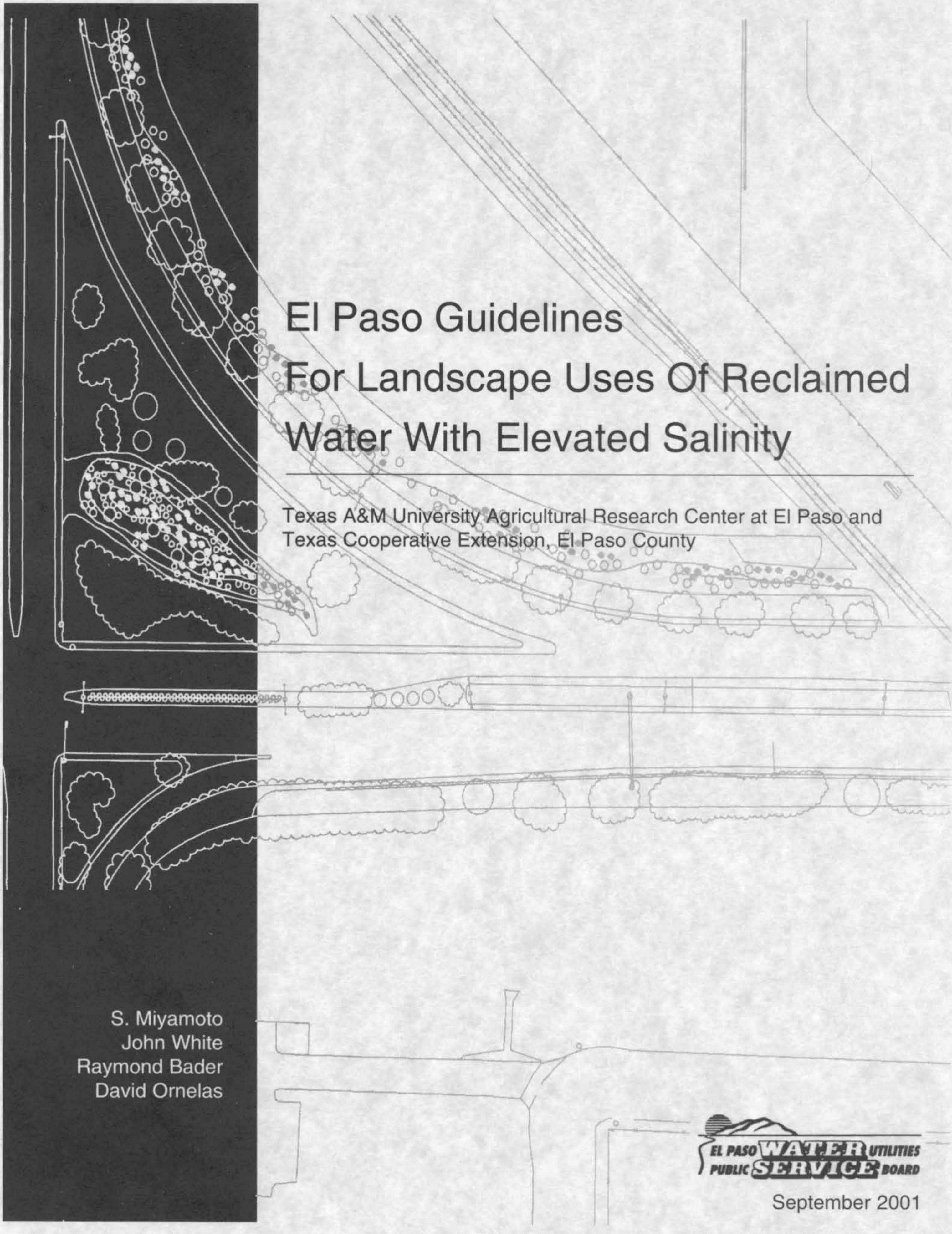

El Paso Guidelines For Landscape Uses Of Reclaimed Water With Elevated Salinity

Texas A&M University Agricultural Research Center at El Paso and
Texas Cooperative Extension, El Paso County

S. Miyamoto
John White
Raymond Bader
David Ornelas

El Paso Water Utilities
Public Service Board

September 2001

Acknowledgment

The information presented in this document was developed for assisting potential users of reclaimed water with elevated salinity in irrigating landscaped areas in and around El Paso. The data collection was supported by a joint project between El Paso Water Utilities, and the Texas Agricultural Experiment Station with a matching grant from the Water Conservation Field Service Program administered by the U.S. Bureau of Reclamation. The following personnel have contributed to the preparation of this document: Raymond Bader, El Paso County Cooperative Extension, John White, formerly El Paso County Cooperative Extension, David Ornelas, Manager of Biosolids & Water Reuse, El Paso Water Utilities, and S. Miyamoto, Professor at Texas A&M University Agricultural Research and Extension Center at El Paso. The document was reviewed by John Balliew, Manager of Environmental Compliance at El Paso Water Utilities, and by David Allen, the Bureau of Reclamation, El Paso Field Division.

Contents

About the Documents

This publication was prepared mainly for the convenience of ground maintenance supervisors/managers and landscaping professionals who may use reclaimed water which has elevated salinity. Technical data are available in Attachment which is a companion document to this publication. For regulatory compliance, one should refer to applicable state codes as well as to local regulations. If you are a water planner or manager, please contact us for additional documents. If you need a simple write-up of reclaimed water projects or an application form for reclaimed water service, please contact Water Utilities.

El Paso Guidelines For Landscape Uses Of Reclaimed Water With Elevated Salinity

S. Miyamoto, John White, Raymond Bader and David Ornelas

Synopsis

The use of reclaimed water for landscape irrigation is subject to regulatory compliance plus modest upgrading of management knowledge and skills to control soil salinity and foliar-induced salt damage. If the landscape is developed on well-drained sandy soils using salt tolerant plants, little or no modification would be required. In some cases, however, salt-sensitive plants might have to be replaced by those which are tolerant to salts; some soils may have to be amended to enhance salt leaching, and/or sprinkler systems and scheduling may have to be modified to reduce foliar-induced salt damage or runoff. The need for these measures is site-specific. The soils should be managed to maintain permeability and be irrigated adequately to leach salts, but not to the extent of causing excessive percolation losses. The regulatory rules are primarily to safeguard against potential public health hazards and water contamination. The costs involved in implementing some of these measures will likely be offset by the savings that result from the lower prices of reclaimed water, especially in large landscape areas. The conversion to reclaimed water in El Paso has been mostly successful in landscapes developed on sandy soils when followed with good management.

Benefits of Reclaimed Water Irrigation

There are three fundamental reasons why reclaimed water is being considered for irrigating urban landscapes in the arid west, including El Paso. The first reason is to conserve limited freshwater resources to meet the domestic water need of growing cities. The second reason, probably more important to water users, is the price of water. Currently, reclaimed water from the Northwest Treatment Plant costs 48¢ per 100 cf, as opposed to $.80 to 1.80 per 100 cf of potable water supply. The prices of potable water increase with increasing uses of the water. At a prevailing rate of $1.48/100 cf for the potable water, the irrigation of one acre of turf (43,560 sq ft) with the potable water costs 2150 dollars/acre annually, and 697 dollars with reclaimed water. This would save $1452 per year per acre or $7,260 over a 5-year period. These savings can be plowed into whatever improvements or modifications necessary to use the reclaimed water. Obviously, the prices of water, both potable and reclaimed will change in the future. The latest proposed rate is $1.63/100cf for potable water, and 49¢/100 cf for reclaimed water.

