Advanced Water Purification

PROPOSED PROGRAM
ROADMAP

NOVEMBER 2023

ADEQ
Arizona Department of Environmental Quality
Clean Air, Safe Water, Healthy Land for Everyone

Advanced Water Purification Proposed Program Roadmap

ARIZONA DEPARTMENT OF ENVIRONMENTAL QUALITY (ADEQ)

ADEQ's MISSION/VISION

To protect and enhance public health and the environment in Arizona.

Through consistent, **science-based** environmental regulation; and **clear, equitable engagement** and communication;

With **integrity, respect,** and the highest standards of **effectiveness** and **efficiency**;

Because Arizonans treasure the unique environment of our state and its essential role in sustaining well-being and economic vitality, **today and for future generations**.

DISCLAIMER

This document represents a summary of ADEQ's proposed Advanced Water Purification (AWP) program, drafted under advisement of the Technical Advisory Group (TAG) process and provided here for the limited purpose of informal stakeholder review and input. As such, this document does not represent the final rule and may be revised and updated throughout the stakeholder and rulemaking processes.

ACKNOWLEDGEMENTS

Arizona Department of Environmental Quality (ADEQ) has engaged numerous stakeholders to gather information on public sentiment toward AWP, technical considerations, and other key considerations to develop this Roadmap. ADEQ formed a Technical Advisory Group (TAG) to assist in developing an implementable AWP rule and program. The TAG consisted of ADEQ staff, academics, utilities, regulators, consultants, and scientists collaborating to provide recommendations on topics including pathogen removal, chemical control, enhanced source control, operations, treatment and outreach. This committed team worked diligently from October 2022 through June 2023. In addition, public feedback and sentiment was established through one-on-one stakeholder interviews and surveys conducted by HMA Public Relations and its research partner, BrandOutlook, as well as other communications tactics (e.g., meetings, listening sessions, and presentations). Below is a list of the editorial and TAG committee members who in addition to dedicated ADEQ staff who, alongside numerous other contributors, helped bring this Roadmap together.

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Executive Summary

Arizona relies on a combination of surface water and groundwater sources for its potable water supply. Persistent drought in western states, including Arizona, has resulted in historically low water levels in regional reservoirs, requiring Arizona to reduce Colorado River water consumption. Ongoing water scarcity highlights the need to develop additional sources of water to meet municipal and agricultural water demands. In response to State water scarcity, the Arizona Department of Environmental Quality (ADEQ) is charged with expanding its water reuse programs, most recently through the development of regulations for the reuse of treated municipal wastewater as drinking water. This program is known as the Advanced Water Purification (AWP) program. The proposed AWP Roadmap (Roadmap) is a resource to assist stakeholders, including utilities, the State of Arizona (Arizona) employees, consultants, planners, business owners, and the public, in understanding.

GUIDING PRINCIPLES

ADEQ's vision for AWP program rule development is based on guiding principles reflecting ADEQ's mission to protect and enhance public health and the environment in Arizona, as well as ADEQ's belief that AWP regulations should be developed through clear and effective communication with stakeholders, guided by reasonable and protective regulations, and driven by forward-thinking goals. The guiding principles are:

- Protect public health and the environment.
- Support local communities.
- Account for future conditions and growth.
- Scientifically grounded.
- Reasonable affordability.
- Transparent, informative, and communicative.
- Specific, practical, flexible, and implementable.

ROADMAP KEY ELEMENTS

PERMITTING

A permitting process will be developed pursuant to the Arizona Revised Statutes (A.R.S.) and will be adopted into the Arizona Administrative Code (A.A.C.) in accordance with rulemaking requirements in the Arizona Administrative Procedure Act. The permitting process will adhere to all applicable state laws and will aim to serve the regulated community while being protective of public health and the environment. ADEQ envisions this permitting process will function similarly to other ADEQ permits such as Aquifer Protection Permits.

ADVANCED WATER TREATMENT AND REMOVAL

ADEQ's proposed treatment objectives and removal standards specific for implementing AWP use a risk management approach for pathogens and chemicals that meets or exceeds the standards of the Safe Drinking Water Act (SDWA) for conventional drinking water treatment facilities (DWTFs).

Pathogen Removal Standards:

Pathogen reduction will be achieved through the use of multiple-barrier treatment, monitoring critical control points and operations, among other methods. The Roadmap proposes two options:

- Option 1 – no site-specific monitoring is performed, and the standard minimum log reduction for viruses (LRVs), Giardia, and Cryptosporidium are 13, 10, 10, respectively. 1-log reduction is 90% reduction in the initial concentration of the pathogen, 2-log reduction is 99% reduction in the initial concentration and 3-log reduction is 99.9% reduction and so on.
- Option 2 – site-specific log reduction targets are calculated based on specific concentrations detected over time in treated wastewater, with minimum log reduction thresholds for viruses, Giardia, and Cryptosporidium, as 8, 6, 5.5, respectively.

AWTFs are required to have at least one filtration and one disinfection step that removes each target pathogen, and no treatment barrier can be awarded more than six LRVs. Pilot testing is required to demonstrate pathogen LRVs.

Chemical Removal Standards:

AWTF treatment trains must consist of at least three separate treatment processes, using diverse treatment mechanisms and must include advanced oxidation and physical separation.

Chemical identification and monitoring uses a three-tier approach:

- Tier 1 includes regulated chemicals currently covered under the Safe Drinking Water Act (SDWA).
- Tier 2 includes chemicals that are not federally regulated, but may pose a significant health concern.
- Tier 3 includes performance-based indicators used to monitor treatment train performance.

Examples of Tier 1 include: arsenic; nitrate; and disinfection by-products (DBPs). Examples of Tier 2 include: N-Nitrosodimethylamine; 1,4-dioxane; and perfluorooctanesulfonic acid. Examples of Tier 3 include: TOC; sucralose; sulfate; and carbamazepine.

ENHANCED SOURCE CONTROL

Traditional source control programs are designed to protect the wastewater treatment plant infrastructure, the collection systems, and the receiving water bodies under an existing regulatory framework through the National Pretreatment Program (NPP) of the federal Clean Water Act. Because AWP projects create potable water directly without an environmental buffer, the proposed program will require Enhanced Source Control. Enhanced Source Control includes the control, elimination, or minimization of constituents of concern discharged from non-domestic dischargers into a wastewater collection system. For enhanced source control, constituents of concern include regulated chemicals, AWP regulated chemicals, and performance-based indicators, which are necessary to eliminate or minimize discharges of constituents of concern into the wastewater collection system that is providing the source water for the AWP. The proposed Enhanced Source Control program includes the following components:

- **Regulatory Authority** – AWP applicants shall demonstrate adequate legal authority to implement the Enhanced Source Control program, which shall include authority for oversight/inspection of upstream dischargers, review of new connections in the sewershed, development and implementation of local limits, reporting requirements for dischargers, and the ability to establish and enact compliance programs.
- **Monitoring and Assessment of Non-Domestic Sources** – New and evolving industry/commercial establishments discharging into the sewershed shall be tracked and communication must occur with dischargers about any changes in operation that may impact the AWP.
- **Chemical and Discharger Inventory** – A comprehensive inventory of non-domestic establishments and discharges of constituents of concern into AWP source water shall be maintained.
- **Source Investigations** – Investigations of the sewershed to identify sources of chemical peaks at facilities which are determined to have a potential of impacting or adversely affecting the facility and human health.
- **Pollutant Reduction and Elimination Plan** – A Pollutant Reduction and Elimination Plan specific to Enhanced Source Control to build relationships with non-domestic sources, increase participation in pollution prevention methods to control release of Constituents of Concern in the sewershed, and educate the general public on protecting the source water.
- **Response Plans** – A response plan which includes steps to identify exceedances, communication strategies, notifications to ADEQ, and bypass or shutdown procedures as necessary.

OPERATIONAL REQUIREMENTS

AWP involves the operation of multiple complex and interrelated treatment and monitoring processes. Operations and maintenance procedures promote consistent operation at each treatment facility, thereby ensuring potable water meets all standards. The proposed key operational requirements for AWP are as follows:

- **Full-Scale Verification Testing Plan** – A plan identifying the steps necessary to complete performance testing of each component of the AWTF treatment train, to be submitted by the AWP applicant at the time of application.
- **Operations Plan** – A plan describing the activities that will be conducted to operate and maintain AWP facilities, to demonstrate that they are performing as designed, and to provide contingency plans for emergency situations.
- **Response to Off-Specification Water** – A plan for responding to treated water that does not meet standards.

OTHER REQUIREMENTS

- **Operator Certification** – ADEQ is proposing a new certification, the Advanced Water Treatment Operator (AWTO) certification, that will encompass critical AWP knowledge, skills, and abilities.
- **Technical, Managerial, and Financial (TMF) Capacity Assessment** – A TMF assessment is required for AWTFs to determine the technical, managerial, and financial capacity to properly operate and maintain the AWP utility.
- **Utility Collaboration** – The AWP applicant will be required to demonstrate evidence of a formal agreement that identifies all partner entities and describes their roles and responsibilities within the AWP project.

MONITORING AND REPORTING

AWTFs are required to comply with existing SDWA monitoring requirements. Additional, proposed ongoing compliance and performance monitoring requirements for AWP are as follows:

Pathogen Monitoring – If an AWTF chooses to demonstrate lower pathogen levels in their influent (i.e., treated wastewater) through monthly monitoring (Option 2 in Advanced Water Treatment and Removal), lower log reduction targets than the baseline (Option 1: 13, 10, 10) can be achieved. The associated monthly pathogen monitoring must be performed for a minimum of two years, with at least 24 samples prior to design and construction. Pathogen removal performance tracking will involve online monitoring at CCPs and grab sampling.

Chemical Monitoring – Baseline monitoring of constituents of concern in the treated wastewater is required monthly for at least one year prior to design and construction of the downstream AWTF. Ongoing monitoring will be required with sampling frequency based on detection history and relevance as described below:

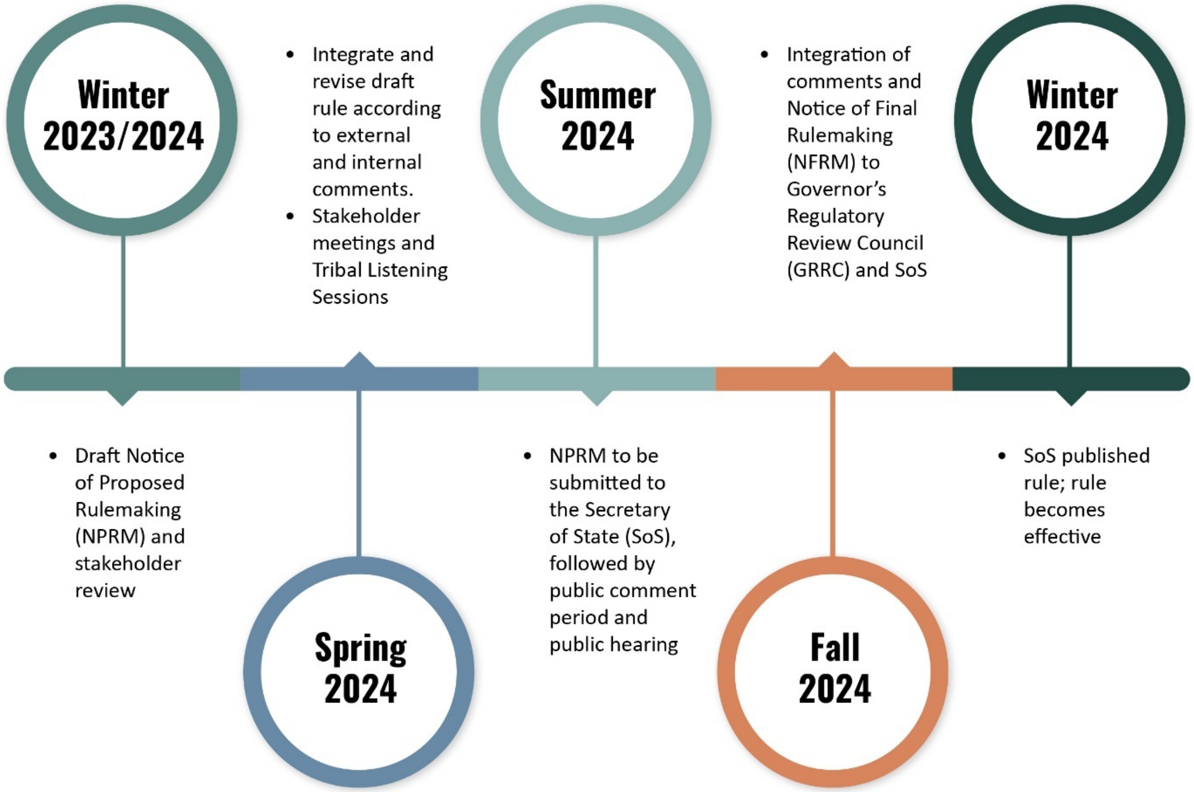
- Tier 1 chemicals will be monitored quarterly at treated wastewater (source to the AWTF) and finished water locations.
- Tier 2 chemicals will be sampled once a month for a year at startup and will be monitored at the treated wastewater and finished water locations.
- Tier 3 chemicals will be regularly monitored at CCPs and in the Advanced Treated Water (ATW). The monitoring frequency may be changed at ADEQ’s discretion.

Reporting – Once an AWTF is operational, reporting will be an important component of documenting the performance of the system. ADEQ intends to establish electronic formats for reporting AWP program monitoring compliance data similar to the current format for Self-Monitoring Report Forms (SMRF) under APP and SDWA (SDWIS).

PUBLIC COMMUNICATIONS

The AWP utility and associated partners must develop and implement a Public Communication Plan within their service area to notify the public, address public concerns, build public confidence, and garner public acceptance for the AWP.

NEXT STEPS


Winter 2023/2024
• Draft Notice of Proposed Rulemaking (NPRM) and stakeholder review
Spring 2024
• Integrate and revise draft rule according to external and internal comments.
• Stakeholder meetings and Tribal Listening Sessions
Summer 2024
• NPRM to be submitted to the Secretary of State (SoS), followed by public comment period and public hearing
Fall 2024
• Integration of comments and Notice of Final Rulemaking (NFRM) to Governor's Regulatory Review Council (GRRC) and SoS
Winter 2024
• SoS published rule; rule becomes effective

1. Introduction

1.1. Arizona’s Water Supply Challenges

Arizona's potable water supply relies on a delicate balance between surface water and groundwater sources. Notably, the Colorado River, a significant surface water source, contributes around 40% of the state's total water (Arizona Department of Water Resources, 2022). However, Arizona faces several challenges related to its water resources. The state experiences an average annual precipitation of approximately 12 inches, but climate data reveal a concerning trend: a consistent reduction of 0.9 inches of rainfall per year over the past three decades (Arizona State University, 2023). This prolonged decrease in precipitation has contributed to persistent drought conditions, which have been affecting various western states, including Arizona. These conditions have led to historically low water levels in Colorado River system reservoirs, forcing Arizona and other states to implement measures to reduce their consumption of Colorado River water. As a result of the on-going “mega-drought”,, a Drought Emergency Declaration has been in place since 1999 (Arizona Department of Water Resources, 2022).

Of particular concern, in 2022, the U.S. Federal Government called on the Colorado River states to conserve between 2-4 million acre feet per year to address the critically low levels in Lake Powell and Lake Mead. These delivery cutbacks mean Arizona will forgo a substantial 21% of its Colorado River water allocation (U.S. Department of the Interior, 2022), representing a 16% reduction from the previous drought restrictions (Arizona Department of Water Resources, 2022). Looking ahead, climate projections and historical trends indicate that the state is likely to face increasing average temperatures and reduced rainfall in the coming years. These factors are expected to further compound the challenges of maintaining an adequate and sustainable water supply for Arizona's growing population.

In addition to the dwindling water supply, population growth presents water providers with increasingly formidable challenges in meeting demand. According to recent data (US Census Bureau, 2021), Arizona witnessed a substantial 12% population surge between 2010 and 2020, and this growth shows no signs of abating, see Figure 1. Projections indicate an additional influx of over one million residents in the next decade, as reported by the Arizona Commerce Authority in 2022. Predictably, this population boom has corresponded with an increase in water demand. The volume of water supplied by public utilities rose from 700,000 acre-feet per year to 1,350,000 acre-feet between 1985 and 2010, as highlighted in Figure 2 (Molly A. Maupin et al., 2018). To put this in perspective, a single acre-foot of water can support approximately three single-family homes in Arizona for an entire year (Arizona Department of Water Resources, 2021). As this growth continues, much of Arizona's projected increased demand for limited water resources will likely come from municipal and industrial sectors (US Bureau of Reclamation, 2012). This reality underscores the critical need for sustainable and innovative water resource management strategies to accommodate the state's evolving needs.

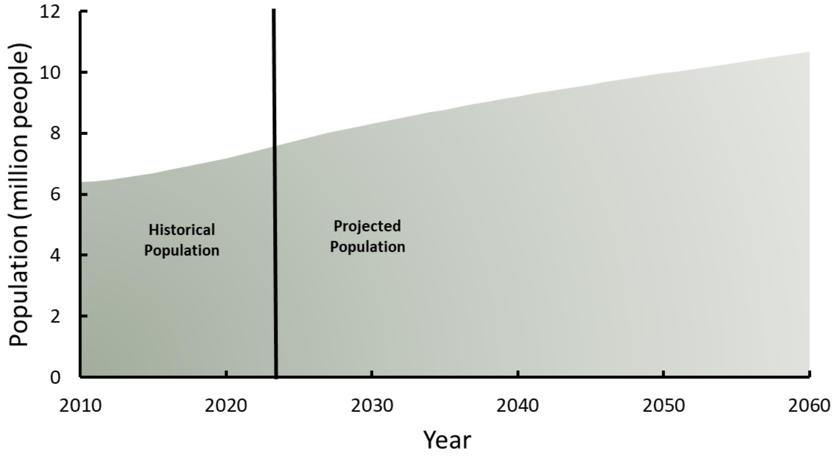


Figure 1: Population Projection of Arizona. Arizona's population has increased over 10% in the last decade, and further population increases are expected in the coming decades. The population increase is expected to further strain Arizona's water supply (Arizona Commerce Authority, 2023).

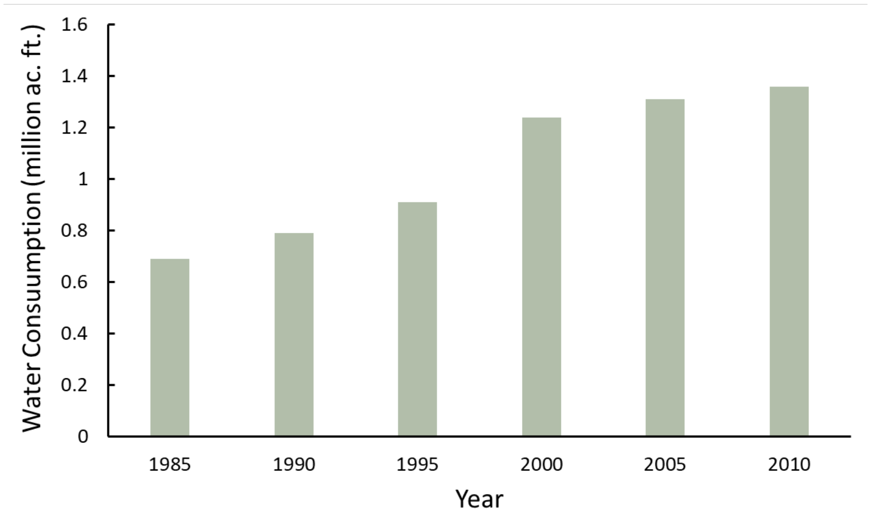


Figure 2: Historical Water Consumption from Public Water Supplies in Arizona. Increasing water demand for municipal water supplies has made reused water an attractive option to maintain water security (Molly A. Maupin et al., 2018). Public supply refers to water withdrawn by public and private water suppliers that provide potable water to at least 25 people, or that have a minimum of 15 connections.

