify an adequate amount of overburden clays of adequate depth for borrow materials.

SPILLWAY

Our investigations included an analyses of spillways to pass the PMP flood without overtopping the dam, assuming the dam were raised by (a) 5 feet above the present crest level, or (b) 10 feet above the present crest level. Schematic details of the

proposed dam raises and spillway locations are shown on Figures 8, 9, and 10. Preliminary summaries of cost estimates for these various plans are shown on Table III. In our opinion, all of the schemes shown are feasible from the soils engineering, hydrologic and geologic standpoint; however, the scheme involving a 10-foot raise of the dam and a spillway over the left abutment as shown on Figure 10, appears to be the most economical of the three studied.

GENERAL INFORMATION

The exploratory data presented herein were collected to help develop preliminary design and cost estimates for this project and thus have limited value for indicating underground conditions for final design or contractor bidding and construction. Further investigations are, in our opinion, necessary to provide final design criteria. If it is necessary to portray underground conditions well enough to enable contractors to more accurately evaluate conditions for bidding and execution of work, we recommend considering exploratory work developed for that purpose, after the affected designs are essentially finalized.

Professional judgments on design alternatives and criteria are presented in this report. These are based partly on evaluations of technical information gathered, partly on our understanding of the characteristics of the facility being planned, and partly on our general experience with subsurface conditions in the

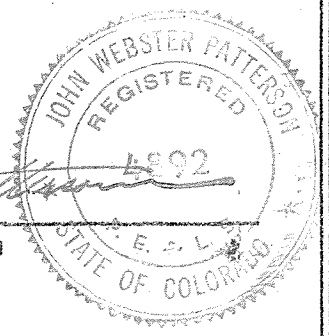
area. We do not guarantee the performance of the project in any respect, only that our engineering work and judgments rendered meet the standard of care of our profession.

The test holes drilled for this investigation were spaced to obtain a reasonably accurate picture of subsurface conditions for preliminary design and cost estimating purposes. Variations from the conditions portrayed which were not indicated by the test explorations frequently appear. These variations are sometimes sufficient to necessitate modifications in even preliminary design criteria. Construction of earth dams involve the use of natural materials which, by their nature, vary so much that it is not possible to cover all eventualities in design. Other aspects of construction at this site fall into the same category. This necessitates guidance in decisions at all stages of future final investigations and construction which must be made by competent and experienced personnel. We recommend that additional investigations be undertaken to provide final design criteria should you decide to renovate Englewood Dam. We further recommend that construction be continuously observed by a soils specialist, fully trained and experienced in the field, to take advantage of all opportunities to recognize differing conditions and minimize the risk of having undetected conditions which would affect the performance of the dam.

CREDITS

Our investigations and analyses were made under the supervision of Messrs. John W. Patterson, Frank J. Holliday, and R. J. Irish. Mr. Ted Johnson assisted in analyses of data and prepared a portion of the draft of the report. Information on the proposed raises of the dam was provided by Mr. L. Scott Tucker, Executive Director of the Urban Drainage and Flood Control District. The report has been reviewed and approved by the undersigned.

If we can be of further service in discussing the contents of this report, or in analyses of structural features from the soil and foundation viewpoint, please call.



By _____
John W. Patterson
Vice President

TDJ:m

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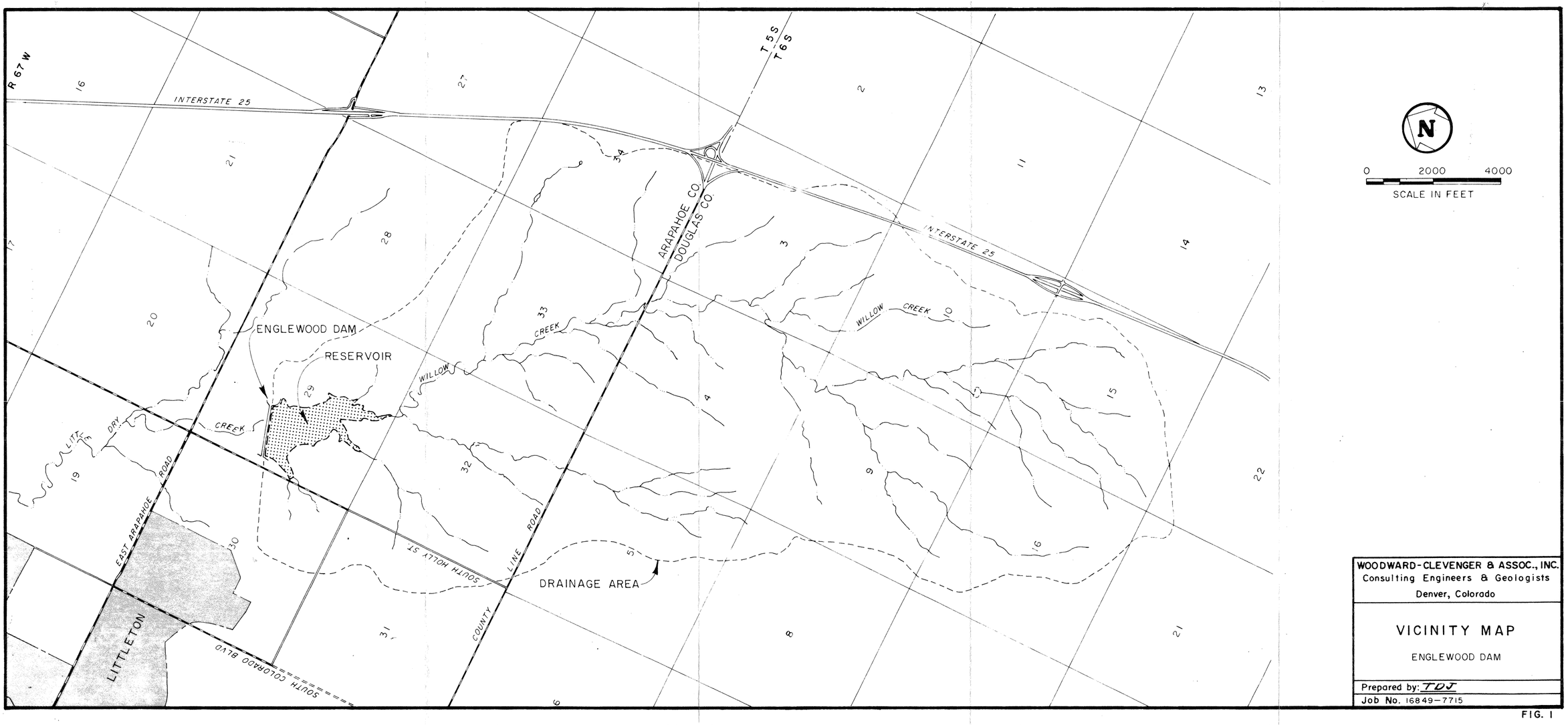

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VICINITY MAP

ENGLEWOOD DAM

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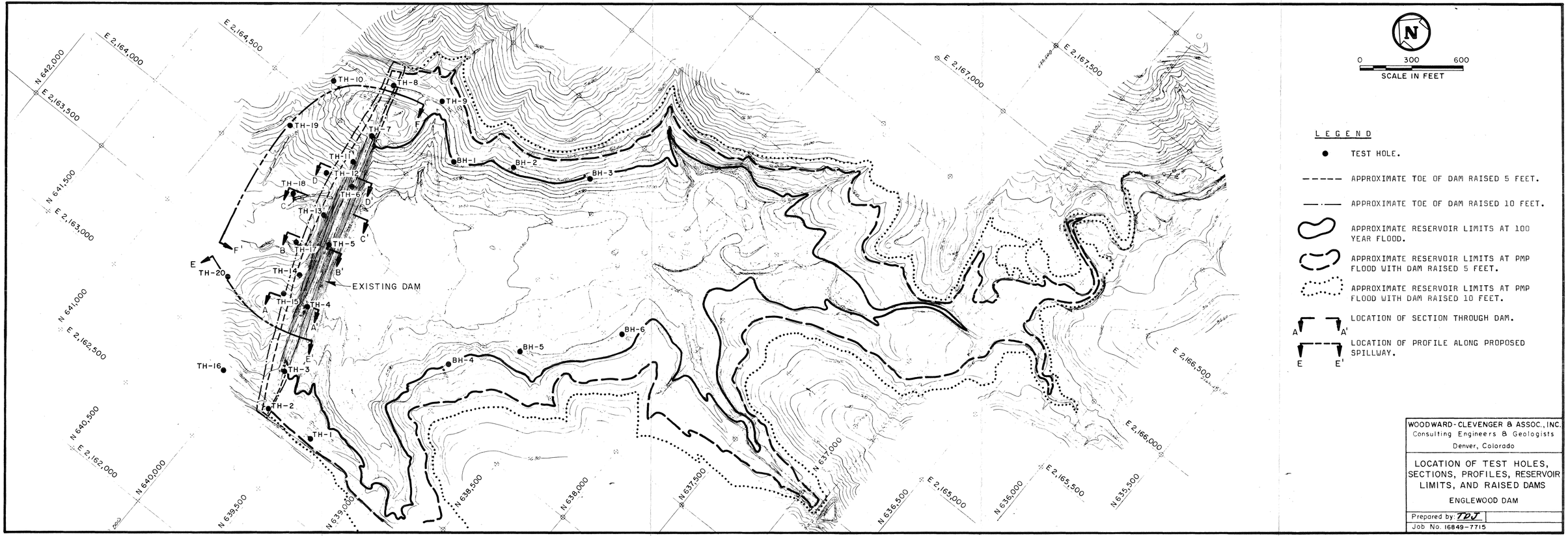
FIG. 1



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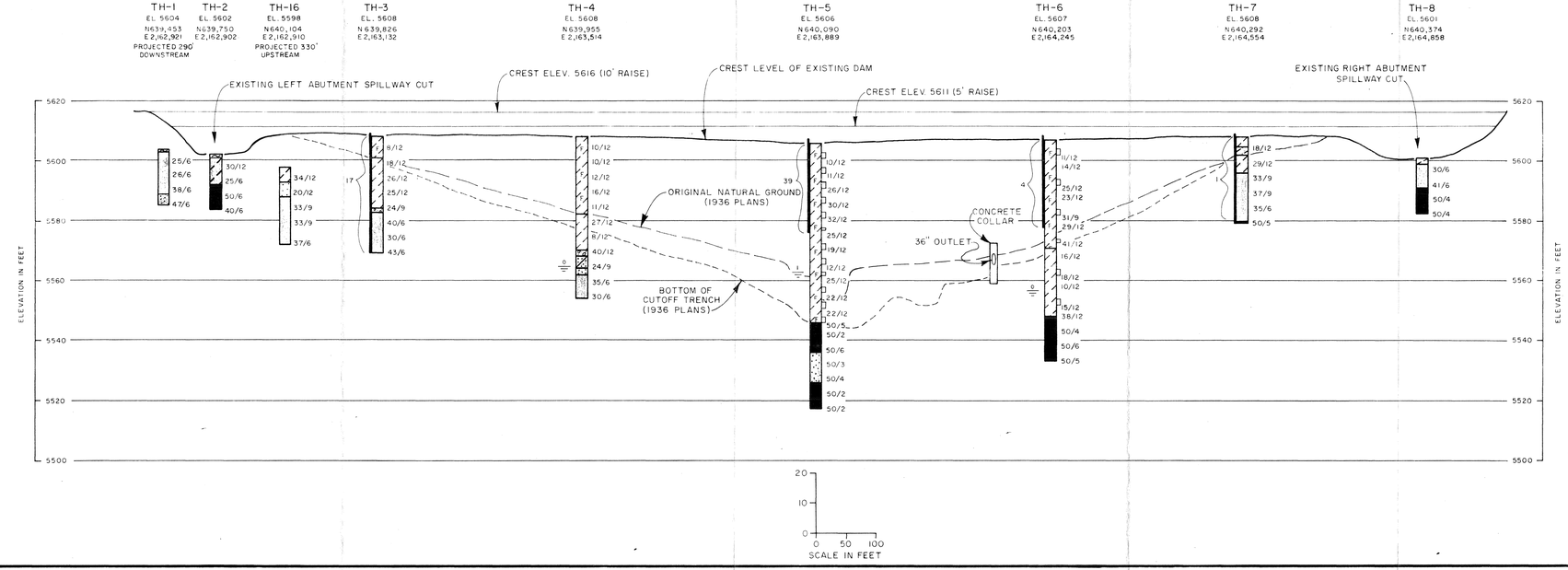
LOCATION OF TEST HOLES, SECTIONS, PROFILES, RESERVOIR LIMITS, AND RAISED DAMS

ENGLEWOOD DAM

Prepared by TDJ

Job No. 16849-7715

FIG. 2



LEGEND

- TOPSOIL, CLAY, ROOTS, MOIST TO VERY MOIST, LIGHT BROWN, DARK BROWN.
- EXISTING DAM FILL, CLAY, STIFF TO VERY STIFF, SLIGHTLY SANDY TO VERY SANDY, SOME CLAYSTONE AND SANDSTONE PIECES AND FRAGMENTS, MOIST, BROWN, GRAY, RUST-BROWN, YELLOW-BROWN (CL).
- CLAY, STIFF TO VERY STIFF, SLIGHTLY SILTY, SLIGHTLY SANDY TO SANDY WITH VERY OCCASIONAL SAND LENSES, OCCASIONALLY GRAVELLY AND CALCAREOUS, MOIST TO VERY MOIST, LIGHT BROWN, DARK BROWN, REDDISH-BROWN (CL).
- SAND, MEDIUM DENSE, CLEAN TO SLIGHTLY SILTY, OCCASIONAL GRAVEL, MOIST TO WET, LIGHT BROWN (SP-SM).
- SAND AND GRAVEL, MEDIUM DENSE TO DENSE, CLEAN, MOIST, BROWN (SP-GP).
- CLAY, STIFF, MOIST, BROWN (CL) (WEATHERED BEDROCK).
- CLAYSTONE, FIRM, MOIST, BROWN, OLIVE (BEDROCK).
- CLAYSTONE, MEDIUM HARD TO HARD, SLIGHTLY SANDY, THIN LENSED IN PART, MOIST, BROWN, OLIVE, DARK BROWN (BEDROCK).
- CLAYSTONE, VERY HARD, SLIGHTLY SANDY, OCCASIONAL SANDSTONE AND SILTSTONE LENSES, MOIST, LIGHT BROWN, DARK BROWN, BROWN, OLIVE (BEDROCK).
- SANDSTONE, MEDIUM HARD TO HARD, OCCASIONALLY CLAYEY, MOIST, BROWN (BEDROCK).
- SANDSTONE, VERY HARD, OCCASIONAL VERY HARD CLAYSTONE LENSE, MICACEOUS, MOIST, DARK GRAY, DARK BROWN, BLUE-GRAY (BEDROCK).

