CONNECTICUT RIVER FLOOD CONTROL

LITTLEVILLE

DAM & RESERVOIR

MIDDLE BRANCH, WESTFIELD RIVER, MASSACHUSETTS

DESIGN MEMORANDUM NO. VII

EMBANKMENTS & FOUNDATIONS

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS WALTHAM, MASS.

DECEMBER 1961

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U. S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
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ADDRESS REPLY TO:
DIVISION ENGINEER

REFER TO FILE NO.

NEDGW

14 December 1961

SUBJECT: Littleville Reservoir, Middle Branch, Westfield River, Connecticut River Basin, Massachusetts, Design Memorandum No. VII - Embankment and Foundations

TO: Chief of Engineers
Attention: ENGCW-E
Department of the Army
Washington, D. C.

There are submitted herewith for review and approval ten (10) copies of Design Memorandum No. VII - Embankment and Foundations for Littleville Dam and Reservoir, Connecticut River Basin, in accordance with EM 1110-2-1150.

FOR THE DIVISION ENGINEER:

JOHN WM. LESLIE
Chief, Engineering Division

Incl.
Des. Memo No. VII
(10 cys)

DUAL-PURPOSE FLOOD CONTROL AND WATER SUPPLY PROJECT

LITTLEVILLE DAM AND RESERVOIR

MIDDLE BRANCH, WESTFIELD RIVER

CONNECTICUT RIVER BASIN

MASSACHUSETTS

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	Preliminary	6 Jul 1960*	1 Aug 1960
	Final	25 Apr 1961	26 May 1961
II	General Design Memorandum *	21 Apr 1961	29 May 1961
III	Concrete Materials	16 Jun 1961	7 Jul 1961
IV	Site Geology	31 Aug 1961	18 Sep 1961
V	Real Estate	2 Jun 1961	21 Aug 1961
VI	Relocations	2 Jun 1961	13 Jul 1961
VII	Embankments and Foundations	14 Dec 1961	
VIII	Detailed Design of Structures	28 Jul 1961	7 Sep 1961
IX	Reservoir Management *		

* Initial submission in draft to secure approval of spillway design flood and top of dam.

LITTLEVILLE DAM and RESERVOIR

DESIGN MEMORANDUM NO. VII

EMBANKMENTS and FOUNDATIONS

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U. S. ARMY ENGINEER DIVISION, NEW ENGLAND
WALTHAM 54, MASSACHUSETTS

DUAL PURPOSE FLOOD CONTROL AND WATER SUPPLY PROJECT

LITTLEVILLE DAM AND RESERVOIR

MIDDLE BRANCH, WESTFIELD RIVER

CONNECTICUT RIVER BASIN

MASSACHUSETTS

NOVEMBER 1961

DESIGN MEMORANDUM NO. VII

EMBANKMENTS AND FOUNDATIONS

A. INTRODUCTION

1. Location and Description of Project. The Littleville Reservoir Project is located on the Middle Branch of the Westfield River within the towns of Huntington and Chester in western Massachusetts, at the westerly side of the Connecticut River Basin. The dam site is about one mile upstream of the confluence of the Middle Branch and the Westfield River and about 2.7 miles north of the town of Huntington. The completed structure will consist of an earth fill dam and dike and appurtenant structures. Locations, arrangements, and details of the structures are shown on Plates Nos. 1 and 2.

2. Pertinent Data.

a. Purpose. Flood Control and Water Supply

b. Drainage Area at Dam Site. 52.3 square miles

c. Reservoir Elevations, MSL.

(1) Maximum Future Water Supply Pool - 518

(2) Permanent Pool - 518

(3) Spillway Crest - 576

(4) Maximum Surcharge - 591

(5) Top of Dam - 596

d. Dam.

(1) Maximum Height - 164 feet

(2) Length - 1,360 feet

e. Dike.

(1) Maximum Height - 46 feet

(2) Length - 935 feet

3. General Notes. Programs of subsurface investigation and soils engineering studies were undertaken for the design of the Littleville Dam and Dike. Subsurface investigations included subsurface explorations and laboratory test programs performed to determine the distribution and characteristics of foundation and embankment materials and to determine soil conditions pertinent to excavations and to the design and construction of embankments. Soils engineering studies, based on data obtained from the subsurface investigations, were conducted to develop safe and economical earthwork designs and construction methods, and to obtain pertinent soils data required for the designs for certain of the concrete structures.

B. SUBSURFACE INVESTIGATIONS

4. Subsurface Explorations. Subsurface explorations were laid out and made in conformance with current criteria and practices as described in the pertinent sections of the Engineering Manual for Civil Works Construction. The majority of the explorations were drive sample borings or machine excavated test pits. The subsurface exploration program completed to date is considered adequate for design purposes. Additional explorations are in progress to obtain data for construction control for the foundation cut-off of the dam and for the pervious borrow areas. The locations, types, and general purposes of the explorations completed prior to August 1961 are discussed in Design Memorandum No. IV "Site Geology." The location of subsurface explorations completed prior to November 1, 1961, are shown on Plates Nos. 3, 4 and 5. The geology of the site and area pertinent to the types and distribution of soils is described in Design Memorandum No. IV, "Site Geology."

5. Laboratory Tests.

a. General. All laboratory tests, except as noted, were performed in accordance with current standard procedures as described in the Engineering Manual for Civil Works Construction and other publications of the Corps of Engineers. All soil samples were classified visually in the laboratory in conformance with the Unified Classification System. Grain size analyses and determinations of Atterberg Limits were performed on selected samples to

confirm visual classifications and to provide more precise data where considered necessary. Specific gravities were determined for selected samples. Natural moisture contents were determined for selected samples of soil, particularly those from the proposed impervious borrow area. These moisture contents were determined for both the total material and for the component passing the No. 4 Sieve. Standard AASHO Compaction Tests were performed on samples considered representative of the proposed embankment materials. Natural density tests were performed on chunk samples from a test pit in the borrow area selected for impervious embankment material (Area B) and on plug samples from borings in the dike foundation.

b. Permeability Tests. Permeability tests were performed in the laboratory on selected samples of embankment materials using de-aired water and a falling-head type of test apparatus. The permeameters were 5.5-inch diameter lucite cylinders. Each specimen was prepared so that its length was equal to or slightly less than its diameter. Prior to testing, each specimen was de-aired under a vacuum not greater than 15 psi. The maximum applied hydrostatic head was not permitted to exceed 120 centimeters and generally was on the order of 60 centimeters. Permeability tests were performed on specimens prepared at various densities in order to obtain the relationship of the void ratio and the co-efficient of permeability for each soil sample.

c. Shear Tests. The shear strength characteristics of selected soil samples of impervious embankment materials under the conditions outlined in the Engineering Manual for Civil Works Construction were determined for the fractions of the samples passing the No. 4 Sieve using specimens compacted at moisture contents representative of anticipated placement moisture contents. The Standard AASHO compaction test curves were used in determining specimen densities at the various moisture contents. Specimens for the R (consolidated-undrained) and S (consolidated-drained) tests were saturated under vacuum prior to testing. All tests were triaxial compression tests performed on 2.8-inch diameter specimens having minimum slenderness ratios greater than 2.1.

6. Presentation of Data. The results of subsurface investigations, except for the geological sections and records of subsurface explorations, are presented in this memorandum. Engineering soils reports (engineering logs of soils explorations) are presented in Appendix D. These reports were prepared for all pertinent explorations by the design soils engineer with the aid of laboratory test data and the assistance of an experienced soil classifier. Included in these reports are the description of the soils and soils strata based on the engineer's examination of the samples and on his interpretation of all test results and exploration data. These descriptions include the consistency of the material, estimated or measured percentages of the soil components,

color, stratification, presence of foreign matter, geological names, and other data considered to be of significance in determining the characteristics of materials for design and construction purposes. Soil profiles for the dam and dike embankment foundations based on these engineering logs are shown on Plates Nos. 6 7, 8 and 9. Plates showing selected laboratory test results are included in this memorandum. A summary of laboratory test results is presented in Appendix A. Detailed shear test data are presented in Appendix B.

C. CHARACTERISTICS OF EMBANKMENT FOUNDATION SOILS

7. Distribution and Description of Materials.

a. Dam

(1) Left Abutment.

(a) The foundation of the left abutment of the dam is covered with a relatively thin mantle of overburden. The bedrock surface, beneath this mantle is very irregular consisting of saw-tooth ridges and troughs oriented in a north-south direction and therefore the overburden thickness varies abruptly and frequently. Upstream of the axis of the dam the average thickness of overburden is about 12 feet with an observed range of from 0 to 22 feet. Downstream from the axis, the overburden is thinner, averaging about 9 feet in thickness with an observed range of from 0 to 12 feet. Numerous large boulders are scattered over the surface of the abutment area.

(b) The overburden on the left abutment of the dam consist principally of a glacial outwash deposit capped by about a foot of topsoil and forest debris. At the higher elevations on this abutment, there is glacial till which occurs in scattered discontinuous pockets underlying varying depths of outwash materials. There are numerous cobbles and boulders in the overburden on this abutment, many of which are highly weathered. Materials to a depth of 4 feet are loose as a result of frost action.

(c) The outwash materials consist principally of variable roughly stratified moderately compact to compact brown gravelly silty sand (SP-SM and SM) and silty sandy gravel (GP-GM and GM) having silt contents ranging from 15 to 30 percent of the component passing the No. 4 Sieve. In places, there are layers from 1 to 3 feet thick of sandy silt (ML) and silty fine sand (SM) having silt contents of from 25 to 50 percent occurring between the topsoil and the outwash materials. The glacial till consists of unstratified compact gray brown to gray gravelly silty sand (SM) with occasional phases of silty sandy gravel (GM). Gravel contents of the till generally range from 10 to 30 percent and silt contents generally range from 20 to 40 percent of the component passing the No. 4 Sieve.

(2) Valley Section and Right Abutment.

(a) In the valley bottom there are extensive exposures of bedrock downstream of the axis of the dam. Upstream, however, as much as 55 feet of overburden covers the rock in the

valley bottom while on the right abutment it is covered by from 40 to over 100 feet of overburden. As on the left abutment, the bedrock surface is very irregular having a ridge and trough texture oriented in a north-south direction. The ground surface is somewhat bouldery with numerous large boulders present in the river bed and on the surface of the right abutment at the higher elevation. A portion of the overburden in the terrace on the right abutment west of the East River Road has been excavated to obtain gravelly material leaving a pit.

(b) The overburden in the valley bottom and on the right abutment consists of glacial till and glacial outwash deposits capped with about a foot of topsoil except in the river bed and the area of previous excavations. The till overlies the bedrock to the west of a northwest-southeast line through Station 8+50 on the axis of the dam. East of this line, the till is absent and the bedrock is overlain by the outwash materials. West of this line, the outwash materials cover the glacial till to depths of from 10 to 50 feet. Materials to a depth of about 4 feet are loose as a result of frost action.

(c) The glacial outwash materials consist of roughly stratified moderately compact to compact brown silty sandy gravel (GP-GM and GM), gravelly silty sand (SP-SM and SM), sandy gravel (GP), and isolated pockets and lenses of sandy silt (ML). Some of the siltier materials contain silt laminae. The silt contents of the outwash materials are generally below 30 percent of

the component passing the No. 4 Sieve. In the valley bottom about half of the outwash materials have silt contents below 15 percent of the component passing the No. 4 Sieve. These materials contain numerous cobbles and boulders of which many are highly weathered. The presence of these weathered stones is believed to be the reason for the appearance of numerous mica particles in some of the samples from this deposit. In much of the area, there is a layer of from 1 to 3 feet of sandy silt (ML) and silty fine sand (SM) containing from 25 to 50 percent silt occurring between the top soil and the outwash materials.

(d) The glacial till consists of unstratified compact generally gray gravelly silty sand (SM) and gravelly sandy silt (ML) with cobbles and boulders. The gravel contents range from 10 to 30 percent, in general. Silt contents generally range from 30 to 50 percent of the component passing the No. 4 Sieve although there are occasional small pockets of material having silt contents as low as 15 percent of the component passing the No. 4 Sieve which are scattered throughout the deposit. There is some evidence that there is a zone of silty sandy gravel (GP-GM) at the base of the till deposit immediately above the bedrock surface in which the silt contents range from 15 to 30 percent of the component passing the No. 4 Sieve. While it is doubtful that this relatively pervious zone is continuous beneath the entire till deposit, there is a possibility that it may be so through the dam foundation area along the eastern edge of the deposit.

(e) Stiff sandy clay occurs at the locations of borings FD-55 and FD-17 on the right abutment of the dam. At FD-55, the clay is 6 inches thick while at FD-17 it is about 4 feet thick. The absence of reports of clay in the other borings indicates that these samples represent either two isolated clay pockets or a narrow stratum extending upstream of the axis of the dam between Sta. 6+50 and 7+50. Conservative embankment design practice indicates the advisability of considering the latter possibility to be the case.

d. Dike.

(1) Bedrock in the dike foundation area is relatively shallow at the right abutment but drops rapidly and is covered with more than 50 feet of overburden to the left (east) of Sta. 25+00. The character of the bedrock surface is essentially the same as that in the dam foundation described above. The overburden consists of glacial till blanketing most of the bedrock surface and highly variable glacial outwash materials overlying much of the till. The till consists of unstratified compact to very compact generally gray gravelly silty sand (SM) containing less than 30 percent gravel and having silt contents varying from 30 to 45 percent of the component passing the No. 4 Sieve. The till contains numerous cobbles and boulders. The outwash consists of three general types of materials. The predominant type consists of roughly stratified compact brown variable silty sandy gravel (GP-GM and GM) and gravelly silty sand (SP-SM and SM) having silt contents ranging from 10 to 30 percent of

the component passing the No. 4 Sieve. At the ground surface between Sta. 25+00 and 27+00, there is a zone, from 5 to 10 feet thick, of unstratified loose to moderately compact brown soil having gradation characteristics similar to those of the glacial till. To the left (east) of Sta. 23+50 at depths of from 20 to 30 feet, there is a zone averaging 20 feet in thickness of very compact highly stratified gray silty fine sand (SM) containing from 25 to 50 percent silt. This zone contains occasional laminae and strata of sandy silt (ML) and is interbedded to some extent with strata of the predominant type of material discussed above. The outwash in the dike foundation contains numerous cobbles and boulders some of which are highly weathered. The surface of the dike foundation area is covered by topsoil to an average depth of less than 1 foot. In places, the topsoil is underlain by about 1 foot of sandy silt (ML) and silty fine sand (SM) containing from 25 to 50 percent silt.

8. Shear Strengths. No shear tests were performed on samples of embankment foundation soils. On the basis of experience with similar soils, it is estimated that the outwash materials in the foundations have undisturbed shear strength parameters averaging $\phi = 30$ degrees and $c = 0$ for both the R (consolidated-undrained) and S (consolidated-drained) conditions. For purpose of design, however, it is considered advisable to select a range of ϕ values for these materials which would cover the effects of their variability. It is considered that a range of from 25 to 30 degrees would provide a reasonable and conservative basis for stability studies. The

shear strengths of the surficial layers of sandy silt (ML) and silty fine sand (SM) have not been estimated in as much as these layers will be required to be removed as part of the foundation stripping operation. It is estimated that the undisturbed shear strengths of the glacial till materials in the embankment foundations are at least equal to those of the fill materials selected for the impervious sections of the embankments after their placement in the embankments. The clay occurring in the foundation of the right abutment of the dam is estimated to have a shear strength of from 1 to 2 tons per sq. foot.

9. Permeability. Permeability tests were not performed on samples of embankment foundation soils. On the basis of visual examinations of samples, grain-size distribution curves and the results of tests on samples of the borrow materials, the permeability coefficients are estimated to be as follows:

Material	K_V cm/sec	$\frac{K_H}{K_V}$
Glacial Till	0.1×10^{-4}	4
Pervious Zones in Till	1.0 to 10×10^{-4}	9
Glacial Outwash (Dam)	1.0 to 100×10^{-4}	9
Glacial Outwash (Dike)		
a. Predominant Type and Till-like Phase	0.1 to 20×10^{-4}	9
b. Highly Stratified Phase	1 to 10×10^{-4}	25

In the foundation of the dam, permeabilities of the outwash materials in the valley bottom generally fall within the upper half of the range given above while those of the outwash materials in the abutments generally fall within the lower portion of the range.

10. Consolidation - Consolidation tests were not performed on samples of embankment foundation soils. The compressibility characteristics and generally high natural densities of these materials are such that little or no settlements of the foundations are anticipated under the proposed embankment loadings.

D. CHARACTERISTICS OF FOUNDATION BEDROCK

11. Bedrock Foundation for Embankments.

Bedrock at the site consists of a series of thin-bedded, steeply dipping mica schists, quartz schist or quartzite, and hornblende schist. The mica schists which are composed largely of sericite and biotite micas are locally graphitic, foliated, soft to moderately hard and range in texture from fine to coarse-grained. The quartz schists or quartzites are very hard and durable, fine-grained, poorly to fairly well foliated and are composed predominantly of quartz with finely disseminated mica. The hornblende schists are very dark gray to black, generally fine-grained and include thin beds and irregular pods of limestone. The depths of the bedrock surface below the ground surface in the foundation areas are discussed in Paragraph 7, above.

The trend of the bedrock structure is very uniformly north-south or essentially parallel to the river channel through the dam foundation and all the beds dip westward at approximately 70°. Differential weathering caused by the variation in relative hardness of the various beds has resulted in a very prominantly ridged and troughed surface. The relatively thin ribs and ridges

commonly project 3 to 5 feet above the bottom of the adjacent narrow troughs and variations of as much as 8 to 10 feet may be expected. Removal of loose blocks and slabs from the ribs and excavation of weathered material in the troughs will tend to accentuate further the overall roughness of the natural rock surface. Weathering of the bedrock along closely-spaced open foliation planes and joints is common to depths of 2 to 5 feet and locally the close-jointed and broken, weathered zones extend to depths of 15 feet or more.

12. Excavated Bedrock Surfaces and Bedrock Foundations for Concrete Structures.

Foundation grades for concrete structures will be located on sound rock below zones of close jointing or severe weathering. The very irregular ridge and trough bedrock surface may require more than usual foundation preparation in some areas including removal of narrow protruding rock ribs and perhaps concrete fill in the deeper troughs to obtain a practical construction foundation surface. Recently completed explorations along the alignment for the water supply conduit indicate that a deep trough in the rock surface extends approximately 200 feet along the conduit near the centerline of the dam. The rock surface in this area is generally below the crown of the conduit on the river side and because of close-jointing and weathering along a short reach of the conduit, suitable rock for foundation may not be available down to or even slightly below design foundation grade. Side slopes of structure excavations in rock will be controlled to a great extent by the orientation of the excavations

in relation to the bedrock structure. On the eastern or up-dip side of excavations, the side slopes will tend to conform to the natural cleavage planes of the rock which are approximately 3 vertical on 1 horizontal. On the western or down-dip side of excavations the side slopes will be very ragged and rough where close drilling and line drilling is required. Where line drilling or close drilling is required, considerable overbreak caused by fall-out of loose joint blocks and unsupported slabs must be anticipated. A grouting program is planned at the water supply conduit and the spillway weir and drain holes in rock will be provided as required for relief of pressure at concrete slabs and walls. Detailed discussion of bedrock conditions in relation to concrete structures and the flood control outlet tunnel is included in Design Memorandum No. IV, "Site Geology" and Design Memorandum No. VIII, "Detailed Design of Structures."

E. CHARACTERISTICS OF EMBANKMENT MATERIALS

13. General. In the course of the subsurface investigations for this project, a large deposit of glacial till was located in Area B. In view of the extent of this deposit, its proximity to the project, and the relatively impervious character of the material in it, the design of the embankments was based upon the maximum feasible utilization of material from this source together with the maximum practicable utilization of material from the required excavations. Further subsurface excavations were made to locate sources of granular and pervious types of material which would be required

to permit such utilization of the materials from Area B and the required excavations. The characteristics of the materials selected for use in the embankments are discussed herein.

14. Impervious Embankment Material.

a. General. For the reasons discussed in Paragraph 13, above, impervious embankment material will be obtained from Area B, the location of which is shown on Plate No. 1. This area is located on the top and east slope of the ridge forming the left abutment for the dike. About one-half of the area is wooded, the remainder being cleared pastures. The western portion of the area is traversed by a gravel surfaced town road which will be relocated further to the west to permit use of this area. The limits of the borrow area from which impervious embankment material is to be obtained will be established within Area B.

b. Distribution and Description of Materials. The glacial till in Area B is limited by outcrops of bedrock which are visible west of the road in Area B and also to the east of the road to the north of the area. The subsurface exploration logs indicate that the rock surface drops sharply to the east of these outcrops to depths of 100 feet, or more, below the ground surface. The overburden in Area B is covered with less than 1 foot of topsoil and consists of glacial till of relatively uniform character except for occasional surficial layers of slightly coarser material from 4 to 9 feet thick. The soils in this deposit consist principally of gravelly silty sand (SM and SM-SC) and gravelly sandy silt

(ML and ML-CL) with occasional gravel phases (GM). Color varies from gray-brown near the surface to gray at lower levels. Gravel contents vary but are generally less than 25 percent. Silt contents range from 40 to 60 percent of the component passing the No. 4 sieve except in the surficial zones where they may be as low as 30 percent. Soils in the southern half of this deposit have generally higher silt contents than in the northern half and include several slightly plastic phases having liquid limits of from 19 to 24 and plasticity indices of from 1 to 7. The sand components of the soils in this deposit are generally deficient in coarse sand sizes. Densities are relatively high, ranging from moderately compact to very compact except in the zone of frost action. The deposit contains numerous cobbles and occasional boulders. Subsurface water levels in Area B generally range from 5 to 25 feet below the ground surface as indicated by observation well readings. At borings BD-13 and 15, however, artesian water levels have been observed at 1.5 and 4.6 feet above the ground surface, respectively. The observations indicate that subsurface water levels in this area are subject to seasonal fluctuations.

c. Permeability. Permeability tests were performed on two samples of soil from Area B. On the basis of the results of these tests, visual examination of all other samples, and their grain size characteristics, it is estimated that the average coefficient of permeability of compacted impervious embankment material will be on the order of 0.1×10^{-4} cm/sec., vertically and 0.9×10^{-4} cm/sec., horizontally.

d. Consolidation. Consolidation tests were not performed on samples of impervious embankment material. Experience with similar materials indicates that this material is of low compressibility when compacted and that no significant settlements will occur in compacted fills of this material.

e. Compaction Characteristics. Standard AASHO compaction tests were performed on two samples of impervious embankment material from test pit BT-3 in Area B with the following results:

Sample	Maximum Dry Density	Optimum Water Content
B-2	123.1 pcf	11.9 percent
B-11	127.3	10.5

Sample B-2 is considered to be representative of the bulk of the impervious embankment material with respect to gradation characteristics. Sample B-11 is considered to be representative of the portion of the impervious embankment material falling in the finer range of gradation characteristics. Natural densities determined for chunk samples from BT-3 averaged about 95 percent of maximum compacted densities. Information from the exploration logs, however, indicate that at depths greater than in BT-3, the natural densities are appreciably higher and in places may exceed 100 percent of maximum compacted density. Natural water contents of the chunk samples from BT-2 determined for the component passing the No. 4 Sieve averaged between 3 and 4 percent above optimum. Since the test pit was excavated in rainy weather, it is probable that

these values are in error on the high side. Comparable natural water contents of samples from the borings in this area are from 1 to 2 percent lower than those of the samples from the test pit. It is anticipated that during construction the water contents in the borrow area will range from 1 to 3 percent over optimum but after excavation, hauling, and spreading will range from optimum to 2 percent over optimum.

f. Shearing Characteristics. Sample B-11 from test pit BT-3 was selected for shear testing as being representative, with respect to gradation and other physical characteristics, of that phase of impervious embankment material having the least shear strength. Sample B-2 was selected for limited shear testing as being representative, with respect to gradation and other physical characteristics of the bulk of the impervious embankment material. Test specimens of B-11 were compacted at optimum water content and optimum plus 2 percent to corresponding densities on the compaction test curves. Test specimens of B-2 were compacted at optimum plus 2 percent only. All tests were of the controlled strain type using rates of strain of 0.05 inch per minute for the Q (unconsolidated-undrained) tests, 0.02 inch per minute for the R (consolidated-undrained) tests, and 0.006 inch per minute for the S (consolidated-drained) tests. The latter rate of strain was determined from the consolidation characteristics of the test specimens in order to assure adequate dissipation of pore pressures during these tests.

Only Q (unconsolidated-undrained) tests were performed on sample B-2 as it appeared that any significant differences in shear characteristics between it and B-11 would be most evident under this test condition.

15. Embankment Materials from Required Earth Excavations.

a. General. Exclusive of stripping, about 175,000 cubic yards of earth excavation will be required for the construction of this project. Since the bulk of these materials will become available at the same time that the embankments are being constructed, economical considerations require that as much of the excavated materials as practicable should be used in the permanent work without stockpiling. As a relatively wide range of soil types will be obtained from these excavations, provisions have been made to include random fill zones in the embankment sections in which these materials may be utilized. As discussed below, circumstances make it possible to select relatively pervious materials for use in the random fill zone of the dike embankment.

b. Distribution and Description of Materials. The major required earth excavations for this project include the excavation of the foundation cut-off trench for the dam, the excavation of the foundation drain trenches for the dam and the dike, the excavation to bedrock on the left abutment of the dam, and the excavation of the spillway channel. Most of these excavations will be made in the glacial outwash materials described in Paragraph 7, above. The spillway excavation will be made in materials

similar to those on the left abutment of the dam. In order to utilize the excavated materials most efficiently, the cut-off trench will be excavated in two stages. Initially, excavations will be limited to the valley bottom with subsequent extension onto the right abutment in the second stage. Materials from the first stage cut-off trench excavation will be placed in the random fill zone of the dike embankment so as to avoid stockpiling. These materials will consist principally of silty sandy gravel (GP-GM and GM) and gravelly silty sand (SP-SM and SM) with phases of sandy gravel (GP) and gravelly sand (SP). (A minor amount of glacial till may be obtained from the bottom of the excavation, but at this stage, it will not be used in the embankments.) The silt contents of these materials are generally less than 20 percent of the component passing the No. 4 Sieve and for about half of the material the silt contents are less than 15 percent of the component passing the No. 4 Sieve. With a minor amount of selection, therefore, it will be possible to obtain a relatively pervious type of random fill material for use in the dike embankment. The materials from the second stage of the cut-off trench excavation and the other excavation will be much more variable, including glacial till as well as outwash material and less pervious than the materials from the first stage cut-off excavation. In some instances, the silt contents of these materials are as high as 40 percent of the component passing the No. 4 sieve. On the basis of economical and practical considerations, these materials have been selected for use in the random fill zone of the dam embankment.

c. Permeability. No permeability tests were performed on samples of embankment materials from required excavations. On the basis of visual examinations of the samples and their grain-size characteristics, it is estimated that their coefficients of permeability when computed are as follows:

Material	K_v cm/sec	K_h/K_v
Material from 1st Stage Cut-off Excavation	20 to 100 x 10^{-4}	9
Material from Other Excavations	0.1 to 100 x 10^{-4}	9

d. Consolidation. Consolidation tests were not performed on samples of embankment materials from required excavations. Experience with similar materials indicates that they are of low compressibility when compacted and that no significant settlements will occur in compacted fills of these materials. Provision will be made for the removal and spoiling of any compressible material encountered in the excavations.

e. Compaction Characteristics. No compaction tests were performed on samples of embankment materials from required excavations. On the basis of experience with similar types of materials it is estimated that maximum test densities are on the order of 125 pcf and that while optimum moisture contents vary, the sensitivity to changes in water content is relatively low for the bulk of these materials. In general, it is anticipated that water contents during placement will be within ranges permitting adequate compaction although some of the materials from the valley bottom below river level may have to be wasted because of excessively high moisture contents.

f. Shear Strength. Shear tests were not performed on samples of embankment materials from required excavations. Experience with similar materials indicates that a wide range of compacted shear strengths may be expected for these materials in general. In view of the variability of these materials in this respect, the random fill zone of the dam has been located in the central portion of the embankment section where the shear strength of the material placed therein will not be critical. Materials from the first-stage excavation of the cut-off trench, which are to be placed in the dike embankments, will be less variable with respect to shear strength because of the characteristics of the materials being excavated and because some degree of selection will be exercised in their excavation and utilization. It is therefore estimated that while the shear strengths of these materials will also be variable, their shear strength parameters will be in excess of $\phi = 25$ degrees and $c=0$ when placed in the random fill zone of the dike.

g. Degradation During Compaction. The presence of numerous highly weathered boulders and cobbles in the deposits from which embankment materials from required excavations will be obtained indicated the possibility that the gradation characteristics of these materials might be subject to significant change during compaction. To determine the degree to which such degradation might occur, a series of special tests were performed on samples of material typical of those to be obtained from the required excavations. The tests consisted of the performance of

mechanical analysis on the samples before and after the samples had been subjected to the compactive effort of the Standard AASHO Compaction Test. The results of these tests show that while some degradation occurred it was of minor magnitude, the net increase in the percentage of the sample passing the No. 200 Sieve being less than 2 percent. For purposes of design this amount of degradation is not considered significant.

16. Embankment Drainage Materials and Gravel Bedding.

a. General. Extensive reconnaissance was made to locate sources of gravel bedding and embankment drainage materials for use in the internal wick drain of the dam embankment, the foundation drains, and the drainage blankets. Potential borrow sources for about two-thirds of the required quantity of these materials were located within the reservoir area, but no other potential borrow sources were found in the vicinity of the project. Several developed and undeveloped commercial sources were located within 15 miles of the dam site, however, from which the remainder of the material could be obtained. In view of the insufficient quantities of available borrow, therefore, it is planned to have the contractor furnish a portion of these materials from approved sources.

b. Sources.

(1) Borrow Sources.

(a) General. Three areas (Areas C, D, and E) within the reservoir limits were investigated as potential borrow

sources for embankment drainage materials and gravel bedding. These areas are located on low terraces along the river from 1/4 to 1-1/2 miles upstream of the dam site as shown on Plate No. 1. The materials in these terraces consist of sands and gravels overlying glacial till or bedrock at relatively shallow depths. The terraces are blanketed with topsoil and silt to depths of from 1 to 6 feet.

(b) Area C. The silt and topsoil blanket in Area C is from 1 to 4 feet thick. Depths to bedrock or glacial till range from 12 to 25 feet in general. The materials in this area, beneath the blanket and above the till or bedrock, consist of roughly stratified, loose to compact, brown sandy gravel (GP), silty sandy gravel (GP-GM), gravelly silty sand (SP-SM), and scattered lenses of sandy silt (ML) with occasional phases of silty sands and gravels in the SM and GM categories. These materials contain numerous cobbles of which a significant number are highly weathered. In general, gravel contents range from 30 to 70 percent and silt contents range from 5 to 20 percent of the component passing the No. 4 Sieve. For the bulk of these materials, however, the silt contents are less than 15 percent of the component passing the No. 4 Sieve. In view of the presence of weathered cobbles, special tests were made to determine the degree of degradation to which materials from this source may be subject during compaction. It was found that, in some cases, compaction may increase the portion of the materials passing the No. 200 Sieve by as much as 2 percent.

(c) Area D. The silt and topsoil blanket in Area D is from 1 to 5 feet thick. Depths to bedrock or glacial till range from 5 to 15 feet. The sands and gravels in this area are similar to those in Area C. Their distribution, however, is more erratic and in a considerable portion of the area the silt and topsoil blanket directly overlies glacial till. For this reason, the development of this area as a government designated borrow area for gravel bedding and embankment drainage materials is not economically feasible. It is planned, however, to make this area available to the contractor as a source of sand and gravel for construction roads. It is possible that limited quantities of contractor furnished materials may be obtainable from this area.

(d) Area E. The silt and topsoil blanket in Area E is from 1 to 6 feet thick. Depths to bedrock or glacial till range from 4 to over 12 feet. The sands and gravels in this area are similar to those in Area C except that their gravel contents are generally higher and their silt contents tend to be lower.

(2) Commercial Sources.

(a) Donovan Brothers, Inc. Donovan Brothers, Incorporated, operates a processing plant in Huntington at a haul distance of about 3 miles from the dam site. Materials for processing are obtained from several pits in the vicinity of the plant including the pit in the right abutment of the dam and a pit at the south end of Area C. Bank-run materials from this source are similar to those in Areas C and E except that with the company's present excavation methods silt contents are higher because of nominal stripping. The plant produces concrete sand and crushed gravel aggregates.

(b) Bill Willard, Inc. Bill Willard, Incorporated operates a processing plant in Northampton at a haul distance of about 17 miles from the dam site. Materials for processing are obtained from a gravel pit in Westhampton at a haul distance of about 12 miles from the dam site. This company's pit can furnish bank-run sands and gravels with numerous cobbles having silt contents averaging about 10 percent of the component passing the No.4 Sieve. The plant produces concrete sand and crushed gravel aggregates.

(c) Hampshire Sand and Gravel Co. The Hampshire Sand and Gravel Company operates a processing plant in Westhampton at a haul distance of about 12 miles from the dam site. Materials for processing are obtained from a sand deposit near the plant and a gravel pit adjacent to that operated by Bill Willard, Incorporated. Bank-run materials from this source are similar to those from the Willard Pit.

(3) Summary. Gravel bedding and embankment drainage materials having gravel contents of from 30 to 70 percent and silt contents of less than 15 percent of the component passing the No. 4 Sieve can be obtained with a moderate amount of selection from borrow areas established in Areas C and E. Bank-run sands and gravels having lower silt contents are available commercially from the Westhampton sources and other undeveloped sources within 15 miles of the project.

c. Gradation Specifications.

(1) General. Investigations of the various sources of gravel bedding and embankment drainage materials indicate that the following gradation specifications can be satisfied by natural materials from either borrow sources within the reservoir or from commercial sources within 15 miles of the project. As discussed in Paragraph 13, above, the embankment designs are based on the characteristics and availability of these materials. The specifications for materials which will act as filters will provide materials which meet the filter design criteria set forth in the Engineering Manual for Civil Works Construction. The following gradation limits for those materials which are to be obtained from government designated borrow areas will not be inserted in the contract specifications, but will be used by field personnel to control excavations in these borrow areas.

(2) Gravel Bedding. Gravel bedding material for use in the embankments and elsewhere on the project shall consist of sandy gravel and gravelly sand obtained from borrow excavations in Areas C and E. Of the portion of the material passing the 3-inch Sieve, from 25 to 60 percent shall pass the No. 4 Sieve and, of the component passing the No. 4 Sieve, no more than 15 percent shall pass the No. 200 Sieve.

(3) Pervious Fill. Pervious fill material for use in the internal wick drain of the dam embankment shall consist of gravelly sand or sandy gravel obtained from borrow excavation

in Areas C and E. Of the component passing the No. 4 Sieve, no more than 15 percent shall pass the No. 200 Sieve. To the extent practicable, material containing over 60 percent passing the No. 4 Sieve shall be used as pervious fill so as to conserve material in these areas suitable for use as gravel bedding.

(4) Gravel Fill. Gravel fill material for use in those portions of the foundation drains and the drainage blankets shall consist of sandy gravel furnished by the contractor from approved sources. Of the portion of the material passing the 3-inch Sieve, from 25 to 50 percent shall pass the No. 4 Sieve, and of the component passing the No. 4 Sieve, not more than 10 percent shall pass the No. 200 Sieve.

(5) Sand Fill. Sand fill material for use in drainage blankets and foundation drains shall consist of sand or gravelly sand furnished by the contractor from approved sources. Of the portion of the material passing the 3-inch Sieve from 50 to 100 percent shall pass the No. 4 Sieve, and of the component passing the No. 4 Sieve, no more than 10 percent shall pass the No. 200 Sieve.

(6) Gravel Filter. Gravel filter material for use in the filter zone of the dike embankment shall consist of sandy gravel furnished by the contractor from approved sources. Of the portion of the material passing the 3-inch Sieve, no more than 80 percent shall pass the 3/4-inch Sieve, from 30 to 55 percent shall pass the No. 4 Sieve and at least 10 percent shall

pass the No. 40 Sieve. Of the component passing the No. 4 Sieve, no more than 10 percent shall pass the No. 200 Sieve.

(7) Oversize Stones. Stones having maximum dimensions greater than 2/3 the thickness of the layer in which any of the foregoing materials are to be placed shall be removed either at the source of the material or from the fill.

d. Permeability Tests. Permeability tests were not performed on samples of gravel bedding and embankment drainage materials. On the basis of visual examination of the samples and their grain size characteristics, the following coefficients of permeability have been estimated:

Material	k_v, cm/sec	k_h/k_v
Pervious Fill	1 to 100 x 10^{-4}	4
Gravel Bedding	20 to 300 x 10^{-4}	4
Sand Fill, Gravel Fill, and Gravel Filter	20 to 100 x 10^{-4}	4

e. Shear Characteristics. Shear tests were not performed on samples of gravel bedding and pervious embankment materials. On the basis of experience with similar materials the following shear strength parameters are estimated as being conservative:

Material	Ø, Degrees	c, T/SF
Gravel Bedding, Pervious Fill and Sand Fill	30	0
Gravel Fill and Gravel Filter	32	0

17. Rock Fill and Rock Slope Protection Materials. The rock to be excavated consists predominantly of several types of schist with minor quartzite beds and local small granitic stringers and dikes as described elsewhere herein. The schist is very well foliated and although moderately hard and generally fresh in situ, will tend to break along the foliation during blasting and handling to produce flat, slabby shapes and a high proportion of micaceous fines. The more quartizitic phases of the schist will provide blockier and irregular shapes and will not break down readily to small sizes. Because of the relatively minor quantity of the harder rocks, control will be required during blasting, handling, stockpiling and placement operations of all the excavated rock to preserve the suitably graded sizes and to prevent breakdown and shattering of the rock insofar as practicable. A bulking factor 1.3 has been assumed for the rock from the excavations but losses during excavation, handling and placement will probably largely discount the bulking so that the volume of suitable rock available for rock fill and rock slope protection has been assumed as the in-situ volume of the rock to be excavated. It has been assumed that little or none of the rock from the tunnel excavation will be suitable for use in rock fills. Oversize stones from the fill materials will be used in the rock fill and rock slope protection layers. Material required in addition to that obtained from required rock excavations will be obtained from a government designated quarry within the reservoir limits containing the same type of rock as the required rock excavation areas.

F. DESIGN OF EMBANKMENTS.

18. Design Criteria. Current design criteria as set forth in the pertinent sections of the Engineering Manual for Civil Works Construction were followed in the design of the embankments for this project.

19. Materials for Construction.

a. Required Earth Excavation. Of the estimated 250,000 cu. yds. of required earth excavation for this project, about 83,000 cu. yds. will consist of topsoil, silt, and other stripping material unsuitable for use in the construction of the embankments. To the extent feasible, the remaining 167,000 cu. yds. of required earth excavation will be utilized as random embankment material. To a large extent, the final quantity of such random material placed in the embankment will depend upon the sequence of construction adopted. On the basis of the construction sequence discussed in Paragraph 26, below, it is estimated that about 143,000 cu. yds. of this material can be placed directly from required earth excavation. Excess materials may be used by the contractor for construction fills and auxiliary cofferdams or may be wasted.

b. Required Rock Excavation. It is estimated that about 106,000 cu. yds. of rock excavation will be required for the construction of this project. These materials will be utilized in the rock fills and the rock slope protection. In view of the necessity for stockpiling most of these materials prior to their use, the

general quality of the rock to be excavated, and the anticipated quantities of unsuitable materials, it is estimated that, despite bulking, the embankment volume of materials from the required rock excavation will not exceed the excavated volume of 106,000 cu. yds.

c. Borrow Excavation.

(1) Area B. Over 2,000,000 cu. yds. of impervious embankment materials are available from Area A after stripping about 85,000 cu. yds. of topsoil and similar unsuitable surficial deposits. It is anticipated that losses due to shrinkage, oversize, waste, and other causes will not exceed 10 percent.

(2) Area C. It is estimated that about 170,000 cu. yds. of sandy gravel and gravelly sand having silt contents of less than 15 percent of the component passing the No. 4 Sieve can be obtained from Area C. To uncover this material, about 50,000 cu. yds. of stripping will be required to remove the topsoil and silt blanket covering the deposit. In view of the variable character of this deposit, the presence of silt lenses and oversize stones, shrinkage and wasteage, it is anticipated that losses will be about 30 percent and that, therefore, about 120,000 cu. yds. (embankment volume) of material are available from this source.

(3) Area E. It is estimated that about 50,000 cu. yds. of sandy gravel and gravelly sand having silt content of less than 15 percent of the component passing the No. 4 Sieve can be obtained from Area E after stripping about 20,000 cu. yds. of topsoil

and silt. Losses due to oversize stones, silt lenses, shrinkage and other causes are anticipated to be about 30 percent. About 35,000 cu. yds. (embankment measure) of material, therefore, are available from this source.

(4) Rock Quarry. It is estimated that over 50,000 cu. yds. of rock fill and rock slope protection material of the same character as that from the required rock excavations are available in a government designated quarry in the reservoir area.

(5) Materials Furnished by the Contractor. Gravel fill, sand fill, gravel filter, and selected rip-rap will be furnished by the contractor from approved sources.

d. Materials Usage. A chart showing the proposed usage of materials from required excavations and borrow excavation is shown on Plate No. 29. The quantities shown are preliminary and will be subject to modification during final design studies.

20. Selection of Embankment Sections.

a. General. The embankments for the dam and the dike will be compacted earth fill structures with rock slope protection and small downstream rock fill toes. This type of construction was adopted as being the most economical and practicable for this project after studying embankment foundation conditions, the distribution and characteristics of available embankment materials, and construction conditions. Typical embankment sections as developed by the studies and analyses discussed in this memorandum are shown on Plates Nos. 15 and 16.

b. Dam. The embankment section selected for the dam is essentially a homogeneous impervious fill section with impervious foundation cut-off, a wick type internal drain with a horizontal drainage blanket, rock slope protection, and a small downstream rock fill toe. The section also includes a relatively small random fill zone in which a portion of the required earth excavation may be utilized.

c. Dike. The embankment section selected for the dike consists of an impervious fill zone and a random fill zone serving as a pervious zone with an upstream impervious fill blanket, rock slope protection, and a downstream rock fill toe. This type of section has been selected so as to facilitate utilization of required earth excavation at the early stages of construction. The random fill zone has been designed so that it may be built in advance of the impervious fill if necessary to obtain this end.

21. Slope Protection. The upstream embankment slopes will be subject to the action of waves up to 3 feet in height. For this wave height and a 1 on 3 slope, current criteria require a minimum thickness of 12 inches of graded riprap consisting of stones weighing from 8 to 240 pounds and averaging 60 pounds. In order to permit the use of material from required rock excavations which might not meet this gradation and in order to improve the stability of the slopes against reservoir drawdown, a 5-foot thick

layer of rock slope protection has been adopted for the upstream embankment slopes. In order to protect the downstream embankment slopes against erosion, a 2-foot layer of rock slope protection has been adopted. On the upstream slope of the dam between Elevation 508 and 528, where sustained exposure to waves on the water supply reservoir surface will occur, a 2-foot layer of selected riprap of high quality stone of satisfactory size and gradation will be placed in the surface of the rock slope protection.

22. Seepage Control.

a. Dam.

(1) Seepage through Embankment. Seepage through the dam embankment will be controlled by the arrangement and characteristics of the impervious and random fill zones, the internal wick drain, the drainage blanket, and the downstream rock fill toe. The location of the internal wick drain was determined on the basis of intercepting seepage well within the embankment thus preventing the development of seepage pressures which could affect the stability of the downstream portion of the embankment significantly. The horizontal drainage blanket has been designed to provide drainage for the wick drain as well as for the foundation. In the valley bottom the drainage blanket will include a layer of processed sand so as to provide additional drainage capacity without an excessive increase in blanket thickness. The processed sand will be material meeting the gradation specifications for fine concrete aggregate.

(2) Seepage through Foundation. Seepage through the overburden in the foundation of the dam embankment will be controlled by the impervious foundation cut-off extended to bedrock or glacial till, the foundation drain, and the horizontal drainage blanket. Seepage through weathered zones in the bedrock in the foundation of the dam embankment will be controlled by the grout curtain and by those portions of the foundation drain and the horizontal drainage blanket which will be in contact with the bedrock surface. The foundation drain and the horizontal drainage blanket have been designed to prevent the development of seepage pressures beneath the downstream part of the embankment resulting from seepage by-passing the cut-off through sand seams in the glacial till or the grout curtain. The foundation drain, in addition to relieving foundation seepage pressures, has also been designed to assist in carrying seepage from the wick drain on the right abutment laterally to the valley bottom thereby reducing the load on the drainage blanket.

(3) Seepage Quantities. On the basis of preliminary flow net studies, it is estimated that seepage from the water supply reservoir through the dam will be on the order of 0.5 c.f.s., of which about 0.4 c.f.s. will pass through the foundation bedrock. For these studies it was assumed that the coefficient of vertical permeability of the impervious fill would be 0.1×10^{-4} cm/sec and that the coefficient of vertical permeability of the foundation overburden and the upper 10 feet of the foundation bedrock would be

20×10^{-4} cm/sec. The ratio of horizontal to vertical permeability was taken as 9. It was further assumed that the grout curtain would be ineffective in reducing the amount of seepage. The estimated quantity of seepage is not considered significant and a more refined analysis, therefore, is considered unnecessary.

b. Dike.

(1) Seepage through Embankment. Seepage through the dike embankment will be controlled by the arrangement and characteristics of the impervious and random fill zones, the horizontal drainage blanket, the gravel filter layer, and the downstream rock fill toe. The random fill materials to be placed in the dike embankment are relatively pervious in comparison to the impervious fill materials. The random fill zone of the dike, therefore, has been designed to act as a large downstream pervious zone which will intercept seepage well within the embankment thereby preventing the development of seepage pressures which could affect the stability of the downstream slope of the embankment significantly. The drainage blanket, gravel filter layer, and rock fill toe have been designed to control seepage emerging from the embankment.

(2) Seepage through Foundation. Seepage through the foundation of the dike embankment will be controlled by the upstream impervious blanket and the foundation drain since depths to glacial till or bedrock in the foundation are too great for the practicable construction of a cut-off. The impervious blanket has

been designed so that seepage gradients through the foundation will not exceed 10 percent with the reservoir pool at its maximum flood control level and so that seepage gradients through the blanket will not exceed those through its foundation. The blanket will be provided with a 5-foot cover layer of spoil for frost protection. The foundation drain has been designed to prevent the development of detrimental seepage pressures beneath the downstream portion of the embankment. The horizontal drainage blanket has been provided principally to carry seepage away from the foundation drain.

c. Construction Requirements. In order to assure the maximum efficiency of the seepage control features discussed above, the following construction requirements will be incorporated in the contract specifications.

(1) Impervious Fills on Bedrock. It will be specified that all bedrock surfaces upon or against which impervious fill is to be placed shall be prepared in such a manner as to assure:

(a) The tightest practicable contact between the fill and the bedrock surface. (Breaking down of some of the narrow, over-hanging bedrock ribs will be required to obtain this.)

(b) Adequate compaction of the fill adjacent to the bedrock surface.

(c) Protection against the migration of fill materials into joints and similar openings in the bedrock under seepage forces.

(2) Foundation Drains and Drainage Blankets on Bedrock. It will be specified that all bedrock surfaces upon or against which foundation drains and drainage blankets are to be placed shall be prepared in such a manner as to assure adequate drainage of the joints and similar openings in the bedrock beneath these drainage features.

23. Embankment Stability.

a. General. The embankment sections selected for the dike and the dam have been analyzed for stability against shear failure using the method of infinitesimal slices except for certain special studies in which the wedge analysis was used. The design shear strengths for the impervious embankment materials were selected on the basis of laboratory shear test results. Design shear strengths for other embankment materials and the foundation soils were selected on the basis of experience with similar materials.

b. Conditions Analyzed.

(1) End of Construction. The embankments were analyzed for stability at the end of construction on the assumption that the time required to construct the embankments would be too short to permit either consolidation under the applied embankment loads or the dissipation by drainage of pore pressures in the impervious fills. Since the conditions of this assumption are analogous to those of the unconsolidated undrained (Q) shear test,

the analyses were made using design shear strengths based on this test condition.

(2) Operating Conditions

(a) Steady Seepage. The embankments were analyzed for stability under the steady seepage condition. Since the internal wick drain of the dam, the random fill zone of the dike, the foundation drains, the drainage blankets, and the grout curtain have been designed to prevent the development of seepage pore pressures in locations where they could affect embankment stability significantly, these analyses were made assuming no seepage pore pressures. Design shear strengths based on the consolidated-drained (S) and consolidated-undrained (R) shear strengths which shear strengths are considered to govern the ultimate or long term stability of the embankments were used in the analyses.

(b) Partial Pool. Analyses were made of the upstream slopes of the embankments at various pool levels to determine the pool levels at which embankment stability would be at a minimum. Design shear strengths for the consolidated-undrained (R) condition were used for the impervious materials in these analyses.

(c) Sudden Drawdown. The upstream slopes of the embankments were analyzed to determine their stability during the sudden drawdown of the reservoir pool using consolidated-undrained (R) shear strengths for the impervious materials. Drawdowns from maximum pool (El. 591) and spillway crest (El. 576) to Elev. 510 (8 feet below normal water supply pool level) were considered as well as drawdown from water supply pool (El. 518) to outlet invert (El. 432).

c. Selection of Design Values.

(1) Unit Weights. The random and impervious fill materials for the embankments will be compacted with sheepsfoot or rubber-tired rollers in accordance with a compaction specification which has been used by this Division in the past for embankments of similar materials. Experience with this specification indicates that the densities of the upper layers of fills compacted at moisture contents within the range anticipated for this project will average about 98 percent of maximum test density while the densities of the deeper layers will approach 100 percent of maximum test density. The design unit weights for the random and impervious fills, therefore, have been selected on the basis of the maximum test densities as adjusted to include the weight of the average stone contents. The design unit weights for other embankment materials have been selected on the basis of experience with similar materials. The design unit weights for the foundation soils have been selected on a similar basis.

	Unit Weight in Pounds per Cu.Ft.			
	Dry	Moist	Saturated	Submerged
Rock Fill and Rock Slope Protection	120	-	140	78
Gravel Bedding and Gravel Filter	135	142	147	85
Sand Fill, Gravel Fill and Pervious Fill	120	132	138	76
Random Fill and Impervious Fill	130	140	145	83
Foundation Soils	130	140	145	83

(2) Shear Strengths. The design shear strength parameters for the impervious fills have been selected on the basis of the minimum values indicated by the laboratory shear tests. The design shear strength parameters for the other embankment fills have been selected on the basis of conservative interpretation of experience with similar materials. In view of the variable nature of the foundation soils with respect to distribution and physical characteristics, it has been considered advisable to select two sets of shear strength parameters which would bracket the values estimated on the basis of experience with similar deposits.

