The “Real Dirt” on Managing Recycled Water

Factors affecting salt accumulation in irrigated landscapes and turf.

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Who is the audience today?

- Golf Industry / Superintendents
- Water Agencies
- Engineering / Consulting Firms
- Other

- Golfers vs. Non Golfers

Perspective on Water Costs:

$1,500 AF
$3.45 CCF

$325,851 AF
$749 CCF

$724,114 AF
$1664 CCF

$351,980 AF
$809 CCF

$410,141 AF
$942 CCF

Sports Event, Airport, etc.

$3.00 /16 oz

$7,820,424 AF
$17,977 CCF

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Golf Course Management
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Link to article:

http://www.gcsaa.org/_common/templates/GcsaaTwoColumnLayout.aspx?id=6985&LangType=1033

research

Factors affecting salt accumulation in irrigated fairways and roughs in the arid Southwest

Many factors can be involved in salt accumulation, including irrigation systems and management, soil properties, and vegetative cover. Identifying the causes of salt accumulation is key to developing irrigation plans and appropriate management strategies.

Seiichi Miyamoto, Ph.D.

As the demand for low-salt water increases, mostly for urban developments, many golf courses in arid areas may have to use water with elevated salinity for irrigation. A survey conducted by GCSAA, for example, indicates that in the Desert Southwest of the United States, where water shortages are chronic, 37% of the courses surveyed in 2009 were using reclaimed effluent for irrigation (16). Salinity is by far the single most recognized constraint — at least in Texas (5) — on using reclaimed water for irrigation. However, many golf courses in the Southwest are also using groundwater with elevated salinity and sodicity. This paper examines the factors affecting salt accumulation in irrigated fairways and roughs in golf courses in arid areas of the Southwest.

Quality of water sources

Water resources used for irrigating golf courses in the arid Southwest are highly diverse in terms of dissolved salt content and composition (Table 1), although the traditional supply from the river systems has comparatively low salinity. Some water sources have a high proportion of sodium (that is, they are sodic), and others are rich in calicum and sulfate ions (that is, they are gypsic).

The water-quality data in Table 1 are for the water sources currently used, but the salt concentration of groundwater reserves can be much higher. An estimated three-quarters of the groundwater reserves in New Mexico, for example, is saline (8), and the majority of groundwater reserves in West Texas are highly saline, with some exceeding 5,000 ppm. Therefore, salt problems may become more than just an occasional nuisance — if they are not already — in many parts of the Southwest.

Water-quality guidelines

The prevailing thinking among water supply engineers appears to be that the salinity of water used for irrigation dictates salt accumulation in soils and, therefore, salt damage to plants. This has led to the development of water-quality guidelines for irrigation (17). These guidelines also incorporate sodicity, which is commonly expressed by the sodium adsorption ratio (SAR). High sodicity is known to cause soil structural degradation and reduced soil permeability.

The guidelines proposed by Wescott and Ayers (17) originated from the water-quality guidelines for agricultural crop irrigation and state that slight to moderate salt problems may result when water with 450 ppm to 2,000 ppm of dissolved salts is used for golf course irrigation. Several other guidelines have been proposed, and a commonly used baseline in the Southwest is 1,000 ppm dissolved salt contents and a sodium adsorption ratio of 6 or less.

Experience in the Southwest

Experience indicates that significant foliar damage can occur when broadleaf trees and shrubs are hit by irrigation sprinkler streams containing

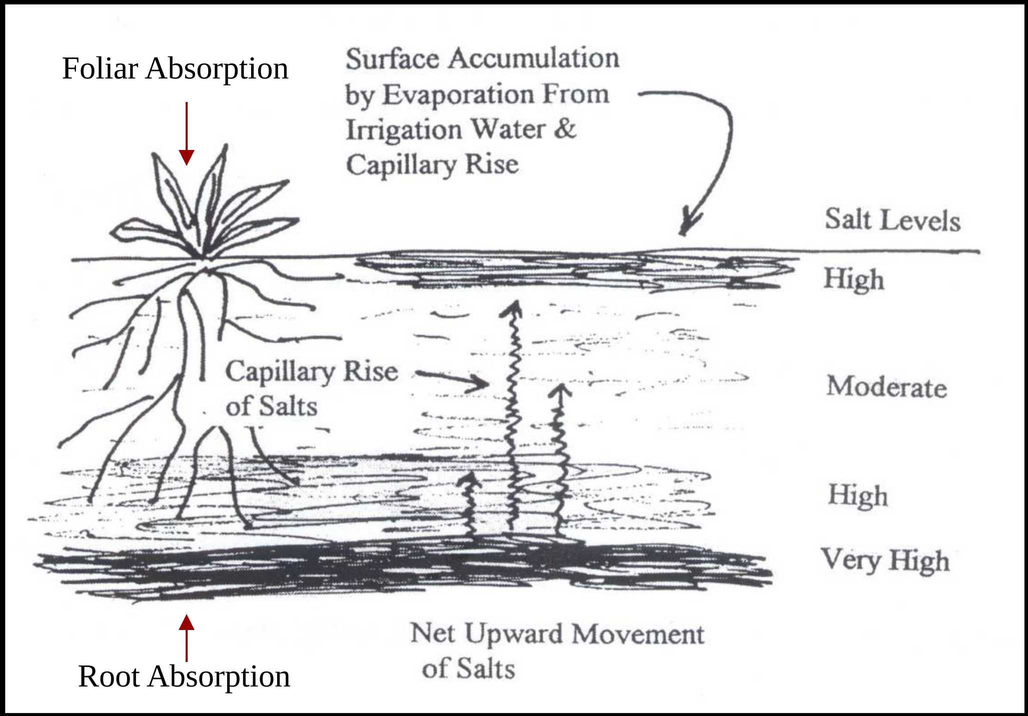
Landscape Stresses & Influences

Moral of the Story - It's never just one thing

- Heat / Cold Tolerance
- Humidity
- Shade
- Drought Avoidance
- Drought Tolerance
- Insects
- Diseases*
- Traffic
- Plant Salt Tolerance
- Soil & Water
  - Irrigation Distribution
  - Leaching & Drainage
  - Soil Characteristics
    - Texture
    - Compaction
    - Layering
    - Drainage
  - Clay 'Parent Materials'
    - Shrink / Swell Factor
- Factor X

