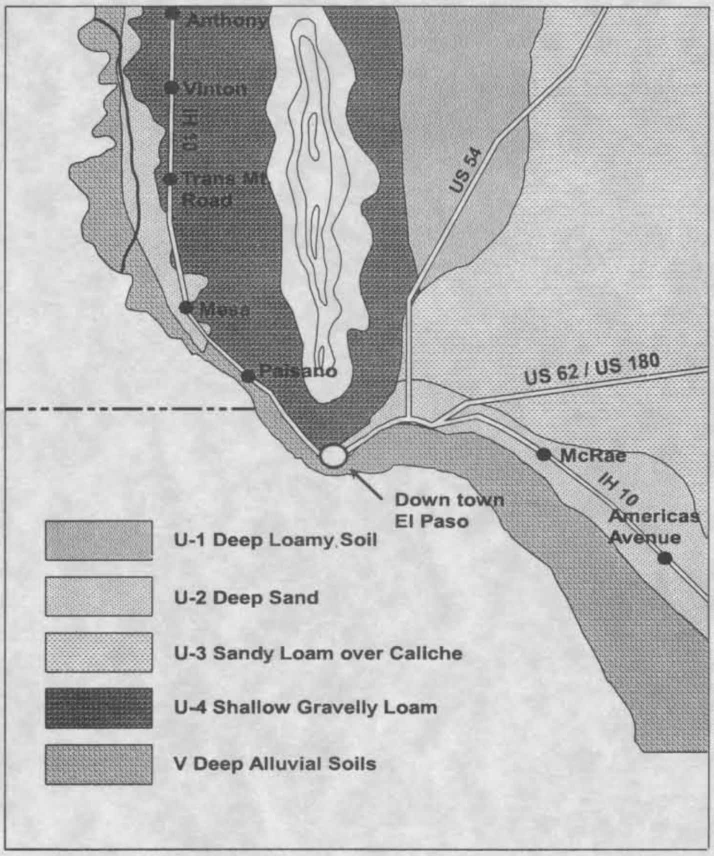
Soil Resources of El Paso

Characteristics, Distribution, and Management Guidelines



Texas A&M University, Agricultural Research Center at El Paso

Texas Agricultural Experiment Station

September, 2000

Acknowledgment

This bulletin was prepared through a cooperative agreement between the Texas Agricultural Experiment Station, and the U.S. Bureau of Reclamation, El Paso Field Division. The funding was provided in part by the Water Conservation and Management Grant administered by U.S. Bureau of Reclamation under grant No. 1425-97FC-40-21650, and by the Texas Water Initiative.

The following personnel (in alphabetical order) have contributed to the preparation of this bulletin, Ms. Cindy Falkenstein, an Intern student from New Mexico State University who conducted information gathering and tabulation, Ms. Shilpa Mulik, and Dr. Manas Borah who prepared a detailed soil map; and S. Miyamoto, Professor at the Texas A&M University Agricultural Research Center who served as the principal author. Logistic support in terms of typing and preparation of illustrations was provided by Ms. Rebecca Ontiveros, Secretary, and Mr. Arthur Chacon, Juan Soto and Mark Padilla, Student Technicians at the Texas A&M Univ. Agricultural Research Center. The manuscript was reviewed by Mr. Joe Brummers, Soil Scientist with US. Bureau of Reclamation, Mr. Rudy Garcia, Water Quality Specialist, Natural Resources Conservation Service, and Dr. L.B. Fenn, Professor, Texas A&M University Agricultural Research Center at El Paso.

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SOIL RESOURCES OF EL PASO:
Characteristics, Distribution and Management Guidelines

S. Miyamoto

INTRODUCTION

Because of the complex geological history and land formation, soil resources of the El Paso area are highly variable. We find stony or gravelly soils along the slopes of the Franklins, and sandy loam soils developed over caliche at lower elevations referred to as the Hueco Basin. The flood plain of the Rio Grande yet presents another type of alluvial soils with textures ranging from sand to clay. Both the physical and chemical make-up of these soils are also variable. This diversity in soils has provided opportunities to grow many different crops as well as diverse plant species to enrich our environments. At the same time, this diversity created some confusion over how to utilize and manage them. Sizeable areas of clay soils in the valley were, for example, planted to pecans. This was later found to be a monumental mistake due to inadequate soil permeability and resulting salt accumulation. In urban settings, clay soils were hauled at considerable expense to topsoil sandy uplands, but later were found not to have sufficient permeability and formed a solid crust. These are just a few examples of misuse.

The most significant threat to soil resources today is a process known as soil salinization and/or sodification resulting from irrigation of poorly drained soils. As one person wrote to us; "We bought a tract of land in the valley with a dream of beautiful gardens for our retirement. However, everything we have planted has died, and our neighbors tell us that the soil is too salty. Please tell us what we might do." This problem, although not yet wide-spread, is occurring primarily in the valley, and is beginning to appear in upland soils containing subsoil indurated with caliche. The problem of soil salinization can increase with degradation of water quality and with increasing uses of saline water, including salty reclaimed water for irrigation, unless management practices are modified.

This bulletin was prepared to help reduce misuse and/or mishandling of soil resources. The focus is on explaining soil characteristics and how to condition and manage them for sustainable uses in light of the increased uses of poor water quality for irrigation. We hope that the information presented is useful to planners, water managers, educators, ground maintenance professionals, crop producers, and property owners.

The content of this bulletin is divided into four chapters. The first chapter describes the geological history, and the soil formation, and the second chapter, the characteristics of different soil types. The third chapter presents guidelines for utilization and management under irrigation for sustained uses. The fourth chapter was added later to show the use of soil information for land use and water management planning. Ms. Cindy Falkenstein, a student majoring in Community Planning at New Mexico State University has made a significant contribution to this chapter. Attachments consist of a soil map, the information on plant water use and salt tolerance and glossary of soil terms. If an additional soil map is desired, contact Texas A&M University, Agricultural Research Center at El Paso at the address shown in footnote.

The author is a Professor of Soil and Water Science, Texas A&M University, Agricultural Research Center at El Paso, 1380 A&M Circle, El Paso, TX 79927

I. LANDSCAPE AND SOIL FORMATION

1. Geological History

Geologists believe that the area presently known as the El Paso/Juarez area was once under the ocean. The rising of the ocean floor, estimated to have occurred about 1 billion years ago, brought marine calcareous deposits to the surface. This was followed by a brief period of volcanic activities some 20 million years later (Lovejoy and Cornell, 1996). After the volcanic activities, the area is believed to have submerged again under the sea, and received additional marine calcareous sediments, some of which then developed into limestone. During this period, known as the Cretaceous period in geological terms, about half of the North American continent is believed to have been under the sea. The sea ultimately receded more or less to the present position about 100 million years ago.

The formation of the Franklin Mountains as well as Sierra de Juarez was accelerated about 50 million years ago through uplifting and tilting through compression. The intrusion of magmas into the Cretaceous rocks also occurred, and igneous rock hills such as Cerro de Cristo Rey and Three Hills were formed during this period. The uplifting created a closed basin in the east side of the Franklins, which is presently known as the Hueco Basin. The ancestral Rio Grande flowed into the basin through the gap between the northern Franklin Mountains and the southern Organ Mountains, which is otherwise known as Fillmore Pass or Anthony Gap (Fig. I-1). Deep seepage of the ancestral Rio Grande has formed the underground aquifer, known as the Hueco Bolson, from which El Paso is currently pumping water for municipal water supplies.

The Rio Grande then changed its course to the present position, probably about 1 million years ago. There are different theories as to how this event took place. Seager (1981) suggests that the shift in the flow may have occurred as a result of the uplift of the eastern side of the Organ-Franklin chain at the fault zone which runs from El Paso to the east side of the Organ Mountains near Las Cruces. The uplifting on the east side of the mountain chain caused the westward tilting of the Franklins, which is quite visible today. Lovejoy and Cornell (1996) believe that the Hueco Bolson was filled with water from the ancestral Rio Grande, and the sediment accumulation in the basin caused overflow into the present position. There are, however, the boundary faults on the west side of the southern Organ Mountains (adjacent to the northern Franklins) as well as on the west side of the Franklins (Lovejoy and Cornell, 1996) which could also have triggered the change in course. In any case, the Rio Grande began to flow through the narrow gap between Cerro de Cristo Rey and the igneous rock hills near the University of Texas El Paso campus, which later became known as the pass to the north.

The last major geological event which took

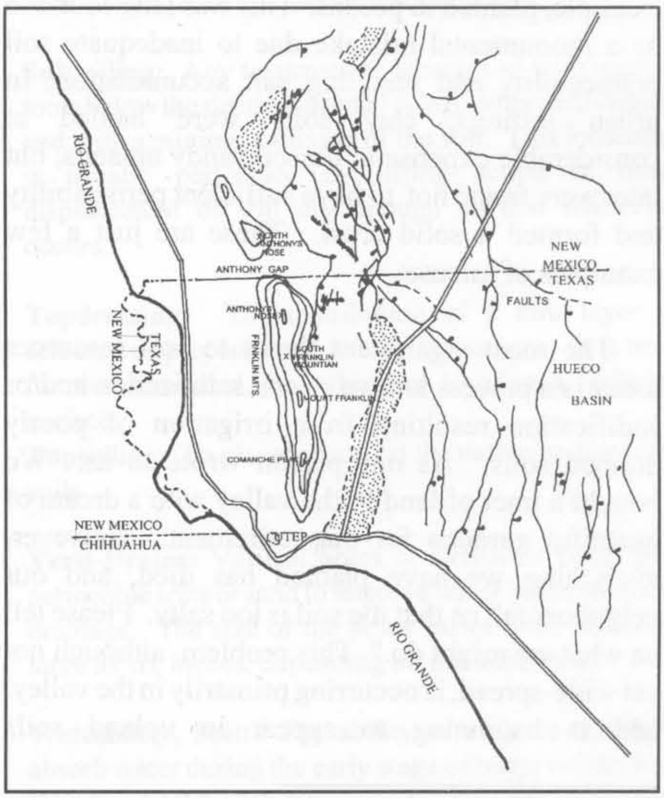


Fig I-1. A geological map of the El Paso-Juarez area (After Seager, 1981).

place in this area was a series of volcanic eruptions along the western horst of the present Rio Grande flood plain, commonly known as La Mesa Plains (Fig I-1). This volcanic activity is believed to have continued for thousands of years in the time frame of 400,000 years ago, and some of the lava flow reached the Rio Grande. Such an example is seen in the La Mesa area hidden behind the Pecan orchard operated by Stahman Farms.

2. Soil Formation

Upon uplifting of the land presently known as the Franklin Mountains, the sediments, which had once covered the land, were washed toward the foothills and to the edges of the lower basins. The newly deposited sediments along the slopes of the mountains naturally contained large fragments, including some rocks and stones. The soil which developed on such stony sediments along the slopes and foothills of the Franklins was later named as the Delnorte soil by the Soil Conservation Service (Fig. I-2). Stony sediments are often indurated with calcium carbonate commonly known as caliche. Marine calcareous deposits and limestones, which form the peak of the Franklins, are believed to be the primary source of the caliche we find in the subsoil of the Delnorte soil series.

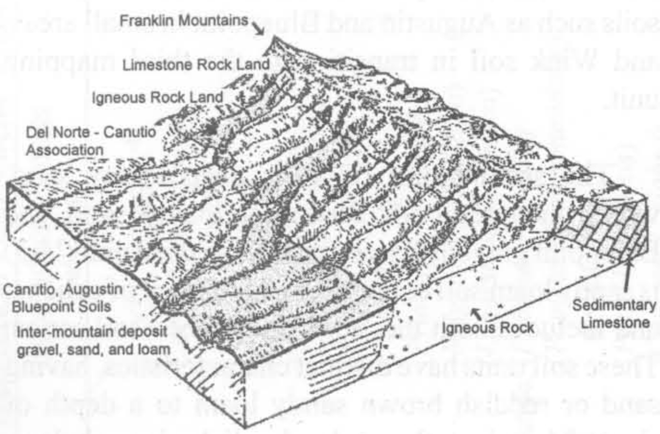


Fig. I-2 Soil formation of the western slope of the Franklins; a three-dimensional view from El Paso to the northern direction (SCS, 1971).

The sediments which were washed to lower elevations naturally contain smaller fragments, namely sand, silt and clay, and at times, some gravel in alluvial fans and arroyos. The deep soils developed from gravelly sediments in alluvial fans and arroyos in the foothills of the Franklins were later named Canutio, Augustin, and Bluepoint soils (Fig I-2), all of which are in the order of Entisols. On the eastern slope, there are some deep loamy soils (Pajarito, Turney, and Berino series) below the area occupied by the Canutio or Augustin soils. None of these soils, including Canutio and Augustin soils, contains a caliche layer, but only powdery deposits or concretions of calcium carbonates.

The stratified soils in the low elevation above the UT El Paso location and below the Sunland Mall area are currently classified as part of the Delnorte series. However, some soils in the area are actually the sediments of an old playa, instead of alluvial deposits directly from the Franklins. This stratified soil has a caliche layer, but induration is weak and much less stony than Delnorte soil. This soil, upon disturbance, is more closely allied with Augustin gravelly loam. In addition, this stratified soil has high salinity and sodicity, because of its geological history of being in a closed basin, and will be referred to as Delnorte soil, low land. The present flow of the Rio Grande is 10 to 15 feet

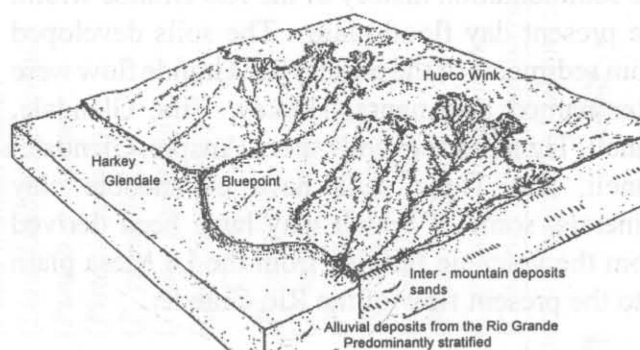


Fig. I-3 Soil formation in the East district of El Paso; a three-dimensional view as entering El Paso from the South along Interstate 10 (SCS, 1971).

below the old playa sediments due to deepening erosion by the river flow. Soil development in the Hueco Basin is believed to have occurred over different periods. During the first period, the area was essentially a closed shallow lake (or playa), and the sediments from the ancestral Rio Grande and adjacent areas have accumulated. Since the adjacent areas, both the Franklins and the Hueco Mountains to the east, are made of limestones, large amounts of calcium carbonates might have been washed into the basin with runoff. The change in the course of the Rio Grande was followed by drying of the playa, then by the second period of soil formation which involved the translocation of calcium carbonates from the surface layer of the soil to the subsurface. The soils developed in this manner were later named as the Wink soil at higher elevations and the Hueco soil in nearly level lower grounds (Davis and Leggat, 1965), both of which fall into the order of Aridisols.

The soils in the valley were developed from sediments of the Rio Grande in the presence of high water tables (Fig. I-3), and most fall into the category of Entisols, Aquents. This soil forming process is comparatively new in geologic time, thus the soils in the valley do not have the recognizable B horizon, which usually contains translocated clay particles, calcium carbonates, or oxides. Soil textures and soil profiles vary widely, depending on the sedimentation history of the Rio Grande within the present day flood plain. The soils developed from sediments of the present Rio Grande flow were later named as Anapra, Harkey, Gila, Glendale, Saneli, Tigua, and several others. Anapra, Glendale, Saneli, and Tigua soils have expandable clay minerals, some of which may have been derived from the volcanic fallouts from the La Mesa plain into the present flow of the Rio Grande.

The origin of the sand deposits usually found above the flood plains of the Rio Grande but below the Hueco Basin along Interstate 10 (Fig. I-3) is not known conclusively. Some believe that the sand is wind-blown from the present Rio Grande flood plain, and others believe that the sand is part of the ancient deposits of the Hueco Basin. Some also believe that the sand was deposited by the Rio Grande, and became exposed as a result of deepening river beds over an extended period. In any case, the sandy soil was later named the Bluepoint soil series, Entisol.

3. General soil map

The general soil map attached at the end of this chapter is adopted from the general soil map prepared for El Paso County by the Soil Conservation Service (SCS, USDA, 1971). A detailed soil map may be found at the end of this bulletin. The detailed soil map was also adopted from the SCS map and soil textural families were used for grouping various soil types into a manageable number of mapping units. The relationship between the present mapping units and the official designation of soil series or types is shown in Table I-1.

The soils in the upland area are grouped into five management units, and are numbered in the sequence of increasing difficulties for management. The first unit (U-1) consists of deep loamy soils located along the eastern foothills of the Franklins, and is among the easiest to manage. The applicable soils include Pajarito, Turney, and Berino soil series. There may be some inclusion of sandier soils such as Augustin and Bluepoint in small areas, and Wink soil in transition to the third mapping unit.

The second unit (U-2) is deep loamy sand, which includes both Bluepoint loamy sand and Bluepoint gravelly coarse sand. The third unit (U-3) is sandy loam soil containing a hard layer of caliche, and includes both the Wink and Hueco soil series. These soil units have distinct characteristics, having sand or reddish brown sandy loam to a depth of about 24 inches, then a hard caliche layer below. Hence, the boundaries to other soil units are readily recognizable.

The fourth unit (U-4) is deep gravelly sandy loam or loam developed on deep gravelly or stony sediments, and includes Augustin, Canutio, and Delnorte series with stony subsoil, which was disturbed artificially or has minimal induration with caliche. The fifth unit (U-5) is the stony or rocky soils with steep slopes (8 to as much as 30%), following the official designation of Delnorte - Canutio, hilly association. Some areas of this unit may contain Canutio, Augustin, or Bluepoint soil, especially in and around arroyos between hills, plus Rockland with little soil covers at higher elevations. In the general soil map (Fig. I-4), soil units U-4 and U-5 are treated as one mapping unit.

The soils in the valley were grouped into four units, in sequence of increasing orders of management difficulty (Table I-1). However, in the General Soil Map (Fig. I-4), all soils in the valley are grouped into one mapping unit for simplicity. In the detailed map attached at the end, grouping was made based primarily on soil textural family and, to a lesser extent, on soil stratification.

High water tables prevalent in the valley (usually 5 to 8 feet deep) are obviously another factor to consider. Local experience indicates that salinity of the shallow water table is a more direct indicator of potential problems for growing plants than the depth to the water table. Although salinity of the Rio Grande aquifer had been surveyed (e.g., TDWR, 1980), the physical boundaries for the high saline water table areas have not yet been clearly defined. As a rule, saline soils affected by high water tables appear most frequently in the lower half of the Upper El Paso Valley. Salt frosting of the grounds is quite evident, for example, in the Sunland Park area near the river. Salinity of these soils often exceed 4 dS m^{-1} in the soil saturation extract, and that of the ground water usually exceeds 6 dS m^{-1} in these areas. Plant species consist mostly of salt tolerant types, such as tamrix (or salt cedars), and saltbush.

Table I-1. Description of soil mapping units for management, and the official designation of applicable soil series or types.

Groups		General Description	Extent	Official Designation[1]
Uplands			%	
	U - 1	Deep loamy soils	-	Pajarito (PAA), Turney-Berino (TBB)
	U - 2	Deep sand	-	Bluepoint (BPC, BUC)
	U - 3	Sandy loam over caliche	-	Hueco (HW), Wink (WKA)
	U - 4	Shallow gravelly loam over gravels	-	Augustin (AGB), Canutio-Delnorte (DCB)
	U - 5	Shallow steep stony soil	-	Delnorte (DCD)
Valley[2]				
	V - 1	Loam over loamy sediments	8	Gila (Ga), Harkey (Ha), Glendale (Gd)
	V - 2	Sandy loam over sandy sediments	22	Brazito (Br), Gila (Gc), Vinton (Vn)
	V - 3	Silty clay loam over sand to loam	46	Anapra (An), Harkey (Hk), Glendale (Ge) Saneli (Sa)
	V - 4	Deep silty clay over sand to loam	23	Glendale (Gs), Saneli (Sc), Tigua (Tg)

[1] These are official designations of applicable soils given in the Soil Survey, El Paso County, (1971).
[2] In the General Soil map, the soils in the valley are treated as one mapping unit.

