Soil water and root characteristics of 1-to 53-year old strip mine spoils in southeastern Montana
by John Wayne Wyatt

A thesis submitted in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in SOILS
Montana State University
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Abstract:
A study was initiated in June, 1976, at Colstrip, Montana, to determine the soil water and rooting characteristics of 1 - to 53-year-old strip mine spoils and undisturbed soils of the surrounding area. Minespoils were divided into two groups for comparison—old (28 to 53 years old) and new (1 to 7 years old).

Infiltration velocities, which ranged from 5.93 to 15.30 cm hr , were not significantly different between minespoils and undisturbed soils. This similarity was partially explained by the textural compositions of the surface soil horizons.

Three general trends were shared by minespoils and undisturbed soils regarding soil water contents: soil water contents of surface horizons were generally only limiting in August and September, 1976; although soil surface horizons were partially recharged in October, 1976, entire soil profile water contents reached their minimum levels during this month; and the upper 30 cm of the soil profiles were partially recharged under frozen soil conditions in February, 1977, possibly by unsaturated water flow from substrata.

Deep percolation was more common in new minespoils than in undisturbed soils, and was almost nonexistent in old minespoils. The quantity of soil water passing through the root zone was inversely proportional to the quantity of roots in the lower soil profiles.

Water use was correlated with root biomass at 50 and 100 cm in the soil profiles of new minespoils and undisturbed soils, but not in old minespoils. This difference was probably explained by the fact that vegetation on old minespoils obtained a substantial amount of their soil water from deeper soil depths.

Maximum observable rooting depths were determined for 41 plant species using radioactive tracer techniques. Grasses, forbs and shrubs had greater rooting depths in undisturbed soils than in minespoils, old and new. However, old minespoils had approximately 30 percent more active roots below 76 cm in their soil profiles than in new minespoils and undisturbed soils, which indicated that plant roots were most abundant at lower soil profile depths in old minespoils.

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by

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A thesis submitted in partial fulfillment
of the requirements for the degree

of

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in

SOILS

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ABSTRACT

A study was initiated in June, 1976, at Colstrip, Montana, to determine the soil water and rooting characteristics of 1- to 53-year-old strip mine spoils and undisturbed soils of the surrounding area. Minespoils were divided into two groups for comparison--old (28 to 53 years old) and new (1 to 7 years old).

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CHAPTER 1

INTRODUCTION

An estimated 1 million acres of the 1.7 million acres of land previously disturbed by stripmining still need reclamation and about 100,000 acres a year will need reclaiming after future stripmining (SCS, 1977). This estimation assumes, rather optimistically, that coal consumption will remain at present levels. Even so, these figures emphasize the necessity of adequate reclamation if our country is to maintain a quality environment and protect its economic land base.

Reclamation studies in Montana began at Colstrip in 1968 under direction of the Montana Agriculture Experiment Station of Montana State University. Lands mined since 1968 and nearly all abandoned spoils from earlier mining activities were recontoured and reseeded in an effort to control erosion and increase forage production. The few abandoned spoils that were not recontoured provide controls for evaluating the effectiveness of existing reclamation technology.

Successful reclamation in the semiarid region of southeastern Montana is very dependent on soil water and plant rooting characteristics because of their influence on plant establishment, erosion control and soil development. The specific objectives of this investigation were to characterize these two interrelated factors in old and new minespoils, and undisturbed soils of the Colstrip area.

CHAPTER 2

LITERATURE REVIEW

Soil Water

Infiltration is defined as, "the downward entry of water into soil," and infiltration rate as, "the volume of water passing into the soil per unit of area per unit of time having the dimensions of velocity (LT^{-1})" (Richards, 1952). The term infiltration rate implies that water is present in excess, maximum steady-state rate is reported, and adequate precautions are taken regarding border effects (Horton, 1933, 1940). A more general term, infiltration velocity, is used when these restrictions are not met (U.S. SLS, 1969).

Infiltration is mainly a function of the soil's matric and gravitational potentials, which are both at a maximum during the early stages of infiltration. Matric potentials decrease near the surface as the wetting front moves deeper into the soil profile, causing a decrease in infiltration over time. Other factors often contribute to this decrease: swelling of soil colloids; surface compaction by raindrops; and the clogging of soil pores with silt particles (Diebold, 1954). Occasionally, infiltration increases over time because the wetting front reaches a more permeable layer.

Only a few investigators have studied infiltration in stripmine spoils. Linstrom (1960) demonstrated the effect of compaction in infiltration in North Dakota stripmine spoils. He found that infiltration

rates dropped from 10.0 cm hr^{-1} on ungraded spoils to 1.0 cm hr^{-1} on graded spoils.

Arnold and Dollhopf (1977) studied the effect of topsoiling and revegetation on infiltration in stripmine spoils of southeastern Montana. They used a rain-simulator type infiltrometer to measure infiltration on topsoiled-revegetated spoils (7.81 cm hr^{-1}), topsoiled spoils (4.46 cm hr^{-1}), non-topsoiled revegetated spoils (1.78 cm hr^{-1}) and an undisturbed soil in the area (12.4 cm hr^{-1}). Topsoiling had a greater effect than revegetation on infiltration and together they had a positive interaction effect. These data also indicated that infiltration rates decreased with the age of recently topsoiled and revegetated spoils.

Infiltration was measured by Dollhopf et al. (1977) on stripmine spoils in Montana and North Dakota which had received topsoiling and surface manipulation treatments. Their results indicated that spoils receiving topsoiling and chiseling treatments had greater infiltrations than spoils receiving gouging or dozer basin treatments and no topsoil.

Curtis (1973) conducted a related study on stripmine spoils in Kentucky where he measured surface densities over an extended time period on graded spoils. He found that surface densities decreased substantially after winter; he attributed the decrease to frost action.

For a greater understanding of the theoretical aspects of the infiltration process, the reader is referred to two excellent books written by Hillel (1971) and Bauer et al. (1972). A multitude of

factors that affect infiltration are described by several investigators (Dortignac et al., 1955; Grumbs et al., 1972; Lewis and Powers, 1938). The various methods and equipment used to measure infiltration are reviewed by Mutchler and Hermsmeir (1965) and Beutner et al. (1952).

When precipitation infiltrates a soil it may translocate soluble salts and clay particles downward into the soil profile. Some of the water may eventually enter the groundwater table and some may evaporate into the atmosphere, but a good portion remains in the soil and is utilized by plants. Therefore, it is important that an attempt is made to maximize a minespoil's water-holding capacity during reclamation procedures.

The preferred method of measuring *in situ* soil water content utilizes neutron scattering techniques. This method is particularly useful when monitoring soil moisture changes over extended time periods since access tubes may be left in place and soil samples need not be removed as in other methods, thus preventing site destruction (Merriam, 1960; Steward and Taylor, 1957; Visvolingan and Tandy, 1972).

The only serious drawback of the neutron scattering method is that it underestimates soil water contents near the surface-atmosphere interface. This happens because the sphere of influence, the volume of soil in which a counting device is influenced by the slow neutron density, extends beyond the soil surface. This underestimation is confined to the top 10 cm in wet soils, but extends to 30 cm in dry soils

(Grant, 1975). Lesser measurement error may result if field calibrations are not determined for each soil type under investigation (Rawls and Asmussen, 1973).

As with infiltration, only a few investigations have been made concerning soil water contents in stripmine spoils. Verma and Thames (1975) used the neutron scattering method to measure soil water contents in Arizona stripmine spoils. They reported that soil water contents remained near the wilting point, a point at which most plants are unable to obtain soil moisture, to a depth of 200 cm during the period from September to May. They also showed that soil water contents increased the most during the snowmelt period.

Dollhopf et al. (1977) measured soil water contents in stripmine spoils of Montana and North Dakota using neutron scattering methods. The purpose of their study was to determine the effects of topsoiling and surface manipulation treatments on soil water contents. Moisture levels reached a maximum in upper 50 cm profiles during February on all treatments, while lower profiles reached a maximum during June. Their data indicated that topsoiled-gouged and topsoiled-chiseled treatments usually resulted in higher soil moisture levels than their nontopsoiled counterparts. They suggested that the swelling of expanding type clays during the infiltration process can adversely affect soil water contents.

Sindelar et al. (1973) measured soil water contents in Montana stripmine spoils with soil moisture blocks. They found that soil water

contents remained below wilting points in upper 120 cm soil profiles and above wilting points in lower soil profiles during the period from May to November.

The relationship between soil water content and wilting point depends on the soil water potential, defined as, " the amount of work that must be done per unit quantity of pure water in order to transport reversibly and isothermally an infinitesimal quantity of water from a pool of pure water, at a specific elevation and at atmospheric pressure, to the soil water at the point under consideration" (ISSS, 1963).

Thermocouple psychrometers (TCPs) are routinely used for measuring soil temperature and relative humidity from which soil water potentials are accurately estimated using the Kelvin equation:

$$\Psi = \frac{RT}{V} \ln \frac{P}{P_o}$$

where Ψ is the soil water potential, R is the ideal gas constant, T is the absolute temperature, V is the volume of a mole of water and $\frac{P}{P_o}$ is the relative humidity of the soil (Rawlins, 1966).

The greatest source of error associated with *in situ* TCP use is caused by temperature gradients in the top 40 cm of soil (Merrill and Rawlins, 1972; Millar et al., 1970). A difference of 0.10°C between the TCP's exterior and its inner point of measurement represents an error of 1.0 bar (Rawlins and Dalton, 1967). This error can be mini-

mized by positioning TCPs horizontally, parallel to the temperature gradient, in the top 40 cm soil profile (Merrill and Rawlins, 1972). This has shown to be particularily important when using double-junction type TCPs. Several researchers have stressed the importance of calibrating TCPs if small soil water potential differences are being examined (Campbell and Gardner, 1971; Lang, 1967).

Root Characteristics

The principal soil factors affecting root characteristics are temperature, moisture, aeration, physical impedence, and nutrient supply. These factors mainly affect production of growth regulators in the root and subsequent variation of supply of these regulators to the meristematic regions of the plant (Russel, 1973).

Low soil temperatures (<8°C) significantly reduces plant respiration, cell wall permeability, and ability to take up ions (Salisbury and Ross, 1969). These reductions minimize plant root branching and elongation. Higher soil temperatures stimulate root production and nutrient uptake, but extremely high soil temperatures may damage roots.

Gingrich (1963) studied the effect of soil temperature on the uptake of phosphorus in winter wheat. He found that while total amounts of phosphorus in top growth increased with soil temperature, the percentage of phosphorus in top growth remained unchanged.

Soil moisture conditions may also affect root elongation. Fluker (1958) demonstrated that plant roots will not grow into soils with water potentials greater than that from which a plant is capable of extracting water. For instance, the roots of some semiarid grasses can grow into soils having soil water potentials of -15 bar, while the roots of wheat, oat and barley cannot grow into soils having water potentials greater than -8 bar (Rosenberg, 1974).

Albertson (1937) demonstrated that rooting depths are very dependent on water supply by excavating root systems in a short-grass prairie after a run of drought years and a run of wet years. His illustrations showed that root systems grew profusely to a depth of 2 meters in average years, but were restricted to the top meter in dry years.

Huck (1970) examined the effect of soil aeration on taproot elongation of cotton and soybeam and found that poor aeration resulted in the accumulation of carbon dioxide near near the roots in quantities that were detrimental to plant growth. Reductions in oxygen levels near the roots to 5 percent contributed to the reduction in taproot elongation.

In a similar study conducted by Tackett and Peason (1964) on cotton seedlings, it was found that root growth was depressed at oxygen levels below 10 percent in soils with bulk densities of less than 1.5 g cm^{-3}. Higher bulk densities were reported to be more detrimental to root growth than low oxygen levels.

A great deal of knowledge has been accumulated over the past 25 years about the effects of nutrient supply on root characteristics using radioisotope techniques. For instance, radioactive phosphorus (^{32}P) was employed to show that a microbial population living in the rhozosphere, a soil zone adjacent to root surfaces, competes with roots for nutrients, competition which can be particularly severe when nutrients are in short supply (Russell, 1973).

Nye and Foster (1958) investigated ^{32}P uptake in relation to specific root activities of different plant species, but found no significant differences. Their work supported the concept of the "labile phosphate pool" which is believed to maintain an equilibrium chemical potential in the soil solution where ^{32}P exchanges freely with soil phosphorus.

Hammes and Bartz (1955) discussed factors which influence soil fixation of ^{32}P, including isotopic dilution, moisture, pH, texture, voids, and ped surface areas. They concluded that, "differential fixation of injected ^{32}P is of minor importance to the interpretation of

root development. . ." and suggested that no attempt need be made to correct for any factors influencing ^{32}P uptake.

The same conclusions were reached by Lipps et al. (1956) after having formulated a method for determining correction factors that accounted for ^{32}P availability. In the same paper evidence was given which indicated that phosphorus uptake is influenced by soil moisture, but that it doesn't necessarily parallel water absorption. They found that phosphorus absorption from the surface soil may remain relatively high even after the soil becomes dry. They concluded that plants are capable of absorbing phosphorus without appreciable water absorption.

The studies cited above concerning root uptake of ^{32}P were conducted under laboratory conditions. *In situ* use of ^{32}P usually involves its injection into the soil and removal of above ground portions of plants growing near the injection holes to the laboratory for analysis (Boggie et al., 1956; Arenkorah, 1975). Unfortunately, this procedure has the disadvantage of destroying all or parts of the plant under analysis. Burton et al. (1954) circumvented this problem by measuring *in situ* radioactivity with a survey meter held in contact with the vegetation they were studying.

CHAPTER 3

Study Area

The study area is located on the Missouri Plateau in southeastern Montana near Colstrip, approximately 350 km east of the Montana State University campus in Bozeman (Figure 1). The Colstrip area is characterized by valleys, rolling hills, and scattered sandstone outcroppings. Typical vegetation is predominantly mixed prairie and pine savanna (Appendix I). The area overlays the Fort Union Formation which has approximately 1.4 million acres of strippable coal in southeastern Montana alone (Van Derwalker, 1975).

The climate in the Colstrip area is of the semiarid steppe type, with low temperatures down to -36°C in winter and high temperatures as high as 42°C in summer. The area has a frost-free period of 120-140 days. Precipitation averages 40 cm, much of which occurs as rain in April, May, and June. Winds with average velocities of 15-20 km hr^{-1} occur much of the time. Well-defined warming winds called "chinooks" occur in winter and spring, and strong winter windstorms called "blizzards" are not uncommon.

Most soils have developed on sedimentary rocks, residium and colluvium consisting of sandstone, siltstone and shale. Solum thicknesses rarely exceed 50 cm. Important soils of the area include Ustic Torriorthents, Borollic Camborthids, and Aridic Haploborolls.

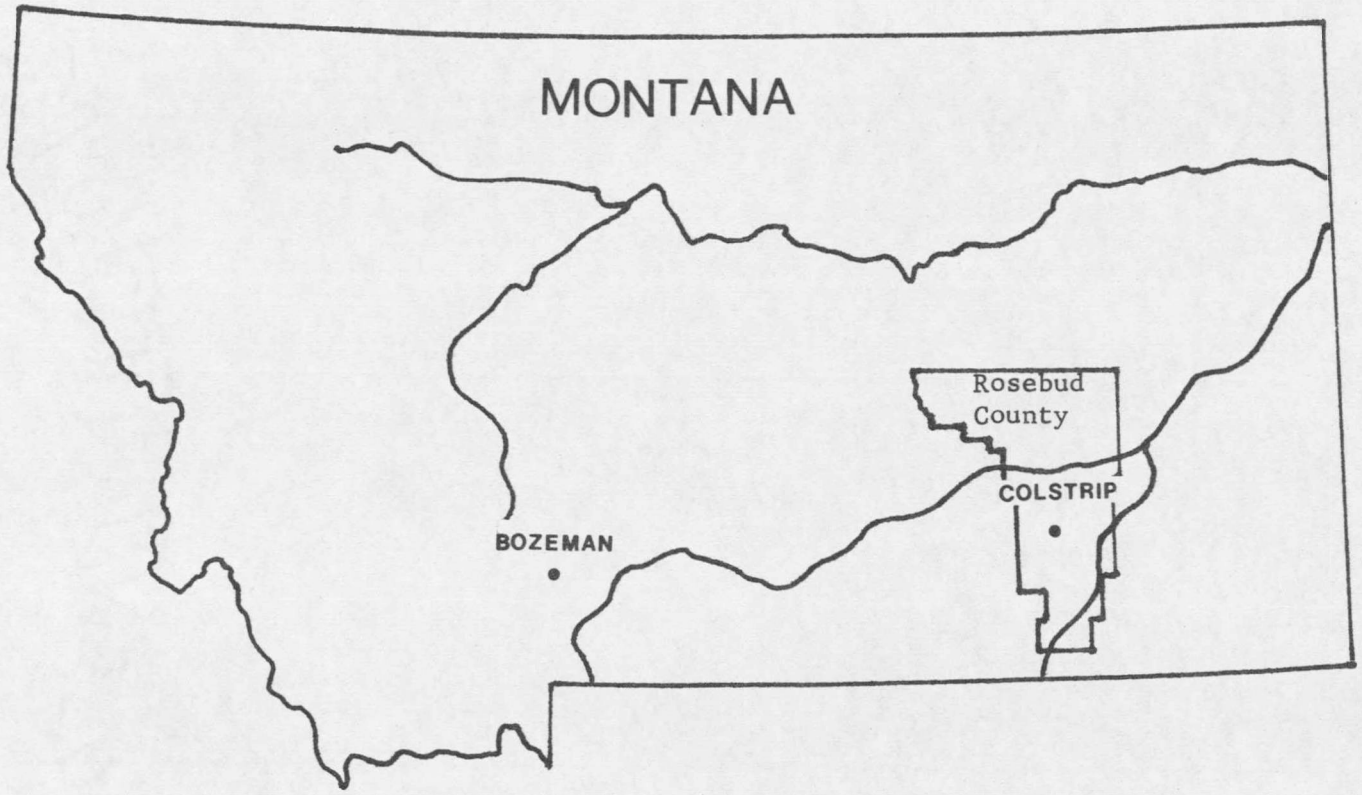


Figure 1. Location of Colstrip study area.

Site Description and Design

Fifteen study sites were selected in the area surrounding Colstrip--five on 29 to 53 year-old minespoils, five on 2 to 8 year-old minespoils, and five on undisturbed soils (Figure 2).

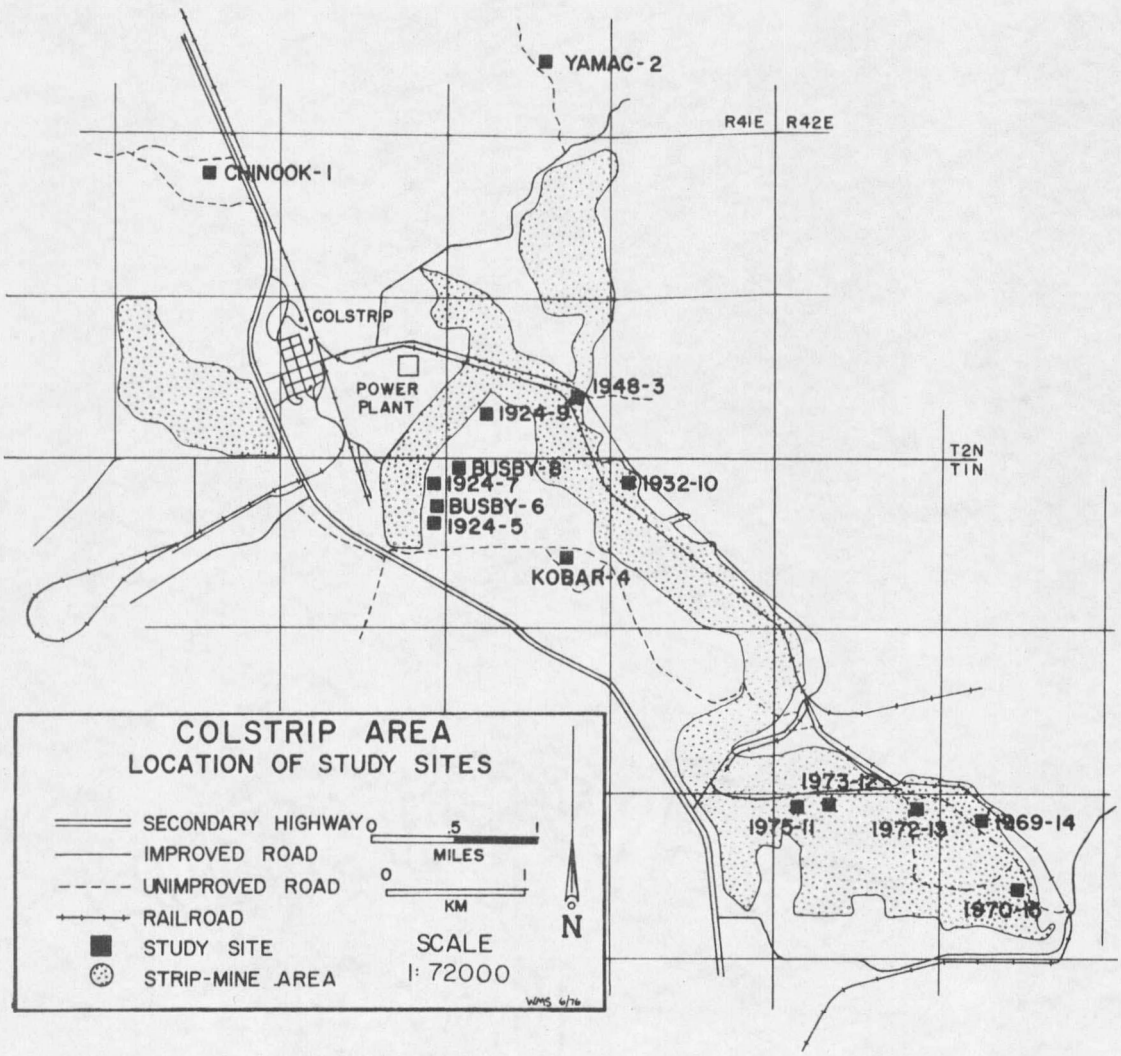


Figure 2. Location of study sites in the Colstrip area.

Square plots on each site measuring 18.3 m on a side were fenced with barbed-wire in an effort to keep livestock away from radioactive materials used for characterizing root distributions. Neutron probe access tubes and Spanner-type double-junction thermocouple psychrometers were installed in the plots as shown in Figure 3. Soil pits approximately 200 cm deep were dug on each site for soil classification and analysis.[1]

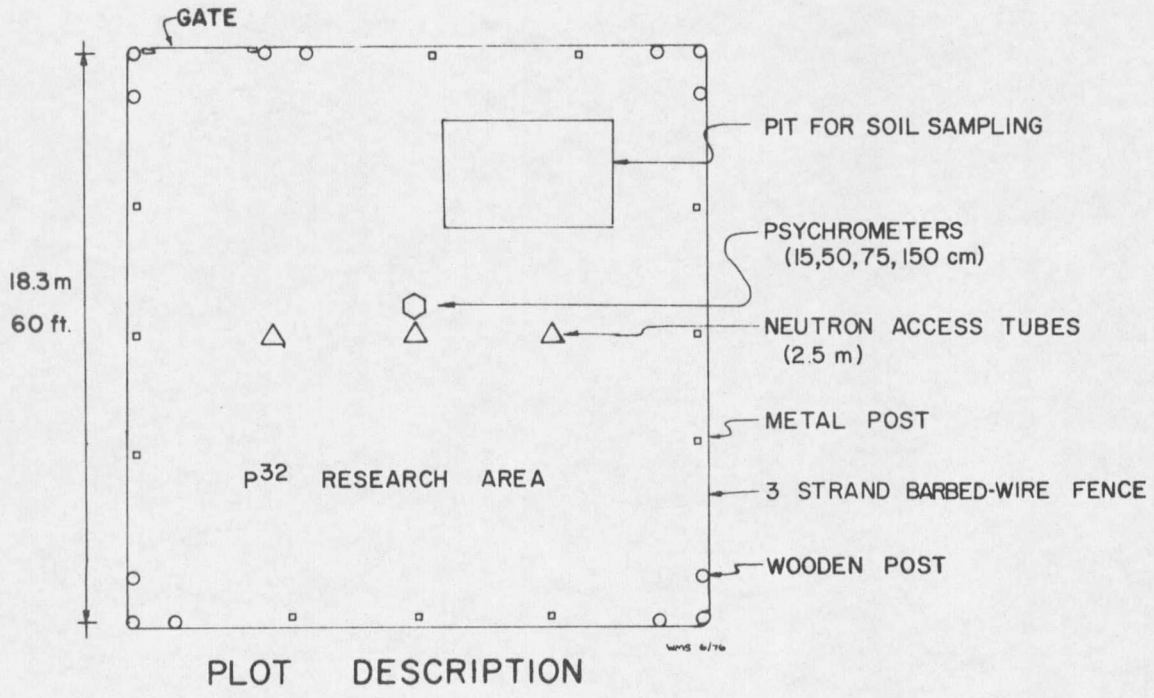


Figure 3. Plan view of study sites showing layout of plot.

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[1]Soil profile characteristics were described by Montana State University Professor G. A. Nielsen and members of the U.S. Soil Conservation Service. Soil samples were analyzed at SCS laboratories in Lincoln, Nebraska (USDA, 1967).

Infiltration Velocity

Infiltration velocities were determined on three randomly-selected positions on each site in August, 1976, with a rain-simulator type infiltrometer. Meeuwig (1971) described the construction of this apparatus. The infiltrometer was positioned approximately 50 cm above the soil surface and water was applied through 517 capillary tubes on a 0.31 m area. A flow meter registered the rate of water application which simulated a severe rain storm in volume, but not in collision force. Runoff was measured at four-minute intervals. The difference between the application rate and the runoff rate was equal to the soil's infiltration velocity.

Soil Water Content

Soil water contents of upper 240 cm profiles were measured with a Troxler 100 mCi Am-Be source, BF_3 detector type neutron probe. Field measurements were correlated to volumetric soil water percentages using the factory calibration supplied with the probe. Soil desorption characteristics were determined using undisturbed soil cores.

Soil Water Potential and Soil Temperature

Soil water potentials and ambient soil temperatures were measured at four soil depths (15, 50, 90, 150 cm) with Spanner-type double-junction thermocouple psychrometers (TCPs). TCPs were removed to the laboratory for cleaning and calibration in March, 1977 (Sundberg,

1974). Calibration results were statistically correlated to a theoretical equation that related a TCP's EMF, electromotive force, to the soil's water potential (Rawlins, 1972). Soil water potentials were standardized to 20°C using temperature correction factors devised by Wiebe and Campbell (1972).

Root Biomass

Root biomass was estimated for each profile using five 1000 cm^3 soil samples that were collected from three depth intervals--5-15, 45-55 and 95-105 cm. The samples were hand-washed over a 30 mesh (0.25 mm) sieve until roots were free of soil. The cleaned roots were oven-dried at 60°C to a constant weight and then dry-ashed at 600°C for 24 hours and reweighed. The difference between the two weighings represented the root weight. This method was devised by Dr. G. A. Nielsen and W. M. Schafer. Samples were collected on September 15, 1976.

Root Activity-Radioactive Tracer (^{32}P)

Vertical rooting distributions were determined *in situ* using radioactive tracer techniques. Basically, the procedure consisted of injecting a concentrated solution of plant available ^{32}P into the soil at specified depths and monitoring above ground portions of plants growing near the injection holes for radioactivity. The ^{32}P solution was prepared by diluting carrier-free ^{32}P in HCl solution with an aqueous solution of 2.2×10^{-3} N KH_2PO_4 and 2.4×10^{-2} N HCl to a

concentration of 0.10 mCi ml^{-1}. Injections were made with a leur-lok syringe connected to a suitable length of steel tubing capable of delivering a 2.0 ml sample of the solution into the bottom of hole that was punched to a specified depth with a metal rod. After an injection was made, the tubing was rinsed with 5 ml of distilled water and 5 ml of air before withdrawing it from the hole. The hole was refilled with soil.

On June 10-11, 1976, one ^{32}P injection was made at 15, 46, 76, 107, 137 and 183 cm depths in thirteen sites. The 1948 spoils and the Kobar undisturbed soil were not injected the first year due to logistical problems. Injection holes were placed near to as many different plant species as possible in an orientation similar to the one depicted in Figure 4.

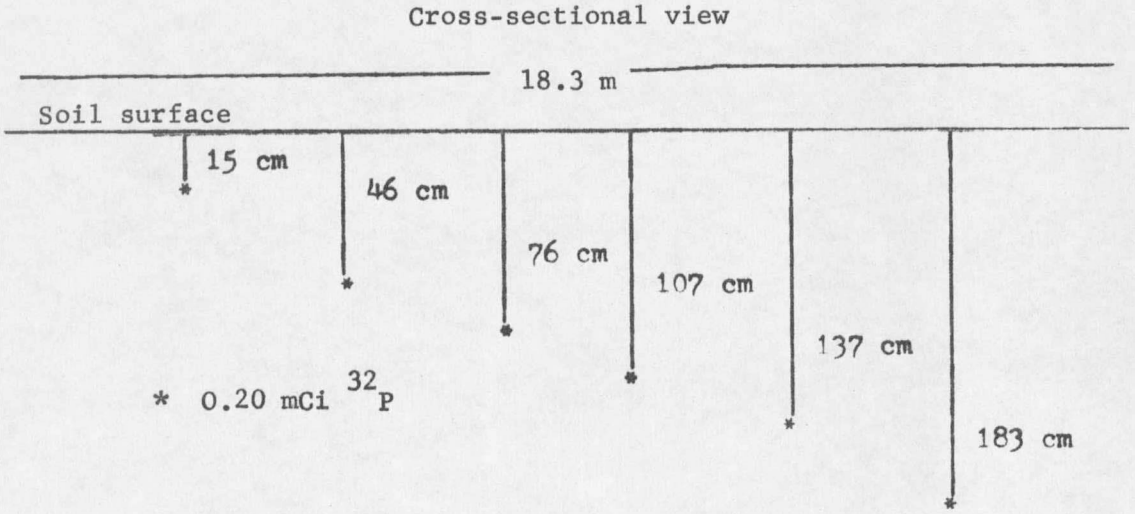


Figure 4. Site orientation of ^{32}P injections - 1976.

In situ radioactivity measurements were taken on the above ground portions of plants growing within 1 m of injection holes immediately after all ^{32}P injections were made. Measurements were taken with an anti-coincidence Geiger-Muller detector and scaler that were especially designed and constructed for field use. An anti-coincidence system was used to reduce error from background radiation. A diagram of the detector and the scaler's electronic circuitry appears in Appendix A.

The counting procedure used during the first year's investigation consisted of locating radioactive plants with a Thyac survey meter and counting the plant's radioactivity within 1 m of injection holes with the anti-coincidence counter. Three 1-minute counts were taken if the plant was highly radioactive, but if not, one 10-minute count was taken. It was realized that the experimental design and counting procedure of the first year's ^{32}P experiment did not readily lend itself to statistical analysis. Therefore, some alterations were made in the experimental design and counting procedure during the second year's ^{32}P experiment in an effort to overcome the shortcomings of the first year's experiment.

The experimental design was changed in two ways: (1) three sets of ^{32}P injections were made in one profile from each soil group in order to estimate the variability of plant radioactivities within an undisturbed soil, an old spoil and a new spoil; and (2) ^{32}P injections

were made adjacent to plant species that were common to all soils and spoils.

The counting procedure was modified the second year in the following way: two plants were randomly selected at the beginning of the growing season for monitoring throughout the investigation; and three 1-minute counts were recorded for each radioactive plant regardless of the intensity of the radioactivity.

Furthermore, all ^{32}P injections were randomly distributed over the research areas for statistical considerations. Details of the second year's ^{32}P injections appear in Table 1.

The accuracy of the field counting unit was estimated by comparing its readings to the more reliable readings obtained through Liquid Scintillation Counting (LSC) techniques. At the end of each year's field measurements, a number of radioactive plants were clipped and taken to the laboratory for analysis. The plant clippings were oven-dried at 110°C for 24 hours, ground, dry ashed, dissolved in a LSC emulsifier cocktail and counted in a Tri-carb LSC spectrometer.

The dry-ashing procedure consisted of baking a 1.0 gram sample of ground plant at 600°C for five hours. The dry-ashed samples were dissolved in 2.0 ml of 2 $\underline{N}$ HNO_3 and 23.0 ml of hot, double-distilled water. These solutions were filtered and two 1.0 ml samples were pipetted into separate counting vials to which 10.0 ml of Biofluor cocktail was added.

Table 1. ^{32}P injection dates and dosages at Colstrip study area in 1977.

Profile	Depth (cm)	Dosage (mCi)	Injection date	Reps
Native Soil				
Chinook	15	0.20	3-24	3
	15	0.20	4-6	3
	15	0.10	4-6	1
	46	0.20	4-6	3
	46	0.10	4-6	1
	76	0.20	3-24	3
	76	0.20	4-6	3
	107	0.20	4-6	3
	137	0.20	4-6	3
	137	0.10	4-6	1
	183	0.20	3-24	3
	183	0.20	4-6	3
	214	0.20	4-6	3
Yamac	15	0.20	3-24	1
	15	0.10	4-6	1
	46	0.20	3-24	1
	46	0.10	4-6	1
	76	0.20	3-24	1
	107	0.20	3-24	1
	137	0.20	3-24	1
	137	0.10	4-6	1
	183	0.20	3-24	1
Busby	15	0.20	4-6	1
(8)	15	0.20	4-6	1
	46	0.20	4-6	1
	46	0.10	4-6	1
	76	0.20	4-6	1
Busby	107	0.20	4-6	1
(cont.)	137	0.20	4-6	1
	137	0.10	4-6	1
	183	0.20	4-6	1
	214	0.20	406	1
Old Spoil				
1932	15	0.20	3-24	3
	15	0.10	4-6	1
	46	0.20	3-24	3
	46	0.10	4-6	1
	76	0.20	3-24	3
	107	0.20	3-24	3
	137	0.20	3.24	3
	137	0.10	4-6	1
	183	0.20	3-24	3
	214	0.20	4-6	3
1948	15	0.20	3-24	1
	46	0.20	3-24	1
	76	0.20	3-24	1
	107	0.20	3-24	1
	137	0.20	3-24	1
	183	0.20	3-24	1
	214	0.20	3-24	1
New Spoil				
1969	Same as 1948 Spoil			
1970	Same as 1932 Spoil			
1972	Same as Busby Soil			
1973	Same as Busby Soil			
1975	Same as Busby Soil			

CHAPTER 4

RESULTS AND DISCUSSION

Infiltration Velocity

Figures 5, 6 and 7 represent infiltration characteristics of undisturbed soils, old spoils and new spoils, respectively. Generally, infiltration velocities dropped slightly at the beginning of the 30-minute test period before attaining steady-state conditions. A similar type of infiltration pattern was reported for recently stripmined spoils in the Colstrip area by Dollhopf et al. (1977). They provided evidence which indicated that the clay types (non-expanding) in the area were partially responsible for this pattern since they swell little upon wetting and, hence, do not significantly restrict water flow. Infiltration was also influenced by the amount of clay as explained in the following paragraphs.

Infiltration in undisturbed soils. Figure 5 represents infiltration velocities of five undisturbed soils in the Colstrip area. Infiltration velocities were moderately rapid[2] on all undisturbed soils. Infiltration velocities on the Chinook and Busby undisturbed soils showed less fluctuation over time and reached steady-state conditions more quickly than on the less sandy Yamac and Kobar undisturbed soils.

The Kobar undisturbed soil had the greatest clay content of all

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[2] SCS permeability classes.

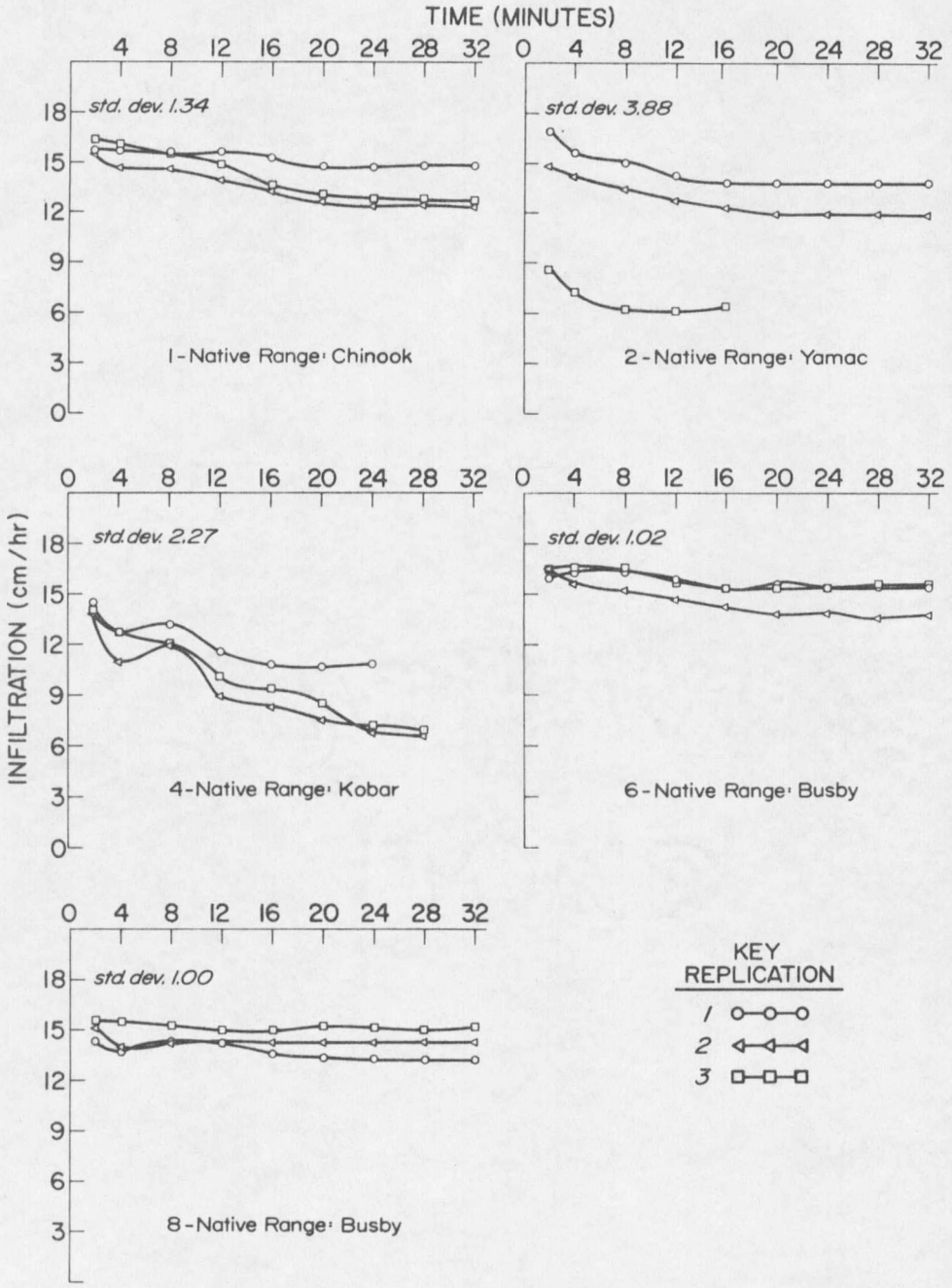


Figure 5. Infiltration vs. Time measured in undisturbed soils at the Colstrip study area in August, 1976.

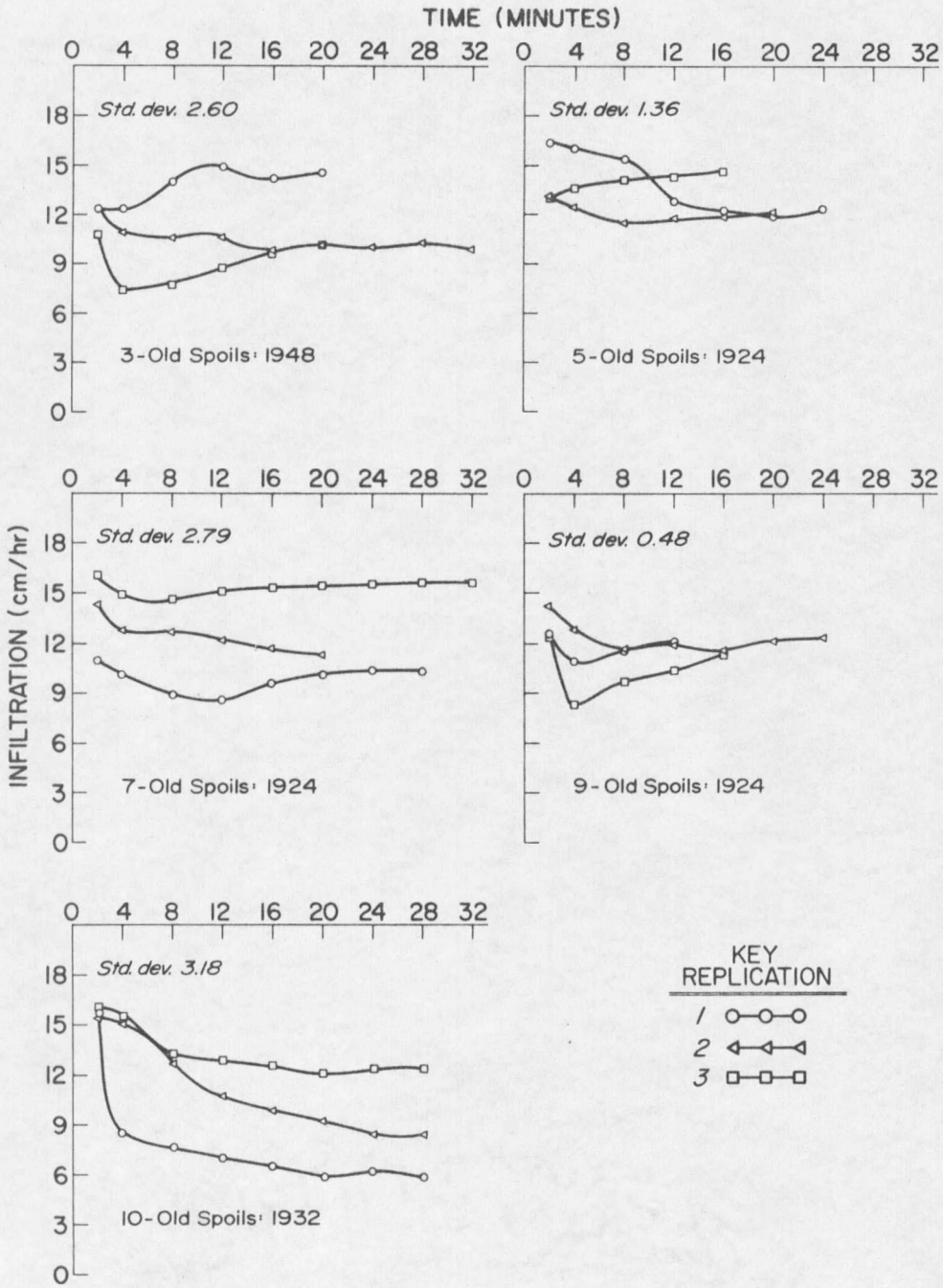


Figure 6. Infiltration vs. Time measured in old spoils at the Colstrip study area in August, 1976.

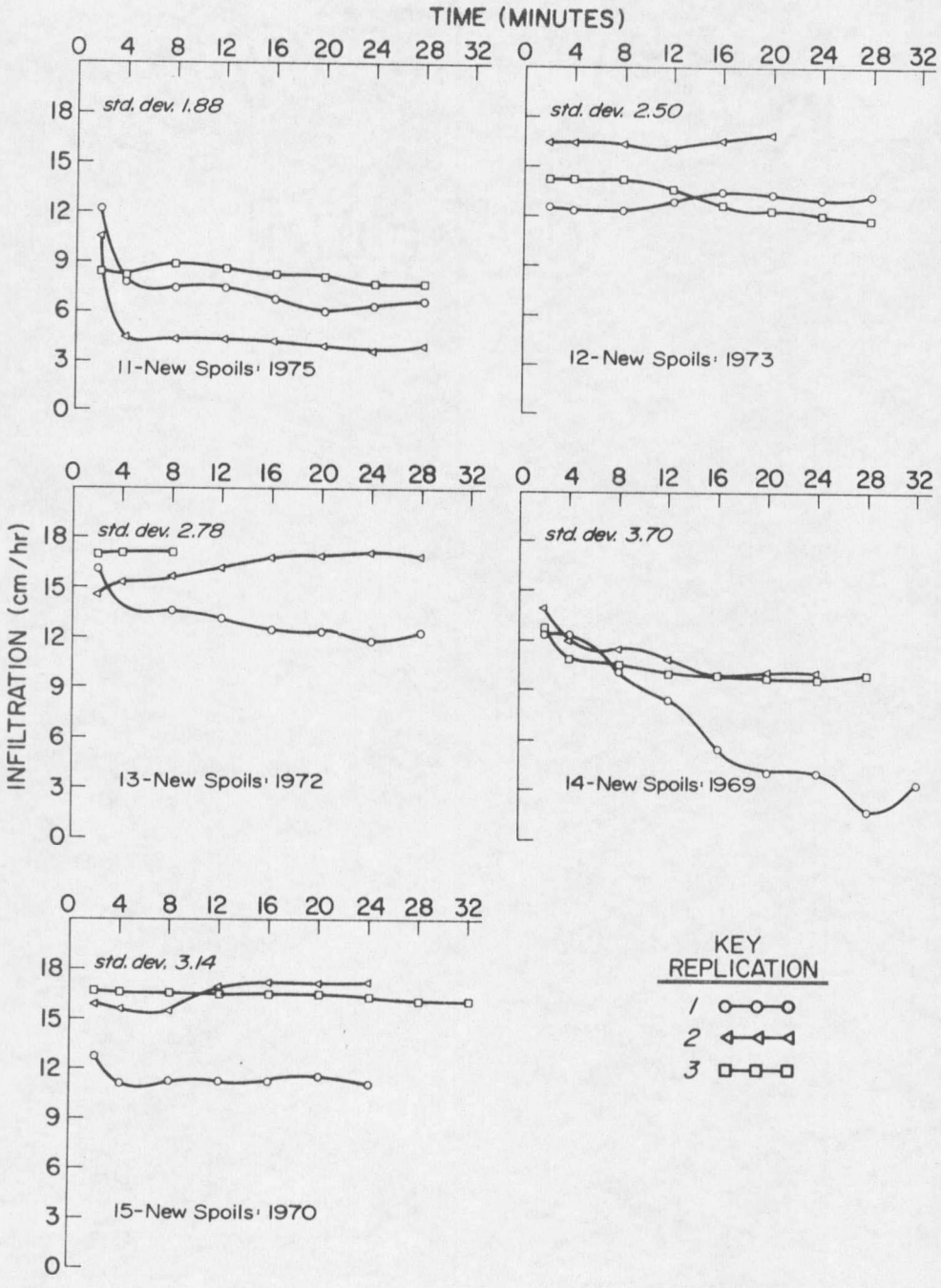


Figure 7. Infiltration vs. Time measured in new spoils at the Colstrip study area in August, 1976.

sites tested and was the only one to receive a B2t horizon designation (Table 36, Appendix D). The fact that the Kobar undisturbed soil had the slowest infiltration velocity of all sites tested, except for the 1975 spoil, lends support to the idea that the amount of clay influenced infiltration.

Infiltration in old spoils. Figure 6 represents infiltration velocities of 28 to 52 year-old stripmine spoils in the Colstrip area. Infiltration velocities were moderately rapid on all old spoils. Infiltration velocities on these old spoils showed greater variation over time and took longer to reach steady-state conditions than on undisturbed soils, possibly because the surface horizons in old spoils were more stratified due to mining operations than in undisturbed soils and the wetting front traveled at different velocities through these stratifications.

The three 1924 spoil had practically the same infiltration velocities at the end of the test period as they did at the beginning, possibly indicating that the swelling together of pore spaces due to the expansion of clays was not significant in the 1924 spoil. The same type of infiltration pattern was noted in the 1948 spoil, which had a high amount of clay in its surface horizons and would, therefore, be expected to have a notable decrease in infiltration over time. Perhaps infiltration on the 1948 spoil remained unchanged because of some effect attributed to the coal fragments that were common throughout its profile

(Table 43, Appendix D). Water flow through the coal fragments may not have been affected by the expansion of the surrounding clay particles when they were wetted. Only on the 1932 spoil did infiltration velocities drop substantially before attaining steady state conditions. This was not surprising since the clay content of the 1932 spoil was more than twice that of the 1924 spoils.

Infiltration on new spoils. Figure 7 represents infiltration velocities of 1 to 7 year-old stripmine spoils in the Colstrip area. Infiltration velocities were moderately rapid on all new spoils, except for the 1972 spoil which had a rapid infiltration velocity. Generally, infiltration velocities on these new spoils showed less variation over time than on old spoils. However, one replication on the 1969 spoil was found to be an outlier ($P = .99$)[3] and was eliminated when computing its mean.

Only on the 1975 spoil did infiltration velocities drop appreciably before attaining steady-state conditions. This may be explained by the high (77%) silt content in the surface horizon of the 1975 spoil. Apparently, these silt particles washed into the profile and partially clogged its pores and voids, thereby restricting water flow. This phenomenon was first reported by Diebold (1954).

The mean infiltration velocities of all fifteen sites are

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[3]Grubb's test (Dunn and Clark, 1974).

represented in Figure 8. Values range from 5.93 cm hr^{-1} on the 1975 spoil to 15.30 cm hr^{-1} on the 1972 spoil. The mean infiltration velocity of all fifteen sites was 11.91 cm hr^{-1}.

One site from each group was omitted for statistical analysis because they were not representative of their groups. The Chinook undisturbed soil was eliminated because it had buried soil horizons, a very rare occurance in the Colstrip area. The 1948 spoil was ommited because it contained a high percentage of coal fragments throughout its profile. The 1969 spoil was deleted because it was actually an old spoil that had been regraded.

Table 2 represents the analysis of variance[4] for mean infiltration velocities. The F-value was significant at the .95 level (P = .001), meaning that infiltration velocities between sites were

Table 2. ANOV for infiltration velocities of sites at the Colstrip study area in August, 1976.

Source	D.F.	S.S.	M.S.	F-Value	P-Value
Sites	11	299.8	27.26	4.585	.001
Reps	2	8.496	4.248	0.715	.504
Error	22	130.8	5.945		
Total	35	439.1			

[4] Statistical model appears in Appendix B.

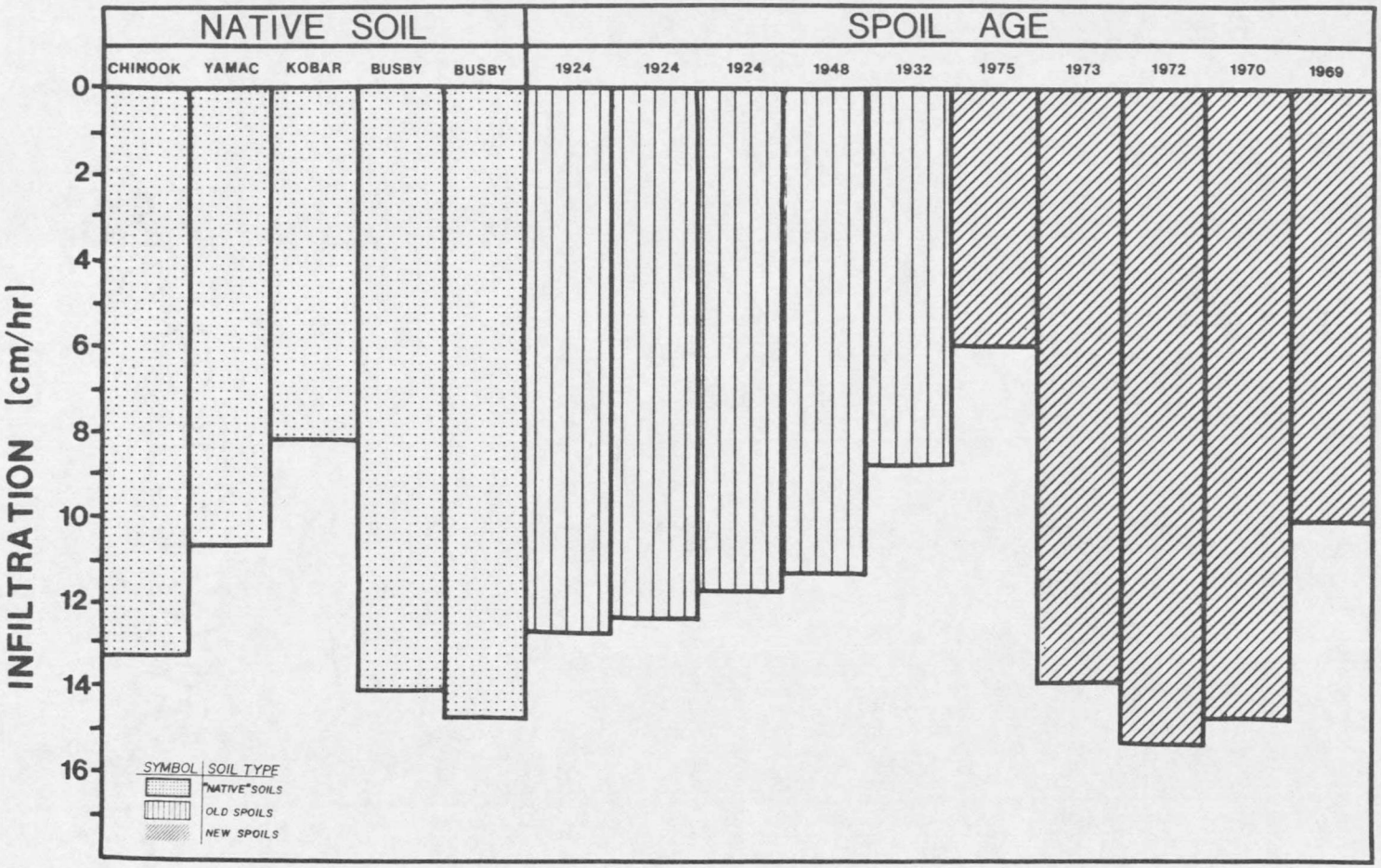


Figure 8. Mean infiltration velocities of sites at Colstrip study area - August, 1976.

significantly different. This difference was expected to be significant, especially since replications within a site were dependent on that particular site and one of the basic assumptions of the statistical model was, therefore, invalidated.

A difference greater than 1.07 cm hr^{-1} between mean infiltration velocities was considered significant (L.S.D. - .95). Table 3 lists those sites which had similar infiltration velocities. The infiltration velocities of the different sites representing the same undisturbed soil (Busby) and old spoil (1924) were not significantly different between themselves, indicating that the variation within sites was small.

Table 3. Infiltration velocities (LSD) at the Colstrip study area in August, 1976.

Site	Infiltration (cm hr^{-1})	Site	Infiltration (cm hr^{-1})
1975 Spoil	5.93^{a}	1924 (5) Spoil	12.83^{d}
Kobar Soil	8.20^{b}	1973 Spoil	14.00^{e}
1932 Spoil	8.90^{b}	Busby Soil (8)	14.23^{ef}
Yamac Soil	10.63^{c}	Busby Soil (6)	14.87^{ef}
1924 (9) Spoil	11.83^{d}	1970 Spoil	14.87^{ef}
1924 (7) Spoil	12.43^{d}	1972 Spoil	15.30^{f}

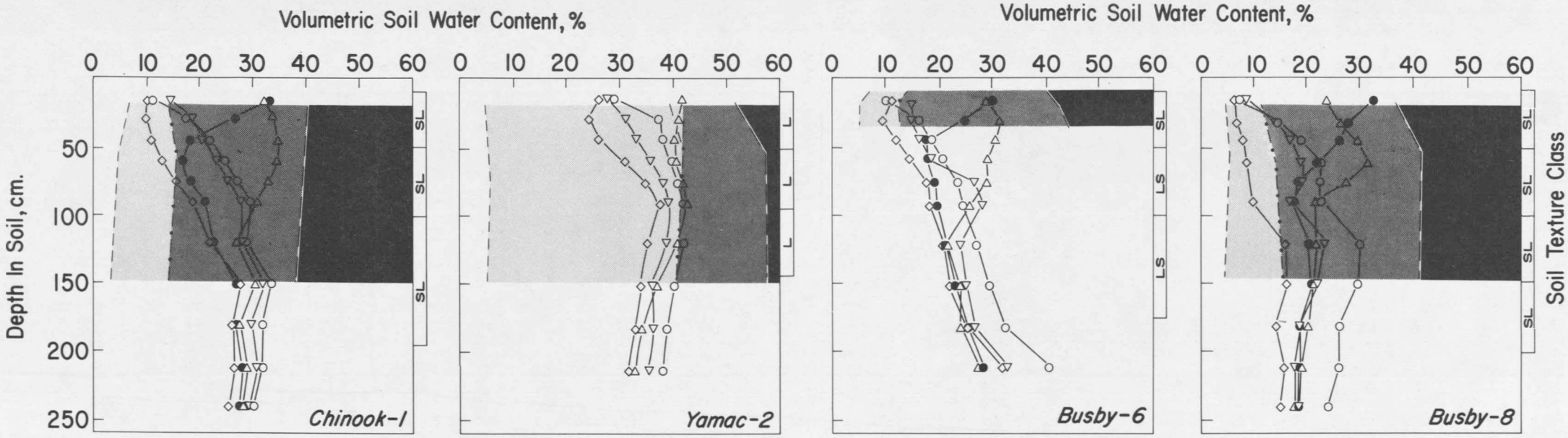
Table 4 represents the analysis of variance for infiltration velocities of undisturbed soils (11.98 cm hr^{-1}), old spoils (11.50 cm hr^{-1}) and new spoils (12.52 cm hr^{-1}). The F-value was not significant at the .95 level (P = .91), meaning that infiltration velocities were not significantly different between undisturbed soils and minespoils, old and new. The main reason for the similarity of infiltration velocities between groups was probably related to the similarities of textural compositions. Although the correlations between steady-state infiltration velocities and the percentages of sand (r = .36), silt (r = -.33) and clay (r = -.38) of the upper 50 cm of the soil horizons were not significant at the .95 level, these correlations established that infiltration velocities were partially explained by textural compositions.

Table 4.--ANOV for infiltration velocities of groups.

Source	D.F.	S.S.	M.S.	F-Value	P-Value
Groups	2	2.104	1.052	.097	.908
Error	9	97.92	10.88		
Total	11	100			

Soil Water Content

Figures 9, 10 and 11 represent seasonal soil water characteristics of undisturbed soils, old spoils and new spoils groups,respectively.



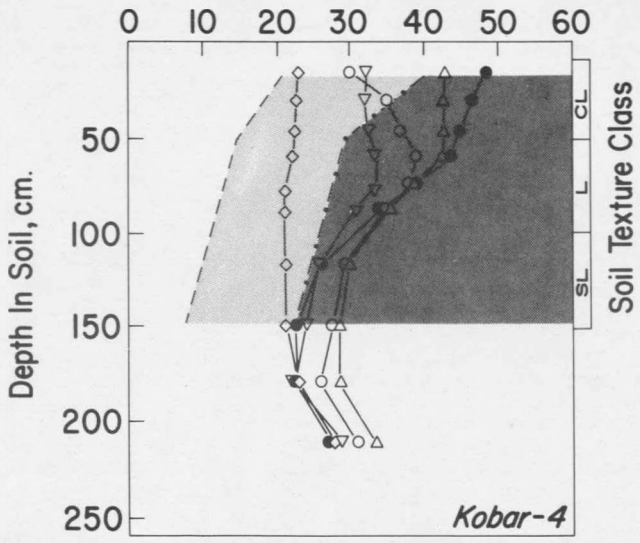


Figure 9. Seasonal soil water contents, desorption characteristics and texture classes of Undisturbed Soils.

