NUMBER 62
SEPTEMBER, 1976

NORTH DAKOTA
RESEARCH
REPORT

Runoff and Erosion From Snow-Melt on Surface Mined Sites in Western North Dakota

John E. Gilley, Glendon W. Gee, Armand Bauer*

AGRICULTURAL EXPERIMENT STATION
NORTH DAKOTA STATE UNIVERSITY
FARGO, NORTH DAKOTA 58102

ACKNOWLEDGEMENTS

The research was supported by Old West Regional Commission Grant No. 10470016.

The authors express appreciation to North American Coal Corporation personnel for their assistance in conducting this study.

Runoff and Erosion From Snow-Melt on Surface Mined Sites in Western North Dakota

John E. Gilley, Glendon W. Gee, Armand Bauer*

INTRODUCTION

A knowledge of methods to maintain soil erosion losses within acceptable limits is needed for efficient land management. Information has been collected since 1930 on runoff and erosion from small field plots under a variety of interrelated soil, crop and climatic conditions. These data have been incorporated into a soil loss equation used for predicting rainfall-erosion losses from cropland (12).

Excessive soil erosion sometimes results from construction activities at urban and residential development sites (1, 9). Meyer, et al. (7) measured 54 tons per acre erosion from 5 inches of intense rainfall on an exposed subsoil site with a 12% slope gradient. Similar excessive soil losses could occur on lands disturbed by surface mining. By the year 2000 over 200,000 acres in the Northern Great Plains states of Montana, Wyoming, North Dakota and South Dakota are expected to have been committed to energy development (11).

Snow-melt runoff produces a significant percentage of the total annual runoff in many northern areas of the United States (2, 10). Little detailed information on soil losses from snow-melt however, is presently available. The purpose of this investigation was to determine erosion and runoff losses associated with snow-melt from typical surface mined areas in North Dakota.

**Research Associate in Agricultural Engineering, Research Scientist in Soils, Professor of Soils.*

PROCEDURE

Runoff and erosion studies were conducted at the North American Coal Corporation Indian Head mine near Zap, North Dakota. The treatments included a native range site; three spoil sites representing three textures; and a site at which topsoil was placed on spoil material.

The native rangeland site of sandy loam texture was located on an 8.6% slope. The grass cover was last harvested in September, 1974.

Bare spoil plots of sandy clay loam texture were located on slope gradients of 4.8 and 17.6%, while plots with slopes of 10.0 and 12.9% were established on clay loam and silty clay loam spoil, respectively. The sodium absorption ratios (SAR) of these spoils was 33 or greater. Study site characteristics are described in Table 1.

The treatment of sandy loam topsoil thickness of 6 inches was established in July 1975 on a slope of 8.9%. The topsoil was taken from a soil classified as a Flaxton sandy loam. The clay loam spoil material of SAR 37 on which the topsoil was

Table 1. Study Site Characteristics

Surface Material	Texture[1]	Slope, %	SAR[2]	Bulk Density[3] g/cm^3	Particle Size Analysis, % by Weight Sand	Silt	Clay
Rangeland							
	SL	8.6	0.3	1.12	63	23	14
Spoil							
	SCL	4.8	41	1.34	58	25	17
	SCL	17.6	37	1.40	58	19	23
	CL	11.3	37	1.31	31	38	31
	Si CL	13.4	33	1.14	12	49	39
Topsoil							
	SL	8.9	3.4	1.40	54	26	20

[1]*SL - sandy loam, SCL - sandy clay loam, CL - clay loam, Si CL - silty clay loam.*
[2]*When concentrations are expressed in milliequivalents per liter,* $SAR = Na/[(Ca+Mg)/2]^{\frac{1}{2}}$.
[3]*Bulk density determinations were taken at the 0-6 inch soil depth.*

placed was disked to a depth of 3 to 4 inches prior to topsoil placement.

The area on which the spoil and topsoil sites were located was mined in 1971 and reshaped in 1973. Plot borders were installed in October and November 1974. The spoil and topsoil plots were rototilled four times during the summer of 1975 with the final tillage operation conducted in early November 1975.

The nonreplicated plots were 13.3 feet across the slope by 72.6 feet long. All plots were located on north facing slopes. Four-foot snow fences were installed in early November near the east and west borders of each plot. A runoff plot installation, including snow fences, is shown in Figure 1. Electrical heating equipment was employed to prevent freezing of the measuring and storage equipment. Samples for soil loss determinations were collected daily during the snow-melt period. The runoff plot equipment is diagrammed in Figure 2.

