Coventry Lake July 2022

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A Bluegreen Algae Bloom is Meat, Not Salad.

Peter H. Rich, Ph.D. 1976

- **What Happened?**
  - The Ecology of the Bloom Organisms
  - The Progression of Bloom Dynamics

- **Why did the Bloom Happen?**
  - Nutrient Enrichment from the Watershed
  - Internal Nutrient Loading from the Sediments
  - Recent Climatic Variability

- **Are Such Blooms Likely in the Future ?**
  - Yes, Blooms Following Turnover
    - Blooms result in Increased Oxygen Demand, Decreased Light Penetration, and Increased Internal Nutrient Loading
  - Will Fall Blooms become more intense?   (Probably?)
  - Will cyanobacteria persist through winter? (Maybe, Depends on Mother Nature)
  - Will more cyanobacteria in the Fall mean more akinete seeds next year? (Probably?)

- **Can We Do Something to Reduce the Risk of Future Blooms?**
  - Are there options for adapting to Changing Climatic Conditions? (To Be Determined)
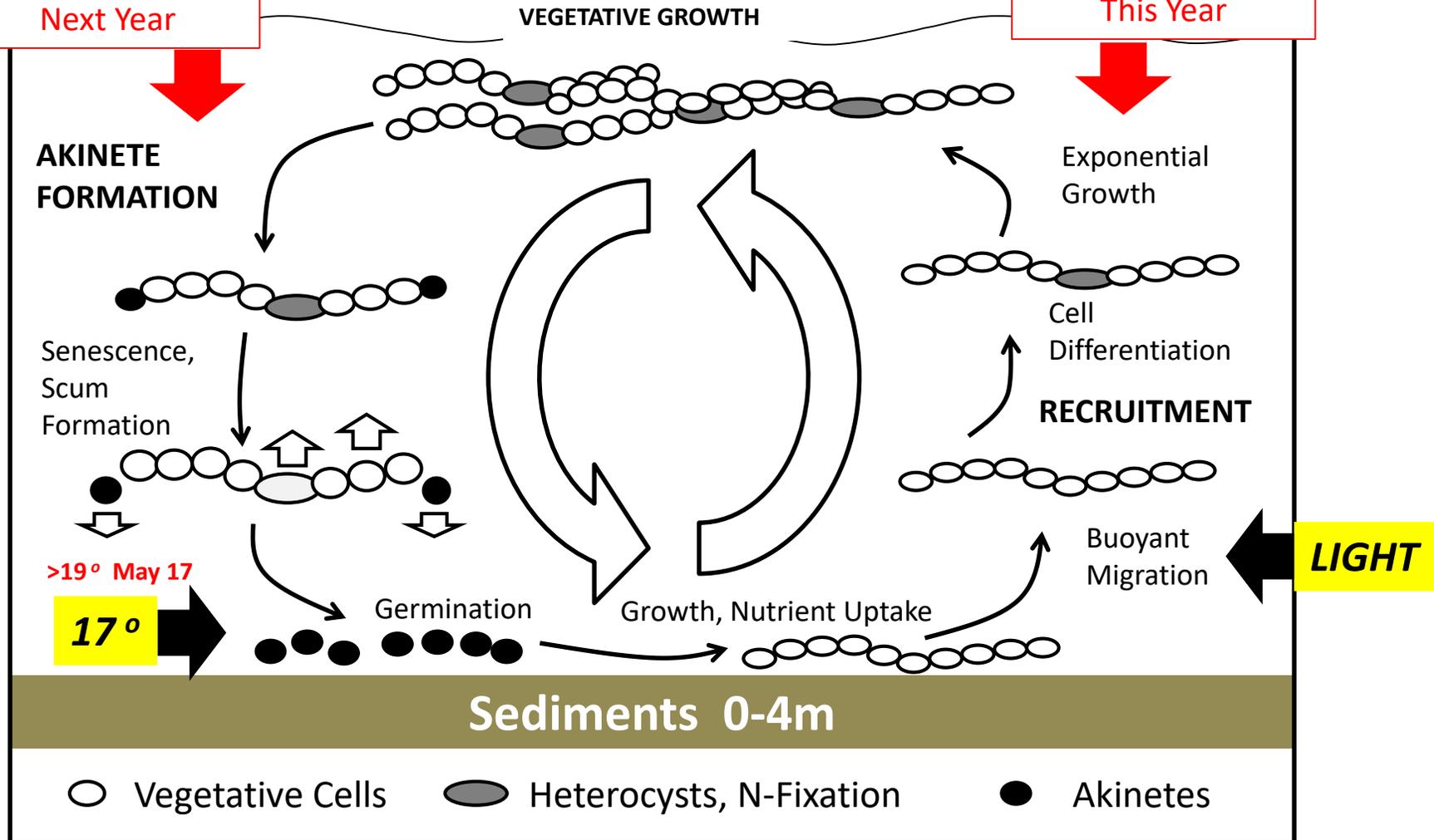 - Are there *Appropriate* Methods to reduce the Cyanobacteria Risk directly? (To Be Determined)

Life Cycle of N-Fixing Akinete-Forming Cyanobacteria
(*Gleotrichia, Anabaena, Aphanizomenon*)

(Modified from Kortmann, 2015)

VEGETATIVE GROWTH

Manage to control Next Year

Manage to control This Year

AKINETE FORMATION

Exponential Growth

Senescence, Scum Formation

Cell Differentiation

RECRUITMENT

>19° May 17

17°

Germination

Growth, Nutrient Uptake

Buoyant Migration

LIGHT

Photosynthetic Bacteria

Fix Atmospheric N
Regulate Buoyancy
Prefer High Temp
Produce Akinete "Seeds"
Not High on the Menu for Grazers

