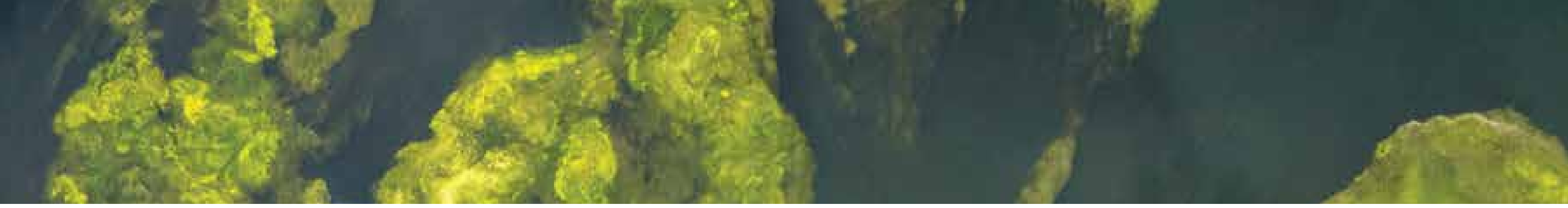

waterscapes

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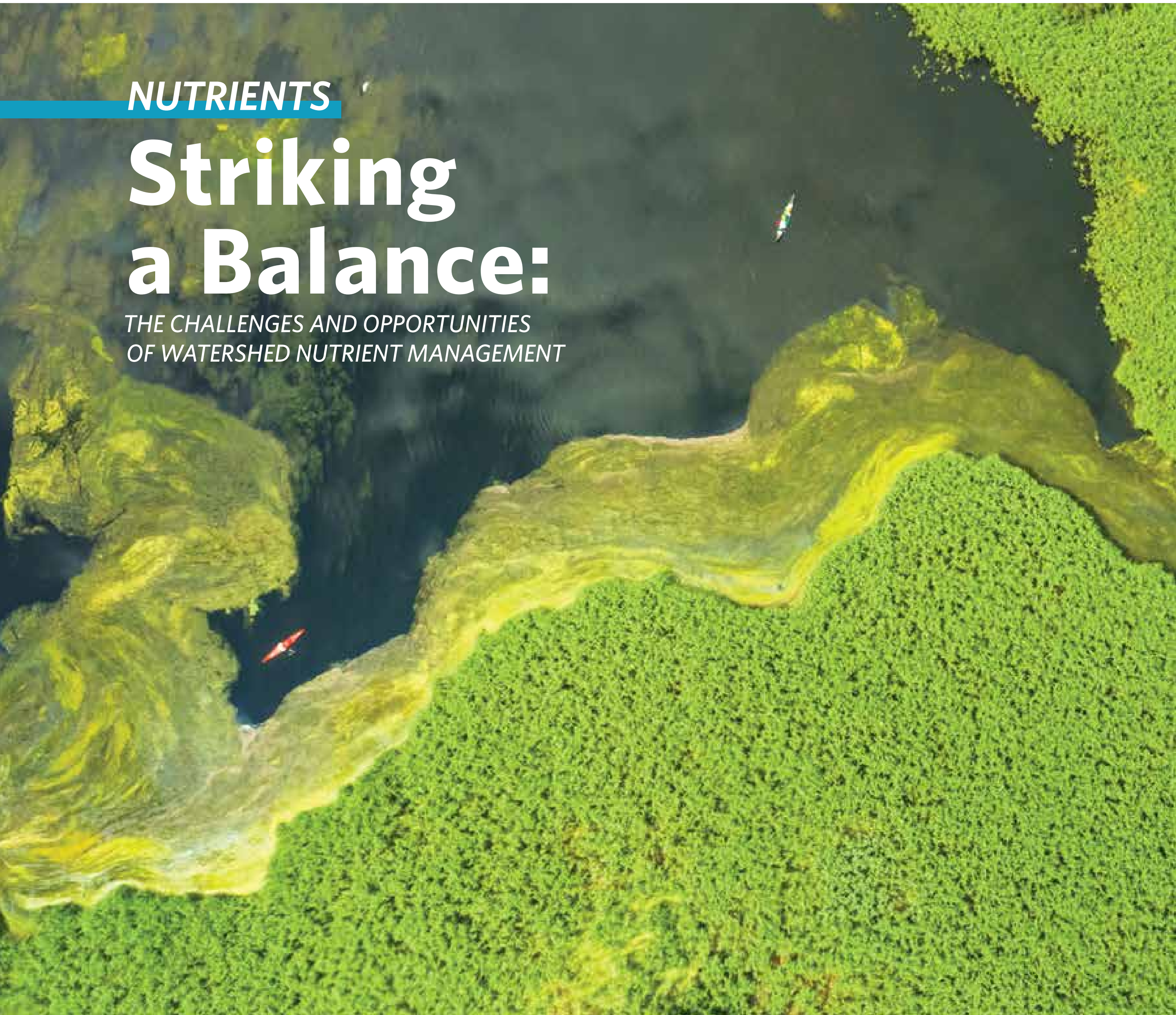
2023, ISSUE NO. 1



NUTRIENTS

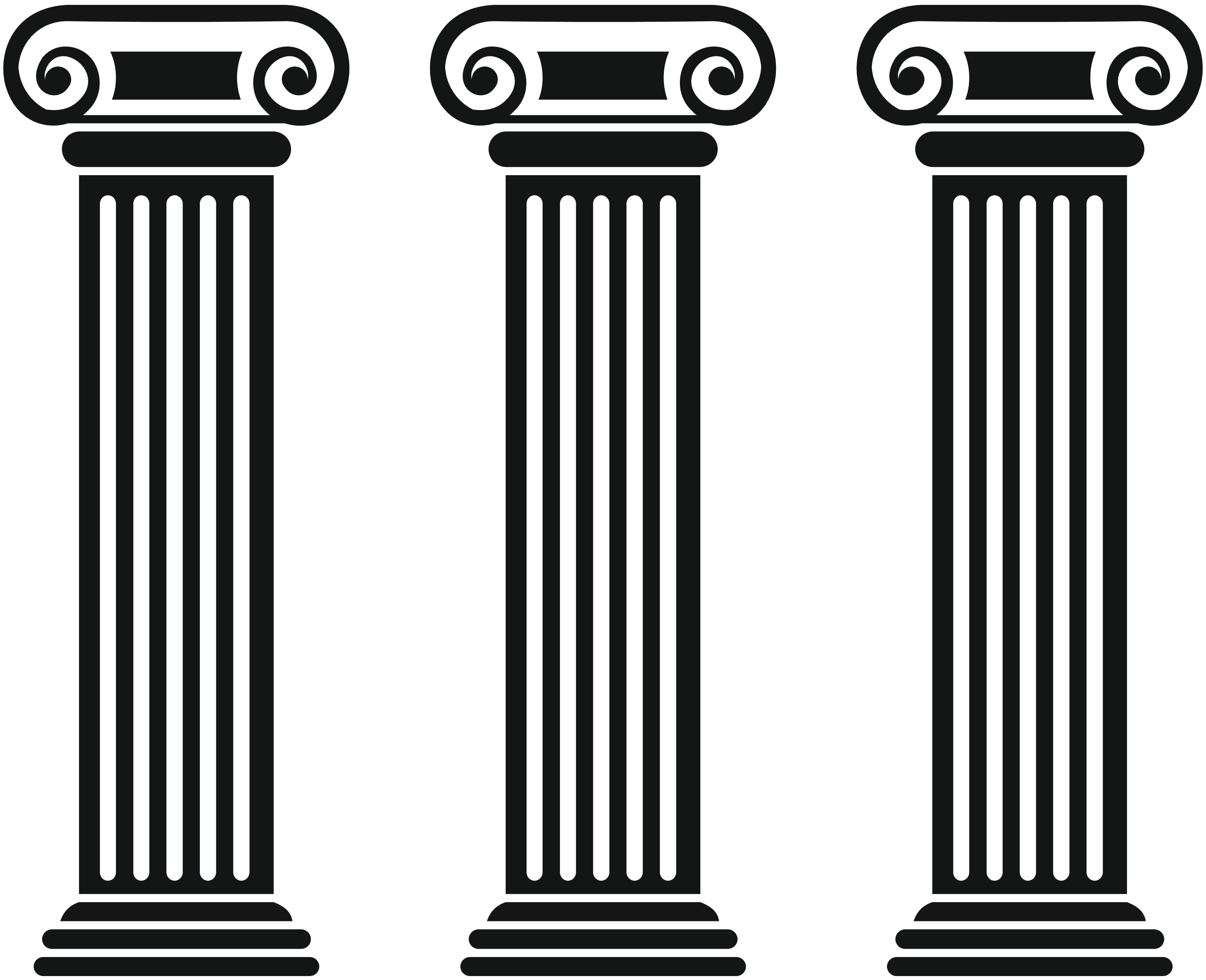
Striking a Balance:

THE CHALLENGES AND OPPORTUNITIES OF WATERSHED NUTRIENT MANAGEMENT

PRACTICES

POLICIES

PARTNERSHIPS



nu·tri·ents

Too many nutrients, mainly nitrogen and phosphorus, act like fertilizer, causing excessive growth of algae. Significant increases in algae harm water quality, food resources and habitats, and decrease the oxygen that aquatic life needs to survive.

2023, NO. 1

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Striking a balance for sustainable nutrient management in light of challenges.

In this edition of Waterscapes, we discuss the evolution of nutrient removal wastewater treatment as a technical practice, as well as policy issues that present compliance challenges, and the need for partnerships to further efforts to successfully manage water quality. The practices, policies and partnerships framework from The Water Research Foundation project titled "Holistic Approach to Improved Nutrient Management" (WRF4974) provides a guide to planning sustainable nutrient management.

The history of wastewater nutrient removal technology and our current understanding of the importance of nutrient speciation is addressed in Dr. JB Neethling's review of over a half-century of nutrient control practice technology. Outside the fence of the Water Resource Recovery Facility, nutrient reduction by other means in nature-based solutions looks to natural systems to assist in nutrient management. The Billion Oyster project is a unique opportunity to protect water quality in New York Harbor by restoring the natural biology, as described in the article by Christopher Coccaro.

Stormwater practices have also evolved over the past half-century with increasing emphasis on water quality. Julie Stein and Leila Talebi address urban stormwater practices and policies in their article titled "Urban Stormwater Control Measures for Nutrients Management." Adding nutrients to the list of targeted urban pollutants for stormwater best management practices calls for a multifaceted approach. A key benefit of implementing stormwater control measures at a watershed scale is improved water quality and ecosystem health. Watershed scale implementation reduces nutrient loadings, enhances aquatic habitat, protects the health of plants, animals and humans, and may also sequester carbon.

Trent Stober's article on Clean Water Policies captures both the creativity of unique Clean Water Act legislation from a half-century ago, as well as the challenge we face operating in that framework today. While great progress has been made in improving receiving water quality, further progress in many watersheds will depend upon more than technical practices alone. Flexible policies that foster collaborations in broad partnerships may unlock pathways for more creative solutions to nutrient management challenges. A One Water perspective is more important than ever in overcoming the challenges of nutrient management, new regulatory requirements, asset renewal and replacement, competing demands for utility funding and climate change.

Victoria Johnson discusses how environmental justice considerations influence decision making and shape nutrient policies and practices. Inclusion of community-based organizations, individuals and tribes is important to identifying solutions. New requirements for environmental justice considerations foster accounting for equity in determining community and environmental benefits.

