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New and Innovative Rare Earth Technology for Low-Level Phosphorus Removal

Ohio One Water 2014

27 August 2014
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One Water

Discussion Outline

- Rare Earth Technology Introduction
  - What are rare earths?
  - Rare earth versus traditional P removal
- Preliminary Lab Studies
- Field Validation Trials
  - Equipment setup
  - Facility processes
  - Trial results
- Conclusions

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Rare Earth Technology

- Rare earth elements are located in the lanthanide series (plus Sc and Y) of the periodic table
- Most prominently known for high strength, permanent magnets
- Unique reactivity with oxyanions, such as phosphate

1 H																	2 He
3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca		21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
37 Rb	38 Sr		39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
55 Cs	56 Ba	*	71 Lu	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
87 Fr	88 Ra	**	103 Lr	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Uun	111 Uuu	112 Uub	113 Uut	114 Uuq	115 Uup	116 Uuh	117 Uus	118 Uuo

*	57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb
**	89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No

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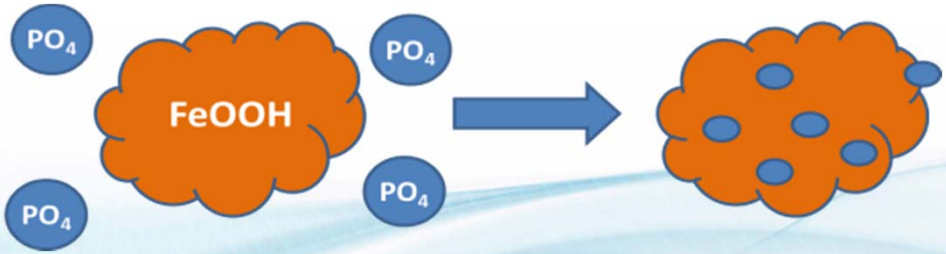
Phosphorus Removal Mechanism

- Rare earth elements form strong, crystalline bonds with phosphorus
  - Forms insoluble rhabdophane precipitate

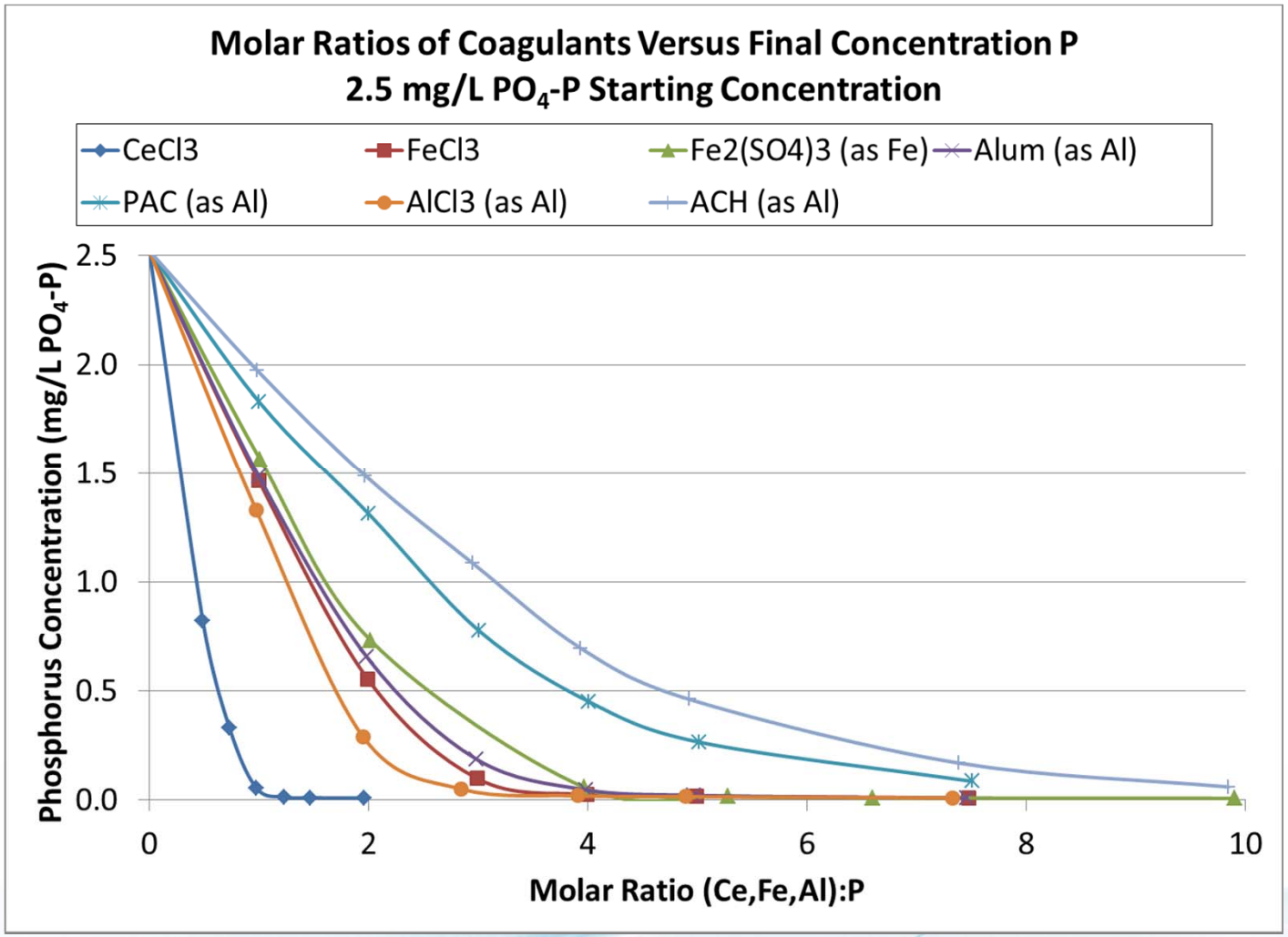
- Iron and aluminum based products form amorphous “cloud” in solution
  - Adsorbs phosphate onto metal hydroxide flocc



