POINT SOURCE STRATEGIES FOR NUTRIENT REDUCTION

TMDL Workshop
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Outline of Presentation

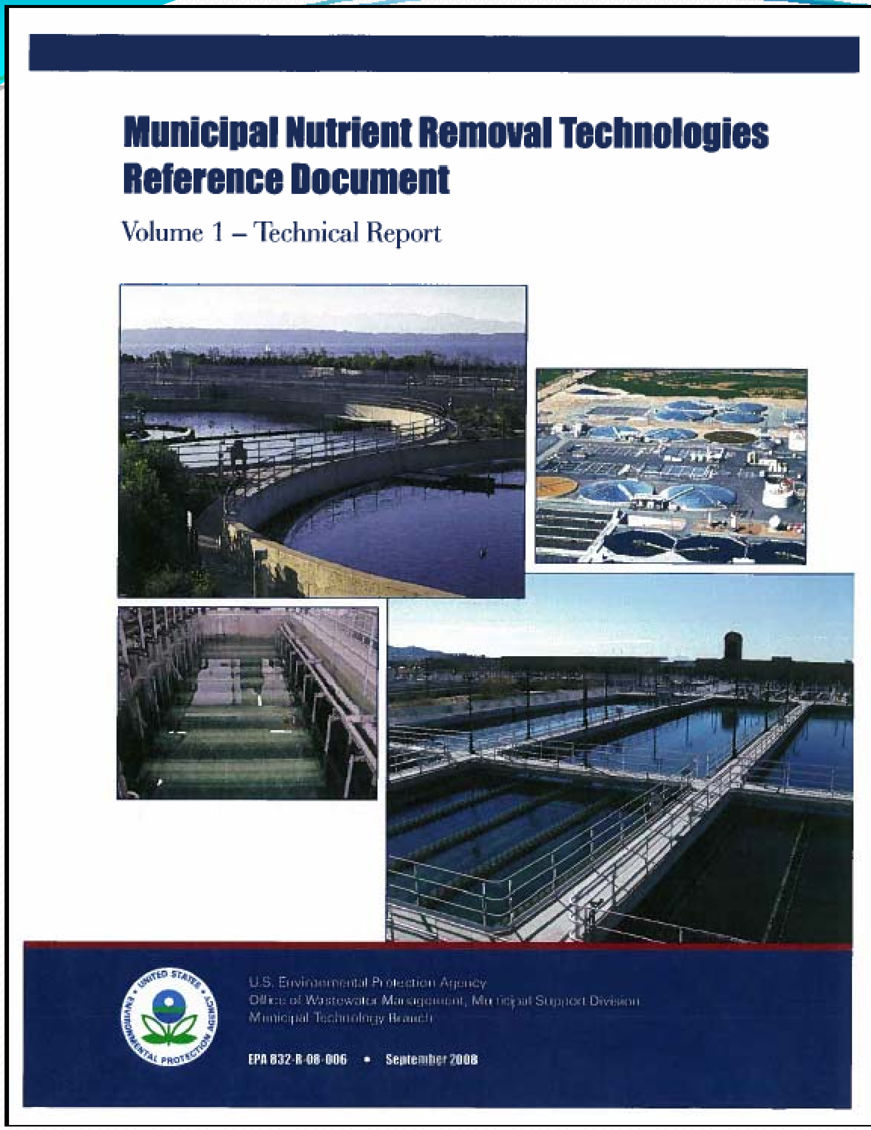
- Long term strategies
- Introduction of Nutrient Removal technologies Manual, EPA, 2008 and a new study by WEF/WERF
- Nitrogen Reduction
- Phosphorus Reduction
- Costs- capital, O&M and energy
- Costs of Nutrient Trading
- Future: Emerging Technologies
- Future: TMDL Considerations
- Summary

Long term strategies for nutrient reduction

- IJC – Great Lakes on P : 80 %, 1 mg/l, at 1 MGD or +
- Chesapeake Bay : 40% for N and P, more now
- TMDLs
- Reduction
  - of nutrients into sewer system- low p detergent, low nutrient fertilizer, etc.
  - Reduction of overflows during wet weather periods via green infrastructures
- Recovery of nutrients, P and N as fertilizers

Goals of the EPA Manual, 2008

- A planning reference for permit writers and permittees
- Current nutrient reduction technologies and their reliability
- Costs of technologies
- Factors for design and operation



The Municipal Nutrient Removal Technologies Reference Document is available on the EPA web site at: http://www.epa.gov/owm/mtb/index.htm

Highlights of EPA Reference Document(2008)

- 30 plants volunteered to participate
- Provided 12 months data
- Provided capital and O&M costs
- In-depth case studies at 9 plants

WEF/WERF Cooperative Study of Nutrient Removal Plants:

Achievable Technology Performance Statistics for Low Effluent Limits

Overall Highlights of The Two References

- 47 well-operating plants participated
- All regions of the U.S. and Canada represented
- No attempts were made to optimize operation
- A few plants were operated at design flow; most were operated under design flow
- Permit limits varied at most facilities

Nitrogen Species

- Ammonia---NH_3 or NH_4^+
- Organic Nitrogen
- Nitrite ---NO_2^-
- Nitrate ---NO_3^-

Nitrogen Cycle

- Ammonia N---Nitrification to NO_3^-
  - Increase aeration
- Organic N
  - If available, oxidation/nitrification to NO_3^-
  - If not available, develop definition and protocol
- NO_2^- ---nitrification to NO_3^-
  - Increase aeration
- NO_3^- ---denitrification to N_2
  - Set up anoxic conditions