Sediments 0-4m

○ Vegetative Cells   ⬤ (grey) Heterocysts, N-Fixation   ● Akinetes
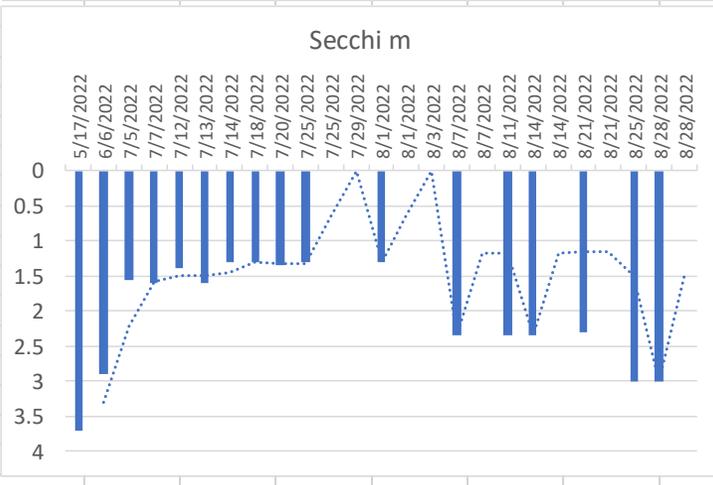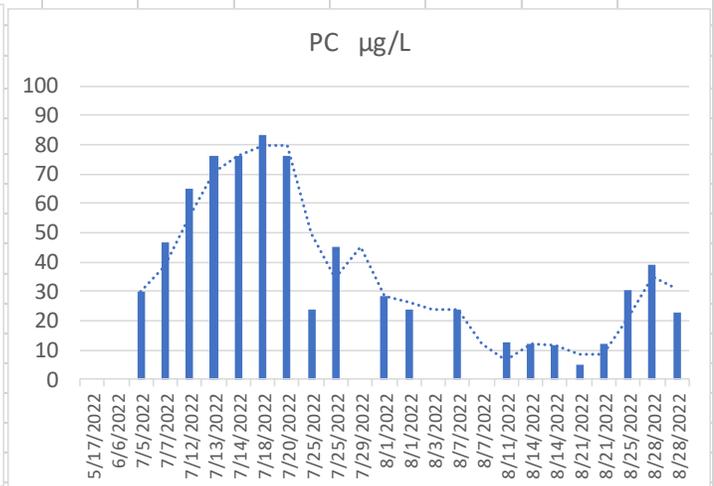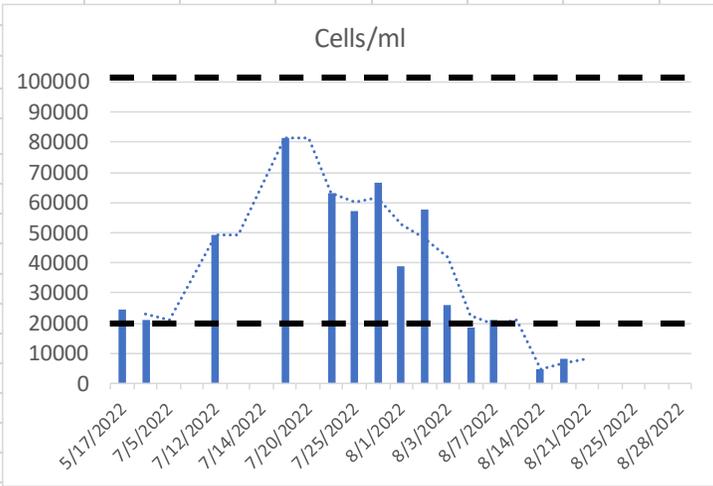
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Coventry Lake Cyanobacteria Tracking

End of State Ramp Dock

Center of Lake

		Secchi m	Chlorophyll CH µg/L	Phycocyanin PC µg/L	Phycoerythrin PE µg/L	Cyano Cells/ml
5/17/2022	Center	3.7				24690
6/6/2022	Center	2.9				21233
7/5/2022	Ramp Dock	1.55	8.6	30	2.6	
7/7/2022	Ramp Dock	1.6	15.73	46.85	2.6	
7/12/2022	Ramp Dock	1.4	10.54	65	2.2	49,145
7/13/2022	Center	1.6	5.99	76	2.18	
7/14/2022	Center	1.3	8.7	76	2.3	
7/18/2022	Ramp Dock	1.3	10.36	83.53	2.54	81,214
7/20/2022	Ramp Dock	1.35	10.5	76	4.6	
7/25/2022	Ramp Dock	1.3	12.1	24	0.55	63,237
7/25/2022	Lisicke Beach	na	12.5	45	1.1	57,224
7/29/2022	NEAR Ctr Lake					66,500
8/1/2022	Ramp Dock	1.3	14.9	28.6	1.06	38,843
8/1/2022	Lisicke Beach	na	14.9	23.9	0.8	57,653
8/3/2022	NEAR Ctr Lake					26,268
8/7/2022	Ramp Dock	2.35	4.8	24.1	0.82	18,468
8/7/2022	Lisicke Beach	na	na	na	na	21,034
8/11/2022	Ramp Dock	2.35	23	12.8	1.26	
8/14/2022	Ramp Dock	2.35	24	12		4,824
8/14/2022	Lisicke Beach	na	24	11.8		8,459
8/21/2022	Ramp Dock	2.3	11.54	4.94	0.917	
8/21/2022	Lisicke Beach	na	5.67	11.99	1.003	
est, on bottom	8/25/2022	Ramp Dock	3	8.165	30.62	1.42	
est, on bottom	8/28/2022	Ramp Dock	3	13.200	39.1	0.74	
	8/28/2022	Lisicke Beach	na	8.907	22.89	0.649	

Cyanobacteria Bloom Categorization

······· Category Two

– – – Category Three
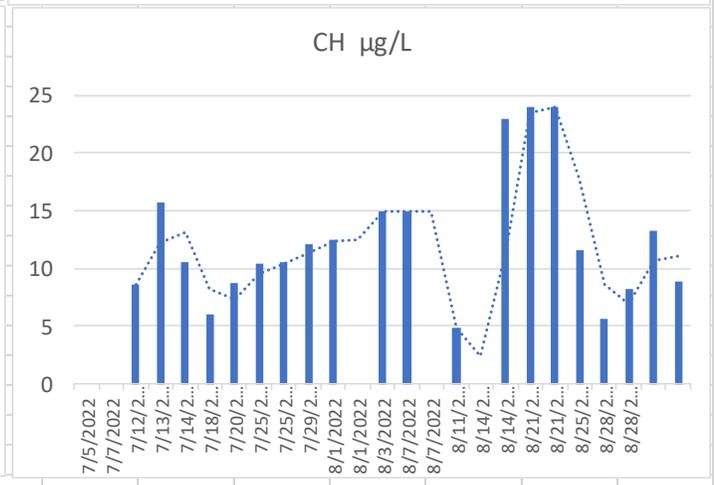
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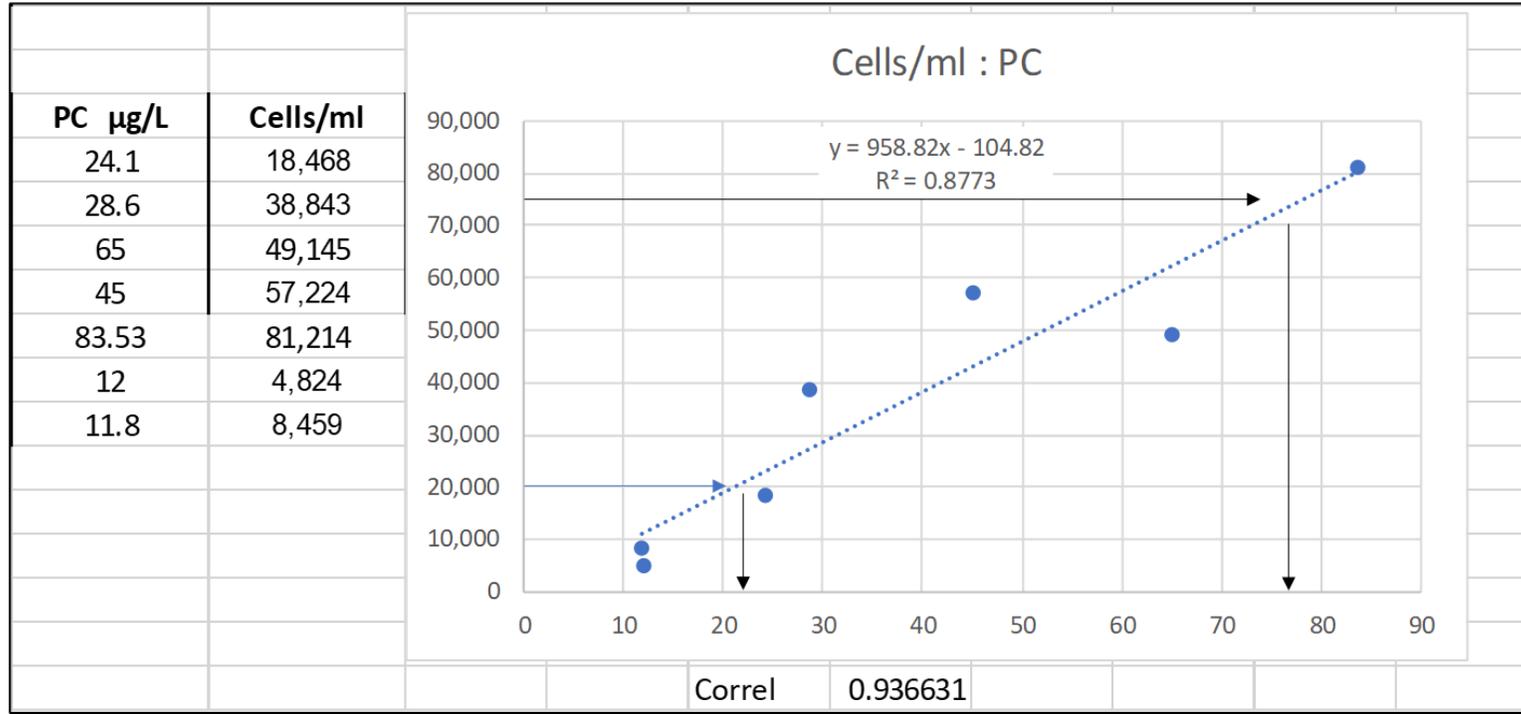 - The Ecology of the Bloom Organisms
  - The Progression of Bloom Dynamics