	S Condition (DC)		R Condition (CU)		Q Condition (UU)	
Material	ϕ, degrees	c, T/SF	ϕ, degrees	c, T/SF	ϕ, degrees	c, T/SF
Rock Fill and Rock Slope Protection	40	0	-	-	-	-
Gravel Bedding and Gravel Filter	35	0	-	-	-	-
Sand Fill, Gravel Fill, and Pervious Fill	30	0	-	-	-	-
Random Fill, Dike	25	0	25	0	25	0
Impervious Fill	31.5	0	31	0.1	21	1.11
Foundation Outwash Soils	25 to 30	0	25 to 30	0	-	-

d. Sections Analyzed.

(1) Dam. The upstream portion of the dam embankment at Station 9+50 was chosen for analysis as being the most critical on that side of the dam with respect to stability because it combines

maximum height with an appreciable depth of foundation soil. The downstream portions of the dam at Stations 9+50 and 8+70 were chosen for analysis because the latter combines a relatively high slope with an appreciable depth of foundation soil and the former has the maximum slope height.

(2) Dike. The upstream portion of the dike embankment at Station 25+00 and the downstream portion of the dike embankment at Station 23+65 were selected for analysis as being the most critical with respect to analyses because they have the maximum slope heights and appreciable depths of foundation soils.

e. Results of Embankment Stability Analyses.

(1) The results of the embankment stability analyses are summarized on Plates Nos. 17, 18, and 19 for the dam and on Plates Nos. 24 and 25 for the dike. Typical analyses are shown on Plates Nos. 20 through 23 and 26 through 28. The minimum factors of safety against shear failure as determined by the analyses are as follows:

Condition Analyzed	Minimum Factor of Safety	
	Dam	Dike
End of Construction (Downstream Slopes)	1.66 to 1.85	1.83 to 2.05
Ultimate (Steady Seepage) Downstream Slopes)	1.58 to 1.61	- -
Partial Pool (Reference to Plate Nos. 17 & 24 for critical pool elevations	1.67 to 1.77	1.64 to 1.81

Condition Analyzed Cont'd	Minimum Factor of Safety	
	Dam	Dike
Sudden Drawdown		
Maximum Pool to Elevation 510	1.24	1.11 to 1.24
Spillway Crest to Elevation 510	1.30	1.27 to 1.40
Elevation 518 to Elevation 432	1.25 to 1.38	- -

NOTE: Where a range of values is shown, the lower figure represents the minimum factor of safety at the lower limit of the design shear strength range for the foundation soils and the higher value represents the minimum factor of safety at the upper limit of the design shear strength range for the foundation soils.

(2) The foregoing minimum factors of safety are considered to be adequate and the results of the stability analyses indicate that the selected embankment sections are safe against shear failure.

f. Special Stability Studies.

(1) Dam at Sta. 13+60. The downstream slope of the dam at Sta. 13+60, in the reach where a 1 on 2 downstream slope is required, was studied to determine if the proposed rock fill zone was of adequate size to maintain stability. It was found that the section would have an adequate factor of safety provided that the rock fill were placed directly on the bedrock surface.

(2) Dam at Sta. 7+20. As discussed in Paragraph 7, above, there is a possibility that a thin clay stratum occurs at a depth of about 30 feet in the upstream portion of the dam foundation in the vicinity of Sta. 7+20. It is estimated that the clay

has a shear strength of at least 1.0 T/SF. A wedge analysis for the sudden drawdown condition was made of the upstream part of the dam embankment at this location. To simplify computations, it was assumed that the shear strength parameters for the embankment materials and the foundation soil above the clay stratum were equal to $\phi = 30$ degrees and $c = 0$. It was determined that for this case the minimum factor of safety would be 1.61 which is considered adequate particularly in view of the probability that the clay stratum is not continuous.

24. Settlements. The foundation and embankment materials for this project are of types which normally exhibit very low compressibility. While the clay in the right abutment of the dam foundation is somewhat more compressible, it occurs in a thin layer or lens and the magnitude of any consolidation would be very small. No significant settlements are therefore anticipated in either the foundations or the embankments.

25. Removal and Disposal of Unsuitable Materials. All topsoil and other organic surficial material will be removed from the embankment foundation areas, together with all surficial boulders and rock blocks. In addition, surficial deposits of silt and silty fine sand will be removed. These materials will be spoiled in designated areas. Boulders and blocks removed from the foundation areas may be used in rock fill if practicable.

26. Construction Considerations.

a. Dewatering Construction Areas. Dewatering will be specified for all areas in which embankment fill is to be placed

including the foundation cut-off trench for the dam and the foundation drain trenches. The dewatering of other construction areas will be required to the extent necessary to facilitate construction. All excavations in the embankment foundations, other than stripping excavations, shall be done in the dry so that the least practicable amount of earth excavation will be spoiled because of excessive water content resulting from high ground water levels. It is anticipated that the dewatering of the construction areas in general will be possible by common methods of construction drainage including open pumping. In the trench excavations in the river valley, however, it is anticipated that special methods such as well pointing or the use of deep wells may be necessary.

b. Rate of Embankment Construction. The lengths of the dam and dike embankments and the topography of their foundations are such that embankment construction in partial reaches is neither practicable nor desirable. It will be specified, therefore, that each embankment will be constructed to its full length. In general, it will be specified that the top surfaces of all embankment fills shall be maintained in an approximately horizontal condition at all times during construction except for slight drainage slopes. Construction in this manner will permit adequate compaction of all fill materials thereby preventing the development of potential planes of weakness or variable permeability within the embankments. Exceptions to this requirement will be made to allow construction of the embankment cofferdam for the dam in

advance of the rest of the dam embankment and to permit placement of random fill materials in the dike ahead of the other materials. To the extent required to avoid stockpiling of excavated materials, exception to this requirement will also be made to permit placement of limited quantities of random fill in the dam ahead of the rest of the embankment.

c. Sequence of Construction. In order to achieve the maximum utilization of materials from required earth excavations in the permanent work without stockpiling, the sequence of embankment construction for the dam and dike will be more closely governed by the specifications than usual. The chief requirement in this respect will call for the excavation of the foundations cut-off trench for the dam in the valley bottom and of the foundation drain trench for the dike following completion of the water supply conduit and the diversion of the river with the concurrent placement of the excavated materials in the random fill zone of the dike. All other excavations shall be coordinated with the construction of the dam embankment and the remainder of the dike embankment so that the least practicable quantity of excavated material, other than stripping, will be spoiled.

G. PERMANENT CUT SLOPES

27. Earth Cut Slopes. In general, all permanent earth cut slopes in the spillway, intake, and outlet channels will be topsoiled and seeded for protection against erosion. Rock slope

protection, however, will be placed on those slopes which may be subject to damage from the action of waves or currents and on those slopes steeper than 1 on 3 which may be subject to damage from run-off, seepage, or frost action. Permanent earth cuts in Borrow Area B will be finished at slopes of 1 on 3, covered with a layer of stripping material, and seeded.

28. Rock Cut Slopes. The side slopes of the permanent rock cuts which are throughout less than 50 feet deep will be very largely controlled by the strongly developed rock structure. Because of the smooth, steeply dipping foliation and the inherently slippery character of the sericitic and graphitic schists, design slopes of 3 vertical on 1 horizontal are planned on the easterly or up-dip side of excavations in rock. This slope approximates the dip of the foliation and should assist in minimizing the under-cutting of the natural major slip planes in the rock. On the westerly or down-dip side of excavations and in excavations which tend to cut more directly across the rock structure, side slopes of 4 on 1 will be employed. Provision will be made for rock bolts where applicable. Along the crests of the cuts it may be necessary in areas of close-jointing or weathering to roll back the slopes to minimize fall-outs and the overburden will be removed to provide a 10-foot berm on the rock surface. Safety mesh will also be provided to reduce hazard of fall-outs during construction.

H. NATURAL SLOPES

29. Some of the natural earth slopes in the reservoir area are steeper than 1 on 3 and subsequently must be considered to be subject to slides during draw-down of the reservoir pool. For the most part, such failures would be of limited extent posing no serious threat to the permanent work, life, or property. Where such failures might be critical, the slopes will be cut back as much as possible and, where necessary, provided with rock slope protection.

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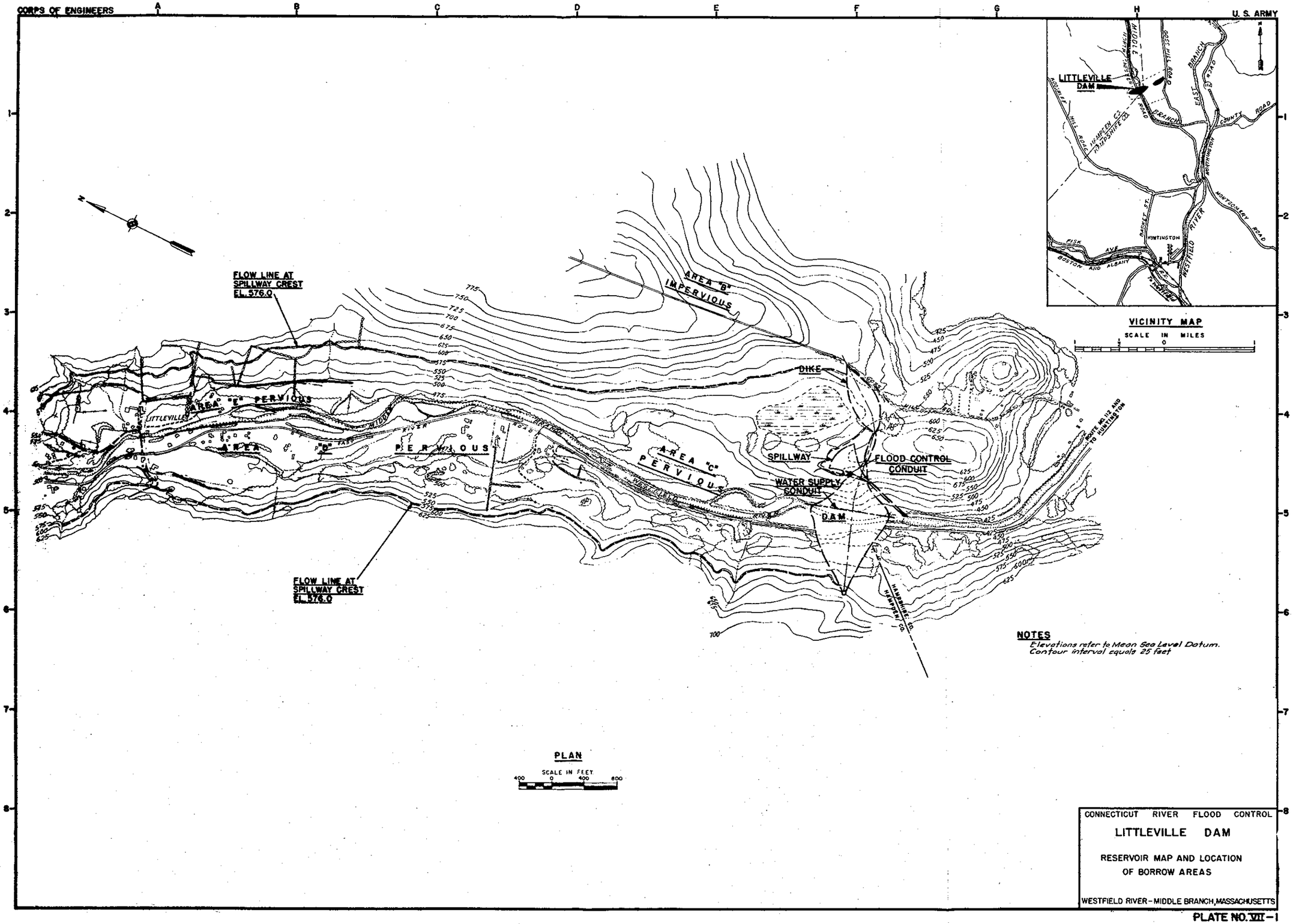


CONNECTICUT RIVER FLOOD CONTROL

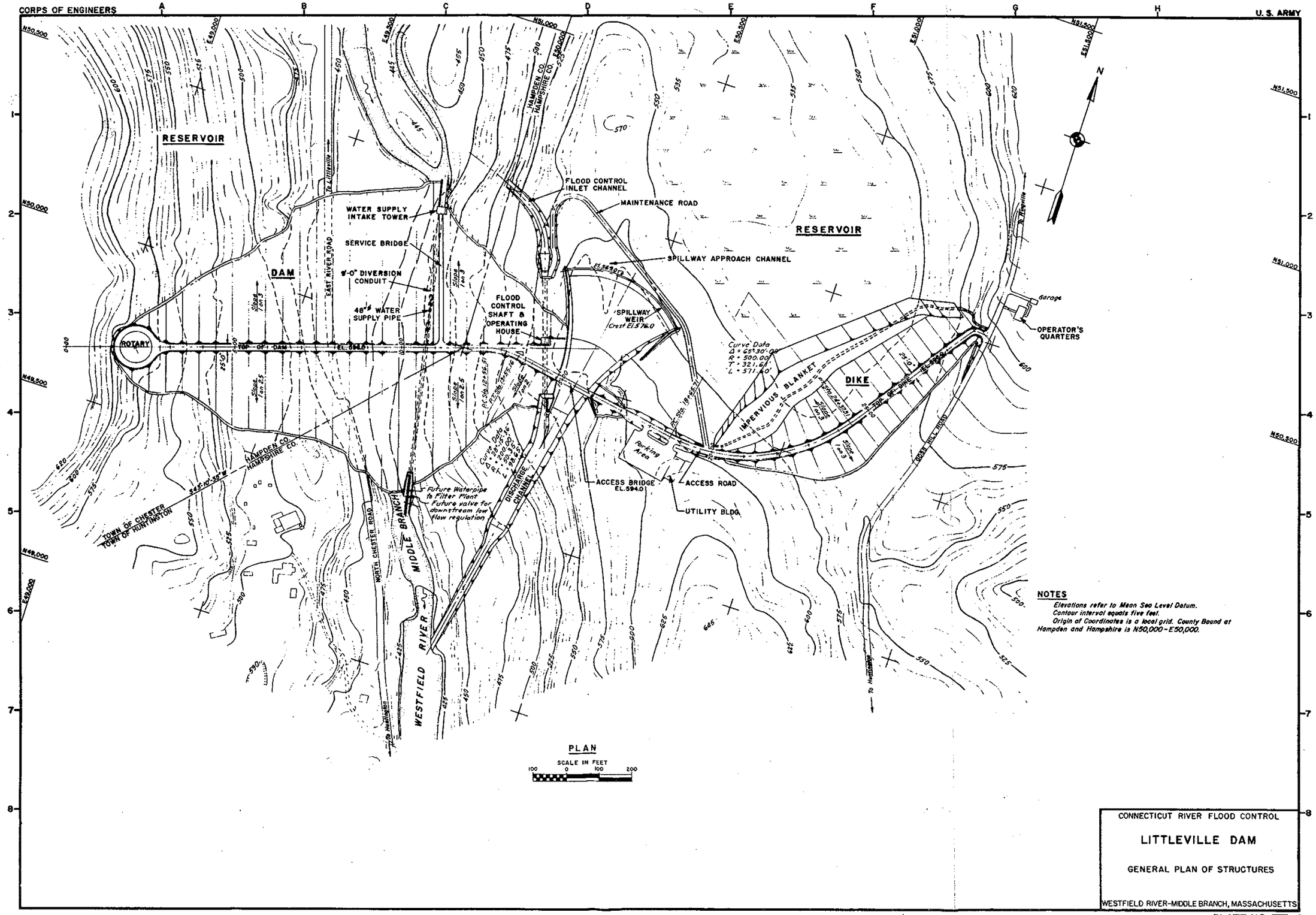
LITTLEVILLE DAM

RESERVOIR MAP AND LOCATION OF BORROW AREAS

WESTFIELD RIVER - MIDDLE BRANCH, MASSACHUSETTS

PLATE NO. VII-1

CORPS OF ENGINEERS U. S. ARMY



NOTES

Elevations refer to Mean Sea Level Datum.
Contour interval equals five feet.
Origin of Coordinates is a local grid. County Bound at Hampden and Hampshire is N50,000-E50,000.

CONNECTICUT RIVER FLOOD CONTROL

LITTLEVILLE DAM

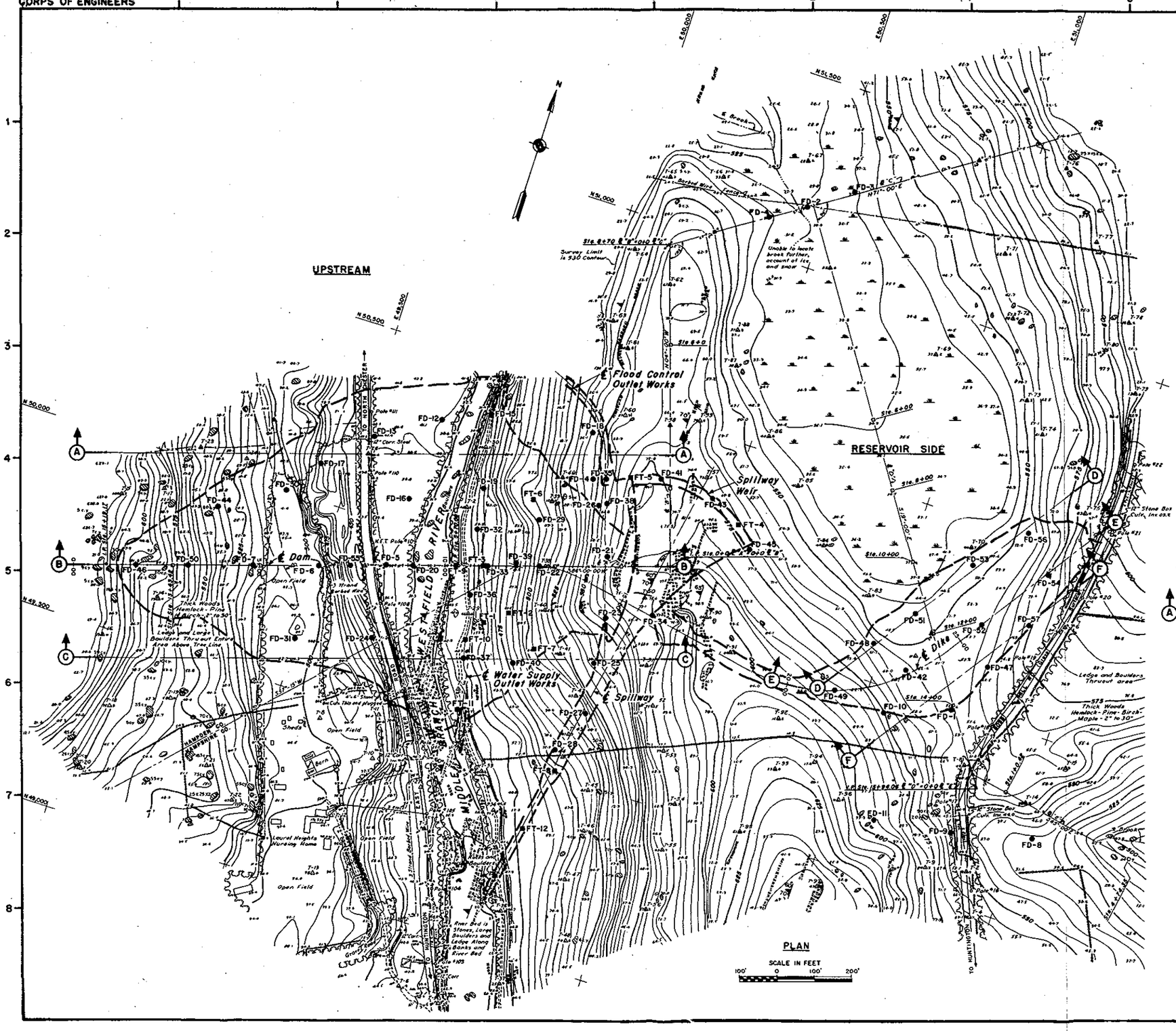
GENERAL PLAN OF STRUCTURES

WESTFIELD RIVER-MIDDLE BRANCH, MASSACHUSETTS

PLATE NO. VII-2

CORPS OF ENGINEERS

U. S. ARMY



LEGEND

- ● FD Foundation Test Boring
- ■ FT Foundation Test Pit
- Bedrock Outcrop
- Boulder or Rock Block
- Strike and Dip of Foliation
- A---A Location and Direction of View for Engineering Log Profiles

NOTES

Elevations refer to Mean Sea Level Datum.
Contour interval equals 5 feet.

Origin of Coordinates is a local grid. County Bound at Hampden and Hampshire is N 50,000 – E 50,000

CONNECTICUT RIVER FLOOD CONTROL

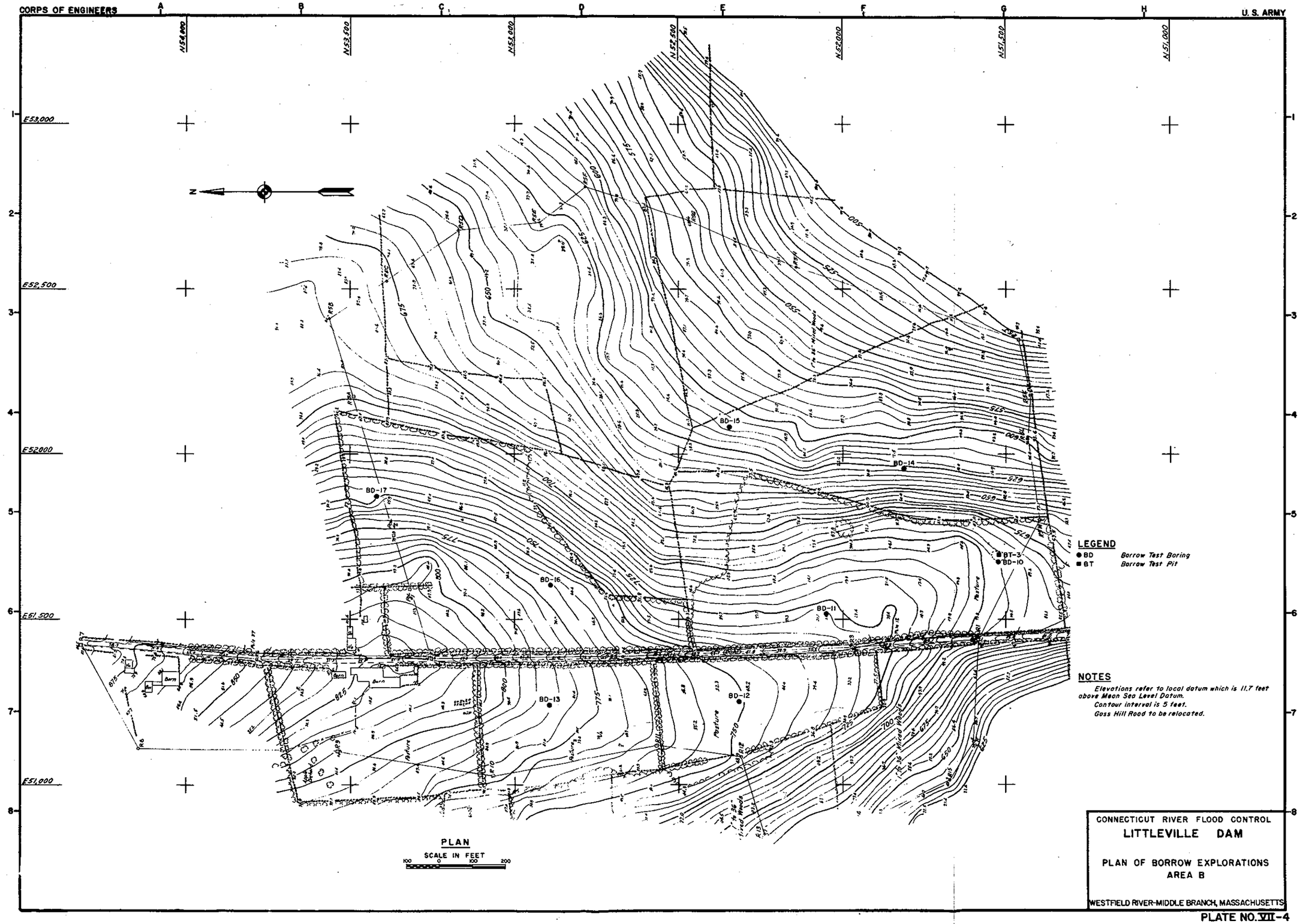
LITTLEVILLE DAM

PLAN OF FOUNDATION EXPLORATIONS

WESTFIELD RIVER-MIDDLE BRANCH MASSACHUSETTS

PLATE NO. VII – 3

CORPS OF ENGINEERS U. S. ARMY



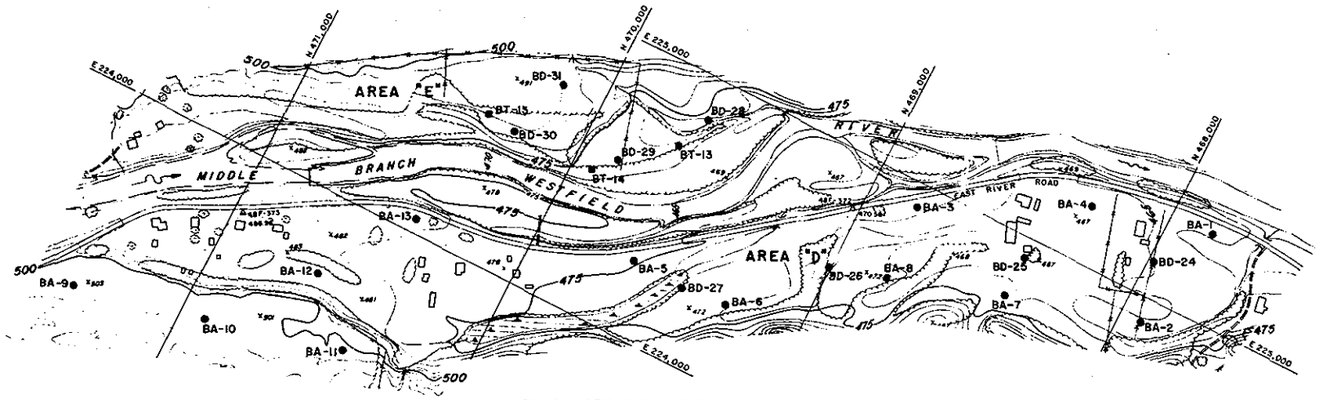
CONNECTICUT RIVER FLOOD CONTROL

LITTLEVILLE DAM

PLAN OF BORROW EXPLORATIONS
AREA B

WESTFIELD RIVER-MIDDLE BRANCH, MASSACHUSETTS

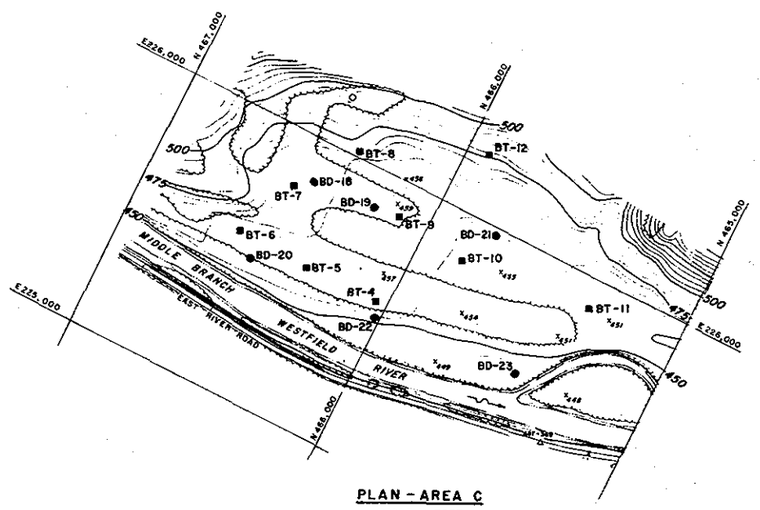
PLATE NO. VII-4



PLAN - AREAS D AND E

SCALE IN FEET

200 0 200 400



PLAN - AREA C

SCALE IN FEET

200 0 200 400

LEGEND

- ● BD Borrow Test Boring
- ◆ BA Borrow Hand Auger Boring
- ■ BT Borrow Test Pit

NOTES

Elevations refer to Mean Sea Level Datum

Contour interval is 5 feet

1000 foot Grid based on Massachusetts Plane Coordinate System

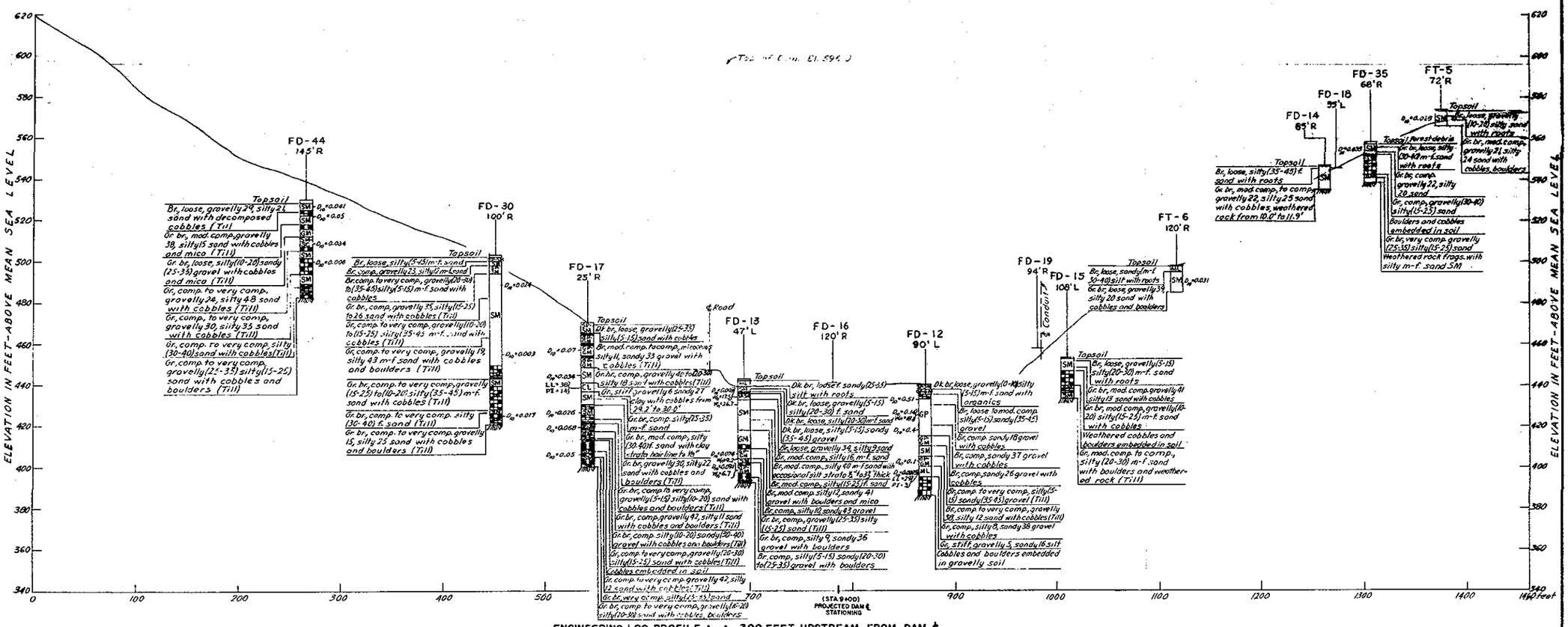
CONNECTICUT RIVER FLOOD CONTROL

LITTLEVILLE DAM

PLANS OF BORROW EXPLORATIONS
AREAS C, D AND E

WESTFIELD RIVER-MIDDLE BRANCH, MASSACHUSETTS

PLATE NO. VII-5



ENGINEERING LOG PROFILE A-A, 300 FEET UPSTREAM FROM DAM ℄

(LOOKING UPSTREAM)

NOTES

For Location of Explorations, see Plate VII-3

For Legend of Engineering Logs, see Appendix D

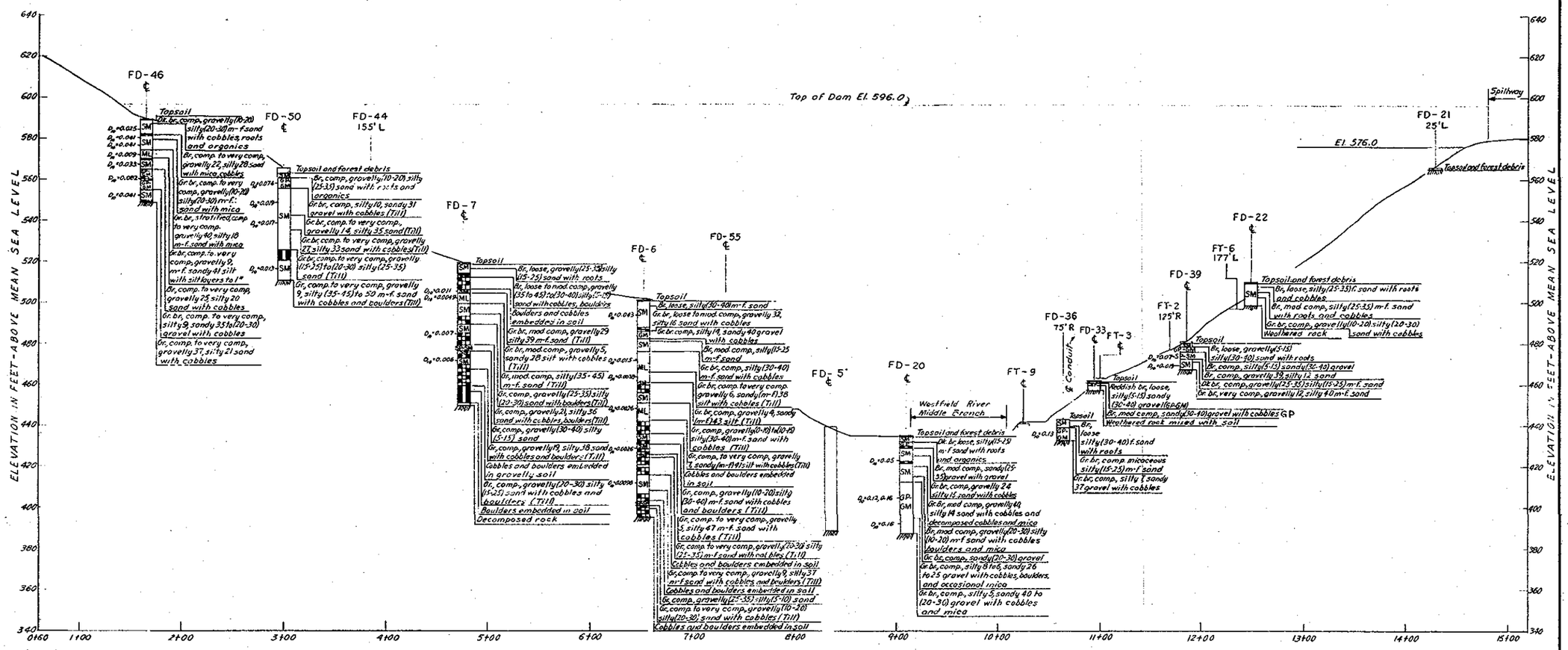
CONNECTICUT RIVER FLOOD CONTROL

LITTLEVILLE DAM

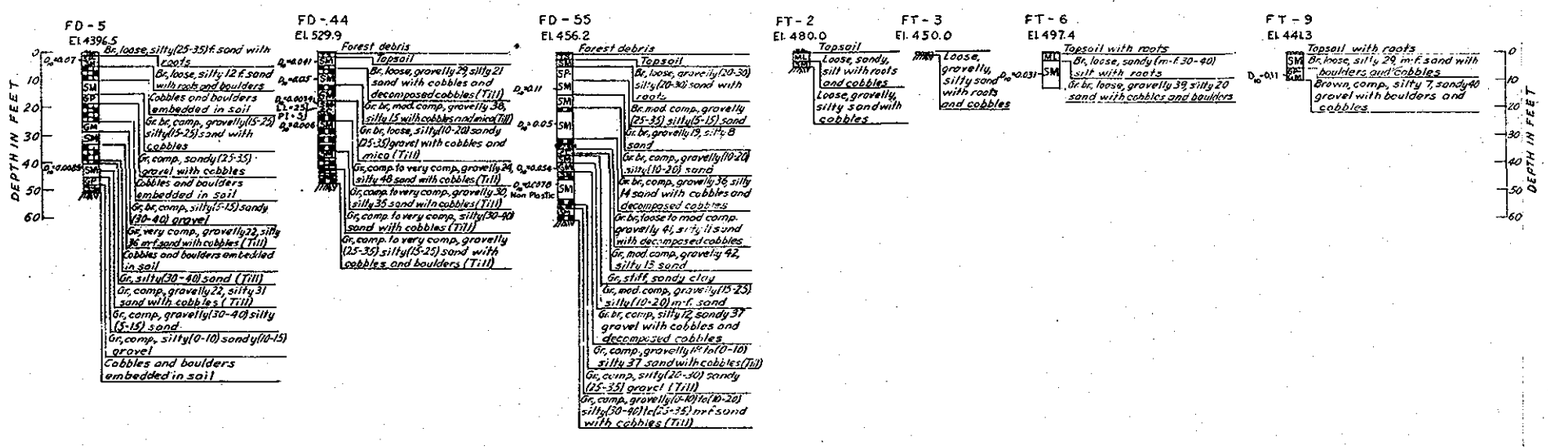
DAM

ENGINEERING LOG PROFILE A-A

WESTFIELD RIVER-MIDDLE BRANCH, MASSACHUSETTS



ENGINEERING LOG PROFILE B-B, ALONG DAM ℄
(LOOKING UPSTREAM)



NOTES

For Location of Explorations, see Plate VII-3

For Legend of Engineering Logs see Appendix D

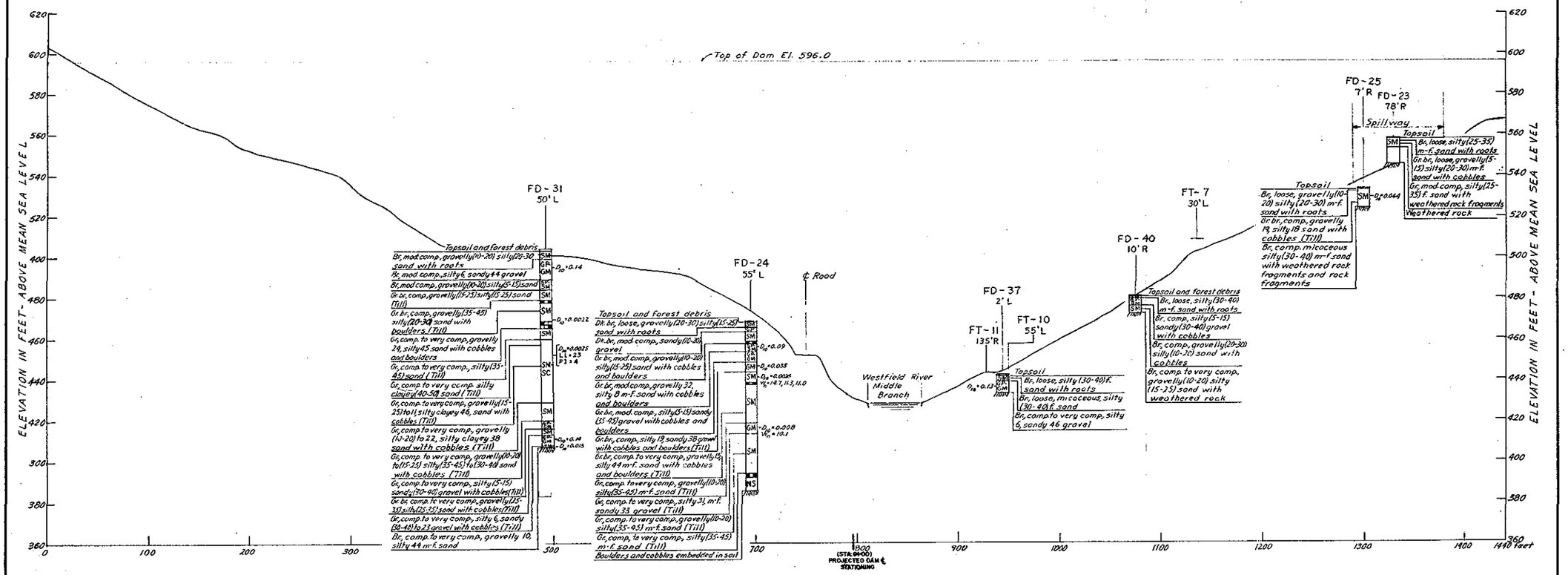
CONNECTICUT RIVER FLOOD CONTROL

LITTLEVILLE DAM

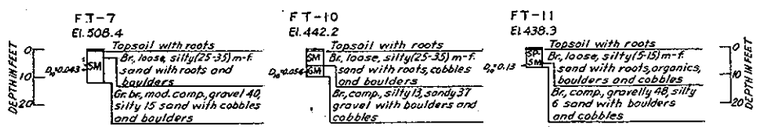
DAM

ENGINEERING LOG PROFILE B-B

WESTFIELD RIVER-MIDDLE BRANCH, MASSACHUSETTS



ENGINEERING LOG PROFILE C-C, 250 FEET DOWNSTREAM FROM DAM ¢
(LOOKING UPSTREAM)



NOTES

For Location of Explorations, see Plate VII-3

For Legend of Engineering Logs see Appendix D

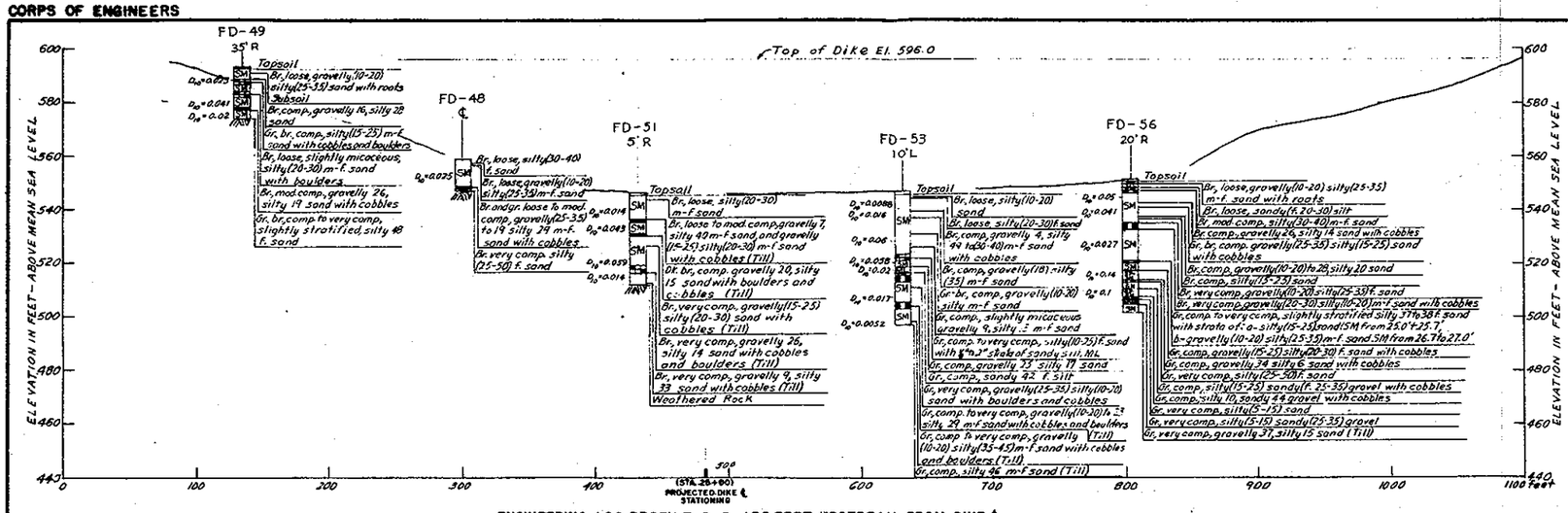
CONNECTICUT RIVER FLOOD CONTROL

LITTLEVILLE DAM

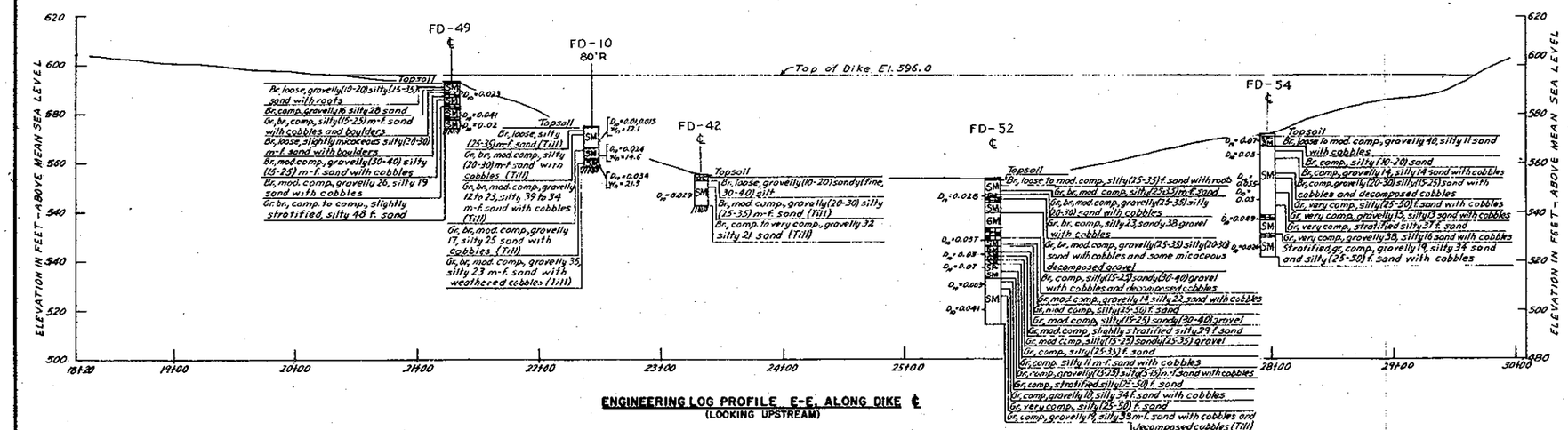
DAM

ENGINEERING LOG PROFILE C-C

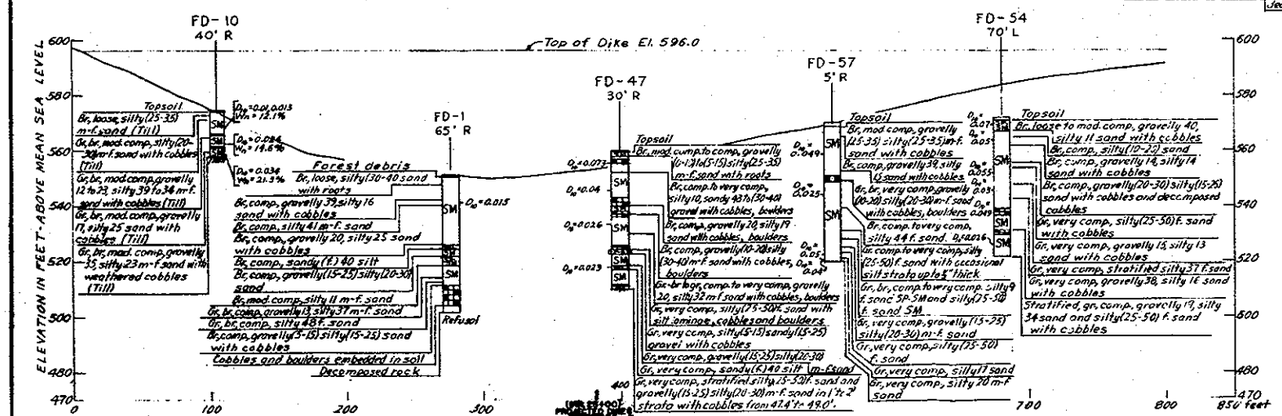
WESTFIELD RIVER-MIDDLE BRANCH MASSACHUSETTS



ENGINEERING LOG PROFILE D-D, 130 FEET UPSTREAM FROM DIKE ℄
(LOOKING UPSTREAM)



ENGINEERING LOG PROFILE E-E, ALONG DIKE ℄
(LOOKING UPSTREAM)



ENGINEERING LOG PROFILE F-F, 75 FEET DOWNSTREAM FROM DIKE ℄
(LOOKING UPSTREAM)

NOTES

For Location of Explorations, see Plate VII-3
For Legend of Explorations see Appendix D

CONNECTICUT RIVER FLOOD CONTROL

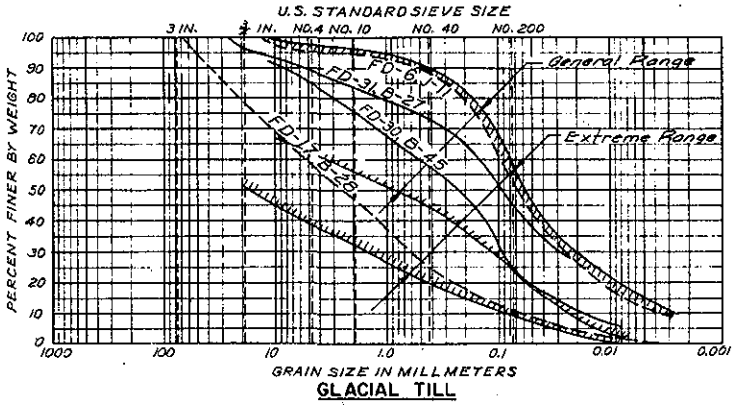
LITTLEVILLE DAM

DIKE

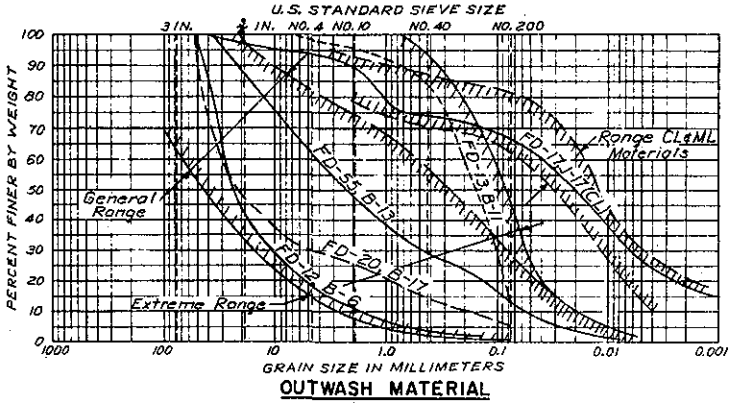
ENGINEERING LOG PROFILES D-D, E-E AND F-F

WESTFIELD RIVER-MIDDLE BRANCH, MASSACHUSETTS

DAM

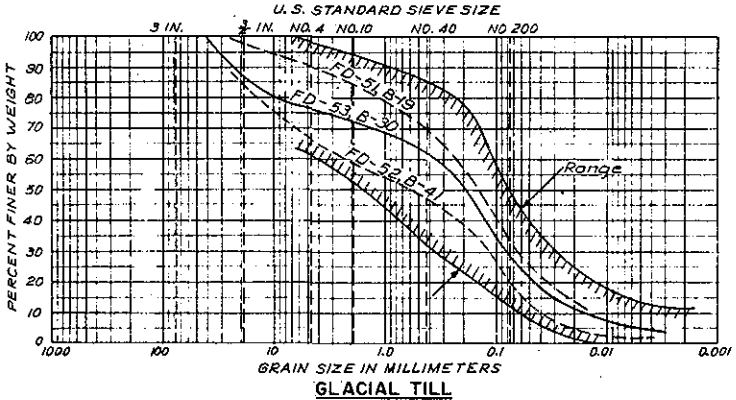


GLACIAL TILL

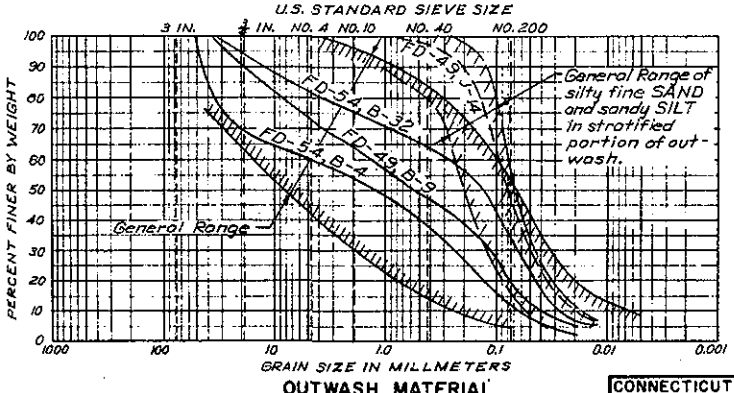


OUTWASH MATERIAL

DIKE



GLACIAL TILL



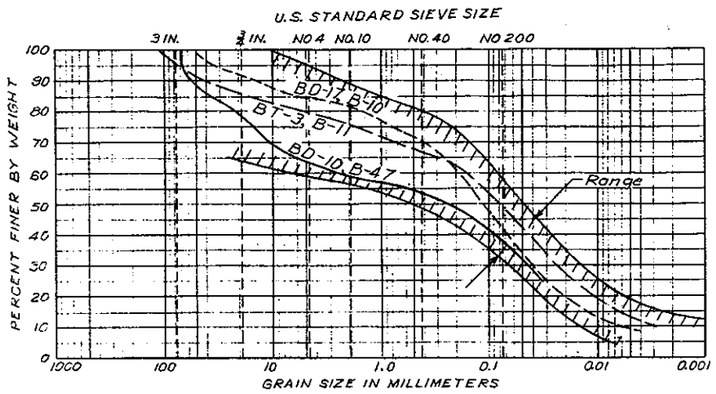
OUTWASH MATERIAL

CONNECTICUT RIVER FLOOD CONTROL

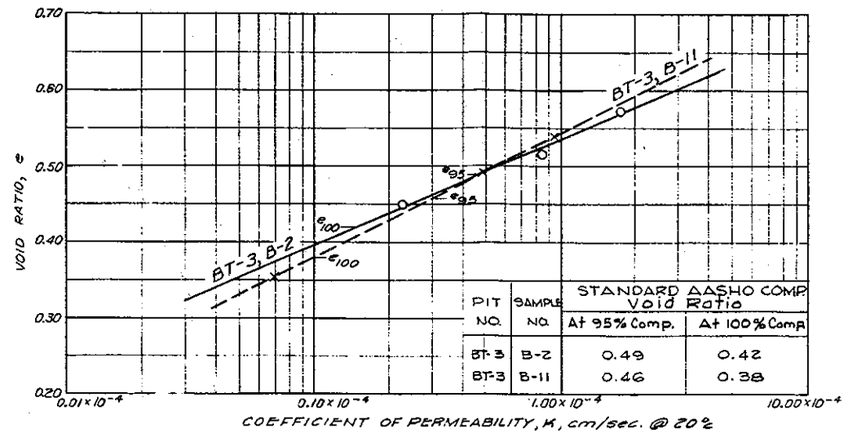
LITTLEVILLE DAM

SELECTED TEST DATA
FOUNDATIONS

WESTFIELD RIVER - MIDDLE BRANCH . MASSACHUSETTS



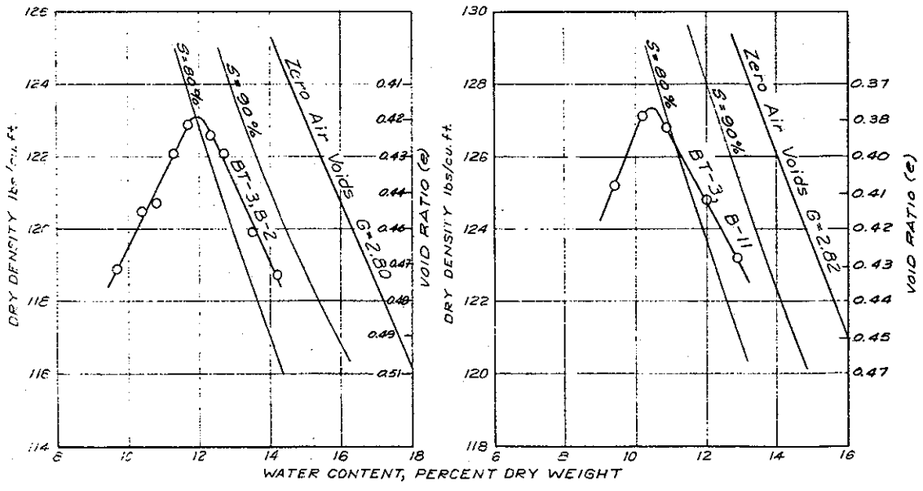
GRADATION RANGE



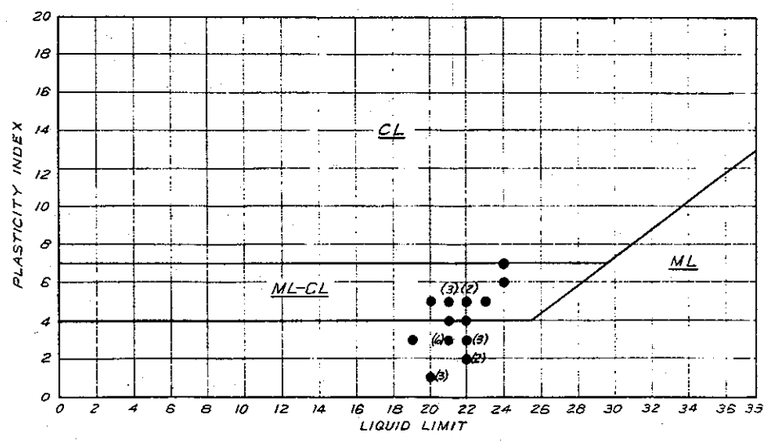
PIT NO.	SAMPLE NO.	STANDARD AASHO COMP. Void Ratio At 95% Comp.	At 100% Comp.
BT-3	B-2	0.49	0.42
BT-3	B-11	0.46	0.38

PERMEABILITY vs VOID RATIO

e_{100} = Void Ratio at 100% Standard AASHO Comp.