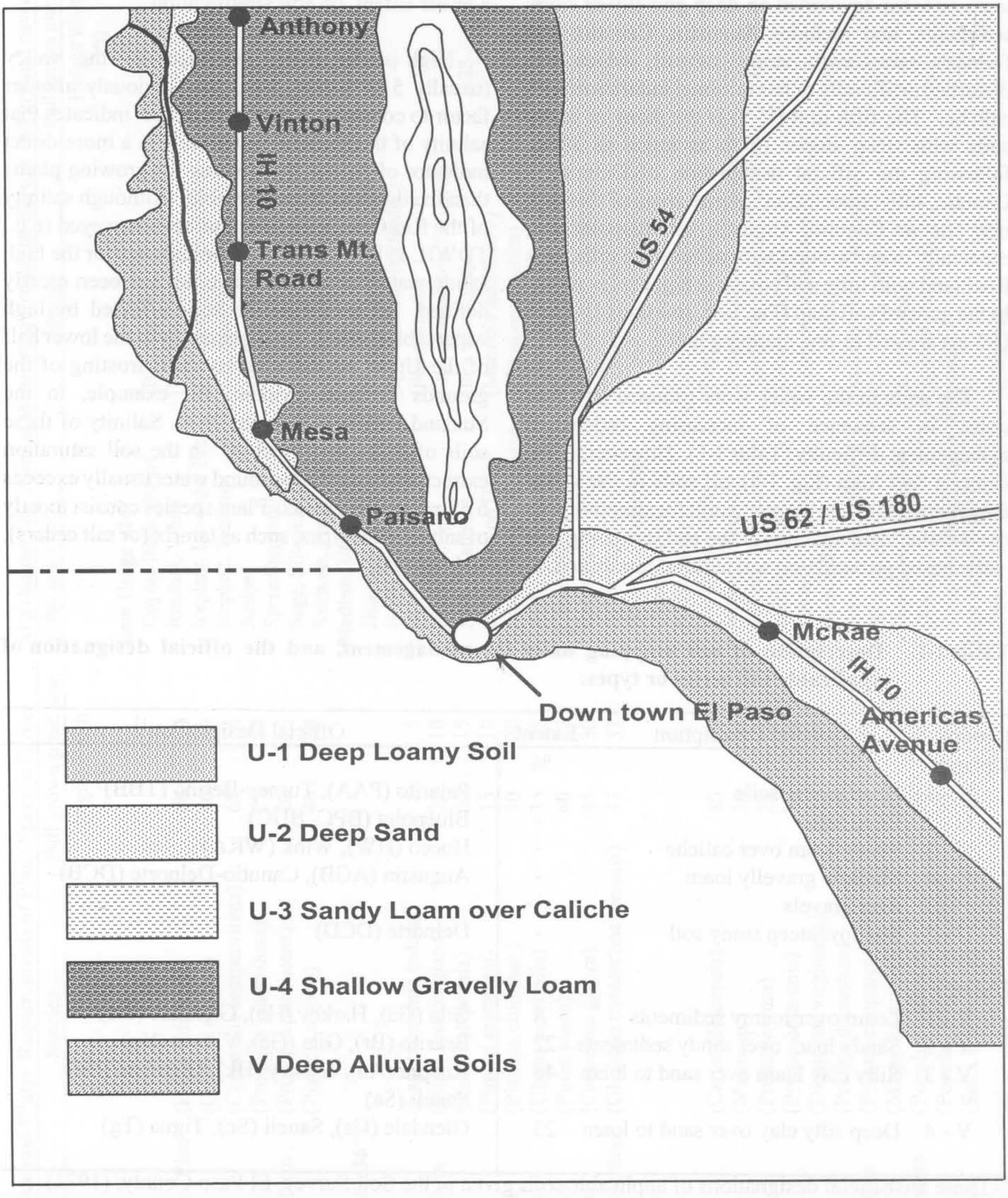


Fig. I-4. General soil map of El Paso and its vicinity (SCS, 1971).

II. SOIL CHARACTERISTICS AND PROPERTIES

Readers who are primarily interested in knowing general characteristics of various soils may wish to refer to the general description of mapping units attached to the general or detailed soil map. Detailed information is presented in the following text as well as in Attachments 1A and 1B for upland and valley soils separately.

1. Typical Soil Profiles

Upland Soils: The first group of upland soils (U-1), consisting of Pajarito, Turney, and Berino soil series (Table I-1), has a surface layer (or A horizon) of sandy loam to a depth of 10 to 18 inches. The B horizon consists of sandy loam in Pajarito, and clay loam in Berino and Turney, all extending to a depth of 34 to 37 inches. The C horizon (made of the parent materials) consists of sandy loam in Pajarito, loam in Berino, and clay loam in Turney with weakly cemented caliche or powdery caliche. The boundary between the A and B horizons is gradual, whereas the boundary to the C horizon is clear. Plant roots penetrate deep in Pajarito sandy loam, whereas in Berino and Turney soils, they usually remain in the upper portion of the B horizon consisting of clay loam. A typical profile is shown in Fig. II-1.

The second group of upland soils (U-2) is made of Bluepoint loamy sand or gravelly coarse sand. The loamy sand extends to a great depth, as much as 100 feet in some areas. The gravelly sand, which usually appears in arroyos as well as on the tops and the sides of rolling hills, extends to a depth of a foot to as deep as 10 feet over the deep loamy sand. The loamy sand is structureless, but the gravelly sand has visible stratified layers of different sand and gravel. Plant roots can extend to a great depth in this soil group.

The third group of upland soils (U-3) consists of Hueco and Wink sandy loam; both of them are alike, except that the Wink series has a higher content of calcium carbonates and clay than the Hueco series. The surface layers of both soils consist of loamy sand or sandy loam to a depth of 4 to 6 inches, and the B horizon is sandy loam extending 24 to 26 inches deep (Fig II-1). Below is a hard caliche layer cemented with calcium carbonate plus silica. The thickness of the caliche layer is highly variable, and ranges from 2 feet to as deep as 6 feet in some areas. Below the caliche layer is a series of sediments ranging from sand to loam in texture. Plant roots usually do not penetrate into this caliche layer, unless it is fractured.

The fourth group of upland soils (U-4) is Augustin and Canutio series, but the area mapped actually includes Delnorte series. The surface layer of the Augustin series ranges from 4 to 30 inches in thickness, and has a gravel content of 10 to 35%. The layer below may contain gravel up to 50% of the soil mass. The average texture is gravelly loam. The Canutio series has a thin layer of topsoil, about 6 inches, and contains gravel and stones; 25 to 50% at the surface, and 35 to 75% below. The sizes range from half an inch to as large as 6 inches or more. This gravelly or stony soil is considered deep, because the C horizon is permeable and friable. Plant roots can extend into the gravel layer with a possible exception of the Delnorte soil which may have stony subsoil cemented with caliche.

The fifth group of upland soils (U-5) consists primarily of the Delnorte soil which has a hard stony or rocky layer indurated with caliche within 6 to 8 inches from the soil surface (Fig. II-1). The thickness of the stony indurated layer varies from 4 to 24 inches. Below the caliche layer is a series of gravelly sediments. The gravel plus stone fractions are similar to those of the Canutio series, but the induration with caliche separates the Delnorte from the Canutio series. The indurated stony caliche usually restricts root penetration, unless it is loosened mechanically.

Valley Soils: The first group of valley soils (V-1) consists of Gila loam (Ga) and Harkey loam

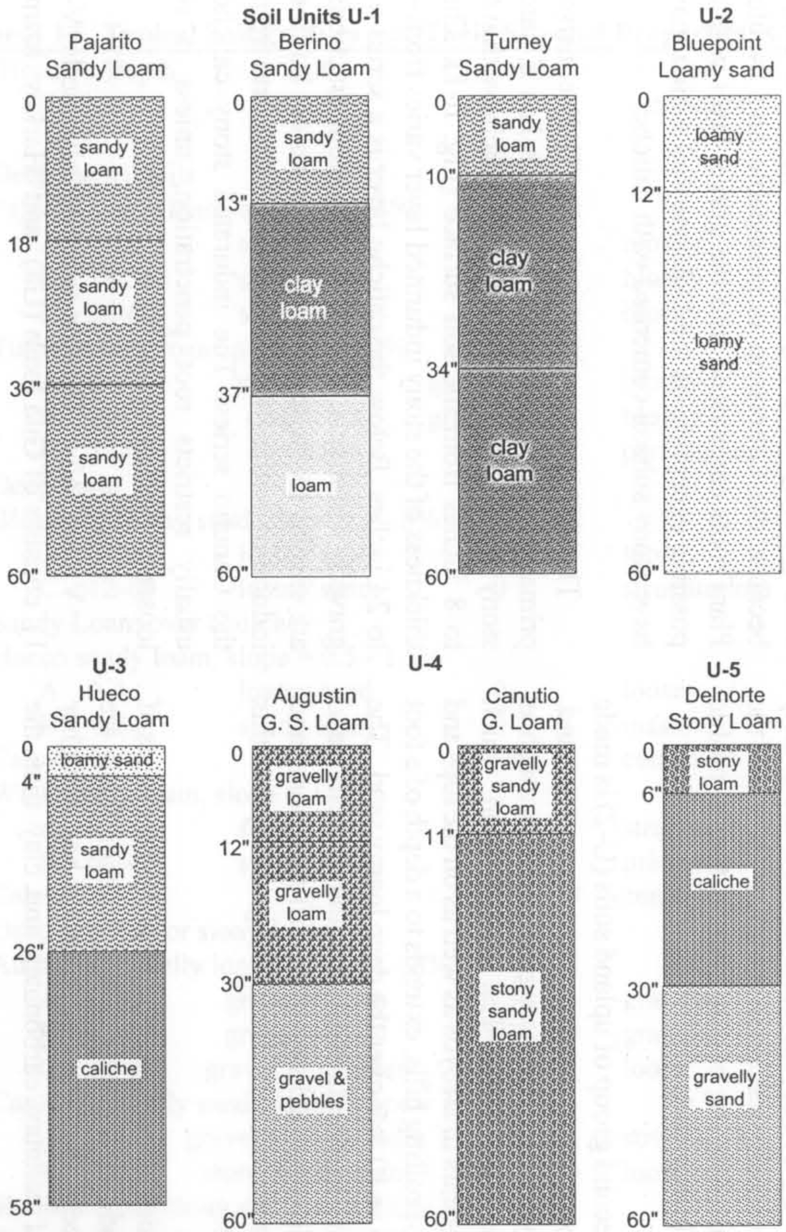
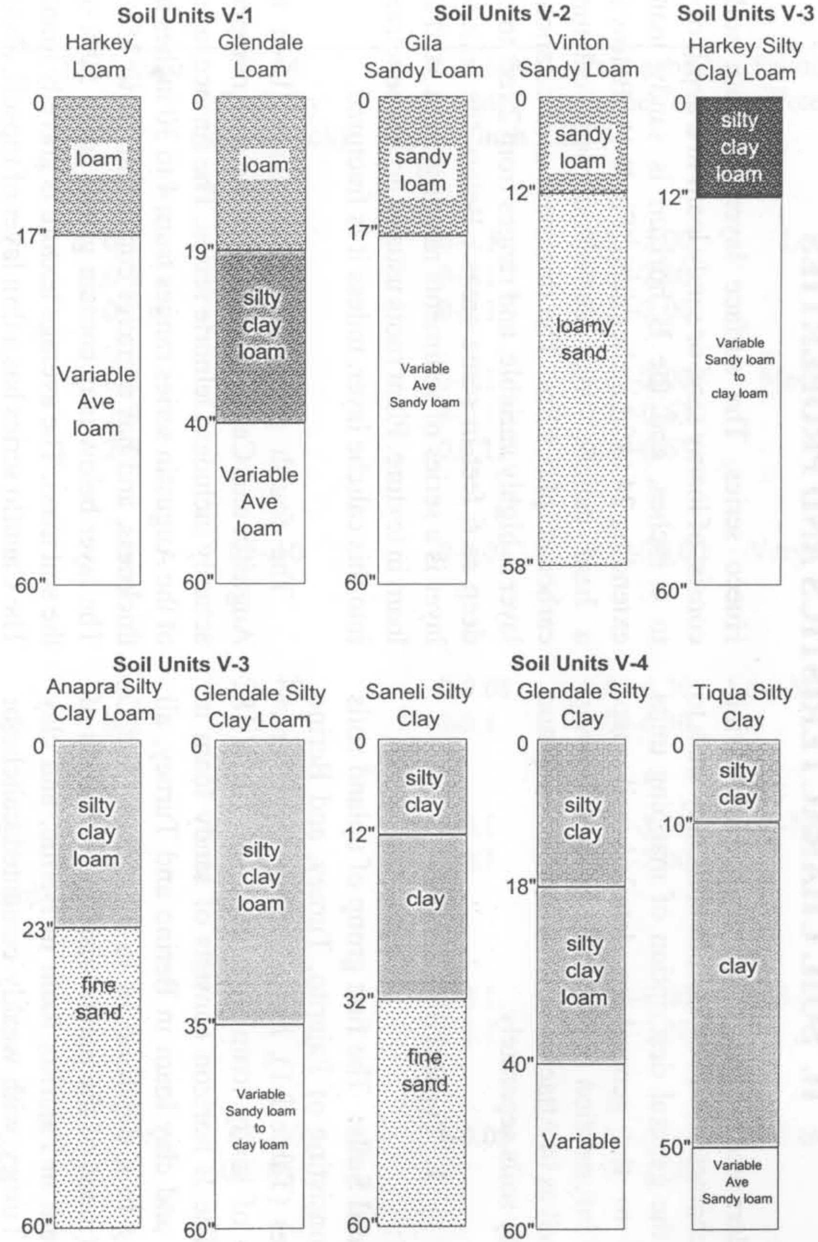


Fig II-1 Typical profiles of selected upland soils in El Paso.



FigII-2 Typical profiles of selected valley soils in El Paso.

(Ha), both of which have a similar profile. The surface loam layer of about 17 inches lies over a series of sediments with an average texture of loam. Glendale loam (Gd) is also included in this unit, but it has subsoil consisting of silty clay loam with expandable clays, starting at about 17 to 19 inches. This soil may be placed in the transition from Soil Group V-1 to V-3. In short, the soils of this group have a surface loam layer of 17 to 19 inches over the sediments with textures ranging from loamy sand to silty clay loam, with an average texture of loam. Plant roots usually penetrate into subsoils, except in Glendale loam.

The second group of valley soils (V-2) can best be characterized by Vinton sandy loam (Vn) having a surface layer of sandy loam to a depth of 10 to 12 inches over loamy sand. Brazito loamy sand (Br), limited in distribution, has loamy sand to an extended depth, and Gila sandy loam (Gc) has variable subsoil, but sandy loam on the average. If loam or silty clay loam appears in substrata, the soils should be grouped into the first category along with Gila loam (Ga) or Glendale loam (Gd). In short, the second group of valley soils has a surface layer of sandy loam to a depth of 10 to 20 inches over subsoil consisting of loamy sand to sandy loam. Plant roots usually penetrate into the sandy subsoils.

The third group of valley soils (V-3) has a surface layer of silty clay loam over loamy sand (Anapra, An), and over a series of sediments with textures ranging from loam to silty clay loam (Harkey, Hk, and Glendale, Ge). Saneli silty clay loam (Sa) has a surface layer of silty clay loam to a depth of about 18 inches. The subsoil consists of clay about 16 inches thick. This soil is included in Group V-3, but can be placed in the transition from Group V-3 to V-4. The depth of the silty clay layer typically extends 1, 2 and 3 ft for Harkey, Anapra, and Glendale soils, respectively. Harkey silty clay loam, in places, contains a reddish clay layer at 30 to 45 inches, which is practically impervious. The existing soil map does not delineate the presence or absence of this clay layer which ranges from a few inches to as thick as 2 feet. This clay layer restricts internal drainage. The boundary from silty clay loam to sandy substrata is abrupt, especially in Anapra and Glendale soil. Plant roots usually remain in the surface layer, except in Harkey silty clay loam.

The fourth group (V-4) has a deep layer of silty clay or silty clay loam. The surface layer of silty clay extends 10 to 18 inches (designated as a plow layer), followed by about 2 feet of silty clay loam in Glendale, and 20 to 40 inches of clay in Saneli and Tigua, respectively. Below is sediment consisting of loamy sand in Saneli, and variable textures in Glendale and Tigua. The boundary to the loamy sand layer is abrupt and often wet. Some of these profiles are shown in Fig. II-2. Plant roots usually remain in the surface layer. This group of soils has low permeability and is usually salt-affected.

2. Physical Properties

Upland Soils: Group U-1 soils which include Pajarito, Berino, and Turney loam have soil permeability of 0.6 to 2.0 inches per hour if not compacted. However, clay loam which usually appears at a depth of 8 to 10 inches in Turney and Berino series, has a permeability rating of 0.20 to 0.6 inches per hour. The water holding capacity of the surface layer is at least 0.10 inches per inch of soil, and increases to 0.15 inches per inch of clay loam subsoil (Attachment 1A). In the native dry state, these soils are hard, but once wet, they do not present root penetration problems. The shrinkage potential is low (less than 2%) in sandy loam, and is moderate (2 to 9%) in the clay loam layer. This provides the blocky structure which helps internal drainage. Soil aggregates of this soil group are moderately stable against sodium dispersion, because of partial cementation with calcium carbonates.

Group U-2 soils consisting of Bluepoint loamy sand and gravelly coarse sand have very high permeability (6 to 20 in/hr) and low water holding capacity (0.08 in/in or less). However, the loamy sand which makes up the surface layer of Bluepoint loamy sand is subject to dispersion and compaction, and the actual permeability is substantially lower than the listed value. The water holding capacity of these soils under turf is also substantially higher than the listed rating due to accumulation of organic matter, as discussed in Chapter III. Trafficability over the unconsolidated sand is low when dry. Loamy sand is highly erodible both by wind and water.

Group U-3 soils, consisting of Hueco and Wink sandy loam, have high permeability (2-6 in/hr in Hueco and 0.6-2.0 in/hr in Wink). Soil water retention capacity of the sandy loam is rated low (0.10 in/in), but the actual retention capacity under field conditions is considerably higher due to the presence of the caliche layer which reduces water penetration. Wink soil is harder than Hueco soil due to a higher content of calcium carbonate and clay. The caliche layer is very hard, especially at the surface, but is readily broken with a ripper. The surface of this soil group is stable against sodium dispersion, because of the presence of Fe and Al oxides, but can form shifting sand. The shrinkage and swelling potential is rated low. However, this soil group is known to have, in places, sodium-affected subsoils which can swell upon wetting.

Group U-4 soils, consisting of Augustin gravelly loam and Canutio gravelly sandy loam, have high permeability (0.6 to 6 in/hr) and low water holding capacities (0.05 to 0.10 in/in). These soils are unconsolidated alluvial sediments, and plant roots penetrate readily. Group U-5 soils made of Delnorte stony loam have a thin layer of surface soil which is readily permeable (0.6 to 2.0 in/hr), and low in water retention (0.05 in/in). The subsoil is a stony layer indurated with caliche, and is not easy to break with ordinary equipment. Permeability of this stony subsoil varies with the degree of induration with caliche, and in places, it is nearly impervious.

Valley Soils: Group V-1 soils consisting of Gila, Harkey and Glendale loam have high (0.6 to 2.0 in/hr) to moderate permeability (0.20-0.6 in/hr), if not compacted. Gila loam is prone to compaction, and the actual permeability may drop by as much as a factor of 10 upon compaction. Water holding capacity is moderate, averaging about 0.15 in/in. Soil shrinkage and swelling potential is low, and soil aggregates are subject to dispersion with sodium.

Group V-2 soils consisting of Brazito, Gila and Vinton sandy loam have higher permeability (0.6 to 6 in/hr) and lower water retention capacity (0.08 to 0.10 in/in) than Group V-1 soils due to sandier soil texture. All of these soils are prone to soil compaction, but remain permeable because of sandy texture.

Group V-3 soils, consisting of Anapra, Harkey, Glendale, and Saneli silty clay loam, have low permeability (0.06 to 0.20 in/hr), but high water retention capacity averaging 0.17 in/in. The actual water retention capacity is usually higher than this rating due to soil stratification. The linear shrinkage of soil paste of Anapra, Glendale and Saneli soils is 10 to 15%, thus they develop soil cracks. Soil permeability is reduced to practically zero once these soil cracks are sealed. Soil aggregates are subject to dispersion, and the plasticity index is high. The combination of clayey soil textures and weak soil aggregate presents slow water infiltration, even when not compacted (Figs. II-3 and II-4). This group of soils is subject to salinization.

Group V-4 soils, consisting of Glendale, Saneli and Tigua silty clay, have low permeability (0.06 to 0.20 in/hr), and the water retention capacity is high, averaging 0.18 in/in. The linear shrinkage ranges from 15 to 20%. The formation of soil cracks in this soil group helps improve initial water infiltration (Fig. II-4). Soil permeability is reduced to practically zero once these soil cracks are sealed. Water ponding and drainage problems are severe, and this group of soils is also subject to soil salinization.

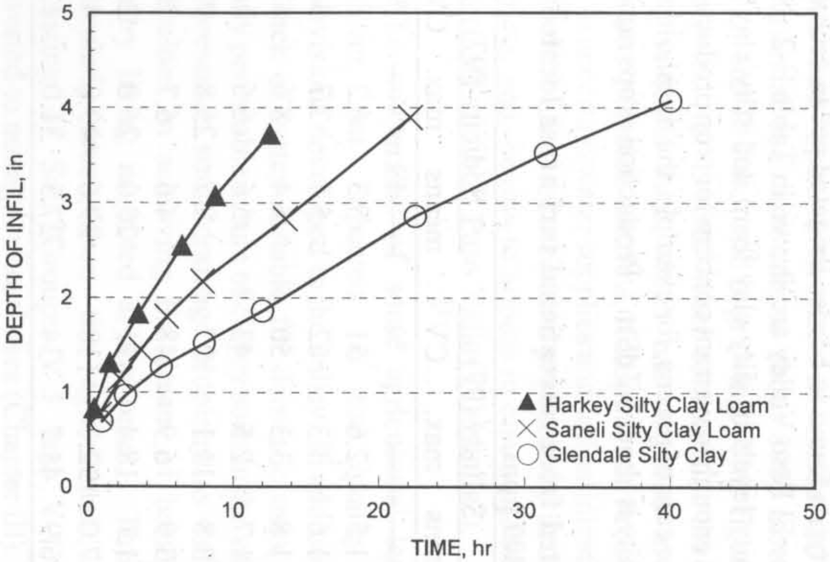


Fig II-3 Water infiltration into three valley soils when the soils are plowed, extensively disked and dry.

