QUALIFICATIONS

Drinking Water

Biological treatment

Carollo

Engineers... Working Wonders With Water™
Carollo Engineers is an environmental consulting firm with nearly 600 employees in 31 offices throughout the United States. All of our work is performed in the areas of water and wastewater, resulting in a level of understanding of key project issues that few can match. Carollo strives to maintain the tradition of using sound and proven engineering principles while moving progressively forward to keep abreast of changing times and new technologies.

This is a specialty Statement of Qualifications (SOQ) for Carollo Engineers detailing some of our experience and expertise in the field of water treatment specific to this topic.

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BACKGROUND

The use of microbial biomass for the degradation of contaminants, nutrients, and organics has been common in the wastewater field since the early 1900s. However, the biological treatment of drinking water has been much more limited in the U.S. and only recently has been expanded to include the treatment of a wide variety of organic and inorganic contaminants. In contrast, biological removal of organics, ammonia, and nitrate from drinking water has been practiced in Europe for decades.

Biological treatment is an effective means of reducing the concentration of organic content and other contaminants in water supplies, and may be aerobic or anaerobic in nature. As a result, the oxidation and reduction of contaminants and organics is possible. Fixed-bed (FXB), fixed-film biological treatment, which is often referred to as biofiltration, has been successfully employed in water treatment facilities for organic and inorganic degradation, metal oxidation, and nutrient removal. Biological filtration may also be coupled with pre-ozonation for improved organic removal and an increase in overall effluent quality. The use of granular activated carbon (GAC) as a biogrowth support medium can further enhance these pre-ozonated biological systems. The use of pre-ozonation followed by biological filtration is being implemented in many plants across the U.S. to meet the Stage 2 Disinfection/Disinfection By-Products (D/DBP) rule.

APPLICATIONS

The applicability of biological drinking water treatment includes surface water and groundwater, and covers a wide range of organic and inorganic contaminants, as illustrated on the following page.
WHY CONSIDER BIOLOGICAL TREATMENT?

The use of biological processes has several potential advantages over other treatment technologies, including:

- Operating costs can be very low.
- Water recoveries are high.
- Contaminants are destroyed instead of sequestered and concentrated.
- Multiple contaminants can be removed simultaneously.
- Sludge production is minimal.
- Hazardous waste streams are not generated.
- Minimal-to-no-chemical addition is required.
- Processes can be robust over a wide range of operating conditions and water quality characteristics.

These characteristics make biological treatment highly efficient and environmentally sustainable. Process designs are simple and bioacclimation can be achieved with microorganisms indigenous to the raw water source.
CAROLLO IS A LEADER IN BIOLOGICAL TREATMENT

The breadth of Carollo’s biological drinking water treatment experience is unmatched in the industry and includes a wide range of organic and inorganic contaminants, as illustrated by the table on page 2; FXB, fluidized-bed, and suspended growth reactors; heterotrophic (i.e., organic carbon used for biogrowth) and autotrophic (i.e., inorganic carbon used for biogrowth) systems; and molecular and culture-based microbial analytical techniques.

Examples of key Carollo achievements leading to the current viability of biological drinking water treatment in the U.S. include:

► Establishing Engineered Biofiltration. Currently, biofiltration is largely operated as a passive process in the water treatment industry. Particle/turbidity removal and headloss drive the design and operation of conventional filtration as well as biofiltration. Thus, biofilter design parameters are typically limited to media configuration, backwash strategy, and loading rate. The biological removal of dissolved organic and inorganic contaminants is an anticipated benefit of biofiltration. However, common design and operational practice does not seek to enhance the biological activity responsible for those removal mechanisms.

As part of a Water Research Foundation Tailored Collaboration Project with the City of Arlington, TX, Carollo is developing methods for enhancing the performance of standard biofiltration processes through improving microbial health. Biofilter feed water at typical water treatment facilities has non-detectable amounts of phosphorus due to general source water limitation and removal through coagulation. As phosphorus is an essential nutrient for biological growth and health, its limitation may be detrimental to biofilter operation. Low concentrations of phosphoric acid were dosed to a pilot-scale biological filter to satisfy critical ratios of carbon to phosphorus for healthy microbial activity. This work showed that phosphorus supplementation greatly enhances biological filter hydraulic and water treatment performance. Observed benefits included longer filter run times and improved MIB, manganese, and dissolved organic carbon removal.

The primary goal of this work was to establish the basis for moving biofiltration from a passive process designed and operated around conventional filtration objectives to an intentionally operated biological system (i.e., “engineered biofiltration”). Engineered biofiltration targets multiple water quality objectives while maintaining, or even improving, hydraulic performance.

► Designing the First Centralized Biodenitrification Drinking Water Facility. An 8-month pilot test was initiated in May 2007 (Riverside, CA), the objective of which was to evaluate the use of FXB biological treatment to remove nitrate from the reverse
osmosis (RO) by-pass water at Western Municipal Water District’s (WMWD’s) Arlington Desalter facility (nitrate currently limits the amount of water that can by-pass the costly RO treatment process). A second pilot test was performed from May-August 2008 to evaluate a polishing filter step to remove turbidity from the effluent of the nitrate-reducing biological reactor (bioreactor). Design parameters obtained during the two pilot tests are being used to develop the preliminary design for a 3-mgd biodenitrification facility that will treat RO by-pass water at the Arlington Desalter and distribute the blend as potable water. The data showed that:

- Using an empty-bed contact time as low as 4 minutes 75 mg/L of nitrate was removed to below 5 mg/L. Nitrite accumulation was not observed.
- The FXB bioreactor also removed perchlorate and dibromochloropropane (DBCP) from the raw water.
- Interstage degasification and polymer addition is required to produce effluent ≤0.1 NTU.
- Nitrate removal performance was minimally impacted by various planned process disturbances, including backwashing, raw water quality fluctuations, feed flow fluctuations, system shut-downs, and acetic acid shut-downs.

The FXB biological process has key features that make it an attractive nitrate removal technology, including contaminant destruction, high efficiency, relatively low O&M costs, broad contaminant applicability (e.g., nitrate, perchlorate, VOCs), and process robustness. Pilot testing at the WMWD’s Arlington Desalter facility confirmed these features of FXB biological nitrate treatment. Pertinent conditions of the California Department of Public Health (CDPH) FXB biological treatment technology approval letter have been addressed during these pilot studies, and the preliminary design for a 2.4-mgd biodenitrification facility at the Desalter is complete. Final design is expected to begin in late 2010, and construction of the nation’s first centralized biodenitrification facility can then begin.

Patented Process to Remove Algae-Derived Tastes, Odors, and Toxins. The presence of objectionable taste and odor (T&O) compounds in surface water supplies is a growing problem facing drinking water utilities across the country and worldwide. Two of the most common surface water T&O-causing compounds are 2-methylisoborneol (MIB) and trans-1,10-dimethyl-trans-9-decalol (geosmin), which are metabolites of cyanobacteria (blue-green algae) and actinomycetes bacteria. MIB and geosmin produce an earthy/musty T&O that can be detected by human senses at concentrations as low as 4 ng/L (ppt). In addition
to T&O metabolites, cyanobacteria can also produce toxic compounds that damage the neuromuscular system, liver, kidneys, gastrointestinal system, or skin.

Conventional treatment methods, such as pre- and post-chlorination, coagulation, sedimentation, and filtration, are marginally effective at reducing algal metabolite concentrations. Powdered activated carbon (PAC) is often supplemented to these processes to achieve adequate removal, though its use can be cost prohibitive over lengthy or intense algal events. Ozone + biofiltration can also be considered for algal metabolite removal, but concerns with costs, by-product formation, and process robustness also limit its applicability.

To address the limitations of existing treatment technologies, Carollo developed a biologically-based process to removal algal metabolites from drinking water, which recently patent approval from the U.S. Patent and Trademark Office (Patent No. 7,294,273). The process, called Substrate-Enhanced Microbial Oxidation of Trace Organics (SEMOTO), relies on the addition of an easily degradable primary substrate (food source) prior to treatment in a biofilter. The primary substrate increases the biological activity in the biofilter, which subsequently increases the rate of secondary substrate degradation in the biofilter (i.e., algal metabolites are degraded as secondary substrates since their environmental concentrations are very low). The algal metabolites are destroyed, thus eliminating the generation of a contaminated waste stream such as exhausted PAC. Dosing the primary substrate can also minimize bioacclimation time and enhance the robustness of the biofilter during transient system upsets. Bench-scale testing on this concept demonstrated sustained 90-percent removal of feed water MIB and geosmin concentrations, and minimal impact on feed fluctuations.

