No. 2

CANADA

DEPARTMENT OF MINES AND TECHNICAL SURVEYS

GEOLOGICAL SURVEY OF CANADA
TOPICAL REPORT NO. 42

MACKENZIE RIVER DRAINAGE BASIN
DAM SITE INVESTIGATION

SITE NO. 4

LIARD CANYON (Upper) DAM SITE

(MAP AND PRELIMINARY REPORT)

BY
E. B. OWEN

OTTAWA
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CONTENTS

Illustrations

CONTENTS

LIARD CANYON (UPPER) DAM SITE

General Description

Liard Canyon (Upper) dam site is located on Liard River about 5 miles southeast of the community of Watson Lake Wye, Yukon Territory. An alternate site, designated as Liard Canyon (Lower) dam site, is located about 1 mile downstream. The Lower site is described in Topical Report No. 43, site No. 5.

Liard Canyon, in which both sites are located, is about 3 miles long. 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.

The Upper site is about 1 mile west of Alaska Highway. It is readily accessible from the Highway by a good trail commencing at mile 628.8. It can also be reached by shallow draft boats from the bridge over Liard River at mile 642 on the Highway.

At the site Liard River is flowing in a southerly direction between two steep, rocky cliffs which rise abruptly from the edges of the river to heights greater than 150 feet. Bedrock exposed in the lower parts of the bluffs consists chiefly of Palaeozoic sedimentary rocks which have been briefly described by Dawson[1]. The greater part of overburden exposed at the site consists of glacio-fluvial sand and gravel overlaid with a thin deposit of yellowish-brown silt. Till is believed to underlie the glacio-fluvial material but it was nowhere exposed in the area mapped.

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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. 97.

Above the bluff forming the right (west) wall of the canyon an uneven terrace covered in part with glacio-fluvial sand and gravel extends westward beyond the limit of tha area mapped. Bedrock is frequently exposed on this terrace suggesting overburden covering it is thin. A similar terrace exists above the bluff forming the left wall of the canyon. The elevations of the terraces are the same, being slightly higher than 2,100 feet above sea level. This is approximately the same elevation as that of similarly situated terraces at the Lower site. The width of the river varies from 270 to 400 feet. The temperature of the water about 12 inches beneath the surface was 53.5 degrees fahrenheit (August 27, 1961). There is no shortage of construction materials with the possible exception of riprap and rock fill.

Unconsolidated Deposits

Three types of unconsolidated deposits were identified in the area about the Upper site at Liard Canyon. These are as follows:

1. Talus and Residual Soil: Talus is material resulting from the mechanical disintegration of adjacent bedrock. It occurs on the canyon walls as small, rock fragments ranging from sand-size particles to platey cobbles 6 inches in diameter. In localities where the source rock is fairly massive the talus sometimes contains rock fragments up to 24 inches in diameter. The residual soils, which have been derived from the decomposition of underlying bedrock, occur chiefly on the terrace above the left (east) wall of the canyon. This material consists of clay, silt and fine-grained sand with numerous, platey fragments of bedrock up to 4 inches in diameter. The contact between the residual soil and the underlying, parent rock is usually gradational. Test pits put down in the residual soil seldom reached a depth greater than 18 inches,

beneath this, the material was sufficiently solid to prevent digging. In many places in the site area the processes of disintegration and decomposition are going on simultaneously with the result it was impossible to differentiate between the talus and residual soil. Consequently they have been included as a single unit on the geological map accompanying this report.

2. Glacio-lacustrine (silt): This material consists of a thin deposit of yellowish-brown silt which covers relatively small areas on the terraces above the canyon walls bordering both sides of the river. The maximum thickness encountered was 18 inches. The silt directly overlies glacio-fluvial sand and gravel, till, talus and residual soil. A potential use would be as impervious material for an earth-fill dam. An extensive test pitting program should be conducted in the areas where the silt is known to occur to determine the quantity available. Deposits of similar material occur at the Lower site.

3. Glacio-fluvial (sand, gravel): This material consists of sandy gravel containing minor quantities of silt. It occurs extensively on the downstream part of the terrace west of the river and to a lesser extent on the terrace above the canyon wall on the opposite side of the river. In places some of the material has slid down from the terraces and covered the upper parts of the canyon walls with a thin veneer of sand and gravel.

The gravel contains numerous cobbles and large boulders of porous, volcanic rocks similar to the Tertiary volcanics exposed in the right abutment of the Fort Selkirk dam site (Topical Report No. 15, site No. 9, Yukon River drainage basin). The source of the porous, rock material is uncertain. Numerous exposures of volcanic rocks occur several miles west of the site and also upstream at the junction of Liard and Francis Rivers. The last ice-sheet to exist in the region moved in a general easterly direction[1] and may have transported the material from the outcrop areas to the west. However, the type of bedding in the glacio-fluvial material indicates the water which deposited it was flowing in the same direction as Liard River. This would indicate an upstream (northerly) source for the material. The cobbles and boulders of porous, volcanic rock in the gravel should be considered deleterious substances in assessing the adequacy of the material as aggregate.

Bedrock

General Description

Bedrock consists of hard, laminated, black and grey shale with minor quantities of thinly-bedded limestone and sandstone. It is similar to that at the Lower site except it is less disturbed and weathered. In places the rock has been altered to a soft, grey calcareous schist. Local folding has produced considerable distortion in the bedding exposed in the right (west) wall of the canyon in the downstream part of the map-area. Bedrock is also tightly folded and contorted in several places along the left wall of the canyon. Small, irregular, quartz veins are common but are not as numerous as at the Lower site.

Bedrock Structures

Much of bedrock exposed at the site has been tightly folded and distorted. Consequently the attitudes of the bedding are exceedingly

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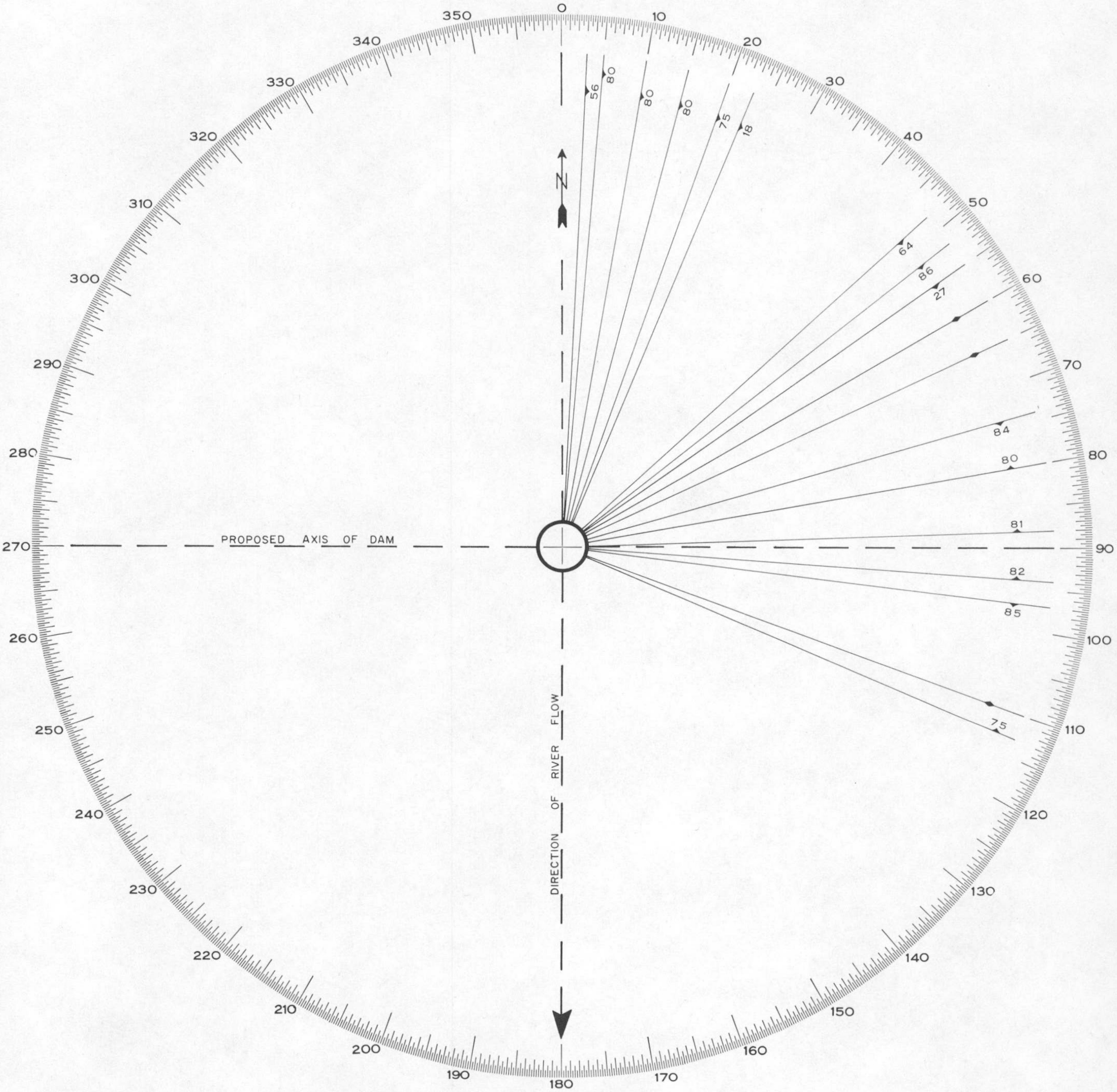
[1] Price, L.L., and Gabrielse, H.: McDame Map-area; Geol. Surv., Canada, Preliminary Map 54-10 with descriptive notes, 1954