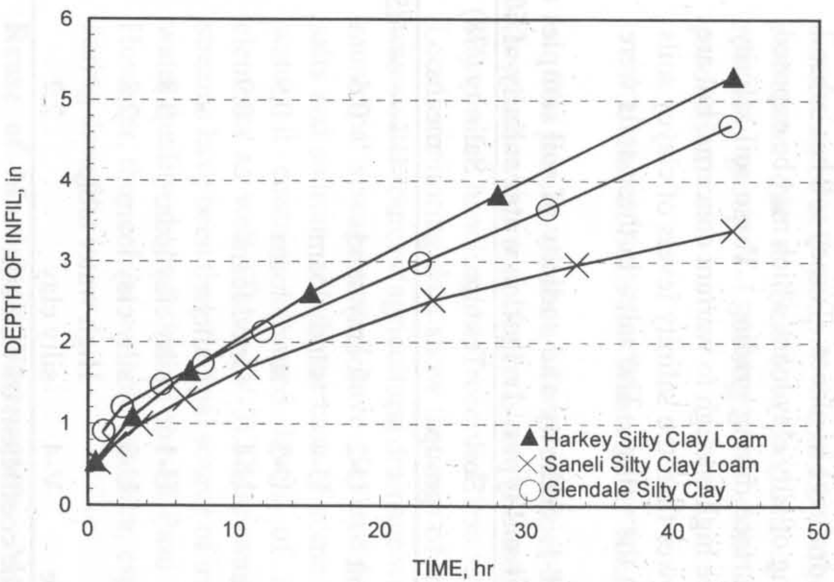


Fig II-4 Water infiltration into three valley soils when the soils were previously irrigated.

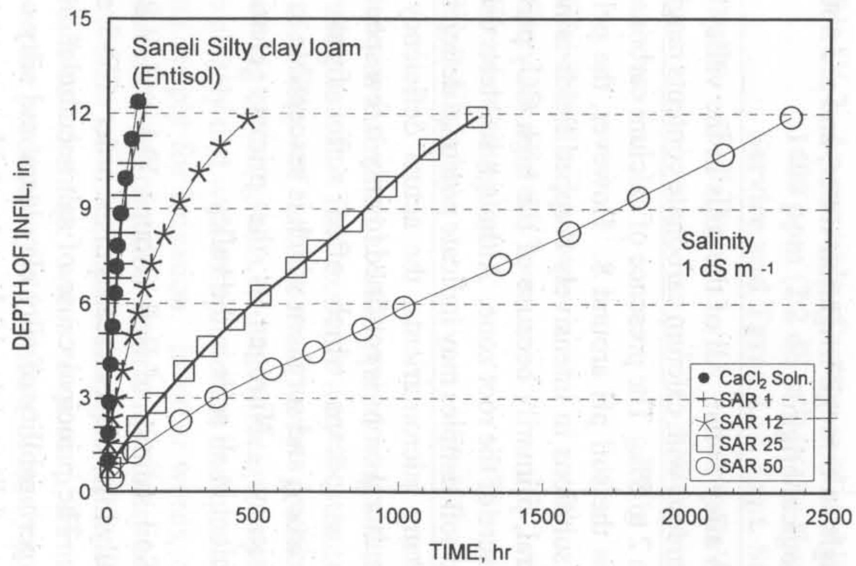


Fig. II-5 Water infiltration into Saneli silty clay loam having different sodium levels.

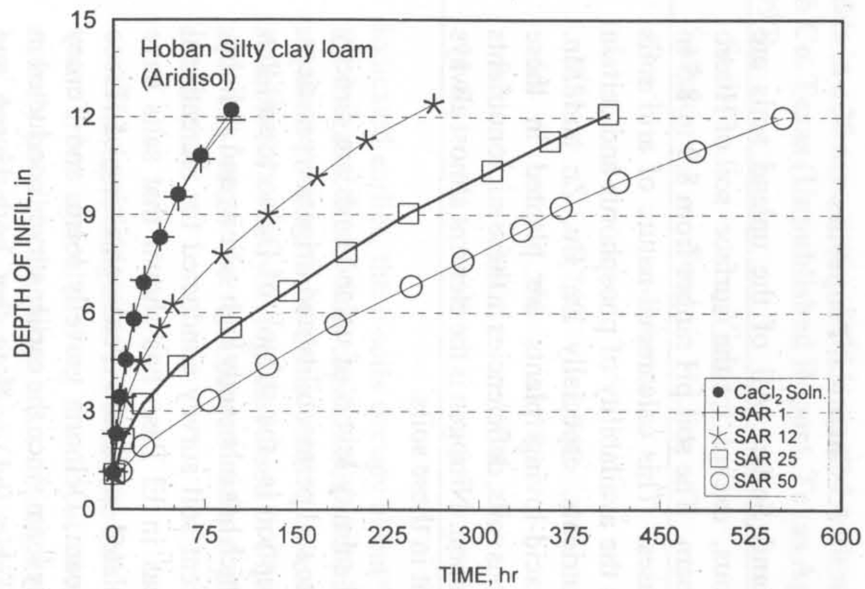


Fig. II-6 Water infiltration into Hoban silty clay loam having different sodium levels.

3. Chemical Properties

Upland Soils: All of the upland soils are calcareous, except for the surface soil of Hueco sandy loam. The soil pH ranges from 8.0 to 8.5 in most cases. This calcareous nature of arid soils reduces the availability of phosphorus and certain micronutrients, especially Fe, Cu, Zn and Mn. When acid-loving plants are planted in these calcareous soils, deficiencies in these micronutrients are common. Nitrogen is the element almost always deficient in these soils.

Soil salinity levels of upland soils are directly related to soil permeability and irrigation practices. An exception is the subsoil of Delnorte soil-low land, which has inherently high salinity and sodicity. Our recent soil survey conducted for recreational turf areas in El Paso has shown that salts have accumulated in certain areas consisting of Hueco sandy loam, Delnorte gravelly loam, and Turney silty clay loam since the earlier survey conducted in 1978 (Table II-1). Note that both Hueco and Delnorte soils have a caliche layer (Fig. II-1) which restricts drainage in places. Turney soil has subsoil consisting of silty clay loam which may be exposed to the surface during grading. These soil salinity levels are high enough to warrant concerns, but are much lower than the salinity levels of clayey soils found in the valley. The salts in these soils were brought in through irrigation water, and are not of geological origin.

Valley Soils: All of the soils in the valley are calcareous with calcium carbonate contents ranging from 2 to 8%. The presence of calcium carbonates keeps the soil pH around 8. However, the pH of soil solutions in intensively cropped fields is near neutral, primarily because of the high CO_2 partial pressure of the root zone. Although soil tests using dried soil samples may indicate potential deficiency in many micronutrients, the actual deficiency in agricultural crops is confined to only a few species, such as pecans which often suffer from Zn deficiency, and sorghum which is susceptible to Fe deficiency. Nitrogen is the primary element deficient in all soils in the valley.

Soil salinity of Soil Groups V-1 and V-2 is usually low, and it increases in the order of V-3, and V-4. The principal cause of salt accumulation is low permeability of silty clay loam and silty clay layers, followed by high water tables in certain areas. Examples of salt accumulation in different soil types found in border-irrigated pecan orchards in the El Paso Valley are shown in Table II-2. Soil salinity levels in silty clay loam and silty clay are high enough to warrant concern for crop production. In the case of pecans, for example, the threshold soil salinity is about 2.2 dS m^{-1}. Production drops rapidly

Table II-1. Salinity and sodicity of soil samples collected from recreational turf areas located on different soil types: Irrigation water salinity of 600 to 800 ppm.

Soil series	Soil group	Texture	Salinity ('78) means	Salinity (97) means	Salinity (97) max.	Salinity (97) CV[1]	Sodicity ('97) means	Sodicity ('97) max.	Sodicity ('97) CV[1]
			dS m^{-1}	dS m^{-1}	dS m^{-1}	%	dS m^{-1}	dS m^{-1}	%
Bluepoint	U-2	loamy sand	0.6	1.5	2.6	51	5.3	6.2	21
Canutio	U-4	sandy loam	-	1.6	3.3	62	5.8	7.7	31
Hueco	U-3	sandy loam	0.9	1.8	3.3	50	5.4	8.6	42
Delnorte	U-4	Grav. loam	0.9	1.7	2.5	43	5.6	6.6	14
		Caliche	-	3.8	11.1	127	9.7	25.8	93
Turney	U-1	silty clay loam	0.8	3.9	6.9	48	4.6	6.7	28
Harkey	U-3	silty clay loam	2.8	11.1	18.4	71	20.0	26.0	26
		High water table	-	27.0	32.0	110	29.6	49.0	47
Glendale	V-4	silty clay	2.7	36.9	45.7	34	27.5	31.0	12

[1] CV: the coefficient of variability

Table II-2. Salinity and sodicity of soil samples collected from border irrigated pecan orchards in the El Paso Valley: Irrigation water salinity of 880 ppm.

Soil series	Soil group	Texture	Salinity ('78) means	Salinity (97) means	Salinity (97) max.	Salinity (97) CV[1]	Sodicity ('97) means	Sodicity ('97) max.	Sodicity ('97) CV[1]
			dS m^{-1}	dS m^{-1}	dS m^{-1}	%	dS m^{-1}	dS m^{-1}	%
Gila	V-1	loam	1.1	1.3	1.5	25			
Harkey	V-1	loam	1.4	1.5	2.1	30	6.4	7.9	19
Saneli	V-3	silty clay loam	2.8	1.5	2.5	32	-	-	-
Glendale	V-3	silty clay loam	3.6	1.7	3.7	47	6.1	8.7	24
Glendale	V-4	silty clay	3.6	3.6	5.0	17	8.1	8.8	9
Glendale	V-4	silty clay	-	4.6	8.0	37	10.0	17.0	26
Tigua	V-4	silty clay	4.4	4.5	6.3	24	10.0	15.4	28

[1] CV: the coefficient of variability

as soil salinity exceeds the level. Also note that soil salinity levels observed in the pecan orchards are much lower than those observed in similar soils used for recreational turf. The difference in soil salinity between these cases are related to soil management, salt tolerance of plants, and irrigation practices.

Soil sodicity levels usually increase with increasing salt levels, registering high values when soil salinity levels are high (Tables II-1 and II-2). In Soil Groups V-3 and V-4, soil sodicity is usually high enough to deter water infiltration. Examples of sodium effects on water infiltration are shown in Figs. II-3 and II-4, using two soil types. The water infiltration observed with a calcium chloride solution represents the infiltration rate when sodium effects are negligible. Note that water infiltration decreases with increasing sodicity. High sodicity of the soil causes soil aggregates to disintegrate or disperse. Salinity of irrigation water used was 1 dS m^{-1} (635-680 ppm), comparable to salinity of the Rio Grande in the Upper Valley. Water infiltration decreases more when rain water is involved. In fact, it is common for rain water to stand, instead of infiltrating into the soils in the Valley. These examples illustrate that chemical properties of soils and water affect physical behavior of the soils.

Heavy metal accumulation in irrigated soils of the valley is presently at a level well below the threshold concentrations for potential food chain contamination through plant uptake (Miyamoto et al., 1995) with a possible exception of some very limited areas where illegal dumping may have occurred.

Table II-2. Salinity and sodicity of soil samples collected from border irrigated pecan orchards in the El Paso Valley. Irrigation water salinity of 550 ppm.

Soil series	Soil group	Soil texture	Salinity (SS) mean	max.	CV†	Sodicity (SS) mean	max.	CV
			dS m-1		%	dS m-1		%
[illegible]	V-1	loam	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	V-2	loam	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Saneli	V-3	silty clay loam	0.8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Glendale	V-3	silty clay loam	1.6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	V-4	silty clay	4.6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	V-4	silty clay	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Tigua	V-4	silty clay	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

†CV: the coefficient of variation.

soil salinity exceeds the level. Also note that soil salinity levels observed in the pecan orchards are much lower than those observed in similar soils used for recreational turf. The difference in soil salinity between these cases are related to soil management, salt tolerance of plants, and irrigation methods.

Soil sodicity, or sodium hazard, increases with increasing salt levels, registering high values when soil salinity levels are high (Tables II-1 and II-2). In soil groups V-3 and V-4, soil sodicity is usually high enough to deter water infiltration. Examples of sodium effects on water infiltration are shown in Figs. II-3 and II-4, using two soil types. The water infiltration observed with a calcium chloride solution represents the infiltration rate when sodium effects are negligible. Note that water infiltration decreases with increasing sodicity. High sodicity of the soil causes soil aggregates to disintegrate or disperse. Salinity of irrigation water used was 1 dS m-1 (~550-650 ppm), comparable to salinity of the Rio Grande in the Upper Valley. Water infiltration decreases more when rain water is involved. In fact, it is common for rain water to stand, instead of infiltrating into the soils in the Valley. These examples illustrate that chemical properties of soils and water affect physical behavior of the soils.

Heavy metal accumulation in irrigated soils of the valley is presently at a level well below the threshold concentrations for potential food chain contamination through plant uptake (Miyamoto et al., 1995) with a possible exception of some very limited areas where illegal dumping may have occurred.

III. Utilization and Management Guidelines

1. Use of Soils for Urban Landscapes

The diverse soil types found in the El Paso area can support a wide array of plants ranging from rare cactus in uplands to bog plants in the valley. However, plant selection in most landscapes, especially in home gardens and apartment complexes seems to reflect personal tastes and preferences more so than ecological compatibility. With increasing costs of water and landscape maintenance, it is advisable to plant those species which are better adapted to local soil and dry climatic conditions. In addition, there are increasing indications that future irrigation of landscapes may have to rely more on nonpotable saline water, which includes salty reclaimed water and drainage water, in order to conserve fresh water for domestic uses. Saline water sources considered for irrigation mostly contain 1000 to 1500 ppm of dissolved salts with elevated levels of sodium (8 to 12 in SAR). The use of such saline water sources for landscape irrigation requires careful soil selection and preparation, plus appropriate plant selection and irrigation practices.

Landscapes in Uplands: Upland soils in the El Paso area, as discussed in Chapter II, are highly variable. In general, they usually have sufficient permeability, but lack water holding capacity, due to sandy texture or insufficient soil depths. An exception to this rule is Soil Group U-1, consisting of Pajarito, Berino, and Turney sandy loam. These soils, found in some areas of the Northeast (Fig. I-4), are deep. To grow plants which require a lot of water in uplands, frequent irrigation and/or soil modification are usually required, except in areas of Soil Group U-1.

Soil group U-2, consisting of Bluepoint loamy sand or gravelly coarse sand, has high permeability, but low water retention capacity. However, this soil is very deep and contains no subsoil which can impede root and water penetration (Fig. II-1). Therefore, plants with deep root systems and low to moderate water requirements are best suited (Attachments 2A and 2B). Drought-tolerant deep-rooted trees such as pistachio, mesquite and Afghan pine can be maintained upon establishment in this soil type with occasional or no irrigation, if runoff water can be guided to planting areas. (These deep-rooted trees, however, can intrude into sewer lines if planted too close). If this soil group is to be used for growing shallow-rooted, water demanding plants, such as turfgrass and flowers, light and frequent irrigations are required (as frequently as every other day during summer months). Irrigation in excess of 1 inch per application can cause excessive percolation losses in shallow rooted plants. This problem can be minimized by incorporating soils and/or organic matter, which increase the water holding capacity (Table III-1).

The highly permeable nature of Group U-2 soils, however, becomes a distinct advantage when salty water is used for irrigation. Our soil salinity survey (Table II-1) has shown no significant level of salt accumulation in this soil group, except when topsoiled with loam or finer soils. Such soils, when used for topsoiling, reduce both water infiltration and penetration when light irrigation is made with sprinklers, thus leading to salinization of the topsoil. The soils used for topsoiling should ideally have textures coarser than loam, especially when saline water is used for irrigation.

Another consideration in using this soil group for lawns is its slope which often reaches 5 to 10%. In spite of sandy texture, runoff is a common problem in loamy sand, due to soil compaction, poor wettability, and the use of wrong soil for topdressing, besides the slope itself. Loamy sand is subject to compaction. If sloped areas are to be turfed, the final grade should ideally be topdressed with medium or coarse sand to a depth of about an inch prior to or after grass establishment. The sand layer usually helps reduce soil compaction, runoff, and water evaporation, but can increase water-repellency.

Soil group U-3, consisting of Hueco-Wink sandy loam, has a somewhat higher water holding capacity than group U-2 soils. The native topsoil depth usually extends to 2 feet in this soil group (Fig. II-1), but the actual depth varies due to erosion, grading, and at times, the removal of topsoil for sale. This soil group supports various species of trees and shrubs, including pecans and fruit trees, when the soil is at the normal depth of 2 ft. The subsoil is hard caliche which helps retain water, but does not allow root penetration unless physically or mechanically disturbed. For planting trees and deep-rooted shrubs, the hard caliche should ideally be broken at least in and near the planting holes. The caliche layer is the hardest at the first few inches because of silica cementation, in addition to calcium carbonate induration. The hardness of the caliche layer decreases with increasing depth. If the caliche layer is exposed, it should be chiseled and topsoiled to a depth of 6 to 8 inches for growing lawns. The surface layer of the Wink soil series, adjacent to the caliche layer, usually contains a high enough content of clay and powdery caliche to cause water infiltration problems, especially in sloped areas. If such a profile is exposed, it should also be chiseled and topsoiled prior to lawn establishment. An alternative is to cover with gravel mulch and to grow plants only in limited areas.

The surface soils of the Hueco and Wink soil series have been marketed extensively for topsoiling residential lots or commercial landscapes. Soil quality, however, varies depending on the depths from which the soil was obtained. The surface few inches of undisturbed Hueco sandy loam usually do not contain calcium carbonates, which is quite rare for the soils of the arid region. This soil had been excessively leached during the geological time, and offers a rare opportunity to grow acid-loving plants with a small application of sulfur. The concentrations of calcium carbonates and clay, however, increase suddenly, once the caliche layer is encountered, especially in the Wink soil series.

Table III-1. Soil modification measures commonly used in urban landscapes.

Types of measures	Purpose(s)	Applicable soil groups
Topdressing (place a thin layer of sand, or organic matter)	Improve soil structure and water infiltration, Reduce evaporation	Any groups
Topsoiling (place a layer of soil or sand over undesirable soils)	Supplement shortage of topsoil, Improve water infiltration and retention	U-4, U-5 V-3, V-4
Incorporation (mix sand or organic matter into soils)	Improve soil physical conditions through textural modification	U-2 V-3, V-4
Chiseling (Fracture compacted or cemented soils)	Alleviate compaction or cementation of soils	U-3, U-5 V-3, V-4
Subsoiling (similar to chiseling, but implemented into subsoils)	Improve subsoil permeability and internal drainage	U-3, U-5 V-3, V-4
Verti-drains (auger holes or pits punched through clay or hard pan)	Improve internal drainage, salt leaching, and root extension	U-3, U-5 V-3, V-4
Tile or open drains	Lower water tables	

When the topsoil brought in contains powdery caliche or many fragments of caliche, one should avoid using it for topdressing sloped areas, as it causes runoff upon compaction. The loamy sand or the coarse sand from Group U-2 is better suited for topdressing.

Salt problems in this soil group are reported only in places where undisturbed caliche layers are exposed or appear within 6 to 10 inches from the topsoil. If saline water is to be used for irrigation, the subsoil should be loosened to ensure water penetration and drainage.

Soil Group U-4, consisting of Canutio, Augustin, and disturbed Delnorte soil, has low water retention capacity, but has the deep gravelly or stony profile (Fig. II-1). For this reason, this soil group is most suited for planting deep-rooted trees and shrubs with low to moderate water requirements (Attachments 2A and 2B). In the case of Delnorte soil, an undisturbed layer of stony caliche may be found near the surface (Fig. II-1). If so, the subsoil should be loosened before planting trees or shrubs, as most plant roots can not penetrate into the subsoil.

When this soil group is used for growing lawns, topsoil placement (topsoiling) is usually required because of gravelly or stony soil conditions. In the case of Delnorte soil, the surface soil is shallow and this thin layer of topsoil is usually lost during grading and construction. The soil used for topsoiling should be of sandy loam or loamy sand to a depth of about 6 to 8 inches, and the final grade in sloped areas should be topdressed with about one inch of medium or coarse sand to reduce compaction and runoff.

The permeable nature of group U-4 soils makes salt accumulation most unlikely. However, in Delnorte soil with stony subsoil indurated with caliche, there have been reported cases of salt accumulation (Table II-1), as the indurated subsoil restricts drainage. The indurated subsoil should be loosened if saline water is to be used for irrigation.

