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DCNO 82

TASK 6

13

Design Calculation Cover Sheet

ACRES

PROJECT No. P5700

FILE No. P5700.14.06

SERIAL No. 0028

PROJECT TITLE Susitna Hydroelectric Project

Alaska Power Authority

DEPARTMENT Geotech - Buffalo

CALCULATIONS FOR: Impervious Core Gradation Study. (PRECEDENT CASES, TILL)

ORIGINAL BY L. Duncan/T. Shaw DATE 11/ 19 / 81

CHECKED BY DATE / /

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CONTENTS:
1. Cover Sheet - 1 pg.
2. Comparison Data Sheet - 1 pg.
3. Composite Curves - D&H - 2 pgs. & 2 overlays
4. Comparison Gradations - 12 pgs. (incl. one blue line)
5. Comparison Gradations - Total Range - 1 pg.
6. Comparison Gradations - D&H, D Range Curves - 2 pgs.

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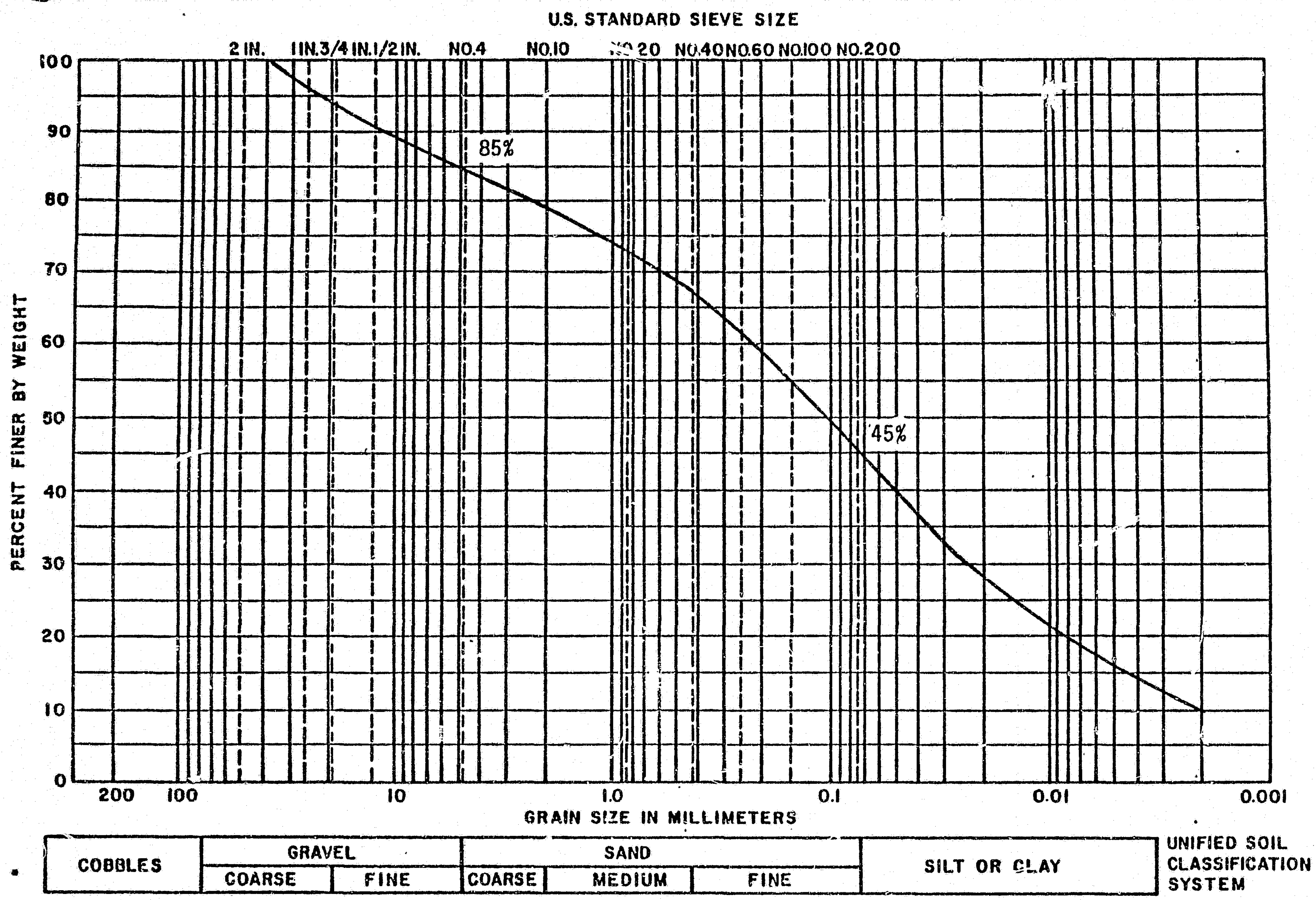
DATE 15 / MAR / 82

xc to DWL VS 11/23/81

TOTAL No. OF SHEETS 21 pgs w/ cover

ACRES **Calculation Criteria, Data and References** WATANA DAM CORE MATERIAL COMPARISONS	**Project No.** P5700 **File No.** P5700.14.06 **Serial No.** 0028

The attached graphs represent the published gradations of glacial till used as dike and/or dam core material. The Watana Borrow Area D composite and Area H composite curves are from November 1981 test results, the gradation band that is superimposed on the composite reference case sheet represents the normal range from all 1978-1981 individual sample testing.



G=2.71

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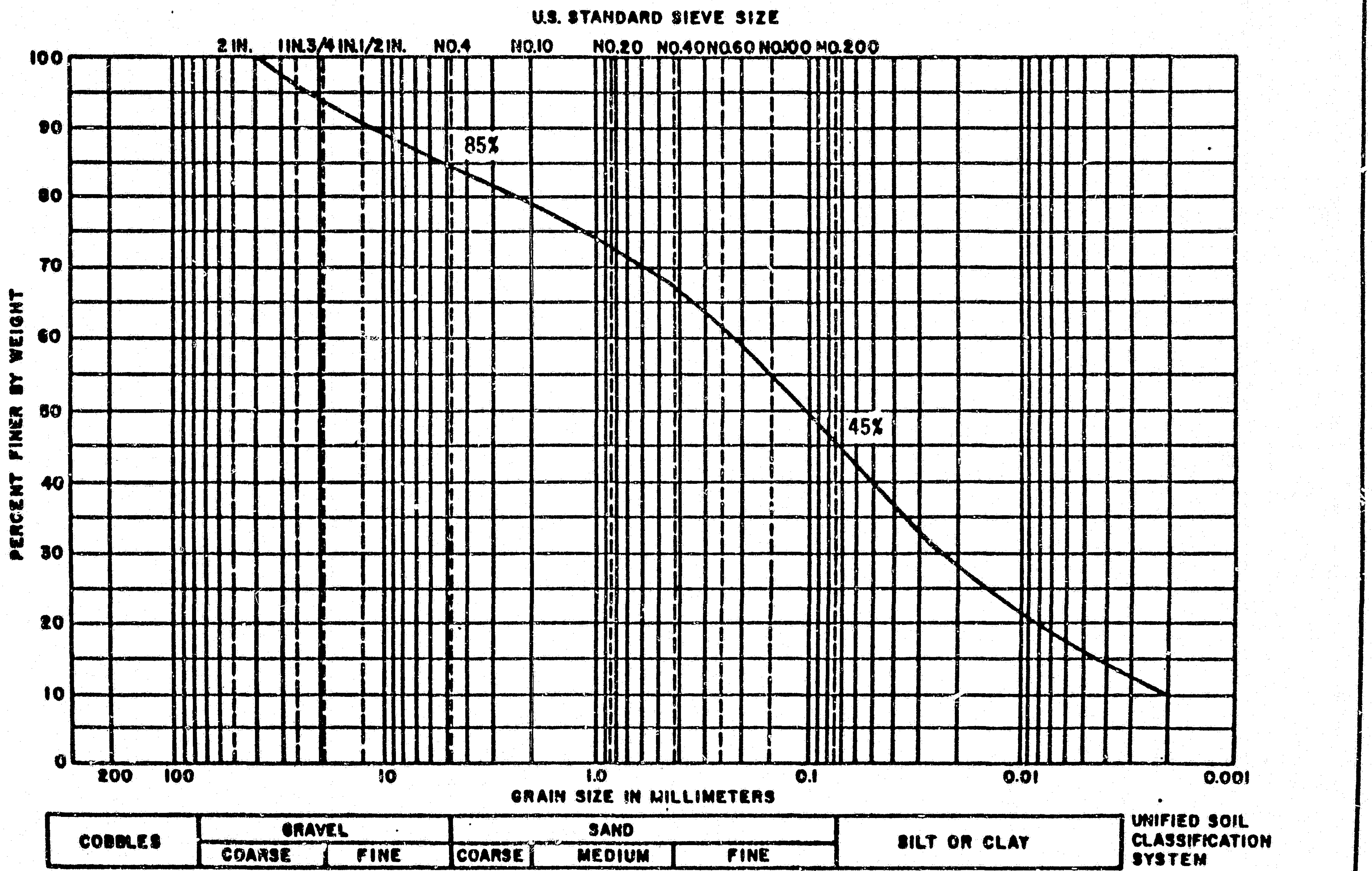
BUFFALO, NEW YORK

COMPOSITE CURVES FOR AREA D

GRADATION ANALYSIS CURVES

FILE: | DATE: 11/19/81 | FIG.



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COMPOSITE CURVES FOR AREA D

GRADATION ANALYSIS CURVES

FILE:

DATE:

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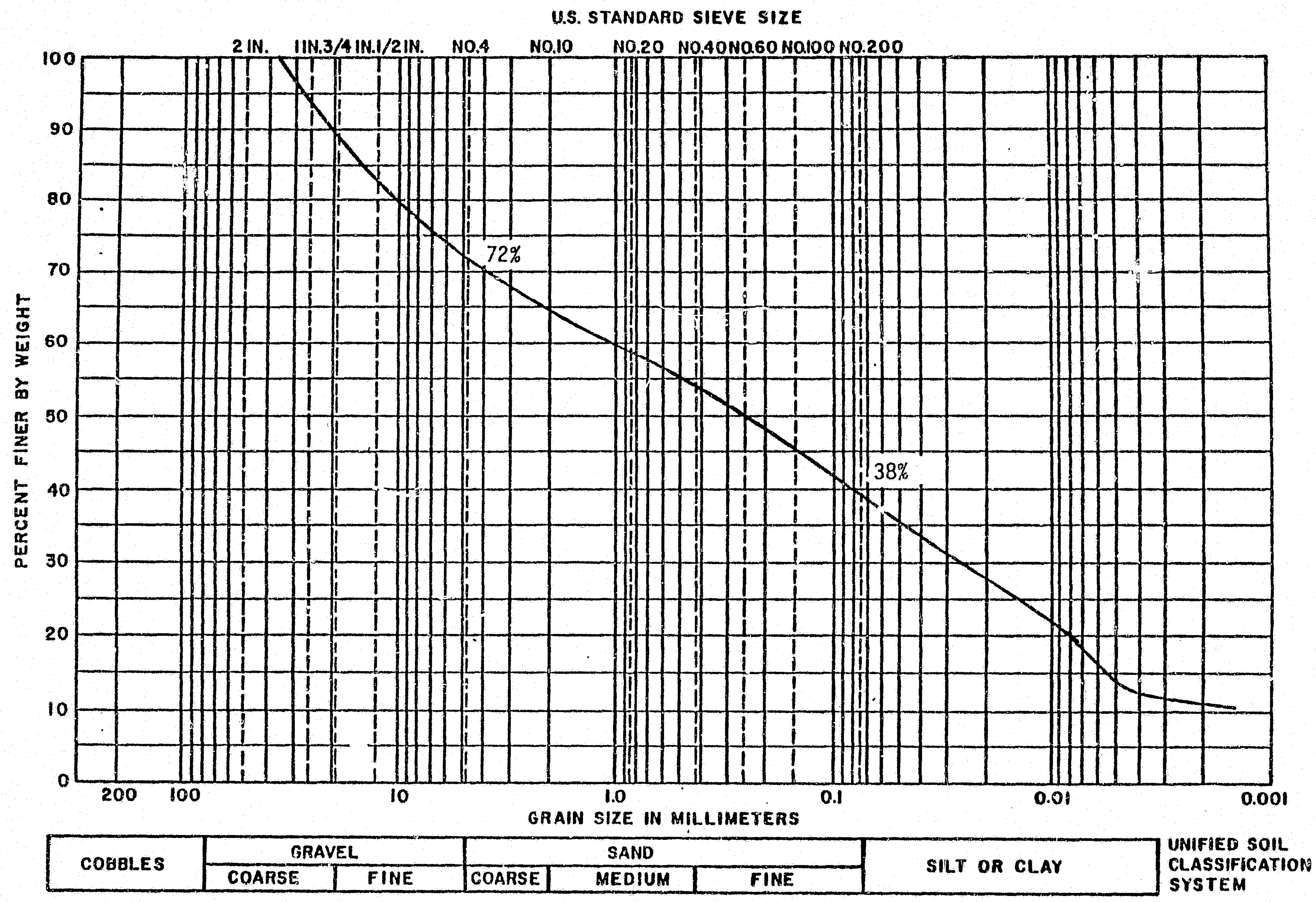

G=2.72

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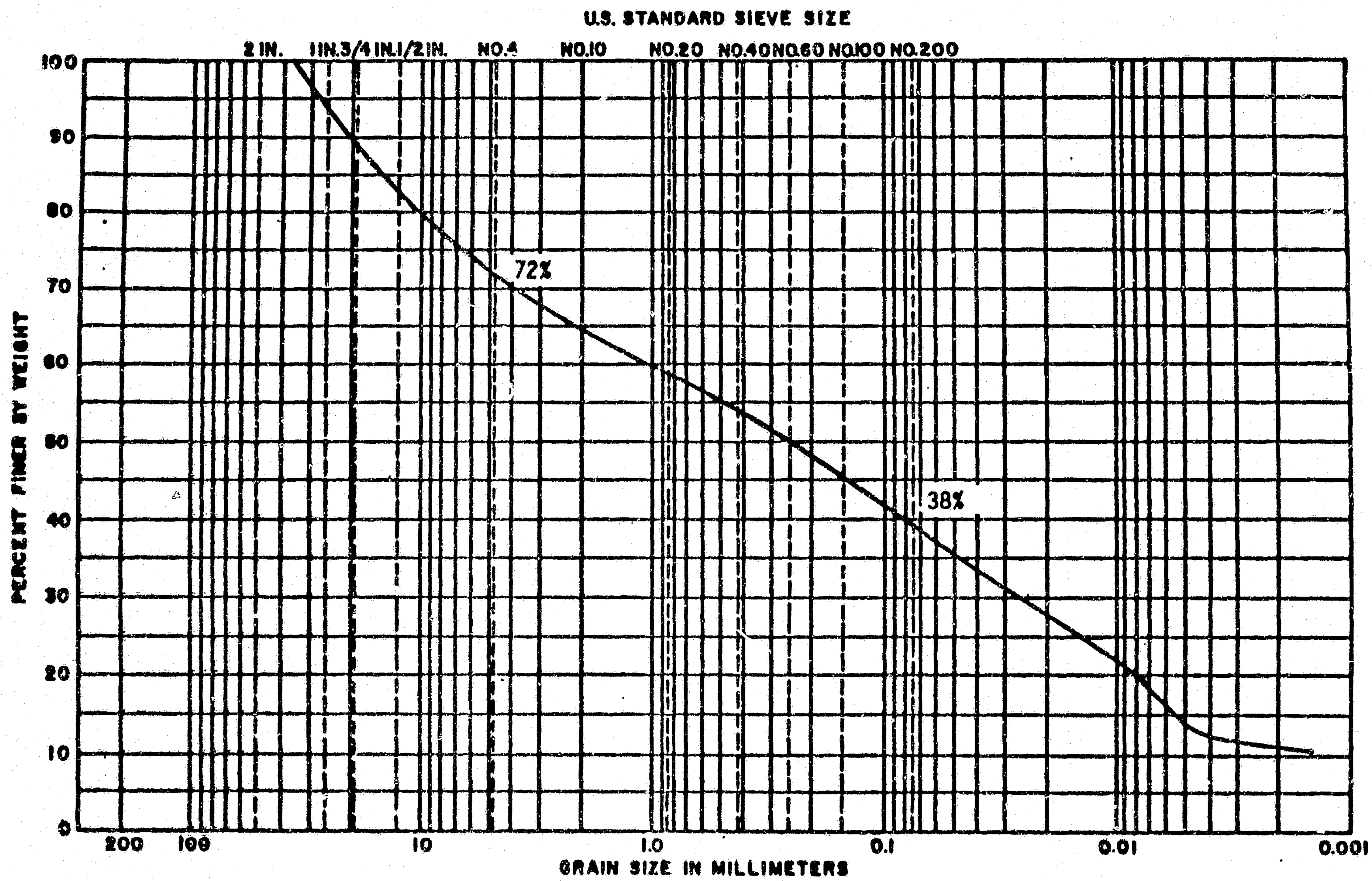
COMPOSITE CURVES FOR AREA H

GRADATION ANALYSIS CURVES

FILE:

DATE: 11/19/81

FIG.



COBBLES	GRAVEL		SAND			SILT OR CLAY	UNIFIED SOIL CLASSIFICATION SYSTEM
	COARSE	FINE	COARSE	MEDIUM	FINE		

G=2.72

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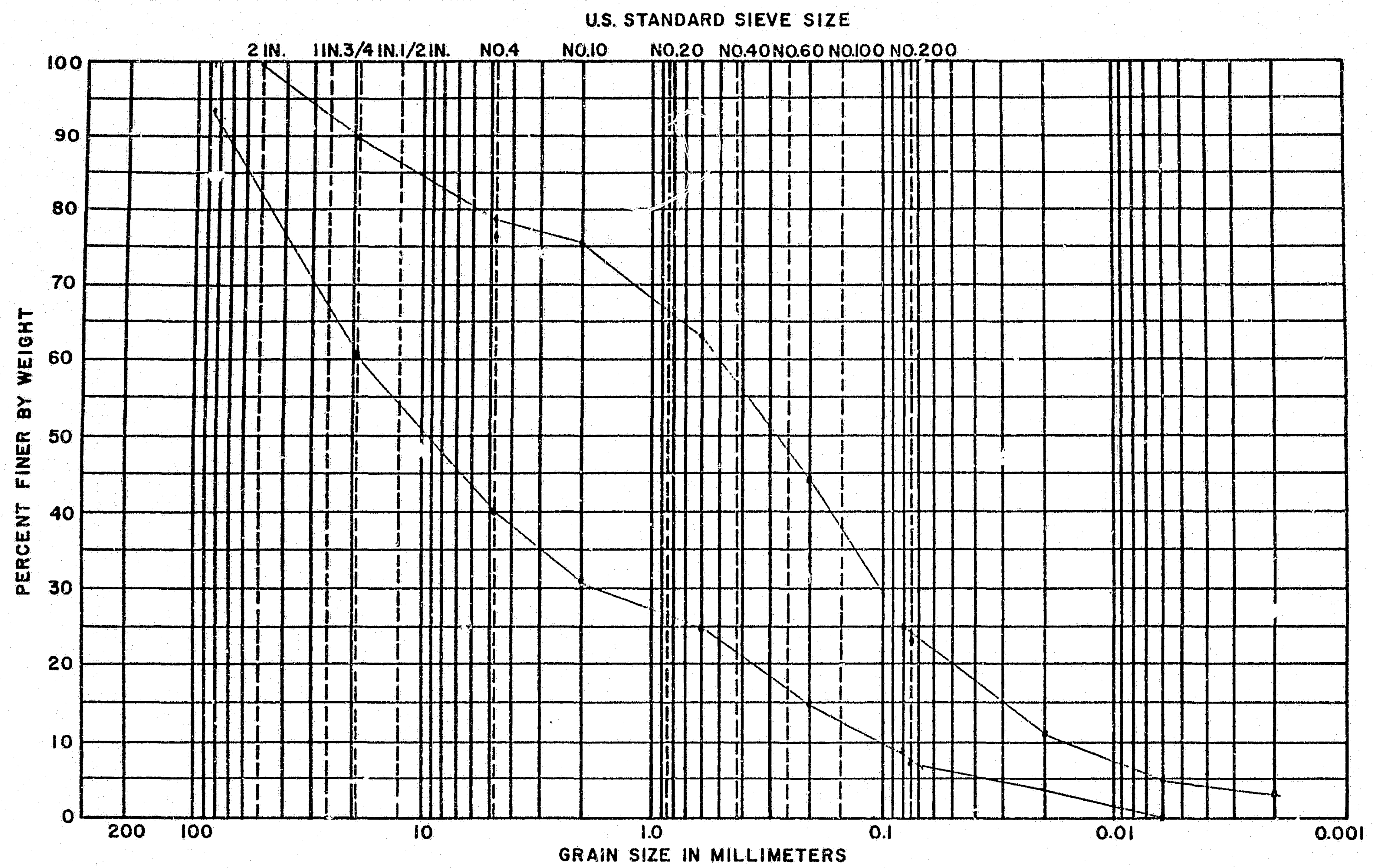
COMPOSITE CURVES FOR AREA H

GRADATION ANALYSIS CURVES

FILE: | DATE: | FIG.



COBBLES	GRAVEL		SAND			SILT OR CLAY	UNIFIED SOIL CLASSIFICATION SYSTEM
	COARSE	FINE	COARSE	MEDIUM	FINE		

LAB TEST NO.	BORING NO.	SAMPLE NO.	DEPTH	CURVE SYMBOL	CLASSIFICATION

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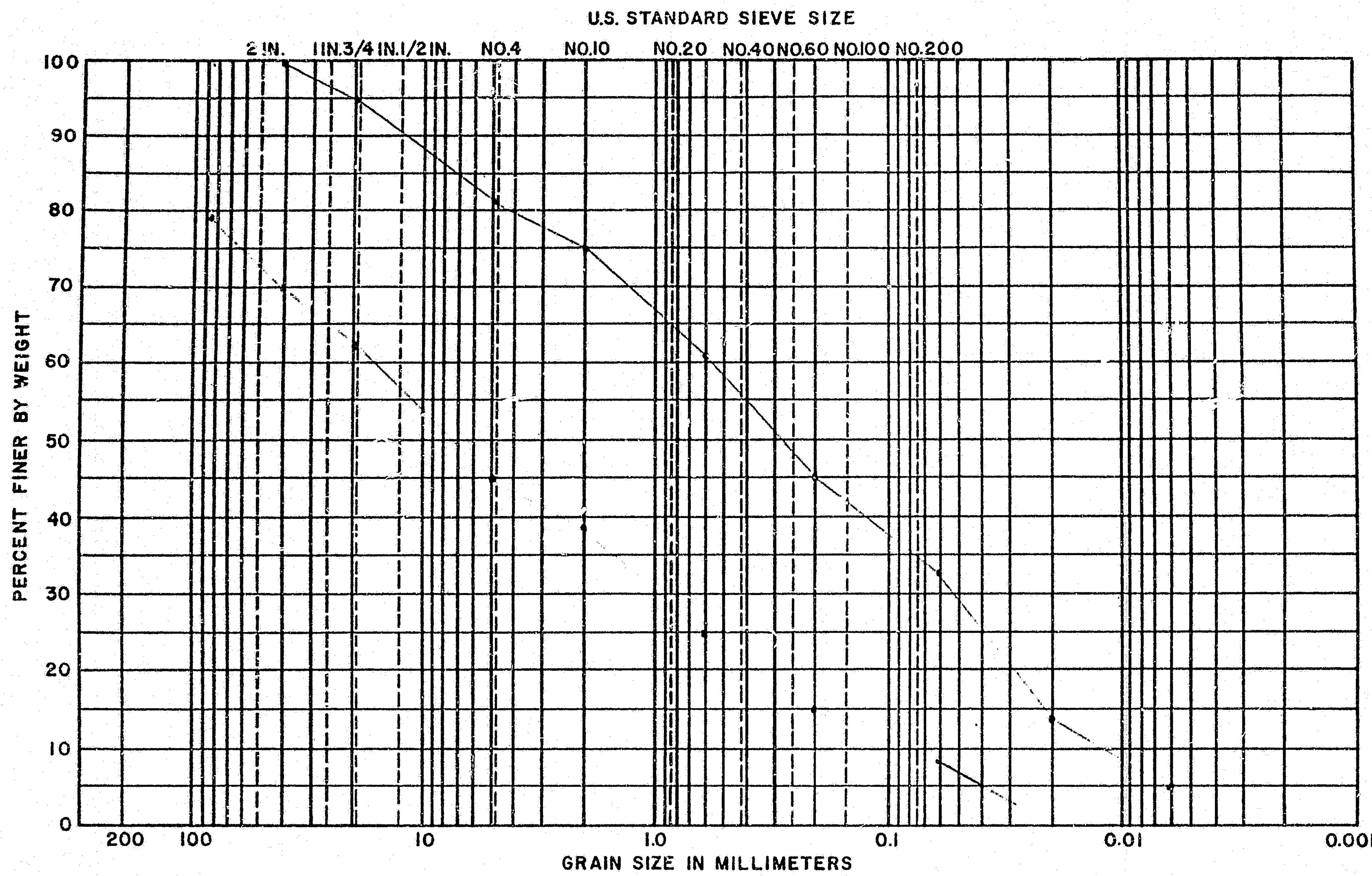
GULL ISLAND

GRADATION ANALYSIS CURVES

FILE: P5700 | DATE: 11/19/81 | FIG.



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

UNIFIED SOIL CLASSIFICATION SYSTEM

LAB TEST NO.	BORING NO.	SAMPLE NO.	DEPTH	CURVE SYMBOL	CLASSIFICATION

GRADATION ANALYSIS CURVES

ACRES

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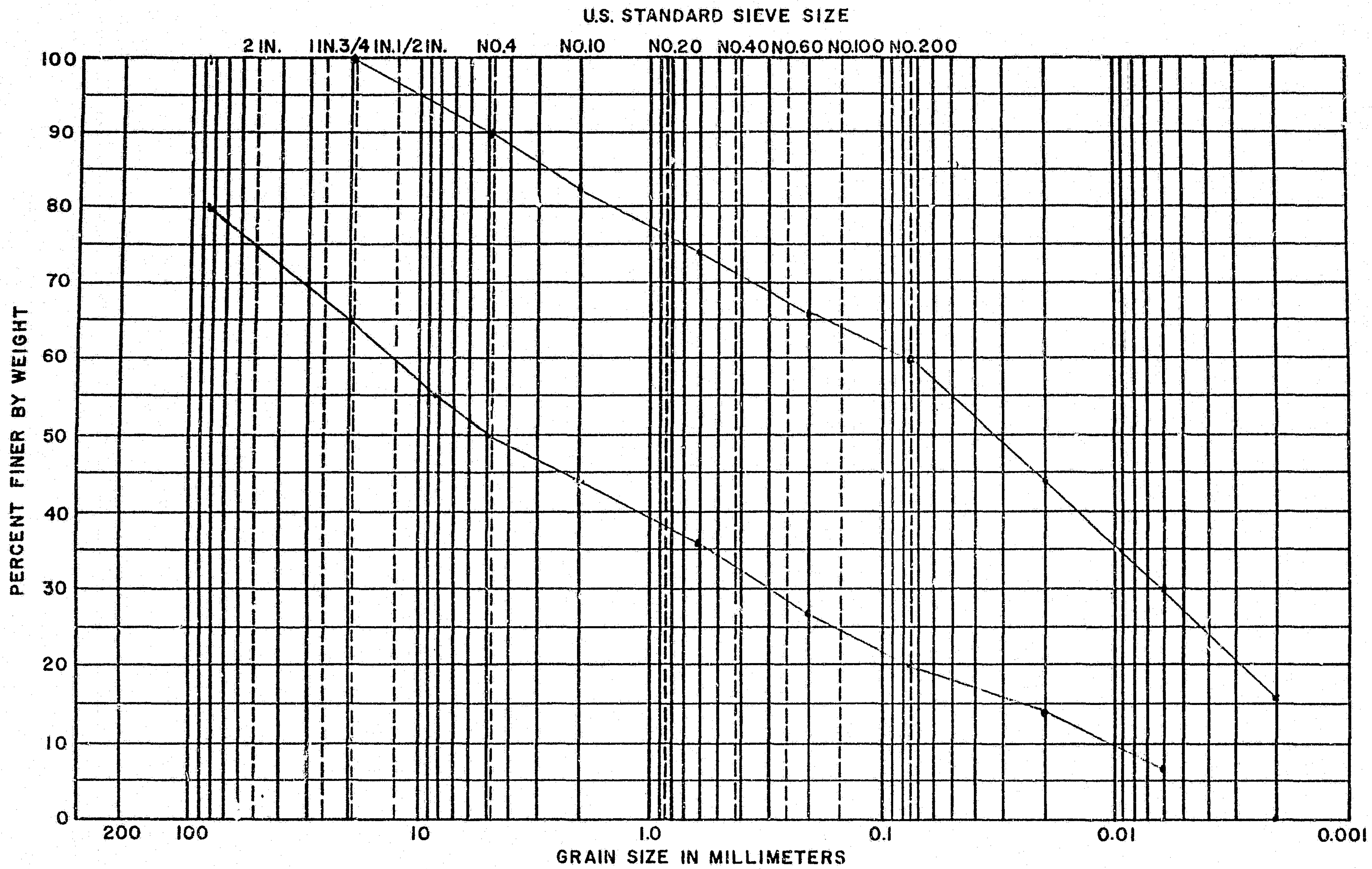
BUFFALO, NEW YORK

CHURCHILL FALLS

FILE: P5700	DATE: 11/19/81	FIG.



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

UNIFIED SOIL CLASSIFICATION SYSTEM

LAB TEST NO.	BORING NO.	SAMPLE NO.	DEPTH	CURVE SYMBOL	CLASSIFICATION

ACRES AMERICAN INCORPORATED

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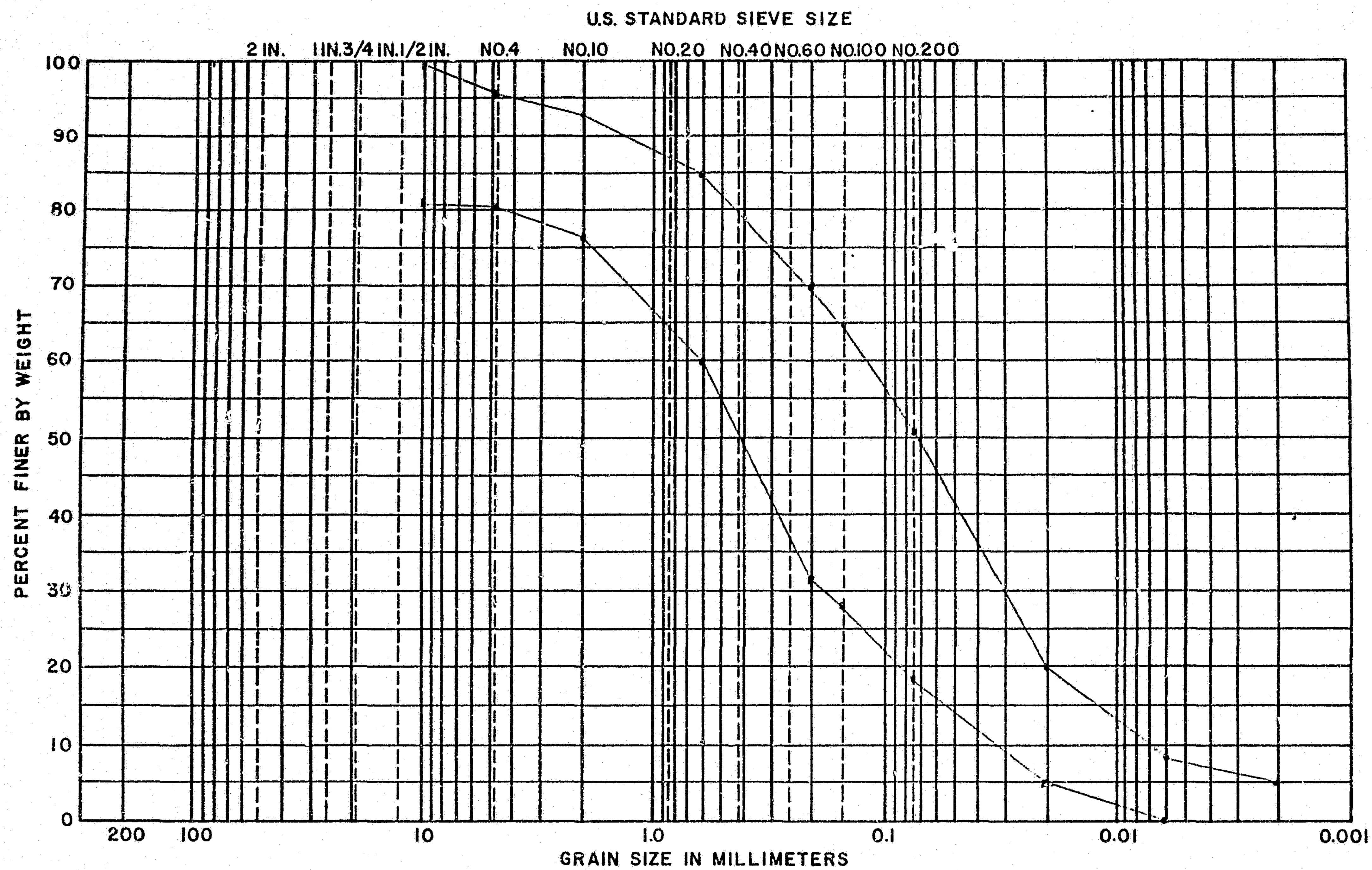
MICA

GRADATION ANALYSIS CURVES

FILE: P5700 | DATE: 11/19/81 | FIG.



COBBLES	GRAVEL		SAND			SILT OR CLAY	UNIFIED SOIL CLASSIFICATION SYSTEM
	COARSE	FINE	COARSE	MEDIUM	FINE		

LAB TEST NO.	BORING NO.	SAMPLE NO.	DEPTH	CURVE SYMBOL	CLASSIFICATION

GRADATION ANALYSIS CURVES

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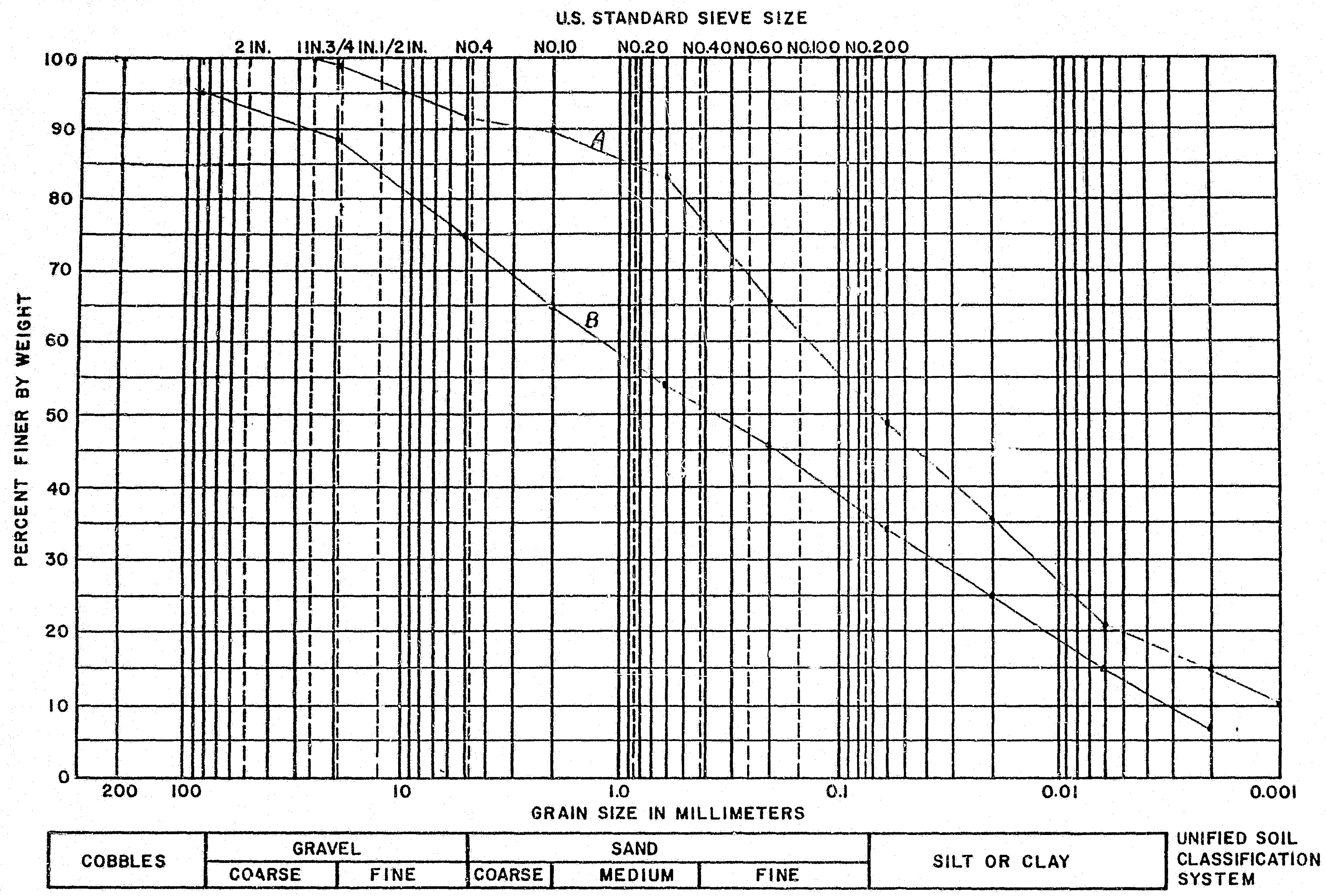
BERSIMIS

FILE: P5700 | DATE: 11/19/81 | FIG.



