Roseland Lake

Analysis of Data Collected by ECCD

Recommendations for Nutrient Reduction

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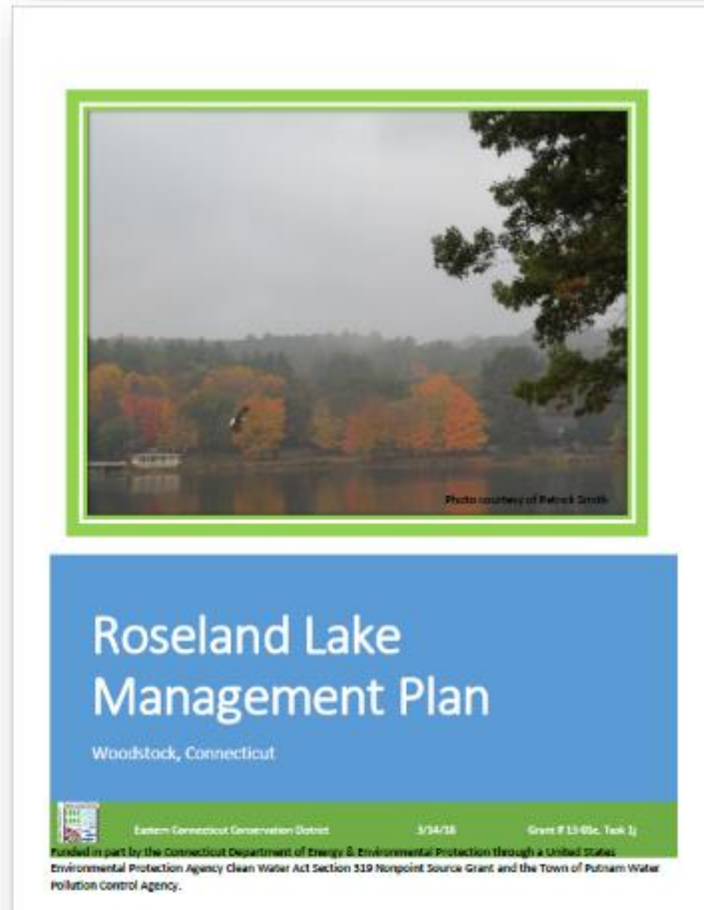
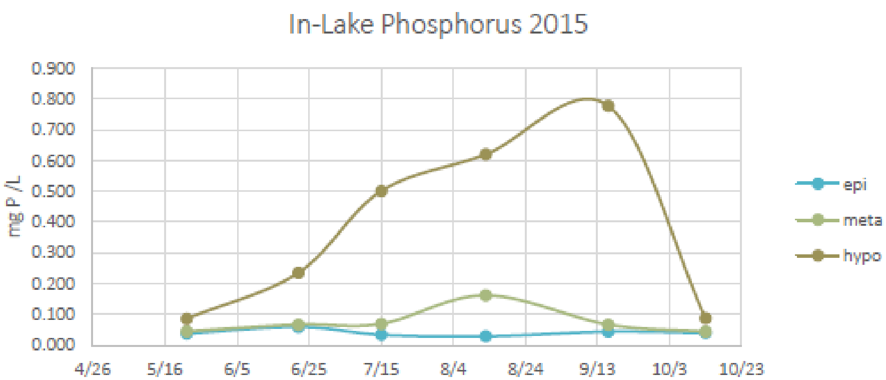
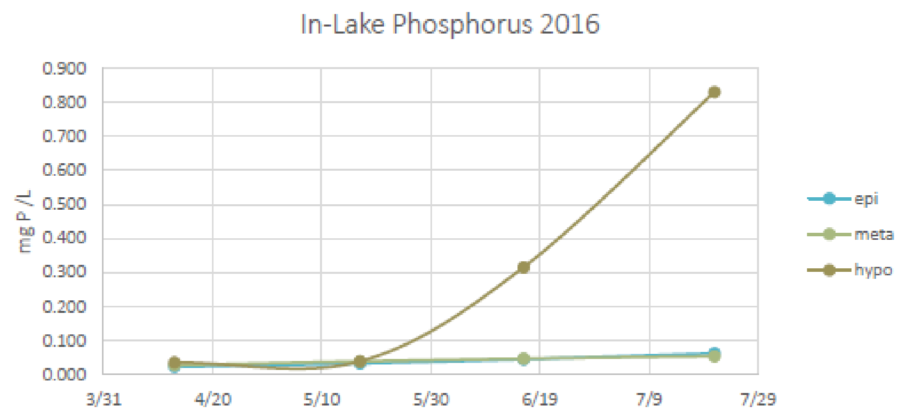
Overview of Our Work: Review As Much Data As Possible & Make Informed Decisions

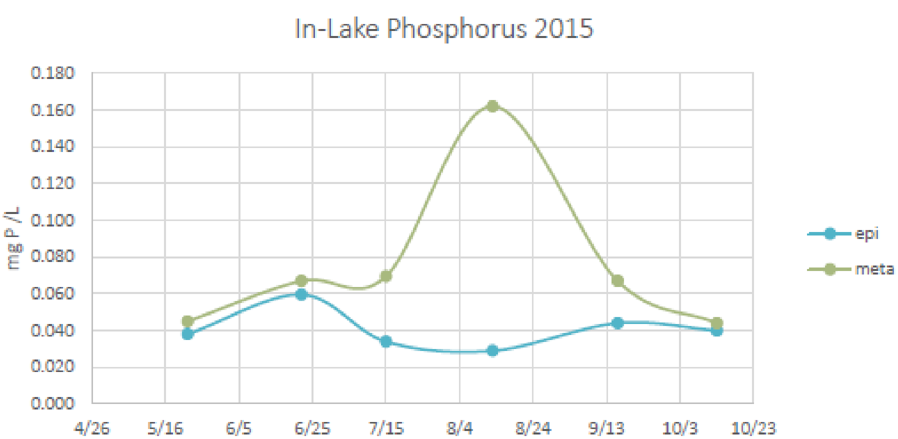
1. Review Roseland in-lake nutrient data
2. Examine lake profile measurements and clarity
3. Critical review of watershed and internal nutrient loading models
4. Volumetric nutrient mass calculations
5. Examination of rainfall patterns during sampling period
6. Review Historical Studies & Review 2018 cyanobacteria pigment monitoring data
7. Review ECCD Lake Management Plan
8. Make Management Decisions