irregular. The trend is generally north-northeast. All the bedding attitudes taken at the site have been plotted on the accompanying bedding rosette. The bedding intersects the river at angles varying from zero to 55 degrees and generally dips at low angles upstream or toward the right abutment. Bedding exerts considerable control over the manner in which bedrock breaks. Many of the platy rock fragments in the talus have broken off along bedding planes. This characteristic of bedrock is important because it will influence the size and shape of the rock fragments produced by blasting and might cause the right abutment to be unstable when excavated.

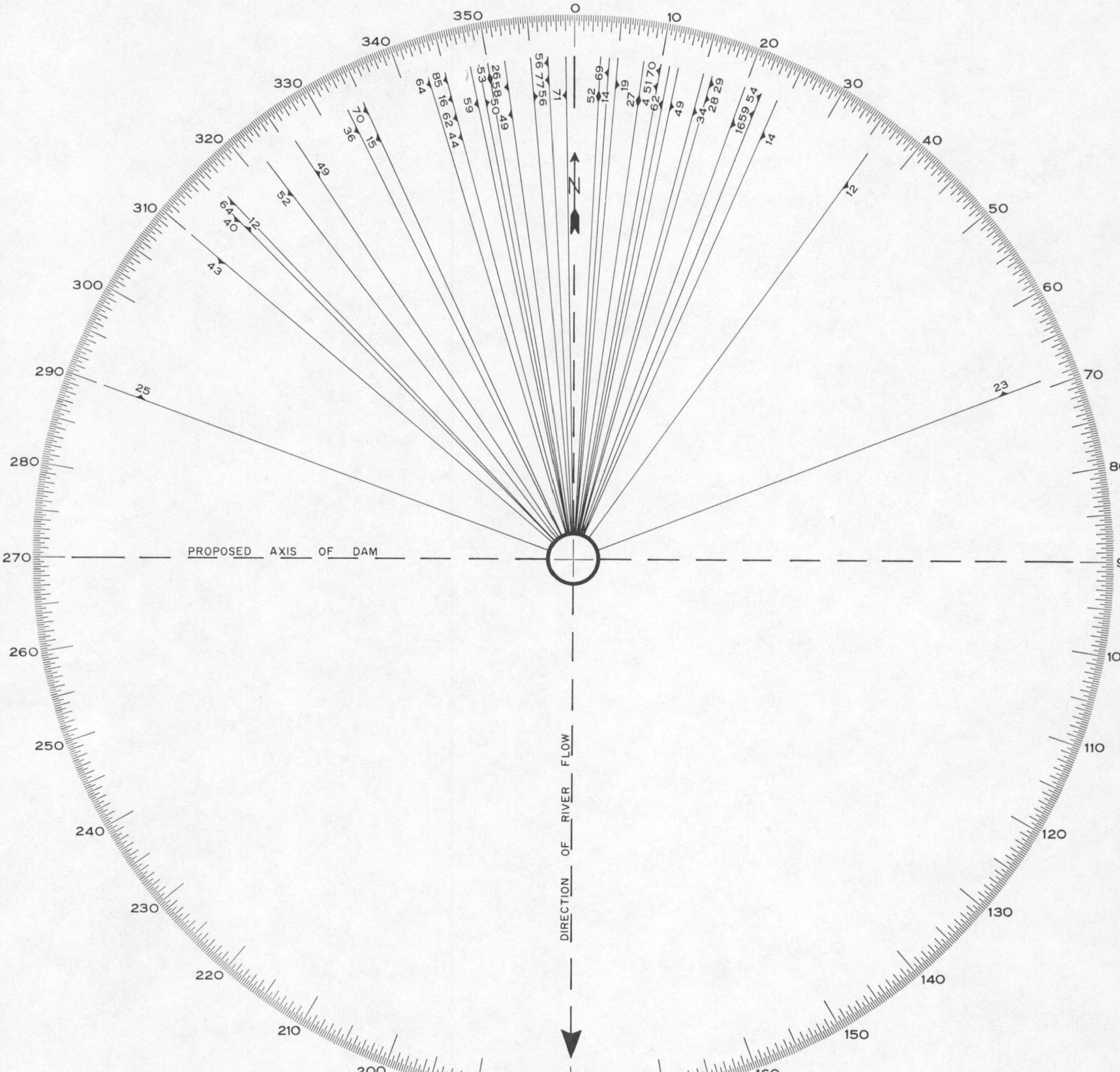
There are 2 principal sets of joints at the site. Both sets have a considerable range of strike and dip. The most prominent intersects the river at angles between 2 and 42 degrees and the other between 67 and 88 degrees. The dips are relatively steep, ranging from 75 degrees to vertical. The spacing varies from a few inches to several feet. Most joints are tightly closed and do not act as aquifers. They will, however, influence the manner in which the rock will break during excavation.

Minor faulting is common in the site area. Numerous bedding faults whose attitudes are parallel to the strike and dip of the bedding are exposed in both walls of the canyon. Bedrock adjacent to the faults is not badly fractured and there is little impervious, clayey gouge present. There are two consistant shear planes in bedrock exposed at the site. The more prominent shear dips steeply west toward the right abutment and the other has a more shallow dip east toward the left abutment. The strikes of the two shears are approximately parallel ranging from north 45 degrees west to north 24 degrees east. They intersect