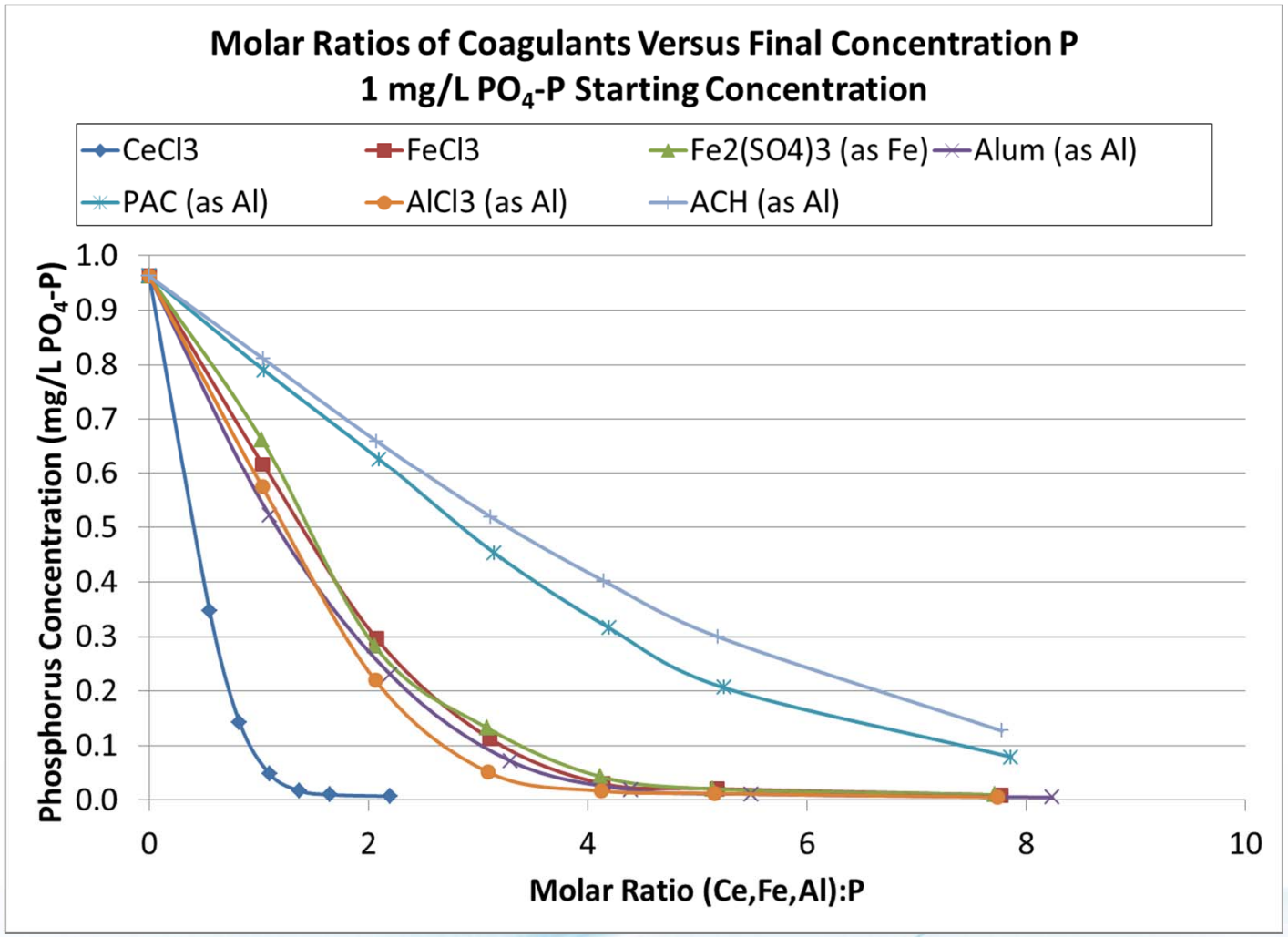
Product Characteristics

- Active Ingredient: $CeCl_3$
  - Concentration: 31.5% $CeCl_3$
- Density: 1.47 g/mL
  - 12.3 lbs/gal
- pH: 3.5
  - Non-hazardous rating

