Spectrum Analytic, Inc.

GUIDE TO INTERPRETING IRRIGATION WATER ANALYSIS

Soil Analysis
Plant Analysis
Fertilizer Analysis
Manure Analysis

1087 Jamison Road
PO Box 639
Washington C.H., Ohio 43160

1-800-321-1562
(740) 335-1562
Fax: (740) 335-1104
www.spectrumanalytic.com

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Introduction

While a few aspects of irrigation water quality have a direct impact on plants, the primary goal of water analysis is to judge the effect of the water on the soil, and ultimately on the plants grown on the soil. As such, much of the interpretation of the water analysis is based on a prediction of the consequences for the soil. The interpretation of the test results is, in many cases, dependant on the intended use of the water. Some plant species and production systems may have much different requirements or tolerances. The interpretation guide lists some of these conditions and will help you evaluate your results.

Water Salinity

Water salinity is a measure of the total dissolved salts. Saline water poses several hazards:

- As the salinity of the soil is increased by the use of water containing appreciable soluble salts, plants have increasing difficulty absorbing water.
- A primary cause of water salinity is excess sodium (Na). As Na accumulates in the soil it can compete with other nutrients for uptake by the plants and may become directly toxic.
- Excess sodium in natural soil can lead to the loss of soil structure, causing the loss of soil permeability and leading to poor plant growth.
- Water with too little dissolved salts can also be a problem in that it may lead to soil permeability problems.
- Where irrigation is applied by overhead sprinklers, excess water salinity can lead to foliage damage.

SALINITY HAZARD LEVELS*

Application	Units	None	Increasing	Significant	High	Severe
All seedlings	mmho/cm	<0.2	0.2-0.7	0.8-1.0	1.1-1.5	>1.5
Container plants	mmho/cm	<0.5	0.5-0.7	0.8-1.0	1.1-2.0	>2.0
Nurseries**	mmho/cm	<0.2	0.2-0.7	0.8-1.25	1.26-3.0	>3.0
Field crops	mmho/cm	<0.75	0.75-1.0	1.1-2.0	2.1-3.0	>3.0
Hydroponics Field crops	mmho/cm	<0.75	0.75-1.0	1.1-2.0	2.1-3.0	>3.0
Soil Permeability***	mmho/cm	>0.5				<0.4

* See appendix A for more specific information

** Some common salt sensitive plants include Contoeaster horizontalis, Photina fraseri, Ilex cornuta, Vinca minor, Hibiscus rosasinensis, Nanadina domestica, Azalea, Bardenia, and Limonium perezii. This list is not comprehensive

*** The University of California has found that irrigation with exceptionally “pure” water has caused soil permeability problems with some vineyard soils in Eastern CA

Water pH, Alkalinity, Bicarbonates, and Carbonates

Water pH

The pH is a measurement of the relative acidity or basicity of the water. The pH range is from 0 to 14. Values from 0 to 6.9 are acidic and those from 7.1 to 14 are basic or alkaline, with 7.0 being neutral. The pH scale is logarithmic, meaning that a change of 1.0 unit is a ten-fold change in either acidity or basicity. Therefore, changes of less than 1.0 unit may be significant. This characteristic of the water has a significant influence on other characteristics or reactions in the soil and water, as well as the way plants perform. A water pH between 6.0 and 7.0 is normally considered to be the most desirable for irrigation. When the pH is outside of this range, it indicates that special actions may need to be taken to improve crop performance.

Alkalinity

This indicates the ability of the water to increase the pH of the soil or growing media, and the buffering power (resistance to change) of the water itself. In other words, the ability of the water to act as a liming agent. Alkalinity is defined as the combined effect of bicarbonates (HCO_3^-) plus the carbonates (CO_3^{--}). High alkalinity indicates that the water will tend to increase the pH of the soil or growing media, possibly to a point that is detrimental to plant growth. Low alkalinity could also be a problem in some situations. This is because many fertilizers are acid-forming and could, over time, make the soil too acid for some plant. If the water is also somewhat acidic, the process would be accelerated.

Another aspect of alkalinity is its potential effect on sodium (Na^-). Soil or artificial growing media irrigated with alkaline water may, upon drying, cause an excess of available sodium. Several potential problems could result.

- The excess available sodium could become directly toxic to some plants
- The salinity of the soil could be increased to the point that plant growth is damaged.
- Excess sodium could damage the structure of natural soil to the point that air and water infiltration are prevented, and root growth is restricted.

Among the components of water alkalinity, bicarbonates are normally the most significant concern. Typically, bicarbonates become an increasing concern as the water increases from a pH of 7.4 to 9.3. However, bicarbonates can be found in water of lower pH. Carbonates become a significant factor as the water pH increases beyond 8.0 and are a dominant factor when the pH exceeds about 10.3. High levels of bicarbonates can be directly toxic to some plant species. Bicarbonate levels above 3.3 me/l (200 ppm) will cause lime (calcium and magnesium carbonate) to be deposited on foliage when irrigated with overhead sprinklers. This may be undesirable for ornamental plants. Similar levels of bicarbonates may also cause lime deposits to form on roots, which can be especially damaging to many tree species. High water alkalinity can be corrected with acid injection (see **appendix D**).

