CH2M Recipient of the 2015 Stockholm Industry Water Award

ORIGINAL APPLICATION SUBMITTED JANUARY 21, 2015

ch2m SM

Water Corporation of Western Australia, Beenyup Visitor Centre

"Water should not be judged by its history, but by its quality"

-Dr. Lucas van Vuuren, National Institute of Research, South Africa

CH2M's Contributions to Global Water Reuse: Leading the Evolution and Acceptance for a Half Century

CH2M has long recognized that our global community cannot afford to use water once and dispose of it: fresh water sources are precious and growing more scarce. Purifying wastewater effluent to create drinking water seems the logical solution, and CH2M has been at the forefront of removing the technical and public acceptance hurdles to getting water reuse projects up and running. In fact, many of the water reuse projects described in this application have been pivotal milestones in the water industry and our company's growth over the past 50 years. And while technological innovation is an important part of that story, projects would never have been built if the public hadn't accepted them. Rather than "one off" engineering exercises, CH2M has approached water reuse as a holistic integrated challenge, marrying the best in science and technology with innovative public education tools.

CH2M's Contributions to Water Reuse over Time

As with most emerging ideas, the evolution of water reuse has been punctuated by the questions that arose along the way. CH2M's holistic, forward-looking approach to answering those questions is what sets the firm apart, as described below and illustrated by the timeline and project descriptions.

CH2M's legacy of contributions to a sustainable water future

"We forget that the water cycle and the life cycle are one."

- Jacques Cousteau

1960s

Becoming better stewards of fresh water bodies

CH2M's commitment to potable water reuse technology began with the design and operation of the **first full-scale advanced wastewater treatment facility** in the United States, in South Lake Tahoe, in 1965. This plant upped the ante for effluent quality by incorporating such tertiary treatment firsts as: lime chemical treatment for phosphorus removal resulting in elevated pH to promote ammonia-nitrogen stripping, followed by granular tri-media filtration and carbon adsorption. The process had never been done before, was highly successful, and transformed CH2M from a small regional firm into a world-recognized pioneer in advanced wastewater treatment.

1970s

Cost-effectively reclaiming drinking water

The technology developed for the South Lake Tahoe project was the inspiration for the Upper Occoquan Service Authority's (UOSA) state-of-the-art Regional Water Reclamation Plant in Northern Virginia. Water quality degradation of the Occoquan Reservoir created new solutions and led to one of the **world's first and largest indirect potable reuse plants**. After 30 years of highly successful operations, UOSA reclaimed water is an increasingly important component of the drinking water supply strategy for the Washington metropolitan area. Once again, CH2M raised the bar.

1980s

Addressing concerns about public health, safety and reliability

CH2M's design of the Denver Potable Reuse Demonstration Plant and—later—the Singapore NEWater potable reuse projects were **milestones in the advancement of water purification technology and health effects testing** to prove the safety of potable reuse. Both projects included full, 2-year, whole animal toxicological testing to confirm the safety of potable reuse treatment technology. No other potable reuse projects have undertaken this level of testing since and the projects serve as pinnacles advancing the viability of potable water reuse as a water management solution globally as no adverse health effects were detected.

1990s

Making potable reuse affordable for widespread adoption

In the 1990s, CH2M introduced a technology revolution for the Reedy Creek Improvement District (Orlando, Florida) that helped make potable water reuse technology **more affordable**. The facility was the **first in the world to use innovative dual membrane treatment [microfiltration (MF) and reverse osmosis (RO)] for advanced water reuse**. Today, nearly all potable reuse plants using RO technology have implemented CH2M's approach of MF pre-treatment.

2000s

Combining technology innovation with communication tools to increase acceptance

With the Singapore NEWater Study in the early 2000s, CH2M moved to the international stage, **pioneering a hands-on transparent approach to public outreach** and conducting the **most sophisticated and comprehensive study of reclaimed water to date**. CH2M designed and implemented a visionary program to build understanding and acceptance. The centerpiece was a visitor center that has received well over a million visitors.