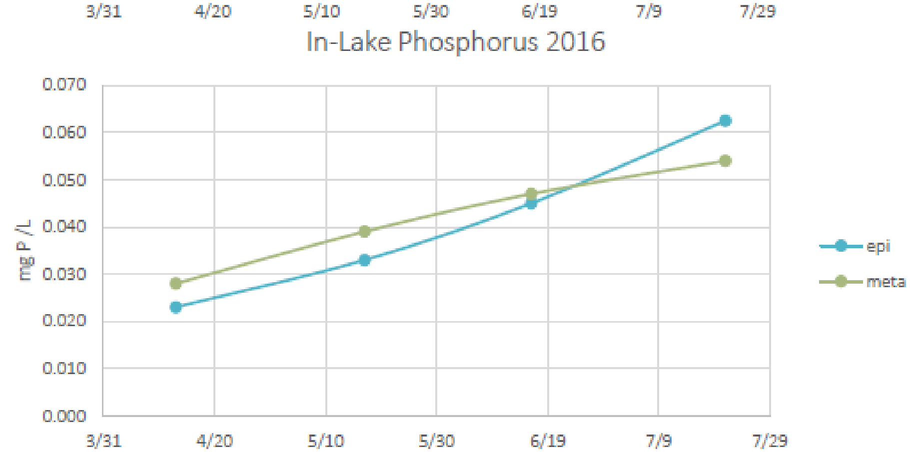


Task #1: Review Roseland in-lake nutrient data





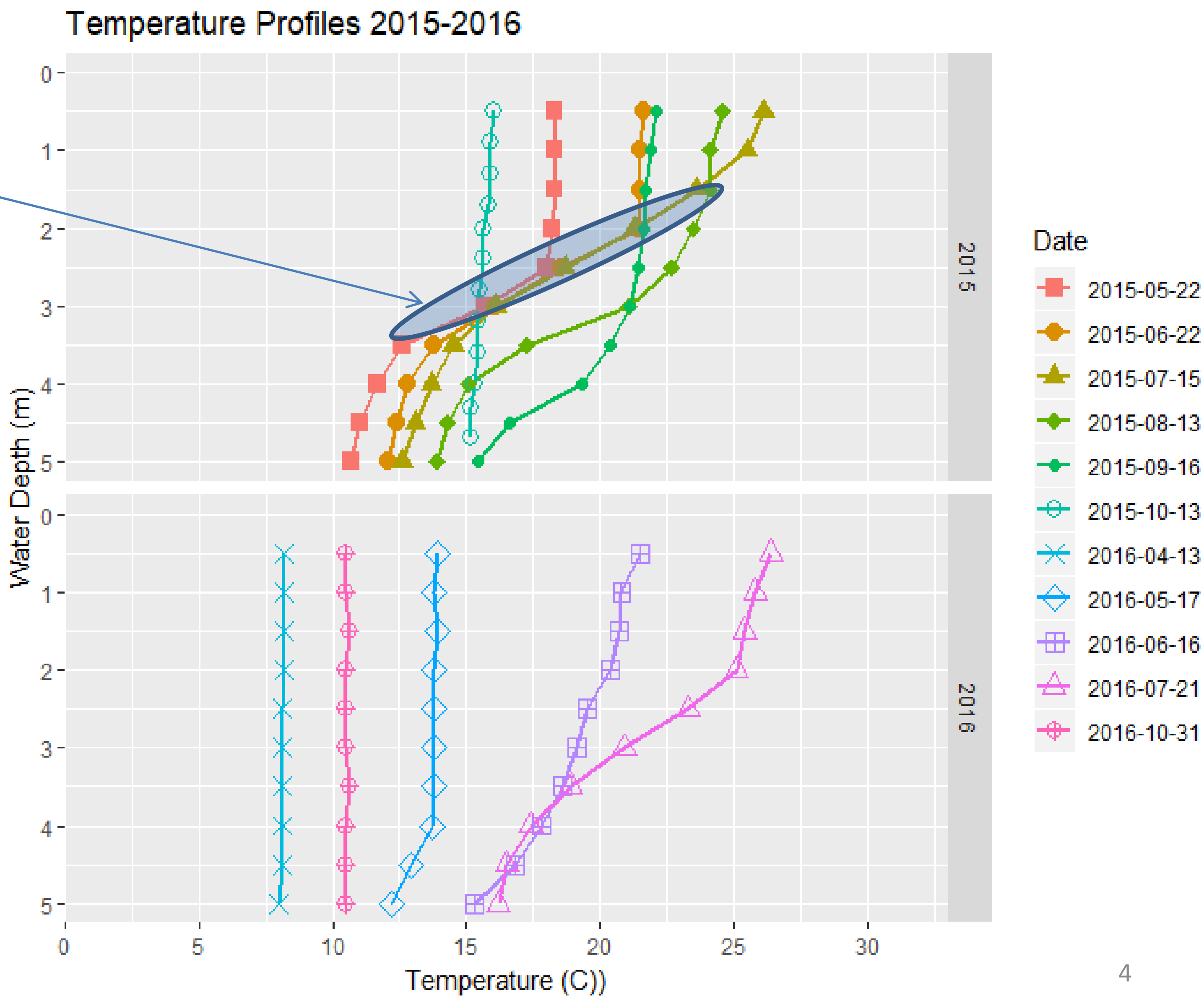




#2: Profile Data Analysis

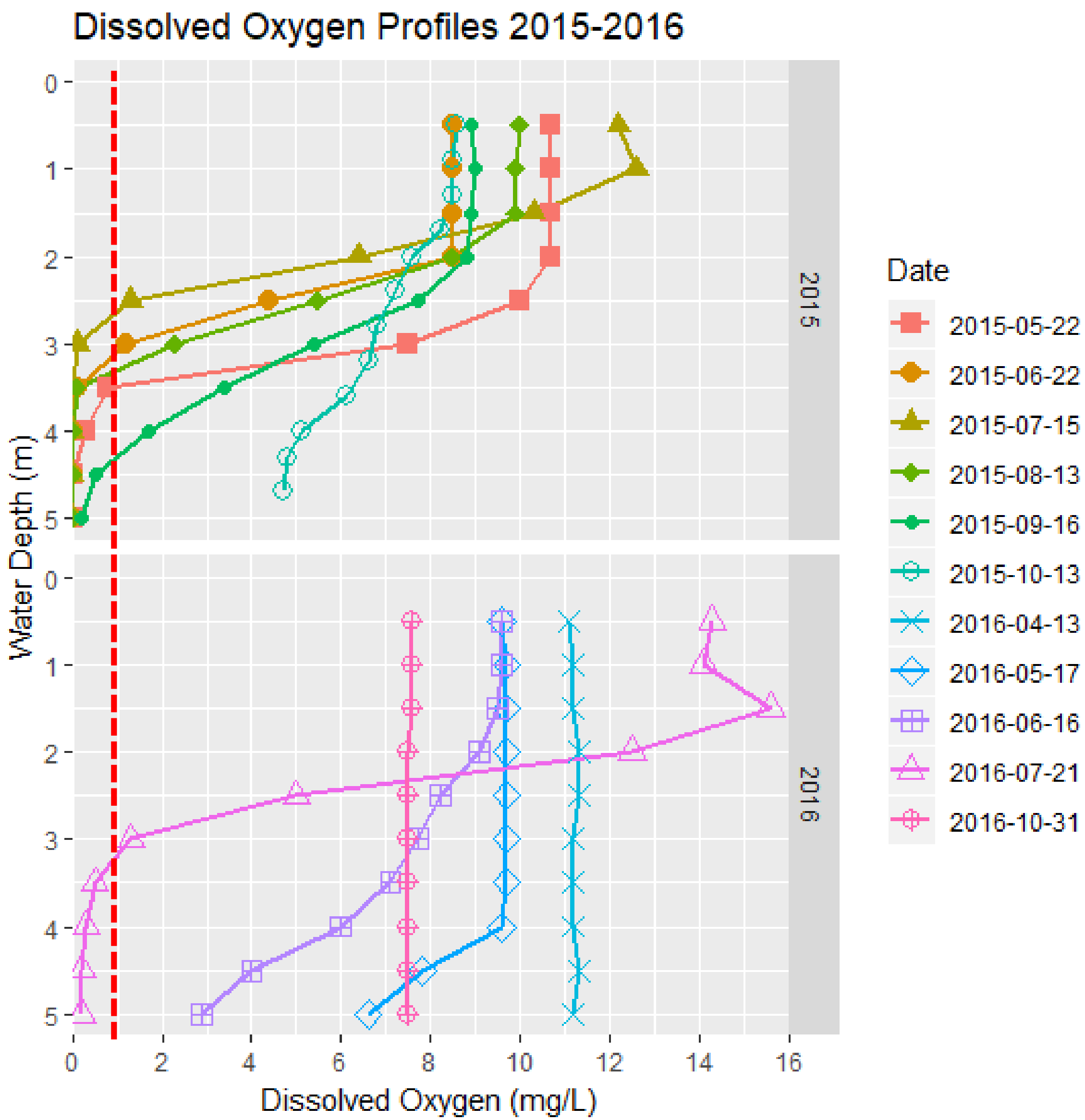
Stratification (formation of a <u>thermocline</u>) inhibits lake mixing

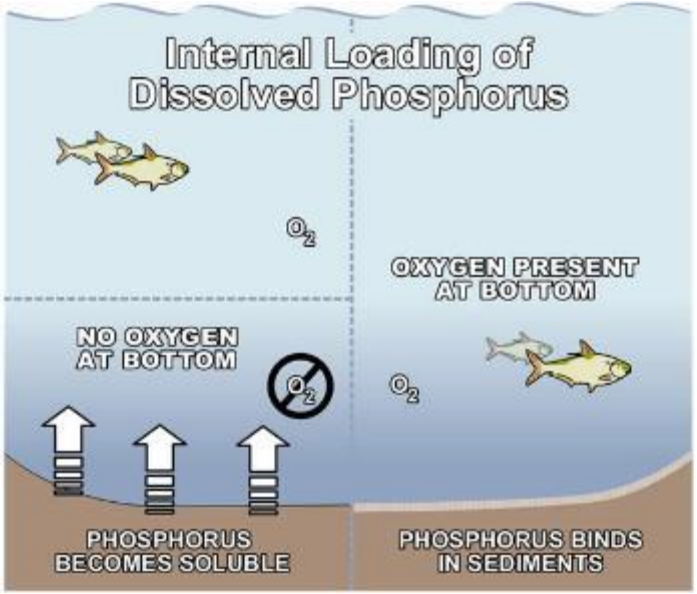
- Look at 2018 Temp profiles
- Water column more stratified in 2015 than 2016



Task #2 (continued)

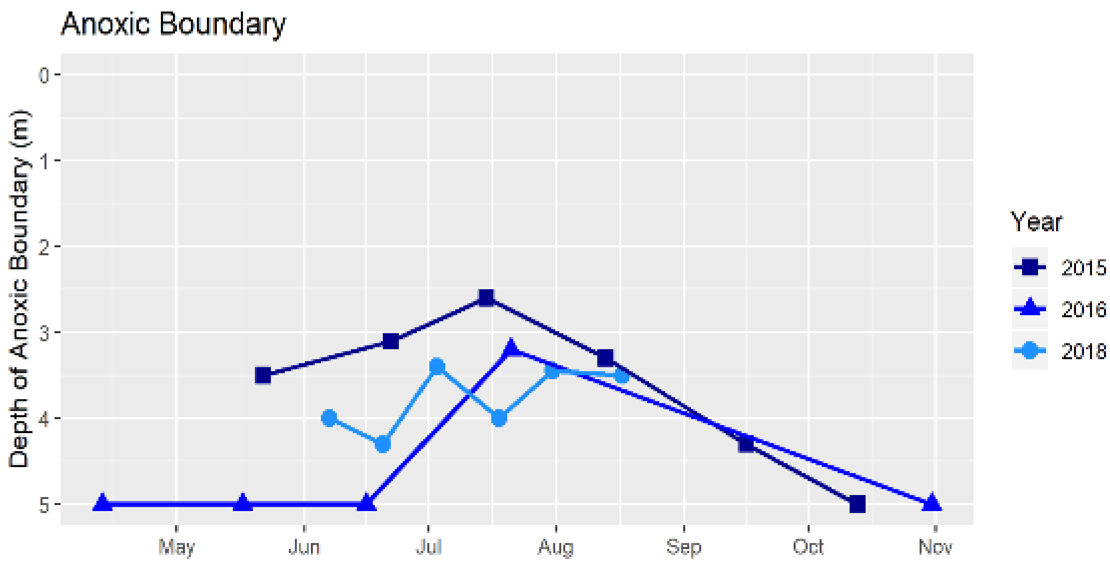
Oxygen Data Analysis

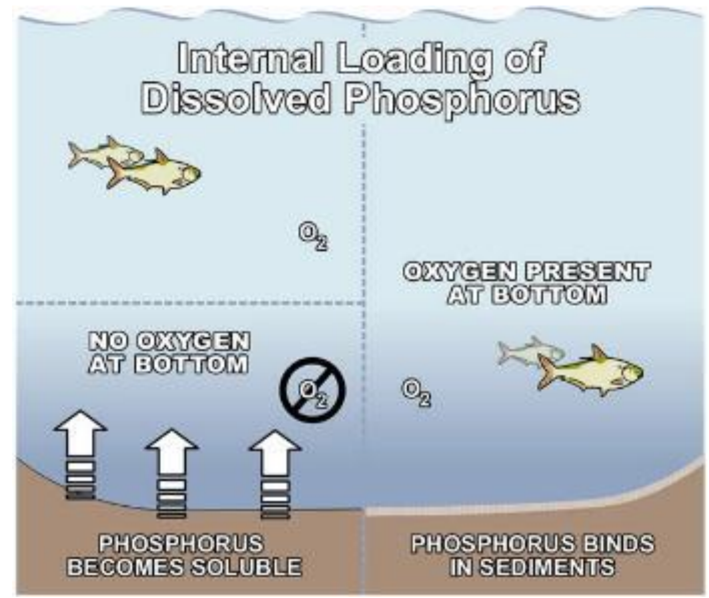




Task #2 (continued)