Since Augustin and Canutio soils are highly permeable and located near active arroyos, excessive fertilization and irrigation should be avoided. Otherwise, fertilizer elements may seep into the arroyos, thus causing storm water contamination.

Group U-5 soil, consisting of shallow, stony Delnorte soil, is best suited for growing native plants which require little water and minimal soil depths. However, if trees are to be planted, the stony caliche must be loosened to allow root and water penetration. Otherwise, tree roots usually develop only on the soil surface, and the trees are prone to drought stress as well as uprooting. Once the hard caliche layer is loosened, tree roots usually find a way to penetrate into deeper layers consisting of loose sand and gravel (Fig. II-1), thereby supporting healthy growth.

When U-5 soil group is to be used for growing lawns, topsoiling is a must. The guidelines mentioned for Soil Group U-4 can be used, but the depth of topsoil placement may be increased somewhat, since the subsoil is stony and retains little water. Without adequate topsoil placement, frequent irrigations would be needed to maintain lawns. In addition, the potential for soil pore plugging in the stony subsoil by translocated soil particles is reduced by increasing the depth of topsoil placement.

Landscapes in the Valley: Residents in the valley have traditionally enjoyed dense greenery. A large number of cottonwoods and Chinese elms were planted by pioneers, then mulberry trees and pecans by newcomers. This rare dense greenery was made possible through the fresh water supply from the middle Rio Grande Project. However, the situation in the valley is changing. New subdivisions with small lot sizes now seldom receive the inexpensive irrigation water; leaky irrigation canals which used to provide fresh shallow well water have largely been cemented. Salinity of shallow ground water and soils have increased in many areas, thus causing deterioration of salt sensitive trees such as cottonwoods, pecans and fruit trees, while experiencing the spreading of salt tolerant species, such as salt cedars. The evidence of salt damage is especially obvious in the lower half of the Upper Valley, as well as in Soil Groups V-4 which has clayey soils with low permeability.

Plant selection for the valley, especially for new subdivisions appears to be moving toward the blend of landscaping plants used for uplands. The recent city ordinance to prohibit the use of mulberry trees (because of allergy-causing pollen production) has also impacted on tree selection and shade characteristics. Unlike mulberry and common bermudagrass which grow in almost any soils of the valley, many plant species currently used have more specific requirements with regard to soil preference and soil salinity levels (Attachments 2 and 3). Thus, the compatibility of plant species with soil and water conditions, especially soil salinity must be considered, along with water saving techniques.

Soil groups V-1 consisting of Gila, Harkey and Glendale loam, and Group V-2 consisting of Brazito, Gila, and Vinton sandy loam (Table I-1) are suited for growing many types of trees, shrubs, ground covers, and vegetables without soil amendment. This includes such trees as cottonwood, pecans, and fruit trees, which are rather salt-sensitive (Attachment 3A). Salts usually do not accumulate in these soils, as long as prudent irrigation management is followed. An exception to this rule applies to Glendale loam which has the subsoil consisting of silty clay loam (Fig. II-2).

Soil group V-3, consisting of Anapra, Harkey, Glendale, and Saneli silty clay loam, is low in water infiltration, especially when compacted or affected by sodium. Poor water infiltration leads to water ponding in low lying areas and salt and sodium accumulation in the soils. Harkey silty clay loam, in places, has a reddish clay layer at a depth of 30 to 40 inches. The layer thickness ranges from a few inches to as thick as 20 inches, depending on location. This clay strata is nearly impervious, and often presents wet and salty soil conditions which are harmful to many tree species, especially pecans and fruit trees. Likewise, water penetration and drainage are restricted in Anapra, Glendale, and Saneli soils because of clayey textures and soil stratification (Fig II-2). These soils are difficult to manage if saline water is used for irrigation.

If Group V-3 soil is to be used for tree or shrub plantings, planting holes should be large and deep enough to reach the underlying sandy strata. The planting holes can be refilled with sandy soils from Groups V-1 and V-2, or with a mixture of sand and the original silty clay loam. Details of these measures are described in Section III-3. Application of agricultural grade gypsum or sulfur (Table III-2) is helpful in leaching excessive amounts of salts and sodium often present in this soil group, especially when combined with verti-drains. If saline water is to be used for irrigation, salt tolerant species (Attachment 3) should be used.

If Group V-3 soil is to be used for lawn, topsoiling with Group V-2 soil to a depth of 4 to 6 inches helps maintain water infiltration. In addition, some drain holes can be made in low-lying areas to reach sandy strata for improving internal drainage. The sandy strata usually appear at a depth of 16 to 24 inches in these soils (Fig. II-2). Details of these measures are described in Section III-2. Anapra, Glendale, and Saneli silty clay loam (An, Ge, Sa) have low permeability, and water usually stands if not topsoiled with sandy soils. Group V-3 soil can also support vegetable gardens and flowers, provided that low salt water is used for irrigation. However, Anapra, Glendale, and Saneli soils are difficult to till unless amended with sand or organic matter (Table III-2).

Soil Group V-4 (silty clay) is unsuited for recreational turf unless topdressed extensively. These soils have high contents of expandable clay, and low soil permeability, unless the soil is amended through topsoiling. When the property area is so large as to make topsoiling impractical, a mixture of common bermuda and Jose wheatgrass may be planted for pasture or ground covers; both

Table III-2. Soil amendments commonly used in urban landscapes.

Types of Amendments	Purposes	Applicable soil groups
Chemical Amendments		
Gypsum ($CaSO_4 \cdot 2H_2O$) native or industrial byproducts	Reduce Na levels and improve soil structure	V-3, V-4
Sulphur(s) industrial byproducts	Reduce Na levels and maintain soil structure	U-5 V-1, V-3, V-4
Polyacrylamide (PAM) (synthetic polymer)	Improve water infiltration and retention	U-5 V-3, V-4
Wetting agents	Improve water infiltration in poorly wettable soils	U-2, U-5 V-2
Organic Amendments		
Compost	Improve water and fertilizer retention and soil structure	V-2 U-2
Woodchips	Improve water infiltration and tillability	V-3, V-4
Pecan shells	Used primarily as mulch	all types

are highly salt-tolerant. Poor water infiltration and penetration usually lead to salt accumulation in the soils, which is not good for most trees. However, if sandy soils are brought in for planting holes, salt tolerant trees such as pistachio, Afghan pine, honeylocust and mesquite have been grown successfully.

The lands which are affected by a high water table appear primarily in the lower half of the Upper Valley. If the soil is sandy and the shallow ground water is not salty, it can readily support water loving trees such as creeping willows and cottonwoods. However, the soils in high water table areas usually have a high salt content. Salt tolerant trees such as pistachio, Afghan pine, and mesquite can be grown on high grounds. If the soils are constantly wet and contain lots of salts, tamrix and saltbushes are the last resort. However, these species are invasive. Many turfgrass species are salt-tolerant (Attachment 3A) and they can be grown after topsoiling with sand or sandy soils. When the saline water table reaches within 30 inches or less, however, a special measure is usually required for lawn establishment as discussed in Section II-2.

In summary, one should pay greater attention to soil differences existing in the El Paso area, and to select plant species best adapted to the particular soil conditions. Even so, some soils, especially clayey soils in the valley and stony soils in the foothills of the Franklins require extensive modification for growing lawns and shade trees. The lack of adequate soil preparation is among the most serious deficiencies in landscape development in El Paso, and creates tough maintenance problems. Technical readers may wish to find details from the discussion given in subsequent sections (Sections III-2 and III-3).

2. Use of Soils for Recreational Turf and Athletic Fields

General Considerations: In using soils for recreational turf or athletic fields, the following factors must be taken into consideration. The first factor is soil compaction induced by human and equipment traffic. The second is a requirement to maintain ground moisture levels suitable for recreational or athletic activities. This means that light and frequent irrigations are generally preferred over deep soaking which makes the ground condition too wet to be functional. Light and frequent irrigation is, however, not always compatible with salinity control objectives. The third requirement is to keep the grasses growing fast enough to recover from abrasion. This usually means applying more water than that required simply to keep grasses or plants alive.

These factors place stringent requirements on soil selection for recreational turf and athletic fields. First, the soils should be resistant to soil compaction, and must have good permeability and a degree of resiliency. The soils should also be deep enough to support good growth of turf, and should not contain subsoils which restrict drainage. When sodic water is used for irrigation, the soils should be resistant to dispersion. There are only a few soils which come close to meeting these requirements, and they include Bluepoint loamy sand, Pajarito sandy loam, and Hueco-Wink sandy loam in uplands, plus Gila and Vinton sandy loam in the valley (Chapter II). The clayey soils in the valley, especially Groups V-3, and V-4, as well as Group U-4 soil in uplands are not suitable unless amended or modified extensively.

In the past, recreational turf and ball fields in the El Paso area were developed on whatever soils come with the land with little or no modification. A consequence is wide-spread soil salinization and sodification of clayey soils in the valley (Table III-1) along with tough maintenance problems. Soil salinization is largely a result of poor water infiltration and drainage, thus the recreational turf experiencing salinization usually has water ponding as well as soil compaction problems, neither of which is a desirable feature for recreational or athletic activities. These problems have developed even with the use of potable water for irrigation. Unless appropriate measures are taken to improve the soils, these problems can be aggravated if salty water is used for irrigation. This section outlines the process of soil salinization and sodification, and potential corrective measures.

Soil Salinity and Sodicity Control: Soil salinity usually increases in proportion to salinity of irrigation water. Therefore, it is more convenient for estimating salt accumulation potential to use a parameter referred to as the salt concentration ratio, SCR, which is the salinity of the soil saturation extract divided by salinity of the irrigation water used. Examples are shown in Table III-3 for root zone soil samples collected from recreational turf areas. The potential for salt accumulation increases with increasing values of SCR. The SCR usually increases with increasing the saturation water contents of the soils, and the rate of the increase is usually grater in Entisols developed in the valley than in Aridisols developed in uplands (Fig. III-1). The saturation water contents reflect clay contents and, to a lesser extent, the exchangeable sodium levels in soils. Note that the SCR increases sharply when the saturation water content exceeds about 35g/100g of dry soil in Entisols, and 40 g/100g or more in Aridisols. This level of saturation water content reflects the soil texture of loam or silt loam.

The actual soil salinity can be estimated by multiplying salinity of irrigation water to the SCR. If salinity of irrigation water is 2 dS m^{-1}, for example, soil salinity is equal to two times the SCR. Soil salinity should be kept below 6 to 8 dS m^{-1} for the optimum growth of moderately salt tolerant species such as ryegrass and fescue, and somewhat greater values for tolerant species such as bermudagrass (Attachment 3A). Soils for saline water irrigation should have a saturation water content below a range of 30 to 35g/100g or textures no finer than loam. In the case of gravelly loam or

Table III-3. Salt concentration ratio (SCR[1J]) of the surface soils (6 to 8 inches) and structural degradation potential (SDP) of different soil types in the El Paso Area.

Soil Types	Distribution area	SCR	SDP
Bluepoint coarse to loamy sand	Along I-10 and active arroyo	1.2 - 1.8	Low
Canutio gravelly Sandy loam	Outwash of the Franklins	1.2 - 2.0	Low
Hueco Sandy loam	Eastside above I-10 to Montana	0.8 - 2.8	Low
Gila/Vinton Sandy loam	Rio Grande Valley	1.0 - 3.0	High
Delnorte gravelly Loam	Foothills of the Franklins	1.3 - 3.8	Medium
Delnorte Indurated	Upper Foothills of the Franklins	1.8 - 5.8	Medium
Turney silty clay loam	Northeast	2.5 - 5.4	Medium
Harkey silty clay loam	Rio Grande Valley	9.1- 13.0	High
Harkey high water table	Upper Valley	24. - 30.	High
Glendale silty clay	Rio Grande Valley	29. - 44.	High

[1J] SCR is salinity of the soil saturation extract divided by salinity of irrigation water, and is an indication of soil salinization potential.

gravelly clay loam, the saturation water contents can be lower than 30 g/100g, due to a high content of coarse fractions, yet these soils usually behave like clay loam upon compaction.

Fig. III-2 shows the relationship between soil salinity and sodicity of the saturation extract (SAR_e), which is approximately equal to the exchangeable sodium percentage of the soil. The data were obtained from the surface soil survey conducted for recreational turf irrigated with the city potable water having a sodium adsorption ratio of 5.5 to 6.5. Note that soil sodicity increases with increasing soil salinity. This indicates that soil salinity must be controlled first if one wishes to control soil sodicity. Soil selection for irrigation with sodic water should then be limited to those with textures no finer than loam. Medium or coarse sand is not subject to dispersion by sodium. Water infiltration decreases with increasing exchangeable Na percentage, as discussed in Chapter II (Figs. II-5 and II-6).

An additional factor that needs to be considered is that soil is not uniform, especially when graded. The heterogenous distribution of soils induces uneven accumulation of salts, even when irrigation is made uniformly. Fig. III-3 shows soil salinity measurements taken at 10 feet intervals along a transect from high to low grounds, and another transect along the contour of the high grounds. This golf course was established on the Hueco-Wink soil, and has been irrigated with salty water (2 to 2.5 dS m^{-1}). Note that salt accumulation in the high ground made of Wink soil is highly irregular, whereas it is relatively uniform in the low ground consisting of Hueco sandy loam. The native topography of these soils has a series of mounds made of wind-blown sandy loam. Low salt readings are usually associated with fill-portions, and high readings at the cuts made during grading which can develop into so-called "salt spots". High salinity readings along the contour transect on the high grounds were associated with a shallow caliche layer. The grounds for large turf areas should be prepared as uniformly as possible. In this example, the grounds should have been deep-chiseled and topsoiled in shallow soil areas prior to turf establishment. The use of salty water for irrigation usually accentuates the variability in salt accumulation, thus leading to the development of salt spots.

Soil improvement projects begin with land survey and soil profile examination. If the soil contains subsoils restricting drainage, chiseling and subsoiling must be planned. Such measures are often needed in Delnorte and Hueco-Wink soils in uplands, and clayey soils in the valley. The soil examination should include the availability of sandy subsoils which can be used for topsoiling or

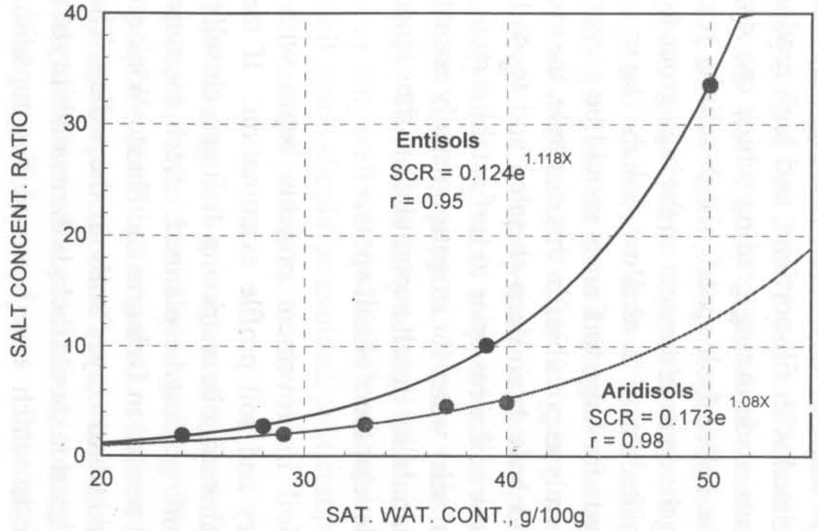


Fig. III-1 The relationship between the salt concentration ratio and the saturation water content in two soil groups used for recreational turf areas in El Paso

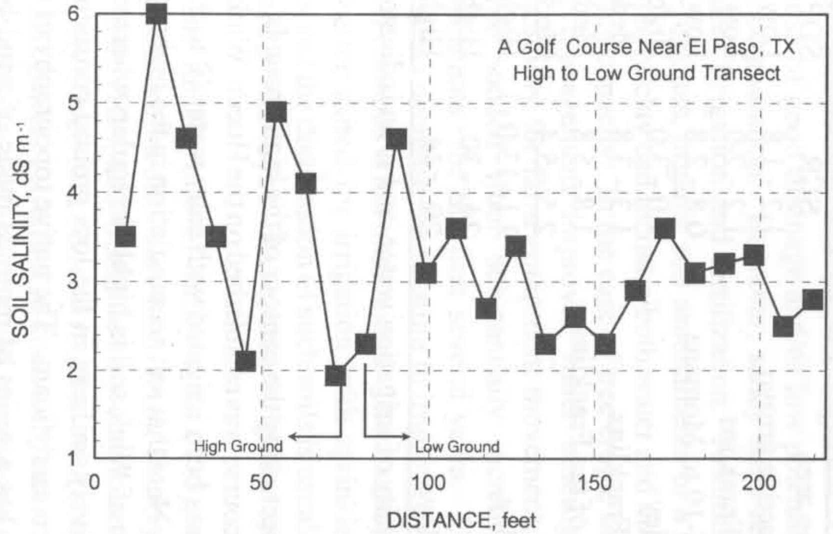


Fig. III-3 Soil salinity variation along a sampling transect from high to low ground in a golf course developed on Hueco-Wink soil which has been irrigated with salty water (1300 to 1600 ppm)

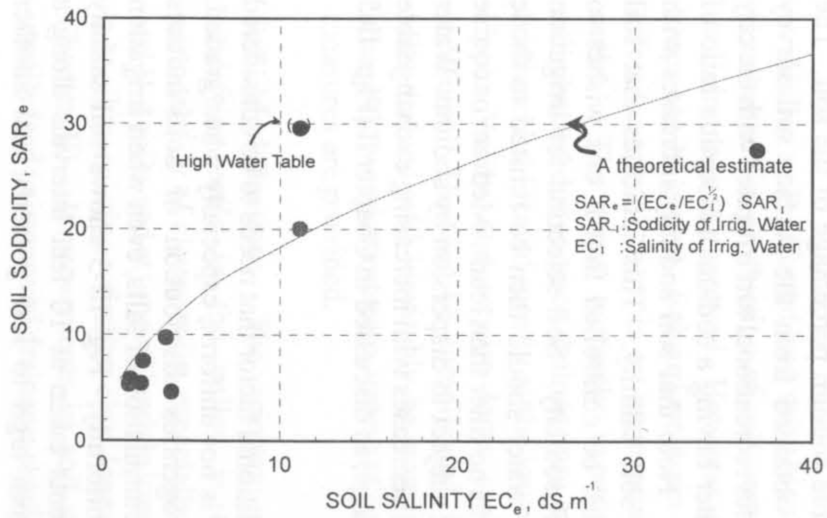


Fig III-2 The relationship between soil sodicity (SAR_e) and soil salinity (EC_e) in eight major soil series used for recreational turf areas in El Paso.

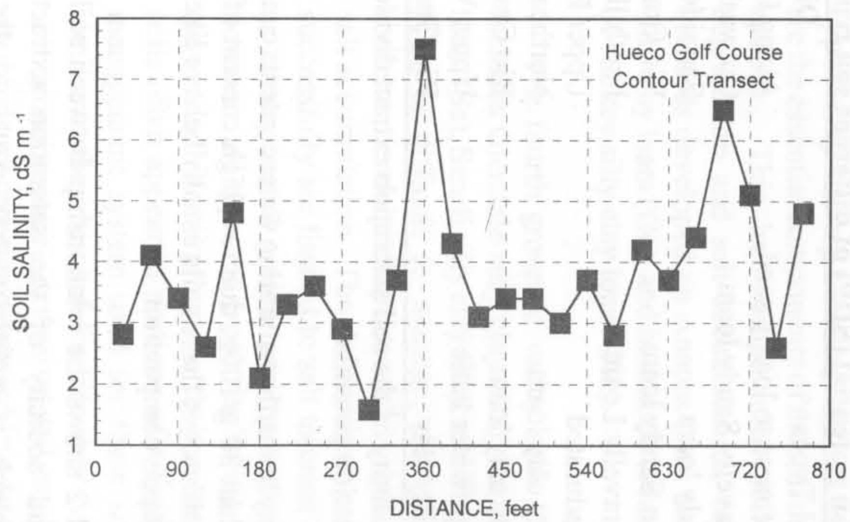


Fig. III-4 Soil salinity variation along the contour transect on the high ground in a golf course developed on Hueco-Wink soil which has been irrigated with salty water (1300 to 1600 ppm).

topdressing. If high water conditions prevail, subsurface drainage measures should be considered. This will then be followed by land grading. The slope should be kept at minimum necessary to allow surface drainage after rainstorms . If the surface soil is finer than sandy loam or contains gravel and stones, topsoiling and/or topdressing would be necessary. The soils used for topsoiling should be loamy sand or sandy loam, and the final grade should be topdressed with medium or coarse sand, especially if the land is sloped (medium sand has the sand grain size of 0.25 to 0.5 mm, and coarse sand 0.5 to 2.0 mm). For preparing the ground for athletic fields, laser-guided leveling equipment is commonly available. Some of these measures can be costly, but there is little justification to develop recreational turf or athletic fields which are difficult to maintain.