32/12 INDICATES THAT 32 BLOWS OF A 140-POUND HAMMER FALLING 30 INCHES WERE REQUIRED TO DRIVE A 2-INCH DIAMETER SAMPLER 12 INCHES.

FREE WATER LEVEL AND NUMBER OF DAYS AFTER DRILLING THAT MEASUREMENT WAS TAKEN.

INDICATES "UNDISTURBED" SHELBY TUBE SAMPLE.

INDICATES 3-INCH DIAMETER PLASTIC (PVC) PIPE IN TEST HOLE FOR PERMEABILITY TESTS.

4 DEPTH INTERVAL CALCULATED COEFFICIENT OF PERMEABILITY (FT./YR.) FROM FIELD PERMEABILITY TESTS.

FOR NOTES, SEE FIGURE 4.

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SUMMARY LOGS OF TEST HOLES

PROFILE ALONG DAM AXIS

ENGLEWOOD DAM

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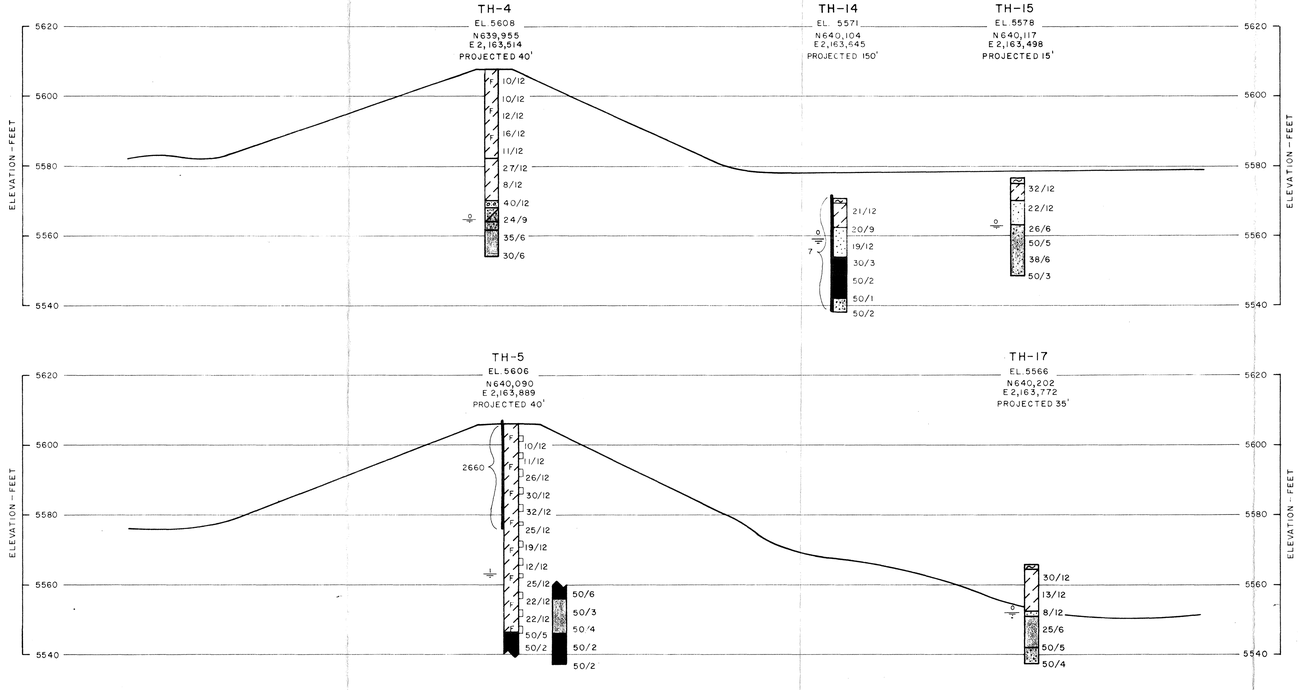
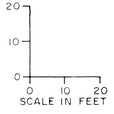
Job No. 16849-7715

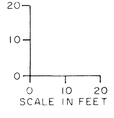
FIG. 3



SECTION A–A'



SECTION B–B'



LEGEND

- TOPSOIL, CLAY, ROOTS, MOIST TO VERY MOIST, LIGHT BROWN, DARK BROWN.
- EXISTING DAM FILL, CLAY, STIFF TO VERY STIFF, SLIGHTLY SANDY TO VERY SANDY, SOME CLAYSTONE AND SANDSTONE PIECES AND FRAGMENTS, MOIST, BROWN, GRAY, RUST-BROWN, YELLOW BROWN (CL).
- CLAY, STIFF TO VERY STIFF, SLIGHTLY SILTY, SLIGHTLY SANDY TO SANDY WITH VERY OCCASIONAL SAND LENSES, OCCASIONALLY GRAVELLY AND CALCAREOUS, MOIST TO VERY MOIST, LIGHT BROWN, DARK BROWN, REDDISH-BROWN (CL).
- SAND, MEDIUM DENSE, CLEAN TO SLIGHTLY SILTY, OCCASIONAL GRAVEL, MOIST TO WET, LIGHT BROWN (SP-SM).
- SAND AND GRAVEL, MEDIUM DENSE TO DENSE, CLEAN, MOIST, BROWN (SP-GP).
- CLAYSTONE, MEDIUM HARD TO HARD, SLIGHTLY SANDY, THIN LENSED IN PART, MOIST, BROWN, OLIVE, DARK BROWN (BEDROCK).
- CLAYSTONE, VERY HARD, SLIGHTLY SANDY, OCCASIONAL SANDSTONE AND SILTSTONE LENSES, MOIST, LIGHT BROWN, DARK BROWN, BROWN, OLIVE (BEDROCK).
- SANDSTONE, MEDIUM HARD TO HARD, OCCASIONALLY CLAYEY, MOIST, BROWN (BEDROCK).
- SANDSTONE, VERY HARD, OCCASIONAL VERY HARD CLAYSTONE LENSE, MICACEOUS, MOIST, DARK GRAY, DARK BROWN, BLUE-GRAY (BEDROCK).
- 32/12 INDICATES THAT 32 BLOWS OF A 140-POUND HAMMER FALLING 30 INCHES WERE REQUIRED TO DRIVE A 2-INCH DIAMETER SAMPLER 12 INCHES.
- FREE WATER LEVEL AND NUMBER OF DAYS AFTER DRILLING THAT MEASUREMENT WAS TAKEN.
- INDICATES "UNDISTURBED" SHELBY TUBE SAMPLE.
- INDICATES 3-INCH DIAMETER PLASTIC (PVC) PIPE IN TEST HOLE FOR PERMEABILITY TESTS.
- 7 DEPTH INTERVAL CALCULATED COEFFICIENT OF PERMEABILITY (FT./YR.) FROM FIELD PERMEABILITY TESTS.

NOTES:

1. TEST HOLES WERE DRILLED ON JANUARY 11 TO 18, 1973 WITH A 4-INCH DIAMETER HELICAL AUGER POWERED BY A CENTRAL MINE EQUIPMENT (CME 55) DRILLING RIG.
2. ELEVATION AND COORDINATE LOCATIONS ARE APPROXIMATE AND WERE FURNISHED BY MERRICK & COMPANY.
3. DRILL LOGS IN THIS REPORT ARE SUBJECT TO LIMITATIONS, EXPLANATIONS, AND CONCLUSIONS OF THIS REPORT.
4. THESE DRILL LOGS SUMMARIZE FINDINGS RELIED ON IN FORMULATING THE DESIGN CRITERIA PRESENTED IN THIS REPORT. THE EXPLORATIONS WERE NOT MADE TO DEFINE CONDITIONS FOR CONSTRUCTION NOR IS THE INFORMATION PRESENTED HEREIN FOR THAT PURPOSE.

WOODWARD-CLEVENGER & ASSOC., INC.
Consulting Engineers & Geologists
Denver, Colorado

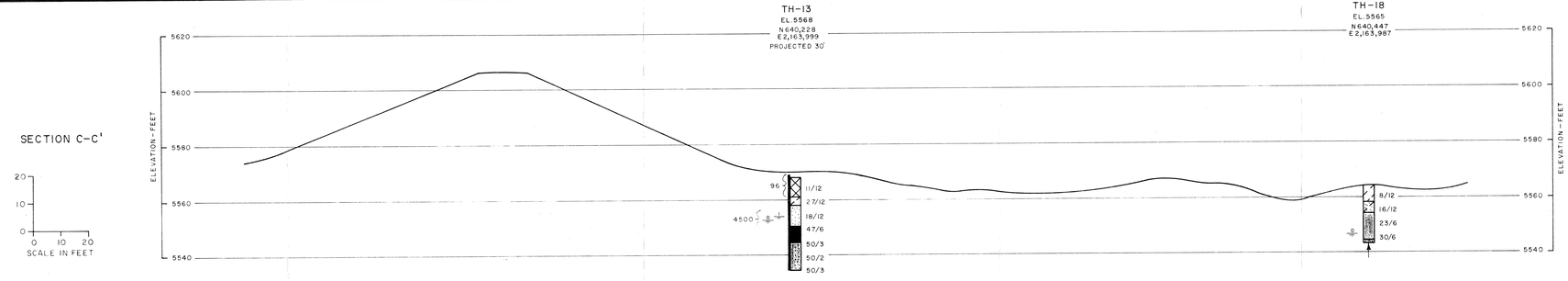
SUMMARY LOGS OF TEST HOLES

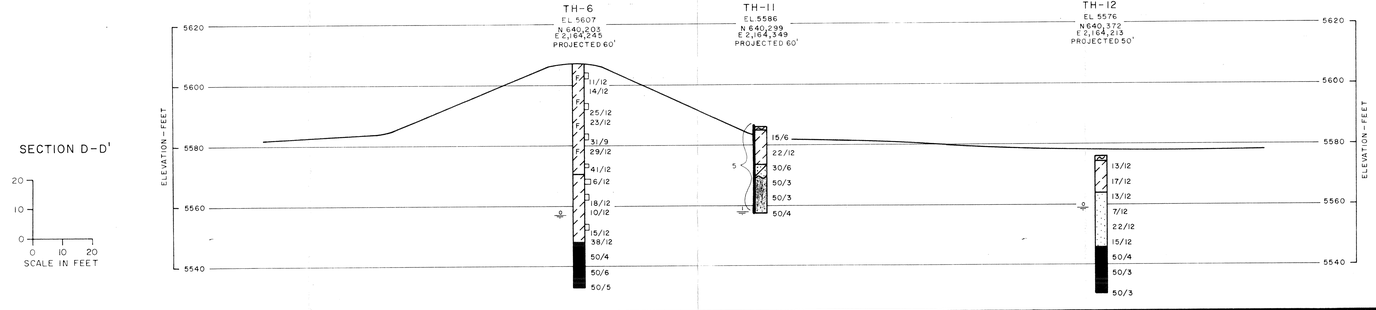
SECTIONS A–A' & B–B'

ENGLEWOOD DAM

Prepared by: TCJ
Job No. 16849-7715

FIG. 4





LEGEND

- MAN-MADE FILL, MIXED PIECES OF SANDSTONE AND CLAYSTONE, SOME CLAY, MOIST, BROWN.
- TOPSOIL, CLAY, ROOTS, MOIST TO VERY MOIST, LIGHT BROWN, DARK BROWN.
- EXISTING DAM FILL, CLAY, STIFF TO VERY STIFF, SLIGHTLY SANDY TO VERY SANDY, SOME CLAYSTONE AND SANDSTONE PIECES AND FRAGMENTS, MOIST, BROWN, GRAY, RUST-BROWN, YELLOW BROWN (CL).
- CLAY, STIFF TO VERY STIFF, SLIGHTLY SILTY, SLIGHTLY SANDY TO SANDY WITH VERY OCCASIONAL SAND LENSES, OCCASIONALLY GRAVELLY AND CALCAREOUS, MOIST TO VERY MOIST, LIGHT BROWN, DARK BROWN, REDDISH-BROWN (CL).
- SAND, MEDIUM DENSE, CLAYEY, MOIST, LIGHT BROWN (SC).
- SAND, MEDIUM DENSE, CLEAN TO SLIGHTLY SILTY, OCCASIONAL GRAVEL, MOIST TO WET, LIGHT BROWN (SP-SM).
- CLAYSTONE, MEDIUM HARD TO HARD, SLIGHTLY SANDY, THIN LENSED IN PART, MOIST, BROWN, OLIVE, DARK BROWN (BEDROCK).
- CLAYSTONE, VERY HARD, SLIGHTLY SANDY, OCCASIONAL SANDSTONE AND SILTSTONE LENSES, MOIST, LIGHT BROWN, DARK BROWN, BROWN, OLIVE (BEDROCK).
- SANDSTONE, MEDIUM HARD TO HARD, OCCASIONALLY CLAYEY, MOIST, BROWN (BEDROCK).
- SANDSTONE, VERY HARD, OCCASIONAL VERY HARD CLAYSTONE LENSE, MICACEOUS, MOIST, DARK GRAY, DARK BROWN, BLUE-GRAY (BEDROCK).