1.2. Advanced Water Purification

Advanced Water Purification (AWP) is defined as the treatment and distribution of a municipal wastewater stream for use as potable water without the use or with limited use of an environmental buffer (US EPA, 2017). AWP has been shown to be a safe and effective source of potable water over decades of implementation in projects that have been installed worldwide at facilities in Big Spring, Texas (2013); Wichita Falls, Texas (2014); Namibia (1968 and 2002); Singapore (2019); and South Africa

(2011) (Lahnsteiner et al., 2018). A generalized diagram in Figure 3 illustrates this treatment approach. AWP applications typically consist of a conventional water reclamation facility (WRF) or wastewater treatment plant (WWTP) that performs solids, carbon, nutrient, and pathogen removal and an advanced water treatment facility (AWTF) that provides additional pathogen and trace chemical removal. An AWTF is a utility or treatment plant where recycled wastewater is treated to produce purified water to meet specific AWP requirements. AWTFs use a multi-barrier approach where several redundant unit processes in series are installed to treat WRF effluent to potable water standards.

Depending on the site-specific infrastructure configuration and treatment capabilities, the AWTF effluent may be introduced into several different locations of the potable water treatment and distribution system to be reused:

i. In the intake to the existing drinking water treatment facility (DWTF).
ii. After the DWTF and prior to the potable water distribution system.
iii. Directly into the potable water distribution system.

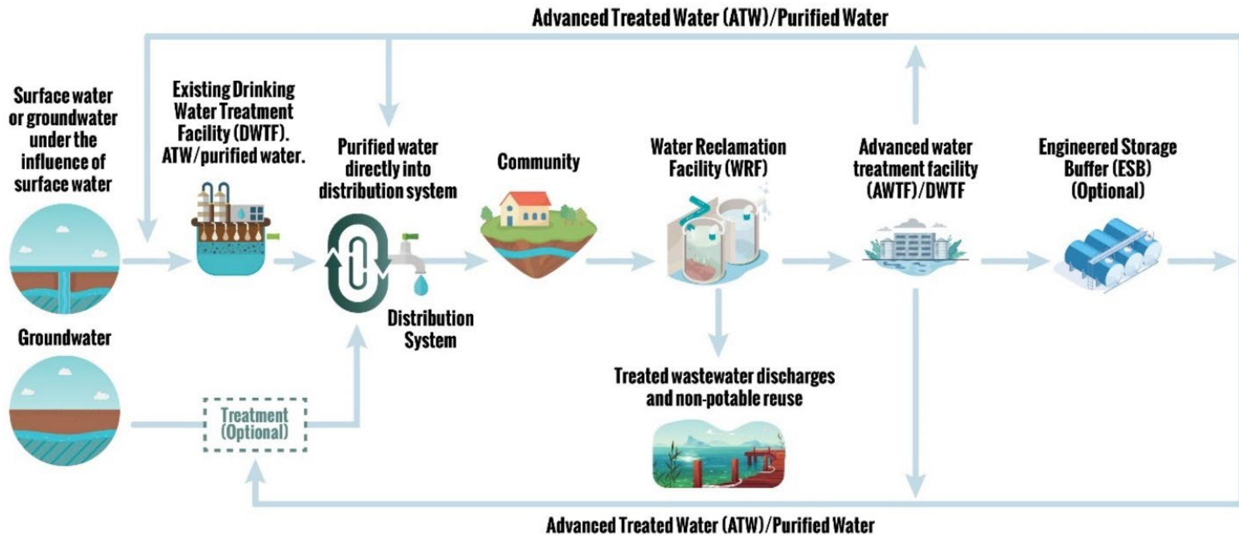


Figure 3: AWP Treatment and Distribution. Different configurations are possible for AWP. Original surface or groundwater may be blended with advanced treated water (ATW) treated in a WRF and AWTF. ATW may be blended into the distribution system prior to the DWTF, after the DWTF, or discharged into the distribution system without blending.

1.3. Statutory Authority

ADEQ will establish its AWP program pursuant to Arizona Revised Statutes (ARS) 49-211, which gives ADEQ authority to "adopt all rules necessary to establish and implement a direct potable reuse [AWP] of treated wastewater program, including rules establishing permitting standards and a permit application process." To meet the statutory objective, ADEQ will use guiding standards from the Safe Drinking Water Act (SDWA) of 1974 (42 United States Code (USC) 300f *et seq*.), including basic standards for potable water treatment and quality. As reused water has been increasingly used as a water supply in the United States (US), the US Environmental Protection Agency (US EPA) has published guidance for potable water reuse under the SDWA (US EPA, 2017). ADEQ has utilized key elements of this and other guidance documents in developing this roadmap for the prospective Arizona AWP regulations. Specifically, the Roadmap includes a description of ADEQ's current regulatory proposal for AWP as it relates to pathogen control and chemical control, as well as an overview of the decision points required to implement AWP and a summary of the information that will be used to develop ADEQ's AWP regulations.

1.4. Public Survey

A survey of public perceptions of AWP was performed by HMA Public Relations and its research partner, BrandOutlook, on behalf of ADEQ. A summary of the study results is included as follows:

i. Residents of Arizona view Arizona's water supply as a serious and imminent issue and expect shortages within five years.
ii. Population growth, inadequate water supply, and lack of widespread conservation efforts are viewed as key contributors to Arizona's water situation.
iii. The majority of respondents either perform additional treatment (e.g., filtration) or consume bottled water in the home. Taste and safety concerns were primary reasons respondents gave for why they did not drink water directly from the tap.
iv. 70% of people were somewhat or very likely to drink AWP water. Reasons given for their support of AWP included that they viewed it as safe/clean/drinkable, general support, and already having additional treatment. These responses still identified concerns with taste and odor impacting their acceptance.
v. For the 30% who responded unfavorably to drinking AWP water, primary concerns were the safety of the water, the "yuck" factor, preference for other water sources, and taste concerns.
vi. Primary barriers identified for the acceptance of AWP included higher costs, skepticism about the safety and quality of the water, and lack of familiarity with AWP treatment processes.
vii. The study also found that statements likely to impact acceptance of AWP were that AWP is drought-proof, local control over water supply, and ability to offset shortages.

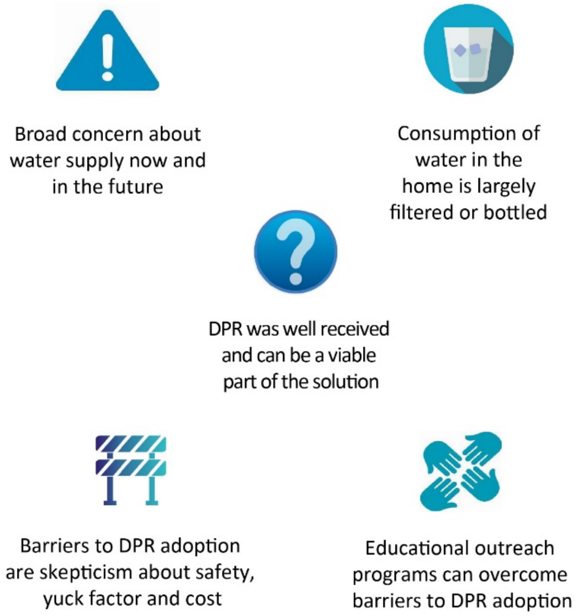


Figure 4: Summary Results of the HMA Public Relations/BrandOutlook Survey. Responses found broad concern for water availability in the near future and acknowledged AWP as a viable potential solution, but skepticism remains regarding the cost, safety, and characteristics of AWP water.

2. Roadmap Development Process

2.1. Purpose of the Roadmap

ADEQ has prepared this AWP Roadmap as a resource to assist stakeholders, including utilities, state of Arizona (Arizona) and government employees, consultants, planners, business owners, and the public, in understanding ADEQ's current proposed approach to AWP implementation in Arizona.

2.2. Guiding Principles

ADEQ's vision for AWP program implementation, as described in this Roadmap, is based on the following guiding principles:

i. Protective of public health and the environment.
ii. Community supported.
iii. Scientifically based.
iv. Reasonably affordable.
v. Transparent, informative, and communicative.
vi. Specific, practical, flexible, and implementable.
vii. Accounts for future conditions and growth.

These principles reflect ADEQ's overall mission to protect and enhance public health and the environment. ADEQ considers water recovered and beneficially used via AWP a valuable resource that should be managed through clear and effective communication with stakeholders, reasonable and protective regulations, and forward-thinking goals.

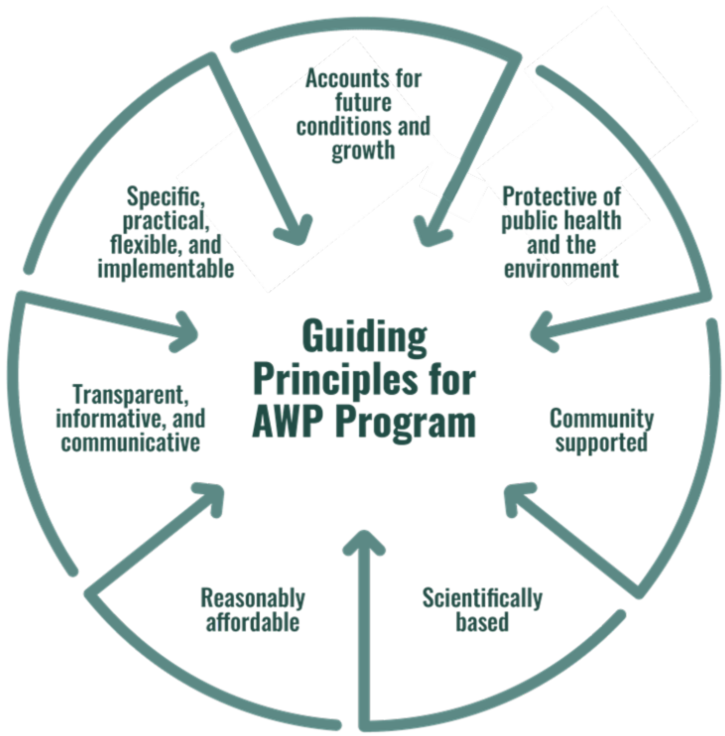


Figure 5: Guiding principles.

2.3. Stakeholder and Public Engagement Conducted

Public acceptance of AWP projects was identified as a key objective for the successful implementation of an AWP program. ADEQ engaged several stakeholders, including

(i) public and private utilities
(ii) other state regulatory agencies
(iii) risk assessors
(iv) academics
(v) vendors
(vi) manufacturers
(vii) laboratory experts
(viii) toxicologists
(ix) treatment plant operators (drinking and wastewater)
(x) city and county staff
(xi) general public
(xii) engineering consultants

to gather information on public perception toward the proposed AWP program, what they valued about purified water, technical considerations and its development. This information was synthesized to develop this proposed Roadmap, which will be used to garner additional feedback from stakeholders and in the development of the rule. Forums for engagement in AWP discussions have included focus groups, the Technical Advisory Group (TAG), and other workgroups. A summary of the number and type of stakeholder engagement is shown in Figure 6.

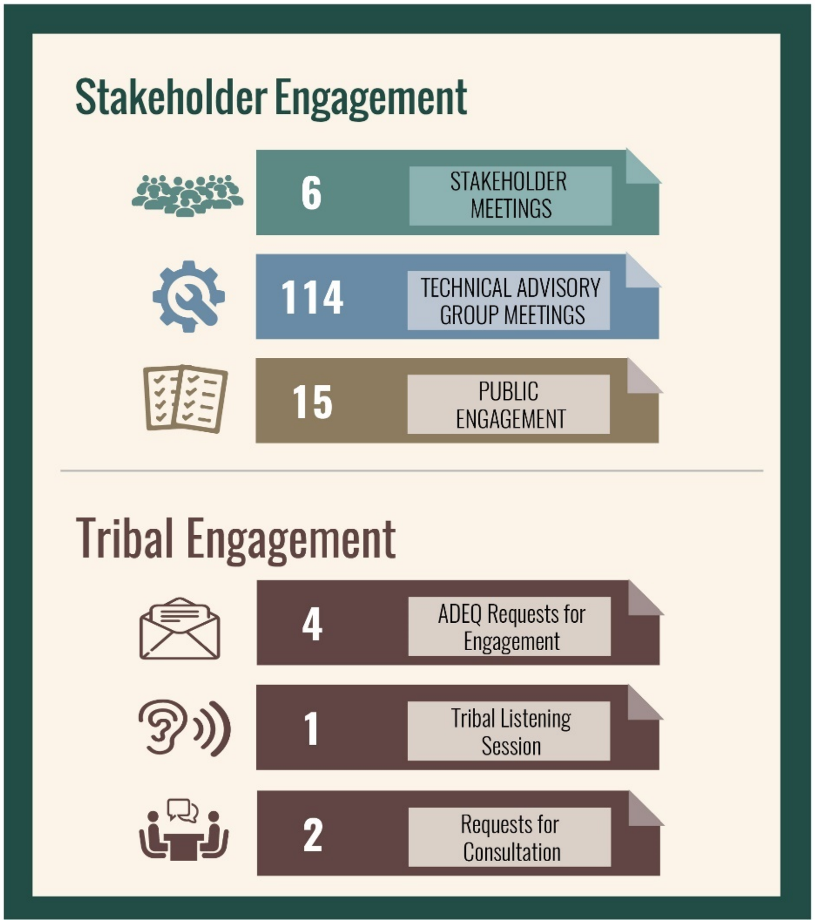


Figure 6: Summary of the number of types of stakeholder engagement.

3. Program Description

i. What will the Arizona AWP Program Look Like?

ADEQ proposes that the AWP Program will combine components of the Aquifer Protection Permit (APP) Program and drinking water program. The design and review of the AWTF and WRF will leverage the approval to construct (ATC) and approval of the construction (AOC) processes currently used within the drinking water program. However, given the complexity of the designs, the permitting process will be similar to APP in terms of billing and fees. The enhanced source control, sampling (chemicals and pathogens), and piloting approval will be reviewed and approved in accordance with an AWP-specific conceptual framework.

ii. Applicability of APP and SDWA within AWP Program

All AWTF facilities that are permitted as DWTFs will have to comply with requirements of both SDWA and AWP programs. In some cases where the AWTF is not permitted as a DWTF, and provides feed water to an existing DWTF, only AWP program requirements will apply, however, downstream DWTF facilities receiving ATW will have to comply with SDWA requirements. As water produced is drinking water, reporting under SDWA will apply in addition to AWP reporting requirements, which can be submitted separately.

All WRFs that are providing treated wastewater as source water to the AWTF will continue to have an APP as all WRFs are considered discharging facilities. If an AWP program leverages the WRF infrastructure to receive credit for pathogens or nitrogen removal, then the AWP program review will extend into the WRF.

iii. ADEQ Program Staff

ADEQ will train, hire or contract for the technical expertise required to implement the AWP program. ADEQ is currently evaluating the needed staff resources. In order to better understand the required technical expertise of the future AWP program, ADEQ has consulted with multiple states that have AWP programs in development. ADEQ estimates the need to hire at minimum the following categories of technical staff:

a. Permit writer (technical writing and project management skills).
b. Review Engineer to review WRF design, and APP requirements.
c. Review and coordination engineer (to review and coordinate enhanced source control program, source water characterization program (chemicals and pathogen).
d. Review engineer to review AWTF design and SDWA requirements.
e. Compliance and enforcement staff to review compliance data and conduct compliance and inspection functions of the program.
f. Operator certification coordinator.
g. Other new hires and current staff members would add to the administrative and support functions of the new program.

iv. Permit Types or Approvals

a. Optional Tier II, site specific pathogen characterization and piloting approval: The approval is for the review and approval of the enhanced source control program encompassing the Tier II chemical list, analytical methods and bioassay, pathogen sampling alternative procedures and WWTP operational requirements, review for the WWTP and proposed design for piloting. While this approval is not required, it is highly recommended in order to avoid costly rework.

b. Approval to Construct (ATC): Approval of the design of AWTF and WRF along with Tier II chemical list, piloting (example Tier III), recommendation by the project advisory committee, and other design and operational requirements
c. Approval of Construction (AOC): Review of full-scale verification data along with as-builts, engineering inspections and other relevant data. Upon approval of the AOC, the utility can distribute purified water.
d. Demonstration permit: This type of permit will be for the approval of the AWTFs for showcasing the AWTF train for public outreach, using ATW for tasting purposes or for other beverages. The demonstration AWTFs can be of any scale, however, if there are similarities in scale, it can substitute the piloting requirement and also towards operator certification experience requirements. Other piloting requirements still apply.

v. Permitting and Administration

a. Permit conditions, amendments, terms and renewal: Permits will be issued, denied, amended, and conditioned pursuant to ADEQ's AWP Program rules. As there is no Federal equivalent to the AWP program, permit requirements do not have any parallels with the current drinking water program. ADEQ proposes that permits will be issued for a fixed term and permits must be renewed every six years. ADEQ intends to provide permits with clear language, defined terms and a delineation of authorities for permit conditions.
b. Annual review of compliance monitoring data: ADEQ will require submittal of a comprehensive annual report containing monitoring data for all three chemical tiers along with pathogen data.

vi. Advanced Operator Certification Program

ADEQ will develop an operator certification program for the AWP program. ADEQ anticipates that the structure of this program will be similar to existing operator certification programs.

vii. Project Advisory Committee (PAC)

ADEQ may establish an AWP technical advisory committee to ensure an unbiased and thorough examination of proposed AWP projects. The advisory committee will be charged with conducting a technical review of the proposed project and provide written recommendations to ADEQ. The panel would consist of independent experts selected by ADEQ to help ensure that all important program components are reviewed and analyzed. PAC recommendations are advisory only and ADEQ is the final decision-making authority. Review by the project advisory committee may be required for a project for the items listed below, but is not limited to these items:

a. Site-specific log reduction approach, when this option is selected by the utility, to ensure that the data and information is sufficient and protective of human health.

b. Tier II chemical selection: A comprehensive review of the sewershed, contributing industries, and identification of Constituent(s) of concern (COCs).
c. Review of carbon train designs and other innovative treatment technologies or trains.

The PAC is a temporary panel in place for a specific project and participants are not ADEQ staff. The PAC will likely consist of the following expertise:

a. Toxicologist.
b. State of Arizona licensed engineer.
c. Epidemiologist.
d. Microbiologist.
e. Chemist.

viii. Cost and Funding

ADEQ is developing a cost model for the proposed program. The cost for the program will come from technical staff (engineers, operator certification coordinators, project managers, inspectors), leadership, training, travel, data management, and the cost of legal support. Technical staff costs are expected to be shared with the Aquifer Protection, Reclaimed and Recycled Water programs; those costs will be borne by the customers of those programs. ADEQ's AWP program is proposed to be funded by a combination of permitting fees, annual fees for those customers with permits in addition to other funding sources. Listed below are different types of fees that are proposed for the AWP program:

a. Hourly fee for review: It is expected that the hourly review fees begin with the first pre-application meeting and continue throughout the development of the permit.
b. Compliance schedule item (CSI) review fee: This will include any amendments to permit conditions, such as, updates or modification to operations.
c. Annual registration fee: Fees collected for the review of compliance data and for facility inspection and to pay for the reasonable and necessary costs of administering the registration program.
d. Operator certification fee: Fees collected to support the operator certification program.

ix. Public Notice Requirements

ADEQ's public participation process for AWP approvals will be similar to that for the existing APP permitting program, and for other permitting programs at ADEQ. ADEQ will provide public notice of proposed permit actions and establish a minimum of 30 days public comment period. ADEQ will provide public notice for both new permits and for amendments to permits. ADEQ will issue a public notice that provides the draft permit and provides a fact sheet containing principal facts and the significant factual, legal, methodological, and policy questions considered in preparing the draft permit. When there is a significant degree of public interest in a draft permit, ADEQ will hold a public hearing. ADEQ will give a 30-day notice for the public hearing. ADEQ will provide a written response to all comments received during the public comment period.

x. Licensing Time Frames (LTFs)

It is expected that LTF requirements will be similar to the current APP permits.

xi. Reporting

ADEQ will establish electronic formats for reporting AWP program monitoring compliance data similar to the current format for Self-Monitoring Report Forms (SMRF) under APP and SDWA (SDWIS). Initially, ADEQ will provide forms for other types of reporting, such as for Total Organic Carbon and Alkalinity or other reporting requirements contained within SDWA.

xii. Compliance and Enforcement

ADEQ will establish a proactive compliance and enforcement program to verify permit conditions. ADEQ will concentrate its efforts on compliance assistance and maintaining a dialogue with facilities to ensure that facilities remain in compliance. A proactive compliance and enforcement program, including inspections and timely resolution of violations, serves the public. ADEQ plans to create a robust inspection program of the AWP facilities operating in the state.