Text & images from *WateReuse Research Foundation*

2010s

Understanding that words, images, and the context of the urban water cycle enhance public acceptance

CH2M has been successful in **positively shaping public perception** of and **gaining acceptance** for potable reuse projects. Our public outreach programs have effectively dispelled the myths that might otherwise have prevented projects from moving forward. CH2M has developed cutting-edge research projects that have changed the way we talk about reuse and have shown that words, images and context matter.

2015 and Beyond

Creating a sustainable water future

Whatever the details of our new challenges turn out to be, the evolution of water's use and reuse will depend on how well technology is interwoven with effective programs for public education and engagement. Decades of water innovation by CH2M have laid the foundation for a sustainable water future. We have been a pioneer in both technology and communication and we will continue to lead the charge to advance sustainable water technology and clearly communicate the needs, benefits, safety, technology, and science of water reuse. Our philosophy that water can be effectively used and reused remains steadfast.

1965

Becoming better stewards of fresh water bodies

CH2M's commitment to potable water reuse technology began with the design and operation of the **first full-scale advanced wastewater treatment facility** in the United States, in South Lake Tahoe, in 1965. This plant became a major catalyst for "advanced" wastewater treatment, upped the ante for effluent quality by incorporating such tertiary treatment firsts as: lime chemical treatment for phosphorus removal resulting in elevated pH to promote ammonia-nitrogen stripping, granular tri-media filtration, and carbon adsorption.

Before South Lake Tahoe, wastewater was treated to simply remove biochemical oxygen demand (BOD) and total suspended solids (TSS) to minimize impacts on aquatic life in receiving bodies. CH2M had done a lot of work along those lines, winning recognition for finding new ways to filter water and clean up rivers after World War II. It was the firm's leadership in filtration that prompted the South Tahoe Public Utility to ask for its help to restore the water in Lake Tahoe to its original pristine state. Development and recreational activities had degraded the lake through the proliferation of nitrogen and phosphorus. The question was: How could the water be purified to restore it to its original unadulterated quality? CH2M conducted an extensive pilot study to answer that question. First-ever processes took the understanding of water quality to new levels, enabling engineers to create new processes to remove more organic contaminants. Phosphorus and trace metals were extracted through high lime treatment that raised the pH of the water. The process turned soluable ammonia into a gas, then ran it through an air stripper to remove the ammonia. The water was then polished with a granular media filter and further polished with carbon absorption, finally released to another lake. The process had never been done before, was highly successful, and transformed CH2M from a small regional firm into a world-recognized pioneer in advanced wastewater treatment.

South Lake Tahoe Advanced Water Treatment Plant

Upper Occoquan Service Authority: world's first and largest indirect potable reuse plant

1970s

Cost-effectively reclaiming drinking water

The technology developed for the Lake Tahoe project was the inspiration for the Upper Occoquan Service Authority's (UOSA) state-of-the-art Regional Water Reclamation Plant in Northern Virginia, one of the **world's first and largest indirect potable reuse plants**. CH2M's long involvement with UOSA, begun in the 1970s, is often cited in the industry as a milestone project in the development of potable water reuse.

When water quality studies indicated the 41.8-billion-cubic-meter Occoquan Reservoir was seriously degraded, the major source of drinking water for the million+ people in the Fairfax County/Washington DC area was at risk. The problem had developed as a result of inadequately treated sewage discharged from 11 small wastewater treatment plants upstream of the reservoir. While one solution would have been to expel all wastewater out of the Occoquan watershed so it wouldn't pass through the reservoir, this would have been extremely expensive. Instead, CH2M recommended that the dozen small wastewater treatment plants be replaced with one regional wastewater treatment plant; and that the new plant use advanced treatment methods to produce near-drinking-water quality effluent that could be released to the reservoir upstream of a drinking water plant. This cost-effective approach and rigorous design requirements once again raised the bar for wastewater treatment, including reliability and process advances. The cost savings afforded by biological treatment helped minimize costs (the more expensive physical-chemical processes were only used to augment treatment once biological treatment had removed conventional pollutants). CH2M has continued to provide engineering services for 40 years to UOSA, and the reservoir water quality remains high.

