

STUDY OF PHYSICAL AND CHEMICAL
CHARACTERISTICS OF SOME
SALINE-ALKALI SOILS
IN OKLAHOMA

By
WEERAPUN CHOTIVANICH
" "
Bachelor of Science
Kasetsart University
Bangkok, Thailand
1969

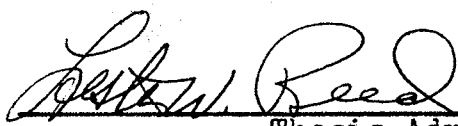
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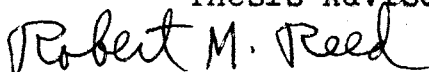
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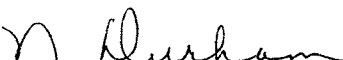
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Thesis Approved:



Thesis Adviser





Dean of the Graduate College

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CHAPTER I

INTRODUCTION

Saline and alkali (sodic) soils are serious agricultural problems and are recognized as a serious threat to crop production in many areas. The soils contain alkali in areas varying in size from a few square feet to thousands of acres. Most of the saline and alkali soils form in arid and/or semi-arid areas, although they may occur in humid climates. The rapid extension of irrigated agriculture has caused the alkali problem to become more acute in various places. In Oklahoma the number of acres affected by soluble salts is about 897,750 acres (24). Although the area of saline and alkali soils is relatively small in the total area of Oklahoma, the presence of large quantities of soluble salts in soils creates problems to those concerned with erosion control, plant growth and proper use of water resources.

The objective of this study is to examine the physical and chemical characteristics of some saline and alkali soil areas adjacent to the Great Salt Plain near Cherokee, Oklahoma. From the results of physical and chemical analysis, a suggestion for reclamation of these saline and alkali soils and for improving their productivity may be found.

CHAPTER II

REVIEW OF LITERATURE CITED

Formation of Saline and Alkali Soils

The presence of saline and alkali soils was observed and studied long before scientists were able to account for their origin. Today many of the factors causing the formation of these soils is still difficult to determine. The first step in the development of soil is the formation of parent material, accumulated largely through rock weathering. Parent materials have a strong effect on the type of soils developed in many places. In semi-arid and arid regions, clay minerals may often become dominated by sodium salts and if the exchange capacity is dominated by sodium the soils become impervious to water.

Hilgard (12) pointed out that alkali soils occurred due to insufficient rainfall for leaching out the salts that are formed by progressive weathering of (the decomposed soils or) soil minerals of which all soils largely consist. Therefore, with insufficient rainfall, there is the more chance for the accumulation of ^{alkali} salts in soils.

Sigmondy (27,28) concluded that genesis of alkali soils chiefly depend upon three factors; these are (1) the arid or

semi arid area, (2) an impervious subsoil, and (3) peculiar hydrological circumstances enabling an intermittent superabundance of moisture in the soil. He stated that alkali soils may originate under arid and semi arid conditions, where in part, there is in the soil a temporary abundance of moisture followed by long dry periods. In the case where there is an impervious subsoil there was opportunity for the sodium salts to accumulate at the surface. The more or less concentrated sodium salts will react and replace in some degree the exchangeable calcium, potassium and magnesium.

Burgess (4) stated that the presence of "white alkali" soils is largely due to three causes: (1) drying up of a sea bed or terrestrial salt lands, (2) the washing down of salt accumulated on upland into lowland areas by rainfall, streams and irrigation systems, and (3) the accumulation of salt on the soil surface by capillary rise of water from a high water-table due to impervious subsoil or over-irrigation. "Black alkali" soils are probably a secondary product derived indirectly from white alkali soils. V

According to Byers et al. (33) salinization can occur on practically any kind of soil and gives rise to the development of saline soils. Salinization is the process of accumulation of various kinds of salts in the soil including sodium chloride, bicarbonate, carbonate, and sulfate; and lesser amounts of calcium, magnesium and potassium salts. Saline soils are fairly common in old

lake bottoms and on low alluvial deposits along seacoasts, even in humid regions. When the drainage systems on saline soils are improved and when they are irrigated or receive fresh water from other sources, the salts are gradually dissolved and leached away. When the calcium content is low and the sodium content high, the sodium clays will hydrolyze to form free sodium hydroxide-carbonate as soon as the greater part of the salts have been removed and the soil solution becomes strongly alkali. Accompanying the deflocculation of the clays, organic matter is dispersed and colors the whole soil dark brown or black. This soil is popularly known as a "black alkali" soil.

As noted by Kelley (14), it has been reported by the Punjab Irrigation Research Institute that salt may accumulate in large amounts on the soil surface or subsurface soil layers even where the water table is much below the possibility of capillary rise to the surface. They apparently believed that salts may diffuse several feet through thin films of water on soil surfaces. Large areas in the Punjab area of India became excessively saline after a few years of irrigation although the upper three or four feet of soil was practically salt free before the initiation of irrigation.

Kellogg (17) studied the solonetz-complex of western North Dakota and discussed the genesis of alkali soils in that area and concluded that salinization is due to soluble soil salts high in sodium. When the excess salts are

removed from the soil the colloids (clay) show an increased mobility and the soil becomes highly alkaline as a result of the hydrolysis of the sodium to form sodium hydroxide-carbonate. As a result of the removal of soluble salts by leaching, sodium salts gradually move downward and the soil becomes relatively impervious to water due to the dispersion of clay. As soon as alkali soils form they immediately begin to react with the environment to form a profile which develops into a soil representing the soil-environment complex.

In Oklahoma saline and alkali soils are only a minor problem economically. These areas, when compared to the total area are relatively small. Most of saline and alkali soils in Oklahoma are only a few feet in diameter, although some may occupy several acres.

Gray and Galloway (11) discussed the saline and alkaline soil in Oklahoma and concluded that they occurred dominantly in arid and semi-arid regions. The processes of development of these soils are intimately influenced by climate and geology. In some instances, the salts that are present in saline and alkali soils were originally present in the parent material and effective water leaching has not been sufficient to deplete them of salts. In other cases these salts may accumulate in depressions and flat areas due to topography or insufficient drainage water.

Murphy and Daniel (22) discussed the presence of "alkali spots" in Oklahoma and concluded that they are

probably due to the accumulation of sodium salts in the sediments laid down by a receding sea in Permian time. As the result of evaporation or the result of arid conditions, the salts were accumulated and a saline soil was formed. When excess salts were leached out by water, hydrolyses of the Na-clay and sodium hydroxide-carbonate formed and caused the soil to become more or less alkaline in reaction and highly dispersed. This retarded further leaching, and with the prevailing climatic condition an alkali soil was developed.

Reed (24) reported that the saline-alkali soils of Oklahoma were usually created by one or more of the following processes; (1) the deposit of salts in alluvial soil or the deposit of salts on the flood plains of the major rivers, (an example of these soils are the Great Salt Plains of the Arkansas River); (2) the evaporation of saline water rising from an impervious subsoil; (3) "Alkali-spots" also occur on local areas of soil parent material of saline saturated Permian and Pennsylvania shales and some are due to the uneven erosion of the top soil with an occasional exposure of saline-alkali subsoil; (4) the contribution of salt water separated from a mixture of oil and salt water, in Oklahoma much of oil produced probably floats on salt water and the separation of oil and salt water is done by flotation and the disposal of the salt water through surface drainage, evaporation ponds and salt water pipeline breaks has caused salt water to contaminate

nearby soils; (5) saline irrigation water and even irrigation water of low salinity on some types of soils when used incorrectly or in too small quantities salts tend to accumulate and eventually become a serious problem. Some of the large streams in Oklahoma which are salty because of a geological influence include the Salt Fork of the Arkansas River, the Cimarron River east of Edith, and the Elm Fork of Red River.

Characteristics of Saline and Alkali Soils

The nomenclature used for describing the characteristics of saline and alkali soil is often confusing. Grouping must be built upon general principles, which do not exclude the insertion of all the special local varieties and terms. The principles of a grouping may be the general chemical and the general physical characteristics of the soils. The United States Salinity Laboratory (31) has classified soils associated with soluble salts and exchangeable sodium as saline, non saline-alkali and saline-alkali soil.

Saline soil is soil which has a conductivity of the saturation extract greater than 4 mmhos/cm at 25°C and an exchangeable sodium percentage less than 15%. Ordinarily the pH is less than 8.5. Saline soil is often recognized by the presence of a white crust of salts on the surface. When adequate drainage is established, the excessive

soluble salts may be removed by leaching. The chief anions are chloride, sulfate and sometimes nitrate. Sodium seldom comprises more than half of the soluble cations. Owing to the presence of excess salts and the absence of significant quantities of exchangeable sodium, saline soil generally is well flocculated. The permeability is equal to or higher than that of similar non-saline soil.

A soil that contains sufficient exchangeable sodium, with or without appreciable quantities of soluble salts, so as to interfere with the growth of plants, is known as a non-saline alkali soil. The exchangeable-sodium percentage is greater than 15% and the conductivity of the saturation extract is less than 4 mmhos/cm at 25°C. The pH usually ranges between 8.5 to 10. The soil has a dark color due to the solubility of a small amount of organic matter in sodium carbonate. These soluble salts of soil organic matter may be deposited on the soil surface by evaporation, thus causing darkening of the surface soil and giving rise to the term "black-alkali" soil.

A saline-alkali soil is a soil that combines the result of the process of salinization and alkalization. It is defined as a soil for which the conductivity of the saturation extract is greater than 4 mmhos/cm at 25°C and the exchangeable-sodium percentage is greater than 15%. Under conditions of excess salts, the pH is seldom higher than 8.5 and the soil clay remains flocculated. If the excess soluble salts are leached downward, the properties

of this soil may change markedly and become similar to those of nonsaline-alkali soil. Saline-alkali soils continue to be a problem until the excess salts and exchangeable sodium are removed from the root zone and a favorable physical condition of the soil is reestablished.

Any attempt to reclaim saline and alkali soils must consider the chemical abnormality of saline-alkali soils. These abnormalities are due to an excess of soluble salts or excess exchangeable Na. Both properties are often found in the same soil and either one or the other may predominate. Many practical methods have been employed for the reclamation of saline-alkali soils. Many of the reclaimed soils have been returned to a condition favorable for crop growth in a relatively short time. To prevent the reoccurrence of saline and alkali soil conditions these reclamation procedures must be repeated periodically. In general, the methods of reclamation of saline-alkali soils may be accomplished by good drainage with sufficient high quality and quantity of water for leaching, soil amendments for replacing exchangeable Na^+ and good irrigation agriculture practices including water control and cropping and tillage practices.