3.1. Program Standards

The use of treated wastewater as source water for AWP poses distinct risks compared to other traditional drinking water sources (i.e., surface and groundwater) (Ben Stanford et al., 2015). Therefore, ADEQ is proposing AWP specific standards for the control of both pathogens and chemicals to ensure protection of public health. The rationale for establishing the removal or reduction standards for pathogens and chemicals is based on the best available science and TAG recommendations as outlined in the following sections.

3.1.1. Pathogen Removal Standards

ADEQ proposes pathogen log reduction targets based on a tolerable annual risk of infection of 1 in 10,000 (10^{-4}), which was originally proposed and used by the U.S. EPA for control of Giardia in drinking water when developing the Surface Water Treatment rule (Regli et al., 1991) and has also been used in the development of potable reuse regulations in other states. This acceptable risk has been applied to each of the reference pathogens (California State Water Resources Control Board, 2016). These pathogens, along with pathogenic bacteria (e.g., Salmonella), are the major contributors to gastrointestinal episodes in the United States. Designing for viruses, *Giardia*, and *Cryptosporidium* will be protective of bacteria based on historical precedent (Amoueyan et al., 2019; Regli et al., 1991; Soller et al., 2017) and quantitative microbial risk assessments (QMRAs) in the peer-reviewed scientific literature (Gerrity et al., 2023).

Similar to US EPA and other state pathogen monitoring requirements for conventional DWTFs, Giardia cysts, Cryptosporidium oocysts, and enteric virus (specifically norovirus) are proposed by ADEQ as the reference pathogens for the AWP regulation. This approach is also consistent with the proposed and final regulatory approaches for AWP used in California (California State Water Resources Control Board, 2016), Colorado (Colorado Department of Public Health and Environment, 2023a), and Texas (Texas Commission on Environmental Quality, 2022).

To meet the SDWA risk goal for AWP program, given the comparatively higher concentration of reference pathogens in the AWTF source water (i.e., treated wastewater), ADEQ is proposing conservative log reduction requirements. QMRAs, at a minimum, establish the baseline pathogen log reduction calculated by comparing expected raw wastewater and safe pathogen concentrations (See

Table 1). QMRA scenarios were evaluated using DPRisk (version 1.01; 11.05.2020), a publicly available web-based tool that was developed by the Water Research Foundation to facilitate the development of regulatory frameworks for potable reuse (Daniel Gerrity, 2021; Gerrity et al., 2023).

Consistent with the U.S. EPA's Long Term 2 Enhanced Surface Water Treatment Rule (LT2) and the raw wastewater monitoring campaign in Pecson et al. (2022), characterization of pathogen concentrations for a given location is often based on approximately 24 samples (N = 24). 97.4th percentile was selected as it coincided with N = 24 samples and was estimated using Percentile = (Rank – 0.375) / (N + 0.25). See Blom (1958) for more details.In addition, log reduction targets were also calculated as (i) the difference between raw sewage maximum density of the reference pathogen and tolerable drinking water density using Arizona specific data (ii) appropriate dose-response models and (iii) an ingestion volume of 2.5 L/day.

Table 1: Pathogen Removal Requirements

Pathogen	Goal – Max. reference pathogen concentration in finished water	Standard log reduction standard	Minimum log removal requirement
Viruses	$10^{-6.7}$ MPN/L	13	8
Giardia cysts	$10^{-5.3}$ cysts/L	10	6
Cryptosporidium oocysts	$10^{-7.9}$ oocysts/L	10	5.5

For the purpose of establishing log reduction goals for the AWP program, listed below are two proposed approaches a utility can pursue, as presented in Figure 7 and outlined below:

i. Standard log reduction approach (as shown in Table 1): The sum of the treatment process validated pathogen log reductions for the treatment train is at least 13-log for virus, 10-log for Giardia cysts, and 10-log for Cryptosporidium oocyst. Site-specific pathogen monitoring is not required for AWP projects using this approach.
ii. Site-specific log reduction approach: AWP projects can reduce the standard log reduction requirements by performing a QMRA study using pathogen densities from treated wastewater specific to that the AWP project. However, the log reduction target may not be less than 8-log for virus, 6-log for Giardia, and 5.5-log for Cryptosporidium, regardless of the results of the site-specific sampling campaign. Minimum log reduction targets should be determined by site-specific monitoring programs (i.e., replacing non-detect treated wastewater concentrations with study-specific limits of quantification). Thus, a study with larger sample volumes and/or higher recoveries might be able to justify lower log reduction targets, assuming all concentrations are non-detect. For example, assuming a study with all non-detects had a Limit of Detection (LOD) of 1 oocyst per 100L with 1% recovery, the resultant log reduction requirement would be 7.0, but if they could improve the study to 1000L volumes that would decrease the log reduction requirement by a factor of 10 to 6.0.

While the standard log reduction approach provides a straightforward, conservative, strategy for the design of an AWP project, the latter provides design flexibility by accounting for pathogen removal at the WRF. In addition, ADEQ will allow traditional DWTFs to be used as part of the AWP treatment process for the purpose of calculating AWTF LRVs. DWTFs must comply with the same validation and CCP requirements as AWTFs to receive LRV credits.

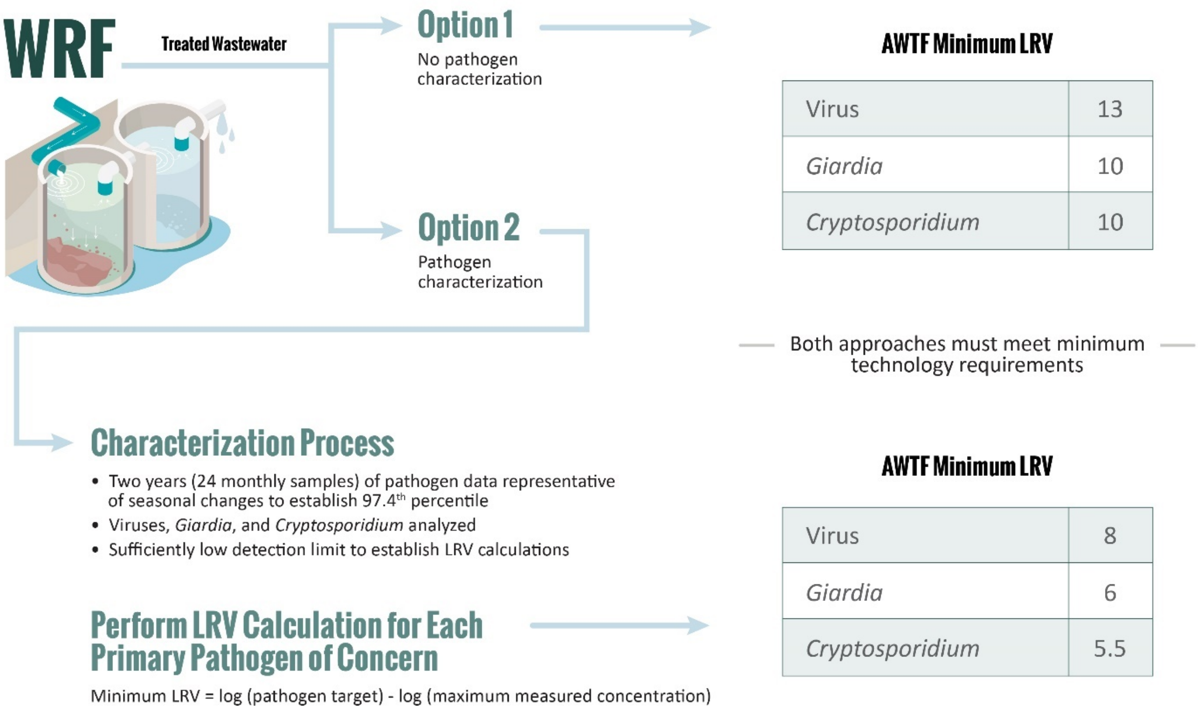


Figure 7: Minimum pathogen log reduction options for an AWP project treatment train. This figure shows the two options available to establish AWP project treatment train pathogen log reduction targets.

3.1.2. Chemical Removal Standards

Chemical control is essential for preventing, eliminating, or reducing chemicals with acute threats or chronic exposure threats (California State Water Resources Control Board, 2023). The objectives of chemical control include: i) identifying chemicals that need to be regulated; ii) determining chemical concentrations that are permissible in drinking water; and iii) determining monitoring requirements. Chemicals can be controlled through treatment at the WRF and AWTF, and through an enhanced source control program as a part of mitigation.

For AWP projects, many chemicals that are introduced into wastewater from domestic and non-domestic sources should be identified and eliminated or reduced to protect public health. Chemical compounds that may be present in wastewater include the following:

i. Trace organic compounds (TOrCs) such as pharmaceuticals, personal care products, and hormones.
ii. Disinfection byproducts (DBPs), which are chemicals that are formed by the reaction of disinfectants (e.g., chlorine and ozone) with organic or inorganic matter found in treated water or wastewater with oxidizing disinfection processes (e.g., chlorine, chloramines, ozone, etc.).

Some examples of DBPs include trihalomethanes, Haloacetic acids, N-nitrosodimethylamine (NDMA), and bromate and a DBP precursor is TOC.

iii. Pesticides.

iv. Inorganics such as nitrate, nitrite, ammonia, radionuclides, heavy metals, and salts.

v. Volatile organic compounds (VOCs) and semi-volatile organic compounds (SVOCs).

Chemicals, such as those listed above, may pose acute or chronic health risks depending on the duration and concentration of exposure and toxicity. The sections **Chemical monitoring** under **Initial Source Water (i.e., treated wastewater) Characterization** describes how chemicals can be identified and **Chemical Removal monitoring** under section **Ongoing compliance monitoring** describe how chemicals can be controlled in an AWP project. ADEQ is proposing a three-tier approach to identify chemicals to treat and monitor in the WRF and AWTF. The three-tier monitoring approach is outlined in Figure 8. WRFs providing source water for the AWP project and AWTFs will be required to follow the tiered approach to identify these chemicals as outlined in the following sections.

Three-Tier Monitoring Approach	Tier 1 SDWA Regulated Contaminants	Tier 2 AWP Specific Contaminants	Tier 3 Performance Based Indicators
Definition	Regulated contaminants are those that have requirements under the US EPA SDWA regulated contaminants.	Contaminants, not currently regulated under the SDWA, but identified as potential risks within an AWP program due to their potential to impact human health or interfere with treatment processes.	Surrogates that are used to monitor treatment train performance.
Approach for Identification	Federal and state regulations	See description in Section Chemical Removal Standards	Site-specific pilot data, specific removal by individual treatment processes, treatment operational guidance
Example Constituents	Arsenic, nitrate, disinfection by-products (DBPs)	N-Nitrosodimethylamine, 1,4-dioxane, perfluorooctanesulfonic acid	TOC, sucralose, sulfate, carbamazepine

Figure 8: Three-Tier Monitoring Approach. ADEQ has established a three-tiered monitoring approach to manage regulated chemicals currently covered under the Safe Drinking Water Act (SDWA) (Tier 1), AWP specific contaminants that are not federally regulated, but may pose a health concern (Tier 2), and performance-based indicators used to establish treatment performance (Tier 3).

i. Tier 1: SDWA Regulated Contaminants

Regulated compounds are those that have requirements under the US EPA SDWA. AWTFs along the WRFs, must be designed and operated such that federal drinking water quality standards (maximum contaminant levels, MCLs) are met. AWTFs will be required to collect samples at the influent of the AWTF (location at which treated wastewater will be diverted to the AWTF) and advanced treated water or finished water. Samples shall be analyzed for chemicals with primary MCLs. The monitoring and reporting process will be similar to the SDWA requirements.
AWTFs will be required to collect confirmation samples when the result of the monitoring at the location identified above indicates a concentration of a chemical exceeding a primary MCL. Confirmation samples will be collected within 24 hours of notification of the result and analyzed for the chemical to confirm the initial result. Notification to ADEQ will be required within 24 hours by the Advanced Water Purification Responsible Agency (AWPRA) if the average of the initial sample and confirmation sample in the finished water exceeds the primary MCL or a concentration that may exceed the capacity of the treatment system to reduce the concentration to below the MCL.

ii. Tier 2: AWP Specific Contaminants

Tier 2 includes AWP specific contaminants that are not currently regulated in drinking water by the US EPA or ADEQ, but have been identified as potential risks relevant to AWP. ADEQ proposes an approach that is analogous to the National Pretreatment program (NPP) for WRFs that are publicly owned and meet the criteria of ≥ 5 MGD, but adds commercial establishments as well. The goal of NPP is to protect receiving waters under the federal Clean Water Act and prevent pollutants from entering a WRF that can interfere or pass through WRF processes. The purpose of enhanced source control for AWP is similar to NPP, except, the goal is to condition wastewater such that it can be treated to drinking water standards and not just the protection of the WRF infrastructure or to make waters fishable and swimmable as required by the CWA. ADEQ proposes to add commercial dischargers as they can become significant contributors particularly in small WRFs (e.g., < 5 MGD).

Tier 2 contaminants may be candidates for future regulation depending on their human health effects, public perception, and frequency of occurrence. For such chemicals, the US EPA has not established an MCL, but toxicity studies indicate a cause for concern. These chemicals may pose a health risk particularly in the context of AWP. Also, chemicals that are recalcitrant to some treatment barriers (such as 1,4- dioxane, or DBPs with wastewater-associated precursors that may form after or during early treatment steps [such as NDMA]) merit the greatest vigilance (Colorado Department of Public Health and Environment, 2023a). Therefore, ADEQ proposes that the AWPRA shall generate an inventory of chemicals based on all industrial and commercial establishments within the sewershed. The method that should be used for developing this inventory is shown in Figure 9 and a detailed description is included in **Appendix A**.

ADEQ proposes that the AWTF or ADEQ, will set an action level for each monitored Tier 2 chemical. Some contaminants have established action levels or health criteria, such as the U.S. EPA's Drinking Water Health Advisories (US EPA, 2018). Existing action levels should remain in place and new action levels should only apply to contaminants without action levels. The AWTF shall further propose a series of responses that will be implemented if any chemical exceeds the respective action level. This response will include, at a minimum, notifying ADEQ along with notifying the customers via public notices.

ADEQ proposes that AWTFs will be required to collect samples at least monthly at the treated wastewater and ATW or finished water. ADEQ may allow, upon request, to decrease the sampling frequency from monthly to quarterly, based on a review of no less than the most recent two years of monthly analytical results showing a chemical has not been detected. The monitoring frequency may be decreased from quarterly to annually following ADEQ approval, based on a review of no less than the most recent three years of quarterly analytical results showing the chemical has not been detected.

AWP projects will be required to collect confirmation samples when a result of the monitoring at the ATW or finished water location indicates a concentration of a chemical exceeding an action level. Confirmation samples will be collected within 24 hours of notification of the result and analyzed for the chemical to confirm the initial result. Notification to ADEQ and consumers via public notice will be required by the AWTF if the average of the initial sample and confirmation sample exceeds the action level. The AWTF will be required to increase the monitoring frequency of the chemical to weekly, initiate an investigation of the source of the chemical, cause of elevated result, and the efficacy of the treatment process to reduce the concentration of the chemical to below the action level. A report will be submitted by the AWPRA to ADEQ summarizing the monitoring conducted, corrective actions taken, the results of the evaluation of the treatment system, and of the source of contamination. The analytical results also need to be reported in the SDWA consumer confidence report. The AWPRA may request for ADEQ approval to resume monthly sampling for the chemical after providing a report summarizing the treatment evaluation and source control investigation to ADEQ. Public notification is a requirement in the Colorado DPR Rules, and it is proposed as a rule in California.

In addition to the above steps, if the average of the initial and confirmation sample exceeds 10 times the action level (for chemicals with non-cancer toxicological endpoints) or 100 times the action level (for chemicals considered to pose cancer risk and corresponds to a lifetime cancer risk of $1x10^{-4}$), the AWPRA must notify ADEQ within 24 hours of the notification of the result and report that detection in the water system’s annual consumer confidence report (CCR). Reporting of this information is required as per California’s proposed regulations. The AWTF will be required to:

a. take the source out of service immediately.
b. utilize treatment or blending to meet the action levels upon returning the source to service, and
c. provide public notification within 30 days of being notified by the laboratory of the exceedance.

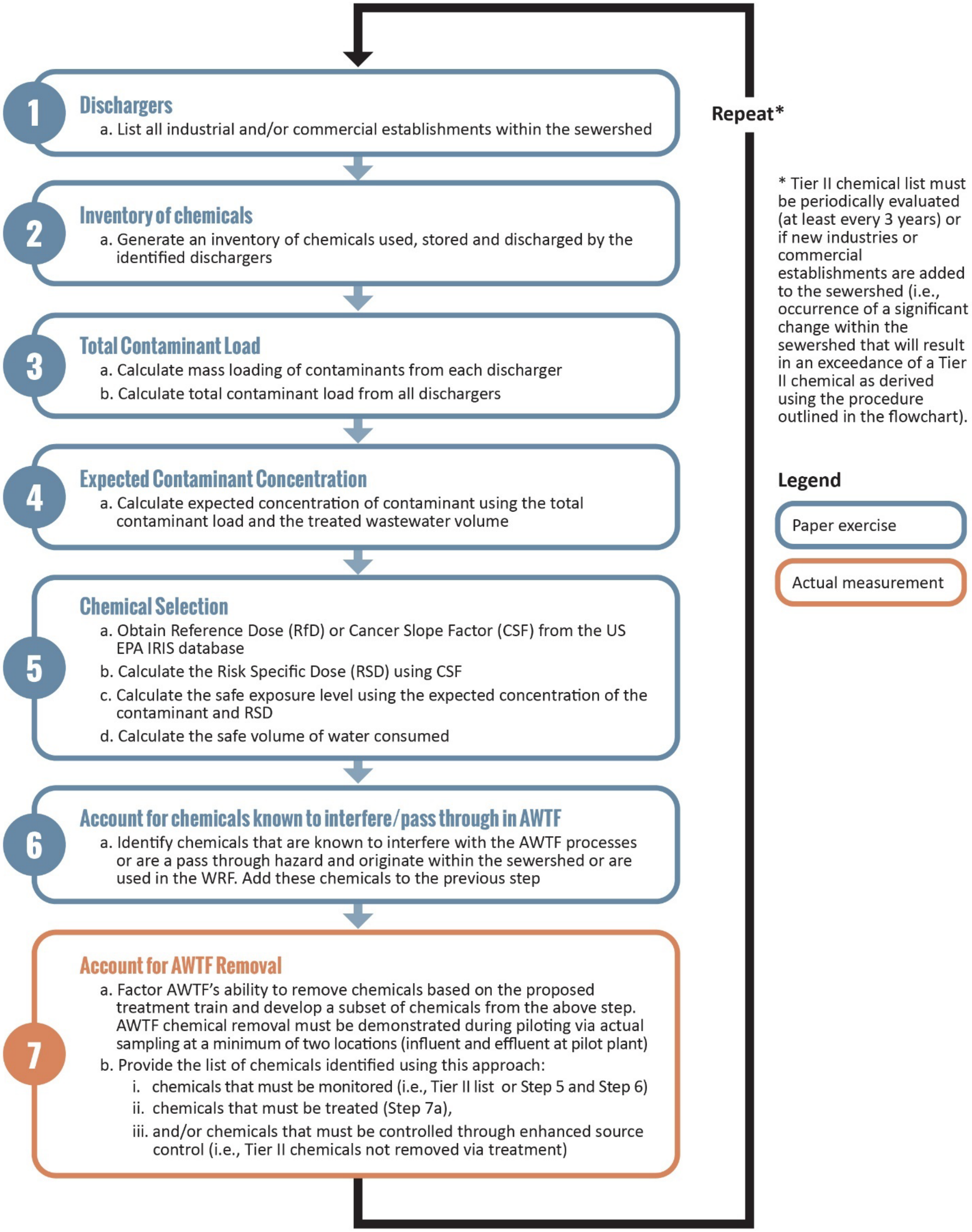


Figure 9: Method to Establish Tier 2 Chemicals. A list of chemicals will be established using the steps outlined in this flowchart. The identification will be performed in conjunction with the Enhanced Source Control Program.

iii. Tier 3: Performance-based Indicators

Tier 3 chemicals are those chemicals that can be used to monitor treatment train performance. AWTFs and in some cases WRFs will be required to monitor a select set of site-specific performance-based indicators at CCPs. For example, sucralose is a useful indicator of AWTF (e.g., RO) treatment processes and would be targeted for treatment at the AWTF. Other examples include carbamazepine and sulfamethoxazole as ozone performance indicators or acetone and formaldehyde as BAC performance indicators or 1,4-dioxane for AOP (California State Water Resources Control Board, 2016).

