Pardee Workshop: Nutrient Reduction by Optimization and Upgrades Update

27 October 2017

HDR

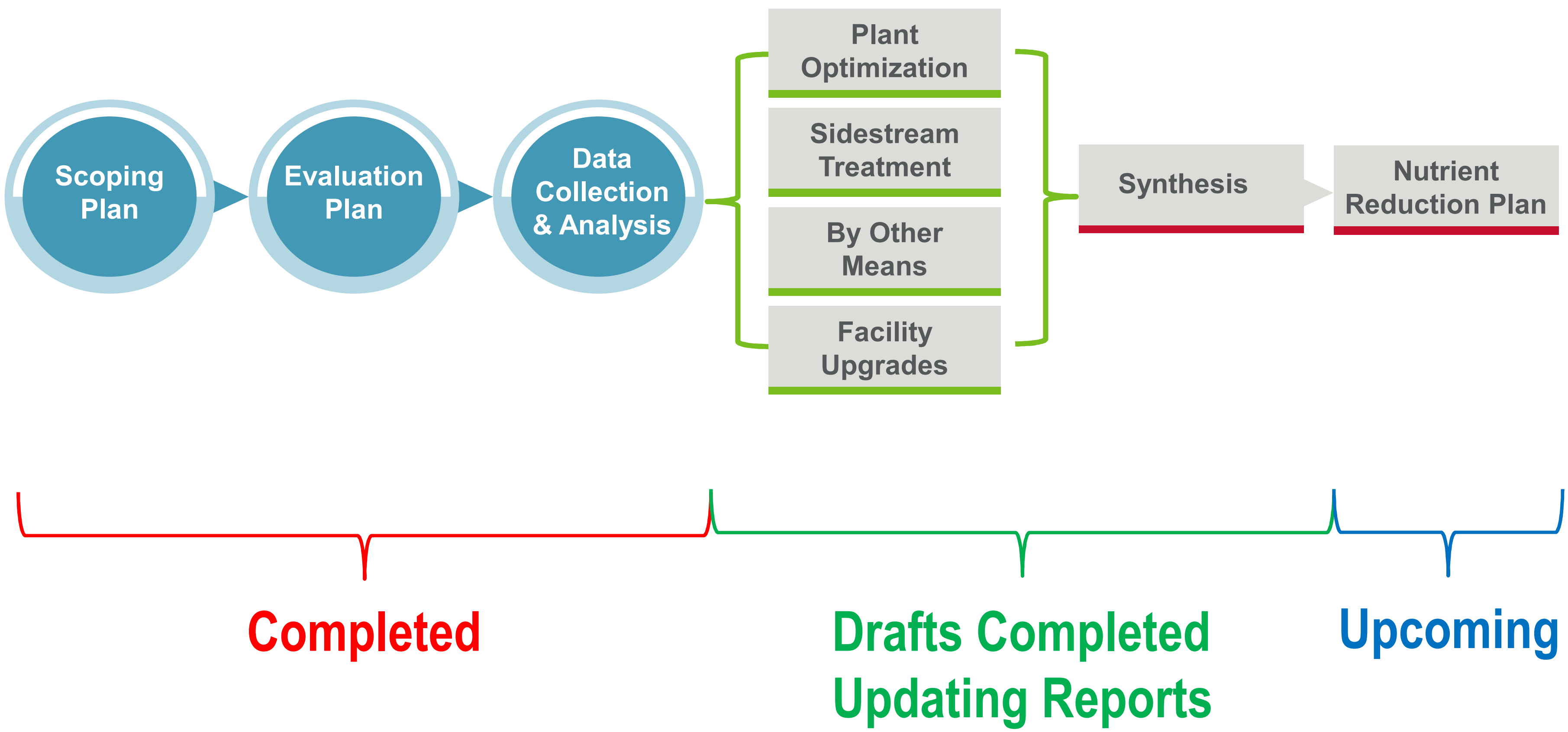
Brown AND Caldwell

BACWA BAY AREA CLEAN WATER AGENCIES

Agenda

1. Project Status
2. Group Annual Report Findings
3. Summary of Key Draft Report Comments
4. Draft Findings of Nutrient Removal Reports
5. Key Variables that Impact Results
6. Role of Phosphorus
7. Results of Recycled Water/CIP Surveys
8. Next Steps

Overview / Status of Study

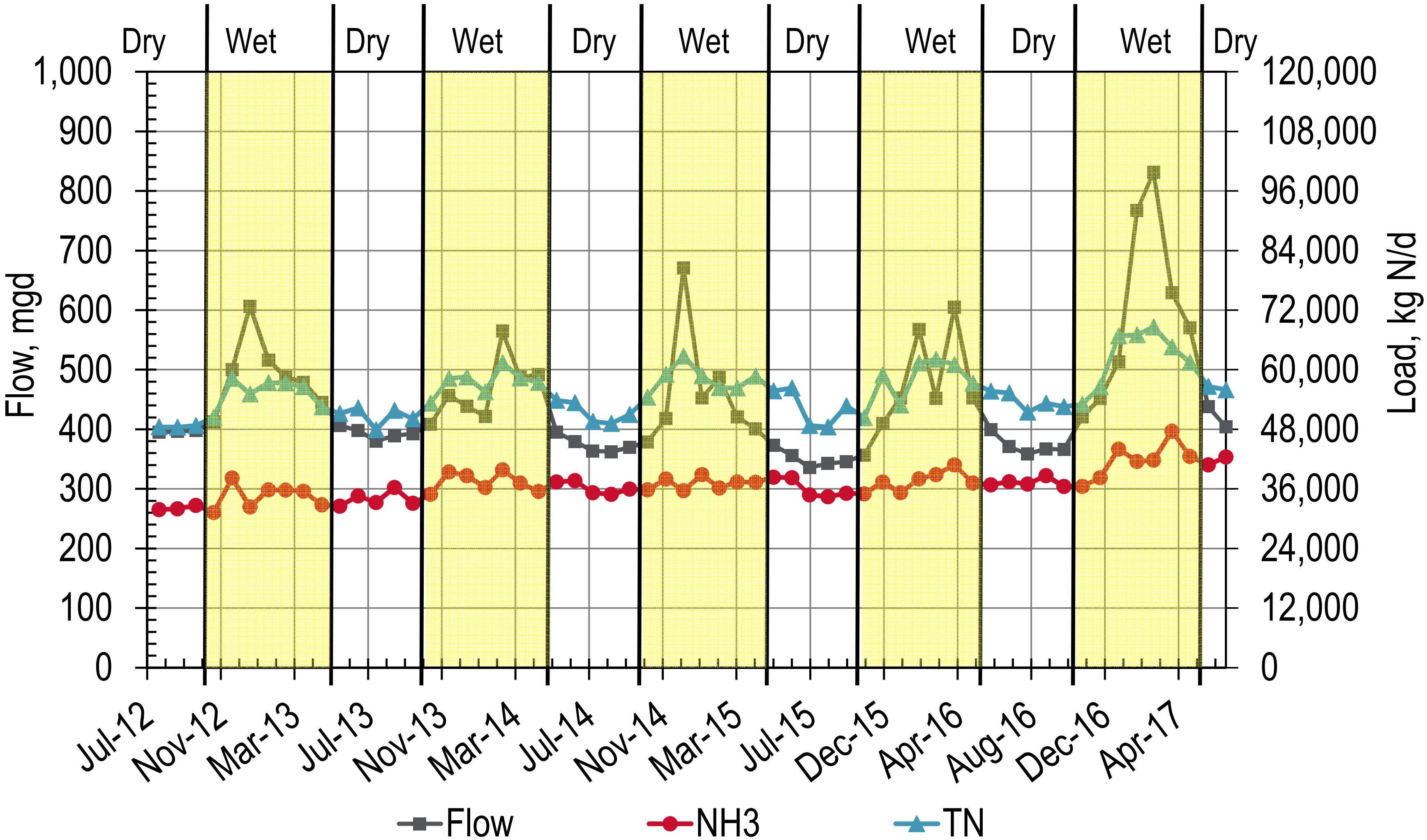


2017 Group Annual Report Findings

2017 Group Annual Report Summary

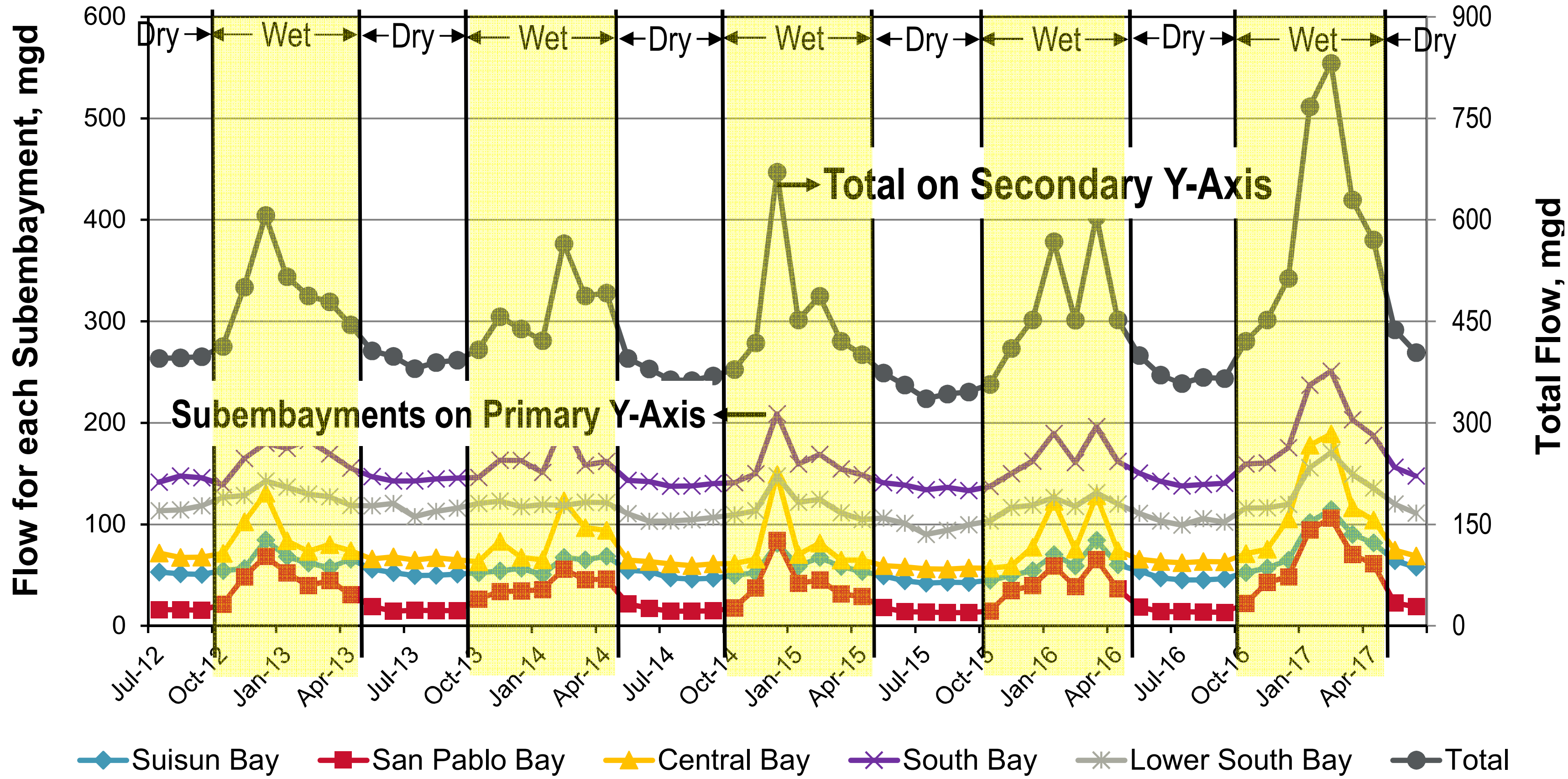
- 2016/2017 dry weather flows increased to pre-drought levels
- Annual average flows were the highest since sampling began in July 2012
- Ammonia, TN, and TP loads were the highest since sampling began in July 2012 (for both dry and average annual)

