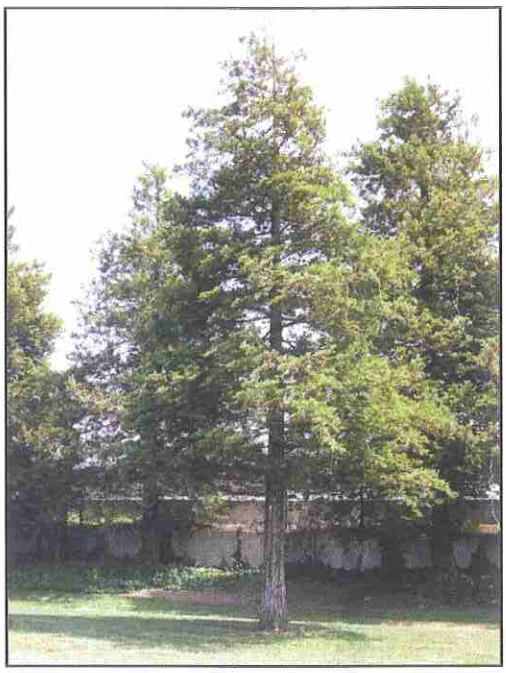
Redwood Tree/Recycled Water Study

Dublin Sports Park and Emerald Glen Park



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HORT SCIENCE

Redwood Tree/Recycled Water Study
Dublin Sports Park and Emerald Glen Park

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Redwood Tree/Recycled Water Study
Dublin Sports Park and Emerald Glen Park

Dublin Sports Park, located at the Civic Center complex, is an active park facility with sports fields, restrooms and picnic areas. Emerald Glen Park is a large community park nearby. Both facilities are located within the City of Dublin, are easily accessible from arterial streets and provide the citizens of Dublin with centrally located facilities for youth and adult sports activities. The trees on these properties provide important environmental benefits as visual screens, buffers for sound, and filters for pollutants between the parks, the major thoroughfares within the city, and adjacent highway 580. Because of their size, the trees also provide economic benefit by adding significant value to the park setting and the neighborhood. The trees, however, are in an observable state of declining health to the extent that the community will lose the benefits they currently enjoy as well as economic value if a remedy is not sought.

Both locations are irrigated with recycled water. The constituents in the water are suspected to be causing foliar damage to many of the trees. Park managers are concerned with the health of the coast redwoods (*Sequoia sempervirens*) at both locations, and the camphor (*Cinnamomum camphora*) trees at Emerald Glen Park. HortScience, Inc. was asked to examine the trees, determine the causes of decline, and provide recommendations to correct problems and deficiencies.

Investigation Approach
Our approach to evaluate plant decline was to examine the redwood and camphor trees, collect plant tissue and soil samples, and analyze for salts or other problems. We installed moisture monitoring stations to evaluate water movement through the soil profile, assist in irrigation scheduling and management, and assess the potential effectiveness of leaching programs.

This report includes:

1. Results of soil samples taken on site and comparison to historical soil test data.
2. Results of plant tissue samples taken on site.
3. Evaluation of water suitability for the plant palette.
4. Results of soil moisture monitoring equipment
5. Identification of problems and deficiencies at both sites.
6. Recommendations for corrective action.
7. A long-term plan for tree sustainability using recycled water.

Method of Study
On June 25, 2009 we selected trees for study that represented a range of good, fair and poor condition (see Table 1). Four coast redwood trees at Dublin Sports Park and two coast redwood trees at Emerald Glen Park were measured, tagged, described, photographed and mapped (see Table 2 and Exhibit 1). For each of the coast redwood trees soil and tissue samples were taken. Historic soil reports for both sites from October 2002 were provided by the City of Dublin, and recycled water quality information for 2008 was provided by the Dublin San Ramon Services District (www.derwa.org) for evaluation purposes. On July 24, 2009 moisture monitoring stations were set up to track the moisture status of the soil between irrigations at the dripline of coast redwood trees at Dublin Sports Park and at Emerald Glen

Park. Two Watermark soil moisture sensors were installed at each location – one placed at a depth of 6" and one placed at 14". The sensors were connected with data cables to a battery-operated WatchDog data logger weather station, mounted on an irrigation riser, and placed in an irrigation valve box buried level with the soil surface. The WatchDog was set to record soil moisture readings every two hours, and two monitoring periods were downloaded to a computer using the SpecWare software to read out and chart the logged data. The manual for the Watermark soil moisture sensors is included in this report as Exhibit 6.

Table 1: Redwood tree condition rating guidelines.

Condition	Canopy	Foliage
good	• Deep green color • Full canopy density • No dieback present	• Branchlets full and healthy • 25% or less browning or loss of needles • Needles spring back when pinched
fair	• Yellowish, dull green or brownish color • 50-75% of normal canopy density • Trunk partially visible through canopy	• 25-50% necrosis on previous year's growth • Current season's growth appears normal • Older growth may be pale and/or dull in color
poor	• Brownish color; may be some bright green areas • Less than 50% canopy density • Trunk visible throughout canopy	• Thinning of branchlet segments (loss of needles) • >50% necrosis on previous year and current year's growth

Dublin Sports Park
The landscape at Dublin Sports Park was comprised primarily of large turf grass areas utilized as outfields, soccer fields and other organized field play with trees planted along the perimeter and at the interface at highway 580, between ballfields, activity areas, picnic areas and sidewalks. The prevailing wind out of the northwest was light to moderate during the morning hours, with increasing intensity and stronger gusts observed in the afternoon. Trees were irrigated primarily with rotors in the turfgrass area and spray heads in the perimeter planters. It was noted that there was inconsistent irrigation coverage around the study trees ranging from dry spots in some areas to standing water in others.

We selected four *Sequoia sempervirens 'Aptos Blue'* for study in representative tree condition ratings of good, fair and poor. The trees were approximately 25 years old, mature in form and structure, and ranged in size from 42" to 63" in circumference measured at a standard height of 4 ½ feet from the ground. All trees had single trunks with a strong central leader. Trunk wounds, bleeding or decay conks were not observed.

Foliage samples containing branchlets with second year growth were removed from the lower perimeter canopy of all four trees and were scanned, cataloged and sent to Perry Laboratory for analysis. Root crown elevations were determined to be at the appropriate level. Each tree was measured, described, photographed, mapped and tagged with numbers **#173 to 176**.

