WASTE-TECH (PTY) LIMITED

Report on the Geotechnical and Geo-hydrological Conditions at the Proposed SA Quarry Site for Waste Disposal at Westville (Durban)

Project 199 . 111

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BLWiiD
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SYNOPSIS

A detailed investigation, comprising various individual geotechnical studies, has been undertaken on behalf of Waste-Tech (Pty) Limited, to examine the SA Crushers Quarry site for the disposal of waste.

The quarry measures about 150 000 square metres in plan and has a maximum available air space of roughly 5 million cubic metres.

The site is geologically situated on jointed tillite bedrock and although the ground water is very close to the floor of the quarry, it should be possible to develop the site as a Class I waste disposal facility by taking the necessary precautions.

The most important consideration is to ensure that any leachate, eminating from the disposed waste, is properly controlled. For this purpose a suitably designed and engineered low-permeability earth liner has been recommended. Suitable clayey soil for building such a liner has been successfully prospected at Ridgeview quarry.

The SA Crushers rock quarry is characterized by steep, cliff-like slopes that are considered to be locally unstable over parts. It has therefore been recommended that the long-term disposal plan takes due cognizance of the structural stability of the quarry slopes.

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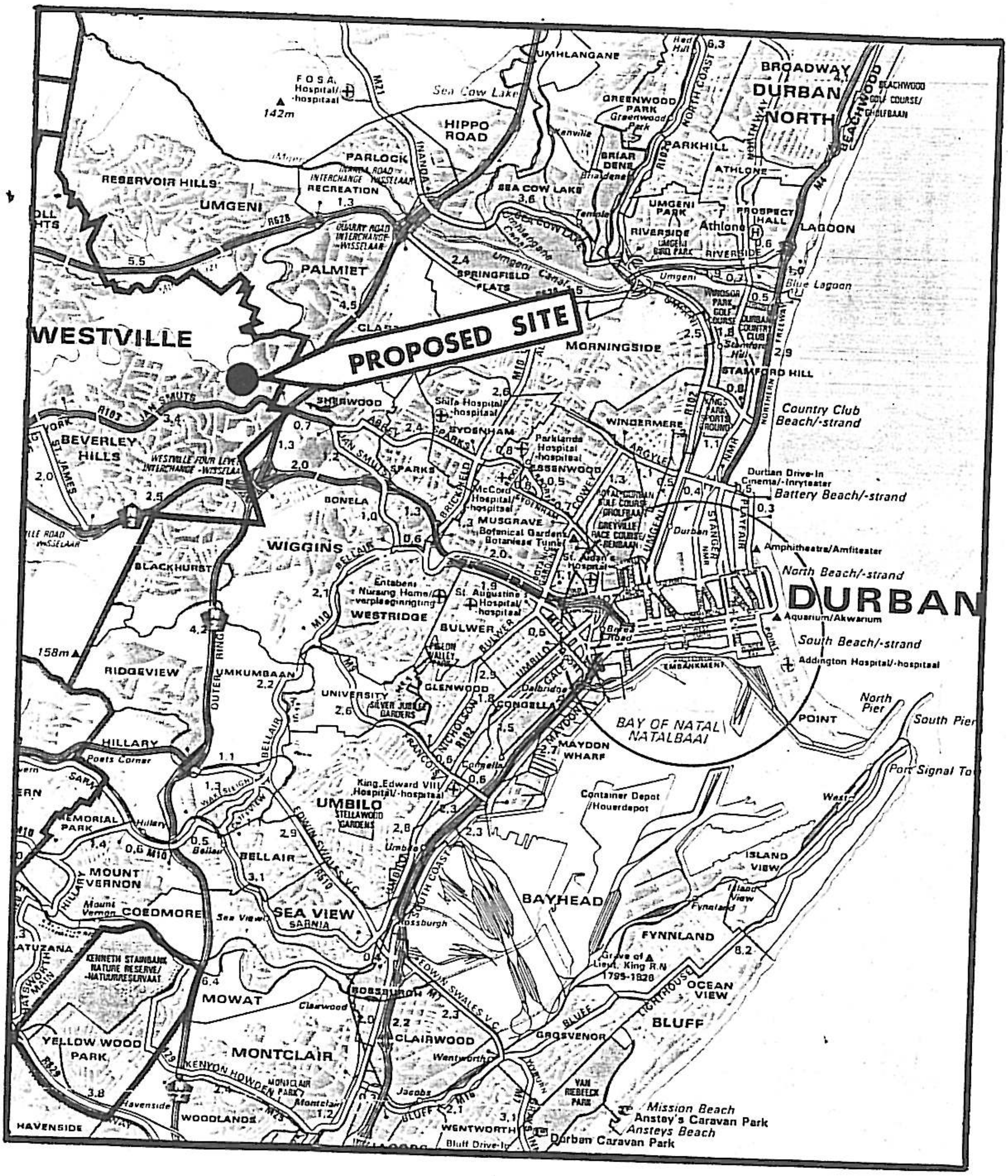

LOCALITY PLAN

scale: 1 : 100 000

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1. Introduction.

It is the intention of Waste-Tech (Pty) Limited to develop the S A Crushers quarry site in Westville as a disposal facility for Class I waste. The decision to consider the site for Class I waste was, from a technical point of view, based on the outcome of a preliminary assessment and the ensuing discussions with officials of the Department of Water Affairs, concerned with the licensing of waste disposal sites.

Since the initial investigations started at the beginning of 1988, several geotechnical studies of varying detail were undertaken to examine the different problems identified, as work progressed. The expertise of local consultants was also employed extensively during the course of the project.

This report, in essence is a concise summary of all the geotechnical input collected on the relevant issues on which data is required to formulate a formal licence application for the disposal of waste.

Furthermore, the primary function of this report is, in accordance with the terms of agreement, to provide Waste-Tech (Pty) Limited with the necessary geotechnical information to support their licence application which they themselves will submit to the Department of Water Affairs.

2. The Site and Environment.

General: The quarry site is situated immediately to the south-east of the University of Durban-Westville where it is bounded on the east and north by

University Road. The southern edge of the quarry is skirted by highway 103, Jan Smuts Highway. These details are illustrated by the simplified plan given in figure 1. See also the locality plan at the front of this report.

Topographically, the quarry is situated on a north-south trending ridge which slopes down towards the Palmiet River in the west. At one point near the north-western corner, the quarry is only about 50 metres from the Palmiet River which joins the Umgeni River some 500 metres downstream.

The geographic location of the site is:

Longitude:	30° 57' 15"
Latitude:	29° 49' 33"

The surrounding area is hilly and characteristic of a dissected topography with steep slopes, some close to 1 : 3 where drainage paths are deeply incised. The regional topography slopes from west to east with high points in the immediate vicinity of the quarry at between about 150 to 220 metres above mean sea level. The bottom of the valleys are at about 30 to 60 metres above mean sea level.

These various topographical features are very clearly illustrated by the 1 : 10 000 government ortho-photo maps, reference 2930 DD 9 and DD 10 of 1985.

The Quarry: Stone aggregate has been mined for a long time and development has taken place at various levels as illustrated in colour Plates I and III.

The northern portion of the quarry, where it is intended to commence with waste disposal, lies downslope of the old crushing plant and has been mined to between about 50 and 60 metres below original ground level with very steep, near-vertical rock faces, some showing signs of local instability. This aspect is discussed in greater detail elsewhere.

The working of the quarry has been controlled, to a large extent, by the structural geology of the site. For instance, a number of prominent, near-vertical fault or shear zones cut across the site and have been left unmined because of the highly weathered and deleterious nature of the material for use as an aggregate. The result is that there are island remnants and peninsulars of heavily sheared and weathered rock, giving the quarry a very irregular shape as shown in figure 2.

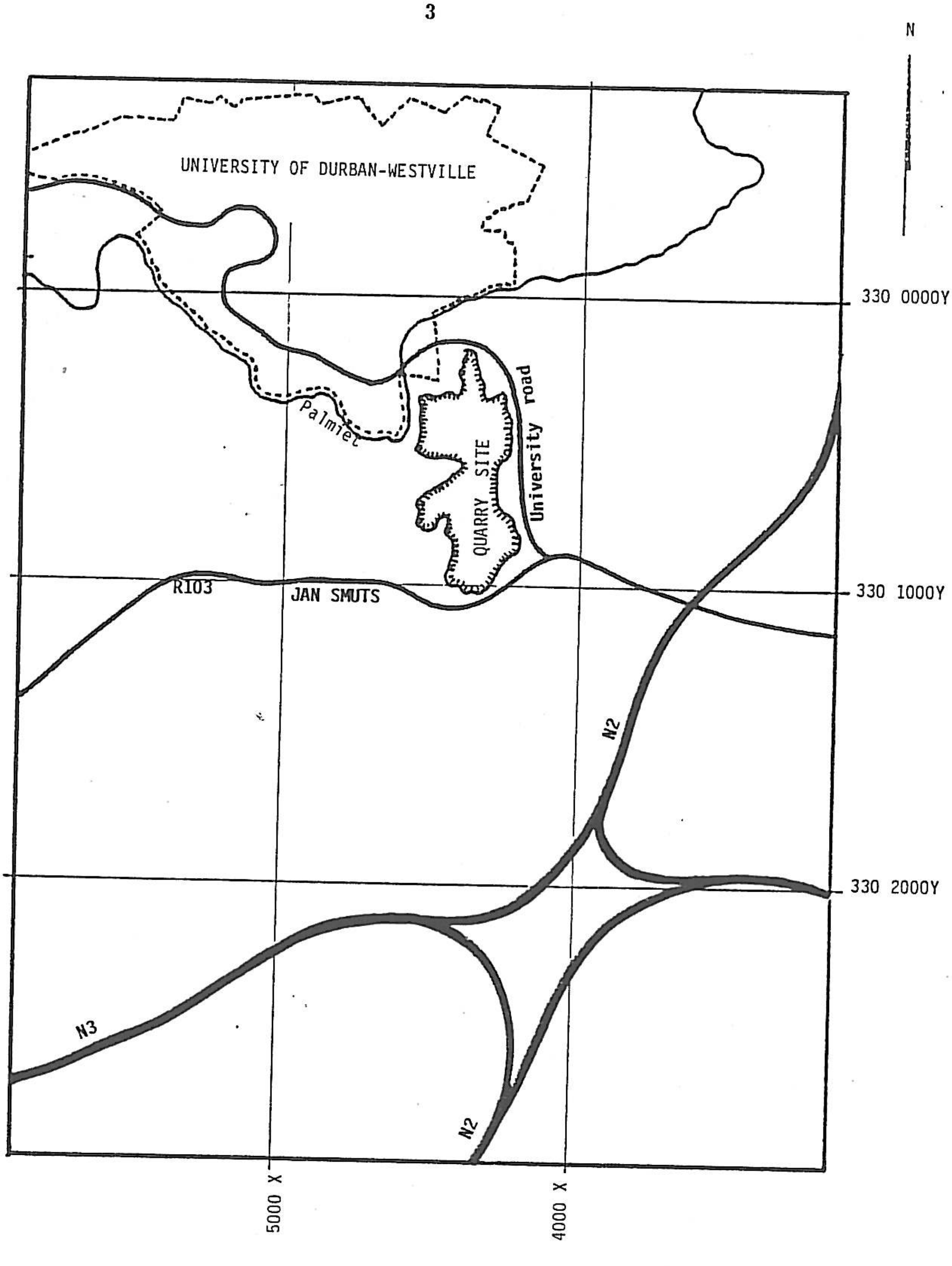

FIGURE 1. WASTE-TECH (PTY) LTD: PROPOSED SA CRUSHERS SITE.

Simplified plan showing the general location of the proposed waste disposal site at Westville.

scale: 1 : 20 000

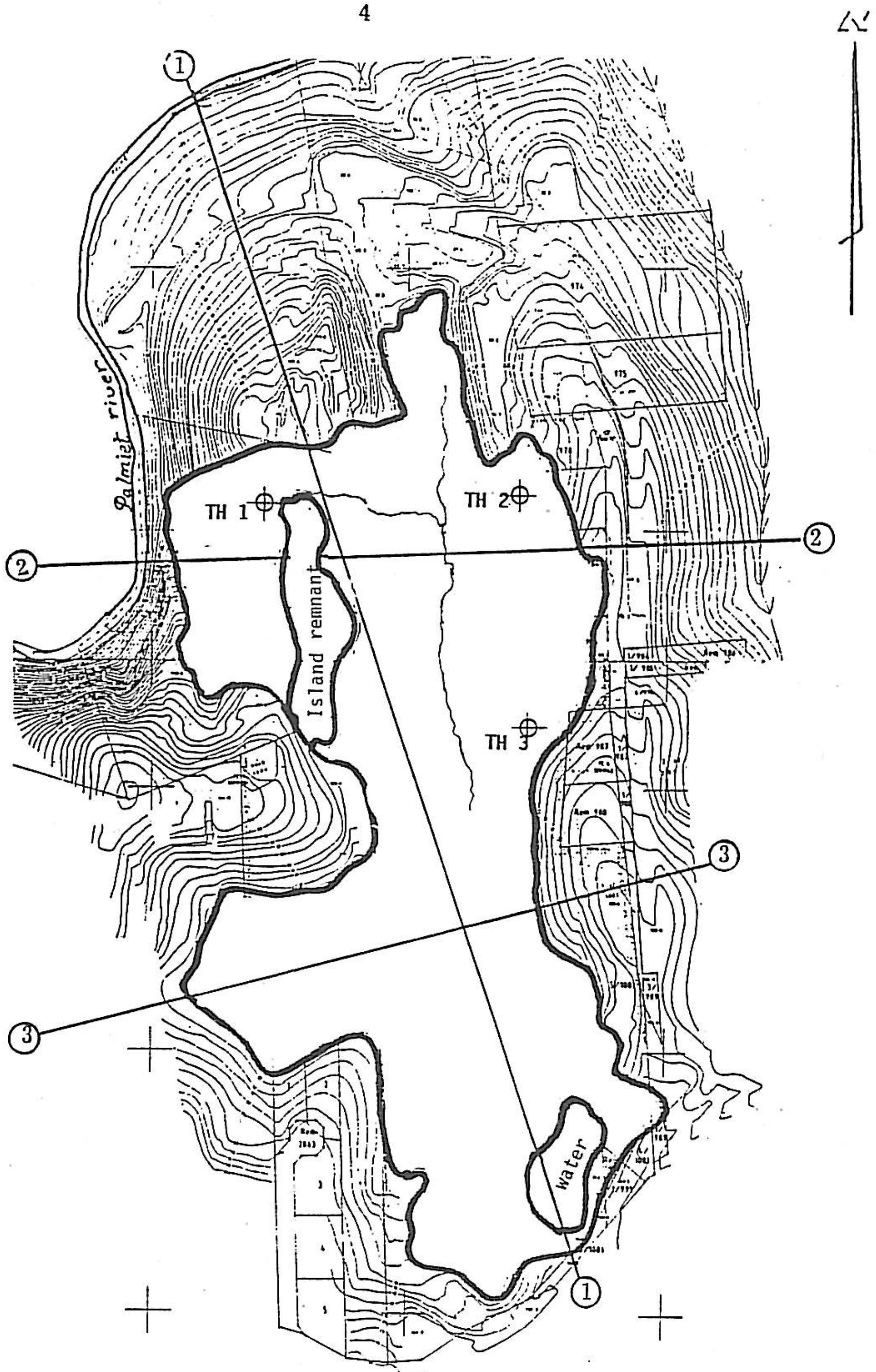

FIGURE 2. WASTE-TECH (PTY) LTD: PROPOSED SA CRUSHERS SITE.

Plan showing the irregular shape and extent of the proposed waste disposal site together with the positions of the three test bore holes where permeability tests were undertaken.

scale: 1 : 5 000

The plan area of the quarry is estimated at about 150 000 square metres. By taking full advantage of the maximum available height across the whole site, the total available air space could be in the range of 5 million cubic metres if the quarry can be filled to original ground level. This, however, should be regarded as a very rough estimate, particularly since the actual usable air space will depend very much on how the over-all waste disposal operation is to be planned and engineered.

3. Climatic Conditions.

The area of Westville lies fairly exposed and consequently the general climate resembles more closely inland conditions than that obtaining along the coast some 10 kilometres away.

The average annual rainfall is 934 millimetres. This value is based on measurements at the Pinetown Magistrate's Court that stretch over a period of 55 years. Of all the weather stations, the data for Pinetown is regarded* to be the most representative of the conditions at Westville.

The average annual evaporation for Westville is 1 410 millimetres and thus exceeds the average annual precipitation by a factor of about 1,5.

The relationship between average monthly evaporation and average monthly precipitation is illustrated graphically in figure 3. For the purpose of comparison, the corresponding data obtained from the Weather Bureau for their stations at Louis Botha Airport and in Pietermaritzburg, are also shown. It is clear from this presentation that the weather conditions under consideration at Westville correspond more closely with those recorded inland at Pietermaritzburg than at the coast at Louis Botha Airport.

An important point concerning these average values is the extremely large degree of variation contained in the data. As shown in Table I, which lists the rainfall data for Pinetown, the calculated average monthly figures have coefficients of variation of over 200%. While these high coefficients apply mainly to the dry

*Personal communication: Prof. R E Schulze, Dept. of Hydrology, Natal University.

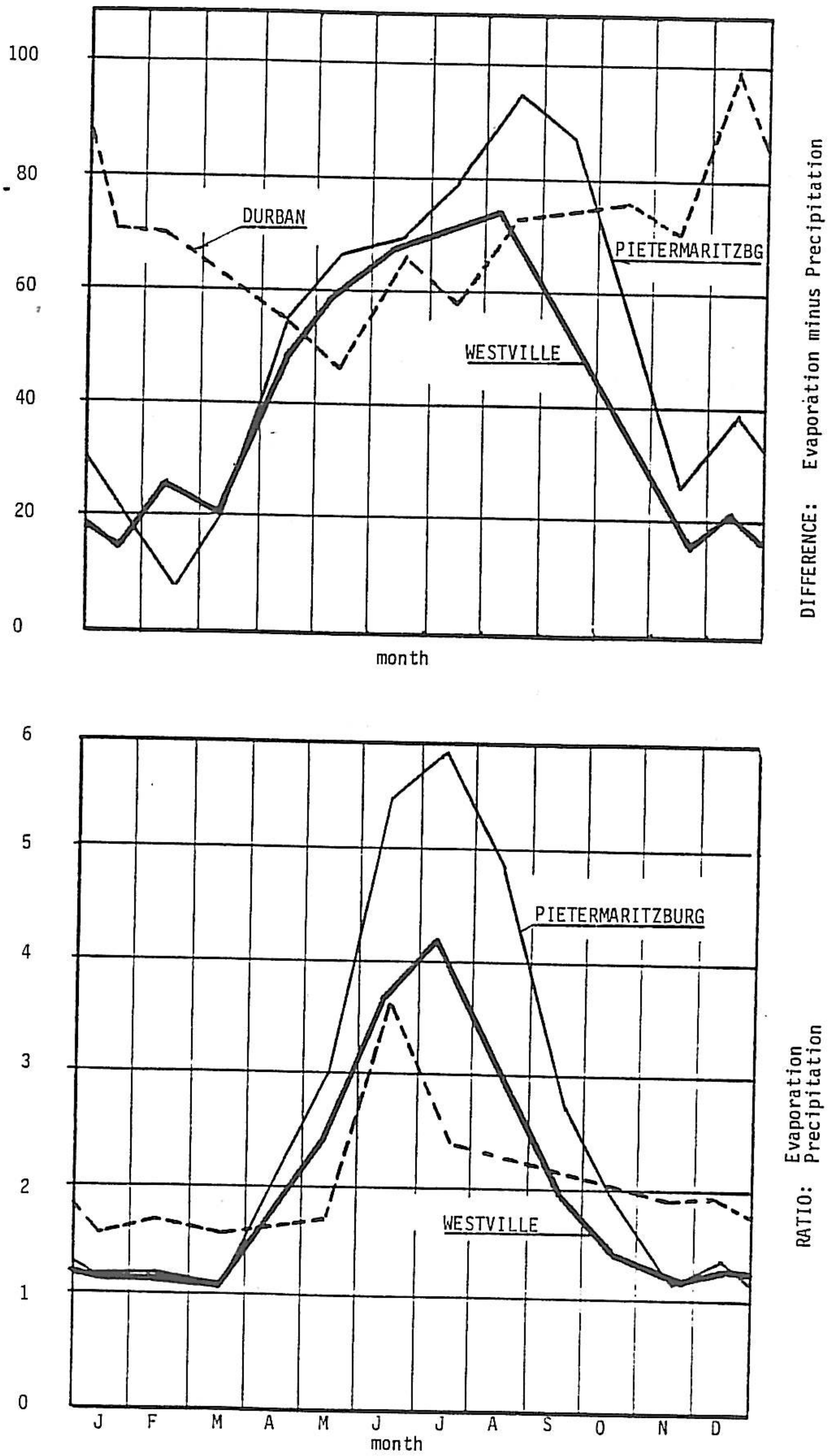

FIGURE 3. **WASTE-TECH (PTY) LTD: SA CRUSHERS SITE WESTVILLE. Relationship between precipitation and evaporation.**

TABLE I

Summary of Average Monthly Precipitation and Evaporation Data
Recorded at the Pinetown Magistrates Court

month	ave evaporation mm	ave precipitation mm	coeff. of variation %
January	145	131	48
February	135	112	63
March	140	119	82
April	115	65	94
May	102	41	131
June	90	25	224
July	92	24	159
August	102	34	98
September	105	59	74
October	125	92	32
November	125	110	53
December	135	114	53

winter months, it emphasizes the serious limitations of such data and also illustrates that any relationship between precipitation and evaporation that is based on average monthly figures may often have little meaning with regard to the day-to-day running of a waste disposal facility.

The prevailing wind directions at Westville are as follows:

Winter;	April to July:	South-West
Summer;	remaining months:	North-North-East

These two directions account for about 80% of all the wind experienced at Westville and for the remaining 20%, the wind could blow from practically any other direction*. The average annual wind speed is just over 3 m/s with gusts of nearly 40 m/s.

4. Site Geology.

The quarry and surrounding area lies on tillite of the Dwyka Formation. The tillite is of glacial origin and characteristically comprised of an unsorted, unorientated accumulation of rock and mineral fragments in a fine-grained argillaceous rock matrix. The tillite, though extensively jointed, has nevertheless a generally massive appearance where exposed in the quarry. This massiveness is accentuated by the absence of any bedding in the formation.

Below a thin and generally insignificant cover of residuum, the tillite is initially highly weathered to a yellowish brown, friable, weak rock with black discolouration along the joints. The degree of weathering and the frequency of jointing decreases rapidly with depth where typical blue-grey fresh tillite is encountered.

The most important structural feature of the tillite rock formation is the degree of jointing as this dictates both the extent of ground water movement and the long-term stability of the exposed quarry faces.

These various features are shown in colour Plates I to V.

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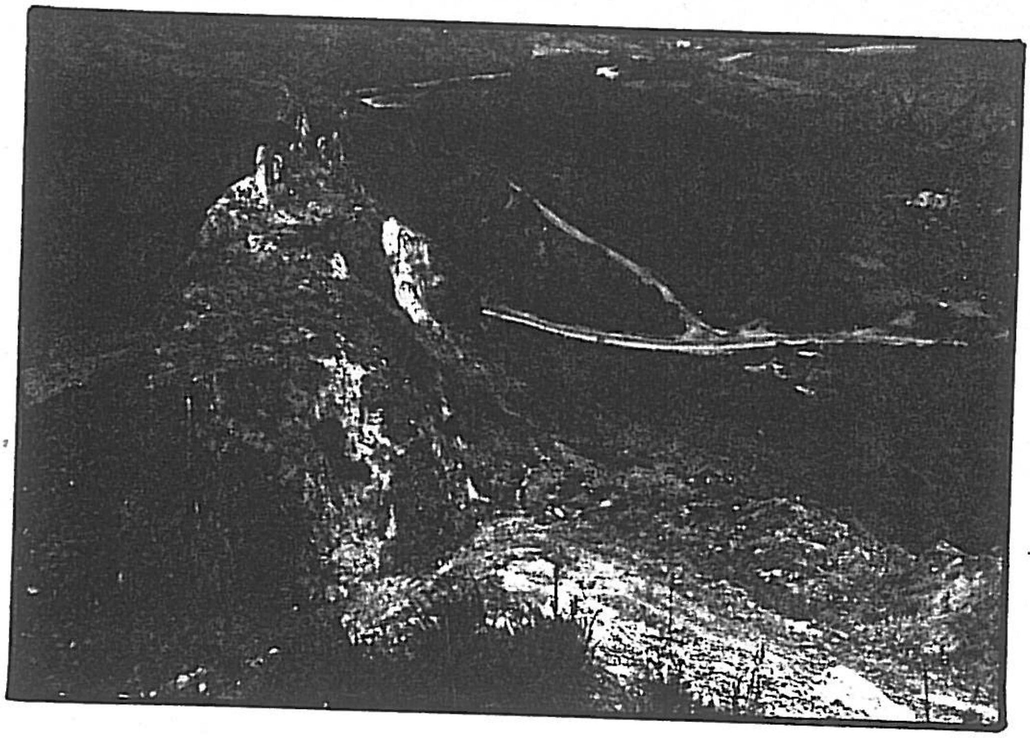
*Personal communication: Prof. H de Villiers, Dept. of Geography, University of Durban-Westville.



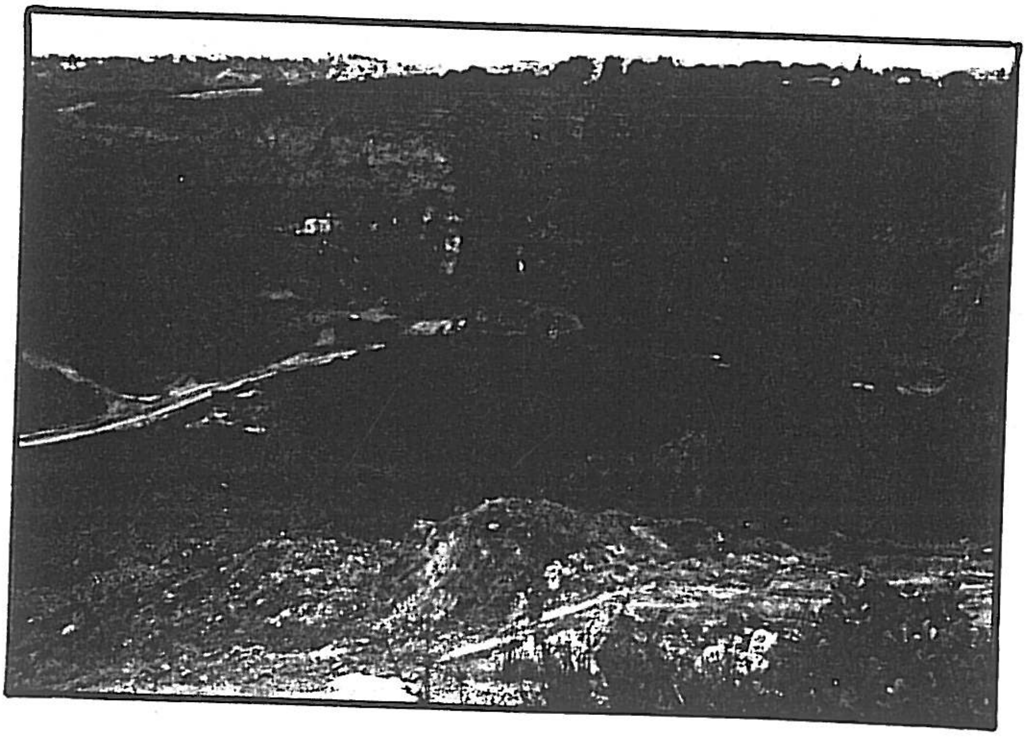
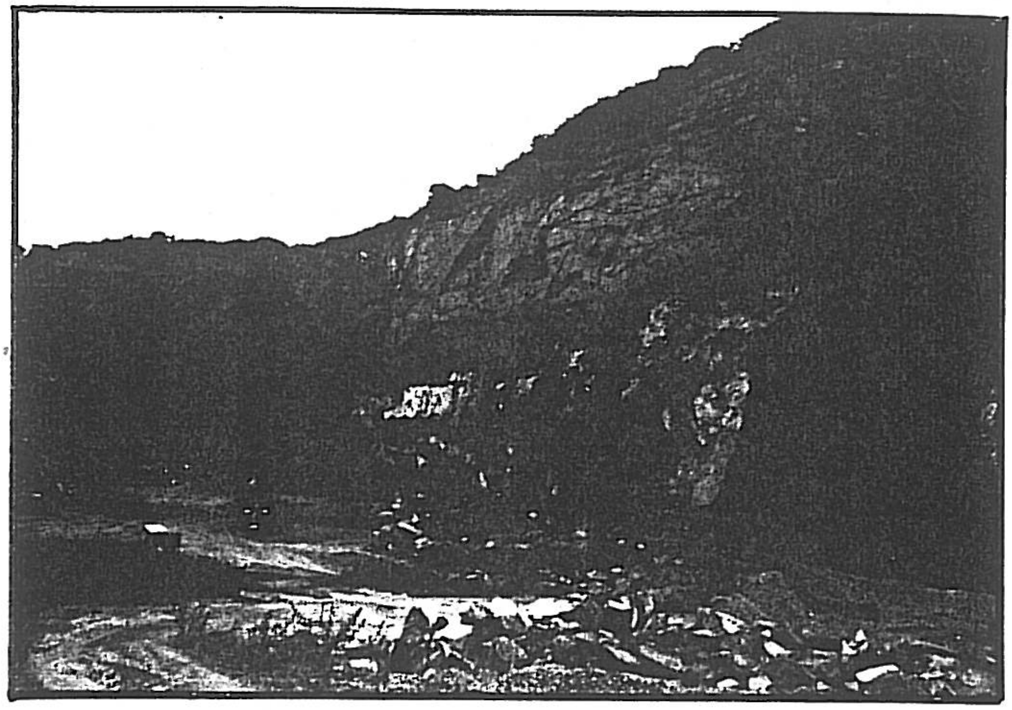


PLATE I. General view of the site showing the irregular shape of the quarry Note the steep rock slopes and the large island remnant of highly weathered and sheared tillite in the above photograph.



