Framework for the Implementation of Potable Reuse in Florida

Prepared for

Florida Potable Reuse Commission

Collaborative Partners

WateReuse Florida

Florida Section of the American Water Works Association Water Utility Council

Florida Water Environment Association Utility Council

Water Research Foundation

WateReuse Association

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January 2020

Disclaimer

This report was prepared for the Florida Potable Reuse Commission, which is a partnership of the WateReuse Florida, Florida Section of the American Water Works Association Water Utility Council, Florida Water Environment Association Utility Council, and the Water Research Foundation. Any opinions, findings, conclusions, or recommendations expressed in this report are advisory and informational. The partnership organizations and their member agencies assume no responsibility for the opinions or statements of facts expressed herein. The mention of trade names of commercial products does not represent or imply the approval or endorsement by the Florida Potable Reuse Commission or its partners. This report was published solely for informational purposes.

About the Florida Potable Reuse Commission

The Florida Potable Reuse Commission is a coalition of a diverse group of water resource, industry, agricultural, environmental, and health professionals. The purpose of the Potable Reuse Commission is to create a consensus driven partnership to develop the framework for the implementation of potable reuse in Florida. The framework will support the use of potable reuse as a water supply alternative in Florida to meet future water supply needs while protecting public health and the environment.

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PREFACE

By 2035, Florida will need an additional 1.1 billion gallons of fresh water per day to meet projected needs. The development of alternative sustainable water sources is critical to meet projected water needs as well as to support Florida's economic success and status as a world-class travel destination. Potable reuse has been safely implemented in other parts of the U.S. and internationally and has the potential to provide Florida with a new water source. Although potable reuse is an established practice, additional information and supporting regulations are needed to advance potable reuse in Florida.

The Potable Reuse Commission (PRC) was organized to develop a consensus-based framework for use by the water industry, regulators, and stakeholders to advance the safe implementation of potable reuse in Florida. In the framework, relevant technical information is summarized and specific recommendations are made that will support the greater adoption of potable reuse.

The framework was developed to safeguard the protection of public health and the environment, provide regulatory and financial certainty to communities considering potable reuse, and ensure consistency in permitting and implementation of potable reuse projects throughout the state. The framework presents a path to the broader adoption of potable reuse and provides communities across the state with a new tool to help them meet future water demands.

Because a range of perspectives was necessary for the success of the PRC, the commission includes associations that represent water and wastewater utilities as well as other key stakeholders. Statewide water and wastewater associations on the PRC include WateReuse Florida, Florida Water Environment Association Utility Council, and Florida Section American Water Works Association Water Utility Council. Stakeholders on the PRC include organizations representing agricultural, environmental, public health, and regulatory interests. The Florida Department of Environmental Protection and the South Florida, Southwest Florida, and St. Johns River Water Management Districts also participated as ex officio members. This broad representation on the commission ensured that the recommendations in the framework are balanced and potable reuse in Florida will be protective of public health and the environment.

The PRC also recognized that developing the framework for advancing potable reuse in Florida required a robust and transparent approach. As a result, to encourage participation in the process by stakeholders and to provide opportunities for public comment and review of information presented, the PRC conducted multiple publicly-noticed meetings, conference calls, and technical workshops for over a year. All materials presented at the meetings, as well as drafts of this report, were made available for stakeholder and public review and comment. The PRC welcomed stakeholder and public input and considered all comments during the preparation of the framework and its recommendations. The broad-based stakeholder and public involvement helped the PRC develop a consensus-based framework that provides recommendations on technical, regulatory, and public engagement to support the practice of potable reuse in Florida.

A critical factor for implementing potable reuse is public understanding that potable reuse is a safe and sustainable alternative water source. Through public engagement, including public education and outreach, the state and communities can develop public trust that potable reuse is safe. Public understanding will be supported by increased experience and advancements in technology that will demonstrate and reinforce the safety and benefits of potable reuse.

The successful development of this framework resulted from the substantial efforts of a number of organizations, including the Water Research Foundation, and stakeholders from the public, environmental advocacy, public health groups, agricultural and industrial communities, and water and wastewater utilities. The PRC is very grateful to all the individuals and organizations for their dedication, commitment, and hard work that made the framework possible.

Lynn Spivey, City of Plant City, WateReuse Florida, Chair

Bart Weiss, Hillsborough County, WateReuse Florida, Vice- Chair

Brian Wheeler, Toho Water Authority, Florida Section of American Water Works Association Water Utility Council, Vice- Chair

Paul Steinbrecher, JEA, Florida Water Environment Association Utility Council, Vice- Chair

Dr. Donna Petersen, University of South Florida College of Public Health

Chuck Weber, City of Tampa, Florida Section of American Water Works Association Water Utility Council

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Kerry Kates, Florida Fruit & Vegetable Association

Dean Bodager, Florida Department of Health

Garrett Wallace, Nature Conservancy of Florida

Jim Spratt, Associated Industries of Florida

*Jo Ann Jackson representing the City of Altamonte Springs, Florida Water Environment Association Utility Council served on the PRC through May 16, 2019.

ACKNOWLEDGMENTS

This report, *Framework for the Implementation of Potable Reuse in Florida,* was prepared for the Florida Potable Reuse Commission.

Florida Potable Reuse Commission

The 11-member Potable Reuse Commission (PRC) consists of a diverse water-related stakeholder group comprised of water, environmental, and industry professionals. The PRC's Mission is to develop a framework for potable reuse implementation in Florida to augment future water supplies and to support water quality initiatives as well as to advise elected officials and regulatory agencies on statutory and regulatory challenges, and to present consensus-based solutions. The PRC was established to provide leadership in the expansion of potable reuse as an alternative water supply option (right water, right time, and right place).

The members of the PRC include utility representatives from WateReuse Florida, Florida Water Environment Association (FWEA) Utility Council, Florida Section American Water Works Association (FSAWWA) Water Utility Council, and stakeholders representing agriculture, environment, public health, associated industries, and the Florida Department of Health (FDOH).

The members of the commission are:

- Lynn Spivey, City of Plant City, WateReuse Florida, Chair
- Bart Weiss, Hillsborough County, WateReuse Florida, Vice- Chair
- Brian Wheeler, Toho Water Authority, Florida Section of American Water Works Association Water Utility Council, Vice-Chair
- Paul Steinbrecher, JEA, Florida Water Environment Association Utility Council, Vice- Chair
- Dr. Donna Petersen, University of South Florida College of Public Health
- Chuck Weber, City of Tampa, Florida Section of American Water Works Association Water Utility Council
- Ed Torres, City of Altamonte Springs, Florida Water Environment Association Utility Council
- Jo Ann Jackson, City of Altamonte Springs, Florida Water Environment Association Utility Council*
- Kerry Kates, Florida Fruit & Vegetable Association
- Dean Bodager, Florida Department of Health
- Garrett Wallace, Nature Conservancy of Florida
- Jim Spratt, Associated Industries of Florida

* Jo Ann Jackson representing the City of Altamonte Springs, Florida Water Environment Association Utility Council served on the PRC through May 16, 2019

Alternate PRC members include the following:

- Rick Hutton, Gainesville Regional Utilities, Florida Water Environment Association Utility Council
- Lisa Wilson-Davis, City of Boca Raton, Florida Section American Water Works Association Water Utility Council

The PRC was supported and facilitated by Mark Hammond, former resource management director for the Southwest Florida Water Management District, who planned and moderated the PRC meetings.

Collaborative Partners

The following organizations served as partners for this effort. These partners provided funding or other support to make this report possible.

- WateReuse Florida
- Florida Section of the American Water Works Association Water Utility Council
- Florida Water Environment Association Utility Council
- Water Research Foundation

Ex-Officio Organizations

Ex-officio members of the PRC include the Florida Department of Environmental Protection (FDEP) and Florida's Water Management Districts (WMDs). The FDEP and the State's WMDs provided support for the PRC and its collaborative efforts and participated in the meetings and workshops. Additionally, South Florida, Southwest Florida, and St. Johns River WMDs provided financial support through WateReuse Florida. The ex-officio members were as follows:

- Florida Department of Environmental Protection
- Northwest Florida Water Management District
- Suwannee River Water Management District
- St. Johns River Water Management District
- Southwest Florida Water Management District
- South Florida Water Management District

Stakeholder Workshops

Three public workshops with stakeholders were held to discuss regulatory and technical topics related to potable reuse. The PRC collaborated with the Water Research Foundation (WRF) to organize and facilitate these day-long workshops.

The workshops were facilitated by Julie Minton of WRF and Jeff Mosher and Pranjali Kumar of Carollo Engineers. The purpose of the workshops was to present regulatory and technical information, receive input from stakeholders, and develop a list of regulatory topics, managerial topics, public engagement approaches, and industry best practices to summarize in the framework report. The information would be used by the PRC to consider as part of developing regulatory recommendations for the framework.

Contributors

The primary contributors to this report included the following:

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ACRONYMS

AOP	advanced oxidation process
ARB	antibiotic resistant bacteria
ARG	antibiotic resistance genes
ATT	appropriate treatment technology
AWTF	advanced water treatment facility
BAC	biological active carbon
BAF	biologically active filtration
BMAP	Basin Management Action Plans
BNR	biological nutrient removal
BOD	biochemical oxygen demand
CCL	Contaminant Candidate List
CCP	critical control point
CDC	Center for Disease Control and Prevention
CEC	constituents of emerging concern
CF	cartridge filtration
COD	chemical oxygen demand
COP	critical operating point
CT	contact time
CUP	Consumptive Use Permit
CWA	Clean Water Act
DBP	disinfection byproduct
DIT	direct intensity test
DPR	direct potable reuse
DWP	Domestic Wastewater Permit
DWSRF	Drinking Water State Revolving Fund
DWTF	drinking water treatment facility
ED	electrodialysis
F.A.C.	Florida Administrative Code
FDEP	Florida Department of Environmental Protection
FDOH	Florida Department of Health

F.S.	Florida Statutes
FSAWWA	Florida Section American Water Works Association
FWEA	Florida Water Environment Association
GAC	granular activated carbon
IPR	indirect potable reuse
IU	industrial user
LRV	log reduction value
LT2 ESWTR	Long Term 2 Enhanced Surface Water Treatment Rule
MBR	membrane bioreactor
MCL	maximum contaminant level
MCLG	maximum contaminant level goal
MF	microfiltration
MFL	Minimum Flows and Levels
MOU	memorandum of understanding
NDMA	N-nitrosodimethylamine
NF	nanofiltration
NPDES	National Pollutant Discharge Elimination System
NRC	National Research Council
NWRI	National Water Research Institute
O&M	Operation and maintenance
PFA	Priority Focus Areas
PFOA	perfluorooctanoic acid
PFOS	Perfluorooctanesulfonic acid
PRC	(Florida) Potable Reuse Commission
POTW	publicly owned treatment work
PPCP	pharmaceuticals and personal care products
PWSP	Public Water System Permit
QMRA	quantitative microbial risk assessment
RO	reverse osmosis
SCADA	supervisory control and data acquisition
SDWA	Safe Drinking Water Act
SRT	solids retention time
SWTR	Surface Water Treatment Rule

TCEQ	Texas Commission on Environmental Quality
TDS	total dissolved solids
TMF	technical, managerial, and financial
TMDL	Total Maximum Daily Load
TDS	total dissolved solids
TOX	total organic halides
TSS	total suspended solids
TOC	total organic carbon
UF	ultrafiltration
UIC	Underground Injection Control
U.S. EPA	U.S. Environmental Protection Agency
UV	ultraviolet light
UVDGM	Ultraviolet Disinfection Guidance Manual
UVT	ultraviolet light transmittance
WERF	Water Environment Research Foundation
WE&RF	Water Environment & Reuse Foundation
WRF	Water Research Foundation
WMD	Water Management District
WUP	Water Use Permit
WRCA	Water Resource Caution Area
WWC	Water Well Construction
WWTP	wastewater treatment plant
ZLD	zero liquid discharge

ABBREVIATIONS

bgd	Billion gallons per day
L	Liter
mg	Milligram
mg/L	Milligram per liter
mL	Milliliter
ng	Nanogram
ng/L	Nanogram per liter
psi	Pounds per square inch
µ	Micron
µg/L	Microgram per liter

TERMINOLOGY

Term	Definition
Advanced treated water	Water produced from an advanced water treatment process for potable reuse applications.
Advanced water treatment facility (AWTF)	The treatment facility where advanced treated water is produced. The specific combination of treatment technologies employed will depend on the quality of the source water, the type of potable reuse (i.e., IPR or DPR), and the existing treatment in place.
Appropriate Treatment Technology (ATT)	The treatment technology selected by a utility to address emerging constituents and pathogens in reclaimed water as part of a potable reuse project.
Barrier	An action implemented to control microbial or chemical constituents in advanced treated water. A barrier can be technical/ engineered, operational, or managerial in nature. Log reduction credits are assigned only for technical barriers.
Concentrate	A liquid waste stream containing elevated concentrations of total dissolved solids and other constituents.
Constituent	Any physical, chemical, biological, or radiological substance or matter found in water, wastewater, and reclaimed water.
Critical control point (CCP)	A point in water treatment where control can be applied to an individual unit process to reduce, prevent, or eliminate process failure and where monitoring is conducted to confirm that the control point is functioning correctly. The goal is to reduce the risk of pathogen and chemical constituents in the finished water.
De facto potable reuse	The downstream use of surface water as a source of drinking water that is subject to upstream wastewater discharges (also referred to as "unplanned potable reuse"). Can also be applied to the downgradient use of a groundwater that is subject to upgradient wastewater discharges.
Direct potable reuse (DPR)	Introduction of advanced treated water into a raw water supply immediately upstream of drinking water treatment facility or directly into a potable water supply distribution system.
Disinfection byproducts (DBPs)	Chemicals formed by the reaction of a disinfectant (e.g., chlorine or ozone) with organic or inorganic matter found in source water including wastewater or reclaimed water.
Drinking water	Water that is supplied for potable uses (including drinking, cooking, bathing, and other household uses) that meets the standards prescribed by the National Primary Water Regulations (40 CFR Part 141) of the U.S. Environmental Protection Agency and any applicable state or local regulations.

Term	Definition
Drinking water treatment facility (DWTF)	A treatment component of a public water system that provides water for human consumption. This could be an advanced water treatment facility used for potable reuse.
Emerging constituents	Pharmaceuticals, personal care products, and other unregulated chemicals. Also referred to as constituents of emerging concern or CECs.
Engineered storage	A storage facility used to provide retention time after advanced treatment to provide time to conduct testing to evaluate water quality or to hold the water in the event that it does not meet specifications.
Finished water	Water produced by a drinking water treatment facility that meets all federal, state, and local regulatory requirements. Finished water can be introduced directly into a water supply distribution system.
Inactivation	Killing microorganisms or rendering them incapable of reproducing, and thereby preventing their ability to cause illness.
Indirect potable reuse (IPR)	The planned delivery or discharge of reclaimed water to ground or surface waters for the development of, or to supplement, potable water supply.
Log reduction	Log reduction corresponds to a reduction in the concentration of a constituent or microorganism by a factor of 10. For example, a 1-log reduction would correspond to a reduction of 90 percent from the original concentration. A 2-log reduction corresponds to a reduction of 99 percent from the original concentration.
Log reduction credit	The number of credits assigned to a specific treatment process (e.g., microfiltration, chlorine disinfection, or ultraviolet disinfection), expressed in log units, for the inactivation or removal of a specific microorganism or group of microorganisms. A reduction of 90 percent would correspond to 1-log credit of reduction, whereas a reduction of 99 percent would correspond to 2-log credits of reduction.
Nonpotable reuse	General term for all water reuse applications except those related to potable reuse.
Pathogen	A microorganism capable of causing illness in humans.
Potable reuse	Augmentation of a drinking water supply with advanced treated water from a municipal wastewater source.
Project definition	A reference for regulators, managers, and stakeholders and defines a project in terms of specific elements and parameters and includes a description of benefits, drivers, and problems that the project would address.
Public outreach	The process of communicating with and educating/informing the public on options and proposed plans for implementing potable reuse projects, as well as receiving input and suggestions from the public, including questions and concerns that need to be addressed.

Term	Definition
Public water system	A system used to provide the public with water for human consumption through pipes or other constructed conveyances, if such a system has at least 15 service connections or regularly serves at least 25 individuals; see Section 1401(4)(A) of the Safe Drinking Water Act.
Reclaimed water	Reclaimed water is defined as "water that has received at least secondary treatment and basic disinfection and is reused after flowing out of a domestic wastewater treatment facility." [F.A.C 62-610.200 (48)]
Redundancy	The use of multiple treatment barriers to attenuate the same type of constituent so that if one barrier fails, performs inadequately, or is taken offline for maintenance, the overall system still will perform effectively and risk is reduced.
Relative risk	Estimating the risks associated with a particular event for different groups of people.
Risk	In risk assessment, the probability that something will cause injury combined with the potential severity of that injury.
Source control	The elimination or control of the discharge of constituents into a wastewater collection system that at certain quantities can impact wastewater collection and treatment, are difficult to treat, or can impair the final quality of the treated wastewater effluent.
Treatment reliability	The ability of a treatment process or treatment train to consistently achieve the desired degree of treatment, based on its inherent redundancy, robustness, and resilience.
Treatment train	A grouping in series of treatment technologies or processes to achieve a specific treatment or water quality goal or objective.
Water reuse	The use of treated wastewater (reclaimed water) for a beneficial purpose.

Sources: Tchobanoglous, G., J. Cotruvo, J. Crook, E. McDonald, A. Olivieri, A. Salveson, and R.S. Trussell (2015). *Framework for Direct Potable Reuse*, WateReuse Foundation, Alexandria, VA.

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EXECUTIVE SUMMARY

Florida's need for a safe and sustainable alternative safe water supply

> *"Everyone understands that water is essential to life. But many are only just now beginning to grasp how essential it is to everything in life – food, energy, transportation, nature, leisure, identity, culture, social norms, and virtually all the products used on a daily basis." – World Business Council for Sustainable Development*

Floridians understand the value and importance of water, as well as the need for a reliable, high quality and safe water supply. The Florida Potable Reuse Commission (PRC) was created to develop a framework for potable reuse implementation in Florida that will augment future water supply and support water quality initiatives. The framework will support the implementation of potable reuse in Florida that protects public health, is compatible with Florida's unique environment, and is a viable water resource option available for communities to meet their future water demands.

Water is vital to our health, environment, prosperity and future. Though much of the state receives an average of 50 or more inches of rain per year, most of that falls within a four-month period beginning in June and ending in September. More than 75% of our water supply comes from groundwater, and the availability of additional fresh groundwater is becoming limited in many areas of the state. Floridians currently utilize nearly 6.5 billion gallons of water per day and are projected to need an additional 1.1 billion gallons of water per day by 2035. Our continued growth, status as a world travel destination, and economic success depend on the identification of safe, sustainable alternative water supplies.

The evolution to a One Water perspective

> *"All the water that will ever be is, right now." – National Geographic, October 1993*

As Florida's need, and indeed the world's need, for more water has grown, the realization that "all the water that will ever be is, right now" has resulted in a *one water* perspective. Water is a finite natural resource. We can't make more if we run out. Every drop is valuable, and its use should be carefully considered.

This one water evolution has resulted in a recognition that water should not be labeled by its source – <u>storm</u>water, <u>ground</u>water, <u>reclaimed</u> water – but should be considered simply "water." The water present today is the same water as existed with the dinosaurs and it will be the same water that exists with future generations. Whatever its source, the technology exists to treat it for any purpose, including drinking.

Potable reuse can help meet future water supply needs

Communities in Florida have been utilizing reclaimed water for landscape irrigation and industrial uses since the early 1970s. Today, Florida is the national leader in water reuse, utilizing 48 percent of the total domestic wastewater in the state for nonpotable uses.

Florida is now paving the way for potable reuse to be an alternative water supply that can be harnessed to help meet the additional water needs of the state while protecting both public health and the environment, as well as ensuring a robust economic future. Potable reuse involves the use of reclaimed water to directly or indirectly augment drinking water supplies. Indirect potable reuse (IPR) involves the planned discharge of reclaimed water to ground or surface waters for the development or supplementation of potable water supply. Direct potable reuse (DPR) involves introducing advanced treated reclaimed water into a raw water supply immediately upstream of drinking water treatment facility or directly into a potable water distribution system.

IPR has been practiced in the United States for over 50 years. Advances in technology, a growing need for drinking water, and improving affordability have resulted in several Florida communities considering IPR to meet their future needs, including recent successful demonstrations in Clearwater and by JEA in Jacksonville.

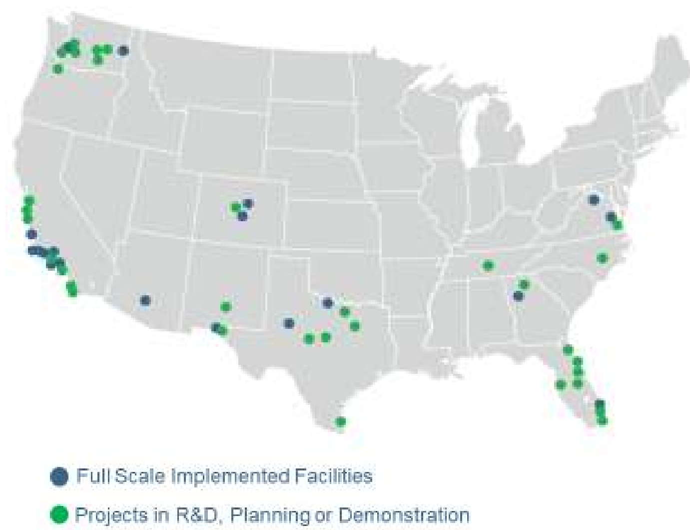

Figure ES.1. Potable Reuse Projects Implemented or In Development in the U.S. *(Courtesy of JEA)*

DPR has been utilized to meet drinking water needs in some water scarce regions of the world for more than 50 years (Windhoek, Namibia), but has only recently been implemented in the U.S. Two utilities in Texas implemented DPR in response to recent drought conditions, and others around the country are exploring DPR to meet future needs. Some Florida communities have investigated and are also considering DPR, including Altamonte Springs, Daytona Beach, Hillsborough County and JEA who have recently completed or are in the process of completing successful DPR pilot-scale or demonstration-scale projects.

Developing a potable reuse framework

Florida adopted regulations for the use of reclaimed water more than 20 years ago which set the stage for a successful statewide reuse program. Although current reclaimed water regulations exist in Florida for IPR for augmenting surface water, they do not address IPR involving groundwater replenishment, and the regulations do not address DPR. Additionally, regulations for potable reuse need to reflect advancements in technology, research efforts, and water supply planning efforts, including integrated resources planning. Florida needs to evaluate opportunities to advance the use of reclaimed water, including potable reuse to ensure the state's water supplies are sustainable for the future.

The Potable Reuse Commission (PRC) was organized to develop a framework for advancing the implementation of potable reuse in Florida. It was envisioned that a framework for the implementation of potable reuse in Florida would be developed through a stakeholder engagement process supported by technical and scientific expertise. The framework would be built on existing regulations and established approaches that protect public health and the environment.

Guiding principles

The PRC's report presents a consensus-based effort by water professionals and a diverse stakeholder group to identify and address technical, regulatory, and implementation barriers to potable reuse in Florida. The PRC includes representatives from WateReuse Florida, Florida Water Environment Association Utility Council, Florida Section American Water Works Association Water Utility Council, and stakeholders representing agriculture, environment, public health, associated industries, and the Florida Department of Health. In addition, the Florida Department of Environmental Protection and representatives from the South Florida Water Management District, Southwest Florida Water Management District and St. Johns River Water Management District participated in the PRC as *ex officio* members. Collectively, these stakeholders recognized that advancing potable reuse within Florida required a common and united purpose.

The PRC examined Florida's existing regulatory framework of statutes, rules, and practices that apply to the processes involved in the potable reuse of reclaimed water to determine what changes to that framework would better facilitate potable reuse. In this effort, the PRC adhered to the following principles:

- Protect public health
- Protect the environment
- View reclaimed water as a potential source water for potable use
- Where possible, achieve public health and environmental protection through existing regulatory programs
- Respect existing state and federal permitting programs applicable to potable reuse

The PRC also recognized the need for this process to be conducted in a way to encourage broad stakeholder participation and to provide information in a public forum. Monthly public meetings, workshops and teleconferences were held during which the public was given an opportunity to comment, ask questions, voice concerns, and provide input to the framework.

The PRC is recommending the framework in this document to proactively ensure potable reuse is implemented safely in a manner that is protective of the environment, and with consideration for the interests of Florida's industry, agriculture, and other stakeholders.

Potable reuse treatment processes are proven, safe, and protective of public health and the environment

Potable reuse has the potential to contribute to a diversified, resilient, and sustainable water supply portfolio that includes conservation, nonpotable reuse, desalination, stormwater and traditional groundwater and surface water supplies. As previously noted, experience with potable reuse is expanding in other states and abroad, including Australia and Singapore. This experience and other factors, such as advancements in technology and recent research efforts, demonstrate the safety and benefits of potable reuse.

The PRC acknowledges reclaimed water is an alternative water supply that requires appropriate treatment and water quality assurances. The treatment processes used in potable reuse have existed for decades and are proven effective in producing high quality, safe drinking water that is protective of public health and the environment. A common feature of these treatment processes is the use of a "multi-barrier approach" which uses a combination of treatment processes to provide reliability and redundancy within the process to produce water protective of public health and the environment.

In addition to the ability of the treatment process to produce safe drinking water, the utility implementing potable reuse must have the technical, managerial, and financial (TMF) capacity to provide safe and dependable water to its customers. Under the Safe Drinking Water Act, Florida has an existing program to assess the TMF capacities of water systems and assist those in need of developing or improving their TMF capacity. For a utility considering potable reuse, they must demonstrate the ability to:

- Build, operate, manage, and sustain a potable reuse system for the long-term
- Plan, achieve, and maintain regulatory compliance
- Provide effective public health and environmental protection
- Make efficient use of public funds and sustainable public investments

Consensus-based recommendations of the PRC

> *"Water is personal, water is local, water is regional, water is statewide. Everybody has a different idea, a different approach, a different issue, a different concern. Water is the most personal issue we have." – Susan Marks, Aquashock: The Water Crisis in America, 2009*

As discussed, the PRC represents a diverse group of Florida water stakeholders. The proposed framework provides a number of consensus-based recommendations from the PRC to advance potable reuse within the state and ensure that it is done safely, in a manner that is protective of the environment, and with consideration for the interests of the state's industry and agriculture.

The PRC identified a number of proposed regulatory changes that would require the Florida Legislature to enact legislation to provide authority and direction to FDEP to revise existing rules and/or adopt new rules to advance potable reuse within the State of Florida. The proposed regulatory framework provided in this document is recommended to ensure protection of public health and the environment. The proposed recommendations will provide regulatory and financial surety to water and wastewater utilities, and will ensure consistency in permitting and implementation of potable reuse projects throughout the state. A summary of those recommendations is included in the following Summary of Regulatory Recommendations.

SUMMARY OF REGULATORY RECOMMENDATIONS

The PRC identified a number of proposed regulatory changes (Section 10) that would require the Florida Legislature to enact legislation to provide authority and direction to the Florida Department of Environmental Protection (FDEP) to revise existing rules and/or adopt new rules to advance potable reuse within the State of Florida.

Place potable reuse requirements in drinking water regulations

The PRC recommends moving Florida's existing reclaimed water regulations that apply to potable reuse (in Chapter 62-610, Florida Administrative Code [F.A.C.]) into the appropriate drinking water regulation rule chapters of Division 62, F.A.C. The PRC also recommends that new regulations addressing potable reuse also be placed within Florida's drinking water program regulations. The goal in doing so is to separate nonpotable reuse from potable reuse and place potable reuse requirements under the appropriate drinking water regulation chapters in Division 62, F.A.C. and to have a clear, concise, and enforceable point of regulatory compliance.

Revise existing drinking water regulations to specify reclaimed water as a water supply source and employ appropriate treatment technologies to address pathogens and emerging constituents

Existing drinking water regulations address differences in various sources of water. For example, treating surface water versus groundwater requires more disinfection because it is more common to find waterborne pathogens in surface waters like rivers or lakes than in aquifers. Similarly, reclaimed water, which comes from treated wastewater, may have elevated concentrations of pathogens such as bacteria and viruses. It may also have higher concentrations of emerging constituents, such as pharmaceuticals and personal care products. In addition, other chemicals could potentially be present in reclaimed water coming from discharges by industrial and commercial users.

Require potable reuse to meet drinking water standards

To protect public health, the PRC recommends revising Florida's drinking water regulations (Division 62 F.A.C.) to consider reclaimed water as a source water. With this recommendation, drinking water produced from all potable reuse projects would be required to meet existing primary and secondary drinking water standards.

Provide pathogen treatment to meet drinking water standards

In addition, the PRC recommends that FDEP adopt potable reuse treatment requirements for pathogens within the drinking water regulations. This would be done by having a water utility examine the potential for pathogens in the reclaimed water source, and then apply appropriate treatment technology to reduce, remove or inactivate those pathogens to acceptable water quality standards consistent with current drinking water rules. With this recommendation, pathogens in potable reuse projects would be treated to meet drinking water standards.

Require industrial pretreatment and source control

To further support this approach, the PRC also recommends that existing industrial pretreatment requirements (found in chapter 62-625, F.A.C.) apply to potable reuse projects. Industrial pretreatment requirements prevent unacceptable industrial discharges from entering domestic wastewater facilities. To complement this, the PRC recommends domestic wastewater facilities used for potable reuse also implement source control to prevent other unacceptable wastes from entering those facilities.

Addressing emerging constituents

Finally, the PRC recommends addressing emerging constituents, such as pharmaceuticals and personal care products, in potable reuse. Currently, there are no established standards for emerging constituents. As such, the PRC recommends FDEP adopt a treatment technique approach to address emerging constituents.

The treatment technique the PRC recommends is the use of Appropriate Treatment Technology (ATT). The ATT concept involves using technically and economically feasible treatment technologies to treat emerging constituents. These are proven means for treating water.

The recommended approaches for employing ATT to treat emerging constituents vary slightly between DPR and IPR. For DPR, the PRC recommends including reclaimed water in the source water characterization of the drinking water treatment facility and applying ATT as necessary with the existing drinking water treatment process to meet the required treatment objectives. For IPR, the evaluation must consider the impact of the environment (soil, groundwater or surface water) on the treatment, attenuation and dilution of emerging constituents. Depending on the project, ATT may need to be employed prior to discharge to the environment, after discharge to the environment but before final drinking water treatment, or some combination of both.

Monitoring should also be required when employing ATT. Monitoring would be done before and after use of the ATT to ensure ATT is working effectively. Because it is not practical to monitor emerging constituents directly, a surrogate would be monitored to demonstrate effective treatment. If that monitoring detects inadequate treatment (i.e., “off-spec water”), the water would be retreated or discharged elsewhere and not sent out for public consumption.

For IPR projects environmental monitoring is recommended. Monitoring is currently required for nonpotable reuse projects discharging reclaimed water to groundwater or surface waters. To address the potential risk associated with emerging constituents, the PRC recommends FDEP amend these monitoring requirements to also require monitoring for a representative emerging constituent in IPR projects. The utility would select the representative emerging constituent with FDEP review and approval. If that monitoring detects an issue, the utility would report the issue to FDEP and work with FDEP to determine the cause and address the issue.

The specific treatment processes used with ATT will vary depending upon the project scenario, emerging constituent(s) concentrations, desired finished water quality, and the capability of the facility. Specific ATTs employed may also evolve over time as new treatment technologies develop, new emerging constituents are identified, and criteria for emerging constituents are further refined.

Other recommendations to improve potable reuse regulation while protecting the public health and environment

In addition to the items discussed above, the PRC also recommends the following:

- **Continue to exempt DPR from needing to obtain a consumptive use permit (CUP) or water use permit (WUP).** Existing Florida Statutes do not require a CUP or WUP for reclaimed water use because no water is withdrawn from the environment. This should continue to apply to DPR as the potable reuse framework is implemented.
- **Clarify that IPR projects must comply with existing spring discharge standards.** Currently Rule 62-610.850, F.A.C., provides "reuse and land application projects shall not cause or contribute to violations of water quality standards in surface waters." Revisions to this rule may be necessary as the other potable reuse recommendations are implemented to clarify that existing surface water quality standards apply to groundwater discharges of reclaimed water migrating into spring flow as a result of an IPR project.
- **Expand existing definition of IPR to include groundwater recharge when used to augment the supply of water available for drinking water**. The current, Chapter 62-610, F.A.C., definition of "indirect potable reuse" is limited only to the discharge of reclaimed water to surface waters. This should be expanded to include groundwater so that all types of IPR projects fit within the definition.
- **Specify point of compliance with drinking water standards.** For potable reuse, confusion could occur as to where in the process drinking water standards must be met. To ensure clarity and protect public safety, the statutes and rules should specify that compliance is determined at the point where finished potable water is finally discharged from the drinking water treatment facility.
- **FDEP and the water management districts should enter into a memorandum of agreement to coordinate permitting for IPR projects**. A number of permits are required from FDEP and the water management districts to authorize IPR projects. Coordination among these agencies on these permits avoids duplication and ensures consistency. Coordination also ensures protection of public health and the environment and reduces the burden upon the permit applicant. This coordination review would only occur at the applicant's request.
- **FDEP should review the current groundwater recharge requirements in Chapter 62-610, F.A.C.** in conjunction with the effort to move the IPR requirements in that chapter to the drinking water sections of Division 62. The goal of this review would be to ensure continued environmental and public health protection.

Next steps

Florida must have additional sustainable alternative water supplies to meet the future needs of its residents, agriculture, and industry, and to secure a robust economic future. Potable reuse is one such alternative supply. Potable reuse has been implemented in other states and countries and has been proven to be safe and protective of the environment.

This proposed framework is recommended to protect public health and the environment. The proposed recommendations will also provide regulatory and financial surety to water and wastewater utilities, and consistency in permitting and implementation of potable reuse projects. Failure to implement this framework may jeopardize the ability to meet future water supply needs efficiently and cost-effectively, risks inconsistent implementation of potable reuse throughout the State, and increases the potential risk to public health and the environment.

As a result, the PRC recommends the following actions to further the implementation of this proposed framework.

Implement regulatory recommendations collectively and through Technical Advisory Committees

The PRC intends the regulatory recommendations in this framework to be undertaken collectively. Many of the recommendations in this report require action by the Florida Legislature and/or FDEP. Where it is recommended that FDEP adopt or modify rules, the PRC recommends FDEP convene and lead one or more technical advisory committees (TACs) of a broad and diverse group of stakeholders to assist in the development of these regulations. These TACs would include representatives from the wastewater utility industry, the water utility industry, the environmental community, the business community, the health community, the general public, and the agricultural community. By developing these regulations in this manner, FDEP can address multiple perspectives and develop rules that will protect the public health and environment.

Incentivize and protect public investments in potable reuse

Potable reuse projects require significantly more planning and financial investment than other types of reuse projects. Utilities need certainty that the investment of their ratepayers' funds will be protected. The PRC recommends that it, in coordination with FDEP and the water management districts, would facilitate the creation of a working group to examine CUP and WUP statutes and rules in the context of incentivizing and protecting investments in these long-term potable reuse projects. The working group should consist of diverse stakeholders, including but not limited to, PRC members, water management district and FDEP representatives, water and wastewater utilities representatives, agricultural organizations representatives, environmental organizations representatives, and other interested parties. One of the goals of the working group will be to develop consensus-based recommendations regarding clarifying existing statutes and rules related to impact offsets derived from the use of reclaimed water and how IPR projects are to be treated as an alternative water supply in determining the duration of the CUP or WUP. The working group would also further explore additional consumptive use permitting incentives that may facilitate the development of potable reuse projects and examine how the water management districts' cost share funding programs can be leveraged to facilitate development of potable reuse projects. The development of a plan by the working group regarding the implementation of any recommendation is also proposed. If there is consensus on recommendations by the working group, then such changes will be recommended to the Florida Legislature or FDEP and the water management districts as appropriate.

Continue public education and outreach

Public confidence, understanding, acceptance, and support are essential for the successful implementation of potable reuse projects. Achieving this public confidence, understanding and support requires extensive public education and outreach by the water industry, communities considering potable reuse, FDEP, and the water management districts.

The PRC will develop and implement a statewide potable reuse education and outreach program contingent upon future funding. The PRC recommends that FDEP and the water management districts engage in activities that positively impact public perception of potable reuse. To that end, FDEP and the water management district should be prepared to communicate openly and candidly with the public and stakeholders not only about the challenges associated with implementing potable reuse, but also that potable reuse has been and can be done safely. There is no new water on the planet. We must efficiently and effectively optimize every source of water available to ensure our future.

PART 1: INTRODUCTION AND BACKGROUND

CHAPTER 1: INTRODUCTION

1.1 Background and Purpose

The State of Florida faces the significant challenge of continuing to meet all water supply needs while protecting natural resources. Between 2015 and 2035, the population in Florida is expected to grow by 27%, from 19.8 million to 25.2 million. During the same period, it is estimated that Floridians will require an additional 1.1 billion gallons of water per day (bgd) beyond 2015 use, growing from 6.4 bgd in 2015 to 7.5 bgd in 2035, a 17% increase (FDEP, 2017). In addition, different areas of the state face a range of water resources issues. Groundwater is the primary source of drinking water for Florida; however, increasing groundwater withdrawals are impacting springs, streams, lakes, wetlands and overall natural systems throughout the state. Managing water resources in Florida is crucial to protecting the environment, maintaining water supply, and supporting the state's substantial agriculture industry. To meet the increasing competition for water resources in the state, new strategies are necessary. Potable reuse, the augmentation of drinking water supplies with advanced treated water (i.e., water produced from an advanced water treatment process for potable reuse applications), is a potential sustainable alternative water supply to address future demands. Potable reuse has emerged as a viable alternative water resource for some entities because the cost of development of potable reuse has become competitive with other alternative water sources such as brackish and saline sources. A framework for implementing potable reuse in the state is essential to advance potable reuse in Florida.

Potable Reuse is the "augmentation of drinking water supplies with advanced treated water."

Florida has an existing statutory and regulatory framework in place for the management of the state's water resources. The Water Management Districts (WMDs) are required to assess the condition of water resources within their district against existing and future demands, to identify water resource caution areas (WRCA) or water use caution areas (WUCA), where existing or future undesirable environmental impacts result from those demands. Presently more than two thirds of the state has been designated as either a WRCA or WUCA. In some of these areas the traditional source of potable water, groundwater, is not adequate to meet projected future demands. Florida's natural climate variability combined with the impacts of climate change have resulted in more frequent weather extremes, making the impacts of short-term droughts severe. Some of the observed environmental impacts resulting from stressed groundwater aquifers include diminished spring flow, degraded wetlands and saltwater intrusion into groundwater basins particularly in the coastal regions.

Challenges facing Florida's Water Resources

- *Increasing population*
- *Competing demands*
- *Development*
- *Intermittent droughts*
- *Salt water intrusion*
- *Water Resource Caution Areas*
- *Springs Priority Focus Areas*
- *Basin Management Action Plan requirements*

To address the future water supply challenges while maintaining and restoring its unique water dependent environment, the state has proactively pursued reductions in water demands through conservation while developing the availability of alternative water supplies. The WMDs, regional water supply authorities, and local utilities are actively engaged in developing and implementing water supply plans which encompass alternative water supply strategies and technologies including expanded water reuse. Florida does not have a shortage of water resources similar to other regions of the country.

From a water resource perspective, Florida is a water rich state. However, until recently, because of the accessibility and high quality of available relatively inexpensive fresh groundwater, Florida has not pursued development of its other water resources. Development of most of Florida's other water resources for potable purposes will require a significant investment of effort and resources. Over the past thirty years, reuse has emerged as an alternative water supply available to meet some of the future needs of the state. The cost of producing potable reuse has become comparable to the costs associated with some of the other water supply alternatives, allowing potable reuse to emerge as another viable alternative water supply source in Florida.

Potable Reuse supports a diversified, resilient, and sustainable water supply portfolio.

Until recently reuse has been utilized for nonpotable purposes such as landscape and golf course irrigation, industrial uses, agriculture, groundwater recharge, and other uses which offset demand for existing potable sources. Florida is a recognized leader of reuse for beneficial purposes. Implementing potable reuse will increase the potential opportunity for reuse to be evaluated for local water supply need. Potable reuse will provide water suppliers with another alternative source to consider when developing alternative sources. A number of potable reuse projects are under consideration and being implemented in several areas of the state. Pilot and demonstration projects are provided in **Section 2.5.**

Potable reuse is another potential tool in the toolbox to support a diversified, resilient, and sustainable water supply portfolio that also includes conservation, brackish groundwater, brackish and saline sources, surface water, nonpotable reuse, and traditional water supplies. Experience with potable reuse has been increasing in other states and abroad (including Australia, and Singapore). This experience and advancements in technology and research have demonstrated the safety and benefits of potable reuse. Technology advancements have made the costs of treating potable reuse cost competitive with other alternative water supply sources such as seawater and brackish desalination.