The performance-based indicators must be an adequate indicator of treatment performance of each CCP. The AWPRA must submit a list of performance-based indicator compounds to ADEQ for approval. Some amount of flexibility about which performance-based indicator to select will be provided by ADEQ to accommodate site-specific factors and the evolving state-of-the-science (see **Appendix A**, Table A - 1). It may be challenging to meet all the criteria in the Table A - 1 contained in **Appendix A** with indicator compounds that are prevalent in treated wastewater at relevant concentrations. While the criteria represent the ideal, site-specific pilot study data can be used by the AWPRA and ADEQ to select the appropriate number and type of Tier-3 chemicals.

ADEQ will use total organic carbon (TOC) as a bulk Tier 3 chemical removal indicator in AWTF processes. TOC is selected as an indicator because TOC removal correlates with TOrC removal (NWRI Independent Expert Advisory Panel, 2019; Schimmoller et al., 2020). TOrCs refer to an array of natural and manufactured substances, including industrial chemicals, household chemicals, metabolites excreted by people, and by-products formed during water treatment processes (Hai et al., 2016). Some TOrCs have high toxicity, such as NDMA and perfluorooctanoic acid (PFOA), while others are considered nontoxic, such as sucralose. TOC removal also correlates with regulated DBP precursor removal (Christopher Hill, 2018). If the TOC is greater in the purified water than in the original drinking water source, it also creates uncertainty about bacterial regrowth in the distribution system, which also presents a challenge for public acceptance. More importantly, an increase in TOC breakthrough could indicate process failure, process exhaustion, or the breakthrough of a recalcitrant industrial contaminant (Marron et al., 2019).

3.2. Technical Requirements and Design Criteria

3.2.1. Technical Requirements

3.2.1.1. Enhanced Source Control

Traditional source control programs are designed to protect the wastewater treatment plant infrastructure, the collection systems, and the receiving water bodies. ADEQ is proposing that an AWP source water will require the implementation of an enhanced source control program due to the use of wastewater as a source for drinking water. Enhanced source control is the control, elimination, or minimization of COC discharges from non-domestic sources into a wastewater collection system. For enhanced source control, COCs include regulated chemicals, AWP regulated chemicals, and performance-based indicators.

An effective enhanced source control program identifies COCs from nondomestic sources, determines where COCs enter the collection system, and enforces limits for applicable pollutant dischargers. There is an existing regulatory framework in place to perform source control through the National Pretreatment Program (NPP), which is an integral component of the National Pollutant Discharge Elimination System (NPDES) permit program. NPDES is a federal regulatory program designed under the 1972 Clean Water Act (CWA) to control discharges of COCs into waters of the US. ADEQ will draft an Enhanced Source Control Program guidelines document to simplify the process, particularly for those WRFs that are less than 5 MGD.

Enhanced source control is applied to a wastewater collection system that goes beyond traditional methods of industrial pretreatment to control, minimize, or eliminate local drinking water contaminant sources (NWRI Independent Expert Advisory Panel, 2019). It is the first of the multiple strategies used in an AWP project to protect public health. The goal of enhanced source control is to control, eliminate, or minimize the discharge of COCs into the wastewater to ensure that purified water is protective of human health. To successfully implement an enhanced source control program, WRF staff should coordinate with the community through requiring permits for industrial users' pretreatment programs (for non-domestic sources), requiring permits for septage haulers, and educating commercial establishments and residents.

The following sections describe the components of ADEQ's proposed enhanced source control program.

3.2.1.1.1. Regulatory Authority

AWP applicants shall demonstrate local authority to effectuate an enhanced source control program and demonstrate that in the permit application to ADEQ. At the local level, an enhanced source control program must include authority for oversight/inspection, review of new connections in the sewershed, development and implementation of local limits, reporting requirements, and the ability to establish and enact enforcement response programs. The WRFs must ensure that industrial wastewater discharge permits and other control mechanisms can effectively regulate and reduce the discharge of COCs and that the enforcement response program can identify and respond rapidly to accidental or illegal discharges of COCs. In addition, the enhanced source control program must include interagency collaboration that allows for the local authority to extend to agreements with other treatment plants participating in AWP projects. Alternate controls besides permits are available to WRFs to control the discharge of COCs in the wastewater, including implementing a pollutant mitigation plan for nondomestic and domestic sources designed to protect the source water.

3.2.1.1.2. Monitoring and Assessment of Non-Domestic Sources

WRFs shall continuously track new and evolving industries into the sewershed and maintain communication with dischargers about any changes in operation that impact the AWP. During the initial planning phase, and prior to AWP project design submission to ADEQ, monitoring and assessment of non-domestic sources-via one-year monthly sampling on the treated wastewater effluent to the AWTF for the suite of COCs identified in the three-tiered method should be performed. Based on the results from the initial screening, the WRF should consider additional local limits, address routine monitoring activities, or other activities needed to protect the AWTF from pass-through and interference. Once the baseline monitoring is complete, the frequency of routine sampling can be reduced based on monitoring results. At a minimum, ongoing monitoring shall be performed by WRFs quarterly. The AWP shall continuously track new industries/commercial establishments discharging into the sewershed and establish an open communication strategy with industries to capture any changes in operation that impact the AWP.

Noncompliant and illegal discharges are a realistic and common occurrence within a wastewater collection system. For an AWP project, it is important to implement elements within the enhanced source control program that ensure the program is performing as designed and that it includes mitigation strategies for future events. The Response Plan section of this roadmap discusses the necessary elements of a response program that addresses adverse events to the normal operating processes of the service area. However, with the designated tools, personnel, and resources, ADEQ believes the most effective and cost-effective method to address chemical peaks is through prevention.

3.2.1.1.3. Chemical and Discharger Inventory

The inventory of chemicals and discharges should be maintained by the WRF. The WRF should establish communication and conduct routine site visits to the identified non-domestic sources to verify chemical use and potential discharge to the wastewater collection system. The AWTF in partnership with the WRF, should conduct collection system investigations of the sewershed to identify the source of chemical peaks at the plant, as needed. These investigations can include identifying all sewer lines, manholes, lift stations, and other collection system components in the service area. In addition, the WRFs must verify flows from facilities into the collection system for the establishment of future locations of the early warning system, and ensure that there is a map of the entire collection system.

3.2.1.1.4. Source Investigations

The enhanced source control program is dependent on an inventory of chemicals that have a potential to impact or adversely affect the AWTF and human health. ADEQ proposes that AWTFs shall follow the steps in the Figure 9 Method to Establish Tier II Chemicals for the selection of COCs. Before developing the inventory of chemicals, the AWTF should first identify an inventory of nondomestic sources within the service area that have the potential to discharge COCs into the collection system. ADEQ is working on a methodology to assist the AWTFs in developing an inventory of nondomestic sources using the North American Industry Classification System (NAICS) code and compared against publicly available data such as the Toxics Release Inventory (TRI) program annual reports, Arizona State Emergency Response Commission (AZSERC) Tier 2 annual chemical inventory reports, hazardous waste annual reports, and the National Pretreatment Program (NPP) annual reports among other reports. Mapping tools such as Geographical Information System (GIS) may be used to link inventories and service areas. The inventory of nondomestic sources, which likely include industrial and commercial establishments, is a beginning step of the Method to Establish Tier II Chemicals for the selection of COCs to determine the chemical inventory for the establishment of local limits within the service area.

In addition to identifying nondomestic sources that can discharge to the collection system, the enhanced source control program should include an investigation of septage haulers through an established septage hauler program that addresses discharges which are not part of the regulated service area. This program will monitor and track discharges from septic wastes or other wastewater delivered to the WRF by trucks. The AWTF shall work with the WRF to establish and implement local authority to develop a permitting program for septage haulers that provides collected load information before discharging including the establishment of a load sampling program to identify noncompliant loads.

ADEQ proposes that establishing local limits shall be a component of the AWTFs enhanced source control program. The AWTF shall obtain and demonstrate to ADEQ that local authority is established to implement and enforce specific local limits based on the investigation of chemicals from the service area. Because new dischargers to the sewershed are continually being added, and because new commercial and industrial chemicals are continually developed, the development of local limits with a regular review is an integral part of AWP that allows risk to be identified and mitigated as necessary for successful implementation.

This inventory of the nondomestic sources and the chemical inventory should be updated, at minimum, every three years or when new industries and commercial establishments are added or change processes. In addition, routine monitoring and site investigations should be implemented as an important element of the enhanced source control program.

3.2.1.1.5. Early Warning System

ADEQ proposes that AWTFs will be required to implement an early warning system, specific to the needs of the service area, that can monitor the collection system to address chemical peaks. Early warning systems enable utilities to actively monitor the collection system upstream of the WRF, identify an increase in chemical contamination that may adversely impact the operations of the AWTF treatment, and help initiate a remedial action plan.

Noncompliant and illegal discharges pose a risk to the AWP project as these discharges may exceed the design and capability of the WRF to handle such events and can lead to chemical peaks, or chemical spike, events that can significantly impact or adversely affect the source water. Because the nature of chemical peaks is unknown and can be introduced by any contributor to a service area or through an illegal discharge. It is not practical or feasible to design WRFs and AWTFs to handle chemical peaks due to the many unknowns.

The system uses a series of detectors that can trigger alerts and feed information into a decision hierarchy so that an automated system or a human operator can make decisions and act. A utility can develop its own early warning system by systematically deploying the required sensors, configuring software to detect events, and creating the response rules.

In recent years, emerging technologies that provide sophisticated real-time or near-real-time monitoring are available to treatment plants to detect and respond to chemical peak events. An early warning system can include programmable sensors that can be designed to provide data associated with parameters such as flow, pH, turbidity, temperature, volatile organic compounds, and hydrogen sulfide, that allows a trained operator to interpret the data and take action.

3.2.1.1.6. Pollutant Reduction and Elimination Plan

ADEQ proposes that the AWTF shall work with WRFs to develop a pollutant reduction and elimination plan as part of an enhanced source control program that addresses both non-domestic and domestic sources. It is important to prevent COCs from any source from entering the wastewater collection system and impacting the quality of water for the AWP project. Municipal wastewater is made up of various non-domestic sources that include both industrial and commercial establishments.

At a minimum, the Plan include the following:

i. A program that educates and encourages non-domestic sources to protect the wastewater collection system by considering chemical substitution and develops targeted outreach programs for certain sectors, for example drycleaners, food establishments, medical offices, and vehicle repair shops.
ii. Encourage non-domestic source participation in pollution prevention programs and environmental stewardship programs that reduce or eliminate the discharge or COCs into the sewershed.
iii. Develop a cooperative program with cities, counties, or other jurisdictions within the AWP service area to disseminate information to the public about COCs and acceptable discharges into the wastewater collection system.
iv. Conduct public outreach to promote the proper disposal of pharmaceuticals and household products containing COCs. For example, WRFs can develop pharmaceutical and household hazardous waste collection programs.
v. Conduct outreach to schools to teach students about AWP and how they can participate in sewershed stewardship through source control efforts.
vi. Provide public notices or hearings for program approval, program amendments, local limits development and amendments, and inform the public of non-domestic sources in significant non-compliance.

3.2.1.1.7. Response Plan for Enhanced Source Control

ADEQ proposes to require WRFs and AWTFs to monitor the source water quality and respond to exceedances which can include chemical peaks. WRFs and AWTFs will be required to develop a response plan including steps to identify the source causing exceedances, identify the leading agency and communication between the utilities, when and how to notify ADEQ and, if necessary, bypass and/or shutdown the AWTF. The response plan should be clear and comprehensive to be used as a tool for responding personnel. A training program shall be established to ensure that the elements of the response plan are understood and can be implemented by the responsible personnel.

An example of the process for responding to exceedances is as follows:

i. If a COC is detected in excess of established limits of the chemical control evaluation at the WRF or AWTF, then the operation and calibration records for online meters and any relevant analytical methods should be reviewed.
ii. If data quality assurance and quality control suggest the result is valid, the AWTF and the WRF would coordinate to initiate a review of sources of the COC.
iii. If no source is identified, then the WRF should initiate a wastewater collection system sampling program.

A memorandum of understanding (MOU) or other contractual agreement between various agencies may be needed to protect the source water quality, respond to exceedances, and share data (NWRI, 2019).

3.2.1.2. Pilot Testing

ADEQ proposes that all AWP projects should conduct a site-specific pilot study to pilot the proposed advanced water treatment train to demonstrate technical, managerial and financial capacity of the organization, to provide training for operators, to facilitate public outreach, and to demonstrate finished water quality. Pilot studies serve multiple important purposes for an AWP program. The pilot testing assists in making decisions about the selection of specific AWT processes, verifying the performance of chosen treatment processes, providing the opportunity to evaluate the effectiveness of different types of treatment processes and designing of the full-scale AWP process (Mosher & Vartanian, 2018). Listed below are the proposed requirements for a pilot study:

i. The pilot study should be conducted for a minimum of one year and pilot trains should be operated continuously during that period.
ii. ADEQ recommends conducting initial source water characterization prior to pilot study, however, source water characterization may occur in parallel with pilot study.
iii. The pilot train should be representative of scale and performance of the full-scale AWT and selected processes.
iv. A pilot train can be operated during full-scale facility design and construction.
v. During pilot study, AWTF must pilot each pathogen and chemical critical control point to generate empirical data to demonstrate the effectiveness of treatment and reliability and consistency of the barriers to comply with the AWP Regulations (Colorado Department of Public Health and Environment, 2023a).
vi. A pilot study plan can be submitted to ADEQ for approval during the optional Tier II, site specific pathogen characterization and piloting approval stage prior to start-up of pilot train and at minimum should include:
    a. Pilot objectives.
    b. Initial source water characterization if conducted prior to piloting.
    c. Description of proposed pilot treatment train and design criteria for each treatment process.
    d. Proposed monitoring and instrumentation, including critical control points
    e. Finished water sampling plan.
vii. A final report for pilot study shall be submitted to ADEQ for approval during the AWP permit application submittal, prior to initiation of the full-scale construction of the AWTF. The final report should include:
    a. Demonstration of the effectiveness of treatment and reliability and consistency of the barriers by presenting water quality data collected in accordance with the established sampling plan.

3.2.1.3. Water Reclamation Facility

3.2.1.3.1. Minimum Requirements

WRFs are expected to ensure that the effluent produced is a reliable and suitable source for AWTFs, while continuing to meet existing discharge requirements. Since most WRFs were not initially designed to supply water to AWTFs, it may be necessary to make improvements to the existing WRF infrastructure to enhance the quality of treated wastewater for use in AWTFs. The specific changes required will vary from one WRF to another, as the quality of effluent water with respect to critical constituents like nutrients, metals, microorganisms, and organic compounds varies among WRFs. The WRFs act as the initial and crucial critical control point for the AWP project (Colorado Department of Public Health and Environment, 2023a). The primary objective of wastewater treatment is to remove or inactivate physical, chemical, and microbial components (Mosher & Vartanian, 2018). Listed below are the minimum treatment requirements for WRFs to produce treated wastewater for AWTFs:

i. Secondary Treatment Requirements: The WRFs must provide at least secondary wastewater treatment to produce the oxidized water to remove the biodegradable organic matter and suspended solids. The WRFs shall meet the discharge limit requirements for Biological Oxygen Demand (BOD), Total Suspended Solids (TSS) and pH as specified in Arizona Administrative Code R18-9-B204(B)(1). For enhanced wastewater treatment, it is recommended that the wastewater treatment train is designed to provide solids retention time (SRT) exceeding 10 days. The longer solids retention times can be used to remove nutrients and enhance removal of trace organic chemicals (Andrew Salveson et al., 2012).
ii. Nitrogen Removal Requirements: The WRFs with nitrification and denitrification treatment to remove nitrogen from wastewater provides benefit for AWTFs which includes i) improved performance of subsequent AWTF, ii) increased reliability of overall AWTF train and iii) reduced contaminant load (NWRI, 2018). However, ADEQ will allow flexibility to achieve nitrogen removal through wastewater treatment train at WRF or through full-stream RO or other appropriate treatment technology at AWTF for AWP Program. However, WRF must follow the requirements of total nitrogen for Aquifer Protection Program (APP) per A.A.C. R18-9-B204 in order to discharge any treated wastewater or off-spec treated wastewater which cannot be supplied to the AWTF.

3.2.1.3.2. Wastewater Treatment Optimization Strategies

Modifying existing WRF for use in AWP projects may necessitate a rigorous technical assessment, innovative engineering solutions, and potential upgrades to the wastewater management infrastructure, in addition to corresponding operation and management activities. In a broad sense, WRFs can be reconfigured or designed with modifications to enhance their overall performance, reliability, and yield effluent quality that aligns with the requirements for advanced treatment in AWP applications. Some measures can be implemented to enhance the performance and reliability of both existing and planned WRFs, including enhanced screening process, influent flow and load equalization, elimination or equalization of untreated return flows, improved disinfection while preventing DBP formation and post-treatment filtration (Mosher & Vartanian, 2018):

Flow equalization after the WRF prior to the AWTF can assist in attenuating potential chemical discharge peaks. WRFs should evaluate the need for flow equalization based on diurnal water quality variation to optimize process performance and efficiency. WRFs can evaluate whether flow equalization is necessary for their plant to implement an AWP program. Equalization of flow may be necessary if the WRF influent and treated water effluent total nitrogen concentrations fluctuate above the treatment goal, concentrated decant from solids handling processes, or if the WRF does not consistently meet MCLs for ammonia and nitrate concentrations. Information on flow equalization will be included in the design report.

3.2.1.4. Technical, Managerial, and Financial Capacity Demonstration

A technical, managerial, and financial (TMF) capacity is the ability of a water utility to continuously provide safe and reliable water to its customers (Mosher & Vartanian, 2018). Higher level of accountability shall be required by AWTFs to implement AWP due to the complexity associated with the operation, maintenance and monitoring of AWP facilities (California State Water Resources Control Board, 2016). A TMF assessment for AWP is a valuable tool for evaluating a utility's capacity in several key areas including ability to construct, operate, manage and maintain a AWTFs, assessing competence in planning, achieving and sustaining regulatory compliance, ensuring public health and environmental protection and ability to make efficient use of public funds and to invest sustainably in the infrastructure required for AWP (Mosher & Vartanian, 2018).

ADEQ proposes to have a requirement for TMF capacity assessment for all AWP facilities. The TMF capability documentation should be integrated into the design report for evaluation. Furthermore, ADEQ proposes to have periodic TMF capacity evaluation. This evaluation will take place every six years, coinciding with the renewal of AWP permits. Additionally, it will be triggered whenever there are modifications to the approved TMF capacity for the AWP facility. The following sections outline ADEQ's TMF requirements for AWP (Mosher & Vartanian, 2018).

i. Technical Capacity: Technical capacity demonstrates the performance and operation of the AWTF (Mosher & Vartanian, 2018). The demonstration for technical capacity must include the following:
    a. Demonstration of the availability of an existing water source or contingency plans for an alternative source in the event of AWTF failure.
    b. Comprehensive technical and engineering specifications for the AWTF including design and treatment capacity, information on storage, and distribution processes, manufacturer specifications showing life span of components. This information shall be included in the design/engineering report.
    c. Documentation of monitoring plan of finished water.
    d. Demonstrate ability to respond to emergency situations including water quality excursions.
    e. Documentation that the AWTF will be operated by a certified AWT operator as outlined in Section **Operator Certification**.
    f. Operations plan including maintenance requirements per manufacturer's specification, repair, and replacement protocols, as described in **Operational requirements**.

ii. Managerial Capacity: Managerial capacity demonstration pertains to the realm of governance (Mosher & Vartanian, 2018). The demonstration for managerial capacity shall include the following:
    a. Documentation for ownership, management, and organization information with organizational chart, job description, and responsibilities.
    b. Information on contractual agreement for rights on purified water from the AWTF. The agreement includes the sale prices of source water, quality of source water, duration of agreement, and compliance and reporting responsibilities.
    c. Management of the groundwater or surface water discharge permit or recycled water permit to discharge water during upset conditions, as applicable

d. Information on operations including certified operator credentials, training for staff, technical competency, technical knowledge and implementation, and operations plan.
e. An outline of tools and procedures employed in the realms of management and accounting, encompassing essentials like a strategic asset management plan and a computerized maintenance management system (California State Water Resources Control Board, 2023)

iii. Financial Capacity: Financial capacity signifies a utility's financial ability in maintaining and operating its current infrastructure, alongside its financial planning for future necessities (Mosher & Vartanian, 2018). The key features of financial capacity demonstration are for:
a. Capital cost of the project.
b. Identification of ongoing cost which includes operation and maintenance costs, capital replacement costs, energy cost, personnel cost and 20-year lifecycle cost of equipment (California State Water Resources Control Board, 2023).
c. Identification of 5-year financial projection, planning and management and continuing funding sources to cover the costs.
d. Financial audits and bond rating.
e. Perform rate studies or assessment of impact fees need to be in place for AWP project.