The third reason is to contain the increasing cost of potable water supply. The cost of acquiring a new source of potable water is very high, and fresh water resources in the El Paso area are depleting faster than saline water resources. The treatment costs to make salty water suitable for domestic uses are high, and the disposal of brine rejects also adds to the cost. The use of salty water for landscape irrigation is a cost-effective alternative.

There are also some logistical reasons why the use of reclaimed water is considered a sensible alternative. The existing potable water supply capacity in some service areas, for example, is short of meeting the peak summer water demand which is driven by landscape irrigation. Using nonpotable water for irrigation will help alleviate this problem. Also, the use of reclaimed water for irrigation provides flexibility in water management options during a period of drought.

Quality of Reclaimed Water

Municipal sewage water after secondary treatment has been used successfully to irrigate landscapes in many communities in the Southwest and California (Table 1). Because of the improvements in water treatment technology, water quality problems associated with pathogens became manageable. However, some limited salt problems have been reported, especially when salinity of irrigation water exceeds a range of 500 to 1000 ppm. Locally, Ascarate Golf Course has been using reclaimed water from the Haskell Plant with no incidence of health hazard. Salinity of this reclaimed water averages 1000 ppm. The reclaimed water from the Northwest Plant has salt concentrations of 1100 to 1400 ppm, and a sodium adsorption ratio (SAR) of 9 to 11. When compared with the city potable water, salinity of the reclaimed water is 1.5 to 2 times higher, and the concentration of sodium (Na) 2 to 3 times higher. The main reason for the elevated salinity and sodicity is the intrusion of shallow saline ground water into the collection system placed in the valley. The annual salt loading that results from using the reclaimed water from the Northwest Plant is 5 to 6 tons per acre, which must be leached to sustain plant growth. As will be discussed later, Coronado Golf Course and several city parks in the Northwest service area are beginning to use this reclaimed water for irrigation.

The concentrations of trace elements, suspended solids, and nutrient elements vary with the treatment processes used (Attachment 1). The concentrations of trace elements in the outflow from the Northwest Plant are lower than those in some other reclaimed water sources. Suspended solids average 2 ppm which are also among the lowest, because this plant is equipped with filtration capability. This reclaimed water is practically free of odor, and is also disinfected

Table 1. Examples of golf courses irrigated with reclaimed municipal effluent in the Southwest and California.

Name Location	Salinity ppm	Sodicity SAR	Soil types	Years irriged.	Problems reported
Andrews G.C. Andrews, TX	300 - 500	2.5	sandy loam	15	No problem on fairways or greens
Municipal G.C. Tucson, AZ	450	1.2	sandy loam	22	No problem
Painted Dunes G.C. El Paso, TX	630	5.6	sandy loam	5	No problem on fairways or greens
Tustin Ranch G.C. Tustin, CA	700-950	1.5	sandy loam	6	Problems with green maintenance
Harding Park G.C. Los Angeles, CA	800-1000	3.3	sandy loam	9	Problems with green maintenance
Name withheld Los Angeles, CA	1000-1400	3.5	sandy loam	8	Problems on green and clay areas
Coronado G.C. El Paso, TX	1100-1400	9.0	sandy loam	3	Salt accumulation in caliche areas. Foliar damage

[3] SAR.: Sodium Adsorption Ratio

with chlorine and an ultraviolet treatment. Therefore, salinity and sodicity control and fertilization adjustments are the primary concerns when using this reclaimed water source for irrigation.

Three Types of Salt Problems

There are three types of problems caused by salts. The problems may or may not appear, depending primarily upon soil types and management practices. The first type is degradation of plant growth, appearance, and/or vigor when salts accumulate in soils to a level exceeding plant salt tolerance. This type occurs mostly in clayey soil (clay loam to clay), or in soils with poor water infiltration or poor drainage. It can appear over time, even when salinity of water is below 1000 ppm. Such soils are distributed mostly in the valley as shown in the attached soil map or Attachment 2. Salt problems have also developed in soils which contain an indurated caliche layer. Detailed soil profile characteristics are given in Attachment 3, and salt accumulation potentials in Attachment 4. The salt accumulation potentials are expressed by the ratio of soil salinity to salinity of irrigation water, or the salt concentration factor (SCF). Soil salinity is to be measured by the saturation extract method.

Salt accumulation potentials are greater as the SCF values go up, especially above 3.0. An example of salt accumulation in clayey soils of the valley is shown in Fig. 1. Inadequate or frequent light irrigation can also cause soil salinization as discussed in a later section.

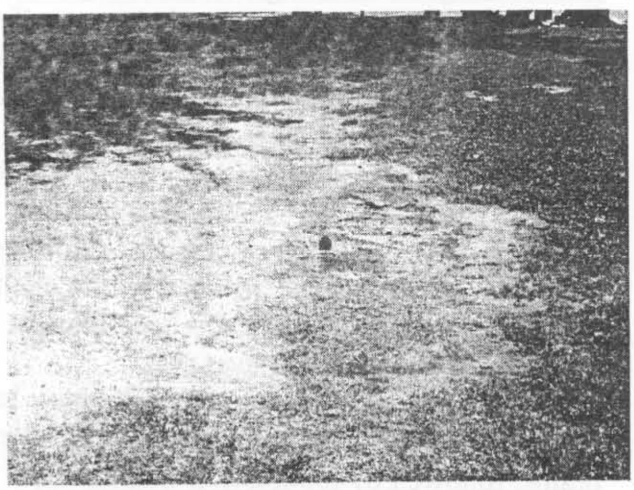

Fig. 1. An example of salt accumulation in clayey soils of the El Paso Valley.

The second type occurs when plant leaves are frequently sprayed or sprinkled with saline water. This form of salt damage, commonly referred to as foliar-induced salt damage becomes rather common when salinity of irrigation water exceeds about 1000 ppm. However, the extent of foliar damage is highly variable, depending on plant species, types of sprinklers used, and scheduling of irrigation. Foliar-induced salt damage occurs most frequently under daily irrigation, and the damage is significantly reduced by irrigating every other day or at longer intervals. An example of locust trees affected by foliar salt adsorption is shown in Fig. 2. Many tree and shrub species are sensitive to foliar-induced salt damage. The tolerance of various landscape plants to this form of salt damage is given in Attachment 6.

The third type is the degradation of soil structure caused by sodium salts. Sodium ions, when adsorbed on the surface of soil particles, are known to encourage disintegration of soil aggregates, especially when salinity of irrigation water is low. This can lead to soil hardening and poor water infiltration, especially rainfall

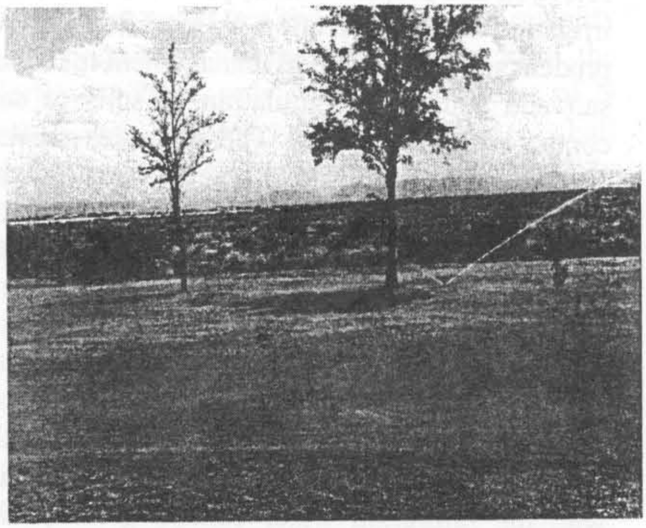

Fig. 2. Honey Locust trees affected by foliar salt adsorption under sprinklers.

infiltration. Our water infiltration study conducted with four different soils from the El Paso area, however, indicates the elevated levels of sodicity of the reclaimed water from the Northwest Plant, up to the SAR of 12, had little effect on the rate of initial water infiltration, because of the elevated salinity of the water. The sodium effect appears at low salinity (below 1000, especially below 500 ppm), primarily in the valley soils which have weak soil structure, when large quantities of water are used in an attempt to leach salts. The results have also shown that the differences in water infiltration caused by water quality were much smaller than those inherent to different soil types.