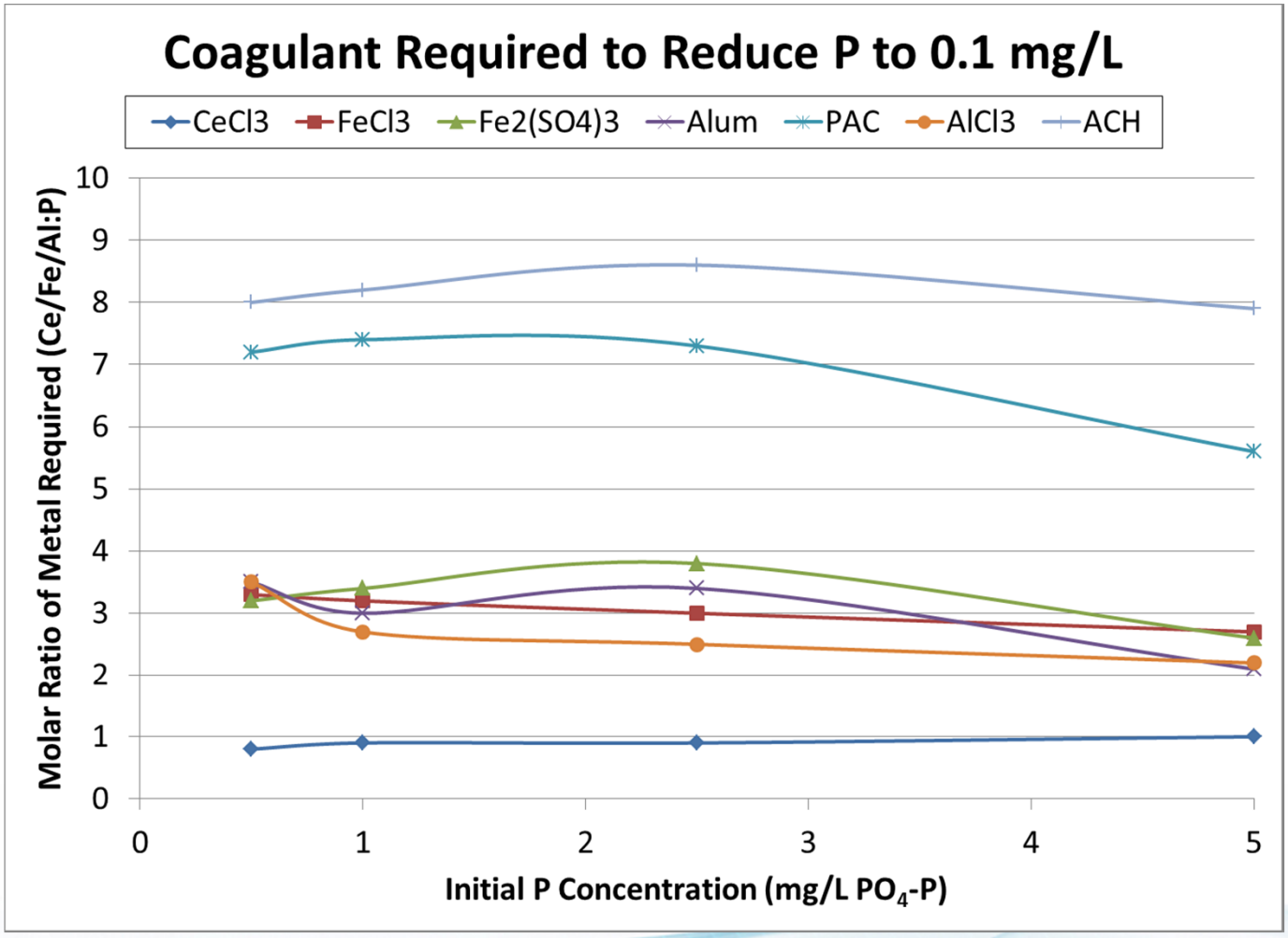
Coagulant Comparison – 2.5 mg/L



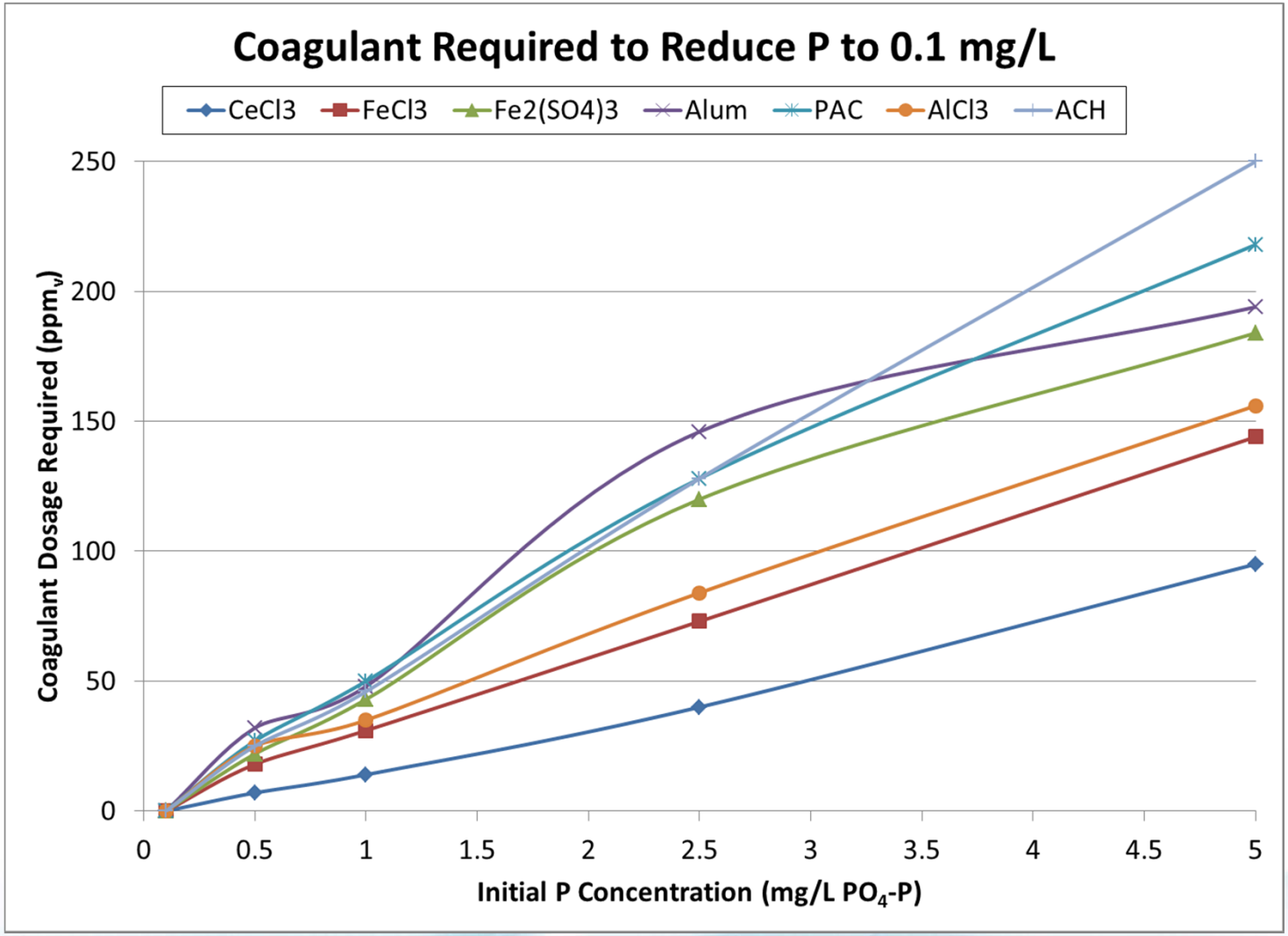
Coagulant Comparison – 1 mg/L



