No. 2

CANADA

DEPARTMENT OF MINES AND TECHNICAL SURVEYS

GEOLOGICAL SURVEY OF CANADA
TOPICAL REPORT NO. 41

MACKENZIE RIVER DRAINAGE BASIN
DAM SITE INVESTIGATION

SITE NO. 3

LOWER CANYON DAM SITE

(MAP AND PRELIMINARY REPORT)

BY
E. B. OWEN

OTTAWA
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LOWER CANYON DAM SITE

General Description

Lower Canyon dam site is located on Frances River about 12 miles from its junction with Liard River. It is about 3 miles downstream from the bridge which forms part of the new road presently under construction north from Watson Lake toward the community of Ross River. The site is most easily reached by walking downstream along either side of Frances River from the new bridge. Shallow draft boats, commencing at the bridge over Liard River at mile 642, Alaska Highway, can readily ascend Liard and Frances Rivers to the lower end of the canyon. The River as it passes through the canyon is extremely rough and dangerous and it is recommended experienced, local river men be used if it is necessary to take boats up or down through the bad water.

At the site Frances River is flowing generally northeast between two steep, rocky cliffs which rise abruptly from both sides of the River to heights greater than 200 feet. Bedrock exposed in the bluffs consists chiefly of Palaeozoic sedimentary rocks which have been briefly described by Dawson[1].

The area included in the accompanying geological map extends along the downstream part of the canyon for about 4,000 feet. There is a drop of about 20 feet in the level of the water surface as the River passes through the area. The average width of the River is about 200 feet. The temperature of the water was about 56 degrees fahrenheit on July 23, 1961.

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[1] Dawson, G.M.: "Report on an Exploration in the Yukon District, N.W.T. and adjacent northern portion of British Columbia"; Geol. Surv., Canada, 1898, p. 101.

Overburden at the site consists almost entirely of till with shallow deposits of talus derived from adjacent bedrock exposures occurring on both abutment slopes. The till is a common deposit throughout the area. It was encountered in many places along the new road between Watson Lake and Frances River and is exposed in the high bluffs along both sides of the River between the top of the canyon and the new bridge.

A narrow, bedrock terrace in the left wall of the canyon is covered with a thin layer of talus and till slumped from the upper part of the bluff. The elevation of the terrace is 2,260 or about 70 feet above the River. A similar terrace occurs in the right wall at approximate elevation 2,325.

There is a distinct shortage of natural aggregate in the area. Glacio-fluvial sands and gravels, which in many parts of Yukon Territory are important sources of construction materials, do not exist. It is believed the till which occurs at the site may be suitable for the impervious core of an earth-fill dam or dyke. Frozen till was encountered in a few localities on the wooded slope bordering the left side of the River.

Unconsolidated Deposits

1. Recent Alluvium (silt, sand, gravel): This material has been deposited by the present River. It consists chiefly of silt, sand and gravel containing boulders up to 12 inches in diameter. The rock bluffs forming the canyon walls usually rise vertically from the River and have prevented the formation of alluvial deposits in most parts of the canyon. Consequently there is only one small locality in the entire area mapped where alluvium exists. It is not an important deposit and the limited quantity available prevents it from becoming a source of construction material.

2. Talus: Talus is spalled material derived from bedrock exposed along bluffs. At the site a thin deposit of talus covers about 5 per cent of the walls of the canyon. In most instances it has originated in adjacent bedrock. The rock fragments vary from sand-size particles to boulders several feet in diameter. The largest rock fragments and those most suited for riprap and rock fill occur beneath the exposures of andesite in the downstream part of the proposed right abutment. Talus originating in the sedimentary rocks consists chiefly of small, weathered, rock fragments.

3. Till: The material exposed in the bluffs bordering the River at the site consists chiefly of till directly overlying bedrock. The till consists of a greyish-brown, dense, sandy, clayey material containing a few large, subrounded boulders up to 12 inches in diameter. Excellent sections of the till can be seen along the bluff west of the River near stations L-2 and L-6. Grain size analyses curves for two representative samples of the till are included at the end of this report (samples Nos. 34 and 35). The quantity of silt and clay-size particles present in the samples was not determined in the analyses. However, the medium dry strength of the till, when examined in the field, indicated both silt and clay are present.

Similar till was encountered in many places along the new road between Watson Lake and Frances River. Here it is being used as road fill and subsequently covered with about 24 inches of gravel as surfacing material. The density of the till was sufficiently great that a D-8 Caterpillar bulldozer equipped with a hydraulic ripper was required to loosen the material before it could be removed by a scraper.

It is believed the till may be suitable for the impervious core of an earth-fill dam or dyke. Tills usually produce impervious materials with satisfactory shearing strength but removal of any boulders will be necessary in order for the soil to be compacted satisfactorily. Permeable sand or gravel lenses were not observed in the till exposed at the site.

Bedrock

General Description

Bedrock exposed at the site consists of fine-grained, buff-coloured limestone and conglomerate along with lesser quantities of bluish-grey quartzite and red shale. The conglomerate occurs as irregular lenses usually interbedded with the limestone. Many of the contained rock fragments have been flattened parallel to the bedding. In some places bedrock is completely shattered. In others, irregular schistose structures, usually associated with the conglomerate and quartzite, have developed. Volcanic rocks consisting of fine-grained, grey andesite and bluish-grey rhyolite overlie the sediments in the downstream part of the right wall of the canyon.

Numerous, white, quartz veins are visible in bedrock exposed in both walls of the canyon. The veins are exceedingly irregular and vary in width from a few inches to about 3 feet. They are frequently stained brown due to the oxidation of iron-bearing sulphides.