Monitoring the Bloom

Cyanobacteria Bloom Categorization

Coventry Lake Tracking, Current Estimated Category= **High Category Two or Low Category 3**   7/12/2022

Category	Description	Secchi	CH µg/L	PC µg/L	PC RFU	Cyano Cells/ml
One	Visible material is not likely cyanobacteria (pollen, detritus, plant fragments, etc.), or water is generally clear.	> 2.5m	< 15	< 35	< 0.20 RFU	< 20K/ml
Two	Cyanobacteria present in low numbers. There are visible small accumulations but water is generally clear.	1-2.5 m	15 to 25	35 to 75	0.2 to 3.0 RFU	20K/ml to 100K/ml
Three	Cyanobacteria present in High Numbers. Scums may or may not be present. Water is discolored throughout. Large areas affected. Color assists to rule out sediment and other algae.	< 1m	> 25	> 75	> 3.0 RFU	> 100K/ml *

* Varies by State, some use 70k cells/ml

Coventry Lake 2022 Cyanobacteria : Phycocyanin

PC µg/L	Cells/ml
24.1	18,468
28.6	38,843
65	49,145
45	57,224
83.53	81,214
12	4,824
11.8	8,459

Cells/ml : PC

$y = 958.82x - 104.82$
$R^2 = 0.8773$

Correl	0.936631

Cyanotoxins

TOXIN GROUP	Cyanobacteria genera	Affects	Ecostrategist Categories	Natural Forcing Factors
Alkaloids				
Anatoxin-a	***Anabaena, Aphanizomenon,*** *Planktothrix (Oscillatoria)*	Nerve Synapse	Buoyant N-Fixers	N:P Ratio, pH, Temp, De, Light Penetration, Grazing Rate
Aplysiatoxins	*Planktothrix (Oscillatoria), Lyngbya, Schizothrix*	Skin Rash	Benthic, Stratifying,	Stratification Boundaries, Light Penetration
Cylindrospermopsins	*Cylindrospermopsis,* ***Aphanizomenon***	Liver Function	Buoyant N-Fixers	N:P Ratio, pH, Temp, De, Light Penetration, Grazing Rate
Lyngbyatoxin	*Lyngbya*	Gastro-Intestinal, Skin	Benthic, Stratifying, Buoyant	Stratification Boundaries, Light Penetration
Saxitoxins	***Aphanizomenon,*** *Cylindrospermopsis*	Nerves	Buoyant N-Fixers	N:P Ratio, pH, Temp, De, Light Penetration, Grazing Rate
Cyclic Peptides				
Microcystins	*Microcystis,* ***Anabaena,*** *Planktothrix (Oscillatoria), Nostoc*	Liver Function	Buoyant N-Fixers	N:P Ratio, pH, Temp, De, Light Penetration, Grazing Rate
Nodularin	*Nodularia*	Liver Function	Brackish	Nitrogen Availability and Form

Cyanotoxins are not produced by all species of a genera, and a specific population may or may not be producing a toxin.

- **What Happened?**
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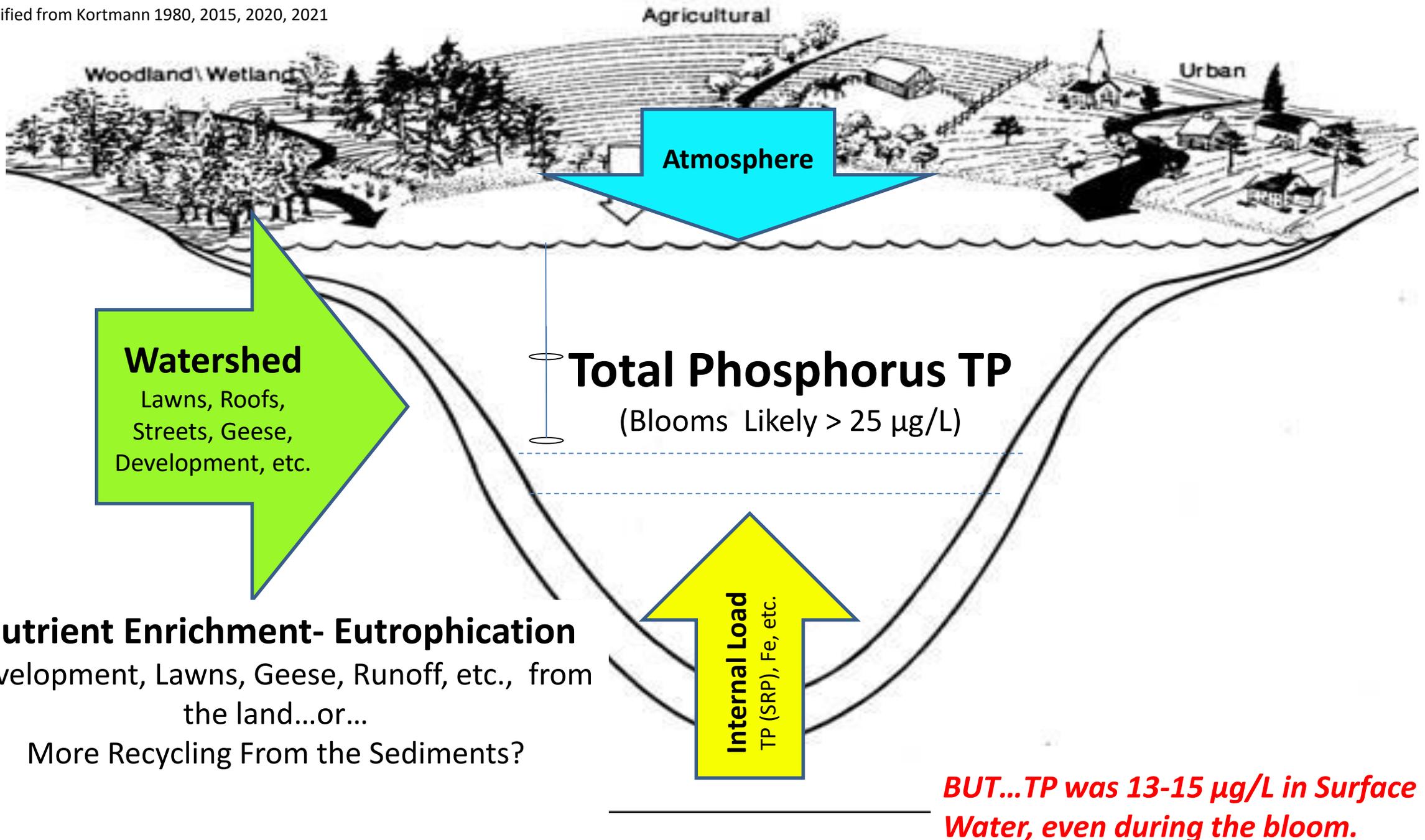 - The Progression of Bloom Dynamics

