# Full-Scale Nitrogen Removal
## in a High-Purity Oxygen Activated Sludge Process

By EBMUD staff Donald Gray (Gabb), Rogelio Zuniga-Montanez, Justin Shih, Kristine Yung, Robert Starke, Brian Dunstan, Christopher Aman, Kevin Dickison, William Loconte, Rochelle Verspui, Joseph Barge, Ryan Quezada, Sue Berg and the rest of the EBMUD Laboratory

Nitrogen, a nutrient present in wastewater, can have detrimental impacts when discharged into receiving water bodies. East Bay Municipal Utility District (EBMUD) has explored both sidestream and mainstream nutrient removal approaches through its recently completed Master Plan. The agency is also working on a parallel effort to characterize the ability to remove total inorganic nitrogen (TIN) using the existing high-purity oxygen-activated sludge (HPOAS) system. Utilizing HPOAS for nitrogen removal poses several challenges, and the available literature at full scale is sparse.

EBMUD provides wastewater treatment services to 740,000 residents in California's east San Francisco Bay Area. The District's Main Wastewater Treatment Plant (MWWTP) treats approximately 60 million gallons per day (MGD) of wastewater during the dry weather months – April to October – and has used HPOAS for secondary treatment since the 1970s.

The system consists of eight reactor trains (with four stages each) and twelve secondary clarifiers (Figure A), with a rated capacity of 168 MGD during wet weather. High-purity oxygen is generated from an on-site cryogenic oxygen air separation plant (Figure B).

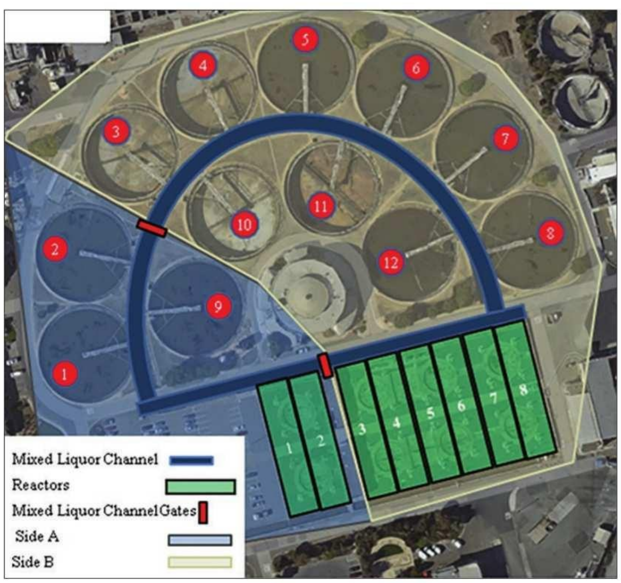


Figure A: East Bay Municipal Utility District Main Wastewater Treatment Plant layout and split-plant configuration. Side A and Side B operate at high and low mean cell residence times, respectively, during split-plant testing.

Figure B: Cryogenic oxygen generation plant for high-purity oxygen activated sludge process.

In the early 2000s, the first stage of each reactor was converted to an anaerobic selector to control sludge bulking. The EBMUD's MWWTP has been in perfect compliance with effluent limits in its National Pollutant Discharge Elimination System (NPDES) discharge permit for the last twenty-two consecutive years.

In 2014, the San Francisco Bay Regional Water Quality Control Board issued its first regional order (referred to as the San Francisco Bay Nutrients Watershed Permit) to address the potential impacts of nutrient discharges on the San Francisco Bay. The second Nutrients Watershed Permit issued in 2019 included estimated TIN load targets for each wastewater agency. EBMUD is planning to meet TIN effluent discharge limitations required by the third Nutrient Watershed Permit to be issued in 2024.

"While the MWWTP typically operates at a mean cell residence time (MCRT) of 1-1.5 days, much longer MCRTs are needed to support nitrifying bacteria – the main microorganisms that oxidize inorganic nitrogen," said Donald Gray, EBMUD's Manager of Wastewater Technical and Emerging Issues. "The subsequent increase in solids inventory can present challenges to the existing infrastructure, including a much higher solids load to the clarifiers."

There are additional concerns with insufficient alkalinity for complete nitrification – oxidation of ammonia to nitrite, and then to nitrate, the lack of internal recycle for denitrification – reduction of nitrate and nitrite to nitrogen gas, the potential for rising sludge blankets in the clarifiers from the gas formed from denitrification or nitrite impacts on hypochlorite disinfection.

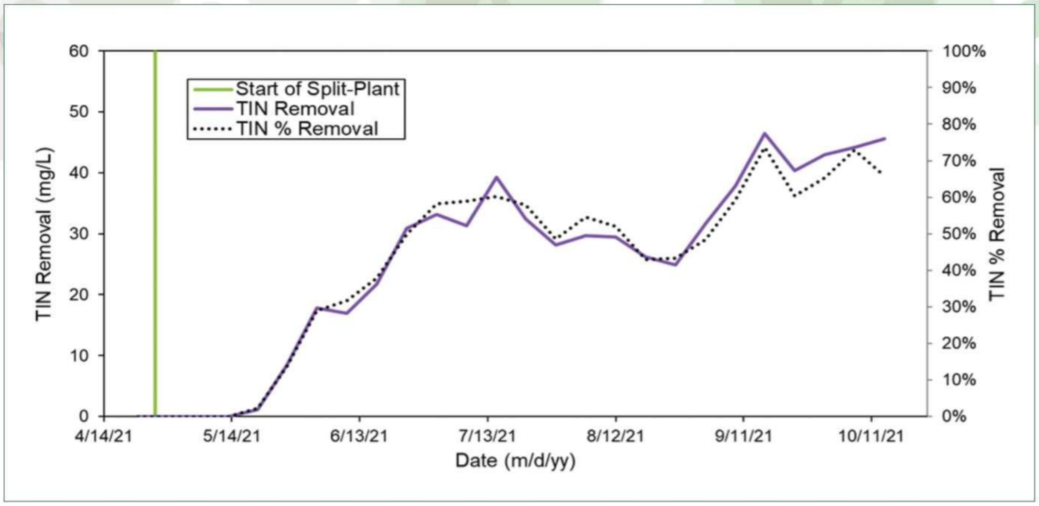


Figure C: Total inorganic nitrogen (TIN) removal in full-scale high-purity oxygen activated sludge process.