STANDARD AASHO COMPACTION TEST CURVES



ATTERBERG LIMITS

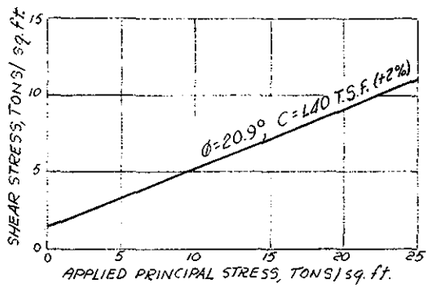
NOTE
Where results of several tests are identical, number of such tests are shown in parenthesis.

CONNECTICUT RIVER FLOOD CONTROL

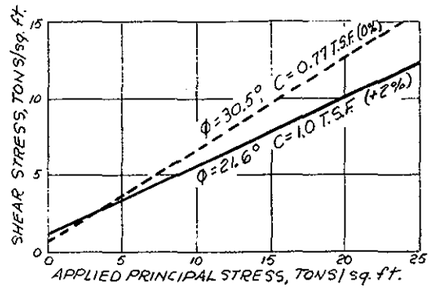
LITTLEVILLE DAM

SELECTED TEST DATA
IMPERVIOUS EMBANKMENT
MATERIAL
AREA "B"

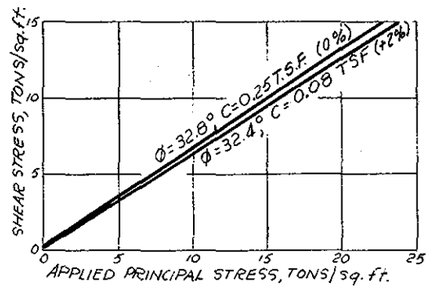
WESTFIELD RIVER-MIDDLE BRANCH MASSACHUSETTS



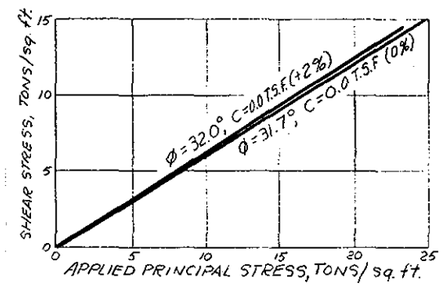
Q TESTS (U-U), BT-3, B2



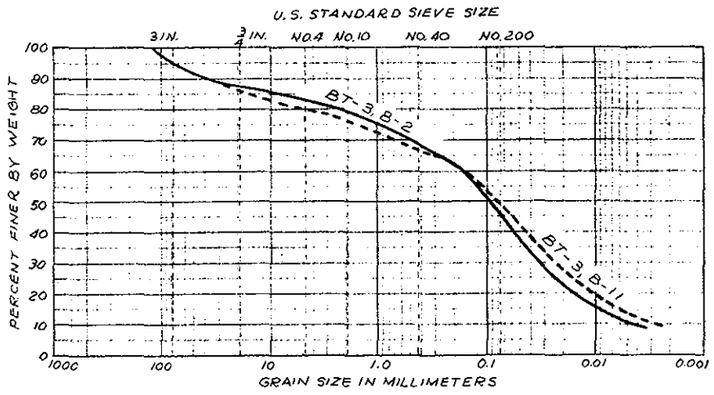
Q TESTS (U-U), BT-3, B11



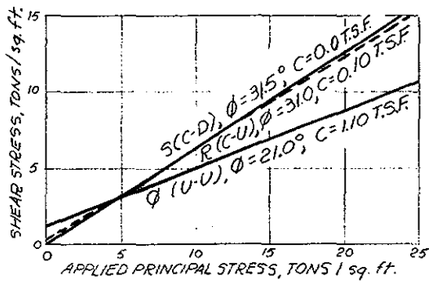
R TESTS (C-U), BT-3, B11



S TESTS (C-D), BT-3, B11



GRADATION CURVES



DESIGN SHEAR STRENGTHS

NOTES

Atterberg Limits
BT-3, B-2: LL=21, PI=1
BT-3, B-11: LL=21, PI=3

All tests of triaxial compression type

Tests performed on component of samples passing No. 4 Sieve

Figures in parentheses represent differences between molding water content and optimum water content

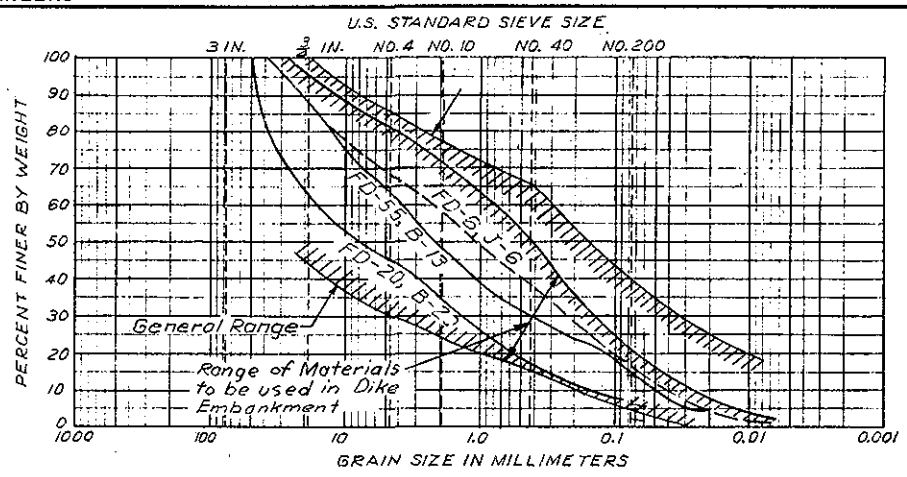
Detailed shear test data bound in Appendix B

CONNECTICUT RIVER FLOOD CONTROL

LITTLEVILLE DAM

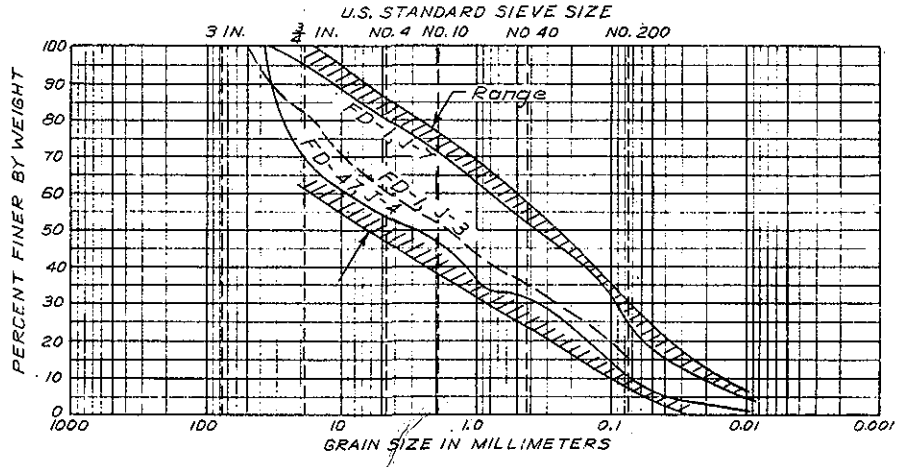
SELECTED SHEAR STRENGTH DATA
IMPERVIOUS EMBANKMENT
MATERIAL
AREA "B"

WESTFIELD RIVER – MIDDLE BRANCH MASSACHUSETTS



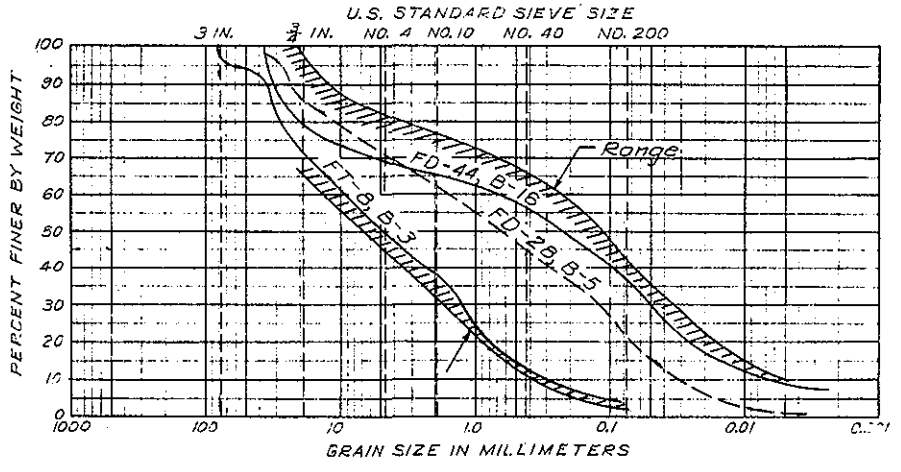
GRADATION RANGE

MATERIALS FROM EXCAVATION IN DAM FOUNDATION



GRADATION RANGE

MATERIALS FROM EXCAVATION IN DIKE FOUNDATION



GRADATION RANGE

MATERIALS FROM EXCAVATION IN SPILLWAY CHANNEL

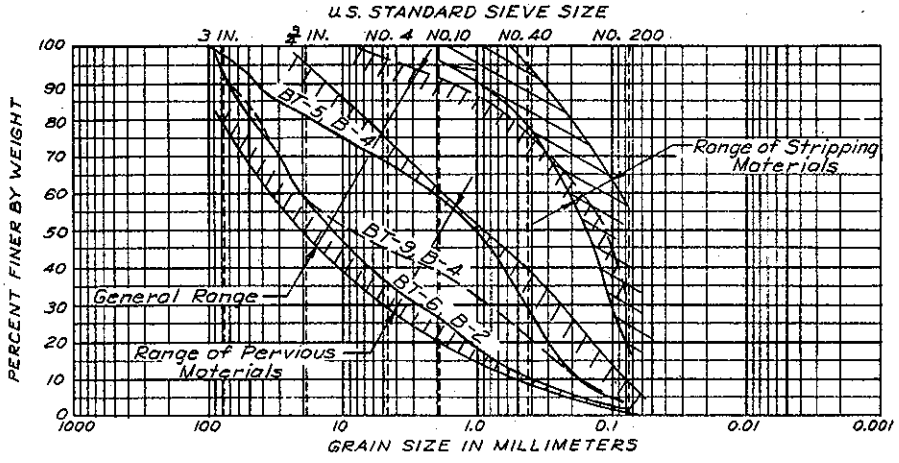
CONNECTICUT RIVER FLOOD CONTROL

LITTLEVILLE DAM

SELECTED TEST DATA

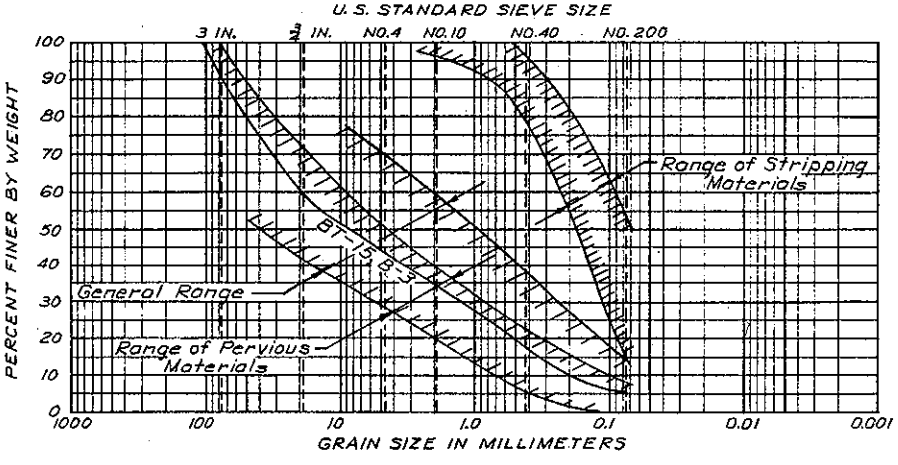
EMBANKMENT MATERIALS FROM REQUIRED EARTH EXCAVATIONS

WESTFIELD RIVER-MIDDLE BRANCH MASSACHUSETTS



GRADATION CURVES

AREA "C"



GRADATION CURVES

AREA "E"

NOTE

On Gradation Ranges for Areas "C" and "E" only materials containing less than 15% fine (of component passing No. 4 Sieve) have been considered as pervious embankment materials.

CONNECTICUT RIVER FLOOD CONTROL

LITTLEVILLE DAM

SELECTED TEST DATA

PERVIOUS EMBANKMENT MATERIALS

AREAS "C" AND "E"

WESTFIELD RIVER-MIDDLE BRANCH MASSACHUSETTS

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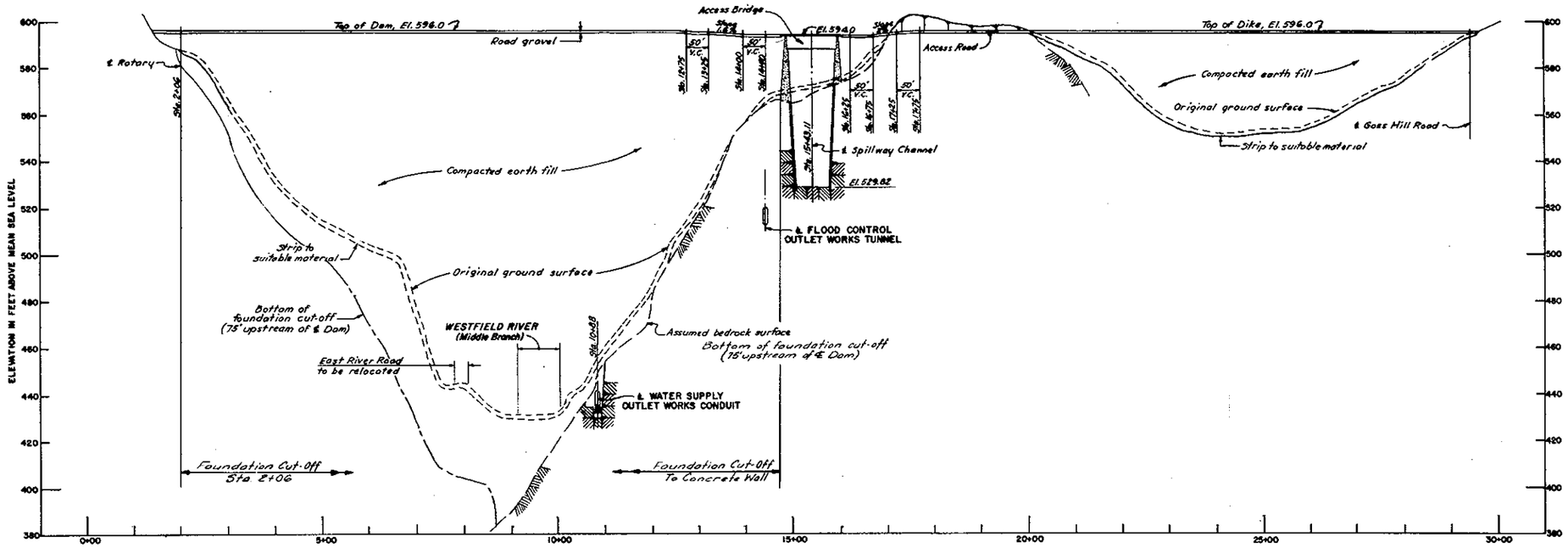
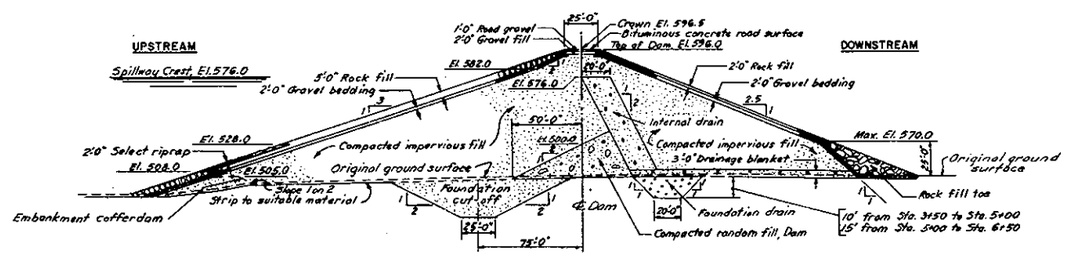


PROFILE ALONG ℄ DAM & DIKE

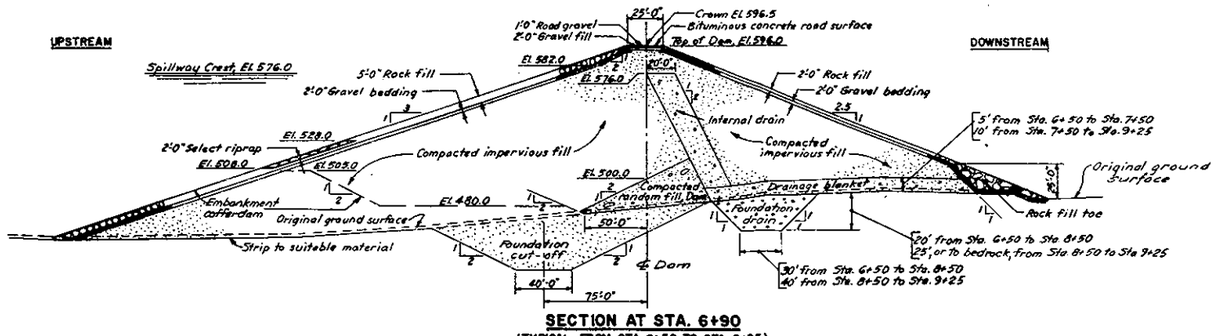
SCALE: HOR. 1"=100' VERT. 1"=20'



SECTION AT STA. 6+00

(TYPICAL FROM STA. 3+00 TO STA. 6+50)

SCALE: 1"= 40'



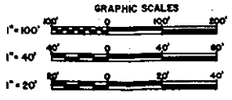
SECTION AT STA. 6+90

(TYPICAL FROM STA. 6+50 TO STA. 9+25)

SCALE: 1"= 40'

NOTES

Elevations refer to Mean Sea Level Datum.
Limits shown for random fill zone of dam are tentative and represent maximum extent of this zone.



CONNECTICUT RIVER FLOOD CONTROL

LITTLEVILLE DAM

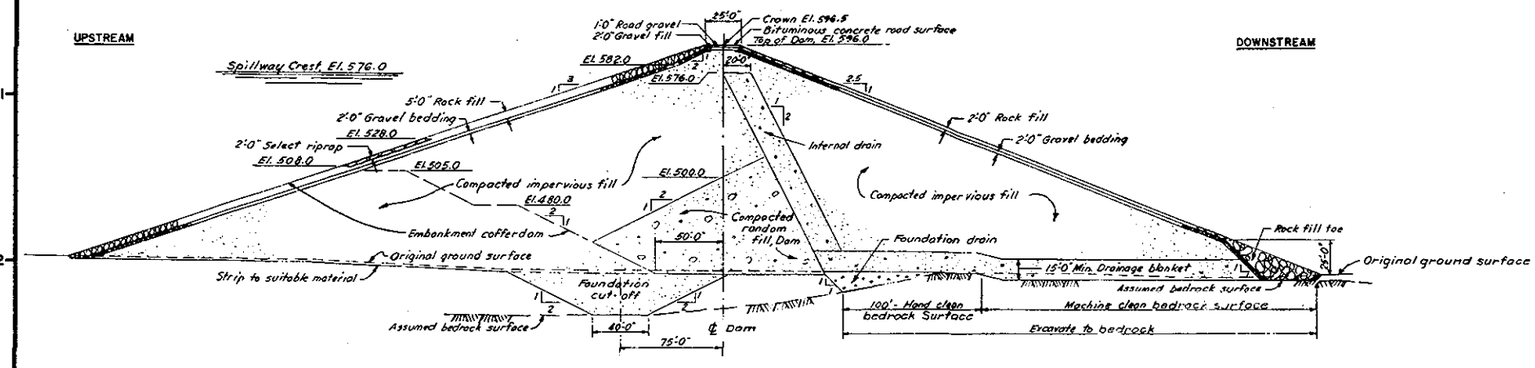
DAM AND DIKE

TYPICAL EMBANKMENT SECTIONS AND PROFILES

WESTFIELD RIVER-MIDDLE BRANCH, MASSACHUSETTS

PLATE NO. VII-15

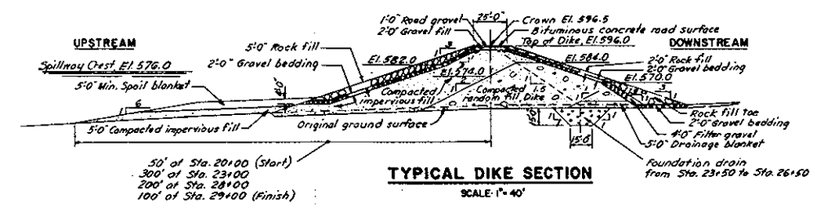
CORPS OF ENGINEERS U. S. ARMY



SECTION AT STA. 9+50

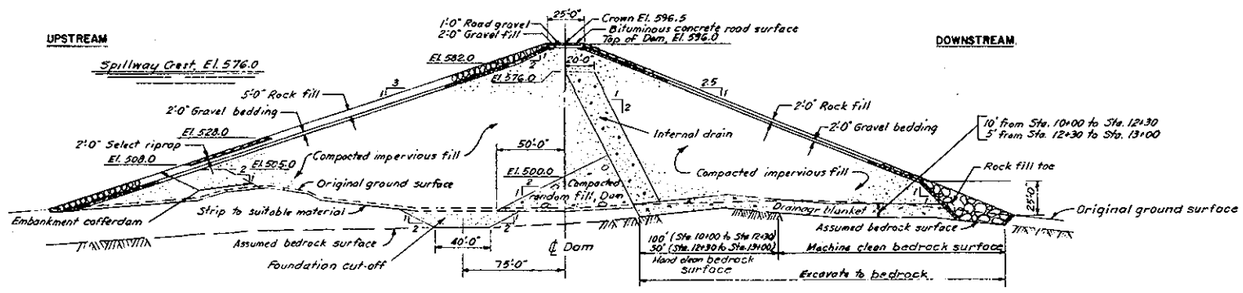
(TYPICAL FROM STA. 9+25 TO STA. 10+00)

SCALE- 1" = 40'



TYPICAL DIKE SECTION

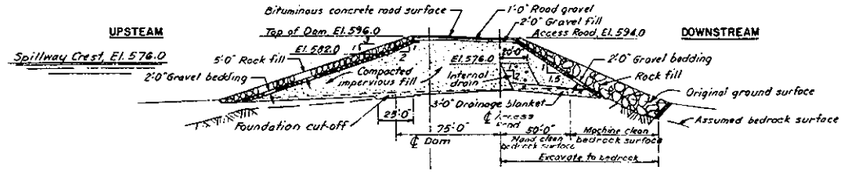
SCALE: 1" = 40'



SECTION AT STA. 11+65

(TYPICAL FROM STA. 10+00 TO STA. 13+00)

SCALE- 1" = 40'



SECTION AT STA. 14+00

(TYPICAL FROM STA. 13+00 TO STA. 15+00)

SCALE- 1" = 40'

NOTES

Limits shown for random fill zone of dam are tentative and represent maximum extent of this zone.

GRAPHIC SCALE 1" = 40' — 40' 0 40' 80'

CONNECTICUT RIVER FLOOD CONTROL

LITTLEVILLE DAM

DAM AND DIKE

TYPICAL EMBANKMENT SECTIONS

WESTFIELD RIVER-MIDDLE BRANCH, MASSACHUSETTS

PLATE NO. VII-16

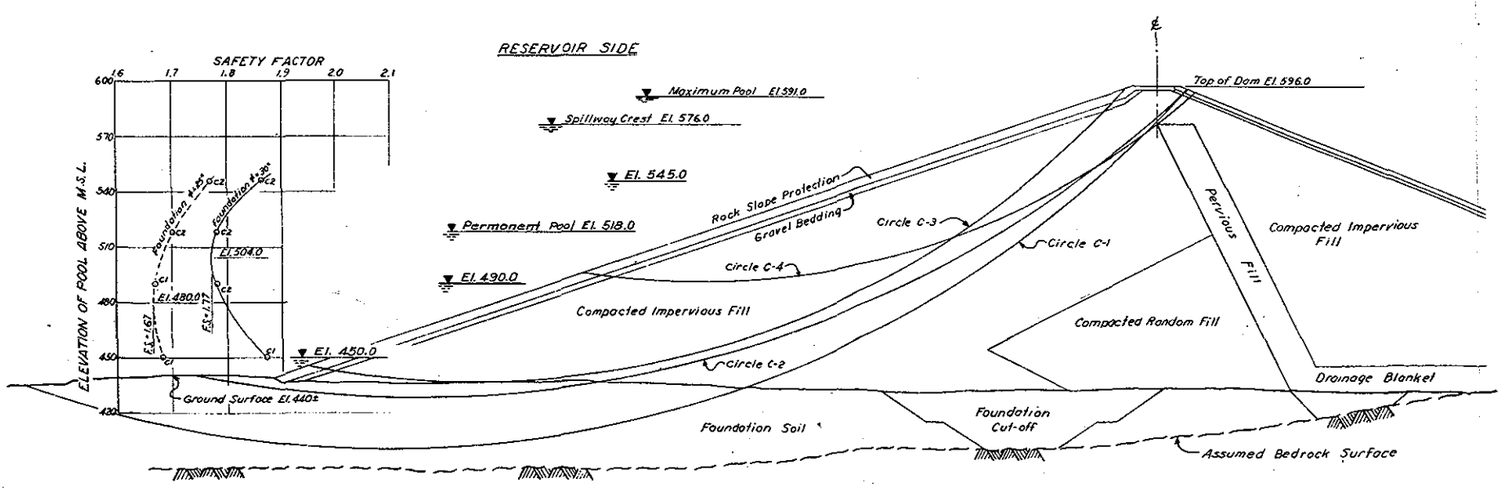
SUMMARY OF STABILITY ANALYSES

CASE	PORE PRESSURE ASSUMPTION	COMPUTED SAFETY FACTOR: UPSTREAM SLOPE, FOUNDATION ϕ = 25° ARC	S.F.	UPSTREAM SLOPE, FOUNDATION ϕ = 30° ARC	S.F.	DOWNSTREAM SLOPE, FOUNDATION ϕ = 25° ARC	S.F.	DOWNSTREAM SLOPE, FOUNDATION ϕ = 30° ARC	S.F.
1. CONSTRUCTION CONDITION									
a. Strength	—							A-1	2.22
								A-2	1.92
								A-3	2.53
a. Sta. 9+50		—	—	—	—	—	—	A-4	3.09
								A-5	2.16
						B-1	1.66	B-1	1.85
b. Sta. 8+70		—	—	—	—	B-2	1.90	B-2	2.03
						B-3	1.96	B-3	2.03
						B-4	1.71	B-4	1.90
						B-5	1.95	B-5	1.88
2. OPERATING CONDITION									
R Strength		C-2	1.77 (El. 545.0)	C-2	1.86 (El. 545.0)				
		C-2	1.70 (El. 518.0)	C-2	1.78 (El. 518.0)	—	—	—	—
a. Partial Pool Analysis	(1)	C-1	1.67 (El. 490.0)	C-2	1.78 (El. 490.0)				
		C-1	1.68 (El. 450.0)	C-1	1.71 (El. 450.0)				
b. Steady Seepage Analysis								D-1	S=1.70, R=1.77 } 1.74
R and S Strengths		—	—	—	—	—	—	D-2	S=1.61, R=1.64 } 1.63
								D-3	S=1.58, R=1.64 } 1.61
1. Sta. 9+50								D-4	S=1.68, R=1.74 } 1.70
								D-5	S=1.58, R=1.63 } 1.61
	—								
						E-1	S=1.58, R=1.57 } 1.58	E-1	S=1.76, R=1.76 } 1.76
						E-2	S=1.71, R=1.74 } 1.73	E-2	S=1.84, R=1.88 } 1.86
2. Sta. 8+70	—	—	—	—	—	E-3	S=1.61, R=1.66 } 1.64	E-3	S=1.68, R=1.73 } 1.71
						E-4	S=1.58, R=1.63 } 1.61	E-4	S=1.59, R=1.65 } 1.62
						E-5	S=1.58, R=1.65 } 1.62	E-5	S=1.61, R=1.69 } 1.65
3. SUDDEN DRAWDOWN									
R Strength		E-1	1.31	E-1	1.51				
		E-2	1.29	E-2	1.37				
		E-3	1.26	E-3	1.42				
a. From Maximum Pool (El. 591.0 to El. 510.0)	(2)	E-4	1.41	E-4	1.41	—	—	—	—
		E-5	1.30	E-5	1.30				
		E-6	1.36	E-6	1.36				
		E-7	1.24	E-7	1.24				
		E-1	1.34	E-1	1.55				
		E-2	1.32	E-2	1.40				
b. From Spillway Crest (El. 576.0 to 510.0)	(2)	E-3	1.30	E-3	1.45	—	—	—	—
		E-4	1.45	E-4	1.45				
		E-5	1.41	E-5	1.41				
		E-6	1.45	E-6	1.45				
		E-7	1.30	E-7	1.30				
		F-1	1.78	F-1	1.78				
c. From Permanent Pool (El. 518.0)	(2)	F-2	1.31	F-2	1.37	—	—	—	—
		F-3	1.25	F-3	1.38				

(1) Submerged weights below pool elevation.
(2) Saturated weights for driving forces and submerged weights for resisting forces.

DESIGN VALUES

MATERIAL	UNIT WEIGHT (P.C.F.) γ_{Sat}	γ_{Moist}	γ_{Dry}	γ_{Sub}	SHEAR STRENGTH CD (S) ϕ	C.T.S.F.	CU (P) ϕ	C.T.S.F.	UU (Q) ϕ	C.T.S.F.
Rock Fill, Rock Slope Protection	140	—	120	76	40°	—	—	—	—	—
Gravel Bedding	147	142	135	85	35°	—	—	—	—	—
Drainage Blanket, Foundation Drain	138	132	120	76	30°	—	—	—	—	—
Random Fill	145	140	130	83	25°	0.0	25°	0.0	25°	0.0
Impervious Fill	145	140	130	83	31.5°	0.0	31°	0.1	21°	1.11
Foundation Soil	145	140	130	83	30,25°	0.0	30,25°	0.0	30,25°	0.0
Pervious Fill	138	132	120	76	30°	0.0	30°	0.0	30°	0.0



OPERATING CONDITION - PARTIAL POOL ANALYSIS - STA. 9+50

SPACE SCALE 30 0 30 60 ft.

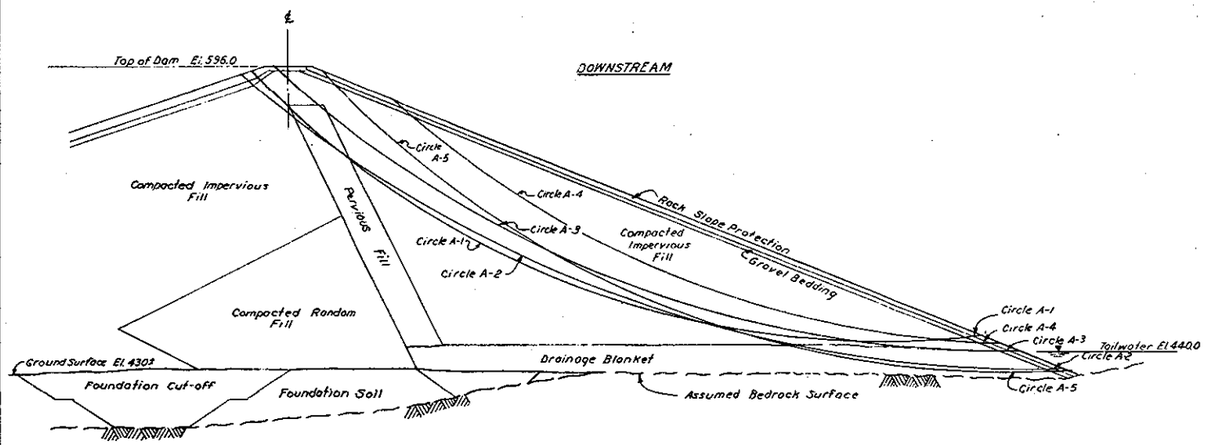
CONNECTICUT RIVER FLOOD CONTROL

LITTLEVILLE DAM

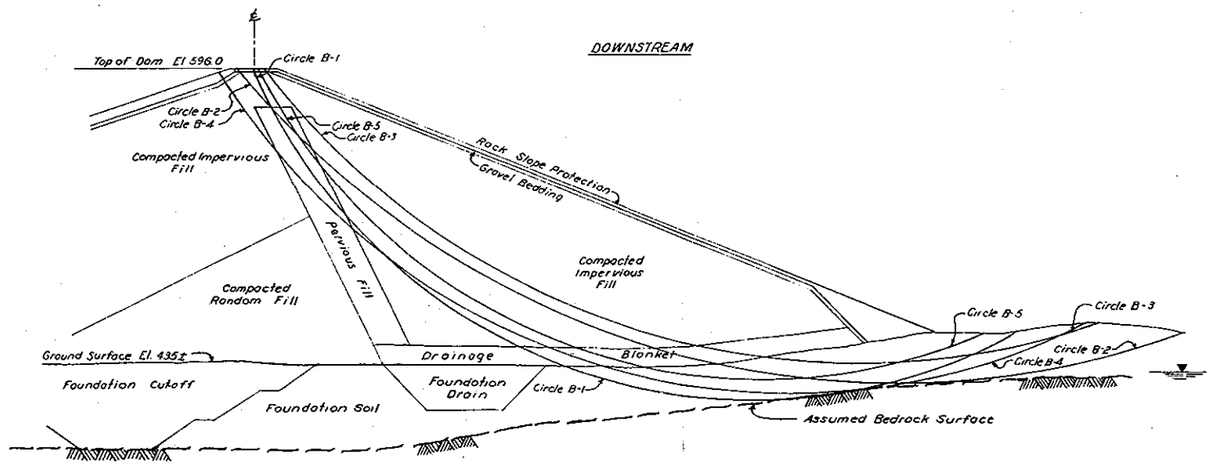
DAM

SUMMARY OF STABILITY ANALYSES

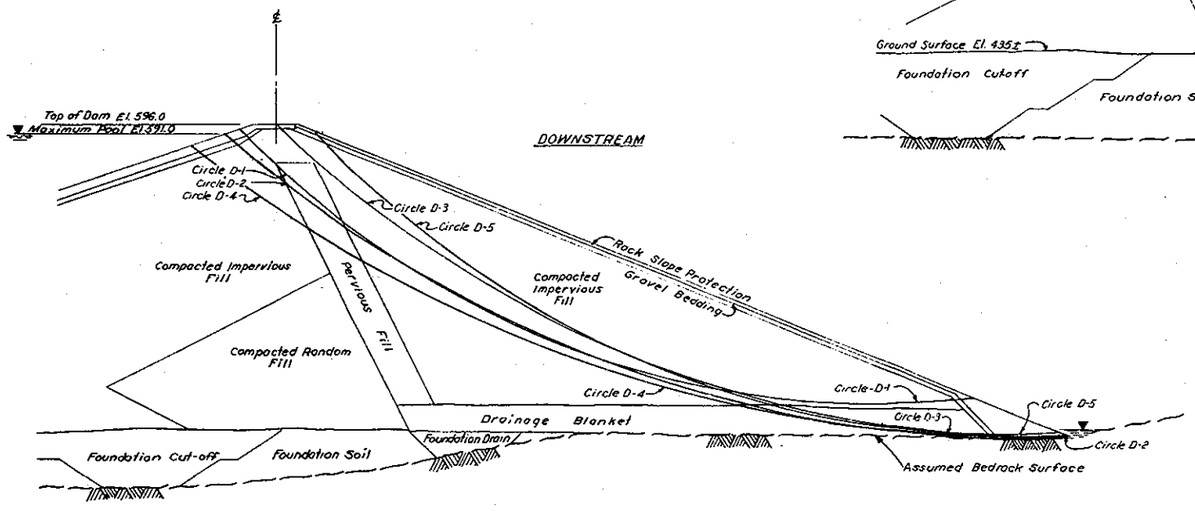
WESTFIELD RIVER-MIDDLE BRANCH MASSACHUSETTS



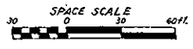
CONSTRUCTION CONDITION ANALYSIS–STA. 9+50



CONSTRUCTION CONDITION ANALYSIS–STA. 8+70



OPERATING CONDITION-STEADY SEEPAGE ANALYSIS–STA. 9+50



CONNECTICUT RIVER FLOOD CONTROL

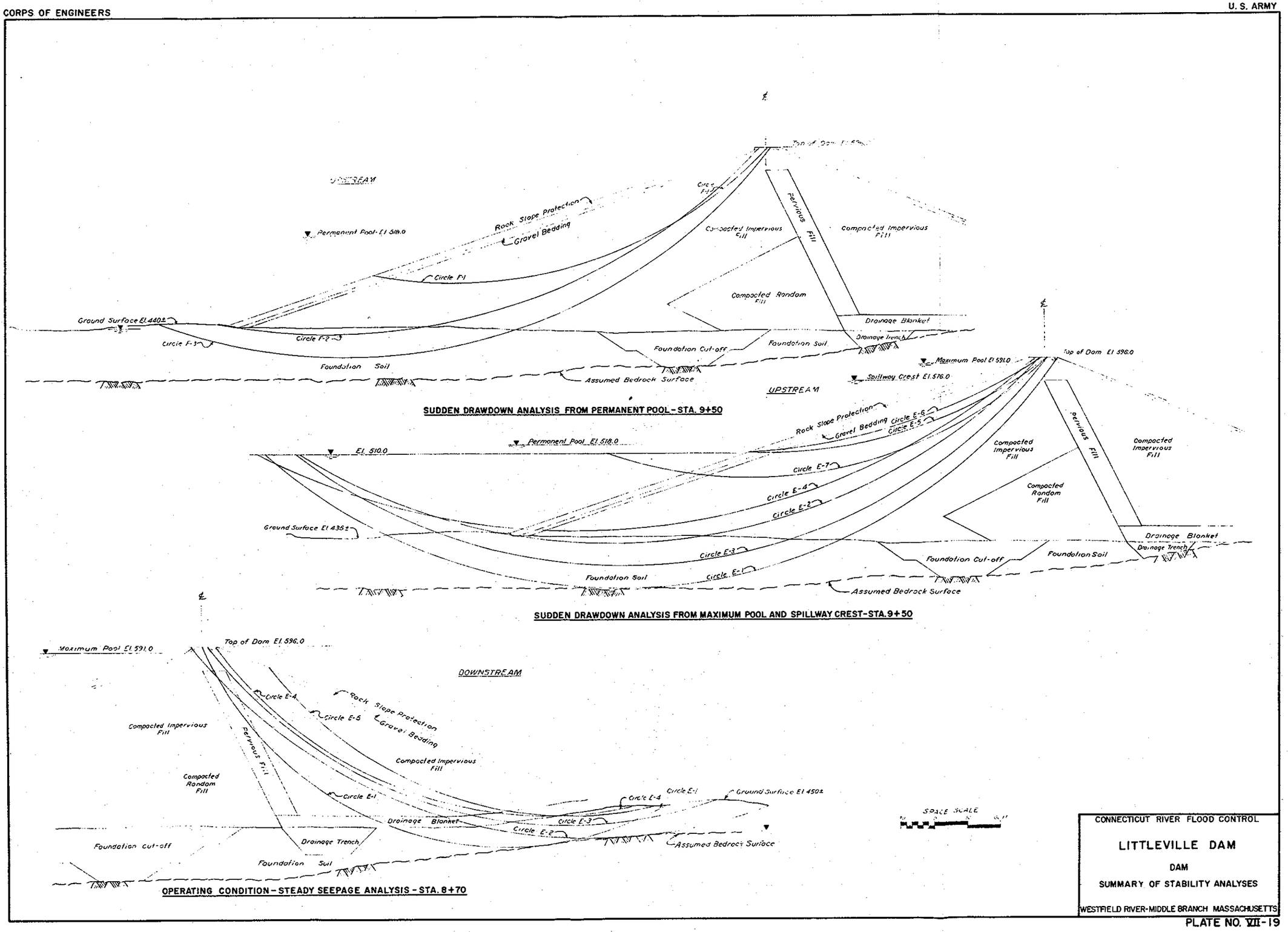
LITTLEVILLE DAM

DAM

SUMMARY OF STABILITY ANALYSES

WESTFIELD RIVER-MIDDLE BRANCH MASSACHUSETTS

PLATE NO. VII-18



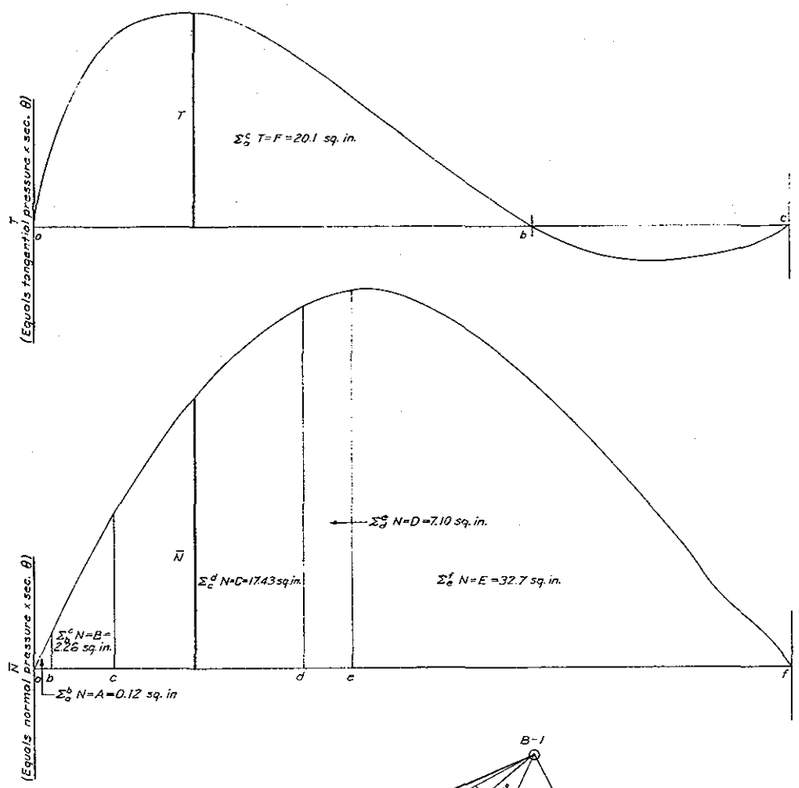
CONNECTICUT RIVER FLOOD CONTROL

LITTLEVILLE DAM

DAM

SUMMARY OF STABILITY ANALYSES

WESTFIELD RIVER-MIDDLE BRANCH MASSACHUSETTS



WEIGHT VECTOR RATIOS 62.5 lbs. = 1.00	
MATERIAL	VECTOR RATIO (V_R)
Rock Slope Protection (Dry)	120 ÷ 62.5 = 1.92
Gravel Bedding and Drainage Blanket (Moist)	142 ÷ 62.5 = 2.27
Pervious Fill (Moist)	132 ÷ 62.5 = 2.11
Compacted Impervious Fill (Moist)	140 ÷ 62.5 = 2.24
Foundation Soil (Sat.)	145 ÷ 62.5 = 2.32
Foundation Soil (Sub.)	82.5 ÷ 62.5 = 1.32