Coagulant Comparison – Varying Initial P



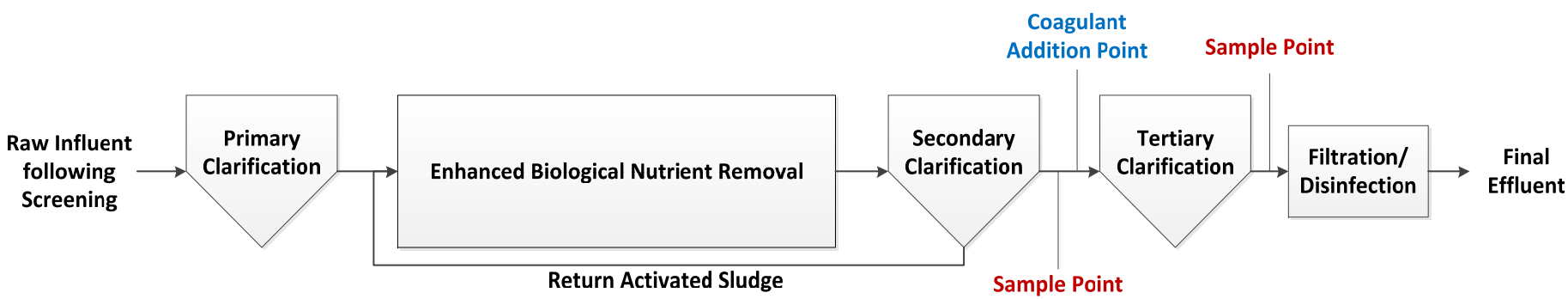
$CeCl_3$ Requires Lower Volume than Traditional Coagulants