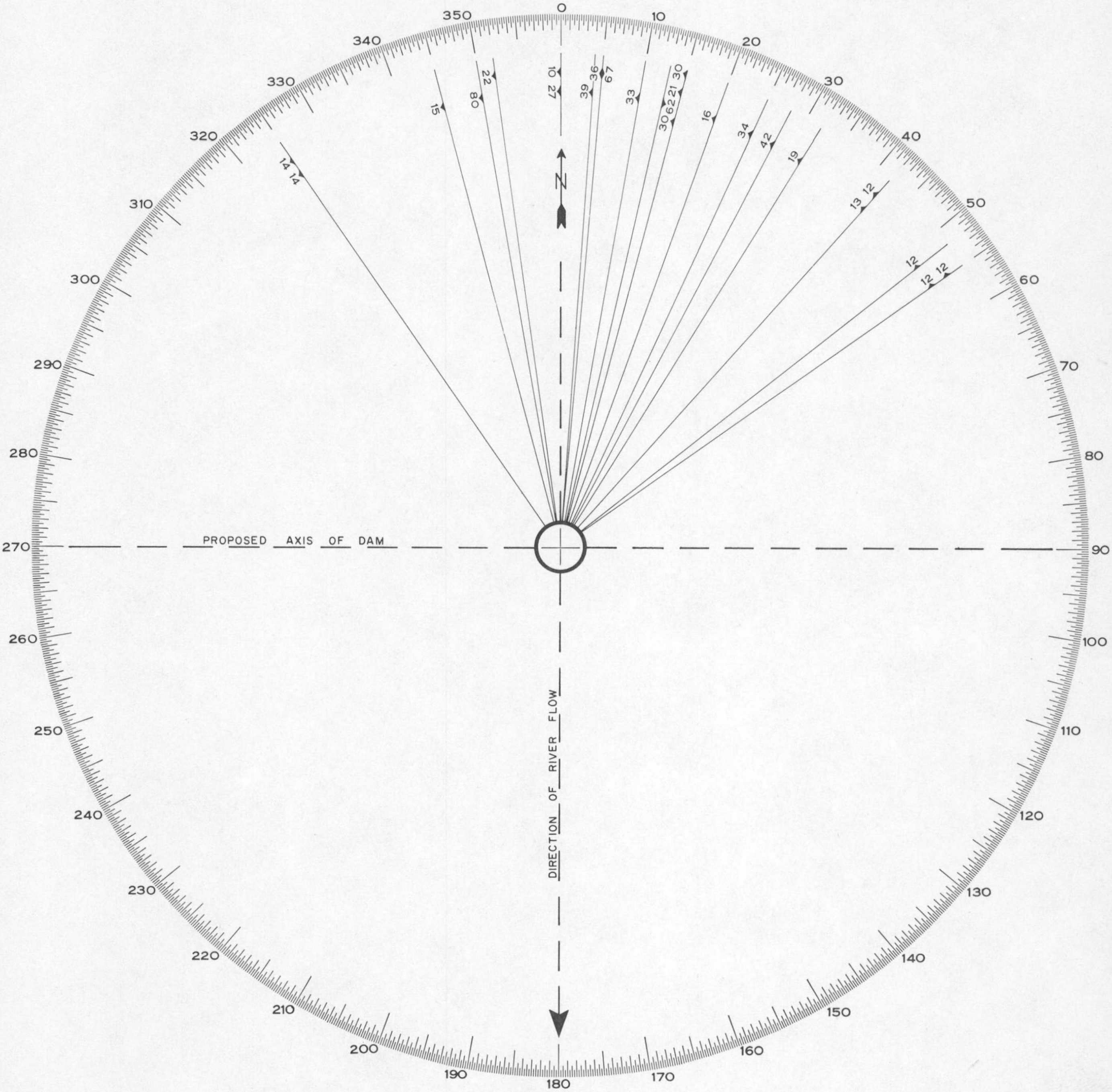
JOINT ROSETTE

The above illustration presents diagrammatically the direction and dip of the jointing in bedrock exposed at Liard Canyon (upper) dam site



SHEAR ROSETTE

The above illustration presents diagrammatically the direction and dip of the shearing in bedrock exposed at Liard Canyon (upper) dam site



BEDDING ROSETTE

The above illustration presents diagrammatically the direction and dip of the bedding in bedrock exposed at Liard Canyon (upper) dam site the river at angles from zero to 50 degrees. Frequently the surfaces of the shear planes are smooth and slickensided. They are usually tightly closed so that water seepage is negligible.

Quality of Bedrock

Bedrock conditions at the Upper site at Liard Canyon indicate it would be suitable for a masonary dam. The most competent rock exists in the centre part of the map-area where little faulting or folding occurs. Bedrock here consists of grey to black, laminated shale with narrow interbeds of fine-grained, grey sandstone.

Engineering Considerations

Depth of Overburden

Bedrock is exposed almost continuously in the canyon walls along both sides of the river. Overburden here consists of a thin deposit of talus and residual soil mixed with small quantities of silt, sand and gravel which have slumped from the terraces. It is nowhere believed to be more than 10 feet in thickness. Overburden covering the terrace east of the canyon is also believed to be thin. Test pits put down on the terrace west of the canyon encountered till beneath 3 to 4 feet of glacio-fluvial material. Overburden here may be relatively thick although bedrock is exposed in some places on the upstream part of the terrace. There is no information regarding the thickness of overburden beneath the river. Test borings will be necessary here to determine the elevation of bedrock surface. Drilling in Liard Canyon will be a dangerous, expensive task. It can best be done during periods of low water probably in the latter part of August and throughout September.

Abutments and Foundations

Bedrock exposed in the Upper site at Liard Canyon is relatively competent and is believed suitable as abutment and foundation material. Any diversion tunnel driven through these rocks would have to be lined, at least in part. The shallow dip of the bedding into the right abutment may cause slides if the dips are flatter than the slope of the excavation face. The soundest rock is exposed at the centre of the area mapped. Here, only a small amount of talus exists and little loose material will have to be removed before fresh, solid rock against which concrete can be placed will be obtained. The permeability of the rock should be the same on both sides of the canyon. Seepage will be confined chiefly to any fault zones that might occur in the walls. These rocks are relatively insoluble and it is doubtful if caverns or underground solution channels exist in them. Grouting may not be necessary except in the fractured rock associated with the faulting.

Construction Materials

Aggregate

The glacio-fluvial sand and gravel which occurs on the terraces above the canyon walls on both sides of the river is not believed suitable as aggregate. The material consists of fairly well graded, silty, sandy gravel containing rounded to semi-rounded boulders up to 24 inches in diameter. Many of the cobbles and boulders are porous, volcanic rocks similar to those located at the Fort Selkirk site on Yukon River. Rocks of this type are deleterious in aggregates.

Extensive deposits of glacio-fluvial sand and gravel occur east of the site along Alaska Highway and in the vicinity of the community of Watson Lake Wye some 5 miles north. Pit-run gravel from these deposits has been frequently used as aggregate in concrete footings and walls during construction of local buildings. About 25 per cent (by volume) of the rock fragments in the gravel is greater than 4 inches in diameter. This portion of the material is usually screened off before the gravel is used as aggregate. Unlike the gravel at the site this material does not contain fragments of porous, volcanic rock and consequently produces more satisfactory aggregate.

Sample No. 52 consists of sandy gravel used as aggregate during construction of the concrete footings and walls for a new school at Watson Lake Wye. The concrete was placed during August and September, 1961.

Similar gravel is exposed in several borrow pits along Alaska Highway. It is usually passed through a 4-inch screen and the material passing is crushed to 1-inch size and used in Highway maintenance.

There is little information concerning the thickness of the glacio-fluvial deposits in the area. At the site about 4 feet of the material overlies till whereas, at Watson Lake Wye, water well drillers report up to 50 feet of gravel. The gravel exposed in known pits along the Airport Road and Alaska Highway ranges in thickness from zero, in places where the underlying till has reached ground surface, to 30 feet.

Grain size analyses curves for several representative samples of potential aggregate are included at the end of this report. The samples were taken from glacio-fluvial deposits located near Watson Lake Wye and along Alaska Highway. The curves were prepared in the Soils Laboratory of the Water Resources Branch in Vancouver.

Impervious Material

The till which underlies the glacio-fluvial sand and gravel throughout the area should be investigated as a source of material suitable for the impervious core of a rolled earth dam. The quantity available is unlimited. Till was encountered in several test pits put down along the British Columbia - Yukon Territory boundary west of Liard River. It is also exposed in a small borrow pit on the east side of the Airport Road about 3 miles north of Watson Lake Wye and in the foundation excavations for a new motel at mile 635.2, Alaska Highway.

Pervious Material

Material suitable for the pervious shells, filters or drains of an earth dam can be obtained from the gravel deposits described under the aggregate heading. The gravel would have to be washed, screened and reblended to obtain the coarse, granular material required.

Riprap and Rock Fill

Bedrock exposed at the site will not provide suitable riprap or rock fill. The most accessible source of material from which satisfactory riprap could be obtained is the talus derived from granitic rocks exposed near Rancheria at mile 707.4, Alaska Highway. The rock fragments are roughly squared, durable and have a relatively high specific gravity. The major defects in using this material as riprap are the small size of the rock fragments and the long haulage distance along Alaska Highway to the site (about 80 miles). An extensive talus made up of fragments of porous, volcanic rocks occurs at mile 707.7, Alaska Highway. These rocks are less durable and have a lower specific gravity than the granite and consequently will provide less satisfactory riprap. It has been suggested[1] bedrock exposed along Liard River downstream from the canyon be examined as a possible source of riprap. Precambrian rocks consisting of blocky sandstone occur along the river immediately below the mouth of Irons Creek. Another source of riprap might be a blocky, thick-bedded, dolomitic rock which is exposed along the river about 20 miles downstream from Contact Creek.

