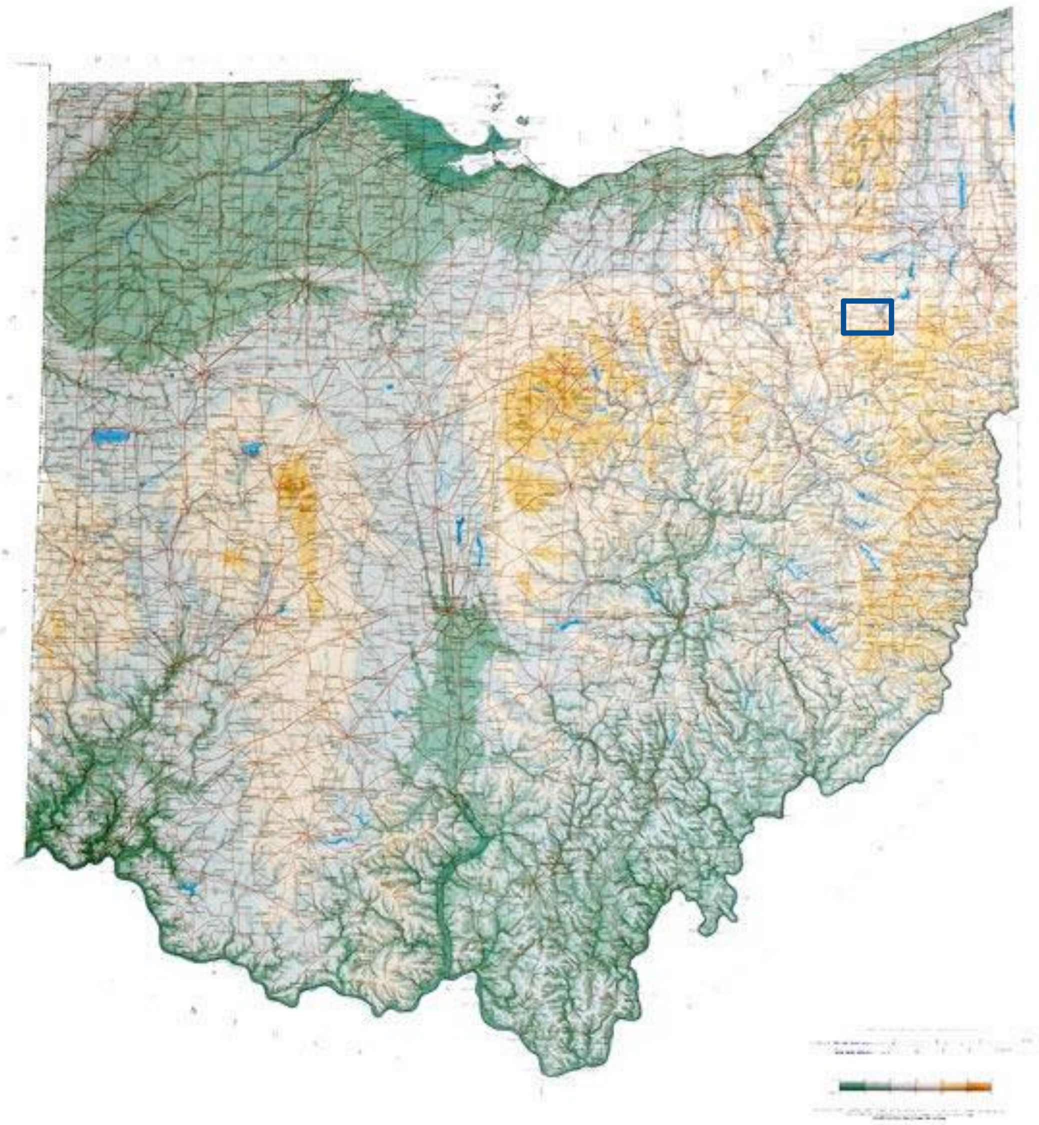
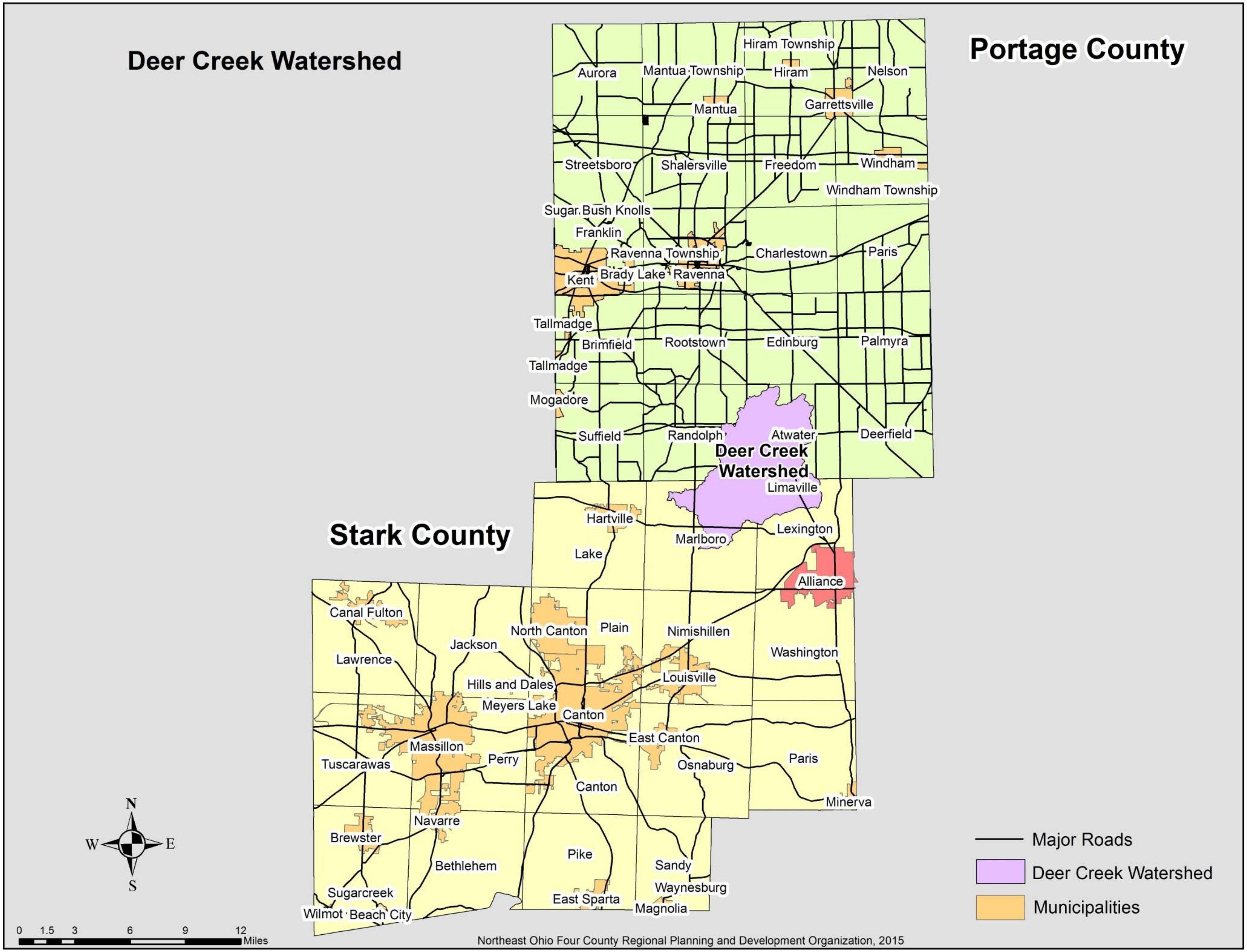
Alliance's Experience