3.2.1.5. Utility Collaboration

ADEQ proposes that the Advanced Water Treatment Facility (AWTF) consider establishing a formal agreement in the form of a Memorandum of Understanding (MOU) or an inter-governmental agreement (IGA). This document should outline the coordination procedures to be followed by all relevant partnering entities, such as Water Reclamation Facilities (WRFs), Drinking Water Treatment Facilities (DWTFs), utility providers, and relevant departments. This agreement should encompass the following elements (California State Water Resources Control Board, 2023):

i. Identification of all involved partner entities and description of their roles and responsibilities associated with the AWP project and the legal authority of each partner agency to fulfill its roles and responsibility.
ii. Established procedures to ensure that the AWTF will have knowledge of the current treatment status of Water Reclamation Facilities (WRFs) and the status of water quality monitoring.
iii. Procedure to ensure the enhanced source control program complies with the requirements under Section **Enhanced Source Control**.
iv. A communication plan ensuring the timely dissemination of information regarding treated wastewater quality status and monitoring and finished water quality status and monitoring among the partnering entities.
v. Procedure to provide access to all involved facilities of AWP program, operations and records for inspection at any time by ADEQ.
vi. Procedures to execute cross-connection control requirements.
vii. Procedures that will be implemented to notify partnering entities and the ADEQ regarding treatment failure incidents and the corresponding corrective actions taken, and reporting the incident to ADEQ.
viii. A plan outlining the enforcement actions should a partnering entity fail to meet the legally-binding requirements of the document.

The MOU or IGA must be submitted to ADEQ for approval prior (during the AOC application submittal) to operation of the AWTF. ADEQ proposes that any changes to the approved agreements need to be submitted to ADEQ for review and approval.

3.2.2. Design Criteria

3.2.2.1. Multiple Barrier Treatment

Multiple treatment barriers at the AWTF allow for security and redundancy to safely purify the effluent from a WRF. An advantage of using multiple treatment barriers is if one treatment process fails, another process can compensate, allowing the facility to continue to produce water that meets regulatory standards. Some treatment barriers, such as ozone treatment, can act as barriers for both chemicals and pathogens.

3.2.2.1.1. Pathogens

Control of pathogens will require a minimum of one filtration (physical separation) and one disinfection (chemical or physical destruction) treatment mechanism per each target organism (i.e., virus, Giardia, Cryptosporidium) to achieve specific LRV targets. Treatment using different treatment mechanisms are required to promote robust pathogen removal. Broadly, the general mechanisms commonly implemented are biological removal, filtration, chemical disinfection, photolysis (e.g., UV), and AOPs. ADEQ will require AWTFs to have at least one filtration and one disinfection step that removes each target pathogen (i.e., Giardia, Cryptosporidium, and virus). For example, RO combined with UV/AOP would meet this constraint, as both processes remove all three target pathogens. Alternatively, microfiltration and chlorine disinfection alone would not meet the constraint, because these technologies do not remove all three target pathogens (refer to Table B - 1 in **Appendix B**). In this case, an additional filtration and disinfection process that can remove the missing pathogen would be required to meet the treatment requirement. A more detailed description of effective technologies for use in AWTFs is included in Table B - 2 in **Appendix B**.

The cumulative pathogen log reduction achieved by the treatment process train must meet or exceed the following thresholds: a minimum of 13 log reduction for enteric viruses, 10 log reduction for Giardia lamblia cysts, and 10 log reduction for Cryptosporidium oocysts.

In addition, each pathogen treatment barrier must provide a minimum of 0.5 LRV, and no treatment barrier can be awarded more than six LRVs. Furthermore, there should be an accurate pathogen monitoring strategy (including approved performance monitoring for surrogates) for an AWTF to receive LRVs for a technology. Typical LRVs for common unit treatment processes are included in Table B - 1 in **Appendix B** for reference. LRV targets for pathogen control must be included in the design report.

3.2.2.1.2. Chemicals

Chemical removal treatment processes can be counted between the treated wastewater and the ATW. The treatment train must consist of at least three separate treatment processes, using diverse treatment mechanisms, including AOPs and physical separation. To be used as a chemical barrier, an AOP can demonstrate performance one of in two ways:

i. One indicator compound (1,4-dioxane).
ii. At least nine indicator compounds, with at least one from each specific functional group.

ADEQ will require that AWTFs and WRFs coordinate to mitigate chemical peaks that can be a human health hazard or impact AWTF treatment processes in treated wastewater. Chemical peaks are an abnormal increase in chemical levels in the sewershed due to intentional or unintentional discharges. Chemical peaks can impact treatment processes or result in high concentrations in COCs that could potentially be dangerous to human health. Aside from enhanced source control, chemical peak mitigation strategies include robust design of treatment barriers, flow equalization techniques, and blending. An enhanced source control program and real-time monitoring should complement and increase the robustness of the overall peak mitigation strategy.

Another concern for AWP projects is to maintain acceptable TDS concentrations in drinking water (Colorado Department of Public Health and Environment, 2023a). WRFs and AWTFs should analyze the potential blending impacts based on site-specific bench or pilot testing. Each treatment technology in an AWTF should perform a unique role in chemical removal through implementation of diverse removal mechanisms. A more detailed description of effective technologies in AWTFs for chemicals is included in Table B - 1 in **Appendix B**.

3.2.2.2. TOC Management

Several approaches were evaluated for the management of TOC. A target TOC value of 2 mg/L is proposed in the finished water. Local data from utilities support that an increase beyond 2 mg/L of TOC in the finished water results in exceedance of DBPs. However, ADEQ will continue to engage the stakeholders to further refine this approach.

3.2.2.3. Salinity Management

Every AWPRA implementing AWP must submit a comprehensive water system mass balance, projecting whether the implementation of AWP will lead to an increase in total dissolved solids (TDS) in the water. It is important to note that there is a secondary maximum contaminant level of 500 mg/L TDS set by the US EPA. Additionally, a gradual increase in TDS concentrations over time could raise concerns about water corrosiveness. As part of the application for review and approval, ADEQ will assess the long-term sustainability of the AWP project. In cases where the water system intends to use over 50% of their water as AWP or if the water system mass balance indicates that overall TDS levels will rise over time without reaching a steady state, ADEQ will require the system to present a plan to address the accumulation of ions in the system. Such a plan may include periodic flushing, side-stream reverse osmosis to remove salts, or other appropriate solutions.

Other states, such as Texas, Colorado and California have included TDS limits as part of their AWP programs. Monitoring of sodium is mandatory in Colorado AWP projects, along with its reporting to the local health department. ADEQ proposes to manage salinity through total dissolved solids (TDS). TDS goals are outlined in Table 2. However, ADEQ will continue to engage the stakeholders to further refine this approach.

Table 2: TDS Goals.

Existing Potable Water TDS Concentration	TDS Concentration for AWP (limits)
<500 mg/L	500 mg/L
500–1,500 mg/L	No more than 100 mg/L greater than the local drinking water TDS concentration.
> 1,500 mg/L	1,500 mg/L

3.2.2.4. Nitrogen Removal

ADEQ proposes to allow flexibility for nitrogen removal through the WRF or through full-stream RO, side stream RO or other appropriate treatment technology at AWTF. Listed below are two approaches that can allow for the removal of nitrogen:

i. WRFs that employ a nitrification-denitrification process to consistently produce denitrified effluent play a pivotal role in mitigating nitrate and nitrite concentrations. To ensure the quality of source water supplied by AWTF, continuous online analyzers must be use for monitoring nitrate and nitrite levels, with a designated point for diverting off-spec water in the event of exceedances. In this context, the treated wastewater or source water from AWTFs with an off-spec diversion point serves as the initial Critical Control Point (CCP) for managing nitrate and nitrite. The second CCP involves monitoring finished water to confirm compliance with nitrate and nitrite for Maximum Contaminant Levels (MCLs) of 10 mg/l and thus safeguarding water quality.

ii. For WRFs that do not reliably denitrify, the primary treatment barrier(s) for nitrate and nitrite must be built into the AWTF treatment scheme. The AWTF must demonstrate nitrogen removal, necessitating implementation of robust processes such as full-stream RO or other appropriate nitrate treatment technologies (such as tertiary MBR, moving bed bioreactor etc.) to appropriately remove nitrate and nitrite and meet the MCLs. In this scenario, the AWTFs will be required to provide a minimum of two, but potentially more, CCPs. The first CCP for source water to AWTFs to monitor influent ammonia (if applicable), nitrate, and nitrite to assess the treatability of the water. Other(s) CCPs will be required with each treatment barrier(s) for ammonia (if applicable), nitrate, and nitrite to confirm appropriate removal of nitrate and/or nitrite at each step. At the final CCP location, monitoring of finished water must occur to verify water quality compliance with nitrate and nitrite MCLs.

3.2.2.5. Advanced Oxidation Process

Advanced Oxidation Process (AOP) is an oxidation process that produces hydroxyl radicals acting as reactive electrophiles that readily react with most electron rich organic compounds and in a fast and non-selective way to destroy organic contaminants in water such as pesticides and herbicides, fuels, solvents, drugs, and other potential endocrine disruptors (Crittenden et al., 2012). Advanced oxidation processes encompass methods like ozone combined with hydrogen peroxide, ultraviolet light with hydrogen peroxide, or ultraviolet light with hypochlorite. (Colorado Department of Public Health and Environment, 2023a). AOPs serve as robust defenses, offering a safeguard against a broad spectrum of chemical compounds (Brian Pecson et al., 2020).

ADEQ proposes that all AWTF treatment trains will require an AOP unit process. All AOPs must achieve the 0.5-log reduction for 1,4-dioxane as a performance benchmark (i.e., action level). This specific target is based on the current research that demonstrated quality and quantity of specific trace organics removal when 0.5-log reduction of 1,4-dioxane performance is achieved (Brian Pecson et al., 2020; Eva Steinle-Darling et al., 2016). If proposed AOP does not meet 0.5-log removal of 1,4 dioxane, an alternative approach can be provided showing the removal of COCs similar to the initial benchmark study.

In addition to performance demonstration, all AOP designs must address major challenges of AOP processes such as scavenging of hydroxyl radicals by carbonates, bicarbonates, nitrites, nitrate, bromides and NOM, pH and UV light absorption (Brian Pecson et al., 2020). The AOP's efficacy in significantly reducing an approved indicator compound must be validated through pilot tests. These indicators should be ADEQ-approved (during the ATC application stage) and resistant to elimination through other treatment methods, including biological degradation, adsorption processes, RO/NF, and conventional oxidation techniques such as hypochlorite, chloramines, permanganate, or chlorine dioxide (e.g., 1,4-Dioxane). Each pilot study should involve spiking and measuring indicator compound removal. ADEQ expects spiking 1,4-Dioxane (i.e., reference compound) and calculating removal percentages to compare with other widely accepted advanced oxidation standards. In pilot testing, the final concentration of any indicator compound post-AOP treatment should exceed the minimum reporting limit (Colorado Department of Public Health and Environment, 2023a).

ADEQ proposes to establish operational conditions as part of the permitting process and verify critical monitoring parameter ranges based on pilot findings. Ozone to TOC ratio set points, adjusted for nitrite, must be substantiated through pilot data for the specific treated wastewater source. If comprehensive piloting is not conducted (e.g., shorter timelines or limited scope), the advanced oxidation process must achieve at least 69% removal of 1,4-Dioxane. Additional analogous applications of advanced oxidation processes must be referenced when pursuing this option (Colorado Department of Public Health and Environment, 2023a).

3.2.2.6. Water Quality Assurance and Engineered Storage Buffers

An ESB located after an AWTF improves the failure response time after a water quality exceedance can help ensure that treated water meets all required standards before being put into the distribution system. The AWPRA is not required to install an ESB; however, it is very likely that an ESB will be needed after the AWTF as treatment requirements are the minimum needed. As additional pathogen removal requirements were not added to the minimum log removal requirements, it is highly likely that an ESB may be required for an AWP project. In addition, measures and strategies to maintain nitrogen levels below 10 mg/L on a continuous basis, considering diurnal load variations and the impact of recycle streams is necessary. This information is essential for ensuring effective water treatment and compliance with regulatory standards and may dictate the use of ESB. The use and size of an ESB will vary between AWP projects depending on many factors, including the level and redundancy of online instrumentation desired, the sophistication and speed of automated alarm responses, and the availability of onsite operators and their response time. At a minimum, an ESB must be sized to hold water for a time period no shorter than the failure response time, ensuring that ATW does not get distributed unless in full compliance with operational and regulatory parameters.

WRFs and AWTFs must ensure that in the absence of an ESB, appropriate process control water quality assurance is provided, managerial control for demand is present, and an operational barrier for pathogen control and chemical peaks attenuation is provided. Each AWP project must address the ESB element in the project design. If the design will include an ESB, a justification for the volume selection must be included in the design report. If the design will not include an ESB, a justification on the alternative approach to an ESB must be included in the design report.

3.3. Operational Requirements

3.3.1. Full Scale Verification Testing

ADEQ is proposing a requirement for full-scale verification testing of Advanced Water Treatment Facilities (AWTF) once construction is completed. This verification testing aims to ensure that every treatment process, online analyzers, critical control points, alarm systems, and data recording across the entire treatment train function as designed, meet intended specifications, and comply with regulatory requirements.

The comprehensive full-scale verification testing plan should encompass the following elements:

i. Detailed Testing Plan: This plan should outline the verification testing procedure for each process within the AWTF.
ii. Monitoring Plan: The sampling plan should adhere to the guidelines specified in Section **Ongoing compliance monitoring**.
iii. Alarm System and Shutdown Testing: Verify the functionality of all regulatory alarms and shutdown mechanisms.

The full-scale verification testing plan shall be submitted to ADEQ for review and approval (during ATC application stage). ADEQ is proposing a minimum one-year verification testing period for AWTFs. Throughout this verification and system performance testing period, the ATW may be directed into a sanitary sewer, discharged into a recharge groundwater basin, or diverted into a retention basin, pending approval by ADEQ.

Upon the successful completion of the one-year verification testing, a final report must be submitted for review during the AOC application submittal. This report should encompass all information related to the verification testing, including documents, sample results, and a summary of the testing and data analysis. Once the final report is approved, the AWTF will be authorized to deliver purified water to its customers.

3.3.2. Operations Plan

AWP treatment train involves the operation of multiple complex and interrelated treatment and monitoring processes. The implementation of a robust operations plan is essential to ensure consistent and reliable operation at each treatment facility, ultimately assuring that the purified water meets the required public health standards. In the context of AWP, particular emphasis is placed on the development of operations plans to address treatment failures and emergency scenarios. Effective operation and maintenance activities span a project's lifecycle; they begin with the design and construction of the AWTF and continue throughout its operation (Tchobanoglous et al., 2015; Troy Walker et al., 2017).

ADEQ proposes that the AWPRA must develop an operations plan for the AWTF and submit it to ADEQ for review and approval. This operations plan should also be subject to updates whenever there are modifications to the treatment processes that lead to changes in operational procedures. In such cases, the updated plan should be submitted to ADEQ for review and approval as part of an amendment. AWTFs must be operated per the approved operations plan. The operations plan shall include the following criteria:

i. Description of operation of each treatment processes, and Standard Operating Procedures (SOPs) to ensure the reliability of operations (California State Water Resources Control Board, 2023).
ii. Process schematics highlighting critical control points for pathogen and chemical removal, alarms and on-line analyzers (Colorado Department of Public Health and Environment, 2023a).
iii. A description of inspection, and maintenance requirements per manufacturer's recommendation for treatment process equipment including online analyzers and alarms inspection, maintenance and calibration (California State Water Resources Control Board, 2023).
iv. A description of the compliance monitoring including surrogate and operational parameter monitoring as described in Section **Ongoing compliance monitoring** and description of the reporting requirements as described in section **Reporting** (California State Water Resources Control Board, 2023).
v. A description of decision-making procedure to divert any off-spec water due to any process failure or water quality deviations.
vi. Information on staffing requirements including roles and responsibilities, certified operator requirements and a description for a continuing education program, provisions for training new personnel (California State Water Resources Control Board, 2023).
vii. A description of the SCADA system and its use to determine compliance of AWTF. The plan must include information on how the SCADA system acquires and uses monitoring data to inform operators, identifies and responses to a failure of CCP and a protocol for testing the SCADA system and a testing schedule (California State Water Resources Control Board, 2023).
viii. A plan identifying upset conditions or emergency situations including, but not limited to failure of critical control points, diversion of off-spec treated wastewater quality, loss of continuous source water, off-spec finished water etc., and description of emergency response plan for these situations including investigating failure, taking corrective actions and addressing the cause of a failure (California State Water Resources Control Board, 2023).
ix. Protocols for diversions, shut-offs, and returning to normal operation after a diversion or shut off (California State Water Resources Control Board, 2023).
x. Description of a communication plan where the AWPRA has to communicate and coordinate with the treatment plant operators (WRF and DWTF operators). The AWPRA must provide a description of normal operations, upset conditions, and emergency response protocols, including, but not limited to: power outage, natural disasters, staffing issues, loss of communications, action limit exceedances, alert limit exceedances, evidence of pollution entering the collections system, or any unexplained excursions (Colorado Department of Public Health and Environment, 2023a).

3.3.3. Vulnerability Assessment

A Vulnerability Assessment is required by the Federal Bioterrorism Preparedness and Response Act (21 Universal Standard Code 350d) for systems that will serve a population of greater than 3,300 people. However, under the AWP program, vulnerability assessments are proposed to be required for all AWTFs regardless of population size. A vulnerability assessment identifies areas and processes within the water system that could be vulnerable to attack, sabotage, or disruption (Mosher & Vartanian, 2018).

The AWPRA shall conduct a vulnerability assessment for the AWP project, with the primary purpose to assess potential hazards associated with contaminants in the municipal wastewater source. Based on the vulnerability assessment, the AWPRA should develop an emergency response plan for potential problems the AWP project may face. The AWPRA will be required to periodically review the vulnerability assessment at a minimum every six years, as part of the permit renewal. During these updates, the AWPRA must identify any new or supplementary hazards that have arisen and propose corresponding risk management controls.

3.3.4. Response to Off-Specification Water

The operations plan must outline the necessary steps for responding if the treated water falls short of meeting the specified chemical and pathogen removal performance standards. This will encompass the establishment of alert levels and action levels at each CCP, accompanied by a corresponding action plan with defined timelines for addressing instances where alert levels and action levels are exceeded. It will also involve considering alternative water sources, if required, to ensure a continuous water supply. Given the need for swift response in the event of purified water failing to meet treatment standards at an AWTF, a comprehensive failure response plan is essential. Key components of the response plan include and must be integrated into the operations plan:

i. A structured process for identifying and rectifying issues.
ii. Clear specifications regarding the time required for response and the utilization of automated systems equipped with triggers and alarms, potentially facilitated through SCADA.

3.3.5. Shutdown Plan

A Shutdown Plan consistent with existing ADEQ requirements for DWTFs will be required for AWTFs. This should encompass steps to drain any piping and tanks in situations where there is a risk of freezing or the presence of stagnant non-compliant water. Post-shutdown, certain systems may require continued moisture, thus, the protocol for managing such stagnant water during the startup preparation must also be addressed.

3.3.6. Corrosion Control

A new water source and/or treatment changes (such as the introduction of ATW) will require review and approval under the R-18-4-111. Control of Lead and Copper – 40 CFR Part 141, within no less than six months prior to implementing a source water and/or treatment change. When estimating water quality as a result of blending of ATW and traditional water source, mass balance calculations may be used only as a partial analysis for chemical stability and corresponding corrosion potential because the complexity of the corrosion phenomenon (particularly when a significant increase in TDS occurs) requires that each water blend should be examined individually (Tang et al., 2006).