Watershed management partnerships have become increasingly important to successful watershed management efforts. Lacey Hirschvogel highlights notable accomplishments in three key watershed partnerships: Neuse River, Yahara and Middle Cedar River. An interview with Dr. Jennifer Biddle explores research focused on improving the effectiveness of collaborative governance with lessons from watershed partnerships. To wrap up this edition of Waterscapes, Dr. Michael Falk highlights the nutrient reduction analysis and importance of effective partnerships in managing San Francisco Bay water quality.

David L. Clark, PE, WEF Fellow

Wastewater Director

Over a Half-Century of **Nutrient Pollution Control**

By JB Neethling, PhD, PE, WEF Fellow - Wastewater Treatment & Effluent Management Director, Folsom, CA

Chesapeake Bay was a focus of early adoption of nutrient reduction.

For more than 50 years, the United States has required nutrient pollution elimination from its waters, but the focus to control nutrient discharges increased in the 1990s when the Environmental Protection Agency published Ecoregional Nutrient Criteria Rivers and Streams.

Nutrient removal was required in sensitive water bodies (Chesapeake Bay, Lake Tahoe, and others) in conformance with the Clean Water Act requirements. Many other countries implemented nutrient control earlier (in particular, South Africa, Australia, and others) where eutrophication of lakes and streams, coupled with water scarcity, created a demand for nutrient reduction.

Technologies for nutrient removal originated primarily in locations where nutrient pollution led to deteriorated water quality (excessive plant growth, odor, recreation and commercial impacts, and impact source water for water supply).

EPA's Ecoregional Criteria established receiving water criteria with very low nutrient concentrations. Building on experiences elsewhere, innovations in technologies and approaches emerged in the U.S. and worldwide, improving the efficiency of nutrient reduction through innovative process, better operational controls and optimization of existing processes through new equipment and treatment processes, coupled with more strategic approaches to meet water quality objectives inside and outside the fence of the Water Resource Recovery Facility.

This article includes past practices for nutrient removal and a discussion of approaches that take advantage of new and emerging technologies to improve performance and reduce investment and operating costs.

RETROFIT FOR NUTRIENT REMOVAL

Nutrient removal has been practiced in the U.S. and across the world since the late 1960s and 1970s. Both biological and physical/chemical treatment technologies emerged to meet nutrient water quality objectives. The 1972 Clean Water Act provided a huge stimulus in technologies to meet secondary treatment and reuse requirements for Biochemical Oxygen Demand and Total Suspended Solids; in some cases, technologies for nitrogen and/or phosphorus removal were also developed. This led to two main process streams as shown in Figure 1.

NEW TECHNOLOGIES AND APPROACHES

The 12-year Water Research Foundation Nutrient Removal Challenge (Project #4827 - Efficient, Cost-Effective Nutrient Removal from Wastewater) led by our team included over 500 individuals collaborating from 245 organizations to produce 30 research reports in addition to compendiums, presentations, conference presentations and research papers. This project

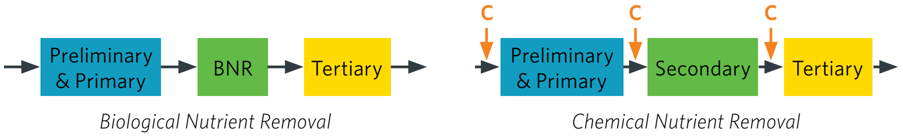


Figure 1. Chemical nutrient removal is simple to retrofit into existing infrastructure and easier to operate but typically more costly in the long run.

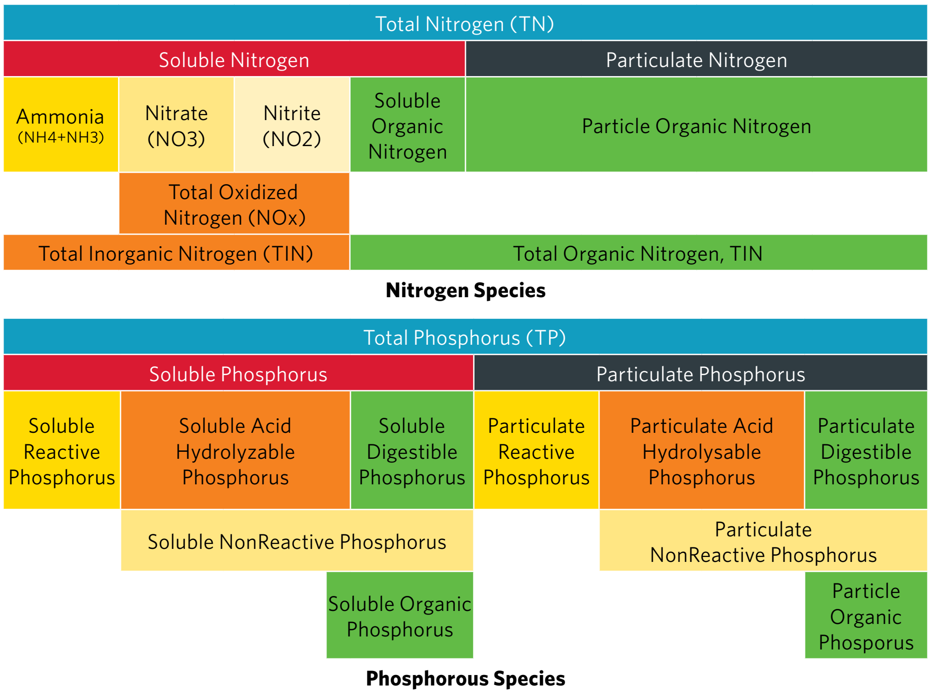


Figure 2. Key nutrient species.

developed new fundamental knowledge in process technologies for nutrient removal, assessed performance reliability and outlined practical solutions to improve nutrient removal.

Understanding the nutrient species (Figure 2) is key to designing and optimizing nutrient removal technologies. Research has shown that some soluble organic nutrient species that remain in secondary treated water resist further chemical and biological treatment; inorganic nutrient species, on the other hand, are readily removed by conventional nutrient removal process.

The WRF report identified three stages of nutrient removal as seen in Table 1. Conventional nutrient removal uses conventional biological treatment process without supplemental carbon addition for nutrient removal. Chemicals are sometimes added for phosphorus removal. Tertiary nutrient removal requires treatment process modifications and enhanced particle removal (using processes such as granular media filtration or microfiltration) and chemical addition (such as carbon for denitrification or metal salts for phosphorus removal). Advanced nutrient removal typically uses reverse osmosis membranes to remove nutrient containing molecules or ions and may generate a brine reject stream. Advanced nutrient removal would be required under very special/ stringent conditions.

NUTRIENT REMOVAL BY OTHER MEANS

Nutrient reduction from the discharge effluent of a Water Resources Recovery

TABLE 1. NUTRIENT REMOVAL TREATMENT STAGES

	Conventional Nutrient Removal	Tertiary Nutrient Removal	Advanced Nutrient Removal
Primary	Optional Chemical addition for Phosphorus removal	Optional Chemical addition for Phosphorus removal	Optional Chemical addition for Phosphorus removal
Conventional	Biological Nutrient Removal with suspended growth, biofilm, hybrid	Multistage Biological Nutrient Removal Chemical addition	Multistage Biological Nutrient Removal Chemical addition
Tertiary	No	Filtration Chemical addition	Filtration Chemical addition
Advanced	No	No	Molecular separation, advanced oxidation, biofiltration
Other features	No	Carbon supplement such as fermentation or chemical sidestream management	Carbon supplement such as fermentation or chemical sidestream management Brine disposal
Performance Range	**Conventional Nutrient Removal**	**Tertiary Nutrient Removal**	**Advanced Nutrient Removal**
Ammonia, mg N/L	2–5	0.5–2.0	<0.1
Total nitrogen, mg N/L	8–15	3–8	<0.2
Total phosphorus, mg P/L	0.5–2.0	0.03–0.10	<0.01

Source: Neethling et al. 2019. Neethling, J.B., D.L. Clark, H.D. Stensel, J. Sandino, and R. Tsuchihashi. 2019. "Nutrient Removal Challenge Synthesis Report." WRF (The Water Research Foundation). Report NUTR5R14g/4827g.

WHAT IS IN THE FUTURE?

New treatment technologies that can achieve more reliable and more efficient performance, often at a lower operating cost, have emerged. These improvements focus on several themes:

- Emerging technologies can provide process intensification for increasing biomass concentrations to gain capacity in the same volume.
- Reduced energy and chemical usage with more efficient equipment and control strategies or selecting more cost-effective chemicals.
- Use of automated real-time controls to optimize process performance while maintaining effluent quality.
- Big data/artificial intelligence that can be used to maintain optimal performance.

Facility can be achieved outside the liquid treatment process boundaries. These opportunities are often more efficient (lower dollar-per-pound nutrient removed) than conventional treatment and may provide secondary benefits. Nutrient removal from reject water from solids dewatering operations, wastewater and stormwater collection system, or industrial sources will reduce the nutrient discharge. See Table 2 for additional information.

PILOT TESTS

There are several promising emerging technologies for the removal of nutrients at wastewater facilities. While there are many benefits of applying these technologies, there is also risk due to limited full-scale application performance data. Demonstration testing of emerging technologies is a great way to demonstrate the performance of the technology at a particular facility while also gaining operational experience and informing a potential future full-scale design. Following are three examples of how we guided clients through the process of demonstrating and testing emerging technologies for nutrient removal.

Philadelphia Water Department Demonstration Testing Planning

In response to low dissolved oxygen concentrations in the Delaware River, the Delaware River Basin Commission has studied strategies to increase dissolved

TABLE 2. NUTRIENT REMOVAL BEYOND LIQUID TREATMENT

Strategy	Description	Disadvantages	Benefits
Reject water treatment	Treat return flows from dewatering processes that are high in nitrogen and phosphorus.	Requires additional infrastructure and operations.	Unit removal cost ($/lb) lower than liquid stream treatment.
Collection system	Collect and manage/treat overflows from sanitary and storm sewers.	High capital cost to manage occasional events. Remote facilities are more complex to operate.	Reduce/eliminate uncontrolled discharges to the environment.
Industrial source control	Establish pretreatment requirements to limit nutrients entering the collection system. High organic biological oxygen demand streams are beneficial to nutrient removal, and cost formulas for accepting compounds of emerging concern are already in place.	None! Need to ensure treatment plant has sufficient capacity.	Reduction in nutrient loads reduces need and cost for chemical addition. Other compounds (such as compounds of emerging concern and PFAS) should be included in pretreatment requirements as appropriate.
Effluent polishing nature-based solutions	New, nature-based processes (lagoons, horizontal levee, subsurface flow treatment, and others).	Low-rate processes that typically require large footprint. Performance characteristics still evolving.	Low-cost treatment option. Able to reach very low concentrations. Provide effluent peak flow attenuation. Horizontal levee can provide protection against sea level rise. Nature-based solutions are considered a public asset for education or recreation.

Source: Neethling et al. 2019. Neethling, J.B., D.L. Clark, H.D. Stensel, J. Sandino, and R. Tsuchihashi. 2019. "Nutrient Removal Challenge Synthesis Report." WRF (The Water Research Foundation). Report NUTR5R14g/4827g.