Kortmann, 2015;
Modified from WHO

Coventry Lake 2022 Bloom

Possible Forcing Factors (Causes):
- Nutrient Enrichment from Watershed, esp. TP…***NO***
- Unanticipated effect of fluoridone treatments…***Not Likely***

- Altered Competition between Plants and Phytoplankton …***Not Likely***
- Altered Zooplankton Grazer Community***… To Be Determined***
- Effects of Climatic Weather Patterns starting in 2018
    - Altered Phytoplankton Seasonal Succession
    - Impacts to Stratification Structure – D_e vs AB
    - Increased Anoxic Factor (area and duration of oxygen loss)
    - Cyanobacteria Persist through Winter
    - Extended Stratification Period / Growing Season
    - Altered Nitrogen Availability, Nitrate Depletion (N:P)
    - Altered Micronutrient Availability (Silica, Fe)
    - Shift in pH, hence Free CO_2 Availability
    - Early Turnover (We had Three Named Tropical Storms in 2021)
    - Hurricane August 4, 2020 Mixed the lake very early- More Fall Cyanobacteria)

- More Internal Nutrient Loading, More Cyanobacteria after turnover, More "akinete seeds for next year", more Cynaobacteria persist through winter.
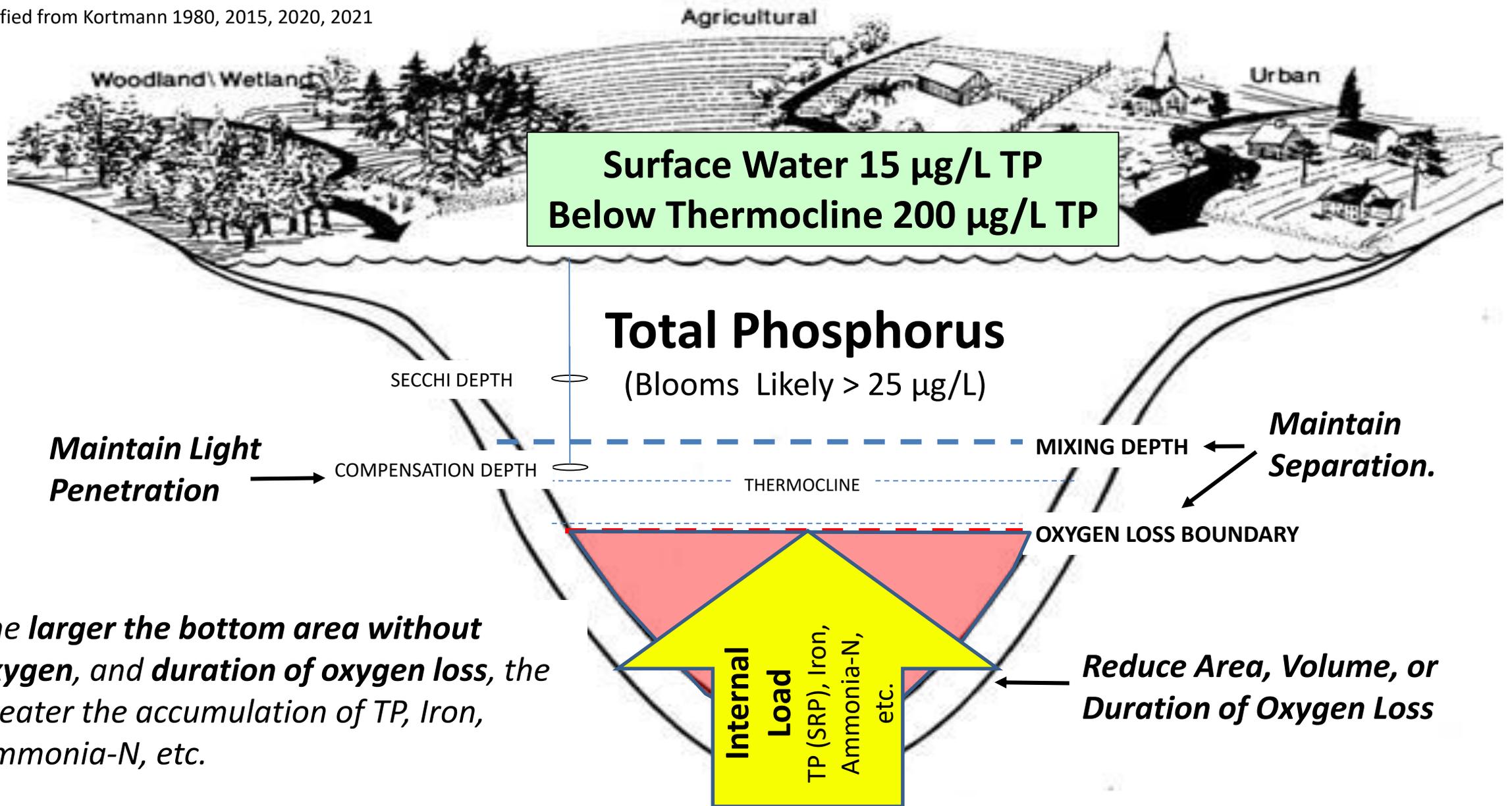
- **Why did the Bloom Happen?**
    - Nutrient Enrichment from the Watershed
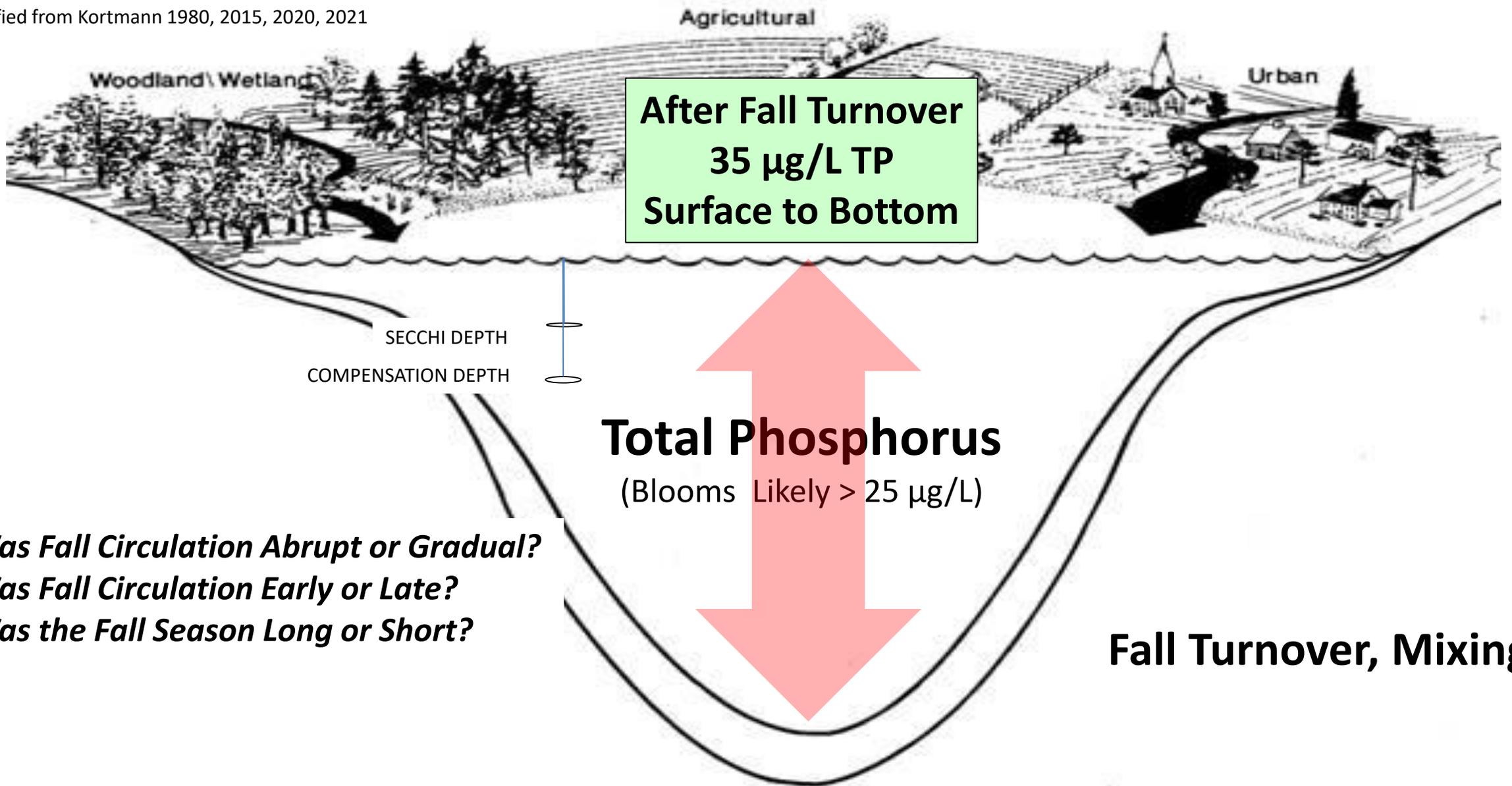   - Internal Nutrient Loading from the Sediments
    - Recent Climatic Variability