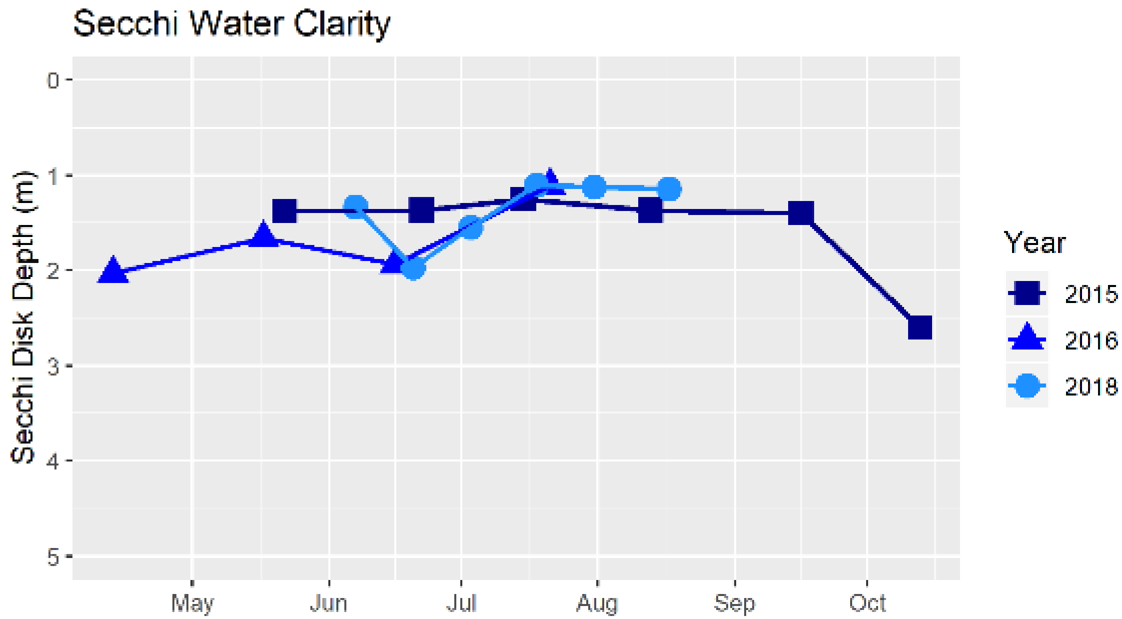
Oxygen Data Analysis

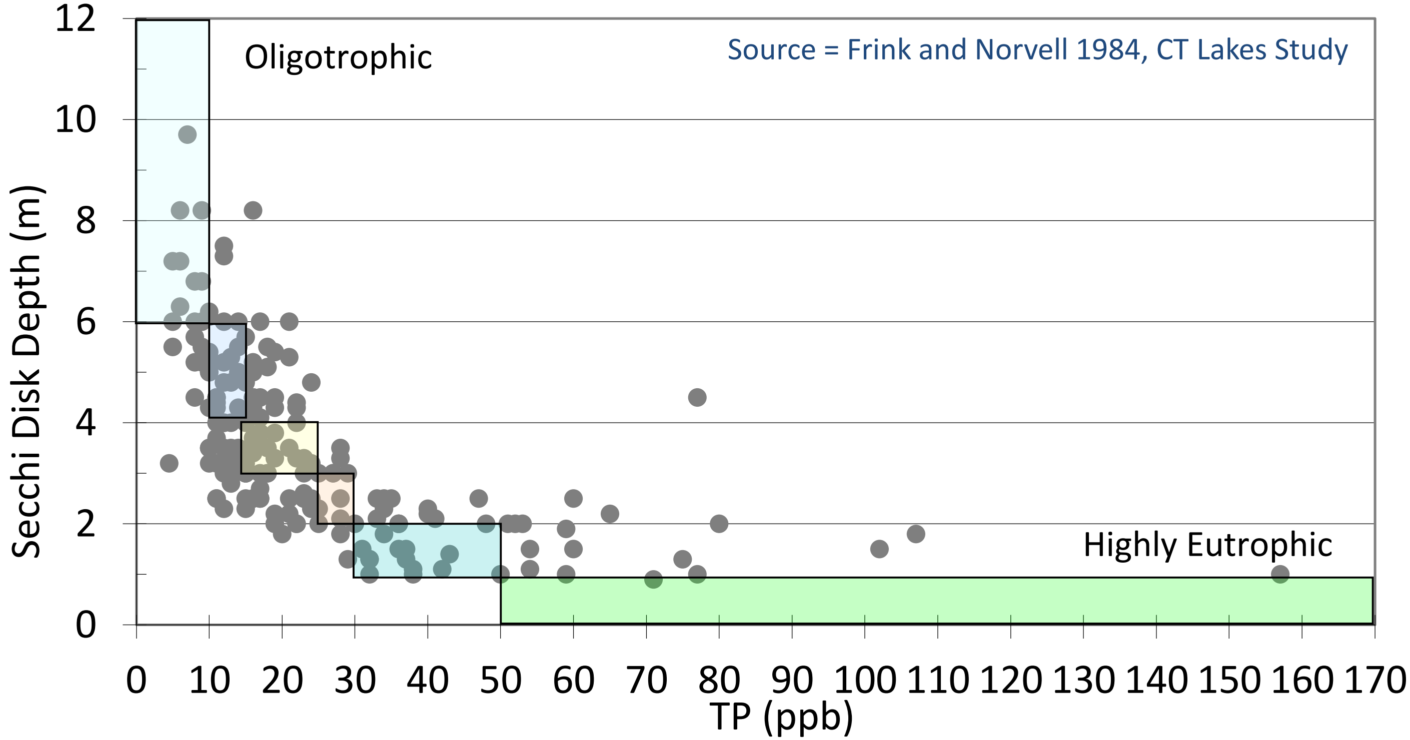




Try to figure out how much area of lake bottom (and respective volume of water loses oxygen and for how long).

Relationship Between Secchi Clarity and Total Phosphorus





#3. Review watershed & internal nutrient loading models

Dr. Rick Canavan used Nurnberg (1995 and 2005) internal P-loading models

Table 10. Range of anticipated internal loads as express by L_{int} based on AF and RR values

AF values	days/summer
2015 (136 days, 38.4 acres)	54.4
2016 (74 days, 38.4 acres)	29.6
Average AF (15 days 38.4 acres)	42
RR values	mg P/ m^2day
Maximum measured sediment total P (3.02 mgP/g)	14.6
Minimum measured sediment total P (1.93 mgP/g)	10.4
Average measured sediment total P (1.93 mgP/g)	12.6
L_{int} values	mg P/m^2 summer
Maximum AF x RR	795
Minimum AF x RR	308
Average AF x RR	528
Summer load in Roseland Lake	lbs P/summer
Max L_{int}	681
Min L_{int}	264
Average L_{int}	453

kgs P/summer
309
120
205

Note annual variability

Right to assume only 38.4-acres?

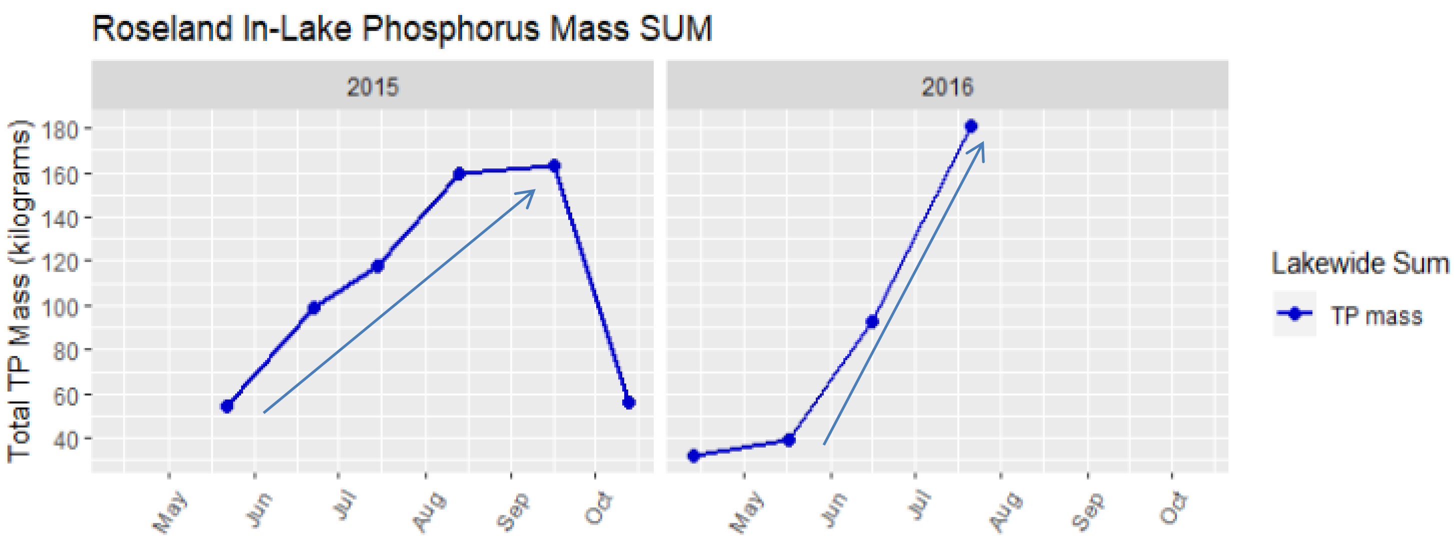
TOTAL
Empirical Model Estimates depend heavily on residence time and flushing rate (9-25days) – aka rainfall

WATERSHED
Land-Use Watershed Model = 1338kgs/year

Using the estimated land use watershed load of 2,950 lbs P/yr the internal load represents between 8-19% of a total annual load with an average 135 contribution. Because the internal is only released during the summer it accounts for 21-55% of the P-load during five months of the summer and fall when anoxia is likely to occur.