Breazeale and McGeorge (3) reported that sodium hydroxide rather than sodium carbonate is the source of alkalinity in "black-alkali" soils. The reclamation of calcareous, "black-alkali" soils by leaching is possible,

but it is an extremely long and tedious process unless irrigation water high in soluble calcium is available.

Zurr (34) reported that many agricultural lands in the Netherlands were once under brackish lakes and the North Sea. The absorption complex of the soil reclaimed from the sea contains a rather large amount of sodium. Because of the large amount of gypsum formed after drainage the concentration of salts in the soil moisture remains sufficiently high to keep the complex flocculated. Moreover the excess gypsum changes the sodium clay into calcium clay. The requirement for reclamation of this land is good drainage and time. Nearly ten years after ditching, the soil has been almost completely leached free of soluble salts.

Burgess (4) reported that many years ago the water table at the Yuma Valley Experimental Farm of California had risen to within 2 or 3 feet of the surface allowing a heavy accumulation of alkali in the first and second foot. The important process for the reclamation of this soil was to ascertain the position of the water table and removed the excess salts from the soil. The land was plowed and carefully leveled. After several heavy leachings, soil amendments were added. These amendments were calcium chloride, calcium plus manure, gypsum, gypsum plus manure and manure alone in different quantities. The results of alkali soil reclamation were; the use of manure was almost as effective alone as when used in conjunction with either calcium chloride or gypsum. Over 350,000 pounds of salts

had been removed from the surface 6 feet of soil from each acre of the experiment.

The most obvious mode of utilizing alkali lands is to occupy them with crops not affected by the excess salts. Unfortunately only few crops of general utility have been found for the stronger class of alkali lands. Loughridge (19) had observed and given the details of the tolerance for various plants. From his study he found that grapes, olives and almonds were unaffected by a total alkali 45,760, 40,160, and 25,500 pounds per acre to four depths respectively. Kearney (13) listed the crop plants which are most likely to succeed on land of different degrees of salinity as shown in Figure 1. Thomas (30) studied the reclamation of a white-alkali soil and reported that the concentration of soluble salts brought to the surface by the capillary rise of water from a high water table soil in California. The reclamation of these white-alkali soils can be brought about by leaching without any special treatment such as gypsum or sulfur provided the drainage system is good and the water table must be kept well below the root zone if good results are to be expected.

Kelley and Thomas (15) reported on the reclamation of "black-alkali" soil and concluded that good drainage conditions must be established and the right kind of materials had to be applied. Gypsum, sulfur, iron sulfate and alum produce beneficial effects on "black-alkali" soils but at different rates of improvement. The kind and amount of

Weak salinity (0.1-0.4 percent)			Strong salinity (0.8-1 percent)	Sugarbeets, Mangels Strawberry clover, Rhodes grass, Bermuda grass, Blue stem, Smooth brome grass, Tall oatgrass
		Medium strong salinity (0.6-0.8 percent)		Slender wheat grass, Crested wheatgrass, Italian ryegrass, Meadow fescue, Rape, Kale Sorgo, Barley (haycrop)
		Medium salinity (0.4-0.6 percent)		Sweet clover, Cotton, Asparagus, Foxtail millet Wheat (haycrop), Oats (haycrop), Barley (grain crop), Rye (grain crop), Rice, Sunflower
				Wheat (grain crop), Emmer (grain crop) Oats (grain crop), Grain sorghum, Proso, Alfalfa, Vetch, Horribean, Field peas, Red clover

Figure 1. Crop Plants Which Are Most Likely To Succeed In the Presence of Different Degrees of Salinity

soil amendment required for the best results will vary in different localities depending on the content of sodium carbonate and the amount of replaceable sodium present in the clay materials in the soil.

The methods of reclaiming saline-alkali soil has been emphasized upon supplying calcium for exchange with sodium on the soil exchange complex. The usual practice is to supply a neutral calcium salt amendment to the soil and to leach with irrigation water. Reclamation by this procedure often fails or is so slow that it is not economically feasible, mainly because of the low permeability of saline-alkali soil to irrigation water. If the water fails to move into and through the soil, regardless of whether calcium has been added to the soil or is available in the soil, reclamation will obviously not take place. Very soluble calcium salts such as calcium chloride may be used to supply calcium at a high electrolyte concentration, but for the most part the high costs of these salts makes this impractical.

Reeve and Bower (25) used the high salt irrigation waters as a flocculant and source of divalent cations for reclaiming "sodic" or "alkali" soils and they used what they called the "basic or valence dilution effect." In a soil-water system in which absorbed cations are in equilibrium with the cations in solution, the equilibrium may or may not be shifted by the addition of water, depending upon the valence of the cations involved. The experiments

for the reclamation of a sodic or alkali soil resulted in the observation that the higher the divalent cation concentration the more rapidly the exchange will take place. The calcium in the water may be considered as an acceleration in the reclamation process through its flocculative effect on the soil and from the resulting increase in soil permeability. The most important process in this method is that drainage must be adequate for removal and discharge of reclamation by-products and excess salts.

Reeve and Doering (26) used the same method for the reclamation of a "sodic-soil" near Hemet, California. They developed an equation for calculating the amount of water required for reclaiming "sodic-soils" based on the composition of water used, the exchangeable sodium percentage of the soil and the rate at which the leaching water is diluted.

Recently Muhammed et al. (29) modified the "high-salt water" method of Reeve and Bower (25) for reclaiming "sodic-soils." Although the use of such waters reduces the time required for reclamation, the depth of water penetration required for reclamation with the high-salt water method is generally large. Instead of using only high-salt water, they saturated all water used with gypsum. Their results indicated that the high-salt water saturated with gypsum was the most effective procedure for reclaiming "sodic-soils."

CHAPTER III

METHODS AND PROCEDURE

Twenty-five soil samples were collected on December 20, 1971 from each horizon of four saline-alkali soil profiles of the Drummond, Gracemont and Dale series. These soil profiles are located in Alfalfa County, Oklahoma. The soil samples were air-dried and then processed to pass a 2mm screen. Physical and chemical analyses were then made on these soil samples.

Particle size distribution analyses were determined by the hydrometer method described by Day (8). Due to soluble salt content of these soils, all soil samples were washed 4 to 5 times with distilled water. Organic matter was removed from the surface and sub-surface soil samples by treating with 6% hydrogen peroxide (H_2O_2) (31). Carbonates were removed by the method described by Kittrick and Hope (18). The samples were then oven dried and 40 grams of each soil samples were taken for particle size analysis. Fifty ml of 10% sodium carbonate solution was added to the sedimentation cylinder and the suspension was made up to approximately 500 ml with distilled water and allowed to soak for at least 10 minutes then the suspension was mixed for 5 minutes with the mechanical mixer, transferred to a

sedimentation cylinder, and brought to 1,000 ml with distilled water. A blank of 50 ml of 10% sodium carbonate solution diluted to 1,000 ml with distilled water was used. The sedimentation cylinder was placed in a constant temperature room at 23°C until it reached a constant temperature. Then the suspension and blank sedimentation cylinders were shaken and hydrometer readings were taken at the ends of 30 seconds and 1 minute. Subsequent hydrometer measurements were made at 3 minutes, 10 minutes, 30 minutes, 1 hour, 4 hours, 8 hours and 12 hours. The temperature of the suspension and the hydrometer readings (R) at various times were recorded. The concentration of the suspension was calculated in grams per liter from the equation $C = R - R_0$, where R_0 represented the blank reading, and the summation percentage (P) from the equation $P = 100 (C/C_0)$, where C_0 represented the oven-dry weight of the soil sample. These data were used to calculate the corresponding particle diameters (d), in microns, by means of the equation $d = \theta/t^{\frac{1}{2}}$, where " t " is the sedimentation time in minutes and θ is a parameter (Table for values of θ for determination of particle size from observed hydrometer readings by Day (8).), obtained by entering the table with the value of uncorrected R . P is plotted versus d on semi-logarithmic paper, using log scale for d . The particle size proportion is interpolated from the curve as the summation percentages at 2 and 50 microns. The percentage of sand was determined by difference.

The chemical analyses consisted of the determination of pH, cation exchange capacity, extractable cations, exchangeable cations, electrical conductivity, water soluble cations and anions, carbonates, bicarbonates and total solids. The pH of the soil samples from each horizon was determined on a 1:1 soil-distilled water paste and on a 1:1 mixture of soil and 1N KCl solution as described in the U.S.D.A. Handbook No. 60 (31). pH was determined on a model M2 Beckman, glass electrode pH meter.

The cation exchange capacity was determined by saturating the soil samples with calcium chloride. Ten gram soil samples were washed four times with 25 ml of 1N calcium chloride and the excess of Ca was removed by washing three times, one time with distilled water and two times with 80% acetone. Washing consisted of shaking the samples for five minutes on a reciprocating shaker and then centrifuging until the soil particles were out of suspension. The calcium chloride and acetone washings were decanted as completely as possible and discarded. Calcium was then replaced with sodium by washing four times with 25 ml of 1N sodium chloride. The supernatants were combined and diluted to 100 ml and calcium was determined by titration to a bright blue end point with standardized EDTA.

Extractable Ca, Mg, Na and K for each soil horizon was obtained by leaching 5 gram samples three times with 33 ml of 1N ammonium acetate at pH 7.0. The leachate was diluted

to 100 ml and the extractable sodium and potassium were determined with the atomic absorption spectrophotometer (31). The extractable calcium and magnesium were determined using the EDTA titration (5).

Exchangeable Ca and Mg in each soil sample were determined by washing 10 grams of a soil sample five times, three times with distilled water and two times with 95% ethanol. The exchangeable Ca and Mg in the soil sample were then replaced by NH_4^+ by washing three times with 33 ml of 1N ammonium acetate, pH 7.0. These washings were saved and diluted to 100 ml. The samples were then analyzed by adding 4 parts of the washing and 1 part of 5.0% lanthanum chloride and the content of Ca and Mg determined on the atomic absorption spectrophotometer. Exchangeable Na and K were determined by the difference between extractable Na and K and water-soluble Na and K.

Electrical conductivity was determined after a 1:1 soil-water extract was prepared on 250 gram samples of soil. These samples were shaken on a Burrell wrist-action shaker for 4 hours before filtering on Buchner funnels. The resistance readings were taken on a model RC1B Industrial Instruments Inc. conductivity bridge. The 1:1 soil-water extract was also analyzed for Ca, Mg, Na, K, Cl and SO_4 . Ca, Mg, Na and K were determined on the atomic absorption spectrophotometer. Ca and Mg samples were first prepared by adding 4 parts of the extract and 1 part of 5.0 percent lanthanum chloride.