In addition to the salt problems mentioned above, water users should be aware that the salts brought through reclaimed water can leave white spots on vehicles and buildings if sprays are allowed to drift. Most of these salt problems, including the three types mentioned earlier can be corrected through good planning and prudent management. At the same time, salts can cause severe problems if not managed properly.

Reducing Salt and Sodium Problems

There are four key elements in successful use of reclaimed water for landscape irrigation; i) soil selection and preparation, ii) plant selection, iii) irrigation system selection or modification, iv) prudent soil and irrigation management to reduce salt and sodium accumulation in soils or salt contact with plant leaves. These features are also applicable to irrigation with potable water, but the degree of control or management usually must be elevated when water of elevated salinity and/or sodicity is used.

Soil Selection and Preparation

To avoid salt accumulation, the soil should have textures no finer than loam. Clayey soils with the saturation water content greater than about 35% are prone to soil salinization (Fig. 3). The salt concentration factor (SCF) is the ratio of

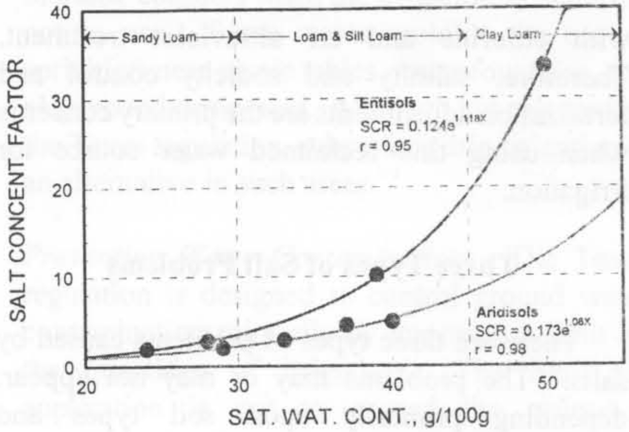

Fig. 3. The salt concentration factor (SCF) of Entisols (valley soils) and of Aridisols (upland soils) as related to the saturation water content.

soil salinity to salinity of irrigation water used, and it is an indication of the potential for soil salinization under reasonable irrigation management.

The ideal soil should not contain subsoil which restricts drainage or root penetration, such as a hard pan indurated with caliche. If present, the subsoil can be loosened to improve root penetration, drainage and salt leaching. Salty water should not be used in waterlogged areas with high water tables, unless the soil is modified to allow drainage.

The main technique used to reduce salt accumulation in soils containing subsoils indurated with caliche (such as Delnorte and Hueco soils) is chiseling or subsoiling. If the topsoil is shallow, the area should be topsoiled, typically 6 to 8 inches deep, using sandy loam or loamy sand. Under no circumstances, should clayey soils or caliche be used for topsoiling, as they will impair water infiltration. The final grade should ideally be topdressed with medium to coarse sand, especially on slopes. If trees or large shrubs are to be planted in areas with caliche, planting holes should be made deep enough to break through the caliche layer.

The main technique used to reduce salt accumulation in clayey soils of the valley is verti-drains, followed by topdressing with medium to coarse sand. If the soil is already affected by salts and sodium, broadcast applications of gypsum or other soil conditioners should be made prior to topdressing with sand (Attachment 5). The application rate of gypsum ranges from 1 to 5 tons/acre; the high rate usually applies to clayey soils in the valley. Repeated applications may be necessary if sodium ions remain high in the soil. Soil tests for "Exchangeable Na" are useful for making the decision. The soils in the valley with the exchangeable Na percentage greater than 6 to 10% usually respond to chemical treatments. If trees are to be planted in clayey soils of the valley, planting holes should be deep enough to reach the sandy substrata below the clay. The holes should be refilled with sandy soils or loamy sand prior to tree planting. An exception to this is the area with a high water table. In such cases, deep topsoil placement (topsoiling) over the original ground may be necessary.

When the ground consists of silty clay or silty clay loam with expandable clays, the use of ordinary verti-drains is of limited value, especially in high traffic areas. Aerification with a large core remover followed by sand topdressing may yield better results. Alternatively, topsoiling of the clay layer which has vertical drainage holes with loamy sand is another option. The clay strata should be deep-chiseled before topsoiling. A technique similar to this can also be used in high water table areas. However, a layer of gravel must be placed below the topsoil to prevent the upward capillary flow of the saline water from the table. In both cases, the salt balance in the topsoil is maintained through occasional leaching irrigations. Additional techniques for soil preparation are described in a technical bulletin (Soil Resources of El Paso) cited in the reference section.

Plant Selection

Plant selection is another important step in using reclaimed water with elevated salinity. The primary criteria for selection are salt tolerance and water requirements. However, some species are prone to diseases, insects or freeze damage, and these characteristics should also be considered. Consult with local horticulturists and nursery or landscape professionals when selecting plants.

Turf and Ground Cover Grasses: Most grass species are tolerant to both root and foliar-induced salt damage. However, some species, such as bentgrass and bluegrass, are not adapted to salty conditions (Table 2). Consult with turfgrass specialists for improved species or cultivars for use in putting greens. Moderately sensitive species shown in the table and in Attachment 6A have been grown in sandy soils with salt concentration factors (SCF) less than 3, but usually with considerable difficulty. Salt-tolerant or moderately tolerant species are a better choice. In fact, many of these tolerant species, especially common bermudagrass, have been grown successfully even in clayey soils with SCF much greater than 3.0.

Shrubs and Ground Covers: Shrubs and ground covers vary in their salt tolerance (Table 2), and some shrubs and vines are susceptible to foliar-induced salt damage (Attachment 6D). Sensitive species shown in Attachment 6B can be grown only in sandy well-drained soils using irrigation methods which minimize foliar contact with salty water. Most of these salt-sensitive species also prefer acidic to neutral soils, thus application of acidulants may also be necessary. The use of moderately salt-sensitive shrubs and ground covers (Attachment 6B) should also be limited to sandy, well-drained soils, preferably under mulch. If these shrubs are already established on poorly permeable soils, the soil may have to be amended to increase water infiltration, drainage, and salt leaching. Soil salinity tests are useful for determining such needs. The use of sprinklers (especially microjet and impact sprinklers) increases foliar-induced salt damage, especially when irrigated during day-hours when stomata are open. Moderately tolerant and tolerant species listed on Attachment 6B can be grown in most soils, even under sprinklers. Most of these species are also drought-tolerant.

Trees: Tree species have a wide range of tolerance to both root and foliar-induced salt damage (Table 2 and Attachment 6C). Pecans and most fruit trees are sensitive to both forms of salt damage. However, if the soil is highly permeable (SCF less than about 1.5), some of these trees have grown successfully with surface irrigation or under canopy sprinklers. Bare-root transplants of many of these species are susceptible to salt damage; and the use of low salt water reduces establishment problems. Tree species ranked as moderately tolerant and tolerant can be grown after good soil preparation in most soils with salty reclaimed water, especially if their root systems extend into sandy substrata. Most tree species prefer upland soils with good drainage, but some species, such as willows and some pines, can survive high water table conditions of the valley. Most of these species, especially willow, poplar, and cottonwoods, and to a lesser extent, locust and afghan pines can not tolerate direct sprinkling of water with elevated salinity. Salt cedars survive highly saline conditions, and they actually prefer saline soils. However, they are not only invasive, but also transport salts to their leaves, thus damaging adjacent plants upon salt excretion.