Two-stage granular activated carbon adsorption contactors at Denver Potable Reuse Demonstration Plant

1980s

Exploring direct potable reuse - technology and acceptability

CH2M's design of the Denver Potable Reuse Demonstration Plant and—later—the Singapore NEWater projects were **milestones in the advancement of water purification technology and health effects testing** to prove the safety of potable reuse. Both projects included full, 2-year, whole animal toxicological testing to confirm the safety of potable reuse treatment technology. No other potable reuse projects have undertaken this level of testing. They serve as pinnacles in advancing the viability of potable water reuse as a safe water management solution globally.

For the Denver Potable Reuse Demonstration Project, the question was: is direct potable reuse possible? The—radical—idea was to recycle reclaimed water directly, essentially removing the environmental filter

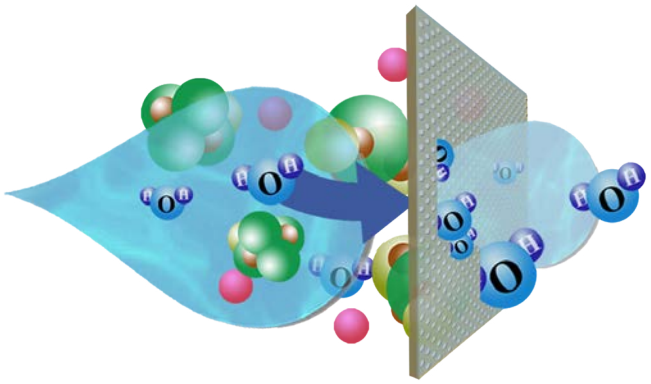
of “indirect” potable reuse. The question was: *Did we have the technology to turn wastewater into drinking water that was as good or better than the Rocky Mountain snow melt, source of water supply for Denver area?* CH2M provided the preliminary planning, design, and service during construction of the demonstration project to find the answers.

The Denver project included service during construction of a 1-million-gallon-per-day (mgd) demonstration plant, from 1985 to 1992, to evaluate alternative treatment approaches and, ultimately, select an advanced water reclamation treatment train. Advanced treatment processes evaluated included high pH lime clarification, recarbonation, filtration, activated carbon adsorption, reverse osmosis, air stripping, ozonation, and chlorination. The project was the first to prove the effectiveness of reverse osmosis.

But while it had become clear that wastewater could be treated to the level of drinking water quality, the question became: *How do we get the public to accept that as fact?* We needed to look at the health effects—not just of individual contaminants—but of the synergistic effects of all contaminants. Using the testing model of the pharmaceutical industry, the team set out to prove the efficacy and safety of reclaimed water.

The best available technology for assessing the combined potential health effects of the complex mixture of trace organic compounds found in wastewater involves extracting and concentrating organics from water and feeding the organic concentrate to rats and mice for 2 years to measure reproductive, developmental, and carcinogenicity health effects. While “whole animal” health effects testing is time-consuming and expensive, it is the only viable means of truly measuring the potential health effects of a complex mixture of trace organic compounds. To our knowledge, there are only two examples of full 2-year, “whole animal” toxicological testing conducted on reclaimed water: CH2M’s Denver demonstration project and Singapore NEWater Study. In both cases, CH2M was the advanced water treatment engineering services provider. No adverse health effects were detected in either the 2-year chronic toxicity testing or the generation reproductive study for any of the waters evaluated. It was clear that water reclaimed from wastewater could be every bit as safe as the regular water supply.

That message was conveyed to the community through a comprehensive outreach program that included a small interpretive center, and tours of the demonstration plant. A public survey concluded that people’s perceptions often change when they can actually see reuse technology in action. Thousands of site tours were conducted for people from all over the world and public opinion surveys were conducted to measure public acceptance. From the beginning, **CH2M has approached the issue of public acceptance differently**. Instead of simply hosting public meetings with talking heads and engineering diagrams, we have sought to provide opportunities for the public to see for themselves how water is recycled. We have found that when an experiential environment for learning is created, people’s minds and hearts can be changed. When they can see the treatment processes up close and witness, for example, the clarity of the purified water, people tend to be more accepting. In addition, the words and images used can change mental models from “***yuck to yes***.”