Chloride was determined by a silver nitrate titration method described by Bower and Wilcox (2). The pH of a 10 ml aliquot of the water extract was adjusted to 10 with sodium bicarbonate. Two drops of 5% potassium chromate was then added as an indicator and the solution was titrated with standard silver nitrate until the appearance of a red or reddish-brown precipitate was observed.

Sulfates were determined by the method reported by Page (23). A ten ml aliquot of the soil-water extract was used for the determination. The sample was diluted to 25 ml with deionized water and 25 ml of a pH 4.8 sodium acetate buffer was added. The barium sulfate precipitate was developed by adding 0.5 ml of 1% gum arabic, 0.5 gram of 30 mesh barium chloride crystals and shaken mechanically. The barium sulfate in suspension was determined by reading % absorption on the Bausch-Lomb Spectronic 20 colorimeter at 700 millimicrons and the results were converted to part per million sulfates from a standard curve.

Alkaline earth carbonates were determined by an acid neutralization method as described by Allison and Moodie (1). A 10 gram soil sample was treated with 50.0 ml of standard 0.5 N hydrochloric acid. The soil-acid mixture was boiled gently for 5 minutes and then cooled. The mixture was filtered through a retentive paper, and washed thoroughly with water to remove the excess acid. The filtrate was then back titrated with 0.25 N. NaOH to the

phenolphthalein end point. The data obtained were reported as percent carbonates.

Total solids were determined by slowly evaporating to dryness 20 ml of a 1:1 extract (31). Samples were then placed in the oven at 105°C and upon removal the samples were placed in a desiccator to dry before weighing on an analytical balance and data obtained were reported in parts per million pounds of soil.

CHAPTER IV

RESULTS AND DISCUSSION

A detailed preliminary investigation was made of some saline-alkaline areas in Alfalfa County, Oklahoma in an attempt to study the physical and chemical characteristics of these soils and to suggest reclamation treatments.

The particle size distribution in the profiles of the four saline-alkali soils studied are shown in Table I and Figures 2-5. Soil No. 1, tentatively identified as a Drummond loam. The percentage of sands generally increased with depth while the percentage of silt decreased with depth. The percentage of clay increased to the 20 inch depth and then decreased. In soil No. 2, Drummond silty clay loam, the percentages of sand and silt generally decreased with depth. For clay the percentage increased sharply from the surface downward to the 50 inch depth. For soil No. 3 Gracemont sandy loam, the percentages of silt and clay generally decreased with depth and the percentage of sand increased with depth. This soil is a sand to loamy sand in texture. At a depth of 48 inches, the percentage of sand is nearly 83 percent. When this soil profile was collected, it was found that the soil was very wet at the 20-48 inch depth. Therefore, the water table of

TABLE I

PARTICLE SIZE ANALYSIS OF SALINE-ALKALI
 SOIL NO. 1 DRUMMOND LOAM SAMPLE TAKEN
 FROM 1200 FT. N. 50 FT. E. OF S.W.
 CORNER, SEC. 5, T23 N, R 12 W

December 20, 1971

Soil Depth	Sand (%)	Silt (%)	Clay (%)
0-4"	40.70	32.40	26.90
4-8"	46.10	23.25	30.65
8-20"	45.25	22.50	32.25
20-32"	51.50	18.91	29.59
32-50"	50.03	20.25	29.70
50-68"	57.80	17.25	24.95

PARTICLE SIZE ANALYSIS OF SALINE-ALKALI
 SOIL NO. 2 DRUMMOND SILTY CLAY LOAM
 SAMPLE TAKEN FROM 1600 FT. N. 250
 FT. E. OF S.W. CORNER, SEC.
 26, T27 N, R 11 W

December 20, 1971

Soil Depth	Sand (%)	Silt (%)	Clay (%)
0-1"	28.50	50.25	21.25
0-6"	28.25	50.80	20.95
6-12"	20.70	48.75	30.55
12-20"	14.75	49.2	42.05
20-32"	15.50	32.50	52.0
32-50"	18.00	28.40	53.60

TABLE I (Continued)

PARTICLE SIZE ANALYSIS OF SALINE-ALKALI
 SOIL NO. 3 GRACEMONT SANDY LOAM
 SAMPLE TAKEN FROM 200 FT. E.
 100 FT. S. OF N.W. CORNER
 SEC. 8, T27 N, R 10 W

December 20, 1971

Soil Depth	Sand (%)	Silt (%)	Clay (%)
0-1"	51.00	32.25	15.75
0-4"	66.05	21.2	12.75
4-12"	61.60	26.30	12.10
12-20"	69.30	19.50	11.20
20-42"	73.10	19.70	7.20
42-48"	82.40	10.70	6.90

PARTICLE SIZE ANALYSIS OF SALINE-ALKALI
 SOIL NO. 4 DALE SILT LOAM SAMPLE
 TAKEN FROM 2100 FT. S. 100 FT.
 E. OF N.W. CORNER SEC. 20,
 T27 N, R 10 W

December 20, 1971

Soil Depth	Sand (%)	Silt (%)	Clay (%)
0-4"	22.70	50.80	26.50
4-11"	24.90	44.80	30.30
11-24"	23.90	46.60	29.50
24-33"	30.80	41.50	27.70
33-40"	48.10	35.90	16.00
40-45"	47.60	38.10	14.30
45-60"	47.80	34.20	18.00