4. Volumetric Mass Calculations (aid in models evaluation)

- Measure in-lake TP mass to compare to load estimates



kgs P/summer
309 (2015)
120 (2016)
205 (AVG)

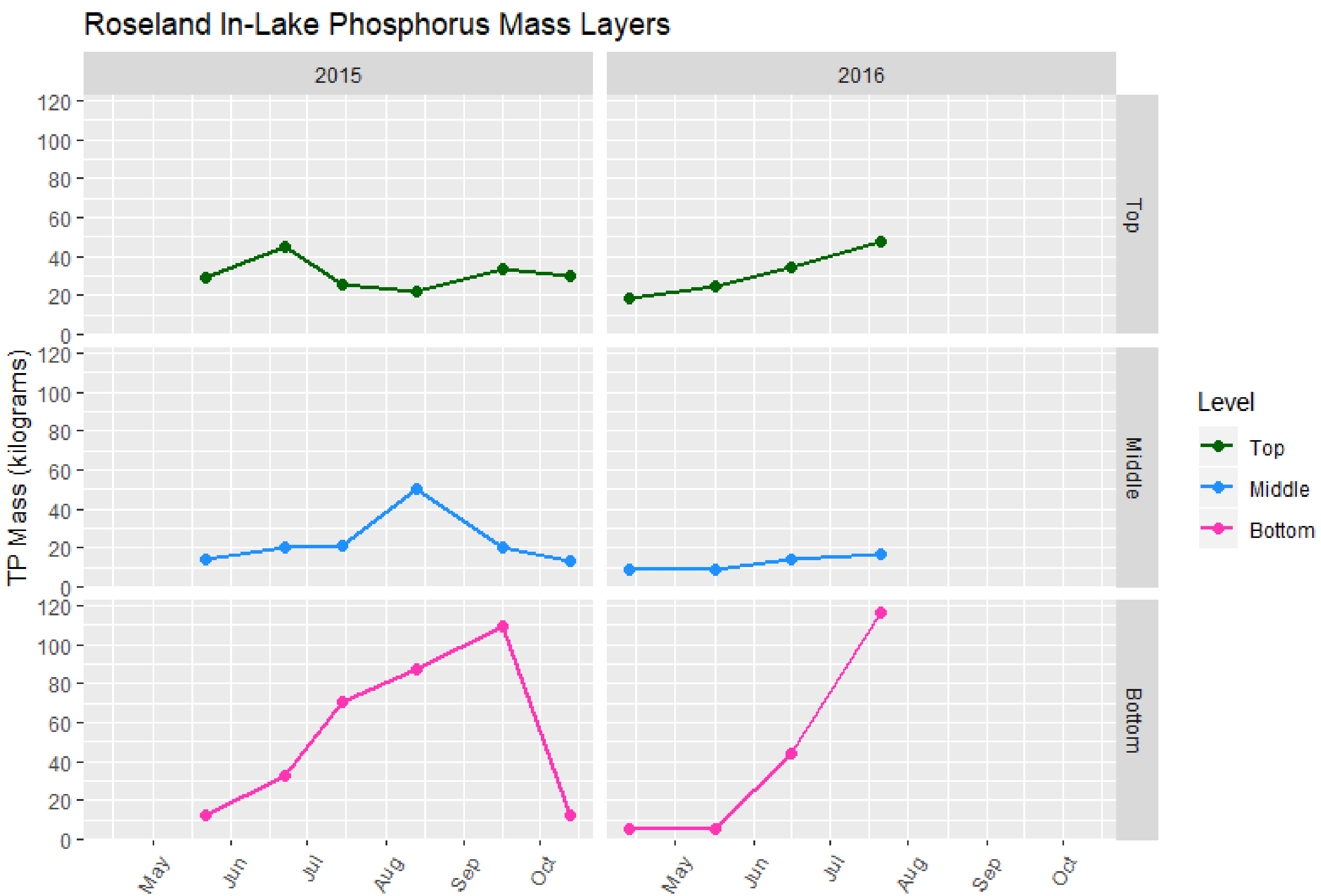
109kg increase

142kg increase ← A quantifiable fraction of internal load

Only possible to measure a certain fraction of the actual internal summer P release because water is still flowing out of the lake all season…. Roseland Lake could be discharging about 850kgs TP from May to September (simple model given rainfall quantity and Little River concentrations)

We don't have outflow volume so can't truly quantify outflow TP mass.

#4 (continued): TP Mass Increase Occurs Most Prominently at Bottom



#5: Rainfall Patterns (measured in inches)

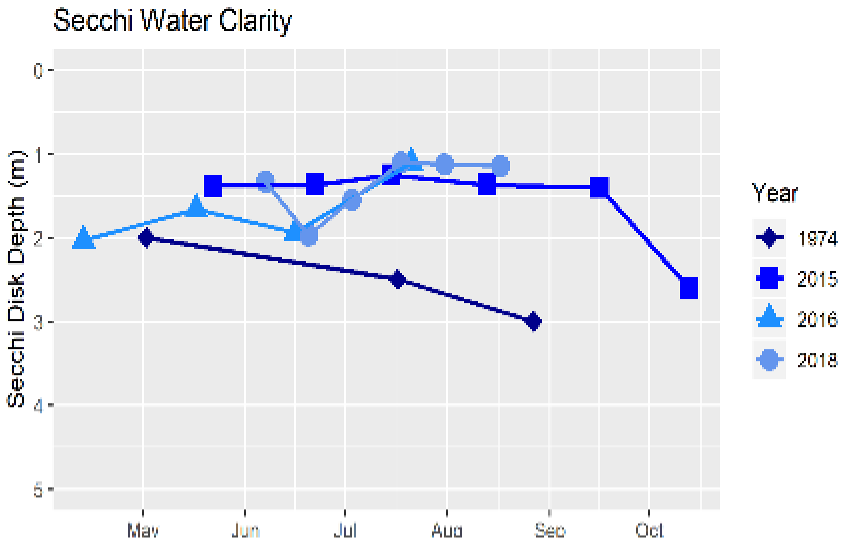
	2015	2016	2018
	Thompson	Thompson	Thompson
Jan	3.16	2.6	4.72
Feb	2.74	5.11	5.62
Mar	3.64	2.38	5.49
Apr	3.36	4.14	5.02
May	0.23	2.57	2.78
June	7.62	2.05	3.65
July	2.12	1.87	4.8
Aug	1.07	5.62	4.92
Sept	2.56	1.18	12.3
Oct	4.34	6.17	4.22
Nov	2.19	2.49	8.4
Dec	1.18	5.98	3.11
Sum	**34.21**	**42.16**	**65.03**

Year	Period	InchesSUM	%SUM
2015	Jan-May	13.13	38.4
2016	Jan-May	16.8	39.8
2018	Jan-May	23.63	36.3
2015	June-Sept	13.37	39.1
2016	June-Sept	10.72	25.4
2018	June-Sept	25.67	39.5

- Thompson, CT
- Source US Climate Data
- Huge difference in annual rainfall and huge difference in annual external nutrient load (from watershed)
- Very large difference in flushing rates too
- Deeper understanding of variability in watershed load – rainfall did not seem to change summer Secchi clarity very much!

Task #6: Review Historical Data - 1974 Frink and Norvell Study

- Look at 5-meter TP summer concentrations
- Much better late summer clarity in 1974
- Much lower historical hypo-TP

