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By

SEDIMENTATION AND EROSION STUDIES IN WILSON CREEK WATERSHED, MANITOBA, WITH PARTICULAR REFERENCE TO

SHALE BANK RETREAT

THE UNIVERSITY OF MANITOBA

"SEDIMENTATION AND EROSION STUDIES IN WILSON CREEK WATERSHED, MANITOBA, WITH PARTICULAR REFERENCE TO SHALE BANK RETREAT"

by

VERNON HARDAT SINGHROY

A dissertation submitted to the Faculty of Graduate Studies of the University of Manitoba in partial fulfillment of the requirements of the degree of

MASTER OF ARTS

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ABSTRACT

Wilson Creek Watershed is located on the eastern slopes of Riding Mountain National Park in Manitoba and covers an area of 8.18 square miles. It contains two main streams--Packhorse and Baldhill--which join to form Wilson Creek at the foot of the Manitoba Escarpment.

Field data collected from 1964 to 1974 show that the 47 shale banks are the main source of sediment. The shale banks are eroded in horizontally bedded calcareous shale that weathers to produce screes at their bases. Mean slope angles of 35 scree slopes, measured over a ten-year period, range between 32.55 and 29.97 degrees. Moreover, it has been shown statistically that the instability of shale screes is a function of their location 'at' or 'away' from the creek. The annual rate of retreat of the shale banks is 0.5 feet for Packhorse and 0.2 feet for Baldhill. Over the period 1964-1972, there was a substantial net loss of debris on Packhorse Creek. The cumulative size of screes along Packhorse Creek has, therefore, markedly diminished, whereas there has been an overall growth of screes on Baldhill Creek.

Longitudinal profile determinations revealed a general rise in stream bed. Degradation and aggradation studies show that lateral erosion was more extensive than vertical erosion

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and aggregate deposition was three times greater than aggregate erosion.

Weathering is the most extensive process producing shale plates which are subsequently removed by mass wasting, wind transportation and surface water erosion. Soil creep, slumping and gullying are confined to till slopes in the upper reaches of the Watershed; talus shift, wind erosion, debris fall and basal undercutting predominate on the shale screes and free face banks.

Within the Watershed, log cribs and rip raps are the most effective bank protection methods. Revegetation by willows is valuable in promoting shale stabilization. The sediment trap at the foot of the escarpment is not only a flood control device, but an efficient system for monitoring bedload.

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CHAPTER I

INTRODUCTION

Brief Description of Wilson Creek Watershed

Wilson Creek Watershed is located on the eastern slopes of Riding Mountain National Park, approximately five miles southwest of the town of McCreary, Manitoba (Fig. 1). The highest part of the Watershed is 2,400 feet above sea level, and covers an area of 8.1501 square miles (Fig. 2). It contains two main streams - Packhorse and Baldhill - which join to form Wilson Creek at the foot of the Manitoba Escarpment. For experimental purposes, the Watershed is arbitrarily defined from the foot of the Manitoba Escarpment, enclosing the area drained by Packhorse and Baldhill Creeks. As a geomorphic unit, Wilson Creek Watershed forms part of the headwaters of Turtle River which flows into Lake Dauphin, 853 feet above sea level. The Watershed is characterised by steep V-shaped valleys that cut 300-500 feet through shale bedrock (Fig. 3) leaving huge shale banks exposed to the agents of weathering, mass wasting and erosion (Fig. 4). Within the Watershed, in a distance of four miles, the main streams fall approximately 1,300 feet from the Manitoba Escarpment to the alluvial fan at the basin outlet. From there the land slopes to Lake Manitoba.









Figure 3. V-Shaped Valley Cutting Through Shale Bedrock.



Figure 4. Shale Banks Exposed to the Agents of Weathering, Mass Wasting and Erosion.

Glacial till covers Upper Cretaceous shale bedrock of the Riding Mountain and Vermillion River Formations. The shales of the Riding Mountain Formation are hard and siliceous, characteristically medium to light grey (Wickenden, 1945).

Previous Research

To date, seven theses have been written on various aspects of Wilson Creek Watershed. Rosemary Cox (1968) investigated stream flow and ground water in the Watershed and found through chemical analyses that the ground water contributing to discharge is local and surficial in origin.

F. W. Schwartz (1970) investigated the geohydrology and hydrogeochemistry of the ground water of the Watershed. It was found that there is a downward hydraulic gradient characterized by transverse local and intermediate ground water flow patterns above Packhorse-Baldhill confluence and that ground water enters the surface water system east of the Watershed outside its boundaries.

H. G. MacKay's (1970) study is of more interest to the author, especially in his quantitative estimate of erosion and sedimentation within the Watershed as a geomorphic unit during the period since deglaciation. It was estimated that about 430 million cubic yards of material have been eroded from the Watershed during the period. This estimation was based on the assumption that northern and southern boundaries

of the Watershed have not been eroded. Using sediment data for the period 1962-1970, MacKay calculated the average sediment load - suspended and bed - at the basin outlet, as 8.51 tons per day. From various estimates, MacKay concluded that over the past decade erosion rates were considerably less than previously.

M. Sydor (1970) constructed a mathematical model of Wilson Creek Watershed. "The model consisted of a computer program which uses rainfall and evaporation data as input and which produces hourly stream-flow hydrographs as output."¹ This model closely coincides with the actual recorded streamflow.

D. Cass (1970) investigated evaporative heat transfer over snow surfaces for the Watershed. The results of this research were compared with similar studies done by other researchers for different areas and it was found that the energy budget approach to snow melt cannot be used with confidence.

N. G. Banera (1972) used hydrometeorological data available for Wilson Creek Watershed as representative in estimating evapotranspiration along the Manitoba Escarpment.

M. Sydor, "Computer Simulation Model of Wilson Creek Watershed" (Unpublished M.Sc. Thesis, University of Manitoba, 1970) p. 1.

Using semi-empirical methods to analyze data from May to September inclusive for the period 1965-1971, Banera's estimates of evapotranspiration range between 1.30 to 5.47 inches of water within the Watershed. Other components of the monthly water budget were also estimated with assumptions made regarding snow melt, soil moisture, ground water, etc. In his attempt to derive coefficients applicable to the Watershed, Banera concluded that each of the six techniques used in seasonal estimates of actual transpiration is controlled by the net solar radiation reaching the ground and by soil moisture properties.

W. Bilozor (1972) investigated storm-rainfall runoff relations within the Watershed, and found that basin moisture prior to each storm is the most important parameter affecting the rainfall-runoff relationship. Other parameters such as seasonal change, intensity, duration and areal distribution of precipitation showed some inconsistencies when plotted individually on the graph depicting the rainfall runoff relationship.

Objectives of Research

Wilson Creek Watershed was set up by a combined effort of the Federal and Provincial governments for experimental and in-depth investigation, to be beneficial to researchers in the attempt to solve the problems of rapid erosion, deposition and

flooding. As a result of rapid erosion of the shale banks, large amounts of sediment are transported downstream, leading to channel filling at the foot of the Escarpment. This infilling causes flooding when there is rapid runoff.

Thus the purpose of this research is to study erosion and deposition processes in Wilson Creek Watershed with particular reference to shale bank retreat. This encompasses a study of the morphological characteristics of the shale banks and the rate of retreat as well as the processes responsible for it. In addition, an estimate of the proportion of total sediment contributed by the shale banks will be made, and an assessment of the present bank stability measures in terms of their effectiveness in reducing erosion will be undertaken.

Field data for this entire investigation covers the years 1964 to 1972 inclusive. Considerable efforts have been expended in the Watershed in the systematic collection of hydrometeorological data. In addition, shale bank retreat measurements were taken for the past decade of which the author was directly involved in recent months. The availability of this data for analysis was an important consideration in the choice of the study, together with the author's interest in the processes of erosion and deposition fashioning the Watershed.

CHAPTER II

RETREAT OF THE SHALE BANKS

Occurrence of the Shale Banks

The purpose of this chapter is to estimate the volume of material eroded from the shale banks on both Packhorse and Baldhill Creeks, and their rate of retreat. Calculation is based on measurements of bank retreat in the period from 1964 to 1974.

Within the Wilson Creek Watershed there are 23 shale banks along Packhorse Creek and 24 along Baldhill Creek. Shale banks are erosional features, as opposed to stable or vegetated zones that occur between these areas of shale outcrop. According to MacKay and Stanton (1964), "the stream is running in a sharply incised V-shaped channel. The sides are made up almost entirely of bedrock, calcareous shale which weathers very rapidly. Flood plains in this reach of the channel are very restrictive or non-existent. This means that the flow frequently impinges on the shale banks."² These banks are eroded in the shales of the Riding Mountain Formation. Figure 5 shows the longitudinal profiles of Packhorse and Baldhill Creeks and the location of the shale

G. H. MacKay, C. R. Stanton, "Wilson Creek Study. Erosion and Sedimentation Control", Proceedings: Fourth <u>Hydrology Symposium</u>. (Hydrology Subdivision, N.R.C. 1964), p. 8.





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banks. The latter occur between the heights of 1,400 and 1,780 feet above sea level, and range from 30 to 200 feet in amplitude of relief--defined as the vertical distance from the water mark of the river channel to the bank crest. The shale banks are the result of denudational processes associated with fluvial erosion since deglaciation of the region. These processes produce deeply incised valleys possessing numerous shale banks that effect considerable sediment input into stream channels.

For the sake of convenience, the shale banks can be classed as occurring 'at' or 'away' from the stream. Those described as 'at' the stream are the banks at whose base the stream impinges. Those described as 'away' are located at some distance from the stream channel, but within the valley. These two types of shale banks supply sediment to the stream channel by means of mass wasting, fluvial processes and wind erosion.

Geology of the Shale Banks

The shale banks of Wilson Creek Watershed are eroded in horizontally-bedded non-calcareous shales, that weather to produce platey debris, which slides or falls to their bases and accumulates as shale cones. The rock structure, as exposed in the banks, is basically uniform, although some outcrops on Baldhill Creek reveal contorted and fractured shale beds. This probably reflects a certain amount of instability in the geological history. More important,

however, is the influence of structure on ground water movement. R. A. Cox (1968) found more springs in these fractured zones than in the horizontally-bedded shale banks. Interbedded with the shales are siltstone layers and sometimes ironstone concretions. Occasionally, there are occurrences of bentonite layers, three to six inches thick, within the shale units. An analysis by R. A. Carr (1965) shows that the bentonite is composed of calcium montmorillonite with traces of illite. Because this formation is so rich in clay minerals, it is essentially impermeable and therefore, forms the origin of springs in the area.

Collection of Data

In order to estimate the rate of retreat of all the, shale banks on both Packhorse and Baldhill Creeks, the approximate volume of material eroded from them must be ascertained. On those shale banks at the base of which cones had developed, scree measurements were taken at least twice during the summer for each year since 1964. In addition, the rate of retreat of two shale banks devoid of scree, here termed free faces, was measured.

Measurement of the horizontal thickness of scree deposits at the base of the shale banks was achieved by the method of probing, which involved the use of a steel probe, forced horizontally into the scree material until bedrock was reached (Figure 6). Three scree surface parameters were investigated; slope angle was measured using a clinometer;



Figure 6. Measurement of Scree Thickness by Probing and Scree Slope Angles by Clinometer.

and, height and downstream length of the scree were measured by tapes. These measurements are used to provide a volumetric estimate of the debris that comprises each shale cone.

The downstream lengths of shale banks were measured simultaneously on every occasion scree measurements were made, so as to ascertain whether there was growth of the shale outcrop. In all cases, shale banks exhibit pronounced erosion; these banks are interspersed with relatively stable vegetated areas.

Surface measurements were made on each scree apron or cone at the base of the shale bank. These enabled estimation of the volume of shale eroded from the banks. The record reveals substantial variation in the size of the scree accumulations.

FIG.7 - MEASUREMENT OF VOLUME OF SHALE SCREE.



Height = Slope Distance x Sine +

The following equation is used to calculate the volume of shale scree at the base of the shale banks (Figure 7).

Volume =

 $\frac{\text{Average Probe Depth x Height}}{2} \times \frac{\text{Length of Scree}}{27} \dots (eq. I)$

The computed volume is in cubic yards whereas all linear measurements are in feet. Field data from May, 1964 to November, 1972, as well as the computed volume of individual shale scree on the banks of Packhorse and Baldhill Creeks are found in Appendix I.

Data from May, 1964 to December, 1972, collected at the two free face banks--one on Packhorse and the other on Baldhill--are found in Tables 1 and 2. Measurements of free face retreat were obtained by using "a grid-system of iron pins".³ Twenty-five pins installed in the free face along Packhorse Creek and twenty-two in that on Baldhill Creek were used to monitor the changes. These are four-feet by threequarter-inch iron pins, driven horizontally into the free faces and their specific locations established by survey. The top three inches of each pin were left exposed and painted red for ease of observation. Free face retreat was measured periodically by progressive pin exposure due to mass wasting and erosion. Each year after the amount of exposure

J. E. Thomlinson, "Report on Activities in Wilson Creek Watershed", (Manitoba Regional Office, P.F.R.A.. 1965), p. 15.

TABLE 1

Retreat of Free Face Shale Bank Packhorse Creek (1964-1972) All Measurements in Feet

Dim #	May	Aug.	July	Aug.	Aug.	Aug.	Aug.	Aug.
rin #	1964	1965	1966	1967	1968	1970	1971	1972
A	0.20	0.70	0.15	0.50		0.95	0.50	
В	0.35		0.50		600- Gada	0.45	0.20	
C			0.45	0.15		1.20	0.65	4.00
D	0.15		0.30	0.35			0.15	-
Е	0.15		0.70	0.35	1.35	0.70		0.85
F	0.30	0.25	1.60	0.25	0.50	1.35	1.00	0.20
G		1.20	1.00	0.30	0.20	0.20		0.15
Н	0.30	0.35	0.20	0.15	1.00	1.55	1.50	
I	0.40	1.00	0.20	1.20	0.40	0.40	0.55	0.15
J	0.65	0.30	0.30	0.20	0.20	0.25	0.10	4.00
K	0.30	0.45	0.40	0.15			1.00	
L	1.10	2.15	0.95	0.35	0.25	0.70		
M			4276 6131	-	0.25	0.35	0.20	0.50
N	0.20	0.30		0.60	2.60			
0	0.10		0.90	0.50	0.40	0.85		0.40
Р		1.00		0.55	0.60			
Q	0.20		1.90	2.40	0.55			0.20
R	0.25	0.30	0.35	0.50	1.80	1.45	0.30	0.25
S			0.65	0.40			2.10	1.10
Т		0.70	0.30			0.75	4.00	0.15
U		3.70	1.50			2.00	1.15	
v	0.20				0.40			
W				0.25	0.20			
Х			0.35		0.60		0.15	
Y	0.40	0.30	0.25	0.65			0.95	0.30
Average Retreat	0.22	0.52	0.52	0.44	0.67	0.53	0.58	0.67

NOTE: No Measurements were taken in 1969.

(--) No Measurements Recorded.

TABLE 2

Retreat of Free Face Shale Bank Baldhill Creek (1964-1972) All Measurements in Feet

Dia #	Aug.	Aug.	July	Aug.	Aug.	Aug.	Aug.	Aug.
Pin #	1964	1965	1966	1967	1968	1970	1971	1972
A		-						
В	0.25							·
C							0.80	0.40
D			0.20	0.20	4.00	0.20	4.00	
Е	0.40	0.25	0.40	0.40	0.45	0.40		0.55
F	0.25							
G	0.15			-				0.10
н					6000 0000	0.30		0.10
I	0.05		0.25	0.10		0.15	1.30	0.15
J	0.50							
К	0.10	0.60	0.30				0.45	0.15
L	0.40		0.65	0.20	0.40			
М	0.35		0.25	0.50	1.30			0.25
N	0.20		0.15	0.40		0.90	0.65	0.50
0			0.15		0.25			-
Р	0.15				0.40			
Q	0.30				0.20			0.25
R	0.20						0.50	
S	0.60		0.20	0.60	0.55	0.95	0.20	-
T	0.30		0.40	0.70	0.40	0.95	0.40	0.25
U					0.50		0.30	0.20
v	0.25			1.20		2.40	0.30	0.40
W	0.15			-				0.30
Average Retreat	0.21	0.04	0.13	0.19	0.32	0.27	0.38	0.17

NOTE: No Measurements were taken in 1969.

(--) No Measurements Recorded.

is recorded, the pin is pounded further into the shale outcrop until only the top three inches are exposed (Figure 8).

Slope Analysis

Scree slopes are basically depositional features. In Wilson Creek Watershed, the numerous scree slopes are influenced by their particular input-output system, the coarse plate-like nature of the shale fragments and the absence of vegetation.

Means of slope angles were computed for each scree accumulation, designated by a number/letter symbol from measurements made at different times over a decade (Tables 3 and 4). Mean slope angles occurring on Packhorse and Baldhill Creek shale screes range between 32.55 and 39.97 degrees with the exception of Bank 20 on Baldhill where the mean scree gradient is 27.55 degrees. Using a class limit of one degree, the frequency distributions of the mean slope angles of Packhorse and Baldhill scree populations (35 screes in each population) are shown in Figure 9. From this graph the characteristic angle, defined by Young (1972, p. 163) as "the angle with maximum frequency", is observed to be 36 degrees in the case of Baldhill screes and 37 degrees for Packhorse screes.

"Limiting angles are those which describe the range of angle within which given forms occur or given processes operate, either on all slopes, under particular conditions of



Figure 8. Measurement of Amount of Pin Exposure on Free Face Shale Bank, Packhorse Creek.



TAB	L	E	3
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Slope Angles - Packhorse Creek 1964-1974

Date										
Date	1	2 A	2 B	3	4	5	6	7	8	9A
Nov 64	34	36	36	39		37	35	39		38
June 65 July 65 Aug 65 Nov 65	39 38 40 39	34 40 36 35	36 37 34 36	36 37 38 38		38 38 38 38	40 38 41 39	37 40 41 37	42 	33 32 34 38
June 66 Aug 66 Sept 66	38 37 37	37 38 37	36 35 33	38 38 38		35 39 42	38 40 39	42 42	 	32 34 36
May 67 June 67 July 67 Aug 67 Oct 67	36 38 39 30 37	36 37 36 37 38	34 35 35 38 36	37 41 39 35 38		39 42 40 39 36	39 40 40 41 40	40 39 40 40 40		32 33 33 33 33 39
June 68 July 68 Aug 68 Sept 68	37 37 37 40.5	38 38 37 35	37 36 39 35	38 39 38 39		40 39 42 39.5	39 39 39 40	41 41 41 40		32 34 34 30
May 69 Aug 69	36.5 42	36 41	35 36	37.5 41		37 38	40.5	41 		30 31
June 70 Oct 70	39 39	41 39	36	41 40		42 38		<u></u> 36		34 35
June 71 Sept 71	36 46	36 43	34 37	38 42		39 45				36 35
July 72 Sept 72	42 39	42 41	39 30	32 40		45 				35 32
June 74 Aug 74	37 35	36.5 37	31 32	37 35		43 40		<u></u> 39		34 32
Mean Angle	37.96	37.69	35.30	38.13		39.40	39.19	39.79		33.74
Std. Dev.	2.90	2.29	2.11	2.15		2.28	1.41	1.65		2.28

Number of the Shale Banks

N.B. No Measurements were taken in 1973.

-- Denotes Lack of Existence of Scree.

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Slope Angles - Packhorse Creek 1964-1974

Date									
	9 B	9 C	10	11A	11B	11C	12	13A	13B
Nov 64	·		37	35	37		37	36	34
June 65 July 65 Aug 65 Nov 65	44 42 41 36	37 39	39 36 37 35	36 37 38 38	37 35 37 35	40 39 37 37	37 39 39	36 36 36 36	34 36 37 36
June 66 Aug 66 Sept 66	38 38 38	37	37 37 37	38 37 36	35 36 36	41 42 41	37 38 37	40 37 40	37 37 37
May 67 June 67 July 67 Aug 67 Oct 67	38 32 41 40 36	35 33 36 37 36	38 36 37 38 37	38 37 38 38 38	36 36 36 31 36	41 41 42 41 37	40 37 38 37 40	35 37 37 36 38	37 36 36 36 36
June 68 July 68 Aug 68 Sept 68	35 40 41 35	35 38 38 37	35 37 37 37	36 37 38 39.5	35 36 36 35	40 41 40 40	40 41 36 40.5	37 36 36 39	37 36 36 36.5
May 69 Aug 69	38 36	38	35 26	37 40	34 34	44 39	40.5 41	36 36	34.5 34
June 70 Oct 70	34 37	37 36	35	40 38	36 36	38 36	39 39	35 37	
June 71 Sept 71	39 39	38	30	35 41	33 36	38	 39	37 37	38
July 72 Sept 72	39 37	37 39	34 31	34 40	39 35	39 37	39 39	30 35	40 36
June 74 Aug 74	40 36	37.5 36	39 33	37 32	32 34	38 	37 36	32 35	
Mean Angle	37.90	36.83	34.44	37.35	35.15	39.54	38.50	36.28	36.18
Std. Dev.	3.03	1.44	7.07	1.96	1.46	2.00	1.53	1.96	1.40

Number of the Shale Banks

N.B. No Measurements were taken in 1973.

-- Denotes Lack of Existence of Scree.

TABLE 3 (Cont'd)

Slope Angles - Packhorse Creek 1964-1974

Date												
	14	15	16	17A	17B	18	19A	19B	19C			
Nov 64	38	39	37		39	37	39	39	34			
June 65 July 65 Aug 65 Nov 65	38 36 38 35	44 41 39 37	36 37 38 37	39	40 42 40 39	37 38 38 44	41 39 39 41	37 38 37 37	33 34 36 34			
June 66 Aug 66 Sept 66	37 38 36	40 40 39	39 36 39	39 37 39	39 38 39	39 37 34	41 39 38	37 39 39	34 37 37			
May 67 June 67 July 67 Aug 67 Oct 67	35 38 35 39 37	40 38 40 39 40	41 38 40 37 41	38 37 	39 38 40 37 38	36 39 34 42 35	40 39 39 41 40	37 37 38 38 38	37 35 35 35 35			
June 68 July 68 Aug 68 Sept 68	34 37 36 36.5	40 40 40 39.5	37 37 37 41	41 38 36	41 41 38 36.5	34 40 38 38	38 39 39 38.5	37 39 38 38.5	36 36 35 37			
May 69 Aug 69	39.5	39.5 39.5	35.5 36	36	38.5 38	36.5 43	37.5 37	38.5 28	36 36			
June 70 Oct 70	37 37	40 39	37 40	38	39 37	40 39	41 41	37 38	35 35			
June 71 Sept 71		42	45	 39	45 40	39 40	39 41	42 36	35 35			
July 72 Sept 72	38 39	40	36	36	40 40	43 37	36 40	41 37	37 34			
June 74 Aug 74	39 34	37 37	47 38	37 35	38 39	36 34	39 37	40 35	32 34			
Mean Angle	36.96	39.58	38.90	37.69	39.22	35.06	39.22	37.63	35.33			
Std. Dev.	1.58	1.49	3.14	1.54	1.73	2.81	1.40	2.42	1.47			

Number of the Shale Banks

N.B. No Measurements were taken in 1973.

-- Denotes Lack of Existence of Scree.
Slope Angles - Packhorse Creek 1964-1974

Data									
	20A	20B	21A	21B	21C	22A	22B	22C	23
Nov 64	34		37	37		39	39	39	34
June 65 July 65 Aug 65 Nov 65	27	39 34 38 38	38 37 36 37	34 33 36 34	41 41 36 36	39 38 39 39	41 40 38 36	37 37 40 35	41 37 31
June 66 Aug 66 Sept 66	38 38 36	39 39 38	37 38 32	33 34 34	37 36 38	37 41 40	40	35	34
May 67 June 67 July 67 Aug 67 Oct 67	39 36 37 38 37	41 37 37	38 36 37 36 38	34 35 34 35 35	38 36 36 38 38	40 36 39 39 41	 38 36 39 39	 39 41	41
June 68 July 68 Aug 68 Sept 68	38 37 37 37.5	37 37 37	36 37 36 37	34 36 34 36.5	35 39 38 40	41 37 37 37	37 38 40		
May 69 Aug 69	36.5 31		26.5 42	33 39	33	 30	33		
June 70 Oct 70	35 36		38 36	27 34	37	40 35	40 36	40 35	
June 71 Sept 71	 35	 35	36 39	39 38	34	38 35	35 40	 41	
July 72 Sept 72	36 35	35	36 34	35 39	38 35	43 39	38 36	39 34	
June 74 Aug 74	36 33		36 35	37.5 34	36	34 33	36 35	38 33	
Mean Angle	35.78	37.43	36.26	34.94	36,95	37.92	37.78	37.53	36.71
Std. Dev.	2.63	1.87	2.71	2.45	2.10	2.84	2.09	2.61	3.86

Number of the Shale Banks

N.B. No Measurements were taken in 1973.

-- Denotes Lack of Existence of Scree.

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TABLE	4
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Slope Angles - Baldhill Creek 1964-1974

Number of the Shale Banks

vare	_		ter and the second s						
	1	2	3	4	5	6 A	6 B	7	8
May 64 Aug 64 Sept 64		35.3 35 36	36 40 38	36.3 36 34	33.3 36.3 36.3	38.3 36.3 36	38.3 37.3	37.3 37.3 38	38 36 37
June 65 July 65 Nov 65		33 34 32	 31 31	34 32 34	38 35 36	38 35 37	37	39 37 38	38 36 38
July 66 Aug 66 Sept 66		35 36 33	38 36	35 33 36.5	37 34 34.5	39 38 38.5	 37	37 38 37	36 36 38.5
May 67 June 67 July 67 Aug 67 Sept 67		37.5 35 37 37 35	36 38 36 35 36	35 36 34 37 37	35 33 34 35 36.3	39 37 39 39 39	36 33 37 37 35	37 37 39 38 38	35 36 35 37 36
June 68 July 68 Aug 68 Sept 68		36 36 35 37.5	36 35 34	36 36 37 40	36 37 36 36	37 39 36 36	38 37 38 37.5	37 38 38 39	36 38 36 36
May 69 Aug 69		33.5 37	37	37 33	33.5 34	37 39	32.5 35	37 41	35.5 36
July 70 Oct 70		35 36	36	36 33	35 34	38 37	35 36	36 37	39 38
July 71 Sept 71		36 36		37 37	39 31	39 34	40 39	37 39	38 37
July 72 Sept 72		37 35	38 37	35 35	36 32	39 34	36 37	38 37	37 36
June 74 Sept 74		36 34	37 36	33 33	38 35	36 36	37 35	34 34	37 34
Mean Angle		34.00	36.05	35.24	35.21	37.40	36.77	37.49	36.69
Std. Dev.		1.37	2.13	1.80	1.81	1.58	1.60	1.40	1.20

N.B. No Measurements were taken in 1973.

Slope Angles - Baldhill Creek 1964-1974

Number of the Shale Banks

N.B. No Measurements were taken in 1973.