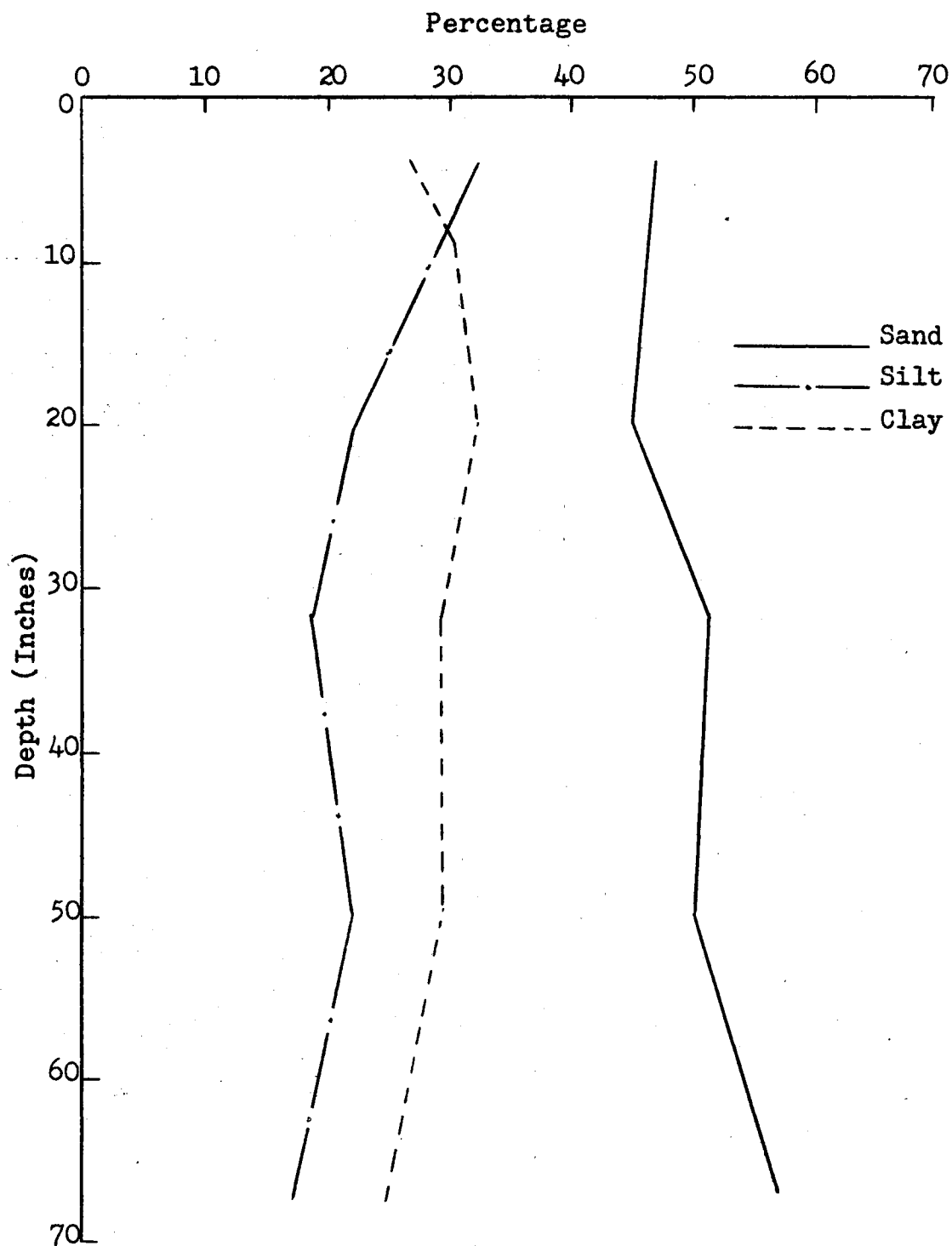


Figure 2. Particle Size Distribution in the Profile of Soil No. 1 Drummond Loam

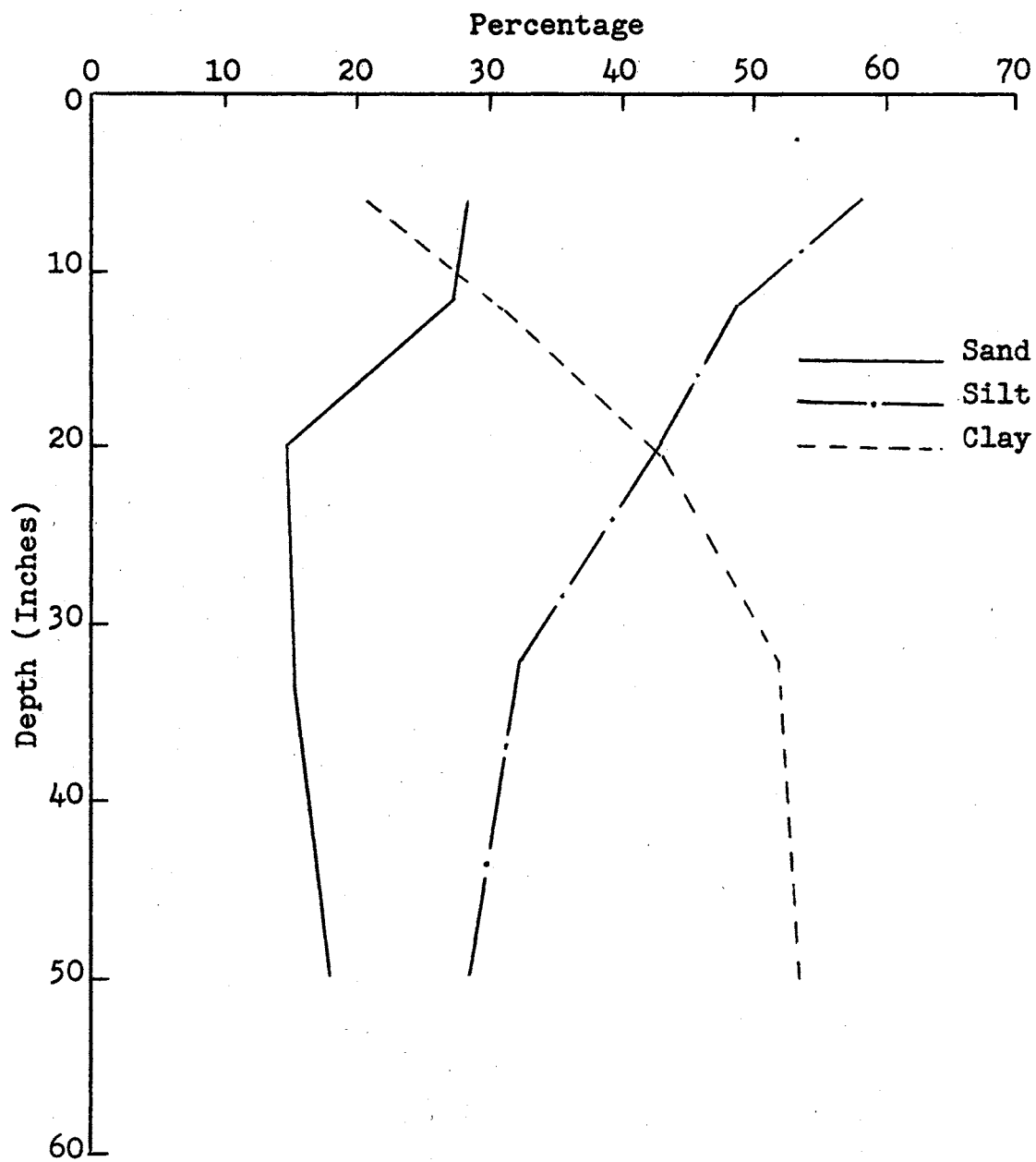


Figure 3. Particle Size Distribution in the Profile of Soil No. 2 Drummond Silty Clay Loam

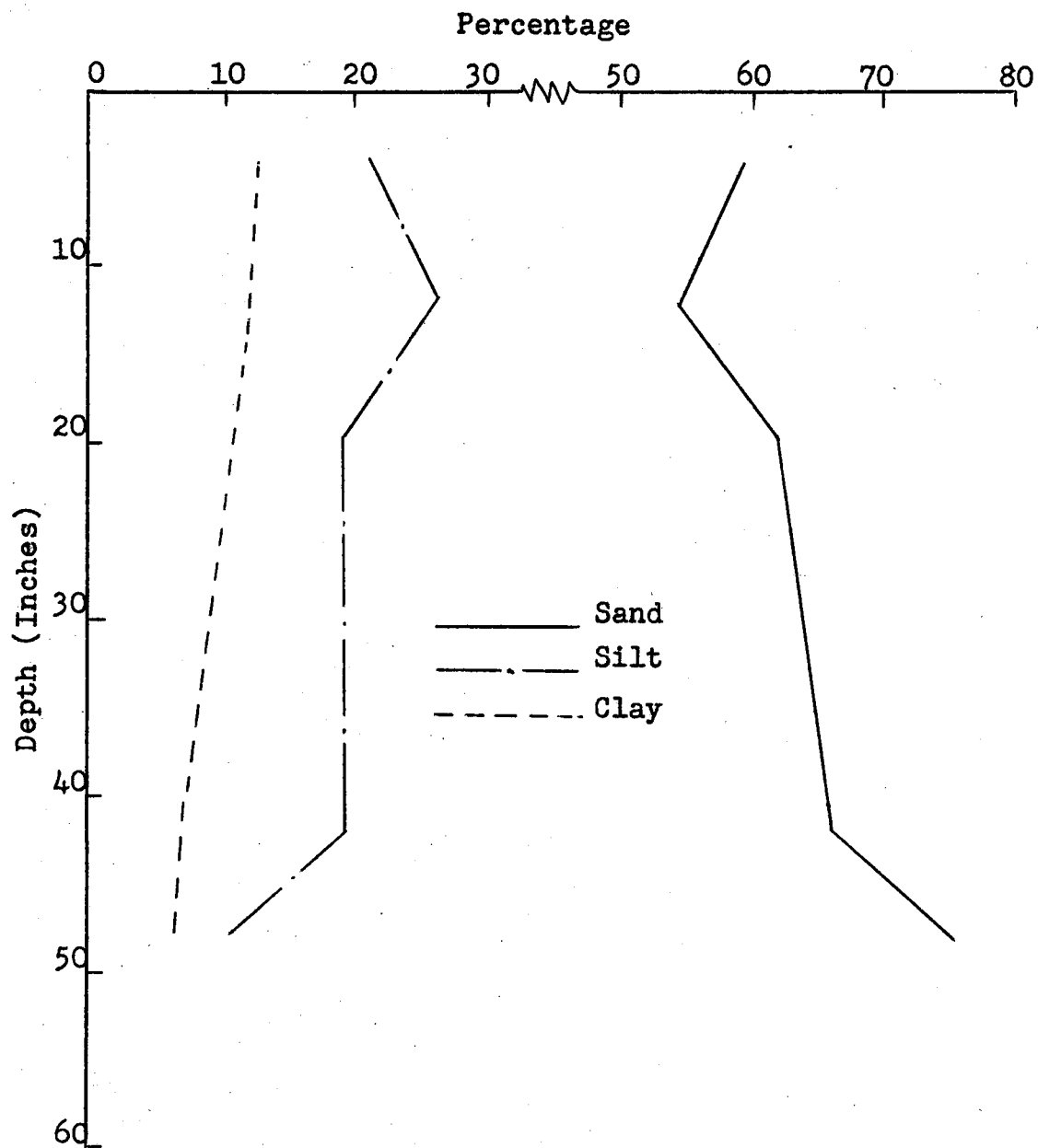


Figure 4. Particle Size Distribution in the Profile of Soil No. 3 Gracemont Sandy Loam

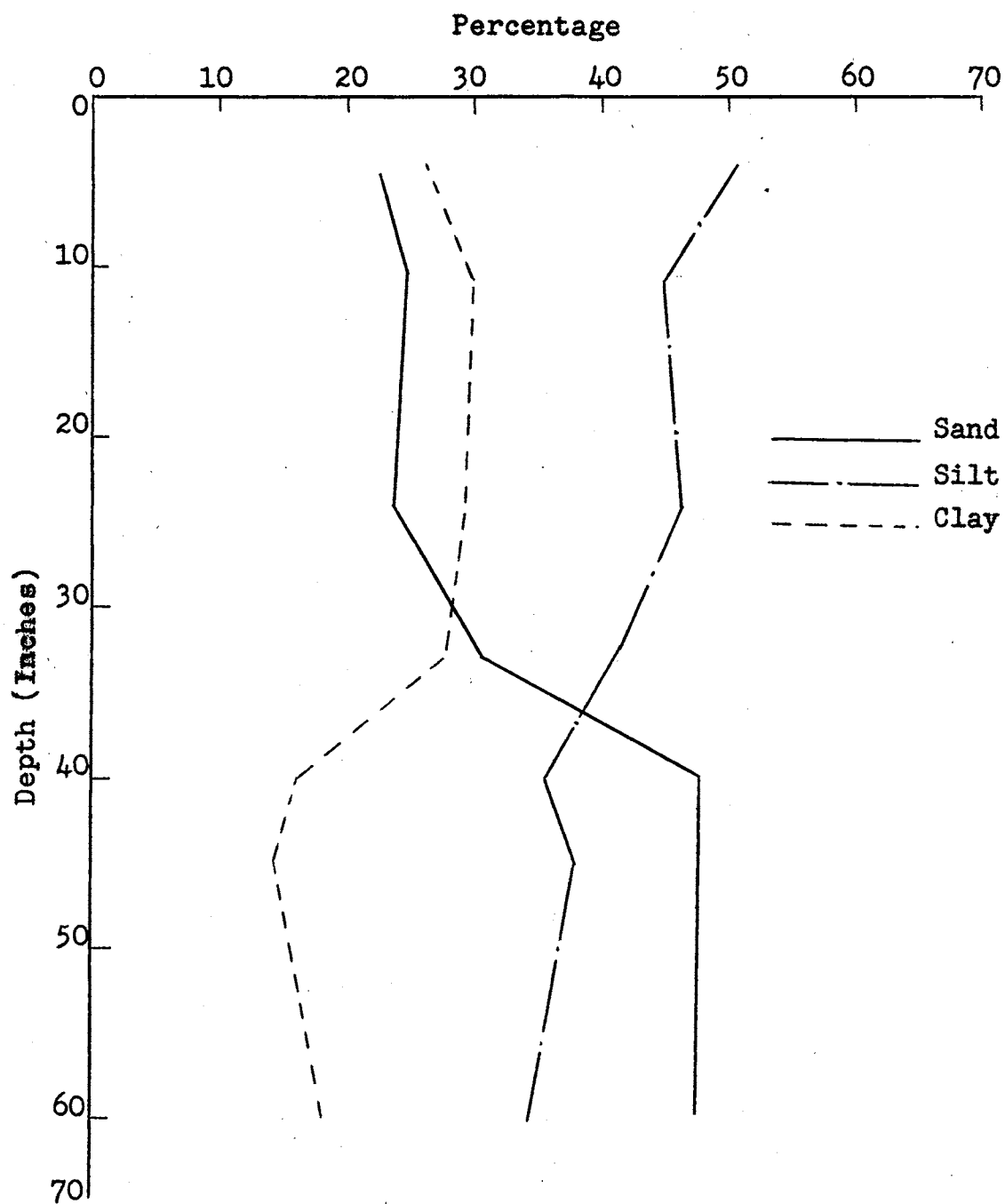


Figure 5. Particle Size Distribution in the Profile of Soil No. 4 Dale Silt Loam

this soil profile is high enough to cause the accumulation of salts on the soil surface by capillarity. In soil No. 4 Dale silt loam, the percentages of silt and clay generally decreased with increasing depth and the percentage of sand increased with depth.