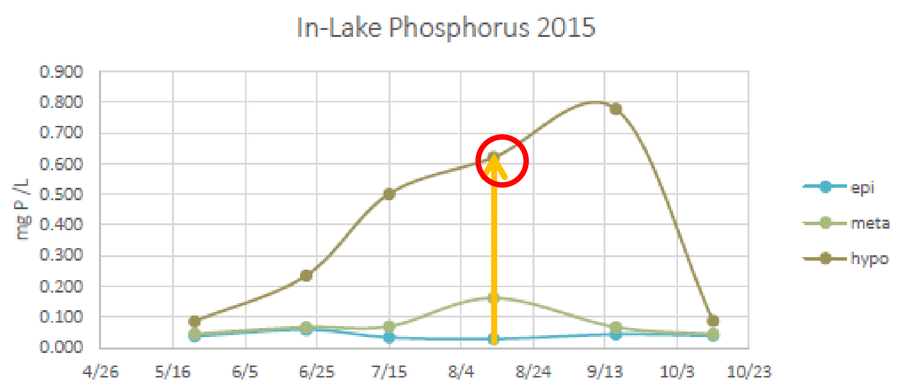


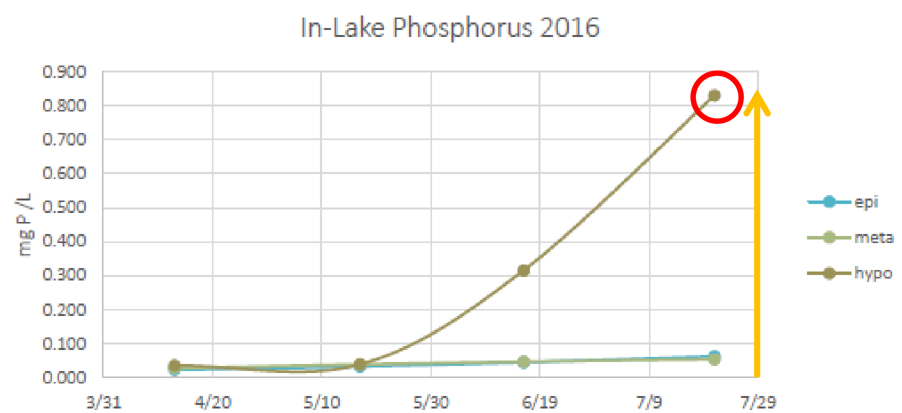
Agency	Date	Depth meters	NO2 N Mg/L	NO3- N Mg/L	NH3-N Mg/L	TN Mg/L	Ortho P Mg/L	Total P Mg/L	N/P ratio
CAES[4]	10/23/73	.2		0.390	0.090	0.900	0.015	0.024	37.5/1
		3		0.330	0.080	0.880	0.014	0.031	28.4/1
		5		0.380	0.120	0.970	0.012	0.037	26.2/1
CAES	5/2/74	.2		0.500	0	0.950	0.009	0.030	31.7.1
		3		0.500	0.030	0.930	0.010	0.034	27.4/1
		5		0.500	0.030	0.980	0.010	0.038	25.8/1
	7/17/74	2-0.2		0.260	0.110	1.220	0.018	0.047	25.9/1
		3		0.029	0.180	1.114	0.021	0.048	23.8/1
		5		0.130	0.800	1.520	.0092	$\boxed{0.125}$	12.2/1
	8/27/74	0-3		0.030	0.040	0.650	0.012	0.029	22.4/1
		5		0.230	0.320	1.390		$\boxed{0.114}$	12.2/1
DEP[5]	8/30/77	0.2	<0.02	0.00	0.04	0.640		0.07	9.1/1
		0.2	<0.02	0.00	0.05	0.070		0.07	1.1/1
		3-4	<0.02	0.10	0.20	1.000		0.11	9.1/1

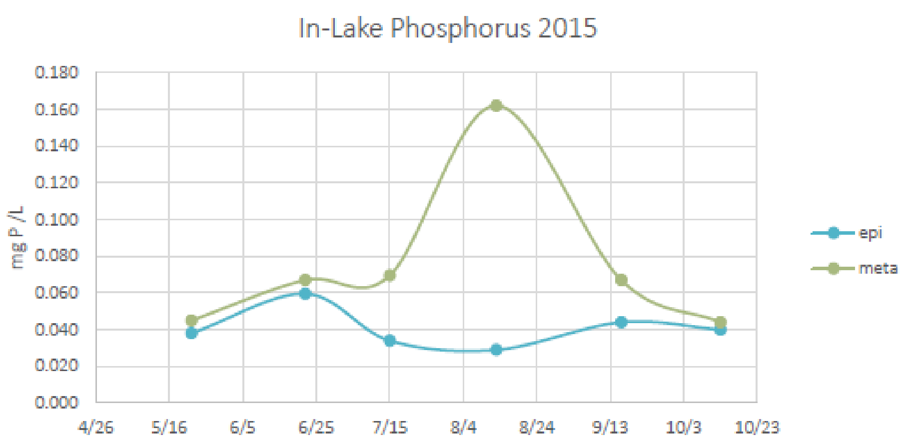
Seasonal P-concentration Trends:

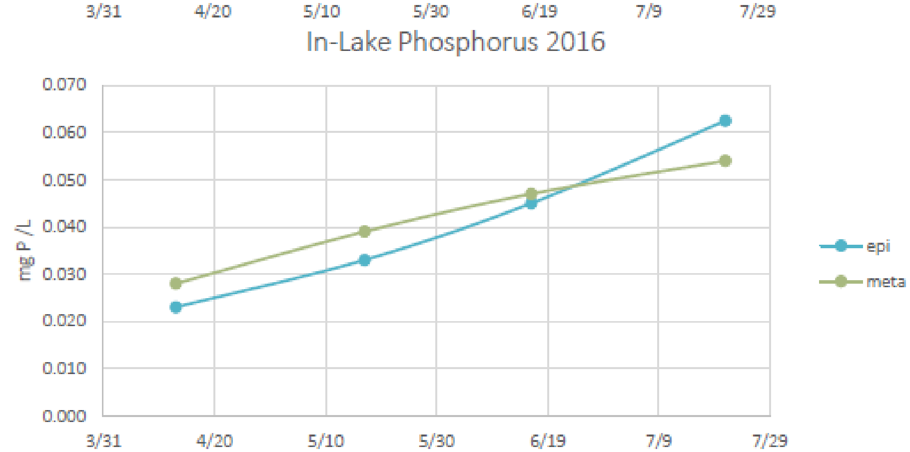
Figures From Presentation 12/20/17

Drastic increase in hypolimnetic TP release in 2015-2016 summer months today in comparison to 1974 (Frink and Norvell)



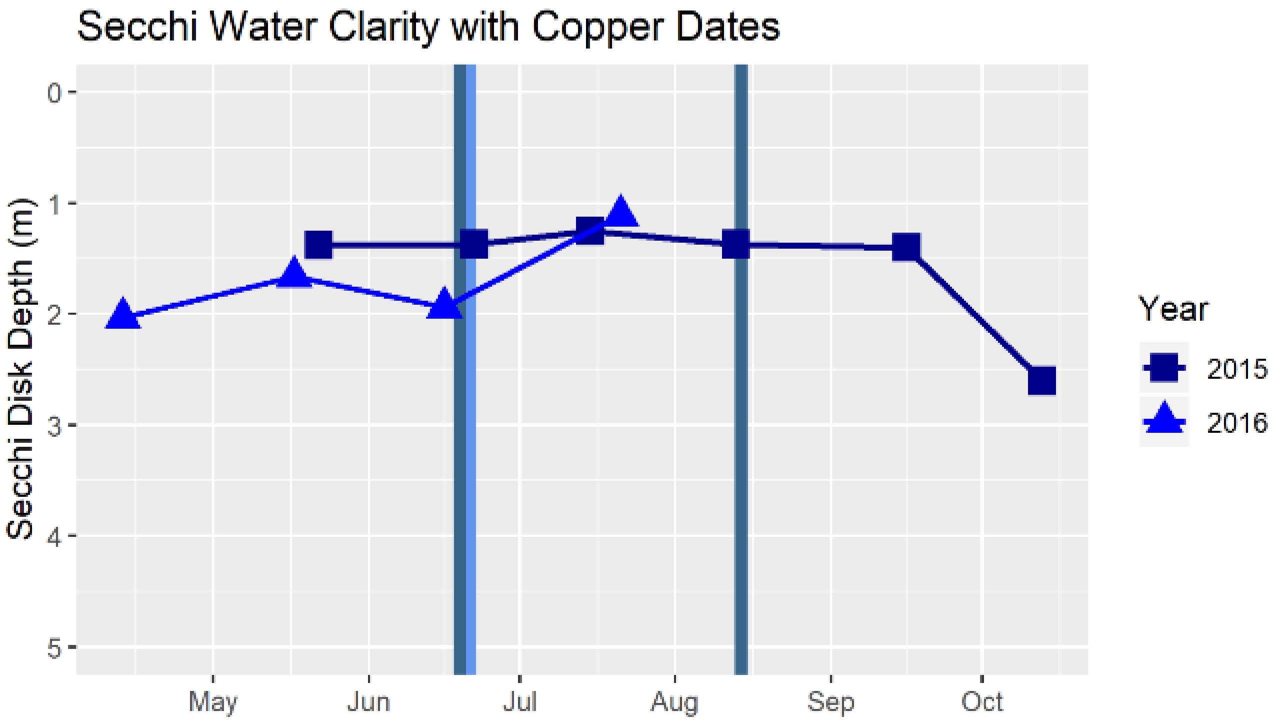






Task #6 continued: Review Recent Copper Treatment Results

- Darker blue vertical line = 2015, lighter blue vertical line = 2016
- Copper Sulfate treatments do not appear to improve water clarity



