ADVANCING DIRECT POTABLE REUSE TO OPTIMIZE WATER SUPPLIES AND MEET FUTURE DEMANDS

EXECUTIVE SUMMARY | SEPTEMBER 2018

WateReuse Colorado

carollo
Engineers...Working Wonders With Water®

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Acknowledgments

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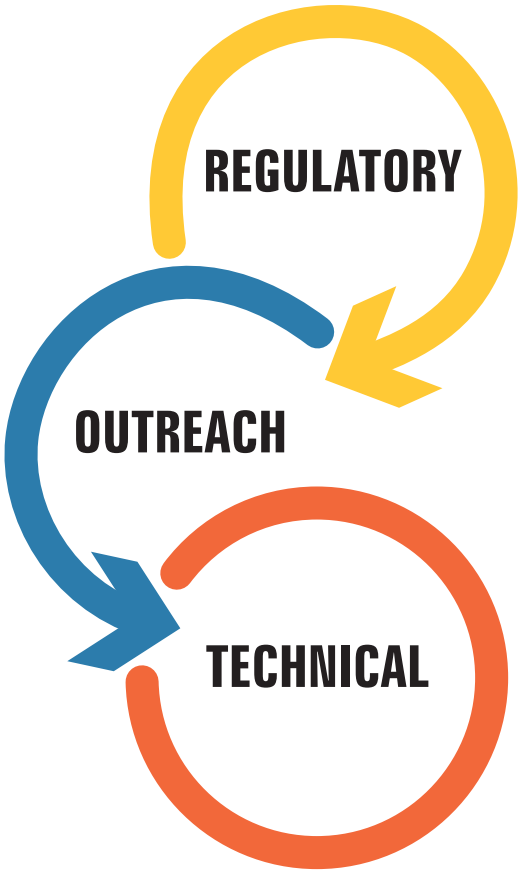
Project Overview and Goals

Meeting Colorado's water needs is an increasingly difficult challenge, requiring new thinking and nontraditional supplies. Non-potable reuse has increasingly helped meet water needs in Colorado, but faces numerous technical and cost constraints in implementation. The 2015 Colorado Water Plan projects a potential for significant water shortages in Colorado and acknowledges the role that potable reuse can play in addressing those challenges. This project builds on direct potable reuse (DPR) progress in other states to prepare Colorado for implementation of DPR, while Colorado utilities are considering DPR as part of water supply planning before they actively employ DPR. The project was conducted in three interrelated tasks, corresponding to three focus areas. Each of these three focus areas is described in further detail in the sections that follow in this document.



REGULATORY

Document the basis and framework for development of DPR regulations in Colorado that are protective of public health and reflective of best management practices. **PAGES 3 - 10**

OUTREACH

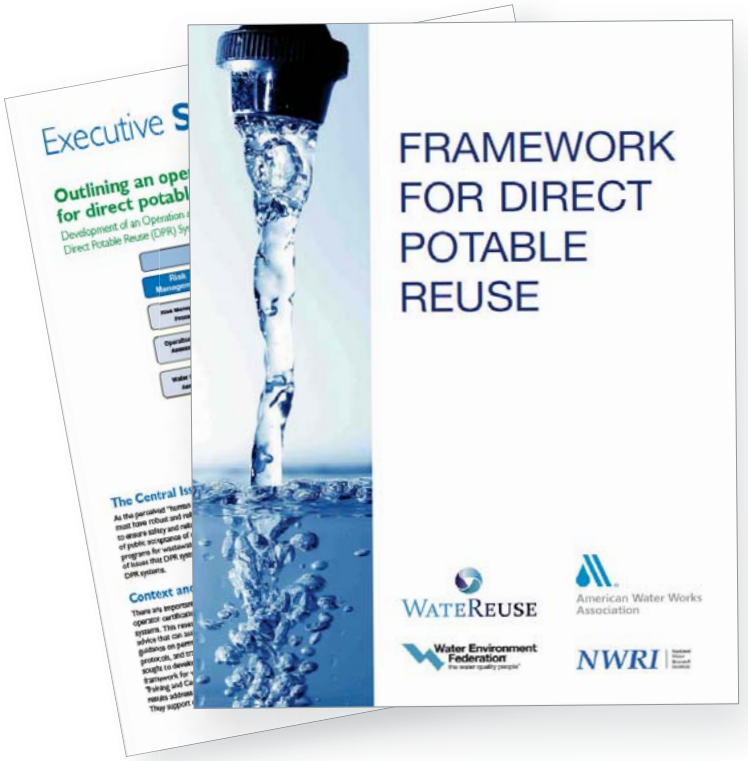
Support state- and local-level potable reuse public outreach and messaging efforts by providing tools and information and operating the PureWater Colorado demonstration project. **PAGES 11 - 20**

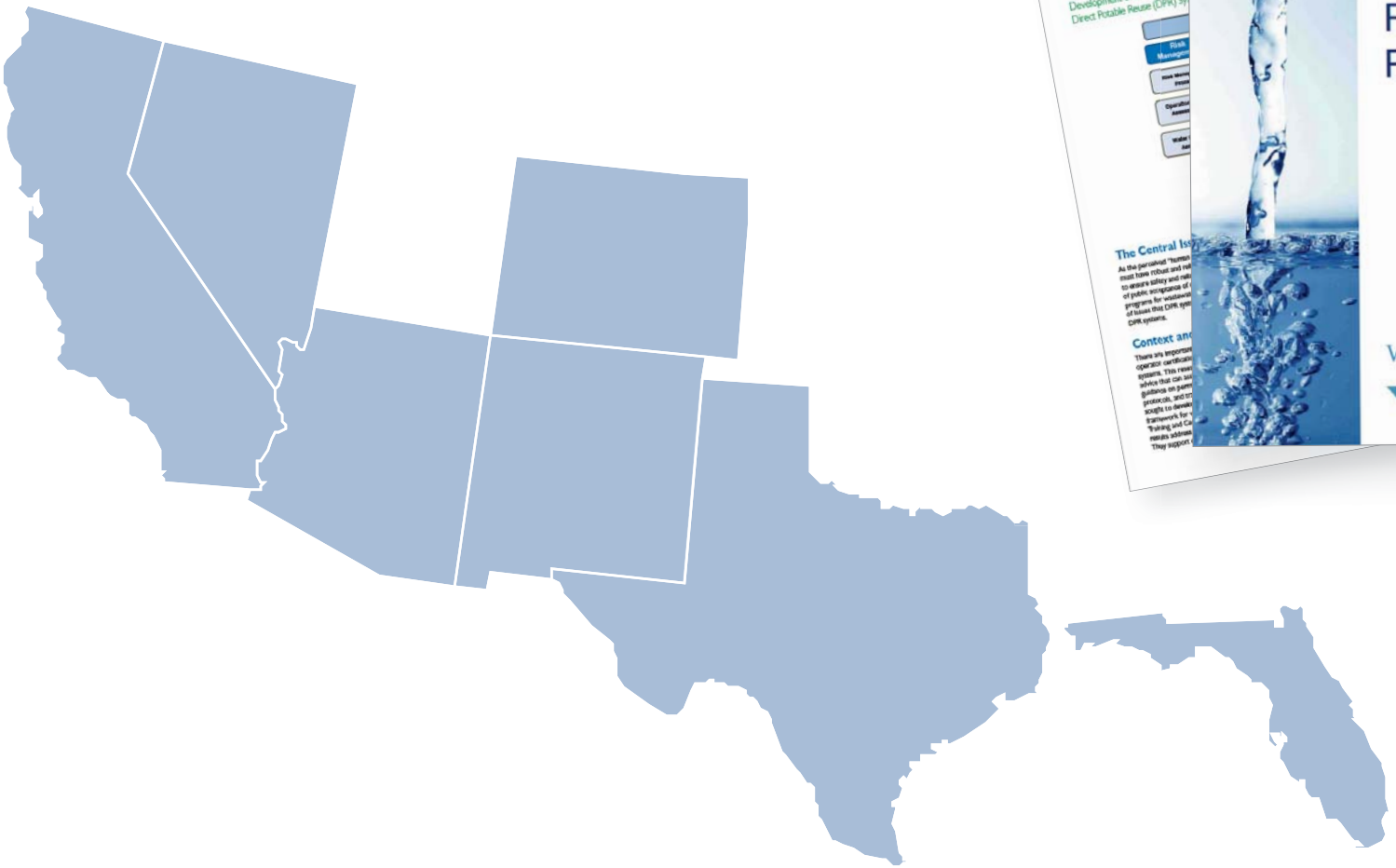
TECHNICAL

Enhance existing planning tools and assist Colorado utilities with their assessment of DPR as a potential supply option. **PAGES 21 - 24**