**Tachi Palace Full-Scale Biological Nitrification Facility.** Tachi Palace Hotel & Casino (Tachi) operates a 1,400-gpm filtration system treating groundwater. Originally after the treatment system was constructed, the operational goal was to use free chlorine as the residual disinfectant. With high levels of ammonia (approximately 1 mg/L-N) and low levels of total organic carbon (approximately 2 mg/L), a dose of 18 mg/L of chlorine is required to obtain a 1 to 2 mg/L residual of free chlorine. High levels of disinfection by-products (DBPs) resulted from this high-chlorine dose. Part of the process upgrades at the water treatment facility will be to reduce DBP levels by conversion of the residual disinfectant from free chlorine to chloramines. Ammonia levels will be reduced by converting the existing dual-media filters to BAF. The existing filters will require modifications to the underdrain system and potentially a new type of media.
Pilot testing was conducted to confirm the feasibility of using a biological active filter for this water supply. The pilot testing was conducted over a 3-month duration and used one of the two full-scale filter trains. Flow through the filter train was reduced to provide a 9 minute empty bed contact time (EBCT). Additionally, dissolved oxygen of the feed water was increased to 5 mg/L. The filter media was not seeded with nitrifying bacteria but used naturally occurring bacteria in the raw groundwater. It took approximately two weeks before ammonia reduction was observed across the filter. Influent ammonia levels dropped from 1.2 to 0.5 mg/L-N. The addition of phosphorus in the feed water to the biological active filter improved ammonia removal down to 0.2 mg/L-N. It is anticipated that with higher and more stable dissolved oxygen levels, more stable phosphorus levels, and improved filter medium for bacterial growth, that ammonia levels can be further reduced for this water supply.

**High-rate biofilters.** Carollo provided engineering services for the design of the new 24-mgd Appleton Water Treatment Facility (WTF), including an upgrade to biologically enhanced activated carbon (BAC) filters, which control taste and odors through adsorption and remove biodegradable organic carbon (BDOC) through biological oxidation. Water quality, treatability, and predesign studies conducted by Carollo provided a basis for the overall plant design, which includes lime softening, recarbonation, BAC with 20 minutes of EBCT, and ultrafiltration. The filters remove 1.5-2.0 mg/L of BDOC, thereby minimizing regrowth potential in the distribution system. In addition, the oxidation of organic compounds in the BAC filters produces CO₂, which reduces post-lime softening recarbonation requirements.

**Conditional DHS (now called California Department of Public Health [CDPH]) acceptance of FXB biological perchlorate treatment.** Carollo conducted a 6-month pilot study at the Castaic Lake Water Agency, Santa Clarita, CA, to evaluate the use of FXB bioreactors to treat perchlorate-contaminated groundwater and to address some of the concerns associated with the full-scale implementation of such a process. The pilot data showed that: 1) perchlorate-reducing FXB bioreactors can be acclimated using organisms indigenous to the local aquifer; 2) sustained perchlorate removal to below detection levels can be achieved using reasonable contact times and acetic acid doses in a FXB bioreactor; 3) effluent water from these processes can be biologically stable; 4) FXB bioreactors do not foster the growth of pathogenic bacteria; and 5) FXB biological perchlorate treatment is robust with respect to system upsets. Based on the results of this pilot-scale work, Carollo submitted a comprehensive FXB biological perchlorate treatment engineering report to the CDPH,
Technology Acceptance Application Program. On November 15, 2004, CDPH granted Carollo Conditional Acceptance of FXB Biological Treatment for the Production of Drinking Water from Perchlorate Contaminated Water, thereby making it possible for the first time to consider the full-scale design and implementation of FXB biological perchlorate treatment in California.

**Converting Drinking Water Residuals To Reuse: Taking Aeration Out of Oxidation.** A new process was developed that decreases aeration demand during secondary wastewater treatment. The innovative process, called the Biodestruction of Blended Residual Oxidants (BIOBROx™) (U.S. Patent No. 7,318,895), blends oxidant-laden residuals (e.g., nitrate- or perchlorate-laden membrane concentrate from drinking water processes, perchlorate waste from solid rocket manufacturing) with screened municipal wastewater followed by treatment in a FXB bioreactor. Bacteria, which grow on a GAC bed in the bioreactor, couple oxidant reduction with the oxidation of wastewater-derived organics (i.e., biochemical oxygen demand [BOD$_5$]). Total suspended solids (TSS) and turbidity are also removed across the bioreactor (which are subsequently removed from the fixed-bed periodically through backwashing), making it possible to meet Type I reuse requirements (i.e., BOD$_5$ < 10 mg/L, TSS < 5 mg/L, turbidity < 2 NTU) in a single, compact process. A 7-month pilot study at the Magna Water District (Magna, UT) demonstrated the efficacy of the process and produced the requisite design and operating criteria for full-scale treatment. Based on these design criteria, a 3.8-mgd BIOBROx™ facility was constructed at the Magna Water District in 2008, and operation of this facility began in 2009. An EDR-based drinking water treatment plant (WTP) discharges a perchlorate-laden concentrate stream to the local sewer. In the sewer line, the concentrate blends with raw municipal wastewater from the eastern portion of the Magna’s collection system and travels directly to a new headworks facility and then on to one of six FXB BIOBROx™ reactors, all of which were constructed at the existing WWTP. Raw wastewater from the western portion of Magna’s collection system is treated through the conventional wastewater treatment processes, which include oxidation ditches (with a 14-hour hydraulic residence time), secondary sedimentation, and disinfection. The BIOBROx™ train treats 1/3 to 1/2 of Magna’s total wastewater flow, uses no aeration, has an EBCT of 10 minutes, and a footprint that is 1/20 the size of the conventional secondary processes. Preliminary data show effluent that even under these conditions, BOD$_5$ and TSS levels in the effluent from the BIOBROx™ process are similar to those in the conventional secondary treatment effluent.
The project profiles on the following pages present highlights of Carollo’s key achievements in biological treatment for drinking water. These examples illustrate our ability to:

- Implement innovative technologies to improve process design and performance.
- Integrate engineering and research to achieve practical solutions tailored to specific client needs.
- Involve project participants early in the process to “demystify” advanced technology and fully understand each other’s needs.
- Offer advanced solutions that are practical, affordable, and reliable.

Upon request, we would be happy to provide client references that can attest to the quality and responsiveness of Carollo’s services.
In 1997, the Castaic Lake Water Agency detected widespread perchlorate contamination of the Saugus Aquifer, the source of which is a local explosives manufacturing facility. In addition to perchlorate, the Saugus Aquifer contains nitrate and may also be impacted by TCE and explosives such as HMX and RDX. Consequently, three local wells have been shut down, resulting in a substantial reduction in usable groundwater supply.

In an effort to restore the impaired groundwater, the Agency selected Carollo to perform a preliminary design study. At the inception of the project, Carollo developed and executed a CDPH-approved well water sampling protocol to generate a comprehensive raw water characterization. Data from this characterization were used as inputs to membrane, ion exchange (IX), and biological treatment process models that Carollo developed for perchlorate removal sensitivity analyses. These models were used to screen treatment alternatives and identify appropriate processes for bench- and pilot-scale testing. Following a process screening workshop conducted by Carollo, a 7-month bench- and pilot-testing program was initiated and completed using protocols developed by Carollo and approved by CDPH. Bench-scale testing included single-pass ion exchange and pilot testing involved fixed- and fluidized-bed bioreactors. Pilot data showed that: 1) perchlorate-reducing FXB bioreactors can be acclimated using organisms indigenous to the Saugus aquifer; 2) perchlorate can be removed to below detection using reasonable contact times and acetic acid doses; 3) effluent water from these processes is of high quality; and 4) the process is robust with respect to system upsets. Detailed process and engineering analyses indicate that FXB biological processes can ensure the delivery of perchlorate-free potable water under steady state and non-steady state operating and water quality conditions.

Based on the results of this pilot-scale work, Carollo submitted a comprehensive FXB biological perchlorate treatment engineering report to the CDPH Technology Acceptance Application Program. On November 15, 2004, CDPH granted Carollo Conditional Acceptance of FXB Biological Treatment for the Production of Drinking Water from Perchlorate Contaminated Water, thereby making it possible for the first time to consider the full-scale design and implementation of FXB biological perchlorate treatment in California.
Innovative Biological Treatment Alternatives for Residuals Containing Nitrate/Perchlorate

Recent regulatory changes prompted the need for development and evaluation of technologies used to treat perchlorate and nitrate in drinking water. Currently, the most widely used and accepted treatment technologies for removal of these contaminants involve the generation of a concentrated waste stream that must be further treated or disposed. Carollo took part in an AWWA-sponsored study to investigate innovative biological treatment alternatives for perchlorate and nitrate brine.

