A Watershed Based Approach for Managing Nutrients in San Francisco Bay

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THE PROBLEM

While San Francisco Bay is recognized as a nutrient-enriched estuary, it has not been adversely impacted by nutrient loading because of a turbid environment that limits the depth of the photic zone, strong tides that limit periods of stratification, and a large clam population that effectively grazes on phytoplankton. Stakeholders in the Region are concerned that the Bay may be losing its resiliency since more recent monitoring shows lower turbidity levels, fewer clams due to greater predation, and small increases in phytoplankton production. If San Francisco Bay continues to lose its resiliency, nutrient concentrations could support levels of phytoplankton growth that could cause impairment (Cloern and Jassby, 2012).

While the Bay is not impaired, stakeholders are interested in advancing understanding of the system and potential future management options via a combination of scientific studies and engineering to evaluate future nutrient management strategies. The San Francisco Bay Regional Water Quality Control Board (Water Board) adopted a Nutrient Watershed Permit in 2014 (R2-2014-0014) that required the development of engineering recommendations for San Francisco Bay Water Resource Recovery Facilities (WRRFs) (n = 37; 827 mgd total permitted capacity) that ranged from optimization to enhanced nutrient removal (BACWA, 2018) because these WRRFs contribute about two-thirds of the nutrient loading to the Bay. A map of the Bay and the various dischargers that are covered under the Nutrient Watershed Permit is provided in Figure 1. The Water Board adopted a 2nd Regional Nutrient Watershed Permit in 2019 (R2-2019-0017) that requires the WRRFs to evaluate the nutrient reduction potential of nature-based solutions (NbS), such as constructed treatment wetlands, and of planned recycled water projects.

Objective: The proceedings will present nutrient load reduction and cost findings from the 1st Nutrient Watershed Permit and draft preliminary findings from the 2nd Nutrient Watershed Permit.

THE SOLUTION/APPROACH

The Bay Area WRRFs are represented by the Bay Area Clean Water Agencies (BACWA). BACWA is a joint powers agency, formed under the California Government Code by the five largest wastewater treatment agencies in the San Francisco Bay Area. BACWA members include the many municipalities and special districts that provide sanitary sewer services to more than 7.1 million people.

While the Bay is not impaired by nutrients, BACWA and its member agencies aim to ensure protection of the beneficial uses and overall health of the Bay. Given that, the BACWA Nutrient goal statement is as follows: Nutrient management strategies should be protective of the environment, ensuring that all beneficial uses of the Bay are achieved; be based on robust scientific investigations; and make effective use of the public's resources in achieving this goal.

BACWA and its member agencies have been working collectively and collaboratively on the nutrient topic for over a decade. BACWA has been developing a menu of options if nutrient management beyond the status quo is required. The efforts have included conducting nutrient sampling to characterize flows and loads, monitoring any changes in the Bay and modeling biochemical phenomena to predict potential outcomes given a variety of circumstances, supporting science, funding engineering studies, etc.

BACWA also provides funding to the San Francisco Bay Nutrient Management Strategy (NMS), which is a regional initiative for developing the science needed for informed decisions about managing nutrient loads and maintaining beneficial uses within the Bay in response to the apparent changes in the Bay's resilience to nutrient loading. San Francisco Bay NMS partners include federal and state agencies, local governments, non-profit organizations, and academic institutions. The goal of the NMS is to lay out a well-reasoned program to generate the scientific understanding needed to fully support major management decisions. Studies performed under the auspices of the NMS are led by the San Francisco Estuary Institute (SFEI).

In 2014, the Water Board adopted a Nutrient Watershed Permit (R2-2014-0014) that resulted in a coordinated compliance effort across the BACWA members, including funding the science, effluent monitoring and reporting, and special studies. The Nutrient Watershed Permit included the requirement to perform a special study to evaluate four key elements of nutrient load reduction opportunities at WRRFs (if future load reductions are supported by science):

1. Plant optimization
2. Sidestream treatment
3. Plant upgrades (conventional and enhanced nutrient removal)
4. Nutrient reduction by other means (including source control, natural treatment systems, diversion of effluent to water recycling, and others)

A list of the nutrient targets associated with each of these elements is provided in Table 1. Note that the nutrient reduction by other means task is a compilation of existing documentation by agency.

