CROCKER & ASSOCIATES, INC.
Manufacturer's Representative for Water, Wastewater, and Odor Control

Wastewater Treatment Phosphorus Removal Methods and Processes

GAWP District 6 Meeting

June 18, 2008

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What is Phosphorus?

- Essential part of the nutrient cycle in nature, along with others such as sodium, potassium, calcium, iron, copper, etc.
- Atomic Number = 15
- Word derives from Greek *phosphoros*: light bearing; ancient name for the planet Venus when appearing before sunrise)
- Brand discovered phosphorus in 1669 by preparing it from urine.

Sources of Phosphorus

- Fecal and waste materials
- Paint strippers, soft drinks, toothpaste, and baking powder
- Industrial and commercial uses
- Synthetic detergents and cleaning products

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Why Remove Phosphorus in Wastewater?

- Contributes to eutrophication, which leads to deterioration of water quality in lakes
- Eutrophication is a condition in an aquatic ecosystem where high nutrient concentrations stimulate blooms of algae (e.g., phytoplankton).
- Creates conditions that interfere with the recreational use of lakes and estuaries, and the health and diversity of indigenous fish, plant, and animal populations.

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Algal blooms hurt the ecosystem in two ways:

1. Cloud the water and block sunlight, causing underwater grasses to die.
   - Because these grasses provide food and shelter for aquatic creatures, spawning and nursery habitat is destroyed and waterfowl have less to eat when grasses die off.
2. When algae die and decompose, oxygen is consumed
   - Dissolved oxygen in the water is essential to most organisms living in the water

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Phosphorus Limits in GA Lakes:

Lake Lanier
- 36,900 pounds / year

West Point Lake (from Chattahoochee River)
- 1,400,000 pounds / year

Lake Allatoona
- 16,200 pounds / year to each of:
  - Bartow County
  - Cobb County
  - City of Canton
  - Cherokee Co. WSA

Lake Jackson
- Discharge specific basis

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Nutrient Removal Trends

- Nitrogen and phosphorus loading concerns on receiving waters
- Both point source and non-point sources are a concern
- Trend is towards lower discharge levels due to TMDLs and Waste Load Allocation
- Nutrient removal can play a role in reuse applications

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Regional Target Levels

- GA 0.5 NH_3-N, *1.5 Org N (discussed),* 0.13 Total P
  "Metro Atlanta Limits"
- FL 3.0 Total N, 1.0 Total P
- Chesapeake Initiative: State specific, 4.0-8.0 Total N, 0.3-2.0 Total P
- Michigan 5 TIN (NH_3 + NO_2^- + NO_3^-), 1 TP

NOTE: EPA-Region 4 is encouraging GAEPD to develop nutrient standards for all waters. Currently, GAEPD is requiring 1.0 mg/L for new and expanding facilities >1.0 MGD (or 8.34 lbs/day for <1.0 MGD); and for existing facilities renewing their permit, monitor only. This is being done because of nutrient criteria coming soon.

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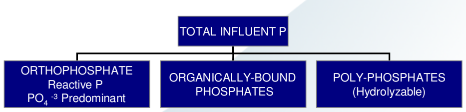
Division of the Influent P Into Constituent Fractions



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Poly-Phosphates:

- Poly-phosphates include molecules with two or more phosphorus atoms, oxygen atoms, and hydrogen atoms, combined in a complex molecule
- Not removable by metal salt addition
- Reduced over time through hydrolysis to orthophosphate
- De-polymerized in anaerobic step of biological phosphorus removal

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Orthophosphates:

- Available for biological metabolism without further breakdown
- This is the reactive form of phosphorus
  It is the ONLY form of phosphorus whose removal can be enhanced by metal salt addition.

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Available Phosphorus Removal Options

- Goal: Incorporate Phosphorus into TSS
- Conventional: 1-2% P in WAS
  (typical 10-30% removal using secondary treatment)
- Augmented: 3-6% P in Waste Sludge
  - Biological
  - Chemical

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Biological Solids are Typically
3 - 5% Phosphorus
(No Chemical Involved)

Effluent TSS	P in Effluent TSS
2	0.06 - 0.10
5	0.15 - 0.25
10	0.3 - 0.5
15	0.45 - 0.75

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Effluent Total-P < 1.0 mg/l

Enhanced Bio-P Removal
Single-Point Metal Salt Addition
Tertiary Filtration

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Effluent Total Phosphorus < 0.5 mg/l

Enhanced Bio-P Removal
Single Point Metal Salt Addition
Polymer Addition
Tertiary Filtration

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Effluent Total Phosphorus < 0.2 mg/l

Enhanced Bio-P Removal
Multiple-Point Metal Salt Addition
Polymer Addition
Tertiary Filtration

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Effluent Total Phosphorus < 0.1 mg/l

Enhanced Bio-P Removal
Multiple-Point Metal Salt Addition
Organic Polymer Addition
Advanced Solids Separation Process

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Membranes

- Should NOT be thought of as cure-all for phosphorus removal
- Membranes are just a type of filter
  (A relatively expensive one, too)
- Should phosphorus be in soluble form, membranes will not take it out
- Other options available

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Enhanced Biological Phosphorus Removal

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Enhanced Biological Phosphorus Removal (EBPR)

- Incorporate P into sludge
  Earliest research performed by Levine and Shapiro in 1965
- Reduce metal salt costs
- Reduce polymer costs
- Reduce alkalinity adjustment costs
- Denitrification benefit

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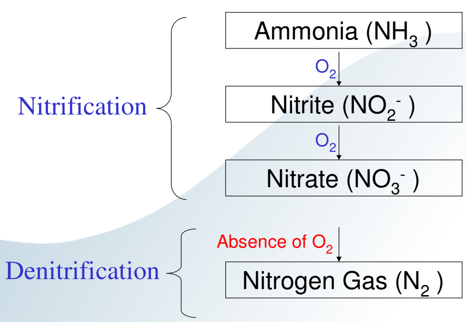
Nitrogen Removal Principals



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Anoxic vs. Anaerobic

Anoxic reaction conditions mean that no oxygen is present in solution, but nitrite (NO_2^-) or nitrate (NO_3^-) is available. Nitrate and nitrite act as electron acceptors for the oxidation of the organic substrate.