Danger from high alkalinity is governed in part by the volume of soil or artificial media involved. For example, greenhouse transplant production (plugs) have very little soil media and are less tolerant of a given alkalinity level than most other container production systems. Field production will typically be the most tolerant. An example of this effect is illustrated in the guidelines published by the Univ. of Massachusetts.

SUGGESTED ALKALINITY GUIDELINES (ppm $CaCO_3$)		
Container Size	**Acceptable Alkalinity**	**Concern Level**
Plugs	60-100	<40, >120
Small Pots	80-120	<40, >140
4 -5 Pots	100-140	<40, >160
>6 Pots	120-180	<60, >200

At Spectrum Analytic, we have chosen the following guidelines, based on multiple sources of information. However, these levels should be viewed in light of the pH requirements of the crop. Alkalinity hazards may be slightly higher for acid-loving crops, and less for high pH tolerant crops.

ALKALINITY HAZARD LEVELS						
Application	**Units**	**None**	**Increasing**	**Significant**	**High**	**Severe**
Field crops	me/l $CaCO_3$	<1.0	1.0-2.0	2.0-3.0	3.0-4.0	>4.0
	ppm $CaCO_3$	<50	50-100	100-150	150-200	>200
Greenhouse and Nurseries*	me/l $CaCO_3$	<1.0	1.0-1.5	1.5-2.0	2.0-3.0	>3.0
	ppm $CaCO_3$	<50	50-75	75-100	100-150	>150
Greenhouse "Plugs"	me/l $CaCO_3$	<1.0	1-1.25	1.25-1.5	1.5-2.0	>2.0
	ppm $CaCO_3$	<50	50-63	63-75	75-100	>100
* Some floriculture crops may have an upper alkalinity limit of 2 me/l or 100 ppm $CaCO_3$ equivalent.						

BICARBONATES (HCO_3) HAZARD LEVELS						
Application	**Units**	**None**	**Increasing**	**Significant**	**High**	**Severe**
Field crops	me/l HCO_3	<1.0	1.0-2	2.0-3.0	3.0-4.0	>4.0
	ppm HCO_3	<61	61-122	122-183	183-244	>244
Greenhouse and Nurseries*	me/l HCO_3	<1.0	1.0-1.5	1.5-2.0	2.0-3.0	>3.0
	ppm HCO_3	<61	61-92	92-122	122-183	>183
Greenhouse "Plugs"	me/l HCO_3	<1.0	1.0-1.25	1.25-1.5	1.5-2.0	>2.0
	ppm HCO_3	<61	61-76	76-92	92-122	>122
*Bicarbonate levels above 3.3 me/l (200 ppm) will cause lime (calcium and magnesium carbonate) to be deposited on foliage when irrigated with overhead sprinklers. This may be undesirable for ornamental plants. Similar levels of bicarbonates may also cause lime deposits to form on roots, which can be especially damaging to many tree species. Acid injection into the irrigation water is needed to correct this condition. (See appendix D).						

Carbonates (CO_3)

Carbonates in water typically consist of precipitated calcium ($CaCO_3$) or magnesium carbonate ($MgCO_3$). They are the same compounds as the active portions of lime and have a similar effect on soil and plant growth as lime. Generally, water that contains appreciable carbonates will have already exceeded desirable bicarbonate levels. The carbonate content of water is considered in conjunction with bicarbonates for several important evaluations such as alkalinity, the sodium adsorption ratio (SAR), adjusted sodium adsorption ratio (SAR adj.), and residual sodium carbonate (RSC). Carbonates will not be a significant component of water at a pH below 8.0, and will likely dominate at a pH above 10.3.

Sodium Adsorption Ratio (SAR)

The SAR is used to predict the danger of sodium (Na) accumulation in the soil. While some plants, such as table beets, spinach, celery, and possibly others have a relatively high requirement for, or tolerance of Na, most plants have minimal needs for, or tolerance of high Na levels. The SAR relates the relative concentration of Na to the combined concentration of Ca and Mg. Another hazard that excess Na presents in natural soils is the danger of loss of soil structure with the resulting reduction in soil permeability and aeration. The interpretive guidelines for SAR are as follows.

SAR HAZARD LEVELS*					
Application	**None**	**Increasing**	**Significant**	**High**	**Severe**
Most Production Systems	<1	1-2	2-4	4-5	>5
Hydroponics	<3	3-7	7-8	8-9	>9

*The SAR, and SAR adj. can be reduced by

1. Increasing the calcium content of the water or soil by adding gypsum or another soluble calcium salt (see appendix B).
2. The SAR and SAR adj. can be reduced by reducing the bicarbonate (HCO_3) level. This is normally accomplished by acidifying the irrigation water.

Adjusted Sodium Adsorption Ratio (SAR adj.)

The SAR adj. (sometimes symbolized as Adj R_{Na}) is a modification of the original SAR calculation. It serves the same purposes, but is modified to include the effects of bicarbonates and carbonates, in addition to Ca and Mg. It is generally considered to be more useful information.

