Irrigation Water Testing and Interpretation: Case Studies from the Field

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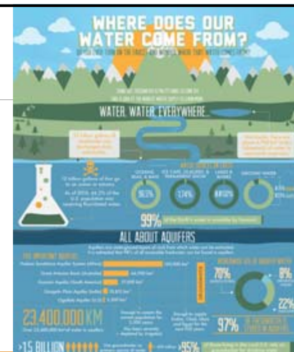
Where does your water come from?



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Global Water

96.5% seawater (average total soluble salts = 34,486 mg/L)

2.5% freshwater reserves (includes surface water and groundwater)

Other sources include swamps, glaciers, snow cover, and ground ice/permafrost

Groundwater – 1.7% of total global water supply

- More than half of groundwater is saline, remaining is considered freshwater
- About 30.1% of freshwater reserves is from groundwater

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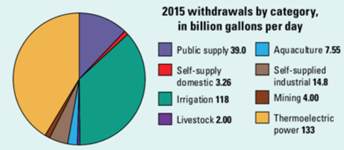
Estimated Water Use in the United States in 2015 – USGS Report published in 2018



- Total withdrawals in 2015, were **322** billion gallons per day (Bgal/d), resulting in a **9** percent decrease since 2010
- Since 2010, population increased **4** percent and total domestic use decreased **3** percent, which reduced per-capita use to **82** gallons per day
- Consumptive use accounted for **62** percent of water used for irrigation, and **3** percent of water used for thermoelectric power in 2015
- Withdrawals for thermoelectric power, irrigation, and public supply accounted for **90** percent of total withdrawals in 2015

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Goal: Gain knowledge of water quality parameters important for turfgrass irrigation

Objectives:

1. Understand specific irrigation water quality parameters and measurements
2. Understand irrigation water quality reports
3. Know best management practices for specific irrigation water quality and soil problems that may affect turfgrass quality and health

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Overview of several water quality parameters

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Soluble salt ions in irrigation water

Cations (+)	Anions (-)
Calcium (Ca^{+2})	Bicarbonate (HCO_3^-)
Magnesium (Mg^{+2})	Carbonate (CO_3^{-2})
Sodium (Na^+)	Chloride (Cl^-)
Potassium (K^+)	Sulfate (SO_4^{-2})
	Nitrate (NO_3^-)
	Boron (BO_3^{-2})

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General Water Quality Parameters

pH

Hardness

Alkalinity

Bicarbonate (HCO_3^-)

Carbonate (CO_3^{-2})

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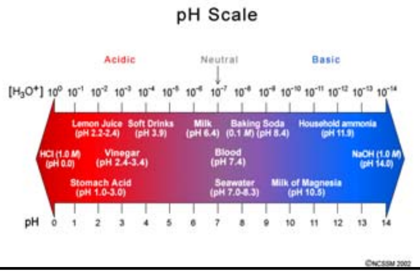
pH – measurement of dissolved hydronium ions (H_3O^+) in solution



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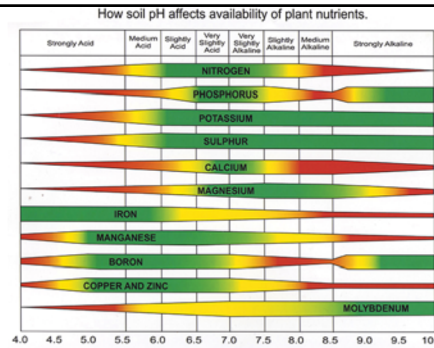

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Hardness

- Related mostly to the Ca and Mg in the water (also Fe, Mn, Al, and Zn can contribute to hardness)
- Can lead to scaling in pipes
- Expressed in calcium carbonate ($CaCO_3$) equivalent
- Typically reported in ppm (parts per million) or mg/L (milligrams per liter)
- Remember: 1 mg/L = 1 ppm

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Hardness

- Soft: < 50 mg/L $CaCO_3$ equivalent
- Moderate: 50 – 150 mg/L $CaCO_3$ equivalent
- Hard: 150 – 300 mg/L $CaCO_3$ equivalent
- Very Hard: >300 mg/L $CaCO_3$ equivalent

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Alkalinity

- Is a measurement of acid-neutralizing potential
- Measure of the ability to absorb H^+ without significantly changing pH
- Takes into account bicarbonate (HCO_3^-), carbonate (CO_3^{-2}), and hydroxide (OH^-)
- Expressed in calcium carbonate ($CaCO_3$) equivalent
- Typically ranges from 20-300 mg/L $CaCO_3$ equivalent

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Bicarbonate (HCO_3^-) and Carbonate (CO_3^{-2})

- Sodic soils: If bicarbonates are >120 mg/L and carbonates are > 15 mg/L and sodium (Na) is >100 mg/L, then there is potential to create sodic soil conditions. This is bad for soils and for turf growth. Will discuss later.
- High concentrations of bicarbonates and carbonates with high Ca and Mg can lead to deposits of calcium or lime.
- Irrigation water with a high pH (>8.0) often contain higher bicarbonates and carbonates.

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Additional Water Quality Parameter

Related to bicarbonates and carbonates

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Residual Sodium Carbonate

Alkalinity and Hardness are not extremely useful for turfgrass irrigation.

Instead, the residual sodium carbonate (RSC) is often used.

RSC = (carbonates + bicarbonates) – (Ca + Mg); expressed in meq/L (milliequivalents per liter)

Milliquivalents per liter (meq/L) is a measure of chemical equivalency.