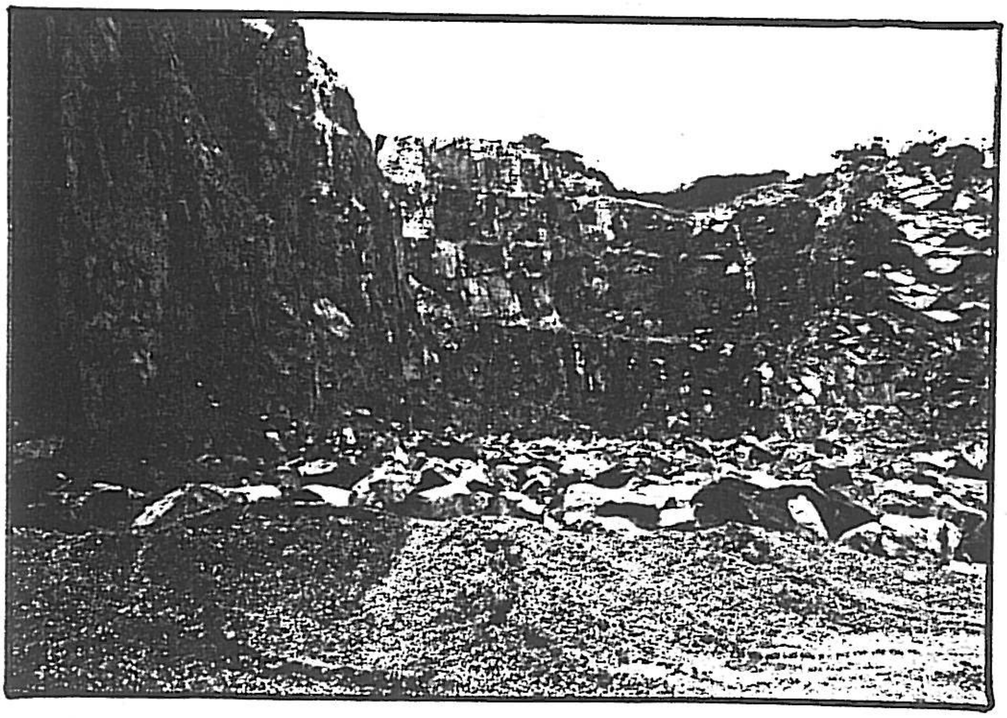
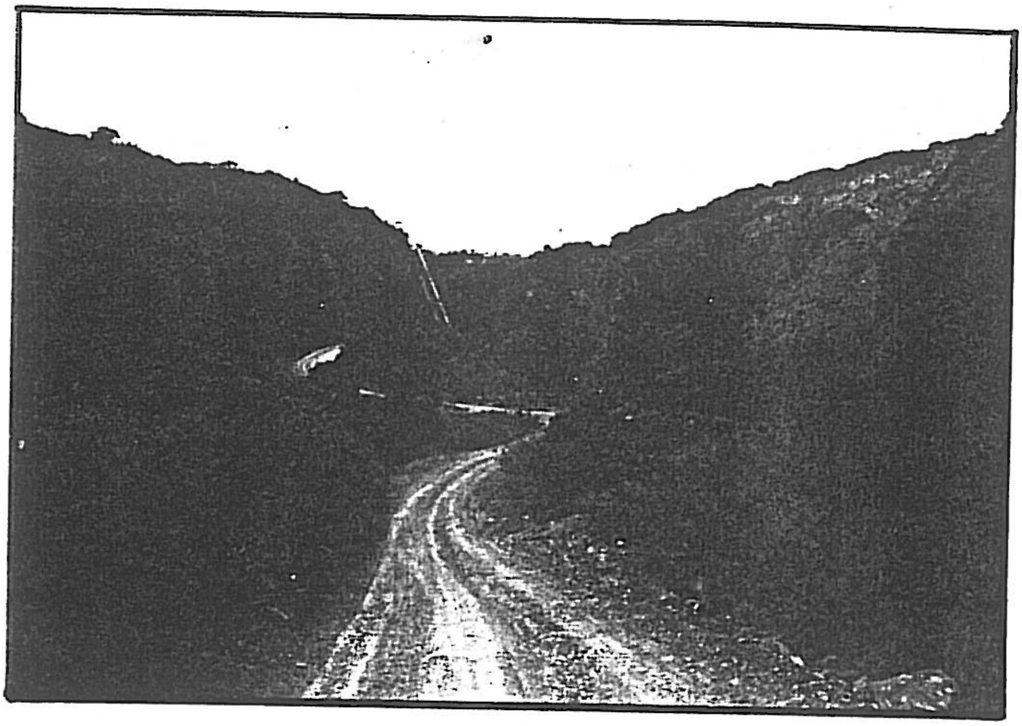


PLATE II. Typical exposures of some major joint planes in the tillite rock formation.



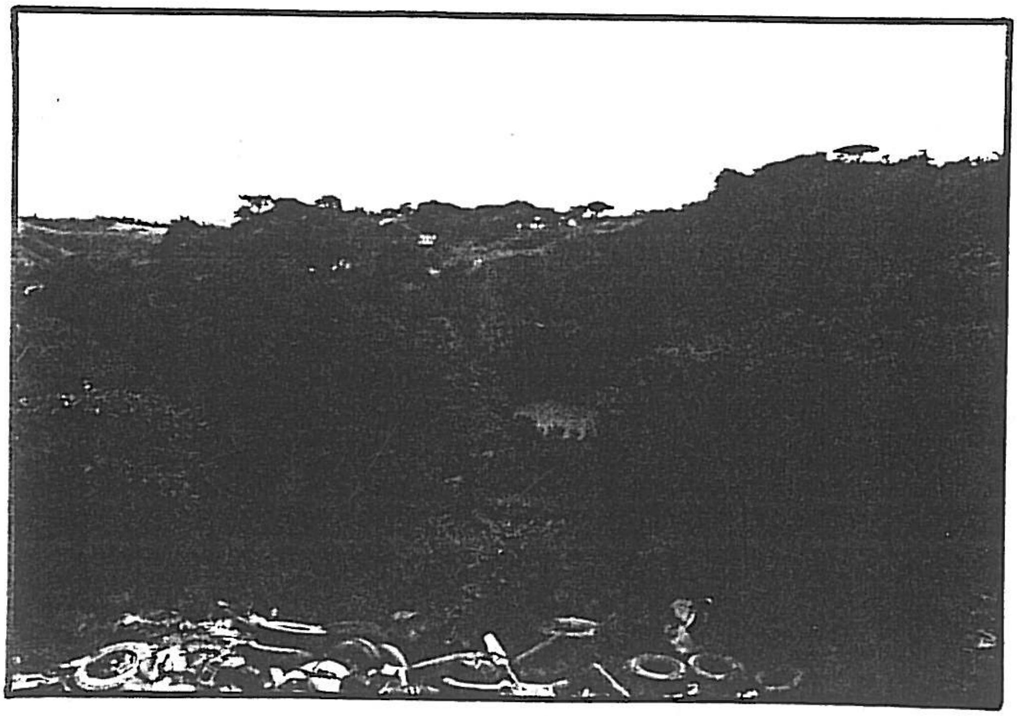


PLATE III. General view of the quarry looking south towards the plant area (above) and local deep section at southern end presently filled with water which is regarded to represent the ground water phreatic level.

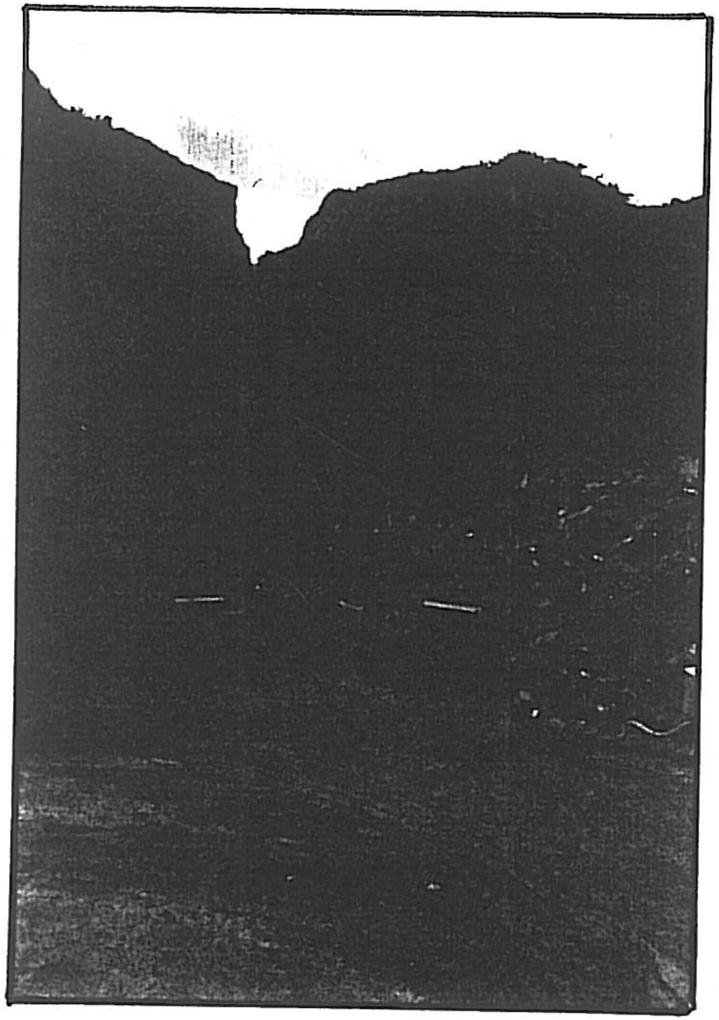


PLATE IV. Quarrying operations at the deepest section (approx. 60m above msl) at the north-western end. Note severe jointing in the rock and water seepage in foreground of right hand photograph.

PLATE V. Typical thin ground cover (top photograph) and corestone development in the tillite formation near the Palmiet River at the north-western corner of the quarry.

A detailed structural analysis by Messrs Moore Spence Jones and Partners (MSJ&P) has revealed three steeply dipping major joint sets. A further 3 joint sets of less prominence, and which appear to have a more random orientation, were also identified. The relevant details are fully described in the MSJ&P report[1], reference 88/203 of March 1989. A copy of this report, in reduced format, is given in Appendix I to facilitate easy reference. However, to ensure that no details are lost in this manner, an original copy of this important document is to accompany this report.

5. Ground Water.

General: The Dwyka tillite in the fresh, unweathered state is a strong and impervious rock with a very low porosity; probably of the order of only a few percent. In certain areas, particularly in the Southern Cape Province, good supplies of ground water may be obtained where the formation is heavily jointed and fractured.

In Natal, on the other hand, the Dwyka formation is mostly uncleaved and only slightly jointed with the result that despite the reasonably high rainfall, yields are very low and boreholes few and far between. Because of the paucity of producing bore holes in the Dwyka formation, detailed chemical analyses are equally scarce. Bond[2] lists only 6 analyses of bore hole water and in spite of the very low concentration of dissolved solids (TDS average = 450 mg/ℓ) he prefers to describe the water as 'moderately hard' and 'slightly saline' although the author does not regard them as brackish. Du Toit[3], however, states that the tillite in Natal invariably yields fresh water.

Site Conditions: Ground water seepage is evident at various positions in the quarry. At the southern top end, close to Route 103, the mined out section of the quarry has water standing at a level of about 105 metres. It is believed that this is ground water and although it may contain some accumulated run-off, it represents the phreatic level of the ground water. See Plate III, lower photograph.

According to the observed seepage and measurements in the test bore holes, (see figure 2) the water level at the northern deep section of the quarry is at an elevation of about 64 metres. This is roughly 1,5 metres below quarry floor level.

As illustrated in figure 4, the ground water appears to have a steep slope of about 1 : 8 (a gradient of roughly 12%) in a generally south to north direction.

There is no evidence of any clearly defined zones of preferred ground water flow in the tillite below the quarry floor and, in the true sense of the word, there is no aquifer of any significance. Ground water movement is along intersecting joints and discontinuities.

Pump tests at bore holes 1 and 3 gave values of between 1 x 10^{-6} m/s and 5 x 10^{-7} m/s for the secondary or bulk permeability of the tillite formation below quarry floor level (between 40 and 60 metres below original ground level).

During the draw-down stage of the tests, difficulty was experienced in maintaining a sufficiently low pumping rate to obtain realistic results. The recovery data was regarded to be more reliable but still gave relatively high values that are considered to represent the upper bound limits for the permeability of the tillite formation as a whole. Based on visual examination of the joints and their frequency, a somewhat lower permeability coefficient, of about 1 x 10^{-7} m/s would perhaps be more realistic.

It may, however, be possible that the measured permeability values are the result of induced fractures in the tillite below floor level, caused by the regular blasting during quarrying operations. With this possibility in mind, it is therefore suggested that the in situ measured coefficient of permeability be accepted as being representative of the 'worst' conditions that can be expected at the site, even though the values appear too high for the tillite formation in general.

Finally, on the assumption that a homogeneous flow pattern existed during the pump tests, the transmissivity of the tillite below quarry floor level amounts to about one square metre per day. This is a very low figure and despite some uncertainties regarding the test data and the assumptions made in the calculations, such a low transmissivity clearly reflects the poor water bearing properties of the tillite formation at the site.

6. Structural Stability of the Quarry Sides.

As mentioned previously, the quarry has some very steep sides, particularly over

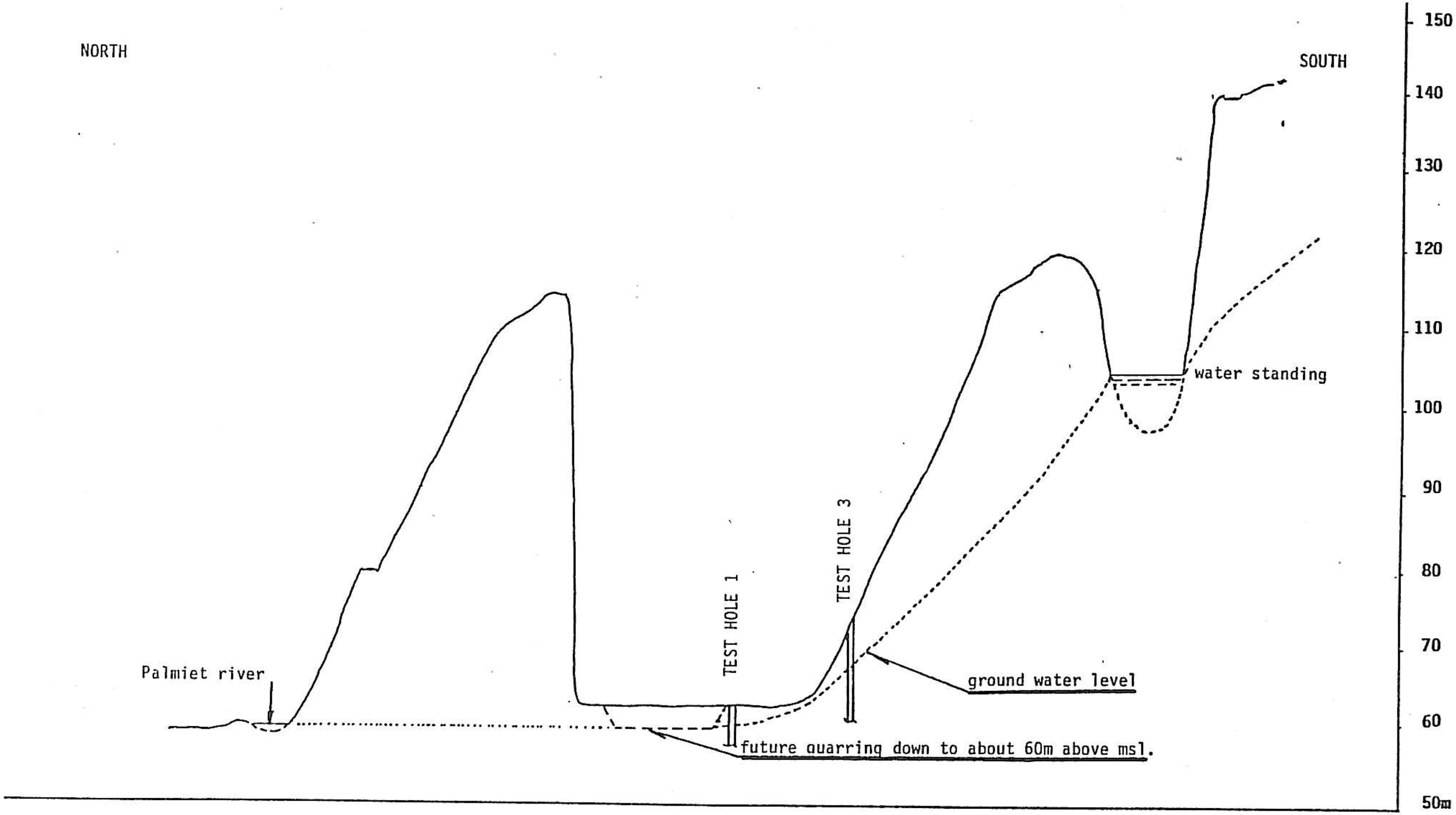


FIGURE 4. WASTE-TECH (PTY) LTD: PROPOSED SA CRUSHERS SITE WESTVILLE.

Simplified cross-section from north to south showing the expected ground water rest level. Note: vertical exaggeration about 6 times.

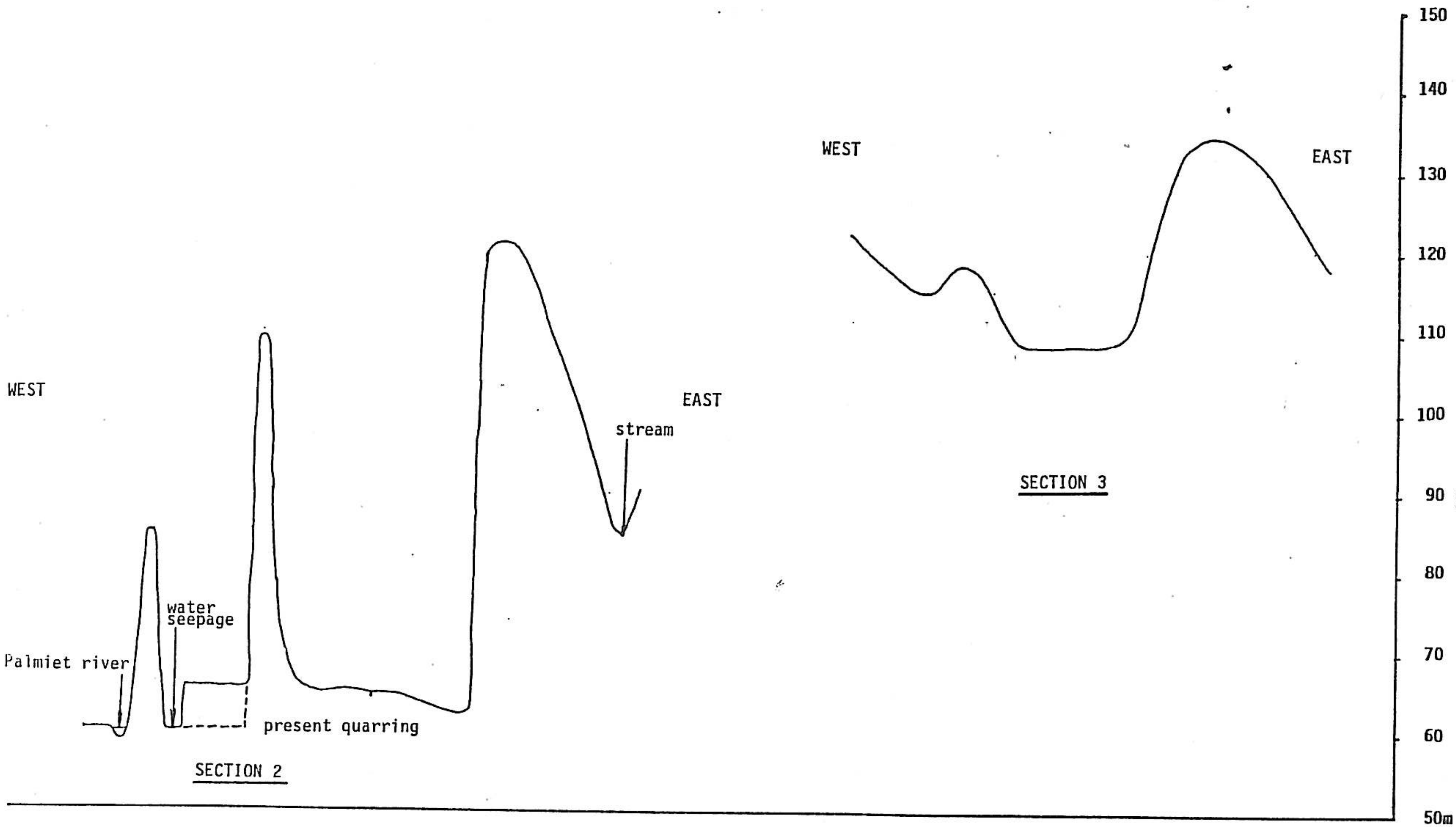


FIGURE 5. **WASTE-TECH (PTY) LTD: PROPOSED SA CRUSHERS SITE WESTVILLE.**

Simplified cross-sections 2 and 3 from nwest to east.
Vertical exaggeration about 6 times.

the deeper northern sections where there are near-vertical rock cliffs up to 60 metres high as illustrated by the photographs in Plate II.

A detailed preliminary assessment of the structural stability of the rock slopes has been undertaken by the consulting firm of Moore Spence Jones and Partners (MJS&P). Their report[1] (see Appendix I) indicates various slip failures that have occurred in the overlying soil layers and in parts of the highly weathered tillite. Evidence is also presented where ravelling and minor failures of some of the rock faces have taken place.

The MSJ&P report describes 12 individual areas where the structural stability of the quarry slopes has been assessed. At practically all of these localities evidence has been found of varying degrees of instability. A summary of their data is reproduced in Table II of this report. The explanatory diagram to Table II is given in figure 6.

The general findings of the MSJ&P investigation are quoted below:

> "In general, the west facing slopes at the quarry appear to be relatively stable, except where there are shear zones present within the tillite. The peninsulars or buttresses of rock left unmined because of the presence of shear zone material, are generally in an unstable condition. In all cases, large scale earthworks will be required to stabilise these peninsular areas. The east facing slopes are generally unstable because of the presence of the north to south trending joint set which dips steeply towards the west, resulting in potential toppling type failures within these slopes. The north and south facing slopes are generally relatively stable except for the possibility of minor wedge type failures.
>
> The site will have to be carefully engineered to promote the long-term stability of the rock slopes. In this regard, the earthworks will have to be carefully planned in conjunction with the development of the site to optimise

costs. The peninsulars, comprising shear zone materials, will of necessity have to be removed or partially removed to enhance stability. This shear zone material should, however, prove suitable for use as a cover material in the landfill operation. Thus, with careful planning of the earthworks for bunded areas and cover material, earthwork costs could be optimised."

The stability of the rock slopes of the quarry is apparently of no direct concern to the Inspector of Mines. According to the Chief Inspector of Mines for this region, Mr M Steward of the Dundee Office, it is incumbent on the owners of the quarry to appoint a 'Responsible Person' to attend to the safety of the quarry until a Certificate of Closure has been granted. At this stage the Chief Inspector of Mines has indicated that their office would not require any details regarding our geotechnical investigations concerning the proposed waste disposal operation at the quarry

7. Potential for Ground Water Pollution.

It has been suggested that a realistic upper bound value for the coefficient of permeability of the tillite formation at quarry floor level, and immediately below, is of the order of 1×10^{-6} m/s.

For an assumed effective porosity of (say) 20% due to open fissures and discontinuities and a hydraulic gradient of unity, this permeability value translates into a vertical flow velocity of nearly 160 metres per year. Horizontal migration along the estimated 8% gradient of the water table will be in the region of 10 metres per year.

These values are sensitive to the assumed permeability of which only the order of magnitude is known. Equally, the assumptions concerning the effective porosity of this formation are very approximate and therefore the calculated velocities given above only reflect the expected order of magnitude.

The important issue, however, is that there is a distinct risk that any leachate

TABLE II

Tabulated Summary of Slope Stability Analysis by MSJ&P

Section	Chainage * (metres)	Slope Face	Plate No.	Description
SECTION A	0 to 20	East facing	4	Approximately 40 metre high rock slope, comprising highly fractured and jointed tillite adjacent to shear zone. Potential toppling failure along Joint A1, as shown in Figure 7c. Potential circular slip failure similar to that along Section E. Slope considered unstable. Recommend slope be battered back to at least a gradient of 1 in 1½. Removed shear zone material should be suitable for use as a cover material in the landfill operation.
	20 to 50	South facing	5	Approximately 25 metre high rock slope of medium to widely jointed W2/3 tillite, overlain by thin soil cover. Potential for small wedge failures along joints 1A and 4B, and 1B and 3B, and also potential toppling failures due to joints 2A and 3A - See Figure 6b. Considered relatively stable, low probability of slope failure except for minor blocks. Recommend that loose blocks be barred down, and weathered, overburdened sloped back to 1 in 1½.
	50 to 150	Rock Peninsular	3, 6 & 7	Rock peninsular, comprising a near vertical shear zone together with the unmined slightly weathered tillite on either side. This rock peninsular is considered unstable and it is recommended that it be removed. The removed material should prove suitable for use as cover material in the landfill operation.
SECTION B	250 to 340	West facing slope	8 & 9	Approximately 20 metre high rock slope overlain by residual soil and fill material. Prominent north to south trending joint set well exposed. Rock slope considered relatively stable. However, loose overburden requires to be trimmed back to a slope of 1 in 1½. Dense aquatic vegetation, indicating shallow groundwater level, occurs at the toe of this slope.
	340 to 390	Rock buttress	8 & 10	Approximately 15 to 20 metre high peninsular, comprising highly fractured and weathered tillite overlying W3/2 tillite. Seepage is evident at the toe of this buttress. This buttress of highly fractured rock, left unmined, is considered unstable. Mining on 3 sides has resulted in the joints opening up due to stress release. This rock buttress requires to be removed and the exposed south facing slope battered back to a safe slope angle.
	390 to 410	South facing slope	11 & 12	Approximately 30 metre high rock slope overlain by loose residual tillite and fill material. The loose overburden is considered unstable as is evident from the failure, and scree material present at the toe of the slope - See Plate 12. The loose overburden requires to be battered back to a slope of at least 1 in1½ from the crest of the hard competent blue tillite. Groundwater seepage is evident in this rock slope, approximately

TABLE II (continued)

Section	Chainage * (metres)	Slope Face	Plate No.	Description
SECTION D (Cont'd)	390 to 410	South facing slope	11 & 12	10 metres up from the toe. Potential wedge type failures along joint sets 1A and 4B, and 1B and 3B, as shown in Figure 6b, are considered possible. In addition, toppling type failure is also considered likely due to joints 2A and 4A. The overall stability of this south facing slope is considered sensitive. The stability of this slope will have to be carefully assessed by a detailed investigation.
SECTION C	410 to 650	West facing slope	13 & 14	Approximately 60 metre high W2/3 tillite rock slope dipping at about 80 degrees from the horizontal. W2/3 tillite overlain by residual soil and brown, highly weathered and fractured tillite. The overall rock slope considered stable except for the possibility of relatively small potential wedge type failures long joint sets 2A and 3B, 1A and 3A, and 3B and 4A, as shown in Figure 7b. The sensitivity of this slope to wedge type failures will have to be carefully assessed. The residual soil and weathered overburden will require to be battered back to a slope of at least 1 in 1½.
	410 to 625	Northwest facing	13, 15 and 16	Approximately 50 metre high tillite rock slope. The tillite is bisected by a number of near vertical shear zones which trend in north to south and east to west directions. The presence of these shear zones have reduced the overall stability of the rock slope. Plate 15 shows the intersection of two shear zones at approximately 90 degrees to each other behind a wedge of W2/3 tillite. Note the failure which has occurred in the shear zone material at the crest of this section of the slope. The wedge of W2/3 tillite in front of the shear zones is considered unstable. The overall stability of this portion of the quarry will have to be carefully assessed by a detailed investigation.
SECTION D	700 to 750	East facing	17	This east facing slope, situated adjacent to the primary crusher, is considered unstable. A large portion of this section of the rock face over hangs. Toppling failure along joint set A1 is considered likely, as shown in Figure 7c. This type of failure is evident in the exposed rock face.
	750 to 875	Peninsular and Box Cut	18, 19 and 20	Rock peninsular, comprising a near vertical shear zone together with the unmined W3/2 tillite on either side - See Plate 18. This rock peninsular is considered unstable, and it is recommended that it be removed. Consideration could be given to placing and compacting the removed material in the 'box-cut' in the southwestern corner of the quarry to stabilise the rock slopes. The north facing rock slope in the 'box cut' is considered

TABLE II (continued)

Section	Chainage * (metres)	Slope Face	Plate No.	Description
SECTION D (Cont'd)	750 to 875	Peninsular and Box Cut	18, 19 and 20	relatively stable except for the possibility of minor block failures a along intersecting joint sets. However, similar to the east facing slope between chainages 700 and 750 metres, sections of the near vertical east facing slope within the 'box cut' overhang, as shown in Plate 20. Overhanging is due to joint 1A, which dips into the slope at approximately 75 degrees and is responsible for toppling type failures evident within this slope. As such, the east facing slopes along this section of the Quarry are considered unstable. The slopes along Section D, therefore, will have to be carefully engineered to promote stability.
SECTION E	875 to 1050	East facing slope of Peninsular	21, 22 and 23	Section E of the quarry comprises the east facing slopes of the prominent peninsular of rock left by mining operations, and the adjacent scree material. As outlined in Section 6, the peninsular comprises a near vertical shear zone. From careful inspection of this section of the quarry, it is evident that a large circular slip type failure occurred in this east facing slope of the peninsular. The slip scar is still evident near the crest of the slope, together with the loose scree at the toe. It is considered that the scree material at the toe of the peninsular has attained a stable slope angle. However, the near vertical slopes of the peninsular of rock left by mining are considered unstable. In order to stabilise the east facing slopes of this peninsular, it will be necessary to reduce the height of the peninsular. Remove and place the removed material at a safe slope angle against rock peninsular.