Groundwater

There is little information concerning groundwater conditions in the area about the proposed dam site. Seepages were not observed in either wall of the canyon and there was no indication they have occurred in the past. The terraces above the canyon are very dry. Swamps or ponds with open water do not exist. Groundwater was not encountered in any of the test pits put down. Accurate information concerning the water table can only be obtained by installing groundwater observation holes and measuring them at regular intervals.

Frozen Ground

Frozen ground was not encountered in the area about the proposed dam site.

Comparison between Upper and Lower Sites, Liard Canyon

The results of the investigation indicate that, geologically, the Upper site at Liard Canyon is more favourable for construction of a dam than the Lower.

1. Location: Both sites are located in Liard Canyon. The Lower site is about 1 mile downstream from the Upper.

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[1] H. Gabrielse: personal communication.

2. Accessibility: The sites are about a mile west of Alaska Highway. They are both easily accessible from the Highway.

3. Overburden: Overburden at the two sites is the same. It consists of a thin layer of glacio-lacustrine silt overlying glacio-fluvial sand and gravel which in turn overlies a dense, silty, sandy till. Bedrock underlies the till. The relative thicknesses of the unconsolidated deposits vary considerably throughout the two sites.

4. Bedrock: Bedrock exposed at the two sites is the same. It consists chiefly of hard, laminated shale with thin interbeds of sandstone and limestone. In places bedrock is badly faulted, tightly folded and contorted. Permeability is negligible although some leakage might occur at the Lower site through the fractured rock associated with the faulting. The bedding surfaces are generally tight.

5. Quality of Bedrock: Bedrock at the Upper site is more competent and structurally sound than at the Lower. There is less faulting and folding and considerably less weathering.

6. Construction Materials: With the possible exception of rip-rap and rock fill there is no shortage of construction materials at either site. Because of the proximity of the sites to one another the same sources of materials could be used for both sites.

7. Frozen Ground: Grozen ground is not believed to be common at either site. It was encountered in one locality at the Lower site but in no place at the Upper site.

Further Investigations - Conclusions

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 upon a rapid, field examination of the soils and bedrock exposed at the site. The test pits put down seldom reached depths greater than 3 feet.

The results of the investigation indicate the Upper site is more acceptable than the Lower. However, considerable more information is required before the suitability of either site can be determined. Test borings should be put down to ascertain the elevation of bedrock surface beneath the present river and the thickness of overburden covering the terraces above the canyon walls. The borings should penetrate 15 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 water table noted. The physical characteristics of bedrock exposed at the site should be determined; especially in regards to its shear strength and sliding tendencies.

Chemical Analyses of Liard River Water

During the 1961 field season samples of Liard River water were taken at the Upper site at Liard Canyon and at the Contact Creek site some 40 miles downstream. The samples were analysed for their mineral content by the Industrial Waters Sections, Mines Branch, Department of Mines and Technical Surveys, Ottawa. The results of the analyses are included on the following page. For comparison an analysis of Liard River water taken in 1952 from the bridge at mile 642 Alaska Highway is included. The reported value of the turbidity should be considered only as indicative. Flash floods may cause a rapid increase in the sediment load. A proper sediment study, therefore, requires regular sampling, often in the case of flash flooding, at hourly intervals.

Chemical Analyses of Liard 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 $CaCO_3$
Liard River at Watson Lake Wye*	Aug. 21, 1952	41,400 c.f.s.	7.9		26.3	5.6	1.0	0.4	0.06	0	98.6	9.5	0.7	0.1	Tr.	0.9	106
Liard Canyon (upper site); centre of river; 12 inches beneath surface of water	Aug. 27, 1961	Low	7.8	6.0	26.3	6.8	1.3	0.6	0.07	0	102.0	11.0	0.4	0.05	0	0.4	93.8
Contact Creek site; centre of river; 12 inches beneath surface of water	Aug. 30, 1961	Low	7.6	5.8	28.2	6.6	1.3	0.6	0.07	0	107.0	11.7	0.3	0.02	0	0	97.8

* Thomas, J.F.J.: Mackenzie River and Yukon River Drainage Basins in Canada, 1952-52; Mines Branch, Can; Water Survey Rept. No. 8, 1957, p. 48.

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 coarse and fine aggregate based upon a 6-inch maximum size.

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

(c) Curves showing individual percentages of the coarse and fine fraction retained on each screen or sieve size. For these purposes the sample is divided at the No. 4 sieve into coarse and fine fractions. Samples Nos. 47 and 49 were analysed as potential impervious material, the remainder as potential aggregate.

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)	Permeability* (cm. per. sec.)
47	On terrace 700 feet west of Liard River at centre of map-area; 36 inches below ground surface	Dense, silty, sandy till; numerous cobbles up to 6 inches in diameter; no weathering	18 inches of silt	No information	Extensive; probably constitutes most of the material forming the terrace	10^{-6}
49	Borrow pit on east side of Airport Road about 3 miles north of Watson Lake Wye; sample taken in pit face 10 feet below ground surface	Fairly dense, gravelly till; sub-rounded boulders up to 18 inches in diameter; minor weathering in upper 12 inches of material; numerous, black, chert pebbles; no sand or gravel lenses in pit face	12 inches of silt	15 + feet	Length: 400+ feet Width: 300+ feet Depth: 15+ feet	Similar material exposed in the sewer excavation for a new motel at mile 635.2, Alaska Highway; here it underlies 12 inches of gravel

* Permeability computed in the field using a Soiltest Permeameter, Model K-620.

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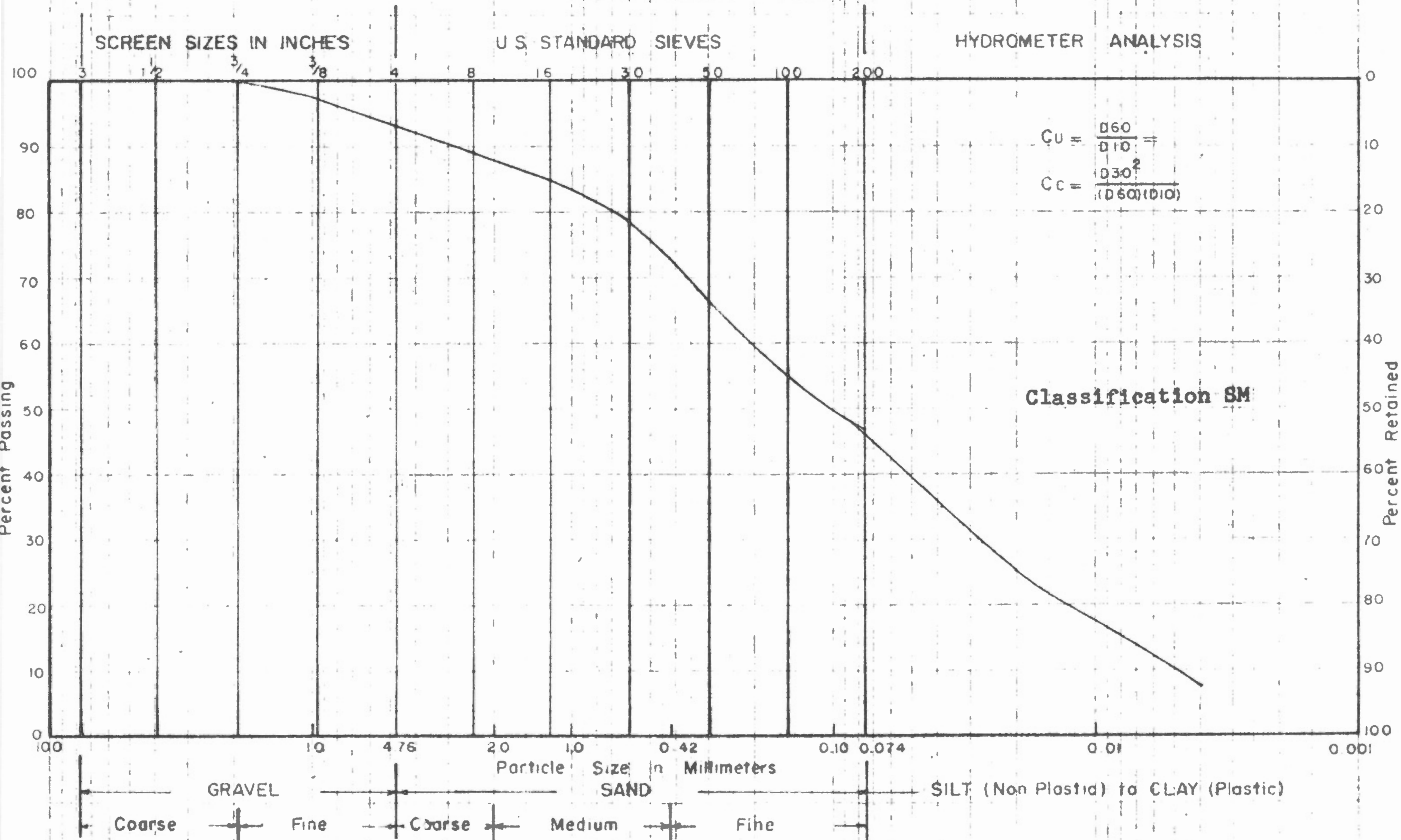
WATER RESOURCES BRANCH

