Draft White Paper Discussion On:

Proposed Changes for Modeled Long-Term Treatment

October 5, 2023

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Executive Summary

In 2021, the State Water Board released the first Drinking Water Needs Assessment (Needs Assessment).[1] A core component of the Needs Assessment is the Cost Assessment. The Cost Assessment is a model comprised of decision criteria, cost assumptions, and calculation methodologies used to estimate a statewide cost for implementing long-term and interim solutions for Failing public water systems,[2] At-Risk public water systems, At-Risk state small water systems and domestic wells.[3]

In 2022, the State Water Board began re-building its Cost Assessment Model to update and enhance its estimation outputs. The State Water Board is seeking public input on the proposed updates to the Cost Assessment Model through a series of webinar workshops and associated white papers. The State Water Board has released two white papers and hosted two public workshops to seek stakeholder feedback on the Cost Assessment Model re-build:

(1) August 2022: *Proposed Changed for the Cost Assessment*.[4]
(2) July 2023: *Proposed Updates to the Drinking Water Cost Assessment Model – Physical Consolidation Analysis*.[5]

This white paper follows the recommendations from the previous white papers and is the next step in the proposed updated Cost Assessment Model. **When modeled consolidation as a *Joining*[6] system is not viable**, the Cost Assessment Model will identify treatment technologies as possible long-term solutions for Failing water systems and At-Risk state small water systems and domestic wells.

The State Water Resources Control Board (State Water Board) is proposing an updated, streamlined methodology for estimating modeled **long-term treatment capital**

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[1] 2021 Drinking Water Needs Assessment Report: https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/documents/needs/2021_needs_assessment.pdf

[2] Failing Water Systems Criteria: https://www.waterboards.ca.gov/water_issues/programs/hr2w/docs/hr2w_expanded_criteria.pdf

[3] 2023 Risk Assessment Results for public water systems, state small water systems and domestic wells: https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/documents/needs/2023needsassessment.pdf

[4] Proposed Changes for the Cost Assessment White Paper: https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/documents/needs/cost-assessment-white-paper.pdf

[5] Workshop 1, July 14, 2023: Proposed Updates to the Drinking Water Cost Assessment Model – Physical Consolidation Analysis White Paper: https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/docs/2023/20230714-final-cost-assessment-consolidation-white-paper.pdf

[6] Joining Systems: Commonly smaller public water systems, state small water systems, and domestic wells that are dissolved into an existing Receiving public water system and are no longer responsible for providing water to their own customers.

and operations and maintenance (O&M) costs. The proposed changes to the Cost Assessment Model include:

- Utilizing additional information about each Failing water system to better identify which systems to include in the treatment analysis and better match potential modeled treatment to the Failing system's violations. For example, systems that are Failing for multiple monitoring and reporting violations will ***not*** have treatment modeled as a potential solution.
- Removing the sustainability and resiliency assessment to accommodate the new approach for matching potential model solutions to each system based on their challenges identified by Failing criteria or the Risk Assessment for state small water systems and domestic wells.
- Lowering the modeled decentralized treatment threshold for Failing public water systems from 200 to 20 service connections for most, but not all contaminants. This means more water systems will be assessed for centralized treatment over decentralized treatment.
- Enhancing underlying capital and O&M cost estimate assumptions to reflect current market prices utilizing updated U.S. Environmental Protection Agency (U.S. EPA) treatment models, vendor-provided quotes, data from State Water Board funded projects, and staff recommendations.

The focus of this white paper is to provide an overview of these proposed enhancements to the modeled treatment analysis component of the Cost Assessment Model and solicit public feedback. It is important to note that the purpose of the Cost Assessment Model is to assist the State Water Board in making budget decisions for the Safe and Affordable Drinking Water Fund and informing other policy matters. The Cost Assessment Model will not be used to inform system or community-level decisions around drinking water solution implementation or funding allocations. The State Water Board recognizes that the ultimate solution in each case will involve a more detailed investigation of each water system and should include the input of the community and other stakeholders.

The State Water Board will continue to host public workshops[7] to provide opportunities for stakeholders to learn about and contribute to the State Water Board's efforts to develop a more robust Cost Assessment Model for public water systems, state small water systems, and domestic wells. Future workshops will explore underlying cost assumptions associated with each potential model solution included in the Cost Assessment Model.

[7] Workshop 1, July 14, 2023: Proposed Updates to the Drinking Water Cost Assessment Model – Physical Consolidation Analysis White Paper: https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/docs/2023/20230714-final-cost-assessment-consolidation-white-paper.pdf

Modeled Treatment Analysis Overview

The goal of the Cost Assessment is to estimate the potential long-term and short-term costs of addressing issues for Failing water systems, At-Risk water systems, At-Risk state small water systems, and At-Risk domestic wells. A core component of the Cost Assessment Model is the selection and cost estimation of treatment technologies for Failing water systems and At-Risk state small water systems and domestic wells where modeled physical consolidation is not viable as a *Joining*[8] system. At-Risk public water systems are excluded from the long-term modeled treatment analysis. Depending on the At-Risk public water system's economic status and size, the system may be assessed for an Administrator, technical assistance, and other essential infrastructure in the Cost Assessment Model.[9]

It is important to note that the Cost Assessment is not intended to identify actual solutions that should be implemented for a given system. An evaluation of each system will be needed to identify and cost a range of solutions. As the State Water Board's data improves, the Cost Assessment will improve over time.

The original 2021 Cost Assessment Model methodology was developed in partnership between the State Water Board, University of California, Los Angeles (UCLA) Luskin Center for Innovation, Corona Environmental Consulting (Corona), and Sacramento State University Office of Water Programs. The original Model was developed through extensive stakeholder engagement through public workshops and published white papers from 2019 through 2021. All materials related to the 2021 Cost Assessment Model are available on the State Water Board's website.

The original 2021 Model employed a three-step approach for identifying the best long-term modeled treatment solution for Failing water systems with water quality violations (Figure 1). In Step 1, the Model would assess Failing water systems; select treatment technologies based on the system's failing analyte(s); estimate capital and operational costs for centralized treatment, decentralized treatment, and physical consolidation; and then compare the different potential solutions across several criteria in Step 2 (Sustainability & Resiliency Assessment) of the Model before selecting the final modeled solution in Step 3.

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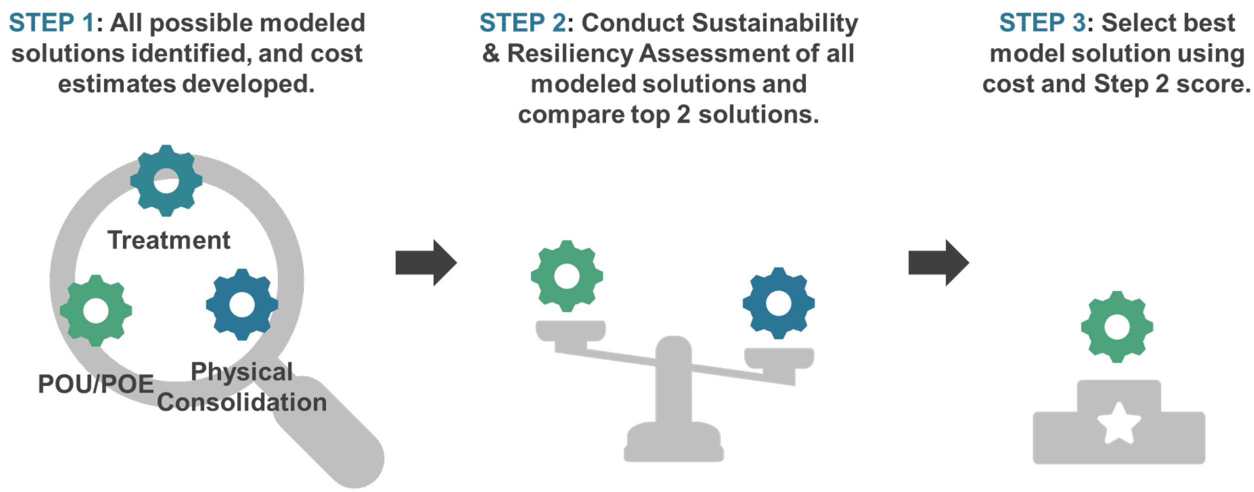
[8] Joining Systems: Commonly smaller public water systems, state small water systems, and domestic wells that are dissolved into an existing Receiving public water system and are no longer responsible for providing water to their own customers.

[9] The Cost Assessment Model's methodology and cost assumptions for Administrator, technical assistance, and other essential infrastructure will be explored in the December 2023 White Paper and public webinar workshop.

Figure 1: 2021 Cost Assessment Model Long-Term Solution Selection Process for Failing Water Systems



For Failing water systems, the 2021 Cost Assessment selected decentralized treatment (POU/POE) for 35%; centralized treatment for 45%; and physical consolidation for 20%. At the time of publication, the State Water Board recognized inherent limitations in the original Model that led to the over-selection of decentralized treatment and under-selection of physical consolidation as the modeled long-term solution. These limitations were attributed to the lack of data availability; the exclusion of modeled regional consolidation projects that would have driven down the modeled cost estimate of physical consolidation; and the inability of the Model's design to account for the inherent risk and long-term maintenance challenges posed by decentralized treatment. Therefore, the 2021 Cost Assessment's results did not fully reflect the State Water Board SAFER program's core mission and direction to promote physical consolidations where feasible and only advance decentralized treatment where no other long-term options may be viable.

Based on stakeholder feedback and internal deliberations, the State Water Board began rebuilding the Cost Assessment Model in 2022. The proposed updated Model takes a more streamlined approach to identifying **long-term solutions** for Failing public water systems with water-quality related violations (Figure 2).[10] The Model first assesses the viability for physical consolidation for all Failing systems. If physical consolidation is not viable, then alternative centralized and decentralized treatment solutions are explored

[10] Failing water systems that are failing due to monitoring and reporting violations will not be assessed for long-term or short-term modeled treatment. Depending on the Failing system's economic status and size, the system may be assessed for an Administrator, technical assistance, and other essential infrastructure. These cost estimate assumptions will be explored in the next workshop and white paper.

At-Risk public water systems are excluded from the long-term and short-term modeled treatment analysis, steps 2 and 3 in Figure 2. Depending on the At-Risk public water system's economic status and size, the system may be assessed for an Administrator, technical assistance, and other essential infrastructure.

State small water systems and domestic wells at high-risk in the Risk Assessment's *Water Quality* category are assessed for decentralized long-term solutions only in the treatment analysis.

by the Model. The State Water Board has recommended the removal of the "Sustainability & Resiliency Assessment" (STEP 2 in Figure 1) comparing estimated physical consolidation capital costs to centralized and decentralized treatment.

Figure 2: Proposed Updated Cost Assessment Model Long-Term Solution Selection Process for Failing Public Water Systems

The State Water Board released a draft White Paper on July 14, 2023, providing an overview of the proposed changes to STEP 1; determining if modeled physical consolidation is viable. In the proposed updates to the Cost Assessment Model, physical consolidation analysis is conducted in advance of any other modeled long-term solution for Failing water systems to ensure that it is the first modeled solution considered. Summary of public feedback received on the proposed changes to the Cost Assessment Model's physical consolidation analysis methodology are summarized in Appendix D.

Where physical consolidation is not viable for Failing water systems or where the Receiving water systems is Failing, the Cost Assessment Model will assess if centralized or decentralized treatment is the best modeled long-term solution. It is important to note that the Cost Assessment Model will continue to exclude At-Risk public water systems from the treatment analysis. The Model will assess POU/POE for At-Risk state small water systems and domestic wells where water quality is the driver for their risk status.

The following sections of this white paper summarize the proposed steps taken within the updated Cost Assessment Model to identify the best modeled long-term treatment solution for Failing water systems, At-Risk state small water systems, and domestic wells where modeled physical consolidation is not viable. These steps also include an overview of how the Cost Assessment Model will estimate capital costs and 20-year O&M costs:

STEP 1: Identification of Systems to Include in the Modeled Treatment Analysis

STEP 2: Matching System Challenges to Modeled Treatment Technologies

STEP 3: Calculate Estimated Modeled Treatment Capital Costs

STEP 4: Calculate Estimated Modeled Treatment Operations & Maintenance (O&M) Costs

STEP 5: Estimate Additional Needs: Administrator; Technical Assistance; and Other Essential Infrastructure

NOTE: The State Water Board will be publishing a white paper summarizing STEP 5 cost assumptions and model criteria in December 2023.

Step 1: Identification of Systems to Include in the Modeled Treatment Analysis

The 2021 Cost Assessment Model only assessed treatment as a long-term solution for Failing water systems with water-quality related primary and secondary MCL violations. It also modeled decentralized treatment for At-Risk[11] state small water systems and domestic wells.

Failing Public Water Systems

Since 2021, the State Water Board has expanded the Failing criteria for public water systems to include treatment technique violations, monitoring and reporting violations, and *E. coli* violations.[12] The proposed updated Cost Assessment Model will continue to model long-term treatment for Failing water systems with water-quality related violations (Table 1) where modeled physical consolidation as a *Joining* system is not viable. Failure due to monitoring and reporting violations will be assessed for potential Administrator and/or technical assistance in Cost Assessment Model. Modeled long-term and interim solutions related to these needs will be explored in the next white paper and workshop.

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[11] 2023 Drinking Water Needs Assessment Report, Appendix B, Risk Assessment Methdology for state samll water sysems and domestic wells, P221: https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/documents/needs/2023needsassessment.pdf

[12] Failing Water Systems Criteria: https://www.waterboards.ca.gov/water_issues/programs/hr2w/docs/hr2w_expanded_criteria.pdf

Table 1: Failing Public Water Systems Assessed for Modeled Long-Term Treatment

Failing Water Systems	2021 Model	Recommended Update
Systems where modeled consolidation is viable	Excluded	Included, but only where the modeled consolidation *Receiving* system is Failing for a water-quality related violation. Treatment is not modeled for *Joining* Failing systems.
Systems where modeled consolidation is NOT viable		
Primary MCL	Included	Included
Secondary MCL	Included	Included
E. coli MCL	Excluded[13]	Included
Treatment Technique	Excluded[14]	Included
Monitoring & Reporting	Excluded[15]	Excluded

Table 2 summarizes how the proposed updates in Table 1 may impact the number of Failing water systems the Cost Assessment Model would assess for long-term treatment. Failing water systems are determined using the most up-to-date criteria utilized by the State Water Board.[16] The current list of Failing systems can be accessed through the SAFER Dashboard.[17]

[13] Failing criteria did not exist at the time the 2021 Cost Assessment Model was released.

[14] Failing criteria did not exist at the time the 2021 Cost Assessment Model was released.

[15] Failing criteria did not exist at the time the 2021 Cost Assessment Model was released.

[1616] Failing Criteria for Public Water Systems
https://www.waterboards.ca.gov/water_issues/programs/hr2w/docs/hr2w_expanded_criteria.pdf

[1717] SAFER Dashboard
https://www.waterboards.ca.gov/safer/safer_data.html

Table 2: Preliminary Estimate of Failing Water Systems Assessed for Modeled Long-Term Treatment

Total Failing Water Systems[18]	2021 Model Criteria[19]	Recommended Updated Criteria[20]
381	195 (51.2%)[21]	200 (52.4%)[22]

At-Risk State Small Water Systems and Domestic Wells[23]

The 2021 Risk Assessment[24] methodology for state small water systems and domestic wells was based on identifying areas where groundwater is at high-risk of containing contaminants that exceed safe drinking water standards. At-Risk state small water systems and domestic wells were evaluated for two long-term solutions in the 2021 Cost Assessment: physical consolidation,[25] and decentralized treatment (POU/POE).

Since 2021, the Risk Assessment methodology for state small water systems and domestic wells has evolved to identify locations served by these systems that are at high-risk in the following categories: *Water Quality*, *Water Shortage* (added in 2022), and/or *Socioeconomic Risk* (added in 2023).

The proposed updated Cost Assessment Model will evaluate long-term solutions for communities served by state small water systems and domestic wells that are designated high-risk in the Risk Assessment's two categories: *Water Quality* and *Water*

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[18] Failing list of systems is from January 1, 2023.

[19] This count excludes 11 systems that are Failing due to Monitoring and Reporting violations.

[20] This count excludes 7 systems that are Failing due to Monitoring and Reporting violations.

[21] The number of systems where physical consolidation is viable is 134 Failing water systems, utilizing the 2021 Cost Assessment Model criteria and assumptions.

[22] The number of systems where physical consolidation is viable is 169 Failing water systems, utilizing the proposed updated Cost Assessment Model criteria and assumptions.

[23] 2023 Drinking Water Needs Assessment Report, Appendix B, Risk Assessment Methdology for state samll water sysems and domestic wells, P221: https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/documents/needs/2023needsassessment.pdf

[24] 2021 Drinking Water Need Assessment Report: https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/documents/needs/2021_needs_assessment.pdf.

[25] Physical consolidation is explored by the Cost Assessment Model for At-Risk state small water systems and domestic wells that have high modeled risk for water quality or water shortage, detailed Risk Assessment methodology is presented in Appendix B of the 2023 Drinking Water Needs Assessment report. The proposed physical consolidation criteria for At-Risk state small water systems and domestic wells includes both distance and cost viability criteria. Distance criteria: within 0.38 miles of a Receiving community water system boundary or intersecting the modeled route of a modeled physical consolidation of two public water systems. Cost criteria: the modeled physical consolidation cost is < $2 million for a state small water system and < $150,000 for a domestic well.

Shortage. Locations that are only high-risk in the third category, *Socioeconomic Risk*, will be excluded from the Cost Assessment.

The physical consolidation analysis within the updated Cost Assessment Model will include state small water systems and domestic wells that are designated high-risk in either the *Water Quality* or *Water Shortage* categories of the Risk Assessment. However, in the long-term treatment component of the updated Cost Assessment Model, only state small water systems and domestic wells that are (1) high-risk within the *Water Quality* category and (2) not meeting the modeled physical consolidation criteria will be included in the analysis. Therefore, state small water systems and domestic wells that are high-risk within the *Water Shortage* category that are not meeting the modeled physical consolidation criteria will be excluded from the modeled long-term treatment analysis.[26] The updated Cost Assessment Model will develop a cost estimate for the construction of a new well as a long-term solution for these systems. The detailed criteria for systems included in the new well analysis is discussed in "Proposed Changes for the Cost Assessment" draft white paper.[27]

Table 3: Preliminary Estimate of At-Risk State Small Water Systems and Domestic Wells Assessed for Decentralized Treatment

Systems High-risk for *Water Quality*	Total Systems	2021 Model Criteria	Recommended Updated Criteria
State Small Water Systems	**699**	303[28]	288[29]
Domestic Wells	**99,814**	36,911[30]	43,651[31]

[26] Constructing a new well is considered a long-term solution that will be further discussed and evaluated in future workshops assessing "Complementary long-term solutions and emergency solutions cost assumptions."

[27] Draft White Paper Discussion on "Proposed Changes for the Cost Assessment": https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/documents/needs/cost-assessment-white-paper.pdf

[28] The count of state small water systems where the Model selected decentralized treatment as the long-term solution in the 2021 Needs Assessment. 2021 Drinking Water Need Assessment Reprot, P75: https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/documents/needs/2021_needs_assessment.pdf. The number of systems where physical consolidation is viable was 142, utilizing the 2021 Cost Assessment Model criteria and assumptions.

[29] The number of state small water systems where physical consolidation is viable is 451, utilizing the 2023 Risk Assessment results and the updated modeled distance criteria, as detailed in Appendix D. Refer to the Physical Consolidation Analysis White Paper for more details: https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/docs/2023/20230714-final-cost-assessment-consolidation-white-paper.pdf

[30] The count of domestic wells where the Model selected decentralized treatment as the long-term solution in the 2021 Needs Assessment. 2021 Drinking Water Need Assessment Reprot, P75: https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/documents/needs/2021_needs_assessment.pdf. The number of domestic wells where physical consolidation is viable 25,696 domestic wells. utilizing the 2021 Cost Assessment Model criteria and assumptions.

[31] The number of domestic wells where physical consolidation is viable is 64,476, utilizing the 2023 Risk Assessment results and the updated modeled distance criteria, as detailed in Appendix D. Refer to the

Step 2: Matching System Challenges to Modeled Treatment Technologies

The Cost Assessment Model utilizes Failing water system information regarding water quality violations and associated contaminants to identify potential long-term treatment solutions when modeled physical consolidation as a *Joining* system is not viable. Best Available Technologies (BAT) will be identified by the Cost Assessment Model that can reduce contaminant concentrations that exceeded the Maximum Contaminant Level (MCL).

The 2021 Cost Assessment Model included multiple modeled treatment solutions based on Title 22 California Code of Regulations (CCR).[32] Title 22 defines applicable BATs as the technologies identified by the State Water Board as the best available technology, treatment techniques, or other means available for achieving compliance with MCLs. While selecting BATs for contaminants of concern, many factors should be taken into consideration such as feasibility, availability, economic viability, and environmental wastes or impacts.

Centralized Treatment

Centralized drinking water treatment is when a water system extracts water from one or more sources and treats that water before conveying it through a distribution system to its customers. In the Cost Assessment Model, centralized treatment is modeled for Failing public water systems. Compared to decentralized treatment, centralized treatment can often result in cost savings by treating a larger volume of water at a more central location and distributing potable water to customers. By centralizing treatment, less labor and materials may be required to maintain the treatment technologies and practices compared to decentralized treatment. Furthermore, centralized treatment technologies often have the ability to remove many more contaminants that otherwise cannot be removed with decentralized treatment.

In the 2021 Cost Assessment Model, centralized treatment was modeled for Failing water systems with service connection greater than 200. For the proposed updated Cost Assessment Model, the centralized treatment threshold is lowered to 20 service connections for most contaminants. This change will ensure that more Failing public water systems are assessed for modeled centralized treatment. The Cost Assessment Model excludes state small water systems and domestic wells from modeled centralized treatment due to its higher capital and O&M costs compared to decentralized treatment.

There are many centralized treatment technologies that are available to reduce contamination; however, the State Water Board designed the Cost Assessment Model

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Physical Consolidation Analysis White Paper for more details: https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/docs/2023/20230714-final-cost-assessment-consolidation-white-paper.pdf

[32] Title 22, Article 12, Table 64447.2-A, Table 64447.3-A, Table 64447.4-A https://govt.westlaw.com/calregs/Browse/Home/California/CaliforniaCodeofRegulations?guid=I799B50E05B6111EC9451000D3A7C4BC3&originationContext=documenttoc&transitionType=Default&contextData=(sc.Default)

to include modeled treatment technologies that have lower operational costs and are easier to maintain. This decision was, and continues to be, driven by the high percentage of Failing water systems that are small (less than 3,000 service connections). Small water systems often have less financial capacity to sustainably operate more sophisticated and resource-intensive treatment technologies.

Due to the high expenses associated with waste disposal for certain types of contaminants, the Cost Assessment Model assumes that liquid stream residuals disposal is not available on-site for the Failing water systems included in the analysis. This assumption eliminated treatment technologies like reverse osmosis and electrodialysis from the Cost Assessment Model because the residuals volume requiring disposal would be physically and cost prohibitive. Further, while processes like lime softening may be effective for some contaminants, they are rarely implemented for Failing water systems. Therefore, the Cost Assessment Model only includes the bolded technologies in Table 4. Table 5 summarizes the drinking water BATs applied for each violation type.

Table 4: Summary of Drinking Water BATs for Common Water Quality Violations

Violation-Related Contaminant	Chemical Class	BAT
Arsenic	Inorganic	• Activate Alumina • Ion Exchange • **Coagulation/Filtration**[33] • Lime Softening • Reverse Osmosis • Electrodialysis • Oxidation Filtration
1,2,3-trichloroproproane (1,2,3-TCP)	Organic	• **Granular Activated Carbon**
Nitrate	Inorganic	• **Ion Exchange** • Reverse Osmosis • Electrodialysis
Uranium (Combined)	Radionuclides	• **Ion Exchange** • Coagulation/Filtration • Lime Softening • Reverse Osmosis
Combined Radium-226 and Radium-228	Radionuclides	• **Ion Exchange** • Lime Softening • Reverse Osmosis
Fluoride	Inorganic	• **Activate Alumina**

[33] Adsorption is assumed for systems with less than 500 service connections due the relatively simple operations when compared to coagulation/filtration.

Table 5: Summary Comparison of Failing Water System Modeled Centralized Treatment Criteria

Treatment Technology	2021 Model	Recommended Update

Granular Activated Carbon (GAC)	Failing public water systems ≥ **200** service connections.
	
	Failing Contaminants:
	• Dibromochloropropane (DBCP)
	• Ethylene Dibromide (EDB)
	• 1,2,3- Trichloropropane (1,2,3-TCP)
	• 1,1-Dichloroethylene (1,1-DCE)
	• Disinfection Byproducts (DBPs)
	    o Total Trihalomethanes (TTHM)
	    o Haloacetic Acids (five) (HAA5)
		Failing public water systems ≥ **20** service connections and modeled physical consolidation as a *Joining* system is not viable.
		
		Failing Contaminants:
		• Dibromochloropropane (DBCP)
		• Ethylene Dibromide (EDB)
		• 1,2,3- Trichloropropane (1,2,3-TCP)
		• 1,1-Dichloroethylene (1,1-DCE)
		• Disinfection Byproducts (DBPs)
		    o Total Trihalomethanes (TTHM)
		    o Haloacetic Acids (five) (HAA5)

Adsorption	Failing public water systems with service connections < **500**. Failing Contaminant: • Arsenic	Failing public water systems with service connections between **20** ≤ N < **500** and modeled physical consolidation as a *Joining* system is not viable. Failing Contaminant: • Arsenic influent conc. < 50 µg/L
Coagulation Filtration	Failing public water systems with service connections ≥ **500**. Failing Contaminant: • Arsenic	Failing public water systems with service connections ≥ **500** and modeled physical consolidation as a *Joining* system is not viable. Failing Contaminant: • Arsenic influent conc. ≥ 50 µg/L
Filtration	Failing public water systems with service connections ≥ **200**. Failing Contaminants: • Iron	Failing public water systems with service connections ≥ **20** and modeled physical consolidation as a *Joining* system is not viable.

Treatment Technology	2021 Model	Recommended Update
	• Manganese	Failing Contaminants: • Iron • Manganese
Regenerable Resin Anion Exchange	Failing public water systems with service connections ≥ **200**. Failing Contaminants: • Nitrate • Radium	Failing public water systems with service connections ≥ **20** and modeled physical consolidation as a *Joining* system is not viable. Failing Contaminant: • Nitrate influent conc.< 25 mg/L • When mean sulfate concentration <250 mg/l
Regenerable Resin Cation Exchange	Excluded.	Failing public water systems with service connections ≥ **20**. Failing Contaminant: • Radium 226 and 228
Single-Use Ion Exchange	Failing public water systems with service connections ≥ **200**. Failing Contaminants: • Uranium • Perchlorate • Gross Alpha	Failing public water systems with service connections ≥ **20** and modeled physical consolidation as a *Joining* system is not viable. Failing Contaminants: • Uranium • Perchlorate • Gross Alpha
Activated Alumina	Failing public water systems with service connections ≥ **200**. Failing Contaminant: • Fluoride	Failing public water systems with service connections ≥ **20** and modeled physical consolidation as a *Joining* system is not viable. Failing Contaminant: • Fluoride
4-log Virus Treatment	Failing public water systems with groundwater sources. Failing Contaminants: • Fecal contaminants (microorganisms) ○ *E. coli*	Failing public water systems and modeled physical consolidation as a *Joining* system is not viable. • Groundwater sources. Failing Contaminants: • Fecal contaminants (microorganisms)

Treatment Technology	2021 Model	Recommended Update
		○ *E. coli*
Surface Water Treatment Package Plant *4-log Virus Treatment included.*	Failing public water systems with surface water sources. Failing Contaminants: • Aluminum • Turbidity • Fecal contaminants (microorganisms) ○ *E. coli*	Failing public water systems and modeled physical consolidation as a *Joining* system is not viable. • Surface water sources. Failing Contaminants: • Aluminum • Turbidity • Fecal contaminants (microorganisms) ○ *E. coli*

In the proposed updated Cost Assessment Model, water sources are assumed to be far enough apart from each other that separate treatment is needed for each source. Given that assumption, the Cost Assessment Model selects modeled treatment technologies per source, rather than per water system.

Some Failing water systems have one or more active sources that have multiple (co-occurring) contaminants exceeding an MCL. For these Failing water systems, the Cost Assessment Model will identify the modeled treatment technology needed to address each contaminant. Each technology will be costed out by the Cost Assessment Model separately per contaminant, per source. The Cost Assessment Model then determines the final treatment cost estimate for the Failing water systems using the following decision criteria (refer to Appendix A for more details):

- If the co-contaminants can be removed with the same treatment technology and have the same modeled treatment costs; then, the Cost Assessment Model will only include the cost of **a single treatment technology** per source.
- If the co-contaminants can be removed with the same treatment technology, but each contaminant has different modeled annual O&M costs; then the Cost Assessment Model will select the single treatment technology with the **highest** annual O&M cost.
- If the co-contaminants cannot be removed with the same treatment technology; then, the Cost Assessment Model will **combine** the costs of multiple treatment technologies.
- If the Failing water system has one or more sources with co-contaminants that would have different modeled treatment technologies; then, the Cost Assessment Model will utilize a set of more comprehensive decision criteria to select which **treatment**

technology(ies) best suit the co-contaminants. Refer to Combined Treatment Cost Assumptions in Appendix A for the example decision.

Decentralized Treatment

Decentralized treatment, such as POU and POE devices, are often installed at individual homes or businesses when centralized treatment is not feasible. Centralized treatment may not be feasible due to the lack of financial resources to support an operator, invest and maintain distribution infrastructure, and/or the distance may be too great to connect a customer to a centralized drinking water system.

In the 2021 Cost Assessment Model, decentralized treatment was modeled for Failing water systems with less than 200 service connections. However, on average, more than 50% of Failing water systems have less than 200 service connections. Therefore, the State Water Board recommends lowering the decentralized treatment threshold from less than 200 to 20 service connections for the proposed updated Cost Assessment Model. This change will ensure that more Failing water systems are assessed for modeled centralized treatment when modeled physical consolidation is not viable.

Failing water systems that serve schools, have less than 20 service connections, and have MCL violations related to inorganic contaminants will not be assessed for decentralized (POU) treatment in the updated Cost Assessment Model. Instead, these systems will be assessed for centralized treatment. Table 6 below summarizes key differences in modeling POU and POE between the 2021 Model and the recommended update.

Table 6: Summary Comparison of Failing Water System Modeled Decentralized Treatment Criteria

Treatment Technology	2021 Model	Recommended Update

Point of Use (POU)	• Automatically selected for Failing public water systems ≤ **200** service connections.
	
	Failing Contaminants:
	• Inorganics[34]
	  ○ When mean Nitrate concentration < 25 mg/l
	• When no bacteriological contaminant is present.
		• Automatically selected for Failing public water systems ≤ **20** service connections when modeled physical consolidation as a *Joining* system is not viable.
		
		Failing Contaminants:
		• Inorganics
		  ○ When mean Nitrate concentration < 25 mg/l
		• When no bacteriological contaminant is present.

[34] Inorganics include aluminum, arsenic, antimony, barium, cadmium, chromium, copper, fluoride, gross alpha radioactivity, gross beta radioactivity, lead, mercury, nickel, nitrate, perchlorate, radium 228, thallium, uranium chromium hexavalent.

Treatment Technology	2021 Model	Recommended Update
Point of Entry (POE)	• Automatically selected for Failing public water systems ≤ **200** service connections. Failing Contaminants • Organics[35]	• Automatically selected for Failing public water systems ≤ **20** service connections when modeled physical consolidation as a *Joining* system is not viable. Failing Contaminants • Organics

Centralized treatment is considered unfeasible for At-Risk state small water systems and domestic wells due to its higher upfront capital costs and on-going O&M expenses. Therefore, decentralized treatment is the only modeled treatment option that is included in the Cost Assessment Model. Table 7 below summarizes system criteria and where POU or POE devices are modeled.

Table 7: Summary Comparison of State Small Water Systems and Domestic Wells POU/POE Criteria

Treatment Technology	2021 Model	Recommended Update

Point of Use (POU)	At-Risk due to water quality.
	
	High water quality Contaminants:
	• Inorganics
	  ○ When mean Nitrate concentration < 25 mg/l
	• When no bacteriological contaminant is present
		At-Risk due to high water quality score and modeled physical consolidation is not viable.
		
		High water quality Contaminants:
		• Inorganics
		  ○ When mean Nitrate concentration < 25 mg/l
		• When no bacteriological contaminant is present

Point of Entry (POE)	At-Risk due to water quality. High water quality Contaminants: • Organics	At-Risk due to high water quality score and modeled physical consolidation is not viable. High water quality Contaminants: • Organics

[35] Organics include ethylene dibromide (EDB), dibromochloropropane (DBCP), 1,2,3-trichloropropane, benzene, benzo(a)pyrene, carbon tetrachloride, chloroform, di(2-ethylhexyl) phthalate (DEHP), dichloromethane (methylene chloride), MTBE (methyl-tert-butyl ether), n-nitroso dimethylamine, pentachlorophenol, tetrachloroethene, total trihalomethanes, trichloroethene, vinyl chloride.

Step 3: Calculate Estimated Modeled Treatment Capital Costs

The Cost Assessment Model utilizes a set of assumptions to develop estimates for long-term treatment capital costs when modeled physical consolidation is not viable. The 2021 Cost Assessment Model included many treatment cost assumptions which are detailed in the 2021 Drinking Water Needs Assessment.[36] The State Water Board has reviewed the 2021 Cost Assessment Model's cost assumptions, conducted internal and external research, and has proposed additions and updates to ensure the updated Cost Assessment Model incorporates current market values.