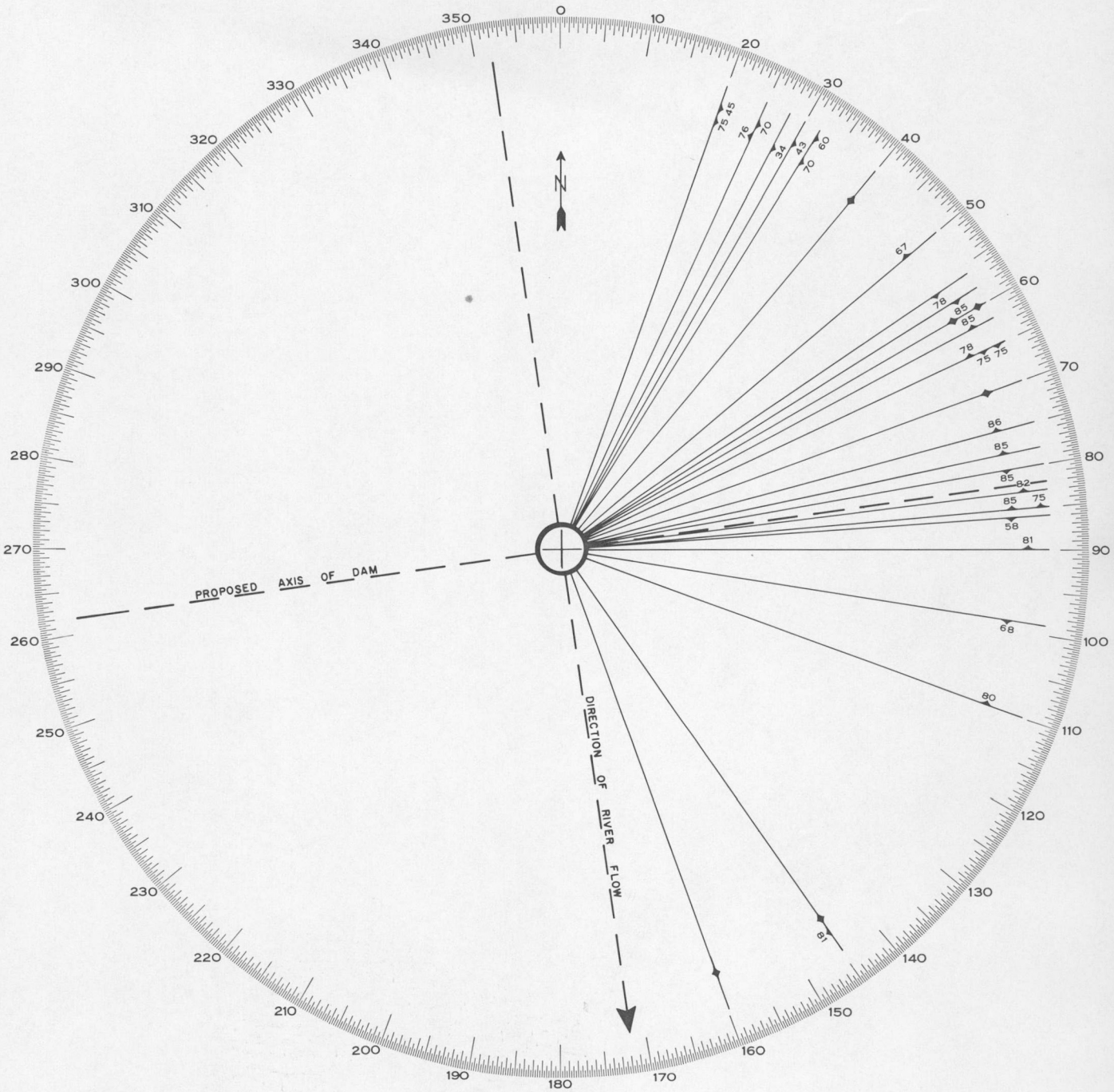
Bedrock Structures

The general strike of the bedding in the site area is north 20 degrees west and the dip varies between 15 and 30 degrees west. The existence of considerable local folding, however, has created many deviations

from these figures. A minor anticlinal fold extends from station S-6 on the right side of the River toward station E-8 on the left side. The strike of the fold is about north 7 degrees west. The River here is rapid and rough with a visible drop of 4 to 5 feet within a very short distance. Another small, anticlinal fold, striking north 12 degrees west, extends from a point on the right side about 100 feet downstream from station S-9 toward E-14 on the left bank. Minor folding and distortion in the limestone beds was observed about 250 feet downstream from station S-6, about 200 feet upstream from S-5 and along the edge of the River below stations S-1 and S-2. The folded rock is usually badly broken and highly weathered.

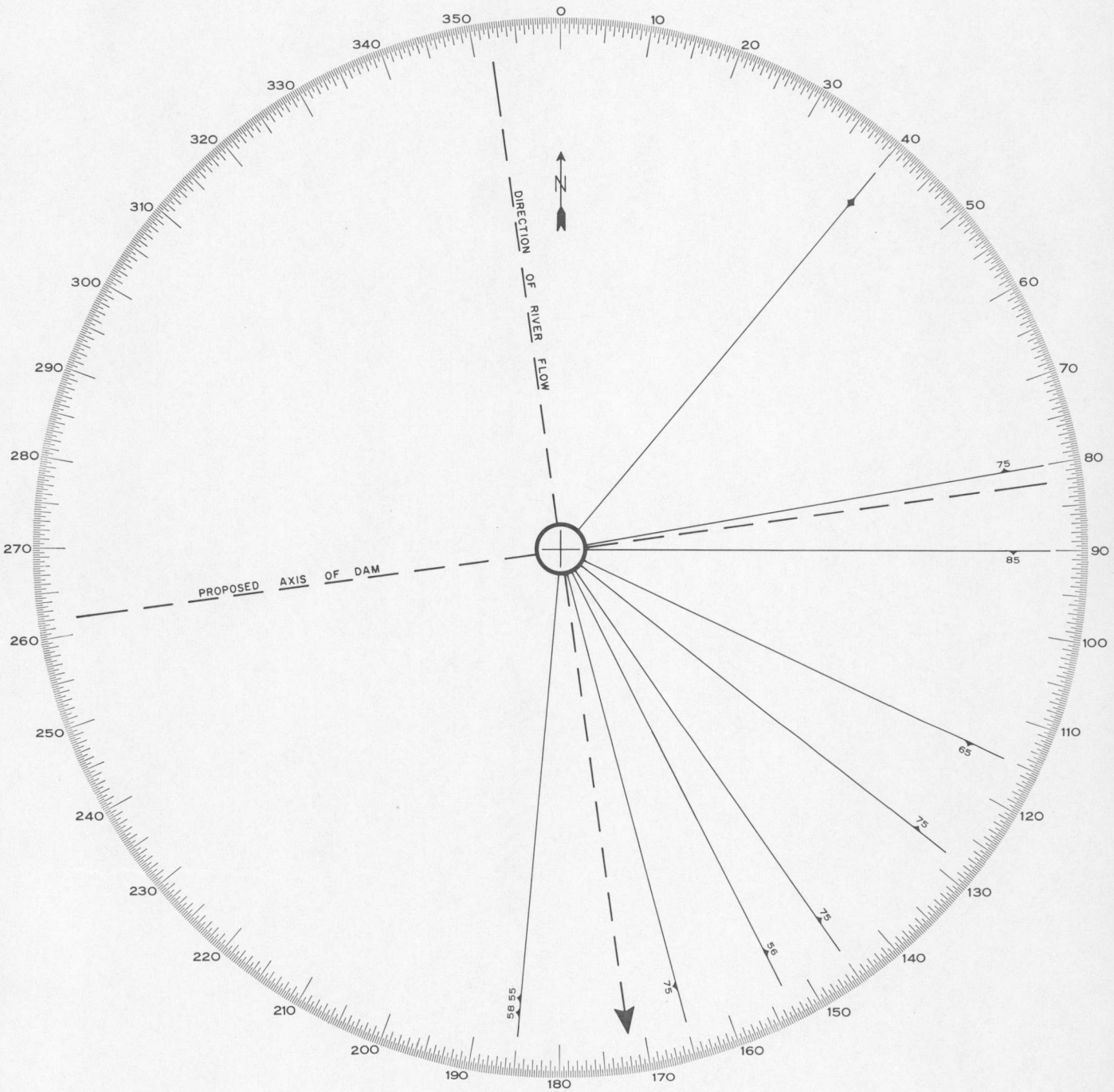
Considerable faulting is visible in the bluff along the right side of the canyon. In many instances it is associated with the folding and parallel to it. Numerous small seepages of groundwater were observed at the base of the bluff issuing from the broken rock in the fault zones.

Jointing is common at Lower Canyon dam site. The attitudes are exceptionally variable. The jointing intersects the proposed centre line of the dam at angles between zero and 70 degrees with relatively steep dips. Rosettes indicating the relation of the various bedrock structures at the site to the proposed dam axis are presented on the following pages.