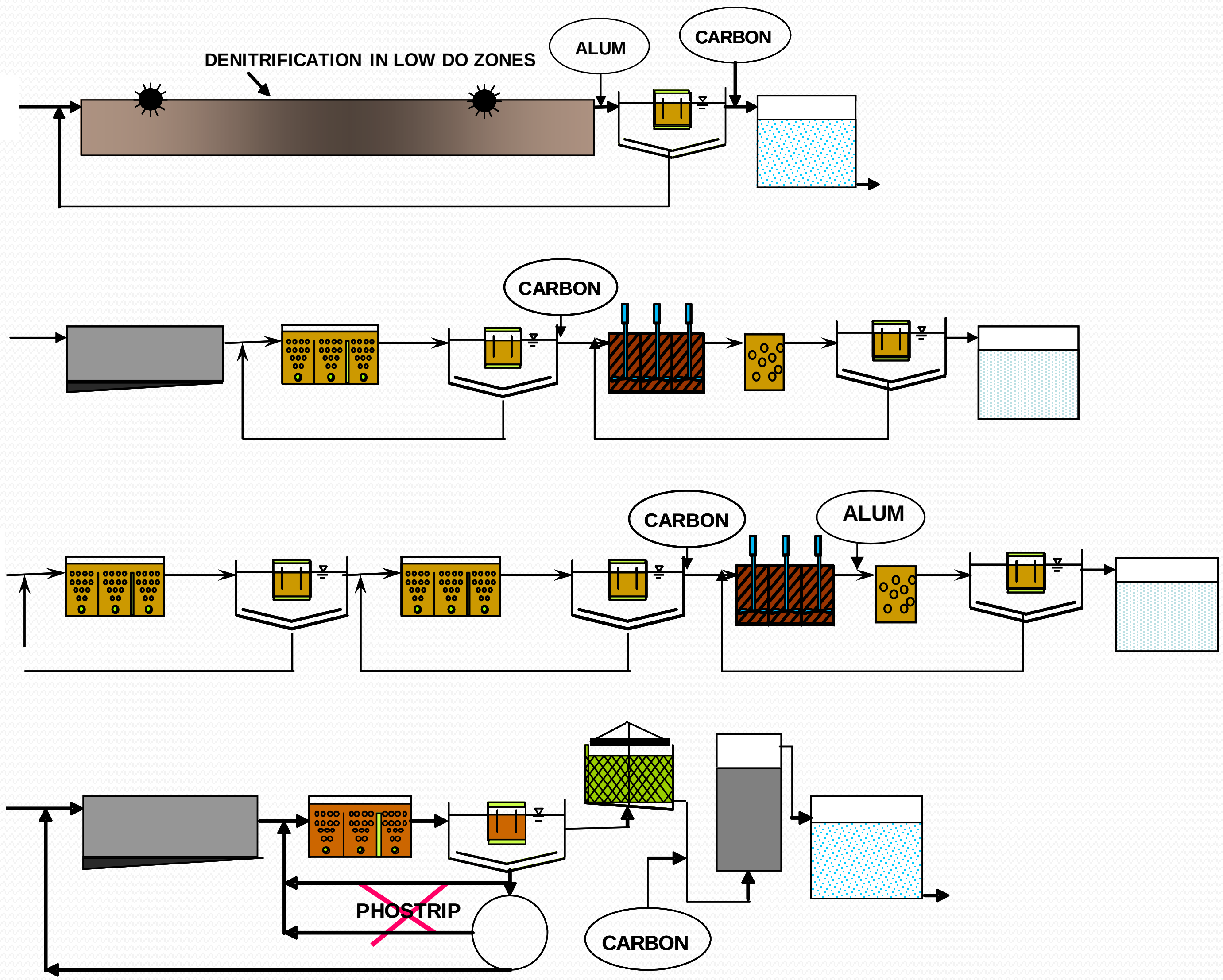
Best Performing Nitrogen Removal Plants (WERF)