The Water Board adopted a 2nd Nutrient Watershed Permit in 2019 (R2-2019-0017) with a requirement to perform a special study that focuses on recycled water (RW) and NbS opportunities. The study will identify drivers/barriers for implementing RW/NbS projects, as well as the corresponding costs and nutrient load reductions for such RW/NbS projects.

The goal of these two permits is to advance the science while developing a menu of nutrient management opportunities per agency, subembayment (up to 4 in total), and Baywide (if supported by science). The findings from these coordinated studies for WRRFs across the Bay are presented in the sections that follow.

THE OUTCOME

The primary results for the 1st Nutrient Watershed Permit (R2-2014-0014) are presented in Table 2. The results suggest that optimization and sidestream treatment represent the most cost-effective means in terms of unit costs (i.e., $/gpd and/or $ per pound removed) to reduce nutrient loads across the Bay. In contrast, both upgrades elements (conventional and enhanced nutrient removal) require at least an order of magnitude or more increase in unit cost compared to optimization/sidestream to implement, albeit with an increase in load reduction potential.

The optimization values were compared against those in the literature for benchmarking purposes. The evaluation suggests that the Bay Area optimization values align with those in the literature, such as those from the USEPA Optimization Guide (USEPA, 2015; Falk et al., 2019).

While the 1st Nutrient Watershed Permit (R2-2014-0014) results gave insight into identifying opportunities across the Bay, they were limited to opportunities inside the WRRFs and did not consider a holistic approach. The 2nd Watershed Permit (R2-2019-0017) expands upon the 1st Watershed Permit (R2-2014-0014) by including options outside the WRRF "fence line" to identify a menu of options for future nutrient management (if reductions are supported by science).

A request for information (RFI) was sent out to the BACWA member WRRFs in early 2020 to initiate the RW and NbS investigation. The subsections that follow will provide draft preliminary results from the RFI and the on-going 2nd Watershed Permit (R2-2017-0017) efforts. The final report to be submitted to the Water Board is due on July 1, 2023.

Recycled Water (RW)

A plot of the current and projected RW demands across the Bay is provided in Figure 2. The projected RW demands have the potential to nearly double from current (draft year 2019 data at 54 mgd (61,000 AFY)) to 105 mgd (118,000 AFY) over the next 25 years. For perspective, the WRRFs currently discharge flows to the Bay on the order of 445 mgd (498,000 AFY; based on the last 8-years of data). If RW demands did not exist, the WRRF discharge flows to the Bay would increase from approximately 445 mgd (498,000 AFY) to 500 mgd (560,000 AFY) which translates to an increase on the order of 12 percent.

While a nearly doubling of RW over the next 25 years is significant, it is important to note that the listed projects are a combination of i) planned projects that are moving forward, ii) projects that have been identified in planning documents (e.g., Master Plan), or iii) projects that are still in the conceptual phase. As the RW task further advances, the likelihood of projects moving forward will be refined with a subsequent range of values for RW demands.

The various type of RW users is provided for years 2019 and 2045 in Figure 2. The top three RW users are landscape, industrial, and environmental enhancement. Environmental enhancement includes wildlife habitat, wetland/marsh applications, and natural system restoration. In such systems, the nutrients are typically naturally assimilated.

The various type of RW uses does not necessarily translate to diverting loads from the Bay as the loads eventually end up in the Bay. For example, an industrial user that relies on RW for a boiler/chiller concentrates the nutrient loads with little or no removal that eventually end up in the Bay. Figure 2 attempts to calculate the nutrient loads the do not end up in the Bay which is based on the sum of irrigation users (landscape, golf course, and agricultural).