"EBMUD has performed full-scale TIN removal testing during dry weather for the past three years using its existing HPOAS process," Justin Shih, senior civil engineer for EBMUD said.

Through a series of valves, gates, and pumps, the existing HPOAS reactor and clarifier configuration can be physically split into two parallel processes with entirely separate biomass (Figure A). This allows for full-scale testing of higher MCRTs to treat up to 25% of the secondary influent flow (Side A) while maintaining the existing process for regular treatment (Side B).



"There is also the ability to configure a 50/50 split. Both sides' effluent combines before disinfection, dechlorination, and discharge," he said. "The 'split-plant' testing can run for approximately four to six months during dry weather and depending on plant conditions."

Each split-plant season has provided additional evidence towards both the benefits and challenges of operating an HPOAS system for nitrogen removal. In 2021, up to 74% TIN removal was demonstrated for flows up to 5 MGD (Figure C).

On average, the nitrite concentrations in the secondary effluent were more than six times higher than those of nitrate, suggesting a nitritation/denitritation process.

'This year's focus is to increase effluent flows, evaluate the potential benefits of flocculant use to control effluent total suspended solids, and further explore different operating parameters," EBMUD assistant engineer, Rogelio Zuniga-Montanez said. "Data collection efforts were expanded from last year by increasing the sampling frequency and analytical tests conducted."

A nitrous oxide sensor was installed in the high MCRT reactor to evaluate dissolved concentrations of this nitrogen removal side-product and potent greenhouse gas as the process activity evolves, accompanied by planned gas sampling events of the reactor headspace. Mixed liquor samples are regularly sent for DNA sequencing to characterize the biomass to identify the key organisms involved in the process.

"This testing effort has resulted in extensive documentation of the startup and operation of HPOAS at high MCRTs," Gray said. "Although increasingly less common, many wastewater agencies still successfully operate and maintain their HPOAS systems."

Gray said that these agencies (including EBMUD) are faced with the difficult determination of whether the system can continue to be rehabilitated and adapted to regulatory changes. Running split-plant testing is an extensive effort throughout the Wastewater Department for Operations, Maintenance, Engineering, and the Laboratory; however, nitrogen removal in HPOAS plants remains a promising strategy for reducing TIN discharges to the San Francisco Bay and elsewhere.

"We look forward to documenting our findings for future publication," Zuniga-Montanez said.



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# EBMUD ingenuity protects the bay and our ratepayers

**Every day, waste from nearly 740,000 East Bay residents and businesses flows into EBMUD's Wastewater Treatment Plant where it is treated before it's discharged to the San Francisco Bay.**

*Our wastewater treatment plant operates around the clock every day of the year.*

Our plant is great at removing solids, pathogens and pollutants from the water sent down your drains. Our processes protect public health and support a vibrant bay ecosystem.

But one challenge has remained: reducing discharges of nitrogen compounds that can contribute to harmful algal blooms.

Over the past five years, EBMUD has been experimenting to find a solution. Now, our staff have developed a first-of-its kind process to significantly cut nitrogen loads.

We've modified our operations and existing infrastructure to grow bacteria that break down inorganic nitrogen compounds such as ammonia, nitrite and nitrate that are common in wastewater. That's important because just as these compounds are used in fertilizers to feed plants, they can contribute to harmful algae growth in the bay.

The results of our biological nitrogen removal process have been extraordinary. By the end of next year we expect to reduce nitrogen levels in our wastewater discharge by up to 65 percent.

On top of delivering environmental benefits, this example of EBMUD ingenuity could save ratepayers $2 billion in estimated costs we may have otherwise needed to spend to install a new mainstream treatment process for removing nitrogen.

There's more work to do, but we're driven to apply our scientific knowledge, engineering know-how, and culture of innovation to tackle challenges and protect the bay.

EBMUD's 2022-23 Biennial Report, **"Flowing into the Future: A Report to Our Community,"** is now available. We used the multimedia StoryMap platform to highlight the last two years. Find it at ***ebmud.com/publications***.

EBMUD | 100 FLOWING INTO THE FUTURE

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**EBMUD Mission Statement**
To manage the natural resources with which the District is entrusted; to provide reliable, high-quality water and wastewater services at fair and reasonable rates for the people of the East Bay; and to preserve and protect the environment for future generations.