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Residual Sodium Carbonate

If sodium (Na) > 100 mg/L
RSC = $(CO_3^{-2} + HCO_3^{-}) - (Ca^{+2} + Mg^{+2})$; expressed in meq/L

RSC in meq/L	Sodium (Na) hazard
<0 (a negative number)	No hazard. Ca and Mg will not precipitate, they remain to "block" Na accumulation
0 – 1.25	Low hazard
1.25 – 2.50	Medium hazard
> 2.50	High hazard. Most of Ca and Mg removed, leaving Na to accumulate (no blocking).

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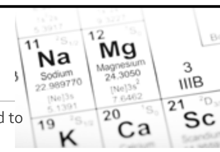
What about Sodium (Na^+)



High Na in water is generally considered bad; can lead to sodic and saline-sodic soils.

Sodium, Calcium, and Magnesium are important when discussing sodic soils.

Calcium is a primary ion for soil stabilization.

Magnesium is important for secondary stabilization

If sodium builds up in the soil, it can displace calcium and magnesium from the soil particles

When sodium builds up on soil particles, it destroys soil structure (deflocculation)

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Sodium Permeability Hazard

If there is excessive sodium buildup in the soil:
- Reduced water infiltration and percolation through the soil
- Standing water/puddling – wet roots – rot
- Low oxygen diffusion into the soil profile
- General turf decline and possible death

- Assessment and management must be based on the specific soils and irrigation water at the site
- Must routinely and regularly monitor water quality and soil profile
- May determine use of the site; is it fit for turf use?
- Will determine species and cultivar selection

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Sodic Soils

Very difficult to manage

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Sodium Adsorption Ratio (SAR)

SAR is generally used to assess sodium status in soils

The SAR of irrigation water can also be determined and is typically reported on irrigation water quality reports

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

Na - sodium meq/L
Ca – calcium meq/L
Mg – magnesium meq/L

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Adjusted SAR – adj SAR

adj SAR = SAR (1 + 8.4 – pHc)

Adjusted SAR accounts for the influence of bicarbonate and carbonate in irrigation water

The pHc value is a caculated pH value based on the influence of Ca, Na, Mg, bicarbonate, and carbonate

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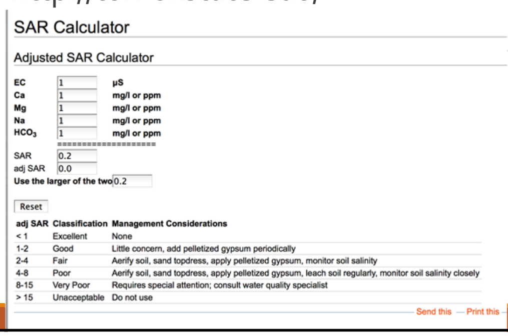
http://turf.okstate.edu/


SAR Calculator

Adjusted SAR Calculator

EC	1	μS
Ca	1	mg/l or ppm
Mg	1	mg/l or ppm
Na	1	mg/l or ppm
HCO_3	1	mg/l or ppm
	====================	
SAR	0.2	
adj SAR	0.0	
Use the larger of the two	0.2	

Reset

adj SAR	Classification	Management Considerations
< 1	Excellent	None
1-2	Good	Little concern, add pelletized gypsum periodically
2-4	Fair	Aerify soil, sand topdress, apply pelletized gypsum, monitor soil salinity
4-8	Poor	Aerify soil, sand topdress, apply pelletized gypsum, leach soil regularly, monitor soil salinity closely
8-15	Very Poor	Requires special attention; consult water quality specialist
> 15	Unacceptable	Do not use

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Salinity

Saline soil conditions are one of the more common issues when dealing with marginal to poor irrigation water quality

Measured as "total salts" but often called
- Total soluble salts (TSS)
- Total dissolved salts (TDS)

Can be confusing for some since TSS is also used for "total suspended solids" which is not a measurement of total salts.

Can also be measured and reported as "electrical conductivity" (EC)

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Total Salts vs Electrical Conductivity

Electrical conductivity (EC) is relatively easy to measure in the lab.

EC can be reported in confusing units
- dS/m – decisiemens per meter
- mS/cm – millisiemens per centimeter
- µS/cm – microsiemens per centimeter
  - 1 dS/m = 1 mS/cm = 1,000 µS/cm

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Total Salts vs Electrical Conductivity

1 dS/m = 1 mS/cm = 1,000 µS/cm

Also for EC:
- mmhos/cm – millimhos per centimeter
  - 1 mmhos/cm = 1 dS/m
- µmhos/cm – micromhos per centimeter
  - 1 mmhos/cm = 1000 µmhos/cm

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Total Salts vs Electrical Conductivity

1 dS/m =

1 mS/cm =

1,000 µS/cm =

1 mmhos/cm =

1,000 µmhos/cm

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Total Salts vs Electrical Conductivity

EC can be converted to total dissolved salts (TDS)
- TDS in mg/L = 0.64 x EC (µS/cm or µmhos/cm)
- TDS in mg/L = 640 x EC (dS/m or mmhos/cm)

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Total Salts and EC

To make things "easier", this does not always fit:
- TDS in mg/L = 0.64 x EC (µS/cm)
- TDS in mg/L = 640 x EC (dS/m)

Not all salts have the same conductivity

So, you may see conversion factors from 0.55 (550) to 0.75 (750), depending on the situation

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Total Salts and EC

For most cases, you can use the "standard" conversion
- TDS in mg/L = 0.64 x EC ((µS/cm or µmhos/cm)
- TDS in mg/L = 640 x EC (dS/m or mmhos/cm)

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Table 1. Classification of irrigation water based on Total Salts (TS,mg/L or ppm) and EC (µS/cm).