Fiesta Village
Fiesta Village

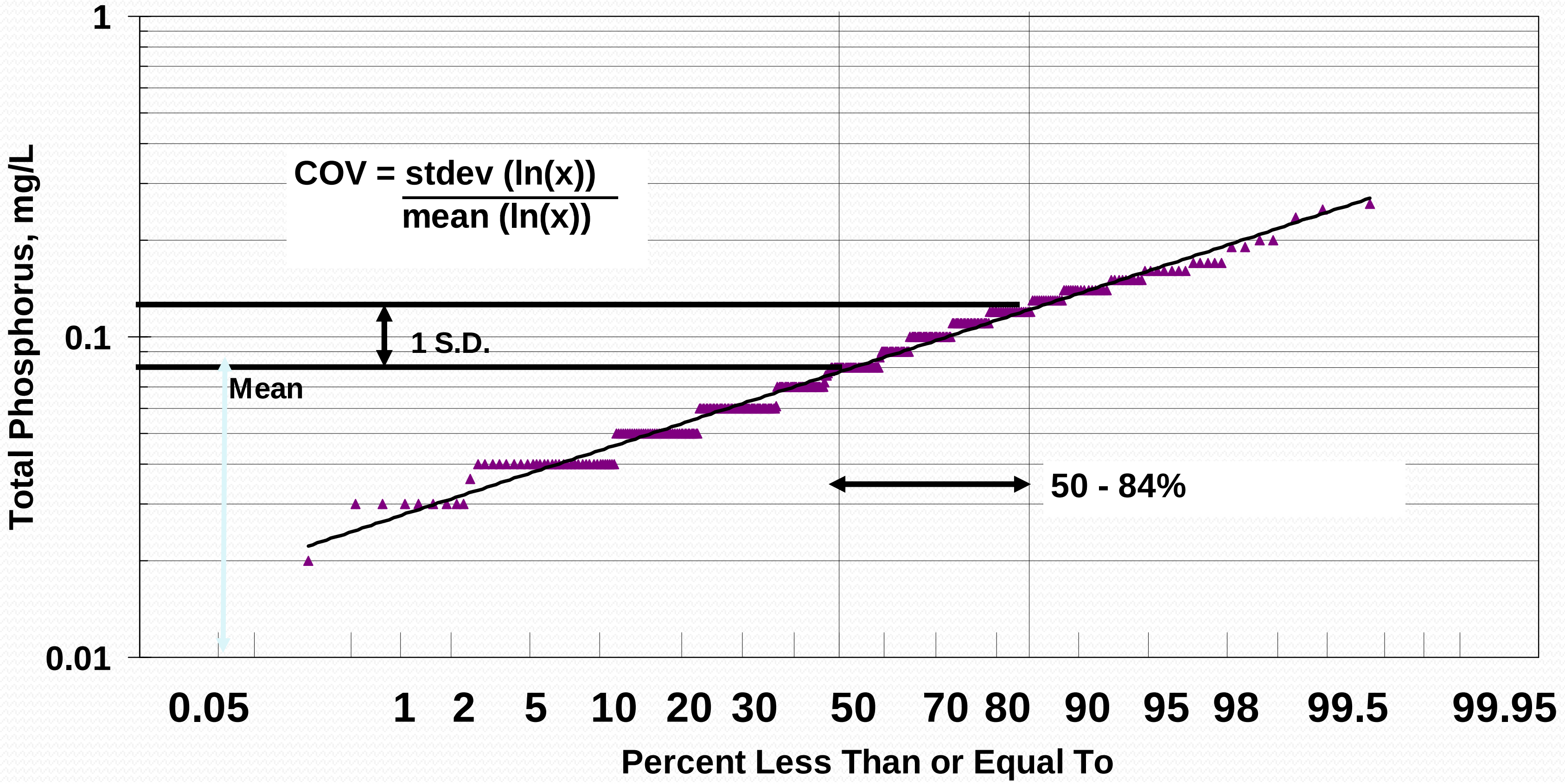
River Oaks
River Oaks

Western Branch
Western Branch

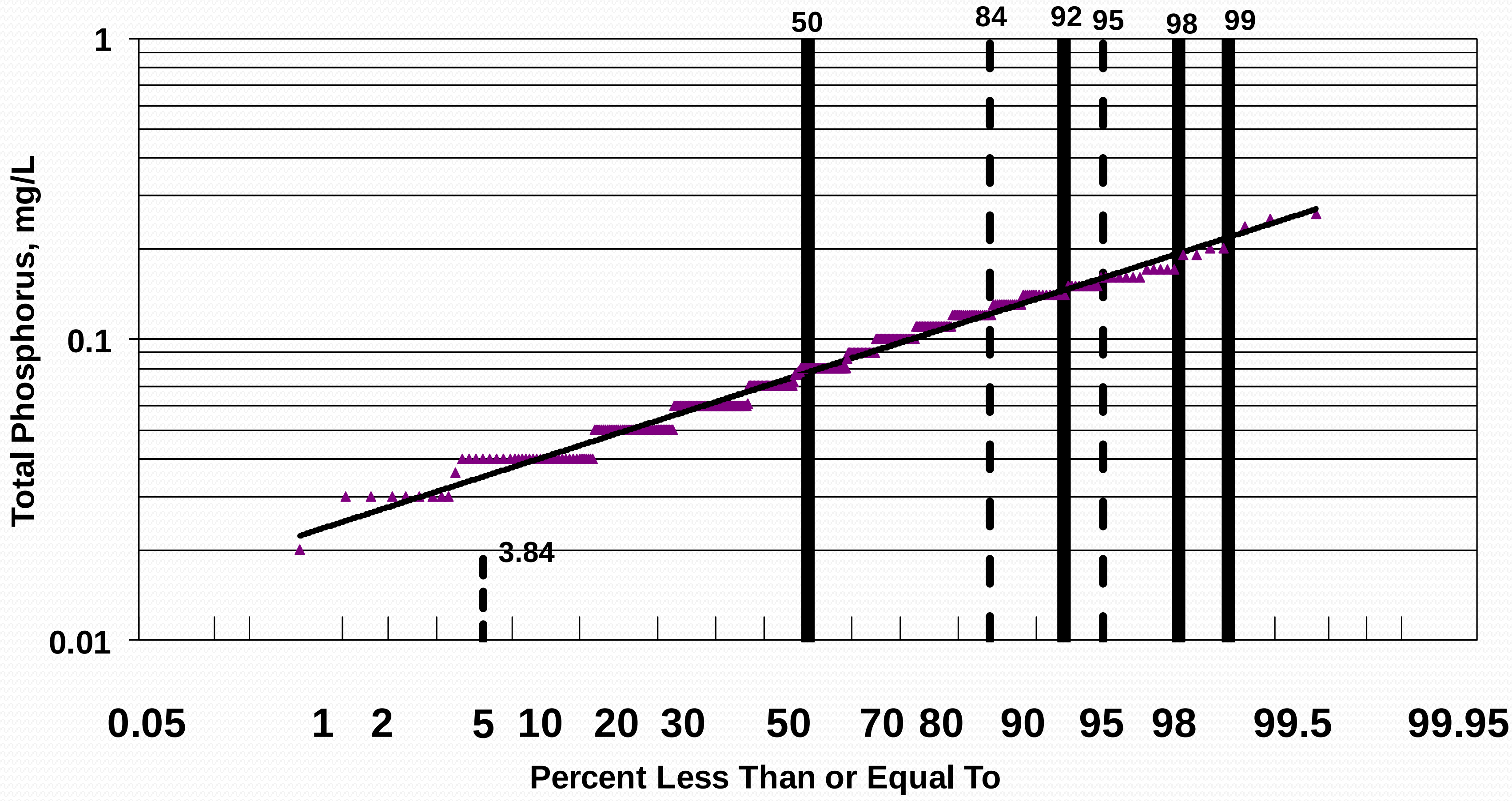
Truckee Meadows
Truckee Meadows



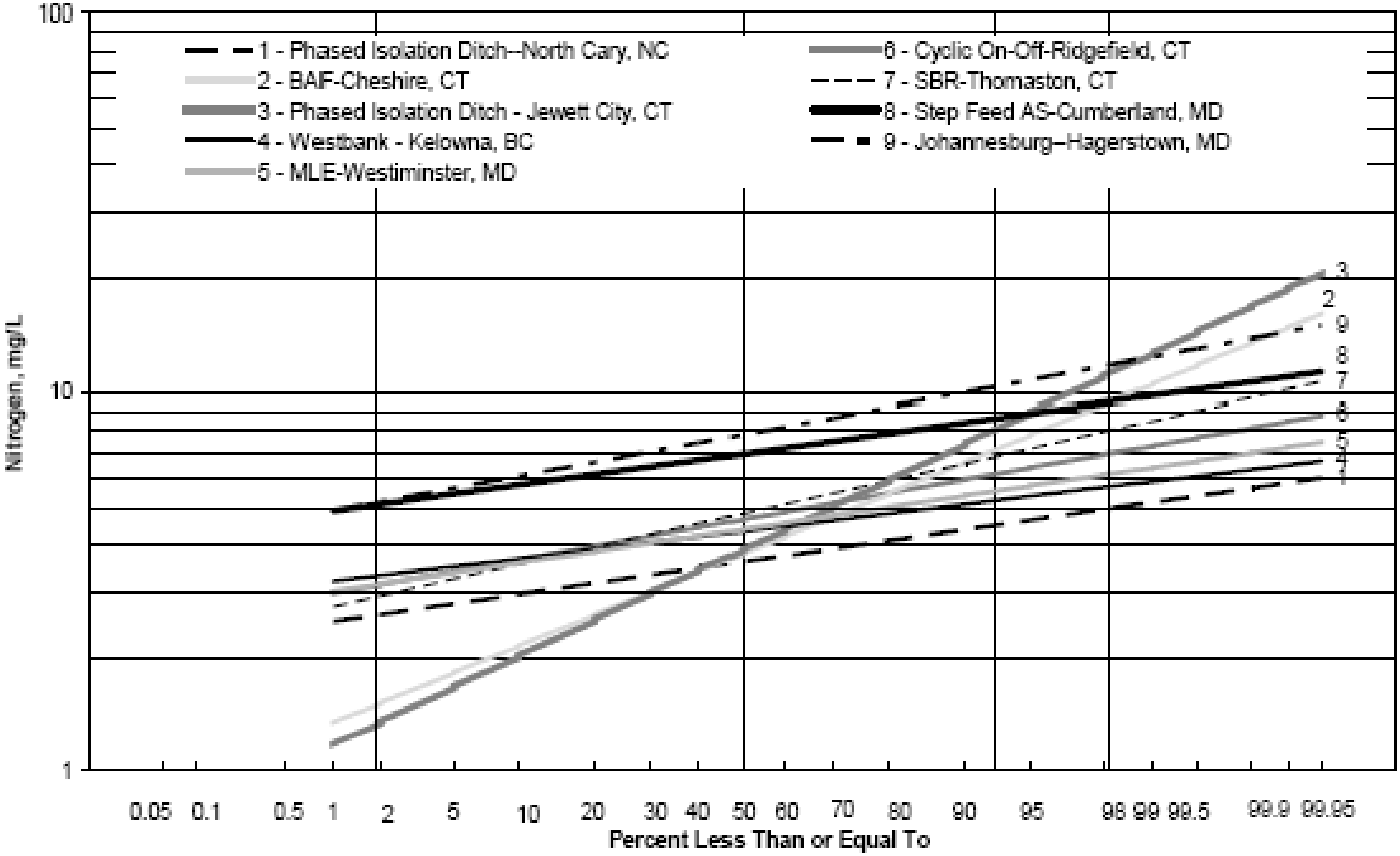
Log-Normal Probability



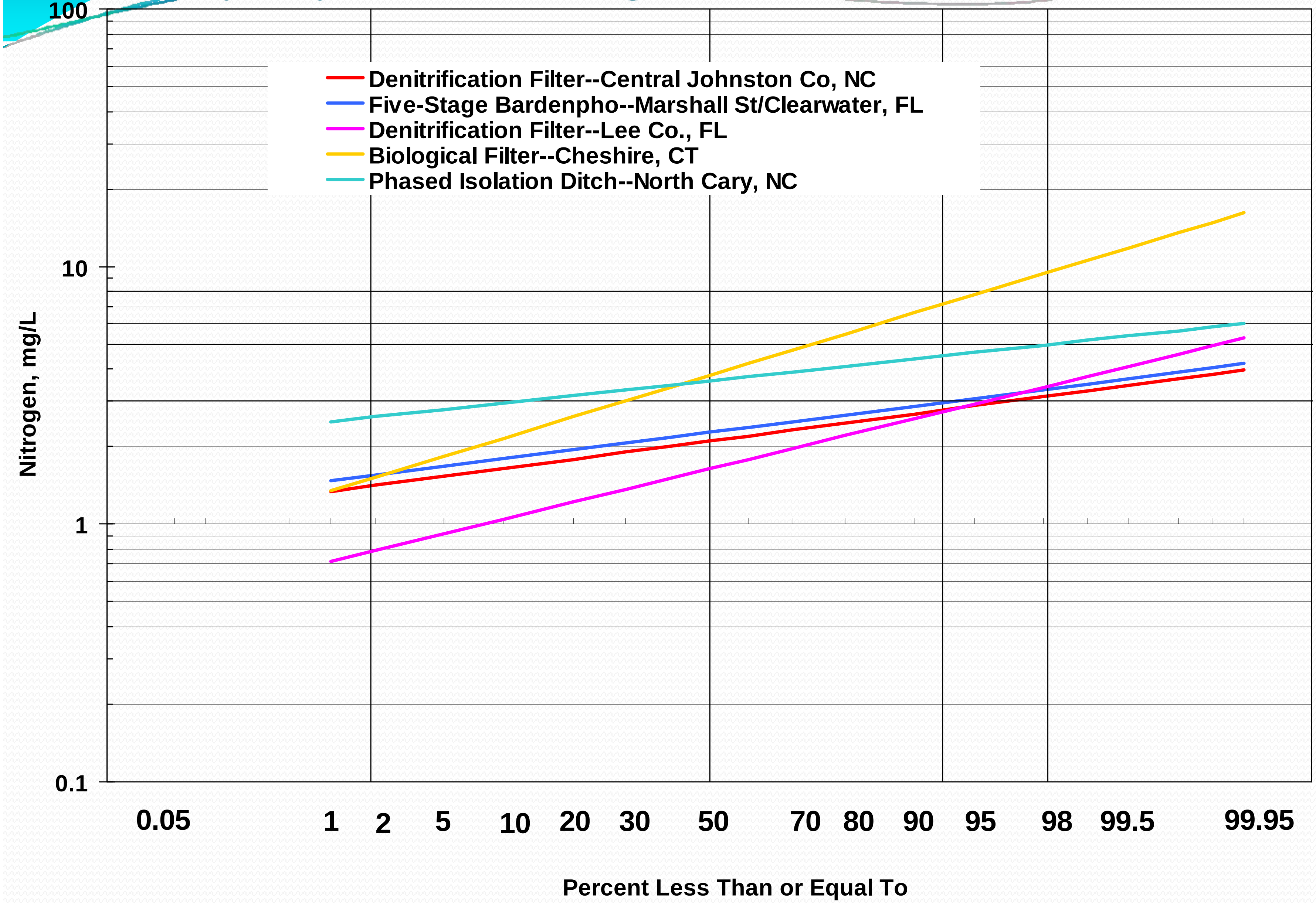
Comparison of Percentiles



N technologies



Exemplary N Technologies

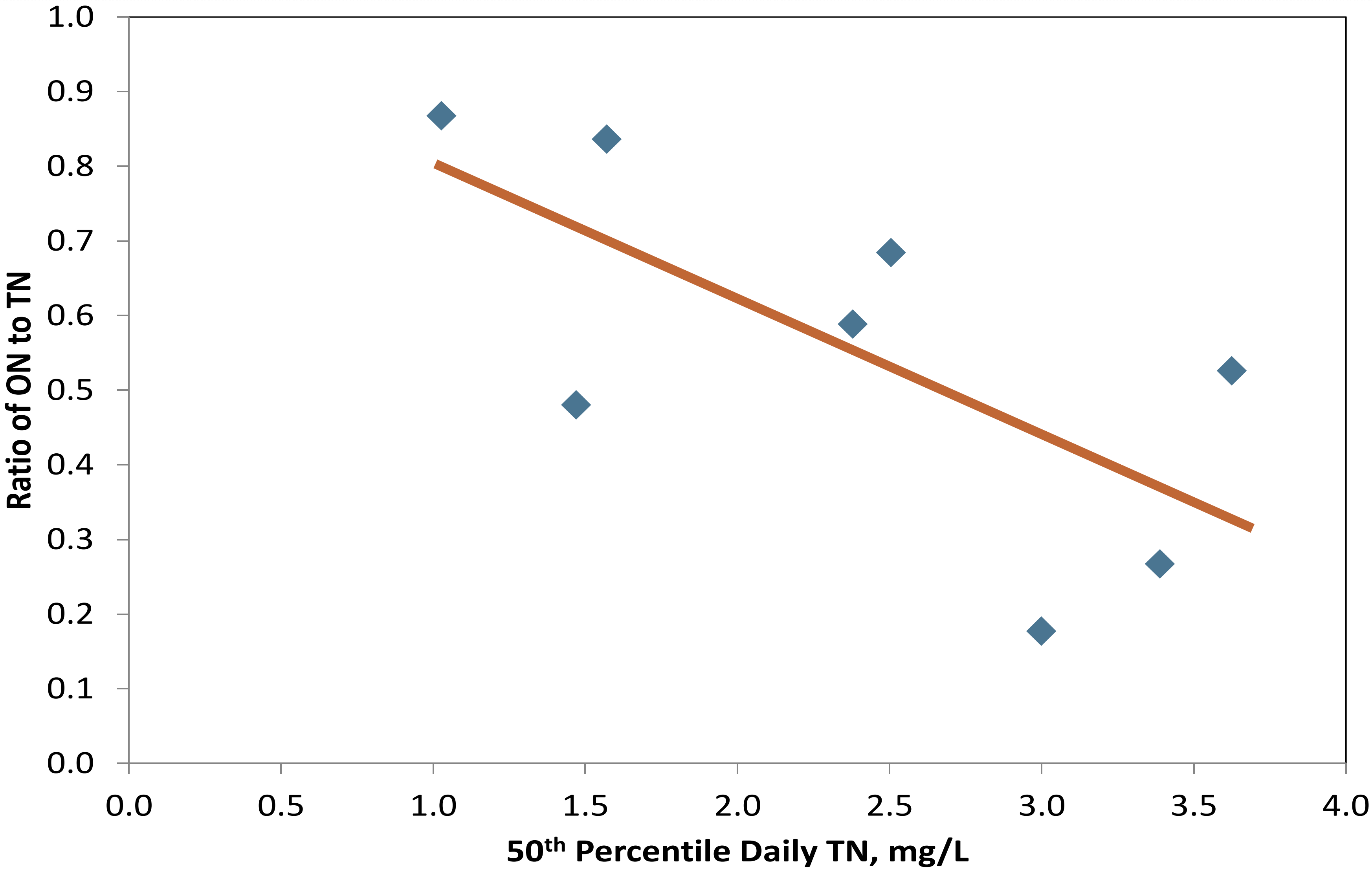


Nitrogen Removal Technology Selection Menu

Permit Condition	Target Concentration	Technologies
Annual Average	8 mg/L (TN)	All*
(50th Percentile)	5 mg/L	Phased Isolation Ditch, MLE, Westbank, others
	3 mg/L	Denitrification Filter, 4-Stage Bardenpho
Maximum Month	8 mg/L	MLE, Westbank
	5 mg/L	Phased Isolation Ditch
	3 mg/L	**AVAILABLE?**
Maximum Day	8 mg/L	MLE, Westbank
	5 mg/L	Phased Isolation Ditch
	3 mg/L	**NOT AVAILABLE**