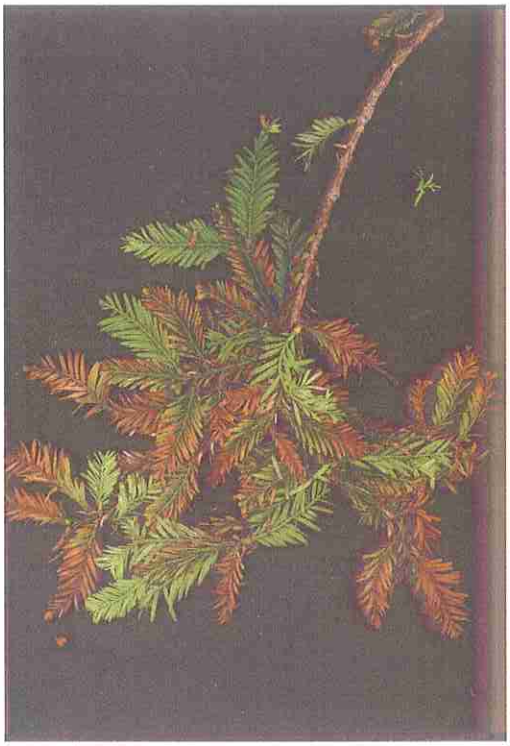


Photo 1. The leaflet above illustrates a poor tree condition rating where 50% of the needles on the leaflet are dead. Notice the several stages of leaf necrosis from tip browning to partial yellowing and finally to complete leaflet necrosis.

Tree **#173** was located in a planting strip along the south side of the park between the turf and the soundwall along highway 580 (see Table 2). The canopy was thinning so that the trunk was visible through the foliage and the overall coloration of the tree was brownish. There was tip necrosis and needle browning on the current and previous year's growth. The ivy groundcover at the base of the tree combined with needles and cones that had fallen to the ground which formed a thick, loose mat over the tree roots. The ivy was growing up the trunk approximately two feet, and the crown of the tree was raised to nine feet with branches hanging down to three feet. The irrigation stains on the trunk were up to and wetting low hanging foliage. The soil was moist. The condition rating of tree **#173** was poor (see Photo 1).

Tree **#174** was adjacent to and just northwest of tree #173 and located in the turf area. The crown was raised up to nine feet, and there were wetting stains on the trunk up to the low hanging foliage from irrigation spray. The soil moisture ranged from moderately dry to moist. The canopy was thinning, the foliage had an overall yellowish appearance, and the needles exhibited tip necrosis and needle browning on the previous year's growth. The tree had 75% or more of the normal canopy density and was rated in fair condition.

Tree **#175** was located in the turf in the northeast picnic area nestled among concrete tables and benches. There was soil compaction in the area from the heavy foot traffic around the tables and through the picnic area to the nearby restroom facility, and from the ballfields and adjacent areas. There was no mulch at the base of the tree, and surface roots were exposed. At the time of inspection, the soil around the tree was moist, and there was standing water in the turf grass just outside the picnic area. Ruts in the soil from the maintenance equipment were visible. This tree was selected for study because of the confines in which it was growing and the fact that it was representative of other trees in the park in fair condition. The canopy

was thinning, the tree was a brownish-green color overall, and there was browning and necrosis in approximately 50% of the tree's previous year's foliage.

By comparison, tree **#176** was located on the west side of the park in an area that was at a higher grade that the other three trees. As with trees #174 and 175, this tree was also situated in the turfgrass and had been crown-raised to nine feet. The soil in the area was moist and consistent around the tree. The overall appearance of the tree was deep green in color with a full canopy, and it had a vigorous top with no visible dieback. The trunk could not be seen through the canopy. The needles were a bright green color, the branchlets were full and healthy, there was no browning or loss of leaflets, and the needles would spring back when pinched. There was a slight browning on the needles in the second year's growth which was perceptible upon close inspection but not visible at a distance. This tree was in good condition.

Table 2: Tree inspections and condition rating.

Tree tag #	Site	Species & cultivar	Tree circumference (in,)	Condition rating
173	DSP	*Sequoia sempervirens 'Aptos Blue'*	60"	poor
174	DSP	*Sequoia sempervirens 'Aptos Blue'*	42"	fair
175	DSP	*Sequoia sempervirens 'Aptos Blue'*	57"	fair
176	DSP	*Sequoia sempervirens 'Aptos Blue'*	63"	good
177	EGP	*Sequoia sempervirens 'Soquel'*	14"	poor
178	EGP	*Sequoia sempervirens 'Soquel'*	23"	good
1 (no tag)	EGP	*Cinnamomum camphora*		poor
2 (no tag)	EGP	*Cinnamomum camphora*		fair
3 (no tag)	EGP	*Cinnamomum camphora*		good

Dublin Sports Park – Tissue, Soil and Water Quality Analyses

Tissue Analyses

Composite tissue samples of redwood needles were collected from all four trees which were representative of trees in good, fair and poor condition. Each sample was analyzed for concentrations of nitrogen, phosphorus, potassium, calcium, magnesium, sodium, iron, boron, zinc, copper, manganese and chloride. The analyses of constituents present in the redwood tissue samples are provided in the attached plant tissue analyses report from Perry Laboratory (see Exhibit 2). Below is a summary of the findings.

1. Nitrogen was in the normal range, but phosphorus and potassium concentrations were lower than considered optimum for many plants.
2. Calcium and magnesium were balanced and largely within the normal range.
3. Sodium and chloride were generally within the toxic range for many plants, with the exception of the sodium levels for tree **#176**. There was a wide range in sodium concentrations between the samples. For example, sample DSP 4 **(#176** good condition) had 0.36% (3,600 ppm) compared to samples DSP 2 **(#174** fair condition) which had 1.08% (10,800 ppm), and DSP 3 **(#175** poor condition) which had 0.91% (9,100 ppm).
4. The concentrations of the minor constituents of iron, boron, zinc, copper and manganese were within the normal range for many plants, with the exception of iron which was in the toxic range.

Soil Analyses

Four composite samples were obtained from Dublin Sports Park. The samples were analyzed for pH, electrical conductivity, saturation percentage, calcium, magnesium, sodium, chloride, boron, sodium adsorption ratio (SAR), and exchangeable sodium ratio (ESP). Results of the soil sample analyses are described below (see Exhibit 3 for the Perry Laboratory soil analyses).

1. Soil pH was in a desirable range for most plants, from slightly acid (6.8) to slightly alkaline (7.7).
2. Soil salinity (Ec_e) was desirably low and within the range of tolerance for most landscape plants.
3. Saturation percentage (SP) was typical of a loamy soil texture that is balanced between sand, silt and clay, with DSP-3 (tree **#175**) containing more sand and qualifying as a sandy loam.
4. Sodium adsorption ratio (SAR) and exchangeable sodium percentage (ESP) were within acceptable ranges. It is unlikely that there are problems with soil permeability as sodium is adequately balanced between calcium and magnesium.
5. Calcium and magnesium were well supplied in three samples, and elevated in DSP-4 (tree **#176**).
6. Boron concentration was within the range that is tolerated by most landscape plants in all samples.
7. Sodium and chloride were within the range that is tolerated by most landscape plants in all samples with a few exceptions. DSP-4 (good condition) had a high concentration of sodium, and DSP-3 (poor condition) and DSP-4 (good condition) had a high concentration of chloride. In these cases sodium and chloride were present at potentially toxic levels.