Slope Angles - Baldhill Creek 1964-1974

Number of the Shale Banks

TABLE 4 (Cont'd)

Slope Angles - Baldhill Creek 1964-1974

Number of the Shale Banks

11984	the second se								
	20B	20C	21A	21B	210	22	2 3 A	23B	24
May 64 Aug 64 Sept 64	37.3 36.3 34	37.3 25 25	37.3 36.3 38	35 36.3 37	33 36 37	42 35 39	39 39.3 38	38 36.3 38	37.3 39 38
June 65 July 65 Nov 65	23 25 25		 39 38	34 33	38	42 41 41	 39 38	39	36 35
July 66 Aug 66 Sept 66	37 35.5 35	37 36.5 36.5	 38 38	39 32	37	41 39	40 39 38	37 39 38	39 37 37
May 67 June 67 July 67 Aug 67 Sept 67	35 37 35 39 25	35 24 24 24 36	39 35 40 34 38	39 36 39 33	33 39	39 37 39	38 38 39 39 39	 38 38	35 35 37 34
June 68 July 68 Aug 68 Sept 68	36 37 34	24 24 24 24	35 39 37 37	39 38 39	38 	39 36 39	39 41 39 38.5	38 38 	35 35 34 34
May 69 Aug 69	35.5 36	24 24	27 39	39 34.5		30	36.5 39		38 37
July 70 Oct 70	35 35	37 26	38 38	 38	38	38	38 38		36 36
July 71 Sept 71	34 36	25 24	40	40 39	35	35 37	 39	38 38	24 37
July 72 Sept 72	37 36	24 35	40 39	40 39	39	37	39 40		37 33
July 74 Sept 74	32.5	23 22.5	34	39 34	36	35 35		37 35	33
Mean Angle	33.91	27.66	37.23	37.03	36.63	37.90	38.65	37.69	35.53
Std. Dev.	4.34	5.65	2.79	2.55	1.98	2.93	1.00	1.01	2.94

N.B. No Measurements were taken in 1973.

rock or climate or in a local area" (Young, 1972, p. 165). The upper (maximum) limiting angle of the shale cone slopes in Wilson Creek Watershed is 47 degrees, recorded from Packhorse Bank 16 in June, 1974 (Table 4). The lower limiting angle of 23 degrees was recorded in July, 1974 on the Baldhill scree slope 20C. This relatively large difference of slope angles is causally related to a number of factors. The most important are the angle of repose of coarser and finer shale fragment accumulations and the basal steepening of scree slopes by the stream.

Standard deviation is a measure of dispersion about the mean. For a normal distribution, two-thirds of all the population of angles fall within one standard deviation and ninety-five percent of the angles should occur within two standard deviations of the mean. The standard deviations of the frequency distributions of mean angles were computed using the formula:

$$s = \sqrt{\frac{(x_1 - \overline{x})^2}{n}}$$

where x_i is each individual value, \overline{x} is the mean of observation and n is the number of cases (Doornkamp and King, 1971).

Tables 3 and 4 show the means and standard deviations of all the scree angles in the Watershed indicating variations over a ten-year interval. The standard deviations of scree slope angles on Baldhill Creek range between 0.92 and 5.65 and those on Packhorse Creek range between 1.40 and 7.07.

These relatively large ranges of standard deviations of scree slope angles on both creeks reflect the process-form interactions on the shale screes, as well as the imbalance of debris supply, transport and removal (Tables 5 and 6).

In Wilson Creek Watershed, the instability of shale scree slopes--hence, changes in slope angles--is determined, to a great extent, by the location of the screes in relation to the streams. This observation is determined both statistically and by visual inspection of data presented from Tables 3 and 4 and Appendix I.

From Appendix I it is noted that screes are located 'at' and 'away' from the stream. The terms 'at' and 'away' are indicative of locational changes of the stream channel with reference to a particular scree. A temporal comparison of the location of each scree on Packhorse and Baldhill Creeks was carried out. It was found that only the scree on Bank 1 on Packhorse Creek and the screes on Banks 5 and 7 on Baldhill Creek were located 'at' the streams, i.e., the streams impinged on their bases during the entire period 1964-1972. Also, only the screes on Banks 8, 9, 23A and 23B on Baldhill Creek were located 'away' from the stream for the entire period of 1964-1972. All the other screes on Packhorse and Baldhill Creeks at some time during the period changed their location in relation to the streams.

In Table 4 it is shown that the standard deviations of scree slope angles on Baldhill Banks 8, 9, 23A and 23B are 1.20, 0.92, 1.01 and 1.00 degrees respectively. On the other

TABLE 5

Volume of Shale Eroded from Shale Banks and Shale Screes on Baldhill Creek (1964-72)

(All Measurements in Cubic Yards)

Date	AT Scree Volume	AWAY Scree Volume	AT Erosion From Banks To Scree	AWAY Erosion From Banks To Scree	AT Erosion From Scree To Stream	AWAY Erosion From Scree To Stream
			Debris	Debris	Debris	Debris
			<u>Supply</u>	<u>Supply</u>	<u>Removal</u>	<u>Removal</u>
May 64	1206.4	4951.6				
Aug 64	1211.6	5063.2	5.2	111.6		
Sept 64	1256.8	5236.2	45.2	173.0		
June 65	1784.2	6104.3	527.4	868.1		
July 65	1776.3	6751.3		637.0	8.1	
Nov 65	1552.8	6872.7		131.4	223.5	
July 66	1955.4	7036.0	402.6	163.9	•	
Aug 66	1490.2	6822.3			468.2	213.7
Sept 66	1341.5	6965.8		143.5	148.7	
May 67	1188.0	5782.0			153.5	1183.8
June 67	1343.0	6064.0	155.0	282.0		
July 67	1434.0	5523.0	91.0			
Aug 67	1503.0	5677.0	69.0	154.0		
Sept 67	1486.0	5498.0			17.0	541.0
June 68	1525.0	5760.0	39.0	262.0		
July 68	1351.0	5867.0			174.0	179.0
Aug 68	1960.2	6587.5	609.2	720.0		
Sept 68	950.4	8921.3			1010.2	107.0

TABLE 5 (Cont'd)

Volume of Shale Eroded from Shale Banks and Shale Screes on Baldhill Creek (1964-72)

(All Measurements in Cubic Yards)

Date	AT Scree Volume	AWAY Scree Volume	AT Erosion From Banks To Scree	AWAY Erosion From Banks To Scree	AT Erosion From Scree To Stream	AWAY Erosion From Scree To Stream
			Debris	Debris	Debris	Debris
			Supply	Supply	<u>Removal</u>	<u>Removal</u>
May 69	1445.4	6370.1	495.0	448.8		
Aug 69	1130.3	4699.2			315.1	666.2
July 70	1182.0	7055.0	51.7	2355.0		
Oct 70	1238.0	7190.0	56.0	135.0		
June 71	879.0	6494.0			359.0	1670.7
Sept 71	1291.0	6889.0	412.0	395.0		
July 72	1251.0	6105.0			40.0	696.0
Sept 72	961.0	6489.0		328.0	290.0	784.0
Total A			2958.3	7308.3		
Total B					3207 3	6041 4

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TABLE 6

Volume of Shale Eroded from Shale Banks and Shale Screes on Packhorse Creek

(1964-72)

(All Measurements in Cubic Yards)

Date	AT Scree Volume	AWAY Scree Volume	AT Erosion From Banks To Scree	AWAY Erosion From Banks To Scree	AT Erosion From Scree To Stream	AWAY Erosion From Scree To Stream
			Debris	Debris	Debris	Debris
			<u>Supply</u>	<u>Supply</u>	<u>Removal</u>	<u>Removal</u>
Nov 64	2645.8	1102.7				
June 65	3013.4	1654.6	397.6	551.9		
July 65	3515.6	1433.3	499.2			221.3
Aug 65	3386.6	1175.3			129.0	258.0
Nov 65	3070.1	1419.6		244.0	316.5	
June 66	2094.4	2094.7		675.1	975.7	
Aug 66	1953.5	2162.7		68.0	140.0	
Sept 66	2292.8	2414.8	339.3	252.7		
May 67	1596.0	2383.0			696.8	31.8
June 67	1944.0	2306.0	348.0			77.0
July 67	1735.0	2337.0		31.0	209.0	
Aug 67	1681.0	2389.0		57.0	54.0	
Oct 67	1989.0	2592.0	308.0	203.0		
June 68	1743.0	2775.0		183.0	246.0	
July 68	1945.0	2624.0	202.0			151.0
Aug 68	2239.0	2105.0	294.0			519.0
Sept 68	1725.0	3079.0		974.0	514.0	

TABLE 6 (Cont'd)

Volume of Shale Eroded from Shale Banks and Shale Screes on Packhorse Creek

(1964-72)

(All Measurements in Cubic Yards)

Date	AT Scree Volume	AWAY Scree Volume	AT Erosion From Banks To Scree	AWAY Erosion From Banks To Scree	AT Erosion From Scree To Stream	AWAY Erosion From Scree To Stream
			Debris Supply	Debris Supply	Debris <u>Removal</u>	Debris <u>Removal</u>
May 69	1821.0	2451.0	96.0			628.0
Aug 69 June 70	534.0	1722.0	105 0	501 0	1289.0	729.0
0 ct 70	1397.0	1775.0	668.0	201.0		448.0
June 71	185.0	1919.0		144.0	1211.0	440.0
Sept 71	889.0	2054.0	703.0	135.0		
July 72	884.0	1656.0			5.0	398.0
Sept 72	596.0	1871.0		215.0	288.0	
Total A			4050.1	4234.7		
Total B					6074.0	3461.1

hand, the standard deviations of scree slope angles on Packhorse Bank 1 and Baldhill Banks 5 and 7 are 2.90, 1.81 and 1.40 degrees respectively (Tables 3 and 4). It is, therefore, evident that the screes found 'at' the streams were more unstable than those 'away' from the streams because the former possess a larger variation in slope angles, probably as a result of basal erosion.

With regard to the remaining scree slope angles on Packhorse and Baldhill Creeks, it is shown (Tables 3 and 4) that their standard deviations vary between 1.33 and 7.07 degrees. This large range is determined by the continuous changes in lateral position of the stream channels and high and low discharges resulting in the varying location of each scree relative to the stream. This phenomenon is discussed in some detail in the following section. Instances of changes of scree position relative to the stream are found in Appendix I.

Estimation of Bank Retreat

This section deals with the estimation of the volume of material eroded from the shale banks and screes, and the rate of retreat of two free face banks--one of Packhorse Creek and the other on Baldhill Creek. Field data for volumetric estimation and rate of retreat extend over the period 1964-1972.

Assuming no basal removal, the volume of material comprising each scree is equivalent to the amount eroded from the shale banks. The scree volume is calculated by using

Equation I. Figure 7 shows diagrammatically how this equation is derived. The data required to calculate the volume of scree material available for stream transport include average probe depth, the downstream length of the scree, scree slope angle and slope height. These parameters together with the calculated volume of scree materials on each bank for Packhorse and Baldhill Creeks are shown in Appendix I.

Other data in Appendix I also reflect the mobility of stream channels and the rapidity of scree development and removal. For instance, there are numerous cases where a particular scree is recorded as located 'at' the creek and later recorded as 'away' from the creek. This is because of high and short duration discharges after storm events. As Cox (1968, p. 27) noted, "each stream has the characteristically sharply inclined rising limb, crest of very short duration." This rapid runoff from storms and spring melt often results in stream channels changing their courses, sometimes washing away existing screes and developing new ones. Also, "because of the rapidity of weathering, these banks contribute not only large quantities of shale, but also a considerable amount of vegetation being undermined at the top of, and lateral to, the slope. Perhaps fifty percent of the time, this means stronger current pressures against rather than away from the banks and the direct shale and tree contribution is locally increased as a result" (MacKay and Stanton, 1964, p. 8).

In some cases, as can be demonstrated in Appendix I, several newly developed screes merge on a particular bank to form a large scree. In others, peak discharge, high velocity and tree deflection--noted previously--caused existing screes to be washed away. In order to monitor this rapid development and removal of screes, the letters 'A', 'B' and 'C' are used in Appendix I, indicating that more than one scree may exist at the base of a particular shale bank at the time of data collection, but may be non-existent at a later date.

Tables 5 and 6 show total volumes removed from the shale banks and shale screes for the period 1964-1972. They, in effect, summarize the aggregate volumes at different dates as shown in Appendix I. The volume of material eroded from the shale banks bears a close relationship to that added to the screes below. The material eroded from the screes is eventually supplied to the stream and so provides a measure of output from each scree system. The scree system is a dynamic one, in which most of the debris supplied to the screes is in temporary storage. Output is usually from storage, but on occasion may be material directly supplied from overlying shale banks that has passed down the entire scree slope via rolling or sliding. Having estimated the volume of scree materials at a specific time, any subsequent addition to scree storage from shale banks is classed as 'debris supply'. If the aggregate scree volume is less than the previously estimated one, this is termed 'debris removal' by the stream. The debris removal actually refers to net loss of material from the scree, as storage could be reduced by reduced input,

while the rate of removal remains constant. From 1964-1972, erosion from the banks is calculated as follows:

Baldhill Creek...10,266.60 cubic yards...Total A, Table 5 Packhorse Creek...8,284.80 cubic yards...Total A, Table 6

Erosion from screes to streams is as follows:

Baldhill Creek...9,248.70 cubic yards...Total B, Table 5 Packhorse Creek...9,535.10 cubic yards...Total B, Table 6

From the estimates, three conclusions can be drawn. First, in gross terms, there is more erosion on the shale banks of Baldhill Creek than on Packhorse. Assuming all other conditions are equal, this may be attributed to the fact that banks are larger on Baldhill than on Packhorse. Thus, the banks on Baldhill are potentially a larger supplier of scree materials than those on Packhorse. Data collected during August, 1967 is typical and support this reasoning.

		Packhorse Creek	<u>Baldhill Creek</u>
Average	Probe Depth	5.83'	7.00*
Average	Slope Height	10.67'	11.30'
Average	Slope Distance	17.45'	18.30'
Average	Bank Length	84.02'	90.55'

Secondly, in gross volumetric terms, Packhorse Creek erodes more material from its screes than Baldhill does from its screes, despite the fact that the screes on Baldhill are larger. This can be accounted for by the fact that Packhorse Creek impinges on a greater number of screes than does Baldhill, thus acquiring more loose material for transport. It is, therefore, a matter of location 'at' or 'away' from the stream. However, the 286.40 cubic yards of difference between volumes eroded from screes at Baldhill and those at Packhorse Creek is not very large.

Thirdly, one of the most interesting results of volumetric analysis is obtained by considering the scree as an input-output system. From 1964-1972 a summary of volumetric data is as follows:

A. Baldhill screes . . . input . . . 10,266.60 . . . output . . . 9,248.70 Net Gain 1,017.90

B. Packhorse screes . . . output . . . 9,535.10 . . . input . . . 8,284.80 Net Loss 1,250.30

Thus, based on consideration of the scree population as an input-output system for the 1964-1972 period, there was a substantial net gain of 1,017.70 cubic yards of material on Baldhill Creek, whereas there was an even more significant net loss of 1,250.30 cubic yards of debris on Packhorse screes. Therefore, over the eight-year period, there has been an appreciable overall development of scree along Baldhill Creek, whereas, the cumulative size of those along Packhorse has markedly diminished. The principal determinant of the latter condition seems to be the relatively limited supply of shale fragments from the banks along Packhorse Creek.

Because of the nature of the data collected, it is difficult to estimate the actual rate of recession of each bank on Packhorse and Baldhill Creeks. However, data collected on two free faces--one on Packhorse and the other on Baldhill--are indicative of rates of retreat. The stream erodes the base of each free face and determines to a large extent the rates of retreat. Details as to how the data were collected were described earlier. However, Tables 1 and 2 reveal that average free face retreat on Packhorse Creek is far greater than that of Baldhill. For Packhorse, the average yearly retreat ranges from 0.22 to 0.67 feet, whereas, for Baldhill the average yearly retreat ranges from 0.04 to 0.38 feet over the period 1964-1972. Detailed study of the processes determining retreat will be discussed later.

CHAPTER III

STREAM BED EROSION AND DEPOSITION

Sediment Trap

In 1963, a retaining structure was constructed 1,100 feet downstream from the gauging weir near the basin outlet with the objective of trapping sediment in order to determine the total sediment load (that is, solid load) of the two main creeks. The structure is a simple rock fill five feet high which causes a reduction in stream velocity, thereby encouraging deposition of suspended and bed material.

A profile and cross-sections of the sediment trap, showing individual and accumulated volumes of shale deposition for the period June 6, 1968 to August 20, 1968 are included in the thesis to exemplify the methods used to estimate total sediment load. Similar measurements were made each time the trap was filled and emptied. These diagrams (Figures 10-25)--Sediment Trap Profile and Cross-Sections included--were obtained from the Engineering Division, P.F.R.A., Winnipeg.

Figure 10 shows the location of the fifteen crosssections and the downstream length of the trap. This length is 737.6 feet and the width ranges between 75 and 120 feet. Figures 11 to 25 show graphs of individual cross-sections. Each graph shows a continuous line, depicting the emptied

DEPARTMENT OF AGRICULTURE - CANADA

P.F.R.A.

WILSON CREEK PROJECT

PROFILE AND CROSS SECTIONS WILSON CREEK

FROM GAUGING WEIR TO SHALE TRAP IN SEC. 24, TWP. 20, RGE. 16 W.P.M.

SHOWING INDIVIDUAL AND ACCUMULATED VOLUMES OF SHALE DEPOSITION - PERIOD JUNE 6. 1968 TO AUG. 20. 1968

SCALES AS SHOWN

FEB. 1969

NOTE: ELEVATIONS ARE TO GEODETIC DATUM. DISTANCES ARE SHOWN IN FEET.

REFERENCES:

FIELD BOOKS: R-T-84 & R-T-103 FOR DETAILED PLOTTING OF X-SECTIONS REFER TO PLAN W-R-1623

















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trap at a particular section on June 6, 1968. The dotted line represents the level of sediment at the same section on August 20, 1968 when the trap is filled. From the two survey lines on each graph, areas of erosion can be recognized. Section 8 (Figure 18) illustrates this clearly. Thus, the volume of material deposited over each period can be calculated by using the following equation:

$$\sum_{k=1}^{\infty} (A_d \times L) - (A_e \times L) = Volume \dots Eq. 2$$

when: $\sum = sums of individual volumes between each$

cross-section

 A_d = cross-sectional area of deposit

L = Length between each section

 A_e = cross-sectional area of erosion

Figure 26 shows a longitudinal profile of the original bottom and the level of deposition of the silt trap, as well as the individual and accumulated volume of erosion and deposition for the period June 6, 1968 to August 20, 1968. It should be realized that measurements of cross-sections and longitudinal profiles were taken on the same date. From this technique, the annual total of sediment deposited in the trap for the period 1964-1972 was obtained (Table 7).

Annual Total Sediment Load Deposited in Trap 1964-1972

1964	998.20	cubic	yards
1965	2,012.00	cubic	yards
1966	1,973.70	cubic	yards
1967	1,147.80	cubic	yards
1968	1,255.03	cubic	yards
1969	4,087.97	cubic	yards
1970	2,553.77	cubic	yards
1971	4,318.27	cubic	yards
1972	1,025.60	cubic	yards
	í		
Total	19,435.10	cubic	yards

Analysis of Sediment Trap Data

During the period 1964-1972, 19,435.10 cubic yards of sediment, predominately shale, were deposited in the trap (Table 7). According to MacKay (1970, p. 15), "the volume of sediment deposited in the 'silt trap' represents the total sediment load of the stream during the measuring period." However, in periods of high rainfall, because of the rapid runoff response, the trap is filled up faster than normal and a small fraction of the total sediment load passes over the trap and is deposited further downstream.⁴

A comparison of the total annual discharge (Table 8) and the annual volume of sediment in the trap (Table 7), shows that the largest deposit corresponds to the period of greatest discharge. In addition, it is shown (Figure 27) that there is a linear relationship between total annual discharge and sediment deposition with a correlation coefficient of 0.76.

Despite a correlation coefficient of 0.76, there seem to be two cases when the relation is inverse. The total annual discharge in 1966 was much less than in 1965, yet the volume of sediment deposited in the trap in 1966 was virtually the same as in 1965. This is because the rainfall frequencies in 1965 and 1966 were very similar, but during 1966, the maximum intensity and duration were greater than in

^{4.} Personal communication with Jim Thomlinson (Watershed Engineer).



Total Annual Discharge in CFS/Days

a = -10.05 b = 1.23 $R^2 = 0.55$ R = 0.76

Figure 27. Regression Between Total Annual Discharge and Sediment Deposition (1964-1972).

1965. For example, from May 1 to September 30, 1965, there were 65 days with rainfall and nine days with storms, each exceeding one inch of rain. In 1966, there were 63 days with rainfall but only three days with storms exceeding one inch. However, in 1966 the maximum intensity occurred on August 6 when 4.60 inches of rain fell over a one-hour period, whereas in 1965 the maximum intensity occurred on August 1 when 1.06 inches of rain fell in 15 minutes (Thomlinson, 1966). Thus, larger volumes of sediment could have been transported during the intense storms of 1966, accounting for the anomalous situation in 1965 and 1966.

The second anomalous case is the situation in 1969 and 1970. Specifically, 4,087 cubic yards of sediment were deposited in the trap during 1969 and the average annual stream discharge was 2,547 c.f.s. By contrast, in 1970 there was a higher discharge of 3,023 c.f.s. but only 2,523 cubic yards of sediment deposited (Tables 7 and 8). This anomaly arose because of a 48-hour storm on June 25 and 26, 1969 that was accompanied by high winds and a total of six inches of rainfall. The hydrograph (Figure 28) prepared by P.F.R.A. Drafting Division shows the rapid response of the rainfall runoff relationship. This runoff response was accompanied by such rapid erosion, stream transportation and deposition of sediment that altogether 1,533.3 cubic yards of sediment were deposited in the trap from June 6 to July 1, 1969 (Thomlinson, 1969). It appears that storm intensity is a principal factor in the determination of sediment yield.

Total Annual Discharge of Wilson Creek 1964-1972

1964	680	c.f.s./days
1965	2,025	c.f.s./days
1966	1,240	c.f.s./days
1967	1,662	c.f.s./days
1968	1,257	c.f.s./days
1969	2,547	c.f.s./days
1970	3,023	c.f.s./days
1971	2,048	c.f.s./days
1972	981	c.f.s./days

NOTE: Total Annual Discharge - refer to the period April 1 to October 31.



There are two possible sources of sediment output in Wilson Creek Watershed. These are erosion from the shale banks and erosion from the stream beds. It appears, for the following reasons, that the main source of sediment deposited in the sediment trap is from the shale banks.

First, aggradation and degradation studies described in detail show that the stream bed has risen in the middle and lower reaches during the period 1964-1971 and that lateral erosion exceeds vertical erosion. Consequently, the banks are retreating and the bed is rising.

Secondly, it has been shown in Chapter II that 18,381 cubic yards of sediment were eroded from the shale banks during the period 1964-1972. Within this same period, 19,435 cubic yards of sediment representing total solid load were recorded in the sediment trap. The degradation and aggradation studies show that the stream beds are not a major source of sediment and it is now shown quantitatively that the shale banks are the main suppliers of sediment in Wilson Creek Watershed.

Degradation and Aggradation

In attempting to define degradation and aggradation processes, Frenette and Harvey (1973, p. 301) noted:

When a stream is capable of carrying more sediment than is supplied to it, it carries away material from its bed and thus tends to lower it. This cutting down, designed degradation, increases the slope of the tributary streams, which will erode themselves and bring down more material until new conditions of equilibrium are marked. If, on the other hand, the rate at which sediment is brought to the stream becomes substantially larger than the capacity of transport in the stream, deposition or aggradation will occur and the bed will tend to rise.
In the Wilson Creek Watershed, degradation and aggradation studies were carried out from 1967-1970.

Metal pins were placed on each bank for chainage reference and the elevation of the centre of the stream channel opposite each set of pins was obtained several times during the summer. These elevations were taken at the locations of the 12 flood crest gauges (Figure 30) established previously along Wilson Creek and its two main branches. Comparison of these elevations indicates a period of deposition downstream of the junction of Packhorse Creek and Baldhill Creek in 1969 with as much as 1.8 feet being deposited in the reach of the stream. (Thomlinson, 1970, p. 11)

Figure 29, a reproduction of Thomlinson's map, identifies areas where the zones of degradation and aggradation occur between 1967 and 1970. There are two areas of stream bed erosion; firstly, 0.90 feet on Packhorse Creek near crest gauge eleven; and, secondly 0.6 feet on Baldhill Creek, near crest gauge six. Other reaches downstream show considerable deposition. In Figure 29 the area of dominant stream bed erosion in the Watershed is identified. However, in Chapter II, Figure 5, it was shown that all shale banks occur in this zone and that these banks are retreating at the rate of 0.5 feet per year on Packhorse Creek and 0.2 feet on Baldhill Creek. Consequently, the major source of sediment is from the shale banks which retreat at a faster rate than the corresponding stream beds are lowered.

Additional evidence to support the assertion that the rates of lateral erosion exceeds those of vertical erosion and that aggradation exceeds degradation are shown by comparing the cross sections of the streams. Figure 30 shows the location of twelve crest gauges within the Watershed





Figure 30 Location of Crest Gauge, Wilson Creek Watershed.

where cross sections were taken once in each year of 1964 and 1971. "A" cross sections were surveyed 25 feet downstream from the crest gauges and "B" cross sections were made 25 feet upstream from the devices. The broken line on each graph (Figures 31-54) denotes a cross section surveyed in 1964 and the continuous line denotes a section surveyed in 1971.

Twenty-four cross sections were taken (J. Thomlinson) throughout the Watershed (Figures 31-54). Since each pair of 1964 and 1971 cross sections were taken at the same point, it was easy to measure and compare areas of stream erosion and deposition by superimposing one cross section on the other for a particular section of the stream. Erosion is signified where the dotted line (1964) is above the continuous line (1971); the reverse situation represents deposition. Cross-sectional areas of erosion and deposition were measured by a Numonics Electronic Planimeter Model 277-137. The purpose of these measurements is to assess aggradation and degradation.

With regards to the computed values of channel cross sectional areas along Wilson, Packhorse and Baldhill Creeks, aggradation is roughly three times greater than degradation, since the total area of deposition is 0.16985 hectares and that of erosion is 0.05607 hectares. In most reaches of each stream, areas of aggradation exceed areas of degradation occurring at least once along each crest gauge except for Gauge #10 (Cross Sections 10A and 10B - see Figures 49 and



Figure 31.







Figure 33.







Figure 35.







Figure 37.

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Figure 38.







5 - B

Figure 40.

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8 - A

Figure 45.



Figure 46.







9 - B

Figure 48.







Figure 50.

















Figure 54.

