

https://dspace.org/

Erosion of the slopes of gold-residue dams on the Transvaal highveld

Douglas, Ian Dorren

2015-01-19
http://hdl.handle.net/10539/16584

Downloaded from a DSpace repository. https://dspace.org/

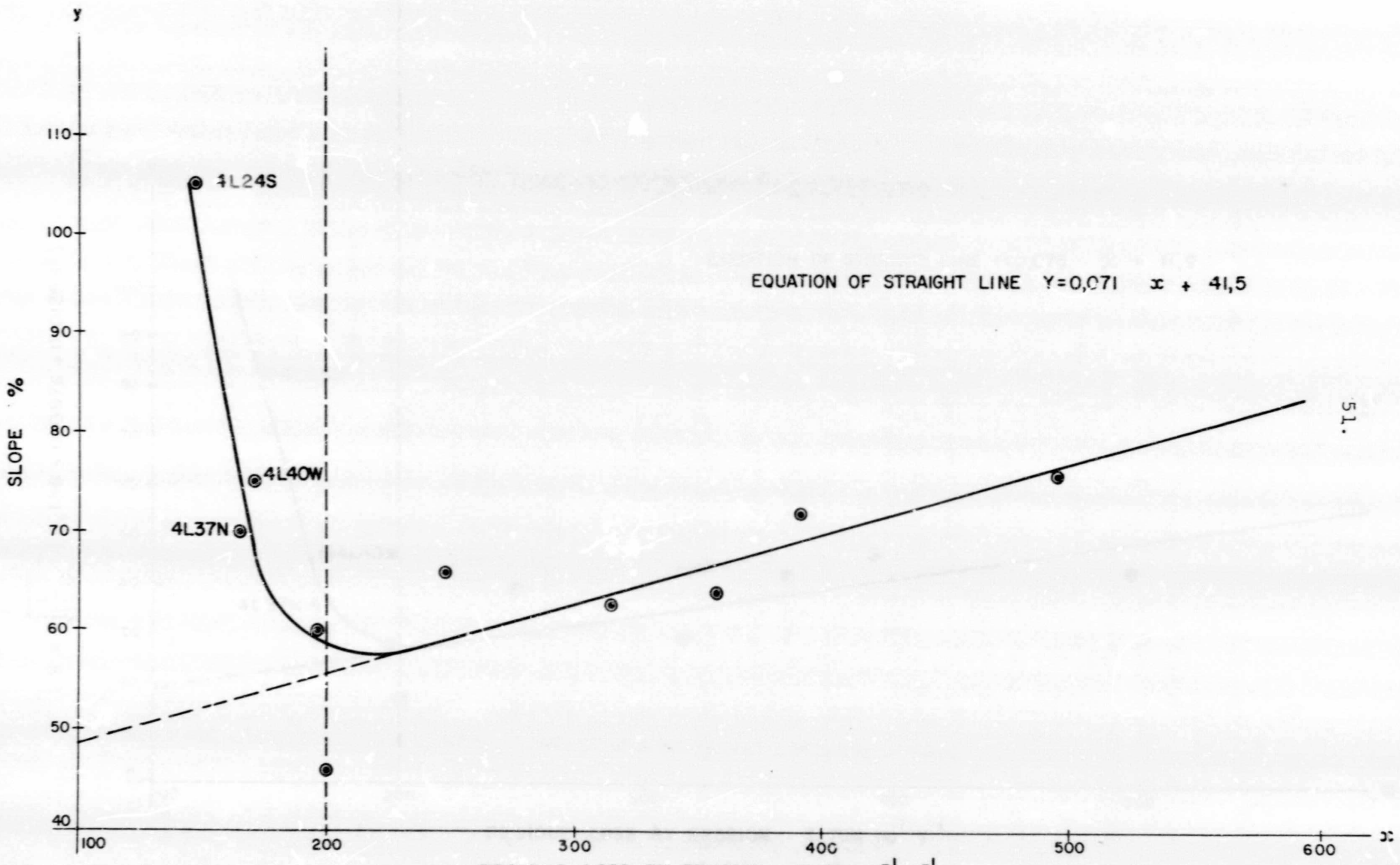
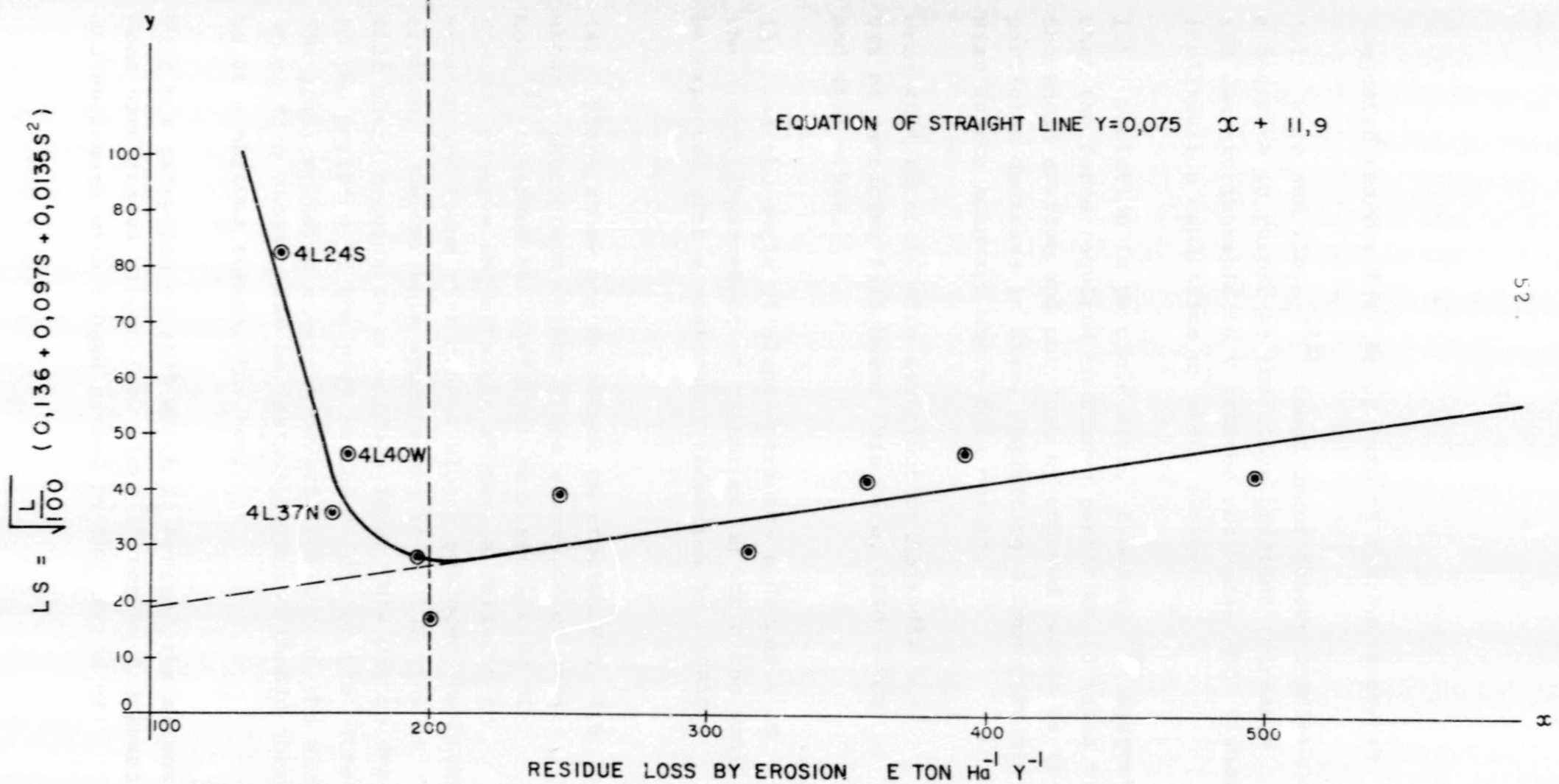