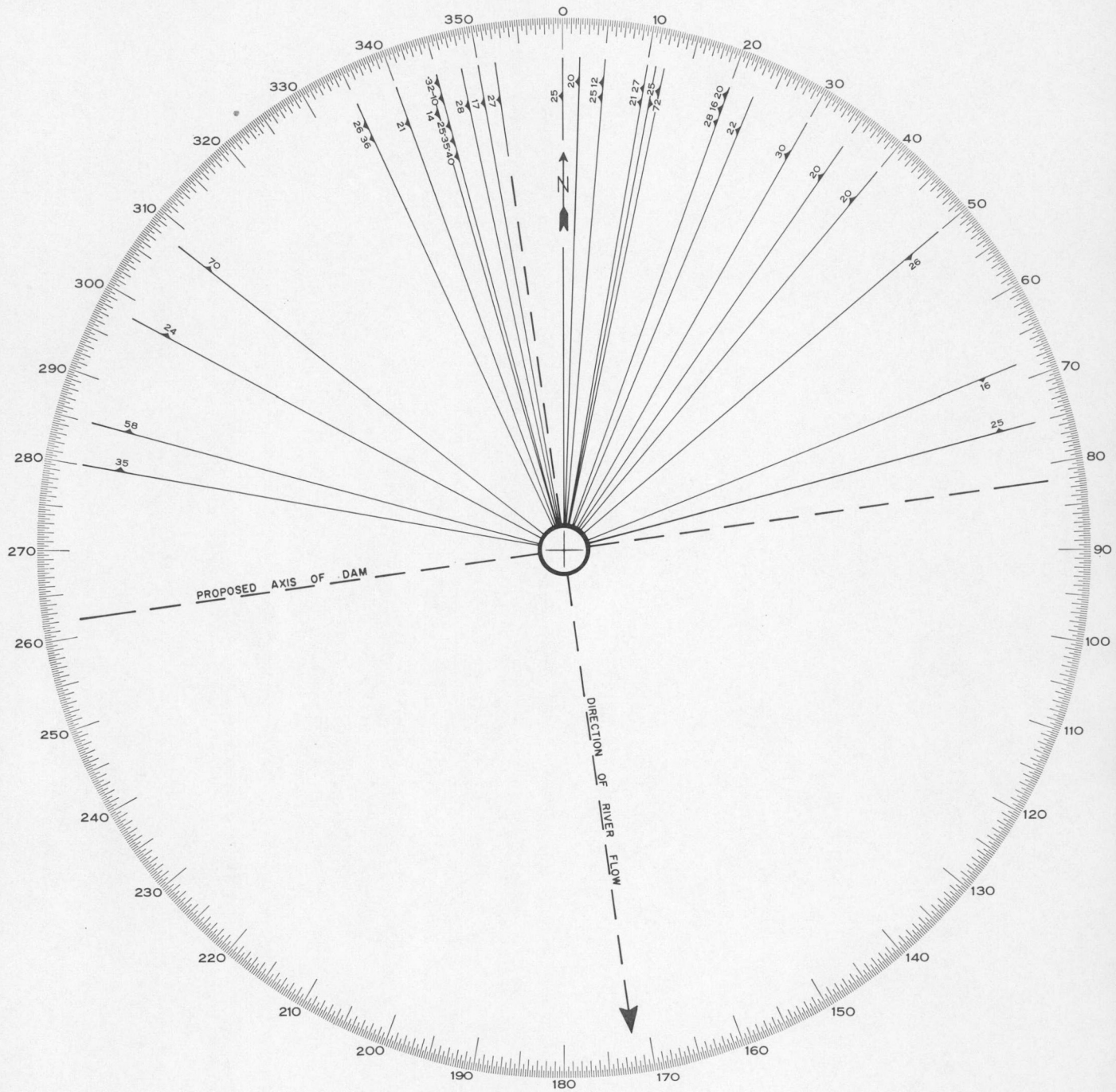
JOINT ROSETTE

The above illustration presents diagrammatically the direction and dip of the jointing in bedrock exposed at Lower Canyon dam site, Frances River



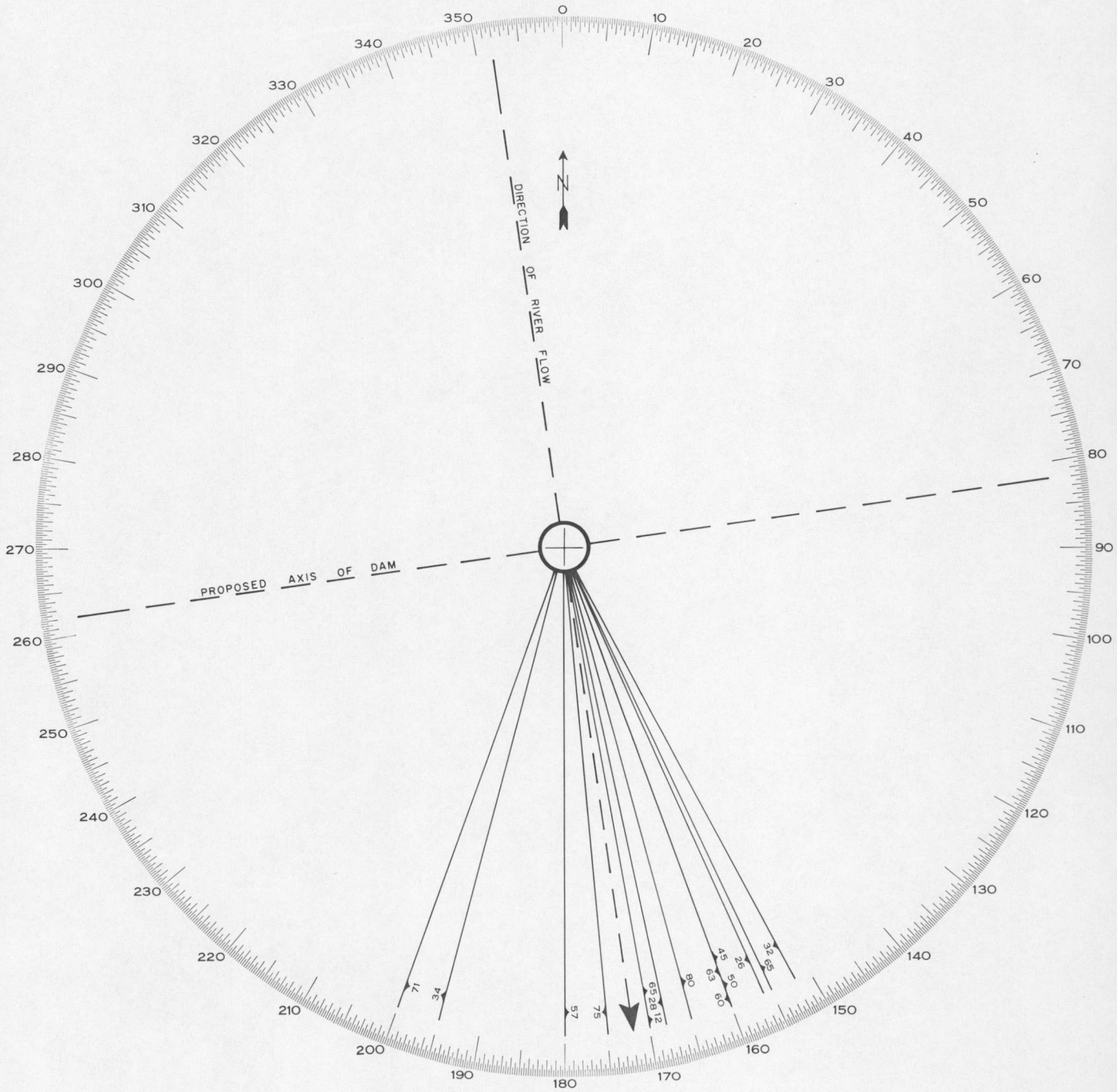
FAULT ROSETTE

The above illustration presents diagrammatically the direction and dip of the faulting in bedrock exposed at Lower Canyon dam site, Frances River



BEDDING ROSETTE

The above illustration presents diagrammatically the direction and dip of the bedding in bedrock exposed at Lower Canyon dam site, Frances River



SHEAR ROSETTE

The above illustration presents diagrammatically the direction and dip of the shearing in bedrock exposed at Lower Canyon dam site, Frances River

Quality of Bedrock

Much of bedrock exposed at Lower Canyon dam site is too badly shattered to provide suitable abutment material for a dam. The presence of considerable faulting and numerous schistose zones render it unsound for engineering purposes. It is suggested test borings be put down along the bases and tops of the bluffs bordering the canyon to investigate the quality and permeability of the rock and the possibility it could be grouted. The most competent rock in the area mapped is exposed in the steep bluff on the right side of the River between stations S-3 and S-4.