- *Biomass is NITRIFIED*

Anaerobic reaction conditions require that no O_2, NO_3^- and NO_2^- is present in solution to act as electron acceptors.

- Biomass is *DENITRIFIED*

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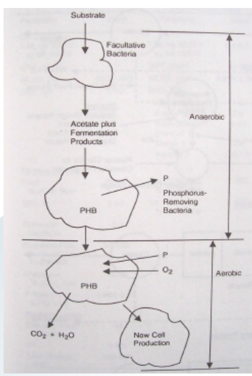
Schematic of EBPR



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EBPR: Basic Features

- Anaerobic Conditions: Release Phosphorus
- Aerobic Conditions: Store Phosphorus
- Selects microorganisms that accumulate higher levels of intracellular phosphorus than other microorganisms
  - Phosphorus accumulating organisms (PAOs) exhibit "luxury uptake"

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Anaerobic Step

Phosphorus accumulating organisms (PAOs) (e.g., *Acinetobacter*, *Pseudomonas*) assimilate short-chain volatile fatty acids (VFAs) and other fermentation products produced by other facultative bacteria (e.g., *Aeromonas*)

- VFAs are stored as intracellular poly-hydroxy-alkanoates (PHAs)

While at the same time…

Bacteria release soluble phosphorus

- Released phosphorus comes from adenosinetriphosphate (ATP), a stored energy form inside the bacterial cell
- Bacteria break the phosphate bonds of the ATP to obtain enough energy to adsorb the VFAs
- Here, ortho-phosphorus is released as poly-phosphorus is depolymerized

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Aerobic Step

Bacteria begin to oxidize the stored fermentation products (PHAs)

- Synthesize new cells
- Produce the reducing equivalents for ATP production

While at the same time…

Bacteria consume phosphorus

- Rebuild the stored energy ATP
- While doing so, soluble phosphorus is removed from wastewater
- Uptake during this period is relatively high, resulting in net removal when sludge is wasted from the system
  - Phosphorus uptake/release ratio ~ 1.2

The ability of phosphorus-removing microorganisms to rapidly assimilate the fermentation products give them a competitive advantage over other microorganisms and results in their preferential growth

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Anaerobic Reactor Conditions

- Dissolved Oxygen < 0.5 mg/l
- Nitrate (NO_3^-) < 8-12 mg/l
  - High levels of nitrate will slow down or stop phosphorus release—bacteria will use nitrate for respiration
- Substrate Availability
  - Soluble Organics
  - Volatile Fatty Acids (VFA)

Barnard cautions against having too long of an anaerobic contact time. Phosphorus release may occur without the uptake of VFA compounds. When this occurs, there are not sufficient carbon storage products within the cell to produce enough energy to force the full uptake of the released phosphorus in the aerobic contact period

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EBPR Issues

- Low BOD/TP ratios result in BPR failure because PHA storage becomes too low to produce the reducing equivalents for ATP production in the aerobic stage
- Excessive BOD/TP ratios have been found to act as an inhibitor to PAOs
- Appropriate BOD/TP ratios ~ 20-30:1 (Peurifoy WPCP~34:1)
- Only readily biodegradable COD can be converted to VFAs, which are taken up by PAOs in anaerobic stage
- Phosphorus release in anaerobic conditions is faster in higher concentration sludge than lower
- If TKN/COD ratio > 0.14, insufficient denitrification occurs—Complete denitrification occurs at < 0.08
- Recycles must be accounted for (P and N)

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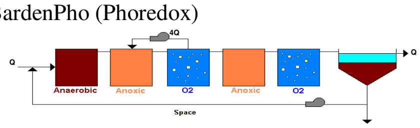
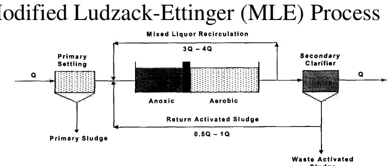
EBPR Systems

- BardenPho (Phoredox)



- Modified Ludzack-Ettinger (MLE) Process



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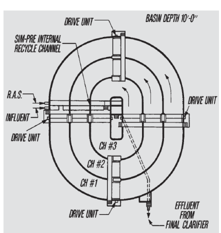
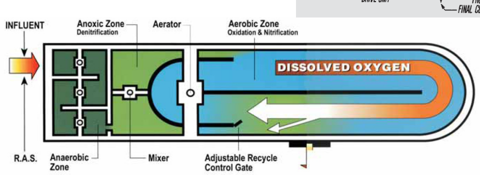
Oxidation Ditch EBPR Examples





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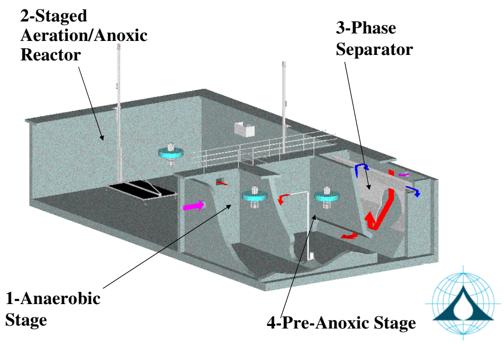
AquaPASS™ Process Stages