Nitrogen Loads Track with Flow



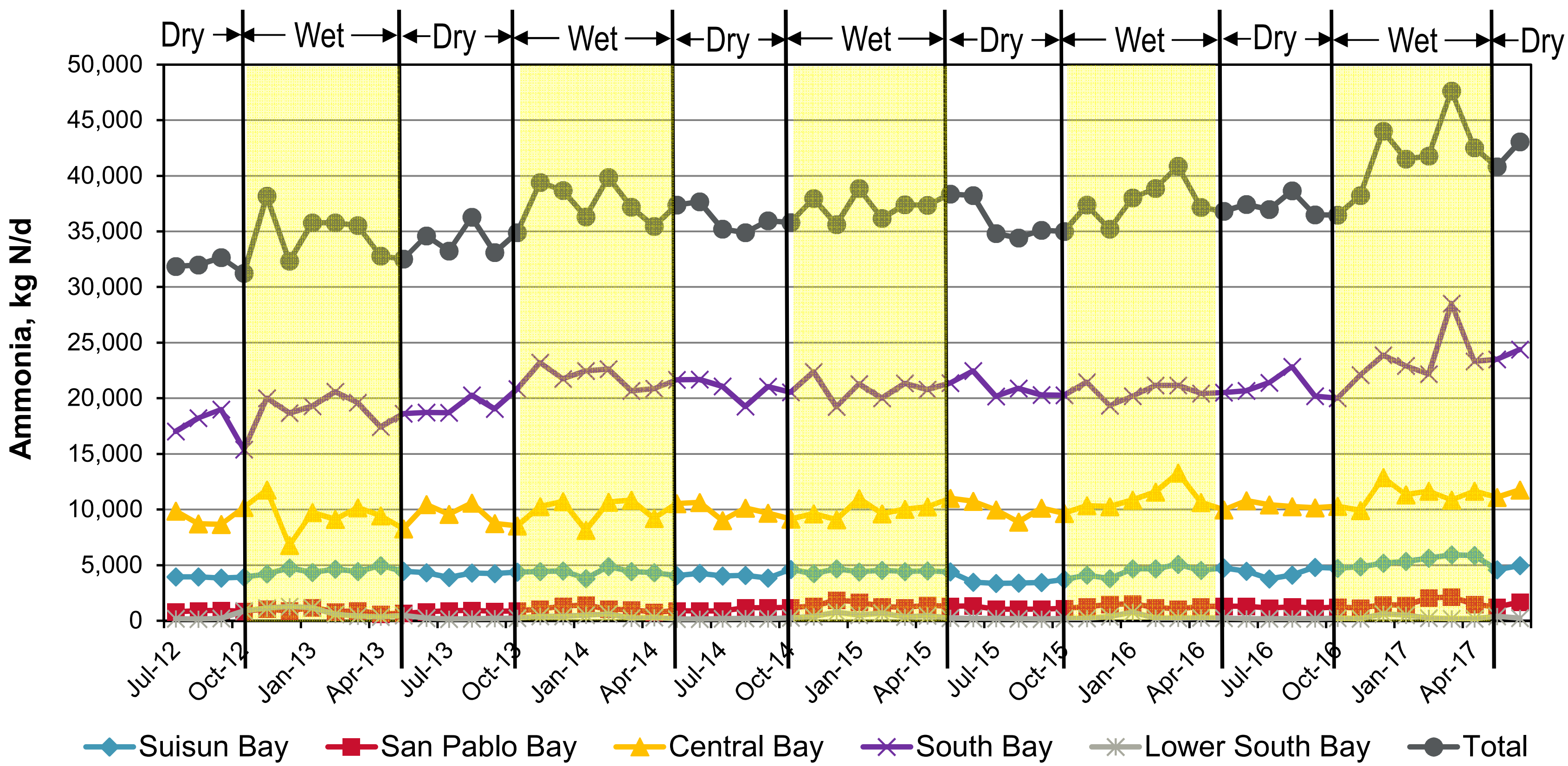
2017 Group Annual Report: Flow

- Total average annual flow for 2016-17 was the highest since 2012 at 510 mgd (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



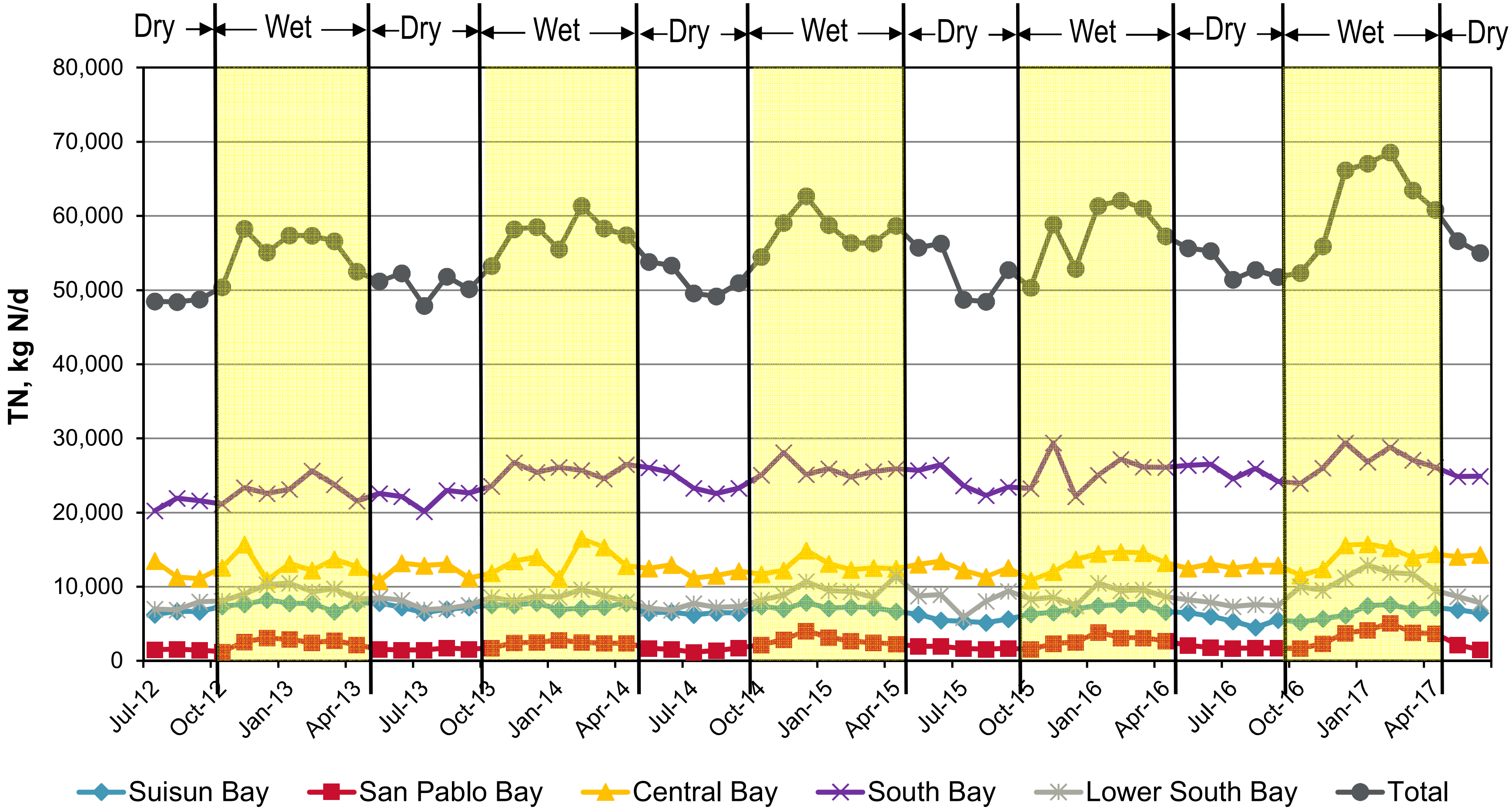
2017 Group Annual Report: Ammonia

- 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



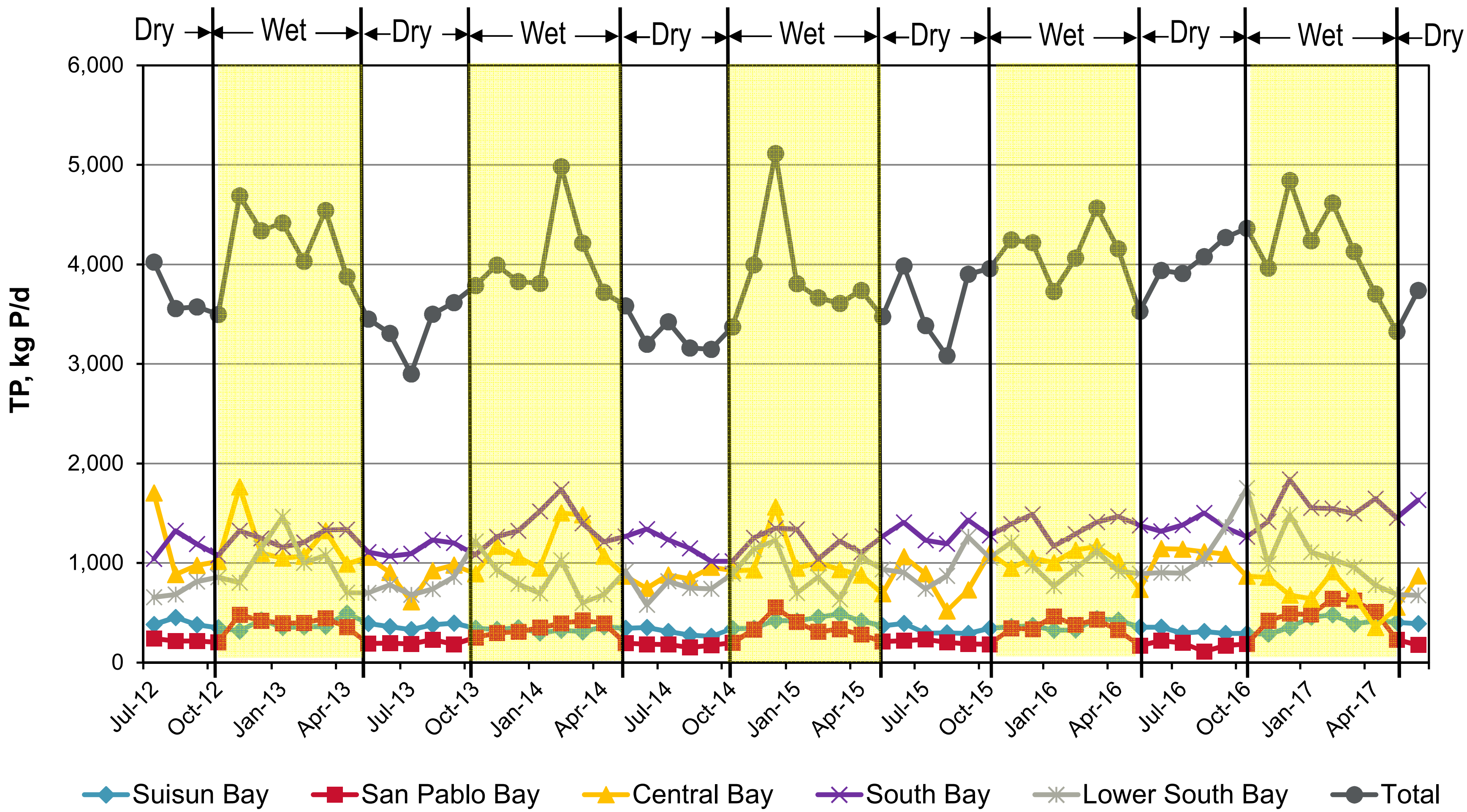
2017 Group Annual Report: Total Nitrogen