Salinity Pathways

- Root absorbed
  - Infiltrated irrigation water
  - Capillary rise
  - Perched water table
- Foliar absorbed
  - Sprinkler spray
  - Ocean Spray
  - Deicing splash
  - Fertilizer Burn
- Environmental
  - Evaporation
  - Drought
- Management
  - Deficit irrigation



Recycled Water Quality

Ions of Concern:

- Calcium
- Magnesium
- Chloride
- Sodium
- Bicarbonate
- Boron
- Nutrients
  - Nitrate
  - Ammonia
  - Phosphorous

Parameters:

- Electrical Conductivity
  - Total Dissolved Salts
- Sodium Adsorption Ratio
- Adjusted SAR
- Adjusted RNa
- pH

Golf course water quality in the arid Southwest

Water type[†]/location (golf course code)	EC[‡] (dS/m)	TDS[‡] (mg/L)	SAR[‡]	Sodium	Calcium	Magnesium	Bicarbonate	Chloride	Sulfate
				milliequivalents/liter					
Calcic water									
RW, Tucson, Ariz., GA1	0.7	450	3.7	4.1	2.0	0.6	4.1	—	—
GW, Las Cruces, N.M.	1.0	672	1.5	5.4	3.6	4.5	5.9	3.4	10.0
Colorado River, Yuma, Ariz.	1.0	740	2.2	4.0	4.7	2.1	2.6	2.0	6.3
SW, Rio Grande, El Paso, Tex., G3	1.1	860	3.3	6.2	5.1	1.8	3.6	3.6	5.0
RW, Las Vegas, Nev., GN4	1.8	1,207	3.8	8.6	5.1	5.2	2.4	6.8	9.5
Sodic water									
SW, Salt River, Ariz.	1.5	891	6.4	9.6	3.1	1.3	3.2	10.1	0.8
RW, El Paso, Tex., G4	1.5	880	6.9	9.6	2.9	1.1	2.7	6.2	3.9
RW, El Paso, Tex., G4	2.1	1,190	9.7	14.3	3.2	1.0	3.1	8.0	6.3
Gypsic water									
GW, Midland, Tex., G6	2.6	1,676	3.4	10.1	8.5	9.4	3.8	9.3	14.9
RW, Alamogordo, N.M., G7	2.7	1,512	5.0	12.3	8.7	4.0	5.0	13.7	4.8
GW, Tularosa, N.M.	3.2	2,700	3.7	13.4	15.7	10.4	3.2	6.3	31.0
Pecos River, N.M.	3.3	2,398	3.2	11.3	16.9	9.0	3.1	12.1	22.3
GW, Midland, Tex., G8	3.5	2,220	3.2	11.3	12.4	11.9	1.3	17.4	16.9

[†] GW, groundwater; RW, reclaimed water; SW, surface water.
[‡] EC, electrical conductivity; TDS, total dissolved salts; SAR, sodium adsorption ratio.

Table 1. Examples of quality of water used for golf course irrigation in the arid Southwest.

Water Quality – TDS / ECw

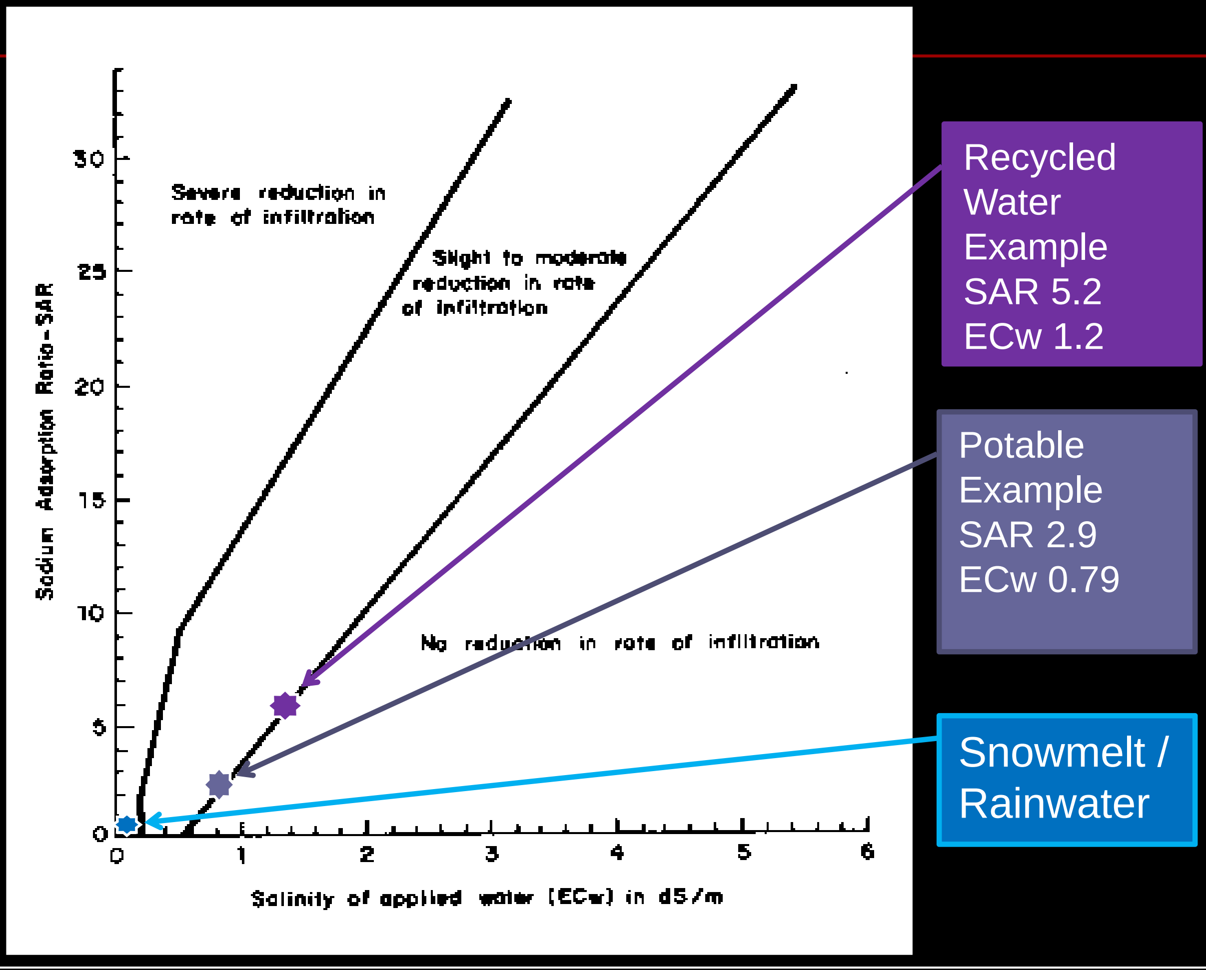
Hazard	TDS / ppm / mg / l	ECw / dS / m mS / cm
Low	500	0.75
Medium	500 - 1000	0.75 – 1.5
High	1000 – 2000	1.5 – 3.0
Very High	>2000	>3.0