#7: Review ECCD Nutrient Management Plan

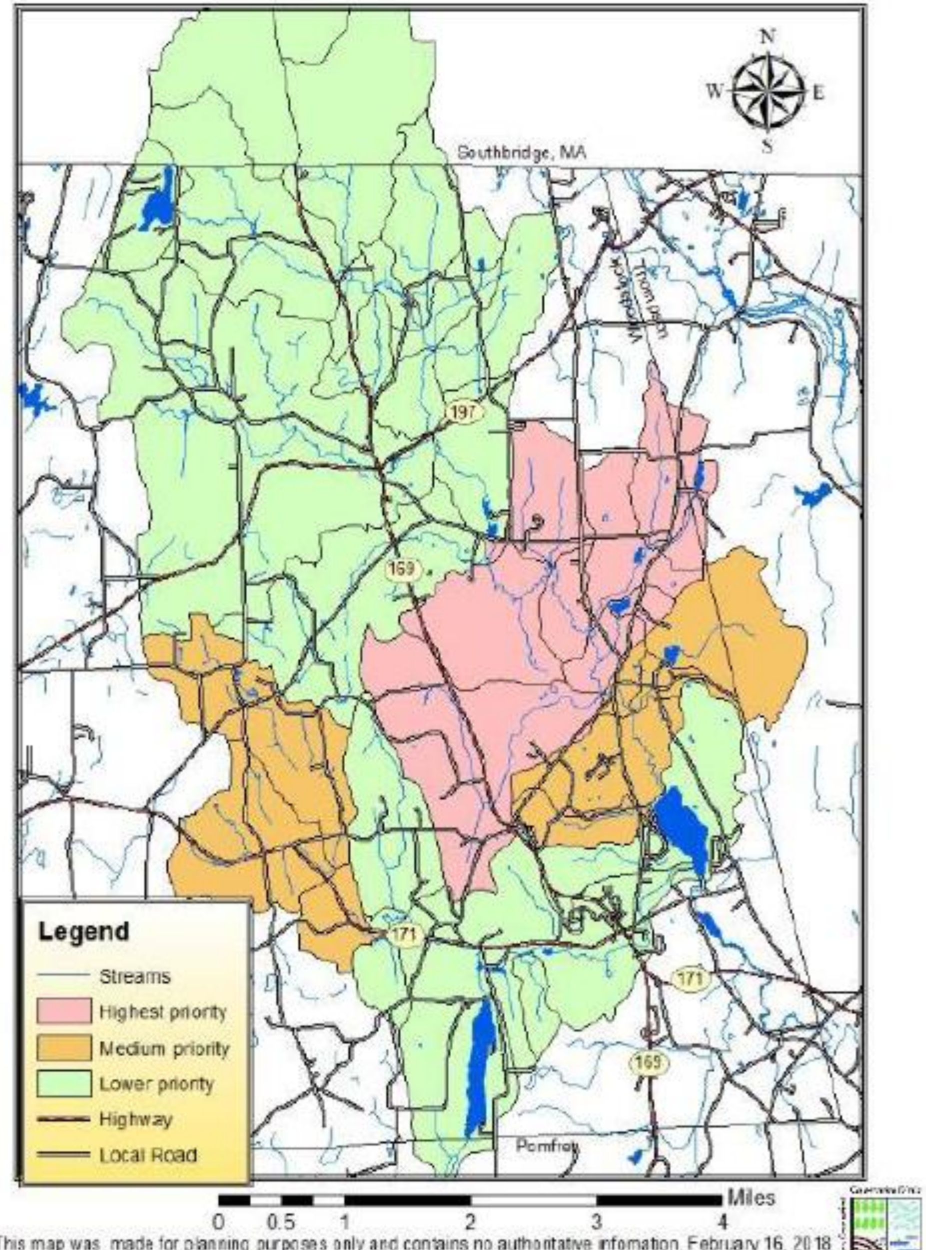
- Understand the watershed
- Already reviewed all in-lake data & loading models
- Look to inlet nutrient concentrations
  - Muddy Brook
  - Peckham Brook
  - Mill Brook

Inlet concentrations are very high!

TN > 1mg/L baseflow?!

Dry TP loading okay, but stormwater erosion appears to be a huge issue

Roseland Lake Watershed Prioritization for Restoration Work



#7: Review Plan's List of In-Lake Solutions

Outlined in Table 16 in Roseland Lake Management Plan

- **Dredging bottom sediment** – not financially feasible; would need subsequent flocculent treatment to settle fine particles after dredging
- **Hypolimnetic Withdrawal** – CT DEEP not likely to permit due to issues with downstream hypoxia (fish kills, sulfur smells, oxidized iron films, etc.)
- **Aeration / Oxygenation** – Roseland's extremely high sediment oxygen demand makes this impractical; also requires immense amount of power and a permanent staging station for compressors and pumps. Roseland Lake shape not conical, poorer results.
- **Destratification** – The lake is already polymictic (meaning it stratifies and destratifies during the summer depending on weather); destratification can accidentally cause mixing of bottom-water nutrients to surface and worsen algae blooms. Improper system sizing is a common issue.
- **Alum (Aluminum sulfate)** – Sediment 'capping' phosphorus immobilization treatment, good track record in lake management, drastically reduce internal phosphorus loads, and approved for use in drinking water reservoirs
- **Phoslock (Lanthanum)** – Sediment capping treatment, similar concept to Alum in that the Lanthanum modified bentonite clay binds phosphate, potentially more-so than Alum but product is more expensive and no large case studies to date

#8: Make Hard Management Decisions…. (Alum)

- What is Alum?
  - Aluminum sulfate + water → aluminum hydroxide + hydrogen ions

    (lowers pH of water, which is why buffering solution needed to stabilize pH)
  - Aluminum hydroxide precipitates as a flocculent material, has a high capacity to bind free phosphate ions
  - Initially used as drinking water treatment technology
  - Also used to reduce phosphorus outputs from wastewater treatment
  - Has been used around the world in lake restoration for 40yrs but better technology and more successful treatments in last 15yrs.

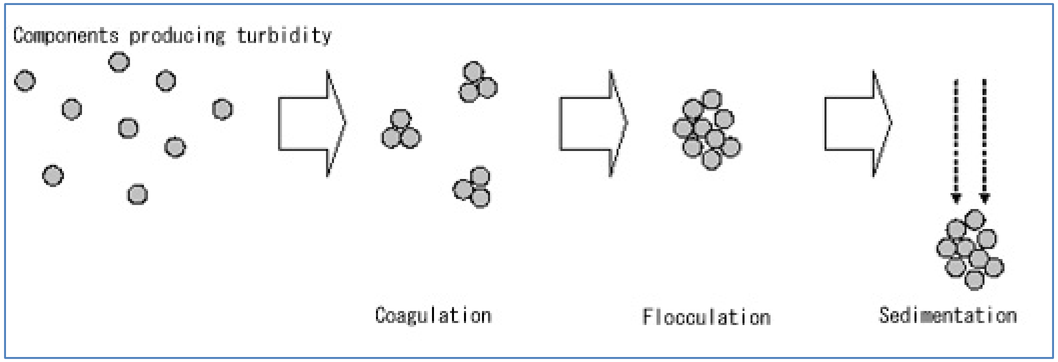


Photo demonstrates flocculation and water clarity process (http://www.devrkenterprises.com/coagulant-chemicals.htm)

Public Option about Alum is Good, NALMS stands by usage

- Alum treatments featured in 2018 NatGeo article NATIONAL GEOGRAPHIC
  https://www.nationalgeographic.com/environment/2018/10/aluminum-sulfate-clears-polluted-lakes-algae-blooms/
- North American Lake Management Society (NALMS) Alum position paper http://z0ku333mvy924cayk1kta4r1-wpengine.netdna-ssl.com/wp-content/uploads/2016/05/NALMS-Alum-Position-Statement.pdf

1. “Safe and effective,
2. Applications need to be designed and controlled to maintain appropriate pH
3. Useful in cases where watershed phosphorus reductions not adequate nor timely.”

NALMS

Inherent Risks with Alum Treatments

- pH imbalance has caused fish kills with historical (pre-2008) lake Alum treatments
  - Usually a result of improper dosing and irresponsible applicators who failed to monitor pH and adjust buffer solution as necessary
- Avoid Alum fish toxicity by maintaining neutral pH of lake water (~7) using sodium aluminate buffer

Sediment Sampling Results – determining Alum dose

The following table displays the results of the laboratory analyses.

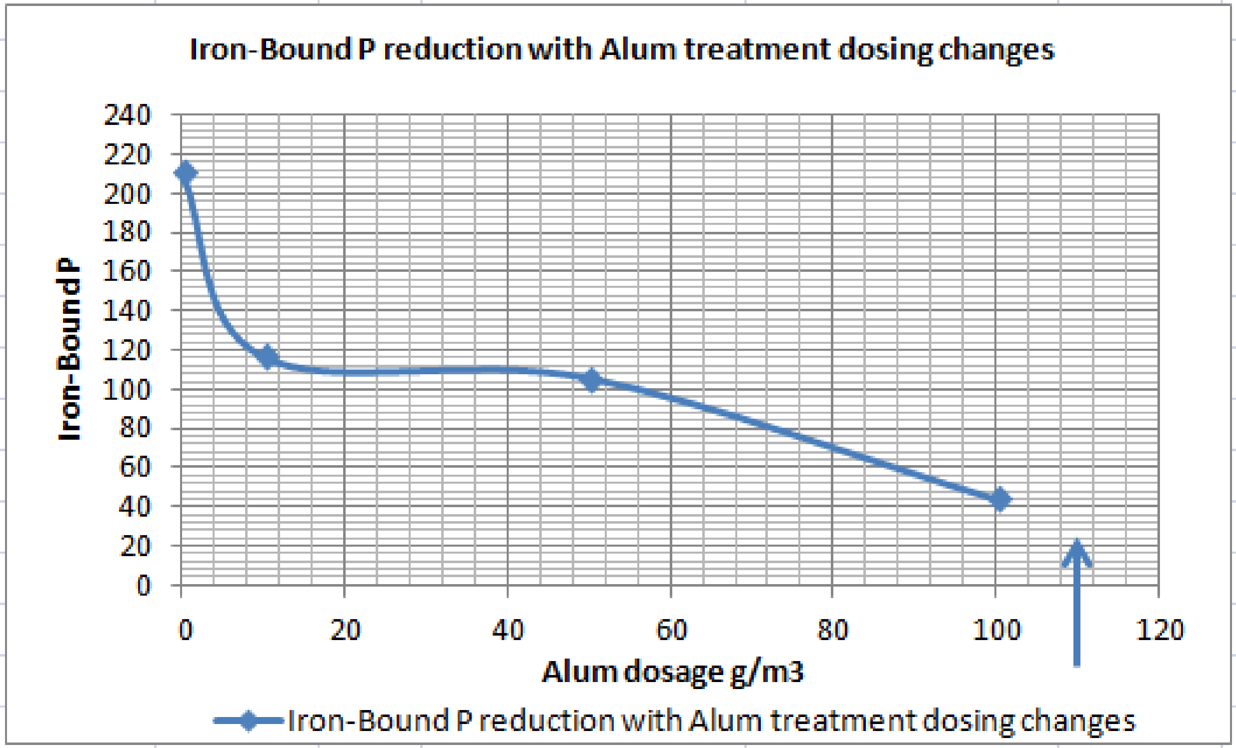
Lab ID#:	Sample Description	Iron Bound Phosphorous (mg/kg dry weight)	Loosely Sorbed Phosphorous (mg/kg dry weight)	Moisture %	Total Phosphorous (mg/kg dry weight)	Ash % (Organic)	Total Solids %
1667837-01	RL-410-01	949	55.0	87.3	3,020	74.8	13.6
1667837-02	RL-411-02	985	51.1	86.4	2,750	74.8	13.6
1667837-03	RL-411-02B	840	40.8	86.5	2,680	73.8	13.5
1667837-04	RL-412-03	812	39.4	86.6	1,930	75.2	13.4
1667837-05	RL-413-04	570	43.7	86.6	2,020	77.1	13.4