Florida adopted regulations protective of public health and the environment for the use of reclaimed water over two decades ago, which set the stage for a successful statewide reuse program.[1] Existing Florida regulations provide for the implementation of indirect potable reuse (IPR) for augmenting a surface water supply. However, regulations do not address IPR through groundwater replenishment or the implementation of direct potable reuse (DPR), the direct augmentation of a drinking water system with advanced treated reclaimed water. Additionally, regulations for potable reuse need to reflect advancements in technology, research efforts, and water supply planning efforts, including integrated resources planning.

Recognizing the need for a framework to implement potable reuse in Florida, several utility organizations proposed establishing a broad stakeholder engagement process supported with technical and scientific expertise. This process would evaluate the current state of potable reuse practices in other

[1] Chapter 62-610 Part V, F.A.C. https://www.flrules.org/gateway/ChapterHome.asp?Chapter=62-610

states, critically assess existing regulations in Florida, and develop a framework that would enable the expansion of indirect potable reuse projects and establish an expanded regulatory pathway for direct potable reuse in Florida. This framework would be built on existing regulations and established approaches that protect public health and the environment.

The Potable Reuse Commission (PRC) was organized to develop a framework report for advancing the implementation of potable reuse in Florida.

1.2 Overview of Florida Potable Reuse Commission

The PRC was established as a consensus-based body of stakeholders to develop a framework for potable reuse implementation in Florida that will augment future water supply and support water quality initiatives. This partnership, which included water professionals and a diverse water-related stakeholder group, has worked collaboratively to produce consensus based recommended policies and a regulatory framework to help inform elected officials and regulatory agencies on the development of statutory and regulatory basis for the implementation of potable reuse.

PRC Mission:

Develop a framework for potable reuse implementation in Florida that will augment future water supply and support water quality initiatives.

The PRC adopted the following guiding principles for developing the framework for Florida:

- Consensus-based effort by water professionals and a diverse stakeholder group to identify and address technical, regulatory, and implementation barriers to potable reuse in Florida.
- The PRC will provide recommendations for a path to establish a statutory framework for the further implementation of potable reuse.
- The PRC will provide leadership in developing the regulatory framework for implementation of potable reuse as an alternative water supply option (right water, right time, and right place).

The members of the PRC include utility representatives from WateReuse Florida (WRFL), Florida Water Environment Association (FWEA) Utility Council, Florida Section American Water Works Association (FSAWWA) Water Utility Council, and stakeholders representing agriculture, environment, public health, associated industries, and the Florida Department of Health (FDOH). The members of the PRC are listed in **Table 1.1**.

Table 1.1 Members and Officers of the Florida Potable Reuse Commission

Representing (Office)	Name	Affiliation
WateReuse Florida (PRC Chair)	Lynn Spivey	City of Plant City
WateReuse Florida (PRC Vice Chair)	Bart Weiss	Hillsborough County
Florida Water Environment Association Utility Council (PRC Vice Chair)	Paul Steinbrecher	JEA

Florida Section American Water Works Association Water Utility Council (PRC Vice Chair)	Brian Wheeler	TOHO Water Authority
Florida Department of Health	Dean Bodager	Bureau of Epidemiology, Food and Waterborne Disease Program
Agriculture	Kerry Kates	Florida Fruit & Vegetable Association
Public Health	Dr. Donna Petersen	University of South Florida College of Public Health
Associated Industries of Florida	Jim Spratt	Magnolia Consulting
Florida Water Environment Association Utility Council	Ed Torres	City of Altamonte Springs
Florida Water Environment Association Utility Council	Jo Ann Jackson*	City of Altamonte Springs
Environment	Garrett Wallace	Nature Conservancy of Florida
Florida Section American Water Works Association Water Utility Council	Chuck Weber	City of Tampa
Florida Water Environment Association Utility Council (Alternate)	Rick Hutton	Gainesville Regional Utilities
Florida Section American Water Works Association Water Utility Council (Alternate)	Lisa Wilson-Davis	City of Boca Raton

* Jo Ann Jackson representing the City of Altamonte Springs, Florida Water Environment Association Utility Council served on the PRC through May 16, 2019.

Ex-officio members of the PRC include the Florida Department of Environmental Protection (FDEP) and Florida's Water Management Districts (WMDs), as listed in **Table 1.2**.

Table 1.2 Ex-Officio Members of the PRC

Ex-Officio Members of PRC
Florida Department of Environmental Protection
Northwest Florida Water Management District
Suwannee River Water Management District
St. Johns River Water Management District
South Florida Water Management District
Southwest Florida Water Management District

The FDEP and the State's WMDs have indicated their support for the Florida PRC and its collaborative efforts and participated in all meetings and workshops. Additionally, South Florida, Southwest Florida, and St. Johns River WMDs provided financial support through WateReuse Florida.

1.3 Summary of the PRC Process

The PRC established a process that was transparent, stakeholder driven, and supported by technical and scientific information to develop a policy and regulatory framework for the implementation of potable reuse. There were two primary objectives of the process: 1) developing a summary of industry best practices on implementing potable reuse; and 2) the development of a regulatory framework, including specific legislative and regulatory recommendations, to advance potable reuse in Florida.

The efforts of the PRC were conducted through monthly PRC meetings and three public workshops to discuss technical topics. All meetings were advertised in the Florida Administrative Register and were open to the public. A website was established to post meeting agendas, presentations, meeting minutes, reports and other relevant information.

- **Monthly PRC meetings.** Starting in February 2018, the PRC held monthly meetings to plan and direct the regulatory and technical efforts. The meetings were held in person with conference call participation. Mark Hammond, former resource management director for the Southwest Florida Water Management District was contracted to facilitate the meetings and manage the PRC efforts. The meetings provided a forum for the PRC members to discuss the process and to make decisions in support of the objectives of the PRC, including the development of regulatory recommendations.
- **Workshops.** Three advertised workshops, open to the public, were held to discuss regulatory and technical topics related to potable reuse. The PRC collaborated with the Water Research Foundation (WRF) to organize and facilitate these day-long workshops. WRF is an internationally recognized 501c3 nonprofit research organization that is a respected source of research demonstrating that potable reuse can be protective of public health when appropriate treatment and water quality criteria are employed. The workshops covered a range of policy topics and issues related to potable reuse. The purpose of the workshops was to present regulatory and technical information, receive input from stakeholders, and develop a summary of recommended best practices for potable reuse in Florida.

The PRC established a Communication Team and a Regulatory Team to assist in this process. The Communication Team held internal discussions on short and long-term communication efforts needed to advance the PRC's goals for potable reuse and submitted those concepts to the PRC for discussion. The Regulatory Team reviewed the state's laws and regulations regarding reuse and submitted options and recommendations to the PRC for consideration.

The outcomes of the PRC meetings, supported by the workshops, resulted in this regulatory framework for implementing potable reuse in Florida. The PRC efforts were based on consensus-based approval of the findings and recommendations.

1.4 Scope and Organization of the Framework

This framework report aligns with the outcomes of the PRC process. Based on the PRC meetings and workshop, the report is organized into three parts:

- **Part 1: Introduction and Background.** The chapters in this part provide a summary of the PRC and an overview of potable reuse, including a summary of potable reuse activities in the United States (U.S.) and in Florida.
- **Part 2: Managerial, Public Engagement, and Technical Best Practices.** The chapters in this part address several areas: research efforts; public health considerations; available resources; and best practices for managerial, technical, and public engagement topics. The best practices reflect current experience with potable reuse across the U.S. and the current state-of-the-science.
- **Part 3: Florida Potable Reuse Regulatory Framework.** The chapters in this section present the proposed regulatory approaches for the various potable reuse scenarios envisioned for Florida, including specific recommendations endorsed by the PRC.

The best practices listed in Part 2 are focused on technical, managerial, regulatory, and outreach components of a potable reuse program and are organized into three categories: regulatory; industry best practices; and outreach. Certain components must be addressed in regulations to ensure that potable reuse is protective of public health and the environment. Many components of a potable reuse program are more appropriately addressed in industry best practices to allow for flexibility as experience with projects is gained over time and additional data become available from experience and advances in research. Since public engagement is considered a critical element of a potable reuse program, public outreach was an important focus in the process.

The recommendations presented in Part 3 were developed by the PRC to address regulations pertaining to potable reuse, inclusive of IPR and DPR. The recommendations support potable reuse in Florida that is protective of public health and the environment.

CHAPTER 2: POTABLE REUSE

In the U.S., drinking water supplies have been derived from a variety of local and regional sources, including local and imported surface water, groundwater, stormwater capture, and desalinated brackish water and seawater. Florida's drinking water supplies primarily come from groundwater sources as shown in **Figure 2.1.** In many places in the U.S., and particularly Florida, these supplies are being stressed by factors such as increasing demand from population growth, urbanization, extended droughts, and climate change. As a result, alternative strategies such as potable reuse are needed to help communities meet future water demands and develop more reliable and sustainable water supplies (Tchobanoglous et al., 2015). Potable reuse involves the augmentation of a drinking water supply with advanced treated water, which is water produced from an advanced water treatment process for potable reuse applications. In this chapter, an overview of potable reuse is provided along with examples in the U.S., including Florida.

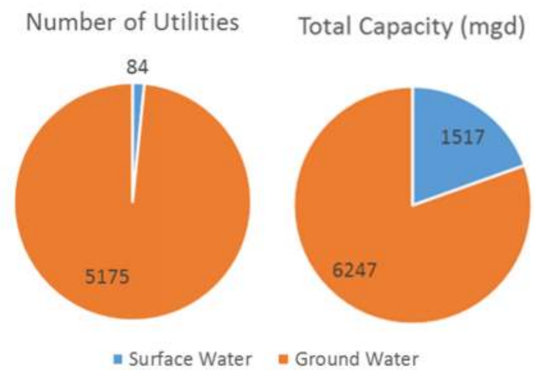

Figure 2.1: Florida water supply by source.

2.1 Overview of Water Reuse Applications

Water reuse involves a range of uses, including nonpotable and potable reuse applications. Nonpotable reuse involves the use of reclaimed water for applications other than augmenting potable water supplies. Potable reuse includes *de facto* (unplanned) potable reuse and planned potable reuse (i.e., groundwater replenishment, surface water augmentation, and DPR).

2.1.1 Nonpotable Reuse

The planned use of reclaimed water for nonpotable reuse applications has been practiced in Florida and across the U.S. for many years. Florida leads the U.S. in nonpotable reclaimed water use (NRC, 2012). In 2016, nonpotable reuse in Florida reached 760 million gallons per day with the use categories shown in **Figure 2.2**. Major uses included public access reuse systems used to irrigate residences, golf courses, parks, and schools (58%), industrial (17%), groundwater recharge (12%), and agriculture irrigation (8%).

Using reclaimed water has had many advantages in Florida, including offsetting potable water demand, thereby reducing demand for ground and surface water, reduction or elimination of wastewater discharges, and recharge of groundwater (Toor and Rainey, 2016).

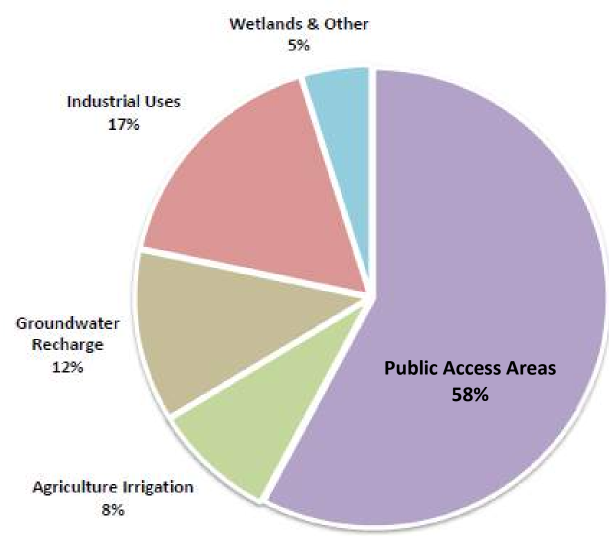

Figure 2.2: 2016 Reclaimed water utilization in Florida. (FDEP, 2017)

Reclaimed water **(Figure 2.3)** has provided an environmentally sound means of both wastewater and water resource management in Florida. Reclaimed water use reduces environmental impacts by reducing discharge to surface waters and helps conserve potable water supplies by providing an alternative affordable water source to meet irrigation and nonpotable commercial and industrial needs. Many reuse irrigation applications (golf course, agricultural, and residential irrigation; groundwater recharge, etc.) ultimately provide some recharge to groundwater in Florida.

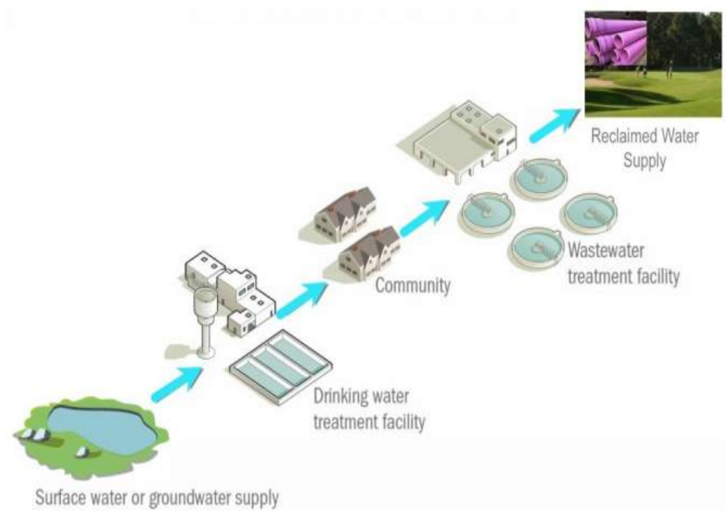

Figure 2.3: Schematic of nonpotable reuse scenario. (Source: Modified from AWWA, 2015)

2.1.2 Unplanned (*de facto*) Potable Reuse

De facto potable reuse (**Figure 2.4**) is the unplanned or incidental presence of treated wastewater in a downstream surface water supply source or downgradient in the case of groundwater impacted by the discharge of treated wastewater (NRC, 2012). The downstream use of surface water as a source of water that is subject to upstream wastewater discharges is shown in **Figure 2.5**.

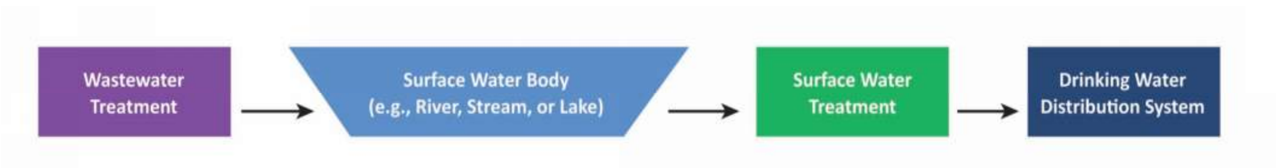

Figure 2.4: Schematic of unplanned (*de facto*) potable reuse. Figure courtesy of Olivieri et al. (2016).

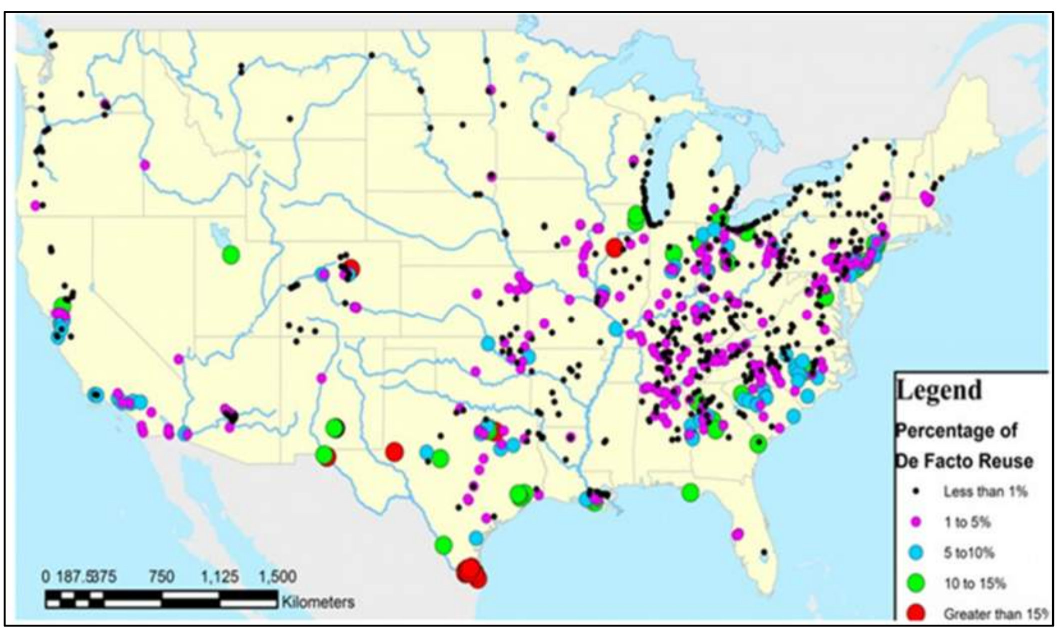

Figure 2.5: The downstream use of surface water as a source of water that is subject to upstream wastewater discharges. (Rice et al., 2013)

2.1.3 Planned Potable Reuse

Planned potable reuse involves the intentional use of reclaimed water to augment drinking water supplies. IPR is the planned delivery or discharge of reclaimed water to ground or surface waters for the development of, or to supplement, potable water supply (**Figure 2.6**). IPR has been practiced in the United States for over 50 years (Crook, 2010).

Figure 2.6: Indirect potable reuse schematic. (Adapted from USEPA, 2018)

When the environmental buffer is a groundwater aquifer, reclaimed water can be applied by the discharge of reclaimed water through rapid infiltration basins (RIBs) to take advantage of the potential for soil aquifer treatment or by direct injection through a well depending on the evaluation of site-specific conditions as determined by comprehensive feasibility study. For example, the level-of-treatment evaluation in a karst aquifer system would address the potential for increases in certain constituents, such as arsenic that could result from anaerobic biological activity stimulated by the introduction of advanced treated water into an aquifer.

The main functions of the environmental buffer include providing: (1) additional treatment through natural processes, which is dependent on site conditions; (2) water quality equalization; and (3) time to respond to any process failures or out-of-compliance water quality monitoring results (Drewes and Khan, 2011). Longstanding experience, including numerous examples in the U.S., has demonstrated that groundwater replenishment and surface water augmentation can be protective of public health (NRC, 2012).

An emerging application is DPR, which involves introducing advanced treated water into a raw water supply immediately upstream of a drinking water treatment facility or directly into a potable water supply distribution system when the water meets all drinking water standards. In place of an environmental buffer, these systems require additional storage, treatment, and other safety features to provide treatment reliability and an appropriate failure response time. DPR can provide flexibility beyond IPR applications, including avoiding the need for using groundwater or surface water and by utilizing existing drinking water infrastructure.

As shown in **Figure 2.7,** the two main types of DPR include:

- **Advanced treated water is introduced into a raw water supply immediately upstream of a drinking water treatment facility.** In the United States, two projects using this form of DPR have been permitted, both in Texas: (1) Colorado River Municipal Water District's Big Spring Raw Water Production facility, and (2) the City of Wichita Falls DPR Project.[2]
- **Advanced treated water that is introduced directly into a potable water distribution system.** A long-standing DPR project in Windhoek, Namibia, is the only example of this form of DPR in

[2] The Wichita Falls Direct Potable Reuse project in Texas was permitted by the Texas Commission on Environmental Quality as an emergency water supply and was operated from July 2014 to July 2015.

operation (Tchobanoglous et al., 2015). The City of Altamonte Springs, FL and El Paso Water in Texas, have completed pilot testing for this type of DPR. El Paso Water is in the process of permitting a full-scale DPR facility.

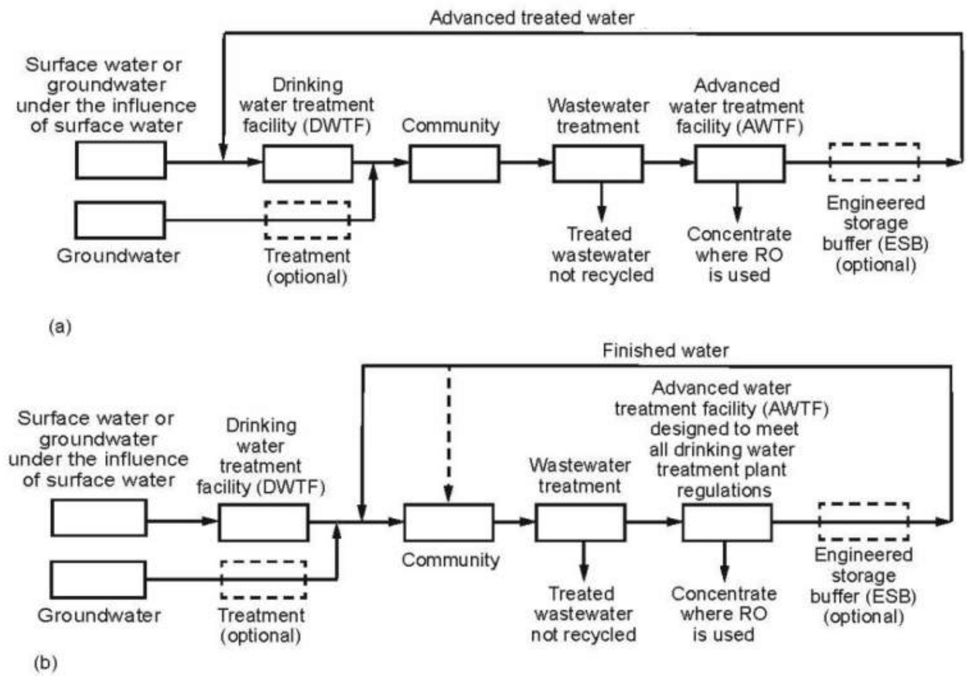

Figure 2.7: Flow diagrams for DPR: (a) advanced treated water is introduced into the raw water supply immediately upstream of a drinking water treatment facility; and (b) advanced treated water introduced directly into a potable water distribution system. Figure courtesy of Tchobanoglous et al. (2015).

2.2 National Research Council Studies on Potable Reuse

The National Research Council (NRC, 1998, 2012) conducted two assessments of potable reuse in the past 20 years. During these assessments, potential challenges were identified and appropriate solutions were suggested to ensure planned potable reuse is a safe practice from the perspective of public health. The 1998 study focused solely on IPR, while the 2012 study addressed both IPR and DPR. The 2012 study benefited from advances made in treatment technologies and monitoring capabilities along with increased research.

The 2012 NRC report concluded that “expanding water reuse – the use of treated wastewater for beneficial purposes including irrigation, industrial uses, and drinking water augmentation – could significantly increase the nation’s total available water resources.” This endorsement of reuse as an option to supplement and diversify drinking water supply by a science-based, expert body played an important role in convincing decision makers that the practice of potable reuse was worthy of consideration in the water resource planning process.

Both studies emphasized the need for potable reuse projects to be protective of public health. Findings from NRC (2012) with respect to chemical and microbial constituents indicate that potable reuse does not present any higher risk than current drinking water treatment systems. These findings are summarized in **Table 2.1.**

Table 2.1 Findings from NRC (2012) as Related to Risks from Chemical and Microbial Constituents

Type of Risk	Findings
Risk from chemical constituents	Water quality is ensured through source control programs, treatment technologies that meet drinking water MCLs and other limits, and monitoring for constituents that present a public health risk. For advanced water treatment trains, most chemicals are not detected; those that are detected are found at levels lower than those found in conventionally treated drinking water supplies (NRC, 2012).
Risk from microbial constituents (i.e., pathogens)	The risk from pathogens in potable reuse "does not appear to be any higher, and may be orders of magnitude lower, than currently experienced in at least some current (and approved) drinking water treatment systems (i.e., *de facto* reuse)" (NRC, 2012).

Sources: NRC (2012) and Tchobanoglous et al. (2015).

2.3 Reclaimed Water as a Drinking Water Supply Source

The Safe Drinking Water Act (SDWA) was established in 1974, during an era when the focus of regulatory efforts was limited to source waters from streams, rivers, lakes, and groundwater aquifers. Since then, reclaimed water has increasingly been used throughout the nation as a source of water supply. In addition, advanced water treatment technologies, such as advanced oxidation processes, are becoming more common. By building on key elements of the SDWA and using available advanced treatment processes, the water industry can use reclaimed water as a drinking water supply source.

2.4 Potable Reuse Projects

Potable reuse has been practiced in United States for a number of decades; however, it has evolved over the past 50 years. As water availability and water quality issues became more prevalent in rapidly growing areas, water managers began to consider the use of reclaimed water to augment water supplies and improve water quality. Between the 1960s and 1980s, a small number of potable reuse projects were built. Several of these early projects were groundwater recharge projects built in Southern California. In the 1960s, groundwater recharge with reclaimed water was used in Los Angeles County Sanitation District's Montebello Forebay project, followed in 1976 by Orange County California's Water Factory 21. In the 1970s, the Upper Occoquan Service Authority in Fairfax County, Virginia used effluent from an advanced treatment plant to augment a surface water reservoir. During the 1980s projects were developed in Texas and Georgia.

As water scarcity became a more serious issue in the 1990s, other communities began to consider potable reuse projects based on the experiences in California, Virginia, Georgia, and Arizona. In addition, advances in the science and technology associated with potable reuse helped demonstrate the increased confidence in public health protection and acceptance by the public. Public acceptance of alternative water supply sources has also increased as conventional sources have been adversely affected by recent severe droughts in states like Texas, California, and Arizona, and demand has increased amid rapid population growth.

In the 2000s, severe drought conditions were a driver for utilities to implement DPR projects. Communities that have implemented DPR include Big Spring, Texas (2013) and Wichita Falls, Texas (2014). DPR was essentially the only feasible solution to address the water resource challenges for these communities.

The map in **Figure 2.8** shows the locations of a number of potable reuse projects across the United States. The map represents existing projects, pilot and demonstrations projects, and planned projects. The majority of projects are in California; however, many other states, including Florida, are pursuing potable reuse.

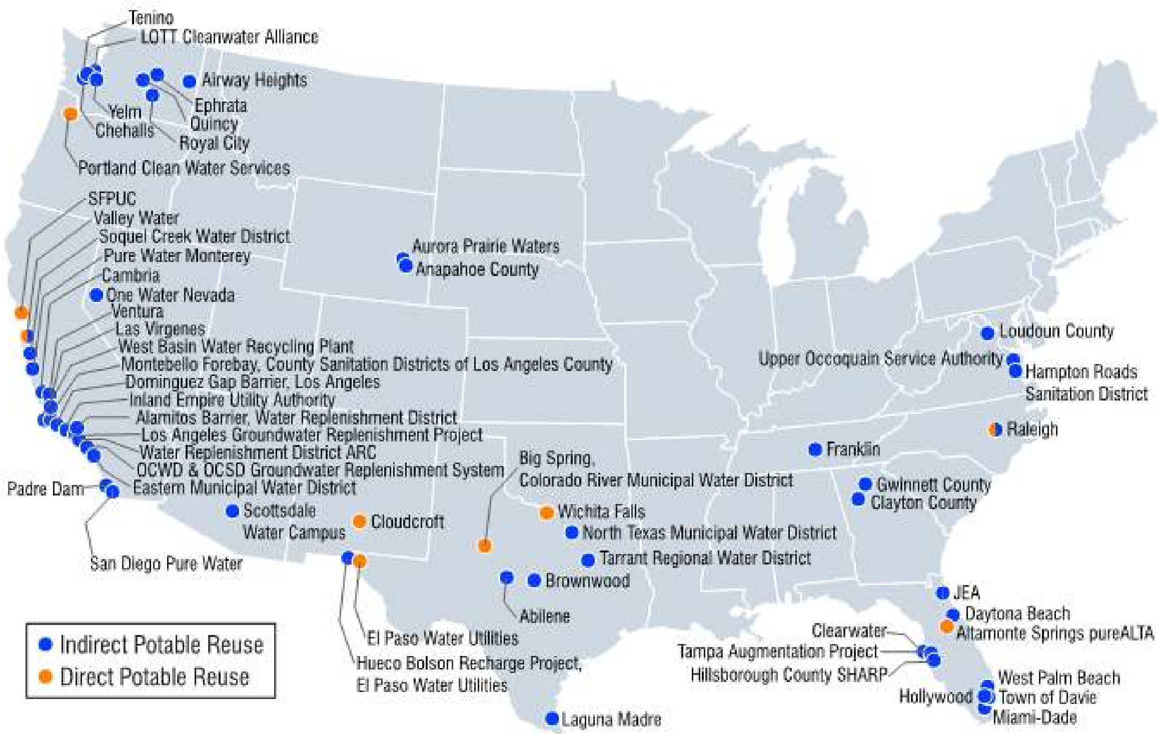

Figure 2.8: Current and planned potable reuse projects in the U.S. as of 2017. (Adapted from USEPA, 2017)

Table 2.2 summarizes some of the potable reuse projects outside of Florida. The table lists the project, location, year that the project started, and the type of potable reuse. The potable reuse projects include groundwater spreading, groundwater injection, surface water augmentation, and DPR.

Table 2.2 Example Potable Reuse Projects Outside of Florida

Project Name	Location	Start (End) Year	Size (MGD)	Type of Potable Reuse
Montebello Forebay, County Sanitation Districts of Los Angeles County	Los Angeles, CA	1962	44	Groundwater recharge via spreading
Water Factory 21, Orange County (decommissioned)	Orange County, CA	1976-2004	15	Groundwater recharge via seawater barrier

Upper Occoquan Service Authority, Fairfax (UOSA)	Fairfax, County VA	1978	54	Surface water augmentation
Huecco Bolson Recharge Project, El Paso Water Utilities	El Paso, TX	1985	10	Groundwater recharge via injection
Clayton County	Georgia	1985	18	Surface water augmentation
West Basin Water Recycling Plant	El Segundo, CA	1995	17.5	Groundwater recharge via injection
Gwinnett County	Gwinnett County, GA	1999	60	Surface water augmentation
Scottsdale Water Campus	Scottsdale, AZ	1999	20	Groundwater replenishment via injection
Dominguez Gap Barrier, Terminal Island, City of Los Angeles	Los Angeles, CA	2002	6	Groundwater replenishment via injection
Alamitos Barrier, Water Replenishment District of So.CA, Long Beach	Long Beach, CA	2005	8	Groundwater replenishment via injection
Chino Basin Groundwater Recharge Project, Inland Empire Utility Agency	Chino, CA	2007	18	Groundwater replenishment via soil-aquifer treatment
Orange County Groundwater Replenishment System (GWRS)	Orange County, CA	2008	100	Groundwater replenishment via injection and spreading basins
Arapahoe County/Cottonwood	Colorado	2009	9	Groundwater replenishment via riverbank filtration
Prairie Waters Project, Aurora	Aurora, CO	2010	50	Groundwater replenishment via riverbank filtration
Big Spring – Colorado River Municipal Water District (CRMWD)	Big Spring, TX	2013	1.8	DPR (into a DWTF)
City of Wichita Falls	Wichita Falls, TX	2014-2015	7	DPR (into a DWTF)
Cambria Emergency Water Supply	Cambria, CA	2014	0.65	Groundwater replenishment via injection
Village of Cloudcroft	Cloudcroft, NM	Delayed	0.026	DPR (into a DWTF)
Hampton Road Sanitation District SWIFT demonstration project	Virginia Beach, VA	2018	120	Groundwater replenishment via injection
San Diego Pure Water	San Diego, CA	2023 (In Design)	18	Surface water augmentation
El Paso – Advanced Water Purification Facility	El Paso, TX	2023 (In Design)	10	DPR (into a distribution system)

In the United States, approximately 32 billion gallons of municipal wastewater effluent is produced per day. Of this amount, only about 7 to 8 percent is beneficially reused (EPA, 2012). In addition, a sizable amount of this discharge contributes to *de facto* reuse, in which the treated wastewater becomes the source of downstream drinking water (NRC, 2012). A significant portion of the wastewater effluent could be made available for further reuse, including potable reuse.

2.5 Potable Reuse Projects in Florida

Previous and ongoing Florida potable reuse pilot studies and projects are presented in **Table 2.3**. These include IPR projects involving groundwater recharge and surface water replenishment, and DPR projects**.**

The City of Plantation, Miami-Dade County, Town of Davie, and City of Sunrise evaluated recharging the Biscayne aquifer with advanced treated reclaimed water, using different treatment schemes. Each evaluated scheme utilized a combination of advanced processes like membrane bioreactors (MBR), reverse osmosis (RO), and Ultraviolet light (UV) disinfection to meet required nutrient levels and water quality targets for groundwater recharge, demonstrating reliability in advanced processes.

Hillsborough County Public Utilities successfully operated the first pilot DPR project in Florida to produce a finished water product that met all drinking water regulations. To promote DPR and increased public outreach, the finished water was used by home brewers to make beer. This project continues to serve as an excellent example for public outreach and education. The Cities of Clearwater and Daytona Beach operated potable reuse demonstration projects using reverse osmosis. The City of Clearwater project was cooperatively funded by the Southwest Florida Water Management District, and has completed final design, permitting, and public outreach components of the project as of the 2018. The City of Daytona Beach demonstration project is still operational.

The City of Altamonte Springs piloted one of the first ozone-biofiltration based potable reuse projects without the use of RO to test an alternative lower energy treatment technology that does not produce a concentrate requiring disposal. The piloted treatment train could be a viable option in areas with low salinity levels in their source water. The project received a 2018 Market-Changing Water Technology award from the International Water Association in Tokyo, Japan and the 2017 WateReuse Innovative Project of the Year award at the annual WateReuse Symposium in Phoenix, Arizona. JEA recently completed the first phase of exploring cost-effective and site-specific solutions for potable reuse by piloting both ozone-biofiltration based and RO based treatment techniques side-by-side.

Table 2.3 Florida Potable Reuse Projects

Sponsor	Program	Operated	Capacity (each train)	Pilot/Demo Program Cost ($M)
City of Plantation	Advanced Wastewater Treatment Pilot Project	Sept. 2007 - Mar. 2008 (7 months)	10 GPM	$0.3M (2007)
City of Sunrise	Southwest Wastewater Treatment Facility Advanced Wastewater Treatment and Reuse Pilot Testing Program	Apr. 2007 - Oct. 2007 (7 months)	--	--
Miami-Dade County	Coastal Wetlands Rehydration Demonstration Pilot Project	Feb. 2009 - Jul. 2009 (5 months)	120 GPM (Total)	$1.7M (2009)

Town of Davie	Advanced Wastewater Treatment for Aquifer Recharge and Indirect Potable Reuse Pilot Study	Jul. 2010 - Jan. 2011 (7 months)	15 GPM	N/A
City of Pembroke Pines	Aquifer Recharge Pilot Plant	Nov. 2010 - Jan. 2011 (3 months)	12 GPM	N/A
City of Hollywood	Effluent Recharge Treatment Pilot Study	Jan. 2013 - Nov. 2013 (11 months)	10 GPM	$3.0M (2013)
City of Clearwater	Groundwater Replenishment	Jul. 2013 – Jul. 2014 (12 months)	20 GPM	$2.7M (2013)
Hillsborough County	DPR Demonstration	July 2016 (1 month)	2 GPM Batch	~$0.2M (est.) (2016)
Hillsborough County	Indirect Potable Reuse Project (SHARP)	Aug. 2015 - ongoing	2 MGD	$2.5M (2015)
City of Altamonte Springs	pureALTA	2016 - ongoing	20 GPM	$1.0M (2016)
JEA	Water Purification Treatment Evaluation and Pilot Testing	2017-2018 (12 months)	70-80 GPM (0.10-0.12 MGD)	$2M (est.) (2017)
City of Daytona Beach	Potable Water Supplementation Program Demonstration Test System	Sept. 2018 - Sept. 2020	0.2 MGD	$3.4M (2017)
City of Tampa	Tampa Augmentation Project – Recharge and Recovery	Preliminary Design	50 MGD	TBD

Source: Adapted from Mulford, L. et al. (2018) and the Florida Potable Reuse Commission

PART 2:
MANAGERIAL, PUBLIC ENGAGEMENT, AND TECHNICAL BEST PRACTICES

CHAPTER 3: INTRODUCTION AND BACKGROUND

3.1 Introduction

Part 2 of the potable reuse framework for Florida focuses on addressing best practices for regulatory and technical topics, as well as for public engagement. General information is provided for the implementation of potable reuse, including available resources. Specific best practices for Florida are organized into categories: regulatory, industry best practices, and outreach. The information presented is based on the premise of protecting public health and to ensure public acceptance of potable reuse as a water supply option.

Chapter 3 is intended to provide background information on potable reuse based on the current experience across the U.S. and guidance developed to support potable reuse. This chapter provides an overview of considerations for implementing potable reuse, available resources, and an overview of potable reuse research.

The remainder of Part 2 provides information on public health, technical, managerial, and outreach topics for implementing potable reuse in Florida. These topics are organized into the following chapters:

- **Chapter 4: Public Health and Water Quality Criteria.** This chapter provides an overview and background for the control of pathogens and chemicals in potable reuse.
- **Chapter 5: Managerial Topics.** This chapter covers managerial-related topics associated with a potable reuse program.
- **Chapter 6: Public Outreach/Engagement**. This chapter reviews best practices associated with public outreach and engagement for potable reuse.
- **Chapter 7: Technical Topics.** This chapter reviews the range of technical topics needed for potable reuse.
- **Chapter 8: Emerging Topics**. The chapter summarizes several topics that should be considered when planning for a potable reuse project, but are still in a research stage and will become better refined in the future.

3.1.1 Considerations for Implementing Potable Reuse

In the development of regulations and guidance for potable reuse, including the permitting of projects, best practices for potable reuse have been summarized. These practices are based on the recognition that potable reuse projects involve a range of components that support the implementation of potable reuse.

3.1.1.1 Components of a Potable Reuse Project

Based on experience with current potable reuse projects and research studies, the key components necessary for a successful and sustainable potable reuse program include the following: 1) regulatory considerations; 2) technical components needed for the production of a safe drinking water source; and

3) public outreach to increase understanding and assure the community of the safety of the water supply (Tchobanoglous et al., 2015). The success of a potable reuse project will depend on meeting the objectives of these key components (see **Figure 3.1**).

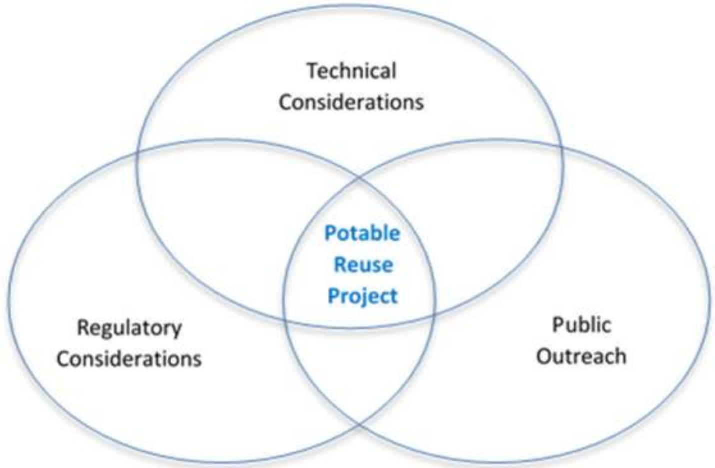

Figure 3.1: Key components of a potable reuse project. (Tchobanoglous et al., 2015)

Regulatory Considerations

Regulatory agencies have the responsibility to ensure that public water supply projects comply with applicable federal and state laws and regulations. Federal regulations do not exist for potable reuse, and existing potable reuse regulations vary by state. In addition, there are no state regulations for DPR with the current exception of Texas, which has permitted DPR projects on a case-by-case basis.

To assist regulators in evaluating a proposed potable reuse project, a project or engineering report that contains a complete description of the project can be helpful. This project or engineering report should:

- Include provisions that address public health, including control of pathogen and chemical constituents.
- Define the purpose of the treatment process, including each unit process, in the proposed advanced water treatment train, which can be a standalone facility or part of the potable water treatment.
- Define the means for complying with all requirements specified by the regulatory agency.

For potable reuse, and particularly DPR, additional treatment barriers, increased treatment reliability, enhanced on-line monitoring, trained operators, appropriate response plans, and an adequate failure response time can be used to ensure water quality is protective of public health. The failure response time provides the time necessary to identify and correct water quality deficiencies (primarily from constituents presenting acute risks, such as pathogens) before the water is released to the drinking water system (Crook, 2010).