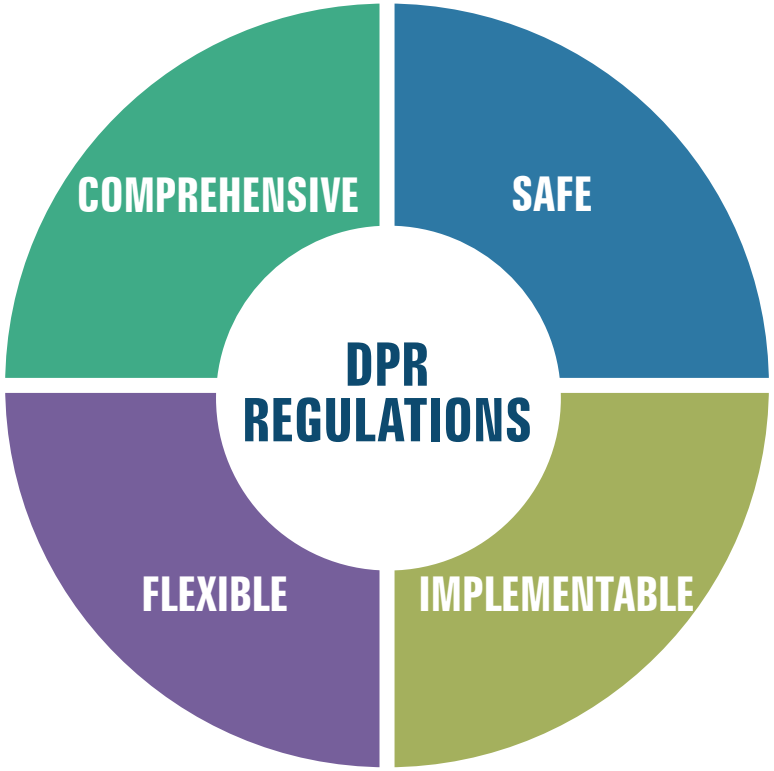
Regulatory Development

Several states have already made legislative and/or regulatory progress and advanced the acceptance of DPR for future projects. Progress in California, Arizona, Nevada, Colorado, New Mexico, Texas, and Florida has set the framework for overcoming potential pitfalls.





Regulatory Approach



The DPR regulatory workgroup collaborated with CDPHE representatives to develop a framework for future Colorado DPR regulations. Key goals included regulatory flexibility and adaptability, while assuring public health protection. For example, the DPR regulatory system should be set up to accommodate evolving treatment technologies, while including measures to assure compliance with water quality standards and provide public health protection. The workgroup developed 11 categories of regulatory coverage, as described on page 5. The workgroup populated a regulatory matrix with the type of content that should go into regulation, policy, and guidance for each of the 11 categories, as detailed on pages 7 through 10.

Regulatory flexibility and adaptability can be accomplished through use of Colorado's existing three-tiered approach to regulatory administration:

REGULATION

Fundamental and enforceable requirements, not to be changed frequently.

Water Quality Control Commission hearing process required to modify regulation.

POLICY

Interprets the Regulation, provides specifics.

Can be modified by Water Quality Control Division staff, approved by Commission.

GUIDANCE

Best practices and information for utilities to follow in implementing elements of the Regulation.

11 Categories for Regulatory Development

The workgroup developed 11 categories of regulatory coverage and populated a regulatory matrix (shown on pages 7 through 10). This matrix includes regulation, policy, and guidance for each of these 11 categories.

TERMINOLOGY: Clear definitions lead to clear regulations. Clearly defining DPR also helps establish when the regulation applies to a given system or scenario, and when it does not.

SOURCE CONTROL: Wastewater source control programs protect treatment processes and downstream ecosystems; additional scrutiny is required for potable reuse. The concept of the Enhanced Source Control Program is developing.

WASTEWATER TREATMENT: Equalized and consistently high quality effluent becomes the focus, in addition to NPDES compliance. Higher quality nitrified/denitrified effluent is ideal to reduce impact on subsequent advanced treatment systems.

PATHOGEN DISINFECTION AND REMOVAL: Due to the acute risk to public health represented by pathogens, these are the primary focus of potable reuse treatment. This is similar to the focus in conventional water treatment.

CHEMICAL REMOVAL: Chemical removal remains important, maintaining all regulated chemical pollutants below mandated levels and providing an additional buffer for chemical pollutants that pose an acute risk.

ADVANCED TREATMENT PROCESSES: The nature of the source water (wastewater) requires more treatment for chemical and biological pollutants than conventional source water. Advanced treatment processes provide this additional treatment.

MONITORING REQUIREMENTS: Potable reuse facilities will need clear determination of responsibility and detailed reporting, including monitoring of WWTP and WTP operations and accounting for pathogen and chemical pollutant removal.

REPORTING: Each key treatment process must have performance verification measures to demonstrate that each process is attaining its respective performance goal. The monitoring location for these critical tests is known as a Critical Control Point (CCP).

FACILITY OPERATIONS AND CERTIFICATION PROGRAMS: Potable reuse facilities must have qualified operations staffs who are trained to operate advanced treatment processes. Typically Class A or equivalent operators are to be in charge of the facility.

EDUCATION AND OUTREACH: Potable reuse provides tremendous value to a community. Successful project implementation requires an open and continuous dialogue with the community about the value of water and the safety of potable reuse.

TECHNICAL, FINANCIAL, AND MANAGERIAL CAPACITY: Facilities that move forward with potable reuse must demonstrate the ability to fund and manage these complex projects, and the technical depth to protect public health.

Next Steps for Regulatory Development

The framework and regulatory matrix (shown on pages 7 through 10) developed in this effort will be expanded upon by an NWRI expert panel and CDPHE to support development of a final DPR Regulation.