- Welch and Jacoby (2001) study analyzed large number of Alum treatments and found over 80% projects successful, average **54% internal P load reduction**
- Another study later on as lake Alum dosing improved over time; Cooke et. al. 2005 found average **90% reduction** internal P load (4-lake study)
- Most likely will need booster Alum treatment after couple years, depends on water quality monitoring results (general $2.50 to 4.00 per gallon cost for Alum and sodium aluminate buffer)

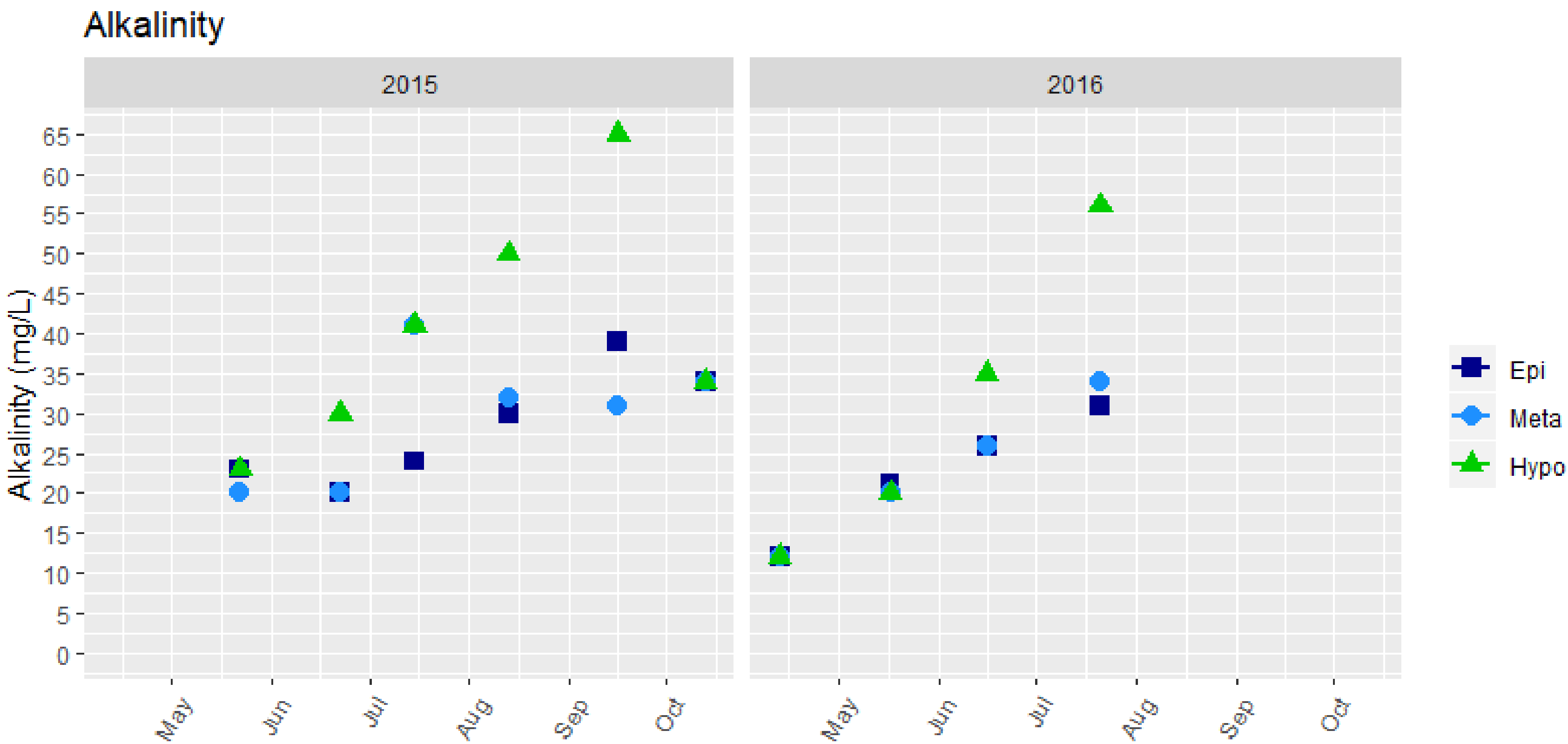
Reviewing Previously Proposed Alum Dosage…

- If shooting for 90% reduction in Iron-bound P, we should aim for **110g/m2** Alum dose (slightly higher than what Solitude gave a price quote for…)
- But Osgood Index = Zm/sq(A) = 4.0 for Roseland
- Huser et al. 2016 predict less Alum treatment success longevity for lakes with OI < 6 and residence time <0.1 years (Roseland is <0.08 yrs)

Solitude Sediment Alum Jar Test Results				
Test#	Control	Units	Loosely-Bound P	Iron-Bound P
1	0	g/m2	4.9	212
2	10	g/m2	3.1	117
3	50	g/m2	3.5	106
4	100	g/m2	2.7	44.2
Dose?	**~110**	g/m2		**21.2**



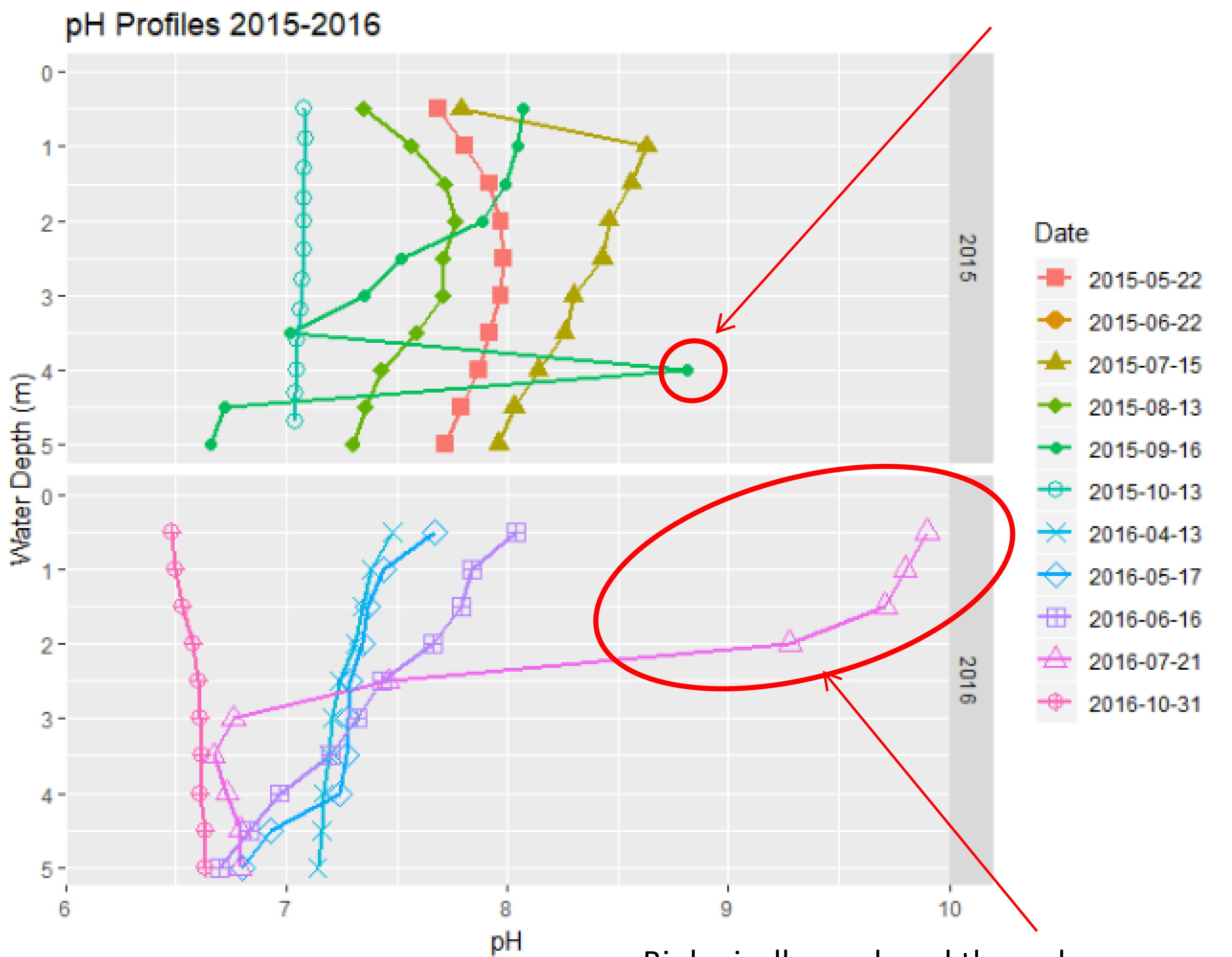
Alkalinity



- Because of the sensitive nature of pH stability during Alum treatments, the Alkalinity and water pH of the season leading up to an Alum treatment should be measured – pH also needs to be constantly measured during the actual treatment

pH (Measure of free H+ ions: acidity)

Biologically produced spike, layer of cyanobacteria at top of anoxic boundary



Biologically produced through photosynthesis depleting DIC (very concerning) – above most fish tolerances

Proposed Alum-treatment Contractor & Experience

HAB AquaticSolutions

Nebraska Office:
5100 Van Dorn Street #6096
Lincoln, NE 68506

Minnesota Office:
97 S. Victoria Street #20
St. Paul, MN 55105

Many other smaller projects in range of 50-300 acres with good nutrient inactivation success.