50 respectively). There are, however, instances where areas of degradation are larger than the areas of aggradation. These occur at Cross Sections 1A, 4A, 5A, 6A, 8A, 10B and 12B (see Table 9 and Figures 31, 37, 39, 41, 45, 50 and 54). It is not possible from this analysis to explain each occurrence of degradation or aggradation because of local determinants such as the behaviour of the meandering stream, sinuosity and cutting and channel gradient, among others. In addition these "short term fluctuations of the level of river beds make it very difficult to observe underlying very slow trends for the bed to degrade, or the reverse, to aggrade" (Gessler, 1971, pp. 8-1). Nevertheless, there is very little net change in river channel size in relation to aggradation and degradation on Packhorse Creek than that of Baldhill Creek. Cross-sectional areas of aggradation are equivalent to areas of degradation in three cases (Table 9) of which all occur on Packhorse Creek (see Figures 49, 52 and 53). It is also interesting to note that there has been an unusually large amount of deposition around Crest Gauges 7, 8 and 9 (Figures 43-48) on Baldhill Creek. This is due to sedimentation at the confluence of Baldhill and South Branch Creeks.

This latter analysis, therefore, provides additional evidence to that already presented supporting the assertion that aggradation exceeds degradation in Wilson Creek Watershed. Hence, the channels are storage and transporting media rather than suppliers of new sediment by bed erosion. It is evident, then, that the shale banks are the major supplier of sediment in Wilson Creek Watershed.

TABLE 9

Measurements of Areas of Aggradation and Degradation

Figure	Cross	Section	Comments	Deposition in Areal Units	Erosion in Areal Units*
31		1A	Degradation	0.00260	0.00383
32		1B	Aggradation	0.00228	0.00156
33		2 A	Aggradation	0.00437	0.00000
34		2 B	Aggradation	0.00384	0.00046
35 36		3 A 3 B	Aggradation Aggradation	0.00577 0.00447	0.00153
37 38	۵	4 A 4 B	Degradation Aggradation	0.00209 0.00259	0.00257
39		5 A	Degradation	0.00233	0.00251
40		5 B	Aggradation	0.00254	0.00114
41		6 A	Degradation	· 0.00139	0.00411
42		6 B	Aggradation	0.00186	0.00163
43		7A	Aggradation	0.01910	0.00000
44		7B	Aggradation	0.01290	0.00140
45		8A	Degradation	0.00750	0.01030
46		8B	Aggradation	0.03086	0.01710
47 48		9 A 9 B	Aggradation Aggradation	0.04070 0.01660	0.00000
49 50		10A 10B	No Change Degradation	0.00011 0.00012	0.00011
51 52		11A 11B	Aggradation No Change	0.00221	0.00020 0.00276
53		12A	No Change	0.00040	0.00040
54		12B	Degradation	0.00046	0.00151

1964-71 From 24 Cross Sections (Figures 31-54)

TOTAL 0.16985 0.05607

*The Areal Units were obtained by planimetric measurements of cross sectional areas of erosion and deposition in stream channels.

CHAPTER IV

SLOPE PROCESSES

Weathering, mass wasting and surface transport are the major groups of processes responsible for the formation of shale scree in Wilson Creek Watershed. Chapter Two assessed the volume of scree material produced by erosion of shale bedrock resulting from these types of processes. Although most processes occurring on slopes can be monitored in the field, and have been well documented in many geomorphic studies, it is nevertheless beyond the scope of the current research to investigate slope processes in detail, hence the lack of field measurements in the Watershed. It is, therefore, the purpose of this chapter to identify in general terms some of the major slope processes that contribute to the production of sediment from the shale banks.

Weathering

Weathering, as defined by Ollier (1969, p. 1), "is the breakdown and alteration of materials near the earth's surface to products that are more in equilibrium with newly imposed physico-chemical conditions." This is the initial stage of denudation in which weathering usually occurs before debris is removed.

On the basis of field observations, it is clear that weathering of shale in the Watershed is mainly physical. As Leopold, Wolman and Miller (1964, p. 113) have indicated, this involves "stresses generated in the rock by growth of ice crystals, by heating and cooling, wetting and drying and by organic activity. Because forces from several of these sources may act more or less simultaneously, their individual importance and degree of interaction are not easily evaluated." A significant result of physical weathering in the Watershed is that it increases the aggregate surface area of the shale, thus making the fragments more susceptible to chemical weathering.

Alternate wetting and drying of shale is a very important weathering process in Wilson Creek Watershed. Because the shales are thinly bedded (Figure 55), water from spring melt and rainfall percolates along bedding planes, resulting in the expansion of particles of clays such as montmorillonite. During the drier periods the clay minerals in the shale contract and this alternate expansion and contraction causes separation into flakes.

Ollier (1969, p. 21) observed that, "possibly repeated wetting and drying allows the water molecules to become increasingly ordered, assuming a quasi-crystalline nature and exerting expansive force that thrusts against the confining wall." This force causes the shale to separate along zones of weakness to produce shale plates (Figure 56). The



Figure 55. Layered Structure of Exposed Shale.



Figure 56. Shale Flakes Resulting from Weathering.

smaller and lighter fragments are either blown down by wind or fall under the influence of gravity to the base of the shale banks to produce shale screes (Figure 57).

Another aspect of physical weathering of shale is ice crystal growth. Volume changes due to crystal growth set up stresses within the shale. During freezing spells the water trapped between the shale laminae forms ice crystals, resulting in the expansion of the intervening spaces. When the ice thaws the stress is released, thus weakening the laminae.

According to Ollier (1969, p. 12), "When there is alternate freezing and thawing, movement of rock particles occurs as an indirect effect of frost action. After a thaw the fragments may settle in new positions and small particles may fall into cracks, preventing them from closing back to their original position. With repeated freezing and thawing it would be expected that there would be much more chance for rock disintegration than with steady low temperatures, but the actual relationship can be quite complex."

This phenomenon of "thermal shattering"⁵ is dependent on freeze-thaw cycles. These cycles occur many times throughout the year in the Watershed, especially in the spring and fall when the temperature frequently oscillates about freezing point diurnally. A combination of freeze-thaw activity and the wetting and drying processes cause the breaking up of shale bedrock.

Tricart, J., 1970, <u>Geomorphology of Cold Environments</u>, MacMillan and Co. Ltd., London, p. 75.



Figure 57. Weathering of Shale Bedrock, Producing Shale Scree.
Other weathering processes in Wilson Creek Watershed are more difficult to identify. Chemical weathering caused by water and gases involves changes in the chemical composition of shales and clays. One visible aspect of chemical weathering in the Watershed is the oxidation of ferrous compounds in the shales, resulting in decomposition and significant loosening of shale bedrock. Bunting (1967) associates this oxidation in shales with the slow movement of water, and where leaching increases the solubility, hence the removal of This removal of iron oxides and hydroxides, or the iron. "iron stained appearance", 6 is typical of the Odanah shales Where concealed bentonite beds in in Wilson Creek Watershed. the shales of Wilson Creek are light grey, the exposed beds have a light yellow colour. Bannantyne (1963) believes that this "discolouration effect of weathering" on the bentonite layers is "caused by oxidation of small amounts of iron in the clay from the ferrous to the ferric state."7

The amount of solution erosion on shales and bentonite clays devoid of carbonates in Wilson Creek Watershed is

Bannantyne, B. B., 1970, Clays and Shales of Manitoba, Manitoba Department of Mines and Resources, Mines Branch Publication #67-1, p. 61.

Bannantyne, B. B., 1963, Cretaceous Bentonite Deposits of Manitoba, Manitoba Department of Mines and Resources, Mines Branch Publication #62-5, p. 1.

negligible.⁸ Bannantyne (1963) tested samples of shales of the Vermilion River Formation, over which part of Wilson Creek flows, for their swelling properties and found "no swelling, and small fragments show no tendency to disintegrate in water."

In general, the rate of weathering in Wilson Creek Watershed depends on specific combinations of disintegration and decomposition, and on the particular conditions of exposure of shale bedrock to atmospheric conditions. On "transport slopes" (Culling, 1965, p. 231), the rate of weathering is the most important means of supplying transportable materials to Packhorse and Baldhill Creeks.

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^{8.} Personal communication with G. H. MacKay, Chairman Watershed Committee.

Mass Wasting

In a broad sense, mass wasting has been used in the literature to encompass, "a variety of processes by which large masses of earth material are removed by gravity either slowly or quickly from one place to another."⁹ Often mass movement is regarded as synonymous with mass wasting. Carson and Kirkby (1972, p. 99) identify the main types of mass movement as slides, flows and heaves.

In Wilson Creek Watershed, scree slopes are major sites of transfer and deposition of shale debris, supplied from higher elevations; the processes of debris supply and mass wasting on slopes existing in similar environments to Wilson Creek Watershed have been well documented in the works of Schumm (1956), Culling (1963), Young (1963, 1969, 1972), Melton (1965), Kirkby (1967), Gardiner (1969, 1970a and b) and Dingwall (1972), among others. The following account briefly considers specific mass wasting processes in Wilson Creek Watershed.

i) <u>Soil Creep</u>. Soil creep is the gradual movement of soil particles downslope, under the influence of the force of gravity. Its character and causes have been extensively studied. Consequently, the selected references in this section are intended to pertain only to the processes that are presumed to occur in Wilson Creek Watershed. Strahler (1952) suggested that soil

A.I.G. Glossary of Geology and Related Sciences, 1957, p. 308, American Geological Institute, Doubleday and Company Inc., New York.

creep is the result of random movements of soil particles. Young (1972, p. 48) suggested that soil creep is caused by two-fold action. "Regolith particles normally at rest undergo disturbance by some agent, and the force of gravity, acting upon the weight of the particles, then adds a vertical component to the stress. Vertical movement is prevented by the underlying rock so the effect of gravity is to add a downslope component to all individual particle movements, and therefore, to the net movement of the regolith."

In Wilson Creek Watershed, the main agents of disturbances are frost heave, rain-splash and rain-wash. Soil creep is facilitated by the addition of moisture from spring snow-melt which acts as a lubricant. High moisture content reduces soil strength and encourages slope failure. The greatest number of occurrences of accelerated soil creep in Wilson Creek Watershed were observed after the spring melt. As it is particularly effective in the spring, it can therefore be considered a "seasonal" phenomenon (Kirkby, 1967, p. 360).

Apart from seasonal hydrological conditions, soil creep in Wilson Creek Watershed is influenced by the nature of surficial material on slopes. For instance, there is no evidence of soil creep on the shale screes, essentially because of their coarse fragmented nature. However, soil creep is predominant on the clayey till slopes, and somewhat less on the sandy till slopes found

in the upper reaches of Packhorse and Baldhill Creeks. This is because downslope movement is facilitated by the higher percentage of clay which retains more moisture than sand. Figures 58 and 59 show by the letter A in each case, the sites of soil creep on sandy and clayey till slopes respectively. In Figure 59 'B' indicates the adjacent sandy till. Zone A in Figure 58 identifies the area of sandy till where fines are removed downslope by rain-splash and rain-wash. It is likely that the soil creep rates on the clay and sandy till are rather dissim-In view of the diversity of slope forms, Melton ilar. (1965) maintains that the nature of surficial material on slopes is at least as important as other factors and that the different processes including soil creep that occur on slopes vary considerably in relative importance depending on elevation, slope angles and the nature and properties of the bedrock.

Although, in general, the rate of movement on hillsides is proportional to the gradient (Culling, 1963), the two till slopes observed in the Watershed have similar gradients. Their dissimilar rates of soil creep demonstrate that the nature of the surficial material is highly important in determining the relative rapidity of movements of this type of mass wasting.

ii) <u>Talus Shift</u>. Soil creep is by no means the only mass wasting effect on the slopes of Wilson Creek Watershed. Talus shift (Gardiner, 1969) is the "very slow



Figure 58. Soil Creep and Debris Slide on Sandy Till.



Figure 59. Debris Slide on Clayey Till (A) and Soil Creep on Sandy Till (B).

movement of surface layers of slopes of rock fragments on scree typically occupying the foot of steep cliffs" (Hutchinson, 1968, p. 689). Evidence of talus shift in Wilson Creek Watershed is found on the shale scree slopes of Mount Dunning (Figure 60). Rows of willows were planted in a contour trench--free of wind-blown shale flakes--in the summer of 1961. This stability measure was used to prevent downslope movement of shale particles. Four years later, the willow plants had shifted approximately three feet downslope. Although the willows reduce the tendency for shale flakes to be blown away, talus shift continued progressively, being facilitated by "surface heaving and compaction" (Schumm, 1967, p. 560) due to freeze-thaw processes. On the shale screes, any disturbances by wind, debris fall, or by humans causes considerable movement of dry shale flakes downslope. MacKay and Stanton (1964, p. 8) noted that "it is possible to sit close to one of these shale banks even on calm days and observe the material sloughing off to build up a continuous fan at the toe of the slope."

As Kirkby and Statham (1975) point out, most screes are developed under conditions of weathering and rockfall. In Wilson Creek Watershed, observations corroborate the view (Statham, 1973) that the falling shale fragments continue to move after impact on the scree slope and they, in turn, displace particles with which they collide. For this reason, the largest shale





plates are always at the base of scree slopes in the Watershed.

On 40° shale slopes in Western Colorado--similar to that in Wilson Creek Watershed--Schumm (1967) found that frost action in the weathered shale zone is a major factor causing surficial rock creep of weathered shale. More detailed investigations on talus shift in Wilson Creek Watershed would probably verify Schumm findings on surficial rock creep on shale slopes.

iii) Slumping. Slumping is a mass wasting process that involves "the downward slipping of one or several rock units or rock debris usually with a backward rotation with respect to the slope over which movement takes place" (Thornbury, 1962, p. 46). Slumping is a common phenomenon on the till-covered banks in Wilson Creek Watershed. The main cuase of slumping here is the undercutting of slopes by Baldhill and Packhorse Creeks. This process occurs during the spring on the wet till slopes, in the upper reaches of the Watershed. MacKay and Stanton (1964, p. 8) note that "there are some contributions to the streams in the form of slumping. These slumps are grass covered for the most part and are generally associated with wet areas." Figure 61 shows a "slump face" (MacKay and Stanton, 1964) or scarp on clay till resulting from the creation of rotated masses such as the slump identified by 'S'. Figure 62 shows the effects of slumping on the banks of Packhorse Creek;



Figure 61. Slumping.



Figure 62. Slumping and Tree Fall.

these are characterized by a matrix of fallen trees and mud resulting from rotational sliding caused by basal stream erosion of the slope. Figure 63 depicts a slump scarp 'S' and a transverse ridge 't' occurring on sandy till debris mantle in the upper reaches of Baldhill Creek; the underlying shale beds are exposed in the scarp.

iv) <u>Debris Sliding</u>. Debris slide involves the sliding of debris downslope resulting from "abnormal saturation, and taking place on comparatively steep slopes" (Sparks, 1972, p. 58). In Figure 58, 'B' identifies the slide zone occurring on sandy till. In Figure 59, 'A' identifies a larger slide zone occurring on clayey till. Both these examples of debris slide were observed in the upper reaches of Wilson Creek Watershed.

Gully Erosion

Slope erosion by gullying is evident on the till slopes of the upper reaches of the Watershed. Gullying is essentially a linear erosion process that moves material downslope. Heinemann and Piest (1975) maintain that the development of gullies requires two conditions. There must be weathering or mass wasting to furnish soil debris for gully transportation and runoff to transport the debris. These conditions are both satisfied in Wilson Creek Watershed. Weathering loosens the material on the slopes, thus preparing them for transportation. Therefore, the movement



Figure 63. Slumping Due to Basal Erosion.

of material within gullies, at any given time, is a function of sediment transport, runoff and the rate of soil detachment (Piest, Bradford, Wyatt, 1975).

Figure 64 shows the development of gullies on an unvegetated slope on sandy till in Wilson Creek Watershed. There are, however, no gullies on the shale screes due to infiltration rates on loose talus materials. The occurrence of gullies on sandy till and their absence on the shale screes show that material type predominates over all other factors in gully development within the study area. It has also been observed that the gullies developed on the till do not exceed one foot in width, but their depths are usually greater, perhaps due to piping. However, it is beyond the scope of this research to investigate these phenomena in more detail.

On the whole, C. B. Beaty's following description of the role of gullying on slope retreat adequately applies to the sandy till banks of Packhorse and Baldhill Creeks. "When heavy rain falls, surface runoff again collects in partially filled gullies and again flushes them out, thus intensifying the relief. The cycle is repeated; slice by slice, the slope is literally peeled away" (Beaty, 1959, p. 1481).



Figure 64. Example of Gullying.

Wind Erosion and Debris Fall

These two processes are grouped together in the Watershed because they often occur simultaneously. Here, debris fall is initiated primarily by wind. The shale debris that had accumulated by fall (identified as 'E' in Figure 65) was displaced mainly by wind erosion.

Wind is an important agent in the transport of shale flakes downslope to the stream channel. The effect of wind was observed on the slopes of Mount Dunning, where the contour trenches--in which willows were planted for shale stabilization--were filled by wind-blown shale flakes. The infilling occurred particularly in the summer when the weathered shale flakes on the surface of screes are light and dry.

A simple experiment was carried out by the author to demonstrate the effect of wind and debris fall as a supplier of sediment to the stream channel. In July, 1974, a meshed trough three feet by two feet by one foot was placed at the base of the pin bank on Packhorse Creek. After an hour, with an average wind speed of twelve miles per hour--recorded at the crest of the Watershed--the trough was filled with shale flakes contributed by wind and debris fall. In Figure 66, 'D' identifies the shale fragments at the base of the free face. It is apparent that the trough only captured a small amount of shale flakes blown by wind or falling directly by gravity into the stream below, but this simple experiment



Figure 65. Shale Removal by Wind and Debris Fall.

indicates the role of wind and debris fall as a contributor to channel sediments.

Wind removal of material is not important on the till slopes found in the upper part of the Watershed. This is because the slopes are mainly vegetated and this underlying fairly moist regolith does not facilitate removal by wind.

Basal Undercutting

Basal undercutting or "basal sapping" (Packer, 1964) is the result of loosening or detachment and removal of rock or scree by the stream at the toe of a shale slope or bank. Undercutting of free faces is responsible for parts of the bank falling into the stream, thus adding material directly to the stream and facilitating lateral retreat. Basal undercutting is caused by lateral stream corrasion, especially under high discharge conditions. The pin banks in Wilson Creek Watershed are examples of parallel retreat (Chapter II) caused by the combined action of basal undercutting, rock fall, weathering and wind erosion. Figure 66 shows an example of basal undercutting (identified as 'U') occurring at the foot of the pin bank on Packhorse Creek.

Conclusion

This chapter isolates and describes, generally, the major processes that are responsible for the retreat of shale and till banks in the Watershed. Less extensive, and therefore, relatively minor processes that are nonetheless significant include debris slides and debris flows on clay



Figure 66. Basal Undercutting and Debris Fall.

till especially during wet periods. The combined effect of all these processes is to produce sediment available for transport by the creeks. On most slopes, two or more of these processes occur simultaneously. The predominance of any one of the major processes described earlier depends on the nature of the material, weather conditions and the morphology of the slopes.

Having identified the major processes of shale bank retreat, a model for the development of shale banks and screes in Wilson Creek Watershed can now be attempted.

Figure 67 (Stage I) shows the initial stage of bank erosion. This stage is characterized by a relatively small exposure of till or regolith due to removal of vegetation. Weathering, basal sapping, debris fall and rill development are the main processes. Slope angles vary from 15 to 25 degrees.

Stage II (Figure 68) is characterized by the first exposure of shale beds forming an erosion scar that is partly in bedrock. Basal sapping continues to be an important process. Slope angles vary from 25 to 35 degrees.

Stage III (Figure 69) is typified by cliffing due to continued stream undercutting and a consequent larger exposure of shale bedrock. Rock fall of shale plates and debris fall of overlying material for the first time produce a thin debris cover on narrow ledges or concave facets of the bank. Slope angles vary from 35 to 45 degrees.



Figure 67. Stage I - Exposure of Soil and Till by Removal of Vegetation.



Figure 68. Stage II - Erosion of Surficial Material and Exposure of Shale Bedrock.



Figure 69. Stage III - Cliffing, Rock Fall and Debris Fall.

Stage IV may be characterized by a well-developed free face (Figure 70) with precipitously steep gradients (i.e., over 50°) due to pronounced basal undercutting. Alternatively, if undercutting ceases due to lateral stream migration, screes may develop downslope from the free faces (Figure 57).



Figure 70. Stage IV - Fully Developed Free Face.

CHAPTER V

BANK PROTECTION AND SHALE STABILIZATION

In order to prevent excessive bank erosion in Wilson Creek Watershed, protection and stabilization methods are necessary. Bank protection measures in the Watershed have two purposes. Firstly, they retard the flow along the base of the banks, hence promoting deposition. Secondly, they provide a bulwark against direct lateral stream erosion of the banks.

Revetments are the most common methods of protection used within the Watershed. Because the physical characteristics of revetments are variable, a precise definition of the term is difficult.

The material of which they are constructed must be sufficiently durable and strong to prevent destruction and displacement by the force of the river current and by the impact of debris carried along the river. In addition, they must be flexible enough, particularly in the case of continuous revetments, to readily adjust to the contours of the river bank above water surface and to the changing contours below surface water. (Winkley, 1971, p. 19)

According to Linsley and Franzini (1964), a revetment that is considered effective must extend from the top of the bank to below the water level. It is important to consider the type of sediment, sediment transport, slope morphology, channel depths, discharges and flow direction in choosing the type of revetment to be used.

The most effective revetments used in Wilson Creek Watershed are rock rip raps (Figures 71 and 72). Rock rip raps are uncemented boulders placed at a lower slope gradient than the angle of repose of the bank material. Their purpose is to protect the stream bank from erosion. Most rip raps have been placed on concave outer banks of meanders where rapid erosion otherwise results in materials slumping into the stream channel (Figure 71). There are, however, instances where rip raps were placed on the banks of straight channels subject to undermining. Since "undermining or scouring of the foundation material by high velocity currents has been the original cause of most bank protection failures",¹⁰ the rock rip raps used in the Watershed were placed at the bases of the banks where such processes occur. All rip raps used in the Watershed were made from local granitic and limestone boulders. When boulders are properly placed in relation to flow direction and slope morphology, they are considered "one of the most effective methods of bank protection" (Barnes, 1971, pp. 28-21).

Another effective bank protection device used in the Watershed is the log crib (Figures 73 and 74). Log cribs are temporary structures employed to prevent bank caving. They are found mainly on steeper banks where the use of

^{10.} Barnes, R. C., 1971, "Erosion Control Structures", in <u>River Mechanics</u>, Vol. II, edited by Hsieh Wen Shen, Fort Collins, Colorado.



Figure 71. Rip Rap on Concave Bank of Meander.



Figure 72. Rip Rap on Straight Channel Bank.





Figure 74. Double-Layer Log Crib.

rip raps is impractical. The main problem with such cribs is that the logs rot in a few years time and consequently, constant checking and repairs are necessary. There are two types of log cribs in Wilson Creek Watershed. These are the single-layer and double-layer log cribs. The single-layer variety (Figure 73) protects the bank from scouring by high velocity currents and from the accompanying caving. The double-layer crib (Figure 74) has an additional layer of logs built away from the stream; the riparian layer has the same function as the single-layer log crib, but the layer farther away from the stream serves to retard the movement of scree material.

A method used to prevent the movement of shale flakes downslope involves the placing of tires on exposed shale Tires are tied to one another with wires to scree sites. prevent their movement. An experiment carried out to test the effectiveness of this method was initiated in August, 1964, on the slopes of Mount Dunning (Figure 75). The site is unvegetated, steeply sloping and exposed to the wind. The potency of wind action at this site is acknowledged by MacKay and Stanton (1965, p. 19) who note "that during high winds on Mount Dunning it is not possible to face into the wind because of flying shale particles." In the experiment, Juniper trees (Juniperus horizontalis) were planted within the tires. It was expected that the anchoring effect of juniper roots and the blanket effect of tires would stabilize the finely weathered fragments on Mount Dunning slopes.



Figure 75. Shale Movement Around Tires, August 1964.

This experiment proved unsuccessful, because by May, 1965, shale flakes had nearly covered the tires (Figure 76) due to wind action.

Another experiment aimed at stabilizing the shale screes on the slopes of Mount Dunning was the planting of willows (<u>Salix acutifolia</u>) in contour trenches (Figure 77). This method was considered "most promising" by MacKay and Stanton (1964, p. 18) in that the willow plants tended to anchor more shale fragments around their roots than did the juniper planted within the tires in the other experiment.

The effectiveness of willows in stabilization is amply demonstrated by MacKay and Stanton (1964, p. 20) who have observed that the:

vegetative bank protection has relied heavily on willows. One particularly sharp curve was improved by removal downstream of portion of the convex side. The concave side presented a very large bank formerly a direct contributer of shale. With the extra room thus gained, it was possible to build a boulder revetment backed by a 'willow spider' work.

Thus in Wilson Creek Watershed, both mechanical and vegetative methods of bank protection and shale scree stabilization have been applied. Rock rip raps and log cribs are very effective, simple to construct and require minimal maintenance. Revegetation by planting willows appears encouraging. Although most of these protective devices were still in position at the time of field investigation, it is, however, beyond the scope of this research to assess these stability measures quantitatively in terms of estimating the reduction in sediment output from the shale banks. Table 7



Figure 76. Shale Movement Around Tires, May 1965.


Figure 77. Willow Planted in Contour Trenches.

in Chapter III shows that for the 1964-1972 period, the total amount of bedload material varies considerably from year to year. This may be due partly to bank protection. Additional research in this area, however, might reveal the effectiveness of these methods in relation to total sediment production. Nevertheless, protective and stability measures such as rock rip raps, log cribs and revegetation by willows have been demonstrably effective in preventing bank erosion and reducing shale movement downslope at certain sites in Wilson Creek Watershed.

CHAPTER VI

CONCLUSION

The current study of shale bank retreat and sediment transport in Wilson Creek Watershed can be accommodated within the process-response system described by Kennedy and Chorley (1971, p. 136) and reproduced as Figure 78. According to this model, the Watershed can be divided into slope and channel subsystems. Within the slope subsystem, processes on the shale banks generally produce screes in a late stage of bank development. The debris produced from the slope processes operating on the shale banks, including scree slopes, constitute a major input to the channel subsystem.

Located in the middle reaches of Packhorse and Baldhill Creeks and extending from 30 to 200 feet in height, the banks are eroded in horizontally bedded shales that weather to produce platey fragments which fall or even slide to produce basal screes. The screes along Packhorse and Baldhill Creeks have a characteristic angle of about 37 degrees. Moreover, as demonstrated statistically in Chapter II, the screes located 'at' a stream are less stable than those 'away' from a stream.



Figure 78. Process Response Model (Kennedy and Chorley,

1971).