WATEREUSE COLORADO

REGULATION, POLICY, GUIDANCE FRAMEWORK

NWRI National Water Research Institute

DEVELOP TREATMENT AND MONITORING

REGULATORY MATRIX
ITEMS 1 - 7 AND 10

CDPHE COLORADO Department of Public Health & Environment

DEVELOP IMPLEMENTATION PROGRAMS

REGULATORY MATRIX
ITEMS 8, 9, AND 11

WATER QUALITY CONTROL COMMISSION RULEMAKING

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REGULATION AND POLICY GUIDANCE

Regulatory Matrix

CATEGORY	INCLUDING	REGULATION	POLICY	GUIDANCE
1. Terminology	The Framework for Direct Potable Reuse (NWRI/WEF/AWWA/WateReuse) provides a detailed list of terminology. Consider inclusion/adoption to maintain consistency within the industry. Example important definitions/terminology include: • Source Control - First described national pretreatment program material. Next, define source control as it could apply to potable reuse projects. • Potable Reuse - define the basic concept of potable reuse, and that any type of potable reuse is intended to result in the same water quality that is protective of public health. Then, define de facto potable reuse, indirect potable reuse, and then direct potable reuse. Context of the urban water cycle is important. Define the key building blocks to convert and use purified water for public consumption, which includes treatment and infrastructure. • Environmental Buffer - define the environmental buffer as it applies to IPR projects and how the use of Engineered Storage can provide diversion. Define also how the environmental buffer is used within the current regulatory context in Colorado.	✓ Determine which definitions are regulatory and specific to DPR.	✓ Some terms should not have regulatory definitions – some can be set in policy and guidance. These terms should be referred to as "terminology" and not "definitions."	✓ To be determined at a later date
2. Source Control	• Build on existing pretreatment programs. • Source control programs for potable reuse are "water first" programs, with a different focus compared to conventional pretreatment programs (which are focused on WWTP processes protection and NPDES permit compliance). • Recognize that potable reuse requires a source control program that is "enhanced," typically requiring more sampling and analysis of industrial users and broader pollutant monitoring within the collection and treatment system compared to conventional programs. • Rigorously and repeatedly inventory industrial users. • Define other user concerns (e.g., truck haulers). • Emergency response - an emergency response plan should be designed for sampling and determination of source control violations.	✓ List regulations that match the Reg. II contaminant control. ✓ Require a source control program that focuses on finished potable water quality. ✓ Require frequent updates and review of the source control program. ✓ Require regulatory review of the source control program periodic monitoring results.	✓ Specify requirements for all DPR scenarios. ✓ Detail how to reclassify existing water sources for use in DPR. ✓ Specify a robust communication protocol between WWTP and AWTF (ERP) ✓ Specify required components of the program. ✓ Specify requirements for monitoring and compliance including frequency, location, pollutants to analyze, and emergency response plans	✓ Each DPR scenario should have best practices. ✓ All DPR projects should have a public/industrial outreach program. ✓ Include forms and best implementation plans for pretreatment. ✓ List best practices for sampling and emergency response.
3. Wastewater Treatment	• Specify treatment targets and/or objectives for secondary effluent – Same as current discharge requirements – DBP minimization – Nitrogen Control • Recognize the value of flow equalization on process performance and efficiency. • Recognize operational impacts of secondary effluent quality on downstream purification processes. • Develop an emergency response plan to protect AWPF source. • Consider wastewater treatment optimization for downstream DPR.	✓ Meet requirements in existing Reg. 22, ensure secondary treatment compliance.	✓ Specify additional monitoring for WWTP upstream of a DPR facility. ✓ Recommend levels and types of wastewater treatment to provide more stable water quality for downstream purification. ✓ Specify criteria for and/or objectives secondary treatment, and minimum requirements of an ERP.	✓ Ensure reliability of WW supply and water quality. ✓ Best practices for ERPs; process for state approval of ERP; optimization guidance. ✓ Review the value of flow equalization. ✓ Link DBP minimization and nitrogen control with subsequent purification processes. ✓ Review how purification processes can compensate for lower secondary effluent quality, but they come at higher cost.

Regulatory Matrix

CATEGORY	INCLUDING	REGULATION	POLICY	GUIDANCE
4. Pathogen Disinfection/ Removal 	• Meet all federal and state drinking water regulations. • Meet source water standards. • Create pathogen reduction goals that include reduction across an entire treatment scenario (source to distribution). • Targets Pathogens – Protozoa (Cryptosporidium and Giardia) – Viruses • Treatment goal – Risk-based Approaches • California/NWRI approach with 12-10-10 log removal requirements (Virus/Giardia/Crypto) • Data Driven Model - Texas Approach – Log removal vs. concentration	✓ Require pathogen removal and disinfection to meet all federal (and state) drinking water regulations. ✓ Require pathogens be removed or inactivated, with a goal of 10-4 annual risk of infection. This method and risk level have been adopted in CA, NM, NV, TX, and in national regulatory guidance documents. ✓ Require a multiple barrier treatment approach. Approach uses precise and conservative monitoring systems to measure treatment process performance based on a 10 4 risk level. ✓ Develop log credit system based upon approved treatment technologies. ✓ Two potential approaches to regulation: 1. Set the log reduction requirements from raw wastewater through treatment to potable water for virus, Giardia, and Cryptosporidium to be 12-log, 10-log, and 10-log, respectively. This is the “California” model. 2. Set the log reduction requirements to meet a 10-4 annual risk of infection based upon treated effluent characterization to determine LRV requirements. This is the “Texas” model.	✓ Specify requirements for all DPR scenarios. ✓ Detail how to reclassify existing water sources for use in DPR. ✓ Specify a robust communication protocol between WWTP and AWTF (ERP). ✓ Specify required components of the program. ✓ Specify requirements for monitoring and compliance including frequency, location, pollutants to analyze, and emergency response plans.	✓ Each DPR scenario should have best practices. ✓ All DPR projects should have a public/industrial outreach program. ✓ Include forms and best implementation plans for pretreatment. ✓ List best practices for sampling and emergency response.
5. Chemical Removal 	• Contaminants – List of approved regulatory methods for chemicals – Which chemicals to regulate (MCLs, Secondary MCLs, NLs, CECs, DBPs) – Short list of unregulated chemicals and CECs to regulate or monitor, statewide or site-specific – Regulate TOC , turbidity, other water quality parameters – 1,4-dioxane and NDMA, applications in other locations – Review or modify frequency for classes of contaminants – Perfluorinated compounds (PFOS, PFOA, etc.) – Evaluate acute vs. chronic risk impacts of chemical contaminants	✓ Only require MCLs	✓ Other monitoring requirements. ✓ Define a broad range of trace level chemicals that are under investigation by EPA for potential health concerns as well as chemicals that are of interest to the public. This demonstrates proactive monitoring by the water utility. ✓ Review treatment targets and technology application in other States as they apply to unregulated chemicals. ✓ Relate classes of contaminants and monitoring to reporting requirements and public notification.	✓ Provide latest information/research (ex. DBP formation). ✓ Utilize terminology “health action level” or recommendation for terminology developed in conjunction with the outreach program messaging.

Regulatory Matrix

CATEGORY	INCLUDING	REGULATION	POLICY	GUIDANCE
6. Advanced Treatment Processes 	• Membranes (MF/UF/RO) • Ozone or Ozone AOP • Ozone and Biologically Active Filtration • The use of non-RO systems • UV/ UV AOP • Chlorine AOP • Best Available Demonstrated Control Technology (BADCT) approach • Required processes • Site-specific treatment (focus on salts) • Multiple-barriers required • Redundancy • Pilot testing - Define need and value	✓ Allow for a flexible combination of any or of a large list of approved treatment technologies. ✓ Use EPA drinking water criteria where appropriate. ✓ Following the surface water treatment rules, define a minimum number of barriers (2 or 3). ✓ Pilot plant used for treatment demonstration to be offline, side-stream, and sent to waste. ✓ Pilot testing required only for novel technologies or for novel applications.	✓ Develop a list of approved treatment technologies with pathogen/chemical removals. ✓ Define varying classes of DPR with increased LRV goals based on risk with each scenario. ✓ A BADCT approach that can validate specific treatment trains or unit processes ✓ Recognize where EPA drinking water criteria are inaccurate and cannot be applied to wastewater treatment and purification. ✓ Highlight performance and credits for purification processes that have been used in other states.	✓ Describe DPR treatment scenarios and treatment trains used with corresponding results and pros/cons.
7. Monitoring Requirements 	• Monitoring leads to ERP and diversion of off-spec water - clearly defining the upset to match the reporting and response (notification vs. stop supply). • Monitoring – Define purpose for all monitoring requirements – Frequency – Defining detection limits • Use of indicators and surrogates - to include surrogates already utilized in CO for RO and other technologies such as sulfate/TOC for RO as opposed to an EC requirement. • Limits for “off spec” water conditions • Critical control points – Purpose – Where to place online monitoring • Demonstration of treatment performance • Use of long-term monitoring – Documentation and trending of surrogates	✓ Require online monitoring and specific critical control points for DPR unit processes in the treatment trains. ✓ Define failure and response time requirements.	✓ Recommend surrogates to measure for each unit process with a CCP. ✓ Recommend methods to monitor and respond to monitoring results, including pathogen and chemical concerns. ✓ Define and example critical control point monitoring system for unit processes in several treatment trains.	✓ Provide analyzer information and historical data. ✓ Describe the use of CCPs for operations.