SAR adj. HAZARD LEVELS*					
Application	**None**	**Increasing**	**Significant**	**High**	**Severe**
Direct plant Impact	<3	3-6	6-8	8-9	>9
Permeability of Natural Soil	<6	6-7	7-8	8-9	>9

*The SAR, and SAR adj. can be reduced by

1. Increasing the calcium content of the water or soil by adding gy psum or another soluble calcium salt (see appendix B).
2. The SAR adj. can be reduced by reducing the bicarbonate (HCO_3) level. This is normally accomplished by acidifying the irrigation water.

Residual Sodium Carbonate

Residual sodium carbonate (RSC) exists in irrigation water when the carbonate (CO_3) plus bicarbonate (HCO_3) content exceeds the calcium (Ca) plus magnesium (Mg) content of the water. Where the water RSC is high, extended use of that water for irrigation will lead to an accumulation of sodium (Na) in the soil. The results of this include 1) Direct toxicity to crops, 2) Excess soil salinity (EC) and associated poor plant performance, and 3) Where appreciable clay or silt is present in the soil, loss of soil structure and associated decrease in soil permeability.

RSC HAZARD					
Units	**None**	**Increasing**	**Significant**	**High**	**Severe**
me/l	<1.24	1.25-1.7	1.7-2.1	2.1-2.5	>2.5

*See appendix B for gypsum recommendations to counter a high RSC.

Lime Deposition Potential

Lime Deposition Potential (LDP) is used by fruit producers to avoid or minimize or avoid the occurrence of lime spots on fruit or tree roots. Fruit deposition is unsightly and detracts from the value of the crop, while root deposition can be harmful to the trees. While no data exists supporting the use of this evaluation for other plants, it would seem useful in other circumstances where clean fruit or foliage is important, or with root deposition on most tree species.

LDP HAZARD LEVELS						
Application	**Unit**	**None**	**Increasing**	**Significant**	**High**	**Severe**
“Overhead Irr. or Evaporative Cooling”	$CaCO_3$ (me/l)	<2	2.1-2.5	2.6-3.0	3.1-4.0	>4.0
	$CaCO_3$ (ppm)	<100	101-125	126-150	151-200	>200

Individual Elements or Compounds

Nutrient Elements

The status assignments are related to the amounts typically found in acceptable irrigation water and not necessarily related to adequacy for crop growth. Some micronutrients (B, Cu, Fe, Mn, and Mo) may be present in sufficient or excessive amounts for some species.

RELATIVE STATUS							
Element	**Application**	**Units**	**V. Low**	**Low**	**Medium**	**High**	**V. High**
pH	All, 5.0 – 7.0 is normally acceptable. Some species benefit from more acid conditions.						
pH	micro-irrig. blockage		<6.5	6.5-7.2	7.2-7.6	7.7-8.0	>8.0
Nitrogen, Total (N)	All	ppm	<18	19-36	37-54	55-90	>90
Nitrate-N (NO_3-N)	All	ppm	<15	16-30	31-45	46-75	>75
Ammonium-N (NH_4-N)	All	ppm	<3	4-6	7-9	10-15	>15
NH_4-N + NO_3-N	Hydroponics	ppm	<5	6-13	14-21	22-30	>30
Phosphorus (P)	All	ppm	<1	1-1.9	2-2.9	3-5	>5
Potassium (K)	All	ppm	<3	3.1-4.5	4.6-6.0	6.1-10.0	>10
Calcium (Ca)*	All	ppm	<40	41-80	81-120	121-150	>150
Magnesium (Mg)	All	ppm	<8	9-16	17-24	25-30	>30
Sulfate-S (SO_4-S)	All	ppm	<24	25-50	51-240	241-300	>300
Boron (B)**	Greenhouse, Nursery	ppm	<0.25	0.26-0.5	0.51-0.8	0.81-2.0	>2.0
Boron (B)**	Field crops	ppm	<0.75	0.76-1.17	1.18-1.6	1.61-2.0	>2.0
Boron (B)	Hydroponics	ppm	<1.0	1.1-1.25	1.26-1.6	1.61-2.0	>2.0
Copper (Cu)	All	ppm	<0.05	0.06-0.10	0.11-1.20	0.21-0.30	>0.30
Iron (Fe)	All	ppm	<0.20	0.21-0.30	0.31-0.40	0.41-0.50	>0.50
Iron (Fe)	micro-irrig. blockage	ppm	<0.20	0.21-0.63	0.64-1.0	1.1-1.5	>1.5
Manganese (Mn)	All	ppm	<0.50	0.51-0.75	0.76-1.0	1.1-2.0	>2.0
Manganese (Mn)	micro-irrig. blockage	ppm	<0.10	0.11-0.57	0.58-1.0	1.1-1.5	>1.5
Molybdenum (Mo)	All	ppm	<0.005	.006-0.01	0.011-.020	.021-0.05	>0.05

*See appendix B for gypsum recommendations.

