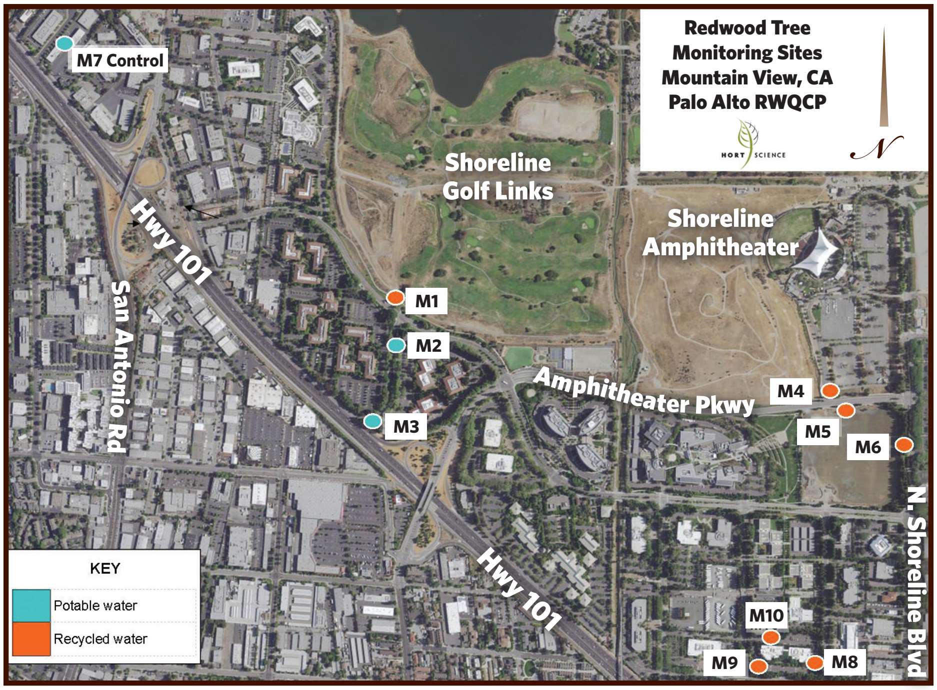
Operated by the City of Palo Alto for the East Palo Alto Sanitary District, Los Altos, Los Altos Hills, Mountain View, Palo Alto and Stanford