SAR – Sodium Adsorption Ratio

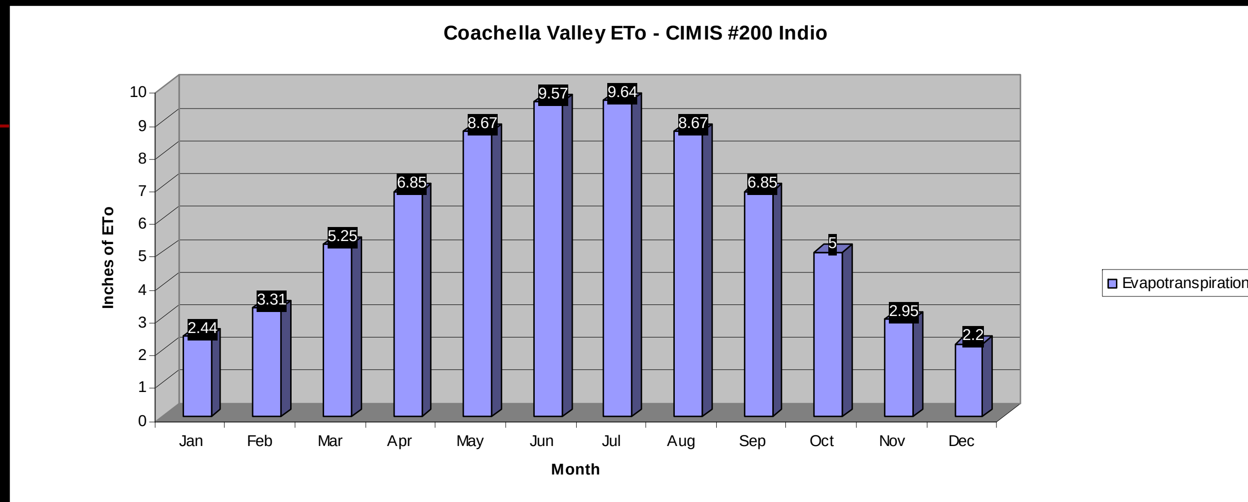
$$SAR = \frac{Na}{\sqrt{\frac{Ca + Mg}{2}}}$$

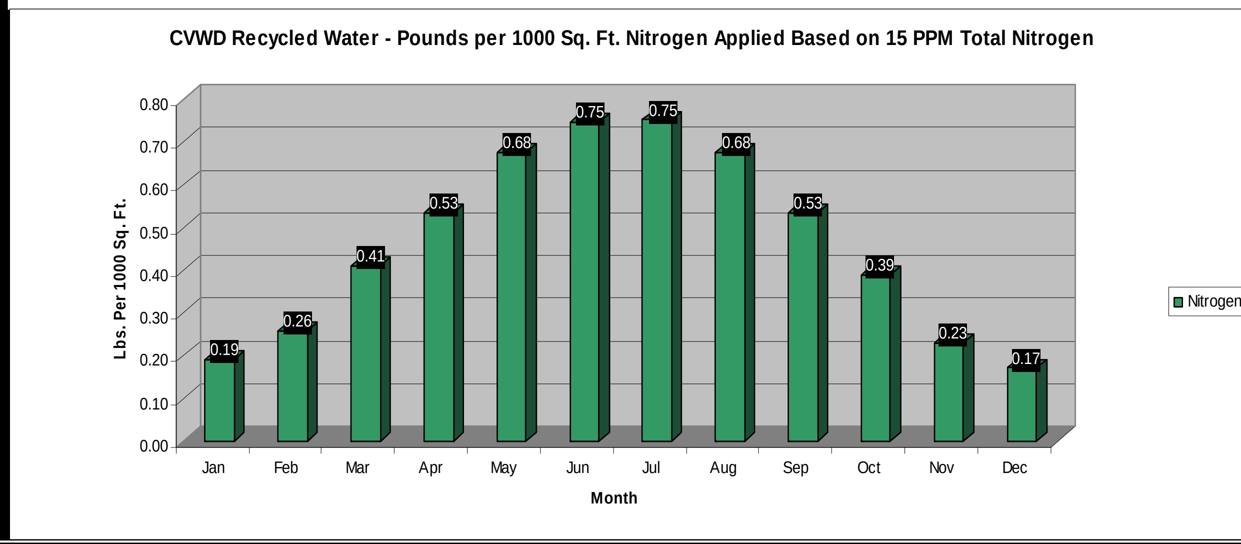
SAR provided on laboratory reports

Water Quality
ECw and SAR Infiltration Effect



Recycled Water & Nutrient Management





Soil Temperature	Time (Weeks)	Percent Nitrification
75° F	2	100%
52° F	12	100%
47° F	12	77%
42° F	12	35%
37° F	12	5%

Rapid Blight (*Labyrinthula terrestris*)
Soil Sodium ≥114 PPM & ECe ≥2.0

Soil Salinity Tolerance - ECe

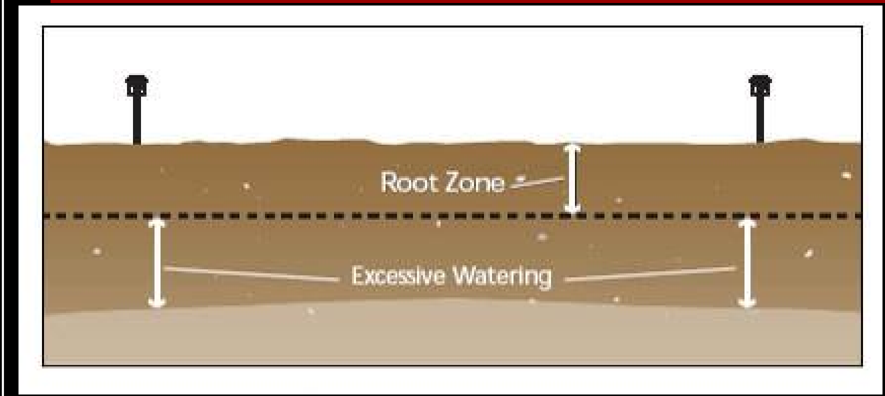
Cool Season Vs. **Warm Season** Turfgrasses