Historic soil test reports from October 2002 prepared by A & L Western Agricultural Laboratories were provided by the City of Dublin. Soil samples were taken from the East, East Middle, Middle and West sections of the park site. Soil pH ranged from 7.0 to 7.4 which was less variable than the samples taken on June 25, 2009, which ranged from 6.8 at tree **#175** to 7.7 at tree **#173**. Since testing in 2002, concentrations of calcium had increased from a low to medium range, and sodium increased from a medium to high range. Chloride was not rated in 2002, but is currently in the high or toxic range.

Water Quality Analyses

Recycled water quality information was provided by the Dublin San Ramon Services District in the form of an annual report which summarizes the range of inorganic chemicals, regulated and unregulated (boron) contaminants and the average units for the period. In the most recent report published for calendar year 2008, chloride (189 mg/L) total dissolved solids (689 mg/L) and sodium (171 mg/L) spiked to a top range toxic to sensitive and moderately sensitive ornamental landscape plant species, with averages in the range toxic to sensitive species.

Emerald Glen Park

The landscape at Emerald Glen Park was comprised primarily of large, open turfgrass areas for soccer play and other organized sport activities. It was similar in design layout and landscape function to Dublin Sports Park with trees planted along the perimeter as a buffer between the parking lot on Gleason Drive and Tassajara Road, and in the interior between the skateboard park and large field areas. The park was located approximately two miles northwest of Dublin Sports Park and the wind conditions here were also out of the northwest - lighter in the morning with heavier gusts in the afternoon and constant throughout the day.

Two redwood trees south of the skateboard park were selected for study and were identified as *Sequoia sempervirens 'Soquel'*. At approximately 15 years old, they were still immature in stature and measured 14" and 23" in circumference at a standard 4 ½ feet from the ground. The trees had single trunks, they had not been topped or limbed from the ground, and both had a strong central leader. Trunk wounds, bleeding or decay conks were not observed. Foliage samples containing branchlets with second year growth were removed from the lower perimeter canopy of both trees and were scanned, cataloged and sent to Perry Laboratory for analysis. Root crown elevations were determined to be at the appropriate level. Each tree was measured, described, photographed, mapped and tagged with numbers **#177** and **178**.

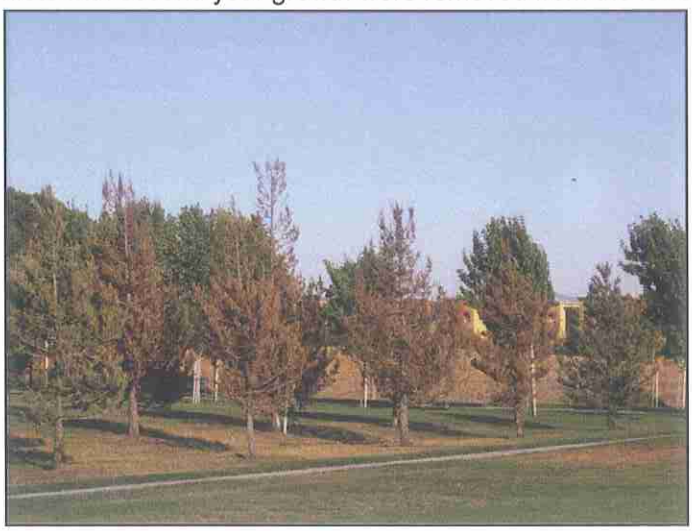


Photo 2. Redwood tree #177, and the trees adjacent to it, were brownish-green in overall color, and the turfgrass underneath them was sparse and dry.

Tree **#177** was brownish-green in overall color, as were the other trees in the area. The trunk was visible through the canopy and there was thinning at the top of the crown. There was loss of needles on branch segments, and necrosis on previous year and current year's growth,

especially around the base of the tree from sprinkler wetting. The turfgrass in the area was sparse and the ground was dry as can be seen in Photo 2. The condition of this tree was poor.

Nearby, tree **#178** which was the same age but was much larger, had deep green needle color, a full canopy, minor tip needle burn, and exhibited no foliar toxicity from sprinkler wetting. This tree was in good condition. The soil moisture between the two trees was dramatic. Both trees were irrigated by large rotors in the turfgrass area, and it was noted at the time of inspection that there was inconsistent irrigation coverage around the trees ranging from dry spots with sparse turf and no mulch around tree **#177** to saturated soil and standing water on the southwest side of tree **#178**.

Emerald Glen Park – Tissue, Soil and Water Quality Analyses

Tissue Analyses

Composite tissue samples of redwood needles were collected from both trees which were representative of trees in good and poor condition. Each sample was analyzed for concentrations of nitrogen, phosphorus, potassium, calcium, magnesium, sodium, iron, boron, zinc, copper, manganese and chloride. The analyses of constituents present in the redwood tissue samples are provided in the attached laboratory report (see Exhibit 2). Below is a summary of the findings.

1. Nitrogen was in the normal range, but phosphorus and potassium concentrations were lower than considered optimum for many plants.
2. Calcium and magnesium were balanced and largely within the normal range.
3. Sodium was generally within the toxic range for many plants both tree **#177 and #178**, and chloride was within the toxic range for tree **#177**, but within a normal range for tree **#178.**
4. The concentrations of the minor constituents of iron, boron, zinc, copper and manganese were within the normal range for many plants, with the exception of iron which was in the toxic range.

Soil Analyses

Two composite soil samples were obtained for the redwood trees at Emerald Glen Park. The samples were analyzed for pH, electrical conductivity, saturation percentage, calcium, magnesium, sodium, chloride, boron, sodium adsorption ratio (SAR), and exchangeable sodium ratio (ESP). The laboratory report is attached (see Exhibit 3) and the samples are described below.

1. Soil pH was in a desirable range for most plants at 7.1, slightly alkaline.
2. Soil salinity (Ec_e) was desirably low and within the range of tolerance for most landscape plants.
3. Saturation percentage (SP) was typical of a loamy soil texture that is balanced between sand, silt and clay, with DSP-3 (tree #175) containing more sand and qualifying as a sandy loam.
4. Sodium adsorption ratio (SAR) and exchangeable sodium percentage (ESP) were within acceptable ranges. It is unlikely that there are problems with soil permeability as sodium is adequately balanced between calcium and magnesium.
5. Calcium and magnesium were well supplied in three samples, and elevated in DSP-4 (tree #176).
6. Boron concentration was within the range that is tolerated by most landscape plants in all samples.

7. Sodium and chloride were both within a range that is potentially toxic, and the level of chloride was slightly higher in tree #178 (good condition).

Historic soil test reports from October 2002 from A & L Western Agricultural Laboratories were provided by the City of Dublin. Soil samples were taken from several sections of the park including the east side, planting beds and turf central. Soil pH ranged from 7.7 to 7.9 which was higher than the samples taken on June 25, 2009, which were rated at 7.1 each. Concentrations of calcium and sodium remained within a moderate range since testing in 2002. Chloride was not rated in 2002, but was in the high or toxic range in the samples taken on June 25, 2009.