Internal research and outreach included a thorough review of projects funded by the State Water Board and consultations with knowledgeable staff. External research and outreach consisted of a literature review, as well as consultations with water systems, vendors, manufacturers, service providers, and/or consultants. Appendix B and C details the cost assumptions used in the 2021 Cost Assessment Model and summarizes new capital component cost estimates from both internal and external sources for each modeled treatment technology. It includes the State Water Board's proposed recommendations and an explanation of how each recommendation was developed.

It is worth noting that the Cost Assessment Model utilizes estimated Maximum Daily Demand (MDD), rather than Average Daily Demand (ADD) in calculating estimated capital costs. MDD allows the Cost Assessment Model to accommodate or "size" modeled treatment technologies for potential population increases or account for any seasonal supply variances. The calculation methodology is detailed in Appendix B.

For some contaminants, U.S. EPA's work breakdown structure (WBS) Model[37] has been utilized to calculate total capital costs or itemized unit cost estimates. Special attention was made to ensure cost assumptions were tailored to reflect California pricing as much as possible.

The Cost Assessment Model's estimated treatment technology capital costs are adjusted using several multipliers as summarized Table 8. Refer to Appendix B for additional details.

[36] 2021 Drinking Water Need Assessment: https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/documents/needs/2021_needs_assessment.pdf

[37] Older U.S. EPA's WBS Model versions are not available online and are regularly replaced with newer versions. Most recent U.S. EPA WBS models is from March, 2023: https://www.epa.gov/sdwa/drinking-water-treatment-technology-unit-cost-models

Table 8: Capital Cost Adjustments

Multiplier	Adjustment Purpose	Technologies
Engineering multiplier	Convert unit capital cost to installed cost.[38]	GAC, Adsorption, Coagulation Filtration, Filtration, Single Use Ion Exchange, Activated Alumina
ENR CCI	Adjust the cost to current market price.	GAC, Adsorption, Coagulation Filtration, Filtration, Single Use Ion Exchange, Activated Alumina, Cation Exchange, Anion Exchange

Step 4: Calculate Estimated Modeled Treatment Operations & Maintenance (O&M) Costs

The Cost Assessment Model includes an estimation of long-term operations and maintenance (O&M) costs for the modeled treatment technologies when physical consolidation is not viable. The State Water Board includes estimated O&M expenses related to modeled long-term technologies because SAFER program funding can support qualifying O&M expenses.[39] Therefore, for planning purposes, it is important for the Cost Assessment to estimate how much O&M assistance may be needed by Failing water systems to operate a new treatment.

The 2021 Cost Assessment Model's O&M methodology included cost estimates capturing four cost category components detailed below. For purposes of the Cost Assessment Model, labor and energy cost estimates utilize the same methodology and assumptions across all treatment technologies except for POU and POE.

Consumables

Water treatment systems require parts and chemical products to be replenished or replaced to properly achieve their intended purpose. Depending on the modeled treatment technology, O&M estimates may account for:

- Chemical Replacement
    - Regeneration salt
    - pH adjustment (carbon dioxide, caustic soda, sulfuric acid)
    - Disinfectant
    - Coagulant (ferric chloride)
- Part Replacement
    - Virgin Granular Activated Carbon
    - Adsorption media

[38] Unit capital cost represents the equipment purchase cost only, the installed capital cost represents total purchase and installation cost. Installation may include labor, piping, and wiring.

[39] FY 2022-23 Fund Expenditure Plan (pp. 3-4) https://www.waterboards.ca.gov/water_issues/programs/grants_loans/docs/2022/final-2022-23-sadw-fep.pdf

- Membranes
- Ion exchange resins
- Cartridge filters

Appendix B and C provides an in-dept overview of which consumables are included in the treatment technology O&M estimates. It also includes information on how the cost estimates were developed.

Waste Discharge

Water treatment processes generate waste, both solid and liquid, that must be disposed of properly to avoid direct or indirect contamination of drinking water or the environment. Waste disposal can significantly increase the operational cost associated with certain treatment technologies. For example, waste disposal can be very expensive due to restrictions and requirements related to its transportation and receiving facility. There are optimization opportunities where water system waste streams can be eliminated (GAC re-use for non-drinking water applications) or minimized (wastewater or backwash can be disposed on-site rather than off-site; eliminating transportation costs). Learn more in Appendix B.

Labor

Operators are responsible for a variety of tasks involving running and maintaining the system to provide an adequate and safe water supply to their customers. Permitted treatment facilities are assigned a minimum operator grade level by the State Water Board. The operator grade level corresponds with the level of operator expertise and knowledge needed to safely operate and maintain the treatment facility. Labor cost estimates are based on the operator grade per treatment technology. Learn more in Appendix B and C.

Electricity

General power supply is needed to run the treatment plant, mainly to pump water and overcome head loss due to friction and elevation changes. For the updated proposed Cost Assessment Model, State Water Board staff conducted external research and internal discussion and recommend maintaining the same power assumptions and equation utilized in the 2021 Cost Assessment Model. Learn more in Appendix B.

20-Year O&M Estimation

The Cost Assessment Model will develop a lifecycle O&M Net Present Value (NPV) cost estimate for each modeled treatment technology. All NPVs are developed based on a 20-year period and an annual 4% interest rate.

Equation 1: O&M NPV Calculations

O&M NPV = Total Annual O&M x [1+i] ^(n-1)/ [i x (1+i) ^n]

Where: Total Estimated Annual O&M = (Consumables + Waste Discharge + Labor + Electricity) i = 4% interest rate

n = 20-year life cycle

It is important to note that the Cost Assessment Model's O&M estimates are not representative of the total O&M costs needs to sustainability run a drinking water system. They only represent the estimated cost associated with the new modeled treatment.

Step 5: Model Additional Infrastructure/Admin Needs

Systems that have long-term modeled treatment will also be assessed for additional interim solutions, other essential infrastructure needs, technical assistance, Administrator assistance, etc. These additional costs will be included in the final statewide Cost Assessment results. The State Water Board expects to publish a white paper in **December 2023** to provide an overview of proposed updates to the Cost Assessment Model's assumptions and cost estimates for additional infrastructure and administration needs. The State Water Board will be seeking public feedback on its proposed updates.

New Well

The State Water Board is proposing to model new well costs for state small water systems and domestic wells that are at high-risk within the Risk Assessment's *Water Shortage* category.[40]

Other Essential Infrastructure (OEI)

Many Failing and At-Risk public water systems have aging infrastructure. Upgrading and replacing them is essential to maintaining compliance with drinking water standards and to ensure system reliability. In the 2021 Cost Assessment Model, OEI needs were developed based on a Kern County, California case study conducted by Corona Environmental on behalf of the State Water Board. The case study identified OEI needs for Failing water system in the County and developed OEI statewide need assumptions.

In the proposed updated Cost Assessment Model, the State Water Board will be assessing OEI needs based on system and location-specific information rather than the Kern County case study assumptions. This new approach will also integrate the Senate Bill 552[41] drought resiliency infrastructure requirements into the OEI estimates. OEI needs include:

- Metering all un-metered service connections.

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[40] 2023 Drinking Water Needs Assessment Report, Appendix B, Risk Assessment Methdology for state samll water sysems and domestic wells, P221: https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/documents/needs/2023needsassessment.pdf

[41] Senate Bill No. 552, Section 10609.62, Chapter 245: https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=202120220SB552

- Backup source of water supply (new well or intertie) for systems with a single source.
- Backup power to ensure continuous operation during a power failure.
- Sounder device to measure static well levels.
- Replace well pump and motor.
- Adding additional storage.
- Adding SCADA (supervisory control and data acquisition) and electrical upgrades.

Bottled Water

The State Water Board is proposing to cost out bottled water as an interim and long-term solution for state small water systems and domestic wells that are at high-risk in the Risk Assessment's Water Quality and/or Water Shortage categories, with the following conditions:

- Physical consolidation is not viable within the Cost Assessment Model.
- Modeled decentralized treatment is not viable due to:
  - Elevated Nitrate concentration > 25mg/l.
  - Microbial contamination.
- Drilling a new well may not be viable.

Bottled water will also be included in the Cost Assessment Model as a possible interim solution for all system types. More details will be available in the 2023 December White Paper.

Additional Costs

Depending on the water system and their identified challenges, the Cost Assessment Model may model additional interim and long-term solution costs. Additional costs may include technical assistance, Administrator assistance, etc. These additional costs will be explored in a subsequent 2023 Cost Assessment Model workshop in December 2023.

Desired Public Feedback and Next Steps

Desired Feedback

The State Water Board is committed to engaging with the public and stakeholder groups to solicit feedback and recommendations on the proposed updates detailed in this paper. Specifically, feedback is desired on the Cost Assessment Model's methodology and underlying assumptions for estimating long-term centralized and decentralized treatment capital and O&M costs. The received feedback will help refine the updated Cost Model over time. **Feedback is due on November 6, 2023**. Feedback may be submitted directly to DDW-SAFER-NAU@waterboards.ca.gov.

The State Water Board will continue to host public workshops to provide opportunities for stakeholders to learn about and contribute to the Cost Assessment Model re-build process. Stakeholders are encouraged to sign-up for the SAFER Program's email list-serve to receive notifications of when the public workshops are scheduled to occur.

The State Water Board is specifically seeking public feedback on the following:

Matching System Challenges to Modeled Treatment Technologies: Step 2 above summarizes the Cost Assessment Model's criteria for selecting treatment technologies for water systems Failing for one or more contaminant. The State Water Board is seeking public feedback on the criteria, including lowering the service connection threshold for modeled centralized treatment.

Treatment Capital Cost Methodology and Assumptions: Appendix B and C detail the proposed updated Cost Assessment Model's methodologies and underlying assumptions for modeled long-term treatment capital cost estimates. The State Water Board is seeking public recommendations and data that can be used to enhance the Cost Assessment Model's output.

Treatment O&M Cost Methodology and Assumptions: Appendix B and C detail the proposed updated Cost Assessment Model's methodologies and underlying assumptions for modeled long-term treatment O&M cost estimates. The State Water Board is seeking public recommendations and data that can be used to enhance the Cost Assessment Model's output.

POU/POE Cost Information: As detailed in Appendix D, the State Water Board conducted extensive internal and external outreach to update the underlying capital and O&M cost assumptions for POU/POE devices. Limited information was readily available and/or public. The State Water Board is seeking cost data related to POU/POE installation and O&M to enhance the Cost Assessment Model.

Bed Volume Estimation Methodology: The Cost Assessment Model includes bed volume estimates for many treatment technology O&M cost estimates. Estimating bed volumes is typically used to measure the performance (*i.e.*, throughput) of treatment media or resin.[42] The State Water Board, in consultation with external water professionals, is seeking a methodology to enhance BV assumptions for the Cost Assessment Model. This effort includes either further validating existing assumptions or developing a new BV estimate methodology that is driven by water quality data for each contaminant.

Next Steps

The State Water Board intends to host one more public workshop in 2023 to provide an opportunity for stakeholders to learn about and contribute to the State Water Board's efforts to develop a more robust Cost Assessment Model for public water systems, state small water systems, and domestic wells. The third and final workshop of this series will

[42] Bed volume number is defined as the volume of contaminated water passing through the media or resin up to the breakthrough point divided by volume of media or resin.

explore the underlying cost assumptions associated with Administrator, technical assistance, essential infrastructure, and emergency solutions.

Appendix A: Methodology for Modeling Treatment for Failing Water Systems with Co-Contaminants within One or More Source

Combined Treatment Cost Assumptions

The Cost Assessment Model will estimate capital and operations and maintenance (O&M) treatment costs for Failing water systems with water quality violations for multiple contaminants within one or more source when modeled physical consolidation is not viable. The Cost Assessment Model employs a set of decision-making criteria to determine the best modeled treatment technology(ies) to address co-occurring contaminants. Table 9 summarizes the decision criteria for a set of frequent co-contaminant combinations.

Table 9: Determination of Final Modeled Treatment Cost Estimate for Co-Contaminants

Criteria	Decision	Co-Contaminants
• Co-contaminants can be removed with the same treatment technology; and • Have the same modeled treatment costs.	The Cost Assessment Model will only include the cost of **a single treatment technology** per source.	**Iron + Manganese**
		TTHM + HAA5
		Nitrate + Nitrite
		Uranium + Gross Alpha
		SWTR-related Contaminants
• Co-contaminants can be removed with the same treatment technology; but • Each contaminant has different modeled annual O&M costs.	The Cost Assessment Model will select the single treatment technology with the **highest** annual O&M cost estimate.	**VOC + VOC**
		Uranium + Perchlorate
		Nitrate + Perchlorate
		Nitrate + Uranium[43]
		Nitrate + Radium[44]
• Co-contaminants cannot be removed with the same treatment technology.	• The Cost Assessment Model will combine the costs of **multiple treatment technologies**	**Arsenic + 1,2,3-TCP**
		Arsenic + Uranium
		Arsenic + Fluoride

[43] In the 2021 Cost Assessment Model, the final modeled capital and O&M costs were estimated by combining the costs of two treatments.

[44] In the 2021 Cost, nitrate and radium used the same modeled treatment technology and the Model only included the cost of a single treatment.

Criteria	Decision	Co-Contaminants
	determined per contaminant. • Refer to Table 4 & Table 5 for the treatment technology per contaminant.	**Uranium + 1,2,3-TCP**
		Nitrate + Iron/Manganese
• Failing water system has one or more sources with co-contaminants that would have different modeled treatment technologies.	***Example*** Coagulation Filtration is chosen as a modeled treatment technology best suit the co-contaminants due to arsenic.	***Example*** **Arsenic + Iron/ Manganese**

Appendix B: Long-Term Centralized Treatment Capital & Operations and Maintenance (O&M) Cost Assessment Model Assumptions

The sections below detail the **capital** and **operations and maintenance (O&M)** cost methodology for each treatment technology utilized in the proposed updated Cost Assessment Model. The capital cost estimates include infrastructure costs incurred by installing treatment. The O&M cost estimates represent the core estimated costs associated with sustaining ongoing treatment.

The Cost Assessment Model O&M cost estimates capture four cost category components: consumable costs, waste discharge costs, labor costs, and electricity costs. Consumable costs and waste disposal costs vary depending on each modeled treatment technology. The Cost Assessment Model's assumptions and calculation methodologies for these components are detailed in each treatment technology section within this Appendix. The electricity and labor O&M cost estimates associated for each modeled treatment utilize the same underlying assumptions and calculations methods. Therefore, to reduce redundancy in this Appendix's documentation, the cost assumptions and calculation methodology for electricity and labor O&M estimates are summarized below. The estimated labor and electricity O&M component costs will be calculated and added to the consumable and water disposal costs calculated for each treatment type.

General Centralized Treatment Model Assumptions

Estimating Water Demand and Flow Rates

The development of estimated water demand for each water system is required to calculate capital and O&M costs within the Cost Assessment Model. Historically, the State Water Board has collected annual demand data from public water systems through the Electronic Annual Report (eAR). However, due to limitations in the eAR's survey design, many public water systems have reported annual demand data in the wrong units of measure or have submitted data that does not meet the Cost Assessment's standards for data quality. Therefore, the 2021 Cost Assessment Model utilizes a standard demand estimation formula to estimate a water system's Average Daily Demand (ADD) and Maximum Day Demand (MDD).[45] After internal discussions with a workgroup of expert engineers, the State Water Board recommends continuing to use the same method for estimating water demand in the updated Cost Assessment Model.

[45] Based on 1,2,3-Trichloropropane Maximum Contaminant Level Regulations, Initial Statement of Reasons and in the California Code of Regulations, Title 22, division 4, chapter 16, section 64454.

https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/documents/123-tcp/sbddw17_001/isor.pdf

Average Daily Demand

Annual water production in million gallons is estimated based on average daily demand, which is used to compute estimated annual O&M costs. Based on the assumptions in the *Initial Statement of Reasons for the1,2,3-Trichloropropane Maximum Contaminant Level Regulations in Title 22, California Code of Regulations*, the following equations are utilized:

Equation 2: Estimating Average Daily Demand (ADD)

Average Daily Demand (ADD) in Gallons per Day (GPD) = Population[46] x 150 gallons/person/day[47]

Equation 3: Converting ADD in Million Gallons (MG) To Estimate Annual Water Production

Annual Water Production in Million Gallons (MG) = (Average Daily Demand (ADD) in Gallons per Day (GPD) x 365 days/year) ÷ 1,000,000

Maximum Daily Demand

The maximum daily demand with a 2.25 peaking factor[48] is used to estimate the capital costs to meet the dry season's water demand. To ensure that the proposed treatment capacity is conservative and to recognize that it is unrealistic to assume a source continuously operates 24 hours per day, treatment capacity is calculated by assuming the MDD must be produced over 16 hours a day. Hence, the following equations are utilized to estimate MDD in gallons per minute.

Equation 4: Estimating Maximum Daily Demand (MDD)

Maximum Daily Demand (MDD) in Gallons per Day (GPD) = Average Daily Demand (ADD) in Gallons per Day (GPD) x 2.25

Equation 5: Converting MDD in Gallons per Minute (GPM)

MDD in Gallons per Minute (GPM) = Maximum Daily Demand (MDD) in Gallons per Day (GPD) ÷ (16 hours/day x 60 minutes/hour)

General O&M Assumptions: Electricity and Labor

Electrical Cost

General electricity supply is needed to run a treatment plant, primarily to pump water and overcome headloss due to friction and elevation changes. For the updated

[46] Population is obtained from the water system annual population obtained from the Electronic Annual Reports (eARs).

[47] This ADD is based on the water usage provided to the State Water Board by 386 California urban water suppliers in June 2014 with an additional 10% demand.

[48] A peaking factor of 2.25 is a common practice to scale an average demand to a maximum demand.

proposed Cost Assessment Model, State Water Board staff conducted external research and internal discussions and recommend maintaining the same electrical assumptions and equation utilized in the 2021 Cost Assessment Model.

Equation 6

Electricity Cost = (0.746[49] x flow x headloss x electrical rate) / (3,960[50] x pump efficiency x motor efficiency)

Table 10 below summarizes the electrical cost equation components and assumptions.

Table 10: Electrical Cost Components and Assumptions

Component	Assumption[51]
Flow in Million Gallons (MG)	Estimated annual production for each Failing system
Headloss (ft)	23.07
Electrical Rate ($/kWh)	0.1646
Pump Efficiency	0.8
Motor Efficiency	0.9

Labor Cost

Treatment operators are responsible for maintaining treatment facilities, equipment, and processes to ensure water supplied to the public meets all regulatory standards and is at all times pure, wholesome, and potable. Treatment facilities are required to be permitted by the State Water Board prior to operation or upon change to the design capacity or treatment process within a treatment facility. The State Water Board assigns a minimum shift and chief treatment operator grade to each permitted treatment facility. The required treatment operator grade corresponds with the level of operator expertise and knowledge needed to safely operate and maintain the treatment facility. The grade level is determined using a point system defined in Title 22 of the California Code of Regulations.[52] The minimum treatment operator grade level and point range is summarized in Table 11.

Table 11: Minimum Treatment Operator Grade[53]

Total Points	Minimum Operator Grade Level
Less than 20	T1

[49] Unit constant to convert mechanical horsepower to kilowatts.

[50] The constant 3,960 is obtained by dividing the number of foot-pounds for one horsepower (33,000) by the weight of one gallon of water (8.33 pounds).

[51] These assumptions were developed by Corona Environmental and utilized in the 2021 Cost Assessment Model. All assumptions have been re-verified by State Water Board staff.

[52] Title 22 Code of Regulations, Chapter 13, Article 2. Operator Certification Grades, § 63765.

[53] Title 22 California Code of Regulations, Chapter 15, Article 2. Operator Certification Grades, § 64413.1

Total Points	Minimum Operator Grade Level
20 through 39	T2
40 through 59	T3
60 through 79	T4
80 or more	T5

Operator salaries typically correlate with the operator's grade level. The higher the grade, the higher the operator's salary. State Water Board staff researched current 2023 operator salaries from online job postings[54] throughout California. The table below summarizes the State Water Board's recommended updates to the Cost Assessment Model's labor costs per treatment operator grade.

Table 12: Treatment Operator Salary Per Grade

Operator Grade[55]	2021 Model Estimate Salary	Updated 2023 Estimate Salary
T1	$97,353	$105,000
T2	$105,092	$123,192
T3	$132,463	$127,992
T4	$163,937	$137,280

In the 2021 Cost Assessment Model, treatment operator grade was selected based on general assumptions, such as treated source type, labor time intensity, and number of treated contaminants. Based on consultation with internal staff experts, the State Water Board recommends maintaining the same treatment operator grades and time intensity utilized in the 2021 Cost Assessment Model with a few modifications as listed below:

1. In the proposed updated Cost Assessment Model surface water turbidity is always assumed to be between (15 - 100) Nephelometric Turbidity Unit (NTU), therefore; lower surface water treatment operator grade from T4 to T3
2. If a water system treats multiple contaminants using different treatment technologies, then the next higher treatment operator grade will be selected by the Cost Assessment Model to account for the increased operational difficulty.
3. Utilize current operator salary information for treatment operator grade.

Table 13 below matches the operator grade with the treatment technology.

[54] LinkedIn, ZipRecruiter, and CareerBuilder

[55] T5 is not listed in this table because there is no identified need for this grade level in the Cost Assessment Model.

Table 13: Operator Grade Per Treatment Technology

Treatment Technology	Operator Grade	Operator Time Intensity (% of Annual Salary)[56]
Granular Activated Carbon	T2	10%
Adsorption	T2	10%
Coagulation Filtration	T2	20%
Filtration	T2	10%
Anion Exchange	T2	25%
Cation Exchange	T2	25%
Single-Use Ion Exchange	T2	20%
Activated Alumina	T2	20%
4-log Virus Treatment	T2	10%
Surface Water Treatment	T3	25%

Individual Treatment Technology Capital & O&M Assumptions

Granular Activated Carbon

A clean carbon surface has a strong attraction for organic compounds and other non-polar contaminants. Thermal activation of carbon significantly improves its pore volumes, surface area, and structure, thus a filter with granular activated carbon (GAC) is a proven option to remove certain chemicals, particularly organic chemicals, from water. In the Cost Assessment Model, GAC is the assumed treatment technology for volatile organic compounds (VOCs) and two types of disinfection byproducts (DPBs) as listed in Table 14.

DBPs are formed when disinfectants react with natural organic matter (NOM) which is present in all water sources. NOM is measured as total organic carbon (TOC). DBPs can be controlled by either removing the precursor (*i.e.*, TOC) or removing DPBs after they are formed. While GAC has been proven to effectively remove both the TOC and DBPs, removal of DBPs from drinking water was the preferred approach in the 2021 Cost Assessment Model rather than TOC removal from source water. The State Water Board's internal workgroup recommends maintaining the same approach for the proposed updated Cost Assessment Model for the following two reasons: removing DBPs from finished water is deemed to be more efficient than treating the raw water for the precursor removal; and there potentially are water systems receiving treated water

[56] Operator time intensity is the fraction of the annual operator salary corresponding to the percentage of the annual operator time spent while running and maintaining the treatment plant, The percentages listed in the table were developed by Corona Environmental and utilized in the 2021 Cost Assessment Model, these assumptions have been re-verified by State Water Board staff.

from consecutive systems.

Table 14: Contaminants Treated by GAC in the Cost Model

Contaminants	System Criteria
Dibromochloropropane (DBCP)	• Failing systems with an MCL exceedance; and • Service connections ≥ 20.
Ethylene Dibromide (EDB)	
1,2,3- Trichloropropane (1,2,3-TCP)	
1,1-Dichloroethylene (1,1-DCE)	
Disinfection Byproducts (DBPs) • Total Trihalomethanes (TTHM) • Haloacetic Acids (five) (HAA5)	

GAC Capital Cost Components & Assumptions

The 2021 Cost Assessment Model used multiple quotes provided by multiple vendors for water treatment vessels, which were originally solicited between 2015 and 2018. The original quotes were adjusted to 2021 dollars using Construction Cost Indices (CCI) published by Engineering News Record (ENR) and averaged by vessel size. The average cost was then translated to an installed capital cost by applying an engineering multiplier of approximately 2.36.[57]

For DBP removal, the 2021 Cost Model applied an additional capital cost accounting for a booster pump station that is required to overcome the headloss caused by the GAC treatment. A flat cost of $30,000 was applied to all water systems regardless of system size, pump capacity, or other factors that can potentially affect pump costs. The same engineering multiplier used for the treatment vessel was applied on the booster pump to estimate the installed capital cost.

For the proposed updated Cost Assessment Model, the State Water Board recommends no modifications for estimated modeled vessel costs except for adjusting the cost estimates to current ENR CCI[58]; and recommends developing a regression equation for estimating booster pump costs based on pump capacity rather than using a static cost estimate applied to all systems. For the regression analysis, it is recommended to utilize the vendor-provided quotes, originally used for Other Essential Infrastructure (OEI) costs in the 2021 Cost Assessment Model[59] with an adjustment for current ENR CCI.

[57] Refer to Table C3.1 in ATTACHMENT C3: Treatment Cost Methodology Details (pp. 1-2) for the details of GAC engineering multiplier. https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/documents/needs/c3.pdf

[58] Aug 2023 ENR CCI: 13,472.56

[59] 2021 Drinking Water Cost Assessment and Gap Analysis (p. 88) https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/documents/needs/results_and_methodology_cost_assessment_gap_analysis.pdf

Table 15 summarizes the recommended updates to the GAC capital cost estimate components.

Table 15: Summary Comparison of GAC Capital Costs

Cost Component	2021 Model	Recommended Update
Treatment Vessel	Based on multiple quotes from multiple vendors, solicited between 2015 – 2018, adjusted to 2021 ENR CCI. • Averaged by vessel size and translated to installed capital cost with an engineering multiplier of 2.36. • Refer to Table 16 for the cost by flow range.	Continue to use the 2021 Model cost assumptions applying current ENR CCI to adjust the cost to current price.
Booster Pump[60]	A flat cost of $30,000 applied to all systems. • Translated to installed capital cost with an engineering multiplier of 2.36.	Develop a regression equation to estimate the costs based on pump capacity.

The following sections provide additional details on each cost component included in GAC capital cost estimate.

Treatment Vessel

Internal and external research conducted by State Water Board staff suggests that vessel costs can be wide ranging, depending on vendors, location, design parameters, scope of installation work, and many other site-specific circumstances.

In the 2021 Cost Assessment Model,[61] lead-lag configuration was assumed with the vessel pairs that have diameter of either 6, 8, or 12 feet (ft). Different sizes of vessels were translated into the flow rates that each vessel size can accommodate. In the cases where the flow rate is greater than the capacity of a single pair of the largest unit, a configuration with multiple vessels was assumed. Within the vendor-provided cost estimates, the largest unit was capable to run up to 875 gallons per minute (gpm) and the cost for the flow rate of 876 - 1,750 gpm was assumed to be twice the 875-gpm vessel (Table 16).

[60] Only applied in DBPs removal.

[61] ATTACHMENT C3: Treatment Cost Methodology Details (pp. 1-3) https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/documents/needs/c3.pdf

State Water Board funded projects related to GAC treatment construction (or improvements) for organic chemicals or DBP mitigation were reviewed and compared to the 2021 Cost Assessment Model estimates. Table 16 summarizes the cost data for GAC treatment vessels collected through different sources.

The State Water Board's internal workgroup reviewed the 2021 Cost Assessment Model assumptions for vessel costs and recommends no modifications for the proposed updated Cost Assessment Model except for adjusting the cost estimates to current ENR CCI as summarized in Table 16.

Table 16: GAC Treatment Vessel Cost by Flow Rate Range

Diameter (ft)	Flow Rate (gpm)	2021 Model[62]	State Water Board Funded Projects	State Water Board's Recommendation[63]
6	1 – 250	$436,000	$456,000 (2023)[64]	$505,000
8	251 – 425	$536,000	N/A	$621,000
12	426 – 875	$745,000	N/A	$863,000
Two Pair-12	876 – 1,750	$1,490,000	$990,000 (2021)[65] $1,312,000 (2020)[66]	$1,726,000

Booster Pump Station

The 2021 Cost Assessment Model assumed a flat additional cost of $30,000 for a booster pump station when the GAC treatment was selected by the Model for DBP removal, and the cost was translated to an installed capital cost by applying an engineering multiplier of 2.36.

Staff reviewed State Water Board funded projects to collect more recent booster pump station cost estimates in an effort to update the cost assumptions used in the 2021 Cost Assessment Model. Internal and external research conducted by State Water Board staff suggests that pump costs often vary depending on the pump's size. Pump size is affected by various site-specific parameters, such as flow rate, minimum/maximum pressure required in the water main, etc. Table 17 below summarizes the booster pump costs collected from State Water Board funded projects and external quotes, and compares them with the 2021 Cost Assessment Model assumptions.

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[62] Installed capital cost.

[63] Installed capital cost, Adjusted to Aug. 2023 ENR CCI: 13,472.56.

[64] Westhaven Community Services District (design flow rate = 50 gpm, vessel diameter = 5-ft). Equipment cost with installation & start-up service costs included. Other construction-related costs or multipliers were excluded.

[65] Del Rey Community Services District (well capacity = 1,400 gpm). Equipment cost with installation & vessel piping costs included. Other construction-related costs or multipliers were excluded.

[66] City of Parlier (design flow rate = 1,700 gpm). Equipment cost with installation cost included. Other construction-related costs or multipliers were excluded.

Table 17: Booster Pump Station Capital Costs

Capacity (gpm)	2021 Model	State Water Board Funded Projects	External Quotes[67]	State Water Board's Recommendation
100	$71,000 (2021)[68]	$26,000 (2022)[69] $75,000 (2022)[70] $12,000 (2023)[71]	$46,000	Cost estimates by regression equation based on external quotes. (Equation 7)
200		$80,000 (2022)[72]	$81,000	
300		N/A	$95,000	
400		N/A	$116,000	
500		N/A	$133,000	
750		$31,000 (2019)[73]	$151,000	
1,000		$250,000 (2022)[74]	$174,000	
1,500		$300,000 (2022)[75]	$307,000	

Rather than applying a static cost estimate, the State Water Board recommends updating the Cost Assessment Model to estimate booster pump costs based on estimated pump capacity using a cost equation. Vendor-provided quotes used in the 2021 Cost Assessment Model[76] for OEI Cost Assessment were adopted to perform a linear regression analysis with an adjustment for current ENR CCI. Figure 3 shows the regression chart and the equation derived. The distribution of estimated booster pump costs by estimated pump capacity utilizing the proposed equation are summarized in Table 18.

[67] Vendor-provided quotes, used in 2021 Cost Model for OEI Needs Cost Assessment. Adjusted to August 2023 ENR CCI.

[68] Installed capital cost. Engineering multiplier of 2.36 applied to $30,000.

[69] Lancaster Mobile Home Park (equipment cost for packaged booster pump station including skid, electrical control, piping, appurtenances, etc., capacity = 20 gpm)

[70] Village Mobile Home Park (capacity = 25 gpm)

[71] Westhaven Community Services District (capacity = 50 gpm)

[72] East Pasadena Water System (capacity = 200 gpm)

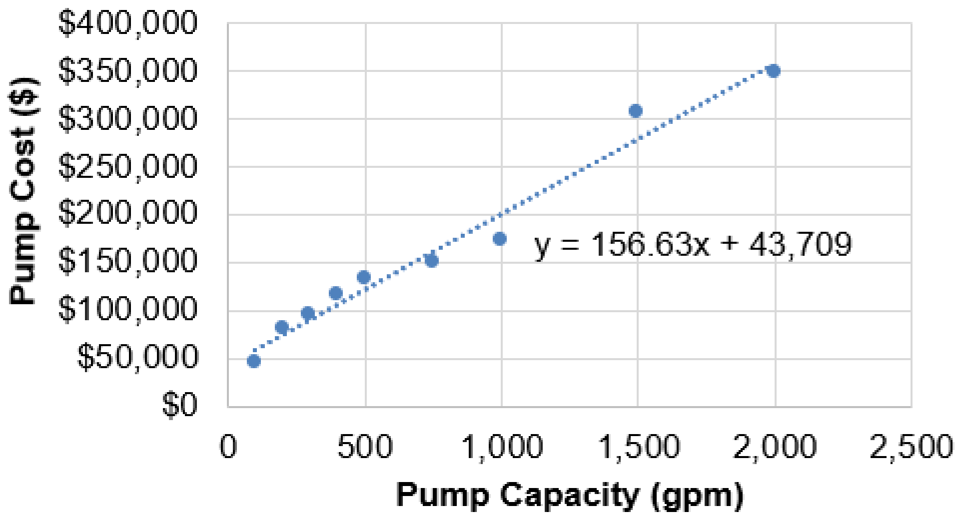
[73] Water Replenishment District of Southern California (capacity = 750 gpm)

[74] East Pasadena Water System (capacity = 1,000 gpm)

[75] East Pasadena Water System (capacity = 1,400 gpm)

[76] 2021 Drinking Water Cost Assessment and Gap Analysis (p. 88) https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/documents/needs/results_and_methodology_cost_assessment_gap_analysis.pdf

Figure 3: Booster Pump Costs Regression



Equation 7: Booster Pump Station Cost Estimate

y = 156.63x + 43,709

where, y = Booster Pump Station Cost ($)

x = Maximum Daily Demand (MDD) in gallons per minute (gpm)[77]

Table 18: Booster Pump Station Costs Estimated by Proposed Updated Model

Pump Capacity (gpm)	Model-Estimated Pump Cost ($)
100	$59,372
200	$75,035
300	$90,698
400	$106,361
500	$122,024
750	$161,182
1,000	$200,339
1,500	$278,654

GAC O&M Cost Components & Assumptions

The primary component of ongoing GAC operational costs is the periodic replacement of virgin GAC, including transportation and installation, and disposal of the spent GAC media. Thus, the cost can be wide ranging from site to site depending on GAC change-out frequency, which is mainly affected by water quality, amount of GAC per change-

[77] For the Cost Assessment Model purposes, MDD in gpm is estimated based on the population served and daily water consumption per capita with a peaking factor of 2.25, assuming 16-hour of daily operation (*i.e.*, [population x 150 gallons/day x 2.25] ÷ [16 hours/day x 60 minutes/hour]).

out, and regionally varying unit cost.