If salt-sensitive trees are already established, their survival will depend on soil types and irrigation management. If planted in sandy soils (such as Bluepoint series) or deep gravelly soils (such as Canutillo series), salt damage is likely to be minimal with good irrigation practices.

Table 2. The threshold salinity of some landscaping plants used in the Southwest: Root-induced damage[1].

Sensitive species EC_e[2] < 3 dS m^{-1} (2000 ppm), C_c[2] < 6 dS m^{-1}

Turf grass: bentgrass, bluegrass, centipede grass
Ground covers: jasmine, love grass, orchard grass, strawberry
Others: citrus, holly, pecan, plum, tulip tree, nandina, roses

Moderately sensitive: EC_e = 3-6 dS m^{-1} (2000-4000 ppm), C_c = 6-12 dS m^{-1}

Turf grass: creeping bentgrass, red-fescue
Ground covers: alfalfa, bahiagrass, brome, clover, lantana, spreading juniper,
Others: arborvitae, bamboo, boxwood, hawthorn, magnolia, privet, pyracantha, sage,

Moderately tolerant: EC_e = 6-8 dS m^{-1} (4000-5000 ppm), C_c = 12-16 dS m^{-1}

Turf grass: rye, tall fescue, zoysia grass
Ground covers: african daisy, coyote bush, rosemary,
Others: black pine, aleppo pine, oleander, pistachio, pomegranate, bottlebrush

Tolerant species: EC_e > 8 dS m^{-1} (> 5000 ppm), C_c > 16 dS m^{-1}

Turf grass: bermuda, paspalam, St. Augustine, wheatgrass
Ground covers: iceplant, saltgrass
Others: mesquite, palm, saltbush

[1] The salt tolerance data originally developed by a number of scientists are for comparative purposes only, and the actual tolerance can vary depending on variety, climatic conditions, and water management practices employed.

[2] EC_e and C_c; The salinity of the saturation extract or that of soil solutions expressed in conductance units above which plant performance may decline. A factor of 635 to 680 should be multiplied to convert dS m^{-1} to ppm.

Otherwise, trees can deteriorate over time as soil salinity increases gradually, unless the soil and/or irrigation practices are modified to enhance salt leaching.

Irrigation System Selection

Irrigation systems have to be compatible with soils and the plants to be grown. When using saline water, it is also necessary to control foliar-induced salt damage, as well as runoff and public nuisance problems. Irrigation systems must also meet the regulatory requirements which are discussed in a separate section (refer to Attachment 10).

Sprinkler irrigation is suited for irrigating lawn areas and recreational turf established on sandy soils, and is most advantageous when the soil is shallow. Sprinkler coverages have to be sufficient to avoid creating dry spots where salts will accumulate. In soils with textures finer than sandy loam, sprinkler irrigation can cause runoff, especially when the ground is slopped or compacted. Sprinkler irrigation can also cause foliar-induced salt damage in shrubs, flowers and many tree species when their leaves are sprinkled frequently. Refer to Attachment 6D for their relative tolerance. In the case of large trees, foliar-induced salt damage can be reduced by converting to low-angle sprinklers or by extending irrigation intervals. In shrubs and flower beds, the system can be converted to bubblers and/or drip systems. Mulching the ground surface reduces salt accumulation, runoff as well as soil structural degradation.

Potable sprinklers placed on quick-couplers are still used in public parks and school grounds, mainly because of the low costs of initial installation. Some quick-couplers can be easily tampered with, and are prone to leak. These systems are not suitable for reclaimed water.

Bubblers are ideally suited for irrigating shrubs and small trees, especially those species sensitive to foliar-induced salt damage (Fig. 4). They come in different sizes and flow capacities. In shallow soils, bubbler spacings should be designed to obtain as uniform coverage as possible. This is particularly true when this system is to be installed in plantings which have been irrigated with sprinklers. The plant roots under sprinkler irrigation are often shallow and spread laterally. If the conversion is considered, be aware that the water supply system designed for wide-spaced sprinklers may not be compatible with bubbler irrigation. Mulching helps reduce soil structural degradation and control weeds. Bubbler irrigation, when designed correctly, provides good salt leaching and reduces nuisance problems associated with sprinklers.

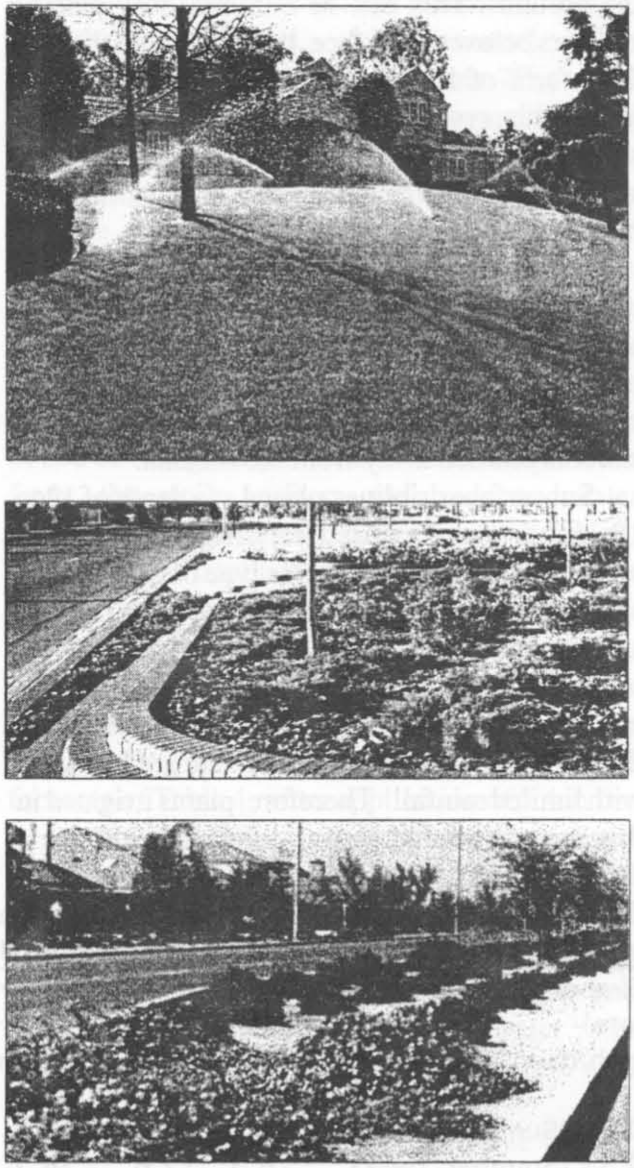

Fig. 4. Three types of irrigation systems; sprinklers, bubblers and drip systems from top to bottom figures.

Drip (or trickle) irrigation is an option for irrigating shrubs, ground covers, and trees. Emitter plugging has been a problem in the past because of the high concentrations of particulates in reclaimed water. Improved filter and emitter designs have substantially reduced these problems. In addition, many of the newer wastewater treatment plants are equipped with a filtration system, and do not allow ponding which causes algae growth. Surface-placed drip irrigation is used commonly in shrubs or flower beds. Salts usually accumulate at the edge of the wetting fronts, and may leave unsightly marks on the ground. This can be minimized by placing emitters below the surface, then mulching the bed. This form of installation is also used for trees. When this system is to be installed in shallow soils or in shrub plantings previously irrigated with sprinklers, adequate coverages must be provided.