Management Guidelines, Upland Soils: Upland soil group, U-1, consisting of Pajarito, Berino and Turney sandy loam, does not require extensive preparation for recreational turf establishment, except for topdressing with medium to coarse sand to reduce soil compaction and to sustain water infiltration. In the case of Turney sandy loam, however, the subsoil consisting of silty clay loam (Fig. II-1) can reduce water penetration and salt leaching, especially when saline water is used for irrigation. This subsoil usually has good drainage, due to blocky soil structure. However, if the topsoil consisting of sandy loam is shallow due to grading, chiseling may be employed to ensure adequate drainage, and, if necessary, implement topsoiling, then topdressing with medium to coarse sand.

If Group U-1 soil is already used for recreational turf or ball fields, the soil is likely to be compacted. The use of a verti-drain core aerator, followed by topdressing with medium to coarse sand helps alleviate this problem. If the topsoil depth is shallow, repeated applications of the above measures may be required. In the case of Turney sandy loam, leaching irrigation during winter may become necessary if salty water is used for irrigation. Fortunately, the water supplies (including reclaimed water) in the Northeast area (where U-1 soil is distributed) have low salinity.

Soil group U-2, consisting of Bluepoint loamy sand and coarse sand is ideal for recreational turf development, if it can be irrigated frequently. However, this soil group, especially Bluepoint gravelly coarse sand, does not retain moisture until a thick stand of turf is established. An alternative is to incorporate sandy soils into the top 6 inches or so into the coarse sand. Incorporation is preferred over topsoiling. Under no circumstances should clayey soils or even loam be used for topsoiling coarse sand as they restrict water penetration into the sand. This can lead to salinization of the topsoil, unless leaching irrigation is practiced. The final grade should be topdressed with medium to coarse sand.

One additional consideration for managing U-2 soil group is to control soil wettability, especially when the ground is sloped. Poor wettability of this soil group is induced by the excretion of wax-like compounds from stems of dormant bermudagrass. The wax-like compounds tend to coat sand particles when irrigation depths are not deep enough to wash them out. This problem appears primarily during spring. The standard method of dealing with this problem is to apply wetting agents, followed by soaking irrigation to wash out the wax-like compounds. Water-repellency problems can also be reduced by overseeding with cool-season grasses, such as rye-grass and fescue.

Soil group U-3, consisting of Hueco and Wink sandy loam, is also suited for turf establishment, provided that the topsoil has not been removed. The topsoil of this group is structurally stable and usually extends about 2 feet, but the subsoil is hard caliche (Fig. II-1). In Wink soil, the surface soil adjacent to the caliche layer usually has clay and calcium carbonate contents high enough to cause compaction and poor water infiltration when they are exposed to the surface. Under such circumstances, chiseling and topsoiling would be required.

As indicated earlier, salt accumulation in Group U-3 soil, especially in Wink soil, tends to be highly variable as grading of mounds creates heterogenous soil conditions. The cut-portions should be subsoiled to minimize the development of salt spots when saline water is used for irrigation. If the caliche layer is exposed or appears in less than 6 inches, topsoiling would also be required after chiseling.

Soil group U-4, consisting of Augustin, Canutio, and Delnorte soil, has good drainage, and supports excellent turf under frequent irrigations. However, topsoiling with sandy soil is a must, because the surface soil is usually shallow and contains large amounts of gravel and stones (Fig. II-1). Loamy sand or sandy loam is an ideal material for topsoiling. However, loamy sand is highly erodible, and is subject to compaction. The final grade should be topdressed with medium to coarse sand, especially on slopes. Alternatives used in slopped areas include topsoiling with sandy loam, then topdressing with sand after establishment or to use sodding or spray seeding. The depths of topsoil placed on these soil types range from 6 to 8 inches, provided that the original soils are made sufficiently permeable through chiseling.

Soil group U-5, consisting of Delnorte soil with stony subsoil indurated with caliche, is among the most difficult soils to manage, especially when sloped. However, once the subsoil is loosened and topsoiled properly, turf can be adequately maintained. Salts usually accumulate when the subsoil indurated with caliche restricts drainage. Irrigation of this soil with sodic water can plug soil pores in the subsoil with the soil particles dispersed and translocated from the topsoil, especially during rainstorms. This problem can be minimized by loosening the subsoil and/or by increasing the depths of topsoil placement. The use of chemical amendments is an alternative. However, the primary strategy is to have an adequate depth of topsoil, then to maintain good stands of grasses to help reduce soil particle dispersion.

Management Guidelines, Valley Soils: The soils in the valley are fertile, but are structurally weak and highly susceptible to both soil compaction, and dispersion by sodium. Poor water infiltration, water ponding, and salt accumulation are common, except Group V-2 soils consisting of Brazito, Gila, and Vinton sandy loam. Even in these sandy soils, there can be soil compaction problems.

Soil Group V-1, consisting of Gila, Harkey and Glendale loam can support turfgrass species tolerant or moderately tolerant to salts, provided that soil compaction problems are managed, for examples, by the use of a verti-drain core aerator followed by topdressing with sand. The use of saline water with elevated sodium levels can compound salt and sodium problems. Drainage can become a problem in Glendale loam which has subsoil consisting of silty clay loam (Fig. II-2).

Soil Groups V-3 and V-4, consisting of silty clay loam and silty clay (Fig. II-2) are unsuited for recreational turf or athletic fields unless amended or modified extensively. A proven method is to replace or topsoil the clayey soils with sandy soil or loamy sand, and to provide verti-drains extending to sandy strata (Fig. III-5). The clay soil must be deep-chiseled prior to topsoiling, and be treated with gypsum. Topsoil should be anywhere from 4 to 8 inches, depending on the subsoil conditions and the expected levels of usage. In high usage ball fields, the final grade should be topdressed with a layer of medium or coarse sand. Sandy loam or loamy sand is subject to compaction. In most cases, sandy soils are present below the clay layer (Fig. II-2). If such sandy subsoils are to be used for topsoiling, the soil should be leached, preferably with the aid of gypsum prior to turf establishment. In addition, occasional leaching irrigations should be applied to wash out the salts from the topsoiled layer.

The problem with the above method is high cost, and interruption of turf usage. An alternative is to gradually build up the topsoil through the use of verti-drain core aerators and coarse sand topdressing. If this option is to be used, gypsum or

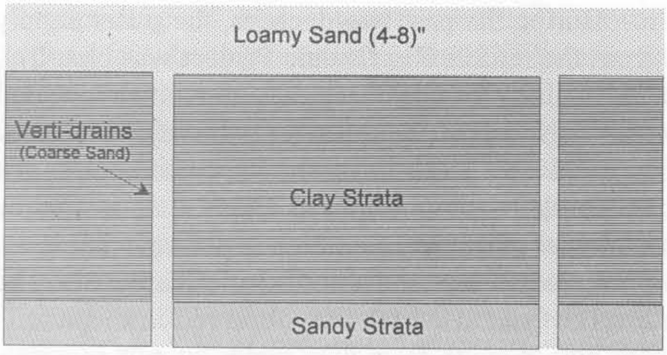


Fig III-5. A cross-sectional view of ground preparation used on clayey soils withsandy sub-strata below.

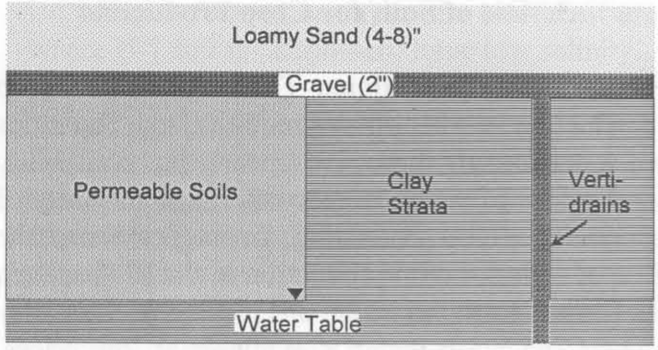


Fig III-6. A cross-sectional view of ground preparation in high water table areas with permeable sub-soils or claysub-soils with verti-drains.

other soil amendments should be applied prior to sand topdressing to enhance sodium leaching. The sand to be used for topdressing should be medium to coarse sand. This method is commonly referred to as partial modification and applies primarily to Soil Group V-3 rather than V-4. The use of conventional verti-drain core aerators is only partially effective in Group V-4 soils containing silty clay. Soil Group having salt-affected high water tables is also unsuited for recreational turf or athletic fields unless amended extensively. A conventional method is to place tile drains, provided that drain water can be disposed of. Another method is to place a layer of gravel below the topsoil so as to reduce the upward movement of the saline ground water to the surface. Fig. III-6 shows the ground preparation in the presence of high water tables affected by high salinity. If the subsoil is permeable, the verti-drains may not be required. The soils to be used for topdressing should be loamy sand or sandy loam with the final grade finished with medium to coarse sand. Periodic leaching irrigations are needed to leach out the salts from the topdressed layer.

3. Use of Soils for Crop Production

General Considerations: The use of soils for crop production in arid climates requires large quantities of water for irrigation. This means that availability and prices of water largely determine usability of the soils for crop production. In practical terms, the use of soils for crop production in the El Paso area is limited to those which are present in the valley where irrigation water is available at low prices. Minor exceptions to this rule are the cases where large quantities of wastewater are available for irrigation, and such practices are regulated by State Law TAC 210.

In addition to the availability and prices of water, water quality, especially salinity and sodicity, affects the types of crops which can be grown profitably. Irrigation water from the middle Rio Grande Project has comparatively low salinity (600-1000 ppm) and low sodicity (SAR < 5.5), whereas irrigation return flow, some reclaimed sewage water, and most well water in the valley have elevated salinity and/or sodicity (Table IV-3, Chapter IV). Irrigation return flow and reclaimed sewage water are generally blended into the project water supply, but at inconsistent mixing ratios depending on the flow of the project water. Consequently, salinity and sodicity of the irrigation water delivered to each field are not always consistent, and vary with season and location.

During the past two decades, the water supply from the middle Rio Grande Project was plentiful, and salinity of the water has remained low and stable. However, the soil salinity surveys conducted in 1985 and 1997 have shown considerable salt accumulation in Group V-3 and V-4 soils. Some examples of salt accumulation in pecan orchards are presented earlier in Table II-2 of Chapter II. The levels of salt accumulation observed in these soils are high enough to reduce yields of salt sensitive crops, such as pecans and vegetable crops, which provide about half of the project revenue. The quality of future irrigation water can deteriorate as discussed later in Chapter IV. The soils in the valley must be selected and managed with an objective of reducing soil salinization and sodification.

The primary cause of salt accumulation is poor permeability induced by clayey texture, soil compaction, and soil stratification as discussed in Chapter II. The presence of sodium also adversely affects water infiltration (Figs. II-5, II-6, Chapter II), as well as salt leaching. The soils in the valley, known as Entisols, are structurally weak and unstable in the presence of sodium. Since the soil type distribution is highly irregular in alluvial basins, salinity distributions are also irregular as shown in Fig. III-7 and Fig. III-8. In general, salinity levels are usually higher in clayey portions of a field than in sandy portions. In the case of the

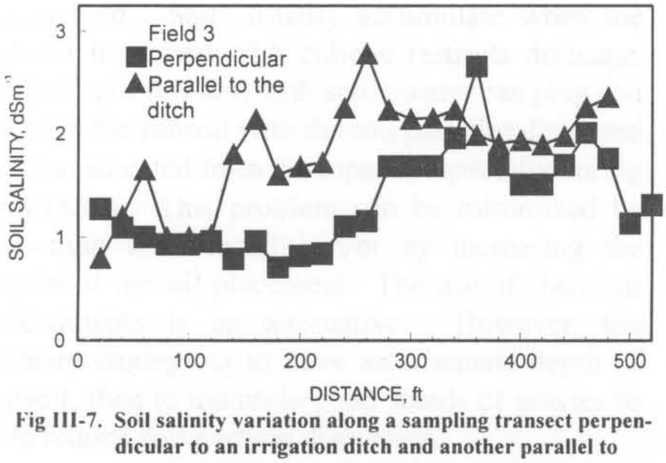


Fig III-7. Soil salinity variation along a sampling transect perpendicular to an irrigation ditch and another parallel to the ditch in a furrow-irrigated cotton field (Miyamoto and Cruz, 1987).

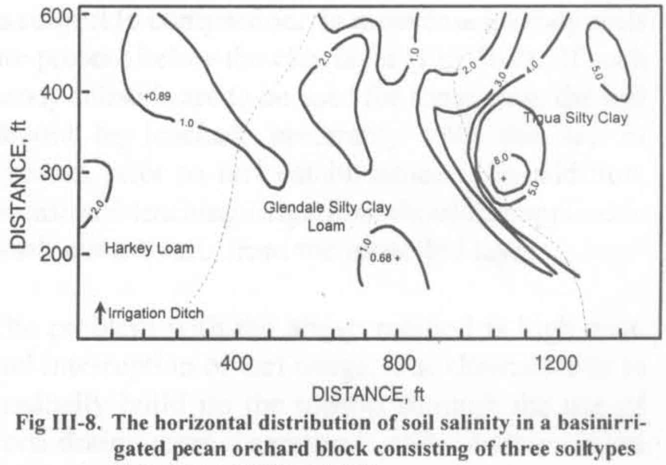


Fig III-8. The horizontal distribution of soil salinity in a basinirrigated pecan orchard block consisting of three soiltypes (Miyamoto and Cruz, 1986).

cotton field shown in Fig. III-7, high salinity was associated with Glendale silty clay. In the pecan orchard shown in Fig. III-8, high salinity was found in areas consisting of Tigua silty clay.

When dealing with variable soil conditions, several basic principles should be observed. First, salt sensitive crops (Attachment 3D) should be planted on sandy soils but not in a field dominated by clayey soils, especially those belonging to Soil Groups V-3 and V-4. Planting salt sensitive pecans in such soils is the beginning of life-long problems. The second principle is to manage the field in accordance with soil type distributions as much as possible. For example, soil modification intended to improve water infiltration and salt leaching should be targeted primarily to areas consisting of clayey soil types. Irrigation should be made to achieve as uniform salt leaching as possible, while avoiding over-irrigation which compounds drainage problems.

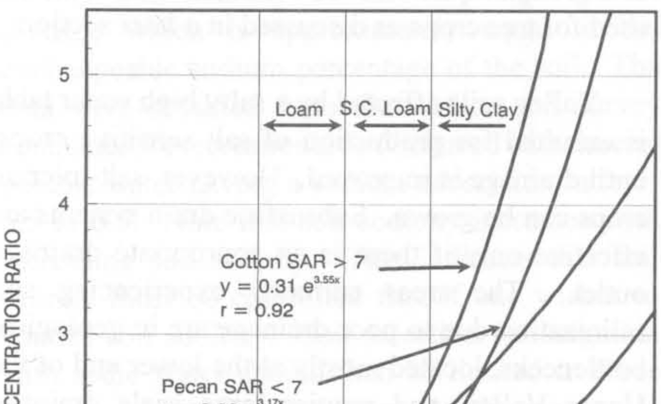


Fig. III-9 **The salt concentration ratio of the root zone as related to the saturation water content under different cropping systems in the El Paso Valley.**

An additional consideration is the impact of cropping systems on salt accumulation. Fig. III-9 shows the salt concentration ratio (soil salinity/irrigation water salinity) as related to the saturation water content of the soils under different cropping systems. The soil depths considered are within the major root zone. When the sodium adsorption ratio (SAR) is below 7.0, salts are usually leached in the field with cotton and milo rotations. This observation reflects extensive chiseling and the preseason leaching irrigation practiced. Salts tend to accumulate in vegetable fields, mainly because of the frequent irrigations employed. Salt accumulation in pecan orchards usually becomes a problem in clayey soils, due to reduced opportunities for chiseling. When the sodium adsorption ratio (SAR) exceeds 7.0, salt accumulation increases in clayey soils due to a reduction in soil permeability.

Soil Compatibility and Management: The first group of valley soils (V-1) which includes Gila loam (Ga), Harkey loam (Ha), and Glendale loam (Gd), is suited for growing most crops listed in Attachment 3D. This soil group ordinarily does not require any special soil improvement measures, except for leveling and occasional chiseling to maintain soil permeability and salt leaching, especially following cultivation of vegetable crops. There is little need to add any chemical soil conditioners, except during seedling establishment of vegetable crops, or to counter against high Na when municipal sewage water or drainage water is used for irrigation. The deep soil profile and high water retention make it ideal for surface irrigation as well as for drip irrigation. There is, however, one exception; Glendale loam has subsoil consisting of silty clay loam usually starting at a depth 17 to 19 inches (Fig. II-1, Chapter II). This subsoil limits drainage and leads to salt accumulation when developed for an orchard. For planting tree crops or alfalfa, this subsoil should be modified as discussed in a later section.

The second group of valley soils (V-2), which includes Vinton sandy loam (Vn), Brazito loamy sand (Br), and Gila sandy loam (Gc), is especially suited for pecans and certain vegetable crops, because of good drainage and/or low potential for salt accumulation. However, sandy soils require frequent irrigation and fertilization. Additions of crop residues, organic soil amendments or a small amount of clay can increase both water and nutrient holding capacity. In the case of tree crops, sodded floor management improves water holding and trafficability for farm equipment movement, even though sodded floor substantially increases N requirements for the first several years. Cotton yields can decrease if a rotation to improve organic matter contents is not maintained. These sandy soils are better suited for irrigation with sprinklers or drips, but the distribution of such soils is usually too limited in size to justify a separate irrigation system.

The third group of valley soils (V-3), which includes Anapra silty clay loam (An), Harkey silty clay loam (Hk), and Glendale silty clay loam (Ge), is ideally suited for cotton in rotation with sorghum or small grains. Alfalfa also does well, but at times suffers from weed invasions, and stand losses due to water ponding. Pecans do well in this type of soils, but only for the first 7 to 15 years. Thereafter, tree vigor and nut quality deteriorate because of inadequate water infiltration, poor drainage, and salt accumulation. Some vegetable crops such as cabbage and squash also do well in this soil group, even though these soils are difficult to manage and have low trafficability after irrigation or rain. Obtaining consistent crop stands is another problem, especially with vegetable crops which have tender seedlings, such as peppers, lettuce, onions, and tomatoes. The use of salty sewage water, drainage water or salty well water with high sodium levels on this soil group should be avoided, as it compounds salt and sodium problems.

The existing soil management system for this soil group involves laser leveling, deep chiseling, and preplant leaching irrigation, combined with appropriate crop rotations. This system has made it possible to maintain soil productivity at a high level for field crops for many years. Introduction of pecans into this soil group has reduced the opportunity for deep chiseling and soil drying which are the essential components of the soil management system. This has compounded soil structural degradation and salt accumulation, especially in orchards developed on Anapra (An) and Glendale silty clay loam (Ge), and in limited areas consisting of Harkey silty clay loam (Hk).

The fourth group of valley soils (V-4) which includes Glendale silty clay (Gs), Saneli silty clay loam (Sa), Saneli silty clay (Se), and Tigua silty clay (Tg), is difficult to manage, due to high clay contents, inadequate permeability, and associated salt accumulation. The crops which can be grown successfully are limited to salt tolerant types, such as cotton, small grains, and pasture. In reality, however, all types of crops, including pecans, are grown on this soil group, partly because these clay soils often appear in portions of a field. The soil management system used for these soil types is similar to the one used for Group V-3 soils. This soil group requires extensive soil modification if used for tree crops as discussed in a later section.

Valley soils affected by a salty high water table is unsuited for production of salt sensitive crops, until drainage is improved. However, salt-tolerant crops can be grown. Subsurface drain systems are effective only if there is an appropriate drainage outlet. The areas currently experiencing soil salinization due to poor drainage are in geological bottlenecks, located mostly at the lower end of the Upper Valley, and require large scale drainage measures. This can be complicated, because the salts drained will inevitably be transferred to the areas below or downstream, unless salt containment measures are provided.

Soil Modification: The primary objective of modifying soils in the valley is to improve permeability of clayey soils, especially Group V-3 and V-4 soils, and at times Glendale loam which has subsoil consisting of silty clay loam (Fig. II-2, Chapter II). Improvements in soil permeability usually lead to improved drainage, aeration, and salt leaching. The methods commonly used include slip-plowing, deep plowing, pitting/short trenching, and continuous trenching (Table III-6).

Slip-plowing was first introduced into the Imperial Valley of California for the purpose of breaking the horizontal orientation of soil layering. The equipment became increasingly large, and new models can reach as deep as 6 feet or more. This technique is used in the El Paso Valley primarily to fracture compacted or dense soils and, at the same time, to improve subsoil drainage. This leads to improved aeration, salt leaching, and visible crop responses, when the crops are under salt stress or affected by poor internal drainage. The effect can last for many years when implemented in compacted sandy soils with poorly permeable subsoil. In silty clay or silty clay loam, however, the effect usually does not last very long as the slits or soil cracks created by slip-plowing are sealed back rather quickly. Slip plows are a form of deep chisel, and are not designed to mix the soil profile, although a streak of subsoil may appear along the slits. Some suggest to topdress the slip-plowed area with sand to help sustain permeability.

Slip-plowing in high water table areas should be implemented with caution. There have been a few incidences of a sudden rise in water table after slip-plowing, as irrigation water leaks massively through the slits for the first several irrigations. If this method is to be tried, it is essential to examine soil profiles and water table situations, then determine an appropriate depth of slip plowing. Otherwise, the rise in water table can bring salts upward into the root zone.

