Balancing Nutrient Limits with Net Environmental Benefits

JB Neethling
HDR Engineering

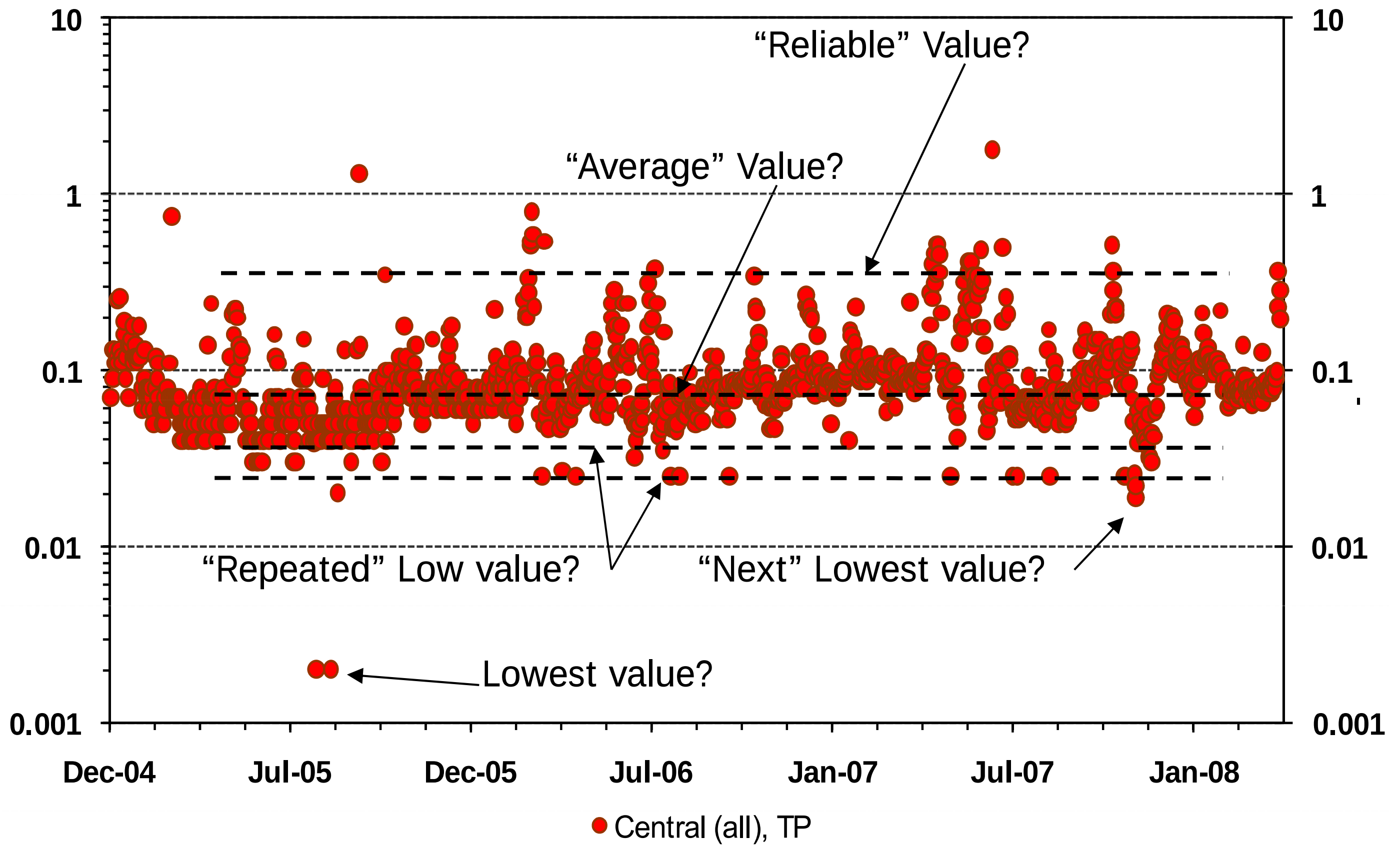
“Real World Wastewater Technologies Workshop”
CBP’s Scientific & Technical Advisory Committee (STAC)
Richmond, VA
May 16, 2012

Outline

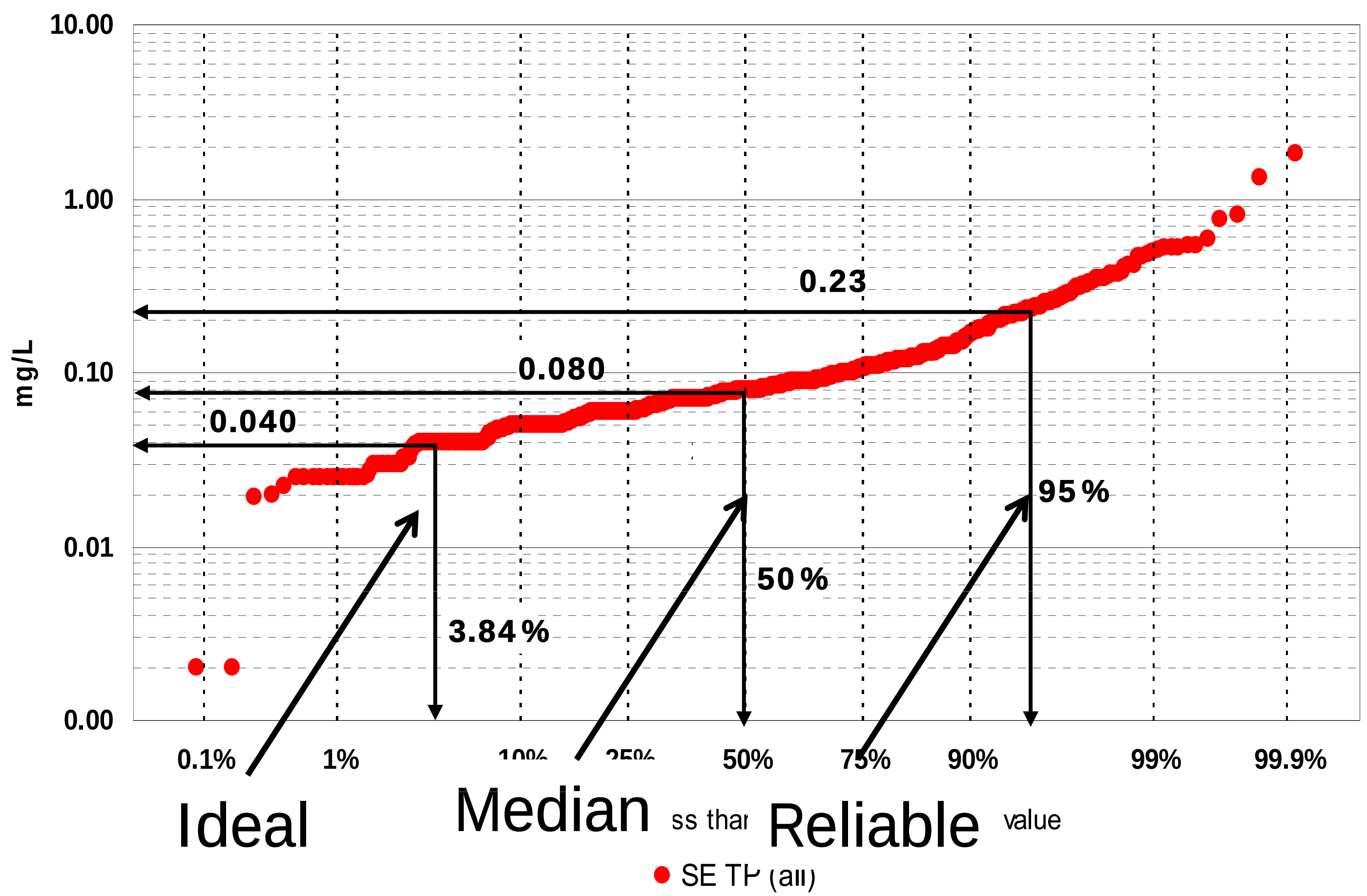
- How reliable does good operating plants perform?
- What are the costs/features/break points of nutrient removal?
- What are the benefit/impact of nutrient removal limits?