FIG. 4.4 CORRELATION BETWEEN SLOPE ANGLE AND RESIDUE LOSS BY EROSION 'S' GRAPH

EQUATION OF STRAIGHT LINE Y=0,075 x + 11,9



CORRELATION BETWEEN L S FACTOR AND RESIDUE LOSS BY EROSION

FIG. 4.5

Suggested reasons for the up turn of the curve are :-

(1) Yair and Klein [12] found under desert conditions a decrease in runoff as the slope gradient increased and was attributable to a greater roughness and higher infiltration capacities on steep slopes.

(2) Variation in particle size. Raudkivi[13] suggests that the force required to remove particles is taken by the whole surface and not just by exposed grains as the particles decrease in size, suggesting 0,08mm particle size as the boundary where this occurs.

From 4L24 particle size distribution (Appendix A.6) 94% of particles fall below this size, 4L40 - 90% and 4L37 - 91%.

(3) As the angle of slope increases a decrease in the direct impingement of raindrops on the slope would be expected with a consequent reduction in erosion.

(4) Slope shape has an effect on erosion. Fig. 4.6 shows a photograph of the slope curvature of 4L24. Holy[2] observed the different characteristics of convex, concave and straight slopes in relation to erosion and found that convex slopes produced the highest erosion. However this appears not to be the case in 4L24 where erosion is relatively low. This may be due to the position of the pegs in the middle of the slope. The gradient being steepest towards the toe of the slope where flow should also be fastest, erosion should therefore be at a maximum towards the toe.

With the exception of 3L39 which is benched, the slimes dams have graded slopes i.e. slope steepness increases and decreases with length caused by the method of

deposition. This gives rise to variations in erosion intensity throughout the slope length.

(5) The aspect of the slope does not appear to be a factor influencing the residue loss as 3 north facing slopes vary between 165 T/ha/y to 360 T/ha/y, 3 south facing slopes vary from 150 T/ha/y to 500 T/ha/y, 3 east facing slopes vary from 200 T/ha/y to 400 T/ha/y and 1 west facing slope at 170 T/ha/y.

(6) 4L[illegible]h and 4L40 west have shear strength of 288 kPa [illegible] Pa respectively with slope length of 25m and [illegible] shows that it may be the different surface shear strengths that leads to the double valued correlation in Fig. 4.4.



Fig. 4.6 Convex Slope Shape - 4L24

The combination of slope angle and length (Fig. 4.8) using the equation from the U S L E may be used for angles up to 35 degrees and varying slope lengths above which angle other factors may have to be taken into account. Further research is needed on slopes with angles greater than 35 degrees as there appears to be a transition in erosional behaviou between 35 and 37 degree slopes.

4.3.3 SHEAR STRENGTH OF SLIMES DAMS SURFACE

The average shear strength was plotted against erosion and a linear regression analysis carried out excluding 4L36 E (Fig. 4.7). The general trend of the points indicates that, as the shear strength of the residue reduces the erodability increases, hence the best straight line tends to have a negative gradient.

There was one outlier in 4L36 E which showed a very low shear strength which is again substantiated by the peak E T C O M readings of between 50 - 74 kPa in summer and and 25 - 49 kPa in winter. A low reading of erosion is also observed. This may be due to :

(1) Positioning of the plot slightly uphill from the centre of the slope.

(2) Positioning of pegs at 3,0m centres may give rise to the probability of all pegs missing a rill or gulley.

4.3.4 PREDICTION OF EROSION FROM 'L', 'S', 'P', GRAPHS

Erosion rates were predicted u ing the regression lines on all three graphs the erosion rates were then summed and averaged. This average was then compared to the actual rate and a percentage difference calculated (Table 4.5)