32/12 INDICATES THAT 32 BLOWS OF A 140-POUND HAMMER FALLING 30 INCHES WERE REQUIRED TO DRIVE A 2-INCH DIAMETER SAMPLER 12 INCHES.

- FREE WATER LEVEL AND NUMBER OF DAYS AFTER DRILLING THAT MEASUREMENT WAS TAKEN.
- GRADUAL CHANGE IN MATERIALS. EXACT STRATA CHANGE NOT LOCATED.
- INDICATES "UNDISTURBED" SHELBY TUBE SAMPLE.
- INDICATES PRACTICAL DRILL RIG REFUSAL.
- INDICATES 3-INCH DIAMETER PLASTIC (PVC) PIPE IN TEST HOLE FOR PERMEABILITY TESTS.
- 5 DEPTH INTERVAL CALCULATED COEFFICIENT OF PERMEABILITY (FT./YR.) FROM FIELD PERMEABILITY TESTS.

FOR NOTES, SEE FIGURE 4.

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SUMMARY LOGS OF TEST HOLES

SECTIONS C-C' & D-D'

ENGLEWOOD DAM

Prepared by: TDS

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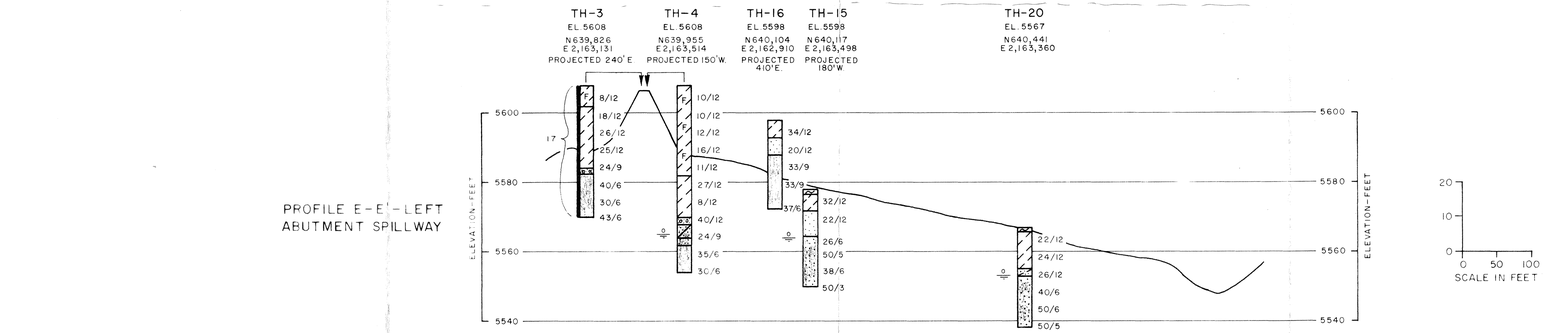
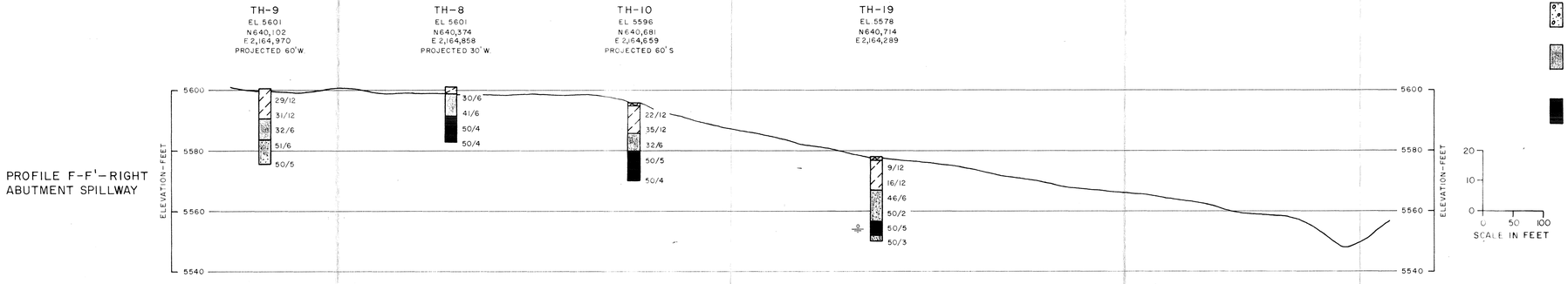
FIG. 5





LEGEND

- TOPSOIL, CLAY, ROOTS, MOIST TO VERY MOIST, LIGHT BROWN, DARK BROWN.
- EXISTING DAM FILL, CLAY, STIFF TO VERY STIFF, SLIGHTLY SANDY TO VERY SANDY, SOME CLAYSTONE AND SANDSTONE PIECES AND FRAGMENTS, MOIST, BROWN, GRAY, RUST-BROWN, YELLOW-BROWN (CL).
- CLAY, STIFF TO VERY STIFF, SLIGHTLY SILTY, SLIGHTLY SANDY TO SANDY WITH VERY OCCASIONAL SAND LENSES, OCCASIONALLY GRAVELLY AND CALCAREOUS, MOIST TO VERY MOIST, LIGHT BROWN, DARK BROWN, REDDISH-BROWN (CL).
- SAND, MEDIUM DENSE, CLAYEY, MOIST, LIGHT BROWN (SC).
- SAND, MEDIUM DENSE, CLEAN TO SLIGHTLY SILTY, OCCASIONAL GRAVEL, MOIST TO WET, LIGHT BROWN (SP-SM).
- SAND AND GRAVEL, MEDIUM DENSE TO DENSE, CLEAN, MOIST, BROWN (SP-GP).
- CLAYSTONE, MEDIUM HARD TO HARD, SLIGHTLY SANDY, THIN LENSED IN PART, MOIST, BROWN, OLIVE, DARK BROWN (BEDROCK).
- CLAYSTONE, VERY HARD, SLIGHTLY SANDY, OCCASIONAL SANDSTONE AND SILTSTONE LENSES, MOIST, LIGHT BROWN, DARK BROWN, BROWN, OLIVE (BEDROCK).
- SANDSTONE, MEDIUM HARD TO HARD, OCCASIONALLY CLAYEY, MOIST, BROWN (BEDROCK).
- SANDSTONE, VERY HARD, OCCASIONAL VERY HARD CLAYSTONE LENSE, MICACEOUS, MOIST, DARK GRAY, DARK BROWN, BLUE-GRAY (BEDROCK).

32/12 — INDICATES THAT 32 BLOWS OF A 140-POUND HAMMER FALLING 30 INCHES WERE REQUIRED TO DRIVE A 2-INCH DIAMETER SAMPLER 12 INCHES.

FREE WATER LEVEL AND NUMBER OF DAYS AFTER DRILLING THAT MEASUREMENT WAS TAKEN.

INDICATES "UNDISTURBED" SHELBY TUBE SAMPLE.

INDICATES 3-INCH DIAMETER PLASTIC (PVC) PIPE IN TEST HOLE FOR PERMEABILITY TESTS.

17 — DEPTH INTERVAL CALCULATED COEFFICIENT OF PERMEABILITY (FT./YR.) FROM FIELD PERMEABILITY TESTS.

FOR NOTES, SEE FIGURE 4.

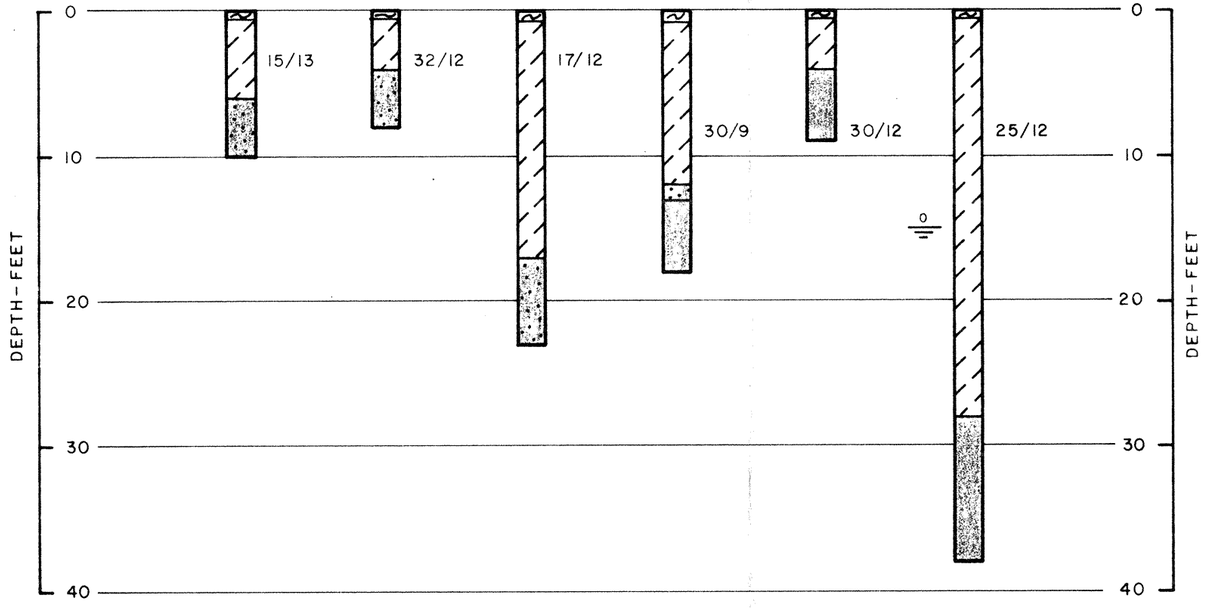
WOODWARD-CLEVENGER & ASSOC., INC.
Consulting Engineers & Geologists
Denver, Colorado

SUMMARY LOGS OF TEST HOLES
PROFILE E-E' & F-F' PROPOSED LEFT AND RIGHT ABUTMENT SPILLWAYS
ENGLEWOOD DAM

Prepared by: TDJ
Job No. 16849-7715

FIG. 6

BH-1	BH-2	BH-3	BH-4	BH-5	BH-6
EL.5598	EL.5600	EL.5599	EL.5599	EL.5592	EL.5593
N639,832	N639,534	N639,169	N639,099	N638,821	N638,421
E2,164,732	E2,164,921	E2,165,151	E2,163,779	E2,164,098	E2,164,562



LEGEND

TOPSOIL, CLAY, ROOTS, MOIST TO VERY MOIST, LIGHT BROWN, DARK BROWN.

CLAY, STIFF TO VERY STIFF, SLIGHTLY SILTY, SLIGHTLY SANDY TO SANDY WITH VERY OCCASIONAL SAND LENSES, OCCASIONALLY GRAVELLY AND CALCAREOUS, MOIST TO VERY MOIST, LIGHT BROWN, DARK BROWN, REDDISH-BROWN (CL).

CLAYSTONE, MEDIUM HARD TO HARD, SLIGHTLY SANDY, THIN LENSED IN PART, MOIST, BROWN, OLIVE, DARK BROWN (BEDROCK).

SANDSTONE, VERY HARD, OCCASIONAL VERY HARD CLAYSTONE LENSE, MICACEOUS, MOIST, DARK GRAY, DARK BROWN, BLUE-GRAY (BEDROCK).

32/12 INDICATES THAT 32 BLOWS OF A 140-POUND HAMMER FALLING 30 INCHES WERE REQUIRED TO DRIVE A 2-INCH DIAMETER SAMPLER 12 INCHES.

$\frac{0}{\nabla}$ FREE WATER LEVEL AND NUMBER OF DAYS AFTER DRILLING THAT MEASUREMENT WAS TAKEN.

FOR NOTES, SEE FIGURE 4.