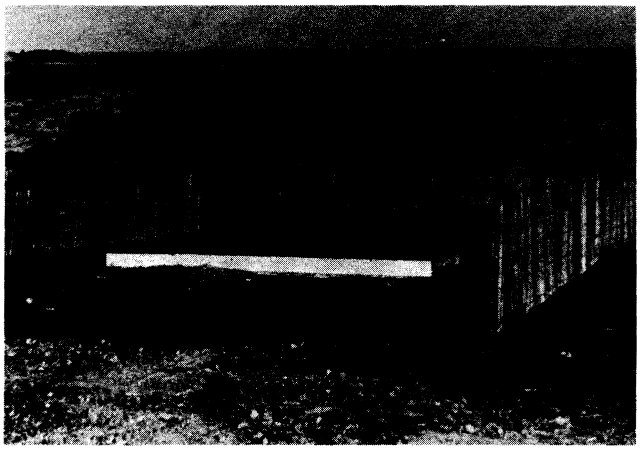

Figure 1. Runoff plot installation

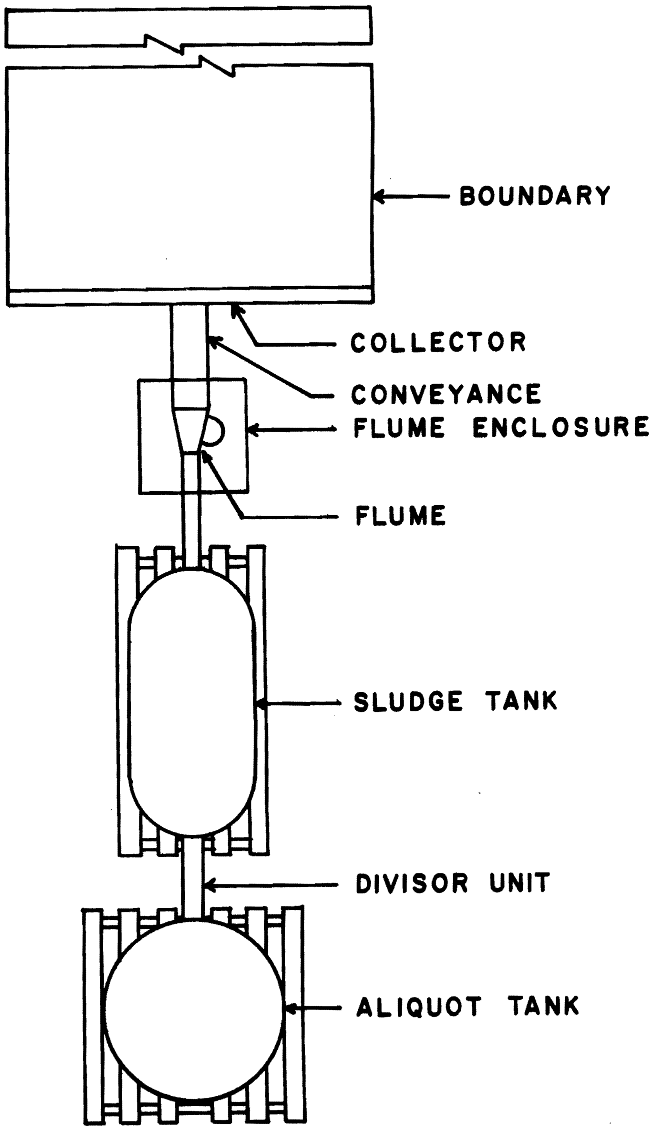

Figure 2. Runoff plot equipment

RESULTS AND DISCUSSION

Snow Sampling

The snow cover on the plots was core sampled prior to spring thaw to determine snow depth, equivalent water depth and snow density. Snow density is the water equivalent of the snow pack divided by the snow depth. The January 26 core sampling (Appendix Table 7) represents snow pack conditions prior to initiation of runoff. Snow cover information after the initial, but preceding the second runoff period, is presented in Appendix Table 8. Snow depth decreased and snow density increased from the January 26 to March 8 sampling dates as a result of thawing during the period.

Runoff and Erosion

The primary runoff events occurred on February 16 to February 28 and March 9 to April 2. The snow-melt contribution in February was small compared with the March runoff flows. Information on erosion and runoff on a daily basis for each of the runoff plots is presented in Appendix Tables 1-6.