Engineering Considerations

Depth of Overburden

Bedrock is exposed almost continuously along the right edge of the River and on about 50 per cent of the adjoining bluff. Numerous bedrock exposures also occur along the left side of the River.

Overburden in the map-area consists chiefly of glacial till and talus. The thickness of the talus which usually occurs close to the bedrock exposures is believed to be generally less than 10 feet. The thickness of the till deposits is not believed to be great. In places where till is the only material exposed on the bluffs bedrock surface probably rises as it proceeds from the River and consequently the height of the bluff is not indicative of the thickness of the till. In the upstream part of the area mapped bedrock outcrops in the River in the form of several, small, scattered, rocky knobs. The presence of these bedrock islands suggests the thickness of the alluvium underlying the River is not great.

Abutments and Foundations

Much of bedrock exposed at Lower Canyon dam site has been badly shattered by faulting and folding and is not believed suitable as abutment and foundation material. An intensive test boring program will be necessary to investigate the quality and permeability of bedrock at the site. It is possible bedrock can be consolidated by grouting. The fractures are extensively interconnected and the grout solutions should be able to permeate the entire bedrock mass. The limestone is not especially soluable and consequently it is doubtful if caverns or large channels occur in this rock type. Bedrock exposed in the bluff suggested as the right abutment is relatively solid. It is believed it would be less difficult to construct a diversion tunnel here than in other parts of the canyon where the rock is less competent. However, all the rocks exposed at the site are believed to have a relatively high water-bearing capacity and groundwater will be undoubtedly encountered in any excavation made in them.

Construction Materials

Aggregate

There is a widespread lack of natural aggregate in the region about Lower Canyon dam site. Deposits of glacio-fluvial sand and gravel, which are the chief sources of granular material throughout much of Yukon Territory, do not exist. Little gravel was encountered for several miles north and south of the bridge over Frances River during construction of the Watson Lake - Ross River road.

The gravel from one small deposit located on the west side of the road about two miles south of Frances River was used successfully

as surface material for the road. The total quantity available was about 25,000 cubic yards of which about 5,000 cubic yards had been used (July 26, 1961). The maximum thickness of the deposit is about 10 feet, the upper 2 feet of which is badly weathered. The material consists of a stratified, well graded, sandy gravel. It would have to be processed by washing, screening and reblending before a satisfactory aggregate would be obtained.

A representative sample (No. 37) was taken and forwarded to the Soils Laboratory of the Water Resources Branch in Vancouver for a grain size analysis. The resultant curve is included at the end of this report.

It is believed the limestone and andesite exposed at the site are potential sources of aggregate. The limestone is somewhat softer than the andesite and would probably be less expensive to process. The material should be quarried from bedrock and not taken from the talus because the latter contains a high percentage of weathered and schistose rock deleterious to aggregate.

Impervious Material

Sufficient quantities of material suitable for the impervious core of an earth-fill dam are located at Lower Canyon dam site. The material consists of a dense, sandy, clay till which is exposed in the bluffs on both sides of the River at the site and is a common deposit throughout the region. The quantity available is unlimited.

The permeability of the till is probably low. There are few large boulders present which would prevent the proper compaction of the

material. Grain size analyses curves for two representative samples of the till (Nos. 34 and 35) are included at the end of this report. Also included is a curve for an extremely dense, blue-grey, clay till (No. 36) encountered beneath the brown, sandy, clay till during excavation for the south approach to the new bridge over Frances River. The extent of the lower till is unknown. It was encountered along the road for a distance of about 900 feet commencing 100 feet south of the River.

Pervious Material

Materials suitable for the pervious shells of an earth-fill dam were not observed in the vicinity of Lower Canyon dam site. The experience of Department of Public Works personnel who are supervising the construction of the new road has been that there is an extreme shortage of this type of material in the area.

Riprap and Rock Fill

Suitable riprap could be obtained from the andesite exposed in the upper part of the bluff forming the right wall of the canyon. The outcrop extends upstream from the south edge of the area mapped for a distance of about 1,200 feet. Rock fill could be obtained from either the andesite or the buff-coloured limestone immediately underlying it. Much of the rock exposed in the canyon walls is too badly shattered to provide suitable riprap or rock fill.

Groundwater

It is believed the groundwater table in the dam site area is relatively high. Seepages were noted issuing from bedding planes and fault

zones in bedrock exposed in the right wall of the canyon. Many of the rock fragments in the fault zones have a brown coating of iron-bearing carbonate probably deposited by circulating groundwater. Groundwater will almost certainly be encountered in any excavation made into the rock exposed in either wall of the canyon. Accurate information concerning the groundwater table can only be obtained by installing groundwater observation holes and reading them at regular intervals.

Frozen Ground

Frozen till was encountered (July 22, 1961) in several places on the left (west facing) abutment slope beneath several inches of moss and decayed vegetation. About 3 miles upstream from the site frozen ground was also encountered while excavating for the south approach to the new bridge. Here the frozen material consisted of a dense, blue-grey, clay till. The frost occurred about 20 feet beneath ground surface. Places where frozen ground was encountered in the site area are indicated on the accompanying geological map.

Proposed Location of the Dam

A proposed centre line for the dam has been indicated on the accompanying geological map by a line of proposed bore-holes which crosses the River in the downstream part of the area mapped. The line of borings extends from station E-4 on the left side of the River to the vertical limestone bluff on the opposite side. The thickness of the till deposit overlying bedrock on the proposed left abutment is not believed to be greater than 25 feet. The limestone constituting the right abutment is relatively competent and is believed

to be the most suitable of all the rock exposed in the canyon for construction of a diversion tunnel.

Conclusions

Many test borings will be required before the suitability of Lower Canyon as a dam site can be determined. Much of the bedrock exposed in the canyon walls is badly shattered and is unlikely to provide satisfactory foundation and abutment material. There will undoubtedly be a serious leakage problem through bedrock.

If it is desired to construct a dam using local materials, an earth-fill structure utilizing the unlimited quantities of till available at the site should be considered. There is a decided shortage of natural aggregate in the area about the site.

Further Investigations

It should be remembered this geological investigation is a preliminary one designed to furnish the engineer with general geological information regarding the proposed dam site. The report is based on a rapid examination of the soils and bedrock exposed at the site. The test pits put down into the overburden seldom reached depths greater than 3 feet. If it is decided more information is required at the site the following test borings are suggested as part of the program. It is assumed the centre line of the proposed dam would be located approximately as indicated on the accompanying geological map.

Hole No.	Location
1	Left abutment, 230 feet east of station No. E-4
2	Left abutment, 130 feet east of station No. E-4
3	Left abutment, 30 feet east of station No. E-4
4	River, 70 feet west of station No, E-4
5	River, 170 feet west of station No. E-4
6	Right abutment, 270 feet west of station No. E-4
7	Right abutment, 370 feet west of station No. E-4
8	Right abutment, 470 feet west of station No. E-4

All borings should penetrate at least 25 feet below the lowest elevation of bedrock surface encountered; soil samples should be taken every 5 feet or where there is a change in material; permeability tests should be conducted and the elevations of the groundwater table determined.

Chemical Analyses of Frances River Water

On July 23, 1961 a sample of Frances River water was taken from the centre of the River opposite station S-6. The sample was analysed for its mineral content by the Industrial Waters Section, Mines Branch, Department of Mines and Technical Surveys, Ottawa. The results of this analysis along with similar analyses of Frances River water taken at False Canyon and Upper Canyon sites are included on the following page.