How well does good operating plants perform?

What is the Best “Performance” for This Real-World WWTP Dataset?



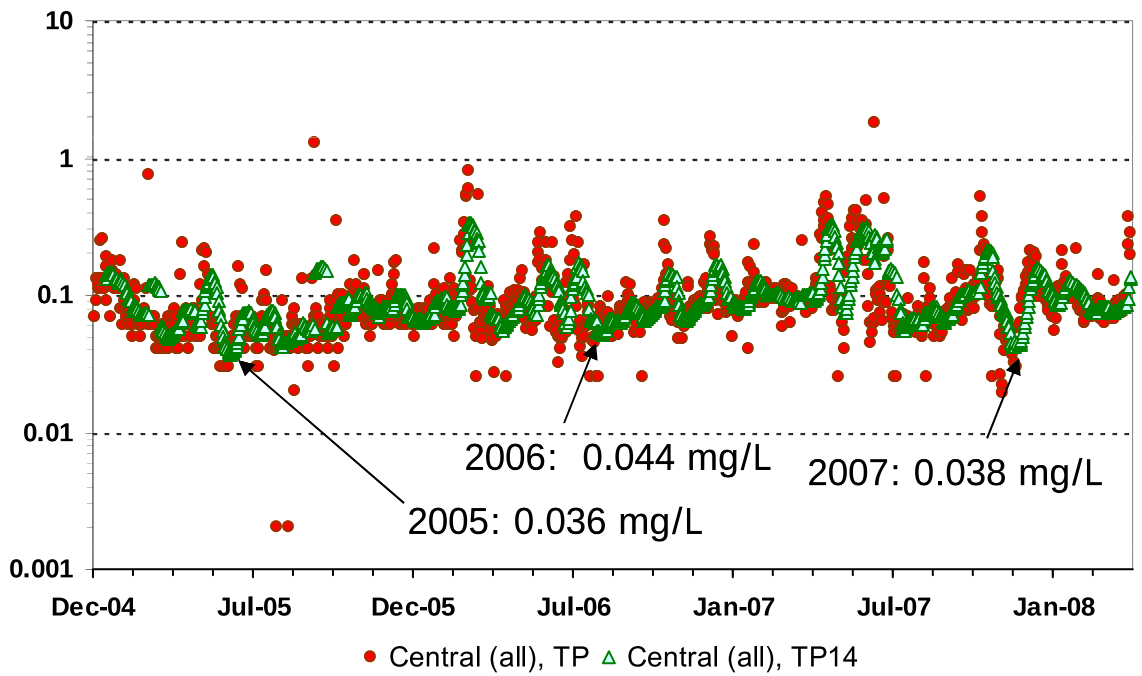
Define Performance on a Statistical Basis



Three TPSs shown

- TPS-14d (3.84%)
  - Ideal Performance
  - 14-day performance level
- TPS-50%
  - Median Performance
  - “Average” performance
- TPS-95%
  - Reliable Technology Achievable Performance