1990s

Making potable reuse affordable for widespread adoption

In the 1990s, for the **Reedy Creek Improvement District** in Orlando, Florida, CH2M introduced a technology revolution that helped make potable water reuse technology **more affordable**. The facility was the **first in the world to use innovative membrane filtration [microfiltration (MF) and ultrafiltration (UF)] and reverse osmosis (RO) for advanced water reuse**. Prior to this treatment advancement, the preferred treatment train included expensive and operationally intensive lime softening.

The Reedy Creek Improvement District—water supplier to Disney World—was interested in using advanced treatment to purify water for Disney World's many water features. While the district wanted to use RO, it needed to find a way to remove the suspended solids before the RO process without the use of lime. While effective, lime treatment is messy—requiring large amounts and creating excessive chemical sludge. The pioneering research conducted by CH2M at the Reedy Creek facility demonstrated that RO could be significantly improved with MF as a pretreatment in lieu of the "high lime" process that was state-of-the-art for indirect potable reuse at the time. Now an industry best practice for pretreatment, MF produces excellent water quality that improves the operation and cost of downstream RO. This breakthrough allowed many utilities to dispense with lime treatment, with significant cost savings.

The **Lower Rio Grande Valley Development Council Reuse Feasibility Study** in McAllen Texas, further reduced the cost of treatment by using **membrane bioreactor technology in combination with RO, another first**. Up until then, raw sewage had typically been drawn through a bioreactor, secondary clarifier, membrane filter, and finally RO. CH2M engineers questioned the need for the secondary clarifier: *Couldn't wastewater simply be routed straight to the bioreactor and bypass secondary clarification, which had its own operational issues?* This pilot study proved that secondary clarifiers could be eliminated from the treatment process, along with the operational headaches and added cost.

2000s

Combining technology innovation with communication tools to enhance acceptance

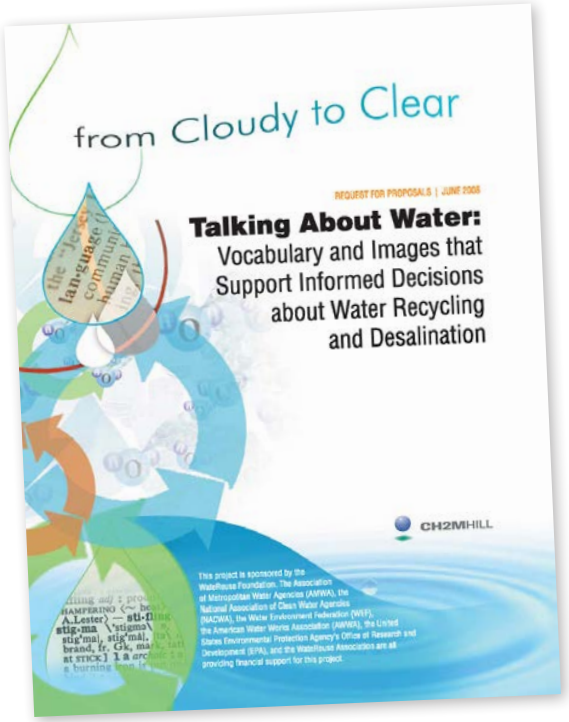
With the Singapore NEWater Study, for the Republic of Singapore in the early 2000s, CH2M moved to the international stage, **pioneering a hands-on transparent approach to public outreach** and conducting the **most sophisticated and comprehensive study of reclaimed water to date**. This pilot project fully integrated the best in technology with the best in public education tools to create unprecedented public acceptance of water reuse.

The NEWater study explored the suitability of using advanced treated recycled water as a future alternative water source to meet the growing demand for water on this island nation. The idea was to produce pristine water from secondary treatment effluent that had undergone advanced post treatment with dual membrane (MF and RO) and **UV disinfection technologies**, taking full advantage of all of the technological improvements to that point. The new technology involved the addition of a UV disinfection process, which provided even more barriers to microbial pathogens in drinking water and eliminated the need for chlorination. As a result of this work, many utilities have now shifted to the use of UV light in lieu of chlorination.