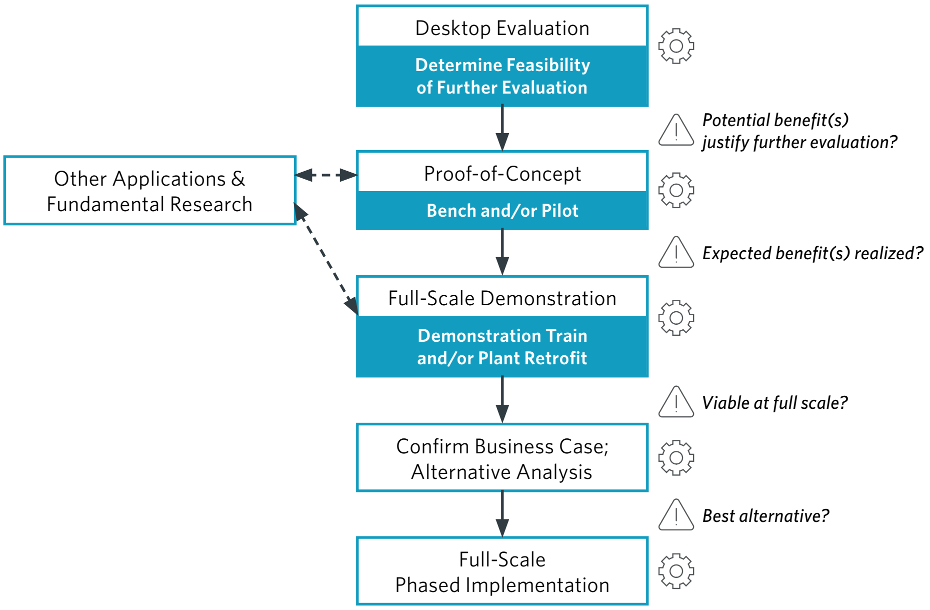


Figure 3. Stepwise execution phase for Nuvoda MOB research, testing and potential full-scale plantwide adoption with performance checks and exit ramps between each phase.

oxygen concentrations. The Commission is proposing effluent ammonia limits for seven dischargers to reduce nitrogenous oxygen demand load to the river. The Philadelphia Water Department's water pollution control plants represent three of the five largest ammonia load dischargers to the Delaware River and therefore face a high degree of regulatory focus. PWD began evaluating options for upgrading the three water pollution control plants for ammonia removal several years ago. These planning studies focused on established mainstream and sidestream technologies. However, PWD is also in the process of identifying and testing potential cost-saving ammonia removal technologies and is using the above framework as a guide. One such technology, Nuvoda Mobile Organic Biofilm, also known as MOB, was identified as a potential high-impact candidate.

A research and demonstration program was formed to systematically test MOB in a phased approach to obtain the information needed to determine whether MOB can be considered a viable alternative to conventional technologies. The program progression included proof-of-concept and demonstration testing phases with exit points if needed based on the results obtained as testing progresses. This plan also included discussions with key stakeholders to decide on testing options, a communication plan to get cross-organizational buy-in, and initial concepts for bench, pilot and full-scale testing.

A desktop study evaluated conceptual ammonia removal upgrade requirements for MOB. Compared to conventional alternatives for year-round ammonia removal at PWD's two conventional activated sludge plants, MOB showed the potential to save approximately 65 percent in lifecycle costs versus the conventional alternative. Savings were primarily due to dramatic reduction of secondary process tankage required and capital cost savings. Such compelling potential savings advanced MOB to further testing.

Bench testing was completed in spring 2022 with primary effluent feed. Results showed that MOB could sustain nitrification at aggressive conditions of 12°C and 3-day flocculent solids retention time (SRT). Challenges at bench scale required increased dissolved oxygen setpoint to 4 mg/L and supplemental media addition to 5 percent fill fraction to achieve stable nitrification similar to the 12-day SRT control reactor. When MOB media was removed at the end of testing after stable nitrification was demonstrated, nitrification was immediately lost, indicating that MOB rather than the flocculant biomass was responsible for nitrification.

The results of the bench testing justified MOB advancing to pilot testing. The overall pilot goal is to evaluate the viability of MOB as an alternative for the future Northeast and Southeast Water Pollution Control Plant upgrades for nitrification to meet the proposed Delaware River Basin Commission ammonia limit. To this end, the following objectives and performance metrics will be assessed:

1. **Validate nitrification with MOB at low flocculent SRT.** While MOB has been utilized in other facilities and nitrification at low flocculent SRTs has been observed, PWD's water pollution control plants include some unique conditions (such as dilute influent concentrations) and it is worth validating the performance before larger scale testing is undertaken, such as dilute concentrations of ammonia.

2. **Evaluate settling characteristics of MOB mixed liquor.** While improved settling characteristics are expected, such improvements are

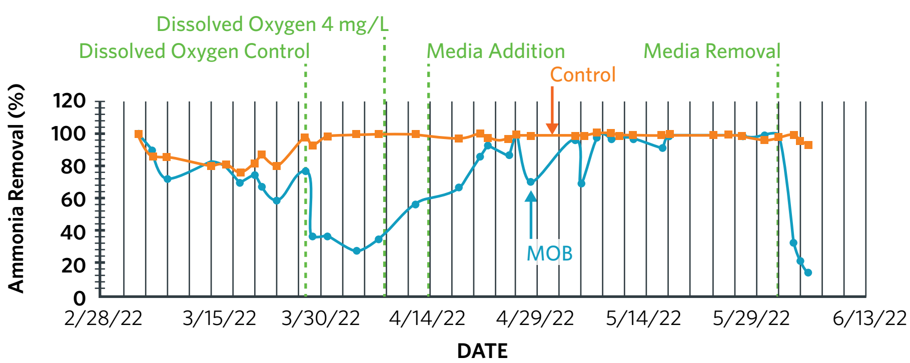


Figure 4. Ammonia removal performance for 12-d SRT control and 3-d SRT MOB bench-scale reactors at 12 degrees Celsius. Stable nitrification in MOB reactor occurred in the latter half of May. MOB media removal resulted in dramatic loss of nitrification.

not necessarily required for success of the MOB pilot. However, if MOB decreases the settleability of the mixed liquor suspended solids (flocs and media), this would negatively impact the performance of the final settling tanks and therefore increase the cost of MOB application by requiring additional final settling tanks.

3. **Further develop MOB understanding for future evaluation/design.** Special studies and data gathered during the pilot will be used to further characterize the benefits and impacts of MOB to inform future MOB evaluations and possible design.

Pilot procurement is underway with delivery of the pilot scheduled for January 2024. Siting and utility connection planning has been completed, and an experimental and sampling plan has been developed.

Pilot Testing to Reach 12 µg Total Phosphorus/L in a Hatchery Effluent

The Powder Mill State Fish Hatchery in New Durham, NH, received a new National Pollution Discharge Elimination System monthly average total phosphorus effluent limit of 12 µg/L, which is currently the lowest known TP limit in the country. Under current operations, the hatchery effluent annual average TP concentration is 24 µg/L with peak concentrations in a range of 50 to 100 µg/L during the main fish growth season in summer months. All phosphorus species of particulate phosphorus, soluble reactive phosphorus and soluble nonreactive phosphorus were present in the hatchery effluent. Due to this, it is necessary to identify treatment technologies and methods capable of removing each individual phosphorus species to a single digit concentration (<10 µg/L).

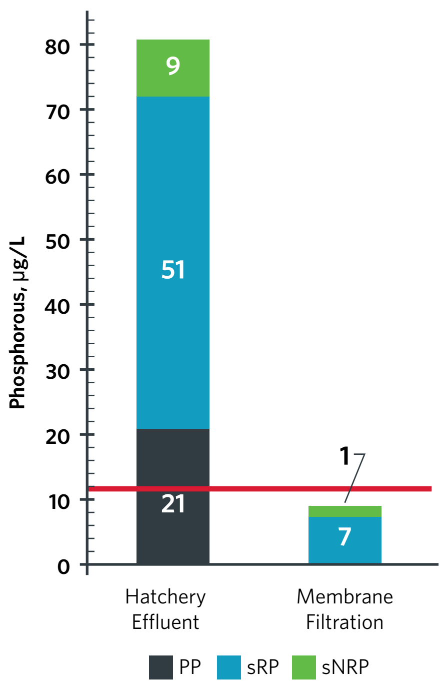
Pilot testing was conducted between July and September 2022, coinciding with the peak TP effluent concentrations during the main fish growth season. The pilot consisted of a membrane filtration ZeeWeed 500M unit followed by ion exchange and adsorption columns operated in parallel. Overall objectives of the pilot study were to assess the hatchery effluent TP speciation, investigate selected treatment technologies efficiency, establish critical design parameters and develop operating strategies.

The results highlighted the known challenges with measuring phosphorus at ultra-low levels (<50 µg/L). Split samples were analyzed by different labs deploying EPA-approved methods for detection limits of 10 µg/L. The measurements showed inconsistent results with deviations as much as 100 percent between the split samples. This high variability could be related to a variation in digestion and filtration methodologies, and other unknown sources of interference and contamination. This inconsistency in measurements poses practical challenges for full-scale compliance monitoring and process control. To resolve the issue, the recommended solution involves deploying an online phosphorus analyzer and conducting daily sample collection and testing. This approach helps to minimize variability, enabling operational adjustments and allowing the plant to address occasional excursions effectively.

The pilot study showed that individual technologies were not capable of removing phosphorus to meet the monthly average 12 µg/L limit and a combination of solutions is required. Membrane ultrafiltration must be a part of compliance treatment to remove the particulate phosphorus but is incapable of meeting the TP limit alone. The use of membrane ultrafiltration with upstream ferric addition successfully met the effluent limit when dosages with a molar ratio of 115 mg ferric/mg phosphorus and higher were employed (Figure 5). However, this approach requires solids disposal management and additional process instrumentation and control, which makes this alternative less appealing. Similarly, membrane ultrafiltration followed by ion exchange met the permit (Figure 6) but requires onsite media regeneration, brine recovery/disposal and dedicated certified operators. The pilot study concluded that the combination of membrane ultrafiltration and downstream adsorption met the effluent limit while requiring minimal operator attention or chemicals, both of which are especially relevant in such a remote location.

City of Coeur d'Alene Technology Demonstration Pilot to Achieve Low Phosphorus

The City of Coeur d'Alene invested nearly $5 million in applied research of low-level phosphorus removal and nitrification



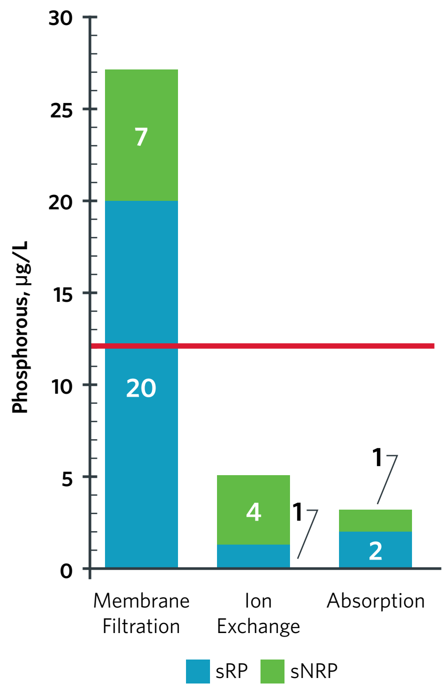


Figure 5. Membrane Filtration with Coagulant Addition (left).
Figure 6. Ion Exchange and Adsorption Columns Phosphorus Removal (right).