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# Update on Nutrient Watershed Permit

## Board of Directors

August 13, 2024

# Agenda

- Background
- Nutrient Watershed Permit
- Comments and Response
- Next Steps

# Background

- 40 Wastewater Plants
- 7.1M service population
- Individual permitted flows from **0.03 mgd** to **167 mgd**
- Individual dry season total inorganic nitrogen loads **0 to 10,000 kg/day**

**Wastewater Plants discharge ~ 80% of the annual nitrogen loads to San Francisco Bay**


Source: Bay Area Clean Water Agencies

# Nutrient Watershed Permits (Old)

## Watershed Permit 1: 2014 – 2019

- Effluent Monitoring
- Analysis of Loading Trends via Group Annual Report
- Support for Scientific Studies ($880 k/year)
- Treatment Optimization and Upgrade Studies

## Watershed Permit 2: 2019 – 2024

- <u>Influent and</u> Effluent Monitoring
- Analysis of Loading Trends via Group Annual Report
- <u>Increased</u> Support for Scientific Studies $2.2 M/year
- <u>Load Reduction via Recycled Water and Nature Based Solutions</u> Studies

Source: Bay Area Clean Water Agencies

# Nutrient Watershed Permit (New)

**Watershed Permit 3: 2024 – 2029**

**Influent and Effluent Monitoring**

**Interim and Final Limits**

**Annual Reports on actions to meet final limits**

**<u>Continued</u> Support for Scientific Studies**

**Regional Planning and Multi-Benefit Solutions**

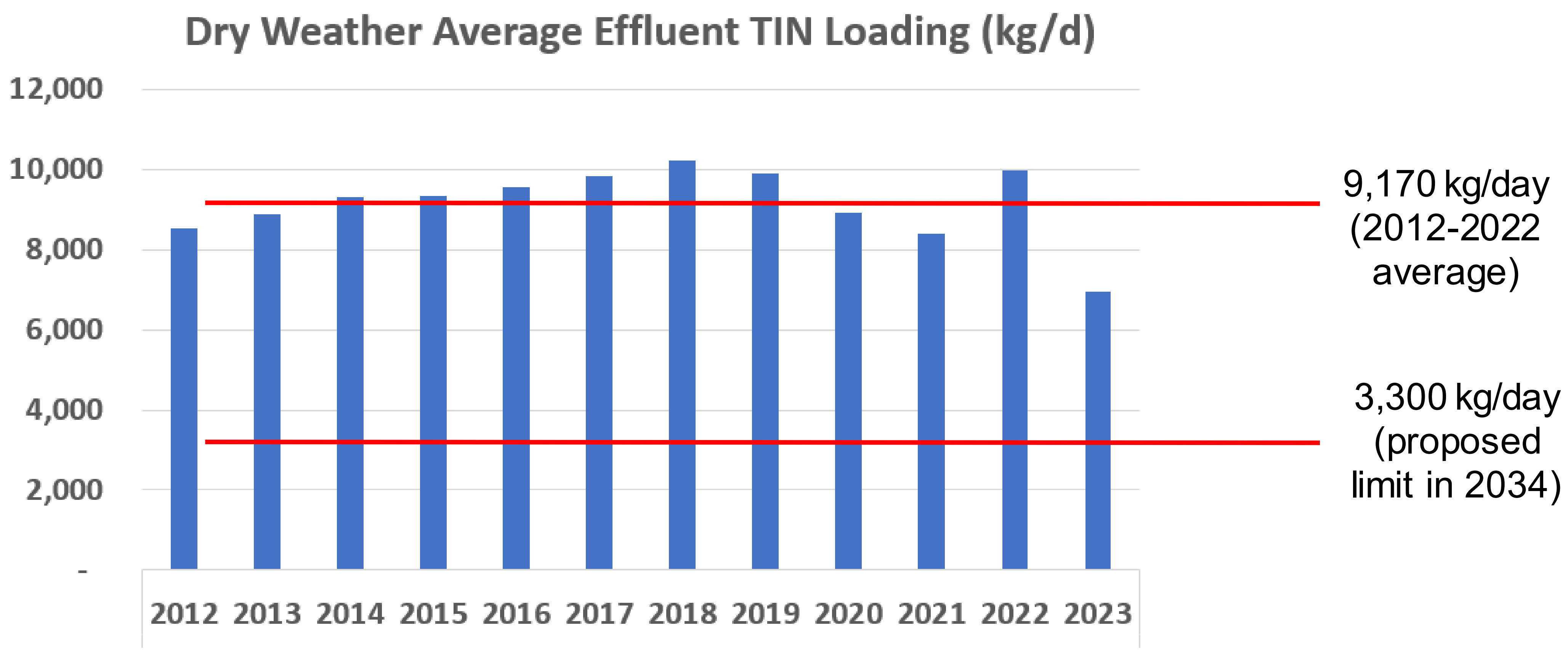
Source: Bay Area Clean Water Agencies

# Nutrient Limits for EBMUD

- Interim Effluent Limit of 11,000 kg/day Total Inorganic Nitrogen (TIN)
  - From permit adoption to September 30, 2034
- Final Effluent Limit of 3,300 kg/day TIN (65% reduction from 2022)
  - Beginning October 1, 2034
- Effluent Limits averages between May 1 and September 30
- Annual reporting

Total Inorganic Nitrogen (TIN) = ammonia + nitrate + nitrite

# EBMUD Nutrient Discharge 2012-2023




*Note: 2023 values reflect nutrient reduction pilot efforts*

# RWQCB Responses to Comments

- Reasonable potential exists which mandates numeric limits (recent HAB events)
- Science progress sufficient to establish direct correlations (nutrient loads to low DO in SF Bay)
- Agreed that District qualifies as an “Early Actor”
- Acknowledged high cost of nutrient removal
- Agreed that compliance time not adequate
    - Adopted a new resolution for developing an alternative compliance pathway

HAB: harmful algal bloom, DO: dissolved oxygen, RWQCB: Regional Water Quality Control Board