Dr. Dean Reynolds,
Superintendent
Alliance Water Treatment Department

OHIO




Deer Creek Watershed
Portage County
Stark County
Hiram Township
Aurora
Mantua Township
Hiram
Nelson
Mantua
Garrettsville
Streetsboro
Shalersville
Freedom
Windham
Windham Township
Sugar Bush Knolls
Franklin
Ravenna Township
Charlestown
Paris
Kent
Brady Lake
Ravenna
Tallmadge
Brimfield
Rootstown
Edinburg
Palmyra
Tallmadge
Mogadore
Suffield
Randolph
Atwater
Deerfield
Deer Creek Watershed
Limaville
Hartville
Lexington
Marlboro
Lake
Alliance
Canal Fulton
North Canton
Plain
Nimishillen
Jackson
Washington
Lawrence
Louisville
Hills and Dales
Meyers Lake
Canton
East Canton
Massillon
Tuscarawas
Perry
Osnaburg
Paris
Canton
Minerva
Navarre
Brewster
Bethlehem
Pike
Sandy
Waynesburg
Sugarcreek
East Sparta
Wilmot
Beach City
Magnolia
N
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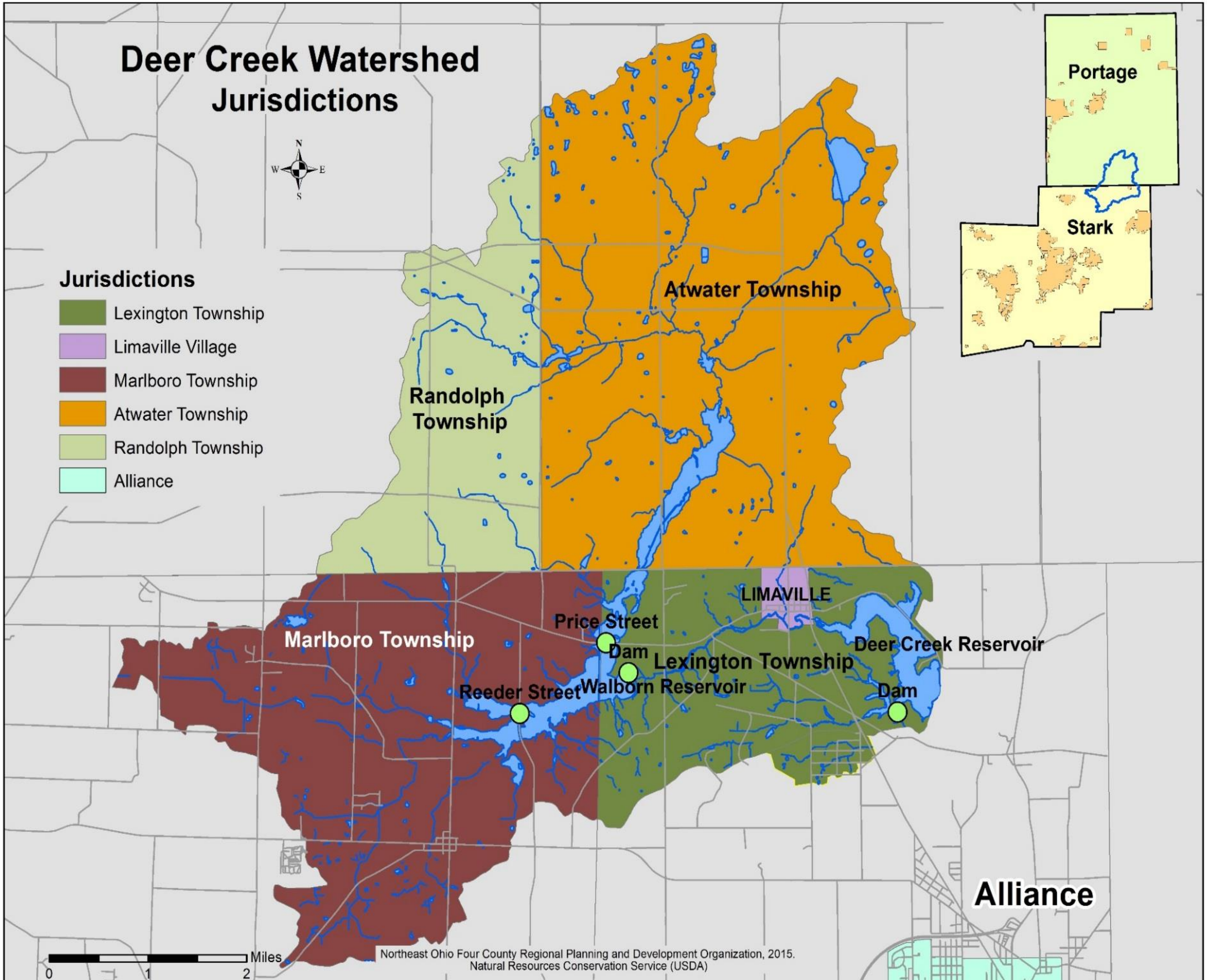
E
S
0 1.5 3 6 9 12 Miles
Major Roads
Deer Creek Watershed
Municipalities
Northeast Ohio Four County Regional Planning and Development Organization, 2015



Deer Creek Watershed
Jurisdictions
N
S
E
W
Jurisdictions
Lexington Township
Limaville Village
Marlboro Township
Atwater Township
Randolph Township
Alliance
Portage
Stark
Atwater Township
Randolph Township
LIMAVILLE
Price Street
Dam
Marlboro Township
Lexington Township
Deer Creek Reservoir
Reeder Street
Walborn Reservoir
Dam
Alliance
0
1
2
Miles
Northeast Ohio Four County Regional Planning and Development Organization, 2015.
Natural Resources Conservation Service (USDA)

The alliance Review

First in local news since 1888 | Thursday, January 22, 2009 | Alliance Ohio • 50 Cents

Alliance hunting for source of musty smell in drinking water

Alliance Schools seek renewal of operating levy

7.8-mill issue will appear on May 5 ballot

By STEPHANIE UJHELYI
The Review

The Alliance Board of Education will go back to the primary ballot, hoping for a levy renewal.

During Tuesday's regular meeting, board members voted to put its 7.8-mill operating levy up for renewal on the May 5 ballot.

Treasurer Kirk Heath said that the issue, if passed, would raise $2 million annually.

This levy was passed back in March 2003 by a 2,493 to 2,081 margin. At that point, the district was facing cutting 56 positions and busing changes if the levy failed.

Owners of a $50,000 home would continue to pay $110.50 a year, Heath explained.

In other action, Sharon Walker, a high school technology resources instructor, will retire at the end of the year after 23 years with the district.