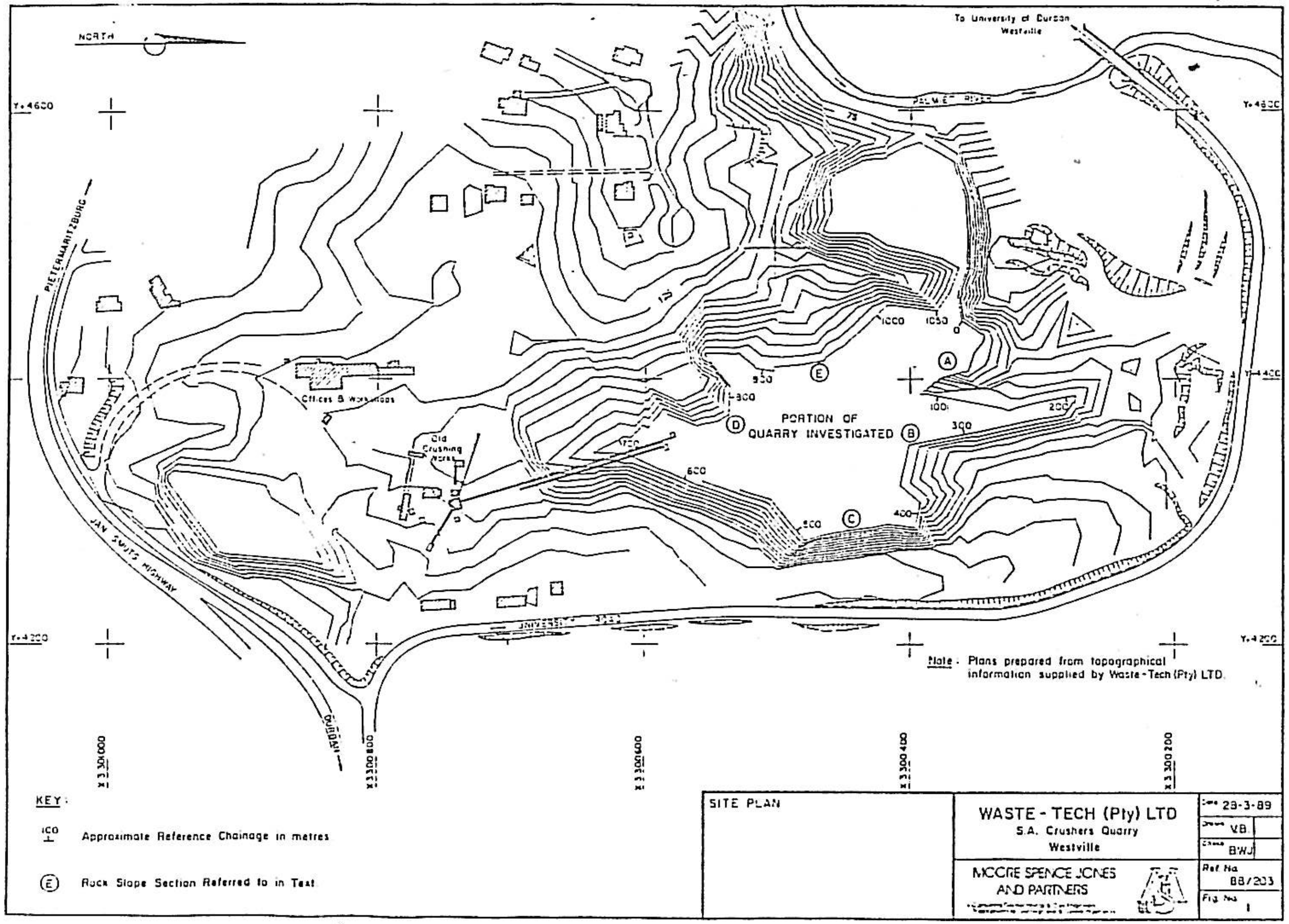


FIGURE 6. WASTE–TECH (PTY) LTD: PROPOSED SA CRUSHERS SITE, WESTVILLE.
Plan showing sections where detailed structural data was collected on the stability of the rock slopes. See also Table II. All data from MSJ&P[1].

eminating from disposed waste will migrate through the tillite formation.

Such flow will initially be vertically down at a relatively high rate until the phreatic ground water level has been reached and, upon which, slower horizontal migration should follow. Initially, the horizontal flow of migrating leachate is expected to be roughly one tenth of the vertical velocity and in the same general direction as the ground water gradient, ie in a northerly or north-westerly direction towards the Palmiet River.

It is considered unlikely that any significant mixing of the leachate with the ground water will take place and it is suspected that the leachate will tend to flow along the phreatic surface. These deductions are on the assumption that the leachate will have liquid properties close to that of water.

It should be quite clear from the foregoing that to successfully develop the site as a waste disposal facility will require careful preparation of the site together with the construction of a liner to control leachate.

It is believed that a proper earth liner of the correct design, could render the site suitable for the disposal of waste. In this regard it is believed that there would be no merit in considering the derating of the site to a Class II facility, since leachate will remain a problem requiring a suitable liner of practically the same specification needed for the disposal of Class I waste.

Natural material, suitable for an engineered low-permeability earth liner has been prospected and is described in greater detail in the next section.

Laboratory tests on samples obtained from the borrow area have indicated very low permeability values in the range 10^{-10} m/s and 10^{-11} m/s. However, it is often found that the corresponding permeability determined under field conditions is significantly higher than the laboratory values. Nevertheless, by making ample allowance for a considerably higher permeability coefficient under field conditions, (say between 10^{-8} m/s and 10^{-9} m/s) the borrow material proposed by Moore Spence Jones and Partners[4] should still be quite acceptable for the construction of a suitable earth liner.

As an additional long-term precaution against leachate penetrating the liner, it is strongly recommended that the floor of the quarry be shaped during preparation in such a way that any leachate will flow towards collection points or sumps from where its accumulation can be monitored and, if necessary, be pumped out for processing and disposal.

8. The Earth Liner

Source of Material: It is the intention of Waste-Tech (Pty) Limited to import selected liner material from Ridgeview Quarry. A site investigation for suitable borrow material was undertaken by MSJ&P[4] and their report, reference 89/58 is reproduced in Appendix II.

The main findings are that there is an estimated 60 000 cubic metres of suitable clayey residual tillite soil with a laboratory coefficient of permeability of between 10^{-10} m/s and 10^{-11} m/s when compacted to between 90% and 93% of maximum Proctor density. and optimum moisture content.

Based on the results of the above-mentioned report which indicates a certain degree of variability in the occurrence of the deposit, it is recommended that all borrow operations should be carried out under the direct and strict supervision of a qualified geotechnical practitioner in order to ensure that only the correct material is obtained.

Construction of the Liner: It is recommended that the engineered earth liner has a minimum compacted thickness of 450 millimetres, consisting of 3 layers of 150 millimetres each. Depending on the equipment used, light scarification may be required between layers to ensure a good bond and to prevent preferred horizontal flow paths developing along the layer interfaces.

To reduce the danger of surface cracking after completion, it is recommended to cover the compacted liner with a 75 millimetre layer of loose soil.

Provision should also be made for a sufficient number of field tests to accurately control both the density and the in situ permeability of the compacted layers.

The MSJ&P report mentions the possibility of potential expansiveness of the liner material and their recommendation calling for strict control of moisture contents during compaction is strongly reiterated. In this regard, it is also recommended that provision is made for continuous on-going supervision of the earthworks by a suitably qualified person.

It should be assumed that the sides of the quarry are as pervious as the floor and that the low-permeability liner should therefore also be extended upwards, to provide lateral protection against any sideways migration of leachate as the waste disposal operation proceeds from the one bench level to the next. The thickness and degree of compaction must be designed in accordance with the proposed waste disposal plan so as to prevent slumping of the vertical liner occurring under its own weight when substantial heights are reached.

There is some evidence of minor water seepage from the exposed quarry faces above floor level. The exact extent of this seepage has not been examined and it is not known whether or not the seepage is only a minor seasonal feature. If it is found that the seepage from the sides is significant, it will be necessary to incorporate a proper drainage system that will lead the water away, either around or beneath the liner system, depending on the circumstances.

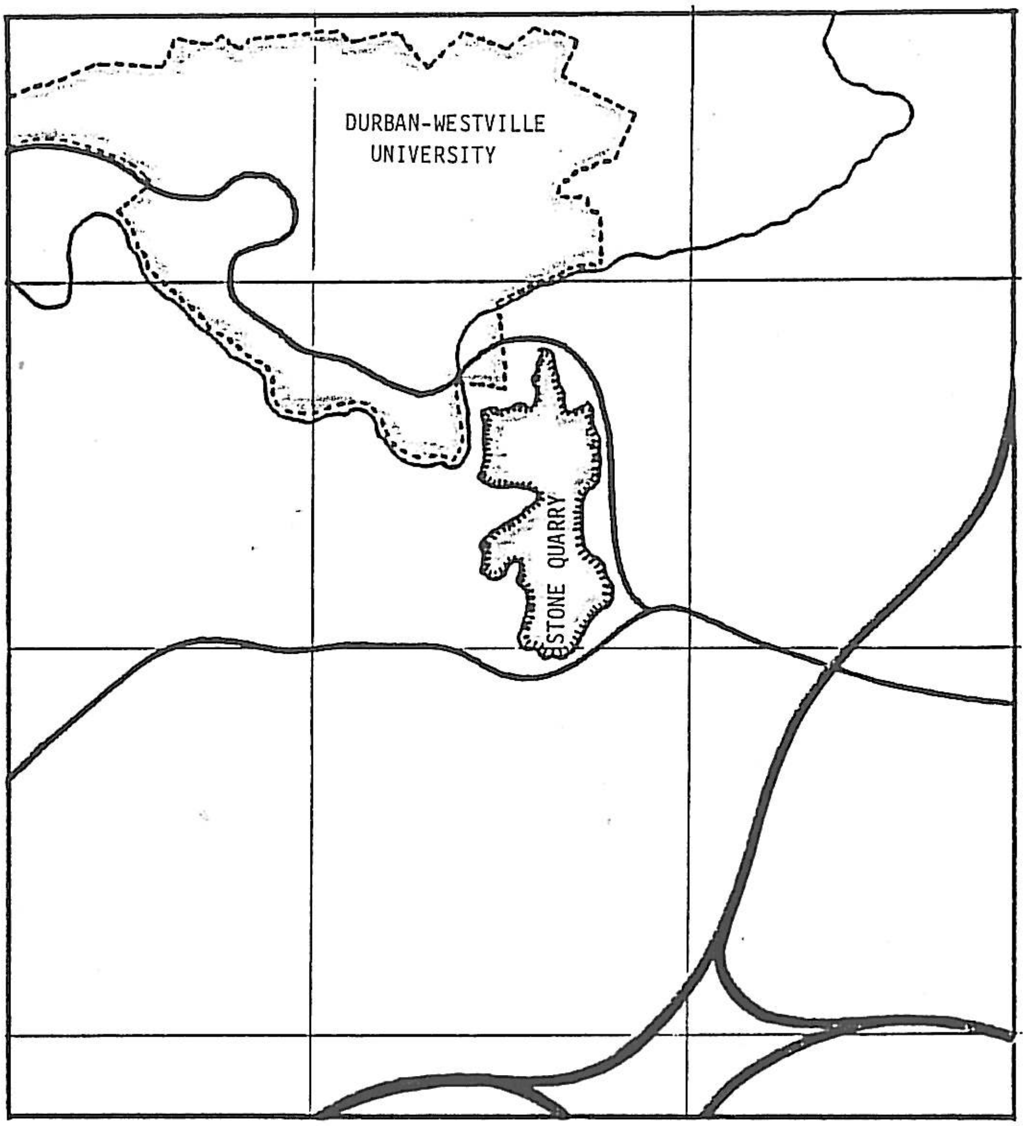
There is also a consistent flow of water along the central part of the quarry. In order to control this water it is recommended that either a properly designed filter drain or an adequate diversion be introduced before constructing the liner.

9. Impact on the Environment.

Most of the area in the immediate vicinity of the quarry is zoned for residential use as shown in figure 7. Based on data collected[5] from the authorities, the land usage over an area of about 10 square kilometres is as follows:

Residential (all categories):	70%
Education:	16%
Unclassified (assumed housing):	7%
Open Spaces and Parks:	4%
Shopping and Business:	1%
Mining (construction materials):	2%

The mined out quarry extends practically up to the property boundaries with the



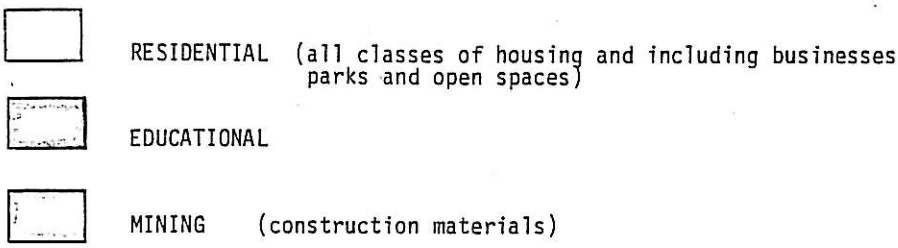


FIGURE 7. WASTE-TECH (PTY) LTD: PROPOSED SA CRUSHERS SITE.

Plan showing the land use in the immediate vicinity of the proposed waste disposal site currently being mined for stone aggregate.

scale: 1 : 20 000

result that there is very little natural ground left. Under these circumstances it would seem pointless to examine the natural fauna and flora, which appears to be virtually non-existent along the narrow corridors surrounding the quarry excavation.

The quarry site is situated in a predominantly residential area and to analyse the implications of a waste disposal site on this type of environment may require a specially detailed investigation.

Because of the potentially complex nature of such an environmental impact study, it is recommended that, for the time being, it need not form an integral part of this investigation or the actual licence application.

It is suggested that a practical approach may be that all present considerations regarding the granting of a licence for waste disposal be conducted on a provisional basis which will be completely subject to the final consent and approval by the various authorities and parties directly concerned with the environmental impact this proposed operation may have on the residential area of Westville.

As a general comment on this subject it may be noted that the controlled disposal of waste could provide a realistic solution to the difficult problem of rehabilitating a large tract of unattractive waste land. When the operation has finally been completed, an additional open space of about 2 Ha should have been created.

10. Surface Drainage.

The ground around the top of the quarry will have to be shaped so as to prevent any run-off water from entering the quarry. Apart from preventing run-off water reaching the disposed waste, it is equally important to minimize the amount of water flowing down the slopes of the quarry as this could give rise to unnecessary erosion and ravelling of the sides. Water seepage down the face could also have a detrimental affect on the structural stability of the quarry slopes.

Since the disposal of waste will initially be limited to specific sections of the quarry, adequate provision will have to be made to protect these areas from any run-off water generated within the quarry. In this regard, cognizance should be taken of the fact that the higher lying southern portion of the quarry constitutes a relatively large catchment for rain water which could flow down towards the deeper northern part of the quarry where it is intended to commence with waste disposal operations. Therefore, it will be necessary to design and engineer the required diversions to protect the waste disposal area(s).

11. Cover Material.

There are various sources of cover material within the quarry where weathered and shear-zone material has been left behind in the form of remnant islands and peninsulars. These materials may range from weathered 'rocky' tillite to completely decomposed residual soil. In order to obtain the maximum benefit of the available materials it would be necessary to extract the different types of material on a selective basis and to introduce a carefully planned stock-piling procedure.

Overburden material from the Ridgeview quarry could also be used for cover material.

The total amount of cover material required will depend on the over-all development plan for waste disposal in the quarry as well as the expected daily quantities that will require covering up. As soon as these details have been finalised, it should be established how the volume of available cover material compares with the total requirement so that a properly integrated long-term plan for the handling and acquisition of cover materials can be developed.

12. Monitoring Bore Holes.

In the absence of all the relevant details concerning the overall disposal plan for the site, only general comments are appropriate at this stage.

Since it will be necessary to provide some form of drainage beneath the proposed low-permeability liner, it is recommended that provision be made for monitoring 'points' in the filter in order to detect the presence of leachate immediately beneath the protective liner. Theoretically, this should be the most positive and effective way to monitor the possible migration of leachate, since this approach allows for the detection of leachate the moment it passes through the protective barrier (low-permeability liner). The effectiveness of this proposed monitoring procedure will greatly depend on the correct design of the monitoring points and the attention to detail during construction and installation.

In addition to these monitoring points, bore holes will have to be positioned between the lower edge of the disposal area and the Palmiet River.

It is recommended that a comprehensive plan be drawn up for the installation of monitoring points and monitoring bore holes together with an operating procedure covering all relevant details on sampling and testing as soon as Waste-Tech has completed their overall development plan for the site.

No chemical analyses have been undertaken on samples of ground water which, as discussed earlier, is regarded to be fresh. Once the monitoring bore holes have been planned and installed a comprehensive chemical analysis will have to be undertaken on samples from various parts of the quarry to provide a detailed set of background values.

13. Conclusions.

- The proposed quarry site is geologically located in predominantly fresh, though extensively jointed and fissured tillite bedrock. The quarry is the result of mining operations for rock aggregate over a long period of time.

- The quarry is fairly irregular in shape and measures approximately 150 000 square metres in plan area. The maximum available air space is very roughly estimated to be of the order of 5 million cubic metres.

- The tillite is extensively jointed and due to continued blasting, the floor of the quarry is considered to be more pervious than would perhaps be expected under ordinary circumstances.

- The ground water rest level is about 1,5 metres below the floor of the quarry where it is at its deepest. Although there is no real aquifer or zone of preferred ground water flow below the quarry floor, pollution is possible. Leachate eminating from disposed waste is expected to migrate in a predominantly horizontal direction towards the Palmiet River. It is very roughly estimated that without taking any precautions to control leakage, small quantities of leachate could reach the Palmiet River within a period of 5 to 10 years later.

- In order to prevent leachate from reaching the jointed bedrock tillite in any significant quantity, it has been recommended that the bottom of the quarry be properly shaped and a 450 mm thick low-permeability earth liner constructed. It is further recommended to design and shape the floor, and hence the liner, in such a manner that any accumulated leachate will flow towards sumps from where it can be monitored and removed for treatment if necessary.

- Under such circumstances, where the proper precautions are engineered to control leachate, it is believed that the site can be successfully operated as a Class I waste disposal facility.

- There are indications that some of the steep cliff-like slopes of the quarry are locally unstable. This aspect has already been the subject of a detailed preliminary investigation and further attention should be given to the matter before finalizing the overall development plan. The way in which the potential slope stability problem is to be handled should form an integral part of the long-term waste disposal operating plan.

- The details concerning the recommended ground water monitoring programme for the site will be drawn up in due course once finality on the proposed operating procedures has been obtained.

B L Wiid PhD
Consulting Engineering Geologist

LIST OF REFERENCES

1. Moore Spence Jones and Partners: Report to Waste-Tech (Pty) Ltd on a preliminary assessment of the stability of the rock slopes at SA Crushers quarry, Westville. Ref. 88/203 1989

2. Bond, G W: A geochemical survey of the underground water supplies of the union of South Africa; Dept. of Mines, Geological Survey Memoir No 41, 1946

3. Du Toit, A L: Geology of South Africa, Oliver and Boyd, Edinburgh, 3rd Edit. 1946

4. Moore Spence Jones and Partners: Report to Waste-Tech (Pty) Ltd on a sub-soil investigation for clay borrow materials at Ridgeview quarry, Durban; Ref. 89/58 1989.

5. Moore Spence Jones and Partners: Annotated City of Durban and Westville Maps showing the present and proposed zoning of over an area of about 10 square kilometres with the SA Crushers site at the centre, 1989.

APPENDIX I

Moore Spence Jones and Partners Report Ref. 88/203

A preliminary assessment of the stability
of the
rock slopes at SA Crushers quarry, Westville

REPORT TO WASTE-TECH (PTY) LTD ON A PRELIMINARY ASSESSMENT OF THE STABILITY OF THE ROCK SLOPES AT SA. CRUSHERS QUARRY, WESTVILLE.

REF : 88/203

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COPY NO. :
REF NO. : 88/203
BWJ/1a

MARCH 1989

C O N T E N T S

REPORT TO WASTE-TECH (PTY) LTD ON A PRELIMINARY ASSESSMENT OF THE STABILITY OF THE ROCK SLOPES AT SA CRUSHERS QUARRY, WESTVILLE

REF : 88/203 28 MARCH 1989

1. SCOPE OF REPORT

This report outlines the results of a preliminary geotechnical appraisal of the stability of the rock slopes, left by mining operations, in the north portion of SA Crushers Quarry in Westville. A site plan of the quarry is given in Figure 1.

The investigation was undertaken to assess the feasibility of using the quarry as a landfill site. The investigation includes a study of the geology, the measurement of joint orientations and joint characteristics, and a preliminary rock slope stability assessment involving the interaction of joint sets. Comment is made on likely remedial works considered necessary to engineer the quarry into a stable condition suitable for use as a landfill site.

2. TERMS OF REFERENCE

In terms of discussions held on site between Mr P Jonker of Waste-Tech and Mr B Wilson-Jones of Moore Spence Jones & Partners, a proposal and cost estimate for a stability investigation was submitted to Waste-Tech in a letter reference 88/203, dated 12 October 1988.

Moore Spence Jones & Partners appointment to carry out the Phase 1 preliminary investigation was confirmed in a letter dated 3 January 1989, received from Waste-Tech. This work was to be carried out under Capital Expenditure Order No. HO 0031 of Waste-Tech (Pty) Ltd.

3. INFORMATION SUPPLIED

The following information was supplied by Waste-Tech during the course of the investigation.

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a) A copy of portion of a Cadastral Plan, showing the extent of the quarry and associated buildings and plant, to a scale of 1 in 1000.

b) A copy of portion of a topographical plan of the quarry, to a scale of 1 in 1000.

c) A topographical contour plan of the quarry, prepared by Waste-Tech (Pty) Ltd, titled, "Project, SA Crushers - Westville", to a scale of 1 in 2500.

d) Topographical sections through the quarry, prepared by Waste-Tech (Pty) Ltd, titled, "SA Crushers - Westville", Sheets 1 through 11, at various scales.

In preparing this report, use has also been made of the following information:

e) City of Durban, Orthophoto Map, Sheet J47, to a scale of 1 in 2000.

4. DESCRIPTION OF THE SITE

The quarry is bounded on the east and north by University Road, which serves the University of Durban-Westville, as shown on the Site Plan in Figure 1.

The northern portion of the quarry under investigation is downslope of the old crushing works. This portion of the quarry has been mined to depths of approximately 50 metres below natural ground level, resulting in near vertical rock cliffs around the perimeter of the mined out area - See Plates 1 and 2.

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To a large extent, quarrying operations were controlled by the structural geology of the site. A number of prominant near vertical fault or shear zones bisect the site. The material in these shear zones is shattered and highly weathered, and unsuitable for use as an aggregate. Consequently, where these shear zones occur in the quarry, they have been avoided, with the result that there are a number of rock peninsulars, comprising shear zone material, which have been left by mining operations. As the shear zones generally trend in a north to south direction, the peninsulars left by mining follow the same trend. These penisulars have generally been left with near vertical side slopes. In plan, therefore, the shape of the perimeter of the mined out area, formed by the near vertical cliffs, is extremely irregular.

The topography of the site is shown on the site plan in Figure 1. General views of that portion of the quarry under investigation are shown in Plates 1 and 2, included at the back of this report.

5. FIELD WORK

The field work was undertaken during the period 26 January to 15 March 1989, and comprised :

a) Geological Mapping,
b) Discontinuity Survey, and
c) Groundwater Monitoring

For ease of reference, the perimeter of the rock faces comprising the northern portion of the quarry have been subdivided into 5 sections, designated A through E. The sections and approximate chainages referred to below are shown on the site plan in Figure 1.

Section	Portion of Quarry	Approximate Chainage (metres)
A	Northwestern Corner	000 to 150
B	Northeastern Corner	250 to 410
C	Eastern Face	410 to 650
D	Southwestern Corner	725 to 875
E	Western Face of Peninsular	875 to 1050

5.1 Geological Mapping

That portion of the quarry under investigation was geologically mapped to determine the nature and characteristics of the residual soils and weathered Dwyka tillite bedrock comprising the exposed slopes in the quarry. The degree of weathering with increasing depth, as exposed in the rock slopes was noted. Particular attention was also given to the orientation and inclination of shear zones present within the tillite. Areas of groundwater seepage, or indications of groundwater seepage out of the exposed rock faces, was also noted.

The geology of the site is shown on the Geotechnical Site Plan in Figure 2. Photographs of the quarry are given in Plates 1 through 27.

5.2 Structural Discontinuity Analysis

To establish the preferred orientations of joint sets, which will to a large degree control rock slope behaviour, a limited discontinuity survey was undertaken on the exposed rock faces. A random joint survey was carried out in preference to other methods such as line sampling because of the preliminary nature of the investigation. The orientation and inclination of the joints were measured using a geological compass, and the length, shape and roughness of the joint sets were assessed and recorded. The structural data was plotted as a polar projection using an equatorial equal area stereonet, and contoured using standard techniques.

As outlined above, the perimeter of the rock slope was subdivided into 5 sections. To assess the consistency of the joint sets throughout the quarry, individual discontinuity surveys were undertaken on the sections of the rock faces, designated A through D. A discontinuity survey was not undertaken on Section E, as the slope faces along this section of the quarry comprise mostly scree material. The results showed a consistent trend in the orientation and inclination of the joint sets throughout the quarry. Therefore, the preliminary assessment of the long term stability of the rock faces is based on a combined steriographic projection of all the structural data. The stereographic projection prepared from joint measurements taken throughout the quarry is given in Figure 3a.

The results of the discontinuity survey indicate that there are 6 fundamental joint sets, as listed in Table 1 below. In assessing the longterm stability of the rock slopes, the critical inclination of the joints has been assumed, and these are shown in Figure 3b.

<u>TABLE 1</u>

ORIENTATIONS OF INDIVIDUAL JOINT USED
IN STABILITY ASSESSMENT

Joint No.	Dip in degrees from the Horizontal	Dip Direction in Degrees
J 1	75	260
J 2	80	340
J 3	75	030
J 4	80	320
J 5	35	030
J 6	05	000

The individual joint sets are described below.

<u>Joint Set 1</u> - This is the most prominent joint set, as shown on Plates 13 and 14. The joint is smooth and planar, but exhibits a zig-zag pattern, which is continuous over distances in excess of 20 metres. This joint set trends in the same direction as the major shear zones which bisect the site.

<u>Joint Set 2</u> - Smooth, planar, stepped joint set which is continuous over distances of greater than 20 metres.

<u>Joint Set 3</u> - Moderately smooth, undulating wavy joints of approximately 5,0 metres in extent.

<u>Joint Set 4</u> - Moderately smooth, stepped joints which are continuous over distances of approximately 5 metres.

<u>Joint Sets 5 and 6</u> - Irregular near horizontal joints.

5.3 Groundwater Monitoring

Groundwater levels were measured and recorded in boreholes previously installed at the site by Waste-Tech. The approximate positions of the boreholes, designated BH1 through BH4, are shown on the site plan in Figure 4. The results of the groundwater level monitoring programme are set out in Table 2 below.

TABLE 2

GROUNDWATER LEVELS RECORDED IN BOREHOLES

Borehole No.	Level of Groundwater below Existing Ground Surface						
	15/3/89	28/3/89					
BH 1	5,86	6,15					
BH 2	0,35	0,38					
BH 3	0,33	0,35					
BH 4	1,89	1,95					

6. GEOLOGY

The Westville Quarry area is underlain by tillite of the Dwyka Formation. A geotechnical plan of the site is given in Figure 2. The tillite being a glacial deposit is comprised of an unsorted, unorientated accumulation of rock and mineral fragments in a fine grained matrix of rock flour.

A thin mantle of residual clayey soil, derived from complete weathering of the underlying bedrock, overlies the tillite. The soil cover is generally less than 2,0 metres thick.

The tillite bedrock exposed in the quarry faces is highly weathered and yellow brown near the quarry crest with black discolouration along the closely to medium spaced joints.

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The degree of weathering and frequency of jointing decreases down the quarry faces, such that the tillite progresses rapidly through moderately weathered and slightly weathered to unweathered blue grey tillite rock with moderate to widely spaced joints. The grades of weathering in the tillite are defined in Appendix A.

The tillite exposed in the quarry is massive and accordingly without bedding planes. As is frequently the case, no thin near horizontal tillite shale layers were observed in the exposed quarry faces.

As discussed in Section 5,4, six individual joint sets were identified. Joints designated J1, J2 and J3 are prominent, with the remainder being less prominent, as shown on the steriographic projection in Figure 3. The less prominent joints, which have a more random orientation, probably resulted from relief of stress. The joint patterns not only have a large influence on the stability of the rock slopes, but also provide the only passage for water through the rock.

Two prominent near vertical zones of shear are evident in the tillite rock mass, trending in a north to south direction parallel to one another, and separated by a distance of approximately 50 metres. As discussed in Section 4 above, these shear zones had a large influence on mining operations. The strike, or trend of these shear zones, as inferred from geological mapping and the discontinuity analysis, are shown on the geotechnical site plan in Figure 2.

The western near vertical shear zone is approximately 23 metres wide, and together with the unmined slightly weathered tillite rock on either side forms the large peninsular of rock

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left by mining operations, as shown in Plates 1, 21 and 23. This western shear zone dips steeply at an angle of about 80 degrees to the horizontal, in a westerly direction. A large circular slip type failure has taken place on the east facing side of this penisular, as shown on the geotechnical site plan in Figure 2, and in Plates 1 and 21. A number of smaller slips have also occurred in the steep slopes of this peninsular.

The easterly prominent zone of shear is approximatley 5 to 10 metres in width. Over the central portion of the quarry, most of the shear zone material has been removed by mining. However, the trend of the shear zone is still evident in the form of two buttresses or peninsulars of shear zone material left by mining operations (See Plates 2, 3, 7 and 18).

In addition, there are a number of other thin, near vertical shear zones present within the tillite. These zones, however, are generally less than 3 metres wide. The trends and extent of these thin shear zones observed in the quarry faces are shown on the site plan in Figure 1, and in Plates 13, 15 and 16.

The materials comprising the near vertical shear zones consist essentially of completely to highly weathered (W5/4) and fractured, grey, very soft to medium hard rock which, when saturated deteriorates rapidly and crumbles into a highly fragmented mass consisting of slightly clayey silt containing angular pebbles and gravel. Present within the zones of shear are narrow near vertical zones of moderately weathered tillite, and calcite veins which are generally highly fractured.

7. GROUNDWATER

Water can be observed standing in the mined out area immediately adjacent to Main Road R103 in the southern portion of the site. The elevation of the water level in this area is approximately 110 metres above MSL. The water standing in this portion of the quarry appears to be groundwater, rather than ponded surface run-off.

In the northwestern corner of the quarry, water can be seen standing in the mined out area immediately adjacent to the Palmiet River. In addition, standing water can be observed at the toe of the west facing slopes in the northeastern portion of the quarry as shown on the site plan in Figure 2. From the available topographical data, the groundwater level over the northern portion of the quarry occurs at an elevation of approximately 64 metres above MSL.

A study of the topography of the area reveals that the quarry is situated on a north to south trending ridge which slopes down to the Palmiet River. Taking all factors into account, it is considered that the configuration of the phreatic surface or groundwater table is gently inclined from south to north.

Groundwater levels are presently being monitored in the boreholes, put down on the site by Waste-Tech, to confirm groundwater levels and fluctuations. It is considered, however, that the water levels within the disused quarry have reached an equilibrium. Large variations in the groundwater levels are not anticipated, because of the low permeability of the rock and the limited source area for groundwater replenishment.