** See appendix E for more information on boron tolerance by crops.

Non-Nutrient Elements

The following elements, when in excess can be damaging to plant growth

TOXICITY HAZARD							
Element	**Application**	**Units**	**None**	**Increasing**	**Significant**	**High**	**Severe**
Sodium (Na)*	Foliar	ppm	<69				
Sodium (Na)*	Woody Ornamentals	ppm	<30	31-35	36-45	46-50	>50
Sodium (Na)*	Others	--------	Use SAR or SAR adj.				
Sodium (Na)	Foliar	ppm	<69	"No specific calibration available"			
Chloride (Cl)**	Foliar	ppm	<40	41-60	61-80	81-100	>100
Chloride (Cl)**	Soil	ppm	<70	71-140	141-240	241-345	>345
Chloride (Cl)	Hydroponics	ppm	<70	71-140	141-240	241-345	>345
Aluminum (Al)	Long Term Irrig.	ppm	<1	1.1-3.0	3.1-4.0	4.1-5.0	>5.0
Arsenic (As)	Long Term Irrig	ppm	<0.1	"No specific calibration available"			
Beryllium (Be)	Long Term Irrig	ppm	<0.1	"No specific calibration available"			
Cadmium (Cd)	Long Term Irrig	ppm	<0.01	"No specific calibration available"			
Chromium (Cr)	Long Term Irrig	ppm	<0.1	"No specific calibration available"			
Cobalt (Co)	Long Term Irrig.	ppm	<0.05	"No specific calibration available"			
Fluoride (Fl)***	Long Term Irrig.	ppm	<1	"No specific calibration available"			
Lead (Pb)	Long Term Irrig.	ppm	<5	"No specific calibration available"			
Lithium (Li)	Long Term Irrig.	ppm	<2.5	"No specific calibration available"			
Nickel (Ni)	Long Term Irrig.	ppm	<0.2	"No specific calibration available"			
Selenium (Se)	Long Term Irrig.	ppm	<0.02	"No specific calibration available"			
Vanadium (V)	Long Term Irrig.	ppm	<0.1	"No specific calibration available"			
*See appendix B for gypsum recommendations to offset excessive Na.							
** Small amounts of chlorides can be toxic or detrimental to blueberries, tobacco, certain Southern soybean varieties, and possibly other plants.							
*** 1 ppm of Fluoride, which is the level added to most fluoridated water, is safe for most plants, but not for members of the lily family and the genera Chamaedorea, Chlorophytum, Ctenanthe, Dracaena, Marantha, and Spathiphyllum. Other unidentified plants may also be sensitive. Fluoride toxicity causes scorch on the tips of older leaves.							

Appendix A

Relative Soil Salt Tolerances of Agricultural and Horticultural Crops

CROP	THRESHOLD SALINITY OF SOIL EXTRACT	REPORTED DECREASE IN YIELD WHEN SOIL CROSSES SALINITY THRESHOLD*
SENSITIVE	**mmhos/cm**	**% yield loss**
Bean, Edible	1.0	19
Carrot	1.0	14
Strawberry	1.0	33
Onion	1.2	16
Almond	1.5	19
Blackberry	1.5	22
Boysenberry	1.5	22
Plum, Prune	1.5	18
Apricot	1.6	24
Orange	1.7	16
Peach	1.7	21
Grapefruit	1.8	16

MODERATELY SENSITIVE		
Turnip	0.9	9.0
Radish	1.2	13
Lettuce	1.3	13
Clover	1.5	12
Grape	1.5	9.6
Orchardgrass	1.5	6.2
Pepper	1.5	14
Sweet Potato	1.5	11
Broadbean	1.6	9.6
Corn	1.7	12
Flax	1.7	12
Potato	1.7	12
Sugarcane	1.7	5.9
Cabbage	1.8	9.7
Celery	1.8	6.2
Corn (forage)	1.8	7.4
Alfalfa	2.0	7.3
Spinach	2.0	7.6
Cowpea (forage)	2.5	11

CROP	THRESHOLD SALINITY OF SOIL EXTRACT	REPORTED DECREASE IN YIELD WHEN SOIL CROSSES SALINITY THRESHOLD*
MODERATELY SENSITIVE (continued)	**mmhos/cm**	**% yield loss**
Cucumber	2.5	13
Tomato	2.5	9.9
Broccoli	2.8	9.2
Vetch, common	3.0	11
Rice, paddy	3.0	12
Squash, scallop	3.2	16

MODERATELY TOLERANT		
Wildrye, beardless	2.7	6.0
Sudangrass	2.8	4.3
Wheatgrass, std crested	3.5	4.0
Fescue, Tall	3.9	5.3
Beet, Red	4.0	9.0
Harding Grass	4.6	7.6
Squash, zucchini	4.7	9.4
Cowpea	4.9	12
Soybean	5.0	20
Trefoil, Birdsfoot	5.0	10
Ryegrass, perennial	5.6	7.6
Wheat, durum	5.7	5.4
Barley, forage	6.0	7.1
Wheat	6.0	7.1
Sorghum	6.8	16

TOLERANT		
Date Palm	4.0	3.6
Bermudagrass	6.9	6.4
Sugarbeet	7.0	5.9
Wheatgrass, fairway, crested	7.5	6.9
Wheatgrass, Tall	7.5	4.2
Cotton	7.7	5.2
Barley	8.0	5.0