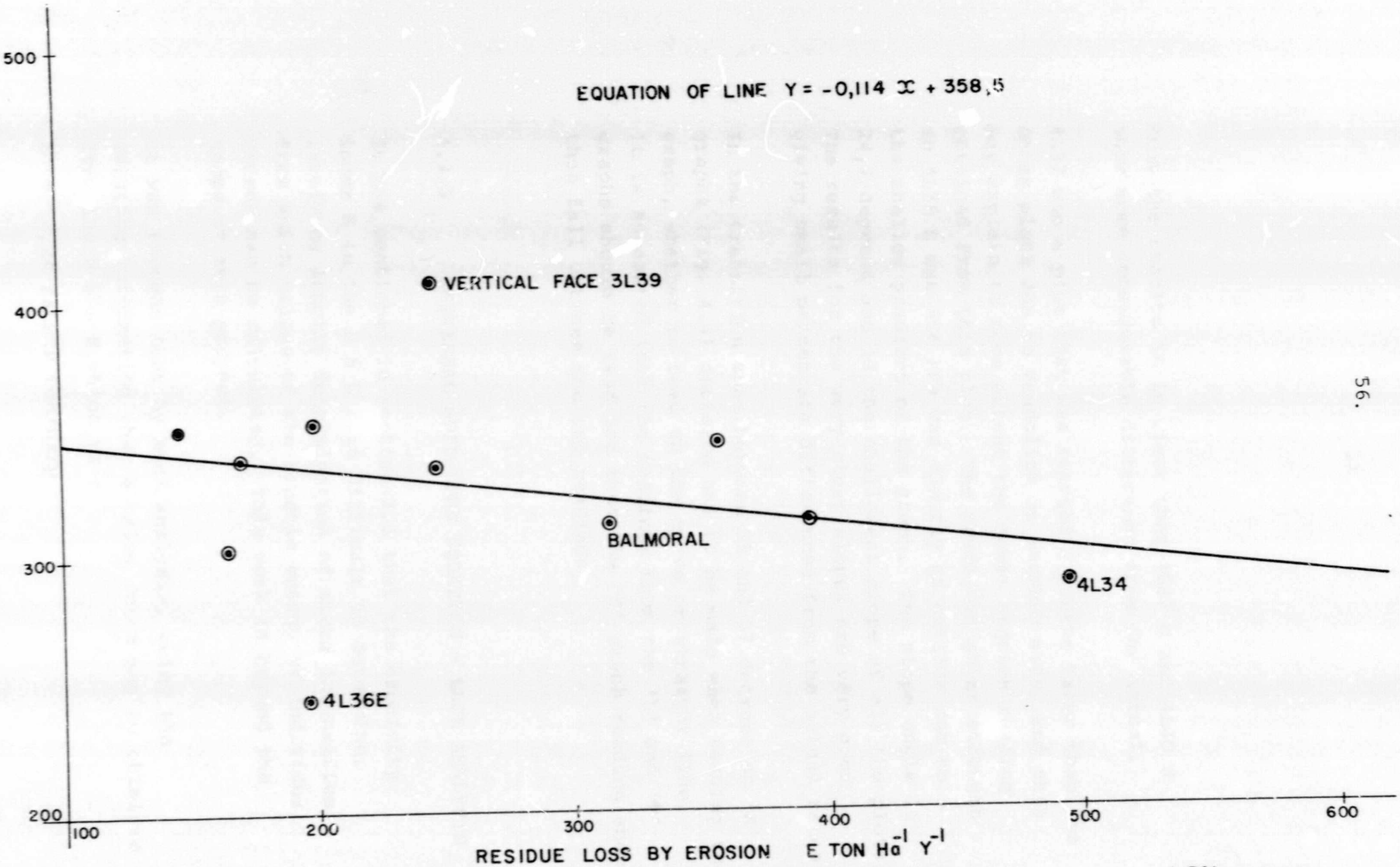


FIG. 4.7 CORRELATION BETWEEN SURFACE SHEAR STRENGTH AND RESIDUE LOSS BY EROSION

'τ' GRAPH

From the results it is clear that 4L37 N and 4L40 S show some considerable difference from the actual.

4L37 was a plot that was started 2 months later than the other plots due to vandalism at another site, and this may explain to some extent the lower erosion reading obtained from this plot. The predicted shear strength in 4L36 E was 996 kPa was clearly an outlier due to the shallow gradient of the graph. The slope angle is 24,7 degrees and is the shallowest slope of all the plots. The results for the very steep slopes are very good giving small percentage differences from the actual rates.

In the transition zone between 35 and 37 degrees on 'S' graphs (Fig. 4.4) decision has to be made when reading the graph, whether to read on the curve or straight line. It is suggested that the readings from the 'L' and '↑' graphs should be read and that the 'S' graph reading should then fall between the two readings.

4.3.5 UNIVERSAL SOIL LOSS EQUATION - BACK ANALYSIS

It was mentioned in section 2.3 that the erosivity index R in the U S L E is difficult to determine, involving lengthy determination of storm intensities from which values of the kinetic energy of individual storms can be calculated. This work is beyond the scope of this project.