One portion of this study investigated the feasibility of using wastewater plant oxidation ditches to treat perchlorate residuals (i.e., residuals discharged to the sewer). A bench-scale batch reactor simulated the oxidation ditches at a wastewater treatment facility owned by Magna Water Company, UT, and wastewater from the plant was spiked with perchlorate for testing. The data showed that organisms indigenous to Magna’s plant can reduce perchlorate while using the natural organic matter present in the wastewater as substrate.

A subsequent portion of this study evaluated the use of a fixed-film reactor upstream of the oxidation ditches to treat perchlorate residuals. Wastewater from Magna’s wastewater facility was used to biologically acclimate virgin GAC in a 2-inch-diameter FXB bioreactor. Perchlorate was spiked to the feed at 1-2 mg/L using a syringe pump. Seeded only with microorganisms indigenous to the raw wastewater, the FXB bioreactors demonstrated efficient perchlorate removal while utilizing only background organics as substrate. Perchlorate removal to below detection (i.e., 4 µg/L) was achieved and sustained at empty-bed contact times as low as 30 minutes. This work demonstrated that blending concentrate streams with municipal wastewater and treating the blended stream in a dedicated bioreactors can be an effective approach for destroying concentrated oxidants.

The results of this work indicate that perchlorate-laden concentrates combined with municipal wastewater may effectively be treated using a FXB biological process.
Magna Water Company, which serves potable water to approximately 28,000 customers in the northwest section of Salt Lake County, UT, has been affected both by perchlorate and arsenic contamination in its groundwater supplies. A 6-month pilot study conducted in 1999-2000 demonstrated that in the presence of high silica and sulfate levels, electrodialysis reversal (EDR) would be the most feasible alternative for removing perchlorate and arsenic.

A substantial obstacle to the effective implementation of EDR treatment for perchlorate and arsenic removal is the need to treat and/or dispose of the associated perchlorate-laden concentrate. Bench-scale research conducted by Carollo and funded in part by the Water Research Foundation investigated the use of a suspended growth and fixed-film biological processes to destroy perchlorate that reaches the headworks of Magna’s WWTP via the disposal of perchlorate-laden concentrates to the sewer.

Pilot testing successfully demonstrated scale-up of the BIOBROx™ process, and design criteria were developed for a 3.8-Mgd BIOBROx™ facility. This facility was constructed at the Magna Water District in 2008, and operation began in 2009. An EDR-based drinking WTP discharges a perchlorate-laden concentrate stream to the local sewer. In the sewer line, the concentrate blends with raw municipal wastewater from the eastern portion of the Magna’s collection system and travels directly to a new headworks facility and then on to one of six FXB BIOBROx™ reactors, all of which were constructed at the existing WWTP. Raw wastewater from the western portion of Magna’s collection system is treated through the conventional wastewater treatment processes, which include oxidation ditches (with a 14-hour hydraulic residence time), secondary sedimentation, and disinfection. The BIOBROx™ train treats 1/3 to 1/2 of Magna’s total wastewater flow, uses no aeration, has an empty-bed contact time of 10 minutes, and has a footprint that is one-twentieth the size of the conventional secondary processes. Preliminary data show that perchlorate is removed from the process stream and that the BOD₅ and TSS levels in the effluent from the BIOBROx™ process are similar to those in the conventional secondary treatment effluent.
Direct FXB Biological Perchlorate Destruction Demonstration

Carollo was awarded a Department of Defense Environmental Security Technology Certification Program project designed to evaluate the efficacy of using FXB bioreactors to remove perchlorate from drinking water.

The project emphasizes the demonstration of sustained removal capabilities, the identification and evaluation of process limitations and potential failure scenarios, and the development of realistic designs and cost estimates for full-scale drinking water FXB biological perchlorate treatment. Post-FXB treatment, which includes aeration, second stage biofiltration, and chlorination, will also be tested.

While FXB bioreactors have been applied as a perchlorate treatment process for several years, no system has been tested at flow rates above ~2 gpm. As a result, scalability is not well understood. This project will address this issue by testing a FXB bioreactor at flow rates up to 24 gpm. Therefore, more realistic design and operating parameters will be developed, which will be used to develop facility layouts and more credible cost estimates. Additionally, process robustness and post-treatment requirements can be more fully characterized.

The major performance strengths of a FXB biological perchlorate-reducing process are as follows:

- Perchlorate is not concentrated, but rather is converted to innocuous chloride and oxygen.
- Multiple contaminants can be in a single reactor (e.g., perchlorate, nitrate, selenium, bromate, other oxidants, DBP precursors, chlorinated solvents).
- Design and operation of FXB bioreactors are not complicated; they are comparable to the design and operation of conventional granular media filters.

Estimates indicate that capital costs for applicable FXB bioreactors are substantially lower than capital costs of membrane-based perchlorate removal processes and are comparable to those associated with IX-based perchlorate removal processes. The real cost benefit of FXB biological perchlorate treatment relates to the low O&M costs.
An 8-month pilot test was initiated in May 2007 with the objective to evaluate the use of FXB biological treatment to remove nitrate from the RO by-pass water at the Arlington Desalter facility (nitrate currently limits the amount of water that can by-pass the costly RO treatment process). A second pilot test was performed from May-August 2008 to evaluate a polishing filter step to remove turbidity from the effluent of the nitrate-reducing bioreactor. Design parameters obtained during the two pilot tests are being used to develop the preliminary design for a 2.4-mgd biotreatment facility that will treat RO by-pass water at the Arlington Desalter and distribute the blend as potable water. Below is a summary of the pilot testing results.

- Using an EBCT as low as 4 minutes, an acetic acid dose of 31 mg/L as carbon, and a phosphoric acid dose of 0.15 mg/L as P, 75 mg/L of nitrate was removed to below 5 mg/L. Nitrite accumulation was not observed.

- The raw water also contained perchlorate and dibromochloropropane (DBCP). Influent and effluent perchlorate concentrations were ~6 µg/L and non-detect (<4 µg/L), respectively. Influent and effluent DBCP concentrations were 0.025 µg/L and non-detect (<0.010 µg/L), respectively.

- When bioreactor effluent was dosed with a low molecular weight cationic polymer and treated through an equalization tank and then through a sand-anthracite polishing filter, system effluent turbidities were typically ≤0.1 NTU, monitored continuously.

- *E. coli* was not detected in the feed or effluent of the FXB bioreactors.

- Nitrate removal performance was minimally impacted by various planned process disturbances, including backwashing, raw water quality fluctuations, feed flow fluctuations, system shut-downs, and acetic acid shut-downs.

The FXB biological process has key features that make it an attractive nitrate removal technology, including contaminant destruction, high efficiency, relatively low O&M costs, broad contaminant applicability (e.g., nitrate, perchlorate, VOCs), and process robustness. Pilot testing at the Arlington Desalter facility has confirmed these features of FXB biological nitrate treatment. Pertinent conditions of the CDPH FXB biological treatment technology approval letter have been addressed during these pilot studies. Design and permitting process for a ~2.4-mgd biotreatment facility at the Arlington Desalter is underway.
Tachi Palace Hotel and Casino (Tachi) operates a 1,500-gpm groundwater treatment plant on the Santa Rosa Rancheria Tachi-Yokut Reservation near Lemoore, CA. The original treatment process was a coagulation/filtration facility using free chlorine for residual. However, elevated DBP (TTHM 120 to 180 µg/L) prompted Tachi to evaluate upgrade options. Groundwater quality in the area is characterized by high ammonia (1.2 mg/L), hydrogen sulfide (1.5 mg/L), and methane (16 mg/L). Total organic carbon is relatively low (2.0 mg/L). However, 18 mg/L of chlorine is required to obtain a residual of 1 mg/L free chlorine.

Several alternatives were evaluated at the desktop and pilot-scale level included air injection (Mazzei injector), ozone oxidation, air stripping, biological filtration, and combinations thereof. Air stripping followed by biological filtration and chloramination were the lowest cost alternative. Bench-scale testing confirmed that the use of chloramines produced 16 µg/L TTHMs (48-hour contact time) when a total chlorine residual of 2.0 mg/L was targeted.

A new air stripper tower and scrubber were designed for 1,500 gpm of capacity with tie-ins and space set aside for a second train in the future. The existing gravity filters will be converted to biological filters. This includes a redesign of the underdrain and air scour system. New chemical systems include sulfuric acid, caustic soda, sodium hypochlorite, sodium bisulfite, aqueous ammonia, and phosphoric acid. Part of the new chemical systems will be housed in a new pre-engineered metal building. The remaining chemicals will be located in the existing Filter Building. A new auxiliary building will be constructed and serve as a main office, new analytical laboratory, and maintenance shop.