Groundwater seepage was also observed emanating from some of the quarry faces above the general groundwater levels. The seepage was generally slight to moderate. However, the seepage does indicate that hydrostatic pressures must be taken into account when assessing the long term stability of the rock slopes.

8. EVALUATION OF POTENTIAL SLOPE INSTABILITY

Factors which govern the likelihood of rock slope failure are :

a) Geometry of the rock slope mass,
b) Orientation of structural discontinuities,
c) Hydrostatic pressures, and
d) Shear strength mobilised along planes or discontinuity patterns upon which and through which failure is likely to occur.

The main rock slope failure types, and the appearance of stereographic projections of geological structural conditions likely to give rise to such failures, are illustrated in Figure 5.

Failure of a rock slope will normally be confined to structural discontinuities, the shear strength along a discontinuity being substantially less than that through the intact rock. The shear strength along a discontinuity depends on such factors as the separation of the two discontinuity surfaces, the presence or otherwise of clay gouge between them, the hardness of the rock, the effects of surface roughness, the extent of the discontinuity, and the influence of water pressure.

Close inspection of the joints and fractures within the tillite at the quarry reveals that the separation of structural discontinuities or joints, and the development of clay

gouge material within these discontinuities, even in the highly weathered zone, is negligible. The only development of clayey material is along the completely to highly weathered near vertical shear zones within the tillite.

Joint measurements and observations indicate that joint sets, designated J1, J2 and J3 shown in Figure 3, are steeply dipping joints possessing a far higher degree of continuity than that of joints J4, J5 and J6. The former joints are considered to be tension joint sets, and may be traced over distances of up to 20 metres in places, creating subvertical cliff faces. The latter joint sets, J4, J5 and J6 have a relatively low degree of continuity with frequent rock bridges, and have possibly been formed as a result of stress relief.

There are a number of instances of large overhanging rock slabs, which have been undercut on the steep rock slopes, that are maintaining some degree of stability. The frictional restraint maintaining this degree of stability from either toppling or sliding, is relatively small. Therefore, even the most prominent and continuous joint sets must possess substantial cohesion, which should be taken into account in any stability analysis. Due to the extreme sensitivity of the factor of safety in the stability calculation to the use of a cohesion value, cohesion has been ignored in the preliminary assessment described in Section 9 below.

9. PRELIMINARY EVALUATION OF POTENTIAL SLOPE PROBLEMS

A detailed stability analysis taking into account the slope geometry, structural geology and shear strengths along discontinuity surfaces, is beyond the scope of this report. However, in order to recognise potential stability problems, and assist in the visual assessment of the stability of the rock slopes, a preliminary stability evaluation has been undertaken using the geological structural data. It must be emphasised, however, that the analysis undertaken is limited to recognising the possibility of topping, wedge, or planar type failures with rock faces with different orientations and slope angles.

The preliminary evaluation has been limited to slopes facing north, south, east and west, and in all instances a slope angle of 70 degrees has been assumed as representative. The results of this analysis are given in Figures 6 and 7.

In the analysis, an angle of friction of 45 degrees has been assumed, and cohesion ignored. This is considered to be very conservative. In view of the low, normal stresses acting on potential failure surfaces in the rock slopes of the Quarry, and the significant compressive strength of the tillite rock adjacent to structural discontinuities, it is considered that movements along joints will be controlled by the roughness of the joint surfaces rather than by shearing through surface irregularities. The significance of the surface irregularities on the shear strength along a joint plane will be to enhance the angle of friction.

From previous laboratory tests carried out on smooth pre-cut planes through tillite, an angle of friction of approximately 30 degrees has been assumed. However, in view of the surface irregularities, it is considered that the magnitude of increase in the friction would be at least 15 degrees using the following relationship.

$$i = JRC \log_{10} \frac{JCS}{\sigma_n}$$

Where i = Effective roughness angle
JRC = Joint roughness coefficient
JCS = Uniaxial strength of the wall material along the discontinuity

= Effective normal stress acting on the joint plane

Therefore, an angle of friction of 45 degrees has been adopted in the preliminary evaluation, as shown plotted in Figures 6 and 7.

10. EVALUATION OF THE STABILITY OF THE QUARRY

An assessment of the longterm stability of the individual rock slopes at the quarry is given in Table 3. This assessment is based on general visual observations and on the results of the preliminary stability evaluation given in Figures 6 and 7. The sections of the quarry and chainages referred to in Table 3 are indicated on the site plan in Figure 1.

TABLE 3

Section	Chainage * (metres)	Slope Face	Plate No.	Description
SECTION A	0 to 20	East facing	4	Approximately 40 metre high rock slope, comprising highly fractured and jointed tillite adjacent to shear zone. Potential toppling failure along Joint A1, as shown in Figure 7c. Potential circular slip failure similar to that along Section E. Slope considered unstable. Recommend slope be battered back to at least a gradient of 1 in 1½. Removed shear zone material should be suitable for use as a cover material in the landfill operation.
	20 to 50	South facing	5	Approximately 25 metre high rock slope of medium to widely jointed W2/3 tillite, overlain by thin soil cover. Potential for small wedge failures along joints 1A and 4B, and 1B and 3B, and also potential toppling failures due to joints 2A and 3A - See Figure 6b. Considered relatively stable, low probability of slope failure except for minor blocks. Recommend that loose blocks be barred down, and weathered, overburdened sloped back to 1 in 1½.
	50 to 150	Rock Peninsular	3, 6 & 7	Rock peninsular, comprising a near vertical shear zone together with the unmined slightly weathered tillite on either side. This rock peninsular is considered unstable and it is recommended that it be removed. The removed material should prove suitable for use as cover material in the landfill operation.
SECTION B	250 to 340	West facing slope	8 & 9	Approximately 20 metre high rock slope overlain by residual soil and fill material. Prominent north to south trending joint set well exposed. Rock slope considered relatively stable. However, loose overburden requires to be trimmed back to a slope of 1 in 1½. Dense aquatic vegetation, indicating shallow groundwater level, occurs at the toe of this slope.
	340 to 390	Rock buttress	8 & 10	Approximately 15 to 20 metre high peninsular, comprising highly fractured and weathered tillite overlying W3/2 tillite. Seepage is evident at the toe of this buttress. This buttress of highly fractured rock, left unmined, is considered unstable. Mining on 3 sides has resulted in the joints opening up due to stress release. This rock buttress requires to be removed and the exposed south facing slope battered back to a safe slope angle.
	390 to 410	South facing slope	11 & 12	Approximately 30 metre high rock slope overlain by loose residual tillite and fill material. The loose overburden is considered unstable as is evident from the failure, and scree material present at the toe of the slope - See Plate 12. The loose overburden requires to be battered back to a slope of at least 1 in1½ from the crest of the hard competent blue tillite. Groundwater seepage is evident in this rock slope, approximately

* Chainage shown on Figure 1

Section	Chainage * (metres)	Slope Face	Plate No.	Description
SECTION D (Cont'd)	390 to 410	South facing slope	11 & 12	10 metres up from the toe. Potential wedge type failures along joint sets 1A and 4B, and 1B and 3B, as shown in Figure 6b, are considered possible. In addition, toppling type failure is also considered likely due to joints 2A and 4A. The overall stability of this south facing slope is considered sensitive. The stability of this slope will have to be carefully assessed by a detailed investigation.
SECTION C	410 to 650	West facing slope	13 & 14	Approximately 60 metre high W2/3 tillite rock slope dipping at about 80 degrees from the horizontal. W2/3 tillite overlain by residual soil and brown, highly weathered and fractured tillite. The overall rock slope considered stable except for the possibility of relatively small potential wedge type failures long joint sets 2A and 3B, 1A and 3A, and 3B and 4A, as shown in Figure 7b. The sensitivity of this slope to wedge type failures will have to be carefully assessed. The residual soil and weathered overburden will require to be battered back to a slope of at least 1 in 1½.
	410 to 625	Northwest facing	13, 15 and 16	Approximately 50 metre high tillite rock slope. The tillite is bisected by a number of near vertical shear zones which trend in north to south and east to west directions. The presence of these shear zones have reduced the overall stability of the rock slope. Plate 15 shows the intersection of two shear zones at approximately 90 degrees to each other behind a wedge of W2/3 tillite. Note the failure which has occurred in the shear zone material at the crest of this section of the slope. The wedge of W2/3 tillite in front of the shear zones is considered unstable. The overall stability of this portion of the quarry will have to be carefully assessed by a detailed investigation.
SECTION D	700 to 750	East facing	17	This east facing slope, situated adjacent to the primary crusher, is considered unstable. A large portion of this section of the rock face over hangs. Toppling failure along joint set A1 is considered likely, as shown in Figure 7c. This type of failure is evident in the exposed rock face.
	750 to 875	Peninsular and Box Cut	18, 19 and 20	Rock peninsular, comprising a near vertical shear zone together with the unmined W3/2 tillite on either side - See Plate 18. This rock peninsular is considered unstable, and it is recommended that it be removed. Consideration could be given to placing and compacting the removed material in the 'box-cut' in the southwestern corner of the quarry to stabilise the rock slopes. The north facing rock slope in the 'box cut' is considered

* Chainage shown on Figure 1

Section	Chainage * (metres)	Slope Face	Plate No.	Description
SECTION D (Cont'd)	750 to 875	Peninsular and Box Cut	18, 19 and 20	relatively stable except for the possibility of minor block failures a along intersecting joint sets. However, similar to the east facing slope between chainages 700 and 750 metres, sections of the near vertical east facing slope within the 'box cut' overhang, as shown in Plate 20. Overhanging is due to joint 1A, which dips into the slope at approximately 75 degrees and is responsible for toppling type failures evident within this slope. As such, the east facing slopes along this section of the Quarry are considered unstable. The slopes along Section D, therefore, will have to be carefully engineered to promote stability.
SECTION E	875 to 1050	East facing slope of Peninsular	21, 22 and 23	Section E of the quarry comprises the east facing slopes of the prominent peninsular of rock left by mining operations, and the adjacent scree material. As outlined in Section 6, the peninsular comprises a near vertical shear zone. From careful inspection of this section of the quarry, it is evident that a large circular slip type failure occurred in this east facing slope of the peninsular. The slip scar is still evident near the crest of the slope, together with the loose scree at the toe. It is considered that the scree material at the toe of the peninsular has attained a stable slope angle. However, the near vertical slopes of the peninsular of rock left by mining are considered unstable. In order to stabilise the east facing slopes of this peninsular, it will be necessary to reduce the height of the peninsular. Remove and place the removed material at a safe slope angle against rock peninsular.

* Chainage shown on Figure 1

11. GENERAL COMMENT

From the results of the preliminary investigation, it is considered feasible to use the quarry as a landfill site. However, careful consideration will have to be given the shallow groundwater level at the base of the quarry, and the longterm stability of the rock slopes.

Over a large portion of the quarry, the groundwater level is at or close to base of the quarry, as discussed in Section 7. Large variations in the groundwater level are not anticipated, but this should be confirmed by a longterm groundwater monitoring programme. Because of the shallow groundwater level, it will be necessary to raise the level of the base of the quarry over certain areas. It is recommended that coarse free draining rock material, available on site, be used for this purpose. It is anticipated that over the low lying portions of the quarry, the base will have to be raised by at least 2,0 metres, corresponding to an elevation of approximately 65 metres above MSL. This, however, will have to be confirmed by the results of the groundwater level monitoring programme. The free draining coarse rock material may then be capped with a suitable cover and liner.

Groundwater seepage was also noted emanating from some of the rock slopes above the base of the quarry. Drainage of this seepage water will have to be carefully considered. A drainage media should be provided between the rock slope and proposed liner. Consideration could be given to the use of a netlon blanket covered by a geofabric placed beneath the proposed liner.

In general, the west facing slopes at the quarry appear to be relatively stable, except where there are shear zones present within the tillite. The peninsulars or buttresses of rock left unmined because of the presence of shear zone material, are generally in an unstable condition. In all cases, large scale earthworks will be required to stabilise these peninsular areas. The east facing slopes are generally unstable because of the presence of the north to south trending joint set which dips steeply towards the west, resulting in potential toppling type failures within these slopes. The north and south facing slopes are generally relatively stable except for the possibility of minor wedge type failures.

The site will have to be carefully engineered to promote the longterm stability of the rock slopes. In this regard, the earthworks will have to be carefully planned in conjunction with the development of the site to optimise costs. The peninsulars, comprising shear zone materials, will of necessity have to be removed or partially removed to enhance stability. This shear zone material should, however, prove suitable for use as a cover material in the landfill operation. Thus, with careful planning of the earthworks for bunded areas and cover material, earthwork costs could be optimised.

The preliminary investigation has, however, revealed the need for a detailed stability evaluation and analysis of each rock slope, and this should be carried out before final planning of the landfill operation.

12. CONCLUSIONS

The results of the preliminary investigation indicate that the quarry is suitable for use as a landfill site provided the site is carefully engineered. Sections of the rock slopes left by mining operations are considered unstable, and will have to be treated and stabilised prior to infilling operations. Development of the site will also have to take into account the shallow groundwater level at the base of the quarry.

The findings of this preliminary report will have to be confirmed by a detailed investigation. The detailed investigation should include a detailed stability evaluation and analyses of individual rock slopes, taking into account the proposed landfill operation to ensure safe working conditions. The detailed investigation should also include a detailed assessment of groundwater conditions and movements.

MOORE SPENCE JONES & PARTNERS

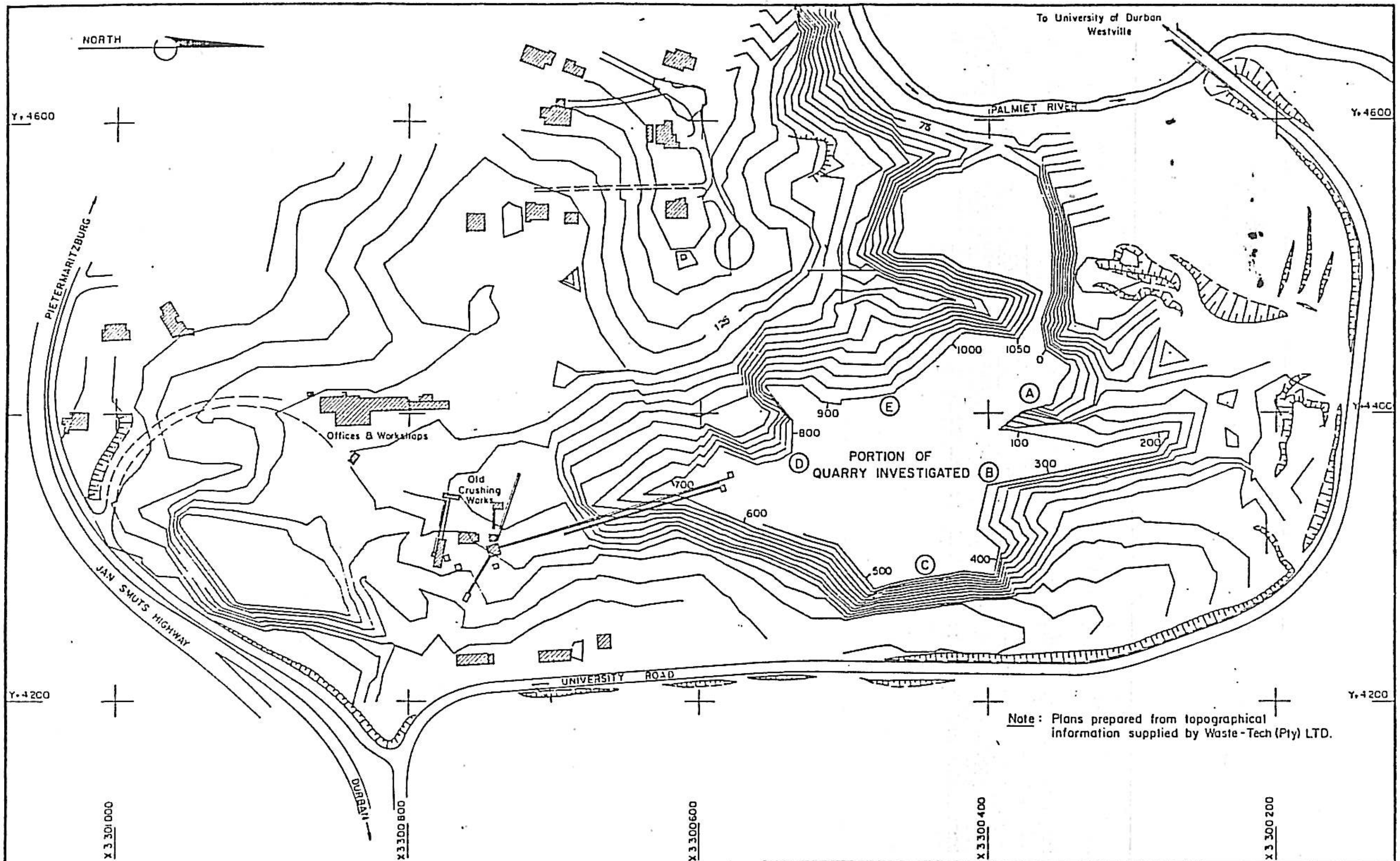
Consulting Geotechnical and
Civil Engineers

DURBAN

APPENDIX A

GRADES OF WEATHERING IN TILLITE

Weathering Scale	Description
W1	Unweathered ('blue') : completely fresh material; very hard rock
W2	Slightly weathered ('1st brown') : similar to blue material, but stained brown on discontinuity planes; hard rock
W3	Medium weathered ('2nd brown') : the material is stained completely brown; soft to hard rock
W4	Highly weathered: yellow pink or white, very soft rock to soft rock retaining original structure
W5	Completely weathered : dark brown to black, gravelly, residual soil with little or no inherited fabric; may be soft, firm or stiff, but usually a loose gravel

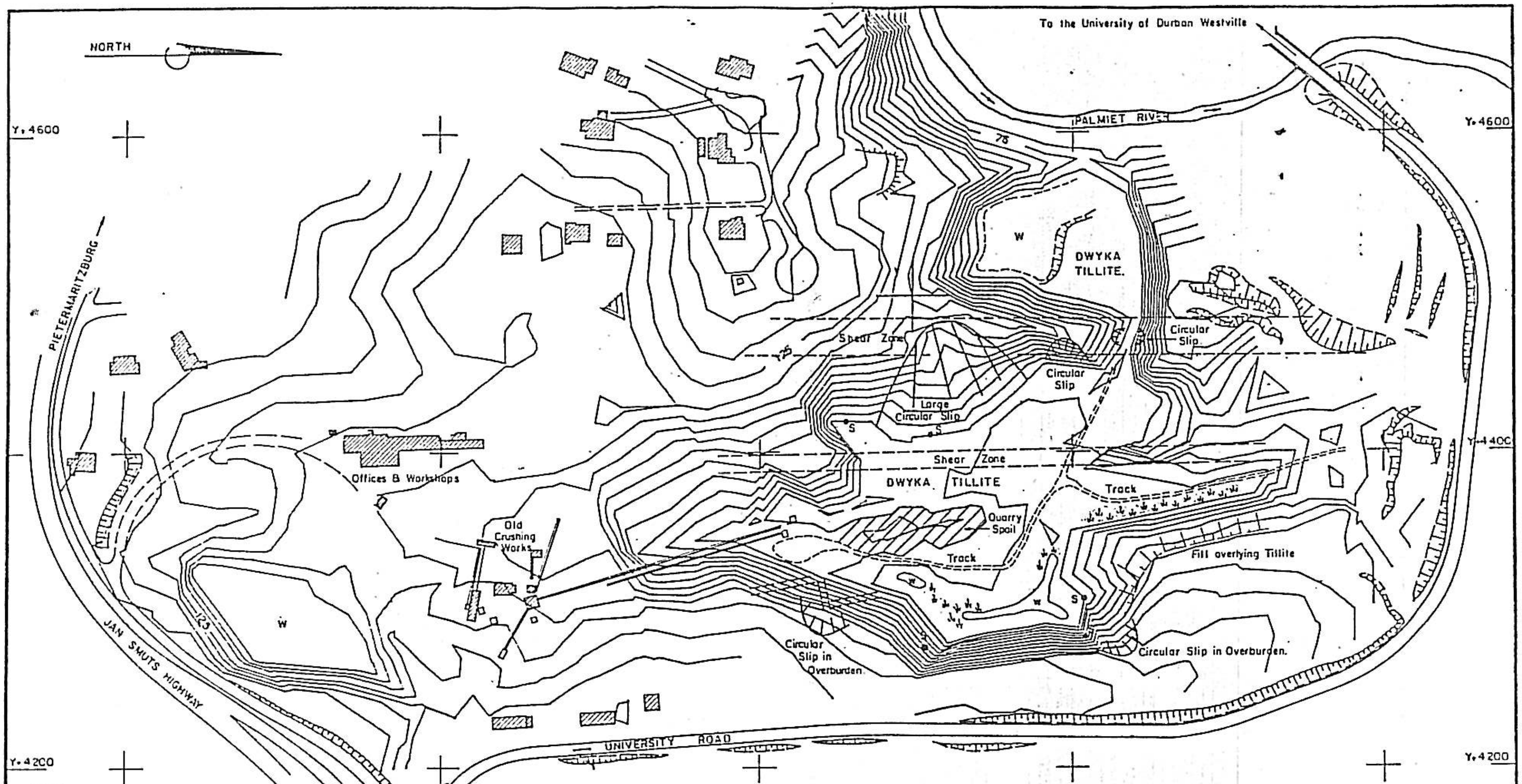


KEY:

100 ⊥ Approximate Reference Chainage in metres.

Ⓔ Rock Slope Section Referred to in Text.

SITE PLAN	WASTE - TECH (Pty) LTD S.A. Crushers Quarry Westville	Date 28-3-89 Drawn V.B. Checked B.WJ
SCALE 1 in 2500	MOORE SPENCE JONES AND PARTNERS	Ref. No. 88/203 Fig. No. 1



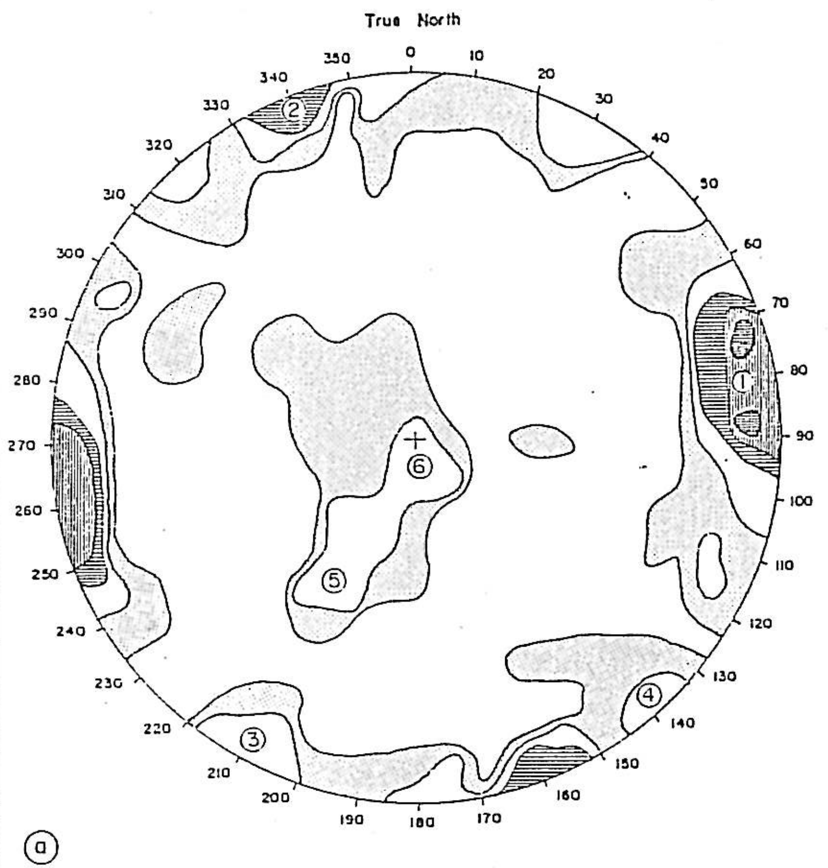
KEY:

- Dwyka Tillite.
- Approximate Extend of Shear Zone within the Tillite.
- W Standing Groundwater.
- Aquatic Vegetation.
- •S Groundwater Seepage out of Rock Face.
- Circular Slip in Soil and highly Weathered Rock Overburden.

X 3 300 600 | X 3 300 400 | X 3 300 200

Geotechnical Site Plan Scale 1 in 2500	WASTE - TECH (Pty) LTD S.A. Crushers Quarry Westville MOORE SPENCE JONES AND PARTNERS • Consulting Geotechnical & Civil Engineers	Date 28-3-89 Drawn: V.B. Check: BWJ Ref. No. 88/203 Fig. No. 2.

EQUAL- AREA STEREONET - EQUATORIAL PROJECTION



(a)

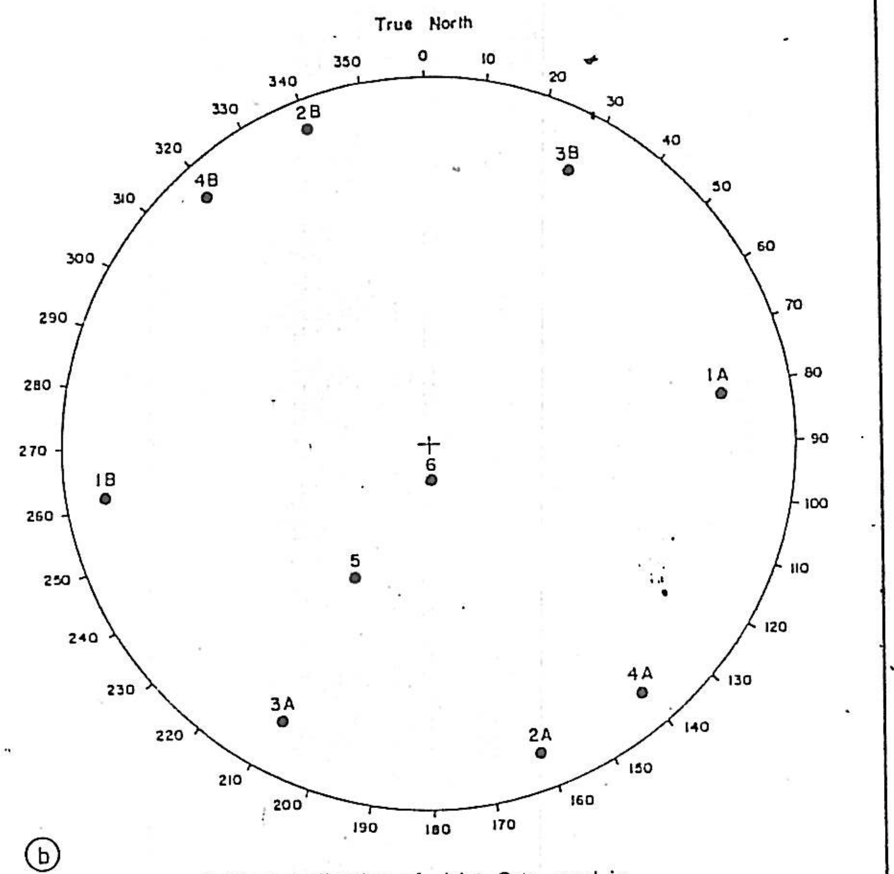
KEY:

	> 14 %
	8 - 14 %
	4 - 8 %
	2 - 4 %
	< 2 %
①	Joint Number

Orientations of Idividual Joints Used In Stability Assessment.

Joint Nº	Most Critical Dip in Degrees from the Horizontal.	Dip Direction in Degrees.
J 1	75	260
J 2	80	340
J 3	75	030
J 4	80	320
J 5	35	030
J 6	05	000

EQUAL - AREA STEREONET - EQUATORIAL PROJECTION

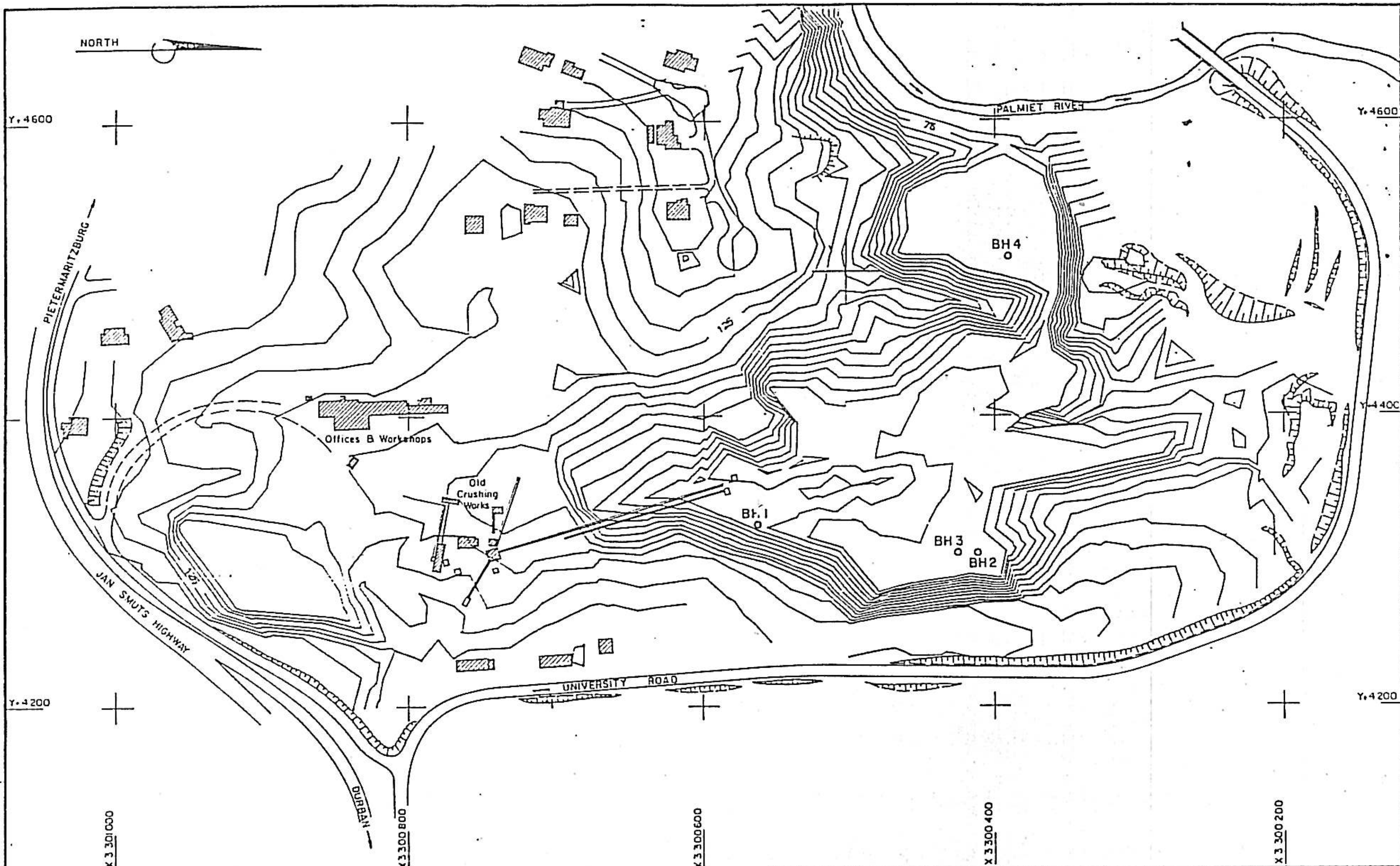


(b)

Critical Inclination of Joint Sets used in Stability Assessment

KEY:
1A ● Principal Design Joints used in Stability Assessment.