Diagnosing dieback in camphor trees

On the north side of Emerald Glen Park along Gleason Drive, camphor trees were planted in a turfgrass berm that slopes from street level to a parking lot. Throughout the study area, the soil was moist and there was no evidence of runoff or standing water. The trees were observed in various stages of vigor and declining health ranging from thick foliage and deep green canopies, to yellowing foliage and branch dieback (see Photo 3). All three trees were described, photographed and mapped (see Exhibit 1).

Photo 3. Camphor trees were observed in varying stages of decline as exhibited by the variation in foliage from deep green to chlorotic yellow. The tree in the foreground had several dead branches in the canopy.

For sampling and identification purposes, the trees were numbered **#1- 3** and ranged in condition from good to poor. Tissue samples were taken of all three camphor trees and soil samples were taken at two tree sites (**#1** and **#2**) and sent to Perry Laboratory for analysis.

A root inspection was conducted at tree **#1** and a root sample was obtained and sent to Plant Disease Diagnosis in Walnut Creek to test for the presence of a root disease organism.

Upon close inspection of tree **#2** it was observed that there was evidence of a progressive necrosis of the leaf beginning at the tip and spreading to a mottled or chlorotic condition between lateral veins and the midribs (see Photo 4). This condition worsened as the leaves died and fell off, leading to the eventual dieback of the stem.

Photo 4. Camphor leaves exhibiting progressive necrosis.

Camphor trees – Tissue, Soil and Water Quality Analyses

Tissue Analyses

Composite tissue samples of camphor leaves were collected from all three trees which were representative of trees in good, fair and poor condition. Each sample was analyzed for concentrations of nitrogen, phosphorus, potassium, calcium, magnesium, sodium, iron, boron, zinc, copper, manganese and chloride. The analyses of constituents present in the camphor tissue samples are provided in the attached laboratory report. Below is a summary of the findings.

1. Nitrogen was in the normal range, but phosphorus and potassium concentrations were lower than considered optimum for many plants.
2. Calcium and magnesium were balanced, slightly elevated and largely within the normal range.
3. Sodium and chloride was generally within the toxic range for many plants in all three trees.
4. The concentrations of the minor constituents of iron, boron, zinc, copper and manganese were within the normal range for many plants.

Soil Analyses

Two composite soil samples were obtained for the camphor trees at Emerald Glen Park for tree **#1** and tree **#2**. The samples were analyzed for pH, electrical conductivity, saturation percentage, calcium, magnesium, sodium, chloride, boron, sodium adsorption ratio (SAR), and exchangeable sodium ratio (ESP). The laboratory report is attached and the samples are described below.

1. Soil pH was in a desirable range for most plants at 7.2 (tree **#1**), and 7.6 (tree **#2**); both slightly alkaline.
2. Soil salinity (Ec_e) was desirably low and within the range of tolerance for most landscape plants.
3. Saturation percentage (SP) was typical of a loamy soil texture that is balanced between sand, silt and clay, with both trees qualifying as a loam.
4. Sodium adsorption ratio (SAR) and exchangeable sodium percentage (ESP) were within acceptable ranges. It is unlikely that there are problems with soil permeability as sodium is adequately balanced between calcium and magnesium.
5. Calcium and magnesium were well supplied in three samples, and elevated in DSP-4 (tree #176).
6. Boron concentration was within the range that is tolerated by most landscape plants in all samples.
7. Sodium and chloride were both within a range that is potentially toxic, and the level of chloride was slightly higher in tree #178 (good condition).

Historic soil test reports from October 2002 from A & L Western Agricultural Laboratories were provided by the City of Dublin. Soil samples were taken from several sections of the park including the east side, planting beds and turf central. Soil pH ranged from 7.7 to 7.9 which is higher than the range of the both samples taken on June 25, 2009, which were rated at 7.1 each. Concentrations of calcium and sodium remained within a moderate range since testing in 2002. Chloride was not rated in 2002, but is currently in the high or toxic range.

Soil Moisture Monitoring

On July 24, 2009 we installed Watermark moisture sensors and WatchDog data loggers at both Dublin Sports Park and Emerald Glen Park (see Exhibit 1). They were installed at 6" and 14" at each location to monitor the moisture content of the soil through the soil profile. The data loggers were set to record soil moisture every two hours, day and night. After three weeks, we downloaded the first set of soil moisture data. At Dublin Sports Park the soils were adequately moist at a depth of 6", but were much drier at the 14" depth. At Emerald Glen Park the soil was very dry, cracked at the surface, and there was no change in soil moisture content over the three week monitoring period, indicating that the irrigation system was not functioning properly (see Exhibit 8). A second set of data was downloaded from the first site at Dublin Sports Park from late August to early October. The soils were adequately moist for a two week period at both the 6" and 14" depth, becoming drier at the lower depth in the following weeks which indicated a decrease in the irrigation water application.

One of the factors contributing to redwood tree decline is the inconsistent and irregular application of irrigation water. Redwoods have among the highest water requirements of all species in the landscape. The species is native to the cool coastal fog belt and requires regular irrigation to perform well in the warm, dry Bay Area climate. During our site inspections and equipment installation at Dublin Sports Park, we observed that the soil was dry within the dripline of the redwood trees and that mulch over the ground was generally thin or nonexistent. At Emerald Glen Park, the soil around tree **#177** was consistently dry on each of our visits, and tree **#178** consistently had soggy , saturated soil on the southwest side, and drier conditions on the north east side. The soil moisture monitoring at both sites confirmed visual observations that the trees received inadequate or inconsistent irrigation water applications.

Summary and Recommendations

Recycled water has higher concentrations of salts (eg. sodium and chloride) than potable water. Based on observations and laboratory tests, the foliar burn symptoms, branch dieback and thinning crowns on the redwoods is due to sodium and chloride toxicity applied during irrigation of recycled water. This is consistent with site conditions and resultant symptoms observed at other sites in the South Bay that are irrigated with recycled water.

Another factor contributing to tree decline is the inconsistent and irregular application of irrigation water, due in part to the provision for drier ballfield conditions to accommodate tournament play. Redwoods have among the highest water requirements of all species in the landscape. The species is native to the cool coastal fog belt and requires regular irrigation to perform well in the warm, dry Bay Area climate. The trees received a modest amount of water indirectly when the turf was irrigated. During the summer trees should receive about 2" of water per week. The soil was generally dry within the dripline of the trees, and mulch over the ground was thin or nonexistent.

Redwood trees are sensitive to salts and irrigation with recycled water has been linked to plant damage. Insufficient irrigation has also played a role in the decline of the trees.

The following steps will assist you as best management practices in providing a more suitable environment for the coast redwood trees. Also see Exhibit 7 for a listing of possible field trials that may be tested with the use of an experiment design and control to determine the effectiveness of the results.