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AquaSBR®
Sequencing Batch Reactor

Your Wastewater Specialists

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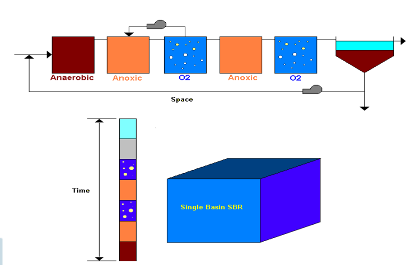
AquaSBR vs. Flow-Through Activated Sludge



- Equalization
- Anaerobic/Anoxic Mixing
- Aeration
- Nitrification
- Denitrification
- Sludge Wasting
- Clarification

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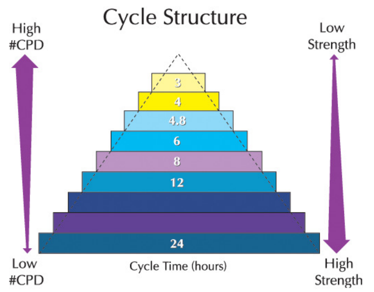

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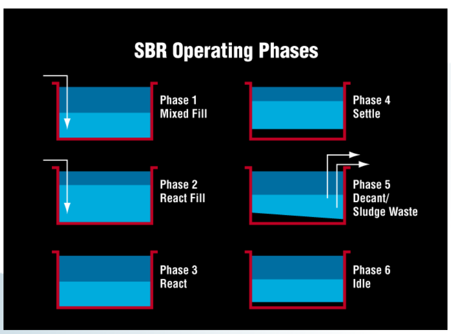
AquaSBR - Operating Phases



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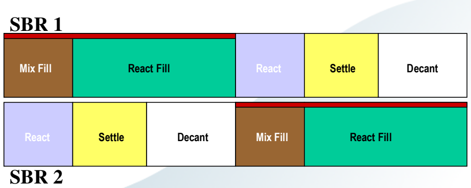
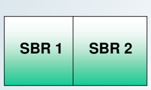
AquaSBR - Operating Phases

Time Based Operation

Increased Operator Control





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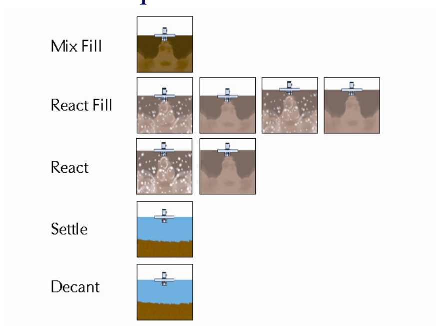
AquaSBR®: EBPR



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Stephen D. Peurifoy WPCP

Stockbridge, GA

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Stephen D. Peurifoy WPCP Operation:

- 4 cycles/day/Basin
  - MF = 100 min.
  - RF = 80 min.
  - R = 75 min.
  - S = 60 min.
  - D = 45 min.

  360 min. Total
- Aeration Timers:

  Total/On
  - 45/30
  - 45/25
  - 30/15
  - 20/20
  - 15/15
- MLSS = 2,400 mg/l

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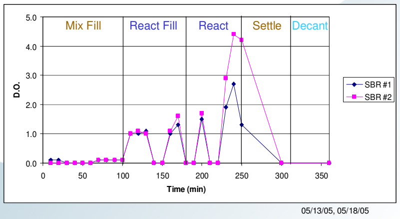
Stephen D. Peurifoy WPCP

Anaerobic, Aerobic, and Anoxic Periods within SBR Cycle



Aeration

- 45/30
- 45/25
- 30/15
- 20/20
- 15/15

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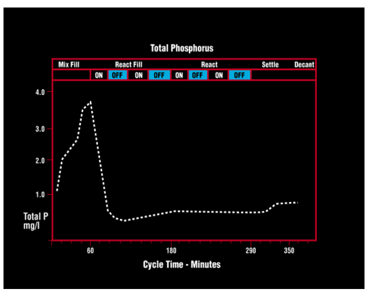
AquaSBR® - Total Phosphorus (typical)



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Peurifoy AquaSBR®

Design Data

	Influent	Effluent
ADF (MGD)	1.5	- -
MDF (MGD)	1.9	- -
BOD5 (mg/L)	250	6.0
TSS	250	20
TKN	40	- -
NH3-N	- -	1.3
Total P	5.0	0.3

Actual (2004)

	Influent	Effluent
ADF (MGD)	0.639	0.577
MDF (MGD)	- -	- -
BOD5 (mg/L)	255	2.9
TSS	222	1.6
TKN	- -	- -
NH3-N	14.1	0.38
Total P	7.4	0.15

0.15 mg/L Total P without chemical addition

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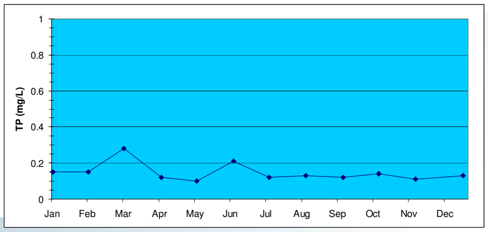
Total Phosphorus in Effluent

Jan – Dec 2004

Stephen D. Peurifoy WPCP



Note: Sampling indicates TP ~0.2 mg/L prior to filters

– Phosphorus being removed overwhelmingly through EBPR –

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Chemical Phosphorus Removal

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Chemical Phosphorus Removal

- Goal: Create insoluble forms of P
- Basic Elements to Precipitate P
  - Ferrous Iron — Fe(II)
  - Ferric Iron — Fe(III)
  - Aluminum
  - Lime — $Ca(OH)_2$