Detailed analyses of the soluble constituents, the electrical conductivity of saturation extract, the extractable cations, the alkaline earth carbonate and exchange characteristics of the 4 saline-alkali soil profiles are shown in Tables II-V and Figures 6-9. Soluble salts are high in all samples. In soil No. 1 a Drummond loam soil, the pH ranged from 8.4 to 8.7 and the pH remained nearly constant from the soil surface to the lower depths. The electrical conductivity of the saturation extract was very high from the surface down to the 20 inch depth and high from the 20 to 32 inch depth. At these lower depths there was an increased accumulation of soluble salts. Sodium, sulfate and chloride ions were found to be very high. All of these ions increased with depth from the soil surface to the depth of 32 inches and then decreased at lower depths. The soluble calcium and magnesium, when compared to other ions, are relatively low in concentration. However, they also increased with depth from the soil surface to the depth of 20 and 32 inches and then decreased at lower depths. Calcium is the dominant exchangeable ion in this profile and generally it decreased with depth. The amount and proportions of exchangeable sodium is relatively high

TABLE II

COMPOSITION OF SATURATION EXTRACT OF SALINE-
ALKALI SOIL NO. 1 DRUMMOND LOAM SAMPLE
TAKEN FROM 1200 FT. N. 50 FT. E. OF
S.W. CORNER, SEC. 5, T 23 N,
R 12 W - DECEMBER 20, 1971

SOIL DEPTH	CONDUCTIVITY mho x 10 ⁶	SOIL pH	PARTS PER MILLION SOLUBLE CONSTITUENTS					TOTAL SOLIDS ppm
			Na	Ca	Mg	SO ₄	Cl	
0-4"	1440	8.7	324	68	12	81	170	662.
4-8"	3880	8.5	794	25	21	525	673	3460
8-20"	12630	8.4	2800	121	52	2475	2792	9747
20-32"	6820	8.5	1360	43	18	725	1942	4967
32-50"	4210	8.6	900	25	9	345	824	2967
50-68"	2150	8.6	380	40	5	530	452	2490

COMPOSITION OF SATURATION EXTRACT OF SALINE-
ALKALI SOIL NO. 2 DRUMMOND SILTY CLAY LOAM
SAMPLE TAKEN FROM 1800 FT. N. 250 FT. E.
OF S.W. CORNER, SEC. 26, T 27 N,
R 11 W - DECEMBER 20, 1971

SOIL DEPTH	CONDUCTIVITY mho x 10 ⁶	SOIL pH	PARTS PER MILLION SOLUBLE CONSTITUENTS					TOTAL SOLIDS ppm
			Na	Ca	Mg	SO ₄	Cl	
0-1"	1010	6.8	24	82	62	10	70	882
0-6"	360	7.0	23	31	9	12.9	79	1205
6-12"	560	7.4	57	53	15	225	59	1157
12-20"	2520	7.6	384	57	24	675	345	1885
20-36"	10100	7.8	996	562	525	4800	540	7834
32-50"	12630	7.7	1420	537	705	5500	788	9260

TABLE II (Continued)

COMPOSITION OF SATURATION EXTRACT OF SALINE-
ALKALI SOIL NO. 3 GRACEMONT SANDY LOAM
SAMPLE TAKEN FROM 200 E. 100 FT. S.
OF N.W. CORNER, SEC. 8, T 27 N,
R 10 W - DECEMBER 20, 1971

SOIL DEPTH	CONDUCTIVITY mho x 10 ⁶	SOIL pH	PARTS PER MILLION SOLUBLE CONSTITUENTS					TOTAL SOLIDS ppm
			Na	Ca	Mg	SO ₄	Cl	
0-1"	1910	8.4	340	56	8	512	159	1802
0-4"	840	8.6	144	68	6	12	66	695
6-12"	1630	8.8	299	40	2	287	239	1665
12-20"	7220	8.2	1244	150	43	779	1010	3537
20-42"	2290	8.3	282	82	18	237	585	1395
42-48"	1680	8.2	140	87	12	200	310	987

COMPOSITION OF SATURATION EXTRACT OF SALINE-
ALKALI NO. 4 DALE SILT LOAM SAMPLE TAKEN
FROM 2100 FT. 100 FT. E. OF N.W.
CORNER, SEC. 20, T 27 N,
R 10 W - DECEMBER 1971

SOIL DEPTH	CONDUCTIVITY mho x 10 ⁶	SOIL pH	PARTS PER MILLION SOLUBLE CONSTITUENTS					TOTAL SOLIDS ppm
			Na	Ca	Mg	SO ₄	Cl	
0-4"	1090	7.1	30	145	43	10	97	862
4-11"	720	7.6	22	83	2	12	70	447
11-24"	1170	8.0	144	62	11	212	248	770
24-33"	11230	7.8	1840	581	211	4725	2118	9362
33-40"	11430	7.9	1680	575	175	4400	1675	9722
40-45"	10050	8.1	1650	556	186	3750	1746	8182
45-60"	11230	8.1	1600	331	93	2090	1693	6985

TABLE III

CATION EXCHANGE CHARACTERISTICS OF SALINE-
ALKALI SOIL NO. 1 DRUMMOND LOAM SAMPLE
TAKEN FROM 1200 FT. N. 50 FT. E. OF
S.W. CORNER, SEC. 5, T 23 N,
R 12 W - DECEMBER 20, 1971

SOIL DEPTH	SOIL pH IN. KCl	SOIL pH H ₂ O WASHED SOIL	EXCHANGEABLE CATIONS IN m.e./100				
			CEC	Na	GM. SOIL K	Mg	Ca
0-4"	7.71	9.57	16.02	3.13	0.52	1.34	7.56
4-8"	8.10	10.00	10.95	7.15	0.97	1.55	5.31
8-20"	8.15	9.75	16.74	5.09	0.40	1.71	6.25
20-32"	8.05	10.10	15.05	6.13	0.42	2.03	5.12
32-50"	7.80	9.95	13.85	4.22	0.50	2.59	5.00
50-68"	7.52	9.60	12.61	3.26	0.91	2.34	5.12

CATION EXCHANGE CHARACTERISTICS OF SALINE-
ALKALI SOIL NO. 2 DRUMMOND LOAM SAMPLE
TAKEN FROM 1600 FT. N. 250 FT. E.
OF S.W. CORNER, SEC. 26, T 27 N,
R 11 N - DECEMBER 20, 1971

SOIL DEPTH	SOIL pH IN. KCl	SOIL pH H ₂ O WASHED SOIL	EXCHANGEABLE CATIONS IN m.e./100				
			CEC	Na	GM. SOIL K	Mg	Ca
0-1"	6.40	7.50	10.75	0.09	2.26	1.87	5.31
0-6"	6.10	7.50	10.79	0.17	1.46	2.39	5.25
5-12"	6.40	8.10	10.95	1.07	0.40	3.07	4.75
12-20"	7.10	8.80	14.26	2.35	1.17	5.46	3.12
20-32"	7.60	8.40	25.63	3.31	1.14	8.07	9.68
32-50"	7.40	8.20	35.76	4.03	1.09	7.96	18.50

TABLE III (Continued)

CATION EXCHANGE CHARACTERISTICS OF SALINE-
ALKALI SOIL NO. 3 GRACEMONT SANDY LOAM
SAMPLE TAKEN FROM 200 FT. E. 100 FT.
S. OF N.W. CORNER, SEC. 8
DECEMBER 20, 1971

SOIL DEPTH	SOIL pH IN. KCl	SOIL pH H ₂ O WASHED SOIL	EXCHANGEABLE CATIONS IN m.e./100 GM. SOIL				
			CED	Na	K	Mg	Ca
0-1"	8.20	9.35	8.26	2.27	0.40	1.89	3.15
0-4"	8.30	9.50	3.07	0.82	0.28	1.23	2.50
4-12"	8.40	10.05	4.42	1.36	0.21	0.94	1.58
12-20"	8.40	9.80	4.13	1.66	0.16	0.11	1.61
20-42"	8.20	9.20	2.37	9.05	0.09	0.22	1.59
42-48"	8.10	9.05	2.58	0.18	0.15	0.23	1.53

CATION EXCHANGE CHARACTERISTICS OF SALINE-
ALKALI SOIL NO. 4 DALE SILT LOAM SAMPLE
TAKEN FROM 2100 FT. S. 100 FT. E. OF
N.W. CORNER, SEC. 20, T 27 N,
R 10 W - DECEMBER 20, 1971

SOIL DEPTH	SOIL pH IN. KCl	SOIL pH H ₂ O WASHED SOIL	EXCHANGEABLE CATIONS IN m.e./100 GM. SOIL				
			CED	Na	K	Mg	Ca
0-4"	7.05	7.50	16.95	0.15	1.97	1.37	8.75
4-11"	7.30	8.20	11.99	0.16	1.22	1.31	8.21
11-24"	7.52	8.90	11.57	0.56	0.65	1.35	8.43
24-33"	7.98	8.30	14.88	4.06	0.39	1.25	7.81
33-40"	8.00	8.25	12.81	3.12	0.22	0.62	5.63
40-45"	8.20	9.30	7.85	2.04	0.24	0.58	4.43
45-60"	8.10	9.50	9.51	3.47	0.30	0.81	4.25

TABLE IV
ALKALINE EARTH CARBONATE CONCENTRATION
IN SALINE-ALKALI SOILS PERCENTAGE
EQUIVALENT TO CaCO_3

Soil No.1 Soil Depth	% CaCO_3	Soil No.2 Soil Depth	% CaCO_3	Soil No.3 Soil Depth	% CaCO_3	Soil No.4 Soil Depth	% CaCO_3
0-4"	3.96	0-1"	2.07	0-1"	11.06	0-4"	2.85
4-8"	11.64	0-6"	1.30	0-4"	9.30	4-11"	4.07
8-20"	12.48	6-12"	2.48	4-12"	7.70	11-24"	5.61
20-32"	11.09	12-20"	2.89	12-20"	5.77	24-33"	5.39
32-50"	5.51	20-32"	5.29	20-42"	2.93	33-40"	4.88
50-68"	4.30	32-50"	4.20	42-48"	3.13	40-45"	5.88