Subsurface drip irrigation is used most effectively for irrigating street medians (Fig. 4) and strips along highways. This form of irrigation has the lowest potential for ground water contamination, as long as the runoff from the street is drained away from the median.

Subsurface driplines placed at a depth of 12 to 18 inches are also used for irrigating turf and some trees. The soils for this type of installation should be deep, such as Bluepoint soils. The line spacings range from 1 to 2 ft in turf and 2 to 4 ft in trees and shrubs. These systems are currently much more costly than sprinklers. The soil above the driplines will eventually be salinized in areas with limited rainfall. Therefore, plants irrigated in this manner should be salt-tolerant, and have a deep root system.

The water supply required to maintain landscapes during hot summer months depends on the types and densities of plants used, and the method and duration of irrigation. Typically, the summer peak demand of landscapes involving turf and shrubs range from 1/4 to 1/3 of an inch per day. These rates of water consumption correspond to 6,800 to 9,000 gallons per acre per day or the water supply rates of 4.7 to 6.3 gpm per acre, assuming 24-hour run at an irrigation efficiency of 100% (Table 3). Sometimes, however, water evaporation rates can reach ½ inch per day. This means that the base flow rate is more like 20,000 gallons per acre per day or 13 gpm per acre at an irrigation efficiency of 70%. This is the minimum required for drip irrigation designed for 24-hr usage per day. Sprinklers and bubblers have specific flow and pressure requirements, and are operated usually less than 24 hrs per day. The actual duration of sprinkler irrigation is also confined by wind, usage schedules as well as by local regulations. Therefore, the actual water supply capacity has to be greater by several folds. Water users should consult with competent irrigation engineers for these details.

When existing irrigation systems are to be converted for irrigation with reclaimed water, it is important to check regulatory codes with Water Utilities. It is also important to check if the existing irrigation system is capable of delivering the water required in a shorter time. Typically, the system capacity needed to apply water to one acre during night hours only is about 20 gpm (which delivers 0.44 inch in 10 hours).

Table 3. Water evaporation rates, and the water supply needed to irrigate 1 acre in various time periods at an assumed irrigation efficiency of 100%.

Evaporation rate[1] inch/day	Water supply to irrigate 1 acre in (gpm)				Water supply to irrigate 1 acre in (cfm)			
	24	12	6	3 hours	24	12	6	3 hours
0.25 (Summer, normal)	4.7	9.4	18.8	37.6	0.62	1.25	2.5	5.0
0.33 (Summer, peak)	6.3	12.6	25.2	50.4	0.84	1.67	3.3	6.7
0.50 (Summer, extreme)	9.4	18.8	37.6	75.2	1.25	2.5	5.0	10.0

[1] 1 acre-inch of water is equal to 27,152 gallons or 3,630 cf.

Soil and Irrigation Management

Soil Management: The soil, especially on slopes should be maintained so as to allow good water infiltration. Physical compaction of the top soil is the most common cause of poor water infiltration. The primary measure to alleviate soil compaction in turf is to use aerification equipment, and if needed, followed by topdressing with sand. In a small area, hand tools can be used to loosen the top soil, then the ground can be topdressed with sand or mulched with other materials. In some cases, it may be necessary to build a walkway to reduce soil compaction.

The structural degradation of soils caused by sodium is another process which lowers water infiltration, especially that of rainfall. Applications of chemical amendments such as gypsum, sulfur and polyacrylamide (PAM) are usually recommended (Attachment 5). However, their effectiveness depends on the soil and water quality. In general, these chemical treatments are most effective when leaching irrigation is to be attempted using water having salinity less than 1.0 dS m^{-1} (650 ppm). These chemicals, however, have limited effects on initial infiltration of less than an inch of water, since the dryness of the soil largely controls the rate of water intake. In any case, chemical amendments are not a substitute for physical means of alleviating soil compaction or undesirable soil texture or profiles. Mulching or a thick stand of grass can also help reduce soil structural degradation caused by sodium.

Water infiltration into old turf areas, especially bermudagrass is reduced by low wettability. Stems of dormant bermudagrass release wax-like compounds and make sandy soils poorly wettable or water-repellent. Deep irrigation with wetting agents usually leaches out the wax-like compounds and restores wettability and water infiltration. An alternative is to aerify throughly or to overseed with cool season grass. This problem should be minimized prior to conversion to the reclaimed water. Otherwise, it leads to runoff, droughty conditions, then salt and sodium accumulation.

Irrigation Management: The annual water requirements for maintaining landscapes vary with the plant species used (Attachments 7A through 7C). Recreational turf is among the high water users; warm season grasses requires about 40 inches, and when overseeded with cool season grasses 50 inches plus. The growing season for warm season grasses typically extends April through September for a period of 6 months. This means an average requirement of 6.6 inches/month, which is usually adjusted to the application efficiency, the soil type, and the rainfall of the particular year. This figure also applies to densely planted trees and shrubs if rapid growth is intended. The annual water requirements shown in Attachments 7B and 7C are lower than 40 inches and are for maintaining grown trees, but not for achieving rapid growth.

The goal of irrigation management is to provide water to meet these estimated requirements as efficiently as possible. This means that irrigation managers have to decide upon the optimum scheduling of irrigation, besides keeping the irrigation system in working order and keeping grass in good shape. The loss of sod covers greatly increases water evaporation from the soil surface and reduces water penetration (Table 4), thus salt leaching. Increasing the depth of irrigation can compensate for the loss of sod cover only if more than ½ inch of water is applied. Daily or bi-daily irrigations using 1/4 or 1/3 inches per application usually do not provide adequate water penetration to cause salt leaching in bare soils. As noted in the footnote of Table 4, water application of 5.4 in/mo is equal to 40.5 in. per 6 months at an assumed irrigation efficiency of 80%, and 3.7 in./mo. to 30 in. per 6 months at an assumed irrigation efficiency of 75%. Reducing irrigation to less than 40 in. per 6 months can cause salt accumulation in most soils when water with elevated salinity is used for irrigating turf with poor sod covers (Attachment 9).

Judging from the data shown in Table 4, deep, but infrequent irrigation yields higher water use efficiency and better salt leaching. However, the

Table 4. Evaporation from water penetration into two soil types as influenced by irrigation regimes.

Water Applied (in./mo.)	3.7 in./mo.[1]				5.4 in./mo.[1]			
Intervals (days)	1	2	3	4	1	2	3	4
(in./application)	.12	.24	.36	.48	.18	.36	.54	.72
Evaporation (% of applied)								
Loamy sand								
with dry sod[2]	71	67	66	64	-	-	-	-
Bare	97	94	93	92	95	90	88	84
Silt loam								
with dry sod[3]	71	69	62	58	-	-	-	-
Bare	96	89	86	81	91	83	78	70
Water penetration (in) after 28 days of irrigation during early spring months								
Loamy sand								
with dry sod[2]	11	12	13	14	-	-	-	-
Bare	2	4.5	5	5	4	7	8.5	10
Silt loam								
with dry sod[2]	5.5	6.5	8.1	9	-	-	-	-
Bare	2	3.5	4.5	6	4	6.4	7.5	9

[1] These values are the net application. For an assumed irrigation efficiency of 80%, they are equivalent to 4.6 and 6.75 in./mo. or 28 and 40.5 in./6 months

[2] The thickness of the dry sod was approximately 0.4 in.