NATIVE SOILS

Date of Sampling

1976	1977
○ July 11	● February 12
◇ October 22	△ April 6
	▽ June 15

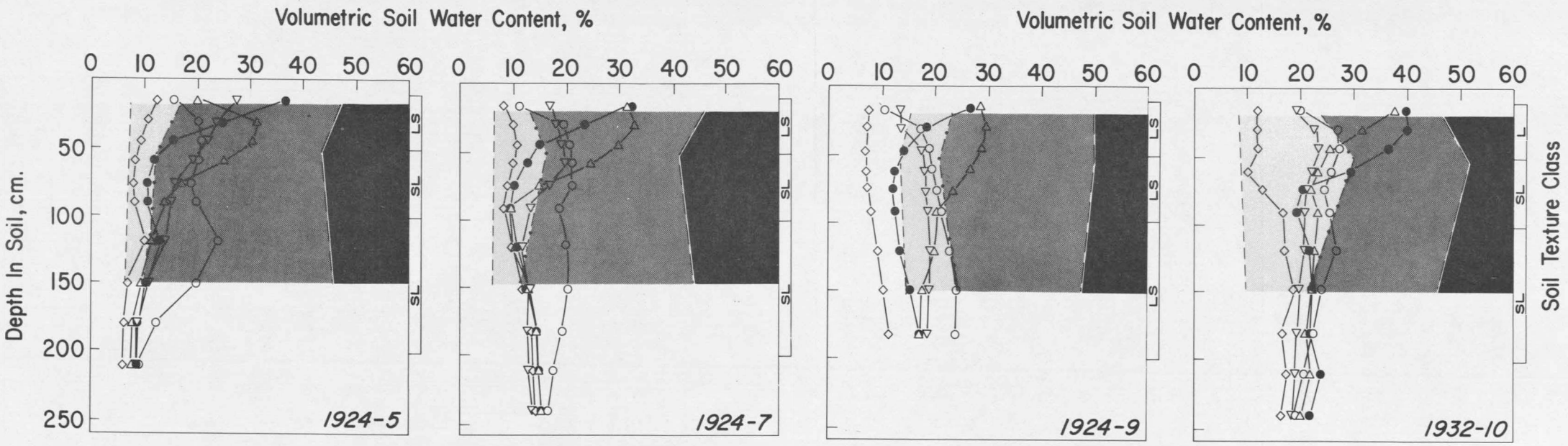
– – – – – Approximate plant wilting line

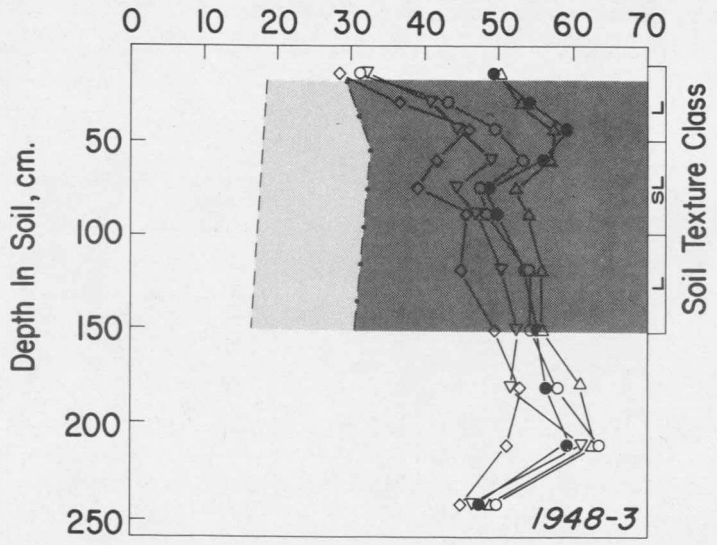
•–•–•– Approximate field capacity line

— — — Approximate soil saturation line

Soil Water Potential Zones

- 0.0 bars (saturation)
- 0.0 to −0.3 bars
- −0.3 to −15 bars
- <−15 bars (approximate plant wilting zone)





OLD SPOILS

Date of Sampling

1976	1977
○ July 11	● February 12
◇ October 22	△ April 6
	▽ June 15

– – – – – Approximate plant wilting line

•–•–• Approximate field capacity line

— — — Approximate soil saturation line

Soil Water Potential Zones

- 0.0 bars (saturation)
- 0.0 to −0.3 bars
- −0.3 to −15 bars
- <−15 bars (approximate plant wilting zone)

Figure 10. Seasonal soil water contents, desorption characteristics and texture classes of Old Spoils.

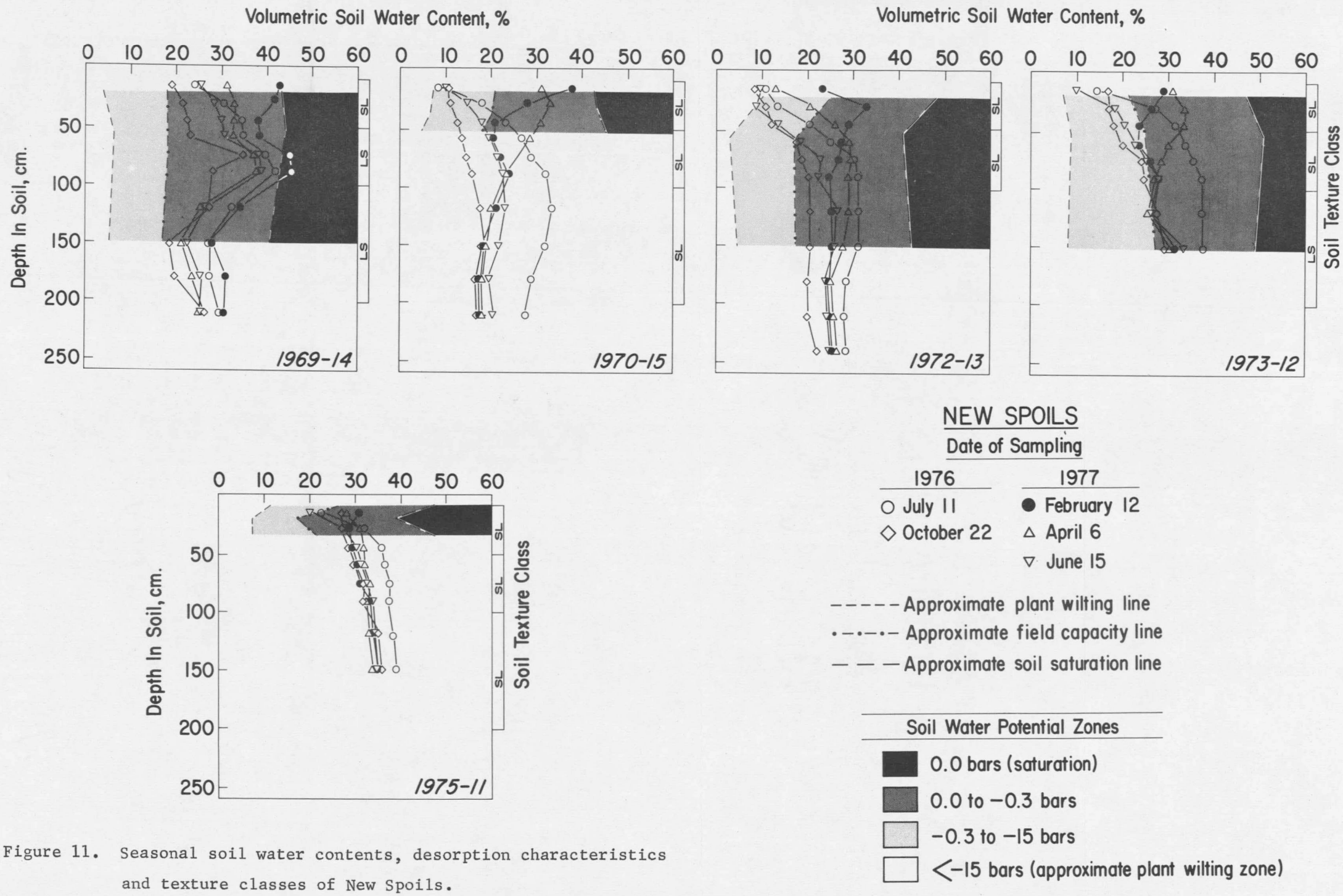


Figure 11. Seasonal soil water contents, desorption characteristics and texture classes of New Spoils.

Due to the need for legible figures, only those measurements which showed significant trends were presented. Average volumetric soil water percentages for 20 measurement dates are presented in Appendix F.

Soil water potentials of 0.0, -0.3 and -15 bars were plotted in Figures 9, 10 and 11 to represent approximate soil saturation, field capacity and permanent wilting point limits. A soil is saturated when all of its pores are filled with water. A soil at field capacity has lost most of its gravitational water. A soil at its permanent wilting point has a moisture content at which most plants wilt and fail to recover their turgidity when moistened. These soil desorption characteristics were determined by W. M. Schafer for thirteen sites using undisturbed soil cores. Such cores were not collected for the 1948 spoil or the Kobar undisturbed soil. However, the SCS determined soil water contents at -0.3 and -15 bar for these two sites using the same method (Appendix E). Since 0 bar moisture contents were not determined for these two sites, it was impossible to graph their saturated soil water potential zones. Their 0.0 to -0.3 bars zones were extended out to the right side of the graphs even though their saturation zones may have fallen within those limits.

Soil water in undisturbed soils. Figure 9 represents soil water characteristics of five undisturbed soils during the period from July 11, 1976, to June 15, 1977. Minimum total profile soil water contents were recorded in all undisturbed soils on October 22, 1976, and

maximum soil water contents were recorded on April 6, 1977. Maximum soil water contents were recorded in upper 150 cm profiles on April 6, 1977. Lower profiles were wettest on July 11, 1976.

The average amount of recharge in upper 150 cm profiles of undisturbed soils (Yamac, Kobar, Busby) during the period from October 22, 1976, to April 4, 1977, was 18.4 cm. This amount varied from 15.2 cm in Busby (No. 6) to 21.7 cm on Busby (No. 8). The average amount of water use in upper 150 cm profiles during the period from April 4 to June 15, 1977, was 8.4 cm. This amount varied from 7.3 cm on Busby (No. 6) to 10.1 cm on Busby (No. 8).

Soil water contents near the surfaces of all undisturbed soils, except Yamac, were low enough to cause permanent wilting of vegetation during August and September, 1976. Soil water contents near the surface of the Yamac undisturbed soil remained above the wilting point during the entire investigation period.

Yamac's favorable soil moisture conditions were partially explained by its textural composition (loam). It had a high water content at -0.3 bar, similar to that of a clay loam (Kobar) and it had a low water content at -15 bar, similar to that of a sandy loam (Busby). Together these properties gave the Yamac undisturbed soil the greatest capacity for holding plant available water of all sites tested.

Unusually high soil moisture levels were recorded in the top 30 cm profiles of undisturbed soils on February 12, 1977. According to

Ferguson (1964) and Willis et al. (1964), these high moisture levels result from unsaturated water flow from substrata towards the frozen soil surface. Although they had not established the exact mechanism of this phenomenon, they believed that it was partially caused by temperature gradients in the soil profile.

Deep leaching of soil water past the root zone may occur during heavy recharge periods. After leaving the root zone this water may eventually enter the ground water table, bringing with it water-soluble minerals and plant nutrients. Deep leaching in undisturbed soils usually occurred during the periods from the beginning of the test period, June 9, 1976, to mid-September, 1976, and from early April to mid-June, 1977. Deep leaching occurred to a much greater degree in 1976 than in 1977, probably because a much greater amount of precipitation fell during the main portion of the growing season (April-June) in 1976 (21.6 cm) than in 1977 (12.1 cm), and what wasn't utilized by plants passed through the root zone.

Soil water in old spoils. Figure 10 represents soil water characteristics of old spoils during the period from July 11, 1976, to June 15, 1977. No general trends were found for old spoils concerning maximum total profile soil water contents. However, general trends were found concerning minimum total profile and maximum upper and lower profile soil water contents. Minimum total profile soil water contents were recorded in most old spoils on October 22, 1976. Maximum soil

soil water contents in upper 100 cm profiles were recorded in most old spoils on April 6, 1977. In the lower profiles of all old spoils, maximum soil water contents were recorded on July 11, 1976.

The average amount of recharge in upper 150 cm profiles of 1924 and 1932 spoils was 18.3 cm during the period from October 22, 1976, to April 4, 1977. This quantity varied from 14.1 cm in 1924 spoil (No. 5) to 24.0 cm in 1924 spoil (No. 9). The average amount of water use in upper 150 cm profiles was 7.1 cm during the period from April 4 to June 15, 1977. Water use varied from 1.6 cm on 1924 spoil (No. 5) to 10.2 cm on 1924 spoil (No. 9).

The undisturbed soils and old spoils were similar in that their surface soil moisture levels fell below the permanent wilting points in August and September, 1976. This also happened in old spoils at other times of the year, but not for undisturbed soils. For instance, soil moisture levels in the 1924 spoil (No. 9) fell below the permanent wilting point during a large part of the investigation period: 7-11-76 (0-15 cm); 8-11-76 (0-60 cm); 8-24-76 to 9-15-76 (0-120 cm); 10-22-76 (0-180 cm); 11-24-76 (0-120 cm); 1-15-76 to 2-12-77 (45-150 cm); 3-13-77 (75-150 cm); 5-2-77 (0-15 cm); 5-15-77 (0-30 cm); 5-29-77 (0-15 cm); and 6-15-77 (0-30 cm). These unfavorable moisture conditions were partially explained by the 1924 spoil's (No. 9) textural composition, the sandiest of all sites tested.

High moisture levels were recorded near the surface of old

spoils on February 12, 1977. Apparently, the mechanism responsible for this phenomenon works just as well in minespoils as it does in undisturbed soils.

Unusually high soil water contents were recorded throughout the 1948 spoil's upper 240 cm profile. It was first postulated that these levels were caused by the capillary rise of water from a high groundwater table. However, data supplied by Wayne Van Voast of the Montana Bureau of Mines indicated that the groundwater table near the 1948 spoil was too deep (>6.5 m) for this to happen.

Another possible explanation for the high moisture levels in the 1948 spoils was that large quantities of water were held in the coal fragments that appeared throughout its profile. Laboratory analysis indicated, however, that coal fragments from the Colstrip area contain approximately 43 percent moisture by volume at saturation. Since moisture levels in the 1948 spoils often exceeded 60 percent, this explanation was not acceptable.

Finally, it was postulated that hydrogen atoms in coal fragments, common to the 1948 spoils, were counted as belonging to water molecules using the neutron scattering method. Consequently, *in situ* moisture determinations on the 1948 spoils were erroneously overestimated. The same type of error was noted in soils high in organic matter by Feustel and Byers (1936). This explanation seems highly probable when one considers that the hydrogen content of coal in the Colstrip area averages

3.4 percent by weight,[5] and that the hydrogen content of humus is 5.0 percent (Waksman, 1954).

Deep leaching probably did not occur below 210 cm of the soil profile of at least two of the 1924 spoils during the entire investigation period. This pattern was not verified in the third 1924 spoil because soil water contents were not measured below 180 cm in its soil profile. This lack of deep leaching in the 1924 spoils was perhaps due to the utilization of excessive quantities of soil water by deep-rooting shrubs which were common on these spoils. Deep leaching probably occurred below 150 cm of the soil profile in the 1932 spoil during the period from mid-June to mid-September, 1976. In the 1948 spoil it was apparent that deep leaching did not occur below 240 cm during the entire investigation period. Since this spoil was vegetated with deep-rooting shrubs, it appeared that they were responsible for this shallow percolation.

Soil water in new spoils. Figure 11 represents soil water characteristics of new spoils during the period from July 11, 1976, to June 15, 1977. The desorption characteristics of these spoils showed much greater variation with depth, especially near their surfaces, than was shown in old spoils and undisturbed soils. The fact that all new

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[5]Personal communication with John Thiebold, engineer for Montana Power Company. Value represents average annual composition of coal used at Colstrip power generating plants 1 and 2.

spoils, except the 1969 spoil, had top soil spread over their surfaces probably accounted for most of the variation.

General trends were not found concerning maximum soil moisture levels in new spoils over time. However, all new spoils had minimum soil moisture levels on October 22, 1976.

The average amount of recharge in the upper 150 cm profiles of new spoils (1970, 1972, 1973 and 1975) during the period from October 22, 1976, to April 4, 1977, was 13.8 cm. This amount ranged from a minimum of 9.9 cm in the 1975 spoil to a maximum of 19.8 cm in the 1972 spoil, possibly due to textural differences. The average amount of water use in upper 150 cm profiles between April 4 and June 15, 1977, was 12.4 cm. Water use ranged from a minimum of 9.8 cm in the 1973 spoil to a maximum of 18.2 cm in the 1972 spoil.

Moisture levels near the surface of the 1970, 1972 and 1973 spoils were below the permanent wilting point in August and September, 1976. The 1972 spoil was more often deficient in plant available water in the upper 15 cm profile than were the 1970 and 1973 spoil. This was not surprising since the upper 15 cm of the 1972 spoils had a much sandier textural composition (Appendix E).

Moisture levels near the surfaces of the 1969 and 1975 spoils remained above the permanent wilting point throughout the investigation period. The upper 15 cm profile of the 1969 spoil had a less sandy textural composition than did the other new spoils and probably held

greater quantities of plant available water. This condition was not verified because desorption characteristics were not determined for the upper 15 cm profile of the 1969 spoil. Moisture levels probably remained above the permanent wilting point of the 1975 spoil not so much for its capacity to hold large quantities of plant available water, which it didn't possess, but because water use on this spoil was minimal due to the lack of vegetation. For instance, water use in the upper 150 cm profile of the 1975 spoil during the period from July 11 to October 22, 1976, was 5.8 cm compared to an average water use of 14.7 cm on other new spoils (Appendix F).

As in undisturbed soils and old spoils, high soil water contents were recorded near the surface of new spoils on February 12, 1977. Dollhopf et al. (1977) had reported similar soil moisture patterns in new spoils of the Colstrip area. They were concerned that soluble salts were possibly translocated towards spoil surfaces if the moisture moves in a liquid phase. Once at the surface these soluble salts could be detrimental to plant growth. Therefore, they suggested that further research be conducted on this phenomenon to ascertain whether or not moisture moves towards the surface in a liquid or vapor phase.

Deep leaching generally occurred below 150 cm of the soil profiles of new spoils during the periods from mid-June to mid-September, 1976, and from mid-March to late July, 1977. The 1975 spoil was an exception in that deep leaching occurred below 75 cm of its soil

profile. Deep leaching was substantially greater in the new spoils than in both the old spoils and undisturbed soils probably because there was less vegetation on new spoils.

In summarizing the foregoing discussion on soil water content, three general trends were discovered that applied to most spoils and undisturbed soils of the Colstrip area: moisture levels near the surface fell below permanent wilting points during August and September, 1976; minimum moisture levels were recorded in upper 150 cm profiles on October 22, 1976; and the upper 30 cm of the soil profiles were partially recharged on February 12, 1977, possibly by the unsaturated flow of water from substrata.

Soil water contents recorded on April 14, 1977 had positive correlations with percentages of silt ($r = .73$) and clay ($r = .46$), and a negative correlation with the percentage of sand ($r = -.66$) in the upper 150 cm of the soil profiles. These correlations were significant at the .95 level for sand and silt, but not for clay ($P = .018$, .007 and .128, respectively; Table 5), indicating that soil water contents were dependent on textural compositions.

Plant available water (P.A.W.), the difference between soil water content at -0.3 and -15 bar, had positive correlations with percentages with silt ($r = .74$) and clay ($r = .60$), and a negative correlation with the percentage of sand ($r = -.77$) in the upper 150 cm

Table 5. ANOV of soil water regression on textural compositions of sites at Colstrip study area on April 14, 1977.

	Source	D.F.	S.S.	M.S.	F-Value	P-Value
Sand:	Regression	1	523	523	7.80	.018
	Error	10	671	67.1		
	Total	11	119			
Silt:	Regression	1	631	631	11.2	.007
	Error	10	563	56.3		
	Total	11	119			
Clay:	Regression	1	254	254	2.71	.128
	Error	10	939	93.9		
	Total	11	119			

of the soil profiles. These correlations were significant at the .95 level (P = .008, .006 and 0.039, respectively; Table 6).

Table 6. ANOV for desorption characteristics (PAW) regression on textural compositions at Colstrip study area.

	Source	D.F.	S.S.	M.S.	F-Value	P-Value
Sand:	Regression	1	343	343	10.9	.008
	Error	10	3.5	31.5		
	Total	11	657			
Silt:	Regression	1	355	355	11.8	.006
	Error	10	302	30.2		
	Total	11	657			
Clay:	Regression	1	235	235	5.55	.039
	Error	10	423	42.3		
	Total	657				

Although the amount of plant available water was highly correlated with textural compositions, actual water use during the growing season was not. No significant trends were found even when this relationship was looked at within groups, a practice which sometimes produces significant results. This indicated that water use by plants was not determined by the soil's textural composition, even though the amount of plant available water was a function of the soil's textural composition.

Deep leaching of soil water past root zones was more pronounced and occurred more frequently in new spoils than in undisturbed soils. It was almost nonexistent in old spoils. The similarity between new spoils and undisturbed soils suggested that vegetation had a major influence on deep leaching because both groups were dominated by grasses and forbs. Furthermore, deep leaching was greatest in new spoils probably because they had the least amount of root biomass and, therefore, utilized smaller amounts of soil water (see Root Biomass section). Deep leaching was almost nonexistent in old spoils probably because the deep-rooting shrubs on these spoils were able to utilize soil water at deeper soil depths.

Soil Water Potentials and Soil Temperatures

Unfortunately, the information obtained using double-junction thermocouple psychrometers during this investigation was deemed

unreliable and, therefore, did not merit a formal discussion. Nevertheless, for sake of completeness all soil water potentials and soil temperatures are presented an Appendix H.

Using information that was gathered during the first few months of the investigation, it was found that soil water potentials, calculated with the calibration equation supplied by the manufacturer, had a low negative correlation with soil water contents. Theoretically, soil water potentials have a high positive correlation with soil water contents, meaning that soil water potentials increase (become less negative) with soil water contents. It was felt that perhaps the manufacturer's calibration equation was in error. Therefore, all TCPs were removed from the field, cleaned and recalibrated. The calibration results were fit to an equation developed by Rawlins (1972). The first year's field data were revised using the new calibration equations, but the same type of relationship between soil water potentials and water contents remained. TCPs were later returned to the field and were monitored for the remainder of the investigation period.

There were other indications that the data derived from TCPs were unreliable. For instance, the soil water potential at 90 cm in the 1970 spoils dropped from -6.5 to -41.7 bars during the period from October 22 to November 24, 1976. There was no reasonable explanation for this drop in soil water potential except that the TCP was faulty.

Such fluctuations were found in virtually every other profile and not just once, but repeatedly.

Root Biomass

Root biomass was determined from fifteen 1000 cm^3 soil samples that were collected from three depth intervals (five from each) in all soil profiles. Mean root biomass, expressed on an ash-free basis, are presented in Table 7. Total root biomass ranged from 1.24 mg ml^{-1} in the 1975 spoil to 4.58 mg ml^{-1} in the 1924 spoil (No. 5).

Table 7.--Root biomass (mg ml^{-1}) at Colstrip study area in 1976.

	Depth Interval (cm)		
Profile (Site No.):	5-15	45-55	95-105
Native Soil			
Chinook	3.59	0.56	0.04
Yamac	1.57	0.00	0.00
Kobar	2.01	0.29	0.17
Busby (6)	4.29	0.06	0.00
Busby (8)	3.35	0.48	0.19
Old Spoil			
1924 (5)	3.36	0.59	0.63
1924 (7)	2.18	0.09	0.04
1924 (9)	1.68	0.12	0.05
1932	2.35	0.61	0.17
1948	3.30	0.27	0.13
New Spoil			
1969	1.66	0.38	0.10
1970	1.74	0.11	0.13
1972	2.23	0.10	0.02
1973	1.45	0.06	0.04
1975	1.23	0.01	0.00

Group comparisons were made using the same four undisturbed soils, old spoils and new spoils that were used in the soil water sections (Table 8). These group values were fitted to an equation of a straight line relating the natural logarithm of root biomass to soil depth:

$$W(\bar{z}) = W(o)e^{-\alpha\bar{z}}$$

where $W(\bar{z})$ is the root biomass at depth $\bar{z}$, $W(o)$ is the root biomass at the soil surface and α is the slope of the line.

Table 8. Group root biomass (mg ml^{-1}) at Colstrip study area in 1976.

Depth Interval (cm)	Native Soil	Old Spoil	New Spoil
5-15	2.81	2.40	1.66
45-55	0.21	0.35	0.07
95-105	0.09	0.22	0.05

The slopes of the straight lines for undisturbed soils, old spoils and new spoils were -.0374, -.0258 and -.0377, respectively. Although root biomass had high negative correlations with soil depth in undisturbed soils (r = -.94), old spoils (r = -.92) and new spoils (r = -.88), these correlations were not significant at the .95 level (P = .23, .27 and 32, respectively). Nevertheless, the vertical rooting distribution in undisturbed soils was similar to the one in new spoils, but different from the one in old spoils. This was explained by the

fact the undisturbed soils and new spoils were dominated by grasses and forbs, while old spoils were dominated by half-shrubs (Appendix D). Grasses and forbs have fibrous roots and half-shrubs have woody roots of greater mass.

Group comparisons showed that root biomass was not significantly different at the .95 level. This was true at the 5-15 (P = .22), 45-55 (P = .22) and the 95-105 (P = .38) cm depth intervals as well as for total root biomass (P = .20; Table 9).

Table 9. ANOV for root biomass at Colstrip study area in 1976.

Source	D.F.	S.S.	M.S.	F-Value	P-Value
5-15 cm:					
Group	2	2.678	1.34	1.80	0.22
Error	9	6.710	0.75		
Total	11	9.389			
45-55 cm					
Group	2	0.159	0.080	1.81	0.22
Error	9	0.398	0.044		
Total	11	0.557			
95-105 cm					
Group	2	0.067	0.033	1.09	0.38
Error	9	0.274	0.030		
Total	11	0.341			
Total Profile					
Group	2	4.347	2.174	1.93	0.20
Error	9	10.13	1.126		
Total	11	14.48			

Root biomass at 45-55 and 95-105 cm depth intervals had high

correlations with water use at corresponding depths during the period from April 4 to June 15, 1977, in undisturbed soils (r = .98 and .97) and new spoils (r = .99 and .93). All of these correlations, except the one for new spoils at the 95-105 depth interval, were significant at the .95 level (Table 10), indicating that water use in the subsurface horizons of undisturbed soils and new spoils, both of which were dominated by grasses and forbs, was a function of root biomass. Corresponding correlations for old spoils were negative (r = -.73 and -.80) and not significant at the .95 level, suggesting that water use in the subsurface horizons of old spoils, which was dominated by half-shrubs, was not influenced by root biomass. Similar correlations for the surface horizons of undisturbed soils (r = .45), old spoils (r = -.84) and new spoils (r = -.75) were not significant at the .95 level. This suggested that other factors besides root biomass influenced water use in upper 15 cm profiles, but evidence was not conclusive since large errors were associated with *in situ* soil water content measurements near the soil surface.

Root Activity - Radioactive Tracer (^{32}P)

Radioautographs showing ^{32}P distribution. Vertical rooting distributions were monitored in 1976 and 1977 by injecting radioactive phosphorus (^{32}P) into the soil and measuring radioactivity in the above ground portions of plants growing near the injections. Radioautographs

Table 10. ANOV of root biomass regression on soil water use (cm) at Colstrip study area from April 4 to June 15,1977.

Source	D.F.	S.S.	M.S.	F-Value	P-Value
Native Soil Group					
5-15 cm	1	.0509	.0509	.511	.549
Error	2	.1992	.0996		
Total	3	.2502			
45-55 cm	1	2.734	2.734	62.5	.012
Error	2	.0875	.0437		
Total	3	2.821			
95-100 cm	1	5.648	5.648	32.0	.026
Error	2	.3528	.1764		
Total	3	6.000			
Old Spoil Group					
5-15 cm	1	7.132	7.132	4.80	.161
Error	2	2.969	1.485		
Total	3	10.10			
45-55 cm	1	12.12	12.12	2.32	.268
Error	2	10.46	5.228		
Total	3	22.58			
95-105 cm	1	16.39	16.39	3.57	.200
Error	2	9.178	4.589		
Total	3	25.57			
New Spoil Group					
5-15 cm	1	.0172	.0172	2.57	.251
Error	2	.0134	.0067		
Total	3	.0307			
45-55 cm	1	6.975	6.975	.116	.006
Error	2	.1201	.0600		
Total	3	7.095			
95-105 cm	1	20.59	20.59	12.8	.068
Error	2	3.223	1.612		
Total	3	23.82			

were taken of radioactive plants that were collected from the Chinook undisturbed soil on July 31, 1977. Figure 12 shows the distribution of ^{32}P in the taprooted half-shrub *Artemisia frigida* and the perennial, cool season bunchgrass *Stipa comata*. These specimens had taken up ^{32}P from 15 and 107 cm, respectively.

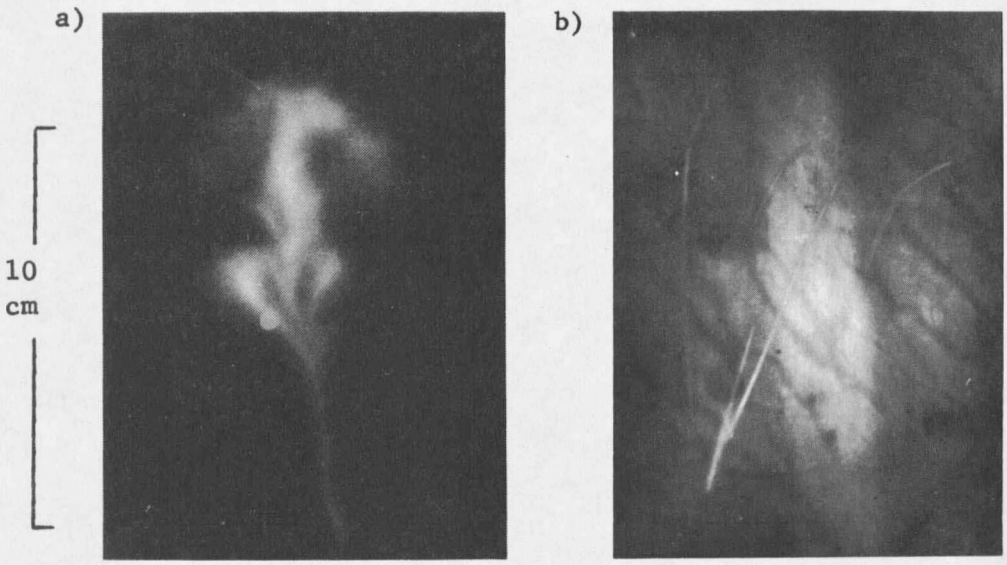


Figure 12. Radioautographs showing ^{32}P distribution in a) *Artemisia frigida* and b) *Stipa comata* at Colstrip study area.

Most of the ^{32}P present in the tops of *Artemisia frigida* was concentrated in its actively growing new leaves and stems. Smaller amounts of ^{32}P were found in its main stem and older (longer) leaves. The area where new growth initiates in *Stipa comata*, the apical point,

had a greater concentration of ^{32}P than did its older leaves.[6]

These radioautographs indicated that ^{32}P concentrations varied within a plant. Since plants do not all have the same structures, it was impossible to compare radioactivities of one particular plant structure across all species. Therefore, all plants were surveyed on each measurement date and the most radioactive part of a plant was selected for counting.

In situ radioactivities - 1976. Figures 13-15 represent plant radioactivities measured *in situ* on thirteen sites during the summer of 1976. Radioactivity in a plant was an indication that its roots were active at the ^{32}P injection depth over which it was growing since only by root absorption and translocation of the injected ^{32}P to the plant's above-ground portions (tops) could there be any radioactivity to measure. The intensity of a plant radioactivity was approximately proportional to the total quantity of ^{32}P that was present in its tops.

The problem of radioactive contamination of soil along the inside wall of injection holes and at the soil surface complicated matters since plants absorbing contaminated ^{32}P appeared to have active roots at the injection depths when in fact they didn't. Fortunately, the amount of ^{32}P available to plants from a full dosage was much

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[6]Personal communication with Dr. E. DePuit, Range Scientist, Animal and Range Department, Reclamation Division, Montana State University.

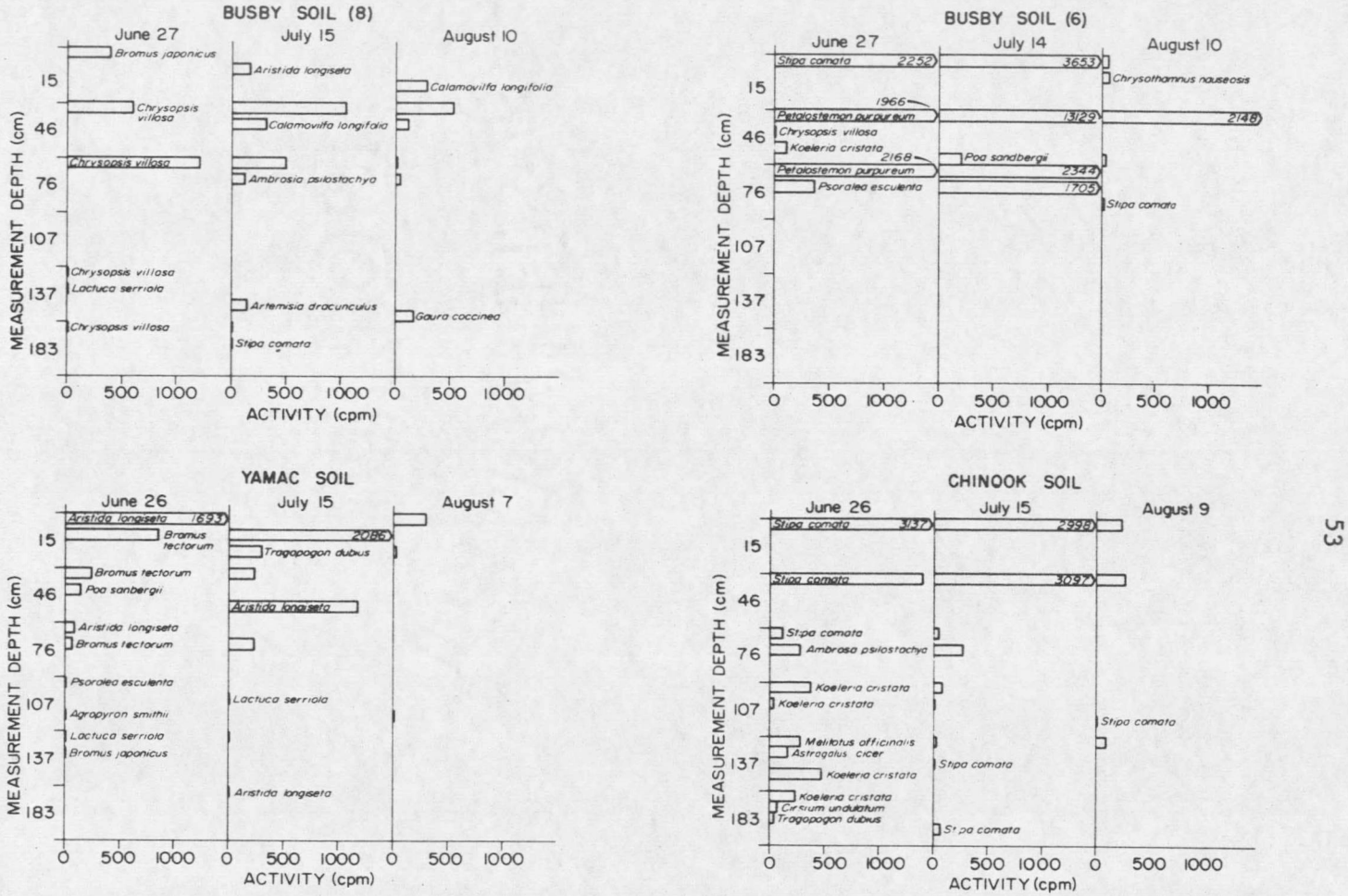


Figure 13. Plant radioactivities measured *in situ* on undisturbed soils at the Colstrip study area in 1976.

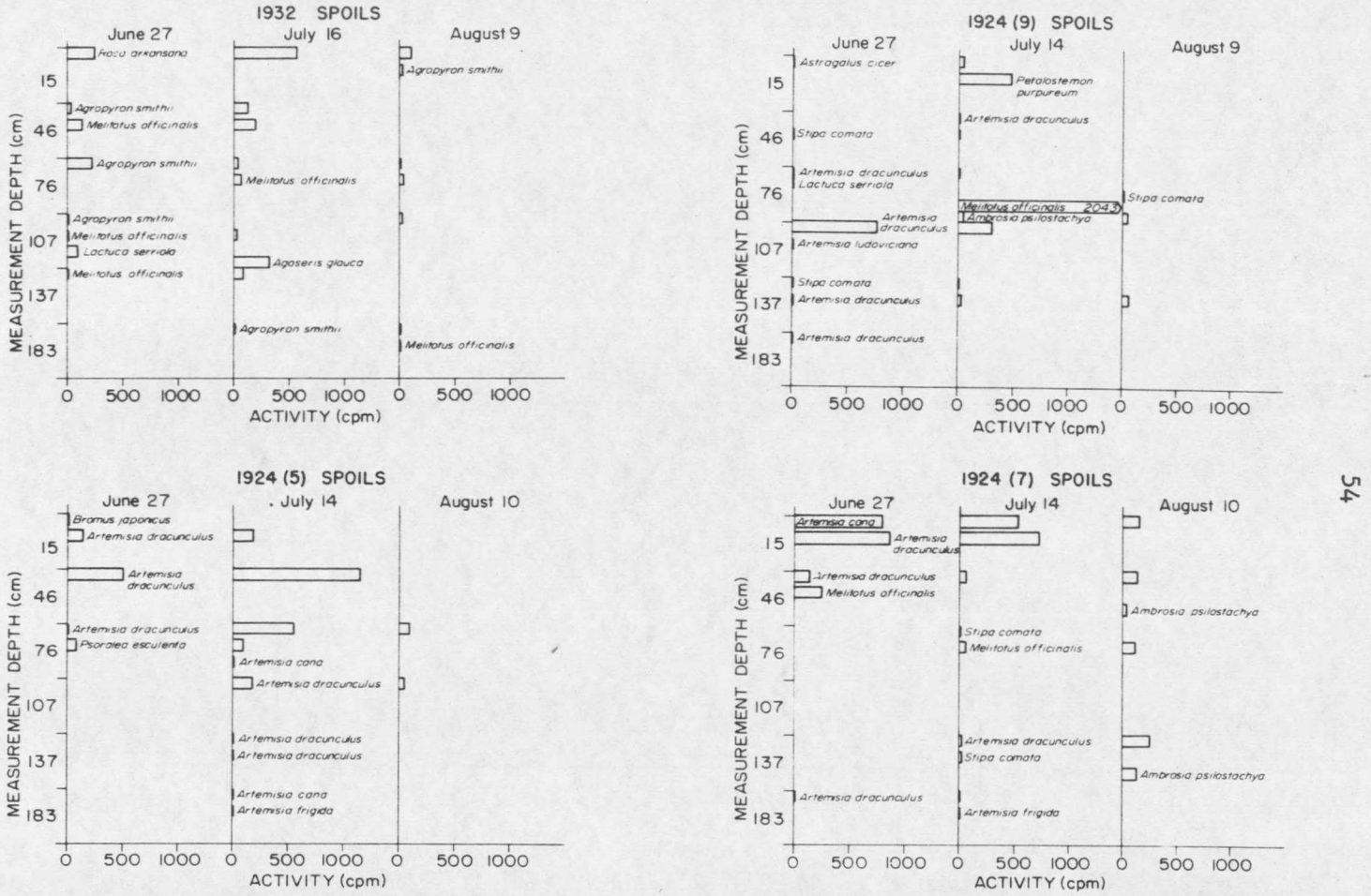


Figure 14. Plant radioactivities measured *in situ* on old spoils at the Colstrip study area in 1976.

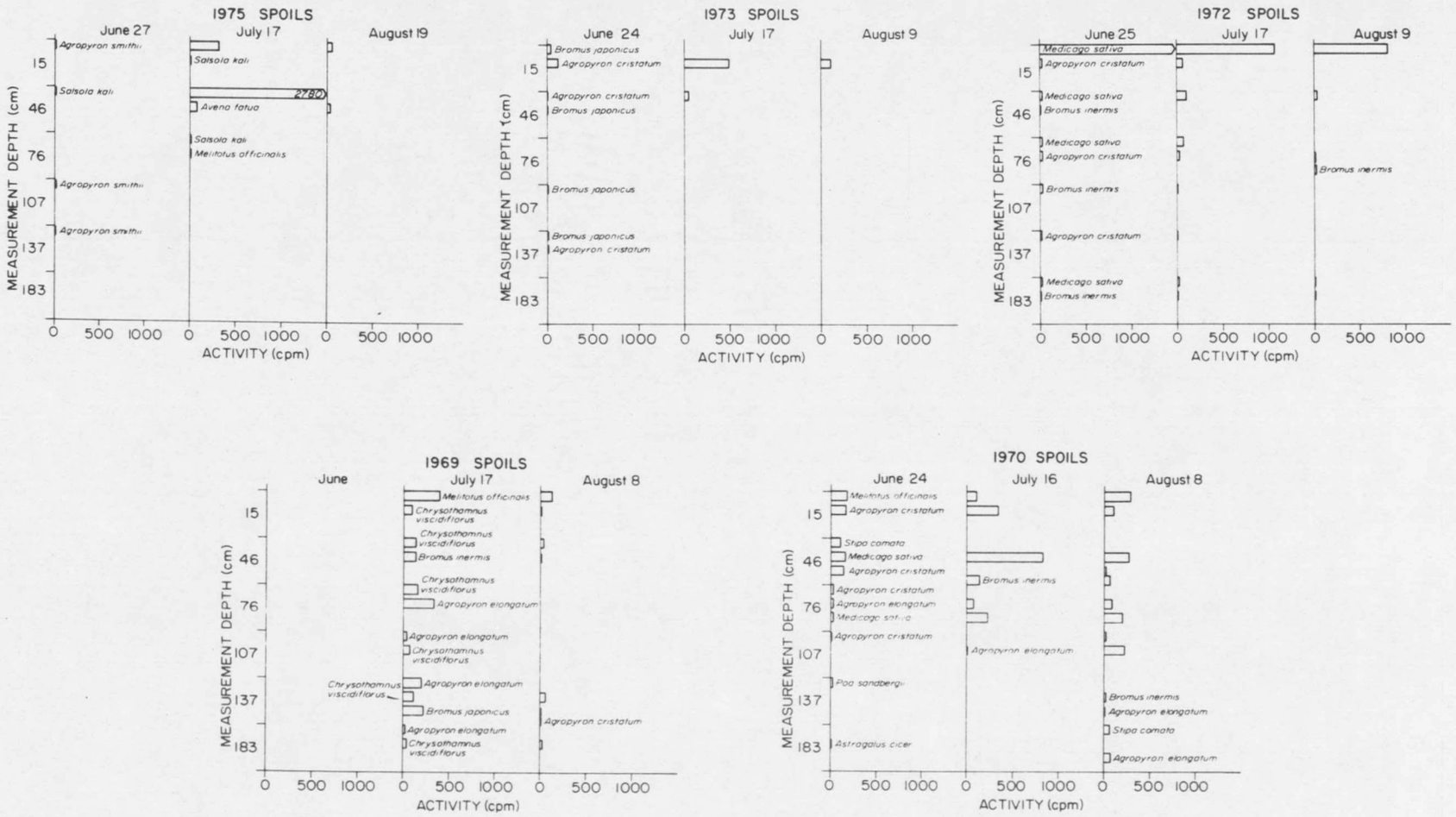


Figure 15. Plant radioactivities measured *in situ* on new spoils at the Colstrip study area in 1976.

greater than from contamination. Consequently, radiation levels in plants obtaining ^{32}P from full dosages usually increased during the first few weeks following injections, whereas radiation levels in contaminated plants usually decreased. By comparing measurements taken during the first few weeks following injections, it was possible to distinguish which plants were contaminated.

Due to problems encountered in the field, measurements were not taken on the following sites: Kobar (all depths); Busby, No. 6 (107, 137, 183 cm); Busby, No. 8 (107 cm); 1924 spoils, No. 7 (107 cm); 1948 spoils (all depths); 1975 spoils (183 cm); and 1969 spoils (all depths in June). Some of the measurements taken in June and August, 1976, were underestimated due to equipment malfunctions, which made for difficult analysis. However, some important findings were made that require consideration. A brief summary of the data collected on each soil or spoil group in 1976 is given below. Afterwards, the various factors that affected plant radioactivities are discussed in detail.

Radioactivity on undisturbed soils. Figure 13 represents radioactivity measurements taken on plants in undisturbed soils during the period from June 24 to August 10, 1976 (Note: these dates and the ones cited later in the thesis are approximately the mid-points during the 3-4 day periods it took to survey every site).

After eliminating those plants which were believed to be contaminated and those whose radioactivities fell below the revised

background count (13 cpm, P = .95), 24 plants were found to have taken up ^{32}P. During the 10-week period, a total of 45 measurements were recorded on these plants, 93 percent on those growing above injections in the upper 76 cm of the soil profiles. The first measurement recorded on a plant which had taken up ^{32}P from soil depths below 76 cm was on July 15 at Busby site No. 8. The total number of radioactive plants measured on each date remained fairly constant. However, radiation intensities generally increased in most plants between June and July, especially in those with active roots at 46 cm.

The perennial bunchgrasses, *Stipa comata*, *Aristida longiseta* and *Poa sandbergii*, accounted for 36 percent of all radioactivity measurements and 39 percent of all radioactivity recorded on undisturbed soils in 1976. Considering that all but one of the plants in this group had taken up ^{32}P from the top 46 cm of the soil profiles, it was apparent that the roots of these bunchgrasses are among the most prevalent in the surface horizons of undisturbed soils.

Considered as a group, including the annual *Bromus tectorum* and the rhizomatous perennial *Calamovilfa longifolia*, grasses accounted for 56 percent of all radioactivity measurements and 48 percent of all radioactivity recorded on plants growing in undisturbed soils, which indicated that the roots of these grasses were among the most prevalent in undisturbed soils in 1976.

The taprooted, leguminous, perennial forbs *Petalostemon*

purpureum, *Psoralea esculenta* and *Melilotus officinalis* accounted for 45 percent of all radioactivity and 18 percent of all radioactivity measurements recorded on undisturbed soils.

The average radioactivity measurement taken on *Petalostemon purpureum* was 4252 cpm. If these measurements were deleted from the computation of the average radioactivity measurement taken on undisturbed soils, it would have dropped from 1169 to 784 cpm.

The remaining 26 percent of the radioactivity measurements represented only 7 percent of the radioactivity recorded on plants growing in undisturbed soils in 1976.

Radioactivity on old spoils. Figure 14 represents radioactivity measurements taken on old spoils in 1976. After eliminating those plants which were contaminated or had radioactivities below the revised background count, 26 radioactive plants remained. A total of 46 measurements were taken on these plants during the test period, 63 percent on those growing above injections in the upper 76 cm of the soil profiles. On July 15, at least one plant was found on each old spoil that showed evidence of having taken up ^{32}P from below 76 cm.

The number of radioactive plants counted on old spoils in July was more than double the number counted in June. This was perhaps due to roots growing into radioactive soil or the roots were already there, but only became active later in the growing season. There was also the possibility that roots absorbed ^{32}P early, but didn't translocate it

to the above-ground portions of the plant until later in the growing season. Substantial increases were also noted for radiation intensities in July, especially in plants with active roots at 76 cm.

The taprooted, half-shrub *Artemisia dracunculus*, domiant on 53-year-old spoils, accounted for 37 percent of all radioactivity recorded on old spoils in 1976. At the beginning of the test period radioactivities were greatest in plants of this species that had active roots at 15 cm. Two weeks later radioactivities were greatest in those with active roots at 46 cm. By the end of the test period, August 10, radioactivities were greatest in those plants with active roots at 137 cm. A few possible reasons have already been given concerning the increase in the number of radioactive plants during the growing season and they can also be related to the increase of radioactivity in plants with active roots at lower injection depths during the latter part of the growing season. This pattern might also be explained by the increase of water use from the lower soil profiles towards the end of the growing season because ^{32}P uptake has been shown to be influenced by soil moisture.

Considered as a group, including *Artemisia cana* and *Rosa arkansana*, half-shrubs accounted for 50 percent of the radioactivity measurements and 59 percent of the radioactivity recorded on old spoils in 1976.

Melilotus officinalis and *Psoralea esculenta*, both taprooted,

leguminous forbs, accounted for most (34 percent) of the remaining radioactivity recorded in old spoils. Although 26 percent of all radioactivity measurements recorded on old spoils were taken on these two forbs, not once was there an indication that they had active roots at 15 dm; their roots were only active at 46, 76 and 107 cm. That was very different from the taprooted *Artemisia dracunculus* which had taken up the majority of its ^{32}P from 15 cm.

Radioactivity on new spoils. Figure 15 represents plant radioactivities on new spoils during the period from June 24 to August 10, 1976. After making the usual eliminations, there were found to be 21 radioactive plants growing on these spoils. During the 10-week test period a total of 44 measurements were recorded on these radioactive plants, 89 percent on those growing above injections in the upper 76 cm profiles. The 1970 spoil was the only new spoil that showed evidence of its plants taking up ^{32}P from below 76 cm in 1976.

Slight increases in the number of radioactive plants measured on new spoils were recorded in July and August. The majority of the ^{32}P taken by plants in June was found in plants with active roots at 15 cm. By mid-July, the radiation intensity of these plants had not increased, but in plants with active roots at 46 cm it had increased substantially. (Note: data collected on the 1969 spoil was unusable because it was impossible to identify which of the plants were contaminated without June's measurements.)

The taprooted forbs *Salsola kali*, *Melilotus officinalis* (legume) and *Medicago sativa* (legume) accounted for 41 percent of all radioactivity measurements recorded on new spoils in 1976. Not only were these forbs the dominant plant type having active roots in new spoils in 1976, but they appeared to have greater affinities for ^{32}P than the other plants on new spoils as evidenced by the fact that they accounted for 76 percent of the radioactivity recorded on new spoils. All of the ^{32}P taken up by these two forbs was from the upper 76 cm of the soil profiles.

The perennial bunchgrasses *Agropyron elongatum* and *Stipa comata* had also accounted for 41 percent of all radioactivity measurements taken on new spoils in 1976, but they only accounted for 17 percent of all radioactivity.

The remaining 18 percent of the radioactivity measurements taken on new spoils accounted for only 6 percent of the radioactivity. These measurements were recorded on the grasses *Agropyron smithii*, *Bromus inermis* and *Avena fatua*.

Nearly half of the radioactive plants measured on new spoils in 1976 grew on the oldest new spoil, 1970. The smallest number of radioactive plants recorded on new spoils grew on the youngest spoil, 1975.

In summarizing the foregoing discussion, it was found that the number of radioactive plants and measurements recorded on undisturbed soils, old spoils and new spoils were nearly identical, implying that

the quantity of roots in these groups was not significantly different. This claim was backed by the results in the root biomass section which showed that the quantity of roots in the upper 100 cm profiles was not significantly different between groups. However, the percentage of radioactivity measurements taken on plants with active roots below 76 cm was approximately 30 percent greater on old spoils than on new spoils and undisturbed soils. Apparently, the half-shrub, *Artemisia dracunculus*, which accounted for half of the radioactivity measurements recorded on plants in old spoils with active roots below 76 cm, had a deeper rooting distribution than the grasses and forbs that dominated new spoils and undisturbed soils.

Average plant radioactivities for groups, dates and depths are presented in Table 11 (Note: Chinook was substituted for Kobar in the undisturbed soil group). Radioactivities were significantly different at the .95 level for groups (P = .00), dates (P = .00) and depths (P = .00; Table 12). Two-way interactions for group and depth (P = .005), and date and depth (P = .032) were significant at the .95 level, indicating that radioactivities of plants with active roots at a specific depth were dependent on the soil group and the measurement date.

A difference greater than 93 cpm between average plant radioactivities was significant at the .95 level (L.S.D.). Table 13 lists those groups, dates and injections depths from where ^{32}P was taken up which had similar radioactivities. Plant radioactivities were

Table 11. Average plant radioactivity (cpm) at Colstrip study area in 1976.

Depth (cm)	Native Soils			Old Spoils			New Spoils		
	6/26	7/15	8/7	6/26	7/15	8/7	6/26	7/15	8/7
15	1984	1843	165	515	422	87	469	401	270
46	1051	2744	625	197	379	82	100	662	91
76	717	935	35	80	471	70	31	122	105
107					173	35			115
137		150	135		30	17			10
183		65							60

Table 12. ANOV for average plant radioactivity at Colstrip study area in 1976.

Source	D.F.	S.S.	M.S.	F-Value	P-Value
Group	2	2,336,349	1,168,174	15.47	.000
Date	3	1,193,790	596,895	7.90	.003
Depth	5	4,554,351	910,870	12.06	.000
Group X Date	4	840,044	210,011	2.78	.055
Group X Depth	10	2,926,526	292,652	3.88	.005
Date X Depth	10	1,981,030	198,103	2.62	.032
Error	20	1,510,317	75,516		
Total	53	15,343,410	289,479		

significantly greater on undisturbed soils than on minespoils, old and new, indicating that some factor or combination of factors occurring in undisturbed soils were more favorable than in minespoils. This factor(s) could have been related in some way to soil properties or to plant properties. These possibilities are explored in detail in the following section. The same type of explanations are given in the

Table 13. Plant radioactivities at Colstrip study area in 1976 (LSD).

		Radioactivity (cpm)
Group	Native Soil	1169[a]
	Old Spoil	246[b]
	New Spoil	271[b]
Date	June 26	644[a]
	July 15	867[b]
	August 7	162[c]
Depth (cm)	15	659[a]
	46	882[b]
	76	355[c]
	107	177[d]
	137	58[e]
	183	60[e]

following section pertaining to differences in plant radioactivities for measurement dates and rooting depths.

Factors affecting plant radioactivity. The effect of groups on radioactivities was mainly due to differences in the phosphate fixing capabilities of undisturbed soils and minespoils, which resulted in larger quantities of plant available ^{32}P in undisturbed soils than in minespoils. Although ^{32}P availability was not measured directly, it was inferred from the following information.

Nye and Foster (1958) provided evidence showing that ^{32}P availability was directly proportional to the "labile phosphate pool" in the soil solution. Assuming that the radioactivity of plant tops was directly proportional to the amount of plant available ^{32}P, the

difference between dates of plant radioactivity divided by water use was an estimation of the concentration of ^{32}P in the soil solution. Of course, the concentration of ^{32}P in the soil solution was not the same as the concentration of ^{31}P in the soil solution. Both of these phosphorus forms in the solution phase were in equilibrium with the solid phase in the soil. This equilibrium was related to the phosphate fixing capacity of the soil.

Radioactivity changes were calculated using the following equation:

$$(1) \quad A = \frac{FC_{t_c}(-\lambda)}{(e^{-\lambda t_2} - e^{-\lambda t_1})}$$

$$(2) \quad FC_{t_c} = FC_{t_2} - (FC_{t_1})e^{-\lambda t_c}$$

where $t_c = t_2 - t_1$; A is the actual plant uptake of ^{32}P by the plant between measurement dates; FC_{t_c} is the corrected field count measured on date 2 obtained from equation (2); FC_{t_2} and FC_{t_1} are the corrected field counts measured on dates 2 and 1, respectively; λ is to 0.693/half-life of ^{32}P (14.3 days). Derivation of these equations are presented in Appendix C.

Changes in total plant radioactivities between June 26 and July

15, 1976 were calculated for plants with active roots in upper 76 cm profiles. Changes in soil water contents between June 29 and July 11, 1976 were calculated for upper 75 cm profiles. Although these two sets of dates did not coincide, they were considered to be close enough to estimate the concentration of ^{32}P in the soil solution (Table 14).

Table 14. Radioactive phosphorus concentration in soil solutions at Colstrip study area in 1976.

	Native soils	Old spoils	New spoils
A (cpm)	4763	1003	1021
Water use (cm)	14.44	20.64	16.40
$[^{32}P]'$ (cpm cm^{-1})	330	49	69

The concentration of ^{32}P in the soil solution of undisturbed soils, old spoils and new spoils had a high correlation (r = .99) with average plant radioactivities (1169, 246, and 271 cpm, respectively). The correlation was significant at the .99 level, indicating that the assumption made at the beginning of this argument was probably correct (Table 15).

Table 15. ANOV for $[^{32}P]'$ regression on average plant radioactivity at Colstrip study area.

Source	D.F.	S.S.	M.S.	F-Value	P-Value
Regression	1	50,303	50,303	3373	.013
Error	1	14.914	14.914		
Total	2	50,318			

Of course, $[^{32}P]'$ was not the actual concentration of ^{32}P in the soil solution. However, this was not to say that $[^{32}P]'$ was not directly related to the actual concentrations of ^{32}P in the soil solution or that $[^{32}P]'$ was not determined by soil properties. $[^{32}P]'$ had a high negative correlation with soil pH (1:1 H_2O; Appendix E) at 15, 46 and 76 cm injection depths ($r = -.99$). The average soil pH for undisturbed soils, old spoils and new spoils was 7.9, 8.4 and 8.4, respectively. The correlation between $[^{32}P]'$ and soil pH was significant at the .95 level ($P = .026$), meaning that the higher the soil pH, the lower the $[^{32}P]'$ (Table 16). This conclusion was supported by the early work of Truog (1946) who showed that phosphorus availability gradually decreased as soil pH increased from 7.5 to 8.5 due to the presence of free calcium carbonate.

Table 16. ANOV for $[^{32}P]'$ regression on soil pH at Colstrip study area.

Source	D.F.	S.S.	M.S.	F-Value	P-Value
Regression	1	50,233	50,233	594	.026
Error	1	84.50	84.50		
Total	2	50,318			

The same type of relationship cited above for $[^{32}P]'$ and soil pH was found for average soil group radioactivities and soil pH; as soil pH increased, average plant radioactivities decreased. This correlation ($r = -.99$) was also significant at the .95 level ($P = .016$; Table 17).

Table 17. ANOV for soil pH regression on average plant radioactivity at Colstrip study area.

Source	D.F.	S.S.	M.S.	F-Value	P-Value
Regression	1	552,673	552,673	1769	.016
Error	1	312.50	312.50		
Total	2	552,986			

The preceding argument asserted that plant radioactivities were on the whole a function of ^{32}P availability and that ^{32}P availability was influenced by soil pH. However, this argument does not explain the effects of rooting depth and time on plant radioactivities.

The effect of time on plant radioactivity was probably partially explained by developmental changes in the plants during the growing season. For instance, phosphorus was probably concentrated in the plant seed head after flowering and later returned to the base of the plant before desiccation in August. Unfortunately, different plant parts were not monitored during the growing season for radioactivity changes and, therefore, no direct evidence was collected to support this explanation.

The effect of rooting depth on plant radioactivities was also probably related to developmental changes in plants during the growing season, especially in annuals. During the early part of the growing season plant roots would be most active near the soil surface because of the adverse effect of colder temperatures at lower depths on root growth. As the subsoil becomes warmer, roots may grow deeper into the soil profile.

Factors not affecting plant radioactivity. Lipps et al. (1956) reported that phosphorus uptake was influenced by soil moisture, but that it didn't necessarily parallel moisture uptake. Total and average radioactivity changes over time (A) in plants with active roots in the upper 76 cm of the soil profiles were poorly correlated (r = .01 and .02, respectively) with soil water use during the period from June 26 to July 15, 1976. Any correlations between total or average A and water use were not significant at the .95 level (P = .97 and .96, respectively), signifying that phosphorus uptake did not parallel water uptake (Table 18).

Table 18. ANOV for total and average A regression on water use (volume %) at Colstrip study area.

Source	D.F.	S.S.	M.S.	F-Value	P-Value
Total A:					
Regression	1	1,212	1,212	.0012	.972
Error	7	.6796E07	970,850		
Total	8	.6797E07			
Average A:					
Regression	1	42.46	42.46	.0025	.960
Error	7	117,245	16,749		
Total	8	117,288			

There were two other possible explanations for plant radioactivity differences between undisturbed soils and minespoils, old and new. One was that plants on undisturbed soils had greater physiological

needs for phosphorus than plant species on old and new spoils. The other explanation was that phosphorus uptake was dependent on root biomass and that undisturbed soils contained more roots than old and new spoils, even if not statistically significant.

Radioactivity differences between individual plant species were not thoroughly examined because of insufficient data. However, radioactivity differences between plant types were examined and found to be greater within plant types across sites, depending on where they were growing, than between plant types (Table 19). Although radioactivities appeared to be affected by plant type, it was inconsequential compared to soil effects.

Table 19. Radioactivity arranged by plant type at Colstrip study area in 1976.

Plant type	Average radioactivity (cpm)		
	Native Soils	Old Spoils	New Spoils
Perennial bunchgrasses	1295	25	112
Grasses	1003	43	104
Taprooted forbs	2991	317	368
Forbs	1778	251	502
Taprooted half-shrubs	--	260	--
Half-shrubs	--	163	--

In a few instances average plant radioactivities had high positive correlations with root biomass, but none were significant at the .95 level (Table 20). However, it appeared that plant radioactivities

within a particular soil group were partially dependent on root biomass at certain times during the growing season.

Table 20. Partial correlations (r) of average plant radioactivities and root biomass at Colstrip study area.