- 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%

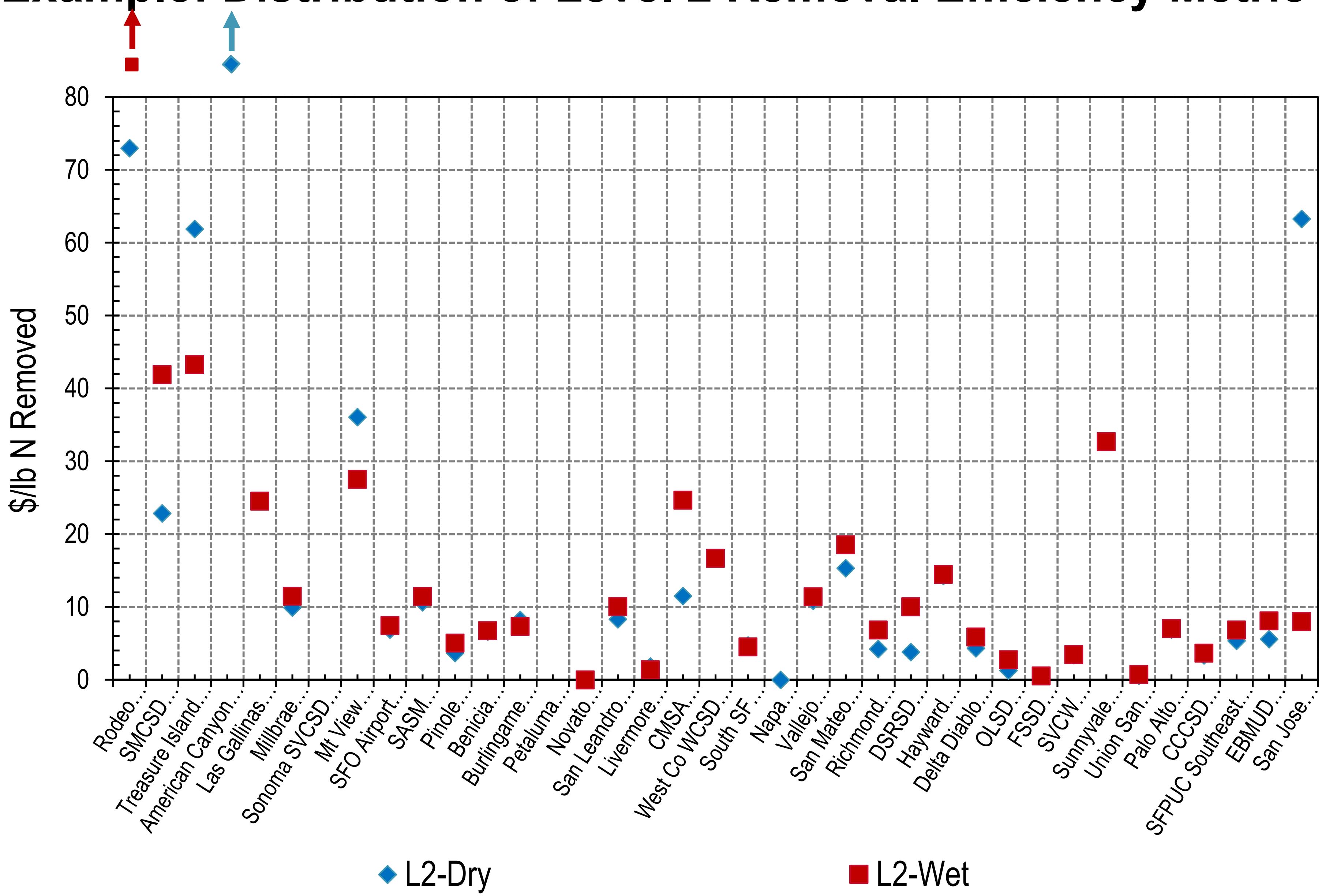
The Plants Currently Reduce Approximately 1/3 of the Ammonia/Nitrogen and 2/3 of the Phosphorus Loads

Draft Report Comments

Draft Report: Comments Applicable to all Reports

Comment	Response
How do you calc $/lb?	Added language to the report AND planning to update the calculation
GHG emissions section needs more clarity. What is the intent and how does this apply to AB 32 and reporting	Additional clarifying language added that addresses the intent, permit requirements, and nitrous oxide emissions
Is Level 2 to 3 additive for capital or stand-alone?	Stand-alone; clarifying language added

Example: Distribution of Level 2 Removal Efficiency Metric



Distribution of $/lb for TN Load Reduction

Dry Permit (Operate Nutrient Removal Year-Round)

Parameter	Total PV, $ Mil	Load Reduction (klb/d)	Years	$/lb
Optimization	120	12	10	2.7
Sidestream	630	30	30	1.9
Level 2	5,800	103	30	5.1
Level 3	7,300	131	30	5.1

Year-Round Permit

Parameter	Total PV, $ Mil	Load Reduction (klb/d)	Years	$/lb
Optimization	150	13	10	3.3
Sidestream	630	30	30	1.9
Level 2	7,300	107	30	6.3
Level 3	9,100	139	30	6.2