TS[1]	*EC*	*Classification*	*Management*
< 320	< 500	Excellent	None
–960	–1,500	Good	Little concern, especially with periodic rainfall
–1,920	–3,000	Fair	Leach salts from soil as needed
–3,200	–5,000	Poor	Routinely leach; monitor soils
–3,840	–6,000	Very Poor	Requires special attention; consult water specialist
> 3,840	> 6,000	Unacceptable	Do not use

[1] TS = Total Salts.

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Salinity and SAR

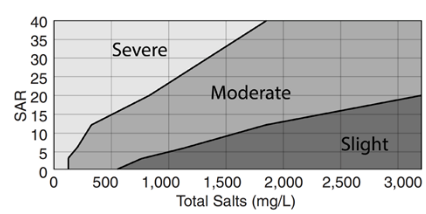

Figure 1. Total salts and SAR are used together to predict the effect of irrigation water on infiltration hazard. Modified from Harivandi, 1999)

Extremely pure water can lead to reduced infiltration, even at low SAR

High total salts can help with infitration at medium to high SAR (15-20); high Ca and Mg can counterbalance effects of high Na

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Interpreting Sodium Hazard Measurements

Harivandi, 2013. CSSA slide set

Potential Irrigation Problem	Unit of measure	Degree of Restriction on Use: None	Slight to Moderate	Severe
Salinity				
ECw	dS m^{-1}	<0.7	0.7–3.0	>3.0
TDS	mg L^{-1}	<450	450–2,000	>2,000
Soil water infiltration				
(evaluate using ECw [dS/m] and SAR together)				
if SAR = 0 to 3 & ECw =		>0.7	0.7–0.2	<0.2
if SAR = 3 to 6 & ECw =		>1.2	1.2–0.3	<0.3
if SAR = 6 to 12 & ECw =		>1.9	1.9–0.5	<0.5
if SAR = 12 to 20 & ECw =		>2.9	2.9–1.3	<1.3
if SAR = 20 to 40 & ECw=		>5.0	5.0–2.9	<2.9

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Specific Ions and Nutrients

Sodium (Na^+), Chloride (Cl^-), and Boron (B) can cause problems when in excess

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Harivandi, 2013. CSSA slide set

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Harivandi, 2013. CSSA slide set

- Chloride (Cl), in addition to contributing to the total soluble salt content of irrigation water, may be toxic to landscape plants.
- It is not particularly toxic to turfgrasses, but can affect many trees, shrubs, and ground covers.

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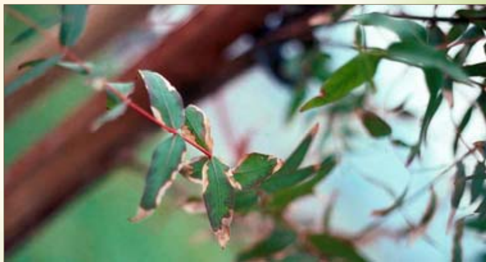

- Injury from excess B -m necrosis on the margins of older leaves.
- Turfgrasses are more sensitive to B toxicity than to either sodium or chloride.
- Most grasses will grow in soils with boron levels as high as 10 ppm.

Harivandi, 2013. CSSA slide set

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TABLE 3.12

Summary of irrigation water quality guidelines

Water parameter	Units	Desired range	Usual range[a]	Average domestic[b]	Average reclaimed[b]
		General water characteristics			
pH	1–14	6.5–8.4	6.0–8.5	7.7	7.1
Hardness	mg/L	<150	—	—	—
Alkalinity	mg/L	<150	—	—	—
HCO_3	mg/L	<120	<610	174	194
CO_3	mg/L	<15	<3	3.0	0
		Total salinity (soluble salts)			
EC_w	dS/m	0.40–1.20	<3.0	0.8	1.1
TDS	mg/L	256–832	<2000	617	729
		Sodium permeability hazard			
SAR_w	meq/L	<6.0	<15	1.9	3.1
adj RNa	meq/L	<6.0	<15	1.9	3.1
RSC	meq/L	<1.25	—	−2.30	−1.88
EC_w	dS/m	>0.40	—	—	—

Duncan, Carrow, and Huck, 2009.

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Summary of irrigation water quality guidelines

Water parameter	Units	Desired range	Usual range[a]	Average domestic[b]	Average reclaimed[b]
		Specific ion impact on root injury or foliage uptake injury			
Na	mg/L	<70	—	—	—
Cl	mg/L	<70	—	—	—
B	mg/L	<0.50	<2.0	0.17	0.44
		Specific ion impact on direct foliage injury from sprinkler irrigation			
Na	mg/L	<70	—	—	—
Cl	mg/L	<100	—	—	—
HCO_3 (unsightly on leaves)	mg/L	<90	—	—	—
		Miscellaneous			
Residual CL_2	mg/L	<1	—	—	—
Total suspended solids	mg/L	<30	—	—	—
pH_c	1–14	>8.4	—	—	—

Duncan, Carrow, and Huck, 2009.