Table 5. Field capacity, available soil water storage capacity, and irrigation depths necessary in different soil types with or without established sod.

Soil texture	Coarse to Loamy Sand	Sandy loam	Silt loam	Clay loam
Soil types	Bluepoint Canutillo	Hueco Delnorte	Harkey	Glendale Saneli
Field Capacity (in/in of the soil)				
soil only	0.05 - 0.10	0.10 - 0.20	0.25 - 0.35	0.35 - 0.45
with turf & thatch	0.15 - 0.20	0.20 - 0.30	0.35 - 0.40	0.40 - 0.45
Leaching Irrigation Depth (inch per 1 ft of the soil)				
soil only	(.6 - 1.2)[1]	1.2 - 2.4	3.6 - 4.2	4.8 - 5.4
with turf & thatch	(1.8 - 3.6)[1]	2.4 - 3.6	4.2 - 4.8	4.8 - 5.4
Irrigation at 50% depletion[2] (inch per 1 ft of the soil)				
soil only	.3 - 0.5	0.5 - 1.0	0.8 - 1.0	0.8 - 1.0
with turf & thatch	.9 1.8	1.0 - 1.8	1.0 2.0	1.0 2.0

[1] Salts in loamy sand are usually leached during normal irrigations without leaching irrigation.

[2] 50% depletion of the available water storage.

depth of irrigation has to be adjusted to soil conditions and the depth of the root zone. Table 5 shows the depth of water which can be retained in the top soils with or without sod. The table also includes the depth of water required to wet dry soils to a depth of 1 ft when the soil is completely dry. In the case of coarse sand or gravelly sandy loam such as Bluepoint and Canutillo soils, it may take only ½ inch of water to wet to a depth of 1 ft, whereas in clayey soil, it may take as much as 5 inches of water to wet 1 ft of the soil. This also means that salts can be leached readily in deep sandy or gravelly soils without using so-called "deep irrigation". Deep irrigation is needed in clayey soils with high water holding capacities or in stratified soils, and is commonly referred to as leaching irrigation.

During the growing season, irrigation water is applied before the soil is completely dried out. In drought-sensitive plants, water is applied when about 50% of the available soil moisture in the root zone is depleted, whereas in most plants, irrigation can be initiated when about 75% of the available soil water storage of the main root zone is depleted. The irrigation depths necessary to refill the depletion to a depth of 1 ft are also shown in Table 5. Typically, irrigation depths in sandy soils range from ½ to 1 inch per application, and 1 to 1½ inches in loamy to clayey soils. When thatch is thick, or topdressing is made, the soil or the thatch increases water retention, thus more water may have to be applied at once. It is always a good idea to check whether water is penetrating to the desired depth or not. At the same time, irrigation depths have to be adjusted by considering runoff, trafficability, etc.

Once the irrigation depth is determined, the frequency of irrigation can be estimated from the information shown in Attachments 7A, 7B and 7C to meet the water requirements of various plant species. Since the plant water requirements are merely an estimate, the scheduling guides are also an estimate. The irrigation frequency guidelines (Attachments 8A, 8B and 8C) are based on the normal weather pattern, assuming no rainfall and the irrigation efficiency of 100%. These intervals may have to be adjusted, depending on the weather condition, plant responses, and salt accumulation potential (Attachment 9).

Many believe that extra water should be applied to leach salts when salty water is used for irrigation. This concept is valid in theory, but much depends on the soil types and salt tolerance of the plants to be grown. At the current level of salinity of the reclaimed water from the Northwest Plant (2 dS m^{-1}), the extra water needed to control salinity is less than 10% of the applied in all plant species, except for sensitive ones (Table 6). This level of drainage can be obtained naturally in deep, well drained, sandy or gravelly soils such as Bluepoint and Canutillo series. In clayey soils, however, salt leaching can not be attained unless extra water is applied. Leaching irrigation may be commenced once or twice during the first irrigation in the early spring when the soil is most permeable. In the case of salt-sensitive plants, irrigation depths must be increased by as much as 20% to keep salt levels within the threshold at each irrigation. This is a main reason why we want to avoid the use of salt-sensitive species as much as possible.

Another important consideration in irrigation

Table 6. The leaching fractions required to maintain soil salinity below the threshold soil salinity.

Soil or water salinity		Sensitive[1]	Moderately sensitive[1]	Moderately tolerant[1]	Tolerant[1]
Soil Extract Salinity (dS m^{-1})		3	6	8	> 8
Threshold Salinity (dS m^{-1})		6	12	16	> 16
Irrig. Water Salinity			Leaching fraction (LF)[2]		
dS $^{-1}$	(ppm)				
1.0	635 ~ 680	.09	.04	.03	<.03
1.5		.14	.06	.05	
2.0	1270 ~ 1360	.20	.09	.07	<.07
2.5		.27	.11	.08	
3.0	1900 ~ 2040	.33	.14	.10	<.10
3.5		.41	.17	.12	
4.0	2540 ~ 2720	.50	.20	.14	<.14

[1] Refer to Table 2 or Attachments 6A, 6B, and 6C for applicable plant species.

[2] LF = C_I (2 C_C - C_I) where C_I the salinity of water, C_C the threshold salinity for plant growth.

management with salty water is to apply water as uniformly as possible over the area in turf. Dry areas will develop into salt spots over time. Even when water is applied uniformly over the turf, salt spots can develop if the soil conditions are not uniform in terms of infiltration and water penetration and drainage. Thus, irrigation management programs should be coordinated with soil management, especially in soils with SCF values greater than about 3.0.

Fertilization

Reclaimed water usually contains elevated levels of plant nutrients, especially N, P, K, and trace elements such as ion, manganese, zinc and copper. In the case of the Northwest plant, the dissolved concentrations of N, P, and K are averaging 10, 2.0, and 12.7 ppm. These amount to 27, 5.4, and 34 lb of N, P and K per acre-ft of water. The annual water application in the El Paso area ranges from 3 to 4 ft for common Bermuda. At an assumed water application of 3 ft per season, the plant nutrient input through irrigation with the reclaimed water from the Northwest Plant amounts to 81, 16, and 102 lb of N, P, and K per acre, respectively. These quantities should be subtracted from fertilizer recommendation rates given in Table 7. Nitrogen concentrations in the reclaimed water from the Haskell Plant are higher, and is expected to change in the near future.

Lawns and Recreational Turf: Nitrogen is usually the most frequently deficient element for growing turfgrass. Nitrogen fertilization in N-deficient soils usually improves growth, turf color, and water use efficiency. The amount of nitrogen required, however, varies with turfgrass species and the growth rate desired. Bermudagrass and ryegrass can respond to nitrogen application of up to 250 lb N/acre (5.7 lb/1000 sf) or more, whereas St. Augustine and Tall fescue can be maintained at lower rates (Table 7). The actual rate of N application should be adjusted to the growth rates and turf quality desired, and what is contained in the reclaimed water. The application is usually made in the spring to early summer months. Nitrogen application in mid-summer causes excessive growth of common bermuda. However, some nitrogen fertilization is required to maintain turf

Table 7. Suggested guidelines for nitrogen fertilization of lawns, recreational turf and deciduous trees.