Advanced Wastewater Treatment Facility, City of Coeur D'Alene, Idaho.

improvements in response to the Spokane River Total Maximum Daily Load-derived speculative permit limits proposed in 2005. Facing effluent limits possibly as low as 0.01 mg/L total phosphorus, vendor demonstration testing was conducted to identify viable technologies in 2006. This was followed by a two-year demonstration pilot (2010–2012), which put three technologies to the test under real-life conditions: a two-stage moving bed sand filter, a tertiary membrane filter and a membrane bioreactor. Each technology is designed for 50,000 gallons per day average flow that is paced to match the diurnal influent pattern. Real-life conditions means treating plant effluent under variable loading, experiencing main plant variable performance, seasonal changes and online instrumentation with controls for autonomous operation. Challenge tests such as loss of chemical feed were conducted.

The objective of this pilot was to determine the lowest achievable phosphorus concentration using commercially available technologies as well as determining full-scale design parameters and operation strategy.

The pilot facility was designed to receive flow paced diurnal influent and was operated by city operations staff. During the first year of testing, the pilot facilities were operated according to conventional design criteria and tracked flow and loadings with the influent wastewater to the treatment plant. During the second year, the objective was to stress the technologies with shock loads, low temperature influent and peak loadings of phosphorus. The overarching approach was to expose these technologies to the real world of wastewater treatment and to gather the necessary design information for full-scale implementation. A second objective was for plant operators to witness the process and assess the operational requirements.

Based on the demonstration pilot scale testing performance at approximately 0.150 million gallons per day, an initial full scale tertiary treatment plant improvement at 1.0 mgd capacity of tertiary membrane facility was constructed, expandable to 6 mgd. This upgrade also included provisions to further boost nitrification in the tertiary filtration system. The demonstration pilot tests showed that when operated with chemical sludge retention, the tertiary membrane filtration system nitrified the residual secondary ammonia, which subsequently became a key feature in the selected tertiary membrane filter design. The reduction in effluent ammonia achieved as part of this upgrade provided meaningful water quality benefit to demonstrate to all stakeholders that the city was making progress towards compliance with the final effluent limits for the entire full-scale plant capacity. The Phase 1 Tertiary Treatment project was a $13 million investment in advanced treatment. Effluent performance is excellent and complied with the interim limits in the NPDES permit.

Finally, the tertiary membrane filter facility was expanded to 5 mgd in 2019. The Phase 2 Tertiary Treatment project represents an additional $16 million investment in advanced treatment. The discharge permit required the city to complete construction by November 30, 2022, which has been done, and gather two years of operating data prior to full compliance with the final effluent limits for ammonia and phosphorus by November 30, 2024.

Conclusion

As nutrient challenges and regulations continue to evolve many utilities are finding growing pressure to reduce nutrient discharge to receiving waters. To tackle these challenges, we will continue to collaborate with our clients and lead research efforts with organizations such as the Water Research Foundation to address regulatory, treatment and effluent management strategies. Research based on a holistic understanding of watersheds and focused on water quality results may improve the prospects for new approaches to nutrient management that foster innovation and new opportunities. While optimizing existing secondary and nutrient removal plants for reduced cost, higher efficiency and reduced nutrient discharge continue to show dividends in the reduction of nutrient discharge and nutrient enrichment of the nation's waters.

We have found that a phased approach with adaptive management is a powerful approach to solve new challenging requirements. In many instances, this approach of incremental progress has provided unexpected benefits that reduce cost and improve overall performance. Incremental progress to meet challenging permits can lead to discovery of alternative technical solutions, buy-in from all stakeholders and managing rate payer expectations.

Contact JB Neethling at jb.neethling@hdrinc.com or +1 (916) 817-4830 for more information.

Nutrient Removal on the Half Shell: Oysters and their Many Benefits

By Christopher Coccaro, ENV SP - Project Manager, White Plains, NY

Billion Oyster Project volunteers.

Oyster reefs are living pieces of infrastructure that serve several purposes within the ecosystem. An individual oyster can filter 50 gallons of water a day; their reefs can protect against coastal erosion and create habitat for other organisms.

Oysters feed by drawing in ambient water and consuming the free-floating plankton in the water column. Through this feeding process, oysters remove suspended particles and excess nutrients that improve water quality. Estuaries are highly productive, nutrient-rich ecosystems; however, with the additional inputs of nutrients from urban runoff, wastewater treatment plants and nonpoint source pollution, they can be prone to harmful algal blooms, eutrophication and poor water quality. Upgrading storm sewers, implementing wastewater effluent standards and developing green infrastructure can help to reduce the loading of estuaries. Nevertheless, these efforts are unable to manage or remove nutrients once discharged to a waterbody. Oysters can provide benefit to an ecosystem by helping to remove excess nutrients within an estuary. An excellent example of the importance of oysters and the benefits they can provide can be seen through the ecological history of New York City.

Before the bright lights of Broadway or "The Big Apple" was in our lexicon, New York City was known for oysters. Over 200,000 acres of oyster reefs surrounded the city, shucking houses lined the shores, while street carts and restaurants sold them for a penny apiece. It was estimated that the total population of oysters within the New York Harbor could be counted in the trillions. This provided New York City with a natural buffer for coastal storms, waters rich with marine life and clear water that supported the economy. However, overfishing and pollution in the 19th century led to a collapse of oyster reefs, leaving the water fetid, the bottom barren and the coastline exposed. Thankfully, with the passage of the Clean Water Act and decades of effort to improve water quality, the city's next generation is leading a resurgence of the oyster.

The Billion Oyster Project is an organization that uses oyster restoration to teach high school students a maritime-based science, technology, engineering and math-focused curriculum through the ambitious goal of planting one billion oysters before 2035. In 2022, BOP received an HDR Foundation community grant, which will help them meet their goal through a rapid upscale of their volunteering program. For the past five years, dozens of HDR professionals have volunteered with BOP, and we are proud to be a part of such a transformative grant that can help enact a major change in our community.

What Would a Billion Oysters Do?

One billion oysters would be able to filter up to 50 billion gallons of water every day! It would mean that the total volume of New York Harbor could be filtered every three days. Oysters provide incredible services that generate sustainable and resilient solutions against the growing threats of climate change including coastal storms, eutrophication and habitat loss. These services are needed all along the coasts of the United States. Though this discussion has been focused on New York City, the same benefits can be seen in any coastal city in the country. Boston, Chesapeake Bay and New Orleans all have rich histories with oysters that have shaped those cultures in multiple ways. To help protect these cities and to provide needed ecosystem services, a solution from their past could just be a key for their future.

Contact Christopher Coccaro at christopher.coccaro@hdrinc.com or at +1 (914) 993-2097 for more information.

Urban Stormwater Control Measures **for Nutrients Management**

By Julie Stein, ENV SP, LEED AP - Stormwater Director, New York, NY and
Leila Talebi - Stormwater Quality Technical Advisor, San Diego, CA

Nutrients are commonly transported in stormwater runoff and are direct contributors to water quality impairments.

According to the United States Environmental Protection Agency, 58 percent of the nation's rivers and streams and 45 percent of our lakes have excess levels of phosphorus, while approximately 60 percent of our coastal areas and more than 30 percent of our estuaries are impaired by nutrients.[1]

Nutrients such as total phosphorus, orthophosphate, dissolved phosphorus, total nitrogen, total Kjeldahl nitrogen (TKN) nitrate, nitrate+nitrite, and ammonia as N are commonly transported in stormwater runoff and are direct contributors to water quality impairments. Excess nutrients from stormwater discharges directly increase aquatic plant growth, harmful algal blooms and anoxia in receiving waterbodies, which adversely impacts fish and aquatic life.[2]

This article describes the current state of stormwater-sector knowledge about nutrients as a pollutant of concern for urban stormwater runoff and the sewer systems that convey stormwater discharges to our receiving waterbodies. Regulatory and permitting approaches are also described including regional approaches for assessing water quality in the San Diego area and identifying effective stormwater control measures based on these assessments to meet numeric water quality criteria.

While the City of San Diego is currently addressing various pollutants in addition to nutrients, the assessment approach, as described in this article, provides specific steps. These steps can be valuable for other communities as more Municipal Separate Storm Sewer (MS4) permits either include Total Maximum Daily Loads specific to nutrients or necessitate regional stormwater management approaches for nutrients. Challenges and benefits of these approaches are summarized as well to further assist other communities with preparation for evolving stormwater management requirements.

Nutrient Pollution in Urban Stormwater

Human activities are a common cause of excessive nutrient loading with specific activities, commonly tied to land use, contributing to high concentrations of nutrients in stormwater runoff. Activities such as urban or residential fertilization, septic systems, yard waste, organic debris, pet waste, trash and food waste, automobile emissions and atmospheric deposition are sources of nutrients discharging to our waterbodies via separate storm sewer outfalls or direct drainage via overland flow.

In the 1990s, early federal guidance for nutrient control (i.e., 1992 TMDL Guidance and 1998 National Nutrient Strategy) focused on wastewater plants, combined sewer overflows, septic tanks, and fertilizers and detergents.

In subsequent decades, the numeric water quality criteria and TMDLs for nutrients began to appear in MS4 permits in Minnesota and Florida and then Virginia and Maryland. Most recently, EPA established new nutrient wasteload allocations in its Massachusetts MS4 permit, and, like the above predecessor states, the cost estimates for communities to comply are significant.

MS4 permits can vary in their approach to expressing water quality-based

[1] *EPA National Aquatic Resource Surveys at https://www.epa.gov/national-aquatic-resource-surveys; EPA Nutrient Pollution – Where This Occurs: Coasts and Bays at https://www.epa.gov/nutrientpollution/where-occurs-coasts-and-bays.*

[2] *National Research Council. 2009. Urban Stormwater Management in the United States. Washington, DC: The National Academies Press. https://doi.org/10.17226/12465.*

requirements. While most permits require controls to reduce the discharge of pollutants to the "maximum extent practicable," many MS4 permits focus on effluent or receiving water quality or loading requirements. For these permits, required watershed or stormwater management plans must demonstrate the implementation of appropriate management actions over time to meet TMDL wasteload allocations or Water Quality-Based Effluent Limits. According to the 2022 National MS4 System Needs Assessment Survey Results, 55 percent of respondents (643 total) reported that their MS4 permits include TMDL requirements.[3]

Ashley Falls Regional BMP provides total nitrogen, total phosphorus and total suspended solids control, as well as flow management in San Diego.

Stormwater Control Measures for Nutrient Management

A stormwater control measure, also known as an SCM, is an action, either structural or non-structural, implemented to manage stormwater by regulating its flow rate, quantity and/or pollution levels. Studies over the past several decades have shown that, after source controls through actions like fertilizer bans and street sweeping, structural SCMs or best management practices are effective at removing nutrients in runoff. Filtration practices such as media filters and high rate bioretention are most effective for reducing total phosphorus and total nitrogen in stormwater runoff. Detention basins, retention ponds, wetland basins and wetland channels are most efficient at removing dissolved forms of nutrients in stormwater runoff.[4] Selecting SCMs for nutrient removal can be complicated given the number of different parameters contributing to nutrient pollution and that specific SCMs are known to export nutrients. Bioretention, grass swales or grass strips, for example, may consist of phosphorus-rich soils or media, or cause ammonification or nitrification of organic nitrogen.