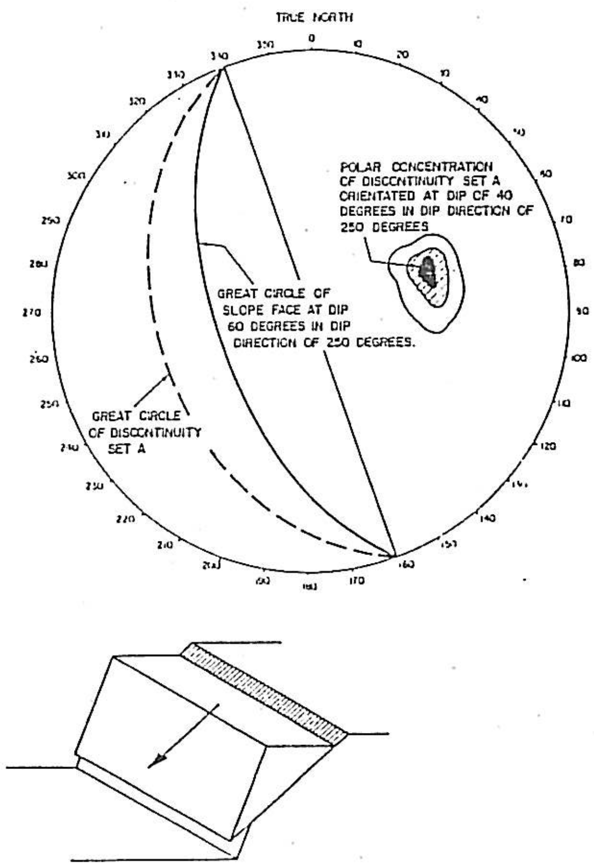
Joint Analysis Equatorial Plots.	WASTE - TECH (Pty) LTD S.A. Chrushers Quarry Westville	Date 28-3-89 Drawn V.B. Check B.W.J
	MOORE SPENCE JONES AND PARTNERS	Ref. No. 88/203 Fig. No. 3



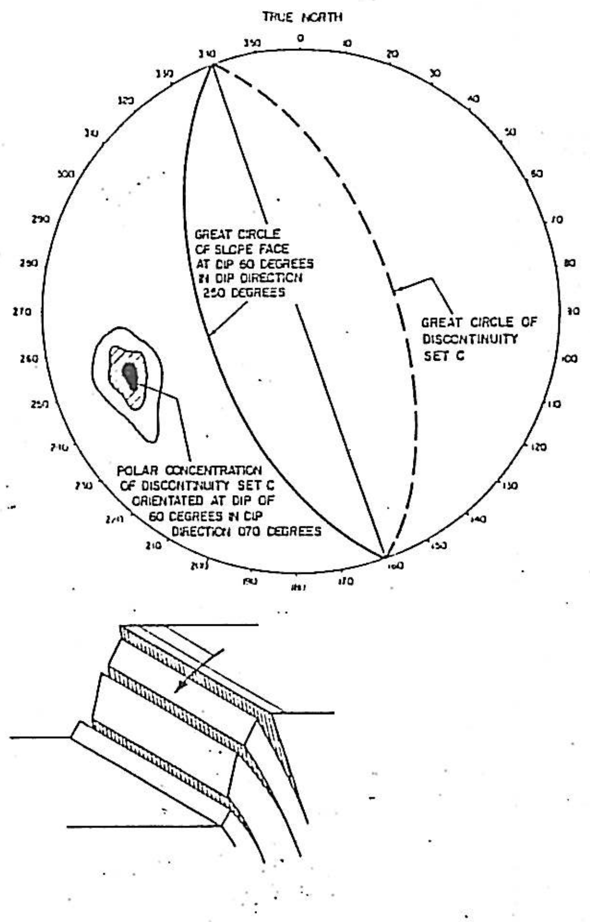
KEY:

BH 1 o — Approximate Position of Boreholes, used to Monitor Groundwater Levels.

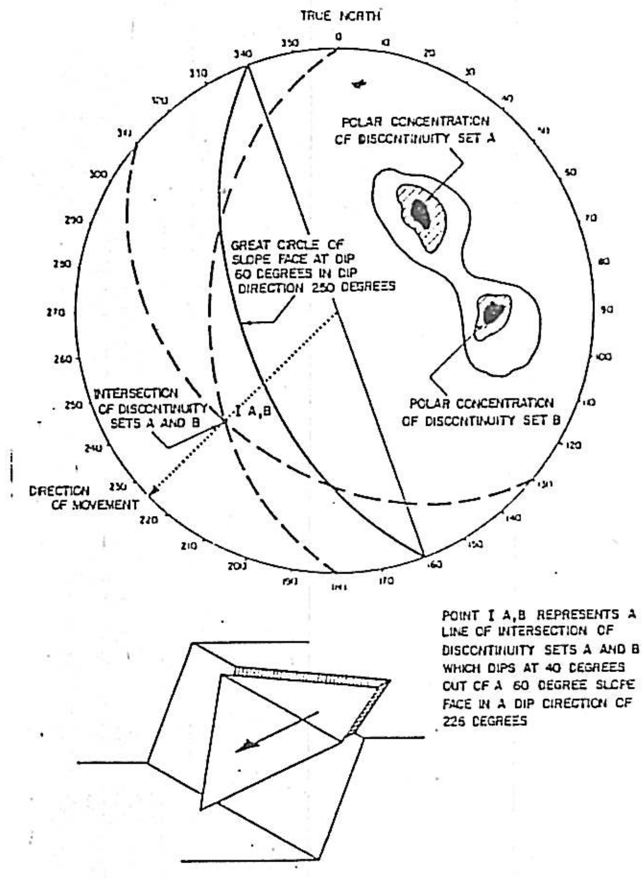
Plan Showing Approximate Positions of Boreholes. Scale 1 in 2500	WASTE - TECH (Pty) LTD S.A. Crushers Quarry Westville MOORE SPENCE JONES AND PARTNERS	Date 28-3-89 Drawn V.B. Check BWJ Ref. No. 88/203 Fig. No. 4



PLANAR TYPE FAILURE



TOPPLING FAILURE IN HARD ROCK WHICH CAN FORM COLUMNAR STRUCTURES SEPARATED BY STEEPLY DIPPING DISCONTINUITIES



POINT I A,B REPRESENTS A LINE OF INTERSECTION OF DISCONTINUITY SETS A AND B WHICH DIPS AT 40 DEGREES OUT OF A 60 DEGREE SLOPE FACE IN A DIP DIRECTION OF 225 DEGREES

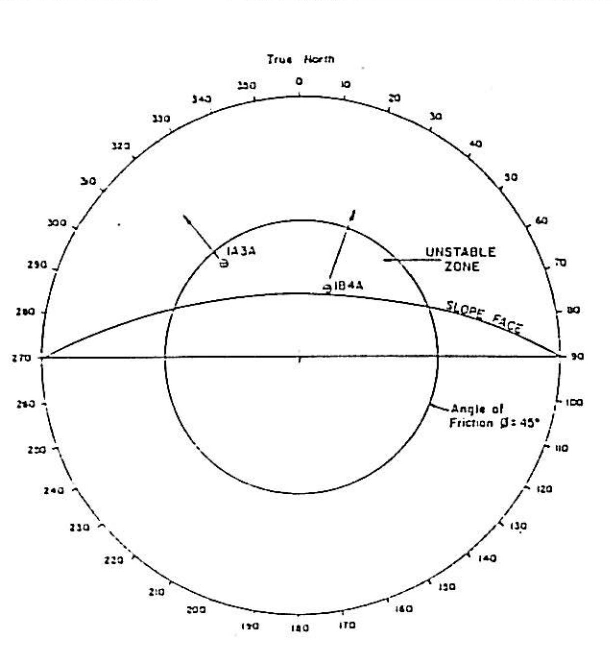
WEDGE FAILURE ON TWO INTERSECTING DISCONTINUITY SETS.

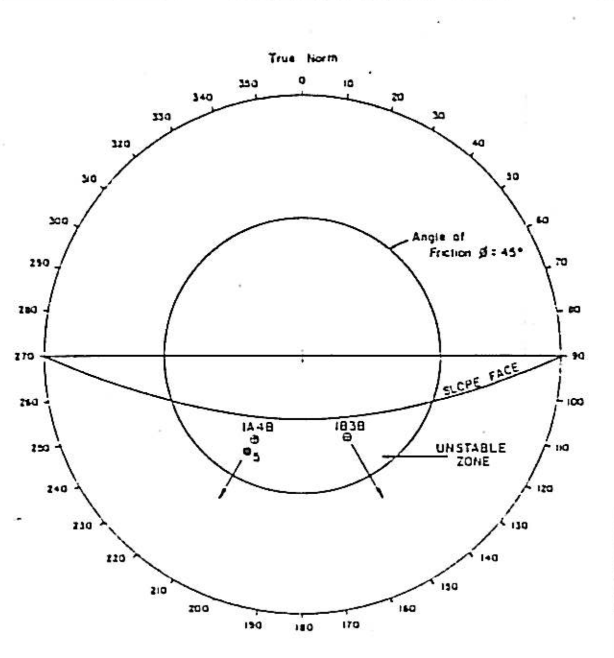
Note:

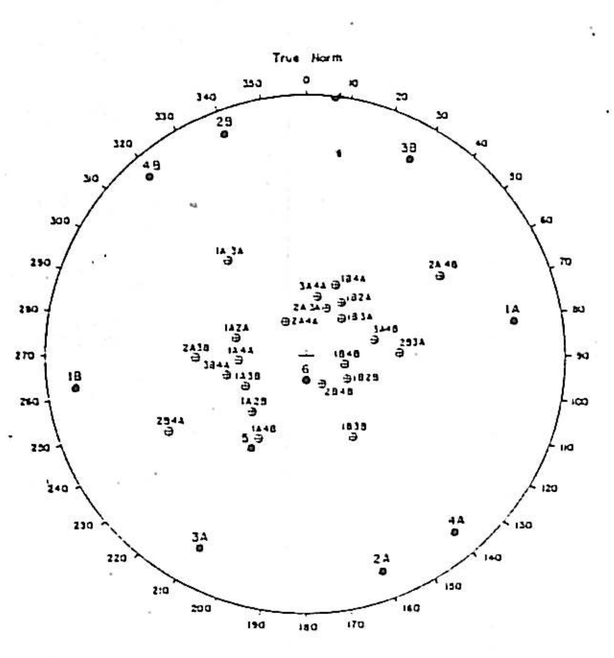
For illustrative purposes these diagrams have been somewhat simplified.

Appearance of Stereographic Projections, Showing Structural Conditions Likely to Give Rise to Different Types of Rock Slope Failure.	WASTE - TECH (Pty) LTD S.A. Chrushers Quarry Westville	Date 28-3-89 Drawn V.B. Check B.W.J
	MOORE SPENCE JONES AND PARTNERS	Ref. No. 88/203 Fig. No. 5

EQUAL- AREA STEREONET - EQUATORIAL PROJECTION	EQUAL- AREA STEREONET - EQUATORIAL PROJECTION	EQUAL- AREA STEREONET - EQUATCRIAL PROJECTION







ⓒ NORTH FACING SLOPES
Assumed Slope Angle 70 Degrees

Potential Types of Failure

Potential Failure Mode.	Design Joints	Dip and Dip Direction of Line of Intersection Degrees.
Wedge	IA 3A	50 / 320
Wedge	IB4A	66 / 020

ⓑ SOUTH FACING SLOPES
Assumed Slope Angle 70 Degrees

Potential Types of Failure

Potential Failure Mode.	Design Joints	Dip and Dip Direction of Line of Intersection Degrees.
Wedge	IA 4B	60 / 210
Wedge	IB 4B	60 / 152
Toppling	3A	75 / 030
Toppling	2A	80 / 340

ⓐ KEY:

- A1 ● Design Joints A1 - See Figure 3.
- IA 2A ⊕ Pole of Line of Intersection of Design Joints.

Preliminary Evaluation of Possible Slope Stability Problems using Geological Structural Data.

WASTE - TECH (Pty) LTD
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Westville

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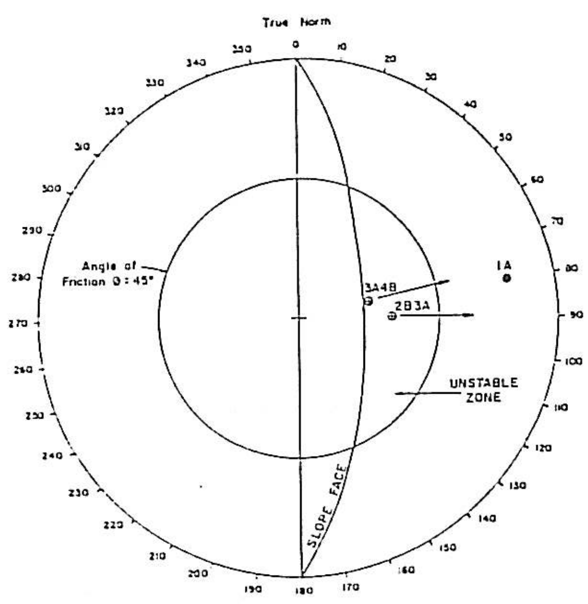
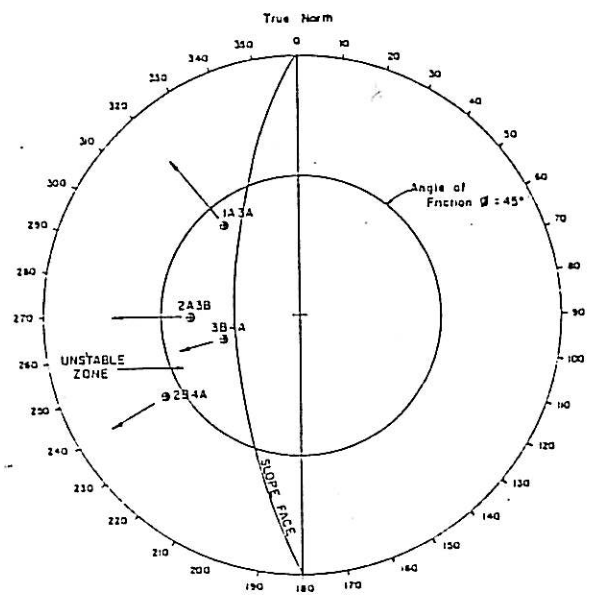
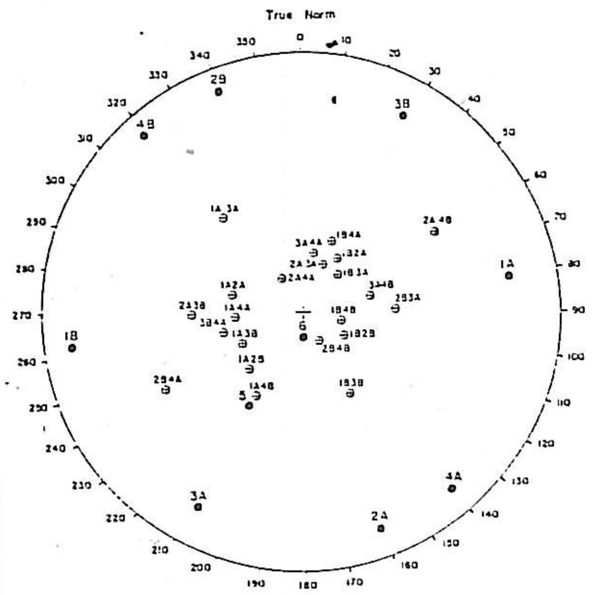
Date	28-3-89
Drawn	V.B.
Check	BWJ
Ref. No.	88/203
Fig. No.	6

EQUAL-AREA STEREONET - EQUATORIAL PROJECTION	EQUAL-AREA STEREONET - EQUATORIAL PROJECTION	EQUAL-AREA STEREONET - EQUATORIAL PROJECTION







ⓒ **EAST FACING SLOPES**

Assumed Slope Angle 70 Degrees

Potential Types of Failure

Potential Failure Mode	Design Joints	Dip and Dip Direction of Line of Intersection Degrees.
Wedge	2B3A	60 / 090
Wedga	3A4B	68 / 078
Toppling	A1	75 / 260

ⓑ **WEST FACING SLOPES**

Assumed Slope Angle 70 Degrees

Potential Types of Failure

Potential Failure Mode.	Design Joints	Dip and Dip Direction of Line of Intersection Degrees.
Wedge	2A3A	56 / 268
Wedge	1A 3A	52 / 320
Wedge	3B4A	65 / 255
Planar	1A	70 / 260

ⓐ

KEY:

A1 ● Design Joints A1 - See Figure 3.

1A 2A ⊕ Pole of Line of Intersection of Design Joints.

Preliminary Evaluation of Possible Slope Stability Problems using Geological Structural Data.

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Ref. No.	88/203
Fig. No.	7

←SECTION D→ ←SECTION E→

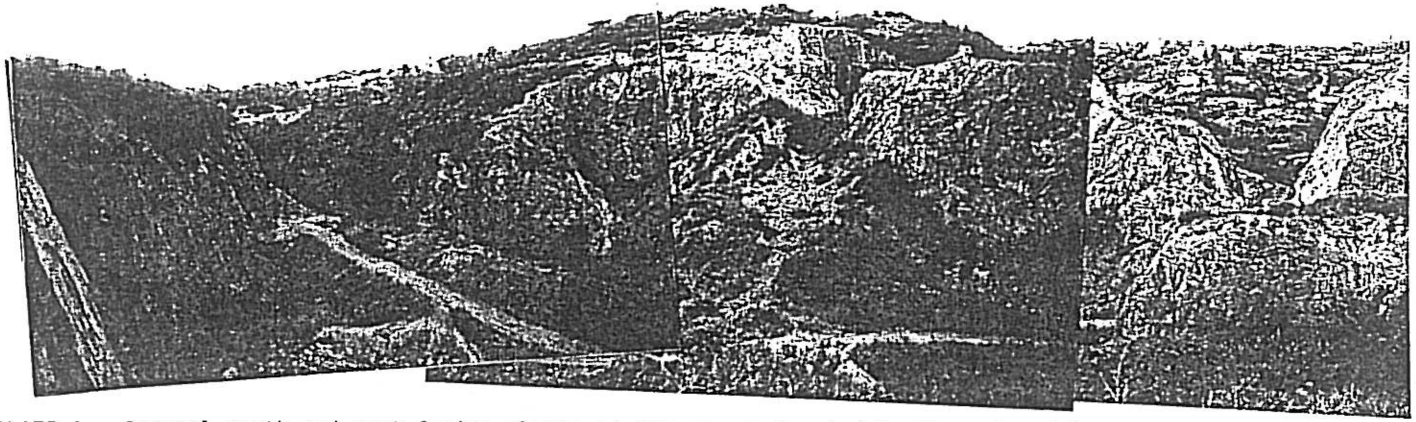
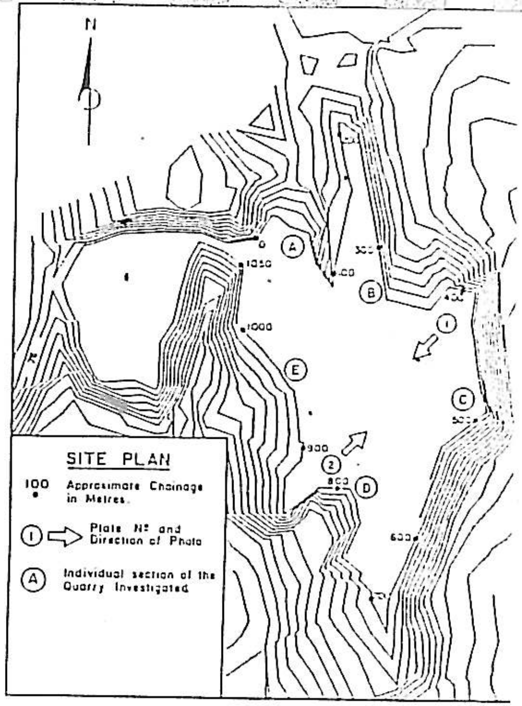


PLATE 1 - General north and east facing slopes of Quarry, designated Sections D and E

Section D - Chainage 725 to 875 metres
Section E - Chainage 875 to 1050 metres



Individual sections of the Quarry investigated

←SECTION A→ ←SECTION B→ ←SECTION C→

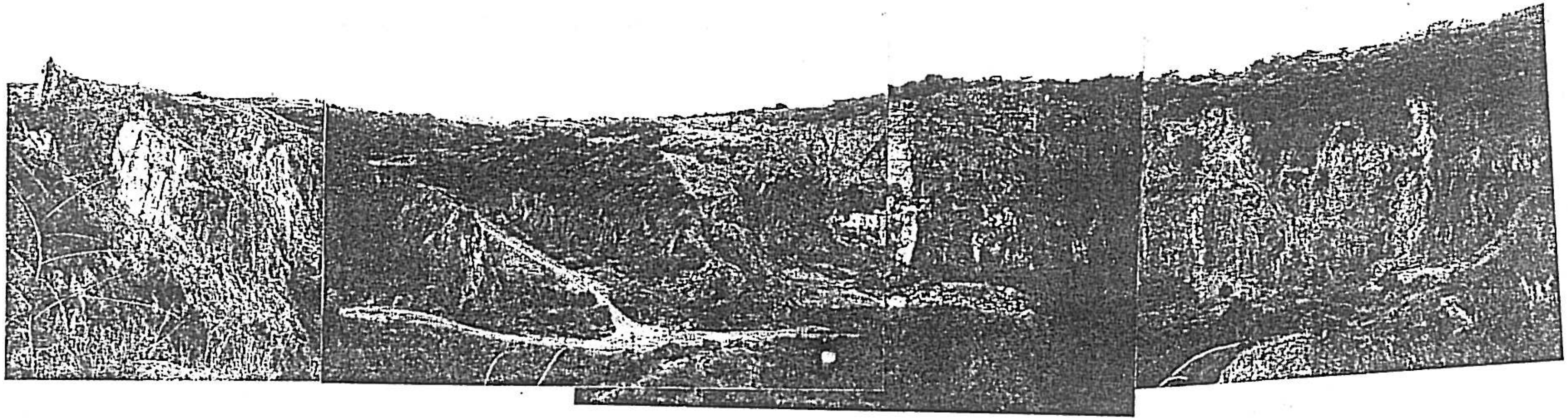


PLATE 2 - General south and west facing slopes of Quarry, designated Sections A, B and C

Section A - Chainage 0 to 150 metres
Section B - Chainage 250 to 410 metres

SECTION A
CH 0 to 150 m.

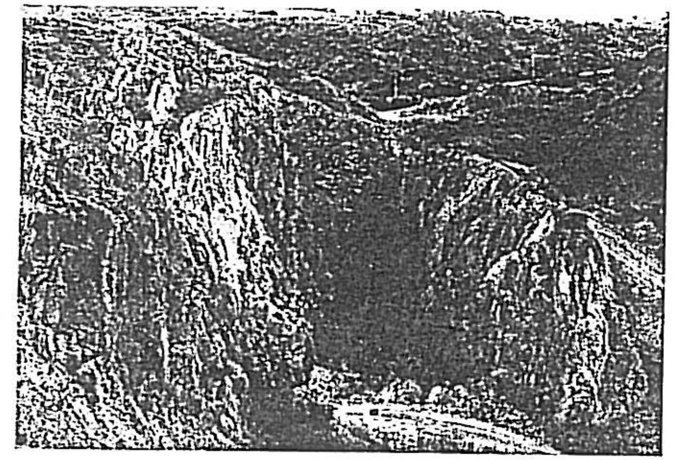
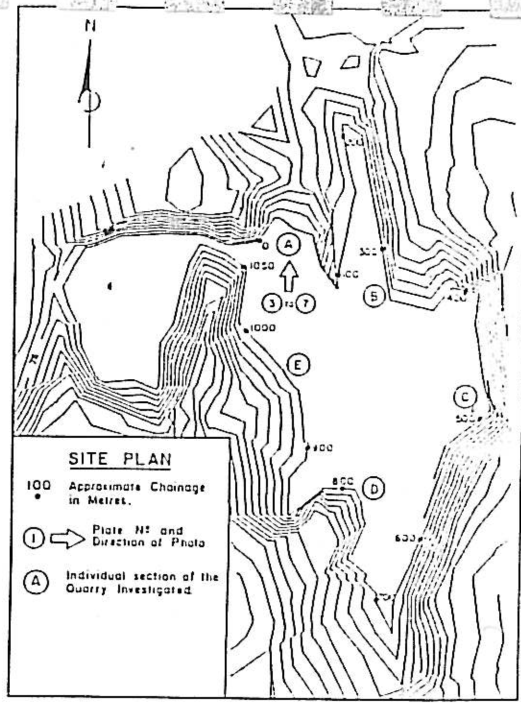


PLATE 3 - General view of SECTION A of Quarry looking north. The east facing slope on the left and the peninsular section on the right, are north-south trending shear zones in the Dwyka Tillite which have been left unmined.

PLATE 4 - East facing slope of 'box-cut'- considered unstable. Note loose scree material at the toe of the slope.



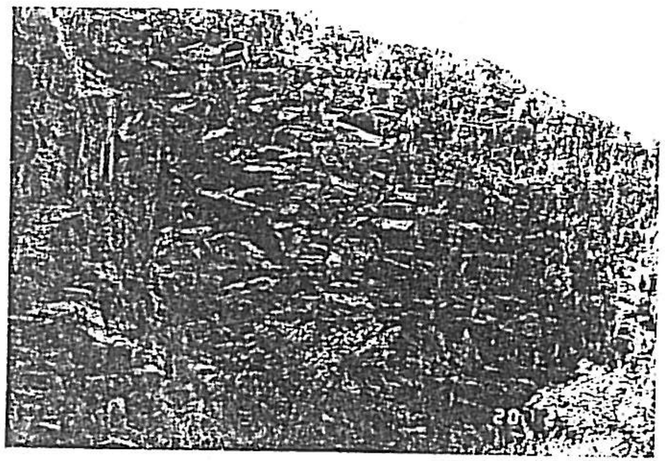


PLATE 5 - South facing slope of 'box-cut', Section A.

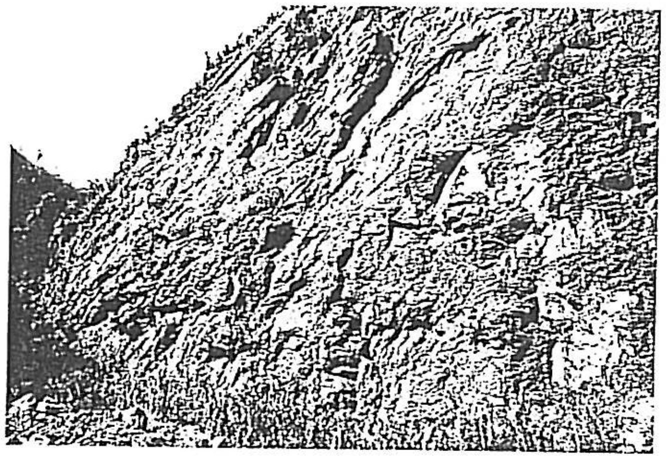


PLATE 6 - West facing slope of peninsular.

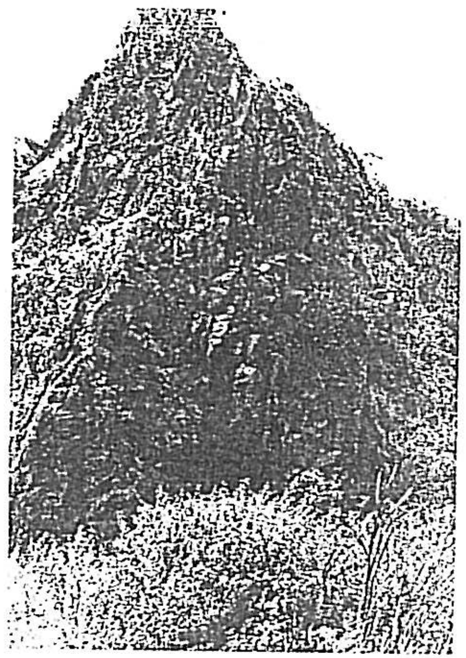


PLATE 7 - Nose of peninsular.

SECTION B - CH 250 to 410 m.

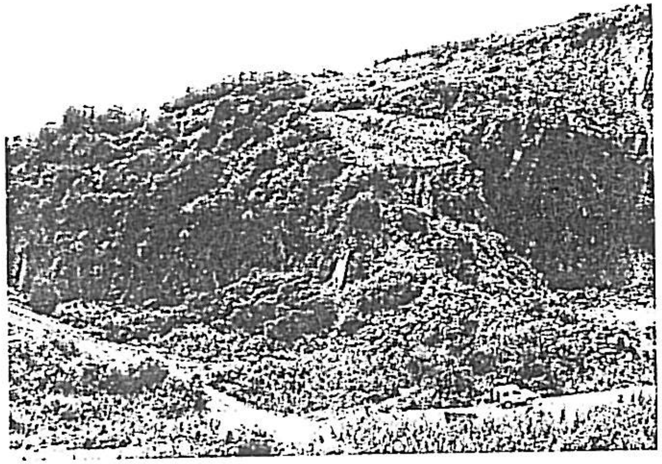


PLATE 8 - General view of SECTION B of Quarry looking northeast. Buttress in the foreground comprises loose scree material.