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Common Chemicals Used

- Alum (Aluminum Sulfate) — $Al_2(SO_4)_3 \cdot 14H_2O$

  $Al^{+3} + H_nPO_4^{n-3} \longrightarrow AlPO_4 + nH^+$
- Ferric Chloride — $FeCl_3$

  $Fe^{+3} + H_nPO_4^{n-3} \longrightarrow FePO_4 + nH^+$
- Poly Aluminum Chloride (PAC)

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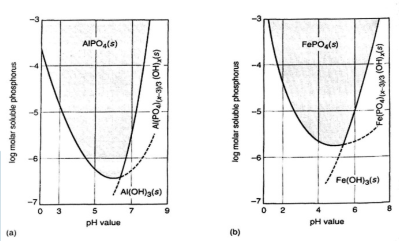
Metal Salt Addition Considerations

- Ideal pH for $AlPO_4$(s) is 6.3
- Ideal pH for $FePO_4$(s) is 5.3



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Metal Salt Addition Considerations

- Ideal pH for $AlPO_4$(s) is 6.3
- Ideal pH for $FePO_4$(s) is 5.3
- Actual Requirements > Stoichiometry
  - Typically 1-3 metal ions per one Phosphorus ion
- Proper location(s) for chemical addition
  - Headworks, Mixed Liquor, Secondary Effluent, Digester
- Chemical Cost
- Dry or liquid

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Metal Salt Addition Considerations (cont.)

- Storage Issues
- Increased removals increase sludge production
- Sludge handling issues
- Disposal issues
- Corrosion and Staining
- Alkalinity supplementation
  - In low alkalinity waters, addition of base may be needed to keep pH in appropriate range

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Metal Salt Addition Considerations (cont.)

- Storage Issues
- Increased removals increase sludge production
- Sludge handling issues
- Disposal issues
- Corrosion and Staining
- Alkalinity supplementation
  - In low alkalinity waters, addition of base may be needed to keep pH in appropriate range

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Typical Aluminum Dosage as a Function of Ortho-Phosphate Removal

% P Reduction	Mg Al per mg P
75	1.2 – 1.5
85	1.6 – 1.9
95	2.1 – 2.6

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Biological Solids are Typically 3 - 5% Phosphorus

Effluent TSS	P in Effluent TSS
2	0.06 - 0.10
5	0.15 - 0.25
10	0.3 - 0.5
15	0.45 - 0.75

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Dick Creek WRF

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Dick Creek WRF Operation:

- 5.33 cycles/day/Basin
  - MF = 50 min.
  - RF = 85 min.
  - R = 50 min.
  - S = 55 min.
  - D = 30 min.

  270 min. Total
- MLSS = 3,210 mg/L
- MLVSS = 2,735 mg/L

- DO Control Program
  Blower Always ON
  Set 3.5-4 mg/L
- pH Control Program
  Setpoint – 6.58
  Gain – 5 (0-10)
- Alum Addition Program
  Dosage - 105 mg/L

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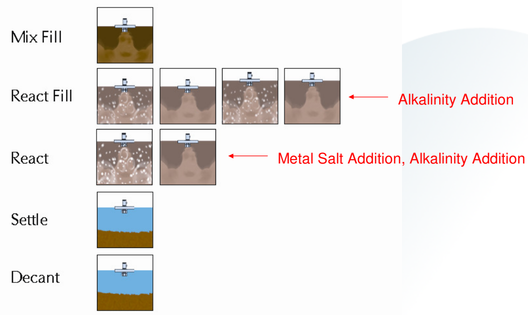
AquaSBR®: Chemical Phosphorus Removal



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Dick Creek WRF Reuse Effluent Data

	INFLUENT					REUSE EFFLUENT				
MONTH	FLOW	BOD	TSS	TKN	TP	BOD	TSS	NH3-N	TURB	TP
Mar-06	0.609	227	206	36.2	5.99	4	3	0.54	1.13	0.16
Apr-06	0.538	232	202	46.2	6.38	3	3	3.98	0.87	1.43
May-06	0.554	221	229	44.4	6.70	2	1	0.18	0.56	2.92
Jun-06	0.576	260	196	42.6	6.10	2	1	0.05	0.86	3.76
Jul-06	0.535	212	209	42.6	6.09	2	1	0.06	0.56	3.93
Aug-06	0.568	207	229	43.4	6.58	2	1	0.10	0.62	3.36
Sep-06	0.574	225	213	39.4	6.15	2	1	0.11	0.39	3.63
Oct-06	0.616	217	240	39.5	6.29	2	1	0.20	0.26	0.58
Nov-06	0.702	221	215	38.9	6.01	2	1	0.11	0.71	0.08
Dec-06	0.676	276	195	39.4	6.64	- -	- -	- -	- -	- -
Jan-07	0.592	301	215	45.2	6.86	- -	- -	- -	- -	- -
Feb-07	0.604	232	213	44.4	7.45	2	1	0.10	0.59	0.10
Mar-07	0.493	278	234	88.8	8.39	2	2	0.01	0.78	0.31
Apr-07	0.465	283	235	72.4	7.65	3	2	0.12	0.81	1.96
May-07	0.489	320	236	80.1	8.30	3	2	0.14	0.70	4.07
Jun-07	0.524	304	293	59.9	7.55	2	2	0.12	0.62	4.13
Jul-07	0.547	253	218	55.5	7.43	2	2	0.28	0.79	4.73
Aug-07	0.575	352	280	56.8	8.13	2	1	0.31	0.60	3.30
Sep-07	0.574	308	294	48.7	7.79	2	2	0.19	0.86	3.91
Oct-07	0.560	313	292	52.8	7.68	3	3	0.22	0.59	2.33
Nov-07	0.540	326	248	55.9	7.89	2	1	0.14	0.30	0.11
Dec-07	0.498	319	249	55.6	8.54	- -	- -	- -	- -	- -
Jan-08	0.520	329	264	55.5	8.69	2	2	0.41	0.36	0.13
Feb-08	0.598	298	286	54.3	7.80	2	2	0.15	0.74	0.11

