BACWA Annual Meeting: Nutrient Reduction by Optimization and Upgrades Update

19 January 2018

HDR

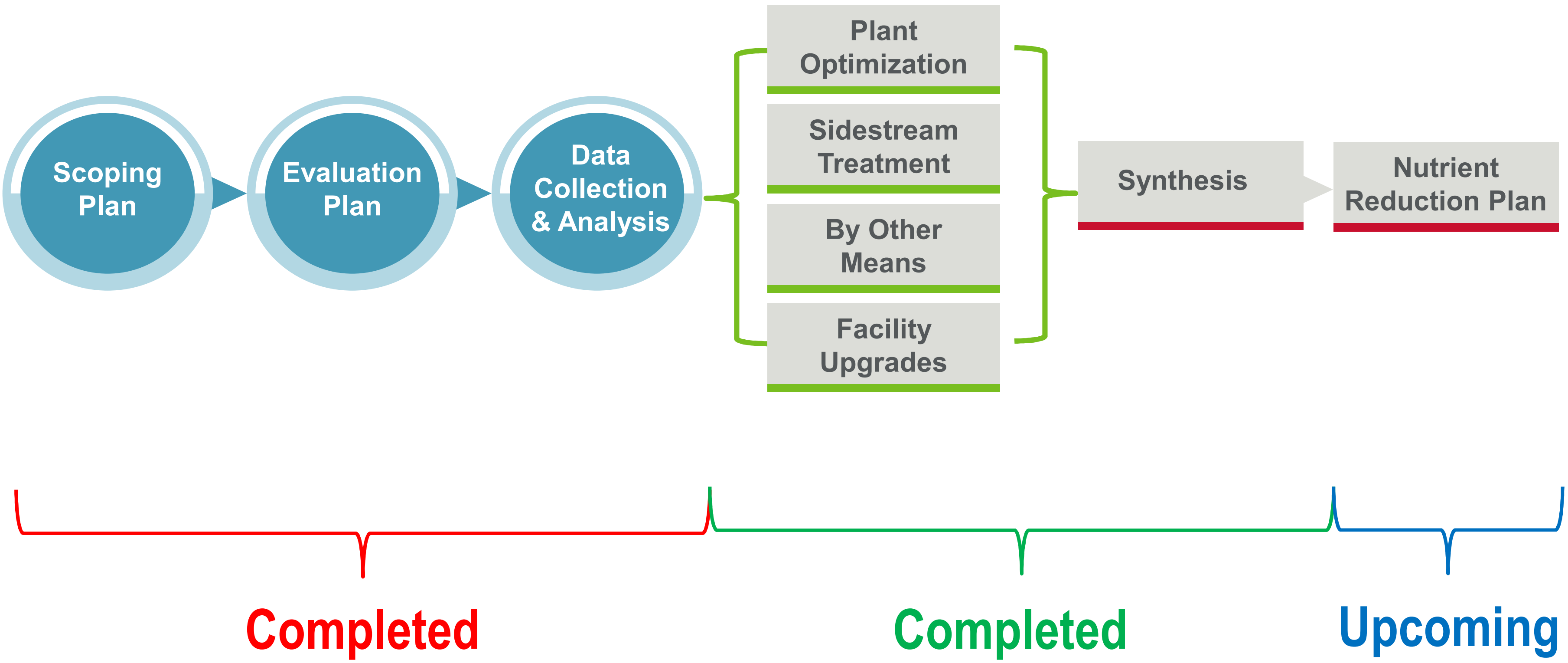
Brown AND Caldwell

BACWA BAY AREA CLEAN WATER AGENCIES

Agenda

1. Project Status
2. Group Annual Report Findings
3. Draft Findings of Nutrient Removal Reports
4. Key Insights
5. Results of Recycled Water/CIP Surveys
6. Sea Level Rise
7. Next Steps

Overview / Status of Study



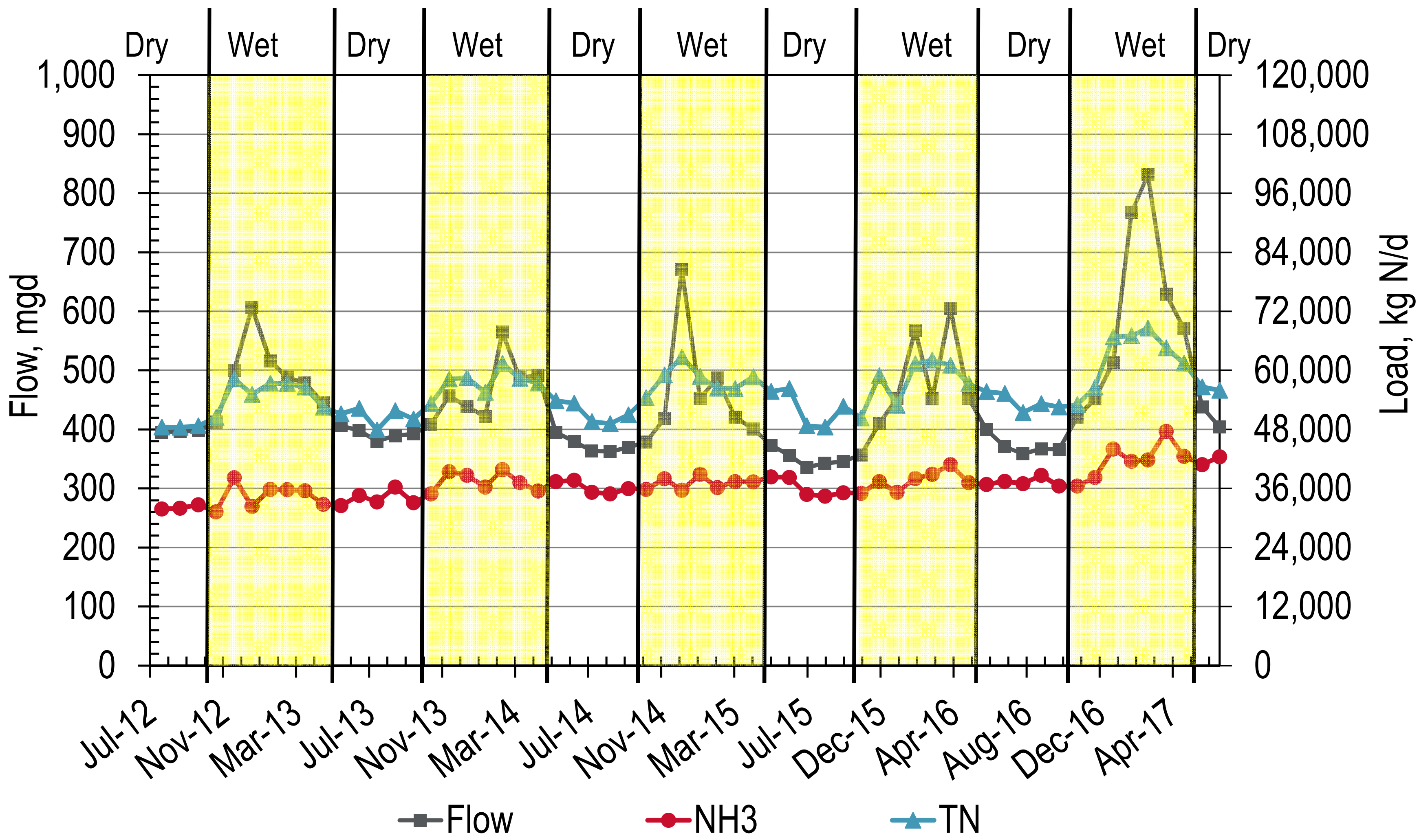
2017 Group Annual Report Findings

2017 Group Annual Report Summary

- 2016/2017 dry weather flows increased to pre-drought levels
- Annual average flows were the highest since sampling began in July 2012
- Ammonia, TN, and TP loads were the highest since sampling began in July 2012

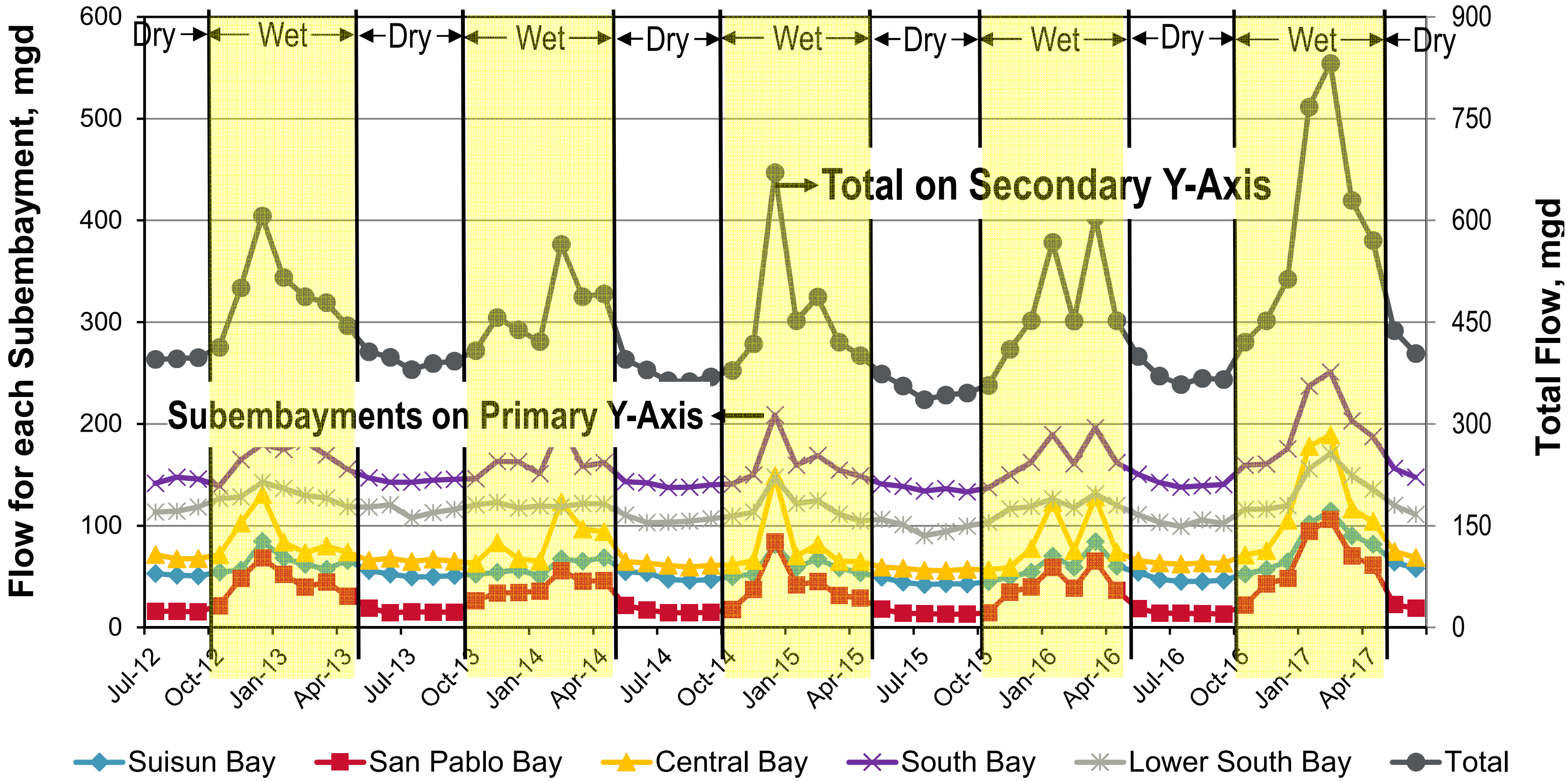
  (for both dry and average annual)

Nitrogen Loads Track with Flow



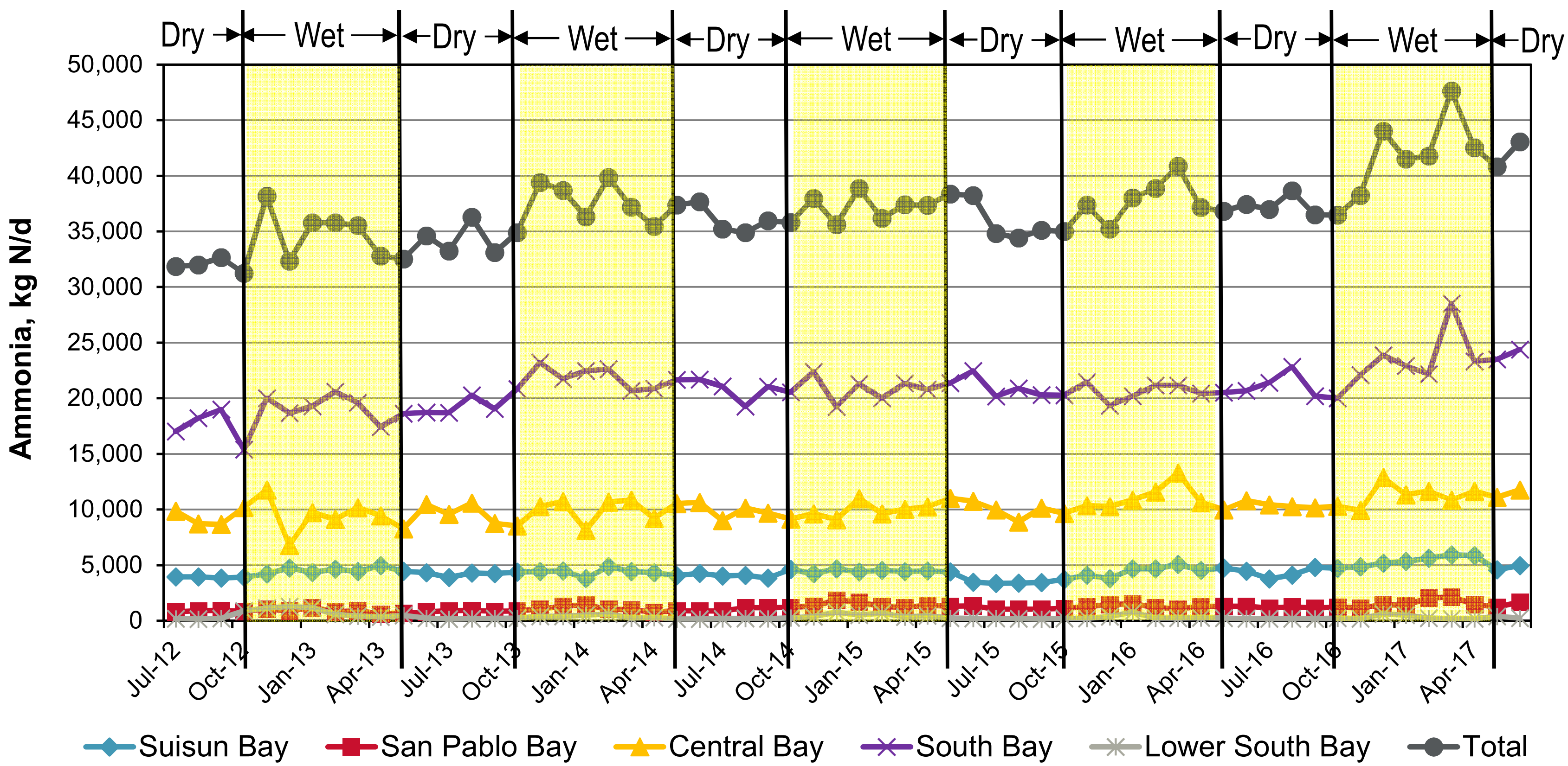
2017 Group Annual Report: Flow

- Total average annual flow for 2016-17 was the highest since 2012 at <u>510 mgd</u> (peak at 840 mgd)
- Increase in average annual flows is primarily due to wet season influence, though dry season flows also increased to 2013-14 levels