# Update on EBMUD Nutrient Reduction Strategy

- Biological Nutrient Reduction (BNR) pilot project began in 2020
- 65% TIN reduction achieved in the pilot study in 2023
- Expansion of the pilot to full-scale BNR in 2025 and 2026
- 3,300 kg/day TIN limit in 2034 – need full capacity of BNR system
- Alternative analyses for redundancy and growth will be identified by 2026

# Potential New Improvements for BNR

- Addition of two new reactor decks
- A new oxygenation unit
- Electrical infrastructure for new process equipment
- Addition of a new sidestream treatment

# Next Steps for Nutrient Reduction

- Rehabilitate or upgrade equipment and infrastructure (reactor decks, pumps, mixers, electrical infrastructure, etc.)
- Identify and evaluate additional sidestream nutrient reduction alternatives
- Continue involvement with the Nutrients Science Program and other regional efforts
- Addition of two new reactor decks for redundancy and future growth

# Key Takeaways

- EBMUD can meet interim and final numeric limits
- Full BNR conversion testing will be completed in 2026
- Potential need to
  - Rehabilitate/rebuild secondary treatment area
  - Add capacity: two new reactor decks, sidestream treatment, new O2 unit etc.

O2: oxygen

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# Infrastructure Workshop

Board of Directors

November 26, 2024

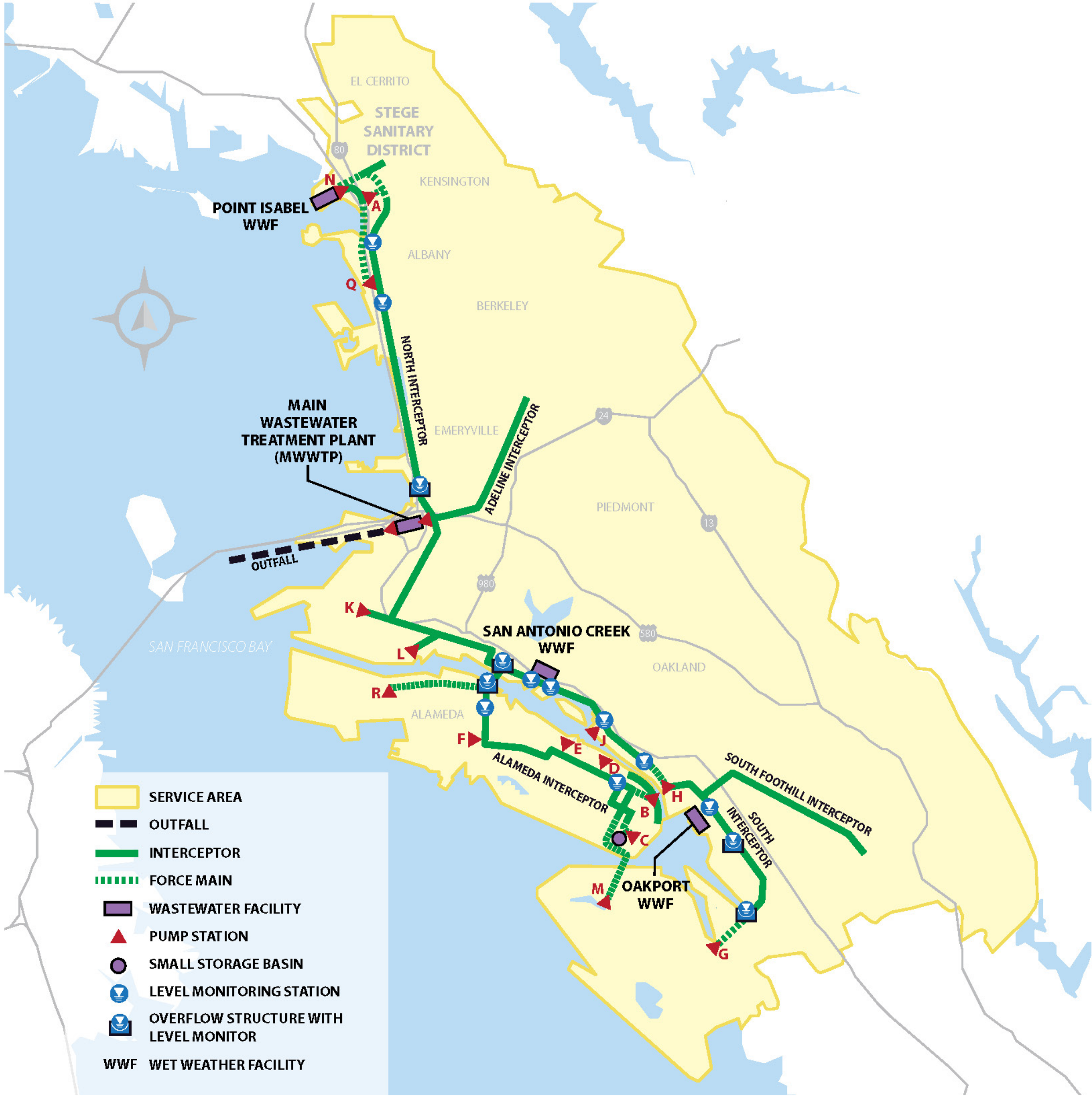
# Wastewater System Infrastructure Summary

## Interceptor System

- 37 miles of interceptors and force mains
- 15 pump stations

## Treatment Facilities

- 1 Main Wastewater Treatment Plant
- 3 Wet Weather Facilities



# Main Wastewater Treatment Plant Facilities


## Key Takeaways

1 Most MWWTP and Interceptor facilities were built 50 – 70 years ago.

2 The MWWTP has an ongoing need for aging infrastructure renewal in a challenging, corrosive environment.

50

# Wastewater Challenges

**Obsolescence**

**Corrosion**

**Increasing Frequency of Failures**

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# Wastewater Infrastructure Renewal