Combined with multiple pollutants of concern for our waterbodies (i.e., pathogens also impacting urban receiving bodies for both combined sewer overflow and MS4 communities), it is important to know which nutrients are impacting a receiving waterbody and review data from the International Best Management Practices Database to select SCMs that will address nutrient loads as well as other loadings. This database provides stormwater managers a centralized, online repository for the effectiveness of BMPs, as well as data on urban and agricultural runoff quality. This resource is particularly valuable for selecting SCMs to implement in watersheds that need to address multiple pollutants where competing costs or siting challenges are expected. These challenges can arise as utilities and public works departments try to fit SCMs into tight or constrained urban spaces.

A Multifaceted Approach

A multifaceted approach is of utmost importance in addressing nutrient pollution in stormwater runoff due to the complexity and scale of the issue. Nutrient pollution, primarily caused by excess nitrogen and phosphorus, poses significant ecological and public health risks. Adopting a multifaceted approach recognizes that nutrient pollution stems from diverse sources such as urban and agricultural runoff, sewage systems and industrial discharges. By considering the wide range of sources, this approach ensures that strategies and interventions are tailored to address each specific contributor, maximizing the effectiveness of pollution reduction efforts.

Furthermore, a multifaceted approach acknowledges the need for a watershed-scale perspective. Stormwater runoff flows through interconnected watersheds, ultimately impacting downstream water bodies. By implementing strategies at various points along the stormwater pathway, such as source reduction measures, green infrastructure, treatment facilities and non-structural strategies, a multifaceted approach can effectively intercept and treat nutrients before they reach sensitive aquatic ecosystems. This comprehensive perspective recognizes the interconnectedness of the stormwater system and ensures a holistic approach to tackling nutrient pollution, ultimately leading to improved water quality and healthier environments for both humans and aquatic life.

While this article focuses on practices based on current permitting goals, partnerships for large-scale or watershed-wide wasteload allocations and TMDL implementation plans are critical for siting SCMs and project delivery as EPA seeks to address the diversity of sources of nutrients to our waterbodies (EPA, 2022).

Mark Doneux, chair of the WEF Stormwater Community and administrator of the Capitol Region Watershed District in Minnesota, is encouraging communities to consider watershed districts to pool resources, pay for SCMs, and take advantage of watershed-based or regional approaches for solving our stormwater challenges.

[3] *WEF. June 2023. 2022 National Municipal Separate Storm Sewer System (MS4) Needs Assessment Survey Results.*
[4] *Clearly, et al. International BMP Database 2020 Summary Statistics Report 2020.*

"In Minnesota, we have employed watershed districts since 1955. Watershed districts have the unique ability to address water resource issues of common concern based on watershed boundaries and not political ones. However, the greatest value of watershed districts comes with sharing and leveraging technologies for stormwater management that are most cost-effective and partnering locally and regionally on projects with multiple benefits for the District and our partners."

Mark Doneux, WEF Stormwater Community chair and Minnesota Capitol Region Watershed District administrator

Understanding and Meeting Water Quality Requirements Beyond Maximum Extent Practicable

The California Regional Water Quality Control Board, San Diego Region, is responsible for implementing and enforcing the MS4 NPDES permit in the region. This permit aims to regulate stormwater runoff and protect water quality in diverse landscapes, urban areas and coastal regions of San Diego. The RWQCB collaborates with municipalities and other entities operating MS4s to ensure compliance with the permit's requirements.

The Regional MS4 permit serves as a comprehensive framework for managing stormwater runoff and mitigating its impact on water quality in the region.

Analytical methods application including modeling and monitoring is crucial for evaluating and establishing the necessary connections between stormwater management practices and desired water quality goals. The following steps have been established to guide co-permittees in achieving compliance with the water quality numeric goals of the Regional MS4 Permit:

1. **Determine stormwater improvement goals for water quality compliance, using the MS4 NPDES Permit.** These goals serve as clear and measurable targets and can be established in collaboration with regulatory bodies or through stakeholder consultation.
2. **Characterize existing conditions and estimate existing nutrient loads.** This requires utilizing available data and employing modeling approaches to accurately assess the nutrient levels. In addition, it is important to consider all stormwater management practices and system assets that are currently in place or implemented at a specified point in time. This comprehensive characterization may require additional resources, such as historical information, environmental data and improved modeling approaches, to ensure accurate estimations.
3. **Calculate required nutrient load reductions.** These calculations are essential for developing targeted strategies and measures to achieve the established goals. Based on the existing conditions characterized above, in combination with water quality targets set by TMDLs or other assessments, the MS4 permit, and/or the watershed or stormwater management plan, specific goals can be determined to address impairments caused by stormwater. These goals typically involve specified reductions in stormwater pollutant loads or concentrations, volumes, or peak flows, and serve as benchmarks for effective stormwater management.
4. **Identify and implement the most effective strategies and management actions for load reduction.** This involves evaluating the effectiveness of various management practices, conducting economic assessments and adopting cost-effective approaches. Through the watershed or stormwater management planning process, opportunities for management actions are identified, including programmatic activities, low impact development practices and municipal capital improvement projects. These strategies ensure that the selected management approach will lead to the attainment of water quality improvement goals.
5. **Monitor the implemented management approach.** This includes conducting ambient monitoring of the water body, tracking nutrient loadings and assessing the effectiveness of specific projects. Monitoring progress is crucial for providing feedback and assessing the effectiveness of the implemented measures.
6. **Track and assess progress toward goals.** This assessment can be conducted through various methods, such as citizen observations, monitoring trend analysis and the development of quantifiable measures. It is important to report the results to stakeholders and the public. Developing quantifiable methods for evaluating progress is an area that requires further resources and research. If progress falls short of expectations, it may be necessary to revisit earlier steps, reassess relationships and strategies, and make necessary adjustments. This assessment process serves multiple purposes, including providing reasonable assurance to stakeholders and regulators, informing future stormwater program enhancements

The San Diego Water Board plays a crucial role in enforcing the Regional MS4 Permit, which covers 39 municipal, county government and special district entities, collectively known as co-permittees.

and capital improvement planning, and highlighting quantitative results that support adaptive management, implementation tracking, and progress toward meeting stormwater improvement goals and requirements.

Urban Stormwater and Controls for Nutrients Challenges

Numeric water quality criteria for nutrients in MS4 permits will always point communities toward a watershed or sub-watershed scale approach for SCM implementation. Implementing watershed-wide structural BMPs comes with its fair share of challenges. Reporting data can be a significant hurdle. Collecting and analyzing data from numerous BMPs across a watershed can be complex and time-consuming. It requires establishing robust monitoring systems and ensuring data consistency and accuracy.

Local pilots, demonstrations and post-construction monitoring or data analysis can help communities determine capital investments. The International BMPs Database 2020 Summary Statistics Report spells out BMP-related data needs in order to provide pollutant removal effectiveness values for nutrients.[5]

Particularly for nutrients, more data is needed related to green infrastructure and their impact on potential nutrient export, how enhanced engineered media mixes (i.e., iron or biochar) may have positive effects on both nutrients and other pollutants of emerging concern, and if nutrient recovery may be useful where soils are nutrient deficient (i.e., for a circular economy, to support agriculture).

Another challenge is the timeline for implementation, which is often identified in permits by regulatory agencies. Implementing SCMs at a watershed scale involves numerous projects and stakeholders, each with their own priorities and schedules. Coordinating and aligning these efforts can be time-intensive and may require overcoming logistical hurdles. Additionally, securing funding resources for large-scale implementation can pose challenges, especially when considering the diverse range of sites and their site-specific considerations, such as land availability, soil conditions and local regulations.

Furthermore, evolving regulatory criteria present a challenge. Stormwater regulations and permits often undergo updates and revisions to address emerging concerns and scientific understanding. Keeping up with these changes, including stricter pollutant reduction, monitoring or reporting requirements, and ensuring compliance across a watershed, can be demanding for project planners and implementers. Staying informed and adaptable to evolving regulatory requirements is essential to successful implementation of watershed-wide stormwater SCMs.

Potential future regulations in stormwater management may involve the adoption of new technologies and practices to improve stormwater quality. Costs of compliance with stormwater regulations can vary depending on factors such as the size of the watershed or community, the condition of the stormwater infrastructure, the level of pollution reduction required and the implementation of SCMs. Compliance costs may include infrastructure upgrades, maintenance expenses, monitoring and reporting activities, stakeholder outreach and staff training.

Benefits and Opportunities

Despite the challenges, there are opportunities associated with implementing watershed-wide stormwater SCMs for nutrient management. Recent permits written by EPA are purposefully general to enable communities to take advantage of flexible and broad watershed approaches, like credit trading, to meet water quality goals and TMDL requirements. EPA's 2022 Memorandum, Accelerating Nutrient Pollution Reductions in the Nation's Waters, provides direction and guidance on these broader approaches for nutrient management including One Water strategies for which stormwater is an important component.[6]

One of the primary benefits of implementing SCMs at a watershed scale is improved water quality and ecosystem health. By implementing SCMs across a watershed, the overall nutrient and pollutant loads entering water bodies can be significantly reduced. This, in turn, improves water quality, enhances aquatic habitat, and protects the health of plants, animals and humans dependent on these ecosystems.

Implementing SCMs at a watershed scale often allows for multiple benefit projects. Many SCMs, such as constructed wetlands, permeable pavement and stormwater ponds, provide additional advantages beyond nutrient reduction. They can help manage stormwater volume, reduce erosion, enhance groundwater recharge and create green spaces that improve aesthetics and provide recreational opportunities. By integrating multiple benefits into a watershed-wide approach, communities can achieve more comprehensive and sustainable stormwater management solutions.

Additionally, a potential future challenge that a watershed-wide approach can help address is climate change resilience. As climate patterns shift, communities may face increased stormwater challenges, such as more frequent and intense rainfall events. Implementing SCMs at a watershed scale can help build resilience and adaptability to these changing conditions by effectively managing stormwater runoff and minimizing its impacts on downstream areas.

[5] The Water Research Foundation. 2020. The International BMP Database 2020 Summary Statistics Report 2020. International Stormwater BMP Database: 2020 Summary Statistics (waterrf.org)

[6] Fox, Radhika. Technical Memorandum: Accelerating Nutrient Pollution Reductions in the Nation's Waters. Published by the United States Environmental Protection Agency, April 5, 2022. accelerating-nutrient-reductions-4-2022.pdf (epa.gov)

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Clean Water Policies:
Regulatory Innovation for the Next 50 Years

By Trent Stober, PE - Utility Management Services Director, Columbia, MO

United States Environmental Protection Agency headquarters.

U.S. water quality has greatly improved over the last 50 years since the inception of the federal Clean Water Act, funded through massive federal, state and local investments.

The CWA and regulations at both the federal and state levels have evolved since 1972 to provide structures for regulating point sources. The clean water community has greatly reduced conventional and toxic pollutants, which caused major water quality impacts in the years preceding the CWA.

Nonpoint sources of pollution are often the most significant water quality impacts in many watersheds with lack of regulatory controls; rather, these sources are primarily funded through incentive-based, voluntary programs. In addition, degradation of ecological conditions, particularly aquatic life habitat, has been reduced through Section 404 regulations, while there are no regulatory structures focused on improving existing habitat conditions.

The CWA provides an elegant framework to improve water quality and ecosystems despite the challenges with regulating all sources of pollution and lack of focus on aquatic habitat. Congress structured the CWA with a two-pronged approach to restore U.S. waters.