Technical Topics

The technical components of a potable reuse system include the physical systems, treatment systems, other infrastructure, source control, monitoring, operational procedures, and related items. Each of these items should be reviewed, evaluated, and operated in a manner consistent with producing a source of drinking water. Specific items can include the following:

- Source control program for the service area of the wastewater treatment facilities providing the source water for the potable reuse facility.
- Wastewater treatment, including optimizing the water quality.
- Advanced water treatment including the technical and operational requirements.

- Equalization and/or engineered storage.
- Drinking water treatment and blending of advanced treated water.
- Back-up supply (Emergency Source) should treatment integrity be compromised.

Public Outreach

A dedicated public outreach program is needed to develop a broad understanding among the public about water sources and quality and to build public confidence and support for a potable reuse project. The engagement should begin during the early stages of planning and be maintained throughout the project. Information and materials are available from research studies and existing potable reuse programs. However, each community should consider their specific demographics when developing their program and build on existing successful outreach and communication programs. Key activities related to the development of a comprehensive public outreach program for potable reuse project include the following:

- Describe the need for the potable reuse project to raise public confidence and awareness of the benefits and value of the project.
- Understand public perception challenges and use that information to develop public engagement strategies.
- Develop a formal communication plan to document approaches for engaging the public, elected officials, and others with the goal of building confidence and support.
- Develop a communication strategy and communication materials that provide objective, accurate, and timely information to raise awareness and address concerns.
- Engage public through advisory and stakeholder committees with active roles in process.

3.1.1.2 Technical, Operational, and Managerial Barriers

The development of a potable reuse project involves the application of the concept of multiple barriers. As shown in **Figure 3.2**, barriers can be technical, operational, and management related. Importantly, the barriers occur at each stage of the process: collection system, source water, treatment system, and storage. The multiple barrier approach envisioned by the U.S. EPA, and applicable to potable reuse, involves risk prevention, risk management, monitoring and compliance, and individual action (U.S. EPA, 2006c). For potable reuse, it is necessary to identify and address the technical, operational, and management barriers needed to prevent treatment system failures, ensure water quality, and protect public health.

As shown in **Figure 3.2**, the barriers are used in series. The goal is to ensure that the failure of a single barrier does not result in the failure of the entire treatment system.

Potable reuse regulations focus on technical barriers; however, both operational and management barriers are essential aspects for implementing potable reuse. The use of multiple independent barriers also results in a high level of reliability by reducing the risk associated with a single barrier. As a result, resilience is enhanced for the overall system.

Additional information on each category of barriers is described below:

- **Technical barriers.** Technical barriers include physical barriers such as unit treatment processes and the application of online monitoring to demonstrate treatment performance. Technical barriers are designed to address the range of chemical and microbial constituents associated with a reclaimed water source.
- **Operational barriers.** These barriers include operations and monitoring plans, failure and response plans, and operator training and certification. If implemented properly, these barriers help the reliable production of advanced treated water.
- **Management barriers.** These barriers include policies, procedures, and plans that are key to the proper functioning and oversight of technical and operational barriers in potable reuse projects. These barriers can be applied from the source of supply through the production of advanced treated water. They provide guidance for staff to make critical decisions that support the proper functioning of the potable reuse project.

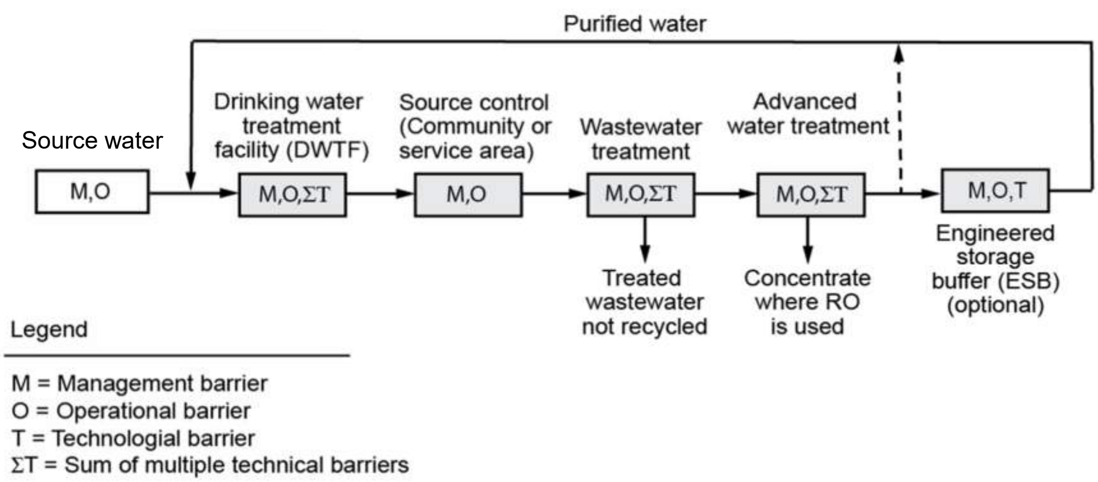

Figure 3.2: Key elements of a multiple-barrier strategy for a direct potable reuse scenario. (Tchobanoglous et al., 2015)

3.2 Useful Resources

A number of resources have been published to support the development of potable reuse regulations and the implementation of potable reuse projects. These resources are summarized in **Appendix B** and include research reports, expert and advisory panel reviews, and guidance manuals. Many of these resources were used to inform the development of this document. The individual reports (**Figure 3.3**) were published by federal agencies, state agencies, research foundations and associations, and international organizations. Regulators, utilities, engineering consulting firms, and stakeholders can use these resources

Figure 3.3: Covers of resource documents listed in Appendix B.

when establishing guidance and operational requirements for potable reuse. Additional information on research foundation efforts on potable reuse is summarized in **Section 3.3**.

3.3 Overview of the Water Research Foundation's Potable Reuse Research

Since the year 2000, the Water Research Foundation (WRF), formed by the merger of the Water Environment & Reuse Foundation (WE&RF) and the WateReuse Research Foundation, has addressed challenges in implementing potable reuse through research, for communities to meet current and projected water demands and to develop sustainable and reliable local water supplies.

In 2012, WRF sponsored the Direct Potable Reuse Initiative to advance DPR as a water supply option. As part of the initiative, the Foundation funded research that addressed regulatory, utility, and community topics. Under the DPR Initiative, the Foundation documented key elements that make up a DPR program, from source control to blending product water. The initiative is a valuable resource for municipalities, utilities, and agencies seeking to implement DPR programs.

The Foundation continues to sponsor and fund water reuse projects that address technical and other topics intended to advance reuse projects. A new research effort, Advanced Potable Reuse Initiative, was established in 2018 to address outstanding questions in states across the U.S. that are developing potable reuse regulations and/or implementing projects.

A detailed summary of WRF's research efforts is provided in **Appendix C**.

CHAPTER 4: PUBLIC HEALTH AND WATER QUALITY CRITERIA

In general, pathogen and chemical constituents in wastewater must be removed and/or inactivated to acceptable levels before discharge to the environment or reuse to meet public health protection purposes (Tchobanoglous et al., 2015). In addition, the SDWA protects public drinking water supplies by setting standards for drinking water quality and establishing programs to ensure drinking water safety. As a result, potable reuse must be designed to provide protection against short-term and long-term exposures to contaminants associated with pathogens and chemicals (NRC, 2012). The protection of public health is the guiding principle for implementing potable reuse (Crook, 2010).

4.1 Public Health Considerations

Treated wastewater effluent contains a wide range of naturally occurring and anthropogenic trace organic and inorganic contaminants, residual nutrients, total dissolved solids (TDS), residual heavy metals, and microorganisms (including pathogens) (Drewes and Khan, 2011). For potable reuse, the goal is to limit human exposure to concentrations of chemicals and pathogens that may be harmful to human health. Drinking water standards under the SDWA are established for chemicals using “maximum contaminant levels” (MCLs) and for pathogens using “log reduction values” (LRVs).

Bacteria, viruses, and protozoan parasites are the most critical microbial constituents to control in reclaimed waters due to the potential human health impacts resulting from short-term exposure. Among the large number of chemical constituents that can be present in reclaimed water, some are of concern due to their potential adverse health effects associated with both short-term and long-term exposures (NRC, 2012).

Beyond the existing regulatory requirements to meet LRVs for pathogens and MCLs for chemical constituents, unregulated chemicals, such as emerging constituents (also referred to as constituents of emerging concern or CECs), must be addressed.

4.2 Criteria for Pathogens

Microbial constituents in reclaimed water can include bacteria, viruses, and protozoan parasites. Pathogenic (i.e., disease-causing) microorganisms could present acute risks to the public and are an important design and operating concern for potable reuse systems. Federal and state drinking water treatment regulations for pathogens are predicated on reducing the risk of infection to minimal levels. In promulgating the Surface Water Treatment Rule (SWTR) in 1989, the U.S. EPA suggested that water be treated for *Giardia* with the goal of ensuring high probability that the population consuming the water would not be subject to a risk of greater that one infection per 10,000 (i.e., 10^{-4}) per person per year (Regli el al., 1991). This level represents an acceptable level of risk. Existing potable reuse regulations in California and DPR projects Texas are based on this 1 in 10,000 assumption for risk of infection.

4.2.1 Federal Regulations for Pathogens in Drinking Water

Federal regulatory requirements for pathogens exist under the SDWA. The SWTR requires drinking water treatment facilities (DWTFs) using surface water sources and groundwater under the direct influence of surface water to provide treatment that typically includes filtration and disinfection, ultimately achieving a minimum of 4-log reduction of virus and 3-log reduction of *Giardia*. The level of treatment required under the Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR) is based primarily on the concentration of *Cryptosporidium* oocysts in the source water. In addition, the U.S. Environmental Protection Agency (U.S. EPA) has established an MCL of <1 fecal coliforms or *E. coli* organisms per 100 milliliter (mL) in drinking water. Total coliforms no longer have a drinking water MCL, but monitoring and follow-up response requirements do exist.

4.2.2 Pathogen Treatment Targets for Potable Reuse

Currently, there are no federal regulations that specifically address potable reuse; however, individual states (e.g., California and Texas) have undertaken efforts to develop treatment criteria for pathogens.

Approach of the State of California for Potable Reuse Using Groundwater Replenishment

In California, the most conservative literature values for pathogen occurrence in raw wastewater were used to develop LRVs for IPR groundwater replenishment (CDPH, 2014). Based on the 1 in 10,000 annual risk assumption and these conservative occurrence levels, the log reduction targets in California for IPR were determined to be: 12-log reduction of enteric viruses, 10-log reduction of *Cryptosporidium*, and 10-log reduction of *Giardia* (see **Table 4.1**).

A portion of these log reduction credits can be achieved during wastewater treatment. The Division of Drinking Water of the California State Water Resources Control Board (SWRCB) has approved pathogen log reduction credits for primary and secondary treatment (WRD, 2013) and is now requiring a source water study to confirm log reduction credits. SWRCB has also approved log reduction credits for advanced treatment processes (more information is provided in **Section 7.3**).

Table 4.1 Pathogen Reduction Criteria of the State of California for Indirect Potable Reuse Using Groundwater Replenishment from Raw Wastewater

Pathogen	Criterion (Minimum Log Reduction)
Enteric Virus	12
Cryptosporidium	10
Giardia	10

Approach of the Texas Commission on Environmental Quality for Direct Potable Reuse

Faced with an urgent need for additional water supplies in parts of the state, starting in 2013, the Texas Commission on Environmental Quality (TCEQ) has approved DPR projects on a case-by-case basis in accordance with the innovative/alternative treatment clause in the Texas Administrative Code [30 TAC §290.42(g)] that allows “any treatment process that does not have specific design requirements” listed in that chapter to be considered for permitting (TAC, n.d.). According to the Texas Administrative Code, innovative/alternate treatment processes will be considered on an individual basis. Where innovative/alternate treatment systems are proposed, the licensed professional engineer must provide pilot test data or data collected at similar full-scale operations demonstrating that the system will produce water that meets all requirements.

TCEQ's case-by-case approach to developing treatment requirements for potable reuse projects is based on determining the difference between the finished water pathogen values and the measurement of project-specific secondary effluent pathogen concentrations.

TCEQ has established baseline log reduction requirements for DPR, as shown in **Table 4.2**, using effluent from wastewater treatment plants (WWTPs) as the starting point. The reduction requirements are based on the 10^{-4} (one in 10,000) annual risk of infection. The baseline removal requirements are a starting point for the TCEQ approval process (TWDB, 2015). The levels could be revised based on data collected to characterize the wastewater effluent. This site-specific WWTP effluent characterization is used to evaluate the need for additional log reduction requirements above the baseline targets.

Table 4.2 Microbial Reduction Criteria of the Texas Commission on Environmental Quality[a]

Microbial Group	Criterion (Minimum Log Reduction)
Enteric Virus	8
Cryptosporidium spp.	5.5
Giardia Lamblia	6

[a] The baseline targets are for the advance treatment process only (i.e., they represent the required reduction between treated wastewater and the finished drinking water). The Texas Commission on Environmental Quality (TCEQ) sets project-specific requirements for pathogen reduction and inactivation for DPR. These minimum baseline targets may be increased based on site-specific data.

Source: TWDB (2015).

The pathogen sampling requirements are, in general, analogous to those required for *Cryptosporidium* under LT2 ESWTR, but also extend to sampling for *Giardia* and enteric virus. This process has been applied to three approved projects in Texas (i.e., Raw Water Production Facility at Big Spring, Wichita Falls Emergency DPR Project, and City of Brownwood DPR Project – the latter project has been approved but not implemented).

In awarding log reduction credits, TCEQ uses an approach based on drinking water, which means challenge testing[3] alone is not sufficient to determine inactivation credits given to common disinfection processes, such as ozonation and ultraviolet irradiation. These processes must adhere strictly to CT (concentration × time) requirements (for ozone) and the validation provisions under the U.S. EPA's *Ultraviolet Disinfection Guidance Manual* (U.S. EPA, 2006a). Membrane-based processes must pass daily integrity tests, as described in and required by the U.S. EPA's *Membrane Filtration Guidance Manual* (2005), to receive any log reduction credit; therefore, log reduction credit for reverse osmosis (RO) membranes and membrane bioreactor processes are not allowed currently under the Texas approach (which is not the case in California).

[3] Challenge testing is a performance and capacity test of a treatment system using a surrogate that is either conservative or has a proven correlation to the parameter of interest.

Beyond the theoretical calculation of log reduction credits, TCEQ also requires that significant pilot testing be completed before a project can achieve final approval. This testing can be achieved from the operation of a dedicated, smaller-scale pilot unit that appropriately mimics the proposed final treatment solution, or through full-scale verification, which would occur during commissioning and start up. This second approval method allows treatment facilities to be approved for construction without completing a pilot study prior to the design of the full-scale system. With a full-scale verification approach (which was the basis for the City of Wichita Falls Emergency DPR project, for example), full-scale facilities were operated in "pilot mode" to collect the data necessary for final approval while finished water was sent to disposal pending final approval by TCEQ to deliver water.

National Water Research Institute Expert Panel

NWRI convened an expert panel to verify microbial and chemical constituent criteria protective of public health to evaluate treatment technologies for DPR that might be applied throughout the United States. The panelists included former staff of the California Department of Health Services (environmental engineers James Crook and Harvey Collins) and former staff of the U.S. EPA (toxicologist Richard Bull, chemist Joseph Cotruvo, and microbiologist Walter Jakubowski). This effort was part of a WateReuse Research Foundation project on *Equivalency of Advanced Treatment Trains for Potable Reuse* (11-02).

As shown in **Table 4.3**, the panel recommended 12-log reduction of enteric virus, 10-log reduction of *Cryptosporidium*, and 9-log reduction or inactivation of total coliform bacteria (NWRI, 2013), and concluded that these microbial log reduction criteria were conservative and actually would achieve risks of infection lower than one in 10,000 per year. The panel also concluded that a 10-log reduction of *Cryptosporidium* will ensure the same or greater removal of *Giardia* as *Giardi*a is larger and more easily disinfected than *Cryptosporidium*. These log reduction criteria include the full treatment cycle from raw wastewater to the final product water.

Table 4.3 Microbial Log Reduction Criteria Recommended by the Independent Advisory Panel of the National Water Research Institute[a]

Microbial Group	Criterion (Minimum Log Reduction)
Enteric Virus	12
Cryptosporidium spp.[b]	10
Total Coliform Bacteria[c]	9

[a] Reduction criteria for the AWTF and secondary wastewater treatment.
[b] Addresses *Giardia* and other protozoa as well.
[c] Addresses enteric pathogenic bacteria, such as *Salmonella* spp.
Source: Adapted from NWRI (2013).

4.2.3 Potential Pathogen Criteria for Potable Reuse in Florida

Pathogen criteria for potable reuse in Florida can be based on policy of 1 in 10,000 risk of infection for the reference pathogens of viruses, *Cryptosporidium*, and *Giardia*. From a technical standpoint, achieving this level of risk of infection, for these reference pathogens can be done by a utility electing to follow either the California approach of calculating LRVs from raw wastewater or the Texas approach of calculating LRVs after wastewater treatment based on characterizing the source water. The utility's source water characterization would assist in deciding which approach to implement.

Each approach provides the needed public health protection for pathogens. The selection of an approach would depend on how the project would be implemented. The Texas approach starts with minimum LRVs after wastewater treatment of 8, 5.5, and 6 for viruses, *Cryptosporidium*, and *Giardia*, respectively, following a source water characterization to verify pathogen concentrations. The California approach uses 12, 10, and 10 for viruses, *Cryptosporidium*, and *Giardia*, in which log reductions credits have to be verified or demonstrated. The utility would select which approach to employ based on the utility's source water characterization, existing treatment technologies, and other factors.

4.3 Criteria for Chemical Constituents

For potable reuse, some chemical constituents represent a potential for long-term chronic health risks if present in high enough concentrations. They also could impact corrosion within the drinking water distribution system, as well as aesthetics (i.e., color, taste, and odor) (TWDB, 2015). Encompassing both regulated and unregulated constituents, chemical constituents could include organic and inorganic chemicals, radionuclides, disinfection byproducts (DBPs), pesticides, synthetic organic chemicals, pharmaceuticals, and consumer care products. The basic requirement for controlling chemical constituents would be to meet all U.S. EPA and State drinking water MCLs and other requirements that apply to public drinking water supplies in Florida.

It is important to note that nitrate presents a potential acute health risk and, as a result, is of particular importance to potable reuse. Nitrate is regulated by the U.S. EPA in drinking water and occurs in wastewater that is not fully denitrified. It will need to be controlled as part of the wastewater or the advanced water treatment process for potable reuse.

Utilities considering the implementation of potable reuse projects should conduct comprehensive analytical studies on the types and quantities of chemicals that can be present in wastewater, and advanced treated water. As discussed later in **Section 5.8**, an aggressive source control program is essential for any potable reuse project to understand and limit the discharge of chemical constituents into the wastewater collection system (TWDB, 2015).

4.3.1 Chemical Targets for Potable Reuse

Chemicals known to be detrimental to human health above certain concentrations are regulated in drinking water through MCLs under the SDWA. Potable reuse projects should meet these requirements and other requirements set by the State of Florida for drinking water. Because of the source (i.e., wastewater) and because of public concerns about chemical contaminants, potable reuse projects also should track a suite of unregulated chemicals in the wastewater source, as described in **Section 7.4**.

A number of efforts have examined the need to address chemical constituents in potable reuse, including:

- Research has been conducted on the concentrations of unregulated trace organic constituents (e.g., PPCPs, flame retardants) in wastewater, their attenuation through conventional WWTPs, and further breakdown during advanced treatment (Baronti et al., 2000; Lovins et al., 2002; Schäfer et al., 2005; Sedlak and Kavanaugh, 2006; Steinle-Darling et al., 2010; Linden et al., 2012; Salveson et al., 2010, 2012; Snyder et al., 2012; Cotruvo et al., 2012, and many others). The majority of these constituents are not found in treated wastewater effluent at concentrations that have been shown to present risks to human health.

- For advanced treated water, trace chemical constituents are controlled by various treatment technologies. Reverse osmosis (RO) has been shown to control most chemical constituents (including trace organic chemicals), to meet low total organic carbon (TOC) limits and to control salinity. Other technologies, such as nanofiltration (NF), ozone and biologically active filtration (ozone/BAF), and granular activated carbon (GAC) can be used to control trace constituents but use higher TOC limits (2 to 4 mg/L) to demonstrate treatment efficacy. These are suitable in areas where control of salinity is not needed and can have an advantage of lower energy consumption and elimination of the need for RO concentrate disposal. Advanced oxidation processes (AOPs) are effective in treating for trace organic chemicals. The selection of treatment processes is determined by regulatory requirements, including: bulk organic limits (i.e., TOC, chemical oxygen demand [COD]), pathogen log reduction requirements, the use of multiple barriers to control for pathogens and chemicals (including trace organic chemicals), and finished water goals (e.g., MCLs) (Mosher et al., 2016).

- For IPR in Florida, a TOC concentration of 3.0 mg/L is used as a bulk parameter of treatment efficacy for organic chemicals, including unregulated and unknown chemicals [62-610.563(3)(d)]. A similar approach has been taken in California for potable reuse involving groundwater replenishment. California set requirements to limit TOC concentrations to <0.5 mg/L. The California TOC level was not set based on health criteria, but instead based upon the ability of a specific treatment scheme to meet this low TOC level. TOC levels in drinking water also are influenced by conventional source water characteristics, notably the natural organic matter present in surface water supplies. For Florida, TOC can be used as a monitoring parameter to assess treatment performance. The potable reuse regulatory framework in Oklahoma adopted the use of TOC as a performance monitoring parameter (Graves, 2017). Florida also uses total organic halides (TOX) as a bulk parameter for treatment efficacy for unregulated organic halide chemicals.

- Both 1,4-dioxane and NDMA are difficult to treat by conventional and membrane-based treatment. NDMA is a disinfection by-product (DBP) formed during water and wastewater treatment (among other sources), while 1,4-dioxane is a potential local concern related to industrial activity in the wastewater collection system. These compounds are amenable to treatment by AOPs such as ultraviolet light-hydrogen peroxide (UV/H2O2) and UV-chlorine (e.g., UV/HOCl) oxidation. California has established a performance expectation for UV oxidation for NDMA. Also, NDMA has a low notification level (10 nanograms per liter [ng/L]). California has set the performance expectation for AOP based upon 0.5-log reduction of 1,4-dioxane, understanding that 1,4-dioxane is a conservative surrogate for the wide-range destruction of organics following RO (CDPH, 2014). A source control program for chemical disposal in the wastewater system should be applied to mitigate or eliminate the occurrence of these and other compounds (see **Section 7.9**).

- Conventional DBPs, such as trihalomethanes, haloacetic acids, bromate, and chlorate, are regulated in the distribution system by the Stage 1 and Stage 2 Disinfectant and Disinfection Byproduct Rules (U.S. EPA, 1996, 2006b). The existing regulatory structure for DBPs is well defined; however, attention should be paid to the potential for DBP formation during potable reuse treatment processes.

4.4 Summary

A summary of the major topics in this chapter related to the protection of public health for potable reuse are as follows:

- For potable reuse, the design and operation of the system must limit pathogens and chemicals to minimize potential short-term and long-term health risks.
- Pathogen criteria for potable reuse in Florida can be based on policy of 1 in 10,000 risk of infection for the reference pathogens of viruses, *Cryptosporidium*, and *Giardia*. Both the Texas TCEQ approach and the State of California approach for developed LRVs are based on this risk level. Each approach involves specific assumptions and implementation requirements that a utility should consider when implementing.
- Treatment target criteria for chemical constituents should include meeting all U.S. EPA and State drinking water MCLs, as well as other requirements that apply to public drinking water supplies in Florida. Many chemicals do not have health-based thresholds and are not regulated. However, the majority of these constituents are not found in treated wastewater effluent at concentrations that have been shown to present risks to human health. Monitoring for unregulated chemicals (including emerging constituents) of interest is useful for evaluating treatment effectiveness.
- Utilities interested in implementing potable reuse should conduct studies on the types and quantities of chemicals present in their wastewater effluent as part of a source control program. These studies could be part of the potable project application process.
- Source control through pretreatment programs, local limits, and other measures can mitigate or eliminate the presence of many chemical constituents in the wastewater collection system and obviate monitoring and treatment for them (see **Sections 5.8 and 10.4** on Source Control).

CHAPTER 5: MANAGERIAL TOPICS

The implementation of a potable reuse project requires addressing the management components of the project and system. The use of sound management practices improves the reliability and increases resilience for the overall system. These practices, policies, procedures, and plans provide the appropriate oversight of technical and operational barriers in potable reuse projects. These practices can be applied from the source of supply through the production of advanced treated water and provide guidance for staff in implementing a potable reuse project.

This section addresses the following management practices for supporting a potable reuse program:

- Terminology
- Project Definition
- Utility Collaboration/Joint Planning
- Technical, Managerial and Financial Capacity
- Types of Barriers
- Small Water Systems
- Permitting Process
- Pretreatment and Source Control
- Operator Training and Certification
- Alternatives Provision
- Emergency Potable Reuse Provision
- Expert Panel Review

Public outreach can be considered a management practice. Because of the importance of public engagement to ensure the understanding and acceptance of a potable reuse project, public outreach is addressed separately in Chapter 6.

Each topic includes a list of best practices that are presented in the following categories: regulation, industry best practices, and outreach.

5.1 Terminology

For potable reuse, specific terms and definitions are needed to effectively communicate with regulators, water utility staff, stakeholders, and the public. Technical terms are needed for use by scientists, regulators and water professionals to describe the treatment processes, types of potable reuse projects, and other aspects of regulating and implementing potable reuse projects. In addition, certain terms will be defined in state regulations.

In communicating with the public, terminology can be an obstacle. Specific public outreach issues associated with terminology include: a lack of consistent water reuse terminology in the water industry; the use of industry jargon; and the lack of public understanding of terms used in the industry. In developing messaging for public engagement on potable reuse projects, the use of positive terms and the use of consistent terminology is essential for successful communications (Millan et al., 2014).

A list of terms and definitions is provided in the Terminology section of this report. This list of terms has been used in public information and technical reports prepared by scientists, engineers, and technologists. Specific terms are often defined in state regulations.

Several publications list terms and definitions and can be used as resources. These publications include the following:

- Tchobanoglous, G., J. Cotruvo, J. Crook, E. McDonald, A. Olivieri, A. Salveson, and R.S. Trussell (2015). Framework for Direct Potable Reuse, WateReuse Foundation, Alexandria, VA. https://www.nwri-usa.org/research

- Mosher, J., G. Tchobanoglous, and G. Vartanian (2016). Potable Reuse Research Compilation: Synthesis of Findings, Water Environment & Reuse Foundation, Alexandria Va. www.werf.org/a/ka/Search/ResearchProfile.aspx?ReportId=Reuse-15-01

- National Research Council (2012). Water Reuse: Potential for Expanding the Nation's Water Supply through Reuse of Municipal Wastewater. National Research Council, National Academies Press: Washington, DC.
www.nap.edu/catalog.php?record_id=13303

- Mosher, J.J., and G.M. Vartanian (2017). Guidance Framework for Arizona Potable Reuse. Prepared for WateReuse Arizona and AZ Water Association, Prepared by National Water Research Institute, Fountain Valley, CA.
https://watereuse.org/wp-content/uploads/2018/02/NWRI-Guidance-Framework-for-DPR-in-Arizona-2018.pdf

- U.S. EPA (2018). Potable Reuse Compendium. U.S Environmental Protection Agency. EPA/810/R-17/002. Washington, DC
www.epa.gov/ground-water-and-drinking-water/2017-potable-reuse-compendium

- ACWA (2016). Water Reuse Terminology. Prepared for Association of California Water Agencies. Prepared by WateReuse California, Association of California Water Agencies, and California Association of Sanitation Agencies.
https://watereuse.org/educate/water-reuse-101/glossary/

Consistent and appropriate terminology for potable reuse is important for several uses, including regulatory, technical, and public engagement purposes. Best practices related to terminology are listed in **Table 5.1**.

Table 5.1 Best Practices for Terminology

Best Practices	Category
Certain terms will be defined in regulations. Work with regulators on setting regulatory definitions.	Regulatory

Many terms may be best addressed as part of industry practices, which allows for flexibility. A number of published sources for terms and definitions are available.	Industry Best Practices
For public engagement, positive, consistent terminology is essential for effective communications. Terms should focus on the quality of the water and use of positive terms is encouraged.	Outreach
A list of possible terms and definitions is provided in this framework.	Industry Best Practices
Water associations in Florida should consider assembling a list of preferred terms and definitions.	Industry Best Practices

5.2 Project Definition

For a potable reuse project, a utility should develop a "Project Definition" for use with regulators, managers, stakeholders, and the public. The Project Definition would define a project in terms of specific elements and parameters. It could include a description of benefits, drivers, and problems that the project would address.

A project definition could include a description of the project scope, the objectives, and participants in a project. In support of the project, the Project Definition could provide a description of specific roles and responsibilities, regulatory context, treatment approach, and other elements that are of interest. The Project Definition can serve as a reference for regulators, manager, and stakeholders.

The Project Definition can review the need, drivers, and benefits of the project, including a detailed description of the project components. The document can assist in communicating about the project with stakeholders and the public. The document can reference more detailed documents such as planning and feasibility studies.

In addition, the Project Definition would support a dialog with regulators. If the Project Definition is developed at the start of a project, the report would support discussion with regulators on the regulatory context and the process and steps for permitting the project.

A Project Definition would allow a utility to determine how to describe and explain the project to different audiences such as regulators, stakeholders, and the public. In developing the Project Definition, the utility could determine what terms would be used and for what purposes such as those defined in regulations and those used for outreach. Best practices for developing a Project Definition are listed in **Table 5.2**.

Table 5.2 Best Practices for Developing a Project Definition

Best Practices	Category
A utility should develop a "Project Definition" for use with regulators, managers, stakeholders, and the public.	Industry Best Practices
A clear definition of the project will help inform the public engagement process with stakeholders and the public.	Outreach

5.3 Utility Collaboration and Planning

Potable reuse projects will require strong interagency cooperation and responsiveness when different regional and local agencies operate the wastewater treatment plant (WWTP), the AWTF, and/or the DWTF.

Interagency cooperation is needed for several possible reasons:

- Appropriate WWTP effluent water quality.
- Implementing an enhanced source control program and pretreatment for managing constituents in the collection systems.
- Development of response plans between the entities operating the WWTP, AWTF, and the drinking water treatment facility to ensure effective planning, communication, and collaboration on technical, engineering, operational, and management topics.
- Assignment of funding of capital and operational expenses.
- Recognition of the unique authority granted to Tampa Bay Water as the sole and exclusive water provider within its service area (section 373.715 Florida Statutes)

Utility collaboration would also be beneficial for other elements of a potable reuse program, including: addressing regulatory questions; informing a Project Definition (see **Section 5.2**); and cooperation on public outreach and engagement efforts.

Best Practices for utility collaboration and planning are listed in **Table 5.3**.

Table 5.3 Best Practices for Utility Collaboration and Planning

Best Practices	Category
Permits may require that certain activities, such as source control, must be conducted by a partnering utility, which should be covered in a MOU or agreement. See Chapter 10 for specific recommendations on the use of MOUs.	Industry Best Practice
Public outreach and engagement efforts to stakeholders and the public should be planned to raise awareness and support a potable reuse project.	Outreach

5.4 Technical, Managerial, and Financial Capacity

Technical, Managerial and Financial (TMF) capacity is the ability of a water utility to provide safe and dependable water to its customers. In general, it includes forms of financial support or assistance (i.e., recurring revenues, grants and loans), regulatory enforcement, and operator certification activities, among others. Florida has an existing capacity development program for public drinking water systems, per requirements in the 1996 SDWA to assess the TMF capacities of water systems and assist those in need of developing or improving TMF capacity.[4]

[4] See FDEP's New Systems Capacity Development Program at https://floridadep.gov/water/source-drinking-water/content/new-systems-capacity-development-program-0)

5.4.1 Background on Technical, Managerial, and Financial Capacity

The 1996 SDWA requires states to incorporate TMF capacity into public water system operations. This requirement helps ensure that public water systems – including small drinking water systems – have long-term sustainability and are able to maintain compliance with all applicable drinking water laws and regulations. In particular, the Capacity Development Program was created under the SDWA Amendments of 1996 and includes the following three major components (U.S. EPA, 2017c):

- **Section 1420(a) New Systems**: States must have a program established to "ensure that all new community water systems and non-transient, non-community water systems commencing operations after October 1, 1999, demonstrate TMF capacity with respect to each national primary drinking water regulation in effect or likely to be in effect, on the date of commencement of operations."

- **Section 1420(c) State Capacity Development Strategies**: States must develop and implement a "strategy to assist public water systems in acquiring and maintaining TMF capacity."

- **Section 1452(a)(3) Assessment of Capacity**: States may not provide Drinking Water State Revolving Fund (DWSRF) loan assistance to systems that lack the TMF capability to ensure compliance, or if the system is in significant noncompliance with any drinking water standard or variance; however, states may provide assistance if the use of such assistance will ensure compliance and the system has agreed to make the necessary changes in operation to ensure that it has the TMF capacity to comply over the long-term.

5.4.2 Technical, Managerial, and Financial Capacity for Potable Reuse

A TMF assessment for potable reuse can be used to determine the capacity of a utility to:

- Build, operate, manage, and sustain a potable reuse system for the long-term.
- Plan, achieve, and maintain regulatory compliance.
- Provide effective public health and environmental protection.
- Make efficient use of public funds and sustainable public investments.

Because wastewater is used as the source water, potable reuse should require a higher level of accountability by the utilities undertaking these projects; therefore, TMF capacity could also address issues such as the quality of the source water, advanced treatment technologies in use at the AWTF, ability to take corrective action for a problem or failure within a shorter response time, and efforts to build and maintain public trust and confidence.

5.4.3 Assessment of Technical, Managerial, and Financial Capacity

A list is included in **Table 5.4** of possible areas to assess when evaluating the TMF capacity for a potable reuse project. The ultimate goal of a TMF capacity assessment should be to help utility administrators, employees, and operators identify potential or existing weaknesses and improve the utility's ability to safely operate a potable reuse system on a long-term basis.

Table 5.4 Potential Areas to Assess for the Technical, Managerial, and Financial Capacity of a Potable Reuse Project

Capacity	Description	Potential Areas to Assess
Technical	Deals with the performance and operation of the treatment process.	• Feasibility of consolidation • Existing water sources • Water system treatment capacity • Monitoring • Number of trained certified operators • O&M plan • Treatment, storage, and distribution facilities • Compliance records, violations of compliance standards, and plans to correct these violations
Managerial	Deals with governance (e.g., administrators must understand the responsibilities of overseeing the AWTF; employees and contractors must understand their roles; adequate time is needed to conduct all required tasks).	• Ownership • Management • Operations (including training and technical competency, and the O&M plan) • Organization • Master planning (including an inventory of equipment and infrastructure) • Emergency response planning • System policies • Customer service
Financial	Deals with financial ability to operate and maintain existing infrastructure and financial planning for future needs. Assessed through budget statements, asset management, and financial audits.	• Capital costs • Lifecycle costs • Budgeting (and budget control) • User fees • Financial audits/bond rating • Rate studies • Financial planning and management • Capital improvement plan (CIP)

5.4.4 Examples of Technical, Managerial, and Financial Capacity Development Components

Specific components to consider as part of a TMF capacity development program for potable reuse may include the following depending on the nature of the project (e.g., IPR or DPR):

- Adequate infrastructure
- Asset management
- Business plan
- Capital Improvement Plan
- Communication/outreach
- Construction
- Distribution
- Emergency response
- Financing, revenue, and water rates
- Management
- Monitoring
- O&M
- Regulations
- Reserve fund
- Source control
- Source water quality
- Technical knowledge and implementation
- Training
- Treatment reliability
- Water security

5.4.5 Best Practices for TMF Capacity

TMF Capacity for potable reuse can be addressed by modifying or expanding the state's existing TMF capacity development program for public water systems. As an alternative, a requirement could be added to the Engineering Report (see **Section 7.1**) for a utility to document their TMF analysis. Lastly, a TMF capacity assessment may become a requirement for applying for State Revolving Fund funding for potable reuse projects. Best Practices for TMF Capacity are listed in **Table 5.5**.

Table 5.5 Best Practices for TMF Capacity

Best Practices	Category
An evaluation could be conducted for potable reuse projects involving a TMF capacity assessment or a similar assessment that builds on the current State TMF program.	Industry Best Practice
As an option, the capacity assessment process for evaluating the ability of a utility to implement potable reuse could be part of the Engineering Report (see **Section 7.1**) developed by the utility.	Industry Best Practice

5.5 Types of Barriers

The concept and importance of multiple barriers is discussed in detail in **Section 3.1.1.2.** Multiple independent barriers, including managerial, operational, and technical barriers (see **Figure 5.1**), help ensure that a failure of a single barrier does not result in the failure of the entire system. This strategy results in a high level of reliability of the system. Potable reuse criteria and regulations focus on technical barriers; however, both operational and management barriers are essential aspects for implementing potable reuse, especially for DPR with the reduced response time. Best Practices for multiple barriers are listed in **Table 5.6**. In addition, specific recommendations for using multiple barriers to address pathogens in potable reuse are contained in **Section 10.2**.

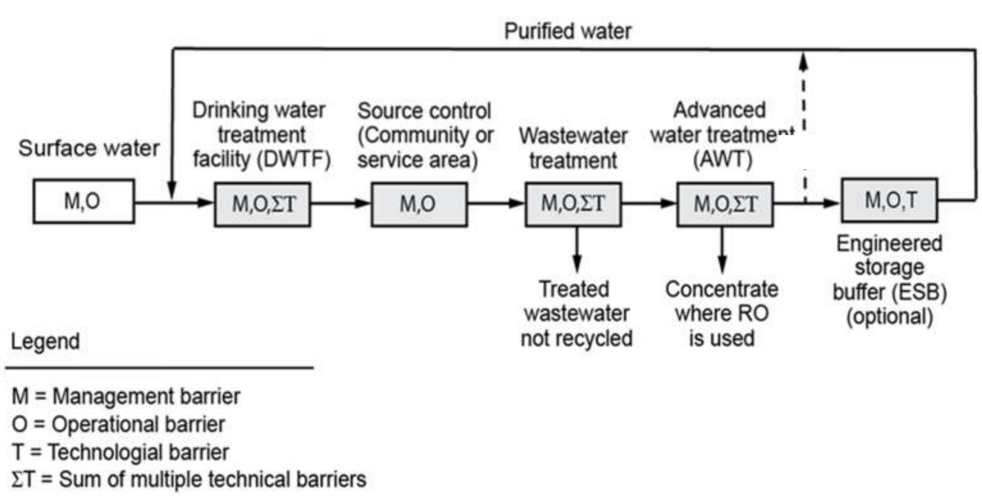

Figure 5.1: Types of barriers in potable reuse. (Tchobanoglous et al., 2015)

Table 5.6 Best Practices for Multiple Barriers

Best Practices	Category
The use of multiple independent barriers should be considered as part of planning, design, and implementation of a potable reuse project.	Industry Best Practice

5.6 Small Systems

Small water systems interested in implementing potable reuse will present unique challenges. Small systems will need to comply with all potable reuse regulations, but may have technical, managerial, and/or financial capacity constraints in implementing a potable reuse project.

In Florida, F.A.C 62-610.451 (Minimum System Size) limits the size of a reclaimed water system:

- (1) Except as provided in subsection 62-610.451(2), F.A.C., no treatment facility with a design average daily flow of less than 0.1 mgd shall have the produced reclaimed water made available for reuse activities covered by Part III (Rules 62-610.450 through 62-610.491, F.A.C.,) of this chapter.
- (2) A minimum system size is not required if reclaimed water will be used only for toilet flushing or fire protection.

However, systems less than 0.1 mgd may petition for a variance or waiver of this rule under section 120.542, Florida Statutes, to implement a potable reuse project.

When processing a variance or waiver request from rule 62-610.451(1), the following should be considered: A review involving TMF capacity would be essential for small utilities/communities interested in implementing potable reuse. The potable reuse standards should be the same for both large and small water systems. Other considerations include the following:

- **Water Quality Criteria.** The water quality criteria should be the same for all system sizes. That is, the pathogen and chemical criteria for DPR should apply equally to all utilities.
- **Source Control.** Small systems are often exempt from federal pretreatment programs; however, small systems considering potable reuse should adopt pretreatment and source control programs.
- **Advanced Water Treatment Technologies.** Advanced water treatment technologies exist on a small-scale and are available to small systems, often in package plants that facilitate O&M.
- **O&M.** Appropriate O&M is necessary because AWTFs are complex systems that must be operated and maintained by well-trained, highly skilled operations staff. It is critical that small system operators receive ongoing training and certification. The appropriate level of O&M needed for small systems interested in implementing potable reuse must be established.
- **TMF Capacity.** Florida's TMF program under the SWDA should provide strategies for small systems to develop the capacity needed for potable reuse. This process would be essential for assessing small systems.