LAB TEST NO.	BORING NO.	SAMPLE NO.	DEPTH	CURVE SYMBOL	CLASSIFICATION

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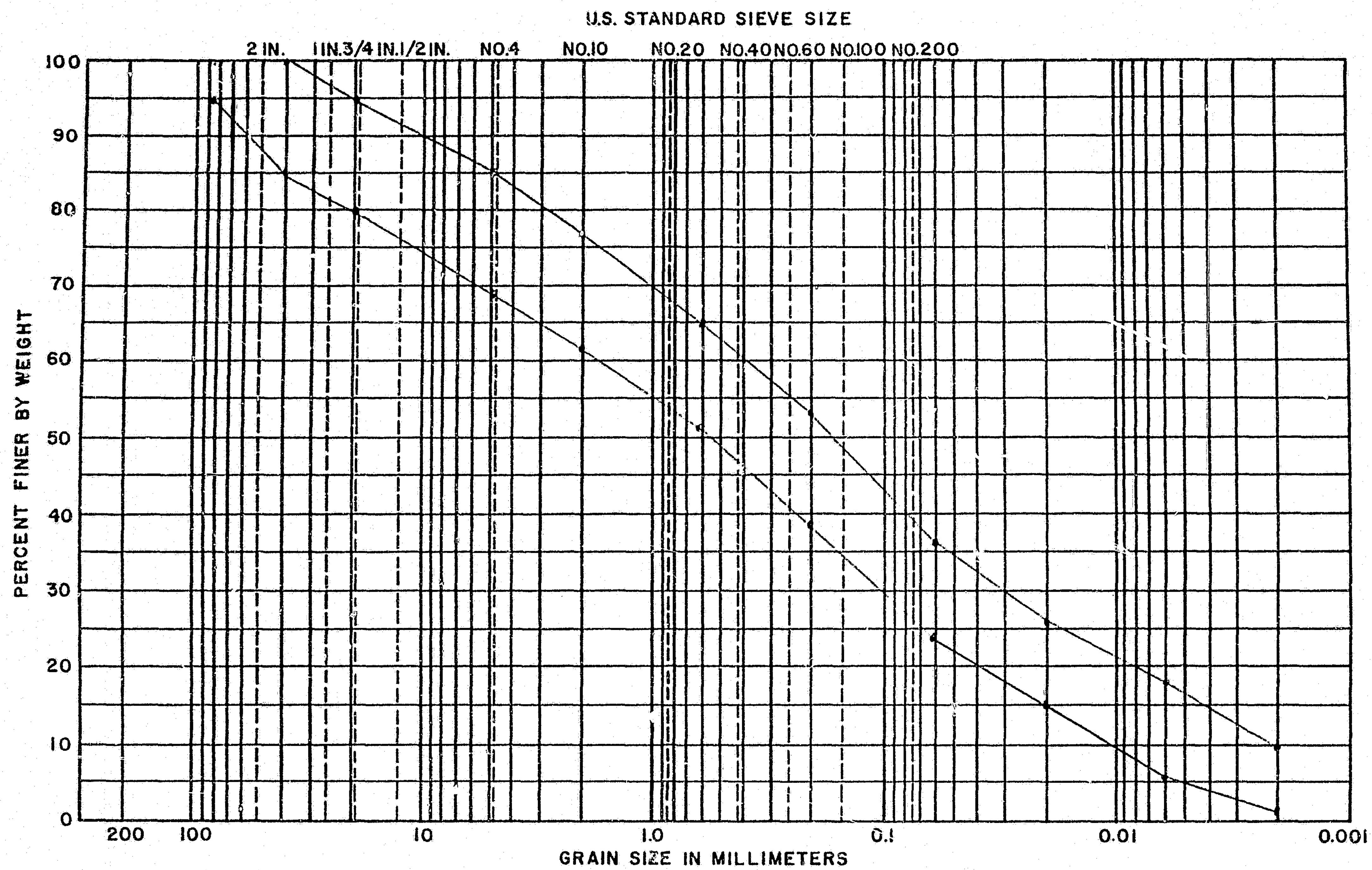
A - OTTER RAPIDS
B - SAINT LAWRENCE

GRADATION ANALYSIS CURVES

FILE: P5700 | DATE: 11/19/81 | FIG.



COBBLES	GRAVEL		SAND			SILT OR CLAY	UNIFIED SOIL CLASSIFICATION SYSTEM
	COARSE	FINE	COARSE	MEDIUM	FINE		

LAB TEST NO.	BORING NO.	SAMPLE NO.	DEPTH	CURVE SYMBOL	CLASSIFICATION

GRADATION ANALYSIS CURVES

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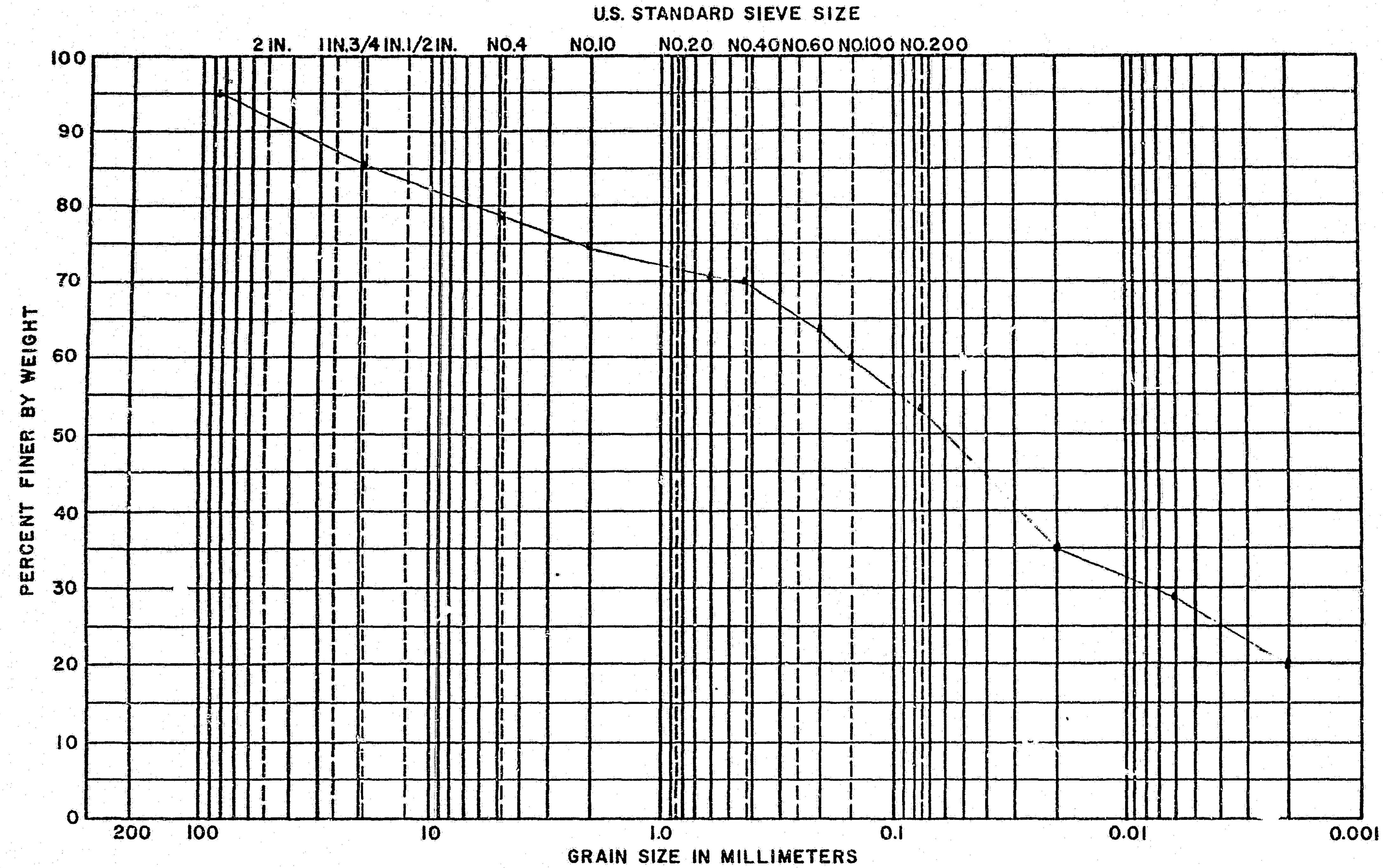
LOWER NOTCH

FILE: P5700 | DATE: 11/19/81 | FIG.



COBBLES	GRAVEL		SAND			SILT OR CLAY	UNIFIED SOIL CLASSIFICATION SYSTEM
	COARSE	FINE	COARSE	MEDIUM	FINE		

LAB TEST NO.	BORING NO.	SAMPLE NO.	DEPTH	CURVE SYMBOL	CLASSIFICATION

ACRES

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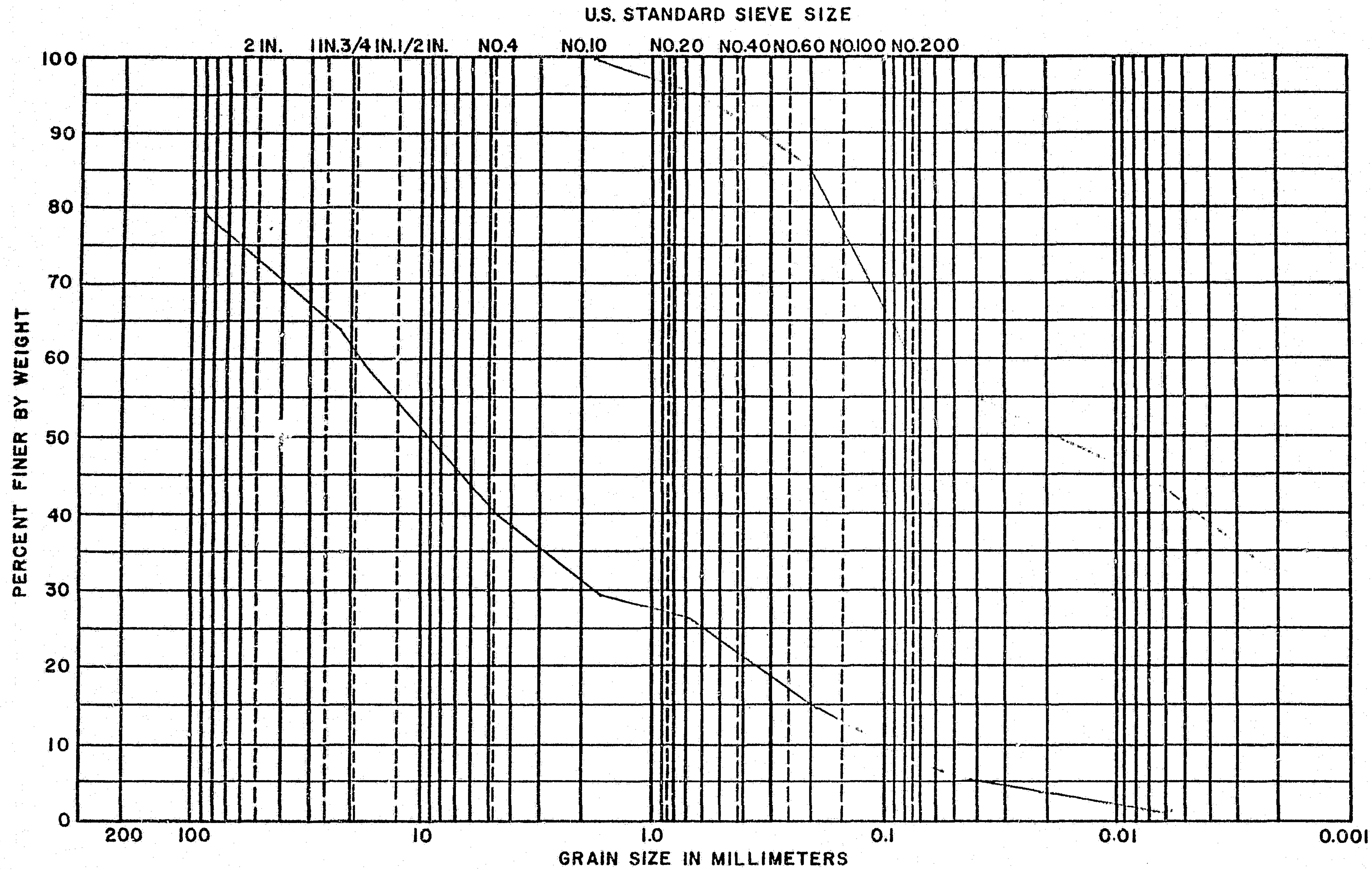
SHAND

GRADATION ANALYSIS CURVES

FILE: P5700 | DATE: 11/19/81 | FIG.

000082



COBBLES	GRAVEL		SAND			SILT OR CLAY	UNIFIED SOIL CLASSIFICATION SYSTEM
	COARSE	FINE	COARSE	MEDIUM	FINE		

LAB TEST NO.	BORING NO.	SAMPLE NO.	DEPTH	CURVE SYMBOL	CLASSIFICATION

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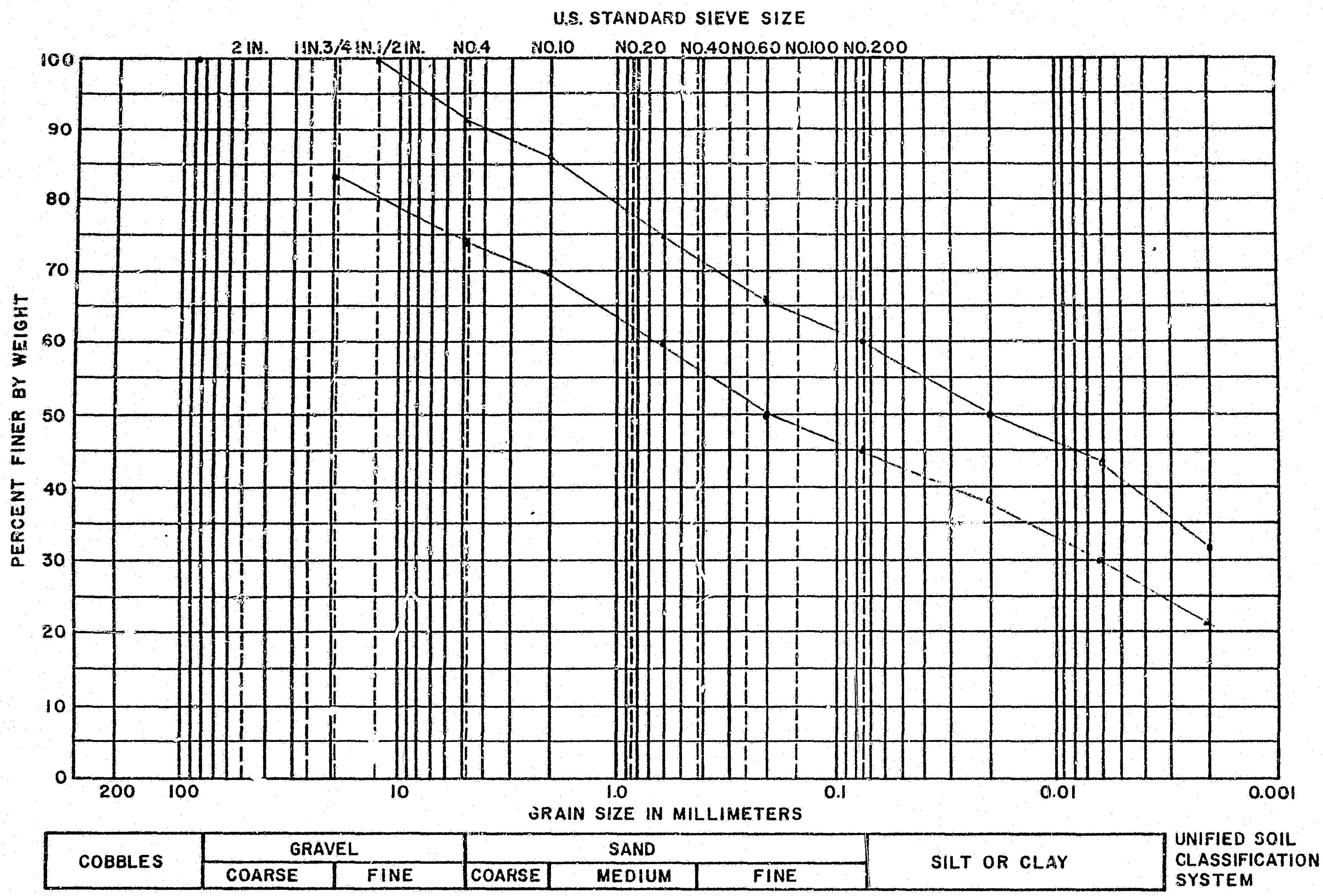
RANGE OF GRADATIONS -
COMPARISON CASES 1-11

GRADATION ANALYSIS CURVES

FILE: P5700 | DATE: 11/19/81 | FIG.



LAB TEST NO.	BORING NO.	SAMPLE NO.	DEPTH	CURVE SYMBOL	CLASSIFICATION

ACRES AMERICAN INCORPORATED
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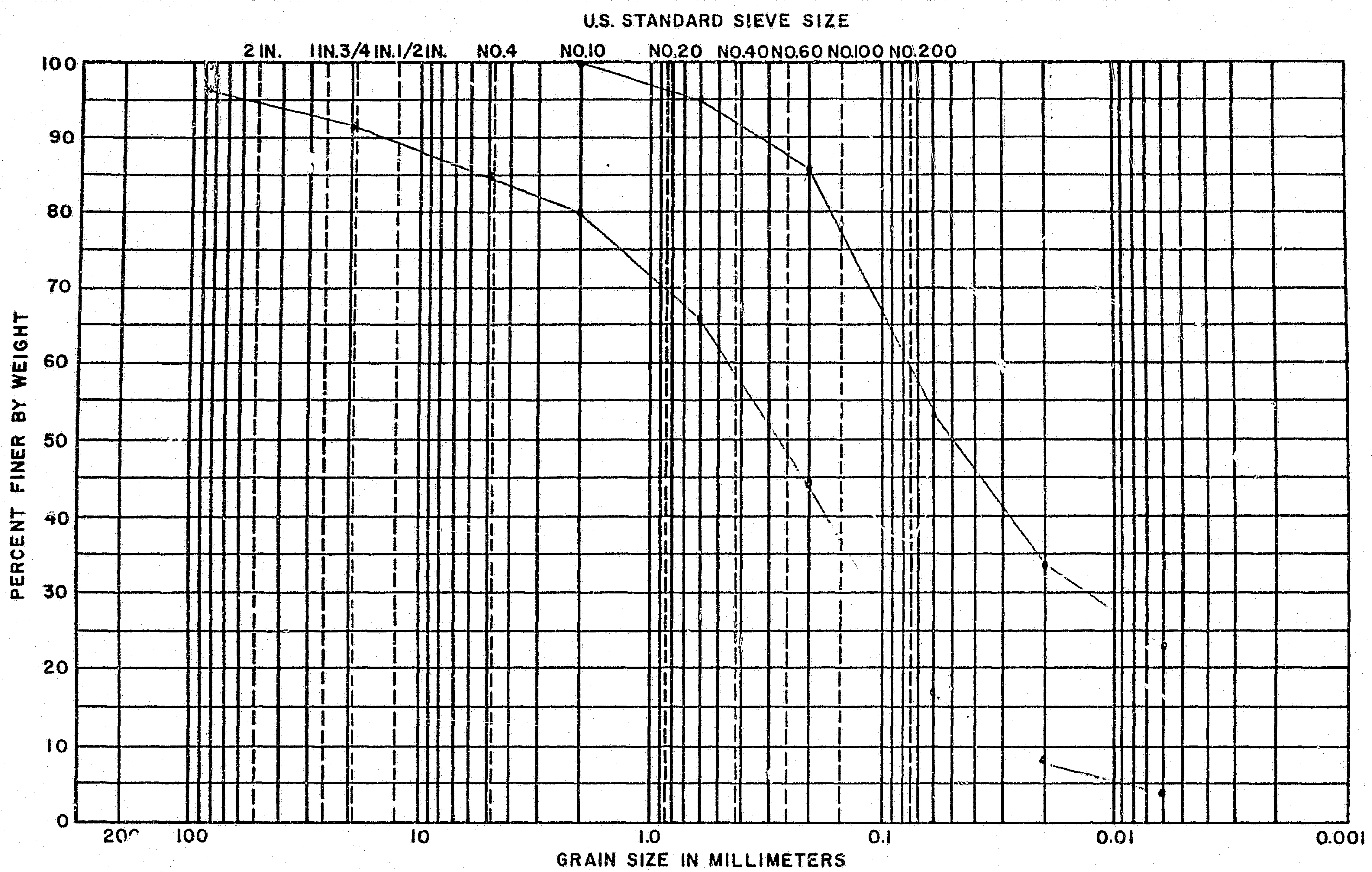
MACTAQUAC

GRADATION ANALYSIS CURVES

FILE: P5700 | DATE: 11/19/81 | FIG.

00008



COBBLES	GRAVEL		SAND			SILT OR CLAY	UNIFIED SOIL CLASSIFICATION SYSTEM
	COARSE	FINE	COARSE	MEDIUM	FINE		

LAB TEST NO.	BORING NO.	SAMPLE NO.	DEPTH	CURVE SYMBOL	CLASSIFICATION

GRADATION ANALYSIS CURVES

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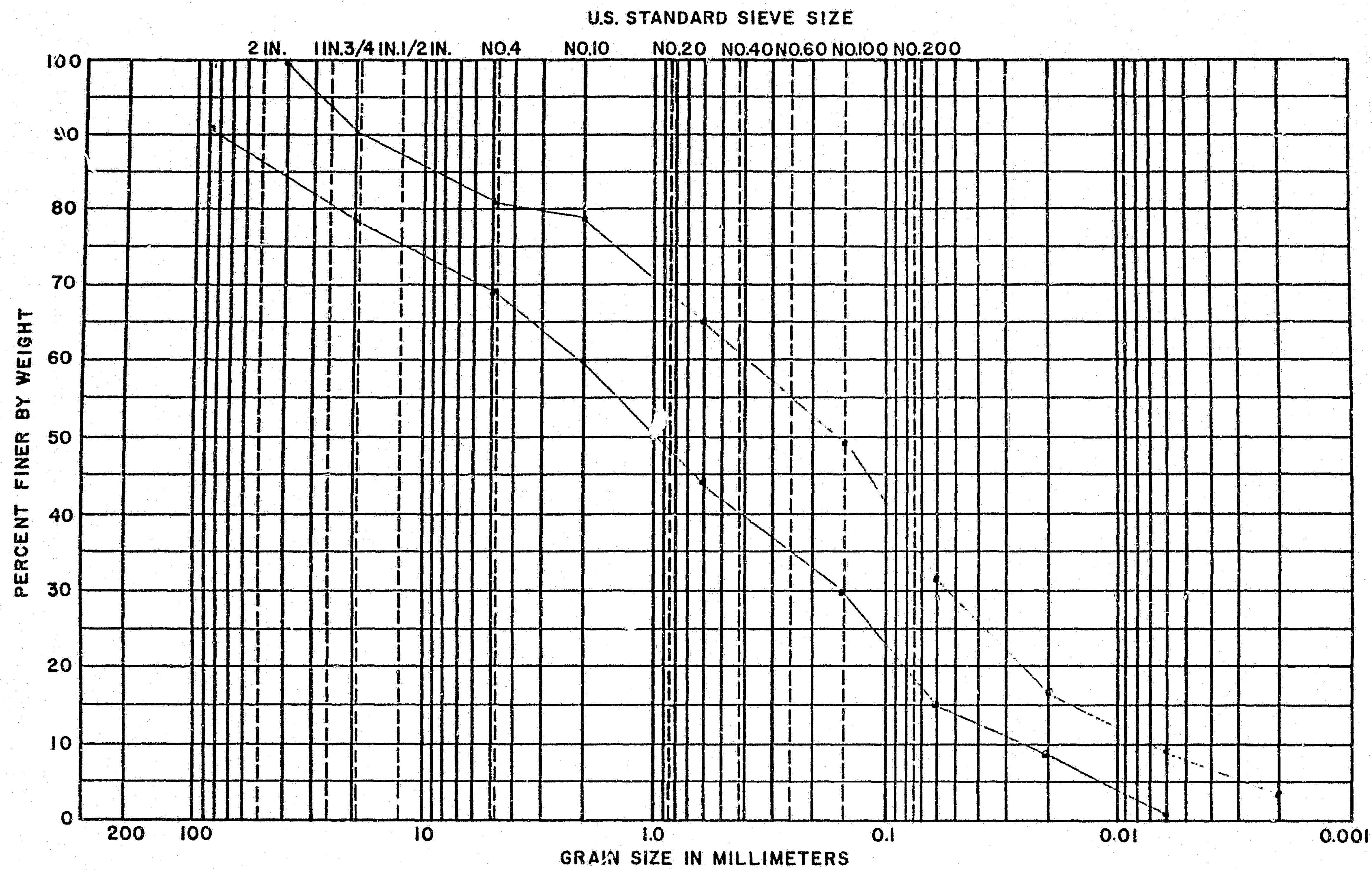
MANIC 3

FILE: P5700	DATE: 11/19/81	FIG.



COBBLES	GRAVEL		SAND			SILT OR CLAY	UNIFIED SOIL CLASSIFICATION SYSTEM
	COARSE	FINE	COARSE	MEDIUM	FINE		

LAB TEST NO.	BORING NO.	SAMPLE NO.	DEPTH	CURVE SYMBOL	CLASSIFICATION

ACRES AMERICAN INCORPORATED
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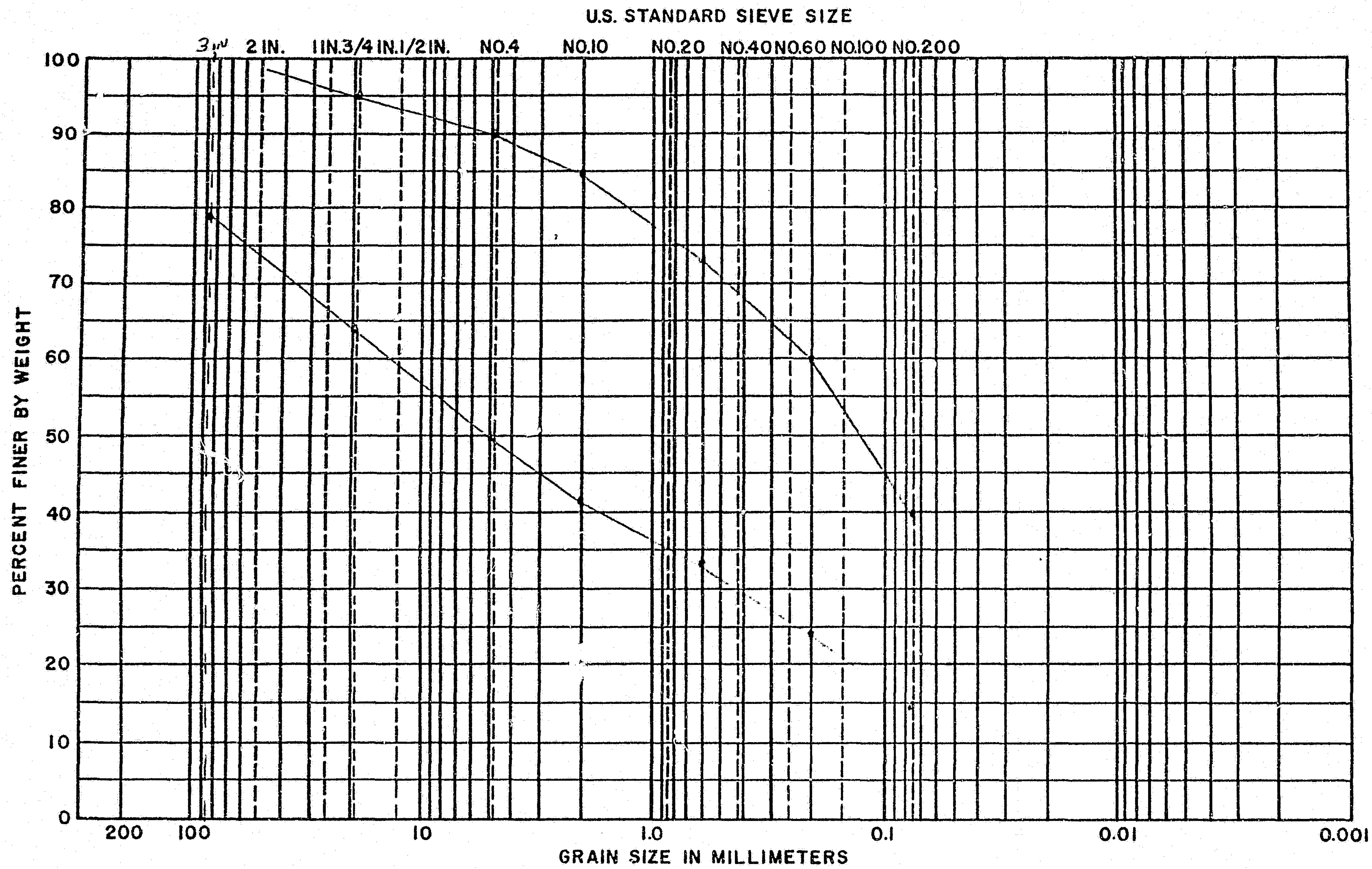
HOLJES

GRADATION ANALYSIS CURVES

FILE: P5700 | DATE: 11/19/81 | FIG.



COBBLES	GRAVEL		SAND			SILT OR CLAY	UNIFIED SOIL CLASSIFICATION SYSTEM
	COARSE	FINE	COARSE	MEDIUM	FINE		

LAB TEST NO.	BORING NO.	SAMPLE NO.	DEPTH	CURVE SYMBOL	CLASSIFICATION

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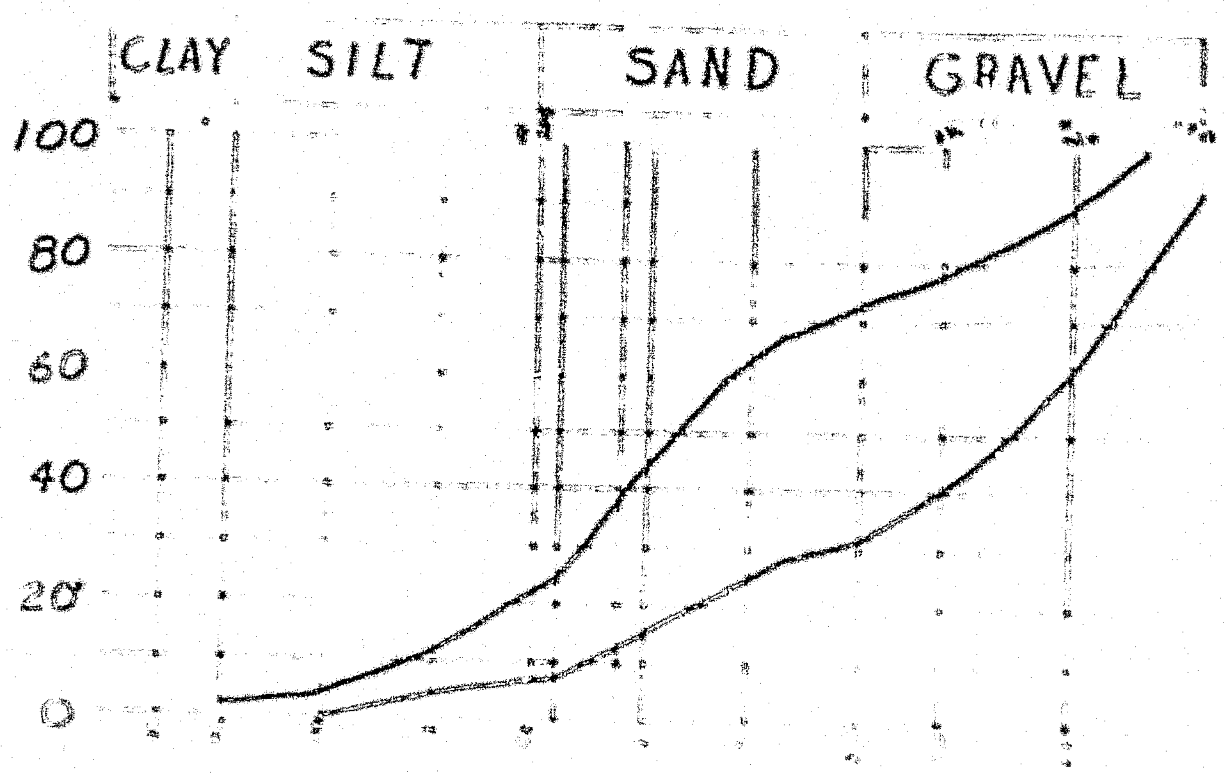
BUFFALO, NEW YORK

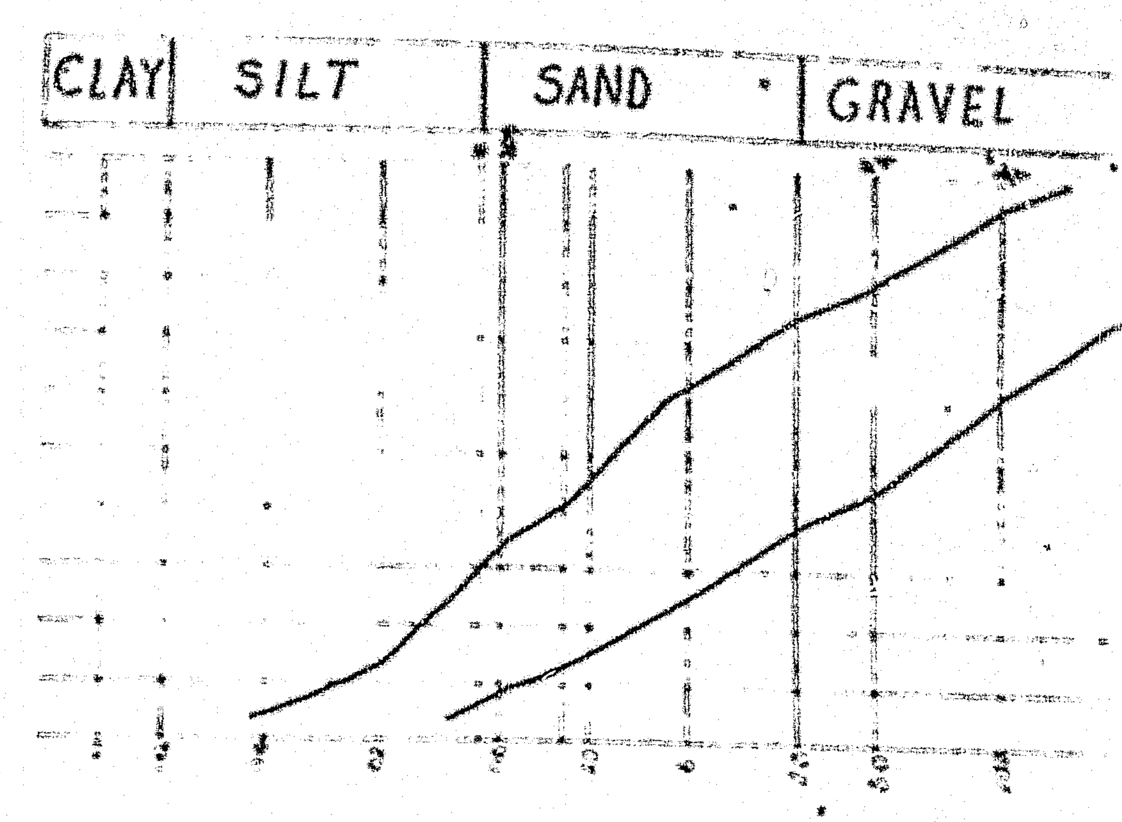
JAMES BAY

GRADATION ANALYSIS CURVES

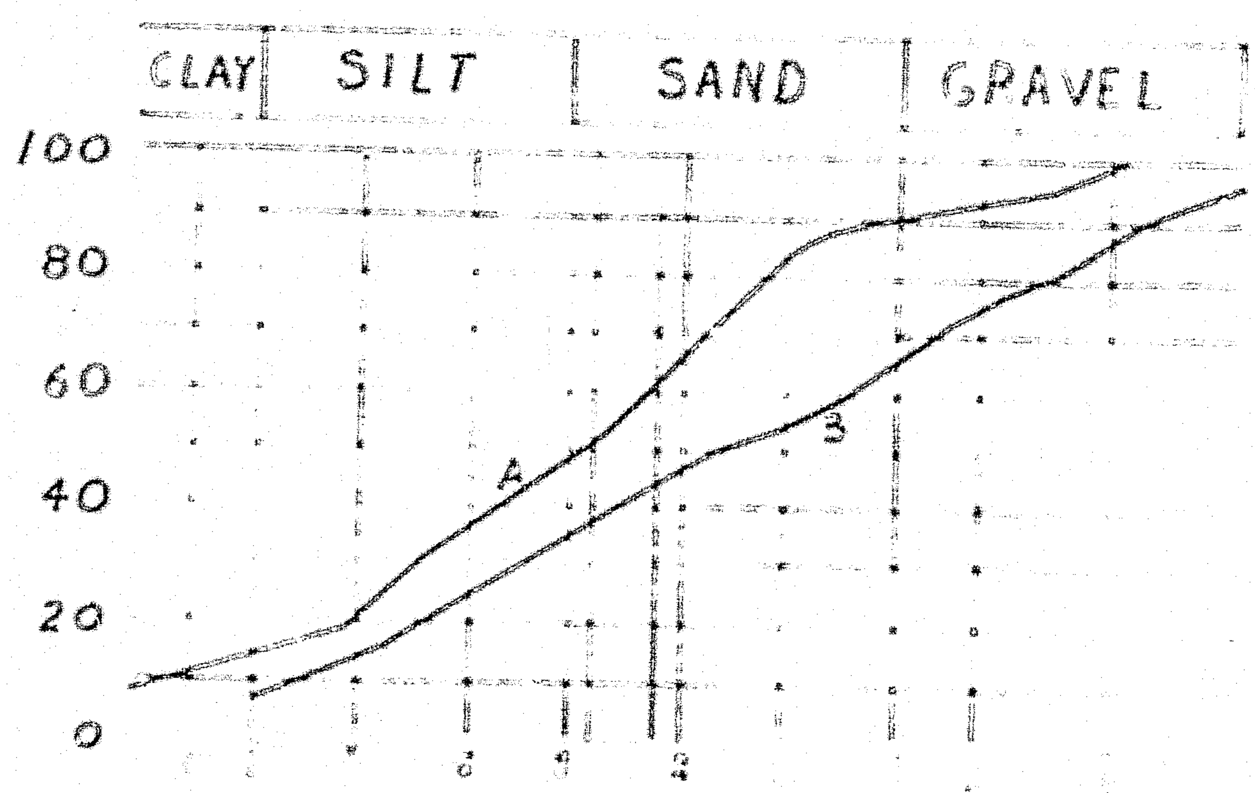
FILE: P5700 | DATE: 11/19/81 | FIG.