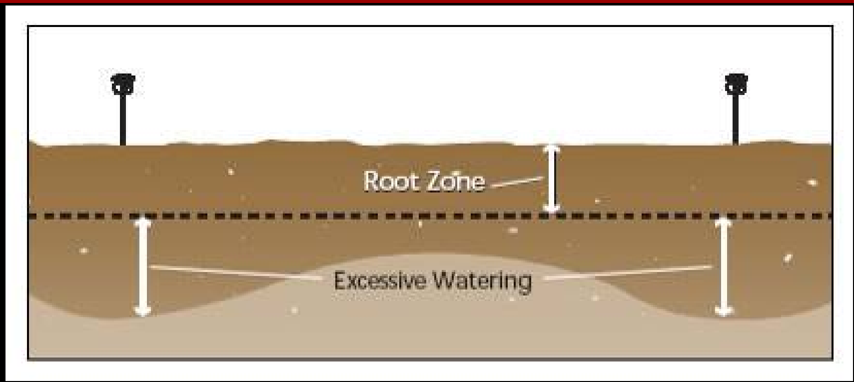
Sensitive <3.0 dS/m	*Mod – Sensitive 3-6 dS/m*	*Mod - Tolerant 6-10 dS/m*	*Tolerant >10 dS/m*
Annual Bluegrass	Annual Ryegrass	Seaside Bentgrass	Alkaligrass
Colonial Bentgrass	Chewings Fescue	Perrenial Ryegrass	**Bermudagrass**
Kentucky Bluegrass	Creeping Bentgrass	Tall Fescue	**Seashore Paspalum**
Rough Bluegrass	Hard Fescue	**Buffalograss**	**St. Augustine**
		Kikuyugrass	
Centipedegrass	**Bahiagrass**	**Zoysiagrass**	

Salinity Stress Damage

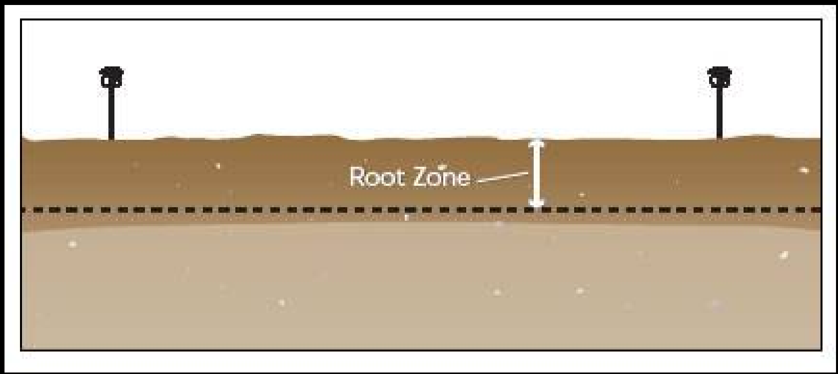
Irrigation System Performance, Water Management, & Leaching

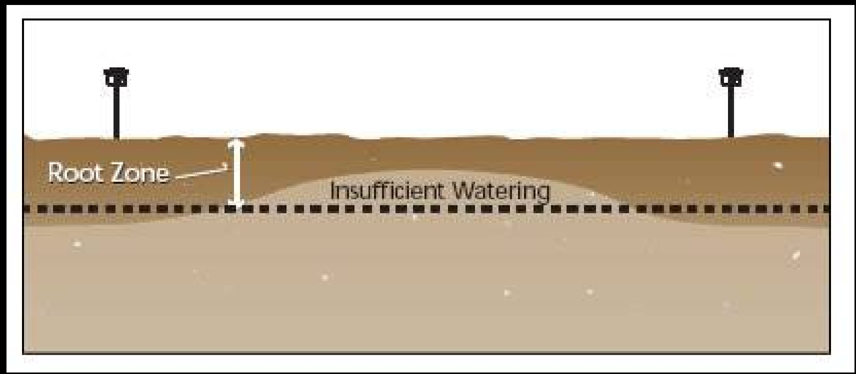
Water Management & Irrigation System Performance





Poor Efficiency with both Good and Poor Uniformity





Good Efficiency with both Good and Poor Uniformity

Highest concentrations of salts will be at the leading edge of the wetting front

Maintenance Leaching Fraction
(Developed in Agriculture not Golf)

$$LR = \frac{ECw}{5ECe - ECw}$$

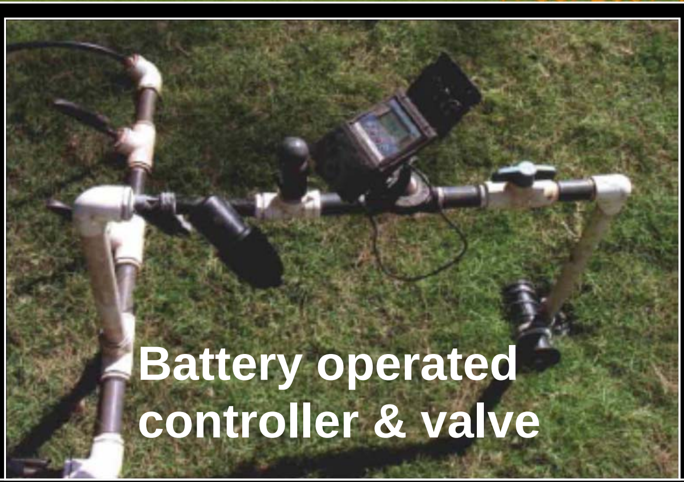
Turfgrass tolerance

Common Soil Properties Coastal Southern California

- Low infiltration & low permeability
- High moisture holding
- Expansive clays with high shrink swell potential
- High CEC – salt and sodium management
- (Each site is unique)