West Branch graduate enjoyed atmosphere at the inauguration

By JONI BOWEN
The Review

at Wheeling Jesuit University. His interest in politics

WATER CHEMICALS USED

Year or Mo.	ALUM Ton	ALUM GPG	FERRIC SULFATE Tons	FERRIC SULFATE GPG	LIME Tons	LIME GPG	CARBON Tons	CARBON PPM	CHLORINE Pre PPM	CHLORINE Post PPM	CHLORINE Tons	SALT VG Brine	SALT Dry
1930	150	1.5	----	---	--	---	---	---	0.5	.22	4.4	----	--
1931	139	1.6	----	---	--	---	---	---	0.7	.25	4.9	----	--
1932	118	1.6	----	---	--	---	---	---	0.7	.28	4.1	----	--
1933	118	1.5	----	---	--	---	---	---	0.7	.31	5.3	----	--
1934	112	1.4	----	---	--	---	---	---	0.7	.25	4.7	----	--
1935	116	1.4	----	---	--	---	---	---	0.8	.38	5.6	----	--
1936	136	1.3	----	---	--	---	---	---	0.7	.40	6.8	----	--
1937	118	1.2	----	---	--	---	---	---	0.9	.38	7.1	----	--
1938	115	1.3	----	---	--	---	---	---	1.3	.54	9.6	----	--
1939	130	1.4	----	---	12	0.8	---	---	1.4	.62	10.9	----	--
1940	138	1.4	----	---	22	0.7	---	---	1.5	.37	10.1	----	--
1941	146	1.2	----	---	24	0.2	---	---	1.4	.53	14.6	----	--
1942	136	1.2	----	---	--	---	---	---	2.5	.47	21.9	----	--
1943	166	1.3	----	---	--	---	---	---	4.7	.62	45.0	----	--
1944	157	1.2	----	---	78	0.5	---	---	5.2	.80	54.5	----	--
1945	163	1.2	----	---	45	0.6	---	---	4.9	.70	48.5	----	--
1946	183	1.4	----	---	--	---	---	---	4.9	.33	48.1	----	--
1947	185	1.4	----	---	198	9.4	---	---	5.4	.70	53.9	----	--
1948	99	1.0	31.0	0.7	966	6.8	---	---	8.0	.87	66.5	16.5	56
1949	74	0.8	16.4	0.5	1046	7.0	---	---	7.1	.74	52.3	18.7	7
1950	106	1.1	7.2	0.3	907	6.1	---	---	5.5	.21	40.8	19.8	0
1951	117	0.9	0.3	0.3	930	6.2	---	---	5.1	.27	40.4	18.6	0
1952	89	0.8	0.3	0.5	1063	7.5	4.5	4.2	7.4	.20	54.8	20.2	0
1953	86	0.7	----	---	1223	7.5	34.0	4.4	6.5	.21	55.7	13.7	0
1954													
Jan.	8.6	0.8	----	---	115	9.2	3.3	5.3	3.3	.00	2.0	0.8	0
Feb.	5.4	0.6	----	---	82	7.9	2.4	4.1	4.9	.01	2.8	1.3	0
Mar.	14.8	1.4	----	---	40	5.5	1.9	3.1	5.8	.34	3.8	1.4	0
Apr.	17.3	1.7	----	---	27	4.8	1.7	2.8	6.0	.27	3.9	1.4	0
May	6.3	0.6	----	---	85	6.[illegible]	2.0	3.3	6.5	.12	4.1	1.4	0
June	15.6	1.5	----	---	78	7.3	1.7	2.6	10.2	.59	7.0	1.4	0
July	3.5	0.3	----	---	144	9.[illegible]	1.3	2.7	8.2	.17	6.2	1.4	0
Aug.	8.0	0.7	----	---	106	8.[illegible]	1.6	2.4	8.7	.38	6.0	0.4	0
Sep.	4.2	0.4	----	---	121	9.2	1.6	2.5	7.9	.12	4.9	0.8	0
Oct.	10.7	1.1	----	---	75	6.9	2.0	3.4	9.5	.29	5.0	1.4	0
Nov.	3.0	0.3	----	---	84	7.2	2.3	4.2	6.4	.04	3.5	1.3	0
Dec.	6.3	0.6	----	---	102	8.2	1.1	2.5	3.0	.01	1.8	1.5	0
TOT.	103.7				1060		22.9				51.0	14.5	0
AVG.		0.8				7.6		3.2	6.7	.19			

Know Your Enemy *********

- Problems algae create
- Algae identification
  - Class
  - Microscopes and slides
- Sampling
  - Where and at what depth
  - Planktonic vs Benthic
- Population shifts

Problems Associated with Algal Blooms and Their Rated Severity

Problem	Yes (%)	No (%)	Do not know (%)	Severe Impact (%)	Moderate Impact (%)	No Impact (%)
T&O	90	3	2	50	47	3
Filter Clogging	48	32	14	23	62	13
Coagulant Demand	36	33	24	31	62	7
Chlorine Demand	50	22	21	13	79	5
THM Formation	17	29	44	23	73	0
Algal Toxins	6	25	54	14	43	43

AWWA, 2008 (114 surface water utilities responded out of 124)

Taste and Odor

- The most common cause of customer complaints
- Most cases, problem is aesthetic not a human health concern
- Surface water systems
- No U.S. EPA or Ohio EPA standards
- Control costs can be staggering

Algae that Produce Taste and Odor

- **Bluegreen algae (Cyanophyta)**
  - Earthy, musty,
- **Green algae (Chlorophyta)**
  - grassy odor; fishy odor if in large numbers
  - *Chara* skunk-like or garlic odor
  - *Nitella* grassy-septic odor

- **Golden or yellow brown algae (Chrysophytes)**
  - ***Dinobryon, Uroglenopsis, Uroglena***
  - ***Synura* – cod liver oil; fishy odor**
- **Yellow green algae (Xanthophyceae)**
  - *Tribonema* filter clogger

Algae that Produce Taste and Odor

- **Diatoms**- bloom during cool temps, stop after stratification
  - Filter clogging frustules-siliceous cell walls
  - *Asterionella, Cyclotella*, and *Tabellaria*
    - Mostly fishy odors
  - Marine species produce toxins

- **Dinoflagellates**
  - *Ceratium, Peridinium*
  - *Fishy, septic odors*

Three Broad Categories of T&O

- Over 200 different compounds produced by algae capable of causing T&O issues

- Earthy-musty
  - Most resistant to oxidation

- Grassy, fishy, cucumber-like, geranium

- Decaying algae- septic, putrefactive and pigpen

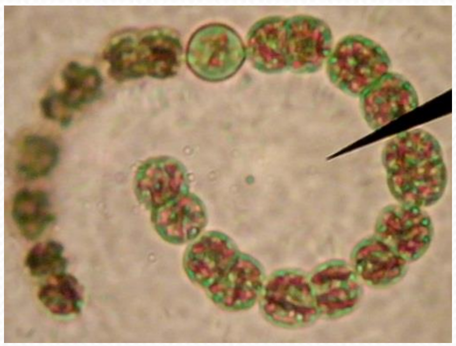
Cyanobacteria

- Geosmin
- 2-isomethylborneol (MIB)
- 2t,4c,7c-decatrienal
- 2t,6c-nonadienal
- Linolenic acid
- ß-cyclocitral
- Isovaleric acid

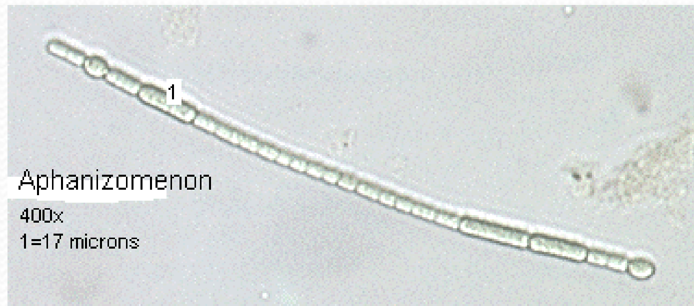
- Earthy-musty
- Earthy-musty
- Fishy
- Cucumber
- Sweet-melon-watermelon
- Sweet fruity-chocolate-pipe tobacco
- Rancid-cheesy-dirty socks-sour

What Causes it?

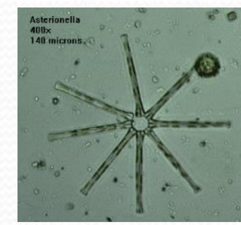
- **Cyclic organic compounds**
- **Produced by some species of bluegreen algae (cyanobacteria)**

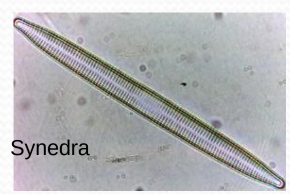


Anabaena



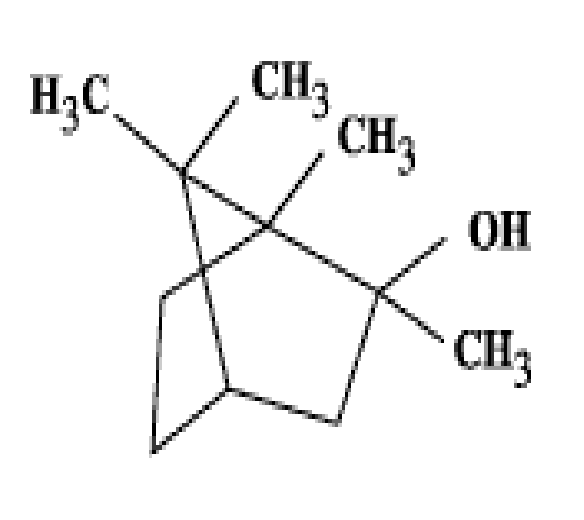
Oscillatoria





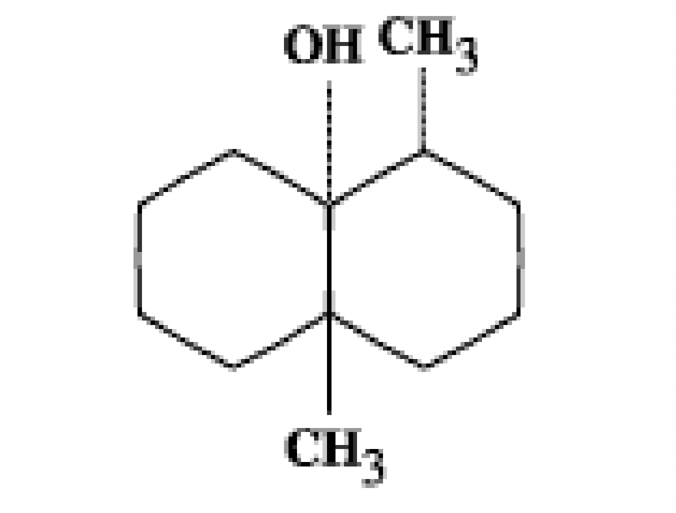
COMPOUNDS GENERATED BY SOME CYANOBACTERIA