Standard Production Costs for Treated Water
In the 2021 Cost Assessment Model, a formula for estimating the ongoing GAC operational cost was developed for each individual contaminant and it was considered as a standard water production cost ($ per thousand gallons of water produced) for each contaminant. Based on the State Water Board's internal workgroup feedback, the State Water Board recommends maintaining the same approach for the proposed updated Cost Assessment Model.

As shown in Equation 8 and Equation 9, the key information in deriving the standard water production costs is the throughput estimated in number of bed volumes (BV).[78] BV numbers vary between contaminants, and normally depend on water quality input (not only the target contaminant but also other competing chemicals potentially present in the raw water) and many other site-specific design parameters. For modeling purposes, the 2021 Cost Assessment Model assumed a static BV number for each contaminant applied to all water systems regardless of the site-specific inputs. As an example, a throughput-estimate of 38,200 BV[79] was used for 1,2,3-TCP assuming it can cover a wide variety of water quality conditions for purposes of the 2021 Cost Assessment Model.

To validate the BV numbers assumed in the 2021 Cost Assessment Model, State Water Board staff reached out to water systems with GAC treatment in-place for removal of organic chemicals, DBP, or TOC (DBP precursor). The water quality information and BV numbers provided by water systems are summarized in Table 19 below.

Table 19: 2021 Model-Assumed vs. Water System-Provided BV Numbers

Water System	Contaminants	Influent Conc.	Treatment Goal	BV Numbers	
				2021 Model-assumed	System-provided
System A	1,2,3-TCP	ND[80]	0.005 µg/L	38,000	73,000
System B	1,2,3-TCP	0.042 µg/L	ND[81]	38,000	29,000
System C	TOC[82]	4.5 mg/L	1.5 mg/L	5,000	12,000[83]

[78] The volume of water passing through the media up to the breakthrough point divided by volume of GAC media.

[79] As cited in the U.S. EPA Drinking Water Treatment Technology Unit Cost Models https://www.epa.gov/sdwa/drinking-water-treatment-technology-unit-cost-models

[80] 10 out of 12 samples have been non-detect. For 1,2,3-TCP, the treatment goal, which is typically equivalent to the maximum contaminant level (MCL), is the same as the detection limit for purposes of reporting (DLR). MCL = DLR = 0.005 mg/L.

[81] Non-detect.

[82] Surrogate of DBPs.

[83] BV number calculated based on water system-provided information for volume of treated water and spent GAC.

As shown in table above, there is some indication that the 2021 Cost Assessment Model BV assumptions were set reasonably conservative for 1,2,3-TCP and TOC (as a surrogate of DBP); however, due to lack of system-provided data, validation of the assumed BV numbers is not feasible for the rest of the contaminants. The State Water Board's internal workgroup reviewed the 2021 Cost Assessment Model's BV number assumptions and water system-provided information and recommends no modifications of the BV numbers for the proposed updated Cost Assessment Model.

In the 2021 Cost Assessment Model, the breakdown costs for each operational cost component were gathered from the U.S. EPA's 2018 Work Breakdown Structure (WBS)[84] Model and adjusted for 2021 ENR CCI. The adjusted Model estimated $2.34 per pound of GAC (Table 20), which is equivalent to $0.28/kgal for produced water to treat for 1,2,3, TCP.

Table 20 below shows the components included in the GAC operational cost along with a comparison of the cost estimates used in the 2021 Cost Assessment Model to the State Water Board's recommended update.

Table 20: Summary Comparison of GAC Operational Costs per Pound of GAC

Cost Components	2021 Model	Recommended Update
Virgin GAC	$2.02[85]	$1.95
Transportation	$0.29	$0.20
Spent GAC Disposal	$0.036[86]	Excluded[87]
Change-out Service	Excluded	$0.30
Reactivation	Excluded	$0
Total	**$2.34**	**$2.45**

Applying the BV numbers used in the 2021 Assessment Cost Model, standard water production cost can be derived for each contaminant. Detailed calculation methodology is provided below.

[84] U.S. EPA does not publish old versions of the WBS Model. The 2023 WBS Model is currently available on their website: U.S. EPA Drinking Water Treatment Technology Unit Cost Models https://www.epa.gov/sdwa/drinking-water-treatment-technology-unit-cost-models

Granular Activated Carbon (GAC) WBS Cost Model Spreadsheet https://view.officeapps.live.com/op/view.aspx?src=https%3A%2F%2Fwww.epa.gov%2Fsystem%2Ffiles%2Fother-files%2F2022-03%2Fgranular-activated-carbon-gac-.xlsm.xlsm&wdOrigin=BROWSELINK

[85] Material and delivery included cost.

[86] Non-hazardous disposal cost.

[87] The State Water Board's recommended updates to GAC O&M assumptions include re-using (reactivation) spent GAC for industrial applications rather than disposing of it and repurchasing new GAC. Reactivation helps reduce annual O&M costs for smaller water systems.

Equation 8: Water Production per Pound of GAC (gal-water/lb-GAC)

BV number (gal-water/gal-GAC) x Carbon specific volume (0.0297 ft^3-GAC/lb-GAC) x Conversion factor (7.48 gal-GAC/ft^3-GAC)

Equation 9: Standard Water Production Cost ($/kgal-water)

Total operational cost ($/lb-GAC) ÷ Water production per pound of GAC (gal-water/lb-GAC) x Conversion factor (1,000 gal/kgal)

Example calculation for 1,2,3-TCP (Proposed Updated Model):

- Water Production per Pound of GAC = 38,200 x 0.0297 x 7.48 = 8,486 gal-water/lb-GAC
- Standard Water Production Cost = 2.45[88] ÷ 8,486 x 1,000 = $0.29/kgal-water

Applying the same calculation methodology, the standard water production cost can be derived for each of the contaminants. Table 21 below summarizes the standard production costs updated for each contaminant based on the State Water Board's recommended updates and compares to the 2021 Cost Assessment Model.

Table 21: GAC Throughput Estimates and Std. Production Costs by Contaminant

Contaminants	Number of BVs	Std. Production Cost ($/kgal-water)	
		2021 Model	Proposed Model
DBCP	65,000	$0.16	$0.17
EDB	60,000	$0.176	$0.184
1,2,3-TCP	38,000	$0.28	$0.29
1,1-DCE	10,000	$1.06	$1.10
TTHM & HAA5	5,000	$2.11	$2.21

The following sections provide additional details on each component included in the GAC operational cost estimate. Labor and electricity will be applied as separate budgetary items consistent with all other treatments.

Virgin GAC

GAC is manufactured from a variety of raw materials with porous structures including bituminous coal, lignite coal, coconut shell, etc. and virgin GAC cost can vary depending on the base material used to manufacture it. U.S. EPA's WBS cost data do not specify a certain type/product of GAC; however, F400[89] was assumed in the 2021 Cost Assessment Model. Therefore, carbon density of 0.54 g/ml (= 0.03 ft^3/lb-GAC) was applied in all unit conversion within the Cost Assessment Model, wherever applicable.

State Water Board funded projects were reviewed to collect GAC treatment operational

[88] Refer to Table 20.

[89] FILTRASORB® 400 (F400) developed by Calgon Carbon https://www.calgoncarbon.com/app/uploads/DS-FILTRA40019-EIN-E1.pdf

costs related to regulatory compliance for organic chemicals or DBP. Expanded outreach was also conducted to multiple manufacturers and service providers to solicit external quotes. Some additional quotes were provided by a consultant based on their past drinking water projects related to GAC treatment.

Table 22 below summarizes the cost data collected from different sources including the most recent version of the U.S. EPA WBS Model released in 2023.[90]

Table 22: Virgin GAC Costs per Pound

2021 Model	State Water Board Funded Projects	External Quotes	State Water Board's Recommendation
\$2.02 (2021)[91]	N/A[92]	\$1.90 - \$2.00 (2023)[93]	\$1.95
		\$1.60 (2022)[94]	
		\$1.48 (2020)[95]	
		\$1.68 - \$2.09 (2023)[96]	

Among the external quotes shown in

Table 22, U.S. EPA's 2023 WBS Model's unit cost (bottom row) for GAC is relatively wide ranging from \$1.68 to \$2.09 based on the quantity selected, which may not be suitable to be used for Cost Assessment Model. The operational cost estimates cited in State Water Board funded projects were also reviewed but GAC media only cost was not available (refer to footnote for additional details).[97]

Based on service provider's feedback and the State Water Board's internal workgroup discussion, the State Water Board recommends employing the average of the most recent external quote provided by vendor (top row), which is equivalent to \$1.95/lb-

[90] US EPA Drinking Water Treatment Technology Unit Cost Models
https://www.epa.gov/sdwa/drinking-water-treatment-technology-unit-cost-models

[91] Material and delivery cost included.

[92] Virgin GAC-only cost is not available. The costs cited in the State Water Board funded projects are lump-sum operational costs including other cost components: City of Parlier \$2.00 (2020); Westhaven Community Services District \$2.50 (2023).

[93] Calgon Carbon: https://www.calgoncarbon.com/

[94] Vendor-provided quote. Additional charge included for slurry truck, labor, and replacement service as a lump sum.

[95] Average of multiple vendor-provided quotes for different types of GAC.

[96] US EPA Drinking Water Treatment Technology Unit Cost Models
https://www.epa.gov/sdwa/drinking-water-treatment-technology-unit-cost-models

GAC unit costs vary depending on quantity selected (1,000 lb: \$2.09/lb; 21,000 lb: \$1.87/lb; 40,000lb: \$1.68/lb)

[97] Virgin GAC-only cost is not available. The costs cited in the State Water Board funded projects are lump-sum operational costs including other cost components: City of Parlier \$2.00 (2020); Westhaven Community Services District \$2.50 (2023).

GAC.

Transportation
The 2021 Cost Assessment Model utilized the transportation cost data from 2018 EPA WBS Model and adjusted to 2021 ENR CCI to be included in the operational cost estimate. The recent external quote collected through the State Water Board's outreach is $0.20/lb-GAC as shown in Table 23 below.

Table 23: Transportation Costs per Pound of GAC

2021 Model	State Water Board Funded Projects	External Quotes	State Water Board's Recommendation
$0.29 (2021)	N/A	$0.20 (2023)[98]	$0.20

Based on service provider's feedback and the State Water Board's internal workgroup discussion, the State Water Board recommends updating the transportation cost utilizing the most recent external quote, which is $0.20/lb-GAC.

Spent GAC Disposal vs. Reactivation
When activated carbon's adsorptive capacity is exhausted, it can be sent to reactivation service site where the adsorbed organic compounds are destroyed with thermal reactivation followed by off-gas treatment. The reactivated carbon can be recycled for continued use and thus, through reactivation, the cost associated with spent GAC disposal can be eliminated. The carbon from the water system is separated from other carbons so the reactivated carbon can be returned to the original water treatment facility, or it can be sold to other users for industrial application. When it is returned to the original facility, roughly 20% virgin GAC is added to make up for the losses during reactivation and, with this option, water system can change the media at a lower cost compared to changing with 100% virgin GAC. While this option is deemed to be likely the most cost-effective, consultation with external water professionals indicates that reactivation followed by re-using for industrial applications is the most common and practical method in the field. Returning the reactivated GAC to drinking water treatment is not readily feasible for several potential reasons, such as limited access to qualified service providers that are capable of NSF 61-certified reactivation, overall procedural complexity, and potential need of a storage for reactivated GAC, which will incur extra cost.

Table 24 and Table 25 summarize and compare the cost data collected through different sources for spent GAC disposal and reactivation, respectively. As the reactivation component is brought in the O&M cost estimate as an alternative means of spent GAC disposal, the disposal cost component can be excluded from the O&M cost consideration.

[98] Calgon Carbon: https://www.calgoncarbon.com/

Table 24: Spent GAC Disposal Costs per Pound of GAC

2021 Model	State Water Board Funded Projects	External Quotes	State Water Board's Recommendation
$0.036 (2021)	N/A	Excluded (2023)[99]	Excluded
		$0.053 (2023)[100]	

Table 25: Reactivation Costs per Pound of GAC

2021 Model	State Water Board Funded Projects	External Quotes	State Water Board's Recommendation
Excluded	N/A	$0 (2023)[101]	$0

Based on service provider's feedback and the State Water Board's internal workgroup discussion, the State Water Board recommends considering spent GAC reactivation component[102] with no cost incurred and eliminating the cost associated with the spent GAC disposal in the operational cost estimate.

Change-out Service

In the 2021 Cost Assessment Model, GAC media change-out service was excluded from the O&M cost estimate. State Water Board staff conducted an internal and external research and vendor outreach, which indicated that the change-out service fee can be either charged separately or embedded, as a lump-sum, in the unit cost of GAC.

State Water Board staff were able to collect one external quote range for GAC media change-out services, $0.20 - $0.40 per pound of GAC. Based on the service provider's feedback and the State Water Board's internal workgroup discussion, the State Water Board recommends developing a GAC change-out service cost O&M component utilizing the average of the recent external quote as shown in Table 26.

Table 26: Change-out Service Costs per Pound of GAC

2021 Model	State Water Board Funded Projects	External Quotes	State Water Board's Recommendation
Excluded	N/A	$0.20 – $0.40 (2023)[103]	$0.30

99 Calgon Carbon: https://www.calgoncarbon.com/

100 US EPA Drinking Water Treatment Technology Unit Cost Models https://www.epa.gov/sdwa/drinking-water-treatment-technology-unit-cost-models

101 Calgon Carbon: https://www.calgoncarbon.com/

102 It specifically means the reactivation followed by re-using for industrial applications.

103 Calgon Carbon: https://www.calgoncarbon.com/
Costs are varied depending on scope of the work.

Adsorption

Arsenic removal from drinking water can be accomplished using a variety of technologies and each has drawbacks and benefits, particularly in terms of effectiveness and cost. Adsorption is a passive treatment approach where untreated water flows through pressure vessels loaded with media. Due to its low cost and simple operational process, adsorption technology can be considered the best method of removing arsenic from small flows. For arsenic removal, iron-based adsorptive media is commonly used.

The Cost Assessment Model is designed to select either adsorption or coagulation filtration technology for arsenic treatment, depending on the criteria each Failing system meets as further detailed below.

In the 2021 Cost Assessment Model adsorption was selected over coagulation filtration for arsenic removal for small water systems with less than 500 service connections due to operational efficiency. This criterion also aligns with the regulatory threshold for system size for selecting coagulation filtration as the best available technology (BAT) for chemical removal. Current California drinking water regulation,[104] specifies that coagulation filtration is not a BAT for water systems with less than 500 service connections.

For the proposed updated Cost Assessment Model, the upper limit of the system size for matching adsorption as the modeled treatment remains the same (500 service connections); however, the system size threshold by which treatment is selected as a long-term solution is lowered from 200 to 20 service connections. Coagulation filtration modeled treatment technology is selected for systems with 500 service connections or greater.

In addition, the State Water Board's internal workgroup recommends expanding the criteria for modeled treatment technology selection for arsenic (*i.e.*, adsorption vs. coagulation filtration) to include both the system size and water quality thresholds. For the proposed updated Cost Assessment Model, the State Water Board's internal workgroup recommends matching adsorption as a modeled treatment technology for Failing water systems with a raw water arsenic concentration exceeding the MCL but less than 50 μg/L per active source. Coagulation filtration modeled treatment technology is selected for the systems with raw water arsenic concentrations of 50 μg/L or greater per active source.

Table 27 summarizes the proposed expanded criteria for matching Failing water systems to modeled adsorption technology as the long-term solution within the proposed updated Cost Assessment Model.

[104] Title 22 CCR § 64447.2
https://govt.westlaw.com/calregs/Document/I79A737D05B6111EC9451000D3A7C4BC3?viewType=FullText&originationContext=documenttoc&transitionType=CategoryPageItem&contextData=(sc.Default)

Table 27: Contaminant Treated by Adsorption in the Proposed Updated Model

Contaminant	System Criteria
Arsenic	Failing systems with an MCL exceedance • 20 ≤ Service connections < 500; and • Raw water arsenic conc. < 50 μg/L.

To determine the arsenic concentration to be used in selecting the modeled treatment technology for a Failing water system, source water quality monitoring data for one compliance cycle (*i.e.*, nine years)[105] is analyzed. After examining various options[106] for calculation method, 75th percentile of all monitoring results was found to be a reasonable option to calculate the arsenic concentration.[107]

Adsorption Capital Cost Components & Assumptions

In the 2021 Cost Assessment Model, the GAC capital cost estimate was utilized in lieu of developing a stand-alone methodology for an adsorption capital cost estimate. Due to the relative simplicity of this treatment approach, an installed capital cost multiplier of 2.36 was applied.[108] Table 28 below summarizes the State Water Board's recommended update.

[105] This is based on the consideration that monitoring schedule for inorganic chemicals varies between water systems depending on water source type, compliance history, laboratory capacity, etc.

[106] Examined methods: maximum, average, average plus standard deviation or 75th percentile of all monitoring results, or average of monitoring results exceeding MCL.

[107] Several systems failing for arsenic were selected and tested for comparison of various concentration calculation methods. The concentration calculated by each method was plugged into the proposed updated Model. Among those methods compared, "75th percentile of all monitoring results" produced the operational costs falling somewhere in middle.

[108] ATTACHMENT C3: Treatment Cost Methodology Details (pp. 7-8) https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/documents/needs/c3.pdf

Table 28: Summary Comparison of Adsorption Capital Costs

Cost Component	2021 Model	Recommended Update
Treatment Vessel	***GAC capital cost methodology was used as a surrogate.*** • Based on multiple quotes from multiple vendors, solicited between 2015 – 2018, adjusted to 2021 ENR CCI. ○ Averaged by vessel size and translated to installed capital cost with an engineering multiplier of 2.36. ○ Refer to Table 16 for the cost by flow range.	Continue to use the 2021 Model cost assumptions applying current ENR CCI to adjust the cost to current price.

Treatment Vessel
All the configuration and specifics for pressure vessels associated with arsenic adsorption align with the methodology used by the Model for GAC capital cost estimates. As detailed in GAC section above, in the 2021 Cost Assessment Model, the pressure vessel costs were based on multiple quotes from more than one vendor. Original quotes, collected from 2015 to 2018, were adjusted to 2021 ENR CCI and then averaged by vessel size. The same engineering multiplier of 2.36 used for GAC capital cost was applied to convert the equipment costs to the installed capital costs. Since the capital cost estimate for adsorption includes a single component, treatment vessel, the capital cost estimate is equivalent to the vessel cost.

State Water Board funded projects for arsenic adsorption treatment were reviewed and compared to the 2021 Cost Assessment Model assumptions. Since each treatment construction project has a different scope of installation and varied approaches for estimating the capital costs, a direct comparison was not readily available. Table 29 below summarizes the adsorption capital cost collected from each data source and the recommended updates. The State Water Board's internal workgroup reviewed the 2021 Cost Model's assumptions for pressure vessel costs and recommends no modifications for the proposed updated Cost Assessment Model, aside from adjusting the dollar amounts to current ENR CCI.

The State Water Board's internal workgroup reviewed the 2021 Cost Model's assumptions for pressure vessel costs and recommends no modifications for the proposed updated Cost Assessment Model. It is recommended to adjust the dollar amounts to current ENR CCI as summarized in Table 29.

Table 29: Summary of Adsorption Capital Costs by Flow Rate

Diameter (ft)	Flow Range (gpm)	2021 Model[109]	State Water Board Funded Projects	State Water Board's Recommendation[110]
6	1 – 250	$436,000	$75,000 (2022)[111]	$505,000
			$168,000 – $360,000 (2021)[112]	
8	251 – 425	$536,000	N/A	$621,000
12	426 – 875	$745,000	N/A	$863,000
Two Pair-12	876 – 1,750	$1,490,000	N/A	$1,726,000

Adsorption O&M Cost Components & Assumptions

In the 2021 Cost Assessment Model, O&M cost estimates for adsorption were developed based on the results of a study for arsenic treatment for drinking water in California.[113] In the study, 14 California water systems responded to the survey for arsenic compliance costs utilizing adsorption treatment along with the annual production and influent/effluent arsenic concentrations. The study assumed that annual O&M costs were mainly comprised of media replacement, spent media disposal, chemicals, analytical testing, and labor. Since many small water systems track the total costs of finished water production but not for individual cost components, itemized costs were frequently unavailable. To allow for comparisons among systems, annual estimated O&M costs were normalized for certain components wherever reported values were missing (*e.g.,* analytical fees). After normalization, estimated annual O&M costs were based on estimated production volumes ($ per kgal of water) for each system.

The 2021 Cost Assessment Model selected the median normalized O&M cost estimate to accommodate the diversity among surveyed systems (annual production, arsenic concentrations, and the variety in existing adsorption treatment processes). The selected median normalized O&M cost estimate was adjusted for 2021 ENR CCI to $1.54/kgal-water production.

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[109] Installed capital cost.

[110] Installed capital cost, Adjusted to August 2023 ENR CCI: 13,472.56.

[111] Lancaster Mobile Home Park. This is the cost per vessel pair and media without other construction-related costs (vessel diameter = 1.5 ft; design flow = 20 gpm).

[112] Colusa County Waterworks District No. 1. The estimated adsorption treatment construction capital cost was provided in a range from (-30%) to (+50%), as displayed in this table. The displayed costs include contingency, sales tax, insurance, some other construction related costs, but exclude construction management cost (vessel diameter = 6 ft; design flow = 200 gpm).

[113] Hilkert Colby, Elizabeth J., Thomas M. Young, Peter G. Green, and Jeannie L. Darby, 2010. Costs of Arsenic Treatment for Potable Water in California and Comparison to U.S. Environmental Protection Agency Affordability Metrics. Journal of the American Water Resources Association (JAWRA) 46(6):1238–1254. DOI: 10.1111/j.1752-1688.2010.00488.x

To enhance the O&M cost estimate, the State Water Board's internal workgroup recommends developing an alternative methodology where the operational cost formula is based on both estimated annual production and arsenic concentration.

Table 30 below compares the methodology for operational cost estimates used in the 2021 Cost Assessment Model to the State Water Board's recommended update.

Table 30: Summary Comparison of Adsorption Operational Costs

	2021 Model	Recommended Update

Operational Cost per kgal of Water Production[114]	• Based on 14 California water system-reported O&M costs in 2010 study.
	  ○ Median compliance cost was selected, equivalent to \$1.54/kgal-water production.
	  ○ Applied to all water systems as a standard water production cost.
		• Develop a regression equation to estimate the operational cost based on both estimated annual production and arsenic concentration.
		  ○ Utilize the data from the same study used in the 2021 Model, with an adjustment for current ENR CCI for O&M cost.

State Water Board staff also reviewed the adsorption related O&M cost estimates from State Water Board funded projects for arsenic mitigation. Table 31 summarizes the adsorption operational costs in the 2021 Cost Assessment Model, a cost estimate cited in a State Water Board funded project and updated operational cost formula for the proposed updated Cost Assessment Model.

Table 31: Summary of Standard Water Production Costs by Adsorption

2021 Model	State Water Board Funded Projects	State Water Board's Recommendation
\$1.54/kgal-water production	\$5.52/kgal-water production (2022)[115]	Cost estimates are based on both water production and arsenic concentration. (Equation 10)

The regression analysis[116] was performed utilizing the arsenic influent/effluent

[114] While the Cost Assessment Model estimates the adsorption operational cost as a lump-sum, the following cost components are assumed to be embedded: chemicals; media replacement; spent media disposal; analytical testing; and labor.

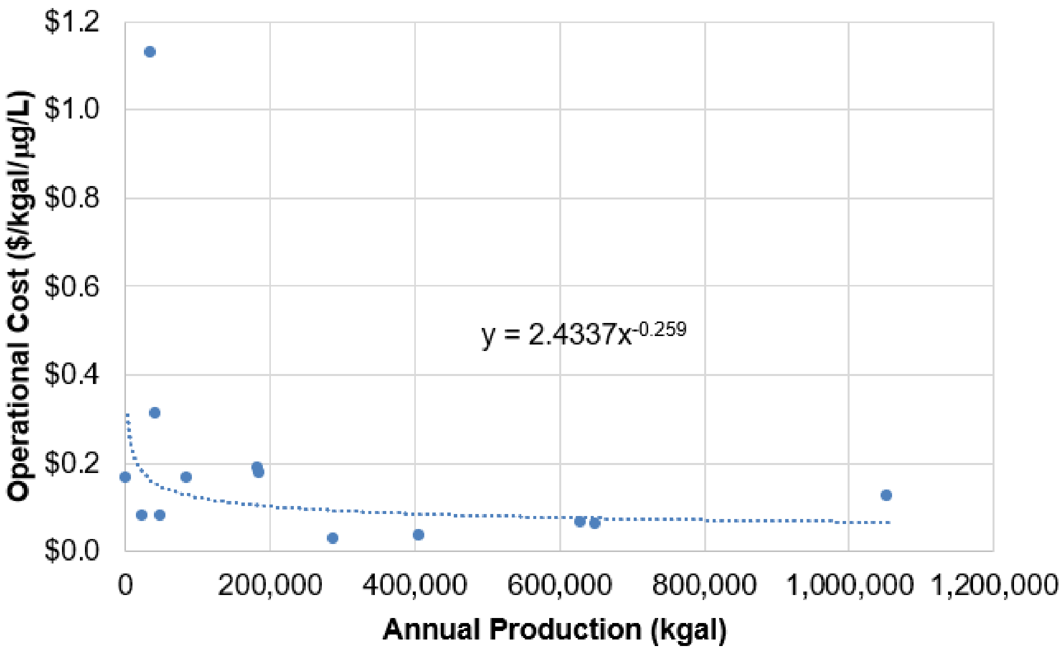
[115] Lancaster Mobile Home Park (design flow = 20 gpm, arsenic conc. ranging 13 - 21 μg/L). Cost including media replacement, chemical, analytical, maintenance, power, and labor.

[116] In the regression analysis, one outlier was identified and excluded due to high arsenic influent concentration (179 μg/L).

concentrations, annual productions, and normalized O&M costs data from the same study used in the 2021 Cost Assessment Model. As shown in the regression graph (Figure 4), the x-axis represents the input annual production in (kgal), while the y-axis represents the output cost in ($/ kgal-water production/ μg/L-arsenic removal). The treatment goal is assumed to achieve 80% of the MCL wherever a water system did not specify effluent concentration. System-reported O&M costs were adjusted to 2023 ENR CCI.

Figure 4 and Equation 10 show the power regression and the regression equation derived, respectively.

Figure 4: Adsorption Operational Cost Regression



Equation 10: Adsorption Operational Cost

$y = 2.4337x^{-0.259}$

where, y = Operational Cost ($/ kgal-water production/ μg/L-arsenic removal)

x = Annual Production (kgal)

State Water Board staff has conducted outreach to water systems with the adsorption treatment installed to control the level of arsenic at the source water. The water system data helped validate the proposed updated Cost Assessment Model's output. It indicates that the Model-predicted operational costs are approximately close to the water system-reported costs as shown in table below.

Table 32 summarizes the annual operational costs solicited from water systems and the costs predicted by the updated Model.

Table 32: Water System-Provided vs. Proposed Model-Predicted Operational Costs

Water System	Annual Production[117]	Arsenic Influent Conc.[118]	Operational Costs	
			System-provided	Model-predicted
System A[119]	245.6 MG	11 µg/L	$76,000 – $90,000	$86,000
System B[120]	0.049 MG[121]	14.8 µg/L[122]	$12,000	$11,000

MG = million gallons

Coagulation Filtration

Coagulation filtration is another treatment technology the Cost Assessment Model selects for arsenic removal. This technology includes coagulation and precipitation followed by filtration, termed coagulation filtration. The coagulation process consists of the addition of metal-based coagulant, such as ferric chloride to arsenic contaminated water to create iron particles and co-precipitate arsenic. Arsenic must be in oxidized form for effective removal, thus oxidant, typically sodium hypochlorite, is added as a pretreatment process. The filtration processes then remove arsenic particulates. Like adsorption, the process is more efficient at lower pH values.

In the 2021 Cost Assessment Model, coagulation filtration was selected over adsorption for arsenic removal for water systems with greater than 500 service connections due to the relative complexity of operation. This criterion also aligns with the regulatory threshold of system size for selecting coagulation filtration as the best available technology (BAT) for chemical removal. Current California drinking water regulation,[123] specifies that coagulation filtration is not a BAT for water systems with less than 500 service connections.

For the proposed updated Cost Assessment Model, the lower limit of the system size for matching coagulation filtration as the modeled treatment remains the same (500 service

[117] Extrapolated based on Drought & Conservation Reporting data (Jan 2023 – May 2023) in the State Water Board's Clearinghouse. Sources with arsenic treatment were identified from mDWW (facilities flow chart) and then system's total annual production was prorated to estimate the water production solely from the sources with arsenic treatment.

[118] 75th percentile of past 9-year data in SDWIS.

[119] Water system size is greater than 500 SC, not meeting the criteria to select adsorption treatment technology. It is utilized for validation purposes only.

[120] Water system size is less than 20 SC, not meeting the criteria to select adsorption treatment technology. It is utilized for validation purposes only.

[121] Annual production estimate collected through the outreach was 0.05 MG.

[122] Arsenic influent concentration collected through the outreach was 10-16 µg/L.

[123] [Title 22 CCR § 64447.2](https://govt.westlaw.com/calregs/Document/I79A737D05B6111EC9451000D3A7C4BC3?viewType=FullText&originationContext=documenttoc&transitionType=CategoryPageItem&contextData=(sc.Default))
https://govt.westlaw.com/calregs/Document/I79A737D05B6111EC9451000D3A7C4BC3?viewType=FullText&originationContext=documenttoc&transitionType=CategoryPageItem&contextData=(sc.Default)

connections). For systems with less than 500 service connections, adsorption modeled treatment technology is selected.

The State Water Board's internal workgroup recommends expanding the criteria for modeled treatment technology selection for arsenic (*i.e.*, coagulation filtration vs. adsorption) to include water quality considerations as well. For the proposed updated Cost Assessment Model, the State Water Board's internal workgroup recommends matching coagulation filtration as a modeled treatment technology for Failing water systems with raw water arsenic concentration of 50 mg/L or greater per active source. Adsorption modeled treatment technology is selected for the systems with arsenic concentration less than 50 mg/L per active source. Table 33 below summarizes the proposed expanded criteria for matching failing water systems to modeled coagulation filtration technology as the long-term solution within the Model.

Table 33: Contaminant Treated by Coagulation Filtration in the Cost Model

Contaminant	System Criteria
Arsenic	Failing systems with an MCL exceedance • Service connections ≥ 500; or • Raw water arsenic conc. ≥ 50 μg/L

Coagulation Filtration Capital Cost Components & Assumptions

Coagulation filtration treatment equipment capital costs include filter vessels, chemical feed systems, and a backwash reclaim system. In the 2021 Cost Assessment Model, capital costs were solicited by flow rate ranges between 500 and 2,500 gpm from two manufacturers and the average costs were used to develop a linear regression equation to estimate treatment capital costs at a given flow rate. The vendor-provided quotes, originally quoted in 2015, were adjusted to 2021 ENR CCI and averaged by flow rate and translated to an installed capital cost by applying an engineering multiplier of 3.06.

Table 34 below summarizes the coagulation filtration capital cost components included in the proposed updated Cost Assessment Model compared to the 2021 Model.

Table 34: Summary Comparison of Coagulation Filtration Capital Costs

	2021 Model	Recommended Update
Treatment Plant Capital Costs	• Based on 2 quotes from 2 vendors, originally solicited in 2015, adjusted to 2021 ENR CCI.[124] o Averaged by flow rate and translated to installed capital cost with an engineering multiplier of 3.06 (refer to Table 35 for cost by flow). o Developed a regression equation to estimate capital cost at a given flow rate.	Continue to use 2021 Model cost assumptions applying current ENR CCI[125] to adjust the cost to current price.

State Water Board funded projects for arsenic coagulation filtration treatment were reviewed and compared to the 2021 Cost Assessment Model assumptions. Since each treatment construction project has a different scope of installation and varied approaches for estimating the capital costs, a direct comparison was not readily available. Table 35 below summarizes the coagulation filtration capital cost collected from each data source and the recommended updates.

The State Water Board's internal workgroup reviewed the 2021 Cost Model's capital cost assumptions and recommends no modifications aside from adjusting the dollar amounts to current ENR CCI[126] as summarized in Table 35.