Deep-plowing is used to break soil layering much more throughly than slip-plowing, but the equipment currently available usually can not reach beyond 3 feet. It works well with Soil Group V-1, but may not in Group V-3 and V-4 soils, many of which have a silty clay loam layer extending deeper than 3 feet (Fig. II-2, Chapter II.). Certain types of deep-plows can also help mix the soil profiles when stratification occurs well within the plow depth. The effect of deep-plowing usually lasts much longer than slip-plowing, especially when the equipment is made to cause soil profile mixing.

Pitting and short trenching are used primarily in

Table III-6. Physical and chemical measures used to modify soils for irrigated crop production.

Measures	Purpose	Applicable Soil Groups
Physical measures		
Slip-plowing	Increase soil permeability, internal drainage and salt-leaching	V-1 V-3 V-4
Deep-plowing	The same as above, except the effect may last longer.	V-1 V-3
Pitting/Short Trenching	Localized improvements in soil permeability, internal drainage and salt leaching	V-3 V-4
Chemical Measures		
Sulfuric Acid and Gypsum	Enhance water infiltration, percolation and leaching of exchangeable sodium and to improve tillability	V-3 V-4
Sulfur, Elemental or Colloidal	Help maintain soil structure, tillability and water infiltration	V-1 V-3 V-4

tree crops (Fig. III-10). The idea is to induce localized improvements in soil conditions by mixing clay and sand layers or by inverting the layering sequence. This method is effective in Group V-3 and V-4 soils, plus Glendale loam which has subsoil consisting of silty clay loam. The roots can fill in the pits or the short trenches in a matter of one or two growing seasons, and extend into the sandy subsoil if the soil moisture and salinity conditions of the sandy layer are favorable. In most instances, the areas beyond the pits are deep-chiseled so as to equalize water infiltration, and to aid root penetration from the pits into the clay layer.

The depth of pits or short trenches is usually 1.5 to 2.0 times the thickness of the applicable clay layer. This depth can be easily attained with a backhoe in Group V-3 soils, but not always in Group V-4 soils where the clay layer may extend 4 to 6 ft. In Group V-4 soils, the short trench may be made in a diagonal direction, and be extended to intercept the chiseling or slip-plow lines (Fig. III-11). The depth of the extended trench should be deeper than the depth of the chiseling or slip-plow lines, and at the center, reaching the sandy strata for drainage. The extended trench should be refilled with a rough mixture of sand and the original clods of clay. The above process may be repeated in the 2nd year on the opposite side of the trees.

Pitting or short-trenching provides a long-lasting effect, as it modifies soil texture. Tree roots develop into the modified soil with high densities. An exception applies to the condition where the soils in the pitted or trenched portions are constantly wet, either due to the presence of a high water table or excessive irrigation. Chiseling the area beyond the trench helps equalize water infiltration and retention.

Continuous trenches are used for various purposes, including preplanting soil preparation for tree crops and for lowering perched water tables. For lowering perched water tables, the trench should be made to the direction of the lowest water table or to the area commonly referred to as a drain field.

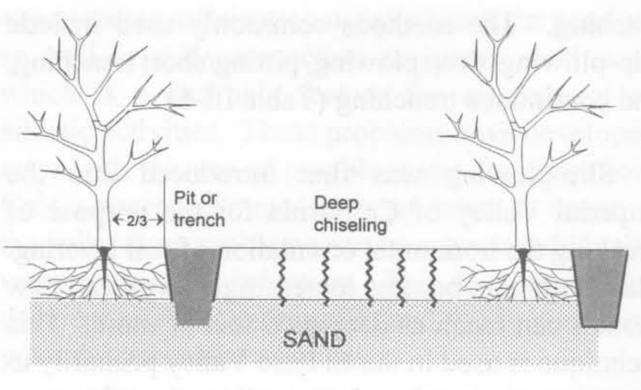


Fig III-10. Pitting or short trenching used to improve internal drainage and salt leaching in tree crops.

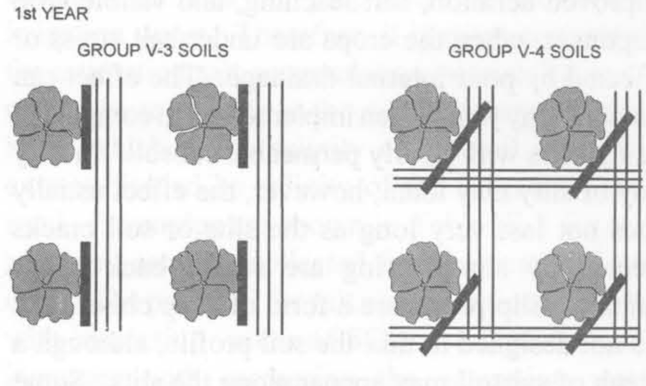


Fig III-11. Location of pits or short trenches relative to chiseling or slip-plow lines.

The determination of the drain field usually requires monitoring of water tables. The lower end of the trench should be filled with gravel or coarse sand, preferably with drain pipes if the excess water is to be carried to the drain field. Consult with drainage engineers for details before undertaking such measures. Continuous trenching is also used in place of pitting when a trencher is used, instead of a backhoe. The trenchers equipped with a digging chain provide good soil mixing, but this method is rather time-consuming. The type which has a rotary digging column is reported to have a good working speed, but it reaches to a depth of 3 feet or less.

Chemical amendments are used primarily to lower soil sodicity, thereby minimizing the formation of surface seal which limits water infiltration and salt leaching. Chemical amendments also help improve tillability of the soil by reducing soil hardness and the plasticity limit. However, chemical amendments are not a substitute for chiseling or pitting, and should be used in conjunction with physical measures on compacted soils. Gypsum is used widely for both soil structural maintenance and sodium and salt leaching in sodium-affected soils. This compound should be broadcast on chiseled and plowed grounds, rather than incorporating it into the soil. Application rates range from several tons to as high as 5 tons per acre depending on the severity of sodium problems. At these rates, grounds will be barely covered with gypsum unless applied fairly uniformly. Gypsum is available as native deposits as well as industrial by-products. Calcium chloride ($CaCl_2 \cdot x\ H_2O$) is another product used for reducing soil sodicity. However, high dosages of this product can induce Cl toxicity if Cl sensitive crops are involved.

Sulfuric acid is the strongest and most dangerous amendment currently used for improving sodium-affected soils. Ground applications of sulfuric acid also help improve plant availability of phosphorus, iron and several other micro-nutrients. High prices and handling difficulties of sulfuric acid tend to limit its usage. One unit weight of sulfuric acid is usually just as effective as two unit weights of gypsum. Ground applications of calcium chloride may not sustain water infiltration throughout the leaching process, because this product is leached out rapidly from the soil surface. Such examples are shown in Fig. III-12, when 6700, 3800, and 5,600 lbs of $CaSO_4 \cdot 2H_2O$ (gypsum) H_2SO_4 (sulfuric acid) and $CaCl_2 \cdot 2H_2O$ (calcium chloride) were surface-applied to 1 acre of Saneli silty clay loam having the exchangeable Na percentage of 17.5%. These application rates are chemically equivalent. The ground application of chemical amendments should be targeted to the areas consisting of clayey soils, instead of applying them indiscriminately. Otherwise, the problem of uneven salt accumulation (as shown in Figs. III-7 and III-8) will remain.

Ammonium polysulfide (NH_4S), sulfuric acid (H_2SO_4), and poly-acrylamide (PAM) are often applied through irrigation water, mainly to improve the structure of the soil surface and water

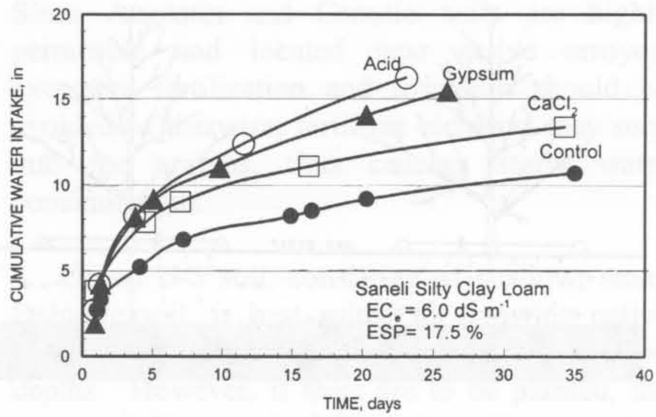


Fig III-12 Water intake into Saneli silty clay loam after acid, gypsum and $CaCl_2$ application at respective rates of 3800, 6700 and 5600 lb/acre (Miyamoto and Enriquez 1990).

infiltration. The application rates range from 100 to 300 lb/acre for NH_4S and H_2SO_4, 1 to 5 lb/acre in the case of PAM. These practices usually do not modify soils, except for micro-structure at the soil surface. Nonetheless, it can improve water infiltration, typically by 10 to 15%. The effectiveness usually increases with increasing sodicity of the soil or irrigation water, and is most effective in reducing ponding of rainfall.

Leaching Irrigation: Leaching irrigation to wash out salts and sodium from the root zone is usually used after the soils are physically modified or chemical soil amendments are applied. The best time to carry out leaching irrigation is during winter or spring when the water table is at its deepest, and in the case of tree crops, when they are dormant.

The quantity of water needed for salt leaching varies with the water holding capacity and salinity of the soil as well as practicality. In clayey soils irrigated with surface methods, 6 to 8 inches of water is usually applied once, then is followed by an additional 4 to 6 inches of irrigation as soon as feasible. This type of leaching irrigation usually washes out salts from the top 12 to 20 inches and is carried out, typically using the leveled border or basin during winter.

When drainage is poor due to high water tables, leaching irrigation can raise the water table, especially when applied after slip-plowing or after

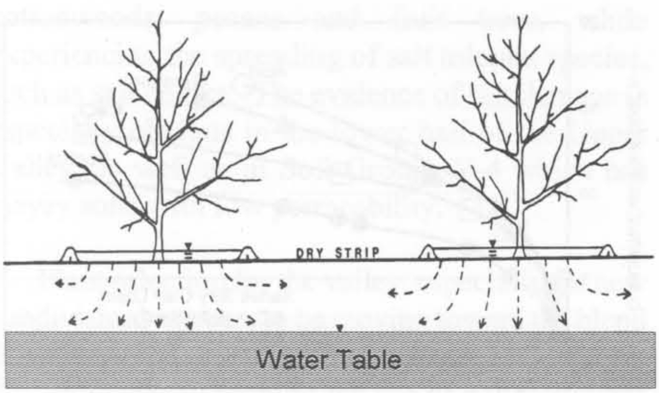


Fig. III-13 Strip leaching of tree crops in the presence of high water tables.

extensive trenching. This makes salt leaching difficult, because the salt leached usually bounces back with the rise of the water table. In such cases, intermittent leaching involving several irrigations over an extended period may have to be employed during winter. If tree crops are involved, irrigation water for leaching may be applied in the strip close to the tree rows by setting borders (Fig. III-13). This method helps leach salts from the tree rows even if there is a high water table. The area between the watering borders can be leached later as drainage permits. Subsequent irrigations, including the area which had not been leached, should follow the depths and frequencies dictated by soil and crop types. Application of extra water during cropping seasons for enhancing salt leaching usually results in water ponding and poor aeration in clayey soils of the valley.

IV USE OF SOIL INFORMATION FOR LAND USE AND WATER MANAGEMENT PLANNING

Land use in urbanizing areas is largely dictated by land market value, and in arid areas like El Paso, by the availability of water. The soils which make up the land are usually considered secondary. Nonetheless, there are cases where land use and water management planning can be improved if soil characteristics are taken into consideration. This idea applies to both community and regional levels, especially when land use involves plant growing under irrigation. Typically, soil properties affect plant growth, irrigation affects soil properties, and the combination of soil properties and irrigation water quality impact on sustainability of irrigated land use. Some of these examples are briefly discussed in this chapter.

1. Urban Land Use

Foundational Uses of Soils: A large portion of soil resources in urban settings is used simply to support man-made structures, such as highways, buildings, and individual homes. In this type of soil use, the content of the land, commonly referred to as dirt, is the concern of civil or foundation engineers, and is beyond the scope of this bulletin. Interested readers may refer to the engineering classification of the soils given in the Soil Survey Report (SCS, 1971). Some engineering properties, such as the linear shrinkage and the plasticity index, are shown in Attachments 1A and 1B.

In addition to the published information, home builders and buyers may wish to review a few incidents of foundation settlings which have occurred in areas consisting of Bluepoint loamy sand. This sand (Fig. I-3 and I-4) is unconsolidated, and is subject to settling, especially when soaked. Cracking of house foundations has also been reported in some areas consisting of Hueco-Wink soil series (Fig. I-3 and I-4). This soil series, in places, has subsoil affected by sodium, and can expand upon wetting. Some clayey soils in the valley (Attachments 1A and 1B) also have a tendency to swell and shrink, but the high water table prevalent in the valley seems to help maintain a stable soil moisture regime, thus the stability of potentially unstable soils.

The soil that is best suited to be placed under building foundations or parking lots is the caliche found in subsoils of the Hueco-Wink soil series. This geological material does not swell or shrink, and is relatively stable even at high water contents. This material is also used to surface county roads.

Landscape Uses of Soils: The soils in the El Paso area, as discussed in Chapter II, are highly variable, ranging from sand to clay, shallow to deep, and nonsaline to saline. Not all of these soils are suitable for landscaping uses or for supporting recreational turf and ball fields (Sections III-1 and III-2). The main problem appears when clayey soils in the valley (Soil Groups V-3 and V-4 given in Table I-1) are used without modification for recreational turf and athletic fields. These clay soils do not have sufficient permeability, thus causing poor water infiltration, salt accumulation, and perpetual maintenance problems. While the initial cost of modifying these soils to the condition suitable for recreational turf and ball field uses is substantial, there is little rationale in developing recreational turf which can not be maintained adequately. Land use planners may wish to review Chapters II and III mainly to understand land use constraints imposed by certain soil properties, and to incorporate measures necessary to make such soils usable.

Topdressing along with subsoil conditioning is currently the most practical way to make these problem soils usable for recreational lawn, athletic fields as well as landscapes involving lawns and shade trees (Sections III-1 and III-2). Huge quantities of topsoil are required for topsoiling shallow gravelly or stony soils along the foothills of the Franklins and clayey soils of the Upper Valley. In addition, many recreational turf areas, ball fields, and school grounds in the valley as well as some areas of the Westside and the Eastside are in need of topsoilng. At present, topsoils are provided mostly by removing the surface soil of the Hueco-Wink soil series distributed on the Eastside. This soil type has topsoil to a depth of about 24 inches, and the subsoil is hard caliche (Fig. II-1). As the urban development expands to the East, some of these lands from where the surface soil was previously removed are now in need of topsoilng. Land use planners and landscaping professionals may wish to consider using Bluepoint loamy sand for topsoiling and/or topdressing. This sand is distributed in scattered areas throughout the city along Interstate 10 as shown in the attached soil map. Bluepoint loamy sand is a deep deposit of sand (Fig. II-1) ideally suited for lawn and turf establishment, as long as appropriate precautions are taken against wind and water erosion until turf is established.

Parks and Open Spaces: Small neighborhood parks in El Paso typically have recreational turf with shade trees, and larger community parks with various ball fields. Our recent survey of the city park system indicates a strong correlation between the condition of turf and soil types. Typically, good turf conditions are found in Soil Groups U-1, U-2, and U-3 in upland, and in Soil Groups V-1 and V-2 in the valley (Table I-1). If given a choice, the recreational park development on these soils can substantially reduce maintenance costs. The reality of the matter seems to be that the land for park developments is decided based on factors other than the content of the land. In fact, many of the lands selected or donated for new park developments have severe constraints, and would likely to require extensive soil modification. This fact should be incorporated into the planning process.

Parks and recreational lawn developments in conjunction with flood control seem to be a coming concept, and successful implementation of such a concept can be found in several city parks in uplands. However, in the valley, this concept has not worked as well as it was hoped, partly because of the presence of saline high water tables or clayey soils with inadequate permeability. These low-lying lands in the valley are often waterlogged and salinized. Land use planners should review soil profiles in order to properly assess internal drainage.

Community parks and school grounds currently provide scarce open-spaces for citizens, and vacant lots seem to provide the remaining open spaces in urban settings. Unfortunately, many vacant lots are poorly maintained, and some have blowing sand. Wind erosion is particularly severe in the East District consisting of Bluepoint loamy sand and Hueco sandy loam. Owners of land with these soil types should be advised as to various measures to control wind erosion, such as gravel or woodchip mulch or the use of chemical sand stabilizers. These measures are generally cost-effective, if implemented correctly.

Development of Steep Land: There seems to be concern over the development of steep stony soils along the foothills and the steep slopes of the Franklins. The land slopes in these areas range from 10 to as steep as 30%, and the native topsoil is shallow to nonexistent (Fig. II-1, Chapter II). Therefore, most landscapes are supported by the topsoil brought in to cover the stony native landscapes. One of the concerns has been the potential erosion and sliding of the topsoil during rainstorms, which can contaminate stormflow or even create mud flow. Our limited survey of the area, however, indicates that the stony soils for the most part have sufficient pore spaces to allow root and water penetration necessary for maintaining the topdressed slopes. There are, however, places where the stony soil is indurated with caliche and allows neither water nor root penetration, thus creating erosion. Such conditions are relatively easy to correct. Some guidelines for landscaping steep hills are warranted as urban developments extend to the steep slopes of the Franklins.

Rare Soil and Ecosystem Preservation: There are at least three types of soils and associated eco-systems which are considered unique and hard to replace. These are the Rockland of the Franklins and adjacent Delnorte series, the Wetland of the Rio Grande, and the Duneland in the far East. The Rockland of the Franklins and adjacent Delnorte stony soil support unique vegetation as well as a number of wildlife species. Some of these areas have been preserved as the Franklin Mountain State Park, and by the Federal Land Reserve for the military.

The wetland of the Rio Grande has largely been drained and converted to agricultural land, and some to other uses. There have been several attempts to preserve an area commonly referred to as Rio Bosque in the Lower Valley. Unfortunately, the wetland and its ecosystem have already been modified to a significant degree. Nonetheless, the few wetlands left provide precious habitats for wildlife species, especially for migrating birds.

The third area is the Duneland located along Highway 180 (or 62) to Dell City in the far East outside the city limit. The area consists of noncalcareous fine sand (similar to the surface soil of Hueco soil series), and supports scattered plant communities consisting of sagebushes, yucca and mesquites. This area is not currently preserved.

2. Agricultural Land Use

Agricultural land use plans for the El Paso Valley were developed shortly after the turn of this century when the middle Rio Grande project was planned. Since then, there has been a shift in cropping patterns, and the land use conversion to residential or commercial uses. Even though the major portion of the irrigated land in the county remains intact, agricultural land use in the valley may be entering a new era due to the possible decline in quantity and quality of water available for irrigation. Under water quality constraints, soil properties, besides water quality, play a decisive role in sustaining irrigated crop production. Some issues are briefly addressed below.

Economic Viability of Irrigated Crop Production: Agricultural land use is based on the fundamental premise of making money out of growing crops, although irrigated farming provides some other benefits, such as biodiversity, protection of certain wildlife species, and the greenery that most desert dwellers can appreciate. To increase farm income, local growers introduced several cash crops, such as pecans and vegetables, plus alfalfa and other forages to support local dairy industries. The irrigated land cropped with pecans and vegetable crops has now reached 21% of the total irrigated lands in the El Paso Valley. What is most significant is that these high value crops now account for 48% of the farm revenue in the El Paso Irrigation District. This excludes the secondary benefits resulting from the processing and marketing, all of which are now performed locally. If the economic viability of agricultural land use is to be maintained, the soil resources must be managed to allow sustained production of these high value crops. Losses in cropping flexibility will not only lower the overall farm revenue from the irrigated land, but also substantially increase operational risks associated with the price fluctuation of a few crop commodities, especially cotton.

Both pecans and most vegetable crops are, however, highly sensitive to salts. Therefore, production of these high value crops requires sandy soils (Groups V-1 and V-2 soils) and a sustained supply of irrigation water with low salinity and sodicity. Salinity and sodicity of irrigation water must be especially low when used on clayey soils which have low permeability and high potentials for salinization. In the case of the El Paso Valley, clayey soils (Groups V-3 and V-4, Table I-1) occupy about 70% of the irrigated lands, and soil salinity levels are now at or above the threshold salinity for growing these high value crops (e.g., Table II-2, Chapter II). Properties of some of these clayey soils can be improved (Section III-3), but it would require a huge and unrealistic investment to change clayey soils to sandy soils. Therefore, the economic production of high value crops, hence the economic viability of agricultural land use in the valley is closely tied with the sustained supply of high quality water for irrigation, and preservation of permeable sandy soils. These realities must be incorporated into agricultural land use and water management planning.