First, municipal and industrial discharges are controlled through minimum treatment technology requirements, which provided the authority to make enormous strides in water quality to reduce the gross pollution that drove the political will for the CWA. However, the technology-based approach focused on achievable and affordable treatment for a limited number of pollutants based on the type of discharge. For municipal wastewater discharges, control of biochemical oxygen demand and total suspended solids are the sole treatment targets to reduce oxygen depletion in receiving waters. Notably, formal technology-based nutrient reduction requirements were not established for point sources under the CWA. However, several states have adopted or are in the process of establishing nutrient reduction requirements for both municipal and industrial discharges.

Second, the CWA includes a set of water quality provisions that have been the primary regulatory drivers over the last 30 years. The water quality framework is structured with a focus on restoring and protecting beneficial uses to achieve the CWA goal of making all waters "fishable and swimmable." Each of these beneficial uses, such as aquatic life protection and recreational uses, are protected by a set of numeric and narrative criteria adopted by states and tribes with delegated authority by the U.S. Environmental Protection Agency. If these beneficial uses are not attained, total maximum daily load, also known as TMDL, studies are required to establish the maximum pollution budget that is allowable to attain the beneficial uses. TMDLs set wasteload allocations for point sources and load allocations for nonpoint sources, the latter of which are largely voluntary and incentive-based reduction strategies. Depending on the structure created through TMDL development, many TMDLs are solely focused on an individual or a limited set of pollutants that create a "zero sum game" that limits creative solutions to achieve beneficial use restoration, particularly the creation of incentives to control nonpoint sources or restore limited aquatic habitats. Water quality improvement has been impeded in many circumstances; however, we can now apply lessons learned to shift the regulatory paradigm to make greater progress to meet the original intent of the CWA.

Today's Communities and Environment Face Unprecedented Challenges

Our communities and environment are facing unprecedented challenges that require regulatory policy innovation to overcome today's water quality challenges in a sustainable, affordable and equitable manner. Today's challenges span from our communities and water sector utilities to our local and global environment.

The water quality of our waterways and estuaries is becoming progressively sensitive to nutrient pollution with the growing occurrence of harmful algal blooms in many major waterbodies. Harmful algal blooms have increasingly impacted drinking water supplies and caused aquatic life mortality. In addition, constituents of emerging concern, such as per- and polyfluoroalkyl substances (PFAS), 1-4 dioxane, 6PPD and microplastics, threaten drinking water supplies, aquatic life, fish consumption and sustainable use of biosolids. These water quality issues exacerbate ecosystem impacts that many times are already compromised by poor habitats.

Climate change is impacting our communities and ecosystem at an alarming rate. Water supply scarcity is a forefront threat to many regions and community, resulting from our hotter, drier and more intense weather patterns. Rising water temperatures also fuel extremes within ecosystems, producing harmful algal blooms, red tides and suppressing dissolved oxygen. While climate change is impacting our nation's waters, the water sector must also take steps to reduce direct and indirect carbon emissions to do our part to fight climate change.

Today's utilities are also balancing internal needs and community priorities while striving to meet CWA obligations. The CWA drove enormous investments into municipal infrastructure through the early 1990s, but reinvestment into the infrastructure that had been largely funded through federal grants is now primarily funded through financing. Hopefully, Congress will continue the recent investments into municipal infrastructure, but these funds will likely be paltry compared to the asset renewal needs that most utilities face. These asset management needs, coupled with expansive growth in many regions, create significant affordability challenges, particularly for low-income households.

Many municipal utilities are also facing significant investments to overcome previous inequitable infrastructure decisions that created disruption, lower levels of service and greater environmental impacts in low-income and minority service areas. These community and utility needs demand more innovative solutions to meet community priorities and regulatory requirements in a sustainable, affordable and equitable path forward.

A One Water and One Environment approach is the future if we are to overcome these challenges and take advantage of the opportunities in front of today's utilities.

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Environmental Justice:
Shaping Nutrient Policies and Practices

By Victoria Johnson - Global Equity Director, Atlanta, GA

The Trust for Public Land Rodney Cook Sr. Park in Historic Vine City, Atlanta.

As the water sector develops nutrient management practices, we must craft inclusive solutions that acknowledge past and current harms of policies, pollution and environmental impact. In recent years, the pandemic, along with expanded reporting of inequities, has continued to uncover the chronic needs of underserved communities.

To achieve equitable outcomes for underserved communities, it's critical the water sector has a clear understanding of how we define environmental justice. In its Equity Action Plan, the U.S. Environmental Protection Agency has "committed to making equity, environmental justice and civil rights a centerpiece of the agency's mission."

According to EPA, environmental justice is the fair treatment and meaningful involvement of all people regardless of race, color, national origin or income, with respect to the development, implementation and enforcement of environmental laws, regulations and policies.

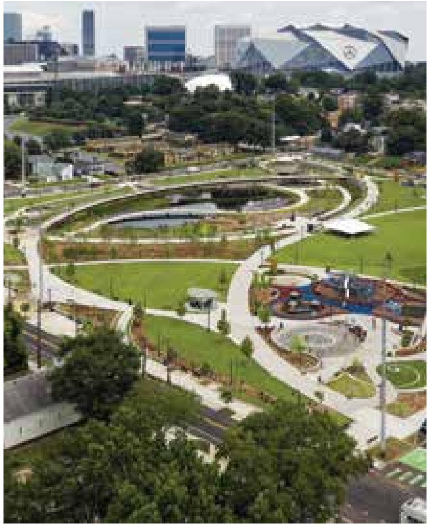
This goal will be achieved when everyone enjoys:

- The same degree of protection from environmental and health hazards, and;
- Equal access to the decision-making process to have a healthy environment in which to live, learn and work.

Diverse service areas that comprise of affluent, middle-class and low-income neighborhoods can illustrate disparities in how funding and resources are allocated, directly affecting ratepayers based on location and ZIP codes. For example, some payouts for natural disasters are based on tax appraisal information, which result in comparable homes with similar damages in two different zip codes being calculated differently.

The water crises in Jackson and Flint, along with Hurricane Katrina, illustrate the persistent challenges of disadvantaged communities, including poor water quality, lead exposure from water supply pipes, sanitary sewer overflows, nutrient pollution and a predisposition to flooding and damage from storm events. Affordability, water scarcity, droughts and rising sea levels are also causes of water stress among ratepayers. While all communities can be affected by these issues, not all are equally equipped to respond and recover.

Federal Executive Order (EO) 13985 directs federal agencies, including the EPA, to assess whether members of disadvantaged communities experience systemic barriers in benefitting from opportunities and investments through the federal government.



As an example of environmental justice considerations integrated into capital projects, the Rodney Cook Sr. Park in Atlanta has been designed to alleviate flooding by capturing and storing up to 10-million gallons of stormwater, while creating a vibrant community amenity to revitalize an underserved neighborhood in downtown Atlanta.

The Justice40 Initiative (i.e., EO 14008) is predicated on the effect of a legacy of redlining on low-income and black and brown communities, who bear a larger burden of water-related impacts.

In "An Equitable Water Future," the U.S. Water Alliance explores historic legislation and public policy in the U.S. that enable some ratepayers to reap multiple benefits from water infrastructure, while others suffer undue hardships, burdens and exclusion from community benefits and overall well-being. "The principal factors in community vulnerability are income, race or ethnicity, age, language ability and geographic location," according to the report.

The Justice40 Initiative is a first-of-its-kind goal in which 40 percent of the overall benefits of certain federal investments flow to specific disadvantaged communities. These communities include those that are marginalized, underserved and overburdened by pollution, including black and brown communities, immigrants, rural and tribal communities and currently or formerly incarcerated people. Justice40 investments will support efforts in climate change, clean energy, skills training, workforce development, remediation, reduction of legacy pollution, and development of critical clean water and wastewater infrastructure.

For example, Rodney Cook Sr. Stormwater Park is situated in the heart of downtown Atlanta in Vine City, a low-income area comprised mostly of black residents. Historically, Vine City was the catalyst for the Civil Rights Movement in the 1960s, and once home to Martin Luther King, Jr. This community has experienced social and economic challenges, outdated infrastructure and severe flooding. HDR led the design of the new Rodney Cook Sr. Stormwater Park, resulting in a new local community amenity, including functional green infrastructure to reduce flooding and runoff, and a tool to alleviate burden to local residents.

Understanding economic and social indicators is critical as we develop nutrient management practices, which can be expensive to implement, particularly for farmers and other landowners, thus creating a barrier to adoption of best practices. Additionally, nutrient management policies and regulations can be politically contentious, particularly in areas where agriculture is a major economic driver. Using socioeconomic data sets like EJ Screen or custom viewers is one avenue to identify marginalized communities and inform public outreach efforts.

Nutrient management policies may include new requirements for considerations of environmental justice. For example, the Washington State Department of Ecology's Puget Sound Nutrient General Permit requires that dischargers prepare a Nutrient Reduction Evaluation for purposes of evaluating treatment alternatives capable of reducing nitrogen discharges. The analysis conducted for the nutrient reduction evaluation must include an environmental justice review with specific content requirements based on recent legislation in Washington state. The Healthy Environment for All Act is the state's first law in Washington to coordinate a state agency approach to environmental justice review that covers seven state agencies including the Department of Ecology and the Puget Sound Partnership.

Effective watershed nutrient management requires public engagement and education. Managers should be prepared to communicate the importance of watershed nutrient management to the public and engage stakeholders in developing and implementing nutrient management strategies. Non-governmental and community-based organizations, individuals and tribes should all be part of solution identification. Leveraging wide-ranging representation in problem-solving will result in supported outcomes that will drive lasting change. Often, this avenue leads to projects that have multiple benefits and partnerships, making the most of investment dollars and community impact. Lastly, consideration should be given to project implementation that engages marginalized communities through contracting and workforce development, so that economic benefits are distributed broadly.

We must also consider the cost of more nutrient removal and water impacts, and site in areas that may have significant socio-economic challenges and provide greater access to nature. Efforts should also engage nature-based solutions to drive climate resiliency and ecological benefits.

As the water sector continues to develop nutrient management practices, we must develop inclusive solutions that remedy disproportionate impacts of the past on marginalized communities and provide benefits to all community members in the future. Thus, we must consider new requirements for environmental justice considerations, which will enable decision makers to account for equity more effectively in determining community and environmental benefits.

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Watershed Management Partnerships:
A 50-Year Retrospective on Achievements and Challenges

By Lacey Hirschvogel - Water Quality Manager, Columbia, MO

Long-term watershed management partnerships are part of the solution in nutrient reduction.

Meaningful nutrient reductions within our nation's watersheds cannot be achieved through wastewater point sources alone. Strong watershed management partnerships are essential to achieve nutrient reduction.

Since our environmental regulators have increased their focus on nutrient reductions through stringent numeric nutrient limits, Total Maximum Daily Loads, and permit limits, it is vital that our wastewater industry leaders look toward affordable, multi-benefit approaches that consider contributions from both point and nonpoint source producers. This approach involves effective collaboration through partnerships among all stakeholders who share a commitment to preserving and improving water quality.

Developing effective watershed partnerships can be challenging. To guide the effort, utility leaders can learn from established watershed partnerships or use public administration research that highlights the necessary elements of a successful partnership leading to outcomes.