Aesthetics: T&O cmpds



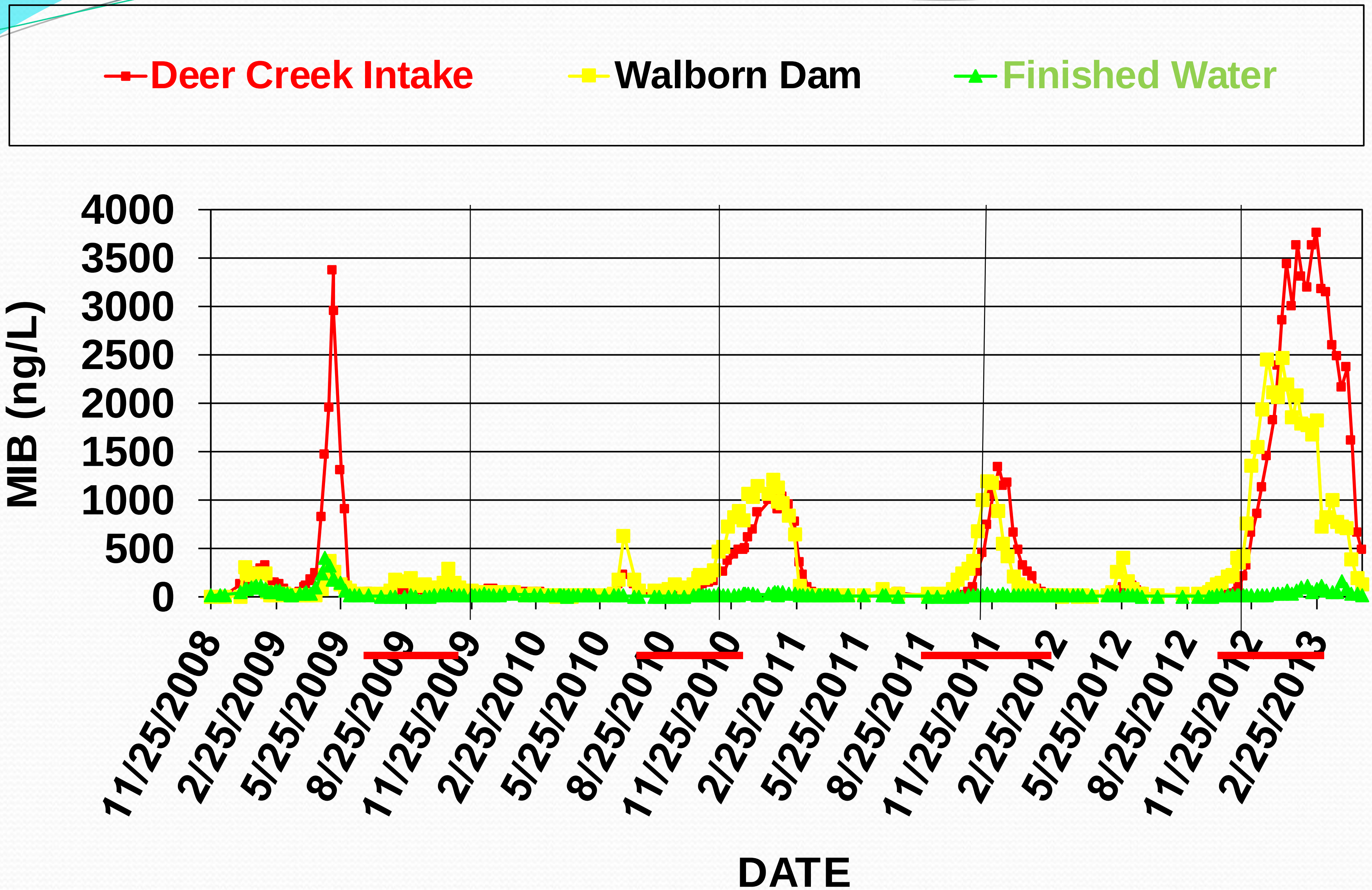
2-Methylisoborneol

(MIB)