GRAIN SIZE ANALYSIS



Site Upper Site, Liard River Pit Sample 47 Depth Plotted

PLAN

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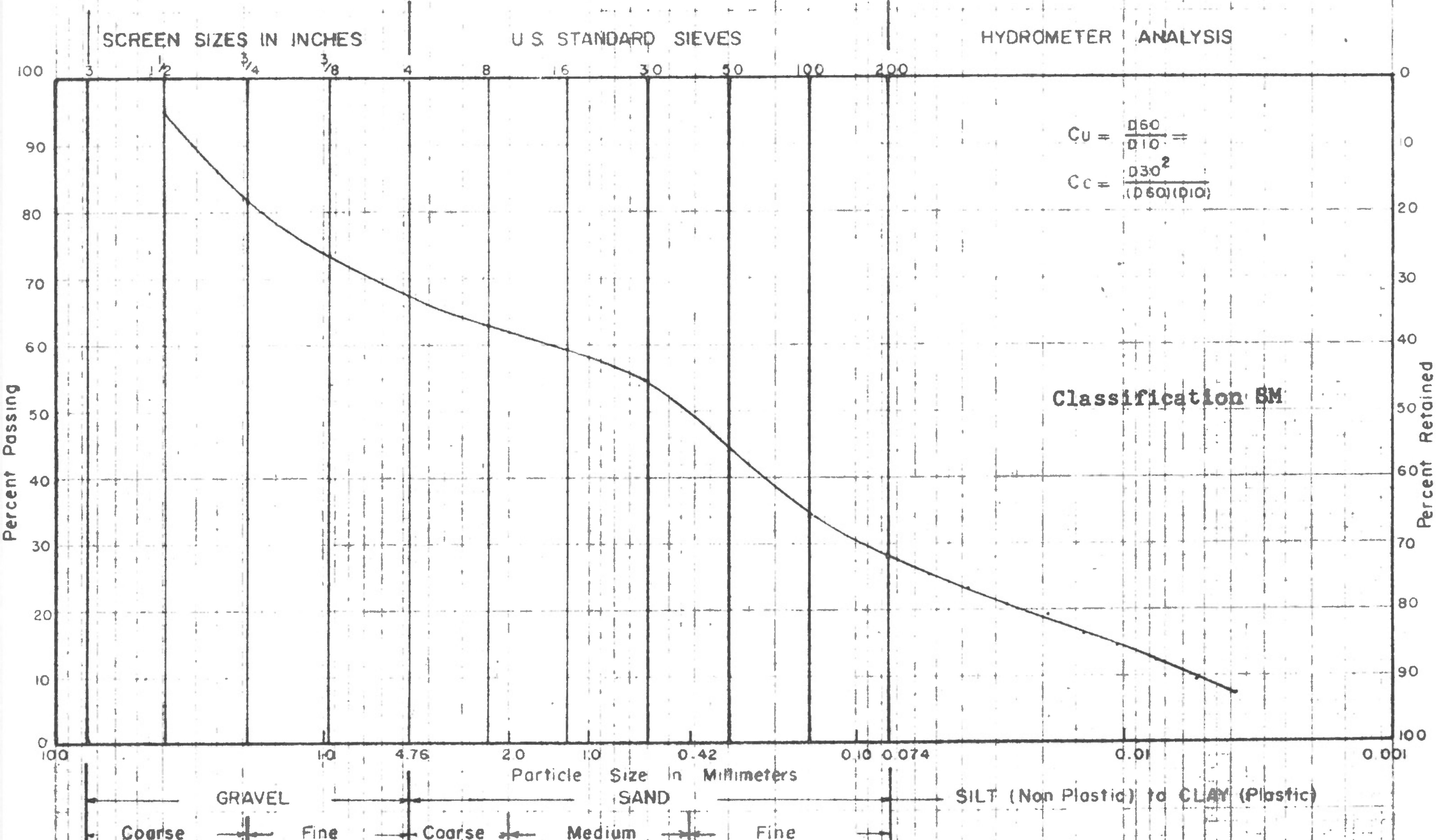
WATER RESOURCES BRANCH

GRAIN SIZE ANALYSIS



Site Upper Site, Liard River Pit Sample 49 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
48	On British Columbia-Yukon boundary 2 miles west of Liard River; 3 feet beneath ground surface	Well graded, sandy gravel; numerous cobbles to 8 inches in diameter; a white lime coating on most gravel-size particles; darker colour due to organic impurities; very little weathering; about 1 per cent of material consists of shale and black chert. Pebble and Cobble Lithology Igneous (granitic, volcanics, quartz) - 30% Sedimentary (sandstone, limestone) - 60% Metamorphic (schist) - 10%	2 + feet of silt	10 + feet	Unlimited	Extensive deposit of glacio-fluvial material; would require construction of a 2-mile road along British Columbia - Yukon boundary
50	Foundation material for new school at Watson Lake Wye; on Airport Road; 4 feet below ground surface	Fine- to medium-grained, poorly graded sand; 12-inch interbed with gravel of sample No. 51; no dry strength	3 feet of gravel as sample No. 51	12 inches	Small	Part of extensive glacio-fluvial deposit in area about Watson Lake Wye and along Alaska Highway