Average May-Sep '06 Reuse Effluent TP--> 3.52

Average May-Sep '07 Reuse Effluent TP--> 4.03

Dick Creek WRF Reuse Effluent Permit: 5 mg/L BOD, 5 mg/L TSS, 3 NTU

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Dick Creek WRF – Sampling Data

	INFLUENT							DIRECT DISCHARGE EFFLUENT						
MONTH	FLOW	BOD	TSS	TKN	Alk	pH	TP	BOD	TSS	NH3-N	TP	ALK	NO3-N	TURB
Mar-06	0.609	227	206	36.2	126	6.93	5.99	2	1	0.61	0.11	87.3	1.6	1.13
Apr-06	0.538	232	202	46.2	135	6.77	6.38	- -	- -	- -	- -	- -	- -	- -
May-06	0.554	221	229	44.4	133	7.05	6.70	- -	- -	- -	- -	- -	- -	- -
Jun-06	0.576	260	196	42.6	127	6.57	6.10	- -	- -	- -	- -	- -	- -	- -
Jul-06	0.535	212	209	42.6	139	6.78	6.09	- -	- -	- -	- -	- -	- -	- -
Aug-06	0.568	207	229	43.4	139	6.87	6.58	- -	- -	- -	- -	- -	- -	- -
Sep-06	0.574	225	213	39.4	133	6.87	6.15	- -	- -	- -	- -	- -	- -	- -
Oct-06	0.616	217	240	39.5	138	7.14	6.29	- -	- -	- -	- -	- -	- -	- -
Nov-06	0.702	221	215	38.9	119	7.03	6.01	2	1	0.17	0.10	76.8	2.4	0.42
Dec-06	0.676	276	195	39.4	136	7.12	6.64	2	1	0.15	0.10	82.3	3.1	0.59
Jan-07	0.592	301	215	45.2	135	7.06	6.86	2	1	0.11	0.10	77.6	2.6	0.56
Feb-07	0.604	232	213	44.4	132	5.78	7.45	2	1	0.08	0.11	70.4	3.7	0.55
Mar-07	0.493	278	234	88.8	162	7.27	8.39	2	1	0.28	0.11	75.0	3.3	0.88
Apr-07	0.465	283	235	72.4	141	7.07	7.65	- -	- -	- -	- -	- -	- -	- -
May-07	0.489	320	236	80.1	165	7.17	8.30	- -	- -	- -	- -	- -	- -	- -
Jun-07	0.524	304	293	59.9	163	6.99	7.55	- -	- -	- -	- -	- -	- -	- -
Jul-07	0.547	253	218	55.5	158	6.99	7.43	- -	- -	- -	- -	- -	- -	- -
Aug-07	0.575	352	280	56.8	159	7.22	8.13	- -	- -	- -	- -	- -	- -	- -
Sep-07	0.574	308	294	48.7	154	7.39	7.79	- -	- -	- -	- -	- -	- -	- -
Oct-07	0.560	313	292	52.8	161	7.41	7.68	- -	- -	- -	- -	- -	- -	- -
Nov-07	0.540	326	248	55.9	171	7.66	7.89	2	1	0.24	0.09	74.5	1.9	0.23
Dec-07	0.498	319	249	55.6	168	7.48	8.54	2	1	0.24	0.08	69.6	2.3	0.41
Jan-08	0.520	329	264	55.5	168	7.52	8.69	2	1	0.27	0.10	64.4	2.4	0.32
Feb-08	0.598	298	286	54.3	158	7.33	7.80	2	1	0.06	0.10	61.0	2.7	0.68

Dick Creek WRF Direct Discharge Effluent Permit (Nov-Apr, 83.0 MG total):
5 mg/L BOD, 5 mg/L TSS, 3 NTU, 1 mg/L NH_3-N, 0.13 mg/L Total P

Crocker & Associates, Inc.
Dick Creek WRF

Chemical Requirement Calculation Data

	Influent (mg/L)	Effluent (mg/L)
BOD_5	236	2
TKN	42	--
NH_3-N	--	0.10
Total P	6.4	0.10*
		* (3.6 mg/L during reuse months)
Alkalinity	133	80
NO_3-N	--	2.7
Flow	0.6 MGD	--

Crocker & Associates, Inc.
Dick Creek WRF – Aluminum Sulfate Requirement

Influent Total P = 6.4 mg/L

Based upon typical phosphorus uptake of approximately 1% of influent BOD, the SBR should attain an effluent Total P of approximately 4.0 mg/L. (6.4 – (236 * 0.1))

✓ This checks approximately with the effluent Total P of **3.6 mg/L** during reuse months.

The chemical dosage is based on the remaining phosphorus after biological uptake less the effluent objective:

3.6 mg/L – 0.10 mg/L = 3.5 mg/L

3.5 mg/L * 0.6 MGD * 8.34 lb/gal = **17.5 lbs/day Total P**

Crocker & Associates, Inc.
Dick Creek WRF – Aluminum Sulfate Requirement

Check the % Total P removal to determine appropriate Aluminum Dose Rate :

(3.6 – 0.1) / 3.6 = **97%**

Since the % removal is quite high, assume Al:P ratio of **2.7 to 1**:

17.5 lbs/day Total P * 2.7/1 = **47.3 lbs/day Al^{+3}**

At **9.1% Al^{+3}** in “Alum”, the dosing rate of $Al_2(SO_4)_3$ is:

47.3 lbs/day / 0.091 = **519 lbs/day $Al_2(SO_4)_3$**

Crocker & Associates, Inc.