Redwood Tree Monitoring Study 2009–2016

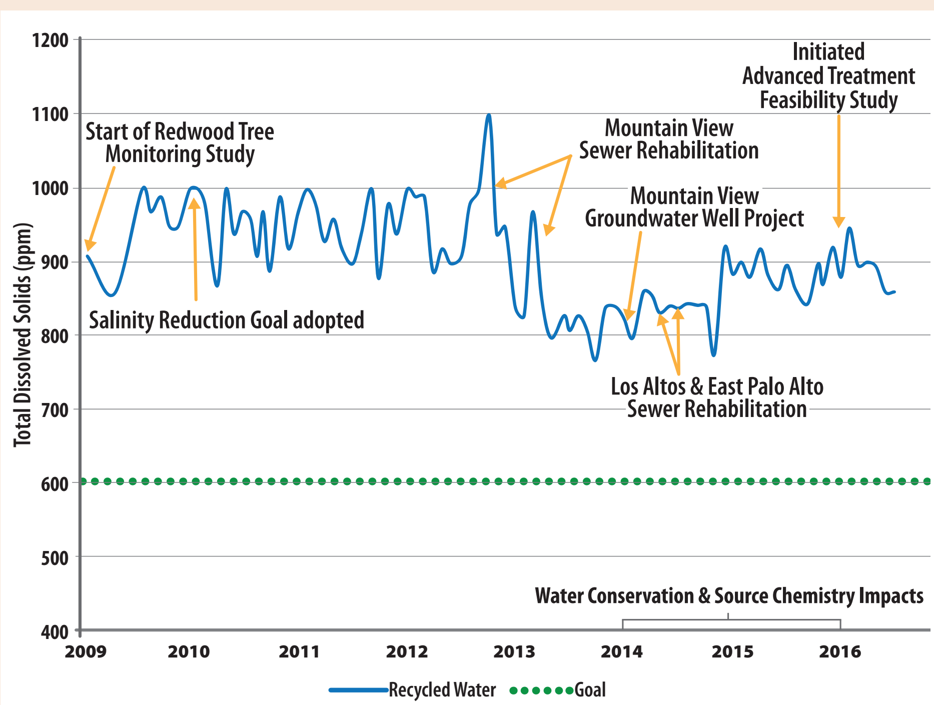
Introduction

In 2009, the Palo Alto Regional Water Quality Control Plant (RWQCP) began delivering recycled water to Mountain View as a sustainable and local alternative to potable water use for landscape irrigation. Mountain View is home to many coast redwood trees, and the RWQCP contracted with HortScience Inc. to monitor the status of these trees and recommend adaptive management strategies. Redwoods have survived locally on potable water despite not being native to the area or naturally adapted to the hot, dry climate. Experience throughout the Bay Area has shown that redwoods are sensitive to recycled water, which typically has a higher salt content than potable water. During this multi-year study the RWCQP and its partners undertook several projects to reduce recycled water salinity.



Monitoring Protocol

Ten trees were monitored through this study: three irrigated with potable water (M2, M3, and M7) and seven irrigated with recycled water (M1, M4–M6, and M8–M10). Three times per year—spring, summer and fall—researchers photographed the study trees and rated their visual appearance. Trees were rated on a scale of 1-4 based on foliage density, color, and presence of dead branches. Researchers also collected soil and tree tissue samples and retrieved data from continuously monitoring soil moisture sensors buried 8″ and 18″ deep.

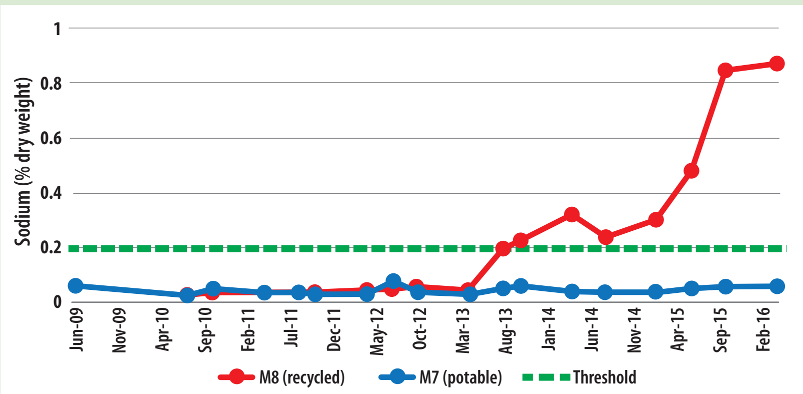


Salinity Reduction Efforts

In 2010, several RWQCP partner agencies adopted a Salinity Reduction Policy with the goal of lowering recycled water salinity to less than 600 parts per million (ppm) of total dissolved solids (TDS). Following adoption of this policy, Mountain View, East Palo Alto, Los Altos, and Palo Alto collaborated on multiple projects to limit the inflow of saline groundwater into the sewer collection systems, a major cause of the recycled water's high salinity. Projects included pipeline repairs, manhole repairs, and redirection of groundwater well discharge away from the sanitary sewers. Cumulatively, these efforts reduced recycled water salinity by approximately 15%. However, severe drought conditions have recently caused salinity levels to increase again. Since the attempted salinity reduction efforts were insufficient to reach the TDS goal, a feasibility study for advanced treatment has been initiated, evaluating new options for reducing recycled water salinity.