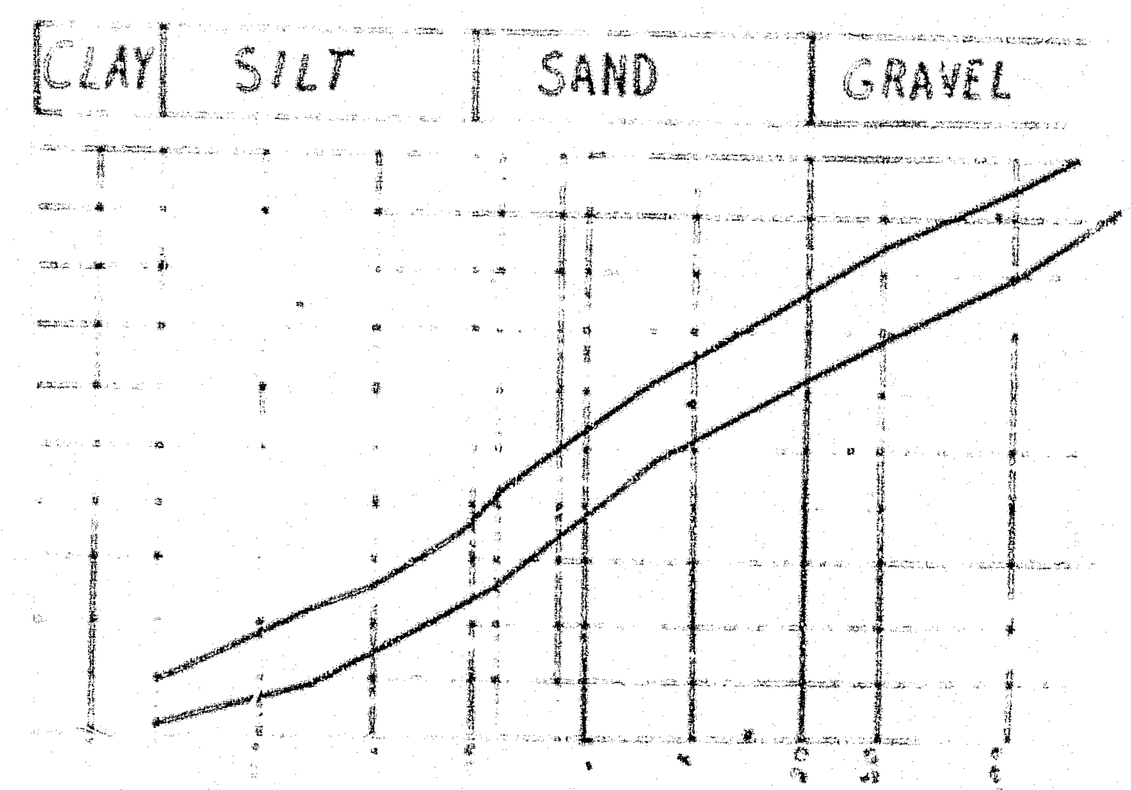
1. GULL ISLAND



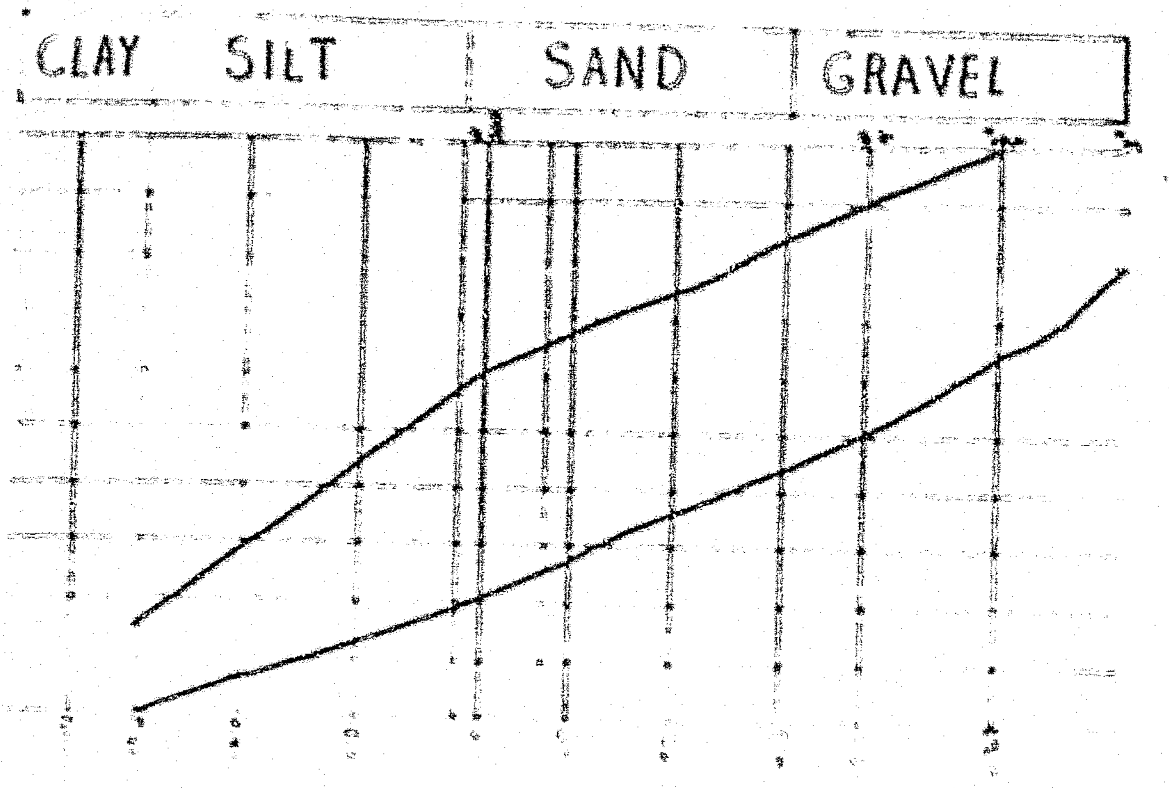
2. CHURCHILL FALLS



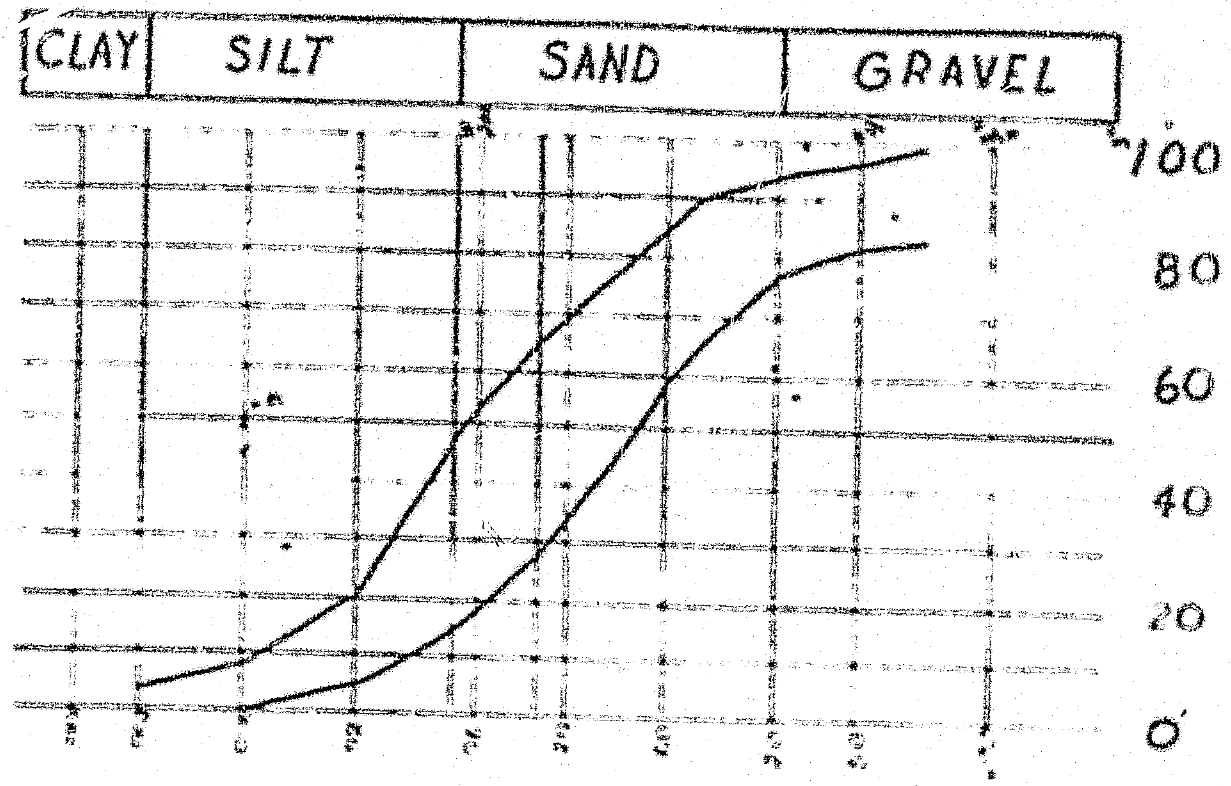
5. A. OTT"R RAPIDS
B. ST. LAWRENCE



6. LOWER NOTCH



3. MICA



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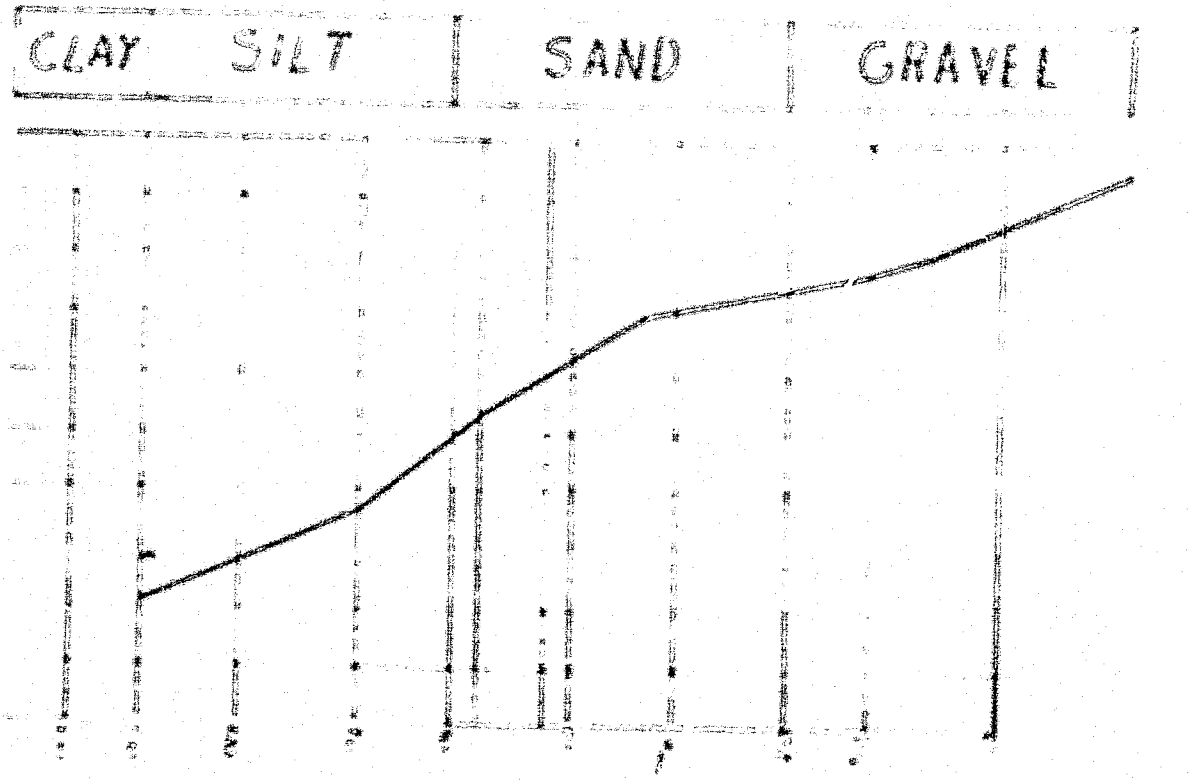
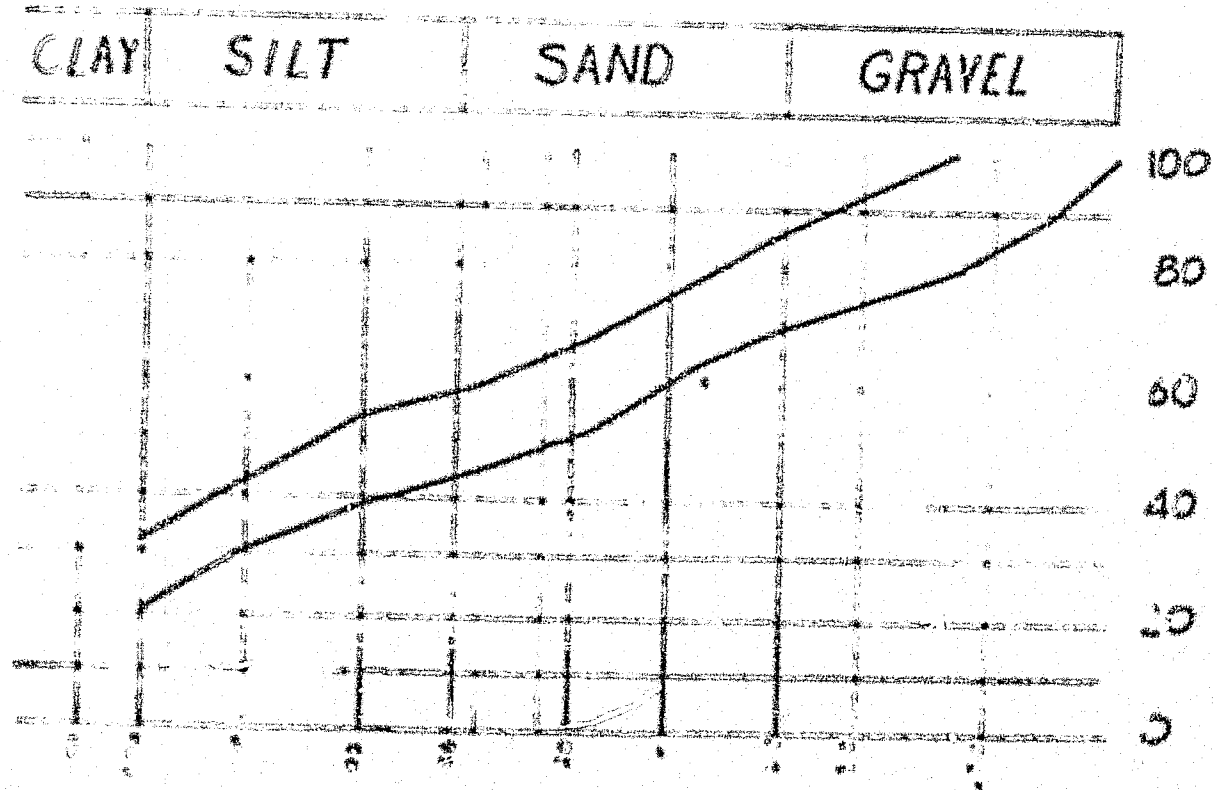
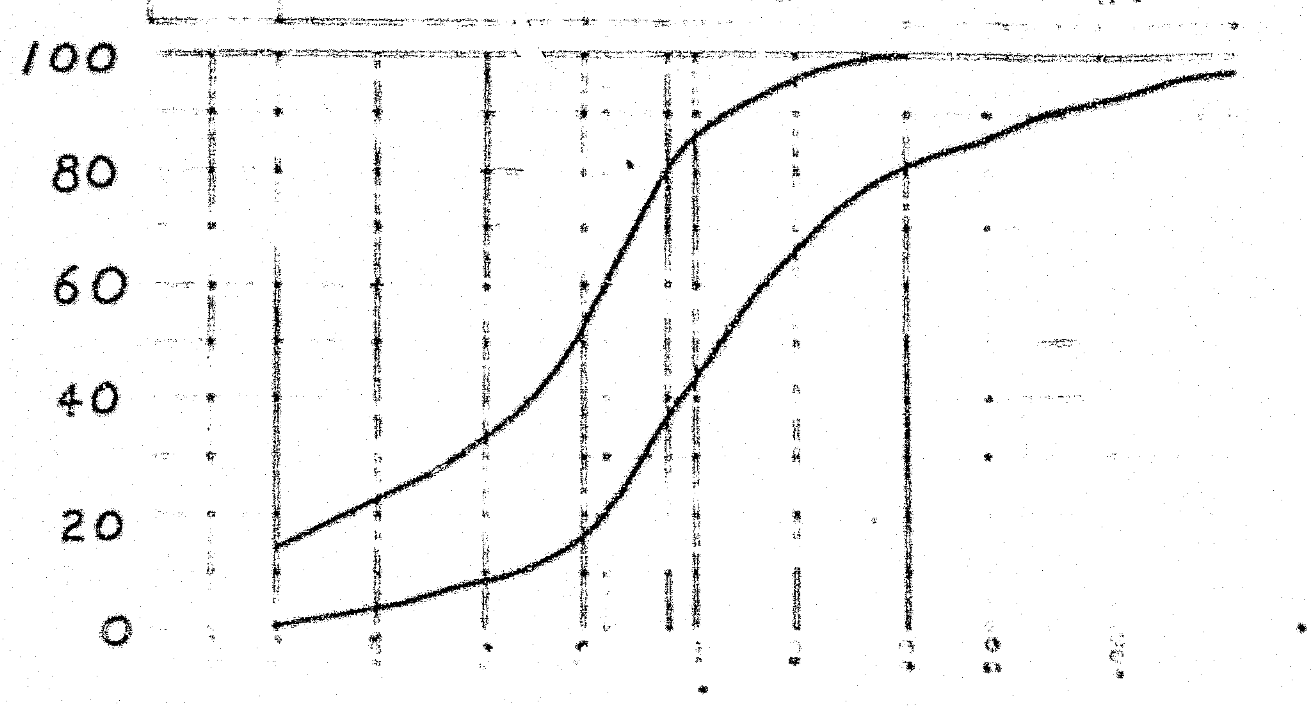
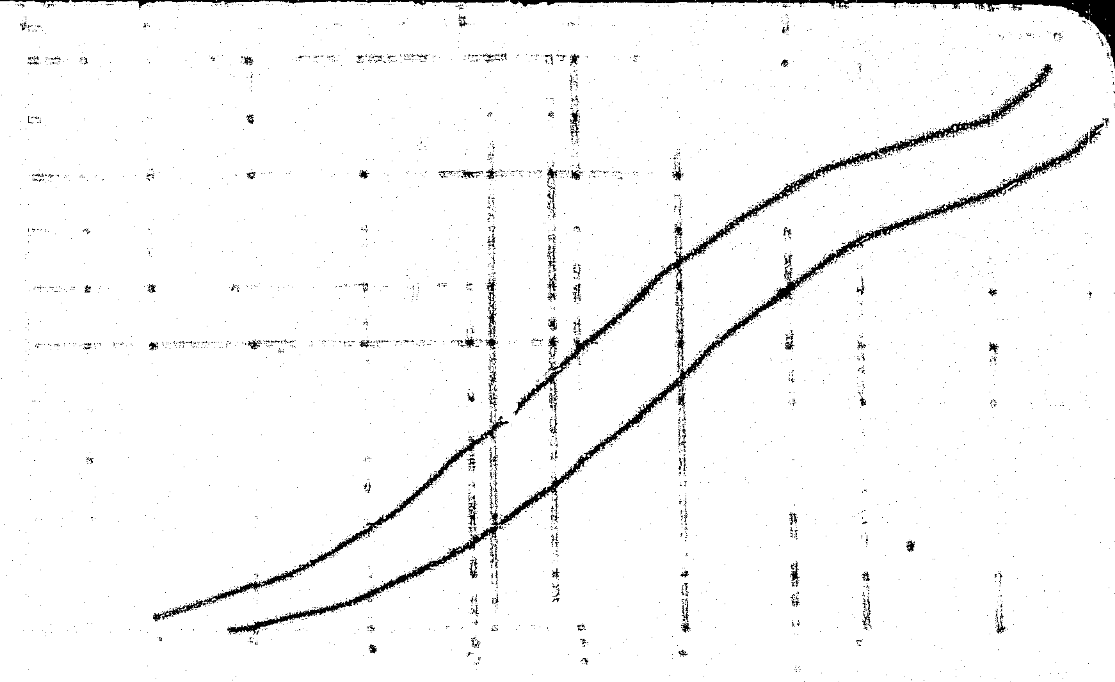


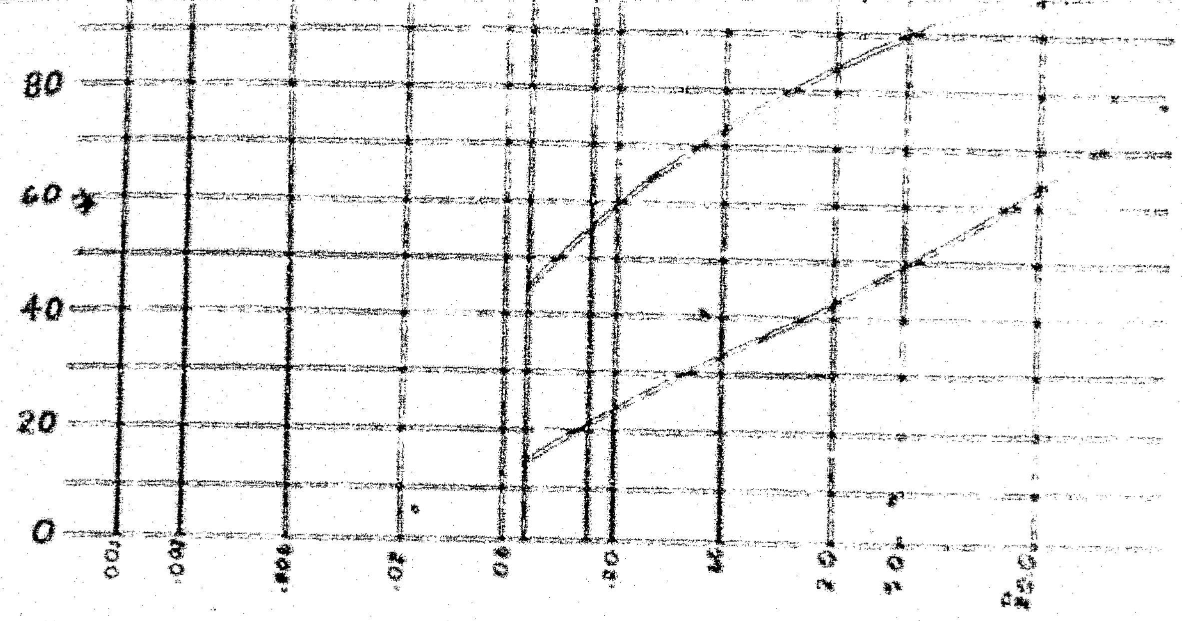




9. MANIC 3



10. HOLJES



II JAMES BAY

1	GULL ISLAND	2.75			7.7	150	2×10^{-5}	150	40
2	CHURCHILL FALLS	2.72			5 to 8	140 to 127	2×10^{-7} to 1×10^{-5}	0 to 5	36 to 40
3	MICA	2.70	22	5	10	131	1×10^{-7}	0	32
4	BERSIMIS				9.3	135	2×10^{-6}	500	36
5	ST LAURENT OTTER RAPIDS			5 3	9 11	142 142	5×10^{-7} 5×10^{-7}	290 150	38 38
6	LOWER NOTCH						[illegible]	[illegible]	38
7	SHAND				[illegible]	134	[illegible] $\times10^{-5}$	970	32
8	MACTAQUAC	2.69	23	10	10.5	127	5×10^{-5}		
9	MANIC								
10	HOLTES		10		[illegible]	[illegible]	1×10^{-6}		
11	JAMES BAY							0	37

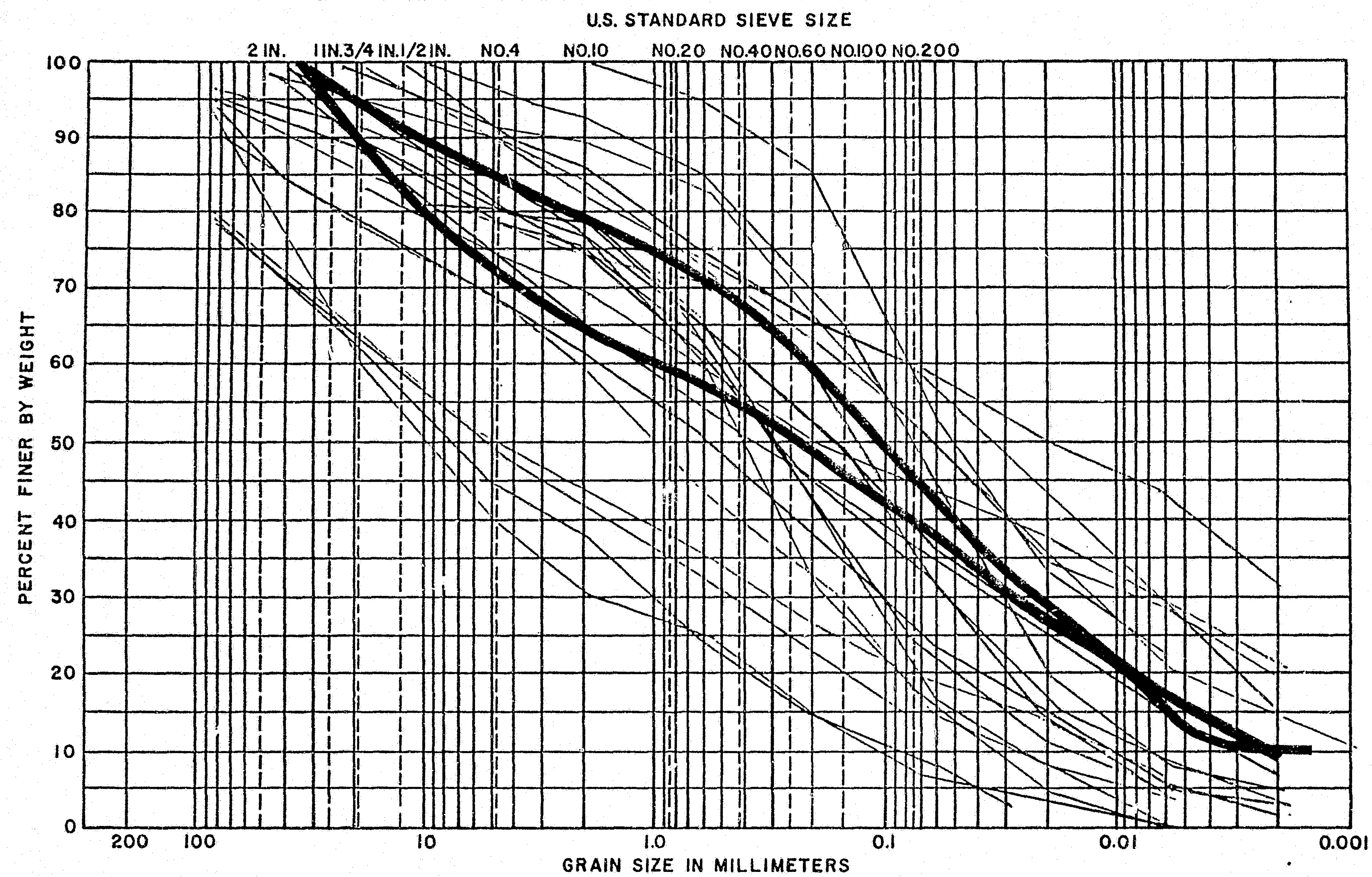
BID DRAWING NOT FOR CONSTRUCTION

AGRES

GLACIAL TILLS IN DAMS

DATE DECEMBER 1990 | SCALE

DEPARTMENT | DRAWING No.



COBBLES	GRAVEL		SAND			SILT OR CLAY	UNIFIED SOIL CLASSIFICATION SYSTEM
	COARSE	FINE	COARSE	MEDIUM	FINE		

LAB TEST NO.	BORING NO.	SAMPLE NO.	DEPTH	CURVE SYMBOL	CLASSIFICATION
				▬▬	D & H

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BUFFALO, NEW YORK

COMPARISION CASES 1-11 VERSUS
WATANA AREA D, H

FILE: P5700 | DATE: 11/19/81 | FIG.

GRADATION ANALYSIS CURVES

COBBLES	GRAVEL		SAND			SILT OR CLAY	UNIFIED SOIL CLASSIFICATION SYSTEM
	COARSE	FINE	COARSE	MEDIUM	FINE		

LAB TEST NO.	BORING NO.	SAMPLE NO.	DEPTH	CURVE SYMBOL	CLASSIFICATION
				▬▬▬	D & H

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COMPARISON CASES 1-11 VERSUS
WATAMA AREA D RANGE

FILE: P5700 | DATE: 11/19/81 | FIG.

GRADATION ANALYSIS CURVES

TASK 6

0029

Waitaper - Dam Foundations

Design Calculation Cover Sheet

ACRES

PROJECT No. P5700.06
FILE No. P5700.14.06.09
SERIAL No. 0029

PROJECT TITLE SUSITNA HYDRO ELECTRIC PROJECT
ALASKA POWER AUTHORITY

DEPARTMENT GEOTECHNICAL - BUFFALO

CALCULATIONS FOR: WATANA - DAM FOUNDATIONS.

ORIGINAL BY NAJ BOND DATE 16 / SEPT / 81

CHECKED BY DATE / /

REV No.	BY	DATE	CHECKED	DATE
Final configuration of curtain		/ /		/ /
in	Feasibility Report	/ /		/ /
		/ /		/ /
		/ /		/ /
		/ /		/ /
		/ /		/ /
		/ /		/ /

SKETCH - G.A.
CRITERIA
SKETCH - GROUTING
REPORT - WATANA DAM FOUNDATIONS
REPORT GALLERIES UNDER EMBANKMENT DAMS.
SKETCH - SECTION.
MEMO.

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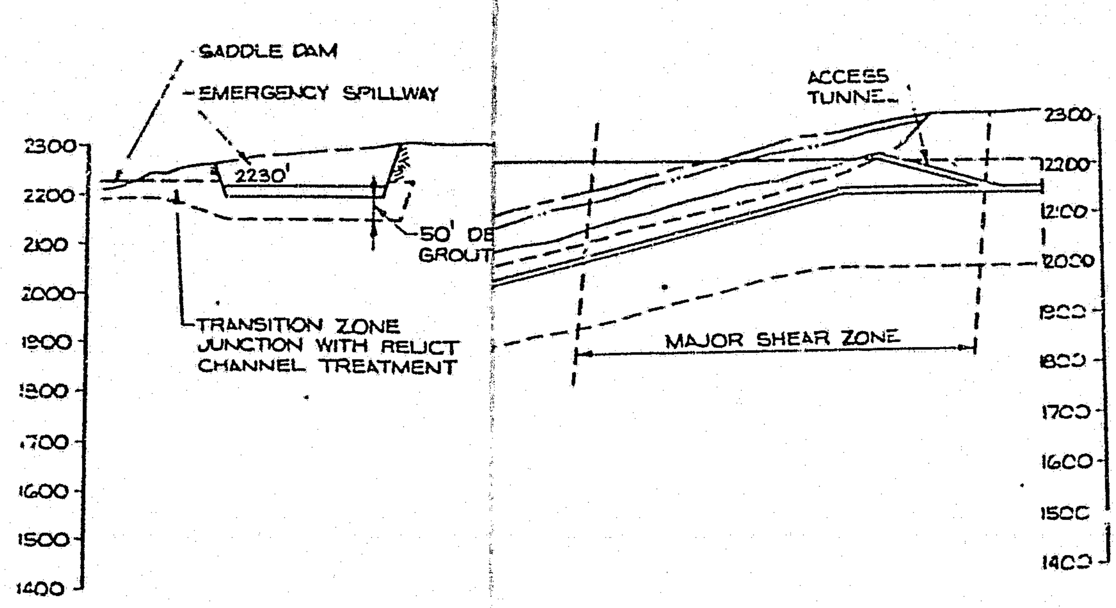
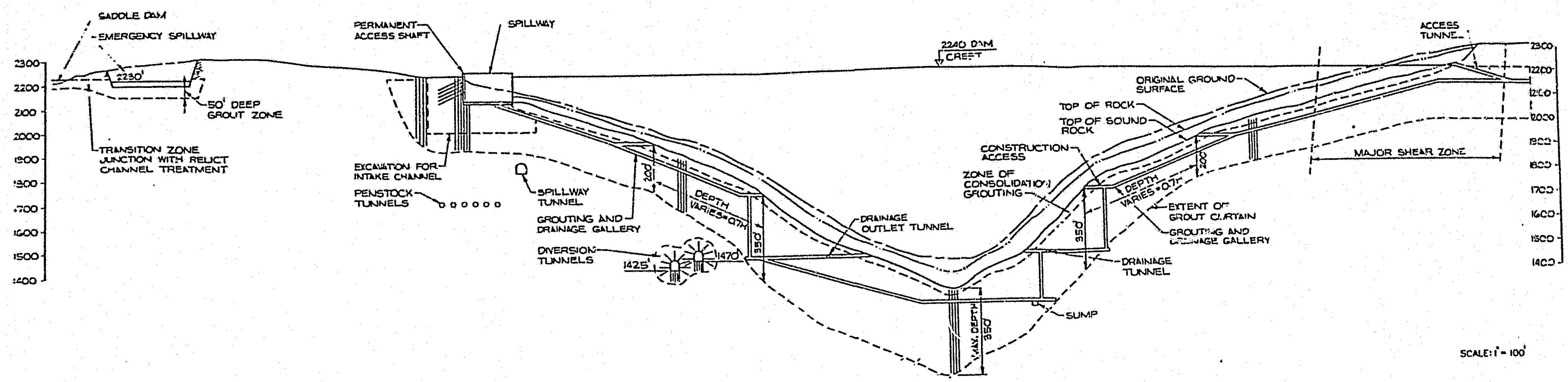
BY

DATE 2/20/83

TOTAL No. OF SHEETS 45 incl. cover


SADDLE DAM
EMERGENCY SPILLWAY
2230'
50' DE
GROUT
TRANSITION ZONE
JUNCTION WITH RELICT
CHANNEL TREATMENT
ACCESS
TUNNEL
MAJOR SHEAR ZONE
2300
2200
2100
2000
1900
1800
1700
1600
1500
1400

SCALE: 1" = 100'



WATANA DAM

FOUNDATION TREATMENT

SUSITNA HYDROELECTRIC PROJECT

WATANA DAM

MAIN DAM

EXCAVATION

OVERBURDEN - AVERAGE 20 FEET DEPTH OVER ALL FOUNDATION AREA.

WEATHERED ROCK UNDER CORE AND FILTERS - 40' DEPTH.

WEATHERED ROCK UNDER SHELLS - 10' DEPTH.

MAXIMUM SLOPES - 1H:2V BELOW 1800' ELEVATION
1H:1V ABOVE 1800' ELEVATION

CONSOLIDATION GROUTING

10' X 10' GRID OF HOLES 30' DEEP OVER AREA OF CORE AND FILTERS.

SUSITNA HYDROELECTRIC PROJECT
WATANA DAM

CURTAIN GROUTING

DOUBLE ROW CURTAIN - VERTICAL.

350′ MAXIMUM DEPTH (AT MAXIMUM HEAD).

50′ MINIMUM DEPTH IN ABUTMENTS.

HOLE SPACING PRIMARY 40′.

SECONDARY TERTIARY QUATERNARY	SPLIT SPACING TO GIVE FINAL SPACING 5′.

GALLERIES FULL LENGTH OF DAM, APPROXIMATE SIZE 10′ X 10′.

DRAINAGE

50′ DEEPER THAN GROUT CURTAIN.

HOLE SPACING 10′.

DRILLED FROM GROUT GALLERIES.

FULL LENGTH OF DAM, EXTENDING 600′ INTO LEFT ABUTMENT.

CONNECTING TO INTAKE AND SPILLWAY STRUCTURES RIGHT ABUTMENT.

HOLES INCLINED DOWNSTREAM 15° FROM VERTICAL.