*EPA Manual, Chapter 5 (2008)

Fraction of Organic N vs. Total N (WERF)



Comparison of Plants with Lowest Effluent Ammonia (WERF)

Plant	Maximum Day, in Record, mg/L	Daily, 99 percentile, mg/L	Annual, 50 percentile, mg/L
Utoy Creek	2.20	0.50	0.057
Kelowna	2.74	1.68	0.39
Fiesta Village	3.11	1.68	0.042
Tahoe Truckee	2.53	0.83	0.28

Best out of 13 Plants Surveyed

MI permits : daily limit : 2.0 mg/l in May-October
30 day average : 0.5 mg/l

Phosphorus Species

- Solid-phase P
- Dissolved P –
  - orthophosphate- PO_4^{3-}
  - Non-reactive P

Available Technologies: Physical/Chemical

- High dose Al, Fe or Ca for precipitation
  - C_p = f(Metal dose, P concentration, pH, Ca^{2+}, HCO_3^-)
  - Single vs. Two Application Points
  - the solubility limit
- Filtration : granular media, cloth media, & Membrane
- Soil Ion Exchange/Infiltration Bed

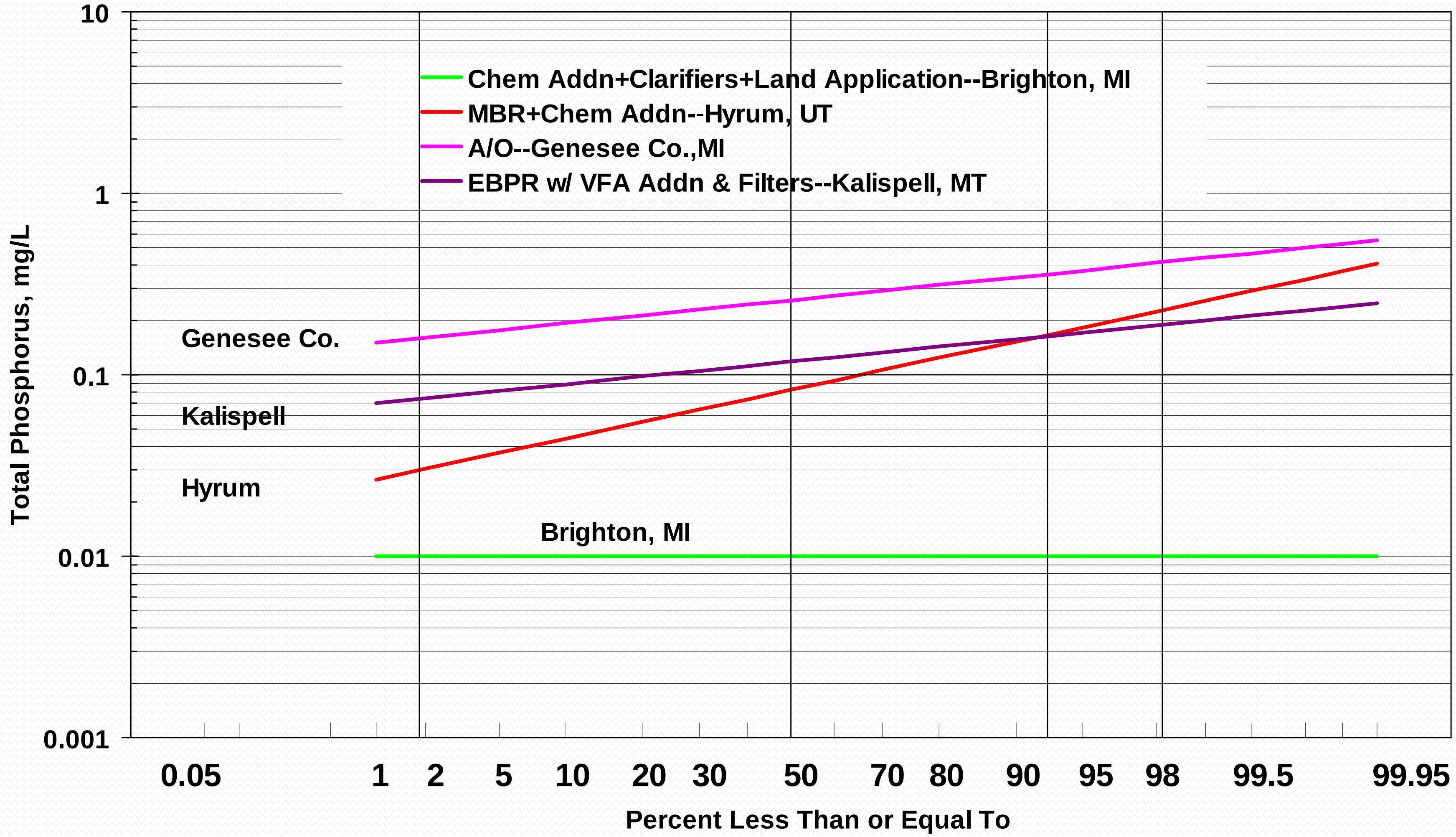
BPR Organisms

- Phosphate Accumulating Organisms(PAO) – Natural in Wastewater
  - PAOs consume carbon source without oxygen or nitrate by generating energy from stored polyphosphate and glycogen
  - PAOs take up phosphate under aerobic conditions
  - PAOs accumulate P up to 4 -6% by weight