WOODWARD-CLEVENGER & ASSOC., INC.
Consulting Engineers & Geologists
Denver, Colorado

SUMMARY LOGS OF TEST HOLES

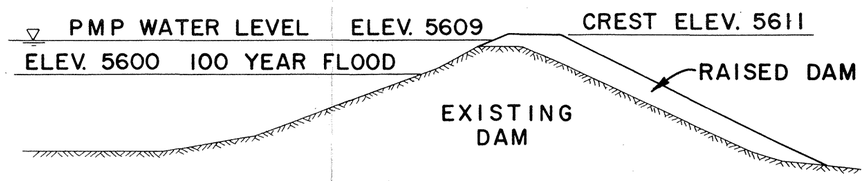
RESERVOIR BORROW AREA

ENGLEWOOD DAM

Prepared by: TDJ

Job No. 16849-7715

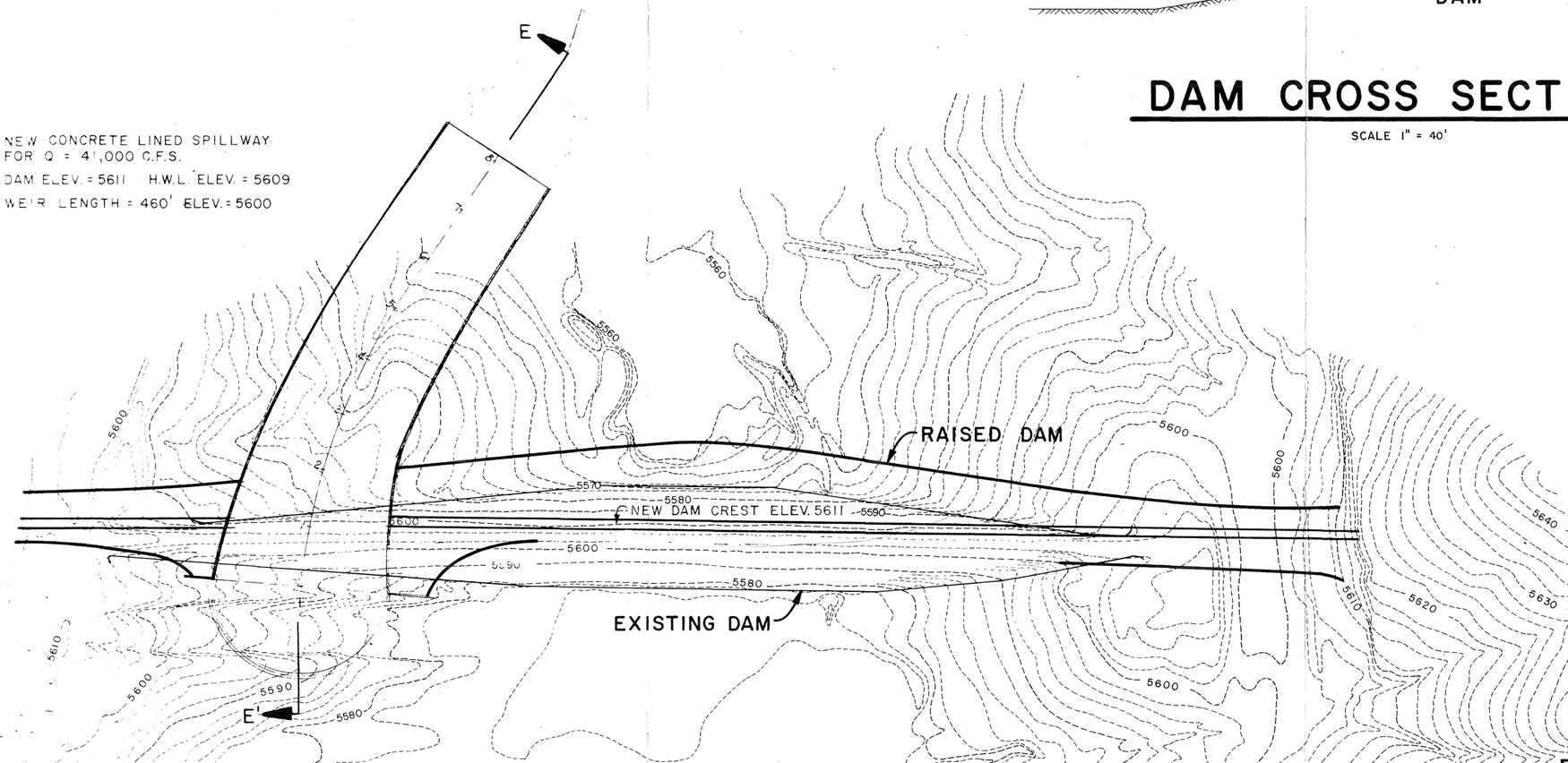
FIG. 7



DAM CROSS SECTION

SCALE 1" = 40'

NEW CONCRETE LINED SPILLWAY
FOR Q = 41,000 C.F.S.
DAM ELEV. = 5611 H.W.L. ELEV. = 5609
WEIR LENGTH = 460' ELEV. = 5600



PLAN
DAM RAISED 5 FEET

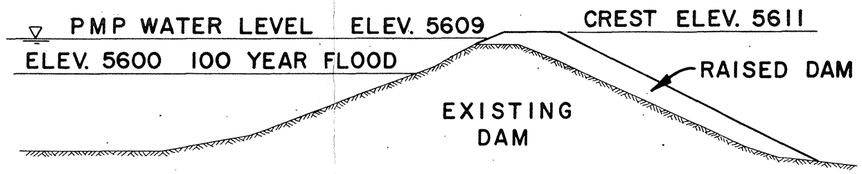
SCALE 1" = 200'

WOODWARD-CLEVENGER & ASSOC., INC.
Consulting Engineers & Geologists
Denver, Colorado

LEFT ABUTMENT SPILLWAY
DAM RAISED
5 FEET
ENGLEWOOD DAM

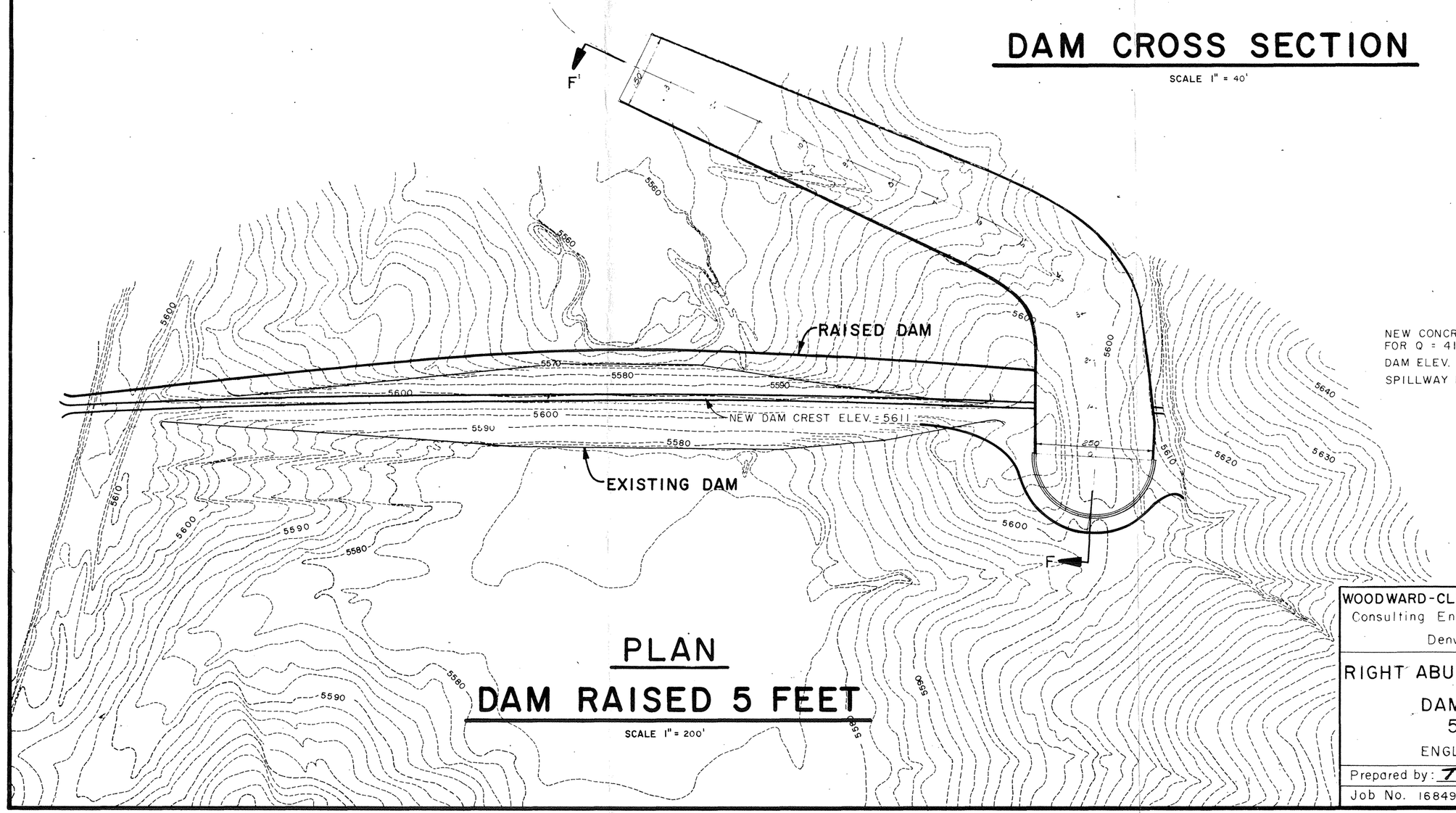
Prepared by: TOJ
Job No. 16849-7715

FIG. 8



DAM CROSS SECTION

SCALE 1" = 40'



PLAN

DAM RAISED 5 FEET

SCALE 1" = 200'

NEW CONCRETE LINED SPILLWAY
FOR Q = 41,000 C.F.S.
DAM ELEV. = 5611 H.W.L. ELEV. = 5609
SPILLWAY LENGTH = 460' ELEV. = 5600

WOODWARD-CLEVENGER & ASSOC., INC.
Consulting Engineers & Geologists
Denver, Colorado

RIGHT ABUTMENT SPILLWAY

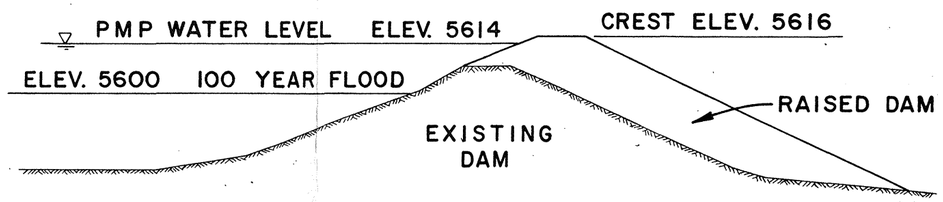
DAM RAISED
5 FEET

ENGLEWOOD DAM

Prepared by: TDJ

Job No. 16849-7715

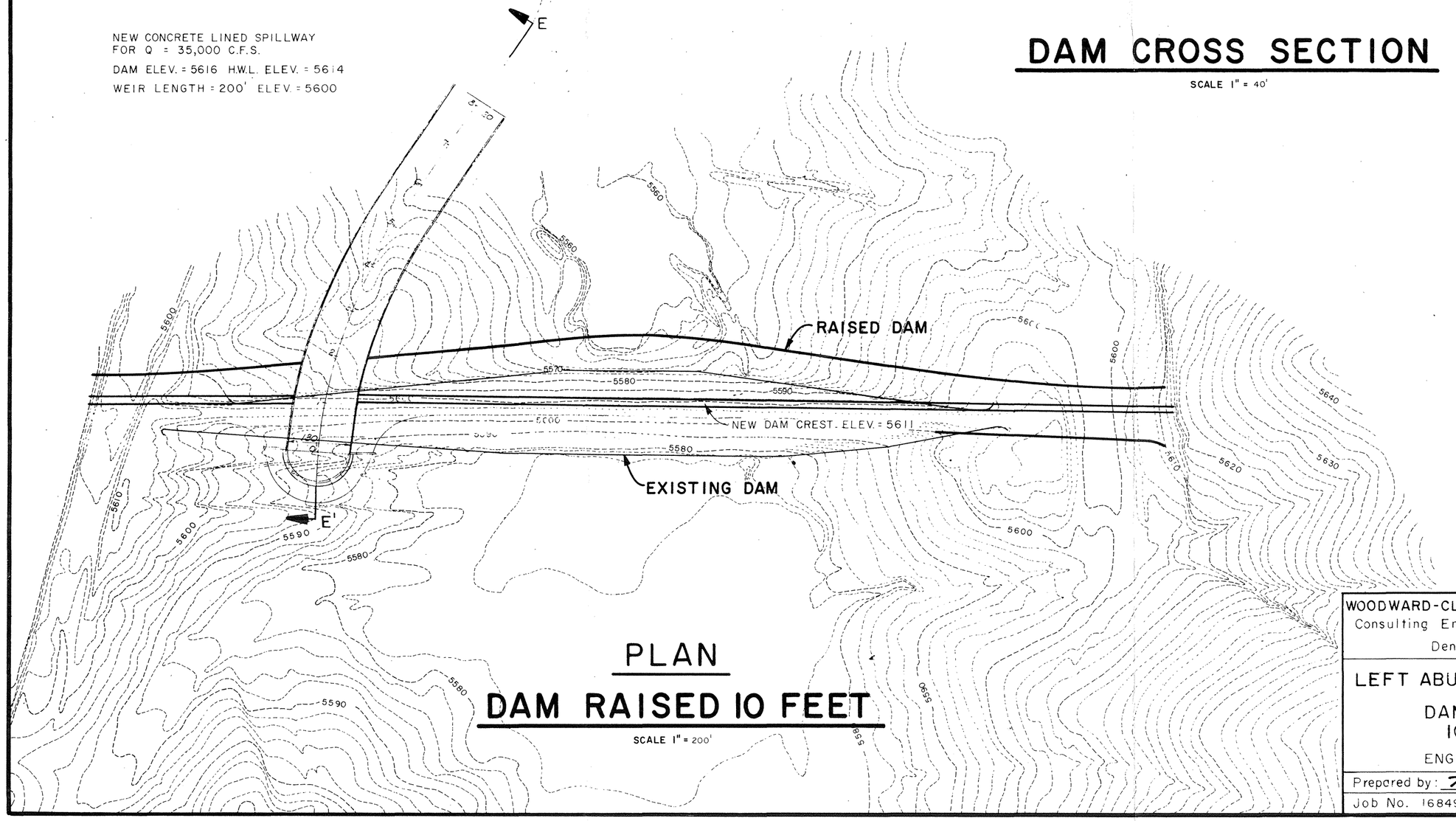
FIG. 9



DAM CROSS SECTION

SCALE 1" = 40'

