NORTHERN TERRITORY GEOLOGICAL SURVEY

REPORT GS 79/10

GEOLOGICAL REPORT ON THE FEASIBILITY OF A DAM ON THE HUGH RIVER AT BIRTHDAY GAP

(Hermannsburg 1:250 000 Sheet SF 53-13)

by

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DEPARTMENT OF MINES & ENERGY

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CONTENTS

APPENDIX

FIGURES

INTRODUCTION

1.1 Aim

The function of this report is to collate the geological investigation activities that have been directed at the Birthday Gap dam site on the Hugh River, so as to delineate any geological factors that may affect the feasibility of the site for a high or low level reservoir development.

1.2 Location and Access

The locality referred to as Birthday Gap is situated on the Hugh River approximately fifty five kilometres west of Alice Springs and about five kilometres north-northwest of Boggy Hole at grid reference point 660 041 on the Hermannsburg SF 53-13 1:250 000 Sheet area (Fig.No.1). Access is by sealed road for 55 km and by unformed track for 6 km.

1.3 Investigation History

The site was inspected by O.G. Fruzzetti in 1974 and a report was prepared recommending a future exploratory drilling program. This report contains a summary of the geology and a photo-interpretation sketch map.

J.C. Beal did some further work and produced a report in 1979 (Beal, 1979). Some joint orientation measurements were taken and tabulated.

Following a request from the Water Resources Branch of the Department of Transport and Works, a drilling program was commenced in March 1979 under the direction of Dr B. Weber. Two drill holes were completed and water pressure tested to determine permeability. Both of these holes were in quartzite and were of a total depth of 23.75 m. A systematic joint analysis was undertaken.

In September 1979 the final stage of investigations covered in this report was commenced by Engineering Geologist R.J. Purser with the assistance of Technical Assistant Mr B. White. This consisted of detail geological mapping at a scale of 1:500, reservoir photogeology interpretation shallow refraction seismic traversing and a reconnaissance f construction materials. Samples were taken and subjected to a number of index tests and a mechanical sieve analysis.

1.4 Summary of Conclusions

a) The site is feasible for a high level development.

b) The site may not be suitable for a low development due t the apparent deep weathering in the proposed spillway location.

c) Considerable grouting is required for any cut-off in the quartzite. This favours a high development and an upstream face design.

d) Materials: Earth core - The maximum possible reserv of suitable materials is 20,000 m^3 and thus inadequate for a high development.

Rockfill - A suitable quarry could be found in the gneiss northwest of the dam site.

Concrete Aggregate - There are adequate reserves of gravel and sand near the dam site but the sand is poorly graded and lacks fines.

e) Stripping to a stable foundation for rockfill will require about 2 m of material to be removed where as about 4 m of excavation should be expected for the plint

REGIONAL GEOLOGY

The Birthday Gap dam site lies in a gap in a quartzite ridge forming part of the Precambrian Arunta Complex.

The complex consists of medium to high grade metamorphic rocks including schist, gneiss, metaquartzite, amphibolite and is intruded by dykes of pegmatite and dolerite. (Refer to Hermannsburg 1:250 000 SF 53-13 geological Sheet).

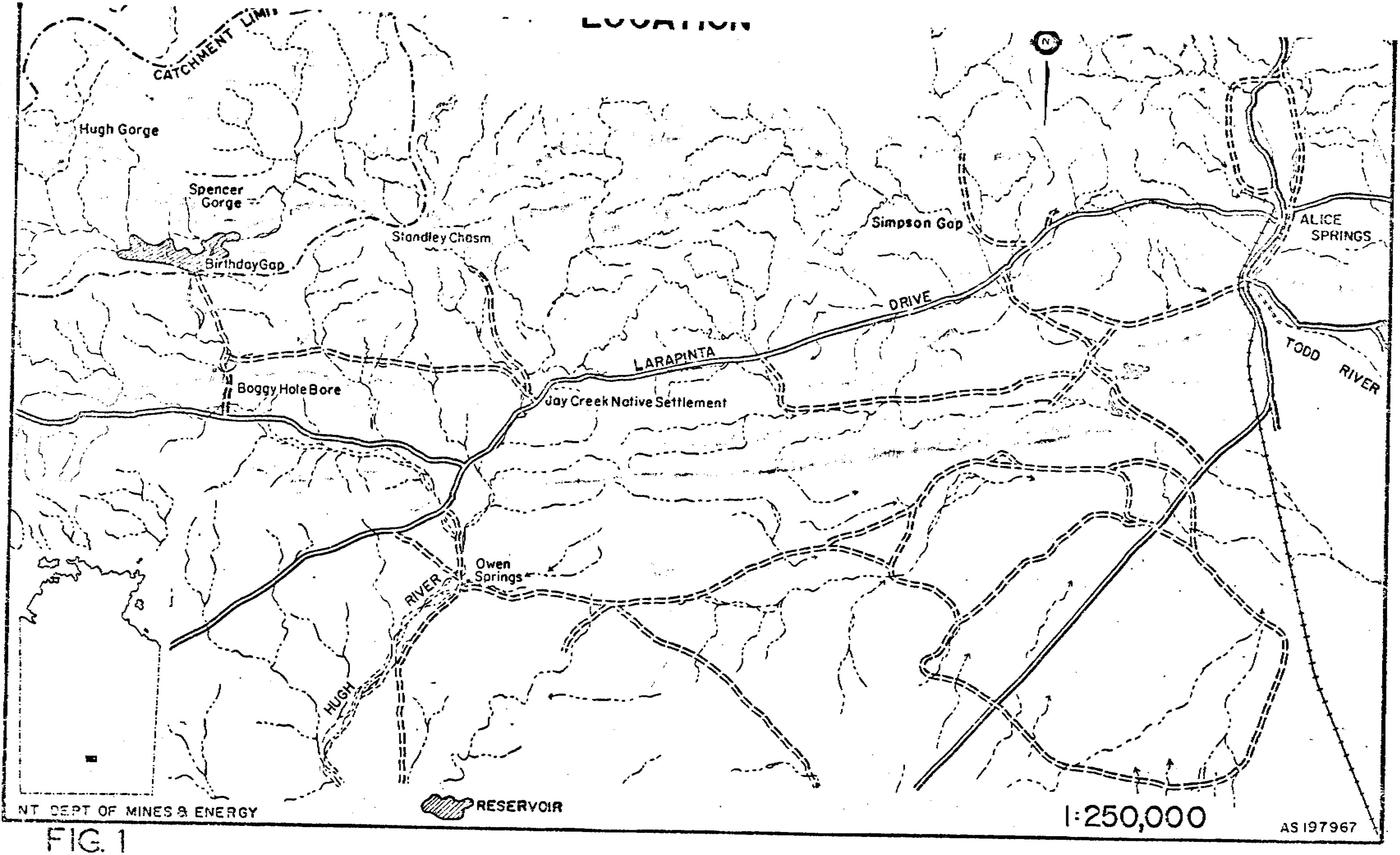

CATCHMENT LIMIT
Hugh Gorge
Spencer Gorge
Birthday Gap
Standley Chasm
Simpson Gap
N
ALICE SPRINGS
DRIVE
LARAPINTA
TODD RIVER
Boggy Hole Bore
Jay Creek Native Settlement
Owen Springs
RIVER
HUGH
NT DEPT OF MINES & ENERGY
RESERVOIR
1:250,000
AS 197967

FIG. 1

The complex has been faulted and sheared by a number of orogenic events leading to a complicated system of folded foliations and shears. To some extent the original sedimentary lithology of sandstone, shale and greywacke is preserved in the form of quartzite, schist and gneiss.

The Arunta Complex is bounded to the south by the Heavitree quartzite and to the north by Tertiary or Quaternary alluvium. Tertiary silcrete caps overlie some small areas of the Arunta Complex to the west of the dam site area (refer Appendix E1) and contain 10-15 m of silicified conglomerates, siltstones and sandstones. Larger Tertiary caps of similar material are found to the east near the Jay Creek Settlement.

Quaternary alluvium consisting of coarse, poorly graded sand and gravel, is largely confined to active stream channels.

DETAIL GEOLOGY

Birthday Gap dam site is situated in a metamorphic sequence of gneiss, quartzite and schist of the Arunta Block which has been injected with dykes of dolerite.

3.1 Gneiss

The gneiss found at Birthday Gap dam site is found on both sides of the quartzite ridge and occupies most of the reservoir area. The majority of outcrops are moderately weathered, but fresh outcrop occurs in the river bed about 3-4 m below the upper weathered rock surfa seen in the river banks. Superficial sandy silty soil (GM -SM is developed over the remaining areas to a depth of 1-2 m (refer to section 5.3 for typical properties).

The rock is foliated coarse grained granitic gneiss with porphyroblasts of potassic feldspar to 25 mm. It locally contains bands of quartzite and schist and occasional aplite lenses parallel to the foliation. (077 75M mag. The joint spacing, other than parallel to the foliation, is very broad and even the foliation joints are widely spread compared to the quartzite and schist.

Below the weathering horizon this rock type is likely to be very massive and hydrologically tight. Although no tests have yet been done in this material it is expected that grouting requirements, for sections of the dam plinth on this rock type, to be minimal.

3.2 Quartzite

The quartzite ridge is the dominant topographic feature of the site and the resistance to weathering of quartzite is the prime cause of this. The quartzite oute c-r narrows towards the east to only 30 m wide on the eastern limit of the detail mapped area as compared with 80 m wide on the western limit. The rock appears either as prominent outcrops or semicovered by coarse angular talus. In places, on the eastern ridge, the massive outcrop is capped by what appears to be completely recemented quartzite talus which may be related to the remnant silcrete caps found in the reservoir area. The quartzite is almost completely microcrystalline quartz with contamination varying the colour. The foliation becomes very prominent with fractures spaced down to 20-30 mm on the southern edge. The quartzite appears to grade into the schist with increasing foliation and accessary minerals.

No soil has been developed over the rock due to the lack of any chemically degradable minerals thus the rock is effectively fresh from the surface. Jointing is well developed (refer Plate 2) and tends to lack adhesion. From the drilling results high permeabilities should be expected at least in the upper 5-10 m. After stripping of superficial loose materials the quartzite will make a sound nonsettling foundation but will require significant grouting to reduce permeability.

3.3 Schist

The schist occurs as a unit immediately south of the quartzite ridge and extends to a contact with the gneiss. Like the quartzite its outcrop area narrows towards the east. The rock is mostly covered by soil and talus and the outcrops are generally highly weathered, friable and fissile. The schist is finely laminated (078°mag 75°N) and contains a large percentage of micaceous minerals. Some areas contain bands of segregated microcrystalline quartz parallel to the schistosity which are more resistent to weathering, resulting in a noticeable change in slope. Where the schist contacts the dolerite dyke, on the left bank, a contact aureole occurs about one metre wide. This narrow hornfels zone is harder and lacks the schistosity of the rest of the unit.

The schist appears to be weathered to a depth of 3-5 m (refer Appendix E.5) of which most is HW-MW rock. Excavation below this order of depth would require blasting. To found the downstream rockshell 2 m of stripping will be required to be sure of a nonsettling, stable foundation.

3.4 Dolerite

No actual outcrops of dolerite are present in the mapped area, however surface boulders of dolerite coincident with a prominent aerial photo lineament was interpretated to indicate the presence of a 17 metre wide dyke on the left abutment, to the south of the quartzite. A narrow gap in the quartzite ridge colinear with the inferred location of the vertical dyke is interpreted as confirmation that the more easily weathered dolerite formerly filled the gap.

Surface boulders of dolerite on the northern side of the quartzite ridge are scarce due either to the dyke pinching out or to an increasing quartzite talus cover.
Other dykes of dolerite are found outside the mapped area and are shown on the reservoir geology map (Appendix E.1).

Seismic investigations (SLF/0-50) indicate that the dolerite is weathered to a depth of 10-12 m and excavations for the plinth will need to be deep in the area of the dyke assuming that the dyke does extend to the north of the quartzite ridge. To found the rockshell about 3-4 m of dolerite will need to be removed. As no outcrops were observed no comment can be made regarding the jointing or probable leakage through this unit.

3.5 Unconsolidated Material

3.5.1 Alluvium

The alluvium near the dam site can be divided into three units. These are:

a) the active stream channel alluvium
b) silty and bank alluvium and the
c) high level older gravel and sand terrace northeast of the dam site.

The channel alluvium consists of coarse sand and gravel up to 4 m thick (based on seismic) immediately over fresh quartzite and gneiss. The gravel particles are generally subrounded with diameters up to 150 mm. The sand is very uniformly graded with 75% falling in the coarse sand fractions (Appendix C - sample BG/1/S1). The sand would be completely free draining. The shallow depth to rock indicates that the channel alluvium is transient and is probably replaced in major floods.

The silty sand bank alluvium appears to be about 2-3 m thick on the left bank and superficial on the right. Although no samples were taken it seems to consist of medium to fine sand with some coarse silt.

The terrace of older gravel and sand on the northern left bank area contains boulders up to 500 mm in diameter along with other sizes down to coarse sand. There are a number of outcrops of gneiss in the terrace which suggests that the material is fairly shallow. The terrace is flat and about 4-5 m above the active stream bed.

3.5.2 Talus

In the vicinity of the quartzite ridge talus covers a large area. This talus consists of angular blocks of quartzite with boulders up to 2 m in diameter near the ridge. There is a lateral grading away from the quartzite outcrop with gravel size particles most common 20 m away. There is little soil developed in the talus except for that contributed by the underlying gneiss, schist or dolerite. The depth of talus cover is highly variable with the greatest thickness near to the quartzite contact.

3.5.3 Residual Soils

Details of gneiss soils are contained in section 5.4. Other soils have not been subjected to sampling and testing but field observations are included here.

The soil developed over dolerite appears to be a reddish silty clay with large boulders. The dolerite weathers spheroidally and produces semispherical boulders which are left on the surface as soil is eroded. This surface armouring is misleading in that apparent rocky areas may be underlain by a significant thickness of soil and highly weathered rock.

The soil developed over the schist is a gravelly silty sand with a large percentage of micaceous material. Over much of the mapped area it is 'blended' or obscured with quartzite Talus.

3.6 Structure

3.6.1 Jointing

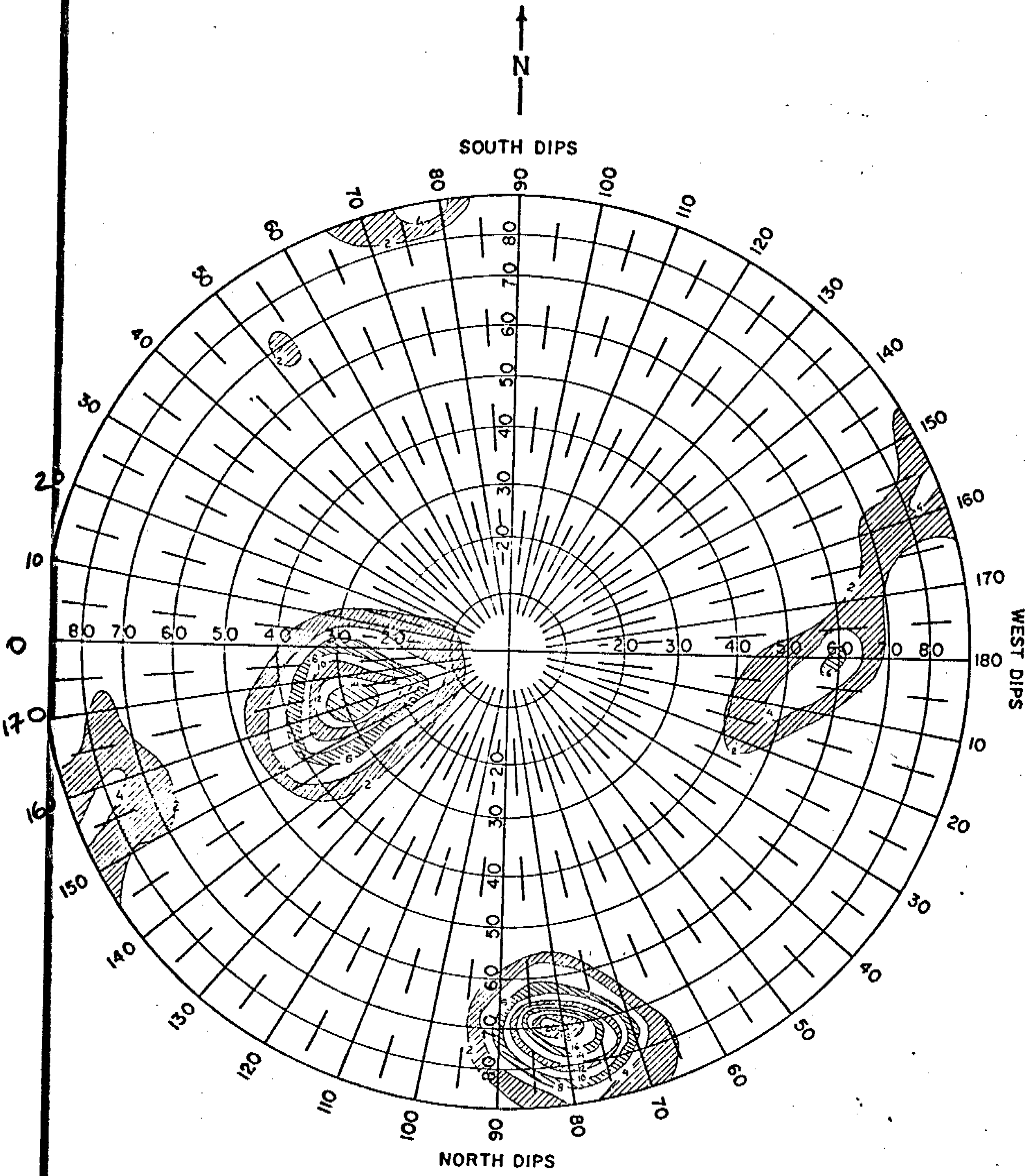
A systematic study of the jointing in the quartzite was conducted by Weber and the geometric distributions are presented in Figures 2, 3, 4 & 5.