1. Irrigate according to tree needs. It is important to achieve uniform wetting of the soil within the dripline and beyond, if possible. Adjust spray heads to provide an even wetting

pattern. Using the Landscape Evapotranspiration Formula[1], it is estimated that the mature redwoods at this site require approximately 2" of water per week (about 0.25"/day) during the growing season to maintain optimum appearance and growth. Perform an irrigation audit. Repair equipment as needed, repeat the irrigation audit, and then design an irrigation schedule or water budget that will maintain a moist soil based on real-time evapotranspiration data.

2. Leach salts below the root zone. Leaching the soil with water is the only way to reduce the concentration of sodium and chloride in the soil. Leaching is accomplished by applying a large volume of water that carries salts accumulated in the root zone farther down into the soil profile. The volume of water required depends on the texture of the soil, the depth of the root zone, and the salt concentration reduction needed.

3. Utilize soil moisture monitors in order to maintain appropriate soil moisture.

4. Do not fertilize within the root zone of the trees as fertilizers contain salts which can contribute to salt toxicity problems.

5. Avoid pruning. Do not prune the trees unless a hazard is recognized or for clearance near houses, buildings, walkways or other improvements. Retain as much crown as possible to allow for the greatest amount of re-growth. Branches with minimal foliage may shade other branches and moderate the microclimate in the crown to promote and protect new growth. All pruning shall be done by a Certified Arborist or Certified Tree Worker in accordance with the *Best Management Practices for Pruning* (International Society of Arboriculture, 2002).

6. Monitor tree condition and soil salinity. Consider re-evaluating tree condition in April 2010. Evaluate tree condition, and test soil (ie. EC_e, Na, Cl, and SAR) from same trees to assess changes in chemical analyses from using potable water and treatments. Test both soil (as above) and tissue (ie. Na and Cl) again in April 2010 to evaluate tree condition and changes in salt concentrations.

7. Maintain a mulch layer of 2-4 inches around trees composed of composted wood chips, bark and leaves to replicate a natural environment, retain moisture, improve soil structure and control competing weeds. Avoid placing against the tree trunks, and replenish as needed.

8. Apply a pelletized, finely ground formulation of gypsum at the rate of 10 pounds per 1,000 square feet at this time, and test the soil again in the spring to determine if another treatment is needed. See Exhibit 7 for a list of possible field trials

The following steps will assist you as best management practices in providing a more suitable environment for the camphor trees:

1. Provide adequate drainage to assure movement of irrigation water through the tree root zone area.

2. Irrigate to satisfy the leaching requirement necessary to avoid salt buildup in the soil.

[1] *A Guide to Estimating Irrigation Water Needs of Landscape Plantings in California.* University of California Cooperative Extension and Department of Water Resources, 2000.

3. To modify the effects of bicarbonate supplied in irrigation water, apply a balanced, acid-forming NPK fertilizer avoiding chlorides to neutralize the water available to the plant, and replace nutrient deficiencies in the soil.

4. Add soluble calcium such as gypsum to maintain safe SAR values.

If you have any questions regarding this report, please feel free to contact me.

Regards,

Carol Randisi

Carol Randisi
Horticultural Consultant

List of Exhibits

Redwood Tree/Recycled Water Study

Dublin Sports Park and Emerald Glen Park

Exhibit 1: Tree and soil moisture monitor location maps

Exhibit 2: Perry Laboratory plant tissue analyses

Exhibit 3: Perry Laboratory soil analyses

Exhibit 4: Plant Disease Diagnosis report

Exhibit 5: Moisture sensor log reports

Exhibit 6: Watermark soil moisture sensor manual

Exhibit 7: Possible Field Trials to Inform Management of Sites Irrigated with Recycled Water