14-day Values Can Vary – Using Rolling Average



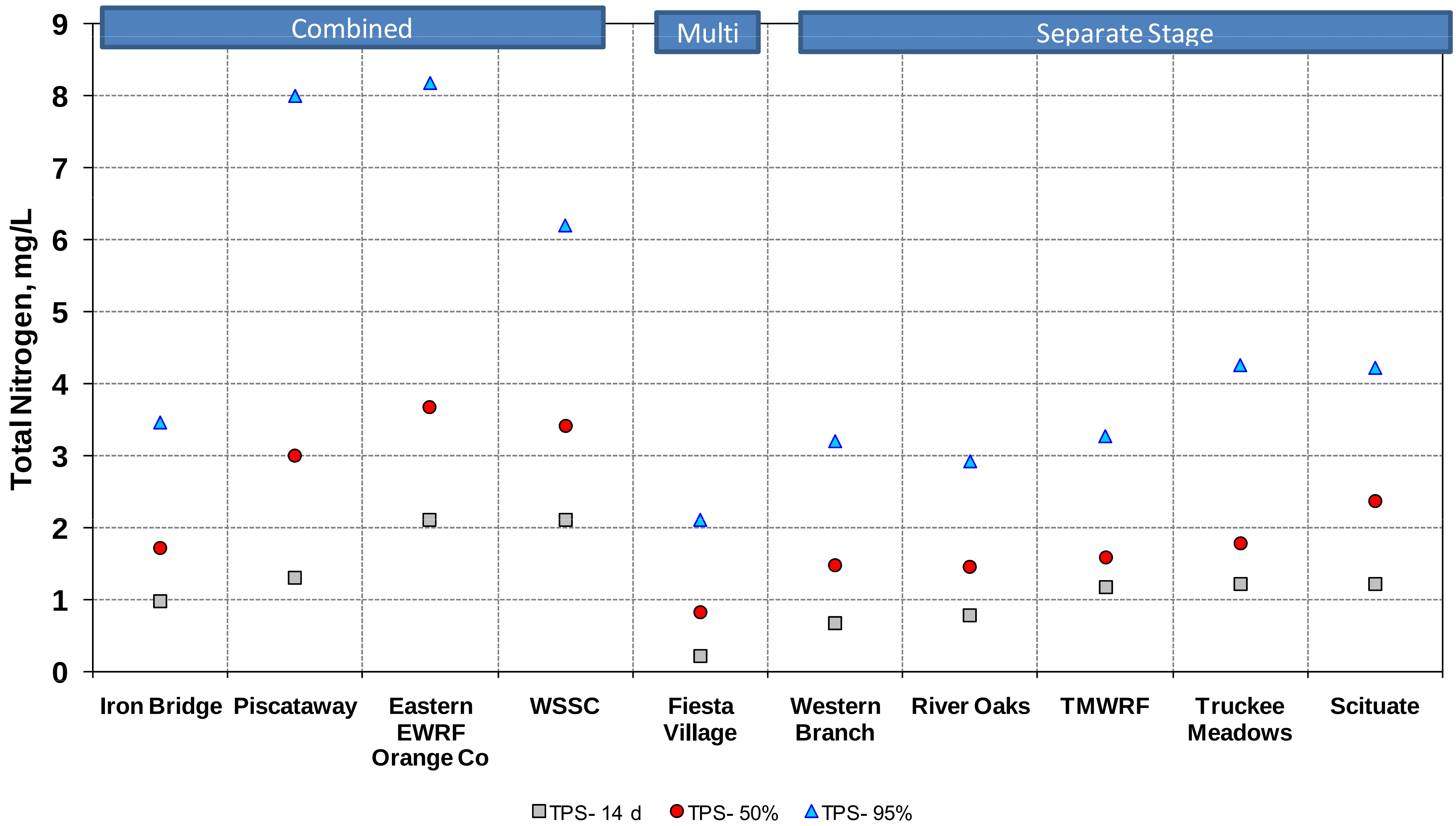
WERF

Nitrogen Process Types

- Separate Stage
  - Separate processes for nitrification, dentrification
  - MeOH added
  - Filter (denitrification)
- Combined
  - Conventional, multiple cell BNR (MLE, Bardenpho, step feed, etc.
  - Effluent filter (no MeOH)
- Multiple Stage
  - Conventional plus denitrification filter

WERF

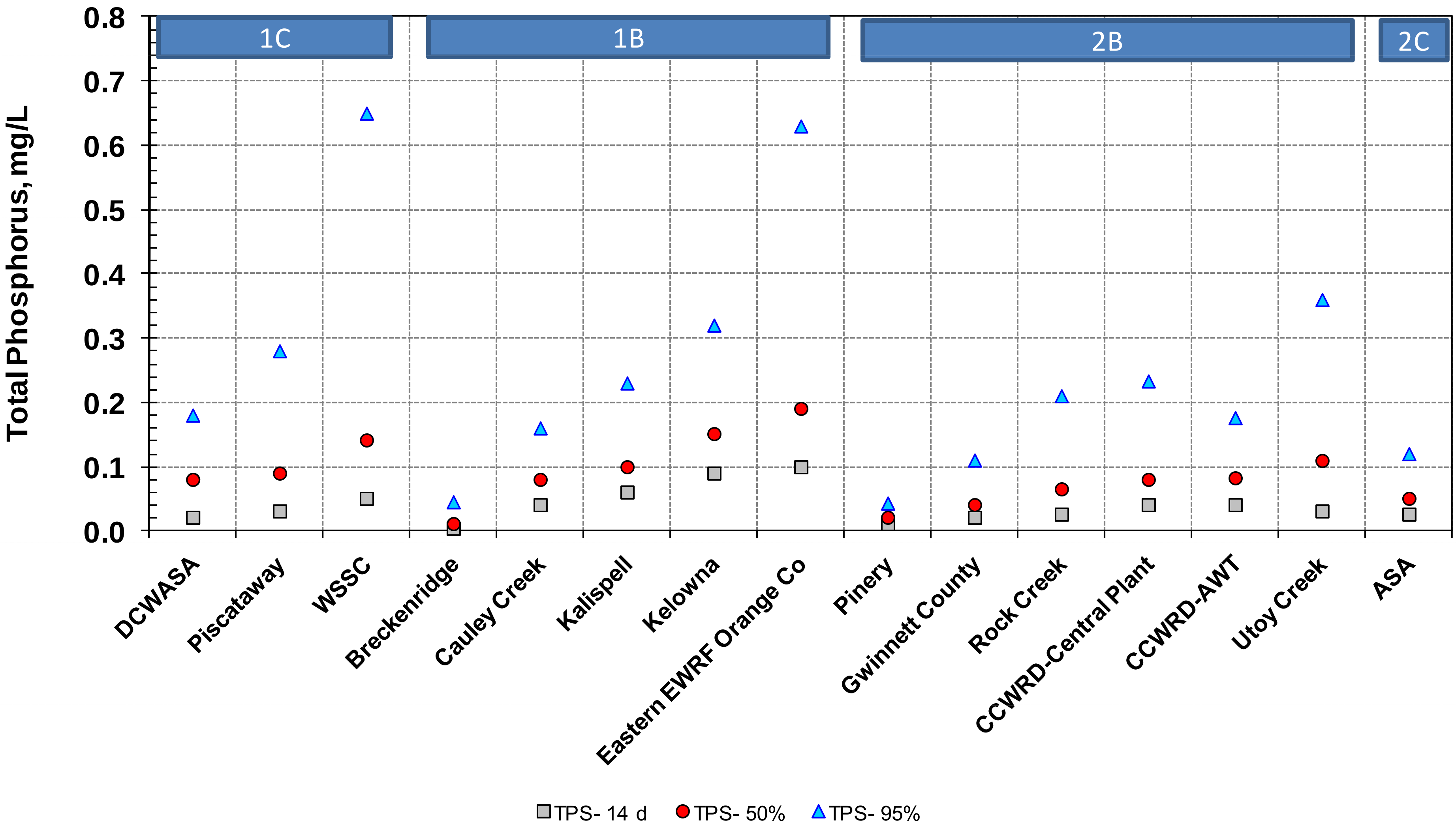
Results: Total Nitrogen – by Process



Phosphorus Process Types

- 1B = Biological Phosphorus Removal with filter polishing
- 1C = Single Chemical Phosphorus Removal with filter polishing
- 2B = Multistage Biological with Chemical polishing
- 2C = Multistage Chemical with Chemical polishing

Results: Total Phosphorus – by Process



Summary

- Technology performance statistics allow for rational approach to data analysis and technology assessment
- Data from well operated nutrient removal plants demonstrated the variability in performance
  - Nitrogen removal plants shows:
    - Best performance 50-60% of median
    - Reliable performance 180-250% of median
  - Phosphorus removal plants shows:
    - Best performance 40-50% of median
    - Reliable performance 200-300% of median

Permit Period and Reliability

Period	Basis (days)	Sample	Permit Percentile (%)	Reliable Percentile (%)	5 yr Excee-dance
Max Day	1	365	99.7	99.9	1.8
Max Week	7	365	98.1	99	2.6
Max Month	30	365	91.8	95	3
Ann Avg	182.5	365	50	90	0.5

WERF

Permit Period and Reliability

Period	Basis (days)	Sample	Permit Percentile (%)	Reliable Percentile (%)	5 yr Excee-dance
Max Day	1	365	99.7	99.9	1.8
Max Week	7	365	98.1	99	2.6
Max Month	30	365	91.8	95	3
Ann Avg	182.5	365	50	90	0.5

Exceed once a year!