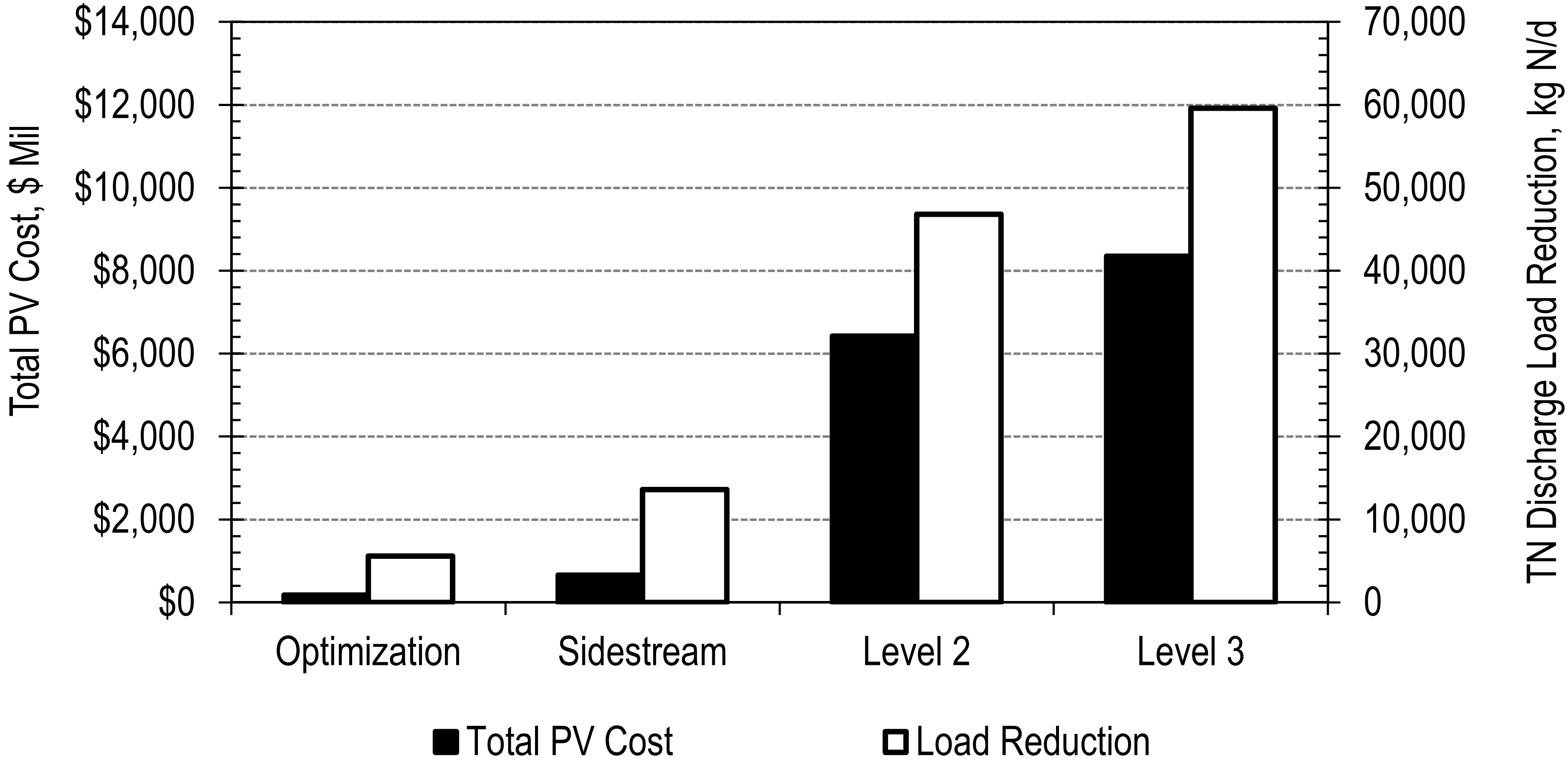
Total PV: Year-Round Permit>>Dry Permit

$/lb N Removed Metrics: Wet>>Dry and Upgrades are Comparable

Draft Findings of Nutrient Removal Reports

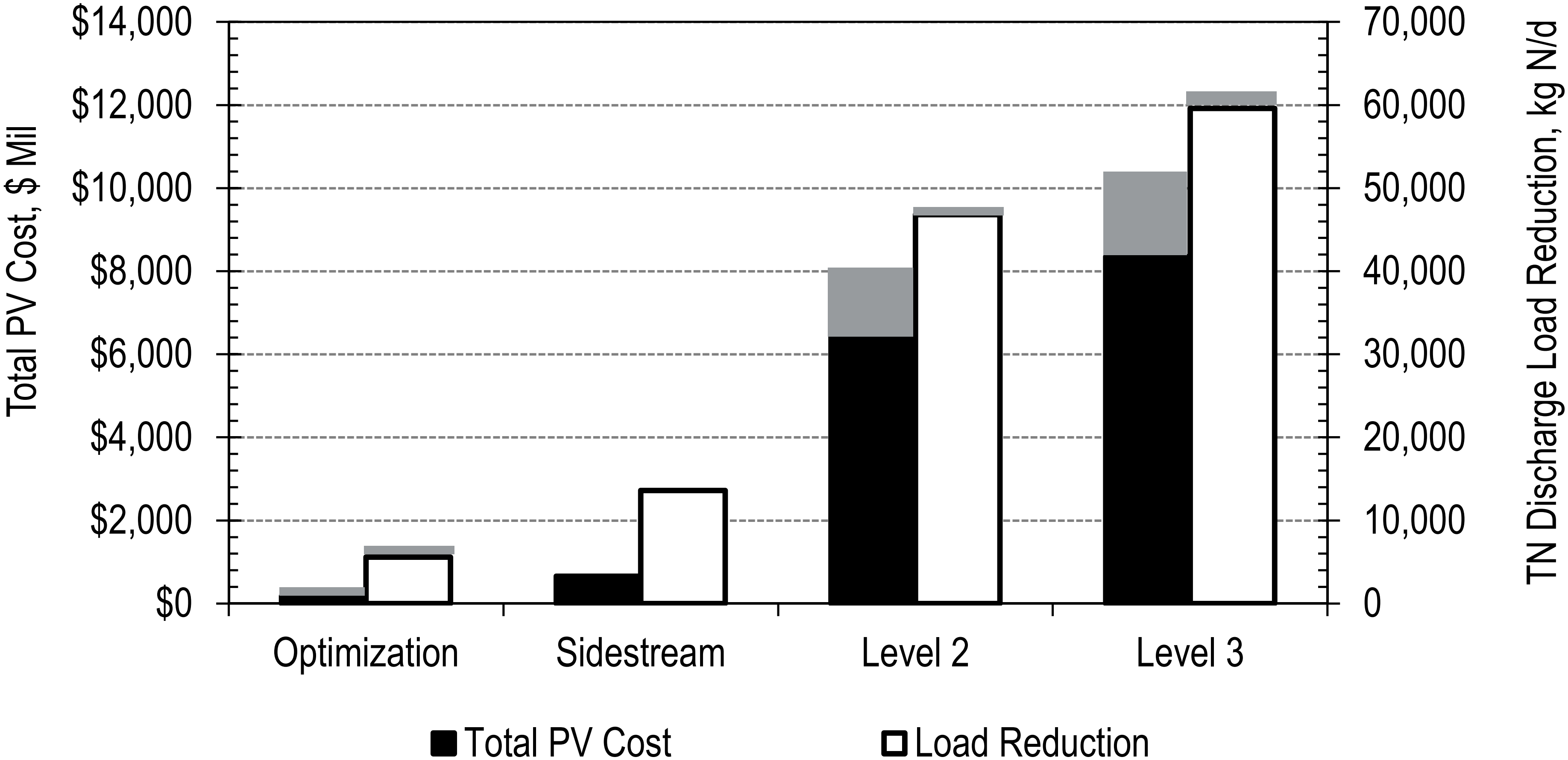
Updated Costs

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

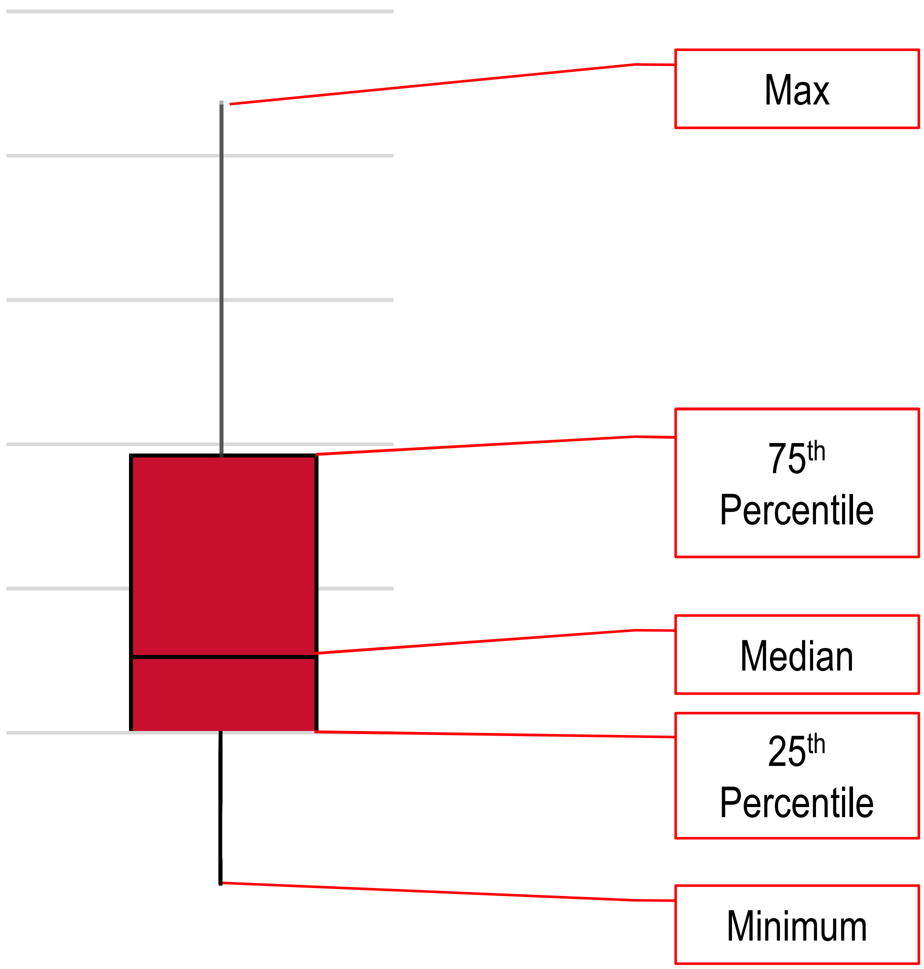
- Total PV
  - $180M Dry Permit and $223M Year-Round Permit
  - Ranged from $0.4M to $28M per plant
- Unit Costs
  - Flow-weighted Total PV unit cost = ~$0.4/gpd
  - Total PV/lb N rem = ~$3/lb N
  - Total PV/lb P rem = ~$7/lb P
- Not all plants can reduce ammonia/TN loads for both dry and year-round permits:
  - 21 of 37 plants for dry permit reduction
  - 19 of 37 plants for year-round reduction

Load Reduction w/Respect to Current Discharge:

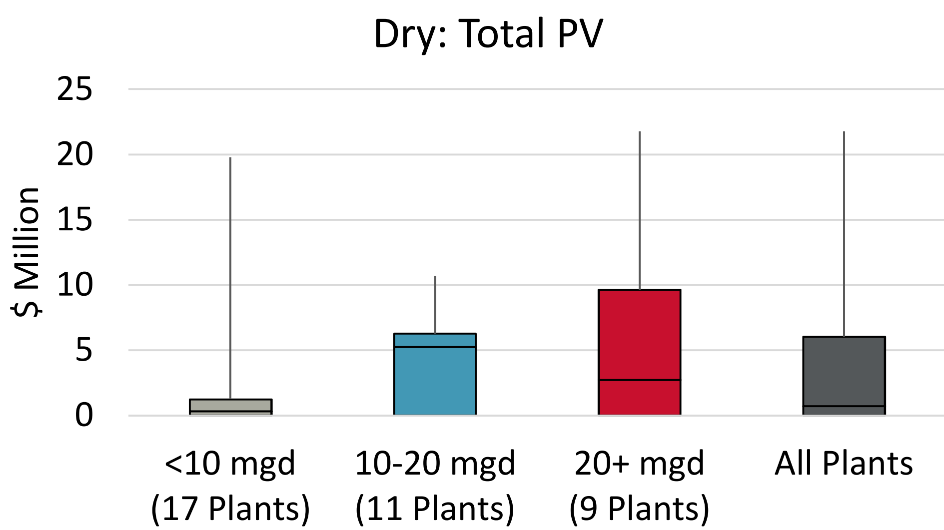
- Ammonia load reduction is 18%
- TN load reduction is 10%
- Overall TP load reduction is 44%

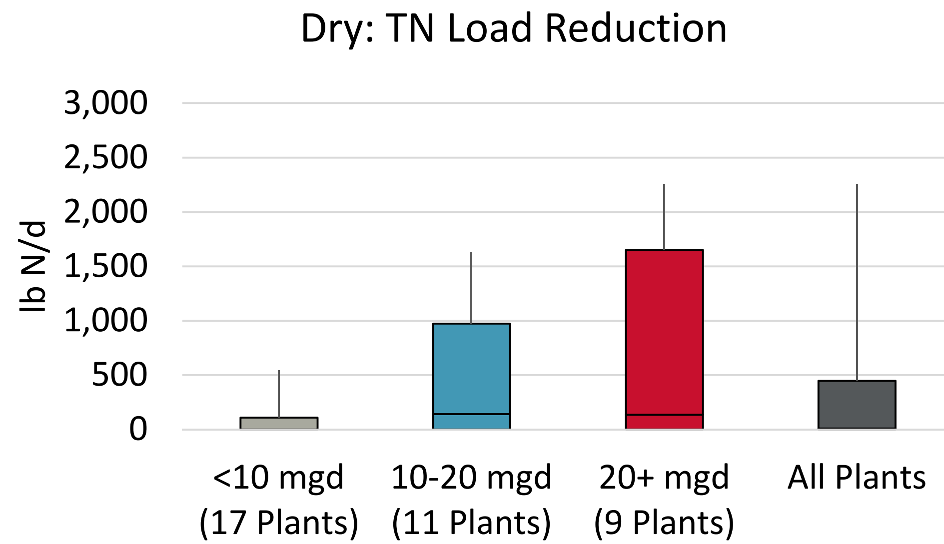
Box and Whisker Plots

- 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

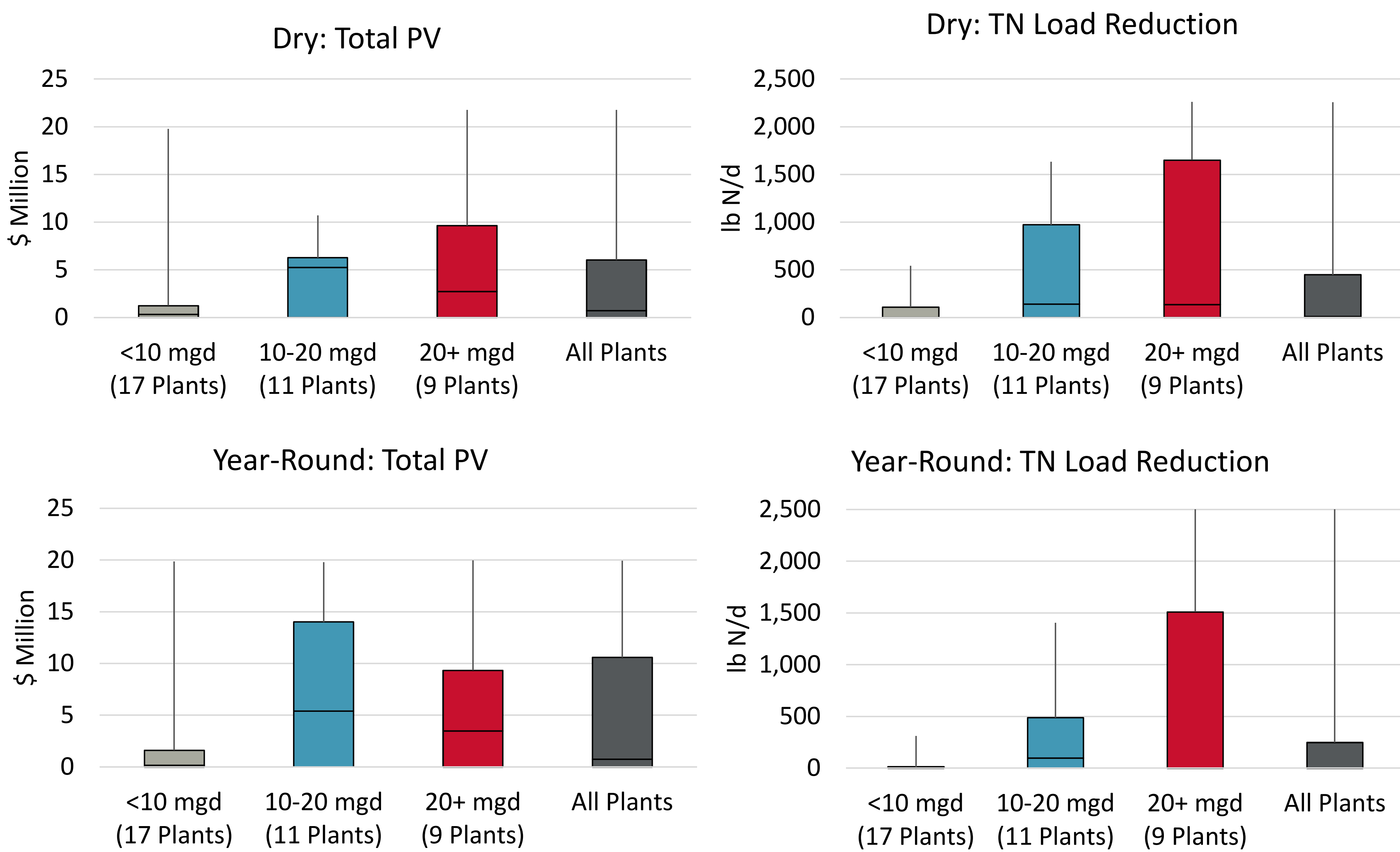


Optimization Total PV Costs and Load Reduction





Optimization Total PV Costs and Load Reduction

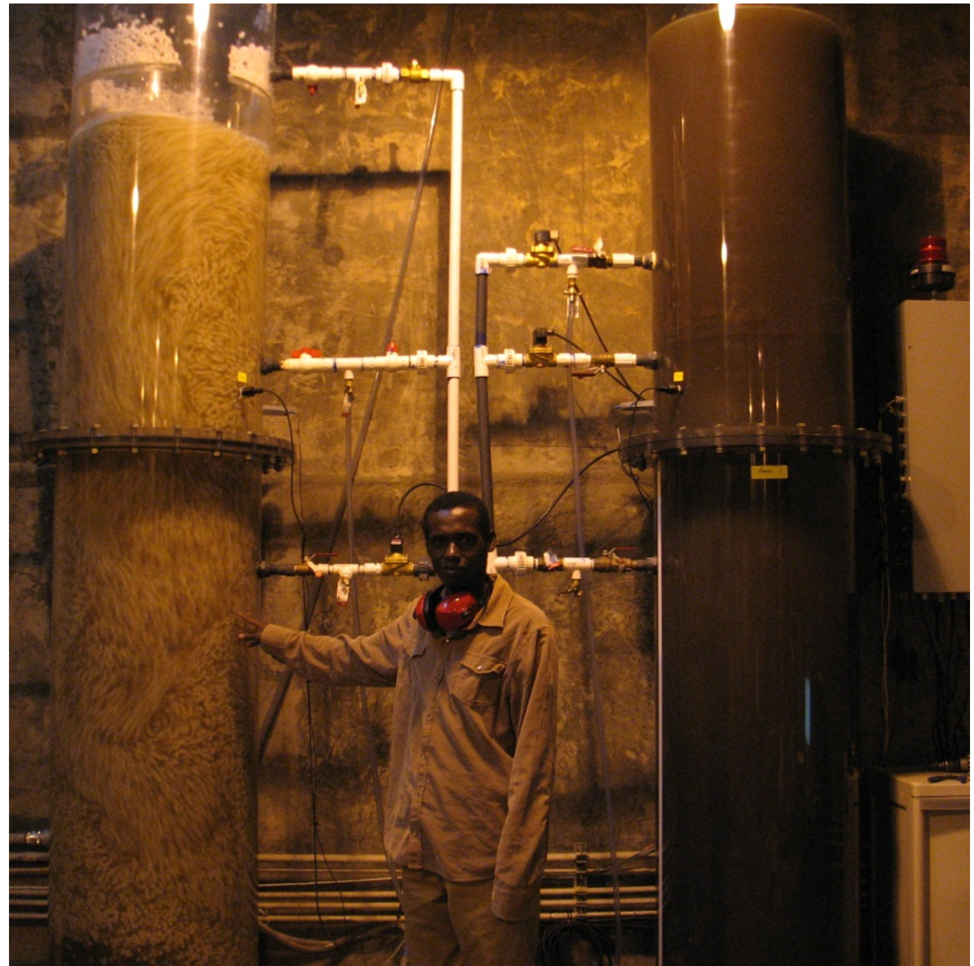


Preliminary Sidestream Results

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 (≥4 days/week)
    - Water temperature governs technology selection
- Concepts
  - Ammonia/TN Removal:
    - Conventional nitrification technology
    - Deammonification technology
  - TP Removal: metal salt precipitation