The principal joint sets as defined by Weber are as below (refer Figs. 3,4 & 5 for equatorial projections).

TABLE 1

		Strike	Dip	Direction
Left Bank	set J1	080°	76°	S
	set J2	162°	27°	E
	set J3	168°	64°	W
	set J4	162°	80°	E
Centre	set J1	080°	73°	S
	set J2	161°	64°	E
	set J3	179°	46°	W
	set J4	161°	80°	E
	set J5	044°	54°	SE (very minor)
Right Bank	set J1	080°	75°	S
	set J2	161°	27°	E
	set J3	169°	65°	W
	set J4	161°	80°	E

No.2



SCHMIDT NET LOWER HEMISPHERE

Graduated for poles of planar elements

Read strike of plane along circumference in degrees east of north.

Read dip of plane along diameter.

N. T. GEOLOGICAL SURVEY

Project BIRTHDAY GAP

Location WHOLE SITE

No. in Sample 200

Discontinuity type JOINTS

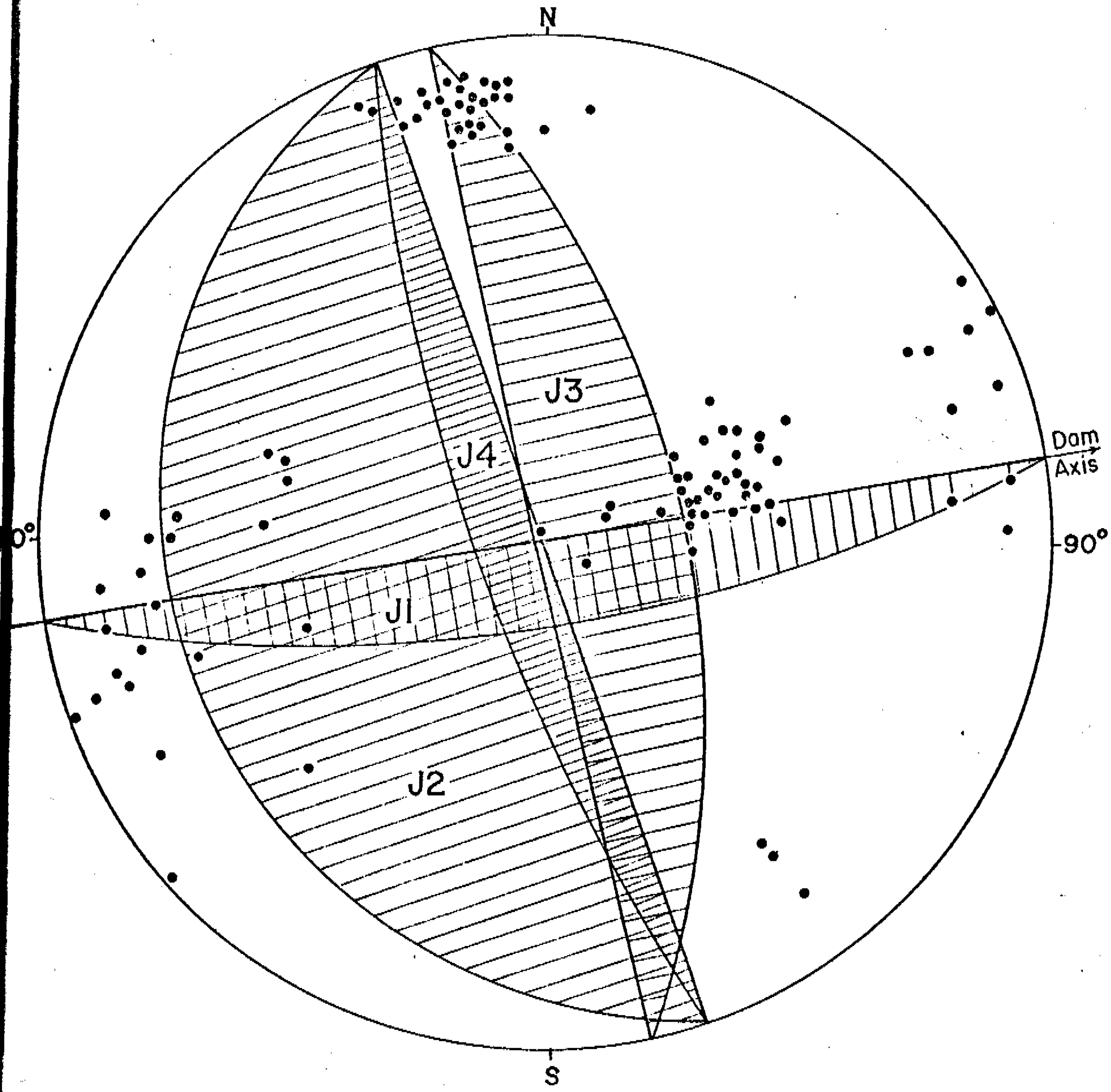
Contour type PERCENTILE

Geology	Drafting
Drn. R.J.P.	Tr. Av.O
Ckd.	Ckd.
Supv.	Supv.

No.3

BIRTHDAY GAP DAM SITE

JOINT DISTRIBUTION (Equatorial Equal Area Net)
LEFT ABUTMENT



Joint Pole

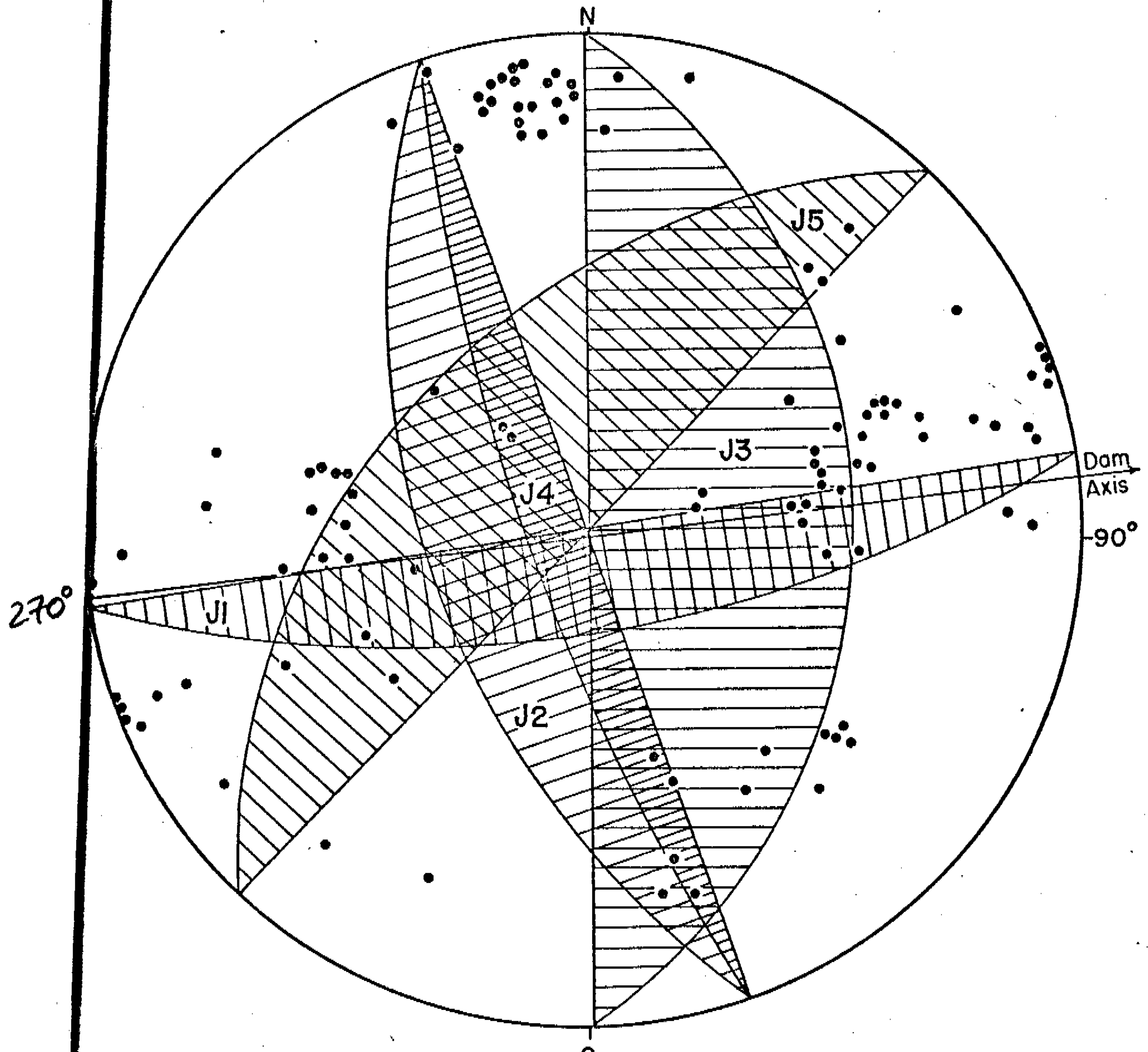
Joint System

.4

BIRTHDAY GAP DAM SITE

OINT DISTRIBUTION (Equatorial Equal Area Net)

RIVER SECTION



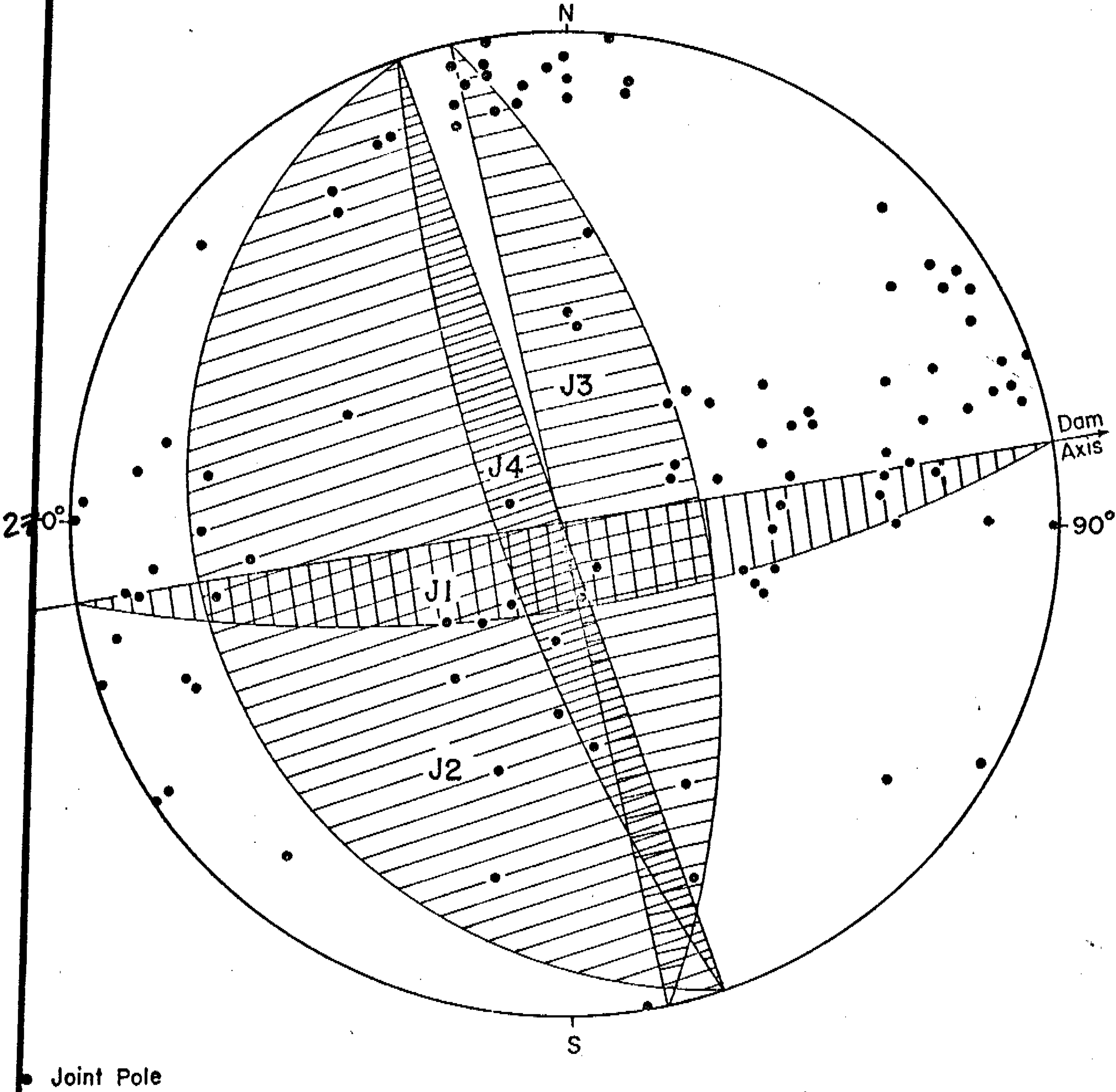
oint Pole

oint System

No.5

BIRTHDAY GAP DAM SITE

JOINT DISTRIBUTION (Equatorial Equal Area Net)
RIGHT ABUTMENT



● Joint Pole

J1 Joint System

Of the above sets J1 is the foliation direction that is also typical of the gneiss and schist. Sets J2, J3 and J4 all are nearly perpendicular to the dam axis and therefore are all potential leakage paths with set J2 being the most common. (Refer to contour lower hemisphere polar projection Fig. 2).

Sets J2 and J3 are pure sheer joints that have formed in response to a maximum stress in the east-west direction (Pl. 7). Set J4 is parallel to the major N-S shearing direction (as represented by Spencer Gorge) and also subparallels the dolerite dyke intrusions. As no outcrop of dolerite was observed relative orders of these events cannot be determined for certain, but the area appears to have been subjected to at least three stress episodes of N-S, E-W and N-S again.

3.6.2 Faults

The two major fault directions are parallel to the J1 and J4 joint sets.

The faults parallel to joint set J1 and the dam axis are strike slip faults with minor vertical movement (refer Pls. 2 and 10) and contain up to 1 m of recemented breccia.

Faults parallel to joint set 4 also have a horizontal displacement with the western side being displaced north. The fault controlled gully on the left abutment (Pl. 9) has a displacement of only one metre but a large fault, 400 m from the river, on the right abutment, has a horizontal displacement of 70 metres.

A minor 'overthrust' fault on the left abutment has been displaced by movement along a fault parallel to the J1 joint set (Pl. 2). This 'overthrust' fault may be a minor potential leakage path.

The distribution of solid rock outcrop in the upstream river section precludes the possibility of a major fault occurring perpendicular to the dam axis in the river bed.

REFRACTION SEISMIC SURVEY

During the course of investigations a number of shallow refraction seismic surveys were attempted using a Huntec F.S.3 portable single channel seismograph. A total of 480 m of traverse length were surveyed using a hammer energy source. For the line location refer to the Detail Geology map Sheet 1 (Appendix E.2).

The seismograph used lacked any signal enhancement capability and the results were difficult to interpret due to the background noise interference. The profiles derived from the data were calculated using the reciprocal method described by Hawkins (1961) and by the intercept time method (Dobrin 1960). They are presented in sections A-A, B-B, C-C, D-D and E-E (refer Appendices E.4, E.5 and E.6).

Due to the above-mentioned interpretation difficulties the results cannot be considered very reliable even though a good correlation exists between the alluvial depths as determined by lines SL/B/0-80 and SL/D/0-98 and that determined by drilling (DDH3).

In general the traverses over alluvial covered quartzite revealed a simple two layer case and traverses over schist or gneiss revealed a three layer case representing the weathering characteristics of the rock types.

MATERIALS

A reconaissance survey of the surrounding area of Birthday Gap was conducted in an effort to find the distribution of materials that could be used in the proposed structure.

Materials searched for were:

a) Rockfill
b) Concrete aggregate
c) Impervious earth core

5.1 Rockfill

The rock types available in the immediate vicinity of the dam site are:

a) Quartzite
b) Gneiss
c) Schist
d) Dolerite

5.1.1 Quartzite

The quartzite of the site is a hard brittle rock that, for the most part, is finely laminated. The drilling of this material for blasting would be very slow with a very high rate of bit wear. The shape of this blasted rock would tend to be very slabby resulting in a low density, poorly compacted rockfill unless great care is taken in placing. For these reasons it is suggested that quartzite would not be the most suitable source of rockfill although some will be obtained from the spillway excavations and probably used.

5.1.2 Gneiss

The gneiss, although foliated, is considerably more massive than the quartzite due to the low density of jointing and the coarser crystalline texture of the rock. Between two to four metres of overburden (based on seismic data interpretation at the dam site) would be expected over the gneiss but may be less in selected areas. Drilling would be moderately hard with a reasonable bit wear due to the high feldspar content of the gneiss. Good quality equidimensional rockfill would be obtainable from the gneiss and it is thus the recommended source. The optimum topographic location would be near the right abutment on the slopes of the northern side of the quartzite ridge as shown in Appendix E.1.

5.1.3 Schist

The schist found on the southern side of the quartzite ridge is finely foliated and micaceous with some quartz rich resistant bands. It is covered by talus, residual soil and weathered rock to a probable depth of 3-5 metres. The majority of outcrops are highly weathered, fissile and friable. The rock would be easy to drill but blasting would produce slabby, soft rockfill that would probably break down under handling. It is not considered to be a suitable source of rockfill.

5.1.4 Dolerite

A dolerite dyke passes through the left abutment quartzite ridge with an apparent width of 17 m. The results of seismic line F/0-50 indicate that the dyke is weathered to at least 10 m below the surface. No true outcrops were found within the mapped region. The fresh rock, once excavated, would make excellent high strength, high density rockfill but the expected amount of overburden and the limited size of the dyke would preclude economic extraction.