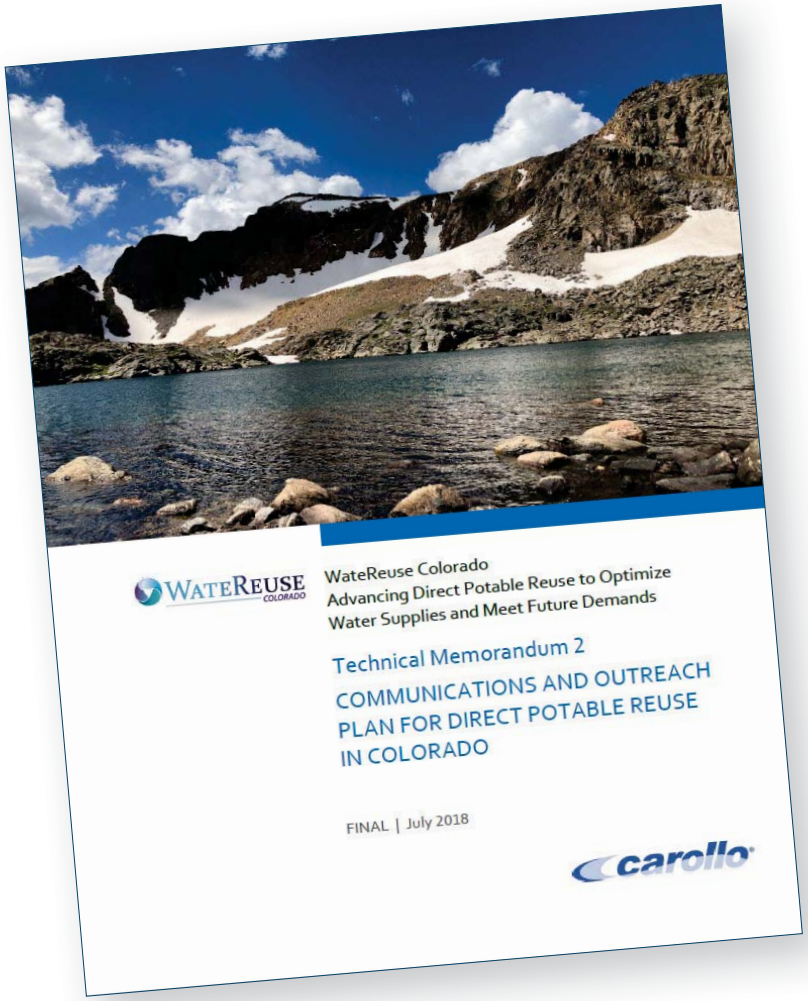
Regulatory Matrix

CATEGORY	INCLUDING	REGULATION	POLICY	GUIDANCE
8. Reporting 	• Who (which agencies/board/?) • What (data, violations) • When (frequency - monthly, yearly, only in case of violation) • Definition of compliance • Use of engineer's report for project description • Annual report • Public right-to-know applicability	✓ Build/expand on the current standard drinking water reporting requirements. ✓ Use of engineer's (or project) report ✓ Use of annual report to regulators and the public	✓ TBD	✓ Detail record keeping requirements for online monitoring. ✓ Detail record keeping requirements for grab-sample monitoring and online equipment calibration.
9. Facility Operations/ Certification Programs 	• Type of operator certification - water, wastewater, other • Level of operator certification required • Further training for Advanced Water Treatment	✓ Specified operator certification - Augment existing operations certification program with "Advanced Water Treatment" program. - Allow operation of purification systems as the AWT program is developed.	✓ Provide examples of AWT responsibilities that are in addition to current wastewater and water training certifications.	✓ Development and use of operator training.
10. Education and Outreach 	• Public hearings • Example successful programs • Information / education for: – Regulators – Politicians – Environmental groups – Advocates – Public	✓ Public outreach strategy required.	✓ Detail public outreach needed to ensure customer equity. ✓ Building on Reg. 22 requirements, but no formal regulatory requirement needed. ✓ Minimum number of public meetings. ✓ Required periodic meetings with partner utilities (i.e., where utility jurisdiction and function overlap).	✓ Example communications and outreach plan with specific items to address such as source control, recommended number of public meetings and right to know information. ✓ Example education and outreach programs; references.
11. Technical, Managerial and Financial (TMF) Capacity 	• Certifications for preparing engineering report/document to submit to the state • Construction and contractor certifications	✓ State TMF review (build on state SDWA TMF program).	✓ Specific requirements and applicability of TMF requirements. Regulatory requirement needed.	✓ Provide information on an IGA plan that includes: contact early in project, water rights requirements, information on who is paying for the project and clear expectations. ✓ Develop training and supporting programs.

Public Education and Outreach

The DPR outreach and education workgroup developed a communications and outreach plan and initial materials to help foster public understanding and acceptance of DPR in Colorado. This includes strategies at both the statewide and local level. The communications and outreach plan provides the initial elements of the approach recommended by Patricia Tennyson and Kristina Ray *(Journal of the American Water Works Association, January 2005)*, summarized in the seven steps to the right.