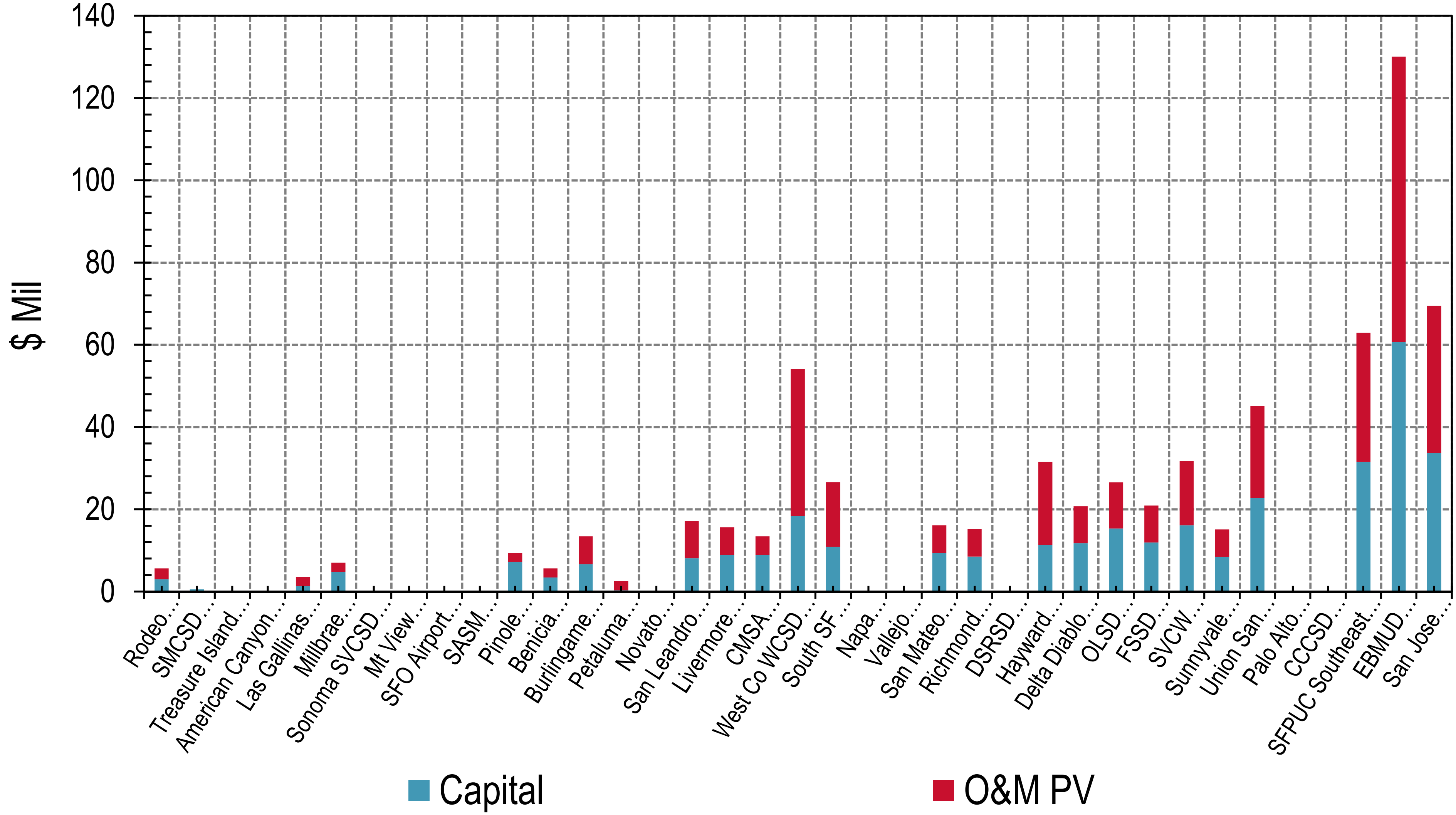
- Acknowledgements
  - EPA Regional Grant led by EBMUD
  - Agencies that hosted pilots: EBMUD, SPFUC SEP, DD, OLSD, USD, CCCSD



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 ($\geq$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 $660 Mil
  - Removal Metric = $1.9/lb N removed
- The overall Ammonia/TN load reduction from Current Discharge is 21 and 17 percent, respectively

Preliminary Upgrades Results

DRAFT Upgrade Findings

Which nutrients are easiest to remove?

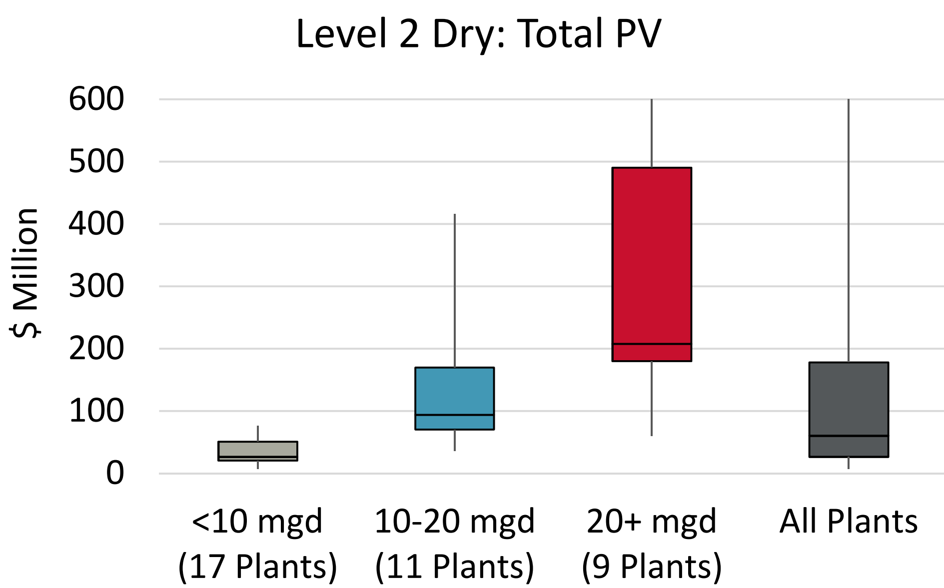
- Ammonia is the most difficult and expensive
  - Bigger basins due to increasing SRT for act sludge plants
  - Expanded aeration system
  - Additional pumping
- TN load reduction requires ammonia removal
  - Level 3 typically require an external carbon source
- TP load reduction is the simplest/most 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

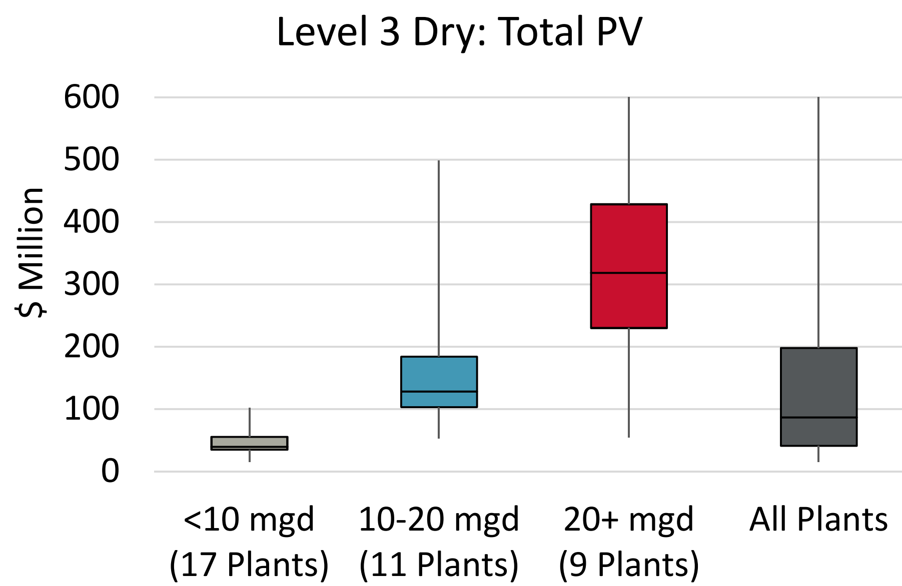
Costs

- Total PV Costs
  - Level 2 = $6.4B Dry & $8.1B Year-Round
  - Level 3 = $8.4B Dry & $10.4B Year-Round
- Total PV Cost Range per Plant
  - Level 2 = $3.8M to $2,240M per plant
  - Level 3 = $21M to $2,470M per plant
- Unit Costs
  - Level 2: $5/lb N Dry & $6/lb N Year-Round
    $30/lb P Dry & $38/lb P Year-Round
  - Level 3: $5/lb N Dry & $6/lb N Year-Round
    $39/lb P Dry & $46/lb P Year-Round

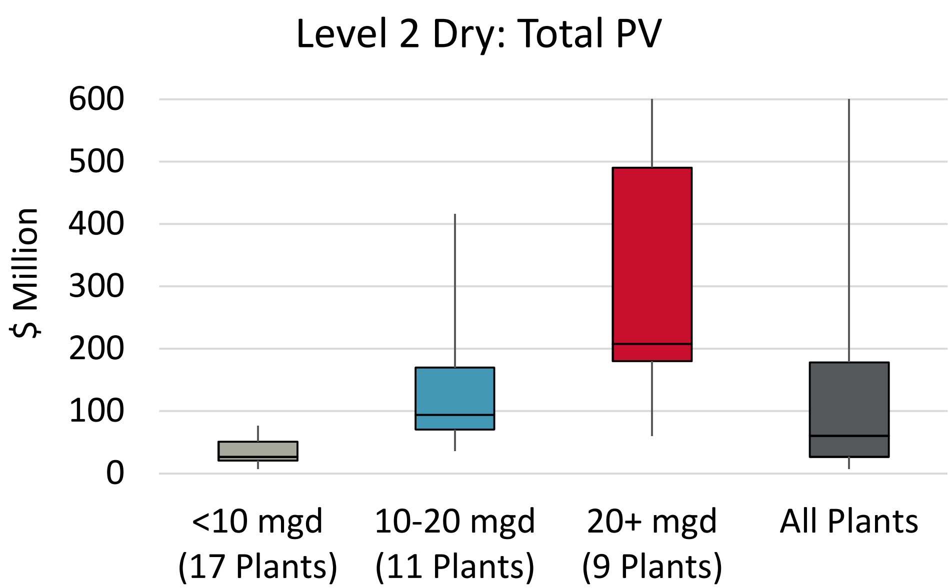
Parameter	Level 2 Load Reduction	Level 3 Load Reduction
Ammonia	>88%	>88%
Total N	>65%	>84%
Total P	>63%	>89%