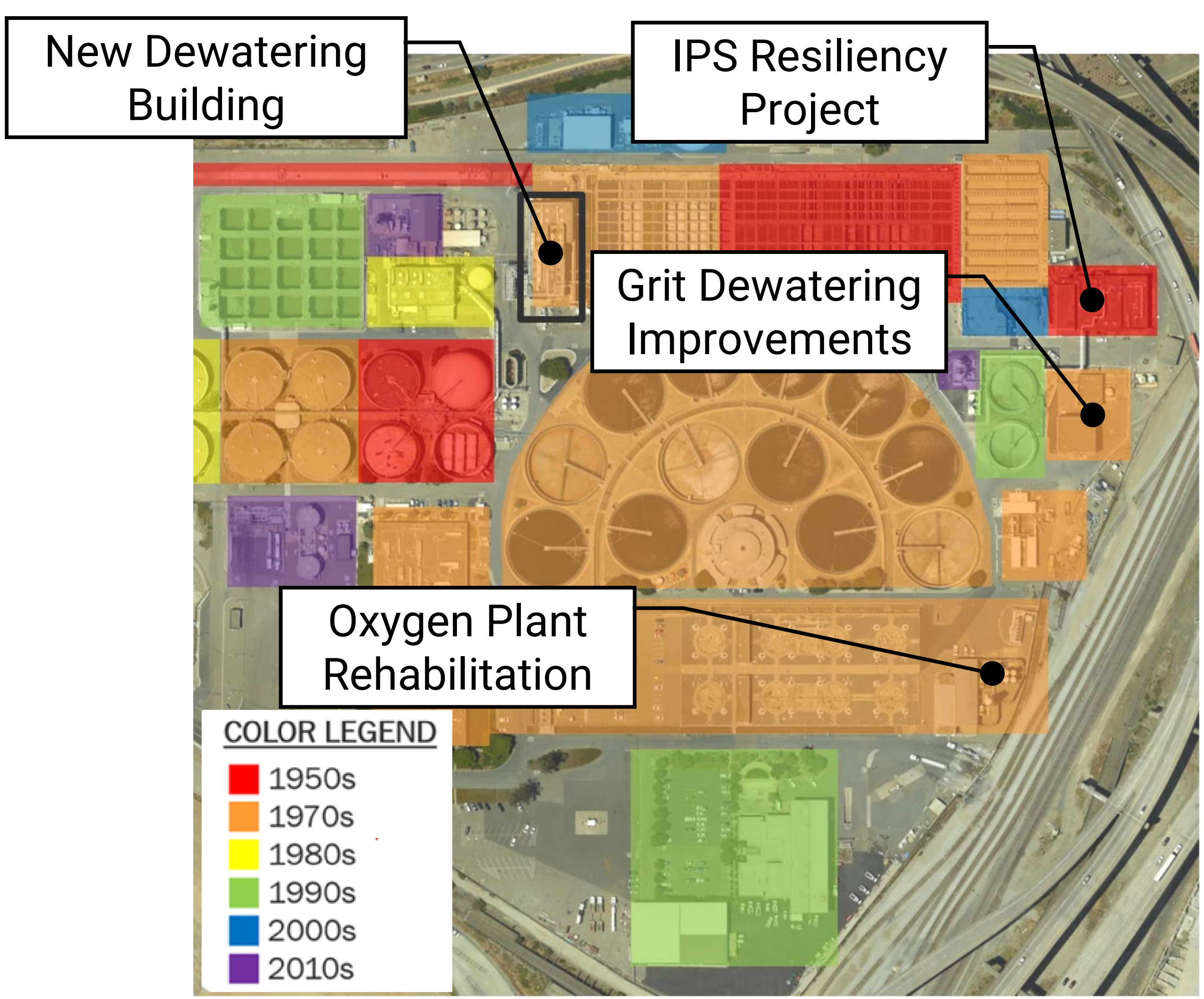
## Interceptors

## Clarifiers


## Dechlorination


## Nutrients

# Near Term Critical Projects




# Influent Pump Station (IPS) Resiliency Project

**Why is this project critical?**

- IPS is the most critical process facility at the MWWTP.
- Vulnerable to complete failure due to an earthquake.
- Critical equipment is obsolete and failing at an increasing rate.
- Approved for FEMA grant covering **$28M** in seismic retrofit costs

- **Scope:**
  - Seismic retrofit of structure, anchorage of equipment
  - Replacement of obsolete equipment with modern
- **Drivers:**
  - Aging Infrastructure
  - Maintenance and Reliability
  - Resiliency
  - Safety
- **Schedule:**
  - Design: Complete FY 2026
  - Construction: FY 2027 to FY 2031

**Obsolete Equipment**

**Seismic Vulnerabilities**

**Increasingly Difficult to Maintain**

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# New Dewatering Building Project

## Why is this project critical?

- 7000+ labor hours of unplanned, corrective maintenance on dewatering equipment each year, and trending up
- Obsolete equipment requires custom replacement parts
- Building configuration limits performance—leading to 10-15% higher biosolids handling costs
- Building is vulnerable to an earthquake

- **Scope:**
  - Completely new dewatering building
- **Drivers:**
  - Aging Infrastructure
  - Maintenance and Reliability
  - Resiliency
  - Safety
- **Schedule:**
  - Design: Complete FY 2028
  - Construction: FY 2028 to FY 2031