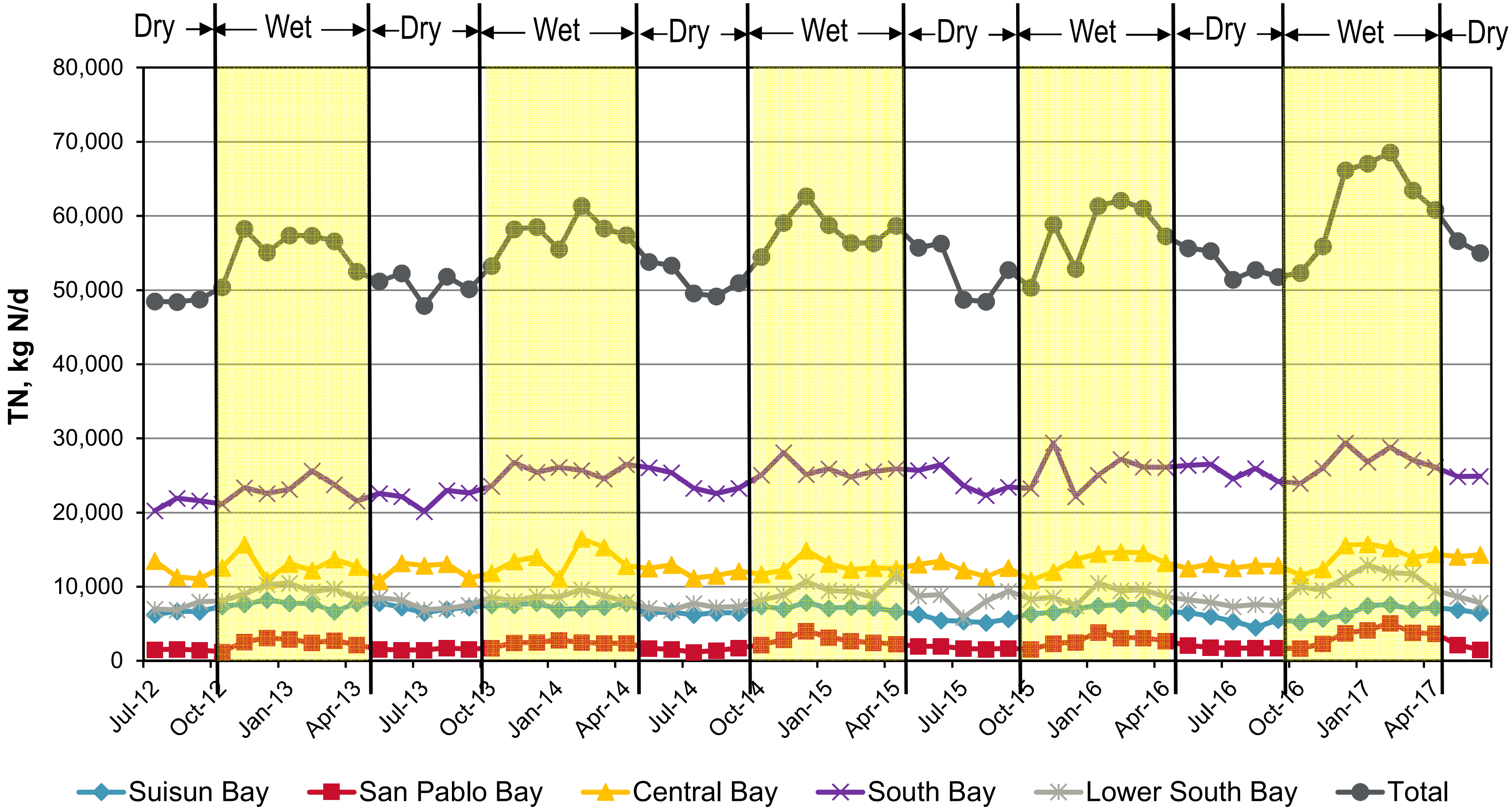
2017 Group Annual Report: Ammonia

- Dry season ammonia load is increasing in all Subembayments except Lower South Bay and Suisun Bay
- Total average annual ammonia load for 2016-17 was the highest since 2012 at 40,700 kg N/d



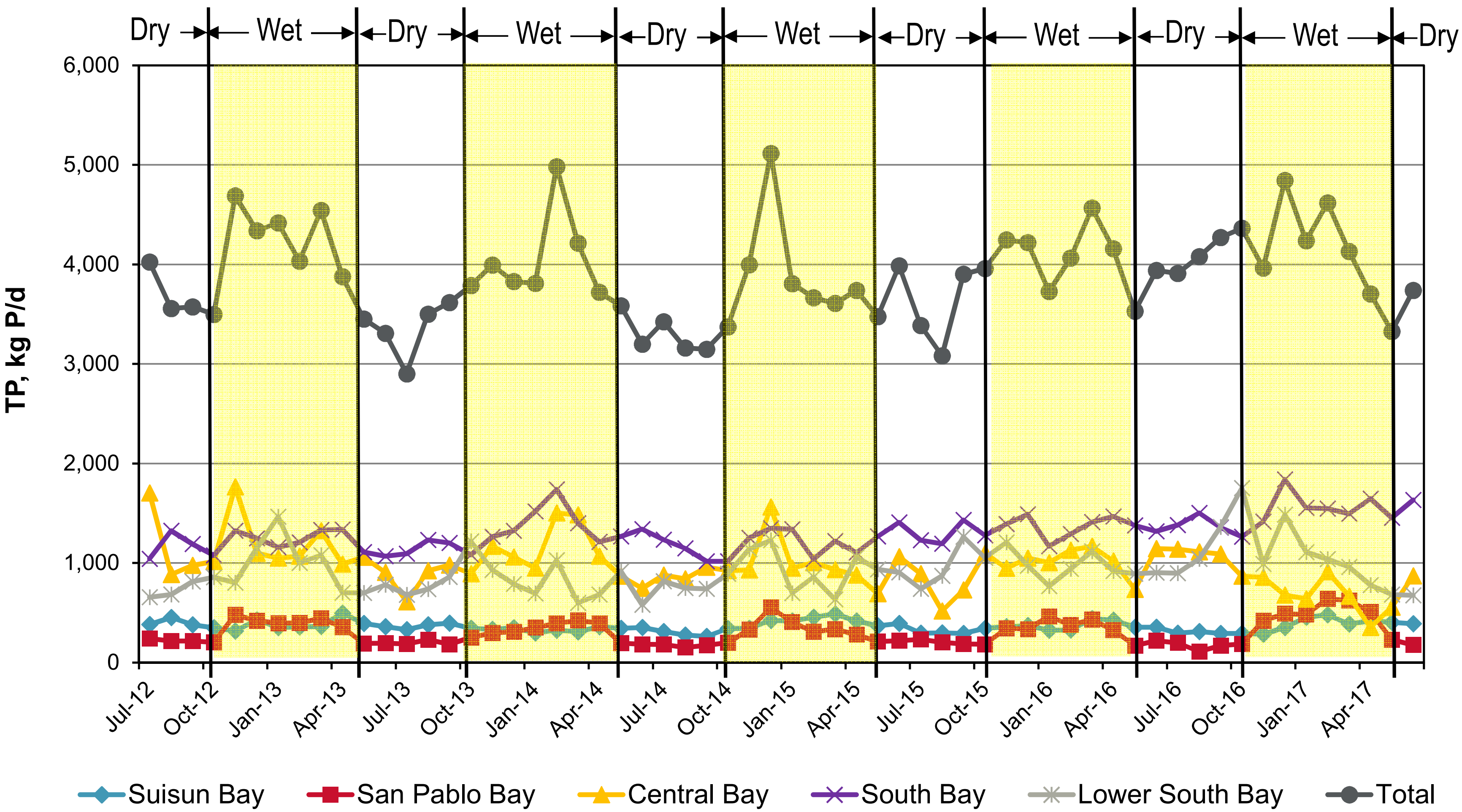
2017 Group Annual Report: Total Nitrogen

- Both dry and annual average TN loads are increasing
- Dry season TN load is increasing in all Subembayments except Suisun Bay (decreasing) and Lower South Bay (no trend)



2017 Group Annual Report : Total Phosphorus

- Both dry and annual average TP loads are increasing
- Dry season TP load is increasing in all Subembayments except Central Bay



2017 Group Annual Report Summary (Rounded Values)

Dry Season Average

Parameter	Units	2012/2013	2013/2014	2014/2015	2015/2016	2016/2017
Total Flow	mgd	399	387	365	359	387
Total Ammonia	kg N/d	32,700	35,500	36,600	35,700	39,100
Total TN	kg N/d	49,900	51,500	52,500	52,200	53,700
Total TP	kg P/d	3,600	3,400	3,400	3,700	3,900

Annual Average

Parameter	Units	2012/2013	2013/2014	2014/2015	2015/2016	2016/2017
Total Flow	mgd	453	434	421	425	510
Total Ammonia	kg N/d	33,800	36,600	36,900	36,800	40,700
Total TN	kg N/d	53,100	55,000	55,800	55,400	58,900
Total TP	kg P/d	4,000	3,800	3,700	3,900	4,100

The increase in 2016/2017 flows and loads is likely due to a combination of i) population increase, ii) a wetter than average rain year, iii) suppressed drought concerns, iv) industrial impacts (resource recovery with organics receiving), and v) others

Load Reduction Across the Plants (Rounded; Limited to 2012-2014 data)

Dry Season Average

Parameter	Units	Influent, 7/2012 – 6/2014	Discharge, 7/2012 – 6/2014	Load Reduction Across the Plant
Total Flow	mgd	419	393	6%
Total Ammonia	kg N/d	53,800	34,100	37%
Total TN	kg N/d	82,000	50,700	38%
Total TP	kg P/d	11,000	3,500	68%

Annual Average

Parameter	Units	Influent, 7/2012 – 6/2014	Discharge, 7/2012 – 6/2014	Load Reduction Across the Plant
Total Flow	mgd	482	444	8%
Total Ammonia	kg N/d	55,000	35,200	36%
Total TN	kg N/d	84,700	54,000	36%
Total TP	kg P/d	11,300	3,900	66%

The Plants Currently Reduce Approximately 1/3 of the Ammonia/Nitrogen and 2/3 of the Phosphorus Loads

Draft Findings of Nutrient Removal Reports

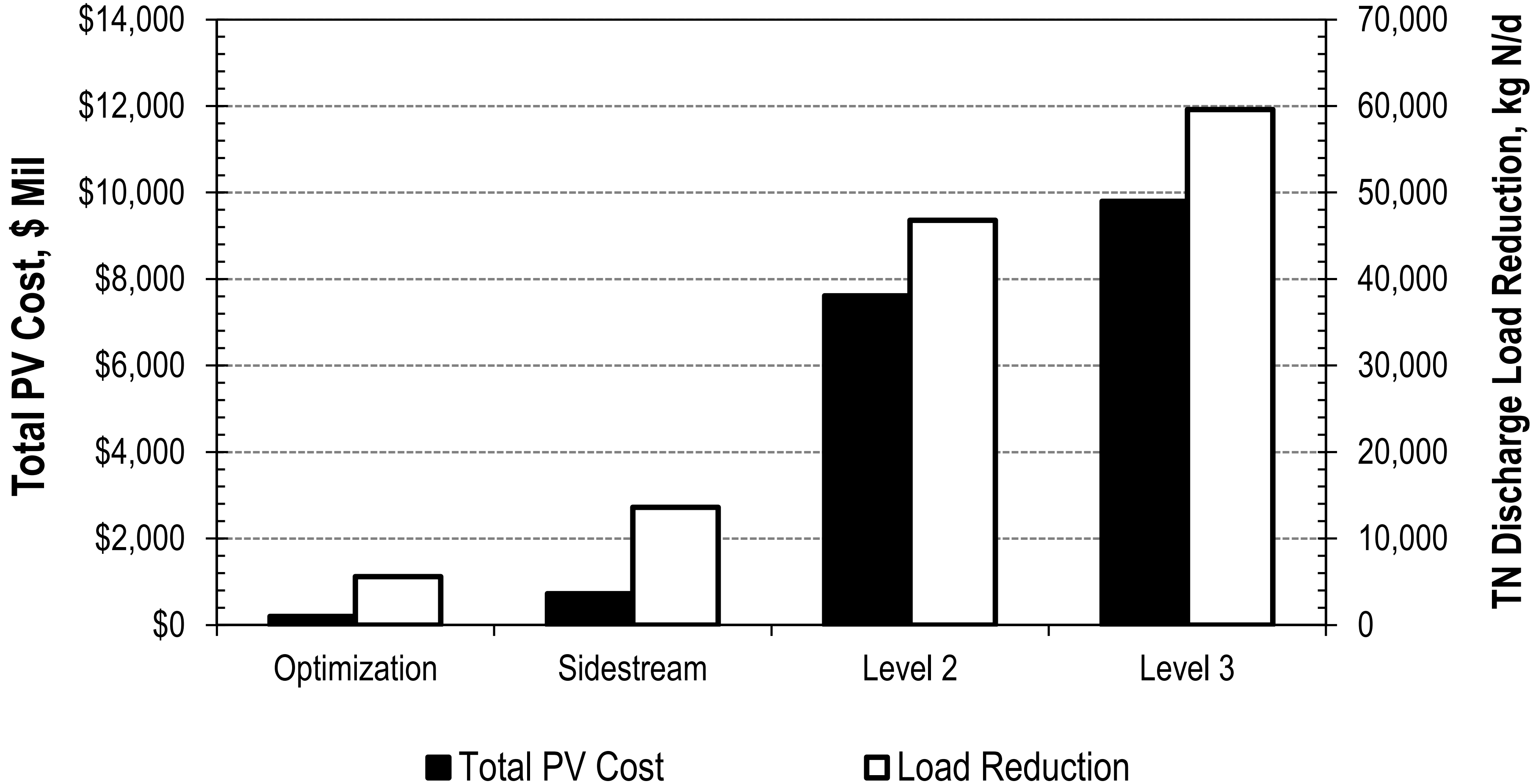
Updated Costs

Treatment Levels

Level	Study	Ammonia	TN	TP
Level 1 *	Optimization	--	--	--
Level 2 *	Upgrades	2 mg N/L	15 mg N/L	1.0 mg P/L
Level 3 *	Upgrades	2 mg N/L	6 mg N/L	0.3 mg P/L

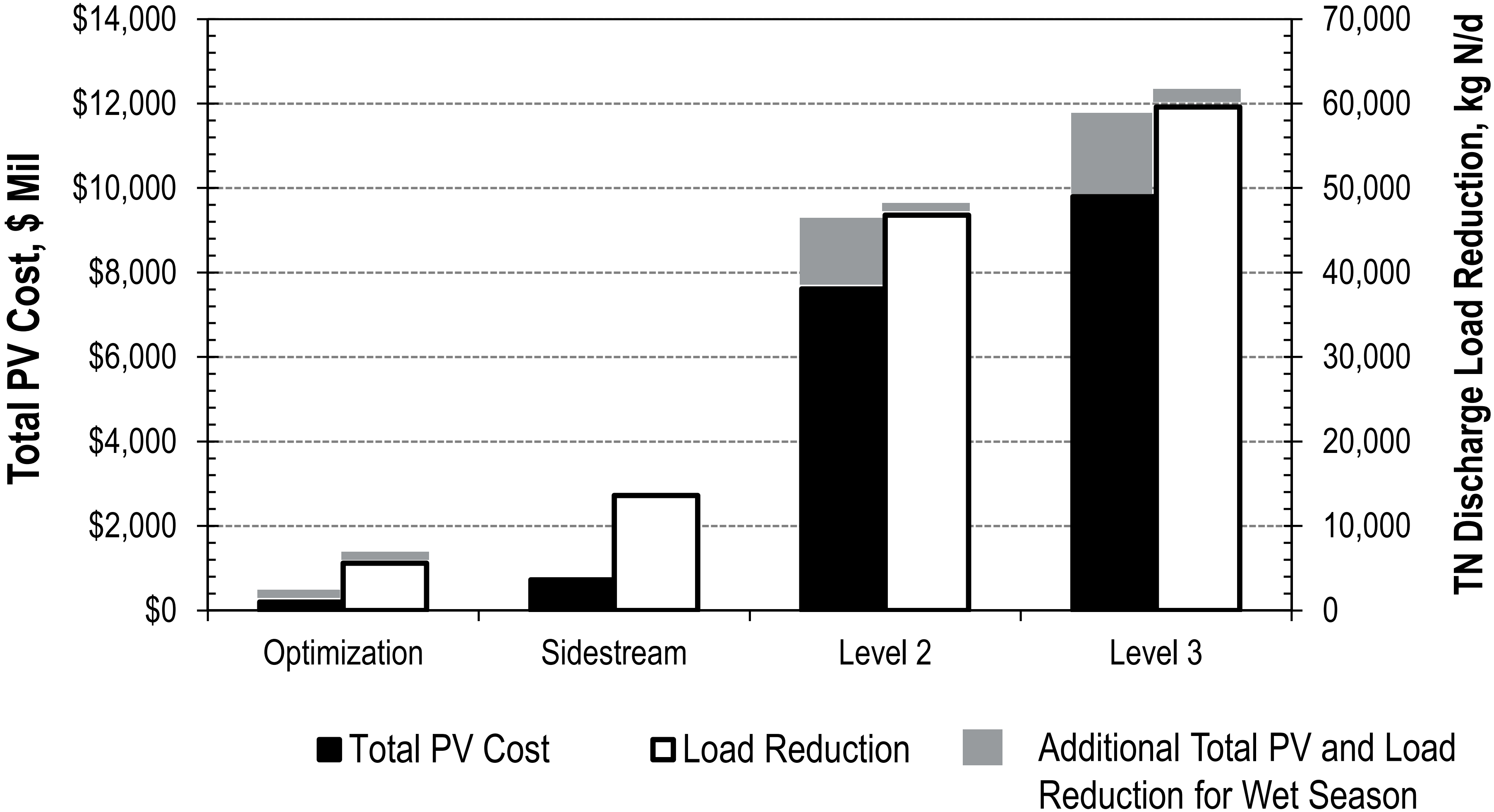
* The seasonal impacts will be considered for all three treatment levels:
- Dry Season = Sized for loads from May 1 to September 30 **but operate nutrient load reduction year round**
- Year Round = Sized for year round loading