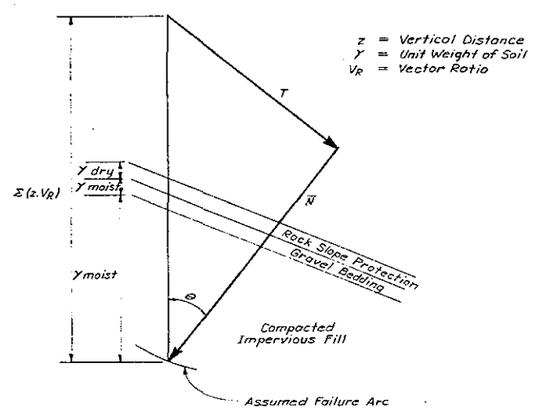
Resisting Force - Summation $\bar{N} \tan \phi + \bar{c}L$
(K = Vector Scale Conversion Factor)

$\int_a^f \bar{N} \tan \phi = [(A+C) \tan 21° + (B+D) \tan 30° + E \tan 30°]K$
$= [(0.12 + 17.43)(0.384) + (2.26 + 7.10)(0.577) + (32.7)(0.577)]\,56.2 = 1,745$ kips

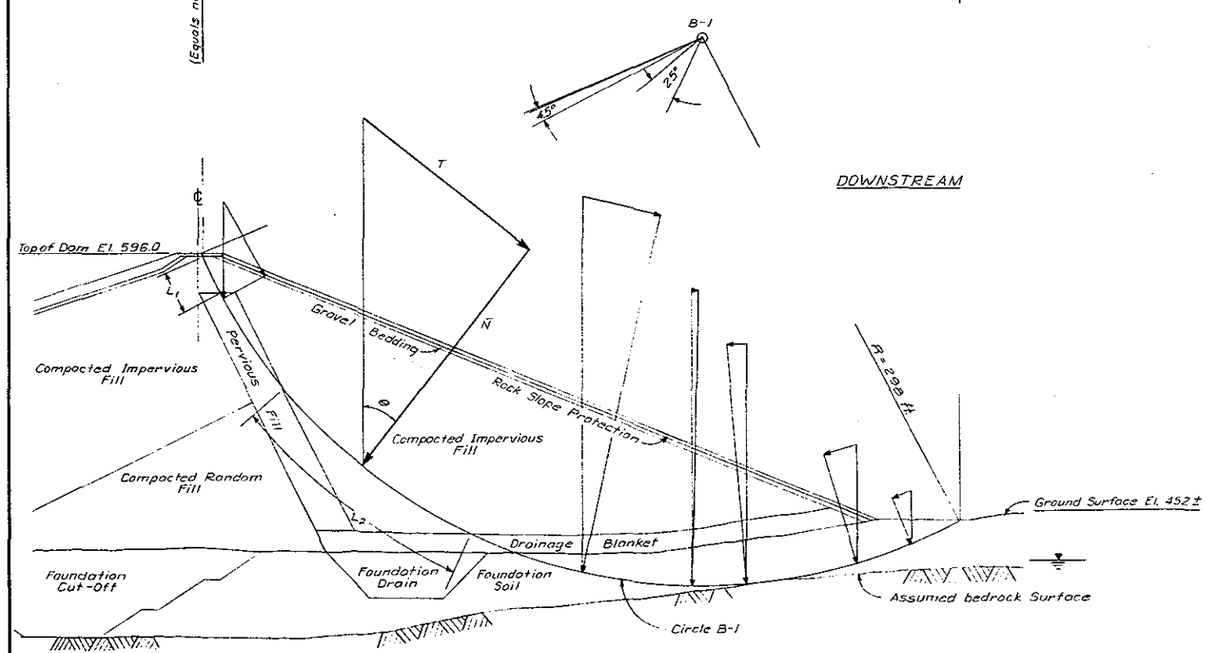
$\bar{c}L = (2.2)(153.5) = 338$ Kips
Total Resisting Force / ft. dam = 2,083 kips

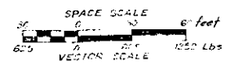
Driving Force - Summation tangential forces
$\int_a^f T = (F)K = (20.1)(56.2) = 1,129$ kips

Factor of Safety
$\frac{\text{Resisting Force}}{\text{Driving Force}} = \frac{2083}{1129} = 1.84$



TYPICAL VECTOR DIAGRAM





CONNECTICUT RIVER FLOOD CONTROL

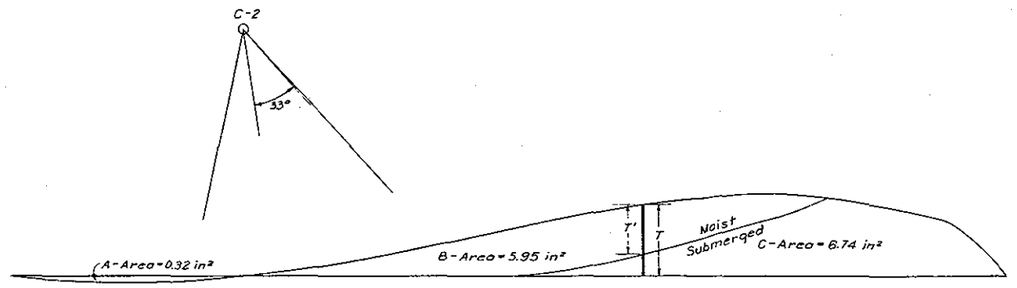
LITTLEVILLE DAM

DAM

TYPICAL STABILITY ANALYSIS
CONSTRUCTION CONDITION—CIRCLE B-1

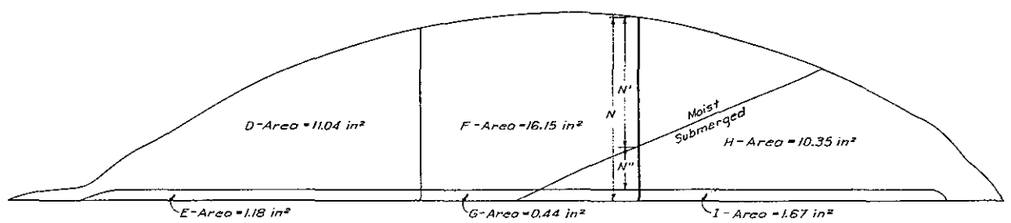
WESTFIELD RIVER-MIDDLE BRANCH MASSACHUSETTS

PLATE NO. VII-20



TANGENTIAL FORCE DIAGRAM

HORIZONTAL SCALE 30 0 30 60 ft
20 0 20 40 ft VERTICAL SCALE



NORMAL FORCE DIAGRAM

HORIZONTAL SCALE 30 0 30 60 ft
20 0 20 40 ft. VERTICAL SCALE

Submerged Impervious / Submerged Foundation $\Big\} = K_1 = \frac{83 \text{ lbs.} \times 30 \text{ ft} \times 20 \text{ ft} \times 1 \text{ ton}}{\text{ft}^3 \quad 2000 \text{ lbs.}} = \underline{24.9 \text{ tons}}$

Submerged Rock $= K_2 = \frac{76 \times 30 \times 20}{2000} = \underline{22.8 \text{ tons}}$

Moist Foundation / Moist Impervious $\Big\} = K_3 = \frac{140 \times 30 \times 20}{2000} = \underline{42.0 \text{ tons}}$

Dry Rock $= K_4 = \frac{120 \times 30 \times 20}{2000} = \underline{36.0 \text{ tons}}$

RESISTING FORCES

$\Sigma N (\text{Tan } \phi) k = (Dk_1 + Ek_2) \tan 30° + (Fk_1 + Gk_2 + Hk_3 + Ik_4) \tan 31°$

$= [(11.04)(24.9) + (1.18)(22.8)](0.577) + [(16.15)(24.9) + (0.44)(22.8) + (10.35)(42.0) + (1.67)(36.0)](0.60) =$

$(300)(.577) + (907)(.600) =$

$173.1 + 545 = \underline{718 \text{ tons}}$

Cohesion

$L = \frac{\pi r \theta}{180°} = \frac{\pi\, 620 \times 33°}{180°} = \underline{357}$

$cL = 357 \times 0.1 = \underline{36 \text{ tons}}$

Total Resisting Force = $\underline{754 \text{ tons}}$

DRIVING FORCES

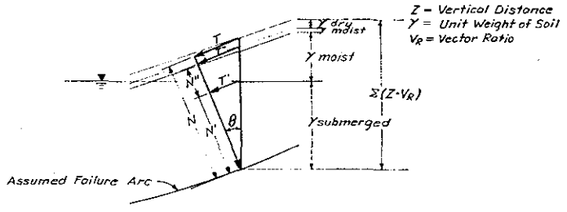
$(\Sigma T)(K) = (Bk_1 + Ck_2) - Ak_1$

$[(5.95)(24.9) + (6.74)(42.0)] - 0.32\,(24.9) =$

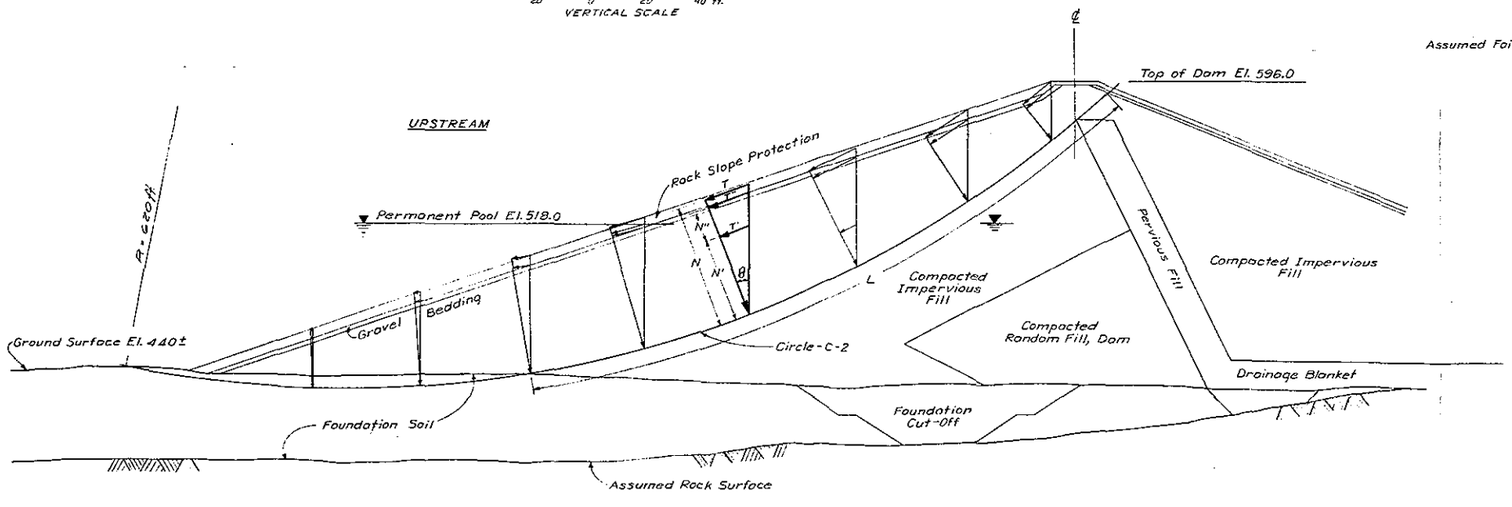
$(148 + 283) - 8 = \underline{423 \text{ tons}}$

SAFETY FACTOR

$SF = \frac{\text{Resisting Force}}{\text{Driving Force}} = \frac{754}{423} = \underline{1.78}$



TYPICAL VECTOR DIAGRAM



SPACE SCALE 30 0 30 60 feet

CONNECTICUT RIVER FLOOD CONTROL

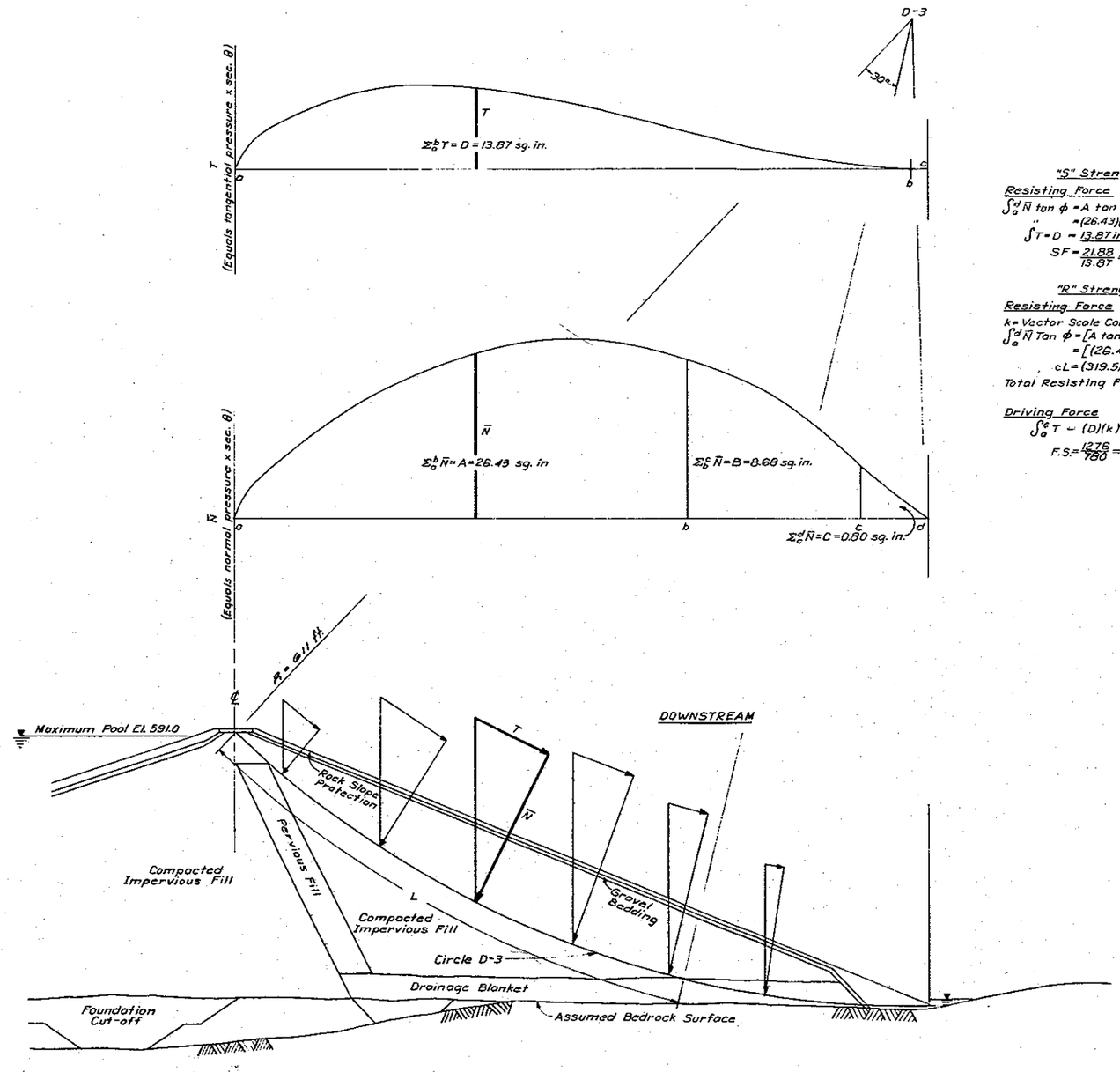
LITTLEVILLE DAM

DAM

TYPICAL STABILITY ANALYSIS
PARTIAL POOL – CIRCLE C-2

WESTFIELD RIVER-MIDDLE BRANCH MASSACHUSETTS

WEIGHT VECTOR RATIOS 62.5 lbs = 1.00	
MATERIALS	VECTOR RATIO (V_R)
Rock Slope Protection (Dry)	120 ÷ 62.5 = 1.92
Rock Slope Protection (Sat)	140 ÷ 62.5 = 2.24
Gravel Bedding Drain Blanket (Moist)	142 ÷ 62.5 = 2.27
Gravel Bedding Drain Blanket (Sat)	145 ÷ 62.5 = 2.32
Impervious Fill (Moist)	140 ÷ 62.5 = 2.24
Pervious Fill (Moist)	132 ÷ 62.5 = 2.11



"S" Strength

Resisting Force

$\int_a^d \bar{N} \tan\phi = A \tan 31.5° + B \tan 30° + C \tan 40°$

$= (26.43)(0.613) + (8.68)(0.577) + (0.80)(0.839) = \underline{21.88 \text{ in.}^2}$

$\int T = D = \underline{13.87 \text{ in}^2}$

$SF = \frac{21.88}{13.87} = \underline{1.58}$

"R" Strength

Resisting Force

k = Vector Scale Conversion Factor

$\int_a^d \bar{N} \tan\phi = [A \tan 31° + B \tan 30° + C \tan 40°]k$

$= [(26.43)(0.601) + (8.68)(0.577) + (0.80)(0.839)]56.25 = \underline{1,212 \text{ kips}}$

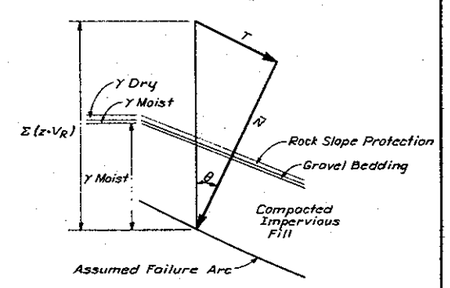
$cL = (319.5)(0.2) = \underline{63.9 \text{ kips}}$

Total Resisting Force / ft. dam = $\underline{1276 \text{ kips}}$

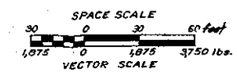
Driving Force

$\int_a^c T = (D)(k) = (13.87)(56.25) = \underline{780 \text{ kips}}$

$F.S. = \frac{1276}{780} = \underline{1.64}$



TYPICAL VECTOR DIAGRAM



CONNECTICUT RIVER FLOOD CONTROL

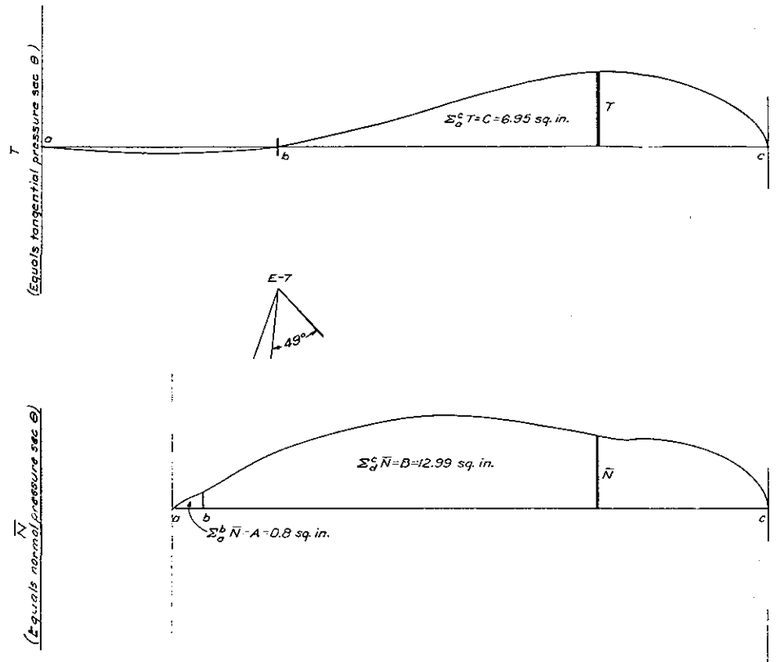
LITTLEVILLE DAM

DAM

TYPICAL STABILITY ANALYSIS
STEADY SEEPAGE CONDITION
CIRCLE D-3

WESTFIELD RIVER-MIDDLE BRANCH, MASSACHUSETTS

WEIGHT VECTOR RATIO 62.5 lbs. = 1.00	
MATERIAL	VECTOR RATIO (V_R)
Rock Slope Protection (Sat)	140 ÷ 62.5 = 2.24
Rock Slope Protection (Dry)	120 ÷ 62.5 = 1.92
Gravel Bedding (Sat)	147 ÷ 62.5 = 2.36
Gravel Bedding (Moist)	142 ÷ 62.5 = 2.28
Impervious Fill (Sat)	145 ÷ 62.5 = 2.32
Water	62.5 ÷ 62.5 = 1.00



Resisting Force — Summation $\int \bar{N} \tan \phi + \bar{c}L$

k = Vector Scale Conversion Factor

$\int_a^c \bar{N} \tan \phi = [A \tan 35° + B \tan 31°]\, k$

$= [(0.80)(0.70) + (12.99)(0.601)]\, 56.25 = \underline{442 \text{ kips}}$

$\bar{c}L = (333)(0.2) = \underline{67 \text{ kips}}$

Total Resisting Force/ft. dam = $\underline{\underline{509 \text{ kips}}}$

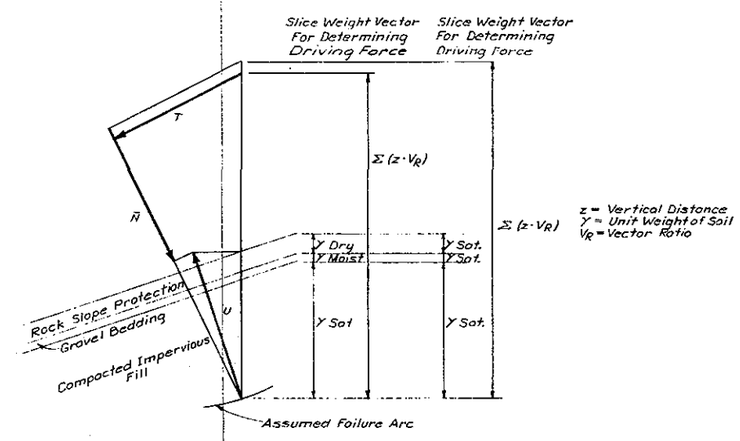
Driving Force - Summation Tangential Forces

$\int_a^c T = (C)\, k$

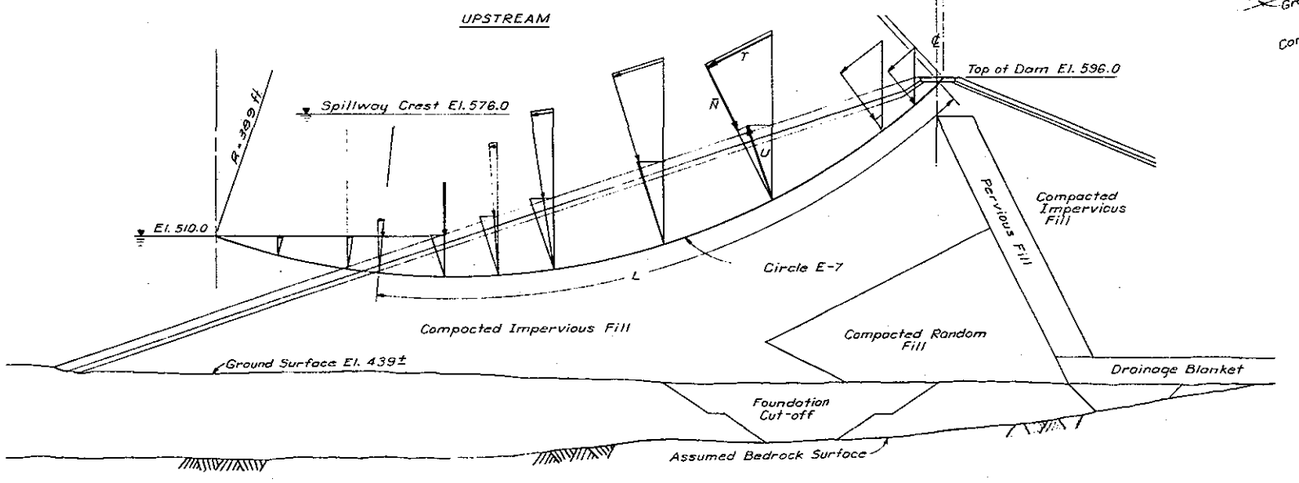
$= (6.95)(56.25) = \underline{\underline{391 \text{ kips}}}$

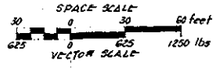
Factor of Safety

$$\frac{\int \bar{N} \tan \phi + \bar{c}L}{\int T} = \frac{509}{391} = \underline{\underline{1.30}}$$



TYPICAL VECTOR DIAGRAM





CONNECTICUT RIVER FLOOD CONTROL

LITTLEVILLE DAM

DAM

TYPICAL STABILITY ANALYSIS
SUDDEN DRAWDOWN FROM SPILLWAY CREST
CIRCLE E-7

WESTFIELD RIVER-MIDDLE BRANCH MASSACHUSETTS

PLATE NO. VII-23

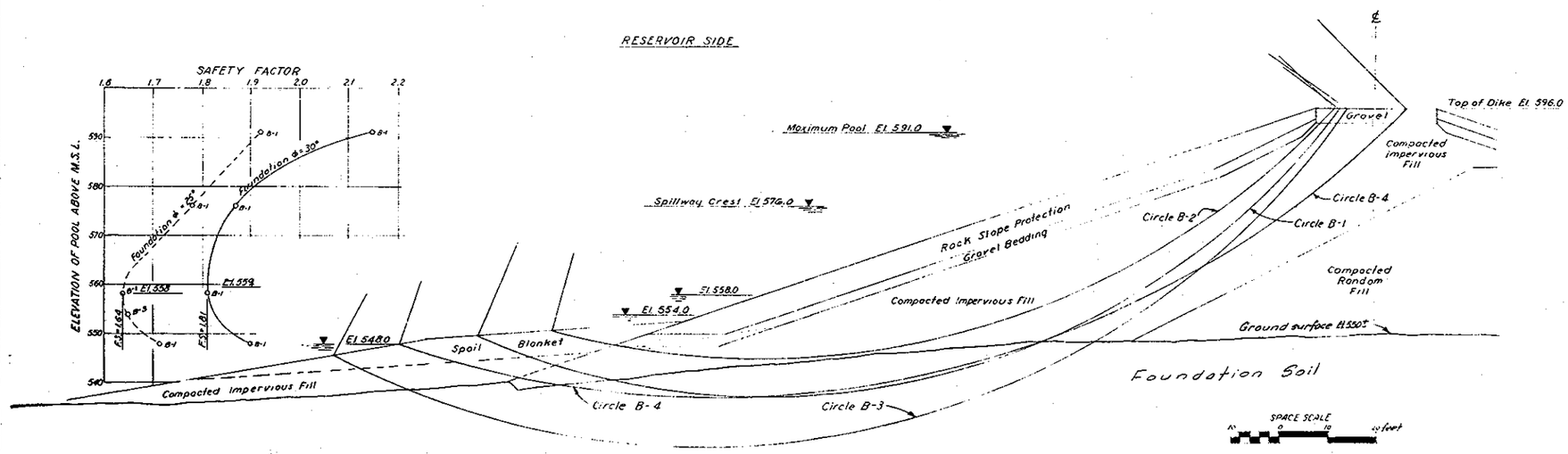
SUMMARY OF STABILITY ANALYSES

MATERIAL	PORE PRESSURE ASSUMPTION	COMPUTED SAFETY FACTOR							
		UPSTREAM SLOPE				DOWNSTREAM SLOPE			
		FOUNDATION φ=25°		FOUNDATION φ=30°		FOUNDATION φ=25°		FOUNDATION φ=30°	
		ARC	S.F.	ARC	S.F.	ARC	S.F.	ARC	S.F.
1. CONSTRUCTION CONDITION UU(Q) Strength	—	—	—	—	—	A-1	2.01	A-1	2.14
						A-2	1.83	A-2	2.13
						A-3	1.96	A-3	2.08
						A-4	1.97	A-4	2.05
2. OPERATING CONDION Partial Pool Analysis CU(R) Strength	(1)	B-1	1.92(El.591.0)	B-1	2.15(El.594.0)	—	—	—	—
		B-1	1.78(El.576.0)	B-1	1.87(El.576.0)				
		B-1	1.64(El.558.0)	B-1	1.81(El.558.0)				
		B-3	1.65(El.554.0)						
		B-1	1.72(El.548.0)	B-1	1.90(El.548.0)				
3 RAPID DRAWDOWN CU(R) Strength a. From Maximum Pool El. 591.0	(2)	C-1	1.41	C-1	1.41	—	—	—	—
		C-2	1.13	C-2	1.29				
		C-3	1.20	C-3	1.42				
		C-4	1.11	C-4	1.24				
b. From Spillway Crest El. 576.0	(2)	C-1	1.60	C-1	1.60	—	—	—	—
		C-2	1.27	C-2	1.44				
		C-3	1.33	C-3	1.56				
		C-4	1.27	C-4	1.40				

(1) Submerged weights below pool elevation.
(2) Saturated weights for driving forces and submerged weights for resisting forces.

DESIGN VALUES

MATERIAL	UNIT WEIGHT (PCF)				SHEAR STRENGTH					
					CD (3)		CU(R)		UU (Q)	
	γ sat	γ moist	γ dry	γ sub	φ	C.T.S.F.	φ	C.T.S.F.	φ	C.T.S.F.
Rock Fill, Rock Slope Protection	140	–	120	76	40°	–	–	–	–	–
Gravel Bedding, Filter Gravel	147	142	135	85	35°	–	–	–	–	–
Drainage Blanket, Foundation Drain	138	132	120	76	30°	–	–	–	–	–
Random Fill	145	140	130	83	25°	0.0	25°	0.0	25°	0.0
Impervious Fill	145	140	130	83	31.5°	0.0	31°	0.10	21°	1.11
Foundation Soil	145	140	130	83	30/25°	0.0	30/25°	0.0	30/25°	0.0
Spoil Blanket	100	–	–	37	0.0	0.0	0.0	0.0	0.0	0.0



OPERATING CONDITION - PARTIAL POOL ANALYSIS - STA. 25+00

CONNECTICUT RIVER FLOOD CONTROL

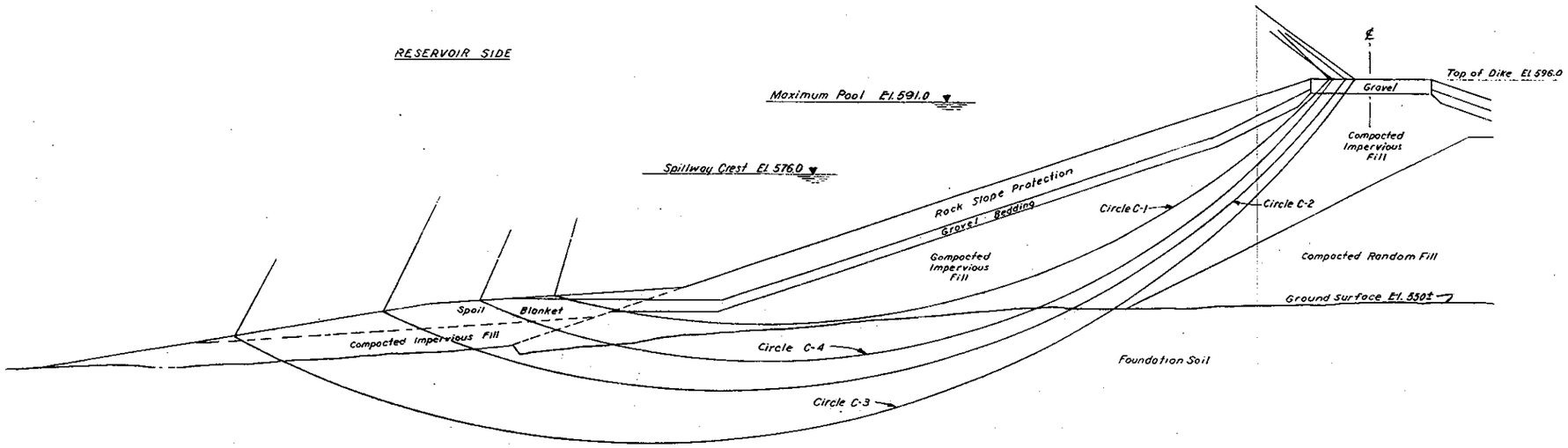
LITTLEVILLE DAM

DIKE

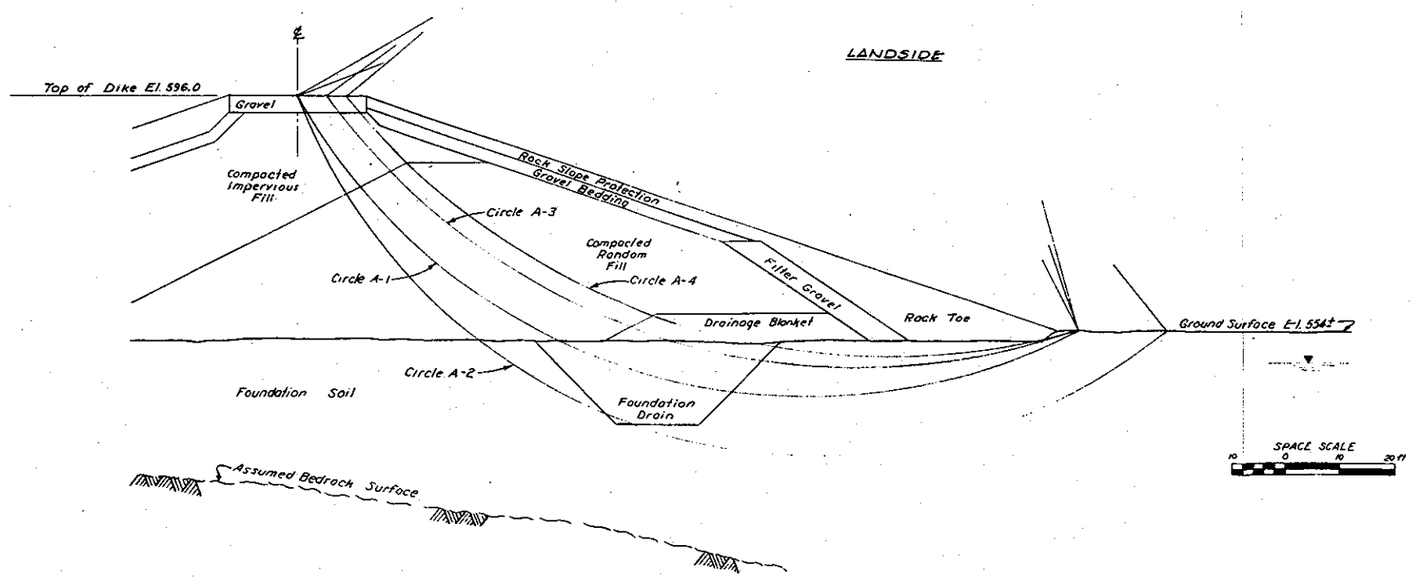
SUMMARY OF STABILITY ANALYSES

WESTFIELD RIVER-MIDDLE BRANCH MASSACHUSETTS

PLATE NO. VII-24



SUDDEN DRAWDOWN ANALYSIS - STA. 25+00



CONSTRUCTION CONDITION ANALYSIS - STA. 23+65

CONNECTICUT RIVER FLOOD CONTROL

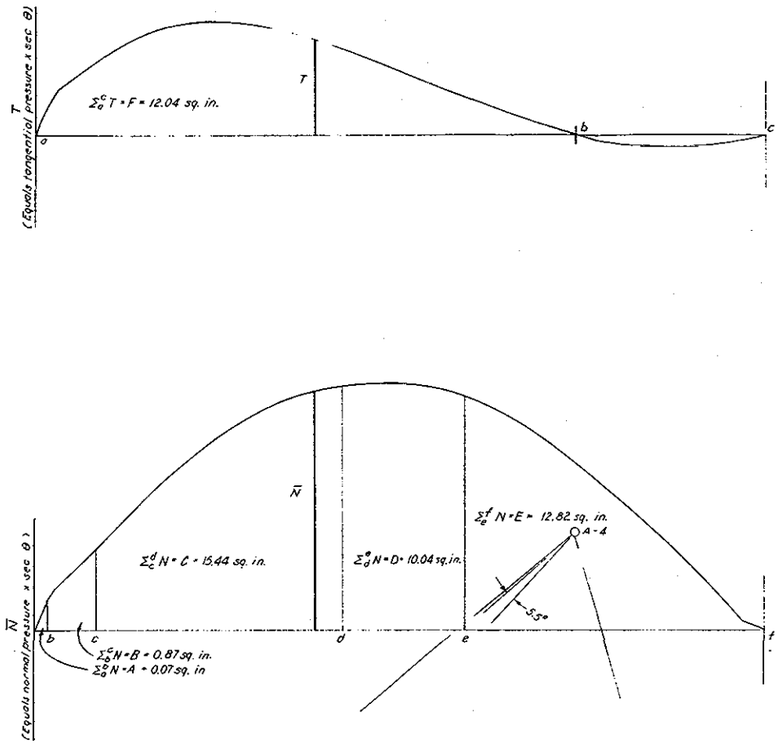
LITTLEVILLE DAM

DIKE

SUMMARY OF STABILITY ANALYSES

WESTFIELD RIVER-MIDDLE BRANCH MASSACHUSETTS

WEIGHT VECTOR RATIOS 625 LBS = 1.00		
MATERIAL		VECTOR RATIO (V_R)
Rock Fill and Rock Slope Protection	(Dry)	120 ÷ 625 = 1.92
Gravel Bedding, Filter Gravel	(Moist)	142 ÷ 625 = 2.27
Random Impervious Fill	(Moist)	140 ÷ 625 = 2.24
Foundation Soil	(Moist)	140 ÷ 625 = 2.24
Foundation Soil	(Sub)	83 ÷ 625 = 1.33
Found. Drain, Drainage Blanket	(Moist)	132 ÷ 625 = 2.11
Found. Drain, Drainage Blanket	(Sub)	76 ÷ 625 = 1.22



k = Vector Scale Conversion Factor

Resisting Force – Summation $N \tan\phi + \hat{c}L$

$\int_a^f N \tan\phi = [(A+D+E)\tan 30° + B \tan 21° + C \tan 25°]k$

$= [(0.07 + 10.04 + 12.82)(0.577) + (0.87)(0.3841) + (15.44)(0.466)]6.25 = 129.7$ Kips

$\hat{c}L = (12.3)(2.2) = 27.0$ Kips

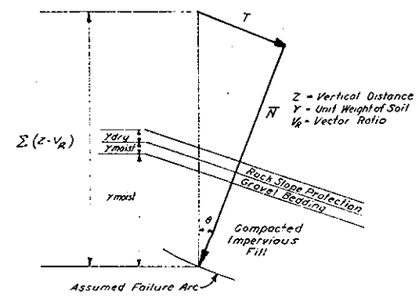
Total Resisting Force/ft. dike 157 Kips

Driving Force - Summation tangential forces

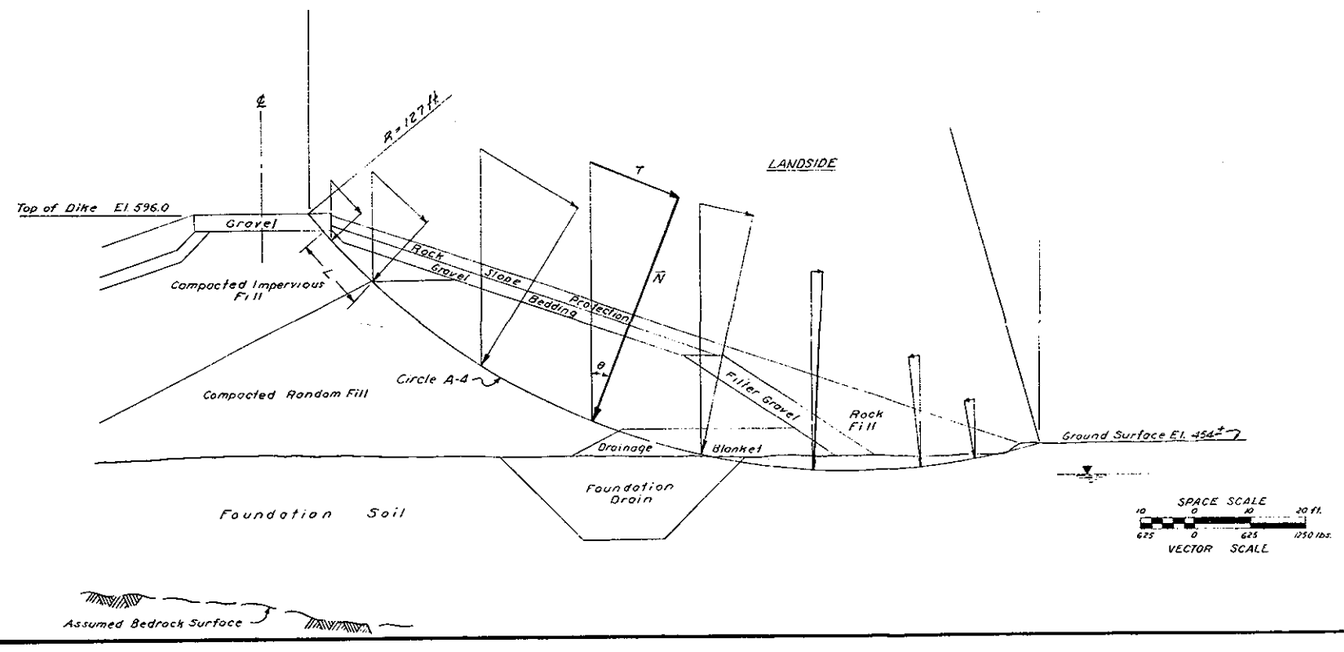
$\int_a^c T = (F)k = (12.04)(6.25) = 75.4$ Kips

FACTOR OF SAFETY

$\frac{\int N \tan\phi + \hat{c}L}{\int T} = \frac{157}{75.4} = 2.05$



TYPICAL VECTOR DIAGRAM



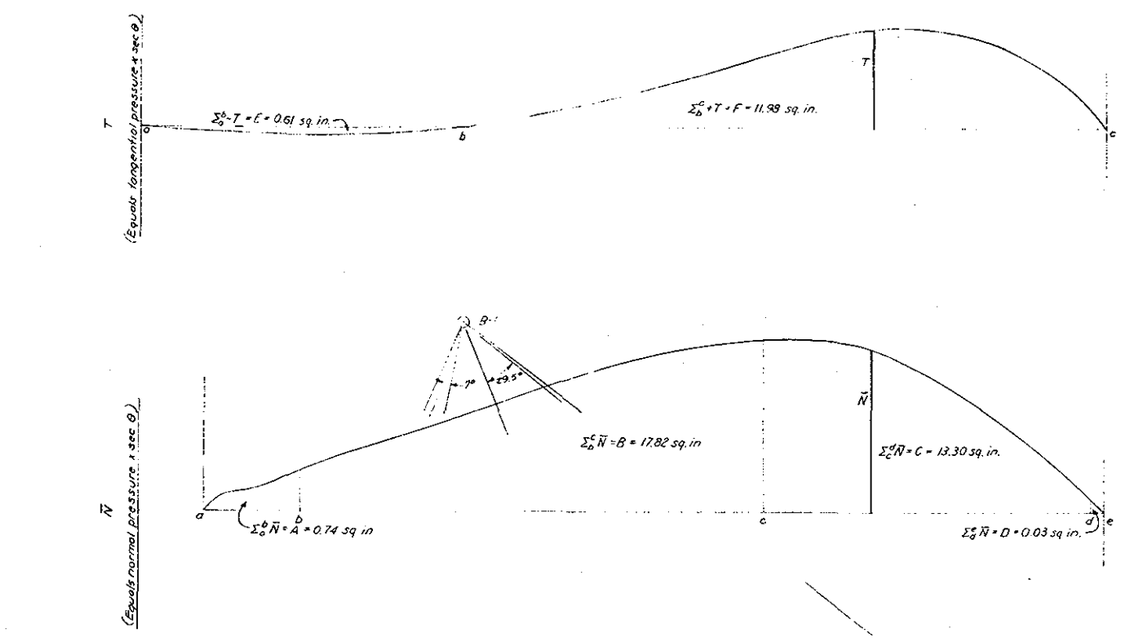
CONNECTICUT RIVER FLOOD CONTROL

LITTLEVILLE DAM

DIKE

TYPICAL STABILITY ANALYSIS
CONSTRUCTION CONDITION
CIRCLE A-4

WESTFIELD RIVER-MIDDLE BRANCH, MASSACHUSETTS



Resisting Force = Summation $\bar{N}$ tan φ + cL

k = Vector scale conversion factor

$\int_a^e \bar{N} \tan\phi = k[(A+C)\tan 31° + B \tan 30° + D \tan 35°]k$

$= k[(0.74+13.30)(0.60) + (17.82)(0.577) + (0.03)(0.700)]10$

$= 187.2$ kips

$cL = (0.2)(93.51) = 18.7$ kips

Resisting Force/ft. Dike = 187.2 + 18.7

= 205.9 kips

Driving Forces = Summation tangential forces

$\int_a^e T = (F-E)k = (11.98-0.61)10$

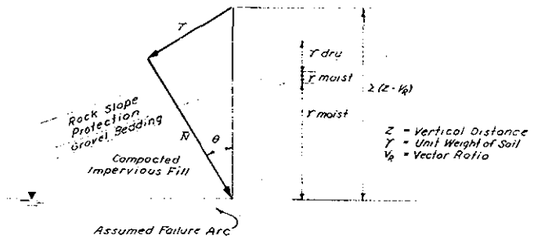
= 113.7 kips

Total Driving Force/ft. Dike = 113.7 kips

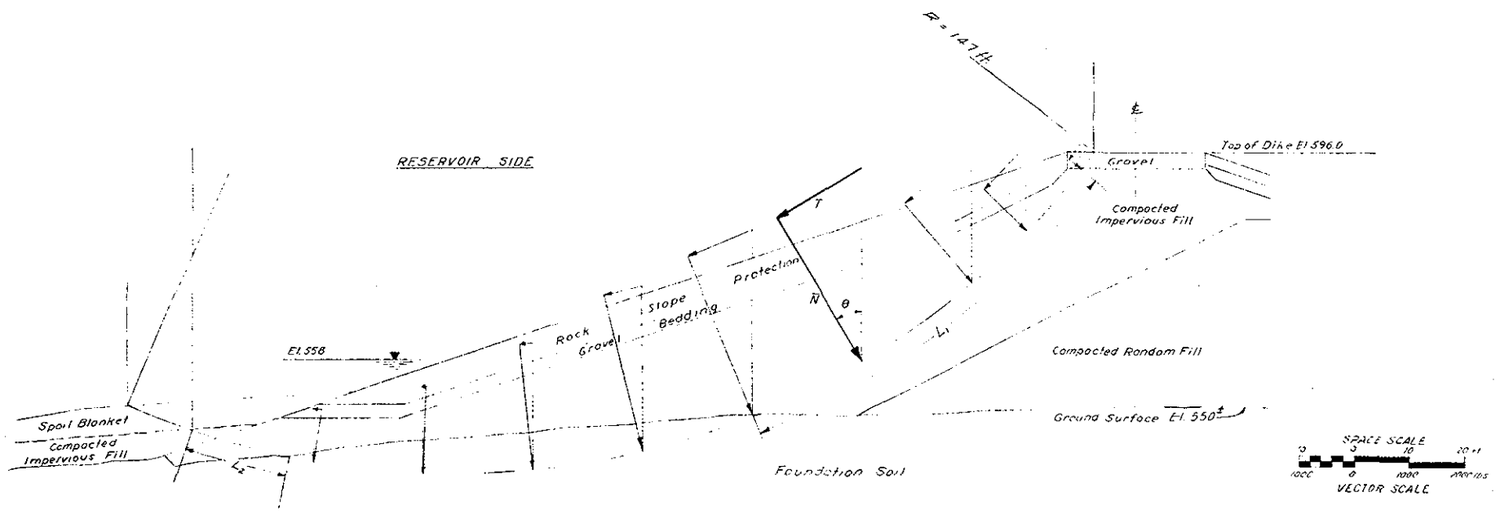
Factor of Safety

$FS = \frac{\text{Resisting force}}{\text{Driving force}} = \frac{205.9}{113.7} = 1.81$

WEIGHT VECTOR RATIOS 100 lbs = 1.00					
MATERIAL		VECTOR RATIO (V_R)			
Rock Slope Protection	(Dry)	120	÷	100	= 1.20
Rock Slope Protection	(Sub)	76	÷	100	= 0.76
Gravel Bedding	(Moist)	142	÷	100	= 1.42
Gravel Bedding	(Sub)	85	÷	100	= 0.85
Impervious Fill	(Moist)	140	÷	100	= 1.40
Impervious Fill	(Sub)	83	÷	100	= 0.83
Foundation Soil	(Sub)	83	÷	100	= 0.83



TYPICAL VECTOR DIAGRAM



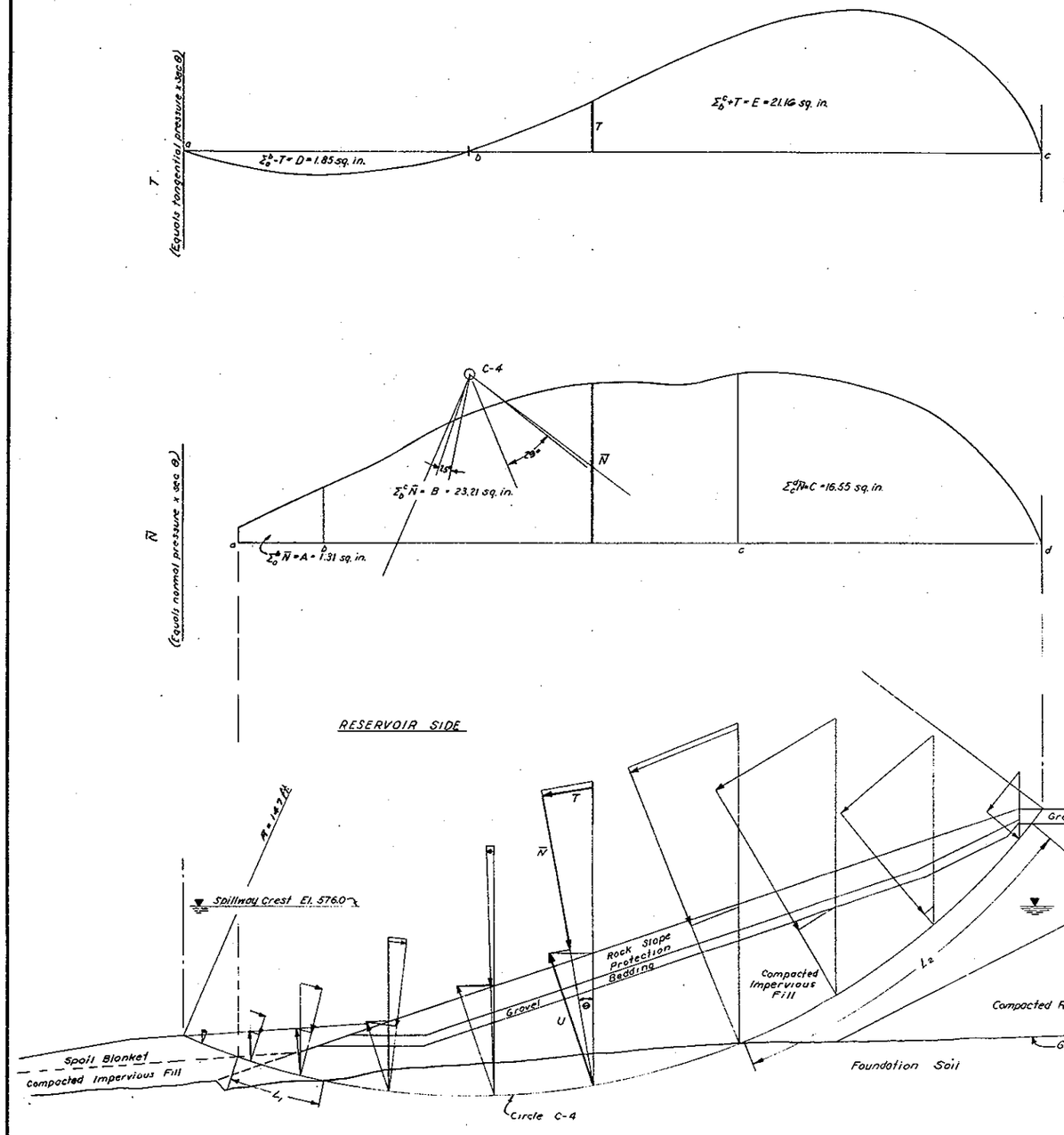
CONNECTICUT RIVER FLOOD CONTROL

LITTLEVILLE DAM

DIKE

TYPICAL STABILITY ANALYSIS
PARTIAL POOL-CIRCLE B-1

WESTFIELD RIVER-MIDDLE BRANCH MASSACHUSETTS



Resisting Force = Summation $\bar{N}$ tan φ + $\bar{c}L$
k = Vector Scale Conversion Factor = 6.25