Failing Pipes

Failing Equipment

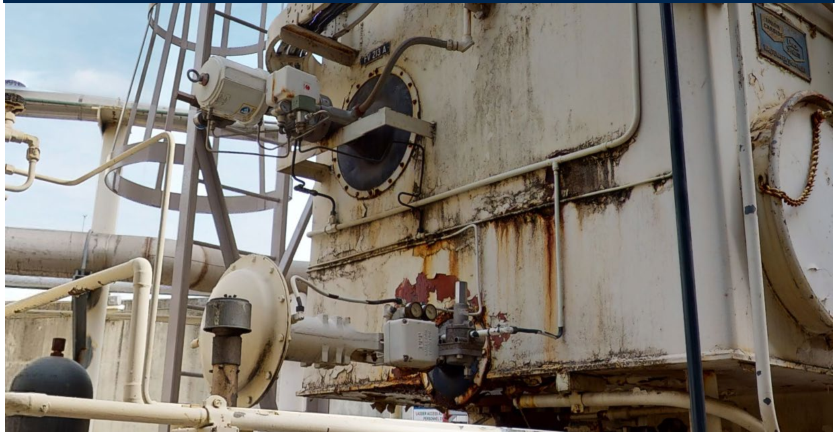

High Maintenance

# Oxygen Plant Rehabilitation

## Why is this project critical?

- Oxygen production is essential to the core biological treatment process; regulatory violations can result from controls failures
- Modernizing equipment will ensure reliable and efficient operation
- Safety improvements included to protect workers
- Nutrient removal requires more oxygen

- **Scope:**
  - Replace obsolete analog equipment with modern digital controls
  - Rehabilitate corroded piping and equipment
- **Drivers:**
  - Aging Infrastructure
  - Regulations
  - Maintenance and Reliability
  - Safety
- **Schedule:**
  - Design: Complete
  - Construction: FY 2025 to FY 2029


Corroded equipment


Failing/Leaking Pipes


Obsolete Equipment

# North Interceptor Rehabilitation Emeryville

**Why is this project critical?**

- Worst condition segment of pipe in the entire Interceptor System
- Location is on the shoulder of I-80 interstate in Emeryville; failure/sinkhole would have major impacts to traffic
- Harsh, corrosive conditions mean condition is degrading

- **Scope:**
  - Rehabilitate large diameter concrete pipe with cured-in-place liner
  - Rehabilitate five large maintenance hole structures
  - Bypass pumping at high traffic highway interchange (Powell Street)
- **Drivers:**
  - Aging Infrastructure
  - Maintenance and Reliability
- **Schedule:**
  - Design: Complete in FY 2025
  - Construction: FY 2025 to FY 2029

**Corroded Concrete Pipe**

**Corroded Maintenance Hole**

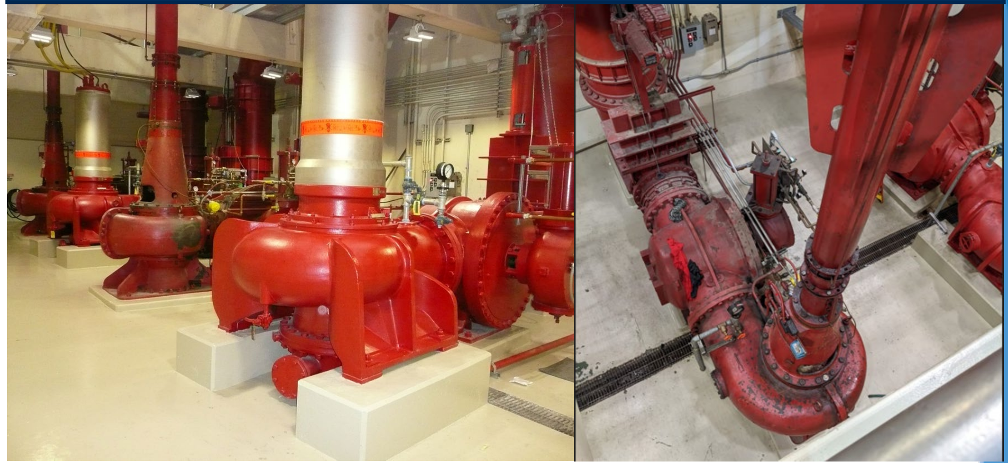
# Pump Station H Improvements Project Phase 2

**Why is this project critical?**

- Largest pump station in the Interceptor System located in East Oakland near High Street and Oakport, pumping 10-20% of system flows
- Lack of redundancy means failures can have outsized impacts
- Obsolete pumps and motors prone to failure

- **Scope:**
  - Rehabilitate degraded, repaired piping and concrete
  - Replace two pumps and motors
  - Construct new bypass connections to improve redundancy
- **Drivers:**
  - Aging Infrastructure
  - Maintenance and Reliability
- **Schedule:**
  - Design: Complete
  - Construction: FY 2025 to FY 2027