***yield losses in a particular field could be significantly different than these reported values**

Trees, Scrubs, and Ornamentals

The following information was obtained from Colorado State University, Cooperative Extension, and Tri-River Area

Deciduous Trees

HIGH TOLERANCE - UP TO 8 mmhos/cm (mS)	
Names Scientific, Common	**Names Scientific, Common**
Acer plantanoides, Norway maple	Gleditsia triacanthos, Honeylocust
Aesculus hippocastanum, Common Horsechestnut	Quercus Alba, White Oak
Ailanthus altissima, Tree of Heaven	Quercus robur, English Oak
Amelanchier canadensis, Shadblow	Quercus rubra, Red oak
Crataegus crus-galli, Cockspur Hawthorn	Robinia pseudoacacia, Black Locust
Elaeagnus angustifolia, Russian Olive – (possibly up to 10 mmhos)	Ptelea trifoliata, Wafer Ash

MODERATELY HIGH TOLERANCE - UP TO 6 mmhos/cm (mS)	
Names Scientific, Common	**Names Scientific, Common**
Acer negundo, Box-elder	Betula alleghaniensis, Yellow Birch
Acer ginnala, Amur maple	Betula papyrifera, Paper Birch
Betula lenta, Sweet Birch	Fraxinus americana, White Ash
Betula populifolia, Grey Birch	

MODERATELY HIGH TOLERANCE - UP TO 6 mmhos/cm (mS)	
Names Scientific, Common	**Names Scientific, Common**
Populus alba, White Poplar	Prunus virginiana, Choke Cherry
Populus deltoides, Eastern Cottonwood	Salix alba `Tristis', Golden Weeping Willow
Populus grandidentata, Large-toothed Aspen	Salix alba `Vitellina', Golden Willow
Populus nigra Lombardy, Poplar	Salix nigra, Black Willow
Populus tremuloides, Trembling Aspen	Sophora japónica, Japanese Pagoda Tree
Prunus padus, European Bird Cherry	Ulmus pumila, Siberian Elm
Prunus serotina, Black Cherry	

MODERATE TOLERANCE - UP TO 4 mmhos/cm (mS)	
Names Scientific, Common	**Names Scientific, Common**
Catalpa speciosa, Northern Catalpa	Fraxinus pennsylvanica, Green Ash
Celtis occidentalis, Hackberry	Ginkgo biloba, Maindenhair Tree
Celtis reticulata, Netleaf hackberry	Koelreuteria paniculata, Goldenrain
Cercis occidentalis, Western Redbud	Maclura pomifera, Osage-Orange
Fraxinus anomala, Singleleaf Ash	Pyrus species, Pear
Fraxinus excelsior, European Ash	Ulmus americana, American Elm

SLIGHT TOLERANCE - UP TO 2 mmhos/cm (mS)	
Names Scientific, Common	**Names Scientific, Common**
Quercus palustris, Pin Oak	Malus species and cultivars, Apple and Crabapple

SENSITIVE OR INTOLERANT	
Names Scientific, Common	**Names Scientific, Common**
Acer rubrum, Red Maple	Plantanus acerifolia, London Plane
Acer saccharinum, Silver Maple	Sorbus aucuparia, European Mountain-Ash
Acer saccharum, Sugar Maple	Tilia Americana, American linden
Cercis canadensis, Eastern Redbud	Tilia cordata, Littleleaf Linden
Juglans nigra, Black Walnut	

Coniferous Trees

HIGH TOLERANCE - UP TO 8 mmhos/cm (mS)	
Names Scientific, Common	**Names Scientific, Common**
Juniperus chinensis, Pfitzer juniper	Pinus mugo, Mugho Pine
Picea glauca ` densata', Black Hills Spruce	Pinus nigra, Austrian Pine

MODERATELY HIGH TOLERANCE - UP TO 6 mmhos/cm (mS)	
Names Scientific, Common	**Names Scientific, Common**
Pinus ponderosa, Ponderosa Pine	Thuja occidentalis, American Arborvitae
Pinus thunbergiana, Japanese Black Pine	

SLIGHT TOLERANCE - UP TO 2 mmhos/cm (mS)	
Names Scientific, Common	**Names Scientific, Common**
Picea abies, Norway Spruce	Psedotsuga menziesii, Douglas Fir
Pinus strobus, Eastern White Pine	Taxus cuspidata, Japanese Yew
Pinus sylvestris, Scotch Pine	

SENSITIVE OR INTOLERANT	
Names Scientific, Common	**Names Scientific, Common**
Abies balsamea, Balsam Fir	Tsuga canadensis, Canadian Hemlock
Pinus resinosa, Red or Norway Pine	