Superintendent becomes a target

Water Management & Leaching



“If salinity of irrigation water is such a dominant factor, soil salinity should increase with increasing salinity of irrigation water, as shown by the dashed line in Figure 1. ***<u>These field data, however, show that soil salinity is highly variable and does not correlate with water salinity.</u>*** *This means that factors other than water salinity must be affecting salt accumulation.”*

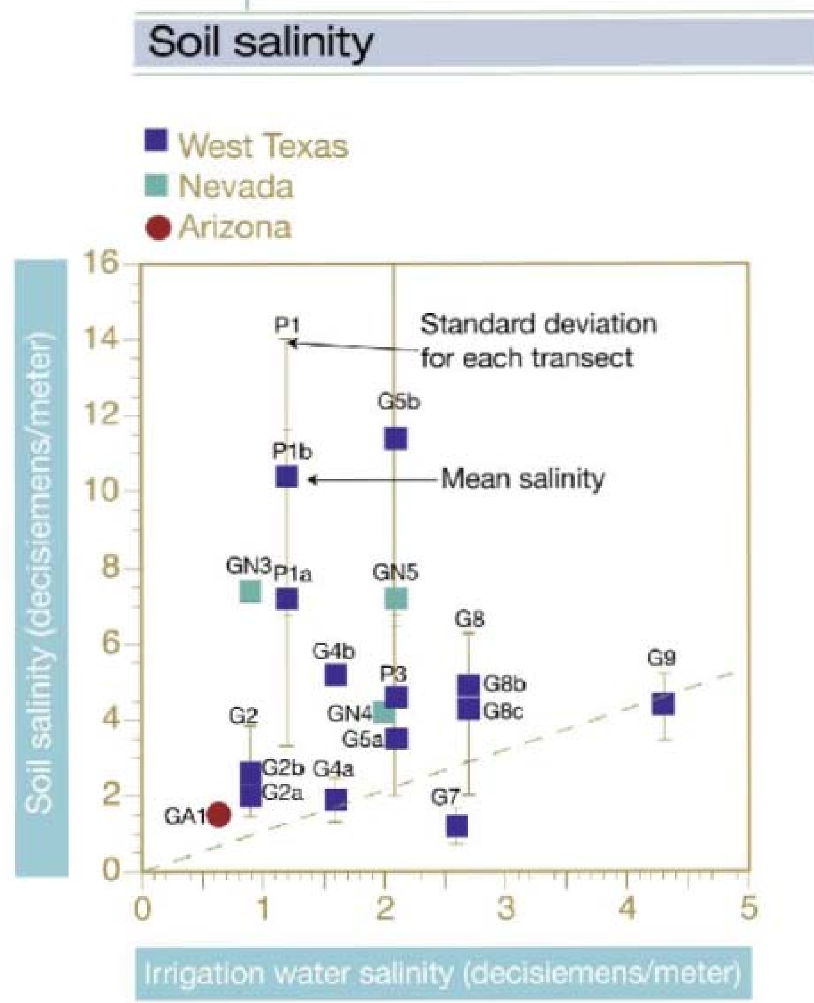


Figure 1. Mean soil salinity and the standard deviation as related to irrigation water salinity at golf courses and regional parks. Golf courses = G; regional parks = P. Letters a, b and c refer to different fairways in a given golf course. These data show no significant correlation between soil salinity and water salinity. The dotted line shows where the values in this graph would lie if soil salinity increased with increasing water salinity ($EC_e = EC_w$).

The best-fit lines indicate that the <u>salt concentration factor increases exponentially with increasing saturation water content</u>, much more in parks than in golf fairways. Soil compaction likely accounts for the difference.

,,,With increasing compaction (which is prevalent in park grounds), the salt concentration factor line shifted away from the best-fit line obtained at the golf course fairway.~ (Figure 3).

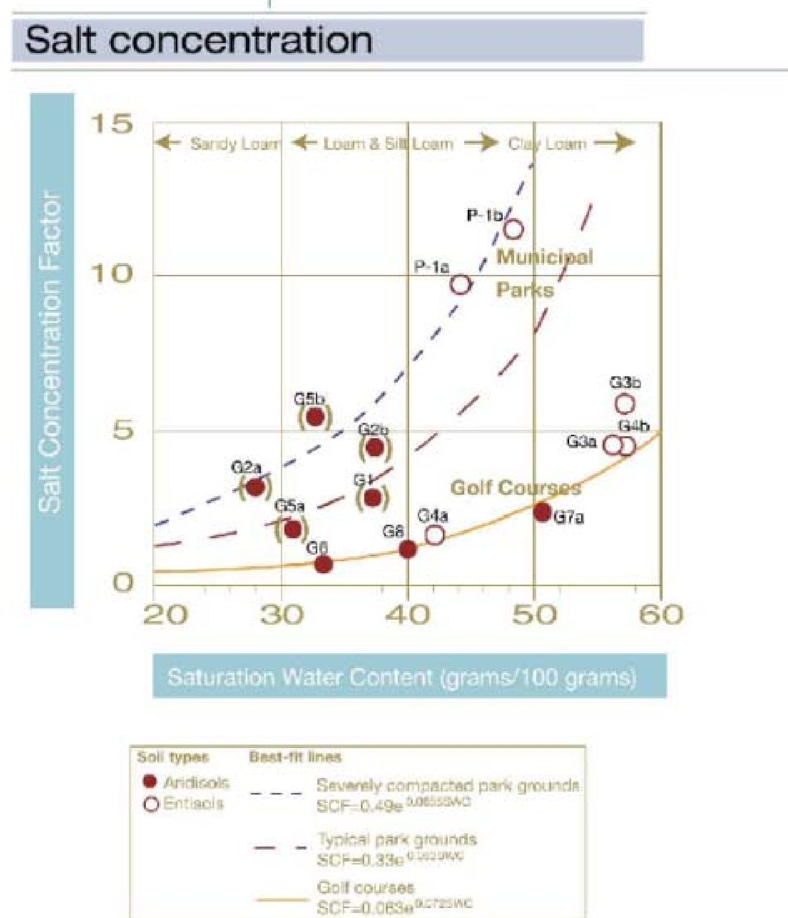


Figure 3. The salt concentration factor expressed by the mean plus the standard deviation as related to the saturation water content. Three best-fit lines were determined in earlier work (13). Two of the data points are from a compacted regional park (P); the rest are from golf courses (G). Data points in parentheses deviated from the best-fit line for golf courses. This figure shows that soil salinity, or more precisely the salt concentration factor defined by equation 3, increases exponentially with increasing saturation water content (an index of soil textural class) as well as with other soil or management factors.