- **Public Acceptance and Outreach.** It is important for small systems to conduct public outreach to gain public understanding of and confidence in a potable reuse project.

Best Practices for small systems are listed in **Table 5.7**.

Table 5.7 Best Practices for Implementing Potable Reuse for Small Systems

Best Practices	Category
Retain the 0.1 mgd minimum WWTP system size limitation in 62-610.451 for potable reuse projects.	Regulatory
All for systems less than 0.1 mgd to petition for a potable reuse project under an "Alternatives Provision" or other provision.	Regulatory
Small water systems interested in implementing potable reuse will present unique challenges. Small systems will need to comply with all potable reuse regulations. An analysis of TMF capacity or similar process for assessing the ability of the small system to implement potable reuse is essential.	Industry Best Practices

5.7 Working with Regulators

Regarding potable reuse regulations and permitting, it is imperative for utilities to understand the regulatory requirements and permitting process. Along those lines, it is critical to reach out to regulators early in the process. Utilities should plan and schedule frequent meetings with regulators to discuss the project, to hear their questions, and to keep them apprised of any developments.

Develop a Project Definition (see **Section 5.2**) for discussion purposes. Work with regulators to determine specific roles and responsibilities for reviewing the potable reuse project, including permitting. The planning and pilot efforts can help to work though potential issues with the regulators. Best Practices for the permitting process are listed in **Table 5.8**.

Table 5.8 Best Practices for Permitting Process

Best Practices	Category
Understand the regulatory requirements and permitting process and reach out to regulators on a regular basis.	Industry Best Practice

5.8 Pretreatment Program and Enhanced Source Control Program

An efficient and cost-effective strategy for managing constituents of concern is to prevent them from being discharged into the wastewater collection system through the pretreatment program and an aggressive enhanced source control program (Tchobanoglous et al., 2015). Enhanced source control programs for potable reuse can be implemented by modifying and building on federal pretreatment programs. An enhanced source control program can be designed to control, limit, or eliminate the discharge of constituents into wastewater that can be difficult to treat or impair the final quality of treated water intended for potable reuse.

An enhanced source control program will require interagency cooperation between the entities operating the WWTP, AWTF, and drinking water treatment plant when the entities operating each are different. In addition, the program will involve coordination with the community through permitting (e.g., for industries) or voluntary action (e.g., for residents). Additional measures can include online monitoring of WWTP influent and effluent to detect illicit discharges to the sewer system.

5.8.1 Background on Pretreatment Requirements in the United States

Under the 1972 Clean Water Act (CWA), the U.S. EPA was given authority to regulate discharges of pollutants into the waters of the United States and regulate quality standards for surface waters. The CWA made it unlawful to discharge any pollutant from a point source (i.e., conveyances such as pipes or man-made ditches) into navigable waters, unless a permit was obtained. The U.S. EPA's National Pollutant Discharge Elimination System (NPDES) permit program is the federal regulatory program designed to control these discharges to surface waters (USEPA, 2017a).

The National Pretreatment Program is an integral component of the NPDES permit program. It authorizes local municipalities to perform permitting, administering, and enforcing tasks related to discharges into publicly owned treatment works (POTWs), which collect and transport wastewater to treatment facilities. The goals are to (1) protect the infrastructure of POTWs, and (2) reduce conventional and toxic pollutant levels discharged by industries and other nondomestic wastewater sources into municipal sewer systems and into the environment (USEPA, 2017b).

Under the National Pretreatment program, industrial and commercial dischargers, referred to as industrial users (IUs), are required to obtain permits or other control mechanisms to discharge wastewater to a publicly owned WWTP. The Pretreatment Program Requirements (40 CFR Part 403.8) of the National Pretreatment Program require all large publicly owned WWTPs (those designed to treat flows of more than 5 million gallons per day [MGD]) and smaller publicly owned WWTPs (that accept wastewater from IUs that could affect the treatment plant or its discharges) to establish local pretreatment programs (LII, n.d.).

Pretreatment standards and requirements include: (1) general and specific prohibitions, (2) categorical pretreatment standards, and (3) local limits (U.S. EPA, 2017b).

5.8.2 Pretreatment Requirements in Florida

FDEP, in its role as approval authority, oversees the development and implementation of local pretreatment programs in the state. These local pretreatment programs are developed and implemented in accordance with the Florida Administrative Code (F.A.C. Chapter 62-625), Florida Statutes (F.S. §403.0885), and the Clean Water Act (33 United States Code, § 1251 et seq.).

5.8.3 Enhanced Source Control Program for Potable Reuse

Although not all publicly owned WWTPs are required to implement pretreatment programs, any community or utility pursuing a potable reuse project, regardless of size, should consider the impacts of industrial and commercial contributions on the wastewater supply and implement an aggressive local pretreatment program. Utilities with formal programs are subject to annual inspections and occasional audits. Source control is addressed further in **Section 10.4**.

The following activities can be undertaken as part of an enhanced source control program:

- **Understanding the Collection System.** Investigate what chemicals are used and disposed of by homeowners and/or commercial establishments (e.g., pesticides and cleaning products). Also, identify the potential for spills and other sources of chemicals (e.g., dry cleaners) that may enter the wastewater collection system.
- **Survey.** Conduct (1) an initial survey (i.e., source study) of discharges into the system to determine what industrial contaminants already exist and (2) sample wastewater effluent for drinking water constituents and emerging constituents. This sampling provides important information about chemicals in the wastewater. The information then can be used to determine what advanced treatment processes and monitoring are necessary. This survey should be conducted every 3-5 years to monitor for new chemicals and/or sources.
- **Classification of businesses.** Compile a list of current commercial and industrial entities that discharge into the wastewater system. Use the Standard Industrial Code (SIC) approach to inventory businesses that discharge into the collection system. Source control criteria will need to be established for new industries or businesses (e.g., medical care facilities, dental clinics, photo processors, and silver jewelry manufacturers) that move into the area.
- **Residential programs.** Education and outreach programs can be used to inform the public about the proper disposal of pharmaceuticals and household products containing chemicals that may be difficult to treat.

Pretreatment programs generally do not completely eliminate pollutant loadings from industrial sources. Hence, an important preventive approach when pursuing and planning for potable reuse is the implementation of an enhanced source control program to minimize or control the discharge of chemicals that might impact the potable reuse treatment process (Tchobanoglous et al., 2015).

5.8.4 Goals of an Enhanced Source Control Program

The goals of an effective source control program (Tchobanoglous et al., 2015) include:

- Understand the sources of chemical constituents entering the collection system from readily managed point sources (e.g., industries, health care facilities, commercial businesses, homes, and waste haulers).
- Minimize the discharge of potentially harmful or difficult-to-treat chemical constituents to the wastewater collection system.
- Improve wastewater quality and the performance of advanced water treatment processes.
- Provide the public with confidence that the wastewater collection system is being managed with potable reuse in mind.

Enhanced Source control cannot eliminate all emerging constituents; however, it is important to identify the constituents that may be present in the collection system, mechanisms by which they may be introduced to the wastewater collection system, and actions that can be taken to minimize their introduction into the wastewater collection system.

5.8.5 Elements of a Source Control Program

The principal elements of an effective potable reuse enhanced source control program are provided in **Table 5.9**. The source control program should be tailored to the individual service area. Guidance is provided in TWDB (2015) regarding source control and enhanced source control program elements to "provide an effective barrier" for potable reuse. For instance, one practice includes establishing local limits to control chemicals and provisions to take action to protect the potable reuse project.

Table 5.9 Elements of a Source Control Program for Potable Reuse

Element	Description
Regulatory Authority	• Legal authority • Discharge permits • Enforcement • Alternative control programs
Monitoring and Assessment of the Wastewater Collection System Service Area (Sewershed)	• Routine monitoring program • Constituent prioritization program • Evaluation of technically-based local limits
Source Investigations	• Industrial and commercial business inventory • Joint response plan of the wastewater treatment plant and advanced water treatment facility • Monitoring of hospital wastewater
Maintaining a Current Inventory of Chemicals and Constituents	• Chemical inventory program • Waste hauler monitoring program • Chemical fact sheets
Public Outreach Program	• Industrial discharges • Service area pollution prevention partnership program • Public education and outreach program for residential customers
Response Plan for Identified Constituents	• Interdepartmental collaboration • Interagency collaboration • Response to water quality deviations
Pretreatment processes	• Add or modify pretreatment processes as needed • Improve wastewater quality

Sources: U.S. EPA (2011), TWDB (2015), and Tchobanoglous et al. (2015).

5.8.6 Best Practices for Pretreatment Program and Enhanced Source Control Program

An aggressive enhanced source control program, building on a pretreatment program, can be an efficient and cost-effective approach to preventing chemicals from entering a wastewater collection system and for improving water quality for potable reuse. The basic elements of a source control program have been defined in available literature. It should be noted that realistic expectations are needed for a source control program; however, employing such a program can be meaningful from a public outreach point-of-view. Best Practices for pretreatment and enhanced source control programs are listed in **Table 5.10**.

Table 5.10 Best Practices for Pretreatment and Enhanced Source Control Programs

Best Practices	Category
An appropriate pretreatment program and source control program should be established as part of a potable reuse permitting process. All utilities, regardless of size, should have a pretreatment program as part of potable reuse project. See **Section 10.4** for specific regulatory recommendations governing pretreatment and source control.	Regulatory
Pretreatment programs should be augmented with an enhanced source control program designed to control the discharge of toxic chemicals and other contaminants to the wastewater collection system from a drinking water perspective. See **Section 10.4** for specific regulatory recommendations regarding source control.	Regulatory
Interagency and interdepartmental cooperation, responsiveness, and agreements between entities operating WWTP, AWTF, and drinking water treatment plant may be needed.	Industry Best Practice
Develop emergency response plans in response to enhanced source control activities.	Industry Best Practice
Public education for industry and for residential customers should be part of enhance source control program	Outreach

5.9 Operator Training and Certification

AWTFs are complex systems that must be operated and maintained by well-trained, highly skilled operations staff. These operators must be able to effectively respond to any issues or challenges that arise at the AWTF, as well as receive ongoing training and certification as new processes and techniques become available.

Training could be provided by utilities, national or state water and wastewater associations, commercial training programs, and community college training classes. Efforts are underway in the State of California to determine what is needed for potable reuse operator training and certification. The California Urban Water Agencies led an effort to develop a framework for potable reuse operator training and certification (CUWA, 2016).

Certification could take the form of “endorsements” to existing operator certification that cover advanced treatment, specific unit process, monitoring, and regulatory compliance. In addition, for potable reuse facilities, where advanced treatment processes are utilized, a new additional category of certification, such as Advanced Treatment Technologies Operator, could be developed (Walker et al., 2017). Training and certification should be consistent with the treatment train in use for a specific project.

For a potable reuse system, the types of certified operators need to be defined. In potable reuse, the use of licensed drinking water certified operators should be required. However, a licensed wastewater operator with advanced water treatment training or endorsement. A dual licensed operator (i.e., licensed in both water and wastewater treatment) should be considered and would provide a more comprehensive understanding of both wastewater and drinking water operations. A lead operator, the operator responsible for the technical operation of the treatment plant, should be designated.

Best Practices for operator training and certification are listed in **Table 5.11.**

Table 5.11 Best Practices for Operator Training and Certification

Best Practices	Category
Highly trained and certified operators are critical to the safe, successful functioning of potable systems. As a good managerial practice, operators should be trained on the potable reuse treatment train process and monitoring for operating advanced treatment systems.	Industry Best Practice
Set the level and types of certification needed. Work with regulators on the specific requirements. That is, how many operators and certification types (drinking water, wastewater, and/or dual). A lead operator should be designated.	Industry Best Practice
As a good managerial practice, lead operators should be Class A licensed water treatment operators, be certified in advanced treatment technologies relevant to the treatment train used, and/or be a dual licensed operator licensed in both water and wastewater treatment.	Industry Best Practice
On-site training can occur during pilot demonstrations and during start up and commissioning of a full scale system and is the responsibility of the utility. Include operator training in an Operations and Maintenance Plan (see **Section 7.8.4**).	Industry Best Practice

5.10 Expert Review

Expert review can provide validation for potable reuse projects for regulators and utilities. Reviewers, who are viewed as credible and independent, can review projects and assess public health protection. A utility can bolster its case by engaging external experts to provide review and oversight. Engaging science-based independent experts can provide advice on the design and implementation of projects.

Engaging experts can help address questions by the public or help where experience with potable reuse is limited. These experts can be comprised of leading water professionals, including academics, former regulators, and independent consultants who have expertise in areas relevant to the project. Expert reviewer reports can be used to guide further studies and as background documents to inform elected officials, regulators, and the public. Best Practices for the use of experts is provided in **Table 5.12**.

Table 5.12 Best Practices for Expert Review

Best Practices	Category
Regulators and/or Utilities should consider the use of experts to help address regulatory, technical, and related implementation questions.	Industry Best Practices

CHAPTER 6: PUBLIC OUTREACH/ENGAGEMENT

The public, in general, lacks basic knowledge about water sources, the systems in place to bring drinking water to the public and the mechanisms employed to assure the quality and safety of water. They are even less knowledgeable about alternative sources and the growing need to develop such sources for the promotion of human life, health and the environment. Within this context, public confidence, understanding, acceptance, and support are essential for the successful implementation of potable reuse projects. Notably, public acceptance is equally as important as technical merit (TWDB, 2015; Macpherson and Slovic, 2011). The public needs to trust that the use of reclaimed water as a source of water supply is protective of public health. For example, one concern could be the health risks associated with chemical constituents, such as emerging constituents, in the water supply. Proponents of potable reuse (i.e., utilities and communities) should develop and launch public outreach programs within their service areas to address public concerns, build public confidence, and garner public acceptance. It is important that local demographics be considered for a utility-specific approach to communications. That is, what works for one utility may not be the best approach for a different community or utility.

6.1 Communication Plan

Utilities should develop a communication plan that documents an organized and robust outreach approach including demonstrations and case studies. Specifically, the following activities are important in developing an outreach program (Millan et al., 2014; Tchobanoglous et al., 2015; TWDB, 2015):

- Designing the outreach program to be strategic, transparent, and thorough.
- Starting outreach early and continuing to engage the public throughout the lifetime of the project (i.e., planning and design, construction, operation, expansion, etc.).
- Using proven techniques and tools to listen to and communicate with the community, engage the media, and address public concerns.
- Providing useful, accurate information that builds awareness of potable reuse and builds confidence in the quality of reclaimed water.
- Developing consistent messages to communicate to the entire community, including different audiences in the community.
- Building relationships with opinion leaders, educators, and other influential community members.
- Creating transparency in all aspects of the project, including costs, water quality, and safety.
- Preparing for tough questions and addressing misinformation.

A number of communication planning tools and guidance materials pertaining to the water industry are available from organizations like the American Water Works Association (AWWA, n.d.), Centers for Disease Control and Prevention (CDC, n.d.), and WateReuse Research Foundation (e.g., Humphreys, 2006; Ruetten, 2004; and Tennyson, 2014); however, a suggested resource for developing a potable reuse focused communication plan is “Model Communications Plans for Increasing Awareness and Fostering Acceptance of Potable Reuse” (Millan et al., 2014).

The written communication plan should contain a detailed set of strategies used to communicate information about the project to the public, elected officials, and others. The plan should be comprehensive and include messaging, outreach tools, and communication strategies. It also should be flexible enough to adapt to the needs of specific locations and situations (Tchobanoglous, 2015; Millan et al, 2014).

A number of factors can influence the scope of the outreach program outlined in the communication plan, such as those listed in **Table 6.1**. These factors should be considered when developing the communication plan.

Table 6.1 Key Factors in a Communication Plan

Factor	Significance
Schedule and Duration	Communication should start early in the process and should continue throughout the design, construction, startup phases, and lifetime operation of the AWTF.
Purpose of Communication	Communication activities should have a clearly stated purpose, which is used to support decisions.
Messages	Messages should provide a framework for understanding the need for the project, including a narrative to engage the public, raise awareness, and gain acceptance. Messages should be consistent, accurate, and understandable to a non-technical audience.
Terminology	Uniform terminology has not been developed for potable reuse, but specific projects have produced terminology that has been effective on a local level. Accessible terms like are more effective with the public than industry jargon like “potable reuse” and “IPR.” Technical terms not understood by the public may not resonate well even when explained.
Problem Solving	A clearly articulated problem will help the public better understand and support the need for potable reuse; therefore, define the water supply condition that will be resolved by the project. Another best practice is to demonstration how the project provides improvements (i.e., the project is improving the quality of life and making things better for the community).
Anticipated Outcomes	The benefits and outcomes of the outreach program should be broad and include: public agreement that wastewater is a resource and should be reclaimed; community trust in the utility to implement potable reuse that produces safe, high-quality water that provides a reliable water supply; and the utility publicly commits to being transparent and seeks community engagement and involvement in project.
Costs and Benefits	Financial considerations may be the primary concern of some communities. Clear and transparent explanation of the costs is necessary to gain public confidence, especially if the potable reuse project is not the least expensive option. The conversation on project costs should include a discussion of benefits (e.g., water reliability and sustainability). Economic development may be an important benefit to some stakeholders.

Factor	Significance
Competing Issues	Communities must consider a number of priority issues, ranging from education to the economy. Water reliability and sustainability are part of the community's discussion, and consideration is needed as to how to illustrate the link between water supply and other important community topics.
Demographics and Environmental Justice	Because certain demographic groups may be less likely to support potable reuse, attention should be given to communicating with these groups. There may be groups also concerned with environmental justice issues.

Sources: Tchobanoglous, 2015, Millan et al. (2014) and Ruetten (2004).

6.2 Outreach Strategies

Various outreach strategies can be used by a utility to engage its community and gain support of a potable reuse project. These strategies should be outlined in the communication plan and should be audience-specific (Millan et al., 2014). Examples of possible outreach strategies are listed in **Table 6.2.**

Table 6.2 Examples of Outreach Strategies

Element/Tactic	Details
Research on Public Perception	Telephone surveys, one-on-one stakeholder meetings, focus groups, and other research activities can be used to assess community concerns and gain an understanding of public perception and acceptance. Results can inform the development of the outreach strategy.
Audience Identification	Communication with diverse audiences is needed because each group may present potential challenges to effective outreach. Specific audiences that require distinct outreach efforts include opinion leaders, community leaders, community organizations, and youth. Maintaining a database of individuals categorized by audience can be helpful in organizing outreach efforts.
Internal Communication	Include an internal outreach component to educate utility staff members. Customers or friends and neighbors may approach staff members with questions about potable reuse; it is important the utility provides a consistent message.
Outreach to Opinion Leaders	Identify opinion leaders in individual communities, as they influence the attitudes and behaviors of others. This group should be made aware of the need to increase water supply sources and the use of reclaimed water as a water supply option.
Outreach to Other Important Leaders	These leaders include: academic and educational staff; business organizations; civic groups; environmental organizations; water wholesalers and retailers; state and local elected officials and staff; and medical, public health, and water quality experts.
Written Materials	Written materials must present confident messages. Possible formats include: briefing binders, e-mail listservs, event invitations, brochures and flyers, newsletter articles, press releases, direct mail, websites, and social media.
Personal Interaction	Meetings and presentations are needed to reach out to all identified stakeholders. Personal interactions can be in the form of one-on-one meetings, town hall meetings, neighborhood gatherings, formal presentations, and civic meetings. Board members and elected officials should be involved in addition to utility staff.

Element/Tactic	Details
Identify Supporters and Champions	Agencies can use individuals or organizations as project partners or supporters. In addition to voicing support, these partners can become public advocates for the project.
Message Plan	Messages can be developed for both a general audience and specific audiences affected by an individual project. Messages should describe the multi-barrier approach including advanced water treatment, underscore the safety of the water and protection of public health, and provide the costs and benefits (e.g., increased water reliability and sustainability) of the project. Informational material needs to be developed and spokespersons need to be trained to deliver this information.
Communicate Effectively	Guidance for effective communication includes: training all project spokespeople; reviewing messages for consistency in presentations, interviews, and meetings with stakeholders; and ensuring written materials reflect the same information provided in oral communications.
Letters of Support	After a presentation or meeting, utility staff should request a letter of support for the project from appropriate audience members. Post these letters on the project website and use them to reach out to other stakeholders.
Common Questions and Answers	Be prepared with answers to common questions. Information can be provided in written format, as well as in briefing materials.
Address Difficult Issues	Be prepared to address difficult topics raised by stakeholders. If needed, seek assistance from experts in the field, including academics, medical doctors, public health officials, and other credible individuals.
Technology Demonstrations	Provide fixed or portable potable reuse treatment demonstrations verifying the ability to reliably produce safe potable water.
Other Specialized Needs	Other issues may need to be addressed as part of the potable project. For example, risk communication and risk management expertise may be needed in response to stakeholder questions. These fields of study often are used in communicating and managing risks associated with public health.

Sources: Tchobanoglous, 2015, Millan et al. (2014) and Ruetten (2004).

6.3 Messaging

An effective potable reuse outreach communication program should provide objective information with consistent messages and meaningful terminology suitable for diverse audiences (Millan et al., 2014). Potential tools and materials used to disseminate this information are listed in **Table 6.3**.

Table 6.3 Examples of Communication Plan Tools and Materials

Tools/Materials	Purpose/Examples
Written Materials	Examples: Fact sheets, frequently asked questions, brochures, bill inserts, posters and banners, materials for youth and children, white papers.

Tools/Materials	Purpose/Examples
Digital Materials	Examples: Project website; slide presentations; e-newsletters; videos.
Mailing Lists	To communicate to different groups for different purposes. Mailing lists can be electronic or physical.
Centralized Internal Information System	To catalogue and store materials.
Media Outreach	To provide timely information and ensure the media is informed, as well as to address misinformation in the media. Examples: spokespeople, media training, contacts, articles, tours, and responding to media requests.
Social Media	To reach certain segments of the population and provide information on a real-time basis.
Speakers Bureau	To facilitate opportunities to speak at group meetings, including business leaders, civic groups, and environmental, multicultural, and other community groups.
Stakeholder Groups	To provide a process for input and feedback from interested parties within a community. Stakeholder group members can become important supporters of the project.
Demonstration Facility/Visitor Center	To provide a positive learning experience for participants. Visitor centers involve educational displays and materials, while demonstration facilities show the treatment processes and treated water for examination. If possible, allow visitors to taste test the product water.
Independent Advisory Panels	To provide credibility and validation of a project. Local physicians and national experts in health, water quality, and technology can provide an independent viewpoint and make recommendations for improvement.
Rapid Response Plan	To swiftly address unexpected events related to the project.
Monitoring and Evaluation	To provide measurable outreach objectives that can be reviewed periodically. The results of the review will provide feedback for adapting or changing the communications plan and/or tools and materials.

Source: (Tchobanoglous, 2015; Millan et al, 2014).

6.4 Community Advocacy

As seen in previous potable reuse initiatives, one essential part of any communication plan is community advocacy. Having respected citizens and leaders of a community stand with the utility and/or local government officials and leaders is an effective approach to gain the trust of the public.

Communication plans should also consider a medical community initiative to facilitate the transfer of information. Such initiatives could include partnerships with research universities, public health officials and the medical community to create a trusted source of researched-based information about water reuse. The goals of a medical community initiative are to:

- Focus the conversation on ensuring water – regardless of the source – meets stringent federal and state water quality standards that protect human health and the environment.

- Create clear, concise content that addresses frequent questions and addresses common myths about water reuse.
- Build a medical advocacy network to disseminate information to doctors, nurses, and other medical professionals.

6.5 Statewide Outreach

It is not the role of the regulators to perform outreach for potable reuse projects or provide guidance to utilities on outreach strategies; however, regulators should be aware of how it can impact the public's perception of potable reuse and develop a strategy for communicating about potable reuse in general. For example:

- Florida water industry associations should consider adopting a general outreach program around potable reuse, especially to address DPR. Guidance on a statewide approach for potable reuse communications and outreach is summarized in this section and available in Millan et al. (2014).
- The State may need to engage in activities that impact public perception of potable reuse. To that end, the State should be prepared to communicate openly and candidly with the public about the safety and challenges associated with implementing potable reuse.
- Water industry associations can help set appropriate terminology that can be used when discussing potable reuse to the public. Efforts have been taken to develop consistent terminology for potable reuse within the water industry (Tchobanoglous et al., 2015).

6.6 Best Practices for Public Outreach

Best practices for public engagement are listed in **Table 6.4**.

Table 6.4 Best Practices for Public Outreach/Engagement

Best Practices	Category
Utilities considering potable reuse should develop and launch public outreach programs and activities within their service areas to address public concerns, build public confidence, and garner public acceptance of potable reuse.	Industry Best Practice

CHAPTER 7: TECHNICAL TOPICS

The technical and operational components of a potable reuse system are important to the production of a drinking water supply. These components include a wide range of topics including the physical systems, treatment systems, other infrastructure, source control, monitoring, operational procedures, and related items. These items contribute to the technical and operational barriers that are involved in producing a source of drinking water.

This section addresses the following technical and operational practices for supporting a potable reuse program:

- Engineering Report
- Microbial Control
- Log Removal Targets
- Chemical Control (regulated, unregulated, emerging constituents)
- Wastewater Treatment
- Advanced Water Treatment
- Long-Term Monitoring, including Critical Control Points (CCPs)
- Analytical Methods
- Facility Operation/Operations Plan, O&M, and Reporting
- Blending
- Residuals Management

7.1 Engineering Report

Florida requires an "Engineering Report" for permit applications for reuse and other projects (F.A.C 62-610.310). Specifically, F.A.C 62-610.310(1) states:

> *In accordance with the requirements and provisions of Chapters 62-600 and 62-620, F.A.C., an engineering report shall be submitted in support of permit applications for new or expanded reuse or land application projects. The engineering report will serve as the preliminary design report for reuse and land application projects.*

An Engineering Report should be prepared for potable reuse projects. For potable reuse projects, Engineering Reports include information on project evaluation, including information on public health, water characteristics, operations and unit processes, design criteria, monitoring points, and operation and control strategies. Best Practices related to an Engineering Report are provided in **Table 7.1**.

Table 7.1 Best Practices for an Engineering Report

Best Practices	Category
An Engineering Report should be developed as part of a potable reuse project.	Industry Best Practice

7.2 Microbial Control

A description is provided in **Chapter 4** of the types of pathogen classes and currently adopted pathogen log reduction requirements used in California and Texas (**Section 4.2.2**). The two approaches are risk-based (e.g., based on a 1 in 10,000 risk of infection) and address enteric viruses, *Cryptosporidium spp.,* and *Giardia lamblia* (also referred to as virus, *Cryptosporidium*, and *Giardia*). As implemented, both methods include significant levels of conservatism and are considered protective of public health from pathogen risks. The two approaches are discussed in more detail in **Section 4.2**; however, brief descriptions are provided below.

- **The TCEQ (Texas) Pathogen Reduction Criteria Approach**. In Texas, the minimum pathogen criteria are 8-log reduction of virus, 5.5-log reduction of *Cryptosporidium*, and 6-log reduction of *Giardia* for potable reuse applications. These log reductions are met after wastewater treatment. A site-specific WWTP effluent characterization or "Source Study" (reviewed by TCEQ) is used to evaluate the need for increasing the minimum log reduction requirements. TCEQ also requires pilot testing (or full-scale verification) to be completed before a project can achieve final approval.

- **The State Water Resources Control Board (California) Pathogen Reduction Criteria Approach.** In California, log reduction requirements have been adopted as part of the regulations for Groundwater Recharge with Reclaimed Water (i.e., IPR). The requirements are 12-log reduction of virus, 10-log reduction of *Cryptosporidium*, and 10-log reduction of *Giardia*, starting with the raw wastewater. A portion of these log reductions can be achieved during wastewater treatment.

California and Texas approaches require a *system to assign log reduction credits based on treatment technologies*; however, they differ in significant respects. California allows for log reduction credits for wastewater treatment. Texas does not allow for log reduction credits for RO because, currently, Texas requires membranes to conduct integrity testing (i.e., a pressure-based or marker-based process usually performed daily to detect breaches in a membrane system), which is not possible for RO membranes or MBR systems (though it could change in the future). In addition, California has a requirement for a minimum number of barriers and has set a maximum log reduction credit allowed for any technology (i.e., a maximum of 6-logs).

In permitting IPR projects using groundwater replenishment in California, the Division of Drinking Water of the California State Water Resources Control Board has approved log reduction credits for individual treatment processes. The approved log reduction credits are reported in **Table 7.2** and represent the maximum reduction credit allowances.

Table 7.2 Approved Log Reduction Credits for Groundwater Replenishment Projects in California

Process	Pathogen Log Reduction Credits Assigned in California		
	Virus	*Cryptosporidium*	*Giardia*
Secondary activated sludge	1.9	1.2	0.8[a]
Microfiltration or ultrafiltration	0	4	4

Process	Pathogen Log Reduction Credits Assigned in California		
	Virus	*Cryptosporidium*	*Giardia*
Filtered and disinfected secondary	5	0	0
Reverse osmosis	2	2	2
Free chlorine post reverse osmosis	4	0	3
Ultraviolet/hydrogen peroxide (Advanced Oxidation Process or AOP)[b]	6	6	6

[a] Waiting for the results of WRF-14-02 regarding potential additional information that may support additional log reduction credits for wastewater treatment plants. California regulators have indicated they will require a demonstration study for assigning log reduction credits for secondary wastewater treatment.

[b] 6-log reduction of virus (including adenoviruses) and 6-log reduction of protozoa, assuming the ultraviolet dose is >300 millijoules per square centimeter (mJ/cm^2) (based on advanced oxidation, typically >900 mJ/cm^2).

Source: Adapted from Olivieri et al. (2016).

Best practices for microbial control are listed in **Table 7.3** See **Section 10.2** for specific recommendations on regulatory changes needed.

Table 7.3 Best Practices for Microbial Control

Best Practices	Category
Pathogens should be removed or inactivated with a goal of 10^{-4} annual risk of infection. This level of risk is consistent with rules promulgated under the SDWA and with other state potable reuse efforts (i.e., California and Texas). This level of risk is also proposed as standard for Florida as further described in section 10.1.	Industry Best Practices
Utilities should implement a defined multiple barrier treatment approach for pathogens to achieve.	Industry Best Practices
The implementation of a log reduction credit approach will need to be established that meets the required pathogen treatment requirements determined for a project. The log reduction approach could be based on a characterization of the source water quality or default levels established by the state. See section 10.1 for more discussion on this recommendation.	Industry Best Practices
Both the California (12/10/10 LRVs for virus, *Cryptosporidium*, and *Giardia* from raw wastewater) and Texas (minimum 8/5.5/6 LRVs for virus, *Cryptosporidium*, and *Giardia* after wastewater treatment) pathogen log reduction approaches will achieve a 1 in 10,000 risk of infection and can be considered by utilities in Florida for potable reuse projects.	Industry Best Practices

7.3 Chemical Control

The control of chemical constituents in potable reuse applications for public health protection is described in **Section 4.3**. Chemicals represent a range of issues including: chronic public health risks; corrosion within the drinking water distribution system and aesthetics (i.e., color, taste, and odor) (TWDB, 2015). Chemical constituents include organic and inorganic chemicals, radionuclides, DBPs, pesticides, synthetic organic chemicals, pharmaceuticals, and consumer personal care products. Important considerations for chemicals in a potable reuse scenario include regulated and unregulated chemicals.

Selecting chemicals for evaluating the efficacy of treatment trains should focus upon certain key factors, including the following (Trussell et al., 2013):

- Meeting MCLs, published guidelines, and health advisory levels.
- Using constituents and parameters as performance indicators that occur in the source water at sufficient concentrations to allow for evaluating treatment trains.
- Appropriately sensitive and specific analytical methods.
- A diversity of constituents and parameters that are broadly representative of the varying types of contaminants of health concern that could be present in wastewater.
- An array of constituents and parameters that broadly represent differing properties of contaminants that affect their removals by various unit processes within a treatment train.

Utilities considering the implementation of potable reuse projects should conduct comprehensive analytical studies on the types and quantities of chemicals that can be present in their treated wastewater effluent and the final advanced treated water. The characterization of treated wastewater effluent should be conducted as part of a "Source Study" to understand the wastewater effluent water quality, as well as pathogen concentrations.

Categories of chemicals to address in potable reuse applications include the following:

- Regulated chemicals, including DBPs resulting from treatment. The nature and concentrations of the DBPs will vary with the types of disinfection used in the treatment train and applied technologies.
- If certain regulated chemicals (e.g., selected pesticides and herbicides) are observed in the wastewater, it may be important to document their removal.
- Numerous constituents occur frequently in wastewater, but generally at concentrations several orders of magnitude below those of health concern. These chemicals can serve as a useful tool for evaluating treatment train performance (NWRI, 2013).
- Pharmaceuticals and personal care product constituents have been studied extensively in wastewater, reclaimed water, and drinking water, and many occur quite commonly (especially in wastewater and reclaimed water) albeit at very low concentrations. These constituents can serve as surrogates/indicators of the performance of water treatment as it pertains to their removal.

- The frequency of monitoring should be reviewed periodically. The frequency of monitoring could be reduced over time where certain chemicals are shown to not occur or to occur at very low levels.
- Additional chemicals can be monitored because they can be measured with the same methods. The inclusion of these compounds can improve the evaluation of treatment train performance.
- There are several general surrogate parameters that provide useful information on the functioning of processes and their continuing performance for removing many chemicals (and microbes). Total organic carbon (TOC) is an example.

Monitoring is used to determine treatment efficiencies for alternative treatment trains and to develop a framework for determining the criteria to protect public health and demonstrate regulatory compliance. In addition, the appropriate locations in the treatment train and frequency of sampling is needed.

7.3.1 Chemical Control: Compliance Monitoring

To control chemicals in a potable reuse application, a tiered monitoring approach for chemical criteria can be implemented to address the range of chemicals, including regulated and unregulated chemicals. The tiers would be based on the type of monitoring:

- Meet SDWA primary standards for regulated chemical constituents, including DBPs.
- Monitor for unregulated chemical constituents that are of public health interest.
- Monitor for unregulated chemical constituents that provide information on the effectiveness of treatment.

The compliance monitoring tiers are as follows:

- **SDWA and State Requirements.** Potable reuse projects must meet all current and future chemical primary MCL requirements under the SDWA and other requirements, if any, set by the State of Florida for drinking water.
- **Emerging Constituents (also referred to as Unregulated Chemicals) of Interest from the Standpoint of Public Health.** Included in **Table 7.4a** is a list of chemicals proposed by the California SWRCB as part of their Recycled Water Policy that could occur in wastewater and are not regulated in drinking water that should be monitored for in a potable reuse program (SWRCB, 2108). In **Table 7.4b** additional chemicals with health criteria that can occur in wastewater were identified by a panel of experts (NWRI, 2013). In addition, some DBPs with Notification Levels in California are included. If detected, some should be monitored in the AWTF product water as well (NWRI, 2013). If the levels in the advanced treated water are above the health criterion, the treatment approach should be evaluated to ensure the levels remain below the health criterion. Another source of potential constituents of concern is U.S. EPA's Contaminant Candidate List (CCL), which is a list of contaminants that are currently not subject to current regulations, but are known or anticipated to occur in public water systems. Contaminants listed on the CCL may require future regulation under the Safe Drinking Water Act (SDWA).[5]

[5] For more information visit: www.epa.gov/ccl/contaminant-candidate-list-4-ccl-4-0.

- **Emerging Constituents (i.e. Unregulated Chemicals) that Are Useful for Evaluating the Effectiveness of Organic Chemical Removal by Treatment Trains.** The chemicals listed in **Table 7.5a** and **Table 7.5b** are considered useful as a surrogate for evaluating the effectiveness of alternative treatment trains and treatment performance. The chemicals in **Table 7.5a** are being proposed by the California SWRCB for potable reuse monitoring. The constituents in **Table 7.5b** are detected frequently and at sufficiently high concentrations relative to their detection limits so as to make them useful measures of the removal of health-significant organic chemicals with a variety of structures and physical chemical properties. All of these chemicals may not need to be monitored in the advanced treated water. Instead, an approach could involve selecting specific chemicals of varying properties for evaluating treatment performance and are shown to be present in the treated wastewater (NWRI, 2013). If the levels in the advanced treated water are above the performance criterion, shut down of the operation may not be necessary; however, the treatment approach should be evaluated in collaboration with regulators to ensure the levels remain below the performance criterion.

7.3.2 Other Considerations for Chemical Control

The tiered approached in **Section 7.3.1** provides a monitoring framework for addressing regulated and unregulated chemicals, including emerging constituents. This compliance monitoring approach would need to be augmented by the treatment processes, performance monitoring (including continuous monitoring), and operational considerations to effectively control for regulated and unregulated chemicals.

Table 7.4a: Unregulated Chemicals of Interest from the Standpoint of Public Health (If Present in Reclaimed Water) (adapted from SWRCB, 2018)

Constituent	Description	Relevance	Reporting limit (ng/L)
1,4-Dioxane	Industrial chemical	Health	100
N-Nitrosodimethylamine (NDMA)	Disinfection byproduct	Health and Performance	2
N-Nitrosomorpholine (NMOR)	Industrial chemical	Health	2

Table 7.4b: Additional Examples of Unregulated Chemicals of Interest from the Standpoint of Public Health (If Present in Reclaimed Water) (adapted from NWRI, 2013)

Chemicals	Criterion (if applicable)	Rationale	Source
Perfluorooctanoic acid (PFOA)	0.4 micrograms per liter (µg/L)	Known to occur, frequency unknown	Provisional short-term U.S. EPA Health Advisory
Perfluorooctane sulfonate (PFOS)	0.2 µg/L	Known to occur, frequency unknown	Provisional short-term U.S. EPA Health Advisory
Perchlorate	15 µg/L, 6 µg/L	Of interest, same analysis as chlorate and bromate	U.S. EPA Health Advisory, California Maximum Contaminant Level (MCL)

Chemicals	Criterion (if applicable)	Rationale	Source
Steroid Hormones			
Ethinyl estradiol	None, but if established, it will approach the detection limit (low nanogram per liter [ng/L]).	Should evaluate its presence in source water	Bull et al. (2011)
17-β-estradiol	None, but if established, it will approach the detection limit (low ng/L).	Should evaluate its presence in source water	Bull et al. (2011)

Table 7.5a: Chemicals that Could Be Useful for Evaluating the Effectiveness of Organic Chemical Removal by Treatment Trains Recommended by SWRCB (adapted from SWRCB, 2018)

Constituent	Description	Relevance	Reporting limit (ng/L)
Gemfibrozil	Pharmaceutical	Performance	10
Sulfamethoxazole	Pharmaceutical	Performance	10
Iohexol	Pharmaceutical	Performance	050
Sucralose	Food additive	Performance	100

Table 7.5b: Chemicals that Could Be Useful for Evaluating the Effectiveness of Organic Chemical Removal by Treatment Trains Based on Occurrence (adapted from NWRI, 2013)

Pharmaceuticals[a]	Criterion[b] (if applicable)	Rationale	Source
Cotinine, Primidone, Phenyltoin	1 µg/L, 10 µg/L, 2 µg/L	Surrogate for low molecular weight; partially charged cyclics	Bruce et al. (2010) Bull et al. (2011)
Meprobamate, Atenolol	200 µg/L, 4 µg/L	Occur frequently at the nanogram (ng) level	Bull et al. (2011)
Carbamazepine	10 µg/L	Unique structure	Bruce et al. (2010)
Estrone	320 ng/L	Surrogate for steroids	Based on an increased risk of stroke and deep vein thrombosis in women taking the lowest dose (0.625 mg/day) of conjugated estrogens/1000[a]
Other Chemicals			
Tris (2-Carboxyethyl) phosphine) hydrochloride	5 µg/L	Chemical of interest	Minnesota Department of Health guidance value (MDH, 2015)

Pharmaceuticals[a]	Criterion[b] (if applicable)	Rationale	Source
N,N-diethyl-meta-toluamide	200 µg/L	Common constituent in treated wastewater	Minnesota Department of Health guidance value (MDH, 2015)
Triclosan	2100 µg/L	Chemical of interest	Risk-based action level (NRC, 2012)

[a]Conjugated estrogens (largely estrone conjugates) administered without progestin increased significantly the risk of deep vein thrombosis and stroke in a large clinical study of postmenopausal women conducted over 5.1 years (it involved groups of >5,000 treated and 5,000 placebo subjects). Cited in RxList (2012).