Scrubs

VERY HIGH TOLERANCE - UP TO 10 mmhos/cm (mS)	
Names Scientific, Common	**Names Scientific, Common**
Atriplex canescens, Fourwing Saltbush	Ceratoides lanata, Common Winterfat
Atriplex convertifolia, Shadscale Saltbush	Chrysothamnus greenei, Greene Rabbitbrush
Atriplex corrugata, Mat Saltbush	Chrysothamnus linifolius, Flaxleaf Rabbitbrush
Atriplex nuttalli, Nuttall Saltbush	Ephedra, Mormon Teas
Atriplex nuttalli cuneata, Castle Valley Clover	Ephedra torreyana, Torrey Epheara
Atriplex nuttalli gardneri, Gardner Saltbush	Kochia americana, Greenmolly Summercypruss
Baccharis emoryi, Emory Baccharis	Sarcobatus vermiculatus, Black Greasewood
Baccharis glutinosa, Seep-Willow	Tamraix pentandra, Westamen Tamarisk

HIGH SALT TOLERANCE - UP TO 8 mmhos/cm (mS)	
Names Scientific, Common	**Names Scientific, Common**
Caragana arborescens, Siberian Peashrub	Rhus trilobata, Squawbush
Chrysothamnus albidus, Alkali Rabbitbrush	Rhus typhina, Staghorn Sumac
Cytisus scoparius, Scotch Broom	Rhamnus frangula, Glossy Buckthorn
Elaeagnus commutata, Silverberry	Shepherdia canadensia, Buffaloberry
Eleaegnus multiflora, Cherry Elaeagnus	Spiraea vanhouttei, Van Houtte Spirea
Euonymous japonica, Spindle Tree	Symphoricarpuos albus, Snowberry
Halimodendron halodendron, Salt-tree	Syringa amurensis japónica, Japanese Tree Lilac
Hippophae rhamnoides, Sea Buckthorn	Syringa vulgaris, Common Lilac
Juniperus chinensis, Pfitzer Juniper	Potentilla fruiticosa `Jackmanii", Jackman's potentilla
Lonicera tatarica, Tararian honeysuckel	Tamarix gallica, Tamarisk
Rhamnus cathartica, Common Buckthorn	

MODERATELY HIGH TOLERANCE - UP TO 6 mmhos/cm (mS)	
Names Scientific, Common	**Names Scientific, Common**
Artemisia frigida, Fringed Sagewort	Juniperus communis, Common Juniper
Artemisia spinescens, Bud Sagebrush	Philadelphus coronarius, Sweet Mockorange
Artemisia tridentata, Basin Big Sagebrush	Purshia glandulsa, Desert Bitterbrush
Buxus microphylla, Japanese Boxwood	Pyracantha fortuneana, Pyracantha
Chrysothamnus nauseosus, Rubber Rabbitbrush	Rhus glabra, Smooth Sumac
Chrysothamnus visci diflorus, Couglas Rabbitbrush	Rhus trilobata, Skunkbush Sumac
Ephedra nevadensis, Nevada Mormontea	Shepherdia rotundifolia, Roundleaf Buffaloberry
Forsythia x intermedia, Showy Border Forsythia	Spirea `Froebel's', Froebel's spirea

SLIGHT TO MODERATE - UP TO 4 mmhos/cm (mS)	
Names Scientific, Common	**Names Scientific, Common**
Artemisia cana, Silver Sagebrush	Rosa woodsii, Wood's Rose
Berberis fremontii, Fremont Barberry	Salix exigua, Coyote Willow
Robinia neo-mexicana, New Mexican Locust	

SLIGHT TOLERANCE - UP TO 2 mmhos/cm (mS)	
Names Scientific, Common	**Names Scientific, Common**
Chaenomeles speciosa, Flowering Quince	Rosa rugosa, Rugosa Rose - may be slightly tolerant
Ligustrum vulgare, Common Privet	Viburnum opulus, High Bush Cranberry

SENSITIVE OR INTOLERANT	
Names Scientific, Common	**Names Scientific, Common**
Cornus racemosa, Grey Dogwood	Rosa, Rose
Cornus stolonifera, Red-osier dogwood	

Vines

HIGH TOLERANCE - UP TO 8 mmhos/cm (mS)	
Names Scientific, Common	**Names Scientific, Common**
Lonicera tataricum `Zabelii', Zabel's Honeysuckle	Parthenocissus quinquefolia, Virginia Creeper

SLIGHT TOLERANCE - UP TO 4 mmhos/cm (mS)
Names Scientific, Common
Lonicera japonica, Japanese Hall's Honeysuckle

Flowers

HIGH TO MODERATE - 6 TO 8 mmhos/cm (mS)	
Names Scientific, Common	**Names Scientific, Common**
Aquilegia micrantha, Cliff Columbine	Psilostrophe bakerii, Paperflower
Machaeranthera xylorrhiza, Common Woody Aster	Stanley pinnata, Prince's Plume - a good indication that the soil is high in selenium

MODERATE SALT TOLERANCE - 4 TO 6 mmhos/cm (mS)	
Names Scientific, Common	**Names Scientific, Common**
Fallugia paradoxa, Common Apache	Yucca elata, Soaptree Yucca
Oenothera caespitosa, Tufted Evening Primrose	Yucca glauca, Small Soapweed
Sphaeralcea coccinea, Scarlet Globemallow	