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Summary of irrigation water quality guidelines

Water parameter	Units	Desired range	Usual range[a]	Average domestic[b]	Average reclaimed[b]
		Selected nutrients/elements			
N	mg/L	<10	<2.2	—	—
P	mg/L	<0.1	<0.66	—	—
K	mg/L	<20	<2.0	4.0	26
Ca	mg/L	<100	<400	67	64
Mg	mg/L	<40	<60	24	23
SO_4 (black layer potential)	mg/L	<90	<960	171	196
Fe	mg/L	<1.00	—	0.16	0.20
Mn	mg/L	<0.20	—	0.01	0.03

(continued)

Duncan, Carrow, and Huck, 2009.

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TABLE 3.12

Summary of irrigation water quality guidelines (continued)

Water parameter	Units	Desired range	Usual range[a]	Average domestic[b]	Average reclaimed[b]
Cu	mg/L	<0.20	—	0.04	0.03
Zn	mg/L	<1.0	—	0.12	0.08
Na	mg/L	<120	<920	70	114
Cl	mg/L	<70	<1062	82	130

[a] From Ayers, R. S. and D. W. Westcot. 1994. Water Quality for Agriculture. FAO Irrigation and Drainage Paper, 29, Rev. 1. Reprinted 1994. Food and Agric. Organiz., Rome, Italy.

[b] From Stowell, L. J. and W. Gelernter. 2001. Negotiating reclaimed water contracts: Agronomic considerations. *Pace Insights*. 7(3): 1–4. PACE Consulting, San Diego, CA.

Duncan, Carrow, and Huck, 2009.

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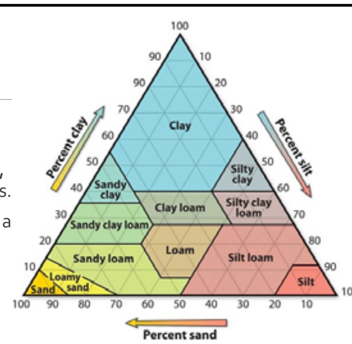
Soil Texture

Good to know your soil texture.

This determines infiltration, leaching ability, other issues.

Can send to soil test lab for a simple texture analysis



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Soil Testing

Good idea to conduct soil test at same time

Can ask for salinity report (saturated paste)

pH

Na, Ca, Mg, K, B, Cl

EC, TDS, SAR, ESP,

CO_3, HCO_3-, NO_3-N, SO_4

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Can Be Confusing

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How good is this water?

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Water Sample Collection

1. Contact your water testing lab to see what size sample is needed. Usually a clean 4 oz plastic bottle will work.
2. **Fill** the bottle as full as possible, **cap** and **submit** to lab.
3. Most labs can usually have results back within a week.
4. Private or state testing labs are fine…usually state labs are less expensive.

- **Make sure sample is representative!**
  - Best to sample from irrigation heads directly
    - Run the system for ~10 minutes before taking the sample

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What to Look for on the Irrigation Water Report; Where to Start?

Note the pH

Note the bicarbonates

Look at EC and TDS

Look at SAR and, if available, adj SAR

It's all important, but this is a good place to start looking.

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Let's look at a few examples.

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Municipal Water Source

Test Results for Irrigation Water

---------- Cations ----------		---------- Anions ----------		---------- Other ----------	
Sodium (ppm)	21	Nitrate-N (ppm)	1.1	pH	7.7
Calcium (ppm)	50	Chloride (ppm)	33	EC (µmhos/cm)	380
Magnesium (ppm)	4	Sulfate (ppm)	39		
Potassium (ppm)	6	Boron (ppm)	0.12		
		Bicarbonate (ppm)	123		

---------- Derived Values ----------		-------- Derived Values(cont'd) --------	
Total Dissolved Salts (TDS in ppm)	277.4	Sodium Percentage	24.9 %
Sodium Adsorption Ratio (SAR)	0.8	Hardness (ppm)	141.0
Potassium Adsorption Ratio (PAR)	0.1	Hardness Class	Hard
		Alkalinity (ppm as CaCO3)	100.5

INTERPRETATION AND REQUIREMENTS FOR *Irrigation Water*

The total dissolved salt and sodium content of this water are low enough that no problem should result from its use.

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Oklahoma State – Municipal

Test Results for Irrigation Water

---------- Cations ----------		---------- Anions ----------		---------- Other ----------	
Sodium (ppm)	42	Nitrate-N (ppm)	2.0	pH	8.0
Calcium (ppm)	33	Chloride (ppm)	30	EC (µmhos/cm)	476
Magnesium (ppm)	15	Sulfate (ppm)	59		
Potassium (ppm)	6	Boron (ppm)	0.12		
		Bicarbonate (ppm)	150		

---------- Derived Values ----------		-------- Derived Values(cont'd) --------	
Total Dissolved Salts (TDS in ppm)	336.7	Sodium Percentage	38.8 %
Sodium Adsorption Ratio (SAR)	1.5	Hardness (ppm)	143.5
Potassium Adsorption Ratio (PAR)	0.1	Hardness Class	Hard
		Alkalinity (ppm as CaCO3)	123.3

INTERPRETATION AND REQUIREMENTS FOR *Irrigation Water*

Water of this quality is suitable for use on most crops under most conditions. A problem may eventually arise with continued use of this water on very heavy soils where essentially no leaching occurs. If rainfall is sufficient, it will dilute the salts and reduce the hazard. If sodium is the main problem, gypsum can be used to help remedy the problem.