Anticipated corrosivity effects must be evaluated through corrosivity tests. If the corrosivity evaluation indicates that corrosivity is expected to be adversely impacted, design must also include a mitigation plan to describe how corrosion will be controlled (EPA 1992, Corrosion Control Treatment).

ADEQ may require the system to conduct additional water quality parameter monitoring in accordance with §141.87(b) to assist in reviewing the system's recommendation.

In summary, corrosivity tests or evaluations should be accomplished by:

i. Developing an understanding of factors affecting internal corrosion.
ii. Determine the extent and magnitude of corrosion.
iii. Assess corrosion control alternatives.
iv. Select a corrosion control strategy.
v. Implement a corrosion control program.
vi. Monitor the effectiveness of the corrosion control program.
vii. Optimize the control program if necessary.

3.3.7. Cross-connection

AWP projects will be generally connected without air gaps between WRFs and AWTFs, leading to cross connection scenarios. The AWPRA shall develop cross-connection control programs, including cross-connection evaluation during design, construction, and operation of the AWTF to prevent inadequately treated or unapproved sources of water from entering into the distribution system (California State Water Resources Control Board, 2019). The AWPRA should conduct an initial cross-connection control survey within one year of the start of full-scale operation and continue ongoing surveys annually thereafter and report any cross-connection incidents summarizing the nature and cause of the cross-connection problem and corrective actions taken.

3.4. Monitoring and Reporting Requirements

3.4.1. Monitoring

3.4.1.1. Initial Source Water (i.e., Treated Wastewater) Characterization

Background, baseline monitoring will be performed on the WRF effluent prior to AWTF design. At a minimum, the baseline monitoring program will consist of chemical monitoring and may include pathogen monitoring as described below:

3.4.1.1.1. Pathogen Monitoring

Monitoring for pathogens is only required if a site-specific approach is pursued by a utility. When the AWPRA is considering accounting for pathogen removal by the WRF, the site-specific approach allows for the sampling of treated wastewater to characterize pathogen densities. The AWPRA should follow the sampling protocol as described below. Other acceptable methods will be added after consultation with the stakeholders.

i. Cryptosporidium and Giardia measurements: Standard method 9711B for quantification of Giardia and Cryptosporidium.
ii. Virus measurement: Stepwise vacuum filtration and centrifugal ultrafiltration can be used for recovery and concentration of viruses from wastewater following methods developed and standardized at the University of Arizona WEST Center (Betancourt et al., 2021). The sequence

of primers and probes used for absolute quantification of the virus genomes are included in Table C - 2 in **Appendix C**.

3.4.1.1.2. Chemical Monitoring

Chemicals shall be sampled from treated wastewater (i.e., at location where treated wastewater will be diverted to the AWTF) and will include chemicals identified in all three Tiers. Regular (monthly for at least one year) composite samples are required prior to design and construction. During initial monitoring, the minimum number of samples should be 12 and depending on the sample data or if the contaminants are present at elevated concentrations, the frequency or number of samples will be increased. These samples must be collected evenly throughout the year to reflect seasonal variability. This monitoring program is expected to work in tandem with the Enhanced Source Control Program to identify primary SDWA regulated contaminants and additional AWP specific contaminants for control under an enhanced source control program.

3.4.1.2. Ongoing Compliance Monitoring

3.4.1.2.1. Pathogen Removal Monitoring

Appropriate surrogate parameters shall be used to monitor the concentration of pathogen reduction by a treatment process and/or that provides an indication of a treatment process failure. Protocol(s) previously approved by other states for use in validating water treatment technologies for pathogen control can be used, such as, verification based on turbidity and periodic particle count monitoring. Surrogate and/or operational parameters that can be measured continuously and that will correlate with the reduction of the pathogen(s) or surrogate(s) for the pathogen(s) must be identified as part of the design report.

3.4.1.2.2. Chemical Removal Monitoring

Chemical monitoring will leverage online and grab samples to reliably meet chemical standards. Table 3 highlights the chemical monitoring approach, including the chemical selection method, monitoring location and frequency, reporting requirements, and action level for each COC. Sampling frequency of COCs measured at the AWTF CCPs may be reduced over time if sampling indicates non-detects for over a year. All public water systems that supply potable water are required to take quarterly samples of constituents with MCLs to establish whether exceedances have occurred. These grab samples are required under the SDWA to confirm that AWPRA meets treatment goals and verify the accuracy of indirect performance monitoring. The AWPRA will be expected to meet all the existing regulatory monitoring requirements of the SDWA to distribute potable water.

Table 3: Three-Tier Monitoring Requirements

Category	Selection	Monitoring Location	Monitoring Frequency	Reporting	Action Levels
Tier 1: Regulated Chemicals	Based on federal and state MCLs	Monitoring is done at two locations (i) treated wastewater and (ii) purified water	Similar to drinking water monitoring	Based on SDWA	Based on SDWA
Tier 2: AWP Specific	List defined by utilities and ADEQ-approved list of AWP specific contaminants	Monitoring is done at two locations (i) treated wastewater and (ii) purified water	Recommended twice per month (at least once per month) is required. Monitoring frequency may be changed at ADEQ's discretion	Purified water monitoring data must be reported in the AWPRA's consumer confidence report	The AWPRA will propose an action level for each chemical monitored as approved by ADEQ. The AWPRA shall further propose a series of responses that will be implemented if chemicals exceed the respective action level. This response shall include, at a minimum, notifying ADEQ
Tier 3: Performance Based Indicators	Indicator compounds have chemical properties that make them removable by some treatment processes but recalcitrant to others	Monitored at CCPs and purified water	Regularly monitored as proposed by the AWPRA	Not required	Not required

3.4.1.2.3. Performance Monitoring (CCPs)

In addition to regulatory monitoring for COCs and MCLs, ADEQ proposes that performance monitoring shall be used to track operational performance of each CCP and overall treatment train performance at an AWTF. Examples of minimum online CCP performance monitoring are included in Table C - 1 contained in **Appendix C** for common treatment technologies. Performance monitoring includes online and periodic sampling for pathogens and chemicals to demonstrate continuous production of high-quality water. Examples of the performance monitoring required for DWTF under the SDWA include the use of turbidity to monitor filter performance and disinfectant residual to establish that an adequate disinfectant dose was achieved. Existing validated strategies to monitor individual unit process performance will continue to be used in AWTFs, although additional performance monitoring requirements for AWTFs will be required beyond those used in conventional DWTFs. For example, periodic grab samples for unregulated chemicals (performance-based indicators), key pathogens, and TOC will need to be sampled in the purified water and at CCPs to confirm treatment performance. The additional monitoring is also necessary to respond rapidly to off-spec water. For instance, TOC is a key treatment performance indicator for AWP applications, but may not be for a conventional DWTF. In the event that the AWTF treatment train cannot attain target treatment design goals, effluent from the AWTF may be diverted or the system may need to be shut down until target performance monitoring goals can be met.

3.4.1.3. Laboratory Analysis

A laboratory performing analyses is required to comply with the requirements of the Health and Safety Code, known as the Environmental Laboratory Accreditation Act. The methods that will be used for chemical analysis shall be approved by the US EPA for use in compliance with the Safe Drinking Water Act as prescribed in 40 Code of Federal Regulations part 141 (National primary drinking water regulations) or part 143 (Other safe drinking water act regulations) or part 136 (Guidelines establishing test procedure for the analysis of pollutants). Other acceptable chemical analysis methods include:

i. Method for the analysis of chemicals published by a state or federal governmental agency or by a non-governmental voluntary consensus standards body such as, a method in the Standard Methods Committee's Standard Methods for the Examination of Water and Wastewater, or the standards of ASTM International.
ii. Alternative method that conforms to the US EPA's Protocol for the Evaluation of Alternative Test Procedures for Organic and Inorganic Analytes in Drinking Water (EPA 815-R-15-007, February 2015), or Protocol for the Evaluation of Alternate Test Procedures for Analyzing Radioactive Contaminants in Drinking Water (EPA 815-R-15-008, February 2015).
iii. For chemicals that are not detectable using known analytical chemical methods, bioanalytical methods or bioassays could be used for their quantification.

3.4.2. Reporting

Once an AWTF is operational, reporting will be an important component of documenting the performance of the system. Reporting associated with an AWTF involves the following:

i. Summary of analytical results for ongoing compliance monitoring of pathogens and chemicals.
ii. Summary of activities for an enhanced source control program such as initial source water characterization study, periodic evaluation of list of Tier 2 chemicals based on any changes in the sewershed, or any expected changes in quality and quantity of the source water or treated wastewater.
iii. Cross connection incidents: Reporting is required for any cross-connection incidents within five days of the occurrence of a cross connection problem that results in contamination of water provided by the AWTF.
iv. Emergencies: Reporting is required as soon as possible but no later than 24 hours after the occurrence of any of the emergencies, such as loss of water supply from a source, loss of water supply due to major component failure, damage to power supply equipment or loss of power, contamination of water in the distribution system from backflow, or chemical or microbiological contamination of the water supply.
v. Summary of any major equipment and treatment process failures and corrective actions taken.

vi. Waterborne disease outbreak: The occurrence of a waterborne disease outbreak that may be attributable to water provided by the AWTF as soon as possible but no later than 24 hours after the public water system receives actual notice of the waterborne disease outbreak.
vii. ADEQ is proposing annual reports that will detail trends in water quality and treatment over the year and list any significant operational or technical challenges. The report will also verify that the required maintenance was performed for each CCP.

ADEQ intends to establish electronic formats for reporting AWP program monitoring compliance data similar to the current format for Self-Monitoring Report Forms (SMRF) under APP and SDWA (SDWIS). Initially ADEQ will provide forms for other types of reporting, such as for Total Organic Carbon and Alkalinity or other reporting requirements contained within SDWA. ADEQ will investigate electronic reporting of this information in the future.

3.5. Operator Certification

Advanced Water Treatment Facilities (AWTFs) comprise complex treatment technology that necessitate the operation and maintenance expertise of well-trained and highly skilled operations personnel. The successful and safe operation of these facilities relies heavily on the competence of their operational staff (Mosher & Vartanian, 2018). For the AWP system, operator certification standards will be required to encompass the specific knowledge, skills and experience to respond adeptly to any system failure. These certified operators play a pivotal role in upholding the reliability, resilience, and continual performance of AWP systems, even during any unexpected challenges.

ADEQ is proposing a new certification, denoted as the Advanced Water Treatment Operator (AWTO) certification, that will encompass a range of critical elements, including comprehensive coverage of AWP technologies, a deep understanding of source water risks and risk management strategies, proficiency in critical control point methodologies, in-depth knowledge of specific AWP regulatory requirements, and the capability to manage operational responses effectively (Troy Walker et al., 2017). An AWTO is required to possess a comprehensive understanding of diverse water purification and monitoring systems. Traditional certifications for both drinking water and wastewater operators primarily emphasize conventional treatment processes, leaving a noticeable void in addressing the specific operational demands of advanced treatment procedures applied in potable water reuse (Troy Walker et al., 2018). The AWT train significantly diverges from traditional water treatment operations in several crucial ways, as outlined by the Clean Water and Wastewater Association (California Urban Water Agencies, 2016):

i. AWT train is more complex than conventional water and wastewater treatment processes and requires multiple barriers using diverse technologies.
ii. Raw wastewater quality into the WRF and secondary or tertiary treated wastewater quality to the AWTF can vary significantly, which can impact the daily operation of the AWTF and potentially the quality of the purified water.
iii. As the source water is treated wastewater, it is crucial that all components of the AWTF are operated and maintained as intended.

ADEQ proposes to develop a certification program for operators of an AWTF, similar to the Advanced Water Treatment Operator program developed by American Water Works Association (AWWA) -

California -Nevada Section (American Water Works Association & CWEA, 2019). This certification program would have parallel requirements to the existing water and wastewater certifications, but would focus on specific advanced treatment technologies required for AWP. In addition, the Advanced Water Treatment certification would include general requirements to define AWP in the broader picture of public health protection, pathogen and pollutant targets, and other issues.

ADEQ performed an analysis to identify the gaps in the Knowledge, Skills, and Abilities (KSA) required for the operation of AWTFs compared to conventional drinking water treatment facilities. This analysis relied on the 'Need to Know Criteria' established by the Association of Boards of Certification for Drinking Water Operator Examinations in Arizona and the content domains specified for operator requirements by the American Water Works Association - California-Nevada Section (AWWA-CA-NV).The findings revealed significant gaps in the existing certification standards, particularly in the areas of advanced treatment processes, including membranes, ozone treatment, biological activated carbon or biofiltration, and advanced oxidation. These advanced techniques were not adequately addressed in the current certification curriculum. Consequently, there is a clear and compelling need for development of a dedicated certification program tailored exclusively for operators of Advanced Water Treatment Facilities. This specialized certification should be underpinned by specific knowledge, skills, and abilities essential for the competent operation of AWTFs.

The AWP program will require that AWTFs be operated by those with an AWTO certification. Listed below are the proposed requirements for the AWTO certification:

i. Qualification requirement for Initial AWTO Certification:
    a. Certification requirements: A Grade 3 Drinking Water (DW) Operator certification and minimum of 2 years of experience in operating a Grade 3 DWTF or Grade 4 DW operator certification and a minimum of 1 year of experience in operating of Grade 4 DWTF and,
    b. Experience requirement: At least 1 year of hands-on experience in the operation of a minimum of 3 Advanced Water Treatment (AWT) processes. These AWT processes can include Ozone-BAC, MF, UF, RO, and UV-AOP, all within a single AWT train. The experience gained during the operation of a pilot plant is considered acceptable and can contribute towards meeting the experience requirements for AWTO certification.
    c. Exam requirement: The operator must pass the AWTO written exam. Similar to drinking water operator certification, 70% or above is considered a pass percentage.

   Similar to drinking water certification requirements, an operator must accumulate at least 30 Professional Development Hours (PDH) during the certification period. At least 10 PDHs must be specifically related to the job function of the operator. Instead of completing PDHs, operators may renew a certificate by passing an exam for the applicable grade.

AWTF Operator Requirements: AWTFs must designate an AWTO who holds a Grade 4 Drinking Water (DW) operator certification to serve as the operator in direct responsible charge. Additionally, an AWTO with a Grade 3 DW operator certification may fulfill the role of a shift operator under the guidance and supervision of an AWTO possessing a Grade 4 DW certification. AWTO should receive continuous ongoing education and training as new processes and techniques become available. AWTFs are encouraged to develop a comprehensive plan for providing periodic training to their operators. This training plan should be included under the facility's Operations plan.

Transition Period: ADEQ proposes a transition period of up to two years until the operator certification program is developed post Rule proposal.

WRF Operator Requirements: For WRFs supplying treated wastewater to AWTFs, it is required that the Operator of Record holds a Grade 4 Wastewater (WW) treatment and Collection System certification.

3.6. Public Communication Plan Requirements

Public confidence, acceptance, support, and trust is required for the successful implementation of AWP projects. Public acceptance is as important as the technical aspects of any AWP project (Mosher & Vartanian, 2018). To build trust that ATW is protective of public health, the WRF, AWTF and DWTF shall develop and launch a public communication plan within their service area. A disclosure aspect is required for the receiving community participating in AWP to educate them about their drinking water source by building awareness, trust, confidence, and transparency. Most importantly, this allows the public to become a partner with industry, the WRF, AWTF, and DWTF related to the AWP project. The implementation of an AWP project is not solely based on a utility decision and the receiving community (consumer) has the right-to-know about their source water.

i. Notifications to All Consumers of Advanced Treated Water: ADEQ will require that all AWTF notify all of its consumers of its intention to apply for and implement AWP allowing the community to gain awareness and knowledge of the source water. The AWTF must meet the minimum notification requirements listed below. During the planning phase, the AWTF must deliver information of its intention to implement an AWP project in all of the following methods to the community receiving ATW:
   - (I) Through a local, publicly accessible repository that contains information including, but not limited to AWP with a means for the public to submit questions and comments, obtain responses from and engage with the AWT. The repository must be active when the AWPRA submits an application to ADEQ and must be maintained for the lifetime of the project.
   - (II) At least one notification by mail or by another ADEQ-approved method to all of its consumers prior to a public meeting related to AWP.
   - (III) The AWTF must hold at a minimum two public meetings to engage the public and build awareness, trust, and transparency:
     1. At least one public meeting must be held in the planning stage of the AWP project.
     2. At least one public meeting must be held no less than six months prior to serving treated water from the AWP project.
   - (IV) At least one additional public communication method as approved by ADEQ.
   - (V) AWTs supplying treated water to a large proportion of non-English speaking consumers must provide the following:
     1. Information in the appropriate language(s).
     2. A telephone number, email address or address where the consumer may contact the AWPRA to obtain a translated copy of written communication or request assistance in the appropriate language for written and oral communications.

ii. Acceptable Methods of Communication: Displaying information and educating the public through any of the following methods are acceptable by ADEQ.
   (I) Coverage through a local news outlet (e.g. television, newspaper, social media).
   (II) Community event(s) (e.g. setting up table/booth).
   (III) Local school(s) and school events.
   (IV) Providing opt in email/text notifications to customers.
   (V) Consumer confidence reports/ Water bill inserts or mail notification
   (VI) Neighborhood association meeting(s).
   (VII) Civic organizations.
   (VIII) Other methods approved by ADEQ.

iii. Communicating with Local Governmental Entities and Other Key Audiences: The AWTF shall involve local government in the process. Involvement of local officials and decision makers in the communication and disclosure process is critical for the success of AWP. Within the Public Notification Plan, the AWPRA must include a list of all pertinent stakeholders they intend to communicate with. The AWPRA should notify and educate local health authorities and medical professionals. ADEQ recommends the AWTF involve other key audiences such as:
   (I) City/town councils and boards.
   (II) Local elected officials.
   (III) Community organizations that represent disproportionately impacted communities.
   (IV) Local environmental groups.
   (V) Industry groups (such as food and beverage), schools/school boards and medical professionals.

   It is highly recommended to assess community members' opinions about AWT prior to conducting communications and outreach through surveys, focus groups and other means to collect and assimilate data on attributes of individuals and groups and their perceptions and opinions of AWT to address the local community's perceptions and preferences.

iv. Certification of the Public Communication Plan: ADEQ will require the AWTF to certify the Public Communication Plan that outlines the minimum requirements listed above. The draft Public Communication Plan will be required with the application and the certified final plan will be required at a minimum 30 days prior to serving treated water. The certification document will include metrics with the actions taken to implement the above requirements such as:
   (I) Repository web address.
   (II) Numbers of mailers sent and method used.
   (III) Number of government entities and other leaders reached.
   (IV) Public meetings held (date, time, and method of delivery).
   (V) Outreach in other languages and the method used.

4. AWP Path Forward

Figure 10 shows the schedule of the key milestones for the development and approval of the AWP program. This schedule is subject to change, based on comment from stakeholders and development of the proposes rules.