Table 35: Summary of Coagulation Filtration Capital Costs by Flow Rate

Flow Rate (gpm)	2021 Model	State Water Board Funded Projects	State Water Board's Recommendation
500	$1,516,000	$568,000 (2021)[127]	$1,756,000
1,000	$2,073,000		$2,402,000
1,500	$2,500,000		$2,896,000
2,000	$3,200,000		$3,707,000

[124] January 2021 ENR CCI: 11,627.94

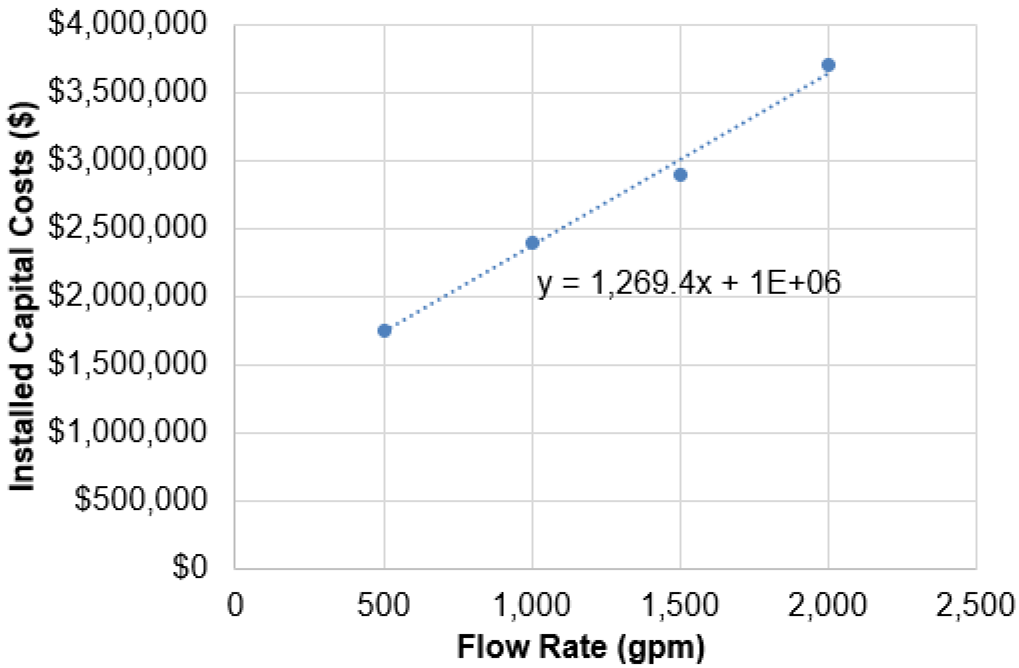
[125] August 2023 ENR CCI: 13,472.56

[126] August 2023 ENR CCI: 13,472.56

[127] Yosemite Unified School District (equipment cost related to filter system, flow = 70 gpm).

The State Water Board updated the linear regression and equation with the adjusted dollar amount (Figure 5 & Equation 11).

Figure 5: Arsenic Coagulation Filtration Capital Costs Regression



Updated regression equation that can estimate the capital cost at a given flow rate is provided below.

Equation 11: Coagulation Filtration Capital Cost

y = 1,269.4x + 1E+06

where, y = Installed Capital Cost ($)

x = Maximum Daily Demand (gpm)[128]

While the proposed updated Cost Assessment Model estimates the coagulation filtration capital cost using Equation 11, the following cost components are assumed to be embedded in the capital cost equation.

Chemical Feed Systems - Storage Tank & Pump

As part of the general treatment process, coagulation filtration requires two chemical feed systems: one for chlorine dosing for pre-oxidation to convert any arsenite (As[III]) to arsenate (As[V]); and another for ferric chloride to be added as a coagulant.

[128] For the Cost Assessment Model purposes, MDD in gpm is estimated based on the population served and daily water consumption per capita with a peaking factor of 2.25, assuming 16-hour of daily operation (*i.e.*, [population x 150 gallons/day x 2.25] ÷ [16 hours/day x 60 minutes/hour]).

Filter Vessel
The coagulated arsenic flows to filter vessels where it can be filtered out as iron arsenate. Vessel costs vary depending on the filter size and optional features or special designs that may be available on request. In general, filter vessels have backwash capability as a standard feature; however, a backwash reclaim system is not assumed to be part of the standard design. The following section provides more details on the backwash reclaim system component.

Backwash Reclaim System – Wash Water Storage & Recycle Pump
The filters are periodically backwashed with treated water from the distribution system to remove the accumulated debris, which helps maintain the integrity and longevity of the media. The Cost Assessment Model assumes reclaiming of wastewater generated from the backwash cycle. The backwash wastewater is sent to a storage tank for holding and settling. To minimize the volume of sludge stored in the tank, the supernatant[129] is periodically reintroduced to the treatment system, ahead of the filters. A backwash wastewater storage tank and recycle pump can be sized based on the backwash frequency and volume of wastewater produced per cycle. The costs may vary depending on tank size, material, pump capacity, etc.

Coagulation Filtration O&M Cost Components & Assumptions

In the 2021 Cost Assessment Model, O&M cost estimate assumptions for coagulation filtration were developed based on the results of a study for arsenic treatment for drinking water in California.[130] In the study, nine California water systems responded to the survey for arsenic compliance costs utilizing the coagulation filtration treatment along with annual production and influent/effluent arsenic concentrations. The study assumed that annual O&M costs were mainly comprised of media replacement, spent media disposal, chemicals, analytical testing, and labor. Some small water systems were not able to provide a breakdown of their O&M costs. To allow for comparisons among systems, annual estimated O&M costs were normalized for certain components wherever reported values were missing (*e.g.,* analytical fees). After normalization, estimated annual O&M costs were based on estimated production volumes ($ per kgal of water) for each system.

The 2021 Cost Assessment Model selected the median normalized O&M cost estimate to accommodate the diversity among surveyed systems, such as wide-ranging annual productions and arsenic concentrations, and the variety in the treatment processes within the coagulation filtration. The selected median normalized O&M cost estimate was adjusted for 2021 ENR CCI to $1.07/kgal-water production.

To enhance the O&M cost estimate, the State Water Board's internal workgroup

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[129] A relative clear liquid overlying material deposited by settling.

[130] Hilkert Colby, Elizabeth J., Thomas M. Young, Peter G. Green, and Jeannie L. Darby, 2010. Costs of Arsenic Treatment for Potable Water in California and Comparison to U.S. Environmental Protection Agency Affordability Metrics. Journal of the American Water Resources Association (JAWRA) 46(6):1238–1254. DOI: 10.1111/j.1752-1688.2010.00488.x

recommends developing an alternative methodology where the operational cost formula is based on both estimated annual production and arsenic concentration.

Table 36 compares the methodology for operational cost estimates used in the 2021 Cost Assessment Model to the State Water Board's recommended update.

Table 36: Summary Comparison of Coagulation Filtration Operational Costs

	2021 Model	Recommended Update

Operational Cost per kgal of Water Production	• Based on 9 California system-reported O&M costs cited in 2010 study.
	  ○ Median compliance cost was selected, equivalent to \$1.07/kgal-water production.
	  ○ Applied to all water systems as a standard water production cost.
		• Develop a regression equation to estimate the operational cost based on both estimated annual production and arsenic concentration.
		  ○ Utilize the data from the same study used in 2021 Model, with an adjustment for current ENR CCI for O&M cost data

Table 37 summarizes the arsenic coagulation filtration operational costs in the 2021 Cost Assessment Model, cost estimate cited in the State Water Board funded projects and updated operational cost formula for the proposed updated Cost Assessment Model.

Table 37: Summary of Standard Water Production Costs by Coagulation Filtration

2021 Model	State Water Board Funded Projects	State Water Board's Recommendation
\$1.07/kgal-water production	\$78,000/year (2019)[131]	Cost estimates based on both water production and arsenic influent concentration. (Equation 12)
	\$14.06/kgal-water production (2021)[132]	

Similar to the Model's proposed adsorption treatment O&M cost estimate method, an additional step was applied to factor in both the estimated water production and level of contaminant concentration to enhance the operational cost estimate. The regression analysis[133] was performed utilizing the arsenic influent/effluent concentrations,

[131] Sutter County Water Works District No. 1 (average demand = 37.2 MG/year; and raw water arsenic concentration = 14 - 23 μg/L).

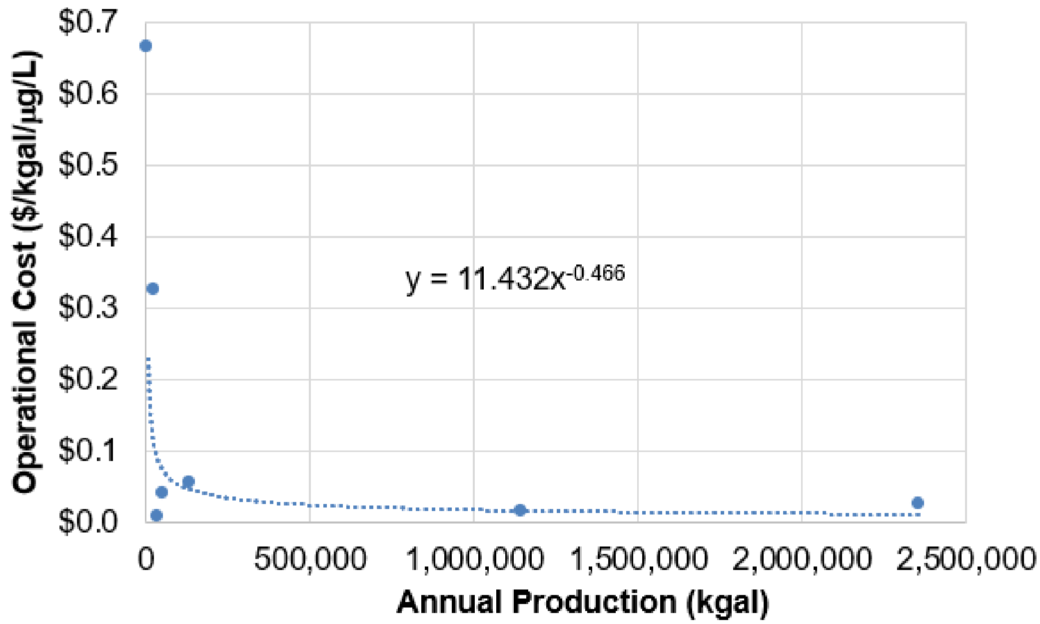
[132] Yosemite Unified School District (flow = 70 gpm). Cost including media replacement, chemicals, sludge disposal, analytical, labor, power, admin costs.

[133] In the regression analysis, two outliers were identified and excluded due to high normalized O&M cost (\$86 and \$27/kgal-production).

estimated annual productions, and normalized O&M cost data from the same study used in the 2021 Cost Assessment Model. As shown in the regression graph (Figure 6), x-axis represents the input annual production in (kgal), while y-axis represents the output cost in ($/ kgal-water production/ mg/L-arsenic removal). The treatment goal is assumed to achieve 80% of the MCL wherever water system did not specify effluent concentration. System-reported O&M costs were adjusted to 2023 ENR CCI.

Figure 6 and Equation 12 show the power regression and the regression equation derived, respectively.

Figure 6: Coagulation Filtration Operational Costs Regression



Equation 12: Arsenic Coagulation Filtration Operational Cost

$y = 11.432x^{-0.466}$

where, y = Operational Cost ($/ kgal-water production/ μg/L-arsenic)

x = Annual Production (kgal)

While the proposed updated Cost Assessment Model estimates the coagulation filtration operational cost as a lump-sum using Equation 12, the following cost components are assumed to be embedded in the operational cost equation. Labor and electricity will be applied as separate budgetary items consistent with all other treatments.

Media Replacement

While the frequency of the filter media replacement depends on site-specific water quality, available literature pertaining to the State Water Board Funded Projects indicates that replacement typically occurs every 10 years.

Chemicals

As part of the general treatment process, coagulation filtration includes pre-oxidation with chlorine to convert any arsenite to arsenate, which commonly uses sodium hypochlorite. Depending on site-specific water chemistry, it may also require pH adjustment which can be achieved by carbon dioxide. Ferric chloride is the most common iron salt used for a coagulation process for arsenic.

Spent Media & Sludge Disposal

Spent media and the sludge resulting from settling of the solids in the backwash water storage tank can be disposed of using a few different options such as on-site disposal, direct sewer discharge, or off-site disposal.

Analytical Testing

Recurring cost, primarily for compliance monitoring.

Filtration

Oxidation followed by filtration is the most common method used for removing iron and manganese in drinking water. The soluble, reduced forms of iron and manganese (Fe^{+2}, Mn^{+2}) are oxidized to (Fe^{+3}, Mn^{+4}), which are then precipitated and trapped in filter media. Filtration is the assumed treatment technology in the Cost Assessment Model for iron/manganese removal as summarized in Table 38 below.

Table 38: Contaminants Treated by Filtration in the Cost Model

Contaminants	System Criteria
Iron	• Failing systems with an MCL exceedance; and • Service connections ≥ 20.
Manganese	

Filtration Capital Cost Components & Assumptions

The modeled capital costs for filtration include filter vessels, chemical feed and storage, and a backwash reclaim system. In the 2021 Cost Assessment Model, the arsenic coagulation filtration modeled capital costs were used for iron/manganese filtration capital costs as a surrogate with slight modifications. Treatment equipment capital costs were solicited by flow rate ranges between 500 and 2,500 gpm from two manufacturers, originally dated 2015 (refer to Coagulation Filtration section for the details). Those quotes were modified by subtracting $30,000,[134] excluding the need for a coagulant feed/storage system in the filtration treatment. The costs adjusted to 2021 ENR CCI were averaged by flow rate and translated to an installed capital cost by applying an engineering multiplier of 3.06.

[134] The dollar amount after adjustment to 2021 ENR CCI was approximately $35,000.

Table 39 summarizes the filtration capital cost components included in the proposed updated Cost Assessment Model compared to the 2021 Cost Assessment Model.

Table 39: Summary Comparison of Filtration Capital Costs

	2021 Model	Recommended Update
Treatment Plant Capital Costs	Coagulation filtration capital cost methodology was used as a surrogate with the following modification: • Subtracted $30,000 to exclude the need for a coagulant feed system. ○ Refer to Table 40 for the cost by flow rate.	Develop a regression equation utilizing the averages of the following cost datasets. • Two cost estimates used in the 2021 Model. • An additional cost estimate with quotes gathered from internal/external sources.

There was a significant variance between the two capital cost estimates solicited and used in the 2021 Cost Assessment Model. Depending on the flow rate capacity, filter vessel costs can vary dramatically. Based on internal discussion, the State Water Board proposes an updated cost estimate methodology that relies on additional quotes gathered from internal and external sources.

For the proposed updated Cost Assessment Model, based on internal discussions and the State Water Board's internal workgroup feedback, the State Water Board recommends an alternative approach where all three datasets[135] can be incorporated in the capital cost estimate assumptions for filtration. As summarized in Table 39, three cost datasets were averaged by flow rate and a regression equation was developed for estimating the capital cost at a given flow rate. The regression graph and equation are provided below (Figure 7 & Equation 13).

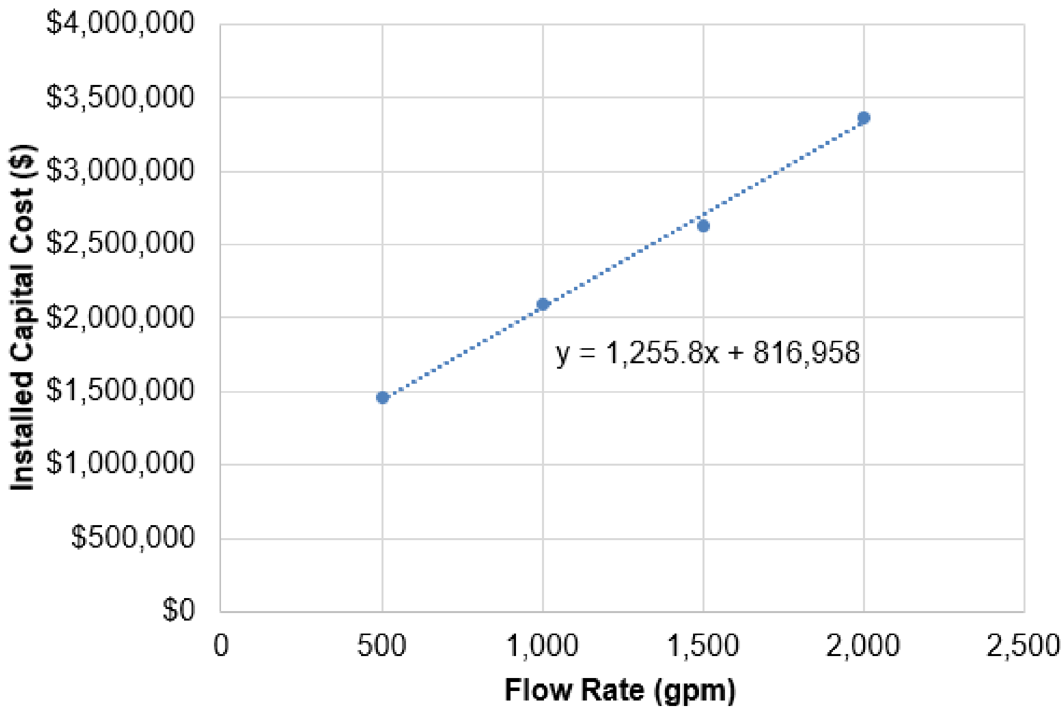
State Water Board funded projects for filtration treatment were reviewed and compared to the 2021 Cost Assessment Model assumptions and the recommended updates (Table 40).

[135] Two cost estimates used in the 2021 Cost Assessment Model, and an additional cost estimate that was developed with quotes gathered from multiple internal / external sources (refer to Table 39Table 39).

Table 40: Summary Comparison of Filtration Installed Capital Cost Estimates

Flow Rate (gpm)	2021 Model	State Water Board Funded Projects	State Water Board's Recommendation
500	$1,409,000	$419,000 (2023)[136] $1,875,000 (2019)[137] $3,000,000 (2021)[138]	$1,457,000
1,000	$1,966,000		$2,092,000
1,500	$2,393,000		$2,626,000
2,000	$3,093,000		$3,372,000

Figure 7: Filtration Capital Costs Regression



Equation 13: Filtration Capital Cost at a Given Flow Rate

y = 1,255.8x + 816,958

where, y = Installed Capital Cost ($)

x = Maximum Daily Demand (gpm)[139]

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[136] Sierra Park Water Company (treatment construction cost, design flow = 50 gpm)

[137] Water Replenishment District of Southern California (treatment construction cost, treatment capacity = 750 gpm)

[138] City of Needles (treatment construction cost, treatment capacity = 2,400 gpm)

[139] For the Cost Assessment Model purposes, MDD in gpm is estimated based on the population served and daily water consumption per capita with a peaking factor of 2.25, assuming 16-hour of daily operation (*i.e.*, [population x 150 gallons/day x 2.25] ÷ [16 hours/day x 60 minutes/hour]).

The following sections provide additional details on the cost estimate dataset that was developed with the quotes gathered from multiple internal and external sources as summarized in Table 39 (last bullet item in the 3rd column).

Filter Vessel

Internal and external research indicates that vessel costs vary depending on the filter size and optional features or special designs that may be available on request. In general, filter vessels are assumed to have backwash capability as a standard feature, but a backwash reclaim system (*i.e.*, wash water storage tank & recycle pump) is not part of the standard design.

State Water Board funded projects for filtration treatment construction were reviewed; however, vessel-only itemized costs were not available. Expanded outreach to third-party vendors was also performed to obtain external quotes (Table 41).

Table 41: Filter Vessel External Quotes[140]

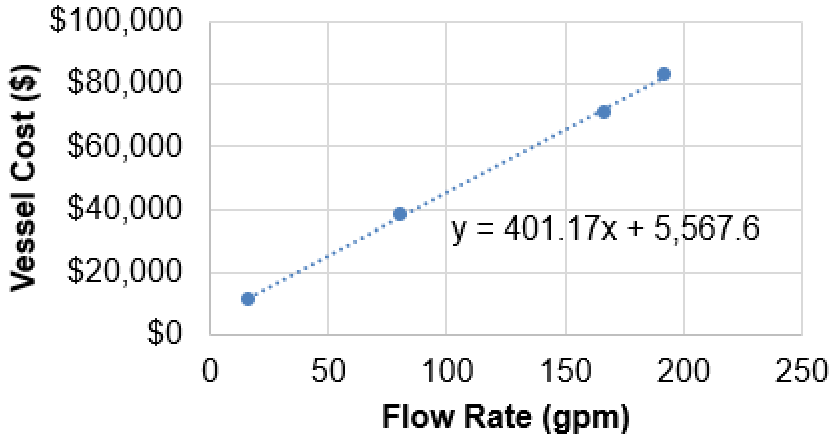
Steel Tank Size (D″ x H″)	Flow Rate (gpm)	Media Qty (ft^3/vessel)	Equipment Cost ($)
24 x 54	16	8	$12,000
54 x 60	80	40	$38,000
78 x 60	166	83	$71,000
84 x 60	192	96	$83,000
Two Units - 84 x 60	384	192	$167,000

The largest unit can run up to 192 gpm and multiple units can be placed working in parallel for greater flow rates. For example, if the flow needs to be doubled, two units can be installed, which will double the cost accordingly. Consultation with a vendor also indicates that configuring with multiple small vessels rather than a single large vessel is beneficial for maintaining an adequate flow rate for backwash[141]. Filter vessel costs extrapolated based on recent external quotes are presented in Figure 8 and Equation 14 below.

[140] Manganese greensand filters. Filter vessels have backwash capability, but no recycling tank and pump embedded. Provided courtesy of Pure Aqua: https://pureaqua.com/

[141] Flow rate for backwash should be higher than normal treatment flow rate.

Figure 8: Filter Vessel Costs Regression



Equation 14: Filter Vessel Cost at a Given Flow Rate

y = 401.17x + 5,567.6

where, y = Filter Vessel Cost ($)

x = Flow Rate (gpm)

Backwash Reclaim System

All filters require periodic backwashing to dispose of accumulated debris and clean the filter media. This is accomplished by reversing the flow using treated water through the unit and then backwashed wastewater goes into an on-site storage tank for holding and settling. The supernatant[142] is periodically recycled to the filtration system. A backwash wastewater storage tank and recycle pump can be sized based on the backwash frequency and volume of backwash water produced per cycle. The costs can be varied depending on tank size, material, pump capacity, etc.

The cost estimates for this component were collected through a review of State Water Board funded projects. The average cost estimate across multiple projects is $126,000 for a backwash reclaim system.

Chemical Feed System for Sodium Hypochlorite

Oxidation processes can occur by feeding a chemical oxidant, most commonly chlorine, using a small chemical storage and feed pump. Chemical feed system costs can be varied depending on storage size, material, pump capacity, etc. The cost estimates for this component were collected through a review of State Water Board funded projects. The average cost estimate across multiple projects is $29,000 for a chemical feed system for sodium hypochlorite.

Filtration O&M Cost Components & Assumptions

The frequency of maintenance for filtration treatment technologies is primarily determined by the concentration of iron and manganese in the raw water and the

[142] A relative clear liquid overlying material deposited by settling.

volume of treated water, thus O&M costs are mainly dependent on the water quality and production volumes. Normally filters have a backwash cycle which helps maintain the integrity and longevity of the media. There are various types of filter media and selection of the proper media also may depend on the water quality. For example, when the combined iron and manganese concentration is in the range of 3 mg/L to 10 mg/L, manganese dioxide-coated greensand media is generally recommended.[143]

In the 2021 Cost Assessment Model, the operational costs for iron and manganese removal used the Model's cost assumptions for arsenic removal with coagulation filtration as a surrogate. Using this approach, the O&M costs were anticipated to be a conservative estimate (refer to "2021 Model" column in Table 34).

Table 42 provides a comparison of the methodology for the filtration operational cost estimate used in the 2021 Cost Assessment Model and the State Water Board's recommended update.

Table 42: Summary Comparison of Filtration Operational Costs

	2021 Model	Recommended Update
Operational Cost per kgal of Water Production	Coagulation filtration operational cost methodology was used as a surrogate. • Standard water production cost applied to all water systems = \$1.07/kgal-water production	Continue to utilize the 2021 Model cost assumptions applying current ENR CCI to adjust the cost to current price.[144]

State Water Board staff also reviewed filtration O&M cost estimates from State Water Board funded projects that are related to regulatory compliance for iron/manganese. Table 43 summarizes the iron/manganese filtration operational costs collected from each data source.

[143] Iron and Manganese in Private Water Systems
https://extension.psu.edu/iron-and-manganese-in-private-water-systems

[144] August 2023 ENR CCI: 13,472.56

Table 43: Summary of Standard Water Production Costs by Filtration

2021 Model	State Water Board Funded Projects	State Water Board's Recommendation
$1.07/kgal-water production	$200,000/year (2021)[145] $211,000/year (2019)[146]	$1.24/kgal-water production

The State Water Board's internal workgroup reviewed the 2021 Cost Assessment Model's assumptions for operational costs and recommends no modifications for the proposed updated Cost Assessment Model except for adjusting the cost estimates to current ENR CCI as shown in Table 43.

Equation 15: Filtration Operational Cost

$1.24/kgal-water production

State Water Board staff conducted outreach to water systems with greensand filtration media installed for iron/manganese treatment. Table 44 below summarizes the operational costs collected from water systems and compares them to the output operational cost using the proposed updated Cost Assessment Model. The water system data was 25% higher than the Model's estimated costs.

Table 44: Water System-Provided[147] vs. Model-Predicted Operational Costs

Water System	Annual Production	Influent Conc.		Cost	
		Iron	Manganese	System-provided	Model-predicted
System A[148]	2.43 MG	730 μg/L	625 μg/L	$4,000/year[149]	$3,000/year

While the proposed updated Cost Assessment Model estimates the filtration operational cost as a lump-sum using Equation 15, the following cost components are assumed to be embedded in the operational cost equation. Labor and electricity will be applied as separate budgetary items consistent with all other treatments.

Media Replacement

The frequency of the media replacement depends on site-specific water quality. Feedback from a manufacturer and the water systems with filtration treatment installed for iron/manganese removal indicate that change frequency is wide ranging from 4-5 years to 10-15 years.

[145] City of Needles (approx. annual production = 630 MG, based on 12 hours per day, 365 days per year at 2,400 gpm).

[146] Water Replenishment District of Southern California (annual production = 190 MG. annual O&M costs including power, chemicals, labor, disposal, and maintenance).

[147] Annual production and contaminants' influent conc. were provided by water system. Labor & electricity are excluded.

[148] Media type: Manganese Dioxide-based, Media change frequency: Every 10-year

[149] Lab and field test costs comprised of more than 50% of the total operational cost.

Chemical
As part of the general treatment process, filtration for iron/manganese removal includes pre-oxidation to convert any soluble forms of iron/manganese to insoluble forms, which commonly uses sodium hypochlorite.

Spent Media & Sludge Disposal
Spent media and the sludge resulting from settling of the solids in the backwash water storage tank can be disposed of using a few different options such as on-site disposal, direct sewer discharge, or off-site disposal.

Analytical Testing
Recurring cost, primarily for compliance monitoring.

Regenerable Resin Anion Exchange

Regenerable resin anion exchange is the process of removing negatively charged ions and exchanging them with similar charged ions on the resin surface, usually chloride. Various contaminants, including nitrate,[150] fluoride, sulfate, and arsenic can all be removed by anion exchange process. Anion resins used to treat water have a finite exchange capacity. When full, they must be regenerated using salt to restore the removal ability. The regeneration frequency varies depending on raw water quality and resin characteristics. The regeneration process creates a wastewater salt brine that must be disposed of. Resin performance degrades over time, which results in the need for resin replacement. Additionally, during anion exchange sulfate concentrations must be monitored to avoid nitrate dumping.[151] This is especially a concern when utilizing non-selective resins.

In the Cost Assessment Model, anion exchange is modeled as a long-term solution for Failing water systems with nitrate water quality-related violations. Table 45 summarizes water quality concentrations that limit the effectiveness and feasibility of anion exchange process.

[150] Biological treatment was not considered for nitrate removal in the Cost Assessment Model.

[151] Dumping is the process of nitrate leakage from resins into the treated water. This is caused by a higher affinity of non-selective resins to sulfate. This is due to a continuous load of sulfate into the resin's bed causing nitrate to be “dumped off.”

Table 45: Contaminants Treated by Regenerable Resin Anion Exchange in the Proposed Updated Cost Assessment Model

Contaminant(s)	System Criteria
Nitrate	• Failing systems exceeding MCL for nitrate as nitrogen, with service connections ≥ 20. • Water source average nitrate concentration < 25 mg/l;[152]or • Mean sulfate concentration < 250 mg/l[153]

Anion Exchange Capital Cost Components & Assumptions

The 2021 Cost Assessment Model[154] utilized U.S. EPA's 2021 WBS anion exchange model[155] to develop capital cost estimates for different design flow rates. The capital costs were inflated by 20% to reflect bid costs for similar treatments installed in California's Central Valley geographic area.

The 2021 Cost Assessment Model detailed in the 2021 Needs Assessment did not include clear documentation of individual Model inputs and detailed assumptions for anion exchange capital cost estimates. The State Water Board has developed an alternative method for the proposed updated Cost Assessment Model utilizing U.S. EPA's 2023 WBS Model.[156] Table 46 summarizes the inputs used to estimate the capital cost for nitrate removal anion exchange:

[152] In the Cost Assessment Model, when average nitrate concentration exceeds 25 mg/l, anion exchange with standard resins will be excluded and other potential long-term solutions will be evaluated, such as constructing a new well or establishing an intertie with a neighboring water system.

[153] In the Cost Assessment Model, when mean sulfate exceeds 250 mg/l, anion exchange with standard resins will be excluded and other potential long-term solutions will be evaluated, such as constructing a new well or establishing an intertie with a neighboring water system.

[154] 2021 Drinking Water Needs Assessment Cost Assessment Methodology Appendix C: https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/documents/needs/c3.pdf

[155] U.S. EPA 2021 WBS Anion Exchange Model is no longer available because it was replaced by the U.S. EPA 2023 WBS Anion Exchange Model that was released in March 2023.

[156] U.S. EPA WBS Anion Exchange Documentation as of March 2023: https://www.epa.gov/sdwa/drinking-water-treatment-technology-unit-cost-models

Table 46: Inputs and Assumptions Utilized in the U.S. EPA 2023 WBS Anion Exchange Model

U.S. EPA 2023 WBS Model Input	Assumption
Resin type	Strong base type II
Flow rate	Standard designs[157]
Empty bed contact time	2-minutes/vessel
Vessel size	Auto sized[158]
No. of vessels	Minimum number of two vessels in series
Throughput	300 BV[159]
Component level	High Cost[160]
System Operation	Fully Automated[161]

The capital cost estimates were calculated for each design flow rate utilizing the inputs listed in the table above. Since the most recent U.S. EPA 2023 WBS Model was published in March, the output cost is adjusted for August 2023 ENR CCI values.

Table 47 provides a summary of capital cost comparison.

Table 47: Summary Comparison of Anion Exchange Capital Costs

	2021 Model	Recommended Update

Anion Exchange Treatment Plant Capital Costs	• Based on U.S. EPA 2021 WBS Model.
	  ○ Cost was inflated by 20% to reflect treatment bids in the Central Vally
		• Based on running U.S. EPA 2023 WBS Model with known inputs
		  ○ Cost is adjusted to the August ENR CCI values.

[157] Design flow rates are based on ranges of population served and their corresponding design flow categories as detailed in the Anion Exchange documentation: https://www.epa.gov/sdwa/drinking-water-treatment-technology-unit-cost-models

[158] The vessel size is auto-sized depending on the selected design flow rates. Therefore, bed depth, diameter, and height are automatically adjusted with each selected design flow rate.

[159] U.S. EPA 2023 WBS anion exchange model default bed volume was (420 BV). Based on a recommendation from an external manufacturer to better align bed volumes with the state-wide average levels of sulfate and nitrate, bed volume is changed to 300 BV instead of 420 BV.

[160] "High Cost" component level is selected to reflect the need for durable construction materials such as stainless-steel pressure vessels and stainless-steel piping. A "Low-Medium Cost" system might include fiberglass pressure vessels and PVC piping.

[161] Due to the required frequent regeneration, "system operation" within the U.S. EPA 2023 WBS anion exchange model was changed to "Fully Automated". Full automation involves monitoring and controlling critical treatment steps, such as chemical addition, routine sampling, chemical metering and backwash pump operation and adjustment, valve operation, etc. Full automation will increase treatment accuracy and decrease labor intervention using built-in automation controls rather than manual process.

	2021 Model	Recommended Update
	○ Capital cost was modeled for nitrate and assumed the same for radium treatment. ○ Treatment flow rates were manually assumed and entered in the U.S. EPA's 2021 WBS Model, refer to Table 48 below for the 2021 Model cost per assumed flow rate range.	○ Capital cost is modeled for nitrate only. ○ Radium is modeled utilizing different methodology. ○ Design flow rates are based on standard flow rate categories utilized in U.S. EPA's 2023 WBS Model corresponding to ranges of population served. Refer to Table 48 below for cost per standard flow rate.

Table 48 below compares the installed capital cost between the 2021 Cost Assessment Model and the proposed updated Cost Assessment Model.

Table 48: Summary Comparison of Installed Capital Costs for Anion Exchange

2021 Model		Recommended Update	
Flow Range (gpm)[162]	Installed Capital Cost ($)	Flow Range (gpm)[163]	Installed Capital Cost ($)
1 – 125	$714,530	≤ 21	$508,000
126 – 275	$1,045,355	22 – 86	$550,000
276 – 400	$1,281,158	87 – 212	$680,000
401 – 550	$1,548,565	213 – 514	$950,000
551 – 700	$1,912,766	515 – 1,494	$2,710,000
701 - 850	$2,574,979	1,495 – 5,115	$5,240,000
851 – 1,000	$2,779,499	5,116 – 15,704	$11,380,000
> 1,000	N/A[164]	15,705 – 52,133	$29,600,000

162 Flow ranges are based on an assumed treatment rate range developed by Corona Environmental and utilized in the 2021 Cost Assessment Model

163 Flow ranges are based on U.S. EPA 2023 WBS anion exchange model documentation, where the standard design flows are based on ranges of population served. https://www.epa.gov/system/files/documents/2022-03/ae-documentation-.pdf.pdf

164 The maximum flow rate utilized in the 2021 Cost Assessment Model was 1,000 gpm. No capital cost was calculated for higher flows.