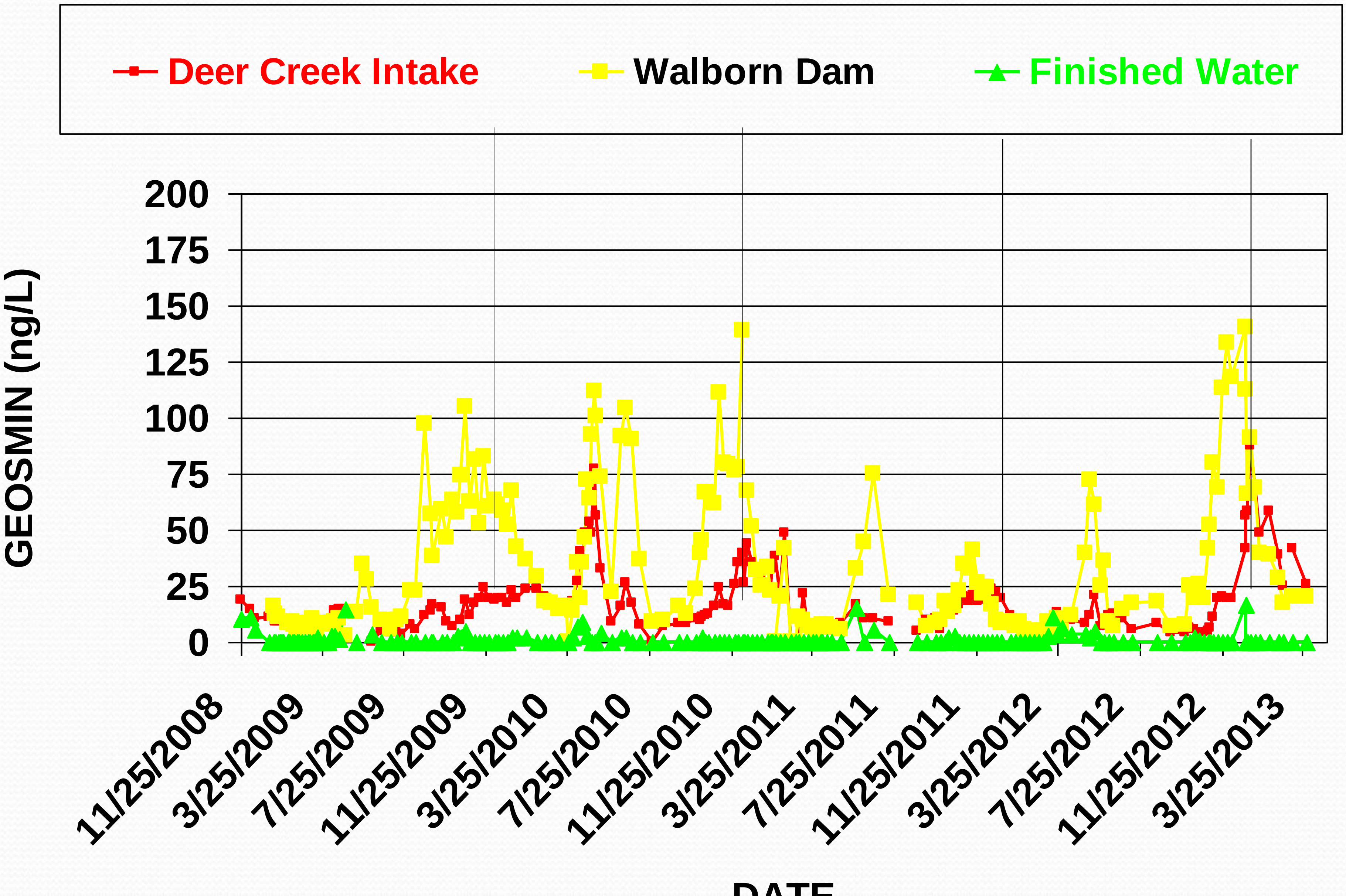


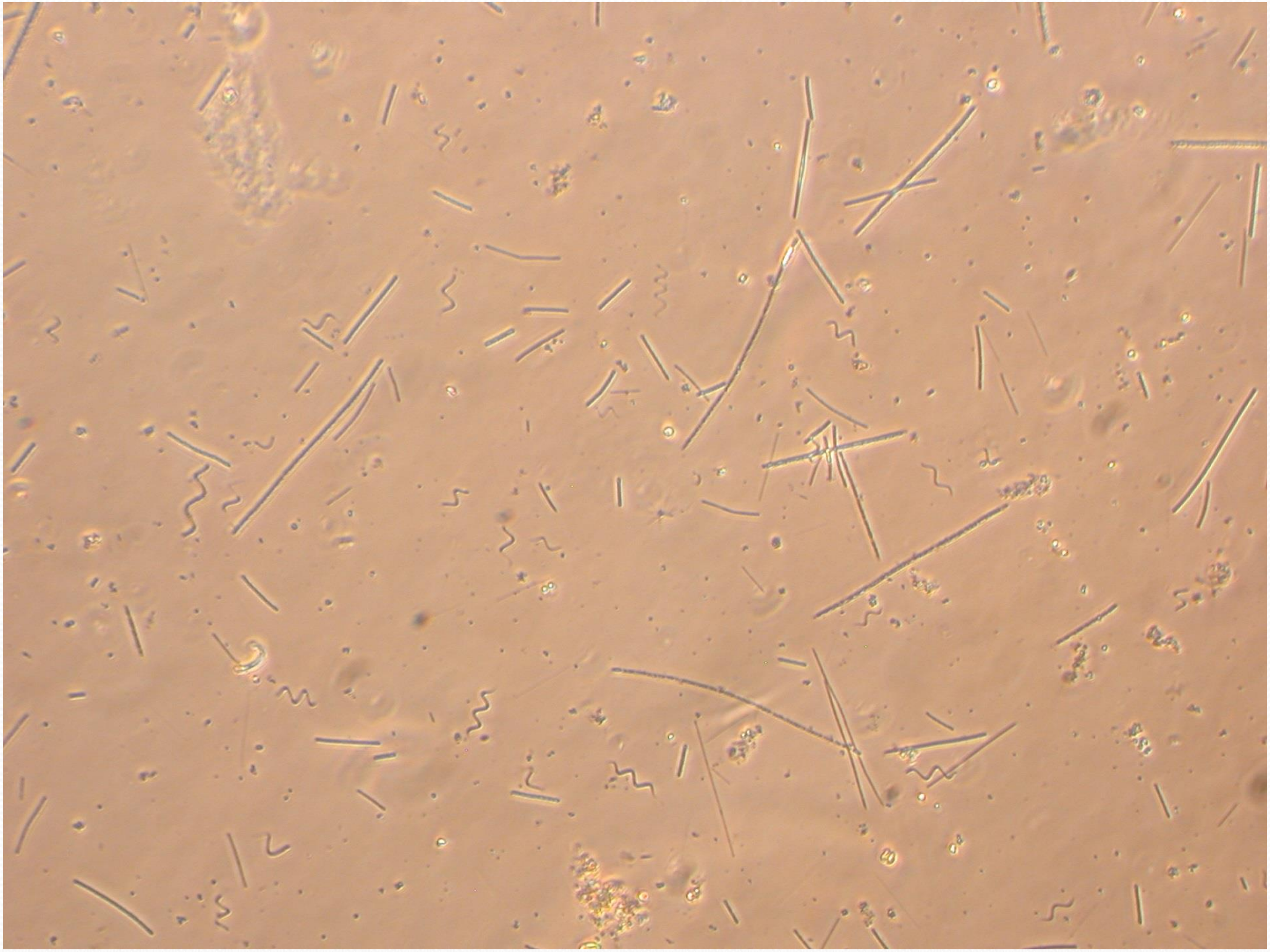
Geosmin

MIB CONCENTRATION



GEOSMIN CONCENTRATION





Algae Identification

OSU Stone Lab Classes 2016 Gibraltar Island

- Algae Identification Workshop
  - August 8 - August 9
  - August 10 – August 11
  - Dr. Rex Lowe, Emeritus Prof. Bowling Green University
- Dealing with Cyanobacteria, Algal Toxins and Taste & Odor Compounds Workshop
  - August 8 - August 9
  - August 10 – August 11
  - Team taught Heather Raymond, Richard Lorenz, others

Algae Identification

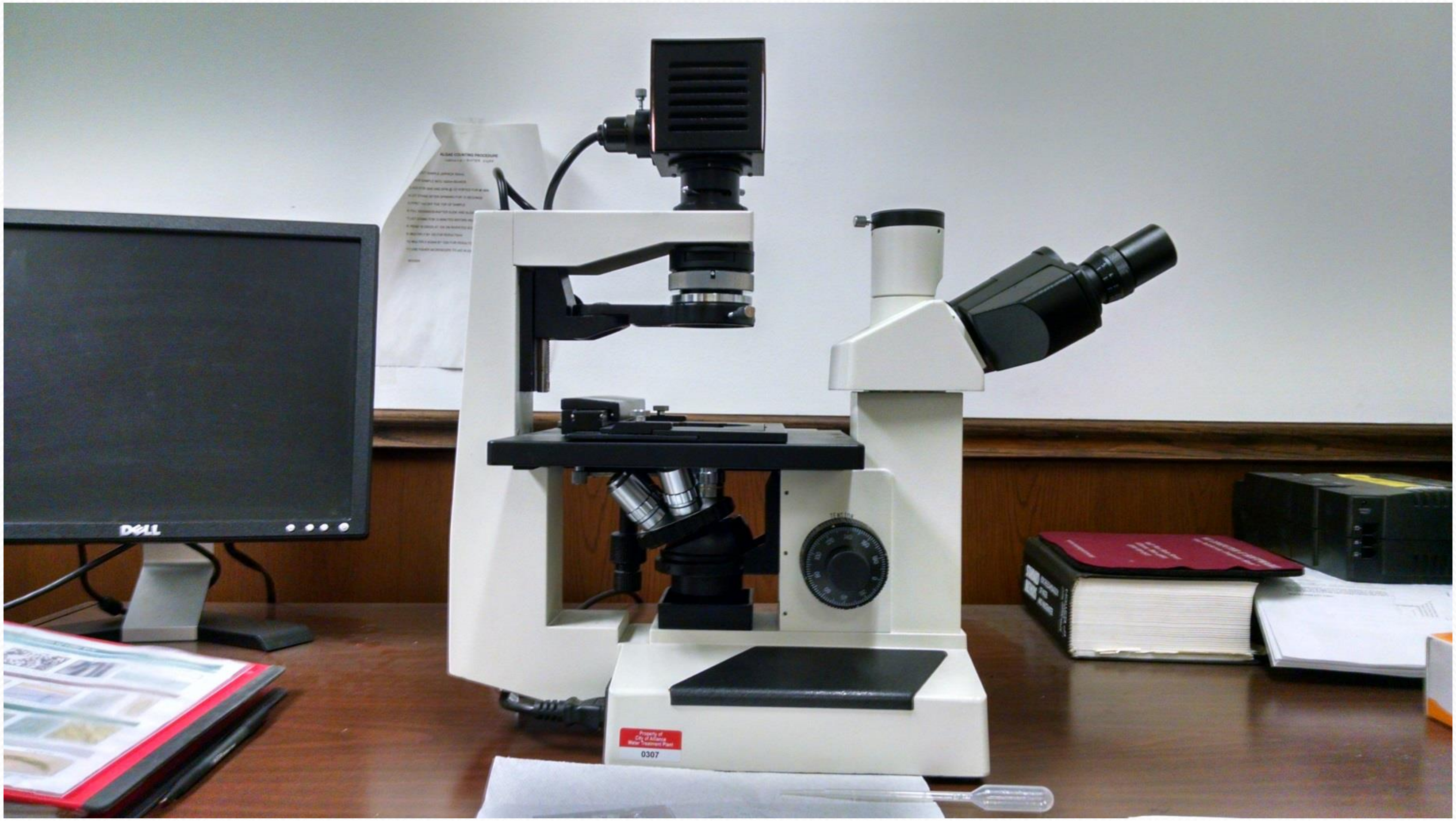
- Texts
  - *Freshwater Algae of North America; Ecology and Classification*. Edited By Wehr and Sheath
  - *Algae Source to Treatment*. AWWA Publication M57
  - *How to Know the Freshwater Algae*. Edited by Prescott
- Web sites
  - http://greenwaterlab.com/algal-id.html
  - http://www-cyanosite.bio.purdue.edu/images/images.html