	Native Soil Date			Old Spoil Date			New Spoil Date		
	6/26	7/15	8/7	6/26	7/15	8/7	6/26	7/15	8/7
r	.88	.25	-.21	.94	.67	.62	.98	.13	.96
P-value	.32	.83	.86	.22	.52	.56	.13	.91	.20

Comparisons between groups showed that average plant radioactivity had a positive correlation (.73) with root biomass (Table 21). This correlation was not significant at the .95 level (P = .48), indicating that plant radioactivity was not very dependent on root biomass.

Table 21. ANOV for average plant radioactivity regression on root biomass at Colstrip study area.

Source	D.F.	S.S.	M.S.	F-Value	P-Value
Group	1	296,184	296,184	1.15	.478
Error	1	256,802	256,802		
Total	2	552,986			

In situ radioactivities - 1977. Objectives of the ^{32}P study the second year were (1) estimation of plant radioactivity variability within an undisturbed soil, an old spoil and a new spoil; (2) examination

of site effect on radioactivities in plant species common to all sites; and (3) verification of results from first year.

Figures 16-31 represent *in situ* radioactivity measurements taken on undisturbed soils, old spoils and new spoils during the period from April 16 to July 31, 1977. Abbreviations were used in place of complete plant names to make the figures more presentable. A key to the names and abbreviations are given in Table 22. Some of the abbreviations in the figures are followed by numbers which identify plants of the same species growing above a particular ^{32}P injection.

Radioactivity on undisturbed soils. Figures 16-18 represent radioactivity measurements taken on three replications of ^{32}P injections in the Chinook undisturbed soil. This soil was chosen to receive ^{32}P replications because, of the eleven sites available for investigation, it had the largest quantity of root biomass and, therefore, represented optimum rooting conditions.

A total of 114 measurements were taken on 27 radioactive plants in 1977, 91 percent on those growing above injections in the upper 76 cm of the soil profile. Radioactivity was first recorded on a plant which had taken up ^{32}P from soil depths below 76 cm on May 13, which was nearly 5 weeks after injection. The total number of radioactive plants recorded at one time gradually increased to 24 on June 15 and then slowly decreased, suggesting that the mid-point of the 1977 growing season occurred during the month of June.

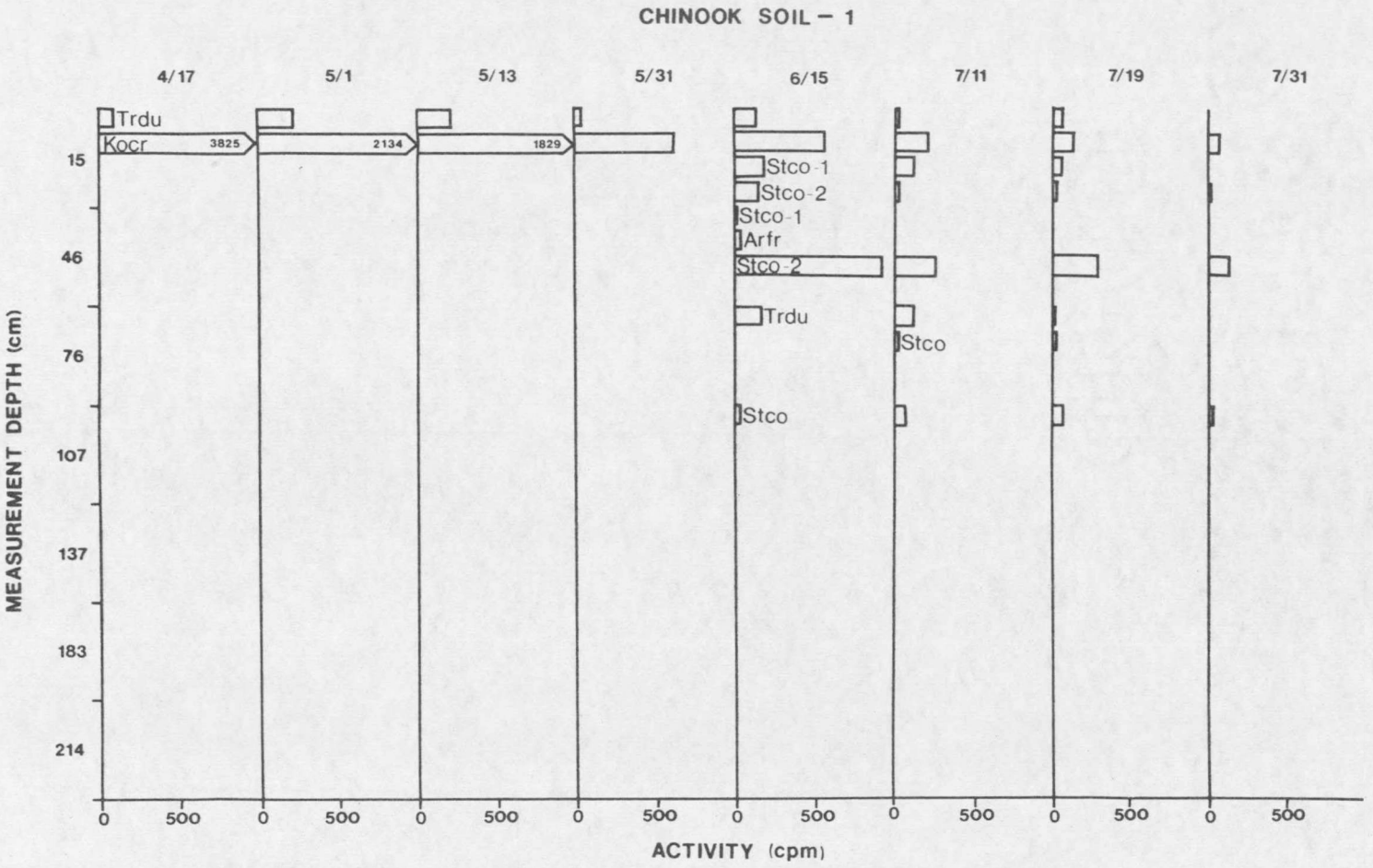


Figure 16. *In situ* plant radioactivities on Chinook undisturbed soil at Colstrip study area - replication 1, 1977.

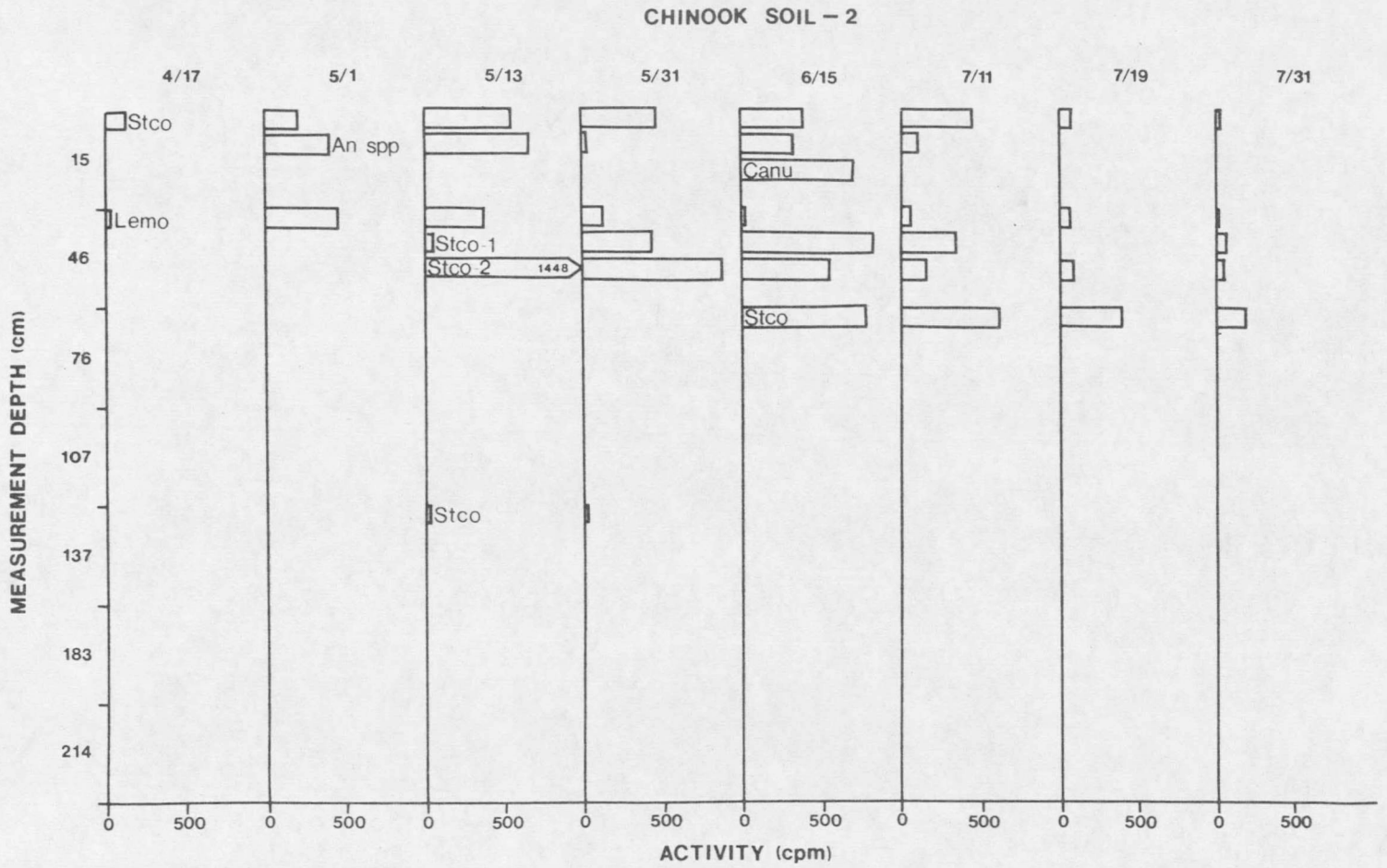


Figure 17. *In situ* plant radioactivities on Chinook undisturbed soil at Colstrip study area - replication 2, 1977.

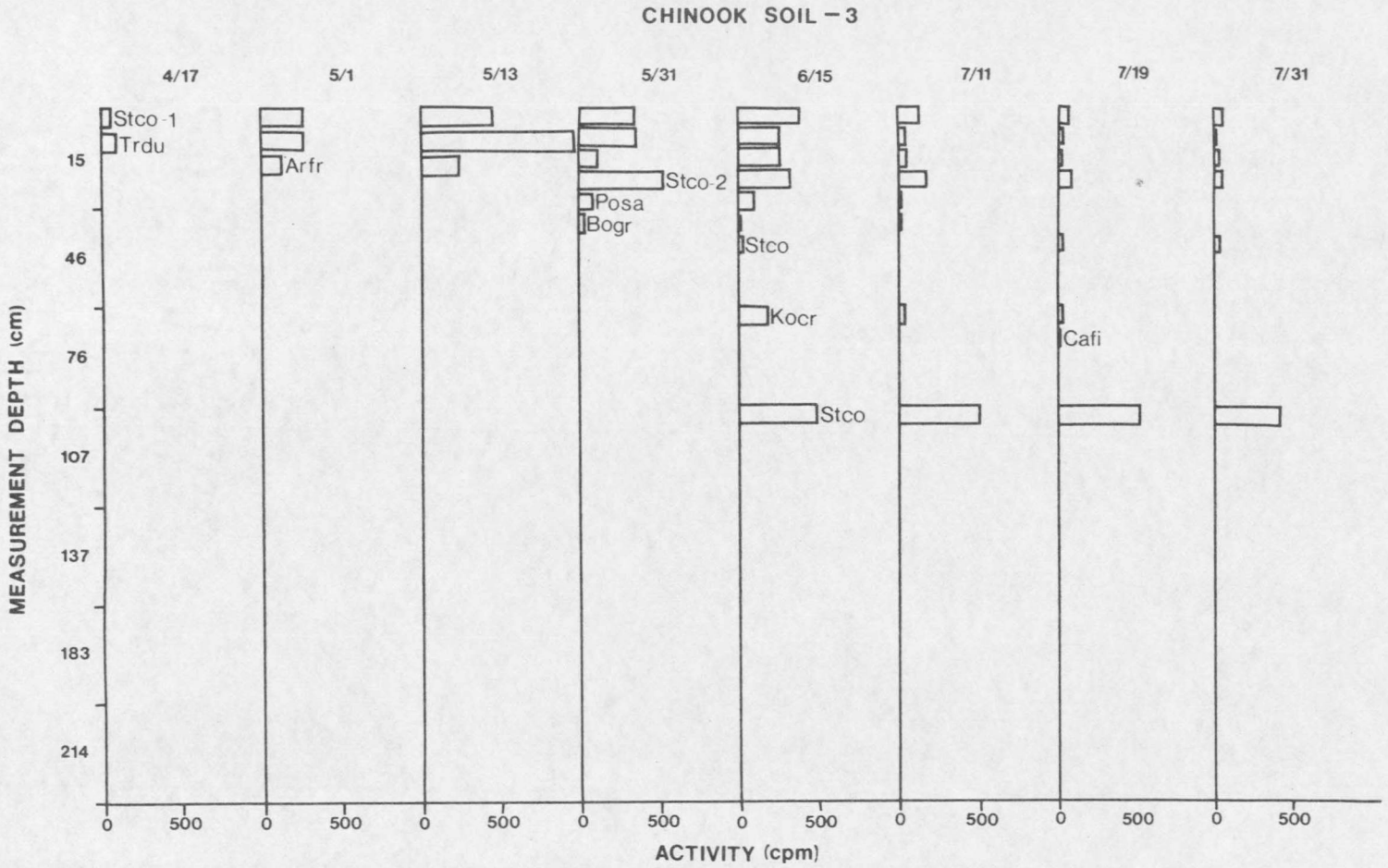


Figure 18. *In situ* plant radioactivities on Chinook undisturbed soil at Colstrip study area - replication 3, 1977.

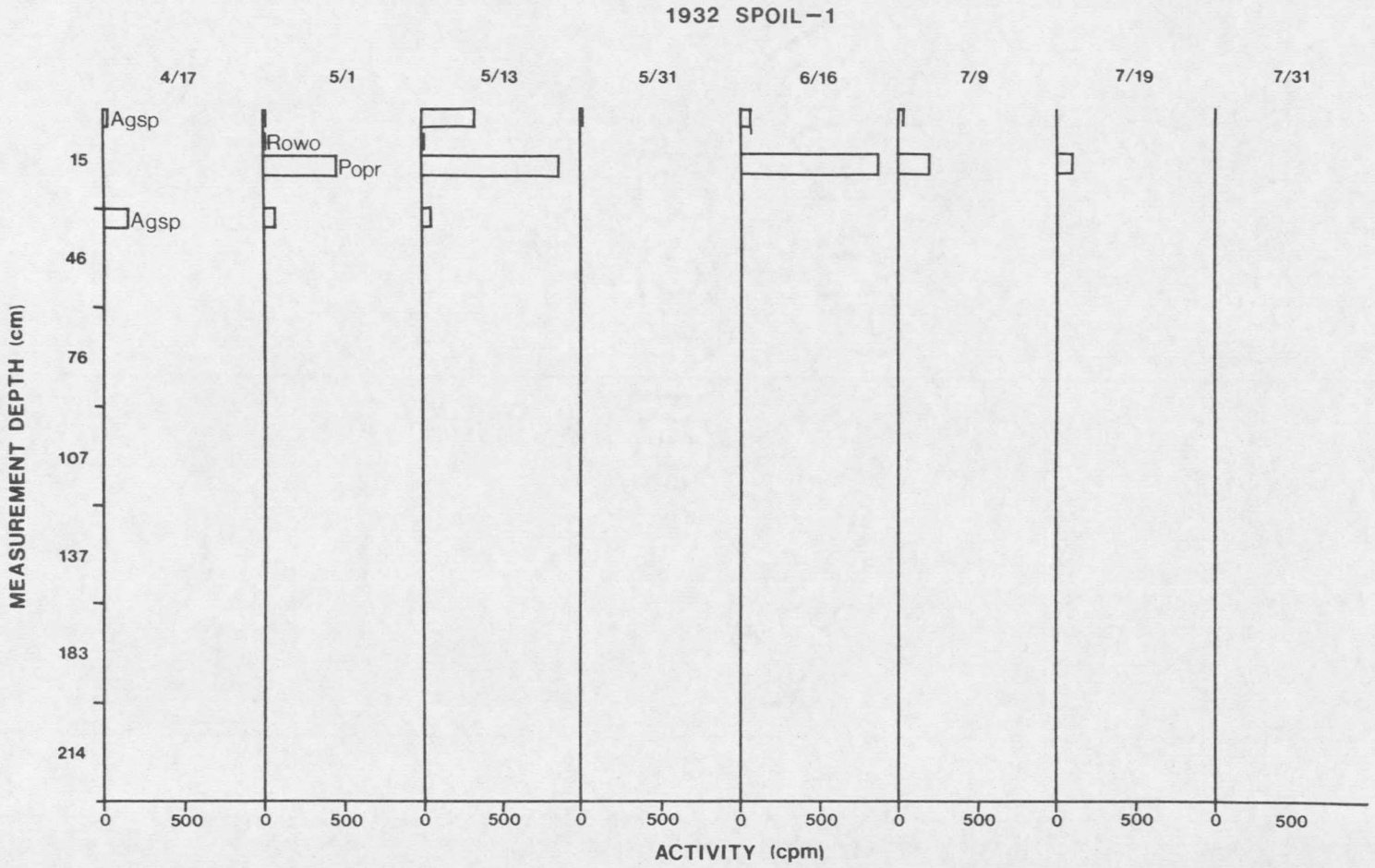


Figure 19. *In situ* plant radioactivities on 1932 spoil at Colstrip study area - replication 1, 1977.

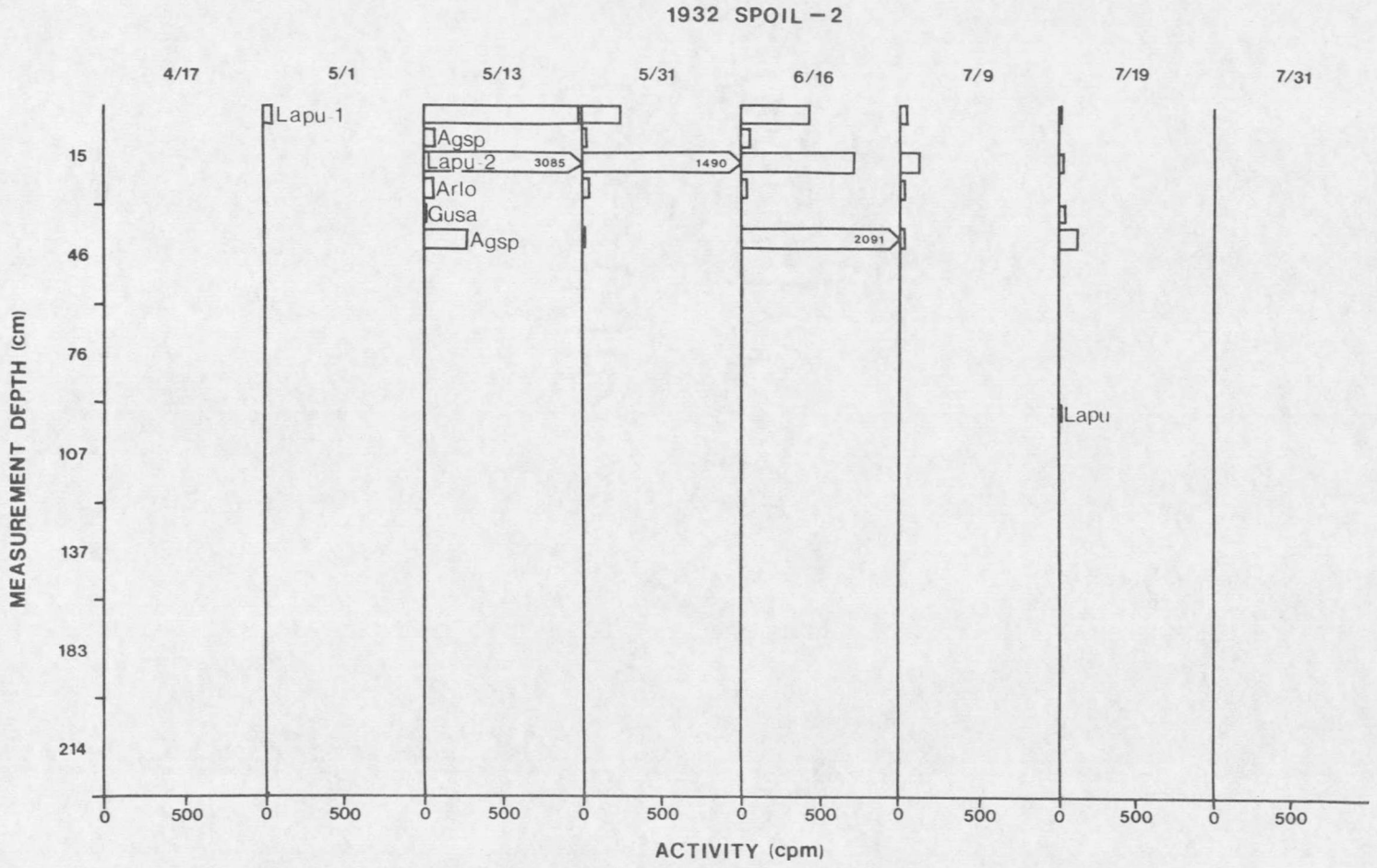


Figure 20. *In situ* plant radioactivities on 1932 spoil at Colstrip study area - replication 2, 1977.

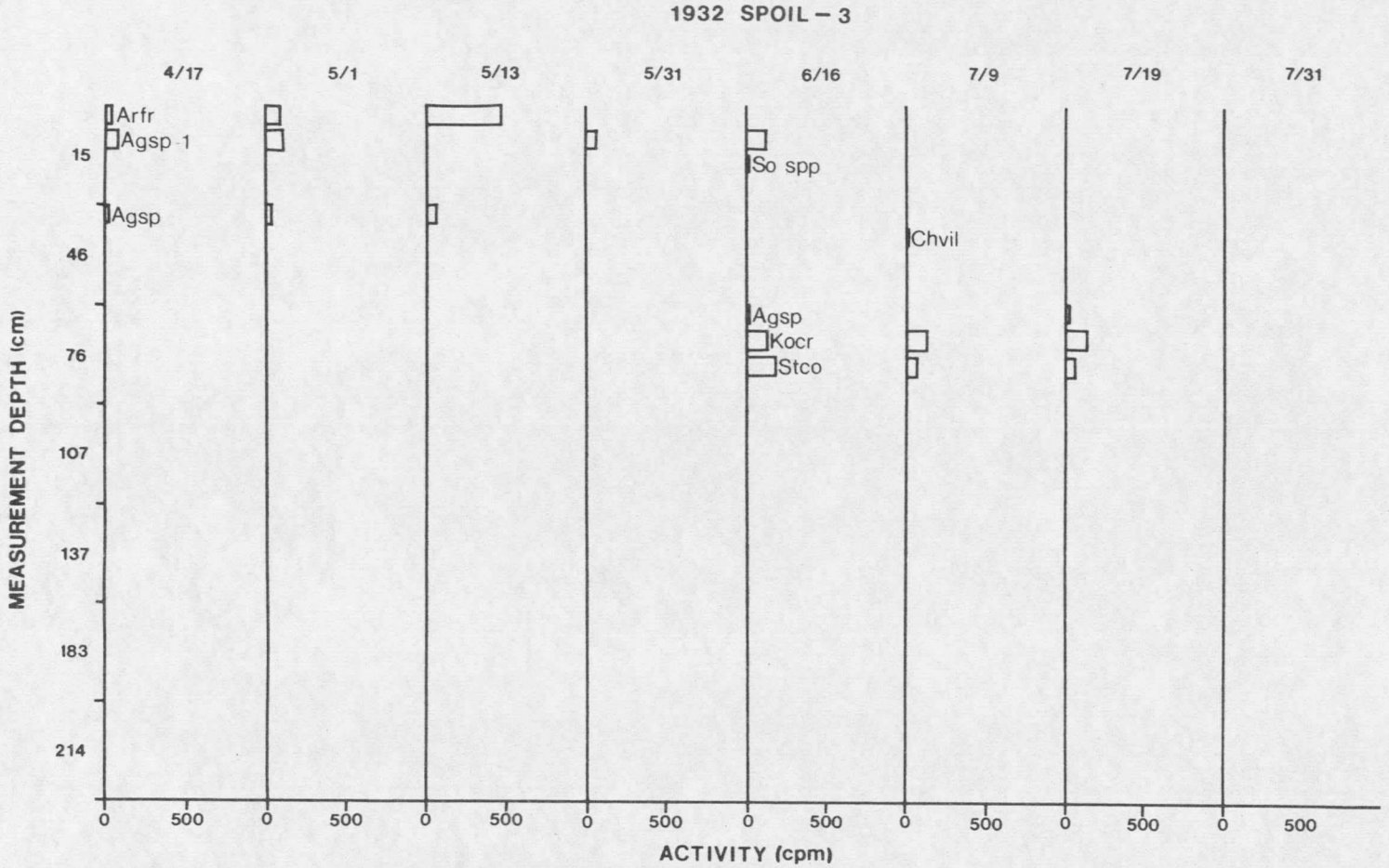


Figure 21. *In situ* plant radioactivities on 1932 spoil at Colstrip study area - replication 3, 1977.

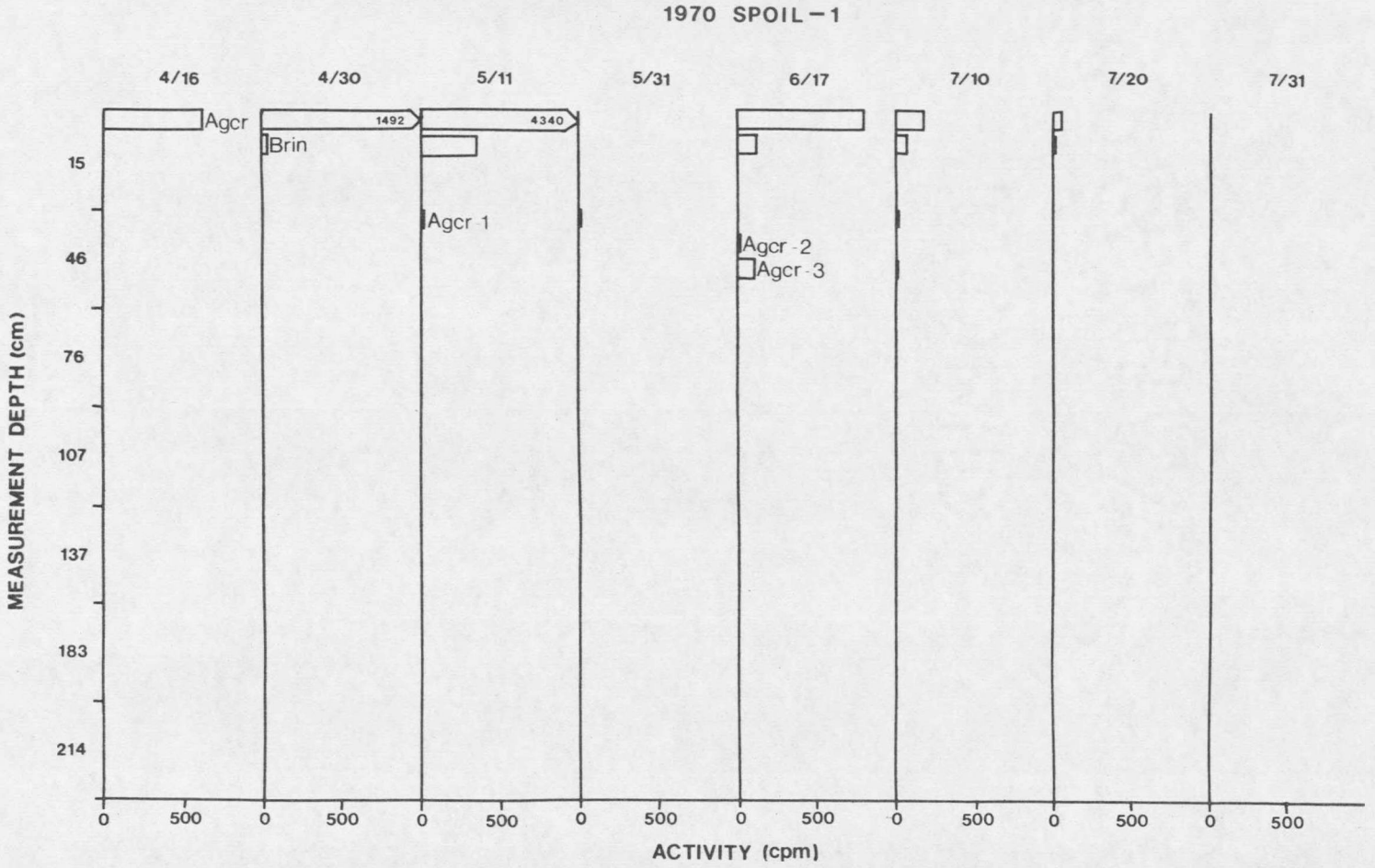


Figure 22. *In situ* plant radioactivities on 1970 spoil at Colstrip study area - replication 1, 1977.

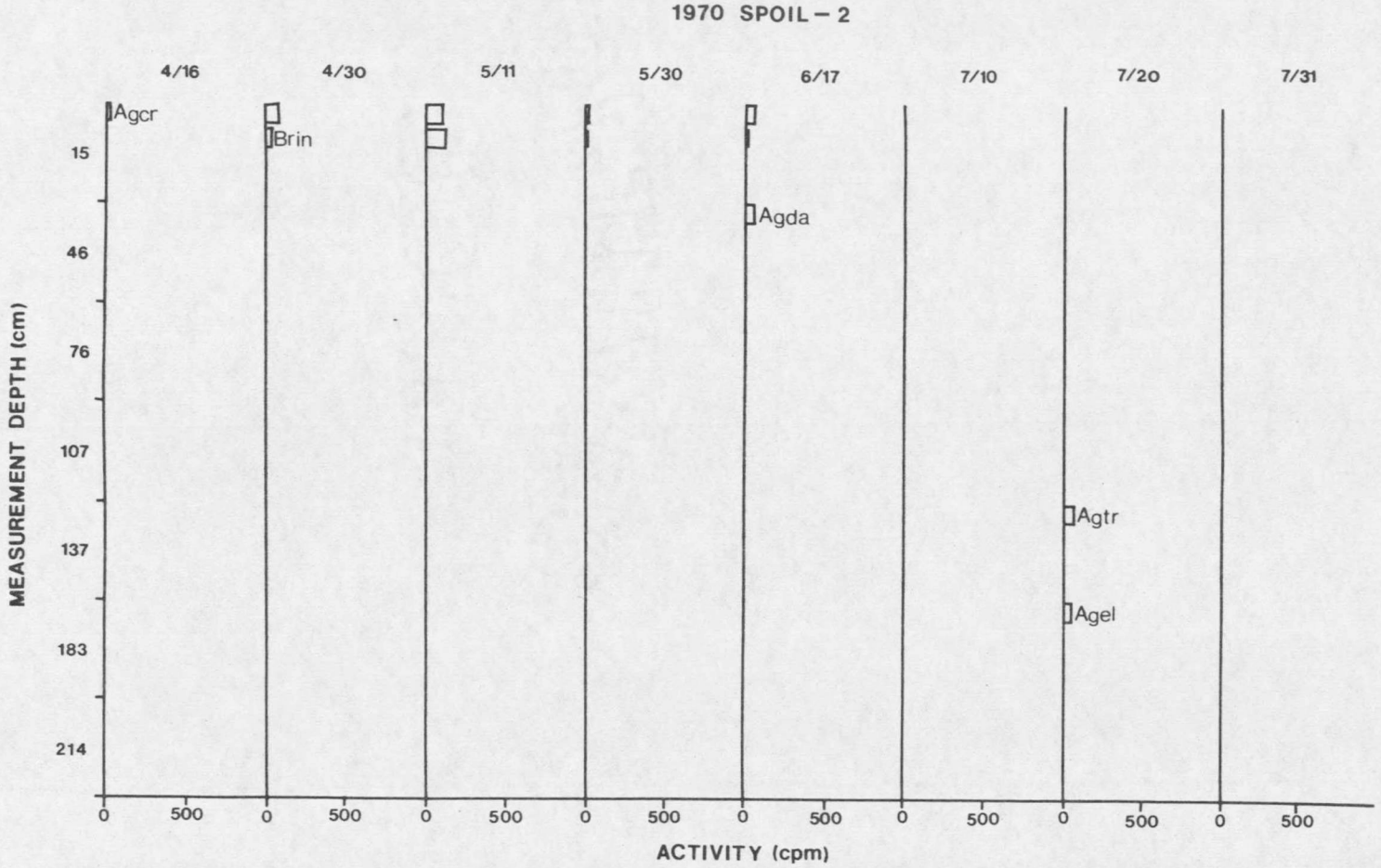


Figure 23. *In situ* plant radioactivities on 1970 spoil at Colstrip study area - replication 2, 1977.

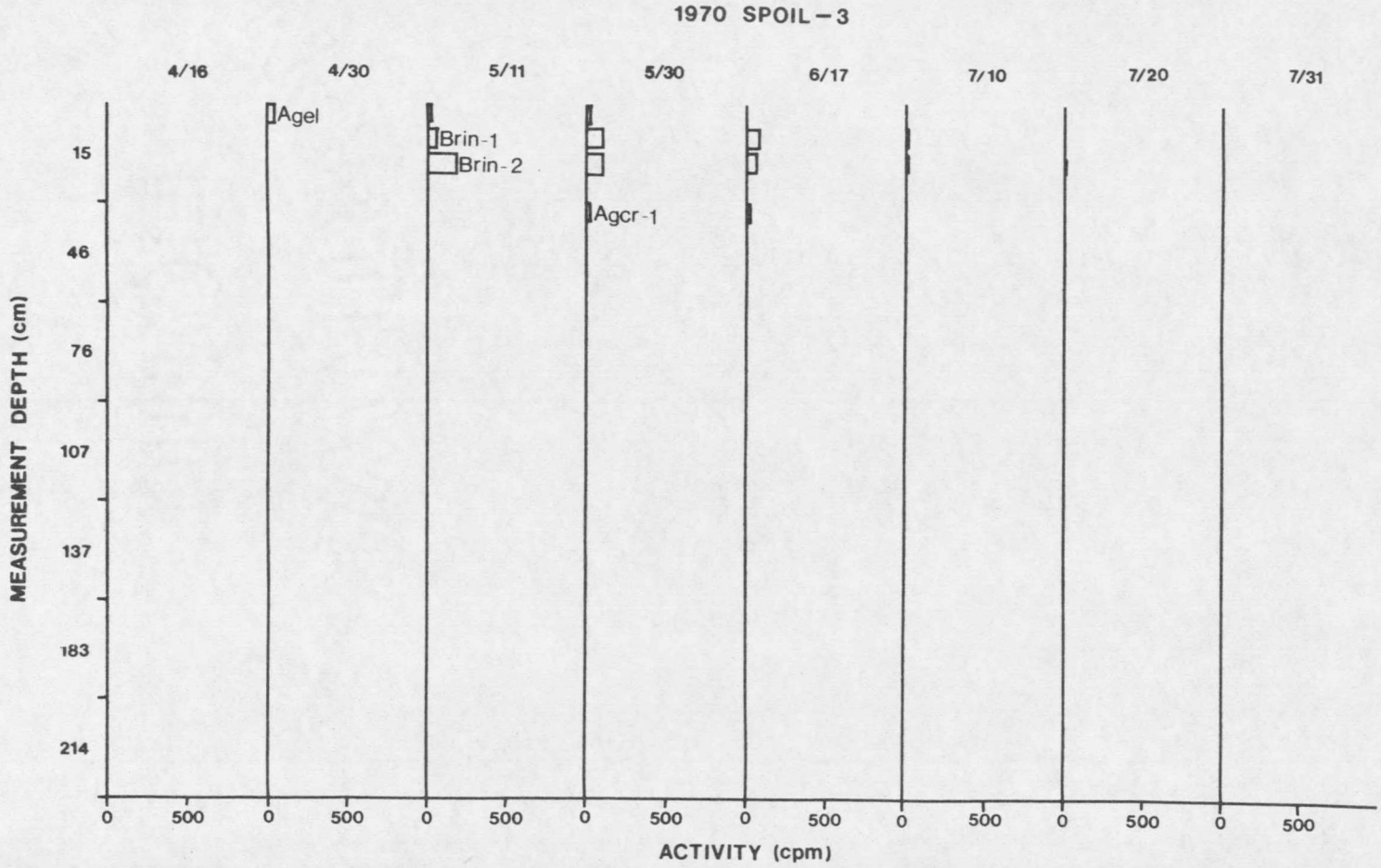


Figure 24. *In situ* plant radioactivities on 1970 spoil at Colstrip study area - replication 3, 1977.

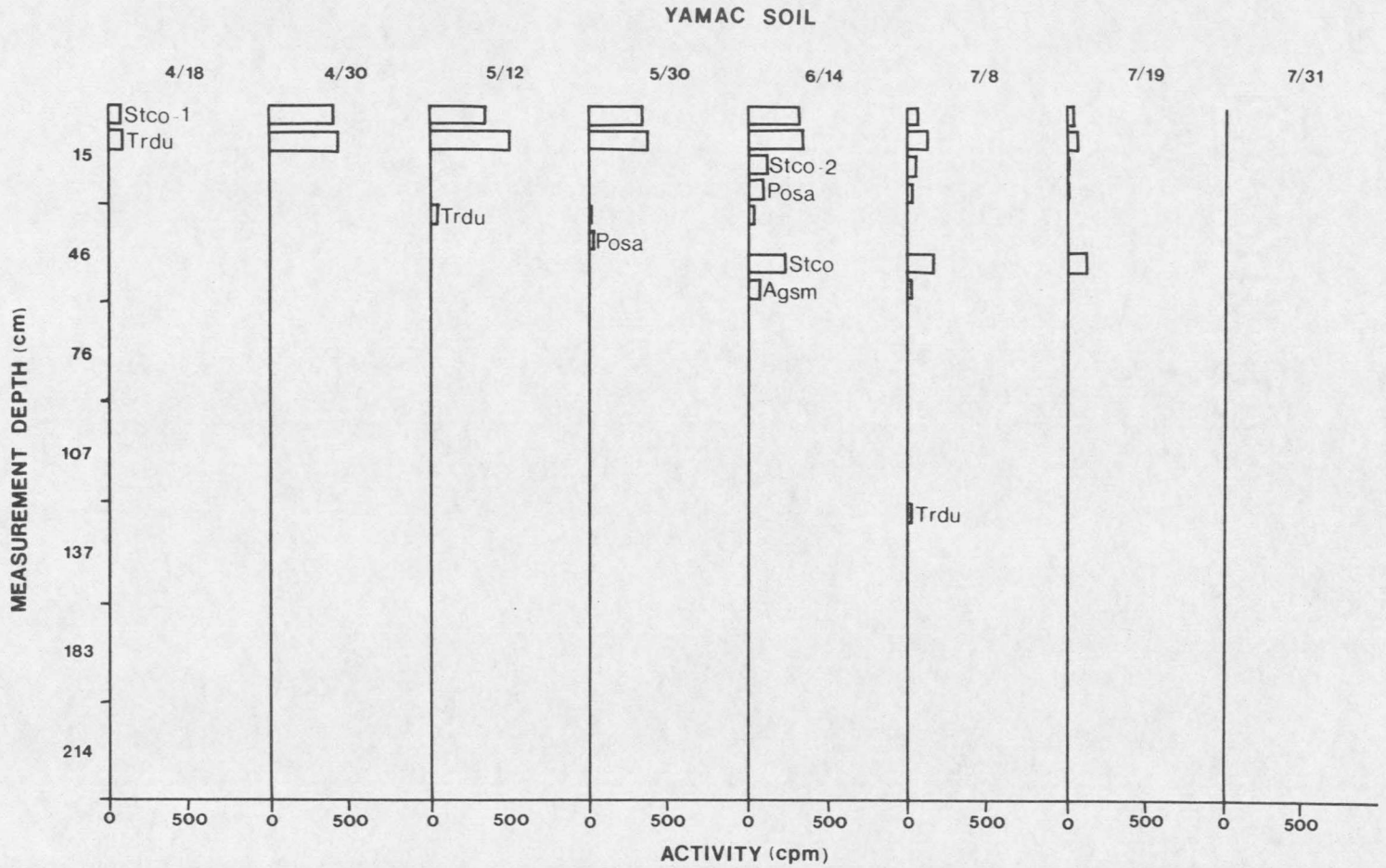


Figure 25. *In situ* plant radioactivities on Yamac undisturbed soil at Colstrip study area in 1977.

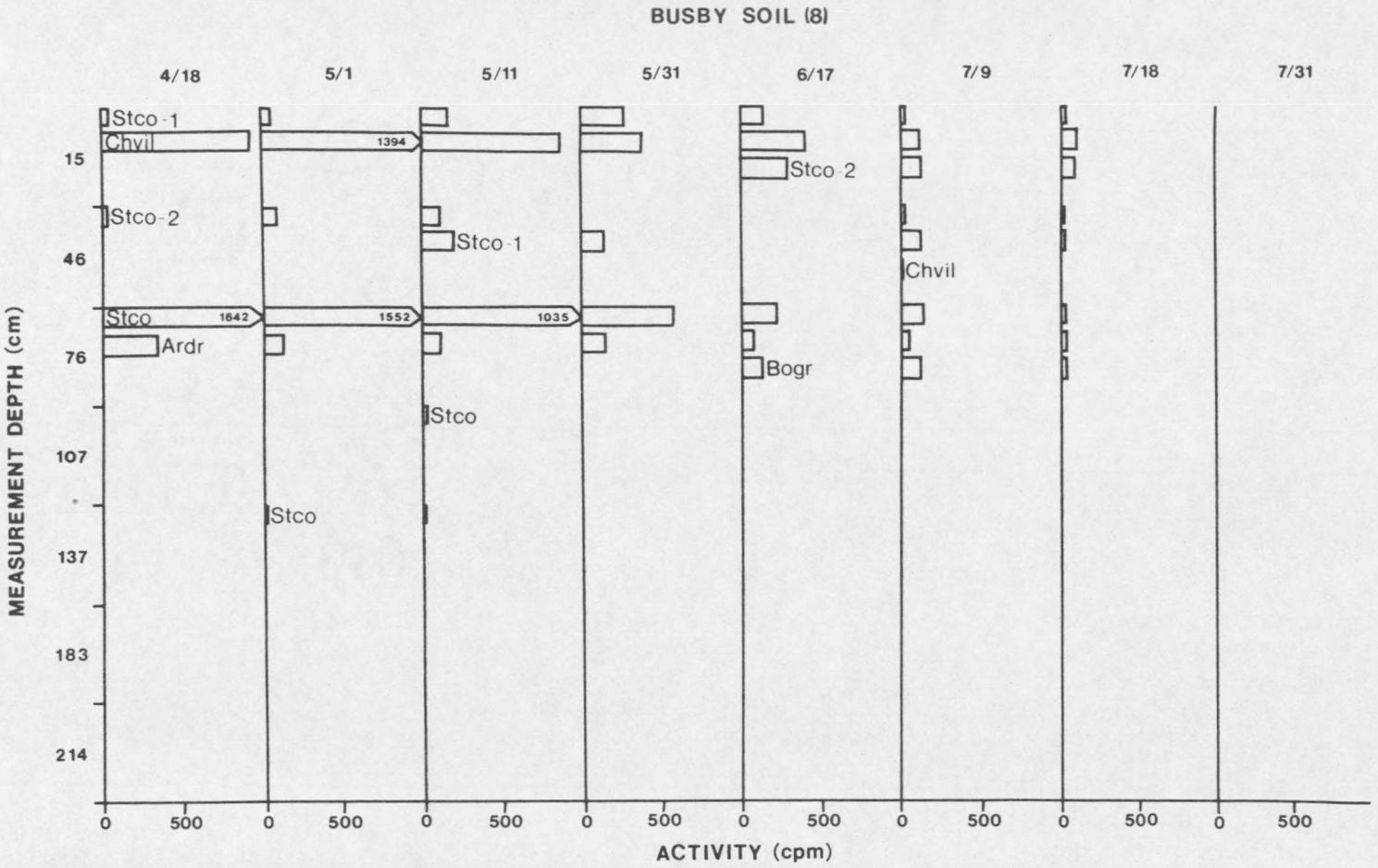


Figure 26. *In situ* plant radioactivities on Busby (8) undisturbed soil at Colstrip study area in 1977.

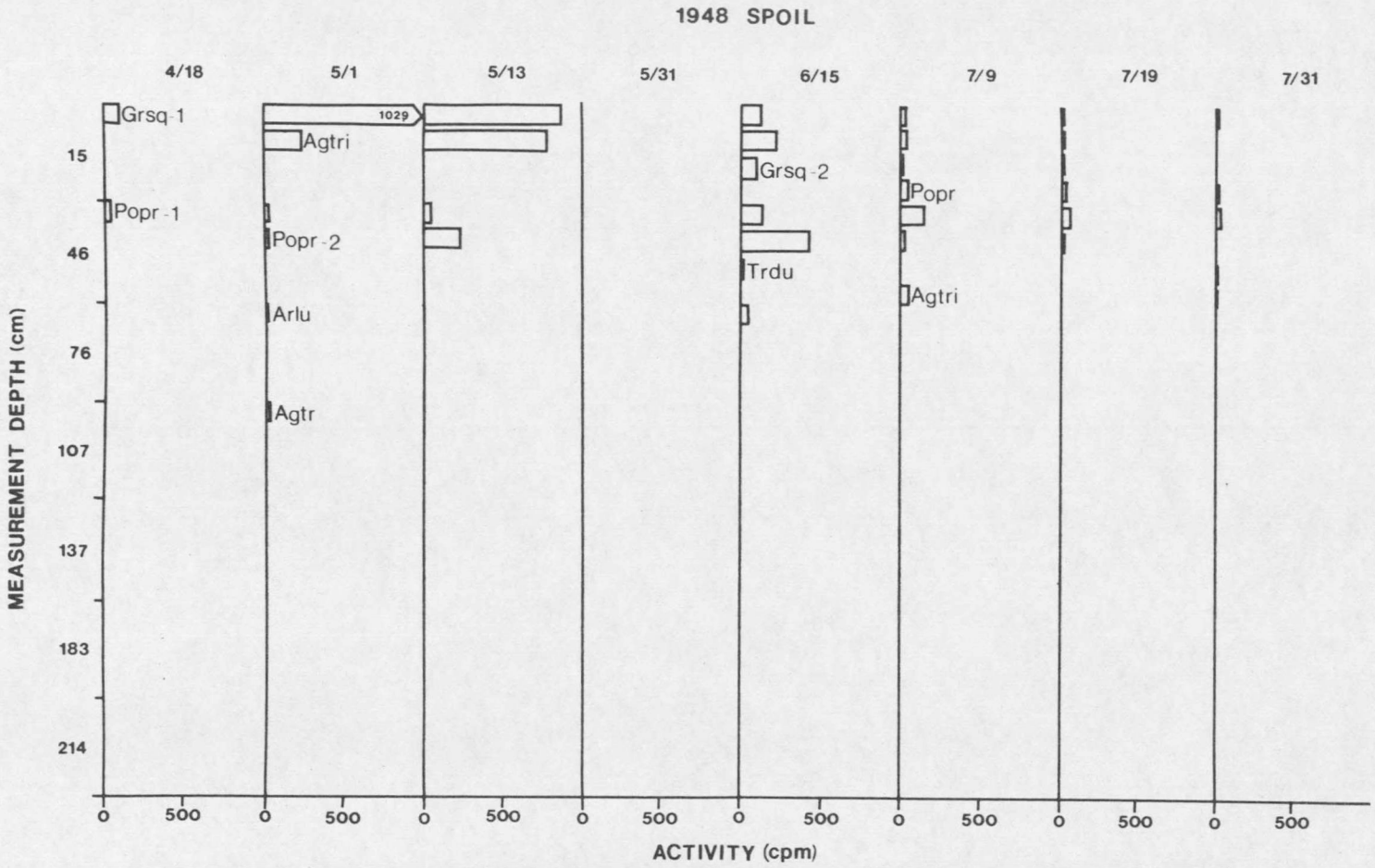


Figure 27. *In situ* plant radioactivities on 1948 spoil at Colstrip study area in 1977.

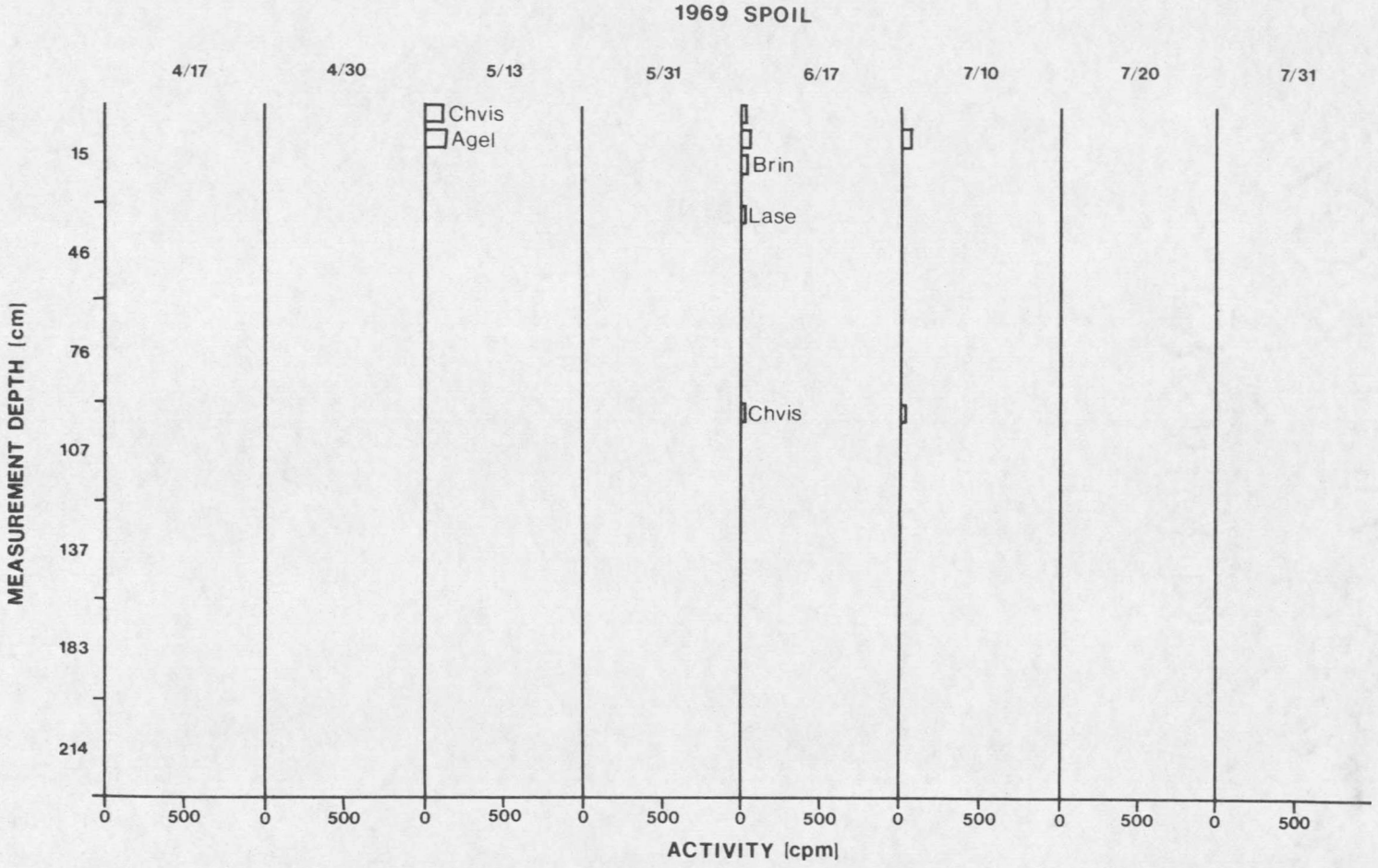


Figure 28. *In situ* plant radioactivities on 1969 spoil at Colstrip study area in 1977.

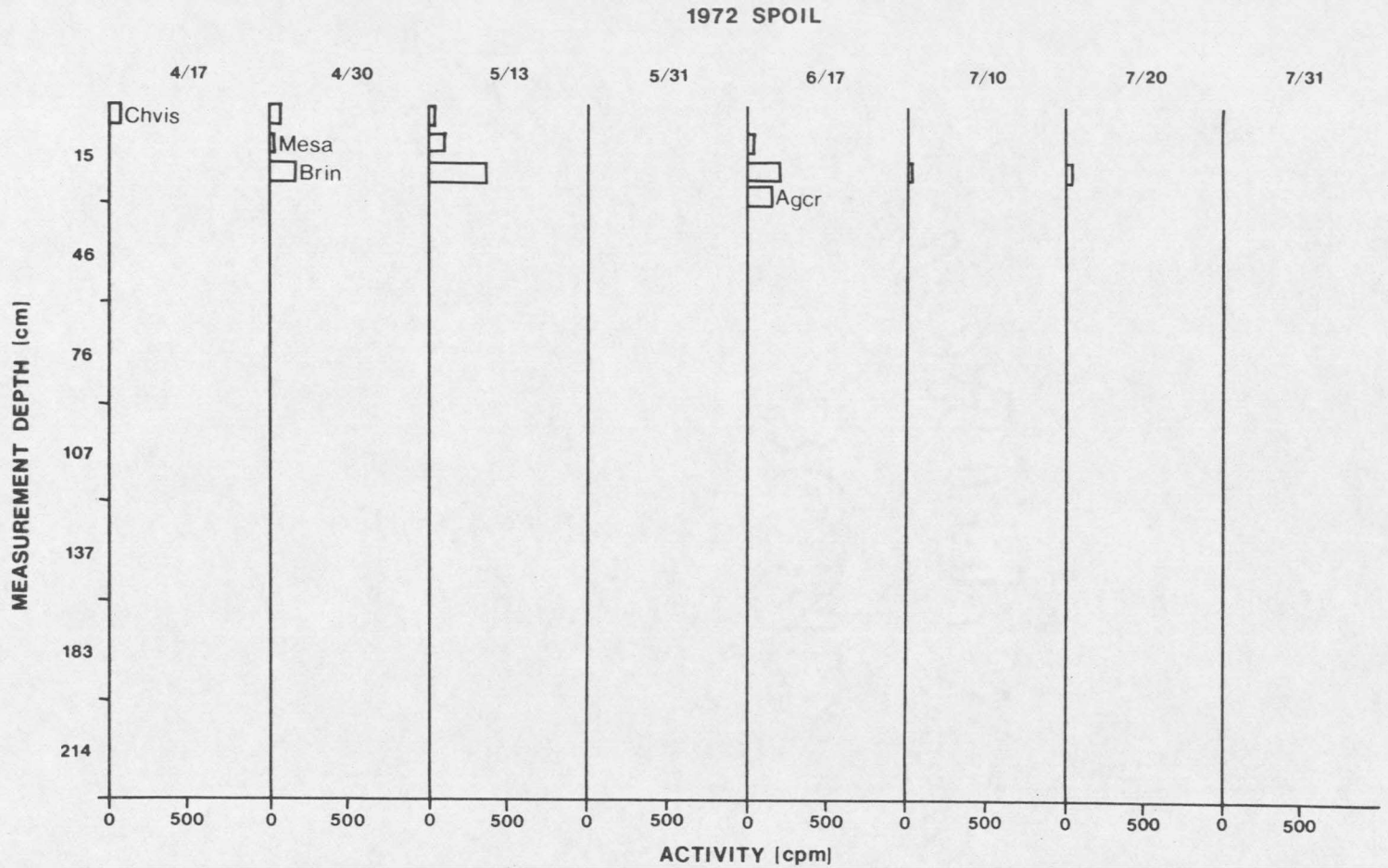


Figure 29. *In situ* plant radioactivities on 1972 spoil at Colstrip study area in 1977.

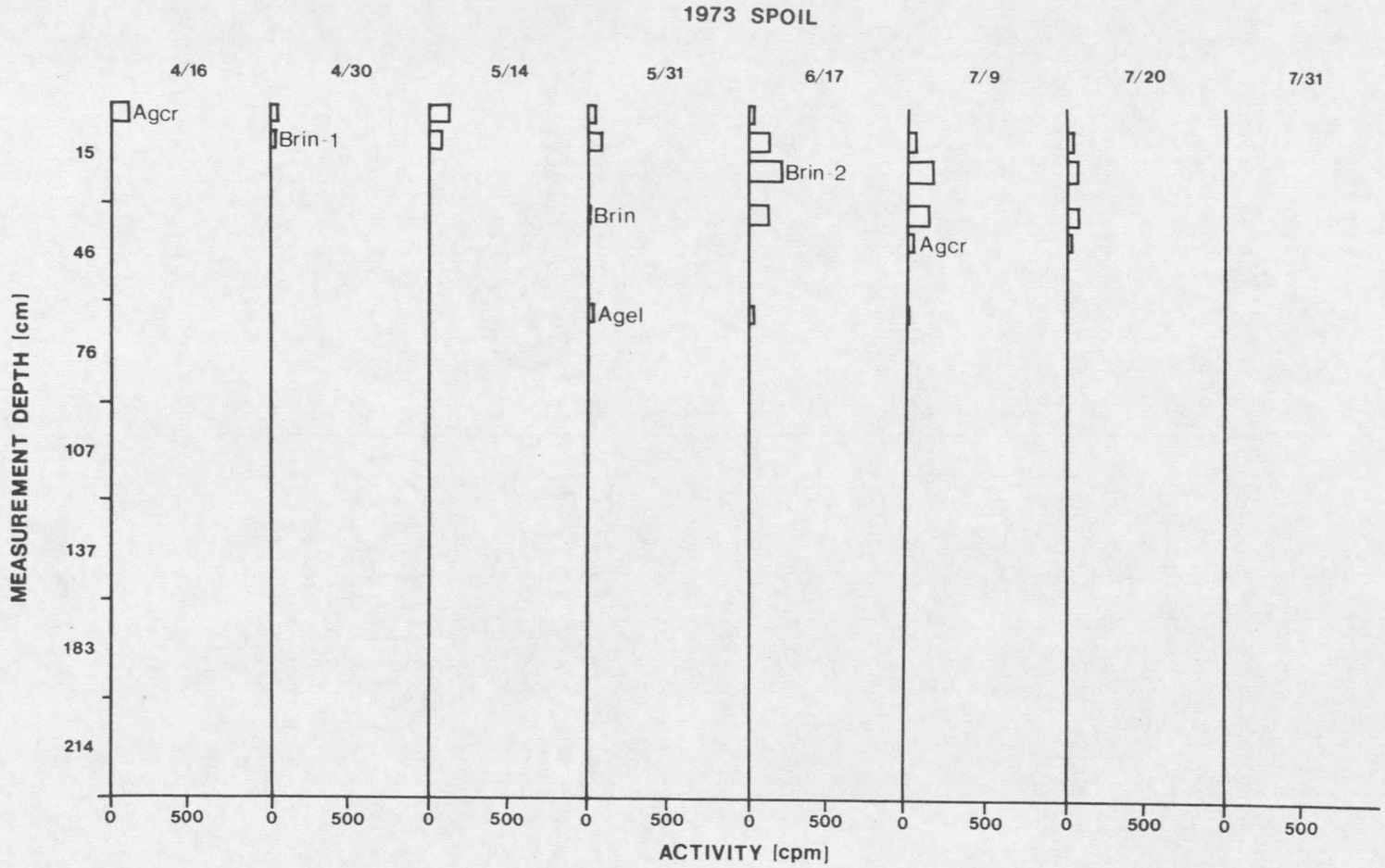


Figure 30. *In situ* plant radioactivities on 1973 spoil at Colstrip study area in 1977.