Sodium and Chloride in Redwood Foliage Was Greater at Sites Irrigated With Recycled Water

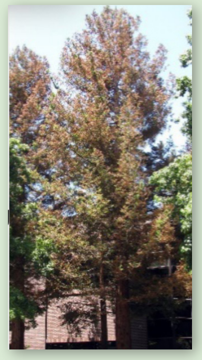
As tree roots absorb water they also absorb chloride and sodium (salts) from the surrounding soil. Salt is transported in the water as it moves upward in the plant and into the foliage. When water exits the tree leaf as vapor, the salt is left behind. Over time, salt accumulates in redwood foliage, and can cause browning and foliage loss (see photos). Each year the new spring foliage may appear healthy and green, but during the summer salt accumulates and the tissue becomes damaged. Within a few years, salt-affected redwoods may defoliate, as shown in the photo of M8. During the study period, salt concentration (sodium and chloride) exceeded the estimated safe threshold for redwood trees at all sites receiving recycled water.




Site M7 Potable Water


Site M8 Recycled Water

Trees located on the north or east side of the site exhibited fewer symptoms of decline than those located on the south or west side. This difference is assumed to be due to sun and wind exposure increasing evapotranspiration rates and thus increasing the volume of water (and salt) absorbed by each tree. Salt concentrations were also higher in dry, water stressed foliage than in well hydrated foliage.



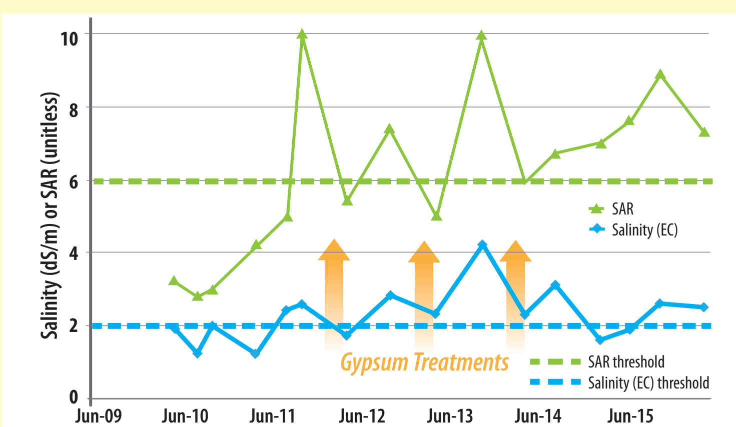

(Left) Redwood tree with southern exposure; (Right) redwood tree with northern exposure. Both were irrigated with recycled water.

Soil Salinity and Sodium Were Higher at Sites Irrigated With Recycled Water

During the study period soil salinity (measured as electrical conductivity, EC) at sites irrigated with recycled water increased and, in most cases, exceeded the maximum threshold for redwoods. Soil salinity remained below the threshold at all sites irrigated with potable water. The sodium adsorption ratio (SAR) measured in soils from recycled water sites also exceeded the maximum threshold for redwoods, indicating an imbalance of certain elements (more sodium, less calcium and magnesium).

Adaptive Management Sought to Mitigate Sodium Buildup

A high SAR value is correlated with soil drainage problems and limits the ability to leach salts from soil. Landscape managers typically address this problem by applying gypsum before the rainy season to reduce the SAR and move sodium below the tree roots. This adaptive management strategy was applied at two sites in the winters of 2012-2014. While these actions reduced soil salinity, there was inadequate rainfall for the treatment to be fully effective.



Key Findings

- **After being irrigated with recycled water for six years, and concurrent with a multi-year drought, test site redwood trees showed moderate to severe foliage damage and defoliation.**
- **The foliage damage is attributed to salts in the foliage, specifically chloride and sodium, which both exceeded the tolerance of the redwoods.**
- **Changes to tree foliage (color and density) were only visible after about 4 years of recycled water irrigation.**
- **Gypsum treatments temporarily reduced the soil salinity and SAR, but did not appear to reduce the severity of tree damage.**
- **Winter rainfall during these drought years was inadequate to maintain soil salinity below thresholds acceptable to redwood trees.**
- **Trees in high exposure microclimates (i.e., south or west-facing) were more impacted than those in shaded, protected areas.**
- **Efforts to reduce the RWQCP's recycled water salinity were insufficient to reach the 600ppm TDS goal.**