DRAFT: Total N Discharge Load Reduction and Costs under Various Scenarios (Dry Season Permit)



- Optimization = 10-yr planning horizon
- Sidestream and Upgrades (Level 2 and 3) = 30-yr planning horizon using Permitted Capacity

DRAFT: Total N Discharge Load Reduction and Costs under Various Scenarios (Year Round Permit)



- Optimization = 10-yr planning horizon
- Sidestream and Upgrades (Level 2 and 3) = 30-yr planning horizon using Permitted Capacity

Preliminary Optimization Results

DRAFT Optimization Findings

Which nutrients are easiest to remove?

- Ammonia load reduction is most difficult
  - Increasing SRT for plants with act sludge
  - Operating Trickling Filter as a Nitrifying Trickling filter
- TN load reduction is possible if ammonia removal implemented
- TP load is easier to remove
  - Most plants already have metal salt chemical feed facilities
  - Some have anaerobic zones
  - Lose TP removal capability by forfeiting anaerobic zone

Costs

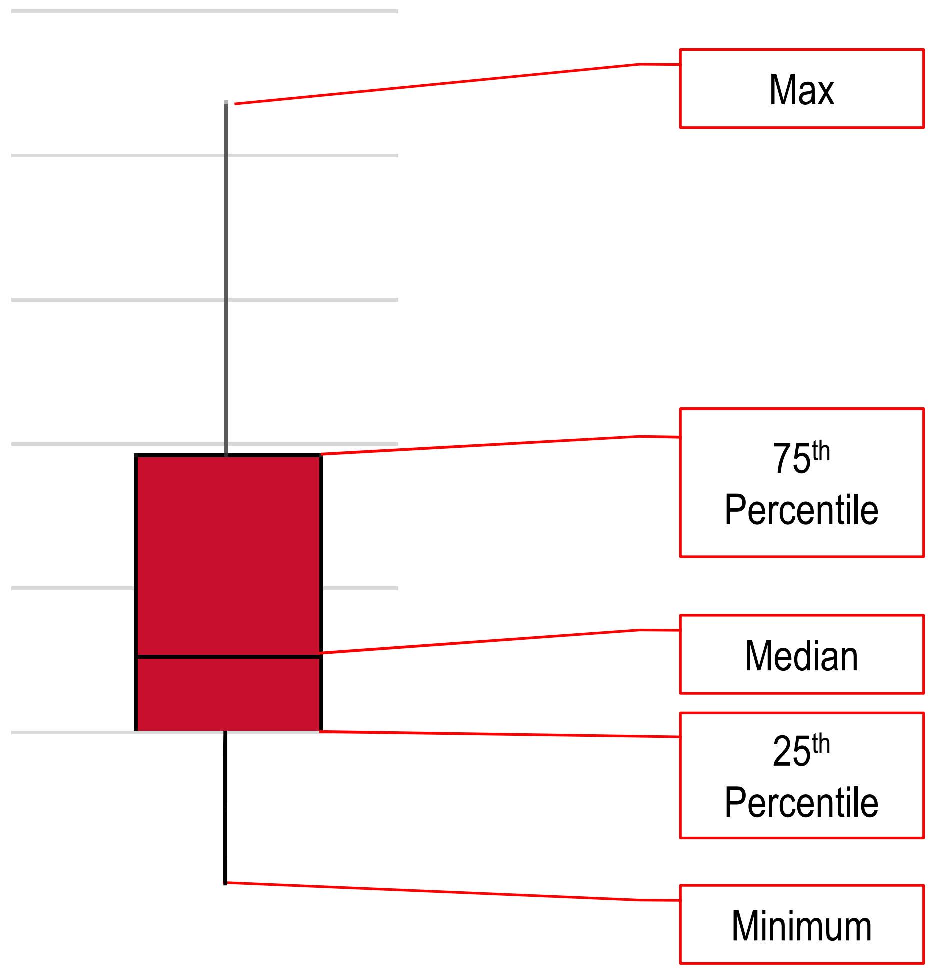
- Total PV
  - $180M Dry Permit and $200M Year-Round Permit
  - Ranged from $0.2M to $34M per plant
- Unit Costs
  - Flow-weighted Total PV unit cost = ~$0.3/gpd
  - Total PV/lb N rem = ~$3/lb N
  - Total PV/lb P rem = ~$7/lb P
- Not all plants can reduce ammonia/TN loads for both dry and year-round permits:
  - 21 of 37 plants for dry permit reduction
  - 19 of 37 plants for year-round reduction

Load Reduction w/Respect to Current Discharge:

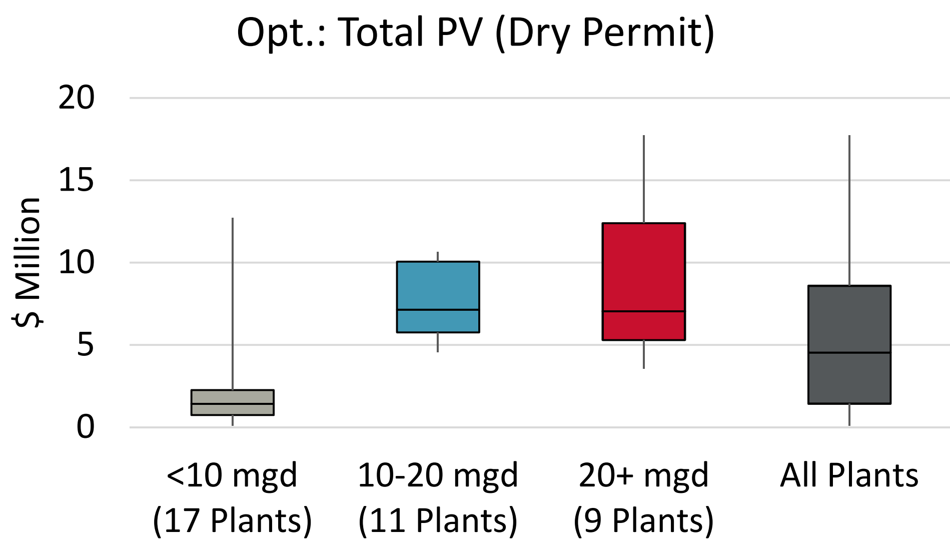
- Ammonia load reduction is 14%
- TN load reduction is 7%
- Overall TP load reduction is 44%

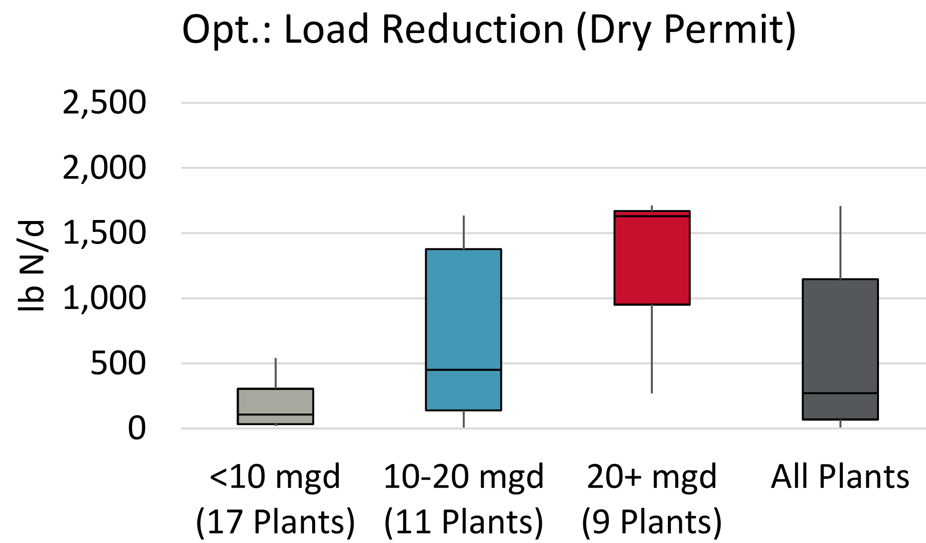
Box and Whisker Plots

- Used to Illustrate Data Distribution, Central Value, and Variability
- Box:
  - Median is horizontal line inside box
  - Box ends represent upper and lower quartiles (25^{th} and 75^{th} percentiles)
- Lines represent max and min values

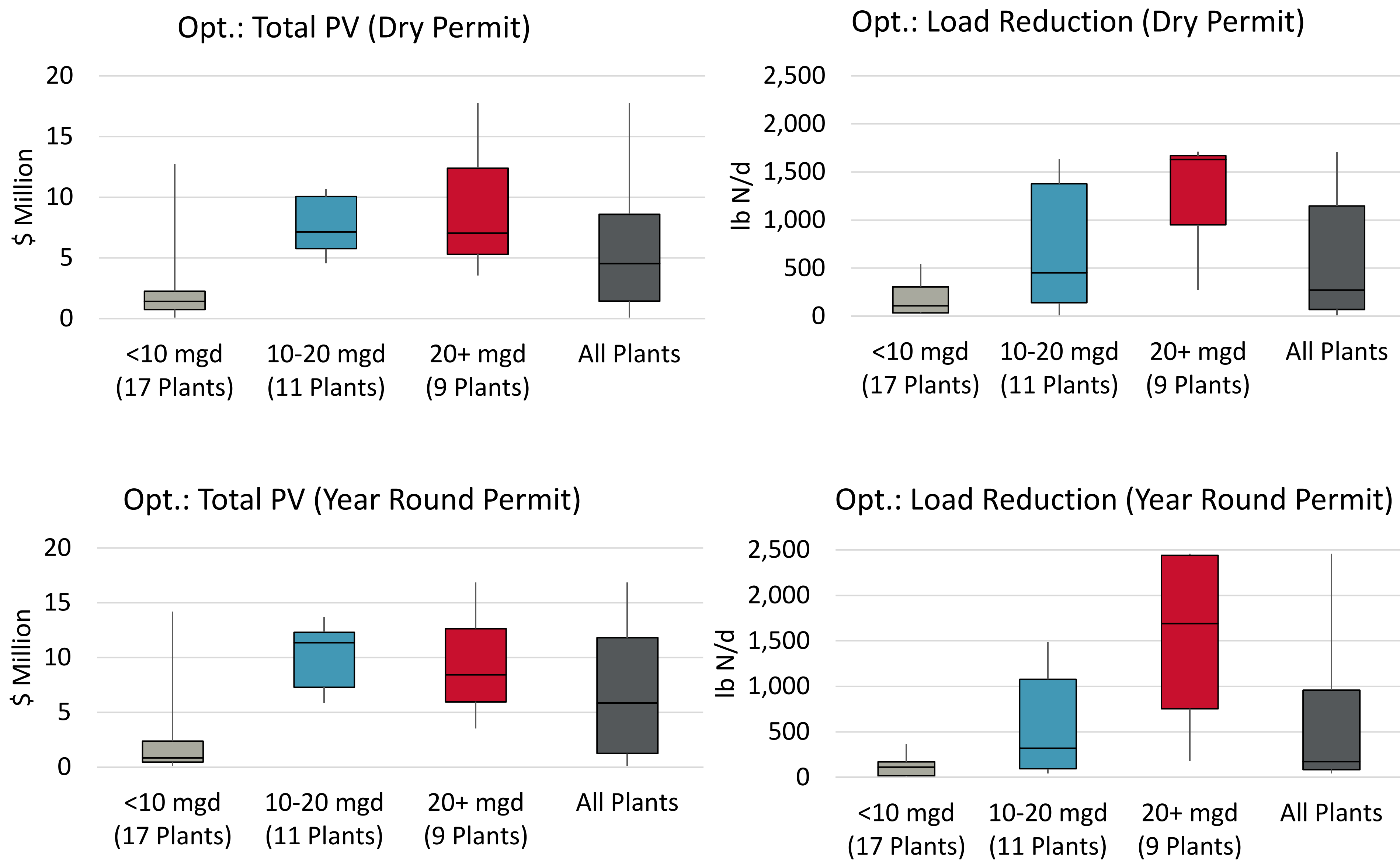


Optimization Total PV Costs and Load Reduction





Optimization Total PV Costs and Load Reduction



Preliminary Sidestream Results

Sidestream Approach

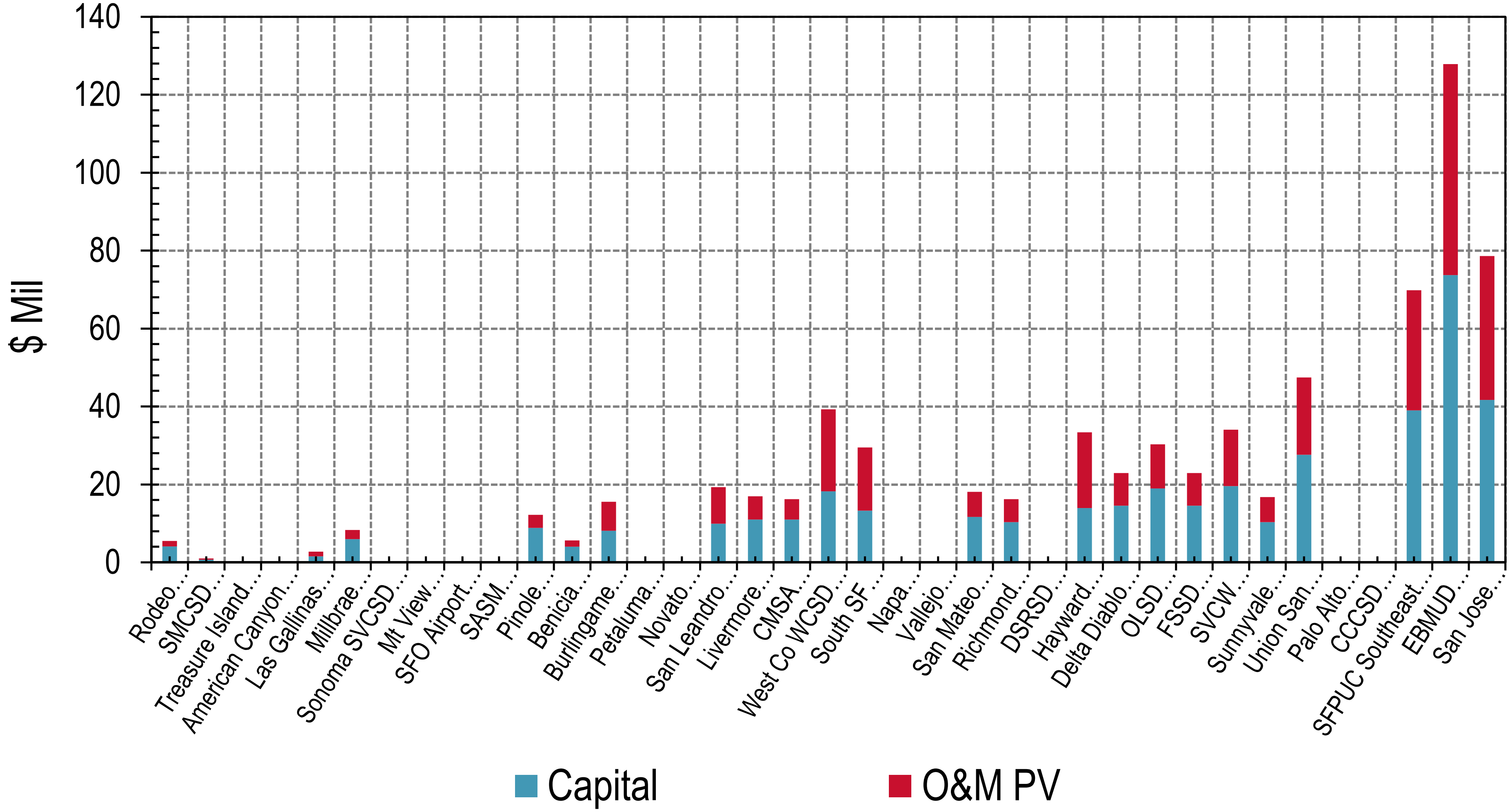
- Basis of Evaluation
  - Identify upgrade strategies to reduce nutrients
  - Planning Period: 30 Years
  - Loading: Design Capacity
  - Design Criteria:
    - Year-round sidestream
    - Sufficient Dewatering Frequency ($\geq$4 days/week)
    - Water temperature governs technology selection
- Concepts
  - Ammonia/TN Removal:
    - Conventional nitrification technology
    - Deammonification technology
  - TP Removal: metal salt precipitation