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Reclaimed Water

Test Results for Irrigation Water

---------- Cations ----------		---------- Anions ----------		---------- Other ----------	
Sodium (ppm)	79	Nitrate-N (ppm)	1.9	pH	7.7
Calcium (ppm)	93	Chloride (ppm)	44	EC (µmhos/cm)	942
Magnesium (ppm)	27	Sulfate (ppm)	89		
Potassium (ppm)	1	Boron (ppm)	0.64		
		Bicarbonate (ppm)	413		

---------- Derived Values ----------		-------- Derived Values(cont'd) --------	
Total Dissolved Salts (TDS in ppm)	747.5	Sodium Percentage	33.3 %
Sodium Adsorption Ratio (SAR)	1.8	Hardness (ppm)	342.8
Potassium Adsorption Ratio (PAR)	0.0	Hardness Class	Very Hard
		Alkalinity (ppm as CaCO3)	338.5

INTERPRETATION AND REQUIREMENTS FOR *Irrigation Water*

Water of this quality is suitable for use on most crops under most conditions. A problem may eventually arise with continued use of this water on very heavy soils where essentially no leaching occurs. If rainfall is sufficient, it will dilute the salts and reduce the hazard. If sodium is the main problem, gypsum can be used to help remedy the problem.

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RECLAIMED

---------- Cations ----------		---------- Anions ----------		---------- Other ----------	
Sodium (ppm)	139	Nitrate-N (ppm)	<1	pH	8.2
Calcium (ppm)	16	Chloride (ppm)	36	EC (µmhos/cm)	717
Magnesium (ppm)	7	Sulfate (ppm)	103	NH4_N (ppm)	0.17
Potassium (ppm)	3	Boron (ppm)	0.79	ICAP_P (ppm)	0.03
		Bicarbonate (ppm)	270		

---------- Derived Values ----------		-------- Derived Values(cont'd) --------	
Total Dissolved Salts (TDS in ppm)	574.5	Sodium Percentage	81.2 %
Sodium Adsorption Ratio (SAR)	7.2	Hardness (ppm)	69.9
Potassium Adsorption Ratio (PAR)	0.1	Hardness Class	Medium
Residual Carbonates (meq)	3.0	Alkalinity (ppm as CaCO3)	221.4

INTERPRETATION AND REQUIREMENTS FOR *Irrigation Water*

This water is generally of sufficiently low quality that its use is considerably restricted. It may be used safely only on very well-drained permeable soils and on salt tolerant crops. It requires careful irrigation practices including applications of excess irrigation water to keep the soil leached of salt when rainfall is insufficient to provide leaching.

Good soil management practices must be used to maintain good physical structure in the soil and to maintain a high level of fertility. Use of this water on medium textured soils may result in problems if care is not exercised. This water is not recommended for heavy textured soils.

If this water is used extensively, it is recommended that a soil sample be obtained every few years from the irrigated fields to determine the extent to which sodium or salts may be accumulating and the need for special management practices.

Residual carbonates are present in excess amounts lowering water quality to unsuitabe.
Water with too high residual carbonates may contain effective sodium in excess of that indicated by the sodium percentage of the water. The calcium and magnesium may precipitate out as lime, thus increasing the percentage of sodium.

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RECLAIMED

INTERPRETATION AND REQUIREMENTS FOR *Irrigation Water*

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Soil Testing: detailed salinity report

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1. Water with high total salts makes for a saline soil.

Water report
Total Salts I **2,700 mg/L**, Poor
SAR I 1.5, Good
HCO_3 I 0.0 mg/L, No adj SAR
Boron I 0.05 mg/L, No Concern

Soil salinity report
TSS I **6,000 mg/L**, Saline
SAR I 2.2, Normal
Boron I 0.03 mg/L, No Concern

Texture report
35% Sand
30% Silt
35% Clay

This irrigation water is classified as **Poor** because of the high total salts. This soil is classified as **Saline** because of the high TSS. This soil is classified as a **Clay Loam** with low permeability.

Plant symptoms. Brown areas, similar to drought stress.
Management strategy. Regularly use excess irrigation water to leach salts from the soil. Use better water if available.

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2. Water with high sodium makes for a sodic soil.

Water report
Total Salts I 1,320 mg/L, Fair
SAR I **7.0**, Poor
HCO_3 I 0.0 mg/L, No adj SAR
Boron I 0.12 mg/L, No Concern

Soil salinity report
TSS I 2,000 mg/L, Normal
SAR I **16,** Sodic
Boron I 0.45 mg/L, No Concern

Texture report
35% Sand
20% Silt
45% Clay

This irrigation water is classified as **Poor** because of the high SAR. This soil is classified as **Sodic** because of the high SAR (high sodium). This soil is classified as a **Clay** with very low permeability.

Plant symptoms. Brown areas, similar to drought stress; soil water fails to drain.
Management strategy. Aerify soil and sand topdress; apply 10 pounds pelletized gypsum/1,000 sq. ft. and repeat in 30 days. Utilize a maintenance program of 5 pounds pelletized gypsum/1,000 sq. ft. per month during growing season with regular flushing and leaching.

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3. Water with both high total salts and high sodium makes for a saline-sodic soil.