Acceptable Risk?

WERF

Reliability at the Permit Limit - TP

Plant	Process	Permit	%	Exceed #Mo/5yr	Exceed #yr/5yr	Period
Breckenridge	2B	0.05	95.7%	2.6	0.2	M
Pinery	2B	0.05	92.8%	4.3	0.4	M
Rock Creek	2B	0.10	72.3%	16.6	1.4	M (50%)
Cauley Creek	1B	0.13	85.7%	8.6	0.7	M
Gwinnett Co	2B	0.13	96.8%	1.9	0.2	M
CCWRD-AWT	2B	0.14	81.7%	11.0	0.9	M
CCWRD-Central	2B	0.14	81.7%	11.0	0.9	M
Kalispell	1B	0.15	76.5%	14.1	1.2	M
ASA	2C	0.18	98.5%	0.9	0.1	M
DCWASA	1C	0.18	93.5%	3.9	0.3	A
Piscataway	1C	0.18	84.4%	9.4	0.8	M

WERF

Reliability at the Permit Limit - TN

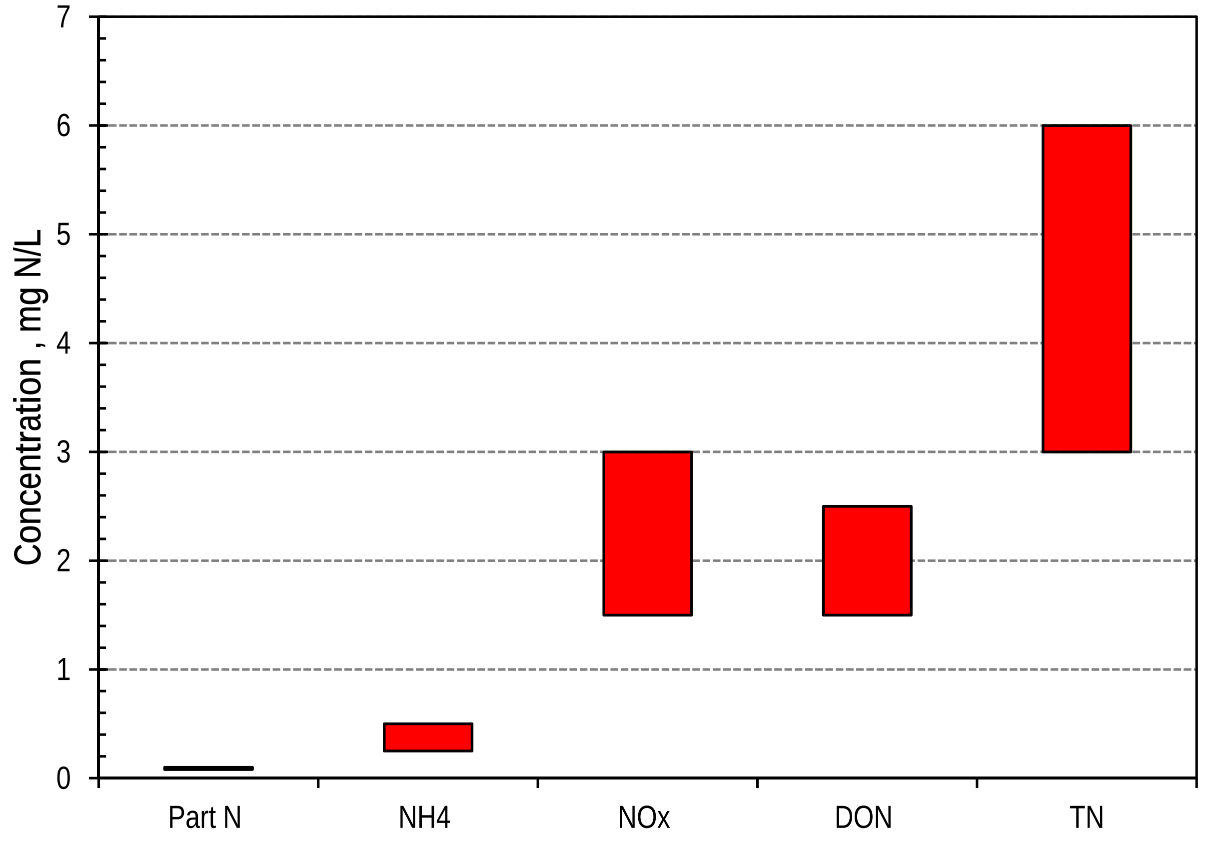
Plant	Process	Permit	%	Exceed #Mo/5yr	Exceed #yr/5yr	Period
TMWRF ('09)	SepSt	2	67.7%	19.4	1.6	M&A
Western Branch	SepSt	3	90.3%	5.8	0.5	M
Fiesta Village	Mult	3	96.8%	1.9	0.2	M&A
River Oaks	SepSt	3	94.6%	3.2	0.3	A
Eastern EWRF Orange Co	Comb	3	34.6%	39.2	3.3	A
Iron Bridge	Comb	3.08	91.9%	4.9	0.4	
Scituate	SepSt	4	87.9%	7.3	0.6	M
WSSC - Parkway	Comb	7	96.8%	1.9	0.2	M
Piscataway	Comb	8	95.8%	2.5	0.2	M

WERF

What is controlling nutrient removal technologies

- What are the nutrient species?
- How well can it be removed?
- What is the removal efficiencies of individual species?
  - Ideal
  - 80th Percentile (1 exceedence/5 yr – annual limit)
  - 95th Precentile (3 exceedences/5 yr – monthly limit)