ACRES **Calculations** SUBJECT: GENERAL ARRANGEMENT OF GROUTING & DRAINAGE HOLE - SECTION	JOB NUMBER P5700.06 FILE NUMBER SHEET 1 OF 1 BY NATB. DATE APP DATE

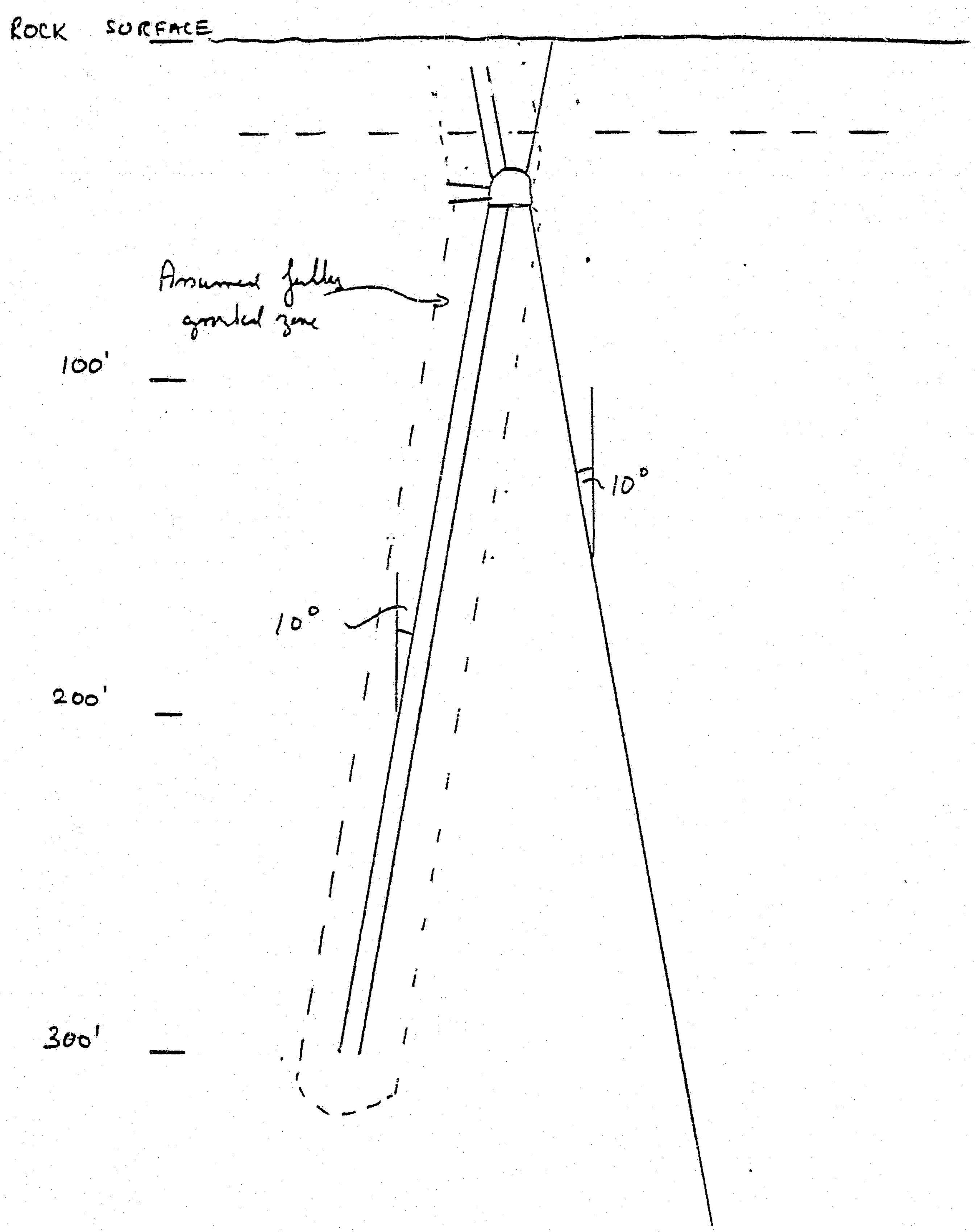


Fig. 9.

FORM NO. 152 REV. 1

WATANA DAM FOUNDATION.

1 - GENERAL

The geotechnical investigations to date have been primarily directed towards investigating the important geological features which may have significant impact on the technical suitability of the site and the project layout. Although sufficient information has been gathered on the site geology for this purpose, the information on the subsurface conditions at specific structure locations is limited. ~~This limitation suggests that~~ Hence, conservative assumptions have been ~~will be~~ made at this time to develop foundation treatment procedures and project cost estimates to provide sufficient contingency. Those areas where lack of detailed information results in assumptions involving large sums of money are identified separately even though they constitute part of the foundation treatment. One such item at Watana is "Relict Channel" at the left abutment. This approach will permit refinements in cost estimates when detailed information is available during the next phase of the design studies and also identifies areas requiring investigations. The geotechnical and geological conditions are documented in detail in Task 5 - Geotechnical Report.

2 - SITE GEOLOGY

The Watana dam site and the appurtenant structures are located on a pluton ~~rock~~ bounded by two prominent shear zones; the Fins on the upstream and Fingerbuster on the downstream ~~side~~. These features are very prominent on the north slope of the river channel, ~~however~~ their continuity, extent, and character on the south side across the valley ~~has~~ not been conclusively determined. ~~The rock between these two features is diorite.~~ Andesite-diorite contacts were found both upstream and downstream. Although numerous shear zones and prominent joint sets have been identified from surface mapping and drilling, the ~~overall~~ rock is hard, competent, and sound. ~~The embankment dam is located between these two shear zones; however,~~ It is suspected that some splayoff features from Fingerbuster may cross the dam at higher elevations on the south bank. The condition of these splayoff shears is groutable as determined from boring BH-12. Another feature under investigation is a suspected slideblock on the north abutment. The significance of these slide blocks can only be evaluated after its ~~presence~~ character and extent is defined.

The river valley is broad U-shaped below elevation 1800 and widens with flatter slopes above. The channel is slightly over 600 ft wide and filled with up to 80 ft deep alluvium at its deepest point. The characteristics of these alluvium and particularly their stability under large earthquake events are unknown. The depth of these alluviums has been confirmed by borings and seismic refraction surveys.

The rock in the abutments is the same diorite pluton. The abutments are covered with talus material, thick in places, and the depth of overburden and talus in gullies may be quite thick.

3 - PERMAFROST

Extensive permafrost is present on the south abutment, and whereas only sporadic permafrost is expected on the north abutment. ~~On the south abutment the depth of permafrost could be as much as several hundred feet.~~ The data is currently being gathered through a series of thermister probes. Heavy vegetation and dense tundra provides insulation to the ground. When this insulation is disturbed, thawing of unconsolidated material takes place rather quickly. This condition could have significant influence on scheduling and cost of foundation preparation and safety. There is a seasonal variation of rock temperature in the top 20 to 30 ft. Temperature measurements in boreholes BH28, AP8 and DR19 show constant rock temperature below 0°C at depth. In the upper 20 to 30 ft, however, temperatures vary above and below freezing with the seasons. Another important area where permafrost will influence the cost is grouting. For proper grouting, the frozen rock will have to be thawed prior to grout placement. Such thawing procedures will have to be developed to meet environmental constraints.

The filling of the reservoir will tend to thaw the surrounding rock, thus affecting the strength and permeability of the rock mass. This is discussed later under "Grouting".

Sketch would help

4 - Description of Dam ?

brief section on dam to identify zones discussed in next section.

Sketch ?

4 - DAM FOUNDATION

Preparation of rock foundations must meet the following objectives under the core contact area: (Ref 2 pag 335)

- The rock under the core including material occurring in faults or joints in the rock mass must be non-erodible ~~or must be protected from erosion~~ under the high seepage gradients that will develop under the core.

- Materials of the core must be prevented from moving down into the foundation (e.g. into cracks or joints) and then through the foundation under the transition zone into the downstream shell or beyond.

- The contact between the core and the rock surface upon which it is founded must remain water tight despite the distortions that will occur in the dam due to its own weight and the thrust of the reservoir both during filling and in service.

- Seepage ~~that passes~~ through the foundation must be controlled and discharged so that excessive seepage pressures do not develop in the downstream shell, in the materials beneath the shell, or downstream of the dam.

The central portion of the dam (core and filters) will be grounded on fresh sound rock. The upstream and downstream shells will be founded on competent rock. The stability of the alluvium under "high" seismic event is questionable, and therefore, alluvium under the entire dam will be removed.

(a) Excavation Under the Core and Filters

The core, the upstream filters, and the downstream filters will be founded on sound rock. This will require excavation of talus on slopes, river alluvium, and weathered rock in the valley bottom and on the abutments. The talus thickness on the abutments perpendicular to the slope face varies from zero to 20 ft, and the weathered rock from a few feet to as much as 40 ft or more. In the river channel, alluvial material consisting of sand, cobbles, and boulders up to 3 ft in maximum dimension exists up to 80 ft depth. The rock below this level is hard and generally lightly weathered. Locally, such as in shear zones, drainage gullies, or highly weathered areas, the rock ~~may be~~ is weathered deeper than 40 ft. Boreholes number BH6 and BH2 indicate (weathered zones at 200 feet depth) Generally, the weathering is not a gradual change in the rock with depth but occurs as zones of weathered, more open, jointed material, which in places are overlain by sound rock.

Excavation of this weathered rock would require removal of large quantities of sound rock as well. Satisfactory consolidation of the less weathered zones can be achieved by grouting. For cost estimates and project layout, an average overburden thickness of 10 ft and weathered rock thickness of 40 ft is to be used.

The maximum rock slope along the abutments is determined to some extent by the valley shape. In general, 1H:1V slope or flatter is ideally preferred (Reference 1) although steeper slopes have been used. However, at Watana dam site, the natural slopes at lower elevations are relatively steeper but still generally less than 1H:2V. Therefore, the overall core foundation slopes will be no steeper than 1H:2V vertical below elevation 1800 and 1H:1V above elevation 1800. The cross cut slopes will be 1H:10V. ~~The~~ An irregular shape of rock under the core is undesirable due to potential for local differential settlements and strains in the core that could cause cracking. These surfaces also make it difficult to compact the core material to form a tight core-rock bond and may provide relatively easier seepage path and erosion potential. Locally, steep slopes and overhangs may be treated with concrete to achieve an acceptable slope where trimming is not desirable or uneconomic. For preliminary stage designs such as feasibility designs, these details are normally covered by contingencies in cost and average slopes of 1H:1V above elevation 1800 ft and 1H:2V below elevation 1800 ft will be used.

(b) Excavation Under Shells

The shells will be founded on competent rock. This will require excavation of Talus, an average of 10 ft thick perpendicular to the face of the slope and removal of loose or detached rock or rock ribs. For cost estimates, an average 10 ft thickness of rock removal is considered. It is possible that further studies may support the concept of removing the river alluvium only under that portion of the shells bounded by 1.5H:1V upstream and downstream. However, for project layout and planning, the removal of alluvium under the entire shell width is considered.

(d) Dental Excavation

Dental excavation over and above normal excavation is expected in zones of intense shearing or highly irregular surfaces. Whereas the need for such excavation has been identified by investigations completed to date, the magnitude has not been properly assessed due to heavy vegetation, tundra cover, and general lack of outcrops and access. A contingency item will be included in the current cost estimates.

Under the impervious core and the filters, special foundation preparations including dental concrete or use of form concrete is likely to be required to provide regular surface for fill placement. Again, these items will be covered under contingency.

5 - GROUTING

The purpose of grouting is to improve foundation and abutment rock conditions for load bearing and seepage considerations, to provide a good contact between poured concrete and rock (contact grouting). The need, extent, and detail of grouting is dependent on site geological conditions, type, and character of rock, reservoir head, and location of specific structures.

As mentioned earlier, Watana dam site is located on diorite rock. The rock is competent as far as load carrying capacity is concerned; however, numerous shear zones normally few inches to several feet in width have been located in a general NW-SE direction and NE-SW direction. Occasionally, the width of shear zones may increase to several tens of feet locally. Most of these zones contain gouge material and under appropriate conditions, may be susceptible to piping. These shear zones are found both in the river channel and the abutments. A complete discussion of these features is presented in the Geotechnical Report.

The permeability tests in the boreholes indicate the rock to be generally impervious with coefficient of permeability ranging from 1×10^{-6} cm/sec to 1×10^{-4} cm/sec. However, these permeability indices do not properly account for shear zones. For example, in Borehole BH-2 on the north abutment, circulation was lost during drilling when the boring encountered a shear zone. Also, due to heavy vegetation, talus cover or limited access it is believed that there may be more shear zones not identified so far. This condition leads us to believe that a properly conducted grouting program of exploratory nature will be required under the dam and in the abutment plus under or around other appurtenant structures. Depending on the results of exploratory grouting, additional grouting including multiple line curtain may be required.

(a) Consolidation Grouting

The rock under the impervious core, upstream filter, and downstream filter will be consolidation grouted. This will provide a rock zone of relatively impermeable character under the entire contact. It is quite possible that locally rock may be sound and free of any discontinuities resulting in virtually no grout take; nevertheless, the joints and shear zones are generally dipping and a particular vertical plane is likely to intersect these zones which are estimated to be 15 to 20 ft apart.

Consolidation grouting will include a 10 ft by 10 ft grid of approximately 30 ft deep holes (Ex. size). Under the spillway and other appurtenant structures, the need and extent will be governed by the location elevation of structure foundation and character of rock. For feasibility level design, it is assumed that all such areas located upstream of centerline of ~~impervious~~ core will require consolidation grouting. For areas downstream, need will be established for each structure separately. In addition, consolidation grouting may be required at tunnel portals and around tunnel openings in specific areas.

(b) Curtain Grouting Under the Dam

The need, effectiveness, and design of grout curtains is a subject on which there is significant disagreements within the engineering profession (Reference 2). Nevertheless, foundations for dams retaining water head in excess of 100 ~~ft~~ feet usually have been grouted in some way (Reference 3). ~~The permeability of the sound rock mass ranges between x 10- cm/sec and x 10- cm/sec and it would in general not be considered necessary to grout.~~ As discussed earlier, the need for a grout curtain for Watana dam is determined by the numerous shear zones obliquely crossing the dam axis and a relatively high water head behind the dam. At this ~~early~~ stage of investigation, information on rock condition at depth is very limited. Therefore, a grout curtain is included in the design.

Only ~~one borehole~~ extends to ~~any~~ a significant depth below the river, Borehole DH-21 ~~was~~ drilled down to elevation 876 ft, approximately 500 ft below dam foundation level. This hole was not water pressure tested and ~~No~~ RQDs were not recorded. Shears and highly fractured zones are indicated at an average of 50 ft intervals to the bottom of the hole.

On the basis of the limited information abot the rock at depth, the curtain should extend to a depth of 0.7H, where H is the head of water behind the dam at a particular location above the dam foundation with a maximum depth of grout curtain in the region of 350 ft.

It is likely that in some areas the grout take at depth will be very low. It is suggested that the primary holes be considered as exploratory holes and ~~will be required to~~ be core drilled. On the basis of the core and water pressure tests in the exploratory holes, the depths of secondary holes can be decided. The exploratory holes may also identify areas that need additional grouting.

All holes will be water pressure tested in stages. The grouting will be determined using these results. Grouting will be carried out using split spacing with the primary holes at 40 ~~ft~~ spacing. The secondary, teritary and quaternary holes would bring the final hole spacing to 5 ft if required.

A double row grout curtain is proposed.

In areas of permafrost traditional grouting will not be effective because the joints will contain ice and obstruct the passage of the grout.

The greatest depth of permafrost so far recorded was in BH-8 when the hole froze up at 175 ft depth.

The permafrost areas will have to be thawed locally before water pressure testing and grouting can be done. Additional boreholes may be required for the thawing of sufficient rock to form an effective curtain. Further studies are required to investigate methods of thawing the rock.

It may be very difficult to assess the extent of thawing and the effectiveness of the grouting. Further grouting may be required when the thawing effect of the full reservoir has full impact. This is a ~~further~~ consideration to support the need for grouting and drainage galleries discussed later.

of the dam and the surface exposures of any shears to the north of the major shear zone will be outside the reservoir area and are unlikely to cause appreciable seepage.

The extent of the grout curtain through the shear zone should be determined from exploration from the grout gallery.

The depth of the grout curtain in the abutments should generally be 200 ft. However, in areas such as the major shear zone discussed above, the depth of the curtain should be 300 ft. Special attention also should be paid to the drainage in the shear zone.

Site investigation BH-12 indicated Artesian water pressure was observed in the shear zone, BH-12. This would indicate that materials with high permeabilities exist in the shear zone.

- Right Abutment

No major shears have been found on the right abutment. The rock is expected to be of good quality. The grout curtain should extend from the spillway intake structure 400 feet into the abutment. The depth of the curtain is 200 feet. Some 1500 feet to the north the cut-off will continue in the region of the relict channel.

The intake structure and spillway gate structure are at present located about 200 ft from the dam centerline. In this location the grout curtain should connect to the southern end of the structure. The grout curtain would continue along the line of the intake and spillway structures from a grout gallery under the structures.

Drainage would be necessary behind the intake and this could best be provided from the gallery within the abutment.

If the intake structure is moved upstream from the dam, then the grout curtain should continue parallel to the centerline of the dam up to the spillway. In this case the curtain would have to be curtailed above the penstock tunnels. Further grouting radially from the penstocks may be required. This grouting from the penstock tunnels should be avoided if possible because of the restrictions it imposes on the program of work.

(d) Grouting in Vicinity of Diversion Tunnel Plugs

The grout curtain holes should be curtailed approximately 30 ft from the diversion tunnels. Radial grouting should then be carried out from the diversion tunnels along the length of the plugs to intermesh with the grout holes from surface.

Contact grouting will be required after the plugs are concreted.

(e) Grouting for Specific Structures

Additional grouting in poor rock areas may be required to consolidate the rock or to control water seepage.

(f) Contact Grouting

Contact grouting will be performed on concrete structures in contact with rock when rock conditions so dictate and behind all tunnel linings and tunnel plugs.

6 - DRAINAGE

Due to presence of shear zones as discussed under grouting, ~~it has been decided to include~~ drainage features have been included for both the dam foundation and the abutments. Although drainage can be provided by drilling open holes downstream of the core, either discharging underneath the dam or downstream, the use of drainage galleries is ~~being considered~~ recommended for the following ~~possible benefits~~: reasons.

- Grouting can be carried out at the same time that the earth embankment is being placed. This will appreciably shorten the time of construction; a crucial factor for Watana dam construction.

- Drain holes drilled in the rock foundation downstream of the curtain can be discharged into these galleries and quantities of seepage can be monitored for each individual hole.

- This will provide access under the dam and any additional grouting or drainage may be installed even after the reservoir is filled.

- Higher grout pressures can be used because of the weight of the overlying embankment if so desired.

- Galleries will help to prevent freezing of drain holes. A heating system could be installed if required.

- Galleries can be used to house the outlets for piezometer lines and other types of measuring apparatus in a more convenient fashion.

Galleries may be in the form of tunnels or a reinforced concrete structure formed in the rock foundation under the impervious core.

The different systems have the following features and advantages:

Tunnels

- Facility to explore the rock at depth;
- The tunnels do not have to follow the rock surface profile and may be arranged to provide easier working than on the relatively steep foundation slopes; and
- If conservative cover is selected, excavation of the galleries may be relatively independent of the foundation excavation.

Surface Galleries

- Do not disturb the rock which is to be grouted later;
- Easier access to the lowest drainage level. The tunnel will be deeper and require a longer access tunnel for force drainage;
- Overhead drilling and grouting is not required. Smaller, cheaper equipment may be used and the work will be easier;
- Allows a flexible program. Some grouting may be carried out in advance of construction of the gallery, if required; and
- To avoid a protrusion into the impervious core, which may prevent proper compaction, the gallery can be recessed into the core foundation and the structure shaped to give a surface for good compaction of the core material.

Tunneled galleries provide great advantages as an exploration tunnel for the rock in the foundation and the abutments. Some engineers recommend that such an exploration tunnel be made for all large dams on rock foundations in any event simply because it is the only way to obtain a complete and detailed understanding of the nature of the rock along the grout curtain.

It is anticipated that the same gallery can be used for grouting and drainage.

(a) Dam Foundation Drainage

It is planned to provide galleries for drainage water collection and grouting. A conceptual arrangement is being prepared. Drain holes (3") will be drilled from these galleries to intercept seepage water and to provide pressure relief. Whether such galleries will be built in the river channel is yet a point of discussion.

The information from boreholes intersecting the larger shear zone suggests that filters may be required in some of the drain holes to prevent washout of fine material.

(b) Abutment Drainage

Drainage galleries and drain hole curtain will be provided the entire length of the grout curtain.

(c) Drainage Around Specific Structures

To be developed after layout is finalized.

7 - RELICT CHANNEL

An ancient buried channel is present on the north side of the Susitna River at the dam site. A detailed discussion is presented in the Geotechnical Report. In general, the depth to bedrock is as much as 500 ft below reservoir level. The overburden consists of several sequenes of glacial deposits, lake sediments, and alluvium varying in character and thickness. At this stage, information on this buried channel is very limited. It is planned to do some sensitivity studies in terms of seepage and piping considerations to evaluate its impact on the project, and need and extent of remedial treatment required. As envisioned at present, the following potential problems could be associated with the buried channel:

- Considering its size and depth below reservoir level, it could form a means of substantial water loss; and

- The phenomenon of piping which is normally associated with large water loss and high seepage gradients may become important considerations.

Preliminary estimates indicate that the gradients could develop along the channel which may be classified as being conductive to piping under appropriate conditions. Therefore, for feasibility design, the following features are provided in the design to assure safety of the project:

- A cement bentonite slurry trench will be constructed across the entire width of the channel. The depth of the slurry trench will approach 100 ft which can be excavated with conventional Kelly-bar system. This will provide a positive means of seepage retardation.

- Below the slurry trench, an exploratory grout curtain (single row) will be installed to identify zones of high permeability. Additional grouting in those zones will be performed to achieve a relatively less pervious continuous system across the entire width of the channel down to bedrock.

- Provisions will be made for pressure relief system downstream of this curtain to relieve/control excessive hydrostatic pressure and to provide for safe passage of seepage water without loss fines.

REFERENCES

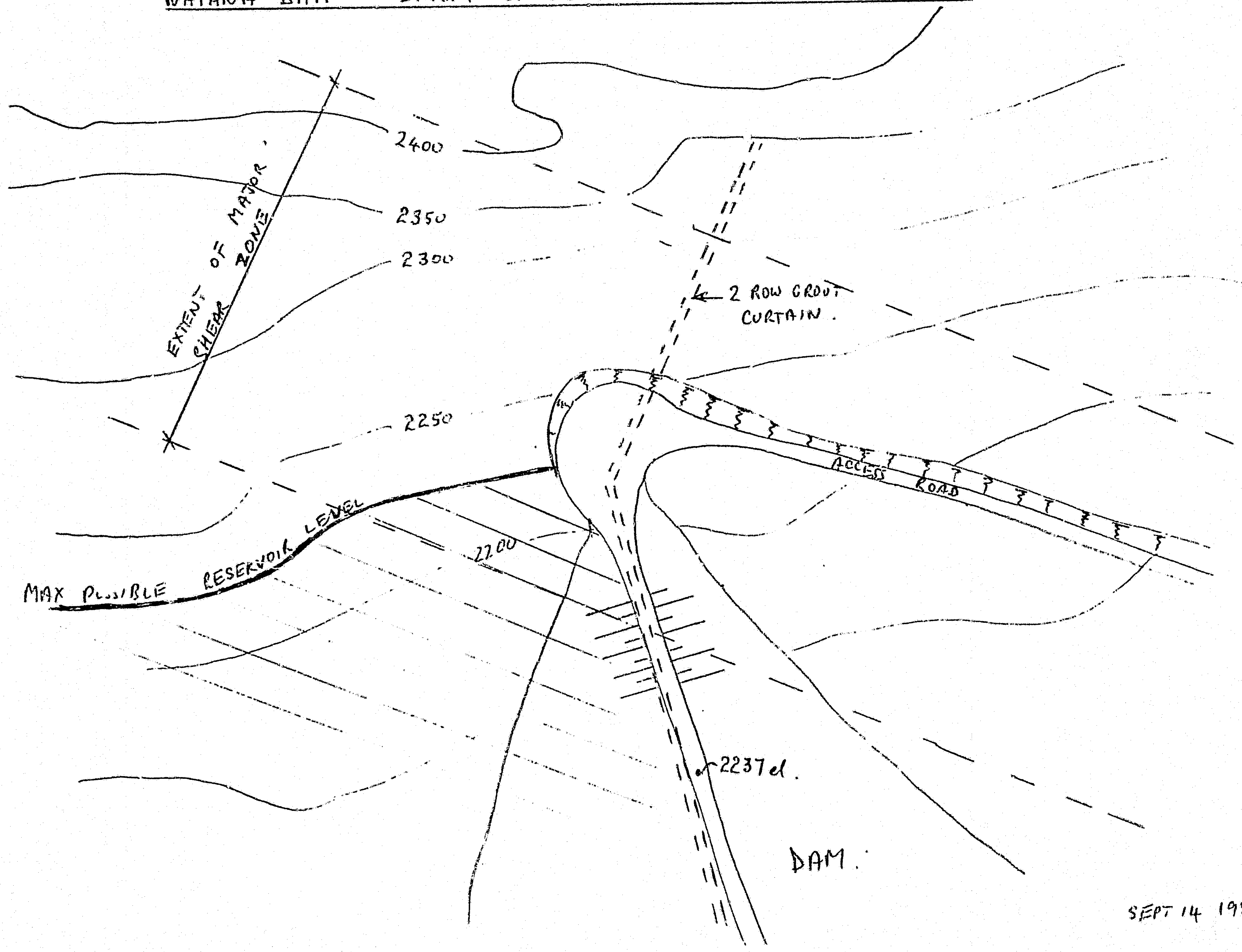
1. Current Trends in Design and Construction of Embankment Dams, page 63, ASCE publication 1979 by S.D. Wilson and R. J. Marsal.

2. Embankment Dam Engineering-Casagrande Volume , John Wiley & Sons.

3. Earth and Earth-Rock Dams by Sherard, Woodward, Gizienski, and Clevenger, John Wiley & Sons, Inc.

SUSITNA HYDROELECTRIC PROJECT

WATANA DAM - EXTENT OF GROUT CURTAIN - LEFT EMBANKMENT

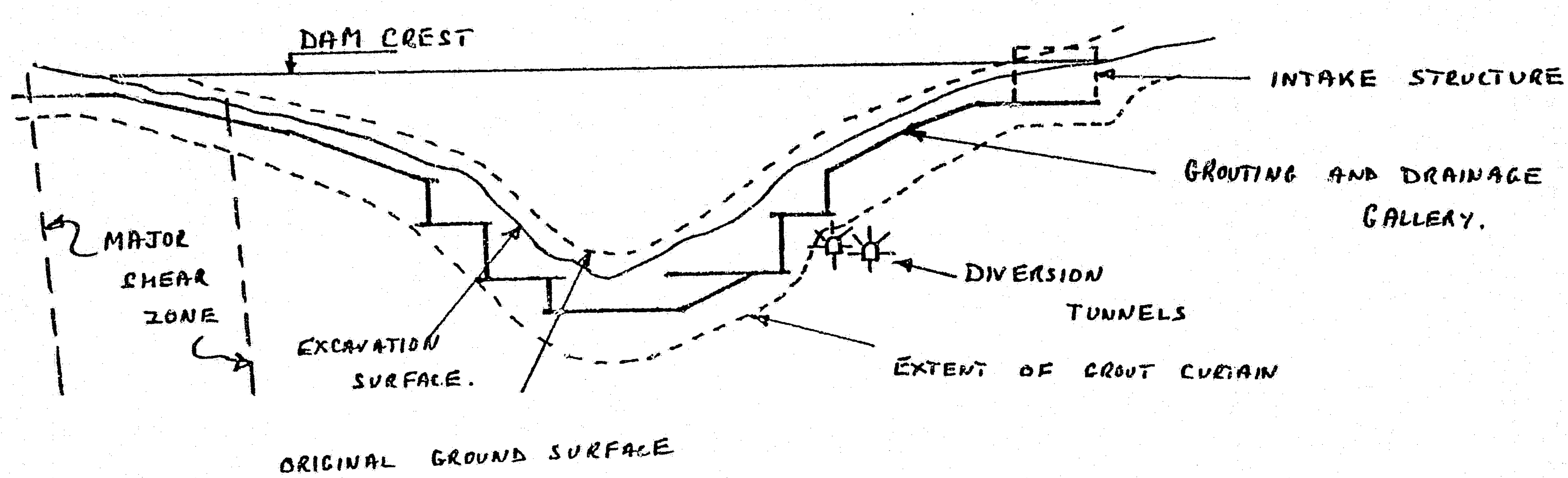


SEPT 14 1981.

SUSITNA HYDRO ELECTRIC PROJECT

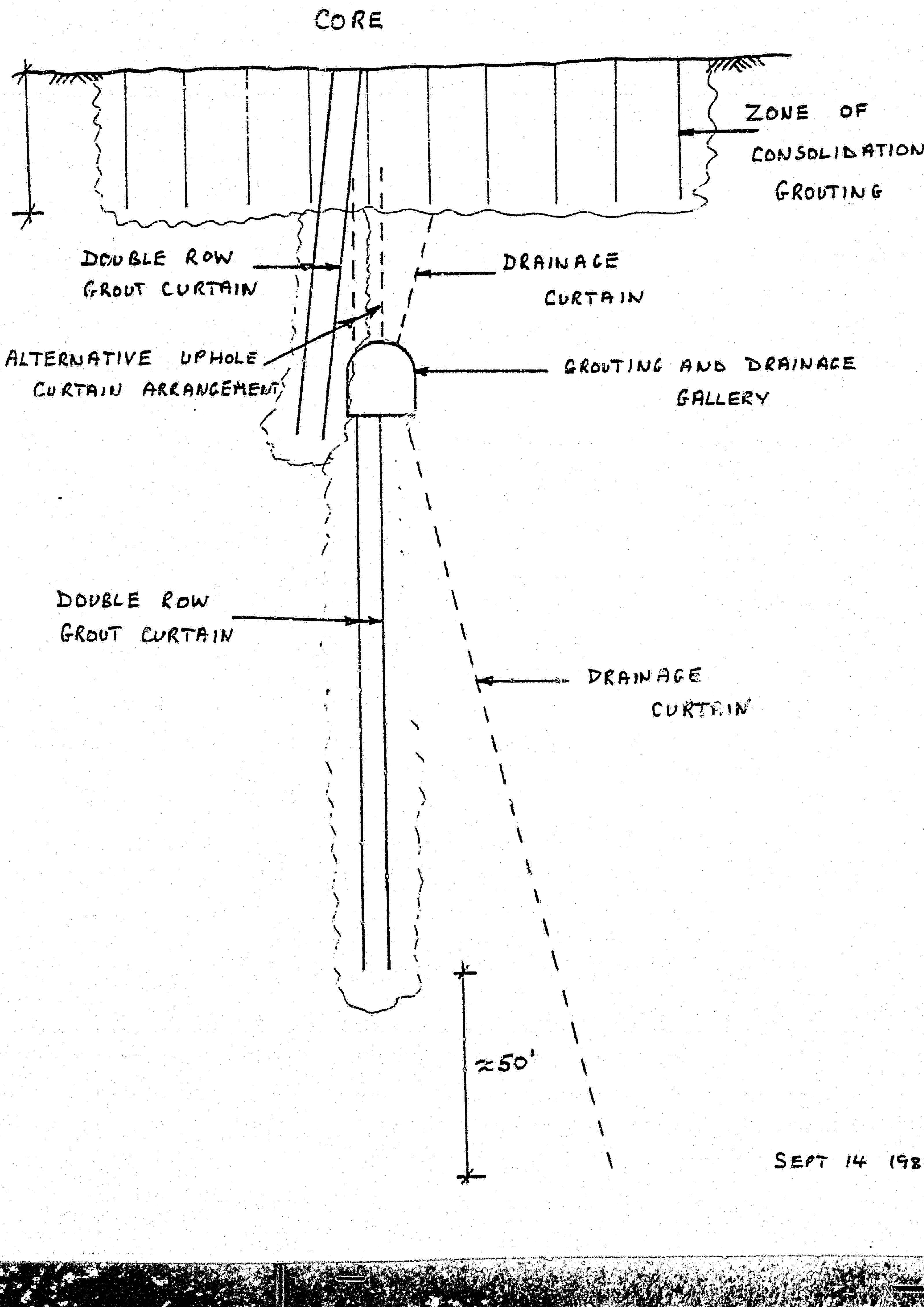
WATANA DAM

GROUTING ARRANGEMENT



SEPT 14 1981

SUSITNA HYDROELECTRIC PROJECT
WATANA DAM
GROUTING AND DRAINAGE GALLERY



SEPT 14 1981

Galleries Under Embankment Dams

Internal galleries large enough for men to enter and work provided for the purpose of grouting and discharging drainage water are a common feature of concrete dams.

Similar galleries or rock tunnels have been provided under many earth dams by European and Far Eastern engineers. However, galleries are not generally provided under embankment dams in the United States.

Some of the major possible benefits to be obtained from the use of galleries in embankment dams are as follows.

i) The rock grouting from the gallery can be carried out independently of the construction of the dam. This can shorten construction times. The grouting can continue further into the winter than would have been possible with surface grouting.

ii) Permanent access is available under the dam for inspection. Additional grouting or drainage holes may be drilled after construction of the dam. This is an important consideration where there is permafrost. The thawing effect of the reservoir may require remedial grouting after impounding has commenced. The galleries would be valuable for access for investigation after an earthquake.

iii) Higher grout pressures can be used if required because of the overlying weight of rock and concrete.

iv) Drainage holes drilled downstream of the grout curtain can be discharged into the gallery. Quantities of flow can be monitored. The galleries will also help to prevent the outlets of the drainage holes freezing which they would do if on the surface. This is of prime importance to the drainage system. If the ends of the holes freeze, then the drainage becomes ineffective. This alone may be sufficient justification for provision of the galleries.

The gallery drainage will be more effective because pressures are relieved at a lower level. The bottom of the hole, therefore, is at a lower head than if the drain hole extended to the surface.

v) The galleries may be used for the installation of instrumentation. Cables and pipes may be strung in the gallery giving protection from the severe climatic conditions. The gallery provides access for the repair and replacement of instrumentation that would be many times more costly from the surface.

vi) Tunneled galleries provide the great advantage as an exploration tunnel for the rock of the dam foundation. The tunnel gives the best opportunity for understanding the nature of the rock along the grout and drainage curtains. This would be invaluable in the faulted and sheared zones.

Brief details of embankment dams with galleries are attached.

All the cases quoted are for much smaller dams than proposed at Watana.

In view of the large height of the dam, the arctic environment, and the location within an earthquake zone, the additional cost of the galleries can be justified. There will be cost savings on instrumentation and on the schedule because of the galleries.

Ever increasing importance is being placed on dam safety. Galleries will provide the opportunity to gain greater understanding of foundation conditions, monitor behavior, and carry out remedial work, if required.

Some examples of the use of galleries under dams are given below.

1. Infiernillo Project, Mexico Balsas River

Dam: Rockfill with impervious core, 148m high, 350m long.

Rock: Highly metamorphosed breccias, agglomerates, sandstones, and clays.

Permeability of rock ranged from 1-4 Lugeon units except for localized areas close to the surface.

Grout Curtain: 50m to 100m depth.

Galleries: Extensive tunnels in abutments and under the river bed, horizontal and inclined, used for grouting and drainage.

Reference: Current Trends in Design and Construction of Embankment Dams, Wilson and Marsal, ASCE Publication.

Anon. - Selected References for Seismic Resistant Design, Acres American Incorporated.

2. Bergeforsen, Sweden

Dam: Rockfill with impervious core, 25m high.

Rock: Gneiss granite with calcitic dikes. Dikes were subject to chemical and mechanical errosion by seepage water. Very good cutoff was required.

Permeability: Of dikes - 10^{-2} to 10^{-3} cm/sec.

Grout Curtain: Two curtains from single gallery under dam and intake structure. 20m to 35m deep.

Gallery: Under the dam, gallery was surface constructed, under intake it was tunneled. Cement grouting, asphalt grouting, and lime water injection were carried out from gallery.

Reference: Aastrup and Sallstrom, Bergeforsen - A Swedish Power Plant Built on Non-Resistant Rock, Seventh Congress on Large Dams, Rome 1961, Question 25, Report 69.

3. Various Embankment Dams in Yugoslavia

Examples of dams with surface constructed galleries for grouting and drainage.

Grouting performed at same time as embankment construction. Galleries constructed of porous concrete. Areas of seepage were grouted in some cases after reservoir filling.

Reference: Jevdjevic and Rajcevic, Some Special Features of Designs and Construction for Earth Dams and Rockfill Dams in Yugoslavia, Forth Congress on Large Dams, New Delhi, 1951, Question 13, Report 16.

4. Trangslet Dam, Sweden

Dam: Rockfill with impervious core, 400 ft high, sloping core 2800 ft long.

Rock: Syenite and porphyry with isolated sections of diabase.

Grout Curtain: To 65 ft depth.

Gallery: Drainage gallery under entire length of the core in tunnel.

5. Alcova Dam, Wyoming, USA

Dam: Earth-rock fill, 185 ft high.

Rock: Tilted sedimentary.

Grout Curtain: 80-90 ft deep. Four widely spaced rows.

Gallery: Surface gallery constructed above downstream curtain. Gallery planned for additional grouting requirements. Now allowed to flood.

Reference: Sherard et al. Earth and Earth-Rock Dams, p. 522-523.

6. Dams in Japan

Ouchi Dam, 1978-1981

Dam: 102m high, 340m crest length, Rockfill.

Rock: Tuff and tuff breccia.

Grout Curtain: 60-60m depth.

Gallery: Entire length of dam, tunneled.

Tamahara Dam, 1976-1982

Dam: 116m high, 600m crest length, rockfill.

Rock: Green tuff breccia. Brecciated conglomerate and andesite.

Grout Curtain: 100m to 200m deep.

Gallery: Grouting gallery entire length of dam, surface gallery.

Miko Dam

Dam: 95m high, 588m crest length.

Rock: Green tuff.

Grout Curtain: 20-50m deep.

Gallery: Surface type.

Kassa Dam

Dam: 90m high, 504m crest length.

Rock: Dacite and volcanic mudflow with andesite lava.

Grout Curtain: 50-75m deep.

Gallery: Tunneled entire length of dam.

Nanakura Dam

Dam: 123m high, 340m crest length.

Rock: Granite.

Grout Curtain: 75m depth.

Gallery: Tunneled 20 to 25m over 50% length of dam.

Tedorigawa Dam

Dam: 153m high, 420m crest length, rockfill.

Rock: Gneiss, biotite gneiss and conglomerate.

Grout Curtain: 60 to 60m deep.

Gallery: Surface type 70% length of dam.

7. <u>Keban Dam, Turkey</u>

<u>Dam:</u> 221m high, crest length 1097m.