Chemical Analyses of Frances River Water
(parts per million)

Location	Date	River Discharge	pH	SiO_2	Ca	Mg	Na	K	Fe	CO_3	HCO_3	SO_4	Cl	F	NO_3	Turbidity	Hardness as $CaCO_3$
Lower Canyon dam site; centre of river; 12 inches beneath surface of water	July 23, 1961	Medium	7.6	6.5	20.7	4.9	1.1	0.5	0.04	0.0	74.5	12.6	1.0	0.11	0.4	0	71.8
False Canyon dam site; centre of river; 12 inches beneath surface of water	Aug. 9, 1961	Medium low	7.5	5.3	20.1	4.5	1.2	0.4	0.01	0.0	70.9	11.4	0.4	0.05	Tr.	0	68.9
Upper Canyon dam site; centre of river; 12 inches beneath surface of water	Aug. 12, 1961	Medium low	7.5	5.4	19.3	4.8	1.0	0.4	0.01	0.0	67.5	11.2	0.3	0.05	0.0	0	67.9

Grain Size Analyses Curves

The grain size analyses curves included in this report were prepared in the Soils Laboratory of the Water Resources Branch in Vancouver. Each grain size sheet for potential aggregate shows the following information:

(a) Limits of fine and coarse aggregate based upon a 6-inch, maximum size.

(b) A cumulative grain size curve for each sample.

(c) Curves showing the individual percentages of the coarse and fine fraction retained on each screen or sieve size.

Samples Nos. 37 and 38 were analysed as potential aggregate; the remainder as potential impervious material.

Description of Potential Impervious Material for the following Grain Size Analyses Curves

Sample Number	Location	Field Description of Material	Field Description of Overburden	Thickness of Deposit	Areal Extent (Estimated)	Remarks
34	6 feet downstream from station L-7 and 10 feet below top of bluff; 24 inches below ground surface	Greyish-brown, dense, sandy, clay till; a few boulders up to 12 inches in diameter; minor weathering in upper 12 inches	None	100+ feet	Unlimited	This till occurs extensively throughout the area; similar material was encountered in many places during construction of the Watson Lake - Ross River road
35	5 feet directly below station L-5 on steep, till bluff	Material similar to that in sample No. 34	None	100+ feet	Unlimited	"
36	Cut on east side of Watson Lake - Ross River road, 200 feet south of bridge over Frances River	Blue-grey, dense, silty, clay till; contains a few small, partly disentegrated, black shale pebbles; appreciable dry strength; medium plasticity; unstratified	20 feet of grey, sandy, clay till	10+ feet	Length: 900+ feet Width: 100+ feet Depth: 10+ feet	Material was exposed during excavation for south approach to bridge

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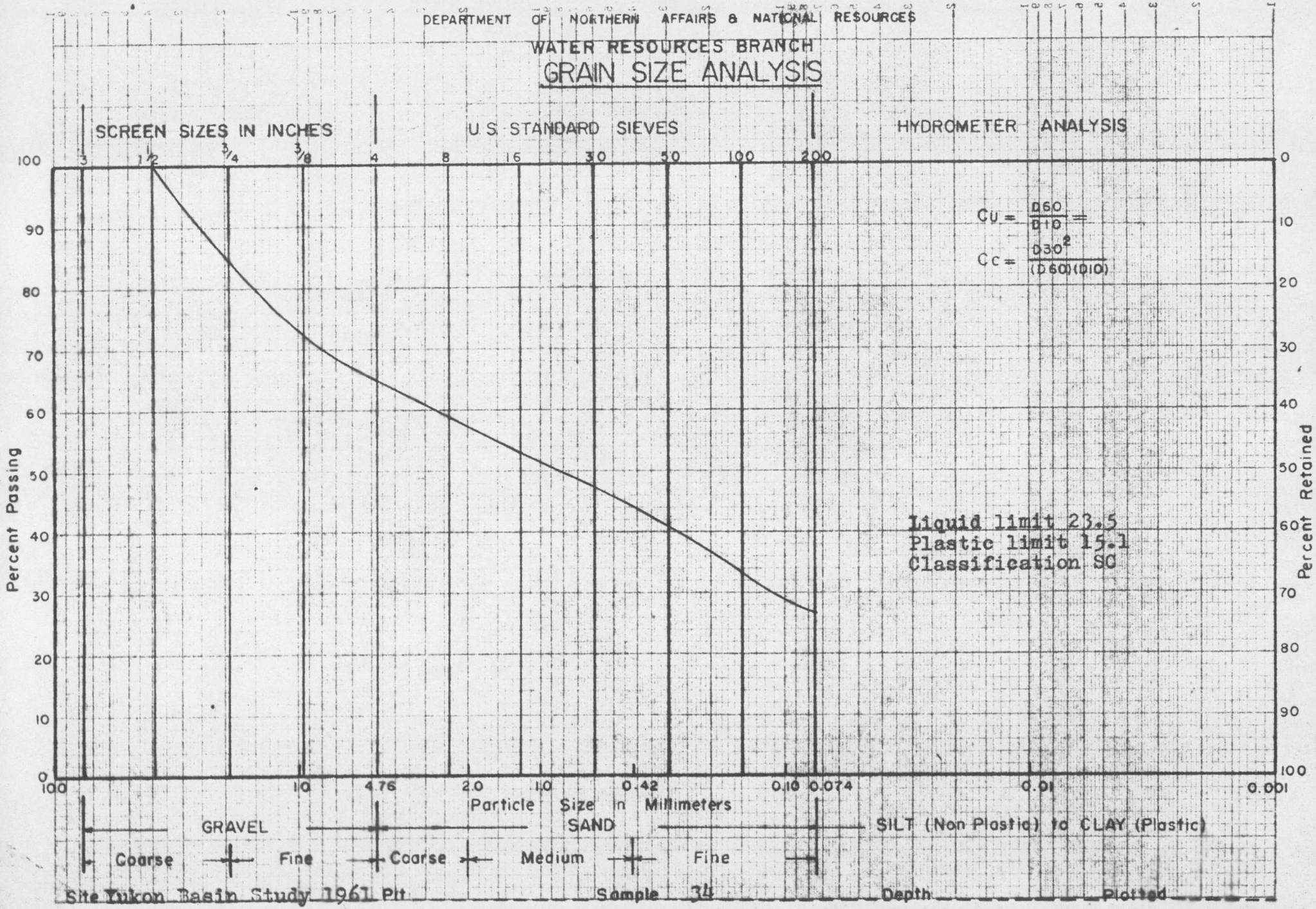
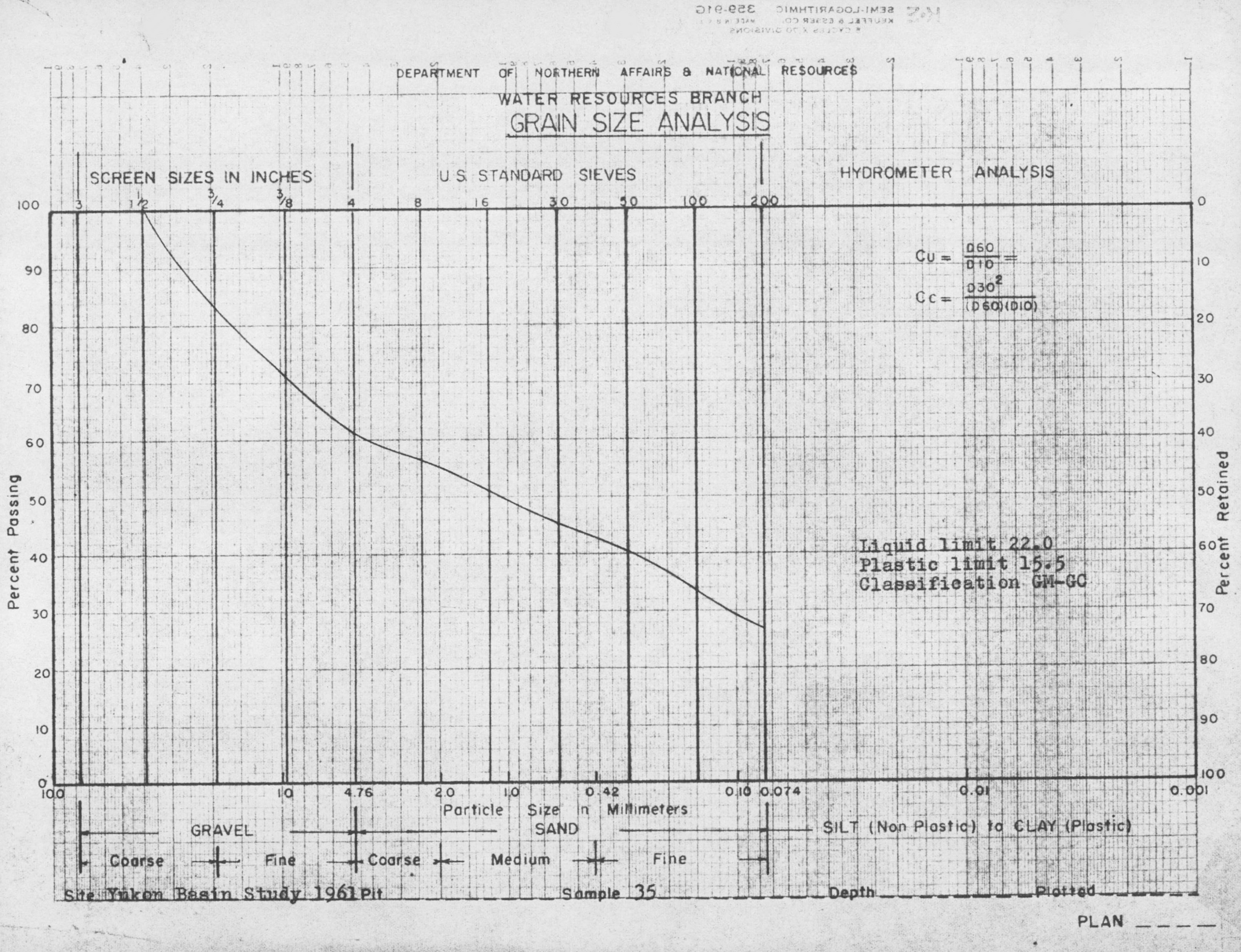
WATER RESOURCES BRANCH