It was thought that by back analysis, using the existing information that a value for R may be obtained from the U S L E which is :

E = 2,24 RKLSCP ton/ha/y

	3L39 E	4L34 S	Balmoral N	4L37 N	4L37 E	4L36 N	4L36 E	4L24 S	4L40 S	4L40 W
'L'graph	263	164	142	131	345	424	170	167	167	217
E T/Ha'S'graph	344	480	302	170	430	316	260	144	63	166
'T'graph	184	615	393	480	393	100	996*	66	48	171
Average E	264	420	279	260	389	280	215	126	93	185
Actual E	248	496	316	165	393	358	196	147	200	171
% Difference	+6	-15	-12	+58	-1,0	-22	+10	-14	-53	+8

Table 4.5 COMPARISON OF PREDICTIONS FROM LENGTH, SLOPE, ANGLE AND SHEAR STRENGTH GRAPHS WITH ACTUAL EROSION

C and P are eliminated because they do not apply, L and S are measurable items and K is obtained from extrapolation of the nomograph Fig. 4.8 The unit for the U S L E are in tons/ha/y and the number 2,24 is a straight conversion from imperial to S.I. units, Mitchell and Bubenzer[14] stated that the factor R does not change in conversion from imperial to SI units otherwise the U S L E and K factor would be dimensionally incorrect. Therefore the nomograph for K is still valid for the SI conversion to tons per hectare.

The back analysis shown in Table 4.6 gives an average value for R of 4,3. This value was then used to work out the predicted erosion, and a comparison with the actual erosion rate made.

The results shows a large percentage difference in 4L37 N which confirms that the actual erosion due to late starting is probably low. 4L24 S and 4L40 W also show a large difference from actual rates and this is put down to the steep angle of 46 and 37 degrees respectively having a dominant effect in the equation for 'LS'.

The equation 'LS' tends neither to generally underestimate or overestimate residue loss, except when angles are over 37 degrees as in the case of 4L24 and 4L40 where the the tendency is to overestimate. The differences though are relatively large but do give an indication of consistency between the angles of 25 to 35 degrees.