SLIGHTLY TOLERANT - 2 TO 4 mmhos/cm (mS)	
Names Scientific, Common	**Names Scientific, Common**
Argemone spp., Prickly Poppies	Gallardia pennatifida, Cutleaf Blankdetflower
Calochorutus spp., Mariposa Lilly	Mentzelia spp., Blazing Stars
Chyrsopsis villosa, Hairy Goldenaster	Physaria australus, Twinpod

Grasses and Other Ground Covers

HIGH TOLERANCE - 14 TO 18 mmhos/cm (mS)	
Names Scientific, Common	**Names Scientific, Common**
Agropyron elongatum, Tall Wheatgrass	Elymus triticoides, Beardless wildrye
Agropyron smithii, Western Wheatgrass	Lotus corniculatus, Birdsfoot trefoil - a legume
Distichlis, Saltgrass	

HIGH TOLERANCE - 14 TO 18 mmhos/cm (mS)	
Names Scientific, Common	**Names Scientific, Common**
Puccinellia, alkaligrass	Sporobolus airoides, Alkali sacaton

MODERATELY HIGH - 8 TO 12 mmhos/cm (mS)	
Names Scientific, Common	**Names Scientific, Common**
Bromus marginatus, Mountain brome	Melilotus officinalis, Yellow sweet clover
Lolium perenne, Perennial ryegrass	Trifolium fragiferum, Strawberry clover
Melilotus alba, White sweet clover	
MODERATE - 8 TO 4 mmhos/cm (mS)	
Names Scientific, Common	**Names Scientific, Common**
Agropyron cristatum, Crested Wheatgrass	Dactylis glomerata, Orchardgrass
Agropyron riparium, Streambank Wheatgrass	Elymus giganteus, Mammoth wildrye
Agropyron trachycaulum, Slender Wheatgrass	Elymus junceus, Russian wildrye
Arrhenatherum elatium, Tall meadow oatgrass	Festuca arundinacea, Tall Fescue
Bromus inermis, Smooth brome	Medicago sativa, Alfalfa
Buchloe dactyloides, Buffalograss	Phalaris arundinacea, Reed Canarygrass

LOW SALT TOLERANCE	
Names Scientific, Common	**Names Scientific, Common**
Alopecurus pratensis, Meadow foxtail	Poa pratensis, Kentucky Bluegrass
Festuca rubra, Red fescue	Trifolium pratense, Red clover
Festuca elatior, Meadow fescue	Trifolium repens, White clover

Appendix B

Calculating Gypsum Requirement

As with most recommendations in agriculture, more than one method of recommending gypsum has been developed. The various methods may not always agree, so we have reported several of them here.

Gypsum is recommended for two primary purposes. They are…

- To remove excess sodium (Na)
- To build soil Ca levels when a pH change is not desired.

Method 1

The following calculations may be used to calculate gypsum (22% Ca) rates in lb./A.

- To reduce Na saturation: Lb. gypsum/acre = C.E.C. x (%Na sat. - 5) x 18
- To build Ca saturation: Lb. gypsum/acre = C.E.C. x (desired %Ca sat. - present %Ca sat) x 18

Method 2

EXAMPLE: Assume that the soil CEC is 20 (meq/100 grams) and the Na concentration is 40%. You want to lower the Na concentration to 10%, or eliminate 30% of the Na saturation (30% of 20 meq/100 grams = 6 meq of exchangeable Na/100 grams of soil). Multiply the milliequivalents of exchangeable Na by 0.85 tons of gypsum to get the required application of gypsum (6 x 0.85 = 5.1 tons of gypsum/acre). Typically, commercial gypsum is not 100% efficient in displacing Na, and some authorities suggest using an 80% efficiency factor. Doing this results in our example changing as follows... 5.1 divided by 0.80 = 6.38 tons per acre.

If your irrigation water has a gypsum content, or your soil contains gypsum, you can deduct these amounts from the required rate of gypsum to apply.

Method 3

Gypsum requirements can also be predicted from the residual sodium carbonate (RSC) value of the irrigation water. This calculation is…

RSC x 234 = pounds of gypsum required to offset the excess sodium in 1 acre foot (325,852 gallons) of irrigation water

Remember, gypsum alone does not solve a high Na problem; you must apply adequate irrigation water or receive enough rainfall to leach the displaced Na out of the root zone.

Appendix C

Leaching Requirement

High salt soils should be leached periodically to remove excess salts from the root zone. **The leaching requirement, as commonly defined, is the percent of applied water that must pass through and beyond the root zone, in excess to the water needs of the crop, to keep the EC (soluble salts, or electrical conductivity in mmhos/cm) of the drainage water below a given level.** In general, the higher the EC of the water, the higher the leaching requirement. The following tables give a more precise method for calculating the leaching requirement under various conditions, however, a “rule-of-thumb recommend” suggested by Washington State University publication EB 0909 is worth repeating for those who do not chose to do the calculations. According to their rule-of-thumb…

- 6 inches of leaching water for every 1 ft. of plant root zone will leach 50% of the salt
- 12 inches of leaching water for every 1 ft. of plant root zone will leach 80% of the salt
- 24 inches of leaching water for every 1 ft. of plant root zone will leach 90% of the salt

Additional suggestions are…

- Intermittent irrigation is more effective than steady irrigation or ponding and periodic drying may improve infiltration rates which, in turn, increase efficiency of leaching.
- To prevent puddling when leaching with sprinkler systems, the application rate should not exceed ½ of the intake rate of the soil. At least 10 pounds of additional pressure should be kept at the sprinklers than is recommended for normal irrigation.
- Keep fertility levels high while crops are growing, since the leaching process removes valuable plant nutrients as well as undesirable salts. Leach when the least amount of nitrogen will be lost or consider leaching before or after the cropping season.