In parallel with data compilation, each WRRF discharger included responses that focused on drivers and barriers to implementing RW projects as follows:

- Barriers that WRRF dischargers selected from:
    - Funding
    - Institutional
    - Jurisdictional
    - Lack of need
    - Other
- Drivers that WRRF dischargers selected from:
    - Water supply need
    - Proposed discharge regulations
    - Institutional
    - Other

The preliminary draft compilation of data suggests that the barriers to implementation of RW projects is in the following order: funding > jurisdictional > lack of need > other > institutional. The funding response more than doubled all other barriers. While funding can be challenging for projects outside of maintaining and meeting regulations at WRRFs, there are opportunities for outside funding sources. As part of the on-going efforts, identifying funding opportunities for RW projects would be worthwhile to assist WRRFs with overcoming funding challenges.

The preliminary draft compilation of data suggests that the drivers to implementation of RW projects is in the following order: water supply need > institutional > proposed discharge regulations > other. Similar to barriers, the driver parameter most frequently identified, water supply need, more than doubled all other drivers. Increasing RW demands to address "proposed discharge regulations" is focused on nutrient regulations, whereby the perspective is that increasing RW demands is more cost effective than upgrading WRRFs to meet potential nutrient regulations in the future.

As of June 2021, the draft data has been compiled and the team is performing individual plant reports for all WRRF dischargers and other RW producers. Approximately 25 percent of the reports have been drafted with the intent of completing all the draft reports in year 2021. The presentation at WEFTEC will include updated values based on additionally drafted and finalized individual WRRF reports. Such information will be used to generate values similar to those from the 1st Watershed Permit (Refer to Table 1) for comparative purposes across various treatment strategies in the future.

Nature-based Solutions (NbS)

The NbS task is occurring in parallel with the RW task. The Bay Area has a history of natural treatment systems that address pollution reduction, habitat restoration, etc. For example, the City of Petaluma polishes their treated water prior to recycled water distribution and/or discharge to a creek. Various WRRFs also send their treated water to marshes prior to Bay discharge, such as Mt. View Sanitary District and Fairfield-Suisun Sanitary District. In addition to historical NbS systems, several WRRFs are actively considering NbS systems and there is even a demonstration facility at Oro Loma Sanitary District as shown in Figure 4.

Similar to the RW task, a survey on NbS was populated by the WRRFs on barriers and drivers for implementing NbS type projects. The survey suggests that approximately 50 percent of the WRRFs across the Bay are interested in NbS. The interest in NbS is based on the following (in order): sea level rise > reduction in contaminants of emerging concern > habitat restoration/enhancement > nutrient removal > addressing aging infrastructure. It is apparent that WRRFs are considering NbS systems for various reasons as there are a multitude of co-benefits.

All the region's WRRFs identified in the 2nd Watershed Permit (R2-2019-0017) were surveyed for information to inform the development of a desk-based study (completed in early-2021). Since then, representatives the each WRRF has been interviewed to receive feedback on the desk-based study and identify the next steps. A graphical depiction of facilities with high potential to deploy NbS for nutrient management (e.g., treatment wetlands or ecotone levees) is provided in Figure 5.

Facilities with high potential for NbS will receive additional analysis in upcoming months that will focus on NbS technology selection, footprint, and cost to implement, etc. Such information will be used to generate values similar to those from the 1st Watershed Permit (Refer to Table 1) for comparative purposes across various treatment strategies in the future.

Comparison of 1st and 2nd Nutrient Watershed Permits: A Menu of Options

A preliminary draft comparison of available costs and unit costs for nutrient management alternatives across the Bay will be presented as part of the WEFTEC presentation. As previously stated, such information will be used to generate values similar to those from the 1st Watershed Permit (Refer to Table 1) for comparative purposes across various treatment strategies in the future. Such a menu of options will be invaluable to BACWA members as they prepare for potential future nutrient load caps.

CONCLUSIONS

The coordinated nutrient load reduction studies from the 1st and 2nd Nutrient Watershed Permits will provide a comprehensive menu of engineering options for holistically managing nutrients across the Bay. These results will assist with making informed decisions for any future nutrient load reductions.