Modified from Kortmann 1980, 2015, 2020, 2021

Woodland\ Wetland

Agricultural

Urban

Atmosphere

Watershed
Lawns, Roofs,
Streets, Geese,
Development, etc.

Total Phosphorus TP

(Blooms Likely > 25 µg/L)

Internal Load TP (SRP), Fe, etc.

Nutrient Enrichment- Eutrophication
Development, Lawns, Geese, Runoff, etc., from
the land…or…
More Recycling From the Sediments?

*BUT…TP was 13-15 µg/L in Surface
Water, even during the bloom.*

Agricultural

Woodland\ Wetland

Urban

Surface Water 15 µg/L TP
Below Thermocline 200 µg/L TP

Total Phosphorus
(Blooms Likely > 25 µg/L)

SECCHI DEPTH

Maintain Light Penetration → COMPENSATION DEPTH

Maintain Separation.

MIXING DEPTH ←

THERMOCLINE

OXYGEN LOSS BOUNDARY

*The **larger the bottom area without oxygen**, and **duration of oxygen loss**, the greater the accumulation of TP, Iron, Ammonia-N, etc.*

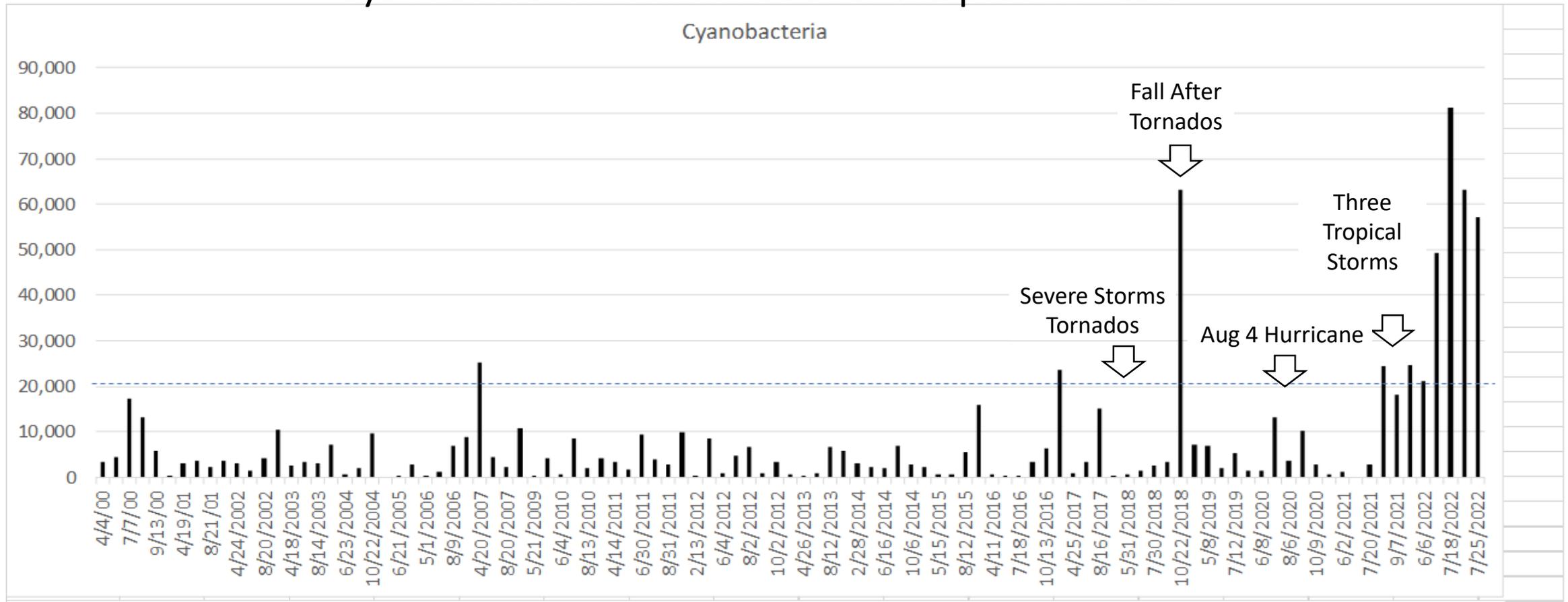**Internal Load** TP (SRP), Iron, Ammonia-N, etc.