NEW CONCRETE LINED SPILLWAY
FOR Q = 35,000 C.F.S.
DAM ELEV. = 5616 H.W.L. ELEV. = 5614
WEIR LENGTH = 200' ELEV. = 5600



PLAN

DAM RAISED 10 FEET

SCALE 1" = 200'

WOODWARD-CLEVENGER & ASSOC., INC.
Consulting Engineers & Geologists
Denver, Colorado

LEFT ABUTMENT SPILLWAY

DAM RAISED
10 FEET

ENGLEWOOD DAM

Prepared by: TDJ

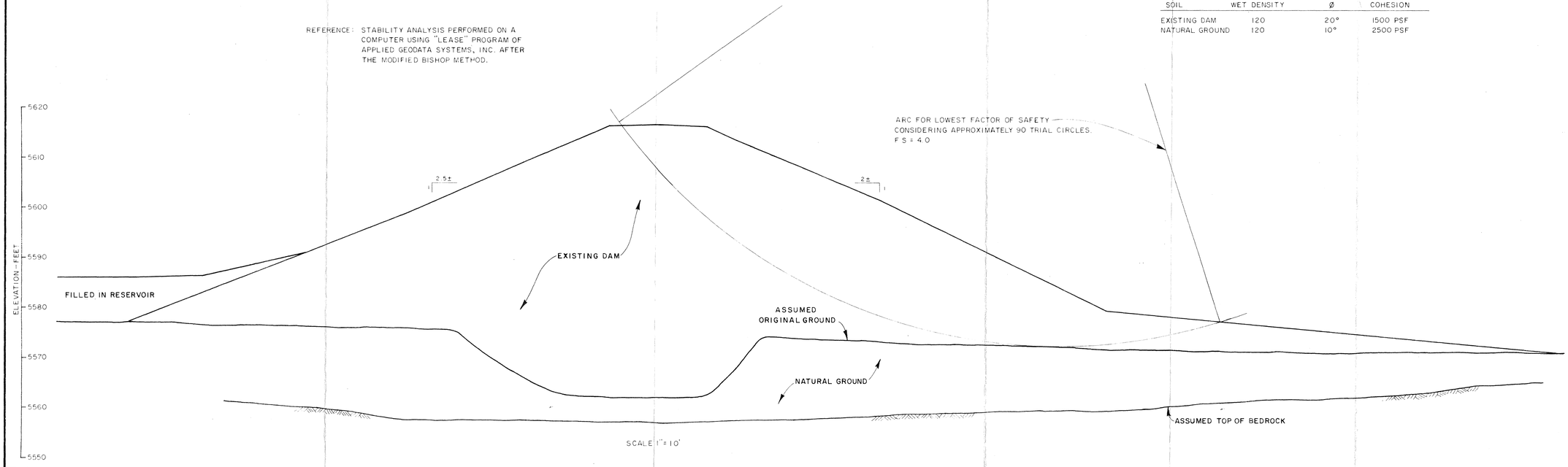
Job No. 16849-7715

FIG. 10

REFERENCE: STABILITY ANALYSIS PERFORMED ON A COMPUTER USING "LEASE" PROGRAM OF APPLIED GEODATA SYSTEMS, INC. AFTER THE MODIFIED BISHOP METHOD.

ASSUMPTIONS :

SOIL	WET DENSITY	Ø	COHESION
EXISTING DAM	120	20°	1500 PSF
NATURAL GROUND	120	10°	2500 PSF



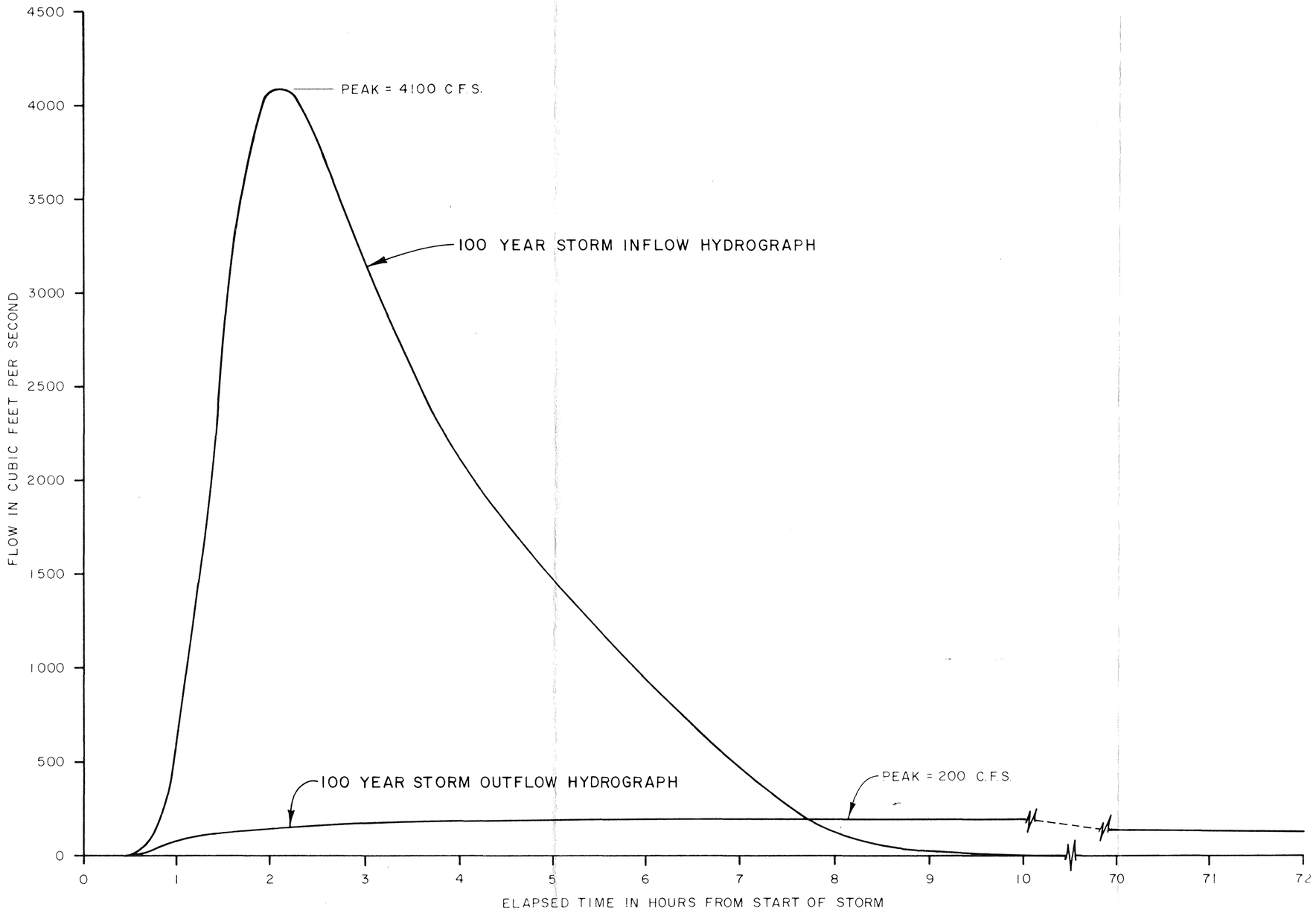
WOODWARD-CLEVENGER & ASSOC., INC
Consulting Engineers & Geologists
Denver, Colorado

STABILITY ANALYSIS

ENGLEWOOD DAM

Prepared by TCJ
Job No. 16849-775

FIG. 11



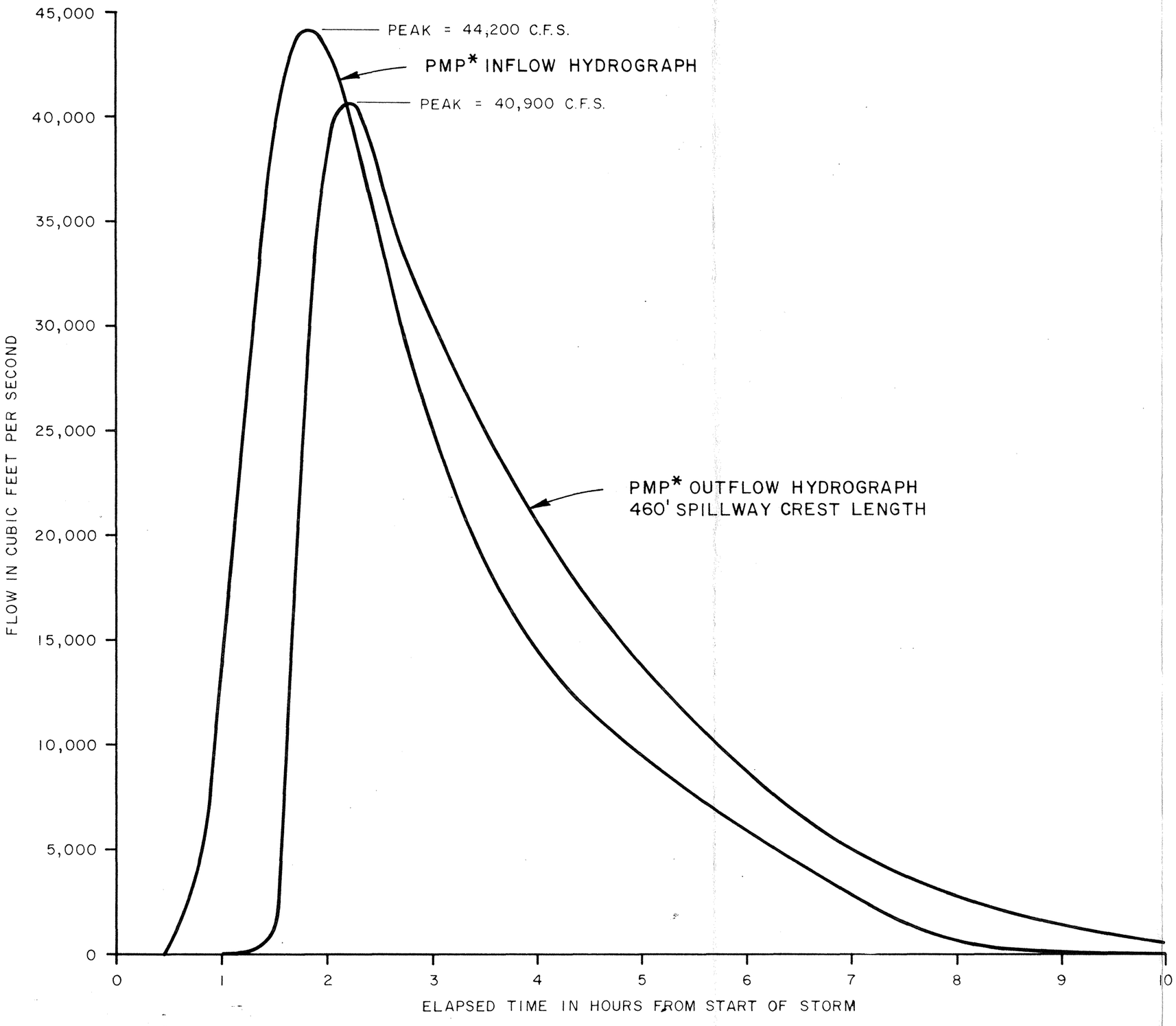
WOODWARD-CLEVENGER & ASSOC., INC.
Consulting Engineers & Geologists
Denver, Colorado

100 YEAR STORM INFLOW AND OUTFLOW HYDROGRAPHS FLOW THROUGH 36 INCH UNGATED OUTLET
ENGLEWOOD DAM

Prepared by: _____

Job No. 16849-7715

FIG. 12



* PROBABLE MAXIMUM PRECIPITATION

WOODWARD-CLEVENGER & ASSOC., INC.
Consulting Engineers & Geologists
Denver, Colorado