Field Validation Trials - Equipment Setup

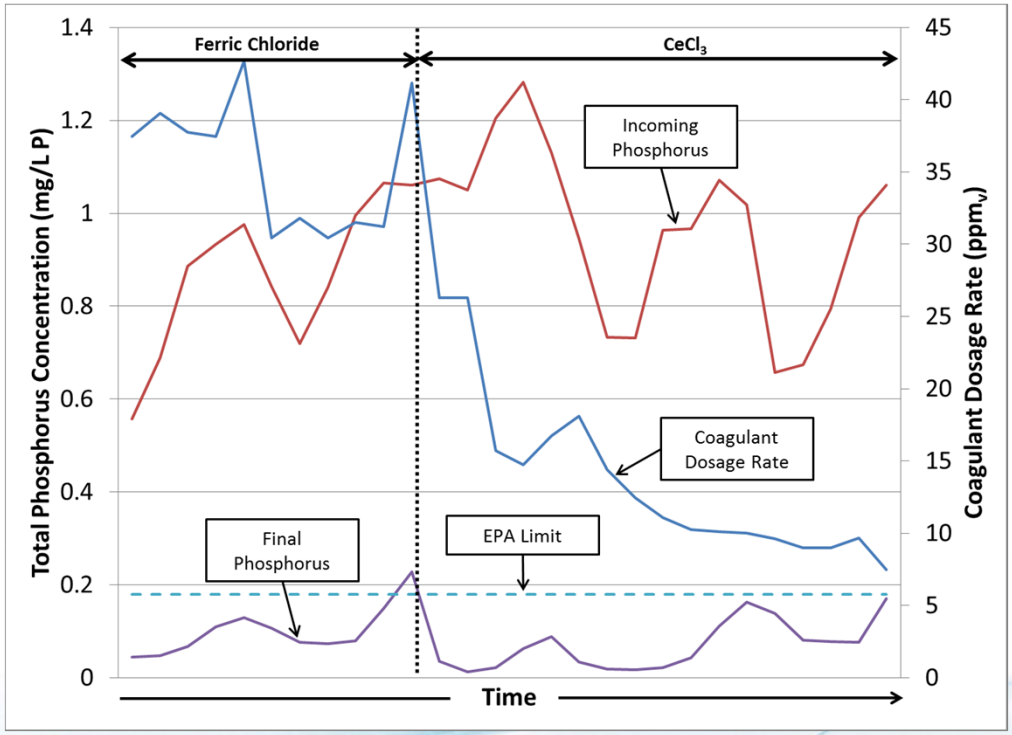
Case Study #1

- 45 MGD municipal WRF located in Mid-Atlantic United States
- Total phosphorus limit of 0.18 mg/L P
  - Target of 0.10 mg/L P
- Interested in seeking new coagulant with lower consumption rate, less chemical solids produced, and less staining of UV



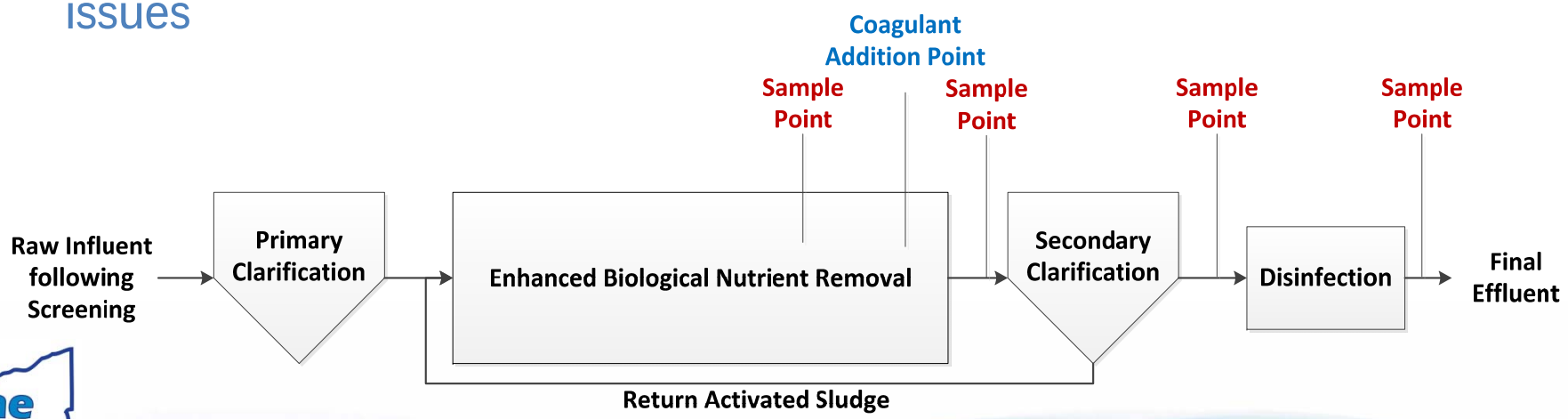
Case Study #1

- $CeCl_3$ maintained phosphorus below limit with dosage rate 3x less than $FeCl_3$
  - $CeCl_3$ dosage rate: 11 ppm_v ; Ferric dosage rate: 34 ppm_v
  - Molar ratios – 0.7:1 Ce/P ; 3.5:1 Fe/P