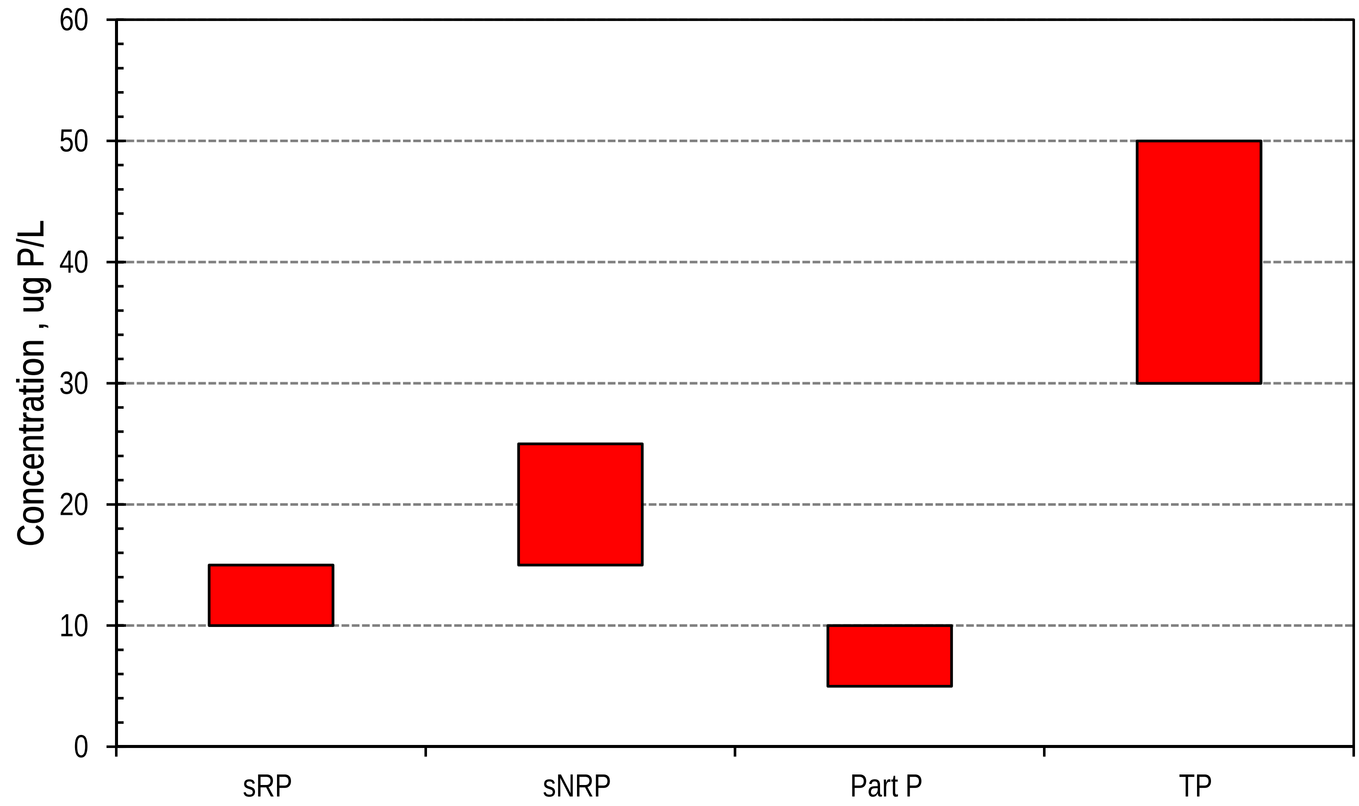
80th and 95th Percentile Nitrogen Species in Advanced Treatment



NH4-N = Ammonia; NOx = Nitrite + Nitrate;
DON = Dissolved Organic Nitrogen; Part N = Particulate N

WERF

80th and 95th Percentile Phosphorus Species in Advanced Treatment



SRP=Soluble Reactive P; SNRP = Soluble Nonreactive P

PP=Particulate P TP = Total P

Can you beat the statistics?

YES!

- At a price…
- Additional facilities
- Increase chemical usage/dose
- Increased solids management cost
- Improved monitoring
- Improved source control – aka reduce influent variability
- BUT…

THERE IS A LIMIT!

WERF

Environmental Impacts and Benefits

Treatment Level Objectives

Level	BOD (mg/L)	TSS (mg/L)	TN (mg N/L)	TP (mg P/L)
1	30	30	-	-
2	<30	<30	8	1
3	<30	<30	4-8	0.1-0.3
4	<30	<30	3	0.1
5	<30	<30	2	<0.02

WERF

Treatment Unit Processes

Level	Primary	Ferm.	Act Sludge Relative Footprint	High Rate Clar.	Filter	MF / RO	Return-Stream Treatment	Metal Salt (Chem.)	Methanol (Chem.)
1	✔		1X						
2	✔		2X		✔			Optional	Optional
3	✔		2-2.5X		✔			✔	✔
4	✔	✔	2-2.5X	✔	Denit.		✔	✔	✔
5	✔		2-2.5X	✔	Denit.	✔ [a]		✔	✔

Tradeoff Between Nutrient Removal and Sustainability

Determine sustainability impacts of five levels of treatment for 10 mgd plant

Determine if there is a point of diminishing returns for sustainability with increased treatment

WERF

What Did We Consider for the Triple Bottom Line?

Economic Pillar:

- Total Project Cost
- O&M Cost

Environmental Pillar:

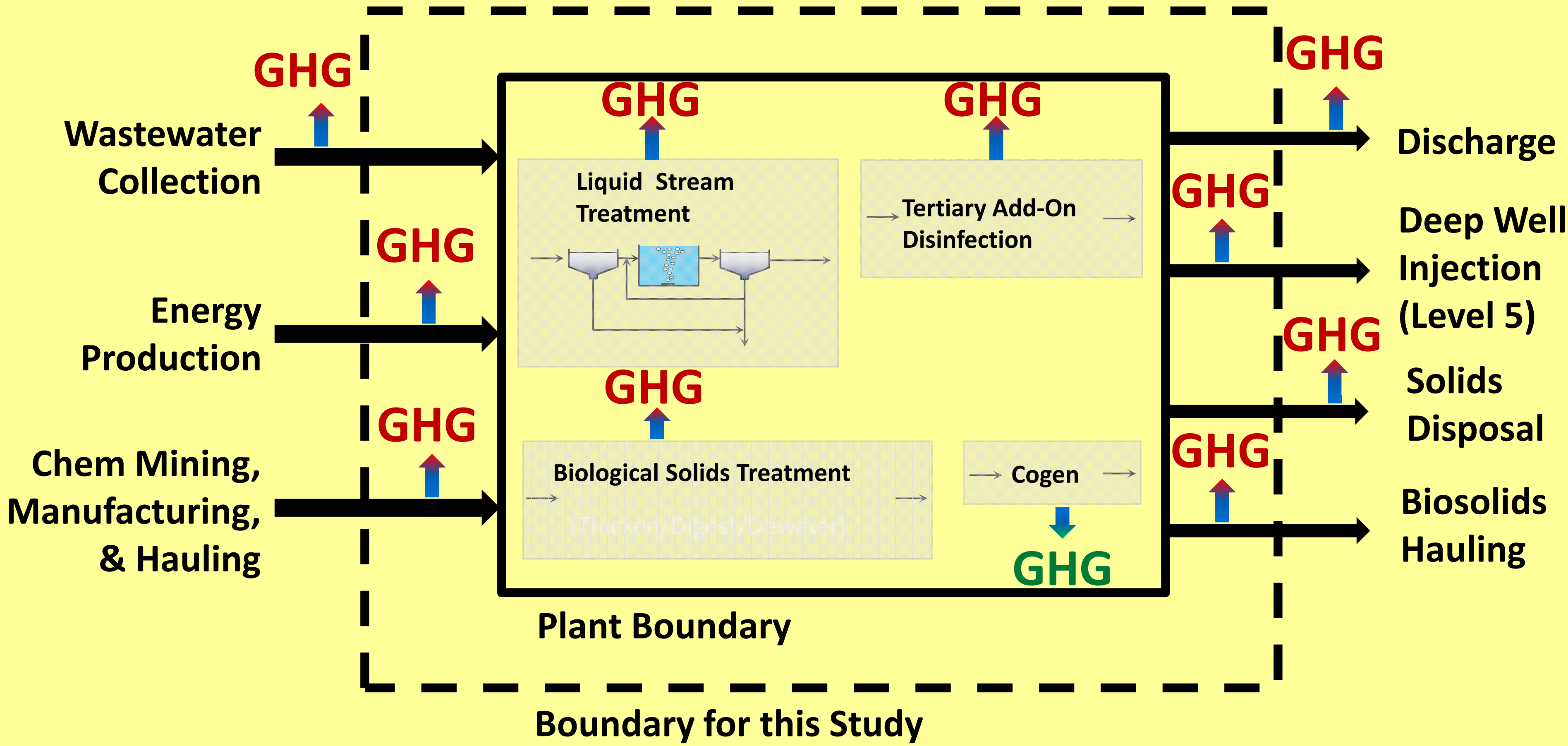
- GHGs (Energy Demand, Chem manufacturing/hauling, N_2O, biosolids hauling)
- Water Quality
- Ancillary Benefits of Increased Treatment

Social Pillar:

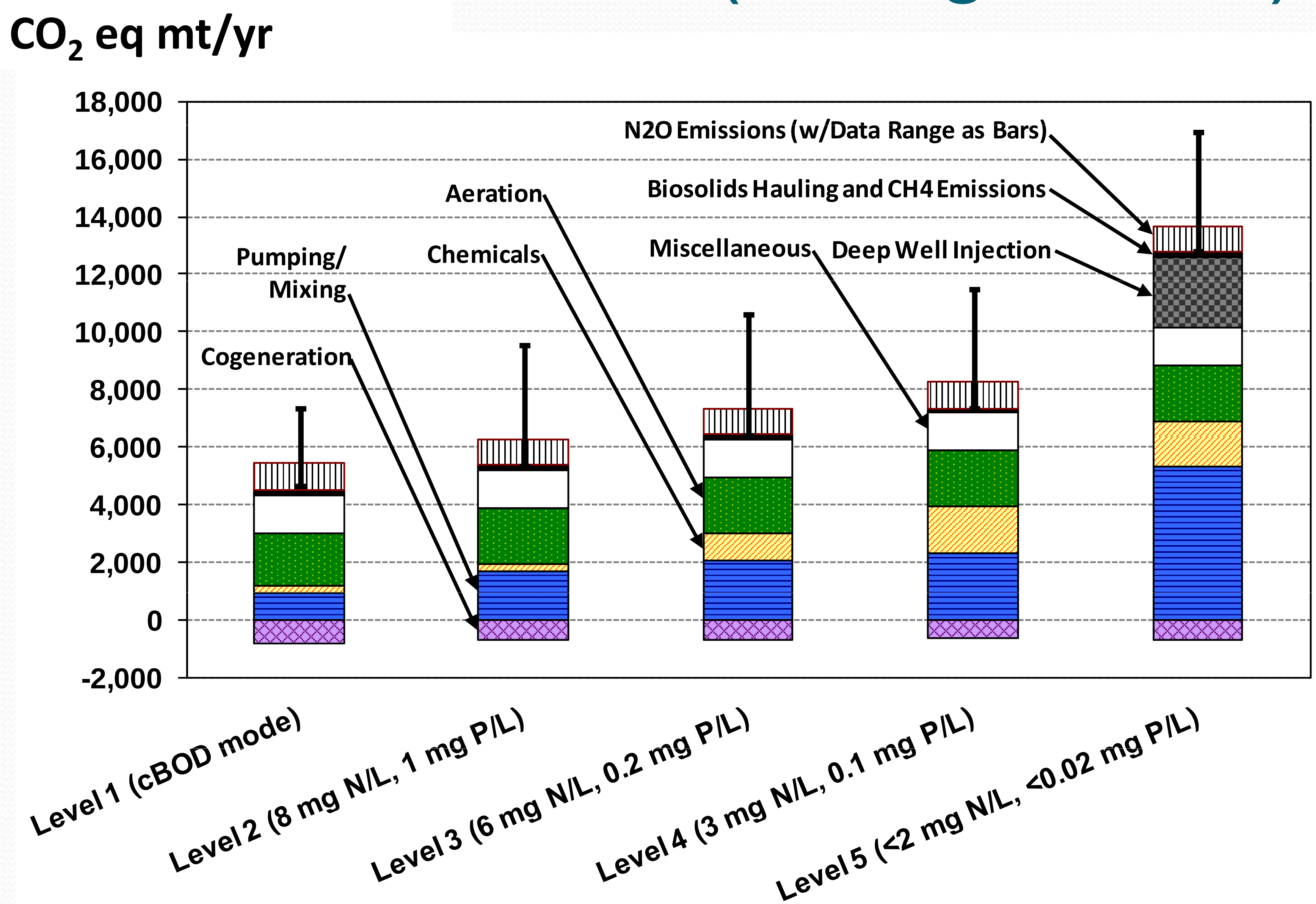
- Discussion in WERF Report
- Existing metrics (Health)
- Future metrics (Social)