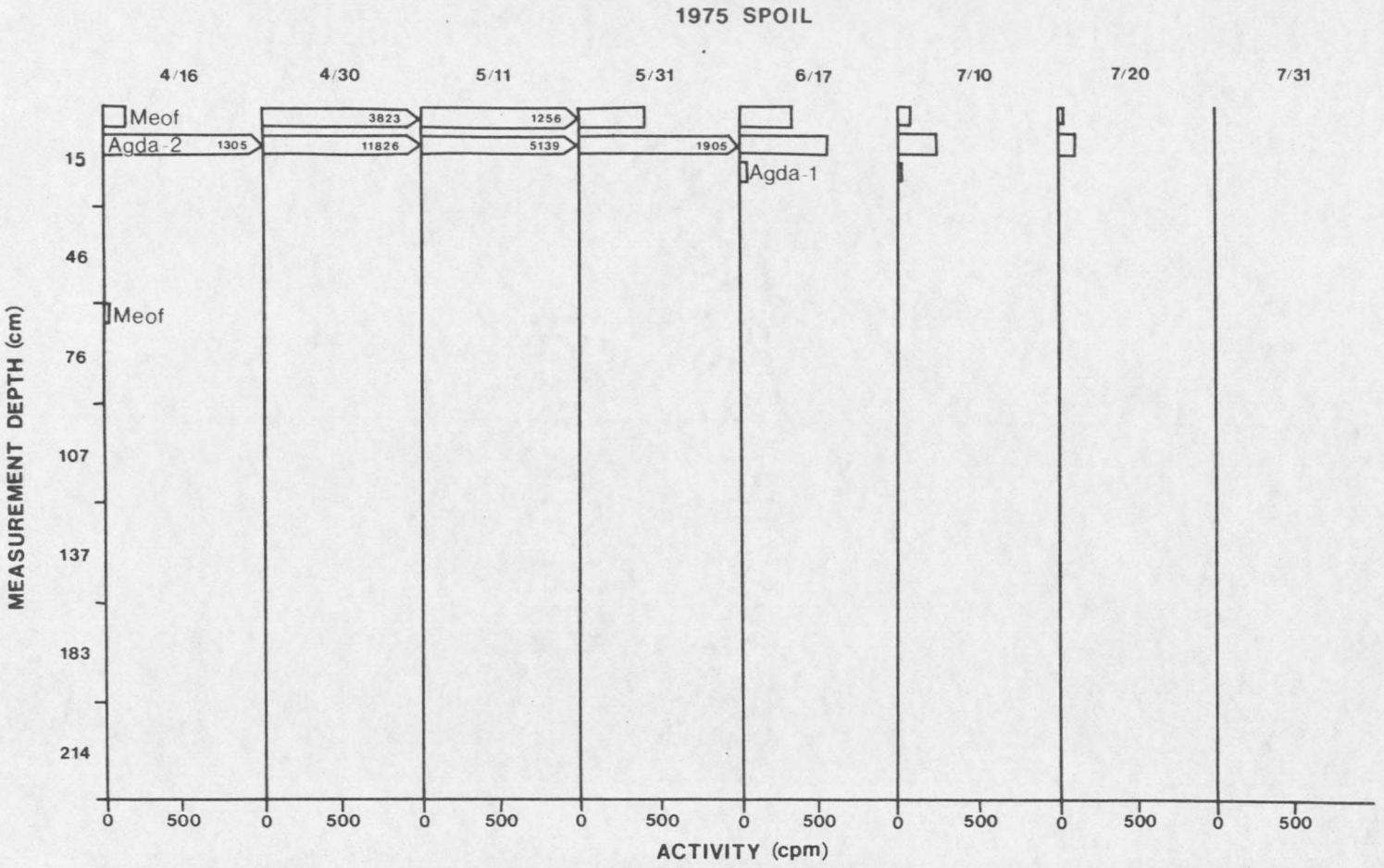


Figure 31. *In situ* plant radioactivities on 1975 spoil at Colstrip study area in 1977.

Table 22. Abbreviations of plant names.

Abbreviation	Plant Name	Abbreviation	Plant Name
Acmi	*Achillea millefolium*	Debi	*Delphinium bicolor*
Agcr	*Agropyron cristatum*	Dagl	*Dactylis glomerata*
Agda	*Agropyron dasystachym*	Feor	*Festuca ovina*
Agel	*Agropyron elongatum*	Grsq	*Grindelia squarrosa*
Agsm	*Agropyron smithii*	Gusa	*Gutierrezia sarothrae*
Agsp	*Agropyron spicatum*	Kocr	*Koeleria cristatum*
Agtr	*Agropyron trachycaulum*	Lapu	*Lactuca pulchella*
Agtri	*Agropyron tricophorum*	Laso	*Lactuca serriola*
Anspp	*Antennia* species	Lemo	*Leucocrinum montanum*
Ardr	*Artemisia dracunculus*	Liin	*Lithospermum incisum*
Arfr	*Artemisia frigida*	Meof	*Melilotus officinalis*
Arlo	*Artistida longiseta*	Mesa	*Medicago sativa*
Arlu	*Artemisia ludoviciana*	Onvi	*Onobrychis viciaefolia*
Asspp	*Astragalus* species	Popr	*Poa pratensis*
Atca	*Atriplex canescens*	Posa	*Poa sandbergii*
Bogr	*Bouteloua gracilis*	Raco	*Ratibida columnifera*
Brin	*Bromus inermis*	Rowo	*Rosa woodsii*
Brspp	*Bromus* species	Somi	*Solidago missouriensis*
Cafi	*Carex filifolia*	Sospp	*Solidago* species
Canu	*Caloshortus nuttallii*	Stco	*Stipa comata*
Cami	*Camelina microcarpa*	Stvi	*Stipa viridula*
Chvil	*Chrysopsis villosa*	Taof	*Taraxacum officinalis*
Chvis	*Chrysothamnus viscidiflorus*	Trdu	*Tragopogon dubius*

^{32}P uptake was generally confined to plants with active roots in the upper 46 cm of the Chinook undisturbed soil during the period from April 17 to May 31, 1977, and it was usually more intense in those plants with active roots at 46 cm. By June 15, a few plants had taken up ^{32}P from 76 and 107 cm and radioactivity was greatest in plants with active roots at 76 cm. For the remainder of the investigation period, average plant radioactivities were greatest in plants with active roots at 107 cm.

The majority of the radioactivity measurements (83%) taken on the Chinook undusturbed soil were recorded on 9 grass species, especially the perennial bunchgrass *Stipa comata* (55%). The biennial forb *Tragopogon dubius* accounted for the remainder of the measurements, (17%). *Stipa comata* accounted for the majority of the radioactivity measurements taken on the Chinook undisturbed soil in 1976.

Average plant radioactivities of the three replications of ^{32}P injections in the Chinook undisturbed soil were significantly different at the .95 level for replications ($P = .018$) as were measurement dates ($P = .020$), but data from different injection depths were not different ($P = .147$, Table 23). Only the top four injection depths were used in this analysis because 97 percent of the radioactivity measurements were taken on plants with active roots in the top 107 cm. Interaction between the three main effects was not significant at the .95 level ($P = .221$) and, therefore, was eliminated from the analysis to give

better resolution to the experiment. A difference greater than 41 cpm was significant at the .95 level (LSD).

Table 23. ANOV for average plant radioactivities on the Chinook undisturbed soil at the Colstrip study area in 1977.

Source	D.F.	S.S.	M.S.	F-Value	P-Value
Reps	2	248,587	124,294	4.23	.018
Date	7	524,394	74,914	2.55	.020
Depth	3	166,939	55,466	1.89	.147
Error	83	2,439,908	29,396		
Total	95	3,379,829	35,577		

Table 24 lists the average radioactivities for replications and dates and signifies which of these averages were similar. It was noted that replication 2 had nearly double the average radioactivity of replications 1 and 3, indicating that ^{32}P uptake on the Chinook undisturbed soil was highly variable possibly because of pH variability in the Chinook soil profile. Average plant radioactivities were similar on quite a few dates, indicating that ^{32}P uptake was similar during most of the growing season and only became significantly different during short periods, perhaps when plants underwent physiological changes; flowering.

The fact that plant radioactivities on the Chinook undisturbed soil were significantly different between replications suggested that ^{32}P availability was highly variable within the test plot.

Table 24. Plant radioactivity on Chinook undisturbed soil at Colstrip study area in 1977 (LSD).

		Radioactivity (cpm)
Replication	1	124[a]
	2	316[b]
	3	160[a]
Date	April 17	74[a]
	May 1	278[b]
	May 13	449[c]
	May 31	268[b]
	June 15	307[b]
	July 9	152[d]
	July 19	91[a]
	July 31	73[a]

Unfortunately, information was not collected during this investigation on the variability of soil properties (i.e., soil pH) within a site. Therefore, it was impossible to verify this assumption.

The difference of plant radioactivities between dates was attributed to developmental changes in the plants during the growing season as explained earlier in the section on factors affecting radioactivity.

Radioactivities were not significantly different between plants taking up ^{32}P from different injection depths. That was not surprising since plant radioactivities were greatly dependent on ^{32}P availability, which was in turn somewhat dependent on soil pH. Soil pH did not vary

with depth in the Chinook undisturbed soil (i.e., 8.2 to 8.5 between 10 and 100 cm).

Radioactivity on old spoils. Figure 19-21 represent radioactivity measurements taken on three replications of ^{32}P injections made in the 1932 spoils. This old spoil was chosen to receive ^{32}P replications because it was the oldest spoil available for investigation in 1977 and, therefore, represented spoil material which had been exposed the longest to soil-forming factors. All three of the 1924 spoils were to be stripmined for coal in the near future and, therefore, could not be injected with ^{32}P.

Sixty-six measurements were taken on 19 radioactive plants in 1977, 93 percent on those growing above injections in the upper 76 cm of the soil profile. Radioactivity was recorded only on one plant that had taken up ^{32}P from soil depths below 76 cm and that was on the last measurement date. The total number of plants recorded on any one date followed the same pattern as described for the Chinook undisturbed soil, except that it fell sharply on May 31, which was attributed to operator error.

^{32}P uptake was confined to plants with active roots in the upper 46 cm profile of the 1932 spoil during the first 6 weeks of the study and radioactivity was greatest in those plants with active roots at 15 cm. By June 16 a few plants had taken up ^{32}P from 76 cm in the soil

profile and it was on these plants that radioactivity was most intense during the remainder of the investigation period.

Two-thirds of the radioactivity measurements on the 1932 spoils in 1977 were recorded on 5 grass species of which half (39%) were on the cool-season bunchgrass *Agropyron spicatum*. This was quite a change from 1976 when *Melilotus officinalis* was the most often monitored plant on the 1932 spoils. The difference was probably explained by the fact that most of the cool-season plants were past their peak growing periods in 1976 when the study got under way in late June and, therefore, were not actively taking up large quantities of nutrients like the taprooted *Melilotus officinalis*. In 1977 the study began in early April and the cool-season grasses had more of an opportunity to take up ^{32}P.

Average plant radioactivities of the three replications of ^{32}P injections in the 1932 spoils were not significantly different for replications ($P = .186$), measurement date ($P = .092$) or injection depth ($P = .158$, Table 25). Only the top three injection depths were used in this analysis because 98% of the radioactivity measurements were taken on plants with active roots in the top 76 cm. Interaction between the three main effects was not significant at the .95 level ($P = .62$) and was dropped from the analysis to give better resolution to the experiment.

Table 25. ANOV for average plant radioactivity on 1932 old spoil at Colstrip study area in 1977.

Source	D.F.	S.S.	M.S.	F-Value	P-Value
Reps	2	283,543	141,771	1.74	.186
Date	6	950,068	158,345	1.94	.092
Depth	2	3.2,491	156,246	1.91	.158
Error	52	4,245,964	81,653		
Total	62	5,792,066			

Average plant radioactivities were not significantly different between replications, implying ^{32}P availability, i.e., soil pH, in the 1932 spoils was not as variable as in the Chinook undisturbed soil. However, the standard error due to replications in the 1932 spoils was greater (±266 cpm) than in the Chinook undisturbed soil. These two contradictory circumstances indicated that the resolution of the analysis was not great enough to assess the true differences between replications on the 1932 spoils. This was probably explained by the relatively small number of measurements recorded on radioactive plants in the 1932 spoils (62) compared to the Chinook undisturbed spoils (114).

Average plant radioactivities on the 1932 spoils were not significantly different between measurement dates, implying that the quantity of ^{32}P taken by plants did not vary much during the growing season. This indicated that the plants growing on the 1932 spoils had

physiological differences compared to the plants growing on the Chinook undisturbed soil, but that seemed unreasonable since they were both dominated by grasses. The inability to distinguish plant radioactivity differences between measurement dates was probably due to the small number of measurements.

The same arguments described above pertaining to the smallness of sample size on the 1932 spoils might also explain why plant radioactivities were not significantly different between ^{32}P injection depths or it might have been related to soil pH. Soil pH at 15, 46 and 76 cm in the 1932 spoils changed by only three-tenths of a unit (8.3 to 8.6).

Radioactivity on new spoils. Figures 21-23 represent radioactivity measurements taken on three replications of ^{32}P injections made in the 1970 spoils. This new spoil was chosen to receive ^{32}P replications because it was the oldest new spoil (Note: the 1969 spoil was actually a regraded old spoil) and had by far the greatest rooting distribution of all new spoils according to the information gathered in 1976.

A total of 14 radioactive plants were monitored on the 1970 spoils in 1977. Only 43 radioactivity measurements were recorded over the 12-week test period. Ninety-five percent of these measurements were on plants growing above injections in the upper 46 cm of the soil profile. Radioactivity was not detected in any plants with roots

below 46 cm until July 20. The total number of plants monitored on any date followed the same pattern as described for the 1932 spoils.

Most of the radioactivity (97%) recorded on the 1970 spoils was found in plants with active roots in the upper 15 cm profile and was most intense on May 13.

All of the radioactivity measurements on the 1970 spoils were recorded on five grasses, four of which belonged to the *Agropyron* genus. Forty-four percent of the measurements were recorded on *Agropyron cristatum* and 42% on *Bromus inermis*. Both of these species were well represented on the 1970 spoils in 1976.

Average plant radioactivities of the three ^{32}P replications were not significantly different at the .95 level for replications (P = .055), measurement dates (P = .436) or injection depths (P = .053; Table 26). Only the top two injection depths were used for this analysis because 95% of the radioactivity measurements were taken on plants with active roots in the top 46 cm profile.

Table 26. ANOV for average plant radioactivity on 1970 new spoil at Colstrip study area in 1977.

Source	D.F.	S.S.	M.S.	F-Value	P-Value
Reps	2	802,236	401,118	3.18	.055
Date	6	764,522	127,420	1.01	.436
Depth	1	507,980	507,980	4.03	.053
Error	32	4,037,619	126,176		
Total	41	6,112,357	149,082		

Average plant radioactivities on the 1970 spoils were not significantly different between replicates, but the standard error due to replications was ±448 cpm. These were the same circumstances described for replications in the 1932 spoils, except that the variation due to replications for the 1970 spoils was approximately double that of the 1932 spoils. As stated before these seemingly contradictory circumstances were probably the result of the small number of samples (44) which gave poor resolution to the analysis of variance.

Average plant radioactivities on the 1970 spoils were not significantly different between measurement dates, suggesting that the amount of ^{32}P taken up by plants did not vary much during the growing season. Again, the inability to distinguish plant radioactivity differences between measurement dates was probably due to the small sample size.

The same problem mentioned above regarding poorness of experimental resolution might also explain why plant radioactivities were not significantly different between injection depths. However, soil pH was not different at 15 or 46 cm (8.3) and, therefore, plant radioactivities should not have been different.

In the foregoing discussion of plant radioactivity variability within sites, it was apparent that experimental error was inversely proportional to the number of plants taking up ^{32}P and the number of measurements taken on those plants (Table 27). Therefore, in order to

reduce the standard error of the 1932 and 1970 spoils to the same level of the Chinook undisturbed soil, it would be necessary to increase their number of measurements on radioactive plants by two and three times, respectively.

Table 27. Rooting variability at Colstrip study area in 1977.

	Chinook Soil	1932 Spoil	1970 Spoil
Radioactive plants	27	19	14
Measurements	114	66	43
Standard Error-sites (cpm)	19	40	63
Standard Error-reps (cpm)	249	266	488

Site effect on radioactivity. The second objective of the second year's ^{32}P research was to examine site effect on plant radioactivities of plant species common to all sites. Actually, only eight sites were used in this study: Chinook, Yamac and Busby(s) undisturbed soils; 1932 old spoil; and 1970, 1972, 1973 and 1975 new spoils. Unfortunately, there were insufficient data to attain the objective because not one plant species under investigation had taken up ^{32}P from every study site profile. The best showing was by *Agropyron cristatum* on four sites (all new spoils). Therefore, it was impossible to achieve the objective of this study so no conclusions could be made on the effect of sites in plant radioactivity.

Verification of results. The third objective of the second year's ^{32}P research was to verify the first year's results. Results

from both years' ^{32}P research were compared by individual sites and in the case of new spoils, by groups. Actually, only the results of eight sites and one group, new spoils, could be compared between years because four of the original twelve sites which had 1976 data were lost to mining activity.

Figure 25-31 represent plant radioactivities measured *in situ* on seven sites during the period from April 16 to July 31, 1977. The key to the plant name abbreviations appears in Table 22. The information that was collected on the three sites which received ^{32}P replications, Chinook, 1932 and 1970, was included in these comparisons.

The information presented in the plant radioactivity figures of 1976 and 1977 was consolidated into Table 28. The information which readily lent itself to comparisons were: number of radioactive plants; percentage of measurements on plants with active roots in upper 76 cm profiles; average plant radioactivities; and the percentage of measurements and radioactivity accounted for by the dominant plant species.

The number of radioactive plants monitored on all eight sites in 1976 (45) and 1977 (50) was not significantly different at the .95 level ($P = .62$; Table 29). The slight increase in the number of radioactive plants in 1977 was probably associated with the greater duration of the test period in 1977 (14 weeks) compared to 1976 (6 weeks), meaning that plant roots had a greater likelihood of intercepting ^{32}P.

Table 28. Comparisons of 1976 and 1977 ^{32}P data.

	No. plants		% of measurements in upper 76 cm[1]		Average radioactivity (cpm)		Dominant plant (% measurements)(% radioactivity)	
Year	76	77	76	77	76	77	76	77
Native Soils								
Chinook*	4	9	89	91	1310	212	*Stipa comata*(89)(95)	*Stipa comata*(54)(66)
Yamac	6	9	100	97	653	153	*Bromus tectorum*(55)(51)	*Stipa comata*(44)(52)
Busby (8)	7	8	82	89	329	221	*Chrysopsis villosa* (27)(60)	*Stipa comata* (59)(30)
Old Spoils								
1932*	7	6	71	98	137	237	*Melilotus officinalis* (38)(26)	*Agropyron spicatum* (39)(7)
1948	--	10	--	97	--	134	--	*Poa pratensis*(42)(25)
New Spoils								
1969	--	--	--	78	--	44	--	*Chrysopsis villosa* (37)(36)
1970*	10	5	77	100	168	237	*Medicago sativa*(27)(51)	*Bromus inermis*(42)(13)
1972	6	4	100	100	320	98	*Medicago sativa*(62)(97)	*Bromus inermis*(42)(63)
1973	2	6	100	100	194	68	*Agropyron cristatum* (100)(100)	*Bromus inermis*(57)(72)
1975	3	3	100	100	649	1702	*Agropyron smithii* (40)(11)	*Agropyron dasytachyum* (56)(78)
Group**	21	18	89	100	271	488	*Medicago sativa*(32)(54)	*Bromus inermis*(46)(10)

*Average of 1977 data. ** 1969 spoil not included

1 - i.e., 1977 data for Yamac soil indicates that only 3 % of the measurements were recorded on plants growing above injections below 76 cm in the soil profile.

Table 29. ANOV for comparison of number of radioactive plants.

Source	D.F.	S.S.	M.S.	F-Value	P-Value
Year	1	1.562	1.562	.269	.617
Error	14	81.37	5.812		
Total	15	82.94			

The percentage of measurements taken on plants with active roots in upper 76 cm profiles in 1976 and 1977 was not significantly different at the .95 level (P = .16; Table 30). This indicated that the vertical rooting distributions in these sites remained unchanged during the investigation period. It was unfortunate that the 1924 spoils were not studied in 1977 because they were dominated by a plant species, *Artemisia dracunculus*, which had very deep rooting habits. Perhaps they would have been more sensitive to factors affecting rooting depth than more shallow rooted plants.

Table 30. ANOV for comparison of percentage of plants with active roots in upper 76 cm profile.

Source	D.F.	S.S.	M.S.	F-Value	P-Value
Year	1	175.6	175.6	2.193	.158
Error	14	1121	80.66		
Total	15	1296			

Average plant radioactivities on the eight sites under considerations in 1976 and 1977 were not significantly different at the .95

level (P = .67; Table 31). This indicated that the factors which affected plant radioactivities, primarily soil pH, had not changed significantly during the two-year test period.

Table 31. ANOV for comparison of average plant radioactivity.

Source	D.F.	S.S.	M.S.	F-Value	P-Value
Year	1	43,260	43,260	.192	.671
Error	14	3,161,000	225,800		
Total 15	15	3,204,000			

All of the spoils in the new spoils group that were used for analysis in 1976 were also studied in 1977. Comparisons of group values in 1976 and 1977 were not significantly different at the .95 level for any of the comparisons listed above--in sequence; P = .62, .42 and .71.

The last two columns in Table 28 list the plant species which had displayed radioactivity most often and the percentage of measurements and radioactivity that it accounted for on its site in 1976 and 1977. It was apparent that only on the Chinook undisturbed soil did the same plant species, *Stipa comata*, dominate in both years. The dominant plant species on the other seven sites were different in 1977 than they were in 1976. These changes might have resulted from differences in test periods during the two years. Only the warm part of the growing season was monitored in 1976 compared to the entire growing season in 1977. This could explain why *Stipa comata*, a cool season

grass, more often displayed radioactivity in 1977 than in 1976. The same could have been true for the cool season grass *Bromus inermis*, which dominated the new spoils group in 1977.

The validity of the ^{32}P experiment in 1976 appeared to be reinforced by the information collected in 1977. There were no significant differences between comparisons of the number of radioactive plants, percentage of measurements taken on plants with active roots in upper 76 cm profiles, and average plant radioactivities. The only difference that was noted between the two years was that more cool season plants were monitored in 1977 than in 1976 and that was probably due to differences of the time of year when the tests were conducted.

Maximum observable rooting depths of grasses, forbs and shrubs using the radioactive tracer technique are presented in Table 32. The reader is reminded that the deepest placement of ^{32}P in the soil was at 214 cm. Usually, grasses, forbs and shrubs had greater rooting depths in undisturbed soils than in minespoils, old and new. However, the number of plant species with rooting depths greater than 76 cm was greater in old spoils (8) than in undisturbed soils (5) and new spoils (3). The more common deeper rooting species were : undisturbed soils--*Melilotus officinalis, Stipa comata* and *Tragopogon dubius*; old spoils--*Artemisia dracunculus, Melilotus officinalis, Ambrosia psilostachya, Stipa comata* and *Agropyron smithii*; and new spoils--*Agropyron elongatum* and *Agropyron trachycaulum*.

Table 32. Maximum detectable rooting depths at Colstrip in 1976 and 1977 (^{32}P).

	Specie	Rooting Depth (cm)		
		Native Soil	Old Spoil	New Spoil
Grass	*Agropyron cristatum*			76
	Agropyron dasystachyum			46
	Agropyron elongatum			183
	Agropyron smithii	46	107	15
	Agropyron spicatum		76	
	Agropyron trachycaulum		107	
	Agropyron tricophorum		46	
	Artistida longiseta	46		
	Avena fatua			46
	Bouteloua gracilis	76		
	Bromus inermis			76
	Bromus tectorum	76		
	Calamovilfa longifolia	46		
	Koeleria cristatum	76	76	
	Poa pratensis		46	
	Poa sandbergii	46		
	Stipa comata	183	137	
Forb	*Agroseris glauca*		107	
	Ambrosia psilostachya	76	137	
	Astragalus cicer		15	
	Calochortus nuttallii	15		
	Gaura coccinea	137		
	Grindelia squarrosa		15	
	Lactuca pulchella		107	
	Lactuca serriola		46	
	Leucocrinum montanum	46		
	Melilotus officinalis	137	137	15
	Medicago sativa			76
	Petalostemon purpureum	76	15	
	Psoralea esculenta	76	76	
	Salsola kali			46
	Tragopogon dubius	137	46	
Shrub (Half)	*Antennia* species	15		
	Artemisia cana		15	
	Artemisia dracunculus	137	137	
	Artemisia frigida	46	15	
	Artemisia ludoviciana		76	
	Chrysopsis villosa	46	46	
	Chrysothamnus nauseosus	15		
	Chrysothamnus viscidiflorus			107
	Gutierrezia sarothrae		46	
	Rosa species		15	

The last portion of this section deals with the accuracy of the field counting unit. Fifty plants were randomly selected on the Chinook undisturbed soil on July 31, 1977, and counted using LSC techniques. Field counts, which were about six times greater than counts obtained in the laboratory due to dilution and decay, had a high positive correlation ($r = .94$) with laboratory counts. This correlation was significant at the .95 level ($P = .001$), indicating that the accuracy of the field unit was adequate (Table 33). Only 8 plant counts were used in the analysis because there were only 8 plants out of the 50 selected which had radioactivities above the background count.

Table 33. ANOV of the field count regression on laboratory count.

Source	D.F.	S.S.	M.S.	F-Value	P-Value
Method	1	1904	1904	48.12	.001
Error	6	237.3	39.56		
Total	7	2141			

Note On ^{32}P Experiment

The major problem regarding the ^{32}P experiment was the influence of soil factors on phosphorus availability. In the pH range of the soils in the Colstrip study area, 7.5 to 8.5, the availability of phosphorus decreases as the soil pH increases, possibly due to the presence of free calcium carbonate. This problem could possibly be overcome by using another radioactive tracer which was not as readily fixed by the

soil; ^{22}Na, ^{24}Na and ^{86}Rb. Furthermore, the longer half-life of one of these isotopes (^{22}Na) might allow a two-year investigation without requiring additional injections the second year (half- life of ^{22}Na is 2.6 years). Other problems might arise depending on the characteristics of the substitute isotope. For instance, radioactive sodium would probably behave like ^{23}Na in the soil and would, therefore be relatively mobile in relation to phosphorus. This might possibly be a problem because the design of the experiment requires that the radioisotope remain at the point of injection.

The experimental design might be strengthened by increasing the number of injection replicates and radioactivity measurements. Data collected during this investigation suggested that the number of replicates in minespoils be 2-3 times the number in undisturbed soils because of differences in root biomass (there were 43 percent less root biomass in new spoils than in undisturbed soils).

The length of time required to describe maximum vertical rooting distributions using the radioactive tracer technique might possibly be shortened to a few weeks if injections were made in the soil just before the mid-point of the growing season and monitoring began soon afterwards. Data collected during this investigation suggested that the mid-point of the growing season was different for cool and warm season plants. Therefore, the plants under investigation would have to be considered with this in mind before injections of the radioisotope were made in the soil.

CHAPTER 5

POTENTIAL APPLICATIONS OF RESULTS

Results of this thesis have potential application to reclamation of strip mined lands in southeastern Montana. The major conclusions that demand consideration pertain to revegetation efforts and management of spoil material.

Root biomass in the upper 100 cm of the soil profiles of new minespoils was 43 percent less than in undisturbed soils and 40 percent less than in old minespoils. These findings were supported by data presented in the standard soil profile descriptions. Therefore, it appears that present day revegetation efforts have not, as yet, succeeded in returning strip mined land to its premining condition in this respect.

Vertical rooting distrubitions were confined mostly to the upper 100 cm of the soil profiles in undisturbed soils and minespoils: ninety-seven percent of root biomass sampled at 10, 50 and 100 cm in the soil profiles of undisturbed soils and new minespoils were located in the upper 50 cm of the soil profiles; and less than 10 percent of the 180 radioactive plants monitored during this investigation had taken up ^{32}P from below 107 cm in the soil profiles. Furthermore, maximum detectable rooting depth of 41 plant species taking up ^{32}P in 1976 and 1977 was 183 cm. These facts suggest that the minimum depth (244 cm) required by Montana's reclamation guidelines for burying toxic overburden materials below the soil surface is adequate, if not excessive.

Infiltration velocities were not limiting in any undisturbed soils or minespoils in this investigation. This indicates that present day management of spoil material at the Colstrip study area seems appropiate in this respect, at least on minespoils that have less than a 3 percent slope.

CHAPTER 6

SUMMARY AND CONCLUSIONS

A study was initiated in June, 1976, at Colstrip, Montana, to determine the soil water and rooting characteristics of 1 to 53 year-old stripmine spoils and undisturbed soils of the area. The minespoils were divided into two groups for comparison, old (28 to 53 years old) and new (1 to 7 years old).

Infiltration velocities were moderately rapid (5.93 to 14.87 cm hr^{-1}) in all minespoils and undisturbed soils, except the 1972 minespoil which had a rapid infiltration velocity (15.30 cm hr^{-1}). Infiltration velocities were not significantly different between old and new minespoils and undisturbed soils which was partially explained by the similarities of their surface horizons' textural compositions.

Three general trends were shared by most minespoils and undisturbed soils regarding soil water contents: 1) soil water contents of surface horizons were generally only limiting in August and September, 1976; 2) although soil surface horizons were partially recharged in October, 1976, total soil profile water contents reached their minimum levels during this month; and 3) the upper 30 cm of the soil profiles were partially recharged under frozen soil conditions in February, 1977, possibly by unsaturated water flow from unfrozen substrata.

Deep percolation occurred only during heavy recharge periods in the summer and fall of 1976 and the spring of 1977. It was greatest in

those soil profiles having the least amount of roots at the lower soil profile depths. The degree of deep percolation was in the order; new minespoils > undisturbed soils > old minespoils. The amount of roots at the lower soil profile depths was in the order: old minespoils > undisturbed soils > new minespoils.

Water use in new minespoils and undisturbed soils had high positive correlations with root biomass at 50 and 100 cm soil profile depths. Water use in old minespoils had no correlation with root biomasses at these depths, which indicated that vegetation in old minespoils obtained a substantial amount of their soil moisture from lower soil profile depths (>76 cm).

Rooting activity was monitored in minespoils and undisturbed soils during the 1976 and 1977 growing seasons using radioactive tracer techniques. The number of plants that had taken up radioactive phosphorus (^{32}P) from minespoils and undisturbed soils was nearly identical. However, the percentage of radioactive plants with detectable roots below 76 cm in the soil profiles was approximately 30 percent greater in old minespoils than in new minespoils and undisturbed soils. This was explained by the fact that deeper rooting vegetation (shrubs) dominated old minespoils, while more shallow rooted vegetation (grasses and forbs) dominated new minespoils and undisturbed soils.

Maximum detectable rooting depths of grasses, forbs and shrubs were generally greater in undisturbed soils than in minespoils, old and

new. However, a greater number of plant species had taken up ^{32}P from below soil depths of 76 cm in old spoils (8) than in undisturbed soils (5) and new spoils (3). The more common plant species with deep roots were: grass--*Stipa comata, Agropyron trachycaulum* and *Agropyron smithii*; forb--*Melilotus officinalis, Tragopogon dubius* and *Ambrosia psilostachya;* and shrub--*Artemisia dracunculus* and *Chrysothamnus viscidiflorus*.

Plant radioactivities were shown to be in part dependent on soil pH and ^{32}P availability. The amount of ^{32}P uptake by plant tops per unit of water use was proportional to the size of the 'labile phosphate pool' in the soil solution. However, ^{32}P uptake did not parallel water use.

Data from the three different methods used in this investigation to determine vertical rooting distributions (visual description - SCS; root biomass; and radioactive tracer) indicated that plant roots were more abundant in old minespoils below soil depths of approximately 75 cm than in new minespoils and undisturbed soils. In addition, data from visual description and root biomass methods showed that plant roots were less abundant in new minespoils below soil depths of 10 cm than in old minespoils and undisturbed soils.

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APPENDIX A. Anti-coincidence Unit

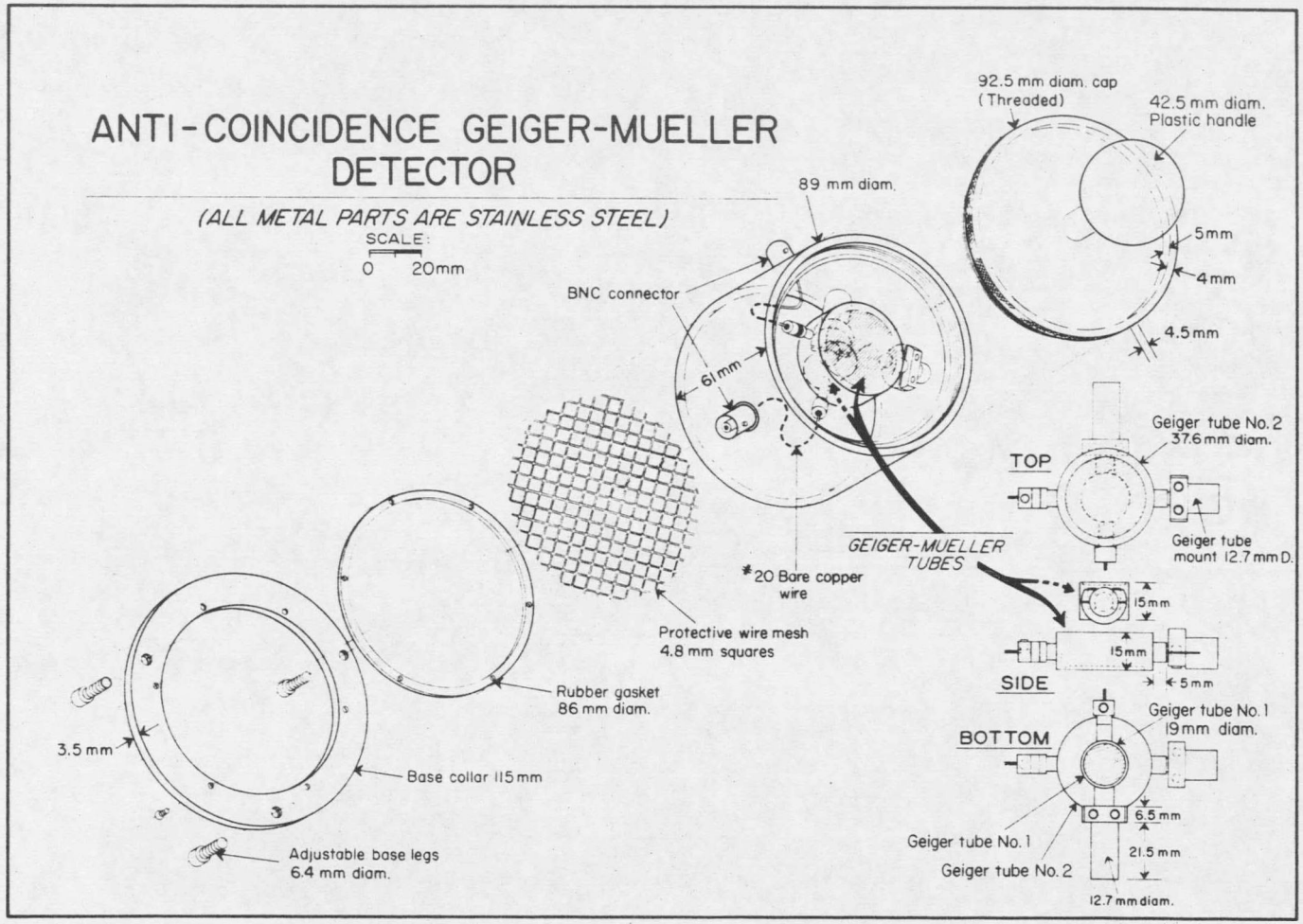
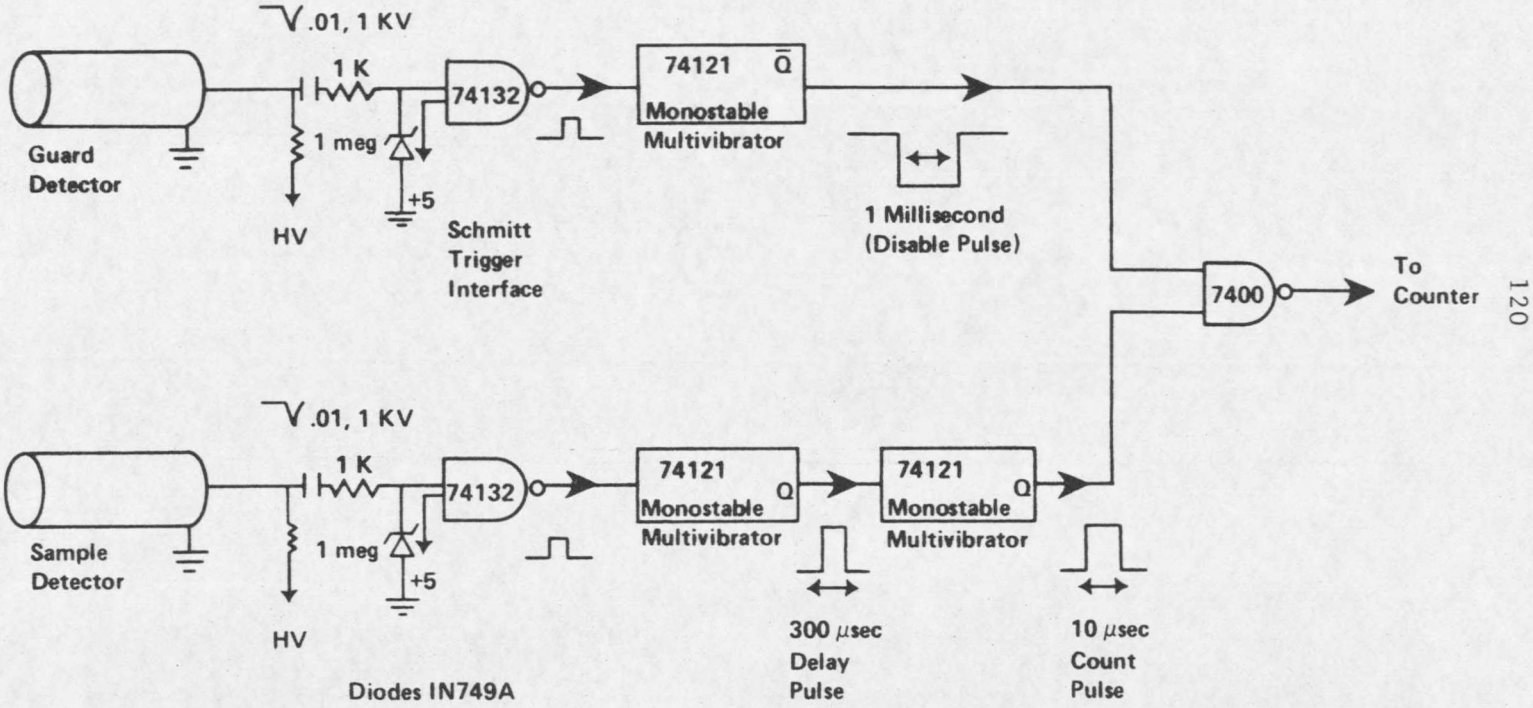


Figure 32. Anti- coincidence detector.

ANTI - COINCIDENCE CIRCUIT



APPENDIX B. Statistical Model

STATISTICAL MODEL

A one-way analysis of variance was used for all statistical analysis presented in this thesis. Analysis was performed using a computer program authored by Dr. Lund of the Statistics Department. The model that forms the basis of this program is

$$Y_{ij} = U + \alpha_i + E_{ij}$$

$$\sum_{i=1}^{a} \alpha_i = 0; \quad E_{ij} \text{IND}(0,\sigma_e^2); \quad i=1,\ldots,a; \quad j=1,\ldots,n.$$

where Y_{ij} = single observation, U = population mean, α_i = treatment effect, E_{ij} = experimental error, and σ_e^2 = variance. The model implies three assumptions:

1) populations are normally distributed

2) population variances are equal

3) observations are independent.

Replications are not independent of one another, but sample means are.

APPENDIX C. ^{32}P Equation

^{32}P Equation

Plant radioactivity is proportional to the amount of ^{32}P in the above ground portion of the plant

(]) Thus, $FC = K_1 (PQ)$

where FC = Field count

K_1 = Proportionality constant (geometry factor)

PQ = Radioactive quanity in plant tops

Decay of all radioactive substances is expressed by the equation

(2) $$N = N_o e^{-\lambda t}$$

where N = Number of atoms remaining at time t

N_0 = Original number of atoms present

$e^{-\lambda t}$ = Decay constant

λ = 0.693/ half-life (]4.3 days for ^{32}P)

Thus, radioactive quanity of ^{32}P taken up by the plant tops from injected ^{32}P in the soil is the sum of ^{32}P accumulated (PA) corrected for decay

(3) $$PQ = \sum_{t=]}^{t=2} (PA)\, e^{-\lambda t}$$

where $PA = K_2 (SQ)$

and $K_2 = K_{21} K_{22} K_{23}$, $K_{21} = \frac{\text{Avail. P}}{\text{Total P}}$, $K_{22} = \frac{\text{Avail. } ^{32}P}{\text{Avail. P}}$,

K_{23} = P uptake by roots and transport to tops factor

and SQ = Avail. ^{32}P in soil

Integrating from t_1 to t_2

$$(4) \qquad PQ = \int_{t=1}^{t=2} (PA)\, e^{-\lambda t}\, dt$$

$$(5) \qquad PQ = \frac{PA\,(e^{-\lambda t_2} - e^{-\lambda t_1})}{-\lambda}$$

Substituting (1) into (5) and rearranging

$$(6) \qquad K_1(PA) = \frac{FC\,(-\lambda)}{(e^{-\lambda t_2} - e^{-\lambda t_1})} = A$$

where $A = K_1(PA)$ and is defined as actual plant uptake of ^{32}P

This equation can be extended to evaluate ^{32}P by a plant top between measurement dates by substracting the residual radioactivity of previous ^{32}P uptake from field count. A modified field count (FC_{t_c}') can be defined as

$$(7) \qquad FC_{t_c}' = FC_{t_2} - FC_{t_1}\, e^{-\lambda t_c}$$

where $t_c = t_2 - t_1$

FC_{t_c}' is the corrected field count at time t_2 suitable for substitution into (7). In this case, in (7) t_2 would be the time elapsed from injection to measurement date 2 and t_1 would be the elaped time from injection to measurement date 1.

APPENDIX D. Site Descriptions

Table 34. Site description of Chinook undisturbed soil (Site No. 1).

SOIL SERIES: CHINOOK

SURVEY SAMPLE NO.: S78PT 173 I
LOCATION: SW 1/4, NW 1/4, NE 1/4, SEC 28 T2N, R4E, 1.5 MILES NW OF GOLDEN, MT.
CLASSIFICATION: ARIDIC ENTIC HAPLOBOROLLS; COARSE-LOAMY, MIXED

SITE NO.: 78 1 | COUNTY: | ELEVATION: 0900 METERS | MONTH SAMPLED: AUGUST
SLOPE: 1 | CLASS: MODERATELY SLOPING | KIND: CONCAVE | ASPECT: NORTH
AIR TEMPERATURE: | ANNUAL: 47 DEGREES F | SUMMER: 68 DEGREES F | WINTER: 24 DEGREES F
SOIL TEMPERATURE | ANNUAL: DEGREES F | SUMMER: DEGREES F | WINTER: DEGREES F
WATER TABLE: | DEPTH: CM. | DATE: AUGUST | KIND: NO WATER TABLE
PRECIPITATION: 340 CM. | CONTROL SECTION LIMITS -- | UPPER: 025 CM LOWER: 100 CM
PERMEABILITY: MODERATELY RAPID | DRAINAGE CLASS: WELL DRAINED
PHYSIOGRAPHY: BASINS, INTERIOR DRAINAGE | STONINESS: CLASS 0
MICRORELIEF: ON SLOPE AND DEPRESSION
VEGETATION: GRASSES AND FORBS
PARENT MATERIAL: SLIGHTLY WEATHERED RESIDUAL MATERIAL, LOCAL COLLUVIUM OR SOLIFLUCTATE CALCAREOUS SANDSTONE

HORIZON	PROFILE DESCRIPTION
A 1	0 - 10 CM. (0 - 4 IN.) BROWN (10YR 5/3) CRUSHED ; FINE SANDY LOAM ; DARK BROWN (10YR 3/3) CRUSHED MOIST ; WEAK VERY FINE PLATY STRUCTURE ; HARD , FRIABLE , NONSTICKY , NONPLASTIC ; MANY FINE ROOTS THROUGHOUT HORIZON ; MANY FINE IRREGULAR PORES , MANY FINE IRREGULAR PORES ; NONCALCAREOUS (HCL) DISCONTINUOUS ; MODERATELY ALKALINE PH- 8.0 (BROMTHYMOL BLUE) ; CLEAR WAVY BOUNDARY .
B 2	10 - 50 CM. (4 - 20 IN.) BROWN (10YR 5/3) CRUSHED ; FINE SANDY LOAM ; DARK BROWN (10YR 3/3) CRUSHED MOIST ; WEAK VERY COARSE PRISMATIC STRUCTURE PARTING TO WEAK TO MODERATE MEDIUM SUBANGULAR BLOCKY ; SLIGHTLY HARD , FRIABLE , NONSTICKY , NONPLASTIC ; MANY FINE ROOTS THROUGHOUT HORIZON ; MANY FINE TUBULAR CONTINUOUS PORES ; NONCALCAREOUS (HCL) DISCONTINUOUS ; MODERATELY ALKALINE PH- 8.4 (BROMTHYMOL BLUE) ; CLEAR WAVY BOUNDARY .
B 3&4	50 - 100 CM. (20 - 39 IN.) PALE BROWN (10YR 6/3) CRUSHED ; FINE SANDY LOAM ; DARK BROWN (10YR 3/3) CRUSHED MOIST ; WEAK MEDIUM SUBANGULAR BLOCKY STRUCTURE ; HARD , FRIABLE , NONSTICKY , SLIGHTLY PLASTIC ; COMMON FINE ROOTS THROUGHOUT HORIZON ; MANY FINE TUBULAR CONTINUOUS PORES ; FEW WEAK SEDIMENTARY FRAGMENTS >2 MM , FEW SANDSTONE FRAGMENTS >2 CM ; MODERATELY EFFERVESCENT (HCL) CONTINUOUS , STRONGLY ALKALINE PH- 9.0 (BROMTHYMOL BLUE) ; GRADUAL WAVY BOUNDARY .
IIA 1B	100 - 200 CM. (35 - 79 IN.) DARK GRAYISH BROWN (10YR 4/2) CRUSHED ; LOAM ; VERY DARK BROWN (10YR 2/2) CRUSHED MOIST ; BROWN (10YR 4/3) CRUSHED ; DARK BROWN (10YR 3/3) CRUSHED MOIST ; 2 PERCENT SOFT LIGHT LOAM BROWN (10YR 4/3) CRUSHED POCKETS OR CONTRASTING MATERIALS - CM THICK) ; MASSIVE ; HARD , FRIABLE , SLIGHTLY STICKY , SLIGHTLY PLASTIC ; FEW FINE ROOTS THROUGHOUT HORIZON , MANY FINE TUBULAR CONTINUOUS PORES ; FEW FE COMMON SOFT VERY COARSE INSECT CASTS ; MODERATELY EFFERVESCENT (HCL) CONTINUOUS ; STRONGLY ALKALINE PH- 9.0 (BROMTHYMOL BLUE) ; NOT REACHED BOUNDARY .

REMARKS: AUG 17, 1976 SOIL TEMP +24.1 C AT 50 CM. PROFILE IS MOIST BELOW ONE METER. >2 MM ROUNDED SANDSTONE FRAGMENTS INCREASE IN NUMBER TO THE BASE OF THE B3C2. THEY ARE ABSENT IN THE II A1. INSECT CASTS IN THE II A1 APPEAR TO BE ANT CHAMBER FILLINGS. THE PROFILE IS SLIGHTLY CALCAREOUS AT 75 CM. WHICH MAY INDICATE RECENT

Table 35. Site description of Yamac undisturbed soil (Site No. 2).

SOIL SERIES: ST6RT-R87-2

SURVEY SAMPLE NO.: 0 173 2
LOCATION: NW 1/4, NW 1/4, SE 1/4, SECT 23, T2N, R41E, 2 MILES NE OF COLSTRIP, MT.
CLASSIFICATION:

SITE NO.: 0 2 — COUNTY: SEE REMARKS — ELEVATION: 1073 METERS — MONTH SAMPLED: AUGUST
SLOPE: 6 — CLASS: STRONGLY SLOPING — KIND: CONVEX — ASPECT: SOUTHWEST
ATM TEMPERATURE: ANNUAL: 46 DEGREES F — SUMMER: 68 DEGREES F — WINTER: 24 DEGREES F
SOIL TEMPERATURE: ANNUAL: DEGREES F — SUMMER: DEGREES F — WINTER: DEGREES F
WATER TABLE: DEPTH: CM. — MONTH: AUGUST — KIND: NO WATER TABLE
PRECIPITATION: 349 CM. — CONTROL SECTION LIMITS -- UPPER: 025 CM LOWER: 100 CM
PERMEABILITY: MODERATE — DRAINAGE CLASS: WELL DRAINED
PHYSIOGRAPHY: ROLLING OR HILLY UPLANDS — STONINESS: CLASS 0
RUNOFF: ON SLOPE
VEGETATION: GRASSES AND FORBS
PARENT MATERIALS: SLIGHTLY WEATHERED RESIDUAL MATERIAL, LOCAL COLLUVIUM OR SOLIFLUCTATE INTERBEDDED SANDSTONE AND SHALE

HORIZON	PROFILE DESCRIPTION
A 11	0 - 1 CM. (0 - 0 IN.) NAVY (GRAYISH BROWN (10YR 4/2) CRUSHED ; LOAM ; VERY DARK BROWN (10YR 2/2) CRUSHED MOIST ; WEAK VERY FINE GRANULAR STRUCTURE ; SOFT , VERY FRIABLE , NONSTICKY , SLIGHTLY PLASTIC ; MANY FINE ROOTS THROUGHOUT HORIZON ; MANY FINE TUBULAR CONTINUOUS PORES ; NONCALCAREOUS (HCL) CONTINUOUS ; MODERATELY ALKALINE PH= 8.2 (PHORTHYMOL BLUE) ; ARBITRARY BOUNDARY .
A 12	1 - 2 CM. (0 - 1 IN.) BROWN (10YR 4/3) CRUSHED ; LOAM ; DARK BROWN (10YR 3/3) CRUSHED MOIST ; WEAK VERY FINE GRANULAR STRUCTURE ; SOFT , VERY FRIABLE , NONSTICKY , SLIGHTLY PLASTIC ; MANY FINE ROOTS THROUGHOUT HORIZON ; MANY FINE TUBULAR CONTINUOUS PORES ; NONCALCAREOUS (HCL) CONTINUOUS ; MODERATELY ALKALINE PH= 8.2 (PHORTHYMOL BLUE) ; ARBITRARY BOUNDARY .
A 13	2 - 5 CM. (1 - 2 IN.) BROWN (10YR 4/3) CRUSHED ; LOAM ; DARK BROWN (10YR 3/3) CRUSHED MOIST ; MODERATE FINE GRANULAR STRUCTURE ; SLIGHTLY HARD , VERY FRIABLE , NONSTICKY , SLIGHTLY PLASTIC ; MANY FINE ROOTS THROUGHOUT HORIZON ; MANY FINE TUBULAR CONTINUOUS PORES ; NONCALCAREOUS (HCL) CONTINUOUS ; MODERATELY ALKALINE PH= 8.2 (PHORTHYMOL BLUE) ; ARBITRARY BOUNDARY .
A 14	5 - 10 CM. (2 - 4 IN.) BROWN (10YR 5/3) CRUSHED ; LOAM ; DARK BROWN (10YR 3/3) CRUSHED MOIST ; MODERATE FINE GRANULAR STRUCTURE ; SLIGHTLY HARD , VERY FRIABLE , NONSTICKY , SLIGHTLY PLASTIC ; MANY FINE ROOTS THROUGHOUT HORIZON ; MANY FINE TUBULAR CONTINUOUS PORES ; NONCALCAREOUS (HCL) CONTINUOUS ; MODERATELY ALKALINE PH= 8.2 (PHORTHYMOL BLUE) ; ARBITRARY BOUNDARY .
A 21	10 - 23 CM. (4 - 9 IN.) YELLOWISH BROWN (10YR 5/4) CRUSHED ; LOAM ; DARK BROWN (10YR 3/3) CRUSHED MOIST ; MODERATE MEDIUM GRANULAR STRUCTURE ; SLIGHTLY HARD , FRIABLE , SLIGHTLY STICKY , SLIGHTLY PLASTIC ; MANY FINE ROOTS THROUGHOUT HORIZON ; MANY FINE TUBULAR CONTINUOUS PORES ; NONCALCAREOUS (HCL) CONTINUOUS ; MODERATELY ALKALINE PH= 8.2 (PHORTHYMOL BLUE) ; CLEAR SMOOTH BOUNDARY .
B 21	23 - 38 CM. (9 - 15 IN.) BROWN (10YR 4/3) CRUSHED ; SANDY CLAY LOAM ; V DK GRAYISH BROWN (10YR 3/2) CRUSHED MOIST ; WEAK MEDIUM PRISMATIC DRY STRUCTURE PARTING TO MODERATE MEDIUM SUBANGULAR BLOCKY ; VERY HARD , FIRM , SLIGHTLY STICKY , SLIGHTLY PLASTIC ; COMMON TO MANY FINE ROOTS BETWEEN PEDS ; MANY FINE TUBULAR CONTINUOUS PORES ; NONCALCAREOUS (HCL) CONTINUOUS ; MODERATELY ALKALINE PH= 8.2 ; CLEAR WAVY BOUNDARY .
B 22	38 - 56 CM. (15 - 22 IN.) YELLOWISH BROWN (10YR 5/4) CRUSHED ; SANDY CLAY LOAM ; BROWN (10YR 4/3) CRUSHED MOIST ; WEAK MEDIUM PRISMATIC STRUCTURE PARTING TO MODERATE MEDIUM SUBANGULAR BLOCKY ; VERY HARD , FIRM , SLIGHTLY STICKY , SLIGHTLY PLASTIC ; COMMON TO MANY FINE ROOTS BETWEEN PEDS ; MANY FINE TUBULAR CONTINUOUS PORES ; MANY SOFT VERY COARSE INSECT CASTS ; NONCALCAREOUS (HCL) CONTINUOUS ; MODERATELY ALKALINE PH= 8.2 (PHORTHYMOL BLUE) ; CLEAR SMOOTH BOUNDARY .
B 23	56 - 69 CM. (22 - 27 IN.) PALE BROWN (10YR 6/3) CRUSHED ; LOAM ; BROWN (10YR 4/3) CRUSHED MOIST ; VERY WEAK COARSE PRISMATIC STRUCTURE PARTING TO MODERATE SUBANGULAR BLOCKY ; VERY HARD , FIRM , SLIGHTLY STICKY , SLIGHTLY PLASTIC ; COMMON TO MANY FINE ROOTS BETWEEN PEDS ; MANY FINE TUBULAR CONTINUOUS PORES ; MANY SOFT VERY COARSE INSECT CASTS ; MODERATELY EFFERVESCENT (HCL) CONTINUOUS ; MODERATELY ALKALINE PH= 8.2 (PHORTHYMOL BLUE) ; CLEAR SMOOTH BOUNDARY .
B 3CA	69 - 75 CM. (26 - 30 IN.) VERY PALE BROWN (10YR 7/3) CRUSPEC ; VERY FINE SANDY LOAM ; BROWN (10YR 5/3) CRUSHED MOIST ; WEAK MEDIUM SUBANGULAR BLOCKY STRUCTURE ; HARD , FRIABLE , SLIGHTLY STICKY , SLIGHTLY PLASTIC ; FEW FINE ROOTS BETWEEN PEDS ; MANY FINE TUBULAR CONTINUOUS PORES ; MANY PROMINENT CALCIUM CARBONATE CUTANS IN ROOT CHANNELS AND/OR PORES ; COMMON TO MANY SOFT THREAD-LIKE MASSES OF LIME , MANY SOFT VERY COARSE INSECT CASTS ; VIOLENTLY EFFERVESCENT (HCL) DISCONTINUOUS ; STRONGLY ALKALINE PH= 8.8 (PHORTHYMOL BLUE) ; CLEAR SMOOTH BOUNDARY .
C 1CA	75 - 100 CM. (30 - 39 IN.) VERY PALE BROWN (10YR 7/3) CRUSPEC ; VERY FINE SANDY LOAM ; BROWN (10YR 5/3) CRUSHED MOIST ; MASSIVE ; HARD , FRIABLE , SLIGHTLY STICKY , SLIGHTLY PLASTIC ; FEW FINE ROOTS BETWEEN PEDS ; MANY FINE TUBULAR CONTINUOUS PORES ; MANY PROMINENT CALCIUM CARBONATE CUTANS IN ROOT CHANNELS AND/OR PORES ; COMMON TO MANY SOFT THREAD-LIKE MASSES OF LIME , MANY SOFT VERY COARSE INSECT CASTS ; VIOLENTLY EFFERVESCENT (HCL) CONTINUOUS ; STRONGLY ALKALINE PH= 8.8 (PHORTHYMOL BLUE) ; GRADUAL SMOOTH BOUNDARY .
C 2	100 - 145 CM. (39 - 57 IN.) PALE BROWN (10YR 6/3) CRUSHED ; VERY FINE SANDY LOAM ; BROWN (10YR 5/3) CRUSHED MOIST ; MASSIVE ; SLIGHTLY HARD , VERY FRIABLE , SLIGHTLY STICKY , SLIGHTLY PLASTIC ; FEW FINE ROOTS BETWEEN PEDS ; MANY FINE TUBULAR CONTINUOUS PORES ; MILDLY EFFERVESCENT (HCL) CONTINUOUS ; STRONGLY ALKALINE PH= 8.4 (PHORTHYMOL BLUE) ; NOT REACHED BOUNDARY .

REMARKS: SEPT. 11, 1976 SOIL TEMP @23.0 C AT 50 CM. PH OF LOWEST HORIZON WAS 8.8 WITH PHENOL BLUE AND 7.8 WITH DIGITAL PH METER.

Table 36. Site description of Kobar undisturbed soil (Site No. 4).