Soil types	Preferred N forms	Application frequency	Annual rates	
			N lb/a	
Lawns and Turf			High user[1]	Medium
Upland	NH_4^+ - forms	2 - 3 weeks	150 - 250	75 - 120
	S- coated urea	2 - 3 months	125 - 200	50 - 100
Valley				
Sandy	The same as Upland soils	3 - 4 weeks	120 - 225	60 - 112
Clayey	Urea plus Ca amendment			
			100 - 200	50 - 100
loamy	Urea x NH_4 mix		100 - 200	50 - 100
Deciduous Trees			lb N/1000 sf[2]	
Upland	NH_4^+- forms	March, April, May	2 - 4	1 - 2
Valley				
Sandy	The same as Upland soils		2 - 4	1 - 2
Loamy	Urea x NH_4 mix	April, May, June	2 - 4	1 - 2

[1] High user: Bermudagrass, and Ryegrass

[2] 1 lb./1000sf equals 43lbs./acre.

color. Fall fertilization is recommended if additional turf growth is desired. When irrigated with reclaimed water, supplemental nitrogen is usually applied during March, April and May to enhance early growth.

The forms of nitrogen fertilizer affect both volatile and leaching losses. To minimize volatile losses, nitrogen fertilizers should be applied just prior to irrigation. To minimize N leaching losses, NH_4-forms of fertilizers such as ammonium sulfate (21-0-0) are preferred over urea (46-0-0) or nitrate forms, especially in gravelly or sandy soils, such as Canutillo and Bluepoint series. Surface-applied urea or nitrate moves with the wetting front after irrigation (Fig. 5), whereas NH_4-forms are retained at the cation exchange sites of the surface soils until they are oxidized to the nitrate form. In clayey soils of the Valley, urea can be used without extensive leaching losses. In either case, N recovery by plants will be enhanced by applying N fertilizers frequently, but at low rates. Nitrogen added in excess of plant uptake capacity will eventually leach out. This is particularly true in gravelly or sandy soils in uplands. The most efficient N application in such soils is fertigation. An alternative is to use a slow-release form of nitrogen, such as sulfur-coated urea, although it can be rather expensive. Mineral forms of N will

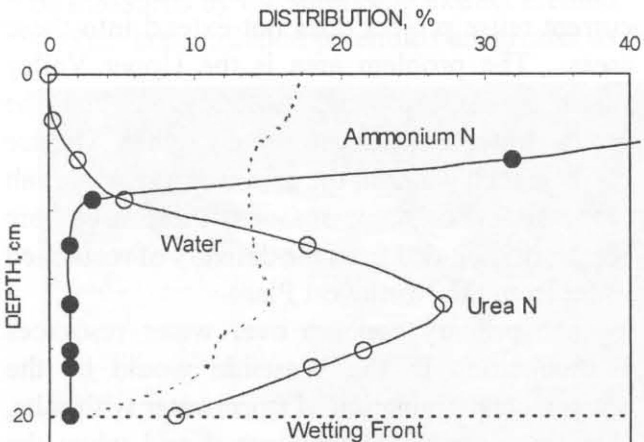

Fig 5. The distribution of surface-applied urea and ammonium sulfate following irrigation of clay loam soils at 2.2 inches (Miyamoto, 1978).

be exhausted in about 30 to 40 days, even applied at high rates, but S-coated urea can last for several months (Miyamoto 1998).

In the clayey soils in the valley, nitrogen fertilizers should be added after leaching irrigation in the spring following soil aerification, and if necessary, sand topdressing or gypsum application. Applications of gypsum or other Ca compounds along with urea or ammonium sulfate tend to stimulate NH_4 uptake and early-season growth, including root growth.

Phosphorus and potassium are usually added to fertilizer blends. Our tests, however, show that grasses grown in local soils rarely respond to application of these elements. Both elements are usually present in sufficient quantity in the reclaimed water. If the treatment process does not have adequate filtration of particulates, phosphorus can accumulate in soils when the reclaimed water is used for irrigation. Application of iron compounds may improve leaf color. Soil or plant analyses can help identify nutritional deficiency and fertilization requirements, if samples are collected correctly. Deficiencies in Fe and P can be induced by poor root growth associated with poor soil physical conditions.

Trees and Shrubs: Deciduous trees usually require nitrogen in the spring when shoot and leaf growth take place. The quantities of N required for high users are in the range of 2 to 4 lb N per 1000 ft area under tree canopy. With the quantity of N present in the reclaimed water from the Northwest Plant, only spring applications of N would be required for most trees. Fall applications of N in deciduous trees tend to increase freeze damage, especially when reclaimed water is used for irrigation. This problem can be minimized by reducing irrigation in the fall to suppress growth. Evergreen trees and most shrubs can be adequately maintained with the nitrogen contained in the reclaimed water.

Many articles recommend high rates of phosphorus application to trees and shrubs. Our experience with the soils in the El Paso area indicates that P deficiency is limited to shallow soils where root growth is restricted. Zinc and

Iron deficiency may also appear in some species. Soil and leaf analyses can help identify nutritional deficiency, but they are not substitute for checking rooting patterns, or excessive irrigation, or poor drainage, any one of which can induce these nutritional deficiencies.

Regulatory Compliance

Irrigation uses of reclaimed water are regulated by TAC Chapter 210 (a summary given in Attachment 10). All reclaimed water users should review the regulations as well as local ordinances. Questions related to the regulatory aspects should be directed first to water suppliers, in this case, El Paso Water Utilities.

The primary purpose of these regulations is to prevent health hazards, water resources contamination, and public nuisance problems. Since the regulations are set for the entire state, it is not possible to cover all possible scenarios or site-specific details. In fact, the existing guidelines do not specifically address the salty nature of the reclaimed water we have in west Texas, except for a statement indicating that soil salinity must be kept below the salt tolerance of plant species grown (TAC210 Section 24). Therefore, water users must use measures and practices which may best meet the purpose of the state regulation.

Health Risks: The primary need is to safeguard against accidental intrusion of reclaimed water into potable water supply directly through cross-piping or through backflow into the potable water lines. All the regulations intended to eliminate this cross contamination should be closely observed. Another concern is abuse or misuse of reclaimed water, especially by children. Reclaimed water from the Northwest plant is disinfected and filtered to reduce the possibility of microbial contamination as much as practical. Therefore, the concern over health hazards through contact is not nearly as significant as commonly believed. Nonetheless, care should be taken to minimize potential abuse and misuse. In some cases, it may be necessary to have additional shut-off values so as to keep reclaimed water out of quick-couplers when the irrigation systems are not in use. Some states prohibit the use of sprinklers near picnic tables, water fountains, and playground equipment. Although not required by the Texas regulation, subsurface drip irrigation is an alternative in such areas.

Preventing Water Contamination: The Texas regulation is designed to control ground water contamination primarily by imposing a limit on the quantities of irrigation. The limit for application is not to exceed the estimated evapotranspiration rate. In the case of salty irrigation water, the state code permits extra irrigation to meet the leaching requirement to control soil salinity. Water users are advised to review the water requirements of various plant species (Attachments 7A, 7B and 7C) and to follow the irrigation management guidelines (Attachment 8A, 8B and 8C) which are designed to keep leaching fractions at minimum. If salt-sensitive plants are to be maintained, the leaching requirement will become excessive. Obviously, the use of salt-sensitive plants is not recommended, even though there is no known aquifer in the Westside which can be tapped.

The situations in the Northeast and the East-Central districts are, however, quite different, because of the presence of the Hueco Bolson which is used for potable water supply. The current reuse project does not extend into these areas. The problem area is the Upper Valley where most areas are waterlogged, and the ground water and soils are already salted. The use of reclaimed water in the area will aggravate salt problems. For these reasons, these areas are presently excluded from the delivery of reclaimed water from the Northwest Plant.