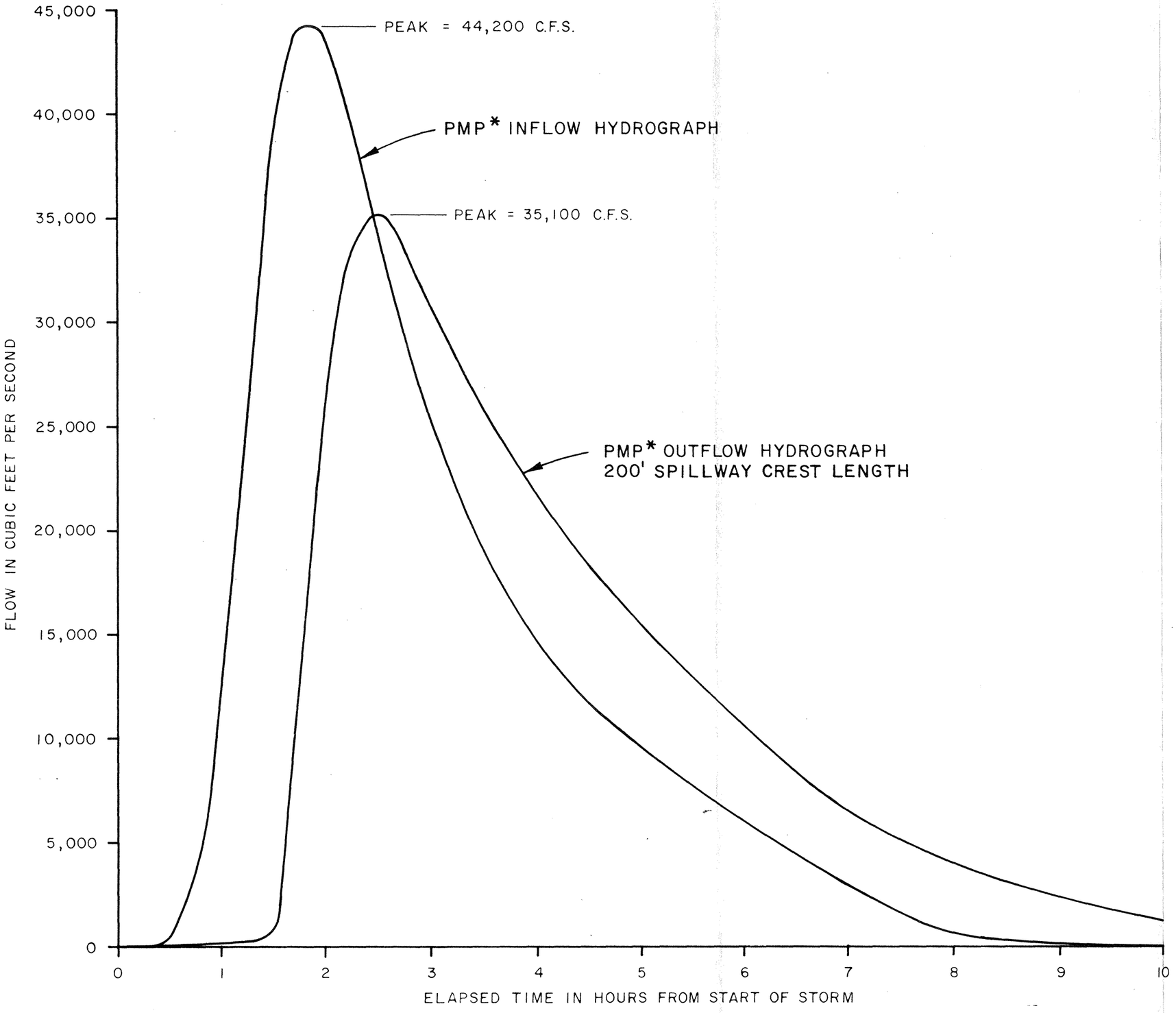
PROBABLE MAXIMUM INFLOW AND OUTFLOW HYDROGRAPHS ASSUME 460 FEET WIDE SPILLWAY CREST

ENGLEWOOD DAM

Prepared by: MJK

Job No. 16849-7715

FIG. 13



* PROBABLE MAXIMUM PRECIPITATION

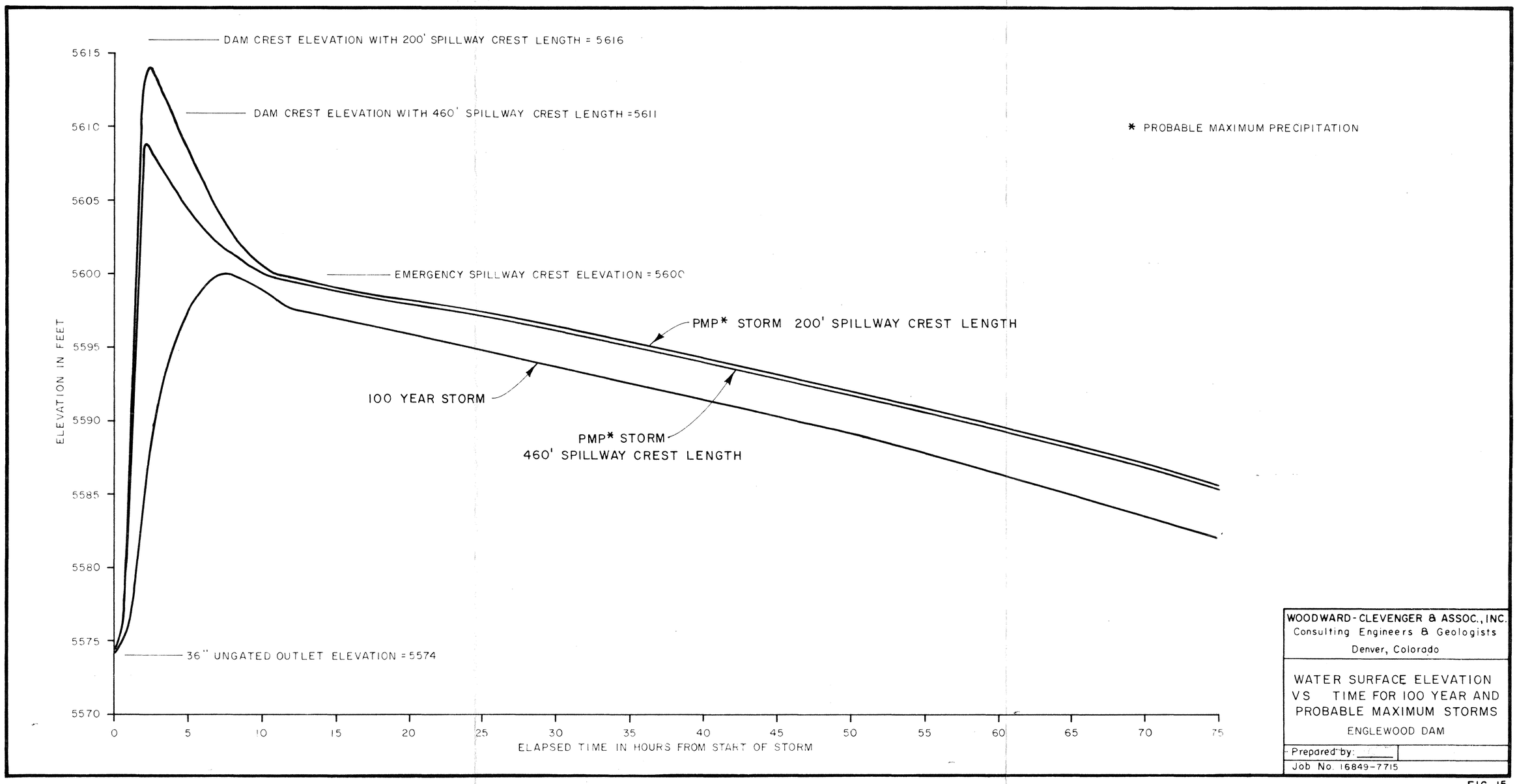
WOODWARD-CLEVENGER & ASSOC., INC.
Consulting Engineers & Geologists
Denver, Colorado

PROBABLE MAXIMUM INFLOW AND OUTFLOW HYDROGRAPHS ASSUME 200 FEET WIDE SPILLWAY CREST
ENGLEWOOD DAM

Prepared by:

Job No. 16849-7715

FIG. 14



WOODWARD-CLEVENGER & ASSOC., INC.
Consulting Engineers & Geologists
Denver, Colorado

WATER SURFACE ELEVATION VS TIME FOR 100 YEAR AND PROBABLE MAXIMUM STORMS
ENGLEWOOD DAM

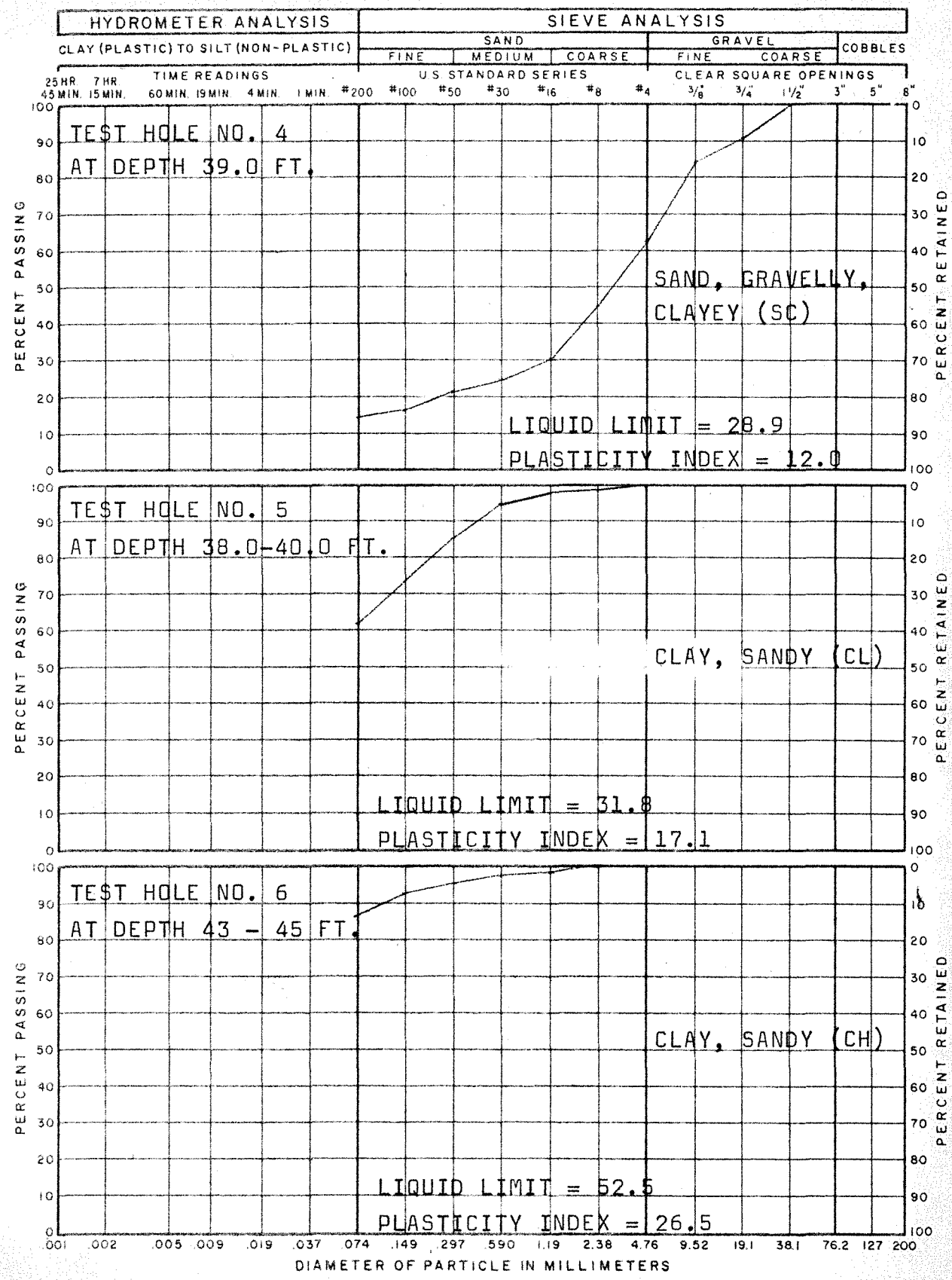
Prepared by: _____
Job No. 16849-7715

FIG. 15

FORM NO. WCAI-4

WOODWARD—CLEVENGER & ASSOCIATES, INC.

GRADATION ANALYSIS



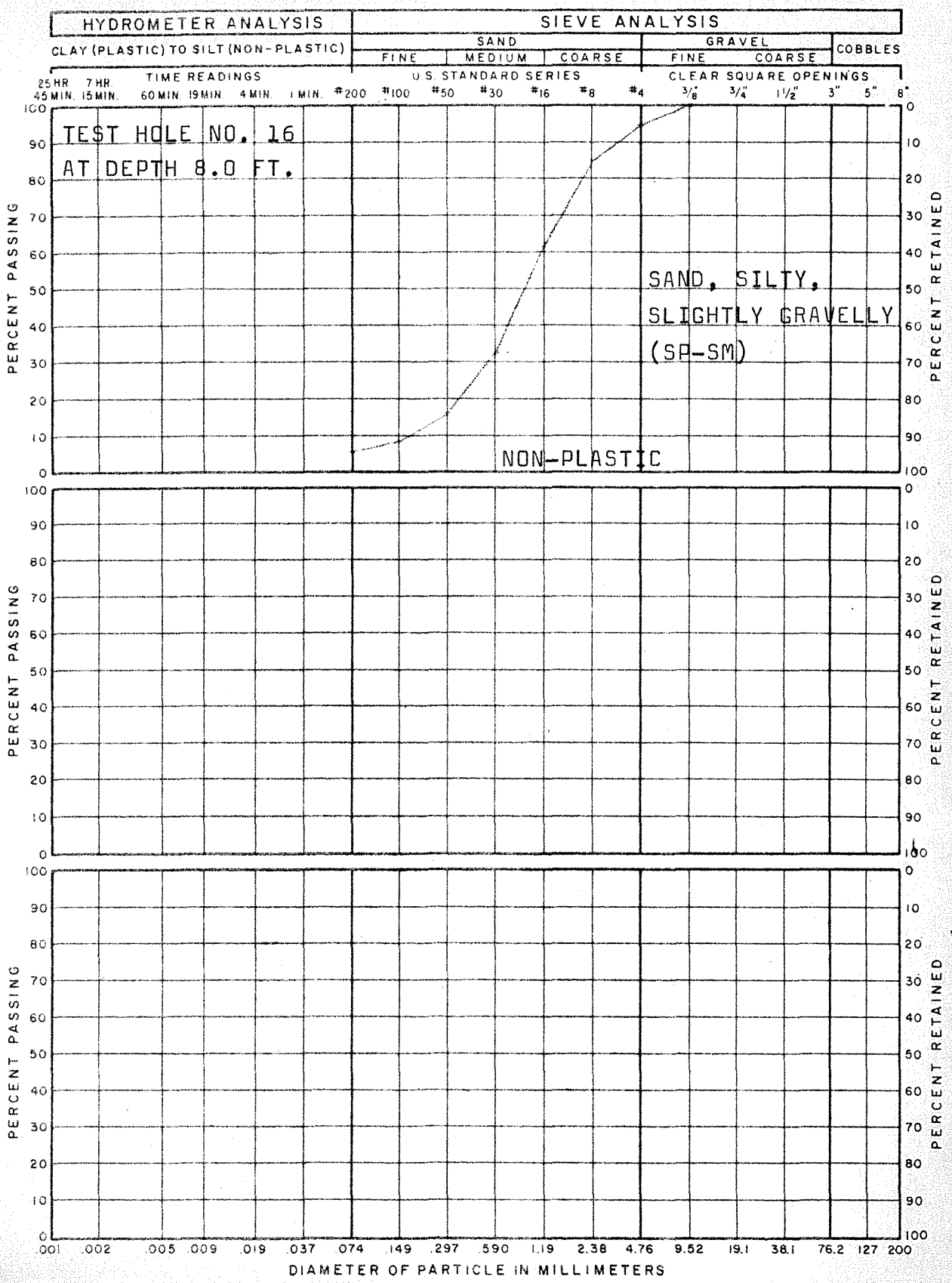
Job No. 16849-7715

FIG. 16

FORM NO. WCAI-4

WOODWARD—CLEVENGER & ASSOCIATES, INC.