SOIL SERIES:		FIRRING	
SURVEY SAMPLE NO.:		START 173 4	
LOCATION:	NW 1/4, NE 1/4, SE 1/4, SECT 2 T3N, R41E, 2 MI SE OF COLSTRIP, MT.		
CLASSIFICATION:	ARTOIC ARGIBOROLLS: FINE , PENTHCHILLUNTTIC		
SITE NO.: TH 4	COUNTY:	ELEVATION: 1006 METERS	MONTH SAMPLED: AUGUST
SLOPE: 4	CLASS: NEARLY LEVEL	KIND: CONVEX	ASPECT: NORTHEAST
ATP TEMPERATURE	ANNUAL: 48 DEGREES F	SUMMER: 68 DEGREES F	WINTER: 24 DEGREES F
SOIL TEMPERATURE	ANNUAL: DEGREES F	SUMMER: DEGREES F	WINTER: DEGREES F
WATER TABLE:	DEPTH: CM.	MONTH: AUGUST	KIND: NO WATER TABLE
PRECIPITATION:	40 CM.	CONTROL SECTION LIMITS --	UPPER: 010 CM LOWER: 050 CM
PERMEABILITY:	MODERATELY SLOW	DRAINAGE CLASS: WELL DRAINED	
PHYSIOGRAPHY:	BASINS, EXTERIOR DRAINAGE		STONINESS: CLASS 0
MICRORELIEF:	ON SLOPE AND DEPRESSION		
VEGETATION:	GRASSES AND FORBS AND SHRUBS		
PARENT MATERIAL:	SLIGHTLY WEATHERED RESIDUAL MATERIAL, LOCAL COLLUVIUM OR SOLIFLUCTATE		
	CALCAREOUS SHALE . HORIZONTAL		

HORIZON	PROFILE DESCRIPTION
A 11	0 - 1 CM. (0 - .5 IN.) PALE BROWN (10YR 6/3) CRUSHED : LOAM : BROWN (10YR 4/3) CRUSHED MOIST : WEAK TO MODERATE FINE PLATY STRUCTURE : SLIGHTLY HARD , VERY FRIABLE , SLIGHTLY STICKY , SLIGHTLY PLASTIC : MANY FINE ROOTS : THROUGHOUT HORIZON : MANY FINE VESICULAR PORES : NONCALCAREOUS (HCL) CONTINUOUS : MODERATELY ALKALINE PH= 8.2 (PHENOLPHTHALEIN BLUE) : ARBITRARY BOUNDARY .
A 12	1 - 2 CM. (0 - 1 IN.) PALE BROWN (10YR 6/3) CRUSHED : SILT LOAM : BROWN (10YR 4/3) CRUSHED MOIST : WEAK TO MODERATE FINE PLATY STRUCTURE : HARD , FRIABLE , SLIGHTLY STICKY , SLIGHTLY PLASTIC : MANY FINE ROOTS THROUGHOUT HORIZON , MANY FINE VESICULAR PORES : NONCALCAREOUS (HCL) CONTINUOUS : MODERATELY ALKALINE PH= 8.2 (PHENOLPHTHALEIN BLUE) : ARBITRARY BOUNDARY .
A 13	2 - 5 CM. (1 - 2 IN.) PALE BROWN (10YR 6/3) CRUSHED : SILTY CLAY LOAM : BROWN (10YR 4/3) CRUSHED MOIST : WEAK TO MODERATE FINE PLATY STRUCTURE : HARD , FRIABLE , SLIGHTLY STICKY , PLASTIC : MANY FINE PORES THROUGHOUT HORIZON : COMMON FINE TUBULAR PORES : NONCALCAREOUS (HCL) CONTINUOUS : MODERATELY ALKALINE PH= 8.2 (PHENOLPHTHALEIN BLUE) : ARBITRARY BOUNDARY .
A 14	5 - 10 CM. (2 - 4 IN.) PALE BROWN (10YR 6/3) CRUSHED : SILTY CLAY LOAM : BROWN (10YR 4/3) CRUSHED MOIST : WEAK FINE PLATY STRUCTURE : VERY HARD , FIRM , STICKY , PLASTIC : MANY FINE ROOTS FREQUENT HORIZON : COMMON FINE TUBULAR CONTINUOUS PORES : NONCALCAREOUS (HCL) CONTINUOUS : MODERATELY ALKALINE PH= 8.2 (PHENOLPHTHALEIN BLUE) : ABRUPT WAVY BOUNDARY .
B 21T	10 - 17 CM. (4 - 7 IN.) BROWN (10YR 5/3) CRUSHED : SILTY CLAY : BROWN (10YR 4/3) CRUSHED MOIST : MODERATE FINE PRISMATIC STRUCTURE PARTING TO STRONG FINE (MEDIUM SUBANGULAR BLOCKY : HARD , FIRM , STICKY , VERY PLASTIC : MANY FINE ROOTS THROUGHOUT HORIZON : MANY FINE TUBULAR CONTINUOUS PORES : 40 PERCENT FAINT CLAY SKINS ON PED FACES : NONCALCAREOUS (HCL) CONTINUOUS : MODERATELY ALKALINE PH= 8.2 (PHENOLPHTHALEIN BLUE) : CLEAR SMOOTH BOUNDARY .
B 22T	17 - 41 CM. (7 - 16 IN.) BROWN (10YR 5/3) CRUSHED : SILTY CLAY : BROWN (10YR 4/3) CRUSHED MOIST : MODERATE FINE PRISMATIC STRUCTURE PARTING TO STRONG FINE (MEDIUM SUBANGULAR BLOCKY : HARD , FIRM , STICKY , VERY PLASTIC : COMMON FINE ROOTS BETWEEN PEDS : MANY FINE TUBULAR CONTINUOUS PORES : COMMON FAINT CLAY SKINS ON PED FACES : NONCALCAREOUS (HCL) CONTINUOUS : MODERATELY ALKALINE PH= 8.2 : CLEAR WAVY BOUNDARY .
B 23	41 - 59 CM. (16 - 20 IN.) LT. YELLOWISH BROWN (10YR 6/4) CRUSHED : SILTY CLAY LOAM : YELLOWISH BROWN (10YR 5/4) CRUSHED MOIST : WEAK VERY COARSE PRISMATIC STRUCTURE PARTING TO MODERATE MEDIUM SUBANGULAR BLOCKY : HARD , FIRM , STICKY , PLASTIC : COMMON FINE ROOTS BETWEEN PEDS : MANY FINE TUBULAR CONTINUOUS PORES : COMMON FAINT CLAY SKINS IN POET CHANNELS AND/OR PORES : MODERATELY EFFERVESCENT (HCL) CONTINUOUS ; STRONGLY ALKALINE PH= 9.0 (PHENOLPHTHALEIN BLUE) : GRADUAL SMOOTH BOUNDARY .
B 3	59 - 105 CM. (23 - 41 IN.) VERY PALE BROWN (10YR 7/3) CRUSHED : SILTY CLAY LOAM : YELLOWISH BROWN (10YR 5/4) CRUSHED MOIST : WEAK VERY COARSE PRISMATIC STRUCTURE PARTING TO WEAK COARSE SUBANGULAR BLOCKY : HARD , FRIABLE , SLIGHTLY STICKY , PLASTIC : FEW FINE ROOTS BETWEEN PEDS : COMMON TO MANY FINE TUBULAR CONTINUOUS PORES : FEW FAINT CLAY SKINS IN POET CHANNELS AND/OR PORES : MODERATELY EFFERVESCENT (HCL) CONTINUOUS : STRONGLY ALKALINE PH= 9.0 (PHENOLPHTHALEIN BLUE) : GRADUAL WAVY BOUNDARY .
C 1	105 - 152 CM. (35 - 60 IN.) PALE YELLOW (2.5Y 7/4) CRUSHED : LOAM : LIGHT OLIVE BROWN (2.5Y 5/4) CRUSHED MOIST : PASSIVE : SLIGHTLY HARD , VERY FRIABLE , SLIGHTLY STICKY , SLIGHTLY PLASTIC : FEW FINE ROOTS BETWEEN PEDS : COMMON TO MANY FINE TUBULAR CONTINUOUS PORES : MODERATELY EFFERVESCENT (HCL) CONTINUOUS : STRONGLY ALKALINE PH= 9.0 (PHENOLPHTHALEIN BLUE) : NOT REACHED BOUNDARY .
REMARKS:	AUG 11, 1976 SOIL TEMP =23.0 C AT 50 CM. GYPSUM CRYSTALS LINE SOME IRR VOIDS IN THE C. HORIZON.

Table 37. Site description of Busby undisturbed soil (Site No. 6).

SOIL SERIES: PERRIL

SURVEY SAMPLE NO.: STORY 173 A
LOCATION: SE 1/4, NE 1/4, NE 1/4, SECT 3 TIN, R41E, 1 MI SE OF COLSTRIP, MT.
CLASSIFICATION: USTIC TORRIORTHENTS; LOAMY , MIXED (CALCAREOUS) , FRIGID , SHALLOW

SITE NO.: 76 6 COUNTY: ELEVATION: 1042 METERS MONTH SAMPLED: AUGUST
SLOPE: % CLASS: NEARLY LEVEL KIND: CONCAVE ASPECT: NORTHEAST
AIR TEMPERATURE: ANNUAL: 46 DEGREES F SUMMER: 68 DEGREES F WINTER: 24 DEGREES F
SOIL TEMPERATURE: ANNUAL: DEGREES F SUMMER: DEGREES F WINTER: DEGREES F
WATER TABLE: DEPTH: CM. MONTH: AUGUST KIND: NO WATER TABLE
PRECIPITATION: 549 CM. CONTROL SECTION LIMITS -- UPPER: 025 CM LOWER: 100 CM
PERMEABILITY: MODERATELY RAPID DRAINAGE CLASS: WELL DRAINED
PHYSIOGRAPHY: ROLLING OR HILLY UPLANDS STONINESS: CLASS 0
MICRORELIEF: ON CREST OF HIGH POINT
VEGETATION: GRASSES AND FORBS
PARENT MATERIAL: SLIGHTLY WEATHERED RESIDUAL MATERIAL, LOCAL COLLUVIUM OR SOLIFLUCTATE
CALCAREOUS SANDSTONE

HORIZON	PROFILE DESCRIPTION
A 11	0 - 1 CM. (0 - 0 IN.) BROWN (10YR 5/3) CRUSHED ; SANDY LOAM ; DK. YELLOWISH BROWN (10YR 4/4) CRUSHED MOIST ; WEAK TO MODERATE MEDIUM SUBANGULAR BLOCKY STRUCTURE ; SOFT , VERY FRIABLE , NONSTICKY , NONPLASTIC ; COMMON TO MANY FINE ROOTS THROUGHOUT HORIZON ; MANY FINE IRREGULAR PORES ; MODERATELY EFFERVESCENT (HCL) CONTINUOUS ; MODERATELY ALKALINE PH= 8.4 (BROMTHYMOL BLUE) ; ARBITRARY BOUNDARY .
A 12	1 - 4 CM. (0 - 1 IN.) BROWN (10YR 5/3) CRUSHED ; SANDY LOAM ; DK. YELLOWISH BROWN (10YR 4/4) CRUSHED MOIST ; WEAK TO MODERATE MEDIUM SUBANGULAR BLOCKY CRY STRUCTURE ; SOFT , VERY FRIABLE , NONSTICKY , NONPLASTIC ; COMMON TO MANY FINE ROOTS THROUGHOUT HORIZON ; MANY FINE IRREGULAR PORES ; MODERATELY EFFERVESCENT (HCL) CONTINUOUS ; MODERATELY ALKALINE PH= 8.4 (BROMTHYMOL BLUE) ; ARBITRARY BOUNDARY .
A 13	4 - 5 CM. (1 - 2 IN.) BROWN (10YR 5/3) CRUSHED ; SANDY LOAM ; DK. YELLOWISH BROWN (10YR 4/4) CRUSHED MOIST ; WEAK TO MODERATE MEDIUM SUBANGULAR BLOCKY STRUCTURE ; SOFT , VERY FRIABLE , NONSTICKY , NONPLASTIC ; COMMON TO MANY FINE ROOTS THROUGHOUT HORIZON ; MANY FINE IRREGULAR PORES ; MODERATELY EFFERVESCENT (HCL) CONTINUOUS , MODERATELY ALKALINE PH= 8.4 (BROMTHYMOL BLUE) ; ARBITRARY BOUNDARY .
A 14	5 - 10 CM. (2 - 4 IN.) BROWN (10YR 5/3) CRUSHED ; SANDY LOAM ; DK. YELLOWISH BROWN (10YR 4/4) CRUSHED MOIST ; WEAK TO MODERATE MEDIUM SUBANGULAR BLOCKY ; SOFT , VERY FRIABLE , NONSTICKY , NONPLASTIC ; COMMON TO MANY FINE ROOTS THROUGHOUT HORIZON ; MANY FINE IRREGULAR PORES ; MODERATELY EFFERVESCENT (HCL) CONTINUOUS ; MODERATELY ALKALINE PH= 8.4 (BROMTHYMOL BLUE) ; CLEAR SMOOTH BOUNDARY .
B 21	10 - 25 CM. (4 - 10 IN.) LIGHT OLIVE BROWN (2.5Y 5/4) CRUSHED ; SANDY LOAM ; DK. YELLOWISH BROWN (10YR 4/4) CRUSHED MOIST ; WEAK TO MODERATE MEDIUM SUBANGULAR BLOCKY STRUCTURE ; SOFT , VERY FRIABLE , NONSTICKY , NONPLASTIC ; COMMON FINE ROOTS THROUGHOUT HORIZON ; MANY FINE IRREGULAR PORES ; MODERATELY EFFERVESCENT (HCL) CONTINUOUS ; MODERATELY ALKALINE PH= 8.4 (BROMTHYMOL BLUE) ; CLEAR SMOOTH BOUNDARY .
B 22	25 - 35 CM. (10 - 14 IN.) LIGHT OLIVE BROWN (2.5Y 5/4) CRUSHED ; SANDY LOAM ; DK. YELLOWISH BROWN (10YR 4/4) CRUSHED MOIST ; WEAK TO MODERATE MEDIUM SUBANGULAR BLOCKY STRUCTURE ; SOFT , VERY FRIABLE , NONSTICKY , NONPLASTIC ; COMMON FINE ROOTS THROUGHOUT HORIZON ; MANY FINE IRREGULAR PORES ; VIOLENTLY EFFERVESCENT (HCL) CONTINUOUS ; MODERATELY ALKALINE PH= 8.4 (BROMTHYMOL BLUE) ; CLEAR WAVY BOUNDARY .
C 1	35 - 50 CM. (14 - 20 IN.) LT. YELLOWISH BROWN (2.5Y 6/3) CRUSHED ; LOAMY SAND ; REDDISH BROWN (2.5YR 5/4) CRUSHED MOIST ; MODERATE COARSE PLATY STRUCTURE ; SLIGHTLY HARD , FRIABLE , NONSTICKY , NONPLASTIC ; FEW FINE ROOTS THROUGHOUT HORIZON ; MANY FINE IRREGULAR PORES ; VIOLENTLY EFFERVESCENT (HCL) CONTINUOUS ; MODERATELY ALKALINE PH= 8.4 (BROMTHYMOL BLUE) ; ARBITRARY BOUNDARY .
C 2	50 - 100 CM. (20 - 39 IN.) PALE BROWN (10YR 6/3) CRUSHED ; LOAMY SAND ; YELLOWISH BROWN (10YR 5/4) CRUSHED MOIST ; MODERATE MEDIUM PLATY STRUCTURE ; SLIGHTLY HARD , FRIABLE , NONSTICKY , NONPLASTIC ; FEW FINE ROOTS THROUGHOUT HORIZON ; MANY FINE IRREGULAR PORES ; MODERATELY EFFERVESCENT (HCL) CONTINUOUS ; MODERATELY ALKALINE PH= 8.4 (BROMTHYMOL BLUE) ; GRADUAL SMOOTH BOUNDARY .
C 3	100 - 176 CM. (39 - 69 IN.) LT. YELLOWISH BROWN (10YR 6/4) CRUSHED ; LOAMY SAND ; YELLOWISH BROWN (10YR 5/4) CRUSHED MOIST ; 5% PERCENT SLIGHTLY HARD LOAMY SAND BROWNISH YELLOW (10YR 7/6) CRUSHED STRATIFICATIONS 06 - CM THICK) ; MASSIVE ; SLIGHTLY HARD , FRIABLE , NONSTICKY , NONPLASTIC ; MANY FINE IRREGULAR PORES ; MODERATELY EFFERVESCENT (HCL) CONTINUOUS ; MODERATELY ALKALINE PH= 8.4 (BROMTHYMOL BLUE) ; NOT REACHED BOUNDARY .

REMARKS: AUG 10, 1976 SOIL TEMP +22.0 C AT 50 CM. SOIL TEMP AT 176 CM +18.5 C. STRUCTUR
E OF C1 HORIZON IS RELATED TO BEDDING OF THE SANDSTONE BEDROCK. STRATIFICATIONS
IN THE C2 ARE INHERITED FROM BEDROCK. THE C3 HORIZON IS SIMILAR TO A PARALITHI
C CONTACT EXCEPT THAT IT IS PERMEABLE AND MAY HOLD AVAILABLE WATER. HOWEVER, RO
OTS CANNOT PENETRATE. THYMOL BLUE INDICATOR GIVES PH VALUES 0.9 TO 1.0 HIGHER T
HAN REFER.

Table 38. Site description of Busby undisturbed soil (Site No. 8).

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SOIL SERIES:                                  CHINOOK

SURVEY SAMPLE NO.:                            SEPT   173  8
LOCATION:       NW 1/4, NW 1/4, NW 1/4, SEC 2 T1N, R21E, 1 MI SE OF COLSTRIP, MT.
CLASSIFICATION: SPINEC   HAPLOBOROLLS; COARSE-LOAMY ,  MIXED

SITE NO.: 78  P   COUNTY:                     ELEVATION: 1015 METERS          MONTH SAMPLED: AUGUST
SLOPE:        3   CLASS:   STRONGLY SLOPING   KIND:      CONCAVE             ASPECT:  SOUTHWEST
MAP TEMPERATURE   ANNUAL:  46 DEGREES F       SUMMER:  68 DEGREES F        WINTER:  24 DEGREES F
SOIL TEMPERATURE  ANNUAL:    DEGREES F        SUMMER:    DEGREES F         WINTER:    DEGREES F
WATER TABLE:      DEPTH:     CM.              MONTH:   AUGUST              KIND:    NO WATER TABLE
PRECIPITATION:    343 CM.                     CONTROL SECTION LIMITS --    UPPER: 025 CM  LOWER: 100 CM
PERMEABILITY:     MODERATELY RAPID            DRAINAGE CLASS:  WELL DRAINED
PHYSIOGRAPHY:     ROLLING OR HILLY UPLANDS                                 STONINESS: CLASS 0
MICRORELIEF:      ON SLOPE
VEGETATION:       GRASSES AND FORBS
PARENT MATERIAL:  SLIGHTLY   WEATHERED   RESIDUAL MATERIAL, LOCAL COLLUVIUM OR SOLIFLUCTATE
                  CALCAREOUS SANDSTONE
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HORIZON	PROFILE DESCRIPTION
A 11	0 - 1 CM. (0 - 0 IN.) GRAYISH BROWN (10YR 5/2) CRUSHED ; SANDY LOAM ; V DK GRAYISH BROWN (10YR 3/2) CRUSHED MOIST ; 10 PERCENT SOFT SANDY LOAM GRAYISH BROWN (10YR 5/2) CRUSHED KROTOVINAS 15 - CM THICK) ; MODERATE COARSE PLATY STRUCTURE ; SOFT , VERY FRIABLE , NONSTICKY , NONPLASTIC ; COMMON FINE ROOTS THROUGHOUT HORIZON ; MANY FINE IRREGULAR PORES ; NONCALCAREOUS (HCL) DISCONTINUOUS ; MODERATELY ALKALINE PH- 8.0 (BROMTHYMOL BLUE) ; ARBITRARY BOUNDARY .
A 12	1 - 2 CM. (0 - 1 IN.) BROWN (10YR 5/3) CRUSHED ; SANDY LOAM ; V DK GRAYISH BROWN (10YR 3/2) MOIST ; 10 PERCENT SOFT SANDY LOAM VERY DARK GRAY (10YR 3/1) EXTERIOR KROTOVINAS 15 - CM THICK) ; MODERATE COARSE PLATY STRUCTURE ; SOFT , VERY FRIABLE , NONSTICKY , NONPLASTIC ; COMMON FINE ROOTS THROUGHOUT HORIZON ; MANY FINE IRREGULAR PORES , MANY PORES ; NONCALCAREOUS (HCL) CONTINUOUS ; MODERATELY ALKALINE PH- 8.0 (BROMTHYMOL BLUE) ; ARBITRARY BOUNDARY .
A 13	2 - 5 CM. (1 - 2 IN.) GRAYISH BROWN (10YR 5/2) CRUSHED ; SANDY LOAM ; V DK GRAYISH BROWN (10YR 3/2) CRUSHED MOIST ; 10 PERCENT SOFT SANDY LOAM (GRAYISH BROWN (10YR 5/2) (BROKEN KROTOVINAS 15 - CM THICK) ; MODERATE COARSE PLATY STRUCTURE ; SOFT , VERY FRIABLE , NONSTICKY , NONPLASTIC ; COMMON FINE ROOTS THROUGHOUT HORIZON ; MANY FINE IRREGULAR PORES ; NONCALCAREOUS (HCL) CONTINUOUS ; MODERATELY ALKALINE PH- 8.0 (BROMTHYMOL BLUE) ; ABRUPT WAVY BOUNDARY .
A 14	5 - 10 CM. (2 - 4 IN.) BROWN (10YR 5/3) CRUSHED ; SANDY LOAM ; DARK BROWN (10YR 3/3) CRUSHED MOIST ; 10 PERCENT SOFT SANDY LOAM (BROWN (10YR 5/3) CRUSHED KROTOVINAS 15 - CM THICK) ; MODERATE COARSE PLATY STRUCTURE ; SLIGHTLY HARD , NONSTICKY , VERY FRIABLE , NONPLASTIC ; COMMON FINE SLOTS THROUGHOUT HORIZON ; MANY FINE IRREGULAR PORES ; NONCALCAREOUS (HCL) CONTINUOUS ; MODERATELY ALKALINE PH- 8.0 (BROMTHYMOL BLUE) ; ABRUPT WAVY BOUNDARY .
B 21	10 - 25 CM. (4 - 10 IN.) YELLOWISH BROWN (10YR 5/4) CRUSHED ; SANDY LOAM ; BROWN (10YR 4/3) CRUSHED MOIST ; 10 PERCENT SOFT SANDY LOAM YELLOWISH BROWN (10YR 5/4) CRUSHED KROTOVINAS 15 - CM THICK) ; VERY WEAK COARSE PRISMATIC STRUCTURE AND WEAK COARSE SUBANGULAR BLOCKY ; HARD , VERY FRIABLE , NONSTICKY , NONPLASTIC ; COMMON FINE ROOTS THROUGHOUT HORIZON ; MANY FINE IRREGULAR PORES ; NONCALCAREOUS (HCL) CONTINUOUS ; MODERATELY ALKALINE PH- 8.0 (BROMTHYMOL BLUE) ; CLEAR WAVY BOUNDARY .
B 22	25 - 50 CM. (10 - 20 IN.) YELLOWISH BROWN (10YR 5/4) CRUSHED ; SANDY LOAM ; DK. YELLOWISH BROWN (10YR 4/4) CRUSHED MOIST ; 10 PERCENT SOFT SANDY LOAM YELLOWISH BROWN (10YR 5/4) CRUSHED KROTOVINAS 15 - CM THICK) ; VERY WEAK COARSE PRISMATIC STRUCTURE AND WEAK COARSE SUBANGULAR BLOCKY ; HARD , VERY FRIABLE , NONSTICKY , NONPLASTIC ; COMMON FINE ROOTS THROUGHOUT HORIZON ; MANY FINE IRREGULAR PORES ; NONCALCAREOUS (HCL) DISCONTINUOUS ; MODERATELY ALKALINE PH- 8.0 (BROMTHYMOL BLUE) ; ABRUPT BROKEN BOUNDARY .
C 11CA	50 - 100 CM. (20 - 39 IN.) PALE BROWN (10YR 6/3) CRUSHED ; SANDY LOAM ; YELLOWISH BROWN (10YR 5/4) CRUSHED MOIST ; VERY WEAK COARSE SUBANGULAR BLOCKY STRUCTURE ; HARD , VERY FRIABLE , NONSTICKY , NONPLASTIC ; FEW TO COMMON FINE ROOTS THROUGHOUT HORIZON ; MANY FINE IRREGULAR PORES , COMMON FINE TUBULAR PORES ; COMMON SOFT THREAD-LIKE MASSES OF LIME ; MODERATELY EFFERVESCENT (HCL) CONTINUOUS ; STRONGLY ALKALINE PH- 8.6 (BROMTHYMOL BLUE) ; GRADUAL SMOOTH BOUNDARY .
C 2CA	100 - 150 CM. (39 - 59 IN.) VERY PALE BROWN (10YR 7/3) CRUSHED ; SANDY LOAM ; YELLOWISH BROWN (10YR 5/4) CRUSHED MOIST ; VERY WEAK COARSE SUBANGULAR BLOCKY STRUCTURE ; HARD , VERY FRIABLE , NONSTICKY , NONPLASTIC ; FEW FINE ROOTS THROUGHOUT HORIZON ; MANY FINE TUBULAR PORES ; COMMON SOFT THREAD-LIKE MASSES OF LIME ; MODERATELY EFFERVESCENT (HCL) CONTINUOUS ; STRONGLY ALKALINE PH- 8.6 (BROMTHYMOL BLUE) ; DIFFUSE SMOOTH BOUNDARY .
C 3	150 - 200 CM. (59 - 79 IN.) VERY PALE BROWN (10YR 7/3) CRUSHED ; SANDY LOAM ; YELLOWISH BROWN (10YR 5/4) CRUSHED MOIST ; MASSIVE ; HARD , VERY FRIABLE , NONSTICKY , NONPLASTIC ; FEW FINE ROOTS THROUGHOUT HORIZON ; MANY FINE IRREGULAR PORES ; MODERATELY EFFERVESCENT (HCL) CONTINUOUS ; MODERATELY ALKALINE PH- 8.4 (BROMTHYMOL BLUE) ; NOT REACHED BOUNDARY .

REMARKS: AUG 10, 1976 SOIL TEMP 22.0 C AT 50 CM. MEDIUM TARGETS AT 3 FOOT SPACINGS PE
NITRATE TO 1.5 METERS.

Table 39. Site description of 1924 old spoil (Site No. 5).

SOIL SERIES: 1924 SPOILS

SURVEY SAMPLE NO.: 0 173 S
LOCATION: NE 1/4, SE 1/4, NE 1/4, SECT 3 T1N, R41E, 1 MI SE OF COLSTRIP, MT.
CLASSIFICATION:

SITE NO.: 0 5 | COUNTY: SEE REMARKS | ELEVATION: 3010 METERS | MONTH SAMPLED: AUGUST
SLOPE: % | CLASS: NEARLY LEVEL | KIND: PLANE | ASPECT:
AIR TEMPERATURE: | ANNUAL: 44 DEGREES F | SUMMER: 68 DEGREES F | WINTER: 24 DEGREES F
SOIL TEMPERATURE | ANNUAL: DEGREES F | SUMMER: DEGREES F | WINTER: DEGREES F
WATER TABLE: | DEPTH: CM. | MONTH: AUGUST | KIND: NO WATER TABLE
PRECIPITATION: | 340 CM. | CONTROL SECTION LIMITS -- | UPPER: 025 CM LOWER: 100 CM
PERMEABILITY: | RAPID | DRAINAGE CLASS: SOMEWHAT EXCESSIVELY DRAINED
PHYSIOGRAPHY: | ROLLING OR HILLY UPLANDS | STONINESS: CLASS 0
VEGETATION: | GRASSES AND FORBS AND SHRUBS
PARENT MATERIAL: | SLIGHTLY WEATHERED UNCONSOLIDATED MINERAL SEDIMENTS
CALCAREOUS SANDSTONE AND CALCAREOUS SILTSTONE

HORIZON	PROFILE DESCRIPTION
A 11	0 - 1 CM. (0 - 0 IN.) BROWN (10YR 4/3) CRUSHED ; LOAMY FINE SAND ; BROWN (10YR 4/3) CRUSHED MOIST ; WEAK FINE PLATY STRUCTURE PARTING TO WEAK FINE GRANULAR ; SOFT , VERY FRIABLE , NONSTICKY , NONPLASTIC ; MANY FINE ROOTS THROUGHOUT HORIZON ; MANY FINE IRREGULAR PORES ; MILDLY EFFERVESCENT (HCL) CONTINUOUS ; MODERATELY ALKALINE PH= 8.0 (PHENOLPHTHALEIN BLUE) ; ABRUPT BOUNDARY .
A 12	1 - 2 CM. (0 - 1 IN.) BROWN (10YR 4/3) CRUSHED ; LOAMY FINE SAND ; BROWN (10YR 4/3) CRUSHED MOIST ; WEAK FINE PLATY STRUCTURE PARTING TO WEAK FINE GRANULAR ; SOFT , VERY FRIABLE , NONSTICKY , NONPLASTIC ; MANY FINE ROOTS THROUGHOUT HORIZON ; MANY FINE IRREGULAR PORES ; MODERATELY EFFERVESCENT (HCL) CONTINUOUS ; MODERATELY ALKALINE PH= 8.2 (PHENOLPHTHALEIN BLUE) ; ABRUPT BOUNDARY .
A 13	2 - 5 CM. (1 - 2 IN.) BROWN (10YR 5/3) CRUSHED ; LOAMY FINE SAND ; BROWN (10YR 4/3) CRUSHED MOIST ; WEAK FINE PLATY, STRUCTURE PARTING TO WEAK FINE GRANULAR ; SOFT , VERY FRIABLE , NONSTICKY , NONPLASTIC ; MANY FINE ROOTS THROUGHOUT HORIZON ; MANY FINE IRREGULAR PORES ; MODERATELY EFFERVESCENT (HCL) CONTINUOUS ; MODERATELY ALKALINE PH= 8.4 ; ABRUPT SMOOTH BOUNDARY .
O 14	5 - 10 CM. (2 - 4 IN.) LIGHT BROWNISH GRAY (2.5Y 6/2) CRUSHED ; FINE SANDY LOAM ; LIGHT OLIVE BROWN (2.5Y 5/3) CRUSHED MOIST ; MODERATE MEDIUM PLATY STRUCTURE ; SOFT , VERY FRIABLE , NONSTICKY , NONPLASTIC ; MANY FINE ROOTS THROUGHOUT HORIZON ; MANY FINE IRREGULAR PORES ; MODERATELY EFFERVESCENT (HCL) CONTINUOUS ; STRONGLY ALKALINE PH= 8.8 (PHENOLPHTHALEIN BLUE) ; ABRUPT WAVY BOUNDARY .
C 1	10 - 29 CM. (4 - 8 IN.) LIGHT GRAY (2.5Y 7/2) CRUSHED ; FINE SANDY LOAM ; GRAYISH BROWN (2.5Y 5/2) CRUSHED MOIST ; FEW FINE PREHISTORIC STRONG BROWN (7.5YR 5/8) CRUSHED MOTTLES ; 20 PERCENT SLIGHTLY HARD ; FINE SANDY LOAM PALE BROWN (10YR 6/3) CRUSHED BANDS 20 - 28 CM THICK) ; MODERATE MEDIUM PLATY STRUCTURE ; SLIGHTLY HARD , VERY FRIABLE , NONSTICKY , NONPLASTIC ; MANY FINE ROOTS BETWEEN PEDS ; COMMON FINE IRREGULAR PORES ; VIOLENTLY EFFERVESCENT (HCL) CONTINUOUS ; STRONGLY ALKALINE PH= 8.8 (PHENOLPHTHALEIN BLUE) ; CLEAR WAVY BOUNDARY .
C 2	29 - 57 CM. (8 - 20 IN.) LIGHT GRAY (2.5Y 7/2) CRUSHED ; FINE SANDY LOAM ; GRAYISH BROWN (2.5Y 5/2) CRUSHED MOIST ; 40 PERCENT VERY HARD FINE SANDY LOAM BROWN (10YR 5/3) CRUSHED BANDS 28 - 38 CM THICK) ; PASSIVE ; SLIGHTLY HARD , VERY FRIABLE , NONSTICKY , NONPLASTIC ; COMMON FINE ROOTS THROUGHOUT HORIZON ; MANY FINE IRREGULAR PORES ; FEW SANDSTONE FRAGMENTS 32 CM ; VIOLENTLY EFFERVESCENT (HCL) CONTINUOUS ; STRONGLY ALKALINE PH= 8.8 (PHENOLPHTHALEIN BLUE) ; SMOOTH WAVY .
C 3	57 - 100 CM. (20 - 39 IN.) LIGHT GRAY (2.5Y 7/2) CRUSHED ; FINE SANDY LOAM ; GRAYISH BROWN (2.5Y 5/2) CRUSHED MOIST ; BROWN (10YR 5/3) CRUSHED ; DARK BROWN (10YR 4/3) CRUSHED MOIST ; 30 PERCENT VERY HARD FINE SANDY LOAM BROWN (10YR 4/3) CRUSHED BANDS OF CONTRASTING MATERIALS - CM THICK) ; PASSIVE ; SLIGHTLY HARD , VERY FRIABLE , NONSTICKY , NONPLASTIC ; COMMON FINE ROOTS THROUGHOUT HORIZON ; MANY FINE IRREGULAR PORES ; VIOLENTLY EFFERVESCENT (HCL) CONTINUOUS ; STRONGLY ALKALINE PH= 8.8 ; ABRUPT BOUNDARY .
C 4	100 - 200 CM. (39 - 79 IN.) LIGHT GRAY (2.5Y 7/2) CRUSHED ; FINE SANDY LOAM ; GRAYISH BROWN (2.5Y 5/2) CRUSHED MOIST ; 30 PERCENT SLIGHTLY HARD FINE SANDY LOAM PALE BROWN (10YR 6/3) CRUSHED BANDS 20 - CM THICK) ; PASSIVE ; SOFT , FRIABLE , NONSTICKY , NONPLASTIC ; COMMON FINE ROOTS THROUGHOUT HORIZON ; MANY FINE IRREGULAR PORES ; VIOLENTLY EFFERVESCENT (HCL) CONTINUOUS ; STRONGLY ALKALINE PH= 8.8 (PHENOLPHTHALEIN BLUE) ; NOT REACHED BOUNDARY .

REMARKS: SKIP-MINE SPOILS NEAR COLSTRIP, MONTANA RELEVELED IN 1924, AUG. 16, 1976. SOIL TEMP 22.0 C AT 50 CM. INCONSISTENT BANDS OF AL MATERIAL OCCUR IN CERVEX UPWARD IN SHAPE AT 10-40 CM IN DEPTH. THESE EXPERIMENTAL STRUCTURES ARE 45 CM WIDE, 15 CM HIGH AND ARE ORIENTED NORMAL TO THE DIRECTION THE SPOIL PLATFORM WAS BUILT. THE BANDS OTHER SURFACE MATERIAL OF DIFFERING LITHOLOGY. MUNSELL HUES INDICATE - GIVES PH VALUES 8.4 TO 8.7 UNITS HIGHER THAN NITRA. PLANT ROOTS IN CI GREW HOR IZONTALLY IN STRUCTURAL VOIDS UNTIL ENCOUNTERING A VERTICAL VOID LARGE ENOUGH FOR DO WNWARD GROWTH.

Table 40. Site description of 1924 old spoil (Site No. 7).

SOIL SERIES: 1924 SPOILS

SURVEY SAMPLE NO.: 0 179 7
LOCATION: NE 1/4, NE 1/4, NE 1/4, SEC 3 T1N R4E, 1 MI SE OF COLSTRIP, MT
CLASSIFICATION:

SITE NO.: 0 7 | COUNTY: SEE REMARKS | ELEVATION: 1630 METERS | MONTH SAMPLED: AUGUST
SLOPE: & | CLASS: NEARLY LEVEL | FIND: PLANE | ASPECT: WEST
AIR TEMPERATURE | ANNUAL: 46 DEGREES F | SUMMER: 68 DEGREES F | WINTER: 24 DEGREES F
SOIL TEMPERATURE | ANNUAL: DEGREES F | SUMMER: DEGREES F | WINTER: DEGREES F
WATER TABLE: | DEPTH: CM. | MONTH: AUGUST | KIND: AC WATER TABLE
PRECIPITATION: | MAP CM. | CONTROL SECTION LIMITS -- | UPPER: 025 CM LOWER: 100 CM
PERMEABILITY: | RAPID | DRAINAGE CLASS: SOMEWHAT EXCESSIVELY DRAINED
PHYSIOGRAPHY: | ROLLING OR HILLY UPLANDS | STONINESS: CLASS 0
VEGETATION: | GRASSES AND FORBS AND SHRUBS
PARENT MATERIAL: | SLIGHTLY WEATHERED UNCONSOLIDATED MINERAL SEDIMENTS
CALCAREOUS SANDSTONE

HORIZON	PROFILE DESCRIPTION
A 11	0 - 1 CM. (0 - 0 IN.) BROWN (10YR 5/3) CRUSHED ; SANDY LOAM ; BROWN (10YR 4/3) CRUSHED MOIST ; MASSIVE ; SOFT , VERY FRIABLE , NONSTICKY , NONPLASTIC ; MANY FINE ROOTS THROUGHOUT HORIZON ; MANY FINE IRREGULAR PORES ; MODERATELY EFFERVESCENT (HCL) CONTINUOUS ; MODERATELY ALKALINE PH= 8.2 (BROMTHYMOL BLUE) ; ARBITRARY BOUNDARY .
A 12	1 - 2 CM. (0 - 1 IN.) PALE BROWN (10YR 6/3) CRUSHED ; SANDY LOAM ; BROWN (10YR 4/3) CRUSHED MOIST ; WEAK TO MODERATE FINE PLATY STRUCTURE ; LOOSE , LOOSE NONSTICKY , NONPLASTIC ; MANY FINE ROOTS THROUGHOUT HORIZON ; MANY FINE IRREGULAR PORES ; MODERATELY EFFERVESCENT (HCL) CONTINUOUS ; MODERATELY ALKALINE PH= 8.4 (BROMTHYMOL BLUE) ; ARBITRARY BOUNDARY .
A 13	2 - 5 CM. (1 - 2 IN.) PALE BROWN (10YR 6/3) CRUSHED ; SANDY LOAM ; BROWN (10YR 4/3) CRUSHED MOIST ; WEAK TO MODERATE COARSE PLATY STRUCTURE ; SOFT , VERY FRIABLE , NONSTICKY , NONPLASTIC ; MANY FINE ROOTS THROUGHOUT HORIZON ; MANY FINE IRREGULAR PORES ; MODERATELY EFFERVESCENT (HCL) CONTINUOUS ; MODERATELY ALKALINE PH= 8.4 (BROMTHYMOL BLUE) ; ARBITRARY BOUNDARY .
A 14	5 - 10 CM. (2 - 4 IN.) PALE BROWN (10YR 6/3) CRUSHED ; SANDY LOAM ; BROWN (10YR 4/3) CRUSHED MOIST , WEAK TO MODERATE COARSE PLATY STRUCTURE ; SOFT , VERY FRIABLE , NONSTICKY , NONPLASTIC ; MANY FINE ROOTS THROUGHOUT HORIZON ; MANY FINE IRREGULAR PORES ; MODERATELY EFFERVESCENT (HCL) CONTINUOUS ; STRONGLY ALKALINE PH= 8.6 (BROMTHYMOL BLUE) ; ABRUPT WAVY BOUNDARY .
C 1	10 - 29 CM. (4 - 8 IN.) PALE RED (2.5YR 7/2) CRUSHED ; SANDY LOAM ; GRAYISH BROWN (10YR 5/2) CRUSHED MOIST ; PALE BROWN (10YR 6/3) CRUSHED ; YELLOWISH BROWN (10YR 5/4) CRUSHED MOIST ; FEW MEDIUM PROMINENT BROWNISH YELLOW (10YR 6/6) CRUSHED MOTTLES ; MODERATE MEDIUM & COARSE PLATY STRUCTURE ; SOFT , VERY FRIABLE , NONSTICKY , NONPLASTIC ; COMMON TO MANY FINE ROOTS THROUGHOUT HORIZON ; MANY FINE IRREGULAR PORES ; VIOLENTLY EFFERVESCENT (HCL) CONTINUOUS ; STRONGLY ALKALINE PH= 8.6 (BROMTHYMOL BLUE) ; ABRUPT WAVY BOUNDARY .
C 2	29 - 50 CM. (8 - 20 IN.) PALE BROWN (10YR 6/3) CRUSHED ; SANDY LOAM ; YELLOWISH BROWN (10YR 5/4) CRUSHED MOIST ; PALE RED (2.5YR 7/2) CRUSHED ; REDDISH BROWN (2.5YR 5/3) CRUSHED MOIST ; 10 PERCENT VERY HARD SANDY LOAM Y OR GRAYISH BROWN (10YR 3/2) CRUSHED MOIST POCKETS OR CONTRASTING MATERIAL 20 - CM THICK) ; MASSIVE ; SLIGHTLY HARD , FRIABLE , NONSTICKY , NONPLASTIC ; FEW FINE ROOTS THROUGHOUT HORIZON ; MANY FINE IRREGULAR PORES ; FEW SANDSTONE FRAGMENTS >2 CM ; VIOLENTLY EFFERVESCENT (HCL) CONTINUOUS ; STRONGLY ALKALINE PH= 8.8 (BROMTHYMOL BLUE) ; ABRUPT WAVY BOUNDARY .
C 3	50 - 100 CM. (20 - 39 IN.) PALE BROWN (10YR 6/3) CRUSHED ; SANDY LOAM ; YELLOWISH BROWN (10YR 5/4) CRUSHED MOIST ; 10 PERCENT VERY HARD SANDY LOAM BROWN (10YR 4/3) CRUSHED POCKETS OR CONTRASTING MATERIAL 20 - CM THICK) ; MASSIVE ; SLIGHTLY HARD , FRIABLE , NONSTICKY , NONPLASTIC ; FEW FINE ROOTS THROUGHOUT HORIZON ; MANY FINE IRREGULAR PORES ; VIOLENTLY EFFERVESCENT (HCL) CONTINUOUS ; STRONGLY ALKALINE PH= 8.8 (BROMTHYMOL BLUE) ; ARBITRARY BOUNDARY .
C 4	100 - 200 CM. (39 - 79 IN.) LT. YELLOWISH BROWN (10YR 6/4) CRUSHED ; SANDY LOAM ; YELLOWISH BROWN (10YR 5/4) CRUSHED MOIST ; MASSIVE ; SLIGHTLY HARD , FRIABLE , NONSTICKY , NONPLASTIC ; FEW FINE ROOTS THROUGHOUT HORIZON ; MANY FINE IRREGULAR PORES ; VIOLENTLY EFFERVESCENT (HCL) CONTINUOUS ; STRONGLY ALKALINE PH= 8.8 (BROMTHYMOL BLUE) ; ARBITRARY BOUNDARY .

REMARKS: STRIP-MINE SPOILS NEAR COLSTRIP, MONTANA LEVELED IN 1974. AUG 10, 1976 SOIL TEMP. = 22.0 C AT 50 CM. COMMON POCKETS OF INHERITED A1 MATERIAL WHICH IS SLIGHTLY HEAVIER IN TEXTURE. ROOTS PROLIFERATE IN BURIED A1 POCKETS. GRAY SANDSTONE IN C1 AND C2 HAS HARD CONSISTENCE. 1-48 SHALE AND SILTSTONE IN C3. INTERMITTENT CONVEX-UPWARDS BAND OF A1 MATERIAL 90 CM WIDE AND 15 CM HIGH OCCUR AS DEPOSITIONAL FEATURES. PROMINENT DIAGONAL SHEAR PLANES PARALLEL TO THE OUTSIDE EDGE OF THE SPOIL PLATFORM MAY REPRESENT THE FORMER EXTENT OF THE SPOIL PLATFORM DURING DEPOSITION. PLATY STRUCTURE NEAR THE SURFACE MAY BE DUE TO COMPACTION BY HORSES HAU

Table 41. Site description of 1924 old spoil (Site No. 9).

SOIL SERIES: 1924 SPOILS

SURVEY SAMPLE NO.: C 179 9
LOCATION: SE 1/4, NW 1/4, SW 1/4, SECT 35, T2N, R41E, 1 MI SE OF COLSTRIP, MT
CLASSIFICATION:

SITE NO.: 9	COUNTY: SEE REMARKS	ELEVATION: 1017 METERS	MONTH SAMPLED: AUGUST
SLOPE: 4	CLASS: NEARLY LEVEL	KIND: PLANE	ASPECT:
AIR TEMPERATURE:	ANNUAL: 46 DEGREES F	SUMMER: 68 DEGREES F	WINTER: 24 DEGREES F
SOIL TEMPERATURE:	ANNUAL: DEGREES F	SUMMER: DEGREES F	WINTER: DEGREES F
WATER TABLE:	DEPTH: CM.	MONTH: AUGUST	KIND: NO WATER TABLE
PRECIPITATION:	340 CM.	CONTROL SECTION LIMITS --	UPPER: 025 CM LOWER: 100 CM
PERMEABILITY:	RAPID	DRAINAGE CLASS: SOMEWHAT EXCESSIVELY DRAINED	
PHYSIOGRAPHY:	ROLLING OR HILLY UPLANDS		STONINESS: CLASS 0
VEGETATION:	GRASSES AND FORBS		
PARENT MATERIAL:	SLIGHTLY WEATHERED CALCAREOUS SANDSTONE	UNCONSOLIDATED MINERAL SEDIMENTS AND CALCAREOUS SILTSTONE	

HORIZON	PROFILE DESCRIPTION
A 11	0 - 1 CM. (0 - 0 IN.) LIGHT BROWNISH GRAY (2.5Y 6/2) CRUSHED : LOAMY SAND : DARK GRAYISH BROWN (2.5Y 4/2) CRUSHED MOIST : MASSIVE : SOFT , VERY FRIABLE , NONSTICKY , NONPLASTIC : COMMON FINE ROOTS THROUGHOUT HORIZON : MANY FINE VESICULAR PORES : MILDLY EFFERVESCENT (HCL) CONTINUOUS : MILDLY ALKALINE PH= 7.6 : ARBITRARY BOUNDARY .
A 12	1 - 2 CM. (0 - 1 IN.) LIGHT BROWNISH GRAY (2.5Y 6/2) CRUSHED : LOAMY SAND : WEAK MEDIUM & COARSE PLATY STRUCTURE PARTING TO MODERATE VERY FINE PLATY : SLIGHTLY HARD , FRIABLE , NONSTICKY , NONPLASTIC : COMMON FINE ROOTS THROUGHOUT HORIZON : MANY FINE IRREGULAR PORES , FINE PORES : MODERATELY EFFERVESCENT (HCL) CONTINUOUS : MODERATELY ALKALINE PH= 8.2 ARBITRARY BOUNDARY .
A 13	2 - 5 CM. (1 - 2 IN.) LIGHT BROWNISH GRAY (2.5Y 6/2) CRUSHED : LOAMY SAND : DARK GRAYISH BROWN (2.5Y 4/2) CRUSHED MOIST : WEAK MEDIUM & COARSE PLATY STRUCTURE PARTING TO MODERATE VERY FINE PLATY : SLIGHTLY HARD , VERY FRIABLE , NONSTICKY , NONPLASTIC : COMMON FINE ROOTS THROUGHOUT HORIZON : MANY FINE IRREGULAR PORES : MODERATELY EFFERVESCENT (HCL) CONTINUOUS : MODERATELY ALKALINE PH= 8.2 : GRADUAL WAVY BOUNDARY .
AC 1	5 - 12 CM. (2 - 4 IN.) LIGHT BROWNISH GRAY (2.5Y 6/2) CRUSHED : LOAMY SAND : DARK GRAYISH BROWN (2.5Y 4/2) CRUSHED MOIST : WEAK VERY COARSE PLATY STRUCTURE : SLIGHTLY HARD , VERY FRIABLE , NONSTICKY , NONPLASTIC : COMMON FINE ROOTS THROUGHOUT HORIZON : MANY FINE IRREGULAR PORES : 10 PERCENT SANDSTONE FRAGMENTS >2 CM : MODERATELY EFFERVESCENT (HCL) CONTINUOUS : MODERATELY ALKALINE PH= 8.2 : ARBITRARY BOUNDARY .
AC 2	12 - 15 CM. (4 - 6 IN.) LIGHT GRAY (2.5Y 7/2) CRUSHED : LOAMY SAND : LIGHT BROWNISH GRAY (2.5Y 6/2) CRUSHED MOIST : WEAK VERY COARSE PLATY STRUCTURE : SLIGHTLY HARD , VERY FRIABLE , NONSTICKY , NONPLASTIC : COMMON FINE ROOTS THROUGHOUT HORIZON : MANY FINE IRREGULAR PORES : 10 PERCENT SANDSTONE FRAGMENTS >2 CM : MODERATELY EFFERVESCENT (HCL) CONTINUOUS : MODERATELY ALKALINE PH= 8.2 : GRADUAL WAVY BOUNDARY .
C 1	15 - 50 CM. (6 - 20 IN.) LIGHT GRAY (2.5Y 7/2) CRUSHED : LOAMY SAND : LIGHT BROWNISH GRAY (2.5Y 6/2) CRUSHED MOIST : LIGHT BROWNISH GRAY (2.5Y 6/2) CRUSHED : DARK GRAYISH BROWN (2.5Y 4/2) CRUSHED MOIST : FEW FINE & MEDIUM PROMINENT REDDISH YELLOW (7.5YR 6/8) CRUSHED MOTTLES : 40 PERCENT VERY HARD LOAMY SAND LIGHT GRAY (10YR 7/2) CRUSHED POCKETS OR CONTRASTING MATERIALS (- CM THICK) : MASSIVE : SLIGHTLY HARD , VERY FRIABLE , NONSTICKY , NONPLASTIC : FEW FINE ROOTS THROUGHOUT HORIZON : MANY FINE IRREGULAR PORES : 30 PERCENT SANDSTONE FRAGMENTS >2 CM , 20 PERCENT SILTSTONE FRAGMENTS : MODERATELY EFFERVESCENT (HCL) CONTINUOUS : MODERATELY ALKALINE PH= 8.2 : CLEAR WAVY BOUNDARY .
C 2	50 - 100 CM. (20 - 39 IN.) LIGHT BROWNISH GRAY (2.5Y 6/2) CRUSHED : LOAMY SAND : DARK GRAYISH BROWN (2.5Y 4/2) CRUSHED MOIST : LIGHT GRAY (2.5Y 7/2) CRUSHED : LIGHT BROWNISH GRAY (2.5Y 6/2) CRUSHED MOIST : 10 PERCENT VERY HARD LOAMY SAND BROWN (10YR 4/3) CRUSHED POCKETS OR CONTRASTING MATERIALS (- CM THICK) : MASSIVE : SLIGHTLY HARD , VERY FRIABLE , NONSTICKY , NONPLASTIC : FEW FINE ROOTS THROUGHOUT HORIZON : MANY FINE IRREGULAR PORES : 30 PERCENT SANDSTONE FRAGMENTS >2 CM : MODERATELY EFFERVESCENT (HCL) CONTINUOUS : MODERATELY ALKALINE PH= 8.2 : ARBITRARY BOUNDARY .
C 3	100 - 200 CM. (39 - 79 IN.) LIGHT BROWNISH GRAY (2.5Y 6/2) CRUSHED : LOAMY SAND : DARK GRAYISH BROWN (2.5Y 4/2) CRUSHED MOIST : MASSIVE : SLIGHTLY HARD , VERY FRIABLE , NONSTICKY , NONPLASTIC : FEW FINE ROOTS THROUGHOUT HORIZON : MANY FINE IRREGULAR PORES : 30 PERCENT SANDSTONE FRAGMENTS >2 CM : MODERATELY EFFERVESCENT (HCL) CONTINUOUS : MODERATELY ALKALINE PH= 8.2 : NOT REACHED BOUNDARY .

REMARKS: STRIP-MINE SPOILS NEAR COLSTRIP, MONTANA LEVELED IN 1924. AUG 9, 1976 SOIL TEMP = 74.0 C AT 50 CM. 14 RARE SANDSTONE FRAGMENTS THROUGHOUT THE PROFILE UP TO 3.0 CM. INTERMITTENT CONVEX-UPWARDS BANDS OF A1 MATERIAL 50 CM WIDE AT 15 CM HIGH OCCUR AS DEPOSITIONAL FEATURES. PROMINENT DIAGONAL SHEAR PLANES PARALLEL TO THE OUTSIDE EDGE OF THE SPOIL PLATFORM MAY REPRESENT THE FORMER EXTENT OF THE PLATFORM DURING DEPOSITION. PLATY STRUCTURE IN SURFACE 2C CM MAY BE DUE TO COMPACTION BY HORSES HAULING SPOIL MATERIAL.

Table 42. Site description of 1932 old spoil (Site No. 10).

SOIL SERIES: 1932 SPOILS

SURVEY SAMPLE NO.: 0 173 10
LOCATION: NE 1/4, NW 1/4, NW 1/4, SEC 1 T1N, R41E, 2 MI ESE OF COLSTRIP, MT.
CLASSIFICATION:

SITE NO.: 0 10	COUNTY: SEE REMARKS	ELEVATION: 1006 METERS	MONTH SAMPLED: AUGUST
SLOPE: %	CLASS: NEARLY LEVEL	KIND: PLANE	ASPECT:
AIR TEMPERATURE	ANNUAL: 46 DEGREES F	SUMMER: 68 DEGREES F	WINTER: 24 DEGREES F
SOIL TEMPERATURE	ANNUAL: DEGREES F	SUMMER: DEGREES F	WINTER: DEGREES F
WATER TABLE:	DEPTH: CM.	MONTH: AUGUST	KIND: AC WATER TABLE
PRECIPITATION:	940 CM.	CONTROL SECTION LIMITS --	UPPER: 025 CM LOWER: 100 CM
PERMEABILITY:	MODERATELY RAPID	DRAINAGE CLASS: WELL DRAINED	
PHYSIOGRAPHY:	LEVEL OR UNDULATING UPLANDS		STONINESS: CLASS 0
MICRORELIEF:	ON CREST AND SLOPE		
VEGETATION:	GRASSES AND FORBS AND SHRUBS		
PARENT MATERIAL:	SLIGHTLY WEATHERED UNCONSOLIDATED MINERAL SEDIMENTS CALCAREOUS SANDSTONE AND INTERBEDDED SHALE AND SILTSTONE		

HORIZON	PROFILE DESCRIPTION
A 11	0 - 1 CM. (0 - 0 IN.) PALE BROWN (10YR 6/3) CRUSHED ; LOAM ; YELLOWISH BROWN (10YR 5/4) CRUSHED MOIST ; MODERATE FINE PLATY STRUCTURE ; SOFT , VERY FRIABLE , NONSTICKY , SLIGHTLY PLASTIC ; MANY FINE ROOTS THROUGHOUT HORIZON ; MANY FINE TUBULAR CONTINUOUS PORES , COMMON TO MANY FINE VESICULAR PORES ; FEW SANDSTONE FRAGMENTS >2 MM , COMMON SILTSTONE FRAGMENTS >2 CM ; MILDLY EFFERVESCENT (HCL) CONTINUOUS ; MODERATELY ALKALINE PH= 8.4 (BROMTHYMOL BLUE) ; ARBITRARY ROUNDARY .
A 12	1 - 2 CM. (0 - 1 IN.) PALE BROWN (10YR 6/3) CRUSHED ; SANDY LOAM ; YELLOWISH BROWN (10YR 5/4) CRUSHED MOIST ; MODERATE FINE PLATY STRUCTURE ; SOFT , VERY FRIABLE , NONSTICKY , NONPLASTIC ; MANY FINE ROOTS THROUGHOUT HORIZON ; MANY FINE TUBULAR CONTINUOUS PORES , COMMON TO MANY FINE VESICULAR PORES ; FEW SANDSTONE FRAGMENTS >2 MM , COMMON SILTSTONE FRAGMENTS >2 CM ; MODERATELY EFFERVESCENT (HCL) CONTINUOUS ; MODERATELY ALKALINE PH= 8.4 (BROMTHYMOL BLUE) ; ARBITRARY ROUNDARY .
A 13	2 - 5 CM. (1 - 2 IN.) LT. YELLOWISH BROWN (2.5Y 6/4) CRUSHED ; VERY FINE SANDY LOAM ; LIGHT OLIVE BROWN (2.5Y 5/4) CRUSHED MOIST ; MODERATE FINE PLATY STRUCTURE ; SLIGHTLY HARD , VERY FRIABLE , NONSTICKY , SLIGHTLY PLASTIC ; MANY FINE ROOTS THROUGHOUT HORIZON ; MANY FINE TUBULAR CONTINUOUS PORES , COMMON TO MANY FINE VESICULAR PORES ; FEW SANDSTONE FRAGMENTS >2 MM , COMMON SILTSTONE FRAGMENTS >2 CM ; MODERATELY EFFERVESCENT (HCL) CONTINUOUS ; STRONGLY ALKALINE PH= 8.6 (BROMTHYMOL BLUE) ; ARBITRARY ROUNDARY .
C 1	5 - 10 CM. (2 - 4 IN.) LIGHT BROWNISH GRAY (2.5Y 6/2) CRUSHED ; VERY FINE SANDY LOAM ; LIGHT OLIVE BROWN (2.5Y 5/4) CRUSHED MOIST ; MODERATE FINE PLATY STRUCTURE ; SLIGHTLY HARD , VERY FRIABLE , NONSTICKY , NONPLASTIC ; MANY FINE ROOTS THROUGHOUT HORIZON ; MANY FINE TUBULAR CONTINUOUS PORES , MANY FINE VESICULAR PORES ; FEW SANDSTONE FRAGMENTS >2 MM , COMMON SILTSTONE FRAGMENTS >2 CM ; MODERATELY EFFERVESCENT (HCL) CONTINUOUS ; STRONGLY ALKALINE PH= 8.6 (BROMTHYMOL BLUE) ; CLEAR WAVY ROUNDARY .
C 2	10 - 50 CM. (4 - 20 IN.) LIGHT GRAY (2.5Y 7/2) CRUSHED ; LOAM ; LIGHT OLIVE BROWN (2.5Y 5/4) CRUSHED MOIST ; MODERATE MEDIUM PLATY STRUCTURE ; HARD , FRIABLE , NONSTICKY , SLIGHTLY PLASTIC ; MANY FINE ROOTS THROUGHOUT HORIZON ; MANY FINE TUBULAR CONTINUOUS PORES ; COMMON MIXED SEDIMENTARY FRAGMENTS >2 MM , FEW SILTSTONE FRAGMENTS >2 CM ; MODERATELY EFFERVESCENT (HCL) CONTINUOUS ; STRONGLY ALKALINE PH= 8.8 (BROMTHYMOL BLUE) ; ARBITRARY ROUNDARY .
C 3	50 - 100 CM. (20 - 39 IN.) LIGHT GRAY (2.5Y 7/2) CRUSHED ; LOAM ; LIGHT OLIVE BROWN (2.5Y 5/4) CRUSHED MOIST ; MASSIVE ; HARD , FRIABLE , NONSTICKY , SLIGHTLY PLASTIC ; COMMON FINE ROOTS THROUGHOUT HORIZON ; MANY FINE TUBULAR CONTINUOUS PORES ; COMMON MIXED SEDIMENTARY FRAGMENTS >2 MM , FEW SILTSTONE FRAGMENTS >2 CM ; MODERATELY EFFERVESCENT (HCL) CONTINUOUS ; STRONGLY ALKALINE PH= 8.8 (BROMTHYMOL BLUE) ; ARBITRARY ROUNDARY .
C 4	100 - 200 CM. (39 - 79 IN.) LIGHT GRAY (2.5Y 7/2) CRUSHED ; CLAY LOAM ; LIGHT OLIVE BROWN (2.5Y 5/4) CRUSHED MOIST ; MASSIVE ; HARD , FIRM , STICKY , SLIGHTLY PLASTIC ; FEW FINE ROOTS THROUGHOUT HORIZON ; MANY FINE TUBULAR CONTINUOUS PORES ; FEW SANDSTONE FRAGMENTS >2 MM , COMMON SILTSTONE FRAGMENTS >2 CM ; MODERATELY EFFERVESCENT (HCL) CONTINUOUS ; STRONGLY ALKALINE PH= 8.8 (BROMTHYMOL BLUE) ; NOT REACHED BOUNDARY .

REMARKS: STRIP-MINE SPOILS NEAR COLSTRIP, MONTANA LEVELED IN 1932. AUG 11, 1976 SOIL TEMP =21.0 C AT 50 CM. UPPER HALF OF C2 HAS MODERATE MEDIUM PLATY STRUCTURE. THYMOL BLUE INDICATOR GIVES PH VALUES 0.5 TO 1.0 HIGHER THAN METER.

Table 43. Site description of 1948 old spoil (Site No. 3).