There are numerous processes responsible for till slope and shale bank evolution and retreat in the Watershed. 0f these, weathering is the most extensive and is instrumental in preparing materials to be removed by various processes of mass wasting, wind transportation and surface water erosion. Soil creep, slumping and gullying are confined to till slopes in the upper reaches of the Watershed. The free faces of the shale banks experience, by and large, rock fall (sometimes initiated by wind erosion and debris fall). Where there is basal undercutting, the free faces may also undergo rock sliding or slumping. Finally, the shale talus slopes are subject to shift by several mechanisms of which individual plate sliding, heaving or rolling, or localized debris sliding may be most important. Fine shale flakes are also eroded from the screes by wind.

In Wilson Creek Watershed, the shale banks have retreated at an average annual rate of 0.5 feet on Packhorse Creek and 0.2 feet on Baldhill Creek. However, collectively, the Baldhill shale banks supply more scree material than do those of Packhorse. During 1964-1972, there has been an appreciable overall development of screes along Baldhill Creek, whereas the cumulative size of those along Packhorse Creek has markedly diminished.

Sediment studies in this research show that the shale banks are the main source of sediment supply to streams in Wilson Creek Watershed. Longitudinal profile determinations reveal a slight, but general rise in stream bed height, hence

most sediment must be derived from lateral erosion of the shale banks. Similarly, determinations of cross-sectional areas of major stream channels at 24 stations for 1964-1971 reveal substantial aggregate net deposition, as over this period aggradation was three times greater than degradation.

Within the Watershed, log cribs and rip raps are the most effective bank protection methods. Revegetation by willows has proved to be valuable in promoting shale stabilization. However, additional field research is required in order to evaluate the actual rate of sediment reduction by using such stabilization measures.

The shale trap on Wilson Creek enables a fair estimate of bedload to be computed. In physical terms, it reduces the infilling of the stream channel further downstream, hence alleviating flooding of agricultural land below the escarpment. However, if the shale trap was located further downstream where the stream velocity is less, it would be more effective in retaining a greater proportion of the bed load and possibly a reduction of bank erosion would ensue.

REFERENCES

- A. I. G. Glossary of Geology and Related Sciences, 1957. American Geological Institute, Doubleday and Company Inc., New York.
- Banera, N. G., 1972. "Evaporation and Wilson Creek Watershed", unpublished M.Sc. Thesis, University of Manitoba.
- Bannantyne, B. B., 1963. "Cretaceous Bentonite Deposits in Manitoba", Manitoba Department of Mines, Resources and Environmental Management, Mines Branch Publication, #62-5.
- Bannantyne, B. B., 1970. "Clays and Shales of Manitoba", Manitoba Department of Mines, Resources and Environmental Management, Mines Branch Publication, #61-1.
- Barnes, R. C., 1971. "Erosion Control Structures", in <u>River Mechanics</u>, Vol. II, Ed. Hsieh Wen Shen, Fort Collins, Colorado.
- Beaty, C. B., 1959. "Slope Retreat by Gullying", Bull. Geol. Soc. of America, Vol. 70, pp. 1479-1482.
- Bilozor, W., 1972. "Storm Rainfall Runoff Relations in Wilson Creek Watershed, Manitoba", Unpublished M.Sc. Thesis, University of Manitoba.
- Bunting, B. J., 1967. <u>Geography of Soils</u>, Adline Publishing Co., Chicago.
- Carr, R. A., 1965. "Geological and Hydrological Reconnaissance of Wilson Creek Basin, Manitoba", Geol. Survey of Canada, Topical Report #106.
 - Carson, M. A. and M. J. Kirby, 1972. <u>Hill Slope Form and</u> Process, Cambridge University Press Ltd.
 - Cass, D., 1970. "Snow Melt as Predicted by Surface Energy Balance", unpublished M.Sc. Thesis, University of Manitoba.
 - Cox, R. A., 1968. "An Investigation into Stream Flow and Ground Water Hydrology of Wilson Creek, a Small Manitoba Watershed", unpublished M.A. Thesis, University of Manitoba.

Culling, W. E. H., 1963. "Soil Creep and the Development of Hillside Slope", Journal of Geology, Vol. 71, pp. 127-161.

, 1965. "Theory of Erosion on Soil Covered Slopes", Journal of Geology, Vol. 73, pp. 230-254.

- Dingwall, P. R., 1972. "Erosion by Overland Flow on Alpine Debris Slopes", <u>Mountain Geomorphology</u>.
- Doornkamp, J. C. and C. A. M. King, 1971. <u>Numerical</u> Analysis in Geomorphology, Arnold, London, 372 pages.
- Frenette, M. and Harvey, 1973. "River Channel Processes" in <u>Fluvial Processes and Sedimentation</u>, proceedings of Hydrology Symposium, University of Alberta, Edmonton, May 8th and 9th, 1973.
- Gardiner, J., 1969. "Observations of Surficial Talus Movement", Zest for Geom., #13, pp. 317-323.
- Gardiner, J., 1970a. "Rockfall, A Geomorphic Process in High Mountain Terrain", <u>Albertan Geographer</u>, Vol. 6, pp. 15-21.
- Gardiner, J., 1970b. "A Note on the Supply of Material to Debris Slope", Canadian Geographer, #14, pp. 369-372.
- Gessler, J., 1971. "Aggradation and Degradation", in <u>River</u> <u>Mechanics</u>, Vol. I, Ed. Hsieh Wen Shen, Fort Collins, Colorado.
- Heinemann, G. H. and R. F. Piest, 1975. "Soil Erosion -Sediment Yield, Research in Progress", <u>Transactions</u>, American Geophysical Union, Vol. 56, No. 3, March 1975.
- Hutchinson, J. N., 1968. Entry on "Mass Movement" in Fairbridge, Rhodes W. <u>Encyclopedia of Geomorphology</u>, pp. 688-695, Reinhold Book Corporation, New York.
- Kennedy, B. A. and R. L. Chorley, 1971. Physical Geography: A Systems Approach, Prentice-Hall, London, 375 pages.
- Kirkby, M. J., 1967. "Measurement and Theory of Soil Creep", Journal of Geology, Vol. 75, pp. 359-718.
- Kirkby, M. J. and I. Statham, 1975. "Surface Stone Movement and Scree Formation", <u>Journal of Geology</u>, Vol. 83, pp. 349-362.
- Leopold, L. B., M. G. Wolman and J. P. Miller, 1964. <u>Fluvial Processes in Geomorphology</u>, W. H. Freedman and <u>Co.</u>, San Francisco, 522 pages.

Linsley, R. K. and J. B. Franzini, 1972. Water Resources Engineering, 2nd Edition, McGraw-Hill, New York.

- MacKay, G. H. and C. R. Stanton, 1964. "Wilson Creek Study: Erosion and Sedimentation Control", in <u>Research</u> <u>Watersheds</u>, Proceedings Hydro Symposium #4, N.R.C., Canada.
- MacKay, G. H., 1970. "A Quantitative Study of the Geomorphology of Wilson Creek Watershed, Manitoba", unpublished M.Sc. Thesis, University of Manitoba.
- Melton, M. A., 1965. "Debris Covered Hillslopes of the Southern Arizona Desert--Consideration on Their Stability and Sediment Contribution", <u>Journal of Geology</u>, Vol. 73, pp. 715-729.
- Ollier, C., 1969. Weathering, Ed. K. M. Clayton, Oliver and Boyd, Edinburg.
- Packer, R. W., 1964. "Stability Slopes in an Area of Glacial Deposition", <u>Canadian Geographer</u>, VIII, 3, pp. 147-151.
- Piest, K. F., J. M. Bradford and G. M. Watt, 1975. "Soil Erosion and Sediment Transport from Gullies", Journal of Hydraulic Division, A.S.C.E., Vol. 101, #Hy I.
- Schwartz, F. W., 1970. "Geohydrology and Hydrogeochemistry of Groundwater: Stream Flow Systems in Wilson Creek Watershed, Manitoba", unpublished M.Sc. Thesis, University of Manitoba.
- Schumm, S. A., 1956. "The Role of Creep and Rain Wash Erosion on the Retreat of Badland Slopes", <u>American</u> Journal of Science, Vol. 254, pp. 693-706.
- Schumm, S. A., 1967. "Rates of Surficial Rock Creep on Hillslopes in Western Colorado", <u>Science</u>, 155, pp. 560-561.
- Sparks, B. W., 1972. <u>Geomorphology</u>, Longmans Group Ltd., London.
- Statham, I., 1973. "Scree Slope Movement Under Conditions of Surface Particle Movement", Institute of British Geographers, Transactions #59, pp. 41-53.
- Strahler, A. N., 1952. "Dynamic Basis of Geomorphology", Bulletin, Geological Society of America, Vol. 63, pp. 923-938.

- Sydor, M., 1970. "Computer Simulation Model of Wilson Creek Watershed", unpublished M.Sc. Thesis, University of Manitoba.
- Thomlinson, J., 1965. "Report on the Activities in Wilson Creek Watershed, Manitoba", Regional Division, P.F.R.A., Winnipeg.
- Thomlinson, J., 1966. "Report on the Activities in Wilson Creek Watershed, Manitoba", Regional Division, P.F.R.A., Winnipeg.
- Thomlinson, J., 1969. "Report on the Activities in Wilson Creek Watershed, Manitoba", Regional Division, P.F.R.A., Winnipeg.
- Thomlinson, J., 1970. "Report on the Activities in Wilson Creek Watershed, Manitoba", Regional Division, P.F.R.A., Winnipeg.
- Thornbury, W. J., 1962. <u>Principles of Geomorphology</u>, John Wiley and Sons Inc., New York.
- Tricart, J., 1970. <u>Geomorphology of Cold Environments</u>, McMillan and Co. Ltd., London.
- Wickenden, R. T. D., 1945. "Mesozoic Stratigraphy of the Eastern Plains, Manitoba and Saskatchewan", Canadian Department of Mines and Resources, Mines and Geology Branch, Geological Survey Memoir 239.
- Winkley, B. R., 1971. "Practical Aspects of River Regulation and Control", in <u>River Mechanics</u>, Vol. I, Ed. Hsieh Wen Shen, Fort Collins, Colorado.
- Young, A., 1963. "Soil Movement on Slopes", <u>Nature</u>, Vol. 200, pp. 129-130.
- Young, A., 1969. "The Accumulation Zone on Slopes Zeit Fur", Geom. 13, pp. 231-233.
- Young, A., 1972. <u>Slopes</u>, Ed. K. M. Clayton, Oliver and Boyd, Edinburgh.

APPENDIX I

"Length of Bank" Denotes the Length of Scree Along the Bank.

Letters 'A', 'B' and 'C' Denote Particular Screes on a Specific (Numbered) Shale Bank.

Shale Bank #	Slope Angles in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
1	34	0.5592	7	3, 9	76	4.7	*		25.8
2	36	0.5878	13	7.6	44	9.3	*		57.6
2 Þ	36	0.5878	13	7.6	200	9.1		*	256.1
3	39	0,6293	13	8.2	236	6.3	*		255.8
4	40	0.1428	10	6.4	134	3.3	*		52.4
5	37	0.6018	9	5.4	196	2.5	*		49.0
6	35	0.5736	8	4.6	110	3.1		*	29.0
7	39	0.6293	12	7.6	150	4.4		*	92.9
8	-	-	-	-	169	-	*		
9	38	0.6157	12	7.4	486	5.0	*		333.0
10	37	0.6018	12	7.2	67	6.6	*		59.0
11A	35	0.5736	4	2.3	50	4.2	*		62.7
11B	37	0.6018	11	6.6	106	7.3	*		94.6
12	37	0.6018	32	19.3	213	9.3 ^{***}	*		708.0
13A	36	0.5878	15	8.8	62	7.9		*	79.8
13B	34	0.5592	6	3.4	66	4.3	*		17.9
14	38	0.6157	11	6.8	101	5.6	*		71.2
15	39	0.6293	10	6.3	183	2.4	*		51.2
16	37	0.6018	11	6.6	150	4.3	*		78.8

SHALE SCREE MEASUREMENTS - PACKHORSE CREEK NOVEMBER, 1964

Shale Bank #	Slope Angles in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
17	39	0.6293	13	8•2	205	5.7	*		177.4
18	37	0.6018	7	4.2	153	5.6	*		66.6
19A	39	0.6293	24	15.1	50	5.3	*		74.1
19B	39	0.6293	24	15.1	124	5.8	*		127.0
19C	39	0.6293	24	15.1	138	4.8	*		185.2
20	34	0.5592	10	5.6	122	4.8	*		60.7
21A	37	0.6018	14	8.4	56	6.7	*		58.4
21B	37	0.6018	14	8.4	279	8.1	*		351.5
22A	39	0.6293	12	7.6	76	5.6	*		59.9
22B	39	0.6293	12	7.6	170	4.0	*		95.7
22C	39	0.6293	12	7.6	71	2.9	*		29.0
23	34	0,5592	10	5.6	129	3.3	*		44.1

SHALE SCREE MEASUREMENTS - PACKHORSE CREEK NOVEMBER, 1964 (continued)

Shale Bank #	Slope Angles in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
1	39	0.6293	11	6,9	28	9,4	*		33.6.
2A	34	0.5592	13	7.3	43	10.5	*		61.0
2B	36	0.5878	14	8.2	176	9. 0*		*	240.5
3	36	0.5878	15	8.8	170	7.4	*		205.0
4	-	-	-	_	137	-	*		-
5	38	0.6157	10	6.2	52	5.3	*		31.6
6	40	0.6428	12	7.7	58	10.5		*	86.8
7	37	0.6018	10	6.0	28	6.0	*		18.7
8A	42	0.6191	5	3.3	22	3.6	*		4.8
8B	45	0.7071	10	7.1	34	5.2	*		23.2
9A	37	0.6018	28	16.9	98	10.3	*		315.9
9B	44	0.6947	5	3.5	42	2.5	*		6.8
9C	33	0.5446	21	11.4	52	11.4		*	125.1
10	37	0.6018	17	10.2	61	8.8	*		101.4
11A	36	0.5878	17	10.0	118	11.2	*		244.7
11B	37	0.6018	16	9.6	48	7.5	*		64.0
11C	40	0.6428	14	9.0	118	10.6	*		208.5
12	38	0.6157	17	10.5	161	7.6	*		237.9
13A	36	0.5878	20	11.8	73	9.7		*	154.7

SHALE SCREE MEASUREMENTS - PACKHORSE CREEK JUNE, 1965

Shale Bank #	Slope Angles in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
1 3B	34	0.5592	22	12.3	61	14.0	*	<u> </u>	194.5
13C	36	0.5878	11	6.5	73	5.4	*		47.5
14A	28	0.4695	8	3.8	50	5.2	*		18.3
14B	38	0.6157	16	9.9	44	7.4	*		59.6
15	44	0.6947	12	8.3	63	6.3	*		61.0
16	36	0.5878	11	6.5	120	6.6	*		95.3
17	40	0.6428	24	15.4	162	7.0	*		323.4
18	39	0.6293	10	6.3	92	8.2	*		88.0
19A	33	0.5446	23	12.5	130	6.3		*	189.6
19B	37	0.6018	22	13.2	110	8.6		*	231.2
19C	41	0.6561	24	15°.8°	79	8.8	*		203.4
20A	39	0.6293	11	6.9	30	6.3	*		24.1
20B	37	0.6018	11	6.6	64	8.4	*		65.7
21A	41	0.6561	16	10.5	100	7.3	*		141.9
21B	34	0.5592	33	18.5	153	10.8		*	566.1
21C	38	0.6157	13	8.0	56	7.3		*	60.6
22A	37	0.6018	17	10.2	28	9.2	*		48.7
22B	41	0.6561	13	8.5	53	4.8	*		40.0
22C	39	0.6293	18	11.3	45	11.1	*		104.5

SHALE SCREE MEASUREMENTS - PACKHORSE CREEK JUNE, 1965 (continued)

Shale Bank #	Slope Angles in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
								·····	
1	38	0.6157	15	9.2	27	7.4	*		34.0
2A	40	0.6428	19	12.2	41	14.6	*		135.2
2B	37	0.6018	18	10.8	144	11.0		*	316.8
3	37	0.6018	21	12.6	114	8.1	*		215.5
4		_	-	· _	137	-	*		-
5	38	0.6157	11	6.8	53	8.2	*		54.7
6	38	0.6157	18	11.1	60	10.1		*	124.6
7	40	0.6428	13	8.4	28	6.0	*		26.1
8 .	32	0.5299	26	13.8	52	10.7	• •	*	142.2
9	42	0.6691	25	16.7	141	9.8	*		427.3
10	36	0.5878	17	10.0	60	9.3	*		103.3
11A	37	0.6018	18	10.8	120	10.8	*		259.2
11B	39	0.6293	15	9.4	87	7.1	*		107.5
11C	35	0.5736	12	6.9	50	6.1	*		39.0
12	37	0.6018	17	10.2	210	8.3	*		329.2
13A	36	0.5878	23	13.5	90	9.4	*		211.5
13B	36	0.5878	26	15.3	62	11.4		*	200.3
14	36	0.5878	14	8.2	95	7.0	*		101.0
15	41	0.6561	14	9.2	63	5.6	*		80.1

SHALE SCREE MEASUREMENTS - PACKHORSE CREEK JULY 1965

Shale Bank #	Slope Angles in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
16	37	0.6018	9	5,4	43	8.4	*	•	36.1
17A	42	0.6691	19	12.7	84	7,8	*		154.1
17B	39	0.6293	15	· 9.4	58	7.8	*		78.8
18	38	0.6157	12	7.4	89	9.2	*		112.2
19A	34	0.5592	23	12.9	94	9. 0*		*	202.1
19B	38	0.6157	20	12.3	108	7. 8 [°]	*	۰.	191.9
19C	39	0.6293	18	11.3	66	8.2	*		113.3
20	34	0.5592	13	7.3	66	9.8		*	87.4
21A	41	0.6561	14	9.2	144	9.4	*		230.6
21B	33	0.5446	30	16.3	100	11.6		*	350.1
21C	37	0.6018	15	9.0	55	10.6		*	97.2
22A	37	0.6018	22	13.2	28	9.6	*		65.7
22B	40	0.6428	14	9.0	40	9.1	*		60.7
22C	38	0.6157	24	14.8	34	12.4	*		115.5
23	41	0.6561	12	7.9	149	7.6	*		165.7

SHALE SCREE MEASUREMENTS - PACKHORSE CREEK JULY 1965 (continued)

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Shale Bank #	Slope Angles in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
1	40	0.6428	14	9.0	en e	6.1	*		49.8
2A	36	0.5878	18	10.6		15.0	*		120.7
2B	34	0.5592	15	8.4		9.3	*		243.0
3	38	0.6157	18	11.1		7.9	*		194.9
4	-	_	_	-	137	-	*		
5	38	0.6157	12	7.4	85	4.7	*		54.7
6	41	0.6561	19	12.5	60	9.5	*		131.9
7	41	0.6561	15	9.8	42	4.4	*		33.5
8	. –	-	_	-	62	-		*	
9A	34	0.5592	16	9.0	54	10.6		*	95.4
9B	41	0.6561	10	6.6	278	5.6	*		190.3
10	37	0.6018	17	10.2	64	8°03	*		96.7
11A	38	0.6157	17	10.5	68	6.4	*		84.6
11B	37	0.6018	18	10.8	118	10.1	*		238.4
11C	37	0.6018	10	6.0	116	5.2	*		67.0
12	39	0.6293	20	12.6	214	8.8	*		493.4
13A	37	0.6018	22	13.2	60	11.7		*	171.6
13B	36	0.5878	20	11.8	87	9.0	*		171.1
14	38	0.6157	21	12.9	94	5.9	*		132.5
15	39	0.6293	14	8.8	57	6.6	*		61.3 µ

SHALE SCREE MEASUREMENTS - PACKHORSE CREEK AUGUST, 1965

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Shale Bank #	Slope Angles in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
16	28	0 6157	16	. 0 01		Q 2	*	<u>.</u>	66 1
10	0C	0.6429	20	2, 2 12 0	44	7 9	*		324 6
1/	40	0.0428	20	12,9	100	6.6	4		924.0
18	38	0.6157	10	0.2	109	0.0	~		02.0
19A	39	0.6293	22	13.8	45	6.7	*		77.1
19B	37	0.6018	20	12.0	92	7.2	*		147.2
19C	36	0.5878	18	10.6	88	6.6		*	114.0
20	38	0.6157	14	8.6	105	8.0	*		133.8
21A	36	0.5878	16	9.4	60	8.3		*	86.7
21B	36	0.5878	27	15.9	100	11.3	.): 	*	86.7
21C	36	0.5878	27	15.9	122	9.5	*		342.8
22A	39	0.6293	18	11.3	39	13.8	*		112.6
22B	38	0.6157	7	4.3	63	8.1	*		40.6
22C	40	0.6428	11	7.1	66	7.3	*		63.2
23	37	0.6018	13	7.8	44	9.6	*		61.0

SHALE SCREE MEASUREMENTS - PACKHORSE CREEK AUGUST, 1965 (continued)

SHALE SCREE MEASUREMENTS	-	PACKHORSE	CREEK	NOVEMBER,	1965
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Shale Bank #	Slope Angles in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
1	39	0.6293	20	12.6	30	8.1	*		56.7
- 2A	36	0.5878	21	12.3	147	9.5		*	318.1
2B	35	0.5736	20	11.5	43	12.0	*		109.9
3	38	0.6157	20	12.3	125	7.5 ^{°°}	*		213.5
4	_	-	-	-	137	-	*		-
5	38	0.6157	15	9.2	53	6.5	*		58.7
6	39	0.6293	20	12.6	58	7.8		*	105.6
7	37	0.6018	16	9.6	34	5.6	*		33.8
8	-39	0.6293	27	17.0	42	12.0		*	158.7
9	36	0.5878	25	14.7	114	10.4	*		322.8
10	35	0.5736	20	11.5	54	6.8	*		78.2
11A	35	0.5736	20	11.5	120	8.3	*		212.1
11B	38	0.6157	15	9.2	51	7.6	*		66.0
11C	37	0.6018	9	5.4	116	5.5	*		78,2
12	39	0.6293	15	9.4	214	5.8	*		216.1
13A	36	0.5878	24	14.1	89	8.3	*		192.9
1.3B	35	0.5736	24	13.8	57	9.5	*		138.4
14	35	0.5736	15	8.6	103	7.7 *	*		126.3
15	37	0.6018	19	11.4	47	5.8	*		57.5

Shale Bank #	Slope Angles in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
16	37	0.6018	14	8.4	45	7.0	*		49.0
17	39	0.6293	28	17.6	163	7.1	*		377.2
18	44	0.6947	12	8.3	87	6.9	*		92.3
19A	34	0.5592	25	14.0	135	6.4		*	224.0
19B	37	0.6018	24	14.4	87	8.2	*		190.2
19C	41	0.6561	23	15.1	77	6.6	*		142.1
20	38	0.6157	16	9.9	111	8.8	*		179.1
21A	36	0.5878	11	6.5	100	7.6	*		91.5
21B	34	0.5592	28	15,7	96	11.9		*	332.1
21C	37	0.6018	18	10.8	58	7.6		*	88.2
22A	35	0.5736	14	8.0	30	6.8	*		30.2
22B	36	0.5878	9	5.3	39	4.9	*		18.8
22C	39	0.6293	20	12,6	47	9.8	*		107.5
23	31	0.5150	17	8.8	38	6.2	*		38.4

SHALE SCREE MEASUREMENTS - PACKHORSE CREEK NOVEMBER, 1965

(continued)

Shale Bank #	Slope Angles in Degrees	Sine of Angle	Slope Distance <u>(</u> feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
1	38.5	0.6225	16	10.0	32	7.0	*		41.5
2A	37	0.6018	22	13.2	42	12.4	*		127.3
2B	36	0.5878	17	10.0	158	9.4		*	275.0
3	38	0.6157	20	-	129	8.0 ^{**}		*	235.1
4	-	-	-	-	136	-	*		-
5	35	0.5736	16	9.2	74	8.2		*	103.4
6	38	0.6157	19	11.7	24	9.0		*	46.8
7	42	0.6691	13	8.7	32	6.0	*		30.9
8	_	_	-	_	73	-	*		1
9A	32	0.5299	24	12.7	54	11.8		*	149.9
9B	38	0.6157	5	3.1	54	4.6	*		14.3
9C	37	0.6018	9	5.4	34	3.9	*		13.3
9D	36	0.5878	24	14.1	126	8.1	*		266.5
9E	38	0.6157	9	5.5	32	2.0	*		6.5
10	37	0.6018	31	18.6	54	8.0	*		148.8
11A	38	0.6157	17	10.5	50	8.2		*	79.7
11B	35	0.5936	21	12.0	113	11.0		*	276.2
11C	41	0.6561	21	13.8	88	5.8	*		130.4

SHALE SCREE MEASUREMENTS - PACKHORSE CREEK JUNE 1966

Shale Bank #	Slope Angles in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
12	37	0.6018	25	15.0	218	8.3	*	<u> </u>	502.6
13A	40	0.6428	22	14.1	66	9.8		*	168.9
13B	37	0.6018	20	12.0	89	11.5		*	227.4
14A	37	0.6018	22	13.2	46	9.0		*	101.2
14B	37	0.6018	22	13.2	52	6.2	*		78.8
15	40	0.6428	14	9.0	41	6.3	*		43.0
16	39	0.6293	15	8.2	40	8.0	*		48.6
17A	39	0.6293	20	12.6	67	6.7		*	104.7
17B	39	0.6293	20	12.6	80	6.1	*		113.9
18	39.5	0.6361	10	6.4	93	5.5	*		60.6
19A	41	0.6561	18	11.8 [*]	48	5.5	*		57.7
19B	37	0.6018	20	12.0	53	8.2	*		96.6
19C	34	0.5592	18	10.1	80	5.1		*	76.3
19D	34	0.5592	18	10.1	14	2.5	*		6.5
20A	38	0.6157	12	7.4	31	7.6	*		32.3
20B	39.5	0.6361	10	6.4	23	3.7	*		10.1
21A	37.5	0.6088	15	9.0	60	7.7		*	77.0
21B	33	0.5446	26	14.2	87	11.8		*	270.0

SHALE SCREE MEASUREMENTS - PACKHORSE CREEK JUNE 1966 (continued)

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Shale Bank #	Slope Angles in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
21C	37	0.6018	10	6.0	150	5.4	*		9.0
22A	37	0.6018	14	8.4	26	8.1	*		32.8
22B	40	0.6428	13	8.4	54	3.4	*		28.6
22C	. 35	0.5736	9	5.2	23	7.0	*		15.5
23	_		_	-	100	· _		*	-

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SHALE SCREE MEASUREMENTS - PACKHORSE CREEK JUNE 1966 (continued)