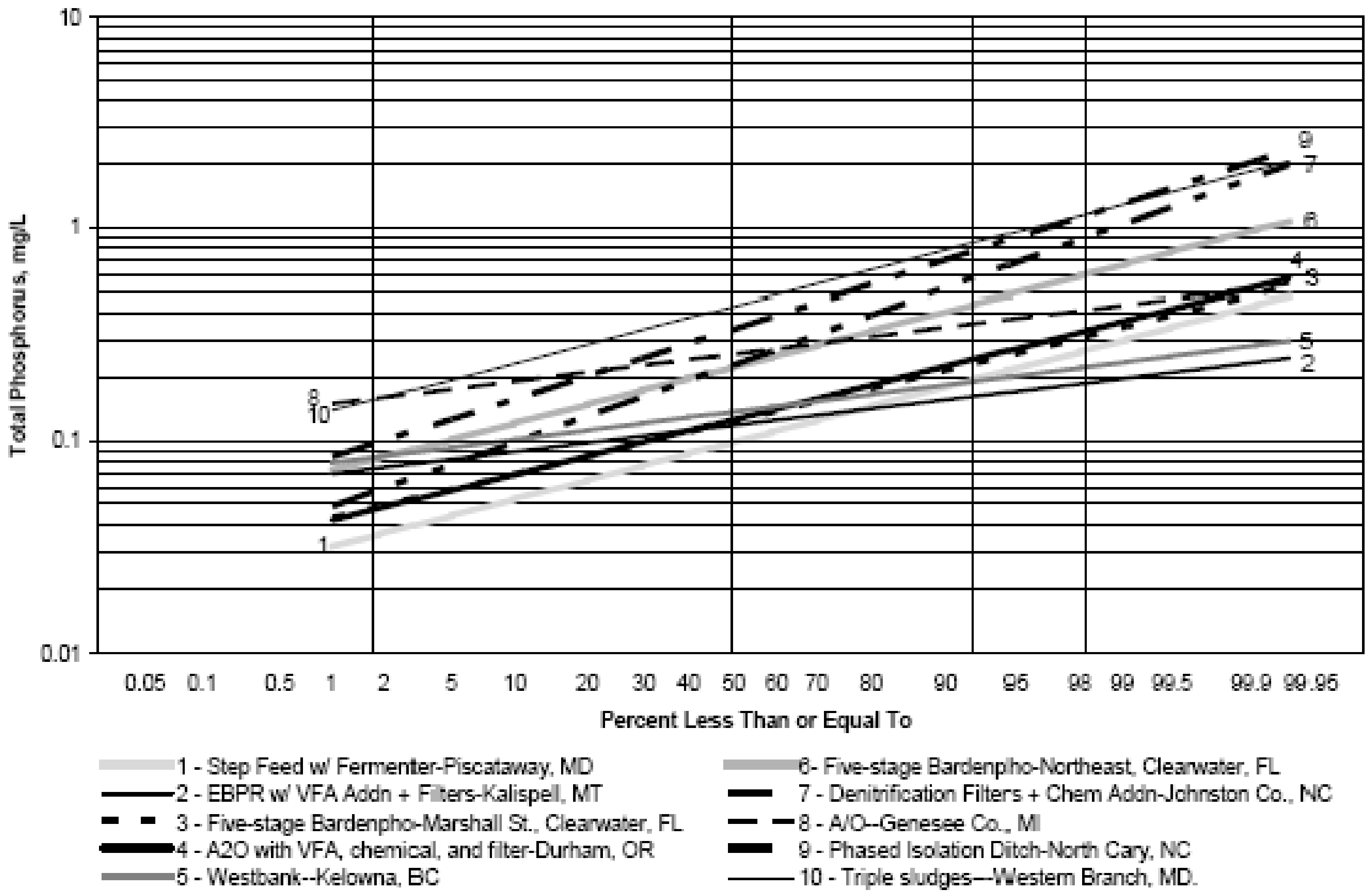
Daily Technology Performance Statistics (mg/L) for Best Performing Phosphorus Removal Plants (WERF and EPA)

Plant	3.84% (14d)	50%	95%	3.84%/50%	95%/50%
Iowa Hill WRF, CO	0.004	0.012	0.045	0.33	3.8
Pinery, CO	0.014	0.023	0.045	0.58	2.0
F. Wayne Hill, GA	0.020	0.040	0.110	0.50	2.8
ASA, VA	0.025	0.050	0.120	0.50	2.4
Brighton, MI	0.01	0.01	0.01	1.00	1.0

Selected P Technologies



P technologies



Bio-Phosphorus Technology Selection Menu

Permit Condition	Target Concentration	Technologies
Annual Average	1 mg/L	All*
(50th Percentile)	0.5 mg/L	All*
	0.2 mg/L	Step Feed with fermenter and filter
Maximum Month	1 mg/L	Step Feed, 5-Stage Bardenpho, A2O
	0.5 mg/L	Step Feed, 5-Stage Bardenpho, A2O
	0.2 mg/L	**NOT AVAILABLE**
Maximum Day	1 mg/L	Step Feed, 5-Stage Bardenpho, A2O
	0.5 mg/L	**NOT AVAILABLE**
*EPA Manual, Chapter 5 (2008)	0.2 mg/L	**NOT AVAILABLE**

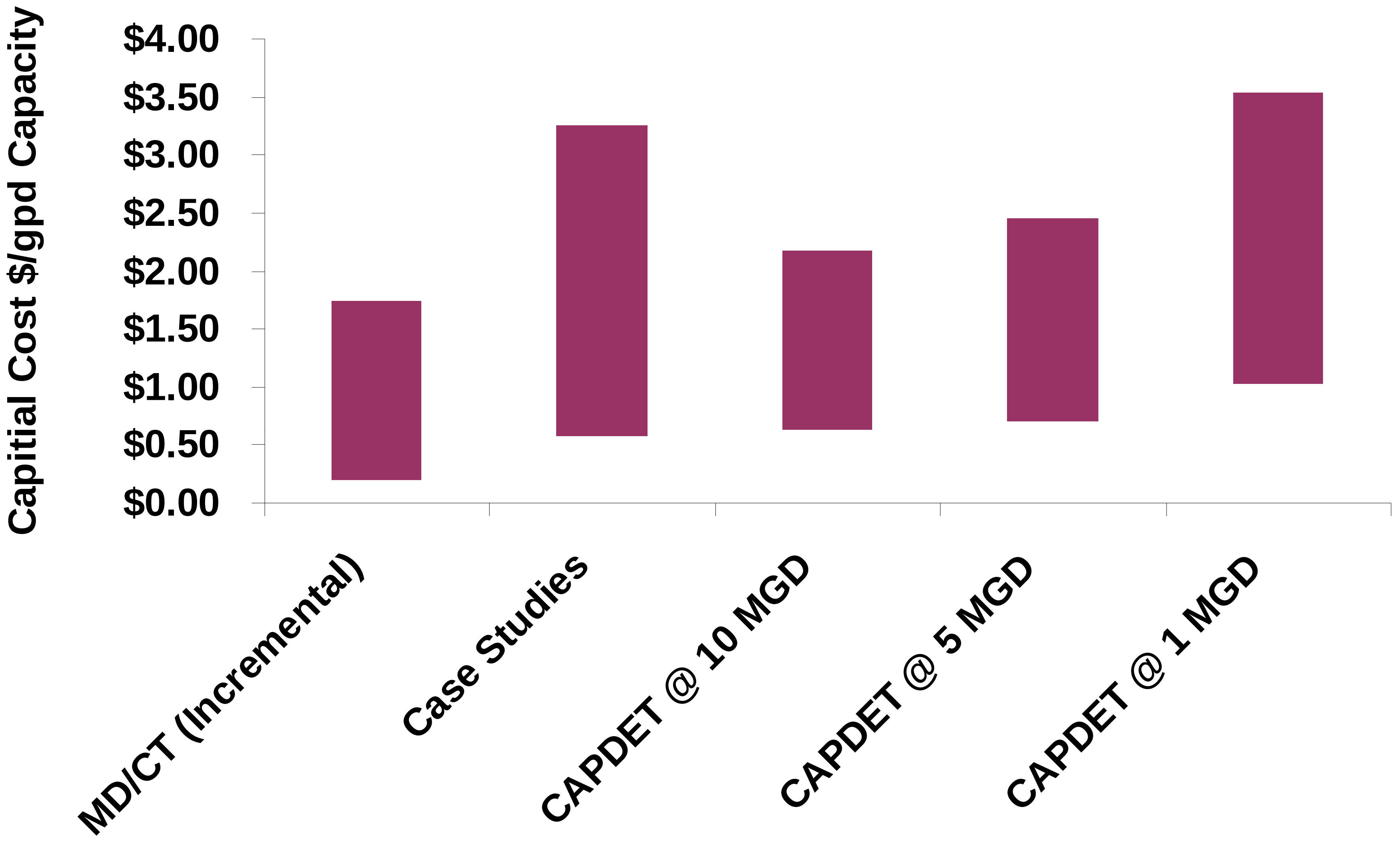
Chemical Phosphorus Technology Selection Menu