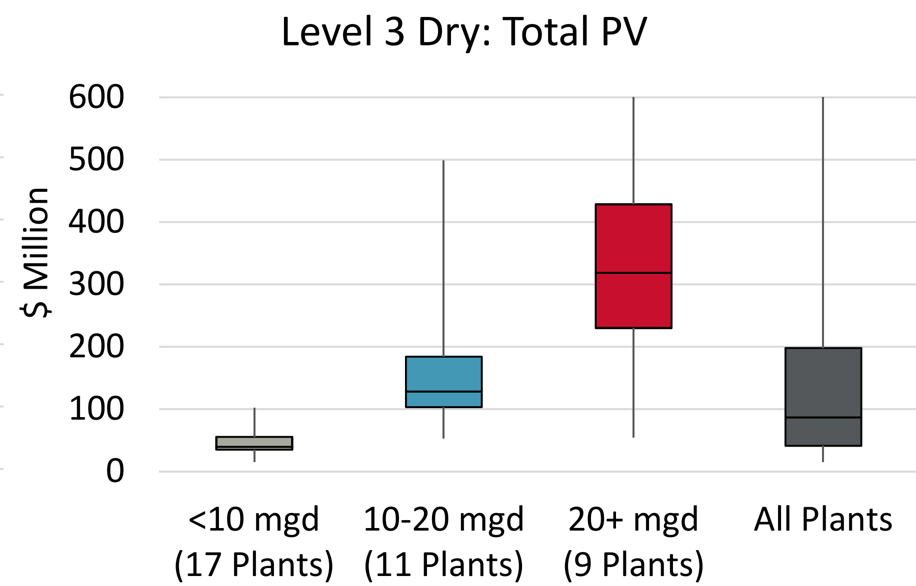
Upgrades Total PV Costs

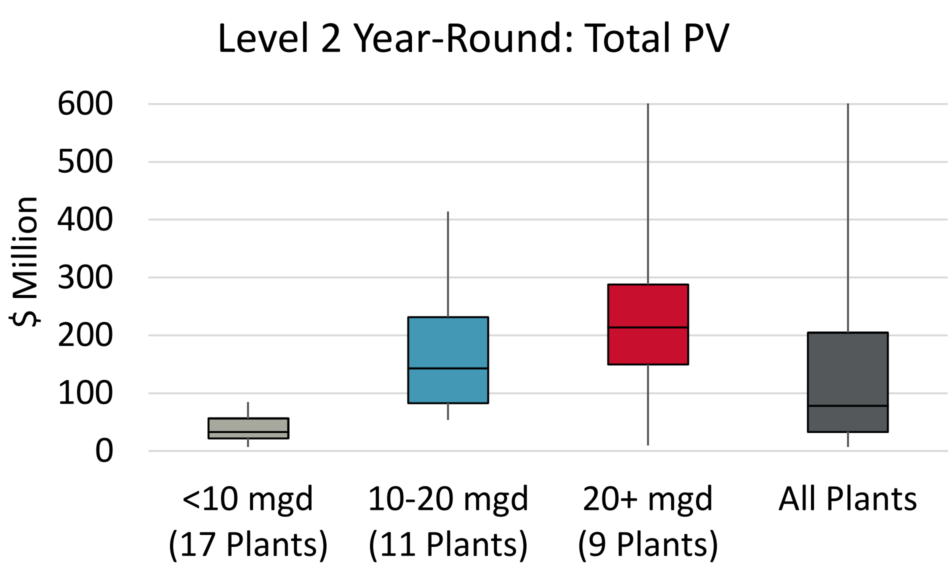


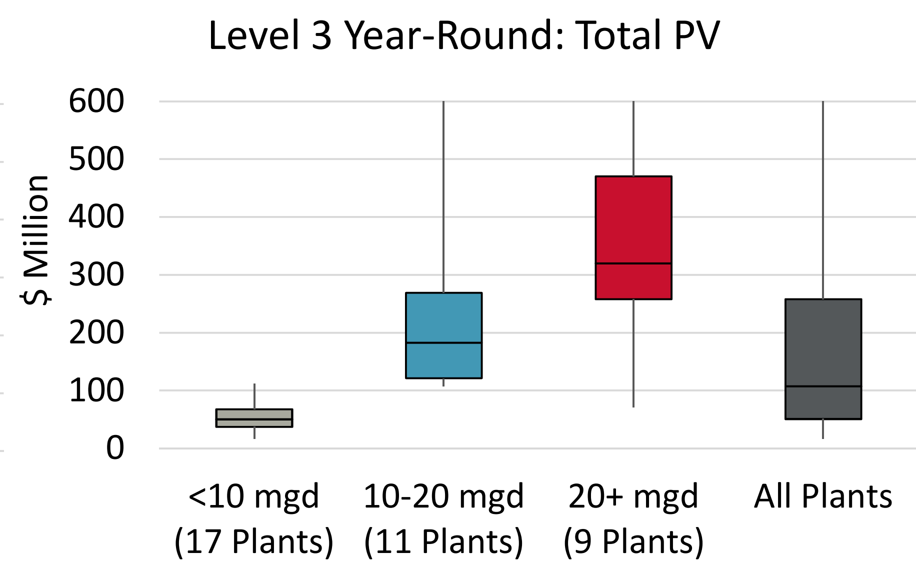


Upgrades Total PV Costs



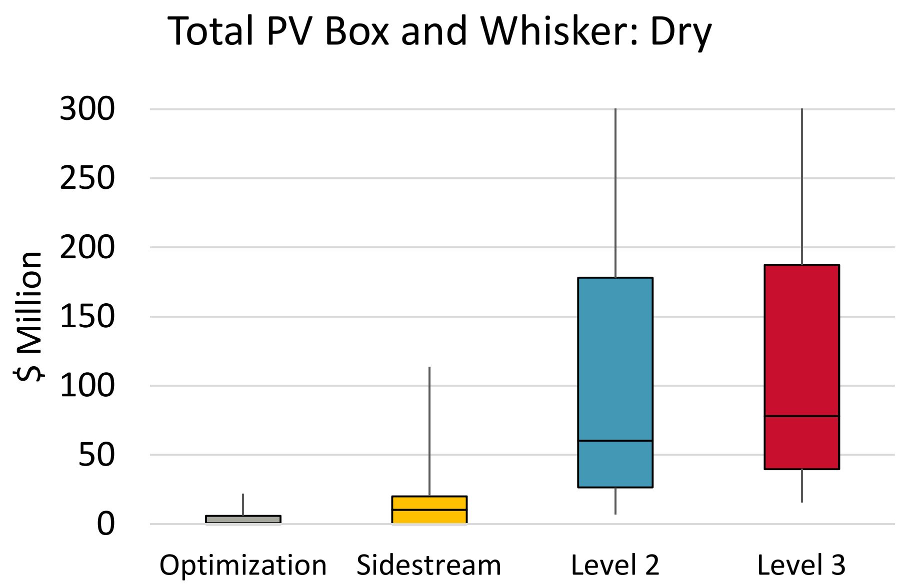


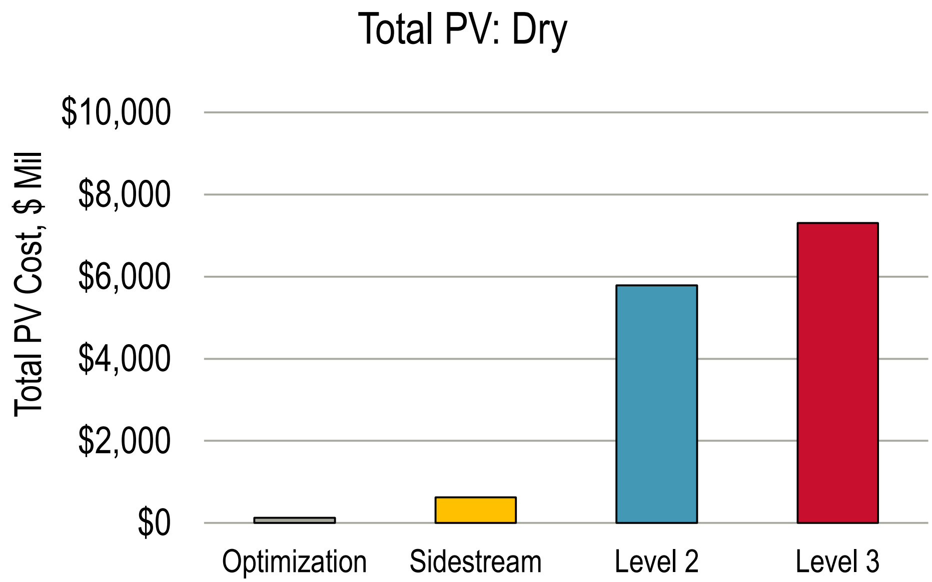


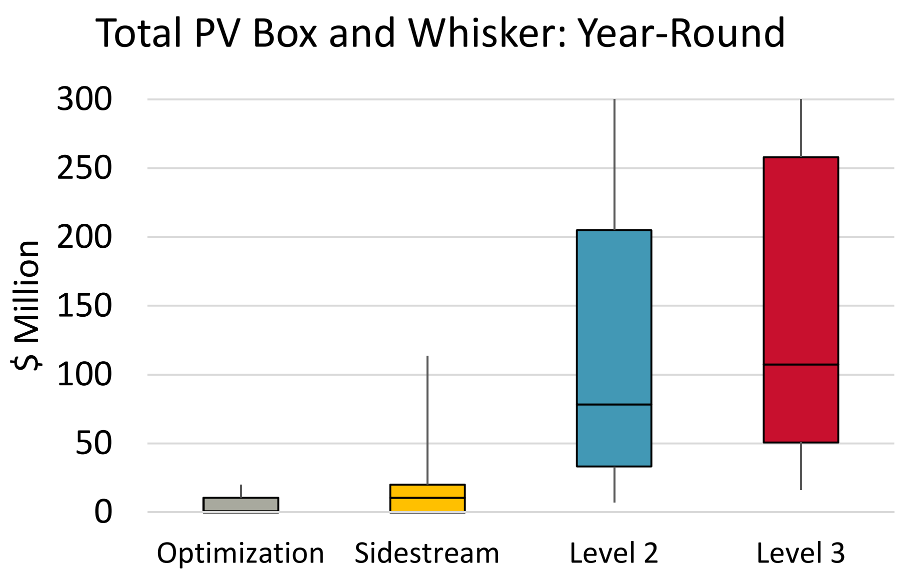


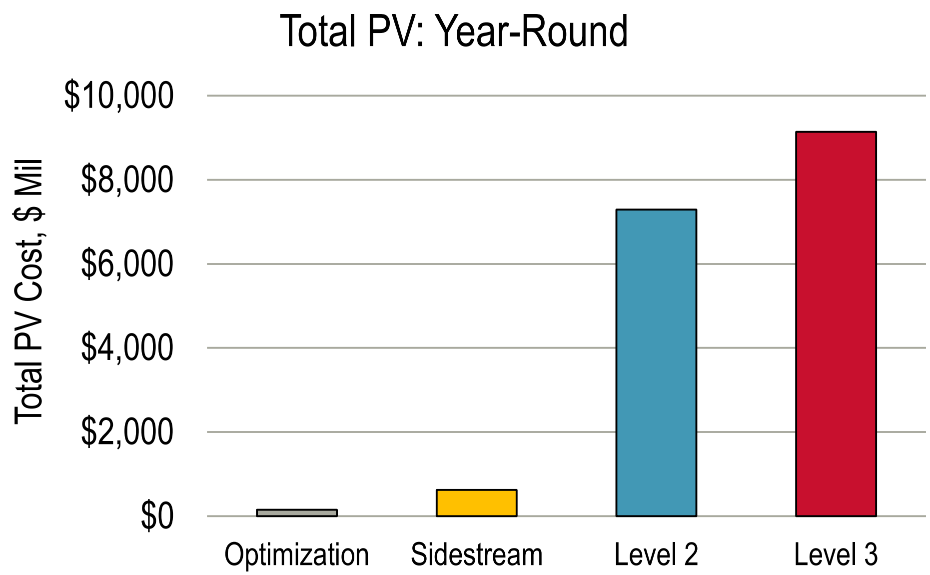
Summary of Results

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

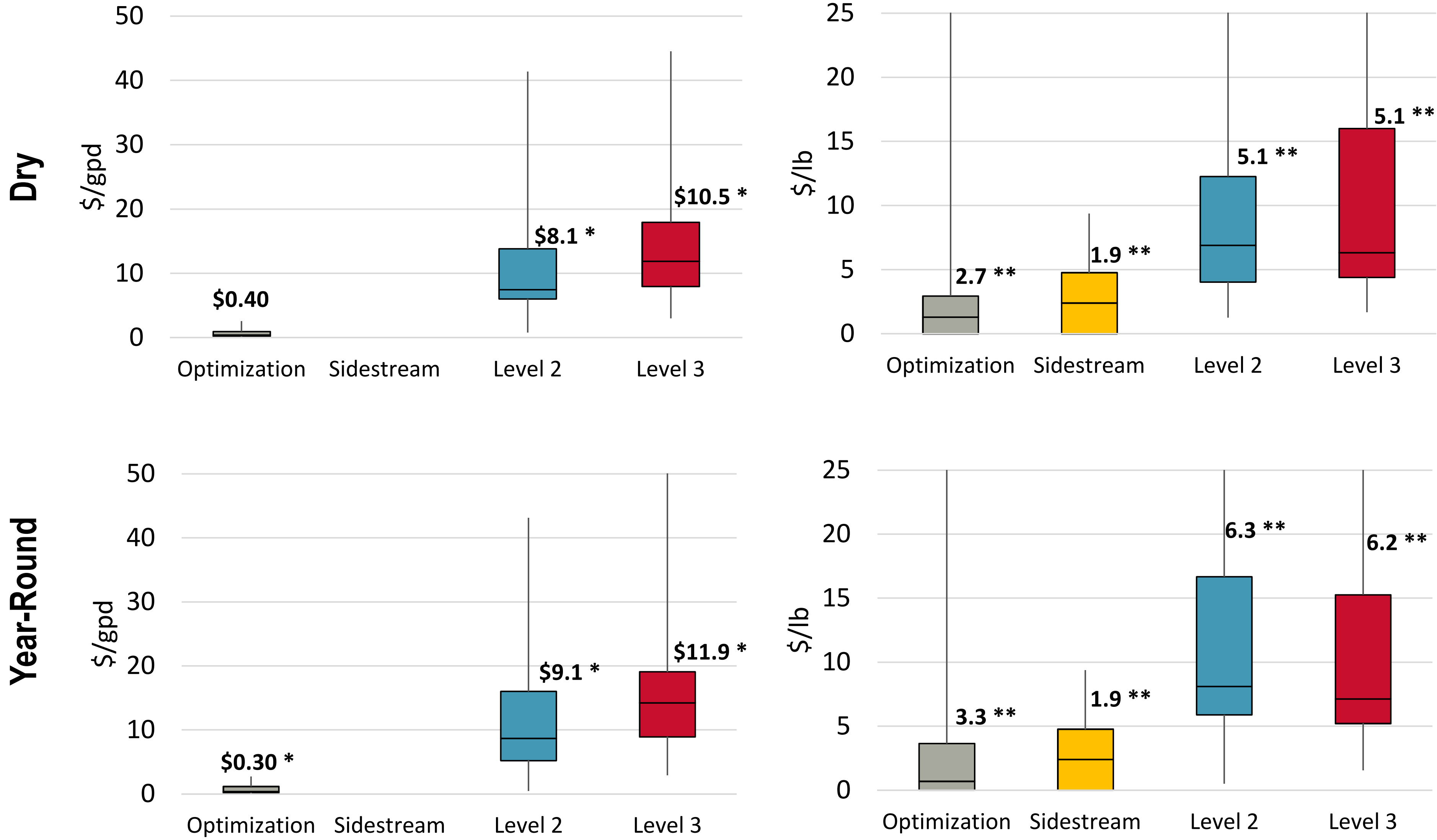








Box and Whisker Plots for TN Load Reduction Metrics: Unit Total PV, $/gpd (Left) and Removal Efficiency, $/lb (Right)



* Flow-Weighted Average for each Parameter

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

Insights

Key Cost Drivers

1. Role of Capital in Total PV (60 – 70% for upgrades)

2. 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

3. Wet weather flow capacity for nutrient load reduction is problematic for several of the plants

4. Site constraints will push several of the plants towards compact technologies, such as MBR (8 plants in the Draft Reports)

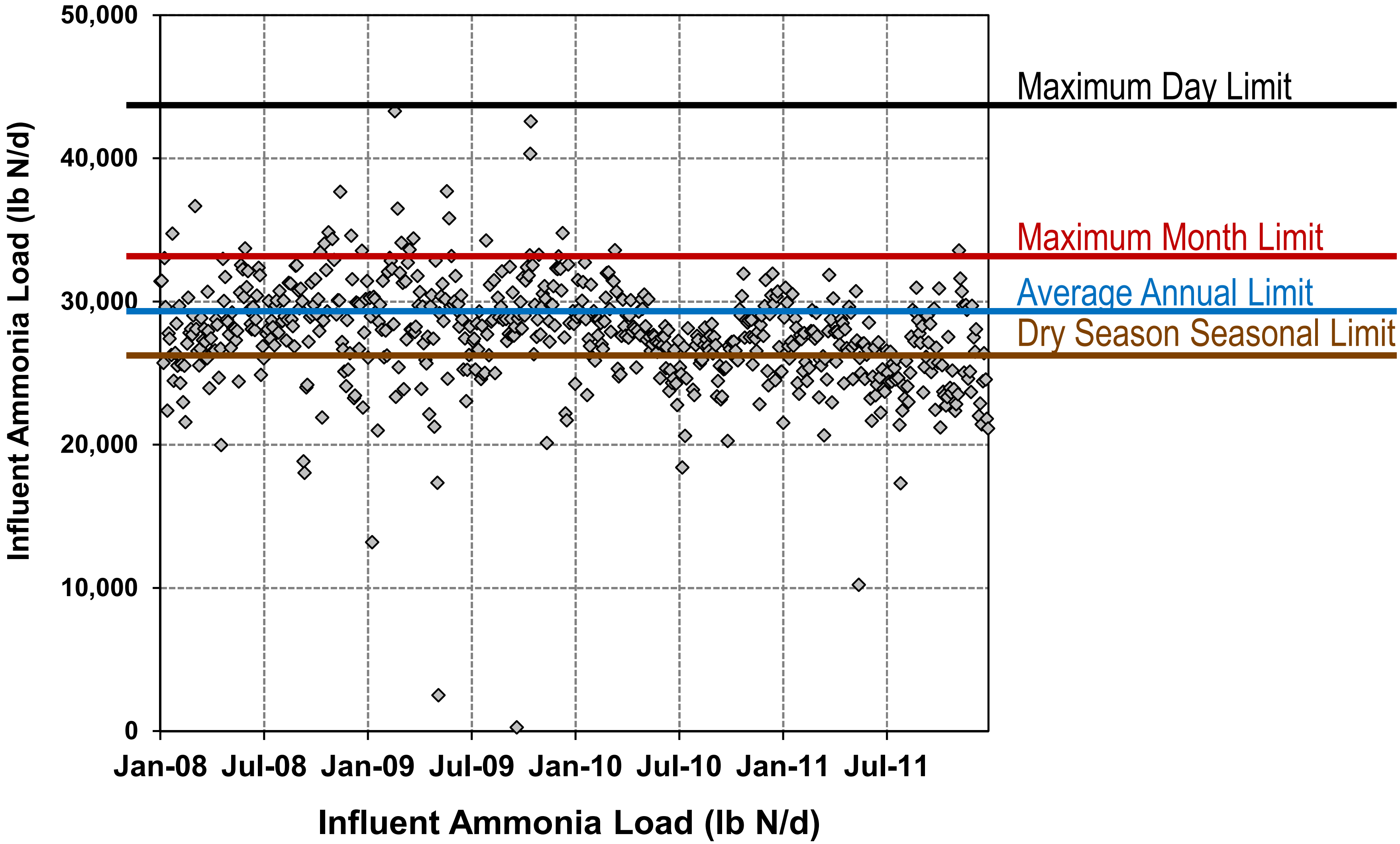
5. Construction estimates have changed since the effort began

6. SF Bay Area is resource limited; planning and prioritization would be key for implementation

7. SRF funding is limited or not available. Plants using bond funding would have higher costs