Additional work related to process upgrades include installation of baffles in one of the existing finished water tanks, approximately 4,000-linear feet of various utility relocation for sanitary sewer, storm drain and water lines, and SCADA screen programming. Construction cost is estimated at $3.5 million.
The City of Arlington, TX, is faced with both operational and water quality complications at their John Kubala and Pierce-Burch water treatment facilities. Both facilities installed ozone and biofiltration in 1999 primarily to help remove taste and odor (i.e., MIB and geosmin), iron and manganese, and turbidity, and to minimize disinfection by-product formation. While the ozone/biofiltration systems performed well for many years, recently observed performance disruptions and the detection of endocrine disrupting compounds (EDCs) require that the City of Arlington evaluate their ozone/biofiltration systems to identify potential modifications to enhance process performance.

This project focused on methods for enhancing the performance of standard biofiltration processes through improving the health of biological activity. Biofilter feed water at typical water treatment facilities has non-detectable amounts of phosphorus due to general source water limitation and removal through coagulation. As phosphorus is an essential nutrient for biological growth and health, its limitation may be detrimental to biofilter operation. Low concentrations of phosphoric acid were dosed to a pilot-scale biological filter to satisfy critical ratios of carbon to phosphorus for healthy microbial activity. This work showed that phosphorus supplementation greatly enhances biological filter hydraulic and water treatment performance. Observed benefits included longer filter run times and improved MIB, manganese, and dissolved organic carbon removal.

The primary goal of this work was to establish the groundwork for moving biofiltration from a passive process designed and operated around conventional filtration objectives to an intentionally operated biological system, i.e. “engineered biofiltration.” Engineered biofiltration targets multiple water quality objectives while maintaining or even improving hydraulic performance.
Carollo is currently leading the Dallas Water Utilities (DWU) and Tampa Bay Water cosponsored Water Research Foundation Tailored Collaboration (TC) Project 4346, *Optimizing Engineered Biofiltration* (scheduled completion on Fall 2014). This project provides essential follow-up studies to Water Research Foundation TC #4215, *Engineered Biofiltration for Enhanced Hydraulic and Water Treatment Performance*, which identified two strategies that provided multiple water quality and hydraulic benefits with minor implementation requirements: 1) nutrient enhanced biofiltration, and 2) peroxide enhanced biofiltration. This project seeks to further validate, optimize, and explore these and other strategies for enhanced biofiltration to yield sustained and robust attainment of a wide range of utility performance goals. This project will also provide valuable information on the studied enhancement strategies for water sources, different to those used by the sponsor utility for TC #4215 (City of Arlington, TX).

This work will investigate process fundamentals (e.g., microbial ecology, bacterial metabolism, and contaminant removal mechanisms) to understand how:

- TOC, T&O, EDCs, and manganese can be more efficiently removed in a single treatment step.
- Biological clogging can be minimized.
- Process efficiency can be increased.
- Overall process robustness can be improved.

The approach will include 14 months of pilot-scale testing to evaluate ozone/biofiltration enhancement strategies. Testing phases for enhancement strategies will include refinement of operating protocol, sustained performance validation, trace organic loading variation, and process robustness evaluation. Microbial tracking will be performed throughout the project to gain a better understanding of the microorganisms present in biofilters, as the type of populations present will affect hydraulics and process performance.

Results will include optimal operating parameters that can be implemented at full-scale water facilities for enhanced ozone/biofiltration performance. The proposed research would benefit the water industry by augmenting the existing body of knowledge pertaining to biological drinking water treatment.
A University of Michigan/Carollo Team was recently awarded a Water Research Foundation unsolicited project to develop and optimize a bench-scale, FXB bioreactor process that simultaneously removes nitrate and arsenic from drinking water.

Nitrate and arsenic frequently coexist in groundwater and are regulated at 10 mg/L NO₃⁻N and 10 µg/L As, respectively. RO and ion exchange can remove these contaminants simultaneously, but produce a concentrated waste stream that requires additional treatment. Furthermore, processes relying on the adsorption of arsenic to ferric/aluminum hydroxides, although effective, can result in the reductive remobilization of arsenic from exhausted media under the reducing conditions that commonly exist in landfills. In contrast, the proposed biological process would reduce nitrate to N₂ gas and sequester arsenic on biogenic iron sulfides that should be stable within the reducing environment of a landfill.

This project will evaluate the impact of EBCT and characterize the robustness of the process with respect to backwashing episodes and periods of system shutdown. Additionally, reactor performance will be correlated to microbial community structure and activity determined by clone library analyses and quantitative polymerase chain reaction (qPCR) targeting 16S ribosomal RNA and functional genes. X-ray diffraction will be used to identify solids formed across the process. The stability of those solids will be characterized using anaerobic batch reactors to simulate landfill deposition.

It is anticipated that this biological process will provide an efficient method for removing nitrate and arsenic from drinking water while eliminating the re-release of either compound back into the open environment.
Mesa Consolidated Water District selected Carollo to prepare design/build plans and specifications for a new treatment facility to remove natural color from groundwater. Carollo prepared a design/build request for proposals package to approximately the 30-percent design level. Carollo also prepared a bidding requirements package specific to the project, which included the contractual forms such as the agreement and the customized design/build conditions of contract.

The facility’s major treatment process is ozonation followed by BAF utilizing GAC contactors. The BAF approach was selected for its enhanced ability to remove natural color and other organic compounds from the plant’s groundwater source. Biological filtration is carried out in GAC contactors constructed in ten 12-foot-diameter steel pressure vessels.

The new ozone facilities include an installed capacity of 3,000 lb/day utilizing liquid oxygen (LOX) from an onsite 13,000-gallon LOX storage tank and three ambient vaporizers. Ozone is generated a concentration of 10 percent by weight and contacted with the colored groundwater using vacuum injectors.

BAF was selected for its enhanced ability to remove natural color and other organic compounds from the plant’s groundwater source.
Ozonation Facilities at the Pierce-Burch and Kubala Water Treatment Plants

Carollo, in association with others, completed the design of pre-ozonation and intermediate ozonation facilities and filtration improvements for two WTPs for the City of Arlington. The design team used computational fluid dynamics (CFD) models to optimize the ozone contactor design. The ozonation improvements include 3,000 pounds per day at the 68-mgd Pierce-Burch WTP and 3,000 pounds per day generation capacity at the 65-mgd John F. Kubala WTP. The design provides for both pre-ozonation and intermediate ozonation contactors at each plant to obtain the maximum benefits for microfloculation and disinfection.

Filter improvements involved upgrading the existing underdrains to Leopold Type III with air-scour and replacing the filter media with GAC over sand. The GAC material is utilized as a support structure to facilitate biological growth for organic material reduction through BAF. These improvements were the result of a year-long treatability study conducted by Carollo, in association with others, to determine Arlington’s best course to comply with impending regulations and address taste and odor problems occurring during the warmer months.

The study concluded that two-stage ozone with GAC/sand filters was the most cost-effective method of meeting Arlington’s water quality goals of eliminating taste and odor problems, reducing trihalomethanes to less than 40 µg/L and providing another barrier against potential Cryptosporidium contamination.

In Fall 2010, Carollo completed a second expansion project at the John Kubala WTP (Expansion II). This project involved hydraulic expansion from 65 mgd to 97.5 mgd through the addition of basins, biological filters, high-service pumps and ozone generation and contacting facilities. The project also included hydraulic adjustments to allow an ultimate flow capacity of 130 mgd at the John Kubala WTP site.
Greenway Water Treatment Plant

Carollo completed the site master plan and design for the City of Peoria’s new 16-mgd WTP. Phase-I of the Greenway Water Treatment Plan design included a 5-million-gallon storage reservoir, a finished water pump station, and treatment processes that utilize conventional treatment combined with ozonation and BAF.

The conventional treatment process utilizes chemical addition, rapid-flash mixing, pre- and final sedimentation, and flocculation. Ozone is used as the primary disinfectant with chlorine added as a secondary disinfectant.

The settled water from the final sedimentation basins passes through BAF filters, designed with GAC and sand media. The BAF filter consists of 60 inches of Calgon F820 GAC overlaid on 12 inches of sand, with loading-rates to the filter designed at 5-gpm/ft² filter bed. A Leopold Type-S air scour underdrain is utilized to support the filter bed media.

Coupled with ozone treatment, BAF filters have demonstrated their effectiveness in minimizing objectionable T&O of the finished water, as well as reducing organic contaminants, resulting in reduction of chlorine demand and precursors to DBPs. Designed at a time when new Federal and State water quality regulations were being promulgated, this plant represents the state-of-the-art for conventional treatment techniques that meet the future regulations in the most cost effective manner.