Communication and Outreach Plan

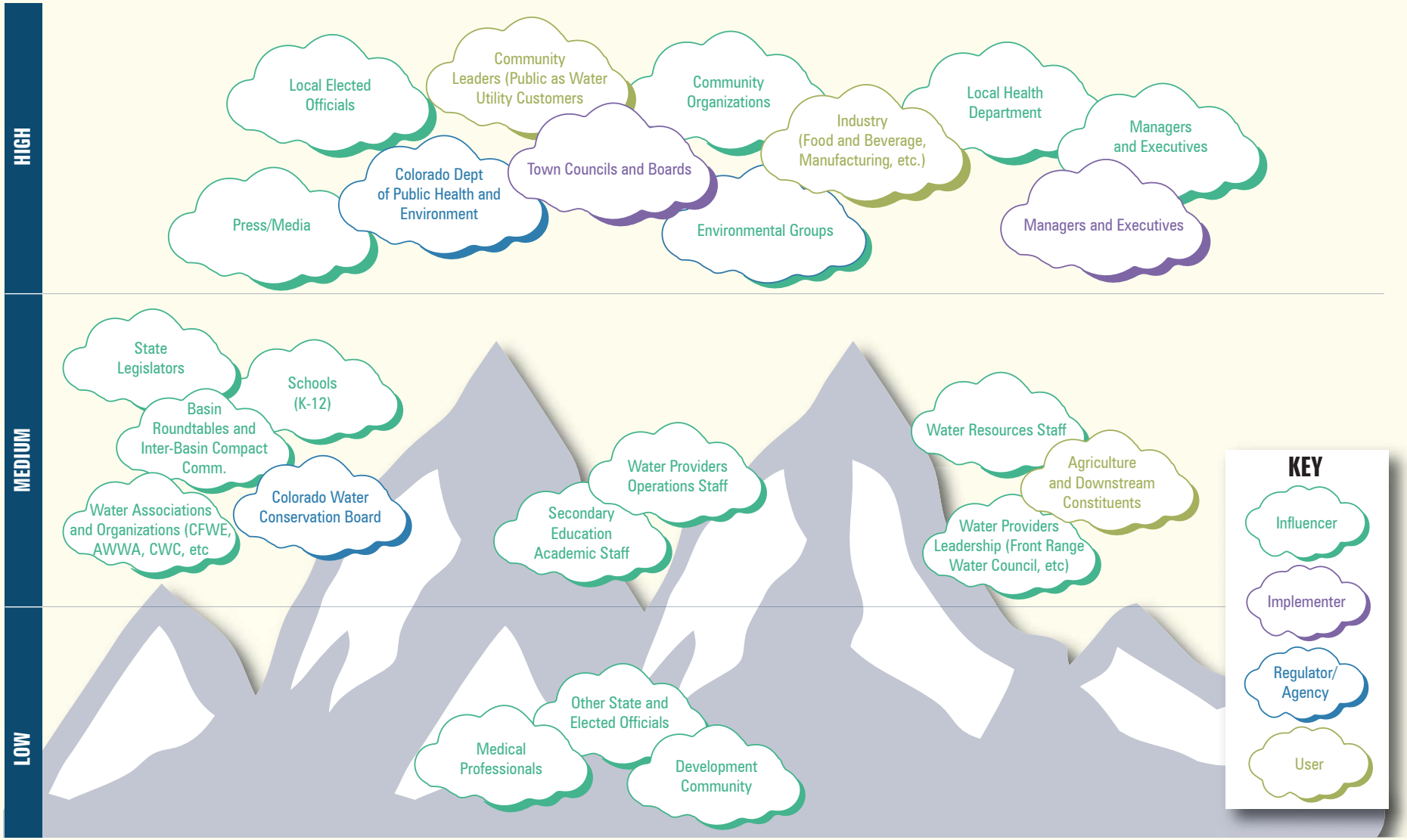


The Communications and Outreach Plan provides a framework for raising awareness and educating a broad range of stakeholders about the safety and value of DPR. The Plan is one of the primary accomplishments of the WateReuse Colorado (WRCO) DPR Project's Public Outreach efforts.

OUTREACH

Audience Outreach and Prioritization

The DPR outreach and education workgroup grouped and prioritized audience types to help guide WateReuse Colorado DPR outreach efforts that can have the most impact. This may not be the case for all utilities or future projects, but is an initial draft for a state-wide overview.



Key Messaging

To provide consistent, fact-based information the DPR workgroup identified three Key Messages when sharing information about potable reuse:

Purified water provides a safe drinking water supply.

Using advanced purified water is good for the environment.

Purified water provides a locally controlled, drought-resistant water supply.

Delivery Mechanisms and Strategy

This Outreach Planning Table includes best practices and linked to desired outcomes. This can guide when to reach each audience based on the goals, messaging and delivery mechanisms shown in the table.

	AUDIENCES	LOCAL ELECTED OFFICIALS (MAYOR, CITY COUNCILORS, HOAS)	PRESS AND MEDIA	TOWN COUNCIL/UTILITY BOARD	COMMUNITY ORGANIZATIONS (E.G., CHAMBER OF COMMERCE, BUSINESS COUNCILS, ROTARY CLUB)	LOCAL HEALTH DEPARTMENTS
DELIVERY MECHANISMS	**WRITTEN COMMUNICATION**	• Concise and consistent message in standard communication channels. • Nextdoor.com • Social media.	• Fact sheets including numbers and stats. • Report showing early adopters, testimonials from health professionals, utilities, and customers use public information office's tools. • Active press pitches. • Reporter briefing by experts for an hour for background information prior to start of the project. • Website with fact sheets, reports.	• Website • News support. • White papers (brief, graphical). • Fact sheets.	• Publications	• Mass email briefing with reg and fact information. • Fact sheets. • Website for CDPHE and stakeholders.
	EVENTS		• Facility tours. • Demonstration facilities. • Recycled water beverage / recycled water reception or event.	• Demonstration facility. • Tours (local, regional, national). • Topical conferences. • Recycled water beverage / reception event.	• Local tours. • Recycled water beverage / reception event.	
	FACE-TO-FACE COMMUNICATION	• Advisory groups. • Study sessions. • Board/ precinct meetings.		• One on one meetings. • Subcommittee • Council/board meeting. • Peer to peer transfer.	• Presentations • Business leaders. • National organizations or affiliates. • One on one meetings. • Small organization meetings.	• Roundtables with messengers. • Organized standing meetings for updates.

Delivery Mechanisms and Strategy

	AUDIENCES	COMMUNITY LEADERS (PUBLIC/WATER UTILITY CUSTOMERS)	CDPHE	INDUSTRIAL, FOOD/BEVERAGE, MANUFACTURING	MANAGERS/EXECUTIVES (AS IMPLEMENTERS)	MANAGERS/EXECUTIVES (AS INFLUENCERS)	ENVIRONMENTAL GROUPS
DELIVERY MECHANISMS	**WRITTEN COMMUNICATION**	• Websites • Television/news	• Fact sheets and prepared materials for presentations and handouts. • Formal scientific report demonstrating the safety of DPR for distribution.	• Fact sheets and prepared materials for presentations and handouts. • Website	• Fact sheets and prepared materials for presentations and handouts.	• Fact sheets and prepared materials for presentations and handouts. • Mass email briefing with reg and fact information.	• Fact sheets and prepared materials for presentations and handouts. • Website
	EVENTS	• Demonstration centers and tour groups.			• Recycled water beverage / reception event.	• Recycled water beverage / reception event.	• Demonstration facility.
	FACE-TO-FACE COMMUNICATION	• K-12 school outreach. • City council meetings/ public forums. • Environmental groups advocating for DPR implementation.	• One on one meetings. • Roundtables with industry experts.	• Forum/ Q&A session with water provider.	• One on one meetings using prepared materials • Presentations given by industry experts.	• Internal meetings with prepared materials.	• Forum/ Q&A session with water provider.

OUTREACH

PureWater Colorado Project

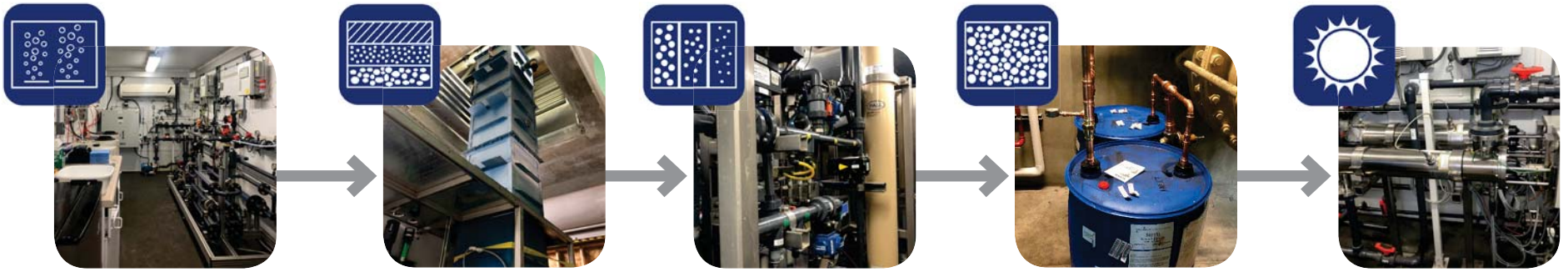
Innovation for Colorado's Future

The PureWater Colorado Demonstration Project used an innovative, advanced water purification process train without reverse osmosis to produce safe, high-quality drinking water. The project represented a viable and much-needed option for future locally-available water supplies in Colorado.