GRAIN SIZE ANALYSIS



Site Yukon Basin Study 1961 Pit Sample 34 Depth Plotted

PLAN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WATER RESOURCES BRANCH
GRAIN SIZE ANALYSIS
SCREEN SIZES IN INCHES
U.S. STANDARD SIEVES
HYDROMETER ANALYSIS
3
1 1/2
3/4
3/8
4
8
16
30
50
100
200
Cu = D60 / D10 =
Cc = D30² / (D60)(D10)
Liquid limit 22.0
Plastic limit 15.5
Classification GM-GC
Percent Passing
Percent Retained
100
90
80
70
60
50
40
30
20
10
0
100
10
4.76
2.0
1.0
0.42
0.10
0.074
0.01
0.001
Particle Size in Millimeters
GRAVEL
SAND
SILT (Non Plastic) to CLAY (Plastic)
Coarse
Fine
Coarse
Medium
Fine
Site Yukon Basin Study 1961 Pit
Sample 35
Depth
Plotted
PLAN

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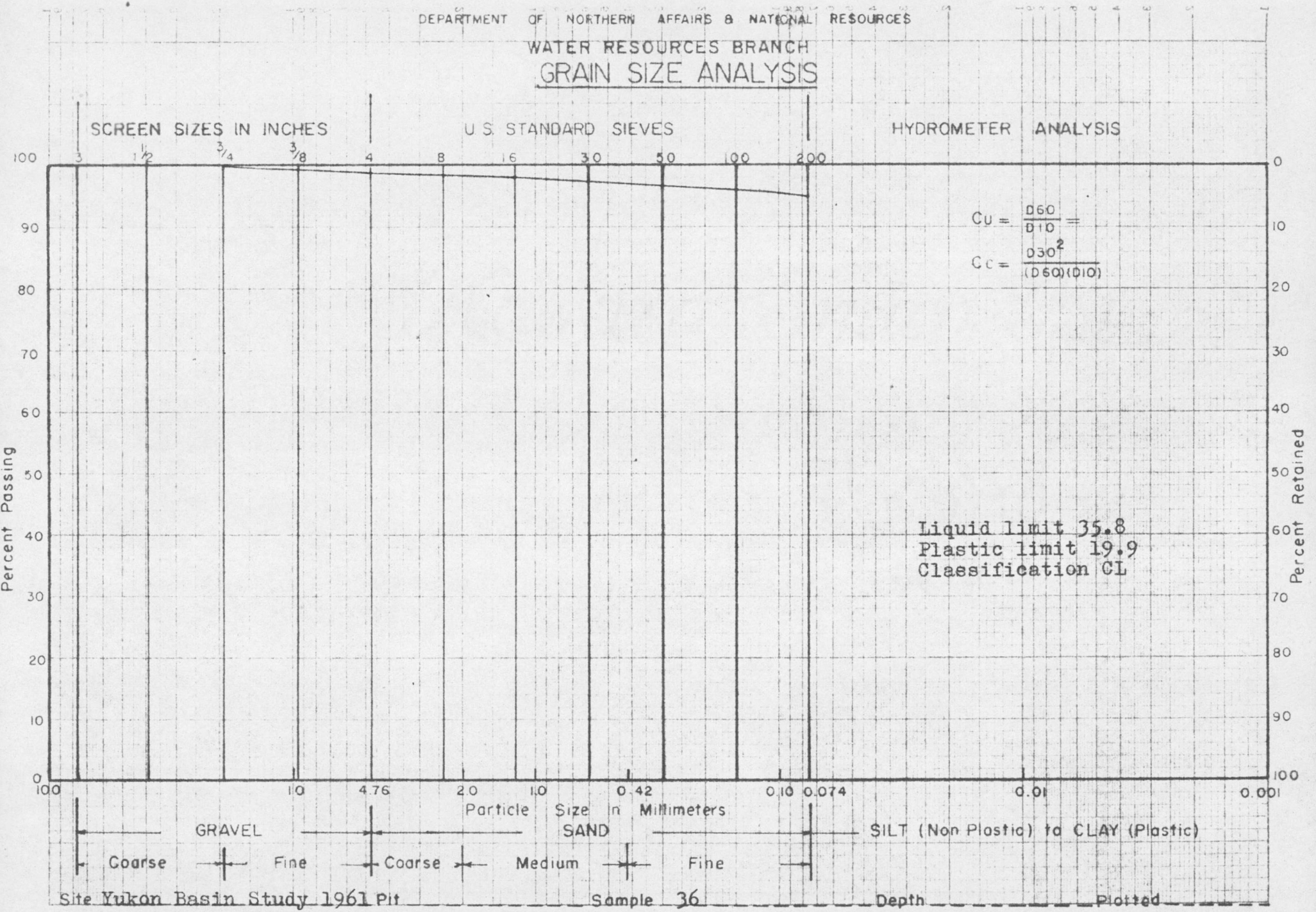
GRAIN SIZE ANALYSIS



Site Yukon Basin Study 1961 Pit _____ Sample 36 _____ Depth _____ Plotted _____

PLAN _____

Description of Potential Aggregate for the following Grain Size Analyses Curves

Sample Number	Location	Field Description of Material	Field Description of Overburden	Thickness of Deposit	Areal Extent (Estimated)	Remarks
37	Borrow pit on west side of Watson Lake - Ross River road 2 miles south of bridge over Frances River; 3 feet beneath ground surface	Well graded, sandy gravel; minor silt and clay; well stratified; cobbles up to 6 inches in diameter; relatively large proportion of shale pebbles; considerable weathering in upper 12 inches; a white coating of carbonate covers the lower sides of many pebbles in the weathered zone Pebble Lithology Igneous (volcanics, granitics) - 20% Sedimentary (limestone, sandstone) -60% Metamorphic (gneiss, schist) -10% Shale - 10%	12 inches of silty sand	10 feet (maximum)	25,000 c.y. of which about 5,000 c.y. has been removed as of July 26, 1961	Used as surfacing material on road between Watson Lake and Frances River; overlies till