The Greenway WTP satisfies many significant and statewide goals, such as meeting regulatory requirements, decreasing dependence on groundwater, and utilizing more surface water.
Fleming Hill Water Treatment Plant Expansion

Carollo completed a comprehensive plant evaluation that identified the necessary upgrades and expansion for the City of Vallejo Fleming Hill WTP. Upgrades were needed for improved control of water quality to meet stringent new drinking water regulations and to improve plant reliability. Vallejo retained Carollo to design process upgrades to bring the plant capacity from 27 to 42 mgd.

Major treatment plant features and facilities included in the design were:

- Horizontal turbine, three-stage flocculation and improved sedimentation.
- Pre- and intermediate ozonation.
- Upgraded and new filters utilizing dual GAC/sand media.
- Chlorine scrubber system and chlorine gas facilities

The design included ozonation upstream of the GAC filters to promote BAF. Utilizing a BAF approach has been shown effective in reducing levels of organic compounds, including precursors to DBP, lowering the chlorine demand later in the disinfection process, and aiding in meeting stringent new drinking water regulations.

Carollo designed the upgrades as well as the new process to fit within the existing constrained residential site. When the construction phase was nearing completion, the Carollo team conducted training sessions for the plant operators so that they would be brought up to speed and feel confident about operating the new facilities.

Carollo successfully delivered the $35-million Fleming Hill WTP in a residential neighborhood without interruption of Vallejo’s water supply.
Carollo conducted a pilot study for Metropolitan Water District of Salt Lake and Sandy, which evaluated several potential treatment trains for the new 70-mgd Point of the Mountain WTP.

Three potential treatment trains for the WTP were evaluated as follows:

- Treatment Train No. 1 – low pressure membrane filtration with conventional pretreatment.
- Treatment Train No. 2 – low pressure membrane filtration and granular activated carbon adsorption with presedimentation.
- Treatment Train No. 3 – ozonation, BAF with GAC, and UV disinfection with conventional pretreatment.

The study set finished water quality goals for 3-Log removal of Cryptosporidium and Giardia, trihalomethanes (THMs) of less than 40 µg/L, and haloacetic acids (HAA-5) of less than 30 µg/L.

Evaluations for cost effectiveness determined a process train utilizing biologically activated GAC filtration would meet the targeted finished water quality goals and provide an economically competitive option. Further bench- and pilot-scale evaluations revealed the GAC media was far superior at removal of TOC and effective for neutralizing T&O problems in the finished water.

Based on the bench testing results, the POMWTP was designed and constructed with the capability to fully manage biological filtration. Intermediate ozonation upstream of the filters enhances biological growth in the filters by increasing the assimilable organic carbon. The plant also has the ability to promote growth by operating the filters without chlorine and by backwashing with chlorine free water. It has the ability to control growth by adding chlorine on top of the filters, by backwashing with typical chlorinated potable water, and by backwashing with superchlorinated water.
Gilbert Water Treatment Plant

Carollo provided conceptual design, detailed design, and construction administration services for the Town of Gilbert’s WTP expansion project. The facility is designed to treat surface water from the Salt River Project Eastern Canal with an upgraded production capacity of 40 mgd.

In addition to capacity expansion, Carollo’s design incorporated the addition of ozone oxidation and the upgrade to dual media filters with BAF utilizing GAC. The Gilbert WTP is one of two facilities in the State of Arizona to employ a ‘state-of-the-art’ BAF process to meet recently revised and more stringent water quality regulations.

The BAF filter design included 40 inches of Norit GAC on 8 inches of sand media with a Leopold Type-S underdrain with air scour for support of the filter media. The use of ozonation and a BAF GAC filter design is fast becoming the new conventional treatment process for drinking water plants due its enhanced ability to meet increasingly tighter regulatory standards and cost effectiveness. The Gilbert WTP expansion was awarded the 2003 ACEC of Arizona Engineering Excellence Grand Award.
As part of the $8.4-billion Comprehensive Everglades Restoration Program, the U.S. Army Corps of Engineers and South Florida Water Managements District selected Carollo to perform the first pilot testing and engineering analysis of water treatment technologies on Lake Okeechobee. The study evaluated alternatives for treating Lake Okeechobee water prior to injection in aquifer storage and recovery (ASR) wells. The goal of the study was to demonstrate compliance with the federal primary drinking water standards. The selected treatment train consisted of bank filtration (BF) in conjunction with ozonation and UV disinfection.

BF, which partially relies on the biological degradation process, has been widely utilized as a drinking water treatment process for over 100 years, particularly in Europe. The study confirmed the ability of bank filtration to address microbial, TOC, color, T&O, and turbidity goals cost effectively; furthermore, BF provides for a robust treatment of variable raw water quality on a wide range of parameters without imparting residuals or a requirement for the addition of a chemical coagulant.

Ozonation provided additional treatment for microbial and organic contaminants and substantially increased UV transmittance of the water, thereby reducing the capital and operation costs of the UV disinfection process.

Bank filtration treatment combined with ozonation/UV disinfection provides multiple barriers to target water quality impairments. Key attributes of the BF/ozonation/UV treatment train include:

- No waste stream disposal.
- Minimal chemical delivery requirements.
- Low operational and maintenance costs.
- Primary drinking water standards met.
Carollo provided design and construction services for an expansion and upgrade for the Weber Basin Water Conservancy District (WBWCD), Davis North WTP increasing the plant capacity from 26 to 46 mgd.

The design includes new conventional flocculation and sedimentation basins, pre- and intermediate ozonation, and ultraviolet disinfection. The design configuration provides ozonation upstream of granular media filtration to promote additional biological removal of organic compounds within the filter bed. The BAF approach promotes the reduction in total organic carbon and is an effective control scheme for odor and taste in the finished water.

An evaluation of disinfection and taste and odor control strategies showed the synergistic combination of ozone and UV disinfection resulted in a facility cost reduction of approximately 50 percent compared with the next lowest cost alternative.
PILOT/DEMO SCALE

25-gpm FXB Bioreactor Pilot

Carollo owns a 25-gpm FXB bioreactor pilot system. The skid, which is contained in a 40-feet x 8-feet x 8-feet trailer, includes three 24-inch diameter pressure vessels that are 8-feet tall and constructed from epoxy-coated steel. Effluent from the bioreactor can travel directly to the biofilter or to an interstage aeration/degasification column ahead of the biofilter. Effluent from the biofilter will be pumped into a backwash tank (two cylindrical 500-gallon polyethylene tanks) and then a chlorine contact tank (one cylindrical, 500-gallon polyethylene tank). A process flow diagram for the bioreactor pilot is provided below. A 3D model of the pilot is presented on the next page.

The skid is also equipped with automatic backwash capabilities, chemical dosing systems for electron donor, hydrogen peroxide, polymer, and chlorine addition, and in-line monitoring and data logging for flow rates, headloss, dissolved oxygen, and nitrate. The trailer houses a Dionex 800 ion chromatograph, which can be used to analyze grab samples for perchlorate. In addition to feed and effluent sample ports, all pressure vessels include depth-wise sample ports that will allow for the simultaneous evaluation of several empty-bed contact times. These sample ports protrude 3 inches into the bed to ensure that representative samples are taken (i.e., eliminate wall effects). Six 3-inch x 12-inch windows run the length of each
pressure vessel that enable the operator to view the media bed during production and backwash. The skid includes a touch screen human-machine interface to monitor and control pilot operations. It can also be connected to the Internet, so that pilot operations can be monitored and data downloaded from remote locations.

### 6-gpm FXB Bioreactor Pilot

Carollo owns a second FXB bioreactor pilot system. This skid contains three 12-inch columns that are 10-feet tall and are operated in series at between 2 and 6 gpm (2.5-7.6 gpm/ft²). The first column serves as the FXB bioreactor; the second column is an open basin, which can be used for flocculation or degasification; the third column served as the polishing filter. Effluent from the bioreactor could also be routed to bypass the flocculation/degasification column (i.e., direct filtration mode). The skid is equipped with automatic backwash capabilities, chemical feed systems for electron donor, nutrient, and nitrate/perchlorate dosing, and on-line monitoring and data logging for monitoring flow rates, head loss, dissolved oxygen (DO) concentrations, and nitrate concentrations. The pilot skid is also equipped with a data acquisition and control (DAC) system, which stores and manages data. The DAC continuously logged date/time, flow, headloss, DO concentration, nitrate concentration, and turbidity. The skid includes a touch screen human-machine interface to monitor and control pilot operations. It was also connected to the Internet so that pilot operations could be monitored and data downloaded remotely.