PureWater Colorado Project

OUTREACH

The PureWater Colorado demonstration project documented elimination of pathogens, near-total removal of trace organic constituents, and the production of high-quality water that is protective of public health.

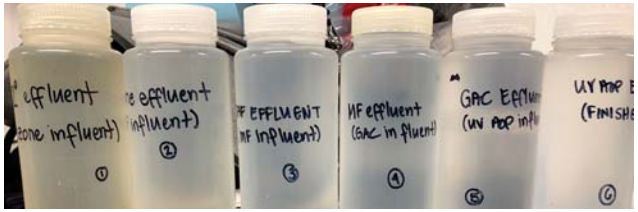


Ozonation | **Biofiltration** | **Microfiltration** | **Granular Activated Carbon** | **Ultraviolet Light/ Advanced Oxidation**

OUTREACH

PureWater Colorado Project

This project demonstrated that clean, safe drinking water can be produced from alternative sources. The project provided opportunities for media outreach, targeted onsite tours, and for members of the public to sample water and beverages produced from the project.



PureWater Colorado Project

OUTREACH

Ongoing efforts for public awareness and outreach continue to broadcast the success of the PureWater Colorado project through video tours as well as beverage production using purified water.

PureWater Colorado Demonstration Project Overview

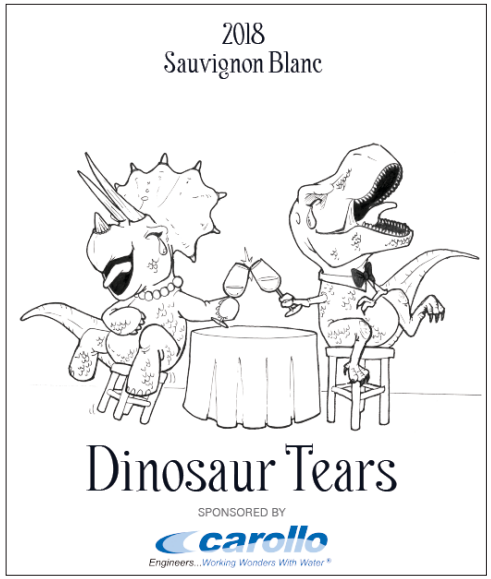
https://www.youtube.com/watch?v=lBo7lm2Ra0I

Videos produced by DENVER WATER

https://www.youtube.com/watch?v=9VGgUH_ieDo

Centurion Pilsner created in collaboration with Denver Water and Declaration Brewing.

(Photo credit: Jay Adams, Denver Water)



Wines created in collaboration with InVINtions Winery.

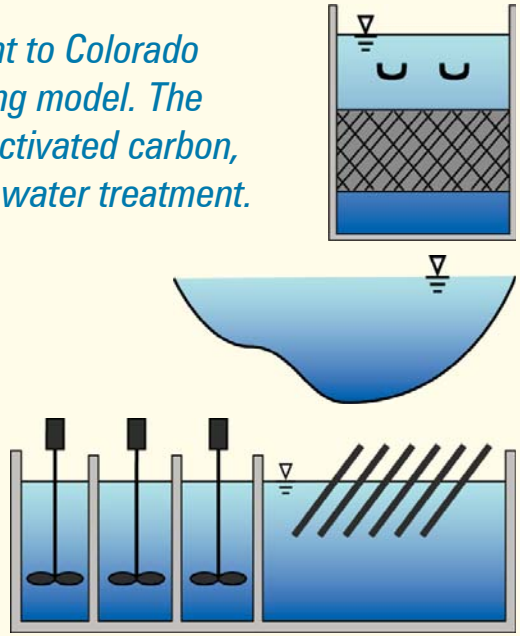
TECHNICAL

Technical Planning Tools for Potable Reuse

The goal of this effort was to adapt and use existing planning tools to perform hypothetical local case studies to test the use of an updated planning tool. The updated planning tool can help utilities screen treatment process trains for pathogen and trace chemical removal.

Innovative Treatment Train Toolbox for Potable Reuse (IT3PR Toolbox)

This project added processes relevant to Colorado utilities to an existing process planning model. The added processes included granular activated carbon, riverbank filtration, and conventional water treatment.



This project also updated the code program to a more powerful software in order to increase tool power and process train options.

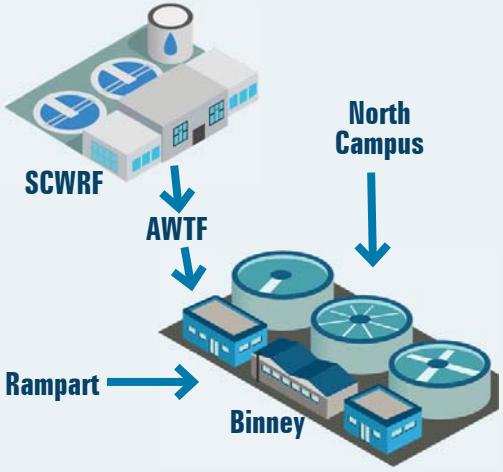
```
for i in people.data.users:
    response = client.api.statuses.user_timeline.get(screen_name=i.scre
print 'Got', len(response.data), 'tweets from', i.screen_name
if len(response.data) != 0:
    ltdate = response.data[0]['created_at']
    ltdate2 = datetime.strptime(ltdate,'%a %b %d %H:%M:%S +0000 %Y'
    today = datetime.now()
    howlong = (today-ltdate2).days
    if howlong < daywindow:
        print i.screen_name, 'has tweeted in the past' , daywindow,
        totaltweets += len(response.data)
        for j in response.data:
            if j.entities.urls:
                for k in j.entities.urls:
                    newurl = k['expanded_url']
                    urlset.add((newurl, j.user.screen_name))
    else:
        print i.screen_name, 'has not tweeted in the past', daywind
```

Potable Reuse Local Case Studies

TECHNICAL

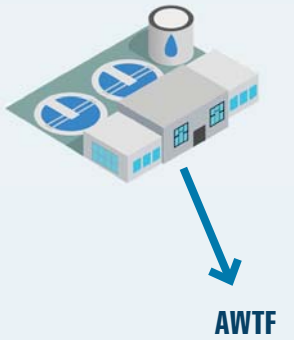
Three utility partners, the City of Aurora, Denver Water, and Plum Creek WRA in conjunction with the Town of Castle Rock partnered with the WateReuse Colorado project to study hypothetical future DPR scenarios. None of these utilities is planning on implementing DPR at this time.

City of Aurora Case Study



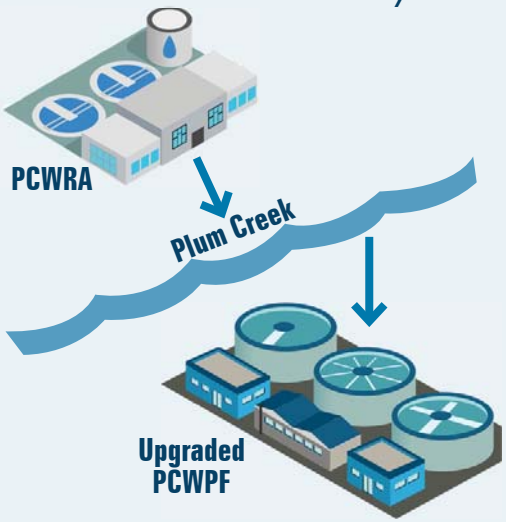
A DPR scenario was analyzed for the City where tertiary treated denitrified reclaimed water from the Sand Creek Water Reuse Facility (SCWRF) would be treated to potable standards in conjunction with a new advanced water treatment facility (AWTF) and the existing Binney Water Purification Facility.