Dublin Sports Park
Redwood Sampling and Monitoring Sites
Dublin, California

Site DSP-1

Monitor redwood #173

Soil moisture station

Site DSP-2

Monitor redwood #174

Site DSP-3

Monitor redwood #175

Soil moisture monitor

Site DSP –4

Monitor redwood #176

HORT SCIENCE

June 25, 2009

Emerald Glen Park
Tree Sample and Monitoring Sites
Dublin, California

Camphor trees

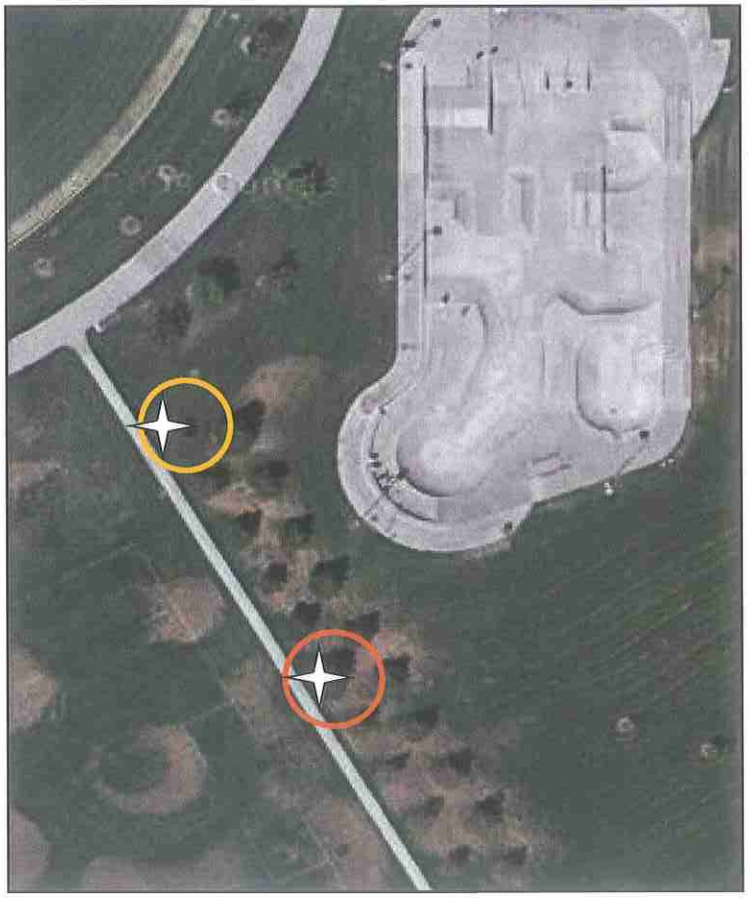
Camphor 1
Soil, root and tissue samples

Camphor 2
Soil and tissue samples

Redwoods
Site EGP-1

Monitor redwood #177

Soil moisture station



Site EGP-2

Monitor redwood #178

Soil moisture station

HORT SCIENCE

June 25, 2009

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July 3, 2009

Plant Tissue Analyses

reported on dry matter basis

Chemical analyses on samples received: June 29, 2009

Sample Identification:	Job 2851-03 Redwood leaves						Camphor leaves		
	DSP 1	DSP 2	DSP 3	DSP 4	EGP 1	EGP 2	1	2	3
CONSTITUENTS									
TOTAL									
Nitrogen (N) %	1.29	1.29	1.29	1.16	1.50	1.22	2.04	2.04	1.36
Phosphorus (P) %	0.04	0.05	0.04	0.04	0.06	0.03	0.10	0.07	0.04
Potassium (K) %	0.60	0.28	0.26	0.54	0.33	0.30	0.95	1.48	0.60
Calcium (Ca) %	1.82	1.53	1.74	2.00	1.79	2.49	2.62	1.43	2.97
Magnesium (Mg) %	0.34	0.29	0.37	0.33	0.33	0.36	0.68	0.38	0.50
Sodium (Na) %	1.01	1.08	0.91	0.36	0.76	0.37	0.54	0.43	0.44
Iron (Fe) ppm	446	239	278	255	112	187	66	60	75
Boron (B) ppm	112	104	84	86	55	46	100	68	81
Zinc (Zn) ppm	60	36	28	26	16	17	20	14	15
Copper (Cu) ppm	13.1	7.0	6.3	5.0	2.8	3.0	5.3	3.7	2.8
Manganese (Mn) ppm	76	66	67	84	64	315	24	26	49
Chloride (Cl) ppm	15975	14910	13845	8520	14555	12425	9230	4260	7100

Respectfully submitted,

Clifford B. Low, M.S.

PERRY LABORATORY
HORTICULTURAL ADVISING AND TESTING

424 AIRPORT BOULEVARD
WATSONVILLE, CA 95076
Telephone 831/722-7606
Fax 831/722-5053

HortScience, Inc.
2150 Rheem Drive, Suite A
Pleasanton, CA 94588

July 3, 2009

Chemical analyses on samples received: June 29, 2009

Sample Identification	pH	Electrical Conductivity dS/m	SP Saturation Percentage	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Chloride (Cl)	Boron (B)	SAR Sodium Adsorption Ratio	ESP Exchangeable Sodium Percentage
				milliequivalents per liter in extract				ppm in extract		
General Guidelines-Ornamental Plants	6.5-7.2	1.0-3.0		>3.0	>2.0	<3.0	<3.0	<1.0	<8.0	<9.0
Job 2851-03										
DSP-1	7.7	1.8	63	6.4	4.0	8.1	8.2	0.2	3.6	4.0
DSP-2	7.1	1.7	74	6.3	4.0	7.9	6.0	0.4	3.5	3.9
DSP-3	6.8	2.1	88	7.4	5.1	8.3	9.6	0.5	3.3	3.7
DSP-4	7.0	2.6	74	10.0	7.4	9.0	10.6	0.6	3.0	3.4
EGP Redwood #177	7.1	3.1	75	11.2	7.3	11.1	13.0	1.1	3.6	4.0
EGP #178	7.7	2.5	73	7.5	3.9	11.8	14.0	0.7	5.0	5.6
Camphor 1	7.2	1.4	68	4.4	3.2	7.7	7.0	0.4	4.0	4.5
Camphor 2	7.6	1.2	63	3.9	2.1	5.5	5.3	0.2	3.1	3.5

Respectfully submitted,

Clifford B. Low, M.S.

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HortScience, Inc.
2150 Rheem Drive, Suite A
Pleasanton, CA 94588

July 3, 2009

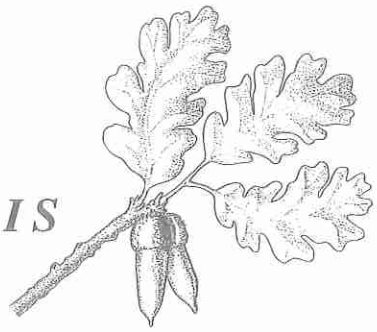
Chemical analyses on samples received: June 29, 2009

Sample Identification	Mechanical Analyses, % by weight, USDA Classifications			
Job 2851-03	Sand	Silt	Clay	Texture
DSP-1	32	48	20	loam
DSP-2	40	46	14	loam
DSP-3	60	28	12	sandy loam
DSP-4	44	40	16	loam
EGP Redwood #177	50	34	16	loam
EGP #178	38	36	26	loam
Camphor 1	40	40	20	loam
Camphor 2	46	34	20	loam

Respectfully submitted,

Clifford B. Low, M.S.

PLANT DISEASE DIAGNOSIS



780 Palmer Road • Walnut Creek, CA 94596
Phone/Fax: (925) 937-3841

Client:
Carol Randisi
HortScience
2150 Rheem Dr. Suite A
Pleasanton, CA 94588

Invoice: 4685

Date: 7/7/2009

Plant: Camphor

Disease: Negative

Discussion:

No Phytophthora or other root pathogens were cultured from the feeder roots in the sample.