This article discusses the successes of long-standing watershed partnerships such as the Neuse River Compliance Association, Lower Neuse Basin Association, Yahara Watershed Improvement Network, Middle Cedar Partnership Project and Cedar River Source Water Partnership. Each of these programs has effectively and affordably reached its targeted nutrient reduction goals and has experienced additional benefits from the partnership such as increased watershed funding, flood control, enhanced business development and innovative nutrient treatment.

> ***Nonpoint source pollution is considered the dominant source of nutrients in our nation's lakes and streams.*** USEPA, 2013

In addition to learning from successful partnerships, the Integrative Framework for Collaborative Governance, developed by Dr. Kirk Emerson (2012) and well-studied by Dr. Jennifer Biddle (2017), specifies the set of necessary elements needed to build an effective partnership that will lead to observed outcomes. We had the opportunity to sit down with Dr. Biddle and discuss her meaningful research on building collaborative partnerships and how effective partnerships can lead to holistic nutrient reduction solutions. Utility leaders can apply this framework to watershed partnerships to strengthen cross-collaboration and enhance nutrient reductions throughout the watershed.

Lessons Learned from Successful Watershed Partnerships

NEUSE RIVER COMPLIANCE ASSOCIATION AND THE LOWER NEUSE BASIN ASSOCIATION

The 1997 Neuse Management Strategy and the 1999 Neuse River Estuary Total Maximum Daily Load both include a goal of reducing total nitrogen, referenced in this article as TN, loading to the Neuse Estuary by 30 percent by 2003. The NRCA and its partner organization — the LNBA — are the core organizations leading point source reduction efforts in the Neuse Basin. The LNBA was formed in 1994 as a monitoring and information-sharing organization and currently includes 18 member organizations serving over 750,000 people, or 70 percent of the Lower Neuse watershed. The LNBA entered into a Memorandum of Understanding with the North Carolina Department of Environment and Natural Resources, Division of Water Quality as a coalition monitoring group. In addition to monitoring 48 sites in the Neuse Basin, the LNBA provides technical resources to its members through annual operator training and optimization of wastewater treatment plants. The NRCA was founded in 2002 by an executive committee of the LNBA and serves as the controlling authority for the watershed aggregate National Pollutant Discharge Elimination System Permit NCC00000. The aggregate permit has driven down TN loading from point sources by approximately 50 percent (Rutgers, 2008).

The trading program works by requiring NRCA members to maintain an individual TN allocation but remain in compliance, provided the NRCA does not exceed its cap. A main feature of the NRCA aggregate permit is that it incentivizes compliance through offset payments, fines and trading. If the NRCA exceeds its group loading limit, the State effectively enforces an exceedance tax through required offset payments to the Wetlands Restoration Fund. However, offset payments have not been required to date since the nitrogen cap has not been exceeded. Regardless of group compliance, the NRCA assesses a financial penalty for members that do not meet their individual limits. Members are eligible for refunds up to 80 percent of the penalty if there is a timely correction. Members can also financially benefit from nutrient reductions through trading. Participants that go beyond their required nitrogen reductions can sell or lease nitrogen credits to other facilities. During an interview with Haywood Phthisic, executive director for the LNBA, he described the partnerships as successful agreements that have driven down nitrogen within the watershed but enhanced the camaraderie and communication across the membership communities. Phthisic said that he looks forward to board meetings because the operators have made it a fun competition to see who can optimize the most to get the most nitrogen loading reductions.

YAHARA WATERSHED IMPROVEMENT NETWORK

The Madison Metropolitan Sewer District was facing $140 million in treatment plant upgrades to meet phosphorus reduction requirements in the Rock River TMDL. However, rather than pursuing plant upgrades, MMSD chose to meet its regulatory obligations through adaptive management. Adaptive management is a phosphorus compliance option available to many wastewater dischargers throughout Wisconsin pursuant to s. NR 217.18 Wis. Adm. Code. MMSD determined this option could be the solution to maintaining affordable utility rates while driving down total phosphorus within the watershed. Understanding that a partnership across the watershed was needed, MMSD established the Yahara Watershed Improvement Networks, which consists of 24 municipal separate storm sewer systems, three wastewater treatment plants, one farmer-led watershed group (Yahara Pride), three county land conservation departments and multiple other parties. In 2016, all municipal partners entered into an Intergovernmental Agreement with Yahara WINS that contractually obligates them to provide funding support for the project, which is proportional to their required phosphorus reductions.

Yahara WINS has provided long-term, flexible funding for soil and water conservation efforts in exchange for implementing conservation practices that provided municipalities with cost-effective nutrient reductions. These organizations within the partnership have since become even more intertwined as a Yahara WINS member now sits on the Yahara Pride Farms Board of Directors and a farmer member sits on the Yahara WINS Executive Committee for the Municipal-Agricultural Watershed Partnerships.

MMSD's additional efforts to partner with county Land and Water Resource Departments provide planning and

YAHARA WINS PARTNERSHIPS AND THE USE OF ADAPTIVE MANAGEMENT HAVE ALLOWED ADDITIONAL PROJECTS TO BE FUNDED AND IMPLEMENTED SUCH AS:

- Manure aeration studies that have reduced phosphorus contents by 90 percent
- Cover-cropping enhancements
- Stormwater basin algae treatment
- Composting studies
- Phosphorus-rich sediment removal

technical assistance to agricultural landowners, producers and other individuals or entities for the implementation of conservation practices or engineered solutions that reduce sediment and nutrients from entering waters. The strength of this relationship is evident in Dane County where, despite privacy concerns, there is an estimated 80-90 percent full cooperation of local farmers with county conservation staff.

Although intended as a four-year pilot project, Yahara WINS was fully implemented in 2016 and has been so successful that it will continue for the next 20 years. For 2022, phosphorus reductions totaled 50,563 pounds (YaharaWINS.org, 2023).

MIDDLE CEDAR PARTNERSHIP PROJECT AND CEDAR RIVER SOURCE WATER PARTNERSHIP

The City of Cedar Rapids is no stranger to implementing effective partnerships for clean water purposes. Cedar Rapids is currently participating in many collaborative efforts, including partnerships with agricultural producers and organizations. As Roy Hesemann, Cedar Rapids utilities director, stated: "Cedar Rapids has been recognized for our work to improve water quality. With the Middle Cedar Partnership Project, we helped install real water quality improvement practices with demonstrable benefits. The Cedar River Source Water Partnership will take what we learned from that project and scale up our efforts to improve water quality in the Cedar River" (Cedar Rapids 2018).

The Middle Cedar Partnership Project focuses on multi-benefit best management practices to protect the Middle Creek River Watershed. The best management practices include cover crops, nutrient management, wetlands and saturated buffers. Cedar Rapids leads the partnership along with 15 other partners including local conservation partners, farmers and landowners. In particular, the Iowa Soybean Association has provided strong support and leadership to plan and implement agricultural best management practices that provide multiple benefits beyond solely nutrient reductions.

The Iowa Nutrient Reduction strategy listed the Middle Creek River Watershed as a priority watershed for nutrient reductions, but Cedar Rapids was able to think big picture and realize that flood control is also an important piece of reducing nutrients from the watershed. "Iowa's second-largest city also sent hundreds of thousands of dollars miles upstream, in hopes of inspiring better conservation practices so the water volume is more manageable and cleaner when it gets to Cedar Rapids" (Morelli 2019). Listing the watershed as a priority watershed opened the doors for Cedar Rapids to secure funding to develop and implement the MCPP through the Regional Conservation Partnership Program. The initial $2 million in startup funding was able to leverage $2.3 million in additional funding from partners to begin large-scale, complementary projects that reduced downstream flooding and improved water quality (Iowa Watershed Approach). Since its inception, the MCPP has been able to secure over $11 million in RCPP grant funding for watershed management measures including 6,539 acres of cover crops, 6,522 acres of nutrient management plans or practices, 9,173 of no-till, strip-till or reduced-tillage practices, and 2 saturated buffers (Source Water Collaborative 2023).

With the successes of the MCPP, Cedar Rapids has continued its stewardship through developing, leading and implementing the CRSWP. In 2020, the RCPP awarded the CRSWP over $7 million in funding to improve water quality to the Cedar River. The CRSWP is a partnership of the City of Cedar Rapids, City of Charles City, Iowa Soybean Association and multiple agricultural groups and landowners to plan and install nutrient management measures throughout the Cedar River Watershed. The Cedar River Watershed consists of about 93 percent agricultural land, making it a priority watershed within the Iowa Nutrient Reduction Strategy. Initially, the funding was allocated to develop the partnership and expand on the earlier efforts of Cedar Rapids to invest in flood reduction mitigation measures that also controlled the flow of nutrients downstream. However, the partnership has been so successful that the CRSWP received an additional $19.3 million to continue efforts that will incentivize farmers to use conservation practices on their farmland. Practices include wetlands, bioreactors and cover crops. Hesemann has been a leader throughout this process, "We've seen the data, and these types of projects have a proven record of reducing nitrates in the Cedar River" (AWWA 2022).

Dr. Jennifer Biddle's Research on Improving the Effectiveness of Collaborative Governance Using Lessons from Watershed Partnerships

Long-term, sustainable partnerships that lead to observed outcomes such as nutrient reductions are not built overnight. These partnerships are created by different groups with differing primary objectives. Dr. Jennifer Biddle, associate professor at the University of North Carolina at Wilmington, focuses her research at the confluence of science, public policy and public administration, evaluating governance factors that build or block adaptive capacity for resilience in linked socio-ecological systems. Her scientific background and training in ecological processes combined with policy expertise and public administration experience enable Dr. Biddle to recognize and understand complex interactions between human organizations and the built and natural environments. Her research highlights the integrative collaborative governance framework that water industry leaders can use to guide the development of a successful partnership.

The collaborative governance framework encourages the "interrelationships among governing institutions, information-sharing among participants, and the adoption of innovative and flexible policy tools that have the potential to overcome political barriers" (Biddle, 2017). To define collaborative governance, Dr. Biddle (2017) uses the integrative framework for collaborative governance developed by Emerson (2012). The framework consists of three major elements of effective collaborative governance and then breaks those categories into smaller subgroups, which were determined to correlate to achieve outcomes.

Dr. Biddle tested the interrelationship of the three elements based on survey data submitted by participants of the Environmental Protection Agency's

COLLABORATIVE GOVERNANCE FRAMEWORK MAJOR ELEMENTS AND SUB-CATEGORIES:

PRINCIPLED ENGAGEMENT

- Mission consensus – defines common purpose and objectives
- Information sharing – integration of knowledge
- Role congruence – clarifying and adjusting tasks and expectations
- Communication – frequent and face-to-face communication

SHARED MOTIVATION

- Sustained participation – continued involvement of partners
- Mutual trust – enables people to go beyond their own frame of reference

CAPACITY FOR JOINT ACTION

- Human capital – expertise, local knowledge and skills
- Technical resources – equipment and data analysis software
- Financial resources – adequate budget

Nonpoint Source Control Long-term Monitoring Partnerships. The research scored their partnership experience and outcomes based on the major elements and sub-categories defined in collaborative governance. Observed outcomes could be measured by nutrient reductions and whether or not BMPs were implemented. The study included 26 of the 28 watershed partnerships that participated in EPA's NNPSMP. The results from the study were clear — the watershed groups that relied on traditional bureaucratic structures were ill-equipped to handle large-scale nutrient reduction efforts. However, the watershed groups engaged in a combination of principled engagement, shared motivation and the capacity for joint action drove higher nutrient reductions.