$\int_a^d \bar{N} \tan\phi = [(A+C)\tan 31° + B \tan 30°]k$

" $= [(1.31+16.55)(0.600)+(23.21)(0.577)]6.25 = \underline{151 \text{ kips}}$

$\bar{c}L = (0.2)(23.8)$ $= \underline{18.8 \text{ kips}}$

Total Resisting Force/Ft. Dike. $= \underline{169.8 \text{ kips}}$

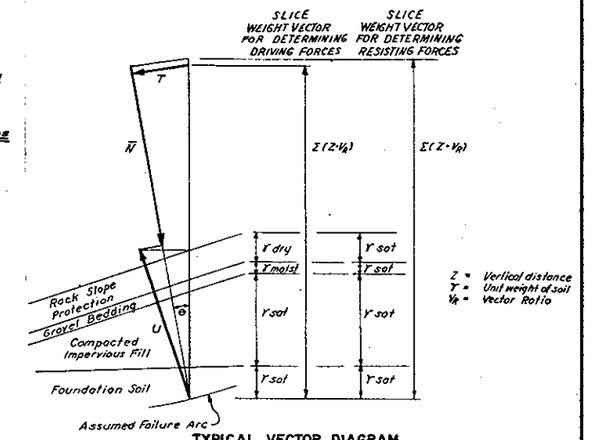
Driving Force = Summation tangential forces

$\int_b^c T = (E-D)k = (21.16-1.85)(6.25)$ $= \underline{120.8 \text{ kips}}$

Factor of Safety

$\frac{\text{Resisting Force}}{\text{Driving Force}} = \frac{169.8}{120.8} = \underline{1.40}$

WEIGHT VECTOR RATIOS 625 lbs. = 1.00						
MATERIAL		VECTOR RATIO (γ/γ₀)				
Rock Slope Protection	(Sat)	140	÷	62.5	=	2.24
Rock Slope Protection	(Dry)	120	÷	62.5	=	1.92
Gravel Bedding	(Sat)	147	÷	62.5	=	2.35
Gravel Bedding	(Moist)	142	÷	62.5	=	2.27
Impervious, Random Fills and Foundation Soils	(Sat)	145	÷	62.5	=	2.32
	(Moist)	140	÷	62.5	=	2.24
Spoil Blanket	(Sat)	100	÷	62.5	=	1.60



TYPICAL VECTOR DIAGRAM

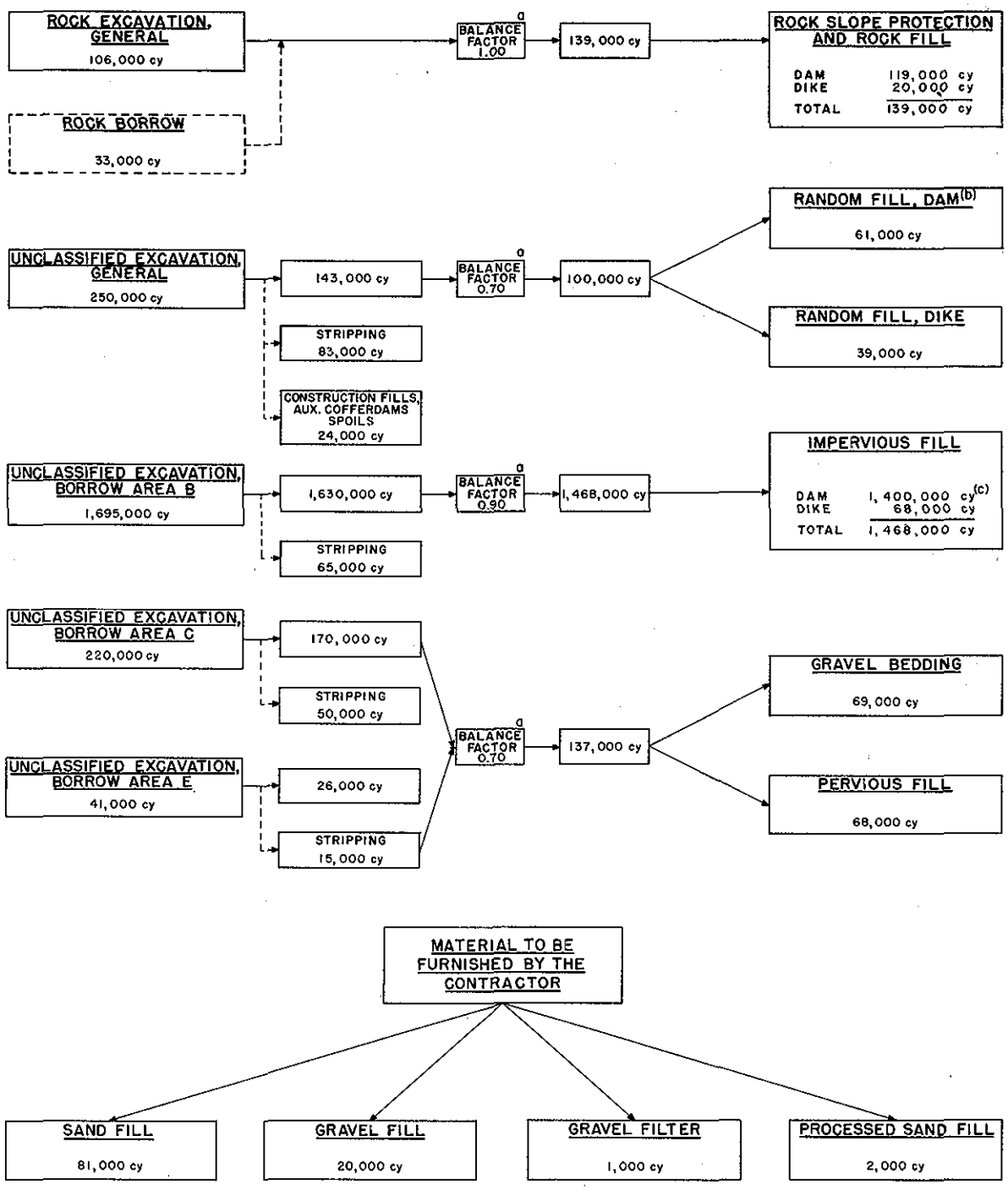
SPACE SCALE
10 0 10 20 ft.
625 0 625 1,250 lbs
VECTOR SCALE

CONNECTICUT RIVER FLOOD CONTROL

LITTLEVILLE DAM

DIKE

TYPICAL STABILITY ANALYSIS
SUDDEN DRAWDOWN FROM SPILLWAY CREST
CIRCLE C-4
WESTFIELD RIVER-MIDDLE BRANCH MASSACHUSETTS



NOTES

(a) *Balance Factor represents effects of shrinkage, waste, oversize stones, etc.*

(b) *Adjustable quantity*

(c) *Variable quantity depending on quantity of Random Fill, Dam*

All quantities subject to change pending more detailed estimates and studies

CONNECTICUT RIVER FLOOD CONTROL

LITTLEVILLE DAM

MATERIAL USAGE CHART
(PRELIMINARY)

WESTFIELD RIVER - MIDDLE BRANCH MASSACHUSETTS

APPENDIX A

SUMMARY OF LABORATORY TEST RESULTS

LITTLEVILLE DAM & RESERVOIR

TEST DATA SUMMARY

EXPL. NO.	TOP ELEV. FT.	SAMPLE NO.	DEPTH FT.	SOIL SYMBOL	MECHANICAL ANALYSIS				ATT. LIMITS		SPECIFIC GRAVITY	NAT. WATER CONTENT % DRY WT		COMPACTION DATA			NAT. DRY DENSITY LBS/CUFT		OTHER TESTS		
														STND. AASHO		*					
					GRAVEL %	SAND %	FINES %	D_{10} mm.	PL	LL		TOTAL	-NO4	OPT. WATER % DRY WT	MAX. DRY DENS. LBS/CU FT	PVD LBS/CU FT	TOTAL	-NO4	SHEAR	CONSOL	PERM.
FD-1	553.2	J-3	5.0- 8.9	SM	39	45	16														
		J-5	10.0-10.8	SM	1	58	41	0.015													
		J-7	15.0-20.0	SM	20	55	25	0.024													
		J-9	25.0-26.0	ML	1	40	59	0.017													
		J-12	30.0-32.7	SP-SM	3	86	11	0.072													
		J-13	32.7-35.0	SM	13	50	37	0.02													
		J-15	37.0-38.7	SM	3	49	48	0.011													
FD-2	503.5	J-2	2.2- 5.0	SM	20	48	32	0.018													
		J-4	10.0-11.6	SM	34	37	29	0.014													
FD-3	534.0	J-1	0.5- 5.0	SM	18	43	39	0.015													
		J-3	8.0- 9.5	SM	11	48	41	0.014													
FD-4	536.0	J-2	3.0- 5.0	SM	22	40	38	0.031													
		J-4	7.0- 8.6	SM	2	56	42	0.026													
FD-5	439.6	J-2	1.0- 5.0	SP-SM	0	88	12	0.07													
		J-7	30.0-33.1	SM	22	42	36	0.007													
		J-9	40.0-42.2	SM	21	42	37	0.0085													
FD-6	501.3	J-3	5.0-10.0	SM	32	52	16	0.043													
		J-5	15.0-19.0	GM	46	40	14	-													
		J-8	25.0-30.0	ML	6	38	56	0.015													
		J-11	35.0-40.0	ML	4	43	53	0.0038													
		J-14	50.0-54.7	ML	7	41	52	0.0026													
		J-17	70.0-72.8	SM	5	48	47	0.0052													
		J-19	85.0-89.8	SM	9	59	32	0.0098													

* PROVIDENCE VIBRATED DENSITY TEST.

LITTLEVILLE DAM

TEST DATA SUMMARY

EXPL. NO.	TOP ELEV. FT.	SAMPLE NO.	DEPTH FT.	SOIL SYMBOL	MECHANICAL ANALYSIS GRAVEL %	SAND %	FINES %	D_{10} mm.	ATT. LIMITS PL	LL	SPECIFIC GRAVITY	NAT. WATER CONTENT % DRY WT TOTAL	-NO4	COMPACTION DATA STND. AASHO OPT. WATER % DRY WT	MAX. DRY DENS. LBS/CU FT	* PVD LBS/CU FT	NAT. DRY DENSITY LBS/CU FT TOTAL	-NO4	OTHER TESTS SHEAR	CONSOL.	PERM.
FD-7	517.0	J-5	13.0-15.0	SM	29	32	39	0.011													
		J-6	15.0-20.0	ML	5	28	67	0.0049													
		J-9	30.0-34.2	SM	21	43	36	0.007													
FD-8	533.3	J-2	2.2- 3.3	SM	9	55	36	0.018													
		J-9	13.9-18.9	SM	14	66	20	0.05				11.8	13.8								
		J-12	21.8-23.9	SM	30	42	28	0.024				9.6	13.8								
		J-15	25.0-27.4	SM	15	56	29	0.021				6.6	7.7								
		J-18	30.2-33.0	SM	3	65	32	0.024				14.1	14.6								
		J-24	43.1-43.5	SM	1	59	40	0.019				12.7	—								
FD-9	557.0	J-3	5.0-10.0	SM	15	48	37	0.02				6.2	7.3								
		J-5	10.0-12.7	GM								10.2	18.2								
		J-5	10.0-12.7	GM	44	38	18	0.053													
		J-8	17.9-20.2	SM	8	62	30	0.03				15.4	16.7								
FD-10	575.0	B-5	3.6- 5.0	SM	12	49	39	0.01													
		B-8	5.0-10.0	SM	22	44	34	0.013													
		J-10	13.5-14.5	SM								14.6	16.2								
		B-11	10.0-15.0	SM	17	58	25	0.024													
		J-12	15.0-15.7	SM	35	42	23	0.034				21.3	22.9								
		J-7	7.0- 7.7	SM								12.1	15.0								
FD-12	440.4	B-6	7.0-10.0	GP	80	18	2	0.51													
		B-8	10.0-15.0	GP	59	37	4	0.14													
		J-11R	15.0-20.0	GP							2.86	18.1	21.7								
		B-12	20.0-25.0	GP	71	26	3	0.4													
		B-16	30.0-35.0	SM	38	50	12	0.074													
		J-17R	30.0-35.0	SM								13.6	22.2								
		B-18	35.0-40.0	GP-GM	54	38	8	0.1													
		J-20R	40.0-45.0	ML	5	16	79	0.0025	26	29											

* PROVIDENCE VIBRATED DENSITY TEST.

LITTLEVILLE DAM

TEST DATA SUMMARY

EXPL. NO.	TOP ELEV. FT.	SAMPLE NO.	DEPTH FT.	SOIL SYMBOL	MECHANICAL ANALYSIS GRAVEL %	SAND %	FINES %	D_{10} mm.	ATT. LIMITS PL	LL	SPECIFIC GRAVITY	NAT. WATER CONTENT % DRY WT TOTAL	-NO4	COMPACTION DATA STND.AASHO OPT. WATER % DRY WT	MAX. DRY DENS. LBS/CU FT	* PVD LBS/CU FT	NAT. DRY DENSITY LBS/CUFT TOTAL	-NO4	OTHER TESTS SHEAR	CONSOL.	PERM.
FD-13	442.8	B-9	7.0-10.0	SP-SM	34	57	9	0.091													
		J-10R	7.0-10.0	SP-SM								17.5	21.5								
		B-11	10.0-15.0	SM	3	81	16														
		J-12R	10.0-15.0	SM							2.74		26.7								
		B-13	15.0-20.0	SM	0	61	39	0.025													
		B-17	25.0-30.0	GM	47	41	12														
		B-22	34.0-39.0	GP-GM	47	43	10	0.074													
		J-25R	39.0-41.0	SM								9.2	12.6								
		B-27	42.0-46.0	GP-GM	55	36	9	0.091													
		J-28R	42.0-46.0	GP-GM								6.7	16.9								
FD-14	546.9	B-6	5.0-10.0	SM	22	53	25														
FD-15	453.3	B-4	1.2- 5.0	SM	41	46	13														
FD-16	440.6	B-3	5.0- 8.0	GP-GM	69	26	5	0.17													
		B-8	10.0-15.0	SM	32	55	13														
		B-16	30.0-35.0	GM	46	36	18														
		B-22	45.0-50.0	GP-GM	59	34	7	0.13													
FD-17	470.0	B-8	12.0-16.0	GP-GM	56	33	11	0.07													
		B-13	22.0-27.0	SM	40	42	18	0.034													
		J-17R	32.0-33.5	CL	6	27	67	0.001	24	38											
		B-23	42.0-45.0	SM	30	48	22	0.026													
		B-28	49.0-51.7	SP-SM	42	47	11	0.068													
		B-38	62.5-63.5	SM	42	45	13	0.05													
FD-19	457.7	B-4	1.6- 5.0	GM	44	43	13														
		B-8	8.7-11.6	SM	21	65	14														

* PROVIDENCE VIBRATED DENSITY TEST.

LITTLEVILLE DAM

TEST DATA SUMMARY

EXPL. NO.	TOP ELEV. FT.	SAMPLE NO.	DEPTH FT.	SOIL SYMBOL	MECHANICAL ANALYSIS GRAVEL %	SAND %	FINES %	D_{10} mm.	ATT. LIMITS PL	LL	SPECIFIC GRAVITY	NAT. WATER CONTENT % DRY WT TOTAL	-NO4	COMPACTION DATA STND. AASHO OPT. WATER % DRY WT	MAX. DRY DENS. LBS/CU FT	* PVD LBS/CU FT	NAT. DRY DENSITY LBS/CU FT TOTAL	-NO4	OTHER TESTS SHEAR	CONSOL.	PERM.
FD-20	435.1	B-6	6.1-10.0	SM	24	61	15														
		B-8	10.0-15.0	SM	40	46	14	0.05													
		B-14	23.5-25.0	GP-GM	66	26	8	0.12													
		B-17	30.0-35.0	GP-GM	69	25	6	0.16													
		B-20	40.0-45.0	GP-GM	55	40	5	0.16													
FD-24	469.4	B-6	11.0-15.0	SP-SM	32	60	8	0.09													
		B-10	20.0-25.0	GM	43	38	19	0.035													
		J-13R	25.0-30.0	SM								14.7	15.0								
		J-14R	30.0-35.0	SM	15	41	44	0.0028													
		J-15R	30.0-35.0	SM								11.3	12.4								
		J-20R	40.0-45.0	SM								11.0	12.3								
		J-22R	45.0-50.0	SM								10.1	12.4								
		B-23	50.0-55.0	GM	36	33	31	0.008													
		J-28R	60.0-65.0	SM								10.6	11.5								
FD-25	533.4	B-5	5.0- 7.3	SM	19	63	18	0.044													
FD-26	553.8	B-8	10.0-15.0	SM	28	52	20	0.035													
FD-27	505.6	B-5	5.0- 8.8	SM	19	48	33	0.017													
FD-28	479.9	B-5	5.0- 9.0	SM	29	49	22	0.032													
FD-29	499.9	B-4	4.1- 7.0	SM	38	47	15														
FD-30	502.7	B-3	3.0- 5.0	SM	23	65	12														
		B-11	14.0-19.0	SM	35	39	26	0.024													
		B-29	52.0-53.3	SM	19	38	43	0.003													
		B-45	76.2-77.0	SM	15	60	25	0.017													

* PROVIDENCE VIBRATED DENSITY TEST.

LITTLEVILLE DAM

EXPL. NO.	TOP ELEV. FT.	SAMPLE NO.	DEPTH FT.	SOIL SYMBOL	MECHANICAL ANALYSIS GRAVEL %	SAND %	FINES %	D_{10} mm.	ATT. LIMITS PL	LL	SPECIFIC GRAVITY	NAT. WATER CONTENT % DRY WT TOTAL	-NO4	COMPACTION DATA STND.AASHO OPT. WATER % DRY WT	MAX. DRY DENS. LBS/CU FT	* PVD LBS/CU FT	NAT. DRY DENSITY LBS/CUFT TOTAL	-NO4	OTHER TESTS SHEAR	CONSOL.	PERM.
FD-31	504.4	B-3	5.0-10.0	GP-GM	50	44	6	0.14													
		B-14	30.0-35.0	SM	24	31	45	0.0022													
		B-27	52.0-54.0	SM-SC	11	43	46	0.0025	19	23											
		B-35	70.0-73.0	SM-SC	22	40	38														
		B-46	96.0-97.0	GP-GM	71	23	6	0.14													
		J-47R	96.0-97.0	SM	10	46	44	0.015													
FD-35	557.8	B-4	2.4- 5.0	SM	22	58	20	0.033													
FD-36	443.3	B-5	5.4- 7.7	GP-GM	56	37	7	0.13													
FD-37	442.4	B-7	5.0- 7.4	GP-GM	48	46	6	0.13													
FD-39	481.1	B-5	5.0- 8.3	SP-SM	39	49	12	0.07													
		B-9	10.0-13.5	SM	12	48	40	0.019													
FD-42	555.0	B-5	5.0-10.0	SM	32	47	21	0.029													
FD-44	529.9	B-1	1.8- 4.4	SM	29	50	21	0.041													
		B-6	8.0-12.0	SM	38	47	15	0.05													
		B-13	19.0-23.0	SM-SC	24	28	48	0.0034													
		J-14R	19.0-23.0	SM					19	24											
		B-16	25.0-28.4	SM	30	35	35	0.006													
FD-46	588.9	B-5	2.1- 5.0	SM	22	50	28	0.025													
		B-11	10.0-15.0	SM	40	42	18	0.041													
		B-13	15.0-19.0	ML	9	41	50	0.009	w/1" Silt Strata												
		B-15	20.0-24.3	SM	25	55	20	0.033													
		B-17	25.0-28.0	GP-GM	56	35	9	0.082													
		B-23	35.0-39.2	SM	37	42	21	0.041													

* PROVIDENCE VIBRATED DENSITY TEST.

TEST SUMMARY DATA

EXPL. NO.	TOP ELEV. FT.	SAMPLE NO.	DEPTH FT.	SOIL SYMBOL	MECHANICAL ANALYSIS GRAVEL %	SAND %	FINES %	D_{10} mm.	ATT. LIMITS PL	LL	SPECIFIC GRAVITY	NAT. WATER CONTENT % DRY WT. TOTAL	NO 4	COMPACTION DATA STND AASHO OPT. WATER % DRY WT	MAX. DRY DENS. LBS/CU FT	* PVD LBS/CU FT	NAT. DRY DENSITY LBS/CU FT TOTAL	NO 4	OTHER TESTS SHEAR	CONSOL	PERM.
FD-47	560.3	J-4	2.6- 3.2	GP-GM	46	43	11	0.073													
		J-9	10.7-12.1	SM	20	61	19	0.04													
		J-17	28.0-29.6	SM	20	48	32	0.026													
		J-24	41.6-42.3	ML	5	40	55	0.023													
FD-48	559.2	B-7	5.6-10.0	SM	19	52	29	0.025													
FD-49	593.0	B-3	2.3- 4.4	SM	17	55	28	0.023													
		B-9	11.3-15.0	SM	27	54	19	0.041													
		J-14	17.6-19.1	SM	0	52	48	0.02													
FD-50	564.8	B-4	5.0-10.0	GP-GM	59	31	10	0.074													
		B-8	15.0-18.0	SM	14	51	35	0.019													
		B-12	25.0-28.0	SM	27	40	33	0.017													
		B-19	49.0-52.0	SM	9	41	50	0.013													
FD-51	546.6	B-3	2.6- 5.0	SM	6	54	40	0.014													
		B-9	11.0-15.0	SM	20	65	15	0.043													
		B-14	20.0-25.0	SM	26	60	14	0.059													
		B-19	30.0-31.0	SM	9	58	33	0.014													
FD-52	553.7	B-8	6.4-10.0	GM	39	38	23	0.028													
		J-19	25.0-26.1	SM	14	63	23	0.037													
		J-23	30.0-31.7	SM	1	70	29	0.03													
		B-27	35.0-37.0	SP-SM	0	89	11	0.07													
		B-32	43.0-45.0	SM	18	48	34	0.033													
		B-41	55.0-56.3	SM	33	48	19	0.041													
FD-53	546.7	B-3	2.5- 5.0	SM	4	47	49	0.0088													
		B-9	7.6- 8.8	SM	18	47	35	0.016													
		B-16	16.0-21.0	SM	9	76	15	0.06													
		B-20	26.0-28.2	SM	25	58	17	0.058													

* PROVIDENCE VIBRATED DENSITY TEST.

LITTLEVILLE DAM

TEST DATA SUMMARY

EXPL. NO.	TOP ELEV. FT.	SAMPLE NO.	DEPTH FT.	SOIL SYMBOL	MECHANICAL ANALYSIS GRAVEL %	SAND %	FINES %	D_{10} mm.	ATT. LIMITS PL	LL	SPECIFIC GRAVITY	NAT. WATER CONTENT % DRY WT. TOTAL	-NO4	COMPACTION DATA STND AASHO OPT. WATER % DRY WT.	MAX. DRY DENS. LBS/CU FT	* PVD LBS/CU FT	NAT. DRY DENSITY LBS/CU FT TOTAL	-NO4	OTHER TESTS SHEAR	CONSOL.	PERM.
FD-53 Cont'd	546.7	J-22	30.0-31.4	ML	3	42	55	0.02													
		B-30	40.0-41.4	SM	23	48	29	0.017													
		B-37	49.0-50.0	SM	3	51	46	0.0052													
FD-54	571.5	B-4	1.0- 5.0	SM	40	49	11	0.07													
		B-8	6.0-10.0	SM	14	72	14	0.05													
		B-18	19.0-22.1	SM	15	72	13	0.055													
		B-22	26.0-29.5	SM	1	62	37	0.03													
		B-27	39.0-40.6	SM	37	47	16	0.049													
		B-32	46.0-48.0	SM	19	47	34	0.026													
FD-55	456.2	B-8	10.0-15.0	SP-SM	19	73	8	0.11													
		B-13	21.0-25.0	SM	36	50	14	0.05													
		B-18	32.0-35.0	SP-SM	41	48	11														
		J-19R	35.0-36.5	SM	42	45	13														
		B-24	40.0-43.0	GM	51	37	12	0.054													
		B-26	43.0-45.0	SM	18	45	37	0.0078													
		J-28R	46.0-49.0	SM					Non-Plastic												
FD-56	561.2	B-11	6.0-8.0	SM	26	60	14	0.05													
		B-16	11.6-14.0	SM	28	52	20	0.041													
		B-25	19.0-22.0	SM	2	61	37	0.027													
		J-29	25.7-26.7	SM													109.4	(plug)			
		B-30	25.7-26.7	SM	8	54	38	0.027													
		B-37	35.0-37.9	SP-SM	34	60	6	0.14													
		B-42	42.0-44.0	GP-GM	46	44	10	0.1													
		B-46	48.0-50.0	SM	37	48	15														
FD-57	570.0	B-5	5.0-10.0	SM	39	46	15	0.049													
		B-15	25.0-29.0	SM	1	55	44	0.025													
		J-16	29.0-31.0	SM													106.8	(plug)			

* PROVIDENCE VIBRATED DENSITY TEST.

TEST DATA SUMMARY

EXPL. NO.	TOP ELEV. FT.	SAMPLE NO.	DEPTH FT.	SOIL SYMBOL	MECHANICAL ANALYSIS GRAVEL %	SAND %	FINES %	D10 MM	ATT LIMITS PL	LL	SPECIFIC GRAVITY	NAT WATER CONTENT % DRY WT TOTAL	-NO4	COMPACTION DATA STD AASHO OPT WATER % DRY WT	MAX DRY DENS LBS/CUFT	* PVD LBS/CUFT	NAT. DRY DENSITY LBS/CUFT TOTAL	-NO4	OTHER TESTS SHEAR	CONSOL	PERM
FD-57 Contd	570.0	J-24	37.0-39.0	SM	w/occ. silt strata to 1/2"												111.5	(plug)			
		B-27	39.0-41.0	SP-SM	3	88	9	0.08													
		B-33	47.0-48.4	SM	5	78	17	0.05													
		J-34	49.0-50.0	SM	0	80	20	0.04													

* PROVIDENCE VIBRATED DENSITY TEST

LITTLEVILLE DAM

TEST SUMMARY DATA

EXPL. NO.	TOP ELEV. FT.	SAMPLE NO.	DEPTH FT.	SOIL SYMBOL	MECHANICAL ANALYSIS GRAVEL %	SAND %	FINES %	D10 mm.	ATT. LIMITS PL	LL	SPECIFIC GRAVITY	NAT WATER CONTENT % DRY WT TOTAL	NO 4	COMPACTION DATA STND AASHO OPT. WATER % DRY WT	MAX. DRY DENS. LBS/CU FT	* PVD LBS/CU FT	NAT DRY DENSITY LBS/CU FT TOTAL	NO 4	OTHER TESTS SHEAR	CONSOL.	PERM
FT-4	571.4	B-3	2.6- 8.0	SM	32	34	34	0.018													
FT-5	573.8	B-3	2.9- 8.0	SM	21	55	24	0.028													
FT-6	497.4	B-3	3.0-13.0	SM	39	41	20	0.031													
FT-7	508.4	B-3	2.9-12.0	SM	40	45	15	0.043													
FT-8	474.7	B-3	2.9-11.0	GP	49	47	4	0.29													
		B-5	11.0-13.0	GM	48	40	12	0.07													
FT-9	441.3	B-1	0.5- 5.8	SM	0	71	29														
FT-9	441.3	B-3	5.8-10.0	GP-GM	53	40	7	0.11													
FT-10	442.2	B-3	6.0-10.0	GM	50	37	13	0.054													
FT-11	438.3	B-3	5.5- 7.0	SP-SM	46	48	6	0.13													

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LITTLEVILLE DAM

TEST DATA SUMMARY

EXPL. NO.	TOP ELEV. FT.	SAMPLE NO.	DEPTH FT.	SOIL SYMBOL	MECHANICAL ANALYSIS GRAVEL %	SAND %	FINES %	D_{10} mm.	ATT. LIMITS PL	LL	SPECIFIC GRAVITY	NAT WATER CONTENT % DRY WT TOTAL	NO 4	COMPACTION DATA STND AASHO OPT WATER % DRY WT	MAX DRY DENS LBS/CU FT	* PVD LBS/CU FT	NAT DRY DENSITY LBS/CUFT TOTAL	NO 4	OTHER TESTS SHEAR	CONSOL	PERM
BD-10	695.5	J-3R	0.6- 5.0	SM									11.5								
		B-4	5.0- 7.1	SM	11	44	45	0.0052	Non-Plastic												
		J-5R	5.0- 7.1	SM									12.7								
		J-6	7.1-10.0	SM									11.5								
		B-7	10.0-12.4	ML-CL	9	33	58	0.0019	17	22	2.80										
		J-8R	10.0-12.4	ML-CL									12.0								
		J-9	12.4-15.0	ML-CL	13	33	54	0.003				11.5	12.0								
		B-12	17.0-17.8	ML-CL	9	36	55	0.0017													
		J-13R	17.0-17.8	ML-CL								12.1	12.8								
		J-16R	20.0-22.7	SM-SC								8.0	9.6								
		J-18R	22.7-25.0	SM-SC					18	23		9.6	9.9								
		J-21R	28.0-30.0	SM-SC								8.0	9.2								
		B-22	30.0-32.6	SM	23	31	46	0.0026	Non Plas.		2.84										
		J-23R	30.0-32.6	SM								8.8	9.2								
		J-25R	32.6-35.4	SM								8.3	8.7								
		J-27R	38.0-38.6	SM								10.1	10.2								
		J-29R	40.0-40.6	SM								9.0	9.2								
		J-31R	42.0-43.0	SM					Non Plastic			9.1	9.4								
		J-32R	43.0-44.2	SM								9.3	9.6								
		B-34	46.0-48.8	SM	20	36	44	0.005	Non Plastic												
		J-35R	46.0-48.8	SM								8.6	8.8								
		B-39	53.0-55.0	SM	16	37	47	0.0049	"	"	2.82										
		J-40R	53.0-55.0	SM								9.1	9.6								
		J-42R	55.0-57.0	SM								6.9	7.8								
		J-44R	57.7-60.0	SM								9.3	10.5								
		B-47	65.0-70.0	GM-GC	34	28	38	0.0049	16	21											
		J-48R	65.0-70.0	SM-SC								9.5	10.0								
		J-51R	70.8-73.3	SM-SC								10.2	10.4								

* PROVIDENCE VIBRATED DENSITY TEST.

LITTLEVILLE DAM

EXPL NO.	TOP ELEV FT.	SAMPLE NO.	DEPTH FT	SOIL SYMBOL	MECHANICAL ANALYSIS GRAVEL %	SAND %	FINES %	D10 MM	ATT. LIMITS P.L.	L.L.	SPECIFIC GRAVITY	NAT WATER CONTENT % DRY WT TOTAL	NOA	COMPACTION DATA STND AASHO OPT WATER % DRY WT	MAX DRY DENS LBS/CUFT	* PVC LBS/CUFT	NAT. DRY DENSITY LBS/CUFT TOTAL	NOA	OTHER TESTS SHEAR	CONSOL	PERM.
BD-11	731.1	B-3	1.6- 5.0	ML	7	37	56	0.0028	19	20	2.82										
		J-4R	1.6- 5.0	ML								14.4	14.5								
		J-6R	5.0- 8.3	SM								14.3	14.6								
		B-8	10.9-15.0	SM	18	35	47	0.0043	Non	Plastic											
		J-12R	17.4-18.2	SM								10.8	11.8								
		B-14	20.0-21.3	SM	26	31	43	0.0043	18	21											
		J-15R	20.0-21.3	SM								12.1	13.1								
		J-17R	21.3-25.0	SM								10.7	11.1								
		B-18	25.0-30.0	SM	24	31	45	0.0024	18	21	2.80										
		J-19R	25.0-30.0	SM								10.7	11.5								
		J-21R	30.0-31.1	ML								14.0	14.4								
		J-23R	31.1-35.0	SM								9.3	11.0								
		B-24	35.0-37.7	SM	29	28	43	0.0021	18	21											
		J-25R	35.0-37.7	SM								9.9	11.6								
		J-26	37.7-40.0	SM								11.8	12.5								
		J-28R	40.0-44.4	SM-SC								9.9	10.8								
		J-31R	46.0-50.0	SM-SC								10.1	11.5								
		B-32	50.0-55.0	SM-SC	23	32	45	0.002	18	22											
		J-33R	50.0-55.0	SM-SC								14.5	15.1								
		J-35R	55.0-58.0	SM-SC								12.4	13.3								
		J-37R	58.5-60.0	SM-SC								14.9	15.6								
		B-38	60.0-65.0	SM-SC	23	30	47	0.012													
		J-39R	60.0-65.0	SM-SC								11.9	12.4								
		J-41R	65.0-70.0	SM-SC								10.4	13.3								
		J-43R	70.0-75.0	SM-SC								9.8	11.5								
		J-45R	75.0-80.0	GM-GC								12.6	17.1								
		J-47R	80.0-85.0	SM-SC								13.1	14.9								
		B-48	85.0-89.0	SM-SC	26	34	40	0.002													
		J-49R	85.0-89.0	SM-SC								9.4	10.6								
		J-51R	89.0-90.0	SM-SC								9.9	10.3								
		J-53R	90.0-95.0	SM-SC								10.8	11.3								
		J-55R	95.0-96.4	SM-SC								9.9	10.5								
		B-44	75.0-80.0	GM-GC	28	27	45	0.0011	18	24											

* PROVIDENCE VIBRATED DENSITY TEST

LITTLEVILLE DAM

TEST SUMMARY DATA

EXPL. NO.	TOP ELEV. FT.	SAMPLE NO.	DEPTH FT.	SOIL SYMBOL	MECHANICAL ANALYSIS GRAVEL %	SAND %	FINES %	D_{10} mm.	ATT. LIMITS PL	LL	SPECIFIC GRAVITY	NAT. WATER CONTENT % DRY WT TOTAL	-NO4	COMPACTION DATA STND AASHO OPT. WATER % DRY WT	MAX DRY DENS. LBS/CU FT	* PVD LBS/CU FT	NAT. DRY DENSITY LBS/CUFT TOTAL	-NO4	OTHER TESTS SHEAR	CONSOL.	PERM.
BD-11 Continued																					
		B-57	97.8-100.0	SM-SC	22	36	42	0.002	15	20											
		J-58R	97.8-100.0	SM-SC								9.6	11.1								
		J-60R	100.0-105.0	"								8.0	8.9								
		B-61	105.0-110.0	"	16	41	43	0.0013													
		J-62	110.0-115.0	"								9.3	9.9								
		J-64R	110.0-115.0	"								15.1	15.5								
		B-65	115.0-120.0	"	13	45	42	0.0021	16	21											
		J-66R	115.0-120.0	"								13.9	14.3								
		J-68R	120.0-122.1	"								15.1	17.7								

* PROVIDENCE VIBRATED DENSITY TEST.

LITTLEVILLE DAM

TEST DATA SUMMARY

EXPL NO.	TOP ELEV. FT.	SAMPLE NO	DEPTH FT.	SOIL SYMBOL	MECHANICAL ANALYSIS GRAVEL %	SAND %	FINES %	D10 mm	ATT. LIMITS PL	LL	SPECIFIC GRAVITY	NAT WATER CONTENT % DRY WT TOTAL	NO4	COMPACTION DATA (STND AASHO) OPT WATER % DRY WT	MAX DRY DENS LBS/CU FT	* PVD LBS/CU FT	NAT. DRY DENSITY LBS/CUFT TOTAL	NO4	OTHER TESTS SHEAR	CONSOL	PERM
BD-12	751.5	J-2R	1.2- 3.1	SM								20.3	21.9								
		J-4R	3.1- 5.0	SM								13.0	14.9								
		J-6R	5.0- 9.4	SM								10.6	14.0								
		B-7	5.0- 9.4	SM	26	49	25	0.026													
		J-8R	9.4-10.0	SM								11.4	11.8								
		J-9R	10.0-13.0	SM								12.1	12.5								
		B-10	10.0-13.0	SM	11	42	47	0.0036	Non Plastic												
		J-11R	13.0-15.0	GM								8.1	8.5								
		J-13R	15.0-19.0	ML								9.4	9.9								
		B-14	15.0-19.0	ML	10	38	52	0.002													
		J-15R	19.0-20.0	ML								9.6	10.8								
		J-17R	20.0-23.0	ML								9.5	10.8								
		J-19R	23.0-25.0	ML								9.6	10.0								
		J-21R	25.0-26.0	ML								10.6	11.1								
		J-23R	26.0-28.7	ML								8.1	9.7								
		B-24	26.0-28.7	ML	11	37	52	0.002	16	19											
		J-26R	30.0-31.8	ML								9.3	10.1								
		J-29R	32.4-35.0	ML								8.9	10.7								
		B-31	35.0-37.8	ML-CL	16	33	51	0.001													
		J-32R	37.8-40.0	ML-CL								9.5	9.9								
		B-35	40.0-43.0	ML-CL	11	35	54	0.001	17	22											
		J-36R	43.0-45.0	ML-CL								8.2	8.7								
		B-39	45.0-48.2	SM-SC	19	32	49	0.0012	17	24											
BD-14	628.2	J-3R	3.0- 5.0	GM								14.9	17.0								
		B-4	5.0-10.0	ML	14	35	51	0.005	20	21											
		J-4R	5.0-10.0	ML								13.1	14.5								
		B-5	10.0-15.0	ML	13	34	53	0.0025	19	22											
		J-5R	10.0-15.0	ML								14.3	14.5								
		J-6R	15.0-20.0	SM-SC								10.6	12.6								
		B-7	20.0-25.0	SM-SC	24	29	47	0.0017	18	22											

* PROVIDENCE VIBRATED DENSITY TEST.

LITTLEVILLE DAM

TEST DATA SUMMARY

EXPL. NO.	TOP ELEV. FT.	SAMPLE NO.	DEPTH FT.	SOIL SYMBOL	MECHANICAL ANALYSIS GRAVEL %	SAND %	FINES %	D_{10} mm.	ATT. LIMITS PL	LL	SPECIFIC GRAVITY	NAT. WATER CONTENT % DRY WT TOTAL	-NO4	COMPACTION DATA STND AASHO OPT. WATER % DRY WT	MAX. DRY DENS. LBS/CU FT	* PVD LBS/CU FT	NAT. DRY DENSITY LBS/CU FT TOTAL	-NO 4	OTHER TESTS SHEAR	CONSOL.	PERM.	
BD-14 Continued																						
		J-7R	20.0-25.0	SM-SC								11.6	12.3									
		B-9	30.0-35.0	SM-SC	24	36	40	0.0036	17	21												
		J-9R	30.0-35.0	SM-SC								9.2	11.1									
		J-10R	35.0-40.0	SM-SC								9.1	12.3									
		J-8R	25.0-30.0	SM-SC								8.8	10.0									
BD-15	609.0	J-6R	7.2-10.0	SM								15.2	15.7									
		B-7	7.2-10.0	SM	13	41	46	0.0042	20	22												
		J-8R	10.0-12.5	SM								19.4	22.0									
		J-11R	15.0-20.0	GM								13.0	13.7									
		B-12	15.0-20.0	GM	41	27	32	0.008	18	21												
		J-13R	20.0-24.0	SM-SC								8.7	9.0									
		B-14	20.0-24.0	SM-SC	18	37	45	0.0021	16	21												
		J-16R	24.0-25.0	SM-SC								9.4	9.7									
		J-17R	25.0-28.0	SM								10.0	10.8									
		J-20R	30.0-33.0	SM								10.6	11.3									
		B-21	30.0-33.0	SM	7	51	42	0.006	Non Plastic													
		J-22R	33.0-33.9	SM								9.2	10.7									
		J-25R	35.7-40.0	SM-SC								8.7	9.3									
		B-26	35.7-40.0	SM-SC	12	45	43	0.003	17	22												
BD-16	770.1	B-5	5.0-10.0	GM	33	29	38	0.0095	Non Plastic													
		J-6R	10.0-15.0	SM								11.9	12.3									
		J-9R	16.0-20.0	ML								7.8	8.4									
		B-10	16.0-20.0	ML	10	33	57	0.0012														
		J-11R	20.0-25.0	SM								9.2	9.3									
		J-13R	25.0-29.2	SM								9.1	9.2									
		J-18R	32.0-35.0	SM								10.3	10.9									
		B-19	32.0-35.0	SM	15	42	43	0.004	Non Plastic													
		J-20R	35.0-38.0	SM								11.0	11.1									
		J-22R	38.0-40.0	SM								11.6	11.8									
		J-24R	40.0-45.0	SM								8.5	9.3									
		J-26	45.0-48.0	SM								7.9	8.6									

* PROVIDENCE VIBRATED DENSITY TEST.

LITTLEVILLE DAM

TEST DATA SUMMARY

EXPL. NO.	TOP ELEV. FT.	SAMPLE NO.	DEPTH FT.	SOIL SYMBOL	MECHANICAL ANALYSIS GRAVEL %	SAND %	FINES %	D_{10} mm.	ATT. LIMITS PL	LL	SPECIFIC GRAVITY	NAT. WATER CONTENT % DRY WT TOTAL	-NO4	COMPACTION DATA STND. AASHO OPT. WATER % DRY WT	MAX. DRY DENS. LBS/CU FT	* PVD LBS/CU FT	NAT. DRY DENSITY LBS/CU FT TOTAL	-NO4	OTHER TESTS SHEAR	CONSOL.	PERM.
BD-16 Continued																					
		B-27	45.0-48.0	SM	17	40	43	0.0034													
		J-30R	51.3-53.1	SM								8.5	9.5								
		J-34R	55.0-58.0	SM								9.1	9.7								
		B-35	55.0-58.0	SM	19	37	44	0.0025	Non Plastic												
		J-36R	58.0-60.0	SM								8.3	9.1								
		J-38R	60.0-62.0	SM								7.9	9.0								
		J-40	62.0-65.0	SM								9.3	10.5								
		B-41	62.0-65.0	SM	20	42	38	0.0041													
		J-43R	67.0-69.8	SM								7.9	9.3								
		J-46	73.4-75.0	SM								8.9	9.5								
		B-48	75.0-78.5	SM	18	50	32	0.0062	Non Plastic			9.1	10.3								
BD-17	747.8	J-3R	2.7- 5.0	SM								18.8	21.1								
		B-6	5.0-10.0	SM	31	45	24	0.025	Non Plastic												
		J-7R	10.0-15.0	SM								13.1	13.4								
		B-10	15.0-20.0	SM	15	43	42	0.006													
		J-11R	20.0-25.0	SM								8.8	9.2								
		B-14	25.0-30.0	SM	17	47	36	0.014													
		J-15R	30.0-32.0	SM								8.5	9.1								
		J-17R	32.0-34.2	SM								8.0	8.1								
		J-20R	35.0-37.0	SM								9.6	10.7								
		B-21	35.0-37.0	SM	19	44	37	0.0071	Non Plastic												
		J-24R	38.8-40.0	SM								14.7	18.3								
		J-25R	40.0-41.7	SM								15.7	15.9								
		J-26	40.0-41.7	SM	9	55	36	0.016													
		J-27	41.7-43.0	SM								15.7	17.2								
BD-18	465±	B-5	5.0-10.0	SP-SM	44	45	11														
		B-7	10.0-15.0	SP-SM	27	64	9	0.088													

* PROVIDENCE VIBRATED DENSITY TEST.

LITTLEVILLE DAM

TEST DATA SUMMARY

EXPL. NO.	TOP ELEV. FT.	SAMPLE NO.	DEPTH FT.	SOIL SYMBOL	MECHANICAL ANALYSIS GRAVEL %	SAND %	FINES %	D_{10} mm.	ATT. LIMITS PL	LL	SPECIFIC GRAVITY	NAT WATER CONTENT % DRY WT TOTAL	NO4	COMPACTION DATA STND AASHO OPT WATER % DRY WT	MAX DRY DENS LBS/CU FT	* PVD LBS/CU FT	NAT. DRY DENSITY LBS/CU FT TOTAL	NO4	OTHER TESTS SHEAR	CONSOL	PERM.
BD-19	460±	B-2	1.4- 5.0	GP-GM	58	34	8	0.09													
		B-10	15.0-20.0	GM	49	39	12														
		B-12	20.0-25.0	SP-SM	26	67	7	0.094													
BD-20	455±	B-4	5.0-10.0	GP-GM	53	37	10	0.074													
		B-6	10.0-15.0	SP-SM	33	56	11														
BD-21	454±	B-8	5.0-10.0	GM	52	36	12														
BD-22	450±	B-7	5.0-10.0	GP	66	30	4	0.24													
		B-9	10.0-14.3	GP-GM	47	42	11														
		B-12	15.0-17.0	SM	6	66	28														
		B-16	20.0-25.0	GP-GM	62	30	8	0.09													
BD-23	445±	B-2	0.0-5.0	SM	0	80	20														
		B-5	5.6-10.0	GP-GM	55	37	8	0.091													
		B-9	15.0-20.0	GP-GM	53	36	11														
BD-24	465±	B-6	5.0- 9.6	GP	57	38	5	0.19													
		B-9	10.0-13.4	GW-GM	53	42	5	0.17													
BD-27	467±	B-4	5.0- 7.8	SP-SM	27	65	8	0.1													
		B-8	10.0-15.0	GW-GM	48	41	11														
BD-28	475±	B-9	10.0-13.9	GP-GM	64	28	8	0.1													
BD-29	472±	B-3	5.0-10.0	GP-GM	64	31	5	0.2													
BD-31	490±	B-8	6.2-10.0	GP-GM	56	36	8	0.1													
		B-10	10.0-13.5	GW-GM	55	39	6	0.15													

* PROVIDENCE VIBRATED DENSITY TEST.

LITTLEVILLE DAM

TEST DATA SUMMARY

EXPL. NO.	TOP ELEV. FT.	SAMPLE NO.	DEPTH FT.	SOIL SYMBOL	MECHANICAL ANALYSIS GRAVEL %	SAND %	FINES %	D_{10} mm.	ATT. LIMITS PL	LL	SPECIFIC GRAVITY	NAT WATER CONTENT % DRY WT TOTAL	NO4	COMPACTION DATA STND AASHO OPT WATER % DRY WT	MAX DRY DENS. LBS/CU FT	* PVD LBS/CU FT	NAT. DRY DENSITY LBS/CU FT TOTAL	NO4	OTHER TESTS SHEAR	CONSOL	PERM
BT-3	690±	B-2	3.4-11.4	SM	17	38	45	0.0044	20	21	2.80			11.9	123.1						
		UC-4	3.4-11.4									12.5	14.1				125.9				
		UC-6	3.4-11.4									13.2	14.6				121.4				
		UC-8	3.4-11.4									15.6	16.6				113.8				
		UC-10	3.4-11.4									13.6	15.1				119.5				
		B-11	11.4-15.0	SM	20	31	49	0.0025	18	21	2.82			10.5	127.3						
		UC-12	11.4-15.0									13.2	14.8				122.3				
		UC-14	11.4-15.0									12.8	15.0				125.1				
		UC-18	11.4-15.0									12.5	14.9				125.8				
		UC-22	11.4-15.0									11.9	12.4				130.4				
BT-4	456.2	B-2	2.7- 8.1	GP	68	29	3	0.42													
		B-3	9.7-12.3	SP	46	50	4	0.15													
BT-5	459.6	B-2	2.2- 8.5	GP-GM	68	22	10	0.74													
		B-3	8.5-10.6	SP	2	95	3	0.13													
		B-4	10.6-12.0	SP	32	65	3	0.16													
BT-6	462.1	B-2	3.1-11.6	GP	63	35	2	0.42													
BT-7	464.0	B-2	1.5- 7.2	SP	47	49	4	0.16													
		B-3	7.2- 8.3	ML	0	50	50														
		B-4	8.3-10.5	SP-SM	36	55	9	0.08													
BT-8	468.3	B-2	2.1- 9.6	SM	34	50	16														
BT-9	460.3	B-2	2.3- 3.5	GP	56	41	3	0.21													
		B-3	3.5- 4.8	SP	0	98	2	0.20													
		B-4	4.8-11.2	GP	55	40	5	0.15													

* PROVIDENCE VIBRATED DENSITY TEST.