[b]In the case of pharmaceuticals, the criterion is given as the drinking water equivalent concentration for the lowest therapeutic dose/1,000. In the case of the anticonvulsant drugs, the lowest daily maintenance dose in adults/10,000 was used in recognition of the teratogenic potential of these drugs (Primidone); however, the numbers for carbamazepine and phenyltoin are based on reported carcinogenicity.

7.3.2.1 Membrane Systems Based on Reverse Osmosis

Membrane systems involving RO have been shown to be capable of removing the constituents described in **Section 7.3.1** for regulated and unregulated chemicals non-detection or to levels well below available health criteria. If an RO-based system is employed, control of these regulated and unregulated compounds for public health protection has been shown to be achievable. RO-based potable reuse systems have a strong record of performance for chemical control based on long-running projects in place in California and Texas.

7.3.2.2 Additional Treatment Systems

In the United States, full-scale potable reuse projects provide multiple barriers for chemicals; however, specific treatment technologies employed at AWTFs vary depending on local regulations and site-specific requirements. In addition, RO is used to control for pathogens, achieve regulatory limits for TOC (e.g., California), and for controlling for salinity. RO-based treatment trains for potable reuse involves significant capital and operational costs, high energy use, the loss of water (the recover for RO in potable reuse systems is typically 85 percent), and requires the disposal of a concentrate. RO may be needed in cases where salinity removal is a driver of water quality. In Florida, RO-based treatment systems are common for brackish water and seawater desalination for producing drinking water and in industry. Non-RO systems are of interest due to the potentially higher operational costs of RO and the cost and sustainability concerns of managing the concentrate from RO (Mosher et al., 2016; Stanford et al., 2017).

Additional treatment options can provide an alternative approach for potable reuse applications. These technologies, such as ozone/biological activated carbon (ozone/BAF) and GAC (carbon-based systems), can be used to control for chemicals in potable reuse applications (Stanford et al., 2017).

Although low bulk organic limits (e.g., TOC, total organic halides [TOX], and chemical oxygen demand [COD], Total Org) do not reflect the toxicity caused by the presence of trace organic chemicals, several states have established regulatory requirements for TOC, TOX, or COD for potable reuse as a surrogate measure for the removal of trace organic chemicals that are unknown or difficult to measure. Florida's reclaimed water regulations (FAC 62-610.563) limit TOC to 3 mg/L (monthly average) and TOX to 0.2 mg/L (monthly average). The regulations also state that treatment "…shall include processes which serve as multiple barriers for control of organic compounds and pathogens" [FAC 62-610(3)(f)]. Virginia's Occoquan Policy, which is the regulatory policy defining requirements for the longstanding IPR project of the Upper Occoquan Service Authority, includes a COD limit of 10 mg/L (approximately 4 mg/L of TOC) (Mosher et al., 2016).

In a number of studies, ozone/BAF, GAC, and AOPs in a potable reuse treatment train have been shown to be capable of achieving significant removals of trace organic compounds. The use of these are being studied extensively for potable reuse applications (Kumar et al., 2017; Mosher et al., 2016; Stanford et al., 2017).

In addition, NF can be used in place of RO to control for trace organic compounds and to limit TOC and TDS concentrations. El Paso Water Utilities has pilot-tested NF for a full-scale DPR project to limit the TDS concentration in the concentrate stream and allow for a surface discharge (Mosher et al., 2016).

If TOC is used to confirm process performance for non-RO treatment technologies, then TOC levels would need to be established for the technologies employed. For instance, in an ozone/BAF treatment scenario, TOC levels in the range of 3 to 4 mg/L are representative of process efficacy. In addition, these higher TOC levels may contribute to higher DBP formation, which would need to be evaluated for individual projects.

7.3.2.3 Related Criteria

Appropriate chemical control in RO-based and non-RO based systems can be achieved using a holistic approach that includes a range of technical, managerial, and operational barriers and requirements. Specifically, the following factors should be considered:

- The use of continuous and periodic water quality testing for unit processes can be an effective measure of performance.
- The use of critical control points (CCPs), including point of compliance monitoring/verification monitoring of each treatment step, to ensure treatment performance.
- Conducting comprehensive analytical studies on the types and quantities of chemicals (including emerging constituents) that can be present in the treated wastewater (i.e., a "Source Study"). The results would help determine how much removal is needed to protect public health and what emerging constituents should be monitored.
- The use of bioassays to assess the removal of regulated and unregulated trace chemicals across treatment processes (see **Section 8**).
- An aggressive source control program to limit the discharge of chemical constituents into the wastewater collection system.
- Managing salinity can be a long-term sustainability issue. As water is reused in a community, chemical constituents will increase in concentration unless some form of salinity control is employed. Salinity can be partially managed through source control by characterizing dischargers to the collection system and requiring industrial users to address total dissolved solids (TDS) in their discharges. RO, NF, and/or ion-selective ion exchange membranes may be used for salinity control.

7.3.3 Summary of Findings on Chemical Control

Chemicals to consider include regulated and unregulated constituents (e.g. emerging constituents), and possibly chemicals that impact aesthetics of the final water quality (e.g., total dissolved solids). Chemicals like emerging constituents are of particular interest to the public and impact public acceptance of potable reuse.

It is possible to use constituents and parameters that occur in wastewater at sufficient concentrations as performance indicators to evaluate treatment unit processes. Diverse constituents and parameters can be identified that are broadly representative of various contaminants of health concern that could be present in wastewater.

Monitoring, including continuous monitoring, can be used to determine treatment efficiencies for alternative treatment trains, such as NF, ozone/BAF, GAC, and AOPs. A monitoring framework can be developed that demonstrates RO-based and non-RO based treatment trains are protective of public health. Appropriate locations in the treatment train and the frequency of sampling for monitoring purposes are needed.

Utilities should augment the monitoring approach with treatment processes, performance monitoring, and operational considerations to effectively control regulated and unregulated chemicals. Water quality testing of indicators and surrogates can be used as effective measures of the performance of unit processes. CCPs, including point of compliance monitoring/verification monitoring, can be used to ensure treatment performance and the safety of the advanced treatment water. The frequency of monitoring should be assessed periodically and modified or reduced based on a review of the results.

7.3.4 Best Practices for Chemical Control

Best Practices for chemical control provided in **Table 7.6**. See **Section 10.3** for specific recommendations on chemical control for potable reuse.

Table 7.6 Best Practices for Chemical Control

Best Practices	Category
A three-tiered monitoring approach (described in **Section 7.3.1**) can be used to assess chemicals for potable reuse and include: • Monitor and meet SDWA and State Requirements (including DBPs and nitrate). • Monitor of unregulated chemicals, including emerging constituents, of interest from the standpoint of public health. • Monitor one or more unregulated chemicals or organic compounds that can be used as surrogates for assessing performance of treatment of emerging constituents. See section 10.3 for more discussion of this approach.	Regulatory
Appropriately sensitive and specific analytical methods are needed.	Industry Best Practices

Conduct comprehensive analytical studies on the types and quantities of chemicals (including emerging constituents) that can be present in the treated wastewater (i.e., a "Source Study"). The results would help determine how much removal is needed and what emerging constituents need to be monitored.	Industry Best Practices

7.4 Wastewater Treatment

For potable reuse projects, the general goal of wastewater treatment is to remove or inactivate physical, chemical, and microbial constituents from raw wastewater so that the reclaimed water can be an appropriate source water. The different levels of wastewater treatment (e.g., primary, secondary, and tertiary treatment) and various treatment processes (e.g., biological wastewater treatment, filtration, and disinfection) may result in a source water quality for potable reuse with a range of differences in concentrations of nutrients, metals, microorganisms, organics, and solids.

The wastewater, reclaimed, and the potable water systems should be designed as an integrated system to ensure compatibility among unit operations and provide reliable performance. Most existing wastewater systems however, were not originally designed for potable reuse applications. As such, enhancements can be made to existing wastewater facilities to improve the quality of effluent for subsequent advanced treatment (Tchobanoglous et al., 2015).

7.4.1 Wastewater Effluent for Potable Reuse Applications

The final water quality of the effluent from the wastewater treatment processes shown in **Table 7.7** that will serve as source water for potable reuse will vary depending on the treatment steps included in the treatment train. Some representative data for the expected effluent quality from different wastewater treatment trains are reported in **Table 7.7**.

Primary treatment removes material that will either float or readily settle out by gravity and includes the screening, grit removal, and sedimentation. Secondary treatment involves the removal of biodegradable organic matter and suspended solids. For the potable reuse process, the benefits of using higher-quality wastewater treatment (which may involve nutrient removal, filtration, nitrification/denitrification, disinfection, or both filtration and disinfection) include:

- Reduced contaminant load, leading to reduced demands on subsequent treatment processes.
- Improved performance of subsequent advanced treatment processes.
- Increased reliability of the overall potable reuse treatment train.

Nitrification and denitrification can be incorporated in most secondary treatment processes to control and remove nitrogen in wastewater. Nitrification involves converting ammonia to nitrate, while denitrification involves reducing and/or removing nitrate. For the potable reuse process, the benefits of nitrification and denitrification include:

- Reduced membrane fouling rates (Trussell et al., 2009) for advanced treatment.
- Reduced degree of nitrate removal that must be achieved in the AWTF.
- Reduced DBP formation potential, especially for NDMA.
- Reduced level of emerging constituents in secondary effluent (Salveson et al., 2012).

Table 7.7 Effluent Quality for Various Wastewater Treatments

Parameter	Units	Untreated Wastewater	Range of Effluent Quality after Indicated Treatment				
			Conventional Activated Sludge[a]	Conventional Activated Sludge with Filtration[a,b]	Activated Sludge with BNR[b]	Activated Sludge with BNR and Filtration[c]	Membrane Bioreactor
Total suspended solids	mg/L	130–389	5–25	2–8	5–20	1–4	<1–5
Turbidity	NTU	80–150	2–15	1–5	1–5	1–5	<1–2
Total organic carbon	mg/L	109–328	20–40	15–30	10–20	1–5	<0.5–5
Ammonia nitrogen	mg N/L	14–41	1–10	1–6	1–3	1–2	<1–5
Nitrate nitrogen	mg N/L	0–trace	5–30	5–30	<2–8	1–8	<8[c]
Trace constituents[e]	µg/L	10–50	5–40	5–30	5–30	5–30	0.5–20
Protozoan cysts and oocysts	No./100 mL	10^1–10^5	10^1–10^2	0–10	0–10	0–1	0–1
Viruses	PFU/ 100 mL[f]	10^1–10^8	10^1–10^4	10^1–10^3	10^1–10^3	10^1–10^3	10^0–10^3

Notes: [a]Conventional secondary is defined as activated sludge treatment with nitrification; [b]BNR is defined as biological nutrient removal for removal of nitrogen and phosphorus; [c]with anoxic stage; [d]with coagulant addition; [e]for example, fire retardants, personal care products, and prescription and non-prescription drugs; [f]plaqueing units.

Source: Tchobanoglous et al. (2015)

Tertiary treated water, including the use of membrane bioreactors (MBRs), is more desirable than secondary treated water because tertiary treatment usually involves additional removal of residual suspended solids by granular media filtration or membrane filtration. Disinfection and nutrient removal may also be included in tertiary treatment. Tertiary treatment can also be performed at the AWTF. For the potable reuse process, the benefits of tertiary treatment include improved water quality for potable reuse.

7.4.3 Modification of Wastewater Treatment Processes

Modifying existing wastewater treatment for use in a potable reuse project may require technical evaluation, innovative engineering, and possible upgrades to the wastewater management infrastructure, along with related operation and management activities. In general, wastewater treatment facilities can be designed or modified to optimize overall performance, enhance reliability, and produce source water for potable reuse applications. Some measures that can improve the performance and enhance the reliability of existing and proposed wastewater treatment include:

- Enhanced screening process and, possibly, fine screening.
- Influent flow and load equalization.
- Elimination (or equalization) of untreated return flows.
- Operational mode for biological treatment process to improve reliability and produce an effluent of consistent quality.
- Improved disinfection while preventing DBP formation.
- Post-treatment filtration (to reduce suspended solids).

More information about such modifications can be found in Tchobanoglous et al. (2015) and TWDB (2015).

7.4.4 Use of Membrane Bioreactors

Membrane bioreactors (MBRs) provide a number of benefits for potable reuse (Helsley, 2017; Erdal, 2017) and can be used in place of conventional wastewater treatment for potable reuse projects. MBRs produce tertiary filtered effluent, which eliminates the need for microfiltration (MF) in an RO-based potable reuse treatment train. As a result, MBR effluent can be used directly for RO or another advanced treatment process. The advantages of MBRs include: reliable performance; pathogen removal; small footprint; and nutrient removal (Helsley, 2017; Erdal, 2017). Notably, the costs of MBRs have decreased over the past 10 years. Overall, MBRs could be a viable option for greenfield, retrofit, or decentralized/distributed projects.

As shown in the last column of **Table 7.7**, MBRs produce high-quality effluent, efficiently and effectively providing high removal rates of BOD, nutrients, and solids. MBRs can provide equal or better treatment than conventional wastewater treatment coupled with MF or ultrafiltration (UF), including 3+ log reduction of a broad range of pathogens (Helsley, 2017). MBRs also can be more effective in the removal of trace organic chemicals than some conventional activated sludge systems based upon the long solids retention time and the complete removal of suspended solids. As a result, MBRs can provide a high-quality source water for RO or other advanced potable reuse treatments processes.

One limitation for MBRs is that there is a lack of Direct Integrity Test[6] (DIT) or other approved method to assess membrane integrity (as is commonly and effectively used to measure MF and UF membrane integrity and, thus, pathogen log removal performance). Historically, MBR manufacturers have not provided DIT components to any type of MBR, though some suppliers now are implementing this approach. DIT cannot be applied to flat sheet MBR membranes. Consequently, pathogen credits have not been given to MBRs. Currently, studies in the United States and Australia (Helsley, 2017) have demonstrated the robust removal of a broad range of pathogens by MBR, even with damaged fibers that could not pass a DIT. States such as California have not yet agreed to allow pathogen removal credits for MBRs without DIT. Other projects are evaluating how DIT can be applied to MBR systems for pathogen credits (Erdal, 2017).

7.4.5 Summary of Wastewater Treatment

Secondary wastewater treatment processes can vary, resulting in a range of reclaimed water quality. Higher quality wastewater effluent (e.g., tertiary treatment, nitrification/denitrification) provides water quality and operational benefits for potable reuse treatment trains.

Enhancements should be considered for existing WWTPs to optimize overall performance, enhance reliability, and produce an effluent quality for use as a source water for potable reuse.

[6] A Direct Integrity Test (DIT) involves a physical test applied to a membrane unit to identify and isolate integrity breaches. Typically, the test involves pressurizing membrane fibers from inside to approximately 12 to 20 pounds per square inch (psi) about 30 to 45 seconds. Once the pressure is stabilized, the pressure source is isolated and the decay test is started. The pressure is recorded over a 5-minute period, or until the pressure decreases to the minimum permissible pressure, as required by the test resolution, whichever occurs first.

7.4.6 Best Practices for Wastewater Treatment

Best Practices for wastewater treatment are listed in **Table 7.8**.

Table 7.8 Best Practices for Wastewater Treatment

Best Practices	Category
For potable reuse applications, the wastewater treatment facilities must meet all existing federal and state regulations.	Regulatory
Credits can be established in literature or utilities can propose credits based on available information or a specific study.	Industry Best Practice

7.5 Advanced Water Treatment Technologies

In a potable reuse system, advanced water treatment technologies are applied to reclaimed water to produce a drinking water source. The advanced treated water must meet all applicable federal, state, and local drinking water and potable reuse regulations to serve as a drinking water supply (Tchobanoglous et al., 2015). The treatment process must be sufficiently robust so that it will pass regulatory review and public scrutiny. Over the past decade, a number of new technologies have been developed and the performance of existing technologies has been significantly improved.

7.5.1 Treatment Technologies Used for Advanced Water Treatment

A summary is provided in **Table 7.9** of the principal advanced treatment technologies currently used to remove particulate, colloidal, and dissolved inorganic and organic constituents found in the effluent from WWTPs. The treatment technology options provided in this table include alternative membrane processes (RO and NF) and non-membrane processes (ozone/BAF, and AOPs). Potable reuse treatment trains will employ a range of different treatment technologies, based on specific water quality goals, operational objectives, and regulatory requirements.

Table 7.9 Summary of Technologies for Advanced Water Treatment

Treatment Option	Use	Notes
Coagulation/ Flocculation/ Sedimentation	Processes used to separate suspended solids portion from water.	A pretreatment step that is being used before ozone/BAF. JEA included this in their pilot test.
Ozone followed by biologically active filtration (BAF)	Process to achieve a reduction in pathogenic microorganisms and trace organics, and condition treated secondary effluent to enhance the performance of downstream processes.	It has been demonstrated that ozone/BAF ahead of MF/UF provides a greater benefit than ozone/BAF after MF/UF, but ahead of RO (Trussell et al., 2013). In some cases, the use of ozone/BAF in combination with other treatment technologies may eliminate the need for RO for advanced water treatment, such as being used in the City of Altamonte Springs pilot study.
Granular activated carbon (GAC)	Removal of trace organic compounds.	Can be used with other technologies for the removal of trace organic compounds.

Treatment Option	Use	Notes
Microfiltration (MF)	Remove residual suspended particles by mechanical sieving.	Typical membrane pore size range is 0.1 to 0.2 micrometers (µm).
Ultrafiltration (UF)	Remove residual suspended particles by mechanical sieving.	Typical membrane pore size range is 0.008 to 0.04 µm. UF is often used in place of MF.
Cartridge filtration (CF)	Remove suspended and colloidal impurities from chemicals added to prevent fouling on RO membranes.	Typical filter cartridge pore size range is 5 to 10 µm.
Electrodialysis (ED)	Remove salt from solution through the use of ion-exchange membranes.	ED is designed mainly for desalinate and is less effective for suspended solids, total organic carbon (TOC), or other contaminants.
Nanofiltration (NF)	Remove dissolved constituents and colloidal solids, primarily divalent ions and trace organics, be means of size exclusion and solution / diffusion.	Typical membrane pore size range is 0.001 to 0.02 µm with a molecular weight cutoff range of 200 to 1,000 Daltons. NF has been used in place of RO when only softening or partial demineralization is needed.
Pasteurization	Heat water to a specified temperature and time to kill or inactivate microorganisms.	No notes.
Reverse osmosis (RO)	Remove dissolved constituents and colloidal solids, including salts and trace organics, by means of size exclusion and solution/diffusion.	Typical membrane pore size range is 0.0001 to 0.002 µm with a molecular weight cutoff of less than 100 Daltons. RO concentrate for wastewater is typically 15 percent of the flow.
Advanced oxidation processes (AOPs)	Destroy or alter chemical constituents that are not completely removed upstream processes, especially trace organics.	AOP may contain a range of processes, but most commonly uses ozone with H_2O_2 or UV with H_2O_2. More recent projects are implementing UV with sodium hypochlorite for AOP. The use of UV, ozone, and sodium hypochlorite also provides disinfection.
Post-processing (when RO is used, decarbonation and stabilization are typically involved)	Decarbonation is used to remove (i.e., strip out) excess carbon dioxide from RO product water to increase pH and reduce the amount of chemicals added for stabilization. Stabilization involves the addition of a chemical (typically lime) to the RO product water to increase hardness and alkalinity and reduce its corrosive properties.	A variety of different corrosivity indices (e.g., Aggressiveness Index, Langelier Saturation Index, calcium carbonate precipitation potential) are used to assess the stability of product water.
Engineered storage, with or without free chlorine	Store water between the AWTF and DWTF. However, engineered storage should not be a requirement.	In some cases, travel time in the pipeline from the AWTF to the DWTF may serve the same purpose.
Soil aquifer treatment	Reclaimed water is discharged into a basin and allowed to infiltrate slowly through the vadose zone, where sorption, filtration, and biodegradation can enhance the water quality.	Appropriate geology is needed, including soils with high permeability.

Source: Adapted from Tchobanoglous et al. (2015) and NRC (2012).

7.5.2 Engineered Natural Systems

For potable reuse applications, engineered natural systems can provide the role of an environmental buffer and are used in combination with above ground engineered process. These systems can consist of constructed wetlands or managed aquifer recharge systems and can have multiple benefits, including removal of pathogens, trace organic chemicals, organic carbon, and nutrients. Engineered natural systems also have a low carbon footprint (NRC, 2012).

Soil aquifer treatment (SAT) systems are managed aquifer systems where water is discharged into a basin and allowed to infiltrate slowly through the vadose zone. SAT can provide storage and enhance water quality by taking advantage of attenuation processes that occur in the vadose zone and saturated aquifer. SAT provides many advantages including a low degree of maintenance, temperature equilibration of the water, variations in water quality is buffered by dispersion and dilution, and water quality improvements. SAT is capable of sustaining the removal of organic carbon, nitrogen, and pathogens. Surface applications do require a substantial aquifer and extensive site assessment (NRC, 2012). In addition, mobilization of arsenic has been shown to be an issue for projects in Florida.

The removal of organic matter during SAT has been shown to be very efficient. Studies have demonstrated the transformation and removal of trace organic chemicals during SAT. In addition, studies have shown the filtration and biodegradation processes during SAT is effective for the inactivation of pathogens (NRC, 2012).

Constructed wetlands for reuse can provide multiple benefits. In addition to providing water quality benefits, engineering treatment wetlands can serve as habitat for birds and provide recreational and educational benefits. Treatment wetlands have been used to treat reclaimed water for potable reuse through surface-flow systems. These systems provide good removal of contaminants originating from wastewater. Studies show that wetlands remove nitrate and phosphorus. Wetlands can provide removal of particle-associated pathogens. In addition, levels of certain trace organics are reduced due to volatilization and attenuation. However, hydraulic short-circuiting can result in decreases in treatment efficacy (NRC, 2012).

7.5.2 Reverse Osmosis Based Treatment Trains

RO based treatment trains have been used successfully in potable reuse treatment trains, including in California, Arizona, and Texas. RO membranes are effective at removing TDS, pathogens, and organic chemicals, including regulated contaminants and emerging constituents such as hormones, pharmaceuticals, endocrine disruptors, and personal care products. Some of the organic constituents that are partially removed by RO membranes are low-molecular-weight compounds, including N-nitrosodimethylamine (NDMA), 1,4-dioxane, and certain disinfection byproducts, including chloroform (Bellona et al., 2008).

Integrated membrane systems incorporating MF or UF followed by RO have been used for reuse projects that require removal of TDS and trace organic chemicals. RO, a pressure-driven membrane process, separates dissolved constituents from water into a concentrate and permeate stream. Treating reclaimed water with RO usually results in product water recoveries of 70 to 85 percent. As a result, there is a net loss of water through disposal of the concentrate. RO applications in water reuse have been used in coastal settings where the RO concentrate can be discharged to the ocean. Inland applications using RO required a disposal option (NRC, 2012)

In California, full advanced treatment (FAT) is a set of unit processes – microfiltration (or ultrafiltration), RO, and an advanced oxidation process (AOP) – specified in potable reuse regulations that are designed to work together to remove pathogens and chemicals, including emerging chemicals, to protect public health. (Bernados, 2018).

7.5.2 Treatment Trains without Reverse Osmosis

Because of high energy cost of operation and logistical issues associated with managing RO concentrate (typically 15 percent of the flow for potable reuse applications), interest exists in developing non-RO based treatment trains. Other treatment processes (e.g., ozone, BAF, UF, GAC, AOP) can be used to meet chemical and pathogen treatment goals. The lack of TDS removal and a higher level of TOC in the finished water are the principal differences between the RO-based and non-RO based treatment trains (Tchobanoglous et al., 2015).

Pathogen control, including meeting required log removal values, can be accomplished in non-RO treatment trains through the use of disinfection treatment and alternative treatment technologies. As discussed in **Section 7.6** on pathogen reduction values for various treatments, a range of technologies can be used to meet pathogen removal objectives. These technologies include conventional disinfection (e.g., chlorine, ozone, UV) MF, UF, and NF. In addition, an effective barrier for pathogens and chemicals are AOPs. As a result, pathogen control can be achieved through a variety of treatment technologies that support a multiple-barrier approach for potable reuse.

Non-RO treatment trains for potable reuse must be able to control regulated and unregulated trace organics and other chemical constituents of interest for potable reuse, including nitrate, commercial and industrial chemicals, DBPs and trace organic chemicals (including pharmaceuticals and ingredients in personal care products). A number of non-RO treatment alternatives are available for potable reuse application that can treat for these constituents.

NF, which operates at lower pressure than RO (i.e., uses less energy) has a higher recovery (i.e., reduced residual stream produced), removes polyvalent ions that contributes to hardness, and has been shown to remove a range of trace organic chemicals, including endocrine disruptors, pharmaceuticals, and personal care products (Snyder et al., 2007).

AOPs have been shown to be effective in controlling trace organic chemicals. Recently, a significant amount of research on ozone/BAF has shown that it provides effective removal of trace organic chemicals in potable reuse applications. GAC, in combination with other treatment technologies, is effective in trace organic chemical removal (Kumar et al., 2017; Tchobanoglous et al., 2015; Mosher et al., 2016).

7.5.3 Role of the Engineered Storage

The use of an engineered storage is an option for potable reuse that can provide benefits. Some water analyses can be made during the storage time, which may be several hours. This monitoring provides time for additional confirmation of water quality to ensure the advanced treated water will only be released to the DWTF (or a finished water will only be released to the distribution system) as long as it is in full compliance with operational and regulatory parameters. The engineered storage could be sized to hold the water for the time period equivalent to the failure response time, which allows for system monitoring, verification of results, potential resampling, calibration of monitoring devices, determination of failure, and operational response. Engineered storage would be part of an integrated operational monitoring and control system that uses online monitoring results for all advanced processes to document that each process is functioning properly and the combined processes are meeting the design targets for the removal of chemicals and pathogens.

Several configurations can be used for the design of the engineered storage, such as plug-flow pipelines, lined and possibly covered reservoirs, baffled tanks, or tanks in parallel operated in a fill, store, and draw mode. Free chlorine can be added to the engineered storage, resulting in additional disinfection credits in line with U.S. EPA standards.

Engineered storage may be replaced by additional or redundant treatment with appropriate and effective monitoring. The additional treatment allows for the continuous production of advanced treated water if one of the major treatment processes does not meet specifications. This approach relies on the use of operational monitoring systems and the ability to immediately divert flow in the event of further process failure (Tchobanoglous et al., 2015).

7.5.4 Operational Bypass

For potable reuse, it is critically important to verify AWTF performance during startup or when there are operational issues that require a portion of the system to be taken out of service for maintenance or repairs. A bypass from the outlet of the system to a nonpotable reuse or disposal option including into the sewer system (if available) or reclaimed back to the start of the treatment process should be included in all projects. This bypass will allow the operators to verify and document that all systems are operating in accordance with the Operation and Maintenance (O&M) Plan (see **Section 7.8.4**). Further, this requires that the wastewater treatment facility maintain other nonpotable reuse or disposal options for times when the AWTF is offline.

7.5.5 Representative Performances of Various Treatment Trains

Final water quality (i.e., solids concentrations, organics, nutrients, metals, and microorganisms) will vary depending upon the treatment technologies used in the treatment processes (Tchobanoglous et al., 2015). Some representative data are provided in **Table 7.10** of the water quality produced from different treatment combinations. The final water quality may need post-processing to stabilize the water to prevent corrosion and related issues.

Table 7.10 Typical Range of Effluent Quality after Various Levels of Conventional Wastewater and Advanced Water Treatment

Constituent	Unit	Untreated Wastewater	Range of Effluent Quality after Indicated Treatment			
			Conventional Activated Sludge with Filtration	Activated Sludge with Ozone/BAF	Activated Sludge with MF and RO	Activated Sludge with MF, RO, and UV-AOP
Total suspended solids	mg/L	130–389	2–8	1–2	≤1	≤1
Turbidity	NTU	80–150	1–10	≤1	≤0.1	≤0.1
Biochemical oxygen demand	mg/L	133–400	<5–20	≤1	≤1	≤1

Constituent	Unit	Untreated Wastewater	Range of Effluent Quality after Indicated Treatment			
			Conventional Activated Sludge with Filtration	Activated Sludge with Ozone/BAF	Activated Sludge with MF and RO	Activated Sludge with MF, RO, and UV-AOP
Chemical oxygen demand	mg/L	339–1016	30–70	≤10–30	≤2–10	≤2–10
Total organic carbon	mg/L	109–328	15–30	2–5	0.1–1	0.1–1
Ammonia nitrogen	mg N/L	14–41	1–6	≤1	≤1	≤1
Nitrate nitrogen	mg N/L	0–trace	5–30	5–30	≤1	≤1
Nitrite nitrogen	mg N/L	0–trace	0–trace	≤0.001	≤0.001	≤0.001
Total nitrogen	mg N/L	23–69	15–35	≤1	≤1	≤1
Total phosphorus	mg P/L	3.7–11	2–6	2–6	≤0.5	≤0.5
Volatile organic compounds	µg/L	<100–>400	10–40	≤1	≤1	≤1
Iron and manganese	mg/L	1–2.5	1–1.4	≤0.3	≤0.1	≤0.1
Surfactants	mg/L	4–10	0.5–1.5	≤0.5	≤0.1	≤0.1
Totals dissolved solids	mg/L	374–1121	374–1121	374–1121	≤5–40	≤5–40
Trace constituents[a]	µg/L	10–50	5–30	≤0.1	≤0.1	≤0.1
Total coliform	No./ 100 mL	10^6–10^{10}	10^3–10^5	350	<1	<1
Protozoan cysts and oocysts	No./ 100 mL	10^1–10^5	0–10	≤0.002	≤0.002	≤0.002
Viruses	PFU/ 100 mL	10^1–10^8	10^1–10^4	≤0.03	≤0.03	≤0.03

Notes: [a]For example, fire retardants, personal care products, and prescription and nonprescription drugs.

Source: Adapted from Tchobanoglous et al. (2015).

7.5.6 Pilot Testing/Demonstration Studies

Florida currently requires pilot testing for IPR projects. F.A.C. 62-610.564 states: "Pilot testing is required for all projects that are required to provide full treatment and disinfection".

Pilot testing/demonstration studies can be used for the following purposes:

- Make decisions about the selection of specific advanced treated water processes for the potable reuse project.
- Verify AWTF performance and gain regulatory approval for the treatment train.
- Evaluate the effectiveness of different types of treatment processes or different vendors of the same treatment processes.
- Inform the design of the full-scale potable system.

Pilot tests and/or demonstration studies should have treatment study goals guided by test plans, which includes a framework for comprehensive monitoring (i.e., performance, CCPs, and water quality).

7.5.7 Summary for Advanced Water Treatment Technologies

No one specific treatment train is required for potable reuse. Advanced water treatment facilities will employ different treatment trains using different treatment technologies, based on specific water quality goals, operational objectives, and regulatory requirements. The proposed treatment train must meet pathogen log reduction criteria and chemical criteria. The treatment trains should be designed to eliminate acute risks (i.e., pathogens) and minimize potential chronic risks (i.e., chemical constituents). The treatment trains include reverse osmosis-based options and alternative advanced treatment options that may include NF, ozone/BAF, AOPs, and GAC.

The use of an engineered storage is not necessary for potable reuse, but can provide additional failure response time. Final water quality will vary depending upon the treatment technologies used in the treatment train, but all treatment processes should be used with the goal of ensuring the protection of public health.

The treatment processes identified in **Table 7.9** do not represent an exhaustive list of treatment options. Research and experience in the field are continuously contributing to the enhancement of current treatment technologies and development of new ones. The consideration of alternative treatment processes for potable reuse should be encouraged. Other treatment technologies could be suitable for potable reuse treatment train scenarios.

7.5.8 Best Practices for Advanced Water Treatment Technologies

Best Practices for advanced water treatment technologies are listed in **Table 7.11**.

Table 7.11 Best Practices for Advanced Water Treatment Technologies

Best Practices	Category
A bypass from the outlet of the AWTF into the sewer system (if available) or recycled back to the start of the treatment process should be included in all potable reuse projects.	Industry Best Practice
Pilot testing or demonstration studies are useful for the design and operation of potable reuse projects.	Industry Best Practice

7.6 Pathogen Reduction Values for Treatment Processes

A wide range of information is available regarding pathogen treatment credits through either chemical inactivation (disinfection) or physical separation (removal). Available information is sufficient to design multi-barrier advanced treatment systems capable of meeting the log reduction requirements for viruses, *Cryptosporidium*, and *Giardia*.

For pathogen control, a risk-based log removal approach for potable reuse is modeled after the U.S. EPA Surface Water Treatment Rule. The foundation of this approach is as follows:

- Establish appropriate risk levels for exposure to pathogens (i.e., viruses, bacteria, and protozoa) consistent with public health protection.

- Understand the concentrations of pathogens in source water by specifying the log reduction values required to meet the appropriate risk levels for health protection.
- Design an integrated treatment process capable of providing the necessary log reduction values using multiple barriers that consist of treatment processes with validated treatment credits.
- Monitor the performance of both individual and integrated treatment processes to ensure their abilities to reliably provide the intended log reduction values.

Using these principles, a suitably designed, well-operated, and properly maintained integrated treatment process is capable of managing pathogen risks in a potable reuse scenario so that human health protection goals are met (Mosher et al., 2016).

7.6.1 Log Reduction Credits

When designing an AWTF, the sum of validated log reduction credits for the individual treatment processes must equal or exceed the log reduction values needed to protect human health. Quantifying the log-reduction performance of treatment technologies has been the subject of considerable research. State regulatory agencies should grant or approve reduction credits based on available research and guidance. California and Texas have developed log reduction values for potable reuse applications.

7.6.1.1 Division of Drinking Water of the California State Water Resources Control Board

In connection with the development of rules and regulations for IPR using groundwater replenishment, the Division of Drinking Water of the California State Water Resources Control Board also developed log reduction values for individual treatment process and for water retention times above and below ground. The approved log reduction credits are reported in **Table 7.12** and represent the maximum reduction credit allowances (Olivieri et al., 2016).

Table 7.12 Approved Log Reduction Credits for Groundwater Replenishment Projects in California

Process	Pathogen Log Reduction Credits		
	Virus	***Cryptosporidium***	***Giardia***
Secondary activated sludge	1.9	1.2	0.8
Microfiltration or ultrafiltration	0	4	4
Filtered and disinfected secondary	5	0	0
Reverse osmosis [a]	2	2	2
Free chlorine post reverse osmosis	4	0	3
Ultraviolet/hydrogen peroxide[b]	6	6	6
Surface application retention time[c]	6	10	10

[a] Log reduction values of 2 are achieved using total dissolved solids and electrical conductivity as a performance measure. Research on alternative measures may demonstrated that log reduction values of greater than 2 may be assigned.

[b] 6-log reduction of virus (including adenoviruses) and 6-log reduction of protozoa, assuming the ultraviolet dose is >300 millijoules per square centimeter (mJ/cm^2) (based on advanced oxidation, typically >900 mJ/cm^2).

[c] Based on a 6-month retention time.

Source: Adapted from Olivieri et al. (2016).

7.6.1.2. Texas Commission on Environmental Quality

The log reductions that TCEQ uses as a basis for granting credits for a particular technology are presented in **Table 7.13**. These values are compared to "upper end reductions" that have been developed based on pilot-scale and full-scale installations, as reported in WRF-11-02 (Trussell et al., 2013). Due to the inability to directly monitor pathogen concentration in a timely manner, indirect measures are used to verify treatment performance. These measures can include methods that: (1) predict pathogen removal performance (e.g., calibrated UV sensors for UV disinfection); (2) estimate pathogen removal performance (e.g., pressure decay tests for membrane monitoring); and/or (3) evaluate overall process performance, without assessing pathogen removal performance (e.g., turbidity) (NWRI, 2013).

In several cases, the technical limitations of integrity testing and/or monitoring programs often are the controlling factors in determining log reduction credits for treatment technologies. For example, referring to **Table 7.13,** TCEQ does not recognize log reductions for RO technology, not because the technology fundamentally fails to serve as a barrier to the passage of pathogens, but because of the lack of a direct integrity test. Improved methods for RO integrity testing and/or monitoring would allow the full pathogen removal capability of the technology to be reflected in its log reduction credit. Upper End Reduction (UER) values are provided in **Table 7.13**; the UERs represent the potential high end of removal values possible by the technology.

Table 7.13 Potential Log Removal Values for Pathogens

Process/Technology	*Cryptosporidium* *(log removals)*		*Giardia* *(log removals)*		Virus *(log removals)*	
	TCEQ	UER	TCEQ	UER	TCEQ	UER
Microfiltration or ultrafiltration	4	4	4	4	0	0
Membrane bioreactor	0	4	0	4	0	0
Reverse osmosis	0	2	0	2	0	2
Nanofiltration	0	---	0	---	0	---
Chlorine	0	0	1	1	3	3
Ultraviolet irradiation disinfection	4	4	4	4	4	4
Ultraviolet/photolysis	4	≥4	4	≥4	4	≥4
Advanced oxidation processes	4	6	4	6	4	6
Ozone	3	3	3	3	5	5
Ozone/biological activated carbon	3	3	3	4	5	5
Stabilization	---	---	---	---	---	---
Engineered storage	---	---	---	---	---	---

Adapted from APAI (2015). See Table 5-1 of APAI (2015) for caveats and limitations associated with these values.

UER = Upper End Reduction value.

7.6.2 Pathogen Removal

Expected log reduction credits for three potable reuse treatment train examples are shown in **Tables 7.14, 7.15**, and **7.16**, respectively. The log reduction credits shown do not include pathogen reduction credits for the upstream wastewater treatment facility or for the downstream DWTF where the advanced treated water is blended upstream of the DWTF. All three example treatment trains provide significant removal of pathogens.

Recent and ongoing research may impact the application of some of these treatment technologies in potable reuse schemes or require special considerations for their use, including:

- **Online Monitoring for Reverse Osmosis Integrity:** Based on preliminary results from WRF-12-07 (WRF, 2019) and WRF-14-10 (TWDB, 2016), it appears that online water quality monitoring techniques (e.g., TRASAR®) may lead to higher log reduction credits for RO, which could result in fewer treatment processes or modified operating and monitoring requirements.
- **Ozone DBPs:** Ozone has the potential to produce unwanted DBPs, such as bromate and NDMA. Mitigation techniques include the use of BAF downstream of ozone to remove NDMA to below pre-ozone levels (Gerrity, 2015), and ammonia addition or the application of ozone at sub-residual doses can control the formation of bromate.
- **Membrane Bioreactors:** MBRs, which have become more common for wastewater treatment, may eliminate the need for MF/UF treatment if proper membrane integrity testing can be provided by manufacturers to confirm adequate pathogen log reduction. Because integrity testing is challenging for MBR membranes, other indicators of treatment performance should be considered, such as turbidity.
- **Engineered Storage:** Engineered storage provides response time (i.e., time to sample, analyze the sample, and react to the result). Providing adequate retention time to meet the failure response time (hours or days) can be prohibitively expensive for medium- to large-sized AWTFs. Appropriate online water quality and performance monitoring, including CCPs, can eliminate the need for engineered storage.

Interim information is provided in **Table 7.17** on an ozone/BAF based treatment train that is being conducted at a facility in Florida. The potable reuse demonstration system has full-scale components. The data reflects information based on 6 months of operation.

Table 7.14 Pathogen Log Reduction Credits for Treatment Train #1

Pathogen	MF[a]	RO[b]	UV/AOP[c]	Storage with Cl[d,e]	Total
Virus	0	2	6	4	12 log
Cryptosporidium	4	2	6	0	12 log

[a] Four-log reduction of *Cryptosporidium* has been assumed for microfiltration (MF), based on credit commonly granted by states for membranes passing daily membrane integrity tests.

[b] Two-log reduction of viruses, *Cryptosporidium,* and *Giardia* have been assumed for reverse osmosis (RO), based on credit commonly granted by states for online monitoring of conductivity or total organic carbon.

[c] Six-log reduction of viruses and *Cryptosporidium* have been assumed for ultraviolet/advanced oxidation processes (UV/AOP), based on testing by ultraviolet manufacturers.

[d] Per the USEPA Surface Water Treatment Rule, free chlorine provides 4-log virus inactivation at a CT of 6 mg/L-min at a temperature of 10°C.

[e] Actually demonstrated values (Gerringer et al., 2015) or values referenced by WRF-12-06.

Table 7.15 Pathogen Log Reduction Credits for Treatment Train #2

Pathogen	Ozone[a,b]	BAF	MF	RO	UV/AOP	Total
Virus	4	0	0	2	6	12-log
Cryptosporidium	0	0	4	2	6	12-log

[a] Per the USEPA Surface Water Treatment Rule, ozone provides 4-log virus inactivation at a CT of 1 mg/L-min at 10°C.

[b] Both chlorine and ozone likely will achieve higher log reduction values than shown if higher CTs are used.