The soil content of runoff was greater from the spoil than from the topsoil and rangeland sites. Data of the total runoff and erosion from each of the plots are presented in Table 2. Snow water equivalents listed in the table were taken from the March 8 sampling date. Comparing the snow water equivalents prior to snow melt with total runoff yields useful information on runoff trends. But it should be recognized that significant portions of the snow cover could have been lost as a result of sublimation.

Runoff as a percentage of the snow water equivalent was least on the rangeland, 41%, and greatest on the topsoil site, 71%. Runoff from the spoil locations averaged 17, 53, and 56% on the silty clay loam, sandy clay loam and clay loam sites, respectively. However, several small piping holes developed on the silty clay loam plot during the thawing period, and it is suggested that this contributed to the low measured runoff. Soil piping and tunneling is reported in various forms and intensities on soils of the type present at the spoil sites (3, 4, 8). A few piping holes were also present on the clay loam textured spoil but none appeared on the sandy clay loam site.

Table 2. Runoff and Erosion from Snowmelt at Surface Mined Sites[1]

Surface Material	Texture[2]	Slope %	Snow Water Equivalent[3] inches	Runoff inches	Soil Content of Runoff[4] %	Soil Loss Tons/acre
Rangeland						
	SL	8.6	7.7	3.18	.01	.04
Spoil						
	SCL	4.8	15.3	7.39	.12	.99
	SCL	17.6	12.7	7.18	.35	2.86
	CL	11.3	11.7	6.59	.37	2.76
	Si CL	13.4	10.2	1.68	.55	1.05
Topsoil						
	SL	8.9	7.3	5.18	.07	.38

[1]*The nonreplicated plots were 13.3 by 72.6 ft.*
[2]*SL - sandy loam, SCL - sandy clay loam, CL - clay loam, Si CL - silty clay loam.*
[3]*March 8, 1976 sampling date.*
[4]*Per cent by weight of soil in runoff = (total soil loss/total runoff) × 100.*

Soil content of runoff on rangeland was 0.01% and the soil loss was 0.04 tons per acre. Soil content of runoff from the spoil plots ranged from 0.12 to 0.55%, the most occurring on the silty clay loam textured plot; soil losses ranged from .99 to 2.86 tons per acre. Soil loss on the topsoil site was .38 tons per acre.

The effect of slope gradient on sediment yield is illustrated by the data from the sandy clay loam sites. An increase in slope from 4.8 to 17.6% increased soil loss by almost 200%.

Due to the presence of snow fences, snow depths on the runoff plots were greater than would be expected under normal conditions; average annual snow-melt would be expected to be much less than that measured from the experimental sites. The sandy clay loam spoil with 17.6% slope, for example, produced a sediment yield of 2.86 tons per acre from snow cover containing 12.7 inches of water. However, the November through March mean precipitation for the study area is only about 2.7 inches (6). Thus, if all of the average November through March precipitation were available for snow-melt and if the measured soil loss to moisture equivalent is valid, an average annual soil loss on the sandy loam spoil of approximately .61 tons per acre would be expected. On this basis, erosion from snow-melt on the spoil sites also appears minimal.

Complete evaluation of the effect of natural precipitation on runoff and erosion has required 10 to 20 years of on-site measurements. While information obtained from this single study year has provided useful information on potential runoff trends, the values should not be viewed as representing an absolute annual loss potential. Several more years of soil loss data are needed to quantify erosion losses from snow-melt within reasonable confidence limits.

Snowmelt Hydrograph

A runoff hydrograph of the snow-melt events was obtained from each of the plots. Figure 3 shows a hydrograph of snow-melt occuring on March 25, 1976, and of the first 12 hours of a rainfall event on April 17, 1976, in which .71 inches of precipitation fell. The snow-melt hydrograph from the 4.8% sandy clay loam spoil plot rose slowly to a maximum discharge rate, maintained that maximum rate and then slowly fell. In comparison, the rainfall hydrograph showed very rapid fluctuations.