Reduce Area, Volume, or Duration of Oxygen Loss ←

Ca. 1 mg TP / Sq. Meter / Day when Oxygen-Rich
Ca. 8 – 12 mg TP / Sq. Meter / Day when No Oxygen

Agricultural

Woodland\Wetland

Urban

**After Fall Turnover
35 µg/L TP
Surface to Bottom**

SECCHI DEPTH

COMPENSATION DEPTH

Total Phosphorus
(Blooms Likely > 25 µg/L)

- *Was Fall Circulation Abrupt or Gradual?*
- *Was Fall Circulation Early or Late?*
- *Was the Fall Season Long or Short?*

Fall Turnover, Mixing

**Much of the TP that accumulates under the thermocline is mixed
throughout the lake during Fall Turnover, especially if Turnover is abrupt.**

Coventry Lake
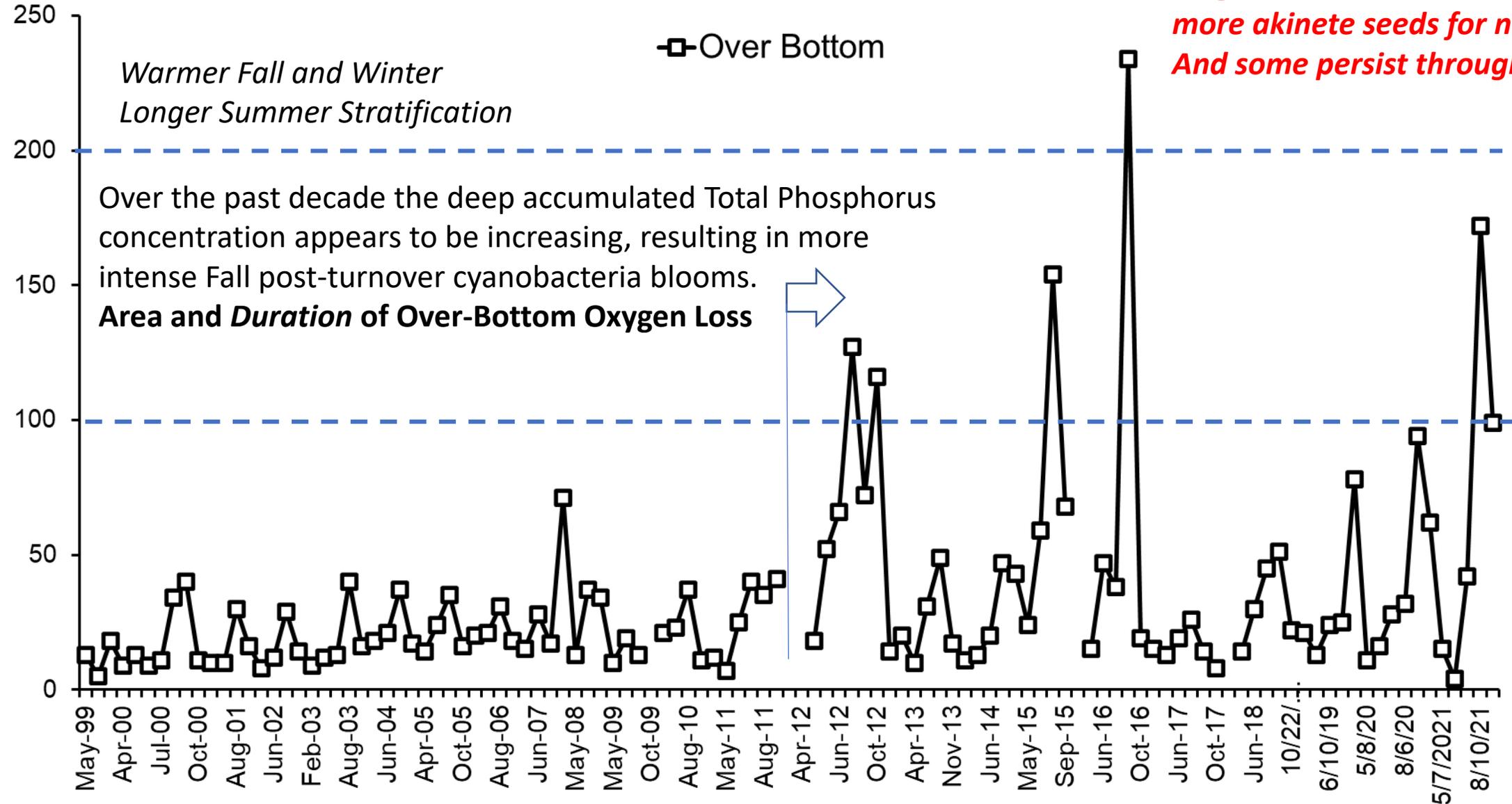## Cyanobacteria Abundance over the past 22 Years

Coventry Lake Total Phosphorus (µg/L) 1999- 2021

Warmer Fall and Winter
Longer Summer Stratification

Over the past decade the deep accumulated Total Phosphorus concentration appears to be increasing, resulting in more intense Fall post-turnover cyanobacteria blooms.
Area and *Duration* of Over-Bottom Oxygen Loss

Larger Fall Blooms that deposit more akinete seeds for next year, And some persist through winter

—☐—Over Bottom

Coventry Lake 2022 Bloom

Lakes are the "canaries in the coal mine" for climate change impacts.

I think I'll tweet this.