Soil Moisture Holding Properties

Saturation %	Texture	CEC	In / foot	In / In
<20	*Sand to loamy sand*	2 to 7	<0.6	<0.05
25-35	*sandy loam*	7 to 15	0.6 - 1.0	0.05 - 0.08
35-50	*loam /silt loam*	15 to 30	1.0 - 1.5	0.08 - 0.13
50-65	*clay loam*	30 to 40	1.5 – 2	0.13 - 0.17
65+	*clay or peat*	>40	>2.0	>0.17

Soil salinity and soil porosity

Soil type/ classification	Soil salinity		Porosity	
Torrifluvent, Entisols	Compacted†	Noncompacted	Compacted†	Noncompacted
	decisiemens/meter		% volume	
Vinton sandy loam	3.9	2.0	48	56
Harkey silt loam	7.4	1.1	37	50
Harkey silty clay loam	9.1	1.8	39	46
Harkey silty clay loam	12.7	2.3	36	56
Saneli silty clay	15.2	3.9	28	38

†Compaction caused mainly by foot traffic.

Table 4. Soil salinity and soil porosity of samples from compacted and noncompacted areas of a park developed on Torrifluvents (13).

Salinity of soil samples collected from compacted areas was markedly higher than salinity of soil from un-compacted areas of the parks surveyed (Table 4).

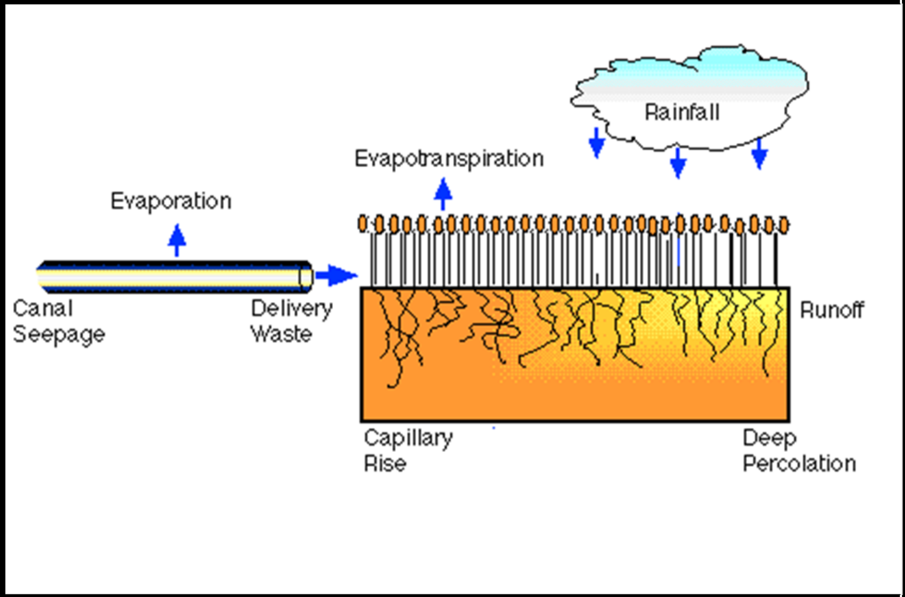
USDA Soil Permeability & Infiltration Classification

Classification	Infiltration Rate (Inches / Hour)	(Inches / 24 Hours)
Very Slow	< 0.06	<1.44
Slow	0.06 to 0.2	1.44 to 4.8
Moderately Slow	0.2 to 0.6	4.8 to 14.4
Moderate	0.6 to 2.0	14.4 to 48.0
Moderately Rapid	2.0 to 6.0	48 to 144
Rapid	6.0 to 20.0	144 to 480
Very Rapid	>20.0	>480


Four days time after one inch of rain
Estimated Infiltration / Permeability Rate 0.38” per day, (<0.02” per hour)

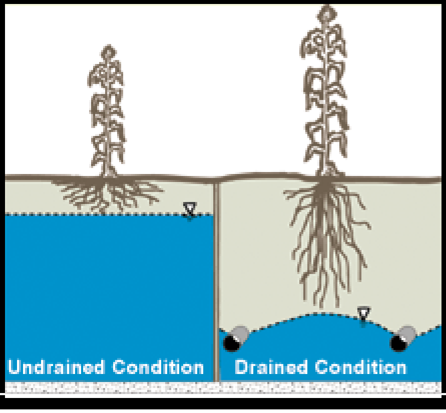
Irrigation Goal = Tall Order

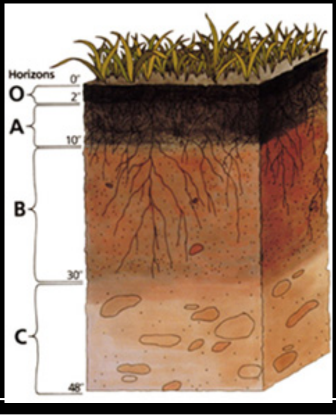
Irrigate deeply to promote salt leaching, while avoiding deep percolation & surface runoff and maintain a firm playing surface.