Table 7.16 Pathogen Log Reduction Credits for Treatment Train #3 (No Reverse Osmosis)

Pathogen	Ozone[a,b]	BAF	UF[c]	UV/AOP[d]	Storage with Cl_2[b,e]	Total
Virus	4	0	2	6	4	16-log
Cryptosporidium	0	0	4	6	0	10-log

[a] Pr the USEPA Surface Water Treatment Rule, ozone provides 4-log virus inactivation at a CT of 1 mg/L-min at 10°C.

[b] Both chlorine and ozone likely will achieve higher log reduction values than shown if higher CTs are used.

Table 7.17 Pathogen Log Reduction Credits for an Ozone/Biologically Active Filtration Based Treatment Train (Salveson, 2018)

Unit Process	Virus	*Giardia*	*Crypto-sporidium*	Notes
Ozone	5-log	-	-	• Ozone operated at sub-residual dose to minimize disinfection byproducts and not impact downstream biofiltration. • Research demonstrates 5-log virus at O_3-to-TOC ratios of 0.6:1.0
BAF	+	+	+	• Protozoa and virus removal possible due to the reduction of total suspended solids, as measured by turbidity reduction following USEPA criteria (USEPA, 2010 and USEPA, 2006d). • May require demonstration testing.
UF	+	4-log	4-log	• Protozoa removals based upon proven Membrane Filtration Guidance Manual concepts (USEPA, 2005) • Virus removal expected, but needs demonstration testing to prove performance.

Unit Process	Virus	*Giardia*	*Crypto-sporidium*	Notes
GAC	-	-	-	• No removal anticipated.
UV (high-dose)	6-log	6-log	6-log	• High dose UV for photolysis of NDMA (~900+ mJ/cm^2) • 235+ mJ/cm^2 necessary for 6-log of all known pathogens
Engineered Storage with Chlorine	4-log	3-log	-	• Free chlorine disinfection based upon EPA CT criteria. • Carefully examine DBP formation potential to balance disinfection and DBP minimization.
Total	**15-log**	**13-log**	**10-log**	• Health standards met without engineered storage. • Additional credit from engineered storage can be obtained.

"+" indicates some removal expected. "-" indicates no removal anticipated.

7.6.3 Summary of Pathogen Removal Credits

The U.S. EPA concluded that for pathogens, a 10^{-4} annual risk of infection represents an acceptable risk (NWRI, 2013). As a result, to remain consistent with this concept of risk, finished drinking water produced from potable reuse projects should meet the level of no more than one infection in 10,000 persons per year (i.e., 10^{-4} annual risk of infection).

The sum of validated log reduction credit for the individual treatment processes (i.e., wastewater treatment, advanced water treatment, and drinking water treatment) in a potable reuse system must equal or exceed the log reduction values needed to protect human health. Quantifying the log-reduction performance of treatment technologies can be developed based on pilot and demonstration studies, available research, and guidance.

California and Texas regulators have instituted log reduction values for pathogen credit systems for potable reuse. These systems can serve as an example for Florida.

Other considerations include the following:

- For RO, log reduction credits of 2 can be demonstrated for viruses, *Cryptosporidium*, and *Giardia* based on online TOC and electrical conductivity before and after RO. It may be possible to demonstrate higher than 2 log reduction credits for RO based on new monitoring methods that are currently being researched (e.g., Trasar®).
- Log reduction credits have been assigned in California for wastewater involving activated sludge treatment; however, additional research is underway to review other approaches involving pathogen data collection and California will likely require a demonstration study to assign credits for wastewater treatment.

7.6.4 Best Practices for Addressing Pathogens

Best practices for addressing pathogen reduction credits are listed in **Table 7.18.**

Table 7.18 Best Practices for Pathogen Reduction Credits for Treatment Processes

Best Practices	Category
A log reduction credit system or approved proposed removals for pathogen reductions for potable reuse treatment technologies can be developed based on systems developed in California and Texas, available guidance, and treatment studies.	Industry Best Practice
As part of the log reduction credit system approach, utilities can verify or demonstrate log reduction levels for unit processes that can be used to assign appropriate log reduction credits for the individual unit processes.	Industry Best Practice

7.7 Monitoring, Instrumentation, and Process Control Requirements

Process monitoring for potable reuse systems involves the following two key components: (1) documentation and review of system performance in accordance with design intent and manufacturer recommendations to ensure water-quality specifications are met; and (2) the ability of the control system to accurately measure operational indicators of chemical and pathogen reduction performance to meet specified criteria.

7.7.1 System Control through Critical Control Points

CCPs are points in advanced water treatment where control can be applied to individual unit processes to reduce, prevent, or eliminate risk from pathogens and chemicals and where monitoring is conducted to confirm proper performance (Walker et al., 2016). The CCP approach also requires the development of specific actions and/or investigations in response to monitoring controls.

For each CCP (i.e., a unit treatment process), surrogates(s) are monitored to assess whether the treatment process is functioning as expected or has been compromised based on the measured data. These surrogate measures need to be continuous. To support response actions by operators and other follow-up actions, the CCP approach would be coupled with a set of alarms, alerts, and critical limits (Walker et al., 2016).

The application of the CCP approach can be used to ensure appropriate operating conditions are maintained. This concept is illustrated in **Figure 7.1** and **Table 7.19** for an example RO-based AWTF treatment train. This example includes the unit processes that are CCPs and the monitoring controls required to demonstrate performance. The application of the CCP concept for an example ozone/BAF based AWTF treatment train is illustrated in **Figure 7.2** and **Table 7.20**.

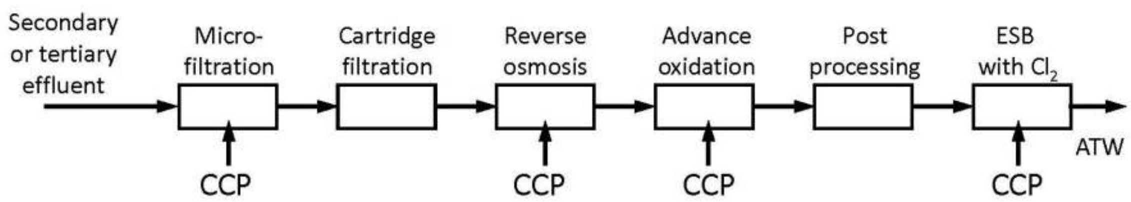

Figure 7.1: Example of an advanced water treatment facility process flow diagram with critical control points identified for the individual treatment processes for both process control and establishing log reduction credits. Figure courtesy of Tchobanoglous et al. (2015).

Table 7.19 Example of Critical Control Point Monitoring Scheme Shown in Figure 7-1 (Tchobanoglous et al., 2015)

Process	**Critical Control Point Monitoring**
Secondary treatment	At present, the science is insufficient, but developing. WE&RF Project 14-16 includes promising work correlating secondary effluent quality (e.g., TOC, bacteria counts, etc.) with pathogen concentrations. Similar investigations have been completed by WERF (CEC4R08) correlating secondary treatment process performance with the destruction of trace organic chemical pollutants.
Microfiltration or Ultrafiltration	Daily Pressure Decay Test following USEPA MFGM.
Reverse Osmosis	Online Electrical Conductivity (feed and permeate) and TOC[a].
Ultraviolet/Advanced Oxidation Processes	Intensity sensors, UVT, and flow rate.
Storage with free chlorine, CL_2, residual ($\geq$0.4 mg/L)	Online Cl_2.

[a] Other methods are under development.

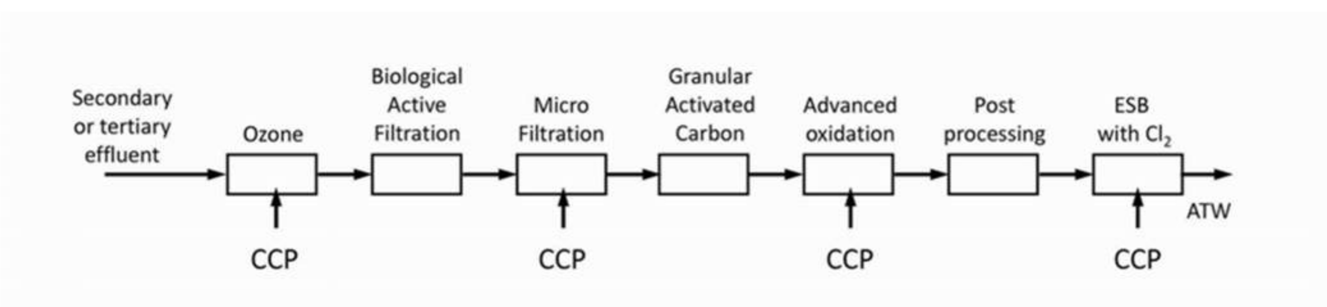

Figure 7.2: Example of an ozone/biologically active filtration based treatment train process flow diagram with critical control points identified for the individual treatment processes for both process control and establishing log reduction credits.

Table 7.20 Example of Critical Control Point Monitoring Scheme for Ozone/Biologically Active Filtration Based Treatment Train*

Process	Critical Control Point Monitoring	Reference Projects/Notes
Secondary treatment	At present, the science is insufficient, but developing. WE&RF Project 14-16 includes promising work correlating secondary effluent quality (e.g., TOC, bacteria count, etc.) with pathogen concentrations. Similar investigations have been completed by WERF (CEC4R08) correlating secondary treatment process performance with the destruction of trace organic chemical pollutants.	• WERF CEC4R08 • WE&RF 14-16
Ozone	The ozone/TOC ratio demonstrates a clear correlation to virus kill (WE&RF 11-02) and the destruction of trace organic chemical pollutants.	• WE&RF 11-02 • Chemical pollutant destruction work led by Dan Gerrity (formerly at the University of Nevada Las Vegas)
Biological active filtration	Pertaining to TOC removal, biofiltration performance monitored online using calibrated TOC meters at the ozone feed location and post BAF. Pertaining to pathogen removal, studies are planned, but not completed, to correlate turbidity reduction through BAF with virus and protozoa reduction.	• Kumar et al. (2017). • Stanford, B., E. Dickenson, E. Wert, M. Inyang (2017). Controlling Trace Organic Compounds Using Alternative, Non-FAT Technology for Potable Reuse. Project Number Reuse 13-10
Microfiltration or Ultrafiltration	Daily Pressure Decay Test for protozoa removal only.	• Following USEPA MFGM
Granular activated carbon	Online TOC and UVT monitoring demonstrate the transition from adsorption to a second stage biofiltration system (documented in WRF 14-16).	• WRF 14-16
Ultraviolet/Advanced Oxidation Processes	Intensity sensors, UVT used for real-time dose monitoring for pathogen kill. Use of an oxidant weighted dose proven to correlate with the destruction of trace organic chemical pollutants.	• Pathogen kill follows USEPA UVDGM. • Oxnard (2018). Engineering Report for Groundwater Replenishment Reuse Project. December 2018. A report by Carollo Engineers, Inc.
Engineered Storage with free chlorine, CL_2, residual ($\geq$0.4 mg/L)	Online Cl_2 used to monitor virus kill and *Giardia* kill in real time based upon Ct measurements.	• Follows USEPA tables • Engineered storage not installed at the Altamonte Springs Demonstration Facility*

7.7.2 Automated System Control – Potable Reuse Treatment Train

The treatment process control system (i.e., the controls programming, Supervisory Control and Data Acquisition [SCADA] system, and human-machine [HMI] configuration) would provide rapid and appropriate operational response. In addition, it should continuously record the CCP data. The control system would allow operators to: proactively review performance to anticipate problems before they occur; respond effectively to alarms and shutdown conditions; provide a thorough investigation of why the problem occurred and transfer lessons learned to improve future operations; and return systems safely and effectively to service in a timely manner (Walker et al., 2016).

The control system also allows for the calculation of the total pathogen log reduction credits in real time, with automated warning systems and, if needed, system shutdown and diversion. Similar alarms could be set based upon the anticipated removal of salts, TOC, and other parameters, depending upon the treatment processes and their respective treatment performance.

7.7.3 Flow Diversion

In the event the entire treatment train cannot attain the target pathogen goals, effluent from the AWTF may need to be diverted (through means of a discharge permit) or the system may need to be shut down until targets are met.

7.7.4 Start-Up/Documentation of Baseline Performance

At startup and prior to system operation, water quality monitoring is needed for each major treatment process and for final product water quality (an example of startup testing is provided in **Table 7.21** for one example treatment train). A Start-Up Performance Plan should be required, similar to existing procedures for Approval of Construction. This monitoring is intended to: (1) document that system performance results in a finished water protective of public health; (2) provide a baseline of system performance for future comparison and analysis; and (3) validate the effectiveness of CCP selection and monitoring. Ideally, this baseline performance would establish a normal distribution of performance and monitoring data. Future deviations from the normal distribution would be flagged for a more detailed evaluation and, potentially, equipment repair.

Sampling protocols for compounds with MCLs and secondary MCLs, as well as specific compounds with Drinking Water Health Advisory values, can be found in U.S. EPA (2012). At start up, monitoring should be conducted to assess chemical control, as discussed in **Section 7.4** for both unregulated and regulated constituents, including emerging constituents.

7.7.5 Performance Monitoring

Performance monitoring can include CCPs and critical operating points (COPs), which focus specifically on operational issues. This monitoring, which can include continuous or periodic sampling, is intended to demonstrate the continuous production of high-quality water protective of public health. Specifically:

- Continuous online sampling for all feasible control parameters and periodic bench-top calibration of online meters are summarized in **Table 7.22** for one example treatment train.
- In lieu of online monitoring, frequent grab samples should be required if online systems are not available.

- Periodic sampling requirements for water quality monitoring are summarized in **Table 7.23** for one example treatment train. Sampling frequency can be reduced over time based on whether sampling shows non-detects for a reasonable time period.

Table 7.21 Example Startup Testing for the Advanced Water Treatment Facility Flow Diagram Shown in Figure 7.1 (Tchobanoglous et al., 2015)

Process	Test	Sample Type and Frequency	Notes
Secondary effluent	Effluent turbidity, biochemical oxygen demand (BOD), and total suspended solids (TSS) microbial indicators	Online (continuous) and grab (daily) for 30 days	Sets baseline water quality.
	Effluent MCLs, secondary MCLs, and health advisory values	Two grab samples over 30 days	Provides a preliminary understanding of trace constituents ahead of advanced treatment.
MF or UF	Pressure Decay Test; Turbidity	Offline testing (daily)	Provides an assessment of performance.
RO	Influent and effluent TOC	Online (continuous) and grab (daily) for 30 days	TOC reduction to <0.5 mg/L is expected with well-functioning RO membranes.
	Influent and effluent EC	Online (continuous) and grab (daily) for 30 days	EC monitoring is required for long-term operation.
	Influent and effluent emerging constituents	Two grab samples over 30 days	Demonstrates removal by key process for CEC reduction (RO).
UV/AOP	Influent and effluent NDMA and 1,4-dioxane (if present in source water)	Two grab samples over 30 days	Demonstrates UV and oxidant doses and removal of indicator constituents difficult to remove by other techniques. 1,4-dioxane is primarily removed by AOP; NDMA by UV photolysis.
	UV sensors	Online (continuous) and verification (weekly) monitoring	Comparisons to anticipated values from manufacturers required.
	Influent ultraviolet light transmittance (UVT)	Online (continuous) and grab (daily) monitoring	Provides as assessment of performance.
	Effluent *E. coli* and total coliform	Grab (weekly) for 1 month	Total coliform is not an MCL, but a general bacteria performance check.
	Effluent MCLs, secondary MCLs, unregulated emerging constituents	Two grab samples over 30 days	Demonstrates quality of advanced treated water ahead of blending.
	Influent and effluent chloramine	Grab (daily) for 30 days	UV/AOP performance correlates with chloramine destruction.
Storage with free chlorination	Effluent free chlorine residual	Online (continuous) and grab (daily) for 30 days	Demonstrates the ability to maintain minimum target residual and minimum CT.

Table 7.22 Performance Monitoring: Example Online and Calibration Sampling for the Flow Diagram Shown in Figure 7-1 (Tchobanoglous et al., 2015)

Process	Test	Type and Frequency of Sampling during Operation
Secondary effluent	Turbidity and microbial indicators	Turbidity: online (continuous) and grab (weekly); microbial: grab (weekly)
	Ammonia, TSS, and BOD	Grab (weekly)
MF or UF	Pressure Decay Test	Offline testing (daily)
	Turbidity	Online (continuous) and grab (weekly)
RO	Influent and effluent EC and TOC	Online (continuous) and grab (weekly)
UV/AOP	UV sensors	Online (continuous) and verification (weekly)
	Influent UVT	Online (continuous) and grab (weekly)
	Influent and effluent chloramine	Online (continuous) and grab (weekly)
Storage with free chlorination	Effluent free chlorine residual	Online (continuous) and grab (weekly)

Table 7.23 Example Performance Monitoring (Only by Grab Samples) (Tchobanoglous et al., 2015)

Monitoring Parameters	Sample Locations	Regulatory Monitoring	Process Monitoring	Frequency
TOC, EC	ROF, ROP		✓	Monthly
MCLs, secondary MCLs	Advanced treated water	✓		Quarterly or as mandated by State
CECs and unregulated	UV/AOP		✓	Quarterly (initially)
Total coliform, *E. coli*	UV/AOP	✓		As mandated by State
NDMA	UV/AOP		✓	Quarterly

Notes: ROF=RO feed, ROP=RO permeate.

7.7.6 Summary for Monitoring

Having redundant monitoring processes (e.g., TOC and EC for RO monitoring) and active CCPs may allow for some process or monitoring excursions, while still producing water that is protective of public health. Automated system control (e.g., turbidity and disinfectant residuals) for the potable reuse system will provide continuously recorded CCP data and calculate total pathogen log reduction credits in real time. Automated water systems can provide system shutdown and diversion. Pathogen credit alarms and system shutdown values should be established.

The use of engineered storage can allow for time to make such decisions. Process monitoring, including continuous online sampling and periodic sampling, is needed to demonstrate the continued production of high-quality water. Periodic calibration of online meters is needed.

7.7.7 Best Practices

Best Practices for monitoring, instrumentation, and process control requirements are listed in **Table 7.24.**

Table 7.24 Best Practices for Monitoring, Instrumentation, and Process Control Requirements

Best Practices	Category
Water quality monitoring is recommended for each major treatment process and final product water quality during startup.	Industry Best Practice
Appropriate process monitoring for potable reuse systems using rapid surrogate measures is needed to measure pathogen reduction performance and to document and review system performance.	Industry Best Practice
In the event of a water quality excursion, the facility needs the ability to shut down or divert out-of-spec water to another system (i.e., the sewer).	Industry Best Practice

7.8 Facility Operations, Maintenance, and Reporting

A potable reuse system involves the use of a number of treatment and monitoring processes. Appropriate O&M is necessary to ensure that the potable reuse system meets all public health objectives and operates consistently and reliably. O&M activities begin with the design and construction of the potable reuse system and continue throughout its lifetime (Walker et al., 2017 and Tchobanoglous et al., 2015).

7.8.1 Initial Startup

Initial startup and system performance testing (commissioning) will demonstrate that the potable reuse system works properly. An initial startup plan will identify the steps necessary to complete performance testing of equipment for water treatment, monitoring, and pumping.

7.8.2 Annual Startup

An annual startup may be needed for systems that are operated intermittently or seasonally. The annual startup plan should include:

- Information identified in the initial startup plan.
- Information on periodic maintenance or cleaning and equipment rehabilitation or replacement.
- A checklist of tasks for each treatment process and the system as a whole, as performed by certified operators who have been trained on the overall operation of the potable reuse system.
- A schedule for completing these tasks.

7.8.3 Shutdown Plan

The shutdown plan should provide the same level of detail as the startup plan, including provisions to drain piping and tanks where freezing or stagnant non-compliant water exists. Some systems after shutdown may need to stay “wet”; therefore, handling this stagnant water during the preparation for startup needs to be addressed.

7.8.4 Operation and Maintenance Plan

An O&M plan demonstrates system performance of the various treatment processes to provide the public and regulators assurance that the potable reuse system is performing as designed. The O&M plan must also include regulatory compliance sampling and monitoring, as well as performance monitoring. In Florida, existing emergency preparedness and response efforts under the Safe Drinking Water Act will inform and support the O&M Plan. Elements of an O&M plan are provided in **Table 7.25**.

Table 7.25 Components of an Operations and Maintenance Plan for a Potable Reuse System

Component	Description
Staffing, Training, and Certification (i.e., for daily operations)	• Appropriately trained staff will be needed to ensure the AWTF is operated properly and routine periodic maintenance is performed. • Licensed drinking water operators (e.g., Class A) are needed to manage day-to-day plant operations, allowing for continued operation in the event of illness or vacation. It is recommended that the drinking water operators have wastewater certification or that some operators could be wastewater-certified operators. Other options to consider include: the development of an advanced water operator certification program or specific advanced treatment endorsements on existing certifications (Walker et al., 2017).A wide range of skills and experience are required to operate the plant; therefore, it may be difficult to hire the required personnel. An alternative would be to use a contracted turnkey service provider to operate the plant with appropriately trained personnel. • Remote monitoring and control capability is necessary to provide 24/7 surveillance. These systems should be demonstrated during startup and commissioning to confirm compliance. • A summary of the various tasks to be performed, along with corresponding hours, can provide insight into the number of operators that would be needed to perform all the required maintenance, sampling, and monitoring.
Checklists for operations procedures (daily, weekly, and monthly)	• Use checklists developed with information provided by manufacturers to ensure routine procedures and duties are performed. • Checklists should include water quality sampling and monitoring to document treatment performance. • Incorporate monthly or other water quality sampling for compliance with state requirements.
Routine maintenance of equipment	• An important aspect of operations is periodic maintenance of equipment and monitoring systems. • Identify routine maintenance as recommended by equipment manufacturers, and verify that online meters are properly integrated for each critical control point (CCP). • Determine the number of hours and type of work needed to perform periodic maintenance and incorporate this information into the annual startup and shutdown plans. • Regularly perform the monitoring and calibration of online instruments to ensure they function properly.
Critical spare parts and failure training	• Identify a list of critical spare parts needed onsite in the event of system failure. • Recommend periodic "failure" drills to verify that staff is trained and parts are available to make rapid repairs to equipment.
Control system	• Operators need to be connected to the Supervisory Control and Data Acquisition (SCADA)

Component	Description
(e.g., SCADA, shutdown procedures, and alarms)	system to constantly monitor system operations. • Program the SCADA system to alert operators when the system is not operating properly and to shut down the system if performance is compromised. • A phone, internet, or cloud-based messaging system could be used to notify operators during non-working hours if an alarm goes off. • The types of alarms that would generate these phone calls need to be determined to ensure operators respond swiftly to the situation. • System shutdown criteria need to be developed to automatically stop the system from allowing out-of-spec water to enter into the distribution system. These systems should be checked at least once per year.
Process monitoring and control	• Operators must know proper procedures for the calibration of online instruments, sampling and testing, and sensor testing. • Additional spare units may be needed to allow for easy change out if the instrument fails or calibration requires that the system be shut down for extended periods of time. • Develop process control during initial startup and verify with vendors, contractors, and operations staff.
Regulatory compliance	• Address regulatory compliance monitoring, including online instruments, daily sampling, monthly compliance sampling and testing, and others. • Regulators will need to determine the number and types of sampling required with online monitoring. • Regulators will need to determine the type and frequency of monitoring used to demonstrate compliance.
Frequency of monitoring	• Process monitoring is needed to monitor the performance of individual equipment or a collection of equipment. • Process monitoring should be based on manufacturer recommendations to ensure the proper operation and performance of equipment. • Process monitoring should involve a combination of online instruments and water quality sampling. • Use the initial startup period to familiarize operators with equipment and various methods of process monitoring. • Employ the SCADA system as a means of monitoring online instruments and processes during non-working hours. • Regulators will need to determine the frequency and types of monitoring used to demonstrate the protection of public health.
Distribution System	• Include periodic sampling of the distribution system during initial startup to determine chemical compatibility between existing drinking water supplies and the advanced treated water. • Implement these tests prior to bringing the project online and on a regular basis during operation. • Consider simple water quality testing comparing existing supplies to the advanced treated water (or blend of the two), including pH, hardness, alkalinity, total ions, and cations. • Ensure that the advanced treated water is conditioned to be compatible with the distribution system corrosion control plan, if one exists, and modify the corrosion control plan as necessary to accommodate the new water supply. Develop a corrosion control plan if one does not yet exist.
Response time to treatment failures or non-compliant water quality	• Operators should be required to be present during facility operation. Remote monitoring and control capability is necessary to provide surveillance.

7.8.5 Response to Off-Spec Water

A response plan is needed in the event of off-spec water at an AWTF. The plan should include: (1) the process to identify and address problems; and (2) the amount of time needed to react and the use of automated systems with triggers and alarms, such as through the use of SCADA. The response plan procedures can be included in the O&M Plan (see **Section 7.8.4**).

7.8.6 Alternative Source of Water

Communities that pursue potable reuse should have an alternative source of water for the short term in case the AWTF is not operational. It may be possible to address this topic through consumptive water use permits in Florida. This could also be addressed in the short term by an alternative source of water or through the Emergency Operations Plan and the Emergency Response Plan (which is required for community water systems that serve more than 3,300 people).

7.8.7 Operator Training and Certification

AWTFs are complex systems that must be operated and maintained by well-trained, highly skilled operations staff. The operators must be able to effectively respond to any issues or challenges that arise at the AWTF, as well as receive ongoing training and certification as new processes and techniques become available. Training could be provided by utilities, national or state water and wastewater associations, commercial training programs, and community college training classes. Operator certification is specifically addressed in **Section 5.9**.

7.8.8 Reporting

Once a potable reuse system is operational, reporting is an important component of documenting the performance of the system. Reporting associated with a potable reuse system could involve the following:

- Start-up monitoring should be reported.
- Performance and compliance monitoring should be reported consistent with State drinking water program reporting requirements.
- An annual report for potable reuse projects should be required. The report should detail trends in water quality and treatment over the year and list any significant operational or technical challenges. It should also verify that the required maintenance has been performed.

7.8.9 Summary

Highly trained and certified operators are critical to the safe, successful functioning of potable reuse systems. Operators should be trained and certified specifically for operating the potable reuse system.

For potable reuse facilities, the following will need to be determined: (1) the number and types of sampling required with online monitoring; (2) the type and frequency of monitoring used to demonstrate compliance; and (3) the frequency and types of monitoring used to demonstrate the protection of public health.

7.8.10 Best Practices for Facility Operations and Maintenance

Best Practices for facility operations and maintenance are listed in **Table 7.26.**

Table 7.26 Best Practices for Facility Operations and Maintenance

Best Practices	Category
The O&M requirements for a potable reuse system may require special operator skills and experience. Potable reuse treatment plant operators should have a Class A level certification as a water treatment plant operator or a dual licensed operator licensed in both water and wastewater treatment.	Industry Best Practice
The details of the number of operators required and level/types of certification needs to be determined for a potable reuse project. Lead operators should be Class A licensed water treatment operators or a dual licensed operator licensed in both water and wastewater treatment.	Industry Best Practice
An O&M plan is needed to define operational procedures. These plans should include procedures for initial startup, annual startup, shutdown, asset management, and O&M. The O&M plan must include regulatory compliance sampling and monitoring.	Industry Best Practice
For potable reuse projects, the following should be considered: start-up reporting, potable reuse system reporting, and an annual report.	Industry Best Practice
A response plan to off-spec water should be developed. The procedures of a response plan to off-spec water can be incorporated into the O&M plan for potable reuse.	Industry Best Practice
Alternative sources of water can be addressed in existing Emergency Operation Plan and the Emergency Response Plan.	Industry Best Practice
Electronic remote sensing system can provide real-time data, appropriate alarms, and automatic response so that operators and other expert support personnel can be on call at all times.	Industry Best Practice

7.9 Potential Water Quality Impacts of Blending

Existing drinking water plants or distribution system may be impacted positively or negatively when advanced treated water is blended upstream of the drinking water treatment facility or in the distribution system. The potential effects of blending advanced treated water from an RO-based potable reuse facility in a DWTF or distribution system could be based on differences in alkalinity or turbidity. The blended water could also affect treatment kinetics and aesthetic acceptance. The potential effects of blending advanced treated water from a non-RO based system such as ozone/BAF could be based on differences in organic content of the blended water. The specific effects will vary based on the blending ratio and chemical characteristics of the waters to be blended. A summary of the potential impacts is provided in **Table 7.27.**

Table 7.27 Potential Water Quality Impacts from Blending before a Drinking Water Treatment Facility and Distribution System

Issue	Potential Impacts[a]	
	Reverse Osmosis-Based Treatment Train	**Ozone/Biologically Active Filtration-Based Treatment Train**
Organic material	Contribution of advanced treated water will decrease organic content of resulting blend, which may result in improvements in efficiency of conventional water treatment.	Depending on efficiency of wastewater treatment process and type of surface water, the advanced treated water could increase or decrease organic content of resulting blend.
Inorganics	Natural occurring minerals (i.e., total dissolved solids [TDS]) and metal concentrations will be reduced. Alkalinity may be reduced.	Naturally occurring minerals (i.e., TDS) and metal concentrations might be increased in the blended water.
Trace-level constituents (e.g., constituents of emerging concern, trace organic chemicals)	The advanced treated water will reduce concentration and composition of trace chemical constituents in surface water.	The advanced treated water will reduce concentration and composition of trace chemical constituents in surface water.
Disinfectant stability and disinfection byproducts	The advanced treated water is likely to provide a more stable disinfectant residual and decrease TTHM and HAAs formation.	Because of different precursors being introduced and depending upon efficiency of advanced treatment process and total organic carbon, disinfection byproducts may form in greater or lesser concentrations and different compositions.
Corrosion and chemical stability[b]	Corrosiveness of the advanced treated water must be addressed by increase in pH, TDS, hardness, and alkalinity. Dosages for conditioning may potentially be reduced through blending.	Depending on blending ratio, potential corrosiveness of blended water will stay the same or decrease.
Aesthetics	Adding advanced treated water may improve aesthetic characteristics of blended water.	
Pathogens	Concentrations of pathogens will be reduced in the blended water.	

[a] Potential impacts depend on the blending ratio (i.e., the ratio of the volume of advanced treated water and the volume of other untreated source waters) and composition of the advanced treated water and other source waters.

[b] When assessing the water quality resulting from blending, mass balance calculations may apply for some of the parameters responsible for corrosion and chemical stability; however, the complexity of the corrosion phenomenon warrants that each water blend should be examined individually (Tang et al., 2006).

7.10 Management Options for Reverse Osmosis Concentrate

For potable reuse treatment trains using RO, the management of the RO concentrate can be a major cost and feasibility consideration. RO concentrate disposal options currently in use are listed in Table 7.28. Most concentrate disposal in Florida is through Underground Injection Control (UIC) wells to groundwater zones that are not considered underground sources of drinking water (USDW) as defined in the Code of Federal Regulations (40 CFR 144.3). Because the cost of RO concentrate disposal can be considerable, regional solutions may be a feasible alternative (Raucher and Tchobanoglous, 2014). Nontraditional uses of concentrate are considered in Jordahl (2006).

Table 7.28 Summary of Reverse Osmosis Concentrate Disposal Options

Disposal Option	Use/Description
Deep well injection	Depends on availability of a geologically suitable subsurface aquifer that is brackish or otherwise unsuitable for domestic uses. This option is limited in inland and some coastal areas of Florida.
Ocean discharge	In other states, a common method for disposal of wastewater RO concentrate is the use of ocean discharges combined with existing wastewater outfalls.
Discharge to the wastewater collection system	Suitable for relatively small discharges in which the increase in total dissolved solids is not significant [e.g., typically <20 to 50 milligrams per liter (mg/L)] and that otherwise comply with sewer ordinance local discharge limits.
Surface water discharge	In other states, a common method of disposal is discharge of reverse osmosis (RO) concentrate to surface waters, including lakes, reservoirs, or rivers, where sufficient dilution capacity is available. Membrane concentrate disposal in surface waters is regulated by the Clean Water Act and would require a permit.
Evaporation ponds (with or without a greenhouse)	Involves discharge of RO concentrate to shallow, lined ponds. A large surface area is required in most regions, with the exception of some southern and western states. Required surface area can be reduced using greenhouses. Solidified constituents may or may not need to be disposed of in industrial waste landfills based on testing.
Land application	Used for some low-concentration RO concentrate solutions, though this option generally is not available. Some RO concentrate solutions can be disposed of in industrial waste landfills.
Zero liquid discharge	Involves use of evaporators (e.g., vapor compression), brine concentrators, and crystallizers or spray dryers to convert RO concentrate to brine, a semisolid product, or a dry product suitable for landfill disposal. The recovery of useful salts may also be possible.

Source: Adapted from Tchobanoglous et al., 2015.

Zero liquid discharge (ZLD) processes can be used to reduce the volume of concentrates and brines. ZLD processes are "high-recovery process where either the final brine is disposed of within the plant boundary (such as in an evaporation pond) or the process produces solids for disposal" (Mickley, 2008). A variety of ZLD treatment processes are available, and many others are under development, to reduce or eliminate the volume of RO concentrate that must be managed; however, the options can be costly. Over time, ZLD processes may become more attractive if costs can be reduced (Mickley, 2008).

Current ZLD processing schemes for treating wastewater brine have included the following processes:

- Reverse osmosis
- Lime softening
- Thermal brine concentrators
- Thermal crystallizers
- Spray dryers

Capital and operation costs for these processes vary based on conditions such as water quality and volumes. Solids from lime softening and crystallization would need to be disposed of in landfills or reused (Mickley, 2008).

Newer commercial technologies are being studied and piloted for municipal applications and benchmarked against current approaches. These include: SAL-PROC (Geo-Processors); HEEPM (EET Corporation); VSEP (New Logic), and ARROW (O'Brian and Gere) (Mickley, 2008).

High-recovery and ZLD processes are technically feasible, but, in general, are not economically feasible for municipal applications. Economic feasibility for municipal applications requires cost reductions. High costs are associated with energy and chemical needs, the evaporative process steps, and final disposal steps, such as evaporation ponds and landfill (Mickley, 2008).

CHAPTER 8: OTHER CONSIDERATIONS

With appropriate regulations, implementing potable reuse that is protective of public health is feasible in Florida. Because of the national interest in potable reuse, the water industry is engaged in research to address information that will support the implementation and operation of potable reuse facilities. With targeted research and increasing potable reuse experience, additional information will be generated that will help reduce the potential for overly conservative designs and increase the knowledge base for facility operation. In addition, the potable reuse industry will need to address topics and issues as new information emerges over time, including issues related to emerging pathogens and chemicals, new treatment technologies, and advances in monitoring and operations. Examples of areas that will benefit from more experience and research are discussed in this chapter. These topics includes:

- Improved **system reliability** through design and monitoring.
- **Bioanalytical tools** for assessing unknown and unregulated chemicals, including emerging constituents, and mixtures of chemicals.
- The growing development of **Antibiotic Resistant Bacteria and Antibiotic Resistance Genes**
- **Research advances** in monitoring techniques and operations.

8.1 System Reliability

Appropriate reliability for potable reuse systems can be achieved by providing multiple independent treatment barriers, incorporating the monitoring of surrogate parameters at each step to ensure treatment processes are performing properly, and developing and implementing rigorous response protocols (such as through a CCP approach). Key attributes that promote reliability include:

- Using a treatment train with multiple, independent treatment barriers (i.e., redundancy) that meet performance criteria.
- Ensuring the independent treatment barriers represent a diverse set of processes (i.e., robustness) in the treatment train that are capable of removing particular types of contaminants by different mechanisms. This diversity better ensures that if a currently unrecognized chemical or microbial contaminant is identified in the future, there is a greater degree of likelihood it will be removed effectively by the treatment train.
- Using parallel independent treatment trains (i.e., resilience and redundancy) and providing sufficient replacement parts, along with trained personnel, to carry out the most frequently needed repairs.

8.2 Bioanalytical Tools for Assessing Chemicals

Bioanalytical tools for assessing water quality are *in vitro* (meaning a procedure in a controlled environment outside of a living organism) bioassays, which are analytical methods to determine concentration or potency of a substance by its effect on living cells or tissues. As a result, bioanalytical tools detect chemicals not by their structure but by their biological activity. Bioanalytical tools use cells (or sometimes proteins) of a targeted organism (i.e., human cells in the case of drinking water and potable reuse) as surrogates for specific human systems and health endpoints.

8.2.1 Chemicals in Potable Reuse Projects

Potable reuse is becoming an increasing integral component of water resource planning and water supply management. Because municipal wastewater is the source water, it is critical that potable reuse projects ensure a water quality that is protective of human health. In addition to pathogen control, chemicals in municipal wastewater must be reduced in potable reuse to levels protective of public health (Drewes, 2018).

There are more than 100,000 chemicals estimated in commercial use, including over 4000 pharmaceuticals. Once released in the environment, these chemicals can also produce numerous transformation products. At the same time, increasingly sensitive chemical analysis methods now allow the detection of chemicals in parts per trillion (ng/L) and lower concentrations. These low concentrations are unlikely to pose a significant health concern. However, there is a lack of toxicological information on many of the chemicals currently in commercial use, which is a challenge for traditional risk assessments, particularly for evaluating complex mixtures of chemicals and transformation products formed during treatment processes (Snyder and Leusch, 2018).

A number of chemicals are regulated under the Safe Drinking Water Act (SDWA) through Maximum Contaminant Levels (MCLs) and by states (e.g., Notification Levels in California). However, the vast majority of chemicals, including emerging constituents, are not regulated. Recommended health base standards have been developed for many emerging constituents (reference NWRI report). Traditional targeted analytical methods exist for regulated chemicals, but only for a fraction of the unregulated chemicals and transformation byproducts. In addition, the health impacts of mixtures of chemicals is a potential concern (Drewes, 2018)

As a result, additional water quality characterization tools are needed to better assess water quality for potable reuse. Advances are being made in targeted chemicals analyses. However, the use of bioanalytical tools can be used to supplement these targeted analyses to assess chemical water quality, including for emerging constituents (Snyder and Leusch, 2018).

8.2.2 Bioanalytical Tools

The large number of chemicals, the limitation of targeted analytical methods, and the potential for mixture effects has increased the interest in the use of “*in vitro* bioassays” to assess water quality. *In vitro* bioassays have been used as a screening tool in the development of drugs for decades. In the water industry, bioassays are commonly referred to as “bioanalytical tools” to underscore that they are analytical methods for measuring water quality.

In this approach, the cells are exposed to substances within a water sample and the response at the molecular or cellular level, which can range from a subtle change in gene expression to cell death, is measured. Cell and protein-based in vitro bioanalytical tools have a specific mode of action that interacts with specific chemicals, including chemicals in mixtures. Cell-based bioanalytical tools target endpoints or mechanisms of toxicity using recombinant cell lines, which have been genetically modified to detect and amplify toxic responses. Bioanalytical tools have been developed for the screening of compounds with specific biological target activities such as dioxin-like activity, endocrine responses (i.e., estrogen, androgen, thyroid activities), and genotoxicity.

In these cell-based bioanalytical tools, cells of a targeted organism (i.e., human cells in the case of drinking water and potable reuse) are used as surrogates for specific human systems and health endpoints.

While targeted methods focus on concentrations of known compounds in water, bioanalytical tools can detect a wide spectrum of known and unknown chemicals, including emerging constituents. Bioanalytical tools can measure chemicals in a mixture that act by the same mechanism (Snyder and Leusch, 2018).

Currently, bioanalytical tools cannot be used to evaluate all possible mechanisms of adverse biological impacts. However, some bioanalytical tools have mechanisms linked to specific adverse outcomes. These bioanalytical tools can be used to support a more comprehensive monitoring program for potable reuse, which can complement existing water quality evaluation techniques. These bioanalytical tools can be used to screen for the occurrence of known and unknown chemicals in water and can help evaluate the occurrence of unknown emerging constituents in potable reuse (Drewes, 2018; Snyder and Leusch, 2018).

8.2.3 Use of Bioanalytical Tools for Assessing Water Quality

There are a number of ways in which bioanalytical tools can be used to support potable reuse. They can be used as an additional measure of water quality during the initial assessment of a new water source. Bioanalytical tools can be used as a measure of treatment effectiveness during validation or verification of a treatment process or train and they can be used as a routine water quality monitoring tool to identify changes in water characteristics that may trigger further investigation. The use of bioassays can help build public support by providing more comprehensive screening of unknown water constituents with endpoints based on human health relevance (Drewes, 2018; Snyder and Leusch, 2018).

Bioanalytical tools cannot determine specific compounds responsible for observed bioactivity and are meant to augment existing targeted instrumental assessments. Bioanalytical tools can be used with targeted analyses (for known chemicals and non-targeted analyses (for known and unknown chemicals)) to identify and prioritize chemical compounds in water samples (Snyder and Leusch, 2018).