Water report
Total Salts I **2,120 mg/L,** Poor
SAR I **6.6,** Poor
HCO3 I 0.0 mg/L, No adj SAR
Boron I 0.55 mg/L, Concern for Sensitive Plants

Soil salinity report
TSS I **5,400 mg/L,** Saline
SAR I **14,** Sodic
Boron I 0.95 mg/L, Concern for Sensitive Ornamentals

Texture report
40% Sand
40% Silt
20% Clay

This irrigation water is classified as **Poor** because of high total salts and high SAR. This soil is classified as **Saline-Sodic** because of the high TSS and the high SAR. This soil is classified as a **Loam** with moderate permeability.

Plant symptoms. Brown areas, similar but not identical to drought stress.
Management strategy. Apply 10 pounds pelletized gypsum/1,000 sq. ft. and repeat in 30 days; utilize a maintenance program of 5 lbs pelletized gypsum/1000 sq. ft. per month during growing season with regular flushing and leaching. Use different water supply for ornamental trees.

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4. Water with high residual sodium carbonate makes for a sodic soil.

Water report
Total Salts I 416 mg/L, Good
SAR I 3.2, Fair
HCO3 I 305 mg/L, adj SAR **4.2,** Poor
Boron I 0.06 mg/L, No Concern

Soil salinity report
TSS I 1530 mg/L, Normal
SAR I **13,** Sodic
Boron I 0.15 mg/L, No Concern

Texture report
22% Sand
40% Silt
38% Clay

This irrigation water is classified as **Poor** because of the high adj SAR of **4.2;** this adj SAR poses a potential, long-term soil problem where calcium is removed from the soil. This soil is classified as **Sodic** with an SAR of 16 because of the high adj SAR in the water. This soil is classified as a **Clay** with very low permeability.

Plant symptoms. Brown areas, similar to drought stress; soil water fails to drain.
Management strategy. Aerify soil and sand topdress; apply 10 pounds pelletized gypsum/1,000 sq. ft. and repeat in 30 days. Investigate the possibility of acidifying this water, but consult with a water quality specialist.

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5. Water with high boron results in soil with high boron.

Water report
Total Salts I 756 mg/L, Good
SAR I **0.7,** Excellent
HCO^3 I 0.0 mg/L, no adj SAR
Boron I **1.93 mg/L,** Concern

Soil salinity report
TSS I 1,260 mg/L, Normal
SAR I 0.9, Normal
Boron I **3.50 mg/L,** Concern

Texture report
40% Sand
40% Silt
20% Clay

This irrigation water is classified as **Good** because of the low total salts, but the high boron makes it potentially harmful to sensitive plants such as Kentucky bluegrass and ornamentals. This soil is classified as **Normal** because of the TSS and SAR, but boron in this soil can be a problem; most turf can tolerate relatively high concentrations of boron, but ornaments such as trees cannot.

This soil is classified as a **Loam** with moderate permeability.

Plant symptoms. Burnt leaf tips; however frequent mowing removes the problem.
Management strategy. Do not use this water on ornamental trees and cool season grasses; consult a water quality specialist if necessary.

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Turf Management and Poor Quality Water

- Identify the problem
- Develop a plan
- Execute the plan
- Re-assess

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Turfgrass Selection

Warm-season turfgrass	Salinity Tolerance	Cool-season turfgrass
Seashore Paspalum	Tolerant	Alkaligrass
Zoysiagrass	Tolerant	Tolerant
St Augustinegrass	Tolerant	Tolerant
Bermudagrass	Moderately Tolerant	
		Creeping bentgrass
		Tall fescue
Buffalograss	Moderately Tolerant	Perennial ryegrass
Centipedegrass	Sensitive	Kentucky bluegrass

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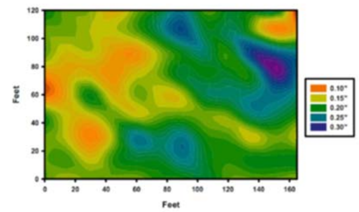
Irrigation Uniformity



Brown and Walworth 2010

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Leaching Fraction

- Dilution of salts in the rootzone through repeated over-application of water.
- This is built into your normal irrigation cycle.

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Table 2
Determination of the Maintenance Leaching Requirement (LR)
(after Rhoades[a])

Concept: Once the soil salinity level in the turfgrass rootzone is at an acceptable or desirable level, the leaching requirement (LR) approach is used to maintain this level. The "leaching requirement" (LR) is the minimum amount of water that passes through the rootzone to control salts within an acceptable range. A good formula to determine LR is:

$$LR = \frac{EC_w}{5EC_t - EC_w}$$

where EC_w = irrigation water salinity (dSm^{-1})
EC_t = threshold soil salinity at which growth starts to decline for the turfgrass on the site. Carrow and Duncan[1] has an extensive listing.

Example: For turfgrass with a threshold EC_t of 6 dSm^{-1} and irrigation water that has an EC_w = 2 dSm^{-1}.

$$LR = \frac{(2)}{5(6) - 2} = 0.0714$$

which means that the LR is 7.1% more irrigation water volume than that needed to meet ET needs. Thus, if irrigation of 0.50 inches of water is required to replace soil moisture lost by ET, an additional 7.1% or (0.50 × 0.07) = 0.035 inches of water would be required for a total of 0.535 inches to maintain a particular salinity level. It should be noted that a *more saline irrigation water* with higher EC_w or a *less-salt-tolerant grass* would *increase the LR*.

Carrow Huck and Duncan - 2000

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Leaching Fraction

Table 1
Properties of saline and potable irrigation water used in the line-source gradient study in Riverside, CA.