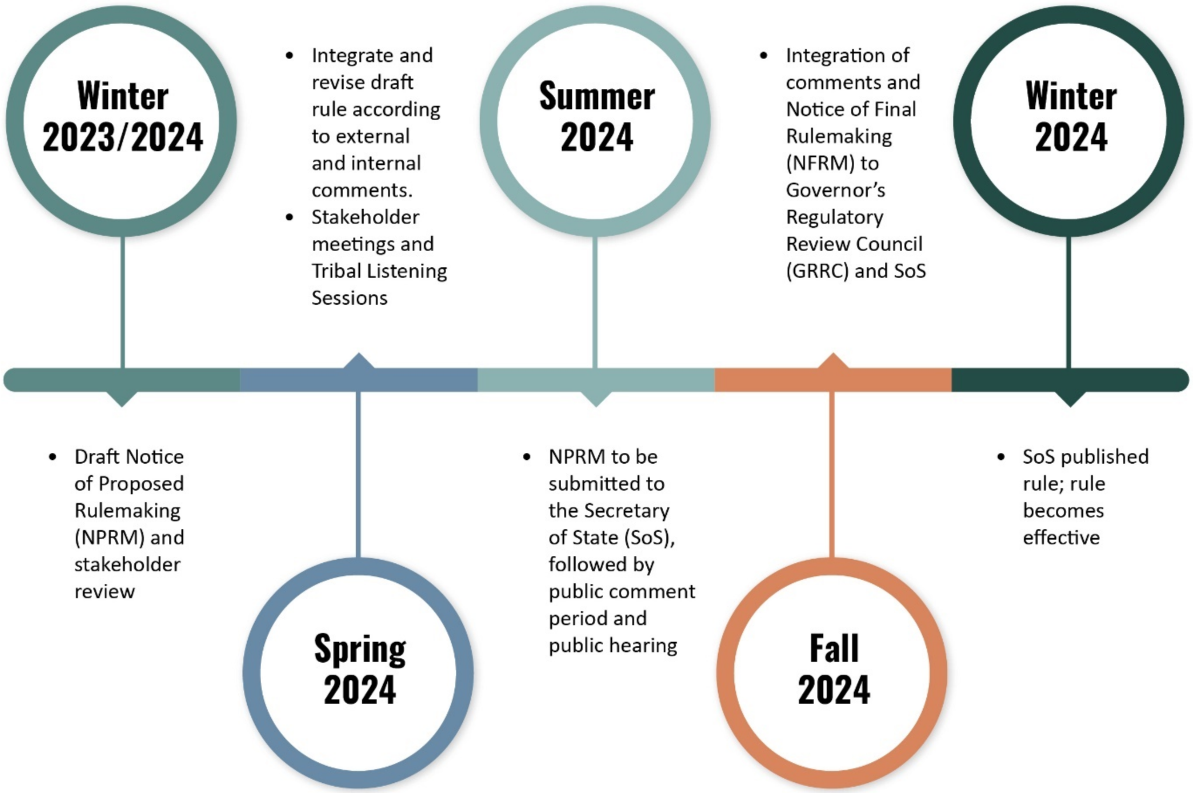


Figure 10: Next steps.

5. Definitions

i. Action level: A limit at a critical control point that, when exceeded, triggers a response to prevent a potentially hazardous event (Colorado Department of Public Health and Environment, 2023a). Exceeding an action level would necessitate taking immediate steps which could include shutting down the production of finished water within a documented time frame until the cause of the event can be identified and eliminated or taking that specific unit offline (if redundant units exist, e.g. multiple filters).

ii. Acute threats: The increased imminent risk of adverse health effects, including infectious diseases and toxic effects from short-term exposures to contaminants in water (California State Water Resources Control Board, 2023).

iii. ADEQ: ADEQ and Department are synonymous.

iv. Advanced Oxidation Process (AOP): A set of chemical treatment processes whereby oxidation of organic contaminants occurs on a molecular level through reactions with hydroxyl radicals or similarly aggressive radical oxidant species. The process breaks down recalcitrant organic molecules into smaller oxidized organic fragments. It is a requirement in all AWP project scenarios (Department of Public Health and Environment, 2023). It shall be designed to provide no less than 0.5 log reduction of the indicator 1,4-dioxane and must be validated to demonstrate that the AOP can reliably achieve no less than 0.5 log reduction of the indicator 1,4-dioxane (California State Water Resources Control Board, 2023).

v. Advanced treated water (ATW) or purified water: Water produced in an AWTF using treated wastewater (at least, subject to secondary treatment) that is introduced as raw potable water source immediately upstream of a DWTF. ATW may or may not meet the requirements of direct introduction into the drinking water distribution system. ATW can be from more than one AWTFs (Tchobanoglous et al., 2015).

vi. Advanced Water Purification (AWP) or Direct Potable Reuse (DPR): The planned introduction of recycled water (with or without retention in an ESB) directly into a DWTF or PWS's potable water pipelines or tanks for distribution to customers (Salveson et al., 2016). Two forms of AWP include (i) introducing ATW into the raw water supply upstream of a DWTF and is called raw water augmentation and (ii) finished drinking water from an AWTF permitted as a DWTF is directly introduced into a drinking water distribution system and is called treated water augmentation (Mosher & Vartanian, 2018; Tchobanoglous et al., 2015).

vii. Advanced Water Purification Responsible Agency (AWPRA): The AWTF or DWTF responsible for compliance with the requirements of the AWP program for a particular AWP project (California State Water Resources Control Board, 2023; Colorado Department of Public Health and Environment, 2023a).

viii. Alert level: A limit at a critical control point that, when exceeded, alerts an operator that a potential problem may require a response (Colorado Department of Public Health and Environment, 2023a). Exceeding an alert limit would necessitate further action and follow up monitoring, but may involve more investigation rather than just shutting down the production of finished water.

ix. Amendment: A change to the permit language resulting from a modification event.

x. Barrier: A measure (technical, operational or managerial) implemented to control microbial or chemical constituents in advanced treated water (Mosher & Vartanian, 2018; Tchobanoglous et al., 2015).Bioassay: Bioassays are tests performed using live cell cultures or mixtures of cellular components in which the potency of a chemical or water concentrate is tested based on its effect on a measurable constituent, such as inhibition or the induction of a response (including carcinogenicity and mutagenicity). Bioassays can be used to measure synergistic, additive, and antagonistic interactions between compounds that may be present in a mixture (Texas Water Development Board, 2015).

xi. Blending: Mixing ATW with another water source that will result in raw water augmentation (prior to DWTP) or treated water augmentation (directly to DS). Blending does not apply to ESB where storage of only AWT treated water takes place.

xii. Challenge Test: A study comparing a pathogen, surrogate parameter, or indicator compound concentration between the influent and effluent of a treatment process to determine the removal capacity of the treatment process. The influent concentration must be high enough to ensure that a measurable concentration is detected in the effluent (i.e., filtrate detection limit) (California State Water Resources Control Board, 2023; Department of Public Health and Environment, 2023).

xiii. Chemical peak: Abnormal increase in the level of a chemical that represents a potential human health hazard that is the result of intentional or unintentional illicit discharges of chemicals to the sewershed. Chemical peaks are different from normal facility variation in water quality (California State Water Resources Control Board, 2016; Jean Debroux et al., 2021).

xiv. Chronic exposure threats: The increased risk of adverse health effects including cancer or other longer-term effects or disease from continued exposures to contaminants in water (California State Water Resources Control Board, 2023).

xv. Commercial establishment: An establishment used for commercial purposes, such as a restaurant, private office, fitness club, dental office, hospital, retail store, bank or other financial institution, supermarket, automobile or boat dealership, or any other establishment with a common business area. It does not include dwellings, where the primary purpose is permanent or temporary occupation by humans for living such as a home, or multi-unit permanent or temporary dwelling where private home viewing occurs, such as a hotel, dormitory, hospital, apartment, condominium, or prison 17 U.S. Code § 119 (D)(12). For the purpose of AWP enhanced source control program, not all commercial establishments are significant. Only some establishments will have a significant impact on the finished water and have the potential to cause an exceedance in a particular Tier I or Tier II chemical. Significance of the establishment is a function of commercial establishment and sewershed size.

xvi. Constituent(s) of concern (CoCs): Potentially harmful or difficult to treat substances that could cause treatment interference, pass-through, or a violation either of a treatment technique requirement or of an MCL in finished water. Constituents of concern include target chemicals (Colorado Department of Public Health and Environment, 2023b).

xvii. Constituent: Any physical, chemical, biological, or radiological substance or matter found in water and wastewater (Tchobanoglous et al., 2015).

xviii. Critical control point (CCP): A point in the treatment train that is specifically designed to reduce, prevent, or eliminate process failure and for which controls exists to ensure the proper performance of that process and verified via monitoring (Colorado Department of Public Health and Environment, 2023a; Tchobanoglous et al., 2015; Troy Walker et al., 2016).

xix. Direct Integrity Test: A physical test applied to a membrane unit in order to identify and isolate integrity breaches (i.e., leaks that could result in contamination of the filtrate) (Department of Public Health and Environment, 2023; Mosher & Vartanian, 2018).

xx. Dose response models: Dose response models used for each of the reference pathogens. For Norovirus: Hypergeometric, *Giardia*: Exponential dose response model, and for *Cryptosporidium*: Beta-Poisson.

xxi. Engineered storage buffer (ESB): A storage facility used to provide retention time—before ATW is introduced into the DWTF or distribution system - to (i) conduct testing to evaluate water quality; (ii) hold the water for a specified time in the event that it does not meet specifications, (iii) complement treatment by providing a barrier for pathogen and chemical control. The ESB is designed to provide sufficient time to monitor process performance and respond to acute contaminants (e.g., pathogens, nitrate). Transmission pipes can serve as ESB (Salveson et al., 2016).

xxii. Enhanced Source Control: A program that enables the AWPRA to prevent constituents of concern (COCs) including target chemicals from negatively impacting the advanced water treatment facility, or the water it produces, by controlling the COCs at their source (Colorado Department of Public Health and Environment, 2023b).

xxiii. Failure response time (FRT): The maximum possible time from when a failure occurs in the treatment system to when the quality of the final product water is no longer affected by the failure. FRT is calculated as a sum of the sampling interval, sample turnaround time and system reaction time, with overall FRT based on treatment process with the highest individual FRT. It is assumed that process failures are inevitable as well as automated failure responses are built into the treatment system (Salveson et al., 2016; Tchobanoglous et al., 2015).

xxiv. Failure: A condition in which an excursion in water quality or loss of performance occurs in one or more of the unit processes that results in a treatment train to not meet a performance metric or deviate from an approved operational range for parameters, necessitating a shutdown of a specific train or the entire plant for compliance.

xxv. Finished water or potable water or finished drinking water: Water produced by an AWTF, which is also permitted as a DWTF, and is introduced into a PWS distribution system for human consumption without additional treatment, except for measures required to uphold water quality within the distribution system (e.g., booster disinfection, corrosion control chemical addition) (California State Water Resources Control Board, 2023; Department of Public Health and Environment, 2023).

xxvi. Indicator compound or indicator or performance-based indicator: A chemical found in municipal wastewater that serves as a representative substance for a particular group of trace organic compounds, embodying their physical, chemical, and biodegradation properties. These indicator compounds exist in concentrations that enable the monitoring of the effectiveness of a treatment process in reducing trace organic compounds or signal potential treatment process failures. Examples include carbamazepine and sulfamethoxazole as ozone performance indicators or acetone and formaldehyde as BAC performance indicators or 1,4-dioxane for AOP (California State Water Resources Control Board, 2023). The AWP train should be designed, built and operated to remove at least 75 percent of each indicator compound as measured from the treated wastewater to the finished water (Colorado Department of Public Health and Environment, 2023a).

xxvii. Limit of Detection (LOD): Same meaning as Non-detects (ND) (Brian Pecson et al., 2021). It is the minimum amount of the target strain or DNA sequence that can be reliably distinguished from the absence of the sample within a given level of confidence (ex. 95% confidence level) (Alfred J. Saah & Donald R. Hoover, 1997).

xxviii. Limit of Quantification (LOQ): Same meaning as detected-but-non-quantifiables (DNQs) (Brian Pecson et al., 2021).

xxix. Log reduction value (LRV): A measure of the ability of a treatment train or a treatment process to remove or inactivate microorganisms such as bacteria, protozoa and viruses. LRV is the log reduction validated or credited for a treatment process or treatment train (California State Water Resources Control Board, 2023).

xxx. Log reduction: The logarithm base 10 of the ratio of the levels of a pathogenic organism or other contaminant before and after treatment (California State Water Resources Control Board, 2023). A reduction in the concentration of a contaminant or microorganism by a factor of 10. For example, 1 log reduction corresponds to a 90-percent reduction from the original concentration (California State Water Resources Control Board, 2019).

xxxi. Modification: Changes to the treatment train or operations or any other component that will result in a change in the water quality of each unit operation or the finished water is called a modification. A modification will require an amendment to the permit.

xxxii. Municipal wastewater: Wastewater that includes mostly domestic waste and may include commercial and industrial waste. For the purposes of the AWP program, municipal wastewater is considered a surface water (California State Water Resources Control Board, 2023).

xxxiii. Non-domestic sources: Includes both industrial and commercial sources.

xxxiv. Non-treatment barrier or management barrier: Policy and maintenance plans that are integral for ensuring the proper functioning and oversight of technical and operational barriers throughout the AWP project's lifecycle. These plans cover activities from the source of supply to the production of ATW and provide essential guidance to project staff for making crucial decisions, such as when to cease operations (i.e., shut down) if water quality data are questionable or treatment performance is compromised (Tchobanoglous et al., 2015). An example of non-treatment barrier include diversion of industrial wastewater away from WWTP to aid in source control or a cap on wastewater contribution and blending with other potable sources (Lahnsteiner et al., 2018).

xxxv. Off-Specification water or Off-Spec water: Water quality that does not meet established drinking water standards such as drinking water MCLs or other requirements (such as, surrogates or indicators) as outlined in the AWP program.

xxxvi. Operational barrier: A barrier in the form of measures that include operations and monitoring plans, failure and response plans, and operator training and certification (Tchobanoglous et al., 2015). It could represent additional treatment options or operational measures that can be used if needed and/or on demand. An example of an operational barrier representing a treatment measure includes the addition of powdered activated carbon if the adsorption capacity of GAC is too low or the organic load of a reclamation plant is too high. An example of an operational barrier that is an operational measure is switching to recycling mode if a water quality excursion occurs for different process units (Burgess et al., 2015; Lahnsteiner et al., 2018) .

xxxvii. Operational parameter: A measurable property used to characterize or partially characterize the operation of a treatment process and must confirm the treatment barriers are intact to ensure the process is meeting the water quality and pathogen/chemical removal goals (California State Water Resources Control Board, 2023; Colorado Department of Public Health and Environment, 2023a).

xxxviii. Oxidized wastewater: Wastewater that is treated to a level beyond simple removal of floating and suspended solids and meets the secondary treatment levels as described in AAC R18-9-B204(B)(1) (Colorado Department of Public Health and Environment, 2023a).

xxxix. Ozone with biologically active filtration (Ozone/BAC): An ozonation process immediately followed by biologically activated carbon (California State Water Resources Control Board, 2023).

xl. Pass-through: A condition where a constituent of concern enters the waterworks in quantities or concentrations that have a significant potential to have serious adverse effects on public health or to cause a violation either of a treatment technique requirement or of an MCL in finished water (Colorado Department of Public Health and Environment, 2023a).

xli. Pathogen Control Point Critical limits: Pathogen control point is the effluent from each pathogen removal process and critical limit is the monitoring value for each treatment process that indicates if each treatment is effective.

xlii. Pathogen. A microorganism such as bacteria, virus, or protozoa that can cause human illness (Tchobanoglous et al., 2015).

xliii. Pilot: Scale should be representative.

xliv. Product water or produced water: Water exiting post a specific treatment of a combination of treatments. Example of product water includes reverse osmosis permeate or ATW is called as final product water.

xlv. Real time or online monitoring: Real time or Online monitoring for treatment performance for each process. Locating instruments directly in the process flow or sample line and monitoring water quality in real-time continuously or semi-continuously, with a sample time of 15 minutes or less.

xlvi. Recalcitrant Total Organic Carbon (rTOC): The TOC found in finished water, which eventually becomes treated wastewater. Unlike anthropogenic TOC present in wastewater, recalcitrant TOC may not be effectively eliminated by the wastewater treatment plant and remains a constituent of the TOC in the treated wastewater.

xlvii. 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 will still perform effectively and risk is reduced (Mosher & Vartanian, 2018; Tchobanoglous et al., 2015).

xlviii. Reference pathogens: Enteric viruses (specifically norovirus), *Giardia* cysts, and *Cryptosporidium* oocysts have been selected as the reference pathogens.

xlix. 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 (Mosher & Vartanian, 2018).

l. Resilience: The ability of a treatment train to adapt successfully and restore performance rapidly when failure occurs (Mosher & Vartanian, 2018; Pecson et al., 2015).

li. Robustness: The ability of an AWP system to address a broad variety of (i) constituents and (ii) changes in the concentrations of the constituents in the source water and resist a failure (Jean Debroux et al., 2021; Mosher & Vartanian, 2018; Pecson et al., 2015).

lii. Surrogate parameter or surrogate: A measurable chemical or physical property, microorganism, or chemical that has been demonstrated to provide a direct correlation with the concentration of an indicator compound or pathogen; that may be used to monitor the efficacy of constituent reduction by a treatment process; and/or that provides an indication of a treatment process failure (California State Water Resources Control Board, 2023). An example is TOC, which is bulk surrogate for trace organic contaminant (Colorado Department of Public Health and Environment, 2023a).

liii. Target Chemical: Any unregulated chemical causing a potential human health concern that may be present in the treated wastewater (Colorado Department of Public Health and Environment, 2023a).

liv. Technical barrier or treatment barrier: A barrier which can be viewed as a physical barrier that can be credited with treatment performance (Tchobanoglous et al., 2015), purification units in constant operation (Lazarova & Asano, 2013). Pathogen log reduction credits are assigned only for technical or treatment barriers (Mosher & Vartanian, 2018).

lv. Trace organic compounds (TOrCs): Compounds such as pharmaceuticals, personal care products, and hormones.

lvi. Treated Wastewater: Any water source from a wastewater treatment plant that has undergone treated wastewater characterization for either enhanced wastewater treatment or secondary wastewater treatment and originates from a wastewater treatment plant that has liquid stream treatment processes that, at a minimum, are designed and operated to produce oxidized wastewater to achieve a defined source water quality for additional treatment by a supplier utilizing Advanced Water Purification (Colorado Department of Public Health and Environment, 2023a).

lvii. Treatment interference: A discharge from a non-domestic source which alone or in conjunction with a discharge or discharges from other sources that inhibits or disrupts the AWPRA's treatment processes or operations that has a significant potential to have serious adverse effects on public health or to cause a violation either of a treatment technique requirement or of an MCL in finished drinking water (Colorado Department of Public Health and Environment, 2023a).

lviii. Treatment mechanism: A physical, biological, or chemical action that reduces the concentration of a pathogen or a chemical contaminant (California State Water Resources Control Board, 2023).

lix. Treatment train: A grouping of physical, chemical, and biological treatment technologies or processes that conditions or treats water to achieve a specific water quality goal (California State Water Resources Control Board, 2023; Mosher & Vartanian, 2018).

lx. Upset: A condition in which a temporary excursion in water quality or loss of performance in one or more of the unit processes, however, one that does not result in a treatment train to meet a performance metric. An upset may or may not result in a failure and may not necessarily lead to a shutdown.

lxi. Water Reclamation Facility (WRF) or wastewater treatment plant (WWTP): An arrangement of devices and structures for collecting, treating, neutralizing, stabilizing, or disposing of domestic wastewater, industrial wastes, and biosolids. For purposes of AWP, a wastewater treatment plant does not include industrial wastewater treatment plants or complexes whose primary function is the treatment of industrial wastes, notwithstanding the fact that human wastes generated incidentally to the industrial process are treated therein. (Colorado Department of Public Health and Environment, 2023a).