Role of Averaging Periods

Importance of Averaging Periods



Role of Averaging Periods on SRT and Basin Volume

Averaging Periods Govern the SRT and Overall Basin Volume

Role of Averaging Periods on Cost: Oro Loma for Level 3

Parameter	Units	Dry Season			Wet Season		
		Ave Annual	Max Month	Max Day	Ave Annual	Max Month	Max Day
Capital PV	$ Mil	60	68	84	66	73	110
O&M	$ Mil /yr	5.7	6.0	6.3	6.1	6.6	7.1
O&M PV	$ Mil	130	134	140	137	147	159
Total PV	$ Mil	190	202	224	203	221	267
NH4 Load Reduction *	%	97	99	>99	92	99	>99

* Dataset used from Hampton Roads Sanitation District VIP Plant as there is daily data over 6-years that enabled an accurate depiction of ammonia load reduction for the various averaging periods

Wet Weather Flow Capacity

Sizing Nutrient Load Reduction Facilities for Peak Flows can Result in Additional Facilities and Impact Footprint, Costs, and Ops

Case Study: City of Millbrae

- 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 compact footprint technology due to peaks

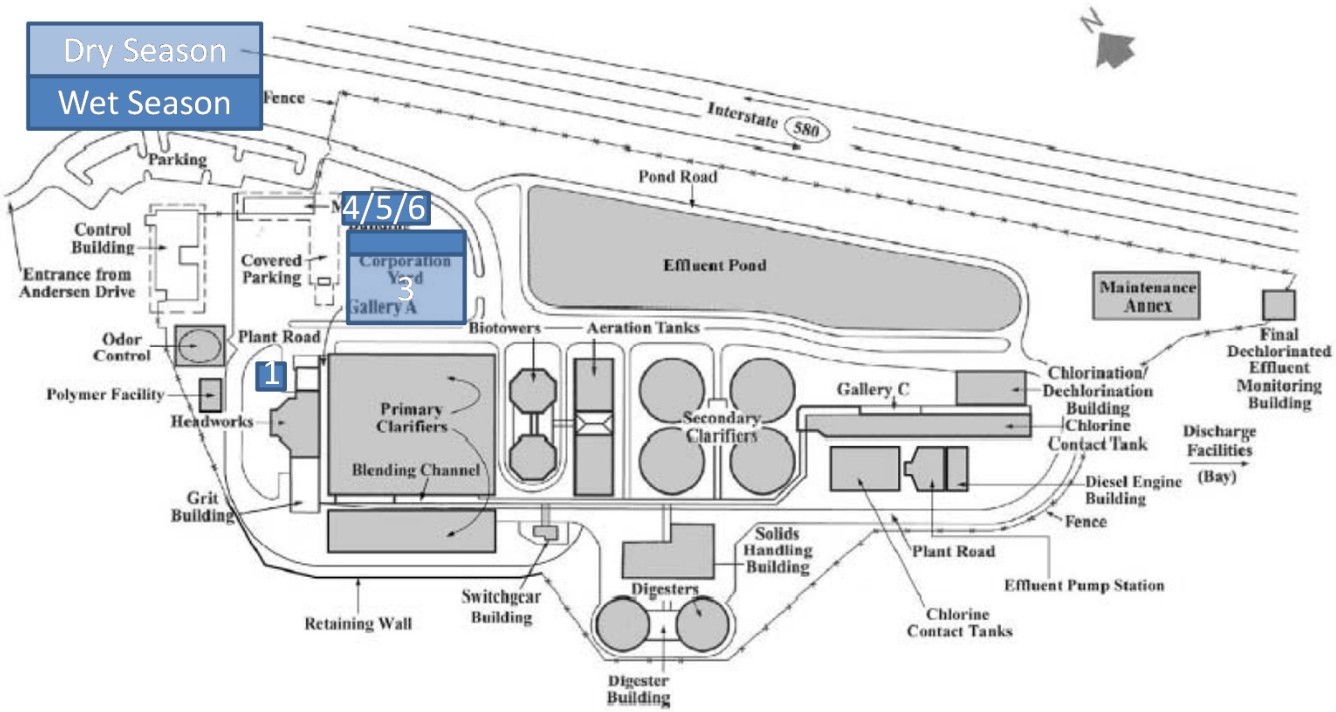
(1) Optimize ferric addition, (2) add polymer, (3) convert act sludge to MBR, (4) expand the aeration basins to create a third train, (5) add alkalinity, (6) add external carbon, (7) decommission the chlorination disinfection system (use for additional aeration basin volume), and (8) add an ultraviolet disinfection system.