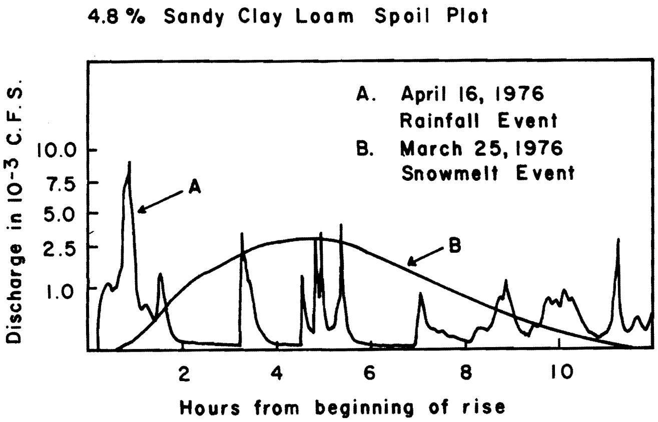

Figure 3. Rainfall and Snowmelt Hydrographs

Infiltration from Snow-melt

Data of soil water on the rangeland, clay loam spoil and topsoil plots preceding and following snow-melt are listed in Appendix Tables 9, 10, and 11, respectively. Soil samples were collected approximately five feet outside of the uphill runoff boundary. Snow cover at the sample collection points was slightly less than the average depth over the runoff plots. The snow melted at the sample collection points by March 20. Soil samples for water content were collected on February 18, March 22 and April 19.

The February 18 soil sampling on the rangeland plot, taken through the snow pack, indicated a soil water gradient of decreasing soil water with depth. This is attributed to thermal factors as soil water moves from areas of higher to lower temperatures. More uniform water distribution was apparent on the March 22 and April 19 sampling dates.

Less soil water was present in the upper foot of the rangeland site following snow-melt than existed prior to the period of thawing. Little change in water content was apparent at the 3- to 12-inch depth between March 22 and April 19. Evaporation perhaps caused the changes at the 0- to 3-inch depth.

Soil water at the 3- to 12-inch depth on the clay loam spoil showed little variation between the three sampling dates. Perhaps a slight increase in water content occurred near the surface as a result of snow-melt. Variations in soil water at the 0- to 3-inch depth between March 22 and April 19 are again attributed to evaporation.

Soil water content of the underlying spoil materials at the 6- to 9-inch depth on the topsoil plot was variable, but at greater depths there was little difference among dates. Less total soil water was present after snow-melt, as was the case on the rangeland site. Although total soil water of the topsoil material was similar on the February 18 and March 22 dates, water content was greater at the 3- to 6-inch depth following snow-melt. As was the case on the rangeland and spoil plots, infiltration from snow-melt produced little effect on changes in soil water content near the upper portion of the soil profile.

SUMMARY

Runoff and erosion were measured from sites representing typical mined and pre-mined conditions. The data show:

1. Runoff averaged 41%, 48% and 71% of snow water equivalent for the rangeland, spoil and topsoil plots, respectively.
2. Soil loss for the rangeland, spoil and topsoil plots averaged .04, 1.92 and .38 tons per acre, respectively.
3. An increase in slope on sandy clay loam spoil from 4.8 to 17.6% resulted in an increase in erosion from .99 to 2.86 tons per acre.
4. Soil content of runoff was greatest near the end of the snow-melt period.

5. Average annual erosion from snow-melt on the rangeland, spoil and topsoil materials is expected to be minimal.

6. Soil water content in the upper foot of the rangeland and topsoil plots decreased following completion of snow-melt with a slight increase in soil water apparent on the spoil plot.

7. Measurements of runoff against time indicate a gradual rise and descent of the snow-melt hydrographs.

LITERATURE CITED

1. Bathurst, V. M. 1965. **Soil erosion in urban areas.** Soil Conservation 30:274-275.

2. Boucher, P. R. 1970. **Sediment transport by streams in the Palouse River Basin, Washington and Idaho, July 1961-June 1965.** Geological Survey Water Supply Paper 1988-C.

3. Downes, R. G. 1956. **Conservation problems on solodic soils in the State of Victoria (Australia).** J. Soil and Water Cons. 11:228-232.

4. Fletcher, Joel E., Karl Harris, H. B. Peterson and V. N. Chandler. 1954. **Piping.** Trans. Am. Geophys. U. 35(2):250-262.

5. Hill, Ronald D. 1971. **Reclamation and revegetation of strip-mined lands for pollution and erosion control.** Trans. ASAE. 14(2):268-272.

6. Jensen, Ray E. 1972. **Climate of North Dakota.** North Dakota State University, Fargo, N. D.

7. Meyer, L. D., W. H. Wischmeier, and W. H. Daniel. 1971. **Erosion, runoff and revegetation of denuded construction sites.** Trans. ASAE. 14(1):138-141.

8. Peterson, H. V. 1954. **Discussion of piping.** Trans. Am. Geophys. U. 35(2):263.

9. U.S. Dept. of Agric. and Dept. of Housing and Urban Dev. **Soil, Water, and Suburbia (Conference Proc.).** 1967. June.