LITTLEVILLE DAM

TEST DATA SUMMARY

EXPL. NO.	TOP ELEV. FT.	SAMPLE NO.	DEPTH FT.	SOIL SYMBOL	MECHANICAL ANALYSIS GRAVEL %	SAND %	FINES %	D_{10} mm.	ATT. LIMITS PL	LL	SPECIFIC GRAVITY	NAT WATER CONTENT % DRY WT TOTAL	NO 4	COMPACTION DATA STND AASHO OPT WATER % DRY WT	MAX DRY DENS LBS/CU FT	* PVD LBS/CU FT	NAT DRY DENSITY LBS/CU FT TOTAL	NO 4	OTHER TESTS SHEAR	CONSOL	PERM
BT-10	458.2	B-3	3.9-10.0	GP-GM	51	42	7	0.13													
BT-11	453.8	B-2	3.9- 9.6	GP	60	36	4	0.17													
BT-12	481.4	B-2	2.3- 7.4	SP	28	68	4	0.21													
		B-3	7.4-11.5	SM	12	61	27														
BT-13	475.9	B-1	0.6- 9.5	GP	70	29	1	0.7													
BT-14	477.3	B-1	0.8- 3.7	SM	0	84	16														
		B-2	3.7-10.6	GP	58	40	2	0.4													
BT-15	491.5	B-2	2.3- 3.8	GP	65	31	4	0.17													
		B-3	3.8- 7.1	GP	57	39	4	0.19													
		B-4	7.1-10.5	GP-GM	62	33	5	0.14													

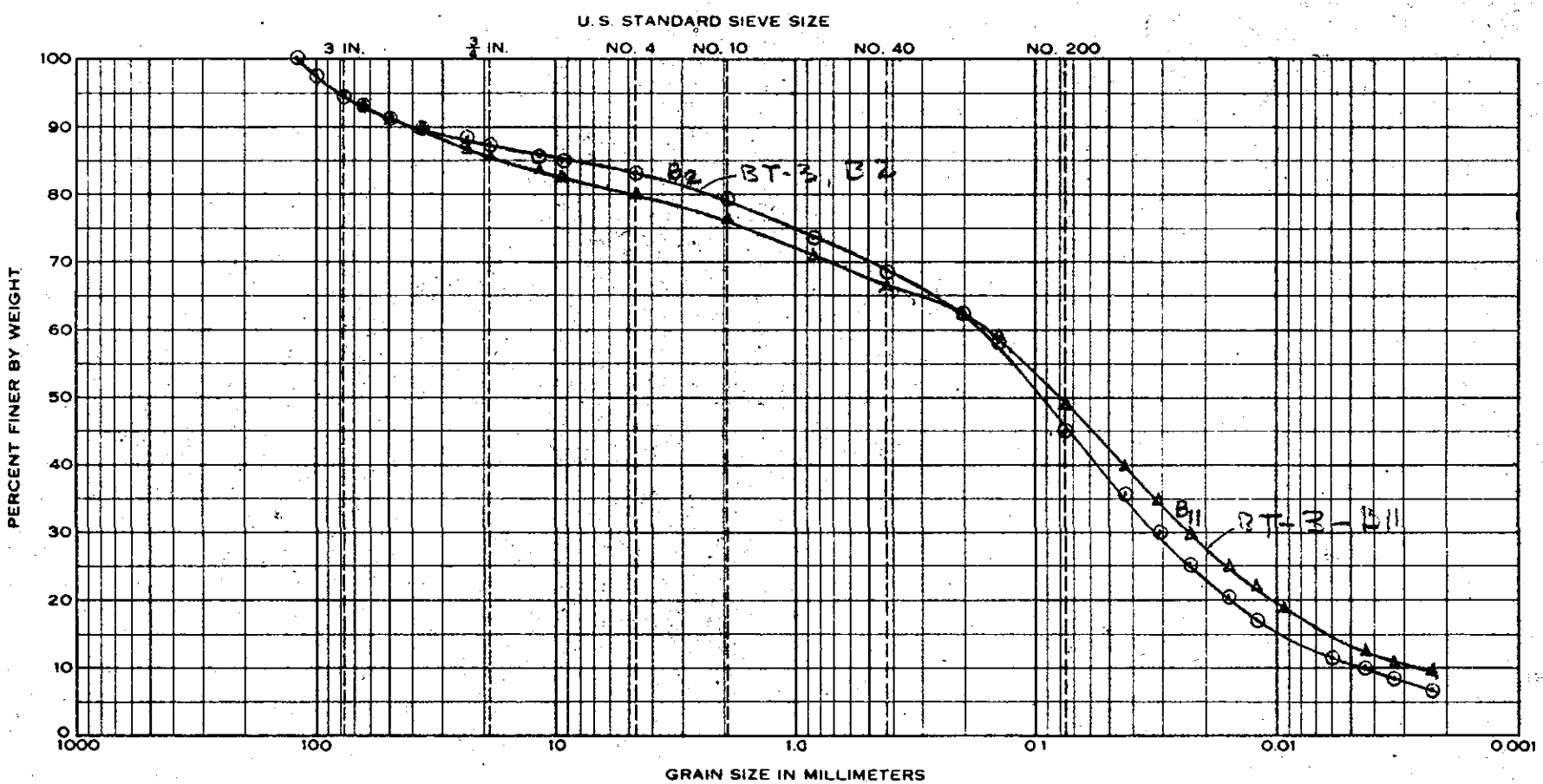
* PROVIDENCE VIBRATED DENSITY TEST

LITTLEVILLE DAM

APPENDIX B
LITTLEVILLE DAM

DETAILED SHEAR TEST DATA
(IMPERVIOUS EMBANKMENT MATERIALS)

Plate No.	Title
B-1	Gradation Curves - BT-3, B-2 & B-11
B-2	Compaction Test Report - BT-3, B-2
B-3	Triaxial Compression Test Report - BT-3, B-2 - Q Test - Optimum +2%
B-4	Compaction Test Report - BT-3, B-11
(B-5 to B-10 - Triaxial Compression Test Reports - BT-3, B-11)	
B-5	S Test - Optimum
B-6	S Test - Optimum +2%
B-7	R Test - Optimum
B-8	R Test - Optimum +2%
B-9	Q Test - Optimum
B-10	Q Test - Optimum +2%



COBBLES	GRAVEL		SAND			SILT OR CLAY
	Coarse	Fine	Coarse	Medium	Fine	

Sample No.	Elev or Depth	Classification	Nat WC	LL	PL	PI	D_{10}
B-2	3.4'-11.4'	grav. silty m-f SAND (SM)		21	20	1	0.0044
B-11	11.4'-15.0'	grav. silty SAND (SM)		21	18	3	0.0025

Project Littleville Dam

Area Impervious Borrow Area "B"

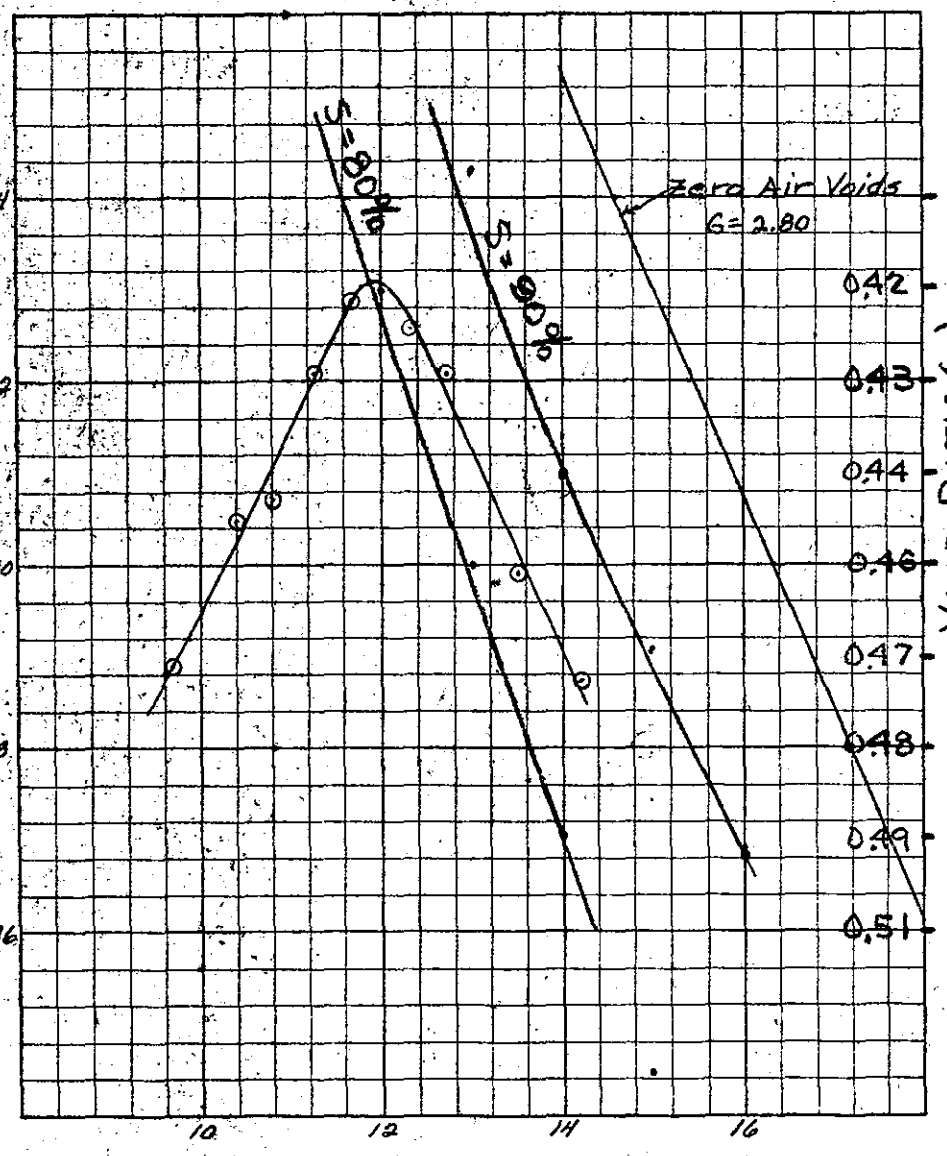
Boring No. BT-3

Date 8 May 1961

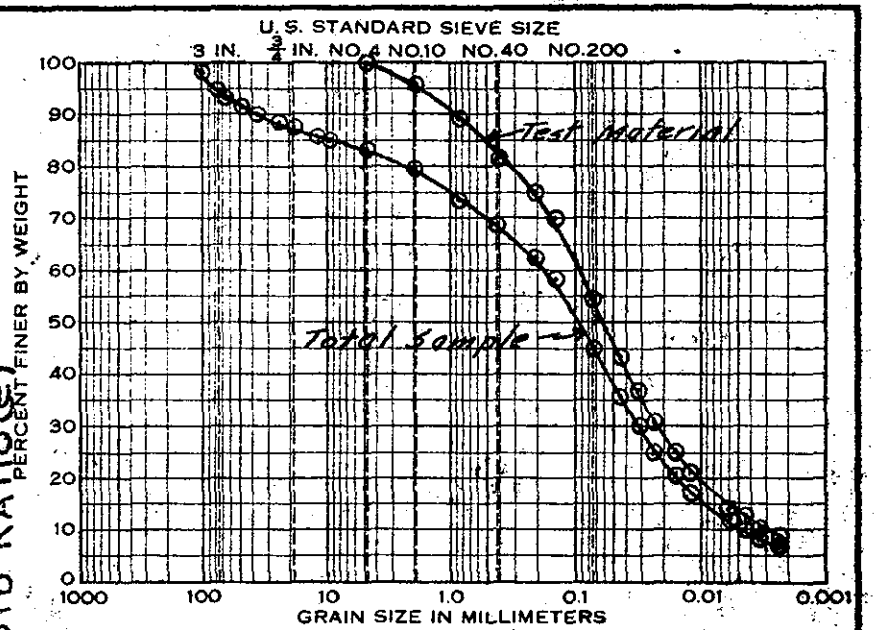
GRADATION CURVES

PLATE NO. B-1

ENG FORM 1 DEC 51 2087 (Translucent) (EM 1110-2-1803)



Standard AASHO; compacted in 3 equal layers @ 25 blows per layer with 5.5# tamper. Height of drop equal to 12 inches. Maximum size particle, #4 sieve.



COBBLES	GRAVEL		SAND			SILT OR CLAY
	Coarse	Fine	Coarse	Medium	Fine	

Sample No.	~~Elev or~~ Depth	Classification	G	LL	PL
B-2	3.4'-11.4'	gray silty m-f SAND (SM)	2.80	21	20

Sample No.		B-2			
Optimum Water Content	%	11.9			
Max Dry Density	Lbs/Cu Ft	123.1			
Optimum Water Content Corr for +	%				
Max Density Corr for +	Lbs/Cu Ft				

Project Littleville Dam

Area Impervious Borrow Area "B"

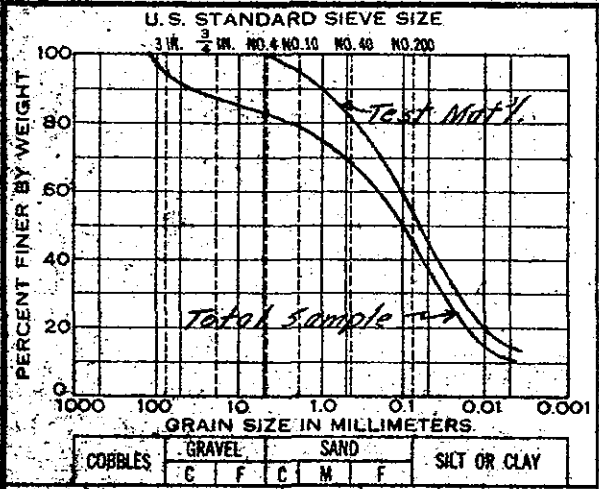
Boring No. BT-3 Sample No. B-2

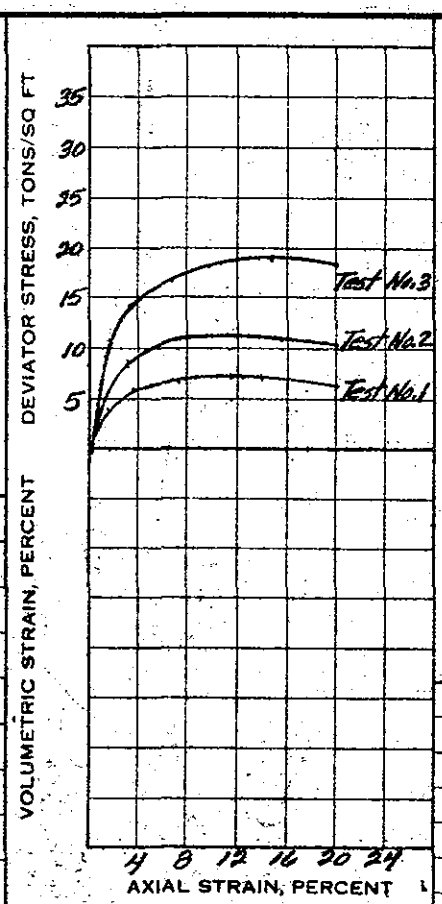
~~Elev or~~ Depth 3.4'-11.4' Date 8 May 1961

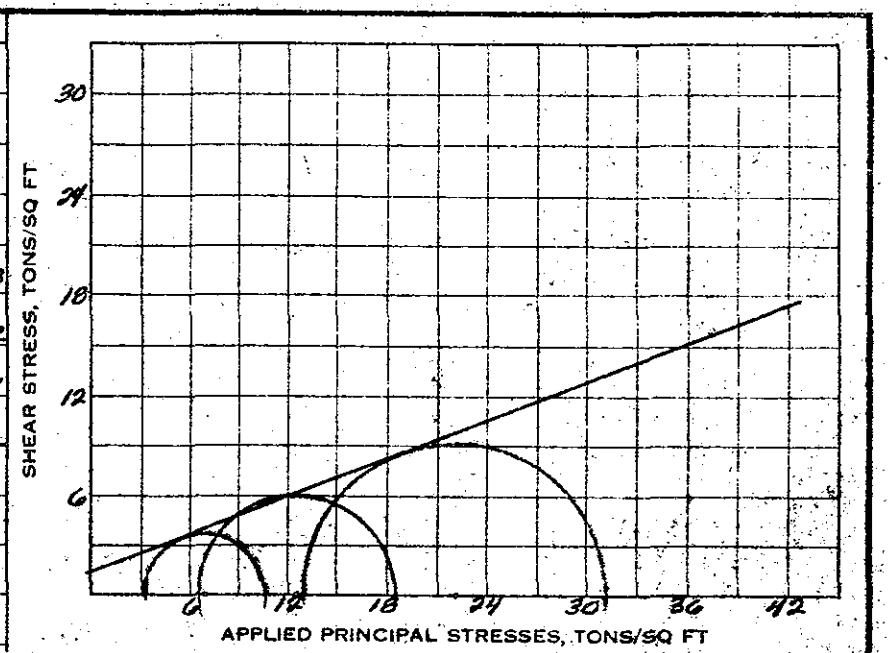
COMPACTION TEST REPORT

PLATE NO. B-2

ENG FORM 2001







	Test No.	1	2	3
INITIAL	Water Content, W_0 %	13.6	14.0	14.0
	Dry Density Lbs/Cu Ft	119.6	119.2	119.2
	Void Ratio, e_0	.461	.466	.466
	Saturation, S_0 %	82	84	84
BEFORE TEST	W.C. after Saturation, W_s %	—	—	—
	Saturation, S %	—	—	—
	Consol Pressure T/Sq Ft	—	—	—
	W.C. after Consol, W_c %	—	—	—
	Void Ratio after Consol, e_c	—	—	—
AT FAILURE	Maj Prin Stress, σ_1 T/Sq Ft	10.74	18.24	31.38
	Min Prin Stress, σ_{III} T/Sq Ft	3.24	6.18	12.96
	Water Content, W_f %	—	—	—
	Void Ratio, e_f	—	—	—
Specimen Diameter Inches		2.80	2.80	2.80
Initial Height Inc		6.10	6.10	6.10
Test Time to Failure Min		15.0	13.8	18.0

Type of Test
Constant Strain; 0.05 in/min
Control
Un Consolidated, Un Drained

Type of Specimen Remolded

ϕ = 20.9°	Tan ϕ = .382	c = 1.40 T/Sq Ft

Classification gray silty m-f SAND (SM)

LL 21	G 2.80
PL 20	D_{10} 0.0044

Remarks:

Samples remolded at optimum moisture plus 2% (13.9%) to density of 119.2 PCF as indicated by standard Proctor test.

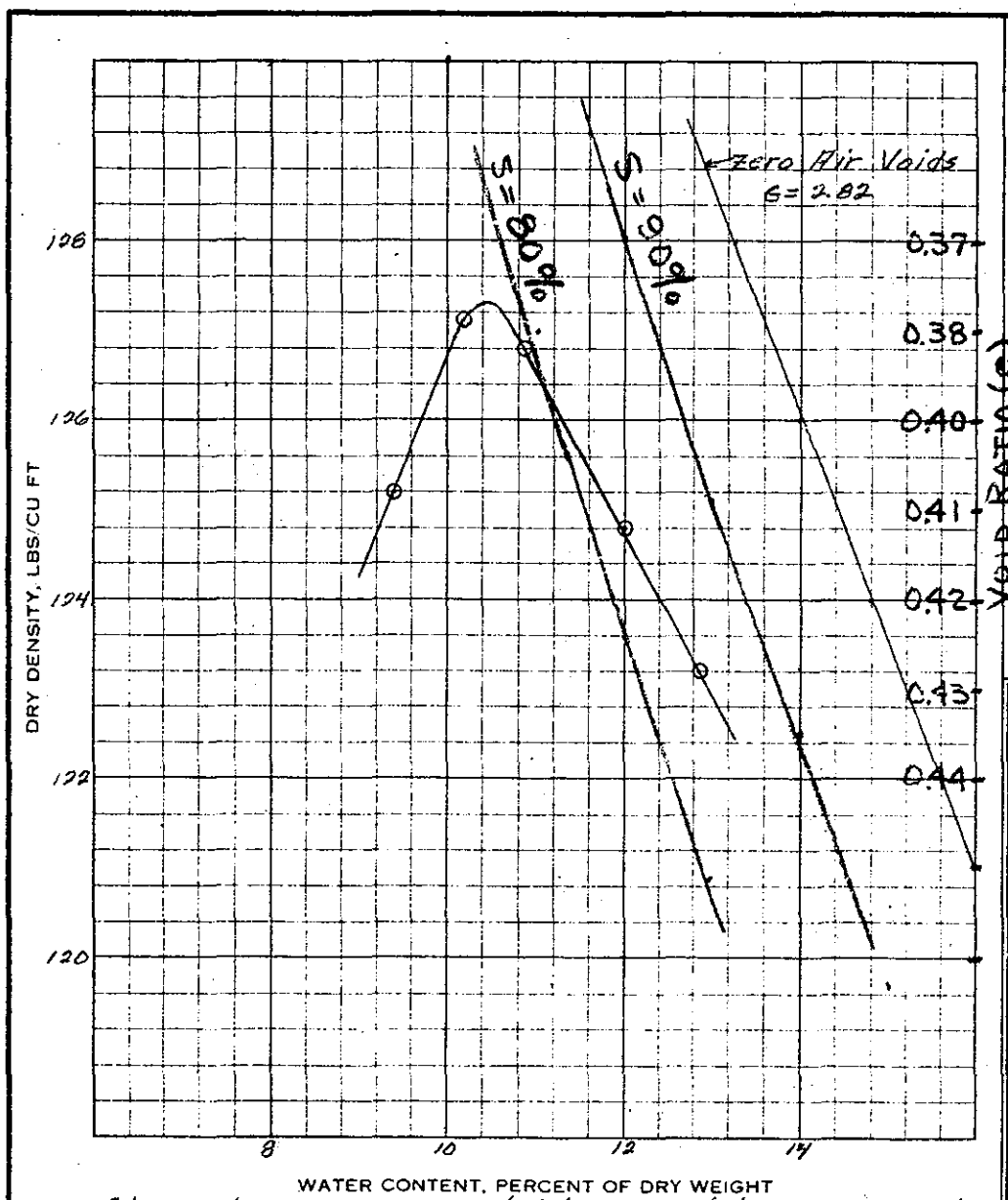
Project Littleville Dam

Area Impervious Borrow Area "B"

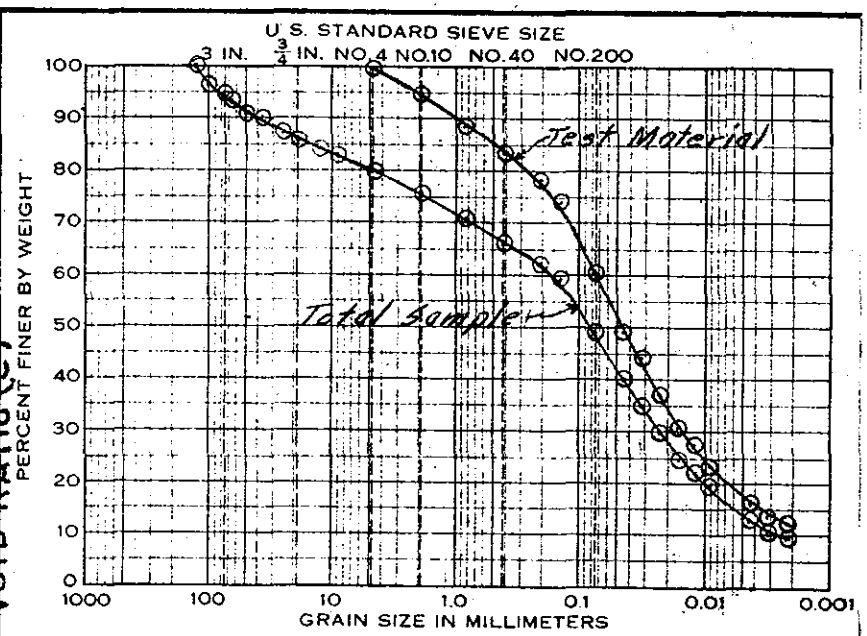
Boring No. BT-3 | Sample No. B-2

~~Elev or~~ Depth 9.4' - 11.4' | Date 23 May 1961

TRIAXIAL COMPRESSION TEST REPORT



Standard AASHO; compacted in 3 equal layers @ 25 blows per layer with 5.5# tamper. Height of drop equal to 12 inches. Maximum size particle, -#4 sieve.



COBBLES	GRAVEL		SAND			SILT OR CLAY
	Coarse	Fine	Coarse	Medium	Fine	

Sample No.	~~Elev or~~ Depth	Classification	G	LL	PL
B-11	11.4'-15.0'	grav. silty SAND (SM)	2.82	21	18

Sample No.	B-11			
Optimum Water Content %	10.5			
Max Dry Density Lbs/Cu Ft	127.3			
Optimum Water Content Corr for + %				
Max Density Corr for + Lbs/Cu Ft				

Project Littleville Dam

Area Impervious Borrow Area "B"

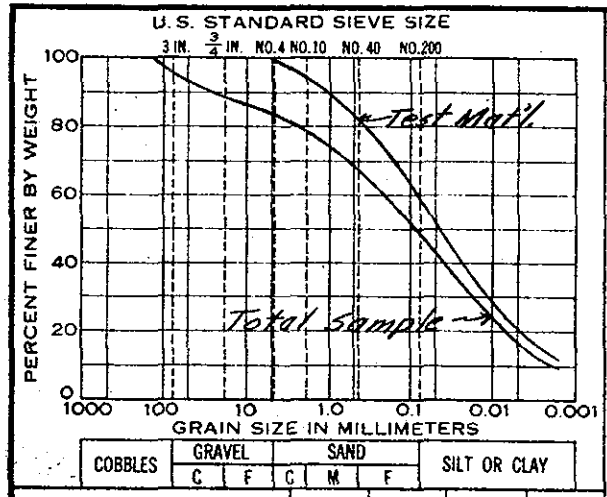
Boring No. BT-3 | Sample No. B-11

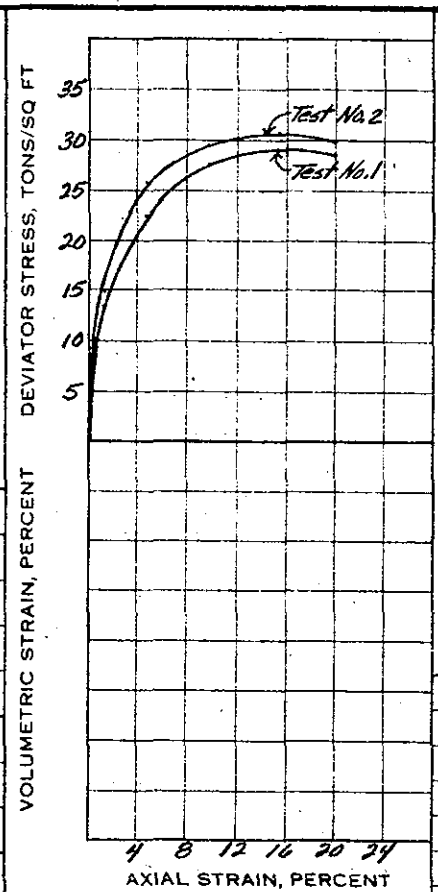
~~Elev or~~ Depth 11.4'-15.0' | Date 8 May 1961

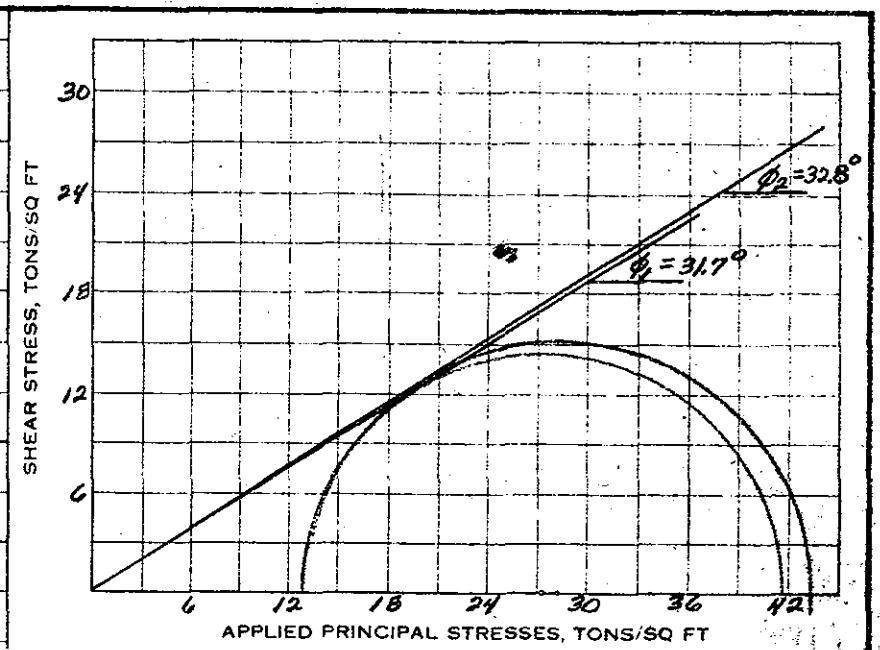
COMPACTION TEST REPORT

PLATE NO. B-4

ENG FORM DEC 52 2091







	Test No.	1	2		
INITIAL	Water Content, W_0 %	10.8	10.5		
	Dry Density Lbs/Cu Ft	127.0	127.4		
	Void Ratio, e_0	.385	.382		
	Saturation, S_0 %	79	78		
BEFORE TEST	W.C. after Saturation, W_s %	13.2	12.3		
	Saturation, S %	96	91		
	Consol Pressure T/Sq Ft	12.96	12.96		
	W.C. after Consol, W_c %	11.3	10.9		
	Void Ratio after Consol. e_c	.333	.341		
AT FAILURE	Maj Prin Stress, σ_I T/Sq Ft	41.70	43.63		
	Min Prin Stress, σ_{III} T/Sq Ft	12.96	12.96		
	Water Content, W_f %	11.0	10.6		
	Void Ratio, e_F	.324	.333		
Specimen Diameter Inches		2.80	2.80		
Initial Height Inr		6.10	6.10		
Test Time to Failure Min		158.0	158.0		

Type of Test
Constant strain; 0.006 in/min
Control
✕ Consolidated, ✕ Drained

Type of Specimen Remolded

ϕ = 31.7°	Tan ϕ = .619	c = 0.001 Sq Ft

Classification grav. silty SAND (SM)

LL 21	G 2.82
PL 18	D_{10} 0.0025

Remarks:
Sample remolded at optimum moisture (10.5%) to maximum density (127.3 Pcf) as indicated by standard Proctor Test.

Project Littleville Dam

Area Impervious Borrow Area "B"

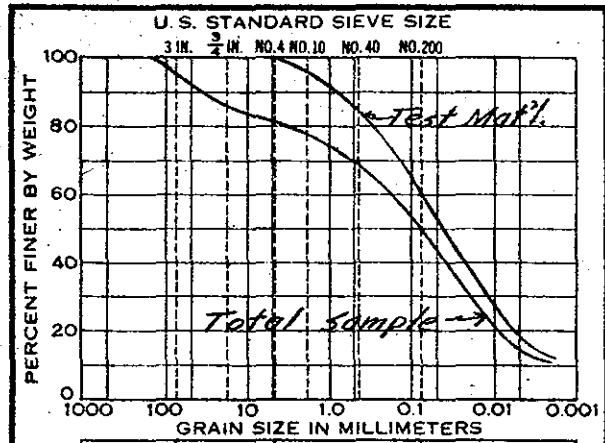
Boring No. BT-3 | Sample No. B-11

~~Elev or~~ Depth 11.4' - 15.0' | Date 1 June 1961

TRIAXIAL COMPRESSION TEST REPORT

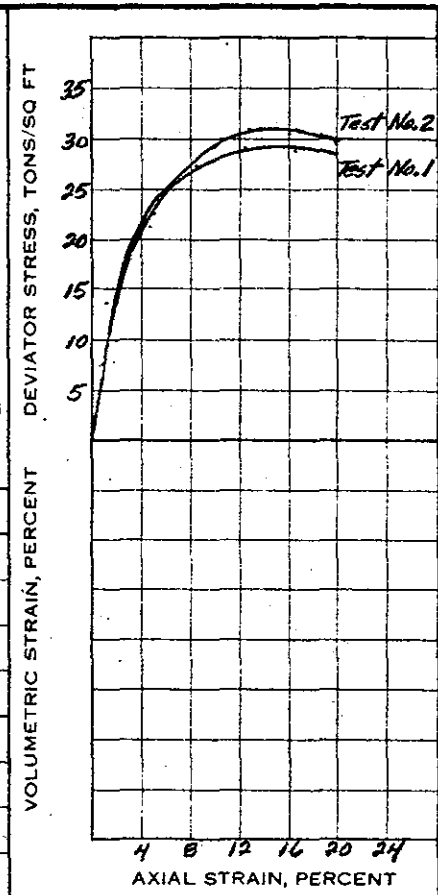
PLATE NO. B-5

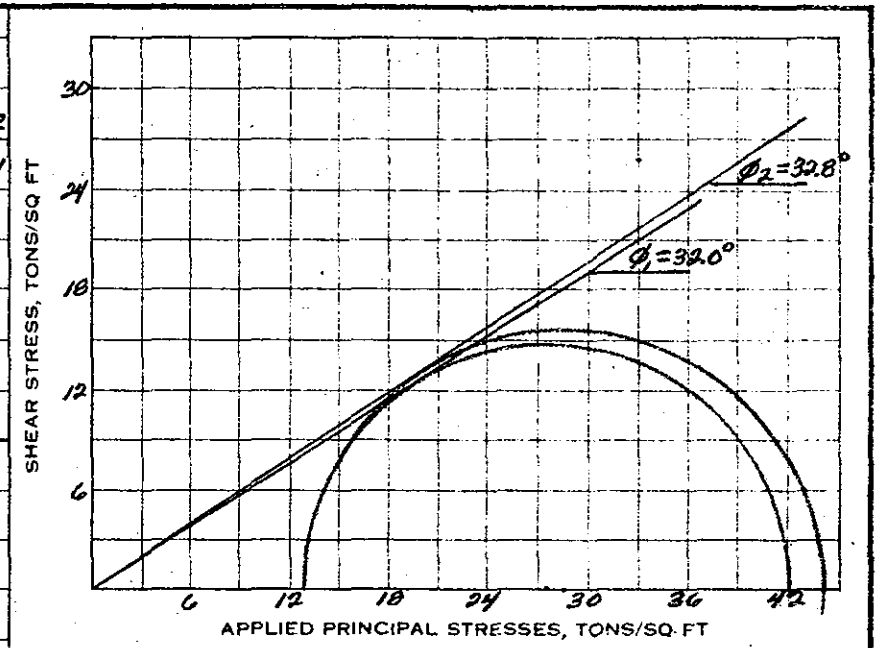
ENG FORM 1 Mar 61 2089



COBBLES	GRAVEL C	GRAVEL F	SAND C	SAND M	SAND F	SILT OR CLAY

	Test No.	1	2
INITIAL	Water Content, W_o %	12.2	12.5
	Dry Density Lbs/Cu Ft	124.1	124.0
	Void Ratio, e_o	.418	.419
	Saturation, S_o %	82	84
BEFORE TEST	W.C. after Saturation, W_s %	13.4	13.6
	Saturation, S %	91	91
	Consol Pressure T/Sq Ft	12.96	12.96
	W.C. after Consol, W_c %	11.8	12.0
	Void Ratio after Consol. e_c	.372	.375
AT FAILURE	Maj Prin Stress, σ_1 T/Sq Ft	42.19	43.78
	Min Prin Stress, σ_{3c} T/Sq Ft	12.96	12.96
	Water Content, W_f %	11.2	11.6
	Void Ratio, e_f	.356	.364
Specimen Diameter Inches		2.80	2.80
Initial Height Inc		6.10	6.11
Test Time to Failure Min		125.0	133.3





Remarks:

Samples remolded at optimum moisture plus 2% (12.5%) to density (123.9 Pcf) as indicated by standard Proctor test.

Type of Test
Constant Strain; 0.006 in/min
Control
x Consolidated, x Drained

Type of Specimen Remolded

ϕ = 32.0°	Tan ϕ = .626	c = 0.0 T/Sq Ft

Classification grav. silty SAND (SM)

LL 21	G 2.82
PL 18	D_{10} 0.0025

Project Littleville Dam

Area Impervious Borrow Area "B"

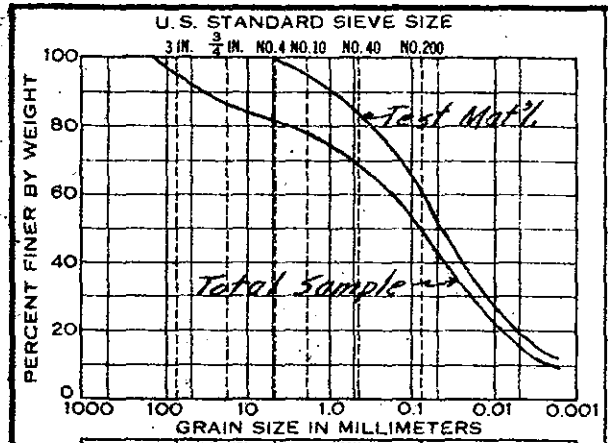
Boring No. BT-3 | Sample No. B-11

~~Elev or~~ Depth 11.4' - 15.0' | Date 5 June 1961

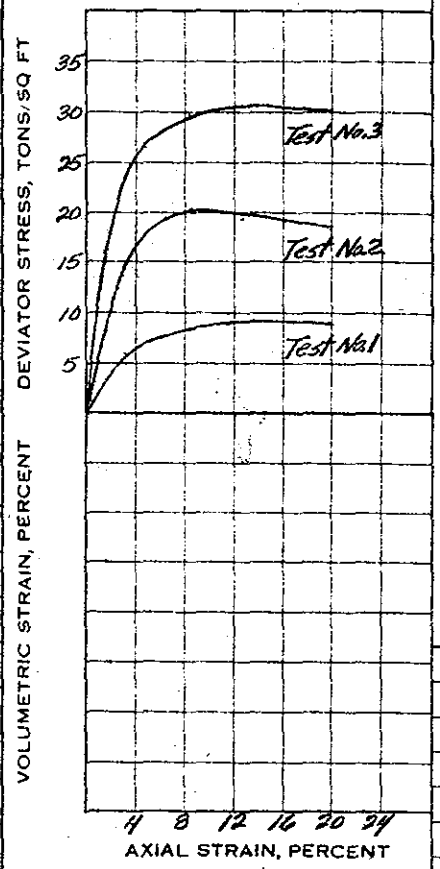
TRIAXIAL COMPRESSION TEST REPORT

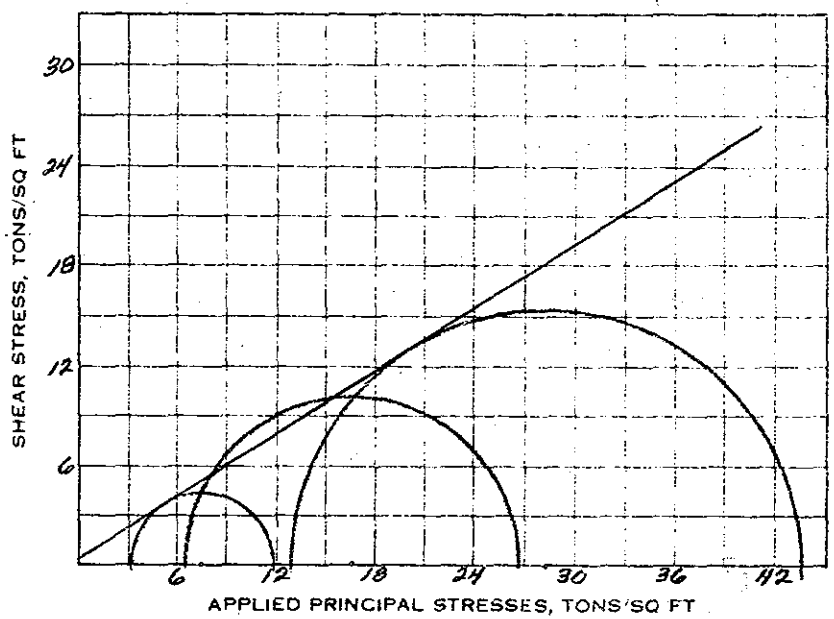
PLATE NO. B-6

ENG FORM 1 DEC 53 2089



COBBLES	GRAVEL C	GRAVEL F	SAND C	SAND M	SAND F	SILT OR CLAY





	Test No.	1	2	3
INITIAL	Water Content, W_0 %	10.6	10.5	10.7
	Dry Density Lbs/Cu Ft	127.3	127.4	127.2
	Void Ratio, e_0	.380	.382	.384
	Saturation, S_0 %	79	78	79
BEFORE TEST	W.C. after Saturation, W_S %	13.0	13.0	12.1
	Saturation, S %	98	96	91
	Consol Pressure T/Sq Ft	3.24	6.48	12.96
	W.C. after Consol, W_c %	12.0	11.6	10.8
	Void Ratio after Consol, e_c	.345	.343	.339
AT FAILURE	Maj Prin Stress, σ_1 T/Sq Ft	11.71	26.65	43.58
	Min Prin Stress, σ_m T/Sq Ft	3.24	6.48	12.96
	Water Content, W_f %	12.0	11.6	10.8
	Void Ratio, e_f	.345	.343	.339
Specimen Diameter Inches		2.80	2.80	2.80
Initial Height Inc		6.10	6.10	6.10
Test Time to Failure Min		52.5	27.5	45.0

Type of Test
Constant Strain; 0.02 in/min
Control
x Consolidated, Un Drained

Type of Specimen Remolded

ϕ = 32.8°	Tan ϕ = .643	c = .95 T/Sq Ft

Classification grav. silty SAND (SM)

LL 21	G 2.82
PL 18	D_{10} 0.0025

Remarks:
Samples remolded at optimum moisture (10.5%) to maximum density (127.3 Pcf) as indicated by standard Proctor test.

Project Littleville Dam

Area Impervious Borrow Area "B"

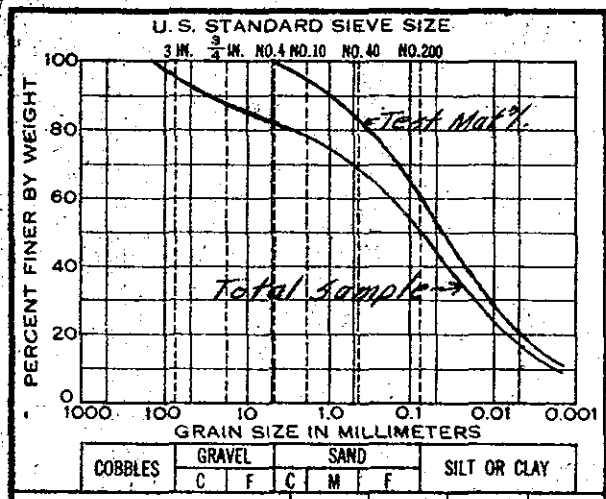
Boring No. BT-3 | Sample No. B-11

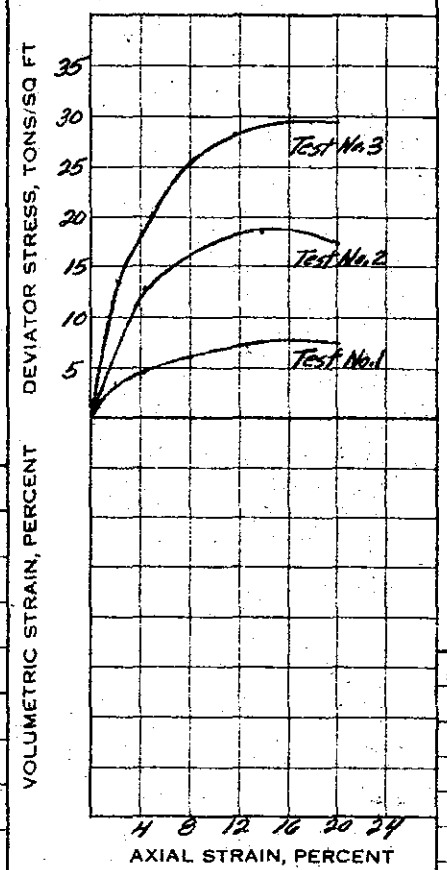
~~Elev or~~ Depth 11.4' - 15.0' | Date 15 May 1961

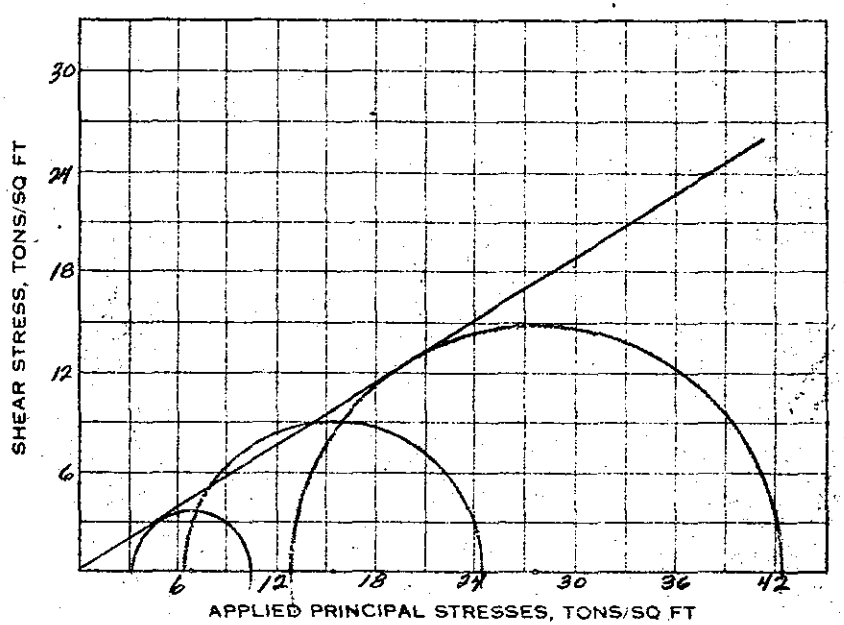
TRIAXIAL COMPRESSION TEST REPORT

PLATE NO. B-1

ENG FORM 1 DEC 52 2089







	Test No.	1	2	3
INITIAL	Water Content, W_o %	12.6	12.5	12.6
	Dry Density Lbs/Cu Ft	123.9	123.9	123.9
	Void Ratio, e_o	.420	.420	.420
	Saturation, S_o %	85	85	85
BEFORE TEST	W.C. after Saturation, W_s %	13.2	13.5	13.6
	Saturation, S %	90	91	91
	Consol Pressure T/Sq Ft	3.24	6.48	12.96
	W.C. after Consol, W_c %	12.4	11.8	11.0
	Void Ratio after Consol, e_c	.393	.383	.367
AT FAILURE	Maj Prin Stress, σ_1 T/Sq Ft	10.81	24.78	42.59
	Min Prin Stress, σ_m T/Sq Ft	3.24	6.48	12.96
	Water Content, W_f %	12.4	11.8	11.0
	Void Ratio, e_f	.393	.383	.367
Specimen Diameter Inches		2.80	2.80	2.80
Initial Height Inc		6.10	6.10	6.10
Test Time to Failure Min		57.5	42.5	55.0

Type of Test
Constant Strain; 0.02 in/min.
Control
X Consolidated, Un Drained

Type of Specimen Remolded

ϕ = 32.4°	Tan ϕ = .632	c = .08 T/Sq Ft

Classification gray. silty SAND (SM)

LL 31	G 2.82
PL 18	D_{10} 0.0025

Remarks:
Samples remolded at optimum moisture plus 2 percent (12.5%) to density of 123.9 Pcf as indicated by standard Proctor test.

Project Littleville Dam

Area Impervious Borrow Area "B"

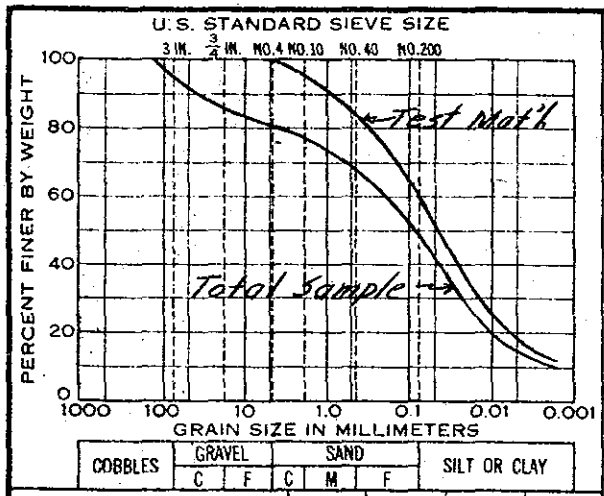
Boring No. BT-3 | Sample No. B-11

~~Elev or~~ Depth 11.4' - 15.0' | Date 15 May 1961

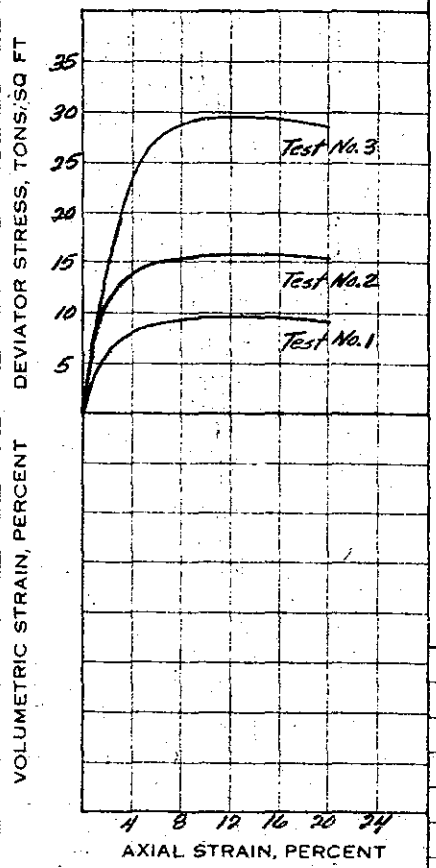
TRIAXIAL COMPRESSION TEST REPORT

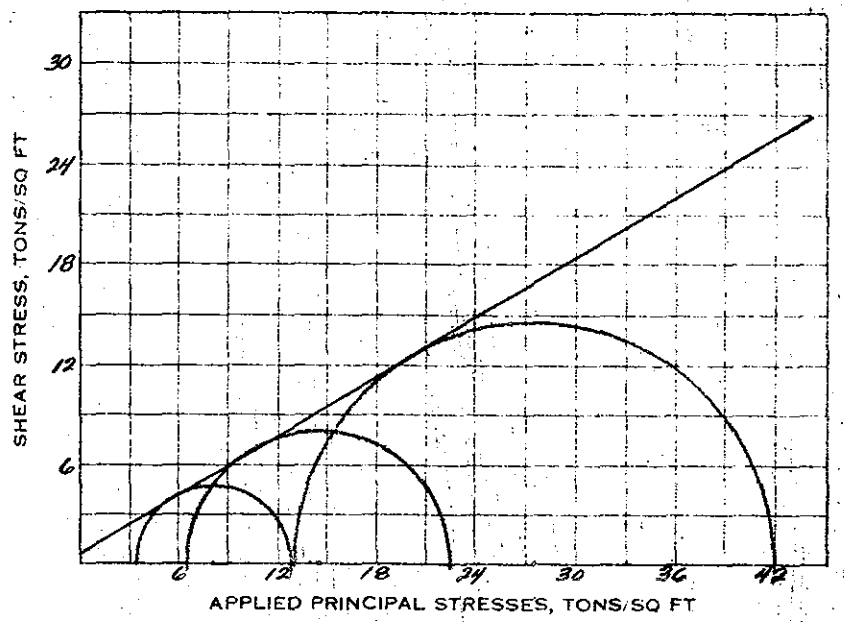
ENG FORM 1 DEC 51 2089

PLATE NO. B-8



	Test No.	1	2	3
INITIAL	Water Content, W_0 %	10.5	10.4	10.2
	Dry Density Lbs/Cu Ft	122.3	122.4	122.5
	Void Ratio, e_0	.384	.381	.380
	Saturation, S_0 %	77	77	76
BEFORE TEST	W.C. after Saturation, W_s %	—	—	—
	Saturation, S %	—	—	—
	Consol Pressure T/Sq Ft	—	—	—
	W.C. after Consol, W_c %	—	—	—
	Void Ratio after Consol e_c	—	—	—
AT FAILURE	Maj Prin Stress, σ_1 T/Sq Ft	12.61	22.46	41.98
	Min Prin Stress, σ_{III} T/Sq Ft	3.24	6.48	12.96
	Water Content, W_F %	—	—	—
	Void Ratio, e_F	—	—	—
Specimen Diameter Inches		2.80	2.80	2.80
Initial Height Inr		6.10	6.10	6.10
Test Time to Failure Min		12.0	14.8	15.0





Remarks:

Samples remolded at optimum moisture (10.5 %) to maximum density (122.3 P.C.F.) as indicated by standard Proctor test.