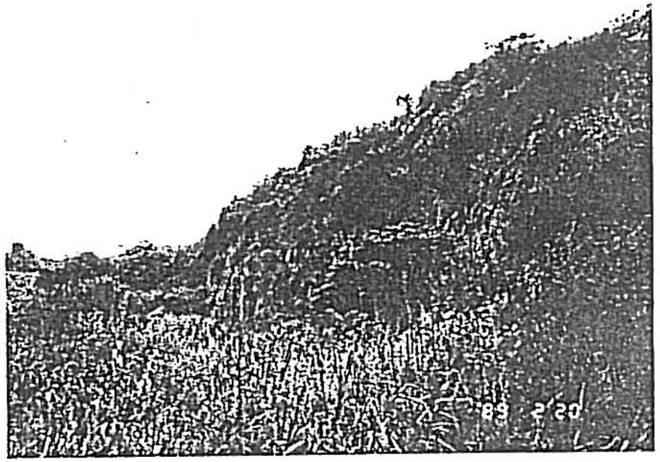


PLATE 9 - West facing slope adjacent to road entering the Quarry.

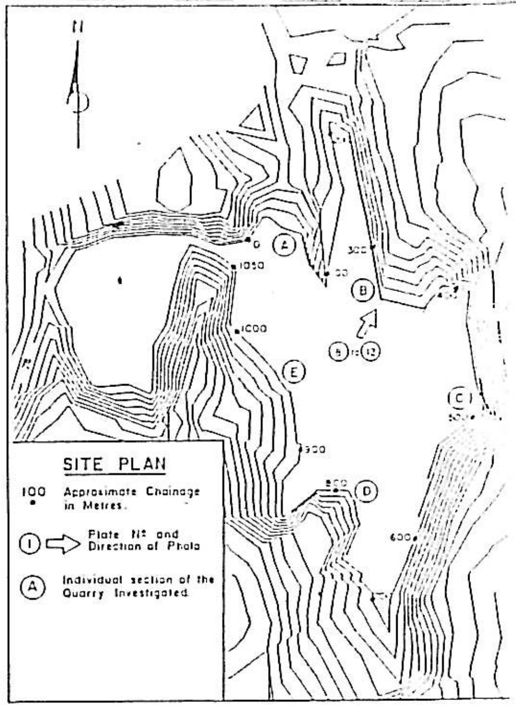


PLATE 10 - Showing highly weathered potentially unstable Tillite near the crest of the unmined buttress.

PLATE 11 - South facing slope of 'box-cut'.

PLATE 12 - Note failure at the crest of the slope and loose scree at the toe of the slope.

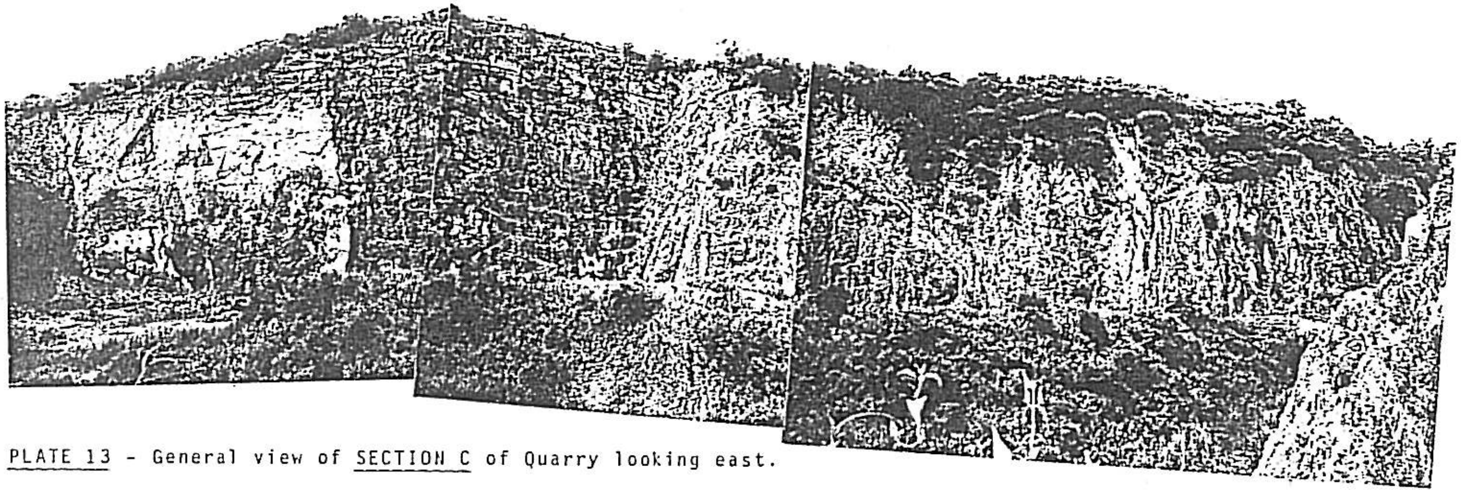
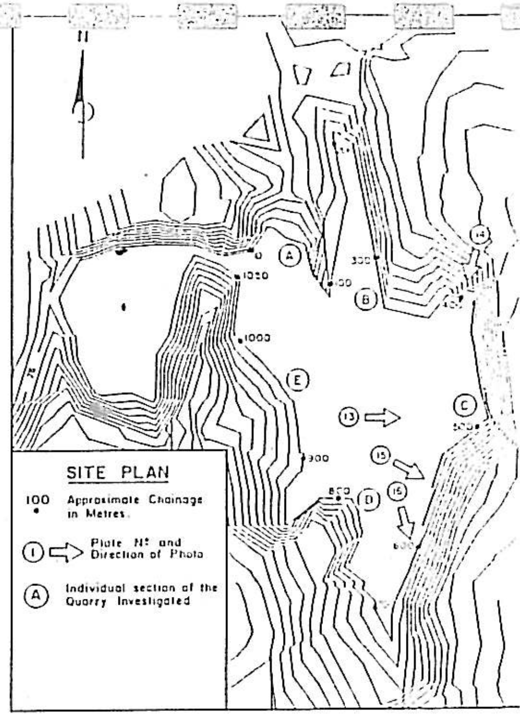


PLATE 13 - General view of SECTION C of Quarry looking east.



SECTION C
CH 410 to 650 m.

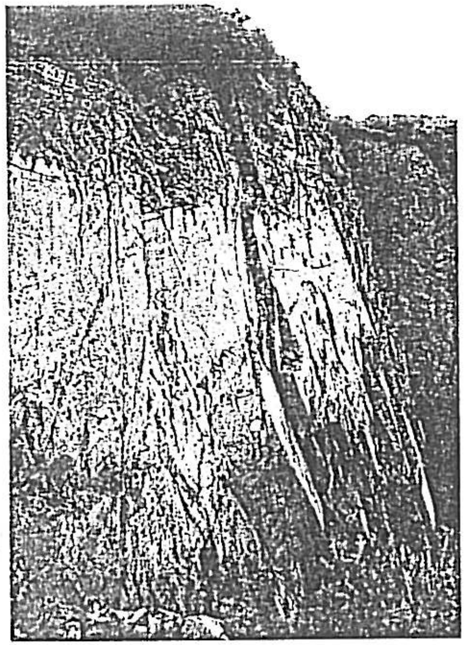


PLATE 14 - Steeply inclined north-south trending major joint set, J1.

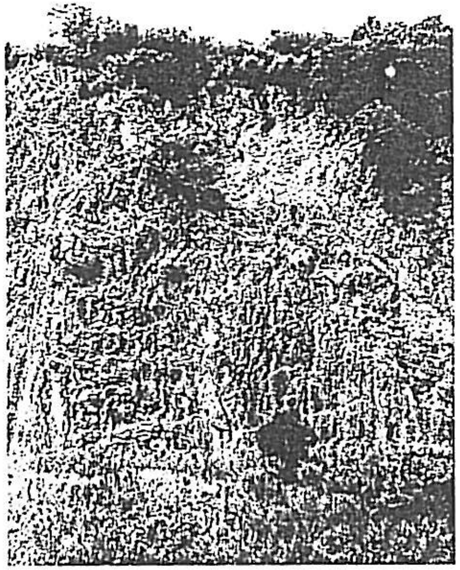


PLATE 15 - Note failure in weathered zone near the crest of the slope, due to presence of two intersecting shear zones.

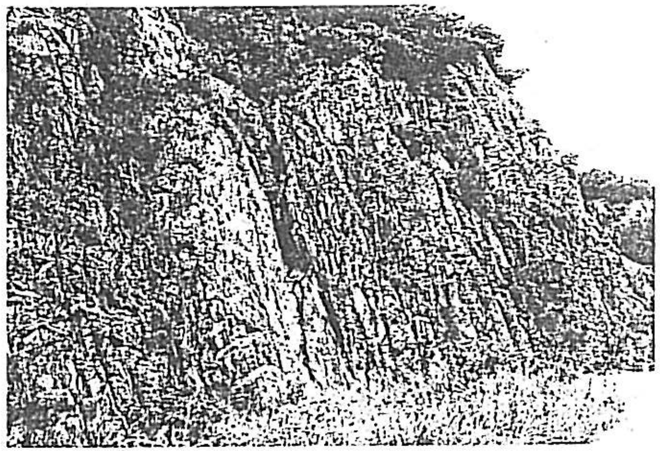
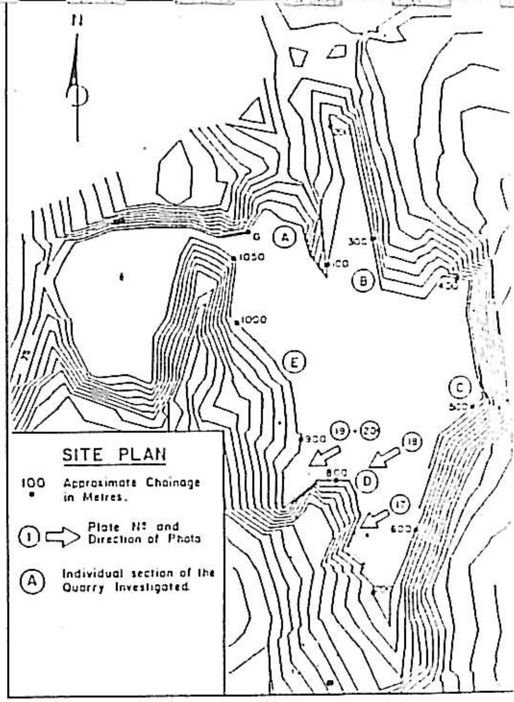


PLATE 16 - Shear zone (light coloured rock) within the Dwyka Tillite.

SECTION D
CH 725 to 875 m.



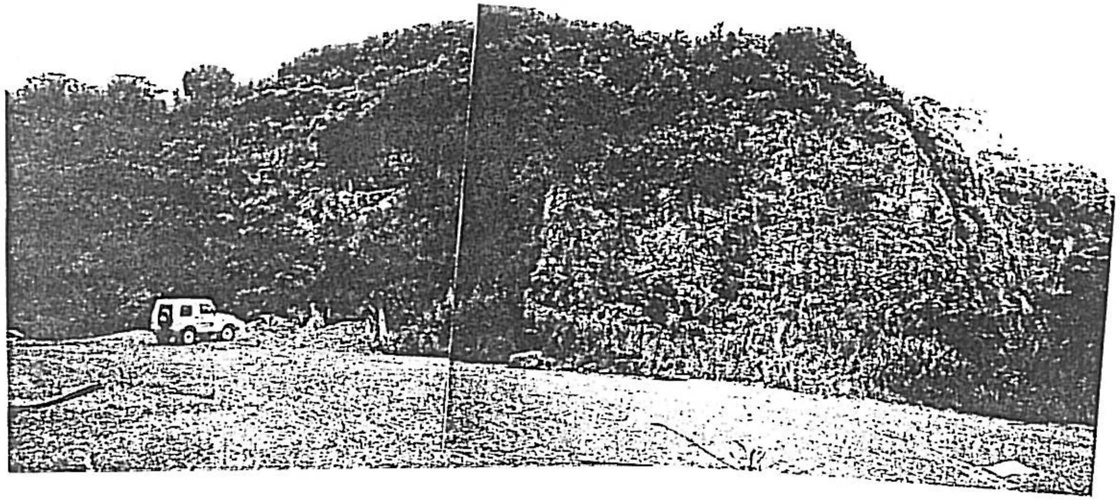


PLATE 17 - General view of east facing slope of SECTION D.

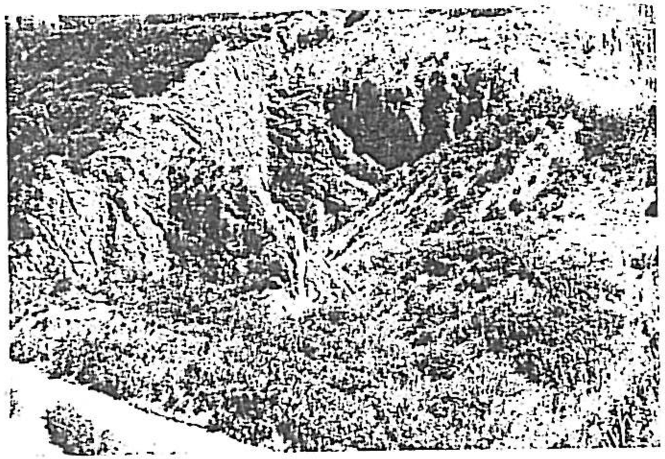


PLATE 18 - General view of 'box-cut'. Note unmined peninsular of shear zone material with slightly weathered Tillite on either side.

PLATE 19 - West facing slope of unstable peninsular comprising shear zone material.

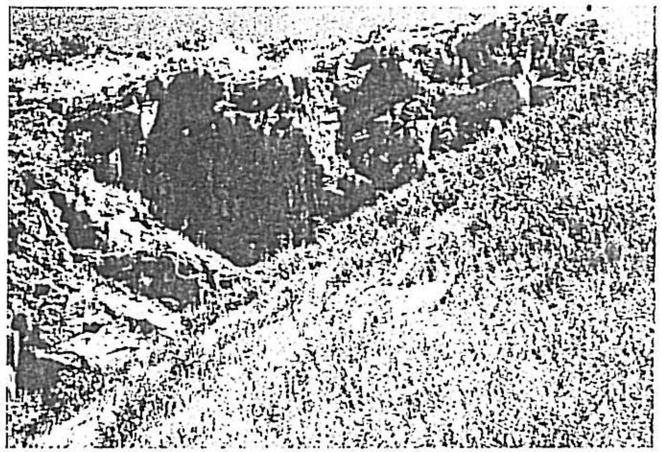
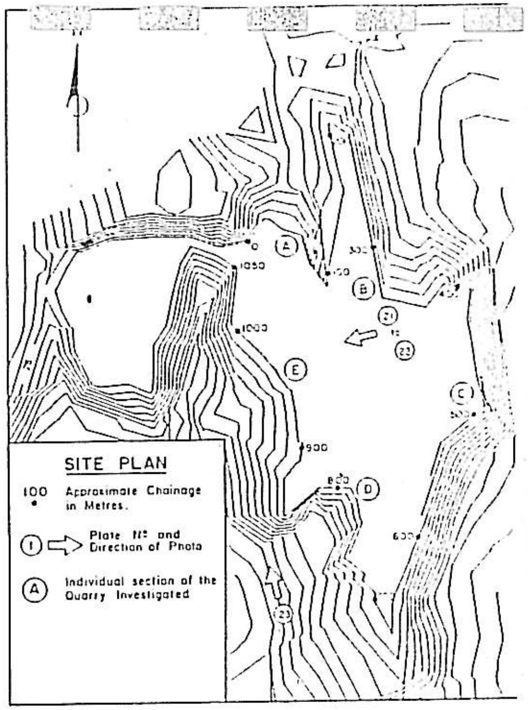


PLATE 20 - East facing slope of 'box-cut'. Note overhanging rock slope due to inclined north-south trending joint which dip towards the west.

SECTION E
CH 875 to 1050 m.



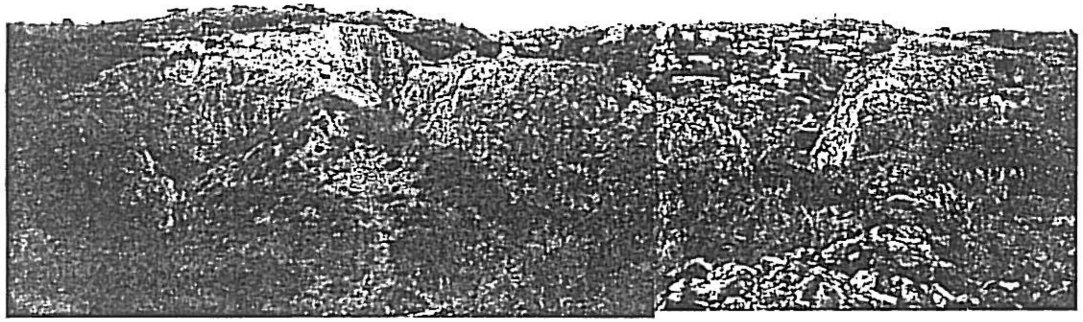


PLATE 21 - General view of SECTION E of Quarry.

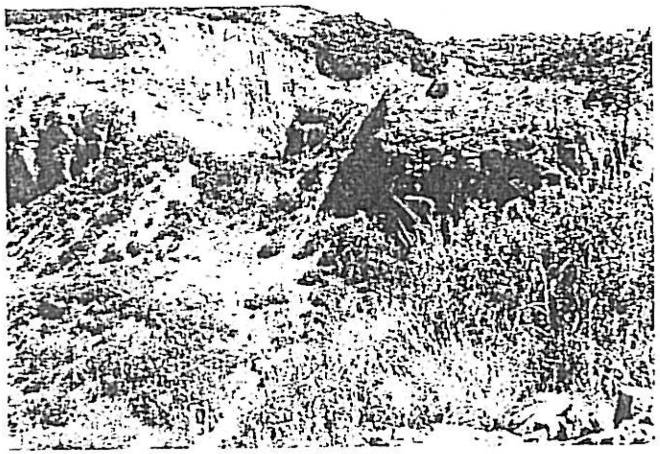


PLATE 22 - Showing failure debris in the foreground.

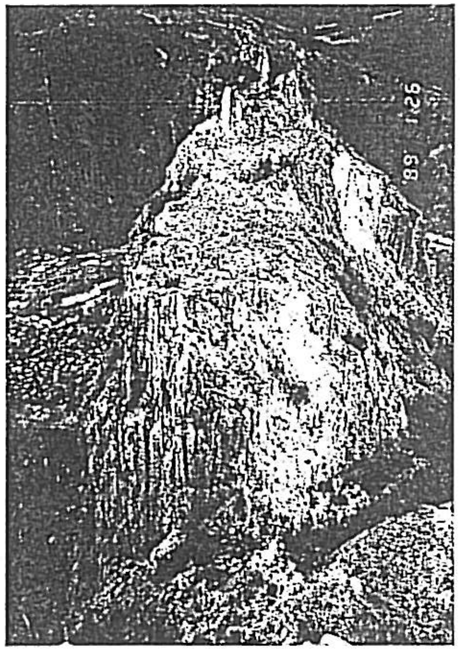


PLATE 23 - Showing the unmined peninsular, comprising a north to south trending, near vertical, shear zone in the Dwyka Tillite.

WESTERN PORTION OF QUARRY

This portion of the Quarry was not investigated because of the general unstable conditions and exposed groundwater level

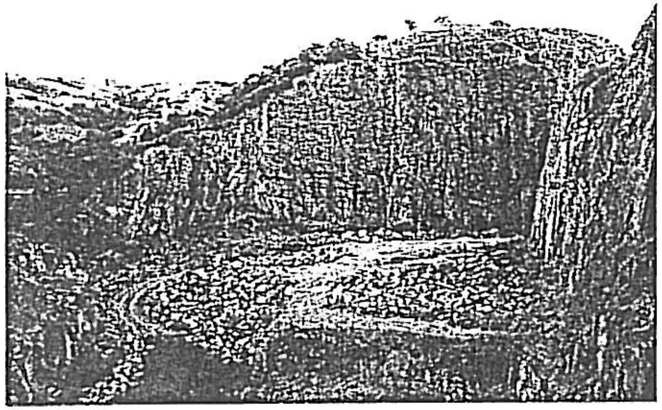


PLATE 24 - Northern face.

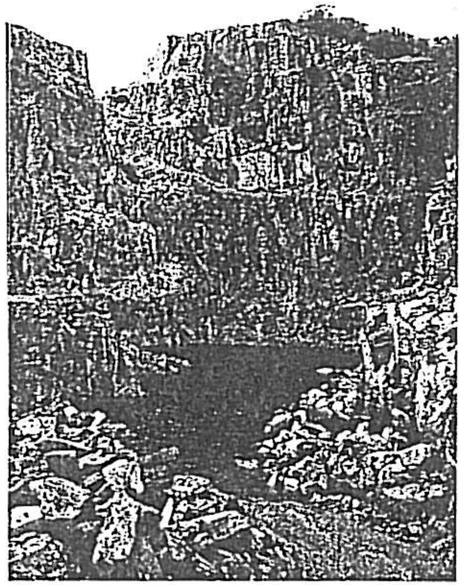


PLATE 25 - Southern face.

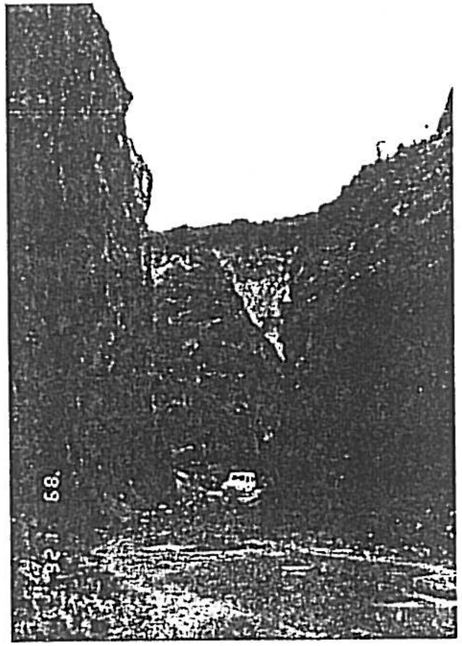
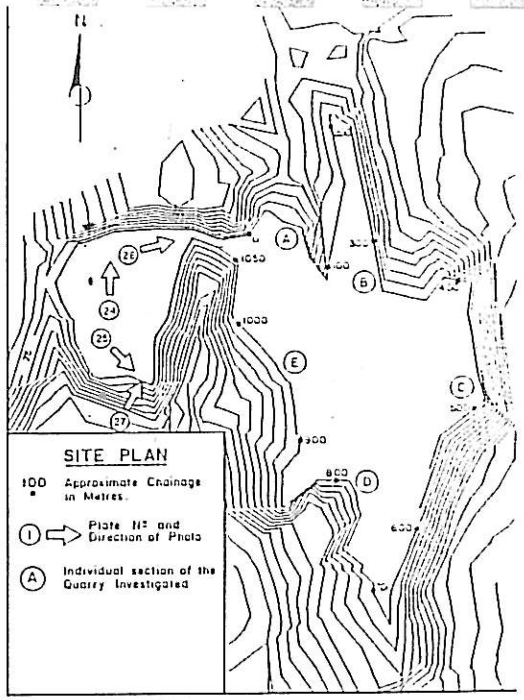


PLATE 26 - This narrow, near vertical cut through the shear zone in the Tillite is the only entrance to this portion of the Quarry. The unstable condition is demonstrated by the failed debris blocking the entrance.



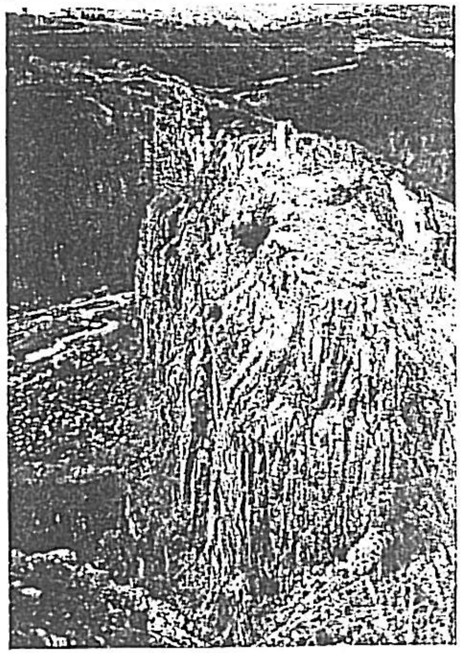


PLATE 27 - Unstable peninsular of rock, comprising near vertical shear zone in the Dwyka Tillite.

APPENDIX II

Moore Spence Jones and Partners Report Ref. 89/58

A sub-soil investigation for clay borrow materials
at Ridgeview quarry Durban

REPORT TO WASTE-TECH (PTY) LTD ON A SUBSOIL INVESTIGATION FOR CLAY BORROW MATERIALS AT RIDGEVIEW QUARRY, DURBAN

REF : 89/58

MOORE SPENCE JONES & PARTNERS

Copy No :
Ref No : 89/58
BWJ/deg

AUGUST 1989

Consulting Geotechnical and
Civil Engineers
P O Box 1263
WANDSBECK 3631
Tel : (031) 861324/5
Fax : (031) 865322

I N D E X

REPORT TO WASTE-TECH (PTY) LTD ON A SUBSOIL INVESTIGATION FOR CLAY BORROW MATERIALS AT RIDGEVIEW QUARRY, DURBAN

REF : 89/58 JULY 1989

1. SCOPE OF REPORT

This report sets out the results of an investigation carried out to assess the suitability of the soil overburden at Ridgeview Quarry for use as a clay liner beneath a proposed Waste Disposal site.

2. TERMS OF REFERENCE

In terms of a letter dated 27 April 1989, received from Waste-Tech (Pty) Ltd, Moore Spence Jones & Partners were requested to investigate the overburden material at Ridgeview Quarry. The investigation was to include an assessment of the subsoils based on both a field investigation and laboratory tests.

3. INFORMATION SUPPLIED

In preparing this report use has been made of the City of Durban's orthophoto map of the area, Sheet G39, to a scale of 1 in 2000, dated June 1978.

It is understood from Mr R Taylor of Ridgeview Quarries, that future quarrying operations would take place over an area between the existing access road to the Quarry and Ridge View Road. However, at this stage, it is not known which portions of the site will be quarried in the future, and the phasing of quarry operations.

/2.....

4. FIELD WORK

The field work was carried out on 13 June 1989. Sixteen inspection pits, designated IP1 through IP16, were put down across the site at the approximate positions shown on the site plan in Figure 1. The inspection pits were excavated using a Case 580G backacter supplied by Pinex Plant Hire.

All the inspection pits were excavated through the clayey overburden into the weathered tillite bedrock, underlying the site. The inspection pits varied in depth between 0,4 and 2,6 metres below existing ground level. Representative samples of the subsoils were taken for laboratory examination and testing.

The logs of the inspection pits are given in Appendix A. The terminology used to describe the soils and rocks in the logs is defined in Appendices B and C.

5. DESCRIPTION OF THE SITE

Ridgeview Quarry is located on the northern bank of the Umbilo River. Access to the quarry is via Ridge View Road.

The area investigated for borrow materials is situated on a general south-facing slope, above the Umbilo River. Two non-perennial natural drainage valleys bisect the area, draining towards the Umbilo River. The extent of the area investigated is shown on the site plan in Figure 1.

6. SUBSOIL CONDITIONS

The area is underlain by colluvial and residual soils, overlying weathered Dwyka tillite bedrock.

/3.....

The colluvial soils are extremely variable, but can generally be described as a greyish brown, medium dense, sandy silt, containing abundant weathered tillite fragments. The average thickness of the colluvial soils is approximately 0,3 metres, in the approximate range 0,1 to 0,6 metres. Frequently present at the base of the colluvial soils is a very thin pebble marker horizon. This marker horizon comprises gravelly sands.

In the relatively low lying valley bottoms, the colluvial soils are underlain by clayey residual soils. The residual soils are derived from complete insitu weathering of the underlying tillite bedrock. The average thickness of the residual clays is approximately 1,6 metres. The yellow brown, reddish brown and mottled light grey residual soils vary in composition from sandy clays to slightly sandy silty clays as shown in Figure 2. The clay contents vary between approximately 20 and 35 percent.

In the valley bottoms the residual soils frequently grade with increasing depth into completely to highly weathered (W5/4) tillite. Over the relatively high lying valley sides the residual soils are generally absent, and the colluvial soils directly overlie yellow brown weathered tillite, at an average depth of approximately 0,6 metres below existing ground level, in the range 0,2 to 0,9 metres. The completely to highly weathered (W5/4) tillite is often overlain by a thin clayey sand horizon, which is a gradational weathered residual soil layer between the completely decomposed residual soils and underlying W5/4 tillite. This layer, however, is generally less than 0,6 metres thick and has a sporadic distribution. In a bulk earthworks operation this yellow brown clayey sand material would be difficult to distinguish from the underlying W5/4 tillite.

With increasing depth the (W5/4) tillite grades into highly weathered (W4), soft rock, yellow brown, tillite.

The approximate extent of the area underlain by residual clays is shown on the site plan in Figure 1.

7. LABORATORY TESTING

Laboratory tests were carried out on representative samples of the subsoil materials for classification purposes. In addition, laboratory permeability tests were carried out on recompacted specimens of the residual clays. The detailed results of these tests are given in Appendix D, and are summarised below.

7.1 Particle Size Distribution Analysis

Particle Size Distribution Analysis were carried out on representative samples of the colluvial and residual soils, and completely to highly weathered (W5/W4) tillite. The results are given in Figures 2, 3 and 4.

7.2 Compaction Tests

The results of the compaction tests are summarised in Table 1 below.

TABLE 1

Summary of Results of Compaction Tests

Inspection Pit No.	Depth metres	Description	Proctor	
			Optimum Moisture Content Percent	Maximum Dry Density kg/m^3
IP 1	0,6 - 1,6	Yellow brown, clayey SAND - (W5/4) tillite	20,5	1748
IP 2	0,2 - 1,4	Dark red, sandy silty CLAY - Residual	14,3	1742

/Continued .....

TABLE 1

Summary of Results of Compaction Tests

(Continued)

Inspection Pit No.	Depth metres	Description	Proctor	
			Optimum Moisture Content Percent	Maximum Dry Density kg/m^3
IP 8	1,5 - 2,1	Light grey mottled yellow, slightly silty sandy CLAY - Residual	18,5	1750
IP 10	0,3 - 1,7	Yellow mottled grey, stiff sandy CLAY - Residual	13,5	1874
IP 14	0,3 - 0,9	Dark brown, dense clayey sandy SILT - Colluvial	10,0	2021

7.3 Permeability Tests

Laboratory permeability tests were carried out on representative samples of the clayey materials, compacted to 90 and 93 percent of maximum Proctor dry density. These tests were carried out in a triaxial test apparatus. The results are summarised in Table 2 below.