Denver Water Case Study



The Denver Water case study modeled a DPR scenario starting with secondary denitrified effluent and using the PureWater Colorado DPR demonstration treatment train.

Plum Creek WRA and Town of Castle Rock Case Study

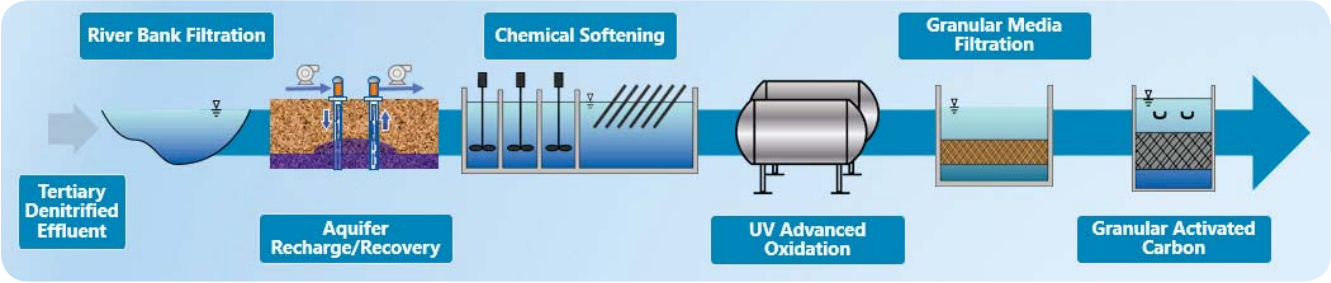


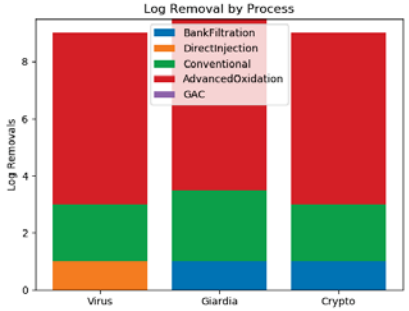
The PCWRA/Castle Rock case study was modeled with 12 hours of travel time in Plum Creek between the PCWRA tertiary effluent discharge and diversion for treatment at the Town's upgraded Plum Creek Water Purification Facility.

TECHNICAL

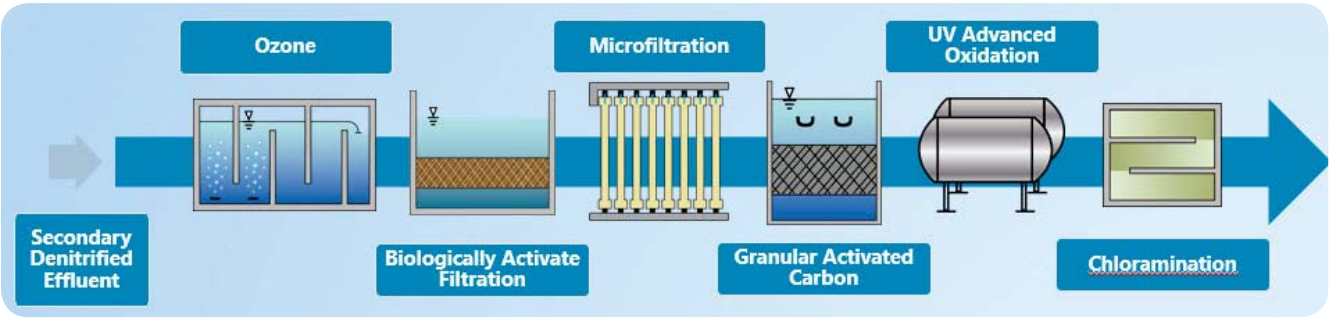
DPR Treatment Train Scenarios and Pathogen Removal

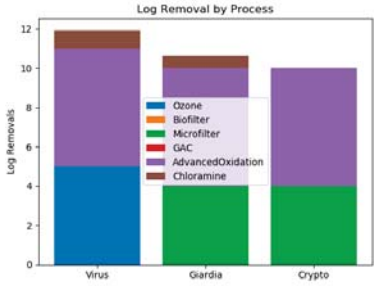
City of Aurora Case Study



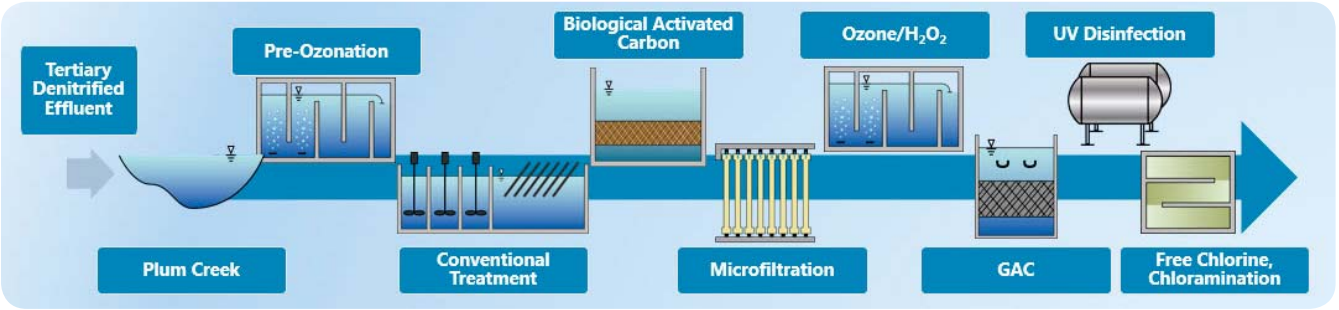


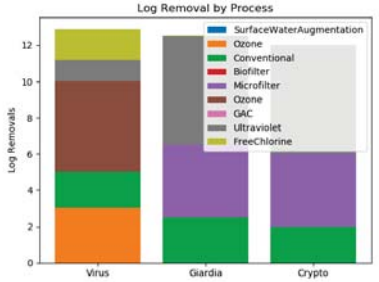
Denver Water Case Study





Plum Creek WRA and Town of Castle Rock Case Study



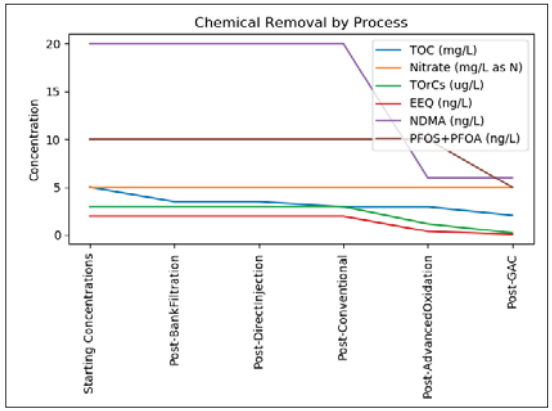


All hypothetical scenarios were able to meet the Texas minimum pathogen log removal requirements of 8-$\log_{10}$ virus, 6-$\log_{10}$ *Giardia*, and 5.5-$\log_{10}$ *Cryptosporidium* starting at secondary or tertiary treated effluent.