Dick Creek WRF – Aluminum Sulfate Requirement

Check against Operator Input to Alum Feed Program:

✓ 519 lbs/day / (0.6 MGD*8.34 lbs/gal) = **104 mg/L vs. 105 mg/L**

Dick Creek WRF uses **49% Aluminum Sulfate** product:

519 lbs/day $Al_2(SO_4)_3$ /(11.0 lbs/gal x 0.49) = **96 gal/day $Al_2(SO_4)_3$**

✓ *Consistent with past chemical usage*

Crocker & Associates, Inc.

Dick Creek WRF – Chemical Solids Production

Solids produced through Aluminum Sulfate addition may be estimated using:

$Al_2(SO_4)_3 * 14\ H_2O + 2PO_4^{-3} \rightarrow 2\ AlPO_4 + 3\ SO_4^{-2} + 14\ H_2O$

At 3.9 lbs $AlPO_4$ produced per lb “P”

17.5 lbs/day Total P * 3.9 = **68.3 lbs/day $AlPO_4$ produced**

Crocker & Associates, Inc.

Dick Creek WRF – Chemical Solids Production

Solids produced through Aluminum Sulfate addition may be estimated using:

$Al_2(SO_4)_3 * 14\ H_2O + 2PO_4^{-3} \rightarrow 2\ AlPO_4 + 3\ SO_4^{-2} + 14\ H_2O$

At 0.87 lbs Al^{+3} utilized per lb “P”:

17.5 lbs/day Total P * 0.87 = **15.2 lbs/day Al^{+3} utilized**

For 519 lbs/day $Al_2(SO_4)_3$ dosage:

519 $Al_2(SO_4)_3$ x 0.091* = **47.2 lbs/day Al^{+3} provided**

*9.1% Al^{+3} in “Alum”

Therefore,

Al^{+3} available for hydrolysis = 47.2 – 15.2 = **32.0 lbs/day**

Crocker & Associates, Inc.

Dick Creek WRF – Chemical Solids Production

Aluminum Hydroxide production may then be estimated using the following:

$Al_2(SO_4)_3 * 14\ H_20 + 6\ HCO_3^- \rightarrow 2\ Al(OH)_3 + 3\ SO_4^{-2} + 6CO_2 + 14\ H_2O$

At 2.9 lbs $Al(OH)_3$ produced per lb Al^{+3}: (assuming adequate alkalinity)

2.9 x 32.0 = **92.8 lbs/day $Al(OH)_3$**

Crocker & Associates, Inc.

Dick Creek WRF – Chemical Solids Production

Therefore,

Total chemical solids produced based on the Aluminum Sulfate dosing rate of 519 lbs/day is:

68.3 lbs/day $AlPO_4$ + 92.8 lbs/day $Al(OH)_3$ = **161 lbs/day solids**

Note: Side reactions, such as $CaSO_4$, may result in the production of additional solids

Compare to estimated WAS produced:

236 mg/L BOD * 0.6 MGD * 8.34 lb/gal * (0.8 lb WAS/lb BOD) = **945 lbs WAS/day**

That's a >17% increase!

Crocker & Associates, Inc.

Dick Creek WRF – Alkalinity Requirement

Nitrification Alkalinity Requirement

$N_{NET} = TKN – N_B – N_R – N_E$

Where:

N_B = Nitrogen used by the biomass (assumed 5% of BOD)
N_R = Refractory Organic Nitrogen (assumed 2 mg/L)
N_E = Effluent NH_3-N

Therefore,

N_{NET} = 42 - (0.05 * 236) - 2 - 0.1 = **28.1 mg/L NH_3-N**

For 7.14 lbs. Alkalinity (as $CaCO_3$) per lb. NH_3-N oxidized,
7.14 * 28.1 = **201 mg/L as $CaCO_3$ required for nitrification**

Crocker & Associates, Inc.

Dick Creek WRF – Alkalinity Requirement

De-Nitrification Alkalinity Recovery

Denitrification in the AquaSBR occurs during the Mix-Fill Phase. It may also occur in the React-Fill and React phases (should nitrates be available, the blowers be turned off, D.O.→ 0 mg/L, and a carbon source is present).

$N_{NET} - [NO_3\text{-}N]_{EFF}$ = 28.1 - 2.7 = **25.4 mg/L NO_3-N denitrified**

For 3.57 lbs. Alkalinity (as $CaCO_3$) per lb. NO_3-N denitrified,
3.57 * 25.4 = **90.7 mg/L Alkalinity recovered**

During facility design, it may be prudent to ignore alkalinity recovery through denitrification as a conservative design approach

Crocker & Associates, Inc.

Dick Creek WRF – Alkalinity Requirement

Theoretical Net Alkalinity = $ALK_{NITE} - ALK_{DENITE} - ALK_{INF}$

201 – 90.7 – 133 = **-22.7 mg/L Net Alkalinity Required**

However, it is prudent to have from 50-100 mg/L Alkalinity as an effluent residual as a buffer to ensure reaction completion.

Therefore,
Required Alkalinity Dosage = $ALK_{NET} + ALK_{BUFFER}$

-22.7 + 80 = **57.3 mg/L as $CaCO_3$**

Or, 57.3 mg/L * 0.6 MGD * 8.34 lbs/gal = **287 lbs/day as $CaCO_3$**

Crocker & Associates, Inc.