Grand Lake St. Marys – largest Alum treatment in USA 2012, 4,900-acres! Resulted **in 55% overall phosphorus reduction**

Alum Application Methods – what will it look like?

- GPS equipped barge adjusts the Alum application rate based on the depth and the speed of the boat for accurate treatment

- Real time pH monitoring to adjust buffer solution

- Maintain dissolved aluminum below CT standards over multiple day treatment

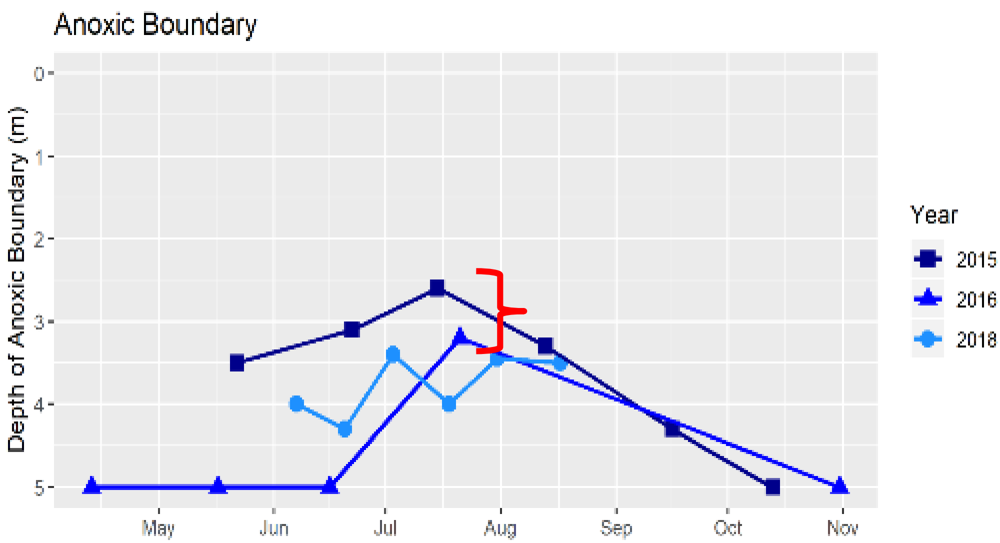
Unique spacing of hose lines to get most effective floc size and P-binding

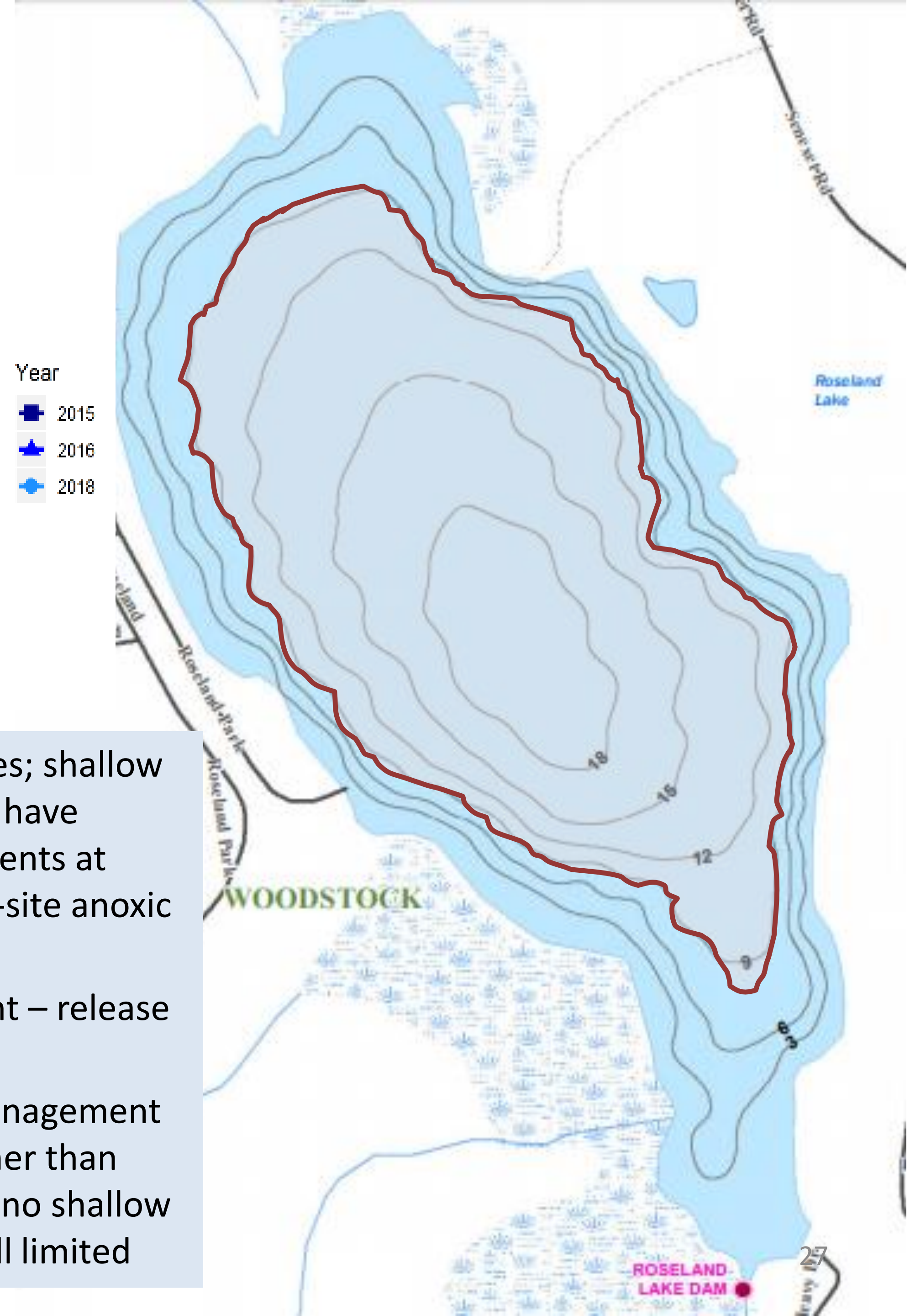
Alum Treatment Costs Breakdown

- HAB Aquatic Solution (NE company)
  1. 65-acre treatment, 110g/m² dose = $296,000 [~1.8m / 6ft]
  2. 60-acre treatment, 110g/m² dose = $276,000 [~2.45m / 8ft]
  3. 45-acre treatment, 110g/m² dose = $213,000 [~3.35m / 11ft]
- Solitude (MA company) – quoted $200,000 for 45-acre treatment of *100*g/m² dose (we recommend 110g/m²)

Pros/Cons of Varied Dose and Treatment Area Size…

Treatment Acreage?





- NEAR knowledge of “wavy” anoxic boundaries; shallow sediments still have an oxygen demand – we have measured anoxic water above shallow sediments at multiple lakes (above depth contour of deep-site anoxic boundary)
- Shallower sediments may lose oxygen at night – release more P (no Roseland data)
- Oxic sediment P release not quantified in Management Plan – could mean that internal P load is higher than initial estimates (potentially 15% higher) but no shallow data to confirm – scientific understanding still limited

Things to Consider Moving Forward

Alum

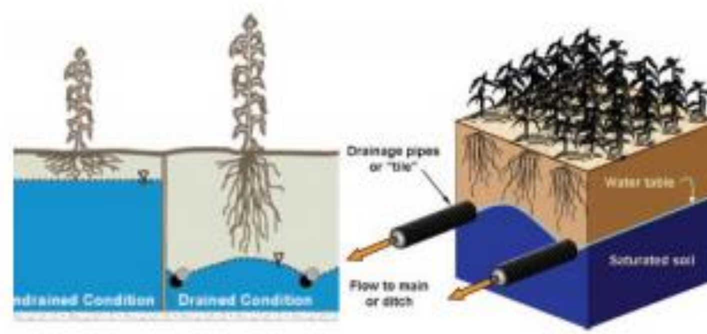
- Alum treatment success & longevity always somewhat uncertain; attempting to manipulate large complex ecosystems systems
- More data = more accurate Alum dose (but adds to preparatory costs)

Watershed

- Nitrogen is still a problem and seems to be more linked to external watershed sources (erosion, agriculture, etc.)
- Continued external P loading will reduce longevity of Alum success – Take incremental watershed improvement steps too!

Good Points from Management Plan

- Inventory tile drain outfalls in watershed
  - Critical for reducing nitrogen loss on fields and load to watershed
  - Also large potential phosphorus load, depending on historical and present manure application rates (usually phosphorus is over-applied which can cause soil P-saturation and leaching)
- Sustainable farming practices to minimize soil loss; from wind and rain erosion
  - <u>Soil runoff and erosion</u> is a major phosphorus source
- Better quantify septic system loading and enforce larger set-back distances and system updates (research suggests that septic soil treatment systems have about 20yrs P binding capacity)
- Pay attention to the shallow-water mat forming algae (usually cyanobacteria that also produce toxins)
  - Do these mats form along the whole shore? Or is the distribution telling us something about nearby loading?



Good literature review on tile drainage and nutrient concentrations from Lake Champlain Basin Program (2016) http://www.lcbp.org/wp-content/uploads/2017/01/83_TileDrainage_LitReview.pdf

Need Ongoing Monitoring

- Secchi disk and view scope ~$75 for both
- Hach temperature and dissolved oxygen meter ~$1,800
- Van Dorn water sampler for nutrient testing
- Can also use ECCD loaned equipment but highly recommend this Hach meter for future sampling
  - No pH or conductivity probes means less calibration needed
  - Probe maintains temp and DO accuracy for nearly a year without calibration; good for volunteers monitors. Replace sensor cap annually ~$100.
- Frequency?
- Secchi, temp, DO: <u>biweekly</u> monitoring from April to mid October in deep spot
  - Plus optional three shallow water sites in June, July, August (temp and DO profiles)

Questions?

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