In parallel to this study, the NMS is conducting scientific studies to determine any nutrient load impacts on San Francisco Bay water quality. All these efforts will be combined to develop a strategy to preserve beneficial uses in the Bay.

This approach, which is to use science to evaluate the health of the San Francisco Bay ecosystem coupled with strategies for nutrient management by WRRFs, has the potential to serve as a template for other watersheds considering nutrient management strategies.

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FIGURES AND TABLES

Table 1. Nutrient Removal Targets used for the 1st Watershed Permit (R2-2014-0014)*

Task	Ammonia	Total Nitrogen	Total Phosphorus	Comment
Optimization	--	--	--	WRRF specific removal potential
Sidestream Treatment	--	--	--	WRRF specific removal potential
Conventional Nutrient Removal Upgrades	2 mg N/L	15 mg N/L	1.0 mg P/L	Typically without filters or external carbon**
Enhanced Nutrient Removal Upgrades	2 mg N/L	6 mg N/L	0.3 mg P/L	Requires filters/external carbon ***

* The nutrient analysis is based on performance and NOT water quality-based objectives.

** Assumed to be achievable by conventional nutrient removal processes without effluent filtration or an external carbon source. Certain participating plant configurations and technologies will require chemicals.

*** An external carbon source will not be required for certain plant configurations and technologies.

Table 2. Bay Area Results for the 1st Watershed Permit (R2-2014-0014; n = 37 WRRFs; HDR (2018)

Parameter	Optimization	Sidestream Treatment	Upgrades for Conventional Nutrient Removal (15 mg N/L; 1 mg P/L)	Upgrades for Enhanced Nutrient Removal (6 mg N/L; 0.3 mg P/L)
Total Present Value	$ 266 Mil	$ 766 Mil	9,420	12,405
Total Phosphorus Load Reduction	34%	12%	59%	88%
Total Nitrogen Load Reduction	7%	19%	57%	82%
Unit Cost	$ 0.5/gpd	$ 0.8/gpd	$ 10.8/gpd	$ 14.3/gpd
Total Phosphorus Load Reduction Unit Cost	$ 8.6/lb P	$ 2.8/lb P	$ 44/lb P	$ 59/lb P
Total Nitrogen Load Reduction Unit Cost	$ 5.6/lb N	$ 2.0/lb N	$ 8.7/lb N	$ 7.7/lb N

Figure 1. WRRFs Participating in the Regional Permits
(n = 37; 827 mgd total permitted capacity across the Bay)