- Acknowledgements
  - EPA Regional Grant led by EBMUD
  - Agencies that hosted pilots: EBMUD, SPFUC SEP, DD, OLSD, USD, CCCSD

DRAFT Findings: Plants Eligible for Sidestream Treatment by Subembayment

Subembayment	No. Plants Eligible for Ammonia Discharge Reduction to the Bay	No. Plants Eligible for Total Nitrogen Discharge Reduction to the Bay
Suisun Bay	1	3
San Pablo Bay	1	4
Central Bay	4	5
South Bay	10	11
Lower South Bay	0	2
Total	**16**	**25**

DRAFT Findings: Total PV Costs for Sidestream



Plants are Still Reviewing the Applicability for Sidestream Treatment

*Draft Results are Sorted by Permitted Capacity

DRAFT Findings: Sidestream

- Criteria for feasible sidestream implementation:
  - Year-round sidestream
  - Year-round discharge
  - Sufficient dewatering frequency (≥4 days/week)
- Number of candidate plants
  - 16 out of 37 plants if ammonia reduction is the discharge objective
  - 25 out of 37 plants if TN reduction is the discharge objective
- Costs
  - The Total PV cost is $690 Mil for TN Load Reduction
  - Removal Metric = $2.1/lb N removed
- The overall Ammonia/TN load reduction from Current Discharge is up to 21 and 17 percent, respectively

Preliminary Upgrades Results

DRAFT Upgrade Findings

Which nutrients are easiest to remove?

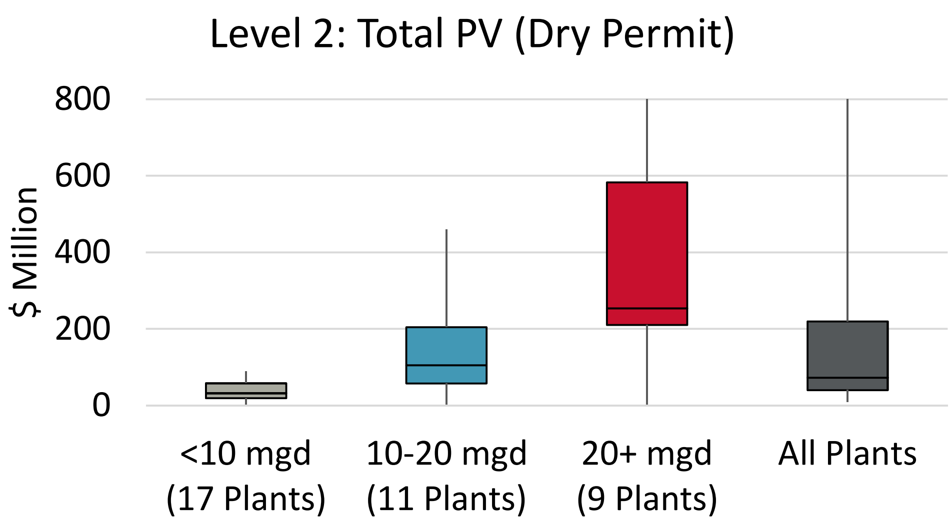
- Ammonia is the most difficult and expensive
  - Bigger basins due to increasing SRT for act sludge plants
  - Expanded aeration system
  - Additional pumping
- TN load reduction requires ammonia removal
  - Level 3 typically require an external carbon source
- TP load reduction is the simplest/most straight forward
  - Level 3 requires tertiary filtration
  - Upgrades use MBR which includes filtration in Level 2
- Number of Plants Already/Planning to Meet Levels:
  - Level 2: 6
  - Level 3: 1

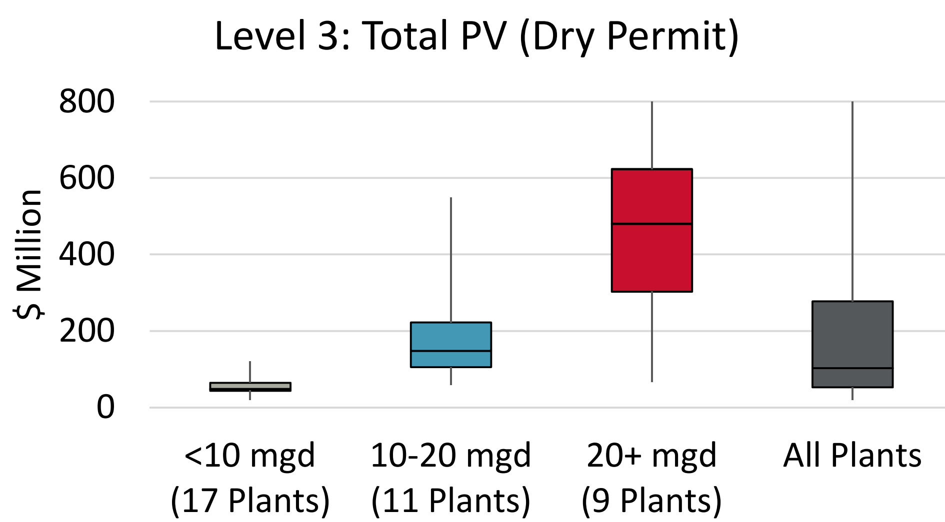
Costs

- Total PV Costs
  - Level 2 = $7.6B Dry & $9.3B Year Round
  - Level 3 = $9.8B Dry & $11.9B Year Round
- Total PV Cost Range per Plant
  - Level 2 = $3.5M to $2,650M per plant
  - Level 3 = $26M to $2,890M per plant
- Unit Costs
  - Level 2: $6/lb N Dry & $8/lb N Year Round
    $32/lb P Dry & $42/lb P Year Round
  - Level 3: $6.3/lb N Dry & $7.4/lb N Year Round
    $48/lb P Dry & $58/lb P Year Round

Parameter	Level 2 Load Reduction	Level 3 Load Reduction
Ammonia	>88%	>88%
Total N	>65%	>84%
Total P	>63%	>89%

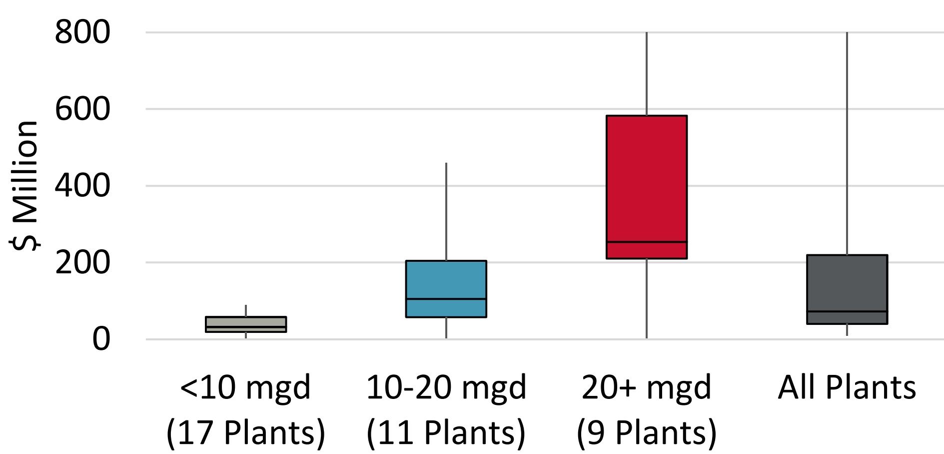
Upgrades Total PV Costs



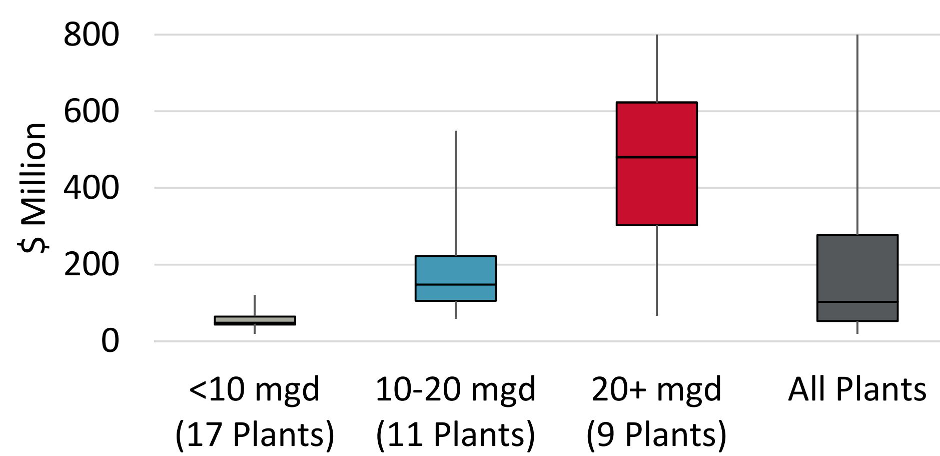


Upgrades Total PV Costs

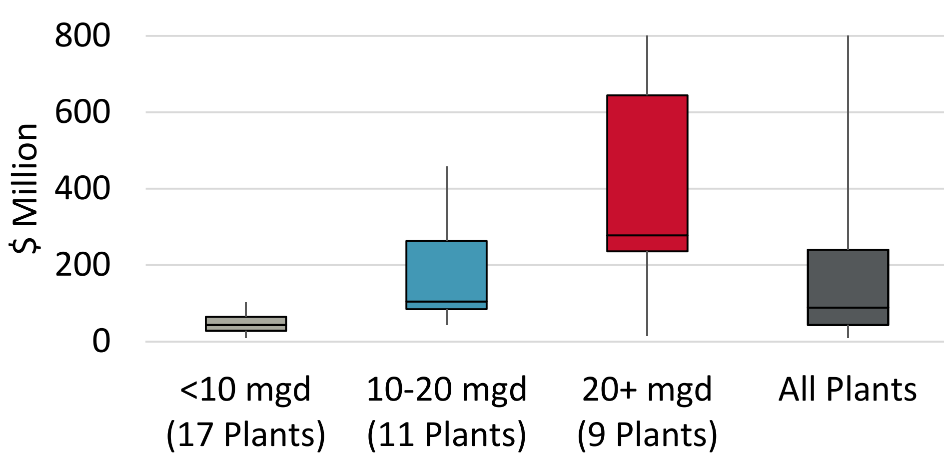
Level 2: Total PV (Dry Permit)



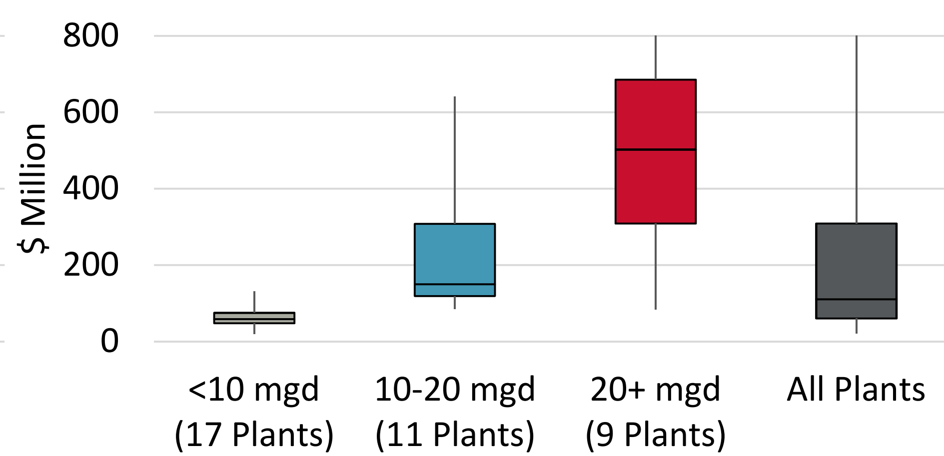
Level 3: Total PV (Dry Permit)



Level 2: Total PV (Year Round Permit)

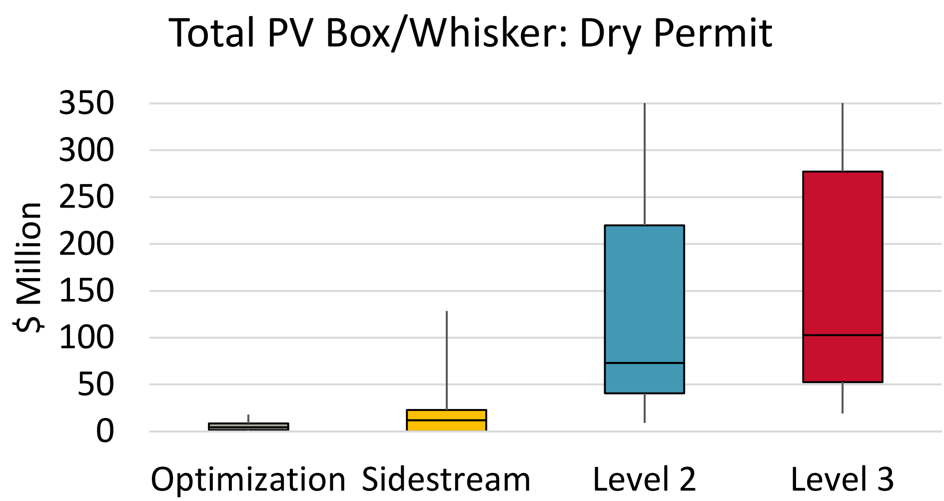


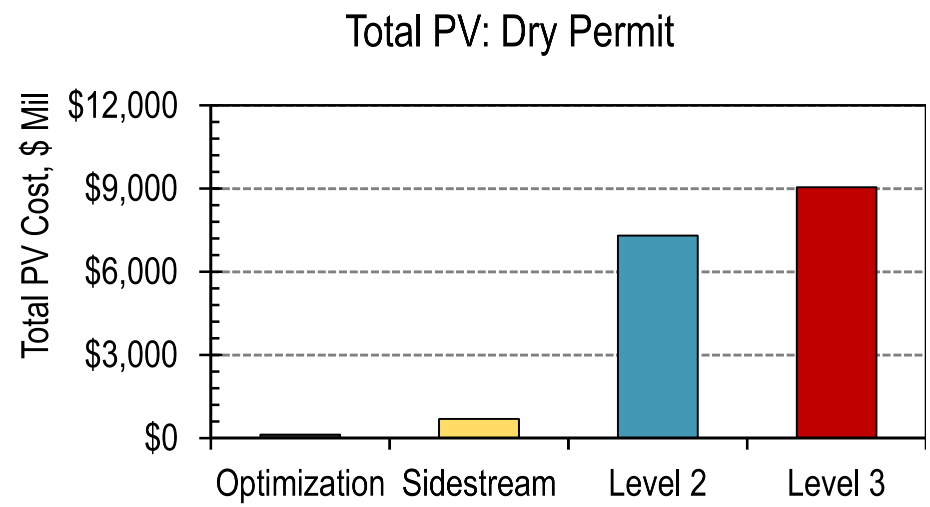
Level 3: Total PV (Year Round Permit)