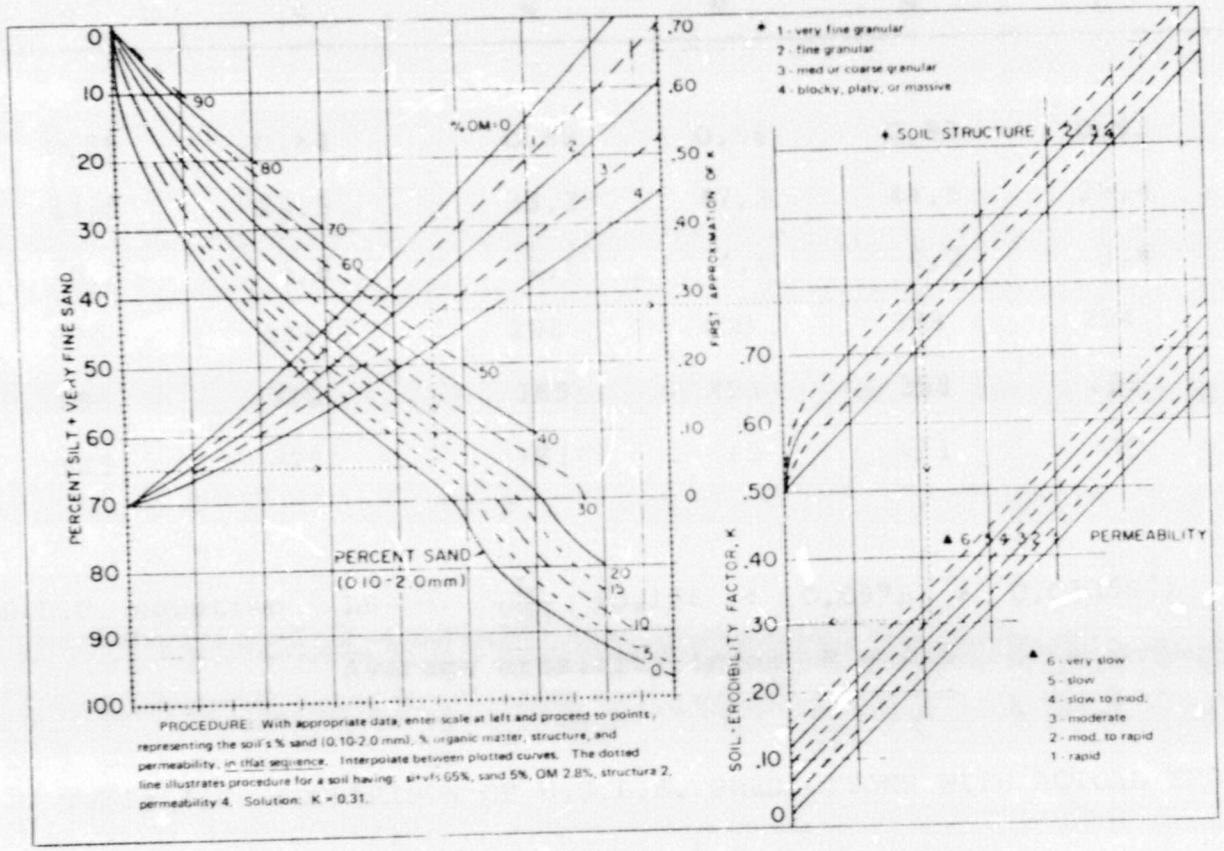


Fig. 4.8 ERODIBILITY NOMOGRAPH FOR FACTOR K OF THE USLE

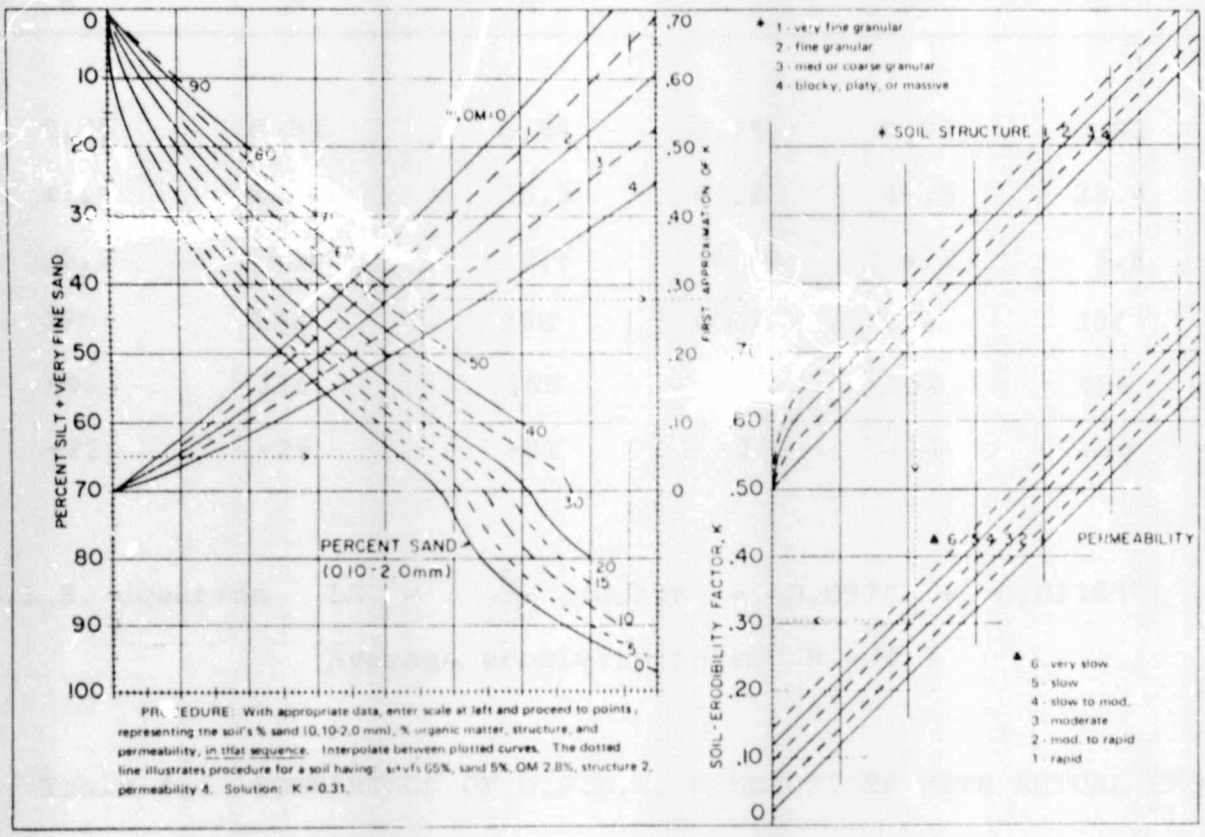


Fig. 4.8 ERODIBILITY NOMOGRAPH FOR FACTOR K OF THE USLE

	3L39 E	4L34 S	Balmoral N	4L37 N	4L37 E	4L36 N	4L36 E	4L24 S	4L40 S	4L40 W
K	0,55	0,88	0,84	0,88	0,88	0,93	0,93	0,88	0,9	0,9
+LS	39,3	43,6	29,5	35,2	47,2	44,5	28,4	82,4	17,1	46,9
R=E/2,24 KLS	6,0	6,3	6,6	2,6	4,4	4,2	3,6	1,0	6,3	2,0
E=2,24 RKLS	208	370	238	298	400	398	254	698	148	406
Actual E	248	496	316	165	393	358	196	147	200	171
% Difference	-16	-25	-25	+81	+2	+11	+30	+374	-26	+137