### 2-gpm Engineering Biofiltration Pilot

Carollo owns a third bioreactor pilot skid, which is designed to evaluate the implementation of engineered biofiltration concepts at surface water treatment plants. This skid contains four 6-inch columns that are 10-feet tall and operated in parallel between 0.5 and 2.0 gpm (2.6 – 10.2 gpm/ft²). Each column is equipped with two chemical dosing ports, multiple ports for aqueous and media sampling along the depth of the media bed, pressure gauges to measure headloss along the length of the bed and across the underdrain. The skid is fully automated (including backwash), and includes online monitoring and data logging for flow rates, headloss, chemical dosing rates, and turbidity. The skid is also equipped with a DAC system, which stores and manages data. The skid includes a touch screen human-machine interface to monitor and control pilot operations. It is also accessible remotely through the Internet.
BENCH SCALE

Our bench-scale testing capabilities are tailored to our clients’ needs for cost-effective, on-site evaluation and optimization of treatment processes. We use innovative bench-scale tools developed to minimize time-consuming and expensive pilot studies.

Fixed-Bed Bioreactor

Carollo maintains a bench-scale, continuous-flow, FXB reactor that can be operated aerobically or anaerobically to evaluate the biological removal of organics or inorganics. The 2-inch inner diameter glass pipe is capped with threaded Teflon® endcaps. Feed water is pumped from a 10-gallon Teflon® influent reservoir to the bioreactor through Norprene® tubing using a peristaltic pump. A floating cover was constructed, which is placed inside the reservoir to minimize oxygen diffusion into the influent for anoxic/anaerobic testing. The bench-scale FXB bioreactor can be operated independently or can be integrated with the bench-scale ozone testing unit to evaluate ozone plus biological filtration treatment.

Continuous Flow Bench-Scale Ozone Testing

The information required to develop design criteria for ozone facilities includes: ozone demand, ozone decay, and screening of ozone application points. Traditionally, this information has been developed using pilot-scale facilities, semi-batch bench-scale testing units, or modeling techniques. The major drawbacks of ozonation pilot studies include the tendency to overestimate the hydraulic efficiency and the high cost and time commitment required to mobilize the equipment. Semi-batch reactors and the use of mathematical models do not provide sufficiently reliable data for extrapolation to full-scale design. To address these drawbacks, Carollo has developed a continuous-flow bench-scale ozone testing unit which combines the reliability of pilot-scale testing and cost-effectiveness of bench-scale methods.

Carollo’s bench-scale unit consists of a six-stage ozone contactor with three chambers operating in counter-current flow for ozone transfer and three chambers operating without gas transfer for ozone contacting. The volume of each chamber available for ozone contacting is adjustable to achieve detention times ranging from 3 to 40 minutes. The ozone concentration in the feed gas is monitored by an UV light absorption spectrophotometer. Ozone residuals in the liquid phase are analyzed by collecting grab samples at the effluent of each of the columns.
System Hydraulics

In order to ensure the applicability of the results, we have designed this system so that the hydraulics are characterized with a $T_{10}/T$ ratio of 0.6 to 0.7. This hydraulic behavior is modeled by seven to nine completely stirred tank reactors (CSTR) in series, corresponding to Peclet numbers of 12 to 16, respectively. This hydraulic characteristic is maintained in Carollo’s pilot-scale ozone systems.

Ease of Mobilization

The ozone system resides in a shipping container for easy transport to various sites for ozone testing. Associated equipment includes ozone contactors, rotameters for measuring liquid and gas flow rates, valves and tubing, and sample taps. This unit also includes a 0.08 lb/day ozone generator. Other equipment required to perform ozone evaluations, such as a feed water pump, UV spectrophotometer, and ozone residual measurement kit, is shipped with the system.