Regenerable Resin Anion Exchange O&M Cost Components & Assumptions

The anion exchange process generates brine waste following column regeneration. Waste disposal costs tend to account for most ion exchange annual operation costs.

In the 2021 Cost Assessment Model, operational cost estimates were modeled based on Purolite's[165] estimate and design. The 2021 Cost Assessment Model assumed brine was stored in a holding tank for unspecified off-site disposal. Operational cost was a function of modeled throughput,[166] and the throughput was used to estimate the salt and brine operational cost utilizing a regression equation. The detailed methodology is discussed in "Treatment Cost Methodology Details," Attachment C3 in the 2021 Needs Assessment.[167]

For the proposed updated Cost Assessment Model, State Water Board staff conducted internal and external research and outreach to validate the 2021 Cost Assessment Model outputs and explore other O&M modeling options, such as Purolite's Resin System Modeling Software (PRSM)[168] and U.S. EPA's 2023 WBS anion exchange model. After internal discussion and review of the results of this research, the State Water Board recommends continuing to use the 2021 Cost Model methodology with a few enhancements. These include updating all unit cost estimates and assumptions and incorporating two new O&M cost components; resin loss and bed replacement (included in the U.S. EPA's 2023 WBS Model). Labor and electricity will be included in the O&M cost as separate budgetary items, consistent with all other treatment types. Table 49 below summarizes and compares O&M cost components for anion exchange treatment.

Table 49: Summary Comparison of Anion Exchange O&M Costs

Cost Component	2021 Model	Recommended Update
Brine disposal cost ($/gallon)	0.20	0.35
Regeneration Salt ($/lb)	0.16	0.25
Resin loss ($/cf)[169]	N/A	291
Bed replacement ($/cf)[170]	N/A	291

cf = cubic feet

[165] Purolite is a chemical manufacturing company that manufacturers ion exchange resins, catalyst, adsorbent and advanced polymers: https://www.purolite.com

[166] Throughput is represented by the volume of contaminated water being passed through the ion exchange resin before exhaustion is reached.

[167] Treatment Cost Methodology Details, Attachment C3, page 6: https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/documents/needs/c3.pdf

[168] Purolite Resin System Modeling Software: https://www.purolite.com/calculator-login?login=true

[169] The U.S. EPA 2023 WBS anion exchange model assumes an annual resin loss rate of 4.5%.

[170] Although the anion exchange resin is regenerated, the resin bed will eventually reach the end of its useful life and require replacement. The U.S. EPA 2023 WBS anion exchange model assumes an annual average bed replacement volume that is 3.8 times higher than resin loss volume.

The sections below discuss each O&M cost component in further detail and provide an overview of the gathered quotes from different data sources.

Brine Disposal Cost

In the 2021 Cost Assessment Model, spent brine was disposed off-site with a unit cost of $0.20/gallon. Neither disposal destination nor method were documented. For the proposed updated Cost Assessment Model, many disposal options are analyzed, such as a brine line or evaporation pond. Disposal through a brine line is not considered feasible since most Failing water systems with nitrate issues are not located near an existing brine line. However, after conducting external research and outreach to waste disposal companies and reviewing waste disposal rate sheets from few California counties, State Water Board staff recommends assuming a non-hazardous waste disposal to an evaporation pond utilizing a vacuum truck with a one-way waste disposal at a rate of $0.35/gallon.

Table 50: Summary Comparison of Brine Disposal Cost per Gallon

<table>
<tr><th>2021 Model</th><th>State Water Board Funded Projects</th><th>External Quotes</th><th>State Water Board's Recommendation</th></tr>
<tr><td rowspan="2">$0.20/gallon (2021)</td><td rowspan="2">N/A[171]</td><td>$0.24/gallon (2022)[172]</td><td rowspan="2">$0.35/gallon</td></tr>
<tr><td>$0.35/gallon (2023)[173]</td></tr>
</table>

Regeneration Salt

In the 2021 Cost Assessment Model, a regeneration salt cost of $0.16/lb was assumed and for each regeneration, 3 bed volumes of spent regenerant brine and 2 bed volumes of rinse were directed to the spent brine waste tank for offsite disposal. For the proposed updated Cost Assessment Model, after internal discussion with expert staff and outreach to external service providers, the State Water Board recommends maintaining the same assumptions for regeneration and rinse bed volumes but update the unit cost for the salt based to current market prices. Due to their higher purity compared with other types of salts, State Water Board staff recommends using solar (sodium chloride) NACL crystals formed through the solar evaporation process. State Water Board staff conducted external outreach and gathered an external quote for solar salt at $0.25/lb. Table 51 below details the salt cost quotes gathered from different sources.

[171] All available data for internally funded projects for nitrate exceedance are based on blending rather than treatment, so disposal cost is not available.

[172] Yolo County Central Landfill Standard Fee Schedule for Liquid wastes (high solids content or special treatment) https://www.yolocounty.org/home/showpublisheddocument/72137/637795635870200000

[173] Cost was developed based on gathering assumptions from waste disposal companies including Clean Harbors and considering internal feedback and recommendations.

Table 51: Summary Comparison of Regeneration Salt Costs per Pound

2021 Model	State Water Board Funded Projects	External Quotes	State Water Board's Recommendation
$0.16/lb (2021)	N/A[174]	$0.80/lb[175] (2023)	$0.25/lb
		$0.25/lb[176] (2023)	

Consistent with the 2021 Cost Assessment Model, the operational cost for both salt consumption and brine disposal will be modeled based on resin performance estimated in bed volumes. In the 2021 Cost Assessment Model, the resin performance estimation was based on ranges of water quality parameters for sulfate and nitrate. For nitrate, each Failing water system requiring nitrate treatment was grouped by its raw nitrate concentration into bins. Sulfate concentrations were also grouped into ranges, and each range was represented by a modeled sulfate value. The modeled sulfate concentration was used as an input to the Model to estimate the number of BV and subsequently brine and disposal costs. The detailed methodology is discussed in the "Treatment Cost Methodology Details" in the 2021 Needs Assessment.[177] For the proposed updated Cost Assessment Model, the State Water Board recommends utilizing actual mean sulfate concentration for each water system rather than using modeled mean sulfate concentrations. This will help enhance the Cost Assessment Model's estimate of the quantity of salt and regenerant disposal potentially needed and its associated annual cost.

Resin Loss and Bed Replacement

Resins and their beds (*i.e.,* columns) undergo loss and degradation; and their useful life depends on water quality and pretreatment measures. Resin life can be controlled by adjusting the backwash flow rate and other related parameters. The 2021 Cost Assessment Model excluded both resin loss and bed replacement cost from the O&M cost estimate. The State Water Board conducted a thorough analysis of U.S. EPA's 2023 WBS anion exchange model and recommends incorporating resin and bed replacement costs for more accurate O&M cost estimation to the proposed updated Cost Assessment Model.

The resin loss and bed replacement quantities are different, and they are estimated based on running U.S. EPA's 2023 WBS anion exchange model using the inputs and assumptions as summarized in Table 46 above. The results of each Model output for different flow ranges are detailed in Table 52. Since the majority of Failing water

174 All available data for internally funded projects for nitrate exceedance are based on blending rather than treatment, so regeneration salt cost is not available.

175 Morton KCl $30/40 lb

176 Morton Solar NaCl salt crystals $10/40 lb

177 Treatment Cost Methodology Details, Attachment C3, page 6: https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/documents/needs/c3.pdf

systems are small, and their estimated flow rate is below 2,000 gpm, State Water Board staff recommends averaging U.S. EPA's 2023 WBS anion exchange model annual resin loss and bed replacement quantities for design flow rates (21 gpm to 1,494 gpm).

Table 52: U.S. EPA 2023 WBS Anion Exchange Model Resin Loss Results per Standard Flow Range

WBS Standard Design Flow Ranges (gpm)	Resin Loss Replacement (cf/yr)	Complete Bed Replacement (cf/yr)
≤ 21	0.4	1.2
22 – 86	1.1	3.3
87 – 212	3.0	8.0
213 – 514	6.0	19
515 – 1,494	18	70
1,495 – 5,115	62	238
5,116 – 15,704	190	727
15,705 – 52,133	646	2,469

For the proposed updated Cost Assessment Model, the estimated replacement unit cost is similar for both resin loss and bed replacement, which is $291/cf. However, the estimated average quantity for each of them is different. Resin loss quantity is assumed to be 5.7 cf/year, while the average estimated bed replacement quantity is assumed to be higher at 20 cf/year. Table 53 summarizes resin and bed replacement total cost calculations.

Table 53: Resin and Bed Replacement Total Cost

Item	Average Quantity	Unit Cost	Total Cost
Resin Loss21	5.7 cf/year	$291/cf	$1,700
Bed Replacement	20 cf/year	$291/cf	$6,000

Regenerable Resin Cation Exchange

Regenerable resin cation exchange is the process of removing unwanted positively charged ions through binding to ion exchange resins. Contaminant cations such as barium, radium, and strontium are removed from feed water by displacing like-charged ions, typically sodium.[178] The regeneration process is carried out using strong acid cation resins. The regeneration process starts by exposing the bed to the brine solution, then slowly rinsing the bed by passing treated water flow through the bed to remove the regenerant ions. Lastly, there is a fast rinse of the bed to flush out any remaining brine.

[178] U.S. WBS-Based Cost Model for Cation Exchange Drinking Water Treatment: https://www.epa.gov/system/files/documents/2022-03/ce-documentation-.pdf.pdf

In the proposed updated Cost Assessment Model, this treatment is assumed a proven technology to remove Radium-226 and Radium-228 with the design considerations as listed in the Table 54 below.

Table 54: Contaminants Treated by Regenerable Resin Cation Exchange in the Cost Model

Contaminant(s)	System Criteria
Radium-226	• Failing systems exceeding MCL for radium • Service connection ≥ 20
Radium-228	

Cation Exchange Capital Cost Components & Assumptions

The 2021 Cost Assessment Model[179] utilized the anion exchange capital cost estimates and methodology to estimate radium removal capital costs. For the proposed updated Cost Assessment Model, the State Water Board recommends utilizing U.S. EPA's 2023 WBS Cation Exchange Model[180] to develop capital cost estimates for cation exchange. Table 55 below summarizes the inputs used to calculate the capital cost:

[179] 2021 Drinking Water Needs Assessment Cost Assessment Methodology Appendix C: https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/documents/needs/c3.pdf

[180] U.S. EPA 2023 WBS Cation Exchange Model: https://www.epa.gov/sdwa/drinking-water-treatment-technology-unit-cost-models

Table 55: Inputs and Assumptions Utilized in the U.S. EPA 2023 WBS Cation Exchange Model

U.S. EPA 2023 WBS Model Input	Assumption
Resin type	Strong acid polystyrenic macroporous resin[181]
Hardness concentration	200 mg/l as $CaCO_3$[182]
Flow rate	Standard designs[183]
Empty bed contact time	2-minutes/vessel
Vessel size	Auto-sized[184]
No. of vessels	Minimum of two vessels in series
Throughput	309 BV[185]
Component level	High Cost[186]
System operation	Fully Automated[187]

Utilizing all inputs listed in Table 55 capital cost estimates were calculated for each design flow rate. Since the most recent U.S. EPA 2023 WBS cation exchange model was published in March 2023, the State Water Board recommends adjusting the output cost with August 2023 ENR CCI values.

The Table 56 below provides a summary of capital cost comparison.

[181] Macroporous resins have better physical stability, and higher resistance to organic fouling and oxidation than Gel-Type resins (AWWA/ASCE 1998). AWWA Water Treatment Plant Design: https://www.awwa.org/Portals/0/files/publications/documents/toc/10009-5ETOC.pdf?_gl=1*1iqail3*_ga*MTY1MTIwMzg3Mi4xNjk0NDczNDI4*_ga_V6LK6LPN9V*MTY5NTE2MzQyMi4zLjAuMTY5NTE2MzQyMy41OS4wLjA.

[182] U.S EPA 2023 WBS Cation Exchange Model default influent hardness concentration

[183] Design flow rates are based on ranges of population served and their corresponding design flow categories as detailed in the Cation Exchange documentation: https://www.epa.gov/system/files/documents/2022-03/ce-documentation-.pdf.pdf

[184] The vessel size in U.S. EPA's Model is auto sized depending on the inputted design flow rates. The U.S. EPA Model also auto-adjusts the bed depth, diameter, and height when the design flow rates are modified.

[185] U.S. EPA 2023 WBS cation exchange model default bed volume. It is estimated based on an assumed default influent hardness concentration of 200 mg/l as $CaCO_3$ and resin type.

[186] "High Cost" component level is selected to reflect the need for durable construction materials such as stainless-steel pressure vessels and stainless-steel piping. A "Low-Medium Cost" system might include fiberglass pressure vessels and PVC piping.

[187] Due to the required frequent regeneration, "system operation" within the U.S. EPA 2023 WBS Anion Exchange Model was changed to "Fully Automated." Full automation involves monitoring and controlling critical treatment steps, such as chemical addition, routine sampling, chemical metering and backwash pump operation and adjustment, valve operation, etc. Full automation will increase treatment accuracy and decrease labor intervention using built-in automation controls rather than manual process.

Table 56: Summary Comparison of Cation Exchange Capital Cost

	2021 Model	Recommended Update
Cation Exchange Treatment Plant Capital Cost	• Same capital cost as nitrate, based on U.S. EPA's 2021 WBS anion exchange model. ○ Cost was inflated by 20% to reflect treatment bids in the Central Vally ○ Capital cost was modeled for nitrate and assumed the same for radium treatment. ○ Treatment flow rates were manually assumed and entered in the U.S. EPA's 2021 WBS Model, refer to Table 57 below for the 2021 Model cost per assumed flow rate range.	• Based on running U.S. EPA's 2023 WBS cation exchange model. ○ Cost is adjusted to the August ENR CCI values. ○ Design flow rates are based on standard flow rate categories utilized in the U.S. EPA's 2023 WBS Model corresponding to ranges of population served. Refer to Table 57 below for cost per standard flow rate.

Table 57 below compares the installed capital cost between the 2021 Cost Assessment Model and the proposed updated Cost Assessment Model.

Table 57: Summary Comparison of Installed Capital Cost for Radium Treatment

2021 Model		Recommended Update	
Flow Range (gpm)[188]	Installed Capital Cost ($)	Flow Range (gpm)[189]	Installed Capital Cost ($)
1 – 125	$714,530	≤ 21	$306,000
126 – 275	$1,045,355	22 – 86	$350,000
276 – 400	$1,281,158	87 – 212	$430,000
401 – 550	$1,548,565	213 – 514	$670,000
551 – 700	$1,912,766	515 – 1,494	$1,900,000

188 Flow ranges are based on an assumed treatment rate range developed by Corona Environmental and utilized I the 2021 Cost Assessment Model

189 Flow ranges are based on WBS standard design flows based on ranges of population served, as detailed in the Cation Exchange documentation referenced in this White Paper.

2021 Model		Recommended Update	
Flow Range (gpm)[188]	Installed Capital Cost ($)	Flow Range (gpm)[189]	Installed Capital Cost ($)
701 – 850	$2,574,979	1,495 – 5,115	$3,730,000
851 – 1,000	$2,779,499	5,116 – 15,704	$8,000,000
> 1,000	N/A[190]	15,705 – 52,133	$21,000,000

Regenerable Resin Cation Exchange O&M Cost Components & Assumptions

Cation exchange treatment includes operational requirements similar to anion treatment. The core operational cost for cation exchange is primarily linked to regeneration salt and brine waste disposal costs.

In the 2021 Cost Assessment Model, the operational cost for radium removal using cation exchange treatment was not modeled; instead, the operational costs for anion exchange nitrate treatment were applied as a surrogate O&M cost estimate.

For the proposed updated Cost Assessment Model, based on internal and external discussion and outreach, State Water Board recommends utilizing U.S. EPA's 2023 WBS Cation Exchange Model to estimate radium treatment operational cost, and apply labor and electricity as separate budgetary items, consistent with all other treatments in the Model. In the modeling design effort, it is assumed that the usable capacity of resin is 27 kilograins $CaCO_3$/cf,[191] with a regenerant dose level of 15 lb/cf of resin. Brine discharge is assumed to be sent to a holding tank to equalize the flow before discharging to a wastewater treatment facility.[192]

Table 58 below summarizes unit cost for operational cost components (based on U.S. EPA's 2023 WBS Model).

Table 58: Cation Exchange O&M Cost Components

Cost Component	Recommended Update
Regeneration Salt ($/lb)	0.10
Resin loss ($/cf)	231.49
Bed replacement ($/cf)	231.49
Spent resin Disposal ($/ton)	112.16
Wastewater Treatment Facility Discharge Fees ($/gallon)	0.006

[190] The maximum flow rate utilized in the 2021 Cost Assessment Model was 1,000 gpm, no capital cost was calculated for higher flows.

[191] U.S. EPA 2023 WBS Anion Exchange Model default resin capacity.

[192] For the purpose of the Cost Assessment Model, the characteristics of spent resin and brine are assumed to be non-hazardous.

The State Water Board ran U.S. EPA's 2023 WBS cation exchange model utilizing all model inputs and assumptions as summarized in Table 58. The Model outputs are then adjusted for a 10% miscellaneous allowance and summarized in **Error! Reference source not found.**. State Water Board staff contacted external manufactures to validate these operational cost estimates based on assumed hardness of 200 mg/L as CaCO3. Manufacturer feedback validated the Model's operational cost estimates and indicated that the O&M cost is reasonable considering the high uncertainties around system specific conditions and water quality conditions.

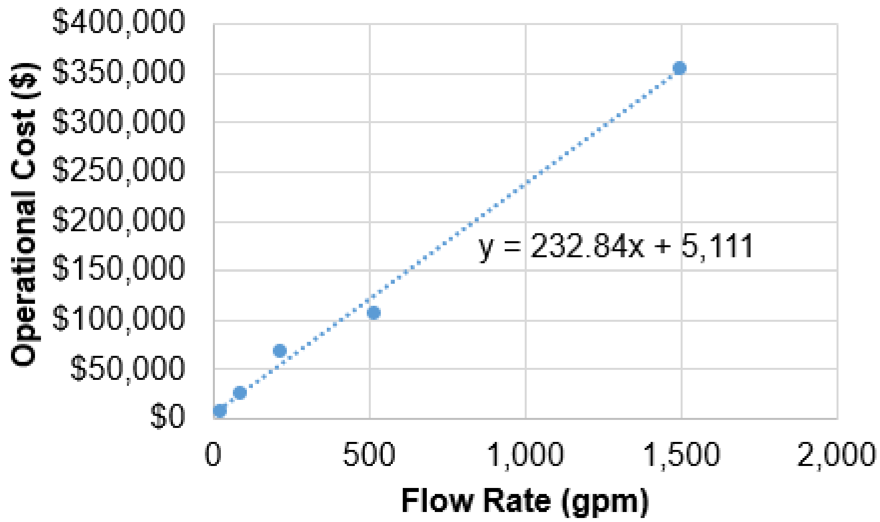
Table 59 below summarizes operational cost for different design flow ranges.

Table 59: Cation Exchange Operational Cost

WBS Standard Design Flow Ranges (gpm)	Operational Cost ($)
≤ 21	$8,000
22 – 86	$26,000
87 – 212	$69,000
213 – 514	$108,000
515 – 1,494	$357,000
1,495 – 5,115	$1,374,000
5,116 – 15,704	$4,730,000
15,705 – 52,133	$15,879,000

To estimate the operational cost for individual water systems based on their flow rate (gpm), a linear regression equation was developed by State Water Board staff utilizing the estimated costs by flow rate ranges as detailed Table 59. Since most Failing systems are small, and their estimated flow rate is typically below 2,000 gpm, State Water Board staff recommends including design flow rates up to 1,494 (gpm) within the proposed updated Cost Assessment Model and excluding larger flows as they may cause the Model to overestimate predicted operational cost values. The figure below shows the results of the regression analysis along with the regression equation.

Figure 9: Cation Exchange Operational Cost Regression



Equation 16: Operational Cost at a Design Given Flow Rate

***y* = 232.84x + 5,111**

where, y = Operational cost ($)

x = Average Daily Demand (gpm)

Single-Use Ion Exchange

Ion exchange is one of the best available technologies[193] to treat uranium and perchlorate in drinking water. Although single-use resin disposal can be expensive, regenerative resin carries the risk of leaching radioactive or hazardous contaminants back into the treated water if not handled appropriately.

In the 2021 Cost Assessment Model, this treatment is modeled as the long-term solution for water systems with uranium, perchlorates, and gross alpha water quality-related violations (Table 60).

Table 60: Contaminants Treated by Single-Use Ion Exchange in the Cost Model

Contaminants	System Criteria
Uranium	• Failing systems with an MCL exceedance; and • Service connections ≥ 20.
Gross Alpha	
Perchlorates	

[193] Title 22 California Code of Regulations, Chapter 15, Article 12, §64447.3. Best Available Technologies (BAT) for Radionuclides and §64447.2. Best Available Technologies (BAT) for Inorganic chemicals

Single-use ion exchange is a passive treatment system, much like GAC, where water is passed through pressure vessels and media. Ion exchange resin is replaced when it becomes exhausted with respect to its target contaminant.

Single-Use Ion Exchange Capital Cost Components & Assumptions

In the 2021 Cost Assessment Model,[194] capital cost estimates for single-use ion exchange were developed based on vendor quotes. These vendor quotes were provided for a range of flow rates corresponding to different vessel sizes. The average quote for each vessel size was adjusted to 2021 dollars, and a standard engineering multiplier of 2.36 was applied to develop an estimate of the installed capital costs. The assumed configuration included lead-lag vessels with a maximum hydraulic loading rate of 8 gpm/ft.^{2} Additionally, it was assumed that each vessel would have a resin depth of 36 inches, with a corresponding cost of $300/cf.

For the proposed updated Cost Assessment Model, State Water Board staff recommend utilizing the same approach as the 2021 Cost Assessment Model but updating the unit installed cost estimate using August 2023 ENR CCI value. The Table 61 below summarizes the recommended updates for the single-use ion exchange capital cost estimates.

Table 61: Summary Comparison of Single-Use Ion Exchange Capital Costs

	2021 Model	Recommended Update

Single-Use Ion Exchange Capital Cost	• Estimated capital cost for a range of vessel sizes based on vendor-provided quotes. The Model estimated the vessel size based on the failing water systems estimated flow rates.
	  ○ The cost was adjusted to the 2021 ENR CCI values and a standard engineering multiplier of 2.36.
		• Continue to use the 2021 Cost Assessment Model cost assumptions.
		  ○ Cost is adjusted to the August 2023 ENR CCI values.

Table 62 below provides a summary comparison of installed capital cost for single-use ion exchange treatment.

[194] Treatment Cost Methodology Details, Attachment C3, page 6: https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/documents/needs/c3.pdf

Table 62: Summary Comparison of Installed Capital Cost for Single-Use Ion Exchange Treatment

Flow Rate Range (gpm)[195]	2021 Model	Recommended Update
1 - 101	$356,888	$414,000
102 - 225	$537,418	$623,000
226 - 401	$712,949	$827,000
402 - 627	$925,929	$1,073,000
628 - 1,256	$1,851,857	$2,146,000

Single-Use Ion Exchange O&M Cost Components & Assumptions

In the 2021 Cost Assessment Model,[196] the operational cost components were the replacement and disposal costs of spent resin for uranium and perchlorate. These operational costs estimates were based on the U.S. EPA's 2016 WBS Model and adjusted to 2021 ENR CCI. The 2021 Cost Assessment Model assumed a unit cost estimate of $0.63 per thousand gallons (kgal) for uranium and $0.12/kgal for perchlorate resin replacement and disposal.

After conducting research and consulting with both internal and external experts, the State Water Board recommends refining the methodology used in the 2021 Cost Assessment Model. The Table 63 below summarizes comparison of single-use ion exchange operational costs. Labor and electricity will be applied as separate budgetary items consistent with all other treatments.

Table 63: Summary Comparison of Single-Use Ion Exchange Operational Costs

Cost Components	2021 Model	Recommended Update
Uranium-Selective Resin Replacement and Disposal Cost	$0.63/ kgal	$1/kgal
Perchlorate-Selective Resin Replacement and Disposal Cost	$115 /cf	$400/cf

Uranium-Selective Resin Replacement and Disposal Cost

In the 2021 Cost Assessment Model, the annual estimated uranium-selective resin replacement and disposal cost was derived from U.S. EPA's 2016 WBS Model,[197]

[195] Flow ranges are based on six vendor quotes for different treatment rate ranges developed by Corona Environmental and utilized in the 2021 Cost Assessment Model.

[196] Treatment Cost Methodology Details, [Attachment C3, page 7](https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/documents/needs/c3.pdf): https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/documents/needs/c3.pdf

[197] State Water Board assumes Corona Environmental utilized U.S. EPA's 2016 WBS Model for perchlorate-selective resin to estimate uranium O&M costs in the 2021 Cost Assessment. A BV estimate of 130,000 was used as an input to complete the calculations.

resulting in a cost of $0.56/kgal.[198] This cost was subsequently adjusted to 2021 ENR CCI and updated to $0.63/ kgal.

In the 2021 Cost Assessment Model, the BV was assumed and not estimated. State Water Board staff conducted research and outreach to develop the following BV estimation for uranium-selective resin replacement and disposal costs.

Equation 17: Estimating Number of Bed Volumes[199]

Number of Bed Volumes (BV) = Treated Flow (cf/yr) ÷ Resin Volume (cf)

In Equation 17, the treated flow[200] is assumed to be 688 gpm, which can be converted to 48,335,578 cf/yr; and the resin volume[201] is considered to be 433/cf. Equation 17 estimates approximately 120,000 BV. This BV is used to estimate the cost per kilo gallons (kgal) of water for resin replacement and disposal.

State Water Board staff contacted California vendors to solicit updated uranium resin replacement and disposal cost estimates for the proposed updated Cost Assessment Model. The State Water Board, in partnership with Purolite[202] developed an updated cost estimate of $1/kgal[203] for uranium-selective resin replacement and disposal. The cost is summarized in Table 64 below.

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[198] A flow rate of 1,600 gpm, treated flow rate of 688 gpm, and BV of 130,000 was assumed by Corona Environmental.

[199] Equation adopted from Lenntech.

https://www.lenntech.com/systems/exchange/vocabulary/ion_exchanger_vocabulary.htm#ixzz7xqo0JFxd

[200] Derived from 2021 Cost Assessment Model assumptions.

[201] Resin volume was estimated based on the vessel volume and the number of vessels required with a height of 4 ft. ($i.e.$, $\pi\ x\ radius\ of\ vessel^2\ x\ height\ of\ vessel\ x\ number\ of\ vessels$). The assumed height of vessel was adopted from the 2021 Cost Assessment Model.

[202] Ion Exchange Resin Manufacturer | Purolite
https://www.purolite.com/index

[203] Purolite recommended using the PGW6002EBF (uranium-selective) resin because it is designed to be buffered, has a high operating capacity, and serves as a strong base anion (SBA) resin to prevent nitrate and arsenic spiking during startup. This resin costs around $300/cf. Purolite also recommended labor, disposal, and transportation costs at a Technologically Enhanced Naturally Occurring Radioactive Material (TENORM waste) accepting facility, estimated at approximately $600/cf. The combined cost of the resin and waste disposal results in a total cost of $900/cf. This cost was further converted into $/kgal using 120,000 bed volumes.

Table 64: Summary Comparison of Uranium-Selective Resin Replacement and Disposal Cost

2021 Model	External Quotes	State Water Board's Recommendation
$0.63/kgal	$1/kgal (2023)	$1/kgal

Perchlorate-Selective Resin Replacement and Disposal Cost

In the 2021 Cost Assessment Model, the annual perchlorate-selective resin replacement and disposal cost was derived from the U.S. EPA's 2016 WBS model,[204] resulting in a cost of $0.10/kgal.[205] This cost was then adjusted to 2021 ENR CCI and updated to $0.12/kgal.

For the proposed updated Cost Assessment Model, the State Water Board reviewed perchlorate-selective single-use ion exchange resin products available in the market and explored the U.S. EPA's 2023 Perchlorate-Selective WBS Model.[206]

State Water Board staff utilized the U.S. EPA's 2023 Perchlorate-selective WBS Model, which estimated cost of perchlorate-selective resin replacement and disposal to be $366/cf.[207]

State Water Board staff also partnered with Purolite, a California vendor, to develop an alternative perchlorate-selective resin replacement and disposal cost estimate.[208] Purolite recommends utilizing perchlorate-selective resin replacement and disposal costs at approximately $400/cf within the Cost Assessment Model.[209] Purolite also provided cost estimates for the water systems failing for perchlorates, based on $400/cf quote. Staff developed a regression equation utilizing the quote provided by Purolite to estimate the costs for different sizes of water systems.

The U.S. EPA's WBS Model is designed to produce national cost estimates. However, California prices tend to be higher than national averages. Therefore, the State Water Board proposes utilizing the cost estimate developed in partnership with Purolite to

[204] State Water Board assumes Corona Environmental utilized U.S. EPA's 2016 WBS Model for perchlorate-selective resin to estimate perchlorate O&M costs in the 2021 Cost Assessment. A BV estimate of 130,000 was used as an input to complete the calculations.

[205] A flow rate of 1,600 gpm, treated flow rate of 688 gpm, and BV of 130,000 was assumed by Corona Environmental.

[206] U.S. EPA 2023 WBS Anion Exchange Model: https://www.epa.gov/sdwa/drinking-water-treatment-technology-unit-cost-models

[207] A flow rate of 1,600 gpm, treated flow rate of 688 gpm, and BV of 120,000 was assumed by the State Water Board staff.

[208] Ion Exchange Resin Manufacturer | Purolite
https://www.purolite.com/index

[209] Purolite estimated cost using perchlorate-related water quality data provided by the State Water Board (No consideration of other competing analytes – comparatively unconservative approach) 150,000 BV was used for most of the scenarios.

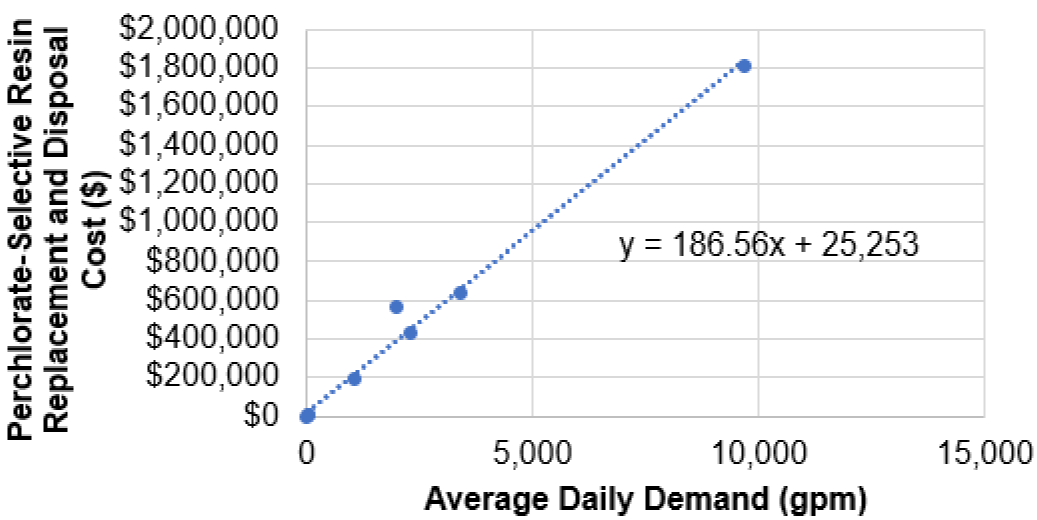
estimate perchlorate-selective resin replacement and disposal costs. Table 65 below summarizes the cost assumptions for perchlorate-selective resin replacement and disposal.

Table 65: Summary Comparison of Perchlorate-Selective Resin Replacement and Disposal Costs

2021 Cost Model	External Quotes	State Water Board's Recommendation
$115/cf	$400/cf[210] (2023)	$400/cf
	$366 /cf[211] (2023)	

Figure 10 below illustrates the regression equation based on the average daily demand (in gpm) and its corresponding cost for perchlorate-selective resin replacement and disposal cost.

Figure 10: Perchlorate-Selective Resin Replacement and Disposal Cost Regression



Equation 18: Perchlorate-Selective Resin Replacement and Disposal Cost

y = 186.56x + 25,253

where, y = Perchlorate-selective resin replacement and disposal cost ($)

x = Annual production (in MG)

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[210] Purolite estimated cost using perchlorate-related water quality data provided by the State Water Board. There was no consideration of other competing analytes. A 150,000 BV assumption was used by Purolite to develop their cost recommendations.

[211] A flow rate of 1,600 gpm, treated flow rate of 688 gpm, and BV of 120,000 was assumed by the State Water Board staff.

Activated Alumina

Activated alumina is the best available technology[212] for removing fluoride from drinking water. It eliminates contaminants through adsorption, wherein the contaminated water passes through a bed of granular activated alumina. In the 2021 Cost Assessment Model,[213] the activated alumina regeneration process was typically assumed to occur in three stages:

- Lowering the pH with sulfuric acid to approximately 5.5 to charge the functional sites of the media.
- Following pH depression, the water passes through pressure vessels loaded with activated alumina media to remove fluoride.
- Subsequently, the pH is typically readjusted, usually with caustic soda.