Sustainability of Agricultural Land Use: Urbanization is expected to demand fresh water in increasing quantity, and will generate municipal sewage effluents in increasing quantity. Traditionally, municipal wastewater as well as agricultural drainage water have been returned back to irrigation or drainage systems. This form of water management has helped maintain the quantity of water available for irrigation, especially during years of reduced water supply from the project. However, such practices contribute to degradation of irrigation water quality, and as indicated earlier, water quality degradation will have a direct impact on the profitability of high value crop production especially in clayey soils of the valley. Some suggest that under water quality constraints, increased production of salt-tolerant crops such as cotton and grains should improve sustainability of irrigated agriculture in the valley. However, experiences from the other parts of the Rio Grande Basin show that agricultural land use tends to decrease rather sharply once salinity of irrigation water exceeds about 1000 ppm (Table IV-1). There are many reasons for this sharp decline in cropping activities, but in essence, the profit margin of these salt-tolerant crops has been too small to adsorb the impact of yield reductions, price fluctuation, or cropping constraints imposed by high salinity.

The experience in the Hudspeth District as well as in the Presidio District is especially relevant to the issue of agricultural sustainability in the El Paso Valley. Salinity of irrigation water supplies to these districts has been well above 1000 ppm, and crop production has fallen. At the same time, the improved supply of irrigation water in the recent past made it possible to regain some of the lost cropping acreages in the Hudspeth District. Nonetheless, the field monitoring conducted in 1997 (Table IV-2) indicates that cotton yields were also affected by high salinity of clayey soils. According to this observation, the potential maximum yield was more than 3 bales which was recorded in a small area having no apparent salt accumulation, but the real field yield averaged fewer than 2 bales per acre. The salinity of irrigation

Table IV-1. Changes in cropped acreages in the Rio Grande Basin (Miyamoto, 1996).

Salinity of irrig. water	Areas involved	US side Peak	US side Current	US side Reduct.	Mexican side Peak	Mexican side Current	Mexican side Reduct.
ppm		1000 acres		%	1000 acres		%
< 660	Lincoln/Mesilla	95.8	83.4	12	NA	NA	NA
600 -1000	El Paso/Juarez	45.9	41.2	10	16.0	13.1	18
	Rio Conchos	NA	NA	NA	377.8	311.1	17
	Del Rio/Laredo	54.8	52.3	4	6.9	6.2	10
	Falcon/The Gulf	765.4	716.0	6	503.7	503.7	0
1000-1500	Rio Salado	NA	NA	NA	121.0	61.7	49
	Rio Alamo/San Juan	NA	NA	NA	261.7	202.5	23
> 1500	Hudspeth	27.6	17.0	38	NA	NA	NA
	Presidio	4.0	0.2	95	NA	NA	NA
	Pecos[1]	250	30	88	NA	NA	NA

[1] The figures for the Texas portion of the Pecos Subbasin are estimates only.

Table IV-2. An example of cotton seed and lint yields in a 20 acre cotton field irrigated with water of 1400 ppm (2.2 dS m^{-1}) in the Hudspeth Co. Texas (Unpublished Report, Texas Agr. Ext. Service and Texas Agr. Expt. Sta., 1997).

Sections	Soil Type	Sat water Content	Soil Salinity	Yields Seed	Yields Lint
		g/100g	dS m^{-1}	-----lb/acre-----	
1.	Glendale silt clay loam	58	2.8	6,760	1,760
2.	Glendale silty clay loam	63	6.4	4,550	1,180
3.	Glendale silty clay	71	8.7	3,600	930
4.	Tigua silty clay	70-100	11.5	0	0

water was estimated at 1400 ppm during the main growing season. This example may illustrate that sustainability of salt tolerant crop production involving cotton, grains, and many forage crops are also closely tied with soil properties and quality of water supply for irrigation. In other words, crop producers need irrigation water with quality better than that of municipal sewage effluent or agricultural drainage water to sustain farming, unless the production field consists of sandy soils.

Land Use Conversion: The agricultural land which had been converted to residential or commercial uses amounts to about 8000 acres in and around El Paso, and is growing. This figure is substantial, yet is small when compared to the loss of agricultural land which has occurred in the adjacent irrigation districts, Hudspeth and Presidio, due to uncertain water supplies and soil salinization. Soil salinization reduced land productivity in these districts, and begins to appear in clay soils of the lower half of the El Paso Valley (Table II-2).

The conversion of some agricultural lands, however, has impacted on the quality of subdivisions developed in the valley. In addition to the lack of water suitable for domestic uses, the poorly permeable nature of clayey soils in the valley has presented some drainage problems as well as difficulties in achieving the dream of beautiful country living as noted at the onset. This is particularly true when the agricultural land consisting of Soil Groups V-3 and V-4 are converted to nonagricultural uses (Chapter III). As indicated earlier, these soils occupy about 70% of the irrigated land. Soil capabilities and measures required to transform these soils to a condition suitable for country living (discussed in Chapters II and III) must be considered when planning conversion.

With increasing conversion of the Rio Grande water from agricultural to municipal uses, it is entirely possible that large areas of irrigated lands may have to be retired from crop production activities in the future. If there is a choice, the lands consisting of soil group V-4 could be targeted for retirement due to their low productivity, while retaining group V-1 through V-3 soils for crop production.

3. Use of Soils for Wastewater Reuse

The primary concern of water entities has been to secure water supplies to meet their needs, and wastewater handling has received less attention. Local monitoring data show that two of the main wastewater sources (agricultural drainage water and municipal sewage water) have elevated levels of salts and sodium, and in the case of some sewage water, it contains elevated levels of nutrient elements as well (Table IV-3).These wastewater streams have been the principal source of irrigation water quality degradation in the El Paso Valley. However, they can be a viable resource, especially during drought.

Reuse of Municipal Wastewater: Municipal sewage effluents currently available have undergone a secondary treatment plus chlorine and/or ultraviolet treatments to control microbial activities. However, the effluents from the wastewater treatment plants located in the valley contain elevated levels of dissolved salts, especially sodium salts (Table IV-3). There are several field reports indicting that the use of such wastewater for crop irrigation in the valley has caused soil structural degradation, especially during fall and winter months when the irrigation water supply from the Project is not available for dilution. For this reason, the municipal sewage effluent has not been used extensively for crop irrigation in the El Paso Valley, but has been used in the Hudspeth District along with agricultural drainage water from the El Paso Valley. This has resulted in excessive salt accumulation as discussed earlier (Fig. III-9 and Table IV-2), as well as significant hardening of the soils. This soil degradation problem needs to be addressed by water planners, as the quantities of sewage effluent are projected to increase with ongoing urbanization.

One way to reduce degradation of the project water quality is to increase reuse of municipal effluents for irrigating urban landscapes. Upland soils are more permeable and are less subject to sodium-induced dispersion than most soils in the valley. Such an idea has already been implemented in the Northeast District, using the reclaimed water from the Fred Harvey Plant, which produces effluent of low salinity and sodicity (Table IV-3). The soils in the Northeast District are mostly permeable (Group U-1 and U-3 soils), thus providing a sustainable system for reuse.

Table IV-3. Quality of various water sources in and around El Paso: 1997*

Water Sources	pH	Salinity		Sodicity (SAR)	Susp. Solid	Nutrients N	P	K
		ppm	EC		ppm	------ppm------		
City Potable Water								
Northwest	8.6	472	0.7				<.1	2.3
Northeast	7.9	527	0.8				<.1	5.8
East	8.1	578	0.9				<.1	9.3
Lower Valley	8.1	805	1.2				<.1	7.0
Reclaimed Water								
Fred Harvey	7.7	632	0.9	5.6	-	3	0.6	15
Haskell	6.7	896	1.7	8.6	8	31	2.0	19
Bustamante	7.2	1125	1.8	7.8	7	23	10.0	19
Northwest	7.4	1269	2.0	9.8	2	10	1.7	13
Agricultural Water Supplies								
Rio Grande								
El Paso	-	760	1.1	3.5	55	-	-	-
Tornillo	-	887	1.3	4.6	-	-	-	-
Hudspeth	-	1810	2.7	8.8	-	-	-	-
Agricultural Drainage water								
Montoya	-	1170	1.7	5.2	-	-	-	-
Tornillo	-	2880	4.2	11.1	-	-	-	-
Salty Well Water								
Eastside	-	1600	2.3	9.0	-	-	-	-
Valley	-	2000	2.9	10	-	-	-	-
		4000	5.9	14	-	-	-	-

*The values shown are typical readings, and the actual values may vary depending on location, and the time.

The situations with other treatment plants located in the valley are more difficult, not only because these effluents have elevated salinity and sodicity, but also because these plants are located in areas with soils which have low permeability. The quantities of salt which will be added through irrigation using such effluents amount to 4 to 6 tons per acre per year at a prevailing irrigation rate of 3 feet per season. The soils to be used must have sufficient permeability to prevent salt and sodium accumulation. Table IV-4 provides a tentative guideline for appraising soil suitability for irrigation with the salty reclaimed water without dilution. The guideline is based on the soil salinity survey conducted for different soil types shown in Table II-1 (Chapter II), and will change with the development of cost-effective soil improvement measures. The soils ideal for irrigation with reclaimed municipal effluents are Group U-2 and U-3 soils (Bluepoint loamy sand distributed along Interstate 10, and Hueco sandy loam in the East District). Detailed soil surveys should be undertaken prior to using salty reclaimed water for irrigation, including an assessment of the potential for ground water contamination.

The main reason for the high dissolved salt content of the Northwest Plant is believed to be the intrusion of saline perched water into the leaky sewer collection systems placed in the valley. Note that the lower end of the Upper valley has soils with high saline water tables. The saline water intrusion problem may also be contributing to the elevated salinity at two other plants located in the valley, but certainly to a lesser extent. Soil characteristics should be considered at least as a factor for future siting of water reclamation plants if reuse for irrigation is to be used as the primary disposal option. Other factors to be considered for minimizing saline ground water intrusion into the collection system, and the distance to and the elevation of the reuse area with suitable soils.

Reuse of Agricultural Drainage Water: The quality of agricultural drainage water varies with location, but on the average, drain water reaching El Paso has salinity levels similar to the municipal effluents, and sodicity levels lower than those of the municipal effluents (Table IV-3). These drain waters have traditionally been mixed into the irrigation water supply as a part of the annual water allotment to the El Paso Irrigation District since the inception of the Rio Grande Project. This practice has helped increase the quantity of water available for irrigation, and seems to have worked for growing cotton and grains, the traditional crop with

Table IV-4. Suitability of different soil groups for irrigation with salty reclaimed water, and potential constraints.

Soil Groups[1]	Soil Textural Families	Suitability in general	Potential Constraints
U-1	Deep loamy soils	Acceptable	Fresh aquifer below
U-2	Deep sand	Suitable	Excessive percolation
U-3	Sandy loam over caliche	Acceptable	Indurated caliche
U-4	Shallow gravelly loam over caliche	Acceptable	Indurated caliche
U-5	Shallow steep stony soil	Acceptable to Questionable	Runoff and caliche
V-1	Loamy over loamy sediments	Acceptable	Compaction
V-2	Sandy loam over sandy sediments	Suitable	
V-3	Silty clay loam	Unsuitable	Low permeability
V-4	Silty clay	Unsuitable	Low permeability

[1] Refer to Table I-1 for soil type identification

moderate to high salt tolerance. This practice is, however, becoming less compatible with water quality requirements to grow cash crops with low salt tolerance, and for supplementing municipal water supply. Various water management options are beginning to be examined, which may yield lower salinity in a cost effective manner. From a salt balance perspective, agricultural drainage water from the Upper Valley can be utilized more effectively for irrigating urban landscapes in upland areas of El Paso.

Agricultural drainage water from the Lower El Paso Valley is highly charged with dissolved salts (Table IV-3), mainly because salinity of the irrigation water used is already elevated. This drainage water is presently used for crop irrigation in the Hudspeth District along with municipal sewage water and a small amount of the project water spilled over from the El Paso Irrigation District. Irrigated farming there has played a role of disposing of saline wastewater in a cost effective manner, even though much of the areas had already been salinized as discussed earlier. Water planners must carefully evaluate water management options to sustain the wastewater disposal forming. Otherwise, it may become necessary to develop a regional salt depository to reduce salt transport from the middle Rio Grande to the Lower Rio Grande. Salinity of the Lower Rio Grande at Amistad is nearing 1000 ppm, and can exceed the level if saline agricultural drainage water is permitted to flow into it freely. The quantities of salts leaving the lower El Paso Valley average four hundred thousands tons annually.

LIST OF REFERENCES

Davis, M.E., and E.R. Leggat. 1965. Reconnaissance investigations of the ground water resources of the Rio Grande Basin, Texas. Texas Water Commission. Bul. 6502. 99 pages, Austin, TX.

Kaddah, M.T. 1976. Subsoil chiseling and slip plowing effects on soil properties and wheat growth on a stratified fine sand soil. Agron. J. 68:36-39.

Lovejoy, E.P., and W.C. Cornell. 1996. El Paso's Geological Past. Texas Western Press. The Univ. of Texas at El Paso.

Miyamoto, S., R. Garceran, and R. Garcia. 1997. Landscape irrigation with salty water, Grounds Maintenance Nov. Issue: 22-24.

Miyamoto, S. 1996. Salinity of the Rio Grande: Trends and management implication. Terra 14:265-278.

Miyamoto, S., L.B. Fenn, and D. Swietlik, 1995. Flow, salts and trace elements in the Rio Grande; A review. TWRI/TAES, MP 1764 College Station, Texas.

Miyamoto, S. 1990. Comparative effects of chemical amendments on salt and Na leaching. Irrig. Sci. 11:83-92.

Miyamoto, S. 1989. Reclamation of salt-affected pecan orchards. Proc. Texas Pecan Grow. Assn. p.1-14.

Miyamoto, S., and S. Helmers. 1988. Selecting soils for irrigated pecan production. Pecan South, 22(2):8-12.

Miyamoto, S., and I. Cruz, 1986. Spatial variability and soil sampling for salinity and sodicity appraisal in surface-irrigated orchards. Soil Sci. Soc. Am. J. 50:1020-1026.

Miyamoto, S., and I. Cruz. 1987. Spatial variability of soil salinity in furrow-irrigated Torrifluvents. Soil Sci. Soc. Am. J. 51:1019-1025.

Seager, W.R. 1981. Geology of Organ Mountains and Southern San Andres Mountains, New Mexico. New Mexico Bureau of Mines & Mineral Resources. Socorro, NM

Soil Conservation Service, USDA and Texas Agricultural Experiment Station. 1971. Soil Survey, El Paso County, Texas.

Texas Department of Water Resources. 1980. Ground Water Development in the El Paso Region, TX with the Emphasis on the Lower El Paso Valley. TDWR Report 246 Austin, TX.

ATTACHMENTS

Attachment 1A Typical Soil Profiles and Their Selected Properties: Upland Soils

Soil Units	Horizon Depth (Inches)	Soil texture	Gravel & stones	Soil structure	Soil hardness	Shrinkage %	Field Capacity (Inches/inch)	Available water (inches/inch soil)	Permeability (inches/hour)	Salinization Potential
U-1	Deep loamy soils									
	Pajarito sandy loam, slope = 1 - 3%									
	A 0-18	sandy loam	0%	blocky	hard	0-2		0-0.1	0.63-2.00	Low
	B 18-36	sandy loam	--	blocky	hard	0-2		0-0.1	0.63-2.00	
	C 36-60	sandy loam	--	blocky	hard	0-2		0-0.1	0.63-2.00	
	Turney sandy loam, slope = 1 - 2%									
	A 0-10	sandy loam	gravel 1-2%	blocky	hard	0-2	.25-.30	0-0.1	0.63-2.00	Medium
	B 10-34	clay loam	gravel 1-2%	blocky	hard	2-9		0-0.16	0.20-0.63	
	C 34-60	clay loam	caliche	part. cement	soft	2-9		0.0.15	0.20-0.63	
U-2	Deep Sand									
	Bluepoint loamy sand, slope = 1 - 8%									
	A 0-12	loamy sand	0	loose	soft	0	.05-.10	0-0.08	6.30-20.00	Very Low
	C 12-60	loamy sand	0	structureless	soft	0				
U-3	Sandy Loam over Caliche									
	Hueco sandy loam, slope = 0.5 - 1.5%									
	A 0-4	loamy sand	0	loose	soft	0	.10-.20	0-0.08	2.00-6.30	Low-Medium
	B 4-26	sandy loam	0	massive	variable	0-2		0-0.1	2.00-6.30	
	Calcic 26-58	--	caliche	cemented	hard	0				
	Wink sandy loam, slope = 1 - 2%									
	A 0-6	sandy loam	0	structureless	variable	0		0-0.1	0.63-2.00	Low-Medium
	B 6-24	sandy loam	0	prismatic	hard	0-2		0-0.1	0.63-2.00	
	Calcic 24-73	--	caliche	cemented	very hard	0				
U-4	Deep gravelly or stony loam									
	Augustin gravelly loam, slope= 1 - 8%									
	A 0-12	gravelly loam	10-30	granular	friable	0		0-0.1	0.63-2.00	Low
	B 12-30	gravelly loam	15-35	granular	friable	0		0-0.1	0.63-2.00	
	C 30-60	gravel & pebbles	50	loose	soft	0				
	Canutio gravelly sandy loam, slope = 1 - 8%									
	A 0-11	gravelly sandy loam	25-50	structureless	friable	0	.05-.10	0-0.05	2.00-6.30	Low
	C 11-60	stony sandy loam	35-75	loose	friable	0	0-0.05		2.00-6.30	
U-5	Shallow steep stony soil over caliche									
	Delnorte stony loam, slope = 1 - 30%									
	A 0-6	stony loam	25-40	granular	friable	0	.10-.15	0-0.05	0.6-2.0	Medium-High
	Calcic 6-30	stony caliche	caliche	cemented	hard	0				
	30-60	gravelly sand	loose	caliche coating	soft	0		0-0.1	2.00-6.30	

Attachment 1B Typical Soil Profiles and Their Selected Properties: Valley Soils

Soil Units	Horizon	Depth (Inches)	Soil texture	Gravel & stones	Soil structure	Soil hardness	Shrinkage %	Field Capacity (Inches/inch)	Available water (inches/inch soil)	Permeability (inches/hour)	Salinization Potential
V-1	Loam over Loamy Sediments										
	Gila loam (Gc) and Harkey loam (Ha)										
	A	0-17	loam	0	structureless	friable	0-2	0.23-0.25	0.11-0.15	0.63-2.00/0.20-0.63	low
	C	17-60	variable	0	massive	friable					low
	Glendale loam (Gd)										
	A	0-19	loam	0	blocky	friable	0-2	0.25-0.27	0.11-0.15	0.20-0.63	
	C	19-40	silty clay loam	0	blocky	hard		0.26-0.28	0.13-0.17	0.06-0.20	
V-2	Sandy loam over loamy sand or sandy loam										
	Gila sandy loam (Ga)										
	A	0-17	sandy loam	0	structureless	friable		0.15-0.18	0.09-0.12	0.63-2.00	very low
	C	17-60	variable	0	variable						low
	Vinton sandy loam (Vn)										
	A	0-12	sandy loam	0	structureless	very friable		0.13-0.15	0.07-0.10	0.63-2.00	very low
	C	12-60	loamy sand	0					0.06-0.08	2.00-6.30	low
V-3	Silty Clay loam over sand to loam										
	Anapra silty clay loam (An)										
	A	0-23	silty clay loam	0	subangular to blocky		10-15	0.25-0.30	0.13-0.17	0.06-0.20	very high
	C	23-60	fine sand	0	structureless		10-15		0.03-0.05	6.30-20.00	low
	Harkey silty clay loam (Hk)										
	A	0-12	silty clay loam	0	structureless	friable	10-15	0.25-0.30	0.13-0.17	0.06-020	high
	C	12-60	variable	0	variable		10-15				medium
	Glendale silty clay loam (Ge)										
	A	0-35	silty clay loam	0	blocky	friable	10-15	0.13-0.17	0.06-0.20		very high
	C	35-60	variable	0			10-15				medium
V-4	Deep silty clay over sand to loam										
	Glendale silty clay (Gs)										
	A	0-18	silty clay	0	weak subangular blocky	very hard	15-20	0.30-0.40	0.14-0.18	0.00-0.06	very high
	C	18-40	silty clay loam	0	variable		15-20		0.13-0.17	0.06-0.20	very high
	Saneli silty clay (Sc)										
	A	0-12	silty clay	0	weak subangular blocky	very hard	15-20	0.30-0.40	0.14-0.18	0.00-0.06	very high
	C	12-32	clay	0	med. & coarse angular		15-20		0.13-0.18	0.00-0.06	very high
	Tigua silty clay (Tg)										
	A	0-10	silty clay	0	weak subangular blocky	very hard	15-20	0.30-0.40	0.14-0.18	0.00-0.06	very high
	C	10-50	clay	0	massive		15-20		0.14-0.18		very high