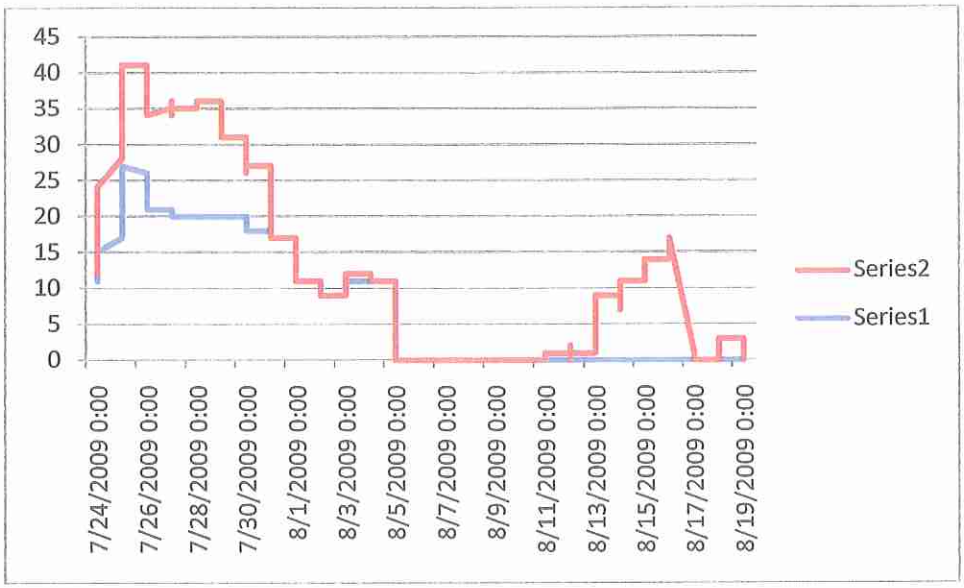
Thank you

Luellen Pierce

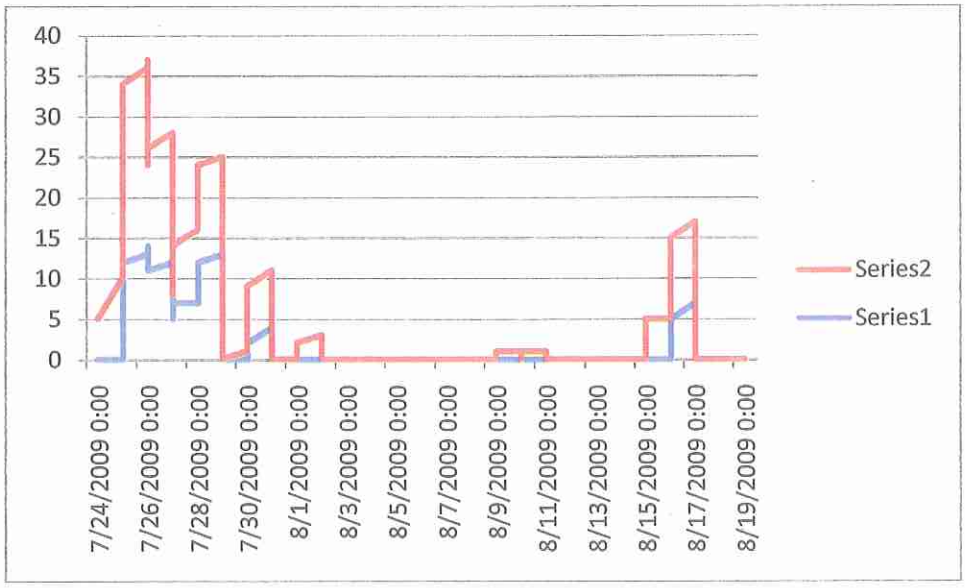
Luellen Pierce

285-03 (M

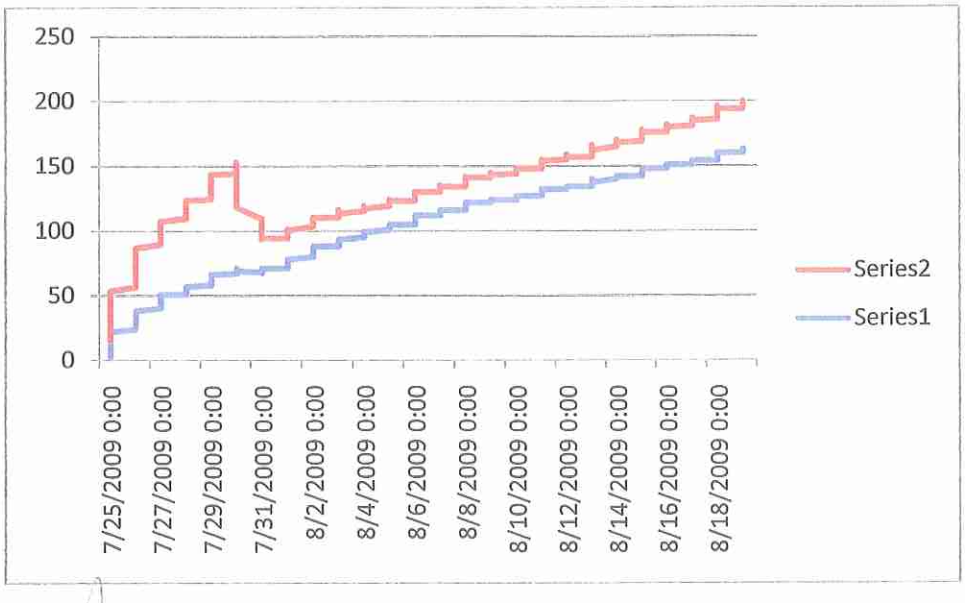
D-1 Dublin Sports Park



D-2 Dublin Sports Park

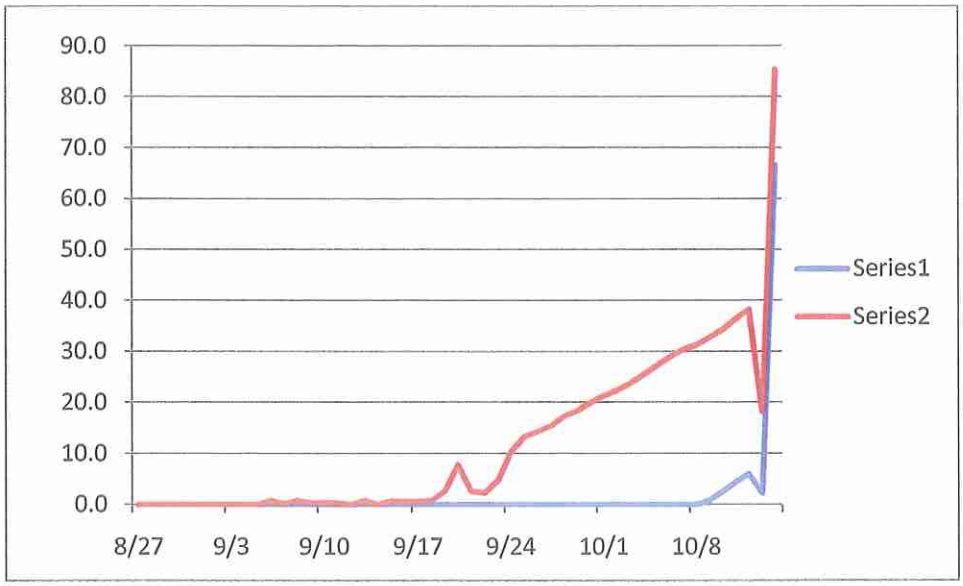


D-3 Emerald Glen Park



D-4 Emerald Glen Park

D1 Dublin Sports Park



WATERMARK SOIL MOISTURE SENSOR

CATALOG # 6450

Spectrum
Technologies, Inc.

CONTENTS

This manual will familiarize you with the features and operation of your new Watermark Soil Moisture Sensor. Please read this manual thoroughly before using your instrument. For customer support, or to place an order, call Spectrum Technologies, Inc. at (800)248-8873 or (815) 436-4440 between 7:30 am and 5:30 p.m. CST, FAX at (815)436-4460, or E-Mail at Info@specmeters.com.
www.specmeters.com

Spectrum Technologies, Inc at 23839 W Andrew Rd.
Plainfield, IL 60544

General overview

Thank you for purchasing a Watermark Soil Moisture Sensor.

Using these sensors in conjunction with the WatchDog Data Logger will give you a better idea of how fast soil water is being depleted in different areas of your field. By keeping track of your field's soil moisture status between irrigations, you can better schedule irrigations and evaluate the effectiveness of rain and irrigation water. Regular monitoring will give you an accurate picture of this process over time.

Specware version 4.18 or greater is required with the Watermark Soil Moisture Sensor. Download the accumulated data at your convenience. SpecWare will present data in graphical and tabular form. Use the software to calculate growing degree days and chill hours, and/or view daily, monthly and yearly reports.