Partnerships for the Future

Our country's waterways are exhibiting indications of extended nutrient loads, leading to more frequent occurrences of algal blooms, hypoxic zones, aquatic life fatalities and reduced recreational usage. Coastal communities are encountering not just water quality issues but also health impacts, diminished income and lost business prospects due to harmful algal blooms. Using effective frameworks such as the integrative collaborative governance framework and lessons learned from successful partnerships such as Yahara WINs, the CRSWP, MCPP and NRBA, we can establish meaningful cross-sector collaboration with the agricultural community, business developers, non-government organizations and regulators to create innovative policies and nutrient reduction practices — resulting in the necessary load reductions to protect our nation's waters.

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A Chat *with* Dr. Biddle

on her Watershed Partnerships Research and Perspectives

Dr. Jennifer Biddle is an Associate Professor at the University of North Carolina Wilmington where she teaches courses in environmental policy and policy analysis.

We had the opportunity to sit down with Dr. Biddle to discuss the importance of partnerships as we look toward holistic nutrient reduction solutions.

HDR: Out of the three key elements and sub-categories listed within the collaborative governance framework, do any rise to the top when building long-lasting effective partnerships that will lead to sustained nutrient reductions?

Dr. Biddle: *Trust. But for most, trust is earned. In my experience, open, two-way communication is key to building trust. This communication strategy is effective because it promotes information sharing in both directions. The benefits of open communication are intensified through active listening. That is, to listen to what the other person is saying with the intention to understand, and without interrupting them or allowing your mind to drift toward your retort. Active listening is a skill that can be learned. The trick is to free your mind of judgment and bias. For example, environmentalists vilify farmers for carelessly polluting waterways with nutrients and waste running off their land, without seeking to understand the economic obstacles prohibiting taking precautions. Farmers blame environmentalists for costly regulations and caring more about the water than the people who live beside it. This misunderstanding creates division and breaks trust. I believe if these two sides could talk face to face, free of judgment, they might find common ground in their shared love of the land (and water) and desire to preserve it for future generations.*

HDR: Can watershed partnerships sustain effective long-term relationships that are required to drive meaningful nutrient reductions? What tools and resources are necessary to enable these long-term relationships to thrive?

Dr. Biddle: *I am an optimist so I think long-term partnerships can be sustained over time. However, in my study of EPA's NNPSMPs, I found a statistically significant negative relationship between the age of watershed partnerships and their capacity to achieve their water quality goals. The study did not include any partnerships less than four years old with the majority being older than 10 years; however, this lack of variability in partnership ages limits any strong determination to be made regarding the significance of partnerships' age. Instead, that study found the action of setting specific goals (e.g., percentage of load reductions in pollutant levels) is fostered by sustained participation from partnership members throughout the lifecycle of the collaborative and conducive to achieving environmental improvement goals.*

As for tools to sustain long-term partnerships, I recommend direct (synchronous) communication pathways, information-sharing platforms accessible to nonexperts, such as dashboards that promote transparency and coordination of efforts, and forums for deliberation and debate.

> ***"I am an optimist so I think long-term partnerships can be sustained over time..."***

HDR: In 2011, the EPA's then-Acting Assistant Administrator for Water, Nancy Stoner, released the Nutrient Reduction Strategy memo. This memo laid out a framework for states to use during the development of their NRS. When asked, multistakeholder forums were commonly cited as a success of the NRS development. Is there an optimal size of multistakeholder forums that will work together to create meaningful reductions? Who should be included and who should lead the partnerships and discussions?

Dr. Biddle: *Olson's The Logic of Collective Action provides a compelling argument for smaller groups being easier to manage. In my research, I have not found the optimal number of people attending as important as an equal understanding of the problem and the ability to share their perspectives. My experience observing Superfund remediation public forums has taught me the power of explanation. People are more engaged when they understand the information and when they feel heard and understood.*

The best people to lead these discussions are trained facilitators and mediators. The NRS can create conflict and division as some feel pressured to comply with state policies more than others.

HDR: In 2022, Assistant Administrator Radhika Fox released a memorandum describing the importance of partnerships with agriculture as a strategy to drive reductions in nutrient pollution. Her approach included working "collaboratively with U.S. Department of Agriculture and the agricultural community will be a central focus of EPA's nutrient agenda." Is EPA on the right path with targeting its partnership efforts with USDA? Who should lead these partnership efforts?

"USDA and EPA must join forces to make lasting progress."

Dr. Biddle: *Absolutely! USDA and EPA must join forces to make lasting progress. EPA has the water quality knowledge and direction, and USDA the agricultural perspective and connection to farmers — both sides of the coin. Through my experience working in EPA's Nonpoint Source Control Branch, I realized the importance of working with state agricultural programs, like Maryland's Conservation Reserve Program, for achieving water quality goals. They had the access and resources to incentivize participation from farmers to retire cropland adjacent to water resources.*

HDR: Are regulatory policies required to drive voluntary partnerships that have been created to advance nutrient management?

Dr. Biddle: *I believe so. Regulations hold everyone to the same standard, which allows leaders to be rewarded for going above and beyond, rather than being penalized by reduced profit margins. The best governance approach involves both carrots (incentives) and sticks (regulations). This creates a baseline for compliance and inspires innovations that raise the bar and lower collective costs due to economies of scale.*

Establishing key partnerships is an industry-wide opportunity to discuss water quality impacts while developing guidelines for nutrient removal strategies.

The Importance of Partnerships while **Managing Nutrients across a Watershed**

By Mike Falk, PhD, PE - West Region Wastewater Sector Lead, Folsom, CA

The goal of Bay Area Clean Water Agencies is to ensure the health of San Francisco Bay.

While San Francisco Bay is recognized as a nutrient-enriched estuary, it has historically not been adversely impacted by nutrient loading due to a combination of water quality features (turbid environment, strong tides that limit periods of stratification, large clam population that effectively grazes on phytoplankton, etc.).

Ensuring the protection of beneficial uses and overall health of San Francisco Bay is a cornerstone for Bay Area treatment plants that are represented by the Bay Area Clean Water Agencies, also known as BACWA.

BACWA and its treatment plant member agencies (37 in total) have been working collectively and collaboratively with the regulators (Water Board), scientists at San Francisco Estuarine Institute, non-governmental organizations, etc. on the nutrient topic for over a decade. The efforts have resulted in a menu of nutrient management options as the Water Board moves toward nutrient limits.

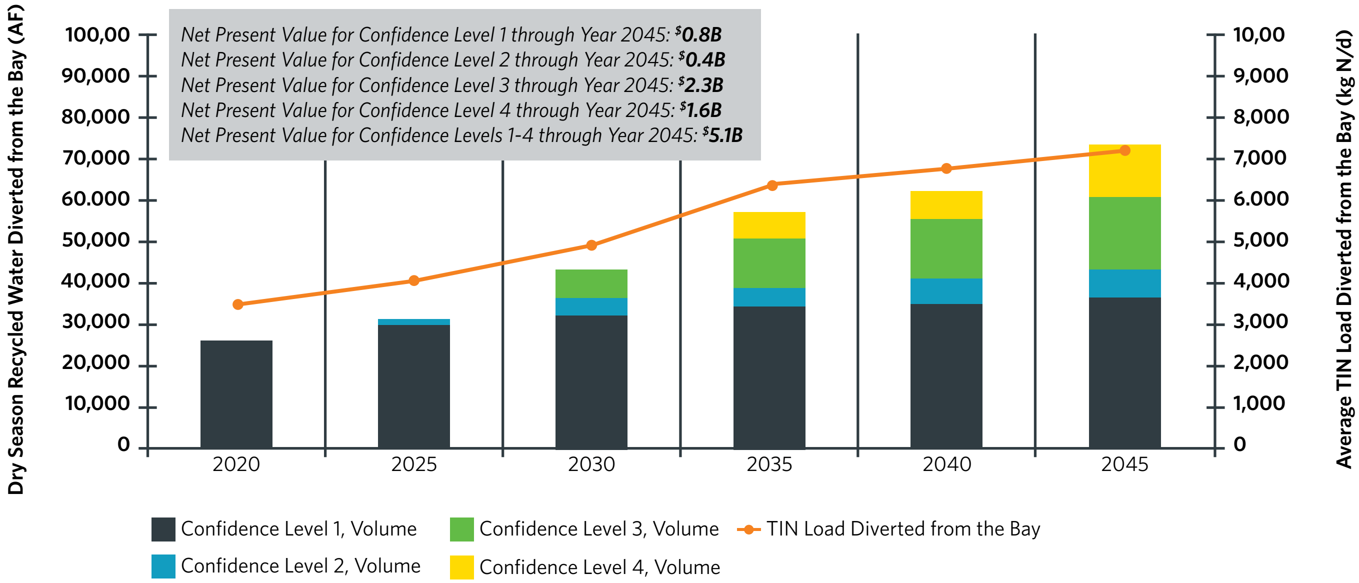
Despite its historic resilience, the San Francisco Bay experienced a harmful algal bloom in August 2022 that resulted in the death of over 10,000 fish. This event has accelerated the implementation of nutrient limits with a vision of compliance by year 2034.

BACWA's efforts to advance the science have included the annual characterization of nutrient discharge loads since 2013, monitoring for changes in eutrophication indicators and modeling biochemical phenomena to predict potential outcomes given a variety of circumstances, supporting science, funding engineering studies, etc. We have specifically led and/or supported annual discharge load reports, statistical analyses for developing load limits and the three cornerstone engineering studies to inform the nutrient management menu of options:

1. Opportunities at the treatment plants via optimization, sidestream treatment and plant upgrades (conventional and enhanced nutrient removal) (HDR, 2018)
2. Nutrient reduction by other means that offers multiple benefits beyond simply nutrient management:
   a. Recycled water as a strategy to divert nutrient loads away from San Francisco Bay (HDR, 2023)
   b. Natural treatment systems to polish nutrient discharge loads (San Francisco Estuarine Institute, 2023)

SUMMARY OF RESULTS FOR OPPORTUNITIES TO MANAGE NUTRIENTS AT THE TREATMENT PLANT:

Strategy	Total N Load Reduction to San Francisco Bay	Total Present Value for Total N Load Reduction to San Francisco Bay ($ Mil in 2018 $)
Optimization	7%	$174M
Sidestream Treatment	19%	$694M
Upgrade Level 2 (15 mg N/L)	57%	$9.0B
Upgrade Level 3 (6 mg N/L)	82%	$11.5B



Overall Summary of Existing and Proposed Dry Season Recycled Water Flows and the Corresponding Total Inorganic Nitrogen Load Diversions from San Francisco Bay Dischargers.

Confidence level = level of confidence in the values provided. 1 = includes projects that are already in place and/or currently budgeted; 2 = includes projects that are in master planning stages; 3 = includes projects that are conceptual, and 4 = includes projects that are conceptual in nature and require agreements across multiple jurisdictions/agencies.

** The total net present value might vary from the sum of the listed confidence levels due to rounding.*

The overall costs for nutrient management across San Francisco Bay are anticipated to be several billion dollars (likely be funded by ratepayers). Rather than address nutrients at each treatment plant individually, we are developing a comprehensive menu of engineering options in collaboration with the listed players to make informed decisions that will balance costs and other benefits (water supply demands, habitat restoration, bay health, greenhouse gas emissions, etc.).

This approach, which uses science to evaluate the health of the San Francisco Bay ecosystem — coupled with partnerships for nutrient management across numerous treatment plants, has the potential to serve as a template for other watersheds considering nutrient management strategies.

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