Type of Test

Constant Strain; 0.05 in/min Control

Un Consolidated, Un Drained

Type of Specimen Remolded

ϕ = 30.5°	Tan ϕ = .589	c = .77 T/Sq Ft

Classification grav. silty SAND (SM)

LL	21	G	2.82
PL	18	D_{10}	0.0025

Project Littleville Dam

Area Impervious Borrow Area "B"

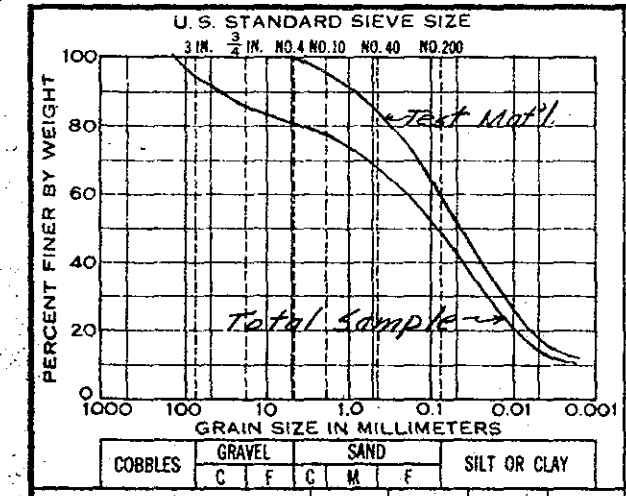
Boring No. BT-3 | Sample No. B-11

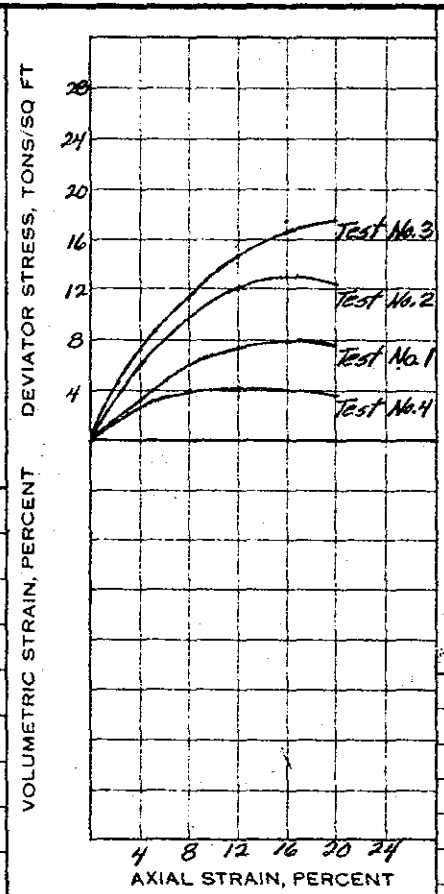
~~Elev or~~ Depth 11.4' - 15.0' | Date 15 May 1961

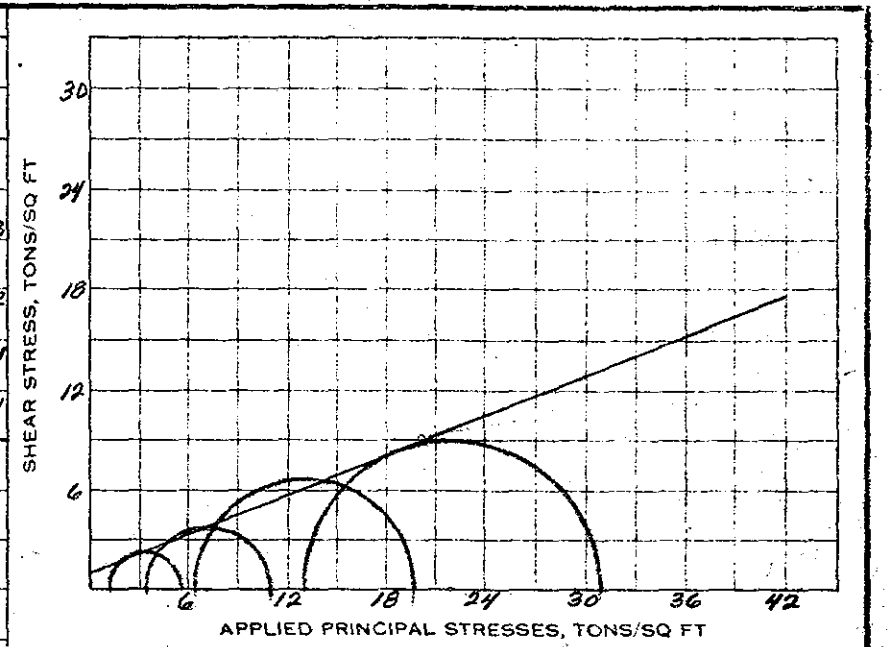
TRIAXIAL COMPRESSION TEST REPORT

PLATE NO. B-9

ENG FORM 1 DEC 53 2089







	Test No.	1	2	3	4
INITIAL	Water Content, W_0 %	12.5	12.4	12.3	12.4
	Dry Density Lbs/Cu Ft	124.0	124.8	123.8	124.1
	Void Ratio, e_0	.419	.410	.421	.418
	Saturation, S_0 %	84	85	82	84
BEFORE TEST	W.C. after Saturation, W_s %	–	–	–	–
	Saturation, S %	–	–	–	–
	Consol Pressure T/Sq Ft	–	–	–	–
	W.C. after Consol, W_c %	–	–	–	–
	Void Ratio after Consol, e_c	–	–	–	–
AT FAILURE	Maj Prin Stress, σ_1 T/Sq Ft	11.24	19.74	30.79	5.30
	Min Prin Stress, σ_{III} T/Sq Ft	3.24	6.48	12.96	1.08
	Water Content, W_F %	–	–	–	–
	Void Ratio, e_F	–	–	–	–
Specimen Diameter Inches		2.80	2.80	2.80	2.80
Initial Height Inc		6.10	6.10	6.10	6.10
Test Time to Failure Min		19.3	21.3	24.0	12.0

Type of Test
Constant Strain; 0.05 in/min.
Control
Un Consolidated, Un Drained

Type of Specimen Remolded

ϕ = 21.6°	Tan ϕ = .395	c = 1.0 T/Sq Ft

Classification grav. silty SAND (SM)

LL 21	G 2.82
PL 18	D_{10} 0.0025

Remarks:
Samples remolded at optimum moisture plus 2% (12.5%) to density (123.9 PCF) as indicated by standard Proctor test.

Project Littleville Dam

Area Impervious Borrow Area "B"

Boring No. BT-3 | Sample No. B-11

~~Elev or~~ Depth 11.4' - 15.0' | Date 5 June 1961

TRIAXIAL COMPRESSION TEST REPORT

PLATE NO. B-10

ENG FORM 1 DEC 51 2089

APPENDIX D
ENGINEERING LOGS OF SOILS EXPLORATIONS
LITTLEVILLE DAM

LEGEND

mod.	moderately
v.	very
comp.	compact
w/	with
f.	fine
m	medium
c	coarse
m-f	medium to fine
SM	Soil Symbol, Unified Soil Classification System
w_n	Natural water content of sample except for certain soils containing gravel for which w_n represents the water content of that part of the sample from which portions of the coarse gravel sizes have been removed.
w_4	Natural water content determined for that portion of the soil passing the No. 4 U. S. Standard sieve.
γ_d	Natural Dry Density (pcf)

LEGEND Cont'd

D_{10}	Effective grain size in millimeters
LL	Atterberg Liquid Limit
PI	Atterberg Plasticity Index
G_s	Specific Gravity
26	A single numeral following a soil component in the description of a soil represents the percentage, by weight, of that component in the soil as determined by a mechanical analysis.
(25-35)	A range of numbers in parentheses following a soil component in the description of a soil, represents the estimated limits between which lies the percentage, by weight, of that component in the soil as determined by visual inspection.
(.04)	Single numeral in parentheses represent estimated values of D_{10}, LL, and PI.

FD-1 Elev. 553.2

0.0' - 0.5'	Forest debris
0.5' - 3.2'	Brown, loose, silty (30-40) sand, SM, w/roots.
3.2' - 8.9'	Brown, comp., gravelly 39 silty 16 sand, SM, w/cobbles.
8.9' - 10.8'	Brown, comp., silty 41 m-f sand, SM, D_{10} = 0.015
10.8' - 25.0'	Brown, comp., gravelly 20 silty 25 sand, SM, w/cobbles
25.0' - 26.4'	Brown, comp., sandy (fine) 40 silt, ML
26.4' - 29.6'	Brown, comp., gravelly (15-25) silty (20-30) sand, SM
29.6' - 32.7'	Brown, mod. comp., silty 11 m-f sand, SP-SM
32.7' - 37.0'	Gray brown, comp., gravelly 13 silty 37 m-f sand, SM
37.0' - 38.7'	Gray brown, comp., silty 48 fine sand, SM
38.7' - 39.7'	Brown, comp., gravelly (5-15) silty (15-25) sand, SM, w/cobbles
39.7' - 46.9'	Cobbles & boulders embedded in soil
46.9' - 50.4'	Decomposed bedrock
50.4'	Refusal

FD-2 Elev. 530±

0.0' - 0.6'	Forest debris
0.6' - 2.2'	Black, loose, silty (25-35) sand, SM, w/organics
2.2' - 14.2'	Gray, mod. comp., gravelly 20 to 34 silty 32 to 29 sand, SM, Till, (D_{10} = 0.018, 0.014) w/cobbles & decomposed rock fragments
14.2'	Top of bedrock

FD-3 Elev. 534.0

0.0' - 0.5'	Black, Topsoil
0.5' - 11.2'	Gray, loose to mod. comp., gravelly 18 to 11 silty 39 to 41 m-f sand, SM, Till, w/cobbles, D_{10} = 0.015, 0.014
11.2'	Top of bedrock

FD-4 Elev. 536.0

0.0' - 0.5'	Black Topsoil
0.5' - 3.0'	Brown, loose, silty (20-30) m-f sand, SM, w/roots
3.0 - 5.0'	Brown, mod. comp., gravelly 22 silty 38 m-f sand, SM. D_{10} = 0.031
5.0' - 7.0	Brown, mod. comp., micaceous, silty (35-45) sand, SM
7.0' - 8.6'	Gray brown, mod. comp., silty 42 sand, SM
8.6'	Top of bedrock

FD-5 Elev. 439.6

0.0' - 1.0'	Brown, loose, silty (25-35) fine sand, SM, w/roots
1.0' - 5.0'	Brown, loose, silty 12 fine sand, SP-SM, w/roots & boulders. D_{10} = 0.07
5.0' - 10.0'	Cobbles & boulders embedded in soil
10.0' - 15.0'	Gray, brown, comp., gravelly (15-25) silty (15-25) sand, SM, w/cobbles
15.0' - 18.4'	Gray, comp., sandy (25-35) gravel, GP, w/cobbles
18.4' - 25.0'	Cobbles & boulders embedded in soil
25.0' - 28.4'	Gray brown, comp., silty (5-15) sandy (30-40) gravel, GM
28.4' - 33.1'	Gray, v. comp., gravelly 22 silty 36 m-f sand, SM, Till, w/cobbles
33.1' - 39.0'	Cobbles & boulders embedded in soil
39.0' - 40.0'	Gray, comp., silty (30-40) sand, SM, Till
40.0' - 42.8'	Gray, comp., gravelly 22 silty 37 sand, SM, Till, w/cobbles, D_{10} = 0.0085
42.8' - 45.0'	Gray, comp., gravelly (30-40) silty (5-10) sand, SP-SM
45.0' - 47.8'	Gray, comp., silty (0-10) sandy (10-15) gravel, GP
47.8' - 50.7'	Cobbles & boulders embedded in soil
50.7'	Top of bedrock.

FD -6 Elev. 501.3

0.0' - 0.5'	Topsoil
0.5' - 3.0'	Brown, loose, silty (30-40) m-f sand, SM
3.0' - 15.0'	Gray brown, loose to mod. comp., gravelly 32 silty 16 sand, SM, w/cobbles, D_{10} = 0.043
15.0' - 19.0'	Gray brown, comp., silty 14 sandy 40 gravel, GM, w/cobbles
19.0' - 20.0'	Brown, mod. comp., silty (15-25) m-f sand, SM
20.0' - 25.0'	Gray brown, comp., silty (30-40) m-f sand, SM, w/cobbles
25.0' - 35.0'	Gray brown, comp. to v. comp., gravelly 6 sandy (m-f) 38 Silt, ML Till, w/cobbles D_{10} = 0.015
35.0' - 40.0'	Gray brown, comp., gravelly 4 sandy (m-f) 43 silt, ML, Till D_{10} = 0.0038
40.0' - 50.0'	Gray, comp., gravelly (0-10) to (10-15) silty (30-40) m-f sand, SM, Till, w/cobbles
50.0' - 58.4'	Gray, comp. to v. comp. gravelly 7 sandy (m-f) 41 silt, ML, Till, w/cobbles, D_{10} = 0.0026
58.4' - 65.0'	Cobbles & boulders embedded in soil
65.0' - 70.0'	Gray, comp. gravelly (10-20) silty (30-40) m-f sand, SM, Till, w/cobbles & boulders
70.0' - 75.0'	Gray, comp. to v. comp. gravelly 5 silty 47 m-f sand, SM, Till, w/cobbles D_{10} = 0.0026
75.0' - 76.7'	Gray, comp. to v. comp., gravelly (20-30) silty (25-35) m-f sand, SM Till, w/cobbles
76.7' - 85.0'	Cobbles & boulders embedded in soil
85.0' - 92.8'	Gray, comp. to v. comp., gravelly 9 silty 37 m-f sand, SM, Till, w/cobbles & boulders, D_{10} = 0.0098
92.8' - 97.7'	Cobbles & boulders embedded in soil

FD-6 Continued

97.7' - 100.0'	Gray, comp., gravelly (25-35) silty (5-10) sand, SP-SM
100.0' - 101.1'	Gray, comp. to v. comp., gravelly (10-20) silty (20-30) sand, SM, Till, w/cobbles
101.0' - 105.6'	Cobbles & boulders embedded in soil
105.6'	Top of Bedrock

FD -7 Elev. 517.0

0.0' - 0.5'	Topsoil
0.5' - 3.0'	Brown, loose, gravelly (25-35) silty (15-25) sand, SM, w/roots
3.0' - 7.3'	Brown, loose to mod. comp., gravelly (35-45) to (30-40) silty (5-15) sand, SM w/cobbles & boulders
7.3' - 13.0'	Boulders & cobbles embedded in soil
13.0' - 15.0'	Gray brown, mod. comp., gravelly 29 silty 39 m-f sand, SM, Till, D_{10} = 0.011
15.0' - 20.0'	Gray brown, mod. comp., gravelly 5 sandy 28 silt, ML, Till, w/cobbles, D_{10} = 0.0049
20.0' - 25.0'	Gray, mod. comp., silty (35-45) m-f sand, SM, Till
25.0' - 30.0'	Gray, comp., gravelly (25-35) silty (20-30) sand, SM, Till, w/boulders
30.0' - 40.0'	Gray, comp., gravelly 21 silty 36 sand, SM, Till, w/cobbles & boulders, D_{10} = 0.007
40.0' - 43.0'	Gray, comp., gravelly (30-40) silty (5-15) sand, SP-SM
43.0' - 51.8'	Gray, comp., gravelly 19 silty 38 sand, SM, Till, w/cobbles & boulders, D_{10} = 0.006
51.8' - 60.0'	Cobbles & boulders embedded in gravelly soil
60.0' - 62.7'	Gray, comp., gravelly (20-30) silty (15-25) sand, SM, Till, w/cobbles & boulders
62.7' - 68.3'	Boulders embedded in soil
68.3' - 69.3'	Decomposed rock
69.3' -	Probable top of bedrock

FD-8 Elev. 533.3

0.0' - 2.2'	Brown, loose, m-f sandy (30-40) silt, ML, w/roots
2.2' - 5.0'	Gray brown, mod. comp., gravelly 9 silty 36 sand, SM, Till. D_{10} = 0.018
5.0' - 6.4'	Gray, mod. comp., gravelly (10-15) silty (25-35) sand, SM, Till
6.4' - 7.7'	Gray brown, mod. comp., silty (15-25) sandy (25-35) gravel, GM, Till
7.7' - 7.9'	Brown, mod. comp., silty (20-30) m-f sand, SM
7.9' - 13.9'	Boulders & cobbles embedded in soil
13.9' - 20.0'	Gray brown, comp., gravelly 14 silty 20 sand, SM, Till, w/cobbles & boulders D_{10} = 0.05, W_n = 11.8, W_4 = 13.8
20.0' - 25.0'	Gray, comp. to v. comp., silty (15-25) sandy (30-40) gravel, GM, Till & gravelly 30 to (10-20) silty 28 sand, SM, Till, w/cobbles D_{10} = 0.024, W_n = 9.6, W_4 = 13.8
25.0' - 30.2'	Gray, comp. to v. comp. gravelly 15 silty 29 sand, SM, Till, w/cobbles D_{10} = 0.021, W_n = 6.6, W_4 = 7.7
30.2' - 35.0'	Gray, v. comp., silty 32 m-f sand, SM, Till, D_{10} = 0.24, W_n = 14.1, W_4 = 14.6
35.0' - 49.0'	Boulders & Cobbles and weathered cobbles & boulders embedded in soil
49.0'	Top of bedrock

FD-9 Elev. 557.0

0.0' - 0.5'	Forest debris
0.5' - 3.0'	Brown, loose, sandy(m-f 35-45) silt, ML, w/organics
3.0' - 5.0'	Gray brown, mod. comp., gravelly (25-35) silty (15-25) sand, SM, Till, w/cobbles
5.0' - 10.0'	Gray brown, mod. comp., gravelly 15 silty 37 sand, SM, Till w/cobbles D_{10} = 0.02, W_n = 6.2, W_4 = 7.3

FD-9 Continued

10.0' - 12.7'	Gray brown, mod. comp., silty 18 sandy 38 gravel, GM, Till, w/cobbles. D_{10} = 0.053 W_n = 10.2, W_4 = 18.2
12.7' - 17.9'	Boulders & cobbles embedded in soil.
17.9' - 20.2'	Gray brown, mod. comp., gravelly 8 silty 30 m-f sand, SM, Till, w/weathered rock & cobbles. D_{10} = 0.03, W_n = 15.4, W_4 = 16.7
20.2' - 21.2'	Gray brown, mod. comp., gravelly (30-40) silty (15-20) sand, SM, w/weathered rock
21.2'	Top of bedrock

FD-10 Elev. 575.0

0.0' - 0.8'	Topsoil
0.8' - 1.6'	Brown, loose, silty (25-35) m-f sand, SM, Till
1.6' - 3.6'	Gray brown, mod. comp., silty (20-30) m-f sand, SM, Till, w/cobbles
3.6' - 10.0'	Gray brown, mod. comp., gravelly 12 to 23 silty 39 to 34 m-f sand, SM, Till, w/cobbles D_{10} = 0.01, 0.013 W_n = 12.1 W_4 = 15.0
10.0' - 15.0'	Gray brown, mod. comp., gravelly 17 silty 25 sand, SM, Till, w/cobbles D_{10} = 0.024, W_n = 14.6
15.0' - 16.6'	Gray brown, mod. comp., gravelly 35 silty 23 m-f sand, SM, Till, w/weathered cobbles, D_{10} = 0.034, W_n = 21.3
16.6	Top of bedrock

FD-11 Elev. 604.0

0.0' - 1.2'	Topsoil
1.2' - 3.0'	Brown, loose, silty (20-30) m-f sand, SM, Till, w/roots
3.0' - 5.2'	Gray brown, loose, gravelly (10-30) silty (15-30) m-f sand, SM, Till
5.2'	Top of bedrock

FD-12 Elev. 440.4

0.0' - 2.3'	Dark brown, loose, gravelly (0-10) silty (5-15) m-f sand, SP-SM, w/organics
2.3' - 5.0'	Brown, loose to mod. comp., silty (5-15) sandy (35-45) gravel, GP-GM
5.0' - 10.0'	Brown, comp., sandy (18) gravel, GP w/cobbles, D_{10} = 0.51
10.0' - 20.0'	Brown, comp., sandy 37 gravel, GP, w/cobbles, D_{10} = 0.14, W_n = 18.1, W_4 = 21.7, G_s = 2.86
20.0' - 25.0'	Brown, comp., sandy (26) gravel, GP, w/cobbles, D_{10} = 0.4
25.0' - 30.0'	Brown, comp. to v. comp., silty (5-15) sandy (35-45) gravel, GP-GM, Till
30.0' - 35.0'	Brown, comp. to v. comp., gravelly (38) silty (12) sand, SM, Till, w/cobbles
35.0' - 40.0'	Gray, comp., silty (8) sandy (38) gravel, GP-GM, w/cobbles, D_{10} = 0.1
40.0' - 45.0'	Gray, stiff, gravelly 5 sandy 16 silt, ML, D_{10} = 0.0025, LL = 29, PI = 3
45.0' - 54.0'	Cobbles & boulders embedded in gravelly soil
54.0'	Top of bedrock

FD-13 Elev. 442.8

0.0' - 1.0'	Topsoil
1.0' - 3.7'	Dark brown, loose, F. sandy (25-35) silt, ML, w/roots

FD-13 Continued

3.7' - 5.0'	Dark brown, loose, gravelly (5-15) silty (20-30) F. sand, SM
5.0' - 6.2'	Dark brown, loose, silty (20-30) m-f sand, SM
6.2' - 7.0'	Dark brown, loose, silty (5-15) sandy (35-45) gravel, GP-GM
7.0' - 10.0'	Brown, loose, gravelly 34 silty 9 sand, SP-SM D_{10} = 0.091, W_n = 17.5, W_4 = 21.5
10.0' - 15.0'	Brown, mod. comp., silty 16 m-f sand SM, W_n = 26.7 G_s = 2.74
15.0' - 20.0'	Brown, mod. comp., silty 40 m-f sand, SM, w/occasional silt strata 1/2"-3½" thick
20.0' - 25.0'	Brown, mod. comp., silty (15-25) f. sand, SM
25.0' - 34.0'	Brown, mod. comp., silty 12 sandy 41 gravel, GM, w/boulders & mica
34.0' - 39.0'	Brown, comp., silty 10 sandy 43 gravel, GP-GM, Till D_{10} = 0.074
39.0' - 41.0'	Gray brown, comp., gravelly (25-35) silty (15-25) sand, SM, Till, W_n = 9.2, W_4 = 12.6
41.0' - 48.0'	Gray brown, comp., silty 9 sandy 36 gravel GP-GM, w/boulders, D_{10} = 0.091, W_n = 6.7, W_4 = 16.9
48.0' - 50.8'	Brown, comp., silty (5-15) sandy (20-30) to (25-35) gravel, GP-GM, w/boulders
50.8	Top of bedrock

FD-14 Elev. 546.9

0.0' - 0.5'	Topsoil & forest debris
0.5' - 1.3'	Brown, loose, silty (35-45) F. sand, SM, w/roots
1.3' - 11.9'	Gray brown, mod. comp. to comp., gravelly 22 silty 25 sand, SM, w/cobbles, w/ weathered rock 10.0' to 11.9'
11.9'	Top of bedrock

FD-15 Elev. 453.3

0.0' - 0.4'	Topsoil
0.4' - 1.2'	Brown, loose, gravelly (5-15) silty (20-30) m-f sand, SM, w/roots
1.2' - 5.0'	Gray brown, mod. comp., gravelly 41 silty 13 sand, SM, w/cobbles
5.0' - 6.2'	Gray brown, mod. comp., gravelly (10-20) silty (15-25) m-f sand, SM w/cobbles
6.2' - 13.6'	Weathered cobbles & boulders embedded in soil
13.6' - 19.0'	Gray, mod. comp. to comp., silty (20-30) m-f sand, SM, Till, w/boulders & weathered rock
19.0'	Top of bedrock

FD-16 Elev. 440.6

0.0' - 0.4'	Topsoil & forest debris
0.4' - 5.0'	Brown, loose, silty (10-20) m-f sand, SM, w/roots & mica
5.0' - 9.0'	Brown, comp., silty 5 sandy 26 gravel, GP-GM, w/cobbles & boulders D_{10} = 0.17
9.0' - 10.0'	Brown, comp., gravelly (30-40) silty (5-15) sand SP-SM, w/cobbles
10.0' - 15.0'	Brown, comp., gravelly 32 silty 13 sand, SM w/cobbles & mica
15.0' - 20.0'	Brown, comp., silty (10-20) sandy (30-40) gravel, GM w/cobbles & Mica
20.0' - 30.0'	Brown, comp., gravelly (30-40) silty (5-15) sand, SP-SM, w/cobbles
30.0' - 35.0'	Dark brown, comp., silty 18 sandy 36 gravel, GM, w/cobbles
35.0' - 40.0'	Gray brown, comp., silty (5-15) sandy (30-40) gravel, GP-GM, w/cobbles
40.0' - 53.5'	Gray brown, comp., silty 7 sandy 34 gravel, GP-GM, w/cobbles & mica, D_{10} = 0.13
53.5'	Top of bedrock

FD-17 Elev. 470.0

0.0' - 1.0'	Topsoil
1.0' - 5.0'	Dark brown, loose, gravelly (25-35) silty (5-15) sand, SP-SM, w/cobbles
5.0' - 22.0'	Brown, mod. comp. to comp., micaeous silty 11 sandy 33 gravel, GP-GM, Till, w/cobbles, D_{10} = 0.07
22.0' - 29.2'	Gray brown, comp., gravelly, (40) to (20-30) silty (18) sand, SM, Till, w/cobbles, D_{10} = 0.034
29.2' - 33.5'	Gray, stiff, gravelly 6 sandy 27 clay, CL w/cobbles, from 29.2 to 30.0', LL = 38, PI = 14
33.5' - 37.0'	Gray brown, comp., silty (25-35) m-f sand, SM
37.0' - 40.0'	Gray brown, mod. comp., silty (30-40) F. sand, SM, w/clay strata hairline to 1/8"
40.0' - 47.6'	Gray brown, comp., gravelly 30 silty 22 sand, SM, Till, w/cobbles & boulders, D_{10} = 0.025
47.0' - 49.0'	Gray brown, comp. to v. comp., gravelly (5-15) silty (10-20) sand, SM, Till, w/cobbles & boulders
49.0' - 53.0'	Gray brown, comp. gravelly 42, silty 11 sand, SP-SM, Till, w/cobbles & boulders, D_{10} = 0.068
53.0' - 56.4'	Gray brown, comp., silty (10-20) sandy (30-40) gravel, GM, Till, w/cobbles & boulders
56.4' - 57.0'	Gray, comp. to v. comp., gravelly, (20-30 silty (15-25) sand, SM, Till w/cobbles
57.0' - 62.5'	Cobbles embedded in soil
62.5' - 65.5'	Gray, comp. to v. comp, gravelly 42 silty 12 sand, SM, Till, w/cobbles, D_{10} = 0.05
65.5' - 66.0'	Gray brown, v.comp., silty (25-35) sand, SM
66.0' - 70.0'	Gray brown, comp. to v.comp., gravelly (10-20) silty 20-30 sand, SM, w/cobbles & boulders
70.0'	Top of bedrock

FD-18 Elev. 545.4

0.0' - 0.4'	Topsoil
0.4' - 1.1'	Brown, loose, silty (35-45) F. sand, SM, w/roots
1.1' - 2.9'	Gray brown, loose, gravelly (5-15) silty (20-30) sand, SM w/weathered rock
2.9'	Top of bedrock

FD-19 Elev. 457.7

0.0' - 0.5'	Topsoil
0.5' - 1.6'	Brown, loose, gravelly (5-15) silty (30-40) m-f sand, SM, w/roots & organics
1.6' - 5.0'	Gray brown, comp., silty 13 sandy 43 gravel, GM, w/ cobbles
5.0' - 8.7'	Gray brown, comp., gravelly (30-40) silty (15-25) sand, SM, w/cobbles & boulders
8.7' - 11.6'	Gray brown, comp., gravelly 21 silty 14 sand, SM, & weathered rock
11.6'	Top of bedrock

FD-20 Elev. 435.1

0.0' - 0.5'	Topsoil & forest debris
0.5' - 3.0'	Dark brown, loose, silty (15-25) m-f sand, SM w/roots & organics
3.0' - 6.1'	Brown, mod. comp., sandy (25-35) gravel, GP, w/boulders
6.1' - 10.0'	Gray brown, comp., gravelly 24, silty 15 sand, SM w/cobbles
10.0' - 15.0'	Gray brown, mod. comp., gravelly 40 silty 14 sand, SM, w/cobbles, decomposed cobbles & mica D_{10} = 0.05
15.0' - 20.0'	Brown, mod. comp., gravelly (20-30) silty (10-20) m-f sand, SM, w/cobbles, boulders & mica
20.0' - 22.5'	Gray brown, comp., sandy (20-30) gravel, GP
22.5' - 40.0'	Gray brown, comp., silty 8-6 sandy 25-26 gravel, GP-GM, w/ cobbles & boulders & occasional mica, D_{10} = 0.12, 0.16

FD-20 Continued

40.0' - 47.3'	Gray brown, comp., silty 5 sandy 40 to (20-30) gravel, GP-GM, w/cobbles & mica D_{10} = 0.16
47.3	Top of bedrock

FD-21 Elev. 564.2

0.0' - 0.8'	Forest debris
0.8'	Top of bedrock

FD-22 Elev. 510.7

0.0' - 0.6'	Forest debris & Topsoil
0.6' - 2.4'	Brown, loose, silty (25-35) F. sand, SM w/roots & cobbles
2.4' - 5.0'	Brown, mod. comp., silty, (25-35) m-f sand, SM w/roots & cobbles
5.0' - 7.5'	Gray brown, comp., gravelly (10-20) silty (20-30) sand, SM, w/cobbles
7.5' - 11.4'	Weathered rock
11.4'	Top of bedrock

FD-23 Elev. 558.2

0.0' - 0.4'	Topsoil
0.4' - 1.8'	Brown, loose, silty (25-35) m-f sand, SM, w/roots
1.8' - 3.3'	Gray brown, loose gravelly (5-15) silty (20-30) m-f sand, SM, w/cobbles
3.3' - 5.0'	Gray, mod. comp., silty (25-35) sand, SM, w/weathered rock fragments
5.0' - 12.5'	Weathered rock
12.5'	Top of bedrock

FD-24 Elev. 468.4

0.0' - 0.4'	Topsoil & forest debris
0.4' - 3.0'	Dark brown, loose, gravelly (20-30) silty (15-25) sand, SM, w/roots
3.0' - 5.0'	Dark brown, mod. comp., sandy (10-20) gravel, GP

FD-24 Continued

5.0' - 11.0'	Gray brown, mod. comp., gravelly (10-20) silty (15-25) sand, SM w/cobbles & boulders
11.0' - 15.0'	Gray brown, mod. comp., gravelly 32, silty 8 m-f sand, SP-SM, w/cobbles & boulders, D_{10} = 0.09
15.0' - 20.0'	Gray brown, mod. comp., silty (5-15) sandy (35-45) gravel, GP-GM, w/cobbles & boulders
20.0' - 25.0'	Gray brown, comp., silty 19 sandy 38 gravel, GM, Till, w/cobbles & boulders D_{10} = 0.035
25.0' - 45.0'	Gray brown, comp. to v. comp., gravelly 15 silty 44 m-f sand, SM, Till, w/cobbles & boulders D_{10} = 0.0028 W_n = 14.7, 11.3, 11.0 W_4 = 15.0, 12.4, 12.3
45.0' - 50.0'	Gray, comp. to v. comp., gravelly (10-20) silty (35-45) m-f sand, SM, Till
50.0' - 55.0'	Gray, comp. to v. comp., silty 31 sandy m-f 33 gravel, GM, Till, D_{10} = 0.008, W_n = 10.1, W_4 = 12.4
55.0' - 65.0'	Gray, comp. to v. comp., gravelly (10-20) silty (35-45) m-f sand, SM, Till
65.0' - 74.8'	Gray, comp. to v. comp., silty (35-45) m-f sand, SM, Till
74.8' - 83.4'	Boulders & cobbles embedded in soil
83.4'	Top of bedrock

FD-25 Elev. 533.4

0.0' - 0.7'	Topsoil
0.7' - 1.5'	Brown, loose, gravelly (10-20) silty (20-30) m-f sand, SM, w/roots
1.5' - 7.3'	Gray brown, comp., gravelly 19 silty 18 sand, SM, Till w/cobbles, D_{10} = 0.044
7.3' - 9.2'	Brown, comp., micaceous, silty (30-40) m-f sand, SM, Till, w/weathered rock fragments & rock fragments
9.2'	Top of bedrock

FD-26 Elev. 553.8

0.0' - 0.4'	Forest debris
0.4' - 1.1'	Brown, loose, gravelly (10-20) silty (20-30) m-f sand, SM, Till, w/roots
1.1' - 3.2'	Gray, brown, mod. comp., silty (20-30) sand, SM, Till
3.2' - 5.0'	Gray brown, comp. to v. comp., micaceous gravelly (30-40) silty (15-25) sand, SM, Till, w/cobbles
5.0' - 19.5	Gray brown, comp., gravelly 28 silty 19 sand, SM, Till, w/some weathered rock from 15.0' - 19.9', D_{10} = 0.035
19.5'	Top of bedrock

FD-27 Elev. 505.6

0.0' - 0.7'	Topsoil
0.7' - 3.8'	Boulders & Cobbles embedded in soil
3.8' - 5.0'	Gray brown, silty (20-30) sand, SM, Till, w/cobbles
5.0' - 8.8'	Gray brown, comp., gravelly 19 silty 33 sand, SM, Till, w/cobbles, D_{10} = 0.017
8.8' - 11.9'	Weathered rock
11.9'	Top of bedrock

FD-28 Elev. 479.9

0.0' - 1.8'	Brown, loose, sandy (f.20-30) silt, ML, w/cobbles
1.8' - 5.0'	Brown, comp., silty (5-15) sandy (35-45) gravel, GP-GM
5.0' - 9.0'	Gray brown, comp., gravelly 29 silty 22 sand, SM, Till, D_{10} = 0.032
9.0' - 9.3	Gray, comp., silty (15-25) m-f sandy (25-35) gravel, GM, Till
9.3' - 10.0'	Weathered rock fragments
10.0'	Top of bedrock

FD-29 Elev. 499.9

0.0' - 0.4'	Topsoil
0.4' - 2.9'	Brown, mod. comp., silty (30-40) m-f sand, SM, w/roots, cobbles & boulders
2.9' - 4.1'	Brown, mod. comp., sandy (f. 30-40) silt, ML, w/roots & organics
4.1' - 7.0'	Gray brown, comp., gravelly 38 silty 15 sand, SM, Till, w/cobbles
7.0' - 12.0'	Gray brown, comp., gravelly (10-20) silty (15-25) sand, SM, Till, w/weathered boulders from 9.3'-12.0'
12.0' - 16.8'	Boulders & cobbles embedded in soil
16.8' - 17.0'	Brown, comp., silty (5-15) sandy (15-25) gravel, GP-GM, Till
17.0' - 21.0'	Boulders & cobbles embedded in soil
21.0' - 22.05'	Brown, comp., silty (15-25) sandy (25-35) gravel, GM, Till
22.05'	Top of bedrock

FD-30 Elev. 502.7

0.0' - 1.0'	Topsoil & forest debris
1.0' - 3.0'	Brown, loose, silty (5-15) m-f sand, SP-SM
3.0' - 5.0'	Brown, comp., gravelly 23 silty 12 m-f sand, SM
5.0' - 9.0'	Brown, comp. to v. comp., gravelly (20-30) to (35-45) silty (5-15) m-f sand, SP-SM, w/cobbles
9.0' - 21.0'	Gray brown, comp., gravelly 35 silty (15-25) to 26 sand, SM, Till w/cobbles, D_{10} = 0.024
21.0' - 40.0'	Gray, comp. to v. comp., gravelly (10-20) to (15-25) silty (35-45) m-f sand, SM, Till, w/cobbles
40.0' - 60.0'	Gray, comp. to v. comp., gravelly 19 silty 43 m-f sand, SM, Till, w/cobbles & boulders, D_{10} = 0.003

FD-30 Continued

60.0' - 75.0'	Gray, comp. to v. comp., gravelly (15-25) to (10-20) silty (35-45) m-f sand, Till, w/cobbles
75.0' - 76.2'	Gray brown, comp. to v. comp., silty (30-40) f. sand, SM, Till
76.2' - 82.0'	Gray brown, comp. to v. comp., gravelly 15 silty 25 sand, SM, Till, w/cobbles & boulders D_{10} = 0.017
82.0'	Top of bedrock

FD-31 Elev. 504.4

0.0' - 1.0'	Top of forest debris
1.0' - 5.0'	Brown, mod. comp., gravelly (10-20) silty (20-30) sand, SM w/roots
5.0' - 15.0'	Brown, mod. comp., silty 6 sandy 44 gravel, GP-GM, D_{10} = 0.14
15.0' - 20.0'	Brown, mod. comp., gravelly (10-20) silty (5-15) sand, SP-SM
20.0' - 25.0'	Gray brown, comp., gravelly (15-25) silty (15-25) sand, SM, Till
25.0' - 30.0'	Gray brown, comp., gravelly (35-45) silty (20-30) sand, SM, Till, w/boulders
30.0' - 38.9'	Gray, comp. to v. comp., gravelly 24 silty 45 sand, SM, Till, w/cobbles & boulders D_{10} = 0.0022
38.9' - 44.0'	Gray, comp. to v. comp., silty (35-45) sand, SM Till
44.0' - 46.9'	Gray, comp. to v. comp., silty, clayey (40-50) sand, SM-SC, Till
46.9' - 57.0'	Gray, comp. to v. comp., gravelly (15-25) to 11 silty, clayey 46 sand SM-SC, Till, w/cobbles, D_{10} = 0.0025 LL = 23, PI = 4

FD-31 Continued

57.0' - 75.0'	Gray, comp. to v. comp., gravelly (10-20) to 22 silty clayey 38 sand, SM-SC, Till, w/cobbles
75.0' - 84.0'	Gray, comp. to v. comp., gravelly (10-20) to (15-25) silty (35-45) to (30-40) sand, SM, Till, w/cobbles
84.0' - 88.0'	Gray, comp. to v. comp., silty, (5-15) sandy (30-40) gravel, GP-GM, Till, w/cobbles
88.0' - 91.0'	Gray brown, comp. to v. comp., gravelly (25-35) silty (25-35) sand, SM, Till, w/cobbles
91.0' - 96.5'	Gray, comp. to v. comp., silty 6 sandy (30-40) to 23 gravel, GP-GM, Till, w/cobbles D_{10} = 0.14
96.5' - 97.0'	Brown, comp. to v. comp., gravelly 10 silty 44 m-f sand, SM, D_{10} = 0.015
97.0'	Top of bedrock

FD-32 Elev. 453.4

0.0' - 3.0'	Brown, mod. comp., silty (15-25) sandy (30-40) gravel, GM
3.0' - 5.0'	Gray brown, comp. to v. comp., silty (20-30) sand, SM, w/weathered rock fragments
5.0'	Top of bedrock

FD-33 Elev. 462.0

0.0' - 0.6'	Topsoil
0.6' - 1.2'	Red brown, loose silty (5-15) sandy 30-40 gravel, GP-GM
1.2' - 2.4'	Brown, mod. comp., sandy (30-40) gravel, GP w/cobbles
2.4' - 4.7'	Weathered rock mixed w/soil
4.7'	Top of bedrock

FD-34 Elev. 574.7

0.0' - 0.8'	Topsoil
0.8' - 2.1'	Brown, loose, f. sandy (25-35) silt, ML, w/roots
2.1'	Top of bedrock

FD-35 Elev. 557.8

0.0' - 0.8'	Topsoil & forest debris
0.8' - 2.4'	Gray brown, loose, silty (30-40) m-f sand, SM w/roots
2.4' - 5.0'	Gray brown, comp., gravelly 22 silty 20 sand, SM D_{10} = 0.033
5.0' - 6.0'	Gray, comp., gravelly (30-40) silty (15-25) sand, SM
6.0' - 15.4'	Boulders & cobbles embedded in soil
15.4' - 17.2'	Gray brown, v.comp., gravelly (25-35) silty (15-25) sand, SM
17.2' - 19.6'	Weathered rock fragments w/silty m-f sand, SM
19.6'	Top of bedrock

FD-36 Elev. 443.3

0.0' - 0.5'	Topsoil
0.5' - 3.3'	Brown, loose, silty (30-40) f. sand, SM, w/roots
3.3' - 4.0'	Gray brown, comp., micaceous silty (15-25) f. sand, SM
4.0' - 10.1'	Gray brown, comp., silty 7 sandy 37 gravel, GP-GM, w/cobbles, D_{10} = 0.13
10.1'	Top of bedrock

FD-37 Elev. 442.4

0.0' - 0.8'	Topsoil
0.8' - 1.7'	Brown, loose, silty (30-40) f. sand, SM, w/roots
1.7' - 3.1'	Brown, loose, micaceous, silty (30-40) f. sand, SM
3.1' - 8.8'	Brown, comp. to v. comp. silty 6 sandy 46 gravel, GP-GM, D_{10} = 0.13
8.8'	Top of bedrock

FD-38 Elev. 558.6

0.0' - 0.4'	Topsoil & forest debris
0.4' - 2.5'	Brown, mod. comp., silty (30-40) f. sand, SM, w/roots
2.5' - 5.0'	Gray brown, comp., silty (25-35) m-f sand, SM, w/weathered rock fragments from 3.3' to 5.0'
5.0' - 6.9'	Weathered rock & rock fragments
6.9'	Top of bedrock

FD-39 Elev. 481.1

0.0' - 0.4	Topsoil
0.4' - 2.4'	Brown, loose, gravelly (5-15) silty (30-40) f. sand, SM, w/roots
2.4' - 5.0'	Brown, comp., silty (5-15) sandy, (30-40) gravel, GP-GM
5.0' - 8.3'	Brown, comp., gravelly 39 silty 12 sand, SP-SM, D_{10} = 0.07
8.3' - 10.0'	Dark brown, comp., gravelly (25-35) silty (15-25) m-f sand, SM
10.0' - 13.5'	Gray brown, v. comp., gravelly 12 silty 40 m-f sand, SM, D_{10} = 0.019
13.5'	Top of bedrock

FD-40 Elev. 487.0

0.0' - 0.3'	Topsoil & forest debris
0.3' - 1.7'	Brown, loose, silty (30-40) m-f sand, SM, w/roots
1.7' - 5.0'	Brown, comp., silty (5-15) sandy (30-40) gravel, GP-GM, w/cobbles
5.0' - 7.0'	Brown, comp., gravelly, (20-30) silty (10-20) sand, SM, w/cobbles
7.0' - 8.7'	Brown, comp. to v. comp., gravelly (10-20) silty (15-25) sand, SM, w/weathered rock fragments
8.7'	Top of bedrock

FD-41 Elev. 557.6

0.0' - 0.4'	Topsoil & forest debris
0.4' - 1.5'	Brown, loose, sandy (f. 30-40) silt, ML, w/roots
1.5' - 2.5'	Gray brown, mod. comp., gravelly (10-20) silty (20-30) m-f sand, SM
2.5' - 5.0'	Weathered rock
5.0'	Top of bedrock

FD-42 Elev. 555.0

0.0' - 0.7'	Topsoil
0.7' - 2.6'	Brown, loose, gravelly (10-20) sandy (f. 30-40) silt, ML
2.6' - 5.0'	Brown, mod. comp., gravelly (20-30) silty (25-35) m-f sand, SM, Till
5.0' - 12.6'	Brown, comp. to v. comp., gravelly 32 silty 21 sand, SM Till, D_{10} = 0.029
12.6'	Top of bedrock

FD-43 Elev. 574.6

0.0' - 2.0'	Topsoil
2.0' - 3.4'	Gray brown, comp., micaceous gravelly (10-20) silty (20-30) sand, SM
3.4'	Top of bedrock

FD-44 Elev. 529.9

0.0' - 0.3'	Forest debris
0.3' - 1.8'	Topsoil
1.8' - 5.8'	Brown, loose, gravelly 29 silty 21 sand, SM, Till, w/cobbles & decomposed cobbles, D_{10} = 0.041
5.8' - 12.0'	Gray brown, mod. comp., gravelly 38 silty 15 sand, SM, Till, w/cobbles & mica, D_{10} = 0.05

FD-44 Continued

12.0' - 17.9'	Gray brown, loose, silty (10-20) sandy (25-35) gravel, GM, Till, w/cobbles & mica
17.9' - 25.0'	Gray, comp. to v. comp., gravelly 24 silty 48 sand, SM-SC, Till, w/cobbles, D_{10} = 0.0034, LL = 24, PI = 5
25.0' - 36.0'	Gray, comp. to v. comp., gravelly 30 silty 35 sand, SM, Till, w/cobbles D_{10} = 0.006
36.0' - 42.6'	Gray, comp. to v. comp., silty (30-40) sand, SM, Till, w/cobbles
42.6' - 47.8'	Gray, comp. to v. comp., gravelly (25-35) silty (15-25) sand, SM, Till, w/cobbles & boulders
47.8'	Top of bedrock

FD-45 Elev. 575.3

0.0' - 0.6'	Topsoil
0.6' - 1.7'	Brown, loose, silty (30-40) f. sand, SM, w/roots
1.7' - 4.0'	Gray, comp., gravelly (10-20) silty (25-35) m-f sand, SM
4.0'	Top of bedrock

FD-46 Elev. 588.9

0.0' - 0.3'	Topsoil
0.3' - 2.1'	Dark brown, comp., gravelly (10-20) silty (20-30) m-f sand, SM, w/roots, organics & cobbles
2.1' - 7.9'	Brown, comp. to v. comp., gravelly 22 silty 28 sand, SM, w/mica & cobbles, D_{10} = 0.025
7.9' - 10.0'	Gray brown, comp. to v. comp., gravelly (10-20) silty (20-30) m-f sand, SM, w/mica, D_{10} = 0.041
10.0' - 15.0'	Gray brown, comp. to v. comp., stratified gravelly 40 silty 18 m-f sand, SM, w/mica, D_{10} = 0.041

FD-46 Continued

15.0' - 19.0'	Gray brown, comp. to v. comp., gravelly 9 m-f sandy 41 silt, ML, w/silt layers to 1", D_{10} = 0.009
19.0' - 24.3'	Brown, comp., to v. comp., gravelly 25 silty 20 sand, SM, w/cobbles, D_{10} = 0.033
24.3' - 34.5'	Gray brown, comp. to v. comp. silty 9 sandy 35 to (20-30) gravel, GP-GM, w/cobbles, D_{10} = 0.082
34.5' - 40.7'	Gray, comp. to v. comp., gravelly 37 silty 21 sand, SM, w/cobbles D_{10} = 0.041
40.7'	Refusal

FD-47 Elev. 560.3

0.0' - 0.4'	Topsoil
0.4' - 2.2'	Brown, mod. comp. to comp., gravelly (0-10) to (5-15) silty (25-35) m-f sand, SM, w/roots
2.2' - 8.0'	Brown, comp. to v. comp., silty 10 sandy 43 to (30-40) gravel, GP-GM, w/cobbles & boulders D_{10} = 0.073
8.0' - 20.0'	Brown, comp., gravelly 20 silty 19 sand, SM, w/cobbles & boulders D_{10} = 0.04
20.0' - 21.8'	Brown, comp., gravelly (10-20) silty (30-40) m-f sand, SM, w/cobbles & boulders
21.8' - 30.0'	Gray brown to gray, comp. to v. comp., gravelly 20 silty 32 m-f sand, SM, w/cobbles & boulders, D_{10} = 0.026
30.0' - 36.0'	Gray, v. comp., silty (25-50) f. sand, SM, w/silt laminae, cobbles & boulders
36.0' - 37.6'	Gray, v. comp., silty (5-15) sandy (15-25) gravel, GP-GM w/cobbles
37.6' - 41.6'	Gray, v.comp., gravelly (15-25) silty (20-30) m-f sand, SM

FD-47 Continued

41.6' - 43.0'	Gray, v.comp., sandy (fine) 40 silt, ML, D_{10} = 0.023
43.0' - 50.0'	Gray, v. comp., stratified, silty (25-50) f. sand, SM and gravelly (15-25) silty (20-30) m-f sand, SM in 1 to 2 foot strata w/cobbles from 47.4 to 49.0
50.0'	Bottom of exploration

FD-48 Elev. 559.2

0.0' - 1.5'	Brown, loose, silty (30-40) f. sand, SM
1.5' - 2.1'	Brown, loose, gravelly (10-20) silty (25-35) m-f sand, SM
2.1' - 11.3'	Brown & gray, loose to mod. comp., gravelly (25-35) to 19 silty 29 m-f sand, SM, w/cobbles, D_{10} = 0.025
11.3' - 11.8'	Brown, v.comp., silty (25-50) f. sand, SM
11.8'	Top of bedrock

FD-49 Elev. 593.0

0.0' - 0.6'	Topsoil
0.6' - 2.3'	Brown, loose, gravelly (10-20) silty (25-35) sand, SM, w/ roots
2.3' - 4.4'	Brown, comp., gravelly 16 silty 28 sand, SM, D_{10} = 0.023.
4.4' - 6.0'	Gray brown, comp., silty (15-25) m-f sand, SM, w/cobbles & boulders
6.0' - 7.1'	Brown, loose, slightly micaceous, silty (20-30) m-f sand, SM,w/boulders
7.1' - 10.5'	Brown, mod. comp., gravelly (30-40) silty (15-25) m-f sand, SM, w/cobbles
10.5' - 16.5'	Brown, mod. comp., gravelly 26 silty 19 sand, SM, w/cobbles, D_{10} = 0.041