6. Acronyms and Abbreviations

AAC	Arizona Administrative Code
ADEQ	Arizona Department of Environmental Quality
AOC	Approval of Construction
AOP	Advanced-Oxidation Process
APP	Aquifer Protection Program
ARS	Arizona Revised Statutes
ATC	Approval of Construction
ATW	Advanced treated water
AWP	Advanced Water Purification
AWTF	Advanced Water Treatment Facility
AZPDES	Arizona Pollutant Discharge Elimination System
BAC	Biologically Activated Carbon
BOD	Biochemical Oxygen Demand
CCP	Critical Control Point
COC	Constituent of Concern
CWA	Clean Water Act
DBPs	Disinfection Byproducts
DIT	Direct Integrity Testing
DNQs	Detected-but-non-quantifiables
DPR	Direct Potable Reuse
DWTF	Drinking Water Treatment Facility
EPDS	Entry Point to Distribution System
ESB	Engineered Storage Buffer
GAC	Granular Activated Carbon
GIS	Geographical Information System
HMA	HMA Public Relations
HMI	Human-Machine Interface
IGA	inter-governmental agreement
IPR	Indirect Potable Reuse
LOD	Limit of Detection
LOQ	Limit of Quantification
LRV	Log Reduction Value
MBR	Membrane Bioreactor
MCL	Maximum Contaminant Level
MF	Microfiltration
mg/kg/day	milligrams per kilograms per day
mg/L	milligram per liter
mJ/cm2	millijoules per square centimeter
MOU	Memoranda of Understanding
MPN	Most Probable Number
NAICS	North American Industry Classification System
ND	Non-Detects

NDMA	N-nitrosodimethylamine
NPDES	National Pollutant Discharge Elimination System
NPP	National Pretreatment Program
NWRI	National Water Research Institute
O&M	Operation and Maintenance
PAC	Project Advisory Committee
PDT	Pressure Decay Testing
PFOA	Perfluorooctanoic Acid
QMRA	Quantitative microbial risk assessment
qPCR	Quantitative polymerase chain reaction
RfD	Reference Dose
RO	Reverse Osmosis
RSD	Risk-Specific Dose
SCADA	Supervisory Control and Data Acquisition
SDWA	Safe Drinking Water Act
SOPs	Standard Operating Procedures
SVOCs	Semi-volatile Organic Compounds
TAG	Technical Advisory Group
TDS	Total Dissolved Solids
TMF	Technical, Managerial, and Financial
TOC	Total Organic Carbon
TOrCs	Trace Organic Chemicals
TSS	Total Suspended Solids
US	United States
US EPA	United States Environmental Protection Agency
USGS	United States Geological Survey
UV	Ultraviolet
UVAOP	Ultraviolet Advanced Oxidation Process
VOCs	Volatile Organic Compounds
WRF	Water Reclamation Facility
WWTP	Wastewater Treatment Plant

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Appendix A – Chemical Risk Management Approach

Management of AWP specific contaminants (Tier 2) is important to ensure the quality of purified water and protect public health. The proposed chemical risk management approach has been established in conjunction with the enhanced source control program. Selection of AWP specific contaminants will be site-specific. This will ensure that each utility only monitors chemicals that are specific to their sewershed and not unduly burden any utility with an expensive monitoring campaign. The AWPRA should propose a list of chemicals along with the rationale for selecting the specific chemicals based on the categories of dischargers (e.g., domestic and non-domestic) in the sewershed. The AWPRA should obtain ADEQ approval prior to the start of any monitoring. This approach will ensure that there is an agreed list prior to the commencement of any sampling and avoid any costly rework. After approval from ADEQ, the AWTF should conduct initial monitoring for the approved list of chemicals. The monitoring data and lab analysis results, including the full lab reports completed with QA/QC need to be submitted to ADEQ along with the submission of the initial application. The AWPRA should provide justification on their selection/design that the proposed design will protect public health.

The list of Tier II chemicals must be periodically evaluated (at least every 3 years) or when new industries or commercial establishments are added to the sewershed and agreed upon by ADEQ by following the specific steps for chemical selection.

The detailed reasoning for the proposed approach is outlined as follows:

i. Step 1: Dischargers: List all industrial and/or commercial establishments within the sewershed.
ii. Step 2: Inventory of chemicals: Generate an inventory of chemicals used, stored, and discharged by the identified dischargers.
iii. Step 3: Total contaminant load:
    a) Calculate mass loading of contaminant from each discharger:
       Mass loading of contaminant (lb/day) = Flow (MGD) x Maximum Concentration (mg/L) x 8.34 (for unit conversion)
    b) Calculate total contaminant load (lb/day) from all dischargers:
       Total Contaminant Load (lb/day) = ∑ Mass loading (lb/day) for all dischargers
iv. Step 4: Expected concentration of contaminant:
    a) Calculate total influent flow (MGD) coming to the AWP plant from all dischargers.
       Total Influent Flow (MGD)= ∑ Flow (MGD) from all dischargers
    b) Calculate expected concentration at AWTF influent (mg/L):

$$Expected\ concentration\ (mg/L) = \frac{Total\ Contaminant\ Load\ (\frac{lb}{day})}{Total\ Influent\ Flow\ (MGD) \times 8.34}$$

v. Step 5: Chemical selection:
    a) Obtain the reference dose (Rfd, mg/kg-day) or cancer slope factor (CSF) from EPA IRIS Database.
    b) Determine risk specific dose, RSD (mg/kg-day):

       RSD= 10^{-4}/CSF

c) Calculate Safe Exposure level at 10% of life span (70 years) for an average person of body weight (BW) of 70 kg. For exposure calculation, 10% of average life expectancy (70 years) was assumed (US EPA, 2002).
Safe Exposure level (mg) = min (RfD or RSD) x BW (kg) x 70 years x 365 days/year x 0.10

d) Calculate safe volume of water consumed (L/day):

$$Safe\ volume\ of\ water\ consumed\ \left(\frac{L}{day}\right) = \frac{Safe\ Exposure\ level\ (mg)}{Expected\ concentration\ \left(\frac{mg}{L}\right) \times (70 \times 365)days\ \times 0.10}$$

I. If the safe volume of water consumed ≥ 2.5 L/day the contaminant is NOT expected to pose any health consequences.
II. If the safe volume of water consumed < 2.5 L/day, consider monitoring the contaminant.

vi. Step 6: Account for chemicals known to interfere/pass through in AWTF:
Identify chemicals that are known to interfere with the AWTF processes or are a pass through hazard and originate within the sewershed or are used in the WRF. Add these chemicals to the previous step.

a) Examples of pass-through hazards for RO-based treatment trains are low molecular weight compounds such as acetone, 1,4-dioxane and NDMA. For non-RO based (carbon based) treatment trains, ICMs (used in medical imaging) such as Diatrizoic acid is a potential pass-through hazard due it's hydrophilicity that makes them challenging to remove with GAC (Tyler Nading et al., 2023).

b) An interference hazard is defined as a chemical that can inhibit or disrupt the treatment system's processes or operations and compromise the safety of water by means other than pass-through. Examples of interference hazard include oxidant and radical scavenging, membrane scaling, biological inhibition, and chemicals with the potential to biodegrade or oxidize into other chemicals that would be more toxic (Tyler Nading et al., 2023). Examples of chemicals that can interfere with RO-based treatment trains are calcium and iodide. Calcium is an interference hazard for RO trains because it can increase RO scaling (Tyler Nading et al., 2023). Also, the presence of certain forms of iodine could be responsible for complications, such as significant rapid flow loss and poor performance in operation of RO membranes. For non-RO based trains, isopropyl alcohol and acetone are examples of interference compounds. Isopropyl alcohol can transform to acetone in ozonation or UV/H2O2 and inhibits biological treatment at high concentrations (Wu et al., 2008; Xiao et al., 2015).

c) Other examples of chemicals that are used in the WRF process, such as polymers, defoaming or antifoaming agents.

vii. Step 7: Account for AWTF removal:

a) Factor AWTF's ability to remove chemicals based on the proposed treatment train and develop a subset of chemicals from the above step. AWTF chemical removal must be demonstrated during piloting via actual sampling at a minimum of two locations (influent and effluent at pilot plant).

b) Provide the list of chemicals identified using this approach:
   I. chemicals that must be monitored (i.e., Tier 2 list or Step 5 and Step 6),
   II. chemicals that must be treated (Step 7(a)),
   III. and/or chemicals that must be controlled through enhanced source control (i.e., Tier II chemicals not removed via treatment)

Table A - 1: Proposed criteria for selection of Tier-3 chemicals (Performance based indicators)(Colorado Department of Public Health and Environment, 2023a)

Criterion	Description
Concentration	The PBI should have a median concentration at least five times greater than its MRL (method reporting limit). Otherwise a high percentage of removal cannot be demonstrated. The median concentration divided by the MRL is referred to as detection ratio (DR).
Prevalence	The PBI should have a detection frequency (DF) over 80% in the site-specific treated wastewater. Otherwise, its absence may be random or seasonal and may not reflect treatment efficacy. For example, sunscreen UV blockers or allergy medications follow a seasonal occurrence pattern in treated wastewater.
Measurability	Sufficiently precise and sensitive analytical methods for the compound are necessary to meet the above two criteria. Analytical methods should be well established in the scientific literature. While some methods may be approved by the EPA, the department can allow other methods that are well-established but not yet EPA approved.
Specificity	The indicator compound should be removable by the process(es) it is intended to monitor. It should be sufficiently recalcitrant to any upstream processes—or at such high concentration in the treated wastewater—that it meets the concentration and prevalence criteria at the influent of the targeted treatment process. Optionally, the indicator compound should be recalcitrant to downstream processes as well, however that may not always be the case. If all indicators meet this sub-criterion, then all indicators could be monitored at just two sampling locations (WPF influent and final effluent). This criterion is based on convenience and operational efficiency, however in practice the department expects that some indicator compounds will be monitoring within the process as well.
Sensitivity	The indicator has good removal by the targeted process, such that 75% removal is feasible only when the process is functioning as designed. • For example, ozone doses in reuse systems are typically around CT10 = 4-11 mg*min/L to balance chemical and pathogen removal against bromate formation (Dickenson, et al. 2009). Some compounds such as hydrocodone are so sensitive to oxidation that they are more than 90 percent removed even when the operationally defined ozone exposure is 0 mg*min/L. Hydrocodone would be a poor indicator for ozonation, since it can be removed below its MRL even if an ozone generator is malfunctioning and dosing less ozone than intended. • On the other hand, ozonation removes chemicals such as chloroform and tris(2-chloroethyl) phosphate by less than 25 percent under typical conditions. Removing more than 75 percent of these compounds with ozone would be cost prohibitive or physically impossible, and would likely cause the bromate concentration to exceed regulation. • Moderately oxidizable compounds such as DEET or iopromide would serve as better ozonation indicators because they are more than 75 percent removed under typical conditions but mostly pass through at lower ozone exposure.
Diversity	The other criteria apply to each PBI individually, but these criteria apply to PBIs as a set. There should be at least one indicator that specifically monitors each chemical treatment barrier. Furthermore, there should be at least one indicator that is partially removed by each treatment barrier, but only removed to a target of at least 75% if all treatment barriers are functioning as intended- a system indicator to monitor the system as a whole.

Basis for Tier II chemical action level determination: The level of ‘100 times the action level’ corresponds to a lifetime cancer risk of $1x10^{-4}$, which is 100 times the de minimis risk level (i.e., a theoretical lifetime risk level of $1x10^{-6}$, or up to one excess case of cancer per million people exposed daily for 70 years). A level greater than 10 times the action level reduces the margin of safety (California State Water Resources Control Board, 2022).

Appendix B - WRF and AWTF Treatment Requirements

Table B - 1: Typical Pathogen Log Removals Observed for Common Treatment Technologies.

Treatment	Virus	*Cryptosporidium*	*Giardia*
MBR (Andrew Salveson et al., 2021)	1	2.5	2.5
Slow sand (40 CFR Part 141)	2	>2	2
Conventional filtration (including BAC with coagulation-flocculation) (40 CFR Part 141)	2	>2	2.5
Diatomaceous earth filtration (40 CFR Part 141)	1	>2	2
Direct filtration (40 CFR Part 141)	1	>2	2
Cartridge Filtration (With Pretreatment) (40 CFR Part 141)	0	2	2
Low pressure membranes MF/UF (US EPA, 2005)	0	4	4
High pressure membranes RO (US EPA, 2005)	1.5 - 3.0 Tier 1: Strontium or sulfate-based monitoring Tier 2: TOC-based monitoring Tier 3: EC-based monitoring (1.5 with Tier 3 and Up to 3 with Tier 1)	1.5 - 3.0 Tier 1: Strontium or sulfate-based monitoring Tier 2: TOC-based monitoring Tier 3: EC-based monitoring (1.5 with Tier 3 and Up to 3 with Tier 1)	1.5 - 3.0 Tier 1: Strontium or sulfate-based monitoring Tier 2: TOC-based monitoring Tier 3: EC-based monitoring (1.5 with Tier 3 and Up to 3 with Tier 1)
High pressure membranes NF (US EPA, 2005)	1	1	1
Chlorine (US EPA, 1999)	Up to 6	0	Up to 6[1]
Monochloramine (US EPA, 1999)	Up to 4	0	Up to 3[1]
Chlorine dioxide (US EPA, 1999)	Up to 4	Up to 3	Up to 3
Ozone (US EPA, 1999)	Up to 6	Up to 1 highest resistance	Up to 6 higher doses than for virus
UV (US EPA, 2020)	4 (186 mJ/cm^2) 6 (276 mJ/cm^2)	4 (22 mJ/cm^2) 6 (84 mJ/cm^2)	4 (22 mJ/cm^2) 6 (84 mJ/cm^2)
UV/AOP (US EPA, 2020)	6	6	6
EC = electrical conductivity MF/UF = microfiltration/ultrafiltration NF = nanofiltration			

Table B - 2: Treatment Technologies Implemented in AWTFs for Pathogen and Chemical Control (NWRI Independent Expert Advisory Panel, 2019)

Category	Unit Process	Reference pathogen removed	Type of chemicals removed	Design Considerations
Filtration	Coagulation/ flocculation with slow sand/ conventional/ direct filtration	*Cryptosporidium*, *Giardia*, viruses *Cryptosporidium*, *Giardia*, viruses *Cryptosporidium*, *Giardia*, viruses	Bulk organic constituents – high molecular weight (>1,000 Da), high specific absorbance, certain heavy metals and radionuclides	Design and performance requirements are included in existing SDWA and ADEQ guidance. Bench or pilot testing recommended to test metal-based coagulants for determining the optimum dose and pH conditions for chemical removal under a variety of secondary effluent water quality conditions that can occur diurnally at WRFs.
	Low pressure membranes (micro or ultrafiltration)	*Cryptosporidium, Giardia*	Turbidity, suspended solids, particulate matter, colloids	Integrity and performance testing required using indicator compounds
	Reverse osmosis	*Cryptosporidium*, *Giardia*	High molecular weight (>200 Da), charged	Minimum salt rejection and integrity testing required. Implementation should be carefully considered because of difficulty disposing waste concentrate. While RO can be used for pathogen removal, and the literature indicates that RO can remove key pathogens by 5 LRVs, RO is typically not credited with more than 2 LRVs. This is due to real time integrity testing challenges (Trussell et al., 2017).
	Nanofiltration	*Cryptosporidium, Giardia*	High molecular weight (>200 Da), charged	Implementation should be carefully considered because of difficulty disposing waste concentrate.

Biofiltration	Biofiltration	*Cryptosporidium, Giardia,* viruses	Assimilable organic compounds	Ozone must operate above an ozone to TOC ratio of 0.5, after demand by nitrate (if applicable). The biofilter minimum empty bed contact time (EBCT) of 10 minutes. GAC or anthracite medium is recommended unless pilot testing supports alternative media. Careful management of the microbial community needed to prevent a release of filter biomass into other AWTF processes.
	Ozone coupled with Biologically active filtration (BAF)	*Cryptosporidium, Giardia,* viruses	Small chain organics	
Disinfection	Free chlorine	*Giardia*, viruses	-	Well established disinfection processes (National Research Council, 1977) for primary disinfection and disinfectant residual (US EPA, 2020) for which existing EPA and ADEQ guidance is available. Key considerations include DBP formation prevention in the presence of key precursors (e.g., TOC). Pilot testing is recommended to establish chemical removal performance.
	Monochlorine	*Giardia*, viruses	-	
	Chlorine dioxide	*Cryptosporidium*, *Giardia*, viruses	-	
Oxidation	Ozone	*Cryptosporidium*, *Giardia*, viruses	Aromatics, carbon-carbon double bonds, deprotonated amines	EPA and ADEQ guidance is available for design. Ozone breaks down rapidly in water so is not typically used to maintain a chemical residual. Some DBPs can be formed if precursors exist in the water (e.g., bromide).
	UV (photolysis)	*Cryptosporidium*, *Giardia*, viruses	Small chain organics, nitrosamines, iodinated compounds, nitro	Photolysis uses UV light to destroy the proteins and deoxyribonucleic acid (DNA) of pathogens and bonds of chemicals.

			compounds, NDMA	Improved performance is observed when paired with other oxidants (e.g., hydrogen peroxide), to create an AOP. Considerations for design include the dosing and pretreatment to prevent interference from other chemicals. UV or AOP generally does not produce a chemical residual (California State Water Resources Control Board, 2016).
	AOP	*Cryptosporidium*, *Giardia*, viruses	Aromatics, carbon-carbon double bonds, deprotonated amines, chemicals recalcitrant to photolysis	
	Ion Exchange	NA	Can target a broad range of positively or negatively charged compounds	Piloting required to establish efficacy of each resin.
Other	Granular-activated carbon (GAC) or powdered-activated carbon	NA	Hydrophobic chemicals including per- and polyfluoroalkyl substances, PFOA	Minimum 15 minutes EBCT with at least two GAC contactors. Coal-based GAC medium is recommended over other products, such as coconut-based media, because of superior chemical removal in AWP applications.
	Air stripping	NA	Volatile and semivolatile	-

Appendix C - Monitoring Requirements

Table C - 1: Example Minimum Online Performance

Technology	Minimum Online Performance Monitoring
WRF	Nitrate and nitrite
	Conductivity, ammonia, pH, turbidity, UV254, flow rate
Low Pressure Membranes (MF/UF)	Daily Pressure Decay Test following the US EPA Membrane Filtration Guidance Manual
	Flow rate
High Pressure Membranes (RO) (integrity testing required)	Turbidity, online electrical conductivity (feed and permeate), flow rate
Convention Filtration (coagulation, flocculation, filtration)	Turbidity, refer to SDWA, flow rate
Biologically Active Filter (after ozone)	Turbidity, refer to SDWA, flow rate
Ozone	Flow rate
UV	Intensity sensors, lamp status, UV transmittance, and flow rate
UV/AOP	
Ozone/AOP	Flow rate
Chlorine Disinfection	Cl_2, residual (0.4 mg/L)
Granular Activated Carbon	Flow rate
Final chemical treatment CCP	UV254, TOC
Notes: AWTFs will be expected to propose additional online indicators to assess system performance.	

Table C - 2: Primers and probes used for quantification of virus genomes by dPCR

Virus	Primer and probe	Sequence (5'→3')[a, b]	Reference
Adenovirus	AQ2 AQ1 AP	GCCCCAGTGGTCTTACATGCACATC GCCACGGTGGGGTTTCTAAACTT FAM- TGCACCAGACCCGGGCTCAGGTACTCCG A-BHQ1	(Heim et al., 2003)
Aichi virus	AiV-AB-F AiV-AB-R AiV-AB-TP	GTCTCCACHGACACYAAYTGGACGTTGTACATRGCAGCCCAGG FAM-TTYTCCTTYGTGCGTGC-MGB-NFQ	(Kitajima et al., 2013)
Enterovirus	EV1F EV1REV	CCCTGAATGCGGCTAAT TGTCACCATAAGCAGCCA FAM-ACGGACACCCAAAGTAGTCGGTTC- BHQ1	(Gregory et al., 2006)
crAssphage	crAssph-F crAssph-R crAssph-P	CAGAAGTACAAACTCCTAAAAAACGTAGAG GATGACCAATAAACAAGCCATTAGC [FAM] AATAACGATTTACGTGATGTAAC [MGB]	(Stachler et al., 2017)
Norovirus GI	COG1F COG1R RING1(a)-TP RING1(b)-TP	CGYTGGATGCGNTTYCATGA CTTAGACGCCATCATCATTYAC FAM-AGATYGCGATCYCCTGTCCA-BHQ1FAM- AGATCGCGGTCTCCTGTCCA-BHQ1	(Kageyama et al., 2003)
Norovirus GII	COG2F COG2R RING2-TP	CARGARBCNATGTTYAGRTGGATGAG TCGACGCCATCTTCATTCACA FAM-TGGGAGGGCGATCGCAATCT-BHQ1	(Kageyama et al., 2003)

[a] Mixed base in degenerate primer and probe is as follows: Y = C, T; D is A, G, or T; and R is an A or G
[b] The FAM (6-carboxyfluorescein) quencher is BHQ-1 (Black Hole Quencher). The FAM quencher is a minor groove binder nonfluorescent quencher (MGBNFQ).

Pretreat virus concentrates with nucleases prior to nucleic acid extraction in order to digest unprotected nucleic acids, thereby reducing the detection of viral DNA/RNA by RT-dPCR/dPCR from virions with degraded capsids. Viral nucleic acids were extracted using the AllPrep PowerViral DNA/RNA kit (QIAGEN Inc, Valencia, CA) following the manufacturer's instructions. The detection and quantification of virus genomes (Adenovirus, GI Norovirus, GII Norovirus Enterovirus, Aichi virus, and crAssphage) were accomplished by digital PCR using QIAcuity Software Suite 1.2. of the QIAcuity dPCR instrument for data acquisition. All these methods were performed following standard protocols previously described (Betancourt, 2023).