/6.....

TABLE 2

Summary of Results of Permeability Tests
Carried out in Triaxial Cell

Inspection Pit No	Depth	Description	Degree of Compaction* Percent	Clay Content Percent	Coefficient of Permeability cm/sec
IP 1	0,6 - 1,6	Dark yellow brown clayey SAND (W5/4 Tillite)	90	18	$1,6 \times 10^{-7}$
			93	18	$5,2 \times 10^{-8}$
IP 2	0,2 - 1,4	Dark red, sandy silty CLAY (Residual)	90	28	$8,2 \times 10^{-8}$
			93	28	$2,6 \times 10^{-8}$
IP 8	1,5 - 2,1	Light grey, mottled yellow, sandy CLAY (Residual)	90	35	$3,0 \times 10^{-9}$
			93	35	$2,2 \times 10^{-9}$

* Percentage of maximum Proctor dry density

8. DISCUSSION

The various subsoil materials underlying the site are discussed separately below.

(a) Colluvial Soils

The dark brown colluvial soils underlie the site to an average depth of 0,4 metres below existing ground level, in the range 0 to 1,2 metres. These soils can generally be described as clayey silts, with a clay content of approximately 15 percent. The colluvial soils are extremely variable in composition, and contain organic vegetation. As such, the colluvial soils are considered unsuitable for use as a clay liner.

/7.....

(b) Residual Soils

From the results of the investigation, it is considered that the residual clays underlying the valley bottoms are suitable for use as a clay liner. These clays, however, are limited in extent as shown on the site plan in Figure 1.

The clay contents range between approximately 21 and 35 percent. Laboratory determined coefficients of permeability conducted on recompacted samples range between approximately $2{,}6 \times 10^{-8}$ and $3{,}0 \times 10^{-9}$ cm/sec. It should be appreciated, however, that laboratory determined coefficients of permeability are generally lower than equivalent field conditions.

How? Should these clays not be stabilised (lime treated)

Taking into account the clay content and plasticity index, it is considered that the residual clays have a medium to high potential for expansiveness. It will, therefore, be important to control moisture content variations in the clays, to prevent shrinkage cracks within the clay liner.

(c) Clayey Sands (W5/4 Tillite)

The clayey sands derived from complete weathering of the underlying tillite, are considered to be marginally suitable for use as a clay liner. Laboratory tests indicate that this material has a clay content of approximately 18 percent. The coefficient of permeability determined on a sample recompacted to 90 percent of Proctor dry density was approximately $1{,}6 \times 10^{-7}$ cm/sec.

This material, however, is sporadically distributed across the site, and is generally less than 0,6 metre thick. Because this material would be difficult to select, it is recommended that the clayey sand (W5/4 Tillite) be disregarded.

/8.....

(d) Completely to Highly Weathered (W5/4) Tillite

The W5/4 tillite is considered unsuitable for use as a clay liner. Laboratory tests carried out on similar materials in the Durban area indicates that the average clay content of the W5/4 tillite is approximately 10 percent, in the approximate range 5 to 15 percent. Frequently present in the tillite are hard fragments of less weathered tillite, giving the material a gravelly composition. As such, the permeability of this material would be high.

9. CONCLUSION

The site is underlain by colluvial and residual soils, overlying weathered Dwyka tillite. The residual clays underlying the natural drainage valleys at the site are considered suitable for use as a clay liner. These clays, however, are limited in thickness and lateral distribution across the site, as shown in the site plan in Figure 1.

Taking into account the thickness and lateral distribution of the clays, it is estimated that approximately 60 000 m^3 of suitable material is available from Ridgeview Quarry.

A P P E N D I X   A

INSPECTION PIT PROFILES

INSPECTION PIT PROFILES

Contractor : Pinex
Machine : Case 580G
Observer : TvN

Ref No : 89/58
Date : 13/6/1989

IP No	Depth	Description
1	0,00 - 0,20	Dry, slightly moist, brown, medium dense, fine sandy SILT and roots and occasional pebbles - Colluvium
	0,20 - 0,45	Slightly moist, dark brown, medium dense, lateritic, slightly clayey SILT and fine roots - Colluvium
	0,45 - 0,60	PEBBLE MARKER comprising gravelly SAND
	0,60 - 1,60	Slightly moist, dark yellow stained dark brown, dense, fissured, clayey SAND. (W5/4) Tillite
	1,60 - 1,80+	Soft rock, light olive stained dark brown, very closely jointed DWYKA TILLITE Bottom of IP 1,80 metres
2	0,00 - 0,20	Dry, slightly moist, greyish brown, loose, fine sandy SILT and abundant pebbles and roots - Colluvium
	0,20 - 1,40	Slightly moist, dark red, firm to stiff, microfissured, sandy silty CLAY and abundant tillite pebbles and occasional roots - Residual
	1,40 - 2,30	Slightly moist, dark yellow stained reddish brown, very dense, slightly clayey SAND - (W5/4) very soft rock Tillite
	2,30 - 2,60+	W5/4, Extremely soft to soft rock, dark yellow to light olive stained reddish brown, very closely jointed DWYKA TILLITE Bottom of IP 2,60 metres

/2.....

IP No	Depth	Description
3	0,00 - 0,30	Dry, light greyish brown, loose to medium dense, fine sandy SILT with abundant tillite fragments and fine roots - Colluvium
	0,30 - 0,70	Dry, dark yellow stained dark brown, dense, fissured, fine clayey SAND containing abundant highly weathered tillite fragments (W5/4) Tillite
	0,70 - 1,10	W5/4, very soft rock to soft rock, dark yellow, very closely jointed DWYKA TILLITE
		Bottom of IP 1,10 metres
4	0,00 - 0,10	Dry, light greyish brown, loose, fine sandy SILT containing abundant tillite fragments and fine roots - Colluvium
	0,10 - 0,40+	W5/4, very soft to soft rock, dark yellow stained dark brown, very closely jointed DWYKA TILLITE with light greyish brown colluvial SILT in open joints.
		Bottom of IP 0,40 metres
5	0,00 - 0,20	Dry, light greyish brown, loose, gravelly, fine sandy SILT with abundant fine roots and tillite fragments
	0,20 - 0,50+	W5/4, dark yellow stained dark brown, very closely jointed DWYKA TILLITE
		Final depth of IP 0,50 metres
6	0,00 - 0,30	Dry, light greyish brown, loose, firm sandy SILT containing abundant Tillite fragments and occasional boulders (up to 800 mm diameter) - Colluvium
	0,30 - 1,20	W5/4, very soft rock becoming soft rock, yellowish olive stained dark brown, very closely jointed DYKWA TILLITE
	1,20+	W4, soft rock, light olive stained dark brown, very closely jointed DWYKA TILLITE
		Bottom of IP 1,20 metres

/3.....

IP No	Depth	Description
7	0,00 - 0,10	Dry, greyish brown, loose, fine sandy SILT with abundant tillite fragments and fine roots and occasional big boulders
	0,10 - 0,60	Slightly moist, dark brown, stiff, microfissured silty CLAY and occasional roots - Residual
	0,60 - 1,30	W5/4, very soft rock, yellow stained dark brown, very closely jointed DWYKA TILLITE
	1,30+	W4, soft rock, light olive stained dark brown, very closely jointed DWYKA TILLITE
		Final depth of IP 1,30 metres
8	0,00 - 0,10	Dry, greyish brown, loose fine sandy SILT
	0,10 - 0,60	Slightly moist, dark brown, very dense fissured clayey SILT with occasional tillite fragments and boulders - Colluvium
	0,60 - 1,50	Slightly moist, dark orange brown becoming orange brown, very stiff, microfissured silty CLAY containing abundant completely weathered tillite fragments - Residual
	1,50 - 2,10	Moist, light grey mottled dark yellow, stiff, fissured, slickensided silty CLAY - Residual
	2,10+	W4/3, medium hard rock, light olive, medium jointed DWYKA TILLITE
		Final depth of IP 2,10 metres
9	0,00 - 0,20	Dry, greyish brown, very loose, firm sandy SILT containing abundant tillite fragments and occasional boulders - Colluvium
	0,20 - 0,50	W5/4, very soft becoming soft rock, light yellowish olive stained dark brown, very closely jointed DWYKA TILLITE with colluvium in joints.
		Final depth of IP 0,50 metres

IP No	Depth	Description
10	0,00 - 0,25	Dry to slightly moist, brown, loose becoming medium dense, fine, sandy, slightly clayey SILT with occasional tillite fragments and boulders.
	0,25 - 0,30	PEBBLE MARKER comprising gravelly sand.
	0,30 - 1,20	Slightly moist, dark orange brown becoming light orange brown, dense, microfissured silty CLAY - Residual
	1,20 - 1,70	Slightly moist, dark yellow mottled light grey, very stiff microfissured sandy CLAY with light grey clay gouge in fissures - Residual
	1,70 - 2,00	W5/4, very soft rock light yellowish brown, very closely jointed DWYKA TILLITE with light grey clay gouge in joints and bedding planes
		Bottom of IP 2,0 metres
11	0,00 - 0,30	Dry, brown, medium dense, microfissured slightly clayey SILT containing abundant tillite fragments - Colluvium
	0,30 - 0,80	Slightly moist, dark yellow stained dark brown, dense, fissured, slightly clayey SAND - (W5/4) tillite
	0,80 - 1,20	W4, soft to medium hard rock, dark yellowish olive stained dark brown, very closely jointed DWYKA TILLITE
		Bottom of IP 1,20 metres
12	0,00 - 1,00	Dry to slightly moist, dark greyish brown, dense, microfissured clayey SILT with occasional tillite fragments - Colluvium
	1,00 - 1,80	Slightly moist, dark orange brown mottled red and grey, firm, microfissured silty CLAY - Residual
	1,80 - 2,20	Slightly moist, dark yellow, stiff, fissured clayey SAND - (W5/4) soft rock tillite
	2,20 - 2,40	W4, dark yellowish olive stained dark brown, very closely jointed DWYKA TILLITE
		Bottom of IP 2,40 metres

IP No	Depth	Description
13	0,00 - 0,20	Dry, slightly moist, brown, medium dense, firm sandy SILT and fine roots - Colluvium
	0,20 - 0,80	Slightly moist, dark brown mottled orange, stiff microfissured silty CLAY - Residual
	0,80 - 1,50	Slightly moist, light yellow mottled light grey, stiff microfissured slickensided gritty CLAY - Residual
	1,50 - 1,70	W5/4, soft becoming medium hard rock, dark yellow stained dark brown, very closely jointed DWYKA TILLITE with light grey clay gouge in joints and bedding planes
		Bottom of IP 1,50 metres
14	0,00 - 0,30	Fill (SAND)
	0,30 - 0,90	Slightly moist, dark brown, dense, fine, sandy, slightly clayey SILT - Colluvium
	0,90 - 1,20	Slightly moist to moist, grey, loose, fine grained slightly clayey SAND - Colluvium
	1,20 - 2,30	Slightly moist, dark orange brown mottled red, firm, microfissured silty CLAY - Residual
	2,30 - 2,50	Slightly moist, dark yellow stained dark brown, stiff, fissured clayey SAND (W5/4) Tillite
		Bottom of IP 2,50 metres
15	0,00 - 0,30	Dry to slightly moist, greyish brown, medium dense, fine, sandy, slightly clayey SILT and occasional tillite fragments - Colluvium
	0,30 - 0,90	Slightly moist, dark yellow stained dark brown and red, very dense, fissured, slightly clayey SAND with colluvium in fissures - (W5/4) Tillite
	0,90 - 1,10+	W5/4, soft rock, dark yellow stained dark brown and red, very closely jointed DWYKA TILLITE
		Bottom of IP 1,10 metres

IP No	Depth	Description
16		Approximately 30 cm Colluvial topsoil stripped off
	0,00 - 0,40	Dry to slightly moist, dark yellow, dense, fissured, slightly clayey SAND (W5/4) Tillite.
	0,40 - 0,60	W4, soft rock, dark yellow stained brown, very closely jointed DWYKA TILLITE
		Bottom of IP 0,60 metres

APPENDICES B AND C

SUBSOIL CLASSIFICATIONS

APPENDIX B

DESCRIPTIONS USED IN SOIL PROFILING

1. MOISTURE CONDITION

Term	Description
Dry	
Slightly Moist	Requires addition of water to reach optimum moisture content for compaction.
Moist	Near optimum moisture content.
Very Moist	Requires drying to attain optimum moisture content.
Wet	Fully saturated and generally below water table.

2. COLOUR

The predominant colours or colour combinations are described including secondary colouration described as banded, streaked, blotched, mottled, speckled or stained.

3. CONSISTENCY

Non-Cohesive Soils

Term	Description
Very Loose	Crumbles very easily when scraped with geological pick.
Loose	Small resistance to penetration by sharp end of geological pick
Medium Dense	Considerable resistance to penetration by sharp end of geological pick.
Dense	Very high resistance to penetration of sharp end of geological pick. Requires many blows of hand pick for excavation.
Very Dense	High resistance to repeated blows of geological pick. Requires power tools for excavation.

Cohesive Soils

Term	Description
Very Soft	Pick head can easily be pushed in to the shaft of handle. Easily moulded by fingers.
Soft	Easily penetrated by thumb. Sharp end of pick can be pushed in 30 - 40 mm. Moulded by fingers with some pressure.
Firm	Indented by thumb with effort. Sharp end of pick can be pushed in up to 10 mm. Can just be penetrated with an ordinary spade.
Stiff	Penetrated by thumb nail. Slight indentation produced by pushing pick point into soil. Cannot be moulded by fingers. Requires hand pick for excavation.
Very Stiff	Indented by thumb nail with difficulty. Slight indentation produced by blow of pick point. Requires power tools for excavation.

4. STRUCTURE

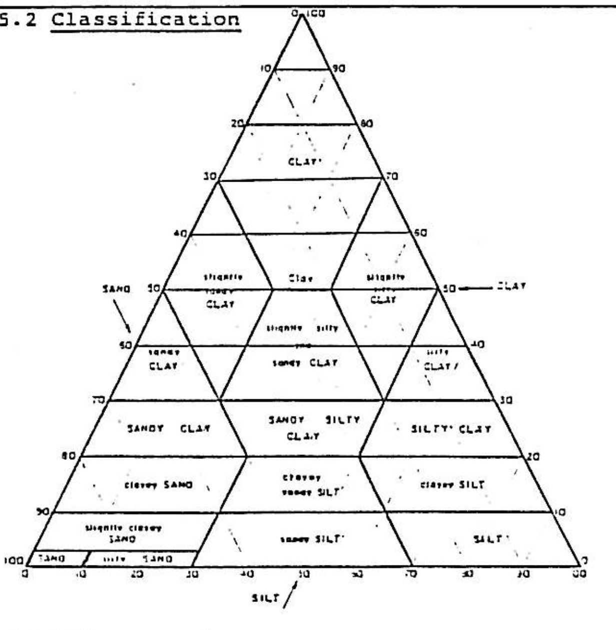
Term	Description
Intact	Absence of fissures or joints.
Fissured	Presence of closed joints.
Shattered	Presence of closely spaced air filled joints giving cubical fragments.
Micro-Shattered	Small scale shattering with shattered fragments the size of sand grains.
Slicken-sided	Polished planar surfaces representing shear movement in soil.
Bedded, Foliated	Many residual soils show structures of parent rock (See rock fabric description).

5. SOIL TYPE

5.1 Particle Size

Term	Size (mm)
Boulder	>200
Pebbles	60 - 200
Gravel	60 - 2
Sand	2 - 0,06
Silt	0,06 - 0,002
Clay	<0,002

5.2 Classification



SOIL CLASSIFICATION

6. ORIGIN

6.1. Transported Soils

Term	Agency of Transportation
Colluvium	Gravity deposits
Talus	Scree coarse Colluvium
Hillwash	Fine Colluvium
Alluvial	River deposits
Aeolian	Wind deposits
Littoral	Beach deposits
Estuarine	Tidal-River deposits
Lacustrine	Lake deposits

6.2 Residual Soils

These are products of in-situ weathering of rocks and are described as eg Residual Shale.

6.3 Pedocretes

Formed in transported and residual soils etc Calcrete and Ferricrete.

APPENDIX C

DESCRIPTIONS USED IN ROCK CORE LOGGING

1. WEATHERING

Term	Symbol	Diagnostic Features
Residual Soil	W6	Rock is discoloured and completely changed to a soil in which original rock fabric is completely destroyed. There is a large change in volume.
Completely Weathered	W5	Rock is discoloured and changed to a soil but original fabric is mainly preserved. There may be occasional small corestones.
Highly Weathered	W4	Rock is discoloured, discontinuities may be open and have discoloured surfaces, and the original fabric of the rock near to the discontinuities may be altered; alteration penetrates deeply inwards, but corestones are still present.
Moderately Weathered	W3	Rock is discoloured, discontinuities may be open and will have discoloured surfaces with alteration starting to penetrate inwards, intact rock is noticeably weaker than the fresh rock.
Slightly Weathered	W2	Rock may be slightly discoloured, particularly adjacent to discontinuities, which may be open and will have slightly discoloured surfaces; the intact rock is not noticeably weaker than the fresh rock.
Unweathered	W1	Parent rock showing no discolouration, loss of strength or any other weathering effects.

2. HARDNESS

Classification	Field Test	Compressive Strength Range MPa
Extremely soft rock	Easily peeled with a knife	<1
Very soft rock	Can be peeled with a knife. Material crumbles under firm blows with the sharp end of a geological pick.	1 to 3
Soft rock	Can be scraped with a knife, indentation of 2 to 4 mm with firm blows of the pick point.	3 to 10
Medium hard rock	Cannot be scraped or peeled with a knife. Hand held specimen breaks with firm blows of the pick.	10 to 25
Hard rock	Point load tests must be carried out in order to distinguish between these classifications.	25 to 70
Very hard rock	These results may be verified by uniaxial compressive strength tests on selected samples.	70 to 200
Extremely hard rock		>200

3. COLOUR

The predominent colours or colour combinations are described including secondary colouration described as banded, streaked, blotched, mottled, speckled or stained.

4. FABRIC

4.1 Grain Size

Term	Size (mm)
Very coarse	> 2,0
Coarse	0,6 - 2,0
Medium	0,2 - 0,6
Fine	0,06 - 0,2
Very fine	< 0,06

4.2 Discontinuity Spacing

Descriptions for : bedding, foliation, laminations	Spacing (mm)	Descriptions for : joints, faults, etc
Very thickly	> 1000	Very widely
Thickly	300 - 1000	Widely
Medium	100 - 300	Medium
Thinly	30 - 100	Closely
Very thinly	10 - 30	Very closely
Laminated	3 - 10	
Thinly laminated	< 3	

5. ROCK NAME

Classified in terms of origin :

IGNEOUS	Granite, Diorite, Gabbro, Syenite, Diabase Dolerite, Trachyte, Andesite, Basalt.
METAMORPHIC	Slate, Quartzite, Gneiss, Schist, Hornfels
SEDIMENTARY	Shale, Mudstone, Siltstone, Sandstone, Dolomite, Conglomerate, Tillite, Quartzite, Limestone

6. STRATIGRAPHIC HORIZON

Identification of rock type in terms of stratigraphic horizons from Formation, Sub-group to Supergroup.

A P P E N D I X   D

LABORATORY TEST RESULTS

LR

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GRADING AND ATTERBERG REPORT SHEET

NAME OF CLIENT: MOORE SPENCE JONES & PARTNERS PROJECT: RIDGEVIEW QUARRY REF. NO: 14502 DATE: 27.06.89

LAB NUMBER	B.H.	DEPTH m	% PASSING SIEVE SIZE (mm)												% SMALLER THAN (mm)									L.L.	P.I.	L.S.
			37,5	26,5	19,0	9,5	4,75	2,36	1,18	,600	,425	,300	,150	,075	,050	,040	,026	,015	,010	,0074	,0036	,0020	,0015			
890336	IP 1	0,6 - 1,6	97	93	88	84	81	78	76	74	74	72	67	60	43	39	35	31	30	27	22	19	18	30	11	5,5
890337	IP 2	0,2 - 1,4	100	99	98	97	96	95	94	92	92	90	85	70	52	46	42	41	38	35	32	28	25	50	22	10,5
890338	IP 8	1,5 - 2,1			100	99	98	97	96	94	94	93	88	80	62	56	52	50	46	43	40	35	32	54	27	13,0
890339	IP 10	0,3 - 1,7			100	95	91	86	83	80	79	77	71	63	43	37	32	31	28	26	24	21	19	33	14	7,0
890340	IP 14	0,3 - 0,9			100	99	98	98	97	93	91	87	71	54	37	29	25	23	20	16	14	12	9	22	7	3,0

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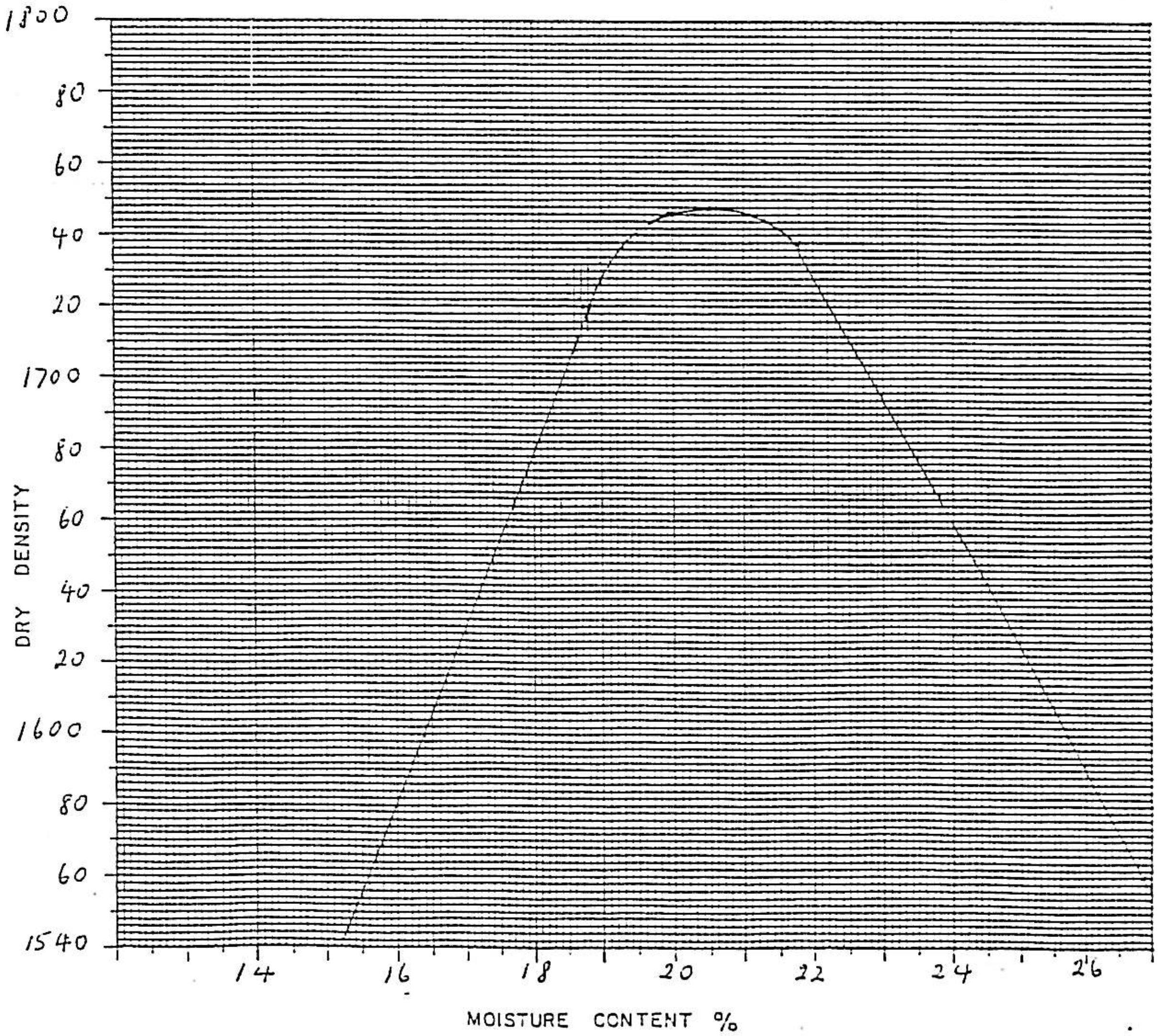
LABORATORY COMPACTION TEST REPORT

NAME OF CLIENT: MOORE SPENCE JONES & PARTNERS DATE: 23.06.89

PROJECT: RIDGEVIEW QUARRY REF. Nº: 14502

LABORATORY STANDARD USED: PROCTOR

Laboratory Nº	890336			
Position	I P 1 0,6 - 1,60 m			
Material Description	Brown weathered TILLITE			
Maximum Dry Density kg/m³	1748			
Optimum Moisture Content %	20,5			



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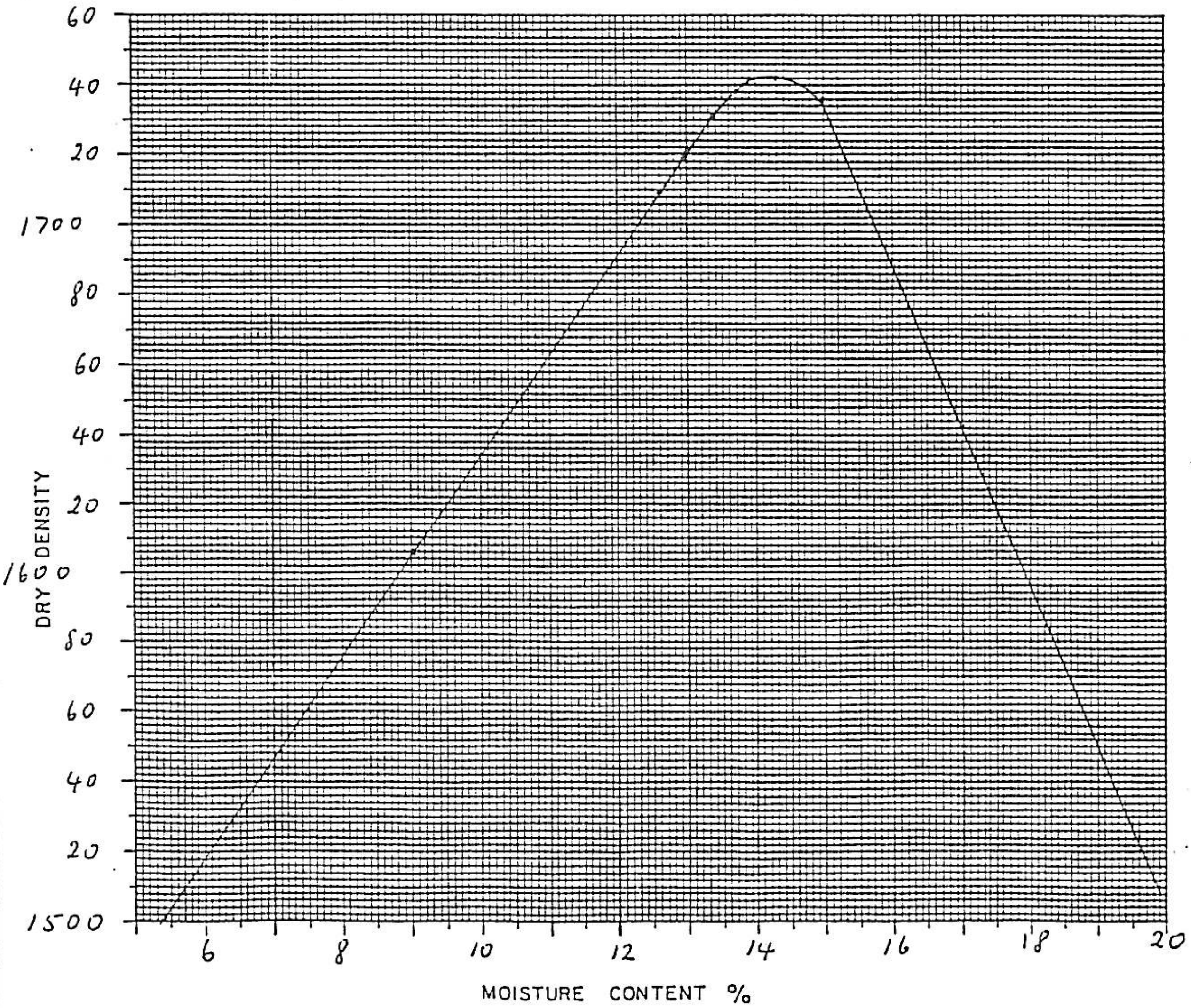
LABORATORY COMPACTION TEST REPORT

NAME OF CLIENT: MOORE SPENCE JONES & PARTNERS DATE: 23.06.89

PROJECT: RIDGEVIEW QUARRY REF. Nº: 14502

LABORATORY STANDARD USED: PROCTOR

Laboratory Nº	890337			
Position	I P 2 0,2 - 1,4 m			
Material Description	Yellow weath. TILLITE		-	
Maximum Dry Density kg/m³	1742			
Optimum Moisture Content %	14,3			