GRADATION ANALYSIS

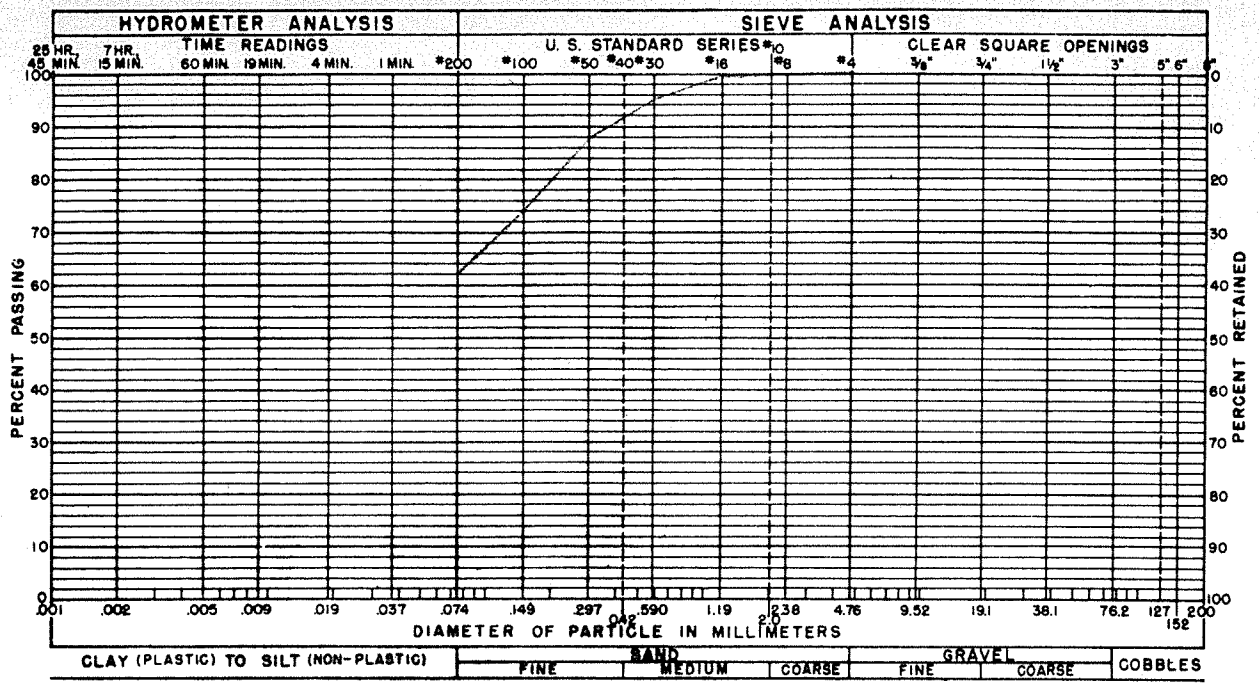


Job No. 16849-7715

FIG. 17

FORM NO.
WCAI 1

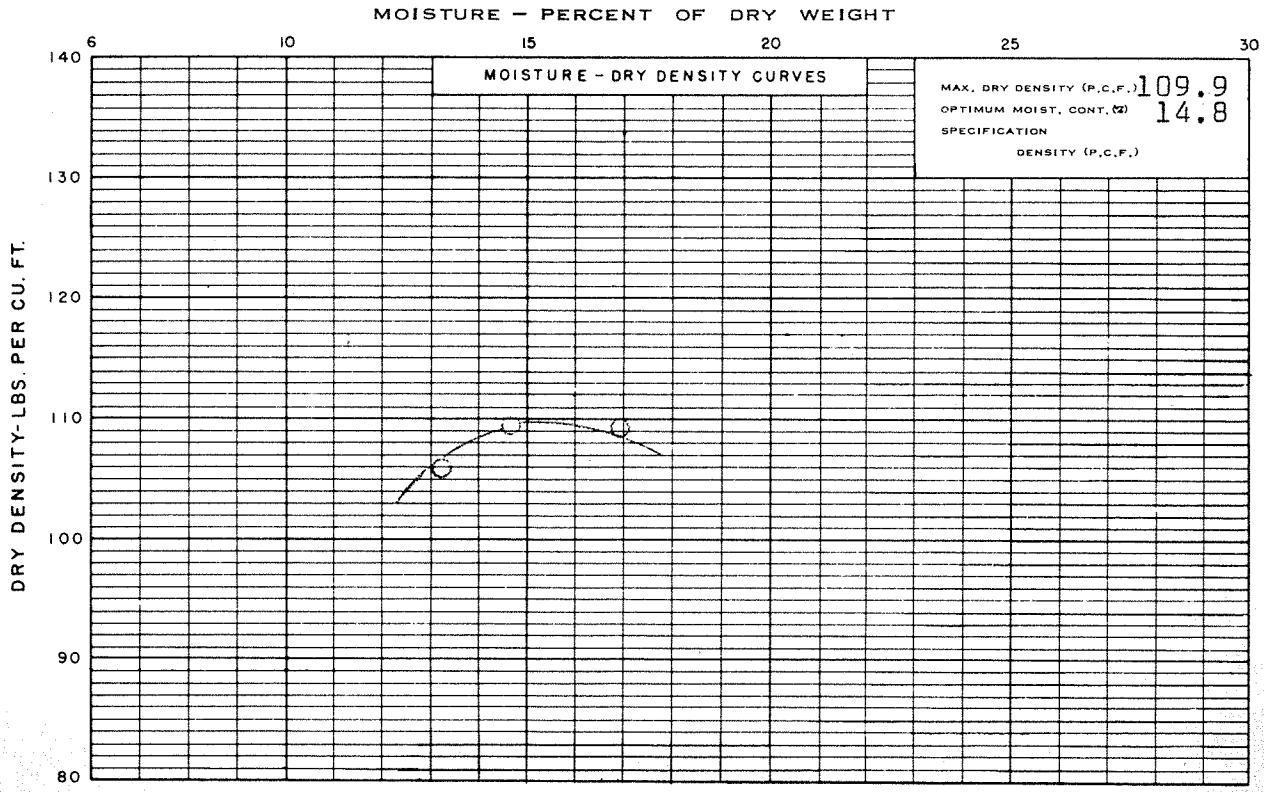
WOODWARD—CLEVENGER & ASSOCIATES, INC.



GRADATION TEST RESULTS

GRAVEL 0 % SAND 38.5% SILT AND CLAY 61.5 %

LIQUID LIMIT 31.8 % PLASTICITY INDEX 17.1%



COMPACTION TEST RESULTS

COMPACTION TEST PROCEDURE ASTM D698-70, Method "A"

Job No. 16849-7715

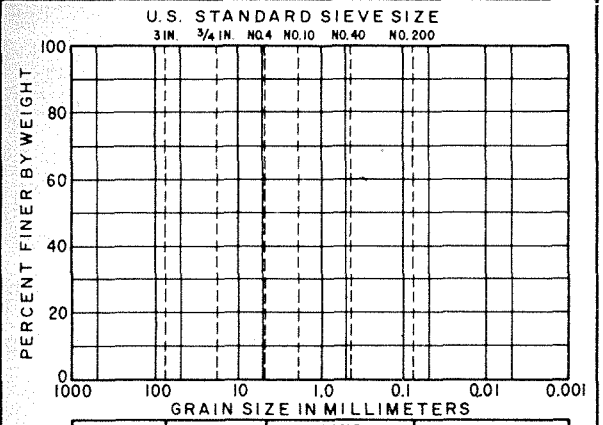
SAMPLE OF Sandy Clay

FROM Test Hole No. 5 DEPTH 38-40 Ft.

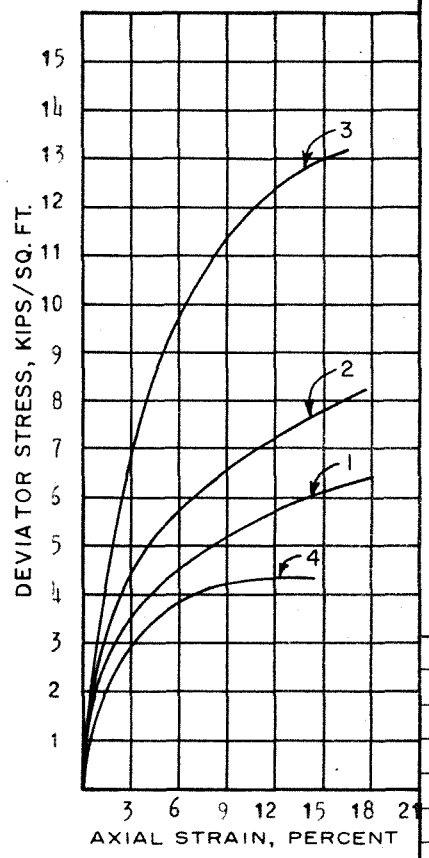
FIG. 18

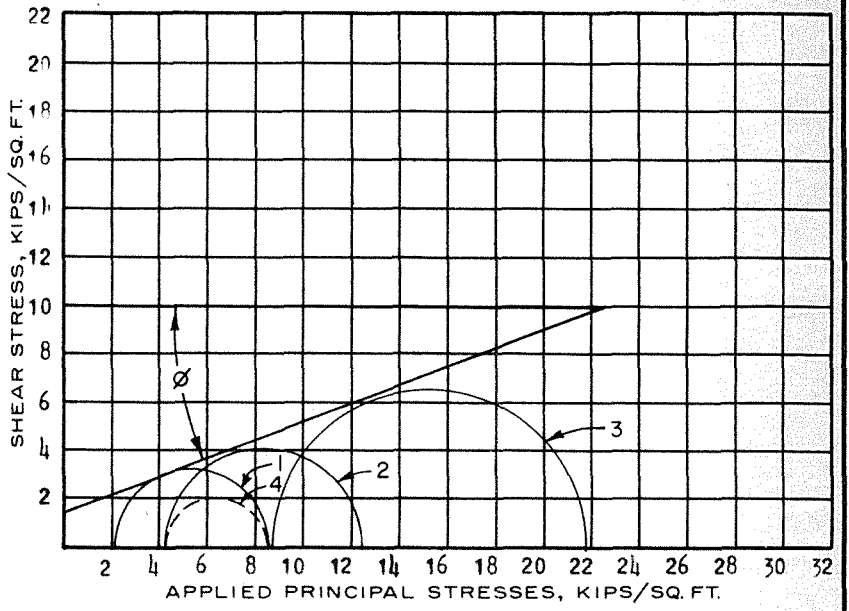
FORM NO. WCAI - 3

WOODWARD—CLEVENGER & ASSOCIATES, INC.



	Test No.	1	2	3	4
INITIAL	Water Content, W_o %	17.3	18.5	16.7	23.0
	Dry Density Lbs/Cu.Ft.	105.6	107.7	108.9	96.4
	Void Ratio, e_o				
	Saturation, S_o %				
BEFORE TEST	W.C. after Saturation, W_s %				SATURATED
	Saturation, S %				
	Consol Pressure K/Sq.Ft.				
	W.C. after Consol, W_c %				
	Void Ratio after Consol, e_c				
AT FAILURE	Maj.Prin.Stress, σ_I K/Sq.Ft.	8.60	12.40	21.75	
	Min.Prin.Stress, σ_{III} K/Sq.Ft.	2.16	4.32	8.64	
	Water Content, W_F %				
	Void Ratio, e_F				
Specimen Diameter Inches		1.93	1.93	1.93	
Initial Height Inches		4.00	4.00	4.00	
Test Time to Failure Min.		4.0	5.0	8.0	





Remarks: SPECIMENS TESTED AT NATURAL DENSITY AND MOISTURE CONTENT

SPECIMEN NO. 4 SATURATED.

Type of Test RATE OF STRESS
Constant
Control 2 KSF/MIN.
UN Consolidated UN Drained

Type of Specimen EXISTING DAM FILL

ϕ = 20 ° | Tan ϕ = 0.36 | c = 1.5 K/Sq.Ft.

Classification CL

LL 31.8 | G

PL 14.7 | D_{10}

PROJECT NO. 16849-7715

PROJECT NAME

BORING NO. 5 | DEPTH 38.0-40.0 Ft.