SOIL SERIES: 1948 SPOILS

SURVEY SAMPLE NO.: 0 173 3
LOCATION: NW 1/4, NE 1/4, SE 1/4, SECT 35, T2N, R41E, 1 MI EAST OF COLSTRIP, MT
CLASSIFICATION:

SITE NO.: 0 3 — COUNTY: SEE REMARKS — ELEVATION: 0991 METERS — MONTH SAMPLED: AUGUST
SLOPE: 0 % — CLASS: NEARLY LEVEL — ASPECT:
AIR TEMPERATURE: ANNUAL: 46 DEGREES F — SUMMER: 68 DEGREES F — WINTER: 24 DEGREES F
SOIL TEMPERATURE: ANNUAL: DEGREES F — SUMMER: DEGREES F — WINTER: DEGREES F
WATER TABLE: DEPTH: CM. — MONTH: AUGUST — KIND: NO WATER TABLE
PRECIPITATION: 340 CM. — CONTROL SECTION LIMITS -- — UPPER: 025 CM LOWER: 100 CM
PERMEABILITY: MODERATELY RAPID — DRAINAGE CLASS: WELL DRAINED
PHYSIOGRAPHY: BASINS, INTERIOR DRAINAGE — STONINESS: CLASS 0
VEGETATION: GRASSES AND FORBS AND SHRUBS
PARENT MATERIAL: SLIGHTLY WEATHERED UNCONSOLIDATED MINERAL SEDIMENTS CALCAREOUS SANDSTONE AND MIXED LITHOLOGY

HORIZON	PROFILE DESCRIPTION
A 11	0 - 1 CM. (0 - 0 IN.) DARK GRAYISH BROWN (10YR 4/2) CRUSHED , LOAM ; VERY DARK GRAY (10YR 3/1) CRUSHED MOIST ; WEAK FINE PLATY STRUCTURE ; SOFT , VERY FRIABLE , NONSTICKY , NONPLASTIC ; MANY FINE ROOTS BETWEEN PEDS ; MANY MEDIUM IRREGULAR PORES , FEW FINE TUBULAR CONTINUOUS PORES ; MODERATELY EFFERVESCENT (HCL) CONTINUOUS ; MODERATELY ALKALINE PH= 8.2 (BROMTHYMOL BLUE) ; ARBITRARY BOUNDARY .
A 12	1 - 2 CM. (0 - 1 IN.) GRAYISH BROWN (10YR 5/2) CRUSHED ; LOAM ; V DK GRAYISH BROWN (10YR 3/2) CRUSHED MOIST ; WEAK FINE PLATY STRUCTURE ; SOFT , VERY FRIABLE , NONSTICKY , NONPLASTIC ; MANY FINE ROOTS BETWEEN PEDS ; MANY MEDIUM IRREGULAR PORES , FEW FINE TUBULAR CONTINUOUS PORES ; MODERATELY EFFERVESCENT (HCL) CONTINUOUS ; MODERATELY ALKALINE PH= 8.2 (BROMTHYMOL BLUE) ; ABRUPT SMOOTH BOUNDARY .
A 13	2 - 5 CM. (1 - 2 IN.) GRAYISH BROWN (10YR 5/2) CRUSHED ; LOAM ; DARK GRAYISH BROWN (10YR 4/2) CRUSHED MOIST ; VERY PALE BROWN (10YR 7/4) CRUSHED ; LT. YELLOWISH BROWN (10YR 6/4) CRUSHED MOIST ; MODERATI COARSE PLATY STRUCTURE ; SLIGHTLY HARD , VERY FRIABLE , NONSTICKY , SLIGHTLY PLASTIC ; MANY FINE ROOTS BETWEEN PEDS ; MANY MEDIUM IRREGULAR PORES , FEW FINE TUBULAR CONTINUOUS PORES ; FEW SANDSTONE FRAGMENTS >2 CM ; MODERATELY EFFERVESCENT (HCL) CONTINUOUS ; MODERATELY ALKALINE PH= 8.4 (BROMTHYMOL BLUE) ; ABRUPT WAVY BOUNDARY .
C 1	5 - 10 CM. (2 - 4 IN.) GRAYISH BROWN (10YR 5/2) CRUSHED ; LOAM ; DARK GRAYISH BROWN (10YR 4/2) CRUSHED MOIST ; VERY PALE BROWN (10YR 7/4) CRUSHED ; LT. YELLOWISH BROWN (10YR 6/4) CRUSHED MOIST ; 20 PERCENT HARD SILT LOAM VERY DARK GRAY (10YR 3/0) CRUSHED POCKETS OR CONTRASTING MATERIALS - CM THICK) ; VERY SLAB VERY COARSE PLATY STRUCTURE ; SOFT , VERY FRIABLE , NONSTICKY , SLIGHTLY PLASTIC ; MANY FINE ROOTS THROUGHOUT HORIZON ; MANY FINE IRREGULAR PORES ; VIOLENTLY EFFERVESCENT (HCL) CONTINUOUS ; MODERATELY ALKALINE PH= 8.4 (BROMTHYMOL BLUE) ; ARBITRARY BOUNDARY .
C 2	10 - 50 CM. (4 - 20 IN.) GRAYISH BROWN (10YR 5/2) CRUSHED ; LOAM ; DARK GRAYISH BROWN (10YR 4/2) CRUSHED MOIST ; VERY PALE BROWN (10YR 7/4) CRUSHED ; LT. YELLOWISH BROWN (10YR 6/4) CRUSHED MOIST ; COMMON MEDIUM & COARSE PROMINENT BROWNISH YELLOW (10YR 6/8) CRUSHED MOTTLES ; 20 PERCENT HARD SILT LOAM VERY DARK GRAY (10YR 3/0) CRUSHED CHARCOAL BANDS 06 - CM THICK) ; PASSIVE ; SLIGHTLY HARD , VERY FRIABLE , NONSTICKY , SLIGHTLY PLASTIC ; FEW FINE ROOTS THROUGHOUT HORIZON ; MANY FINE IRREGULAR PORES ; VIOLENTLY EFFERVESCENT (HCL) CONTINUOUS ; MODERATELY ALKALINE PH= 8.4 (BROMTHYMOL BLUE) ; ARBITRARY BOUNDARY .
C 3	50 - 100 CM. (20 - 39 IN.) VERY DARK GRAY (10YR 3/1) CRUSHED ; LOAM ; BLACK (10YR 2/1) CRUSHED MOIST ; LT. YELLOWISH BROWN (10YR 6/4) EXTERIOR ; YELLOWISH BROWN (10YR 5/4) EXTERIOR MOIST ; COMMON MEDIUM & COARSE PROMINENT BROWNISH YELLOW (10YR 6/8) CRUSHED MOTTLES ; 20 PERCENT HARD SILT LOAM VERY DARK GRAY (10YR 3/0) CRUSHED CHARCOAL BANDS 06 - CM THICK) ; PASSIVE ; SLIGHTLY HARD , VERY FRIABLE , NONSTICKY , SLIGHTLY PLASTIC ; FEW FINE ROOTS THROUGHOUT HORIZON ; COMMON FINE IRREGULAR PORES ; 10 PERCENT COAL FRAGMENTS >2 CM ; VIOLENTLY EFFERVESCENT (HCL) CONTINUOUS ; MODERATELY ALKALINE PH= 8.4 (BROMTHYMOL BLUE) ; ARBITRARY BOUNDARY .
C 4	100 - 150 CM. (39 - 59 IN.) LT. YELLOWISH BROWN (2.5Y 6/4) CRUSHED ; LOAM ; LIGHT OLIVE BROWN (2.5Y 5/4) CRUSHED MOIST ; GRAYISH BROWN (2.5Y 5/2) CRUSHED ; DARK GRAYISH BROWN (2.5Y 4/2) CRUSHED MOIST ; COMMON MEDIUM & COARSE PROMINENT BROWNISH YELLOW (10YR 6/8) CRUSHED MOTTLES ; 20 PERCENT HARD SILT LOAM VERY DARK GRAY (10YR 3/0) CRUSHED CHARCOAL BANDS 06 - CM THICK) ; PASSIVE ; SLIGHTLY HARD , VERY FRIABLE , SLIGHTLY STICKY , SLIGHTLY PLASTIC ; FEW FINE ROOTS THROUGHOUT HORIZON ; FEW FINE IRREGULAR PORES ; FEW COAL FRAGMENTS >2 CM ; VIOLENTLY EFFERVESCENT (HCL) CONTINUOUS ; MODERATELY ALKALINE PH= 8.4 (BROMTHYMOL BLUE) ; NOT REACHED BOUNDARY .

REMARKS: NW 1/4, NE 1/4, SE 1/4, SECT 35, T2N, R41E
STRIP-MINE SPOILS AT COLSTRIP, MONTANA RELEVELED IN 1968 FOR COUNTY ROAD CONSTRU
CTION. AUG. 11, 1974 SOIL TEMP =22.C C AT 50 CM. COAL FRAGMENTS ARE COMMON THR
OUGHOUT WITH COLOR 10YR 3/0 DRY (1C YR 2/0 MOIST). LARGE FRAGMENT OF SHALE OCCU
R BELOW ONE METER. IRON-STAINED MATERIAL ASSOCIATED WITH COAL FRAGMENTS HAS COL
OR OF 10 YR 5/8. ROOTS INCREASE TO COMMON IN SOFT COAL POCKETS AT 110 CM. THE
MATRIX OF THE SPOIL IS A MIXTURE OF FRAGMENTED SHALE AND SILTSTONE WITH SILT TO

Table 44. Site description of 1969 new spoil (Site No. 14).

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SOIL SERIES:                                1969 SPOILS

SURVEY SAMPLE NO.:                            0     173 14
LOCATION:     SE 1/4, NW 1/4, NW 1/4, SECT 17 T1N, R42E, 4 MI SE OF COLSTRIP, MT.
CLASSIFICATION:

SITE NO.:  0 14    COUNTY: SEE REMARKS          ELEVATION: 0991 METERS        MONTH SAMPLED: AUGUST
SLOPE:       1     CLASS:    NEARLY LEVEL      KIND:      CONCAVE            ASPECT:  NORTHWEST
AIR TEMPERATURE    ANNUAL:  46 DEGREES F       SUMMER:  68 DEGREES F         WINTER:  24 DEGREES F
SOIL TEMPERATURE   ANNUAL:    DEGREES F        SUMMER:    DEGREES F          WINTER:    DEGREES F
WATER TABLE:       DEPTH:     CM.              MONTH:  AUGUST                KIND:  NO WATER TABLE
PRECIPITATION:     349 CM.                     CONTROL SECTION LIMITS --     UPPER: 025 CM  LOWER: 100 CM
PERMEABILITY:      MODERATELY RAPID            DRAINAGE CLASS:  WELL DRAINED
PHYSIOGRAPHY:      LEVEL OR UNDULATING UPLANDS                               STONINESS: CLASS 0
MICRORELIEF:       IN SLOPE
VEGETATION:        GRASSES AND FORBS AND SHRUBS
PARENT MATERIAL:   SLIGHTLY    WEATHERED    UNCONSOLIDATED MINERAL SEDIMENTS
                   CALCAREOUS SANDSTONE    AND CALCAREOUS SILTSTONE

  HORIZON                                   PROFILE DESCRIPTION

A  11          0 -  1 CM.  ( 0 -  0 IN.)
LIGHT GRAY (10YR 7/1) CRUSHED  :  FINE SANDY LOAM  :  GRAYISH BROWN  (10YR 5/2)
CRUSHED MOIST     :  FEW TO COMMON   COARSE  PROMINENT   STRONG BROWN    (7.5YR 5/8)
CRUSHED MOTTLES   :  VERY WEAK   FINE    PLATY   STRUCTURE     :  SOFT      ,
VERY FRIABLE      ,  NONSTICKY     ,  SLIGHTLY PLASTIC     :  MANY    FINE    ROOTS
THROUGHOUT HORIZON  :  MANY   FINE   IRREGULAR   PORES    :  10  PERCENT
MIXED SEDIMENTARY   FRAGMENTS   32 MM     :  MILDLY EFFERVESCENT (HCL)   CONTINUOUS   :
SLIGHTLY ACID   PH= 6.4 (PH METER)   :  ARBITRARY   BOUNDARY   .

A  12          1 -  2 CM.  ( 1 -  1 IN.)
LIGHT GRAY (10YR 7/2) CRUSHED  :  SANDY LOAM   :  GRAYISH BROWN  (10YR 5/2)
CRUSHED MOIST     :  FEW TO COMMON   COARSE  PROMINENT   STRONG BROWN    (7.5YR 5/8)
CRUSHED MOTTLES   :  VERY WEAK   FINE    PLATY   STRUCTURE     :  SOFT      ,
VERY FRIABLE      ,  NONSTICKY     ,  SLIGHTLY PLASTIC     :  MANY    FINE    ROOTS
THROUGHOUT HORIZON  :  MANY   FINE   IRREGULAR   PORES    :  10  PERCENT
MIXED SEDIMENTARY   FRAGMENTS   32 MM     :  MILDLY EFFERVESCENT (HCL)   CONTINUOUS   :
MILDLY ALKALINE PH= 7.6 (PH METER)   :  ARBITRARY   BOUNDARY   .

A  13          2 -  5 CM.  ( 1 -  2 IN.)
LIGHT BROWNISH GRAY (10YR 6/2) CRUSHED  :  FINE SANDY LOAM  :  GRAYISH BROWN
(10YR  5/2) CRUSHED MOIST     :  FEW TO COMMON   COARSE  PROMINENT   STRONG BROWN
(7.5YR 5/8) CRUSHED MOTTLES   :  VERY WEAK   FINE    PLATY   STRUCTURE     :  SOFT      ,
VERY FRIABLE      ,  NONSTICKY     ,  SLIGHTLY PLASTIC     :  MANY    FINE    ROOTS
THROUGHOUT HORIZON  :  MANY   FINE   IRREGULAR   PORES    :  1  PERCENT
MIXED SEDIMENTARY   FRAGMENTS   32 MM     :  MILDLY EFFERVESCENT (HCL)   CONTINUOUS   :
MILDLY ALKALINE PH= 7.4 (PH METER)   :  CLEAR   WAVY    BOUNDARY   .

C  1           5 - 10 CM.  ( 2 -  4 IN.)
LIGHT BROWNISH GRAY (10YR  6/2) CRUSHED  :  SANDY LOAM   :  GRAYISH BROWN   (10YR  5/2)
CRUSHED MOIST     :  FEW TO COMMON   COARSE  PROMINENT   STRONG BROWN    (7.5YR 5/8)
CRUSHED MOTTLES   :  VERY WEAK   FINE    PLATY   STRUCTURE     :  SOFT      ,
VERY FRIABLE      ,  SLIGHTLY STICKY  ,  SLIGHTLY PLASTIC     :  MANY    FINE
ROOTS   THROUGHOUT HORIZON   :  MANY    FINE    IRREGULAR   PORES    :  1  PERCENT
MIXED SEDIMENTARY   FRAGMENTS   32 MM     :  MILDLY EFFERVESCENT (HCL)   CONTINUOUS   :
NEUTRAL PH= 7.0 (PH METER)   :  ARBITRARY   BOUNDARY   .

C  2          10 - 51 CM.  ( 4 -  20 IN.)
LIGHT GRAY (10YR  7/2) CRUSHED  :  SANDY LOAM   :  LIGHT BROWNISH GRAY (10YR  6/2)
CRUSHED MOIST     :  FEW TO COMMON   COARSE  PROMINENT   STRONG BROWN    (7.5YR 5/8)
CRUSHED MOTTLES   :  20  PERCENT VERY HARD   BLACK   (10YR  2/0) CRUSHED
CHARCOAL PANDS 10    -  CM THICK )   :  MASSIVE   :  SOFT      ,  VERY FRIABLE      ,
NONSTICKY     ,  NONPLASTIC   :  COMMON   FINE    ROOTS   THROUGHOUT HORIZON   :
MANY    FINE    IRREGULAR   PORES    :  1  PERCENT MIXED SEDIMENTARY   FRAGMENTS
32 MM     :  MILDLY EFFERVESCENT (HCL)   CONTINUOUS   :  MILDLY ALKALINE PH= 7.5
(PH METER)   :  ARBITRARY   BOUNDARY   .

C  3          51 - 100 CM.  ( 20 -  39 IN.)
WHITE   (10YR  8/1) CRUSHED  :  LOAMY SAND   :  LIGHT GRAY (10YR  6/1) CRUSHED
MOIST     :  FEW COARSE  PROMINENT   STRONG BROWN    (7.5YR 5/8) CRUSHED MOTTLES   :  20
PERCENT VERY HARD   BLACK   (10YR  2/0) CRUSHED CHARCOAL PANDS 10    -  CM THICK )   :
MASSIVE   :  SOFT      ,  VERY FRIABLE      ,  NONSTICKY     ,  NONPLASTIC   :  FEW
FINE    ROOTS   THROUGHOUT HORIZON   :  FEW FINE    TUBULAR CONTINUOUS  PORES    :  1
PERCENT MIXED SEDIMENTARY   FRAGMENTS   32 MM     :  MILDLY EFFERVESCENT (HCL)
CONTINUOUS   :  MILDLY ALKALINE PH= 7.6 (PH METER)   :  ARBITRARY   BOUNDARY   .

C  4          100 - 200 CM.  ( 39 -  79 IN.)
LIGHT GRAY (10YR  7/1) CRUSHED  :  LOAMY SAND   :  LIGHT BROWNISH GRAY (10YR  6/2)
CRUSHED MOIST     :  LIGHT GRAY  (10YR  7/2) CRUSHED  :  PALE BROWN  (10YR  6/3)
CRUSHED MOIST     :  MASSIVE   :  SOFT      ,  VERY FRIABLE      ,  NONSTICKY     ,
NONPLASTIC   :  FEW FINE    ROOTS   THROUGHOUT HORIZON   :  FEW FINE
TUBULAR CONTINUOUS  PORES    :  10  PERCENT MIXED SEDIMENTARY   FRAGMENTS   32 MM     :
MILDLY EFFERVESCENT (HCL)   CONTINUOUS   :  MILDLY ALKALINE PH= 7.6 (PH METER)   :
NOT REACHED BOUNDARY   .

REMARKS:   SPTP-NINE SPOILS NEAR COLSTRIP, MONTANA REGRADED IN 1969.  AUG. 1, 1976 SOIL T
EMP = 18.5 C AT 50 CM.  ROOTS IN C4 PROLIFERATE IN SOFT COAL FRAGMENTS.  MANY VE
RY FINE HOLES IN UPPER HALF OF C2.  MOSS MAT 1 CM THICK COVERS SURFACE.  POCKETS
 OF HEAVY LOAM MATERIAL COMPRISE 10% OF VOLUME.  2C3 COAL TO A DEPTH OF UNE METE
R.  CONCENTRIC IRON-STAINED 2 CM. RINGS (7.5 YR 5/8) ARE ASSOCIATED WITH COAL PO
CKETS.  THE RING IS SEPARATED FROM THE COAL BY A 1 MM LAYER OF GYPSUM.  AFFECTED
 COAL CONTAINS PYRITE.  PH OF THE AFFECTED COAL IS 2.3, THE INSIDE OF THE RING I
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Table 45. Site description of 1970 new spoil (Site No. 15).

SOIL SERIES: 1970 SPOILS

SURVEY SAMPLE NO.: G 173 15
LOCATION: NE 1/4, NE 1/4, SW 1/4, SEC 17 11N, R42E, 9 MI SE OF COLSTRIP, MT.
CLASSIFICATION:

SITE NO.: G 15 | COUNTY: SEE REMARKS | ELEVATION: 0991 METERS | MONTH SAMPLED: AUGUST
SLOPE: 4 | CLASS: GENTLY SLOPING | KIND: CONCAVE | ASPECT: SOUTHEAST
AIR TEMPERATURE | ANNUAL: 46 DEGREES F | SUMMER: 68 DEGREES F | WINTER: 24 DEGREES F
SOIL TEMPERATURE | ANNUAL: DEGREES F | SUMMER: DEGREES F | WINTER: DEGREES F
WATER TABLE: | DEPTH: CM. | MONTH: AUGUST | KIND: NO WATER TABLE
PRECIPITATION: 340 CM. | CONTROL SECTION LIMITS -- | UPPER: 025 CM LOWER: 100 CM
PERMEABILITY: MODERATELY RAPID | DRAINAGE CLASS: WELL DRAINED | STONINESS: CLASS 0
PHYSIOGRAPHY: LEVEL OR UNDULATING UPLANDS
MICRORELIEF: ON SLOPE
VEGETATION: GRASSES AND FORBS
PARENT MATERIALS: SLIGHTLY WEATHERED UNCONSOLIDATED MINERAL SEDIMENTS CALCAREOUS SANDSTONE AND CALCAREOUS SILTSTONE

HORIZON — PROFILE DESCRIPTION

A 11 — 0 - 1 CM. (0 - 0 IN.)
YELLOWISH BROWN (10YR 5/4) CRUSHED ; FINE SANDY LOAM ; DK. YELLOWISH BROWN (10YR 4/4) CRUSHED MOIST ; WEAK FINE GRANULAR STRUCTURE ; SOFT , VERY FRIABLE , NONSTICKY , NONPLASTIC ; MANY FINE ROOTS MATTED AROUND STONES AND PEBBLES ; MANY FINE IRREGULAR PORES ; MODERATELY EFFERVESCENT (HCL) CONTINUOUS ; MODERATELY ALKALINE PH- 8.0 (BROMTHYMOL BLUE) ; ARBITRARY BOUNDARY .

A 12 — 1 - 2 CM. (0 - 1 IN.)
YELLOWISH BROWN (10YR 5/4) CRUSHED ; FINE SANDY LOAM ; DK. YELLOWISH BROWN (10YR 4/4) CRUSHED MOIST ; WEAK FINE GRANULAR STRUCTURE ; SOFT , VERY FRIABLE , NONSTICKY , NONPLASTIC ; MANY FINE ROOTS MATTED AROUND STONES AND PEBBLES ; MANY FINE IRREGULAR PORES ; MODERATELY EFFERVESCENT (HCL) CONTINUOUS ; MODERATELY ALKALINE PH- 8.2 (BROMTHYMOL BLUE) ; ARBITRARY BOUNDARY .

A 13 — 2 - 5 CM. (1 - 2 IN.)
YELLOWISH BROWN (10YR 5/4) CRUSHED ; FINE SANDY LOAM ; DK. YELLOWISH BROWN (10YR 4/4) CRUSHED MOIST ; WEAK FINE GRANULAR STRUCTURE ; SOFT , VERY FRIABLE , NONSTICKY , NONPLASTIC ; MANY FINE ROOTS MATTED AROUND STONES AND PEBBLES ; MANY FINE IRREGULAR PORES ; MODERATELY EFFERVESCENT (HCL) CONTINUOUS ; MODERATELY ALKALINE PH- 8.2 (BROMTHYMOL BLUE) ; ABRUPT BROKEN BOUNDARY .

C 1 — 5 - 10 CM. (2 - 4 IN.)
LIGHT BROWNISH GRAY (10YR 6/2) CRUSHED ; FINE SANDY LOAM ; BROWN (10YR 5/3) CRUSHED MOIST ; WEAK PLATY STRUCTURE ; SLIGHTLY HARD , VERY FRIABLE , NONSTICKY , NONPLASTIC ; MANY FINE ROOTS MATTED AROUND STONES AND PEBBLES ; COMMON FINE IRREGULAR PORES ; FEW SILTSTONE FRAGMENTS >2 CM ; MODERATELY EFFERVESCENT (HCL) CONTINUOUS ; MODERATELY ALKALINE PH- 8.4 (BROMTHYMOL BLUE) ; ARBITRARY BOUNDARY .

C 2 — 10 - 50 CM. (4 - 20 IN.)
LIGHT GRAY (10YR 7/2) CRUSHED ; SANDY LOAM ; PALE BROWN (10YR 6/3) CRUSHED MOIST ; 10 PERCENT VERY HARD SANDY LOAM YELLOWISH BROWN (10YR 5/6) CRUSHED POCKETS OR CONTRASTING MATERIALS0 - CM THICK) ; MASSIVE ; SLIGHTLY HARD , FRIABLE , NONSTICKY , NONPLASTIC ; COMMON FINE ROOTS THROUGHOUT HORIZON ; FEW FINE TUBULAR CONTINUOUS PORES ; MODERATELY EFFERVESCENT (HCL) CONTINUOUS ; STRONGLY ALKALINE PH- 8.6 (BROMTHYMOL BLUE) ; ARBITRARY BOUNDARY .

C 3 — 50 - 100 CM. (20 - 39 IN.)
LIGHT GRAY (10YR 7/2) CRUSHED ; SANDY LOAM ; PALE BROWN (10YR 6/3) CRUSHED MOIST ; 10 PERCENT VERY HARD SANDY LOAM YELLOWISH BROWN (10YR 5/6) CRUSHED POCKETS OR CONTRASTING MATERIALS0 - CM THICK) ; MASSIVE ; SLIGHTLY HARD , VERY FRIABLE , NONSTICKY , NONPLASTIC ; COMMON FINE ROOTS THROUGHOUT HORIZON ; FEW FINE TUBULAR CONTINUOUS PORES ; FEW SILTSTONE FRAGMENTS >2 CM ; MODERATELY EFFERVESCENT (HCL) CONTINUOUS ; STRONGLY ALKALINE PH- 8.8 (BROMTHYMOL BLUE) ; ARBITRARY BOUNDARY .

C 4 — 100 - 200 CM. (39 - 79 IN.)
LIGHT GRAY (10YR 7/2) CRUSHED ; SANDY LOAM ; BROWN (10YR 5/3) CRUSHED MOIST ; MASSIVE ; SLIGHTLY HARD , FRIABLE , NONSTICKY , NONPLASTIC ; COMMON FINE ROOTS THROUGHOUT HORIZON ; FEW FINE TUBULAR CONTINUOUS PORES ; 20 PERCENT SANDSTONE FRAGMENTS >2 CM ; MODERATELY EFFERVESCENT (HCL) CONTINUOUS ; STRONGLY ALKALINE PH- 8.6 (BROMTHYMOL BLUE) ; NOT REACHED BOUNDARY .

REMARKS: STRIP-MINE SPOILS NEAR COLSTRIP, MONTANA REGRADED IN 1970. AUG 11, 1976 SOIL IF AP = 21.0 C AT 50 CM. A11 THROUGH A13 CONSISTS OF TOPSOIL MATERIAL. 10% SILTSTONE AND SANDSTONE FRAGMENTS. LITTLE COAL OBSERVED. FEW FERRUGINOUS CONCRETIONS (6 CM). COMMON FINE ROOTS IN UPPER HALF OF C2. THYMOL BLUE GIVES PH 0.5 TO 1.0 HIGHER THAN METER.

Table 46. Site description of 1972 new spoil (Site No. 13).

SOIL SERIES: 1972 SPOILS

SURVEY SAMPLE NO.: 0 173 13
LOCATION: NW 1/4, NE 1/4, NE 1/4, SECT 18 T1N R42E, 4 MI SE OF COLSTRIP, MT.
CLASSIFICATION:

SITE NO.: 0 13	COUNTY: SEE REMARKS	ELEVATION: 1015 METERS	MONTH SAMPLED: AUGUST
SLOPE: %	CLASS: GENTLY SLOPING	KIND: CONVEX	ASPECT: WEST
AIR TEMPERATURE	ANNUAL: 46 DEGREES F	SUMMER: 68 DEGREES F	WINTER: 24 DEGREES F
SOIL TEMPERATURE	ANNUAL: DEGREES F	SUMMER: DEGREES F	WINTER: DEGREES F
WATER TABLE:	DEPTH: CM.	MONTH: AUGUST	KIND: NO WATER TABLE
PRECIPITATION:	340 CM.	CONTROL SECTION LIMITS --	UPPER: 025 CM LOWER: 100 CM
PERMEABILITY:	MODERATELY RAPID	DRAINAGE CLASS: WELL DRAINED	
PHYSIOGRAPHY:	LEVEL OR UNDULATING UPLANDS		STONINESS: CLASS 0
MICRORELIEF:	ON SLOPE		
VEGETATION:	GRASSES AND FORBS		
PARENT MATERIAL:	SLIGHTLY WEATHERED UNCONSOLIDATED MINERAL SEDIMENTS AND CALCAREOUS SANDSTONE AND CALCAREOUS SILTSTONE		

HORIZON	PROFILE DESCRIPTION
A 11	0 - 1 CM. (0 - 0 IN.) BLACK (10YR 2/0) CRUSHED ; FINE SANDY LOAM ; BLACK (10YR 2/0) CRUSHED MOIST ; VERY WEAK FINE PLATY STRUCTURE PARTING TO WEAK MEDIUM GRANULAR ; SOFT , VERY FRIABLE , NONSTICKY , NONPLASTIC ; MANY FINE ROOTS THROUGHOUT HORIZON ; MANY FINE IRREGULAR PORES ; NONCALCAREOUS (HCL) CONTINUOUS ; NEUTRAL PH- 6.9 (PH METER) ; ABRITRARY BOUNDARY .
A 12	1 - 2 CM. (0 - 1 IN.) YELLOWISH BROWN (10YR 5/4) CRUSHED ; SANDY LOAM ; DK. YELLOWISH BROWN (10YR 4/4) CRUSHED MOIST ; VERY WEAK FINE PLATY STRUCTURE PARTING TO WEAK MEDIUM GRANULAR ; SOFT , VERY FRIABLE , NONSTICKY , NONPLASTIC ; MANY FINE ROOTS THROUGHOUT HORIZON ; MANY FINE IRREGULAR PORES ; MILDLY EFFERVESCENT (HCL) CONTINUOUS ; NEUTRAL PH- 7.2 (PH METER) ; ARBITRARY BOUNDARY .
A 13	2 - 5 CM. (1 - 2 IN.) YELLOWISH BROWN (10YR 5/4) CRUSHED ; SANDY LOAM ; DK. YELLOWISH BROWN (10YR 4/4) CRUSHED MOIST ; WEAK MEDIUM GRANULAR STRUCTURE ; SOFT , VERY FRIABLE , NONSTICKY , NONPLASTIC ; MANY FINE ROOTS THROUGHOUT HORIZON ; MANY FINE IRREGULAR PORES ; MILDLY EFFERVESCENT (HCL) CONTINUOUS ; MILDLY ALKALINE PH- 7.5 (PH METER) ; ARBITRARY BOUNDARY .
A 14	5 - 10 CM. (2 - 4 IN.) YELLOWISH BROWN (10YR 5/4) CRUSHED ; SANDY LOAM ; DK. YELLOWISH BROWN (10YR 4/4) CRUSHED MOIST ; VERY WEAK MEDIUM GRANULAR STRUCTURE ; SOFT , VERY FRIABLE , NONSTICKY , NONPLASTIC ; MANY FINE ROOTS THROUGHOUT HORIZON ; MANY FINE IRREGULAR PORES ; MILDLY EFFERVESCENT (HCL) CONTINUOUS ; MILDLY ALKALINE PH- 7.5 (PH METER) ; ABRUPT WAVY BOUNDARY .
C 1	10 - 50 CM. (4 - 20 IN.) PALE BROWN (10YR 6/3) CRUSHED ; SANDY LOAM ; YELLOWISH BROWN (10YR 5/4) CRUSHED MOIST ; MASSIVE ; SOFT , VERY FRIABLE , NONSTICKY , NONPLASTIC ; COMMON FINE ROOTS THROUGHOUT HORIZON ; COMMON FINE IRREGULAR PORES ; MODERATELY EFFERVESCENT (HCL) CONTINUOUS ; MILDLY ALKALINE PH- 7.6 (PH METER) ; ARBITRARY BOUNDARY .
C 2	50 - 100 CM. (20 - 39 IN.) LIGHT GRAY (10YR 7/2) CRUSHED ; SANDY LOAM ; PALE BROWN (10YR 6/3) CRUSHED MOIST ; 20 PERCENT SOFT SANDY LOAM LIGHT GRAY (2.5Y 7/1) CRUSHED BANDS 05 - CM THICK) ; MASSIVE ; SOFT , VERY FRIABLE , NONSTICKY , NONPLASTIC ; FEW FINE ROOTS THROUGHOUT HORIZON ; FEW FINE IRREGULAR PORES ; MODERATELY EFFERVESCENT (HCL) CONTINUOUS ; MILDLY ALKALINE PH- 7.6 (PH METER) ; ARBITRARY BOUNDARY .
C 3	100 - 200 CM. (39 - 79 IN.) LIGHT GRAY (10YR 7/2) CRUSHED ; SANDY LOAM ; PALE BROWN (10YR 6/3) CRUSHED MOIST ; 20 PERCENT SOFT SANDY LOAM REDDISH YELLOW (7.5YR 6/6) CRUSHED BANDS 05 - CM THICK) ; MASSIVE ; SOFT , VERY FRIABLE , NONSTICKY , NONPLASTIC ; FEW FINE ROOTS THROUGHOUT HORIZON ; MODERATELY EFFERVESCENT (HCL) CONTINUOUS ; MILDLY ALKALINE PH- 7.6 (PH METER) ; NOT REACHED BOUNDARY .

REMARKS: STRIP-MINE SPOILS NEAR COLSTRIP, MONTANA REGRADED IN 1972. AUG 12, 1976 SOIL T EMP =19.0 C AT 50 CM. All THROUGH A14 MATERIAL ARE TOPSOIL MATERIAL. FINELY DI VIDED PYRITE AND OTHER YELLOW POWDER IN COAL FRAGMENTS. ACID COAL ENVELOPED BY 1 CM BANDS OF IRON-STAINED DEPOSITS. SMR 10 1 CM OF COAL DUST AT SOIL SURFACE (DOWNWIND FROM COAL-LOADER). HORIZONTAL MAT OF ROOTS AT 50 CM FOLLOWS SURFACE OF GRAY SHALE BAND. ROOT LIMITED PRIMARILY TO UPPER HALF OF C1 HORIZON.

Table 47. Site description of 1973 new spoil (Site No. 12).

SOIL SERIES: 1973 SPOILS

SURVEY SAMPLE NO.: 0 173 12
LOCATION: NW 1/4, NE 1/4, NW 1/4, SEC 18 T1N, R42E, 4 MI SE OF COLSTRIP, MT.
CLASSIFICATION:

SITE NO.: 0 12 COUNTY: SEE REMARKS ELEVATION: 0997 METERS MONTH SAMPLED: AUGUST
SLOPE: % CLASS: MODERATELY SLOPING KIND: CONCAVE ASPECT: NORTH
AIR TEMPERATURE ANNUAL: 46 DEGREES F SUMMER: 68 DEGREES F WINTER: 24 DEGREES F
SOIL TEMPERATURE ANNUAL: DEGREES F SUMMER: DEGREES F WINTER: DEGREES F
WATER TABLE: DEPTH: CM. MONTH: AUGUST KIND: NO WATER TABLE
PRECIPITATION: 340 CM. CONTROL SECTION LIMITS -- UPPER: 025 CM LOWER: 100 CM
PERMEABILITY: MODERATE DRAINAGE CLASS: WELL DRAINED
PHYSIOGRAPHY: ROLLING OR HILLY UPLANDS STONINESS: CLASS 0
MICRORELIEF: ON SLOPE
VEGETATION: GRASSES AND FORBS
PARENT MATERIAL: SLIGHTLY WEATHERED UNCONSOLIDATED MINERAL SEDIMENTS
CALCAREOUS SANDSTONE AND INTERBEDDED SHALE AND SILTSTONE

HORIZON	PROFILE DESCRIPTION
A 11	0 - 1 CM. (0 - 0 IN.) BROWN (10YR 5/3) CRUSHED ; LOAM ; BROWN (10YR 4/3) CRUSHED MOIST ; WEAK FINE PLATY STRUCTURE ; SOFT , VERY FRIABLE , SLIGHTLY STICKY , SLIGHTLY PLASTIC ; MANY FINE ROOTS , THROUGHOUT HORIZON ; COMMON FINE IRREGULAR PORES ; FEW SANDSTONE FRAGMENTS >2 CM ; MODERATELY EFFERVESCENT (HCL) CONTINUOUS ; MILDLY ALKALINE PH= 7.6 (PH METER) ; ARBITRARY BOUNDARY .
A 12	1 - 2 CM. (0 - 1 IN.) PALE BROWN (10YR 6/3) CRUSHED ; LOAM ; BROWN (10YR 4/3) CRUSHED MOIST ; WEAK FINE PLATY STRUCTURE ; SOFT , VERY FRIABLE , SLIGHTLY STICKY , SLIGHTLY PLASTIC ; MANY FINE ROOTS , THROUGHOUT HORIZON ; COMMON FINE IRREGULAR PORES ; FEW SANDSTONE FRAGMENTS >2 CM ; MODERATELY EFFERVESCENT (HCL) CONTINUOUS ; MILDLY ALKALINE PH= 7.5 (PH METER) ; ARBITRARY BOUNDARY .
A 13	2 - 5 CM. (1 - 2 IN.) PALE BROWN (10YR 6/3) CRUSHED ; LOAM ; BROWN (10YR 4/3) CRUSHED MOIST ; WEAK MEDIUM GRANULAR STRUCTURE ; SLIGHTLY HARD , VERY FRIABLE , SLIGHTLY STICKY , SLIGHTLY PLASTIC ; MANY FINE ROOTS THROUGHOUT HORIZON ; MANY FINE IRREGULAR PORES ; FEW SANDSTONE FRAGMENTS >2 CM ; MODERATELY EFFERVESCENT (HCL) CONTINUOUS ; MILDLY ALKALINE PH= 7.5 (PH METER) ; ARBITRARY BOUNDARY .
A 14	5 - 10 CM. (2 - 4 IN.) PALE BROWN (10YR 6/3) CRUSHED ; LOAM ; LIGHT OLIVE BROWN (2.5Y 5/4) CRUSHED MOIST ; WEAK PECIM GRANULAR STRUCTURE ; SLIGHTLY HARD , FRIABLE , SLIGHTLY STICKY , PLASTIC ; COMMON TO MANY FINE ROOTS THROUGHOUT HORIZON ; COMMON FINE IRREGULAR PORES ; FEW SANDSTONE FRAGMENTS >2 CM ; MODERATELY EFFERVESCENT (HCL) CONTINUOUS ; MILDLY ALKALINE PH= 7.5 (PH METER) ; ABRUPT WAVY BOUNDARY .
C 1	10 - 50 CM. (4 - 20 IN.) LIGHT GRAY (2.5Y 7/2) CRUSHED ; SANDY LOAM ; LIGHT OLIVE BROWN (2.5Y 5/4) CRUSHED MOIST ; VERY WEAK VERY COARSE PLATY STRUCTURE ; SOFT , VERY FRIABLE , SLIGHTLY STICKY , SLIGHTLY PLASTIC ; COMMON FINE ROOTS THROUGHOUT HORIZON ; FEW FINE IRREGULAR PORES ; FEW SANDSTONE FRAGMENTS >2 CM ; MODERATELY EFFERVESCENT (HCL) CONTINUOUS ; MILDLY ALKALINE PH= 7.5 (PH METER) ; ABRUPT WAVY BOUNDARY .
C 2	50 - 80 CM. (20 - 31 IN.) PALE YELLOW (2.5Y 7/3) CRUSHED ; SANDY LOAM ; LIGHT OLIVE BROWN (2.5Y 5/4) CRUSHED MOIST ; 40 PERCENT HARD SILTY CLAY LOAM LIGHT GRAY (5Y7/2) CRUSHED BANDS 05 - CM THICK) ; MASSIVE ; SOFT , VERY FRIABLE , SLIGHTLY STICKY , SLIGHTLY PLASTIC ; FEW FINE ROOTS THROUGHOUT HORIZON ; FEW FINE IRREGULAR PORES ; FEW SANDSTONE FRAGMENTS >2 CM ; MODERATELY EFFERVESCENT (HCL) CONTINUOUS ; MILDLY ALKALINE PH= 7.5 (PH METER) ; ABRUPT WAVY BOUNDARY .
C 3	80 - 100 CM. (31 - 39 IN.) LIGHT GRAY (5Y7/2) CRUSHED ; SILTY CLAY LOAM ; OLIVE GRAY (5Y5/2) CRUSHED MOIST ; 20 PERCENT HARD SILTY CLAY LOAM LIGHT GRAY (5Y6/1) CRUSHED BANDS 20 - CM THICK) ; MASSIVE ; HARD , FIRM , STICKY , PLASTIC ; FEW SILTSTONE FRAGMENTS >2 CM ; MODERATELY EFFERVESCENT (HCL) CONTINUOUS ; MILDLY ALKALINE PH= 7.5 (PH METER) ; ABRUPT WAVY BOUNDARY .
C 4	100 - 200 CM. (39 - 79 IN.) PALE YELLOW (2.5Y 7/4) CRUSHED ; SANDY LOAM ; LIGHT OLIVE BROWN (2.5Y 5/4) CRUSHED MOIST ; MASSIVE ; SOFT , VERY FRIABLE , NONSTICKY , SLIGHTLY PLASTIC ; MODERATELY EFFERVESCENT (HCL) CONTINUOUS ; MILDLY ALKALINE PH= 7.8 (PH METER) ; NOT REACHED BOUNDARY .

REMARKS: STRIP-MINE SPOILS NEAR COLSTRIP, MONTANA REGRADED IN 1973. AUG 12, 1976 SOIL TE MP =22.0 C AT 50 CM. MANY VERY FINE ROOTS AND COMMON VERY FINE PORES IN UPPER 1 0 CM OF C1. LAMELLAE IN UPPER C2 RESTRICTS ROOTS TO VERTICAL FRACTURES. 5% HAR D0 COAL IN C1 AND C2. ALL THROUGH A14 ARE TOPSOIL MATERIAL.

Table 48. Site description of 1975 new spoil (Site No. 11).

SOIL SERIES:		1975 SPOILS	
SURVEY SAMPLE NO.:		0 173 11	
LOCATION:	NE 1/4, NW 1/4, NW 1/4, SEC 18 T1N, R42E, 4 MI SE OF COLSTRIP, MT		
CLASSIFICATION:			
SITE NO.: 0 11	COUNTY: SEE REMARKS	ELEVATION: 0995 METERS	MONTH SAMPLED: AUGUST
SLOPE: 1	CLASS: NEARLY LEVEL	KIND: PLANE	ASPECT:
AIR TEMPERATURE	ANNUAL: 46 DEGREES F	SUMMER: 68 DEGREES F	WINTER: 24 DEGREES F
SOIL TEMPERATURE	ANNUAL: DEGREES F	SUMMER: DEGREES F	WINTER: DEGREES F
WATER TABLE:	DEPTH: CM.	MONTH: AUGUST	KIND: NO WATER TABLE
PRECIPITATION:	340 CM.	CONTROL SECTION LIMITS --	UPPER: 025 CM LOWER: 100 CM
PERMEABILITY:	MODERATELY SLOW	DRAINAGE CLASS: MODERATELY WELL DRAINED	
PHYSIOGRAPHY:	LEVEL OR UNDULATING PLAINS		STONINESS: CLASS 1
MICRORELIEF:	ON SLOPE AND DEPRESSION		
VEGETATION:	GRASSES AND FORBS		
PARENT MATERIAL:	SLIGHTLY WEATHERED CALCAREOUS SANDSTONE	UNCONSOLIDATED MINERAL SEDIMENTS AND INTERBEDDED SHALE AND SILTSTONE	

HORIZON	PROFILE DESCRIPTION
A 11	0 - 1 CM. (0 - 0 IN.) PALE BROWN (10YR 6/3) CRUSHED : SANDY LOAM : WEAK FINE PLATY STRUCTURE : SOFT , VERY FRIABLE , NONSTICKY , SLIGHTLY PLASTIC : FEW FINE ROOTS THROUGHOUT HORIZON : MANY FINE VESICULAR PORES : FEW SANDSTONE FRAGMENTS >2 CM : MODERATELY EFFERVESCENT (HCL) CONTINUOUS : MODERATELY ALKALINE PH- 8.3 (PH METER) : ARBITRARY BOUNDARY .
A 12	1 - 2 CM. (0 - 1 IN.) PALE BROWN (10YR 6/3) CRUSHED : SANDY LOAM : DK. YELLOWISH BROWN (10YR 4/4) CRUSHED MOIST : WEAK FINE PLATY STRUCTURE : SOFT , VERY FRIABLE , NONSTICKY , SLIGHTLY PLASTIC : FEW FINE ROOTS THROUGHOUT HORIZON : FEW TO COMMON FINE VESICULAR PORES : FEW SANDSTONE FRAGMENTS >2 CM : MODERATELY EFFERVESCENT (HCL) CONTINUOUS : STRONGLY ALKALINE PH- 8.7 (PH METER) : ARBITRARY BOUNDARY .
A 13	2 - 5 CM. (1 - 2 IN.) PALE BROWN (10YR 6/3) CRUSHED : SANDY LOAM : DK. YELLOWISH BROWN (10YR 4/4) CRUSHED MOIST : WEAK COARSE PLATY STRUCTURE : SOFT , VERY FRIABLE , NONSTICKY , SLIGHTLY PLASTIC : FEW FINE ROOTS THROUGHOUT HORIZON : FEW TO COMMON FINE VESICULAR PORES : FEW SANDSTONE FRAGMENTS >2 CM : MODERATELY EFFERVESCENT (HCL) CONTINUOUS : MODERATELY ALKALINE PH- 8.0 (PH METER) : ARBITRARY BOUNDARY .
A 14	5 - 10 CM. (2 - 4 IN.) PALE BROWN (10YR 6/3) CRUSHED : SANDY LOAM : YELLOWISH BROWN (10YR 5/4) CRUSHED MOIST : WEAK COARSE PLATY STRUCTURE : SLIGHTLY HARD , FRIABLE , NONSTICKY , SLIGHTLY PLASTIC : FEW FINE ROOTS THROUGHOUT HORIZON : FEW FINE TUBULAR CONTINUOUS PORES , COMMON FINE TUBULAR PORES : FEW SANDSTONE FRAGMENTS >2 CM : MODERATELY EFFERVESCENT (HCL) CONTINUOUS : MODERATELY ALKALINE PH- 8.0 (PH METER) : ARBITRARY BOUNDARY .
A 15	10 - 26 CM. (4 - 11 IN.) PALE BROWN (10YR 6/3) CRUSHED : SANDY LOAM : YELLOWISH BROWN (10YR 5/4) CRUSHED MOIST : MASSIVE : SLIGHTLY HARD , FRIABLE , NONSTICKY , SLIGHTLY PLASTIC : FEW FINE ROOTS THROUGHOUT HORIZON : FEW FINE TUBULAR CONTINUOUS PORES : MODERATELY EFFERVESCENT (HCL) CONTINUOUS : STRONGLY ALKALINE PH- 8.7 (PH METER) : ABRUPT WAVY BOUNDARY .
C 1	26 - 50 CM. (11 - 20 IN.) LIGHT GRAY (5Y7/1) CRUSHED : LOAM : LIGHT GRAY (5Y6/1) CRUSHED MOIST : MASSIVE : SLIGHTLY HARD , FRIABLE , NONSTICKY , SLIGHTLY PLASTIC : MODERATELY EFFERVESCENT (HCL) CONTINUOUS : STRONGLY ALKALINE PH- 8.8 (PH METER) : ARBITRARY BOUNDARY .
C 2	50 - 80 CM. (20 - 31 IN.) LIGHT GRAY (2.5Y 7/2) CRUSHED : LOAM : LIGHT BROWNISH GRAY (2.5Y 6/2) CRUSHED MOIST : MASSIVE : SOFT , FRIABLE , NONSTICKY , SLIGHTLY PLASTIC : FEW SANDSTONE FRAGMENTS >2 CM : MODERATELY EFFERVESCENT (HCL) CONTINUOUS : STRONGLY ALKALINE PH- 8.6 (PH METER) : ABRUPT WAVY BOUNDARY .
C 3	80 - 100 CM. (31 - 39 IN.) LIGHT GRAY (5Y7/1) INTERIOR : LOAM : LIGHT GRAY (5Y6/1) EXTERIOR MOIST : MASSIVE : SLIGHTLY HARD , FRIABLE , NONSTICKY , SLIGHTLY PLASTIC : FEW SANDSTONE FRAGMENTS >2 CM : MODERATELY EFFERVESCENT (HCL) CONTINUOUS : STRONGLY ALKALINE PH- 8.7 (PH METER) : ABRUPT WAVY BOUNDARY .
C 4	100 - 200 CM. (39 - 79 IN.) LIGHT GRAY (2.5Y 7/2) CRUSHED : SANDY LOAM : LIGHT BROWNISH GRAY (2.5Y 6/2) CRUSHED MOIST : MASSIVE : SOFT , VERY FRIABLE , NONSTICKY , NONPLASTIC : MODERATELY EFFERVESCENT (HCL) CONTINUOUS : STRONGLY ALKALINE PH- 8.6 (PH METER) : NOT REACHED BOUNDARY .
REMARKS:	STRIP-MINE SPOILS NEAR COLSTRIP, MONTANA REGRADED IN 1975. AUG 12, 1976 SOIL T EMP =23.0 C AT 50 CM. ROOTS ARE MATTED AT THE TOP OF THE C1. PROFILE IS MOIST BELOW 80 CM. ALL THROUGH A,S HORIZONS ARE TOPSOIL MATERIAL.

APPENDIX E. Laboratory Soil Analysis

Table 49. Laboratory analysis of Chinook undisturbed soil (Site No. 1).

SOIL CLASSIFICATION-ARIDIC HAPLOBOROLL
COARSE-LOAMY, MIXED
SERIES - - - - - - -CHINOOK

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE, MTSC
NATIONAL SOIL SURVEY LABORATORY
LINCOLN, NEBRASKA

SOIL NO - - - - - - S76MT-087-1 COUNTY - - - ROSEBUD

GENERAL METHODS- - -1A, 1B1B, 2A1, 2B SAMPLE NOS. 76P0534-76P0537

DEPTH	HORIZON	PARTICLE SIZE ANALYSIS, LT 2MM, 3A1, 3A1A, 3A1B																RATIO
		SAND 2-.05	SILT .05-.002	CLAY LT .0002	FINE CLAY LT .0002	SAND VCOS 2-1	SAND COS 1-.5	SAND MDS .5-.25	SAND FNS .25-.10	SAND VFS .10-.05	SILT COSI .05-.02	SILT FNSI .02-.002	SILT VFSI .002-.005	FAML TEXT SAND 2-.1	INTR TI .2-.02	FINE CLAY TO CLAY	NON-CO3-CLAY	8D1 15-BAR TO CLAY
CM		PCT LT 2MM														PCT	PCT	
000-010	A1	66.8	23.1	10.1		.3	.5	3.4	43.6	19.0	14.2	8.9		47.8			10	.62
010-050	B2	67.4	20.7	11.9		.3	.8	3.9	45.8	16.6	8.7	12.0		50.8			12	.45
050-100	B3CA	68.8	18.6	12.6		.8	.7	3.5	45.5	18.3	11.7	6.9		50.5			13	.43
100-200	2A1B	55.9	26.2	17.9		.1	.6	3.5	37.2	14.5	14.0	12.2		41.4			18	.51

DEPTH	VOL. GT 2	WEIGHT GT 75	PARTICLE SIZE ANALYSIS, MM, 3B, 3B1, 3B2 75-20	20-5	5-2	LT .074	BULK DENSITY 4A1D 20-2 PCT	4A1H 1/3-BAR	4D1 OVEN DRY	COLE	WATER CONTENT- 4B1C 1/10 BAR	4B1C 1/3-BAR	4B2 15-BAR	4C1 WRD	CARBONATE 6E1B LT 2	3A1A LT .002	8C1A 1/1 H2O	8C1E 1/2 CACL
CM	PCT	PCT	PCT LT 75				LT20	G/CC	G/CC		PCT	PCT	PCT	CM/CM	PCT	PCT		
000-010	TR	0	0	TR	1		1	1.3 A					6.3		TR		7.7	7.4
010-050	1	0	0	1	1		2	1.41	1.41	.000		10.9	5.4	.08	4	TR	8.2	7.7
050-100	2	0	0	1	2		2	1.4 A					5.4		12	TR	8.5	8.0
100-200	TR	0	0	TR	TR		TR	1.31	1.40	.023		17.0	9.1	.11	8	TR	9.0	8.3

DEPTH	ORGANIC MATTER 6A1A ORGN CARB	6B1A NITG	C/N	IRON 6C2B EXT FE	PHOS TOTL	EXTRACTABLE BASES 5B4A- 6N2E CA	6O2D MG	6P2B NA	6Q2B K	SUM EXTB	ACTY 6H1A BACL TEA	AL 6G1E KCL EXT	(CAT EXCH) 5A3A EXTB ACTY	5A6A NHAC	RATIO 8D1 NHAC TO CLAY	RATIO 8D3 CA TO MG	CA 5F1 SAT NHAC PCT	(BASE SAT) 5C3 EXTB ACTY PCT	5C1 NHAC PCT
CM	PCT	PCT		PCT	PCT	MEQ / 100 G-													
000-010	1.93	.159	12			TR	TR	.5			.0			9.8	.97				
010-050	.85	.081	10			4.0	.0	.4						7.9	.66				
050-100	.58	.050	12			5.3	TR	.4						4.5	.36				
100-200	1.06	.039	27			24.7	.1	.4						6.0	.34				

DEPTH	SATURATED PASTE 8F1 REST OHM-CM	8C1B PH	8A H2O PCT	NA 502 ESP PCT	NA 5E SAR	SALT 8D5 TOTL SOLU PPM	GYP 6F1A PCT	SATUPATION EXTRACT 8A1- 8A1A EC MMHOS/CM	6N1B CA	6O1B MG	6P1B NA	6Q1B K	6I1A CO3	6J1A HCO3	6K1C CL	6L1C SO4	6M1C NO3	ATTERBERG 4F1 LQID LMIT PCT	4F2 PLST INDX
CM									MEQ / LITER										
000-010		7.2	42.7			410		1.24	8.6	5.5	.1	.8	.0	12.2	.3	.9	.4		
010-050								.20B											
050-100	7800	8.2	28.7			80		.40	1.6	2.0	.1	.5	.0	3.5	.1	.4	.0		
100-200	5000	8.8	34.3		1	150		.63	.3	4.5	1.7	.5	.0	4.7	.1	1.1	.2	26	7 C

(A) ESTIMATE
(B) 1:2 SOIL WATER RATIO.
(C) BY SOIL MECHANICS LABORATORY, USDA, LINCOLN, NE.

Table 50. Laboratory analysis of Yamac undisturbed soil (Site No. 2).

SOIL CLASSIFICATION-BOROLLIC CAMBORTHID
FINE-LOAMY, MIXED
SERIES - - - - - - -YAMAC

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE, NTSC
NATIONAL SOIL SURVEY LABORATORY
LINCOLN, NEBRASKA

SOIL NO - - - - - - S76MT-087-2 COUNTY - - - ROSEBUD

GENERAL METHODS- - -1A, 1B1B, 2A1, 2B SAMPLE NOS. 76P0538-76P0549

DEPTH	HORIZON	PARTICLE SIZE ANALYSIS, LT 2MM, 3A1, 3A1A, 3A1B															RATIO
					FINE	SAND						SILT			FAML	INTR	FINE	NON-	8D1
		SAND	SILT	CLAY	CLAY	VCOS	CORS	MEDS	FNES	VFNS	COSI	FNSI	VFSI	TEXT	SAND	II	CLAY	CO3-	15-
		2-	.05-	LT	LT	2-	1-	.5-	.25-	.10-	.05	.02	.005-	SAND	2-.1	.02	TO	CLAY	BAR
CM		.05	.002	.002	.0002	1	.5	.25	.10	.05	.02	.002	.002	2-.1	.02		CLAY		TO
		PCT LT 2MM															PCT	PCT	CLAY
000-001	A11	48.7	36.4	14.9		.2	2.5	2.5	22.4	21.1	24.3	12.1		27.6			15		.86
001-002	A12	48.9	39.1	12.1		.4	.5	1.6	23.1	23.3	25.5	13.6		25.6			12		.68
002-005	A13	49.0	37.9	13.1		.2	.4	1.3	22.2	24.9	25.4	12.5		24.1			13		.44
005-010	A14	49.1	37.6	13.3		.1	.4	1.4	23.3	23.9	24.4	13.2		25.2			13		.43
010-022	A15	46.9	33.8	19.3		.1	.2	1.1	22.3	23.2	23.5	10.3		23.7			19		.38
022-038	B21	48.7	31.0	20.3		TR	.2	1.1	23.8	23.6	21.1	9.9		25.1			20		.41
038-050	B22	49.3	30.9	19.8		.1	.1	.9	22.5	25.7	20.9	10.0		23.6			20		.40
050-060	B23	47.1	33.2	19.7		.1	.1	.8	19.4	26.7	22.9	10.3		20.4			20		.41
060-075	B3CA	38.1	35.3	26.6		TR	.1	.6	12.8	24.6	24.3	11.0		13.5			20		.35
075-100	C1CA	42.3	34.9	22.8		TR	.1	.3	11.5	30.4	22.0	12.9		11.9			17		.36
100-145	C2	46.3	34.7	19.0		.0	.1	.3	13.3	32.6	21.9	12.8		13.7			19		.38
000-005	(A)																		

DEPTH	(PARTICLE SIZE ANALYSIS, MM, 3B, 3B1, 3B2)						BULK DENSITY				WATER CONTENT				CARBONATE		PH	
	VOL.	WEIGHT																
	GT	GT	75-20	20-5	5-2	LT	20-2	4A1D	4A1H	4D1	4B1C	4B1C	4B2	4C1	6E1B	3A1A	8C1A	8C1E
	2	75				.074	PCT	1/3-	OVEN	COLE	1/10	1/3-	15-	WRD	LT	LT	1/1	1/2
CM	PCT	PCT	PCT	PCT	PCT	PCT	LT20	BAR G/CC	DRY G/CC		BAR PCT	BAR PCT	BAR PCT	CM/ CM	2 PCT	.002 PCT	H20	CACL
000-001	TR	0	0	TR	TR		TR	1.1 B					12.8				7.0	6.3
001-002	TR	0	0	TR	TR		TR	1.1 B					8.1				6.5	5.9
002-005	TR	0	0	TR	TR		TR	1.1 B					5.8				6.3	5.6
005-010	TR	0	0	TR	TR		TR	1.2 B					5.7				6.2	5.6
010-022	TR	0	0	0	TR		TR	1.43	1.48	.003		14.7	7.4	.10			6.4	5.9
022-038	TR	0	0	TR	TR		TR	1.59	1.67	.012		16.8	8.4	.13			6.6	6.1
038-050	0	0	0	0	0		0						7.9		TR		6.9	6.3
050-060	0	0	0	0	0		0						8.1		3		8.0	7.5
060-075	0	0	0	0	0		0	1.62	1.77	.028		14.2	9.3	.08	18	7	8.4	7.9
075-100	0	0	0	0	0		0						8.2		21	6	8.6	8.1
100-145	0	0	0	0	0		0	1.48	1.61	.028		19.4	7.2	.18	15		8.7	8.1
000-005								1.10	1.23	.040		21.3						

DEPTH	ORGANIC MATTER			IRON	PHOS	EXTRACTABLE BASES 5B4A-					ACTY	AL	(CAT EXCH)		RATIO	RATIO	CA	(BASE SAT)	
	6A1A	6B1A		6C2B		6N2E	6Q2D	6P2B	6Q2B		6H1A	6G1E	5A3A	5A6A	8D1	8D3	5F1	5C3	5C1
	ORGN	NITG		EXT		CA	MG	NA	K	SUM	BACL	KCL	EXTB	NHAC	NHAC	CA	SAT	EXTB	NHAC
	CARB			FE						EXTB	TEA	EXT	ACTY		TO	TO	NHAC	ACTY	
CM	PCT	PCT	C/N	PCT	PCT	MEQ / 100					G				CLAY	MG	PCT	PCT	PCT
000-001	3.47	.376	9			13.7	4.4	TR	1.4	19.5	5.0		24.5	18.2	1.22	3.1	75	80	107
001-002	2.32	.207	11			8.2	2.9	.0	1.0	12.1	4.3		16.4	13.5	1.12	2.8	61	74	90
002-005	1.30	.118	11			5.8	2.2	.0	.7	8.7	3.4		12.1	10.5	.80	2.6	55	72	83
005-010	1.14	.106	11			6.7	2.1	.0	.7	9.5	3.2		12.7	11.0	.83	3.2	61	75	86
010-022	.88	.089	10			8.2	3.2	.0	.8	12.2	2.9		15.1	14.0	.73	2.6	59	81	87
022-038	.66	.071	9			8.1	4.4	.0	.5	13.0	2.6		15.6	15.4	.76	1.8	53	83	84
038-050	.56	.063	9			8.1	5.3	.0	.0	13.4	1.9		15.3	14.7	.74	1.5	55	88	91
050-060	.58	.070	8				8.5	.0	.4					13.9	.71				
060-075	.40	.046	9				8.9	.0	.4					11.0	.41				
075-100	.25	.029	9				13.8	.0	.3					10.1	.44				
100-145	.22	.022	10				17.1	.1	.3					10.6	.56				
000-005																			

DEPTH	(SATURATED PASTE)			NA	NA	SALT	GYP	SATURATION EXTRACT 8A1-									ATTERBERG	
	8E1	8C1B	8A	5D2	5E	8D5	6F1A	8A1A	6N1B	6Q1B	6P1B	6Q1B	6I1A	6J1A	6K1C	6L1C	6M1C	4F1	4F2
	REST	PH	H2O	ESP	SAR	TOTL		EC	CA	MG	NA	K	CO3	HCO3	CL	SO4	NO3	LQID	PLST
	OHM-					SOLU		MMHOS/										LMIT	INDX
CM	CM		PCT	PCT		PPM	PCT	CM	(- - - - - - - - - - MEQ / LITER - - - - - - - - - -)									PCT	
000-001		6.4	75.0			1000		1.71	11.5	7.3	.1	2.3	.0	16.8	.5	.8	.0		
001-002								.10C											
002-005								.10C											
005-010								.10C											
010-022								.10C											
022-038								.10C										28	9 D
038-050								.10C											
050-060								.20C											
060-075								.20C											
075-100	3900	8.4						.20C											
100-145	3700	8.3	39.2	1	1	100		.36	.6	2.1	1.0	.1	.0	2.5	.1	.5	.1	28	9 D
000-005																			

(A) CLOD OF A11, A12, AND A13 FOR BULK DENSITY AND MOISTURE RETENTION.
(B) ESTIMATE.
(C) 1:2 SOIL WATER RATIO.
(D) BY SOIL MECHANICS LABORATORY, USDA, LINCOLN, NE.

Table 51. Laboratory analysis of Kobar undisturbed soil (Site No. 4).