Dick Creek WRF – Alkalinity Requirement

Alkalinity required from Aluminum Sulfate addition may be estimated from:

$Al_2(SO_4)_3$ * 14 H_20 + 6 HCO_3^- → 2 $Al(OH)_3$ + 3 SO_4^{-2} + 6CO_2 +14 H_2O

At 0.5 lbs Alkalinity (as CaCO3) required per lb $Al_2(SO_4)_3$:

519 lbs/day $Al_2(SO_4)_3$ x 0.5 = **260 lbs/day as $CaCO_3$**

Compare this to **287 lbs/day CaCO3** from before, and

Therefore,
Total Alkalinity Addition Requirement = 547 lbs/day as $CaCO_3$

Crocker & Associates, Inc.

Dick Creek WRF – Alkalinity Requirement

pH Control/Alkalinity Addition

Source Material	Mg Alkalinity as CaCO3 per mg of Source Mat'l
CaO (Calcium Oxide)	1.8
$Mg(OH)_2$ (Magnesium Hydroxide)	1.4
NaOH (Sodium Hydroxide)	1.2
Na_2CO_3 (Sodium Carbonate)	0.9

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Dick Creek WRF – Alkalinity Requirement

Dick Creek WRF uses NaOH (25%).

Therefore,
547 lbs/day (as CaCO3) / (1.2 * 0.25) = **1,823 lb/day NaOH (25%)**

Or, at 12.76 lb/gal, **143 gal/day NaOH (25%)**

✓Consistent with past chemical usage

Crocker & Associates, Inc.

Chemical Costs

- Ferric Chloride (30%) $0.95/gallon
- Aluminum Sulfate $0.13/lb
- NaOH (50%) $0.14/lb
- Polymer $2.00/lb

I would encourage owners to try different chemicals. Products such as PAC or Sodium Aluminate may be more economical for the overall application.

Crocker & Associates, Inc.

Advanced Solids Separation Technologies

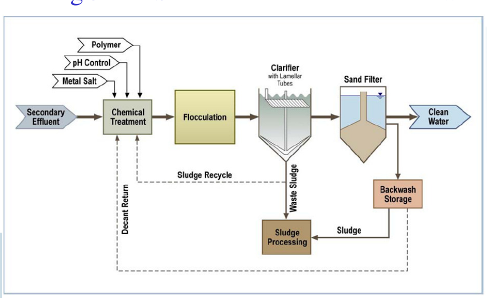
Crocker & Associates, Inc.

Advanced Solids Separation Technologies

- **DensaDeg®**
- **Actiflo®**
- **Dualsand™**
- **Secondary Effluent Membrane Filtration**
- **Membrane Bio-Reactor (MBR)**
- **CoMag™**

Crocker & Associates, Inc.

DensaDeg® and Sand Filtration Process Flow



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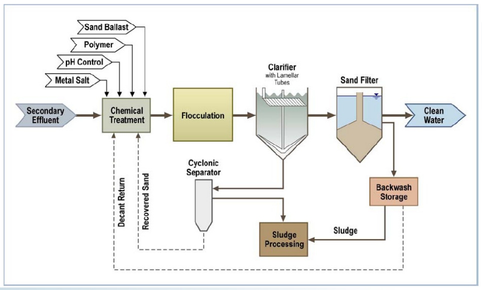
Actiflo® and Sand Filtration Process Flow



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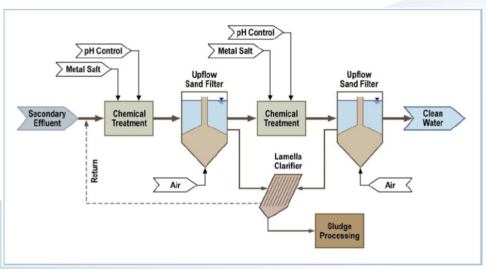
Dualsand™ Process Flow



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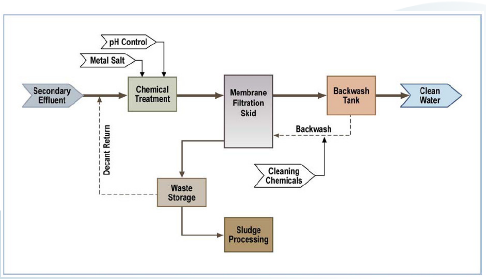
Secondary Effluent Membrane Filtration Process Flow



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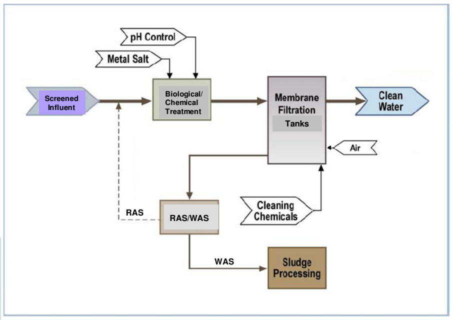
Membrane Bio-Reactor (MBR) Process Flow



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MBR System Overview

A. Headworks

- Coarse Screening (6 mm, ¼”) – *Optional?*
- Grit Removal – *Optional?*
- Fine Screening (1-3 mm) – *Required!*

B. Biological Process

- MLSS = 8,000-10,000 mg/l
- Recycle sludge streams – *Return where?*

C. Membrane Filtration

- Submerged Membranes
- ~0.05 Micron Filtration
- Air Scour Cleaning

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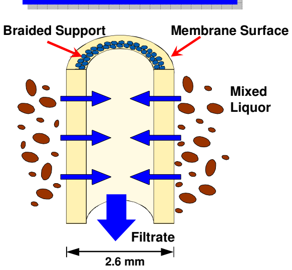
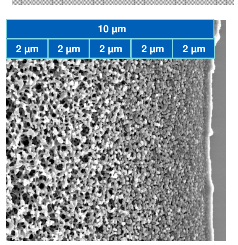
Supported Hollow Fiber