In the 2021 Cost Assessment Model, this treatment is modeled as the long-term solution for water systems with fluoride water quality-related violations (Table 66).

Table 66: Contaminants Treated by Activated Alumina in the Cost Model

Contaminant	System Criteria
Fluoride	• Failing systems with an MCL exceedance; and • Service connections ≥ 20.

Activated Alumina Capital Cost Components & Assumptions

In the 2021 Cost Assessment Model, activated alumina capital cost estimation methodology adopted the Model's capital cost assumptions for GAC adsorption.[214] The 2021 Cost Assessment Model's estimated cost for pressure vessels was based on multiple vendor quotes. These quotes were collected from 2015 to 2018, adjusted to 2021 ENR CCI, and averaged by vessel size. An engineering multiplier of 2.36 was used to adjust the capital cost estimate.

In addition to adopting the underlying GAC adsorption capital costs, the 2021 Cost Assessment Model added additional components for estimated activated alumina treatment capital costs: two chemical feeds and storage systems (for sulfuric acid and caustic soda), enhanced instrumentation (pH and flow meters), and a Programmable Logic Controller (PLC).

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212 Title 22 California Code of Regulations, Chapter 15, Article 12, Table 64447.2-A, Best Available Technologies (BAT), Inorganic Chemicals
https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/documents/lawbook/DW-regulations-2018-10-01.pdf

213 Treatment Cost Methodology Details, Attachment C3, page 10:
https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/documents/needs/c3.pdff

214 Treatment Cost Methodology Details, Attachment C3, page 2:
https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/documents/needs/c3.pdf

For the proposed updated Cost Assessment Model, the State Water Board proposes to maintain a similar approach to estimate the capital costs for treating fluoride but adjust the cost with the August 2023 ENR CCI value as shown in the Table 67 below.

Table 67: Summary Comparison of Activated Alumina Capital Costs

Component	2021 Model	Recommended Update
Activated Alumina Installed Capital Costs	GAC capital cost methodology was used as a surrogate with the following modification: • Added two chemical feeds and storage systems (sulfuric acid and caustic soda), enhanced instrumentation (pH and flow meters), and a programmable logic controller (PLC).	• Continue to use 2021 Model cost assumptions. ○ Adjust the cost to August 2023 ENR CCI values.

Table 68 below compares the installed capital costs between the 2021 Cost Assessment Model and the proposed updated Cost Assessment Model.

Table 68: Summary Comparison of Installed Capital Cost for Activated Alumina

Flow Rate Range (gpm)[215]	2021 Model	State Water Board's Recommendation
1 - 250	$833,000	$965,000
251 - 425	$949,000	$1,100,000
426 - 675	$1,029,000	$1,192,000
676 - 900	$1,199,000	$1,389,000

Activated Alumina O&M Cost Components & Assumptions

In the 2021 Cost Assessment Model,[216] only sulfuric acid and caustic soda costs for pH adjustment were included in the O&M cost estimate for activated alumina treatment. The cost for pH adjustment was modeled assuming an initial pH of 7.9 and alkalinity of 160 mg/L as $CaCO_3$. The pH was adjusted to 5.5 with sulfuric acid and then readjusted

[215] Flow ranges are based on an assumed treatment rate range developed by Corona Environmental and utilized in the 2021 Cost Assessment Model.

[216] Treatment Cost Methodology Details, Attachment C3, page 10: https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/documents/needs/c3.pdf

back to 7.9 using caustic soda after treatment. Periodic media regeneration or replacement costs were not included in the 2021 Cost Assessment Model.

For the proposed updated Cost Assessment Model, the State Water Board aims to refine the 2021 Cost Assessment Model methodology and include the costs associated with media regeneration and replacement. U.S. EPA's 2023 WBS Model[217] estimates the cost of media regeneration and the costs of basic and acidic chemicals for pH adjustment throughout the adsorption process. Table 69 below compares modeled assumptions and cost components between the 2021 Cost Assessment Model and the recommended update.

Table 69: Summary Comparison of Activated Alumina Operational Assumptions

Items	2021 Model	State Water Board's Recommendation
Alkalinity (mg/L as $CaCO_3$)	160[218]	25[219]
Assumed Initial pH	7.9	7.9
Number of BV	Not considered[220]	1,150[221]
Caustic Soda 50%	$0.23/gal	$0.32/lb[222]
Sulfuric Acid 93%	$0.23/gal	$0.93/lb[223]
Regenerative Activated Alumina	Excluded	$161.37/cf[224]

Using the U.S. EPA's 2023 WBS Adsorptive Media Model, a linear regression equation was developed for the water systems failing for fluoride MCL violations, given their

217 U.S. EPA's 2023 WBS Model for Adsorptive Media (xlsm)

https://www.epa.gov/system/files/other-files/2023-04/WBS_adsorb_031323.xlsm

218 Assumes median concentration for Kern County.

219 As of August 17, 2023, the statewide average alkalinity of water systems failing for fluoride was calculated. Water systems with multiple sources and available alkalinity data had their values averaged across all sources. Water systems that reported zero alkalinity, either due to a lack of data or assumptions of concentrations not reaching reporting levels, were excluded from the calculation.

220 BV estimates and regeneration costs were excluded in 2021 Cost Assessment Model.

221 According to U.S. EPA's 2023 WBS Model, BVs vary based on water quality and system configuration. U.S. EPA's WBS guidelines: AWWA (1999) reports 1,000 to 1,300 BV when influent fluoride concentration is 3.0 to 6.0 mg/L. Hence, average BV of 1,150 is assumed.

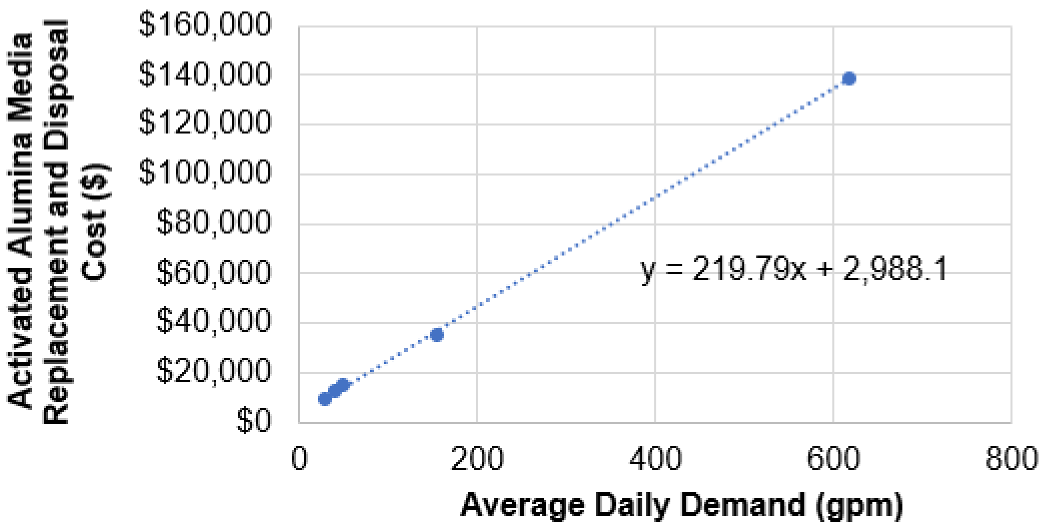
222 Cost data based on U.S. EPA's 2023 WBS Adsorptive Media Model https://www.epa.gov/system/files/other-files/2023-04/WBS_adsorb_031323.xlsm

223 Cost data based on U.S. EPA's 2023 WBS Adsorptive Media Model https://www.epa.gov/system/files/other-files/2023-04/WBS_adsorb_031323.xlsm

224 Cost data based on U.S EPA's 2023 WBS Adsorptive Media Model https://www.epa.gov/system/files/other-files/2023-04/WBS_adsorb_031323.xlsm

average daily demand (in gpm). Labor and electricity will be applied as separate budgetary items consistent with all other treatments.

Figure 11: Activated Alumina Operational Cost Regression for Proposed Updated Model



Equation 19: Activated Alumina Media Replacement and Disposal Cost

y = 219.79x + 2,988.1
where, y = Activated alumina replacement and disposal cost ($)
x = Annual production (in MG)

4-log Virus Treatment

The Ground Water Rule (GWR)[225] may require 4-log virus treatment for groundwater sources that are susceptible to fecal contamination. Virus treatment may include virus removal and/or inactivation. A 4-log virus treatment is analogous to 9,999 out of 10,000 or 99.99% inactivation/removal. Virus treatment is typically accomplished via chlorine, ozone, ultraviolet radiation (UV), chlorine dioxide, or chloramines. However, chlorine and ozone are most common for small water systems.

The 2021 Cost Assessment Model selected 4-log virus treatment as the long-term solution for water systems failing to comply with the GWR (Table 70). The 2021 Cost Assessment Model assumed 4-log virus treatment was achieved through chlorination within a water main for all the flow rate ranges and tank(s) for larger flow rate ranges. Ozone, UV, chlorine dioxide, and chloramines were not considered in the 2021 Cost Assessment Model due to associated higher capital expenses and operational complexity.

[225] U.S. EPA's Ground Water rule (GWR)
https://www.epa.gov/dwreginfo/ground-water-rule

Table 70: Contaminants Treated by 4-log Virus Treatment in the Cost Model

Contaminant	System Criteria
Fecal contaminants (microorganisms)[226] • *E. coli*	• Failing systems for GWR violation. • Groundwater sources.

4-log Virus Treatment Capital Cost Components & Assumptions

In the 2021 Cost Assessment Model,[227] the modeled capital cost for 4-log virus treatment was developed based on U.S. EPA's Disinfection Profiling and Benchmarking Technical Guidance Manual.[228] The 2021 Cost Assessment Model included the following assumptions to estimate 4-log virus capital costs:

- Chlorine dosage of 1.5 mg/L.
- A new water main is needed for all flow rate ranges (1 – 2,100 gpm) for disinfection.
- One new tank is needed for water systems with an estimated flow rate range between 700 to 1,400 gpm, and two new tanks for water systems with estimate flow rate ranges greater than 1,400 gpm to achieve appropriate chlorine contact time.
- Tanks were not considered for the flow rates less than 700 gpm.
- Water temperature of 15°C.
- pH of 8.
- A baffling factor of 0.9 for the water main.
- A baffling factor of 0.3 for the tank(s).
- A 12-inch diameter water main. The modeled water main lengths are determined by the estimated water system flow rates time (Table 71).

Table 71: Assumed Length of Water Main Depending Upon Flow Rate Ranges

Flow Rate Ranges (gpm)	Assumed Water Main Length (lf)
0 - 15	12
16 - 50	40
51 – 175	140
176 – 300	240
301 – 700	50
701 – 1,400	50

[226] U.S EPA's National Primary Drinking Water Regulations
https://www.epa.gov/ground-water-and-drinking-water/national-primary-drinking-water-regulations

[227] 2021 Drinking Water Cost Assessment and Gap Analysis, Attachment C3: Treatment Cost Methodology Details, page 12
https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/documents/needs/c3.pdf

[228] U.S. EPA, Disinfection Profiling and Benchmarking Technical Guidance Manual. June 2020
https://www.epa.gov/system/files/documents/2022-02/disprof_bench_3rules_final_508.pdf

Flow Rate Ranges (gpm)	Assumed Water Main Length (lf)
1,400 – 2,100	50

The 2021 Cost Assessment Model's capital costs were derived from vendor-supplied quotes for tanks and pipes. The original quotes, from 2018 to 2020, were adjusted to 2021 dollars using ENR CCI. The final estimated installed capital cost was determined by applying an engineering multiplier of approximately 3.06 to the estimated equipment unit cost.

The State Water Board evaluated the 2021 Cost Assessment Model approach and assumptions for estimating the capital costs of achieving 4-log virus treatment by conducting internal research and external outreach to vendors and contractors. After extensive review, the State Water Board's internal workgroup recommends the continued use of the 2021 Cost Assessment Model's methodology with a few modifications, as follows:

- Update the estimated unit costs for tanks and water mains.
- Add three new capital cost components: a small-scale SCADA system; a chlorine analyzer; and a pH analyzer.

Table 72 below summarizes the capital cost components for 4-log virus treatment.

Table 72: Summary Comparison of 4-log Virus Treatment Capital Cost

Cost Components	2021 Model	Recommended Update
Tank	Included only for water systems with estimated flows of 700 – 2,100 gpm, a tank cost is estimated at $7/gallon.	Included only for water systems with estimated flows of 700 – 2,100 gpm, a tank cost is estimated at $20/gallon.
Water Main	$115/linear foot (lf)	$220/lf
SCADA	Excluded	$18,000
Chlorine Analyzer	Excluded	$4,000
pH Analyzer	Excluded	$1,081

Table 73 below provides a comparison of the estimated installed capital cost for 4-log virus treatment between the 2021 Cost Assessment Model and the proposed updated Cost Assessment Model.

Table 73: Summary Comparison of Installed Capital Cost for 4-log Virus Treatment

Flow Rate Range (gpm)[229]	2021 Model	Recommended Update
1 – 175	$36,320	$60,000
175 – 300	$62,100	$86,000
300 – 700	$632,690	$656,000
700 – 1,400	$1,361,460	$1,385,000
1,400 – 2,100	$2,063,270	$2,087,000

Water Main

In 2021 Cost Assessment Model, it was assumed that water systems can achieve either full or partial 4-log virus treatment in a water main. The 2021 Cost Assessment Model assumed a new water main is needed for each water system included in the analysis for all estimated flow ranges due to a lack of available asset-related data for Failing water systems.

The 2021 Cost Assessment Model assumed the modeled water mains are 12-inch polyvinyl chloride (PVC) for all estimated flow rates. The 2021 Cost Assessment Model utilized guidance in U.S. EPA's Disinfection Profiling and Benchmarking Technical Guidance Manual to develop estimated water main lengths based on estimated flow rates for each water system included in the analysis (Table 71). The 2021 Cost Assessment Model's assumptions are summarized in the section, 4-log Virus Treatment Capital Cost Components & Assumptions, above.

The State Water Board recommends maintaining the same water main cost estimation methodology for the proposed updated Cost Assessment Model with updated cost assumptions.

Internal and external research conducted by State Water Board staff suggests that water main costs have increased since the 2021 Cost Assessment Model was developed. State Water Board funded projects do not reflect recent quotes; therefore, the State Water Board recommends updating the water main cost assumptions in the 2021 Cost Assessment Model from $155 per linear foot to $220 per linear foot. This cost estimate aligns with recent internal and external water main quotes. Underlying water main cost estimate assumptions are detailed below:

- Material cost for 12" PVC C900[230] = $55/lf

[229] Flow ranges are based on an assumed treatment rate range developed by Corona Environmental and utilized in the 2021 Cost Assessment Model.

[230] C900 PVC: C900 is the American Water Works Association (AWWA) standard for cast-iron-pipe-equivalent outside diameter PVC pressure pipe and fabricated fittings covering nominal pipe sizes from 4

- Installation cost vary with location accessibility, material, and other installation conditions and typically ranges from $75 to $255/lf[231]
- For the purpose of the cost model estimate, assume average installation cost = $165/lf

Equation 20: Installed Water Main Cost Assumption

Cost/Lf = Material ($55) + Installation ($165) = $220/lf

Table 74: Summary Comparison of Water Main Cost[232] Per Linear Foot

2021 Cost	State Water Board Funded Projects	External Quotes	State Water Board's Recommendation
$155/lf[233]	$160/lf[234] (2020)	$220/lf[235] (2023)	$220/lf
	$250/lf[236] (2022)	$198/lf[237] (2022)	

Tank

The 2021 Cost Assessment Model includes the estimated cost of a new tank or tanks with an inlet, outlet, and a baffling mechanism for flow rates greater than 700 gpm, in addition to a water main, to achieve needed chlorine contact time. Water systems with estimated flow rate ranges between 700 to 1,400 gpm were modeled for one new tank and water systems with estimated flow rate ranges between 1,400 to 2,100 gpm were modeled for two new tanks. Water systems with less than 700 gpm estimated flow rates did not have a new tank modeled for them as it is assumed that disinfection will occur completely in the water main for these water systems. The State Water Board recommends maintaining the same tank cost estimation methodology for the proposed updated Cost Assessment Model with updated cost assumptions.

Following discussions with internal and external experts and service providers, the State Water Board recommends revising tank cost assumptions utilizing the average of two external quotes. These tanks are customized to align with the assumed flow rates (700 – 2,100 gpm) by the vendors. The State Water Board does not recommend using State Water Board funded project costs due to the age of the costs and tanks sizes for those projects not aligning with the 2021 Cost Assessment Model's assumed flow rate range of 700 to 2,100 gpm. As summarized in Table 75 below, it is recommended to update

inches through 12 inches. C900 pipes and fittings must comply with the Safe Drinking Water Act requirements, meaning for potable water transmission and distribution. The C900 standard does not include injection-molded PVC fittings.

[231] Ferguson Water Works pipeline installation range.

[232] Pipeline costs include materials and installation costs.

[233] QK estimate collected by Corona Environmental in 2020 for the 2021 Cost Assessment.

[234] Coachella City consolidation project cost estimate.

[235] Ferguson Water Works, assuming average installation cost.

[236] Tulare City consolidation project.

[237] Construction project manager in the City of Independence.

the modeled tank cost from $7 per gallon to $20 per gallon in the updated Cost Assessment Model.

Table 75: Summary Comparison of Tank Quotes

2021 Cost	State Water Board Funded Projects	External Quote/s	State Water Board's Recommendation
$7/gallon[238]	$25/gallon[239] (2022)	$36/gallon[240] (2023)	$20/gallon
	$10/gallon[241] (2022)	$18/gallon [242] (2023)	
	$10/gallon [243] (2020)		

Small-Scale Supervisory Control and Data Acquisition (SCADA) for Chlorination
Use of SCADA is recommended for continuous monitoring of chlorination systems. This is to ensure compliance with 4-log virus treatment through maintaining the required disinfection contact time.

The 2021 Cost Assessment Model excluded small-scale SCADA from the capital cost estimate for 4-log virus treatment. The State Water Board recommends including this cost component in the proposed updated Cost Assessment Model. SCADA is essential for ensuring appropriate chlorination.

Internal research conducted by State Water Board staff suggests that the cost of a small-scale SCADA system varies significantly within State Water Board funded projects due to the difference in water system size, treatment technology, complexity of the SCADA system, and project year. It is also worth noting that the State Water Board funded SCADA systems themselves are not chlorination specific systems. State Water Board staff also reached out to vendors for small-scale SCADA quotes (Table 76). The two quotes collected from vendors differed dramatically and the differences can be attributed to different design capacities and functionality. The higher vendor quote is for a SCADA system that is not chlorination specific.

After internal discussions, the State Water Board recommends utilizing the lower vendor-provided quote, that is chlorination specific. This device's capital cost is

[238] Estimate collected by Corona Environmental in 2018 for the 2021 Cost Assessment. Costs for the major capital improvements (including pipeline installation) provided by QK, Incorporated, which is an engineering design firm in the Central Valley.

[239] Kings Canyon Unified School District project, water supply upgrade and consolidation project

[240] Highland Tanks vendor quote for a fully furnished tank.

[241] Caruthers Community Services District project, Furnish and Install 10,000-gallon tank.

[242] Clear Water Store vendor quote. The quote includes all the inlet/outlet/baffling mechanism.

[243] Richgrove Community Services District, water well and storage tank project, engineer's opinion of probable construction cost

$18,000. This recommendation is based on the presumed capacity and needs of small water systems. The SCADA system cost covers installation and equipment ($14,000) as well as a one-year software and cloud protection plan ($4,000). The Table 76 below summarizes the small-scale SCADA system costs.

Table 76: Summary Comparison of Small-Scale SCADA System

2021 Cost	State Water Board Funded Projects	External Quotes	State Water Board's Recommendation
Excluded	$52,000[244] (2017)	$18,000[245] (2023)	$18,000
	$30,000[246] (2020)	$70,000[247] (2023)	
	$10,000[248] (2019)		

Chlorine Analyzer

A chlorine analyzer is necessary to accurately monitor free chorine, provide real-time results, and ensure regulatory compliance. Chlorine analyzer costs may vary depending on a water system's geographical location as well as the device's display and data logging features.

In the 2021 Cost Assessment Model, the chlorine analyzer capital cost was excluded. The State Water Board proposes to include a cost estimate for a chlorine analyzer in the proposed updated Cost Assessment Model.

After internal discussions, the State Water Board recommends averaging all internal and external quotes. This results in a flat cost of $4,000. Table 77 below summarizes chlorine analyzer costs derived from various sources.

[244] Santa Nella County Water District Water Supply and Blending Facilities project. This is not a chlorination specific SCADA cost.

[245] Xio - Installation and equipment ($14,000) and software & cloud protection plan (per month) $300 - $400 – Chlorination specific.

[246] Shasta County CSA 6 Jones Valley Water System Improvement Project. This is not a chlorination specific SCADA cost.

[247] New frontier technologies including instrument, installation, software, and labor costs. This is not a chlorination specific SCADA cost.

[248] Biola Community Services District Project Engineering Report. This is not a chlorination specific SCADA cost.

Table 77: Summary Comparison of Chlorine Analyzer Cost

2021 Cost	State Water Board Funded Projects	External Quotes	State Water Board's Recommendation
Excluded	$4,000[249] (2019)	$3,000 - $5,000[250] (2023)	$4,000
		$3,803[251] (2023)	

pH Analyzer
If the pH is too high or too low, the efficiency of chlorine as a disinfectant can be compromised. Therefore, a pH analyzer is necessary to accurately monitor the pH value of water for its acidity or alkalinity.

In 2021 Cost Assessment Model, the capital cost for a pH analyzer was excluded. The State Water Board recommends including a cost estimate for a pH analyzer in the proposed updated Cost Assessment Model.

Staff explored State Water Board funded projects and contacted external vendors to develop a cost estimate. No cost information was found in the State Water Board funded projects over the last few years. The costs gathered vary depending upon the retailers. State Water Board staff recommends averaging two external quotes. This results in a flat cost estimate of $1,081 for a pH analyzer as summarized in the Table 78 below.

Table 78: Summary Comparison of pH Analyzer Cost

2021 Cost	State Water Board Funded Projects	External Quote/s	State Water Board's Recommendation
Excluded	N/A	$790[252] (2023)	$1,081
		$1,372.50[253] (2023)	

4-log Virus Treatment O&M Cost Components & Assumptions

In the 2021 Cost Assessment Model, only estimated labor cost was included in the O&M cost estimate for 4-log treatment. The State Water Board conducted extensive research and, with the help of expert internal staff, identified additional O&M cost components proposed for 4-log virus treatment summarized in Table 79 below. Labor

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249 Linda County Water District Well 17 Water Treatment Plant and Storage Tank Project

250 Quotes derived from vendor - Hach
http://www.hach.com/

251 Quotes derived from vendor - JPR Systems (Yokogawa)
http://www.jprsystems.com/

252 Quote collected from vendor – Hach.
https://www.hach.com/

253 Quote collected from vendor - Thermo Scientific
https://www.thermofisher.com/

and electricity will be applied as separate budgetary items consistent with all other treatment technologies.

Table 79: Summary Comparison of 4-log Virus Treatment Operational Costs

Cost Components	2021 Model	Recommended Update
Chlorine Analyzer Reagent	Excluded	$84
12.5% Liquid Sodium Hypochlorite (NaOCl)	Excluded	$7.80/gallon

Chlorine Analyzer Reagents

A chlorine analyzer reagent includes a N,N-diethyl-p-phenylenediamine (DPD) indicator, free chlorine indicator, and buffer solutions. These chemicals are usually sold in sets. The reagents react with the chlorine in a water sample, resulting in a color change. The intensity of color change is directly related to the amount of chlorine in the water sample. These reagents are used with certain types of analyzers available in the market.

The estimated O&M costs associated with a chlorine analyzer reagent were excluded from the 2021 Cost Assessment Model. The State Water Board proposes to include this component in the proposed updated Cost Assessment Model.

The cost of chlorine analyzer reagent can vary depending on the vendor, location, and many other factors. Staff explored State Water Board funded projects and contacted external vendors to develop a cost estimate. No cost information was found in the State Water Board funded projects over the last few years. Two vendors provided quotes which are summarized in Table 80. After internal discussions, the State Water Board recommends averaging the two external quotes to develop a cost estimate for chlorine analyzer reagent. This results in a flat cost of $84.

Table 80: Summary Comparison of Chlorine Analyzer Reagent

2021 Cost	State Water Board Funded Projects	External Quotes	State Water Board's Recommendation
Excluded	N/A	$67.25[254] (2023)	$84
		$101.90[255] (2023)	

[254] HACH J.A.W. Total Chlorine Reagent Kit (P/N 09552H), 30-day supply of TOTAL Chlorine Reagent (J.A.W. = "Just Add Water") for the HACH Chlorine Analyzers
https://www.hach.com

[255] Fischer Scientific, Lovibond™ Process Chlorine Analyzer Reagents: Free Chlorine, Includes: Free Chlorine Indicator Solution (473mL), Free Chlorine Buffer Solution (473mL), DPD Indicator Powder (24g)
https://www.thermofisher.com

12.5% Liquid Sodium Hypochlorite (NaOCl)
12.5% NaOCl, a powerful and widely used chemical to disinfect drinking water. It effectively inactivates harmful pathogens and viruses in water.

The annual costs associated with purchasing 12.5% NaOCl was excluded from the 2021 Cost Assessment Model. The State Water Board proposes to estimate the cost of 12.5% NaOCl in the proposed updated Costs Assessment Model.

The State Water Board obtained one external quote for 12.5% NaOCl. No cost information was found in the State Water Board funded projects over the last few years. State Water Board staff recommends using the external quote listed in Table 81 to develop a cost estimate for 12.5% NaOCl. The cost is estimated at $7.80 per gallon.

Table 81: Summary Comparison of 12.5% Liquid Sodium Hypochlorite (NaOCl) Costs

2021 Cost	State Water Board Funded Projects	External Quote/s	State Water Board's Recommendation
Excluded	N/A	$7.80/gallon[256] (2023)	$7.80/gallon

The annual cost of 12.5% NaOCl needed to disinfect water is estimated[257] using the equation below.

Equation 21: Chlorine Dosage, mg/l

Total Chlorine Dosage (mg/l)[258] = Chlorine Demand, mg/l + Residual, mg/l

Equation 22: Estimated Annual Cost of 12.5% NaOCl ($/yr):

Annual cost of 12.5% NaOCl ($/yr) = (12.5% NaOCl, $/gal) x MGD x 365 days/yr (ppm or mg/L of chlorine[259]) x 8.34 lbs/gal) ÷ (12.5% * 8.34 lbs/gal)

Surface Water Treatment Package Plant

According to the U.S. EPA,[260] the main objective of the Surface Water Treatment Rules (SWTRs) is to minimize the occurrence of illness stemming from pathogens found in

[256] Laballey
https://www.laballey.com/

[257] Adopted from the units and conversion factors document for chlorination and chemical dosage calculations documentation provided by the State Water Board in 2016.
https://www.waterboards.ca.gov/drinking_water/certlic/occupations/documents/opcert/2016/treat_exam_conversion.pdf

[258] Where, Chlorine Demand = 1 mg/L; Residual = 0.5 mg/L. Hence, Total Chlorine Dosage = 1.5 mg/L

[259] Chlorine dosage of 1.5 mg/l.

[260] U.S. EPA, Surface Water Treatment Rules:
https://www.epa.gov/dwreginfo/surface-water-treatment-rules

drinking water. Among the disease-causing pathogens are *Legionella*, *Giardia Lamblia,* and *Cryptosporidium*. Under the SWTRs, water systems are often required to filter and/or disinfect water obtained from surface sources and groundwater under the direct influence of surface water (GWUDI).

A surface water treatment package plant includes both filtration and disinfection.[261] The package plant can minimize space needs and streamline treatment process, making operation easier and enabling remote control with SCADA, if needed.

Table 82: Contaminants Treated by a Surface Water Treatment Package Plant in the Cost Model

Contaminants	System Criteria
Turbidity	• Failing systems with a SWTR violation. • Surface water sources.
Aluminum[262]	
Fecal contaminants (microorganisms)[263] • *E. coli*	

Surface Water Treatment Capital Cost Components & Assumptions

In the 2021 Cost Assessment Model,[264] capital costs for both conventional and membrane package systems were estimated using vendor quotes. Capital costs were averaged and grouped by treatment flow rates. An engineering multiplier[265] of 3.06 was applied to the average cost for each treatment flow rate range to develop an estimate of the installed capital cost. In addition to surface water treatment capital costs, the 2021 Cost Assessment Model also included the capital cost components for 4-log virus treatment within the total capital cost estimate to achieve disinfection credit.

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[261] For purposes of the Cost Assessment Model, the modeled surface water treatment package plant is assumed to include 4-log virus treatment. The State Water Board recognizes that the treatment objective of 4-log virus treatment may be partially met through filtration. However, for simplicity, the Cost Assessment Model assumes full 4-log virus treatment is accomplished within the surface water treatment package plant by disinfection.

[262] Surface water treatment is not considered the best available technology for treating Aluminum. Aluminum is added as a flocculant in drinking water treatment, which can leach out in the treated water. According to California Code of Regulations, Chapter 15, Article, 12, Table 64447.2-A, Best Available Technologies (BAT) Inorganic Chemicals, it is suggested to optimize treatment and reduce aluminum added for flocculation. In the 2021 Cost Assessment Model, it was assumed that the Aluminum would be removed during the filtration stage of the surface water treatment package plant. The State Water Board recommends modeling surface water treatment to address water quality violations associated with Aluminum.

[263] The microorganisms include *Cryptosporidium*, *Giardia Lamblia*, Heterotrophic Plate Count (HPC), *Legionella*, total coliforms (including fecal coliform and *E.coli*), and viruses based on U.S. EPA's National Primary Drinking Water Regulations.
https://www.epa.gov/ground-water-and-drinking-water/national-primary-drinking-water-regulations

[264] Treatment Cost Methodology Details, Attachment C3, pg 10:
https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/documents/needs/c3.pdf

[265] Treatment Cost Methodology Details, Attachment C3, Table C3.9:
https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/documents/needs/c3.pdf

The State Water Board evaluated the 2021 Cost Assessment Model approach and assumptions for estimating the capital costs of surface water treatment by conducting internal research and external outreach to vendors and contractors. The State Water Board's internal workgroup recommends the continued use of the original 2021 Cost Assessment Model's methodology with a few modifications:

- Update the estimated unit costs for tanks and pipelines for 4-log virus treatment.
- Add five new capital cost components: a handheld turbidimeter, small-scale SCADA system, chlorine analyzer, and pH analyzer.

Table 83 below summarizes the comparison of installed capital costs for surface water treatment.

Table 83: Summary Comparison of Surface Water Treatment Capital Costs

Components	2021 Model	Recommended Update
Filtration	Costs for membrane and conventional treatment package systems were compared and grouped together for averaging.[266]	Continue to use 2021 Cost Assessment Model. • Cost is adjusted to the August ENR CCI values.
Handheld Turbidimeter	Excluded	$2,363/unit
Small-Scale SCADA	Excluded	$18,000/unit
Chlorine Analyzer for 4-log Virus Treatment Capital Cost	Excluded	$4,000/unit
Tank for 4-log Virus Treatment Capital Cost	$7/gallon	$20/gallon
Water Main Pipeline for 4-log Virus Treatment Capital Cost	$155/lf	$220/lf
pH Analyzer for 4-log virus inactivation	Excluded	$1,081

Table 84 below provides a comparison of the estimated installed capital cost for surface water treatment between the 2021 Cost Assessment Model and the proposed updated Cost Assessment Model.

[266] https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/documents/needs/c3.pdf

Table 84: Summary Comparison of Installed Capital Cost for Surface Water Treatment Package Plant

Flow Rate Range (gpm)[267]	2021 Model	Recommended Update
1 - 175	$728,200	$914,000
175 - 300	$1,025,380	$1,289,000
300 - 700	$1,682,070	$2,983,000
700 - 1400	$2,421,770	$5,010,000
1400 - 2100	$3,722,170	$7,641,000

The following sections provide detailed overview of the State Water Board's proposed additions to the capital cost estimate for the surface water treatment package plant.

Filtration

Filtration is the most commonly used treatment process to remove turbidity, organic matter, and harmful bacteria from water. In the 2021 Cost Assessment Model,[268] filter cost estimates across different flow rates were collected for many types of filters from multiple vendors. The 2021 Cost Assessment Model incorporated the average of all the collected filter cost estimates to develop a static filter cost estimate for different estimated flow rates. An engineering multiplier[269] of 3.06 was applied to the average cost for each treatment flow rate range to develop an estimate of the installed capital cost for filters (Table 85).

For the proposed updated Cost Assessment Model, the State Water Board proposes to maintain the same methodology for estimating filter costs. The updated Cost Assessment Model will adjust the estimated cost with the August 2023 ENR CCI value as shown in (Table 85).

Table 85: Summary Comparison of Filtration

Flow Rate Range (gpm)[270]	2021 Model	Recommended Update
1 - 175	$703,000	$815,000
175 - 300	$983,000	$1,139,000
300 - 700	$1,461,000	$1,692,000
700 – 1,400	$1,951,000	$2,261,000
1,400 – 2,100	$3,012,000	$3,489,000

[267] Flow ranges are based on an assumed treatment rate range developed by Corona Environmental and utilized I the 2021 Cost Assessment Model

[268] Treatment Cost Methodology Details, Attachment C3, pg 10: https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/documents/needs/c3.pdf

[269] Treatment Cost Methodology Details, Attachment C3, Table C3.9: https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/documents/needs/c3.pdf

[270] Flow ranges are based on an assumed treatment rate range developed by Corona Environmental and utilized I the 2021 Cost Assessment Model.