WERF

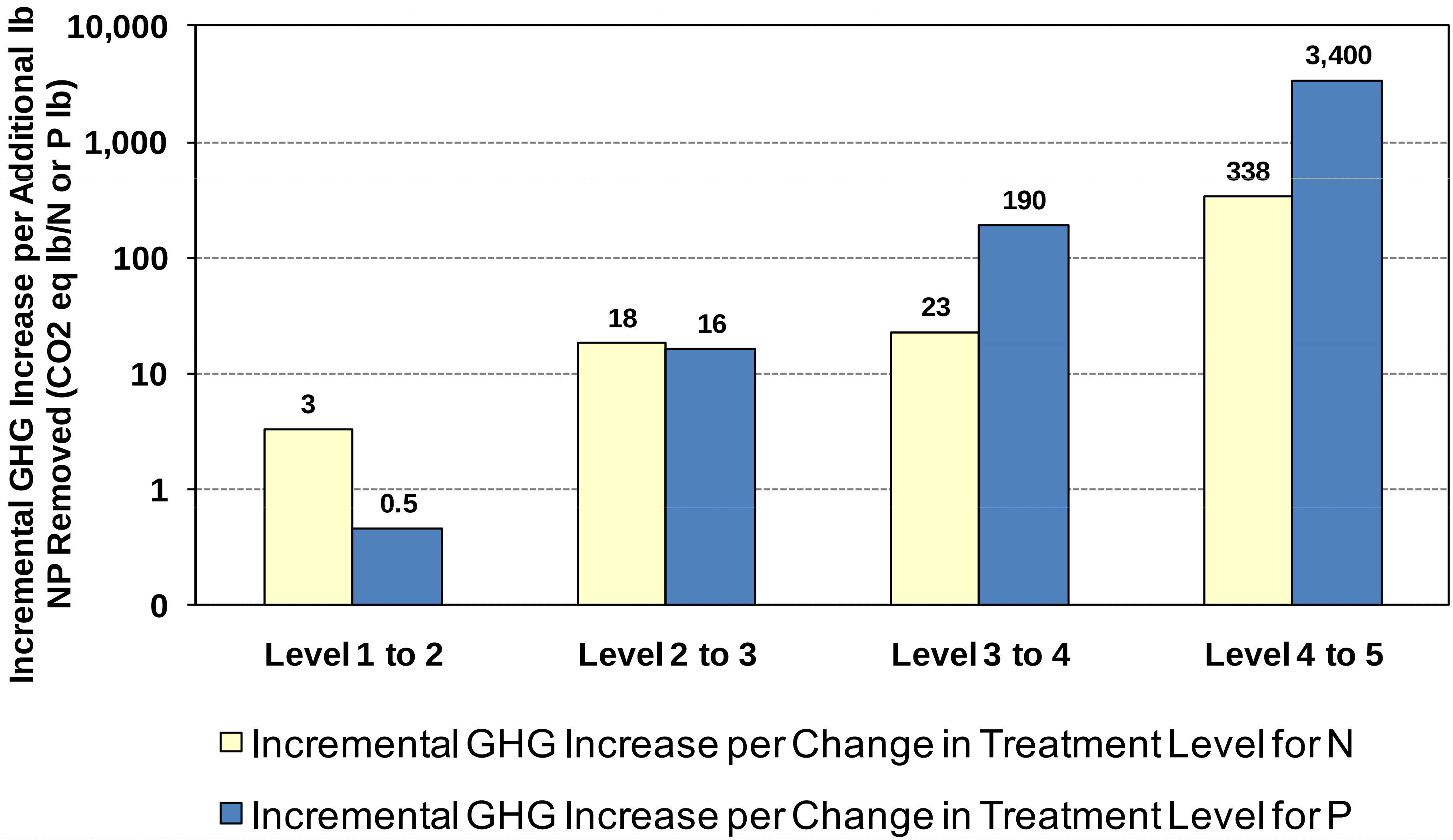
System Inputs



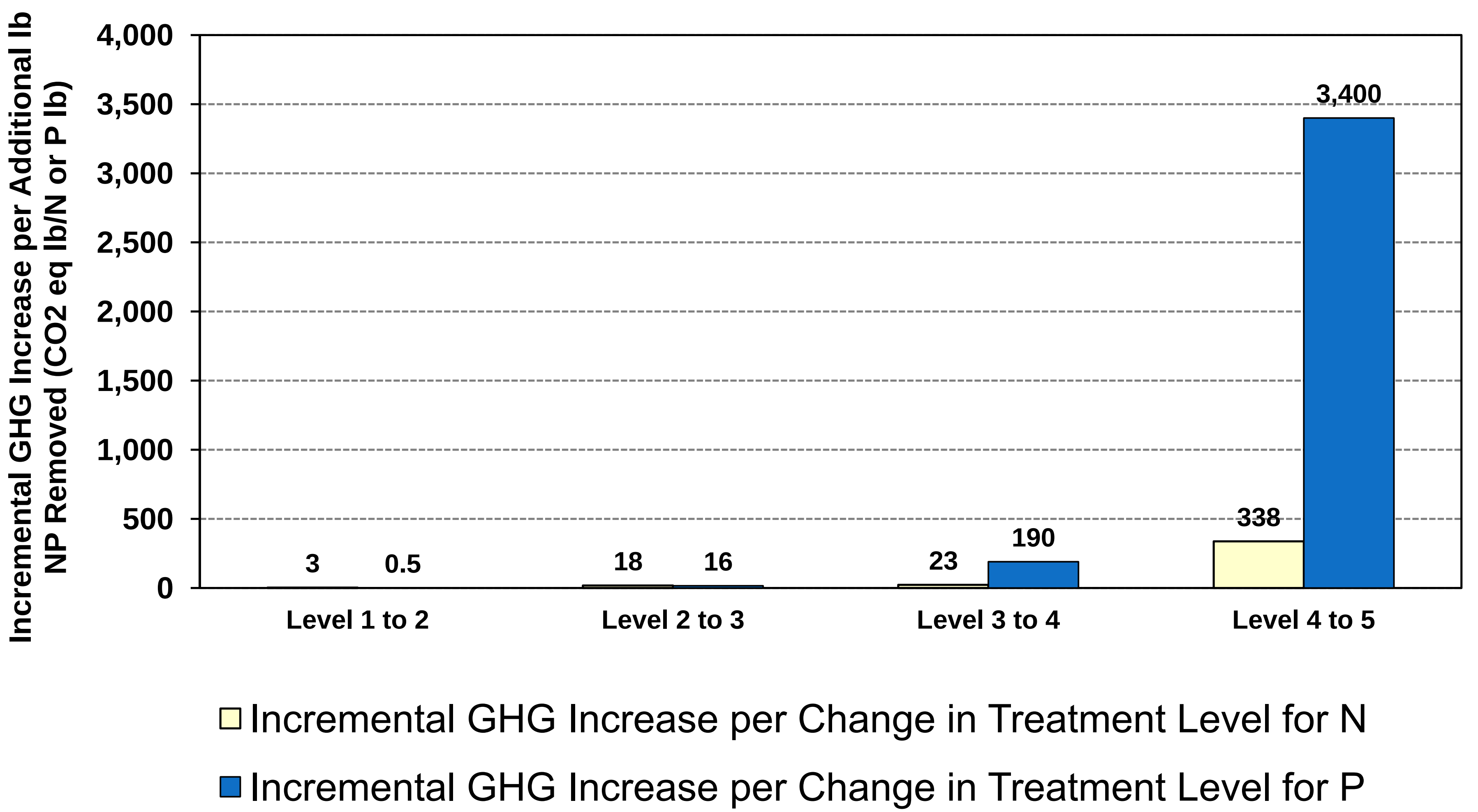
GHG Distribution (10 mgd Plant)