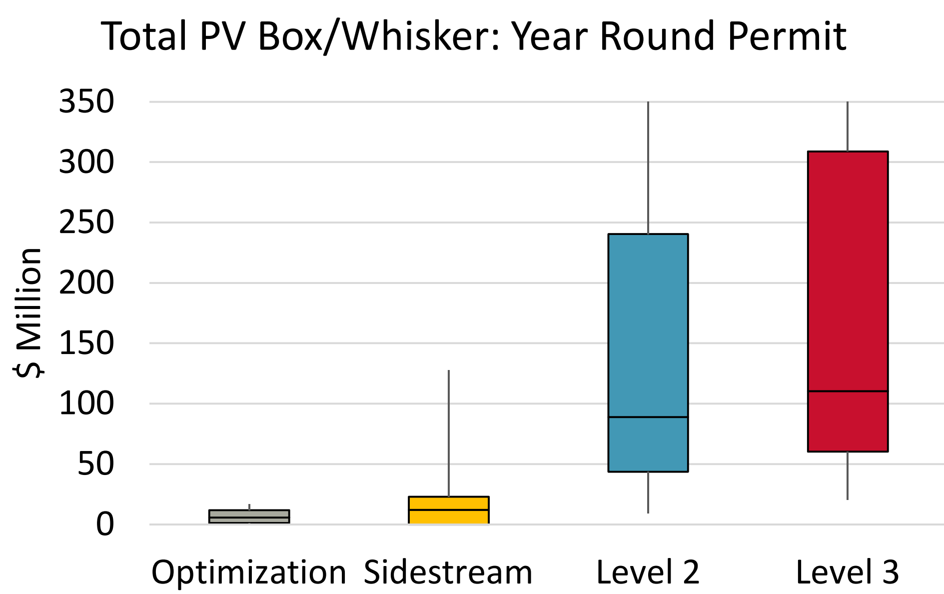


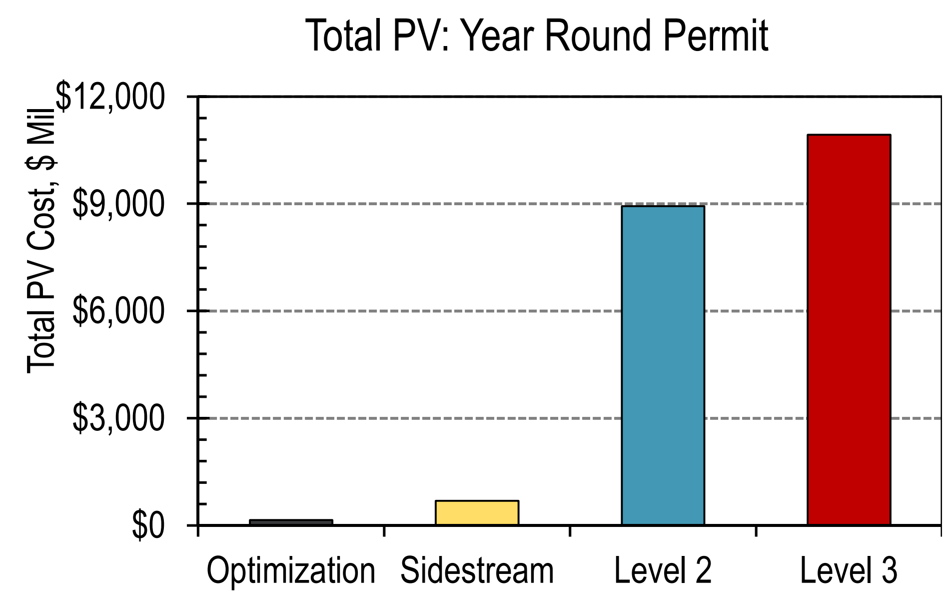
Summary of Results

Total PV for TN Load Reduction: Box and Whiskers (Left) and Total PV (Right)

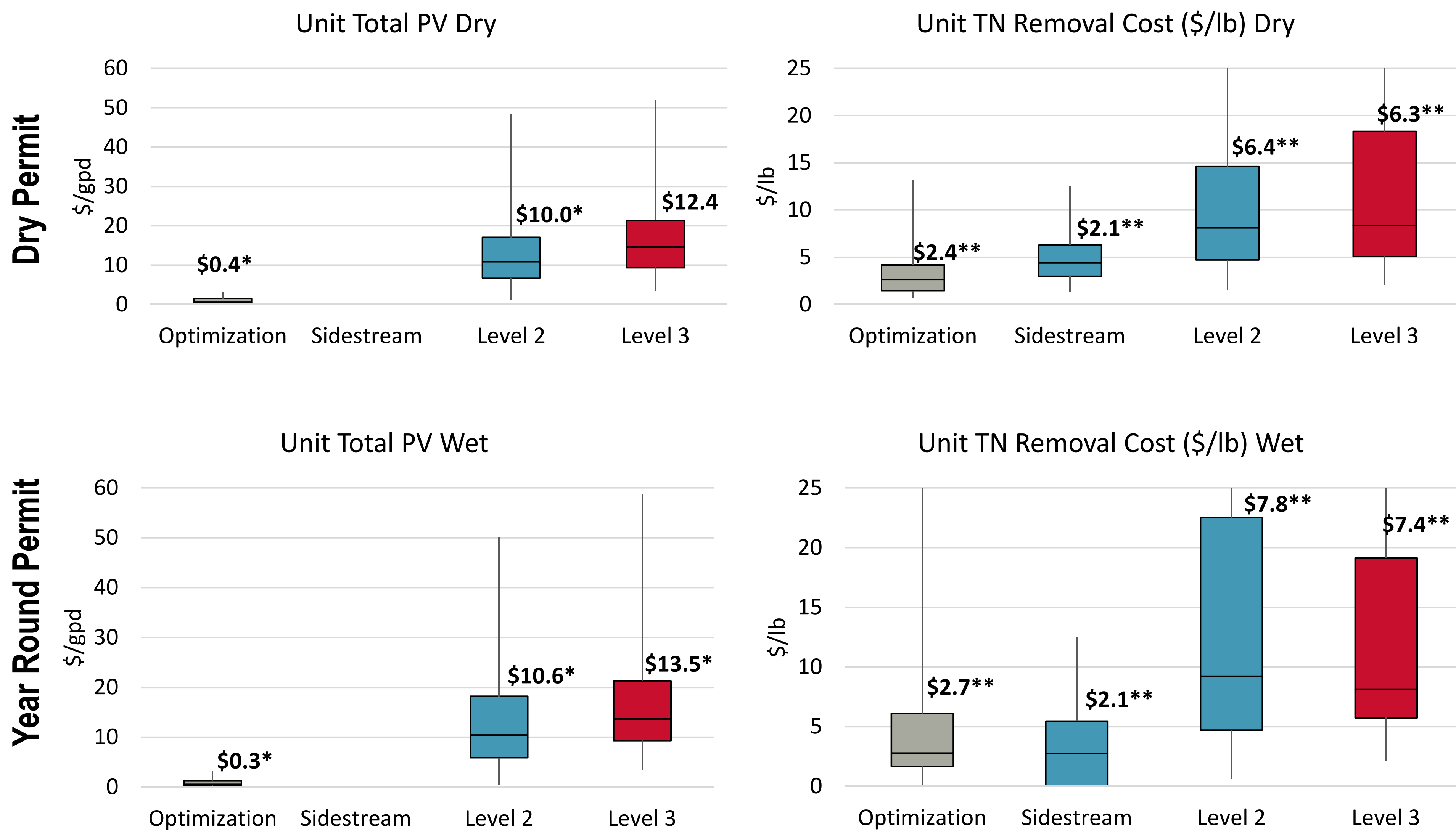








Box and Whisker Plots for TN Load Reduction Metrics: Unit Total PV, $/gpd (Left) and Removal Efficiency, $/lb (Right)



* Flow-Weighted Average for each Parameter

** Total PV divided by Load Reduction over Time (Opt = 10 yrs; Sidestream and Upgrades = 30 years)

Greenhouse Gas Emissions

- Captures the impacts from additional energy and chemicals associated with nutrient load reduction
- Not intended to satisfy GHG emissions reporting requirements
- Nitrous oxide emissions not included but will likely increase during biological nitrogen removal processes

Greenhouse Gas Emissions (mt CO_2 eq/yr) from Additional Energy/Chemicals for Nutrient Load Reduction

Parameter	Opt. Dry	Opt. Year Round	Level 2 Dry	Level 2 Year Round	Level 3 Dry	Level 3 Year Round
Energy	-2,200	-1,700	130,000	140,000	140,000	160,000
Chemicals	5,000	3,400	140,000	150,000	160,000	170,000
Total	**2,800**	**1,700**	**270,000**	**290,000**	**300,000**	**330,000**

Key Insights

Key Insights

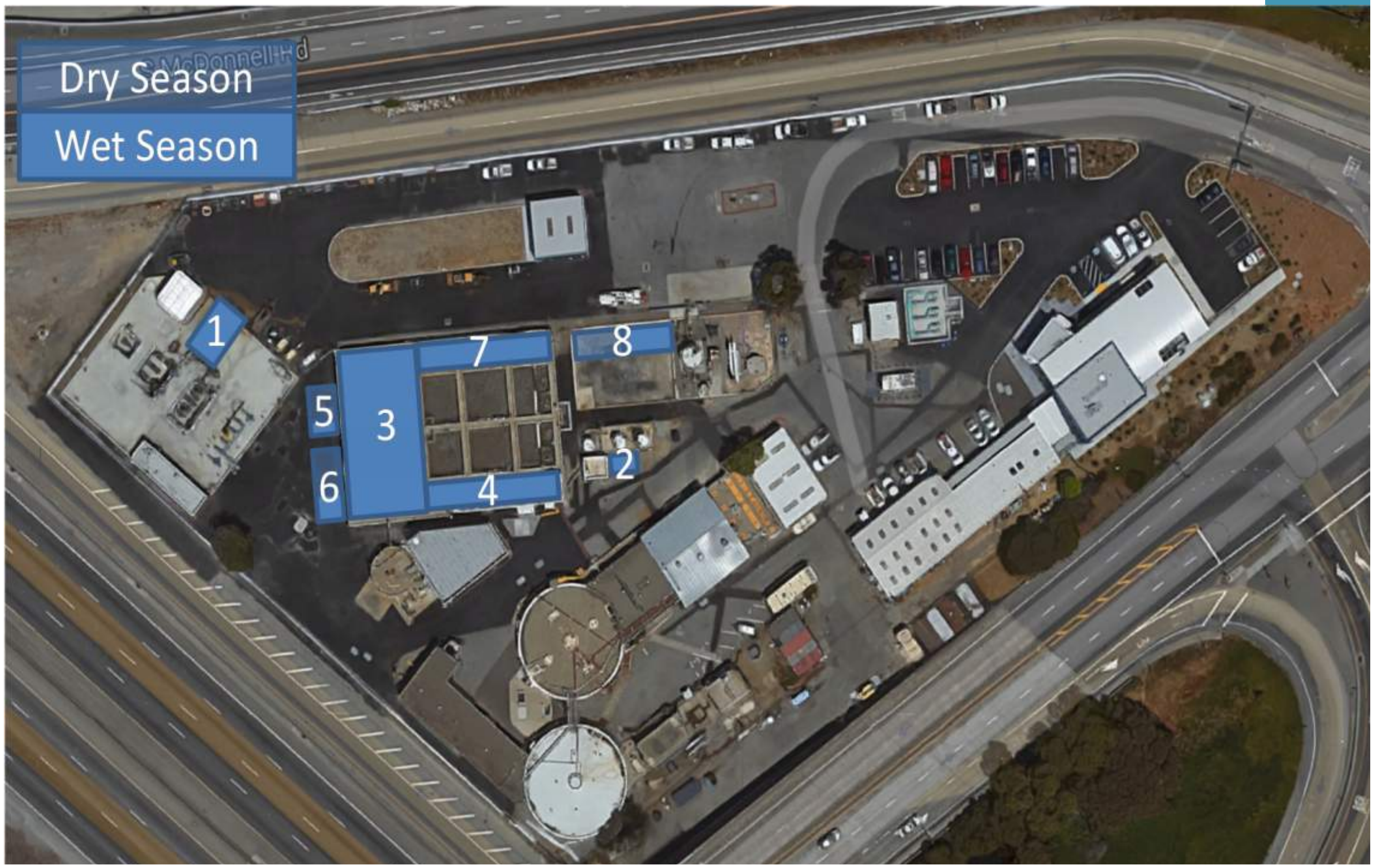
1. Capital makes up approximately 60 – 70% of Total PV
2. **Site constraints played a role in technology selection**
3. **Averaging periods are key to reducing capital costs**
   - **Dry is 75-80% of the capital for wet (for Level 2 or 3 upgrades)**
   - **Design criteria for meeting dry season over year-round limits would be more aggressive**
4. **Technology Status will play a significant role in technology selection**
5. **Water quality objectives based on total nitrogen and total phosphorus versus individual species influences technology selection and capital and O&M cost**
6. **Facility needs for TN versus TN and TP is more pronounced for Level 3 upgrades**
7. SF Bay Area is resource limited; planning and prioritization would be key for implementation
8. SRF funding is limited. Plants using bond funding would have higher costs

Space Constraints

Complexity of Upgrades in a Tight Space

Millbrae Case Study

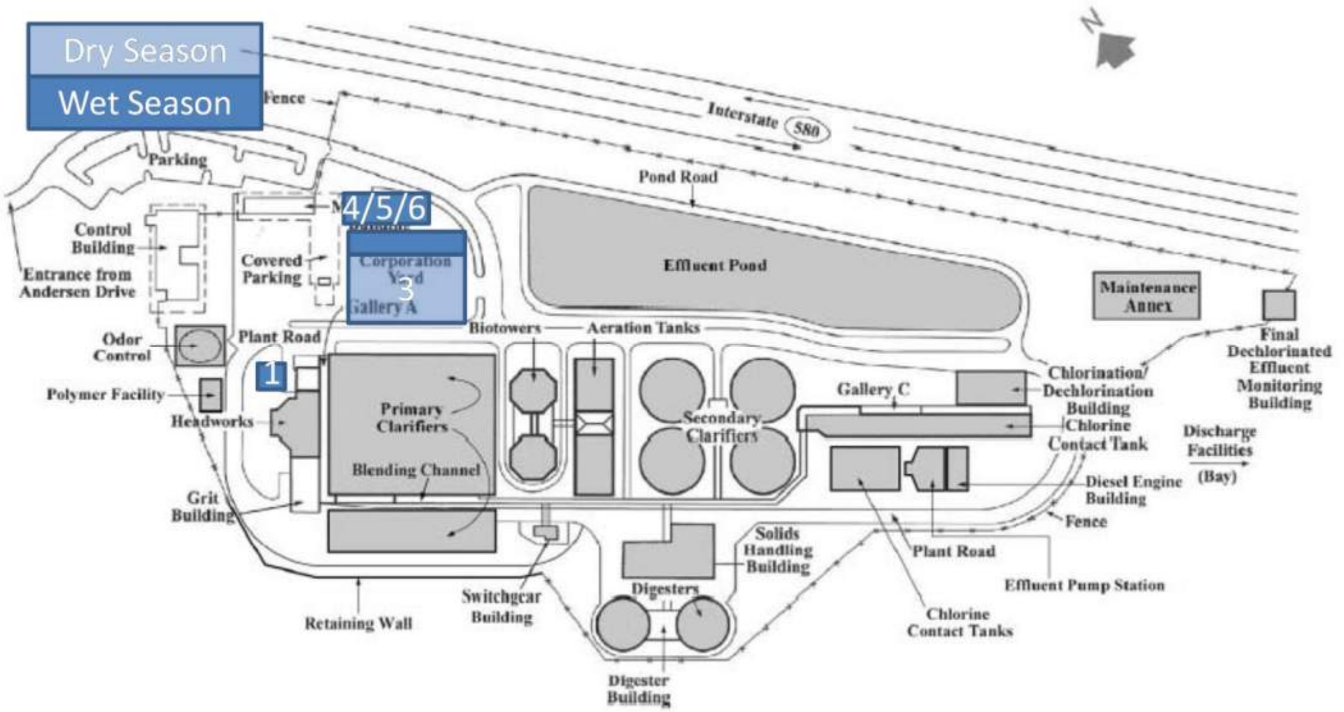
- Permitted Capacity = 3.0 mgd ADWF
- Peak = 9.0 mgd
- Key process:
  - Must be MBR
  - Must move blower building for a train
  - Must move disinfection for a train
  - Add new disinfection
- 8 Plants were pushed to MBR due to space constraints