+LS calculated from U.S.L.E. equation $LS = \frac{L}{100}(0,136 + 0,097S + 0,0135S^2)$

Average erosivity index R = 4,3

Table 4.6 COMPARISON OF U.S.L.E. PREDICTIONS WITH ACTUAL EROSION

5.0 SUMMARY AND CONCLUSIONS

5.1 INTRODUCTION

The method of control of erosion is under investigation by other research parties and it is not the intention to detract from their work by mentioning brief details of prevention of erosion in this project report. The conclusions and recommendations therefore will be on

(1) Validation of E T C O M in predicting erosion.
(2) Prediction by U S L E.
(3) Prediction by 'L' 'S' 'T' graphs.
(4) Further research and refinements.

5.2 VALIDATION OF E T C O M IN THE PREDICTION OF EROSION

Although there is found to be a great consistency in winter readings of E T C O M of between 50 and 100 kPa, no direct correlation could be found based on statistical and regression analyses of the readings. Summer readings tend to be to widely scattered, as the graphs show, with no definite peaks. On average, E T C O M readings tend to be higher in summer than in winter. The graphs of E T C O M readings versus erosion show a positive correlation but with linearity being positive, (i.e. increasing rate of erosion with increasing E T C O M readings,) appears to be a contradiction.

There are several reasons why no correlation with residue loss has been found. The nature of surface flow on the slimes dams tends to orientate particles, which E T C O M fails to simulate in giving random orientation of the particles.

It is the surface shear strength of the slimes which has to be overcome by the velocity of flow over the surface dislodging particles which are then transported in an ever increasing volume down slope. The velocity combined with the turbulence of flow gives rise to erosion. More parameters must be taken into account before a prediction of erosion can be made. These are :-

(1) Grain size
(2) Dry density
(3) Slope length
(4) Slope angle
(5) Shear strength of top 5mm of surface
(6) Permeability to a lesser extent.

Hjulstrom[5] determined the mode which would operate if one knows the velocity of flow and particle size.

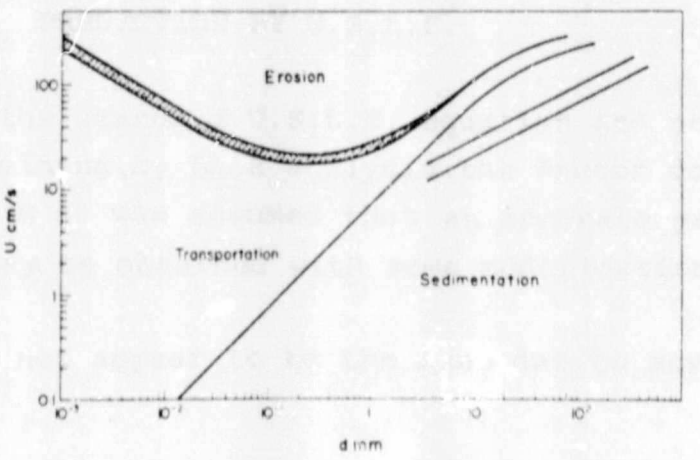


Fig. 5.1 Critical water velocities for erosion transport and deposition as a function or particle size.

From this graph it can be predicted for slimes dams which has a major percentage of particles in the size range O,Olmm to O,lmm, gives a velocity of approximately 22 cm/s.

The procedure of using E T C O M on dry surfaces comes into doubt as the effects of partial saturation,

particularly in winter, would give readings higher than one might expect. Surface runoff only occurs after the infiltration capacity of the slimes and therefore maximum moisture storage has been reached.

The practice of taking a reading at the return of the 'et is also open to question as erosion has already started at lower pressures therefore giving a rate of erosion which is time dependent. A correlation may possibly be obtained if the pressure head could be in the range 100 to 110 kPa based on the data collected in this project.