Mobilization and testing can begin within a half-day of arrival on-site. Only a small sample volume (approximately 5 gallons) is required to develop key design data such as ozone demand and decay relationships, by-product formation, and ozone quenching alternatives.
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<th>Name/Education/Years of Experience</th>
<th>Representative Experience</th>
<th>Expertise</th>
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</table>
| Jess Brown, Ph.D., P.E.           | - Project engineer for a pilot-scale evaluation of biological perchlorate removal from the Saugus Aquifer (Santa Clarita, CA). Authored the associated FXB biological perchlorate treatment engineering report for CDPH. As a result of this report, Carollo Engineers received the Conditional Acceptance of FXB Biological Treatment for the Production of Drinking Water from Nitrate- and Perchlorate-Contaminated Water.                      | • Advanced Water Treatment  
• Water Chemistry  
• Biofiltration  
• Anoxic/Anaerobic Biological Treatment  
• Molecular and Culture-Based Microbial Ecology |
| BA Environmental Science & Public Policy, BS Civil Engineering, MS Environmental Engineering, PhD Environmental Engineering 13 Years of Experience | - Developed and patented the BIOBROx™ process for biologically treating oxidant-laden concentrate streams (U.S. Patent No. 7,318,895). Project manager for a pilot-scale USEPA project designed to develop design criteria for a full-scale BIOBROx™ treatment facility. Process engineer for the design and construction of a 3.8-mgd BIOBROx™ facility treating perchlorate-laden EDR concentration (Magna, UT).  
- Developed and patented the SEMOTO process for biologically treating trace organic contaminants (U.S. Patent No. 7,294,273). Project manager for a 6-month bench-scale study evaluating SEMOTO to remove MIB and geosmin from surface water in Manatee County, FL. This process is now being pilot tested.  
- Co-principal investigator for Water Research Foundation Tailored Collaboration Project 4215, Engineered Biofiltration for Enhanced Hydraulic and Water Treatment Performance. Performed in collaboration with the City of Arlington, TX, the 8-month pilot study focused on identifying methods for enhancing conventional biofiltration performance by focusing on microbial health. The primary goal was to establish a basis for moving biofiltration from a passive process designed and operated only around conventional filtration objectives to an intentionally operated biological process (i.e., “engineered biofiltration”).  
- Project manager for a 5-month pilot study evaluating the application of FXB biological treatment for the removal of nitrate from RO bypass water at the Western Municipal Water District’s (WMWD’s) Arlington Desalter Facility. Specific pilot testing objectives include the demonstration of sustained nitrate removal capabilities, the identification and evaluation of process limitations and potential failure scenarios, and the development of design and operating parameters for full-scale implementation of FXB bioreactors at the Arlington Desalter Facility.  
- Process engineer for the design of the biodenitrification process + post-treatment as part of the Arlington Desalter Facility expansion (Riverside, CA). Working with the CDPH as part of this work to secure permitting for this facility, which would be the only operating potable biodenitrification facility in the U.S. It would also be the first potable, centralized biodenitrification facility in the U.S.  
- Project manager for a Department of Defense Environmental Security Technology Certification Program project designed to evaluate the efficacy of using FXB bioreactors to remove perchlorate from drinking water. The objective of this work was to evaluate the efficacy of using FXB bioreactors to remove perchlorate from drinking water. Specific project emphases include the demonstration of sustained removal capabilities, the identification and evaluation of process limitations and potential failure scenarios, and the development of realistic designs and cost estimates for full-scale drinking water FXB biological perchlorate treatment. |
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<tr>
<td>Patrick Carlson, P.E.</td>
<td>• Assistant project engineer for a FXB biological nitrate removal pilot study for WMWD in Riverside, CA. The pilot study was performed to determine the design requirements for granular-media polishing filters which will be located downstream of the biological denitrification vessels. The pilot study found that in order to achieve the finished water quality goals degassing of the biologically treated water is required prior to polishing filtration. &lt;br&gt;• Process engineer for the preliminary design and site master plan for WMWD, CA, Arlington Desalter Expansion. Process design included biological nitrate removal, polishing filters, and RO concentrate reduction using pellet softeners.</td>
<td>• Granular Media Filtration&lt;br&gt;• Membrane Filtration&lt;br&gt;• Pilot Testing</td>
</tr>
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<td>Gil Crozes, Ph.D.</td>
<td>• Partner-in-charge for the WTP Upgrade for the Tachi Palace Hotel and Casino, CA. This project involves process evaluation (desktop, bench- and pilot-scale), design, and construction management. The original 1,500-gpm dual-media filtration plant had difficulty meeting DBP requirements. The new facility will use a biological filter to remove ammonia to levels that will then be chlorinated to form chloramines. &lt;br&gt;• Project manager for a year-long pilot study to determine the treatment process and design criteria for a new 70-mgd plant for the Metropolitan Water District of Salt Lake and Sandy, UT. For this project, three treatment trains were tested side by side. The third train involved conventional treatment, ozone, biological filtration, and UV. &lt;br&gt;• Project manager for the predesign studies of a 42-mgd WTP retrofit for the Weber Basin Conservancy Water District (WBCWD), UT. This project involved integrated use of ozone, biologically active filtration and UV. &lt;br&gt;• Responsible for all the testing leading to process decisions as part of the Appleton, WI, 24-mgd project. Conducted a bench-scale study to evaluate enhanced softening, ozone and activated carbon. &lt;br&gt;• Project manager for a Water Research Foundation Project, Evaluating Biological Regrowth in Distribution Systems. The project reviewed all factors affecting microbial regrowth in the distribution system and proposed actions for control of regrowth. Special emphasis was given to the various methods available to measure regrowth potential, including measurement of assimilable organic carbon (AOC) and BDOC.</td>
<td>• Water Chemistry&lt;br&gt;• Groundwater Treatment&lt;br&gt;• Membrane Processes&lt;br&gt;• Project Management</td>
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<td>Jason Davis, P.E.</td>
<td>• Project engineer for the WTP Upgrade for the Tachi Palace Hotel and Casino, CA. This project involves process evaluation (desktop-, bench- and pilot-scale), design, and construction management. The original 1,500-gpm dual-media filtration plant had difficulty meeting DBP requirements. The new facility will use a biological filter to remove ammonia to levels that will then be chlorinated to form chloramines. &lt;br&gt;• Project engineer for the West Valley Water District, CA, Feasibility Review for FXB Integration. Conducted technical review to determine the feasibility of installing a FXB bioreactor adjacent to an upflow bioreactor process.</td>
<td>• Groundwater Treatment&lt;br&gt;• Pressure Vessels</td>
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| **Tom Gillogly, Ph.D., P.E.** | • Technical advisor for the WTP Upgrade for the Tachi Palace Hotel and Casino, CA. This project involves process evaluation (desktop, bench- and pilot-scale), design, and construction management. The original 1,500-gpm dual-media filtration plant had difficulty meeting DBP requirements. The new facility will use a biological filter to remove ammonia to levels that will then be chlorinated to form chloramines. <br>• Project engineer or technical advisor for three water quality improvements programs: Sweetwater Authority’s 30-mgd Robert Perdue WTP, CA; Antelope Valley East Kern Water Agency’s 65-mgd Quartz Hill WTP, CA; Elsinore Valley Municipal Water District’s 9-mgd Canyon Lake WTP. Programs included pilot-scale testing of biologically active filtration (multi-media support) following intermediate ozonation to evaluate filter performance and impact on subsequent formation of chlorination DBP. | • Advanced Water Treatment  
• Disinfectants and Disinfection By-Products  
• Inorganic Contaminants  
• Bench- and Pilot-Scale Testing  
• Regulatory Compliance |
| **Ron Joost, P.E.** | • Partner-in-charge for Water Research Foundation Tailored Collaboration Project 4215, *Engineered Biofiltration for Enhanced Hydraulic and Water Treatment Performance*. Performed in collaboration with the City of Arlington, TX, the 8-month pilot study focused on identifying methods for enhancing conventional biofiltration performance by focusing on microbial health. The primary goal was to establish a basis for moving biofiltration from a passive process designed and operated only around conventional filtration objectives to an intentionally operated biological process (i.e., “engineered biofiltration”).  
• Partner-in-charge for the addition of ozonation facilities at the City of Fort Worth’s Holly WTP complex, TX. This project involved 9,750 lb/day of new ozonation capacity and the conversion to biologically-active filters.  
• Technical advisor for the planning and design of the 16-mgd (expandable to 32 mgd) Greenway WTP Phase 1, City of Peoria, AZ. This facility is the City’s first WTP. Phase 1 utilizes conventional treatment processes in combination with ozonation and biologically active filtration to address taste and odor.  
• Project manager for wastewater treatment plant modifications, City of Arlington, TX. Project involved the incorporation of ozone generating and contacting facilities at the Pierce-Burch and John Kubala WTPs. The filters at both plants were retrofitted with granular-activated carbon media and air scour capability to facilitate biological activity and the associated removal of organic material. Ron was also the partner-in-charge for two subsequent expansions (each 32.5 mgd) of the John Kubala WTP. These expansions involved additional ozonation capacity and new biologically-active filters.  
• Partner-in-charge/project manager for the preliminary design and final design of new ozonation generation and contacting facilities for the Metropolitan Water District of Southern California’s 520-mgd Weymouth Filtration Plant, CA. MWD plans to relocate the initial chlorination point downstream of the existing filters to facilitate biological activity. | • Project Management  
• Advanced Water Treatment  
• Water Quality Enhancement |
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<tr>
<td><strong>Graham Juby, Ph.D., P.E.</strong>&lt;br&gt;BS Chemical Engineering/ Biomedical Engineering/ Water Utilization Engineering, PhD Engineering&lt;br&gt;28 Years of Experience</td>
<td>• Project engineer for the City of Corona, CA, preparation of 30-percent design for a design/build membrane bioreactor process (Zenon) for 1-mgd Phase 1 of a new wastewater treatment plant.&lt;br&gt;• Process engineer for the City of Redlands, CA, 6.6-mgd Recycled Water Treatment Facility (WTF). The Treatment Alternative Feasibility Study evaluated granular media filtration versus membrane filtration. The process selected was membrane filtration. The plant was designed such that part of the aeration capacity would continue to operate in a conventional activated sludge mode, while the remainder operates in a membrane bioreactor (MBR) mode.&lt;br&gt;• Project manager for the evaluation of MBR technology as an alternative for expanding the capacity of Plant 3A for the South Orange County Wastewater Authority, CA.&lt;br&gt;• Partner-in-charge for the Colored Water Technology Replacement and Expansion Project for the Mesa Consolidated Water District, CA. The District decided to replace the existing ozone/BAC treatment approach with NF technology to allow them to treat higher colored water from lower in the groundwater basin and increase the treatment plant capacity at the same time.&lt;br&gt;• Project manager for the review of bid documentation for the 5.9-mgd Carson Regional Water Recycling Plant for the West Basin Municipal Water District, CA. The project objective was the production of high-quality water for industrial use from Title 22 feed water. The treatment configuration selected was microfiltration followed by reverse osmosis for TDS reduction. Biological nitrification was selected for treating the microfiltration reject stream.&lt;br&gt;• Partner-in-charge for the Treatment of Perchlorate in Contaminated Groundwater project for the Castaic Lake Water Agency, CA. Alternatives evaluated included biological treatment, ion-exchange, and high-pressure membranes to treat perchlorate, as well as a number of other explosive contaminants in the groundwater basin.&lt;br&gt;• Partner-in-charge for a Department of Defense Environmental Security Technology Certification Program project designed to evaluate the efficacy of using FXB bioreactors to remove perchlorate from drinking water.</td>
<td>• Water Treatment Design&lt;br&gt;• Project Management&lt;br&gt;• Residual Management</td>
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<td><strong>Tim Karlstrand</strong>&lt;br&gt;BA Molecular and Cellular Biology, MS Civil Engineering&lt;br&gt;13 Years of Experience</td>
<td>• Thesis work on the bio-reduction of toxic selenium compounds to non-toxic forms using microbes and plants, both in the laboratory and in-situ, using constructed wetlands at Chevron's Richmond Oil Refinery in California. Work included volatilization experiments to determine selenate and selenite bio-reduction rates, biochemical analysis of the breakdown pathway, molecular amplification of the genes responsible for the breakdown, and DNA sequencing of the genes involved.&lt;br&gt;• Engineer responsible for the Design/Build procurement of the $35-million Mountain House WTP Expansion. The new 15-mgd WTP for this master planned community consists of improvements to the raw water pump station, new flocculation/sedimentation basins, new GAC filters, new UV disinfection, new low lift pump station, and new above-ground filter backwash/sludge drying beds.&lt;br&gt;• Construction project engineer responsible for the Petaluma Water Recycling Facility In Petaluma, CA. This 42-month, $110-million project included a new headworks facility, two orbal-type oxidation ditches with biological nutrient removal capabilities and a bio-solids facility, among other elements.&lt;br&gt;• Construction project engineer responsible for the Modesto Tertiary WWTP. This $24-million project included a high-rate carousel-type oxidation ditch with biological nutrient removal capabilities and the installation of ultra-filtration membrane bioreactor system, among other elements.</td>
<td>• Biological Transformation&lt;br&gt;• Microbiology/ Molecular Biology Techniques&lt;br&gt;• Design/Build Management&lt;br&gt;• Construction Management</td>
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  - Project manager and co-principal investigator of Water Research Foundation Tailored Collaboration project 4346, *Optimizing Engineered Biofiltration*. Project focuses on optimizing nutrient and enzyme enhancement strategies for drinking water biofiltration. Project partnership includes Carollo, City of Dallas, Tampa Bay Water Authority, City of Arlington, University of Michigan, and the Water Research Foundation.  
  - Project engineer for a Department of Defense Environmental Security Technology Certification Program project designed to evaluate the efficacy of using FXB bioreactors to remove perchlorate from drinking water.  
  - Co-developed the patented SEMOTO process. The SEMOTO process is a novel approach to treat trace organic contaminants present in drinking water. Exogenous substrate is added to a biological fixed bed reactor to enhance microbial metabolism and the degradation of trace organics as secondary substrates. No pre-ozonation is required and contact times are minimal, making the SEMOTO process a low-cost treatment option. | - Water Analysis  
  - Biological Transformation                                                                                           |
| Matthew Marshall, P.E.            | - Project manager for a FXB biological nitrate removal pilot study for WMWD in Riverside, CA. The pilot study was performed to determine the design requirements for granular-media polishing filters which will be located downstream of the biological denitrification vessels. The pilot study found that in order to achieve the finished water quality goals degassing of the biologically treated water is required prior to polishing filtration.  
  - Project manager for the expansion of WTP No. 3 from 26 to 46 mgd for the WBWCD, UT. The expansion included a new chemical feed building and inlet structure, flocculation and sedimentation basins, biologically active filters, ozone (for taste and odor control), and UV disinfection.  
  - Project engineer for design of the treatment processes at the Appleton WTF in Appleton, WI. The new plant includes pretreatment contact basins for powdered activated carbon addition, lime softening, GAC contactors, membrane filtration, and high service pumping. | - Project Design  
  - Construction Management                                                                                             |
| Adam Zacheis, Ph.D., P.E.         | - Research engineer for the Mesa Consolidated Water District, CA, Colored WTF. Assessed BAC filter performance and testing of treatment system for corrective measures. Duties included the testing analysis of BAC filter beds through coring tests. Analysis consisted of biomass quantification, effective size classification, backwash turbidity profiling, and media washing.  
  - Project engineer for corrective work at the Mesa Consolidated Water District, CA, Colored WTF. Corrective work was based on field-testing results. Duties included the design of new backwash treatment system using cloth media technology and selection of a new BAC filter underdrain system. Supervised the retrofit of BAC filter underdrains and the construction of a new backwash treatment facility. | - Biological Processes  
  - Pilot Plant Research  
  - Design of Membrane Water Treatment Plants  
  - Advanced Oxidation Technologies                                                                                       |
SELECT BIOLOGICAL PROCESSES PUBLICATIONS - PEER-REVIEWED