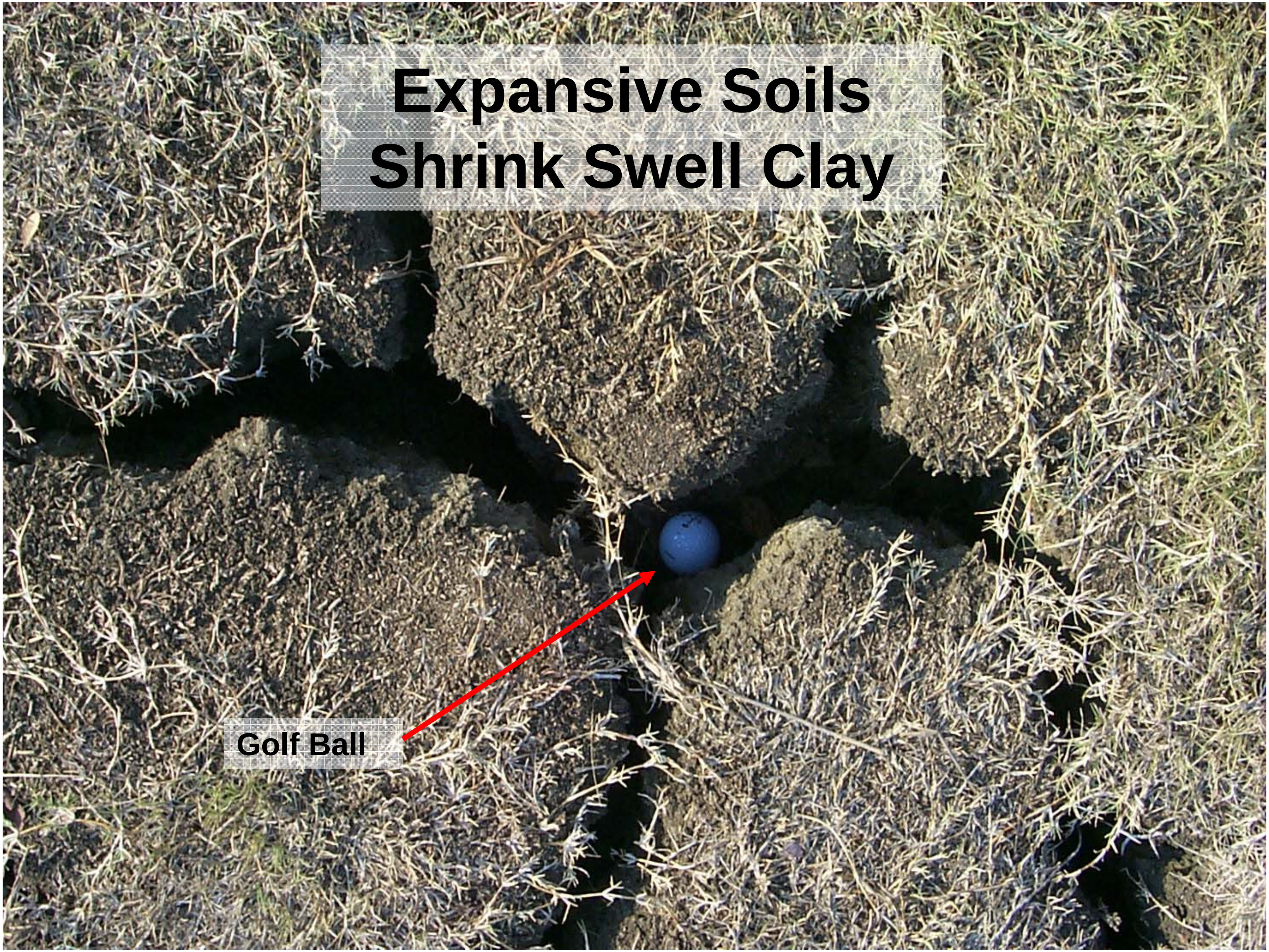


Other Problems

- Expansive Soils
- Shallow Groundwater Table
- Soil Layering / Cultivation Pan
  - Natural vs Self Inflicted
- ‘C’onstruction Root Zone






Expansive Soils
Shrink Swell Clay
Golf Ball

SEM Photos of Clay Types

Sodium Adsorption Ratio & Permeability Hazard Based Upon Clay Type

Clay Type -	Hazard		
Shrink Swell Potential	None	Moderate	Severe
Montmorillonite Clay – *High* ***Shrink Swell***	<6	6-9	>9
Illite Clay – *Medium* ***Shrink Swell***	<8	8-16	>16
Kaolinite Clay – *Low* ***Shrink Swell***	<16	16-24	>24

**Also, kaolinite-like clays that are non-swelling such as Fe/Al oxides.*

General Rule of Thumb - SAR <6 Is Acceptable

USDA Web Soil Survey
http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm

Soil Taxonomy Classification— Summary by Map Unit — Ventura Area, California				
Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
AuC2	Azule loam, 2 to 9 percent slopes, eroded	Fine, montmorillonitic, thermic Mollic Haploxeralfs	14.9	9.3%
AuD	Azule loam, 9 to 15 percent slopes	Fine, montmorillonitic, thermic Mollic Haploxeralfs	16.4	10.3%
CyA	Cropley clay, 0 to 2 percent slopes	Fine, montmorillonitic, thermic Chromic Pelloxererts	50.4	31.6%
LeE2	Linne silty clay loam, 15 to 30 percent slopes, eroded	Fine-loamy, mixed, thermic Calcic Pachic Haploxerolls	0.7	0.4%
MoC	Mocho loam, 2 to 9 percent slopes	Fine-loamy, mixed, thermic Fluventic Haploxerolls	37.0	23.2%
ScD2	San Benito clay loam, 9 to 15 percent slopes, eroded	Fine-loamy, mixed, thermic Calcic Pachic Haploxerolls	9.1	5.7%
ScE2	San Benito clay loam, 15 to 30 percent slopes, eroded	Fine-loamy, mixed, thermic Calcic Pachic Haploxerolls	1.0	0.6%
ScF2	San Benito clay loam, 30 to 50 percent slopes, eroded	Fine-loamy, mixed, thermic Calcic Pachic Haploxerolls	18.5	11.6%
SsE2	Soper loam, 15 to 30 percent slopes, eroded	Fine-loamy, mixed, thermic Typic Argixerolls	0.3	0.2%
SvF2	Soper gravelly loam, 30 to 50 percent slopes, eroded	Fine-loamy, mixed, thermic Typic Argixerolls	10.7	6.7%
W	Water		0.4	0.3%
Totals for Area of Interest			159.3	100.0%


TDSTestr 4™
0 to 19.90 mS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Shallow Groundwater ECw 6.0
Recycled Irrigation Water ECw 0.6 to 1.3