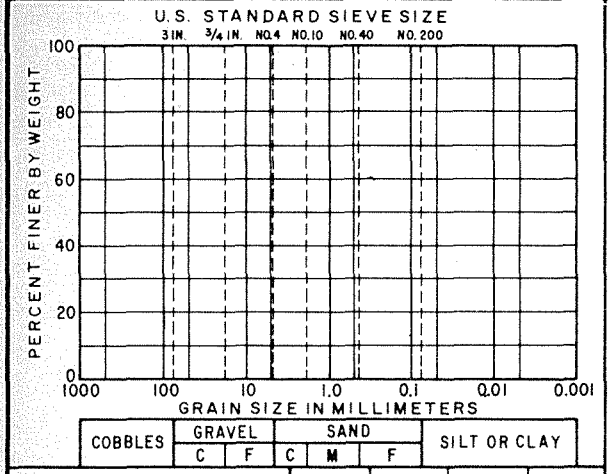
DATE

TRIAXIAL COMPRESSION TEST REPORT

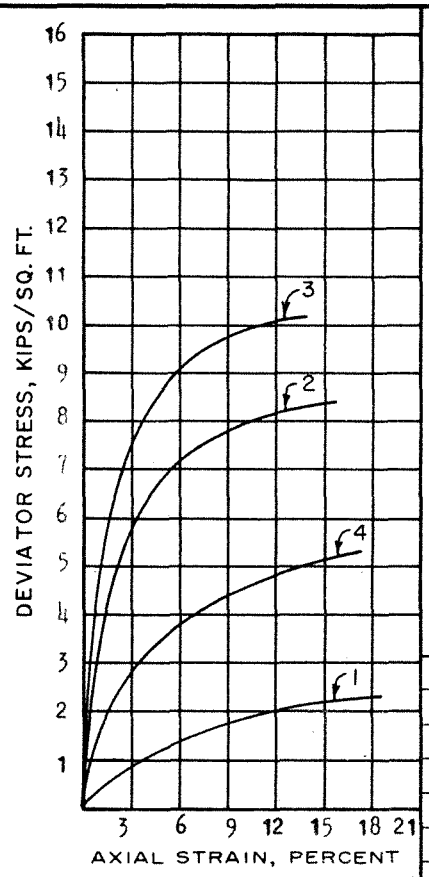
Fig. 19

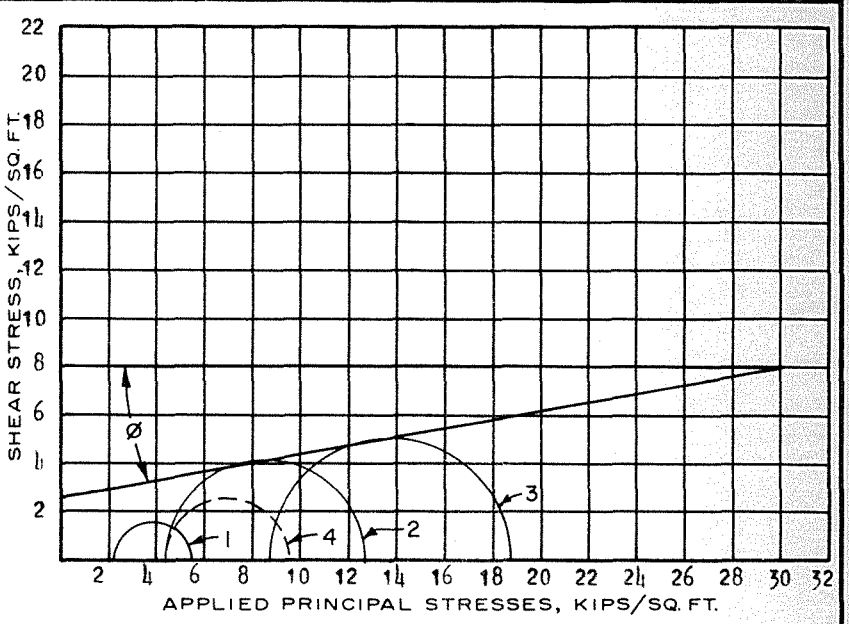
FORM NO. WCAI - 3

WOODWARD—CLEVENGER & ASSOCIATES, INC.



		Test No.	1	2	3	4
INITIAL		Water Content, W_o %	25.9	24.5	30.1	30.3
		Dry Density Lbs/Cu.Ft.	96.3	101.0	91.1	93.6
		Void Ratio, e_o				
		Saturation, S_o %				
BEFORE TEST		W.C. after Saturation, W_s %				SATURATED
		Saturation, S %				
		Consol Pressure K/Sq.Ft.				
		W.C. after Consol, W_c %				
		Void Ratio after Consol, e_c				
AT FAILURE		Maj.Prin.Stress, σ_I K/Sq.Ft.	4.55	12.64	18.73	9.56
		Min.Prin.Stress, σ_{III} K/Sq.Ft.	2.16	4.32	8.64	4.32
		Water Content, W_F %				33.5
		Void Ratio, e_F				
Specimen Diameter Inches			1.93	1.93	1.93	1.93
Initial Height Inches			3.92	4.00	4.00	4.00
Test Time to Failure Min.			1.5	5.0	6.0	3.25





Remarks: SPECIMENS TESTED AT NATURAL DENSITY AND MOISTURE CONTENT. SPECIMEN NO. 4 SATURATED.

Type of Test RATE OF STRESS Constant
Control 2 KSF/MIN.
UN Consolidated UN Drained

Type of Specimen NATURAL

ϕ =	Tan ϕ =	c =
10 °	0.18	2.5 K/Sq.Ft.

Classification CH

LL 52.5	G
PL 26.0	D_{10}

PROJECT NO. 16849-7715

PROJECT NAME

BORING NO. 6 DEPTH 43.0-48.0 Ft.

DATE

TRIAXIAL COMPRESSION TEST REPORT

Fig. 20

FORM NO.
WCAI - 6

JOB NO. 16849-7715

WOODWARD—CLEVENGER & ASSOCIATES, INC.

TABLE I

SUMMARY OF LABORATORY TEST RESULTS

HOLE	DEPTH (FEET)	NATURAL MOISTURE (%)	NATURAL DRY DENSITY (PCF)	ATTERBERG LIMITS		UNCONFINED COMPRESSIVE STRENGTH (PSF)	TRIAXIAL SHEAR TESTS			SOIL TYPE
				LIQUID LIMIT (%)	PLASTICITY INDEX (%)		DEVIATOR STRESS (PSF)	CONFINING PRESSURE (PSF)		
4	3.0	10.4	105.1			17700			(Fill)	CLAY, very sandy, brown
4	13.0	14.1	105.0			17736			(Fill)	CLAY, sandy, brown
4	23.0	17.3	97.4			10684			(Fill)	CLAY, very sandy, claystone chips, brown & yellow
4	33.0	17.0	101.4			5806			(Fill)	CLAY, sandy, brown
4	39.0	5.2		28.9	12.0					SAND, gravelly, clayey, brown
4	43.0	20.0	98.2			15228				CLAYSTONE, very sandy, brown to rust-brown
4	53.0	21.3	105.3			13717				CLAYSTONE, gray brown
5	5.5	14.2	106.2			9516			(Fill)	CLAY, sandy, gray & brown

FORM NO.
WCAI - 6

JOB NO. 16849-7715

WOODWARD—CLEVENGER & ASSOCIATES, INC.

TABLE I

SUMMARY OF LABORATORY TEST RESULTS

HOLE	DEPTH (FEET)	NATURAL MOISTURE (%)	NATURAL DRY DENSITY (PCF)	ATTERBERG LIMITS		UNCONFINED COMPRESSIVE STRENGTH (PSF)	TRIAXIAL SHEAR TESTS			SOIL TYPE
				LIQUID LIMIT (%)	PLASTICITY INDEX (%)		DEVIATOR STRESS (PSF)	CONFINING PRESSURE (PSF)		
5	15.0	16.5	102.8			13851			(Fill)	CLAY, sandy, brown
5	25.0	11.6	119.4			26553			(Fill)	CLAY, sandy, brown to rust-brown
5	38-40	17.3	105.6	31.8	17.1		6438	2160	(Fill)	CLAY, sandy, brown
		18.5	107.7				8078	4320		
		16.7	108.9				13110	8640		
		23.6	96.4					4320		
5	44.5	26.1	97.1			5734			(Fill)	CLAY, slightly sandy, brown, rust brown, gray
5	55.5	27.6	94.3			4574			(Fill)	CLAY to weathered claystone, brown to greenish brown
5	63.0	16.4	110.5			20760				CLAYSTONE, brown
5	73.0	16.2	108.1			10499				SANDSTONE, slightly clayey, gray

FORM NO.
WCAI - 6

JOB NO. 16849-7715

WOODWARD—CLEVENGER & ASSOCIATES, INC.

TABLE I

SUMMARY OF LABORATORY TEST RESULTS

HOLE	DEPTH (FEET)	NATURAL MOISTURE (%)	NATURAL DRY DENSITY (PCF)	ATTERBERG LIMITS		UNCONFINED COMPRESSIVE STRENGTH (PSF)	TRIAXIAL SHEAR TESTS			SOIL TYPE
				LIQUID LIMIT (%)	PLASTICITY INDEX (%)		DEVIATOR STRESS (PSF)	CONFINING PRESSURE (PSF)		
5	88.0	20.0	105.6			27901				CLAYSTONE, brown
6	8.0	21.8	102.4			8812			(Fill)	CLAY, sandy, brown to rust-brown
6	15.5	19.8	105.4			17079			(Fill)	CLAY, sandy, brown to rust-brown
6	25.0	14.6	110.6			20766			(Fill)	CLAY, sandy, brown to rust & gray
6	34.0	12.9	118.0			27563			(Fill)	CLAY, sandy, brown
6	43.0-48.0	25.9	96.3	52.5	26.5		2385	2160		CLAY, sandy, brown
		24.5	101.0				8321	4320		
		30.1	91.1				10091	8640		
		30.3	93.6				5242	4320		
6	54.5	27.1	97.8			2690				CLAY, sandy, brown to rust-brown

FORM NO.
WCAI - 6

JOB NO. 16849-7715

WOODWARD—CLEVENGER & ASSOCIATES, INC.

TABLE I
SUMMARY OF LABORATORY TEST RESULTS

HOLE	DEPTH (FEET)	NATURAL MOISTURE (%)	NATURAL DRY DENSITY (PCF)	ATTERBERG LIMITS		UNCONFINED COMPRESSIVE STRENGTH (PSF)	TRIAXIAL SHEAR TESTS			SOIL TYPE
				LIQUID LIMIT (%)	PLASTICITY INDEX (%)		DEVIATOR STRESS (PSF)	CONFINING PRESSURE (PSF)		
6	63.0	17.8	111.4			15314				CLAYSTONE, sandy, gray
16	8.0	2.2		Non-Plastic						SAND, silty, brown

TABLE II

SUMMARY OF FIELD PERMEABILITY TESTS

TEST HOLE NO.	INTERVAL TESTED (FEET)	TYPE OF TEST	NATURAL WATER LEVEL (FT.)	QUANTITY (GPM)	CALCULATED PERMEABILITY (FT./YR.)
3	0-39	Gravity	Dry	2.1	17
5	0-30	Gravity	Dry	2.6	39
6	0-30	Gravity	Dry	0.3	4
7	0-28.5	Gravity	Dry	0.09	1
11	0-27.2	Gravity	Dry	0.3	5
13*	0-8	Gravity	Dry	0.7	96
13	12.5-17.5	Gravity	14	3.7	4500
14	0-33.2	Gravity	12	0.5	7

N O T E S:

1. Gravity tests were made with a 3-inch diameter casing in the hole.

2. Ground water level was assumed to be below bottom of hole unless otherwise indicated.

REFERENCE: U. S. B. R. Earth Manual, U. S. Government Printing Office, Washington, 1968. p. 544

*Test conducted in hole drilled adjacent to TH-13

Job No. 16849-7715

TABLE III

REHABILITATION OF ENGLEWOOD DAM FOR PROBABLE MAXIMUM PRECIPITATION FLOOD CONDITION

PERTINENT DATA

Reservoir		EXISTING DAM	ALTERNATIVES: 5 FT. RAISE SPILLWAY ON LEFT SIDE	5 FT. RAISE SPILLWAY ON RIGHT SIDE	10 FT. RAISE SPILLWAY ON LEFT SIDE
Water Elevation	- Ft.	5600 (100 Year Flood)	5609	5609	5614
Area Inundated	- Acres	80 (100 Year Flood)	140	140	160
Dam					
Crest Elevation	- Ft.	5606±	5611	5611	5616
Crest Length	- Ft.	1700	2250	2250	2300
Spillway					
Discharge Capacity	- cfs	---	41,000	41,000	35,000
Crest Elevation	- Ft.	5600	5600	5600	5600
Weir Length	- Ft.	---	460	460	200
Chute Width	- Ft.	---	290 to 200 (crest to stilling basin)	290 to 200 (crest to stilling basin)	130 to 120 (crest to stilling basin)
Chute Length	- Ft.	---	810	1380	810

Cost

COST ESTIMATES

ITEM	UNIT COST		QUANTITY	TOTAL COST	QUANTITY	TOTAL COST	QUANTITY	TOTAL COST
Stripping	$1.00/YD^2	---	15,000	$15,000	15,000	$15,000	21,000	$21,000
Outlet Extension	Lump Sum	---	1	$ 5,000	1	$ 5,000	1	$10,000
Riprap @ Dam Toe	$10.00/YD^3	---	200	$ 2,000	200	$ 2,000	400	$ 4,000
Dam Fill	$0.20/YD^3*	---	30,000	$ 6,000	30,000	$ 6,000	45,000	$ 9,000
	$0.75/YD^3**	---	---	---	---	---	30,000	$22,500
Spillway	By Anderson & Hastings			$1,060,850		$1,243,800		$615,900
				$1,088,850		$1,271,800		$682,400
		10% Contingency		108,900		127,200		68,200
		Engineering (design and construction observation)		130,500		153,000		81,700
		TOTAL =		$1,328,250		$1,552,000		$832,300

*Dam Materials From Spillway Excavation