5.2 Concrete Aggregate

An inspection of sections of the river channel, both upstream and down, revealed large deposits of sand and gravel within reasonable distances from the dam site. Samples were taken of the sands in these deposits to determine the size distribution curves (Appendix C) by mechanical sieving. The results indicate that all sands samples fall in to the 'Unified Soil Classification Group SP with approximately 80% coarser than medium sand with one sample (BG/5/S1) showing 93% coarser than medium sand. The poor grading of the sands makes them unsuitable, in untreated form, for use in impermeable membranes either concrete or bituminous, unless an excessive percentage of cement or asphalt was used. The mixing of fine sand-silt from remote sources may have to be considered in order to produce a more usable material.

Although no samples were taken, there appears to be a more than adequate supply of coarser aggregate. The rock types present in the inspected deposits are gneiss, schist, quartzite and dolerite with no material likely to be reactive with alkaline cement. The schist may be weathered. The sand is composed of angular quartz, feldspar and mica primarily derived from weathered gneiss.

5.3 Impervious Core

An effort was made to determine if any potential borrow areas existed for impervious earth core material. All areas within the vicinity of the dam site area that had any soil development were inspected and, in most cases, sampled (refer Appendix E.1). The samples were taken at or near the surface with a small hand auger. No measure of insitu moisture was taken as in most cases this was negligible. The samples were sieved and the plastic and liquid limits were determined. Two samples which had a significant plasticity were tested for linear shrinkage. The results of the above tests are tabulated in Table 1 and all samples were taken from plains, above weathered gneiss.

The only area that showed promising test results was that designated BG/6. This area, near the confluence of two large streams, is only about 200 m by 150 m and has a number of rock outcrops within it. The amount of usable extractable material is probably insufficient to supply the requirements of the high development of this site. There may be enough to supply the low development proposal but further drilling and testing would be required to confirm this. All other areas appear unsuitable due to the expected high permeability of the contained material and the presumed piping risk.

It would appear advisable to eliminate zoned-earth core type structures from consideration.

TABLE 2

	SILT & CLAY	FINE SAND	MEDIUM SAND	COARSE SAND	GRAVEL	LIQUID LIMIT	PLASTIC LIMIT	P.I.	L.S.	U.S.C. SYMBOL
S1	46%	14%	13%	12%	15%	25	13.5	11.5	5.9%	SC-CL
S2	42%	10%	17%	15%	16%	31	13	18	7.5%	SC-CL
S1	45%	16%	14%	16%	10%	18	15	3	NT	SM
S1	29%	23%	15%	17%	16%	19.4	15.1	4.3	NT	SM
/S1	33%	13%	11%	7%	36%	17	12	5	NT	GM
/S1	25%	31%	22%	15%	7%	17.0	15	2	NT	SM

NT = Not Tested

ENGINEERING GEOLOGICAL ASSESSMENT

As no firm design proposals exist for this site except for the two crest height levels as determined by hydrological limits (i.e. EL705 and EL685) assumed designs have been superimposed within geological drawings to assist in making rational comment on the expected engineering performance of the natural conditions of the dam site. These assumptions are that:

a) the optimum design type is an upstream face impermeable membrane dam

b) the slopes of the dam embankment will be 1.5 on 1 for both upstream and downstream faces and

c) the high development (EL 705) will require a diversion outlet conduit or tunnel.

6.1 Foundation Competence

With the above assumptions no large stresses are expected on the embankment foundations and all lithological units, when excavated to moderately-to-slightly weathered rock, should have adequate strength to be virtually nonsettling with the expected vertical loading. Along the line of the plinth, on the upstream face, excavation will have to be taken to slightly weathered to fresh rock for the purpose of ensuring the minimum of surface leakage (and pressure loss) during grouting. On the basis of the seismic results a preliminary estimate of the depth of stripping would be about 2 m for the rockshell foundations and about 4 m for the plinth. These are estimated average figures and local variations should be expected especially in the region of the dolerite dyke. Confirmation of these depths by drilling would be essential in any future investigation program.

The principal load bearing areas in the dam would be at base of the inlet tower (vertical load and toppling load) and on the spillway crest (horizontal shear and hydraulic uplift).

The inlet tower would be founded on fresh massive gneiss and thus should be free from any major problems due to the wide joint distribution and the tight foliation along with the fairly shallow weathering horizon (about 4 m).

For the low development, problems arise in spillway location. The site selected topographically is the saddle in the quartzite ridge formed by the dolerite dyke. For this to be used the crest would have to be founded about 2 m below the present level of this saddle. On the basis of the seismic investigations and on previous experience with basic dykes the material at this depth would be too weathered to support the required load. Approximately 10 m of material would have to be removed to find material of adequate bearing capacity making this spillway site impracticable. The alternatives are:

a) a side shute spillway through the quartzite and

b) design the dam tc pass floods over the top of it.

A side shute spillway of adequate capacity to pass the predicted floods would require a fairly large excavation in the hard-to-drill quartzite and would be a significant cost item. The foundations of the dam appear to be adequate to support a concrete structure (either mass concrete or buttress designs) but the cost would be much higher and difficulties would arise in obtaining a satisfactory cut-off in the quartzite.

For the above reasons the site does not appear suitable for a low development.

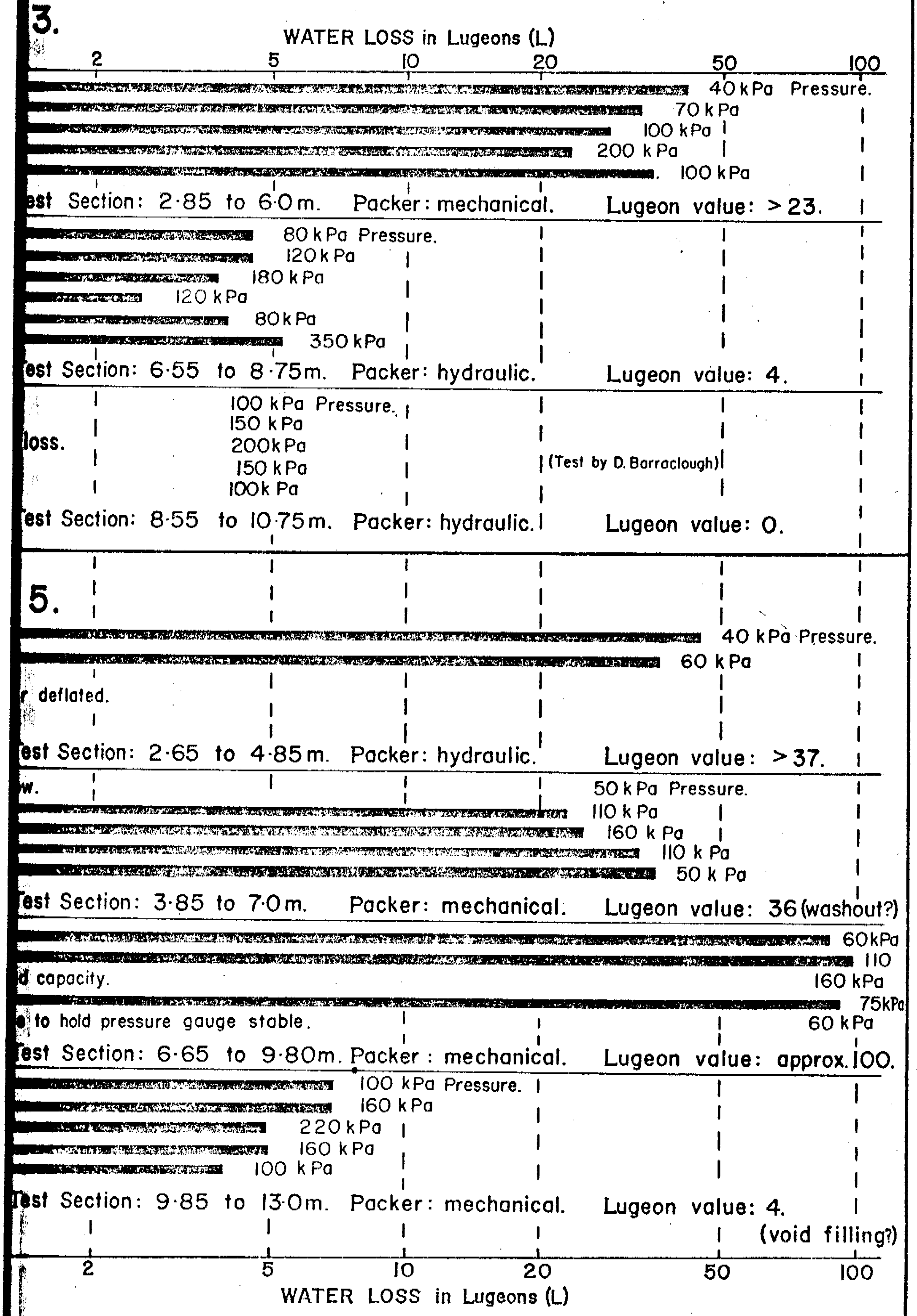
In the high level development alternative the spillway would probably be located in the quartzite ridge to the east of the dam site. Here, depending on the layout of the spillway, a choice could be made on whether to found the crest on gneiss or quartzite. The general close jointing of the quartzite and the looseness of the joint blocks suggest that the gneiss should be favoured for high load bearing foundations, but in doing so the volume of excavation in quartzite is significantly increased. The resolution of the problem awaits drilling results and detailed engineering analysis.

6.2 Foundation Leakage

During the course of the drilling of DDH 3 and DDH 5 water pressure testing was undertaken to determine the permeability of the foundations. The results of these tests are tabulated in Figure 6. Unfortunately both

.6

BIRTHDAY GAP DAM SITE
PERMEABILITY TESTS



these holes are in quartzite and at a low level in the dam. They indicate moderate to high leakage in the first 6-8 m below the bed level of the river. High leakage should be expected in the abutments as weathering and joint tightness is related to the position of the lower limit of the permanent water table. Based purely on relative joint density the gneiss would probably be considerably tighter than the quartzite although stress relief joints and exfoliation sheets may be present but as yet unobserved. The determination of the permeability of the gneiss and the abutments would be essential in any future drilling program.

The geometric distribution of the joints indicate that, for optimum grouting, the grout holes should be angled 30° to the east and 45° to the west in a criss-cross pattern. This would ensure perpendicular intersection of the J2 and J3 joint sets (refer section 3.6) and a good intersection of the near vertical J4 joints. J1 joints are perpendicular to the flow direction and as such would not contribute greatly to the leakage.

For the low development, surface treatments of the steep northeast face of the quartzite ridge (Pl.8) would be required to reduce peripheral leakage. Pneumatically applied mortar would probably be most suitable.

6.3 Slope Stability

The major artificial rock slopes that would be created at the dam sites would be in the spillway and the associated channels for the diversion works. The orientations of these are primarily north-south and thus could be affected by block slide on the J2 and J3 joint sets. By examining the natural slopes, it can be clearly seen that failure of north-south trending slopes are controlled by joint sets with slopes on the right abutment being flatter than those on the left abutment. The J2 set dips towards the east at around 30° and controls the right abutment. The J3 set dips towards the west at around 60° and controls the left abutment.

Artificial rock slopes should, for optimum stability, parallel these joints sets thus producing asymmetric cuts. Rock more than moderately weathered should be treated as an homogeneous gravelly soil and slopes designed accordingly.

RECOMMENDATIONS FOR FUTURE ACTION

Although the information gathered to date on Birthday Gap dam site has obvious deficiencies it is adequate for a general geological assessment of feasibility as stated in the previous section.

The next stage of investigation would be associated with the detailed design of the proposed structures and thus the data collection would, to a large degree, be controlled by the nature of such designs.

As a general statement there is an obvious need to improve the knowledge of the weathering in the various lithological units along with more relevant permeability data. Artificial exposures would be of assistance in the former but generally an extensive drilling program will be required. The exact location, inclination and length of the drill holes cannot be specified until some firm design proposals are made and consultations have taken place with the responsible engineers.

APPENDIX A

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APPENDIX B

LOGS OF DIAMOND DRILL HOLES

DDH 3
DDH 5

N.T. GEOLOGICAL SURVEY

LOG OF DIAMOND DRILL HOLE

PROJECT BIRTHDAY GAP DAM SITE

TYPE FOUNDATION, PERMEABILITY

LOCATION HUGH RIVER

GRID CO-ORDS 1:250,000 HERMANNSBURG 660 042

ANGLE FROM HORIZON 65° DIRECTION 210°

E.L. COLLAR 668 m DATUM Water Resourses 1270 - 9 - 84 B.

HOLE No.

TEMPORARY No 3

DESCRIPTION OF CORE	GROUP SYMBOL	CORE DEPTH	R.Q.D.	DESCRIPTION OF STRUCTURE	FREQUENCY 1 4 16 64	ATTITUDE	CORE LOSS	CASING	Water level	
Channel Alluvium : *Gravel, max size : 70 mm* *medium / coarse sand* *gravel components :* *rounded to subrounded,* *strong to very strong* *fresh, hard : quartzite,* *quartz, gneiss.*	*G.P.*	m 1·0 2·0	*n.a.*		*n.a.*			*NX*		*Casing bi*
Quartzite, light greyish-blue, very hard and abrasive, brittle.		30 40 ·50 60 70 80 90		*8 joints, serizite (?), Fe-stainin* *Core generally very broken.* *Finely broken to pieces.* *85° Fe-stained.* *25°, 85° (2×)* *90° (2×) clay-st.* *90°, 20°* *40° clay* *30°* *80° (2×)* *70°, 10°, 60°* *90° (2×) 85° (2×)* *30° sericite, Fe-st., 80°* *60°, 30°* *20°, 80° (open)* *80°, 20°, 85°, 30° carbonate* *40° Fe-st., 60° clay, 60° (2x)* *30°, 40° slickensides carbonate.* *30° slsds* *60°, 30° quartz.* *55° (2×) 80° clay, 20° slsds* *90°* *30°, 40°* *30° slsds, 30° qtz, 80° qtz* *30° slsds, 20°.* *60° slsds.* *80° slsds.* *55° slsds, 20°, 85°, 80°* *85° (3x) 90°, 30° Fe-st.* *40°, 85°* *85° Fe-st., 35°* *85°, 45°* *30° slsds, 60°, 80°* *35°* *80° Fe-st., 80° (2x)* *finely broken.* *30° Fe-st, 60° (2x)* *10°, 80° (2×)* *80° Fe-st, 75°*				*BX*		*NQ* *Packer Test L > 23 (23 - 41) mechanical packer* *BQ* *Packer Test L = 4 hydraulic packer* *Packer Test L = 0 hydraulic packer*

ROCK SUBSTANCE

Strength Term
ES Extremely Weak
VW Very Weak
W Weak
MS Medium Strong
S Strong
VS Very Strong

Condition Term
Fresh
Slightly Weathered
Moderately Weathered
Highly Weathered
Completely Weathered

ROCK QUALITY DESIGNATION (R.Q.D.)
0-25 Very poor 50-75 Fair
25-50 Poor 75-100 Good to excellent

ATTITUDE OF JOINTS
Angle between feature and core axis
— Flat 0-5° | Steep 60-90°
Low 5-30° x Intersecting
Moderate 30-60°

ENGINEERING GEOLOGY SECTION

Drill No. F130
Type MINDRILL
Driller S. BERGER
Start 6 / 3 / 79
Finish 12 / 3 / 79
LOGGED B.W.
Date 13 / 3 / 7
Traced
Checked
Sheet 1 of 2

GEOLOGICAL SURVEY

LOG OF DIAMOND DRILL HOLE

LOCATION HUGH RIVER

HOLE No.

HERMANNSBURG 660 042

TEMPORARY No. 3

BIRTHDAY GAP DAM SITE

ANGLE FROM HORIZON 65°

DIRECTION 210°

FOUNDATION, PERMEABILITY

E.L. COLLAR 660 m

DATUM Water Resources. 1270 - 9 - 84 D.

DESCRIPTION OF CORE | RQD | DESCRIPTION OF STRUCTURE | FREQUENCY | ATTITUDE | CORE LOSS | CASING | Water level

75°, 80°, 30° s/sds

80° Fe-st, 10°, 60°

70°, 20°

30° (2x) Fe-st.

3rd Packer Test.

11·0

10·75 m.

ENGINEERING GEOLOGY SECTION

Drill No.

Type

Driller

Start / /

Finish / /

Logged

Date / /

Traced

Checked

Sheet 2 of 2

LOG OF DIAMOND DRILL HOLE

HUGH RIVER

HERMANNSBERG 660 042

HOLE No.

TEMPORARY No 5

BIRTHDAY GAP DAM SITE

FOUNDATION, PERMEABILITY.