Space Constraints

Sizing Nutrient Load Reduction Facilities with Level 3 in Mind Can Result in More Costly Technologies due to Footprint Constraints

Case Study: CMSA

- 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 highway or steep hills
- 8 Plants were pushed to compact footprint technology due to space constraints



(1) Use existing ferric chloride for CEPT, (3) Add MBR facilities, (4) add an external carbon source, (5) add alkalinity, and (6) add ferric chloride

Construction Cost Estimates

The DRAFT Cost Estimates are Based on the 2015 Construction Climate

Construction Cost Estimates used in Draft Reports

Planning to update to reflect current pricing environment

Undefined Items	Values
Undefined Unit Processes	20%
Miscellaneous Site Structures	15%
Site Conditions	
Sitework	10%
Yard Piping	5%
Soil Conditions	7%
Site Electrical Power Distribution	1%
Contractor's Costs	
Field General Conditions, Mobilization, Demobilization	12%
Sales Tax (Allowance)	8%
General Contractor Overhead and Profit	10%
Bonds and Insurance	1.5%
Construction Contingency - Change Orders	4%
Soft Costs	
Engineering	10%
Construction Management	10%
Legal, Fiscal, Administration, Environmental	5%

Assumed ENR SF Bay Index of 11,155 (January, 2015)

Unit	Unit Cost
Power	$0.17 per kWh
Labor	$150 per hour
50% Sodium Hydroxide	$350 per ton
Sodium Hypochlorite	$0.43/gal for 12.5%
Ferric Chloride	$619/dry ton
Hydrated Lime	$396/wet ton (45% alkali lime)
Liquid Alum	$0.80/gal
Methanol	$1.25/gal
Citric Acid	$6.38/gal or $1.15/lb
Polymer (Emulsion)	$9.10/gal which is $1.07/lb

Technology Selection

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

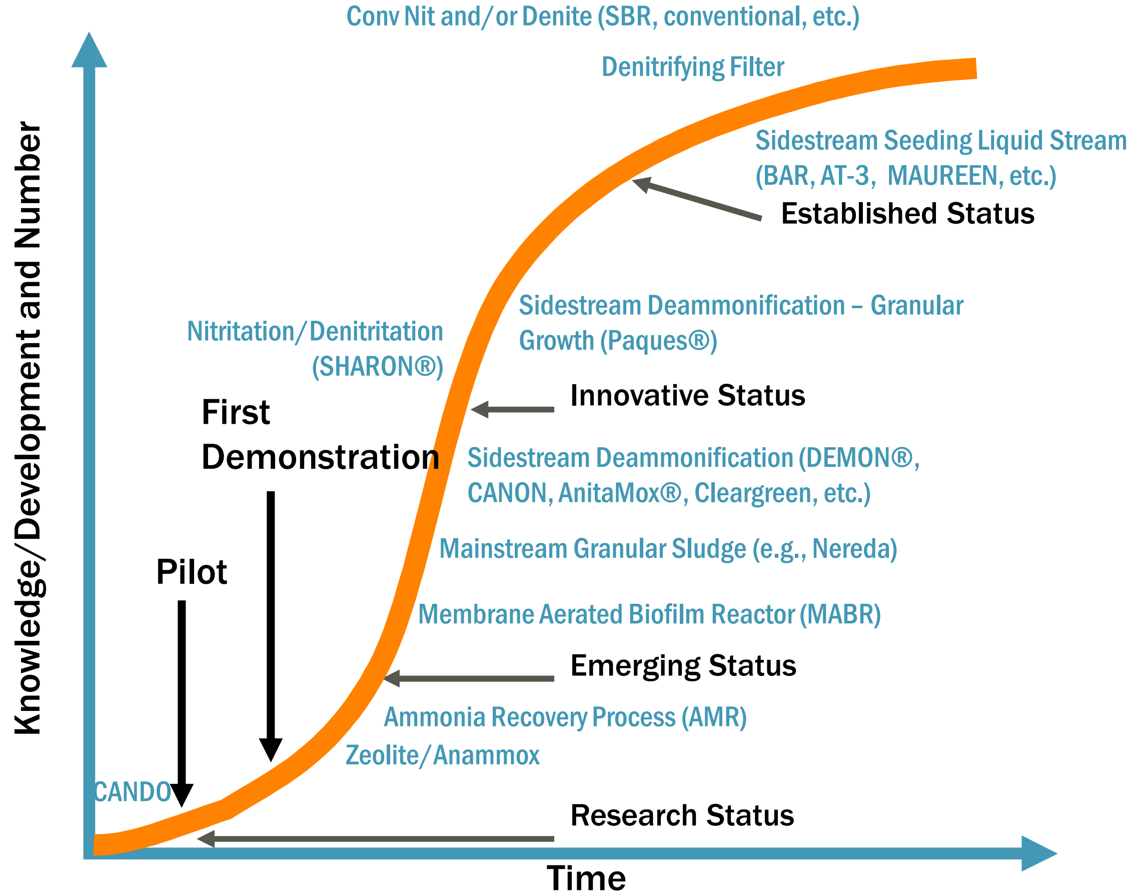
Technology Selection

Assumed established technologies for Draft Reports:

- Confidence in cost estimates
- Footprints are well understood
- Energy and chemicals demands are well understood

Emerging Technologies

- Listed up to 2 technologies per plant to monitor
- They are typically more compact and require less energy/chemicals than established technologies
- The preferred emerging technologies will become established technologies in the future



Adapted from Tetra Tech (2013) and Parker et al. (2011)

Role of Phosphorus

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**

Wet Season

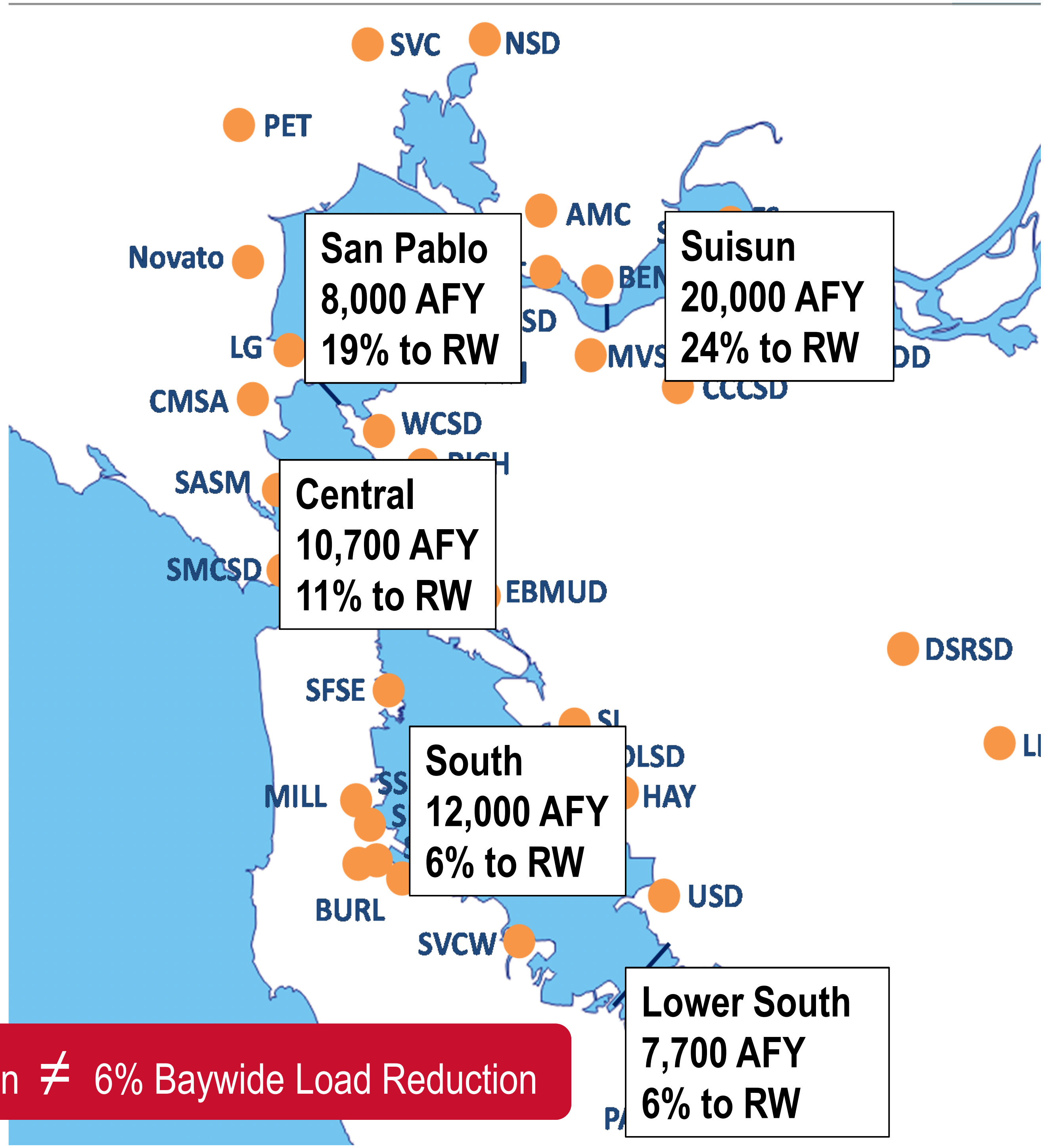
Parameter	Level 2		Level 3	
	Total N	Both N and P	Total N	Both N and P
Capital, $ Bil	5.1	5.2	5.9	6.2
O&M PV, $ Bil	2.2	2.4	3.2	3.8
Total PV, $ Bil	**7.3**	**7.6**	**9.1**	**10.0**

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

Recycled Water

Current Recycled Water Quantities

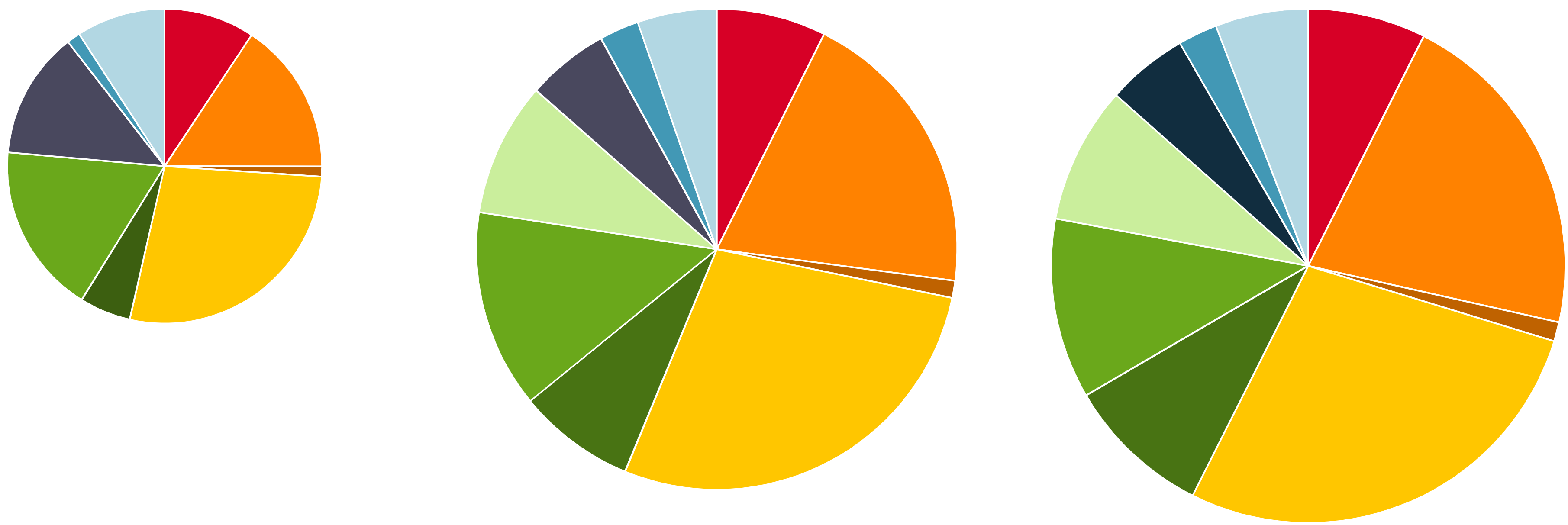
- ~6% of Baywide plant effluent goes to recycled water
- Recycled water is expected to double by 2035
- The primary application is industrial (~40%)



6% Baywide Flow Reduction ≠ 6% Baywide Load Reduction

Recycled Water Distribution over Time

Year 2015 (58,000 AFY)	Year 2030 (117,000 AFY)	Year 2040 (131,000 AFY)



Nutrient Reduction:	Nutrient Reduction:	Nutrient Reduction:
760 kg NH4/d	2,200 kg NH4/d	2,600 kg NH4/d
1,700 kg N/d	3,500 kg N/d	4,000 kg N/d

- Golf Course Irrigation
- Landscape
- Commercial
- Industrial
- Agricultural
- Environ. Enhancement
- Internal Use
- GW Recharge
- Other Non-Potable Reuse
- Not Defined

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

Next Steps

- Updated Plant Reports by Thanksgiving
- Draft Main Body Report in December

Pardee Workshop: Nutrient Reduction by Optimization and Upgrades Update

27 October 2017

HDR

Brown AND Caldwell

BACWA
BAY AREA
CLEAN WATER
AGENCIES