Bioanalytical tools are not yet appropriate to determine if water is “safe” or “unsafe”. The responses from bioanalytical tools do not necessarily suggest an adverse effect in humans and it is important for the industry, regulators, and other stakeholders to understand how bioanalytical tools can be used to assess water quality. Interpretation frameworks, including regulatory frameworks, for bioanalytical tools are only now being evaluated. However, the application of bioanalytical tools for water quality screening can support our understanding of the risks associated with unknown and mixtures of chemicals in water (Drewes, 2018; Snyder and Leusch, 2018).

8.3 Quantitative Microbial Risk Assessment

Controlling for pathogens is a primary water quality objective for potable reuse in terms of public health protection. In addition, raw wastewater contains a variety of pathogens in high concentrations, including viruses, protozoa and bacteria. The current regulatory framework for pathogens in drinking water includes achieving a goal of 10^{-4} risk of infection from pathogens, which is achieved through specific treatment requirements (e.g., 12, 10, 10 log removals for viruses, *Cryptosporidium*, and Giardia, respectively.

An approach to assessing pathogen risk and treatment requirements includes the use of Quantitative Microbial Risk Assessment (QMRA). QMRA is the process of estimating the risk from exposure to pathogens and involves an exposure assessment (based on occurrence of pathogens in wastewater, the treatment processes employed, the resulting levels of pathogens in drinking water, drinking water consumption, and the result exposure); dose-response for the pathogens of interest; and a risk characterization (or incidence of infection). From this analysis, the regulatory requirements for pathogens (i.e., the 12, 10, 10 log removal targets for viruses, *Cryptosporidium*, and *Giardia*) can be verified.

In addition to verifying regulatory requirements, QMRA can be used to verify meeting risk targets for specific treatment trains based on monitoring systems in place. This analysis requires a dataset of influent pathogen concentrations, removals provided by treatment, and infectivity models (dose response) that translate exposure to infection. This information can inform the evaluation of different treatment trains and the monitoring systems or the optimization of a treatment train for a potable reuse project (Salveson et al., 2018).

Although QMRA is an established approach, more information, experience and data are needed. For instance, a robust database of pathogen occurrence is needed across wastewater, reclaimed water, and potable water treatment trains. In addition, a consensus on reference pathogens is still under discussion. Lastly, the complexity and transparency (e.g., listing assumptions) of QMRA models presents a challenge in conducting QMRAs and in interpreting the results.

8.4 Antibiotic Resistant Bacteria and Antibiotic Resistance Genes

The development of antibiotic resistance is a worldwide public health concern as seen in the release of global and national action plans for addressing antibiotic resistance. It is not an issue that is solely related to potable reuse but is of concern in this context. Antibiotic resistant bacteria (ARB) and antibiotic resistance genes (ARG) are known to be present in wastewater due to contributions to collections systems and from the biological activity in wastewater treatment facilities. The advanced water treatment processes used in potable reuse projects are expected to provide a sufficient barrier to bacteria, including those that may be antibiotic resistant. A concern might be the efficacy of treatment for ARGs. Additional study of these issues is needed and includes the following:

- Assemble and evaluate available data on the occurrence of ARB and ARG in potable reuse projects.
- Determine the effectiveness of wastewater and drinking water treatment processes for reducing/inactivating ARB and ARG.
- Determine ARB and ARG concentrations in water which can be helpful in assessing treatment process efficiencies to remove antibiotic resistance causes.
- Identify significant data gaps and research needs (e.g., risks associated with ARB and ARG).

8.5 Research Advances

While the pace of technological developments for potable reuse in the past 10 years has been dramatic, including advances in treatment technologies and monitoring methods, information related to ensuring the safety of potable reuse will continue to grow with continued experience. Research advances are intended to help inform the implementation and operation of potable reuse systems. Two examples of areas of research interest include the following:

- **Access to more real-time monitoring tools**. It is not practical to use the direct measurements of some contaminants to assess treatment processes and identify failure events in potable reuse facilities. Indicators, surrogates, and treatment process parameters are used to demonstrate the removal of many pathogens and emerging constituents. Many monitoring techniques require extensive time periods to obtain results. Research is needed to further develop indicators, surrogates, and other parameters that can reliably monitor water quality and individual treatment processes in real or near-real time in potable reuse facilities.

- **Reviewing facility operation and performance data.** As more potable reuse projects come online, available information covering topics such as treatment plant design, process performance, operation practices, and mechanical reliability will become available. This data can be used to assess current practices, as well as inform new designs.

- **Adoption of advances in technologies.** As new and innovative technologies are proven and become commercially available, it will be important for utilities to be able implement these technologies for potable reuse, which may ensure water quality and reduce costs.

PART 3: FLORIDA POTABLE REUSE REGULATORY FRAMEWORK

CHAPTER 9: OVERVIEW OF REGULATORY FRAMEWORK

9.1 Basic Principles Guiding this Framework

The PRC examined Florida's existing regulatory framework of statutes, rules, and practices that apply to the processes involved in the potable reuse of reclaimed water to determine what changes to that framework would better facilitate potable reuse. In this effort, the PRC adhered to the following principles:

- Protect public health.
- Protect the environment.
- View reclaimed water as a potential source water for potable use.
- Where possible, achieve public health and environmental protection through existing regulatory programs.
- Respect existing state and federal permitting programs applicable to potable reuse.

9.2 Potable Reuse Scenarios

As described previously in this report, potable reuse can occur in a multitude of different configurations. It would be unworkable to analyze every one of these. Therefore, to assist in its regulatory framework examination, the PRC arranged potable reuse practices into the following four general scenarios shown on **Figure 9.1**.

All the potable reuse scenarios may need treatment beyond that shown in the box labeled "additional reclaimed water treatment as necessary." In addition, all the potable reuse scenarios involve the treatment of water to drinking water standards at a DWTF. Treatment at a DWTF is referred to as "Potable Water Treatment" in these scenarios rather than the phrase "advanced water treatment," which is used in some other states to describe this water treatment process. The phrase "Potable Water Treatment" is used below because it is specific to Florida's regulations.

Scenario 1 is generally described as DPR in which reclaimed water is treated from a wastewater standpoint, may undergo additional reclaimed water treatment as necessary, and is then sent to a DWTF and treated to drinking water standards, with the resulting finished water sent out to the public for consumption. Within this general Scenario 1 description, there are variations of this treatment and transmission process such as when groundwater is withdrawn and blended into the reclaimed water before treatment at the DWTF. It would be too complex and lengthy to list all conceivable variations of DPR. Therefore, the PRC determined that the general characterization of Scenario 1 was sufficiently comprehensive to address all issues that might arise from the conceivable DPR variations of Scenario 1.

Scenario 2 is generally described as "IPR through groundwater recharge." It involves first, the treatment of reclaimed water; second, the discharge of that treated reclaimed water to groundwater (either via underground injection or through downward percolation after surface application); third, the withdrawal of groundwater through one or more water production wells; fourth, the treatment of that groundwater to drinking water standards at a DWTF; and fifth, the transmission of that finished water for potable consumption. As in the case of Scenario 1, within the general scope of Scenario 2, variations of this treatment and transmission process can occur. For example, treated reclaimed water could be injected at a distance from the groundwater withdrawal point, or percolated into the ground in close proximity to the groundwater withdrawal point. The PRC considered these many possible variations and differences when evaluating Scenario 2.

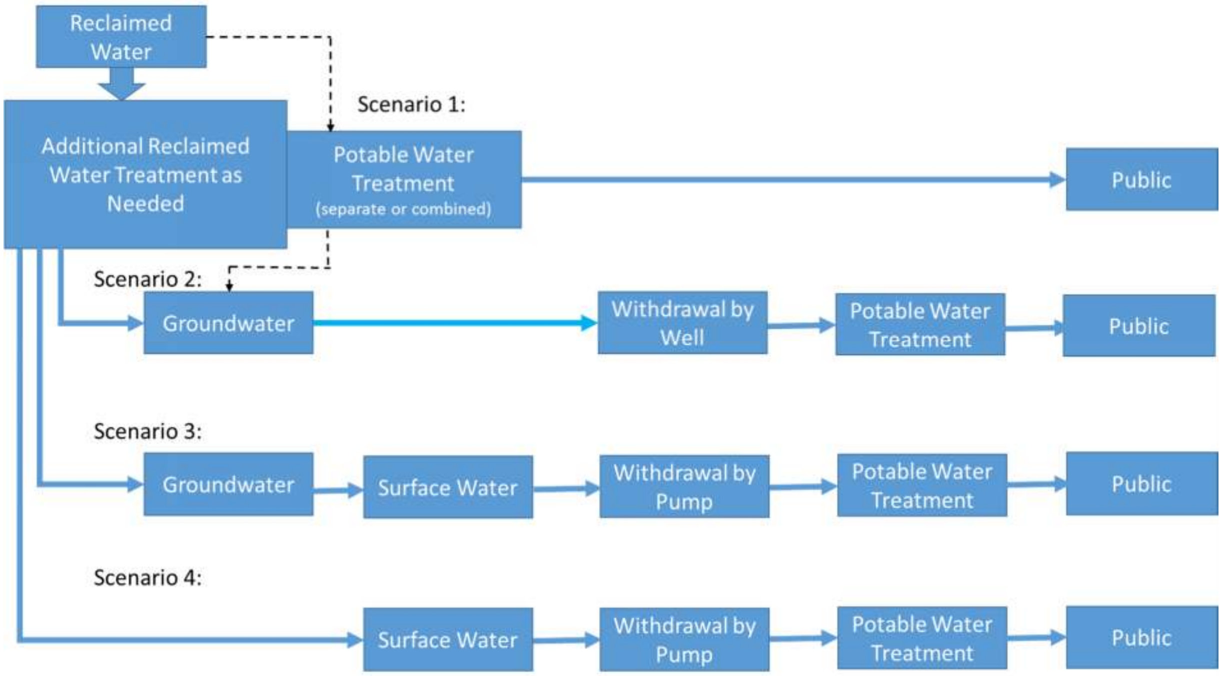

Figure 9.1: Four general potable reuse scenarios.

Scenario 3 is "IPR through groundwater with subsequent surface water discharge." It involves first, treating reclaimed water; second, discharging that treated reclaimed water to groundwater; third, releasing groundwater to surface water (either through percolation, subterranean discharge, or recovery of that groundwater and discharge to surface water); fourth, withdrawing and treating the surface water to drinking water standards at a DWTF; and fifth, transmitting that finished water for potable consumption. There are numerous variations on the general Scenario 3 process that the PRC considered as part of its Scenario 3 evaluation.

Scenario 4 is "IPR via surface water." It involves first, treating reclaimed water at a reclaimed water facility; second, discharging that treated reclaimed water to surface water; third, withdrawing and treating the surface water to drinking water standards at a DWTF; and fourth, transmitting that finished water for potable consumption. As in the case of the other scenarios, there are many variations of this general Scenario 4 process. The PRC considered those variations in its Scenario 4 evaluation.

9.3 PRC Principles – Protect the Public Health and the Environment

Protecting the public health and the environment are two fundamental PRC principles. In developing this potable reuse regulatory framework, the PRC considered where public health and environment protection is necessary in the four potable reuse scenarios described above. **Figure 9.2** illustrates the points at which the public health and environment should be protected in these potable reuse scenarios. For all scenarios, certain types of reclaimed water treatment or potable water treatment may produce a concentrate that would require additional public health and environmental protection (for example RO treatment).

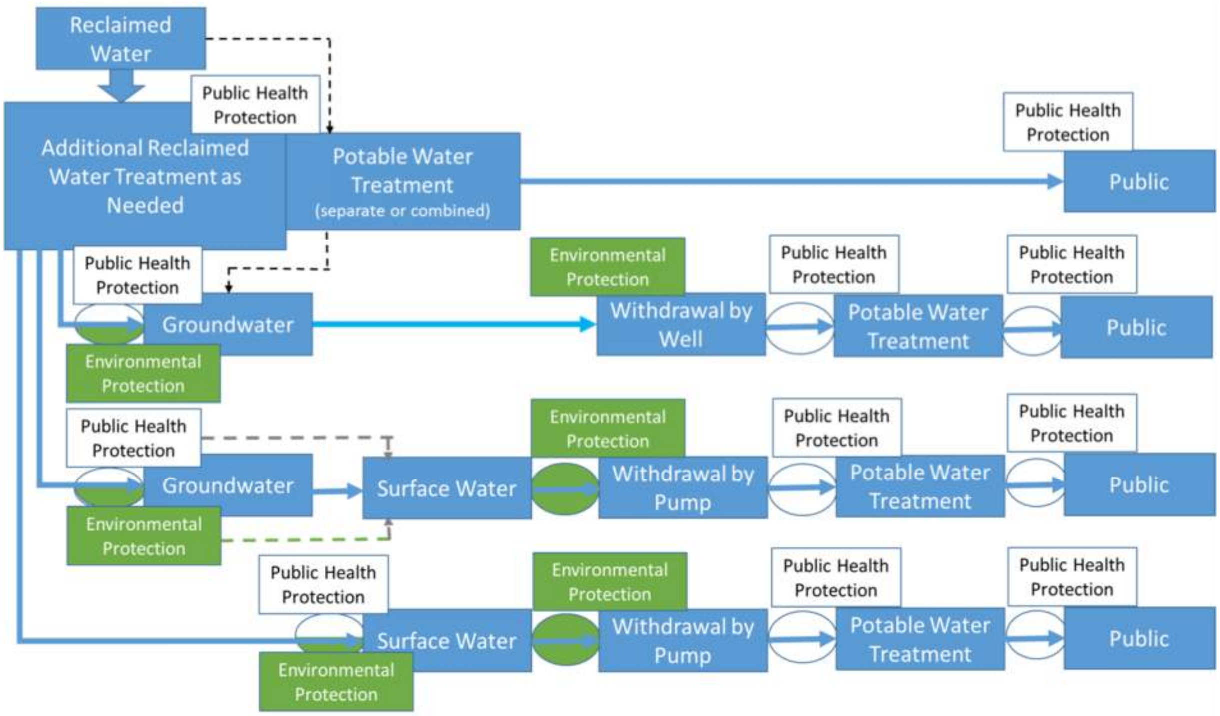

Figure 9.2: Points of public health and environmental protection in potable reuse scenarios.

9.4 Existing Regulatory Programs Governing Potable Reuse

Florida has several existing regulatory programs protecting public health and the environment that are applicable to the various steps or phases of the potable reuse scenarios described above. The PRC sought to respect and build on these existing regulatory programs. Therefore, a basic overview of these existing regulatory programs helps explain how the PRC recommendations build on these programs to promote potable reuse while protecting the public health and the environment.

9.4.1 Existing Public Health Protection

There are many existing Florida statutes and rules that provide public health protection when potable reuse is employed. Starting with the production of reclaimed water, Section 403.086, F.S., regulates the treatment of domestic wastewater and mandates secondary and, when specified, advanced wastewater treatment and the standards for such treatment. Chapter 62-600, F.A.C., is the implementing rule which provides detailed criteria for domestic wastewater facility permitting, design, and treatment. There is also chapter 62-610, F.A.C., which provides for detailed reclaimed water treatment depending upon how that reclaimed water will be used.

As it relates to the production of potable water, many Florida statutes and rules already exist to protect the public health. For example, sections 403.850 through 403.891, F.S., empower the Florida Department of Environmental Protection (FDEP) to regulate public water systems and to enforce drinking water quality standards. FDEP has also adopted rules to protect the public health within the drinking water treatment and transmission process. Most of these rules are patterned after corresponding federal Safe Drinking Water Act requirements adopted by the Environmental Protection Agency (EPA). These rules are summarized as follows:

- Chapter 62-550, F.A.C. – these regulations establish drinking water standards that must be met and monitoring and reporting requirements to ensure compliance with these drinking water standards.
- Chapter 62-555, F.A.C. – these regulations provide standards that must be met for the design, construction, operation, and maintenance of public water systems and facilities to ensure safety and compliance with the applicable drinking water standards.
- Chapter 62-560, F.A.C. – these regulations provide the process and requirements for non-compliant public water systems to get back into compliance and the means of providing public notices of any drinking water issues.
- Chapter 62-521, F.A.C. – these regulations provide standards to protect public supply wellheads from potential contamination.

9.4.2 Existing Environmental Protection

In addition to public health protection, Florida has numerous existing statutes and rules that are applicable to environmental protection in the implementation of potable reuse. For example, in potable reuse Scenario #2 (IPR through groundwater recharge), section 403.086, F.S., specifies domestic waste treatment standards that must be met before reclaimed water can be discharged to groundwater. In addition, chapter 62-520, F.A.C., establishes groundwater quality standards that must be met when reclaimed water is discharged to groundwater. These statutes and rules protect groundwater quality. Moreover, if groundwater is recharged with reclaimed water via direct injection through an underground injection well, then chapter 62-528, F.A.C. ensures such injection will be safe and not harm underground drinking water sources.

For potable reuse Scenario #4 involving IPR through discharge of reclaimed water to surface waters, section 403.0885, F.S., authorizes FDEP to implement the National Pollutant Discharge Elimination System (NPDES) surface water discharge permitting program. This NPDES program regulates discharges to surface waters considered “Waters of the United States”[7] through a point source and ensures that

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[7] As of the date of this publication, the term “Waters of the United States” is defined in 40 CFR 230.3(o) as:

(1) For purposes of the Clean Water Act, 33 U.S.C. 1251 *et seq.* and its implementing regulations, subject to the exclusions in paragraph (o)(2) of this section, the term “waters of the United States” means:

(i) All waters which are currently used, were used in the past, or may be susceptible to use in interstate or foreign commerce, including all waters which are subject to the ebb and flow of the tide;

(ii) All interstate waters, including interstate wetlands;

(iii) The territorial seas;

(iv) All impoundments of waters otherwise identified as waters of the United States under this section;

(v) All tributaries, as defined in paragraph (o)(3)(iii) of this section, of waters identified in paragraphs (o)(1)(i) through (iii) of this section;

(vi) All waters adjacent to a water identified in paragraphs (o)(1)(i) through (v) of this section, including wetlands, ponds, lakes, oxbows, impoundments, and similar waters;

(vii) All waters in paragraphs (o)(1)(vii)(A) through (E) of this section where they are determined, on a case-specific basis, to have a significant nexus to a water identified in paragraphs (o)(1)(i) through (iii) of this section. The waters identified in each of paragraphs (o)(1)(vii)(A) through (E) of this section are similarly situated and shall be combined, for purposes of a significant water quality standards and other environmental safeguards are met. As part of this program, chapter 62-302, F.A.C., establishes specific surface water quality standards that must be met to protect surface water quality. In addition, chapter 62-620, F.A.C, provides NPDES permitting requirements.

There are other rule provisions designed to protect the environment applicable to potable reuse. For example, chapter 62-625, F.A.C., requires the pretreatment of industrial wastes that are discharged into a domestic wastewater treatment facility that is producing reclaimed water. These industrial pretreatment requirements prevent the introduction of pollutants into a domestic wastewater system that may result in pass-through constituents or effluent water quality interference. Also, chapter 62-610, F.A.C., provides requirements for reclaimed water treatment and quality before reclaimed water is used for groundwater recharge or surface water discharge to protect groundwater and surface water quality.

Additionally, when either ground water or surface water[8] is withdrawn as part of IPR, such withdrawals are subject to regulation under part II of chapter 373, F.S. The water management districts administer this program pursuant to chapter 62-40, F.A.C., and chapter 40A-2, 40B-2, 40C-2, 40D-2, or 40E-2, F.A.C., and related rule chapters. The water management districts require a consumptive use permit (CUP) or water use permit (WUP)[9] to be obtained for such withdrawal and use. The use of reclaimed water does not require a CUP or WUP, but when a use includes surface water or groundwater, the CUP or WUP for such sources may include conditions that govern the use of the permitted sources in relation to the feasibility or use of reclaimed water.

To obtain a CUP or WUP, an applicant must establish that the proposed use of water satisfies the following three-pronged statutory test:

1. Must be a reasonable-beneficial use;
2. May not interfere with any presently existing legal use of water; and
3. Must be consistent with the public interest.

In an overall general summary, this test requires a showing that the water being withdrawn is actually needed (i.e., the applicant must prove demand), will not interfere with any presently existing legal use of water, and will not harm the water resource through the permit term. Permits may be conditioned as necessary to assure that such use is consistent with the overall objectives of the water management district and not harmful to the water resources of the area. These requirements ensure that surface or groundwater withdrawals associated with IPR will not cause environmental harm.

Finally, for groundwater withdrawals through water wells, chapters 40A-3, 40B-3, 40C-3, 40D-3, or 40E-3, F.A.C., require that the wells are properly constructed in a manner that does not allow for aquifer cross-contamination.

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nexus analysis, in the watershed that drains to the nearest water identified in paragraphs (o)(1)(i) through (iii) of this section. Waters identified in this paragraph shall not be combined with waters identified in paragraph (o)(1)(vi) of this section when performing a significant nexus analysis. If waters identified in this paragraph are also an adjacent water under paragraph (o)(1)(vi), they are an adjacent water and no case-specific significant nexus analysis is required.

[8] "Water" or "waters in the state" means any and all water on or beneath the surface of the ground or in the atmosphere, including natural or artificial watercourses, lakes, ponds, or diffused surface water and water percolating, standing, or flowing beneath the surface of the ground, as well as all coastal waters within the jurisdiction of the state.
[9] A CUP and WUP provides the right to use a specified amount of water for a specific purpose for a set duration.

9.4.3 Potential Permits Required Under Existing Regulatory Programs for the Potable Reuse Scenarios

The existing regulatory programs described above require a number of permits. A thorough understanding of these permits, the regulatory program to which they relate, and where they apply within these potable reuse scenarios is essential to understanding the basis for the PRC's proposed regulatory framework changes.

Depending upon the potable reuse scenario, the following is a list of the potential permits a potable reuse project may require. These scenarios are also depicted in **Figure 9.3**:

- Consumptive Use Permit or Water Use Permit (CUP or WUP) – a CUP, also referred to as WUP, is required to withdraw ground or surface water for public water supply purposes. CUPs or WUPs are governed by part II of chapter 373, F.S., and chapter 40A-2, 40B-2, 40C-2, 40D-2 or 40E-2, F.A.C., as described above.
- Water Well Construction (WWC) Permit - a WWC Permit is required to authorize the construction and use of a well to withdraw groundwater for public supply purposes. WWC Permits are governed by part III of chapter 373, F.S., and chapter 40A-3, 40B-3, 40C-3, 40D-3 or 40E-3, F.A.C., as described above.
- Public Water System Permit (PWSP) – a PWSP is required to construct and operate a public water supply treatment and distribution facility, which treats the water for public consumption. PWSPs are governed by sections 403.850 through 403.891, F.S., and chapters 62-521, 62-550, 62-555, and 62-560, F.A.C., as described above.
- Domestic Wastewater Permit (DWP) – a DWP is required to construct and operate a domestic wastewater treatment facility, which is the facility that produces reclaimed water used in the potable reuse scenarios (i.e., the source water). DWPs are governed by section 403.086, F.S., and chapters 62-600, 62-602, 62-610, 62-625, and 62-699, F.A.C., as described above. A DWP will also incorporate any Master Reuse Permit required for reuse or land application systems under rule 62-610.800, F.A.C.
- NPDES Permit – an NPDES permit is required to discharge treated reclaimed water through a point source to surface waters that are considered Waters of the United States. For all scenarios, certain types of potable treatment may produce a concentrate that also could require an NPDES permit for surface discharge. Section 403.0885, F.S., and chapters 62-302 and 62-620, F.A.C., govern NPDES permits.
- Underground Injection Control (UIC) Permit - a UIC Permit is required to inject reclaimed water into underground aquifers or formations. UIC Permits are governed by chapters 62-520 and 62-528, F.A.C., as described above. For all scenarios, certain forms of potable treatment may produce a concentrate that also could require a UIC permit for injection underground.

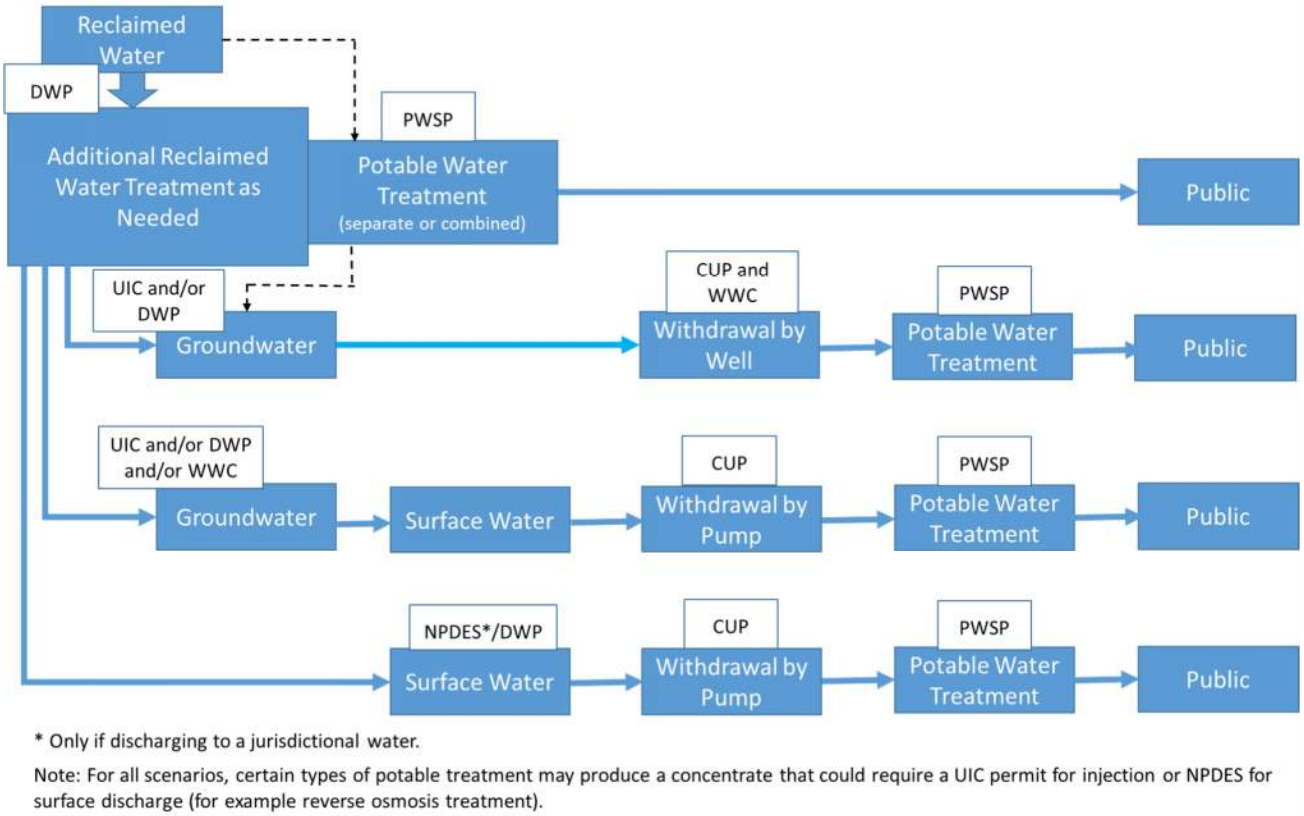

Figure 9-3. Illustration of how various permits apply to the various potable reuse scenarios.

CHAPTER 10: REGULATORY CHANGES THE PRC RECOMMENDS TO PROMOTE POTABLE REUSE WHILE PROTECTING PUBLIC HEALTH AND THE ENVIRONMENT

Using the potable reuse information in Chapters 1 through 8 of this report, and the potable reuse regulatory framework contained in Chapter 9, Chapter 10 sets forth the regulatory changes the PRC recommends to promote potable reuse while protecting public health and the environment.

10.1 Proposed Structure for Potable Reuse Regulations

As an initial overall regulatory change, the PRC recommends the existing potable reuse specific requirements for IPR be moved from Chapter 62-610, F.A.C., and new potable reuse regulations, including for DPR, be added to the appropriate existing chapters in Division 62 that address drinking water regulation, including: Chapters 62-521 (Wellhead Projection), 62-550 (Drinking Water Standards, Monitoring, and Reporting), 62-555 (Permitting, Construction, Operation, and Maintenance of Public Water Systems), and 62-560 (Requirements for PWSs that are Out of Compliance), F.A.C. The goal of this recommendation is to include all potable reuse requirements under the chapters in Division 62 governing drinking water regulation.

This proposed organization provides a clear separation of potable reuse from traditional nonpotable reuse projects under Chapter 62-610, F.A.C. including ground water recharge projects addressed under Chapter 62-610. Potable reuse requirements can be addressed directly in the drinking water chapters in Division 62. In addition, this approach provides alignment with treating reclaimed water as a source water for potable use, which is the specific intent of potable reuse projects. This approach also acknowledges treatment should be specific to the source water quality rather than a one size fits all approach, and that it could be accomplished at a potable water treatment facility.

How to implement this recommendation: To implement this recommendation, the Florida Legislature would enact legislation directing and authorizing FDEP to adopt new rules for potable reuse patterned after the above recommendation.

10.2 Revise Existing Florida Drinking Water Regulations to Address Pathogens in Reclaimed Water Used for Potable Reuse

The PRC recommends revising Florida's drinking water regulations to consider reclaimed water as source water. As explained in detail earlier in this report, for public health protection, the existing drinking water regulations in Florida are based on an acceptable risk threshold of 1×10^{-4} for human pathogens. Existing drinking water regulations do not consider potable reuse in which reclaimed water is a source water. Therefore, Florida's existing drinking water regulation requirements for pathogens should be revised to consider reclaimed water as source water and require treatment as necessary to meet drinking water regulation requirements for pathogens. For all potable reuse scenarios, this would be accomplished by assessing concentrations of viruses, *Cryptosporidium*, and *Giardia* in the source water.

To understand the "source water characterization" component of this recommendation, existing rule 62-555.520, F.A.C., requires a public water utility seeking a public water system construction permit to prepare an engineering analysis of the quality of the raw water source for the proposed DWTF, and to demonstrate the DWTF can treat that raw water considering the raw water's quality. This is commonly known as a "source water characterization." The source water characterization is used to determine the level and type of water treatment needed to produce finished water that meets drinking water requirements and is safe for public consumption.

In addition, potable reuse pathogen treatment requirements should include the implementation of a log reduction credit system using the Appropriate Treatment Technology (ATT) described in **Section 10.3** below. In such case, the utility would provide its approach to meeting the required pathogen treatment requirements in an engineering report as part of a PWS permit application. The utility would then have the option to either provide a FDEP-specified level of treatment or propose its approach to achieving the log reduction targets, based on a source water characterization, sufficient for a pathogen risk of infection that meets the national drinking water criteria of less than 1×10^{-4} annually.

This recommendation would apply to all potable reuse scenarios.

How to implement this recommendation: To implement this recommendation, the Florida Legislature would enact legislation directing and authorizing FDEP to adopt new rules for pathogen treatment in potable reuse patterned after the above recommendation.

10.3 Addressing Emerging Constituents with Appropriate Treatment Technology

The PRC recommends the use of ATT to address emerging constituents. In developing this recommendation, the PRC notes that there are several challenges in addressing emerging constituents. Scientific research into the potential public health risks of emerging constituents is ongoing. While there may be health-based criteria for some of these constituents, there are no applicable primary drinking water standards. As such, no regulatory controls have been promulgated for treatment of emerging constituents. Also, these emerging constituents originate from a variety of sources and, as a result, may already be present at trace levels in ground and surface waters and drinking water supplies. For many emerging constituents, concentrations found in reclaimed water are very low and the appropriate application of ATT can reduce concentrations further to non-detectable levels or very low trace level concentrations.

Additionally, the PRC recognizes the various potable reuse scenarios differ in the extent to which emerging constituents may be present at a level that could present a potential public health risk. They also differ in what ATT is needed to reduce these emerging constituents. As a result, flexibility must be provided to address different potable reuse scenarios (i.e., IPR and DPR). Therefore, to reduce the concentrations of emerging constituents which may be found at trace levels in reclaimed water, the PRC recommends an additional regulatory requirement of employing ATT in potable reuse scenarios. The ATT technologies may also be used for pathogen removal or reduction.

10.3.1 Appropriate Treatment Technology (ATT) to Remove Emerging Constituents

The ATT concept to removing emerging constituents involves using technically and economically feasible treatment technologies. The specific available ATTs employed may evolve over time as new treatment technologies develop, new emerging constituents are identified, and criteria for emerging constituents are further refined. The specific treatment processes used with ATT will also vary depending upon the project scenario, emerging constituent(s) concentration, desired finished water quality, and the treatment capability of the facility.

The following are some examples of ATT, which may be used either individually or employed in combination as determined appropriate, depending upon the constituents to be treated and capability of the specific ATT to effectively remove those constituents:

- Advanced oxidation processes
- Biologically active filtration
- Constructed wetlands
- Granular activated carbon adsorption
- Microfiltration
- Nanofiltration
- Ozone
- Reverse osmosis
- Soil Aquifer Treatment/Natural Attenuation
- Ultrafiltration
- Ultraviolet (UV) treatment

10.3.2 Monitoring as Part of ATT Proposal

The ATT treatment approach for emerging constituents includes requiring appropriate monitoring to evaluate treatment performance. Monitoring would focus on surrogate parameters and controls and may occur before and/or after the ATT treatment process or processes. Monitoring for surrogate parameters is used because it is not practical in real time to measure emerging constituents directly. If the surrogate monitoring detects water not meeting the desired treatment goals, that water would either be disposed, temporarily stored for retreatment, or reused for nonpotable purposes.

Surrogates can be used to demonstrate the performance of ATT. Examples of surrogates for treatment performance include turbidity for microfiltration and total organic carbon (TOC) for reverse osmosis, granular activated carbon, and other processes. ATTs used to treat these surrogates have been shown to be effective in treating emerging constituents (see discussion in **Section 4.3.2** of this report). Monitoring surrogates for treatment processes would demonstrate the ATT is working properly and satisfactorily treating the emerging constituents.

10.3.3 Approaches for Employing ATT

The PRC proposes two approaches for employing ATT to treat emerging constituents. These approaches are based upon the nature of DPR and IPR, and the issues that arise with addressing emerging constituents in those different types of potable reuse. For example, for DPR addressed in Approach No. 1 described below, the issues are more confined because the reclaimed water does not pass into the environment. By comparison, Approach No. 2 covering IPR must account for the impact or effect on ground water and surface water, as well as for the treatment, attenuation and dilution of emerging constituents in ground or surface waters.

Approach No. 1 - For DPR, use ATT as determined necessary by source water characterization (Scenario #1).

For Approach No. 1, the PRC focused on potable reuse Scenario #1 (DPR). For this scenario, the PRC recommends including reclaimed water as part of a DWTF's source water characterization and, if that source water characterization indicates the presence of emerging constituents at levels of public health interest, then employing ATT to address those emerging constituents.

The PRC recommends the source water characterization consider the nature and level of emerging constituents in the reclaimed water supply. The source water characterization would also consider whether and the extent to which ground or surface water is mixed into the direct potable reuse supply reducing the concentration of these emerging constituents. Based on these considerations and others, the source water characterization would determine the types of treatment needed to address emerging constituents and the corresponding surrogate monitoring, for the emerging constituents. This level of treatment and surrogate monitoring for the emerging constituents would then direct the extent and nature of ATT(s) to employ. (It should be noted that pathogen reduction goals will also play a role in determining the nature and extent of ATTs to employ.)

Approach No. 2 – For IPR, a utility would add a representative emerging constituent monitoring protocol and ATT would be applied to the reclaimed water as determined necessary by the monitoring results. The ATT on the potable water use would be determined by the source water characterization (Scenarios #2-#4).

For IPR, where reclaimed water is released or discharged into groundwater or surface waters, emerging constituents may need to be considered due to existing regulatory requirements such as antidegradation and discharge standards. In addition, the emerging constituents may be treated, attenuated or diluted by the groundwater or surface water. How these issues are presented will vary from one potable reuse project to another given hydrological differences and, in the case of groundwater, geological differences.

Existing Monitoring Requirements

Monitoring is currently required in Part V of Chapter 62-610, FAC for projects releasing reclaimed water to groundwater or surface waters. Under the existing rules, this monitoring is described in the engineering report required for each reuse system.

Adding Emerging Constituents to Existing Monitoring Requirements

The existing reclaimed water reuse system monitoring requirements do not directly include monitoring for emerging constituents. To address the risk from emerging constituents, the PRC recommends FDEP amend these monitoring requirements to more directly require monitoring for representative emerging constituents in IPR projects. The utility responsible for the IPR project would select representative emerging constituents to monitor and identify action levels associated with those emerging constituents. FDEP would then review and approve the selection of representative emerging constituent(s), action levels and the accompanying monitoring protocol.

The monitoring protocol would provide that if elevated levels of the representative emerging constituent are detected pursuant to the FDEP approved protocol, the utility must report the elevated detection to FDEP and investigate the source and cause of the elevated level of the representative emerging constituent. If it is determined that the reclaimed water is the source, the utility would develop a plan to remedy or address that cause. The investigation and remedy plan would be subject to FDEP approval.

Employ ATT for IPR as part of potable water treatment depending upon source water characterization

For IPR projects, ATT for emerging constituents may also be performed as part of the potable water treatment as determined necessary by a source water characterization. For IPR scenarios, the source water characterization would consider the nature of the surface or groundwater into which the reclaimed water was released, the distance between the point of reclaimed water release and withdrawal point for the potable water treatment plant, and the rate and extent to which the released reclaimed water could potentially migrate to the utility's water withdrawal point. Evaluating all of this, the source water characterization would then outline whether ATT is needed and, if so, the level of ATT required for treating the emerging constituents to the appropriate levels. The engineering report accompanying the source water characterization would also provide the surrogate monitoring used to determine ATT effectiveness.

How to implement this recommendation: To implement this recommendation, the Florida Legislature would need to enact legislation providing authority and direction to FDEP to revise existing rules or adopt new rules specifying the process described above for addressing emerging constituents.

10.4 Other Regulatory Changes Specific to Particular Potable Reuse Project Scenarios

In addition to the recommendations in sections 10.1 through 10.3 above that would apply to all the potable reuse scenarios, the PRC also proposes the following measures specific to the reuse scenario or scenarios indicated after each regulatory measure:

- **Industrial waste pretreatment and source control program** – Existing Chapter 62-625, F.A.C., requires the pretreatment of industrial wastes before such wastes enter a domestic wastewater treatment system when reclaimed water is discharged to surface waters that are "Waters of the United States." The purpose of this requirement is to avoid introducing industrial pollutants for which the domestic wastewater treatment facility was not designed or intended to treat. The PRC recommends that the existing industrial pretreatment requirements set forth in chapter 62-625, F.A.C., be considered for extension to the other potable reuse scenarios. So, for example, where chapter 62-625, F.A.C., requires industrial pretreatment because a public utility receives pollutants from industrial users which pass through or interfere with the operation of the wastewater treatment facility, then such industrial pretreatment would be required for potable reuse. Conversely, if a public utility does not receive pollutants from industrial users which could pass through or interfere with the operations of the wastewater treatment facility, that public utility would not be required to implement industrial pretreatment when engaged in potable reuse. In addition, this industrial pretreatment could be augmented with a source control program that has an approach similar to chapter 62-625, F.A.C. In this source control program, the wastewater utility would identify the sources needing to be addressed (which may not be limited to significant industrial users as defined in chapter 62-625, F.A.C.). (*Scenario #1 - direct potable reuse; Scenario #2 – indirect potable reuse via groundwater recharge; Scenario #3 – IPR via groundwater with subsequent release to surface water.)*

How to implement this recommendation: To implement this recommendation, FDEP would adopt new regulations or modify existing regulations to specify that the existing industrial pretreatment requirements would be imposed when reclaimed water is used for potable reuse. In addition, FDEP regulations should require a wastewater utility involved in one of these potable reuse projects to implement a source control program for sources the wastewater utility identifies as needing to be addressed.

- **Management of "off-spec" reclaimed water** – Reclaimed water exiting a domestic wastewater treatment facility is regularly monitored to ensure that reclaimed water quality meets applicable regulatory requirements. Should this water quality monitoring detect an instance in which the reclaimed water does not meet regulatory requirements, then rule 62-610.464, F.A.C., requires that the "off-spec" reclaimed water be either disposed of immediately or temporarily stored and not released until such "off-spec" water can either be disposed of or retreated to meet these requirements. For public safety protection, the PRC recommends that a similar type of "off-spec" standard be developed for potable reuse. For the potable reuse "off-spec" standard, a wastewater utility would develop operating protocols to specify "off-spec" water and how "off-spec" water will be addressed through alternative disposal, nonpotable reuse, or temporary storage followed by alternative disposal/reuse or retreatment. (*Scenario #1 - direct potable reuse; Scenario #2 – IPR via groundwater recharge; Scenario #3 – indirect potable reuse via groundwater recharge with subsequent release to surface water; Scenario #4 – indirect potable reuse via surface water discharge.)*

  How to implement this recommendation: To implement this recommendation, FDEP would adopt new regulations providing "off-spec" reclaimed water requirements for potable reuse projects to require temporary storage, disposal, alternative nonpotable reuse, or retreatment of "off-spec" reclaimed water based upon operating protocols established by the utility and approved by FDEP. These new "off-spec" reclaimed water requirements should be patterned after the provisions in existing rule 62-610.464, F.A.C., for addressing reject water.