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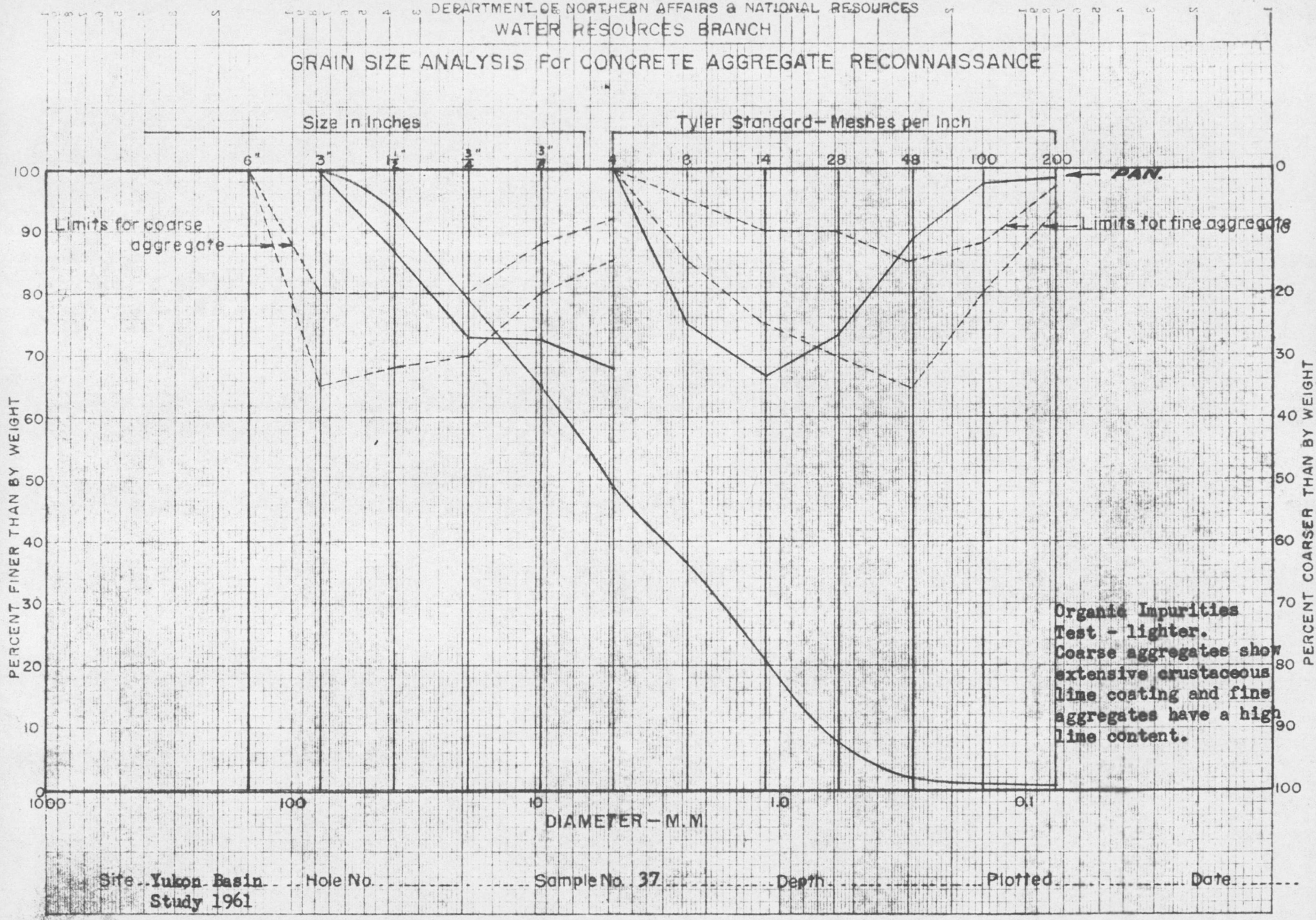
GRAIN SIZE ANALYSIS For CONCRETE AGGREGATE RECONNAISSANCE



Site Yukon Basin Study 1961 Hole No. Sample No. 37 Depth Plotted Date

PLAN No. 100 – 13

Description of Potential Aggregate for the following Grain Size Analyses Curves

Sample Number	Location	Field Description of Material	Field Description of Overburden	Thickness of Deposit	Areal Extent (Estimated)	Remarks
38	Small ridge crossing Watson - Ross River Road at station 305+00 about 6 miles north of Frances River; sample from a trench 380 feet west of road; 3 feet beneath ground surface	Well graded, sandy gravel; numerous cobbles up to 6 inches in diameter; well stratified; considerable weathering in upper 12 inches Pebble and Cobble Lithology Igneous (granitic, volcanic, quartz) - 60% Sedimentary (limestone, sandstone shale, quartzite) - 35% Metamorphic (schist) - 5%	3 feet of silt	10 feet (maximum)	Length: 800+ feet Width: 200 feet Depth: 10 feet	Gravel deposits are scarce in this area; material is chiefly a thin layer of silt overlying till

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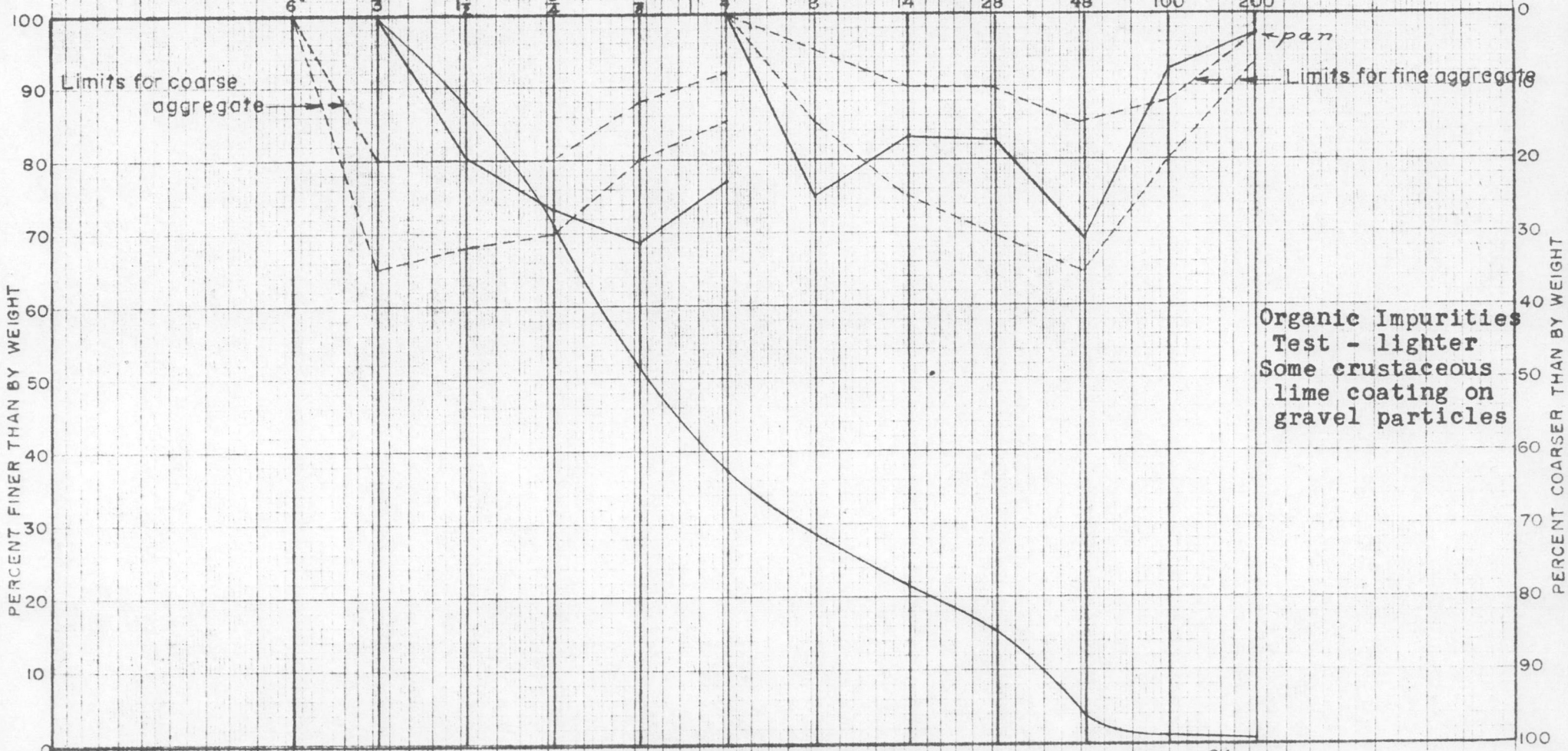
GRAIN SIZE ANALYSIS For CONCRETE AGGREGATE RECONNAISSANCE