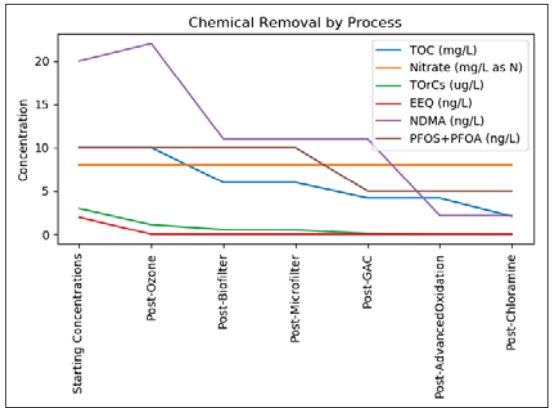
Chemical Results from Case Study Modeling

TECHNICAL

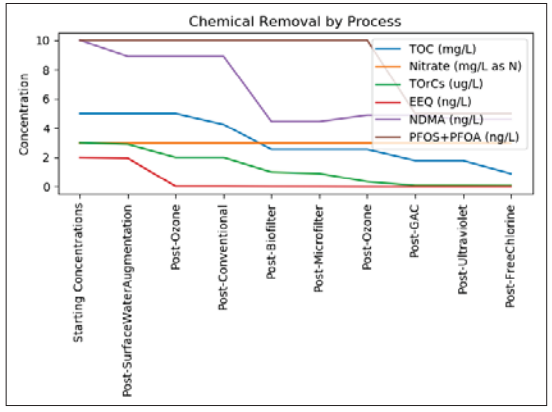
City of Aurora Chemical Results



Denver Water Chemical Results



Plum Creek WRA and Castle Rock Chemical Results



Industry Statistics Table

PARAMETER	GOAL CONCENTRATION IN DRINKING WATER
Total Organic Carbon (TOC)	2-3 mg/L[1]
Nitrate as N	7 mg/L[2]
Trace Organic Chemicals (TOrC)	1 µg/L[3]
Estradiol Equivalency (EEQ)	1 ng/L[3]
N-nitrosodimethylamine (NDMA)	10 ng/L[4]
Perfluorooctanoic Acid (PFOA) + Perfluorooctane Sulfonate (PFOS)	70 ng/L (combined)[5]

Notes:

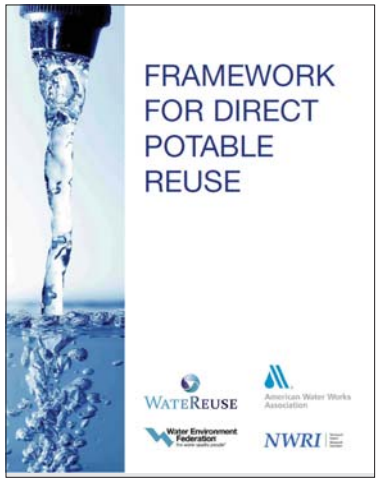
1. Realistic TOC goals for non-RO based treatment range between 2 milligrams per liter (mg/L) and 3 mg/L. Similar to conventional surface water treatment, TOC must be limited in order to prevent excessive formation of disinfection byproducts; precise TOC goals should be established based on site-specific evaluations.
2. The United States Environmental Protection Agency (USEPA) maximum contaminant level (MCL) for nitrate as N = 10 mg/L. A value of 70% of the MCL was chosen to provide a safety margin to the MCL.
3. Steinle-Darling et al. (2016)
4. California State Water Resources Control Board Division of Drinking Water Notification Level of 10 ng/L for NDMA.
5. USEPA Health Advisory level of 70 ng/L for the total concentration of PFOA and PFOS.

- µg/L micrograms per liter
- mg/L milligrams per liter
- ng/L nanograms per liter

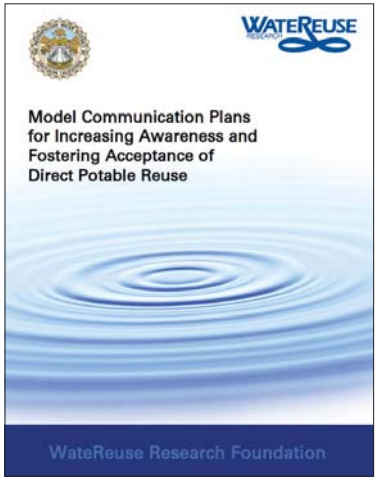
SUMMARY CONCLUSIONS

All three DPR scenarios were able to achieve end water quality regulatory requirements and industry standards within the project assumptions. Utilities considering DPR in Colorado should evaluate their system-specific need for TOC removal and total dissolved solids management.

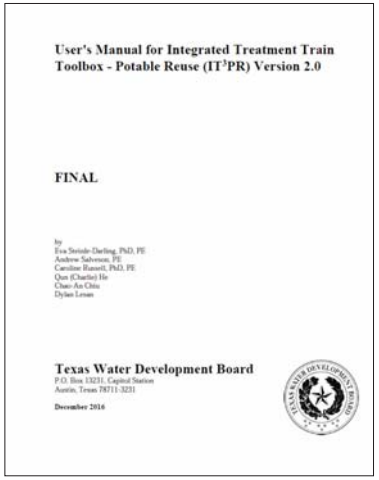
Additional Resources



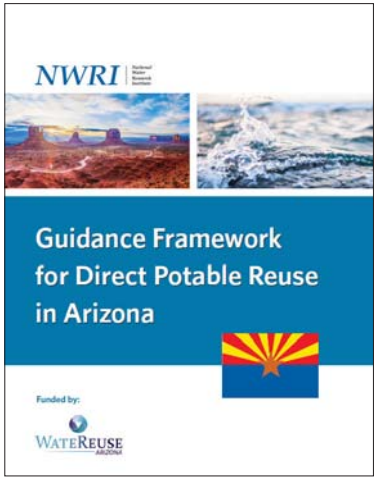
FRAMEWORK FOR DPR



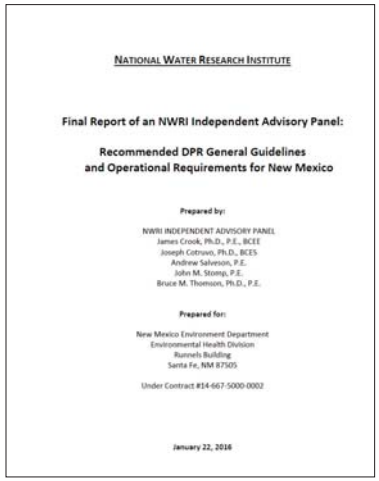
WERF 13-02



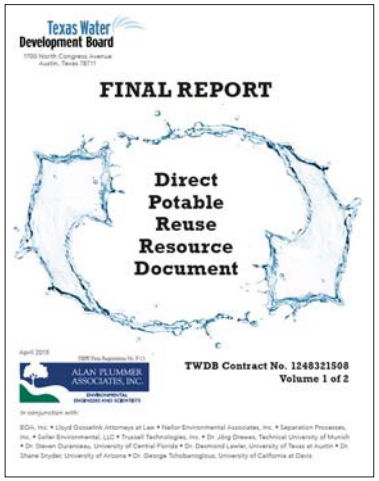
IT3 PR PLANNING TOOL USER'S MANUAL



ARIZONA DPR RESOURCE DOCUMENT



NEW MEXICO GUIDELINE DOCUMENT



TEXAS DPR RESOURCE DOCUMENT

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

– Dr. Lucas Van Vuuren

"With potable reuse, it's like it rains every day."

– Mayor Stephen Santellana, City of Wichita Falls, Texas