Space Constraints

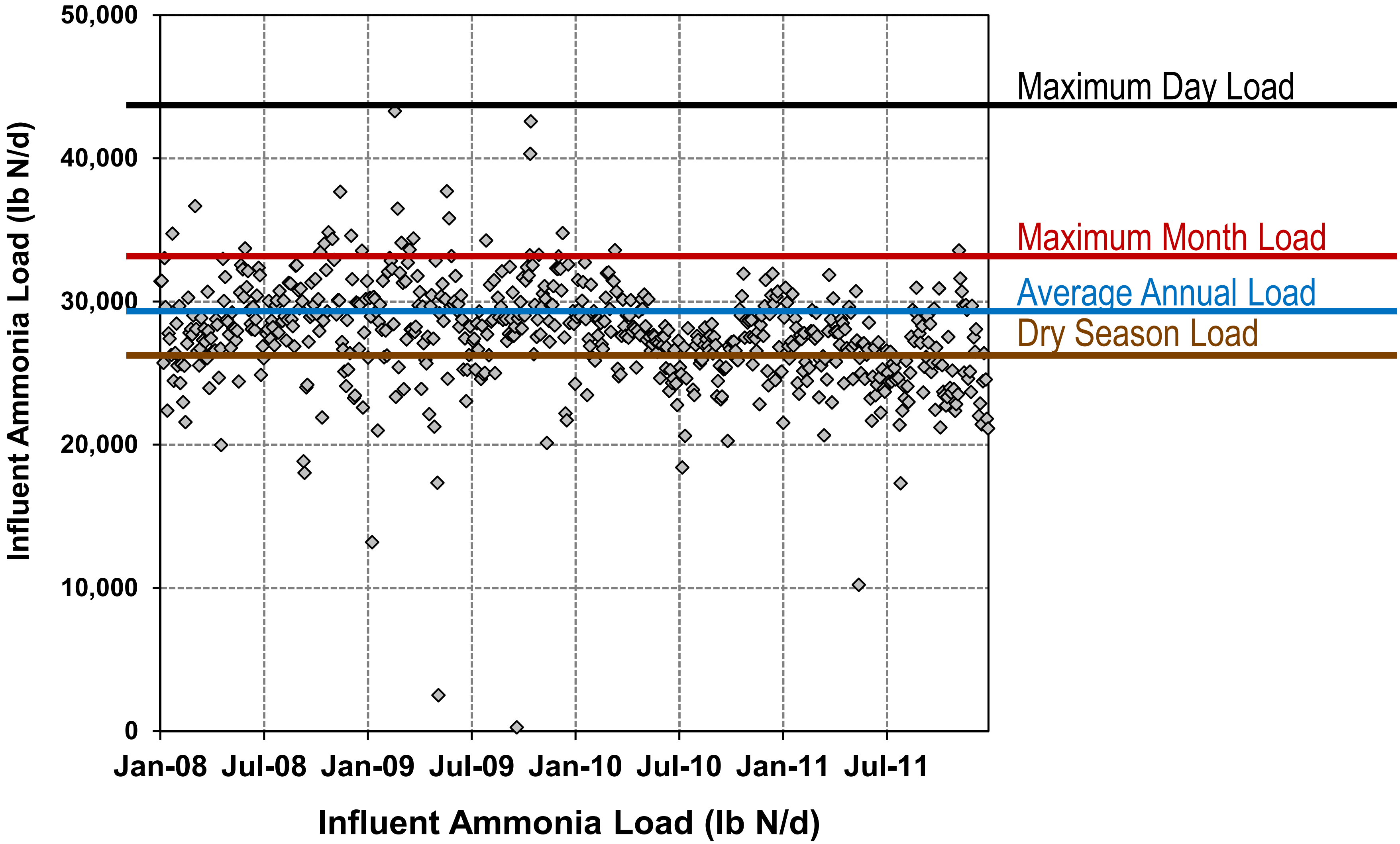
CMSA Case Study

- MBR selected since it's the only option that could meet Level 3 (split treatment with existing facilities would work for Level 2)
- Plant surrounded by high
- 8 Plants were pushed to compact footprint due to space constraints

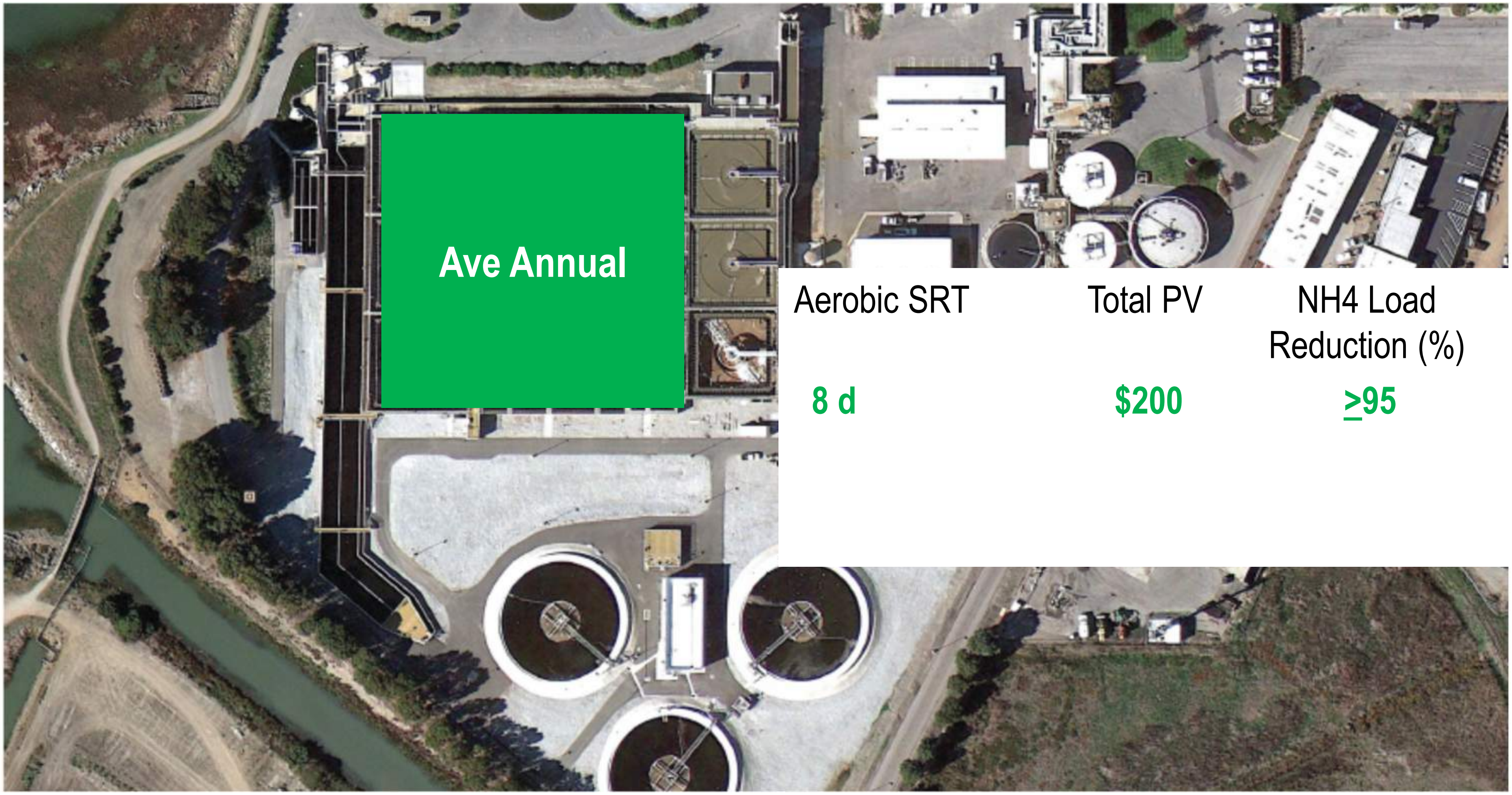


Role of Averaging Periods

Importance of Averaging Periods on Sizing Facilities



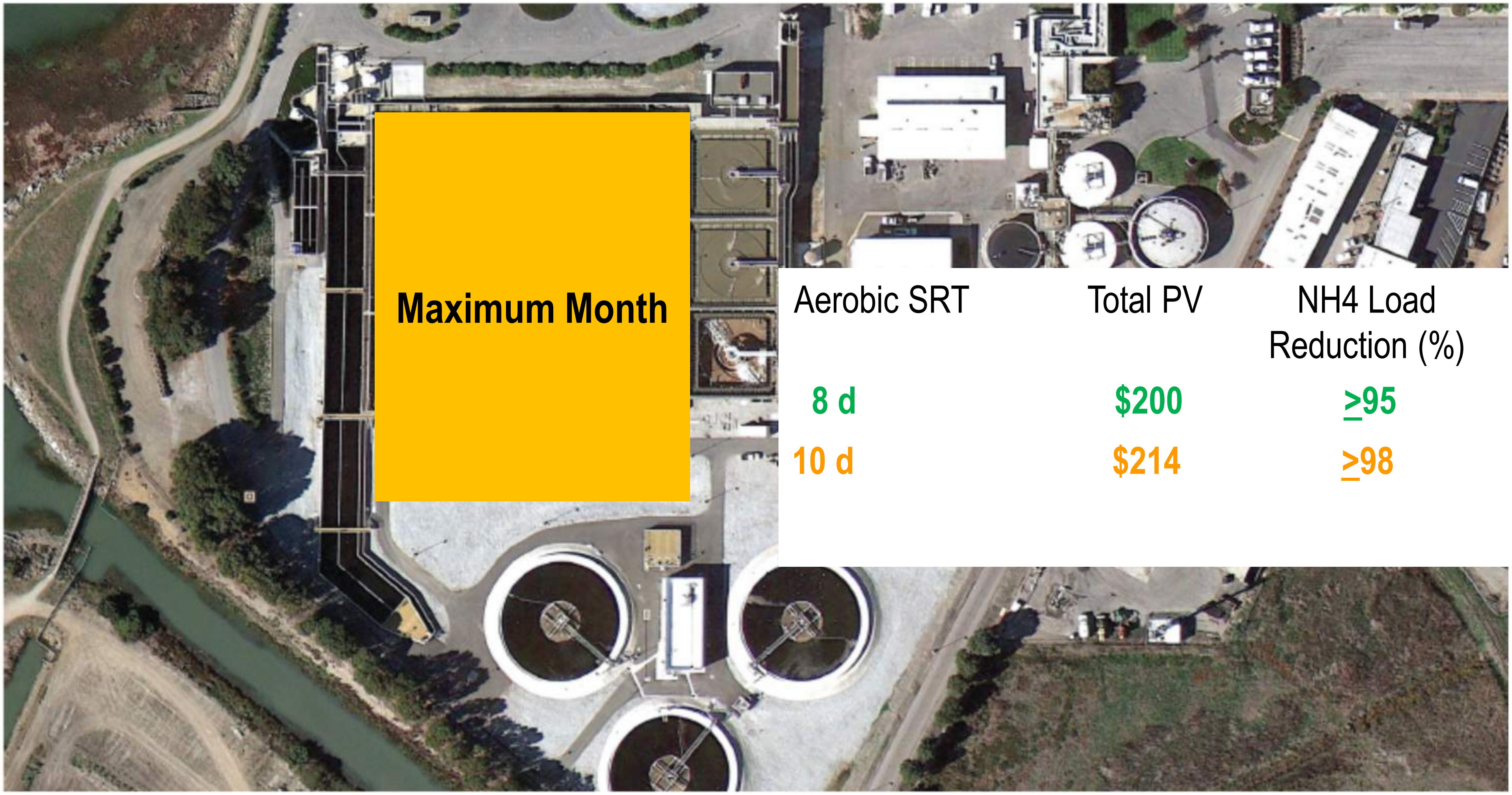
Role of Averaging Periods on SRT and Basin Volume



Aerobic SRT	Total PV	NH4 Load Reduction (%)
8 d	$200	≥95

Averaging Periods Govern the SRT and Overall Basin Volume

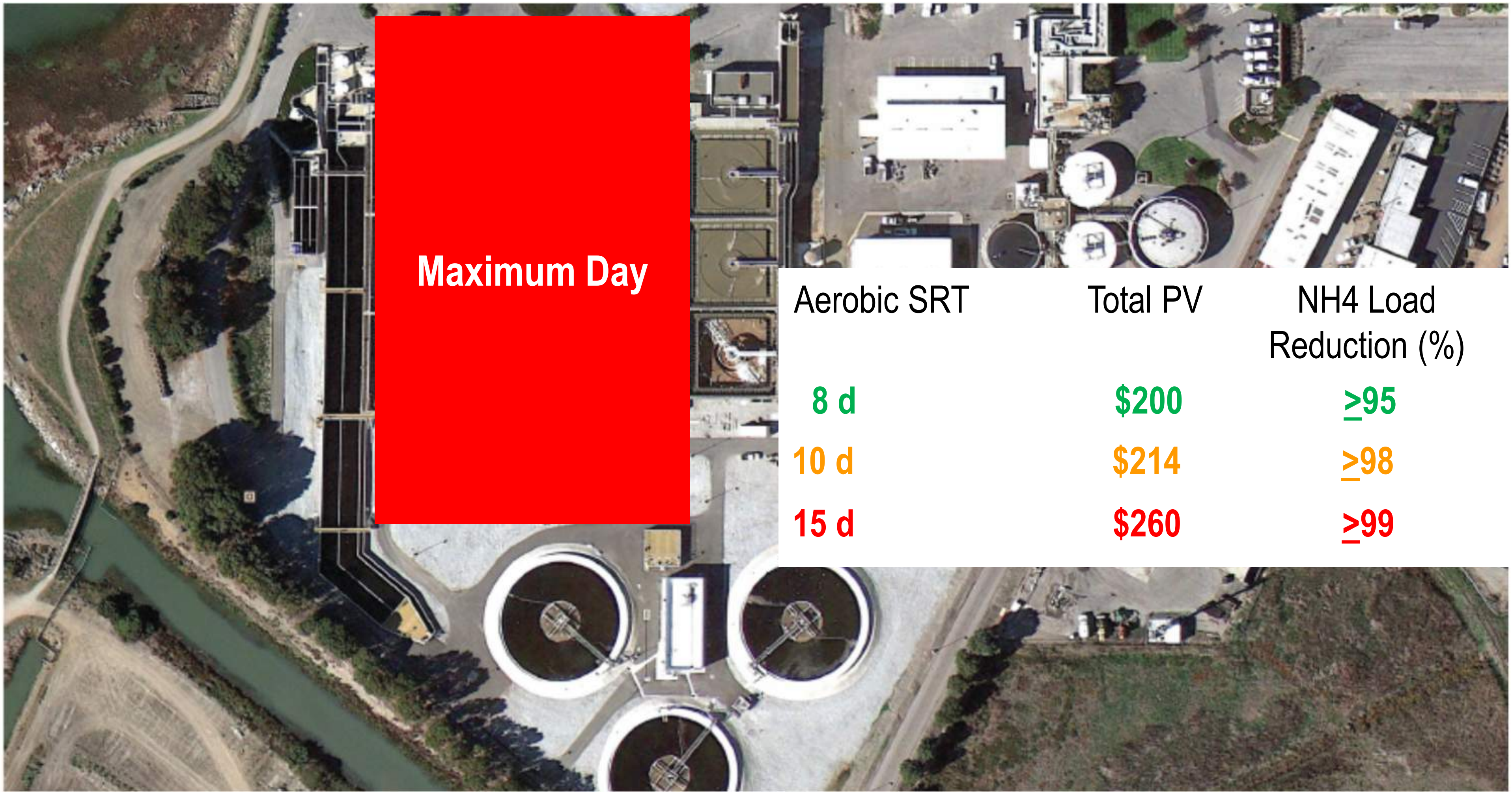
Role of Averaging Periods on SRT and Basin Volume