The E.T.C.O.M. observations helped, when using the 'L' 'S' 'T' graphs, to identify and explain some of the anomalies that occurred, but the overall conclusion is that it does not give a direct prediction of erosion.

5.3 PREDICTION BY U.S.L.E.

By using the standard U.S.L.E. equation and nomographs and determining, by back analysis, the factor for erosivity R it was assumed that an accurate prediction for erosion may be obtained with some modifications.

This does not appear to be the case due to several factors :

(1) The LS equation does not adequately take into account steep slopes.

(2) Averaging the erosivity index R gives a standard deviation of 2,0 which gives a wide scatter of results.

(3) The equation is based on separate factors that are not commonly linked, therefore a back analysis may

not give a true reflection of the erosivity index.

Further research is needed to develop an erosivity index for the Transvaal as well as an investigation into a modified LS equation for steep slopes before an equation similar to the U S L E can be obtained.

5.4 PREDICTION BY 'L' 'S' 'Ƭ' GRAPHS

This method of prediction is the most accurate. By determination of average slope length, angle and shear strength parameters one can predict the rate of erosion to within an average of approximately 19% when 4L37 N is discounted due to the plot starting at a later date. This method also takes into account steep slopes and determines a transition zone between 35 and 37 degrees.

To determine a value for capacity in the design of toe paddock dams it is suggested that the residue loss is obtained from the 'L' and 'Ƭ' graphs and the larger value used for design purposes.

The limitations for the graphs are that they should be only used on slopes of 25 degrees or more. Below 25^{o} there is a tendency to underestimate erosion. The graphs must also only be used on slimes dam slopes and not mine sand slopes. Grading analysis should show that the major percentage of particles are in the sandy silt range of 0,01 to 0,2 mm particles size.

This work is relevant within the Transvaal region only where low winter rainfalls and high intensity summer rain storms occur.

6.5 FURTHER RESEARCH

Further research is possibly needed in expanding the topic on slopes of angles steeper than 35 degrees, as well as more measurements in the shape of slope with length particularly with regard to concave or convex slopes.

Wind erosion is a topic of research on its own and has only briefly been touched upon in this report. Undoubtedly wind has an effect on erosion rates especially in winter and this may be one of the reasons for little difference in the rates or erosion between winter and summer.

More research may be warranted on the effect of permeability and infiltration capacities of the slimes dams. It is well known that the slimes dams exhibits anisotropic behaviour due to the method of deposition. over the years, but it is not known how this affects the rate of erosion.

The assumption made in this report was that erosion was caused by four factors in decreasing order of affect on rates of erosion :-

(1) Surface flow
(2) Rainsplash
(3) Wind erosion
(4) Subsurface flow or infiltration

The topic could be expanded to take into account the effects of erosion on steep road embankments where slopes vary from 25 to 45 degrees. The use of the 'TORVANE' shear vane on embankment erosion could be developed as a rapid means to prediction in this area.

APPENDICES

APPENDIX		PAGE
A.1	3L39 Particle Size Distribution	70
A.2	Balmoral Particle Size Distribution	71
A.3	4L34 Particle Size Distribution	72
A.4	4L37 Particle Size Distribution	73
A.5	4L36 Particle Size Distribution	74
A.6	4L24 Particle Size Distribution	75
A.7	4L40 Particle Size Distribution	76
B.1	3L39 Mayer and Charleton ETCOM readings	78
B.2	4L34 ETCOM readings	79
B.3	Balmoral ETCOM readings	80
B.4	4L37 North ETCOM readings	81
B.5	4L37 East ETCOM readings	82
B.6	4L36 North ETCOM readings	83

Author Dorren Douglas Ian
Name of thesis Erosion Of The Slopes Of Gold-residue Dams On The Transvaal Highveld. 1986

PUBLISHER:
University of the Witwatersrand, Johannesburg
©2013

LEGAL NOTICES:

Copyright Notice: All materials on the University of the Witwatersrand, Johannesburg Library website are protected by South African copyright law and may not be distributed, transmitted, displayed, or otherwise published in any format, without the prior written permission of the copyright owner.

Disclaimer and Terms of Use: Provided that you maintain all copyright and other notices contained therein, you may download material (one machine readable copy and one print copy per page) for your personal and/or educational non-commercial use only.

The University of the Witwatersrand, Johannesburg, is not responsible for any errors or omissions and excludes any and all liability for any errors in or omissions from the information on the Library website.