SHALE SCREE MEASUREMENTS - PACKHORSE CREEK AUGUST, 1966

Shale Bank ∦	Slope Angles in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
1	37	0.6018	18	10.8	29	7 . 8°	*		45.2
2A	38	0.6157	23	14.2	36	14.0	*		132.5
2B	35	0.5736	16	9.2	133	12.2		*	276.4
3	38	0.6157	20	12.3	121	8.1		*	223.2
4		-	_	-	132	_	*		· _
5	39	0.6428	15	9.4	44	9.1	*		69.7
6	40	0.6428	19	12.2	20	10.0		*	45.2
7	_	-	-	_	41	-	*		
8	34.5	0.5664	29	16.4	48	13.8		*	201.2
9	38.5	0.6225	35	21.8	88	15.0	*		532.9
10	37	0.6018	24	14.4	35	9.0	*		84.0
11A	37	0.6018	20	12.0	54	6.4		*	76.8
11B	36	0.5878	22	12.9	110	9.4		*	247.0
11C	42.5	0.6756	20	13.5	70	6.7	*		117.2
12	38	0.6157	12	7.4	43	4.8	*		28.3
1.3A	37	0.6018	30	18.0	60	10.9		*	218.0
13B	37	0.6018	30	18.0	89	7.7		*	228.4
13C	38.5	0.6225	26	16.2	72	-			-

Shale Bank #	Slope Angles in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
	20	0 6157	24	14.8	<u>//8</u>	6.6		*	86.8
15	30 40 5	0.6494	10	12 2	40	5.69	*		54 8
15	40.5	0.6494	14	12.5	40	9.0	*		46 5
10	36	0.5878	14	8.2	54	9.0	~		40.5
17A	37	0.6018	22	13.2	60	7.1		x	104.1
17B	38	0.6157	26	16.0	72	7.8	*		166.4
18	37	0.6018	11	6.6	92	8.1	*		91.1
19A	39	0.6293	23	14.5	46	6.9		*	85.2
19B	39	0.6293	24	15.1	76	8.9	*		184.2
19C	37.5	0.6088	25	15.2	87	7.8	*		191.0
20A	38	0.6157	15	9.2	30	8.6	*		44.0
20B	39	0.6293	13	8.2	25	7.1		*	27.0
21	38	0.6157	17	10.5	60	5.0		*	58.3
22A	34	0.5592	30	16.8	88	11.4		*	312.1
22B	36	0.5878	15	8.8	46	9.0	*		67.5
22C	41	0.6561	21	13.8	26	8.6	*		57.1
23	34	0.5592	15	8.4	33	7.2	*		4.1

SHALE SCREE MEASUREMENTS - PACKHORSE CREEK AUGUST, 1966

(continued)

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Shale Bank #	Slope Angles in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
1	37	0.6018	18	10.8	28	7.5	*	4	42.8
2A	37	0.6018	21	21.6	42	13.2	*		128.4
2B	33	0.5446	19	10.3	143	10.3		*	280.9
3	38	0.6157	22	13.5	116	7.7		*	223.3
4			-	_	136	-	*		-
5	42	0.6691	19	12.7	47	9.0		*	99.5
6	39	0.6293	19	12.0°	24	8.8	*		46.9
7	42	0.6691	16	10.7	26	6.3	*		32.4
8	-	-	-		67	-		*	
9A	36	0.5878	31	18.2	53	12.2		*	218.0
9B	38	0.6157	38	23.4	91	11.9	*		469.2
10	37	0.6018	22	13.2	54	9.7	*		128.8
11A	36	0.5878	20	11.8	46	8.7		*	87.4
11B	36	0.5878	25	14.7	134	11.6		*	423.1
11C	41 •	0.6561	19	12,5	45	4.8	*		50.0
11D	41	0.6561	19	12.5	30	3.8		*	19.4
12A	37	0.6018	11	6, 6	21	5.2	*		13.3
12B	40	0.6428	13	8, 4	164	8.3 [°]	*		211.7
13A	37	0.6018	22	13.2	61	12.7	*		189.4

SHALE SCREE MEASUREMENTS - PACKHORSE CREEK SEPTEMBER, 1966

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Shale Bank #	Slope Angles in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
13B	36	0.5878	30	17.6	89	7.7		*	223.4
14	36	0.5878	17	10.0	47	9,9	*		86.2
15	39	0.6293	22	13.8	60	6.0	*		92.0
16	39	0.6293	14	8,8	80	7.0		*	91.2
17A	39	0.6293	32	20, 5	60	6,6		*	147.4
17B	.39	0.6293	24	15.1	75	10.4	*		218.1
18	34	0.5592	12	6.7	84	7.8	*		81.3
19A	38	0.6157	26	16.0	38	5.3		*	59.7
19B	39	0.6293	28	17,6	78	10,4	*		264.4
19C	37	0.6018	25	15,0	86	5.8		*	138.6
20A	36	0.5878	16	9, 4	34	9,8	*		58.0
20B	38	0.6157	12	7.4	23	7.5		*	23.6
21	32	0.5299	16	8.5	42	7.2	*		47.6
22	40	0.6428	24	15.4	34	9.4	*		91.1
23	39	0.6293	32	20.1	20	11,4	*		84.9

SHALE SCREE MEASUREMENTS - PACKHORSE CREEK SEPTEMBER, 1966 (continued)

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Shale Bank #	Slope Angles in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
1	36	0.5878	19	11	32	7	*		45.0
2A	36.5	0.5948	23	14	42	8		*	87.0
2B	34	0.5594	17	10	150	8	*		222.0
3	37	0.6018	24	14	122	7	*		221.0
4	_		-		145		*		-
5	39	0.6293	18	11	51	6	*		62.0
6	39.5	0.6361	16	10	60	. 8		*	88.0
7	40.5	0.6495	14	9	32	4	*		21.0
8	-	-	-	-	35	-		*	, -
9A	32	0.5299	28	15	54	9		*	135.0
9B	38	0.6158	7	4	37	3	*		8.0
9C	35	0.3537	25	14	122	7		*	221.0
10	38	0.6157	18	11	55	7		*	78.0
11A	38	0.6157	16	10	50	6		*	55.0
11B	36	0.5878	25	15	126	9		*	315.0
11C	41	0.6561	16	11	103	7	*		147.0
12	40	0.6428	17	11	220	5	*		224.0
13A	35.5	0.5807	22	13	62	9		*	134.0

SHALE SCREE MEASUREMENTS - PACKHORSE CREEK MAY, 1967

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Shale Bank #	Slope Angles in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
	37.5	0,6088	25	15	92	9		*	230.0
14	35	0.5736	22	13	44	9		*	95.0
15	40.5	0.6495	16	10	45	5	*		41.0
16	40.5	0.6561	14	9	32	6	*		32.0
174	39 5	0.6361	22	14	64	8	·	*	132.0
17R	38	0.6157	25	13	89	6	*		148.0
18	36	0,5878	14	8	102	8	*		120.0
194	40	0.6425	24	15	55	6		*	91.7
1 0R	37	0.6018	26	16	84	9	*		224.0
100	37	0.5736	28	16	92	6		*	163.0
204	39	0.6293	14	9	37	7	*		43.0
20A 20B	41 5	0.6626		7	46	6	*		36.0
200	38	0.6157	17	10	59	7		*	76.0
21A 21B	34	0.5592	25	14	87	12		*	271.0
21D 21C	38	0.6157		10	104	5	*		96.0
210	50 //0 5	0.6495	23	15	66	7	*		128.0
22	40.5	-	دع _	-	22	_	*		_

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SHALE SCREE MEASUREMENTS - PACKHORSE CREEK MAY, 1967 (continued)

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Shale Bank #	Slope Angles in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
1	38	0.6159	19	12	47	7	*		73.0
2A	37	0.6018	22	13	42	7		*	71.0
2B	35	0.5736	15	9	160	10		*	267.0
3	41	0.6561	20	13	132	8		*	254.0
4	-	-	-	-	130	-	*		· _
5	42	0.6691	13	9	31	8	*		41.0
6	40	0.6428	18	12	39	7		*	61.0
7	39	0.6293	11	7	36	6	*		28.0
8	. · · _		-	-	56	-		*	
9A	33	0.5446	25	14	55	10		*	143.0
9B	32	0.5299	6	3	86	3	* *		14.0
9C	35	0.5736	18	10	133	8		*	197.0
9D	33	0.5446	6	3	86	4	*		18.0
10	36	0.5878	15	9	62	8		*	83.0
11A	37	0.6018	17	10	49	× 9		*	82.0
11B	36	0.5878	19	11	125	10		*	254.0
11C	41	0.6561	18	12	102	7	*		159.0
12	37	0.6018	21	13	170	8	*		327.0

SHALE SCREE MEASUREMENTS - PACKHORSE CREEK JUNE 1967

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Shale Bank #	Slope Angles in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
134	37	0.6018	27	16	63	9		*	168.0
1 3R	36	0.5878	26	15	68	9		*	170.0
14	38	0.6157	20	12	48	8		*	85.0
15	38	0.6157	18	11	49	6	*		60.0
16	38	0.6157	11	7	40	8	*		41.0
17A	37	0.6018	18	11	68	7		*	97.0
17B	.38	0.6157	23	14	70	9	*		163.0
18	39	0.6293	13	8	98	9	*		131.0
19A	39	0.6293	26	16	42	7	×	*	87.0
1 9B	37	0.6018	26	16	87	9	*		232.0
190	35	0.5736	28	17	88	9		*	222.0
20A	36	0.5878	14	8	36	10	*		53.0
20R	37	0.6018	15	9	34	7	*		40.0
202 21A	36	0.5878	17	10	63	7		*	82.0
2111 21B	35	0.5736	26	14	86	12		*	237.0
210	36	0.5878	12	7	102	8	*		106.0
220	36	0.5878	18	11	103	7	*		147.0
2211 22B	38	0.6157	22	14	20	11	*		57.0
23	-	-	-		18	— *	*		-

SHALE SCREE MEASUREMENTS - PACKHORSE CREEK JUNE 1967 (continued)

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Shale Bank #	Slope Angles in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
	39	0.6293	16	10	51	4	*		38.0
2A	36	0.5878	20	12	44	11		*	108.0
2B	35	0.5736	16	9	163	7	*		190.0
3	39	0.6293	21	13	152	6	*		220.0
4	_	_	_	-	134	_	*		-
5	40	0.6428	16	10	96	5	*		89.0
6	40	0.6428	20	13	28	9		*	61.0
7	40	0.6428	16	10	34	7	*		44.0
8	_	-	_	-	64	. -		*	-
9A	33	0.5446	28	14	55	11		*	157.0
9B	41	0.6561	8	5	190	4	*		70.0
9C	36	0.5878	20	12	124	9		*	248.0
9D	38	0.6157	5	3	85	1	*		5.0
10	37	0.6018	18	11	60	5	`	*	61.0
11A	38	0.6157	15	9	46	4		*	31.0
11B	36	0.5878	22	13	128	.10		*	308.0
11C	42	0.6691	17	11	127	4	*		103.0
12	38	0.6057	24	15	212	8	*		471.0

SHALE SCREE MEASUREMENTS - PACKHORSE CREEK JULY, 1967

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Shale Bank #	Slope Angles in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
 13A	37	0.6018	23	14	65	7		*	118.0
13B	36	0.5878	22	13	87	5		*	105.0
14	35	0.5736	21	12	46	6		*	61.0
15A	35	0.5736	5	3	45	4	*		10.0
15B	40	0.6428	17	11	45	4	*		37.0
16	40	0.6428	12	8	66	5	*		49.0
17	40	0.6428	21	13	181	6		*	261.0
18	34	0.5592	11	6	99	7	*		77.0
19A	39	0.6293	21	13	44	.7		*	74.0
1 9 B	38	0.6157	27	17	87	7	*		192.0
19C	35	0.5736	28	16	96	7		*	199.0
20	37	0.6018	13	8	88	6	*		78.0
21A	37	0.6018	13	8	59	7		*	61.0
21B	34	0.5592	27	15	98	9		*	245.0
21C	36	0.5878	11	7	172	6	*		134.0
22A	39	0.6293	23	15	54	7	*		105.0
22B	36	0.5678	14	8	45	6	*		40.0
22C	41	0.6561	10	7	22	6	*		17.0
22D	39	0.6293	6	4	16	4	*		5.0
23	-	-	-	-	96	-	*		-

SHALE SCREE MEASUREMENTS - PACKHORSE CREEK JULY, 1967 (continued)

Shale Bank #	Slope Angles in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
1A	30	0.5000	5	3	55	2	*		6.0
1B	41	0.6561	18	12	÷	6	*		40.0
2A	37	0.6018	23	14	47	8		*	97.0
2В	38	0.6159	16	10	179	8		*	265.0
3A	35	0.5736	7	4	15	4	*		4.0
3B	39	0.6293	20	12	150	6	*		200.0
4	-	-	-	<u> </u>	11 - 1 - 1 - 1 11 - 1 - 1	-	*		-
5A	39	0.6293	18	11	50	7	*		71.0
5B	39 .	0.6293	5	3	127	3	*		21.0
6	41	0.6561	22	14	40	7		*	73.0
7	40	0.6428	18	12	78	4	*		69.0
8		-	-	-	70	-		*	_
9 A	33	0.5446	24	13	50	11		*	132.0
9B	34	0.6428	11	. 7	218	4	*		113.0
9C	37	0.6018	23	14	105	8		*	218.0
9 D	37	0.6018	6	4	88	2		*	13.0
10	38	0.6159	23	14	62	7		*	112.0
11A	38	0.6159	16	10	47	6		*	52.0

SHALE SCREE MEASUREMENTS - PACKHORSE CREEK AUGUST, 1967

Shale Bank #	Slope Angles in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards	
 11B	38	0.6159	25	15	130	9		*	325.0	
11C	41	0.6561	16	11	90	4	*		73.0	
12	37	0.6018	30	18	190	7	*		443.0	
13A	36	0.5878	22	13	60	7		*	101.0	
13B	36	0.5878	24	14	87	6		*	135.0	
14	39	0.6293	22	14	45	5	1:	*	58.0	
15	39	0.6293	16	10	43	5	*		40.0	
16A	31	0.5150	5	3	48	3	*		8.0	
16B	37	0.6018	14	8	43	5		*	32.0	
17	38	0.6157	24	14	178	6		*	277.0	
18	42	0.6691	12	8	87	5	*		64.0	
19A	41	0.6561	22	14	37	7		*	67.0	
19B	38	0.6157	24	15	88	8	*		196.0	
19C	35	0,5736	26	15	96	7		*	187.0	
20	38	0.6157	16	10	103	6	*		114.0	
21A	36	0.5878	16	9	59	7		*	69.0	

SHALE SCREE MEASUREMENTS - PACKHORSE CREEK AUGUST, 1967 (continued)

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Shale Bank #	Slope Angles in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards				
21B	35	0.5736	24	14	85	8		*	176.0				
22A	38	0.6157	12	7	148	5	*		96.0				
22B	39	0.6293	24	15	38	8	*		84.0				
22C	39	0.6293	9	6	47	4	*		21.0				
23	38	0.6157	8	5	66	3	*		18.0				

SHALE SCREE MEASUREMENTS - PACKHORSE CREEK AUGUST, 1967 (continued)

Shale Bank #	Slope Angles in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards			
	37	0.6018	10	6	90	4	*		40.0			
2A	38	0.6157	19	12	46	10		*	102.0			
2B	36	0.5878	16	9	223	7		*	260.0			
3	38	0.6157	14	9	200	9	*		300.0			
4	_	_	_	_	136		*		-			
5	36	0.5878	7	4	181	4	*		54.0			
6	40	0.6428	22	14	42	8		*	87.0			
7	40	0.6428	15	10	88	4	*		65.0			
, 8	_	_	_	_	52	-	*		-			
94	39	0.6293	31	20	46	10		*	170.0			
9R	36	0.5878	20	12	106	4	*		94.0			
9C	36	0.5878	20	12	115	10		*	256.0			
90 910	39	0.6293	8	5	92	2	*		17.0			
10	37	0.6018	17	10	63	8		*	93.0			
11 A	38	0.6157	16	10	49	6		*	54.0			
11R	36	0.5878	24	14	128	11		*	365.0			
11C	37	0.6018	15	9	103	7	*		120.0			
12A	40	0.6428	26	17	226	7	*		498.0			

SHALE SCREE MEASUREMENTS - PACKHORSE CREEK OCTOBER, 1967

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Shale Bank #	Slope Angles in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
12B	38	0.6157	18	11	60	11		*	134.0
13A	36	0.5878	22	13	88	7	*		148.0
14	37	0.6018	19	11	46	7		*	66.0
15A	40	0.6428	6	4	44	3	*		10.0
15B	40	0.6428	20	13	67	5	*		81.0
16A	41	0.6561	5	3	51	5	*		14.0
16B	39	0.6293	15	9	66	6		*	66.0
17	38	0.6157	22	13	181	6		*	261.0
18	35	0.5736	12	7	108	7	. *		98.0
19A	40	0.6428	22	14	47	6		*	75.0
19B	38	0.6157	25	15	100	8	*		222.0
19C	35	0.5736	26	15	96	9		*	240.0
20A	37	0.6018	13	8	32	8.	*		38.0
20B	37	0.6018	12	7	46	4	*		24.0
21A	38	0.6158	16	10	60	5		*	56.0
21B	35	0.5736	26	15	86	9		*	215.0
21C	38	0.6158	12	7	152	6	*		118.0
22A	41	0.6561	21	14	38	9	*		89.0
22B	39	0.6293	15	9	38	5	*		32.0
23	41	0.6561	10	7	72	8	*		75.0

SHALE SCREE MEASUREMENTS - PACKHORSE CREEK OCTOBER, 1967 (continued)

Shale Bank #	Slope Angles in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
1	37	0.6018	15	9.0	49	7	*		57.1
- 2A	38	0.6157	20	12.3	43	11	*		107.7
2B	37	0.6018	17	10.2	200	8		*	302.2
 3 ⁻	38	0.6057	20	12.3	85	7	*		135.5
4	_		_	- .	_	 1			-
5	40	0.6428	15	9.6	52	7		*	64.7
6	39	0.6293	20	12.6	30	9		*	63.0
7	41	0.6561	25	16.4	30	8	*		72.9
8	36	0.5876	8	4.7	26	5		*	11.3
9A	32	0.5299	20	10.6	65	15		*	191.4
9B	35	0.5736	10	5.7	82	5	*		43.3
9C	35	0.5736	10	5.7	32	4	*		13.5
9 D	35	0.5736	17	9.8	122	8	*		177.1
10	35	0.5736	17	9.8	62	7	*		78.8
11A	36	0.5876	15	8,8	50	5		*	40.7
11B	35	0.5736	20	11.5	123	9		*	235.8
11C	40	0.6428	17	10.9	94	6	*		113.8
12	40	0.6428	25	16.1	212	8	*		505.7

SHALE SCREE MEASUREMENTS - PACKHORSE CREEK JUNE, 1968

	(continued)												
Shale Bank ∦	Slope Angles in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards				
	37	0.6018	22	13.2	72	12		*	211.2				
13B	37	0.6018	22	13.2	88	7		*	150.6				
14	34	0.5592	18	10,1	45	7		*	58.9				
15	40	0.6428	16	10.3	44	5	*		42.0				
16	37	0.6018	13	7.8	65	9		*	84.5				
17	41	0.6561	21	13.8	165	7		*	295.1				
18	34	0.5592	13	7.3	105	9	*		127.8				
19A	38	0.6157	20	12.3	40	7		*	63.9				
19B	37	0.6018	20	12.0	112	8	7	*	199.1				
19C	36	0.5876	22	12.9	84	9		*	180.6				
20	38	0.6157	16	9.8	88	8	*		127.8				
21A	36	0.5876	15	8.8	58	6		*	56.7				
21B	34	0.5592	37	20.7	81	12		*	272.6				
21C	35	0.5736	21	12.0	130	7	*		202.2				
22A	41	0.6561	18	11,8	37	8	*		64.7				
22B	37	0.6018	16	9.6	62	6	*		66.1				

SHALE SCREE MEASUREMENTS - PACKHORSE CREEK JUNE, 1968

Shale Bank #	Slope Angles in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
1	37	0.6018	15	9.0	38	9	*		57.0
2A	38	0.6157	21	12.9	44	9	*		94.6
2B	36	0.5878	18	10.6	176	9		*	310.9
3	39	0.6293	21	13.2	82	8	*		106.3
4	-	· _	-	-	135	_		*	_
5	39	0.6293	15	9.4	44	7		*	53.6
6	39	0.6293	24	15.1	24	8		*	53.7
7	41	0.6561	18	11.8	36	6	*		47.2
8	_	-	_	-	60			*	· _
9A	34	0.5592	23	12.9	43	13		*	133.5
9B	40	0.6428	14	9.0	45	4	*		30.0
9C	38	0.6157	20	12.3	116	9		*	237.8
10	37	0.6018	17	10.2	62	8		*	93.7
11A	37	0.6018	16	9,6	50	9		*	80.0
11B	36	0.5878	23	13.3	130	9		*	292.5
11C	41	0.6561	14	9.2	30	5	*		25.6
12	41	0.6561	20	13,1	156	8	*		302.7

SHALE SCREE MEASUREMENTS - PACKHORSE CREEK JULY, 1968

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Shale Bank #	Slope Angles in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
124	36	0.5878	26	15.3	56	10		*	158.6
1 20	36	0 5878	28	16.5	88	7		*	188.2
1/	37	0.6018	25	15.1	46	9	s	*	115.8
15	37 40	0.6428	16	10.3	44	7	*		58.7
164	28	0.6157	7	4.3	. 40	5	*		15.9
16P	37	0.6018	, 14	8,4	39	5		*	30.3
174	57 41	0.6561	26	7.1	58	7		*	128.6
170	41	0.6561	25	16.4	85	7	*		180.7
10	41	0.6428	15	9.6	105	7	*		130.6
	20	0.6293	26	16.4	45	5		*	68.3
10P	30	0.6293	30	18 4	93	7	*		227.8
195	35	0.5878	28	16.5	98	8		*	239.6
190	30	0.6018	15	9.0	102	6	*		102.0
20	27	0.6018	16	9.6		6		*	61.9
21A 01D	37	0.5979	28	16 5	100	9		*	275.0
218	30	0.5078	17	10.7	122	7	*		169.2
210	37	0.6019	1/ 20	10.7	100	8	*		285.9
22	37	0.0018	52	тэ. J	100 02	-	*		—
23	-	-			74	-			

SHALE SCREE MEASUREMENTS - PACKHORSE CREEK JULY, 1968 (continued)

Shale Bank #	Slope Angles in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
1	37	0.6018	21	12.6	34	6	*		47.6
- 2 A	37	0.6018	22	13.2	43	10	*		105.1
2B	39	0.6293	18	11.3	177	8	*		296.3
3	38	0.6157	21	12.9	82	7	*		137.1
4				iiide, ainai-			*		
5	42	0.6691	16	10.7	44	8		*	69.7
6	39	0.6293	20	12.6	24	8		*	44.8
7	41	0,6561	19	12.5	38	5	*		44.0
8					64				
94	34	0.5592	26	14.5	52	10		*	139.6
0 R	41	0.6561	15	9.8	49	5			44.4
90	38	0.6159	21	12.9	114	10	*		273.3
10	37	0.6018	21	12.6	61	6		*	85.4
114	38	0.6157	17	10.5	50	5		*	48.6
11R	36	0.5878	25	14.7	127	8		*	276.6
110	50 40	0.6428	13	8.4	88	5	*		68.4
124	36	0 5878	25	14.7	21	8	*		45.7
100	36	0.5878	30	17.6	154	8	*		401.5
120	36	0 5878	36	15.3	60	8		*	136.0
1 3 R	36	0.5878	26	15.3	85	6		*	144.5
13D	39	0.6293	8	5.0	20	5	*		9.2

SHALE SCREE MEASUREMENTS - PACKHORSE CREEK AUGUST 1968

Shale Bank #	Slope Angles in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
1/	36	0.5878	20	11.8	108	8		*	188.8
15	50 40	0.6428	18	11.6	43	6		*	55.4
16	37	0.6018	14	8.4	102	7	*		111.1
174	38	0.6157	29	17.9	64	5		*	106.1
172	38	0.6157	27	16.6	51	6	*		94.1
170	38	0.6159	25	15.4	20	7	*		39.1
10	20	0.6159	15	9.2	105	7	*		125.2
104	20	0.6203	30	18.9	44	6		*	92.4
19A 10D) 7 1 0	0.6150	18	11 1	100	7	*		143.9
198	20	0.5762	21	12	96	5		*	106.7
190	35	0.5705	16	9 6	70	8	*		102.4
20	37	0.6018	16	9.0	26	7	*		32.3
20A	37	0.6018	10	9.0	20	7	-	*	56.1
21A	36	0.5878	16	9.4	40	/			
21B	34	0.5592	34	19.0	99	9		ж	272.2
210	38	0.6157	17	10.5	119	9	*		208.2
22A	37	0.6018	22	13.2	36	9	*		79.2
22B	38	0.6157	19	11.7	37	9	*		72.2
23					88		*		

SHALE SCREE MEASUREMENTS - PACKHORSE CREEK AUGUST 1968

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Shale Bank #	Slope Angles in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
	40.5	0.6495	17	11.0	31	8	*		50.5
 2A	35.5	0.5897	23	13.4	44	12		*	70.8
 2B	35.0	0.5736	17	9.8	147	10		*	266.8
3	39.0	0.6293	26	16.4	104	8	*		252.7
4	_	-	_	—	136	-	*		-
5	39.5	0.6391	17	10.8	49	9		*	84.7
6	38.0	0.6157	18	11.1	24	11		*	54.2
7	40.0	0.6428	15	9.6	38	6	*		40.5
, 8	· _	_	-	_	68	-		*	-
9A	30.5	0.5075	20	10.2	53	11		*	110.0
9B	30.5	0.5075	6	3.1	50	4	*		11.5
9C	37.5	0.6088	27	16,4	115	9		*	314.3
10	37.5	0.6088	22	13,4	60	7		*	104.2
11A	39.5	0.6361	17	6.8	50	7		*	70.0
 11B	35.0	0.5736	20	11.5	124	11		*	290.5
110	40.0	0.6428	18	11,6	90	6		*	116.0
12A	40.5	0.6428	25	16.0	20	6	*		35.6
12B	40.5	0.6495	25	16.0	131	8	*		310.5

SHALE SCREE MEASUREMENTS - PACKHORSE CREEK SEPTEMBER, 1968

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Shale Bank #	Slope Angles in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
13A	39.0	0.6293	25	15.7	60	10	<u></u> , , , , , , , , , , , , , , , , ,	*	174.4
13B	36.5	0.5948	24	14.3	90	9		*	214.4
14	36.5	0.5948	24	14.3	. 48	10		*	127.1
15	39.5	0.6361	18	11.5	47	7	*		70.1
16	41.5	0.6626	13	8, 6	97	7		*	108.1
17A	36.5	0.5948	15	8,9	67	7		*	77.3
17B	36.5	0.5948	20	11.9	83	8	*		146.3
18	38.0	0.6157	12	7.4	105	9	*		129.5
19A	38.5	0.6225	25	15.6	37	7		*	74.8
19B	38.5	0.6225	25	15.6	100	7		*	202.2
19C	37.0	0.6018	24	14.4	96	9		*	239.2
20A	37.5	0.6088	18	11.0'	51	9	*		93.5
20B	37.0	0.6018	11	6.6	36	8	*		35.2
21A	37.0	0.6018	17	10,2	62	6		*	70.3
21B	36.5	0.5948	39	23.2	90	11		*	425.3
21C	40.0	0.6428	19	12.2	120	9	*		244.0
22A	37.0	0.6018	32	19.3	40	9	*		128.7
22B	40.0	0.6428	18	11.6	47	6	*		60.6
23	_	_	-	-	95	-		*	-