TABLE V

EXTRACTABLE CATIONS IN SALINE-ALKALI
 SOIL NO. 1 DRUMMOND LOAM EXTRACT
 BY 1 N NH_4Ac at pH 7.0

SOIL DEPTH	EXTRACTABLE CATIONS (m.e./100 GM SOIL)			
	Na	K	Ca	Mg
0-4"	5.21	0.87	14.38	1.40
4-8"	12.60	0.58	15.00	1.56
8-20"	18.26	0.42	18.40	1.93
20-32"	13.04	0.43	15.00	2.13
32-50"	9.13	0.51	12.81	2.63
50-68"	5.65	0.52	13.43	2.36

EXTRACTABLE CATIONS IN SALINE-ALKALINE
 SOIL NO. 2 DRUMMOND SILTY LOAM
 EXTRACT BY 1 N NH_4Ac at
 pH 7.0

SOIL DEPTH	EXTRACTABLE CATIONS (m.e./100 GM SOIL)			
	Na	K	Ca	Mg
0-1"	0.19	2.58	7.18	2.13
0-6"	0.28	1.66	7.00	2.50
6-12"	1.41	1.28	7.93	3.85
12-20"	4.34	1.36	8.12	8.64
20-32"	7.39	1.20	25.00	10.41
32-50"	9.56	1.14	33.75	10.93

TABLE V (Continued)

EXTRACTABLE CATIONS IN SALINE-ALKALI SOIL NO. 3 GRACEMONT SANDY LOAM EXTRACT BY 1 N NH_4Ac at pH 7.0				
SOIL DEPTH	EXTRACTABLE CATIONS (m.e./100 GM SOIL)			
	Na	K	Ca	Mg
0-1"	3.47	0.93	20.93	1.95
0-4"	1.45	0.32	20.62	1.25
4-12"	3.26	0.25	20.31	0.46
12-20"	7.47	0.20	11.87	0.29
20-42"	1.39	0.13	8.12	0.30
42-48"	0.78	0.12	8.43	0.30

EXTRACTABLE CATIONS IN SALINE-ALKALI SOIL NO. 4 DALE SILT LOAM				
SOIL DEPTH	EXTRACTABLE CATIONS (m.e./100 GM SOIL)			
	Na	K	Ca	Mg
0-4"	0.3	2.15	20.31	1.85
4-11"	0.28	1.30	23.12	1.78
11-24"	1.21	0.68	10.93	1.50
24-33"	9.86	0.43	20.62	2.13
33-40"	8.90	0.26	10.00	1.35
40-45"	9.34	0.29	19.00	1.36
45-60"	8.90	0.33	11.56	1.20

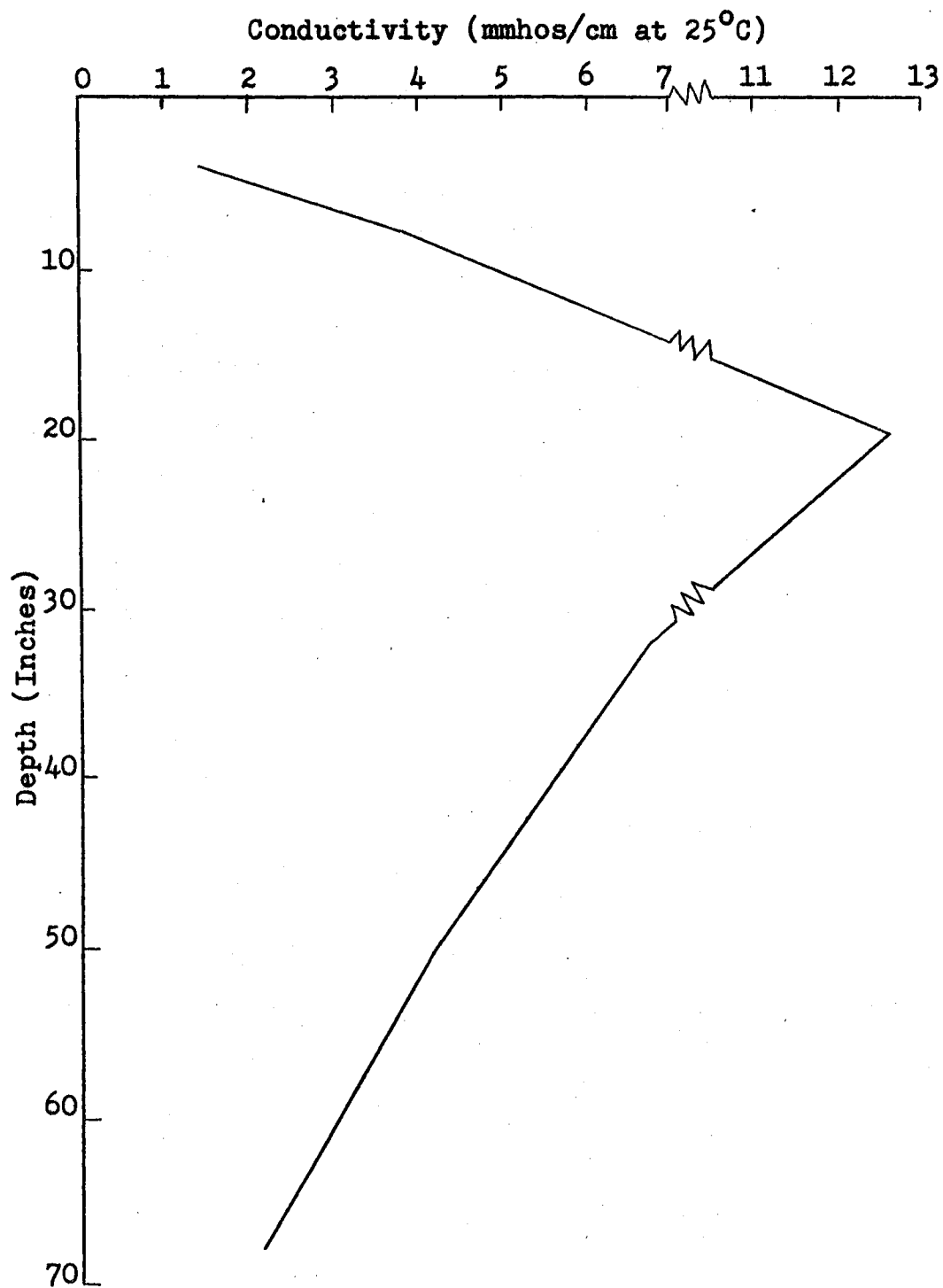


Figure 6. The Electrical Conductivity of the Saturation Extract of Soil Profile No. 1 Drummond Loam

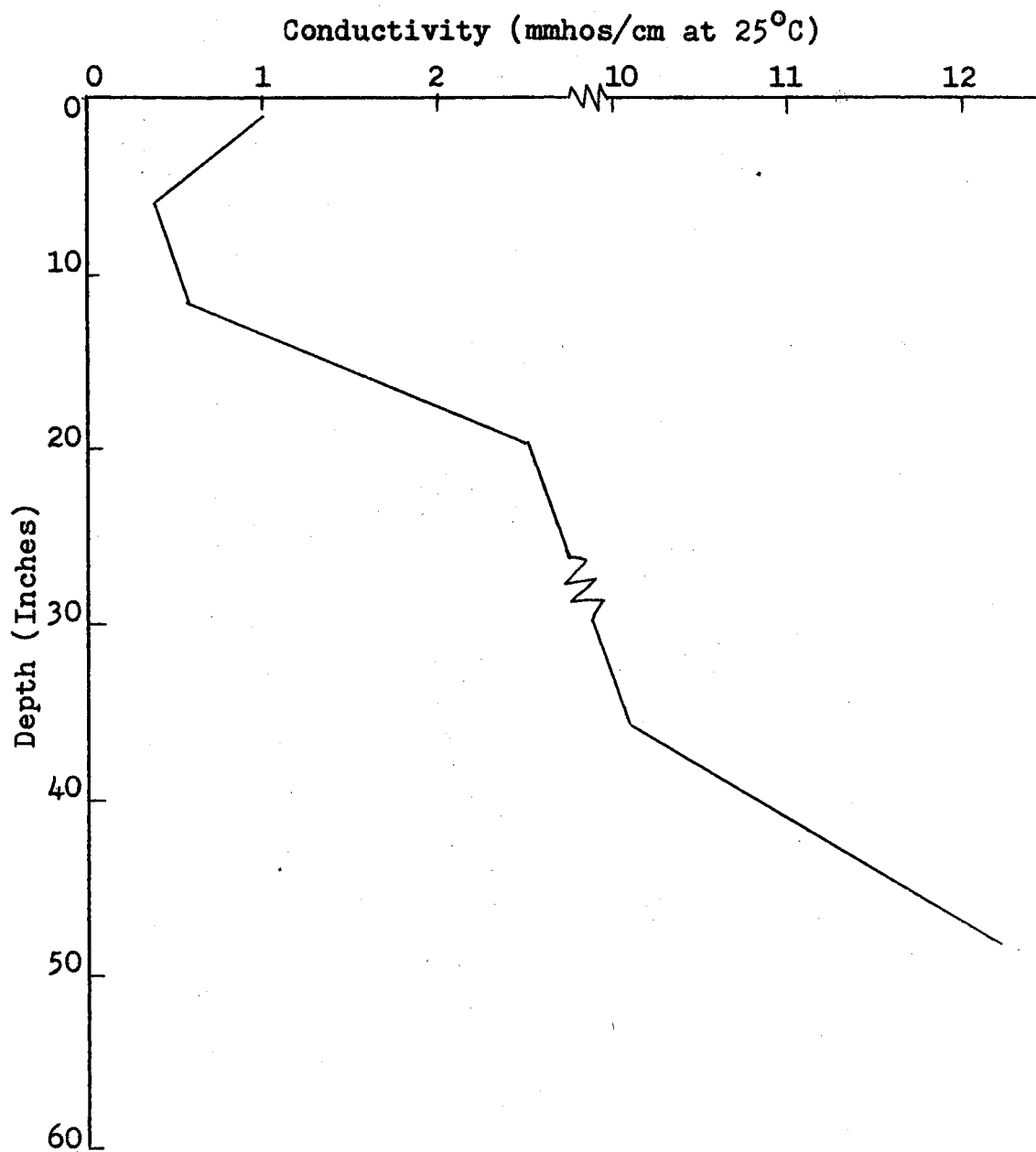


Figure 7. The Electrical Conductivity of the Saturation Extract of Soil Profile No. 2 Drummond Silty Clay Loam