10. U. S. Geological Survey. 1956. **Compilation of records of surface water of the United States through September 1950. Part 13. Snake River Basin.** Geological Survey Water Supply Paper 1317.

11. Vanderwalker, John G. 1975. **Effects of coal development in the Northern Great Plains.** Northern Great Plains Resources Program. Summary Report. May.

12. Wischmeier, W. H. and D. D. Smith. 1965. **Predicting rainfall erosion losses from cropland east of the Rocky Mountains.** Agr. Handbook No. 282, U. S. Dept. Agr., Washington, D.C. 47 pp.

Appendix Table 1. Runoff and Erosion from Snowmelt on Sandy Loam Rangeland with 8.6% Slope.[1]

Date mo.-day	Runoff inches	Soil Loss lb.	Soil Content of Runoff %
2-23	.01	.02	.03
2-24	.17	.17	.02
2-25	.02	.01	.01
2-26	.09	.05	.01
3-17	.04	.04	.02
3-18	1.83	1.09	.01
3-19	.47	.24	.01
3-20	.27	.14	.01
3-22	.07	.00	.00
3-23	.19	.10	.01
3-24	.02	.02	.02

[1]*The nonreplicated plot was 13.3 by 72.6 ft.*

Appendix Table 2. Runoff and Erosion from Snowmelt on Sandy Clay Loam Spoil with 4.8% Slope.[1]

Date mo.-day	Runoff inches	Soil Loss lb.	Soil Content of Runoff %
2-16	.02	.23	.26
2-17	.03	.23	.16
2-18	.03	.23	.16
2-19	.01	.10	.17
2-23	.02	.15	.17
2-24	.05	.35	.16
2-26	.01	.02	.04
3-17	.19	1.13	.12
3-18	.33	.83	.05
3-19	.36	.36	.02
3-20	.29	.29	.02
3-22	.03	.03	.02
3-23	.29	.58	.04
3-24	.31	.63	.04
3-25	.84	2.79	.07
3-26	.28	1.66	.12
3-27	1.69	6.98	.08
3-28	1.08	5.16	.10
3-29	.69	7.54	.22
3-30	.27	2.71	.20
3-31	.31	4.84	.31
4-1	.26	7.07	.55

[1]*The nonreplicated plot was 13.3 by 72.6 ft.*

Appendix Table 3. Runoff and Erosion from Snowmelt on Sandy Clay Loam Spoil with 17.6% Slope.[1]

Date mo.-day	Runoff inches	Soil Loss lb.	Soil Content of Runoff %
2-18	.01	.11	.42
2-19	.01	.06	.51
2-23	.03	1.04	.73
2-24	.21	5.32	.49
2-25	.03	.43	.26
2-26	.25	3.03	.24
2-27	.07	.98	.24
2-28	.01	.05	.15
3-9	.03	.08	.06
3-16	.03	.07	.04
3-17	.14	1.07	.14
3-18	.36	1.30	.07
3-19	1.02	3.10	.06
3-20	.68	2.94	.09
3-22	.20	.72	.07
3-23	.85	7.74	.43
3-24	.09	.60	.13
3-25	.29	1.88	.13
3-26	.61	5.68	.19
3-27	.54	9.88	.36
3-28	.33	6.44	.39
3-29	.52	21.39	.81
3-30	.27	15.28	1.11
3-31	.27	18.04	1.31
4-1	.27	17.35	1.26
4-2	.06	3.02	.95

[1]*The nonreplicated plot was 13.3 by 72.6 ft.*

Appendix Table 4. Runoff and Erosion from Snowmelt on Clay Loam Spoil with 11.3% Slope.[1]

Date mo.-day	Runoff inches	Soil Loss lb.	Soil Content of Runoff %
2-16	.01	.05	.20
2-17	.02	.29	.35
2-19	.01	.02	.18
2-23	.01	.15	.29
2-24	.02	.20	.22
2-25	.01	.02	.11
2-26	.03	.21	.15
2-27	.03	.24	.16
3-9	.13	.85	.12
3-16	.40	2.82	.14
3-17	.33	1.80	.11
3-18	.65	4.17	.13
3-19	1.05	9.49	.18
3-20	1.31	10.89	.16
3-22	.55	5.47	.20
3-23	1.01	19.85	.39
3-24	.29	14.86	1.03
3-25	.47	27.30	1.15
3-26	.25	22.57	1.79
3-27	.01	1.52	2.53