Site Lower Canyon, Francis River Hole No. _____ Sample No. 38 Depth _____ Plotted _____ Date _____

PLAN No. 100 – 13

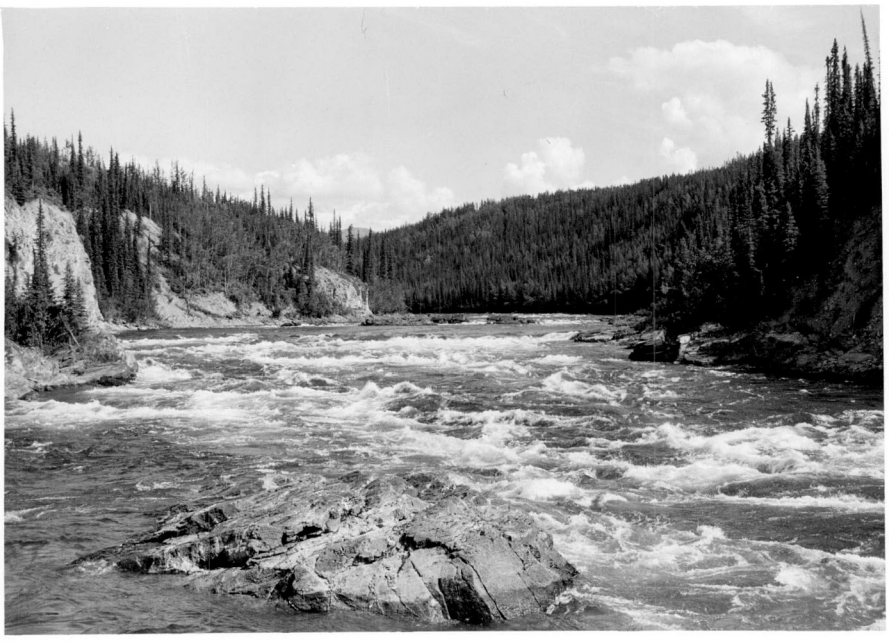


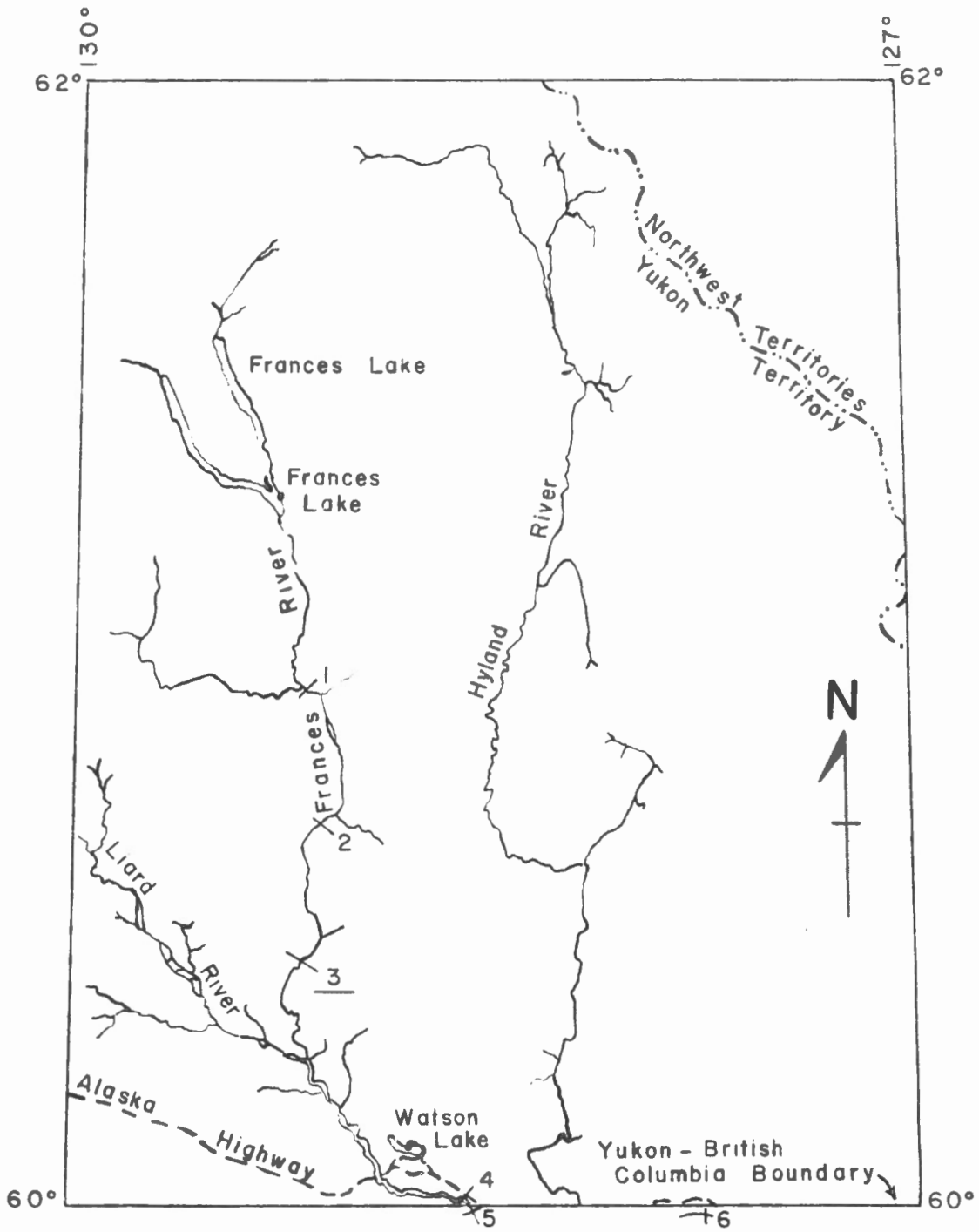
Plate 1

Lower Canyon looking upstream from right edge of River.
G.S.C. 5-3-61

Plate 2

Lower Canyon looking upstream from top of bluff forming right abutment.

G.S.C. 5-6-61



LOCATION OF PROPOSED DAM SITES
MACKENZIE RIVER DRAINAGE BASIN
Scale 1 Inch = 20 miles

Site No.	Name	River
1	Upper Canyon	Frances
2	False Canyon	Frances
3	Lower Canyon	Frances
4	Liard Canyon(upper)	Liard
5	Liard Canyon(lower)	Liard
6	Contact Creek	Liard