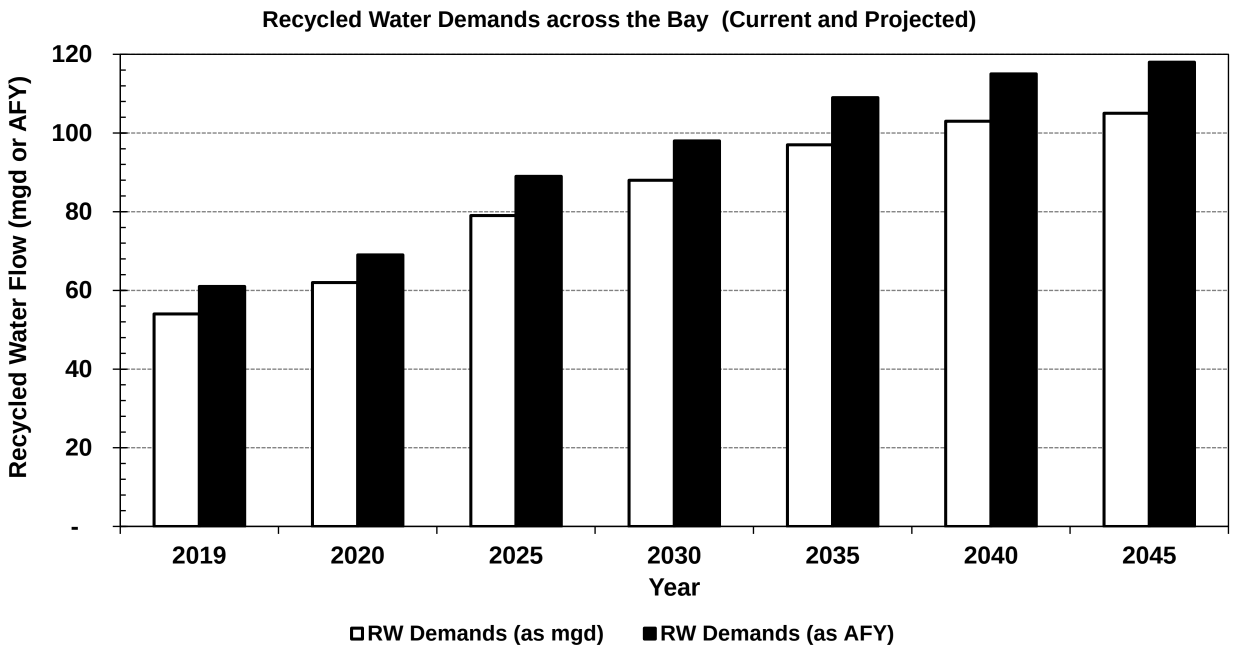

Figure 2. Current and Projected Recycled Water Demands across the Bay

WRRFs across the Bay Discharge on the order of 110,000 lb N/d (52,000 kg N/d) (Based on the last 8-Years of Discharge Data).

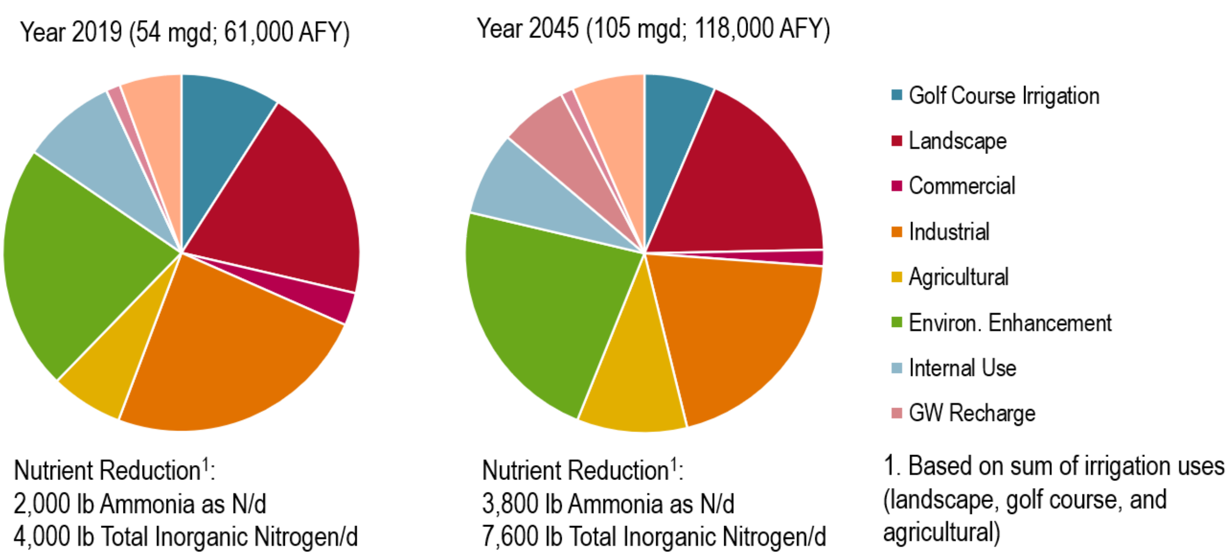

Figure 3. DRAFT 2019 and 2045 Recycled Water Uses across the Bay

Figure 4. NbS Demonstration of a Horizontal Levee at Oro Loma Sanitary District

Figure 5. WRRFs Identified in the Initial Screening Evaluation that have Potential for NbS (n = 37; 827 mgd total permitted capacity across the Bay)