SHALE SCREE MEASUREMENTS - PACKHORSE CREEK SEPTEMBER, 1968

Shale Bank #	Slope Angles in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
1	36.5	0.5948	23	14	29	8	*		59.6
2A	36.0	0.5878	21	12	46	9	*		92.0
2B	35.0	0.5736	20	12	174	6		*	232.0
3	37.5	0.6088	21	.13	105	7	*		176.9
4	_	_	-	-	127		*		-
5A	44.0	0.6947	13	9	60	9		*	90.0
5B	37.0	0.6018	5	3	38	3	*		6.3
6	40.5	0.6495	20	13	30	7		*	50.6
7	41.0	0.6561	8	5	73	4	*		27.0
8	-	_	_	-	69	-		*	
9A	30.0	0.5000	24	12	54	12		*	144.0
9B	38.0	0.6157	9	6	85	3	*		28.3
9C	38.0	0.6159	9	6	54	3	*		18.0
9D	35.0	0.5736	29	17	129	8	*		324.0
9E	38.0	0.6157	6	4	63	3	*		14.0
10	35.0	0.5736	16	9	60	7		*	70.0
11A	37.0	0.6018	12	7	55	7		*	49.9
11B	34.0	0.5592	20	11	125	10		*	254.6

SHALE SCREE MEASUREMENTS - PACKHORSE CREEK MAY, 1969

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Shale Bank ∦	Slope Angles in Degrees	Sine of Angles	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
11C	44.0	0.6947	12	8	90	6	*	7 <u>-</u> ,, ,,,,, ,	80.0
12	40.5	0.6495	25	16	180	8	*		426.7
13A	36.0	0.5878	27	16	68	9	·	*	181.3
13B	34.5	0.5664	20	11	92	7		*	131.2
14	39.5	0.6361	21	13	42	8		*	80.9
15	39.5	0.6361	15	10	49	7	*		63.5
16	35.5	0.5807	13	8	47	6		*	41.8
17	38.5	0.6225	21	13	122	6	*		176.2
18	36.5	0.5948	13	8	85	8	*		100.7
19A	37.5	0.6088	22	13 B	32	8		*	61.6
19B	38.5	0.6225	25	16	80	9.	*		213.3
19C	36.0	0.5878	19	11	90	7		*	128.3
20	36.5	0.5948	16	10	89	7	*		115.4
21A	26.5	0.4462	22	10	59	8		*	87.4
21B	33.0	0.5446	28	15	98	8		*	217.8
21C	38.0	0.6159	21	13	128	8		*	246.5
22A	41.5	0.6626	20	13	145	8	*		279.0
22B	38.0	0.6159	11	7	25	5	*		16.2
23	-	-	-	_	94	- .	* .		_

SHALE SCREE MEASUREMENTS - PACKHORSE CREEK MAY, 1969 (continued)

Shale Bank #	Slope Angles in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
	42	0.6691		7	20	6	*		15.6
2A	41	0.6561	15	10	44	11	*		89.6
2B	36	0.5878	17	10	138	11		*	281.1
3	41	0.6561	16	10	44	8	*		65.2
4	-	_	-	_	140	-	*		
5	38	0.6157	16	10	46	8		*	68.1
6	_	-	-		72	-	*		_
7	-	-	– .	-	36	-		*	_
8	-	-	-	-	67	-		*	_
9A	31	0.5150	19	10	52	13		*	125.2
9B	36	0.5878	18	11	92	9		*	168.7
10	26	0.4384	6	3	35	6	*		11.7
11A	40	0.6428	11	7	50	6		*	38.9
11B	34	0.5592	22	12	102	10		*	226.7
11C	39	0.6293	13	8	27	7	*		28.0
11D	41	0.6561	7	5	23	2	*		4.3
12	38	0.6157	11	7	185	7	*		167.9
13A	36	0.5878	20	12	55	12		*	146.7

SHALE SCREE MEASUREMENTS - PACKHORSE CREEK AUGUST, 1969

	SHALE SCREE MEASUREMENTS - PACKHORSE CREEK AUGUST, 1969 (continued)													
Shale Bank #	Slope Angles in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards					
13B	34	0.5592	14	8	62	10		*	91.9					
14	_		-	_	25	-	*							
15A	39.5	0.6361	13	8	56	6	*		49.8					
15B	36	0.5878	13	8	77	6	*		68.4					
17A	36	0.5878	17	10	26	7		*	33.7					
17B	38	0.6157	12	7	79	5	*		51.2					
18	43	0.6820	8	5	40	6		*	22.2					
19A	37	0.6018	22	13	46	6		*	66.4					
19B	28	0.4695	4	2	91	4		*	13.5					
19C	36	0.5878	25	15	91	7		*	176.5					
20	31	0.5150	9	4	28	6	*		15.6					
21A	42	0.6691	15	10	85	6		*	94.4					
21B	39	0.6293	9	6	75	5	*		41.1					
21C	33	0.5446	3	2	34	5	*		6.3					
22A	35	0.5736	10	6	100	6	*		66.7					
22B	33	0.5446	8	4	39	5	*		14.4					
23	-	_ · _	_		100	-	*		-					

SHALE SC	REE MEA	SUREMENTS	- P	ACKHORSE	CREEK	AUGUST,	1969	
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Shale Bank #	Slope Angle in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
1	39	0.6293		9	33	6	*		33 0
2A	41	0.6561	14	9	67	6	*		67.0
2B	36	0,5878	23	14	139	12		*	432.0
3	41	0.6561	22	14	62	5		*	20.0
4	_		-	_	140	-	*		_
5	42	0.6691	14	-	200	 —	*		_
. 6	_	-	-	· _	86	-	*		-
7	_	-	-	-	36	-		*	·· _
8	42	0.6691	16	11	30	6	*		37.0
9A	34	0.5592	28	16	63	12		*	224.0
9B	34	0.5592	7	4	68	3	*		15.0
9C	37	0.6018	24	14	105	7		*	191.0
10	-	_	_	-	-	-			
11A	40	0.6428	17	11	51	6		*	62.0
11B	36	0.5878	22	13	125	11		*	331.0
11C	38	0.6157	12	7	34	8	*		35.0
12	39	0.6293	12	8	188	7	*		195.0
13	35	0.5736	28	16	58	12		*	206.0

SHALE SCREE MEASUREMENTS - PACKHORSE CREEK JUNE, 1970

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Shale Bank #	Slope Angle in	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank	Average Probe Depth	Bank at Creek	Bank Away From	Volume in Cubic Yards
	Degrees	· · · · · · · · ·	· · · · · · · · · · · · · · · · · · ·	· · · · · · · · · · · ·	(feet)	(feet)		Creek	• • •
14	37	0.6018	7	.4	15	5	*		6.0
15	40	0.6428	20	13	53	7	*		89.0
16	37	0.6018	12	7	58	8		*	60.0
17	39	0.6293	22	14	25	8		*	52.0
18A	38	0.6157	14	9	73	7		*	85.0
18B	40	0.6428	12	8	45	8		*	53.0
19A	41	0.6561	23	15	44	10		*	122.0
19B	37	0.6018	9	5	120	6		*	67.0
19C	35	0.5736	24	14	88	7		*	160.0
20	35	0.5736	6	3	87	6		*	29.0
21A	38	0.6157	20	12	98	8		*	74.0
21B	27	0.4540	5	2	64	4	*		9.0
21C	37	0.6018	7	4	62	7	*		32.0
22A	40	0.6428	12	8	36	7		*	37.0
22B	40	0.6428	10	6	119	8	*		106.0
22C	40	0.6428	11	7	22	8	*		23.0
23	-	0.6428	_	-	36	-	*		-

Bank #	Angle in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
1	39	0.6293	6	4	90	4	*		27
2	39	0.6293	12	8	252	9		*	336
3	40	0.6428	15	10	75	7	*		97
4	, 		. <u> </u>	-	138	-	*		-
5	38	0.6157	15	9	62	5		*	52
6		_		-	35	-	*		-
7	36	0.5878	7	4	122	3			
8		-	-		60	_		*	-
9A	35	0.5736	16	9	77	9		*	116
9B	37	0.6018	8	5	88	4	*		33
9C	36	0.5878	18	11	125	7		*	. 178
9D	33	0.5446	5	3	90	3	*		15
10	35	0.5736	10	6	35	8	*		31
11A	38	0.6157	13	8	55	6		*	49
11B	36	0.5878	20	12	127	10		*	282
11C	36	0.5878	17	10	54	8	*		80
12	39	0.6293	18	11	220	10	*		448
13.	37	0.6018	19	11	66	8		*	108

SHALE SCREE MEASUREMENTS - PACKHORSE CREEK OCTOBER, 1970

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Shale Bank #	Slope Angle in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
14	37	0,6018	7	4	66	6		*	29
1.5	39	0.6293	14	9	46	7	*		54
16	40	0.6428	12	8	46	6	*		41
17	37	0.6018	13	8	175	5	*		130
18	39	0.6293	9	6	57	7		*	44
19A	41	0.6561	17	11	44	7		*	63
19B	38	0.6157	10	6	118	6		*	79
19C	35	0.5738	21	12	134	7		*	238
20	36	0.5878	9	5	90	5	*		42
21A	36	0.5878	28	16	85	8		*	201
21B	34	0.5592	11	6	175	7	*	a.	136
22A	35	0.5738	9	5	40	7	*		26
22B	36	0,5878	15	9	160	7	*		187
22C	35	0.5138	10	6	42	5	*		23
23	. –	_	_	_	_	_	*		-

SHALE	SCREE	MEASUREMENTS	-	PACKHORSE	CREEK	OCTOBER,	1970
			. (0	continued)			
							A 14 1 1 1 1 1 1

Shale Bank #	Slope Angle in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
			<u>نى ئىرىنى بىرى بىرى بىرى بىرى بىرى بىرى بىرى</u>						
1				1.4	33	6		*	51.3
2	36	0.5878	23	14	10%	12		*	303.1
2A	34	0.5592	20	11	124	12		*	63.3
3	38	0.6157	20	12	41	/	4		
4							*		20 1
5	39	0.6293	18	11	32	6	*		39.I
6	-				80		*		
7					44		*		
,					50			*	
8		0 5878	20	12	50	11		*	122.2
9A	30	0.0070	20	13	78	7		*	131.4
9 B	39	0.6293	20		105		*		
10				15	117	9	*		292.5
11A	35	0.5736	26	-	±±7	7	*		53.5
11B	33	0.5446	13	/	59	/	*		
12					200		~	ste	1/1 3
13	37	0.6018	20	12	. 53	12	_	~	141.3
14					17		*		
15					197		*		
1.6	45	0.7071	10	7	116	6	*		90.2
10	4-J 2-D	0 6293	23	14	24	5		*	31.1
1/	22	0 6 2 9 3	10	6	47	6		*	32.7
18	39	0.0293	TO	17	4.0	R		*	105.8
19A	42	0.6691	25	т/	44	0			

.

Shale Scree Measurements - Packhorse Creek June 1971

Shale Bank #	Slope Angle in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
19B	35	0.5736	25	14	132	7	*		239.6
20					34			*	
21A	36	0.5878	11	6	34	7		*	26.4
21B	39	0.6293	29	18	84	9		*	252.0
22A	38	0.6157	15	9	39	4	*		26.0
22B	35	0.5736	10	6	63	6		*	42.0
23					18			*	

Shale Scree Measurements - Packhorse Creek June 1971

Shale Bank #	Slope Angle in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
1	46	0.7193	15	. 11	83	5	*		20.4
2A	43	0.6820	18	12	45	6	*		60.0
2B	37	0.6018	22	13	116	10		*	279.3
3	42	0.6691	22	15	44	8		*	97.8
4	—	_		· _	140	_ ·	*		_
5	41	0.6561	17	11	32	6		*	39.1
6	, -	. –	-	-	304	-		*	
7	-	* _	-	—	40	_	*		
8		_	. –	-	43	-	*		_
9A	38	0.5736	24	14.	65	5		*	84.3
9B	39	0.6293	7	4	68	4		*	20.1
9C	38	0.6151	24	15	97	7		*	188.6
10	30	0.5000	5	3	35	5	*		9.7
11A	41	0.6561	16	10	50	7		*	64.8
11B	36	0.5878	26	15	122	10		*	338.9
11C	38	0.6157	16	10	79	11	*		160.9
12	39	0.6293	20	13	188	6		*	271.6
13A	37	0.6018	25	15	54	7		*	105.0

SHALE SCREE MEASUREMENTS - PACKHORSE CREEK SEPTEMBER, 1971

Shale Bank #	Slope Angles in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
1.3B	38	0.6157	12	7	58	6	*	<u> </u>	45.1
14	- -	-	-	-	20	-		*	-
15	42	0.6691	16	11	40	4	*		32.6
16	45	0.7071	9	6	156	6		*	104.0
17A	40	0.6428	22	14	30	6		*	46.7
17B	39	0.6293	13	8	55	4		*	32.6
18	40	0.6428	10	6	43	6.		*	28.7
19A	41	0.6561	26	17	80	6		*	151.1
19B	36	0.5878	5.	3	124	4	*		27.6
190	. 35	0.5736	22	13	132	6		*	190.7
20A	35	0.5736	7	4	32	6	*		14.2
20B	35	0.5736	8	5	28	4	*		10.4
21A	39	0.6293	12	8	49	. 7	*		50.8
21B	38	0.6157	30	18	83	6		*	166.0
21C	34	0.5592	5	3	142	5		*	39.4
22A	35	0.5736	13	7	80	6		*	62.2
22B	40	0.6428	15	10	142	7	*		184.1
22C	41	0.6561	7	5	39	4		*	14.4
23	_	_		-	21	· _		*	

SHALE SCREE MEASUREMENTS - PACKHORSE CREEK SEPTEMBER, 1971 (continued)

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Shale Bank #	Slope Angle in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards		
1	42	0.6691	7	5	50	5	*		23		
2A	42	0.6691	19	13	58	7	*		97		
2B	39	0.6293	18	11	134	8		*	218		
3A	32	0.5299	4	2	51	6	*		11		
3B	43	0.6820	22	15	66	4		*	73		
4	· · · _	-	-	-	140	-	*		-		
5	45	0.7071	17	12	36	5		*	40		
6	-	-	-	-	26			*	-		
7	-	-	-	-	36	-		*	- ·		
8	-	-		-	43	-		*	-		
9A	35	0.5736	24	14	76	9		*	177		
9B	39	0.6293	9	6	77	5		*	43		
9C	37	0.6018	16	10	105	5		*	97		
10	34	0.5592	7	4	55	7	*		28		
11A	34	0.5592	28	16	124	8		*	294		
11B	39 ·	0.6293	16	10	68	8	*		101		
12	39	0.6293	20	13	188	6	*		272		
13A	30	0.5000	22	11	52	6		*	64		

SHALE SCREE MEASUREMENTS - PACKHORSE CREEK JULY, 1972

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Shale Bank #	Slope Angle in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
13B	40	0.6428	13	8	22	8	*		26
14	38	0.6157	6	. 4	18	4	*		5
15	-	_	· _	_	94	-	*		-
16	_	_	_	_	32	_		*	_
17A	40	0.6428	21	13	26	9		*	56
17B	43	0.6820	14	10	47	6		*	52
18	36	0.5878	4	2	40	9	*		13
19A	41	0.6561	24	16	40	6			
1.9B	37	0.6018	10	6	128	5	*		71
19C	36	0.5878	22	13	96	7		*	162
20	35	0.5736	10	6	90	4	*		40
21A	36	0.5878	8	5	82	5	*		38
21B	35	0.5736	9	5	36	5		*	17
21C	38	0.6157	23	14	38	5	*		50
21D	35	0.5736	16	9	175	4	*		116
22A	43	0.6820	12	8	26	7	*		27
22B	38	0.6157	10	6	162	6	*		108
22C	39	0.6293	14	9	24	6	*		24
23	-	-	-	-	42	-	*		-
		1							

SHALE SCREE MEASUREMENTS - PACKHORSE CREEK JULY, 1972 (continued)

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Shale Bank #	Slope Angle in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
1	39	0.6293	8	5	48	5	*		22
2A	41	0.6561	12	8	54	7	*		56
2B	30	0.5000	21	11	65	6	*		79
3	40	0.6428	22	14	66	4		*	68
4	-		-	-	140	-	*		
5	-	-	-	-	36	-		*	-
6	· _	-	-	-	26	-		*	-
7		-	-	-	36	-		*	· _
8	-	-	-	-	43	-		*	-
9A	32	0.5299	17	9	73	8		*	97
9B	37	0.6018	10	6	94	5	*		52
9C	39	0.6293	23	15	108	7		*	210
9 D	36	0.5878	3	2	15	2	*		1
10	31	0.5150	10	5	52	7	*		34
11A	40	0.6428	14	9	58	6		*	58
11B	35	0.5736	30	17	106	8		*	267
11C	37	0.6018	23	14	68	7	*		123
12	40	0.6428	19	12	80	7	*		124

SHALE SCREE MEASUREMENTS - PACKHORSE CREEK SEPTEMBER, 1972

Shale Bank #	Slope Angle in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
134	35	0.5736	7	4	37	5	*	<u> </u>	14
1 3B	36	0.5878	24	14	50	Z		*	117
14	39	0.6293	5	3	14	4		*	3
15	40	0.6428	20	13	58	4	*		56
16	46	0.7193	7	5	49	4		*	18
17A	40	0.6428	25	16	28	9		*	75
17B	36	0.5878	15	9	72	4	*		48
17C	40	0.6428	18	12	38	4		*	34
18	37	0.6018	8	5	56	6		*	31
19A	40	0.6428	26	17	44	6		*	83
19B	37	0.6018	14	8	124	4	*		73
19C	34	0.5592	30	17	100	6		*	189
20	35	0.5736	7	4	79	4	*		23
21A	34	0.5592	10	6	76	5		*	42
21B	39	0.6293	26	16	36	8		*	85
21C	35	0.5736	20	12	158	5		*	176
22A	39	0.6293	14	9	167	5	*		139
22B	36	0.5878	13	8	27	6		*	24
22C	34	0.5592	15	8	49	6		*	44
23	39	0.6293	3	2	42	2	*		3 4

SHALE SCREE MEASUREMENTS - PACKHORSE CREEK SEPTEMBER, 1972 (continued)

Shale Bank #	Slope Angles in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
1					38		*		
2	35.3	0.5807	4	2.3	92	3.2		*	8.5
-	36	0.5878	3	1.8	35	3.5	*		3.5
4	35.3	0.5807	8	4.6	48	5.7	*		23.3
5	33.5	0.5519	9	5.0	95.4	4.7	*		41.5
5 6A	38.3	0.6225	15	9.3	59.0	5.6	*		56.9
6B	38.3	0.6225	9	5.6	55.0	4.9	*		28.0
° - 7	37.3	0.6088	21	12.8	140	10.2	*		338.5
8	38	0.6157	25	15.4	107	11.9		*	363.1
9	36.3	0.5948	24	14.3	113	8.0		*	239.4
10A	42	0.6691	5	3.3	60	4.0		*	14.7
10B	37	0.6018	26	15.6	128	7.6		*	281.0
100	37	0.6018	36	21.7	250	14.0		*	1406.4
11A	39.30	0.6293	26	16.4	26	6.0	*		47.4
11B	36	0.5878	20	11.8	89	8.1		*	157.5
12A	34.3	0.5664	5	2.8	70.5	2.7	*		9.9
12B	33	0.5446	24.0	13.1	60.0	20.0		*	291.1
13	41.3	0.6626	23	15.2	53	6.5	*		97.0
14A	37	0.6018	11	6.6	47	4.5	*		25.9
14B	37	0.6018	20	12.0	57	6.0	*		76.0

SHALE SCREE MEASUREMENTS - BALDHILL CREEK MAY 1964

Shale Bank #	Slope Angles in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
15	25 3	0.5807	15	8.7	80	4.1	*		52.8
164	30	0 6293	5	3.1	26.8	3.5	*		5.4
16B	36	0.5878	29	17.0	144	9.7		*	439.7
174	37 3	0.6088	13.0	7.9	32	8.0	*		37.5
178	36 3	0.5948	19.5	11.6	100.0	12.0		*	257.8
170	37.3	0.6088	28	17.0	180.0	12.7		*	719.9
170	29.3	0.4929	36	17.7	100.0	13.2		*	432.7
184	37.3	0,6088	20	12.2	88.0	8.0	*		159.1
18B	35	0,5736	6.0	3.4	33.0	2.8	*		5.8
180	33	0,5446	5.0	2.7	12.0	2.9	*		4.4
100	42	0.6691	18.0	12.0	27	3.1	*		18.6
10R	30	0.6293	39.0	24.5	100.0	8.2		*	372.4
100	38	0.6157	15.0	9.2	40.0	4,9		*	33.4
204	37 3	0.6088	16.5	10.0	83.0	3.7		*	56.9
20A 20B	33.3	0.5519	10.0	5.5	61.0	5.6		*	34.8

SHALE SCREE MEASUREMENTS - BALDHILL CREEK MAY 1964

Shale Bank #	Slope Angles in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
	للى يېرىيى مەرىپىنى مەرىپىي مەرىپى مەرىپى 100 مىي				38		*		
+ 2	35	0.5736	6.0	3.4	78	4.3		*	21.1
2	40	0.6428	5.6	36	30	3.6	*		7.2
5	36	0.5878	7.3	4.3	94	5.0	*		37.4
4 5	36.3	0,5948	9.5	5.7	94	6.4	*		16.9
5	36.3	0.5948	9.4	5.6	65	4.9	*		33.0
6 B	37.3	0,6088	16.8	10,2	35	6.2	*		41.0
7	37.3	0,6088	22	13.4	140	7.0	*		243.2
, 8	37.3	0.6088	29	17.7	107	11.1		*	389.3
0 0	36	0.5878	20.5	12.0	113	9.1		*	228.5
104	40.3	0.6494	6.7	4.4	60	4.5		*	22.0
10R	36	0.5878	28	16.5	128	7.0		*	273.8
100	38.3	0.6225	40	24.9	250	13.2		*	1521.7
11	36	0.5878	18	10.5	36	6.2	*		43.4
124	32	0.5299	6.5	3.4	70.5	4.1	*		18.2
12R	31.3	0.5225	20	10.5	60	12.6		*	147.0
13	39	0,6293	16	10.1	210	5.3	*		208.2
1/	40	0,6428	10	6.4	57	5.7	*		38.5
15	37.3	0.6088	16	9.7	80	4.9	*		70.4
164	37.3	0.6888	6.0	3.7	41	3.5	*		9.8
16R	35.3	0.5807	28	16.3	144	10.4		*	452.0

SHALE SCREE MEASUREMENTS - BALDHILL CREEK AUGUST 12, 1968

Shale Bank #	Slope Angles in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
		0 (157	12	7.4	33	6.7	*		30.3
17A	38	0.6157	12	10 1	100	8.5		*	206.2
17B	38.30	0.6225	21	13.1	100	12 0		*	874.0
17C	36.3	0.5948	32	19.0	180	13.0		- L	268 7
170	25	0.4226	36	15.2	100	13.1		X	500.7
104	40	0.6428	23	14.8	86	8.6	*		202.7
TOW	40	0 50/8	11	6.5	33	4.5	*		17.5
18B	36.3	0.5948		۵۰- ۸ 1	42	4.5	*		10.3
18C	36	0.5878	/	4 •⊥	72	5.0	*		11.5
19A	35	0.5736	8	4.6	27	5.0			
108	39.3	0,6361	36	22.9	100	8.9		*	3//.4
190	26.3	0 5948	16	9.5	40	5.8		*	40.8
19C	30.5	0.5940		0 4	83	6.9		*	99.7
20A	39	0.6293	15	9.4	0.5	- 1		*	40.9
20B	34.3	0.5664	9	5.1	61	/ • 1			

SHALE SCREE MEASUREMENTS - BALDHILL CREEK AUGUST 12, 1968

Shale Bank #	Slope Angles in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
				این ^{ار} در این روید انچندی میشور میشور انجام از این	38		*		
1					78	3.9		*	16.3
2	36	0.5878	5.0	2.9	20	2 9	*		6.0
3	38	0.6157	6	3.7	30	2	*		367
4	34	0.5592	7	3.9	94	D •4			118.8
5	36	0.5878	11	6.5	94	10.5	~		24 7
6	36	0.5878	9	5.3	35	7.2	*		24.7
7	38	0.6157	22	13.5	140	10.3	*		360.5
, 8	37	0.6018	25	15.0	107	11.8		*	350./
0	37	0.6018	19	11.4	113	7.4		*	176.5
9	36	0 5878	20	11.8	108	6.6		*	271.1
LOA	00	0.6018	39	23.5	250	15.7		*	1708.1
10B	37	0.0010	16	9.6	100	6.4	*		113,8
11	37	0.0010	10	3.5	71	3.1	*		14.3
12A	30	0,5000	7.0	0.5	60	11.4		*	120.3
12B	32	0.5299	13	7 • J	210	5 3	*		158.7
13	40	0.6428	12	/./	210	1.3	*		31.7
14	37	0.6018	8	4.8	83	4.J	*		51.4
15	38	0.6157	11	6.8	80	5.1			8.4
16A	37	0.6018	5	3.0	41	3.7	ж	.*.	405 7
16B	37	0.6018	28	28	144	11.0		x	495.1
174	36	0.5878	10	5.9	20	7.7	*		10.0
17B	36	0.5837	19.5	11.5	100	12.0		*	225.6

SHALE SCREE MEASUREMENTS - BALDHILL CREEK SEPTEMBER 1964

Shale Bank #	Slope Angles in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
170	34	0.5592	32	17.9	180	14.9		*	889.0
17D	25	0.4246	38	16.1	100	15.7		*	468.1
18A	38	0.6157	23	14.2	86	9.1	*		205.8
18B	37	0.6018	10	6.0	33	4.5	*		165
180	37	0.6018	7	4.2	30	2.5	*		5.3
19A	39	0.6293	8.5	5.3	95	6.4	*		18.7
19B	38	0.6157	37	22.8	100	7.9		*	333.6
19C	38	0.6157	16	9.9	40	4.7		*	34.5
20A	38	0.6157	17	10.5	83	4.5		*	72.6
20B	37	0.6018	10	6.0	61	6.5		*	44.1