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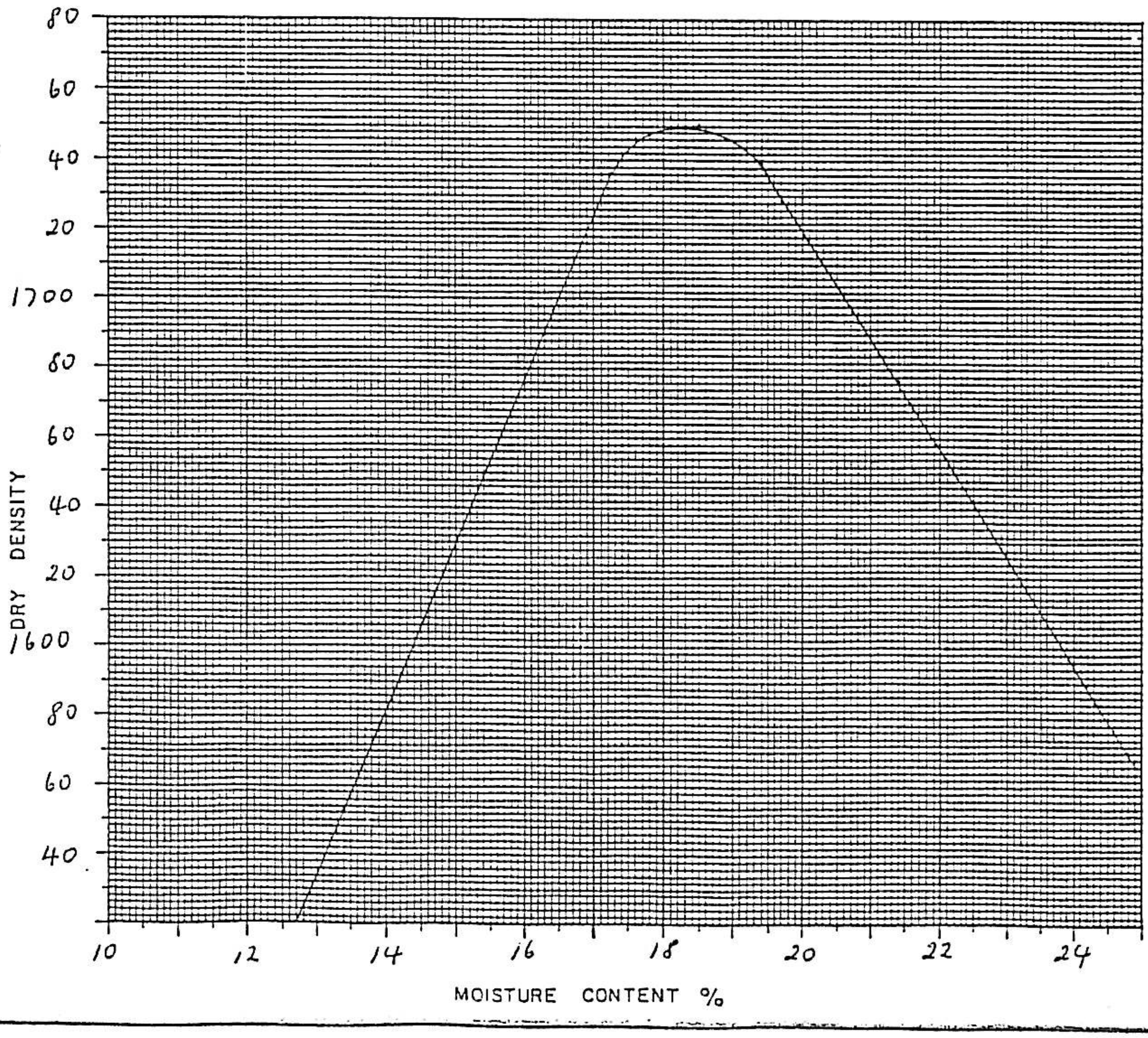
LABORATORY COMPACTION TEST REPORT

NAME OF CLIENT: MOORE SPENCE JONES & PARTNERS DATE: 23.06.89

PROJECT : RIDGEVIEW QUARRY REF. Nº: 14502

LABORATORY STANDARD USED : PROCTOR

Laboratory Nº	890338			
Position	I P 8 1,5 - 2,10 m			
Material Description	Yellow silty CLAY			
Maximum Dry Density kg/m^3	1750			
Optimum Moisture Content %	18,5			



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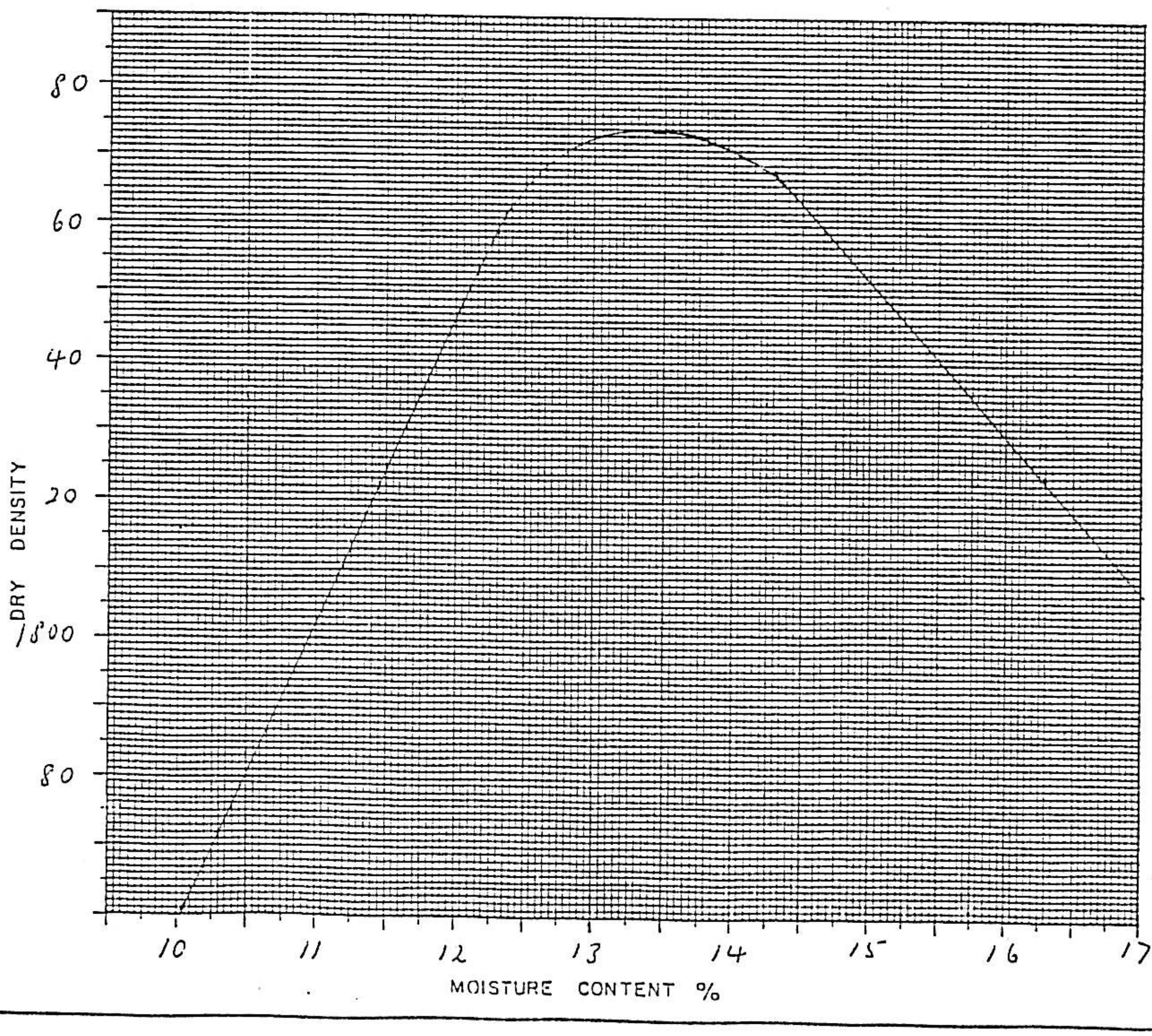
LABORATORY COMPACTION TEST REPORT

NAME OF CLIENT: MOORE SPENCE JONES & PARTNERS DATE: 23.06.89

PROJECT: RIDGEVIEW QUARRY REF. Nº: 14502

LABORATORY STANDARD USED: PROCTOR

Laboratory Nº	890339			
Position	I P 10 0,3 - 1,70 m			
Material Description	Yellow weathered TILLITE			
Maximum Dry Density kg/m³	1874			
Optimum Moisture Content %	13,5			



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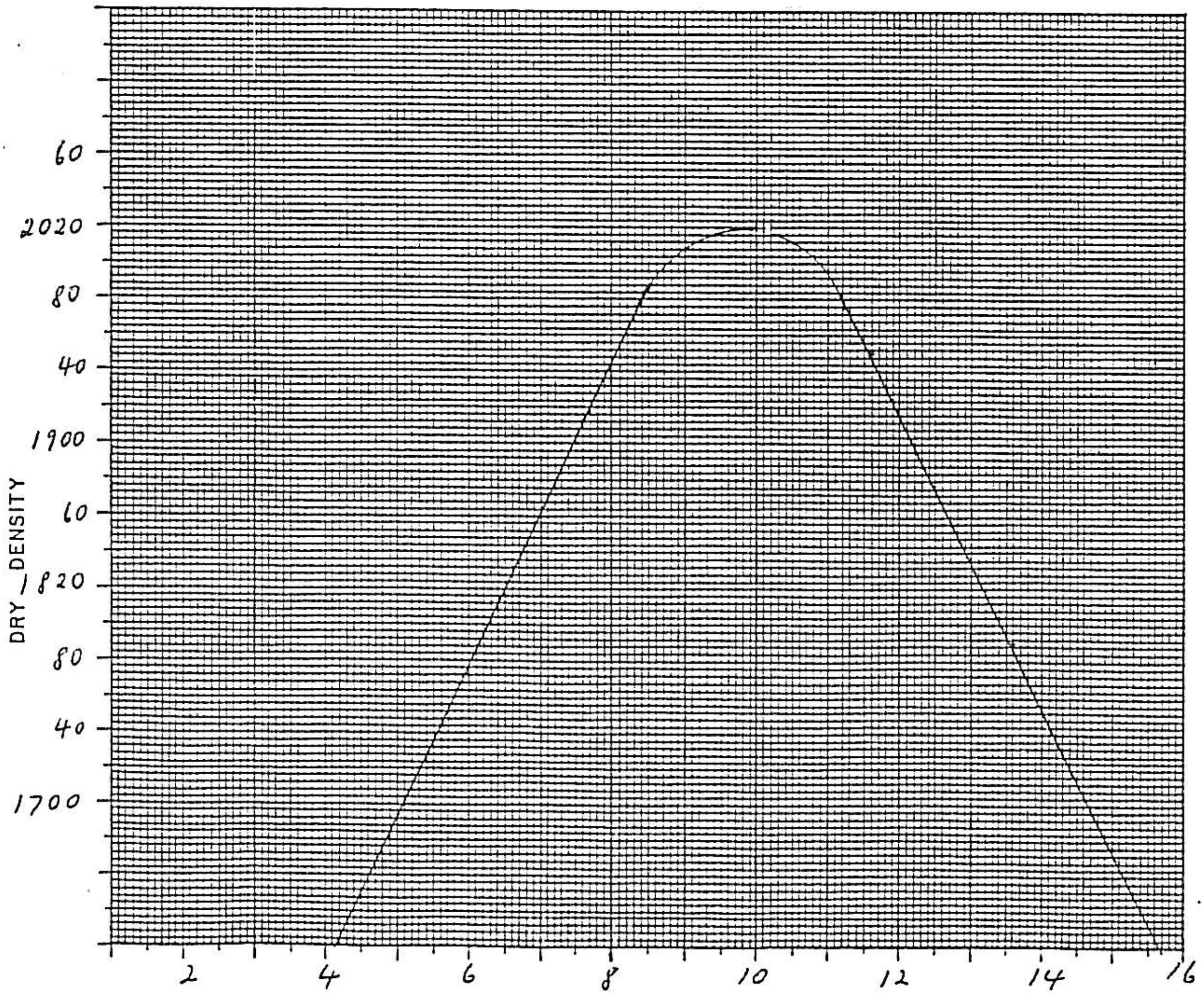
LABORATORY COMPACTION TEST REPORT

NAME OF CLIENT: MOORE SPENCE JONES & PARTNERS DATE: 23.06.89

PROJECT: RIDGEVIEW QUARRY REF. Nº: 14502

LABORATORY STANDARD USED: PROCTOR

Laboratory Nº	890340			
Position	I P 14 0,3 – 0,9 m			
Material Description	Brown grey clayey SILT			
Maximum Dry Density kg/m³	2021			
Optimum Moisture Content %	10,0			



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Results of Triaxial Cell Permeability Test

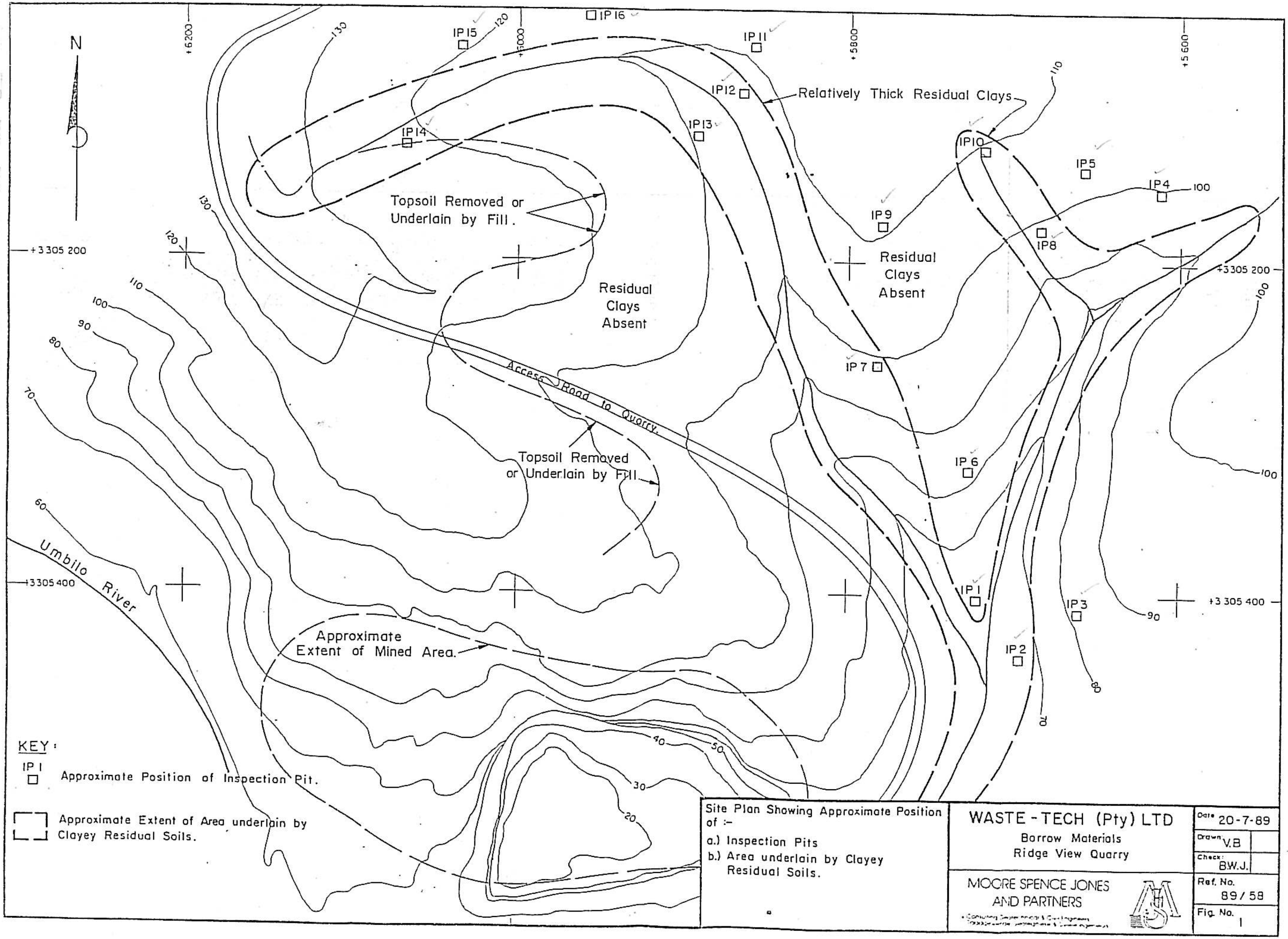
WEBB & PARTNERS
Consulting Civil Engineers
DURBAN

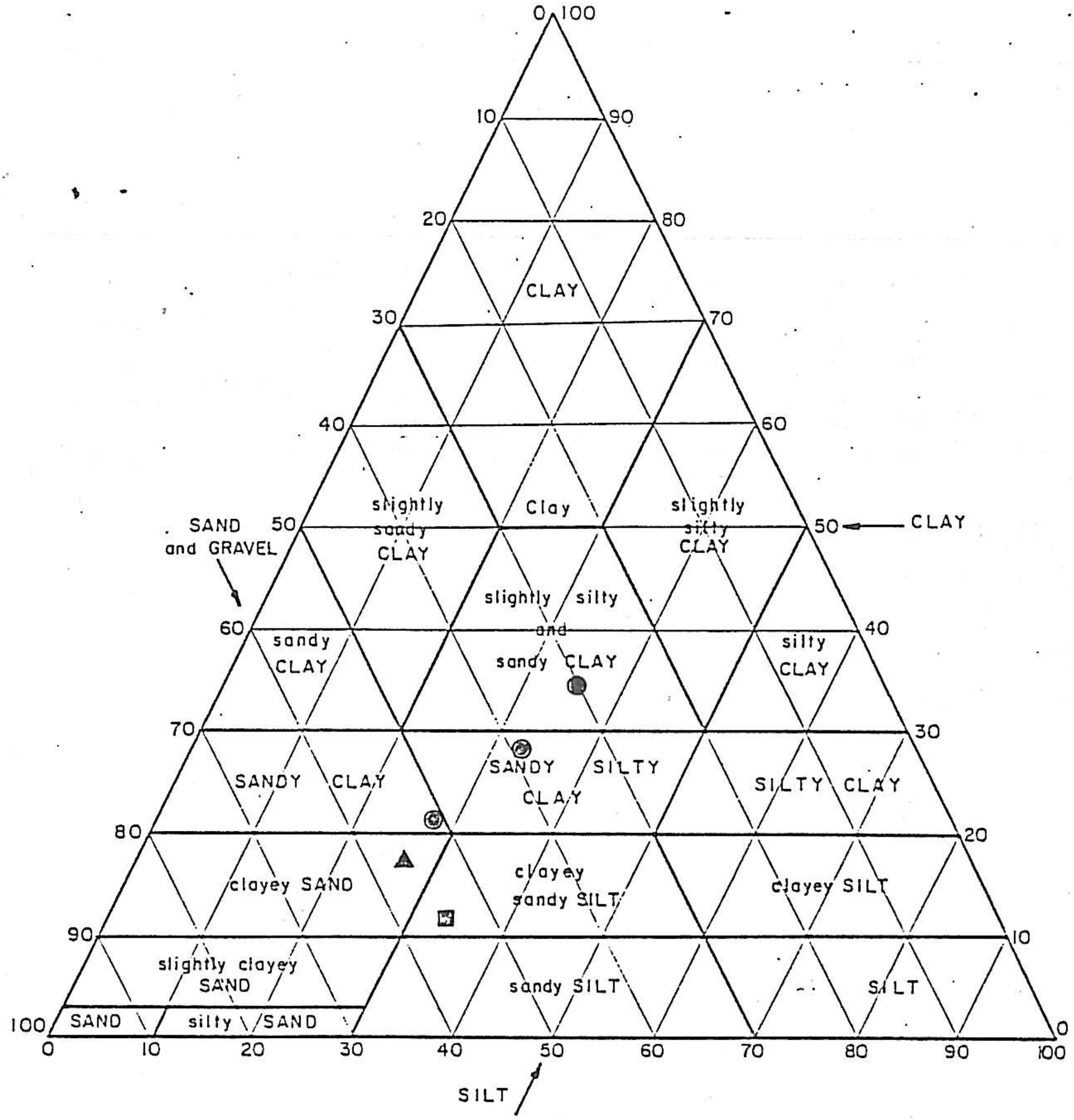
REF: 14502

CLIENT : MOORE SPENCE JONES & PTNRS. PROJECT : RIDGEVIEW QUARRIES

DATE : 24.07.89

Position	Depth (m)	Description	Cell Pressure k Pa	Base Pressure k Pa	Top Pressure k Pa	Dry Density kg/m3	Moisture Content %	k cm/sec
I.P 1	0,6-1,6	Compacted to 90%	500	425	375	1569	20,8	$1,59x10^{-7}$
"	"	Compacted to 93%	500	425	375	1619	21,0	$5,20x10^{-8}$
I.P. 2	0,2-1,4	Compacted to 90%	500	425	375	1569	14,1	$8,52x10^{-8}$
"	"	Compacted to 93%	500	425	375	1624	13,9	$2,63x10^{-8}$
I.P. 8	1,5-2,1	Compacted to 90%	500	425	375	1575	18,5	$2,99x10^{-9}$
"	"	Compacted to 93%	500	425	375	1635	18.6	$2,23x10^{-9}$


N
+6200
+6000
+5800
+5600
+3 305 200
+3305 400
IP 1
IP 2
IP 3
IP 4
IP 5
IP 6
IP 7
IP 8
IP 9
IP 10
IP 11
IP 12
IP 13
IP 14
IP 15
IP 16
Relatively Thick Residual Clays
Topsoil Removed or Underlain by Fill.
Topsoil Removed or Underlain by Fill.
Residual Clays Absent
Residual Clays Absent
Access Road to Quarry.
Approximate Extent of Mined Area.
Umbilo River
130
120
110
100
90
80
70
60
50
40
30
20
KEY:
Approximate Position of Inspection Pit.
Approximate Extent of Area underlain by Clayey Residual Soils.
Site Plan Showing Approximate Position of :-
a.) Inspection Pits
b.) Area underlain by Clayey Residual Soils.
WASTE - TECH (Pty) LTD
Borrow Materials
Ridge View Quarry
MOORE SPENCE JONES AND PARTNERS
Date 20-7-89
Drawn V.B
Check: BW.J.
Ref. No. 89/58
Fig. No. 1



SOIL CLASSIFICATION

KEY:

● Residual Soils.

⊡ Colluvial Soils.

▲ Completely to Highly Weathered (W5/4) Tillite.

NOTE:

Based on the Polish Standard Pn-54 B-02480 (1954) (After Wilum and Stargewski 1972).

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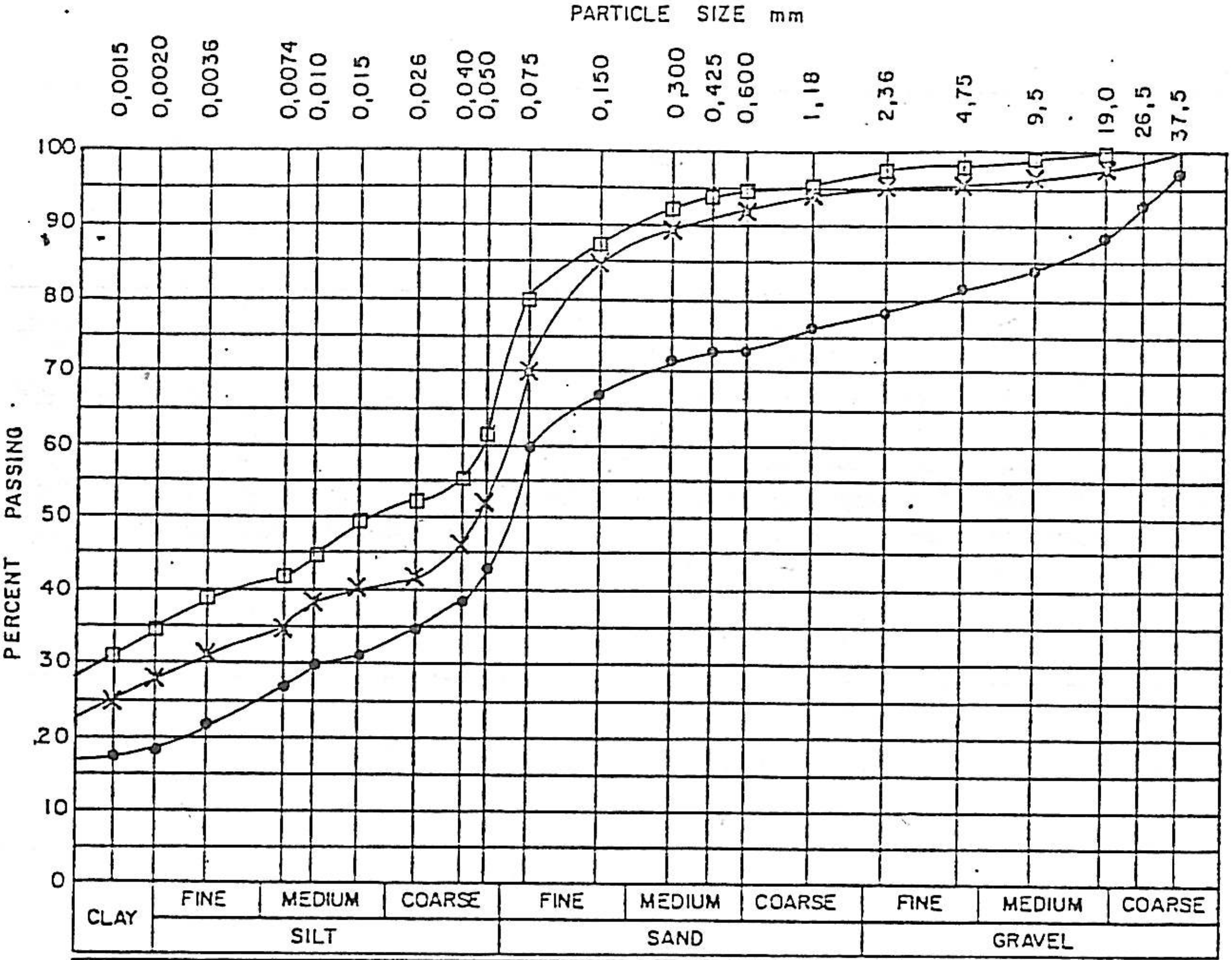
Date:	20-7-89
Drawn:	V.B.
Check:	B.W.J
Ref. No.	89/58
Fig. No.	2

PARTICLE SIZE DISTRIBUTIONS



SYMBOL	LABORATORY SOIL DESCRIPTIONS
o	Dark yellow brown, fissured, clayey SAND (W5 Tillite).
X	Dark red, firm to stiff, SANDY SILTY CLAY (Residual).
□	Light grey mottled yellow, stiff, slightly slity and sandy CLAY (Residual).

HOLE N°	IP 1	IP 2	IP 8		
DEPTH	0,6 - 1,6	0,2 - 1,4	1,5 – 2,1		
SYMBOL	—o—	—X—	—□—		
LIQUID LIMIT	30	50	54		
PLASTICITY INDEX	11	22	27		
LINEAR SHRINKAGE	5,5	10,5	3,0		
% CLAY	18 %	28%	35 %		
% SILT	27%	32%	35%		
% SAND	33%	35%	28%		
% GRAVEL	22%	5%	3%		

WASTE - TECH (Pty) LTD Borrow Materials Ridge View Quarry	Date: 20-7-89	
	Drawn: V.B.	
	Check: B.W.J.	
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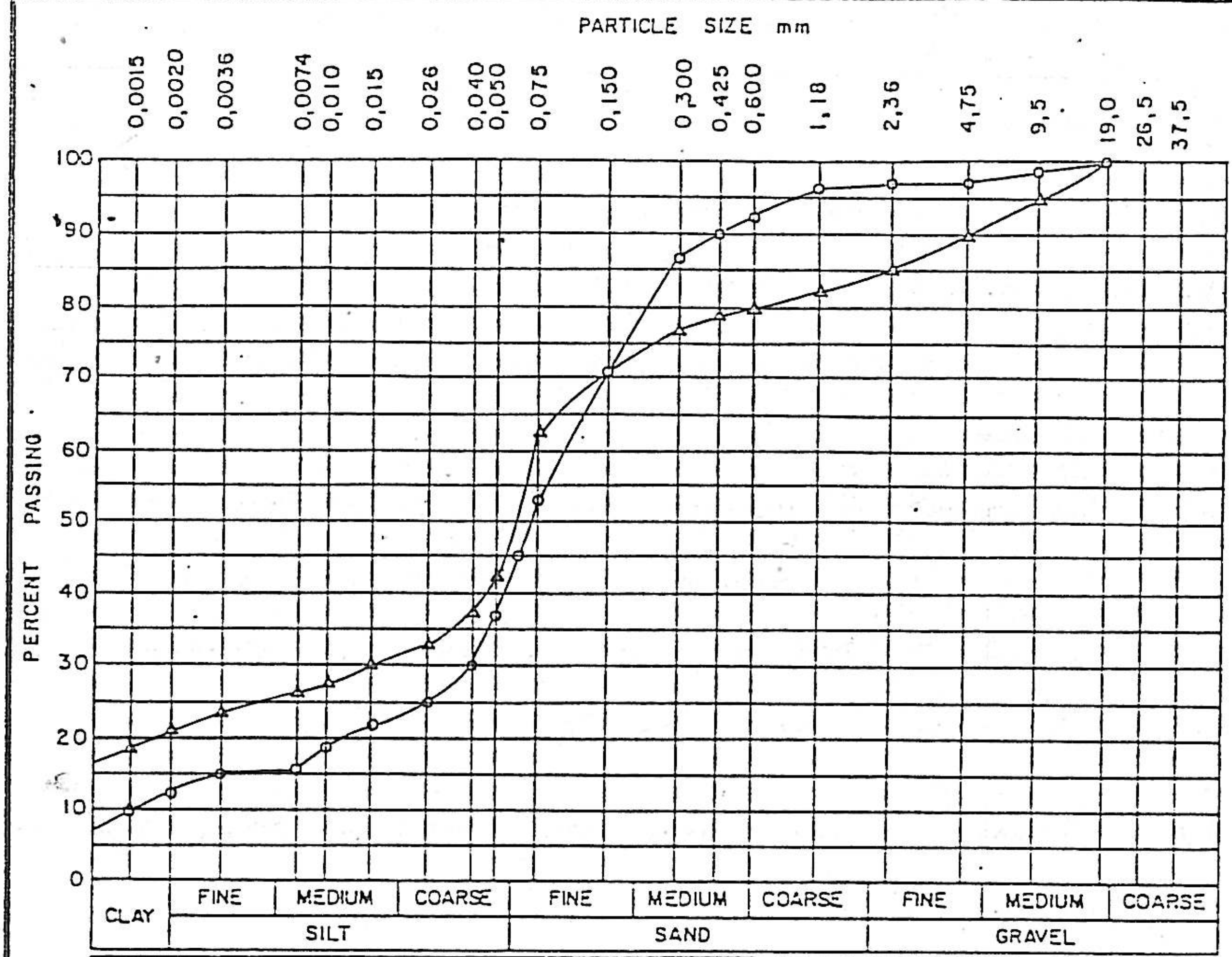
	Fig. No. 3	

PARTICLE SIZE DISTRIBUTIONS



SYMBOL	LABORATORY SOIL DESCRIPTIONS
—△—	Yellow mottled light grey, stiff, SANDY CLAY (Residual)
—○—	Dark brown, dense, clayey sandy SILT (Colluvial)

HOLE N°	IP 10	IP 14			
DEPTH	0,3 - 1,7	0,3 - 0,9			
SYMBOL	—△—	—○—			
LIQUID LIMIT	33	22			
PLASTICITY INDEX	14	7			
LINEAR SHRINKAGE	7,0	3,0			
% CLAY	21%	12%			
% SILT	29%	33%			
% SAND	35%	52%			
% GRAVEL	15%	3%			

WASTE - TECH (Pty) LTD Borrow Materials Ridge View Quarry	Date: 20-7-89 Drawn: V.B. Check: B.W.J.	
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