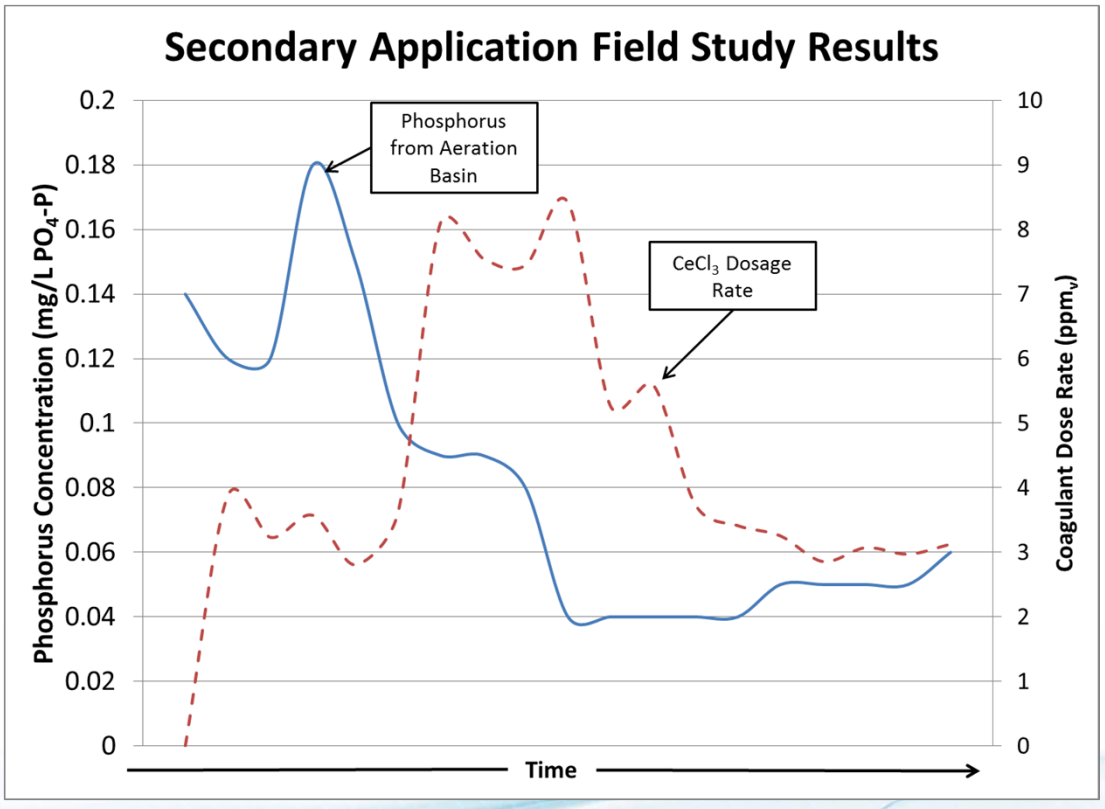
Case Study #2

- 11 MGD municipal WRF located in Northeast United States
- New total phosphorus limit of 0.10 mg/L P
  - Down from limit of 0.70 mg/L P
- Ferric chloride use has caused:
  - Corrosion damage
  - Staining of equipment and facility
  - Discoloration of water
- Facility wanted to discontinue use of ferric chloride due to above issues



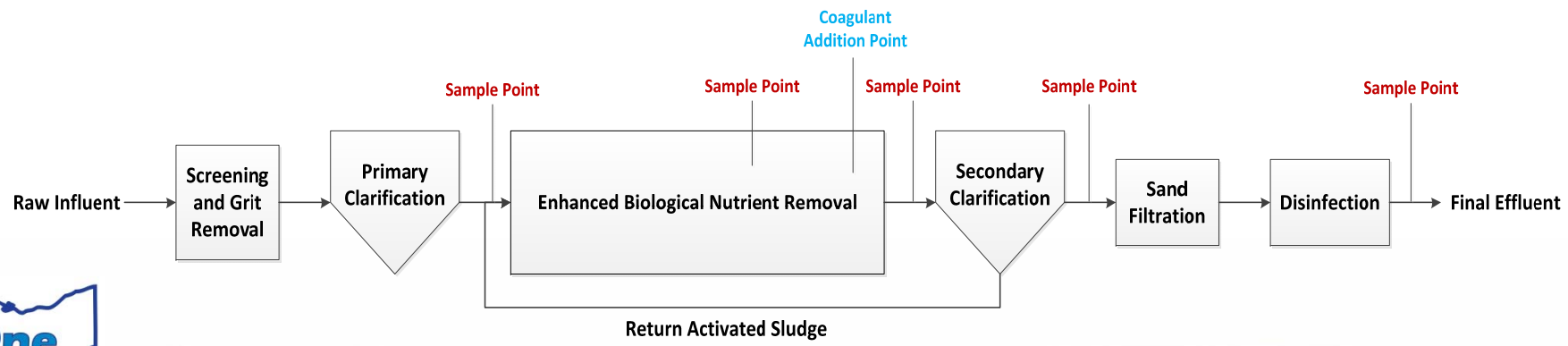
Case Study #2

- $CeCl_3$ maintained effluent P of 0.05 mg/L using dose rate of 3 ppm_v
- Solids being recycled through RAS stream continued to lower P upstream of addition point due to extended solids contact time