Properties	Potable	Saline
pH	7.8	7.6
EC, $dS\ m^{-1}$	0.6	4.4
TSS, $mg\ L^{-1}$	390	2835
SAR, $meq\ L^{-1}$	3.2	18.3
Na^{+}, $mg\ L^{-1}$	53	524
K^{+}, $mg\ L^{-1}$	4	130
Ca^{2+}, $mg\ L^{-1}$	66	126
Mg^{2+}, $mg\ L^{-1}$	12	152
Cl^{-}, $mg\ L^{-1}$	31	996
NO_3^{-}-N, $mg\ L^{-1}$	5.2	5.1
HCO_3^{-}, $mg\ L^{-1}$	215	210
CO_3^{2-}, $mg\ L^{-1}$	0.01	0.01
SO_4^{2-}, $mg\ L^{-1}$	78	708
B, $mg\ L^{-1}$	0.08	0.11

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Table 6
Electrical conductivity and Sodium Absorption Ratio (SAR) of soil saturation extract (EC_e; $dS\ m^{-1}$), in October 2012 for each irrigation treatment (80, 100, 120, and 140% ET_o) and salinity level (0.6, 1.7, 3.0, 3.5, 4.2 $dS\ m^{-1}$) at the end of line-source gradient study in Riverside, CA.

ET_o	0.6 $dS\ m^{-1}$ (EC_w)	1.7 $dS\ m^{-1}$ (EC_w)	3.0 $dS\ m^{-1}$ (EC_w)	3.5 $dS\ m^{-1}$ (EC_w)	4.2 $dS\ m^{-1}$ (EC_w)
%	EC_e ($dS\ m^{-1}$)				
80	1.5 e[1]	3.1 de	6.8 bcde	8.8 bc	16.6 a
100	1.7 e	3.6 de	5.8 bcde	8.8 bc	15.1 a
120	1.4 e	2.6 e	4.7 bcde	8.2 bcd	12.1 ab
140	1.7 e	2.9 de	4.2 cde	5.7 bcde	6.4 bcde

[1] values followed the same letter are not statistically different from one another (α = 0.05).

Table 4
Time (d) for perennial ryegrass quality to fall below a minimally acceptable quality rating of 6 (1–9 scale, 9 = best) during the 442-d line-source gradient study in Riverside, CA. Values were generated by regression equations and are presented for each water quality (EC_w) treatment.

	EC_w	% ET_o[a] 80	100	120	140
	$dS\ m^{-1}$	%			
Turf Quality (Rating = 6)	0.6	207	318	332	441
	1.7	164	259	305	395
	3.0	115	191	275	343
	3.5	96	165	263	323
	4.2	67	126	245	292

[a] % ET_o, irrigation amount.

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Key Points

Only the 140% ET_o irrigation amount led to acceptable turf quality.

Conventional methods of calculating leaching fractions may not be appropriate for some regions/climates.

For cool-season turfgrasses, stress is worsened by extreme ambient and soil temperatures.

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Products on the Market

It depends on the problem

Salinity stress = drought stress
- Wetting agents can help mask the issue

Sodium issues require calcium applications

Bicarbonates can be treated with sulfur or acids

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Calcium-based products: Effects on Na content of leaf tissue

Untreated	1369.67
Gypsum 10#	1325.17
Gypsum 40#	861.33
LSD (0.05)	450.99*

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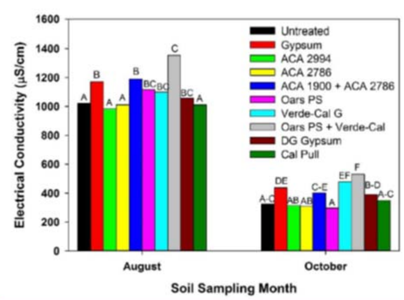

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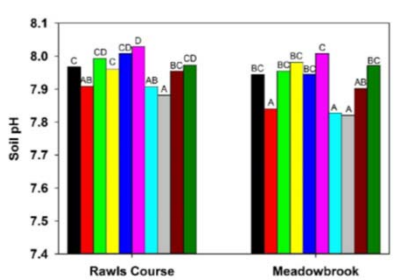

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Key Points

Calcium and Gypsum-containing products help with sodium problems but not necessarily salinity problems.

High pH caused by sodium can be lowered using gypsum-based products.

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Aerification

Absolutely critical to long-term management of all poor quality water issues.

Depth of cultivation not always critical
- Spoon-type or Aerway style can be effective
- What is your goal?

Time aerification with gypsum applications and seasonal rain patterns.

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SAR in sand cap fairway after shockwave aerification

Shockwave	5.70
No Shockwave	7.63
LSD (0.05)	1.76*

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A distinct layer in the profile is inhibiting water movement, resulting in black layer development near the surface. Frequent core cultivation is needed to keep water and salts moving down through the profile.

Carrow Huck and Duncan - 2000

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Benefits of a Sand Cap

- Leaching salts
- Reduced sodium permeability issues
- Avoid using sod to maintain integrity of the sand cap

- *Leached salts build up in sub-grade?*

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Other options

- Building a sand cap through long-term heavy topdressing programs can be effective.