Drainage / Layering

Groundwater Irrigation ECw 6.0

Making Lemonade from Lemons

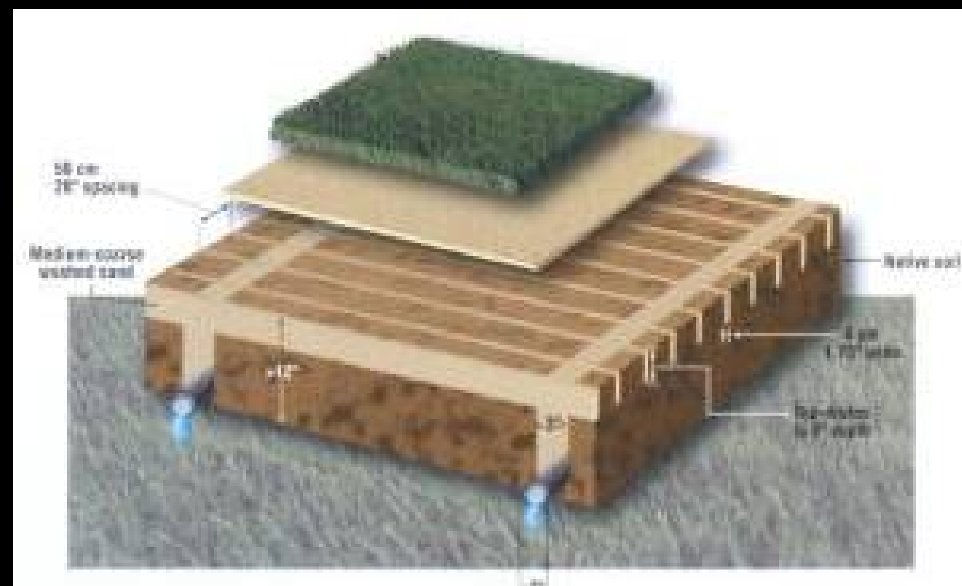
- Monitor soil and water chemistry
- Improve surface drainage (proper grading)
- Improve internal soil drainage (aeration)
  - Add subsurface drainage
  - Soil modification / sand topdressing
- Introduce salt tolerant species for problem areas
- Put together a good long term program,
- Budget appropriately

“Temporary” Soil Modification From Top Down


Soil Modification, from the Top Up

STEC GKB Drainmaster

Stec GKB-Drainmaster

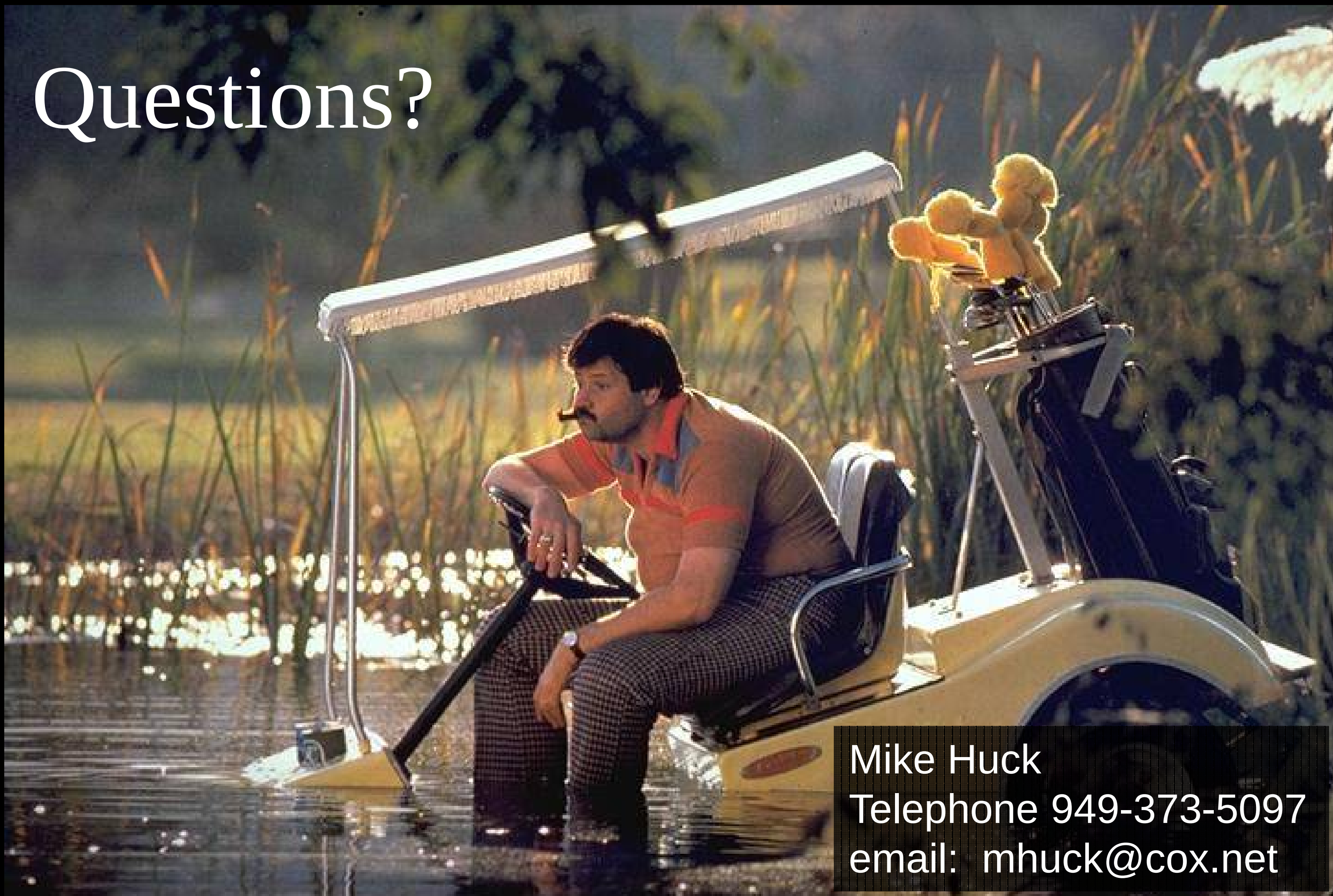


http://www.stecequipment.com/Specialized-Turf-Equipment

Summary

- Recycled water quality affects plants & soils
- Soil characteristics affect salinity accumulation and water movement (leaching)
- An efficient irrigation system is important
- Sites are unique, each with site specific challenges
- Climate impacts success with recycled water
  - Annual Rainfall & Natural Leaching
  - Plant water requirements (Evapotranspiration rate)
    - Temperature, Humidity and other stressors
- Problems related to salinity can take a few years to surface

Questions?



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