Hemocytometer Slide

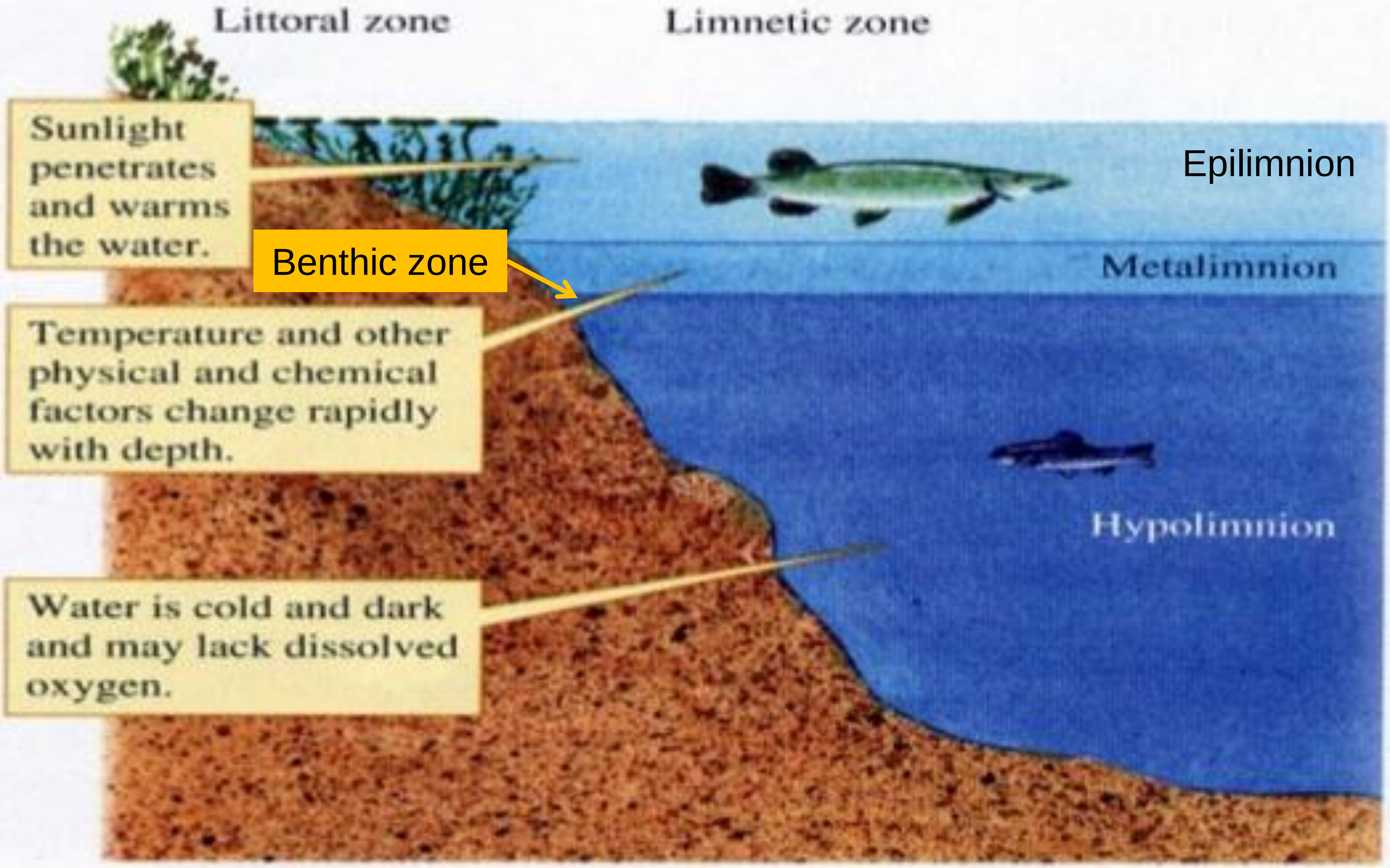
Sedgewick Rafter Counting Chamber Slide

Compound Light Microscope

Inverted Light Microscope



Lake Structure



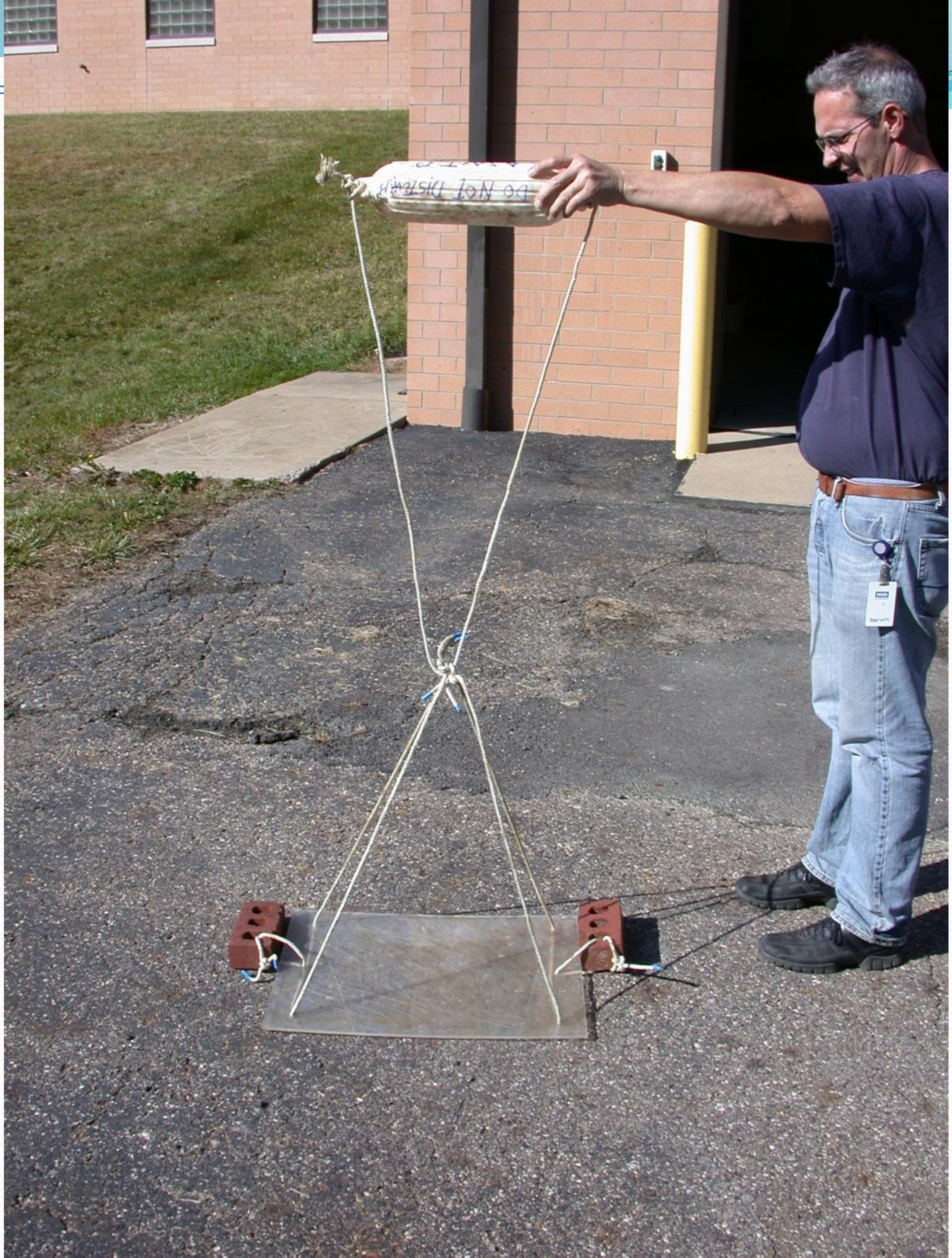
Algae Sampling

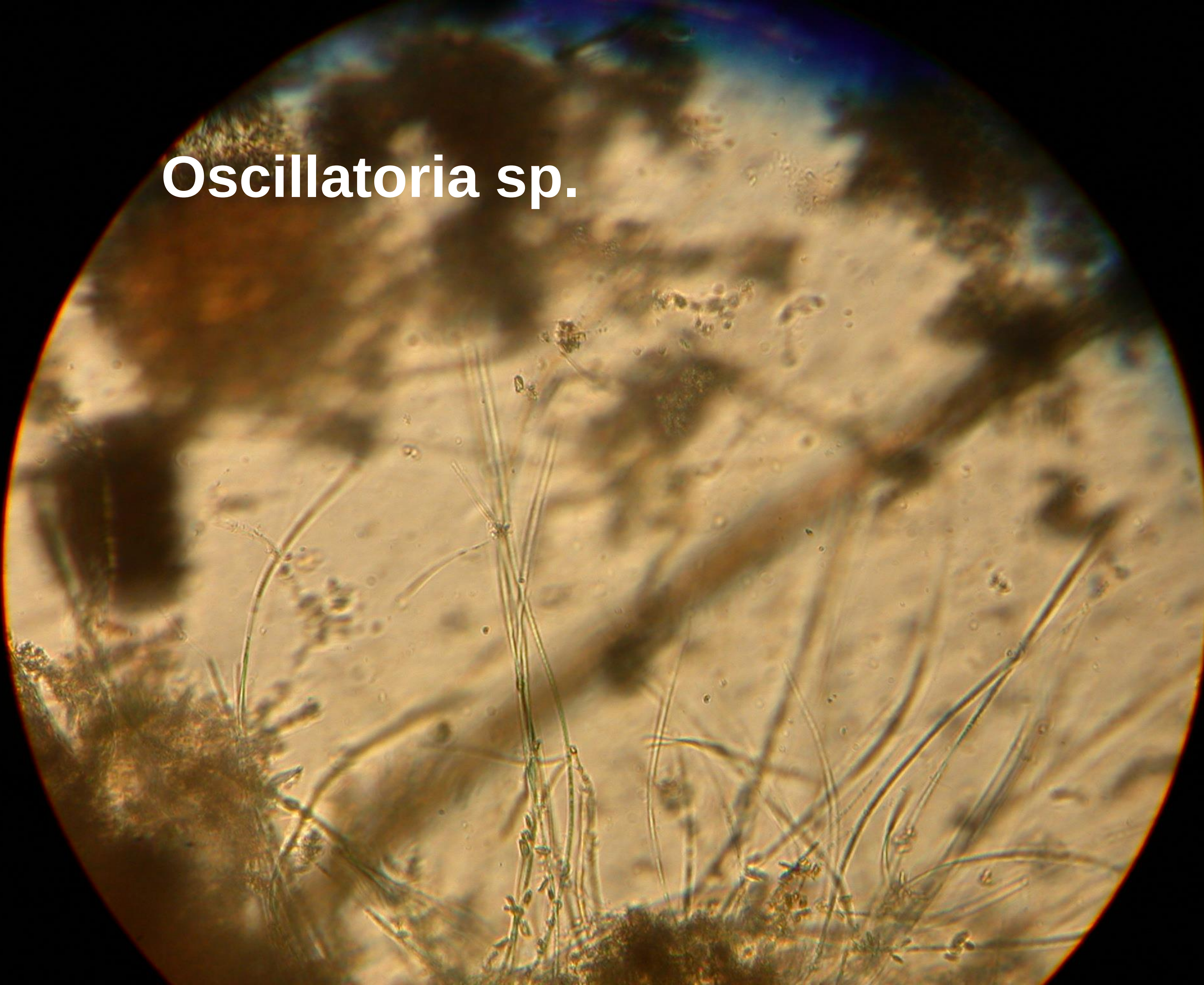
- Where to sample