Membrane Cross Section



Enlargement: 10,000 x

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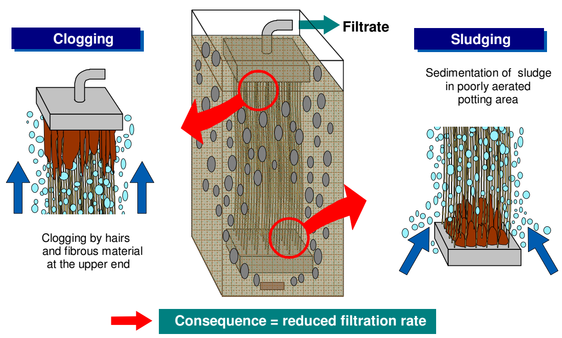
Performance Challenges – Double Header Design



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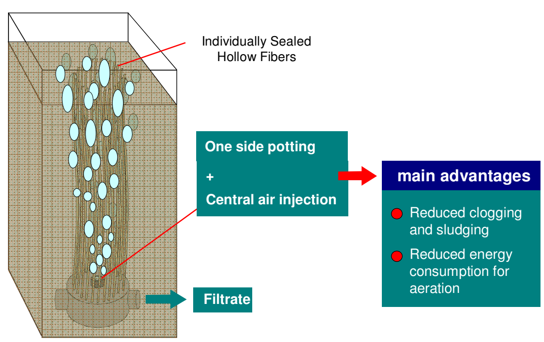
PURON® Membrane Technology

Design Issues – Single Header Concept



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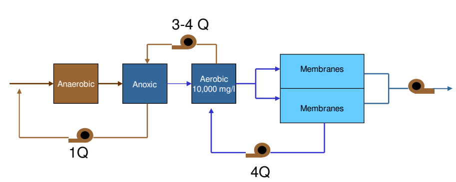
Typical MBR Recycles

BNR (Denitrification & P Removal)



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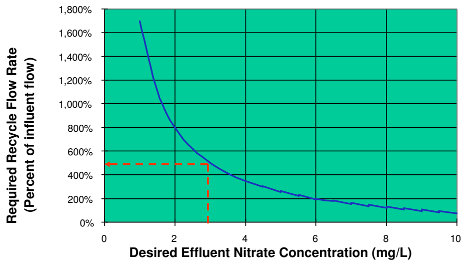
Effluent NO3-N vs. Recycle Rate



Internal N03-N Recycle Pump <u>Not Required</u> with Aqua-Aerobic® MBR!

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Aqua-Aerobic® MBR: General Arrangement

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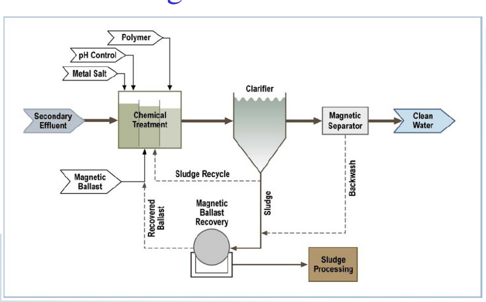
CoMag™ Process Flow



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CoMag™

VIDEO

Crocker & Associates, Inc.

CoMag™

CoMag™ extends the advantages of conventional ballasted clarification to enable significantly higher surface overflow rates (SOR).

CoMag™ utilizes magnetite (SG = 5.2) instead of sand (SG = 2.5)

As shown in the video clip, **CoMag™** clarification is remarkably rapid.

Rapid clarification = Low hydraulic retention times (HRTs)
Lower HRTs = Smaller clarifiers
Smaller Clarifiers = *Smaller footprint and installed costs*

CoMag™'s high gradient magnetic filtration provides an additional polishing mechanism when high levels of contaminant removal are required.

CoMag™ can capture particulate as small as 26 nanometers in diameter.

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Process Removal Alternatives Evaluation Matrix for 0.05 mg/L TP

Criteria	Weight	Actiflo & Sand Filter	DensaDeg & Sand Filter	Dualsand Filter	Membrane	CoMag
Safety	4	○	○	○	○	○
Reliability Factors						
Process flexibility	4	◇	◇	□	○	●
Process reliability	4	◇	◇	□	●	●
Commercial technology	3	○	○	○	○	◇
Implementation Factors						
Impact on other processes	4	○	○	○	○	○
Ease of implementation	3	○	○	○	□	○
Space requirements	3	□	□	■	●	○
Ease of construction	2	●	●	●	◇	●
Phased implementation	2	●	●	□	□	●
Operational Factors						
Staffing Requirements	3	◇	◇	◇	○	●
Community impacts	2	○	○	○	○	○
Total Weighted Score of Differentiating Factors		**123**	**123**	**106**	**131**	**148**
Score as % of Maximum Possible Score		**72**	**72**	**62**	**77**	**87**

5 = Excellent (●); 4 = very good (○); 3 = average (◇); 2 = fair (□); and 1 = poor (■)

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Conclusions

- For above 0.1 mg/L TP, conventional techniques of biological treatment, clarification, chemical addition, and filtration should suffice
- Numerous advanced technologies to achieve <0.1 mg/L TP
- Consideration must be given to many factors, to include effluent limits, initial capital costs, installation costs, replacement/maintenance costs, operational costs, operational flexibility, and complexity

Crocker & Associates, Inc.

Questions?

CROCKER & ASSOCIATES, INC.
Manufacturer's Representative for
Water, Wastewater, and Odor Control

Wastewater Treatment Phosphorus Removal Methods and Processes

GAWP District 6 Meeting

June 18, 2008

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