<u>Rock:</u> Limestone underlain by horizontally bedded shists.
Small faults and breccia zones.

<u>Grout Curtain:</u> Extensive consolidation and deep cutoff.

<u>Gallery:</u> Tunneled.

Bath County pumped storage, two tier drainage galleries under construction.
Ref. V. Singh.

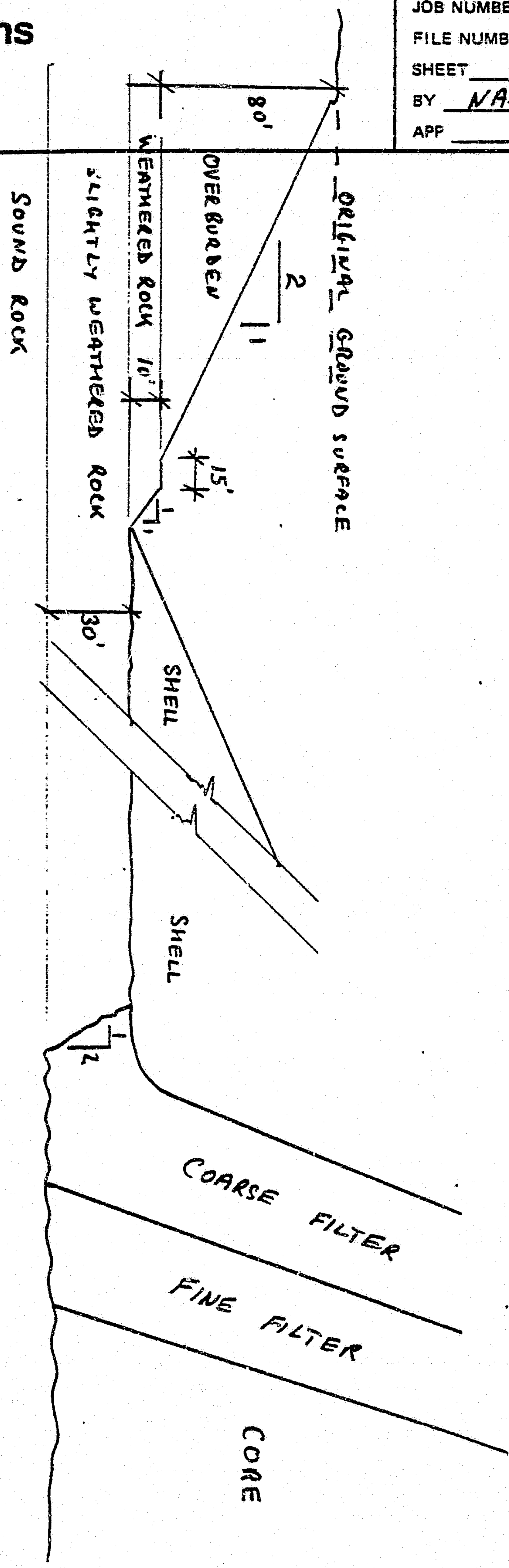
ACRES

Calculations

SUBJECT:

JOB NUMBER	P5700.06
FILE NUMBER	
SHEET	1 OF 1
BY	NAJB
DATE	16 Sept 1981
APP	
DATE	

SUSITNA HYDROELECTRIC PROJECT
WATANA DAM
FOUNDATION EXCAVATION
FOR ESTIMATING PURPOSES.



FORM NO. 152 REV. 1

N. Bond

ACRES

OFFICE MEMORANDUM

TO: R.K. Ibbotson

FROM: N. Bond

SUBJECT: Susitna Hydroelectric Project
Watana Dam Foundation-Excavation

Date: September 21, 1981

File: P5700.14.06.09

This memo sets out the depth of excavation to be used for estimating purposes.

The depths have been largely based on borehole logs (summary attached) with additional information from seismic lines, rock outcrops, photographs, and field observations by geologists.

An appendix is attached giving further criteria used to estimate the elevation of the top of rock in certain areas of the site.

Overburden

The foundation can be divided into two areas:

a) Riverbed

Depth to bedrock in four boreholes in the river ranged from 44 ft to 78 ft. The information available is limited, and for estimating purposes, the average thickness of overburden should be taken as 78 ft, the maximum observed in the boreholes.

b) Abutments

The depths to rock in 12 boreholes ranged from 3.5 ft to 16 ft, averaging 9 ft. However, considering the results of the seismic surveys and the distribution of the boreholes, 15 ft is a more reasonable estimate.

The weighted average over the whole foundation area is 20 ft.

For estimating purposes, it is understood that the volume of overburden material to be removed will be calculated from the "Preliminary Top of Rock Contour Map" September 3, 1981, and topographic maps.

Foundation For Core and Filters

The core and filters shall be founded on sound, competent, unweathered rock. All rock which has weathered to the extent that the rock mass permeability and compressibility have been adversely affected shall be excavated.

Closely spaced jointing will not itself be a criteria for excavation. If the joints are tight and fresh, then excavation will not be required. Joints which are only stained will not be considered as weathered.

Information from 15 boreholes indicates an average depth of weathered rock of 30 ft with depths ranging from zero to 79 ft (see attached borehole data).

Additional excavation of sound rock may be required to form a regular foundation surface on which the core may be well compacted. There is insufficient information at present to assess the degree of irregularity of the foundation. Observations of rock outcrops suggests the foundation surface will be rugged and trimming will be required.

It is proposed, therefore, that a further 10 ft of rock excavation be allowed to cover this requirement and as a further contingency because of the limited data available.

The total rock excavation depth in the core area should, therefore, be taken as 40 ft for present estimating purposes.

It must be emphasized that this is an average figure, and the actual excavation may vary from 5 ft to 65 ft or more.

Weathered joints and shears may extend under the foundation to considerable depths. In such cases where it is impracticable and/or uneconomic to excavate all weathered and sheared material, these zones will be locally excavated to a shallow depth backfilled with concrete and, if necessary, grouted.

It is expected that after excavation of the weathered rock, the exposed rock foundation will contain jointing which will require consolidation grouting. Provision has been made for consolidation grouting to a depth of 30 ft over the area of the core and filter/rock contact.

Rock Excavation Under the Rockfill Shells

The rockfill shells shall be founded on competent rock. This will require the removal of overburden and rippable rock.

Heavily jointed and fractured rock need not be excavated unless there is a substantial amount of joint in-fill material which could be washed out and cause the rock to become unstable or give rise to settlement of the rock surface.

Steep slopes will be required to be trimmed and a regular rock surface formed for placement of the rockfill.

This excavation under the rockfill shells is expected to total 10 ft average depth over the whole shell foundation area.

N. Bond

NB:ccv

cc: D. Meilhede
Geotech file copy circ: L. Duncan
K. White
R. Gorny
N. Bond
File

TASK 6

0036

Watana – Dam
Seepage Calcs

ACRES

Design Calculation Cover Sheet

PROJECT No. P5700.06
FILE No. P5700.14.06.09
SERIAL No. 0036

PROJECT TITLE SUSITNA HYDRO ELECTRIC PROJECT
ALASKA POWER AUTHORITY

DEPARTMENT GEOTECHNICAL BUFFALO

CALCULATIONS FOR: WATANA DAM - SEEPAGE CALCS

ORIGINAL BY N.A.J. BOND. DATE 17 / Sept / 81
21 Dec 81
CHECKED BY DATE / /

REV No	BY	DATE	CHECKED	DATE
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FOUNDATION PERMEABILITY (FEASIBILITY REPORT)
FLOW NETS.
SEEPAGE CALCS. 14 Pages.

APPROVED BY

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BY [signature] DATE 3 / 10 / 83

TOTAL No. OF SHEETS 26 W/COVER

60.04.01 Form 146 A

Note 10.1 has been changed new slot required for this.

DRAFT
P5700.05
NB:adh
12/21/81

SUSITNA FEASIBILITY REPORT

10.0 - WATANA DEVELOPMENT

10.1 - Site Geology

Foundation Permeability

Details of water pressure tests and rock permeability are presented and discussed in Task 5 Geotechnical Report.

The permeability of the rock within the dam site area ranges between 1×10^{-4} cm/sec and 1×10^{-6} cm/sec. The permeability of the rock decreases with depth, see Fig. ____. As would be expected, higher permeabilities are found near the surface and in highly fractured and sheared areas.

The average permeabilities calculated from 12 boreholes shows an approximate linear variation with depth. In the upper 200 feet of rock average permeabilities are greater than 1×10^{-4} cm/sec.

Seepage Under the Dam

Based on results of water pressure tests, calculations were carried out to assess the possible seepage through the foundation rock.

A flow net was developed assuming that the rock is of uniform permeability, down to an impervious layer at 2500 feet depth ~~is impervious~~, the dam shells are free draining, and the dam core and the consolidation grouting zone under the core and filters are impervious.

This analysis gave the following results for the range of rock permeabilities:

Rock Permeability	Total Seepage
1×10^{-6} cm/sec	0.04 ft^3/sec
1×10^{-5} cm/sec	0.43 ft^3/sec
1×10^{-4} cm/sec	4.36 ft^3/sec

The results from the water pressure tests indicate an average rock permeability between 1×10^{-5} cm/sec and 1×10^{-4} cm/sec and thus, without treatment of the foundation, seepage could be of the order of 4 ft^3/sec.

While this flow is not a significant amount in terms of water loss from the reservoir, it could give rise to piping of fine material along shear zones, tend to cause instability of the rock slopes downstream of the dam, and give rise to seepage into the power house area, and is therefore unacceptable.

The seepage rate may be reduced by increasing the length of the seepage path or reducing the permeability of the rock.

The seepage path may be increased by an upstream blanket of impervious material but the stability of the material could not be assured on the steep valley slopes. The blanket would also increase the length of the diversion tunnels and reguire tunnelling through very difficult ground.

A grout curtain increases the seepage path length under the dam depressing the flow path away from the higher permeability rock which ~~ends~~ exists near the surface.

Therefore, grouting, in conjunction with a comprehensive drainage system was adopted to control seepage through the dam foundation.

Flow net 2 shows the effect of a 350-ft deep grout curtain on seepage under the dam. For an average rock permeability of 1×10^{-5} cm/sec the total seepage under the dam is 0.3 ft^3/sec, a reduction of 42 percent in the volume of seepage in the case without grouting.

For grouting alone to have a substantial effect on seepage the permeability of the grouted zone must be practically zero, as assumed in the above calculation (ref Casagrande Volume Embankment Dam Engineering, pg 32-33.) Since grouting can never be this effective it is necessary to provide drainage in conjunction with grouting to ensure adequate seepage control.

The depth of grout curtain is something for which there is no generally recongized rule or design method (ref Casagrande Volume). The average rock permeability decreases significantly around 200 feet depth. A positive cut off 350-feet deep as assumed in flow net analysis, increases the potential flow path by a factor of 1.7, decreasing the average hydraulic gradient from about 0.9 to 0.5.

For medium height dam, a rule used by the COE (ref   ) is for the depth of grout curtain to be 0.7 multiplied by the hydraulic head at a particular location on the foundation.

This rule used for ~~Thus for~~ the large dam at Watana would give a 560-ft deep grout curtain at the deepest point, which is considered excessive for the type of rock foundation existing at Watana.

For the preliminary design, therefore, a maximum depth of grout curtain of 350 feet has been adopted. The minimum grout curtain depth is 50 feet, which is controlled mainly by the depth of weathering and fracturing in the upper abutments. At the intermediate locations the COE rule of 0.7 multiplied by the hydraulic head has been used to determine the depth of the grout curtain.

The major shear zone in the left abutment is an area of high permeability, ~~while~~ the artesian water pressure observed in BH (drilled into the shear zone) ~~DU~~-12 indicates that continuous seepage paths exist along the shear zone. Since this shear zone intersects the reservoir area it was decided to maintain the grout curtain at 200 feet depth in this area.

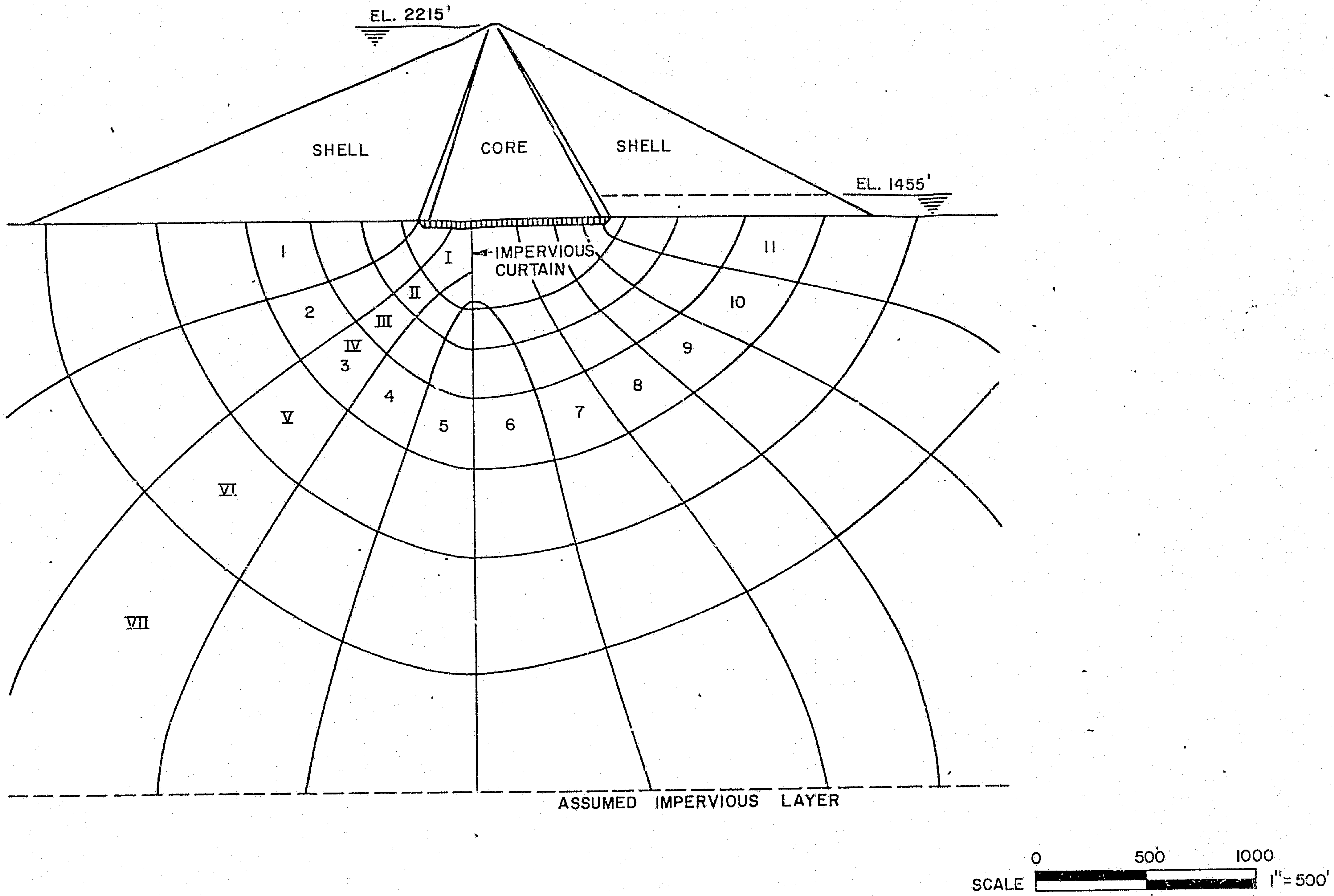
The general trend of major shear zones which are the major potential seepage zones are at an angle of 45° to the dam axis.

In order to assess the magnitude of seepage which could possibly occur in these zones the amount of seepage was calculated assuming a zone 50-feet wide with the maximum head of water acting at the surface of the shear.

Measured permeabilities in shear zones are generally in the order of 1×10^{-4} cm/sec. However, these field measurements were at the limit of the measuring equipment and therefore actual permeabilities may be somewhat higher. It is assumed for this worse case analysis that after treatment by grouting the permeability of the shear zone would be 1×10^{-4} cm/sec.

This gives a seepage volume through the zone of 0.10 ft^3/sec which can be easily controlled by the drainage system provided.

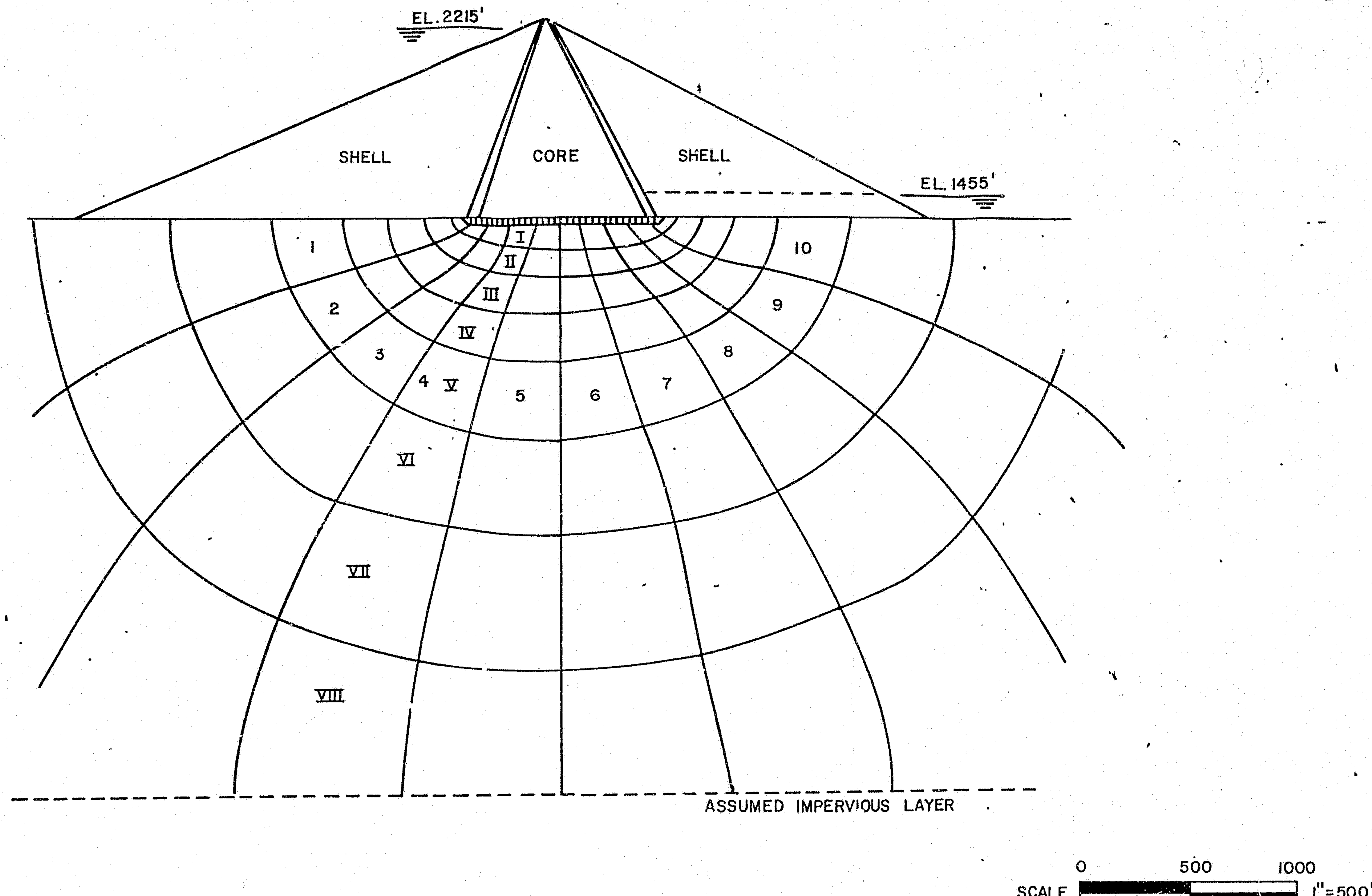
Flow nets 3 and 4 show the effect of drainage on the dam foundation. The uplift pressures and hydraulic gradient on the core foundation are considerably reduced.



WATANA DAM
SEEPAGE FLOW NET 2

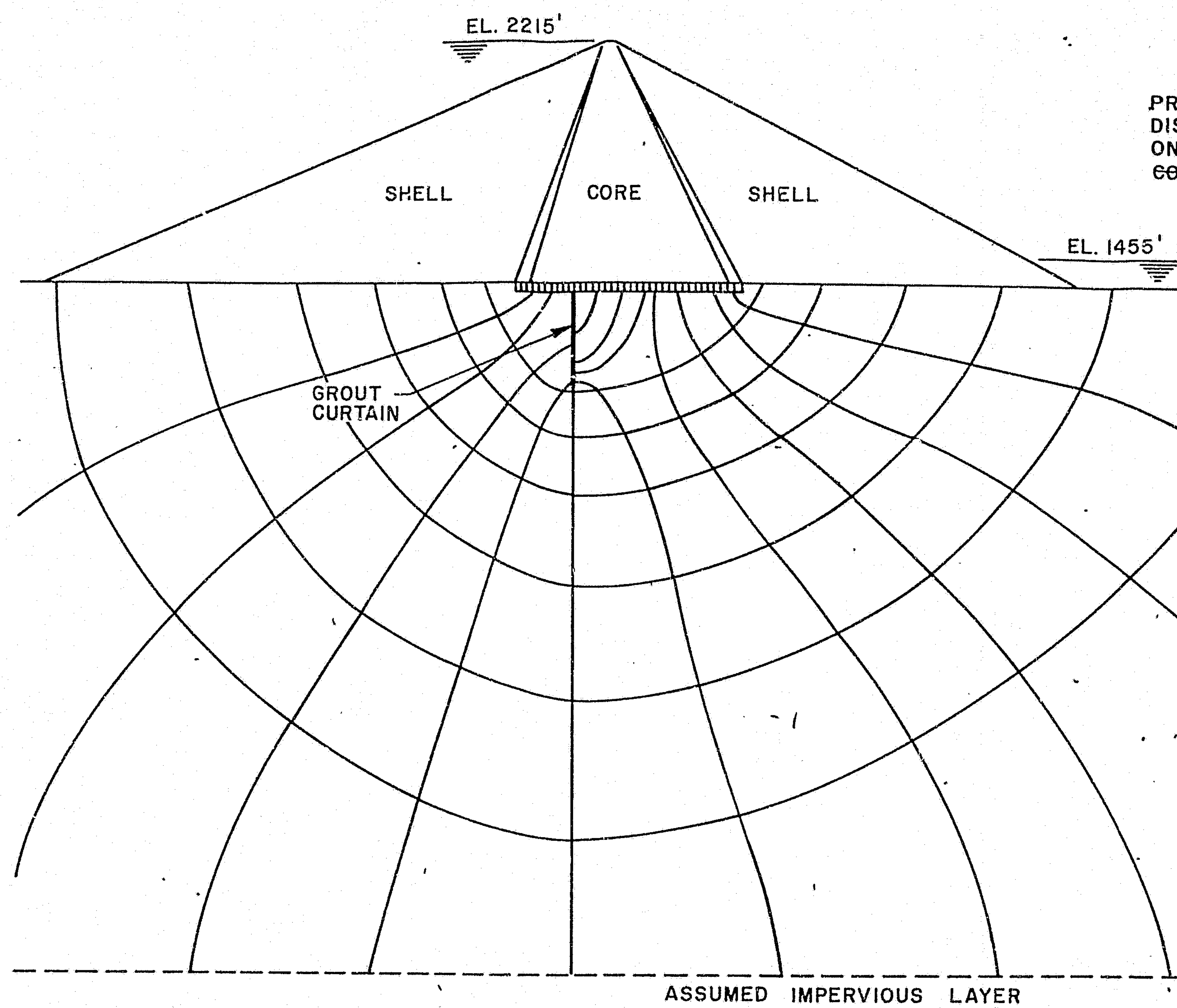
FIGURE

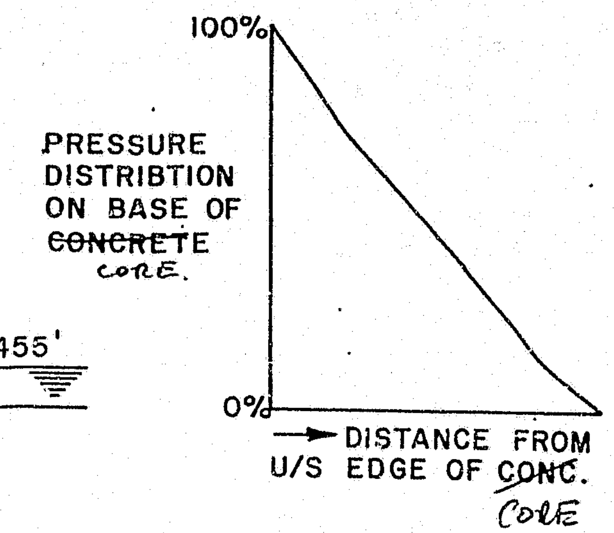
ACRES



WATANA DAM
SEEPAGE FLOW NET I

FIGURE



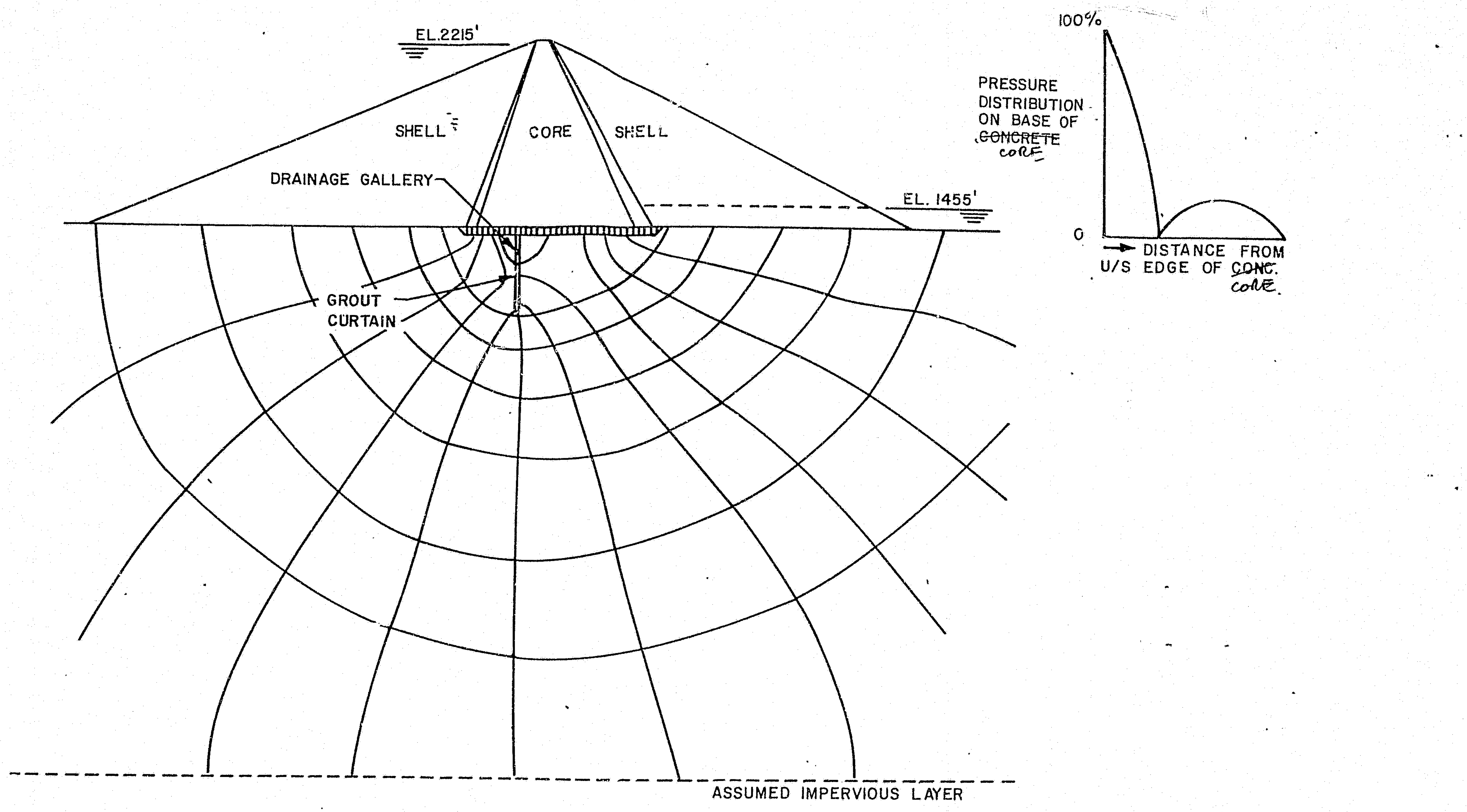


SCALE 0 500 1000 1" = 500'

WATANA DAM
SEEPAGE FLOW NET 3

FIGURE

ACRES



WATANA DAM
SEEPAGE FLOW NET 4

FIGURE

ACRES	**Calculations**	
	SUBJECT: SUSITNA HYDRO ELECTRIC PROJECT WATANA DAM SEEPAGE UNDER DAM.	JOB NUMBER P5700 : 06 FILE NUMBER SHEET i OF 74 BY NAJI DATE 17/9/81 APP DATE

Flow net 1.

Assumptions.

1) Shells are free draining completely pervious

2) Impervious stratum at 2500' depth

3) Rock is of uniform permeability.

4) No grout curtain or drainage.

5) Consolidation zone under core is impermeable.

ACRES	**Calculations**	JOB NUMBER P5700.02
	SUBJECT:	FILE NUMBER
		SHEET 2 OF 14
		BY NAD. DATE
		APP DATE

These calculated seepage volumes are very small and would be undetectable downstream of the dam.

However there are shear zones of higher permeabilities under the dam BH 2 indicated permeability of 1×10^{-4} cm/sec.

If it is assumed the shear zone is 50' wide with maximum head of water acting at the surface of the shear

1×10^{-4} cm/sec $= 3.2\times10^{-6}$ ft/sec

Seepage through the shear zone.

$$Q = 3.2\times10^{-6}\times 760\times\frac{8}{10} = 0.00194 \text{ ft}^3/\text{sec}$$

Over length of 50' $Q = 0.097$ ft³/sec.

Still a negligible quantity.

ACRES	**Calculations**	JOB NUMBER P5700·06
	SUBJECT:	FILE NUMBER
		SHEET 3 OF 14
		BY WAM DATE
		APP DATE

Pressure head loss = 2215' − 1455' = 760

From Sherard et al Earth and Earth Rock dams 54 p 275

$$Q = kh \frac{N_f}{N_d}$$

where k = coefficient of permeability ft/sec

h = total pressure head loss (ft)

Nf = number of flow channels

Nd = number of equal potential drops

Q = rate of seepage ft³/sec

From Flow net 1.

h=760' Nf = 8 Nd = 10 k_1 = case i 1×10^{-5} cm/sec = 3.3×10^{-7} ft/sec

k_2 = case ii 5×10^{-6} cm/sec = 1.6×10^{-7} ft/sec

k_3 = case iii 1×10^{-6} cm/sec. 0.33×10^{-7} ft/sec.

i $Q_1 = 3.3 \times 10^{-7} \times 760 \times \frac{8}{10}$ = 0·000206 ft³/sec per ft length of dam.

ii $Q_2 = 1.6 \times 10^{-7} \times 760 \times \frac{8}{10}$ = 0·000097 ft³/sec per ft length of dam

iii $Q_3 = 0.33 \times 10^{-7} \times 760 \times \frac{8}{10}$ = 0·000020 ft³/sec per ft length of dam.

FORM NO. 152 REV. 1

Assume 1000' length of dam with this seepage.

$Q_1 = 0.206$ ft³/sec

$Q_2 = 0.097$ ft³/sec

$Q_3 = 0.020$ ft³/sec.

Assuming same flow net for $h = 500$.

$Q_1 = 3.3\times10^{-7} \times 500 \times \frac{8}{10} = 0.00013$ } for $l = 1000'$ $Q_1 = 0.13$ ft³/sec

$Q_2 = 1.6\times10^{-7} \times 500 \times \frac{8}{10} = 0.000065$ $Q_2 = 0.06$ ft³/sec

$Q_3 = 0.33\times10^{-7} \times 500 \times \frac{8}{10} = 0.000013$ $Q_3 = 0.013$ ft³/sec.

For remaining section of dam. $h = 200$ $l = 2000$

$Q_1 = 3.3\times10^{-7} \times 200 \times \frac{8}{10} = 0.000053$ } for $l = 2000$ $Q_1 = 0.1$ ft³/sec.

$Q_2 = 1.6\times10^{-7} \times 200 \times \frac{8}{10} = 0.000026$ $Q_2 = 0.05$ ft³/sec

$Q_3 = 0.33\times10^{-7} \times 200 \times \frac{8}{10} = 0.000005$ $Q_3 = 0.01$ ft³/sec

Total seepage under dam

$Q_1 = 0.436$ ft³/sec. for permeability 1×10^{-5} cm/sec

$Q_2 = 0.207$ ft³/sec 5×10^{-6} cm/sec

$Q_3 = 0.043$ ft³/sec. 1×10^{-6} cm/sec.

ACRES	Calculations	
	SUBJECT:	JOB NUMBER P5200.06
		FILE NUMBER
		SHEET 5 OF 14
		BY NAOB DATE
		APP DATE

Flow Net 2.

Impervious curtain 300' deep introduced upstream of centre line of core.

Assumed this curtain is impermeable but in reality the curtain will vary in permeability

From Flow net 2.

$h = 760'$ $\quad N_f = 7$ $\quad N_d = 11$ $\quad k_1 = 1 \times 10^{-5}$ cm/sec (one case only) $= 3.3 \times 10^{-7}$ ft/sec.

Section 1 $\quad Q = 3.3 \times 10^{-7} \times 760 \times \frac{7}{11} = 0.0001596$ ft³/sec $\quad \ell = 1000 \quad Q = 0.159$ ft³/sec

2 $\quad Q = 3.3 \times 10^{-7} \times 500 \times \frac{7}{11} = 0.0001050$ ft³/sec $\quad \ell = 1000' \quad Q \; 0.105$ ft³/sec

3 $\quad Q = 3.3 \times 10^{-7} \times 200 \times \frac{7}{11} = 0.000$[illegible] ft³/sec $\quad \ell = 2000 \quad Q = 0.042$ ft³/sec

$Q = 0.306$ ft³/sec

Reduction of seepage of 42% due to introduction of grout curtain.

FORM NO. 152 REV. 1

ACRES

Calculations

SUBJECT:

JOB NUMBER P5200.06
FILE NUMBER
SHEET 6 OF 14
BY NAOB DATE
APP DATE

Flow net 1. Seepage for case iv 1×10^{-4} cm/sec. = 3.3×10^{-6} ft/sec.

h = 760' Nf = 8 Nd = 10.

$Q_1 = 3.3\times10^{-6}\times760\times\frac{8}{10}$ = 0.00266 ft³/sec per ft of dam. ×1000' = 2.06 ft³/sec

$Q_2 = 3.3\times10^{-6}\times500\times\frac{8}{10}$ = 0.0013 ft³/sec for l = 1000' = 1.30 ft³/sec

$Q_3 = 3.3\times10^{-6}\times200\times\frac{8}{10}$ = 0.00053 ft³/sec for l = 2000' = 1.0 ft³/sec

4.36 ft³/sec

Similarly for flow net with curtain Q = 3.06 ft³/sec for permeability of 1×10^{-4} cm/sec.

FORM NO. 152 REV. 1

ACRES

Calculations

SUBJECT:

JOB NUMBER P5700.06
FILE NUMBER
SHEET 7 OF 14
BY NAMB DATE
APP DATE

Permeability calculations.

Sherard et al. Earth and Earth Rock Dams 5 4 p275.

$$Q = k h \frac{N_f}{N_d}$$

where k = coefficient of permeability ft/sec

h = total pressure head loss ft

Nf = Number of flow channels

Nd = Number of equal potential drops

Q = rate of seepage ft³/sec.

FORM NO. 152 REV. 1

ACRES	**Calculations**	JOB NUMBER P5200.06
	SUBJECT:	FILE NUMBER
		SHEET 5 OF 14
		BY NAON DATE
		APP DATE

$k_1 = 1 \times 10^{-6}$ cm/sec $= 3.3 \times 10^{-8}$ ft/sec

$k_2 = 1 \times 10^{-5}$ cm/sec $= 3.3 \times 10^{-7}$ ft/sec

$k_3 = 1 \times 10^{-4}$ cm/sec $= 3.3 \times 10^{-6}$ ft/sec

for h = 760   length of dam = 1000 ft.

i) $Q_1 = 3.3 \times 10^{-8} \times 760 \times \frac{8}{10}$ = 0.00002006 ft³/sec per ft length of dam.

ii) $Q_2 = 3.3 \times 10^{-7} \times 760 \times \frac{8}{10}$ = 0.0002006 ft³/sec per ft length of dam

iii) $Q_3 = 3.3 \times 10^{-6} \times 760 \times \frac{8}{10}$ = 0.002006 ft³/sec per ft length of dam.

for h = 500   l = 1000

i) $Q_1 = 3.3 \times 10^{-8} \times 500 \times \frac{8}{10}$ = 0.000013 ft³/sec per ft length of dam.

ii) $Q_2 = 3.3 \times 10^{-7} \times 500 \times \frac{8}{10}$ = 0.00013 " " "

iii) $Q_3 = 3.3 \times 10^{-6} \times 500 \times \frac{8}{10}$ = 0.0013 " " "

for h = 200'   l = 2000'

i) $Q_1 = 3.3 \times 10^{-8} \times 500 \times \frac{8}{10}$ = 0.0000053 ft³/sec per ft length of tunnel

ii) $Q_2 = 3.3 \times 10^{-7} \times 500 \times \frac{8}{10}$ = 0.000053

iii) $Q_3 = 3.3 \times 10^{-6} \times 500 \times \frac{8}{10}$ = 0.00053

FORM NO. 152 REV. 1

ACRES Calculations

SUBJECT:

JOB NUMBER P5700.06
FILE NUMBER
SHEET 9 OF 14
BY NAG. DATE
APP DATE

for case i TOTAL FLOW

= 0.0000206 × 1000 = 0.020
0.000013 × 1000 = 0.013
0.0000053 × 2000 = 0.010
TOTAL 0.043 ft³/sec.