- Depth and time of day affects
- Planktonic vs benthic
  - Artificial substrate


Anabaena Bloom
Geosmin producer
Microcystin producer

Artificial Substrate

12 placed in
Walborn Reservoir




Oscillatoria sp.

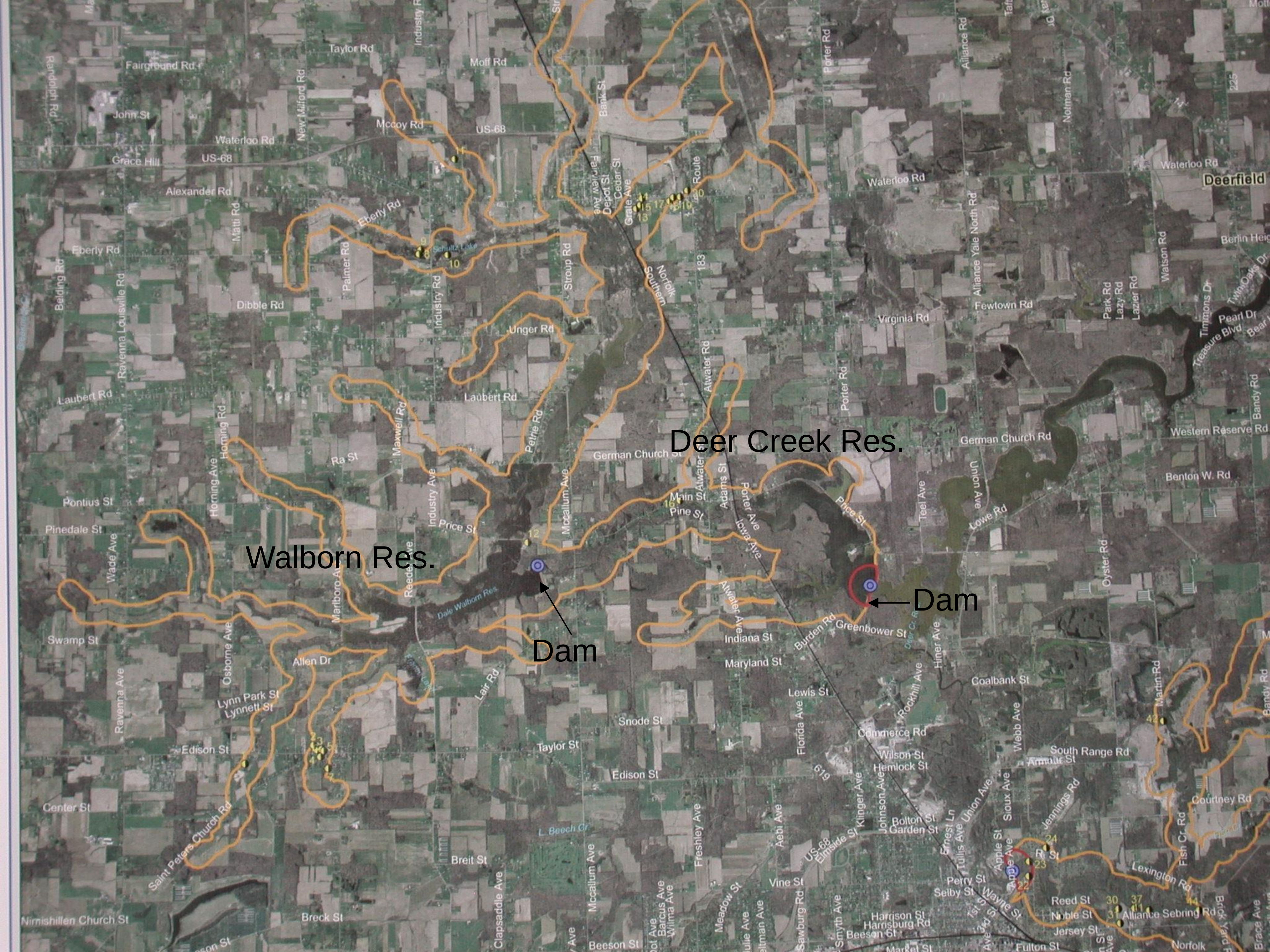
Why do we have a problem with Cyanobacteria?