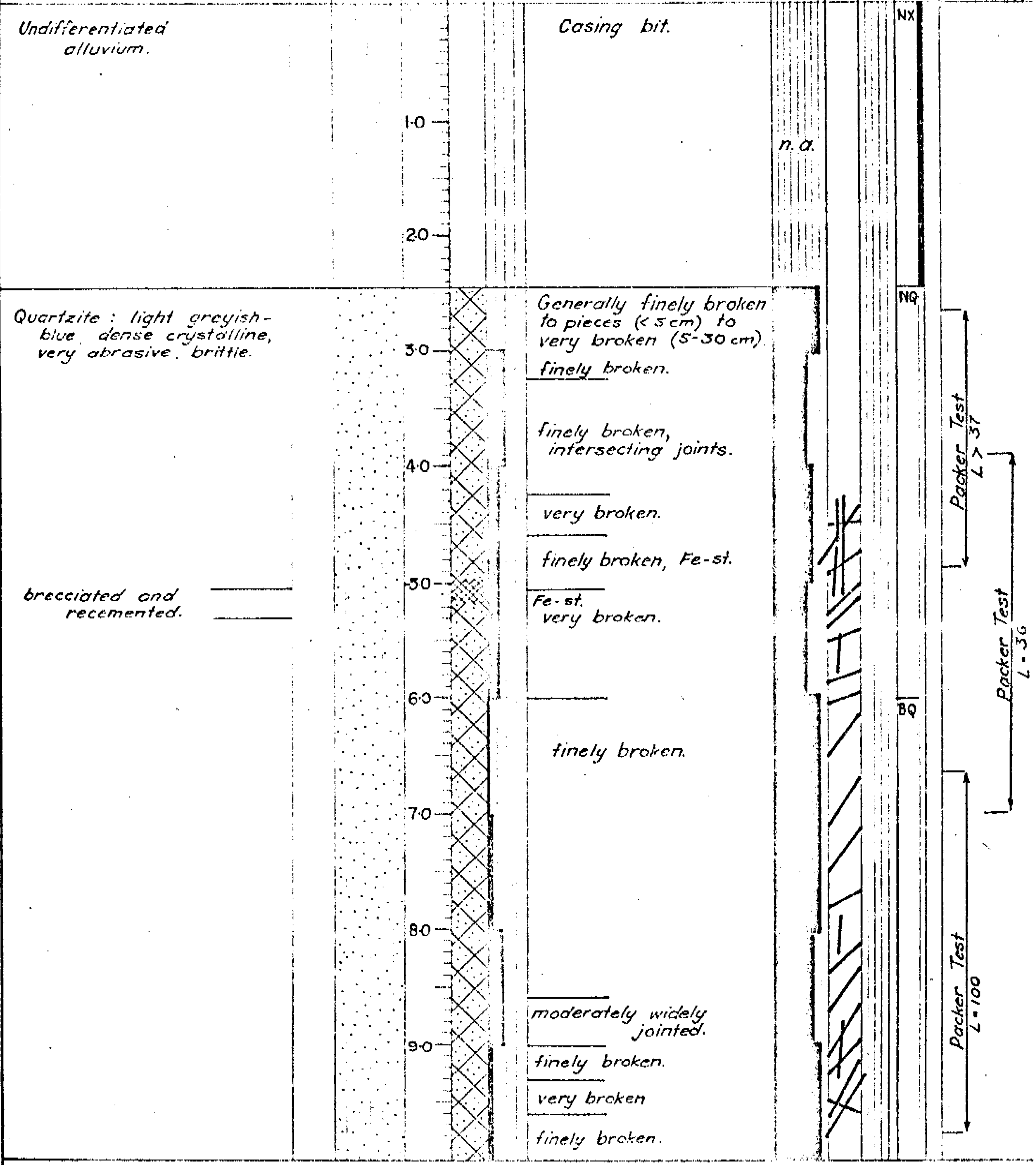
45°

DIRECTION 155°

670 m.

DATUM Water Resourses.

DESCRIPTION OF CORE | DESCRIPTION OF STRUCTURE | FREQUENCY | ATTITUDE | CASING



Undifferentiated alluvium.

Quartzite : light greyish-blue, dense crystalline, very abrasive, brittle.

brecciated and recemented.

Casing bit.

Generally finely broken to pieces (< 5 cm) to very broken (5-30 cm).

finely broken.

finely broken, intersecting joints.

very broken.

finely broken, Fe-st.

Fe-st. very broken.

finely broken.

moderately widely jointed.

finely broken.

very broken

finely broken.

ENGINEERING GEOLOGY SECTION

Drill No F 130

Type MINDRILL

Driller S. BERGER

Start 13 3 79

Finish 19 3 79

21 3 79

Sheet 1 of 2.

N.T. GEOLOGICAL SURVEY

LOG OF DIAMOND DRILL HOLE

LOCATION HUGH RIVER

GRID CO-ORDS 1:250000 HERMANNSBERG 660 042

HOLE No

TEMPORARY No. 5

PROJECT BIRTHDAY GAP DAM SITE

ANGLE FROM HORIZONTAL 45°

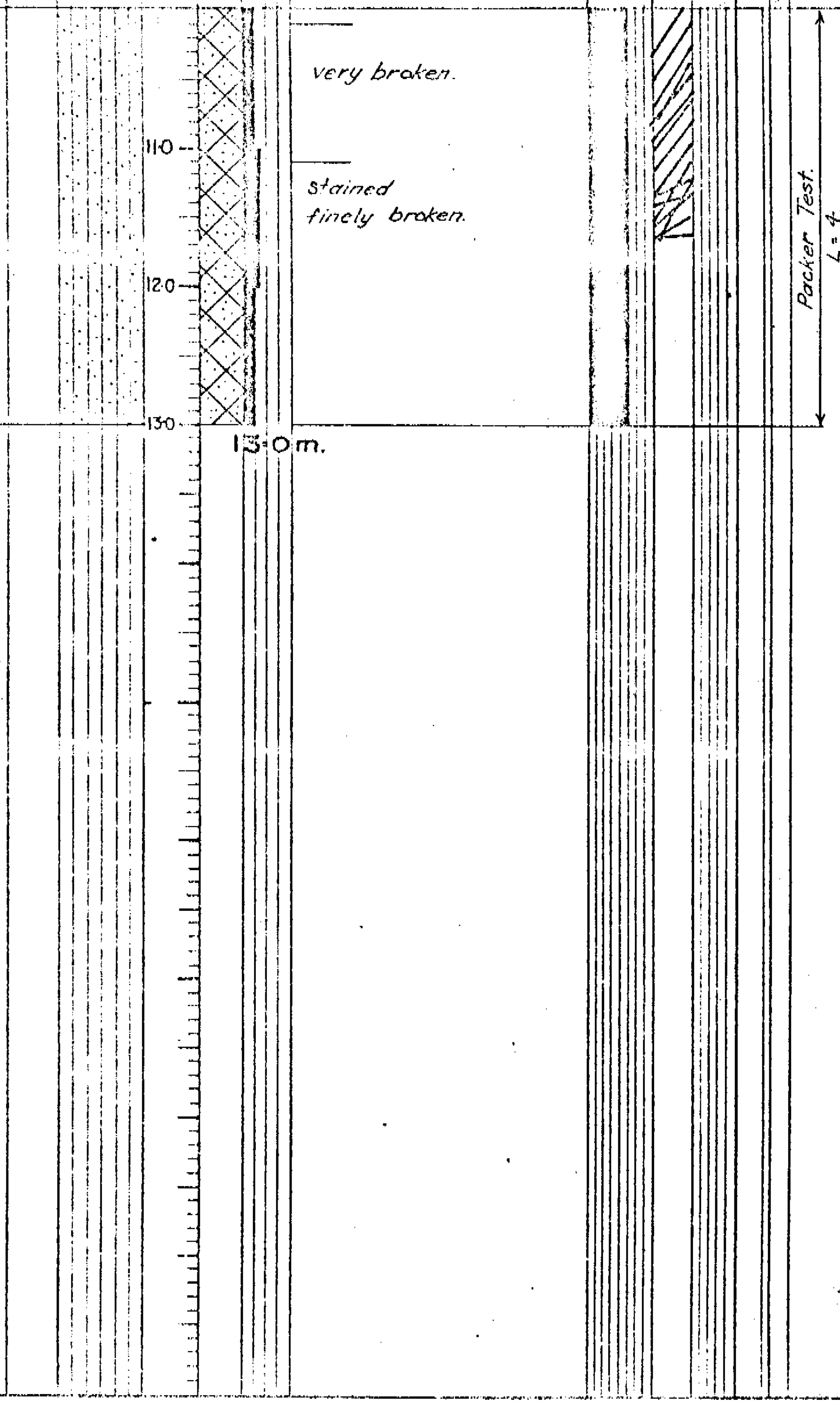
DIRECTION 155

TYPE FOUNDATION, PERMEABILITY.

R.L. COLLAR 670 m

DATUM Water Resources.

DESCRIPTION OF CORE	WEATHERING	STRENGTH	DEPTH	GRAPHIC LOG	CORE RECOVERY	DESCRIPTION OF STRUCTURE	FREQUENCY	ATTITUDE	R.Q.D.	CASING



very broken.

stained finely broken.

ROCK SUBSTANCE

Strength Term		Condition Term
SO	Soil Properties	Fresh
VW	Very Weak	Slightly Weathered
W	Weak	Moderately Weathered
MS	Medium Strong	Highly Weathered
S	Strong	Completely Weathered
VS	Very Strong	

ROCK QUALITY DESIGNATION (R.Q.D.)

0-25 Very poor 50-75 Fair

25-50 Poor 75-100 Good to excellent

ATTITUDE OF JOINTS

Angle between joint and core axis

Horizontal 0-30° Steep 60-90°

Intermediate 30-60°

ENGINEERING GEOLOGY SECTION

Drill No.	LOGGED
Type	Date / /
Driller	Traced
Start / /	Checked
Finish / /	Sheet 2 of 2

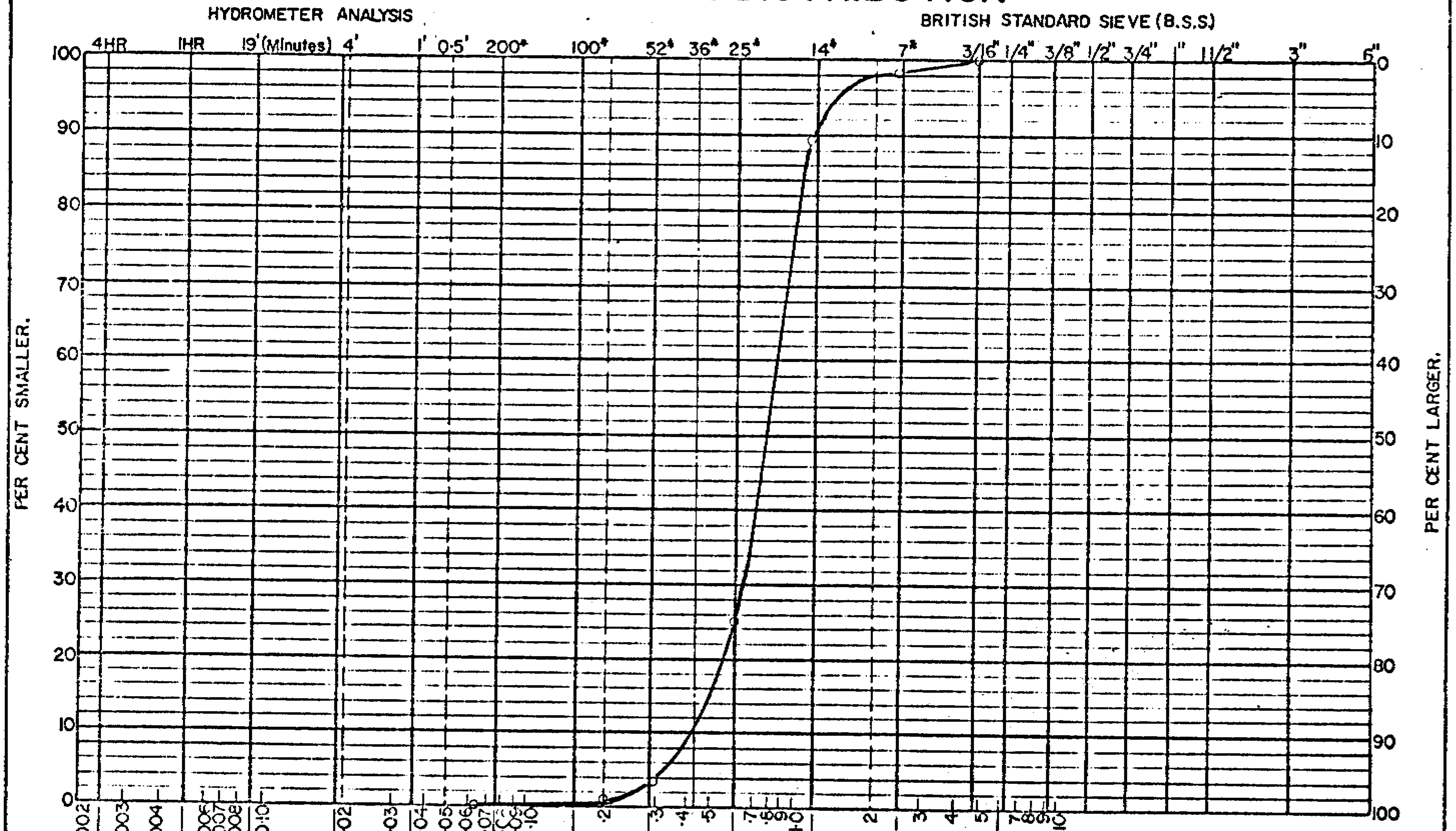
APPENDIX C

SOIL GRADING CURVES

Samples
BG/1/S1
BG/2/S1
BG/2/S2
BG/3/S1
BG/3/S2
BG/4/S1
BG/4/S2
BG/5/S1
BG/6/S1
BG/6/S2
BG/7/S1
BG/9/S1
BG/10/S1
BG/11/S1

N.T. GEOLOGICAL SURVEY

PARTICLE SIZE DISTRIBUTION



NOTES:

N.T. GEOLOGICAL SURVEY

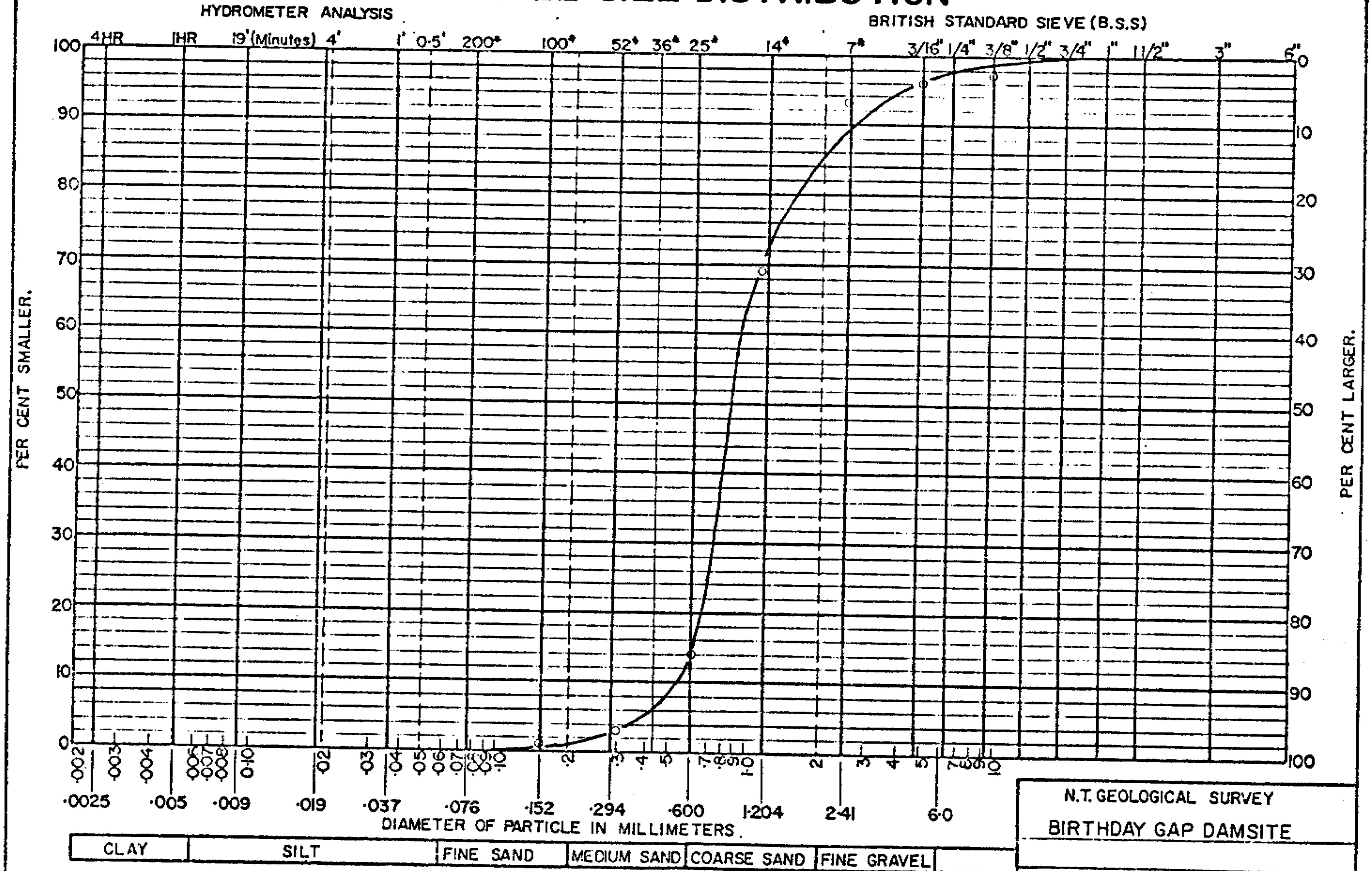
BIRTHDAY GAP DAMSITE

Pit ______ Depth ______ To ______

Lab. Sample No. BG/1/S1

N.T. GEOLOGICAL SURVEY

PARTICLE SIZE DISTRIBUTION



NOTES:

N.T. GEOLOGICAL SURVEY

BIRTHDAY GAP DAMSITE

Pit _____ Depth _____ To _____

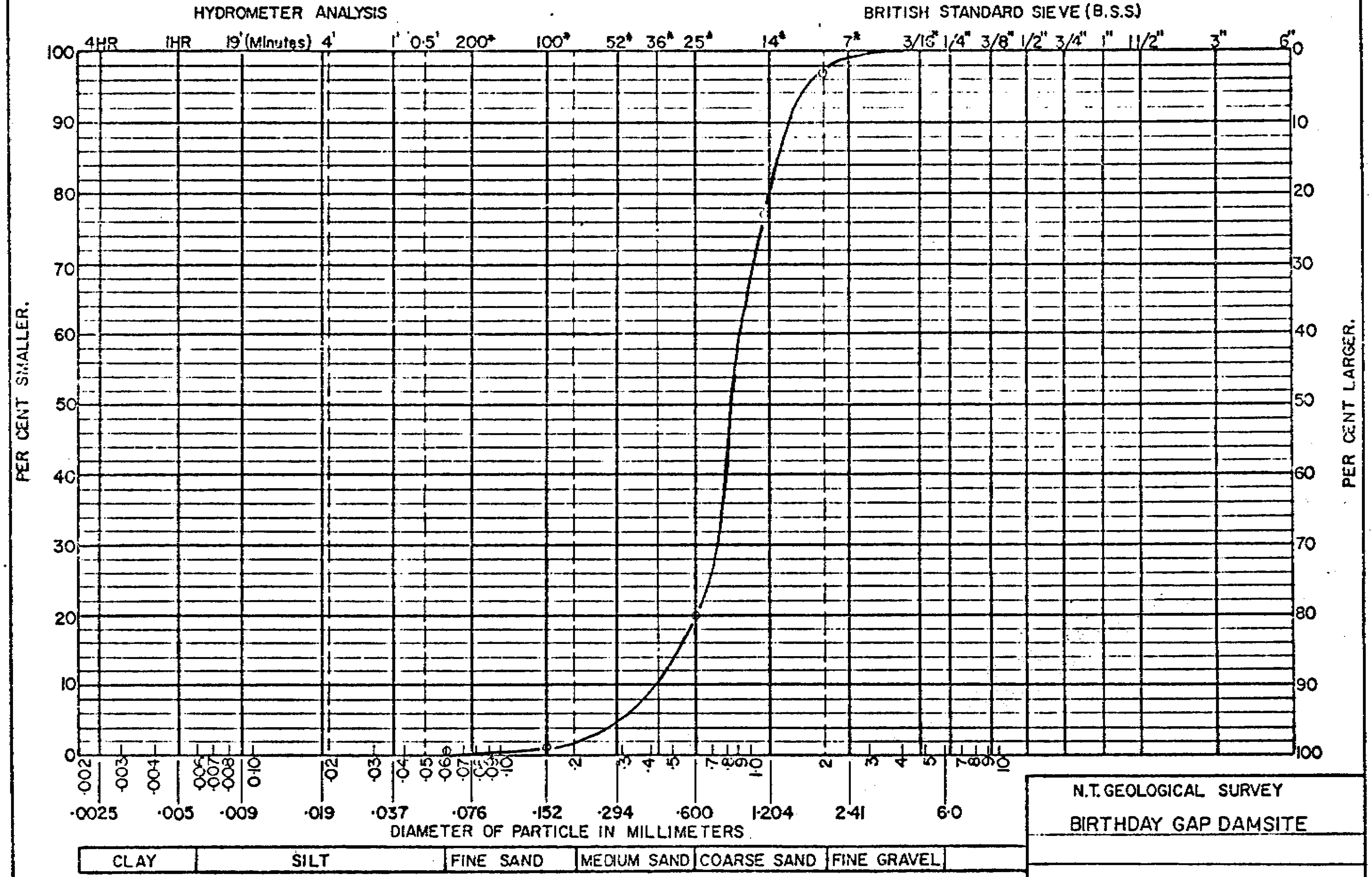
Lab. Sample No. BG/2/S1

Drawn	Checked	Date

Form No. 04

N.T. GEOLOGICAL SURVEY

PARTICLE SIZE DISTRIBUTION



NOTES:

N.T. GEOLOGICAL SURVEY

BIRTHDAY GAP DAMSITE

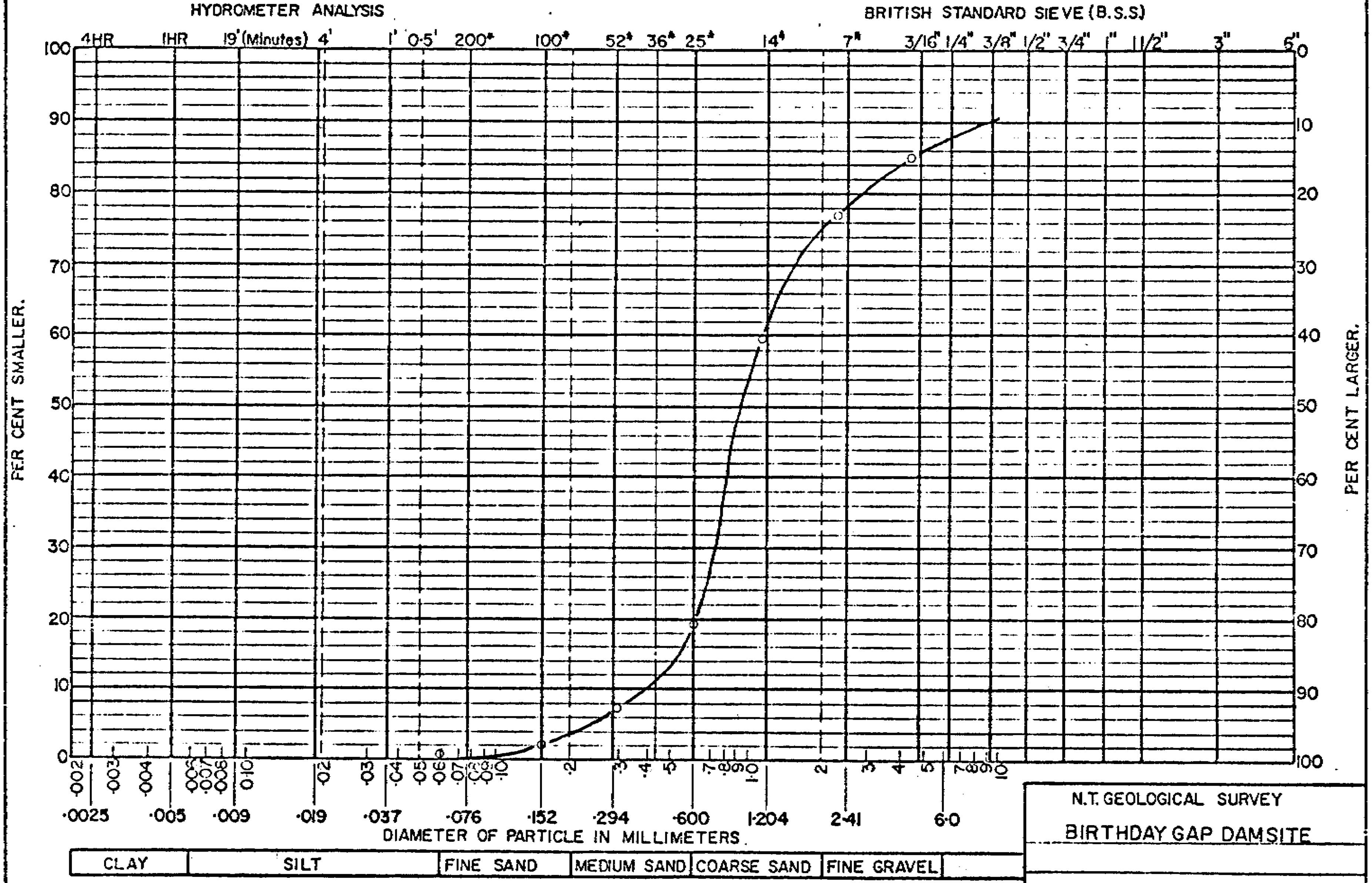
Pit ______ Depth ______ To ______

Lab. Sample No. BG/2/S2

Drawn Checked Date

N.T. GEOLOGICAL SURVEY

PARTICLE SIZE DISTRIBUTION



NOTES:

N.T. GEOLOGICAL SURVEY

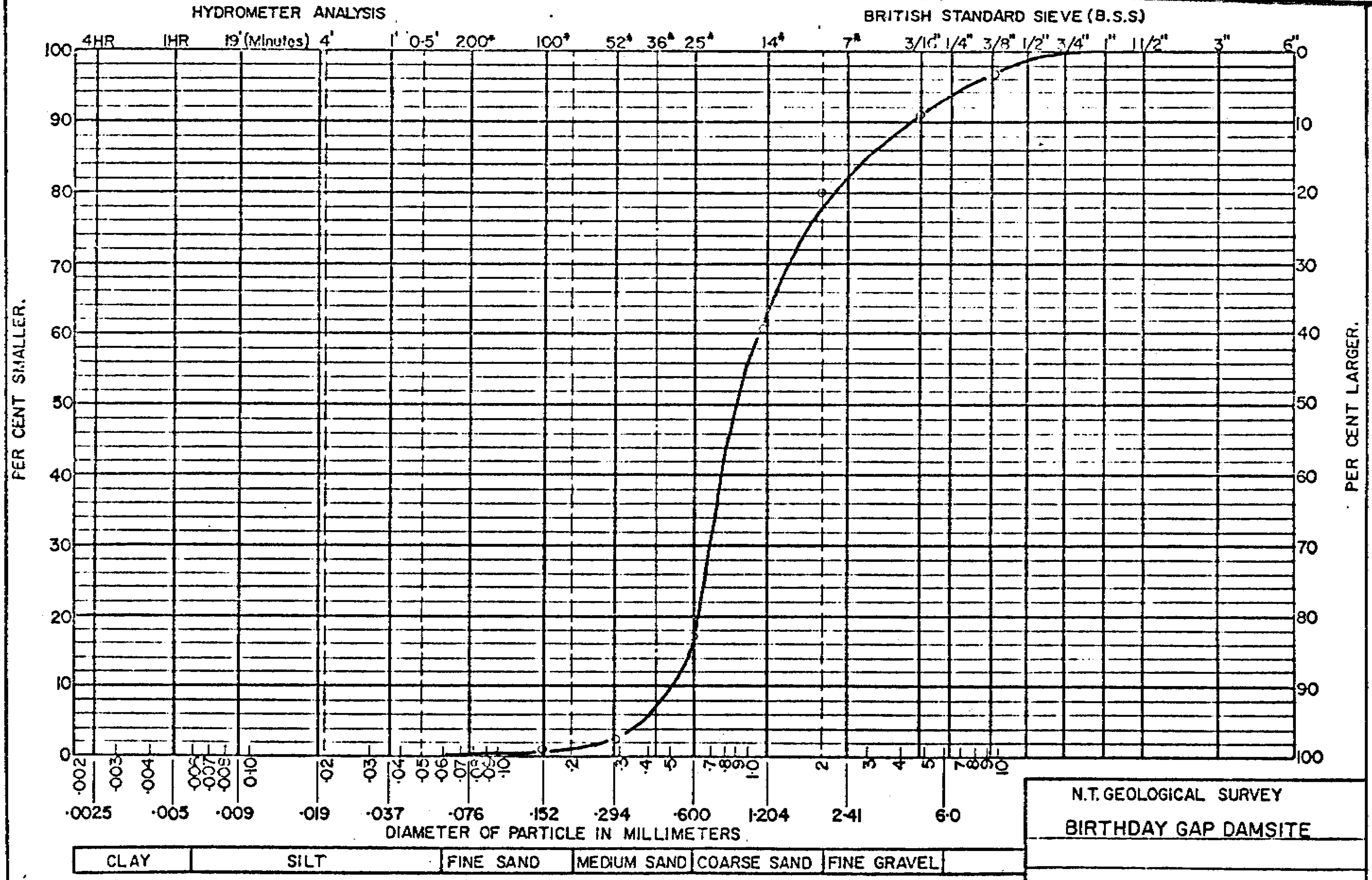
BIRTHDAY GAP DAMSITE

Pit ______ Depth ______ To ______

Lab. Sample No. BG/3/S1

Drawn Checked Date

PARTICLE SIZE DISTRIBUTION



NOTES:

N.T. GEOLOGICAL SURVEY

BIRTHDAY GAP DAMSITE

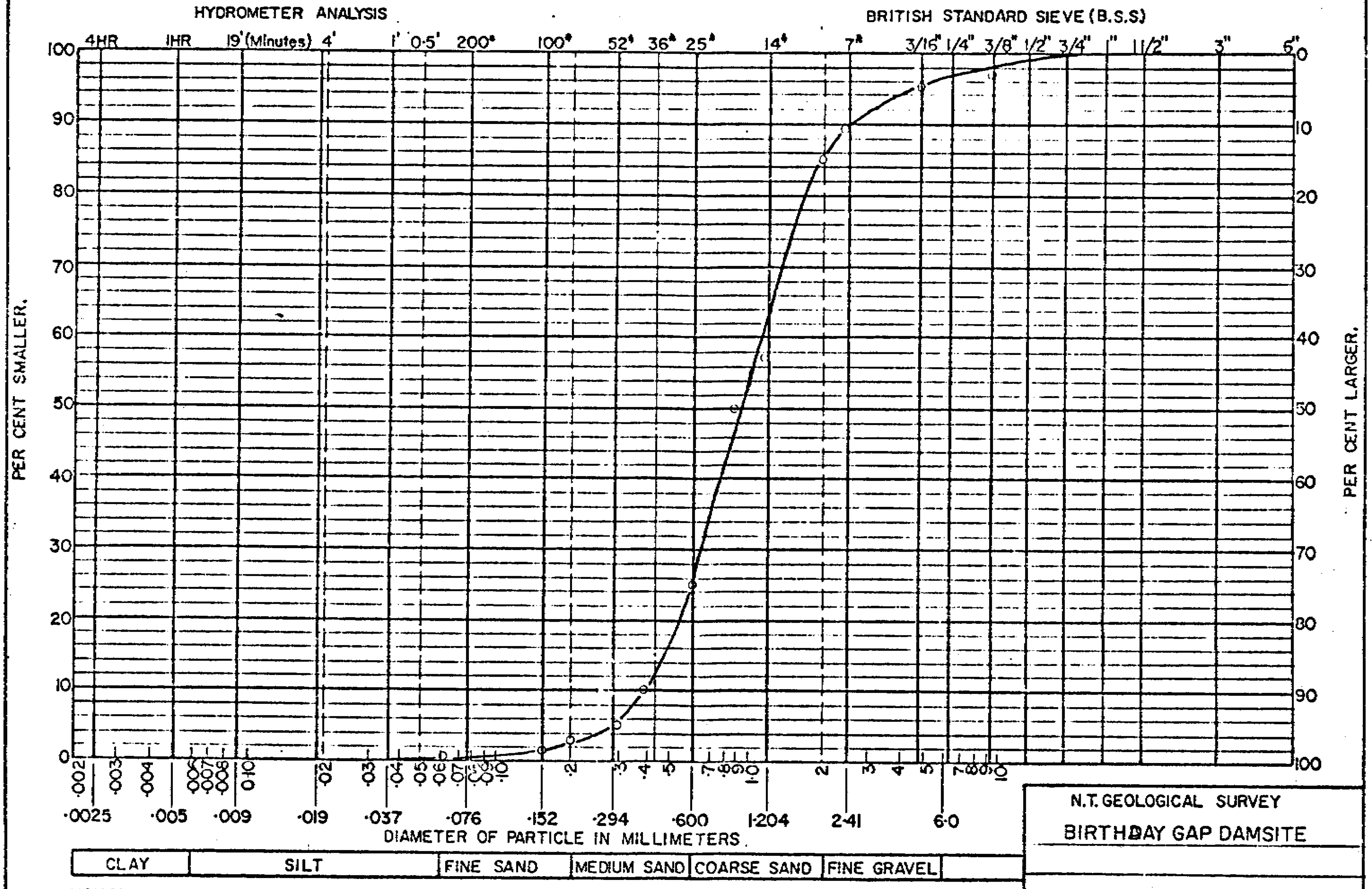
Pit ______ Depth ______ To ______

Lab. Sample No. BG/3/S2

Drawn Checked Date

N.T. GEOLOGICAL SURVEY

PARTICLE SIZE DISTRIBUTION



NOTES:

N.T. GEOLOGICAL SURVEY

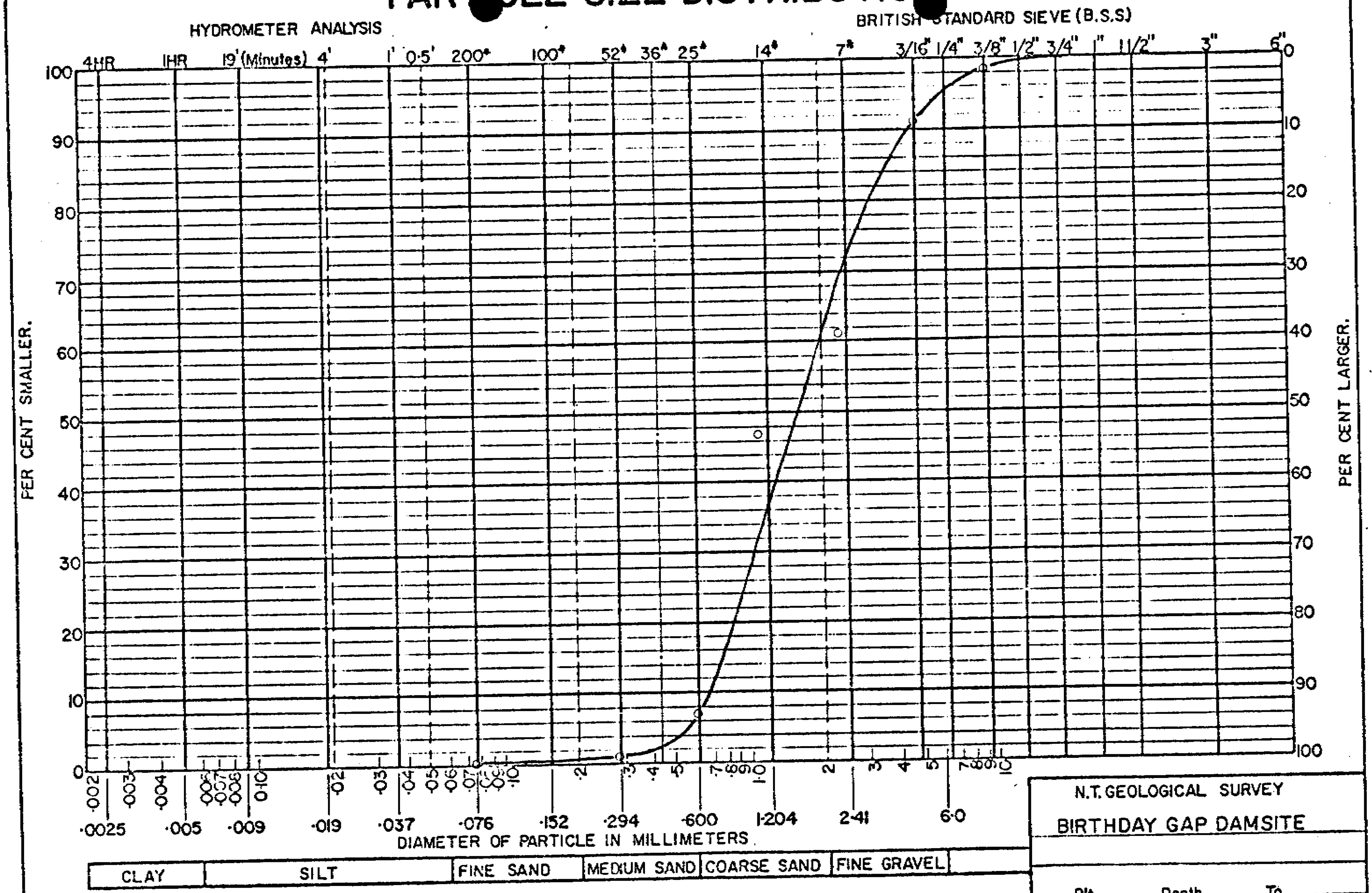
BIRTHDAY GAP DAMSITE

Pit ______ Depth ______ To ______

Lab. Sample No. BG/4/S1

N.T. GEOLOGICAL SURVEY

PARTICLE SIZE DISTRIBUTION



NOTES:

N.T. GEOLOGICAL SURVEY

BIRTHDAY GAP DAMSITE

Pit ______ Depth ______ To ______

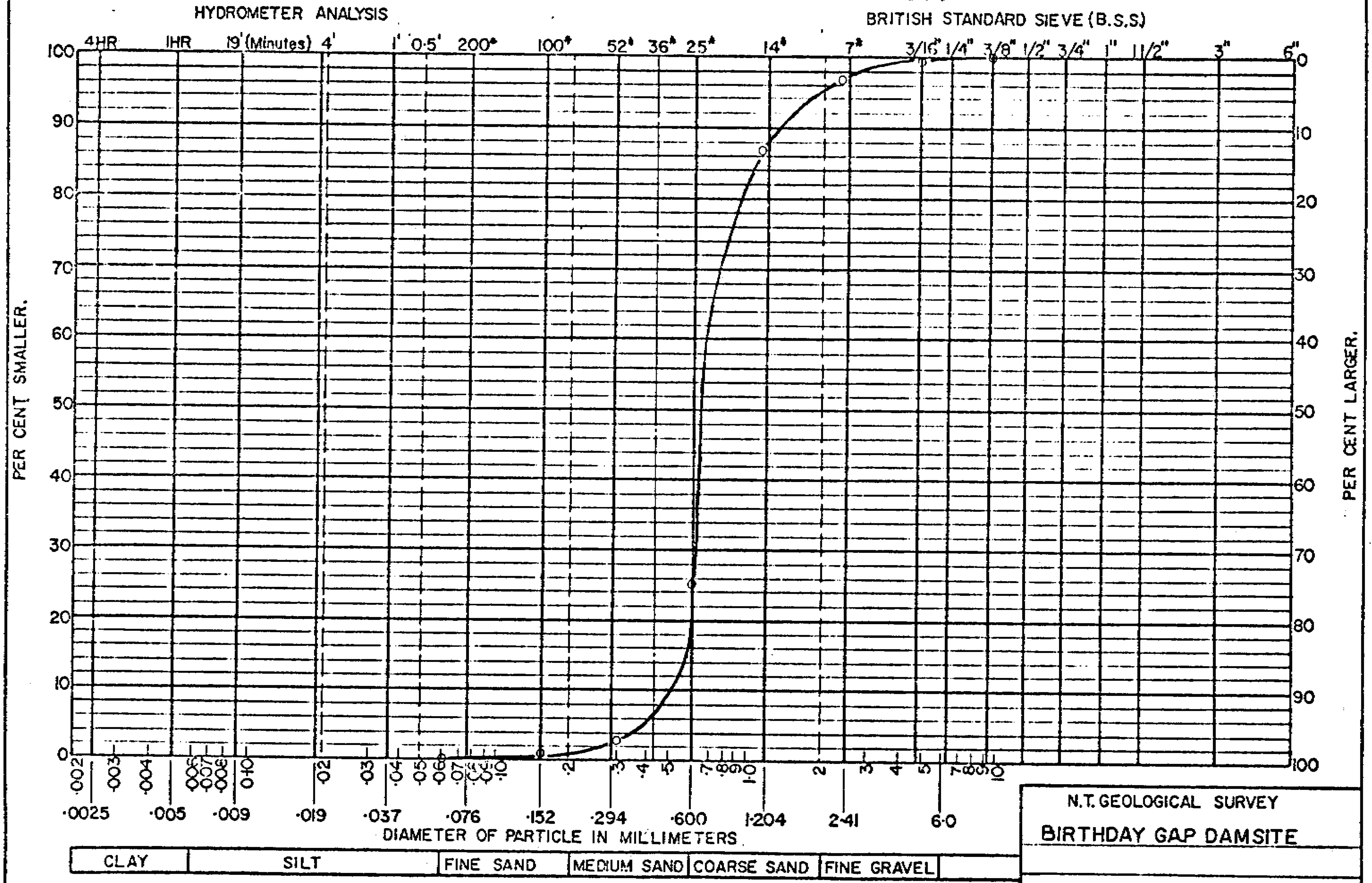
Lab. Sample No. BG/4/S 2

Drawn Checked Date

Form No. 04

N.T. GEOLOGICAL SURVEY

PARTICLE SIZE DISTRIBUTION



NOTES:

N.T. GEOLOGICAL SURVEY

BIRTHDAY GAP DAMSITE

Pit ______ Depth ______ To ______

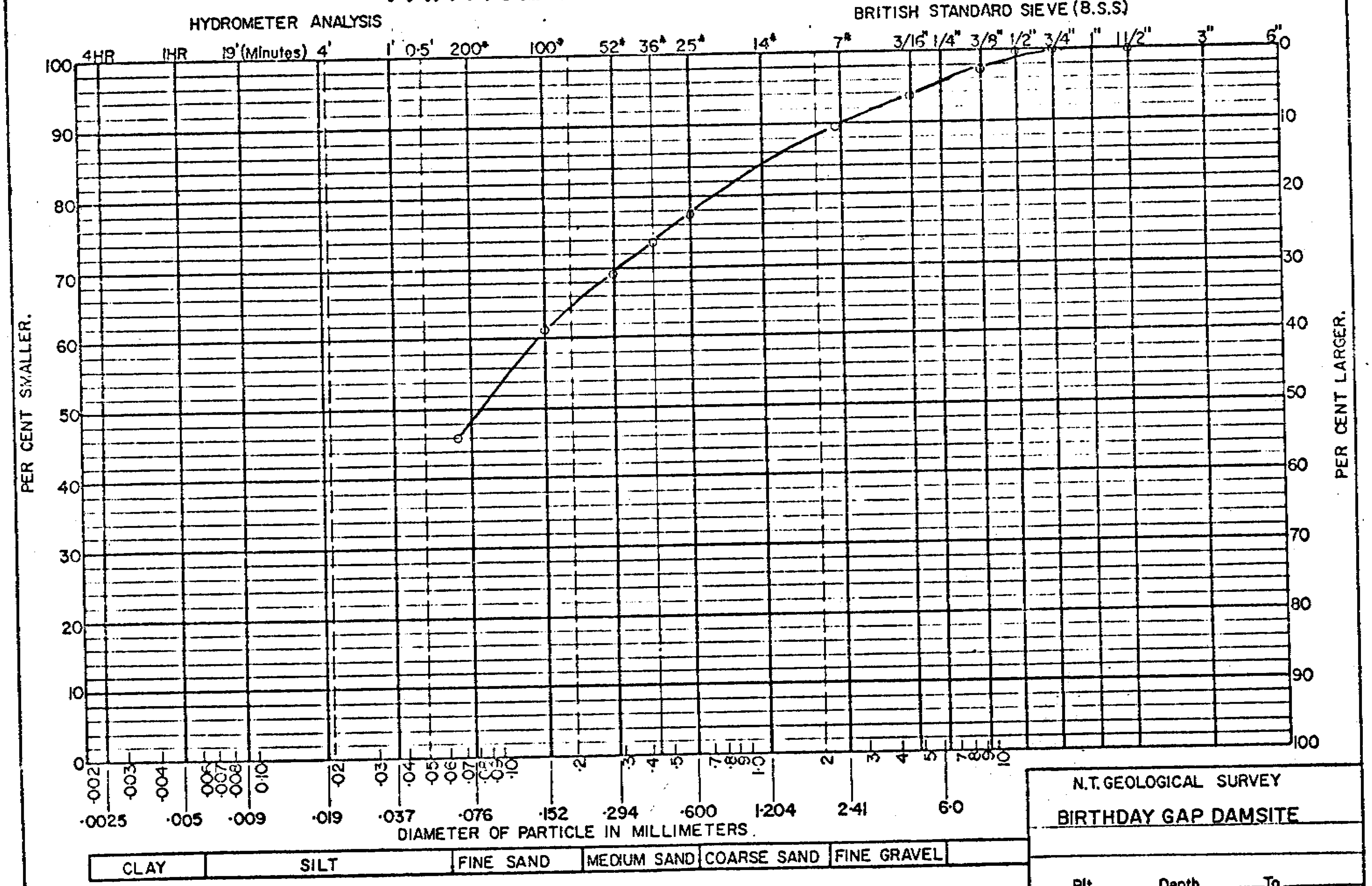
Lab. Sample No. BG/5/S1

Drawn Checked Date

Form No. 04

N.T. GEOLOGICAL SURVEY

PARTICLE SIZE DISTRIBUTION



NOTES:

N.T. GEOLOGICAL SURVEY

BIRTHDAY GAP DAMSITE

Pit ______ Depth ______ To ______

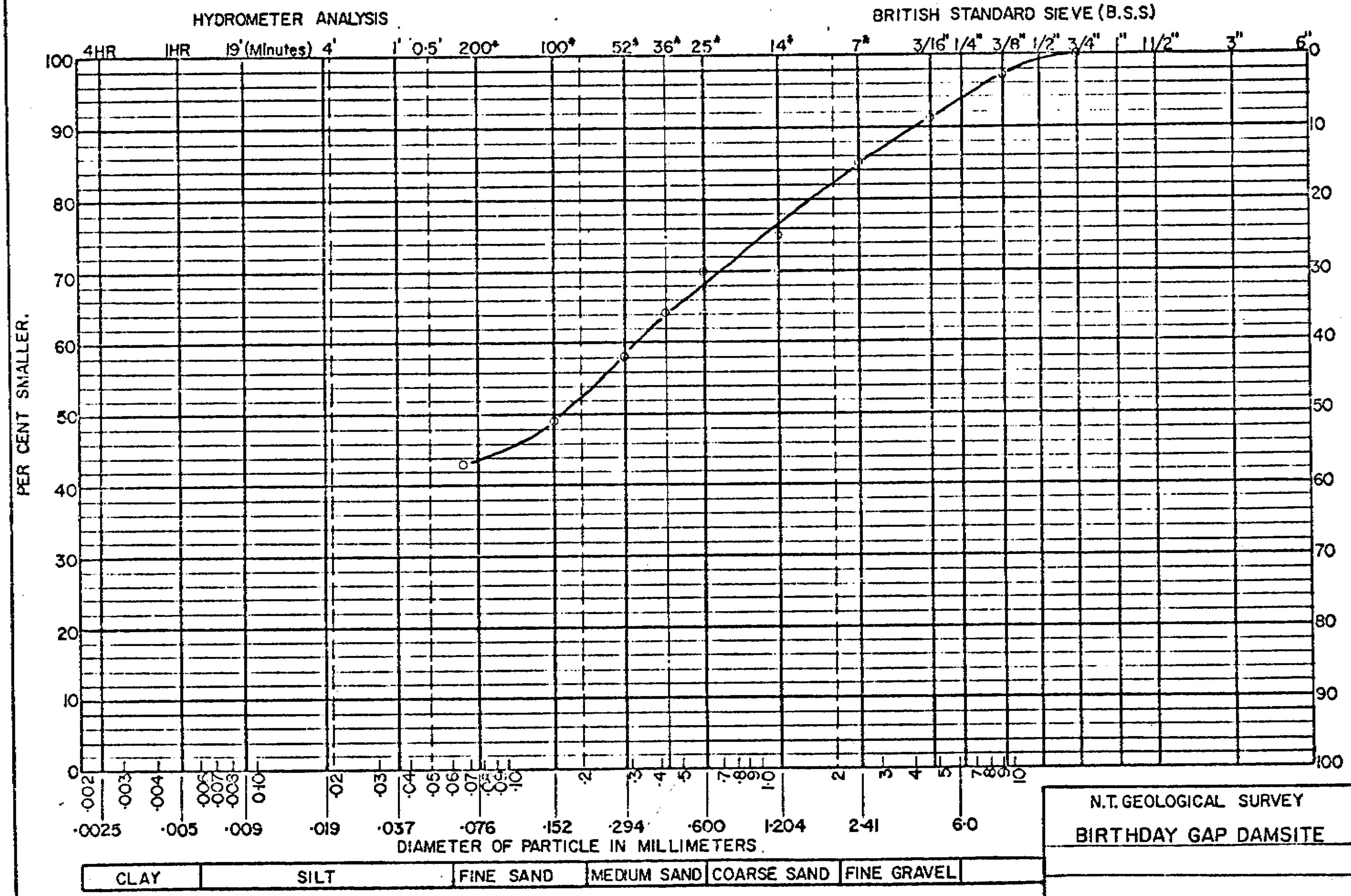
Lab. Sample No. BG/6/S1

Drawn Checked Date

Form No. 04

N.T. GEOLOGICAL SURVEY

PARTICLE SIZE DISTRIBUTION



NOTES:

N.T. GEOLOGICAL SURVEY

BIRTHDAY GAP DAMSITE

Pit ______ Depth ______ To ______

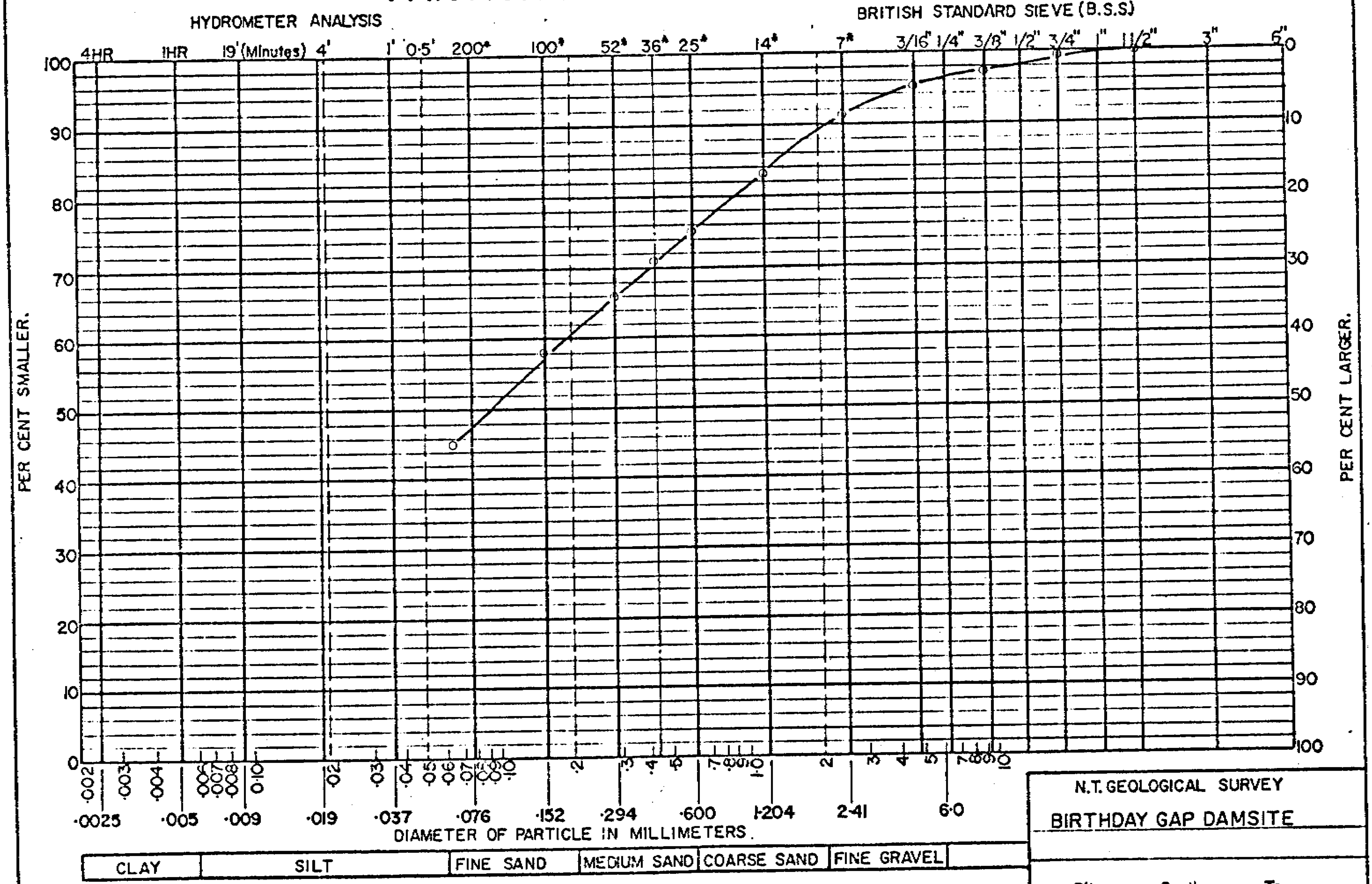
Lab. Sample No. BG/6/S2

Drawn Checked Date

Form No. 04

N.T. GEOLOGICAL SURVEY

PARTICLE SIZE DISTRIBUTION



NOTES:

N.T. GEOLOGICAL SURVEY

BIRTHDAY GAP DAMSITE

Pit ______ Depth ______ To ______

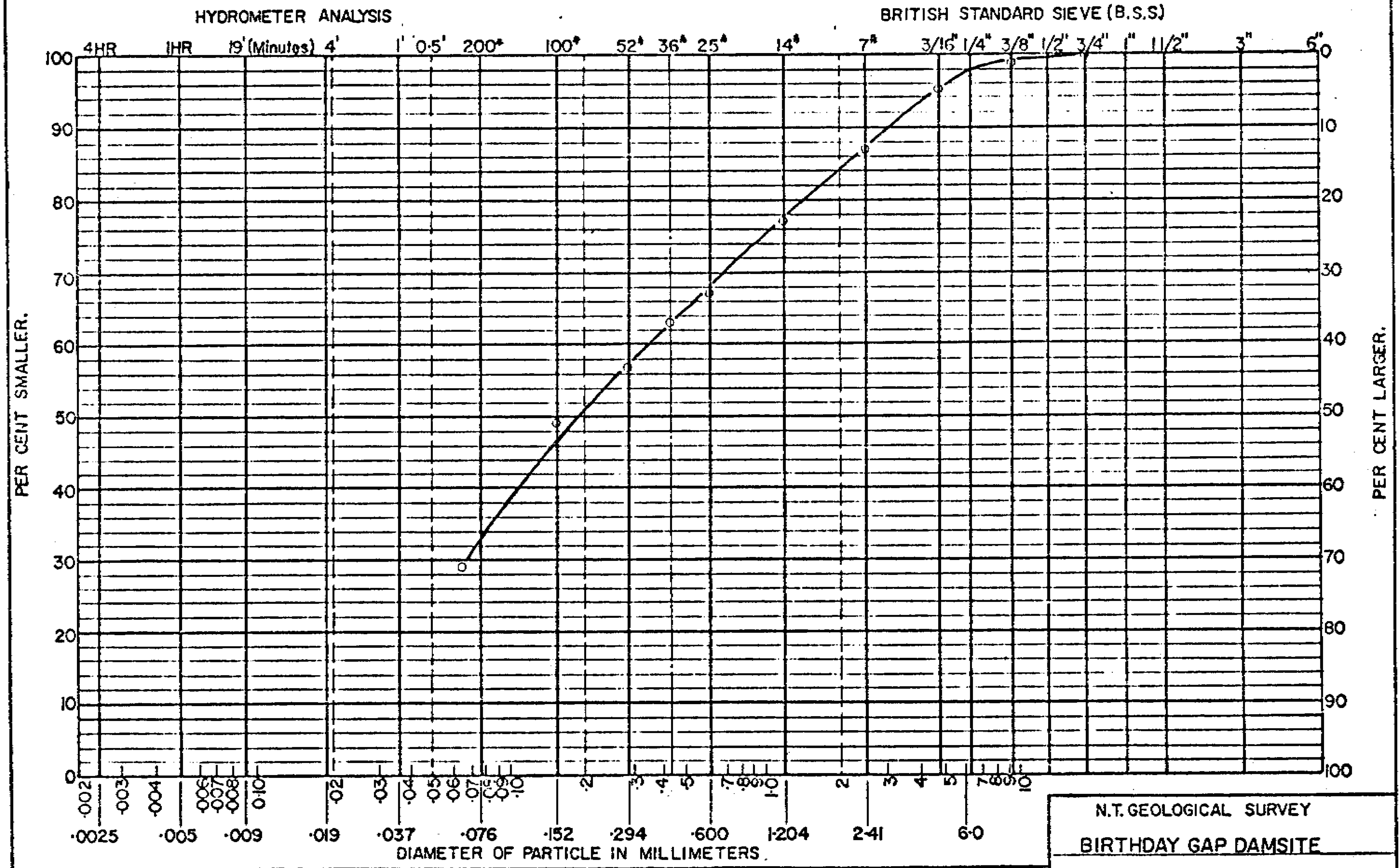
Lab. Sample No. BG/7/S1

Drawn Checked Date

Form No. 04

N.T. GEOLOGICAL SURVEY

PARTICLE SIZE DISTRIBUTION



CLAY	SILT	FINE SAND	MEDIUM SAND	COARSE SAND	FINE GRAVEL	

NOTES:

N.T. GEOLOGICAL SURVEY

BIRTHDAY GAP DAMSITE

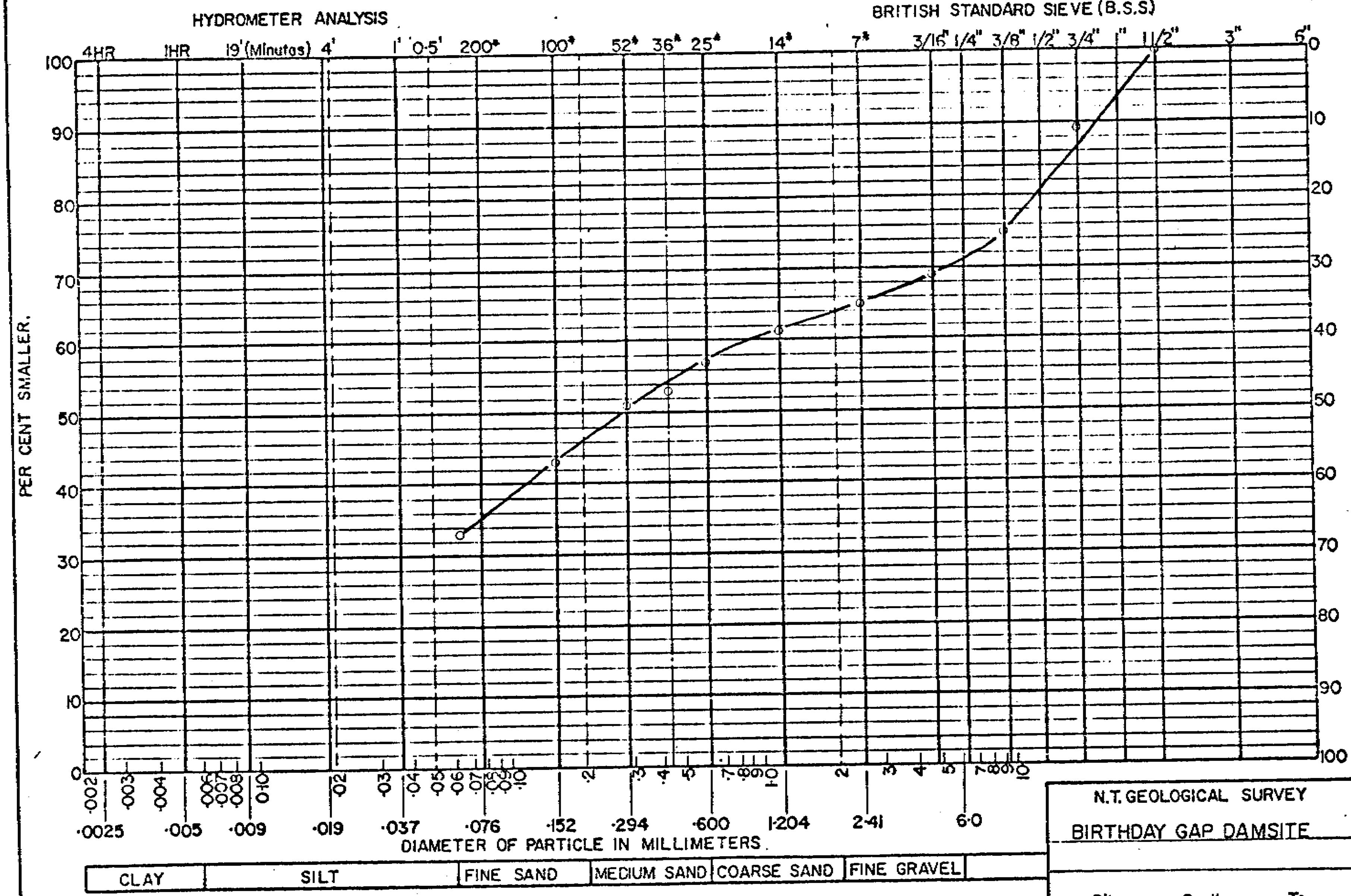
Pit______ Depth______ To______

Lab. Sample No. BG/9/S1

Drawn Checked Date

N.T. GEOLOGICAL SURVEY

PARTICLE SIZE DISTRIBUTION



NOTES:

N.T. GEOLOGICAL SURVEY

BIRTHDAY GAP DAMSITE

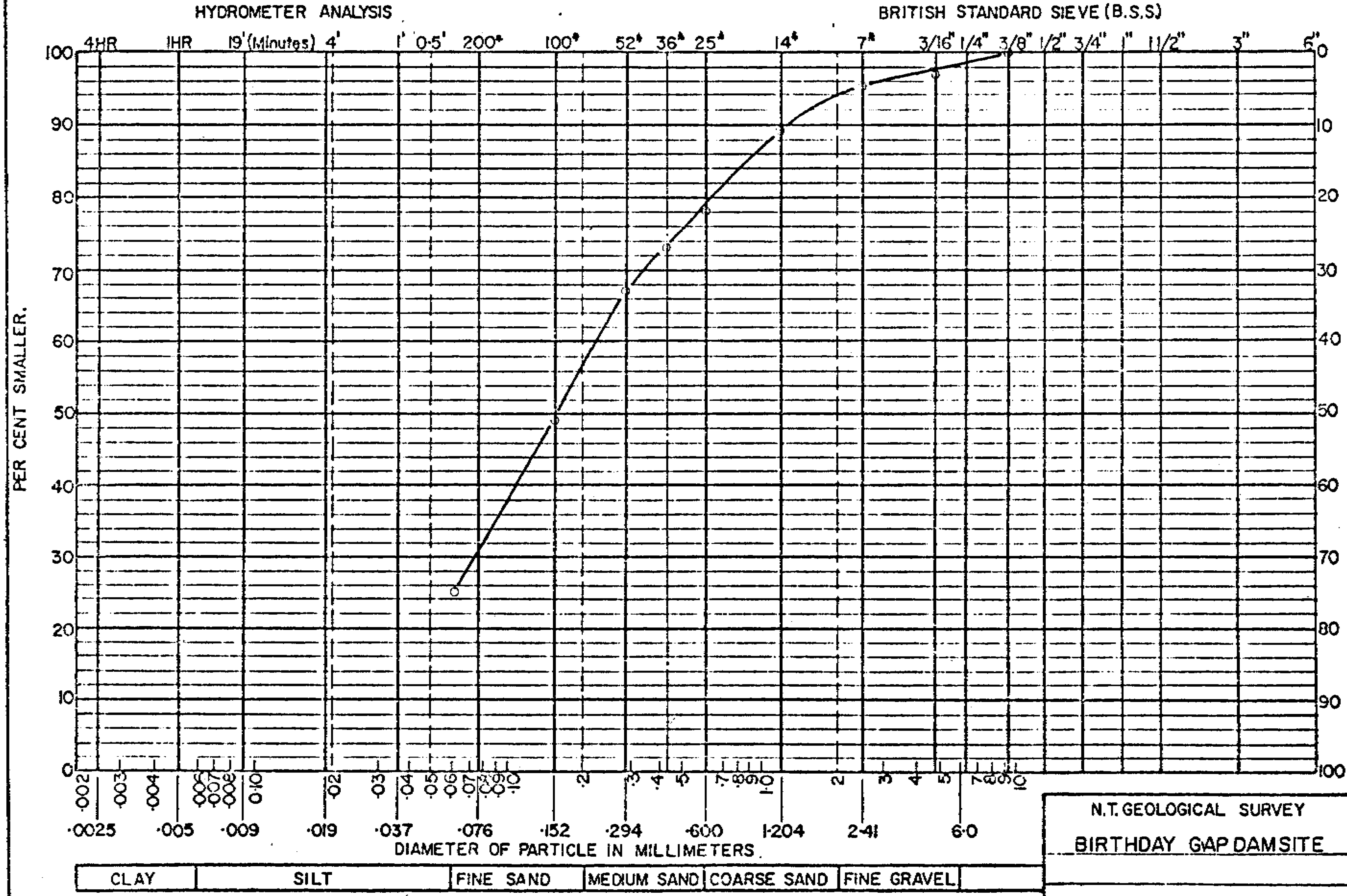
Pit ______ Depth ______ To ______

Lab. Sample No. BG/10/S1

Drawn Checked Date

N.T. GEOLOGICAL SURVEY

PARTICLE SIZE DISTRIBUTION



NOTES:

N.T. GEOLOGICAL SURVEY

BIRTHDAY GAP DAMSITE

Pit ______ Depth ______ To ______

Lab Sample No BG/II/S I

APPENDIX D

PLATES

Nos 1-10

PLATE 1

LEFT ABUTMENT

PLATE 2

VIEW OF LEFT ABUTMENT
SHOWING WELL DEVELOPED J1 JOINTS &
OVERTHRUST FAULT DISPLACED BY STRIKE SLIP FAULT.