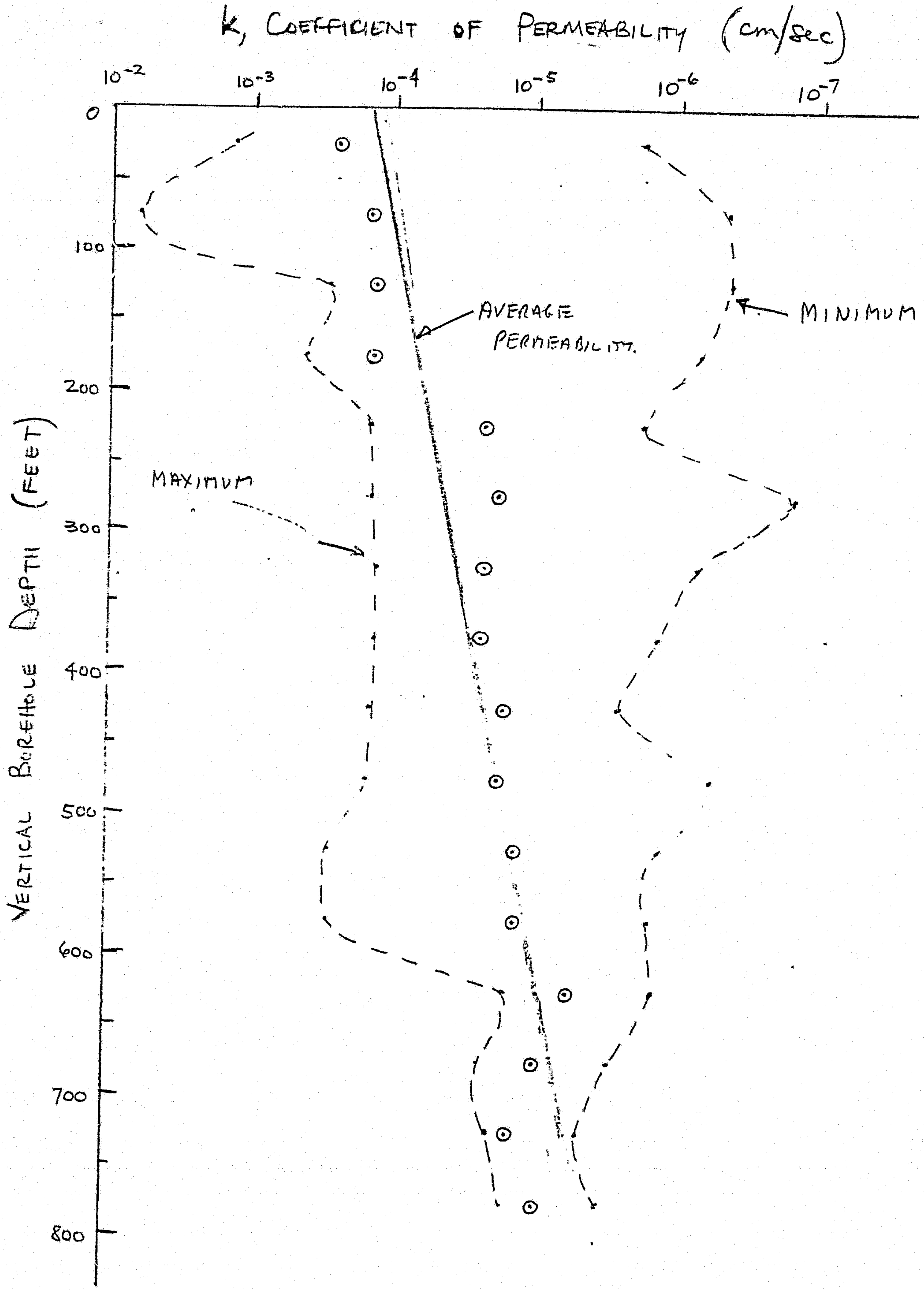
for case ii) TOTAL FLOW

= 0.000206 × 1000 = 0.20
0.00013 × 1000 = 0.13
0.000053 × 2000 = 0.10
0.43 ft³/sec.

for case iii) TOTAL FLOW

= 0.002006 × 1000 = 2.00
0.00130 × 1000 = 1.30
0.00053 × 2000 = 1.06
4.36 ft³/sec.

P5700.05 WATANA ROCK PERMEABILITY ~~VALUES~~ ~~12/14/81~~



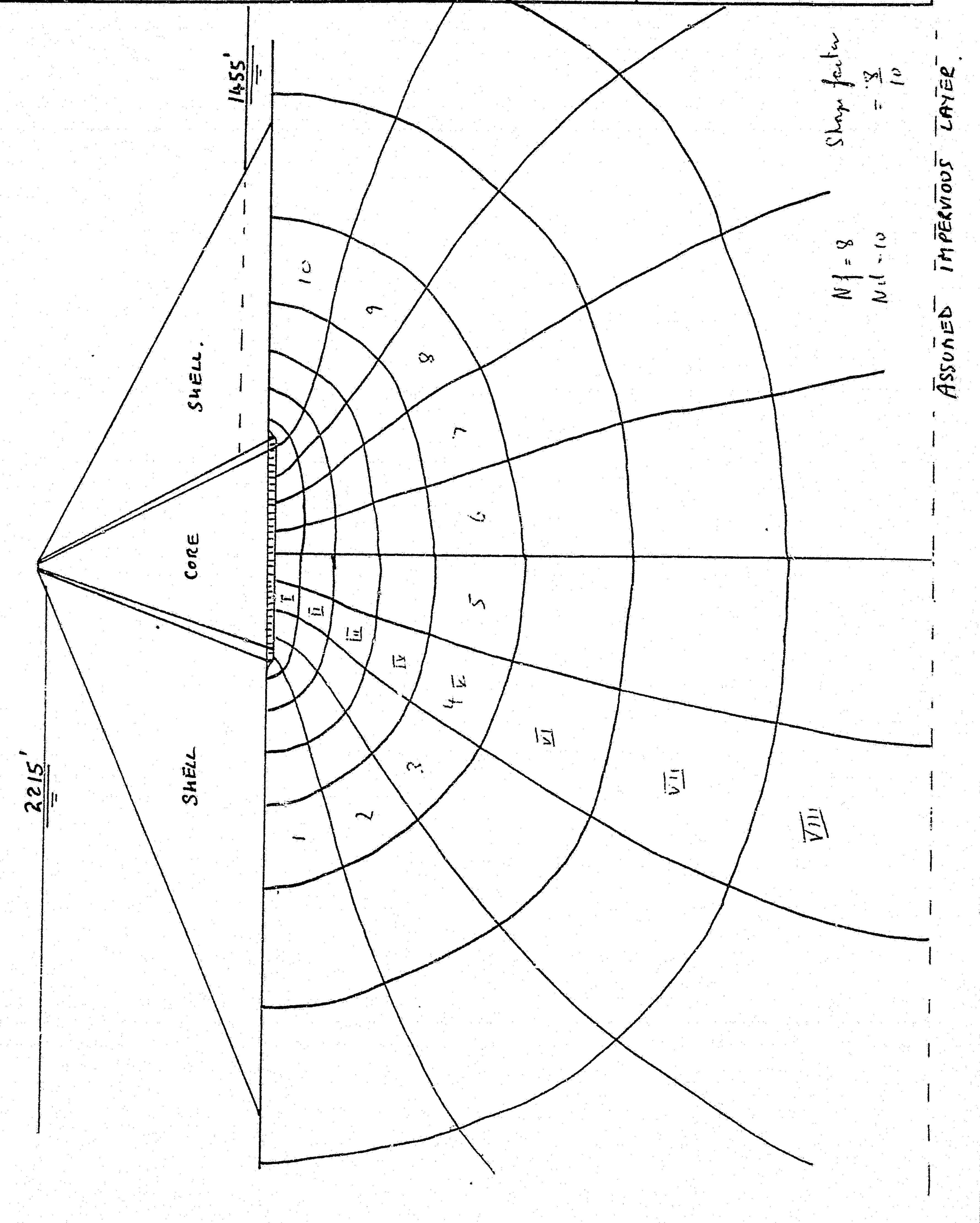
Based on: BH-1 - BH-4, BH-6, BH-8, BH-12, DH-1, DH-3, DH-6, DH-8 - DH-11.

ACRES

Calculations

JOB NUMBER	P5700·06
FILE NUMBER	
SHEET	4
OF	14
BY	WAJB
DATE	
APP	
DATE	

SUBJECT: SUSITNA HYDROELECTRIC PROJECT
WATANA DAM
FLOW NET 1



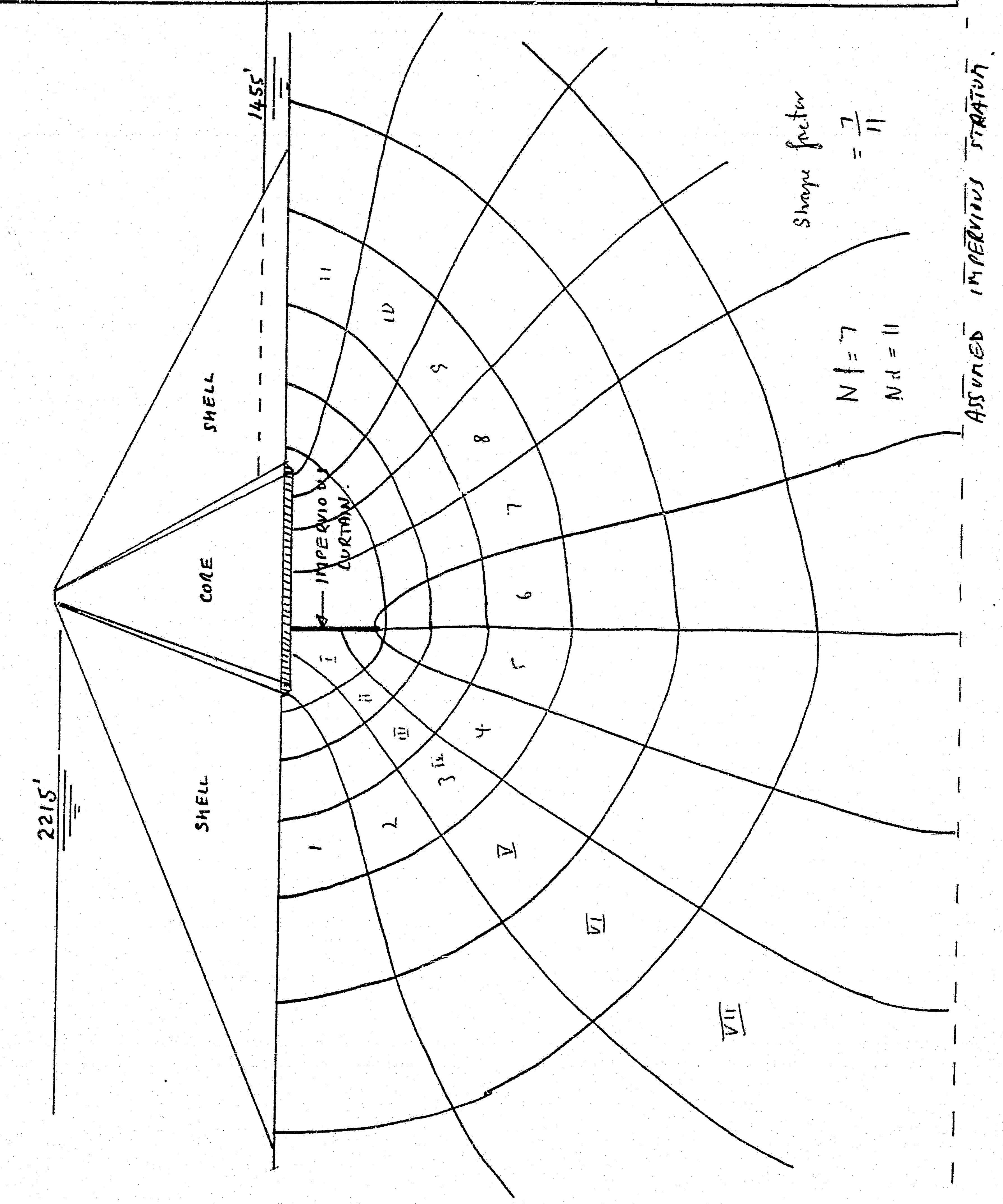
FORM NO. 152 REV. 1

ACRES

Calculations

SUBJECT: SUSITNA HYDROELECTRIC PROJECT
WATANA DAM
FLOW NET 2

JOB NUMBER	P5700.06
FILE NUMBER	
SHEET 12	OF 14
BY NAOB	DATE
APP	DATE



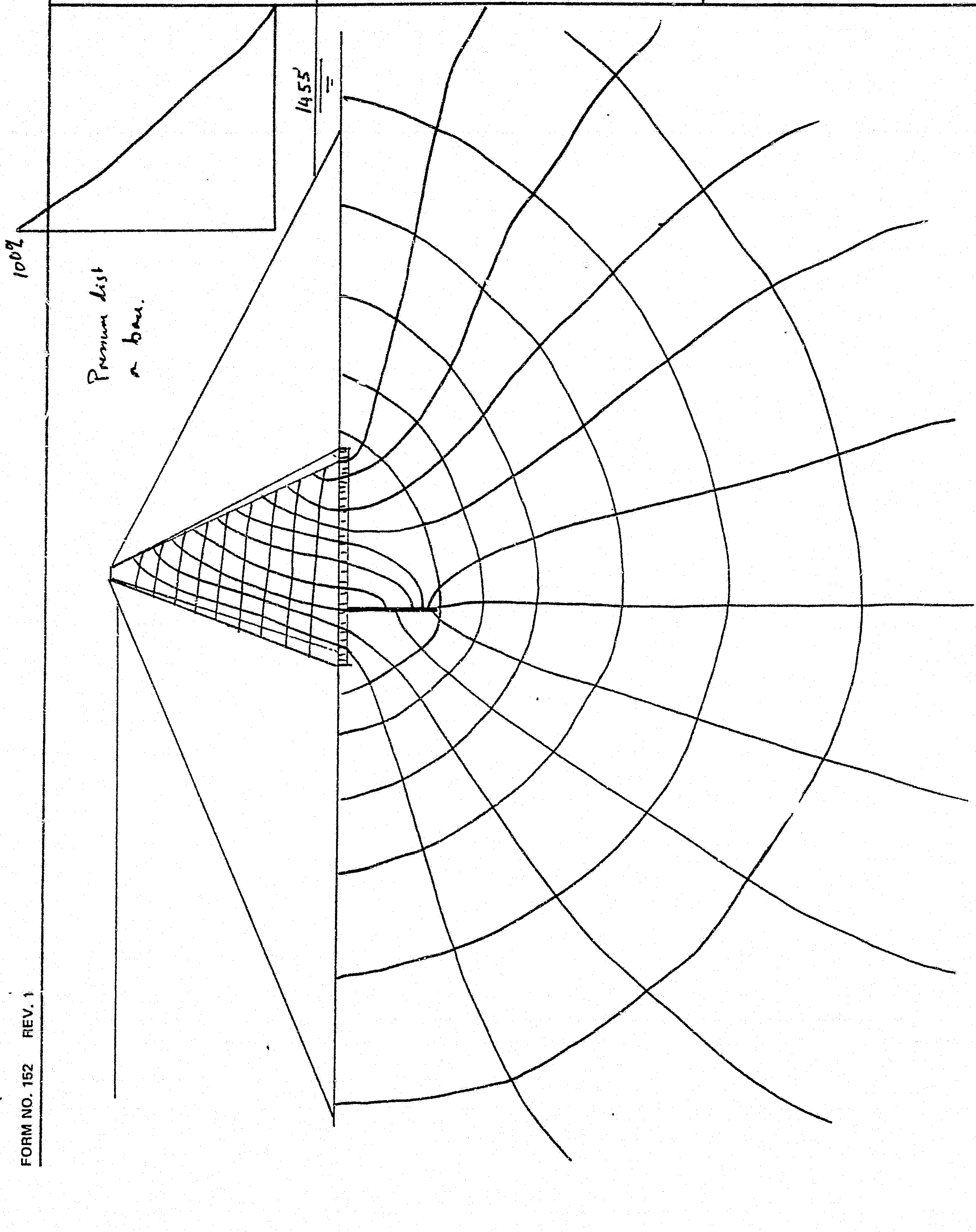
FORM NO. 152 REV. 1

Calculations

ACRES

SUBJECT: SUSITNA HYDRO ELECTRIC PROJECT
WATANA DAM SEEPAGE
GROUT CURTAIN NO DRAINAGE

JOB NUMBER P5700.06
FILE NUMBER
SHEET 13 OF 14
BY NAM DATE
APP DATE



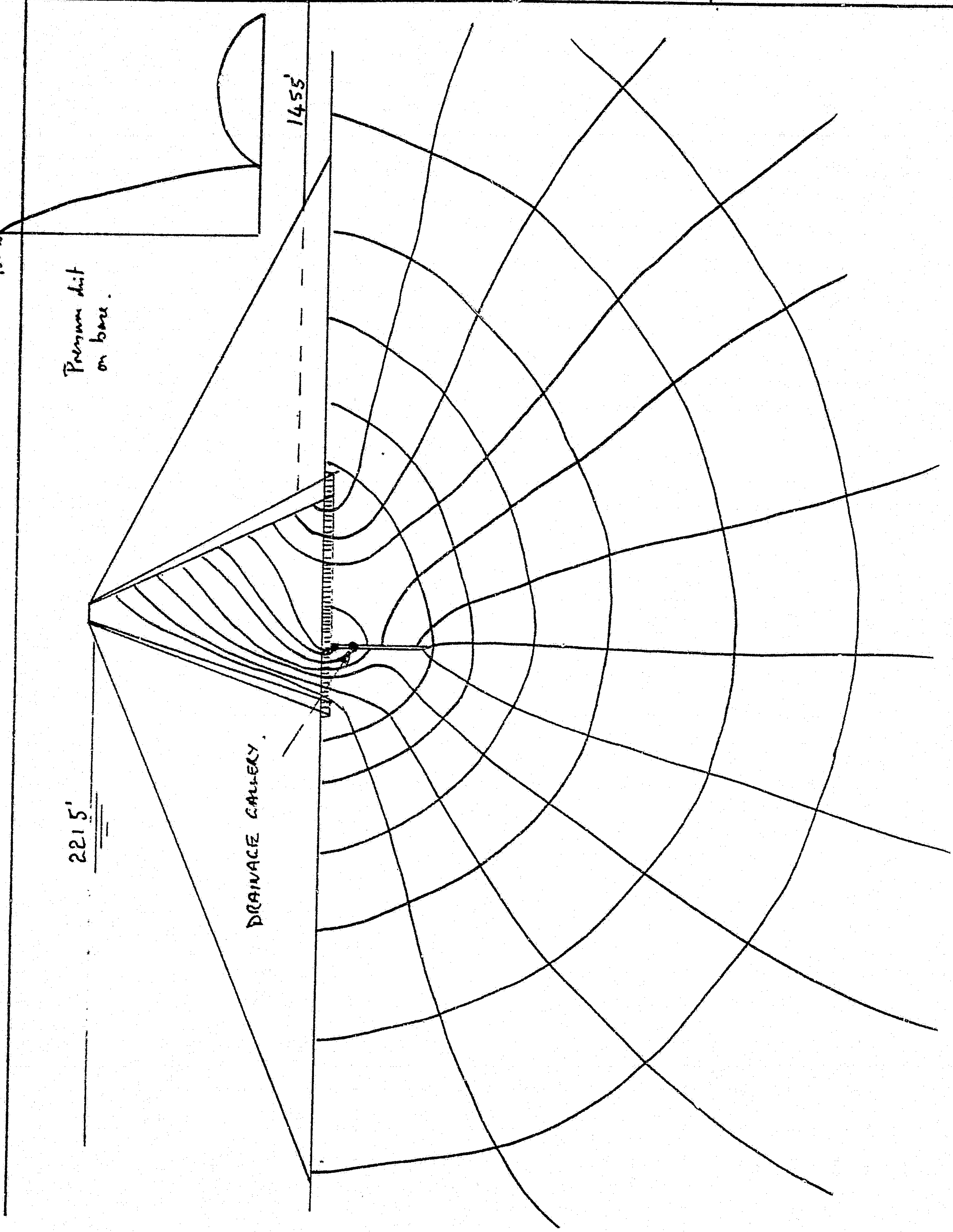
FORM NO. 152 REV. 1

ACRES

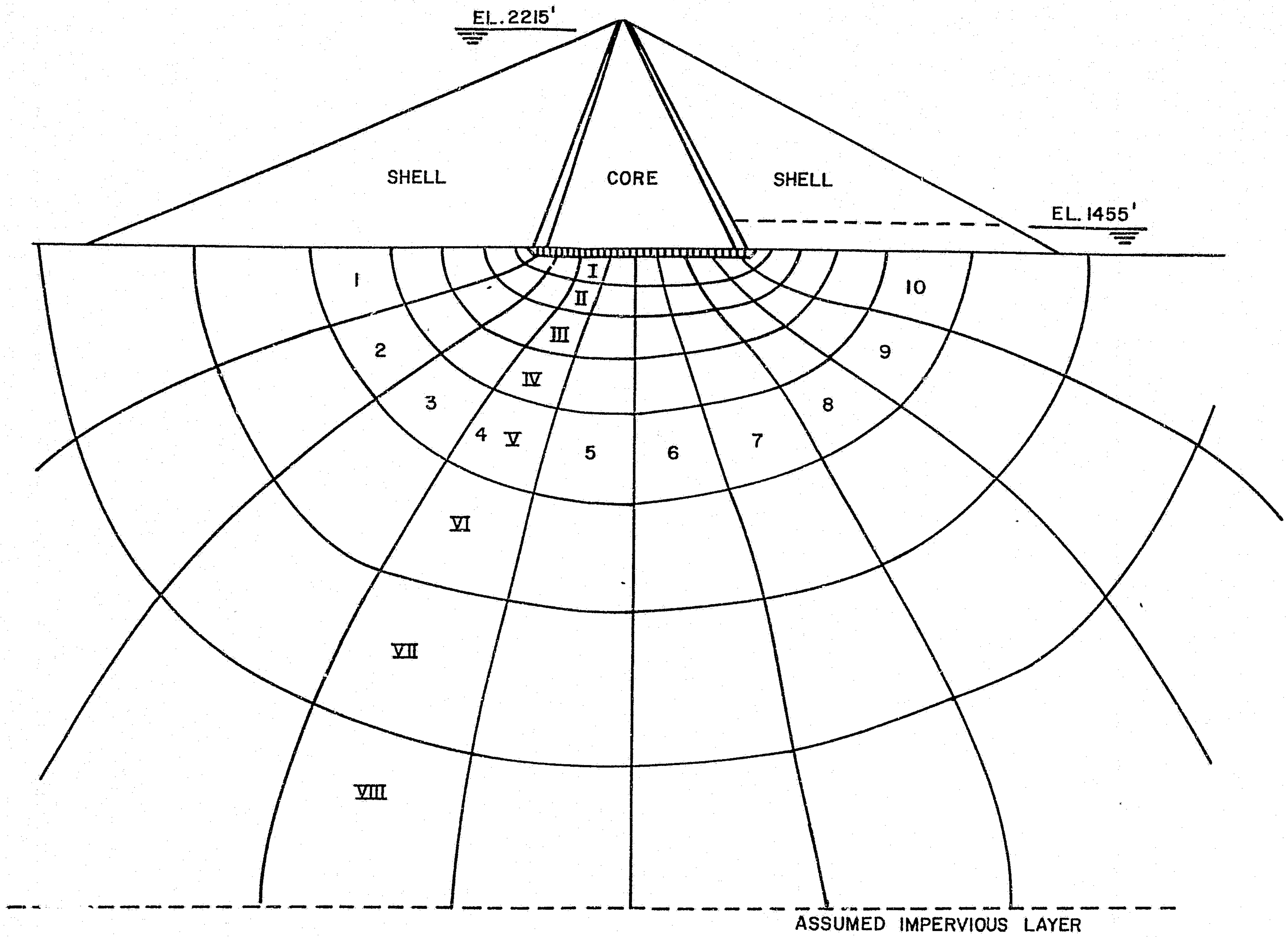
Calculations

SUBJECT: SUSITNA HYDROELECTRIC PROJECT
WATANA DAM
GROUT CURTAIN WITH DRAINAGE GALLERY

JOB NUMBER P5200.06
FILE NUMBER
SHEET 14 OF 14
BY NAOB.
DATE
APP
DATE



FORM NO. 152 REV. 1

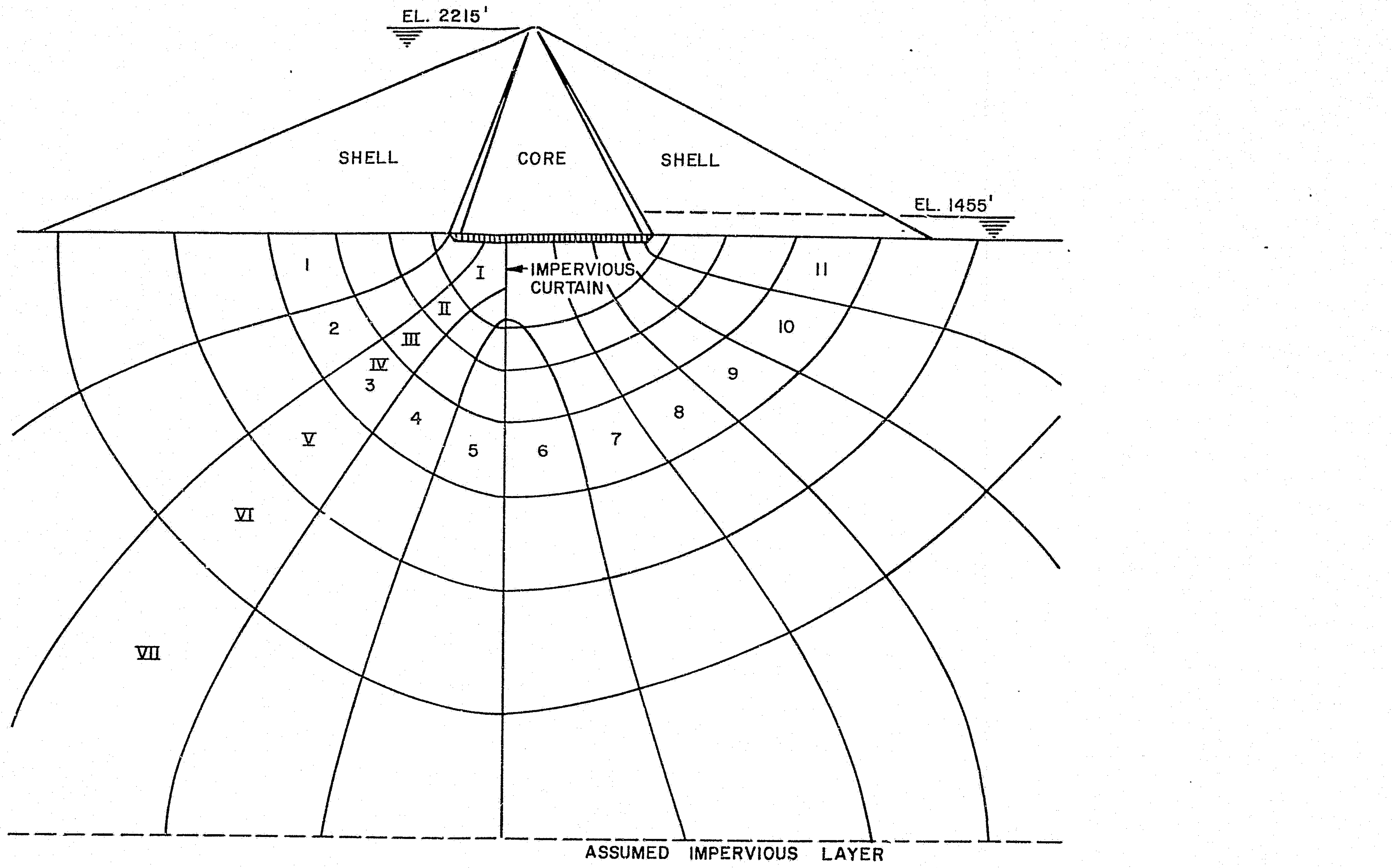


WATANA DAM
SEEPAGE FLOW NET I

SCALE 0 500 1000 1"=500'

FIGURE

ACRES



WATANA DAM
SEEPAGE FLOW NET 2

FIGURE

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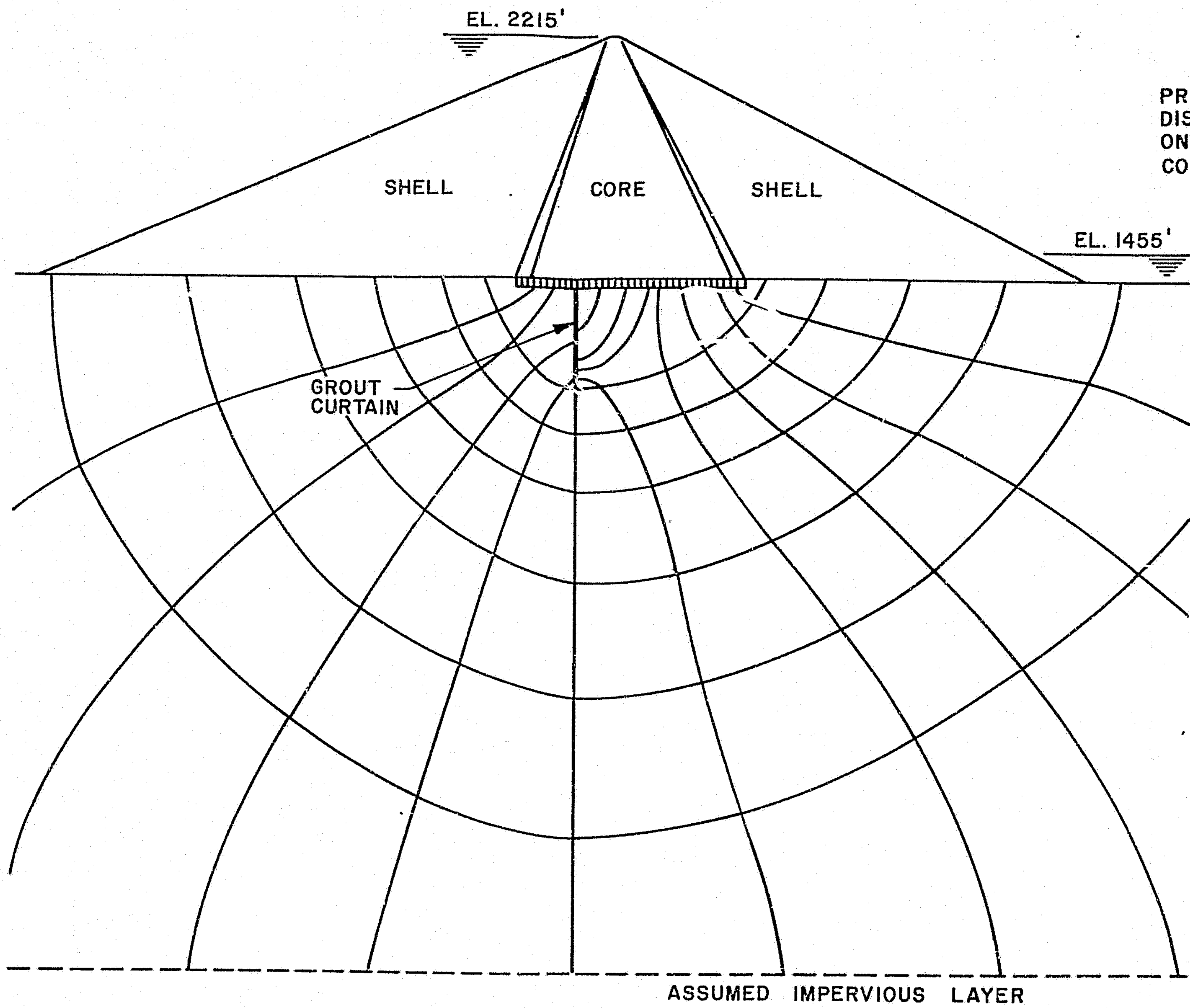
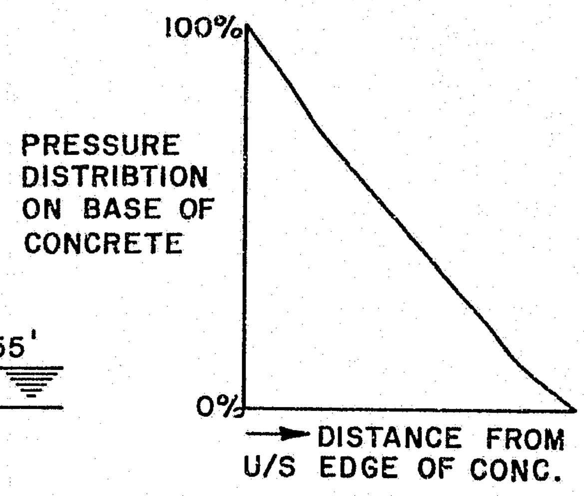
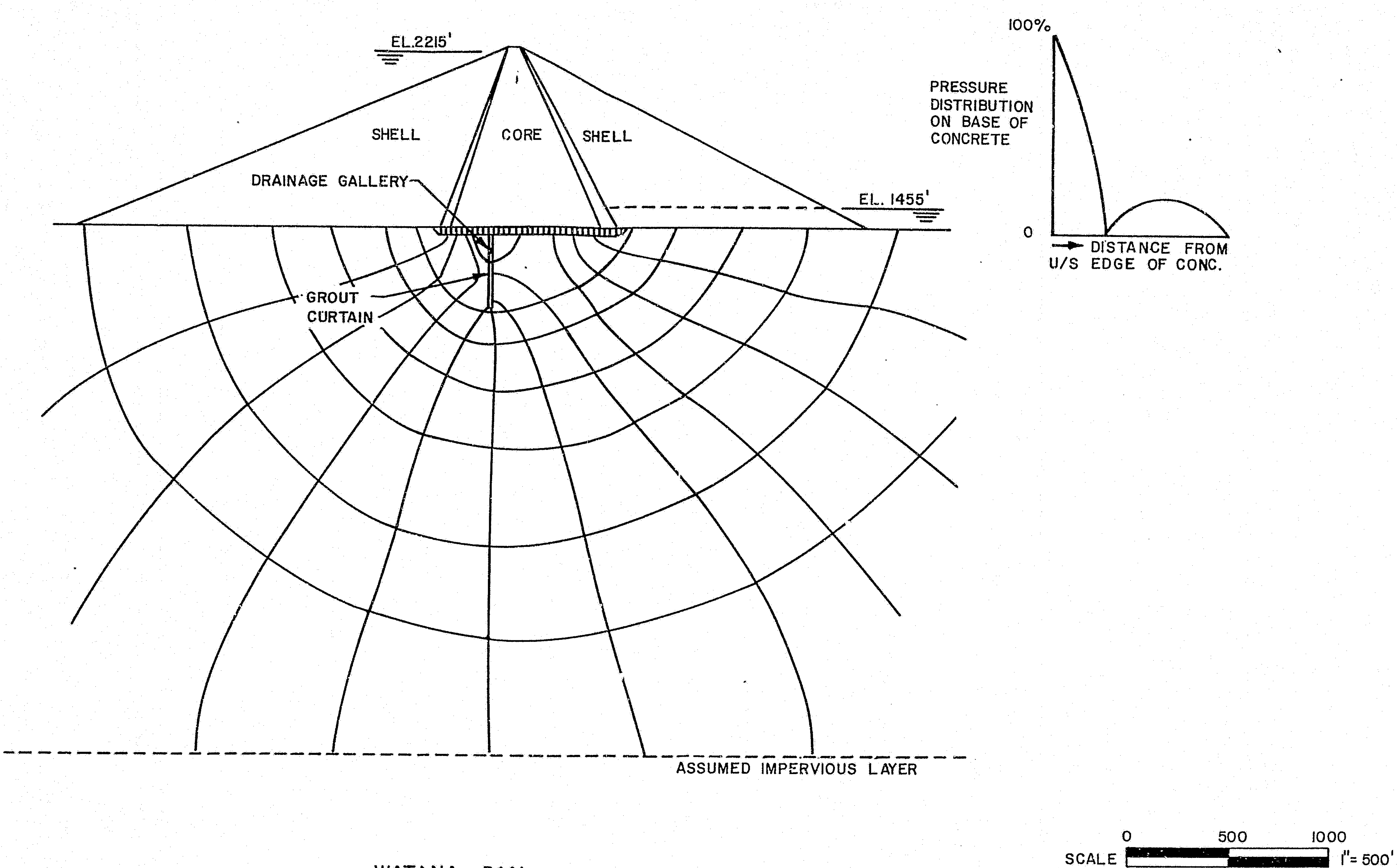




SCALE 0 500 1000 1" = 500'

WATANA DAM
SEEPAGE FLOW NET 3

FIGURE



WATANA DAM
SEEPAGE FLOW NET 4

FIGURE

0038

WATANA –

Underground Structure Supports

ACRES

Design Calculation Cover Sheet

PROJECT No. P5700.06
FILE No. P5700.14.06.09
SERIAL No. 0038

PROJECT TITLE SUSITNA HYDROELECTRIC PROJECT
ALASKA POWER AUTHORITY

DEPARTMENT GEOTECHNICAL BUFFALO

CALCULATIONS FOR: WATANA UNDERGROUND STRUCTURE SUPPORTS.