Permit Condition	Target Concentration	Technologies
Annual Average	1 mg/L	Chemical Addition
(50^{th} Percentile)	0.5 mg/L	Chemical Addition
	0.1 mg/L	Chemical **with Filter**
	0.05 mg/L	Chemical **w/ Special Process**
Maximum Month	1 mg/L	Chemical Addition
	0.5 mg/L	Chemical Addition
	0.1 mg/L	Chemical **with Filter**
	0.05 mg/L	Chemical **w/ Special Process**
Maximum Day	1 mg/L	Chemical Addition
	0.5 mg/L	Chemical **with Filter**
	0.1 mg/L	**NOT AVAILABLE**

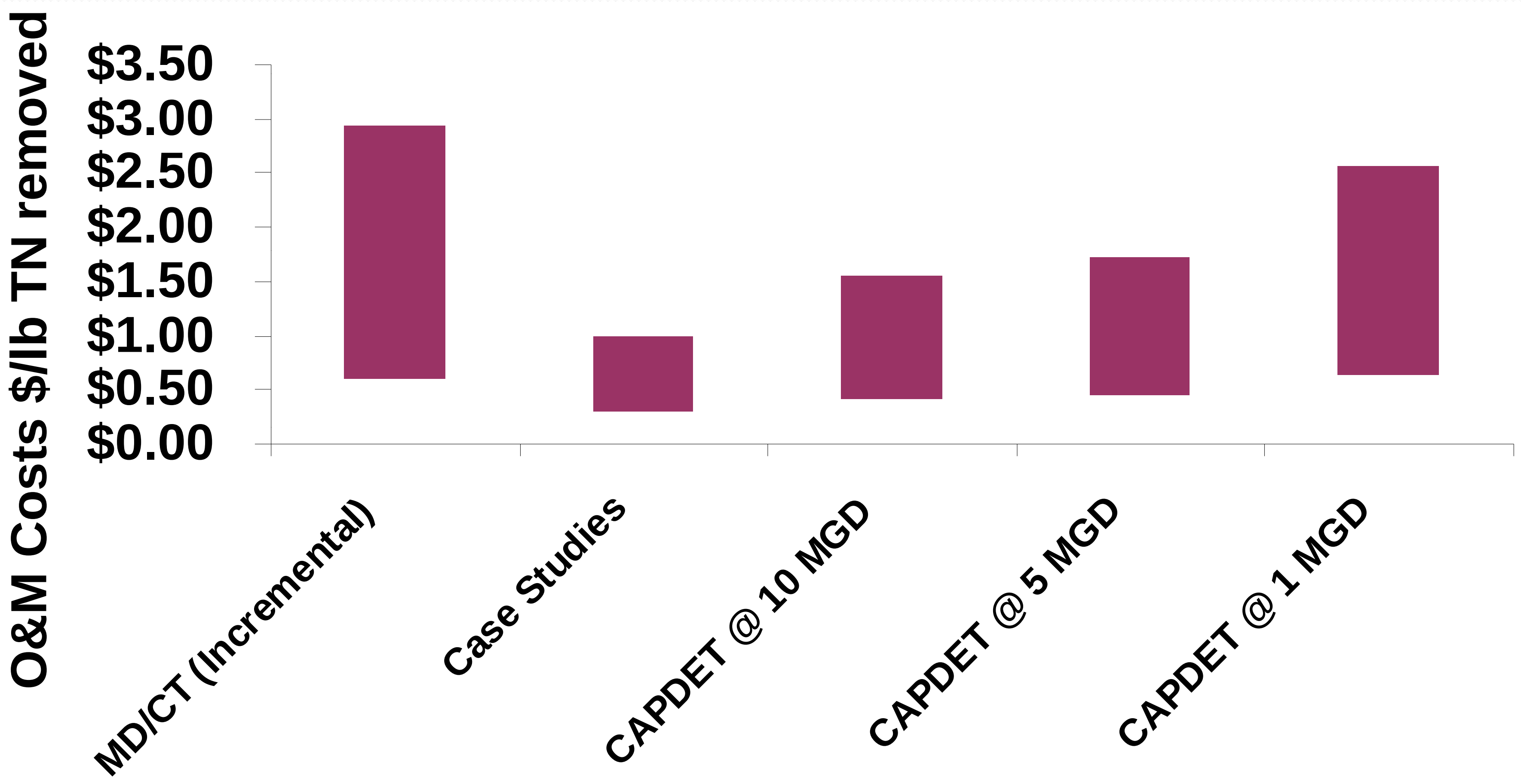
COSTS

- existing facilities
- permit limits
- available site
- wet weather flows

Capital Costs—TN Removal



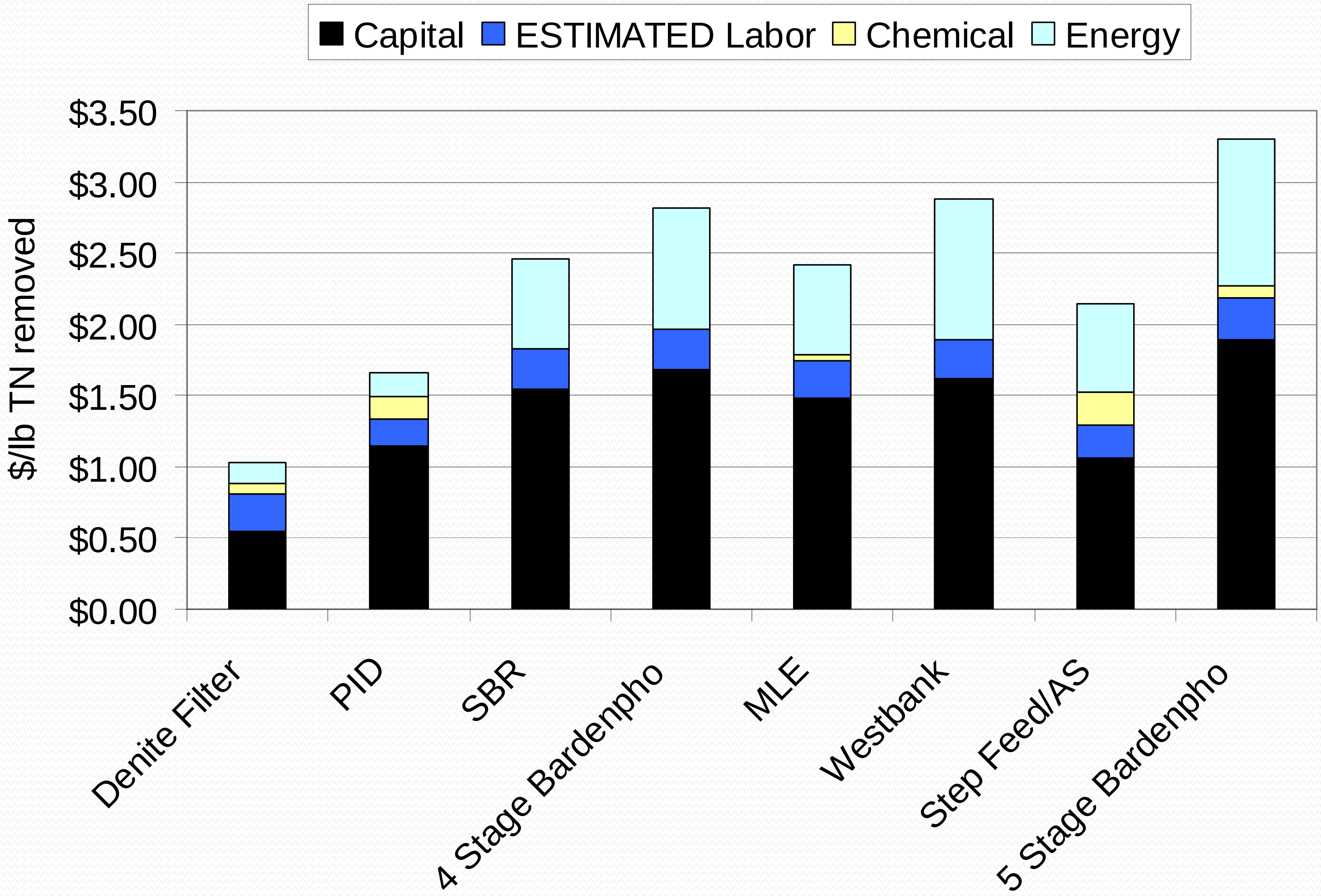
O&M Costs—TN Removal



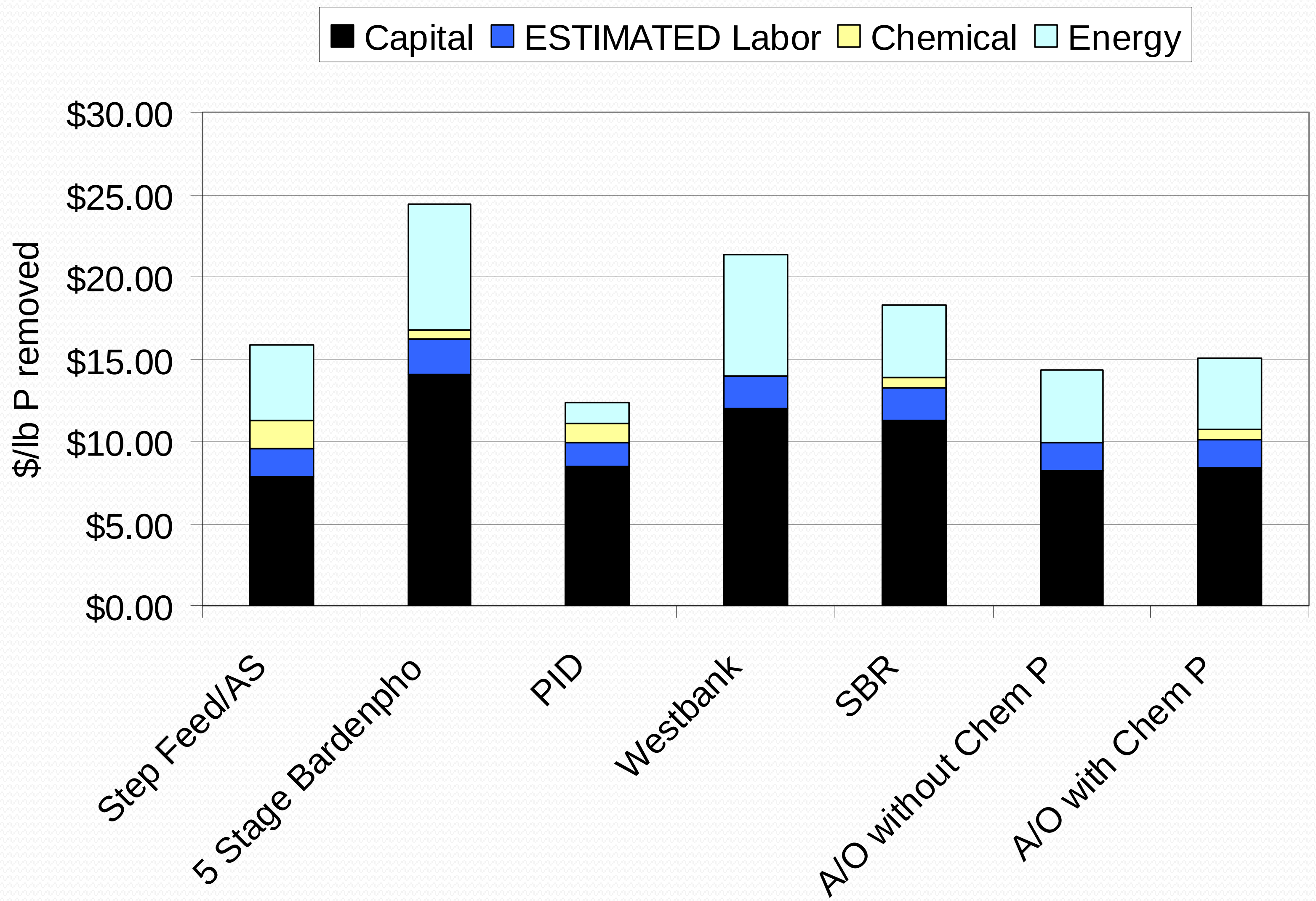
Energy Usage in Wastewater Treatment Plants in U.S.

- Average Plant : 1500 KWh/Million Gallons (MG) treated for secondary treatment
- Advanced Treatment Plant: 2000 – 3000 KWh/MG

N Life-Cycle Cost Breakdown



P Life-Cycle Cost Breakdown



Costs for Nutrient Trading: "Market Rates"

- Nitrogen: $2.00/lb for trading (CT and VA)
- Phosphorus: $4.00/lb for trading (VA)
- *Intended to covers only parts of O&M costs*

- Market rates will vary in the future

Emerging Technologies

- Phosphorus : target at 0.05 mg/l
  - Filtration : Membrane
  - Densadeg®
  - Co-Mag®
  - Ballasted Flocculation/ActiFlo®
  - Soil Ion Exchange/Infiltration Bed
- Nitrogen : below 3 mg/l
  - Membranes (MF/UF or Reverse Osmosis)
  - Biological Aerated/Anoxic Filter
- Both
  - Automatic Controls with on-line sensors