SOIL CLASSIFICATION-APIDIC ARGIBOROLL
FINE, MONTMORILLONITIC
SERIES - - - - - - -ETHRIDGE

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE, MTSC
NATIONAL SOIL SURVEY LABORATORY
LINCOLN, NEBRASKA

SOIL NO - - - - - - S76MT-087-4 COUNTY - - - ROSEBUD

GENERAL METHODS- - -1A, 1B1B, 2A1, 2B SAMPLE NOS. 76P0558-76P0567

DEPTH	HORIZON	PARTICLE SIZE ANALYSIS, LT 2MM, 3A1, 3A1A, 3A1B														RATIO
		SAND 2-.05	SILT .05-.002	CLAY LT .002	FINE CLAY LT .0002	VCOS 2-1	CORS 1-.5	MEDS .5-.25	FNES .25-.10	VFNS .10-.05	COSI .05-.02	FNSI .02-.002	VFSI .005-.002	FAML TEXT SAND 2-.1	INTR II .2-.02	FINE TO CLAY	NON-CO3-CLAY	8D1 15-BAR TO CLAY
CM		PCT LT 2MM														PCT	PCT	
000-001	A11	28.9	48.2	22.9		.5	.3	1.0	12.2	14.9	23.8	24.4		14.0				.40
001-002	A12	27.6	46.1	26.3		.1	.3	.9	12.0	14.3	22.5	23.6		13.3				.45
002-005	A13	24.8	41.7	33.5		.3	.4	.8	10.8	12.5	20.5	21.2		12.3				.25
005-010	A14	22.1	39.6	38.3		.1	.2	.5	9.1	12.2	19.3	20.3		9.9				.25
010-019	B21T	18.3	42.7	39.0		.1	.1	.3	6.5	11.3	20.4	22.3		7.0				.26
019-031	B22T	20.7	46.7	32.6		.1	.2	.6	7.6	12.2	21.9	24.8		8.5				.38
031-050	B23	21.2	47.4	31.4		.1	.3	.6	8.1	12.1	20.1	27.3		9.1				.33
050-100	B3	28.5	47.0	24.5		.1	.1	.7	11.8	15.8	20.3	26.7		12.7				.38
100-152	C1	57.9	27.8	14.3		.4	.4	1.6	32.2	23.3	14.5	13.3		34.6				.38
000-005	(A)																	

DEPTH	PARTICLE SIZE ANALYSIS, MM, 3B, 3B1, 3B2					BULK DENSITY			WATER CONTENT			CARBONATE		PH	
	VOL. GT 2	WEIGHT GT 75	75-20	20-5	5-2	LT .074	20-2	4A1D 1/3-BAR	4A1H OVEN DRY	4D1 COLE	4B1C 1/10 BAR	4B1C 1/3-BAR	4B2 15-BAR	4C1 WRD	6E1B LT 2	3A1A LT .002	8C1A 1/1 H20	8C1E 1/2 CACL
CM	PCT	PCT	PCT LT 75			LT20	PCT	G/CC	G/CC		PCT	PCT	PCT	CM/CM	PCT	PCT		
000-001	TR	0	0	TR	TR		TR	1.48					9.1		TR		6.9	6.7
001-002	TR	0	0	TR	TR		TR	1.48					11.8		TR		7.0	6.4
002-005	TR	0	0	TR	TR		TR	1.58					8.3		TR		6.8	6.4
005-010	TR	0	0	TR	TR		TR	1.55	1.68	.028		18.8	9.6	.15	TR		6.9	6.3
010-019	TR	0	0	TR	TR		TR	1.49	1.67	.040		20.5	10.3	.16	TR		6.8	6.2
019-031	0	0	0	0	0		0						12.3		TR		7.6	7.1
031-050	0	0	0	0	0		0						10.3		16		8.3	7.8
050-100	0	0	0	0	0		0	1.54	1.61	.015		18.4	9.2	.14	15		8.8	8.2
100-152	TR	0	0	TR	TR		TR	1.45	1.50	.012		15.0	5.4	.14	13		8.9	8.2
000-005								1.41	1.52	.025		21.0						

DEPTH	ORGANIC MATTER 6A1A ORGN CARB	6B1A NITG	C/N	IRON 6C2B EXT FE	PHOS TOTL	EXTRACTABLE BASES 5B4A- 6N2E CA	6O2D MG	6P2B NA	6Q2B K	SUM EXTB	ACTY 6H1A BACL TEA	AL 6G1E KCL EXT	CAT EXCH 5A3A EXTB	5A6A NHAC	RATIO 8D1 NHAC TO CLAY	RATIO 8D3 CA TO MG	CA SAT 5F1 NHAC PCT	BASE SAT 5C3 EXTB PCT	5C1 NHAC PCT
CM	PCT	PCT		PCT	PCT	MEQ / 100 G							ACTY						
000-001	2.99	.235	13			9.8	5.1	TR	1.6	16.5	2.4		18.9	14.3	.62	1.9	69	87	115
001-002	1.62	.140	12			8.5	4.7	.0	1.1	14.3	2.3		16.6	14.1	.57	1.8	60	86	101
002-005	1.38	.121	11			8.9	5.0	.0	1.1	15.0	3.3		18.3	14.8	.44	1.8	60	82	101
005-010	1.01	.098	10			9.3	5.0	.0	1.1	15.4	2.3		17.7	16.2	.42	1.9	57	87	95
010-019	.75	.077	10			10.1	6.0	.0	.7	16.8	2.5		19.3	17.9	.46	1.7	56	87	94
019-031	.79	.085	9				8.7	TR	.6					19.3	.59				
031-050	.62	.064	10				9.2	TR	.4					11.7	.37				
050-100	.29	.027	11				22.9	.3	.4					10.1	.41				
100-152	.14	.018	8				10.9	1.0	.2					6.2	.43				
000-005																			

DEPTH	SATURATED PASTE 8E1 REST OHM-	8C1B PH	8A H20	NA 5D2 ESP	NA 5E SAR	SALT 8D5 TOTL SOLU	GYP 6F1A	SATURATION EXTRACT 8A1- 8A1A EC	6N1B CA	6O1B MG	6P1B NA	6Q1B K	6I1A CO3	6J1A HCO3	6K1C CL	6L1C SO4	6M1C NO3	ATTERBERG 4F1 LQID LMIT	4F2 PLST INDX
CM	CM		PCT	PCT		PPM	PCT	MMHOS/CM	MEQ / LITER									PCT	
000-001		6.6	49.6			890		2.23	12.9	11.9	.2	2.9	.0	21.7	1.1	1.4	.0		
001-002								.20C											
002-005								.10C											
005-010								.10C											
010-019								.10C										32	15 D
019-031								.20C											
031-050								.20C											
050-100	3400	8.4	37.3	2	2	130		.48	.4	2.8	2.1	.1	.0	3.7	.1	.5	.2		
100-152	1500	8.5	31.8	8	7	560		2.45	1.1	10.2	16.0	.2	.0	1.9	.9	24.5	.0	22	4 D
000-005																			

(A) CLOD OF A11, A12, AND A13 FOR BULK DENSITY AND MOISTUR RETENTION.
(B) ESTIMATE
(C) 1:2 SOIL WATER RATIO.
(D) BY SOIL MECHANICS LABORATORY, USDA, LINCOLN, NE.

Table 52. Laboratory analysis of Busby undisturbed soil (Site No. 6).

SOIL CLASSIFICATION-

SERIES - - - - - - -SERIES NOT DESIGNATED

SOIL NO - - - - - - S76NT-087-6 COUNTY - - - ROSEBUD

GENERAL METHODS- - -1A, 1B1B, 2A1, 2B

J. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE, NTSC
NATIONAL SOIL SURVEY LABORATORY
LINCOLN, NEBRASKA

SAMPLE NOS. 76P0578-76P0587

DEPTH	HORIZON	PARTICLE SIZE ANALYSIS, LT 2MM, 3A1, 3A1A, 3A1B (PCT LT 2MM)															RATIO
					FINE	SAND					SILT		FAML	INTR	FINE	NON-	8D1
		SAND 2-.05	SILT .05-.002	CLAY LT .002	CLAY LT .0002	VCOS 2-1	CORS 1-.5	MEDS .5-.25	FNES .25-.10	VFNS .10-.05	COSI .05-.02	FNSI .02-.002	VFSI .005-.002	TEXT SAND 2-.1	II .2-.02	CLAY TO CLAY	CO3- CLAY	15- BAR TO CLAY
CM																PCT	PCT	
000-001	A11	76.4	15.0	8.6		.8	1.0	1.6	43.2	29.8	7.2	7.8		46.6			9	.62
001-002	A12	76.9	14.7	8.4		.6	.7	1.4	42.4	31.8	6.6	8.1		45.1			8	.49
002-005	A13	77.8	14.1	8.1		.3	.7	1.4	47.0	28.4	6.4	7.7		49.4			8	.49
005-010	A14	73.7	17.0	9.3		.4	.7	1.3	41.1	30.2	8.1	8.9		43.5			9	.46
010-025	B21	75.1	15.1	9.8		.3	.3	.8	39.0	34.7	7.7	7.4		40.4			10	.44
025-035	B22	77.9	12.9	9.2		.4	.4	.5	43.2	33.4	5.8	7.1		44.5			9	.45
035-050	C1	76.7	15.7	7.6		.1	.1	.4	40.9	35.2	7.5	8.2		41.5			8	.46
050-100	C2	85.0	10.5	4.5		.2	.1	.3	50.9	33.5	4.6	5.9		51.5			5	.51
100-176	C3	86.3	9.0	4.7		.0	.1	.9	53.7	31.6	3.3	5.7		54.7			5	.45
------	AB	73.4	15.6	11.0		.2	.4	5.4	55.6	11.8	8.2	7.4		61.6			11	.38

DEPTH	(PARTICLE SIZE ANALYSIS, MM, 3B, 3B1, 3B2) VOL. WEIGHT						(BULK DENSITY) 4A1D	4A1H	4D1	(WATER CONTENT) 4B1C	4B1C	4B2	4C1	CAPBONATE 6E1B	3A1A	(PH) 8C1A	8C1E
	GT 2	GT 75	75-20	20-5	5-2	.074	20-2 1/3- BAR	OVEN DRY	COLE	1/10 BAR	1/3- BAR	15- BAR	WFD CM/	LT .002	LT .002	1/1	1/2
CM	PCT	PCT	PCT LT 75			LT20	G/CC	G/CC		PCT	PCT	PCT	CM	PCT	PCT	H2O	CACL
000-001	3	0	0	2	3	5	1.3 A					5.3		8		8.0	7.5
001-002	3	0	0	2	2	4	1.4 A					4.1		8		8.1	7.4
002-005	1	0	0	1	1	2	1.38	1.40	.005		10.6	4.0	.09	7		8.1	7.5
005-010	TR	0	0	TR	1	1	1.35	1.37	.005		16.5	4.3	.17	2		8.1	7.4
010-025	1	0	0	1	1	2	1.37	1.41	.010		13.5	4.3	.12	7	TR	8.1	7.5
025-035	2	0	0	2	2	4	1.4 A					4.1		12	TR	8.3	7.6
035-050	1	0	0	1	TR	1	1.34	1.45	.026		14.9	3.5	.15	18	TR	8.4	7.7
050-100	0	0	0	0	0	0						2.3		17	TR	8.6	7.8
100-176	TR	0	0	0	TR	TR	1.63	1.63	.000		7.6	2.1	.09	15	TR	8.6	7.8
------	1	0	0	1	1	2	1.5 A					4.2		TR	TR	8.3	7.6

DEPTH	(ORGANIC MATTER) 6A1A ORGN CARB	6B1A NITG	C/N	IRON 6C2B EXT FE	PHOS TOTL	(EXTRACTABLE BASES 5B4A) 6N2E CA	6O2D MG	6P2B NA	6Q2B K	SUM EXTB	ACTY 6H1A BACL TEA	AL 6G1E KCL EXT	(CAT EXCH) 5A3A EXTB ACTY	5A6A NHAC	RATIO 8D1 NHAC TO CLAY	PATIO 8D3 CA TO MG	CA 5F1 SAT NHAC PCT	(BASE SAT) 5C3 EXTB ACTY PCT	5C1 NHAC PCT
CM	PCT	PCT		PCT	PCT	MEQ / 100 G													
000-001	1.08	.095	11			2.3	TR	.4						7.2	.84				
001-002	.68	.068	10			2.4	TR	.4						6.5	.77				
002-005	.90	.071	13			2.6	.0	.3						6.9	.85				
005-010	.91	.086	11			3.4	.0	.4						8.3	.89				
010-025	.85	.081	10			3.4	.0	.4						7.0	.71				
025-035	.55	.058	9			3.0	.0	.3						5.3	.57				
035-050	.40	.041	10			3.0	.0	.2						4.1	.54				
050-100	.10	.016	6			3.8	.0	.3						3.1	.69				
100-176	.04	.003	13			3.8	.0	.1						3.4	.72				

DEPTH	(SATURATED PASTE) 8E1 REST OHM-	8C1B PH	8A H2O	NA 5D2 ESP	NA 5E SAR	SALT 8D5 TOTL SOLU	GYP 6F1A	(SATURATION EXTRACT 8A1) 8A1A EC	6N1B CA	6O1B MG	6P1B NA	6Q1B K	6I1A CO3	6J1A HCO3	6K1C CL	6L1C SO4	6M1C NO3	ATTERBERG 4F1 LQID LMIT	4F2 PLST INDX
CM	CM		PCT	PCT		PPM	PCT	MMHOS/CM	MEQ / LITER									PCT	
000-001		7.3	36.5			310		1.22	10.9	1.8	.1	.5	.0	10.6	.2	.6	.0		
001-002		7.7	31.1			130		.59	5.1	.9	.1	.3	.0	4.6	.2	.4	.5		
002-005								.208											
005-010								.208											
010-025								.208											
025-035								.208											
035-050								.208											
050-100	7900	8.5						.208											
100-176	8700	8.6						.208											

(A) ESTIMATE
(B) 1:2 SOIL WATER RATIO

Table 53. Laboratory analysis of Busby undisturbed soil (Site No. 8).

SOIL CLASSIFICATION-ARIDIC HAPLOBOROLL
COARSE-LOAMY, MIXED
SERIES - - - - - - -CHINOOK

J. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE, MTSC
NATIONAL SOIL SURVEY LABORATORY
LINCOLN, NEBRASKA

SOIL NO - - - - - - S76MT-087-8 COUNTY - - - ROSEBUD

GENERAL METHODS- - -1A, 1B1B, 2A1, 2B SAMPLE NOS. 76P0597-76P0605

DEPTH	HORIZON	PARTICLE SIZE ANALYSIS, LT 2MM, 3A1, 3A1A, 3A1B															RATIO
					FINE	SAND						SILT		FAML	INTR	FINE	NON-	8D1
		SAND 2-.05	SILT .05-.002	CLAY LT .002	CLAY LT .0002	VCOS 2-1	CORS 1-.5	MEDS .5-.25	FNES .25-.10	VFNS .10-.05	COSI .05-.02	FNSI .02-.002	VFSI .005-.002	TEXT SAND 2-.1	TI .2-.02	CLAY TO CLAY	CO3- CLAY	15-BAR TO
CM		PCT LT 2MM														PCT	PCT	CLAY
000-001	A11	81.7	12.2	6.1		.7	1.4	7.0	60.3	12.3	6.1	6.1		69.4				.72
001-002	A12	83.8	10.6	5.6		.7	1.1	6.5	63.5	12.0	5.7	4.9		71.8				.82
002-005	A13	82.5	10.7	6.8		.6	.7	5.4	64.2	11.6	5.1	5.6		70.9				.50
005-010	A14	81.9	9.7	8.4		.1	.4	4.9	65.8	10.7	4.7	5.0		71.2				.44
010-025	B21	80.8	10.7	8.5		TR	.2	5.0	64.0	11.6	6.0	4.7		69.2				.47
025-050	B22	78.0	9.4	12.6		.1	.2	4.1	61.6	12.0	5.9	3.5		66.0				.36
050-100	C1CA	78.7	10.4	10.9		.2	.2	3.8	60.2	14.3	5.6	4.8		64.4				.38
100-150	C2CA	65.4	19.6	15.0		TR	.4	2.8	47.4	14.8	10.1	9.5		50.6				.37
150-200	C3	74.2	14.5	11.3		.1	.2	2.7	50.9	20.3	10.6	3.9		53.9				.36

DEPTH	PARTICLE SIZE ANALYSIS, MM, 3B, 3B1, 3B2					BULK DENSITY			WATER CONTENT			CARBONATE		PH	
	VOL.	WEIGHT													
	GT 2	GT 75	75-20	20-5	5-2	LT .074	20-2	1/3-BAR	OVEN DRY	COLE	1/10 BAR	1/3-BAR	15-BAR	WRD CM/	6E1B LT 2	3A1A LT .002	8C1A 1/1 H2O	8C1E 1/2 CACL
CM	PCT	PCT	PCT			PCT	LT20	G/CC	G/CC		PCT	PCT	PCT	CM	PCT	PCT		
000-001	0	0	0	0	0		0						4.4		TR		7.4	7.0
001-002	TR	0	0	TR	TR		TR	1.4 A					4.6		TR		7.5	6.9
002-005	TR	0	0	TR	TR		TR	1.40	1.44	.010		16.5	3.4	.19	TR		7.5	6.9
005-010	TR	0	0	TR	TR		TR	1.48	1.51	.007		23.7	3.7	.30	TR		7.4	6.8
010-025	TR	0	0	TR	TR		TR	1.47	1.49	.005		9.5	4.0	.08	TR		7.5	6.8
025-050	TR	0	0	TR	TR		TR	1.46	1.50	.009		10.5	4.5	.09	TR		7.8	7.1
050-100	TR	0	0	TR	TR		TR	1.49	1.53	.009		9.9	4.1	.09	8		8.2	7.5
100-150	TR	0	0	TR	TR		TR	1.5 A					5.5		13		8.5	7.8
150-200	TR	0	0	1	TR		1	1.5 A					4.1		12		8.6	8.0

DEPTH	ORGANIC MATTER			IRON	PHOS	EXTRACTABLE BASES 5B4A-					ACTY	AL	(CAT EXCH)	RATIO	RATIO	CA	(BASE SAT)	
	6A1A ORGN CARB	6B1A NITG	C/N	6C2B FXT FE	TOTL	6N2F CA	6O2D MG	6P2B NA	6Q2B K	SUM EXTB	6H1A BACL TEA	6G1E KCL EXT	5A3A EXTB ACTY	5A6A NHAC	8D1 NHAC TO	8D3 CA TO MG	5F1 SAT NHAC	5C3 EXTB ACTY	5C1 NHAC
CM	PCT	PCT		PCT	PCT	MEQ / 100 G									CLAY		PCT	PCT	PCT
000-001	2.15	.130	17				2.2	TR	.5		1.1			9.0	1.50				
001-002	1.59	.092	17				2.1	.0	.4		.8			7.9	1.40				
002-005	1.12	.075	15				1.9	.0	.4		.8			7.1	1.00				
005-010	.68	.061	11			4.9	1.5	.0	.4	6.8	.6		7.4	6.3	.75	3.3	78	92	108
010-025	.52	.052	10			5.3	1.6	.0	.3	7.2	.7		7.9	7.0	.82	3.3	76	91	103
025-050	.42	.038	11				2.1	.0	.4		.6			7.4	.59				
050-100	.24	.026	9				3.2	.0	.2					5.1	.46				
100-150	.27	.026	10				5.1	.0	.1					5.8	.39				
150-200	.15	.016	9				6.3	.1	.2					4.9	.43				

DEPTH	SATURATED PASTE		NA	NA	SALT	GYP	SATURATION EXTRACT									ATTERBERG		
	8E1 REST OHM-	8C1B PH	8A H2O	5D2 ESP	5E SAR	8D5 TOTL SOLU	6F1A	8A1A EC	6N1B CA	6O1B MG	6P1B NA	6Q1B K	6I1A CO3	6J1A HCO3	6K1C CL	6L1C SO4	6M1C NO3	4F1 LQID LMIT	4F2 PLST INDX
CM	CM		PCT	PCT		PPM	PCT	MMHOS/CM	MEQ / LITER									PCT	
000-001		7.0	41.9			330		1.04	7.2	3.7	.1	1.3	.0	8.8	.7	.6	.0		
001-002								.208											
002-005								.208											
005-010								.108											
010-025								.108											
025-050								.108											
050-100	6800	8.1						.208											NP
100-150	6100	8.3						.208											
150-200								.208											

(B) 1:2 SOIL WATER RATIO
(A) ESTIMATE

Table 54. Laboratory analysis of 1924 old spoil (Site No. 5).

SOIL CLASSIFICATION-

SERIES - - - - - - -SPOIL MATERIAL

SOIL NO - - - - - - S76MT-087-5 COUNTY - - - ROSEBUD

GENERAL METHODS- - -1A, 1B1B, 2A1, 2B SAMPLE NOS. 76P0568-76P0577

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE, MTSC
NATIONAL SOIL SURVEY LABORATORY
LINCOLN, NEBRASKA

DEPTH	HORIZON	PARTICLE SIZE ANALYSIS, LT 2MM, 3A1, 3A1A, 3A1B														RATIO
		SAND 2-.05	SILT .05-.002	CLAY LT .002	FINE CLAY LT .0002	SAND VCOS 2-1	SAND CORS 1-.5	SAND MEDS .5-.25	SAND FNES .25-.10	SAND VFNS .10-.05	SILT COSI .05-.02	SILT FNSI .02-.002	SILT VFSI .005-.002	FAML TEXT SAND 2-.1	INTR II .2-.02	FINE CLAY TO CLAY	NON-CO3-CLAY	8D1 15-BAR TO CLAY
CM		PCT LT 2MM														PCT	PCT	
000-001	A11	76.4	15.1	8.5		.1	2.3	6.7	54.0	13.3	8.6	6.5		63.1				1.02
001-002	A12	79.8	12.6	7.6		TR	1.5	5.3	58.7	14.3	6.1	6.5		65.5				.75
002-005	A13	80.1	11.9	8.0		.1	.7	4.5	60.0	14.8	5.3	6.6		65.3				.50
005-010	AC	78.8	13.9	7.3		.5	1.0	8.0	59.5	9.8	5.0	8.9		69.0				.48
010-020	C1	81.3	12.1	6.6		.1	.6	7.7	62.3	10.6	4.6	7.5		70.7				.47
020-050	C2	78.7	12.5	8.8		.4	.4	7.2	60.2	10.5	5.0	7.5		68.2				.41
050-100	C3	73.7	14.3	12.0		.4	.5	4.9	52.3	15.6	6.5	7.8		58.1				.41
100-200	C4	73.0	15.7	11.3		.5	.5	5.1	52.8	14.1	7.0	8.7		58.9				.43
100-200	C4 (A)	78.4	17.9	3.7		39.8	14.7	6.5	9.1	8.3	7.6	10.3		70.1				.57
000-005	(B)																	

DEPTH	(PARTICLE SIZE ANALYSIS, MM, 3B, 3B1, 3B2) VOL. GT 2	WEIGHT GT 75	75-20	20-5	5-2	LT .074	BULK DENSITY 4A1D 20-2	4A1H 1/3-BAR OVEN DRY	4D1 COLE	WATER CONTENT 4B1C 1/10 BAR	4B1C 1/3-BAR	4B2 15-BAR	4C1 WRD CM/CM	CARBONATE 6E1B LT	3A1A LT .002	PH 8C1A 1/1 H2O	8C1E 1/2 CACL
CM	PCT	PCT	PCT LT 75			PCT LT20	G/CC	G/CC		PCT	PCT	PCT		PCT	PCT		
000-001	TR	0	0	TR	TR	TR	1.3 C					8.7		6		7.4	7.2
001-002	TR	0	0	TR	TR	1	1.3 C					5.7		7		7.6	7.1
002-005	1	0	0	2	TR	2	1.3 C					4.0		7		7.9	7.3
005-010	1	0	0	1	1	2	1.46	1.55	.020		13.3	3.5	.14	7		7.9	7.3
010-020	2	0	0	2	2	4	1.60	1.60	.000		9.2	3.1	.10	7		8.2	7.5
020-050	1	0	0	1	1	2	1.5 C					3.6		9		8.4	7.7
050-100	3	2	2	2	1	3	1.39	1.42	.007		14.0	4.9	.12	11		8.5	7.8
100-200	6	3	4	2	1	3	1.4 C					4.9		11		8.5	7.8
100-200														58		8.8	7.9
000-005							1.28	1.34	.015		13.3						

DEPTH	(ORGANIC MATTER 6A1A ORGN CARB	6B1A NITG	C/N	IRON 6C2B EXT FE	PHOS TOTL	(EXTRACTABLE BASES 5B4A) 6N2E CA	6O2D MG	6P2B NA	6Q2B K	SUM EXTB	ACTY 6H1A BACL TEA	AL 6G1E KCL EXT	(CAT EXCH) 5A3A EXTB ACTY	5A6A NHAC	RATIO 8D1 NHAC TO CLAY	RATIO 8D3 CA TO MG	CA 5F1 SAT NHAC	(BASE SAT) 5C3 EXTB ACTY	5C1 NHAC
CM	PCT	PCT		PCT	PCT	MEQ / 100					G						PCT	PCT	PCT
000-001	4.21	.304	14				4.1	TR	1.2					14.6	1.72				
001-002	2.56	.152	17				2.8	TR	.5					8.3	1.09				
002-005	1.06	.071	15				2.4	.0	.3					6.0	.75				
005-010	.59	.044	13				2.9	.0	.3					4.4	.60				
010-020	.38	.032	12				3.3	.0	.3					3.7	.56				
020-050	.35	.028	13				3.7	.0	.3					4.0	.45				
050-100	.45	.036	13				4.4	.0	.5					4.5	.38				
100-200	.49	.039	13				4.8	.0	.3					4.7	.42				
100-200																			
000-005																			

DEPTH	(SATURATED PASTE) 8E1 REST OHM-CM	8C1B PH	8A H2O	NA 5D2 ESP	NA 5E SAR	SALT 8D5 TOTL SOLU PPM	GYP 6F1A	(SATURATION EXTRACT 8A1) 8A1A EC CA	6N1B	6O1B MG	6P1B NA	6Q1B K	6I1A CO3	6J1A HCO3	6K1C CL	6L1C SO4	6M1C NO3	ATTERBERG 4F1 LQID LMIT	4F2 PLST INDX
CM			PCT	PCT		PPM	PCT	MMHOS/CM			MEQ / LITER							PCT	
000-001		6.7	65.7			920		1.77	12.6	5.2	.1	3.9	.0	15.6	1.6	.7	.0		
001-002		7.2	45.0			360		1.10	8.2	2.6	.1	1.5	.0	9.9	.7	.5	.0		
002-005		7.6	33.8			160		.68	5.1	1.3	.0	.8	.0	5.8	.4	.3	.0		
005-010		7.5	31.9			160		.78	5.7	1.4	.0	.9	.0	3.3	.1	3.3	.0		
010-020		7.7	32.3			100		.500	3.4	.9	.0	.7	.0	3.7	.1	.7	.2		
020-050								.200											
050-100	7100	8.3						.200											NP
100-200	6500	8.3						.200											
100-200																			
000-005																			

(A) WHOLE SOIL, INCLUDING COURSE FRAGMENTS, CRUSHED TO PASS 2 MM SIEVE.
(B) CLOD OF A11, A12, AND A13 FOR BULK DENSITY AND MOISTURE RETENTION.
(C) ESTIMATE
(D) 1:2 SOIL WATER RATIO.

Table 55. Laboratory analysis of 1924 old spoil (Site No. 7).

SOIL CLASSIFICATION-

SERIES - - - - - - -SERIES NOT DESIGNATED

SOIL NO - - - - - - S76MT-087-7 COUNTY - - - ROSEBUD

GENERAL METHODS- - -1A, 1B1B, 2A1, 2B SAMPLE NOS. 76P0588-76P0596

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE, MTSC
NATIONAL SOIL SURVEY LABORATORY
LINCOLN, NEBRASKA

DEPTH	HORIZON	PARTICLE SIZE ANALYSIS, LT 2MM, 3A1, 3A1A, 3A1B: SAND 2-.05	SILT .05-.002	CLAY LT .002	FINE CLAY LT .0002	VCOS SAND 2-1	CORS SAND 1-.5	MEDS SAND .5-.25	FNES SAND .25-.10	VFNS SAND .10-.05	COSI SILT .05-.02	FNSI SILT .02-.002	VFSI SILT .005-.002	FAML TEXT SAND 2-.1	INTR TEXT .2-.02	FINE CLAY TO CLAY	RATIO NON-CO3-CLAY	RATIO 8D1 15-BAR TO CLAY
CM		PCT LT 2MM														PCT	PCT	
000-001	A11	80.5	12.4	7.1		.9	1.4	4.9	57.0	16.3	5.3	7.1		64.2			7	.66
001-002	A12	82.1	11.5	6.4		.2	.4	3.0	61.7	16.8	4.9	6.6		65.3			6	.52
002-005	A13	81.7	10.2	8.1		.2	.5	3.3	61.2	16.5	4.7	5.5		65.2			8	.40
005-010	A14	78.3	14.8	6.9		.9	.4	4.0	59.2	13.8	7.1	7.7		64.5			7	.48
010-020	C1	81.3	12.5	6.2		.2	.4	3.1	62.4	15.2	5.0	7.5		66.1			6	.50
020-050	C2	80.3	12.3	7.4		.2	.4	3.1	62.9	13.7	5.2	7.1		66.6			7	.47
050-100	C3	75.0	14.9	10.1		.2	.4	4.2	54.8	15.4	6.7	8.2		59.6			10	.41
100-200	C4	66.4	20.4	13.2		.7	.5	3.3	45.8	16.1	10.4	10.0		50.3			13	.36
- - - - - - -	AB																	

DEPTH	(PARTICLE SIZE ANALYSIS, MM, 3B, 3B1, 3B2): VOL. GT 2	WEIGHT GT 75	75-20	20-5	5-2	LT .074	BULK DENSITY 4A1D 1/3-BAR	4A1H OVEN DRY	4D1 COLE	WATER CONTENT- 4B1C 1/10 BAR	4B1C 1/3-BAR	4B2 15-BAR	4C1 WRD CM/CM	CARBONATE 6C1B LT 2	3A1A .002	(-PH- 8C1A 1/1 H2O	8C1E 1/2 CACL
CM	PCT	PCT	PCT LT 75			LT20	G/CC	G/CC		PCT	PCT	PCT		PCT	PCT		
000-001	TR	0	0	TR	1	1	1.3 A					4.7		8	TR	7.5	7.2
001-002	TR	0	0	TR	TR	TR	1.4 A					3.3		8	TR	7.9	7.3
002-005	TR	0	0	1	TR	1	1.52	1.54	.005		9.8	3.2	.10	8	TR	7.8	7.3
005-010	TR	0	0	1	TR	1	1.5 A					3.3		9	TR	8.1	7.4
010-020	1	0	0	TR	1	1	1.61	1.63	.004		10.8	3.1	.12	9	TR	8.1	7.5
020-050	TR	0	0	TR	1	1	1.4 A					3.5		9	TR	8.4	7.7
050-100	TR	0	0	TR	TR	TR	1.25	1.47	.057		8.7	4.1	.06	9	TR	8.5	7.8
100-200	TR	0	0	1	TR	1	1.2 A					4.8		5	TR	8.4	7.8
- - - - - - -	TR	0	0	1	TR	1	1.5 A					5.6		TR		8.2	7.7

DEPTH	(ORGANIC MATTER 6A1A ORGN CARB	6B1A NITG	C/N	IRON 6C2B EXT FE	PHOS TOTL	(-EXTRACTABLE BASES 5B4A-) 6N2E CA	6O2D MG	6P2B NA	6Q2B K	SUM EXTB	ACTY 6H1A BACL TEA	AL 6G1E KCL EXT	(CAT EXCH) 5A3A EXTB ACTY	5A6A NHAC	RATIO 8D1 NHAC TO CLAY	RATIO 8D3 CA TO MG	CA 5F1 SAT NHAC	(BASE SAT) 5C3 EXTB ACTY	5C1 NHAC
CM	PCT	PCT		PCT	PCT	(- - - - - - - - - - MEQ / 100 G- - - - - - - - - -)											PCT	PCT	PCT
000-001	2.01	.167	12			2.8	TR	.7						7.7	1.08				
001-002	1.10	.069	16			2.4	.0	.4						5.7	.89				
002-005	.73	.054	14			2.4	.0	.2						5.3	.65				
005-010	.72	.048	15			2.6	.0	.3						5.3	.77				
010-020	.38	.031	12			2.7	.0	.2						4.2	.68				
020-050	.24	.024	10			3.8	.0	.2						4.4	.59				
050-100	.15	.016	9			6.9	.0	.3						5.3	.52				
100-200	.42	.045	9			8.2	TR	.3						7.6	.58				
- - - - - - -																			

DEPTH	(SATURATED PASTE) 8E1 REST OHM-	8C1B PH	8A H2O	NA 5D2 ESP	NA 5E SAR	SALT 8D5 TOTL SOLU	GYP 6F1A	(- - - - - - - - - SATURATION EXTRACT 8A1- - - - - - - - -) 8A1A EC	6N1B CA	6O1B MG	6P1B NA	6Q1B K	6I1A CO3	6J1A HCO3	6K1C CL	6L1C SO4	6M1C NO3	ATTERBERG 4F1 LQID LMIT	4F2 PLST INDX
CM	CM		PCT	PCT		PPM	PCT	MMHOS/CM	(- - - - - - - - - MEQ / LITER - - - - - - - - - -)									PCT	
000-001		6.8	45.9			1000	0	2.67	23.4	7.6	.1	4.2	.0	29.1	.6	.9	.0		
001-002		7.6	33.8			220		.90	7.3	1.8	.0	1.0	.0	8.3	.2	.4	.0		
002-005		7.7	31.7			130		.58	4.6	1.1	.0	.5	.0	4.8	.2	.2	.0		
005-010		7.8	30.6			100		.48	3.7	.8	.0	.4	.0	3.6	.1	.2	.0		
010-020		7.7	29.7			200		.95	7.9	1.8	.0	.6	.0	2.5	.1	6.7	.0		
020-050								.208											
050-100	5900	8.3						.208											NP
100-200	4900	8.0	27.3			90		.47	1.5	3.2	.3	.1	.0	1.2	.1	.7	.6		
- - - - - - -																			

(A) ESTIMATE
(B) 1:2 SOIL WATER RATIO

Table 56. Laboratory analysis of 1924 old spoil (Site No. 9).

SOIL CLASSIFICATION—

SERIES - - - - - - -SERIES NOT DESIGNATED

SOIL NO - - - - - - S76MT-087-9 COUNTY - - - ROSEBUD

GENERAL METHODS- - -1A, 1B1B, 2A1, 2B SAMPLE NOS. 76P0606-76P0615

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE, MTSC
NATIONAL SOIL SURVEY LABORATORY
LINCOLN, NEBRASKA

DEPTH CM	HORIZON	PARTICLE SIZE ANALYSIS, LT 2MM, 3A1, 3A1A, 3A1B — PCT LT 2MM: SAND 2-.05	SILT .05-.002	CLAY LT .002	FINE CLAY LT .0002	SAND VCOS 2-1	SAND CORS 1-.5	SAND MEDS .5-.25	SAND FNES .25-.10	SAND VFNS .10-.05	SILT COSI .05-.02	SILT FNSI .02-.002	SILT VFSI .005-.002	FAML TEXT SAND 2-.1	INTP II .2-.02	FINE CLAY TO CLAY PCT	NON-CO3-CLAY PCT	RATIO 8D1 15-BAR TO CLAY
000-001	A11	78.7	12.4	8.9		.2	.6	5.4	57.2	15.3	8.2	4.2		63.4				.42
001-002	A12	78.8	11.5	9.7		.1	.4	5.0	57.5	15.8	8.0	3.5		63.0				.36
002-005	A13	78.5	12.6	8.9		.2	.3	5.6	58.1	14.3	7.8	4.8		64.2				.38
005-010	AC1	77.3	13.0	9.7		.2	.6	5.9	54.8	15.8	7.7	5.3		61.5				.34
010-015	AC2	80.5	11.8	7.7		TR	.3	5.1	60.7	14.4	7.6	4.2		66.1				.39
015-050	C1	81.0	11.7	7.3		.2	.4	6.0	61.6	12.8	7.0	4.7		68.2				.42
050-100	C2	84.8	6.7	8.5		TR	.4	6.7	65.5	12.2	6.4	.3		72.6				.38
100-200	C3	83.3	9.0	7.7		.2	.4	10.9	60.3	11.5	5.7	3.3		71.8				.36
100-200	C3 (A)																	
000-005	(B)																	

DEPTH CM	PARTICLE SIZE ANALYSIS, MM, 3B, 3B1, 3B2 — VOL. GT 2 PCT	WEIGHT GT 75 PCT	WEIGHT 75-20 PCT LT 75	WEIGHT 20-5 PCT LT 75	WEIGHT 5-2 PCT LT 75	WEIGHT LT .074 PCT LT 75	BULK DENSITY 4A1D 20-2 LT20 1/3-BAR G/CC	BULK DENSITY 4A1H OVEN DPY G/CC	BULK DENSITY 4D1 COLE	WATER CONTENT 4B1C 1/10 BAR PCT	WATER CONTENT 4B1C 1/3-BAR PCT	WATER CONTENT 4B2 15-BAR PCT	WATER CONTENT 4C1 WRD CM/CM	CARBONATE 6F1B LT 2 PCT	CARBONATE 3A1A LT .002 PCT	PH 8C1A 1/1 H2O	PH 8C1E 1/2 CACL
000-001	1	0	0	TR	1		1	1.5 C				3.7					
001-002	1	0	0	TR	1		1	1.5 C				3.5					
002-005	1	0	TR	1	TR		1	1.5 C				3.4					
005-010	1	0	TR	1	TR		1	1.51	1.54	.007	12.5	3.3	.14				
010-015	1	0	TR	1	1		2	1.62	1.66	.008	9.8	3.0	.11				
015-050	34	0	18	27	1		34	1.6 C				3.1					
050-100	5	0	11	TR	TR		TR	1.6 C				3.2		6		8.6	7.9
100-200	13	0	18	1	TR		1	1.65	1.71	.012	13.3	2.8	.17	9		8.5	7.8
100-200	TR	0	0	TR	TR		TR	1.69	1.71	.004	7.6	2.6	.09	9		8.5	7.7
000-005								1.49	1.53	.009	10.4						

DEPTH CM	ORGANIC MATTER 6A1A ORGN CARB PCT	6B1A NITG PCT	C/N	IRON 6C2B EXT FE PCT	PHOS TOTL PCT	EXTRACTABLE BASES 5B4A- 6N2E CA MEQ/100G	6O2D MG	6P2B NA	6Q2B K	SUM EXTB	ACTY 6H1A BACL TEA MEQ/100G	AL 6G1E KCL EXT	(CAT EXCH) 5A3A EXTB ACTY	5A6A NHAC	RATIO 8D1 NHAC TO CLAY	RATIO 8D3 CA TO MG	CA 5F1 SAT NHAC PCT	(BASE SAT) 5C3 EXTB ACTY PCT	5C1 NHAC PCT
000-001	1.08	.062	17																
001-002	.65	.042	15																
002-005	.56	.036	16																
005-010	.38	.028	14																
010-015	.25	.019	13																
015-050	.13	.009	14																
050-100	.13	.012	11				4.0	.0	.1					3.3	.45				
100-200	.08	.007	11				3.5	.0	.1					3.6	.42				
100-200							3.4	.0	.1					3.5	.45				
000-005																			

DEPTH CM	SATURATED PASTE 8E1 REST OHM-CM	8C1B PH	8A H2O PCT	NA 5D2 ESP PCT	NA 5E SAR	SALT 8D5 TOTL SOLU PPM	GYP 6F1A PCT	SATURATION EXTRACT 8A1- 8A1A EC MMHOS/CM	6N1B CA MEQ/LITER	6O1B MG	6P1B NA	6Q1B K	6I1A CO3	6J1A HCO3	6K1C CL	6L1C SO4	6M1C NO3	ATTERBERG 4F1 LOID LMIT PCT	4F2 PLST INDX
000-001		7.4	30.6			270		1.18	10.0	2.6	.1	1.3	.0	10.1	1.1	.9	.0		
001-002		7.8	28.9			100		.55	4.2	.9	.0	.5	.0	4.2	.4	.4	.2		
002-005		7.8	28.9			90		.47	3.6	.9	.0	.4	.0	3.7	.2	.3	.0		
005-010								.20D											
010-015								.20D											
015-050								.20D											
050-100	8200	8.3						.20D											
100-200	8700	8.3						.20D											NP
100-200																			
000-005																			

(A) SANDSTONE FRAGMENTS.
(B) CLOD OF A11, A12, AND A13 FOR BULK DENSITY AND MOISTURE RETENTION.
(C) ESTIMATE
(D) 1:2 SOIL WATER RATIO.

Table 57. Laboratory analysis of 1932 old spoil (Site No. 10).

SOIL CLASSIFICATION-

SERIES - - - - - - -MINE SPOIL

SOIL NO - - - - - - S76MT-087-10 COUNTY - - - ROSEBUD

GENERAL METHODS- - -1A, 1B1B, 2A1, 2B

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE, MTSC
NATIONAL SOIL SURVEY LABORATORY
LINCOLN, NEBRASKA

SAMPLE NOS. 76P0616-76P0624

DEPTH	HORIZON	PARTICLE SIZE ANALYSIS, LT 2MM, 3A1, 3A1A, 3A1B														RATIO
		SAND 2-.05	SILT .05-.002	CLAY LT .002	FINE CLAY LT .0002	SAND VCOS 2-1	SAND CORS 1-.5	SAND MEDS .5-.25	SAND FNES .25-.10	SAND VFNS .10-.05	SILT COSI .05-.02	SILT FNSI .02-.002	SILT VFSI .005-.002	FAML TEXT SAND 2-.1	INTR II .2-.02	FINE CLAY TO CLAY	NON-CO3-CLAY	8D1 15-BAR TO CLAY
CM		PCT LT 2MM														PCT	PCT	
000-001	A11	42.0	46.2	11.8		.4	.5	1.7	26.5	12.9	25.3	20.9		29.1			12	.98
001-002	A12	50.7	38.5	10.8		.5	.4	1.4	30.5	17.9	22.3	16.2		32.8			11	.59
002-005	A13	46.0	40.5	13.5		.5	.6	1.2	25.7	18.0	20.2	20.3		28.0			14	.33
005-010	C1	58.1	29.8	12.1		.3	.5	1.4	35.7	20.2	16.8	13.0		37.9			12	.41
010-050	C2	49.1	33.1	17.8		.2	.5	1.3	32.8	14.3	12.3	20.8		34.8			18	.33
050-100	C3	61.0	26.9	12.1		.1	.4	3.1	43.9	13.5	8.7	18.2		47.5			11	.55
100-200	C4	63.2	25.1	11.7		.3	.4	2.7	46.0	13.8	7.3	17.8		49.4			12	.48
--------	SHALE																	
000-005	(A)																	

DEPTH	(PARTICLE SIZE ANALYSIS, MM, 3B, 3B1, 3B2) VOL. GT 2	WEIGHT GT 75	WEIGHT 75-20	WEIGHT 20-5	WEIGHT 5-2	WEIGHT LT .074	BULK DENSITY 4A1D 1/3-BAR	BULK DENSITY 4A1H OVEN DRY	BULK DENSITY 4D1 COLE	WATER CONTENT 4B1C 1/10 BAR	WATER CONTENT 4B1C 1/3-BAR	WATER CONTENT 4B2 15-BAR	WATER CONTENT 4C1 WRD	CARBONATE 6E1B LT 2	CARBONATE 3A1A LT .002	(-PH- 8C1A 1/1	8C1E 1/2
CM	PCT	PCT	PCT LT 75			LT20	G/CC	G/CC		BAR PCT	PCT	PCT	CM/CM	PCT		H20	CACL
000-001	2	0	0	2	2	4	1.1 B					11.6		TR		7.7	7.1
001-002	2	0	0	2	1	3	1.2 B					6.4		16		7.7	7.3
002-005	2	0	0	2	1	3	1.2 B					4.4		16		7.9	7.4
005-010	2	0	0	2	2	4	1.5	1.58	.008		11.1	5.0	.09	15		8.1	7.5
010-050	TR	0	0	1	TR	1	1.5 B					5.9		15		8.3	7.8
050-100	13	0	0	16	5	21	1.53	1.57	.008		18.5	6.6	.16	14	1	8.6	7.9
100-200	TR	0	0	TR	TR	TR	1.5 B					10.3		20	2	8.5	7.8
--------														3		8.5	7.9
000-005							1.23	1.31	.021		17.2						

DEPTH	(ORGANIC MATTER 6A1A ORGN CARB	6B1A NITG	C/N	IRON 6C2B EXT FE	PHOS 6N2E TOTL	(-EXTRACTABLE BASES 5B4A- 6Q2D CA	6P2B MG	6Q2B NA	K	SUM EXTB	ACTY 6H1A BACL TEA	AL 6G1F KCL EXT	(CAT EXCH) 5A3A EXTB ACTY	5A6A NHAC	RATIO 8D1 NHAC TO CLAY	PATIO 8D3 CA TO MG	CA SAT NHAC PCT	(BASE SAT) 5C3 EXTB PCT	5C1 NHAC PCT
CM	PCT	PCT		PCT	PCT	(- - - - - - - - - - -MEQ / 100					G- - - - - - - - - -)				CLAY				
000-001	4.63	.379	12			4.2	TR	1.3			1.4			17.0	1.44				
001-002	1.84	.188	10			4.0	TR	.5						5.9	.55				
002-005	1.09	.079	14			4.2	TR	.4						4.6	.34				
005-010	.73	.045	16			3.8	TR	.3						4.2	.35				
010-050	.29	.026	11			5.6	TR	.3						5.0	.28				
050-100	.19	.030	6			6.4	.0	.1						3.8	.31				
100-200	.21	.024	9			9.5	.1	.2						5.6	.46				
--------	.19	.026	7			9.5	.1	.3						6.4					
000-005																			

DEPTH	(SATURATED PASTE) 8E1 REST OHM-	8C1B PH	8A H2O	NA 5D2 ESP	NA 5E SAR	SALT 8D5 TOTL SOLU	GYP 6F1A	(- - - - - - - - - SATURATION EXTRACT 8A1- 8A1A EC	6N1B CA	6O1B MG	6P1B NA	6Q1B K	6I1A CO3	6J1A HCO3	6K1C CL	6L1C SO4	6M1C NO3	ATTERBERG 4F1 LQID LMIT	4F2 PLST INDX
CM			PCT	PCT		PPM	PCT	MMHOS/CM	(- - - - - - - - - MEQ / LITER - - - - - - - - -)									PCT	
000-001		6.7	101.0			2400	0	2.86	20.8	9.4	.1	7.0	.0	25.7	2.2	1.6	.0		
001-002		7.1	43.7			580		1.73	13.3	5.2	.1	2.2	.0	16.3	1.6	.7	.0		
002-005		7.1	32.7			340		1.39	10.7	4.0	.1	1.6	.0	11.7	1.2	.7	.0		
005-010		7.4	28.1			170		.87	6.1	2.2	.1	1.3	.0	5.4	.7	.5	.0		
010-050		7.8	35.6			100		.43	2.3	1.5	.1	.4	.0	2.5	.3	.3	.0		
050-100	6200	8.2						.20C											
100-200	4400	8.3						.20C											
--------								.20C											
000-005																			

(A) CLOD OF A11, A12, AND A13 FOR BULK DENSITY AND MOISTURE RETENTION.
(B) ESTIMATE
(C) 1:2 SOIL WATER RATIO.

Table 58. Laboratory analysis of 1948 old spoil (Site No. 3).

SOIL CLASSIFICATION-

SERIES - - - - - - -MINE SPOIL

SOIL NO - - - - - - S76MT-087-3 COUNTY - - - ROSEBUD

GENERAL METHODS- - -1A, 1B1B, 2A1, 2B SAMPLE NOS. 76P0550-76P0557

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE, MTSC
NATIONAL SOIL SURVEY LABORATORY
LINCOLN, NEBRASKA

DEPTH	HORIZON	PARTICLE SIZE ANALYSIS, LT 2MM, 3A1, 3A1A, 3A1B															RATIO
		SAND 2-.05	SILT .05-.002	CLAY LT .002	FINE CLAY LT .0002	SAND VCOS 2-1	SAND CORS 1-.5	SAND MEDS .5-.25	SAND FNES .25-.10	SAND VFNS .10-.05	SILT COSI .05-.02	SILT FNSI .02-.002	SILT VFSI .005-.002	FAML TSXT SAND 2-.1	INTR II .2-.02	FINE CLAY TO CLAY	NON-CO3-CLAY	8D1 15-BAR TO CLAY
CM		PCT LT 2MM														PCT	PCT	
000-001	A11	48.6	37.6	13.8		1.4	1.4	2.2	26.3	17.3	19.8	17.8		31.3				.87
001-002	A12	51.1	35.2	13.7		1.3	1.9	2.7	28.1	17.1	16.3	18.9		34.0				.64
002-005	A13	45.4	36.4	18.2		.6	1.1	2.1	27.3	14.3	17.9	18.5		31.1				.47
005-010	C1	49.9	34.5	15.6		1.2	.9	1.8	31.0	15.0	18.4	16.1		34.9				.55
010-050	C2	45.9	36.8	17.3		.5	1.0	1.9	28.6	13.9	18.5	18.3		32.0				.73
050-100	C3	55.0	31.7	13.3		.6	.8	2.2	34.8	16.6	17.0	14.7		38.4				1.00
100-153	C4	32.7	48.1	19.2		.9	.3	1.0	13.7	16.8	24.9	23.2		15.9				.69
-------	COAL																	

DEPTH	PARTICLE SIZE ANALYSIS, MM, 3B, 3B1, 3B2 VOL. GT 2	WEIGHT GT 75	WEIGHT 75-20	WEIGHT 20-5	WEIGHT 5-2	BULK DENSITY LT .074	4A1D PCT LT2D	4A1H 1/3-BAR	4D1 OVEN DRY	4D1 COLE	WATER CONTENT 4B1C 1/10 BAR	4B1C 1/3-BAR	4B2 15-BAR	4C1 WRD	CARBONATE 6E1B LT 2	3A1A .002	PH 8C1A H2O	8C1E 1/2 CACL
CM	PCT	PCT	PCT LT 75				G/CC	G/CC			PCT	PCT	PCT	CM/CM	PCT	PCT		
000-001	3	0	0	2	3		5	1.2 A					12.0		7		7.6	7.3
001-002	5	0	TR	4	5		9	1.3 A					8.8		8		7.7	7.4
002-005	8	0	2	7	3		10	1.55	1.62	.014		18.1	8.6	.14	9		7.9	7.2
005-010	10	0	0	7	9		16	1.70	1.74	.007		15.8	8.6	.11	12		8.0	7.4
010-050	9	0	0	7	9		16	1.40	1.44	.009		20.4	12.6	.10	11		7.6	7.3
050-100	12	0	0	11	12		23	1.3 A					13.3		10		7.5	7.3
100-153	6	0	0	8	6		14	1.19	1.25	.016		24.0	13.3	.12	9		7.6	7.2
-------									1.21								6.0	5.8

DEPTH	ORGANIC MATTER 6A1A ORGN CARB	6B1A NITG	C/N	IRON 6C2B EXT FE	PHOS TOTL	EXTRACTABLE BASES 5B4A- 6N2E CA	6O2D MG	6P2B NA	6Q2B K	SUM EXTB	ACTY 6H1A BACL TEA	AL 6G1E KCL EXT	CAT EXCH 5A3A EXTB ACTY	5A6A NHAC	RATIO 8D1 NHAC TO CLAY	RATIO 8D3 CA TO MG	CA 5F1 SAT NHAC PCT	BASE SAT 5C3 EXTB ACTY PCT	5C1 NHAC PCT
CM	PCT	PCT		PCT	PCT	MEQ / 100 G-													
000-001	5.11	.333	15			8.2	TR	1.2						24.9	1.80				
001-002	5.01	.213	24			8.4	TR	.8						22.8	1.66				
002-005	4.16	.145	29			9.5	TR	.6						21.9	1.20				
005-010	2.83	.092	31			10.9	.3	.6						17.7	1.13				
010-050	5.94	.129	46			16.2	1.1	.2						30.5	1.76				
050-100	5.52	.131	42			21.2	.6	.2						34.0	2.57				
100-153	5.28	.131	40			19.4	.1	.2						39.5	1.77				
-------	13.08	.959	14	.0C							15.2D	.0E							

DEPTH	SATURATED PASTE 8E1 REST OHM-	8C1B PH	8A H2O	NA 5D2 ESP	NA 5E SAR	SALT 8D5 TOTL SOLU	GYP 6F1A	SATURATION EXTRACT 8A1- 8A1A EC	6N1B CA	6O1B MG	6P1B NA	6Q1B K	6I1A CO3	6J1A HCO3	6K1C CL	6L1C SO4	6M1C NO3	ATTERBERG 4F1 LQID LMIT	4F2 PLST INDX
CM	CM		PCT	PCT		PPM	PCT	MMHOS/CM	MEQ / LITER									PCT	
000-001		6.8	63.2			2000	0	3.83	29.1	15.1	.6	4.6	.0	3.8	3.9	3.2	.0		
001-002		7.5	43.2			620		1.80	14.0	6.3	.2	1.9	.0	14.1	2.5	1.4	.0		
002-005		7.5	41.0			420		1.31	9.3	4.9	.7	1.1	.0	10.6	1.4	1.5	.0		
005-010		7.6	40.0	1	2	430		1.47	6.7	4.8	4.2	1.0	.0	5.1	4.2	5.8	.0		
010-050		7.2	40.9	2	4	1100		3.48	14.6	12.4	13.5	.3	.0	3.5	19.1	21.2	.0		
050-100	830	7.1	41.3	1	2	1900	0	4.96	29.9	31.3	8.7	.2	.0	2.5	28.6	38.1	.0		
100-153	2200	7.3	43.7			510		1.51	7.9	8.8	1.4	.1	.0	3.5	3.9	9.6	.0		
-------		5.9	122.0		1	1000		1.11	4.4	6.6	2.0	.2	.0	5.3	1.0	3.9	TR		

(A) ESTIMATE
(B) ORGANIC CARBON FOR COAL SAMPLE ON <0.25 MM MATERIAL = 35.4 PERCENT AND ON THE <0.002 MM MATERIAL = 37.0 PERCENT.
(C) FE FOR THE <0.25 MM MATERIAL = 0 PERCENT.
(D) ACIDITY FOR THE <0.25 MM MATERIAL = 31.7 MEQ PER 100 G.
(E) AL FOR THE <0.25 MM MATERIAL = 0 PERCENT.

Table 59. Laboratory analysis of 1969 new spoil (Site No. 14).

SOIL CLASSIFICATION-

SERIES - - - - - - -RECLAIMED MINE SPOIL

SOIL NO - - - - - - S76MT-087-14 COUNTY - - - ROSEBUD

GENERAL METHODS- - -1A, 1B1B, 2A1, 2B SAMPLE NOS. 76P0654-76P0665

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE, MTSC
NATIONAL SOIL SURVEY LABORATORY
LINCOLN, NEBRASKA

DEPTH	HORIZON	PARTICLE SIZE ANALYSIS, LT 2MM, 3A1, 3A1A, 3A1B: SAND 2-.05	SILT .05-.002	CLAY LT .002	FINE CLAY LT .0002	SAND VCOS 2-1	SAND CORS 1-.5	SAND MEDS .5-.25	SAND FNES .25-.10	SAND VFNS .10-.05	SILT COSI .05-.02	SILT FNSI .02-.002	SILT VFSI .005-.002	FAML TEXT II SAND 2-.1	INTR CLAY .2-.02	FINE CLAY TO CLAY	NON-CO3-CLAY	RATIO 8D1 15-BAR TO CLAY
CM		PCT LT 2MM														PCT	PCT	
000-001	A11	49.5	35.9	14.6		.4	1.3	2.6	28.7	16.5	12.2	23.7		33.0				1.32
001-002	A12	52.2	34.0	13.8		.3	.9	2.4	33.6	15.0	12.9	21.1		37.2				.61
002-005	A13	56.0	28.6	15.4		.3	.8	2.1	36.5	16.3	7.3	21.3		39.7				.41
005-010	C1	60.2	29.6	10.2		.4	1.1	2.7	43.5	12.5	11.3	18.3		47.7				.65
010-050	C2	78.7	16.0	5.3		.1	.4	4.9	59.7	13.6	4.2	11.8		65.1				.47
050-100	C3	81.4	13.7	4.9		TR	.2	3.4	65.5	12.3	3.8	9.9		69.1				.47
100-200	C4	86.6	5.3	8.1								9.4		71.5				.37
000-005	(A)																	
-------	COAL																	
-------	COAL																	
-------	COAL																	
-------	COAL																	

DEPTH	VOL. GT 2 MM	WEIGHT GT 75 MM	PARTICLE SIZE ANALYSIS, MM, 3B, 3B1, 3B2: 75-20 MM	20-5 MM	5-2 MM	.074 MM LT	BULK DENSITY 4A1D 20-2 MM	4A1H 1/3-BAR	4D1 OVEN DRY	COLE	WATER CONTENT- 4B1C 1/10 BAR	4B1C 1/3-BAR	4B2 15-BAR	4C1 WRD	CARBONATE 6F1B LT 2 MM	3A1A LT .002	PH 8C1A 1/1 H2O	8C1E 1/2 CACL
CM	PCT	PCT	PCT LT 75 MM			PCT	LT20	G/CC	G/CC		PCT	PCT	PCT	CM/CM	PCT	PCT		
000-001	2	0	0	1	2		3	1.2	8				19.3		10		7.4	6.9
001-002	2	0	0	1	2		3	1.3	8				8.4		11		7.3	7.1
002-005	2	0	0	2	14		16	1.3	8				6.3		12		7.3	7.2
005-010	5	0	1	5	4		9	1.38	1.47	.020		16.5	6.6	.13	3		7.2	7.1
010-050	1	0	0	1	TR		1	1.66	1.67	.002		9.4	2.5	.11	10		8.0	7.7
050-100	2	0	0	2	1		3	1.6	8				2.3		11		8.1	7.6
100-200	6	0	4	3	2		5	1.47	1.48	.002		9.9	3.0	.10	10		7.9	7.6
000-005								1.30	1.39	.023		18.3						

DEPTH	ORGANIC MATTER 6A1A ORGN CARB	6B1A NITG	C/N	IRON 6C2B EXT FE	PHOS TOTL	EXTRACTABLE BASES 5B4A- 6N2E CA	6O2D MG	6P2B NA	6Q2B K	SUM EXTB	ACTY 6H1A BACL TEA	AL 6G1F KCL EXT	CAT EXCH 5A3A EXTB ACTY	5A6A NHAC	RATIO 8D1 NHAC TO CLAY	RATIO 8D3 CA TO MG	CA 5F1 SAT NHAC	BASE SAT 5C3 EXTB ACTY	5C1 NHAC
CM	PCT	PCT		PCT	PCT	MEQ / 100 G-											PCT	PCT	PCT
000-001	6.26	.299	21				5.4	TR	.6					24.3					
001-002	2.63	.110	24				4.8	.0	.3					12.3	.89				
002-005	1.82	.068	27				4.7	TR	.2					9.1	.59				
005-010	2.43	.082	30				4.8	TR	.1					13.3	1.30				
010-050	.26	.018	14				4.6	TR	.1					3.4					
050-100	.27	.013	21				3.7	TR	.1					2.5	.51				
100-200	.46	.021	22				4.3	TR	.1					3.8					
000-005																			

DEPTH	SATURATED PASTE 8E1 REST OHM-	8C1B PH	8A H2O	NA 5D2 ESP	NA 5E SAR	SALT 8D5 TOTL SOLU	GYP 6F1A	SATURATION EXTRACT 8A1A EC MMHOS/	6N1B CA	6O1B MG	6P1B NA	6Q1B K	6I1A CO3	6J1A HCO3	6K1C CL	6L1C SO4	6M1C NO3	ATTERBERG 4F1 LQID LMIT	4F2 PLST INDX
CM	CM		PCT	PCT		PPM	PCT	CM	MEQ / LITER									PCT	
000-001		6.7	87.0			2000	0	2.50	25.1	8.5	.1	1.8	.0	13.4	.6	17.6	.0		
001-002		6.8	40.1			970	0	2.65	27.4	9.3	.0	1.1	.0	6.8	.9	28.8	.0		
002-005		6.8	36.0			1100	0	2.99	35.4	9.5	.1	1.0	.0	6.1	.8	38.6	.0		
005-010		6.6	34.5			990		2.98	33.5	10.5	.1	.6	.0	4.2	.6	45.0	.0		
010-050		7.4	28.4			970	0	3.37	26.6	26.4	.2	.4	.0	2.0	.2	56.5	.0		
050-100	2200	7.6	28.6			560		2.19	12.7	17.3	.3	.3	.0	.4	.3	31.3	.0		
100-200	1500	7.4	27.8			890	0	3.17	24.8	24.0	1.1	.3	.0	1.1	.3	51.6	.0		NP
000-005																			

(A) CLOD OF A11, A12, AND A13 FOR BULK DENSITY AND MOISTURE RETENTION.
(B) ESTIMATE

Table 60. Laboratory analysis of 1970 new spoil (Site No. 15).