SHALE SCREE MEASUREMENTS - BALDHILL CREEK SEPTEMBER 1964

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Shale Bank #	Slope	Sine of	Slope	Slope Height	Length	Average	Bank	Bank	Volume
Dank #	in	Augre	(feet)	(feet)	Bank	Depth	Creek	From	Cubic Yards
	Degrees			· · · · · · · · · · · · · · · · · · ·	(feet)	(feet)		Creek	
<u></u>				<u></u>			· · · · · · · · · · · · · · · · · · ·		· · · · · · · · · · · · · · · · · · ·
1	-	· _	-	-	130	-	*		-
2	33	0.5446	11	6.0	90	6.6		*	66.0
3	-	-	-	-	66	_	*		_
4	34	0.5592	13	7.3	56	8.7		*	65.9
5A	38	0.6157	15	9.2	85	10.2	*		147.7
5B	38	0.6157	9	5.5	53	6.5	*		35.1
6	37	0.6018	16	9.6	49	7.1		*	61.8
7	39	0.6293	27	17.0	150	10.1	*		476.9
8	38	0.6157	36	22.2	105	10.4		*	448.9
9	37	0.6018	24	14.4	110	9.9		*	290.4
10A	36	0.5878	24	14.1	190	8.7		*	431.6
10B	39	0.6293	10	6.3	50	8.8	*		51.3
11	38	0.6157	6	4.0	20	5.0	*		7.4
12A	33	0.5446	49	26.7	248	13.4		*	1643.1
12B	41	0.6561	35	23.0	35	9.2	*		137.1
13	36	0.5878	26	15.3	88	10.6	*		264.3
14A	37	0.6018	6	3.6	50	6.4	*		21.3
14B	31	0.5150	27	13.9	60	13.0		*	200.8

SHALE SCREE MEASUREMENTS - BALDHILL CREEK JUNE, 1965

Shale Bank #	Slope Angle in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
15A	37	0.6018	22	13.2	129	7.1	*		223.9
15B	37	0.6018	• 7	4.2	28	5.4	*		11.8
15C	38	0.6157	8	4.9	30	3.6	*		9.8
16	-	-		_	130	-	*		
17	35	0.5736	15	8.6	126	6.6		*	132.4
18	- 33	0.5446	26	14.2	138	11.9	*		431.8
19	39	0.6293	13	8.2	32	9.6		*	46.6
20A	34	0.5592	29	16.2	258	15.8		*	1222.9
20B	23	0.3907	38	14.9	100	16.2		*	447.0
21	38	0.6157	26	16.0	87	11.0	*		283.6
22	42	0.6691	12	8.0	135	5.7	*		114.0
23	39	0.6293	33	20.8	132	9.3		*	472.9
24	34	0.5592	16	8.9	137	6.3		*	142.2

SHALE SCREE MEASUREMENTS - BALDHILL CREEK JUNE, 1965 (continued)

Shale Bank #	Slope Angle in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards	
1	<u> </u>	_	· · · ·		130	_	*			
2	34	0.5592	9	5.0	90	6.5		*	54.2	
3	31	0.5150	4	2.1	67	4.4	*		11.5	
4	32	0.5299	9	4.8	58			*	60.8	
5	35	0.5736	10	5.8	100	9.7	*		104.7	
6	35	0.5736	16	9.2	54	6.4		*	58.9	
7	37	0.6018	26	15.6	150	11.2	*		485.3	
8	36	0.5878	34	20.0	105	11.8		*	458.9	
9	35	0.5736	22	12.6	110	9.4		*	241.2	
10	36	0.5878	22	12.9	190	8.8		*	399.4	
11A	38	0.6157	12	7.4	52	9.6	*		68.4	
11B	36	0.5878	8	4.7	50	5.4	*		23.5	
12	35	0.5736	51	29.3	248	15.4		*	2072.3	
13A	41	0.6561	40	26.2	36	8.4	*		146.7	
13B	36	0.5878	20	11.8	87	13.1	*		249.0	
14A	36	0.5878	7	4.1	61	6.6	*		30.6	
14B	36	0.5878	7	4.1	13	7.1	*		7.0	

SHALE SCREE MEASUREMENTS - BALDHILL CREEK JULY, 1965
· · · ·			· · · · · · · · · · · ·	· · · · · · · · ·					
Shale Bank #	Slope Angle in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
14C	32	0.5299	26	13.8	60	11.7		*	179.4
15A	39	0.6293	22	13.8	55	8.8	*		123.7
15B	38	0.6157	12	7.4	85	7.4	*		86.2
16	-	-		-	130		*		·
17	37	0.6018	16	9.6	86	6.5		*	99.4
18A	35	0.5736	26	14.9	19	7.0	*		36.7
18B	35	0.5736	28	16.1	141	11.7	*		492.8
19	37	0.6018	14	8.4	35	8.2		*	44.6
20A	25	0.4226	39	16.5	100	17.8		*	543.9
20B	36	0.5878	32	18.8	258	15.2		*	1365.3
21A	39	0.6293	27	17.0	8,9	10.9	*		305.4
21B	34	0.5592	7	3.9	80	5.2	*		30.0
22A	41	0.6561	10	6.6	24	5.3	*		15.5
22B	39	0.6293	15	9.4	88	5.8	*		88.8
23	39	0.6293	31	19.5	132	9.7		*	462.4
24	36	0.5878	16	9.4	137	7.2		*	171.7

SHALE SCREE MEASUREMENTS - BALDHILL CREEK JULY, 1965 (continued)

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Shale Bank ∦	Slope Angle in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
1	_		-		136		*		<u> </u>
2	32	0.5299	10	5.3	90	5.3		*	46.8
3	31	0.5150	3	1.6	69	2.7	*		5.5
4	34	0.5592	9	5.0	126	4.5	*		52.5
5	36	0.5878	13	7.6	88	7.5	*		92.9
6	37	0.6018	13	7.8	46	6.4		*	42.5
7	38	0.6157	32	19.7	150	10.5	*		574.6
8	38	0.6157	42	25.9	105	12.2		*	614.4
9	36	0.5878	26	15.3	110	9.8		*	305.4
10	35	0.5736	26	14.9	191	8.0		*	421.6
11A	37	0.6018	7	4.2	52	7.3	*		29.5
11B	37	0.6018	10	6.0	55	4.3	*		26.3
12	36	0.5878	44	25.9	248	15.5		*	1843.7
13A	40	0.6428	42	27.0	45	8.4	*		189.0
13B	37	0.6018	12	7.2	89	10.3		*	122.2
14A	33	0.5446	11	6.0	62	6.6	*		45.5
14B	32	0.5299	31	16.4	60	15.3	с. А.	*	278.8

SHALE SCREE MEASUREMENTS - BALDHILL CREEK NOVEMBER, 1965

Shale Bank #	Slope Angle in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
 15A	37	0.6018	21	12.6	61	8.7	*	· · · ·	123.8
15B	31	0.5150	6	3.1	66	4.0	*		15.2
15C	35	0.5736	7	4.0	28	3.2	*		6.6
16	32	0.5299	8	4.2	28	5.8	*		12.6
17	34	0.5592	16	9.0	129	6.1		*	131.1
18A	28	0.4695	7	3.3	17	6.0	*		6.2
18B	36	0.5878	30	17.6	142	13.9	*		643.3
19	35	0.5736	11	6.3	34	8.2		*	32.5
20A	35	0.5736	35	20.1	238	14.7		*	1411.7
20B	25	0.4226	39	16.5	100	15.8		*	482.8
21A	38	0.6157	27	16.6	87	10.3	*		275.5
21B	. 33	0.5446	7	3.8	69	6.0	*		29.1
22	41	0.6561	9	5.9	25	5.3	*		14.5
23	28	0.6157	37	22.8 😔	132	7.8		*	434.7
24	35	0.5736	15	8.6	137	6.0		*	130.9

SHALE SCREE MEASUREMENTS - BALDHILL CREEK NOVEMBER, 1965 (continued)

Shale Bank ∦	Slope Angle in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
1			· ·		131	_	*	Cannada an an an an Albert San Albert San an Anna San an A	
2	35	0.5736	13	7.4	76	7.4		*	77.1
3	38	0.6157	8	4.9	79	3.8	*		27.2
4	35	0.5736	12	6.9	125	8.2	*		131.0
5	37	0.6018	18	10.8	87	9.5	*		165.3
6	39	0.6293	13	8.2	59	5.2	*		46.6
7	37	0.6018	27	16.2	150	12.3	*		553.5
8	36	0.5878	29	17.0	105	10.6		*	350.1
9	. 36	0.5878	25	14.7	114	7.9		*	245.2
10	36	0.5878	36	21.2	173	7.9		*	536.6
11A	39	0.6293	15	9.4	41	6.7	*		47.8
11B	39	0.6293	10	6.3	58	4.3	*		29.1
12A	37	0.6018	50	30.1	250	14.5		*	2018.7
12B	39	0.6293	43	27.1	37	7.0	*		130.0
13A	37	0.6018	19	11.4	87	9.2		*	169.0
13B	35	0.5736	12	6.9	58	5.9	*		43.7
14A	35	0.5736	7	4.0	17	3.4	*		4.3
14B	32	0.5299	27	14.3	60	11.6		*	184.3

SHALE SCREE MEASUREMENTS - BALDHILL CREEK JULY, 1966

Sha1e Bank #	Slope Angle in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
15A	41	0.6561	32	21.0	66	7.2	*		184.8
15B	34	0.5592	9	5.0	75	6.9	*		47.9
15C	39	0.6293	8	5.0	31	5.1	*		146.3
16	-	-	_	, 	133	_	*		· _
17	36	0.5878	18	10.6	88	7.4		*	127.8
18	35	0.5736	38	21.8	141	11.0		*	626.1
19A	38	0.6157	15	9.2	33	8.0		*	45.0
19B	37	0.6018	20	12.0	55	11.3		*	138.1
20A	35	0.5736	38	21.8	210	15.0		*	1271.7
20B	37	0.6018	42	25.3	100	14.0		*	655.9
21A	39	0.6293	30	18.9	89	10.0	*		311.5
21B	37	0.6018	7	4.2	37	6.0	*		13.3
22A	41	0.6561	8	5.2	38	4.2	*		15.4
22B	41	0.6561	12	7.9	73	5.4	*		57.7
23A	40	0.6428	37	23.8	95	9.0		*	376.8
23B	37	0.6018	13	7.8	35	8.2		*	41.4
23C	39	0.6293	17	10.7	68	7.0		*	94.3
24	38	0.6157	13	8.0	73	7.2		*	77.9

SHALE SCREE MEASUREMENTS - BALDHILL CREEK JULY, 1966 (continued)

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Shale Bank #	Slope Angle in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
1	_	-			131		*		
2	36	0.5878	16	9.4	73	5.1		*	64.8
3	-	-	-	-	79	-	*		_
4	33	0.5446	15	8.2	128	8.2	*		159.4
5	34	0.5592	15	8.4	31	16.0	*		77.2
6	38	0.6157	16	9.8	51	5.0	*		45.8
7	38	0.6157	30	18.5	150	11.9	*		611.5
8	36	0.5878	36	21.2	105	7.5	i (*	309.2
9	36	0.5878	28	16.4	115	8.5		*	296.9
10	35	0.5736	32	18.4	173	8.6		*	507.0
11A	38	0.6157	19	11.7	49	7.3		*	77.5
11B	.36	0.5878	11	6.5	56	5.4	*		36.4
12A	36	0.5878	46	27.0	250	14.8		*	1850.0
12B	40	0.6428	39	25.1	36	8.7	*		145.6
13	36	0.5878	22	12.9	87	10.7		*	222.4
14A	34	0.5592	12	6.7	41	4.9	*		24.9
14B	33	0.5446	30	16.3	60	12.7		*	230.0

SHALE SCREE MEASUREMENTS - BALDHILL CREEK AUGUST, 1966

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Shale Bank #	Slope Angle in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
15A	38	0.6157	28	17.2	65	8.1	*		167.7
15B	37	0.6018	22	13.2	26	3.6	*		22.9
16	-	-	-	-	140	-	*		_
17	37	0.6018	17	10.2	82	5.1		*	79.0
18	34	0.5592	36	20.1	134	10.7		*	533.7
19	37	0.6018	17	10.2	34	8.5		*	54.6
20A	36	0.5878	40	23.5	100	10.9		*	474.4
20B	36.5	0.5948	40	23.8	155	13.1		*	894.9
20C	35.5	0.5807	42	24.4	100	15.7		*	709.4
21	38	0.6157	28	17.2	79	7.9	*		198.8
22	. -	-	-	-	95	-	*		. 🗕
23A	39	0.6293	36	22.6	97	8.6		*	349.1
2 3B	39	0.6293	13	8.2	38	4.9		*	28.3
24A	37	0.6018	17	10.2	74	5.2	*		72.7
24B	38	0.6157	12	7.4	64	7.8		*	68.4

SHALE SCREE MEASUREMENTS - BALDHILL CREEK AUGUST, 1966 (continued)

Shale Bank ∦	Slope Angle in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
	·····	· · · · · · · · · · · · ·	· · · · · · · · · · · · · · ·	· · · · · · · · · · · · · ·		· · · · · · · · · · · · · · · · · · ·	· · · · · · · · · · · ·		
1	-	-	_	· _	141	-	*		-
2	33	0.5446	15	8.2	75	6.9		*	78.6
3		-	-	-	79	-	*		_
4A	36	0.5878	12	7.0	40	5.0	*		25.9
4B	36.5	0.5948	19	11.3	66	7.1	*		98.0
5A	34.5	0.5664	15	8.5	29	11.0	*		50.2
5B	37	0.6018	16	9.6	49	3.9	*		34.0
6	38.5	0.6225	20	12.4	38	7.0		*	61.1
7	37	0.6018	33	19.9	150	10.0	*		552.8
8	38.5	0.6225	44	27.4	108	10.8		*	591.8
9	36	0.5878	25	14.7	114)	9.4		*	291.7
10A	36	0.5878	32	18.8	136	14.1		*	667.6
10B	40	0.6428	16	10.3	41	6.5		*	50.8
11	37	0.6018	9	5.4	37	4.6	*		17.0
12A	37	0.6018	44	26.5	250	13.4		*	1644.0
12B	39.5	0.6361	36	22.9	42	7.1	*		126.4
13	36	0.5878	18	10.6	89	9.6		*	167.7
14A	35	0.5736	10	5.7	46	4.2	*		29.3

SHALE SCREE MEASUREMENTS - BALDHILL CREEK SEPTEMBER, 1966

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Shale Bank #	Slope Angle in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
14B	33	0.5446	26	14.2	60	11.3		*	178.3
15A	40	0.6428	23	14.8	36	6.0	*		59.2
15B	38	0.6157	8	4.9	72	4.4	*		27.4
15C	35	0.5736	9	5.2	28	4.3	*		11.6
16	31	0.5150	7	3.6	26	3.2	*		5.5
17	36.5	0.5948	19	11.3	82	5.8		*	99.5
18	. 36	0.5878	32	18.8	132	12.0		*	551.5
19A	38	0.6157	20	12.3	29	7.3		*	48.2
19B	35	0.5736	19	10.9	62	7.7		*	96.4
20A	38	0.6157	33	20.3	21	10.8		*	85.3
20B	36.5	0.5948	38	22.6	156	16.2		*	1057.7
20C	35	0.5736	41	23.5	100	16.2		*	705.0
21A	38	0.6157	28	17.2	86	9.6	*		263.0
21B	32	0.5299	8	4.2	77	4.2	*		24.2
22A	39	0.6293	13	8.2	20	5.6	*		17.0
22B	38	0.6157	32	19.7	98	10.1		*	361.1
23A	38	0.6157	16	9.8	36	8.8		*	57.5
23B	37	0.6018	18	10.8	76	5.1		*	77.5
24	37	0.6018	13	7.8	64	6.8		*	62.9

SHALE SCREE MEASUREMENTS - BALDHILL CREEK SEPTEMBER, 1966 (continued)

Shale Bank #	Slope Angle in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
1	—	_	_	-	133	—	*	€************************************	
2	37.4	0.5088	18	14	78	5		*	79
3	36	0.5878	7	4	40	4	*		11
4	35	0.5736	23	13	56	7	*		94
5	38	0.6157	20	12	50	8	*	· · ·	88
6A	38	0.6157	15	9	54	6	*		64
6B	36	0.5878	15	9	37	7	*		43
7	37	0.6018	32	19	150	9	*		475
8	35	0.5736	31	18	108	10		*	360
9	36	0.5878	24	14	115	10		*	298
10A	37	0.6018	8	5	60	6		*	33
10B	35.5	0.5807	34	20	137	9		*	456
11	39	0.6293	18	11	108	4	*		88
12	36	0.5878	38	23	250	13		*	1383
13A	39	0.6293	36	23	42	8	*		143
13B	36.5	0.5948	29	17	89	10		*	220
14A	34	0.5592	17	10	54	5		*	50
14B	32	0.5299	33	.17	72	8		*	181

SHALE SCREE MEASUREMENTS - BALDHILL CREEK MAY, 1967

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Shale Bank #	Slope Angle	Sine of Angle	Slope Distance	Slope Height	Length of Book	Average Probe	Bank at	Bank Away	Volume in
	Degrees		(TEGT)	(reer)	(feet)	(feet)	Creek	From Creek	Cubic Yards
15A	39.5	0.6361	27	17		7	<u> </u>	*	220
15B	38	0.6157	8	5	30	2	*		5
16	-	-	_	_	128	_	*	2 2	-
17	37	0.6018	20	12	88	6		*	117
18	35.5	0.5807	29	17	137	11		*	474
19	37	0.6018	18	11	25	8		*	40
20A	35	0.5736	20	12	65	7		*	101
20B	35	0.5736	38	22	200			*	814
20C	25	0.4226	39	16	100	15		*	444
21	39	0.6293	30	19	78	8		*	219
22	-	-	-	-	125	-	*		_
23	38	0.6157	30	18	132	8		*	352
24	35	0.5736	10	6	75	7		*	58

SHALE SCREE MEASUREMENTS - BALDHILL CREEK MAY, 1967 (continued)

Shale Bank #	Slope Angle in	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
1		· _	· _	·	140		*		
2	35	0.5736	17	10	79	6		*	88
3	38	0.6157	9	6	67	4	*		30
4A	36	0.5878	15	9	56	9	*		84
4B	38	0.6157	10	6	27	6	*		18
5	33	0.5446	17	9	94	8	*		125
6A	37	0.6018	18	11	42	6		*	51
6B	38	0.6157	17	10	55	6	*		61
7	37	0.6018	32	19	150	10	*		528
8	36	0.5878	28	16	105	10		*	311
9	36	0.5878	27	16	112	8		*	265
10A	35	0.5736	30	17	136	10		*	428
10B	36	0.5878	9	5	56	6		*	31
11	40	0.6428	16	10	105	6	*		117
12	37	0.6018	36	22	248	13		*	1314
13A	36	0.5878	27	16	88	10		*	261
13B	38	0.6157	27	17	43	7	*		93
14A	36	0.5878	13	8	64	4		*	38

SHALE SCREE MEASUREMENTS - BALDHILL CREEK JUNE, 1967

Shale Bank #	Slope Angle in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
1/B	37	0 5200	24	10	70	1 /			242
154	33	0.5446	0	ст 2	20	14 7		*	243
15R	36	0.5878	<i>э</i> 10	11	20	4	4	~	101
150	30	0.6202	19	10		Г	*		101
164	33	0.0295	7	10	7.5 5.2 (ן ס	~		122
16P	25	0.5726	7	4	D4 8 -	 	л		12
17	26	0.5750	9 . 1 C	2	30	2	ж		14
1/	30	0.5878	16	9	70	9		*	105
18A	37	0.6018	31	19	132	11		*	511
18B	32	0.5299	9	5	18	8	*		13
19A	37	0.6018	15	9	32	8		*	43
19B	35	0.5736	8	5	24	6	*		13
19C	33	0.5446	7	4	24	4	*		7
20A	36	0.5878	18	11	60	8	* .		98
20B	37	0.6018	33	20	203	13		*	978
20C ·	24	0.4067	39	16	100	16		*	474
21A	35	0.5736	11	6	35	6	*		23
21B	39	0.6293	27	17	85	11	*		294
22	-	-			44	-	*		_
23	38	0.6157	32	20	130	9		*	433
24	35	0.5736	15	9	75	7		*	88

SHALE SCREE MEASUREMENTS - BALDHILL CREEK JUNE, 1967

(continued)

Shale Bank #	Slope Angle in Degrees	Sîne of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards			
1	_				134	_	*		-			
2	37	0.6018	14	8	78	7		*	81			
3	36	0.5878	6	4	66	3	*		15			
4A	38	0.6157	10	6	38	5	*		21			
4B	34	0.5592	13	7	57	8	*		59			
5	34	0.5592	14	8	122	5	*		40			
6A	.39	0.6293	12	8	65	5	*		58			
6B	37	0.6018	18	11	37	5		*	38			
7	39	0.6293	19	19	150	11	*		581			
8	35	0.5736	24	14	106	11		*	302			
9	37	0.6018	23	14	105	9		*	244			
10A	37	0.6018	7	4	58	5		*	21			
10B	35	0.5736	34	19	136	9		*	431			
11	39	0.6293	15	9	107	6	*		107			
12	37	0.6018	38	23	248	12		*	1266			
13A	39	0.6293	36	23	40	9	*		153			
13B	36	0.5878	29	17	87	7		*	192			
14A	37	0.6018	11	7	65	7		*	59			

SHALE SCREE MEASUREMENTS - BALDHILL CREEK JULY, 1967

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Shale Bank #	Slope Angle in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
14B	32	0.5299	23	12	66	8		*	117
15A	39	0.6293	221	14	73	5	*		151
15B	38	0.6157	9	6	128	5	*		71
16A	37	0.6018	16	10	28	7	*		36
16B	31	0.5878	8	5	16	4	*		6
16C	. 36	0.5878	8	5	52	3	*		14
17	38	0.6157	18	11	87	5		*	102
18A	37	0.6018	9	5	16	8	*		12
18B	36	0.5878	29	17	129	10		*	405
19A	37	0.6018	7	4	25	4	*		7
19B	34	0.5592	7	4	29	5	*		11
19C	36	0.5878	15	9	32	6		*	32
20A	34	0.5592	21	12	56	7		*	92
20B	35	0.5736	.36	21	209	12		*	975
20C	24	0.4067	38	15	100	16		*	445
21A	40	0.6428	30	19	84	8		*	236
21B	36	0.5878	10	6	36	5	*		20

SHALE SCREE MEASUREMENTS - BALDHILL CREEK JULY, 1967 (continued)

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. :	SHALE SCREE MEASUREMENTS - BALDHILL CREEK JULY, 1967 (continued)												
Shale Bank #	Slope Angle in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards				
21C	33	0.5446	6	3	30	4	*		7				
22	39	0.6293	13	8	20	5	*		15				
23	39	0.6293	32	20	136	9		*	453				
24	37	0,6018	11	7	69	6		*	53				

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Shale Bank #	Slope Angle in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
1	_			_	140		*		_
2	37	0.6018	14	8	78	8		*	92
3A	35	0.5736	7	4	68	5	*		25
3B	37	0.6018	9	5	38	5	*		18
4	35	0.5736	15	9	62	8	*		83
5A	35	0.5736	16	9	140	7	*		163
5B	39	0.6293	13	8	66	6	*		59
6	37	0.6018	17	10	40	6		*	44
7	38	0.6157	30	18	150	10	*		500
8	37	0.6018	32	19	106	8		*	298
9A	36	0.5878	24	14	112	9		*	261
9B	39	0.6293	8	5	57	5		*	26
10	35	0.5736	32	18	137	9		*	411
11	39	0.6293	12	8	113	6	*		100
12A	37	0.6018	40	24	250	12		*	1333
12B	38	0.6157	24	15	50	7		*	97
13	36	0.5878	22	13	98	8		*	189
14A	34	0.5592	10	6	66	5		*	37

SHALE SCREE MEASUREMENTS - BALDHILL CREEK AUGUST, 1967

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Shale Bank #	Slope Angle in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
14B	34	0.5592	10	6	18	4	*		8
14C	32	0.5299	23	12	60	9		*	120
15	39	0.6293	20	13	200	5	*		241
16	35	0.5736	12	7	122	6	*		95
17A	36	0.5878	15	9	128	5		*	107
17B	35	0.5736	7	4	19	7	*		10
18A	37	0.6018	31	18	137	11		*	502
18B	33	0.5446	7	4	28	3	*		6,
18C	33	0.5446	7	4	32	6	*		14
19	36	0.5878	17	10	32	6		*	36
20A	36	0.5878	36	21	270	11		*	1155
20B	24	0.4067	37	15	100	16		*	444
20C	39 :)	0.6293	28	18	87	8		*	232
21A	34	0.5592	10	6	97	5	*		54
21B	39	0.6293	14	9	27	4		*	18
21C	39	0.6293	13	8	23	4	*		14
22	37	0.6018	12	7	20	6	*		16
23	38	0.6157	32	20	138	6		*	307
24	37	0.6018	14	8	73	6		*	65

SHALE SCREE MEASUREMENTS - BALDHILL CREEK AUGUST, 1967 (continued)

Shale Bank #	Slope Angle in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
1	M. M	_		· _	141		*		
2	35	0.5736	15	9	90	6		*	90
3	36	0.5876	7	4	68	4	*		20
4A	37	0.6018	10	6	47	5	*		26
4B	37	0.6018	16	10	58	7	*		75
5	36	0.5878	16	9	137	7	*		160
6A	39	0.6293	16	10	54	5	*		50
6B	35	0.5736	14	8	47	8		*	56
7	38	0.6157	29	18	148	9	*		444
8	36	0.5878	28	16	105	9		*	289
9	37	0.6018	25	15	112	7		*	218
10A	36	0.5878	8	5	60	6		*	33
10B	35 .	0.5736	32	18	135	10		*	450
11	39	0.6293	13	8	113	6	*		100
12	36	0.5878	38	22	250	12		*	1222
13A	39	0.6293	28	18	50	7	*		116
13B	37	0.6018	22	13	102	6		*	147
14A	36	0.5878	11	7	65	5		*	42

SHALE SCREE MEASUREMENTS - BALDHILL CREEK SEPTEMBER, 1967

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Shale Bank #	Slope Angle in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
14B	36	0.5878	6	4	17	3		*	4
14C	34	0.5592	.25	14	60	9		*	140
15A	39	0.6293	26	16	60	7	*		124
15B	35	0.5736	16	9	139	7	*		162
16A	34	0.5592	16	9	58	8	*		77
16B	34	0.5592	16	9	52	5	*		43
17	38	0.6157	19	12	88	5	*		98
18A	37	0.6018	10	6	17	5	*		9
18B	37	0.6018	29	17	138	10		*	434
19A	37 -	0.6018	7	4	29	3	*		
19 B	38	0.6157	8	5	32	6	*		18
19C	39	0.6293	13	8	34	5		*	25
20A	36	0.5878	19	11	62	7		*	88
20B	36	0.5878	36	21	205	12		*	958
20C	25	0.4226	43	18	100	15		*	500
21A	38	0.6157	28	17	87	9		*	246
21B	33	0.5446	10	5	87	6	*		48

SHALE SCREE MEASUREMENTS - BALDHILL CREEK SEPTEMBER, 1967 (continued)