ORIGINAL BY MAJB DATE 13 / JAN / 82

CHECKED BY DATE / /

REV No	BY	DATE	CHECKED	DATE
		/ /		/ /
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TOTAL No. OF SHEETS 33 W/COVER

60.04.01 Form 146 A

RQD.	% length of tunnel.	Q	Diversion Tunnel. 40' ID Concrete lined. 43' excavated Diam $\frac{Span}{ESR}$ = 27 (8.2m)	Access Tunnel. 35' Span (no concrete lining) $\frac{Span}{ESR}$ = 27' (8.2m)	Penstock Tunnel. 17' I.D. 21' excavated span Concrete lined $\frac{Span}{ESR}$ = 13' (4m)	Tailrace Tunnel. 35' I.D. 38' excavated span Concrete lined $\frac{Span}{ESR}$ = 24 (7.2m)
95-100	28	49	No Support	No support.	No support	No support
90-95.	10	46	No support	No support	No support	No support
75-90	21	28	Spot bolting (1 bolt every 10' of tunnel length)	Spot bolting.	No support.	No support.
50-75.	21	7	Bolts 5' centres. + 2" shotcrete crown. Spot bolting walls	Bolts 5' centres. + 2" shotcrete crown. Spot bolting walls.	No support	Bolts 5' centres + 2" shotcrete crown. Spot bolting walls.
25-50	11	1.6	Bolts 3' centres +2" shotcrete crown. Bolts 6' centres wall.	Bolts 3' centres +2" shotcrete crown. Bolts 6' centres wall.	Bolts 3' centres 2" shotcrete crown only.	Bolts 3' centres +2" shotcrete crown. Bolts 6' centres walls
6-25	9	0.4	Steel sets, concrete lined or Bolts 3' centres + 6" shotcrete crown and walls	Steel sets, concrete lined or Bolts 3' centres + 6" shotcrete crown and walls	Bolts 3' centres 3" shotcrete crown + walls.	Steel sets concrete lined or Bolts 3' centres + 6" shotcrete, crown and walls.

ACRES **Calculations**

SUBJECT: SUSITNA WATANA
GROUTING U/S POWER HOUSE

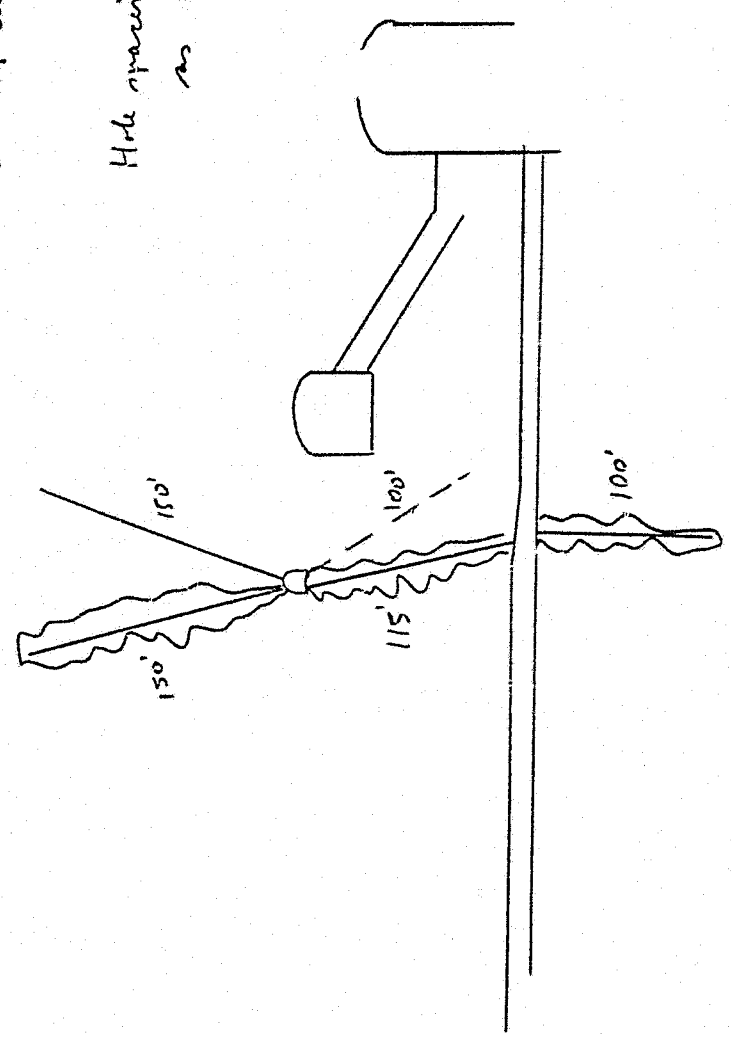
JOB NUMBER P5700.06
FILE NUMBER
SHEET ___ OF ___
BY NAOB DATE 26/1/82
APP ___ DATE ___

Watan Power house

Grouting curtain 600' long.

Hole spacing, lifts etc as dam curtain

FROM SK 5700-C6-518



Drawing not yet complete for Devil Canyon but will be same arrangement i.e. 600 feet long.

FORM NO. 152 REV. 1

ACRES **Calculations**

SUBJECT: SUSITNA.

JOB NUMBER P5700:06
FILE NUMBER
SHEET 1 OF 1
BY NAJB DATE 14/Jan 82
APP ___ DATE ___

DEVIL CANYON AND WATANA
POWER HOUSE CAVERNS.

Revised. Rock bolts for caverns.

1" diam. High Yield steel ASTM A 722-75.

Using 0.6 of yield stress as working stress, working load = 81.6 kips (Design load 80 kips.)

Original 1 3/4" diam #14 bar, grade 60 steel was getting too heavy and requiring large hole size and greater amount of resin grout.

FORM NO. 152 REV. 1

R. BEAL

CONCRETE REINFORCING STEEL INSTITUTE

228 NORTH LA SALLE STREET, CHICAGO, ILLINOIS 60601

CRSI

ASTM STANDARD REINFORCING BARS

BAR SIZE DESIGNATION	WEIGHT POUNDS PER FOOT	NOMINAL DIMENSIONS — ROUND SECTIONS		
		DIAMETER INCHES	CROSS SECTIONAL AREA - SQ. INCHES	PERIMETER INCHES
#2	.167	.250	.05	.786
#3	.376	.375	.11	1.178
#4	.668	.500	.20	1.571
#5	1.043	.625	.31	1.963
#6	1.502	.750	.44	2.356
#7	2.044	.875	.60	2.749
#8	2.670	1.000	.79	3.142
#9	3.400	1.128	1.00	3.544
#10	4.303	1.270	1.27	3.990
#11	5.313	1.410	1.56	4.430

Bar #2 in plain rounds only. These weights have been approved through U. S. Dept. of Commerce Simplified Practice Recommendation 26.

ASTM LARGE REINFORCING BARS

BAR SIZE DESIGNATION	WEIGHT POUNDS PER FOOT	NOMINAL DIMENSIONS — ROUND SECTIONS		
		DIAMETER INCHES	CROSS SECTIONAL AREA - SQ. INCHES	PERIMETER INCHES
#14S	7.65	1.693	2.25	5.32
#18S	13.60	2.257	4.00	7.09

Sizes #14S and #18S are large bars generally not carried in regular stock. These sizes available by arrangement with your supplier.

1 ACRE = 43560 SF

ACRES

Calculations

SUBJECT:

JOB NUMBER______
FILE NUMBER______
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BY______ DATE______
APP______ DATE______

Bolt Load. 80,000 pounds.

Steel Yield stress 60,000 pound/sq in.

Working stress 0.7 × 60,000 = 42,000 pound/sq in

Area required 1.90 in².

1.55 dia. < Std dia 1.41 / Std dia. 1.69

1" diameter. D ASTM A 722-75

0.6 = 81.6 kips.

FORM NO. 152 REV. 1

Calculations

SUBJECT: WATANA POWER HOUSE CAVERNS.

JOB NUMBER
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R Q.D	%	Q.	Powerhouse. Span 74' $\frac{Span}{ESR} = 74'$	Surge Chamber Span 58' $\frac{Span}{ESR} = 58'$	Transformer Gallery. Span 42' $\frac{Span}{ESR} = 42'$
100-95 / 95-90	40		Crown Rock bolts 6' centres. Walls no support.	Ditto Powerhouse.	Rock bolts 6' centres crown (Grade 60)
90-75	20		Crown Rock bolts 6' centres. (High Yield) Walls Rock bolts 5' centres. (Grade 60)	"	Rock bolts. 6' centres crown (Grade 60) Spot bolting walls
75-50. / 50-25	30		Crown Rock bolts 6' centres (High Yield) Walls Rock bolts 5' centres (Grade 60) + 4" shotcrete	"	Rock bolts 5' centres crown (Grade 60) Rock bolts 6' centres walls. (" ")
0-25	10%		Structural steel with insitu concrete 18" thick.	"	Structural steel with insitu concrete 18" thick

① Spot bolting say 10% of 6' centres pattern.

For each opening allow.

Bus gallery	3 rows	6 per row	18 bolts per opening	(as wall bolts)
Draft tube	3 rows	8 per row	24 bolts per opening	(" ")
Penstock	3 rows	8 per row	24 bolts per opening	(" ")

60.04.01 Form 148A

0 0 0 0 8 2

ACRES

Calculations

SUBJECT: WATANA.

JOB NUMBER
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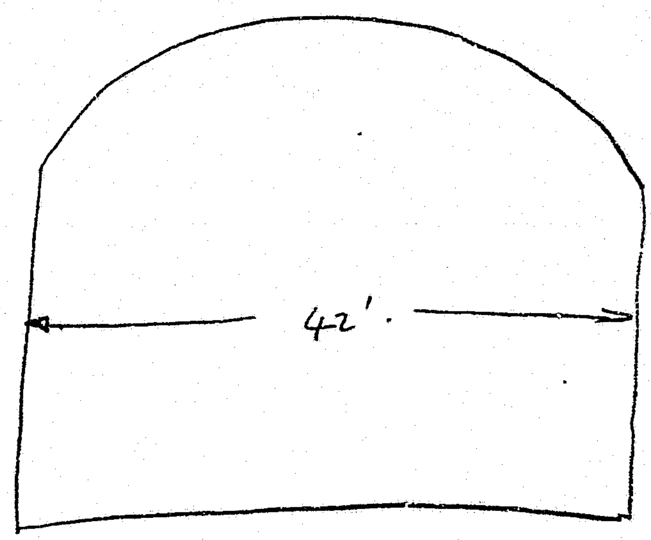
TRANSFORMER GALLERY.



FORM NO. 152 REV. 1

Calculations

SUBJECT: WATANA POWER HOUSE

JOB NUMBER	
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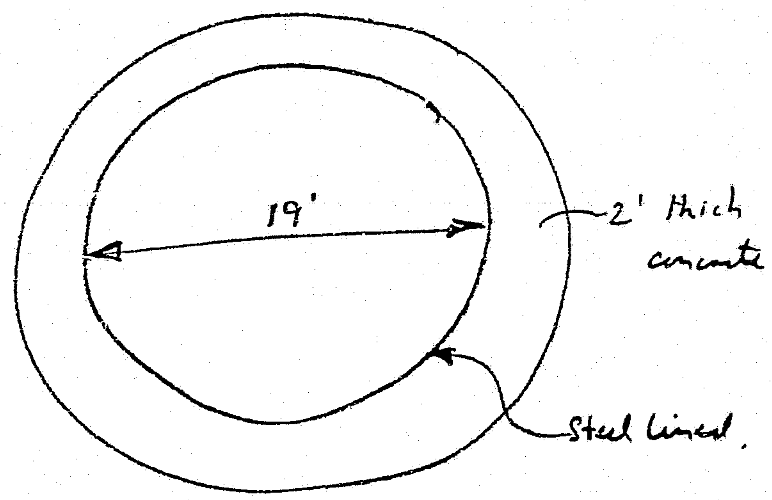
DRAFT TUBE

No support over majority of tunnel length required. Allow substantial support each end at junction with cavern

15' bolts 8×8 = 64 No.
For both ends 128 bolts 15' long per draft tube.

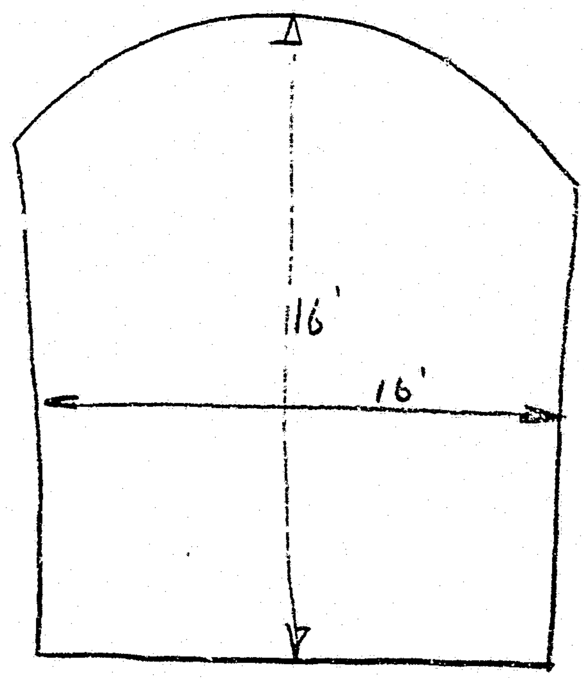


BUS GALLERY

No support over majority of tunnel length required allow substantial support each end at junction with cavern

15' bolts 6×10 = 60 No.

For both ends 120 bolts 15' long per bus gallery.



FORM NO. 152 REV. 1

Calculations

ACRES

SUBJECT: WATANA POWER HOUSE CAVERNS

JOB NUMBER
FILE NUMBER
SHEET OF
BY MAJB DATE 15 Jan 82
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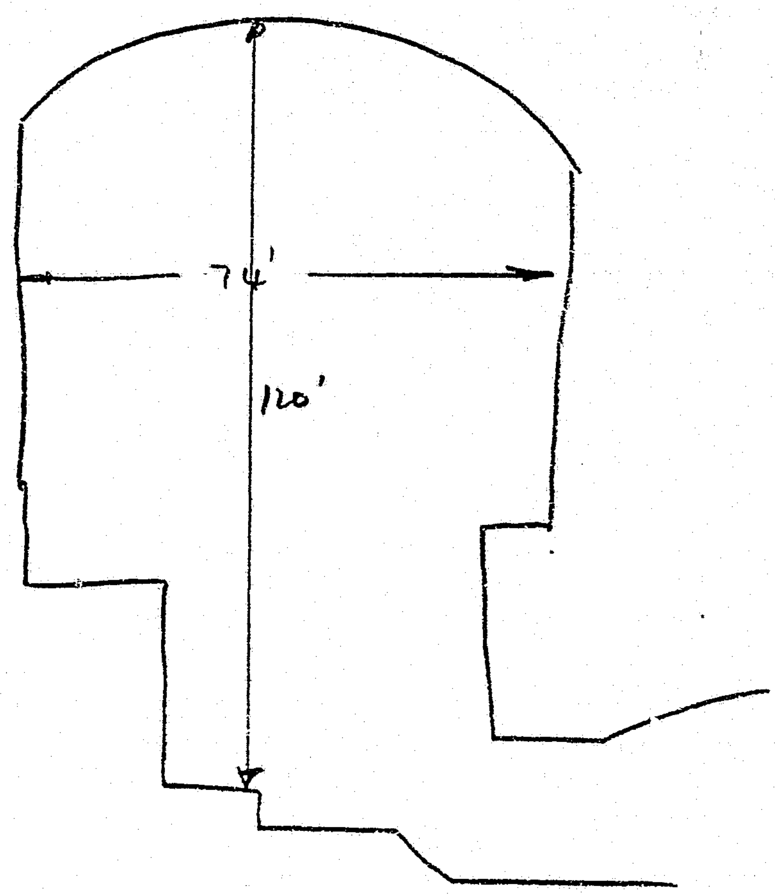
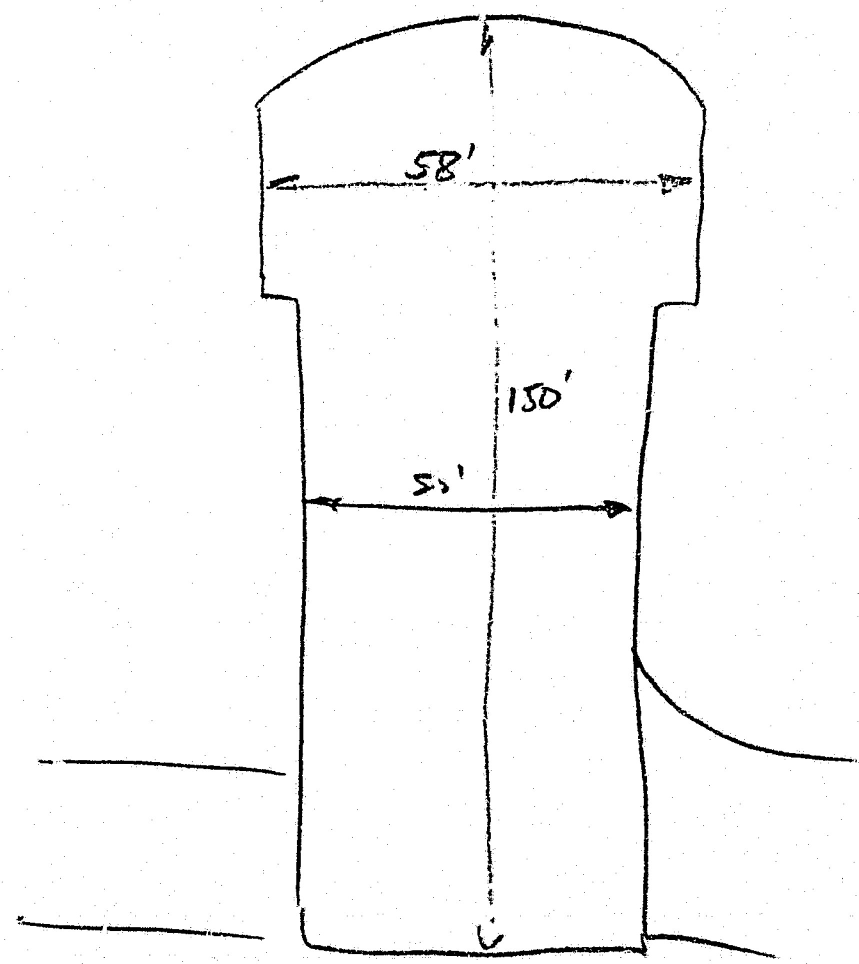
POWER HOUSE



SURGE CHAMBER



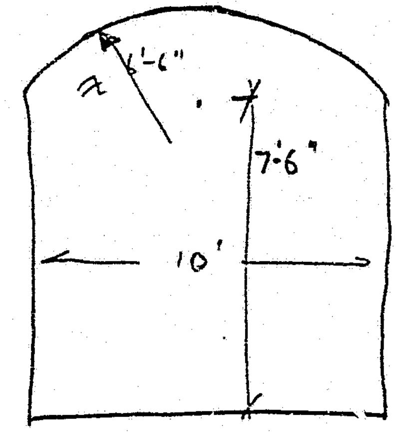
FORM NO. 152 REV. 1

ACRES **Calculations** SUBJECT: SUSITNA. WATANA FOUNDATION GROUTING & DRAINAGE QUANTITIES	JOB NUMBER 5700 05 FILE NUMBER SHEET 1 OF 7 BY NAJB DATE 15/12/81 APP DATE

Note: 2 Access tunnels from 1500' el to d/s toe of dam drainage outlet below tailwater level. Not shown on SK 5700 C6 5?8 Will be shown on dam dwg

Watana Grouting and Drainage.

Galleries. 10'x10'



Floor slab 6" thick concrete unreinforced.

Tunnel support required

Rock bolts. 6'-0" long 3/4" dia.

3'-0" centres

i.e. 4 No bolts per 3 ft tunnel length.

Bolts required 25% of tunnel length

Additional bolts required at portals, junctions etc

26 No. @ 20 additional bolts = 520 bolts

Shotcrete

Assume 20% of tunnel length Crown only 12 feet surface width

Additional 520 feet for junctions & portals

at 2" thick

Mesh 4"x4" x 3/16"ϕ 20% shotcrete area.

Steel Arches 5% of tunnel length @ 3 feet centres.

4"x4" column section with fish plates, tie bars and base plates.

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ACRES

Calculations

SUBJECT:

JOB NUMBER
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Shafts. 10 feet diameter

Rock bolts 6'-0" long. 3/4" dia.

Assume 6 bolts per 3' length of shaft.

25% length of shaft bolted.

Assume Shotcreting 2" thick full circumference.

25% of length of shafts.

Stairway and small elevator required each shaft.

Access tunnel portal.

Portal within dam foundation extra rock bolts already allowed for.
Excavation included in dam item.

4 portals required downstream of dam

Inclined Tunnel

Will require rail mounted car with electrical hoist for each inclined section.

Steps formed in concrete slab will be required.

FORM NO. 152 REV. 1

Calculations

ACRES

SUBJECT: WATANA TUNNEL SUPPORT CALCS.

JOB NUMBER
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RQD	Ave	Jn	Jr	Ja	Jw	SRF	Q
95-100	97.5	4	2	1	1	1.0	49
90-95	92.5	4	2	1	1	1	46
75-90	82.5	6	2	1	1	1	27.5
50-75	62.5	9	1	1	1	1	7
25-50	37.5	9	1	1	1	2.5	1.6
0-25	12.5	9	1	1	0.66	2.5	0.4

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Calculations

SUBJECT:

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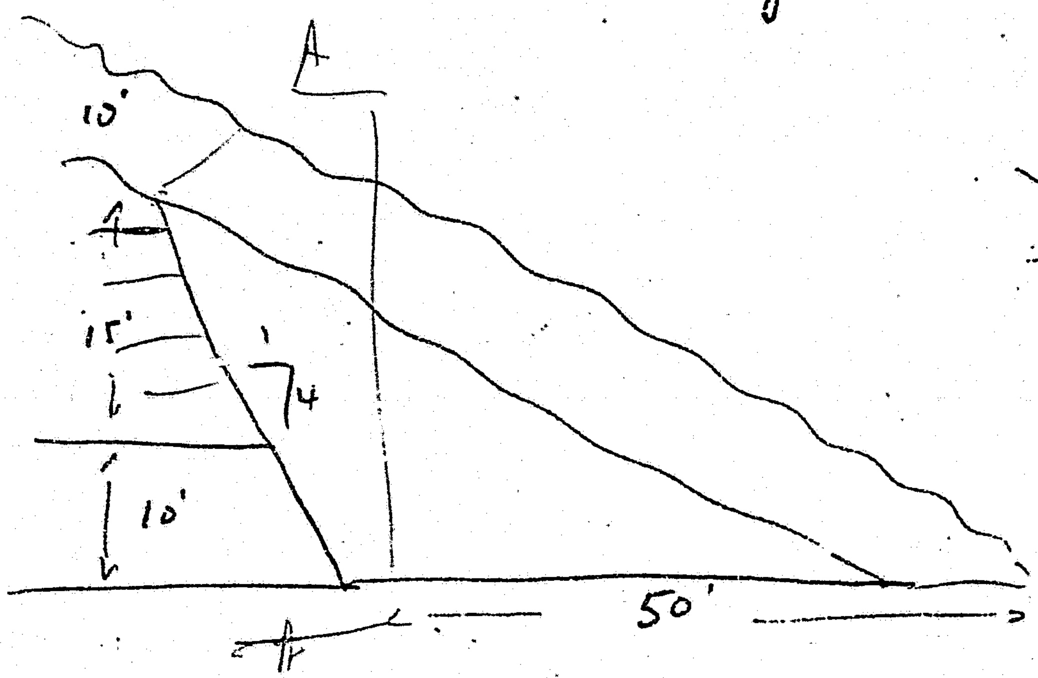
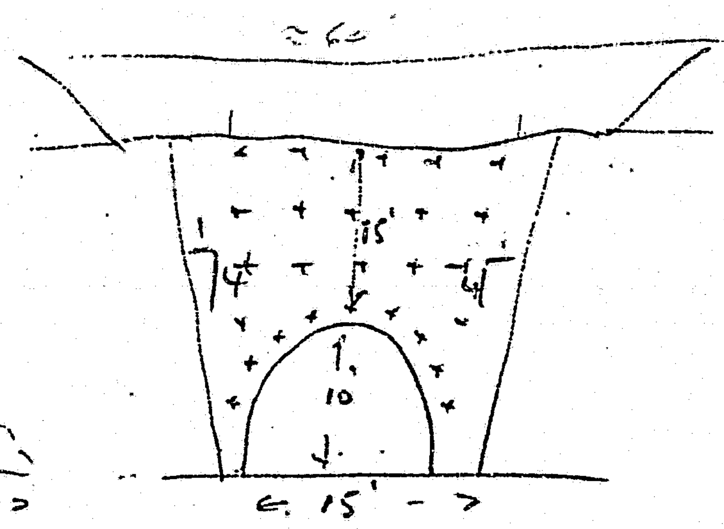
APP DATE

Tunnel Portals. 4 No for access tunnels.





AA.

Excavation. Overburden.

$\frac{60' \times 60' \times 10'}{27} = 4000$ cu yds. (1333 cu. yds.)

Rock. $\frac{40' \times 25'}{2} \times \frac{20'}{27} = 4444$ cu yds. (3700 cu. yds.)

Bolting. 10' long bolts.

Portal face. 5 × 3 rows. = 15

Circum. = 8

23 No × 10' long

= 230 ft.

Walls say. 20 No bolts per portal

= 200'

Total 430 ft rock bolts. Assume 1" dia bolt.

For 4 No portals. Rock Overburden 16,000 cu yds. (5332)

Rock 17,777 cu yds. (1480)

Rock bolts. 1720 ft. ✓

Shotcrete 8 cu yds.

FORM NO. 152 REV. 1

ACRES	**Calculations**	JOB NUMBER
	SUBJECT:	FILE NUMBER
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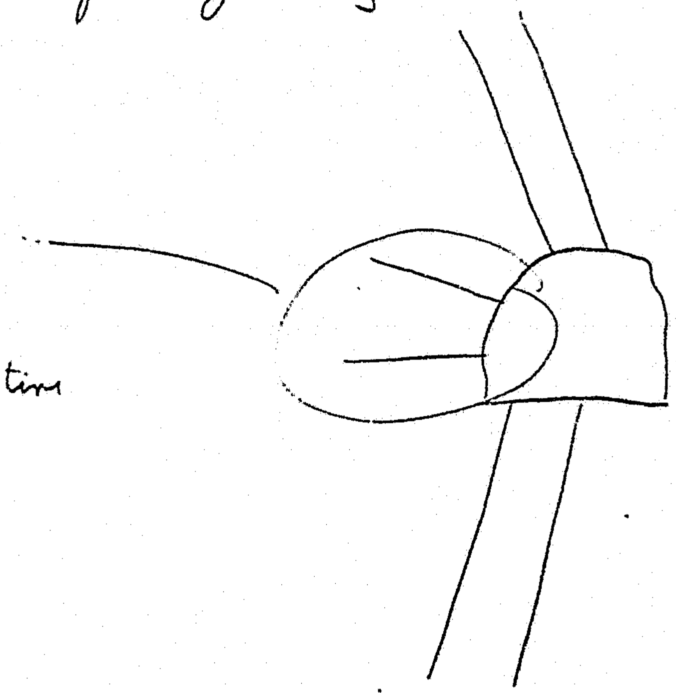
Extra subhorizontal grout holes. from gallery

2 No @ 10 feet long

5' spacing along entire length of gallery



Concrete plugs in access tunnels into dam foundation

6 No. — length - full depth of consolidation grouting zone.
approx 60' horizontal

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ACRES	**Calculations**
SUBJECT: WATANA.	

JOB NUMBER
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<u>Powerhouse Drainage.</u>

See SK 5700 CG 518 Section B-B. Revision 15 Dec 81.

Transformer gallery. 8 Holes 25' long ✓

10' spacing entire length of gallery.

Powerhouse cavern. 12 Holes 40' long.
1 hole 130' long
10' spacing entire length of gallery

Surge chamber 13 Holes 35' long.

10' spacing entire length of surge chamber.

<u>Penstocks</u>

Drainage gallery from transformer gallery.

See SK 5700 CG 518 Section B-B.

FORM NO. 152 REV. 1

Calculations

ACRES

SUBJECT: WATANA

JOB NUMBER ______

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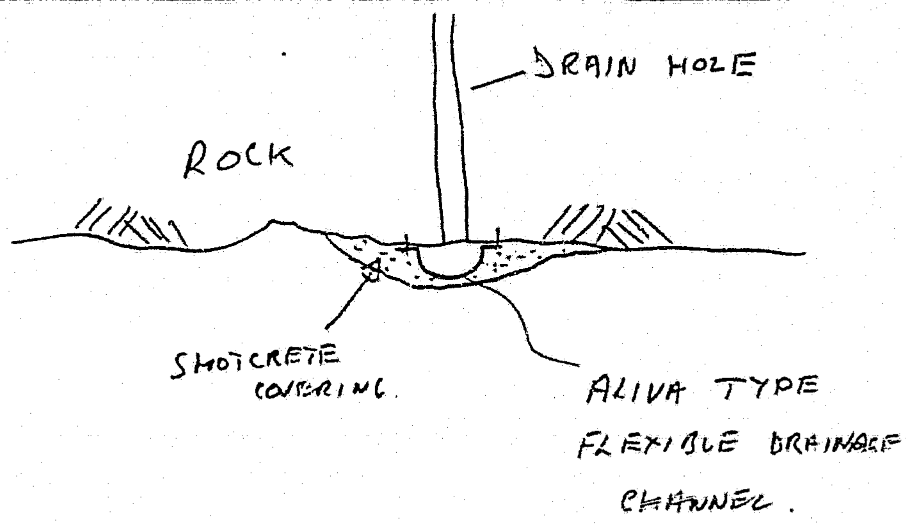
SHEET 6 OF 7

BY ______ DATE ______

APP ______ DATE ______

Surface drains Caverns.



Length -

Transformer gallery 130' @ 10 feet centres entire length of gallery

Power house cavern 250' @ 10 feet centres " " "

Surge chamber. 200 @ 100 feet centres " " "

Additional 10% to allow for connection to drainage system and additional wet areas.

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Calculations

SUBJECT:

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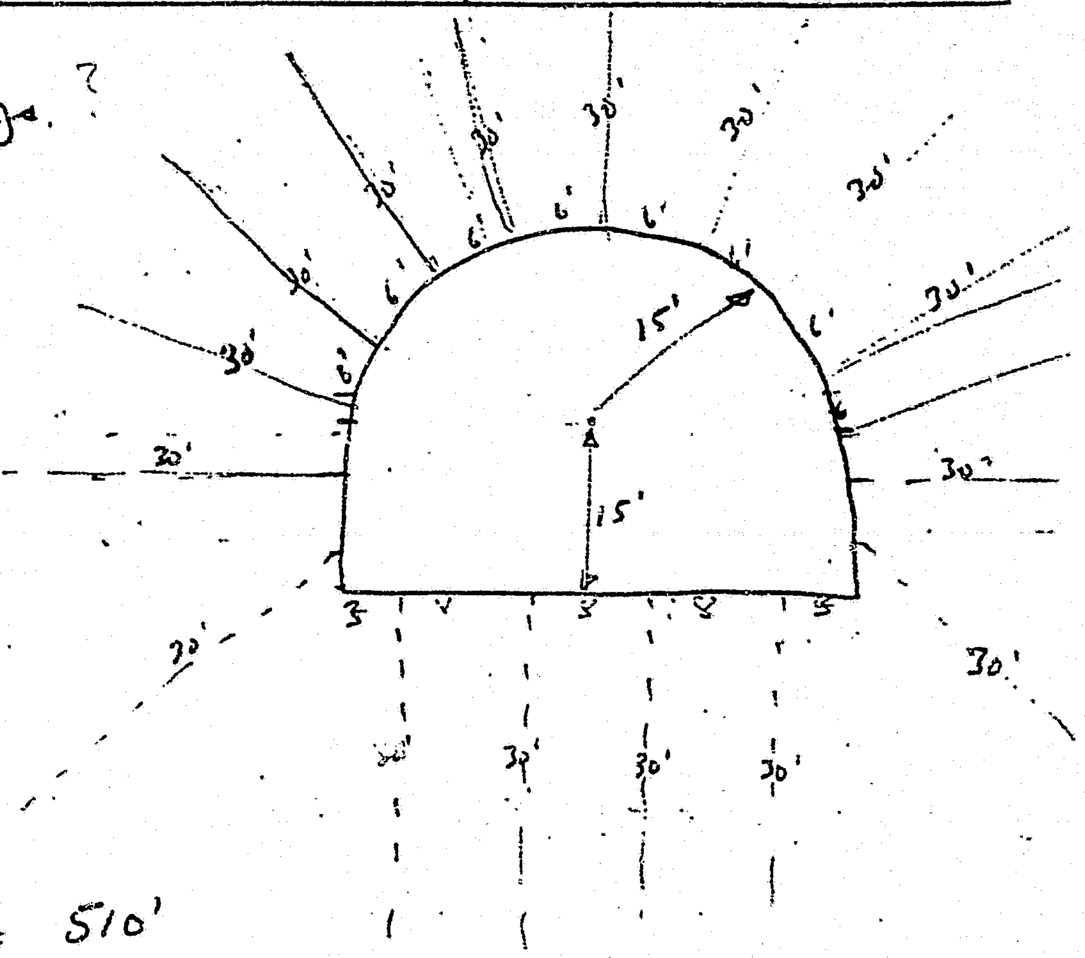
Diversion Tunnel plugs ?

Curtain grouting



17 No holes. @ 30' long = 510'

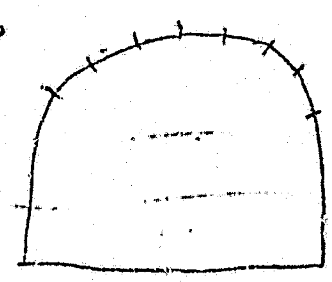
∴ Assume 4 rows. = 2040' ft drill hole.

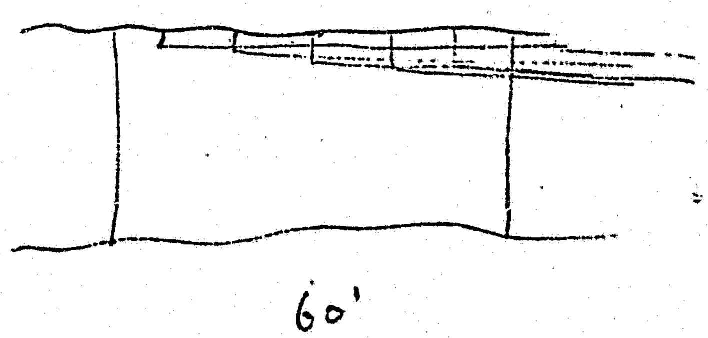
Cement in grout say. 5 lbs / ft drill hole.

Contact grouting - Assuming 60' long plug.

7 No outlets per row

5 No rows.





Length of pipe

7×55 = 385

7×45 = 315

7×35 = 245

7×25 = 175

7×15 = 105.

1225 ft grout pipe.

Cement for grouting included in rates for concrete of plug.

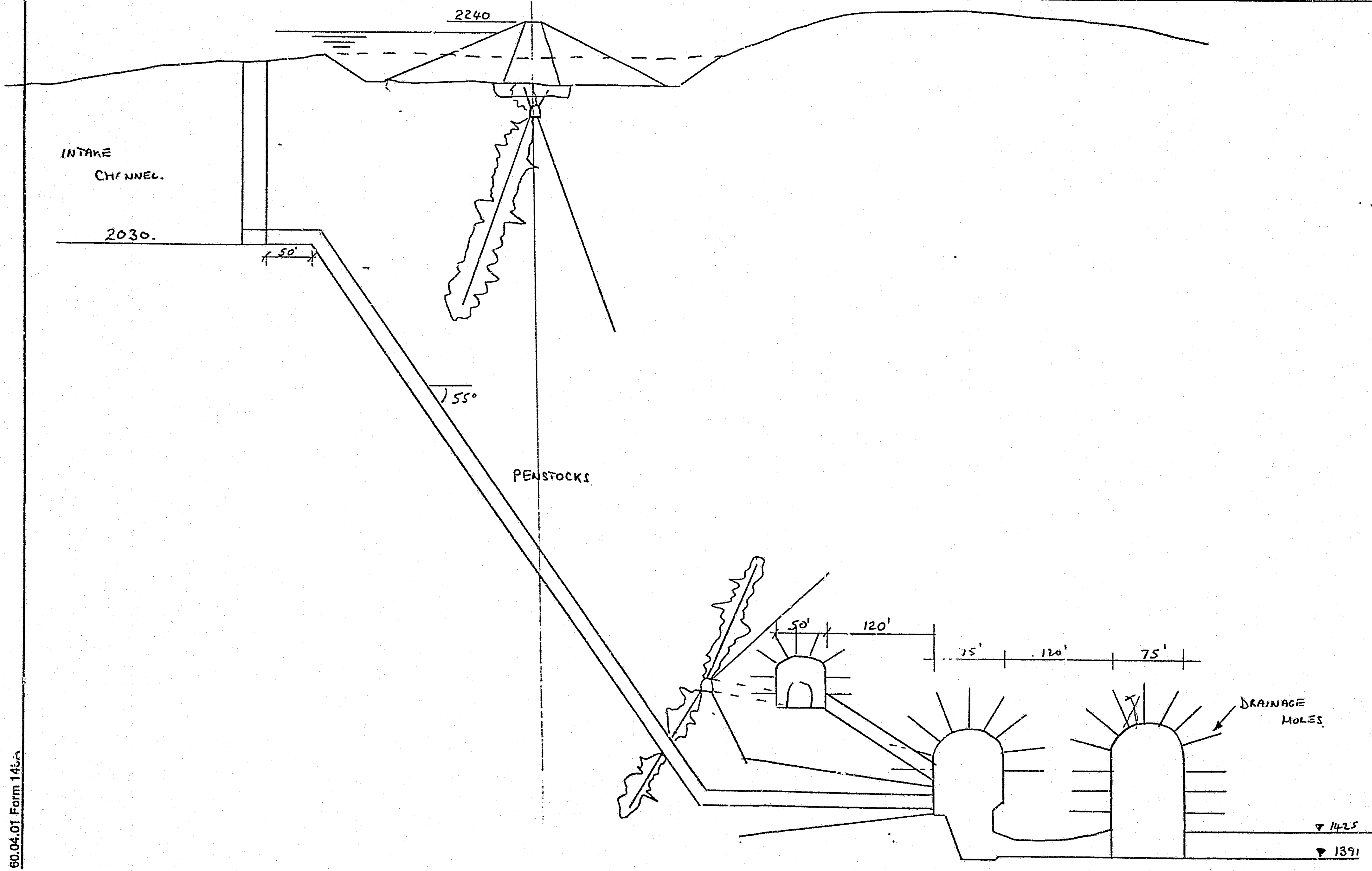
0 0 0 0 8 2

ACRES

Calculations

SUBJECT: SUSITNA HYDROELECTRIC PROJECT
WATANA POWER HOUSE DRAINAGE

JOB NUMBER P5700.05	
FILE NUMBER	
SHEET 1	OF 1
BY NAJB	DATE 12/11/81
APP	DATE



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ACRES

Calculations

JOB NUMBER	P570005
FILE NUMBER	
SHEET	1 OF 3
BY	NAGB
DATE	3 Nov 1981
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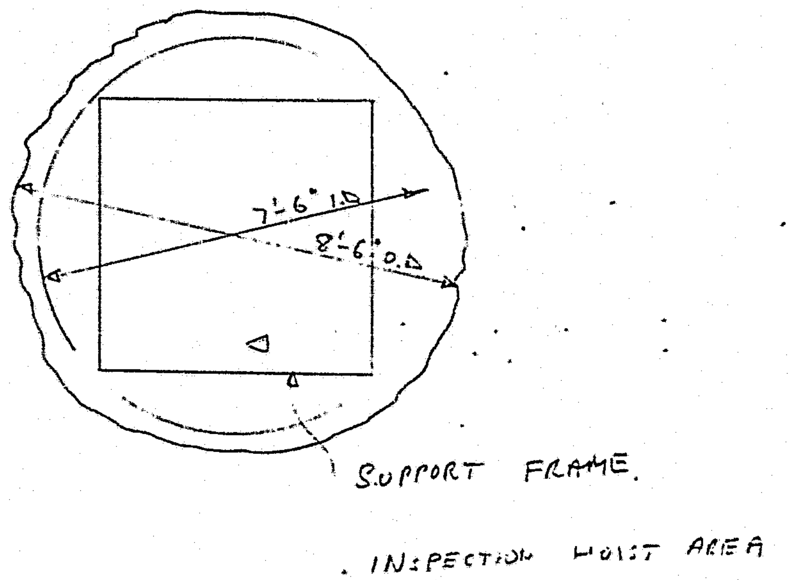
SUBJECT: SUSITNA HYDRO PROJECT. CABLE SHAFTS.