The NEWater study included operation of a 2.6-mgd treatment demonstration, from 1999 to 2003, to evaluate MF, RO, and UV disinfected secondary effluent from the Bedok Water Reclamation Plant for toxicological testing comparison to the Public Utility Board's Bedok Reservoir raw water source. NEWater was the **first study of its type to include chronic testing of fish in parallel with chronic testing of mice**. Groups of mice were fed NEWater and PUB raw water organic concentrates at 500-fold and 150-fold levels for 2 years. In addition to the mouse study, a 1-year Japanese medaka fish study was performed to evaluate estrogenic potential (reproductive and developmental) effects on two generations of fish. No adverse health effects were detected in either the 2-year mouse study or the 1-year fish study.

Following the study, CH2M designed and implemented a demonstration plant and three production-scale treatment plants that are now producing more than 122,000 cubic meters of high-grade water a day.

Public acceptance was key to the success of the NEWater project. Rather than simply host a series of meetings to present projects, CH2M developed a holistic public education program and conducted research to find out what people did and didn't understand about water and why. CH2M designed and implemented a visionary program to build understanding and acceptance. The centerpiece was a visitor's centre that brought together **state-of-the-art communication technology** with the most recent **research on public perception challenges** regarding indirect potable reuse. The center "pulled back the curtain" on treatment technologies, allowing visitors to observe the process in action via an elevated glass-encased walkway. Interactive digital exhibits showcased the advanced treatment technologies and promoted appreciation of water as a sustainable resource. The NEWater visitor centre has become a tourist destination and has been visited by 1.3 million visitors. A postage stamp has even been issued to commemorate its success.



2010s
Public Acceptance

Words, images and the context of the urban water cycle enhance acceptance

CH2M has been successful in **positively shaping public perception** of and **gaining acceptance** for potable reuse projects, critical for moving projects from the drawing board to implementation. In fact, stakeholder groups often determine the success or failure of a reuse project. Rooted in a clear understanding of local stakeholder concerns, the firm's public outreach programs have effectively dispelled the myths that might otherwise have prevented projects from moving forward. By promoting understanding about water and wastewater technology, the team has helped communities make decisions about reuse based on fact—not fear.

CH2M pioneered the application of social science methods to better understand the underlying reasons that people reject the notion of reuse and what might be done to change their minds. As a result of this research, experiential demonstration, transparency about treatment processes, and education about the hydrologic lifecycle have served to make CH2M's water reuse projects succeed where others have failed.

As technology has evolved, so too has the public's perspectives on water reuse and the language used to describe it. What used to be "treated sewage" was soon called "wastewater reclamation" and today, "water purification." In the 1960s, wastewater represented a problem of waste. Over time, people have begun to see wastewater as an integral part of the hydrologic cycle and started valuing water as a resource instead of simply "waste." CH2M has been one of the leaders in that transformation.

The firm's work has propelled the adoption of water reuse by communities around the world. Even though there are numerous nonpotable reuse projects and many municipalities are consuming water downstream of wastewater discharges, only a few indirect potable reuse projects are up and running and a good number of these projects resulted from CH2M's collaboration with forward thinking clients.

CH2M has been at the cutting edge of the research into the art and science of communicating with the public about water reuse, leading such WateReuse Research Foundation projects as ***"Talking About Water: Vocabulary and Images that Support Informed Decisions about Water Recycling and Desalination (WRF–07-03)"*** and ***"The Effect of Prior Knowledge of Unplanned Potable Reuse on the Acceptance of Planned Potable Reuse (WRF-09-01)."*** By teaming with social scientists to better understand the public's attitudes, assumptions, and behavior, the firm has been a leader in developing the language, imagery, and concepts to dispel the myths about water reuse.