(continued)												
Shale Bank #	Slope Angle in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards			
22A	39	0.6293	11	7	25	5		*	16			
22B	39	0.6293	9	6	18	4	*		8			
23	38	0.6157	34	21	138	7		*	376			
24	37	0.6018	14	8	74	6		*	66			

SHALE SCREE MEASUREMENTS - BALDHILL CREEK SEPTEMBER, 1967

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Shale Bank #	Slope Angle in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
1	_	_	· <u>-</u>	-	140		*		-
2	36	0.5878	17	10.0	92	6	ن	*	102.2
3	36	0.5878	9	5.3	69	6	*		40.6
4A	36	0.5878	15	8.8	56	7	*		63.9
4B	36	0.5878	10	5.9	38	8	*		33.2
5	36	0.5878	16	9.4	90	8	*		125.3
6A	37	0.6018	15	9.0	48	6		*	48.0
6B	38	0.6157	14	8.6	55	6	*		52.6
7	37	0.6018	34	20.5	150	10	*	,	569.4
8	36	0.5878	31	18.2	1.05	9		*	318.5
9	35	0.5736	23	13.2	110	8		*	215.1
10A	36	0.5878	29	17.0	135	10		*	425.0
10B	34	0.5592	8	4.5	56	5		*	23.3
11	38	0.6157	13	8.0	132	5	*		97.8
12	37	0.6018	22	22.9	245	12		*	1246.8
13A	36	0.5878	22	12.9	90	8		*	172.0
13B	37	0.6018	28	16.9	45	8	*		112.7
14A	36	0.5878	10	5.9	60	8		*	52.4

SHALE SCREE MEASUREMENTS - BALDHILL CREEK JUNE, 1968

Shale Bank #	Slope Angle in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
14B	32	0.5299	26	13.8	60	13		*	199.3
15	39	0.6293	20	12.6	200	6	*		280.0
16A	37	0.6018	11	6.6	36	5	*		22.0
16B	37	0.6018	11	6.6	46	8			45.0
17	37	0.6018	19	11.4	85	7		*	125.6
18	34	0.5592	24	13.4	134	11		*	365.8
19A	36	0.5878	17	10.0	33	7		*	42.8
19B	36	0.5878	14	8.2	69	6	*		62.9
20A	36	0.5878	36	21.2	261	12	·	*	1229.6
20B	24	0.4067	35	14.2	100	16		*	420.7
21A	35	0.5736	14	8.0	35	8	*		41.4
21B	39	0.6293	25	15.7	86	12		*	300.0
22A	39	0.6293	14	8.8	89	5	*		72.5
22B	39	0.6293	13	8.2	29	5	*		22.1
23	39	0.6293	33	20.8	130	7		*	350.5
24	35	0.5736	13	7.5	72 /	7		*	70.0

SHALE SCREE MEASUREMENTS - BALDHILL CREEK JUNE, 1968 (continued)

Shale Bank #	Slope Angle in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
1A	34	0.5592	7	3.9	45	5	*		16.2
<u>1</u> B	34	0.5592	7	3.9	58	4	*		16.8
2	36	0.5878	16	9.4	90	7		*	109.7
3	35	0.5736	10	5.7	70	5	*		36.9
4	36	0.5878	16	9.4	85	8		*	118.4
5	37	0.6018	15	9.0	93	8	*		124.0
6A	39	0.6293	16	10.1	54	7	*		70.7
6B	37	0.6018	17	10.2	39	7		*	51.6
7	38	0.6157	24	14.8	150	10	*		411.1
8	38	0.6157	32	19.7	105	11		*	421.4
9	37	0.6018	26	15.6	112	10		*	323.6
10A	39	0.6293	9	5.7	60	5		*	31.7
10A	36	0.5878	26	15.3	134	10		*	379.7
11	38	0.6157	12	7.4	130	7	*	à.	124.7
12	36	0.5878	40	23.5	250	12		*	1305.6
13A	40	0.6428	36	23.1	44	8	*		150.6
13B	36	0.5878	18	10.6	94	9		*	166.1
14A	37	0.6018	13	7.8	85	7		*	85.9
14B	32	0.5299	26	13.8	60	8		*	122.7

SHALE SCREE MEASUREMENTS - BALDHILL CREEK JULY, 1968

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Shale Bank #	Slope Angle in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
15A	40	0.6428	24	15.4	100	7	*		199.6
15B	38	0.6157	8	4.9	122	5	*		55.3
16A	38	0.6157	7	4.3	45	6	*		21.5
16B	41	0.6561	11	7.2	47	5	*		13.1
17	38	0.6157	18	11.1	87	6		*	107.3
18	36	0.5878	19	11.2	138	10		*	286.2
19A	36	0.5878	11	6.5	68	6	*		20.2
19B	39	0.6293	13	8.2	33	8		*	40.1
20A	38	0.6157	20	12.3	60	8		*	82.0
20B	36	0.5878	.38	22.3	200	13		*	1073.7
20C	24	0.4067	38	15.5	100	16		*	443.2
21A	39	0.6293	32	20.1	83	9		*	278.1
21B	38	0.6157	11	6.8	32	7	*		28.2
21C	38	0.6157	7	4.3	38	5	*		15.1
22A	36	0.5878	12	7.1	28	5	*		18.4
22B	41	0.6561	12	7.9	48	4	*	•	28.1
23	38	0.6157	32	19.7	135	8		*	394.0
24	35	0.5736	11	6.3	66	6		*	46.2

SHALE SCREE MEASUREMENTS	-	BALDHILL	CREEK	JULY,	1968
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Shale Bank #	Slope Angle in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
14	36	0.5878	6	3.5	44	5	*		14.3
1B	33	0.5446	8	4.4	40	5	*		16.3
2	35	0.5736	18	10.3	90	8		*	137.3
3	34	0.5592	11	6.2	66	5	*		37.9
4	37	0.6018	20	12.0	132	9	*		264.0
5	36	0.5878	22	12.9	92	8	*		175.8
6A	36	0.5878	15	8.8	38	6		*	37.1
6B	38	0.6157	20	12.3	52	8	*		94.8
7	38	0.6157	35	21.6	150	11	*		660.0
8	36	0.5878	34	20,0	105	10		*	388.9
9	37	0.6018	28	16.9	112	10		*	350.5
10A	36	0.5878	31	18.2	134	10		*	451.6
10B	41	0.6561	9	5.9	55	4		*	24.0
11	40	0.6428	16	10.3	132	6	*		151.1
12	37	0.6018	42	25.3	246	12		*	1383.1
13A	36	0.5878	30	17.6	95	10		*	309.6
1.3B	36	0.5878	36	21.2	54	10		*	212.0
14A	33	0.5446	6	3.4	16	4	*		4.0
14B	36	0.5878	14	8.2	58	6		*	52.8

SHALE SCREE MEASUREMENTS - BALDHILL CREEK, AUGUST, 1968

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Shale Bank #	Slope Angle in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
14C	33	0.5446	28	15.3	60	10		*	170.0
15A	42	0.6691	11	7.4	48	5	*		32.9
15B	35	0.5736	6	3.4	34	6	*		12.8
15C	40	0.6428	27	17.4	44	8	*		113.4
16A	38	0.6157	9	5.5	49	4	*		20.0
16B	38	0.6157	9	5.5	46	5	*		23.4
17	37	0.6018	21	12.6	34	7	*		131.2
18	38	0.6157	30	18.5	136	14		*	652.3
19A	37	0.6018	18	10.8	32	9		*	59.4
19B	37	0.6018	9	5.4	64	· 7	*		44.8
20A	36	0.5878	36	21.2	200	12		*	942.2
20B	37	0.6018	20	12.0	64	12		*	170.6
20C	24	0.4067	36	14.6	100	15		*	402.7
21A	37	0.6018	15	9.0	26	7	*		30.3
21B	39	0.6293	30	18.9	79	12		*	331.8
22A	39	0.6293	16	10.1	90	6	*		101.0
22B	39	0.6293	15	9.4	27	5	*		32.2
23	38	0.6157	33	20.3	130	9		*	439.8
24	34	0.5592	15	8.4	66	7		*	71.8

SHALE SCREE MEASUREMENTS - BALDHILL CREEK AUGUST, 1968 (continued)

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Shale Bank #	Slope Angle in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
1	_	_	_	_	133	_	*		-
2	37.5	0.6088	17	10.3	90	7		*	120.0
3	-	-	-	-	-	-	*		-
4	40.0	0.6428	14	9.0	57	8	*		76.0
5	36.0	0.5878	18	10.9	31	7	*		43.8
6A	36.0	0.5878	7	4.1	48	5	*		14.6
6B	37.5	0.6088	16	9.7	38	8		*	54.6
7	39.0	0.6293	28	17.6	148	9	*		434.1
8	36.0	0.5878	34	20.0	70	12		*	311.1
9	37.0	0.6018	28	16.9	110	9		*	309.8
10A	35.9	0.5736	9	5.2	55	5		*	26.5
10B	36.5	0.5948	32	19.6	134	10		*	486.4
11	41.0	0.6561	15	9.8	85	7	*		108.0
12	35.5	0.5807	44	25.6	250	12	*		1422.2
13A	37.5	0.6088	16	9.7	34	7	*		42.8
13B	36.5	0.5948	18	10.7	64	12		*	152.2
14	33.0	0.5446	23	12.5	60	10		*	138.9

SHALE SCREE MEASUREMENTS - BALDHILL CREEK SEPTEMBER, 1968

Shale Bank #	Slope Angle in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
	· · · ·								
15A	43.5	0.6884	25	17.2	100	7	*		223.0
15B	37.5	0.6088	6	3.7	26	4		*	7.1
16	34.5	0.5664	5	2.8	52	3	*		8.1
17	36.0	0.5878	18	10.9	78	7		*	110.2
18	35.5	0.5807	32	18.6	129	.9		*	399.9
19	34.0	0.5592	14	7.8	30	6		*	26.0
20A	39.5	0.6361	25	15.9	60	10		*	176.6
20B	34.0	0.5592	38	21.2	208	12		*	980.0
20C	24.0	0.4076	36	14.6	100	15		*	405.6
21	37.5	0.6088	29	17.7	80	11		*	288.4
22	_		_	· _	82	-	*		_
23	38.5	0.6225	33	20.5	130	9		*	444.2
.24	34.0	0.5592	15	8.4	66	6		*	61.6

SHALE SCREE MEASUREMENTS - BALDHILL CREEK SEPTEMBER, 1968 (continued)

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Shale Bank #	Slope Angle in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
1		_	_		133	_		*	,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,
2	33.5	0.5519	17	9	77	8		*	102.7
3	37.0	0.6018	6	4	65	4	*		19.3
4	37.0	0.6018	10	6	62	6	*		41.3
. 5	33.5	0.5519	10	6	90	7	*		70.0
6A	39.0	0.6293	17	11	39	8		*	63.5
6B	32.5	0.5373	7	4	51	5	*		18.9
7	37.0	0.6018	38	23	149	9	*		571.2
8	35.5	0.5807	36	21	105	11		*	449.1
9	35.0	0.5736	28	16	110	9		*	293.3
10A	35.0	0.5736	30	17	132	12		*	498.7
1.0B	35.5	0.5807	8	5	57	6		*	31.7
11	37.5	0.6088	22	13	83	7	*		139.9
12	35.5	0.5807	46	27	254	12		*	1524.0
13A	29.0	0.4848	18	9	94	9		*	141.0
13B	40.5	0.6495	20	13	33	8	*		63.6
14A	32.5	0.5373	6	3	14	3		*	2.3
14B	33.5	0.5519	8	4	47	5		*	17.4
14C	32.5	0.5373	18	10	60	11		*	122.2

SHALE SCREE MEASUREMENTS - BALDHILL CREEK MAY, 1969

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k Volume y in m Cubic Yards ek
12.5
211.6
19.6
13.0
110.2
561.6
66.7
925.6
85.9
535.2
6.9
243.0
2.7
479.5
103.1

SHALE SCREE MEASUREMENTS - BALDHILL CREEK MAY, 1969 (continued)

Shale Bank #	Slope Angle in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
					133		*		-
2	37	0,6018	16	10	90	8		*	133.3
3	-	_	_	_	67	-	*		_
4	33	0.5446	9	5	87	6	*		48.3
5	34	0.5592	10	6	54	5	*		30.0
6A	29	0.4848	8	4	48	4	*		14.2
6B	35	0.5736	12	7	38	5		*	24.6
7	41	0.6561	24	16	150	8	*		355.6
8	36	0.5878	21	12	110	9		*	220.0
9	34	0.5592	24	13	112	7		*	188.7
10A	36	0,5878	8	5	56	5		*	25.9
10B	35	0.5736	26	15	136	9		*	340.0
11	37	0.6018	17	10	89	8	*		131.9
12	39	0.6293	39	25	245	9		*	1020.8
13A	41	0.6561	24	16	32	4	*		37.9
13B	37	0.6018	20	12	71	8		*	126.2
14A	33	0.5446	12	7	10	6	*		7.8
14B	31	0.5150	. 32	16	68	11		*	

SHALE SCREE MEASUREMENTS - BALDHILL CREEK AUGUST, 1969

				(continue	d)	· · · · · · · · · · · · · · · · · · ·		· · · · · · · · · · · · · · · · · · ·	
Shale Bank #	Slope Angle in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
154		0 6561	30	20	90	7	*		233.3
15R	33	0.5446	7	4	89	4	*		26.4
150	37	0.6018	16	10	23	4		*	17.0
164	37	0.6018	±0 6	4	 73	4		*	21.6
16R	37	0.6018	6	4	48	4	*		14.2
17	39	0.6293	3 19	12	136	7	*		211.6
18	36 5	0 5948	25	15	112	10		*	308.3
19	34	0.5592		11	33	7		*	47.1
204	38	0.6157	24	15	58	10		* *	161.1
2011 2013	36	0.5878	30	18	205	13		*	888.3
200	24	0.4067	36	15	100	15		*	416.7
200	 39	0.6293	26	16	80	10		*	237.0
21R	34.5	0.5664	10	6	43	4	*		19.1
210	-	_	-	-	180	_	*		_
22	39	0.6293	34	21	136	9		*	476.0
24	37.5	0.6088	14	8	75	5		*	55.6

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SHADE DOWER IMMOORTHINTO - DADDHITTED OKERK CODI - TS/C	SHALE	SCREE	MEASUREMENTS		BALDHILL	CREEK	JULY,	1970
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Shale Bank #	Slope Angle in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
1			_		132	_	*		_
2	35	0.5736	17	10	90	8		*	133
3	-	-	° 	-	70		*		-
4	36	0.5878	10	6	77	6	*		51
5	35	0.5736	8	5	85	8	*		63
6A	38	0.6157	16	10	44	8		*	65
6B	35	0.5736	8	5	52	6	*		29
7	36	0.5878	34	20	155	12	*		689
8	39	0.6293	21	13	105	10		*	253
9	36	0.5878	28	16	112	9		*	299
10A	36	0.5878	32	19	130	11		*	503
10B	31	0.5150	8	4	55	7		*	29
11	39	0.6293	17	11	77	8		*	125
12	36	0.5878	40	24	255	15		*	1700
13A	35	0.5736	17	10	89	9		*	148
13B	40	0.6428	22	14	34	6	*		53
14A	31	0.5150	7	4	37	7	*		19
14B	32	0.5299	32	17	79	14		*	348

Shale Bank #	Slope Angle in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
15A	34	0.5592	7	4	158	6	*		68
15B	38	0.6157	26	16	65	6	*		116
16A	36	0.5878	6	4	48	5	*		18
16B	36	0.5878	21	12	47	8	*		84
17	37	0.6018	18	11	80	7		*	114
18	37	0.6018	30	18	130	14		*	607
19	35	0.5736	16	9	32	·9		*	48
20A	26	0.4384	36	.16	100	17		*	504
20B	35	0.5736	36	21	260	14		*	1416
21A	37	0.6018	8	5	58	4	*		21
21B	38	0.6157	28	17	82	10		*	258
22	_	_	-	_	180	_	*		_
23	38	0.6157	32	20	136	8		*	403
24	36	0.5878	13	8	70	7		*	73

SHALE SCREE MEASUREMENTS - BALDHILL CREEK JULY, 1970 (continued)

Shale Bank #	Slope Angle in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
1			_		133		*	<u></u>	
1 2	36	0.5878	15	9	95	5		*	79
2	36	0.5878	.5	3	40	3	*		7
ر 4 ۸	33	0.5446	5	3	44	3	*		7
4A 4B	30	0 5000	7	4	62	5		*	23
4D 5	34	0.5592	, 10	6	97	6	*		65
5	24 37	0.6018	10	6	56	6	*		37
6P	36	0.5878	12	7	48	7		*	44
7	37	0,5070	25	15	155	11	*		474
, o	29	0.6157	23	17	105	9		*	279
0	36	0.5878	27	13	112	10		*	270
9	30	0.5726	8	5	58	6		*	32
LUA	35	0.5750	20	18	132	11		*	484
TOR	36	0.5878	30	10	102	7		*	121
11	4⊥	0.6561	20	13	12	7			1750
12	36	0.5878	47	28	260	13		×	1/53
1.3A	40	0.6428	13	8	59	8	*		70
13B	34	0.5592	15	8	96	7		*	100
14A	32	0.5299	5	3	73	5		*	20

SHALE SCREE MEASUREMENTS - BALDHILL CREEK OCTOBER, 1970
Shale Bank #	Slope Angle in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
 14B	35	0.5736	9	5	16	5	*		7
14C	33	0.5446	26	14	60	11		*	171
15	36	0.5878	20	12	202	10	*		449
16A	38	0.6157	21	13	78	10		*	188
16B	37	0.6018	6	4	58	5	*		22
17	37	0.6018	17	10	136	8		*	202
18A	30	0.5000	6	· 3	41	4		*	9
18B	34	0.5592	32	18	131	15		*	655
19	37	0.6018	9	5	80	6		*	44
20A	39	0.	21	13	58	9		*	126
20B	35		36	21	205	15		*	1196
20C	26	0.4384	40	18	100	16		*	533
21A	38	0.6157	23	14	83	13		*	280
21B	38	0.6157	16	10	45	9	*		75
21C	38	0.6157	8	5	45	6	*		25
22	-	-	-	-	14		*		-
23	38	0.6157	36	22	136	9		*	499
24	36	0.5878	13	8	70	7		*	73

SHALE SCREE MEASUREMENTS - BALDHILL CREEK OCTOBER, 1970

(continued)

Shale Bank ∦	Slope Angles in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
1					38		*		
2	36	0.5878	17	10	92	7		*	119.3
3					70		*		
4	37	0.6018	18	8	88	6	*		42 .7
5	39	0.6293	17	11	49	5	*		49.9
6A	40	0.6428	17	11	51	6		*	62.3
6 B	39	0.6293	11	9	23	7		*	26.8
7	37	0.6018	34	20	157	. 8	*		465.2
8	38	0.6157	30	18	105	10		*	350.0
9A	37	0.6018	27	16	112	10		*	331.9
9 B	37	0.6018	7	4	59	6		*	26.2
10	37	0.6018	33	20	127	11	*		517.4
11	40	0.6428	16	10	63	7		*	81.7
12	36	0.5878	47	28	250	13		*	1658.2
13	35	0.5736	22	13	60	10		*	144.4
14	32	0.5299	29	15	60	13		*	216.7
15A	37	0.6018	12	7	15	5	*		9.8
15B	38	0.6153	28	17	49	8	*		123.4
16	38	0.6157	24	15	74	10		*	205.6
17	37	0.6018	19	11	78	8		*	127.1
18	35	0.5736	35	20	103	14		*	534.1

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SHALE SCREE MEASUREMENTS - BALDHILL CREEK JUNE 1971

Shale Bank#	Slope Angles in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
19A	36	0.5878	18	11	22	11		*	49.3
19B	37	0.6018	24	14	62	11		*	176.8
190	34	0,5592	35	20	198	16		*	1173.3
20	25	0.4226	40	17	116	16		*	503.7
21A	35	0.5736	17	10	24	10	*		44.4
21B	40	0.6428	25	16	77	11	*		251.0
22	35	0.5736	18	10	26	7	*		33.7
23	38	0.6157	30	18	137	10		*	456.7
	37	0.6018	12	7	70	7		*	63.5

SHALE SCREE MEASUREMENTS - BALDHILL CREEK JUNE 1971

Shale Bank #	Slope Angle in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
1			_		132		*	——————————————————————————————————————	_
2	35	0.5736	18	10	90	7		*	116.7
3	-	-	_	-	70	-	*		_
4A	37	0.6018	13	8	17	11	*		27.7
4B	37	0.6018	14	8	53	5		*	39.3
5	31	0.5150	4	2	112	4	*		16.6
6A	34	0.5592	16	10	52	5		*	48.2
6B	39	0.6293	11	9	23	6	*		23.0
7	39	0.6293	32	20	156	12	*		693.3
8	37	0.6018	32	19	110	10		*	387.0
9	36	0.5878	24	14	110	8		*	228.1
10A	38	0.6157	7	4	40	6		*	17.8
10B	36	0.5878	34	20	150	9		*	500.0
11	42	0.6691	18	12	74	8		*	131.6
12	36	0.5878	48	28	250	13		*	1685.2
13A	41	0.6561	24	16	48	5	*		71.1
13B	35	0.5736	21	12	89	6		*	118.7
14A	34	0.5592	5	3	44	4	*		9.8

SHALE SCREE MEASUREMENTS - BALDHILL CREEK SEPTEMBER, 1971

Shale Bank ∦	Slope Angle in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
	30	0 5000	28		78	9	<u> </u>	*	182.0
15A	39	0.6293	24	15	40	6	*		66.7
15R	32	0.5299	6	3	120	5	*		33.3
164	38	0.6157	25.	15	78	11	*		238.3
16R	38	0.6157	8	5	56	4	*		20.7
10D	39	0.6293	16	10	85	7	*		110.2
18	34	0,5592	36	20	105	13		*	505.6
19	34	0.5592	14	8	32	5		*	23.7
20A	37	0.6018	22	13	60	10		*	144.4
20B	36	0.5878	36	21	205	16		*	1275.6
20C	24	0.4067	36	15	100	18		*	500.0
21A	40	0.6428	32	21	80	10		*	311.1
21B	39	0.6293	12	8	86	5	*		63.7
22	37	0.6018	10	6	28	.5	*		15.6
 23A	39	0,6293	36	23	100	11		*	468.5
23B	38	0.6157	14	9	38	8		*	50.7
24	37	0.6018	11	7	70	6		*	54.4

SHALE SCREE MEASUREMENTS - BALDHILL CREEK SEPTEMBER, 1971

(continued)

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Shale Bank #	Slope Angle in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
1	<u></u>	_	_		132	_	*		_
2	37	0.6018	17	10	45	6		*	105
3	38	0.6157	5	3	20	4	*		4
4	35	0.5736	10	6	53	6		*	35
5	36	0.5878	5	3	140	5	*		39
6A	39	0.6293	16	10	40	7		*	52
6B	38	0.6157	10	6	50	4	*		22
7	38	0.6157	36	22	155	10	*		632
8	37	0.6018	32	19	105	7		*	258
9	36	0.5878	22	13	110	8		*	212
10	36	0.5878	36	21	152	7		*	414
11	40	0.6428	17	11	80	5		*	81
12	36	0.5878	45	26	250	12		*	1444
13A	35	0.5736	20	11	87	8		*	142
13B	36	0.5878	20	12	50	7		*	78
14A	33	0.5446	28	15	60	13		*	217
14B	32	0.5299	7	4	42	5	*		15

SHALE SCREE MEASUREMENTS - BALDHILL CREEK JULY, 1972

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Shale Bank #	Slope Angle in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
154		0.6157	12		125	6	*	. <u></u>	97
15B	40	0.6428	26	17	47	5		*	74
16	36	0.5878	22	13	132	9	*		286
17A	38	0.6157	18	11	32	7	*		46
17B	37	0.6018	16	10	78	7	•	*	101
18	33	0.5446	36	20	127	10		*	470
19A	35	0.5736	16	9	32	6	*	•	32
19B	28	0.4695	5	2	27	4	*		4
20A	24	0.4067	36	15	100	14		*	389
20B	37	0.6018	36	22	205	16		*	1336
20C	39	0.6293	20	13	55	7		*	93
21A	36	0.5878	5	3	37	3	*		6
21B	40	0.6428	18	12	54	7	*		84
21C	40	0.6428	28	18	81	9		*	243
22	37	0.6018	14	8	18	6	*		16
23	39	0.6293	24	15	140	6		*	233
24	37	0.6018	12	7	70	6		*	54

SHALE SCREE MEASUREMENTS - BALDHILL CREEK JULY, 1972 (continued)

Shale Bank #	Slope Angle in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
1		67 ex			38	ánte auro	*		
- -	35	0 5736	21	12	91	7		*	142.0
2	37	0.6018	6	4	60	4	*		18.0
5	35	0.5736	15	9	35	7		*	41.0
4 E	32	0.5299	10	5	119	5	*		55.0
5	3%	0.5592	9	5	74	4	*		27.0
6 R	27	0.6018	20	12	39	6		*	52.0
7	27	0.6018	36	22	122	9	*	•	447.0
	26	0.5878	35	21	80	9		*	280.0
8	20	0.5878	20	12	108	8		*	192.0
9	30	0.5070	10		58	4		*	25.0
10A	40	0.5726	10	23	148	7		*	441.0
108	35	0.5730	22	15	83	5	*		115.0
11	41	0.6561	23	. 31	250	11		*	1579.0
12	37	0.6018	52	10	52			*	67.0
13A	35	0.5736	18	10	92	5		*	111.0
13B	33	0.5446	28	15	30	-		*	28.0
14A	31	0.5150	8	4	75	5		*	11 0
14B	31	0.5150	8	4	29	6			240 0
15	39	0.6293	16	. 10	185	. 7	*	·	240.0
16	37	0.6018	25	15	126	8		T	205.0
17	39	0.6293	2 2 ⁴	14	119	· 7		*	216.0
18	32	0,5299	36	19	126	8		*	355.0

Shale Scree Measurements - Baldhill Creek September 1972

Shale Bank #	Slope Angle in Degrees	Sine of Angle	Slope Distance (feet)	Slope Height (feet)	Length of Bank (feet)	Average Probe Depth (feet)	Bank at Creek	Bank Away From Creek	Volume in Cubic Yards
19A	35	0.5736	16	.9	33	4	,	*	22.0
19B	28	0.4695	5	2	27	5		*	5.0
20A	36	0.5878	22	13	53	8		*	102.0
20B	35	0.5736	45	26	203	13		*	1271.0
20C	25	0.4226	38	16	100	14		*	415.0
21A	39	0.6293	23	15	85	9	*		212.0
21B	39	0.6293	23	15	52	6	*		87.0
210	39	0.6293	3	2	4	2	*		3.0
22	-				26		*		-
23	40	0.6428	37	24	127	6		*	339.0
24	33	0.5446	13	7	70	4		*	36.0

Shale Scree Measurements - Baldhill Creek September 1972