PLATE 3

QUARTZITE OUTCROP IN RIVER SECTION AT CENTRELINE

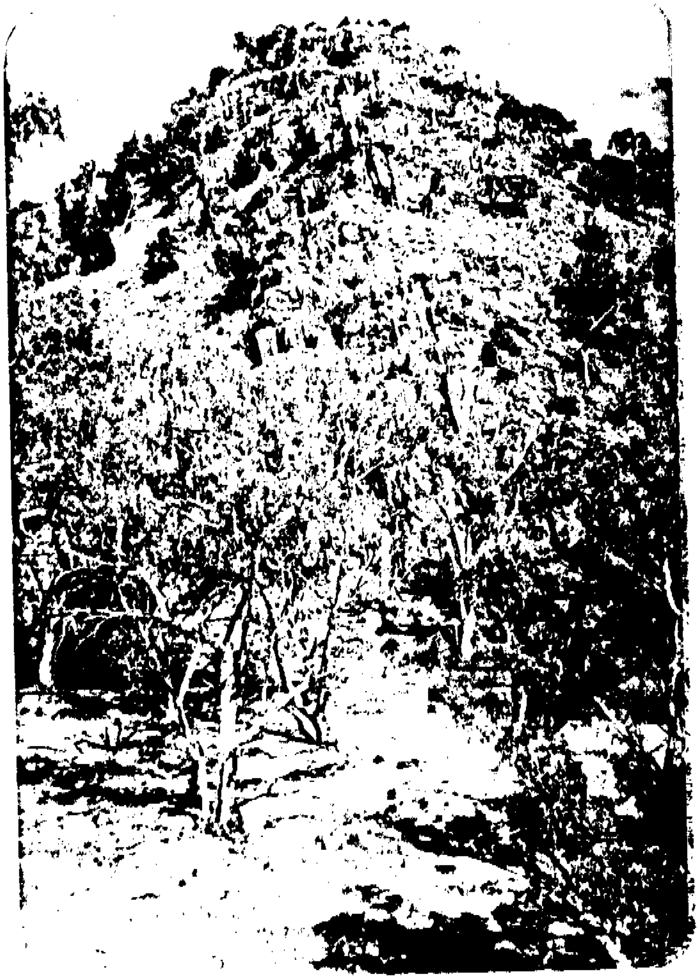


PLATE 4

VIEW OF RIGHT ABUTMENT

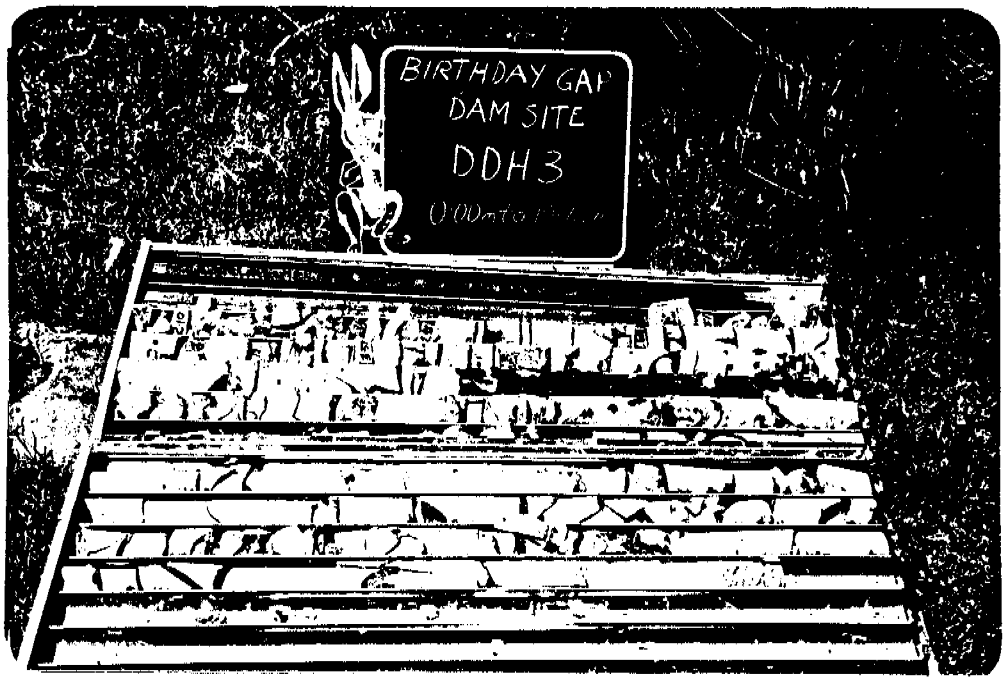


PLATE 5

CORE OF DDH3, BIRTHDAY GAP DAM SITE

RIVER SECTION

PLATE 6

CORE OF DDH5, BIRTHDAY GAP DAM SITE

LEFT ABUTMENT

PLATE 7

J2 & J3 SETS OF PURE SHEAR JOINTS
PRINCIPAL STRESS ACTING E-W
LEFT ABUTMENT

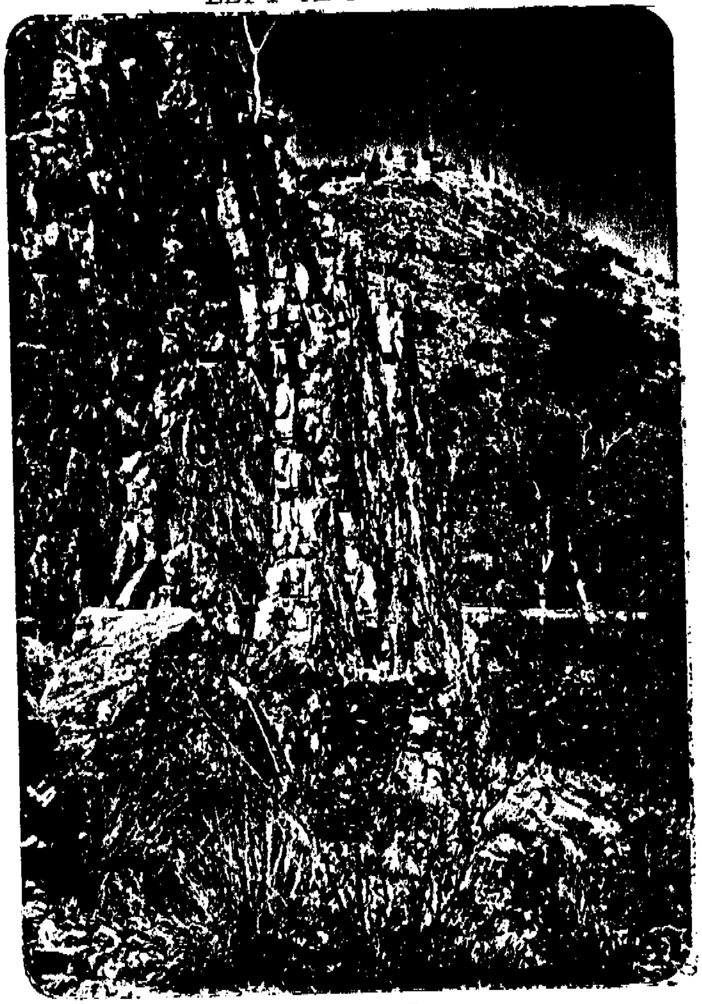


PLATE 8

NEAR VERTICAL FACE FORMED BY J1 JOINTS
LEFT ABUTMENT

PLATE 9

FAULT CONTROLLED GULLY

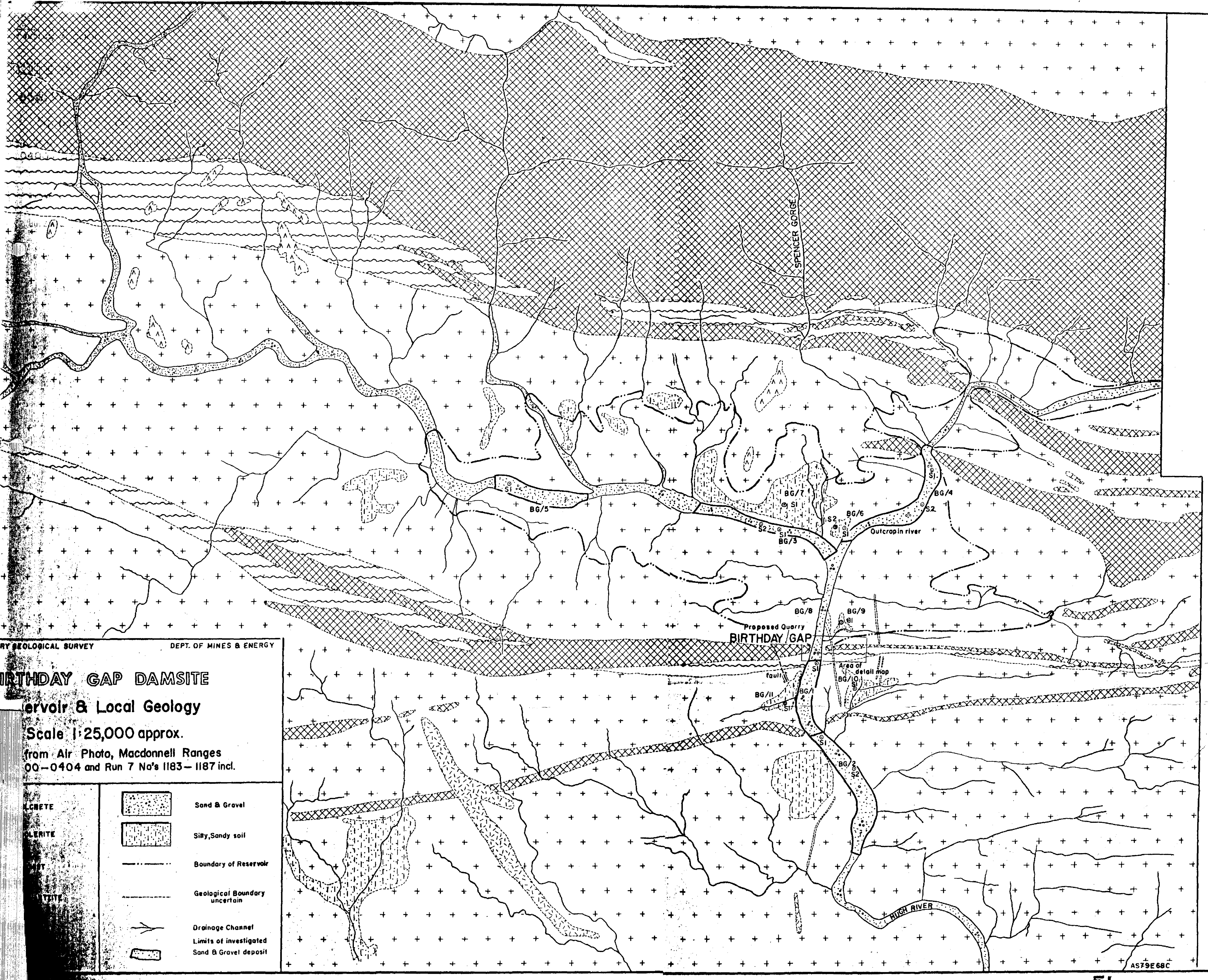
PLATE 10

J1 FAULT & JOINT PATTERN
RIGHT ABUTMENT

APPENDIX E

GEOLOGICAL DRAWINGS

1 Reservoir and Local Geology
2 Detail Geology - Sheet 1
3 Detail Geology - Sheet 2
4 Interpreted Geological Cross Sections A-A and B-B
5 Interpreted Geological Cross Sections C-C and D-D
6 Interpreted Geological Cross Sections E-E



RY GEOLOGICAL SURVEY DEPT. OF MINES & ENERGY

IRTHDAY GAP DAMSITE

ervoir & Local Geology

Scale 1:25,000 approx.

from Air Photo, Macdonnell Ranges
00–0404 and Run 7 No's 1183– 1187 incl.

E1

Notes (1) For locations see drawing No. AS197968
(2) Height Data derived from Water Resources Branch drawing No. 1270-9-848

BIRTHDAY GAP DAMSITE
DETAIL GEOLOGY, SHEET 1 of 2
SCALE 1:500

E2

BIRTHDAY GAP DAMSITE

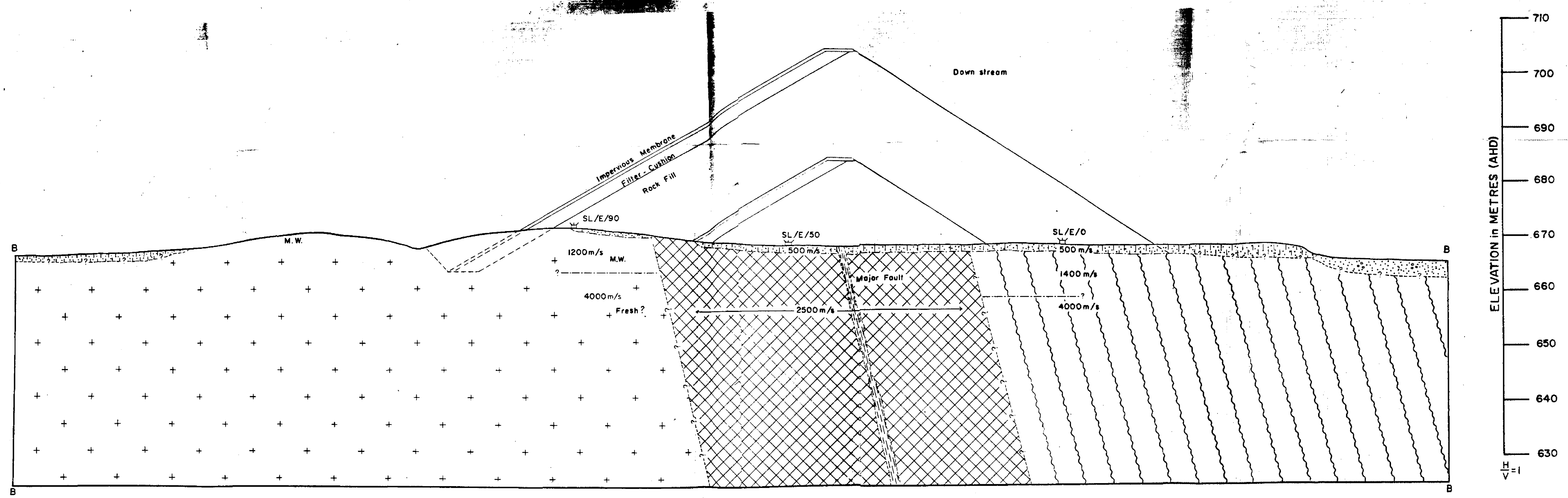
DETAIL GEOLOGY, SHEET 2 of 2

SCALE 1:500

Notes
(1) For locations see Drawing No. AS 197970
(2) Height Data derived from Water Resources Branch drwg. No 1270-9-848

N.T. DEPT OF MINES & ENERGY

SECTION A-A (Looking upstream)



SECTION B-B

BIRTHDAY GAP DAMSITE

Interpreted Geological Sections
A-A & B-B
SCALE 1:500

Legend

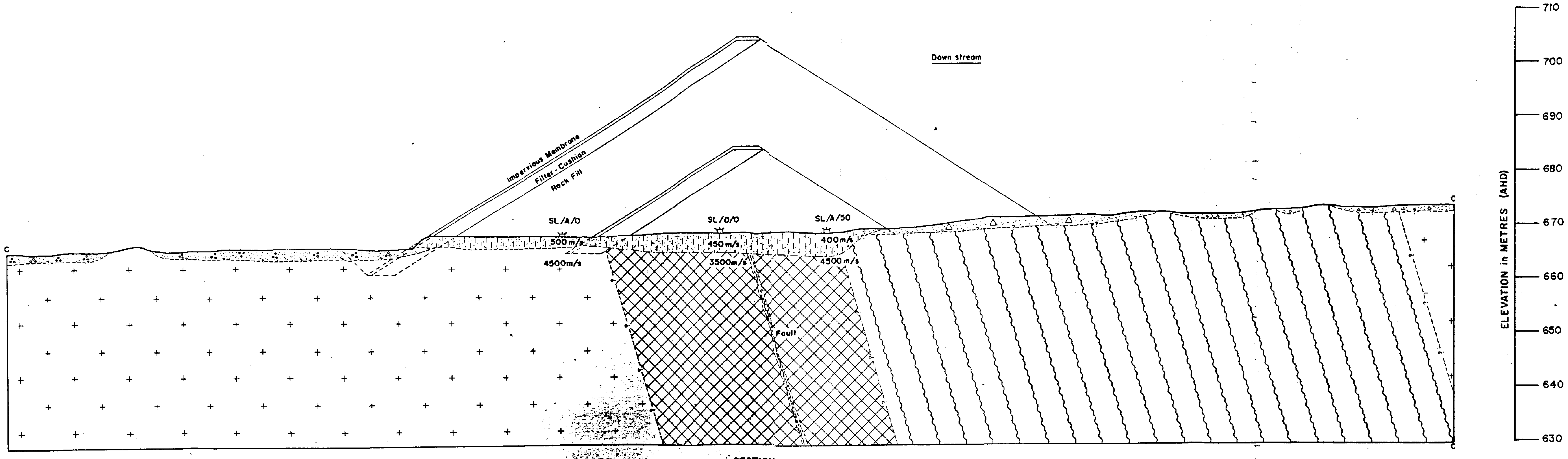
- Sandy Silt
- Talus & Soil
- Sand & Gravel
- Dolerite
- Schist
- Quartzite
- Gneiss
- 500 m/s Seismic boundary& Velocity
- Fault or shear
- Uncertain boundary
- Geophone station

Notes (1) For Locations see Drawing No AS 79E70B

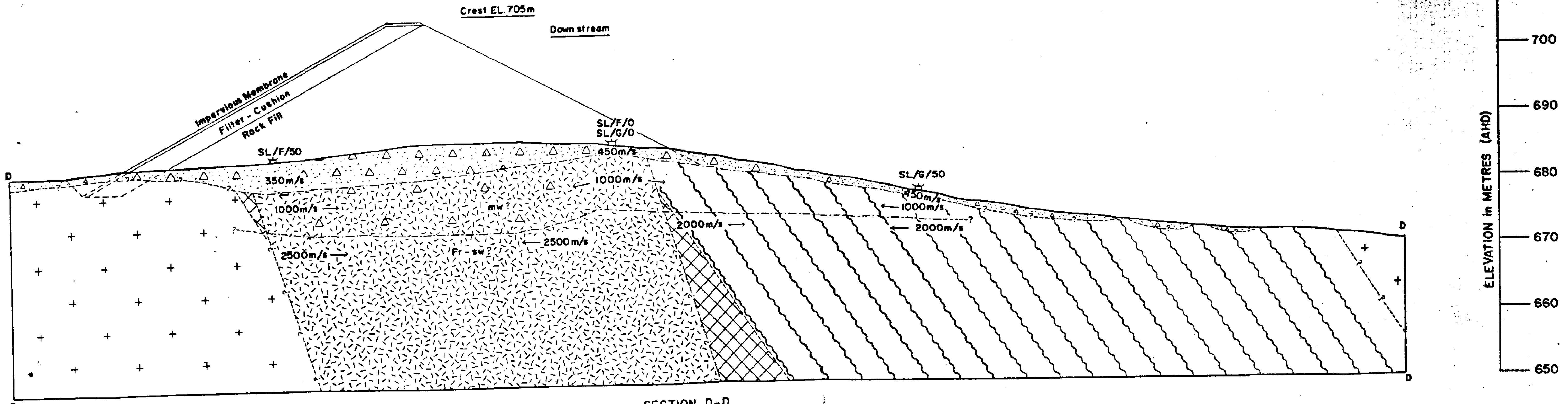
(2) Height Data derived from Water Resources Branch drwg. No.1270-9-84B

E4

N.T. DEPT. OF MINES & ENERGY



SECTION C-C



SECTION D-D

BIRTHDAY GAP DAMSITE

Interpreted Geological Sections
C-C & D-D
SCALE 1:500

Legend

▥	Sandy Silt
△	Talus & Soil
⁘	Sand & Gravel
▧	Dolerite
〰	Schist
▩	Quartzite
+	Gneiss
500m/s	Seismic boundary & Velocity
---------?------	Uncertain boundary
▬	Fault or shear
─┴─	Geophone station

Notes (1) For Locations see Drawing No. AS79E70B
(2) Height Data derived from Water Resources Branch drwg.no.1270-9-84B

AS79E72B

E5

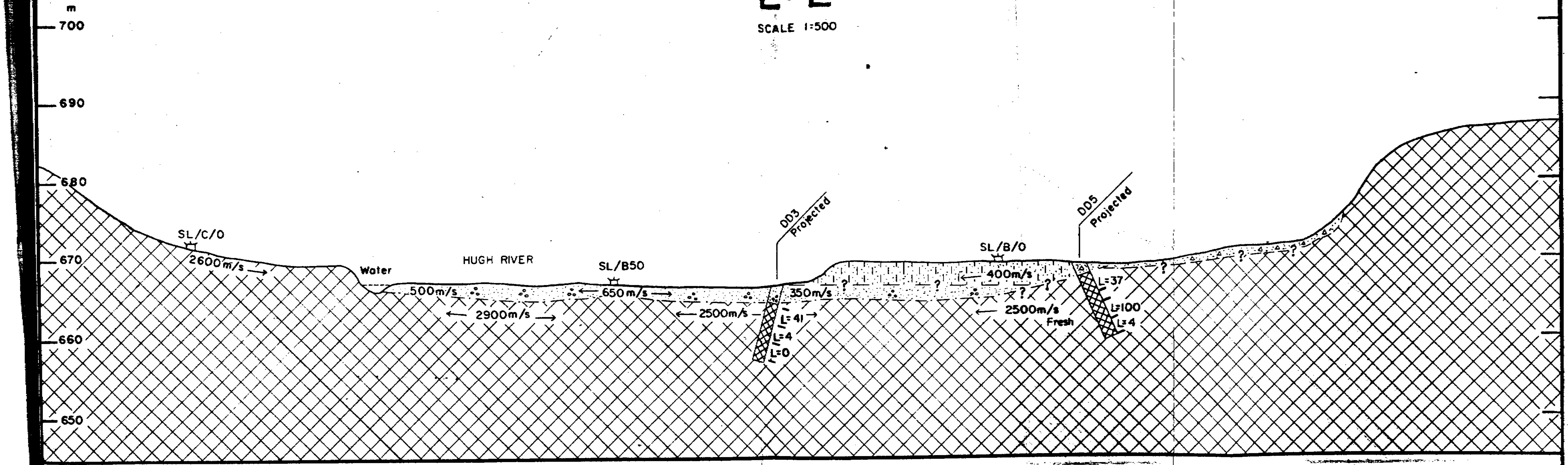
F MINES & ENERGY

BIRTHDAY GAP DAMSITE

Interpreted Geological Cross Section

E-E

SCALE 1:500



Sandy Silt

Talus & Soil

Sand & Gravel

Quartzite

500m/s Seismic Boundary & Velocity

—?—?— Uncertain Boundary

Geophone Station

Notes (1) For Locations see drawing AS 197970

(2) Height Data derived from Water Resources Branch drwg. No. 1270-9-84B

$\frac{H}{V}=1$

N.T. DEPT. OF MINES & ENERGY

AS197969

E6