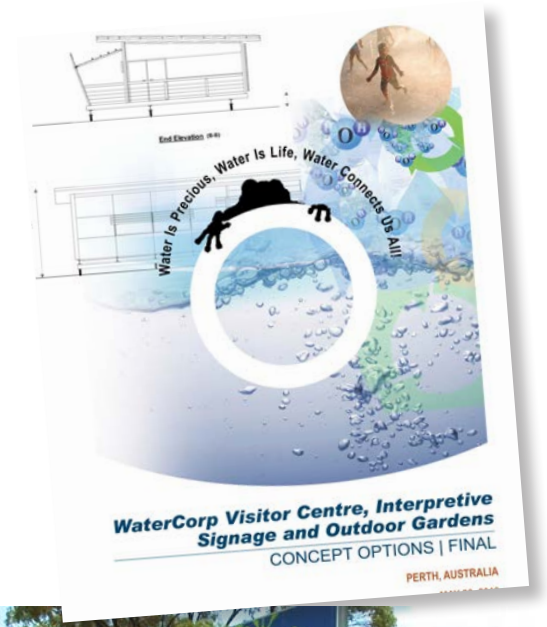
Research

The ***Talking About Water*** project explored the ways in which words and images make a difference in people's acceptance of water reuse. Investigators developed an educational experience based on specific words and images, then measured participant's attitudes before and after engaging the experience. Participants were drawn from one Australian and three U.S. communities. The research proved that some of the language used to describe reuse (sewage and wastewater reuse) were so off-putting that people were not inclined to move forward with reuse projects. To gain acceptance, the industry would need to use different language and imagery.

A second research project, ***"The Effect of Prior Knowledge…"*** explored the effectiveness of explaining reuse within the context of the entire urban water cycle, the notion that **we are all downstream of someone else**. What researchers found was an understanding of the water cycle generally led to acceptance of potable reuse, including direct potable reuse. This flew in the face of many in the water industry who feared that full disclosure would only elevate the public's anxiety; in fact, the opposite proved to be true. The video explaining the water cycle, "Downstream" *(https://www.youtube.com/watch?v=GVm-d-zOxJs)*, now posted on YouTube in Spanish and English, went "viral" in the water industry.

Frames from "Downstream" video, WateReuse Research Foundation WRRF 09-01

All Earth life is water-life.



2014

Bringing potable reuse to Australia

CH2M is directly involved in two landmark projects for Australia: the Western Corridor Recycled Water Project in Southeast Queensland and the Beenyup Advanced Water Recycling Plant in Perth. For the Western Corridor Recycled Water Project, we teamed with Laing O'Rourke to design, construct, and commission the Luggage Point AWTP, which was designed to augment a major water supply reservoir that services Brisbane after further treatment. At a design and construction pace unheard of due to a major water shortage, this project team successfully delivered "first water" in less than 2 years' time, a remarkable achievement for a 70 mega-liter-per-day treatment plant. The project included numerous technical innovations that advanced potable reuse, including chemical precipitation to improve MF and RO performance, preformed monochloramine to limit Nitrosodimethylamine formation while controlling organic fouling, and automated corrosion control to consistently maintain corrosion indices within acceptable limits.

For the Beenyup project, CH2M, as part of a joint venture with Thiess, in an Alliance with Water Corporation Western Australia will design, construct, and commission a full-scale Advanced Water Replenishment Plant (AWRP) in Perth, Australia, that will inject highly treated wastewater effluent into underground aquifers then stored and taken out some time later for further treatment and supply to a drinking water system. This is the first groundwater replenishment project in Australia and represents a major step forward for the Water Corporation's climate resiliency strategy. The plant will use dual membrane treatment (ultrafiltration and reverse osmosis) followed by ultraviolet disinfection. Both membrane processes will be operated to achieve (log) removals for all classes of pathogens and will employ a unique validation strategy to ensure such removal by reverse osmosis.

CH2M applied its social science research for WateReuse Research Foundation to the task of allaying public anxiety about potable reuse, which included Water Corporation as a teaming partner. CH2M designed a small interpretive centre at the demonstration facility that was integral to achieving acceptance.