Handheld Turbidimeter
Turbidity, or the relative clarity of water, can interfere with the effectiveness of surface water treatment. Monitoring turbidity, such as via a handheld turbidimeter, is a necessary indicator of adequate surface water treatment.

In the 2021 Cost Assessment Model, a handheld turbidimeter was excluded from the capital cost estimate components. The State Water Board proposes to include the capital cost for a handheld turbidimeter in the updated proposed Cost Assessment Model.

State Water Board funded projects were explored, and external vendors contacted to develop a cost estimate. No cost information was found in the State Water Board funded projects over the last few years. The State Water Board recommends including an estimated cost of $2,363, the average of the two external quotes (Table 86), for a handheld turbidimeter.

Table 86: Summary Comparison of Handheld Turbidimeter Quotes

2021 Model	State Water Board Funded Projects	External Quotes	State Water Board's Recommendation
Excluded	N/A	$1,926[271] (2023)	$2,363
		$2,800[272] (2023)	

Water Main
In 2021 Cost Assessment Model, it was assumed that water systems can achieve either full or partial 4-log virus treatment in a water main. The 2021 Cost Assessment Model assumed a new water main is needed for each water system included in the analysis for all estimated flow ranges due to a lack of available asset-related data for Failing water systems.

The 2021 Cost Assessment Model assumed the modeled water mains are 12-inch polyvinyl chloride (PVC) for all estimated flow rates. The 2021 Cost Assessment Model utilized guidance in U.S. EPA's Disinfection Profiling and Benchmarking Technical Guidance Manual to develop estimated water main lengths based on estimated flow rates for each water system included in the analysis. The 2021 Cost Assessment Model's assumptions are summarized in the section, 4-log Virus Treatment Capital Cost Components & Assumptions, above.

The State Water Board recommends maintaining the same water main cost estimation methodology for the proposed updated Cost Assessment Model with updated cost assumptions.

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[271] Hach 2100Q Portable Turbidimeters
https://www.hach.com

[272] Quote gathered from a U.S based vendor. The vendor has requested confidentiality; therefore, the vendor's name cannot be provided.

Internal and external research conducted by State Water Board staff suggests that water main costs have increased since the 2021 Cost Assessment Model was developed. State Water Board funded projects do not reflect recent quotes; therefore, the State Water Board recommends updating the water main cost assumptions in the 2021 Cost Assessment Model from $155 per linear foot to $220 per linear foot. This cost estimate aligns with recent internal and external water main quotes. Underlying water main cost estimate assumptions are detailed below:

- Material cost for 12" PVC C900[273] = $55/lf
- Installation cost vary with location accessibility, material, and other installation conditions and typically ranges from $75 to $255/lf[274]
- For the purpose of the cost model estimate, assume average installation cost = $165/lf

Equation 23: Installed Water Main Cost Assumption

Cost/Lf = Material ($55) + Installation ($165) = $220/lf

Table 87: Summary Comparison of Water Main Cost[275] Per Linear Foot

2021 Cost	State Water Board Funded Projects	External Quotes	State Water Board's Recommendation
$155/lf[276]	$160/lf[277] (2020)	$220/lf[278] (2023)	$220/lf
	$250/lf[279] (2022)	$198/lf[280] (2022)	

Tank

The 2021 Cost Assessment Model includes the estimated cost of a new tank or tanks with an inlet, outlet, and a baffling mechanism for flow rates greater than 700 gpm, in addition to a water main, to achieve needed chlorine contact time. Water systems with estimated flow rate ranges between 700 to 1,400 gpm were modeled for one new tank and water systems with estimated flow rate ranges between 1,400 to 2,100 gpm were modeled for two new tanks. Water systems with less than 700 gpm estimated flow rates did not have a new tank modeled for them as it is assumed that disinfection will occur

[273] C900 PVC: C900 is the American Water Works Association (AWWA) standard for cast-iron-pipe-equivalent outside diameter PVC pressure pipe and fabricated fittings covering nominal pipe sizes from 4 inches through 12 inches. C900 pipes and fittings must comply with the Safe Drinking Water Act requirements, meaning for potable water transmission and distribution. The C900 standard does not include injection-molded PVC fittings.

[274] Ferguson Water Works pipeline installation range.

[275] Pipeline costs include materials and installation costs.

[276] QK estimate collected by Corona Environmental in 2020 for the 2021 Cost Assessment.

[277] Coachella City consolidation project cost estimate.

[278] Ferguson Water Works, assuming average installation cost.

[279] Tulare City consolidation project.

[280] Construction project manager in the City of Independence.

completely in the water main for these water systems. The State Water Board recommends maintaining the same tank cost estimation methodology for the proposed updated Cost Assessment Model with updated cost assumptions.

Following discussions with internal and external experts and service providers, the State Water Board recommends revising tank cost assumptions utilizing the average of two external quotes. These tanks are customized to align with the assumed flow rates (700 – 2,100 gpm) by the vendors. The State Water Board does not recommend using State Water Board funded project costs due to the age of the costs and tanks sizes for those projects not aligning with the 2021 Cost Assessment Model's assumed flow rate range of 700 to 2,100 gpm. As summarized in Table 88 below, it is recommended to update the modeled tank cost from $7 per gallon to $20 per gallon in the updated Cost Assessment Model.

Table 88: Summary Comparison of Tank Quotes

2021 Cost	State Water Board Funded Projects	External Quote/s	State Water Board's Recommendation
$7/gallon[281]	$25/gallon[282] (2022)	$36/gallon[283] (2023)	$20/gallon
	$10/gallon[284] (2022)	$18/gallon [285] (2023)	
	$10/gallon [286] (2020)		

Small-Scale Supervisory Control and Data Acquisition (SCADA) for Chlorination
Use of SCADA is recommended for continuous monitoring of chlorination systems. This is to ensure compliance with 4-log virus treatment through maintaining the required disinfection contact time.

The 2021 Cost Assessment Model excluded small-scale SCADA from the capital cost estimate for 4-log virus treatment. The State Water Board recommends including this cost component in the proposed updated Cost Assessment Model. SCADA is essential for ensuring appropriate chlorination.

Internal research conducted by State Water Board staff suggests that the cost of a small-scale SCADA system varies significantly within State Water Board funded projects due to the difference in water system size, treatment technology, complexity of the SCADA system, and project year. It is also worth noting that the State Water Board funded SCADA systems themselves are not chlorination specific systems. State Water

[281] Estimate collected by Corona Environmental in 2018 for the 2021 Cost Assessment. Costs for the major capital improvements (including pipeline installation) provided by QK, Incorporated, which is an engineering design firm in the Central Valley.

[282] Kings Canyon Unified School District project, water supply upgrade and consolidation project

[283] Highland Tanks vendor quote for a fully furnished tank.

[284] Caruthers Community Services District project, Furnish and Install 10,000-gallon tank.

[285] Clear Water Store vendor quote. The quote includes all the inlet/outlet/baffling mechanism.

[286] Richgrove Community Services District, water well and storage tank project, engineer's opinion of probable construction cost

Board staff also reached out to vendors for small-scale SCADA quotes (Table 76). The two quotes collected from vendors differed dramatically and the differences can be attributed to different design capacities and functionality. The higher vendor quote is for a SCADA system that is not chlorination specific.

After internal discussions, the State Water Board recommends utilizing the lower vendor-provided quote, that is chlorination specific. This device's capital cost is $18,000. This recommendation is based on the presumed capacity and needs of small water systems. The SCADA system cost covers installation and equipment ($14,000) as well as a one-year software and cloud protection plan ($4,000). The Table 89 below summarizes the small-scale SCADA system costs.

Table 89: Summary Comparison of Small-Scale SCADA System

2021 Cost	State Water Board Funded Projects	External Quotes	State Water Board's Recommendation
Excluded	$52,000[287] (2017)	$18,000[288] (2023)	$18,000
	$30,000[289] (2020)	$70,000[290] (2023)	
	$10,000[291] (2019)		

Chlorine Analyzer

A chlorine analyzer is necessary to accurately monitor free chorine, provide real-time results, and ensure regulatory compliance. Chlorine analyzer costs may vary depending on a water system's geographical location as well as the device's display and data logging features.

In the 2021 Cost Assessment Model, the chlorine analyzer capital cost was excluded. The State Water Board proposes to include a cost estimate for a chlorine analyzer in the proposed updated Cost Assessment Model.

[287] Santa Nella County Water District Water Supply and Blending Facilities project. This is not a chlorination specific SCADA cost.

[288] Xio - Installation and equipment ($14,000) and software & cloud protection plan (per month) $300 - $400 – Chlorination specific.

[289] Shasta County CSA 6 Jones Valley Water System Improvement Project. This is not a chlorination specific SCADA cost.

[290] New frontier technologies including instrument, installation, software, and labor costs. This is not a chlorination specific SCADA cost.

[291] Biola Community Services District Project Engineering Report. This is not a chlorination specific SCADA cost.

After internal discussions, the State Water Board recommends averaging all internal and external quotes. This results in a flat cost of $4,000. Table 90 below summarizes chlorine analyzer costs derived from various sources.

Table 90: Summary Comparison of Chlorine Analyzer Cost

2021 Cost	State Water Board Funded Projects	External Quotes	State Water Board's Recommendation
Excluded	$4,000[292] (2019)	$3,000 - $5,000[293] (2023)	$4,000
		$3,803[294] (2023)	

pH Analyzer

If the pH is too high or too low, the efficiency of chlorine as a disinfectant can be compromised. Therefore, a pH analyzer is necessary to accurately monitor the pH value of water for its acidity or alkalinity.

In 2021 Cost Assessment Model, the capital cost for a pH analyzer was excluded. The State Water Board recommends including a cost estimate for a pH analyzer in the proposed updated Cost Assessment Model.

Staff explored State Water Board funded projects and contacted external vendors to develop a cost estimate. No cost information was found in the State Water Board funded projects over the last few years. The costs gathered vary depending upon the retailers. State Water Board staff recommends averaging two external quotes. This results in a flat cost estimate of $1,081 for a pH analyzer as summarized in the Table 91 below.

Table 91: Summary Comparison of pH Analyzer Cost

2021 Cost	State Water Board Funded Projects	External Quote/s	State Water Board's Recommendation
Excluded	N/A	$790[295] (2023)	$1,081
		$1,372.50[296] (2023)	

[292] Linda County Water District Well 17 Water Treatment Plant and Storage Tank Project

[293] Quotes derived from vendor - Hach
http://www.hach.com/

[294] Quotes derived from vendor - JPR Systems (Yokogawa)
http://www.jprsystems.com/

[295] Quote collected from vendor – Hach.
https://www.hach.com/

[296] Quote collected from vendor - Thermo Scientific
https://www.thermofisher.com/

Surface Water Treatment Package Plant O&M Cost Components & Assumptions

In the 2021 Cost Assessment Model, only labor costs were estimated for surface water treatment annual O&M expenses. The State Water Board conducted extensive research to identify additional O&M cost components for the proposed surface water treatment package plant. With the assistance of expert internal staff, the State Water Board recommends the addition of the following O&M cost components for surface water treatment as summarized in Table 92. Labor and electricity will be applied as separate budgetary items consistent with all other treatments.

Table 92: Summary Comparison of Surface Water Treatment Package Plant Operational Costs

Cost Components	2021 Model	Recommended Update
Coagulant	Excluded	\$2.75/lb
Filter Aid - Nonionic Polymer	Excluded	\$2/lb
Filter Media Replacement	Excluded	\$220
Pre/post Treatment pH Adjustment	Excluded	Sulfuric Acid 93% - \$1/lb
		Sodium hydroxide (caustic) 50% - \$2.75/lb
Turbidity Standards Calibration Kit	Excluded	\$284
Chlorine Analyzer Reagent for 4-log Virus Treatment	Excluded	\$84
12.5% Liquid Sodium Hypochlorite (NaOCl) for 4-log Virus Treatment	Excluded	\$7.80/gallon

Chemical demand will be calculated in \$/lb. To calculate the estimated volumetric need for treatment chemical, the following formula[297] will be used:

Equation 24: Calculation for Chemical Demand

lb/day = (MGD x (ppm or mg/L) x 8.34 lbs/gal) ÷ % purity (if applicable)

Coagulant - Ferric Chloride

According to the U.S. EPA 1991 Surface Water Treatment Guidance,[298] a coagulant must be used at all times while the treatment plant is in operation. This is because dependable removal of *Giardia cysts* cannot be guaranteed if water is filtered without coagulation. Coagulants are used to clump suspended solid particles in the water. Typically, coagulation includes iron or aluminum salts which have a positive charge such as polyaluminum chloride.

[297] Adopted from the units and conversion factors document for chlorination and chemical dosage calculations documentation provided by the State Water Board in 2016. https://www.waterboards.ca.gov/drinking_water/certlic/occupations/documents/opcert/2016/treat_exam_conversion.pdf

[298] U.S. EPA 1991 Surface Water Treatment Guidance

https://www.epa.gov/sites/default/files/2015-10/documents/guidance_manual_for_compliance_with_the_filtration_and_disinfection_requirements.pdf

In the 2021 Cost Assessment Model, the O&M cost for a coagulant was excluded. The State Water Board recommends including a cost estimate for a coagulant in the proposed updated Cost Assessment Model.

State Water Board funded projects were reviewed, and external vendors contacted to develop a cost estimate. No cost information was found in State Water Board funded projects over the last few years. The costs gathered from various external resources vary depending upon the retailer, quantity, and concentration of the chemical. Based on two external quotes, State Water Board staff recommends including an estimated cost of $2.35/lb from U.S. EPA's vendor cost data, summarized below in Table 93.

Table 93: Summary Comparison of Coagulant

2021 Model	State Water Board Funded Projects	External Quotes	State Water Board's Recommendation
Excluded	N/A	$1.70[299] (2023)	$2.35/lb
		$2 - 4/lb[300] (2023)	

Filter Aid - Nonionic Polymer

Filter aids are used to remove suspended solids to some extent from the water which tend to clog the filter medium during the filtration process. They improve efficiency of the filter and prevent clogging.

In the 2021 Cost Assessment Model, the O&M cost for the filter aid was excluded. The State Water Board recommends including a cost estimate for a filter aid in the proposed updated Cost Assessment Model.

State Water Board funded projects were explored, and external vendors contacted to develop a cost estimate. No cost information was found in the State Water Board funded projects over the last few years. Two external quotes were gathered from national and international resources. Based on two external quotes, the State Water Board recommends including a cost of $2/lb from a U.S. based vendor bid, summarized below in Table 94.

[299] Univar Solutions, https://www.chemcentral.com/water-treatment/delpac-2000-technical-grade-nsf-55-gallon-drum-16145815.html/

[300] Quote gathered from a U.S based vendor. The vendor has requested confidentiality; therefore, the vendor's name cannot be provided.

Table 94: Summary Comparison of Filter Aid Cost - Nonionic Polymer

2021 Model	State Water Board Funded Projects	External Quotes	State Water Board's Recommendation
Excluded	N/A	$2.00/lb[301](2020)	$2.00/lb

Filter Replacement

Contaminants can build up on filters over time, clogging the pores. Sometimes, these contaminants can leach back into treated water and contaminate it. Filter replacement is necessary to maintain filtration efficiency.

In the 2021 Cost Assessment Model, the O&M cost for filter replacement was excluded. The State Water Board proposes to estimate filter replacement cost in the proposed updated Cost Assessment Model.

State Water Broad staff reviewed the U.S. EPA's 2023 WBS Model cost data for filtration replacement cost by million gallons per day (mgd) rate given in the Table 95.

Table 95: U.S. EPA 2023 WBS Model Filter Replacement Cost[302]

Size Needed (MGD)	Size Selected (MGD)	Avg. Unit Cost
0	0.05	$154
0.051	0.144	$154
0.145	0.2	$171
0.201	0.5	$266
0.501	1	$266
1.001	2	$266
2.001	5	$266

State Water Board funded projects were explored, and external vendors contacted to develop a cost estimate for filter replacement. No cost information was found in State Water Board funded projects over the last few years or through external resources. Therefore, the State Water Board recommends using the U.S. EPA's 2023 WBS Model cost data. Due to the low variation in the unit cost across flow ranges within the U.S. EPA's Model, the State Water Board recommends using the Model's annual average unit cost of $220 (across all flow ranges) for filter replacement, as summarized in Table 96.

301 Contra Costa Water District, Quotes based on bid document from Polydyne Inc https://www.ccwater.com/DocumentCenter/View/8621/2100-ITB-NONIONIC-POLYMER-BID-RESULTS?bidId=

302 These estimates were sourced from the U.S. EPA's WBS Reverse Osmosis and Nanofiltration (RO/NF) Model. https://www.epa.gov/system/files/other-files/2022-03/reverse-osmosis-and-nanofiltration-ro-and-nf-.xlsm.xlsm

Table 96: Filter Replacement Cost

2021 Model	State Water Board Funded Projects	External Quotes	State Water Board's Recommendation
Excluded	N/A	$220/MGD[303] (2023)	$220

Pre/post Treatment pH Adjustment
pH is an indicator of the acidity or alkalinity of water. Throughout various stages of water treatment, specific pH levels are needed to ensure that treatment chemicals react effectively with contaminants. As a result, pre- and post- pH adjustment may be necessary. Sulfuric acid and sodium hydroxide (caustic) are the most commonly used substances for neutralizing acids or bases.

In 2021 Cost Assessment Model, the O&M cost for sulfuric acid and sodium hydroxide (caustic) was excluded. The State Water Board recommends including a cost estimate for sulfuric acid and sodium hydroxide (caustic) in the proposed updated Cost Assessment Model.

State Water Board funded projects were explored, and external vendors contacted to develop a cost estimate. No cost information was found in State Water Board funded projects over the last few years. The costs gathered from various resources vary drastically depending upon the retailer, quantity, and concentration of the chemical. Based on various external quotes, the State Water Board staff recommends excluding the U.S EPA's cost data because it is significantly lower than other external quotes collected from vendors that serve California. Staff recommends including a flat estimated cost of $1/lb for 93% sulfuric acid and $2.75/lb for 50% sodium hydroxide (caustic) using the external vendor cost data summarized in Table 97.

Table 97: Summary Comparison of Pre/post Treatment pH Adjustment

Chemical	2021 Model	State Water Board Funded Projects	External Quotes	State Water Board's Recommendation
Sulfuric Acid 93%	Excluded	N/A	$0.20/lb[304] (2023) $1/lb[305] (2023)	$1/lb

[303] Average U.S. EPA cost estimate across all flow ranges in Table 95.

[304] Small Quantity Chemical, U.S. EPA's WBS Model Cost Data (2023) https://www.epa.gov/system/files/other-files/2022-03/reverse-osmosis-and-nanofiltration-ro-and-nf-.xlsm.xlsm

[305] Chemworld https://www.chemworld.com/Sulfuric-Acid-NSF-approved-p/66be-4200.htm

Chemical	2021 Model	State Water Board Funded Projects	External Quotes	State Water Board's Recommendation
Sodium hydroxide (caustic) 50%	Excluded	N/A	$0.32/lb[306] (2023) $2.5/lb[307] (2023)	$2.75/lb

Turbidity Standards Calibration Kit

Turbidity standards calibration kits are used to calibrate turbidimeters. A typical kit contains four sealed vials of 0.1, 20, 100, and 800 NTU standards.

In the 2021 Cost Assessment Model, O&M cost for a turbidity standards calibration kit was excluded. The State Water Board proposes to estimate turbidity standards calibration kit cost in the updated proposed Cost Assessment Model.

Staff explored State Water Board funded projects and contacted external vendors to develop a cost estimate. No cost information was found in State Water Board funded projects over the last few years. One vendor provided a quote which is summarized in the Table 98. The State Water Board recommends utilizing the external quote of $284/unit for a turbidity standards calibration kit in the proposed updated Cost Assessment Model.

Table 98: Summary Comparison of Turbidity Standards Calibration Kit

2021 Model	State Water Board Funded Projects	External Quotes	State Water Board's Recommendation
Excluded	N/A	$284/unit[308] (2023)	$284

Chlorine Analyzer Reagents

A chlorine analyzer reagent includes a N,N-diethyl-p-phenylenediamine (DPD) indicator, free chlorine indicator, and buffer solutions. These chemicals are usually sold in sets. The reagents react with the chlorine in a water sample, resulting in a color change. The

[306]Small Quantity Chemical, EPA's WBS Model Cost Data (2023) https://www.epa.gov/system/files/other-files/2022-03/reverse-osmosis-and-nanofiltration-ro-and-nf-.xlsm.xlsm

[307] Univar Solutions https://www.univarsolutions.com/product-categories/essential-chemicals-ingredients/liquid-caustic-soda?certification=6236&infinity=ict2%7Enet%7Egaw%7Ear%7E537209260014%7Ekw%7Esodium+hydroxide+price%7Emt%7Eb%7Ecmp%7ESearch-+Sodium+Hydroxide+Bulk%7Eag%7ESodium+Hydroxide+Bulk /

[308] Hach, Stablcal® Turbidity Standards Calibration Kit, 2100P Portable Turbidimeter, Sealed Vials https://www.hach.com/p-stablcal-turbidity-standards-calibration-kit-2100p-portable-turbidimeter-sealed-vials/2659405

intensity of color change is directly related to the amount of chlorine in the water sample. These reagents are used with certain types of analyzers available in the market.

The estimated O&M costs associated with a chlorine analyzer reagent were excluded from the 2021 Cost Assessment Model. The State Water Board proposes to include this component in the proposed updated Cost Assessment Model.

The cost of chlorine analyzer reagent can vary depending on the vendor, location, and many other factors. Staff explored State Water Board funded projects and contacted external vendors to develop a cost estimate. No cost information was found in the State Water Board funded projects over the last few years. Two vendors provided quotes which are summarized in Table 99. After internal discussions, the State Water Board recommends averaging the two external quotes to develop a cost estimate for chlorine analyzer reagent. This results in a flat cost of $84.

Table 99: Summary Comparison of Chlorine Analyzer Reagent

2021 Cost	State Water Board Funded Projects	External Quotes	State Water Board's Recommendation
Excluded	N/A	$67.25[309] (2023)	$84
		$101.90[310] (2023)	

12.5% Liquid Sodium Hypochlorite (NaOCl)

12.5% NaOCl, a powerful and widely used chemical to disinfect drinking water. It effectively inactivates harmful pathogens and viruses in water. The annual costs associated with purchasing 12.5% NaOCl was excluded from the 2021 Cost Assessment Model. The State Water Board proposes to estimate the cost of 12.5% NaOCl in the proposed updated Costs Assessment Model.

The State Water Board obtained one external quote for 12.5% NaOCl. No cost information was found in the State Water Board funded projects over the last few years. State Water Board staff recommends using the external quote listed in Table 100 to develop a cost estimate for 12.5% NaOCl. The cost is estimated at $7 per gallon.

[309] HACH J.A.W. Total Chlorine Reagent Kit (P/N 09552H), 30-day supply of TOTAL Chlorine Reagent (J.A.W. = "Just Add Water") for the HACH Chlorine Analyzers
https://www.hach.com

[310] Fischer Scientific, Lovibond™ Process Chlorine Analyzer Reagents: Free Chlorine, Includes: Free Chlorine Indicator Solution (473mL), Free Chlorine Buffer Solution (473mL), DPD Indicator Powder (24g)
https://www.thermofisher.com

Table 100: Summary Comparison of 12.5% Liquid Sodium Hypochlorite (NaOCl) Costs

2021 Cost	State Water Board Funded Projects	External Quote/s	State Water Board's Recommendation
Excluded	N/A	$7.80/gallon[311] (2023)	$7.80/gallon

The annual cost of 12.5% NaOCl needed to disinfect water is estimated[312] using the equation below.

Equation 25: Chlorine Dosage, mg/l

Total Chlorine Dosage (mg/l)[313] = Chlorine Demand, mg/l + Residual, mg/l

Equation 26: Estimated Annual Cost of 12.5% NaOCl ($/yr):

Annual cost of 12.5% NaOCl ($/yr) = (12.5% NaOCl, $/gal) x MGD x 365 days/yr (ppm or mg/L of chlorine[314]) x 8.34 lbs/gal) ÷ (12.5% * 8.34 lbs/gal)

[311] Laballey, 12.5% NaOCl (NSF 60) https://www.laballey.com/products/sodium-hypochlorite-12-5-to-15?variant=41601437368475

[312] Adopted from the units and conversion factors document for chlorination and chemical dosage calculations documentation provided by the State Water Board in 2016. https://www.waterboards.ca.gov/drinking_water/certlic/occupations/documents/opcert/2016/treat_exam_conversion.pdf

[313] Where, Chlorine Demand = 1 mg/L; Residual = 0.5 mg/L. Hence, Total Chlorine Dosage = 1.5 mg/L

314 Chlorine dosage of 1.5 mg/l.

Appendix C: Long-Term Decentralized Treatment Capital & Operations and Maintenance (O&M) Cost Assessment Model Assumptions

The sections below detail the **capital** and **operations and maintenance (O&M)** cost methodology for Point of Use (POU) and Point of Entry (POE) devices utilized in the proposed updated Cost Assessment Model. The Cost Assessment Model will select either POU or POE to reduce a specific contaminant of concern for either a public water system, state small water system, or domestic well. Modeling POU or POE is restricted by many factors, such as the presence of competing ions. Elevated levels of competing ions can significantly reduce the removal efficiency of POU/POE devices. Therefore, assessing source water quality is needed to determine the appropriate modeled decentralized treatment technology solution.

Modeling Decentralized Treatment for Failing Water Systems

In the 2021 Cost Assessment Model, POU/POE was modeled as a long-term solution for Failing public water systems (including schools) with service connections less than 200. More than 50% of Failing water systems have less than 200 service connections. Use of POU/POE is a non-permanent water treatment alternative, that is very time and resource intensive, requiring 100% community buy-in. Due to the challenges in effectively implementing POU/POE, particularly as system size increases, the State Water Board recommends lowering the service connection threshold from 200 to 20 for auto-selecting POU/POE as a solution for Failing public water systems.

Public water systems that predominantly serve schools typically have less than 20 service connections. The proposed updated Cost Assessment Model applies different long-term modeled solution selection criteria for Failing water systems that serve school from other Failing public water systems. The Cost Assessment Model will select small-scale centralized treatment rather than decentralized devices as the modeled long-term solution for systems failing for nitrate, arsenic, uranium, and/or fluoride. POE will be considered for schools with less than 20 service connections, to reduce contaminants concentration and achieve compliance.

For the proposed updated Cost Assessment Model, in a school setting, POUs are not recommended as a viable option to comply with drinking water standards, because it is not feasible to install a POU at each water tap on campus. Therefore, small-scale centralized treatment is modeled to reduce contamination. Considering that most schools include large grassy areas that require irrigation, the capacity of the small-scale treatment will be designed based on 20% of the school's estimated Maximum Daily Demand.

POE devices are typically installed to treat all water entering a building, which provides higher treated flow rates that are distributed equally through all building water taps. In the 2021 Cost Assessment Model, the number of installed units at each school was determined based on the population served by the water system:

- Five POE devices for schools with population 10-50
- Ten POE devices for population > 50

The two assumptions listed above have been re-verified internally and will be utilized in the proposed updated Cost Assessment Model.

Point of Use (POU)

A point of use (POU) treatment device is a decentralized treatment technology that is applied to a single tap and can help reduce contaminant levels. There are various types of POU installations such as under the sink or installation on a countertop. These devices can treat specific contaminants, or a range of contaminants, depending on the need of the customer. In the 2021 Cost Assessment Model,[315] Failing water systems with 200 connections, At-Risk state small water systems, and At-Risk domestic wells were modeled for POU as a long-term solution.

The State Water Board is proposing lowering the service connection threshold, from less than 200 to 20, for public water systems where POU will be modeled as the long-term solution in the proposed updated Cost Assessment Model. The Cost Assessment Model will continue to select POU as the modeled treatment for Failing water systems with water quality for violations for nitrate, arsenic, uranium, or fluoride.

Table 101: Contaminants Treated by POU in the Cost Model

Contaminate	System Criteria
Nitrate	• Failing water systems with < 20 service connections. • At-Risk due to water quality state small water systems. • At-Risk due to water quality domestic wells.
Arsenic	
Uranium	
Fluoride	

POU Capital Cost Components & Assumptions

The State Water Board reviewed the 2021 Cost Assessment Model's cost assumptions and conducted internal and external research. The research included reviewing State Water Board funded projects and consulting with State Water Board technical assistance providers that have extensive experience with installing POU devices. After

[315] 2021 Drinking Water Needs Assessment (pp 263) https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/documents/needs/2021_needs_assessment.pdf

review, State Water Board staff recommends the following changes to the Cost Assessment Model's POU capital cost assumptions as detailed in Table 102.

Table 102: Summary Comparison for Itemized POU Capital Costs

Cost Component	2021 Model	Recommended Update
POU Device Cost per Unit	$1,500	$1,321
Labor Cost per Unit Install	$200	$399
Initial Water Quality Testing	Excluded	$194[316]
Administration/Project Management	$1,000	$551
Community/Household Outreach and Communication Cost	$300	$631
5% Contingency	Excluded	Included
Total Estimated Capital Cost	**$3,000**	**$3,250**[317]

The sections below detail quotes gathered for each capital cost component from different sources along with the State Water Board's recommendation.

POU Device Cost per Unit

In the 2021 Cost Assessment Model the estimated POU unit cost was $1,500. The State Water Board conducted research to either validate or update the POU unit cost assumption in the Cost Assessment Model. Staff reviewed State Water Board funded projects and did not find any projects where POU unit costs were itemized (separate of labor costs). Staff conducted external outreach to collect quotes from POU vendors. Table 103 summarizes the results of this research. The State Water Board recommends updating the Cost Assessment Model's POU unit cost estimate from $1,500 to $1,321. This recommendation was derived from the average of the external quotes collected from State Water Board technical assistance providers. The U.S. EPA cost estimating tool result of $212 was excluded because it is based on default prices for more than one contaminant and older cost assumptions, which do not reflect California market prices.

[316] For state small water systems and domestic wells, $25 will be added to account for total coliform/*E. coli* sampling.

[317] For state small water systems and domestic wells, $25 will be added to account for total coliform/*E. coli* sampling.

Table 103: POU Device Cost Per Unit

2021 Model	State Water Board Funded Projects	External Quotes	State Water Board's Recommendation
$1,500 (2021)	N/A	• $212[318] (2020) • $1,496[319] (2023) • $1,146[320] (2023)	$1,321

Labor Cost per Unit Install

In the 2021 Cost Assessment Model, the labor cost per unit installation was $200. The State Water Board conducted internal and external research and found two external quotes with labor costs for POU units. The data available from State Water Board funded projects has the unit device and labor costs *combined* and could not be itemized, therefore it is excluded from the labor cost analysis. Please see below for a summary of research results.

The labor cost estimate provided by Self-Help (a State Water Board technical assistance provider) is current as of 2023. The U.S. EPA model output was deemed too low and not reflective of California market prices. Therefore, the State Water Board recommends utilizing $399 for labor cost per unit installed within the proposed updated Cost Assessment Model.

Table 104: Labor Cost Per Unit Install

2021 Model	State Water Board Funded Projects	External Quotes	State Water Board's Recommendation
$200 (2021)	N/A	• $85[321] (2020) • $399[322] (2023)	$399

Initial Water Quality Testing

In the 2021 Cost Assessment Model, initial water quality testing was excluded from the Cost Assessment Model's cost estimate methodology for POU capital costs. Based on feedback from State Water Board technical assistance providers, staff recommend including initial water quality testing as part of the capital cost estimate for POU as it is important to know what contaminant(s) are prevalent and the specific filters needed for POU treatment.

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[318] U.S. EPA Point of Use/Point of Entry Cost Estimating Tool https://www.epa.gov/sdwa/point-usepoint-entry-cost-estimating-tool

[319] Price quote provided by Self-Help, in Visalia, California.

[320] Price quote provided by Self-Help, in Visalia, California.

[321] U.S. EPA Point of Use/Point of Entry Cost Estimating Tool https://www.epa.gov/sdwa/point-usepoint-entry-cost-estimating-tool

[322] Price quote provided by Self-Help, in Visalia, California.

Staff conducted a review of State Water Board funded projects and conducted external outreach to develop a cost estimate for initial water quality testing. Table 105 summarizes gathered quotes. Two quotes were available from State Water Board funded projects and averaged by analyte. An external quote was gathered from a California-based laboratory for each analyte. Based on internal discussion, the State Water Board recommends utilizing the average of three quotes gathered from internal and external sources as summarized in Table 105.

Table 105: Initial Water Quality Testing Cost

2021 Model	State Water Board Funded Projects	External Quotes	State Water Board's Recommendation
Excluded	*Based on two projects* (2022)[323] • Nitrate $52 • Arsenic $55 • Uranium $77 • Total Coliform/*E. coli* $25[324]	California-based Laboratory (2023)[325] • Nitrate $79 • Arsenic $27 • Uranium $27 • Fluoride $27	$194[326]

Administration/Project Management

The administration/project management costs refer to the administrative costs associated with POU installation. In the 2021 Cost Assessment Model, the administration/project management cost estimate was $1,000 per unit. Staff analyzed the 2021 Cost Assessment Model documentation t to determine how the $1,000 estimate per unit was generated, but this effort was not successful. Therefore, the State Water Board reviewed administrative costs from different sources to develop a new estimate.

Staff reviewed recent State Water Board funded POU projects and reached out to external technical assistance providers to collect administration/project management cost estimates. Table 106 summarizes the results of this effort. After discussion with an internal workgroup comprised of expert staff, the State Water Board recommends averaging the collected quotes to develop a new administration/project management cost estimate. The average of the three collected quotes is $551 per unit.