- **Point of compliance with drinking water standards** – The PRC noted that with the various regulatory programs applicable to potable reuse, a question can arise as to what point in the process of producing potable reuse should it be determined the water must comply with drinking water standards and other potable reuse requirements. To avoid any confusion, the PRC recommends the statutes and administrative rules be revised to clarify that compliance with these standards be determined at the point where the finished water is finally discharged from the DWTF to the water distribution system. (*Scenario #1 - DPR; Scenario #2 – IPR via groundwater recharge; Scenario #3 – IPR via groundwater recharge with subsequent release to surface water; Scenario #4 –IPR via surface water discharge.)*

  How to implement this recommendation: To implement this recommendation, the Florida Legislature would need to enact legislation specifying that, when reclaimed water is used for potable reuse, the point of compliance with drinking water standards is the final discharge point for finished water from the DWTF. After enactment of this legislation, FDEP would adopt rules as appropriate to carry out the legislation.

- **No need for CUP or WUP for DPR** – DPR involves the potable reuse of reclaimed water existing solely in man-made containment and is solely produced by human activity and, thus, there is no new or additional "withdrawal" of that water from the natural environment. Because there is no new or additional withdrawal of water from the environment, there is no need to evaluate the effects of that withdrawal. Existing Florida Statutes provide that no CUP or WUP is required for reclaimed water use. In implementing this potable reuse regulatory framework, the PRC recommends the existing Florida Statutes exempting the use of reclaimed water for CUP or WUP regulation not be changed or weakened. (*Scenario #1 -DPR)*

How to implement this recommendation: To implement this recommendation, the Florida Legislature, FDEP and water management districts would need to ensure that the existing Florida Statutes exempting the use of reclaimed water from CUP or WUP regulation are not changed when developing this potable reuse regulatory framework.

- **Clarify compliance with existing spring discharge surface water quality standards** – Existing rule 62-610.850, F.A.C., provides "reuse and land application projects shall not cause or contribute to violations of water quality standards in surface waters." Revisions to this rule may be necessary as the other potable reuse recommendations are implemented to clarify that existing surface water quality standards apply to groundwater discharges of reclaimed water migrating into spring flow.

  How to implement this recommendation: To implement this recommendation, FDEP would revise rule 62-610.850, F.A.C., as necessary to ensure the existing surface water quality protections of this rule relating to spring discharge remain in effect after implementation of the other potable reuse recommendations in this report.

- **Review existing regulations to identify outdated requirements and then update existing regulations to reflect current and future potable reuse practices** – The existing regulations governing reclaimed water treatment and potable water treatment were largely adopted before the development of IPR using advanced water treatment technologies. The existing regulations do not reflect the capabilities of these technologies, including, but not limited to, improved sensors and real time SCADA advances. As a result, many of these regulations contain outdated or conflicting requirements that unnecessarily complicate and increase the costs of IPR through aquifer recharge. To address this, the PRC recommends FDEP undertake a comprehensive review of the applicable existing regulations to identify any requirements that are outdated and inconsistent with current practices or are inconsistent with the other potential proposed rule revisions outlined in this report. Based upon the results of this review, FDEP should then revise and update the applicable regulations to reflect current practices while still maintaining existing human health and environmental protection. (*Scenario #2 – IPR via groundwater recharge; Scenario #3 – IPR through groundwater recharge with subsequent release to surface waters.)*

  How to implement this recommendation: To implement this recommendation, FDEP would review in detail the various regulations applicable to potable reuse to look for inconsistencies or other revisions needed to revise these rules to match current practices. Once these inconsistencies and other revisions are identified, FDEP would need to amend these rules to eliminate the inconsistencies and implement the identified revisions.

- **Expand FDEP existing definition of IPR to include groundwater recharge to augment the supply of water available for drinking water** –Currently, Chapter 62-610, F.A.C., defines the term "indirect potable reuse" as "the planned discharge of reclaimed water to surface waters to augment the supply of water available for drinking water and other uses." The PRC believes this definition should be expanded to also include discharges to groundwater done to develop or supplement potable water supply. Therefore, as part of moving potable reuse to Florida's drinking water regulations, the PRC recommends FDEP modify this definition to include the planned discharge of reclaimed water to groundwaters to augment the supply of water available for drinking water. Thus, the revised definition would read: "'Indirect potable reuse' means a project for the planned delivery or discharge of reclaimed water to groundwater or surface water for the development of, or to supplement, potable water supply."

How to implement this recommendation: To implement this recommendation, the PRC recommends FDEP develop rule revisions to incorporate this language and make other changes as needed to accommodate the consistency of this definition.

- **FDEP and the water management districts should enter into a memorandum of agreement to coordinate permitting for IPR projects** – As illustrated by the previous description regarding the multitude of permits required from FDEP and the water management districts to authorize IPR using groundwater recharge or surface water discharge, the PRC identified the importance for these agencies to coordinate their permit review to ensure consistency in the permits and in the technical information requirements which the permits are based upon, and to reduce the chance of one agency requesting redundant information already provided to the other agency. Coordination between FDEP and the water management districts would also help ensure consistency in human health and environmental protection. The PRC recommends FDEP and the water management districts enter into a memorandum of agreement outlining how they will coordinate with each other and with the permit applicant during the review of one or more of the permits required for IPR using aquifer recharge. This memorandum of agreement should provide such coordination will occur only if requested by the permittee to avoid an overly burdensome process for minor permit changes. (*Scenario #2 – indirect potable reuse via groundwater recharge; Scenario #3 – IPR through groundwater recharge with subsequent release to surface waters; Scenario #4 – IRP via discharge to surface waters)*

  How to implement this recommendation: To implement this recommendation, FDEP and the water management districts would enter into a memorandum of agreement that would state, upon the request of an applicant, the agencies would coordinate the review of one or more permits needed for an IPR project. The memorandum of agreement would set forth the procedural requirements for this coordinated review.

10.5 Review Current Reclaimed Water Aquifer Recharge Regulations

FDEP should review its current recharge regulations not related to potable reuse in Chapter 62-610, F.A.C., (e.g. rules 62-610.310(3)(c)9., 62-610.310(4), 62-610.525, 62-610.550, and 62-610.553, F.A.C.) in parallel with adopting new drinking water-based regulations for potable reuse as specified in section 10.1 above. The goal of this review would be to ensure continued environmental and public health protection.

How to implement this recommendation: To implement this recommendation, FDEP would review Chapter 62-610, F.A.C., to ensure continued protection of the environment and public health.

10.6 Implementing PRC Regulatory Recommendations Collectively and Through Technical Advisory Committees

The PRC intends for the regulatory recommendations set forth in sections 10.1 – 10.4 above to be undertaken collectively. By collectively undertaking all these recommendations, potable reuse can be further advanced in Florida while protecting the public health and the environment.

Many of the items in sections 10.1 to 10.4 recommend the Florida Legislature adopt legislation followed by FDEP implementing new regulations based on that legislation. Other items recommend FDEP adopt new regulations or amend existing regulations under current law. There are also several recommendations for FDEP to review and update existing regulations to reflect current practices.

For all rule review and rulemaking changes specified in this report, the PRC recommends the FDEP convene and lead one or more technical advisory committees of knowledgeable and interested stakeholders representing a broad group of interests to assist in the development of these regulations. These technical advisory committees would include stakeholder representatives from the wastewater utility industry, the water utility industry, the environmental community, the business community, the health community, the general public, and the agricultural community. By developing these regulations with the review and input of this diverse stakeholder group working through technical advisory committees, FDEP can address multiple perspectives and structure rules in which the public will have confidence of a safe water supply and adequate protection of the environment.

10.7 Convene a Working Group to Determine if any Changes to existing CUP and WUP Statutes and Rules are Needed to Incentivize and Protect Public Investments in Potable Reuse Projects

Potable reuse projects require significantly more planning and financial investment than nonpotable reuse projects. The goal of these projects is water supply development which could create a new supply or help to sustain or extend current supplies. Utilities need certainty that the planning and financial investment of their ratepayers' funds will be protected. Therefore, utilities expressed a desire to increase confidence for long-term investment in potable reuse projects by clarifying and/or improving CUP and WUP statutes and rules for retaining the environmental and water supply benefits created by such projects. Although the water management districts have existing rules that may accommodate the implementation of most potable reuse projects within the constraints of those current statutes and rules, the PRC recommends convening a working group to examine CUP and WUP statutes and rules in the context of incentivizing and protecting investments in these long-term potable reuse projects.

As part of the preparation of this report, the PRC conducted a preliminary examination of existing CUP and WUP statutes and rules. The goal of this examination was to determine instances where utility investments in potable reuse projects require further protection while also preserving the tenets of Florida water law. Through this examination, the PRC identified two areas where clarification of existing statutes and rules is recommended. First, an existing statute, subsection 373.250(5), F.S., and the Water Resource Implementation Rule (chapter 62-40, F.A.C.), allow utilities to propose impact offsets derived from the use of reclaimed water. However, utilities expressed concern about securing the impact offset benefits resulting from their potable reuse projects. Second, subsection 373.236(5), F.S., addresses longer permit durations (i.e., greater than 20 years) for CUPs and WUPs approving the development of alternative water supplies. Further clarification is recommended to address how IPR projects are to be treated under this provision, including the consideration of longer permit durations.

Additionally, in conducting its preliminary examination of existing statutes and rules, two additional topics of interest to utilities arose warranting further recommendations. First, additional consumptive use permitting incentives should be explored that would facilitate the development of potable reuse projects. Second, the PRC recommends there be additional examination regarding how the water management districts' cost share funding programs can be leveraged to facilitate development of potable reuse projects.

How to implement this recommendation: To implement this recommendation, the PRC, in coordination with FDEP and the water management districts, would facilitate the creation of a working group to examine current CUP and WUP statutes and rules in the context of incentivizing and protecting investments in potable reuse projects. The working group should consist of diverse stakeholders, including but not limited to, PRC members and representatives from the water management districts, FDEP, water and wastewater utilities, agricultural organizations, environmental organizations, and other interested parties. The working group meetings should be noticed and open to the public and efforts should be taken to encourage public participation. At a minimum, a goal of the working group will be to develop consensus regarding the above-referenced recommendations as well as develop a plan regarding the implementation of any such recommendations. If the working group reaches consensus on any changes, the working group would recommend such changes to the Florida Legislature or FDEP and the water management districts as appropriate.

10.8 Conclusion – Implementing Potable Reuse While Simultaneously Protecting Public Health and the Environment

The above-described proposed regulatory framework recommended by the PRC will promote potable reuse, protect human health and the environment, respect and build upon existing regulatory programs, and provide regulatory and financial surety to utilities. This framework will help further promote beneficial use of the water resource. It will also help promote sustainability and increase in Florida's water supplies to meet the demands of a growing population and a robust tourism industry.

Appendices

Appendix A: References

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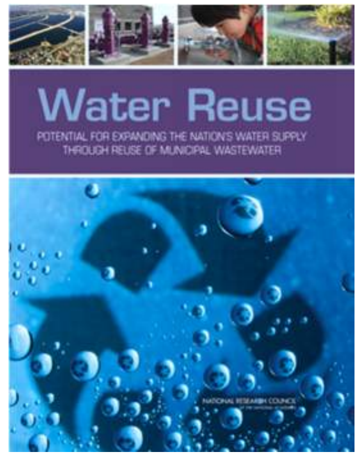
Appendix B: Useful Resources for Potable Reuse

A number of resources have been published to support the development of potable reuse projects, including research reports, expert and advisory panel reviews, and guidance manuals. These reports were published by federal agencies, state agencies, research foundations and associations, and international organizations. Regulators, utilities, engineering consulting firms, and stakeholders can use these resources when establishing guidance and operational requirements for potable reuse.

Federal Resources

- National Research Council (2012). *Water Reuse: Potential for Expanding the Nation's Water Supply through Reuse of Municipal Wastewater.* National Research Council, National Academies Press: Washington, DC. http://www.nap.edu/catalog.php?record_id=13303

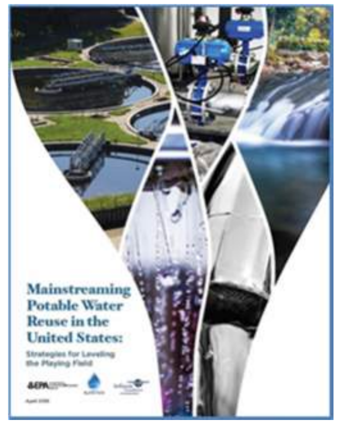
  This report examines how expanding water reuse – the use of treated wastewater for beneficial purposes including irrigation, industrial uses, and drinking water augmentation – can significantly increase the nation's total available water resources. The report by a committee of the National Research council, reviewed a portfolio of treatment options available to mitigate water quality issues in reclaimed water. The committee also conducted an analysis of the risk of exposure to certain microbial and chemical contaminants from drinking reclaimed water that suggests potable reuse does not appear to pose any higher risk than experienced in current drinking water treatment systems, and may be orders of magnitude lower. The report recommends possible changes to the federal regulatory framework that could enhance public health protection for both planned and unplanned (or de facto) reuse and increase public confidence in water reuse.

- U.S. EPA (2018) *Potable Reuse Compendium*. U.S Environmental Protection Agency. EPA/810/R-17/002. Washington, DC www.epa.gov/ground-water-and-drinking-water/2017-potable-reuse-compendium

  This U.S. EPA document supplements the *2012 Guidelines for Water Reuse* and provides a current look at multiple potable reuse topics, including DPR, current treatment technologies, costs of potable reuse systems, and the extent of potable reuse in the United States. Featured within the Compendium are seven case studies from the United States that illustrate potable reuse approaches.

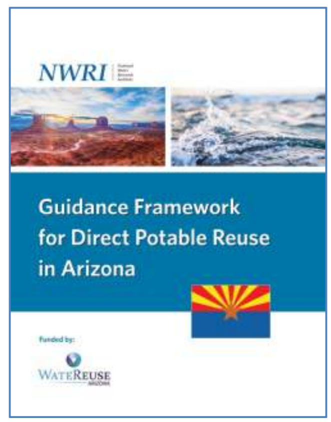
- U.S. EPA (2018). *Mainstreaming Potable Reuse in the United States: Strategies for Leveling the Playing Field.* U.S. Environmental Protection Agency, ReNUWIt, and the Johnson Foundation. www.epa.gov/sites/production/files/2018-04/documents/mainstreaming_potable_water_reuse_april_2018_final_for_web.pdf



Reinventing the Nation's Urban Water Infrastructure (ReNUWIt), the U.S. Environmental Protection Agency (USEPA), and The Johnson Foundation at Wingspread published this report to help leaders across the country overcome the institutional hurdles of potable reuse. Their ideas and insights are presented in this report, which is meant to help municipalities and utilities considering potable reuse to develop their approach to implementing projects by drawing on the experience of a diverse group of experts. The report includes both a review of current projects that are effectively reusing wastewater and an outline of best practices. This report presents an analysis to help municipalities and utilities advance their efforts to develop potable reuse projects and inform federal, state and local agencies and key stakeholders about how they can support the expansion of potable reuse across the United States.

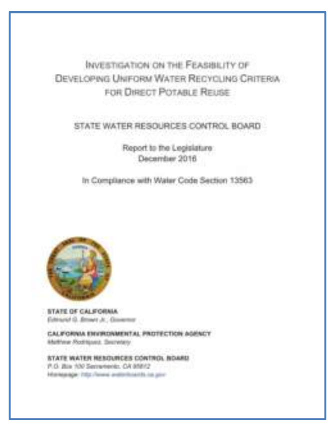
State Resources

- Mosher, J.J., and G.M. Vartanian (2017). *Guidance Framework for Arizona Potable Reuse.* Prepared for WateReuse Arizona and AZ Water Association, Prepared by National Water Research Institute, Fountain Valley, CA.
  https://watereuse.org/wp-content/uploads/2018/02/NWRI-Guidance-Framework-for-DPR-in-Arizona-2018.pdf

  This Guidance Framework provides recommendations on items that would be specifically addressed in the development of regulations in Arizona for DPR that are protective of public health. A number of recommendations are made that would be best addressed in guidance and/or permitting language rather than as part of regulations. Based on current information and experience, it is feasible for the State of Arizona to develop regulations for DPR that would incorporate a level of public health protection as good as or better than what is provided currently by conventional drinking water supplies in the United States.

- SWRCB (2016). *Investigation on the Feasibility of Developing Uniform Water Recycled Criteria for Direct Potable Reuse, California State Water Resources Control Board*, Report to the Legislature, Sacramento, CA, December 2016.
  www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/rw_dpr_criteria.shtml

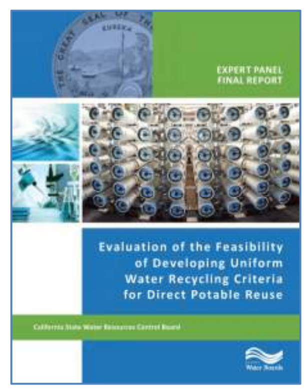
  This California State Water Resources Control Board (SWB) report concludes that it is feasible to develop and adopt regulations for using reclaimed water as drinking water, provided that certain research and key knowledge gaps are addressed. State legislation created an Expert Panel and Advisory Group to assist the staff of the SWB's Division of Drinking Water to investigate the feasibility of creating regulations. This report lays the groundwork for creating regulations for a new and reliable source of potable water.

The SWB prepared the report after considering the recommendations of the Expert Panel and Advisory Group; available research regarding unregulated pollutants as developed pursuant to the SWB's Recycled Water Policy; the regulations and guidelines in place for DPR from jurisdictions in other states, federal government and other countries; water quality and health risk assessments associated with existing potable water supplies subject to the discharges from municipal wastewater, stormwater and agricultural runoff.

- Texas Water Development Board (2015). *Final Report: Direct Potable Reuse Resource Document*. Report prepared for the Texas Water Development Board by Alan Plummer Associates, Inc.: Fort Worth, TX.

  The Texas Water Development Board (TWDB) published a technical resource document related to the implementation of DPR projects in Texas. The intended audience for the document is utilities, consultants, planners, academics, and others interested in evaluating feasibility and/or entering the planning phase of a DPR project. Although the document focuses on DPR, it also contains a review on the use of environmental buffers, such as surface water reservoirs or groundwater aquifers, which are an integral component of IPR projects. The TWDB recommends that decision makers consider all options available, including both IPR and DPR, and the advantages and disadvantages of each before moving forward with a reuse project.
  www.twdb.texas.gov/publications/reports/contracted_reports/doc/1248321508_Vol1.pdf
  www.twdb.texas.gov/publications/reports/contracted_reports/doc/1248321508_Vol2.pdf

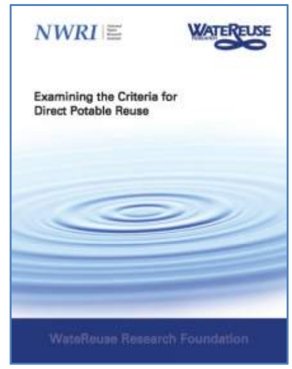
Expert Panels



- Olivieri, A.W., J. Crook, M.A. Anderson, R.J. Bull, J.E. Drewes, C.N. Haas, W. Jakubowski, P.L. McCarty, K.L. Nelson, J.B. Rose, D.L. Sedlak, and T.J. Wade (2016). *Expert Panel Final Report: Evaluation of the Feasibility of Developing Uniform Water Recycling Criteria for Direct Potable Reuse*. Prepared August 2016 by the National Water Research Institute for the State Water Resources Control Board, Sacramento, CA.
  www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/documents/rw_dpr_criteria/app_a_ep_rpt.pdf

  The purpose of this report is to document the efforts and outcomes of an Expert Panel that was mandated by the California Legislature to advise the State Water Resources Control Board on public health issues and scientific and technical matters regarding the feasibility of developing uniform water recycling criteria for DPR (DPR). After a yearlong investigation, the Expert Panel finds it is feasible for the State of California to develop and implement a uniform set of water recycling criteria for DPR that would incorporate a level of public health protection as good as or better than what is currently provided in California by conventional drinking water supplies and IPR systems. The report focused on public health issues and scientific and technical matters regarding the feasibility of developing uniform water recycling criteria, assessing the need for additional research on DPR, and recommending an approach for completion of any needed research. The Expert Panel focused their evaluation around 7 technical topics and put forth 6 research recommendations for further exploration.

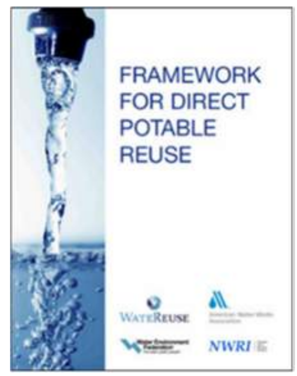
- National Water Research Institute (NWRI) (2013). *Examining the Criteria for Direct Potable Reuse*. Independent Advisory Panel Final Report prepared for Trussell Technologies, Inc., under WateReuse Research Foundation Project No. 11-02, National Water Research Institute: Fountain Valley, CA. https://watereuse.org/watereuse-research/examining-the-criteria-for-direct-potable-reuse/



  To facilitate the transition to DPR, a project was conducted to assess the equivalency of advanced treatment trains and determine what modifications – if any – are necessary to satisfy the public health criteria for DPR. As part of this effort, an Independent Advisory Panel (Panel) lead a 2-day workshop to develop a set of criteria for chemicals and pathogens that are protective of public health to evaluate treatment technologies for DPR. The results of this panel's efforts are documented in this report.

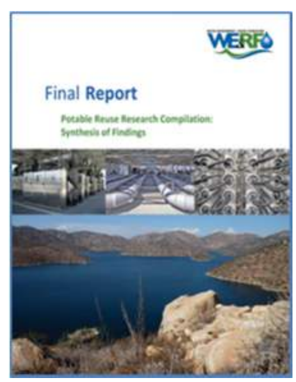
Research Organizations

- Tchobanoglous, G., J. Cotruvo, J. Crook, E. McDonald, A. Olivieri, A. Salveson, and R.S. Trussell (2015). *Framework for Direct Potable Reuse*, WateReuse Association, Alexandria, VA. https://www.nwri-usa.org/research



  A first-of-its-kind guidance document, *Framework for Direct Potable Reus*e, was published in 2015 to help state regulatory agencies and utilities develop guidelines for safely converting wastewater into drinking water through the emerging practice of DPR. The report was sponsored by the WateReuse Association and co-sponsored by NWRI, American Water Works Association, and Water Environment Federation. Until guidelines and regulations are prepared, this framework document can serve as a valuable resource to municipalities, utilities, and agencies interested in implementing DPR programs to augment community water supplies.

- Mosher, J., G. Tchobanoglous, and G. Vartanian (2016). *Potable Reuse Research Compilation: Synthesis of Findings*, Water Environment & Reuse Foundation, Alexandria Va.



  The purpose of this report is to summarize and synthesize key issues and findings related to research involving the technical feasibility of implementing DPR projects. The report aims to provide a clear and comprehensive understanding of the state-of-the-art and state-of-the-science on DPR and to identify unknowns that may require further research.

  The topics addressed in this report include: source control, treatment trains, surrogates and log reduction credits for pathogens, pathogen monitoring, constituents of emerging concern, critical control points to monitor DPR systems, operation and maintenance of DPR facilities, operator training and certification, the resilience of DPR systems, and reliable and redundant treatment train performance.
  www.werf.org/a/ka/Search/ResearchProfile.aspx?ReportId=Reuse-15-01

International Organizations

- *Potable reuse: Guidance for producing safe drinking-water.* Geneva: World Health Organization; 2017. License: CC BY-NC-SA 3.0 IGO. www.who.int/water_sanitation_health/publications/potable-reuse-guidelines/en/

  In response to growing pressures on available water resources, potable reuse represents a practical source of drinking water in specific circumstances. This document describes how to apply appropriate management systems to produce safe drinking water from municipal wastewater. Information is provided on specific aspects of potable reuse, including the quality and protection of source wastewaters, types of control measures, monitoring considerations and public acceptance. Application of potable reuse is also illustrated through a number of case studies.

  The guidance is intended for use by drinking water suppliers and regulators who are familiar with the WHO's Guidelines for drinking water quality and, in particular, the framework for safe drinking water, including water safety plans. This publication may also be useful to others with an interest in potable reuse including environmental health and water resource professionals.

Appendix C: Summary of the Water Research Foundation Potable Reuse Research Efforts

The Water Research Foundation (WRF) has had an active potable reuse research program since the 2000s. A summary of the WRF's research efforts is summarized below.

C.1 Direct Potable Reuse Initiative 2012-2016

WRF, in partnership with WateReuse California, launched the Direct Potable Reuse Initiative (DPR Initiative) in 2012 to advance DPR as a water supply option. This initiative was prompted by the California legislature, which mandated an investigation into the feasibility of developing water recycling criteria for DPR.

This Initiative was based on the research areas identified in the 2010 publication *Direct Potable Reuse: A Path Forward* (Tchobanoglous et al., 2011). In addition, a DPR Research Needs Workshop was held in December 2012 to identify high priority research needs. The outcomes of these efforts set the DPR research agenda under the DPR Initiative.

The 2012-2016 DPR Initiative resulted in raising over $6 million from utilities, consulting firms, and manufacturers. The $6 million was augmented by funding from state grants and in-kind contributions. All total, the $6 million was leveraged into over $24 million of research.

As part of the initiative, 34 DPR research projects (see **Table C.1**) were funded that addressed regulatory, utility, and community topics. One of the notable projects developed under the DPR Initiative was the *Framework for Direct Potable Reuse,* published in 2015 (Tchobanoglous et al., 2015). This report provided an overview of the key elements that make up a DPR program, from source control to blending product water and is a valuable resource for municipalities, utilities, and agencies seeking to implement DPR programs.

Table C.1 Research Projects Conducted under the 2012-2016 WateReuse Foundation DPR Initiative

Project #	Research Project Title	Principal Investigator	Focus
WRF-11-01	Monitoring for Reliability and Process Control of Potable Reuse Applications	Ian Pepper, University of Arizona	Regulatory, Utility
WRF-11-02	Equivalency of Advanced Treatment Trains for Potable Reuse	Rhodes Trussell, Trussell Technologies	Regulatory, Utility
WRF-11-05	Demonstrating the Benefits of Engineered DPR versus Unintentional Indirect Potable Reuse Systems	Glen Boyd, The Cadmus Group	Community, Regulatory
WRF-11-10	Risk Reduction Principles for DPR	Andy Salveson, Carollo Engineers	Regulatory
WRF-12-06	Guidelines for Engineered Storage for Direct Potable Reuse	Andy Salveson, Carollo Engineers	Regulatory, Community, Utility
WRF-12-07	Methods for Integrity Testing of NF and RO Membranes	Joe Jacangelo, MWH	Regulatory

WRF-13-02	Model Public Communication Plan for Advancing DPR Acceptance	Mark Millan, Data Instincts	Community
WRF-13-02 Phase 2	Development of Communication Plan for Advancing DPR Acceptance	WateReuse	Community
WRF-13-03	Critical Control Point Assessment to Quantify Robustness and Reliability of Multiple Treatment Barriers of DPR schemes	Troy Walker, Hazen & Sawyer	Regulatory, Utility
WRF-13-12	Evaluation of Source Water Control Options and the Impact of Selected Strategies on DPR	Alan Rimer, Black & Veatch	Utility, Regulatory
WRF-13-13	Development of Operation and Maintenance Plan and Training and Certification Framework for Direct Potable Reuse (DPR) Systems	Troy Walker, Hazen & Sawyer	Utility
WRF 4508 (WRF-13-14)	Assessment of Techniques to Evaluate and Demonstrate the Safety of Water from DPR Treatment Facilities	Channah Rock, University of Arizona	Utility, Regulatory
WRF 4536 (WRF-13-15)	Blending Requirements for Water from Direct Potable Reuse Treatment Facilities	Andy Salveson, Carollo Engineers	Utility, Regulatory
WRF-14-01	Integrated Management of Sensor Data for Real Time Decision Making and Response	Jeff Neeman, Black & Veatch	Regulatory, Utility
WRF-14-02	Establishing Additional Log Reduction Credits for WWTPs	Zia Bukhari, American Water	Regulatory
WRF-14-03	Develop Methodology of Comprehensive (Fiscal/Triple Bottom Line) Analysis of Alternative Water Supply Projects Compared to DPR	Ben Stanford, Hazen & Sawyer	Utility
WRF-14-08	Economics of DPR	Bob Raucher, Stratus; George Tchobanoglous, UC Davis	Utility, Community
WRF-14-10	Enhanced Pathogen and Pollutant Monitoring of the Colorado River Municipal Water District Raw Water Production Facility at Big Spring, TX	Eva Steinle-Darling, Carollo Engineers	Regulatory
WRF-14-12	Demonstrating Redundancy and Monitoring to Achieve Reliable Potable Reuse	Shane Trussell, Trussell Technologies	Utility, Regulatory
WRF-14-13	From Sewershed to Tap: Resiliency of Treatment Processes for DPR	Sharon Waller, Sustainable Systems	Regulatory
WRF-14-14	Framework for Public Health Monitoring: White Paper	Jeff Soller, Soller Environmental; Jeff Mosher, NWRI	Regulatory, Community
WRF-14-15	Application of Bioanalytical Tools to Assess Biological Responses Associated with Water at DPR Facilities	TBD	Utility, Regulatory
WRF-14-16	Operational, Monitoring, and Response Data from Unit Processes in Full-Scale Water Treatment, IPR, and DPR	Andy Salveson, Carollo Engineers	Utility, Regulatory
WRF-14-17	White Paper on the Application of Molecular Methods for Pathogens for Potable Reuse	Krista Wigginton, University of Michigan	Regulatory

WRF-14-18	Ensuring Stable Microbial Water Quality in Direct Potable Reuse Distribution Systems	Workshop	Regulatory
WRF-14-19	Predicting Reverse Osmosis Removal of Toxicologically Relevant Unique Organics	Kerry Howe, University of New Mexico	Utility
WRF-14-20	Framework for Direct Potable Reuse	Jeff Mosher, NWRI	Regulatory
WRF-15-01	DPR Research Compilation: Synthesis of Findings from DPR Initiative Projects	Jeff Mosher, NWRI; George Tchobanoglous, UC Davis	Regulatory, Utility, Community
WRF-15-02	Creating a Roadmap for Bioassay Implementation in Reuse Waters: A cross disciplinary workshop	WateReuse Research Foundation Workshop	Regulatory
WRF-15-04	Characterization and Treatability of TOC from DPR Processes Compared to Surface Water Supplies	Larry Schimmoller, CH2M	Regulatory
WRF-15-05	Developing Curriculum and Content for DPR Operator Training	Ben Stanford, Hazen & Sawyer	Utility
WRF-15-07	Molecular Methods for Measuring Pathogen Viability/Infectivity	University of Michigan	Regulatory
WRF-15-10	Optimization of ozone-BAF treatment processes for potable reuse applications	Zia Bukhari, American Water	Utility
WRF-15-11	Demonstration of High Quality Drinking Water Production Using Multi-Stage Ozone-Biological Filtration (BAF): A Comparison of DPR with Existing IPR Practice	Kati Bell and Denise Funk, Gwinnett County	Utility
WRF-15-13	NDMA Precursor Control Strategies for DPR	Roshanak Aflaki, LA SAN	Utility
WRF-15-18	Comparing Relative Human Health Risk of Indirect Potable Reuse and DPR	Jim LaVelle, CDM Smith	Regulatory
WRF-16-01	Evaluating Post Treatment Challenges for Potable Reuse Applications	David Hokanson, Trussell Technologies	Utility
WRF-16-02	Building-Scale Treatment for Direct Potable Reuse and Intelligent Control for Real Time Performance Monitoring	Paula Kehoe, SFPUC	Utility
WRF-16-04	Fate of Sulfonamide Antibiotics through Biological Treatment in Water Reclamation Facilities Designed to Maximize Reuse Applications	Sandeep Sathyamoorthy, Black & Veatch	Utility

Included in this program is research to address public perception – which can be one of the largest obstacles for a utility implementing potable reuse. The project *Model Public Communication Plan for Advancing DPR Acceptance* (WRF-13-02), documented approaches to address public acceptance of potable reuse on statewide and community levels (Millan et al., 2014). In the report, approaches to build support and awareness of potable reuse projects were provided based on fostering an understanding of the need for reliable and sustainable water supply sources. The report includes a plan for utilities to develop their own public outreach campaign, including target audiences and messages that were vetted through comprehensive polling and interviews. Additionally, through a partnership with the Australian Water Recycling Centre of Excellence, outreach materials, videos, and tools were developed that can be used by states and communities to support communications efforts.

To complete the DPR Initiative and support the California DPR Expert Panel process, WRF published the synthesis document *Potable Reuse Research Compilation: Synthesis of Findings* (Reuse-15-01) to summarize the results of the 34 research projects funded through the initiative (Mosher et al., 2016). In the report, the results of research across the 34 projects were summarized into nine themes:

- Source Control
- Evaluation of Potential DPR Treatment Trains
- Pathogens (Surrogates and Credits)
- Pathogens (Rapid Continuous Monitoring)
- Risks and Removal of Constituents of Emerging Concern
- Critical Control Points
- Operation and Maintenance and Operator Training and Certification
- Failure and Resiliency
- Demonstration of Reliable, Redundant Treatment Performance

This initiative culminated in a finding from the California State Water Resources Control Board that it is feasible to develop criteria for DPR. The research conducted under the DPR Initiative was cited as being instrumental to this finding.

Although this initiative focused on addressing knowledge gaps associated with DPR, the results of the research are directly applicable to all potable reuse, including groundwater replenishment and surface water augmentation. The research results can support the development of regulations in states and provide guidance and recommendations for water utilities and regulators for water quality criteria for pathogens and chemicals, treatment technologies, monitoring, operations, and public engagement.

C.2 Current Water Research Foundation Projects

The Water Research Foundation continues to sponsor and fund water reuse projects. **Table B.2** lists active WRF water reuse projects. These projects address technical and other topics intended to advance reuse projects.

Table C.2 Current WRF Projects Addressing Water Reuse

Project Number	Title
4600	Soil Aquifer Treatment Characterization with Soil Columns for Groundwater Recharge in the San Fernando Valley (Phase III)
4691	Building-Scale Treatment for Direct Potable Reuse and Intelligent Control for Real Time Performance Monitoring
4715	Anticipating Trade-offs of Using Alternative Water Supplies
4737	Quantifying the Contribution of Disinfection Byproducts to the Toxicity of Wastewaters Purified for Potable Reuse: Which Byproduct Classes Matter?

Reuse-16-06 (4829)	Evaluating Economic and Environmental Benefits of Water Reuse for Agriculture
Reuse-16-07 (4830)	FDA Food Safety Modernization Act (FSMA) Produce Safety rule: Opportunities and Impacts on Water Reuse for Agricultural Irrigation
Reuse-17-01 (4831)	Hybrid NF/RO Sodium Chloride Removal Process: Phase 2 Pilot Study
U1R116 (4872)	Characterization of Organic Carbon and Microbial Communities for the Optimization of Biologically-Active Filtration for Potable Reuse
Reuse-17-25 (4903)	Self-Healing Hydrogel-Composite Membranes: From Proof of Concept to Water Reuse Application
Reuse-17-26 (4904)	Full Scale Validation of Cryptosporidium and Giardia Log Reductions in Secondary Biological Treatment
4905	Assessing the Contribution of Water Reuse Practice to Nutrient Impaired Waters (4905)
4906	Evaluation of Fouling Characteristics and Cleaning Efficacy of Bespoke Membrane Filtration Systems Treating Ozonated Secondary Effluent
Reuse-17-30 (4908)	Demonstrating Real-Time Collection System Monitoring as Part of Enhanced Source Control for Potable Reuse
4909	Development of a Design, Operations and Regulations Guidance Manual and Training Materials for Onsite Non-Potable Water Systems
Reuse-18-03 (4937)	Enhanced Evaluation of the Removal of Contaminants of Emerging Concern in Decentralized Water Reuse Systems by Non-Targeted Analysis

Next steps: Advancing Potable Reuse Initiative and the California State Water Board Grant

The DPR Initiative (see above) was able to address many outstanding questions and provides a large body of information for implementing potable reuse. However, a number of needs remain addressing regulatory, scientific, and technical questions for potable reuse. WRF has established a new research effort, Advanced Potable Reuse Initiative, for the purpose of addressing outstanding questions in states across the U.S. that are developing potable reuse regulations and/or implementing projects.

Funding for this program is based on two recycled water grants from the California State Water Resources Control Board (SWRCB) totaling $4.5 million. Of this amount, $3 million will be dedicated to potable reuse with $1 million for five high priority projects identified by SWRCB and $2 million for projects developed by WRF. In addition, WRF is in the process of raising matching funding to leverage the grants.

SWB Grant 1: Expert Panel Recommendations

The SWRCB Report on the feasibility of developing criteria for DPR included research projects identified in the California DPR Expert Panel report. It is critical for SWRCB that these research topics (**Table C.3**) be conducted concurrently with the development of regulations for DPR in California. Under SWB Grant 1, WRF will research these projects. WRF is initiating the research for these project in 2019.

Table C.3 SWB Grant 1: Priority DPR Research Projects for California

1. **Quantitative Microbial Risk Assessment (4951):** Implement a probabilistic method (Quantitative Microbial Risk Assessment, QMRA) to confirm the necessary removal values for viruses, Cryptosporidium and Giardia based on a literature review and new pathogen data collected, and apply this method to evaluate the performance and reliability of DPR treatment trains.
2. **Pathogen Data Collection in Wastewater (4952):** Require monitoring of pathogens in raw wastewater to develop better empirical data on concentrations and variability.
3. **Feasibility of Outbreak reporting (4990):** Investigate the feasibility of collecting raw wastewater pathogen concentration data associated with community outbreaks of disease, and implement where possible.
4. **Options to reduce chemical spikes (4991):** Identify suitable options for final treatment processes that can provide some "averaging" with respect to potential chemical peaks, particularly for chemicals that have the potential to persist through advanced water treatment.
5. **Low Molecular Weight Unknown Compounds (4992):** Develop more comprehensive analytical methods to identify unknown contaminants, particularly low molecular weight compounds potentially in wastewater that may not be removed by advanced treatment and is not presently detectable by current regulatory monitoring approaches.

SWB Grant 2: Potable Reuse Research

The second SWB grant provides $3.5M in funding for recycled water and relies on the WRF research process to identify research needs and develop research projects. **Table C.4** summarizes the projects that have been selected for funding. These projects began in 2018.

Table C.4 WRF Research Projects funding by SWB Grant 2

Project Number	Project Title
4832	Evaluation of CEC Removal by Ozone/BAF Treatment in Potable Reuse Applications
4833	Understanding Wastewater Treatment Performance on Advanced Water Treatment Processes and Finished Water Quality *(Awarded in Summer 2018)*
4953	Considerations and Blending Strategies for Drinking Water System Integration with Alternative Water Supplies
4954	Integration of High Frequency Performance Data for Microbial and Contaminant Control in Potable Reuse Systems
4955	Indicator Viruses for Advanced Physical Treatment Process Performance Confirmation
4956	Addressing Impediments and Incentives for Agricultural Reuse
4957	Compiling Evidence of Pathogen Reduction through Managed Aquifer Recharge and Recovery
4958	New Techniques, Tools, and Validation Protocols for Achieving Log Removal Credit across NF and RO Membranes
4959	Evaluation of Tier 3 Validation Protocol for Membrane Bioreactors to Achieve Higher Pathogen Credit for Potable Reuse

4960	Review of Industrial Contaminants Associated with Water Quality or Adverse Performance Impacts for Potable Reuse Treatment
4961	The Use of Next Generation Sequencing (NGS) and Metagenomics Approaches to Evaluate Anti-Microbial Resistance, Plant Challenge, Biological Removal Processes
4962	Identifying the Amount of Wastewater that is Available and Feasible to Recycle in California
4963	Developing a New Foundational Understanding of SAR – Soil Structure Interactions to Provide Management Options for Reclaimed Water Use in Agriculture
4964	Assessing the State of Knowledge and Impacts of Recycled Water Irrigation on Agricultural Crops
4979	Design Considerations for Integrating Public Engagement at Potable Reuse Demonstration Facilities