Important: With SpecWare versions 4.19 or earlier, only port B can support the Watermark Soil Moisture Sensors.

Sensor Placement

The sensors should be located in the effective root zone at locations which will give a representative picture of the soil water status of the field. Be sure to use enough sensors to get a good overall view. Water penetration and holding capacity across a field can differ due to soil type, soil interfaces and topography. These sources of variation are good locations for your sensors. Sensors should not be located behind obstructions such as tree limbs which can interfere with water distribution. With drip- or micro-irrigation, sensors must be installed in the wetted area. In furrow/flood irrigation, locate the sensors where water penetration is poorest, generally about 2/3 the way down the run. With center pivots, place sensors at 4-5 locations down the length of the pivot.

The best strategy for anyone using the sensors for the first time is to use an adequate distribution of sensors in small area to get a good feel for the soil moisture patterns and their effect on crop growth.

INSTALLATION

It is important that the Watermark sensor be saturated when installed. It is also critical to get a snug fit between the sensor and the surrounding soil. Lack of a snug fit is the No. 1 problem in sensor effectiveness.

Installation Procedure

1. Just before installation, the sensor should be soaked for several hours in irrigation water. If possible, it is advisable to precondition the sensor by putting it through several wet-dry cycles (30 minutes soaking followed by several hours of drying). This will improve sensor response during the first few irrigations.

2. Make a sensor access hole to the depth required with a 7/8" rod. For very coarse or gravelly soils, a slightly oversized hole (1" - 1¼") may be needed to prevent abrasion damage to the membrane. In this case, you will need to "grout in" the sensor with a slurry made from the sample soil to get a snug fit in the soil.

3. Fill the hole with water and push the sensor down into the hole so it "bottoms out". A length of ½" Class 315 PVC fits snugly over the sensor collar and can be used to push in the sensor. The access hole should be carefully backfilled and tamped down to eliminate air pockets. Avoid having the sensor wire lead straight out of the hole because this can allow water to channel down to the sensor and produce unrealistically high readings.

4. If sensors are removed for winter storage, clean and dry the sensors and place them in a plastic bag.

COMMON PROBLEMS

The most common problems in the field are:

1. Sensor doesn't have a snug fit in the soil. This usually happens when an oversized access hole has been used and the backfilling of the area around the sensors is not complete. Sensor may need to be re-installed.

2. Sensor is not in an active portion of the root zone. or the irrigation is not reaching the sensor area. This can happen if the sensor is sitting on top of a rock or below a hard pan which may impede water movement. Reinstalling the sensor usually solves this problem.

3. When the soil dries out to the point where you see readings higher than 80 cbars, soil/sensor contact can be lost due to soil shrinkage. An irrigation which only partially rewets the soil (soil suction remains above 40 cbars) will not fully rewet the sensor which can result in continued high readings. This is most often seen in heavier soils and during peak crop water demand when irrigation may not be fully adequate. Full rewetting of the soil and sensor usually restores soil/ sensor contact. should give a good indication of this behavior.

ADDITIONAL INFORMATION

-The following is a general guide for interpreting the Watermark readings.

"- - " = Dry or non-conditioned sensor
0-10 cbars = Saturated soil
10-30 cbars = Soil is adequately wet (except for coarse sands which are beginning to lose water)
30-60 cbars = Usual range for irrigation (except heavy clay soils)
60-100 cbars = Usual range for irrigation in heavy clay soils
100-200 cbars = Soil becoming dangerously dry for maximum production.

The Watermark soil moisture sensor has been calibrated for a soil temperature of 70° F. For slightly greater accuracy, the moisture tension values can be adjusted for seasonal temperature fluctuations. Decrease the moisture tension readings by 1% for each degree Fahrenheit greater than 70° F. Likewise, increase by 1% for every degree less than 70.

- When launching the Watermark sensor, select the "Soil Moist-WM" soil moisture option in the Launch Options screen. The other two soil moisture options are for tensiometer pressure transducers and will not give accurate results.

- With SpecWare versions 4.19 or earlier, only port B can support the Watermark Soil Moisture Sensor.

- In general, any failure of the Watermark sensor due to age or malfunction is accompanied by an increase in the resistance level of the sensor. This can be checked by pulling the sensor and soaking it in a bucket of 60 to 70 degree water for an hour. If the sensor reads 5 or greater, the sensor should be replaced.

WARRANTY

The Watermark Soil Moisture Sensor is warranted to be free from defects in materials and workmanship for a period of 1 year from the date of original purchase. During the warranty period, Spectrum will, at its option, either repair or replace products that prove to be defective. This warranty is void if the product has been damaged by customer error or negligence, or if there has been an unauthorized modification.

Returning Products to Spectrum

Before returning a failed unit, you must obtain a Returned Goods Authorization (RGA) number from Spectrum. You must ship the product(s), properly packaged against further damage, back to Spectrum (at your expense) with the RGA number marked clearly on the outside of the package. Spectrum is not responsible for any package that is returned without a valid RGA number or for the loss of the package by any shipping company.

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www.specmeters.com

Possible Field Trials to Inform Management of Sites Irrigated with Recycled Water

Trial	Description	Possible experiment design
Irrigation	Redwood trees show less salt damage when a high soil moisture is maintained. How much extra irrigation is needed can be tested by establishing irrigation schedules based on varying percentages of ET.	Establish sites irrigated at 60%, 80% and 100% ET.
Leaching	The main management technique to reduce soil salinity is to irrigate heavily to leach accumulated salts below the root zone.	Establish sites receiving no leaching and those receiving a 20% ET leaching factor 1, 2 or 3 times a season.
Gypsum	Soil-applied gypsum has proven to be an effective treatment to reduce sodium accumulation and loss of structure in annual agricultural crops. It has not been tested for rates application methods in perennial landscapes that cannot be tilled.	Determine gypsum requirements for test sites (lab test). Apply gypsum as a topdress and/or injected into irrigation system. Test SAR and infiltration rates following treatments.
Anionic polyacrylamide (PAM)	PAM, when applied in solution, has been shown to improve the infiltration rate of water into soils irrigation with water high in salt and sodium under laboratory conditions. This material has not been tested in a landscape situation.	Apply PAM in solution to soils at 2-3 rates and frequencies. Monitor infiltration rates, tree condition and soil salinity.
Humates	Application of humates to soil has been shown to help remediate saline soils by chelating the salts and enhancing biological activity. It has not been tested in a landscape situation and relatively low soil salinities.	Apply granular humates at 2-3 rates and frequencies. Monitor tree condition and soil salinity.
Eximo	A synthetic acid that the manufacturer says will solubilize calcium and other salts and lower soil sodium and bicarbonate levels. http://www.aquatrols.com/labelsandmsds2006/Labels/Eximo%20interim%20label.pdf	Apply product at label rates and frequencies. Monitor tree condition and soil salinity.