SOIL CLASSIFICATION-

SERIES - - - - - - -REVEGETATED MINE SPOIL

SOIL NO - - - - - - S76MT-087-15 COUNTY - - - ROSEBUD

GENERAL METHODS- - -1A, 1B1B, 2A1, 2B SAMPLE NOS. 76P0666-76P0674

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE, MTSC
NATIONAL SOIL SURVEY LABORATORY
LINCOLN, NEBRASKA

DEPTH	HORIZON	PARTICLE SIZE ANALYSIS, LT 2MM, 3A1, 3A1A, 3A1B																RATIO
					FINE	SAND						SILT			FAML	INTR	FINE	NON-	8D1
		SAND	SILT	CLAY	CLAY	VCOS	CORS	MEDS	FNES	VFNS	COSI	FNSI	VFSI	TEXT	SAND	II	CLAY	CO3-	15-
		2-	.05-	LT	LT	2-	1-	.5-	.25-	.10-	.05	.02	.005-	SAND	2-.1	.2-	TO	CLAY	BAR
CM		.05	.002	.002	.0002	1	.5	.25	.10	.05	.02	.002	.002	2-.1	.02	TO	CLAY		TO
		PCT LT 2MM															PCT	PCT	CLAY
000-001	A11	78.4	15.6	6.0		.2	.6	2.1	54.2	21.3	12.0	3.6		57.1					1.72
001-002	A12	81.4	12.7	5.9		TR	.2	1.5	53.0	26.7	9.5	3.2		54.7					.71
002-005	A13	56.8	38.3	4.9		.1	.2	.9	37.0	18.6	32.2	6.1		38.2					.67
005-010	C1	65.9	26.0	8.1		.2	.3	1.5	40.9	23.0	11.4	14.6		42.9					.36
010-050	C2	60.4	30.3	9.3		.2	.6	3.1	37.9	18.6	12.1	18.2		41.8					.38
050-100	C3	71.2	21.5	7.3		.2	.5	3.5	46.2	20.8	8.6	12.9		50.4					.45
100-200	C4	66.2	27.3	6.5		.2	.7	2.6	38.2	24.5	16.8	10.5		41.7					.55
100-200	SHALE	7.9	64.4	27.7		1.4	2.1	1.0	2.1	1.3	6.1	58.3		6.6					
100-200	SHALE																		

DEPTH	PARTICLE SIZE ANALYSIS, MM, 3B, 3B1, 3B2						BULK DENSITY			WATER CONTENT				CARBONATE		PH	
	VOL.	WEIGHT					4A1D	4A1H	4D1	4B1C	4B1C	4B2	4C1	6E1B	3A1A	8C1A	8C1E
	GT	GT								1/10	1/3-	15-	WFD	LT	LT	1/1	1/2
	2	75												2	.002		
CM	PCT	PCT	75-20	20-5	5-2	LT .074	20-2 PCT LT20	1/3- BAR G/CC	OVEN DRY G/CC	COLE	BAR PCT	BAR PCT	BAR PCT	CM/ CM		PCT	PCT	H2O	CACL
			PCT LT 75																
000-001	0	0	0	0	0		0						10.3			6		7.3	7.1
001-002	TR	0	0	0	TR		TR						4.2			8		8.0	7.5
002-005	1	0	0	1	TR		1	1.3 A					3.3			9		8.1	7.5
005-010	2	0	0	2	1		3	1.4 A					2.9			12		8.3	7.6
010-050	1	0	0	TR	1		1	1.6 A	1.70	.071		9.6	3.5	.08		15		8.3	7.3
050-100	5	0	TR	3	5		8	1.5 A					3.3			15		8.5	7.7
100-200	2	0	0	1	3		4	1.65	1.67	.004		10.5	3.6	.11		16		8.4	7.7
100-200																			
100-200								1.28	1.38	.025									

DEPTH	ORGANIC MATTER			IRON	PHOS	EXTRACTABLE BASES 5B4A					ACTY	AL	(CAT EXCH)	PATIO	RATIO	CA	(BASE SAT)	
	6A1A	6B1A	C/N	6C2B		6N2E	6O2D	6P2B	6Q2B		6H1A	6G1E	5A3A	5A6A	8D1	8D3	5F1	5C3	5C1
	ORGN	NITG		EXT	TOTL	CA	MG	NA	K	SUM	BACL	KCL	EXTB	NHAC	NHAC	CA	SAT	EXTB	NHAC
	CARB			FE						EXTB	TEA	EXT	ACTY		TO	TO	NHAC	ACTY	
CM	PCT	PCT		PCT	PCT	MEQ / 100 G									CLAY	MG	PCT	PCT	PCT
000-001	2.24	.178	13				2.7	TR	1.3					6.7	1.10				
001-002	.83	.081	10				2.5	TR	.4					4.4	.75				
002-005	.80	.055	15				2.9	TR	.3					4.2	.85				
005-010	.30	.023	13				3.8	TR	.1					3.1	.38				
010-050	.16	.018	9				4.7	.0	.1					3.4	.37				
050-100	.11	.018	6				4.6	.0	.1					2.7	.37				
100-200	.13	.018	7				5.4	TR	TR					3.0	.46				
100-200	.24	.021	11																
100-200																			

DEPTH	SATURATED PASTE			NA	NA	SALT	GYP	SATURATION EXTRACT 8A1									ATTERBERG		
	8E1	8C1B	8A	5D2	5E	8D5	6F1A	8A1A	6N1B	6O1B	6P1B	6Q1B	6I1A	6J1A	6K1C	6L1C	6M1C	4F1	4F2
	REST	PH	H2O	ESP	SAR	TOTL		EC	CA	MG	NA	K	CO3	HCO3	CL	SO4	NO3	LQID	PLST
	OHM-					SOLU		MMHOS/										LMIT	INDX
CM	CM		PCT	PCT		PPM	PCT	CM	(MEQ / LITER									PCT	
000-001		6.4	58.7			2000	0	3.34	33.7	10.6	.1	9.8	.0	1.5	4.1	2.5	.0		
001-002		7.3	38.3			450		1.50	12.6	3.9	.1	1.7	.0	13.0	1.1	.6	.0		
002-005		7.3	32.5			330		1.26	10.5	4.2	.1	1.1	.0	9.5	.7	1.0	.0		
005-010		7.6	26.8			130		.69	4.8	2.2	.1	.6	.0	4.7	.4	.6	.0		
010-050								.208											
050-100	7200	8.3						.208											
100-200	3000	8.1	29.9		1	290		1.30	4.2	9.3	1.3	.3	.0	1.1	.6	14.5	.0	21	3 C
100-200																			
100-200																			

(A) ESTIMATE
(B) 1:2 SIOL WATER RATIO
(C) BY SOIL MECHANICS LABORATORY, USDA, LINCOLN, NE.

Table 61. Laboratory analysis of 1972 new spoil (Site No. 13).

SOIL CLASSIFICATION-

SERIES - - - - - - -REVEGETATED MINE SPOIL

SOIL NO - - - - - - S76MT-087-13 COUNTY - - - ROSEBUD

GENERAL METHODS- - -1A, 1B1B, 2A1, 2B SAMPLE NOS. 76P0646-76P0653

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE, MTSC
NATIONAL SOIL SURVEY LABORATORY
LINCOLN, NEBRASKA

DEPTH	HORIZON	PARTICLE SIZE ANALYSIS, LT 2MM, 3A1, 3A1A, 3A1B															RATIO
		SAND 2-.05	SILT .05-.002	CLAY LT .002	FINE CLAY LT .0002	SAND VCOS 2-1	SAND CORS 1-.5	SAND MEDS .5-.25	SAND FNES .25-.10	SAND VFNS .10-.05	SILT COSI .05-.02	SILT FNSI .02-.002	SILT VFSI .005-.002	FAML TEXT SAND 2-.1	INTR .2-.02	FINE TO CLAY	NON-CO3- CLAY	8D1 15-BAR TO CLAY
CM		PCT LT 2MM														PCT	PCT	
000-001	A11	61.4	28.1	10.5		.0	.4	1.1	46.7	13.2	19.4	8.7		48.2				.93
001-002	A12	79.1	11.1	9.8		.1	.4	1.8	60.1	16.7	5.4	5.7		62.4				.38
002-005	A13	80.8	13.1	6.1		.1	.5	1.8	63.8	14.6	4.1	9.0		66.2				.62
005-010	A14	81.6	11.5	6.9		TR	.4	1.9	62.9	16.4	4.2	7.3		65.2				.51
010-050	C1	75.5	16.8	7.7		.3	.5	3.6	58.6	12.5	3.1	13.7		63.0				.45
050-100	C2	71.2	25.0	3.8		.0	.4	3.4	59.6	7.8	16.7	8.3		63.4				.55
100-200	C3																	
000-005	(A)																	

DEPTH	PARTICLE SIZE ANALYSIS, MM, 3B, 3B1, 3B2 VOL. GT 2	WEIGHT GT 75	WEIGHT 75-20	WEIGHT 20-5	WEIGHT 5-2	WEIGHT LT .074	BULK DENSITY 4A1D 20-2	BULK DENSITY 4A1H 1/3-BAR	BULK DENSITY 4D1 OVEN DRY	BULK DENSITY 4B1C COLE	WATER CONTENT- 4B1C 1/10 BAR	WATER CONTENT- 4B2 1/3-BAR	WATER CONTENT- 4C1 15-BAR	WRD CM/CM	CARBONATE 6E1B LT 2	CARBONATE 3A1A LT .002	8C1A 1/1 H2O	8C1E 1/2 CACL
CM	PCT	PCT	PCT LT 75				LT2D	G/CC	G/CC		PCT	PCT	PCT	CM	PCT	PCT		
000-001	1	0	0	0	2		2	1.2	B				9.8		TP		7.3	6.3
001-002	TR	0	0	TR	TR		TR	1.4	B				3.7		3		7.8	7.3
002-005	TR	0	0	TR	TR		TR	1.4	B				3.8		3		8.9	7.3
005-010	TR	0	0	TR	TR		TR	1.5	B				3.5		3		8.1	7.5
010-050	7	0	0	7	4		11	1.5	B				3.5		11		8.4	7.7
050-100	TR	0	0	TR	TR		TR	1.5	B				2.1		12		8.5	7.7
100-200	TR	0	0	1	TR		1	1.5	B				2.0		12		8.3	7.6
000-005								1.39	1.39	.000								

DEPTH	ORGANIC MATTER 6A1A ORGN CARB	6B1A NITG	C/N	IRON 6C2B EXT FE	PHOS TOTL	EXTRACTABLE BASES 5B4A- 6N2E CA	6O2D MG	6P2B NA	6Q2B K	SUM EXTB	ACTY 6H1A BACL TEA	AL 6G1E KCL EXT	CAT EXCH 5A3A EXTB ACTY	5A6A NHAC	RATIO 8D1 NHAC TO CLAY	RATIO 8D3 CA TO MG	CA 5F1 SAT NHAC	BASE SAT 5C3 EXTB ACTY	5C1 NHAC
CM	PCT	PCT		PCT	PCT	MEQ / 100 G-											PCT	PCT	PCT
000-001	10.00	.316	32			5.8	TR	1.1		5.2			24.9	2.37					
001-002	1.72	.078	22			2.5	TR	.5					7.0	.71					
002-005	1.07	.067	16			2.4	TR	.4					6.1	1.00					
005-010	.54	.053	10			2.3	.0	.3					5.1	.74					
010-050	.12	.013	9			3.9	.0	.1					3.7	.48					
050-100	.05	.006	8			2.9	.0	.1					2.3	.61					
100-200	.07	.005	14			2.9	TR	TR					2.2						
000-005																			

DEPTH	SATURATED PASTE 8E1 REST OHM-	8C1B PH	8A H2O	NA 5D2 ESP	NA 5E SAR	SALT 8D5 TOTL SOLU	GYP 6F1A	SATURATION EXTRACT 8A1- 8A1A EC	6N1B CA	6O1B MG	6P1B NA	6Q1B K	6I1A CO3	6J1A HCO3	6K1C CL	6L1C SO4	6M1C NO3	ATTERBERG 4F1 LQID LMIT	4F2 PLST INDX
CM	CM		PCT	PCT		PPM	PCT	MMHOS/CM	MEQ / LITER									PCT	
000-001		6.7	60.5			1100		2.09	15.0	8.4	.1	4.0	.0	18.4	1.9	2.0	.0		
001-002		7.3	33.9			240		.95	7.0	2.6	.1	1.4	.0	7.2	.9	.7	.0		
002-005		7.4	31.5			240		1.01	7.8	2.9	.1	1.1	.0	7.8	1.1	.7	.0		
005-010		7.8	31.0			120		.56	3.8	1.7	.0	.5	.0	4.2	.3	.3	.0		
010-050								.20C											NP
050-100	6100	8.1						.20C											
100-200	3200	8.0	28.8		1	280		1.34	6.3	6.6	2.2	.3	.0	.8	.7	16.7	.0		
000-005																			

(A) CLOD OF A11, A12, AND A13 FOR BULK DENSITY AND MOISTURE RETENTION.
(B) ESTIMATE
(C) 1:2 SOIL WATER RATIO

Table 62. Laboratory analysis of 1973 new spoil (Site No. 12).

SOIL CLASSIFICATION-

SERIES - - - - - - -REVEGETATED MINE SPOIL

SOIL NO - - - - - - S76MT-087-12 COUNTY - - - ROSEBUD

GENERAL METHODS- - -1A, 1B1B, 2A1, 2B SAMPLE NOS. 76P0635-76P0645

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE, MTSC
NATIONAL SOIL SURVEY LABORATORY
LINCOLN, NEBRASKA

DEPTH	HORIZON	PARTICLE SIZE ANALYSIS, LT 2MM, 3A1, 3A1A, 3A1B														RATIO
					FINE	SAND					SILT		FAML	INTR	FINE	NON- 8D1
		SAND 2-.05	SILT .05-.002	CLAY LT .002	CLAY LT .0002	VCOS 2-1	CORS 1-.5	MEDS .5-.25	FNES .25-.10	VFNS .10-.05	COSI .05-.02	FNSI .02-.002	VFSI .005-.002	SAND TEXT 2-.1	II .2-.02	CLAY TO CLAY	CO3- CLAY 15-BAR
CM		PCT LT 2MM														PCT	PCT TO CLAY
000-001	A11	56.1	31.9	12.0		1.3	1.1	3.6	36.1	14.0	10.7	21.2		42.1			12 .81
001-002	A12	64.6	24.4	11.0		.3	.8	2.8	43.6	17.1	6.0	18.4		47.5			11 .45
002-005	A13	58.8	28.2	13.0		.4	.7	2.7	40.8	14.2	6.3	21.9		44.6			13 .38
005-010	A14	62.7	26.4	10.9		.2	.3	2.4	42.5	17.3	7.4	19.0		45.4			11 .55
010-050	C1	68.0	23.5	8.5		.2	.9	3.9	48.2	14.8	5.3	18.2		53.2			9 .56
050-080	C2	78.2	15.0	6.8		.1	.2	1.7	49.8	26.4	11.4	3.6		51.8			7 .38
080-100	C3	33.1	49.5	17.4		.2	.5	1.2	18.2	13.0	17.9	31.6		20.1			17 .44
100-200	C4	81.0	12.5	6.5		.1	.4	3.4	57.6	19.5	5.6	6.9		61.5			7 .40
000-005	(A)																

DEPTH	(PARTICLE SIZE ANALYSIS, MM, 3B, 3B1, 3B2) VOL. GT 2	WEIGHT GT 75	75-20	20-5	5-2	LT .074	20-2	4A1D 1/3-BAR	4A1H OVEN DRY	4D1 COLE	(BULK DENSITY) 4B1C 1/10 BAR	4B1C 1/3-BAR	(WATER CONTENT) 4B2 15-BAR	4C1 WRD	CARBONATE 6E1B LT 2	3A1A LT .002	(-PH-) 8C1A 1/1	8C1E 1/2
CM	PCT	PCT	PCT LT 75				LT20	G/CC	G/CC		PCT	PCT	PCT	CM/CM	PCT	PCT	H2O	CACL
000-001	2	0	2	1	1		2	1.3 B					9.7		12		7.6	7.2
001-002	1	0	TR	1	1		2	1.5 B					4.9		13		7.8	7.3
002-005	2	0	0	1	2		3	1.5 B					5.0		13		8.1	7.3
005-010	2	0	TR	2	2		4	1.6 B					6.0		14		8.2	7.6
010-050	10	0	9	3	4		7	1.71	1.75	.007		9.8	4.8	.08	13	TR	8.2	7.7
050-080	6	0	0	4	5		9	1.7 B					2.6		14		8.6	7.9
080-100	3	0	0	4	1		5	1.7 B					7.6		18	TR	8.1	7.8
100-200	2	0	0	2	1		3	1.69	1.71	.004		8.6	2.6	.10	13		8.4	7.8
000-005								1.50	1.57	.015		15.7						

DEPTH	(ORGANIC MATTER) 6A1A ORGN CARB	6B1A NITG	C/N	IRON 6C2B EXT FE	PHOS TOTL	(-EXTRACTABLE BASES 5B4A-) 6N2E CA	6O2D MG	6P2B NA	6Q2B K	SUM EXTB	ACTY 6H1A BACL TEA	AL 6G1E KCL EXT	(CAT EXCH) 5A3A EXTB ACTY	5A6A NHAC	RATIO 8D1 NHAC TO CLAY	RATIO 8D3 CA TO MG	CA 5F1 SAT NHAC	(BASE SAT) 5C3 EXTB ACTY	5C1 NHAC
CM	PCT	PCT		PCT	PCT	-MEQ / 100 G-											PCT	PCT	PCT
000-001	2.42	.166	15			4.7	TR	.7						8.1	.68				
001-002	.86	.053	16			3.9	TR	.4						5.0	.45				
002-005	.49	.033	15			4.6	TR	.3						4.5	.35				
005-010	.38	.027	14			4.5	TR	.3						4.4	.40				
010-050	.50	.023	22			5.3	TR	.1						4.6	.54				
050-080	.09	.014	6			4.1	TR	.1						3.0	.44				
080-100	.35	.024	15			7.0	TR	.2						4.6	.26				
100-200	.09	.009	10			3.7	TR	.1						2.7	.41				
000-005																			

DEPTH	(SATURATED PASTE) 8E1 REST OHM-	8C1B	8A	NA 5D2	NA 5E	SALT 8D5	GYP 6F1A	(-SATURATION EXTRACT 8A1-) 8A1A EC	6N1B	6O1B	6P1B	6Q1B	6I1A	6J1A	6K1C	6L1C	6M1C	ATTERBERG 4F1 LQID	4F2 PLST
		PH	H2O	ESP	SAR	TOTL SOLU		MMHOS/	CA	MG	NA	K	CO3	HCO3	CL	SO4	NO3	LMIT	INDX
CM	CM		PCT	PCT		PPM	PCT	CM	MEQ / LITER									PCT	
000-001		6.7	47.3			870		2.22	15.8	9.8	.1	3.2	.0	20.4	.8	2.2	.0		
001-002		6.8	36.7			430		1.42	9.1	7.2	.1	1.7	.0	10.9	.3	1.5	.0		
002-005		7.0	34.8			280		1.08	6.1	4.8	.1	1.4	.0	7.0	.2	1.8	.0		
005-010		7.4	34.1			190		.81	3.9	3.6	.1	1.1	.0	4.6	.2	2.0	.0		
010-050		7.5	27.7			230		1.13	5.7	6.8	.3	.4	.0	3.2	.2	10.0	.0		
050-080								.20C											
080-100	1600	7.8	41.5			530		1.66	7.9	10.3	1.1	.8	.0	1.3	.1	19.6	1.5		NP
100-200	3000	8.0	29.1			270		1.31	5.6	7.8	.9	.4	.0	.9	.2	12.7	2.1		
000-005																			

(A) CLOD OF A11, A12, AND A13 FOR BULK DENSITY AND MOISTURE RETENTION.
(B) ESTIMATE
(C) 1:2 SOIL WATER RATIO

Table 63. Laboratory analysis of 1975 new spoil (Site No. 11).

SOIL CLASSIFICATION-

SERIES - - - - - - -SERIES NOT DESIGNATED

SOIL NO - - - - - - S76MT-087-11 COUNTY - - - ROSEBUD

GENERAL METHODS- - -1A, 1B1B, 2A1, 2B SAMPLE NOS. 76P0625-76P0634

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE, MTSC
NATIONAL SOIL SURVEY LABORATORY
LINCOLN, NEBRASKA

DEPTH	HORIZON	PARTICLE SIZE ANALYSIS, LT 2MM, 3A1, 3A1A, 3A1B: SAND 2-.05	SILT .05-.002	CLAY LT .002	FINE CLAY LT .0002	SAND VCOS 2-1	SAND CORS 1-.5	SAND MEDS .5-.25	SAND FNES .25-.10	SAND VFNS .10-.05	SILT COSI .05-.02	SILT FNSI .02-.002	SILT VFSI .005-.002	FAML TEXT SAND 2-.1	INTR II .2-.02	FINE CLAY TO CLAY	RATIO NON-CO3-CLAY	RATIO 8D1 15-BAR TO CLAY
CM		PCT LT 2MM														PCT	PCT	
000-001	A11	13.1	76.8	10.1		.1	.2	.5	5.0	7.3	67.9	8.9		5.8			9	.37
001-002	A12	75.7	15.0	9.3		.8	.8	2.6	53.3	18.2	7.3	7.7		57.5			8	.40
002-005	A13	74.6	16.9	8.5		.6	.7	2.9	52.1	18.3	5.5	11.4		56.3			8	.48
005-010	A14	75.9	16.4	7.7		.5	.6	2.6	55.2	17.0	7.5	8.9		58.9			7	.55
010-028	A15	75.7	15.4	8.9		.5	.5	2.7	53.8	18.2	8.5	6.9		57.5			8	.45
028-050	C1	73.1	19.2	7.7		.2	.6	3.0	53.5	15.8	8.7	10.5		57.3			8	.56
050-080	C2	68.8	22.7	8.5		.2	.5	3.0	46.1	19.0	10.6	12.1		49.8			9	.45
080-100	C3	61.3	33.1	5.6		.2	.6	1.7	29.9	28.9	19.8	13.3		32.4			6	.61
100-200	C4	74.6	19.7	5.7		.1	.6	2.7	50.1	21.1	7.9	11.8		53.5			6	.70
000-005	(A)																	

DEPTH	PARTICLE SIZE ANALYSIS, MM, 3B, 3B1, 3B2: VOL. GT 2	WEIGHT GT 75	75-20	20-5	5-2	.074 LT	BULK DENSITY 4A1D 20-2 LT20	4A1H 1/3-BAR	4D1 OVEN DRY	4B1C COLE	WATER CONTENT- 4B1C 1/10 BAR	4B2 1/3-BAR	4C1 15-BAR	WRD	CARBONATE 6E1B LT 2	3A1A LT .002	8C1A 1/1 H2O	8C1E 1/2 CACL
CM	PCT	PCT	PCT LT 75			PCT	G/CC	G/CC			PCT	PCT	PCT	CM/CM	PCT	PCT		
000-001	9	0	2	10	3	13	1.5 B						3.7		11	1	8.3	7.7
001-002	7	0	2	8	2	11	1.5 B						3.7		11	1	8.3	7.7
002-005	4	0	2	5	2	7	1.5 B						4.1		11	1	8.4	7.8
005-010	4	0	2	4	3	7	1.5 B						4.2		10	1	8.4	7.8
010-028	1	0	0	1	1	2	1.5 B						4.0		10	1	8.4	7.8
028-050	1	0	0	2	2	4	1.6 B						4.3		12	TR	8.3	7.8
050-080	3	0	0	3	1	4	1.59	1.62	.006		9.7	3.8		.09	14		8.3	7.7
080-100	1	0	0	1	TR	1	1.76	1.79	.006		14.2	3.4		.19	17		8.0	7.7
100-200	4	0	0	6	1	7	1.6 B						4.0		9		8.1	7.7
000-005							1.47	1.50	.007		11.7							

DEPTH	ORGANIC MATTER 6A1A ORGN CARB	6B1A NITG	C/N	IRON 6C2B EXT FE	PHOS TOTL	EXTRACTABLE BASES 5B4A- 6N2E CA	6O2D MG	6P2B NA	6Q2B K	SUM EXTB	ACTY 6H1A BACL TEA	AL 6G1E KCL EXT	(CAT EXCH) 5A3A EXTB ACTY	5A6A NHAC	RATIO 8D1 NHAC TO CLAY	RATIO 8D3 CA TO MG	CA 5F1 SAT NHAC	(BASE SAT) 5C3 EXTB ACTY	5C1 NHAC
CM	PCT	PCT		PCT	PCT	MEQ / 100 G											PCT	PCT	PCT
000-001	.46	.036	13			3.2	TR	.2						4.2	.42				
001-002	.44	.037	12			3.3	TR	.2						4.1	.44				
002-005	.43	.038	11			3.5	TR	.2						4.1	.48				
005-010	.50	.039	13			4.0	.0	.2						4.5	.58				
010-028	.40	.039	10			3.7	.0	.1						3.8	.43				
028-050	.24	.034	7			3.7	.0	.1						3.9	.51				
050-080	.18	.021	9			3.7	TR	.1						3.5	.41				
080-100	.16	.011	15			4.0	TR	.1						2.6	.46				
100-200	.29	.014	21			4.2	.1	.1						3.5	.61				
000-005																			

DEPTH	SATURATED PASTE 8E1 REST OHM-	8C1B PH	8A H2O	NA 5D2 ESP	NA 5E SAR	SALT 8D5 TOTL SOLU	GYP 6F1A	SATURATION EXTRACT 8A1- 8A1A EC	6N1B CA	6O1B MG	6P1B NA	6Q1B K	6I1A CO3	6J1A HCO3	6K1C CL	6L1C SO4	6M1C NO3	ATTERBERG 4F1 LQID LMIT	4F2 PLST INDX
CM	CM		PCT	PCT		PPM	PCT	MMHOS/CM	MEQ / LITER									PCT	
000-001		7.7	25.1			120		.64	4.8	1.9	.2	.4	.0	4.5	.2	1.4	.0		
001-002		7.8	26.0			100		.56	3.8	1.5	.2	.3	.0	3.5	.1	1.6	.0		
002-005		7.9	25.9			90		.55	3.1	1.6	.3	.3	.0	1.8	.3	1.8	.6		
005-010								.20C											
010-028								.20C											
028-050								.20C											
050-080		7.8	28.2			130		.70	3.6	2.8	.3	.3	.0	1.6	.1	4.9	.7		
080-100	2400	7.6	26.0			350		1.67	12.1	7.9	.5	.5	.0	1.5	.2	18.7	1.7	20	3 D
100-200	2700	7.7	26.8	3		310		1.47	8.5	8.6	.5	.4	.0	1.3	.2	16.2	1.1		
000-005																			

(A) CLOD OF A11, A12, AND A13 FOR BULK DENSITY AND MOISTURE RETENTION.
(B) ESTIMATE
(C) 1:2 SOIL WATER RATIO
(D) BY SOIL MECHANICS LABORATORY, USDA, LINCOLN, NE.

APPENDIX F. Volumetric Soil Water Contents

Table 64.--Volumetric soil water percentages of Undisturbed soils.

Native soil	Depth (cm)	1976 6/9	6/29	7/11	8/11	8/24	9/15	10/22	11/24
	15	21	18	10	05	09	06	10	13
	30	26	25	17	10	12	10	09	14
	45	26	27	21	12	13	11	10	13
	60	27	28	25	14	15	14	12	14
CHINOOK	75	28	29	27	16	18	16	15	17
	90	30	31	29	20	23	19	18	20
	120	28	30	29	24	29	24	22	24
	150	33	34	34	30	32	32	27	31
	180	30	31	32	28	31	29	26	29
	210	31	32	31	29	29	32	26	30
	240	29	30	30	28	31	28	25	30
	15	33	38	27	26	18	18	25	30
	30	37	42	36	26	24	24	23	30
	45	38	41	37	29	26	26	25	28
	60	39	42	38	33	30	30	29	32
YAMAC	75	40	42	39	37	35	35	34	38
	90	41	43	40	40	36	39	36	41
	120	40	42	39	40	37	39	38	41
	150	38	41	38	38	36	38	32	38
	180	38	40	37	37	35	36	31	37
	210	36	39	36	37	36	35	30	36
	15			29	23	20	22	23	26
	30			35	27	25	26	22	27
	45			36	28	26	26	22	26
	60			38	30	26	26	21	26
KOBAR	75			37	29	25	25	21	25
	90			34	29	26	25	20	25
	120			28	27	25	25	21	24
	150			27	27	25	25	21	25
	180			25	26	24	25	22	25
	210			31	31	29	30	27	30

Table 64.--(Continued)

1977

1/15	2/12	3/13	4/6	4/14	5/2	5/15	5/29	6/15	7/8	7/19	7/31
25	32	23	31	20	09	15	22	14	07	06	04
18	26	27	34	25	17	20	24	19	11	10	05
14	18	26	34	28	23	24	24	20	13	12	11
14	16	27	34	29	26	25	25	23	15	13	13
15	18	27	32	31	27	27	26	25	18	17	15
19	20	27	30	31	29	28	27	27	21	20	19
21	22	25	26	31	28	31	27	27	25	24	23
27	27	29	30	31	31	29	31	31	30	28	29
25	26	26	27	30	28	30	28	28	27	26	27
26	27	27	28	28	29	28	30	30	29	29	30
26	27	27	27	25	28	27	29	29	28	28	28
		37	41	37	19	34	31	27	18	17	16
		38	41	33	32	35	35	31	24	21	21
		37	40	39	34	35	35	33	26	24	24
		36	40	39	35	37	36	36	29	26	27
		37	42	40	35	39	37	38	33	32	33
		37	42	41	36	39	38	39	37	35	37
		36	41	40	35	36	38	38	39	38	39
		33	37	38	34	36	36	36	37	34	37
		32	33	36	33	34	35	36	35	34	36
		31	32	34	32	32	34	34	34	33	34
	48	38	42	39	23	32	31	31	25	21	20
	46	38	42	40	36	34	35	31	26	24	26
	44	36	42	40	38	36	35	32	26	24	26
	43	34	42	39	38	36	36	33	28	26	28
	38	30	38	37	38	33	35	32	29	26	29
	33	27	30	32	34	31	32	30	29	27	29
	29	22	24	25	25	23	25	24	25	24	24
	28	22	23	22	23	21	23	23	22	22	23
	28	22	23	23	21	28	21	21	23	23	23
	34	27	28	27	26	31	27	27	28	28	27

Table 64.--(Continued)

Native soil	Depth (cm)	1976 6/9	6/29	7/11	8/11	8/24	9/15	10/22	11/24
	15	13	16	10	03	05	04	11	12
	30	19	23	16	07	07	09	09	15
	45	29	21	19	11	10	07	09	15
	60	21	20	21	15	14	10	12	13
BUSBY	75	24	22	23	18	18	14	19	15
(6)	90	27	23	24	20	19	17	17	18
	120	27	24	27	23	22	19	17	18
	150	30	26	29	25	25	22	21	21
	180	33	29	32	27	28	24	22	23
	210	40	36	40	34	34	26	25	24
	240		37	36	34	33	33	31	30
	15	17	15	07	04	03	03	06	11
	30	21	21	14	09	08	07	06	11
	45	24	23	19	12	11	09	08	11
	60	27	26	22	14	13	11	09	13
BUSBY	75	26	25	22	15	13	12	08	13
(8)	90	26	23	22	15	14	12	10	13
	120	30	30	30	26	23	19	16	20
	150	28	28	29	25	23	20	15	20
	180	25	25	25	28	21	19	13	19
	210	25	25	25	23	22	19	15	20
	240	23	23	23	22	21	19	14	19

Table 64.--(Continued)

1977

1/15	2/12	3/13	4/6	4/14	5/2	5/15	5/29	6/15	7/8	7/19	7/31
21	29	19	28	21	14	11	14	14			
19	24	21	31	24	19	20	20	14			
16	17	19	30	25	23	17	20	16			
16	17	17	28	25	23	20	19	18			
18	18	18	28	26	26	21	20	26			
19	19	19	25	26	28	22	22	28			
21	21	20	21	25	28	24	22	23			
22	23	22	22	25	29	25	24	25			
25	25	28	23	25	30	27	25	26			
28	30	27	27	28	33	31	28	31			
14	32	17	23	17	04	10	14	08	06	04	03
11	27	19	26	20	13	15	18	14	09	07	06
10	25	20	29	23	18	19	21	17	11	10	09
11	22	20	31	26	22	21	23	19	13	11	10
11	17	17	27	25	23	19	21	19	15	13	19
11	17	14	21	23	21	23	19	17	15	13	12
18	20	21	21	24	24	22	23	22	19	17	15
19	20	19	20	20	21	18	22	21	22	20	21
17	19	17	17	18	18	17	18	18	19	19	19
17	17	17	18	18	17	16	17	16	17	16	18
16	18	17	24	17	17	16	17	16	17	17	16

Table 65.--Volumetric soil water percentages of Old Spoils.

Old spoil	Depth (cm)	1976 6/9	6/29	7/11	8/11	8/24	9/15	10/22	11/24
	15	21	20	15	07	07	07	12	16
	30	23	26	20	13	12	12	10	16
	45	22	24	20	12	11	11	09	12
1924	60	22	23	20	12	11	10	08	11
(5)	75	22	21	19	11	10	10	10	10
	90	23	21	20	11	10	10	08	10
	120	27	25	24	14	13	13	10	13
	150	22	21	20	11	10	10	07	10
	180	11	12	12	09	08	08	06	08
	210	08	09	09	09	08	08	06	08
	15	14	10	06	05	04	08	12	13
	30	23	19	10	11	10	10	13	16
	45	24	20	14	12	11	10	12	12
1924	60	24	21	15	12	12	09	12	12
(7)	75	23	20	14	11	10	08	10	11
	90	21	18	14	10	09	08	08	09
	120	21	20	14	11	11	10	10	11
	150	21	20	15	14	13	11	12	13
	180	19	19	18	15	14	13	14	15
	210	17	17	18	16	15	13	14	15
	240	16	16	17	16	16	14	15	16
	15	16	18	10	07	06	00	09	15
	30	20	23	17	13	11	11	10	15
	45	20	23	19	14	11	11	10	12
1924	60	20	22	11	14	11	11	07	11
(9)	75	21	23	20	15	12	12	07	12
	90	22	23	21	16	13	12	10	12
	120	23	24	23	19	15	14	10	14
	150	24	24	24	21	17	16	10	16
	180	24	24	24	23	19	18	12	18

Table 65.--(Continued)

1977											
1/11	2/12	3/13	4/6	4/14	5/2	5/15	5/29	6/15	7/8	7/19	7/31
27	36	25	20	27	10	19	19	27			
18	24	24	31	28	24	20	26	23			
12	15	19	29	27	25	19	24	21			
10	12	12	24	25	23	18	22	18			
09	10	09	17	21	22	17	19	15			
10	11	09	14	15	19	14	17	13			
12	13	11	11	12	14	10	14	13			
10	11	09	10	09	10	07	10	10			
08	09	07	08	08	08	07	08	08			
08	09	07	08	08	08	07	07	07			
20	32	23	31	26	13	16	19	17			
16	23	23	32	28	28	18	25	18			
12	15	19	30	27	32	19	24	19			
11	12	15	24	24	31	17	23	19			
09	10	10	15	17	27	12	20	16			
08	09	08	10	12	19	11	14	13			
09	11	09	10	10	14	10	11	11			
12	13	12	12	12	15	11	11	12			
13	14	12	13	13	16	11	13	13			
14	15	13	14	13	16	12	13	13			
14	15	14	14	14	14	12	14	13			
20	26	22	28	23	09	14	10	13			
17	17	22	29	25	19	21	18	13			
14	14	20	28	24	21	18	22	17			
12	14	17	26	29	21	19	22	17			
12	13	15	23	23	21	19	21	18			
12	12	15	20	21	21	20	21	18			
13	13	14	19	18	18	19	20	18			
15	15	15	17	19	19	18	19	18			
17	17	16	16	18	20	17	18	18			

Table 65.--(Continued)

Old spoil	Depth (cm)	1976 6/9	6/29	7/11	8/11	8/24	9/15	10/22	11/24
	15	28	33	20	09	08	07	12	18
	30	30	50	26	15	13	11	11	17
	45	29	35	27	17	16	14	12	16
1932	60	28	32	25	18	17	15	10	16
	75	26	29	24	18	17	15	13	15
	90	27	29	25	21	20	17	16	18
	120	27	30	26	24	23	20	17	21
	150	24	26	24	24	24	21	19	22
	180	21	23	21	22	22	20	16	21
	210	21	22	20	22	21	20	17	21
	240	19	20	19	20	20	19	16	20
	15			31	21	22	20	28	30
	30			42	37	37	33	35	37
	45			40	48	46	43	45	46
1948	60			52	52	50	47	41	50
	75			46	44	43	40	38	43
	90			48	49	47	44	45	48
	120			53	55	54	49	44	53
	150			54	55	53	50	49	53
	180			58	57	55	51	52	53
	210			59	63	63	57	51	63
	240			50	52	51	47	45	49

Table 65.--(Continued)

1977

1/11	2/12	3/13	4/6	4/14	5/2	5/15	5/29	6/15	7/8	7/19	7/31
23	38	28	39	33	18	24	24	19	12	08	08
20	31	28	39	35	30	26	30	22	17	13	13
16	25	24	36	32	30	24	29	23	18	16	15
14	23	20	29	29	27	22	25	22	18	16	16
14	21	17	20	23	23	20	22	20	18	16	16
15	23	18	19	20	21	20	21	20	18	16	17
18	22	20	20	20	20	18	20	20	20	1[illegible]	19
18	22	19	20	19	18	18	18	19	19	18	18
18	21	19	19	19	12	18	19	19	19	18	18
18	23	19	20	19	19	17	19	19	19	18	18
17	12	18	19	18	19	18					
38	49	44	49	45	27	37	32	31	26	24	20
39	52	48	53	51	42	45	42	41	35	33	32
41	57	50	59	56	49	54	46	45	42	39	40
48	56	52	56	57	57	48	52	49	47	45	48
41	51	46	47	49	50	47	46	43	41	39	41
46	54	48	50	50	49	53	46	47	44	41	42
50	56	52	53	56	55	51	53	50	49	48	49
45	55	51	54	54	53	52	51	52	50	47	47
49	60	52	56	54	53	61	52	52	48	46	48
59	53	59	59	61	61	48	60	61	59	57	59
47	49	47	47	58	49	51	48	49	47	46	46

Table 66.--Volumetric soil water percentages of New Spoils.

New Spoil	Depth (cm)	1976 6/9	6/29	7/11	8/11	8/24	9/15	10/22	11/24
	15	27	36	23	17	17	17	18	22
	30	33	41	30	23	23	22	21	23
	45	35	44	34	27	25	25	22	24
1969	60	35	45	34	28	26	26	23	23
	75	39	48	39	36	35	32	34	29
	90	44	52	42	40	37	38	27	35
	120	31	37	31	29	28	25	26	22
	150	28	31	27	25	24	22	18	22
	180	30	32	27	27	26	24	19	21
	210	29	34	29	29	29	28	26	24
	15	15	17	08	03	02	04	10	10
	30	22	28	18	11	09	09	10	14
	45	24	28	23	15	1[illegible]	12	12	14
1970	60	26	29	26	19	16	16	13	14
	75	28	29	28	21	18	16	14	14
	90	29	32	31	24	19	18	15	16
	120	31	32	32	25	21	20	17	17
	150	30	31	31	26	22	19	18	18
	180	27	27	28	24	21	18	16	17
	210	25	26	26	25	21	20	16	17
	15		05	00	00	00	00	08	04
	30		21	1[illegible]	05	06	07	10	15
	45		28	20	11	10	12	12	17
1972	60		31	25	11	16	17	17	19
	75		33	30	22	21	23	18	22
	90		32	30	23	22	23	20	22
	120		32	31	26	25	26	20	24
	150		31	30	26	24	26	20	24
	180		29	28	25	24	25	20	22

Table 66.--(Continued)

1977

1/15	2/12	3/13	4/6	4/14	5/2	5/15	5/29	6/15	7/8	7/19	7/31
26	42	31	38	32	21	28	26	25	18	15	14
25	41	33	39	35	29	30	29	28	24	22	20
24	37	33	38	36	33	31	33	30	26	23	23
24	38	32	36	37	34	33	32	30	26	25	24
31	44	37	41	41	36	36	33	37	32	29	27
33	45	38	35	41	43	26	42	38	38	37	37
22	34	26	26	27	26	22	26	26	24	22	21
19	28	21	21	22	22	25	22	21	20	19	19
21	31	23	23	24	24	24	25	24	25	23	23
23	31	26	26	26	25	27	23	25	24	24	23
22	37	21	30	20	40	12	09	10	06	03	00
18	27	26	33	27	18	18	20	15	10	08	07
14	20	24	30	27	23	21	22	17	13	11	10
14	20	22	27	28	25	23	22	19	16	14	13
14	22	21	25	28	26	25	23	21	17	16	14
16	23	20	23	28	27	24	24	22	19	17	15
17	21	19	20	24	25	21	23	22	20	18	16
18	19	18	19	21	21	18	21	21	19	18	17
16	17	17	17	18	18	18	18	18	17	16	16
16	18	17	18	18	18	18	18	19	18	16	16
19	23	12	19	25	01	09	01	00	00	00	02
23	32	20	30	29	11	19	15	08	07	05	00
20	28	25	36	33	22	24	21	12	10	09	08
22	27	26	34	34	19	27	24	17	15	12	12
24	26	29	33	34	31	25	28	22	21	18	16
22	24	28	31	33	30	30	27	21	24	21	19
24	25	28	27	31	31	29	28	25	26	24	22
24	25	27	25	26	29	27	27	25	25	23	24
23	23	24	24	24	26	26	25	24	24	22	28

Table 66.--(Continued)

New Spoil	Depth (cm)	1976 6/9	6/29	7/11	8/11	8/24	9/15	10/22	11/24
	210		28	28	26	25	26	19	23
	240		28	28	27	26	28	22	24
	15		23	14	08	07	09	17	15
	30		34	27	16	14	16	16	20
	45		37	31	20	18	19	18	20
1973	60		37	33	23	20	22	20	20
	75		38	35	27	24	25	24	23
	90		39	37	31	28	29	24	26
	120		38	37	31	28	29	27	24
	150		40	37	35	32	33	29	30
	15		27	22	19	19	17	26	
	30		36	32	28	29	27	26	
	45		37	35	31	32	30	28	
1975	60		38	35	33	34	32	30	
	75		38	37	34	36	34	31	
	90		38	36	35	37	35	31	
	120		39	37	36	39	37	34	
	150		39	38	37	40	38	34	

Table 66.--(Continued)

1977											
1/11	2/12	3/13	4/6	5/14	5/2	5/15	5/29	6/15	7/8	7/19	7/31
23	23	23	25	25	26	26	25	24	27	25	25
23	24	24	25	25	24	27	24	23	24	23	22
22	28	23	30	23	09	17	14	09	08	07	05
22	26	26	33	29	22	22	24	18	17	16	15
21	23	25	32	30	26	24	25	20	19	17	16
24	25	24	28	31	29	28	26	24	21	20	20
26	27	26	27	31	27	26	29	27	23	22	22
24	27	24	26	29	28	32	26	25	23	23	23
30	31	29	29	31	33	30	32	31	32	32	33
30	41	27	40	28	15	25	18	20	19	15	13
28	39	31	39	33	30	29	31	27	26	23	23
29	37	31	38	35	32	29	33	29	28	25	25
30	35	31	37	35	34	33	33	31	31	28	28
31	36	33	36	35	35	33	34	32	33	30	31
33	37	33	35	35	35	33	35	33	34	32	32
34	38	33	35	34	35	34	34	33	35	34	34
34	39	33	35	34	34	34	35	34	37	34	36

APPENDIX G. Soil Desorption Characteristics

Table 67. Desorption characteristics (% H_2O by volume) of soil profiles of undisturbed soils.

Soil Depth (cm)	Pressure (bars)	Native Soil (site no.)				
		Chinook	Yamac	Kobar	Busby(6)	Busby(8)
5-15	0				39.8	
	0.3				13.6	
	15				7.1	
15-25	0	40.0	50.8	--	42.0	11.8
	0.3	13.7	39.2	40.0	11.8	11.8
	15	6.9	4.9	20.2	5.5	5.2
30-40	0				44.0	
	0.3				12.5	
	15				5.7	
51-61	0	39.5	55.8	--		41.4
	0.3	15.3	40.1	29.6		13.6
	15	4.9	5.5	14.6		5.8
142-152	0	37.2	56.0	--		40.8
	0.3	13.7	39.9	22.5		15.0
	15	3.2	5.3	8.1		4.4

Table 68. Desorption characteristics (% H_2O by volume) of soil profiles of old spoils

Soil depth (cm)	Pressure (bars)	Spoil Age (site no.)				
		1942(5)	1924(7)	1924(9)	1932	1948
5-15	0	46.0	45.2	49.2	45.6	--
	0.3	16.2	13.0	22.9	23.6	40.0
	15	7.7	6.4	15.1	8.0	20.2
51-61	0	43.0	40.7	49.5	51.4	--
	0.3	12.5	16.0	20.2	27.2	29.6
	15	6.7	6.3	13.6	8.3	14.6
142-152	0	44.5	43.8	47.1	45.8	--
	0.3	11.1	11.2	24.1	20.4	22.5
	15	6.4	5.9	12.1	8.6	8.1

Table 69. Desorption characteristics (% H_2O by volume) of soil profiles of new spoils.

Soil Depth (cm)	Pressure (bars)	Spoil Age				
		1975	1973	1972	1970	1969
5-15	0	47.1				
	0.3	25.9				
	15	10.0				
15-25	0	38.7	46.5	47.8	48.0	42.4
	0.3	16.5	21.4	24.5	21.3	17.2
	15	6.6	7.2	10.0	7.5	4.2
31-40	0	46.2				
	0.3	21.4				
	15	7.3				
40-51	0					
	0.3					
	15					
51-61	0		50.0	40.6	43.0	43.3
	0.3		25.0	16.7	20.4	17.5
	15		8.9	3.3	6.6	5.5
142-152	0		48.6	42.1	45.7	40.0
	0.3		27.4	16.8	18.7	16.1
	15		4.2	5.0	5.0	4.7

APPENDIX H. Soil Water Potentials and Soil Temperatures

Table 70. Soil water potentials (-bars) for undisturbed soils and minespoils at Colstrip study area.

Site	Depth(cm)	DATE 1976 6/29	7/11	8/11	8/24	9/15	10/22	11/24	2/12	3/11*	DATE 1977 5/2	5/10	5/31	6/15	7/9	7/19	7/31
CHINOOK-1	15	12.0	7.1	24.6	7.3	3.0	4.3	8.9			3.0	x	10.7	2.1	19.1	4.4	10.6
	50	3.2	6.1	10.6	11.2	30.0	21.6	8.4			2.3	4.7	10.2	.5	6.4	7.6	9.8
	90	3.7	7.2	5.0	7.1	8.8	4.3	3.3			5.6	5.9	13.8	24.8	1.1	3.3	3.5
	150	4.5	4.6	4.1	1.7	2.2	2.0	15.4			4.0	3.9	4.8	1.7	2.1	2.7	4.5
YAMAC-2	15	4.1	6.7	2.8	4.2	5.9	5.7	20.0			2.6	2.4	3.9	.9	2.0	1.2	7.5
	50	3.4	6.5	1.9	1.6	4.2	6.5	6.2			4.3	3.6	8.8	3.4	2.0	.6	2.6
	90	5.8	11.2	2.0	2.7	4.9	5.3	6.7			4.4	4.6	10.8	2.8	.7	1.0	1.6
	150	16.1	14.7	4.5	2.3	2.2	0.8	20.6			4.0	2.3	5.1	4.5	1.4	1.9	2.0
1948-3	15													4.7	21.8	18.2	16.9
	50													3.4	4.9	6.6	8.0
	90													3.0	1.8	1.5	1.1
	150													1.8	3.8	2.5	2.5
1924-5	15	9.0	2.2	11.4	5.4	23.5	4.0	19.9									
	50	7.6	3.4	20.0	x	x	x	x									
	90	2.1	5.6	1.8	7.5	20.3	18.5	16.5									
	150	15.4	15.2	37.0	x	x	x	x									
BUSBY-6	15	x	2.0	21.6	11.1	11.8	17.0	14.9									
	50	2.9	5.2	7.6	6.9	12.6	3.4	17.6									
	90	3.7	3.5	3.0	2.0	30.2	3.3	17.2									
	150	4.2	5.8	2.4	1.3	2.5	2.1	10.5									
1924-7	15	10.9	2.4	1.3	1.5	4.3	2.1	10.9			10.6	.4	10.0	1.4			
	50	4.2	2.2	x	x	x	x	x			3.4	6.3	8.3	1.1			
	90	16.3	5.2	2.0	4.2	10.0	10.1	18.4			2.5	2.5	x	10.0			
	150	17.1	12.5	3.4	1.6	5.5	3.3	4.4			2.0	4.8	6.6	1.9			
BUSBY-8	15	10.0	1.3	x	x	x	x	x			2.4	1.2	6.8	1.9	10.0	9.5	7.6
	50	9.0	1.8	2.6	4.5	12.7	21.1	17.6			1.8	x	2.9	2.7	4.3	5.0	4.5
	90	7.2	2.3	2.9	5.1	8.3	11.1	9.9			2.6	2.2	2.6	2.3	1.6	1.3	2.3
	150	6.5	6.2	1.7	2.9	3.8	5.7	9.8			2.6	1.0	x	5.4	4.7	4.1	7.4
1924-9	15	6.1	1.4	.7	3.2	10.1	2.0	15.0	x	x							
	50	9.9	3.4	1.9	3.1	6.7	7.4	8.6	18.8	x							
	90	18.3	7.8		2.3	7.7	9.5	32.6	x	x							
	150	11.5	9.4	1.4	2.2	8.1	6.0	14.9	x	x							
1932-10	15	6.4	4.2	6.2	6.5	20.1	5.7	4.0			6.7	x	4.3	18.3	10.1	5.1	10.6
	50	7.0	2.6	10.7	3.2	8.2	12.1	8.2			2.5	3.1	4.8	20.3	x	3.7	4.1
	90	34.9	12.3	5.0	3.0	6.7	8.9	23.5			4.0	3.7	5.7	17.3	.8	1.3	3.7
	150	5.4	6.8	1.8	1.4	3.5	2.2	3.8			4.8	6.5	5.5	13.9	.7	x	x
1975-11	15	4.5	1.8	.5	.6	2.5	4.0	3.6			2.5	1.7	10.5	4.1	.8	.2	.6
	50	1.7	1.7	.9	1.0	1.9	1.3	20.9			5.1	7.4	9.2	1.7	.9	.8	1.0
	90	11.5	3.5	1.0	1.2	1.9	1.5	4.2			12.2	4.0	18.7	11.0	4.3	3.1	3.8
	150	24.7	9.6	1.0	1.3	6.9	1.8	3.7			5.8	2.0	6.3	6.7	3.7	4.6	2.4
1973-12	15	4.5	6.1	4.7	3.4	7.8	x	2.7	3.6		4.4	4.0	10.8	6.2	2.1	7.0	6.2
	50	5.7	5.4	11.9	14.3	22.2	3.8	11.2	15.6		6.2	5.3	2.4	3.0	1.7	1.9	1.9
	90	4.2	5.2	2.9	3.3	2.9	1.2	x	x		5.8	13.4	9.8	3.8	1.4	1.8	2.7
	150	20.5	10.1	2.1	2.4	9.1	.8	17.6	31.4		3.5	3.1	4.8	1.6	1.9	2.6	2.9
1972-13	15	9.5	3.2	29.6	24.1	38.9	4.6	12.1	10.1	x	2.9	4.2	1.1	7.2	16.1	27.7	13.6
	50	14.9	6.7	1.8	2.2	2.3	2.0	5.8	6.6	x	13.8	12.8	19.9	6.2	3.3	4.8	3.8
	90	15.4	7.2	2.5	3.0	4.6	.7	10.2	20.7	18.0	2.0	2.3	6.4	2.6	4.2	3.4	4.3
	150	3.0	1.6	.3	1.0	4.3	3.0	10.3	11.3	x	4.7	5.8	13.0	7.6	3.4	4.1	5.6
1969-14	15	20.9	4.3	9.7	7.8	3.5	1.5				3.7		3.3	6.6	5.4	4.7	x
	50	15.5	4.3	x	x	x	x				3.2		4.2	6.2	1.5	1.6	2.4
	90	10.0	4.5	30.7	x	x	x				6.4		5.5	3.8	2.7	3.0	4.9
	150	15.7	14.6	7.9	x	x	x				x		x	11.6	4.8	4.9	x
1970-15	15	11.1	1.8	19.1	13.8	19.3	6.1	22.8			2.8	1.3	1.3	22.8	2.8	1.3	1.3
	50	6.7	2.6	3.4	4.1	7.0	14.7	10.9			5.3	2.5	6.4	10.9	5.3	2.5	6.4
	90	9.8	8.3	6.0	6.7	6.4	6.5	41.7			4.8	2.4	4.8	41.7	4.8	2.4	4.8
	150	6.1	7.3	2.1	2.7	2.9	3.7	x			9.6	6.0	12.5		9.6	6.0	12.5

* - Psychrometers removed for cleaning and calibration
x - Denotes psychrometer failure

Table 71. Soil temperatures (°C) for undisturbed soils and minespoils at Colstrip study area.

Table Soil temperature (C°) for native soils and mine spoils at Colstrip, Montana.

Site	Depth(cm)	1976 DATE 6/29	7/11	8/11	8/24	9/15	10/22	11/24	2/12	3/13*	1977 DATE 5/2	5/10	5/31	6/15	7/9	7/19	7/31
CHINOOK-1	15	14.9	21.7	22.2	23.4	15.7	6.8	1.1		6.9	14.4	20.7	18.6	18.6	20.5	27.6	24.6
	50	15.9	19.0	23.7	25.1	17.8	5.7	2.3		3.2	13.0	14.2	15.2	19.5	22.0	23.2	21.2
	90	13.7	15.9	21.5	22.0	18.6	11.3	5.9		4.1	10.8	11.3	13.9	16.4	19.5	16.6	19.0
	150	12.0	11.5	18.6	19.5	17.8	14.9	9.1		5.1	8.1	8.6	11.5	13.0	15.9	15.2	15.9
YAMAC-2	15	13.9	19.8	21.2	22.7	16.4	8.4	3.0			11.5	19.5	18.1	24.1	24.6	27.6	22.0
	50	14.2	17.3	22.7	22.9	18.3	10.4	5.2			13.0	13.9	15.7	18.1	20.3	22.2	21.2
	90	13.7	15.4	21.2	21.7	18.6	12.5	6.9			10.8	11.1	13.7	16.1	18.3	19.8	19.3
	150	12.0	12.2	19.0	19.5	18.3	15.2	9.8			8.4	8.8	11.1	12.2	14.2	14.7	15.9
1948-3	15													19.3	21.2	24.9	22.7
	50													18.3	20.0	22.9	22.9
	90													14.9	16.4	17.3	18.8
	150													12.0	13.5	14.7	15.9
1924-5	15	14.7	21.2	24.1	24.4	16.4	5.0	5.0									
	50	13.9	20.0	24.1	24.4	17.6	7.9	3.5									
	90	13.5	19.8	23.2	22.7	17.8	10.4	4.5									
	150	12.0	13.7	20.1	20.0	17.6	14.4	8.4									
BUSBY-6	15	x	21.2	23.2	24.4	16.9	5.0	5.9									
	50	14.9	19.8	22.2	22.7	17.8	10.5	6.4									
	90	13.5	16.9	21.2	21.0	x	12.5	7.6									
	150	12.5	11.0	18.6	18.6	17.1	14.9	10.1									
1924-7	15	10.1	21.5	23.4	25.1	18.6	5.4	4.0			14.7	20.3	13.5	17.1			
	50	13.1	20.0	23.4	24.1	18.8	9.9	4.7			14.7	15.9	15.9	19.3			
	90	12.7	18.6	22.7	23.2	18.8	11.4	5.7			12.5	13.5	x	19.0			
	150	10.8	11.3	18.8	20.0	18.6	15.4	10.1			9.1	10.1	12.7	14.7			
BUSBY-8	15	15.2	22.7	x	x	x	x	1.1			14.9	20.7	13.9	20.5	22.7	31.9	22.7
	50	14.9	21.7	24.9	24.9	20.1	10.1	3.0			14.9	x	15.6	19.0	23.2	23.9	22.9
	90	13.7	18.6	22.9	22.7	20.0	12.5	6.9			12.5	13.5	12.7	16.9	17.8	16.9	18.1
	150	12.0	14.7	20.3	20.4	19.5	15.4	9.8			9.6	10.5	x	15.4	17.3	16.9	5.7
1924-9	15	14.4	22.0	25.1	25.1	18.8	5.4	3.1	1.1	21.5							
	50	14.9	21.2	25.1	25.6	18.1	9.1	3.7	1.3	5.6							
	90	13.9	18.8	x	23.2	18.6	11.4	5.2	1.8	6.7							
	150	11.3	11.5	20.1	20.3	18.1	15.0	9.1	3.7	5.2							
1932-10	15	12.2	23.2	21.5	22.7	19.0	5.4	1.3			13.5	19.3	17.6	18.3	13.5	26.1	22.2
	50	13.5	19.5	23.4	24.1	18.1	9.1	3.3			13.7	14.7	14.7	20.3	x	26.6	23.4
	90	12.7	17.3	22.2	22.7	18.6	11.0	5.0			11.3	11.5	13.7	17.3	22.0	21.0	21.2
	150	12.0	13.9	19.5	20.3	18.6	14.4	8.1			13.2	8.8	11.5	11.9	19.5	x	x
1975-11	15	15.4	20.7	22.7	23.2	16.9	6.2	1.8			13.5	15.9	14.9	24.6	21.0	26.3	21.7
	50	12.7	20.3	23.7	25.6	19.4	9.5	3.5			13.9	15.6	14.5	18.3	22.4	23.7	22.4
	90	12.0	17.8	22.7	23.7	19.1	10.8	5.5			12.0	13.0	14.2	17.1	20.0	21.0	22.0
	150	11.0	13.9	20.3	21.0	19.0	14.9	1.1			9.1	9.6	12.0	14.2	17.1	15.6	17.6
1973-12	15	11.5	17.3	22.2	25.1	18.3	10.5	5.4	1.8		12.5	18.1	14.9	22.9	20.5	24.9	20.7
	50	15.4	17.8	21.5	22.4	15.9	5.7	5.7	1.3		12.0	13.5	13.7	17.3	21.0	22.0	21.2
	90	10.5	14.9	20.5	21.0	17.8	8.6	5.9	2.8		10.1	10.5	12.2	15.4	18.3	19.3	18.8
	150	9.3	11.5	18.3	18.8	17.6	14.2	8.4	4.2		7.9	8.6	11.0	13.0	15.4	15.9	16.4
1972-13	15	12.0	17.8	20.3	22.9	15.4	6.	4.7	1.6	4.2	12.2	18.8	17.3	22.4	22.2	22.4	21.2
	50	12.5	16.6	21.2	22.0	17.1	9.1	5.0	1.8	3.0	12.0	13.2	13.7	17.1	20.7	22.9	21.7
	90	11.8	15.4	20.5	21.5	17.1	10.1	5.4	2.5	3.6	10.1	10.5	12.2	15.6	18.4	19.8	19.3
	150	10.5	12.0	17.8	18.8	17.1	13.1	8.1	4.0	x	7.6	8.1	10.5	12.2	14.4	15.4	16.1
1969-14	15	13.0	19.3	22.0	20.7	15.4	4.0				13.0		18.1	16.9	22.7	24.9	21.7
	50	12.0	19.5	x	x	x					13.0		14.9	19.0	21.2	23.7	22.4
	90	12.5	19.0	21.7	21.5	x					11.8		14.4	17.8	19.8	21.7	21.5
	150	11.0	13.2	18.1	18.6	18.6					x		x	14.9	16.1	17.1	x
1970-15	15	12.7	20.7	22.2	22.0	16.4	5.7	4.0			13.9	16.4	17.8	4.0	13.9	16.4	17.8
	50	13.2	19.1	21.7	22.7	19.0	9.1	4.2			13.7	14.7	14.4	4.2	13.7	14.7	14.4
	90	12.7	16.6	20.5	21.2	19.0	10.8	5.2			11.5	12.0	13.9	5.2	11.5	12.0	13.9
	150	11.5	13.7	18.3	18.8	18.6	13.7	x			9.3	8.6	7.6	x	9.3	8.6	7.6

* - Psychrometers removed for cleaning and calibration
x - Denotes psychrometer failure

APPENDIX I. Vegetation Descriptions

Table 72. Dominant vegetation and ground cover of sites at Colstrip study area in June, 1976.

Site (No.)	Dominant Vegetation	Percent Ground Cover		
		Vegetation	Litter	Bareground
Spoil Age				
1924 (5)	Half-shrub - a. grass	41.3	93.3	5.2
1924 (7)	Half-shrub - a. grass	64.0 e	98.9 e	2.6 e
1924 (9)	P. grass - forb	35.7	84.9	13.1
1932	P. grass and shrub	57.7	96.7	2.3
1948	---	---	---	---
1969	P. grass and shrub	53.8	87.5	7.6
1970	P. grass	41.1	94.6	1.2
1972	P. grass and legume	27.7	99.6	0.7
1973	P. grass	23.4	98.3	2.0
1975	Forb and grass seedling	11.1	0.4	97.3
Native Soil				
Chinook	A. grass - forb	41.6 e	---	20.0 e
Yamac	P. grass - forb	75.0 e	74.6	20.4
Kobar	---	---	---	---
Busby (6)	B. forb - a. grass	64.6	79.9	13.0
Busby (8)	---	---	---	---

e: estimate from other months

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