FD-49 Continued

16.5' - 19.1'	Gray brown, comp. to v. comp., slightly stratified silty 48 T. sand SM, D_{10} = 0.02
19.1'	Top of bedrock

FD-50 Elev. 564.8

0.0' - 2.5'	Forest debris & topsoil
2.5' - 5.0'	Brown, comp., gravelly (10-20) silty (25-35) sand, SM, w/roots & organics
5.0' - 10.0'	Gray brown, comp., silty 10 sandy 31 gravel, GP-GM, Till, w/cobbles D_{10} = 0.074
10.0' - 23.0'	Gray brown, comp. to v. comp., gravelly 14 silty 35 sand, SM, Till, D_{10} = 0.019
23.0' - 30.0'	Gray brown, comp. to v. comp., gravelly 27 silty 33 sand, SM, Till, w/cobbles, D_{10} = 0.017
30.0' - 40.0'	Gray brown, comp. to v. comp., gravelly (15-25) to (20-30) silty (25-35) sand, SM, Till
40.0' - 54.9'	Gray, comp. to v. comp., gravelly 9 silty (35-45) to 50 m-f sand, SM, Till, w/cobbles & boulders, D_{10} = 0.013
54.9'	Top of bedrock

FD-51 Elev. 546.6

0.0' - 1.0'	Topsoil
1.0' - 2.6'	Brown, loose, silty (20-30) m-f sand, SM
2.6' - 10.0'	Brown, loose, to mod. comp., gravelly 7 silty 40 m-f sand, SM & gravelly (15-25) silty (20-30) m-f sand, SM w/cobbles, Till, D_{10} = 0.014
10.0' - 16.0'	Dark brown, comp., gravelly 20 silty 15 sand, SM, w/boulders & cobbles, Till, D_{10} = 0.043
16.0' - 20.0'	Brown, v.comp., gravelly (15-25) silty (20-30) sand, SM w/cobbles, Till

FD-51 Continued

20.0' - 30.0'	Brown, v. comp., gravelly 26 silty 14 sand, SM, w/cobbles & boulders, Till, D_{10} = 0.059
30.0' - 34.1'	Brown, v. comp., gravelly 9 silty 33 sand, SM, w/cobbles, Till, D_{10} = 0.014
34.1' - 34.5'	Weathered rock
34.5'	Top of bedrock

FD-52 Elev. 533.7

0.0' - 0.7'	Topsoil
0.7' - 2.7'	Brown, loose to mod. comp., silty (25-35) f. sand, SM, w/roots
2.7' - 5.0'	Gray brown, mod. comp., silty (25-35) m-f sand, SM
5.0' - 6.2'	Gray brown, mod. comp., gravelly (25-35) silty (20-30) sand, SM, w/cobbles
6.2' - 8.0'	Gray brown, comp., silty 23 sandy 38 gravel, GM, w/cobbles, D_{10} = 0.028
8.0' - 14.0'	Gray brown, mod. comp., gravelly (25-35) silty (20-30) sand, SM, w/cobbles and micaceous decomposed gravel
14.0' - 24.0'	Brown, comp., silty, (15-25) sandy (30-40) gravel, GM, w/cobbles & decomposed cobbles
24.0' - 26.9'	Gray, mod. comp., gravelly 14 silty 22 sand, SM, w/cobbles D_{10} = 0.037
26.9' - 27.3'	Gray, mod. comp., silty (25-50) f. sand, SM
27.3' - 30.0'	Gray, mod. comp., silty (15-25) sandy (30-40) gravel, GM
30.0' - 31.7'	Gray, mod. comp., slightly stratified silty 29 f. sand, SM, D_{10} = 0.03
31.7' - 33.4'	Gray, mod. comp., silty (15-25) sandy, (25-35) gravel, GM

FD-52 Continued

33.4' - 35.0'	Gray, comp., silty (25-35) f. sand, SM
35.0' - 38.0'	Gray, comp. silty 11 m-f sand, SP-SM, w/cobbles D_{10} = 0.07
38.0' - 40.8'	Gray, comp., gravelly (15-25) silty (5-15) m-f sand, SP-SM, w/cobbles
40.8' - 42.0'	Gray, comp., stratified, silty (25-50) f. sand, SM
42.0' - 45.0'	Gray, comp., gravelly 18 silty 34 f. sand, SM, w/cobbles, D_{10} = 0.033
45.0' - 48.0'	Gray, v. comp., silty (25-50) f. sand, SM
48.0' - 59.3'	Gray, comp., gravelly 19 silty 33 m-f sand, SM, w/cobbles & decomposed cobbles, Till, D_{10} = 0.041
59.3' -	Refusal

FD-53 Elev. 546.7

0.0' - 1.1'	Topsoil
1.1' - 1.8'	Brown, loose, silty (10-20) sand, SM
1.8' - 2.5'	Brown, loose, silty (20-30) f. sand, SM
2.5' - 7.6'	Brown, comp., gravelly 4 silty 49 to (30-40) m-f sand, SM, w/cobbles D_{10} = 0.0088
7.6' - 9.5'	Brown, comp., gravelly 18 silty 35 m-f sand, SM, D_{10} = 0.016
9.5' - 16.0'	Gray brown, comp., gravelly (10-20) silty (30-40) m-f sand, SM
16.0' - 21.0'	Gray, comp., slightly micaceous gravelly 9 silty 15 m-f sand, SM, D_{10} = 0.06
21.0' - 25.0'	Gray, comp. to v. comp., silty (10-25) f. sand, SM, w/1/4" to 2" strata of sandy silt, ML

FD-53 Continued

25.0' - 28.2'	Gray, comp. gravelly 25 silty 17 sand, SM, D_{10} = 0.058
28.2' - 31.4'	Gray, comp., sandy (fine) 42 silt, ML, D_{10} = 0.02
31.4' - 36.0'	Gray, v.comp., gravelly (25-35) silty (10-20) sand, SM, w/cobbles & boulders
36.0' - 43.0'	Gray, comp. to v. comp., gravelly (10-20) to 23 silty 29 m-f sand SM, w/cobbles & boulders, Till, D_{10} = 0.017
43.0' - 49.0'	Gray, comp. to v. comp., gravelly (10-20) silty (35-45) m-f sand, SM, w/cobbles & boulders, Till
49.0' - 50.0'	Gray, comp., silty 46 m-f sand SM, Till, D_{10} = 0.0052
50.0' -	Bottom of exploration

FD-54 Elev. 571.5

0.0' - 1.0'	Topsoil
1.0' - 5.0'	Brown, loose to mod. comp., gravelly 40 silty 11 sand, SP-SM, w/cobbles, D_{10} = 0.07
5.0' - 7.0'	Brown, comp., silty (10-20) sand, SM
7.0' - 10.0'	Brown, comp., gravelly 14 silty 14 sand, SM, w/cobbles D_{10} = 0.05
10.0' - 16.0'	Brown, comp., gravelly (20-30) silty (15-25) sand, SM, w/cobbles & decomposed cobbles
16.0' - 18.0'	Gray, v.comp., silty (25-50) f. sand, SM, w/cobbles
18.0' - 24.0'	Gray, v. comp., gravelly 15 silty 13 sand, SM, w/cobbles, D_{10} = 0.055
24.0' - 29.5'	Gray, v. comp., stratified, silty 37 f. sand, SM, D_{10} = 0.03

FD-54 continued

29.5' - 40.6'	Gray, v. comp., gravelly 38 silty 16 sand, SM, w/cobbles, D_{10} = 0.049
40.6' - 50.0'	Stratified gray, comp., gravelly 19 silty 34 sand, SM, and silty (25-50) f.sand,SM, w/cobbles
50.0'	Bottom of exploration

FD-55 Elev. 456.2

0.0' - 0.5'	Forest debris
0.5' - 2.5'	Topsoil
2.5' - 5.0'	Brown, loose, gravelly (20-30) silty (20-30) sand, SM, w/roots
5.0' - 10.0'	Brown, mod. comp., gravelly (25-35) silty (5-15) sand, SP-SM
10.0' - 15.0'	Gray brown, mod. comp., gravelly 19 silty 8 sand, SP-SM, D_{10} = 0.11
15.0' - 20.0'	Gray brown, comp., gravelly (10-20) silty (10-20) sand, SM
20.0' - 31.0'	Gray brown, comp., gravelly 36 silty 14 sand, SM, w/cobbles & decomposed cobbles, D_{10} = 0.05
31.0' - 35.0'	Gray brown, loose to mod. comp., gravelly 41 silty 11 sand, SP-SM, w/decomposed cobbles
35.0' - 36.5'	Gray, mod. comp., gravelly 42 silty 13 sand, SM
36.5' - 36.9'	Gray, stiff, sandy, clay, CL
36.9' - 40.0'	Gray, mod. comp., gravelly (15-25) silty (10-20) m-f sand, SM
40.0' - 43.0'	Gray brown, comp., silty 12 sandy 37 gravel, GM, w/cobbles & decomposed cobbles, D_{10} = 0.054
43.0' - 55.0'	Gray, comp., gravelly 18 to (0-10) silty 37 sand, SM, Till, w/cobbles, D_{10} = 0.0078 non-plastic

FD-55 Continued

55.0' - 56.0'	Gray, comp., silty (20-30) sandy (25-35) gravel, GM, Till
56.0' - 60.8'	Gray, comp., gravelly (0-10) to (10-20) silty (30-40) to (25-35) m-f sand, SM, Till, w/cobbles
60.8' -	Top of bedrock

FD-56 Elev. 561.2

0.0' - 0.8'	Topsoil
0.8' - 1.8'	Brown, loose, gravelly (10-20) silty (25-35) m-f sand, SM, w/roots
1.8' - 3.0'	Brown, loose, sandy (f.20-30) silt, ML
3.0' - 4.0'	Brown, mod. comp., silty (30-40) m-f sand, SM
4.0' - 9.0'	Brown, comp., gravelly 26 silty 14 sand, SM, w/cobbles, D_{10} = 0.05
9.0' - 10.6'	Gray brown, comp., gravelly (25-35) silty (15-25) sand, SM, w/cobbles
10.6' - 14.0'	Brown, comp., gravelly (10-20) to 28 silty 20 sand, SM, D_{10} = 0.041
14.0' - 15.0'	Brown, comp., silty (15-25) sand, SM
15.0' - 16.0'	Brown, v.comp., gravelly (10-20) silty (25-35) f. sand, SM
16.0' - 19.0'	Brown, v. comp., gravelly (20-30) silty (10-20) m-f sand, SM, w/cobbles
19.0' - 30.5'	Gray, comp. to v. comp., slightly stratified, silty 37-38 f. sand, SM, w/strata of (a) silty (15-25) sand, SM, from 25.0' to 25.7' (b) gravelly (10-20) silty (25-35) m-f sand, SM From 26.7' to 27.0' D_{10} = 0.027) = 109.4

FD-56 Continued

30.5' - 34.0'	Gray, comp., gravelly (15-25) silty (20-30) f. sand, SM, w/cobbles
34.0' - 37.9'	Gray, comp., gravelly 34 silty 6 sand, SP-SM, w/cobbles, D_{10} = 0.14
37.[illegible]' - 38.3'	Gray, mod. comp., silty (25-50) f. sand, SM
38.3' - 41.0'	Gray, comp., silty (15-25) sandy (f. 25-35) gravel, GM, w/cobbles
41.0' - 44.0'	Gray, comp., silty 10 sandy 44 gravel, GP-GM, w/cobbles, D_{10} = 0.1
44.0' - 45.0'	Gray, v. comp., silty (5-15) sand, SP-SM
45.0' - 47.0'	Gray, v.comp., silty (5-15) sandy (25-35) gravel, GP-GM
47.0' - 50.0'	Gray, v.comp., gravelly 37 silty 15 sand, SM, Till
50.0' -	Bottom of exploration

FD-57 Elev. 570.0

0.0' - 1.3'	Topsoil
1.3' - 5.0'	Brown, mod. comp., gravelly (25-35) silty (25-35) m-f sand, SM, w/cobbles
5.0' - 17.5'	Brown, comp., gravelly 39 silty 15 sand, SM, w/cobbles, D_{10} = 0.049
17.5' - 21.0'	Gray brown, v. comp., gravelly (10-20) silty (20-30) m-f sand, SM w/cobbles & boulders
21.0' - 31.0'	Brown, comp. to v. comp., silty 44 f. sand, SM D_{10} = 0.025 = 106.8
31.0' - 39.0'	Gray, comp. to v. comp., silty (25-50) f. sand, SM, w/occasional silt strata up to 1/2" thick = 111.5
39.0' - 42.0'	Gray brown, comp. to v. comp., silty 9 f. sand, SP-SM and silty (25-50) f. sand, SM

FD-57 Continued

42.0' - 45.0'	Gray, v. comp., gravelly (15-25) silty (20-30) m-f sand, SM
45.0' - 47.0'	Gray, v. comp., silty (25-50) f. sand, SM
47.0' - 49.0'	Gray, v. comp., silty 17, sand, SM, D_{10} = 0.05
49.0' - 50.0'	Gray, v. comp., silty 20, m-f sand, SM, D_{10} = 0.04
50.0' -	Bottom of exploration

FT-4 Elev. 571.4

0.0' - 0.5'	Topsoil w/roots
0.5' - 2.6'	Brown, loose, gravelly (10-20) silty (20-30) sand, SM, w/roots
2.6' - 8.0'	Gray brown, mod. comp., gravelly 32 silty 34 sand, SM, w/cobbles & boulders, D_{10} = 0.018
8.0'	Top of bedrock

FT-5 Elev. 573.9

0.0' - 0.3'	Topsoil w/roots
0.3' - 2.9'	Brown, loose, gravelly (10-20) silty (20-30) sand, SM, w/roots
2.9' - 8.0'	Gray brown, mod. comp., gravelly 21 silty 24 sand, SM, w/cobbles & boulders D_{10} = 0.028
8.0'	Top of probable bedrock

FT-6 Elev. 497.4

0.0' - 0.3'	Topsoil w/roots
0.3' - 3.0'	Brown, loose, sandy (m-f 30-40) silt, ML, w/roots
3. ' - 13.0'	Gray brown, loose, gravelly 39 silty 20 sand, SM/ w/cobbles & boulders, D_{10} = 0.031
13.0'	Bottom of exploration

FT-7 Elev. 508.4

0.0' - 0.4'	Topsoil w/roots
0.4' - 2.9'	Brown, loose, silty (25-35) m-f sand, SM, w/roots & boulders
2.9' - 12.0'	Gray brown, mod. comp., gravelly 40 silty 15 sand, SM, w/cobbles & boulders, D_{10} = 0.043
12.0'	Bottom of exploration

FT-8 Elev. 474.6

0.0' - 0.4'	Topsoil w/roots
0.4' - 2.9'	Brown, loose, silty (25-35) m-f sand, SM
2.9' - 11.0'	Brown, mod. comp., sandy 47 gravel, GP, w/boulders & cobbles, D_{10} = 0.29
11.0' - 13.0'	Gray brown, mod. comp., silty 12 sandy 40 gravel, GP-GM, w/boulders & cobbles, D_{10} = 0.07
13.0'	Bottom of exploration

FT-9 Elev. 441.3

0.0' - 0.5'	Topsoil w/roots
0.5' - 5.8'	Brown, loose, silty 29 m-f sand, SM, w/boulders & cobbles
5.8' - 10.0'	Brown, comp., silty 7 sandy 40 gravel, GP-GM, w/boulders & cobbles, D_{10} = 0.11
10.0'	Bottom of exploration

FT-10 Elev. 442.2

0.0' - 0.7'	Topsoil w/roots
0.7' - 6.0'	Brown, loose, silty (25-35) m-f sand, SM, w/roots, cobbles & boulders
6.0' - 10.0'	Brown, comp., silty 13 sandy 37 gravel, GM, w/boulders & cobbles D_{10} = 0.054
10.0'	Bottom of exploration

FT-11 Elev. 438.3

0.0' - 0.4'	Topsoil w/roots
0.4' - 5.5'	Brown loose silty (5-15) m-f sand (SP-SM), w/roots, organics, boulders & cobbles
5.5' - 7.0'	Brown, comp., gravelly 48 silty 6 sand, SP-SM, w/boulders, & cobbles D_{10} = 0.13
7.0'	Probable top of bedrock

FT-12 Elev. 452.4

0.0' - 0.5'	Topsoil
0.5' - 3.0'	Light gray, mod. comp., sandy (fine 20-30) silt, ML, w/cobbles & boulders
3.0' - 6.0'	Brown, mod. comp., silty (15-25) sandy (25-35) gravel, GM, w/cobbles & boulders
6.0'	Refusal, probable bedrock

BD-10 Elev. 695.5

0.0' - 0.6'	Topsoil
0.6' - 5.0'	Gray brown, mod. comp., gravelly (10-20) silty (25-35) sand, SM, Till, W_n = 11.5
5.0' - 10.0'	Gray brown, comp., gravelly 11 silty 45 sand, SM, Till, w/cobbles, W_4 = 12.7, 11.5 Non-Plastic D_{10} = 0.0052
10.0' - 20.0'	Gray brown, comp., gravelly 9, 13, 8 sandy, 33, 33, 38 clayey silt ML-CL, Till, w/cobbles & boulders, W_n = 12.0, 11.5, 12.1, W_4 = 12.0, 12.0, 12.8 LL = 22, PI = 4, D_{10} = 0.0019, 0.003, 0.0017, G_s = 2.80
20.0' - 30.0'	Gray brown, v. comp., gravelly (10-20) to (0-10) silty clayey (40-50) sand, SM-SC, Till, w/ cobbles & boulders, W_n = 8.0, 9.6, 8.0, W_4 = 9.6, 9.9, 9.2 LL = 23, PI = 5
30.0' - 40.0'	Gray brown, v. comp., gravelly 23 silty 46 sand, SM, Till w/cobbles & boulders, W_n = 8.8, 8.3, 10.1, W_4 = 9.2, 8.7, 10.2, Non-Plastic, D_{10} = 0.0026, G_s = 2.84
40.0' - 46.0'	Gray brown, v. comp., gravelly (10-20) to (0-10) silty (40-50) sand, SM, Till, w/boulders, W_n = 9.0, 9.1, 9.3, W_4 = 9.2, 9.4, 9.6, Non-Plastic
46.0' - 60.0'	Gray, v.comp., gravelly 20, 16 silty 44, 47 sand, SM, Till, w/cobbles & boulders, W_n = 8.6, 9.1, 6.9, 9.3 W_4 = 8.8, 9.6, 7.8, 10.5, Non-Plastic, D_{10} = 0.005, 0.0049 G_s = 2.82
60.0' - 65.0'	Gray, v. comp., gravelly (10-20) silty (40-50) sand, SM, Till, w/cobbles
65.0' - 70.0'	Gray, v. comp., silty clayey (38) sandy (28) gravel, GM-GC, Till, w/cobbles W_n = 9.5, W_4 = 10.6, LL = 21, PI = 5

BD-10 Continued

70.0 - 73.3'	Gray, v. comp., gravelly (10-20) clayey silty (40-50) sand, SM-SC, Till, W_n = 10.2, W_4 = 10.4
73.3'	Bottom of exploration

BD-11 Elev. 731.1

0.0' - 1.1'	Topsoil
1.1' - 1.6'	Gray brown, loose, gravelly (5-15) silty (20-30) m-f sand, SM
1.6' - 8.3'	Gray brown, loose to mod. comp., gravelly 7 m-f sandy 37, silt, ML, Till, W_n = 14.4, 14.3, W_4 = 14.5, 14.6, LL = 20, PI = 1 D_{10} = 0.0028, G_s = 2.82
8.3' - 20.0'	Gray, comp., gravelly (0-10) to 18 silty 47, m-f sand, SM, Till, w/cobbles & boulders W_n = 10.8, W_4 = 11.8, Non-Plastic, D_{10} = 0.0043
20.0' - 30.0'	Gray, comp., to v. comp., gravelly 26, 24 silty 43, 45 sand, SM, Till, w/cobbles W_n = 12.1, 10.7, W_4 = 13.1, 11.1, 11.5, LL = 21, PI = 3, D_{10} = ~~0.0043~~, 0.0024, G_s = 2.80
30.0' - 31.1'	Gray, v. comp., gravelly (5-15) f. sandy (25-35) silt, ML, Till, W_n = 14.0, W_4 = 14.4
31.1' - 40.0'	Gray, v. comp., gravelly (5-15) to 29 silty 43 sand, SM, Till, w/cobbles, W_n = 9.3, 9.9, 11.8 W_4 = 11.0, 11.6, 12.5, LL = 21, PI = 3, D_{10} = 0.0021
40.0' - 55.0'	Gray, comp., gravelly (10-20) to 23 silty-clayey 45 sand, SM-SC, Till, w/boulders W_n = 9.9, 10.1, 14.5, W_4 = 10.8, 11.8, 15.1, LL = 22, PI = 4, D_{10} = 0.002

BD-11 Continued

55.0' - 60.0'	Gray, comp., gravelly (15-25) to (5-15) silty-clayey (35-45) sand, SM-SC, Till, w/cobbles, W_n = 12.4, 14.9, W_4 = 13.3, 15.6
60.0' - 80.0'	Gray, comp., gravelly 23 to 28 silty-clayey 47 to 45 sand, SM-SC, Till, w/cobbles W_n = 11.9, 10.4, 9.8, 12.6, W_4 = 12.4, 13.3, 11.5, 17.1 LL = 24, PI = 6, D_{10} = 0.0012, 0.0014
80.0' - 89.0'	Gray, v. comp.,gravelly 26 silty-clayey 40 m-f sand, SM-SC, Till, w/boulders, W_n = 13.1, 9.4, W_4 = 14.9, 10.6, D_{10} = 0.002
89.0' -100.0'	Gray, v. comp., gravelly (10-20) to 23 silty-clayey 42, m-f sand, SM-SC, Till, w/boulders W_n = 9.9, 9.9, W_4 = 10.3, 11.1, LL = 20 PI = 5, D_{10} = 0.002
100.0' - 105.0'	Gray, v. comp., silty-clayey (35-45) m-f sand, SM-SC, Till, W_n = 8.0, W_4 = 8.9
105.0' - 122.1'	Gray, v. comp., gravelly 12 to 15 silty-clayey 43 to 45 m-f sand, SM-SC, Till, W_n = 9.3, 15.1, 13.9, 15.1, W_4 = 9.9, 15.5 14.3, 17.7, LL = 21, PI = 5, D_{10} = 0.0013, 0.0021
	NOTE: Sand is c-f from 105 to 110
122.1'	Bottom of exploration

BD-12 Elev. 751.5'

0.0' - 1.2'	Topsoil
1.2' - 3.1'	Gray brown, loose, silty (25-35) m-f sand, SM, Till, w/roots, W_n = 20.3, W_4 = 21.9
3.1' - 9.4'	Gray brown, mod. comp., gravelly 26 silty 24 sand, SM, Till, w/ cobbles, W_n = 13.0, 10.6, W_4 = 14.9, 14.0, D_{10} = 0.026

BD-12 Continued

9.4' - 13.0'	Gray, comp. to v. comp. gravelly 11 silty 47 sand, SM, till, W_n = 11.4, 12.1, W_L = 11.8, 12.5 D_{10} = 0.0036 Non-Plastic
13.0' - 15.0'	Gray, v. comp., silty (35-45) sandy (15-25) gravel, GM, Till, W_L = 8.5
15.0' - 20.0'	Gray, v. comp., gravelly 10 sandy 38, silt, ML, Till, w/cobbles, W_n = 9.4, 9.6, W_L = 9.9, 10.8, D_{10} = 0.002
20.0' - 35.6'	Gray, v. comp., gravelly 11 sandy 37 silt, ML, Till, w/cobbles, W_n 9.5, 9.6, 10.6, 8.1, 9.3, 8.9, W_L = 10.8, 10.0, 11.1, 9.7, 10.1, 10.7, LL = 19, PI = 3, D_{10} = 0.002
35.6 - 45.0'	Gray, v. comp., gravelly 16 to 11 sandy 33 to 35 clayey-silt, ML-CL, Till, w/cobbles W_n = 9.5, 8.2, W_L = 9.9, 8.7, LL = 22, PI = 6 D_{10} = < 0.001
45.0' - 48.2'	Gray, v.comp., gravelly 19 silty clayey 49 sand, SM-SC, Till, LL = 24, PI = 7, D_{10} = 0.0012
48.2'	Bottom of exploration

BD-13 Elev. 785.5

0.0' - 0.5'	Topsoil
0.5' - 2.5'	Gray brown, loose, sandy (m-f, 35-45) silt, ML, w/roots
2.5' - 7.0'	Gray brown, mod. comp., gravelly (10-20) silty (30-40) m-f sand, SM, Till
7.0'	Top of bedrock

BD-14 Elev. 628.2

0.0' - 0.2'	Forest litter
0.2' - 1.0'	Topsoil
1.0' - 3.0'	Brown, soft, sandy (m-f 25-35) silt, ML, w/roots
3.0' - 5.0'	Gray brown, mod. comp., silty (20-30) sandy (25-35) gravel, GM, Till, W_n = 14.9, W_L = 17.0

BD-14 Continued

5.0' - 15.0'	Gray brown, mod. comp., gravelly 13 to 14 m-f sandy 51 to 53 silt, ML, Till, w/occ. cobbles, D_{10} = 0.005, 0.0025, W_n = 13.1, 14.3, W_4 = 14.5, 14.5, LL = 21, 22, PI = 2,3.
15.0' - 25.0'	Gray, mod.comp., gravelly 25 silty-clayey 47, sand, SM-SC, Till, w/occ.cobbles, D_{10} = 0.0017, W_n = 10.6, 11.6, W_4 = 12.6, 12.3, LL = 22, PI = 4
25.0' - 40.0'	Gray, mod. comp. to comp., gravelly 24, silty-clayey 36 sand, SM-SC, Till, w/occ. cobbles, D_{10} = 0.0038, W_n = 8.8, 9.2, 9.1, W_4 = 10.0, 11.1, 12.3 LL = 21, PI = 4
40.0'	Bottom of Exploration

BD-15 Elev. 609.0

0.0' - 0.8'	Topsoil
0.8' - 2.0'	Gray, loose, sandy (f.30-40) silt, ML, w/organics
2.0' - 5.0'	Gray brown, mod.comp.,silty (10-20) sandy (30-40) gravel, GM, Till
5.0' - 7.2'	Gray brown, mod.comp., gravelly (10-20) silty (20-30) m-f sand, SM, Till, w/cobbles
7.2' - 15.0'	Gray brown, mod. comp., gravelly 13, silty 41, m-f sand, SM, Till, w/cobbles & boulders, D_{10} = 0.0042, W_n = 15.2, 19.4, W_4 = 15.7, 22.0, LL = 22, PI = 2
15.0' - 20.0'	Gray, comp., silty 32 m-f sandy 27 gravel, GM, Till, w/cobbles, D_{10} = 0.008, W_n = 13.0, W_4 = 13.7, LL = 21, PI = 3
20.0' - 25.0'	Gray, comp., gravelly 18 silty-clayey 45, m-f sand, SM-SC, Till, w/cobbles D_{10} = 0.002, W_n = 8.7, 9.4, W_4 = 9.0, 9.7, LL = 21, PI=5
25.0' - 28.0'	Gray, comp., silty (35-45) m-f sand, SM, Till, w/cobbles, W_n = 10.0, W_4 = 10.8
28.0' - 35.7'	Gray, comp., gravelly 7 silty 42 m-f sand, SM, Till, w/cobbles & boulders, D_{10} = 0.006, W_n = 10.6, 9.2, W_4 = 11.3, 10.7, Non-Plastic

BD-15 Continued

35.7' - 40.0'	Gray, comp., gravelly 12 clayey, silty 43 sand, SM-SC, Till, w/cobbles D_{10} = 0.003, W_n = 8.7, W_4 = 9.3, LL = 22, PI = 5
40.0'	Bottom of exploration

BD-16 Elev. 770.1

0.0' - 0.8'	Topsoil
0.8' - 5.0'	Gray brown, loose to mod. comp., silty (30-40) m-f sand, SM
5.0' - 10.0'	Gray brown, mod. comp., silty 38 m-f sandy 29 gravel, GM, Till, w/cobbles, D_{10} = 0.0095, Non-Plastic
10.0' - 16.0'	Gray, mod. comp., gravelly (0-10) silty (35-45) m-f sand, SM, Till, W_n = 11.9, W_4 = 12.3
16.0' - 20.0'	Gray, mod. comp., gravelly 10 m-f sandy 33 silt, ML, Till, D_{10} = 0.0012, W_n = 7.8, W_4 = 8.4
20.0' - 29.2'	Gray, comp., gravelly (10-20) silty (35-45) m-f sand, SM, Till, W_n = 9.2, 9.1, W_4 = 9.3, 9.2
29.2' - 32.0'	Gray, comp., silty (30-40) m-f sand, SM, Till, w/boulders
32.0' - 40.0'	Gray, comp., gravelly 15 silty 43 m-f sand, SM, Till, D_{10} = 0.004, W_n = 10.3, 11.0, 11.6, W_4 = 10.9, 11.1, 11.8, Non-Plastic
40.0' - 48.0'	Gray, v. comp., gravelly 16 silty 43 m-f sand, SM, Till, D_{10} = 0.0034, W_n = 8.5, 7.9, W_4 = 9.3, 8.6
48.0' - 48.4'	Gray, v.comp., silty (30-40) m-f sand, SM, Till
48.4' - 53.1'	Gray, v. comp., gravelly (15-25) silty (30-40) m-f sand, SM, Till, w/boulders W_n = 8.6, W_4 = 9.5

BD-16 Continued

53.1' - 54.6'	Gray, v. comp., silty (20-30) m-f sand, SM
54.6' - 60.0'	Gray, v. comp., gravelly 19 silty 44 m-f sand, SM, Till, D_{10} = 0.0025, W_n = 9.1, 8.3, W_4 = 9.7, 9.1, Non-Plastic
60.0' - 65.0'	Gray, v. comp., gravelly 20, silty 38 m-f sand, SM, Till, D_{10} = 0.0041, W_n = 7.9, [illegible], W_4 = 9.0, 10.5
65.0' - 67.0'	Gray, v. comp., gravelly (10-20) silty (25-35) m-f sand, SM, Till
67.0' - 73.0'	Gray, v. comp., gravelly (10-20) silty (35-45) m-f sand, SM, Till, w/boulders, W_n = 7.9, W_4 = 9.3
73.0' - 78.5'	Gray, v.comp.,gravelly 18, silty 32, m-f sand, SM, Till, D_{10} = 0.0062, W_n = 8.9, 9.1 W_4 = 9.5, 10.3 Non-Plastic
78.5' - 79.4'	Gray, v. comp., gravelly (5-15) silty, (35-45) m-f sand, SM, Till
79.4'	Bottom of exploration

BD-17 Elev. 747.8

0.0' - 0.7'	Topsoil
0.7' - 2.7'	Gray brown, loose, silty (30-40) m-f sand, SM, w/roots
2.7' - 10.0'	Gray brown, mod. comp. to comp., gravelly 31 silty 24 sand, SM, Till, D_{10} = 0.025, W_n = 18.8, W_4 = 21.1, Non-Plastic
10.0' - 20.0'	Gray brown, mod. comp., gravelly 16 silty 42 m-f sand, SM, Till, D_{10} = 0.006, W_n = 13.1, W_4 = 13.4
20.0' - 25.0'	Gray brown, comp., gravelly, (10-20) silty (30-40) m-f sand, SM, Till, W_n = 8.8, W_4 = 9.2
25.0' - 38.8'	Gray brown, comp., gravelly 17 to 19 silty 36 to 37 m-f sand, SM, Till, D_{10} = 0.014, 0.007, W_n = 8.5, 8.0, 9.6 W_4 = 9.1, 8.1, 10.7, Non-Plastic

BD-17 Continued

38.8' - 43.0'	Brown, comp., gravelly 10 silty 36 micaceous m-f sand, SM, Till, D_{10} = 0.016, W_2 = 14.7, 15.7, W_4 = 18.3, 17.2
43.0' - 55.1'	Weathered & decomposed rock
55.7'	Top of bedrock

BD-18 Elev. 465±

0.0' - 1.8'	Brown, loose, sandy (f. 30-40) silt, ML, w/roots
1.8' - 3.6'	Brown, mod. comp., silty (25-35) f. sand, SM
3.6' - 5.0'	Brown, mod. comp., sandy (25-35) gravel, GP
5.0' - 10.0'	Brown, mod. comp., gravelly 44 silty 11 sand, SP-SM
10.0' - 15.2'	Brown, loose, gravelly 27 silty 9 sand, SP-SM, D_{10} = 0.088
15.2' - 20.0'	Gray brown, loose, sandy (f. 20-30) silt, ML
20.0' - 20.7'	Gray brown, loose, silty (15-25) f. sand, SM
20.7' - 25.0'	Gray brown, loose, gravelly (10-20) silty (5-15) m-f sand, SP-SM w/cobbles
25.0'	Bottom of exploration

BD-19 Elev. 460±

0.0' - 1.4'	Topsoil
1.4' - 8.0'	Brown, comp., silty 8 sandy 34 gravel, GP-GM, w/cobbles, D_{10} = 0.09
8.0' - 15.0'	Brown, comp., variable gravelly (25-35) to (20-30) silty (10-20) to (15-25) sand, SM, w/cobbles
15.0' - 20.0'	Brown, mod. comp., silty 12 sandy 39 gravel, GM, w/cobbles

BD-19 Continued

20.0' - 25.0'	Brown, mod. comp., gravelly 26 silty 7 sand, SP-SM, w/cobbles, D_{10} = 0.094
25.0'	Bottom of exploration

BD-20 Elev. 458±

0.0' - 0.3'	Topsoil
0.3' - 1.4'	Brown, loose, gravelly (0-10) silty (30-40) f. sand, SM, w/roots
1.4' - 10.0'	Gray brown, mod. comp., silty 10 sandy 37 gravel, GP-GM, w/cobbles, D_{10} = 0.0074
10.0' - 20.0'	Brown, mod. comp., gravelly 33 silty 11 sand, SP-SM, w/cobbles & decomposed gravel
20.0' - 25.0'	Gray brown, mod. comp., gravelly (25-35) silty (15-25) sand, SM
25.0'	Bottom of exploration

BD-21 Elev. 455±

0.0' - 2.0'	Dark brown, soft, sandy, (f. 20-30) organic silt, OL
2.0' - 5.0'	Gray, loose, silty (30-40) m-f sand, SM, w.layers of silt, ML, 1/2" - 1"
5.0' - 11.3'	Brown, mod. comp., silty 12 sandy 36 gravel, GM, w/cobbles
11.3' - 20.0'	Brown gray, comp., silty (15-25) sandy (30-40) gravel, GM, Till, w/cobbles
20.0'	Bottom of exploration

BD-22 Elev. 453±

0.0' - 0.4'	Topsoil
0.4' - 3.0'	Brown, loose, silty (20-30) f. sand, SM
3.0' - 5.0'	Brown, mod. comp., silty (5-15) sandy (25-35) gravel, GP-GM, w/cobbles

BD-22 Continued

5.0' - 10.0'	Brown, loose, silty 4 sandy 30 gravel, GP, w/cobbles, D_{10} = 0.24
10.0' - 14.3'	Brown, loose, silty 11 sandy 42 gravel, GP-GM, w/cobbles
14.3' - 17.0'	Brown, mod. comp., gravelly 6 silty 28 m-f sand, SM
17.0' - 25.0'	Brown, mod. comp., silty 8 sandy 30 gravel, GP-GM, w/cobbles & decomposed gravel, D_{10} = 0.09
25.0'	Bottom of exploration

BD-23 Elev. 445+

0.0' - 5.6'	Brown, loose, silty 20 m-f sand, SM
5.6' - 15.0'	Brown, mod. comp., silty 8 sandy 37 gravel, GP-GM, w/cobbles & weathered cobbles, D_{10} = 0.091
15.0' - 20.0'	Brown, loose, silty 11 sandy 36 gravel GP-GM, w/cobbles
20.0' - 25.0'	Brown, loose, silty (5-16) sandy (30-40) gravel, GP-GM, w/weathered gravel & cobbles & 1/2" layer silty (30-40) f. sand, SM
25.0'	Bottom of exploration

BD-24 Elev. 465±

0.0' - 1.3'	Topsoil
1.3' - 3.2'	Brown, loose, silty (10-25) f. sand, SM
3.2' - 9.6'	Brown, mod. comp., silty 5 sandy 38 gravel, GP, w/cobbles, D_{10} = 0.19
9.6' - 10.0'	Brown, mod. comp., gravelly (20-30) silty (10-20) sand, SM
10.0' - 13.4'	Brown, mod. comp., silty 5 sandy 42 gravel, GW-GM, w/cobbles, D_{10} = 0.17

BD-24 Continued

13.4' - 15.0'	Brown, mod. comp., silty (15-25) sandy (30-40) gravel, GM, Till
15.0' - 16.2'	Gray brown, mod. comp., gravelly (25-35) silty (15-25) sand, SM, Till
16.2' - 19.5'	Brown, gray, mod. comp., silty (25-35) f. sand, SM, w/rock fragments
19.5'	Refusal

BD-25 Elev. 467±

0.0' - 0.6'	Topsoil
0.6' - 2.3'	Brown, loose, silty (25-35) f. sand, SM
2.3' - 5.0'	Brown, loose, silty (10-20) f. sand, SM
5.0' - 5.6'	Brown, loose, silty (30-40) f. sand, SM
5.6' - 9.1'	Brown, mod. comp., silty (10-20) sandy (30-40) gravel, GM
9.1' - 9.4'	Brown, comp., gravelly (20-30) silty (15-25) sand, SM, Till
9.4' - 9.6'	Rock fragments w/silty sand, SM
9.6'	Refusal

BD-26 Elev. 470±

0.0' - 1.8'	Topsoil
1.8' - 5.0'	Brown, loose, silty (20-40) to (10-20) f. sand, SM
5.0' - 10.0'	Gray brown, mod. comp., silty (15-25) sandy (30-40) gravel, GM, Till, w/weathered cobbles and layers of silt & clay to 1/4"
10.0' - 11.1'	Dark brown, loose, micaceous silty (25-35) f. sand, SM
11.1'	Bottom of exploration

BD-27 Elev 467±

0.0' - 1.4'	Dark brown, loose, silty (20-30) m-f sand, SM, w/ roots & organics
1.4' - 7.8'	Brown, mod. comp., gravelly 27 silty 8 sand, SP-SM w/cobbles, D_{10} = 0.1
7.8' - 10.0'	Brown, comp., gravelly (20-30) silty (5-15) sand, SP-SM, w/weathered cobbles
10.0' - 15.0'	Brown, mod. comp., silty 11 sandy 41 gravel, GW-GM
15.0' - 25.0'	Brown, loose, silty (15-25) f. sand, SM, w/occasional 1" strata of silt, ML
25.0'	Bottom of exploration

BD-28 Elev. 470±

0.0' - 5.0'	Dark gray, loose, sandy (f. 30-40) silt, ML, w/roots, organics and mica
5.0' - 6.4'	Dark gray, mod. comp., sandy (f. 30-40) silt, ML
6.4' - 8.3'	Brown, comp., silty (5-15) sandy (30-40) gravel, GP-GM, w/cobbles
8.3' - 14.2'	Gray brown, comp., silty (8) sandy (28) gravel, GP-GM, w/cobbles, D_{10} = 0.1
14.2'	Refusal

BD-29 Elev. 472±

0.0' - 3.7'	Brown, loose, silty (25-40) m-f sand, SM w/turf, roots and organics
3.7' - 11.0'	Gray brown, loose to mod. comp., silty 5 sandy 31 gravel, GP-GM, D_{10} = 0.2
11.0' - 20.0'	Brown gray, comp. to mod. comp., gravelly (20-30) silty (15-25) sand SM, Till, w/fragments of decomposed rock from 11.0 to 15.0'
20.0'	Bottom of exploration

BD-30 Elev. 488±

0.0' - 0.5'	Topsoil
0.5' - 2.6'	Brown, loose, silty (10-40) f. sand, SM, w/roots & silt layers
2.6' - 3.8'	Brown, loose, gravelly (20-30) silty (20-30) sand, SM
3.8' - 4.4'	Brown, loose, silty (5-15) sandy, (25-35) gravel, GP-GM
4.4' - 5.3'	Decomposed rock & rock fragments
5.3'	Refusal

BD-31 Elev. 490±

0.0' - 0.4'	Topsoil
0.4' - 4.3'	Gray, loose, f. sandy (10-20) silt, ML, w/roots
4.3' - 5.0'	Dark gray, loose. f. sandy (30-40) silt, ML, w/organics
5.0' - 5.7'	Dark gray, mod. comp., silty (25-35) m-f sand, SM, w/silt layers
5.7' - 6.2'	Dark gray, mod. comp., sandy (f. 30-40) silt, ML
6.2' - 13.5'	Brown, mod. comp., silty 8 to 6 sandy 36-39 gravel, GP-GM & GW-GM, D_{10} = 0.1, 0.15
13.5' - 14.8'	Gray, comp., sandy (f.30-40) silt, ML, w/weathered schist fragments
14.8' - 15.0'	Brown, silty (15-25) sandy (25-35) gravel, GM
15.0' - 18.0'	Gray, comp., silty (20-30) sandy (25-35) gravel, SM, Till, w/weathered schist fragments
18.0'	Bottom of exploration

BT-3 Elev. 690±

0.0' - 0.5'	Topsoil
0.5' - 3.4'	Brown, loose, sandy (f. 30-40) silt, ML, w/roots
3.4' - 11.4'	Gray brown, comp., gravelly 17 silty 45 m-f sand, SM, Till, w/cobbles, W_n = 13.7, W_4 = 15.1, LL = 21, PI = 1, D_{10} = 0.0044, γ_d = 120
11.4' - 15.0'	Gray, comp., gravelly 20 silty 49 sand, SM, Till, w/cobbles, W_n = 12.4, W_4 = 14.3, LL = 21, PI = 3, D_{10} = 0.0025, γ_d = 126
15.0'	Bottom of exploration

BT-4 Elev. 456.2

0.0' - 0.9'	Topsoil
0.9' - 2.7'	Brown, loose, sandy (f.35-45) silt, ML
2.7' - 9.0'	Brown, comp., sandy 29 gravel GP, w/cobbles & boulders, D_{10} = 0.42
9.0' - 12.3'	Brown, comp., gravelly 46, sand, SP, w/cobbles & boulders, D_{10} = 0.15
12.3'	Bottom of exploration

BT-5 Elev. 459.6

0.0' - 0.8'	Topsoil
0.8' - 2.2'	Brown, loose, silty (35-45) f. sand, SM
2.2' - 8.5'	Brown, comp., silty 10 sandy 22 gravel, GP-GM, w/cobbles & boulders, D_{10} = 0.74
8.5' - 10.6'	Brown, comp., stratified, m-f sand, SP, D_{10} = 0.13
10.6' - 12.0'	Brown, comp., gravelly 32 sand, SP, w/cobbles & boulders, D_{10} = 0.16
12.0'	Bottom of exploration

BT-6 Elev. 462.1

0.0' - 1.3'	Topsoil w/cobbles
1.3' - 3.1'	Brown, comp., silty (30-40) f. sand, SM
3.1' - 11.6'	Brown, comp., sandy, 35, gravel, GP, w/cobbles & boulders, D_{10} = 0.42
11.6'	Bottom of exploration

BT-7 Elev. 464.0

0.0' - 0.6'	Topsoil
0.6' - 1.5'	Brown, loose, silty (35-45) f. sand, SM, w/roots
1.5' - 7.2'	Brown, comp., gravelly 47 sand, SP, w/cobbles & boulders, D_{10} = 0.16
7.2' - 8.3'	Gray, loose, sandy (fine) 50 silt, ML
8.3' - 10.5'	Brown, gravelly 36, silty 9 sand, SP-SM, D_{10} = 0.08
10.5'	Bottom of exploration

BT-8 Elev. 468.3

0.0' - 0.7'	Topsoil & forest debris
0.7' - 2.1'	Brown, comp., sandy (f.35-45) silt, ML, w/roots
2.1' - 9.6'	Brown, comp., gravelly 34, silty 16, sand, SM, w/cobbles & boulders
9.6'	Bottom of explorations

BT-9 Elev. 460.3

0.0' - 0.6'	Topsoil
0.6' - 2.3'	Brown, loose, silty (35-45) f. sand, SM
2.3' - 3.5'	Brown, comp., sandy 41 gravel, GP, w/cobbles D_{10} = 0.21
3.5' - 4.8'	Brown, comp., m-f sand, SP, D_{10} = 0.20
4.8' - 11.2'	Brown, comp., silty 5 sandy 40 gravel GP, w/cobbles & boulders, D_{10} = 0.15
11.2'	Bottom of exploration

BT-10 Elev. 458.2

0.0' - 0.5'	Topsoil & forest debris
0.5' - 1.8'	Brown, loose, sandy (f. 35-45) silt, ML, w/roots
1.8' - 3.9'	Brown, loose, silty (35-45) f. sand, SM
3.9' - 10.0'	Brown, comp., silty 7 sandy 42 gravel, GP-GM, w/cobbles, D_{10} = 0.13
10.0'	Bottom of exploration

BT-11 Elev. 453.8

0.0' - 1.7'	Black, silt & swamp litter
1.7' - 3.9'	Gray, loose, sandy (f. 30-40) silt, ML
3.9' - 9.6'	Brown, comp., sandy 36 gravel, GP, D_{10} = 0.17
9.6'	Bottom of exploration

BT-12 Elev. 481.4

0.0' - 0.9'	Topsoil & forest debris
0.9' - 2.3'	Brown, loose, gravelly (10-20) silty (20-30) sand, SM, w/roots
2.3' - 7.4'	Brown, comp., gravelly 28 sand, SP, D_{10} = 0.21
7.4' - 11.5'	Brown, comp., gravelly 12 silty 27 sand, SM
11.5'	Bottom of exploration

BT-13 Elev. 475.9

0.0' - 0.6'	Topsoil
0.6' - 9.5'	Brown, comp., sandy 29 gravel, GP, w/cobbles & boulders, D_{10} = 0.7
9.5'	Bottom of exploration

BT-14 Elev. 477.3

0.0' - 0.8'	Topsoil
0.8' - 3.7'	Brown, loose, silty 16 m-f. sand, SM
3.7' - 10.6'	Brown, comp., sandy 40, gravel, GP, w/cobbles & boulders, D_{10} = 0.4
10.6'	Bottom of exploration

BT-15 Elev. 491.5

0.0' - 1.0'	Topsoil
1.0' - 2.3'	Brown, loose, sandy (f. 30-40) silt, ML, w/roots
2.3' - 7.1'	Brown, comp., sandy 31, 39 gravel, GP, w/cobbles, D_{10} = 0.17, 0.19
7.1' - 10.5'	Brown, comp., silty 5 sandy 33 gravel, GP-GM, w/cobbles, D_{10} = 0.14
10.5'	Bottom of exploration

BA-1 Elev. 461.6

0.0' - 0.3'	Topsoil
0.3' - 1.3'	Dark brown, loose, silty (20-30) f. sand, SM, w/roots
1.3' - 2.4'	Brown, loose, silty (15-25) f. sand, SM w/roots
2.4' - 3.6'	Brown, loose, gravelly (15-25) sand, SP
3.6' - 5.2'	Brown, loose, m-f sand, SP
5.2' - 6.1'	Dark brown, loose, silty (15-25) m-f sand, SM
6.1' - 6.8'	Dark brown, loose, gravelly (20-30) silty (10-20) sand, SM
6.8'	Hole caving

BA-2 Elev. 466.0

0.0' - 0.6'	Topsoil
0.6' - 1.9'	Dark brown, loose, silty (25-35) f. sand, SM
1.9' - 3.4'	Brown, loose, silty (5-15) m-f sand, SP-SM
3.4' - 5.1'	Brown, loose, gravelly (15-25) sand, SP
5.1'	Hole caving

BA-3 Elev. 469.7

0.0' - 0.6'	Topsoil
0.6' - 1.8'	Brown, loose, silty (20-30) f. sand, SM, w/roots
1.8' - 3.6'	Brown, loose, gravelly (20-30) silty (10-20) m-f sand, SM
3.6' - 3.9'	Brown, loose, gravelly (5-15) silty (15-25) m-f sand, SM
3.9'	Hole Caving

BA-4 Elev. 472.0

0.0' - 0.6'	Topsoil
0.6' - 1.8'	Brown, loose, silty (20-30) f. sand, SM, w/roots
1.8' - 4.6'	Brown, loose, silty (15-25) m-f sand, SM
4.6'	Refusal on gravel

BA-5 Elev. 477.7

0.0' - 0.9'	Topsoil
0.9' - 2.3'	Brown, loose, sandy (30-40) gravel, GP
2.3' - 4.2'	Brown, loose, gravelly (10-20) to (30-40) sand, SP
4.2'	Refusal on gravel

BA-6 Elev. 473.3

0.0' - 0.9'	Topsoil
0.9' - 2.9'	Brown, loose, silty (20-30) m-f sand, SM
2.9' - 3.7'	Brown, loose, silty (10-20) sandy (25-35) gravel, GM
3.7'	Hole caving

BA-7 Elev. 473.6

0.0' - 1.2'	Topsoil
1.2' - 3.4'	Brown, mod. comp., silty (10-20) sandy (25-35) gravel, GM, w/cobbles
3.4'	Refusal on cobbles

BA-8 Elev. 473.1

0.0' - 0.7'	Topsoil
0.7' - 3.0'	Brown, loose, silty (20-30) f. sand, SM
3.0' - 3.5'	Cobbles
3.5'	Refusal on cobbles

BA-9 Elev. 505.1

0.0' - 0.6'	Topsoil
0.6' - 2.2'	Brown, loose, f. sandy (15-25) silt, ML
2.2' - 3.4'	Brown, mod. comp., gravelly (30-40) silty (15-25) sand, SM
3.4'	Refusal on cobbles

BA-10 Elev. 505.0

0.0' - 0.7'	Topsoil
0.7' - 2.8'	Brown, loose, silty (25-35) f. sand, SM, w/root hairs
2.8' - 5.2'	Brown, comp., silt, ML
5.2' - 6.8'	Brown, loose, silty (30-40) f. sand, SM
6.8'	Refusal

BA-11 Elev. 500.4

0.0' - 1.9'	Topsoil
1.9' - 3.4'	Dark brown, loose, silty (15-25) sandy (30-40) gravel, GM, w/roots & cobbles
3.4'	Refusal on cobbles

BA-12 Elev. 482.7

0.0' - 1.7'	Topsoil
1.7' - 2.4'	Brown, loose, m-f sand, SP
2.4' - 3.7'	Brown, loose, gravelly (25-35) m-f sand, SP
3.7'	Bottom of exploration

BA-13 Elev. 481.8

0.0' - 0.6'	Topsoil w/cobbles
0.6' - 3.0'	Brown, loose, gravelly (25-35) sand, SP, w/mica & cobbles
3.0'	Refusal on cobbles