The salt content of the water used to leach a field also plays a role in determining the amount of water required to reduce soil salts. In general, the higher the EC of the irrigation water, the higher the higher the leaching requirement. The following data illustrates this point. In this data, the Leaching Requirement is the percentage of applied water that must pass beyond the effective rooting depth of the crop in order to keep the EC of the drainage water below a given level.

EC of Water (mmhos/cm)	Leaching Requirement (%)
0.3 or less	5
0.4	6
0.6	7.5
1.0	12.5
1.4	17.5
1.8	22.5
2.2	27.5
2.3 or more	Not suitable for irrigation
Washington State Univ. bulletin EM 3552	

A formula for calculating the Leaching Percentage (LP), reported by the USDA, NRCS is...

$$\mathbf{LR = ECiw \div [(5 \times ECe) - ECiw]}$$

Where: **LR** = Leaching Requirement in the percent of irrigation water that must pass beyond the effective rooting zone of the crop.
ECiw = Electrical conductivity of the irrigation water in mmho/cm
ECe = Electrical conductivity of the soil in mmho/cm
The result of this formula is a decimal that must be multiplied by 100 to convert it to a percent.

Appendix D

Acidification Procedures to Neutralize Water Alkalinity

Acidification reduces the amount of bicarbonates and carbonates in water. The acidification process results in the formation of carbon dioxide (CO_2) and water (H_2O). The more commonly used acids are Sulfuric (H_2SO_4), Phosphoric (H_3PO_4), Nitric (HNO_3), and Citric ($H_3C_6H_5O_7$). When deciding which acid to use, you should evaluate…

- Safety and ease of use
- Relative cost
- Plant nutrients that will be included with the acid N, P, or S)
- Availability of the acid

Acids come in varying strengths, some of which are extremely strong and must be used with great caution and care. When handling any acids, the following procedures must always be followed.

- **Wear eye protection, acid-resisting gloves, footwear, and an acid-resistant apron**
- **Always add acid to water. Do not do the reverse**
- **Always use acid resistant containers**

Calculating the Amount of Acid to Use

a. calculate the amount of alkalinity to be neutralized by the following formula

Current alkalinity – Desired alkalinity = Alkalinity to be neutralized

b. Use the following table to determine the amount of various acids to use

CHARACTERISTICS OF ACIDS			
Acid Type	**Typical Strength**	**Nutrient Content (ppm)[a]**	**Neutralizing Power[b]**
Phosphoric	75%[c]	25.6 P, as PO_4	45.0[d]
Sulfuric	93%[e]	43.6 S, as SO_4	136.0
Sulfuric (battery)	35%	16.4 S, as SO_4	51.2
Nitric	63%	14.6 N, as NO_3	52.3

a. Nutrient content when 1 fl. oz. is added to 100 gal. of water. Make appropriate adjustments to fertilizer program
b. Amount of alkalinity (ppm $CaCO_3$) neutralized when 1 fl. oz. of acid is added per 100 gallons of water.
c. Phosphoric acid comes in many strengths, but 75% is common. Use heavy free grade or food grade, if possible
d. Assumes about 1/3 of acid is effective since phosphoric acid does not completely dissociate.
e. 93% sulfuric acid is also known as 66 be' (Baume') acid. Battery acid electrolyte is recommended by some and is about 35% strength

Appendix E

Boron Hazard

	BORON CONTENT OF IRRITATION WATER		
	ppm-B	**ppm-B**	**ppm-B**
EXCELLENT	< 0.33	< 0.67	< 1.00
GOOD	0.33-0.67	0.67-1.33	1.00-2.00
PERMISSIBLE	0.67-1.00	1.33-2.00	2.00-3.00
DOUBTFUL	1.00-1.25	2.00-2.50	3.00-3.75
UNSUITABLE	1.25 +	2.50 +	3.75 +

RELATIVE CROP TOLERANCE TO BORON		
SENSITIVE	**SEMI-TOLERANT**	**TOLERANT**
Pecan	Sunflower	Sugarbeet
Black Walnut	Cotton	Table Beet
Navy Bean	Radish	Alfalfa
Pear	Field Pea	Gladiolus
Apple	Barley	Onion
Peach	Wheat	Turnip
	Corn	Cabbage
	Sorghum	Lettuce
	Oat	Carrot
	Pumpkin	
	Sweet Potato	

NOTE: 0.02 ppm B (0.002 meq/l), or more, in the irrigation water may be required to sustain adequate plant growth (in the absence of fertilizer B). No data exists on unlisted crops.