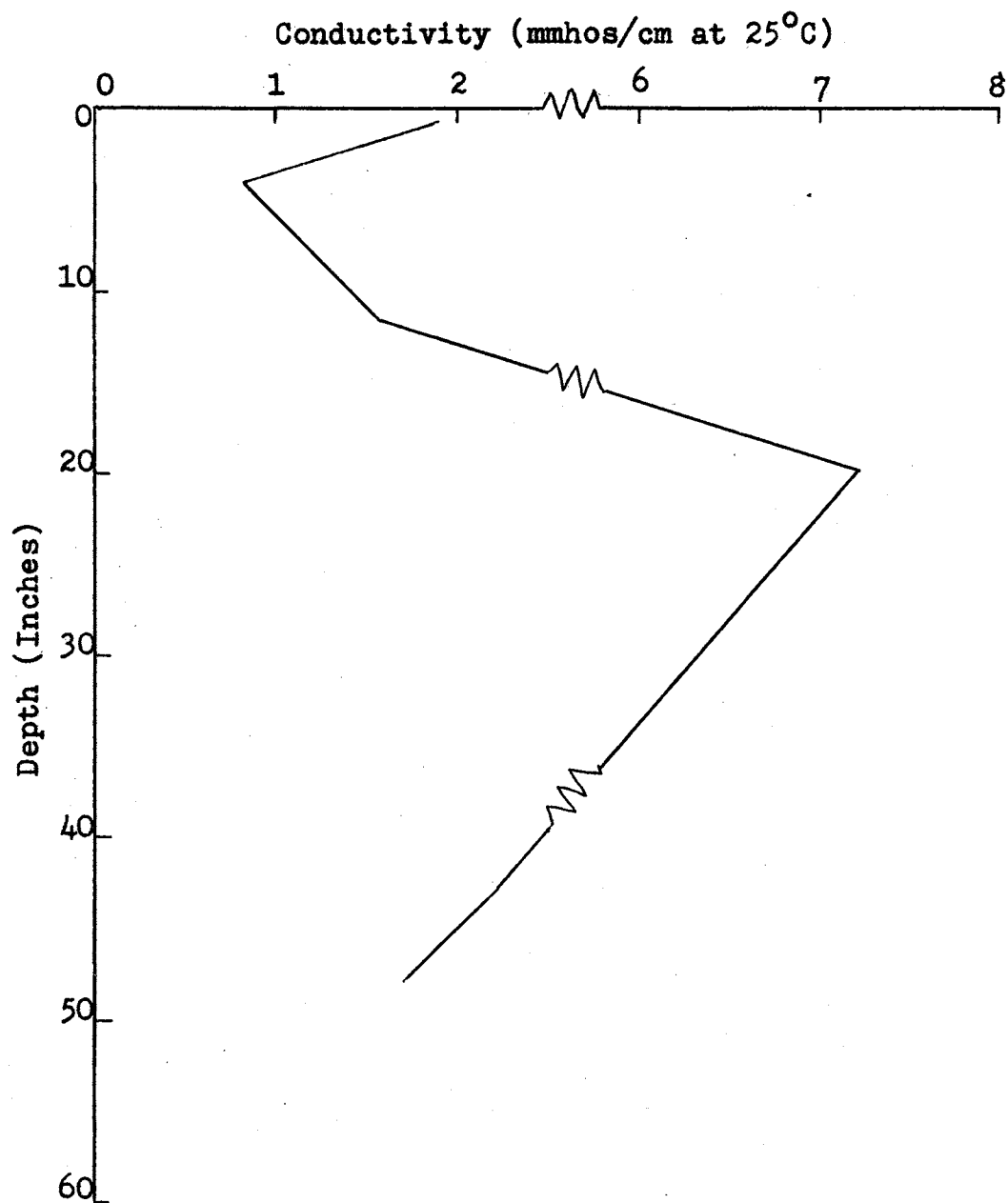


Figure 8. The Electrical Conductivity of the Saturation Extract of Soil Profile No. 3 Gracemont Sandy Loam

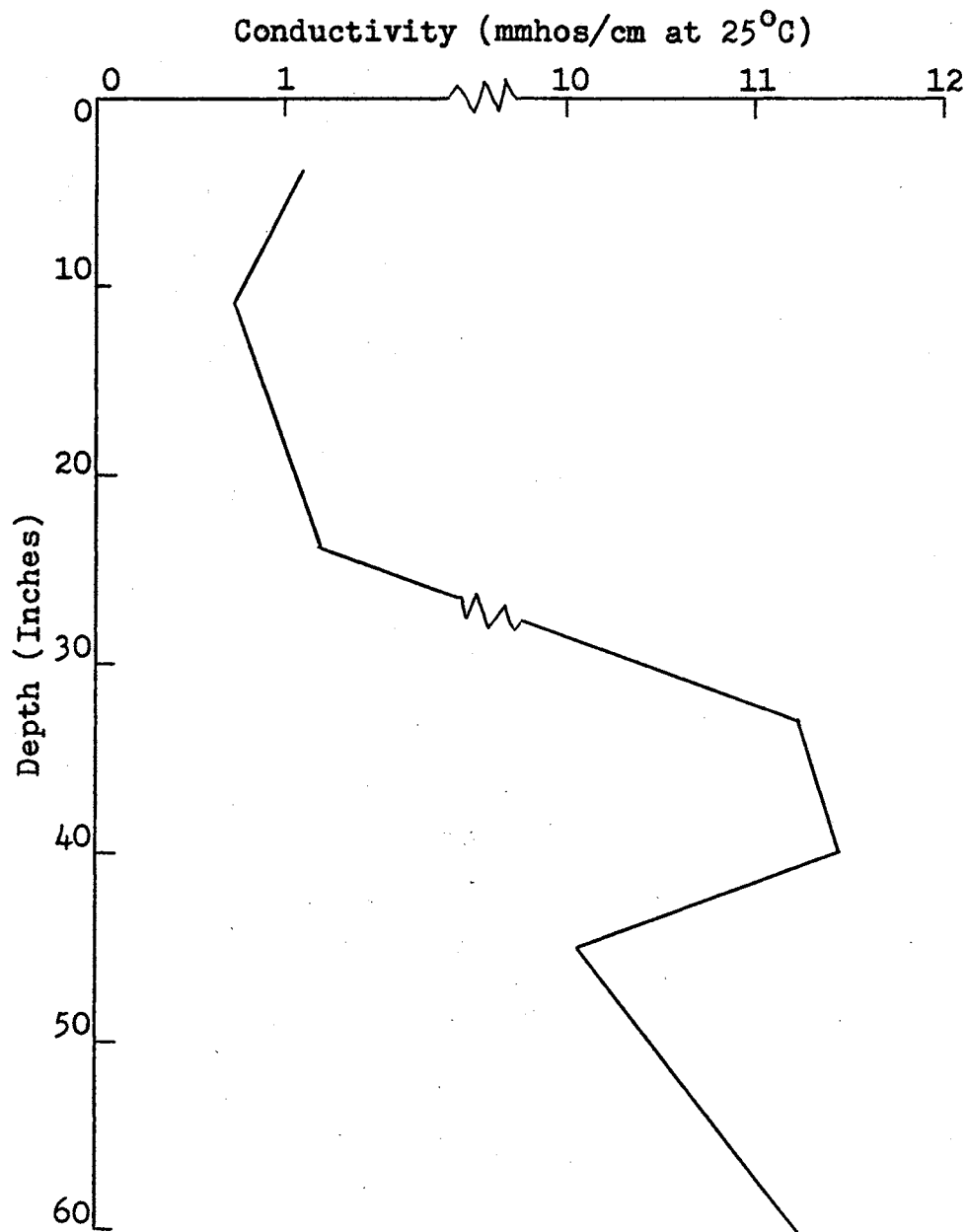
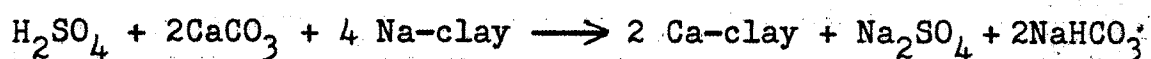


Figure 9. The Electrical Conductivity of the Saturation Extract of Soil Profile No. 4 Dale Silt Loam

as a percentage of total exchangeable bases. The amounts of this ion are high at the depth 4 to 8 inches and then decrease at lower depths. Exchangeable potassium was present at all depths as a small percentage of the total exchangeable bases and it remains nearly constant from the soil surface to lower depths. The content and proportion of exchangeable magnesium is intermediate between the sodium and potassium and in general it increases with depth. The cation exchange capacity ranged between 12.61 to 16.95 m.e./100 g. There was an accumulation of alkaline earth carbonates in the 4 to 32 inch depth.

For the reclamation of this soil, the excessive soluble salts must first be leached out of the profile. The sodium salts of sulfate and chloride in the 8-32 inch depth must be removed before the soil can be treated with some chemical amendment. The land may be flooded to a depth of about 6 inches with fresh water drawn from a well or river. Because of the presence in the soil of some free calcium compounds the soil is high in pH, and sulfur can be utilized effectively in the reclamation of this soil. The amount of sulfur used depends upon the time for reclamation, the cost of sulfur and the exchangeable sodium and soluble salt content of the soil. Small applications of sulfur, such as 1 ton per acre, may be oxidized very rapidly. The reaction of sulfur and sodium may be complete in two or three weeks and heavy application of sulfur of 2-10 tons per acre may have a more prolonged and more

pronounced effect upon the soil. The effectiveness of sulfur depends largely on the presence of calcium carbonate in the soils. The oxidation of sulfur leads ultimately to the formation of sulfuric acid. It is this acid that is primarily responsible for the chemical reactions that occur when sulfur is applied. The end products of the reaction may be expressed by the following equation:



However, the first reactant of sulfuric acid with the soil will be to form gypsum or calcium sulfate. The sodium sulfate and sodium bicarbonate formed must be leached out. (9,14,21,32)

Soil No. 2, a Drummond silty clay loam, the pH values of the soil profile range in value between 6.8 to 7.8. The soil surface is neutral in reaction and the lower depths show increased alkalinity. Generally the electrical conductivity of the soluble salts of this soil profile is low except for the 20-50 inch depth and there is a high accumulation of soluble salts at this depth and the electrical conductivities are very high with values higher than 10 mmhos/cm at 25°C. Soluble sodium salts are low when compared to soil No. 1, but it is high at the 30-50 inch depth. The sulfate content is low at the soil surface and is very high at the lowest depths of the soil profile. The quantity of sulfate at lower depth, when compared to other soluble ions, is significantly higher. Chloride salts

occur in subsoil layers in larger quantities than in the surface soil. Calcium and magnesium are relatively low in percentage of the total soluble salts. Calcium is the dominant exchangeable cation and it increases with depth except at the 12-20 inch depth. However, at the lowest depth the exchange calcium is very high. Exchange magnesium is present in excessive amounts at the 12-50 inch depth. Exchange potassium is high on the soil surface and then decreases at the lower depths. Exchangeable sodium is present in relatively small amounts in the first foot and then increases slightly at lower depths. The cation exchange capacity is about 10.5 m.e./100 g. at the first three depths and then increases sharply to 35.70 at the lowest depth. The distribution of clay as shown in Figure 3 supports the cation exchange capacity distributions. The presence of alkaline earth carbonate is very low when compared to soil No. 1 and ranges between 1.30 and 5.29 percent.