Future Considerations for TMDL: Permit Writers

- Specify the limits for critical periods to protect water quality : annual average, max month, max week , or max day
  - *The worst day in the river is usually the best day at the plant(a low flow & at high temp)*
- TIN (vs. TN) should be considered where appropriate
- Account for development time for new technologies to meet future needs
- Continued Support for technology development, $$$

Future Considerations for TMDL: Permitees

- Match the permit with right technologies(no over-design)
- Make nutrient removal sustainable with respect to energy, greenhouse gases, and new sludge production
- Encourage nutrient recovery, where feasible

Summary – N removal

- Practical limit is Annual average at 3 mg/l.
- 4 or 5-stage Bardenpho plants come close to meeting the TN of 3 mg/l, 95 percent of the time; 10 Florida plants show a capability of 3.5 mg/L.
- More sustainable technologies are feasible for higher target limits
- Organic Nitrogen is a critical variable
- Costs depend on existing facilities and target limit

Summary - P removal

- Practical limits are Annual Average of 0.2 mg/L by biological process, and 0.1 mg/L by chemical addition with filter.
- Lower target limits require site-specific advanced technologies
- Soil ion exchange is possible if sufficient land is available
- Non-reactive P is a critical variable
- Costs depend on existing facilities and target limit
- Recovery of P is encouraged for sustainable future

Thank You!