Aerobic SRT	Total PV	NH4 Load Reduction (%)
8 d	$200	$\geq$95
10 d	$214	$\geq$98

Averaging Periods Govern the SRT and Overall Basin Volume

Role of Averaging Periods on SRT and Basin Volume



Aerobic SRT	Total PV	NH4 Load Reduction (%)
8 d	$200	≥95
10 d	$214	≥98
15 d	$260	≥99

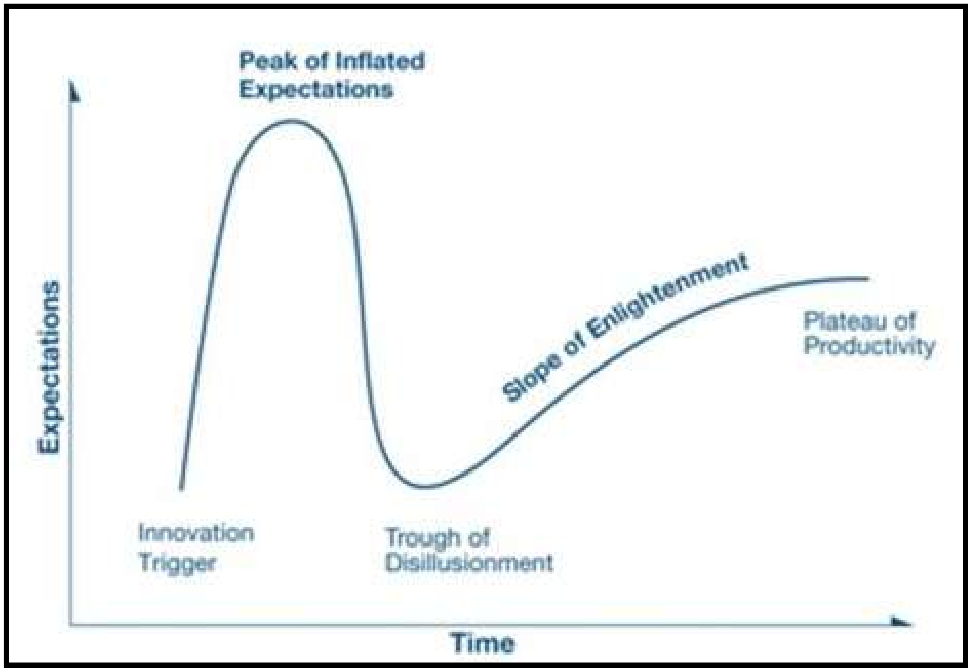
Averaging Periods Govern the SRT and Overall Basin Volume

Technology Selection

DRAFT Findings are based on Established Technologies; Emerging Technologies Should be Considered if Implementation Required

Emerging technologies

- Aerobic Granular Sludge
- FibrePlate Hybrid-membrane
- Membrane Aerated Biofilm Reactors (MABR)
- Dual Processes – Wet Weather/Dry Weather
  - CEPT, Micro-screens
- Cloth Media Filtration Primary Treatment
- Mainstream Deammonification
- Shortcut nitrogen removal
- HydroGrav
- Sidestream Deammonification
- AirPrex (Struvite)
- CalPrex (Brushite)
- Ammonia Recovery Processes
- Advanced Super Critical Water Technology
- Clean B Chlorine Dioxide Solids Stabilization



Gartner Hype Cycle

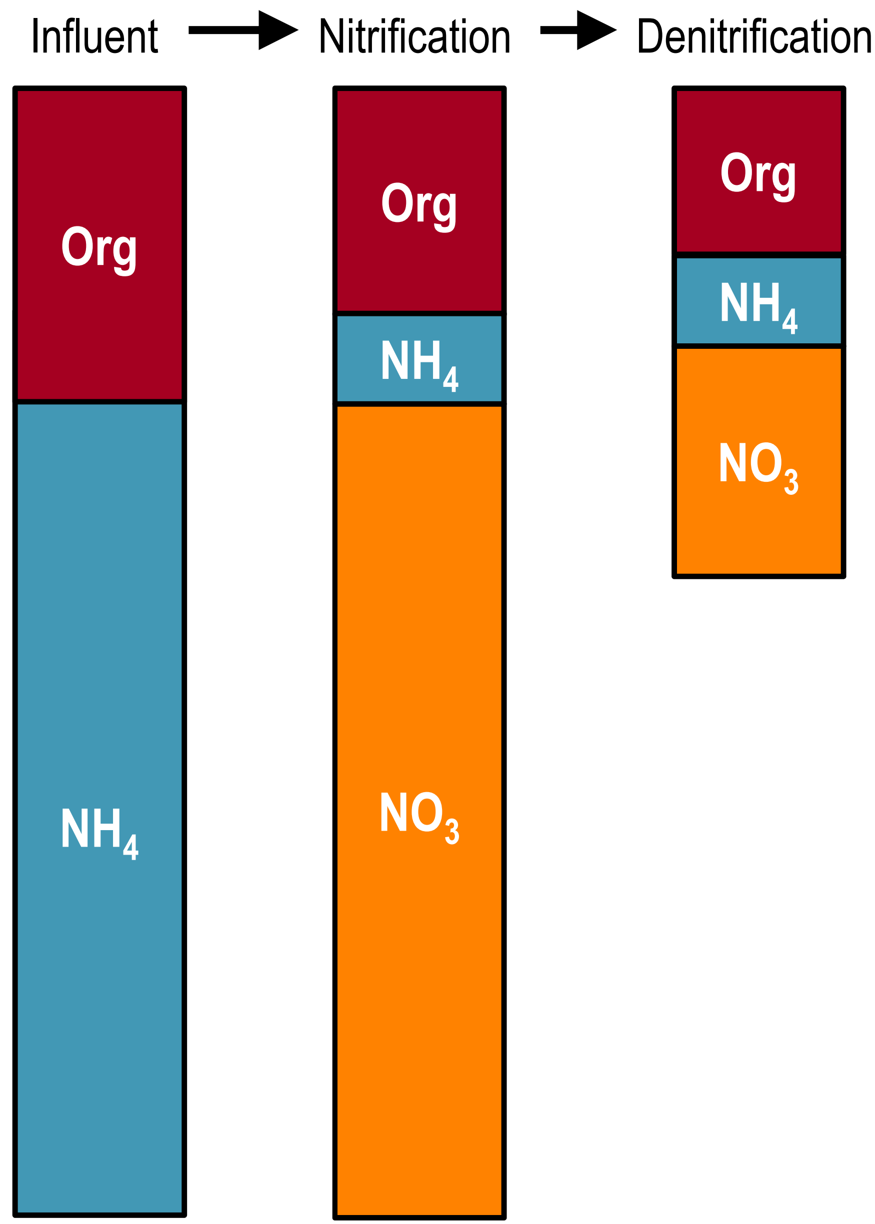
Source for Gartner Hype Curve:
http://www.gartner.com/technology/research/methodologies/hype-cycle.jsp

Water Quality Objectives

Impacts Technology Selection and Capital and O&M Costs

Water Quality Objectives Influence Facility Needs

- On-going water quality studies will determine the important nutrient species
- Use of established technologies relies on full nitrification
- Lumping ammonia with TN provides efficiencies
  - Blending of existing and new technologies
  - Enables use of emerging technologies
  - Potential to reduce capital and operating costs



Facility Needs for TN versus TN and TP

Differences in N and P Removal

Nitrogen Removal

- Challenging to remove with major operational changes
  - Activated Sludge (typical): with longer SRT and intensive mixed liquor returns
  - Biological Filters (to trim): requires large filter footprint plus an external carbon source
- More expensive to remove
- Requires a large footprint
- Energy and chemical intensive (especially for Level 3)
- Can be recovered in the sidestream

Phosphorus Removal

- Straightforward removal
  - Biological P (Act Sludge)
  - Chemical Precipitation: Primaries, Filters, or Sidestream
- Less expensive to remove
- Less additional footprint (extra zone or filters)
- Chemical intensive
- Can be recovered in the sidestream

Role of TP Removal in Cost

Dry Season

Parameter	Level 2		Level 3	
	Total N	Both N and P	Total N	Both N and P
Capital, $ Bil	3.9	4.0	4.6	4.9
O&M PV, $ Bil	1.9	2.0	2.7	3.1
Total PV, $ Bil	**5.8**	**6.1**	**7.3**	**8.0**

Year Round

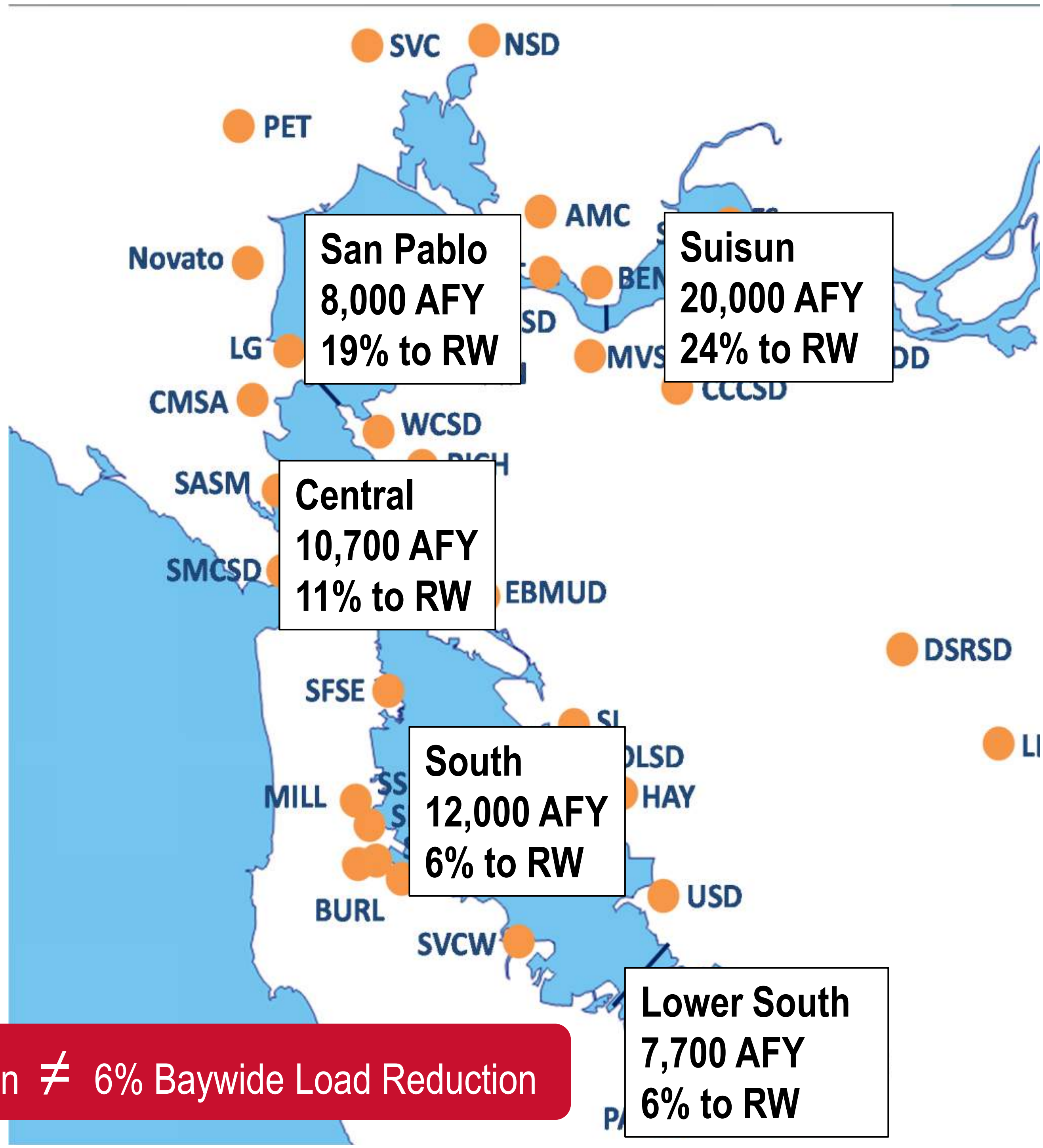
Parameter	Level 2		Level 3	
	Total N	Both N and P	Total N	Both N and P
Capital, $ Bil	5.1	5.2	5.9	6.2
O&M PV, $ Bil	2.2	2.4	3.2	3.8
Total PV, $ Bil	**7.3**	**7.6**	**9.1**	**10.0**

The cost impact for TP removal is more pronounced for Level 3 as it requires filtration and chemicals

Recycled Water

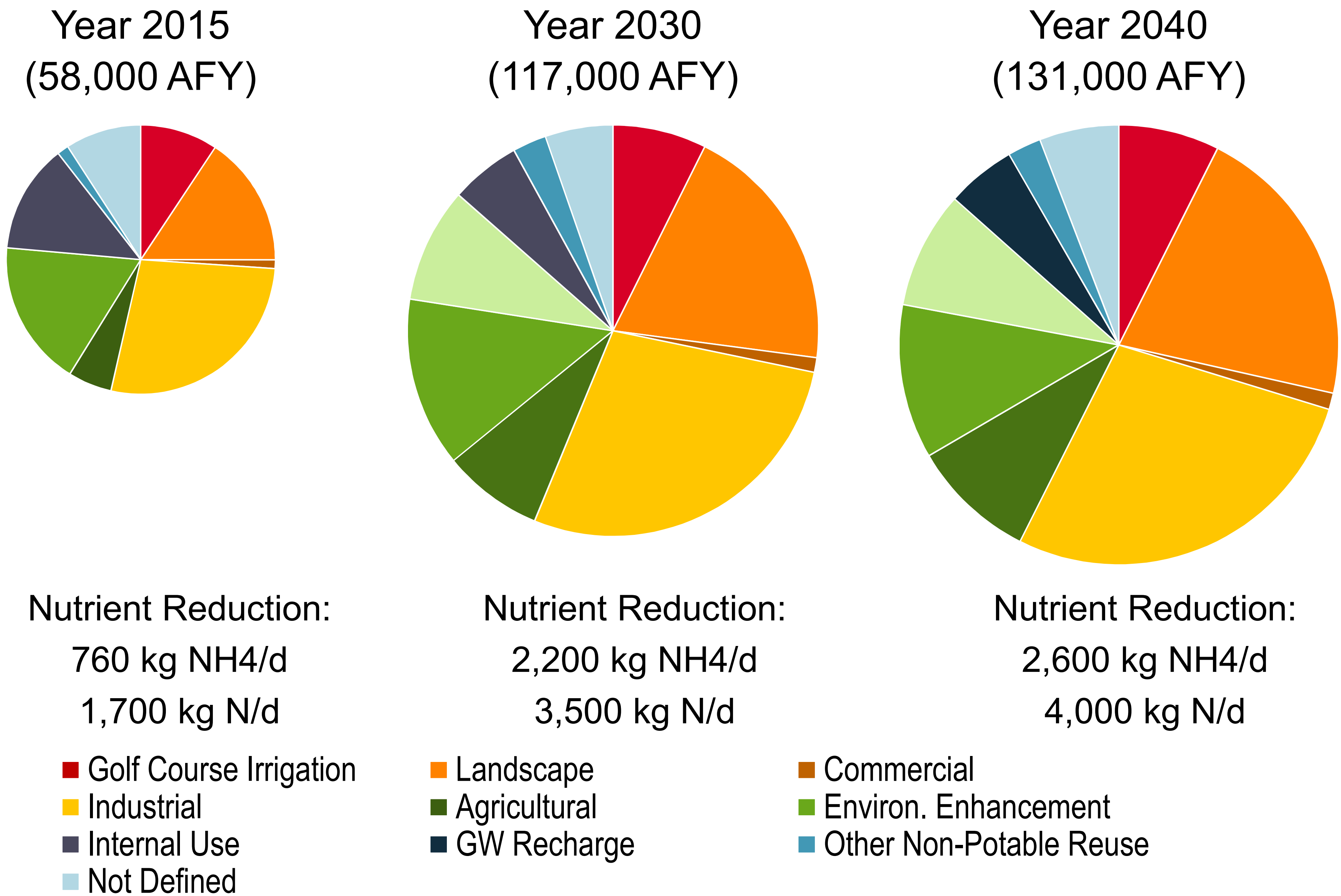
Current Recycled Water Quantities

- ~6% of Baywide plant effluent goes to recycled water
- Recycled water is expected to double by 2035
- The primary application is industrial (~40%)