2 or 3 cable shafts will be required at each of Watana and Devil Canyon power houses.

Depth of shaft – Watana Switchyard 2230 feet elev

Crown Transformer Cavern 1600 feet elev

630 feet deep

– Devil Canyon Switchyard 1600 feet elev

Crown Transformer Cavern 950 feet elev.

650 feet

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ACRES

Calculations

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SUBJECT:

Excavation

The length of shaft required to be excavated would justify use of raise boring equipment.

Support With raise boring minimal rock support of the shaft walls will be required.

Some allowance should be made for safety support at fractured zones, installed prior to concreting.

It may be possible to dispense with concrete lining of the shaft but at this stage the lining will be included. The lining, thickness will be 0.5 feet.

Safety support

Rock bolts 4' long 6 per row rows @ 3' centres over 5% of length of shaft.

Mesh 50% circumference 5% of length of shaft.

If the shaft is raised by drill and blast then the support will be increased to

4' long bolts 6 per row @ 3' centres over 20% of shaft length.

Mesh – 50% circumference 20% of shaft length

Calculations	JOB NUMBER
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Concrete lining for D+B shaft would increase to 1' thickness.

FORM NO. 152 REV. 1

WATANA - BOREHOLE ROCK QUALITY DISTRIBUTION

Borehole	Rock Drilled (ft)	PERCENTAGE OF CORE IN SPECIFIC RQD RANGES 0-25%	25-50%	50-75%	75-90%	90-95%	95-100%
DH-1	79.0	29	56	8	0	7	0
DH-4	45.2	16	5	17	52	10	0
DH-5	117.1	6	15	31	23	3	22
DH-6	146.1	13	30	44	9	0	4
DH-7	113.7	13	26	29	29	0	3
DH-8	133.8	6	11	41	32	8	2
DH-9	278.6	19	18	25	30	7	1
DH-10	183.9	25	12	14	23	10	16
DH-11	279.4	3	5	22	38	17	15
DH-12	290.5	8	17	29	17	12	17
DH-21	519.2	0	2	25	22	14	37
DH-23	112.2	36	22	18	8	9	7
DH-24	133.0	5	14	42	18	9	12
DH-28	91.9	61	29	10	0	0	0
BH-1	291.2	2	4	22	26	18	28
BH-2	391	24	17	30	19	5	5
BH-6	732.4	5	7	22	33	15	18
BH-8	738.6	3	6	22	30	11	28
Site Average	7299.9 ~~4305.6~~	9 ~~11%~~	11 ~~12%~~	21 ~~25%~~	21 ~~25%~~	10%	28 ~~17%~~
BH-12	771.9	6	17	30	19	10	18
BH-3	924.0	7	2	5	12	8	66
BH-4	937.2	6	11	13	9	7	54

WATANA RQD SUMMARY

Borehole Ground Surface El. Top Of Rock El. Borehole Dip		DH-1 1459 1415	DH-4 1462 1384	DH-5 1462 1402	DH-6 1716 1713	DH-7 1716 1708 59%	DH-8 1910 1894	DH-9 1913 1909 45%	DH-10 2033 2020	DH-11 2034 2018 45%	DH-12 1951 1942	DH-21 1480 1407 60%	DH-23 1952 1947 45%	DH-24 2061 2054	DH-28 1971 1958	BH-1 70°	BH-2 1835 1826	BH-3 55°	BH-4 2185 2174 59°	BH-6 1605 1598	BH-8 1976 1964	BH-12	Depth Average	
Vertical Depth	RQD																							
0'-50'	Drilled (ft) RQD length (ft) RQD%	51.4 14.25 28%	45.2 29.95 66%	47.9 22.15 46%	48.9 24.35 50%	49.1 23.6 48%	54.5 32.3 59%	67.0 39.6 59%	48.6 10.2 21%	70.3 49.6 71%	51.6 30.8 60%	59.7 50.95 85%	70.5 31.8 45%	50.9 35.5 70%	29.5 10.6 36%	52.5 41.5 79%	61.2 33.55 55%	59.1 44.5 75%	56.9 25.3 44%	58.5 29.35 50%	59.2 25.75 43%	81.5 46.7 57%	~~1233.2~~ ~~678.85~~ ~~55%~~	1174.0 652.3 56%
50'-150'	"	27.6 12.55 45%		69.2 57.3 83%	97.2 49.25 51%	64.6 38.95 60%	79.3 52.8 67%	139.5 86.4 62%	100.5 68.5 68%	144.1 111.63 77%	99.9 53.35 53%	110.0 93.55 85%	41.7 20.5 49%	82.1 57.4 70%	62.4 6.3 10%	104.8 79.6 76%	119.8 28.1 23%	124.9 119.8 96%	115.7 62.5 54%	118.4 75.5 64%	116.2 86.85 75%	151.7 109.55 72%	~~2085.8~~ ~~1352.25~~ 65%	1969.6 1270.4
150'-250'	"							72.1 31.8 44%	34.8 31.1 89%	65.0 55.3 85%	105.1 80.5 77%	121.7 101.4 83%				109.6 94.15 86%	124.4 67.2 54%	120.0 119.1 99%	120.8 113.5 94%	115.8 99.15 86%	114.5 94.45 82%	154.0 105.4 68%	~~1372.3~~ ~~1087.5~~ 79%	1257.8 993.05
250'-350'	"										33.9 28.8 85%	118.3 96.8 82%				14.3 10.5 73%	85.6 64.55 75%	119.9 104.55 87%	114.9 114.2 99%	115.3 93.65 81%	114.6 91.1 79%	156.1 96.95 62%	~~987.5~~ ~~792.2~~ 80%	872.9 701.1
350'-450'	"											109.5 91.0						119.5 54.8 46%	115.1 114.3 99%	114.4 93.65 82	114.3 95.85 84%	159.3 125.55 79%	~~846.4~~ ~~671.0~~ 79%	732.1 575.15
450'-550'	"																	120.6 115.2 96%	120.0 95.1 79%	115.2 81.35 71%	117.8 95.3 81%	69.3 57.3 83%	~~660.7~~ ~~539.55~~ 82%	542.9 444.25
550'-650'	"																	125.0 119.6 96%	115.1 81.1 70%	94.8 74.7 79%	102.0 89.3 88%		~~538.9~~ ~~455.0~~ ~~84%~~	436.9 364.7 83%
650'-750'																		120.0 115.4 96%	114.7 85.4 74%				234.7 200.8 86%	
750'-850																		15.0 15.0 100%	64.0 60.8 95%				79.0 75.8 96%	
Hole Average	"	79.0 26.8 34%	45.2 29.95 66%	117.1 79.45 68%	146.1 73.6 50%	113.7 62.55 55%	133.8 85.1 64%	278.6 157.8 57%	183.9 109.8 60%	279.4 216.55 78%	290.5 193.45 67%	519.2 433.7 84%	112.2 52.3 47%	133.0 92.9 70%	91.9 16.9 18%	281.2 225.75 80%	391.0 193.4 49%	924.0 807.95 96%	937.2 752.2 80%	732.4 547.35 75%	738.6 578.6 78%	771.9 541.45 70%	~~7430.5~~ ~~5849.85~~ ~~79%~~	7277 5277 72%

MINUTES OF MEETING
December 30, 1981

PRESENT: D.W. Lamb
L. Duncan
[redacted]
R. Allan
J. Plummer
F. Toth
D. Meilhede

PURPOSE: Review and resolve any outstanding matters relative to cost estimating for the Watana Main Dam.

1 - CHANGES

It was stated that final quantities and final estimates are currently being prepared and that any changes affecting cost should only be made through the senior person responsible for the task work.

2 - DAM - GENERAL

Quantities have been taken off using a 2205 ft. elevation. Remaining work to be done includes the take off of zones and the additional material to raise the dam to 2210 ft.

3 - EXCAVATIONS

a) Overburden

- all overburden on side slopes considered wasted
- overburden in river channel (river gravel)
- assume that 50% of this material will be reusable in the downstream shell

b) Rock Excavation

- upper 10 ft of rock considered wasted.
- rock below 10 ft considered reusable. This applies to core area both on side slopes and under the main dam and the river channel.
- excavation depths assumed are 10 ft under shell and 40 feet under core.
- controlled blasting required under core and transition zones.

4 - FOUNDATION TREATMENT

a) Dental Concrete

- an allowance based on the total area of core and transition zone by 1 ft depth; in addition a form work allowance to be made.

b) Consolidation Grouting

- assumed pattern 10 ft x 10 ft x 30 ft deep.
- grout take estimate at 4 cu ft per linear foot of depth.
- current price for drilling to be rechecked. Drilling can generally be estimated using a air track with allowances for test holes, water pressure testing, etc.

c) Slush Grout

- estimate to assume any slush grouting requirements included under dental concrete and consolidation grouting.

5 - DOWNSTREAM SHELL

Material that can be used in the downstream shell:

a) unprocessed river gravel
b) rock from underground excavations
c) rock from above ground excavations

Curtain grouting also mentioned. 2 cu ft grout / lin ft hole. Primary hole core drilled, remainder rotary percussion. All holes washed, pressure tested.

Material used to be 18 in. minus and placed in 3 ft lifts and compacted with 5 passes of a vibrator 10 ton roller or equivalent.

The use of rock to be done on a 50/50 gravel/rock blend, i.e., layers of rock only are not acceptable.

Unprocessed river gravel to be passed through grizzly to remove oversize. Estimate of oversize 10%.

For rock used from excavation, the following recovery assumptions to be used - for underground rock 80%, above ground - 90%. Estimate to be based on moving excavated rock to stockpiles, reloading, transporting and placing in the dam with gravel.

6 - UPSTREAM SHELL

Material specifications acceptable for upstream shell adjusted to 18 in to #4 sieve.

Wastage estimate on this material for oversized - 10%; undersized - 30% - assumed borrow are "E" as source.

Oversized material can be crushed and incorporated into downstream shell. Under sized material can be considered for concrete fine aggregate and road subgrade.

Of the estimated undersized of approximately 10 million cu yds less than 20% of this amount can be considered reusable.

Compaction requirements on upstream shell - stated for downstream - F. Toth to check equivalent compaction use heavier equipment and fewer passes.

7 - FILTER/TRANSITION MATERIALS

- crushing of material acceptable
- suggested limit - 50% crushed material

Alternatively oversized material can be used in downstream shell. Undersized to be wasted.

8 - RIPRAP

24 in rip rap specified. Agreed that rip rap sizes of 36 in. to 48 in. acceptable.

9 - CORE

Assumptions to be used for estimate of core material.

a) Borrow Area

- strip and provide drainage of area 2 times the size required by actually placing quantities.
- material to be run through 6 in. grizzly to remove oversize.

b) Fill

- allowance for harrowing for moisture control.
- compaction by 4 passes of pneumatic and for tamping foot compactor.
- lift thickness 12 in. loose, 18 in. compacted.

c) Frost Protection of Fill

- estimate to include 10 ft. lift of downstream shell material (unprocessed river gravel).

It is assumed that 1 ft. of gravel and 1 ft. of core and transition zones to be wasted each spring.

REVISED JANUARY 5, 1981

MINUTES OF MEETING
December 30, 1981

P5700.09

SUSITNA HYDROELECTRIC PROJECT

PRESENT: D.W. Lamb
L. Duncan
[redacted]
R. Miller
J. Plummer
F. Toth
D. Meilhede

cc: J. Lawrence
D. MacDonald
J. Hayden
R. Ibbotson

PURPOSE: Review and resolve any outstanding matters relative to cost estimating for the Watana Main Dam.

1 - CHANGES

It was stated that final quantities and final estimates are currently being prepared and that any changes affecting cost should only be made through the senior person responsible for the task work.

2 - DAM - GENERAL

Quantities have been taken off using a 2205 ft. elevation. Remaining work to be done includes the take off of zones and the additional material to raise the dam to 2210 ft.

3 - EXCAVATIONS

a) Overburden

- all overburden on side slopes considered wasted
- overburden in river channel (river gravel)
- assume that 50% of this material will be reusable in the downstream shell

b) Rock Excavation

- upper 10 ft of rock considered wasted.
- rock below 10 ft considered reusable. This applies to core area both on side slopes and under the main dam and the river channel.
- excavation depths assumed are 10 ft under shell and 40 feet under core.
- controlled blasting required under core and transition zones.

4 - FOUNDATION TREATMENT

a) Dental Concrete

- an allowance based on the total area of core and transition zone by 1 ft depth; in addition a formwork allowance to be made.

b) Consolidation Grouting

- assumed pattern 10 ft x 10 ft x 30 ft deep.
- grout take estimate at 4 cu ft per linear foot of depth.
- current price for drilling to be rechecked. Drilling can generally be estimated using a air track with allowances for test holes, water pressure testing, etc. Curtain grouting also mentioned, 2 cu ft grout/linear ft hole. Primary holes core drilled, remainder rotary percussion. All holes washed and pressure tested.

c) Slush Grout

- estimate to assume any slush grouting requirements included under dental concrete and consolidation grouting.

5 - DOWNSTREAM SHELL

Material that can be used in the downstream shell:

a) unprocessed river gravel
b) rock from underground excavations
c) rock from above ground excavations

Material used to be 18 in. minus and placed in 3 ft lifts and compacted with 5 passes of a vibrator 10 ton roller or equivalent.

The use of rock to be done on a 50/50 gravel/rock blend, i.e., layers of rock only are not acceptable.

Unprocessed river gravel to be passed through grizzly to remove oversize. Estimate of oversize 10%.

For rock used from excavation, the following recovery assumptions to be used - for underground rock 80%, above ground - 90%. Estimate to be based on moving excavated rock to stockpiles, reloading, transporting and placing in the dam with gravel.

6 - UPSTREAM SHELL

Material specifications acceptable for upstream shell adjusted to maximum size of 18 in to less than 10% passing 3/8 in.

Wastage estimate on this material for oversized - 10%; undersized - 30% - assumed borrow are "E" as source.

Oversized material can be crushed and incorporated into downstream shell. Under sized material can be considered for concrete fine aggregate and road subgrade.

Of the estimated undersized of approximately 10 million cu yds less than 20% of this amount can be considered reusable.

Compaction requirements on upstream shell - stated for downstream - F. Toth to check equivalent compaction use heavier equipment and fewer passes.

7 - FILTER/TRANSITION MATERIALS

- crushing of material acceptable
- suggested limit - 50% crushed material

Alternatively oversized material can be used in downstream shell. Undersized to be wasted.

8 - RIPRAP

24 in rip rap specified. Agreed that rip rap sizes of 36 in to 48 in acceptable.

9 - CORE

Assumptions to be used for estimate of core material.

a) Borrow Area "D"

- strip and provide drainage of area 2 times the size required by actually placing quantities.
- material to be run through 6 in grizzly to remove oversize.

b) Fill

- allowance for harrowing for blending control.
- compaction by 4 passes of pneumatic and/or tamping foot compactor.
- lift thickness 12 in loose, 8 in compacted.

c) Frost Protection of Fill

- estimate to include 10 ft lift of downstream shell material (unprocessed river gravel).

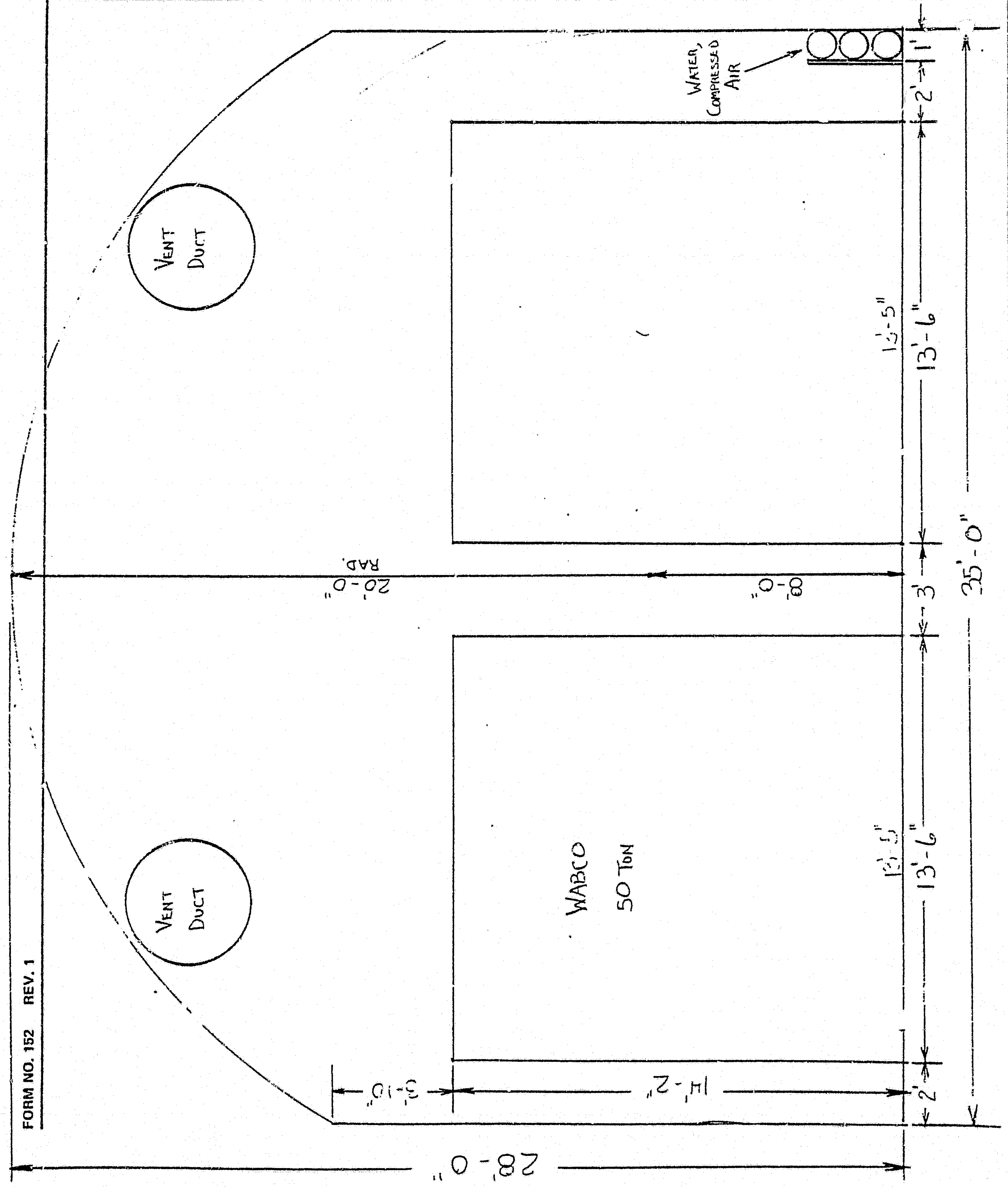
It is assumed that 1 ft of gravel and 1 ft of core and transition zones to be wasted each spring.

ACRES

Calculations

SUBJECT: SUSITNA HYDRO ELECTRIC PROJECT
ACCESS TUNNELS - SIZE

JOB NUMBER P5700.06
FILE NUMBER
SHEET 1 OF 1
BY NAD DATE JAN 1982
APP DATE



FORM NO. 152 REV. 1

TASK 6

0041

WATANA-
— DAM INSTRUMENTATION

Design Calculation Cover Sheet

ACRES

PROJECT No. P5700.06

FILE No. P5700.14.06.09

SERIAL No. 0041

PROJECT TITLE SUSITNA HYDRO ELECTRIC PROJECT

DEPARTMENT GEOTECHNICAL.

CALCULATIONS FOR: DAM INSTRUMENTATION - WATANA.
GENERAL DESCRIPTIONS
QUANTITIES
AND COSTS.

ORIGINAL BY NAJ BOND. DATE 4 / Dec / 81.

CHECKED BY DATE / /

REV No.	BY	DATE	CHECKED	DATE
A.	NAJB.	4 / Jan / 82		/ /
		/ /		/ /
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		/ /		/ /

Comment and content checks by D.W. Lamb - S. Thompson attached.
Arithmetical check by project services.
Copies sent to project services.
Calcs 4 pages.
Description 4 pages.
Comments D.W.L. 4 pages.
" S.T 4 pages.

APPROVED BY

PROFESSIONAL ENGINEERS SEAL

ORIGINAL COPIES PLACED IN MAIN FILE ON CLOSURE OF PROJECT

BY [signature] DATE 2/28/83

TOTAL No. OF SHEETS 16 + cover

50.04.01 Form 146 A

ACRES **Calculations**

SUBJECT: SUSITNA HYDRO ELECTRIC PROJECT INSTUMENTATION.

JOB NUMBER P5700.05
FILE NUMBER
SHEET 1 OF 4
BY NAJB DATE 4 Dec 81
APP DATE

Revised. 4 Jan 82. NAJB.

Instrumentation Watana Dam

Piezometers

Core	200
D/S Shell	50
U/S Shell	50.
Spillway	50.
Power house penstock	50
Relict channel	100
Foundation dam	200
	700.

350 pneumatic @ $200
350 vibrating wire @ $250

pneumatic tubing @ 0.25/ft 1000 ft ave
$87500

vibrating wire cable @ 2.00 ft 1000 ft ave
$700,000

Readout units. 4 × $1500 pneumatic
4 × $1000 vib wire.

Total cost 70,000
87 500
87 500
700,000
6 000
4 000
$1,742,500

Inclinometers.

	Core	30	ave 600' depth
	D/S shell	20	
(inclined)	U/S shell	20.	

= 42 000 ft Casing @ $3.00/ft = 126000
Sensors 3 × 4500 = 13 500
Readout 3 × 8500 = 25 500
= 165,000

Vertical settlement 'Sondex'

Readout 2 × $1300 = 2600
Sensor rings 2100 × $7 = 14,700
$17,300

Cable extensometers. 200 No ave depth 400 ft.
= 80,000 ft @ say $5/ft
= $400,000

FORM NO. 152 REV. 1

ACRES

Calculations

SUBJECT:

JOB NUMBER
FILE NUMBER
SHEET 2 OF 4
BY NAJB DATE 4 Dec 81
APP DATE

Horizontal strain 10 × 1000 ft 1 pair transducers / 50 ft 400 transducers.

transducers $100 × 400	40,000
rod and embedment plates. $5/ft =	50,000
	90,000
Readout units	10,000
	100,000.

Horizontal settlement gauges double fluid acting type.

12 No. average length 2000 ft

Readout units	2 × $20,000	$40,000
Casing, winch, cable pulleys housing etc	$30/ft	$720,000
		$760 000

Surface settlement points 1000 No @ $100 = $100,000.
Revised 9/12/81.

~~Seismic recorders~~

~~3 Dam~~
~~1 Relief channel~~
~~1 Power house~~
~~1 Spillway.~~
~~6 @ $20000~~ = ~~$120,000~~

For detailed program see V Singh

Seepage monitoring weirs.

Dam 6 No
Relief channel 6
Spillway 1
13 No. @ $2000 = $26,000

FORM NO. 152 REV. 1

ACRES **Calculations**

SUBJECT:

JOB NUMBER
FILE NUMBER
SHEET 3 OF 4
BY N AOB DATE 4/Dec/[illegible]
APP DATE

Thermistors.	Abutments.	6 holes × 20 pairs	- 120	
	Dam	10 holes × 30 pairs	= 300	
	Relict channel	6 holes × 20 pairs	- 120	
			540 No. @ $50	27,000
		cables say $1000 per hole.	=	22,000
				47,000

(These instruments will be in addition to those installed in next phase and to replace those damaged etc during construction)

Rock stress measurement in caverns - included in final phase of investigations

Deformation measurements MPBX 50 No ave 50 ft long. @ $2500 = 125,000
4 anchors per hole, remote readout transducer head. readout unit 2 × 2000 = 4000
= $129,000

Rock bolt load cells. 200 No at. $100 = $ 20,000
readout unit $ 2,000
$ 22,000

Tape extensometer measurement in tunnels $ 10,000

Vibrating wire strain gauges on steel arches 100 @ $100 = 10,000
read out unit $2000 2000
$ 12,000

Drilling for. Thermistors. 22 × Ave 300' = 6600 ft.
" " Piezometers 500 × 100' ave. = 30,000 ft
36,600 ft

~~core drilled $75/ft~~ = ~~2,745,000~~

Say 18,300' core drilled at $75/ft. = $ 1,372,500
18,300 rotary percussion drilled @ $40/ft = 732 000

TOTAL 2,104,500

FORM NO. 152 REV. 1

ACRES

Calculations

SUBJECT:

JOB NUMBER
FILE NUMBER
SHEET 4 OF 4
BY WAJB DATE 4 Dec 81
APP DATE

Labour Team of 2 Instrumentation engineers
10 Technicians

12 @ $100,000 year

over period 4 years. $4,800,000

Total price $ 10 435,300

+10% contingencies. $11,478,830

FORM NO. 152 REV. 1

10.6 Feasibility Report

Instrumentation

Long term monitoring programs are an integral part of the design of all dams. Instrumentation layouts are designed to monitor the unusual as well as normal conditions. The instruments are ~~suited~~ selected for ruggedness, reliability and simplicity in reading and maintainence. Long term performance is very important but when this cannot be achieved, provisions will be made for regular replacements to ensure continuity in the observations.

Instrument failures may occur due to malfunctioning equipment, deterioration of materials and improper installation. Additional losses may occur due to excessive ground or structure movement, accidental destruction by construction equipment, and vandalism. The instrumentation program will be designed to keep these losses to a minimum. The program will also be designed ~~when~~ where possible to be simple to maintain and provide ease of instrument reading.

Piezometers

The instruments will be used to measure water pressures in the various embankment materials of the dam, in the rock of the dam foundations, under important structures subject to hydraulic uplift pressures, in the relict channel and in the vicinity of the powerhouse.

There are three basin types used commonly as routine instrumentation.

1) Double tube hydraulic
2) Vibrating wire
3) Pneumatic

It is expected that the vibrating wire and pneumatic types will be used.

Inclinometers

Inclinometers measure relative horizontal movements from a vertical or inclined line within the dam or foundation. These instruments will be used in the embankment dam in conjunction with other deformation measuring instruments to obtain an overall picture of dam movement.

Vertical Settlement

Settlement in the dam will be measured by multiple cable or rod instruments with cross arm reference points at various horizons within the dam.

The inclinometer tubes will also be utilized for measurement of settlement within a "Sondex" probe.

Surface settlement points

Surface settlement will be measured by precise surveying. These points are cheap and simple to install and read. It is expected the points will be distributed along the dam crest, downstream face and relict channel. The precise surveying will also tie in other measuring instruments.

Horizontal Settlement Gauges

These instruments will be of the double fluid acting type and will be installed within the dam embankments with a readout location on the downstream face. The instrument will measure vertical deformations along a horizontal line.

Horizontal Strain

This instrument consists of a rod extensometer with transducers located at embedded reference plates at intervals along the rod. The instrument has a remote electrical readout and may be located anywhere within the dam.

Seepage Monitoring Weirs

Seepage from the various drainage systems will be measured by weirs. Where access is difficult for regular measurement remote readout devices will be installed.

Thermistors

Temperature measurement is required in dam foundations, the abutments, and the relict channel to monitor the permafrost. Thermistors will also be required in specific ~~instruments~~ structures such as the spillway chute. This will generally be an extension of the ~~fixed~~ final next stage site investigation program.

Measurement for Underground Structures

Instrumentation for measurement of in situ rock structures, rock deformation around the tunnels and caverns and performance of tunnel support elements is more of an exploratory nature and will be used mainly for construction and support design and therefore will be discussed in more detail in Section 10.12.

S. Thompson any comments?

ACRES **Calculations**	JOB NUMBER P5700.05
SUBJECT: SUSITNA HYDRO ELECTRIC PROJECT INSTUMENTATION.	FILE NUMBER
See Comments. I don't have handle on $ for instrumentation.	SHEET 1 OF 4
	BY NAJB DATE 4 Dec 81
	APP DATE

Instrumentation Watana Dam

Piezometers

Core	200	350 pneumatic @$200
D/S Shell	50	350 vibrating wire @$250
U/S Shell	50.	
Spillway	50.	
Power house penstocks	50	pneumatic tubing @0.25/ft 1000ft ave.
Relict channel	100	$87 500
Foundation dam	200	vibrating wire cable @ 2.00/ft 1000ft ave
	700.	$700,000

Readout units. 4 x $1500 pneumatic
4 x $1000 vib wire.

Total cost
70,000
87 500
87 500
700,000
6 000
4 000
$1,742 500

Inclinometers.

Core	30	ave 600' depth	= 42 000 ft Casing @ $3.00/ft = 126000
D/S shell	20		Sensors 3 x 4500 = 13 500
(inclined) U/S shell	20.		Readout 3 x 8500 = 25 500
			= 165,000

Vertical settlement "Sondex"

Readout 2 x $1300 = 2600
Sensor rings 2100 x $7 = 14,700
$17,300

Cable extensometers. 200 No ave depth 400 ft.
= 80,000 ft @ say $5/ft
= $400,000

FORM NO. 162 REV. 1

0008

ACRES

Calculations

SUBJECT:

JOB NUMBER
FILE NUMBER
SHEET 2 OF 4
BY NASB DATE 4 Dec 81
APP DATE

Horizontal strain 10 × 1000 ft 1 pair transducers / 50 ft 400 transducers

transducer $100 × 400	40,000
rod and embedment plate. $5/ft =	50,000
	90,000
Readout unit	10,000
	100,000

Horizontal settlement gauges double fluid acting type.

12 No. average length 2000 ft

Readout units	2 × $20,000	$40,000
Casing, winch, cable pulleys housing etc	$30/ft.	$720,000
		$760 000

Surface settlement points 4000 No @ $100 = $400,000

Seismic recorders.
3 Dam
1 Relief channel
1 Power house
1 Spillway.
6 @ $20000 = $120,000

This program being put together by WLOC. Ck with V. Singh about what they are doing

Seepage monitoring weirs.
Dam 6 No
Relief channel 6
Spillway 1
13 No. @ $2000 = $26,000

FORM NO. 152 REV. 1

ACRES

Calculations

SUBJECT:

JOB NUMBER ____
FILE NUMBER ____
SHEET 3 OF 4
BY N.A.O.B. DATE 4/Dec/8[illegible]
APP ____ DATE ____

Thermistors.	Abutments.	6 holes × 20 pairs	– 120		
	Dam	10 hole × 30 pairs	= 300		
	Relict channel	6 hole × 20 pairs.	– 120		
			540 No.	@ $50	27,000
		cables say $1000 per hole.		=	22,000
					47,000

Much more instrumentation planned in next phase of investigation. Some of this should go into that program.

Rock stress measurement in caverns – Adit testing? Same as comment above.

Deformation measurement MPEX 50 No. ave 50 ft long. @ $2500 = 125,000
4 anchors per hole, remote readout transducer head.
readout unit 2 × $2000 = 4000
= $129,000

Rock bolt load cells. 200 No. at $100 = $20,000
readout unit $2,000
$22,000

Tape extensometer measurement in tunnels $10,000

Vibrating wire strain gauges on steel arches. 100 @ $100 = 10,000
readout unit $2000 — 2000
$12,000

Drilling for Thermistors. 22 × Ave 300' = 6600 ft.
" " Piezometers 500 × 100' ave. = 30,000 ft.
36,600 ft
core drilled $75/ft = 2,745,000

FORM NO. 152 REV. 1

0008

ACRES

Calculations

SUBJECT:

JOB NUMBER
FILE NUMBER
SHEET 4 OF 4
BY NAJB DATE 4 Dec 81
APP DATE

Labour Team of 2 Instrumentation engineers
10 Technicians

12 @ $100,000 year

over period 4 years $4,800,000

Total price $ 10,089,800

+10% contingencies $11 million

FORM NO. 152 REV. 1

NAT BOND

Nigel

Dont quite agree
with the way
you get there
& something wrong
with the arithmetic
but I'll settle for
$12 million.

Bill

D. W. Lamb any comments?

ACRES **Calculations** Arithmetic !

SUBJECT: SUSITNA HYDROELECTRIC PROJECT INSTRUMENTATION.

JOB NUMBER P5700.05
FILE NUMBER
SHEET 1 OF 4
BY [illegible] DATE 4 Dec 81
APP DATE

Instrumentation Watana Dam

Piezometers

Core	200	
D/S Shell	50	
U/S Shell	50.	
Spillway	50	
Power house + penstocks	50	
Relict channel	100	
Foundation dam	200	
	700.	

77 ?

350 pneumatic @ $200

350 vibrating wire @ $250

$55 Red Seal purchase price

pneumatic tubing @ 0.25/ft 1000 ft ave. $87 500

vibrating wire cable @ 2.00 ft 1000 ft ave $700,000

Readout units 4 x $1500 pneumatic

4 x $1000 vib wire. 100.

Total cost 70,000
87 500
87 500
700,000
6 000
4 000
$1,742 500

Inclinometers.

	Core	30	ave 600' depth
	D/S shell	20	
(inclined)	U/S shell	20.	

= 42 000 ft Casing @ $3.00/ft = 126000

Sensors 3 x 4500 = 13 500

Readout 3 x 8500 = 25 500

= 165,000

Vertical settlement Sondex

Readout 2 x $1300 = 2600

Sensor rings 2100 x $7 = 14700

$17,300

Cable extensometer. 200 No ave depth 400 ft.

= 80,000 ft @ say $5/ft

= $400,000

FORM NO. 152 REV. 1

ACRES

Calculations

SUBJECT:

JOB NUMBER
FILE NUMBER
SHEET 2 OF 4
BY NASB DATE 4 Dec 81
APP DATE

Horizontal strain 10 × 1000 ft 1 pair transducers /50 ft 400 transducers

transducers $100 × 400	40,000
rod and embedment plate $5/ft =	50,000
	90,000
Readout units	10,000
	100,000

Horizontal settlement gauges double fluid acting type.

12 No. average length 2000 ft

Readout units	2 × $20,000	$ 40,000
Casing, winch, cable pulleys housing etc.	$30/ft	$ 720,000
		$ 760 000

Surface settlement points 4000 No @ $100 = $400,000

Seismic recorders
3 Dam
1 Relict channel
1 Power house
1 Spillway
6 @ $20000 = $120,000

Seepage monitoring weirs.
Dam 6 No
Relict channel 6
Spillway 1
13 No. @ $2000 = $26,000

FORM NO. 152 REV. 1

ACRES

Calculations

SUBJECT:

JOB NUMBER
FILE NUMBER
SHEET 3 OF 4
BY N HOBS DATE 4/Dec/81
APP DATE

Thermistors. Abutments. 6 holes × 20 pairs - 120
Dam 10 holes × 30 pairs = 300
Relict channel 6 holes × 20 pairs - 120
540 No. @ $50 27,000
cables say $1000 per hole. = 22,000
47,000 ?

11,000 or

Rock stress measurement in caverns

Deformation measurements MPBX 50 No. ave 50 ft long. @ $2500 = 125,000
4 anchors per hole, remote readout transducer head.
readout unit $2 × 2000 = 4000
$129,000

Rock bolt load cells. 200 No. at. $100 - $ 20,000
readout unit $ 2,000
$22,000

Tape extensometer measurement in tunnel $10,000

Vibrating wire strain gauges on steel arches 100 @ $100 = 10,000
readout unit $2000 2000
$12,000

Drilling for. Thermistors. 22 × Ave 300' = 6600 ft.
" " Piezometers 500 × 100' ave. = 30,000 ft.
36,600 ft
core drilled $75/ft = 2,745,000
high.

air drilled
$40 OK