Technical Innovation

CH2M has been at the **forefront of developing the advanced treatment processes** required to implement successful potable reuse projects, including membrane filtration (MF), reverse osmosis (RO), granular activated carbon (GAC), ozone, natural treatment, and ultraviolet light and ultraviolet-advanced oxidation (UV-AOP). In a nutshell:

- **Membrane pretreatment**: Chemical precipitation can significantly reduce the organic and solids load to downstream membrane processes, which reduces cost and improves operability and reliability. CH2M has led the industry in membrane pretreatment, such as providing chemical precipitation at the Luggage Point Advanced Water Treatment Plant (AWTP) in Australia to: 1) reduce organic fouling on the downstream membranes, 2) increase membrane flux by reducing the solids load, and 3) control calcium-phosphate scaling on RO.
- **Dual membrane treatment**: Based on pioneering research by CH2M for the **Reedy Creek (Florida) Wastewater Reuse Program**, low pressure membranes (MF/UF) are now the gold standard for pretreatment of RO membranes at potable reuse plants, yielding a "dual-membrane" treatment system that provides robust treatment for the removal or pathogens, organics, and emerging contaminants.
- **Granular activated carbon (GAC)**: GAC is another barrier to trace organics and emerging contaminants. CH2M has incorporated GAC at the **Upper Occoquan Service Authority (UOSA) Regional Water Reclamation Plant** and many other potable reuse plants.
- **Natural treatment systems**: Natural treatment systems can provide an innovative and low-cost treatment barrier for potable reuse. CH2M has engineered treatment wetlands for the Clayton County potable reuse project and has designed wetlands treatment for RO concentrate disposal in Oxnard, California. We are currently piloting an innovative potable reuse treatment process in Tucson, Arizona, that includes soil aquifer treatment (SAT).
- **Advanced oxidation**: Ultraviolet light and/or ozone, often used in conjunction with hydrogen peroxide, is typically provided at potable reuse plants as a barrier to trace organics and emerging contaminants. CH2M has applied ultra violet light, advanced oxidation and ozone at numerous potable reuse plants, including the Singapore NEWater Study; Luggage Point AWTP; F. Wayne Hill Water Resources Center in Gwinnett County, Georgia; and the Leo Vander Lans AWTF in Long Beach, California. UV-AOP is very effective at photolysis of nitrosamine products such as NDMA and other emerging contaminants that are often regulated for potable reuse projects.
- **Sustainability research**: CH2M has pioneered the application of sustainability and triple bottom line approaches to water reuse projects. For the WateReuse Research Foundation, we led a research study (WRRF-10-01) that investigated alternative treatment schemes for potable reuse for applications where some technologies that were not environmentally or economically feasible. This study has contributed to a revolution in potable reuse treatment wherein utilities, regulators, engineers, and researchers are now actively searching for the most sustainable treatment solution to potable reuse projects to avoid the cost of "over-treating."

UV Advanced Oxidation, Luggage AWTP

Oxnard, CA

2015 and Beyond

Creating a sustainable water future

Whatever the details turn out to be, the evolution of water reuse will be based on a single goal: a sustainable future for the generations to come. This will undoubtedly mean judging water by its quality rather than its immediate history. CH2M will continue to lead the charge to advance sustainable water technology and clearly communicate the science to expand understanding of the urban water cycle. Our engineers are also hard at work to find ways to assure the safety and absolute reliability of reuse operations, developing fail-safe instrumentation (alarms, shut-downs, diversions) to ensure untreated water will never be released to the public. And as the leading contractor to the U.S. Environmental Protection Agency for water contaminant-warning systems, CH2M is in a unique position to develop the next generation of reliability tools.

The journey continues and CH2M HILL's commitment to water reuse remains steadfast. We will continue to cast forward by seeking out the technological and communications tools to enable all communities around the world to be assured of access to clean, potable water.

"We can create a sustainable future for generations to come."

-concluding slide from "Downstream"
WateReuse Research Foundation
WRRF 09-01

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Research and teaming partners

Denver Water
South Lake Tahoe Public Utility District
Reedy Creek Improvement District
Singapore PUB
Upper Occoquan Service Authority
WateReuse Association and Research Foundation
Aurora Water
Tucson Water
Water Corporation of Western Australia
Sabesp, São Paulo, Brazil
and many other clients and teaming partners

TECHNOLOGY **steward** **envision** inspiring future generations **sustainable** INNOVATION demonstrate **community** **advanced** **safety** **NEW LANGUAGE, NEW THINKING, NEW POSSIBILITIES**

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