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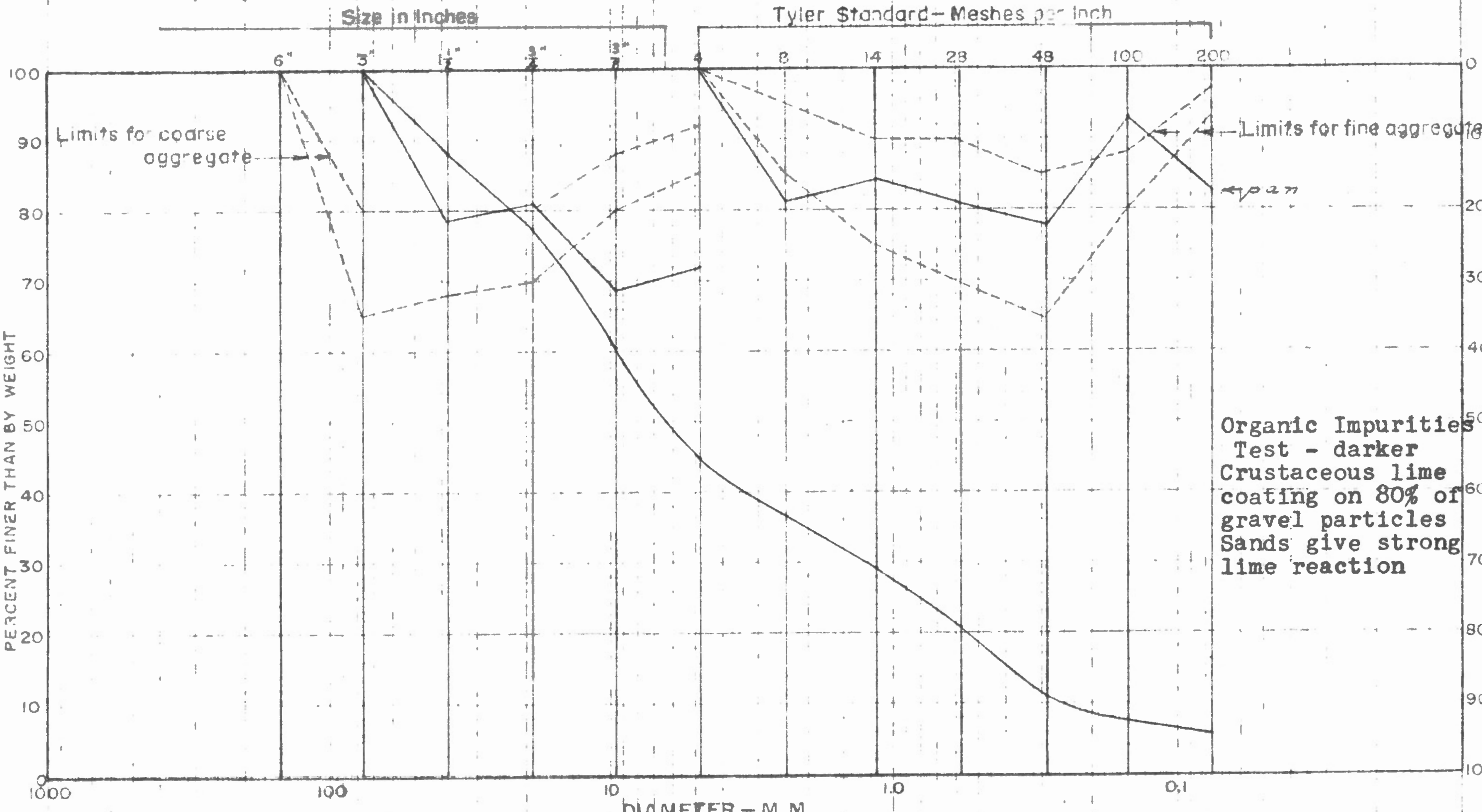
GRAIN SIZE ANALYSIS For CONCRETE AGGREGATE RECONNAISSANCE



Site Upper Site, Liard River Hole No. Sample No. 48 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
51	Foundation material for new school at Watson Lake Wye; on Airport Road; 3 feet below ground surface	Fairly well graded, sandy gravel; very little silt or clay; rounded cobbles up to 8 inches; stratified; weathering in upper 6 inches <u>Pebble and Cobble Lithology</u> Igneous (granite) - 50% Sedimentary (limestone, sandstone) - 35% Metamorphic (gneiss, quartzite) - 10% Shale - 5%	None	10 + feet	Unlimited	Sample taken 12 inches above sample No. 50
52	Borrow pit on Airport Road about 300 feet north of new school at Watson Lake Wye; 6 feet below ground surface	Fairly well graded, sandy gravel; very little silt of clay; numerous cobbles up to 6 inches in diameter; no weathering	None	10 + feet	Unlimited	Material passing 4-inch screen used in concrete foundations for new school

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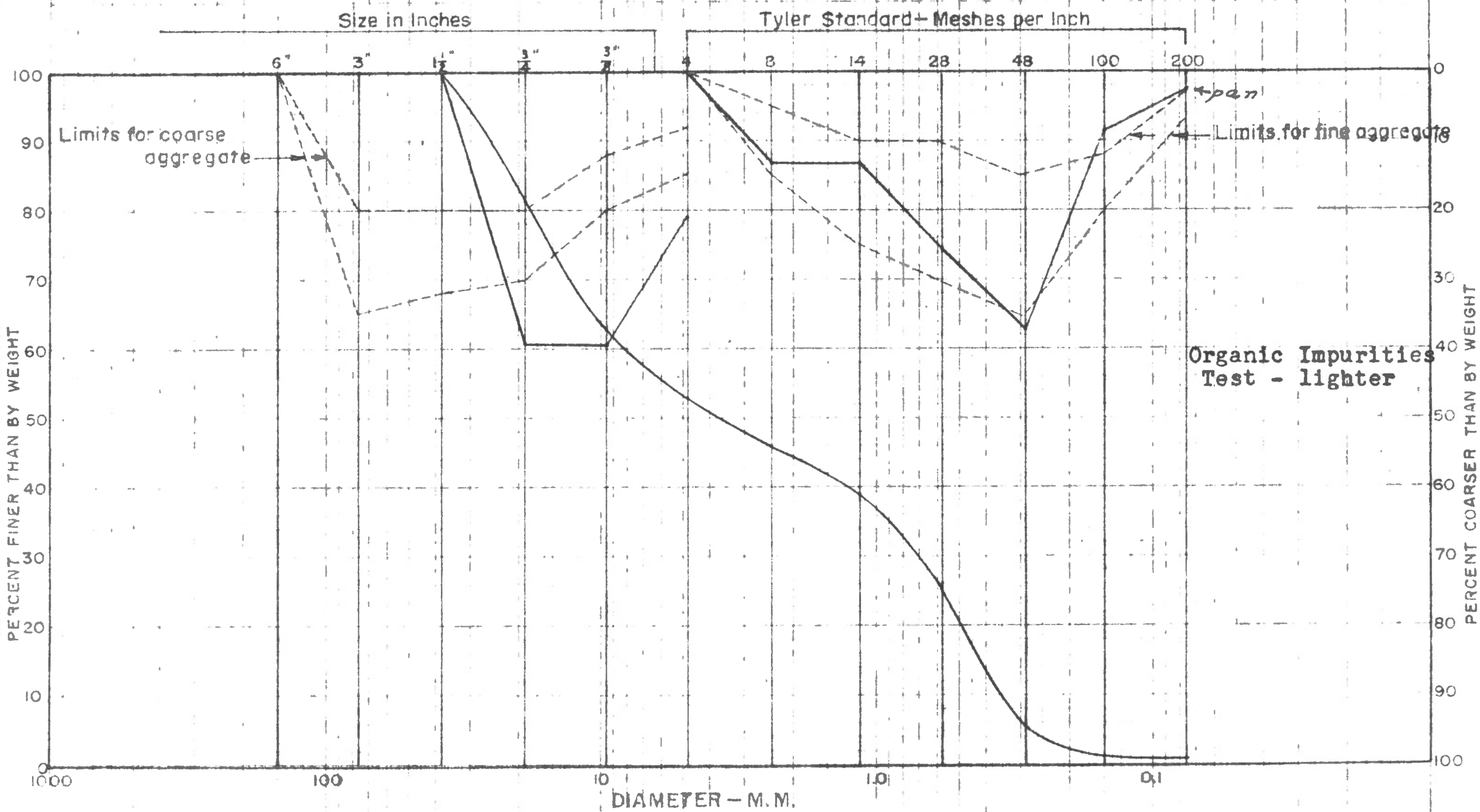
WATER RESOURCES BRANCH

GRAIN SIZE ANALYSIS For CONCRETE AGGREGATE RECONNAISSANCE



Site Upper Site, Liard River   Hole No.   Sample No. 51   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
53	Large borrow pit on north side of Alaska Highway at mile post 640; 10 feet below ground surface	Well graded, sandy gravel; no clay or silt; stratified; a few boulders up to 24 inches in diameter, chiefly porous basalt; considerable weathering in upper 2 feet Pebble and Cobble Lithology Igneous (granite) - 50% Sedimentary (sandstone, limestone) - 30% Metamorphic (gneiss, quartzite) - 10% Shale - 8% Chert - 2%	12 inches of silt	25 + feet	Unlimited; about 30,000 c.y. removed as of September 1961	Material passing 12-inch screen is crushed to 1-inch size and used as surfacing material on Alaska Highway
56	Cut on north side of Alaska Highway at mile 647.7; 15 feet below top of cut and 20 feet above road; 3 feet below ground surface	Fairly well graded, sandy gravel; minor silt and clay; subrounded boulders up to 12 inches in diameter; a few porous, basalt cobbles; sand-size particles are chiefly quartz and quartzite; slight weathering in upper 2 feet	None	35 + feet	Unlimited	Deposit is chiefly coarse-grained sand; it extends along Highway for about one mile