Attachment 2A: Annual Water Requirements of Plant Species: Trees

Water use (Net)	Species	Full grown plant size Height/Width (ft)	
Low Usage <24"			
Afghan or Mondel Pine	(Pinus eldarica)	80	20
Emory Oak	(Quercus emoryi)	60	40
Cypress, Italian	(Cupressus sempervirens)	60	4
Mesquite, Honey	(Prosopis glandulosa)	25	20
Mesquite, Screwbean	(Prosopis pubescens)	20	15
Pistache, Texas	(Pistacia texana)	40	20
Medium Usage (24 - 36")			
Myrtle, Crape	(Lagerstroemia indica)	5	5
Black Pine, Japancia	(Pinus thunbergiana)	20	10
Aleppo pine	(Pinus halepensis)	40	15
Pomegranate	(Punica granatum)	15	10
Pistache, Chinese	(Pistacia chinensis)	30	20
Elm, True Chinese	(Ulmus parvifolia)	35	25
Stone Pine, Italian	(Pinus pinea)	60	25
Cypress, Arizona	(Cupressus glabra)	45	30
Honey locust, Thornless	(Gleditsia triacanthos inermis)	47	37
High Usage >36"			
Pecan	(Carya illinoensis)	80	60
Apple	(Malus sp.)	30	20
Cherry	(Prunus avium)	25	25
Pear	(Pyrus communis)	30	30
Persimmon	(Diospyros virginiana)	30	40
Plum	(Prunus domestica)	25	25
Cherry Plum, Purple	(Prunus atropurpurea)	25	25
Southern Magnolia	(Magnolia grandiflora)	40	25
Cottonwood, Western	(Populus fremontii)	80	50
Poplar, Bolleana	(Populus alba pyramidalis)	35	10
Willow, Weeping	(Salix babylonica)	40	35

Attachment 2B: Annual Water Requirements: Shrubs and ground covers

Water use (Net)	Species	Full grown plant size Height/Width (ft)	
Low Usage <24"			
Coyote Bush, Dwarf	(Babiana)	2	5
Iceplant, White	(Delosperma alba)	1	5
Iceplant, Lavender Pink	(Drosanthemum hispidum)	1	5
Iceplant, Trailing	(Lampranthus spectabilis)	1	5
Juniper	(Juniperus scopulorum)	20	15
Spreading Juniper	(Juniperus chinensis)	20	8
Sage, Silvercloud Cenizo	(Leucophyllum candidum)	3	3
Saltbush, Four-Wing	(Atriplex canescens)	6	8
Medium Usage (24 - 36")			
Heavenly Bamboo	(Nandina domestica)	6	3
Holly, Burford	(Ilex cornuta "Burfordii")	4	3
Holly, Chinese	(Ilex cornuta)	10	8
Holly, Wilson	(Ilex altaclarensis "Wilsonii")	8	8
Holly, Yaupon	(Ilex vomitoria)	25	15
Holly, Oregon Grape	(Mahonia aquifolium)	6	4
Mock Orange, Japanese	(Pittosporum tobira)	6	6
Red Tip, Photinia	(Photinia fraseri)	10	10
Cotoneaster, Pyrenees	(Cotoneaster congestus)	1	5
Cotoneaster, Rock	(Cotoneaster horizontalis)	1	5
Arborvitae	(Thuja orientalis)	15	15
Boxwood, Japanese	(Buxus microphylla japonica)	4	4
Clover, sweet	(Melilotus sp.)		
Privet, Glossy	(Ligustrum lucidum)		
Hawthorn, Indian	(Raphiolepis indica)	4	4
Juniper, Bluepoint	(Juniperus chinensis "Bluepoint")	20	8
Juniper, Hollywood	(Juniperus chinensis "Torulosa")	15	8
Lantana, Bush	(Lantana camara)	6	4
Lantana, Trailing	(Lantana montevidensis)	4	4
Pyracantha	(P. graeberi)	10	8
Sage, Texas, Cenizo	(Leucophyllum frutescens)	8	5
Silverberry	(Elaeagnus pungens)	10	10
Evergreen Euonymus	(E. japonica)	8	6
Oleander	(Nerium oleander)	15	10
Rosemary (Rosmarinus officinalis)		4	4
High Usage (>36")			
Rose	(Rosa sp.)	1	1
Strawberry	(Fragaria sp.)	½	-

Attachment 3A. Salt Tolerance of Plant Species: Trees

Species	Root-induced damage salt level	Foliar-Induced salt damage
Sensitive	**EC_e[1] < 3 dS m^{-1}**	
Pecan	Carya illinoensis)	Frequent
Apple	(*Malus sylvestris*)	Frequent
Cherry	(*Prunus avium*)	Frequent
Pear	(*Pyrus communis*)	Frequent
Persimmon	(*Diospyros virginiana*)	Occasional
Plum	(*Prunus domestica*)	Frequent
Moderately Sensitive	**3 < EC_e < 6**	
Cherry Plum, Purple	(*Prunus atropurpunea*)	Frequent
Magnolia, Southern	(*Magnolia grandiflora*)	Rare
Myrtle, Crape	(*Lagerstroemia indica*)	Most Frequent
Cottonwood, Rio Grande	(*Populus fremontii*)	Frequent
Poplar, Bolleana	(*Populus alba pyramidalis*)	Frequent
Moderately Tolerant	**6 < EC_e < 8**	
Aleppo pine	(*Pinus halepensis*)	Rare
Cypress, Arizona	(*Cupressus, glabra*)	Rare
Black Pine, Japanese	(*Pinus thunbergiana*)	Rare
American Sweet Gum	(*Liquidambar styraciflua*)	Rare
Pomegranate	(*Punica granatum*)	Rare
Pistache, Texas	(*Pistacia texana*)	Frequent
Pistachio, Chinese	(*P. glandulosa*)	Frequent
Elm, True Chinese	(*Ulmus parvifolia*)	Frequent
Oak, Emory	(*Quercus emoryi*)	Rare
Tolerant	**EC_e > 8**	
Stone Pine, Italian	(*Pinus pinea*)	Rare
Mesquite, Honey	(*Prosopis glandulosa*)	-
Mesquite, Screwbean	(*Prosopis pubescens*)	-
Willow, Weeping	(*Salix babylonica*)	Frequent
Salt Cedar	(*Tamarix chinesis*)	Rare
Afghan, Model Pine	(*Pinus eldarica*)	Rare
Cypress, Italian	(*Cupressus sempervirens*)	Frequent
Honey Locust, Thornless	(*Gleditsia triacanthos inermis*)	

[1] EC_e: Salinity of the soil saturation extract and salinity unit of 1 dS m^{-1} is equal to 680 ppm.

Attachment 3B: Salt Tolerance: Shrubs and Ground Covers.

Species	Root-induced damage salt level	Foliar Induced salt damage
Sensitive	**EC_e < 3 dS $^{-1}$**	
Hibiscus, Chinese	(*Hibiscus rosa-sinensis*)	-
Holly, Burford	(*Ilex cornuta, "Burfordii"*)	-
Holly, Chinese	(*Ilex cornuta*)	-
Holly, Yaupon	(*Ilex vomitoria*)	Rare
Heavenly bamboo	(*Nandina domestica*)	Frequent
Oregon grape	(*Mahonia aquifolium*)	Frequent
Photinia, Red Tip	(*Photinia fraseri*)	Frequent
Pittosporum, Japanese	(*Pittosporum tobira*)	-
Cotoneaster, Pyrenees	(*Cotoneaster congestus*)	Rare
Cotoneaster, Rock	(*Cotoneaster horizontalis*)	Rare
Rose	(*Rosa sp.*)	Most Frequent
Strawberry	(*Fragaria sp.*)	Frequent
Moderately Sensitive	**3 < EC_e < 6**	
Arborvitae	(*Thuja orientalis*)	Rare
Boxwood, Japanese	(*Buxus microphylla japonica*)	Very Rare
Clover, sweet	(*Melilotus*)	-
Privet, Glossy	(*Ligustrum lucidum*)	Rare
Hawthorn, Indian	(*Raphiolepis indica*)	Rare
Juniper, Bluepoint	(*Juniperus chineses "Bluepoint"*)	Occasional
Juniper, Hollywood	(*Juniperus chineses "Torulosa"*)	-
Juniper, Spreading	(*Juniperus chineses*)	-
Lantana, Tailing	(*Lantana montevidensis*)	Frequent
Yellow Sage (bush lantana)	(*Lantana camara*)	Frequent
Pyracantha	(*P. graeberi*)	Frequent
Sage, Texas, Cenizo	(*Leucophyllum frutescens*)	Frequent
Sage, Silvercloud	(*Leucophyllum candidum*)	Frequent
Silverberry	(*Elaeagnus pungens*)	Occasional
Southern Magnolia	(*Magnolia grandiflora*)	-
Moderately Tolerant	**6 < EC_e < 8**	
Coyotebush	(*Baccharis pilularis*)	Rare
Evergreen Euonymus	(*E. japonica*)	Rare
Oleander	(*Nerium oleander*)	Rare
Rosemary	(*Rosmarinus officinalis*)	Occasional
Tolerant	**EC_e > 8**	
Ice plants, common	(*Carpobrotus chilensis*)	None
Ice plants, Tailing	(*Lampranthus spectabilis*)	None
Saltbush, Four-wing	(*Atriplex canescens*)	Occasional

Attachment 3C. Salt Tolerance: Turf and Ground Cover Grasses.

Species	Root-induced damage salt level	Foliar Induced salt damage
Sensitive	**EC_e[1] < 3 dS m^{-1}**	No reported cases
Creeping Bentgrass	(*Agrostis palustris*)	
Kentucky Bluegrass	(*Poa pratensis*)	
Centipedegrass	(*Eremochloa ophiuroides*)	
Moderately sensitive	**3 < EC_e < 6**	
Buffalograss	(*Buchloe dactyloides*)	
Creeping bent	(*Agrostis palustris*)	
Red fescue	(*Festuca rubra*)	
Bahiagrass	(*Paspalum notatum*)	
Lovegrass	(*Eragrostis sp.*)	
Orchardgrass	(*Dactylis glomerata*)	
Moderately Tolerant	**6 < EC_e < 8**	
Ryegrass	(*Lolium sp.*)	
Tall fescue	(*Festuca arundinacea*)	
Zoysiagrass	(*Zoysia japonica*)	
Tolerant	**EC_e > 8**	
Common bermuda	(*Cynodon dactylon*)	
Hybrid bermuda	(*Cynodon spp. other than c. dactylon*)	
Paspalum	(*Paspalum L.*)	
St. Augustine	(*Stenotaphrum secundatum*)	
Wheatgrass	(*Agropyron sibiricum*)	
Pampasgrass	(*Cortaderia sellowiana*)	
Saltgrass	(*Distichlis stricta*)	

[1] EC_e: Salinity of the soil saturation extract and salinity unit of 1 dS m^{-1} is equal to 680 ppm.

Attachment 3D. Salt Tolerance: Agricultural Crops

Crop Category / Crops	Soil salinity causing yield reduction 0	10	25	50%
	-----------------	dS m^{-1}	-----------------	
Fiber Crops				
Cotton				
Forage Crops				
Alfalfa	2.0	3.4	5.4	8.8
Sudan	2.8	5.1	8.6	14.0
Fescue	3.9	5.5	7.8	12.0
Rye, perennial	5.6	6.9	8.9	12.0
Bermuda	6.9	8.5	11.0	15.0
Wheatgrass	7.5	4.9	13.0	19.0
Grain Crops				
Corn (maize)	1.7	2.5	3.8	5.9
Sorghum	6.8	7.4	8.4	9.9
Wheat	6.0	7.4	9.5	13.0
Barley	8.0	10.0	13.0	18.0
Tree Crops				
Apricot	1.6	2.0	2.6	3.9
Grapes	1.5	2.5	4.1	6.7
Peach	1.7	2.2	2.9	4.1
Pecans	-	2.5	-	-
Pistachio	-	4.5	-	-
Vegetable Crops				
Beans	1.0	1.5	2.3	3.6
Carrot	1.0	1.7	2.8	4.6
Onion	1.2	1.8	2.8	4.3
Lettuce	1.3	2.1	3.2	5.1
Pepper	1.5	2.2	3.3	5.1
Sweet potato	1.5	2.4	3.8	6.0
Corn, sweet	1.7	2.5	3.8	5.9
Potato	1.7	2.5	3.8	5.9
Cabbage	1.8	2.8	4.4	7.0
Spinach	2.0	3.3	5.3	9.9
Cucumber	2.5	3.3	5.3	8.6
Tomato	2.5	3.5	5.0	7.6
Broccoli	2.8	3.9	5.5	8.2
Squash (Zucchini)	4.7	5.8	7.4	10.0

Attachment 4. Glossary of Soil Terms

Chapter 1

Alluvial soil: Soils developed from river or stream sediments.
Aridisols: The dominant soils developed in arid climate.
Bolson: An intermountain basin which has no outlet or limited outlets.
Calcareous: Soil or geological deposits which contain calcium and or magnesium carbonates.
Calcic Horizon: A layer of soil which consists of caliche.
Entisols: Young soils which have no distinguished petrogenetic horizon.
Family, Soil: A term used by soil scientists to classify soils based on broad soil textural characteristics.
Flood Plain: The area of land adjacent to either sides of a stream which can be flooded in the event of high water levels.
Horizon, Soil: Refer to Chapter 2 listing.

Mapping Unit, Soil: The abbreviated notations on a soil map to identify the soil occupying the area. The notation is usually shown as a capital letter to identify the soil name followed by either another capital letter (indicating a low intensity survey) or a lower case letter to indicate high intensity survey.

Playa: A shallow central basin of a desert plain where rain water accumulates and evaporates.
Salinity: Refer to Chapter 2 listing.

Soil, Series: A conceptualized class of soil bodies (polypedons) that have specified limits on profile make-up. Soil series are used to name dominant or condominant polypedons that are similar in soil profile characteristics, except for texture.

Soil Type: The lowest category of U.S. system of soil classification, and the soil in the same type is supposed to have the same soil texture and profile characteristics.
Sodicity: Refer to Chapter 2 listing.
Subsoil: Refer to Chapter 2 listing.
Topsoil: Refer to Chapter 2 listing.
Upland: Land that has the soil material unworked by water in recent geologic time, and is mostly situated at a high elevation.

Chapter 2

Available water: The amount of moisture held in soils that can be used by plants, and is ordinarily expressed as the difference between the amount of soil water at field capacity and the amount at wilting point.
Calcic Horizon: Refer to Chapter 1 listing.
Dispersion: A process by which soil aggregates disintegrate into individual soil particles.
Exchangeable sodium: Sodium ions held on the cation exchange sites of clay particles.
Lineal Shrinkage: The extent of one dimensional shrinking of soils when the soil moisture content is reduced from a given percentage to the shrinkage limit.

Horizon, Soil: A layer of soil that is parallel to the land surface, and that has different characteristics, but is petrogenetically related to other layers in physical, chemical, and biological properties. The major horizons have assigned letters:
A Horizon - Mineral horizons that formed at the surface and have an accumulation of humus (organic matter) intimately mixed with the mineral fraction or have properties resulting from cultivation, pasturing, or similar kind of disturbance.
B Horizon - This horizon is formed below an A horizon and may have an accumulation of clay, carbonates, gypsum, or silica alone or in combination.
C Horizon - Horizons or layers that exclude hard bedrock, and are little affected by pedogenic processes.

Permeability: The rates of water percolation through a layer of soil, and is equivalent to the saturated hydraulic conductivity.
Plasticity Index: The difference in number between the liquid and the plastic limits, or synonymously, between the lower plastic limit and the upper plastic limit.
Salinity: The concentrations of dissolved salts either in water or in soils, and are usually expressed in ppm (parts per million) or an electrical conductivity unit of $dS\ m^{-1}$. The conductivity of $1\ dS\ m^{-1}$ equals 635 to 680 ppm.

Salinization, Soil: A process by which soil accumulates harmful levels of soluble salts for plant growth. This process usually begins when water penetration into and drainage from the root zone are restricted either by low permeability of the soil, soil stratification, and or by inadequate depths of irrigation.
Salt Concentration Ratio: The ratio of soil salinity to salinity of irrigation water, and is used as an indicator of

salt accumulation potential in soils.

Sand: Rock and mineral fragments in solids that have diameters ranging from 0.05mm to 2.0mm. Most sand grains consists of quartz, but they may be of any mineral composition.
Fine sand - 50% or more fine sand or less then 25% coarse and medium sand, its particle size is from 0.10 to 0.25 mm.
Medium sand - 25% or more coarse and medium sand and less then 50% fine sand; its grain size is 0.25 to 0.5 mm.
Coarse sand - 25% or more coarse and less than 50% any other one grade of sand, which its grain size is 0.5-2.0 mm.

Saturation Water Content: The water content of a saturated soil paste, and is an indication of soil water holding capacity as well as soil texture.
Slaking, Soil Aggregates: A process by which dry soil aggregates are disintegrated into smaller aggregates. This process is induced by rapid air and water entries into soil and is aggravated by the presence of sodium ions.
Sodicity: A measure of dissolved sodium concentrations relative to dissolved Ca and Mg in water or soils. It is expressed by the sodium absorption ratio (SAR) in water or soil extract, or by the exchangeable sodium percentage in the case of soils.
Sodification, Soil: A process by which sodium ions accumulate in the cation exchange sites of soil particles. This process usually begins following soil salinization which causes preferential adsorption of sodium ions on the cation exchange sites, and is accelerated through the use of irrigation water high in sodium.

Sodium Adsorption Ratio (SAR): A relation between dissolved sodium and divalent ions which can be used to predict the exchangeable sodium percentage of soil equilibrated with a given solution. It is computed by dividing Na concentrations in meq/L by the square root of Ca plus Mg concentration in mmol/L.
Subsoil: Usually, the B horizon with distinct characteristics caused by accumulation of clay, sesquioxides, humus, or a combination of these. Also known as true soil, or solum. If soils lack a B horizon, the A horizon is the solum.

Texture, Soil: The fraction of soil particles that contain sand, silt, and clay. Sand being described as coarse, which its particle ranges from 0.5mm to 2.0mm, and most of its grains consists of quartz. Silt comes from the weathering of sand, becoming a finer grain, which ranges in diameter from the upper limit of clay of 0.002 mm to the lower limit of very fine sand of 0.05 mm. After farther weathering of silt, clay is formed as the secondary minerals.

Topsoil: The layer of the uppermost part of the soil that is native or brought in for cultivation.
Water Repellency: A tendency of turf or turfed soils to repel water.

Chapter 3

Chiseling: To break up soil using narrow shank-mounted tools. It can be performed at depths beyond the normal plowing depth.
Gypsum: The common name for calcium sulfate used to supply calcium for ameliorating sodic soils.
Mulching: Any material such as straw, sawdust, leaves, plastic film, loose soil, etc., that is spread upon the surface of the soil to protect the soil and plant roots from the effects of raindrops, soil crusting, freezing, etc.
Polyacrylamide (PAM): Synthetic organic polymers which form weak binding of soil particles.

Subsoiling: Any treatment to loosen soil with narrow tools below the depth of normal tillage without inversion and with a minimum mixing of the soil. This loosening is usually performed by lifting action or other displacement of soil dry enough so that shattering occurs.

Topdressing: The distribution of a thin layer of selected or prepared soil to a turfgrass area. It is used for thatch control, smoothing or leveling a turfgrass surface.
Topsoiling: To place topsoil on the native or dispersed soils.

Verti-Drains: Vertical holes or trench as filled with permeable soils or sand to improve water infiltration and drainage. The size of the holes varies from half to as large as six inches, depending on the situations.

Wettability, Soil: The ability of soils or thatch to absorb water during the early stage of water infiltration.
Wetting Agent: Synthetic compounds used to improve soil wettability.

Unit Conversion

Length

1 mm	= 0.1 cm	1 inch	= 2.54 cm
	= 0.001 m		= 0.083 ft
1 cm	= 10 mm	1 ft	= 12 in
	= 0.01 m		= 30.5 cm
	= 0.394 in		= 0.333 yd
1 m	= 100 cm	1 yd	= 91.4 cm
	= 0.001 km		= 36 in
	= 1.094 yd		= 3 ft
1 km	= 1000 m	1 mil	= 1.61 km
	= 1094 yd		= 5280 ft
	= 0.621 mil		= 1760 yd

Area

1 m^2	= 10000 cm^2	1 ft^2	= 929 cm^2
	= 1550 in^2		= 0.111 yd^2
	= 1.196 yd^2		= 144 in^2
1 ha	= 10000 m^2	1 acres	= 4047 m^2
	= 0.01 km^2		= 0.405 ha
	= 2.47 acres		= 43,560 ft^2
1 km^2	= 100 ha	1 mil^2	= 259 ha
	= 247 acres		= 2.59 km^2
	= 0.386 mil^2		= 640 acres

Volume

1 L	= 1000 ml	1 ft^3	= 28.32 L
	= 0.264 gallons		= 7.481 gallon
1 m^3	= 1000 l	1 AF	= 1233 m^3
	= 35.31 ft^3		= 325,900 gallon
	= 1.309 yd^3		= 43,560 ft^3

Mass

1 g	= 0.0353 oz	1 oz	= 28.35 g
1 kg	= 1000 g	1 lb	= 453.6 g
	= 35.27 oz		= 0.4536 kg
	= 2.205 lb		= 16 oz
1 ton	= 1000 kg	1 short	= 907.2 kg
	= 2204 lb	ton	= 2000 lb

Flow

1 l/s	= 86.4 m^3 /day	1 gpm	= 0.0631 l/s
	= 15.9 gpm		= 1440 gpd
	= 0.070 AF/day		= 0.00442 AF/d
1 m^3/s	= 1000 l/s	1 mgd	= 43.8 l/s
	=15, 900 gpm		= 3785 m^3/day
	= 22.8 mgd		= 694 gpm
	= 35.3 cfs		= 1.55 cfs
	= 70 AF/d		= 3.07 AF/day
			= 36.84 A-IN/day