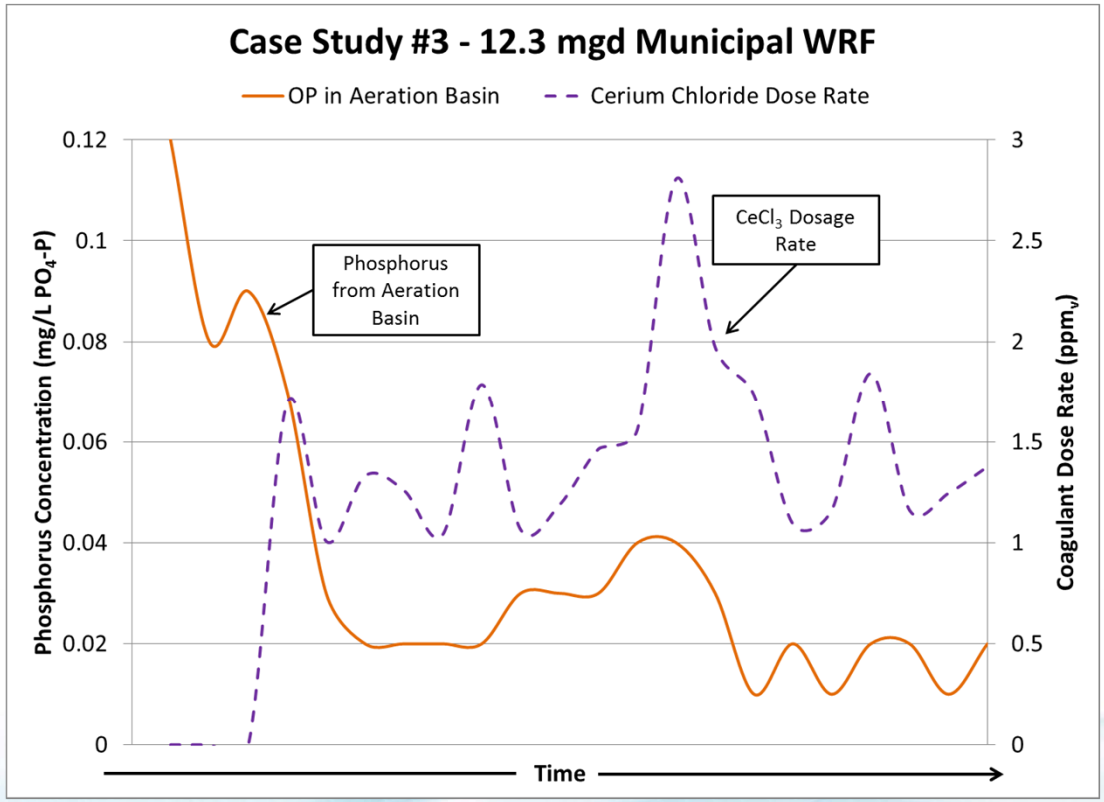
Case Study #3

- 12 MGD municipal WRF located in Mid-Atlantic United States
- Total phosphorus limit of 0.30 mg/L P
- Uses ferric chloride in addition to EBPR to meet limit
  - Experiences decline in biological phosphorus removal in summer
- Current coagulant unable to maintain required discharge during EBPR upset conditions



Case Study #3

- $CeCl_3$ maintained effluent P of 0.04 mg/L using dose rate of 1.5 ppm_v
- Like Case Study #2, solids being recycled through RAS stream continued to lower P upstream of addition point



Conclusions

- Cerium chloride has ability to remove P using less volume than traditional Fe and Al based coagulants
  - Reacts at or below stoichiometric requirements
- RAS recycle increases P removal to above theoretical removal capacity
- General Rules of thumb
  - $CeCl_3$ removes 0.5 lbs P per gallon solution
  - Requires approximately 15 ppm_v $CeCl_3$ per mg/L PO_4-P

Questions?

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