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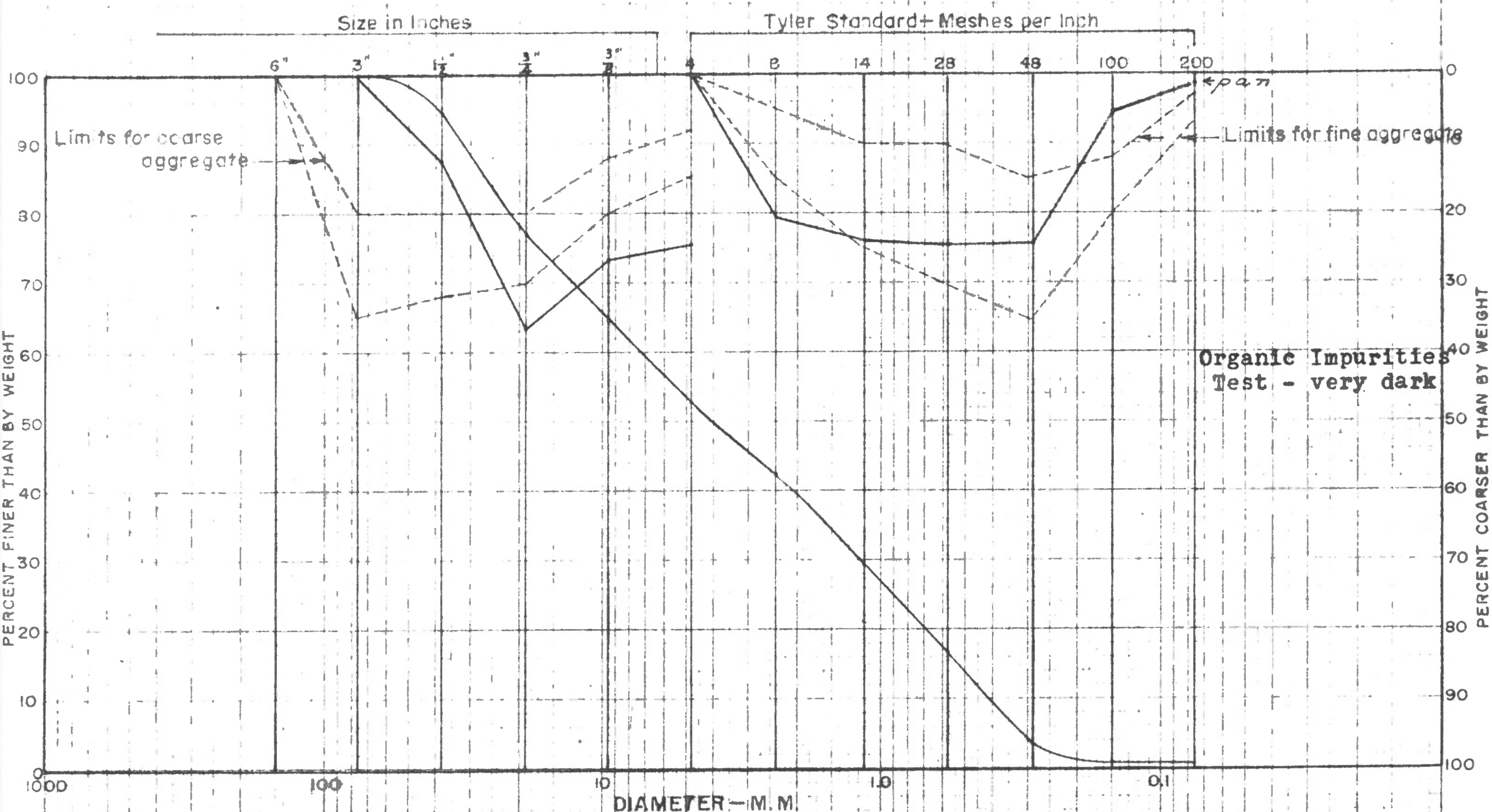
WATER RESOURCES BRANCH

GRAIN SIZE ANALYSIS For CONCRETE AGGREGATE RECONNAISSANCE



Site Upper Site, Liard River Hole No. Sample No. 53 Depth Plotted Date

PLAN No. 100 — 13

DEPARTMENT OF NORTHERN AFFAIRS & NATIONAL RESOURCES
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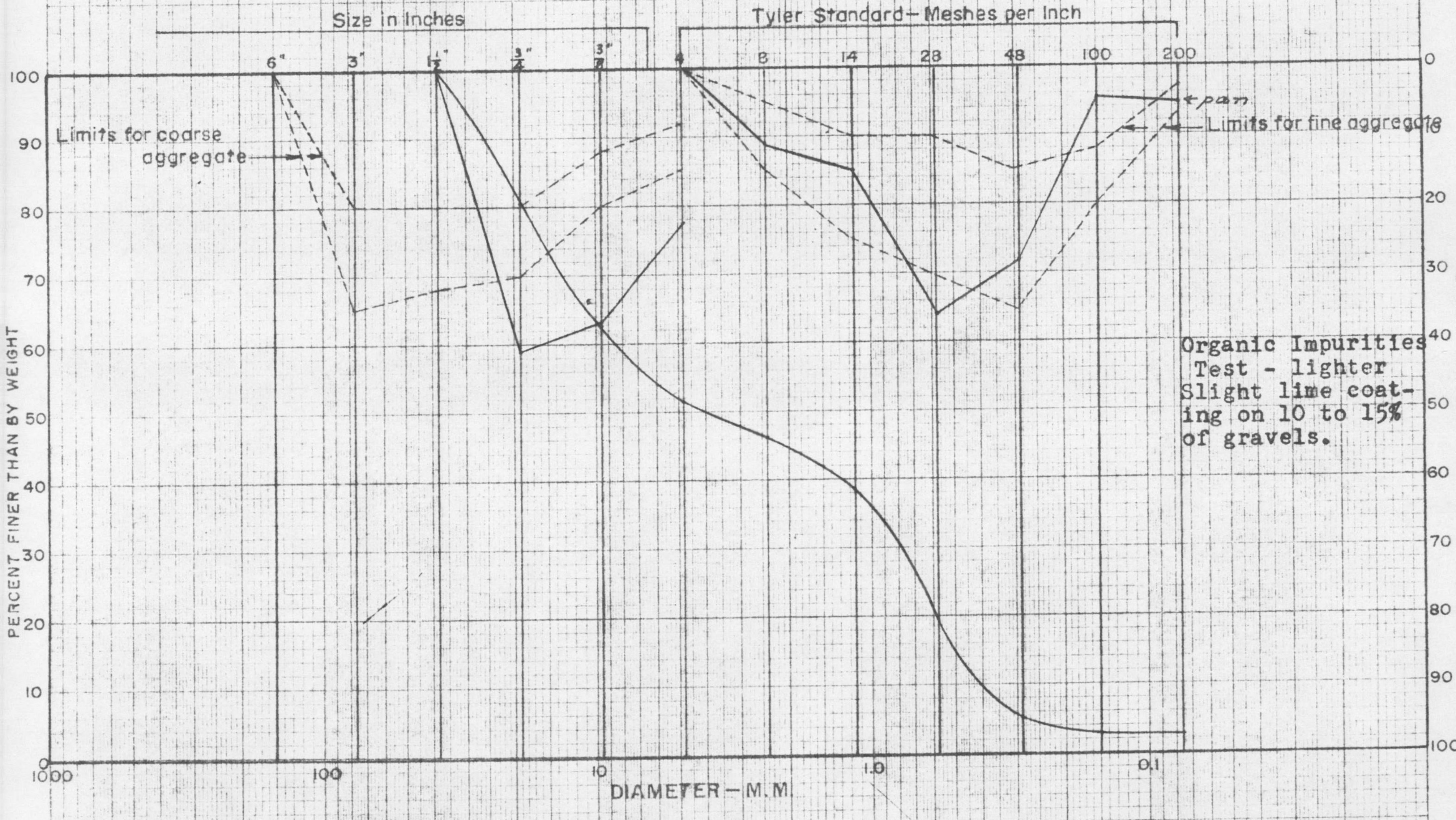
GRAIN SIZE ANALYSIS For CONCRETE AGGREGATE RECONNAISSANCE



Site Upper Site, Liard River Hole No. .... Sample No. 56 .... Depth .... Plotted .... Date ....