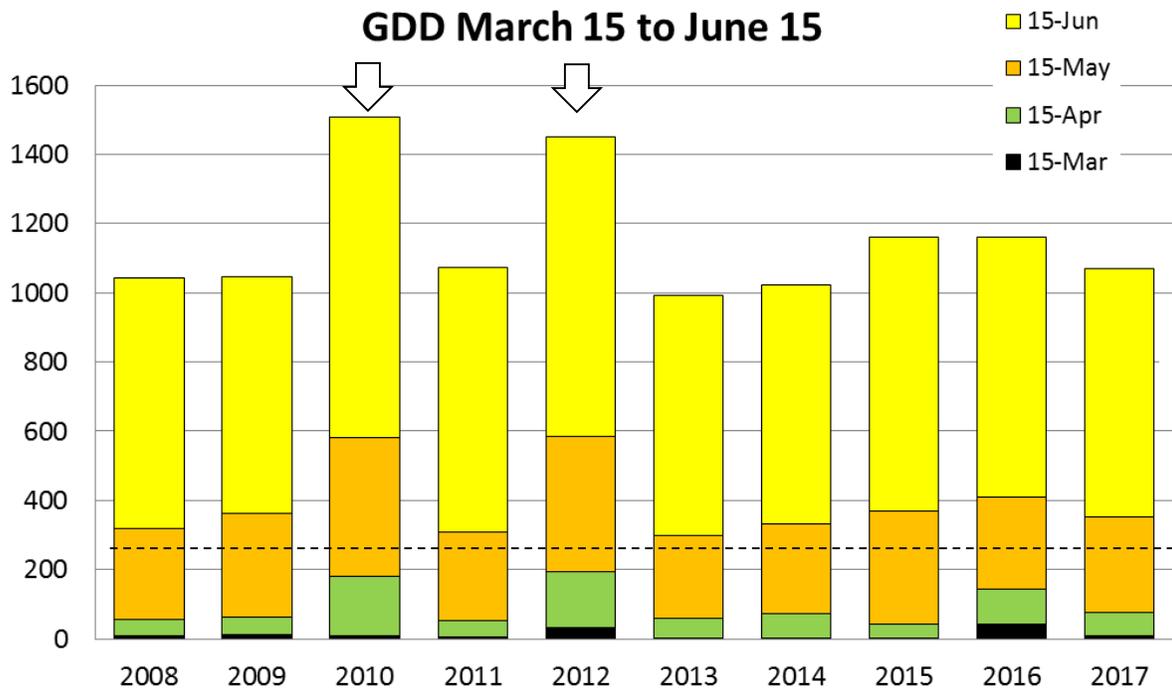## Possible Forcing Factors (Causes):

- Effects of Climatic Weather Patterns starting in 2018
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  - Increased Anoxic Factor (area and duration of anoxia)
  - More Intense Fall Blooms
    - More "Akinete Spores" for next year
    - Cyanobacteria Persist through Winter
  - Extended Stratification Period / Growing Season
  - Altered Nitrogen Availability, Nitrate Depletion (N:P) (no Nitrate in Surface Water)
  - Altered Micronutrient Availability (Silica, Fe)
  - Shift in pH, hence Free CO_2 Availability (pH > 9 in July Surface)
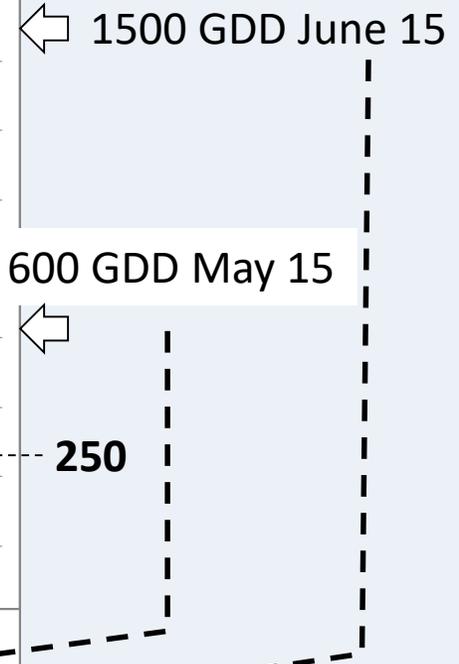
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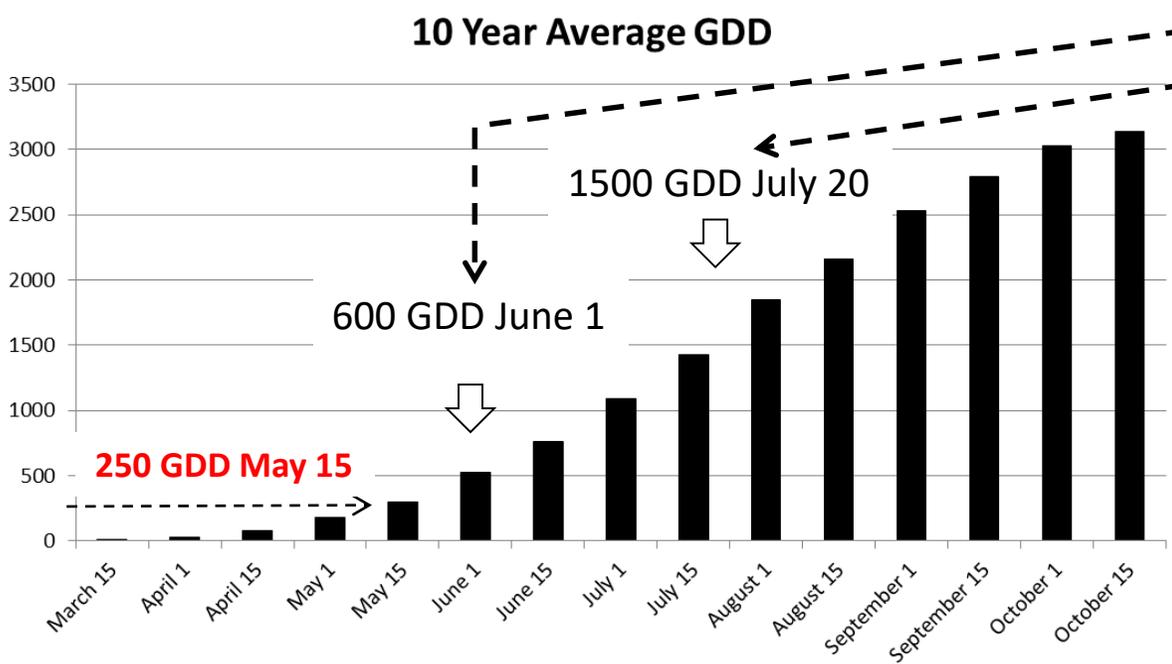
2010 and 2012

GDD March 15 to June 15

1500 GDD June 15

600 GDD May 15

250

10 Year Average GDD

1500 GDD July 20

600 GDD June 1

250 GDD May 15

In 2010 and 2012 GDD were two weeks ahead by May 15, and 5 weeks ahead by June 15.

2022 was similar May 17, 2022 >19ºC

25% More GDD in some years in the past decade.