6% Baywide Flow Reduction ≠ 6% Baywide Load Reduction

Recycled Water Distribution and Future Projection



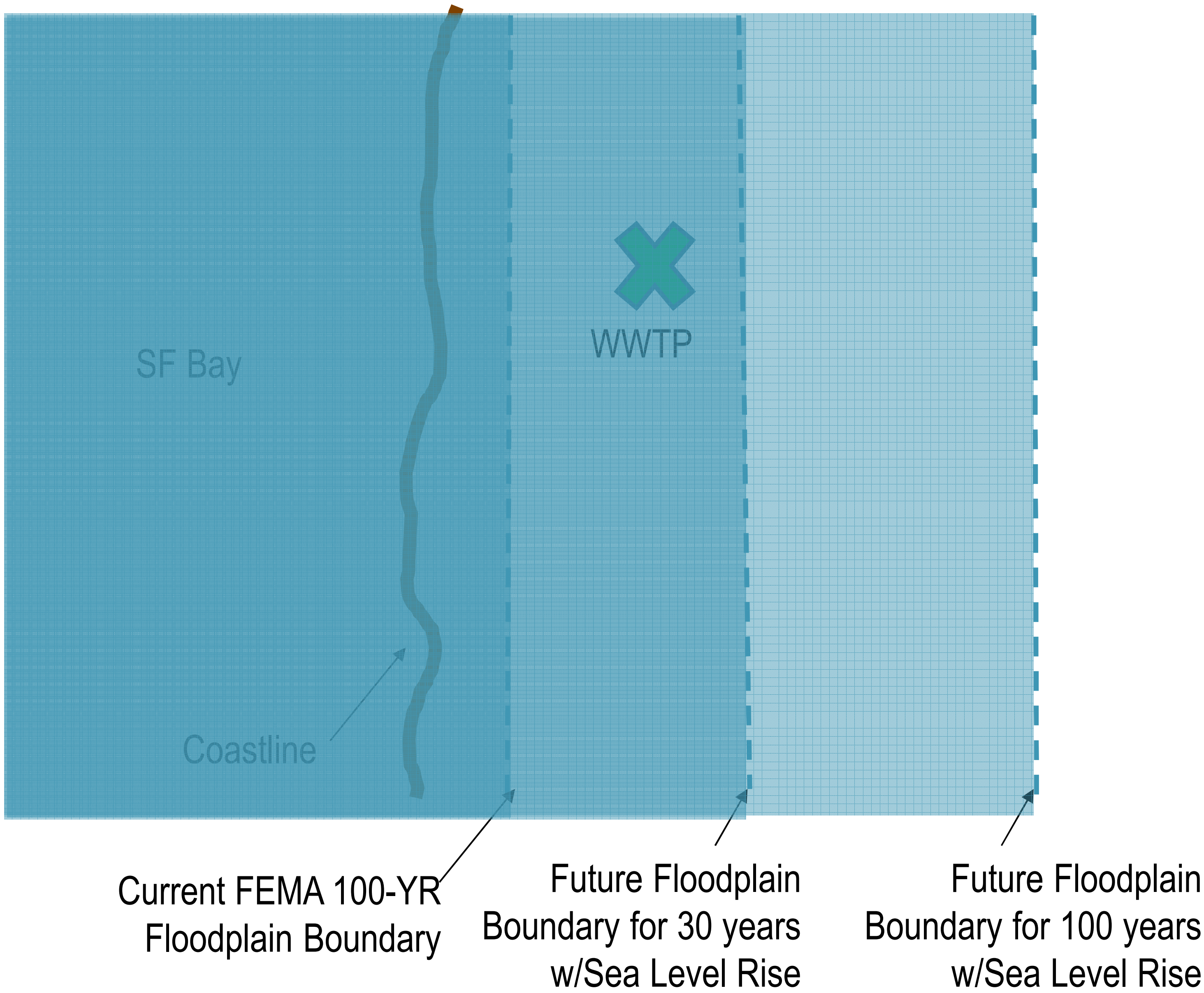
Nutrient Related Projects in CIPs

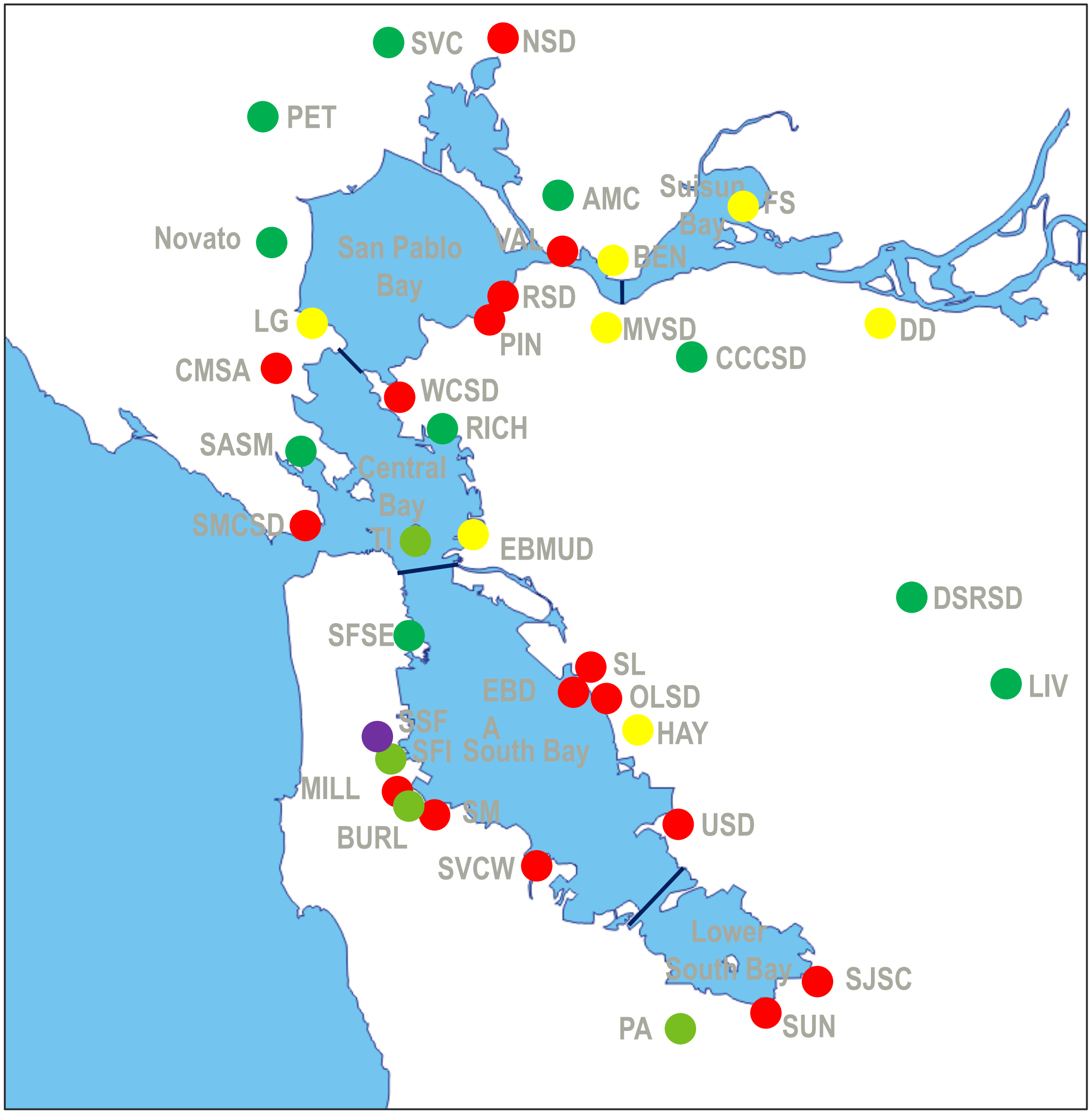
Nutrient Related Projects in CIPs

- 22 out of 37 plants have either on-going or planned CIP projects for nutrient load reduction
- Total Capital Cost of CIPs = $1.5 Bil
- Example: San Mateo
  - Nutrient Removal and Wet Weather Flow Management Update and Expansion Project
  - New headworks, primary clarifiers, and membrane bioreactor with nutrient removal
  - Estimated capital cost = $349-369 Mil

Sea Level Rise

Progression of Sea Level Rise



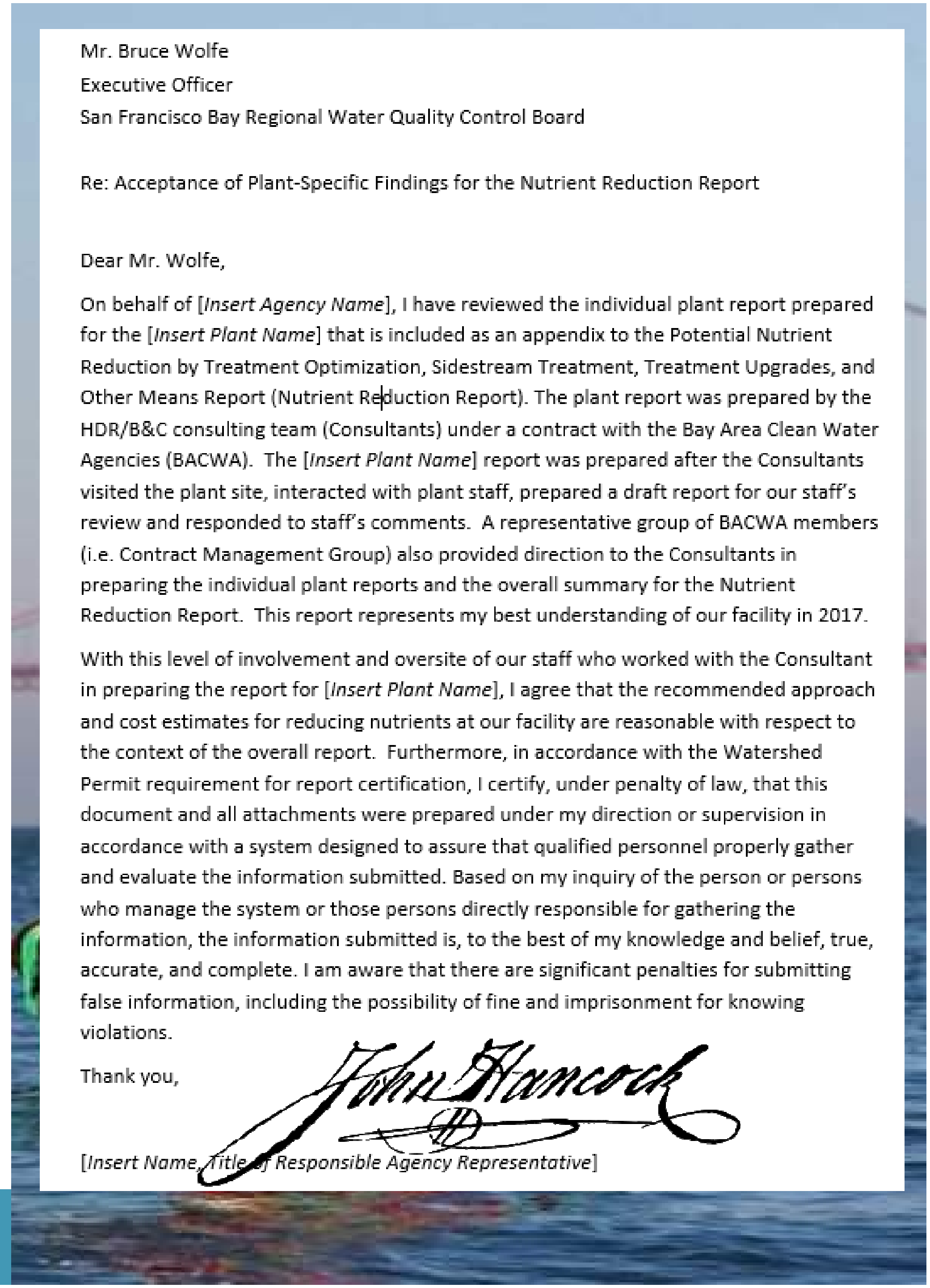


BACWA Flood Risk Assessment

- Within FEMA 100-yr flood hazard (15 of 37 Plants)
- Within 30 years, site will be impacted by sea level rise (Additional 4 Plants)
- Within 50 years, site will be impacted by sea level rise (Additional 1 Plant)
- Within 100 years, site will be impacted by sea level rise (Additional 7 Plants)
- Site is not impacted by sea level rise (10 of 37 Plants)

Next Steps

- Final plant reports this month
- Acceptance letter to be returned within 3 weeks
- Draft Nutrient Reduction Report to be reviewed by CMG
- Final Report due to Regional Board on 7/1/2018



Mr. Bruce Wolfe

Executive Officer

San Francisco Bay Regional Water Quality Control Board

Re: Acceptance of Plant-Specific Findings for the Nutrient Reduction Report

Dear Mr. Wolfe,

On behalf of [*Insert Agency Name*], I have reviewed the individual plant report prepared for the [*Insert Plant Name*] that is included as an appendix to the Potential Nutrient Reduction by Treatment Optimization, Sidestream Treatment, Treatment Upgrades, and Other Means Report (Nutrient Reduction Report). The plant report was prepared by the HDR/B&C consulting team (Consultants) under a contract with the Bay Area Clean Water Agencies (BACWA). The [*Insert Plant Name*] report was prepared after the Consultants visited the plant site, interacted with plant staff, prepared a draft report for our staff's review and responded to staff's comments. A representative group of BACWA members (i.e. Contract Management Group) also provided direction to the Consultants in preparing the individual plant reports and the overall summary for the Nutrient Reduction Report. This report represents my best understanding of our facility in 2017.

With this level of involvement and oversite of our staff who worked with the Consultant in preparing the report for [*Insert Plant Name*], I agree that the recommended approach and cost estimates for reducing nutrients at our facility are reasonable with respect to the context of the overall report. Furthermore, in accordance with the Watershed Permit requirement for report certification, I certify, under penalty of law, that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Thank you,

John Hancock

[*Insert Name, Title of Responsible Agency Representative*]

BACWA Annual Meeting: Nutrient Reduction by Optimization and Upgrades Update

19 January 2018

HDR

Brown AND Caldwell

BACWA BAY AREA CLEAN WATER AGENCIES