[323] Average of two quotes from "Tulare POU" project (2022) and "Household Domestic Well" project (2022).

[324] Only applied to state small water systems & domestic wells incorporating bacti-sampling requirement.

[325] Analytical cost per sample.

[326] A total of averaged costs calculated by each analyte (nitrate $61; arsenic $46; uranium $60; and fluoride $27). For state small water systems & domestic wells, $25 will be added incorporating bacti-sampling requirement.

Table 106: Administration/Project Management Cost

2021 Model	State Water Board Funded Projects	External Quotes	State Water Board's Recommendation
$1,000 (2021)	• $893[327] (2022) • $182[328] (2022)	$579[329] (2023)	$551

Community/Household Outreach and Communication Cost

Community and household outreach and communication costs are an essential part of the process for installing POU devices. In the 2021 Cost Assessment Model, outreach and communication costs were estimated at $300 per unit. The State Water Board conducted internal and external research and outreach and found two external quotes and one State Water Board project with community/household outreach and communication cost data. The State Water Board's recommendation ($631) is derived from averaging the State Water Board funded project quotes and external quotes together. Please see Table 107 below.

Table 107: Community/Household Outreach and Communication Cost

2021 Model[330]	State Water Board Funded Projects	External Quotes	State Water Board's Recommendation
$300 (2021)	$338[331] (2022)	• $845[332] (2023) • $711[333] (2023)	$631

Contingency

In the 2021 Cost Assessment Model, contingency was excluded from the Model. For the proposed updated Cost Assessment Model, the State Water Board conducted internal and external research and outreach and found two quotes for POU-related contingency costs. The external quote from the U.S. EPA Point of Use/Point of Entry Cost Estimating Tool[334] of 10% was deemed too high by State Water Board staff. The State Water Board "224 Budget, Mobile Home Park" project had a 4% contingency for a POU instillation project.

[327] State Water Board funded project with the Tule Basin Water Foundation.

[328] State Water Board funded project with the Kings Water Alliance.

[329] Price quote provided by Valley Water Collaborative, in Modesto, California.

[330] The 2021 Cost Assessment Model data includes communication cost only and not community/household outreach.

[331] State Water Board Funded project with the Kings Water Alliance.

[332] Price quote provided by Self-Help, in Visalia, California.

[333] Price quote provided by Valley Water Collaborative, in Modesto, California.

[334] U.S. EPA Point of Use/Point of Entry Cost Estimating Tool https://www.epa.gov/sdwa/point-usepoint-entry-cost-estimating-tool

Based on feedback from the State Water Board staff and external technical assistance providers, it is recommended to include a 5% contingency to the estimated POU capital cost. The 5% contingency is based on the experience of technical assistance providers that work on POU projects. The cost of POU projects can vary and the feedback received deemed 5% to be a sufficient threshold to help plan for any unexpected expenses. It is important to include to account for variability of POU costs for each project. Please see Table 108 below.

Table 108: Contingency

2021 Model	State Water Board Funded Projects	External Quotes	State Water Board's Recommendation
Excluded	4%[335] (2021)	$10%[336] (2020)	5%

POU O&M Cost Components & Assumptions

Maintaining POU devices over time is critical to ensure they are effectively treating water and protecting public health. Typical POU O&M consists of regular visits by an operator to collect water samples, obtain operational data, and replace filters when appropriate. The State Water Board reviewed the 2021 Cost Assessment Model's annual O&M cost estimate assumptions and suggests making some adjustments for the proposed updated Cost Assessment Model. These suggestions are summarized in Table 109 and reflect recommendations based on internal and external research. Annual O&M costs may vary based on the contaminants being treated by the devices; however, the recommendations try to accommodate these variations as much as possible.

Table 109: Summary Comparison for Itemized POU O&M Costs

Cost Component	2021 Model[337]	Recommended Update
Operator and Communication	$300[338]	$300[339]
Annual Filter Replacement	$100	• Multi-contaminant $321 • Nitrate $123 • Arsenic $189
Water Quality Sampling	• Nitrate/Arsenic $40 • Uranium $110 • Fluoride $60	• Nitrate $158 • Arsenic $54 • Uranium $54

335 State Water Board funded project cost provided by the "224 Budget, Mobile Home Park" project. Contingency is only for the device unit and installation costs.

336 U.S. EPA Point of Use/Point of Entry Cost Estimating Tool https://www.epa.gov/sdwa/point-usepoint-entry-cost-estimating-tool

337 2021 Drinking Water Needs Assessment (p. 263) https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/documents/needs/2021_needs_assessment.pdf

338 Assume three hours.

339 Assume three hours.

Cost Component	2021 Model[337]	Recommended Update
		• Fluoride $54
Total Estimated O&M Costs	$440 – $510	• Nitrate $581 • Arsenic $543 • Uranium[340] $510 • Fluoride[341] $510

The sections below detail quotes gathered for each O&M cost components from different sources along with the State Water Board's recommendation.

Ongoing Operator & Communication Costs

In the 2021 Cost Assessment Model, annual operator and communication costs were estimated at $300 ($100 for 3 hours). Communication costs include outreach to customers to help maintain POU devices and facilitate water quality testing. The State Water Board conducted internal and external research but did not find any State Water Board funded projects or external quotes for annual operator and communication costs associated with maintaining POU devices. Due to the lack of any internal or external quotes, the State Water Board recommends maintaining the cost assumption developed for the 2021 Cost Assessment Model.

Table 110: Operator and Communication Costs

2021 Model[342]	State Water Board Funded Projects	External Quotes	State Water Board's Recommendation
$300 (2021)	N/A	N/A	$300

Annual Filter Replacement

Replacing POU filters is an important aspect of maintaining the treatment capacity of the device. Without proper filtration, human health may be at risk. In the 2021 Cost Assessment Model, the annual filter replacement cost for POU units was estimated at $100 regardless of the contaminant treated by the device. The State Water Board conducted internal and external research and found two State Water Board funded projects and six external quotes with updated annual filter replacement costs for POU

[340] Annual filter replacements costs were not found for uranium. Therefore, the average of the filter replacement costs for nitrate and arsenic was used for uranium and added to the cost for operator and communication and water quality sampling cost for the total O&M.

[341] Annual filter replacements costs were not found for fluoride. Therefore, the average of the filter replacement costs for nitrate and arsenic was used for fluoride and added to the cost for operator and communication and water quality sampling cost for the total O&M.

[342] 2021 Drinking Water Needs Assessment (p. 263) https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/documents/needs/2021_needs_assessment.pdf

units. Of the quotes found, some were for specific contaminants, while others were for multi-contaminants (Table 111).

The State Water Board recommends developing filter replacement costs for specific contaminants and for filters that are designed for multiple contaminants. It is recommended to average the State Water Board funded projects and external multi-contaminant and individual contaminant annual filter replacement costs (excluding the U.S. EPA quote, which is low and not reflective of California pricing). This will provide a working cost estimate based on the available research and data collected. summarizes the results of this research.

Table 111: Annual Filter Replacement Costs

2021 Model	State Water Board Funded Projects	External Quotes	State Water Board's Recommendation
$100 (2021)	• Multi-contaminant $218.63 (2022)[343] • Nitrate $125 (2021)[344]	Self-Help (2023)[345] • Multi-contaminant $255 • Multi-contaminant $525 • Nitrate $108 • Arsenic $189	• Multi-contaminant $321 • Nitrate $123 • Arsenic $189
		Valley Water Collaborative (2023)[346] • Multi-contaminant $285.80 • Nitrate $136	
		U.S. EPA • Multi-contaminant $69.74 (2020)[347]	

343 State Water Board funded project cost provided by the "SAFER Valley Water Collaborative 3-year Budget" project.

344 State Water Board funded project cost provided by the "228 Budget, Mobile Home Park" project.

345 Price quote provided by Self-Help, in Visalia, California.

346 Price quote provided by Valley Water Collaborative, in Modesto, California.

347 U.S. EPA Point of Use/Point of Entry Cost Estimating Tool https://www.epa.gov/sdwa/point-usepoint-entry-cost-estimating-tool

Water Quality Sampling
In the 2021 Cost Assessment Model, the cost estimate for annual water quality sampling was $40 for nitrate and arsenic, $110 for uranium, and $60 for fluoride. The State Water Board conducted internal and external research and outreach concerning analytic-water quality sampling. Three State Water Board funded projects and an external quote for water quality sampling testing were identified. Table 112 summarizes the results of this research. The cost data available from State Water Board funded projects have the laboratory costs as a lump sum and could not be itemized for each analyte. Therefore, the State Water Board recommends utilizing the California based laboratory costs for the proposed updated Cost Assessment Model.

Table 112: Water Quality Sampling Costs

2021 Model	State Water Board Funded Projects	External Quotes	State Water Board's Recommendation
• Nitrate/Arsenic $40 (2021) • Uranium $110 (2021) • Fluoride $60 (2021)	• $175 (2021)[348] • $224 (2022)[349] • $275 (2022)[350]	U.S. EPA (2020)[351] • Nitrate $127 • Arsenic $124 • Fluoride $123 California-based Laboratory (2023) • Nitrate $158[352] • Arsenic/Uranium/ Fluoride $54[353]	• Nitrate $ 158 • Arsenic $ 54 • Uranium $54 • Fluoride $54

Point of Entry (POE)

A point of entry (POE) device is located outside the building and applied to drinking water entering a house or building. Unlike a POU device that treats one tap inside a house or building, a POE device treats all water entering the house or building. Since more water is being treated, POE devices are generally more expensive than POU devices in both capital and O&M costs. POE treatment is selected by the Cost Assessment Model to treat for 1,2,3-TCP, or other volatile organic compounds (VOCs), as exposure can happen through inhalation/ingestion. POU treatment is not considered

348 State Water Board funded project cost provided by the "224 Budget, Mobile Home Park" project.

349 State Water Board funded project cost provided by the "SAFER VWC 3-Year Budget" project.

350 State Water Board funded project cost provided by the "Regional Household Well Assistance Program" project.

351 U.S. EPA Point of Use/Point of Entry Cost Estimating Tool
https://www.epa.gov/sdwa/point-usepoint-entry-cost-estimating-tool

352 Annual cost assuming two samples per year with an analytical cost of $79 per sample.

353 Annual cost assuming two samples per year with an analytical cost of $27 per sample.

for any contaminant that has a risk pathway beyond ingestion. Please see Table 113 below.

Table 113: Contaminants Treated by POE in the Cost Model

Contaminate	System Criteria
VOCs Some examples include: • 1,2,3-Trichloropropane (1,2,3-TCP) • Dibromochloropropane (DBCP) • Ethylene Dibromide (EDB)	• Failing water systems with < 20 service connections. • At-Risk state small water systems. • At-Risk domestic wells.

POE Capital Cost Components & Assumptions

The State Water Board has reviewed the 2021 Cost Assessment Model's POE capital cost assumptions and conducted internal and external research. The internal research included reviewing State Water Board funded projects and external outreach consisted of consultations with vendors and technical assistance providers. State Water Board staff recommends the following updates as detailed in Table 114 below.

Table 114: Summary Comparison of Itemized POE Capital Costs

Cost Component	2021 Model[354]	Recommended Update
POE Device Cost per Unit	$3,700	$1,700
Labor Cost per Unit Install	$1,000	$1,000
Initial Water Quality Testing	Excluded	$575
Administration/Project Management	$1,000	$1,000
Community/Household Outreach and Communication Cost	$300	$300
5% Contingency	Excluded	Included
Total POE Capital Cost	**$6,000**	**$4,804**

354 2021 Drinking Water Needs Assessment (p. 263) https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/documents/needs/2021_needs_assessment.pdf

The sections below detail quotes gathered for each capital cost component from different sources along with the State Water Board's recommendation for the proposed updated Cost Assessment Model.

POE Device Cost per Unit

In the 2021 Cost Assessment Model, the estimated POE device unit cost was $3,700. The 2021 Cost Assessment Model assumed the POE devices are GAC-based with additional prefiltration. The State Water Board conducted research to either validate or update the POE device unit cost assumption in the Cost Assessment Model. Staff reviewed State Water Board funded projects and did not find any projects where the device unit costs were itemized (separate of labor costs). Staff also conducted external outreach to collect quotes from POE device manufacturers. Table 115 summarizes the results of this research.

Among external quotes collected from several vendors, two quotes are for POE devices that have similar prefilter functions to the devices modeled in the 2021 Cost Assessment Model. The higher priced POE device quote collected has additional treatment capabilities beyond what is required in the scope of the Cost Assessment Model. Given that POE is typically modeled for systems with 20 service connections or fewer, as well as state small water systems and domestic wells, the State Water Board recommends utilizing the lower priced POE device quotes. Furthermore, the more expensive POE devices may not be affordable for these communities/households. To be conservative, the State Water Board recommends utilizing the upper-bound price of the recommended quote ($1,700) in the updated Cost Assessment Model.

Table 115: POE Device Cost Per Unit

2021 Model	State Water Board Funded Projects	External Quotes	State Water Board's Recommendation
$3,700 (2021)	N/A	$1,000 - $1,700 (2023)[355]	$1,700
		$1,100 - $1,700 (2023)[356]	
		$6,000 - $8,600 (2023)[357]	

[355] SpringWell: https://www.springwellwater.com/

POE devices equipped with prefilter and GAC filter. Costs vary depending on size of the house and flow rate: $1,016 (1-3 bathroom unit, 9 gpm-12 gpm); $1,200 (4-6 bathroom unit, 12 gpm-15 gpm); and $1,737 (7+ bathroom unit, 20 gpm-24 gpm).

[356] Quality Water Treatment: https://qualitywatertreatment.com/

POE device with carbon filter. Costs vary depending on size of the house and flow rate: $1,110 (1-2 bathroom unit, 6 gpm-7 gpm); $1,223 (2-3 bathroom unit, 6 gpm-7 gpm); $1,425 (3-4 bathroom unit, 8 gpm-10 gpm); and $1,650 (4-5-bathroom unit, 11+ gpm)

[357] ECOsmarte: https://www.ecosmarte.com/whole-house-systems-nosaltwatersoftener-wholehousedrinkingwater

Labor Cost per Unit Install

In the 2021 Cost Assessment Model, the estimated labor cost per POE device installation was $1,000. To evaluate the 2021 Cost Assessment Model's cost assumptions, the State Water Board conducted internal and external research as summarized in Table 116. The data available from State Water Board funded projects has the unit device and labor costs combined and could not be itemized. The external quote from the U.S. EPA Point of Use/Point of Entry Cost Estimating Tool[358]was deemed too low and not reflective of California pricing by State Water Board staff. An additional external quote was collected from a POE manufacturer. Based on internal discussion, the State Water Board recommends utilizing the lower-bound price of the manufacturer quote, which is the same cost estimate utilized as the 2021 Cost Assessment Model.

Table 116: Labor Cost Per Unit Install

2021 Model	State Water Board Funded Projects	External Quotes	State Water Board's Recommendation
$1,000 (2021)	N/A[359]	$85 (2020)[360] $1,000 – $3,000 (2023)[361]	$1,000

Initial Water Quality Testing

In the 2021 Cost Assessment Model, initial water quality testing was excluded from the POE capital cost estimate methodology. Based on feedback from State Water Board staff and external technical assistance providers, the State Water Board recommends including initial water quality testing as part of the capital cost estimate for POE.

Staff reviewed recent State Water Board funded POU/POE projects and reached out to a California laboratory to explore initial water quality testing costs associated with POE instillations. Two quotes were available from recent State Water Board funded projects and averaged by analyte in Table 117. Staff also conducted outreach to a California-based laboratory to collect water quality testing cost estimates. Table 117 summarizes the results of this effort. Based on internal discussion, the State Water Board recommends utilizing the average of the three quotes per analyte gathered from internal

POE devices equipped with prefilter and GAC filter. Costs vary depending on size of the house and other factors, such as flow rate and pipe size. The device is designed to treat indoor, outdoor, hot, and cold water.

358 U.S. EPA Point of Use/Point of Entry Cost Estimating Tool
https://www.epa.gov/sdwa/point-usepoint-entry-cost-estimating-tool

359 POE device unit cost and labor cost combined and could not be itemized.

360 U.S. EPA Point of Use/Point of Entry Cost Estimating Tool
https://www.epa.gov/sdwa/point-usepoint-entry-cost-estimating-tool

361 ECOsmarte: https://www.ecosmarte.com/whole-house-systems-nosaltwatersoftener-wholehousedrinkingwater
Installation costs vary depending on the scope of work.

and external sources to develop an initial POE water quality test cost estimate for the updated Cost Assessment Model. These averages calculated for each analyte were added together to develop the recommended cost estimate, assuming all analytes would need to be tested, for purposes of the initial water quality testing.

Table 117: Initial Water Quality Testing Cost

2021 Model	State Water Board Funded Projects	External Quotes	State Water Board's Recommendation
Excluded	*Based on two projects* (2022)[362] • DBCP/EDB $84 • 1,2,3-TCP $124	California-based Laboratory (2023)[363] • DBCP/EDB $185 • 1,2,3-TCP $200 • Other VOCs $307	$575[364]

Administration/Project Management

The administrative and project management costs refer to the costs associated with POE installation. In the 2021 Cost Assessment Model, the administration/project management cost estimate was $1,000 per unit. Staff analyzed the 2021 Cost Assessment Model documentation to determine how the $1,000 estimate per unit was generated, but this effort was not successful. Therefore, the State Water Board reviewed administrative costs from different sources to develop a new estimate.

Staff reviewed recent State Water Board funded POE projects and reached out to external technical assistance providers to collect administration/project management cost estimates. Table 118 summarizes the results of this effort. After discussion with an internal workgroup comprised of expert staff, the State Water Board recommends averaging the collected quotes to develop a new administration/project management cost estimate. The average of the three collected quotes is $551 per unit.

Table 118: Administration/Project Management Costs

2021 Model	State Water Board Funded Projects	External Quotes	State Water Board's Recommendation
$1,000 (2021)	• $182[365] (2022) • $893[366] (2022)	$579[367] (2023)	$551

[362] Average of two quotes from "Tulare POU" project (2022) and "Household Domestic Well" project (2022).

[363] Analytical cost per sample

[364] A total of averaged costs calculated by each analyte (DBCP/EDB $118; 1,2,3-TCP $150; and other VOCs $307).

[365] State Water Board funded project with the Kings Water Alliance.

[366] State Water Board funded project with the Tule Basin Water Foundation.

[367] Pricing quote provided by Valley Water Collaborative, in Modesto, California.

Community/Household Outreach and Communication Cost

Community and household outreach and communication costs are an essential part of the process for installing POE devices. In the 2021 Cost Assessment Model, outreach and communication costs were estimated at $300 per unit. The State Water Board conducted internal and external research and found two external quotes and one State Water Board project with community/household outreach and communication cost data. The State Water Board recommends averaging the three quotes, which results in $631. Please see Table 119.

Table 119: Community/Household Outreach and Communication Cost

2021 Model[368]	State Water Board Funded Projects	External Quotes	State Water Board's Recommendation
$300 (2021)	$338[369] (2022)	• $845[370] (2023) • $711[371] (2023)	$631

Contingency

In the 2021 Cost Assessment Model, contingency was excluded from the POE unit capital cost estimate. Based on feedback from the State Water Board staff and external technical assistance providers, it is recommended to include contingency in the estimated POE capital cost.

For the proposed updated Cost Assessment Model, the State Water Board conducted internal and external research and outreach and found two quotes for POU-related contingency costs. The external quote from the U.S. EPA Point of Use/Point of Entry Cost Estimating Tool[372] of 10% was deemed too high. The State Water Board "224 Budget, Mobile Home Park" project had a 4% contingency for a POU installation and may be applicable to POE projects.

Based on feedback from the State Water Board staff and external technical assistance providers, it is recommended to include a 5% contingency to the estimated POE capital cost. The 5% contingency is based on the experience of technical assistance providers that work on POU projects. The cost of POE projects can vary, and the feedback received deemed 5% to be a sufficient threshold to help plan for any unexpected expenses. It is important to include to account for variability of POE costs for each project. Please see Table 120.

[368] The 2021 Cost Assessment Model data includes communication cost only and not community/household outreach.

[369] State Water Board funded project with the Kings Water Alliance.

[370] Price quote provided by Self-Help, in Visalia, California

[371] Price quote provided by Valley Water Collaborative, in Modesto, California.

[372] U.S. EPA Point of Use/Point of Entry Cost Estimating Tool https://www.epa.gov/sdwa/point-usepoint-entry-cost-estimating-tool

Table 120: Contingency

2021 Model	State Water Board Funded Projects	External Quotes	State Water Board's Recommendation
Excluded	4%[373] (2021)	10%[374] (2020)	5%

POE O&M Cost Components & Assumptions

Typical POE O&M consists of regular visits by an operator to collect water samples, obtain operational data, and replace filters when appropriate. The State Water Board reviewed the 2021 Cost Assessment Model's cost assumptions and conducted internal and external research. State Water Board staff recommend maintaining the operator and communication cost from the 2021 Cost Assessment Model and updating the annual filter replacement and annual water quality sampling cost estimates. Annual O&M costs may vary based on the contaminants being treated by the devices. The recommendations try to accommodate these variations as much as possible. Please see Table 121 below.

Table 121: Summary Comparison for Itemized POE O&M Costs

Cost Component	2021 Model[375]	Recommended Update
Operator and Communication	$300	$300
Annual Filter Replacement	$410	$84
Annual Water Quality Sampling	$250	$235 - $614[376]
Total POE O&M Cost	**$960**	**$619 - $998**

Ongoing Operator and Communication Costs

In the 2021 Cost Assessment Model, annual operator and communication costs were estimated at $300 ($100 for 3 hours). Communication costs include outreach to customers to help maintain POE devices and facilitate water quality testing. The State Water Board conducted internal and external research but did not find any State Water Board funded projects or external quotes for annual operator and communication costs associated with maintaining POE devices. Due to the lack of any internal or external

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[373] State Water Board funded project cost provided by the "224 Budget, Mobile Home Park" project. Contingency is only for the device unit and installation costs.

[374] U.S. EPA Point of Use/Point of Entry Cost Estimating Tool https://www.epa.gov/sdwa/point-usepoint-entry-cost-estimating-tool

[375] 2021 Drinking Water Needs Assessment (p. 263) https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/documents/needs/2021_needs_assessment.pdf

[376] Cost varies, depending on target analyte(s).

quotes, the State Water Board recommends maintaining the cost assumption developed for the 2021 Cost Assessment Model. Please see the Table 122 below.

Table 122: Operator and Communication Costs

2021 Model	State Water Board Funded Projects	External Quotes	State Water Board's Recommendation
$300 (2021)	N/A	N/A	$300

Annual Filter Replacement

Replacing filters is an important aspect of maintaining the treatment capacity of the POE device. Without proper filtration, human health may be at risk. In the 2021 Cost Assessment Model, the annual filter replacement cost per POE unit was estimated at $410 regardless of the contaminant treated for by the device.

The State Water Board conducted research to either validate or update the annual filter replacement cost assumption used in the 2021 Cost Assessment Model. Staff reviewed State Water Board funded projects but did not find any projects with annual filter replacement cost data. Staff also conducted outreach to POE device manufacturers to collect external quotes. The quotes from two manufacturers are under $100, which is significantly less than the filter replacement cost estimates developed for the 2021 Cost Assessment Model. Staff could not find documentation or any external quotes to support the continued use of the $410 annual filter replacement cost. Based on internal discussion, the State Water Board recommends updating the annual filter replacement cost from $410 to $84 (average of the two external quotes) as summarized in Table 123.

Table 123: Annual Filter Replacement Costs

2021 Model	State Water Board Funded Projects	External Quotes	State Water Board's Recommendation
$410 (2021)	N/A	$73[377]	$84
		$94[378]	

[377] SpringWell: https://www.springwellwater.com/

Sediment filter replacement cost: $40 per year; and
Carbon media replacement cost: $334 per every 1 MG of water treated, which equates to about every 10 years for most households.

[378] ECOsmarte: https://www.ecosmarte.com/whole-house-systems-nosaltwatersoftener-wholehousedrinkingwater

Media replacement cost: $500 for 1-cubic feet per every 8-year, typically. Thus, the total media replacement cost varies depending on sizes of the POE system. The dollar amount, $94/year is an average of the two costs for the most common sizes, 1 and 2-cubic feet.

Water Quality Sampling
In the 2021 Cost Assessment Model, the cost estimate for annual analytic-water quality sampling was $250. The State Water Board conducted internal and external research and outreach. Two quotes were available from State Water Board funded projects and averaged by analyte. Staff also conducted outreach to a California-based laboratory to collect external quotes as summarized in Table 124. Based on internal discussion, the State Water Board recommends utilizing the average of three quotes gathered from internal and external sources for the proposed updated Cost Assessment Model.

Table 124: Annual Analytic-Water Quality Sampling Costs

2021 Model	State Water Board Funded Projects	External Quotes	State Water Board's Recommendation
$250	*Based on two projects* (2022)[379] • DBCP/EDB $168[380] • 1,2,3-TCP $248[381]	California-based Laboratory (2023) • DBCP/EDB $370[382] • 1,2,3-TCP $400[383] • Other VOCs $614[384]	• DBCP/EDB $235 • 1,2,3-TCP $299 • Other VOCs $614

[379] Average of two quotes from "Tulare POU" project (2022) and "Household Domestic Well" project (2022).

[380] Annual cost assuming two samples per year with an analytical cost of $84 per sample.

[381] Annual cost assuming two samples per year with an analytical cost of $124 per sample.

[382] Specific for DBCP & EDB. Annual cost assuming two samples per year with an analytical cost of $185 per sample.

[383] Specific for 1,2,3-TCP. Annual cost assuming two samples per year with an analytical cost of $200 per sample.

[384] For all other VOCs except for DBCP/EDB & 1,2,3-TCP. Annual cost assuming two samples per year with an analytical cost of $307 per sample.

Appendix D: Public Feedback on the Proposed Updates to the Cost Assessment Model – Physical Consolidation Analysis

On July 14, 2023 the State Water Board hosted a public webinar workshop on the proposed updates to the Cost Assessment Model's physical consolidation analysis. The State Water Board released a white paper and provided a summary of the proposed changes to the physical consolidation analysis's methodologies and underlying cost assumptions. The State Water Board solicited public feedback during the webinar and for approximately 30 days after the webinar. The sections below summarize the feedback received and the State Water Board's responses.

From: Leadership Council; Community Water Center; and Clean Water Action

Received: August 14, 2023

"We strongly support the cost assessment's revised methodology of first evaluating the viability of consolidation before considering other solutions, such as centralized or POU/POE treatment. When feasible, consolidation is typically the most sustainable and cost-effective long-term solution and it should be prioritized over other solutions. At times, residents of a potentially subsumed system may prioritize other solutions for community-specific reasons, but for purposes of a statewide needs assessment, this approach makes the most sense."

State Water Board Response: The State Water Board is recommending updating the Cost Assessment Model to assess water systems for physical consolidation first, then treatment, and other long-term solutions before potentially selecting POU/POE as a long-term solution. The State Water Board agrees that POU/POE is not an ideal long-term solution.

From: Leadership Council; Community Water Center; and Clean Water Action

Received: August 14, 2023

"As indicated in our February 24, 2023 comments on the Proposed Changes for the 2023 Drinking Water Needs Assessment, we are concerned that the Combined Risk Assessment Methodology significantly underestimates the number of at-risk state small water systems (state smalls) and domestic wells in California. We are disappointed that the Cost Assessment for state smalls and domestic wells is based solely on this methodology and, as a result, significantly understates the costs related to funding drinking water solutions for state smalls and domestic wells in California.

The Combined Risk Assessment Methodology is a well-intentioned attempt to assess risk based on a composite of water quality, water shortage, and socioeconomic risk.

However, due to the weighting methodology used, a state small or domestic well is only considered at risk and included in the cost assessment if it is in an area with high risk for at least two of the three categories. In reality, a well with high water quality risk or high water shortage risk is at high risk of not being able to supply safe drinking water. For the public water system risk methodology, such a weighting methodology is appropriate for identifying systems at risk for future non-compliance, because failing public water systems have already been identified separately based on current compliance data. While numerous state smalls and domestic wells throughout the state are also failing due to declining groundwater levels and/or groundwater exceeding primary Maximum Contaminant Levels (MCL), comprehensive data are not available to identify them. Instead, the risk assessment is being used to estimate the number of both failing and at-risk state smalls and domestic wells, and we are concerned the Combined Risk Methodology is severely underestimating that number.

As an example, only 28 state smalls in Monterey County are identified as at-risk and would be included in the updated cost assessment. However, the needs assessment identifies 212 state smalls in Monterey County as having high water quality risk, and March 2021 data from Monterey County shows 118 state smalls in the county had samples at or above MCLs for arsenic, nitrate and/or hexavalent chromium (using the proposed hexavalent chromium MCL of 10 ug/L) and had not since demonstrated to the County that they were consistently below MCLs.

Given that state small water systems and domestic wells inherently tend to be at higher risk of having inadequate technical, managerial and financial capacity due to their small scale, it is even more inappropriate to use such stringent requirements to identify them as at-risk.

We have supported the inclusion of a socioeconomic risk indicator in the assessment, but fear the scoring employed is resulting in a dilution of water quality and water shortage risks. For instance, two 1-mile by 1-mile sections in Monterey County near Johnson, Live Oak and McGinnis Roads, are in a severely disadvantaged community but were classified as low socioeconomic risk in the Needs Assessment.

The number of state small water systems included in the Cost Assessment would decrease from 699 in 2021 to 245 with the recommended updates. The number of domestic wells included would decrease from 99,814 to 81,596. Unfortunately, these decreases are not primarily due to the implementation of drinking water solutions or flaws in the 2021 needs assessment, but rather are due to flaws in the Combined Risk Assessment Methodology being used in the recommended updates. We oppose the use of the Combined Risk Assessment in the 2024 iteration of the Needs Assessment unless the scoring of the Combined Risk Assessment is modified to adequately capture the real risks faced by Californians supplied by state small water systems and domestic wells."

State Water Board Response: The purpose of the Risk Assessment for state small water systems and domestic wells is to first, assess for risk of failure and second, to create a transparent and data-driven approach for identifying locations most in need of

State Water Board assistance. The enhancement of the Risk Assessment methodology for state small water systems and domestic wells since 2021 has led to the inclusion of new risk categories to better align with the methodology employed for identifying risk for public water systems. This has led to an overall decrease in the number of at-risk locations served by state small water systems and domestic wells. This decrease represents a smaller, more targeted list of locations where communities are at high risk for water quality, water shortage and/or socio-economic risk. The State Water Board views these locations are the most-in-need based on modeled data.

The State Water Board does publish the results of the Risk Assessment's category risk score/status. The results within the categories can be used internally and externally to help inform decision making.

The State Water Board will continue to enhance the Risk Assessment methodology and data used to assess risk for communities served by state small water systems and domestic wells. Better data collection is needed to better identify areas throughout the state where these systems are failing. Failing data can be used to refine and recalibrate how the Risk Assessment evaluates and weighs its risk indicators.

The State Water Board conducted an analysis to explore how expanding the Cost Assessment Model to include domestic wells and state small water systems that are At-Risk for either water quality or water shortage would impact the physical consolidation modeled results. State Water Board staff reviewed the results of this exercise and are comfortable expanding the inventory of small water systems and domestic wells included in the Cost Assessment. The analysis in Table 125 and Table 126 below compares the results of the physical consolidation analysis for state small water systems and domestic wells between the previous white paper's inventory and distance criteria to the recommendations made above.

From: Leadership Council; Community Water Center; and Clean Water Action

Received: August 14, 2023

"The White Paper proposes decreasing the route distance criterion for State Small Water Systems from .38 to .25 miles. The White Paper bases its reasoning on the consolidation projects the Board has observed. While the Board has conducted outreach to systems with the potential to consolidate and mandated consolidations on a limited number of occasions, the number of consolidations the Board has overseen are largely consolidation projects that were more practical to accomplish. We oppose decreasing the route distance criterion as it is premature to make such change."

State Water Board Response: Staff conducted an analysis to see how this proposed change impacts the number of state small water systems and domestic wells where modeled physical consolidation is viable. The analysis in Table 125 and Table 126 below compares the results of the physical consolidation analysis for state small water systems and domestic wells between the previous white paper's inventory and distance criteria to the recommendations made above.

Table 125: Physical Consolidation Old Proposed Criteria – Combined Risk Only and 0.25-miles Distance

System Type	Statewide Total	At-Risk (combined across three categories)	# of Systems Where Physical Consolidation is Viable
State Small Water Systems	1,297	245	118
Domestic Wells	291,401	81,588	25,480

Table 126: Physical Consolidation Updated Criteria– High Water Quality & Water Shortage Risk and 0.38-miles Distance.

System Type	Statewide Total	Water Quality High-risk	Water Shortage High-risk	# of Systems Where Physical Consolidation is Viable
State Small Water Systems	1,297	699	261	451
Domestic Wells	291,401	99,814	101,393	64,476

From: Leadership Council; Community Water Center; and Clean Water Action

Received: August 14, 2023

"The White Paper does not clearly account for the higher costs associated with conducting outreach in areas served by domestic wells and State Small Water Systems. Outreach and engagement in domestic well communities is typically significantly more resource intensive than outreach in areas served by public water systems. The White Paper should better outline how the higher costs for outreach and engagement in domestic wells and State Small Water Systems consolidations are factored into the Cost Assessment."

State Water Board Response: Staff agree with this recommendation. The Cost Assessment Model may include outreach and engagement costs utilizing the decentralized treatment outreach costs detailed in Appendix C.