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Avoid adding extra salt

- Use low salt index fertilizers
- Don't add gypsum if you don't have a sodium problem

Fertilizer	Formulation	Relative salt content / lb N
Ammonium sulfate	21-0-0	3.3
Ammonium nitrate	33-0-0	3.2
Urea	45-0-0	1.6
Ureaformaldehyde	38-0-0	0.3
IBDU	31-0-0	0.2

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Blending Water Sources Can Be the Key

Table 1. Chemical composition of irrigation water (Las Vegas, NV).

Characteristic†	Shallow aquifer water	Blended irrigation water‡	Municipal water
EC, dS m^{-1}	7.65	5.95	1.08
Na, mmol L^{-1}	31.34	23.16	4.61
K, mmol L^{-1}	1.30	1.13	0.51
Ca, mmol L^{-1}	14.84	11.71	2.35
Mg, mmol L^{-1}	20.55	9.84	1.61
Cl, mmol L^{-1}	21.81	16.12	1.85
HCO_3, mmol L^{-1}	2.97	2.87	2.93
CO_3, mmol L^{-1}	0.00	0.00	0.00
SO_4, mmol L^{-1}	36.28	26.58	3.31
NO_3-N, mmol L^{-1}	1.30	1.02	0.08
Adj. SAR‡	5.95	5.64	2.67
B, mg kg^{-1}	–	3.70	0.38

† EC, electrical conductivity. Adj. SAR, adjusted sodium absorption ratio.
‡ Aquifer water blended with municipal water for a target EC of 6.0 dS m^{-1}.

Turfgrass Quality, Growth, and Water Use Influenced by Salinity and Water Stress
Dorothy E. Dean, Dale A. Devitt,* Linda S. Verchick, and Robert L. Morris

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Management Techniques for Poor Quality Water

- Irrigate with leaching fraction
- Periodic flushing
- Add gypsum if sodium is high
  - (elemental sulfur can be used if soil is calcareous)
- Acid injection for bicarbonates
- Aerification and topdressing
- Subsurface drainage or sandcapping
- Dilute bad water with good water

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Recycled Water - Special Areas of Concern

Human Health and Safety
Regulatory Issues
Quality of Water for Agronomic Use
Quantity of Water

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Quantity of Water

How much do I need and will it be available (reliability)?

Did you factor in leaching fraction?

Must you take a minimum amount?

How to deal with excess water?

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Conclusions

In most cases, less than ideal quality water **can** be successfully used to irrigate turf provided **attention** is given to the following areas:

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Conclusions (cont'd)

1. Periodically, sample and test your irrigation water to determine its quality (seasonally?).
2. Select turfgrasses that are salt and drought resistant.

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Conclusions (cont'd)

3. Understand the limitations associated with water containing high salinity and sodium.

4. Apply appropriate management techniques to prevent excessive salt and sodium accumulation.

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Group Discussion

Regional perspectives

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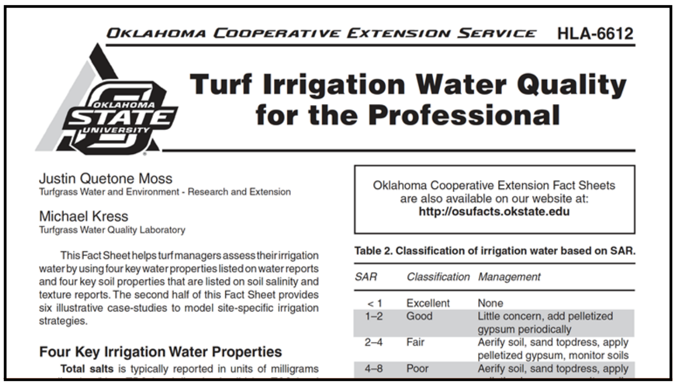

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Turf Irrigation Water Quality for the Professional

Justin Quetone Moss
Turfgrass Water and Environment - Research and Extension

Michael Kress
Turfgrass Water Quality Laboratory

Oklahoma Cooperative Extension Fact Sheets are also available on our website at:
http://osufacts.okstate.edu

This Fact Sheet helps turf managers assess their irrigation water by using four key water properties listed on water reports and four key soil properties that are listed on soil salinity and texture reports. The second half of this Fact Sheet provides six illustrative case-studies to model site-specific irrigation strategies.

Four Key Irrigation Water Properties

Total salts is typically reported in units of milligrams

Table 2. Classification of irrigation water based on SAR.

SAR	*Classification*	*Management*
< 1	Excellent	None
1–2	Good	Little concern, add pelletized gypsum periodically
2–4	Fair	Aerify soil, sand topdress, apply pelletized gypsum, monitor soils
4–8	Poor	Aerify soil, sand topdress, apply

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Interpretation of Results : Resources

Source	Author(s)	Title
University of California	M. Ali. Harivandi	Interpreting Turfgrass Irrigation Water Test Results
Penn State University	Peter Landschoot	Irrigation Water Quality Guidelines for Turf Sites
N.C. State University	Charles Peacock et al.,	Irrigation Water Quality Problems
Clemson University	Dara M. Park et al.,	Interpreting Irrigation Water Quality Reports

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Interpretation of Results : Resources

Source	Author(s)	Title
SportsTurf Magazine	Peter Landschoot	Irrigation Water Quality Guidelines for Sports Turf
PACE Turf	PACE Turf Team	Water Quality Guidelines
Aquatrols	Aquatrols Team	Assessing and Managing Turf Salinity Issues in Irrigation Water and Soils
Textbook	Ronny R. Duncan et al.,	Turfgrass and Landscape Irrigation Water Quality

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Questions?

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EXTENSION

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