**Obsolete Pumps & Motors**



**Failed piping**

**Corroded concrete**

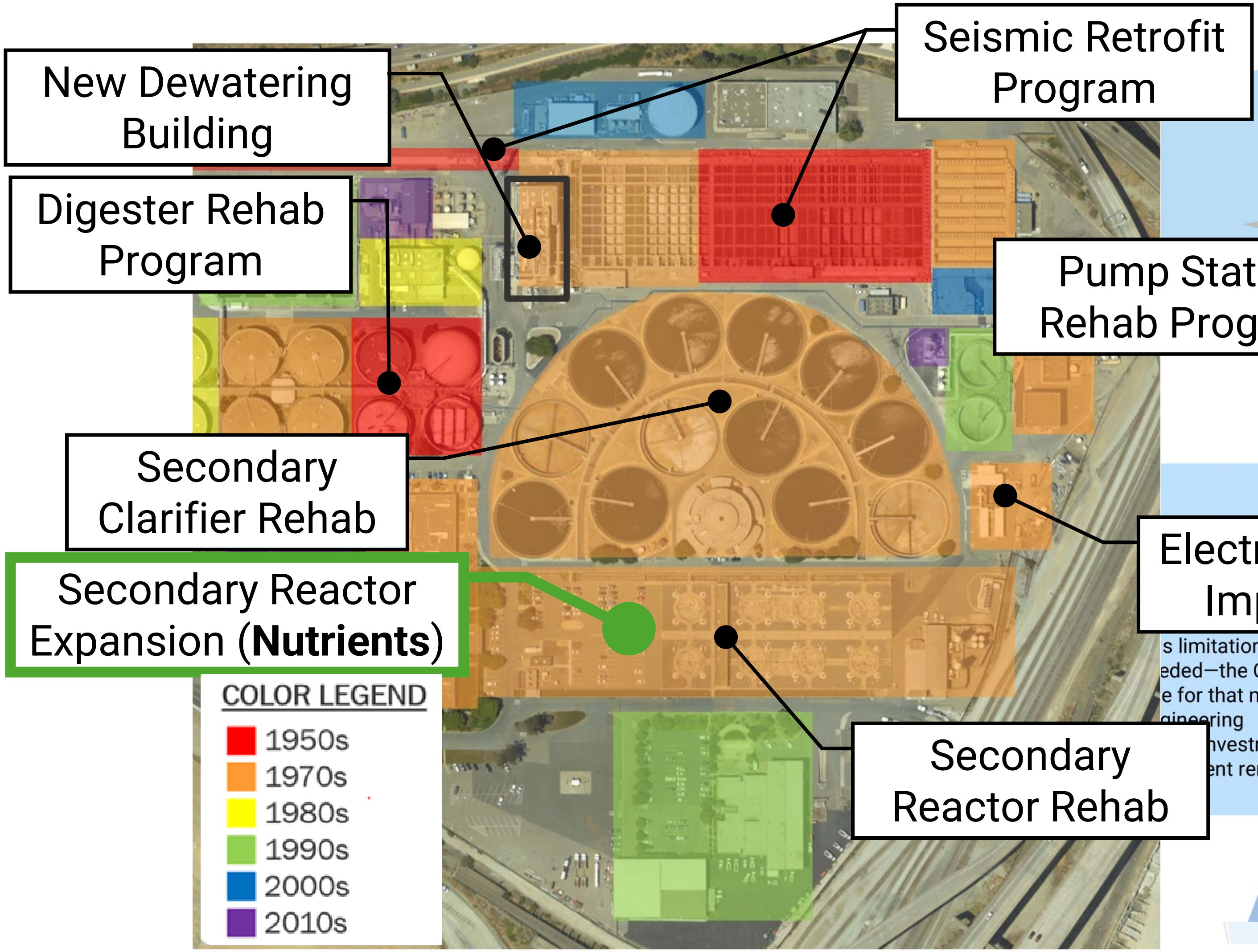
# Grit Dewatering Improvements Project

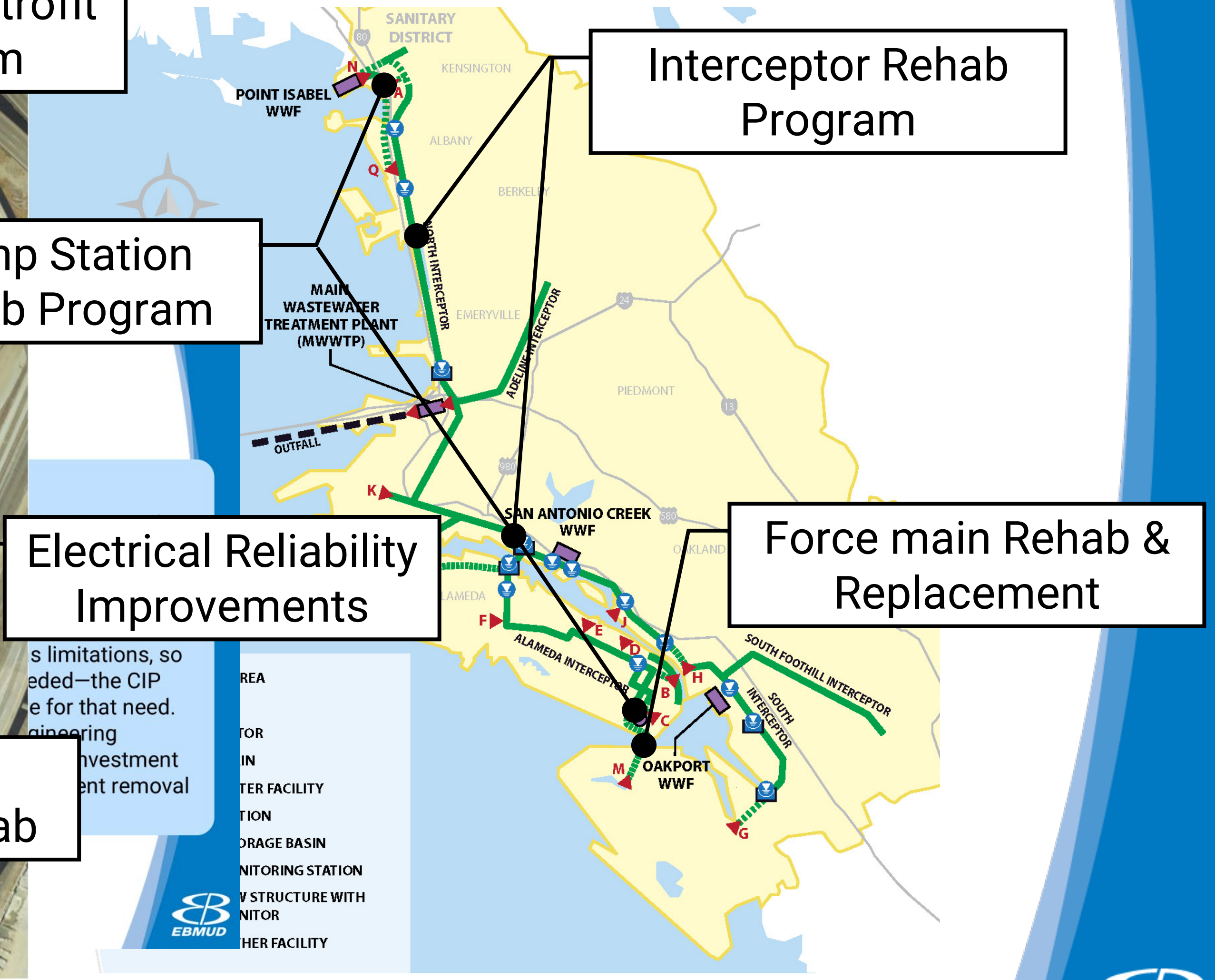
**Why is this project critical?**

- Process facility that, if not operating properly, can disrupt operations during most critical peak wet weather events
- Increasing failures due to harsh conditions and age of equipment
- Install equipment to improve worker safety and efficiency

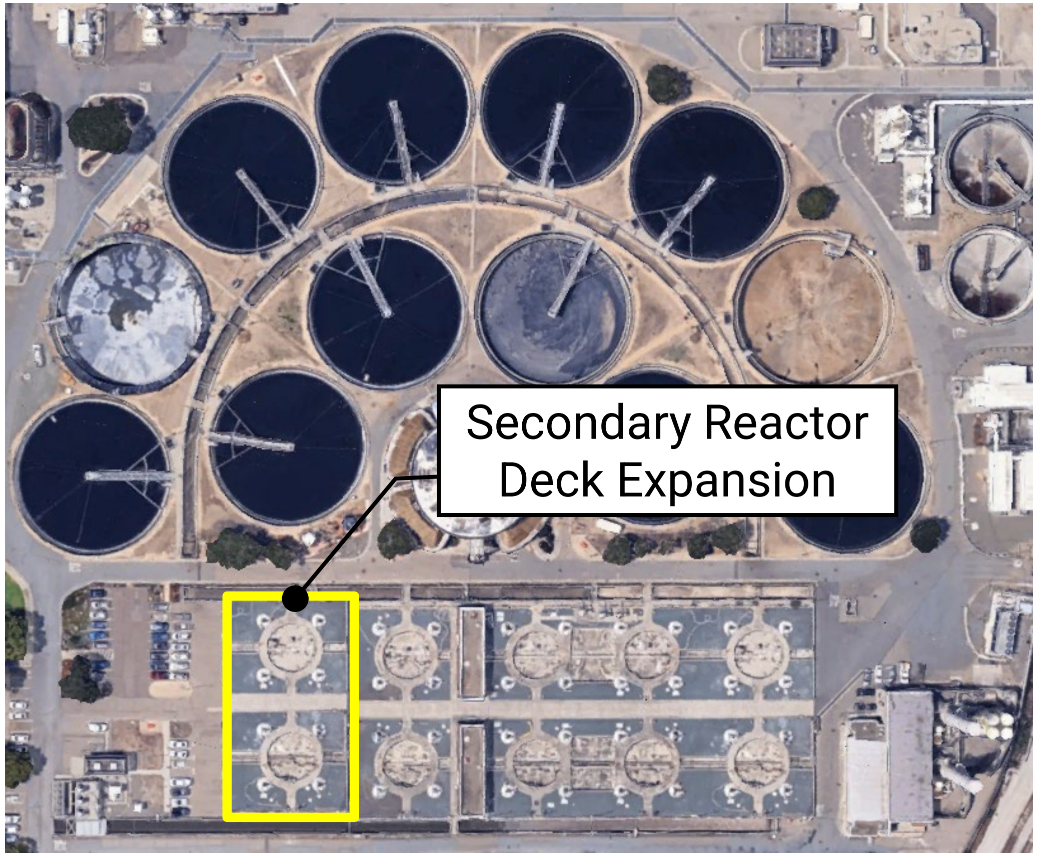

- **Scope:**
  - Replace grit dewatering equipment
  - Rehabilitate grit hopper and install new mobile grit bin equipment
  - Rehabilitate drainage systems
- **Drivers:**
  - Aging Infrastructure
  - Maintenance and Reliability
- **Schedule:**
  - Design: Complete
  - Construction: FY 2025 to FY 2027


# Future Projects Affecting Capital Budget



# Spending Uncertainty: Nutrients




## Key Takeaways

1. New nutrient regulations are a Bay Area region-wide issue—out of the District's control.
2. Innovative testing of nutrient-removal using existing infrastructure will avoid a multi-billion dollar project.
3. However, some capital investment may be needed—the CIP has a $200M project to prepare for that need.
4. Our next step is a thorough engineering evaluation of the complete capital investment solution to comply with future nutrient removal requirements

# Smart Spending Through Innovation