PLAN No. 100 – 13

Plate 1

Looking down Liard River
into the upstream end of
Liard Canyon.
G.S.C. 3-8-61

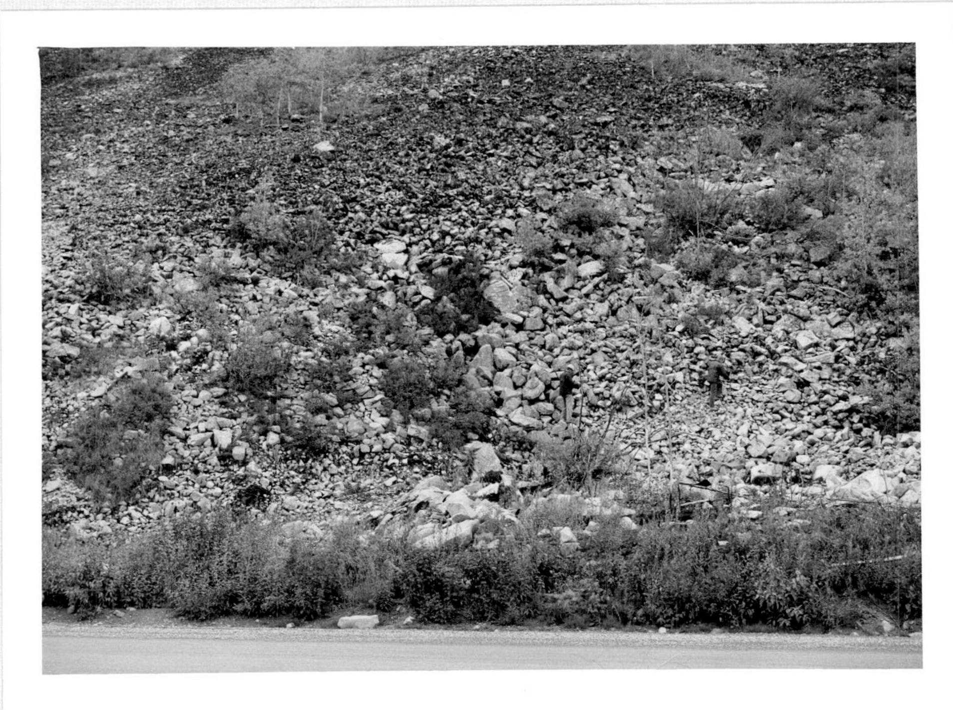


Plate 2

Potential riprap; talus
derived from granitic
rocks at mile 707.4,
Alaska Highway
G.S.C. 9-7-61

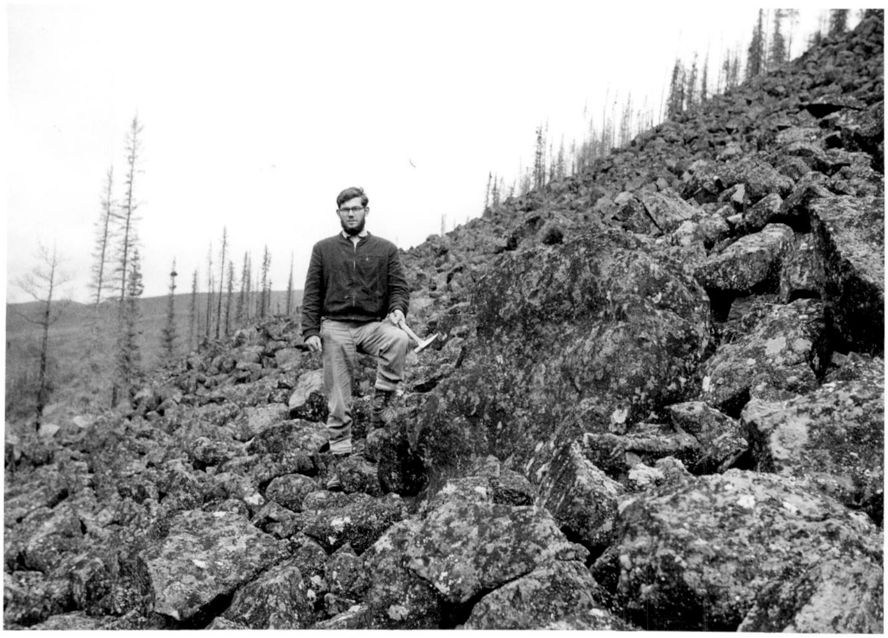
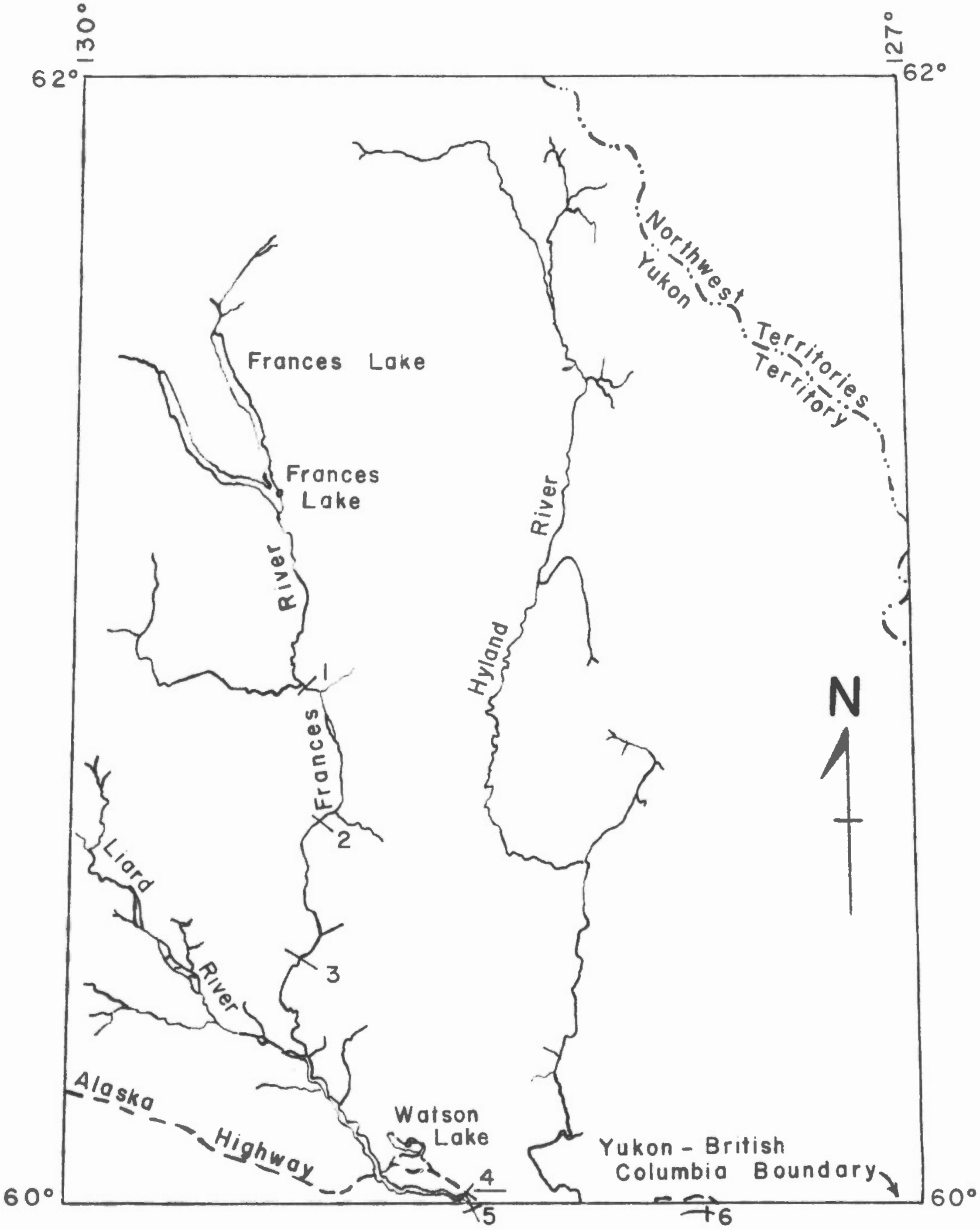


Plate 3

Potential riprap; talus derived from volcanic rocks at mile 707.7, Alaska Highway
G.S.C. 9-8-61



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