The primary concern over water resources contamination in the Westside would be the potential contamination of stormwater with salts, nitrogen, possibly phosphorus if and when the reclaimed water or its seepage flows into active arroyos. These elements encourage algae growth in surface water. Water users must contain runoff of reclaimed water from the use areas. In addition, percolation losses should be kept at a minimum following the irrigation guidelines

(Attachments 8A, 8B and 8C), and unnecessary application of fertilizers should be avoided.

Public Nuisance Problems: The most common complaint associated with sprinkler irrigation of reclaimed water has been the odor problems. However, this has not been the case with the reclaimed water from the Northwest Plant. Another common nuisance problem is salt spots on vehicles, windows and walls. This problem can be minimized by using low-angle sprinklers or other forms of irrigation systems. Runoff into streets or prolonged ponding is another source of frequent complaints, and comes under both the local and the state regulations. Water users must take care of these problems through prudent management.

El Paso Experience and Steps Needed

Painted Dune Golf Course has been irrigated successfully with the tertiary treated reclaimed water which has low salinity (600 ppm). Ascarate Golf Course has also been irrigated for some time with the reclaimed water after the secondary treatment with no reported incidence of health hazard. Coronado Golf Course and two city parks (Cloudview and Snow Heights) have been irrigated for the last three seasons with the reclaimed water with elevated salinity (1200 to 1400 ppm) with no ill-effect on turf, and no incidence of health hazard. However, some trees at Coronado Golf Course suffered leaf damage, because of frequent irrigation with large overhead sprinklers. This golf course has unusually shallow soils, which require frequent irrigation. Two schools (Coronado High and Western Hills) also began to use the reclaimed water, and the turf is now slightly better condition than those existed prior to the conversion. In short, if the condition of landscape was poor prior to conversion, the poor condition seems to persist after the conversion. The landscape in good condition before the conversion has held itself or improved upon conversion, perhaps because of greatest attention to irrigation practices. These experiences seem to suggest that landscape management practices, but not necessarily quality of reclaimed water, determine the success or failure of landscape irrigation with reclaimed water, provided that the soils present are manageable, and that salt-sensitive plants are not the dominant species planted. In the case of reclaimed water from the Haskell Plant, we currently do not have sufficient experience, but these general rules may apply.

The following steps are suggested for using reclaimed water with elevated salinity:

1. Examine the cost of landscape maintenance, especially water bills and maintenance labor costs. If you need to maintain landscapes with large turf areas and shade trees, the conversion may be worthwhile. Keep in mind that the cost of acquiring new sources of potable water is getting very high and will reflect the future cost of irrigating landscapes with potable water. Also consider how critical it is to maintain your landscape in the events that water is rationed. During drought, scarce potable water has to be directed to domestic uses, not for landscape irrigation.
2. Examine the costs of conversion to reclaimed water. The main costs include plumbing modification, soil improvement, irrigation system modification or installation, replacement of certain plant species, plus some management or administrative costs. If your irrigation system is old or not functioning properly, this may be a good time to consider overhaul. Review the user permit and agreement forms attached in Attachment 11.
3. Develop a sound plan for landscape installation, modification, and/or maintenance. The key items which affect landscape plans include topography, soil properties, theme, plant selection, and irrigation system selection. Hopefully, the information presented in this article would be useful for planning. The plan should also include measures for reducing maintenance costs. Large lawn areas, poor soils, poor irrigation systems, and the use of plant species not adapted to local soil and climatic conditions add to the maintenance costs. Do spend some money to prepare soils and to install good irrigation systems. It will save you from many maintenance

problems. Do not plant lawns or shrubs if you do not plan to maintain them.

4. Inspect the progress of construction. Even if the plan may be excellent, things can go wrong during construction. Common problems in landscape construction include use of topsoils which do not meet specifications, short-cuts in irrigation system installations, soil compaction with heavy construction equipment, improper planting of trees and shrubs, no provision for stormwater handling or walkways, and creation of mounds and steep slopes which cause maintenance problems. Test the sprinkler runoff and drift problems so as to avoid complications with regulatory agencies.

5. Monitor irrigation water use and soil salinity at least once a year until soil salinity readings are stabilized. Soil salinity readings usually increase in proportion to the salinity of irrigation water used. If soil salinity readings approach the upper limits recommended for the plants grown, adjust irrigation and soil management practices. If the water use exceeds about 45 inches per season for bermudagrass, and 55 inches for overseeded turf, examine irrigation scheduling and/or practices.

References

Beck, M., J.M. Parsons and R.E. Roberts. Mulches for enhanced, low-cost, low maintenance landscapes. Texas Agricultural Extension Service. College Station, Texas.

Duble, R.L. Lawn fertilization in Texas L1533. Texas Agr. Ext. Service, College Station, TX.

Maas, E.V. 1990. Crop salt tolerance in Agricultural Salinity Assessment and Management. ASCE Tanji (Ed).

Miyamoto, S., 2000. Soil Resources of El Paso: Characteristics, Distribution and Management Guidelines. Texas A&M Agricultural Research Center at El Paso.

Miyamoto, S., R. Garceran, and R. Garcia, 1997. Landscape irrigation with salty water. Grounds Maintenance No. 1997.

Miyamoto, S., and J.B. Storey, 1995. Soil management in irrigated pecan orchards in the Southwestern US. Hort Technology. 5:219-222.

Miyamoto, S., and C. Enriquez. 1990. Comparative effects of chemical amendments on salt and Na leaching. Irrig. Sci 11:83-93.

Miyamoto, S. 1985. Effects of wetting agents on water infiltration into poorly wettable sand, dry sod, and wettable soils. Irrig. Sci. 6:271-279.

Miyamoto, S. 1978. Soil Fertility Tests at El Paso Municipal Parks. A report to the City Parks and Recreation Department. Texas A&M Univ. Agricultural Research Center.

Soil Conservation Service, USDA. 1971. Soil Survey, El Paso County, Texas US Government Printing Office. Washington, D.C.

Welsh, D. F., E.E. Janne and C. Finch, 1997 Fertilizing woody ornamentals. L1097. Texas Agr. Ext. Service, College Station, TX.

White, J., and M. Mackay. 1993. El Paso County Suggested Plant List. Texas Agricultural Extension Service.

Unit Conversion Table

Length

1 inch = 2.54 cm
1 ft = 30 cm
1 mile = 5280 ft
1 liter

Area

1 acre = 43.560 sq ft
= 0.4 ha
1 ha = 2.47 acres

1 sq miles = 640 acres

Volume

1 gal = 4 qts.
= 3.785 liter
= 8.35 lb
=1.05 qt

1 cf = 7.45 gals

1 Acre-inch= 27,152 gals
= 3,630 cf
1 Acre-ft= 325,824 gals

Flow

1 gpm = 1440 g/day
= 0.00223 cfs
= 0.133 cf/min
= 8.02 cf/hour
= 0.00221 acre-in/hr

1 cfs = 449/mim
= 26,928 g/hour
= 646,272 g/day
= 0.992 a-in/hr
= 23.8 a-in/day

Water Delivery

Quantity	Rate	hrs
1 acre-inch	10 gpm	45.2
	100 gpm	4.52
	1 cfs	0.992

Quantity	Rate	hrs
1000 gals	10 gpm	1.66
	100 gpm	0.166
	1 cfs	0.03

Salinity

1 dS m^{-1} = 1 mmho/cm
= 635 - 680 pm
1 ppm = 1 mg per liter

Sodicity

Sodium Adsorption Ratio
$= Na/\sqrt{(Ca+Mg)/2}$
in meq L^{-1}

Nutrient

1 ppm = 2.7 lb/acre-ft = 8.1 lb/3 acre-ft
100 lb/acre = 2.3 lb/1000 sf