SELECT BIOLOGICAL PROCESSES PUBLICATIONS - REPORTS


SELECT BIOLOGICAL PROCESSES PUBLICATIONS/PRESENTATIONS - OTHER


CAROLLO is currently ranked within Engineering News Record’s top 500 design firms . . . ENR’s annual Source Book ranks Carollo among the top 17 firms for water and wastewater treatment plant design.

WATER AND WASTEWATER EXPERTS

Carollo is an environmental engineering firm specializing in the planning, design, and construction of water and wastewater facilities and infrastructure. Carollo’s reputation is based upon client service, a continual commitment to quality, and technical leadership.

During our 79-year history, Carollo has successfully completed more than 20,000 projects for public sector clients. Carollo is currently ranked within Engineering News Record’s top 500 design firms. More importantly, ENR’s annual Source Book ranks Carollo among the top 17 firms for water and wastewater treatment plant design. Unlike many of our competitors, Carollo provides only water and wastewater engineering services.

With our focus on water and wastewater, we recruit nationwide and hire technical staff who have the extensive background and training specific to this field. For that reason, the quality and professional standing of our core group of water and wastewater professionals equals or exceeds that provided by some of the largest engineering firms in the U.S.

Resources

Carollo’s staff numbers nearly 600 employees, including nearly 325 registered engineers. We are a full-service water and wastewater engineering company with the experience and qualified professionals to successfully manage projects of any size. Our staff includes civil, sanitary, electrical, environmental, mechanical, chemical, structural, instrumentation, and corrosion control engineers, as well as architects, planners and specialists in other areas. These individuals perform work solely on water and wastewater related facilities.
MANAGEMENT PHILOSOPHY

Carollo’s management philosophy and the success of our company are founded on simple precepts:

▶ Seek out, hire, and hold onto the best people in the business. We recognize that the most critical element for a successful project is the project team. Carollo aggressively recruits the top candidates from the leading engineering schools across the country. We train and mentor these engineers to become the next generation of leaders for Carollo and the industry. This long-term commitment to developing excellent engineers has resulted in a depth of talent unmatched by other consulting firms.

▶ Specialize in the planning, design and construction management of water and wastewater projects. This is our business. Our success hinges solely upon our ability to provide responsive service to our municipal clients.

▶ Commit our partners to an active role in every project. This provides our clients with top management interest, clear accountability, responsiveness, and talent — and helps to ensure that the necessary staff and resources are committed to each assignment.

▶ Focus on client service. Carollo knows the value of listening to our clients and recognizes that successful projects result from the combined expertise of our staff and the client’s staff. This commitment to understanding client needs and valuing their input is one of the cornerstones of Carollo’s success.

LEADERS IN WATER ENGINEERING

Carollo has provided design and construction management services for over 100 water treatment plants with a total capacity of more than 3.5-billion gallons per day, more than 1,000 miles of water pipeline ranging in size from 6 to 108 inches in diameter, and over 100 water pumping stations with capacities as high as 600 mgd. We have recently completed or are performing ongoing water projects for many of the country’s major municipalities or special districts. A few examples of Carollo’s achievements include:

▶ Conceiving and developing the custom design approach for low-pressure membrane water treatment plant design. Carollo developed our own custom, nonproprietary, non-packaged pilot plant unit, which has been successfully tested in Kansas City, MO.
Engineering the fast-paced design/build expansion of the Palm Coast, FL, RO water treatment plant from 3.2 to 9.6 mgd. Carollo completed preliminary design and obtained all permits just eight weeks after beginning work to help facilitate successful completion of this project in just 15 months.

Conducting the first U.S. testing and evaluation of electrodialysis reversal (EDR) for perchlorate treatment.

Achieving leadership in ultraviolet (UV) disinfection, first for wastewater applications in the western United States and now for UV drinking water applications. Carollo was the primary author of the USEPA UV Disinfection Guidance Manual. We also developed and operate the world’s largest UV validation facility in Portland, OR.

Designing the preozonation and intermediate ozonation at two water treatment facilities for the City of Arlington, TX, using our computational fluid dynamic (CFD) modeling to optimize ozone contactor design. Carollo also conducted a joint research project with various utilities in the Phoenix, AZ, area to evaluate ozonation and biological filtration to meet long-term finished water quality goals, leading to design and construction of ozonation facilities in Gilbert and Peoria, AZ.

Designing, in a joint venture, the world’s largest ozone generation system at a water treatment facility in Las Vegas, NV.

FORMULA FOR SUCCESS

Much of our success as an industry leader is based on our ability to offer advanced solutions that are practical, affordable, and reliable. We strive to maximize the use of existing infrastructure whenever possible, promote environmental conservation, and make the best technologies available at a competitive cost.

A major factor in maintaining Carollo’s ability to integrate new technology is the Carollo Water Research Group (CWRG). The relationship between our design engineers and the CWRG is unique in the industry and serves as a company-wide resource for evaluating water quality and treatability data, performing pilot studies, developing design criteria, tailoring design solutions to water quality issues, and addressing regulatory compliance concerns.
Our firm takes pride in the large number of clients with whom we have maintained continuing working relationships. We have worked with some clients for more than 70 years — a clear indication of the quality of our work, our control of costs, and our ability to meet schedules. This dedication to quality has resulted in a long list of successful projects and satisfied clients, some of which are highlighted in the table below.

### Representative Water Treatment Projects

<table>
<thead>
<tr>
<th>Client/Project</th>
<th>Capacity (mgd)</th>
<th>Conventional Treatment</th>
<th>Membranes</th>
<th>Ozone</th>
<th>UV Disinfection</th>
<th>Automation</th>
<th>Solids Handling</th>
<th>Chemical Handling</th>
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<tbody>
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<td>City of Phoenix, Arizona - Val Vista Water Treatment Plant</td>
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<td>City of Sacramento, California - E.A. Fairbairn Water Treatment Plant</td>
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<tr>
<td>City of Sacramento, California - Sacramento River Water Treatment Plant</td>
<td>160</td>
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<td>Metropolitan Water District of Salt Lake City and Sandy, Utah - Point of the Mountain Water Treatment Plant</td>
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<td>Brazos River Authority, Texas - Brazos River Authority Water Treatment Plant</td>
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