Though this soil profile has a low concentration of soluble salts and low exchange sodium, the problem in the reclamation of this soil is that the soil profile is high in clay and it is very slowly permeable to water. Moreover, the soluble salts that must be removed and the exchangeable sodium and exchangeable magnesium that must be replaced by calcium present at the lowest depth, 20 to 50 inch, will be difficult to achieve. This soil may be reclaimed by using the method of the high-salt-water

dilution for reclaiming saline soil as proposed by Reeve and Bower (25). The use of waters of very low salt content may result in soil dispersion to such an extent that reclamation is not feasible, whereas, a water of medium to high salt content might prove satisfactory. Due to the absence of high exchangeable sodium chemical amendments may not be necessary. High salt well waters, high salt drainage water and other waste effluents and brines, from any sources, may offer possibilities for use in reclamation. To decrease the amount of high-salt water required to reclaim the soil gypsum saturated water should be used in all cases. In any event, drainage is an important consideration, and especially in the case where extra quantities of salt are involved. Drainage must be adequate for removal and discharge of reclamation byproducts and excess salts. If the drainage is poor, use of this method may instead of reducing the soluble salts and excess exchangeable sodium, the soil will be more salinized (6,25,26,29).

In soil No. 3 Gracemont sandy loam, the pH values range from 8.2 to 8.8. pH increases from the soil surface to the 12 inch depth and then decreases. The electrical conductivity of the saturation extracts is less than 3 mmhos/cm at 25°C except the 12-20 inch depth which has a conductivity of 7.22 mmhos/cm at 25°C. There was a significant accumulation of soluble salts on the soil surface and at the 12-20 inch depth. At this depth soluble salts are relatively high as compared to the other depths. Sodium

chloride is the dominant soluble salt in this soil profile; however, its concentration varies at each depth. Most of the soluble salts at the soil surface are sodium chlorides and sulfates. Sulfate and chloride salts are present in small quantities only at the 0-4 inch depth and increase at the deeper depths. Calcium and magnesium occur in relatively small amounts as compared to the total soluble salts. The cation exchange capacity for this soil was low except in the soil surface layer and it decreased with depth. Calcium was the dominant exchangeable cation with sodium in lesser amounts. Exchangeable potassium and magnesium made up a relatively small proportion of the total exchangeable cations. The large quantities of sand present in each depth and low clay percent was responsible for the low cation exchange capacity. 25

In the reclamation of this loamy sand, the water table of this soil profile is high or very close to the soil surface layer. To reclaim it, the physical properties of soil must be improved and the high water table must be reduced. The reclamation of this soil can be accomplished by leaching and drainage with no special treatment required for removal of sodium and magnesium. This soil may produce good yields of the crops if reclaimed by leaching without the application of gypsum or sulfur. Deep drainage and a plentiful supply of irrigation water of good quality are very essential in reclaiming this soil. The use of manure after leaching is also preferable because soils which have

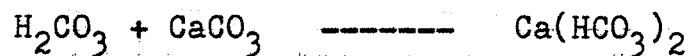
been leached continuously are often found to be temporarily infertile since much of the available nutrient elements have been washed away with the alkali. Moreover the use of manure will improve the structure of the soil. Thus drainage and leaching supplemented by an application of manure may bring about successful reclamation of this soil (9,16, 20,32).

In soil No. 4, Dale silt loam, the pH of the surface layer is neutral, increases slightly in alkalinity at the lower depths with pH values ranging between 7.1-8.1. The electrical conductivity is low in the first three depths and then increases sharply at the 24-60 inch depth. There was a large accumulation of soluble salts at these lower depths with sulfate as the dominant ion in this profile. The quantity of sulfate increased with depth in this soil profile. The second dominant soluble ion is sodium and is also very high at the 24-60 inch depth and the chloride concentration is also very high at this depth. For soluble calcium and magnesium, they are present in relatively small amounts compared to the total soluble salts as shown in Table II. The cation exchange capacities ranges between 9.51 and 10.95 m.e./100 g. and they decrease with depth except at the 24-33 inch depth. Both exchangeable potassium and exchangeable magnesium are present in small quantities and they decrease with depth. Alkaline earth carbonate concentration is not high. There was an accumulation of carbonates at the 11-33 inch depth and at the

40-50 inch depth. This soil is affected by excessive salinity, which occurs mainly on nonirrigated land where methods for improvement are limited. Because of the high cost of chemical amendments, it is not feasible to reclaim this soil.

However, this soil may be reclaimed by leaching combined with vegetative mulch and/or surface protection. Leaching and soil surface protection is the only feasible method (7,14). To achieve satisfactory results for reclamation of this soil a high leaching efficiency is required where the water is applied by flooding of the surface-mulched soil. If moisture in the subsoil is near field capacity, relatively small quantities of water can be effective in reducing salinity, provided the water table is below the root zone. The soil surface should have a vegetative mulch if possible at the beginning of the flooding and leaching sequence.

In addition to the mulch effect of plants there may be an added factor in reclamation due to the growing plants. Roots of all growing plants give off carbon dioxide to form carbonic acid with water in the soil. The result is that calcium carbonate is dissolved as the bicarbonate ion and the calcium ions are thus brought into solution to replace exchangeable sodium. The reaction can be expressed as follows:



Any of several alkali-resistant plants can be of some benefit in reclaiming alkali or sodic soil. Rhodes grass (Chloris gayana), rye grass (Lalium pereune), Sudan grass (Sorghum vulgare sudanese), Melilotus alba are some of the species that may be employed for this purpose (7,10,14).

CHAPTER V

SUMMARY AND CONCLUSIONS

The physical and chemical characteristics of four saline-alkali soils were studied. Recommendation for reclaiming these soils was given for each soil studied. The methods and procedures for reclamation depend upon the physical and chemical characteristics of each soil. Most of these methods have been used in previous experiments as reported in an extensive literature (14).

For soil No. 1 a Drummond loam, the percentage of sand is high with lesser amounts of silt and clay. The accumulation of soluble salts is in the 8-32 inch depth. Soluble sodium chloride and sulfate is present in relatively large amounts. All pH values are slightly alkaline and remains constant from the soil surface to the lower depths. Generally the electrical conductivity is low except at the 8-20 inch depth. Exchangeable calcium and exchangeable sodium are relatively high. The recommendation for reclaiming this soil is that the soil should be leached free of the excess soluble salts and sulfur or gypsum used as a chemical amendment for replacing exchangeable sodium.

In soil No. 2 a Drummond silty clay loam, the percentage of clay is very high at the lower depths and silt is

high in the surface and subsoil while the sand content is relatively small. The pH values are nearly neutral. Soluble sulfate is high at lower depths and is the dominant soluble ion. Sodium, calcium, magnesium and chloride do not vary appreciably. This soil has a low electrical conductivity except at the 20-32 inch depth. The cation exchange capacity is high at the lower depth with calcium is the dominant exchangeable cation. This soil is recommended to be reclaimed by the high-salt water procedure of Reeve and Bower (25). The water used for leaching should be high in divalent cations or saturated with gypsum. After leaching good drainage must be maintained particularly good internal drainage.

For soil No. 3 Gracemont Sandy loam, the percentage of sand is very high at lower depths while silt and clay are high at the soil surface and decrease markedly with depth. The pH values for the entire soil profile are about 8.8. The electrical conductivity generally is low except at the 12-20 inch depth. There was a large accumulation of salts at the 12-20 inch depth. The dominant soluble salt is sodium chloride. The cation exchange capacity of this soil is very low. Exchangeable calcium and sodium make up the total exchangeable cations. The recommendation is that the physical characteristics of this soil should be improved. After leaching, manure should be added as a soil amendment with gypsum added at the time of leaching.

In soil No. 4 Dale silt loam, the percentage of silt present was relatively high at the soil surface and sand is high at the lower depths. The percentage of clay decreases with depth. The accumulation of salts is somewhat lower in the 24-50 inch depth than the 0-24 inch depth. Sulfate salts are the dominant salts in this soil. The electrical conductivity is very high at the lower depths, with most values exceeding 11 mmhos/cm at 25°C. The recommendation for this soil is that it is not economically sound to use chemical amendments or leaching due to the high water table. The excess salts must be leached out and vegetation should be grown for improving the structure of the soil. However, the water table must first be lowered.

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VITA

Weerapun Chotivanich

Candidate for the Degree of
Master of Science

Thesis: STUDY OF PHYSICAL AND CHEMICAL CHARACTERISTICS OF
SOME SALINE-ALKALI SOILS IN OKLAHOMA

Major Field: Agronomy

Biographical:

Personal Data: Born in Rajburi, Thailand, March 1,
1947, son of Chutchaval and Jaru Chotivanich.

Education: Graduate from Amnuay Silpa School,
Bangkok, Thailand, in March 1965; received the
Bachelor of Science degree with a major in Soil
Science from Kasetsart University, Bangkok,
Thailand in April 1969; graduate study at
Oklahoma State University, August 1970-July 1972.

Professional Experience: Employed by the Thai Govern-
ment as agronomist of Agricultural Chemistry
Division, Department of Agriculture, Ministry of
Agriculture from 1969 to 1970. Employed by the
Thai Government as vocational education teacher
of Agricultural School Division, Department of
Vocational Education, Ministry of Education from
1970 to the present.