[1]*The nonreplicated plot was 13.3 by 72.6 ft.*

Appendix Table 5. Runoff and Erosion from Snowmelt on Silty Clay Loam Spoil with 13.4% Slope.[1]

Date mo.-day	Runoff inches	Soil Loss lb.	Soil Content of Runoff %
2-12	.01	.32	.60
2-24	.01	.04	.09
2-26	.01	.07	.23
2-27	.01	.04	.16
3-18	.21	1.68	.15
3-19	.31	4.05	.26
3-20	.29	5.34	.37
3-22	.11	2.21	.40
3-23	.29	10.93	.74
3-24	.18	8.48	.90
3-25	.12	5.72	.94
3-26	.11	7.25	1.26
3-27	.01	.59	1.29

[1]*The nonreplicated plot was 13.3 by 72.6 ft.*

Appendix Table 6. Runoff and Erosion from Snowmelt on Sandy Loam Topsoil with 8.9% Slope.[1]

Date mo.-day	Runoff inches	Soil Loss lb.	Soil Content of Runoff %
2-19	.01	.01	.05
2-23	.05	.18	.07
2-24	.15	.16	.02
2-25	.01	.01	.01
2-26	.01	.01	.01
2-27	.01	.00	.01
2-28	.01	.01	.02
3-9	.22	.11	.01
3-16	.33	.49	.03
3-17	.32	.32	.02
3-18	1.24	2.46	.04
3-19	1.15	6.02	.03
3-20	1.15	2.00	.03
3-22	.28	1.94	.14
3-23	.24	3.27	.27

[1]*The nonreplicated plot was 13.3 by 72.6 ft.*

Appendix Table 7. Snow Depth, Water Equivalent and Density at Several Sites on January 26, 1976.[1]

Surface Material	Texture[2]	Slope %	Snow Depth inches	Water Equivalent inches	Snow Density
Rangeland					
	SL	8.6	28.8	7.5	.26
Spoil					
	SCL	4.8	39.6	9.6	.24
	SCL	17.6	36.0	9.7	.27
	CL	11.3	33.6	11.1	.33
	Si CL	13.4	27.6	9.5	.34
Topsoil					
	SL	8.9	27.6	9.1	.33

[1]*Average of three holes.*
[2]*SL - sandy loam, SCL - sandy clay loam, CL - clay loam, Si CL - silty clay loam.*

Appendix Table 8. Snow Depth, Water Equivalent and Density at Several Sites on March 8, 1976.[1]

Surface Material	Texture[2]	Slope %	Snow Depth inches	Water Equivalent inches	Snow Density
Rangeland					
	SL	8.6	16.7	7.7	.46
Spoil					
	SCL	4.8	39.3	15.3	.39
	SCL	17.6	35.7	12.7	.36
	CL	11.3	26.3	11.7	.45
	Si CL	13.4	25.0	10.2	.41
Topsoil					
	SL	8.9	16.5	7.3	.44

[1]*Average of three holes.*
[2]*SL - sandy loam, SCL - sandy clay loam, CL - clay loam, Si CL - silty clay loam.*

Appendix Table 9. Inches of Soil Water in Sandy Loam Rangeland at Several Dates, 1976.

Date mo.-day	Soil Depth(inches)[1] 0-3	3-6	6-9	9-12
	inches water			
2-18	1.48	.88	.83	.52
3-22	1.07	.72	.68	.74
4-19	.71	.71	.57	.60

[1]*Average of four holes.*

Appendix Table 10. Inches of Soil Water in Clay Loam Spoil at Several Dates, 1976.[1]

Date mo.-day	Soil Depth (inches) 0-3	3-6	6-9	9-12
	inches water			
2-18	1.35	.72	.68	.71
3-22	1.62	.87	.60	.57
4-19	.91	.66	.70	.57

[1]*Average of four holes.*

Appendix Table 11. Inches of Soil Water in Sandy Loam Topsoil over Clay Loam Spoil at Several Dates, 1976.[1]

Date	Soil Depth (inches) 0-3 (topsoil)	3-6 (topsoil)	6-9 (spoil)	9-12 (spoil)	12-15 (spoil)	15-18 (spoil)
mo.-day	inches water					
2-18	1.38	1.18	.97	.76	.78	.81
3-22	1.03	1.34	.76	.73	.74	.66
4-19	.73	.83	1.00	.72	.65	.69

[1]*Average of four holes.*

K'