Longer Summer Stratification, more Internal P in deep strata at Fall Turnover. *Area and Duration of Depleted Oxygen*

Kortmann and Cummins, 2018

Climate Change in the Northeast 1980 to 2018

1980 to 2018

|	Average Annual		DJF Winter	MAM Spring	JJA Summer	SON Autumn
Average Increase Temperature deg. C	1.5		2	0	1	2
Precipitation cm	4		5	-3	-1	3
Wind Speed meters/second	-0.8		-0.9	-0.8	-0.8	-0.6

- Average Temperature is increasing most rapidly during Winter and Autumn
- Stratification and Growing Seasons are Beginning Earlier and Ending later
- Precipitation is also increasing most rapidly during Winter and Autumn
- Wind Speeds are Decreasing, with similar seasonal change

Recent Severe Storms:
- 2018 May-June Tornados
- 2020 August 4 Hurricane
- 2021 Three Named Tropical Storms
  Very Warm Autumn (Warmest December)
- 2022 Late and Brief Winter Weather
  Early Summer Stratification (19° Surface Temp Early May)

Preliminary Conclusion:

- **Early and Prolonged Summer Stratification *Area and Duration of Oxygen Loss***
  - **Greater Deep Accumulation of Total Phosphorus and Ammonia-N**
- **Storm Mixing Events, Early Loss of Stratification, Accumulated Nutrients into Surface Water**
- **Prolonged Summer-like Weather in the Fall**
  - **Increased Intensity of Cyanobacteria Bloom following Turnover**
  - **Enough Cyanobacteria in Fall to Outcompete Diatoms and Persist through Winter**
  - **Very large Deposition of Akinete Seeds for Next Year**

The 2022 Bloom was a result of Vegetative Cells Persisting to the Beginning of the Growing Season and Early Germination of a Bumper Crop of Akinete Seeds Deposited in 2021. TP not adequate to Sustain the Bloom.

Depth (m)	Phycocyanin- Coventry Lake 7/14/2022	8/8/2022
1	60.92	9.61
3	77.94	10.38
5	59.07	10.90
7	27.71	10.35
9	32.18	31.76
11	36.29	59.23

Phycocyanin

7/14/2022

8/8/2022

Mixing Depth

Oxygen Loss
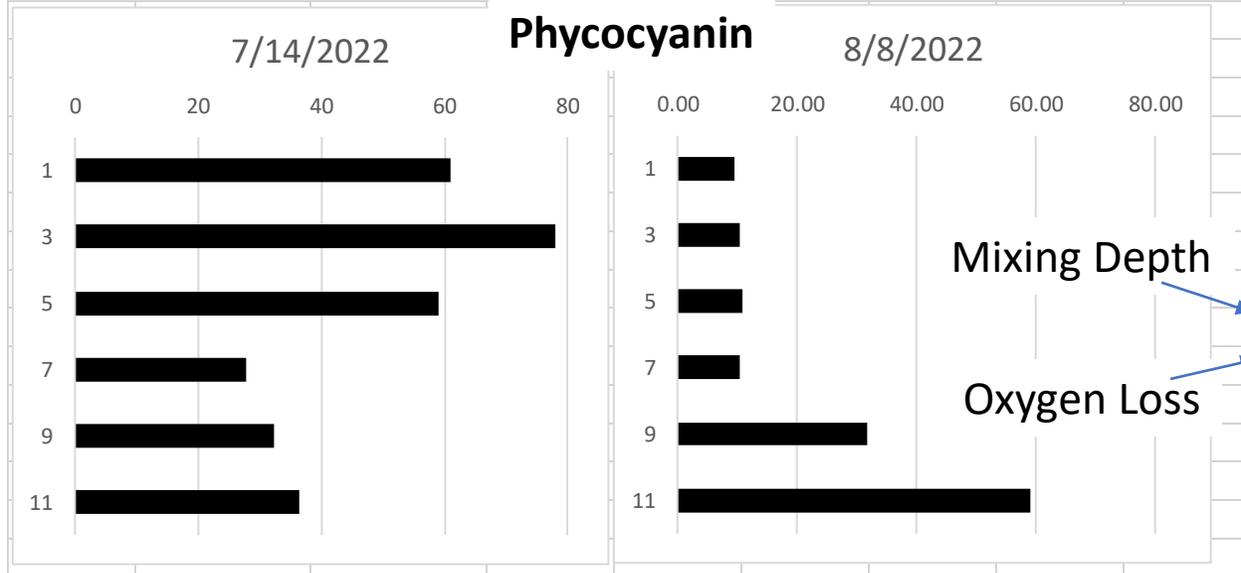
On 8/8/2022 the cyanobacteria-specific pigment was about 10 micrograms/L from the surface to 7m deep.

Anoxia has ascended to about 4m, above the thermocline and very close to the mixing depth.

Will a Summer Bloom Happen Next Year?

We don't know what the water quality of the deep strata will be at Fall Turnover, or how long summer-like weather will continue.

Station	Coventry			
Date	8/8/2022			
SECCHI	2.3	meters	7.5	ft
Anoxic Boundary	4.47	meters		
Sum RTRM	429			

Depth (m)	Temp	DO	%Sat	RTRM	RVG
0.5	28.7	7.0	91.8	0.0	0.0
1	28.7	7.0	91.7	3.6	3.6
1.5	28.7	7.0	91.5	0.0	0.0
2	28.7	7.0	91.3	0.0	0.0
2.5	28.6	7.0	91.3	0.0	0.0
3	28.6	7.0	91.2	0.0	0.0
3.5	28.4	6.6	86.2	10.7	10.8
4	26.8	4.2	53.9	51.9	55.5
4.5	25.0	0.8	9.8	58.9	70.7
5	22.3	0.1	1.2	81.1	115.2
5.5	20.6	0.0	0.1	49.1	83.6
6	18.6	0.0	0.0	47.3	95.6
6.5	17.3	0.0	0.0	31.8	75.1
7	15.8	0.0	0.0	31.0	85.4
7.5	14.8	0.0	0.0	17.1	53.9
8	14.2	0.0	0.0	10.7	37.1
8.5	13.5	0.0	0.0	11.8	44.4
9	13.0	0.0	0.0	8.0	32.6
9.5	12.6	0.0	0.0	6.1	26.6
10	12.2	0.0	0.0	7.3	33.9
10.5	11.9	0.0	0.0	2.8	13.8

Accumulation of TP and Ammonia-N?

Coventry Lake 2022 Bloom

- **Can We Do Something to Reduce the Risk of Future Blooms?**
  - Are there options for adapting to Changing Climatic Conditions?

    (To Be Determined)
  - Are there *Appropriate* Methods to reduce the Cyanobacteria Risk directly?

    (To Be Determined)

At this time, only additional monitoring and study is recommended.
We need to understand this better.

Possible Management Approaches
Specific to Cyanobacteria:
- **Increased Monitoring / Diagnostic-Feasibility Study**
  - Monthly sampling during ice-free months
  - Track Growing Degree Days and Anoxic Factor
  - Record Date of First Frost, Ice-on, Ice-off
  - Frequent "Stop-by" Secchi and Fluorimetry MJJA
- Non-Copper Algaecide
- Sonic Algae Control Devices
- Manage Deep Oxygen Consumption
- Deep Nutrient Inactivation
- Additional Watershed Management
  (Preservation, not Restoration)

To Adapt to Climatic Variability:
- **Increased Monitoring / Diagnostic-Feasibility Study**
- Seasonal Artificial Circulation- Enhance Diatoms
- Manage to Reduce Internal Loading and Vertical Transport
- Manage to Maintain Separation of Mixing Depth and Oxygen Loss

Questions?
(Besides the many I still have.)