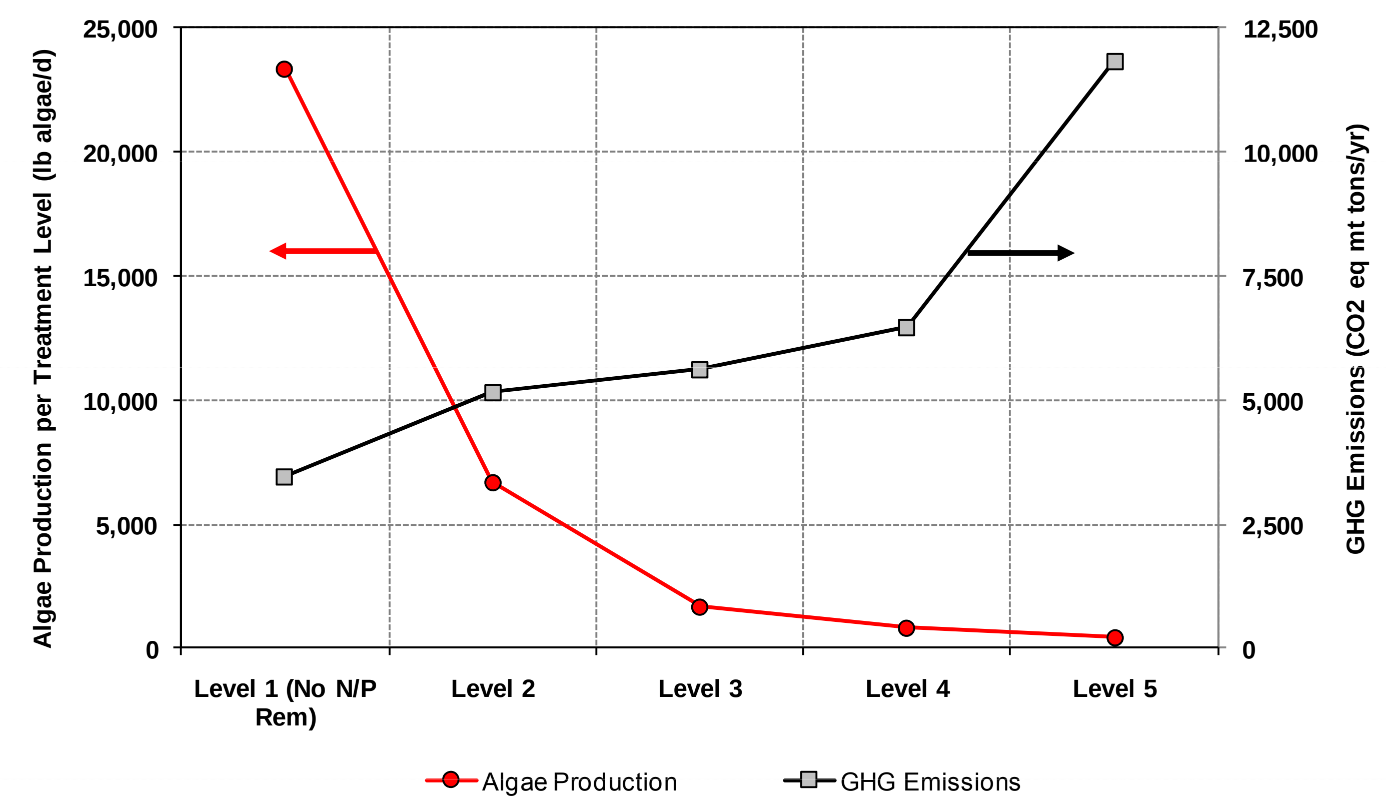
Incremental GHG ↑ per Additional lb N or P Removed



Incremental GHG ↑ per Additional lb N or P Removed



Algal Production - GHG Production



Water Environment Research Foundation (WERF) "*Striking the Balance Between <u>Wastewater Treatment Nutrient Removal and Sustainability</u>*" <u>November 2011</u>

1. *Secondary Treatment (No nutrient removal)*
2. *Biological Nutrient Removal (BNR) TP 1 mg/L TN 8 mg/L*
3. *Enhanced Nutrient Removal (ENR) TP 0.1-0.3 mg/L TN 4-8 mg/L*
4. *Limit of Treatment Technology (LOT) TP <0.1 mg/L TN 3 mg/L*
5. *Reverse Osmosis (RO) TP <0.02 mg/L TN 2 mg/L*

WERF

What's It Going to Cost You for a 10 mgd Plant?

Treatment Level	Total Project Costs ($ Million) [i]	Operations Cost ($/MG) [ii]	Total Present Worth ($ Million) [iii]
1 (No N/P Removal)	93	250	110
2 (8 mg N/L; 1 mg P/L)	127	350	150
3 (4-8 mg N/L; 0.1-0.3 mg P/L)	144	640	180
4 (3 mg N/L N; <0.1 mg P/L)	153	880	210
5 (2 mg N/L N; <0.02 mg P/L)	218	1,370	300

i The total project capital cost are the equipment cost, construction, and "soft costs"
ii Operations cost = energy and chemical cost. Labor and maintenance costs are excluded
Iii The assumed discount rate was 5 percent at an escalation rate of 3.5 percent (capital, energy, non-energy)

Summary/Conclusion

Summary and Conclusion - I

- Even well operating plants shows significant variation in performance
  - The average performance is about 2 times the ideal
- The reliability of meeting a permit requirement depends on:
  - Averaging period
  - Factor of safety to meet permit – Owner risk tolerance
- Restrictive limits (lower and/or short periods) increases the need for redundant units, multiple barriers to meet permits reliably

Summary and Conclusion - II

- Efficiency solids separation becomes critical for phosphorus removal
- Chemical addition provides a tool to improve reliability
- Chemical usage increase for restrictive limits
- Ionic species removal drastically increase the treatment costs and impacts
- The benefit per mass N or P diminish exponentially as the permits become more restrictive

WERF

Balancing Nutrient Limits with Net Environmental Benefits

JB Neethling

HDR Engineering

“Real World Wastewater Technologies Workshop”
CBP’s Scientific & Technical Advisory Committee (STAC)
Richmond, VA
May 16, 2012