- **Reservoirs are Eutrophic**
- **Nutrient contaminants are flowing into the reservoirs from the watershed**
  - **Nitrogen compounds**
  - **Phosphorus**
    - **More efficient than competition**
    - **Absorb and store 10 x what is needed**
    - **Expand 16 x biomass**
  - **N:P ratio very important**
    - **Low ratio favors cyanobacteria**
    - **Some fix their own nitrogen from the environment**

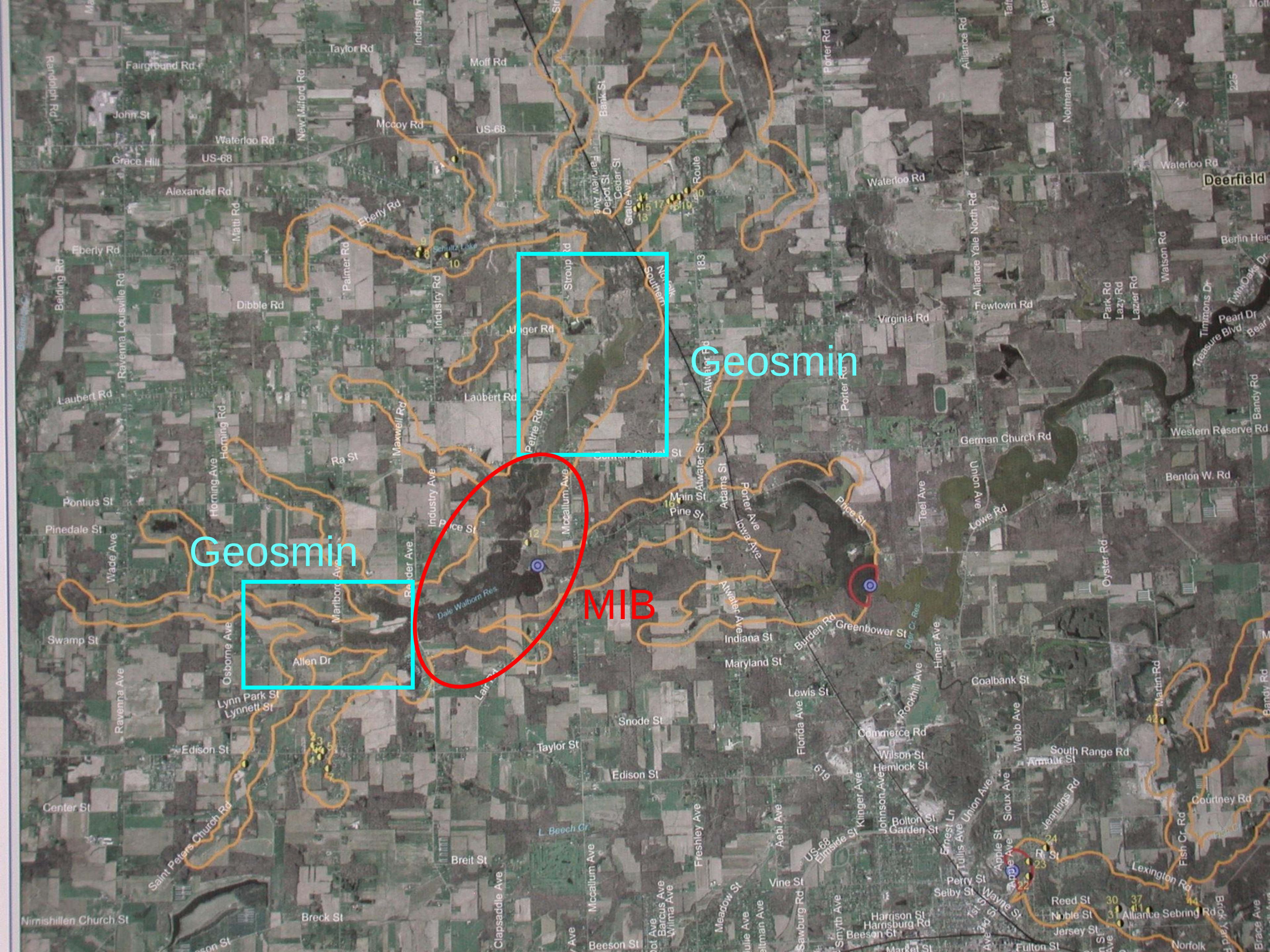
Geosmin

2-methylisoborneol

(MIB)

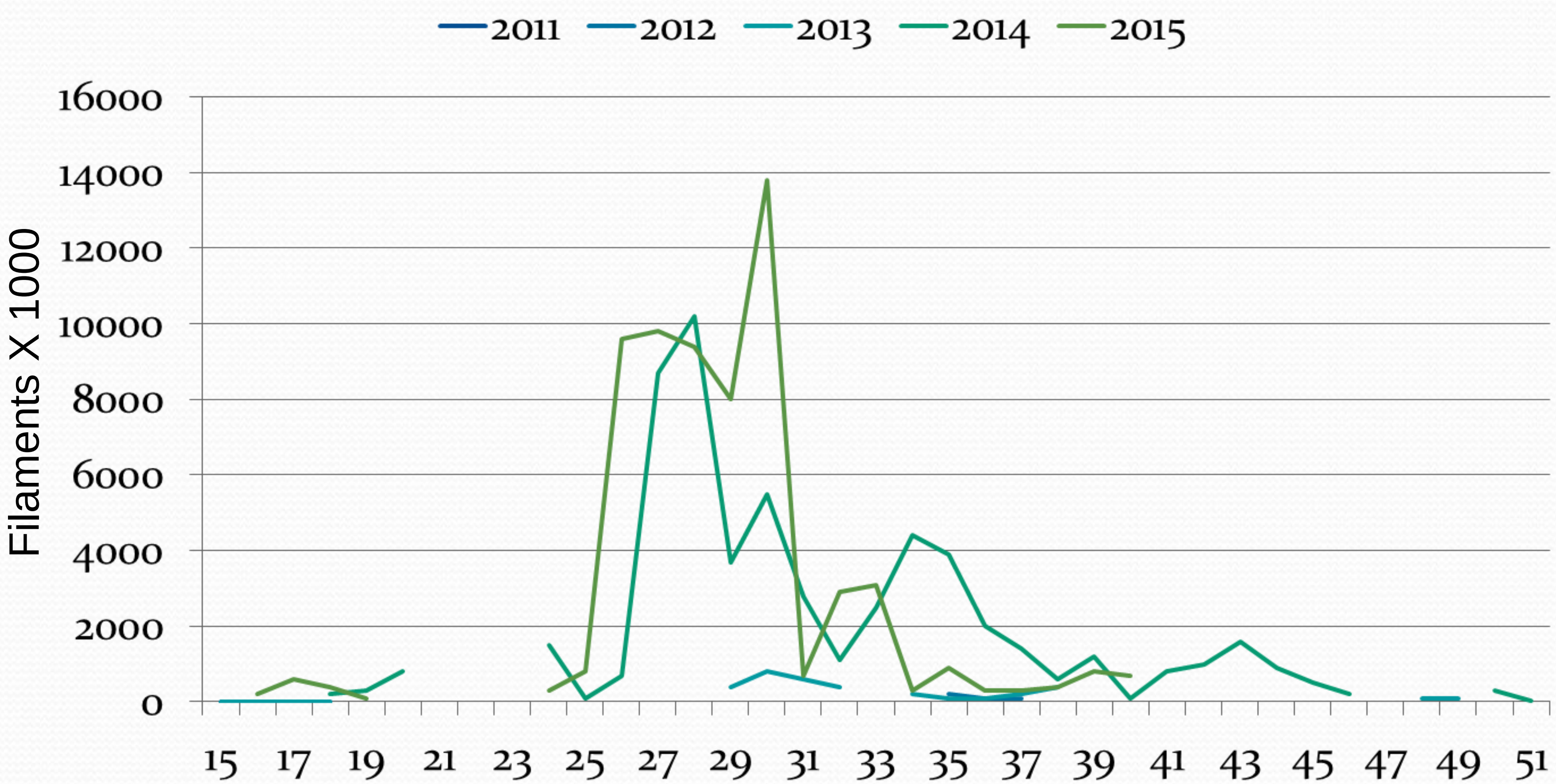

Deer Creek Res.
Walborn Res.
Dam
Dam
Deerfield
Dale Walborn Res.

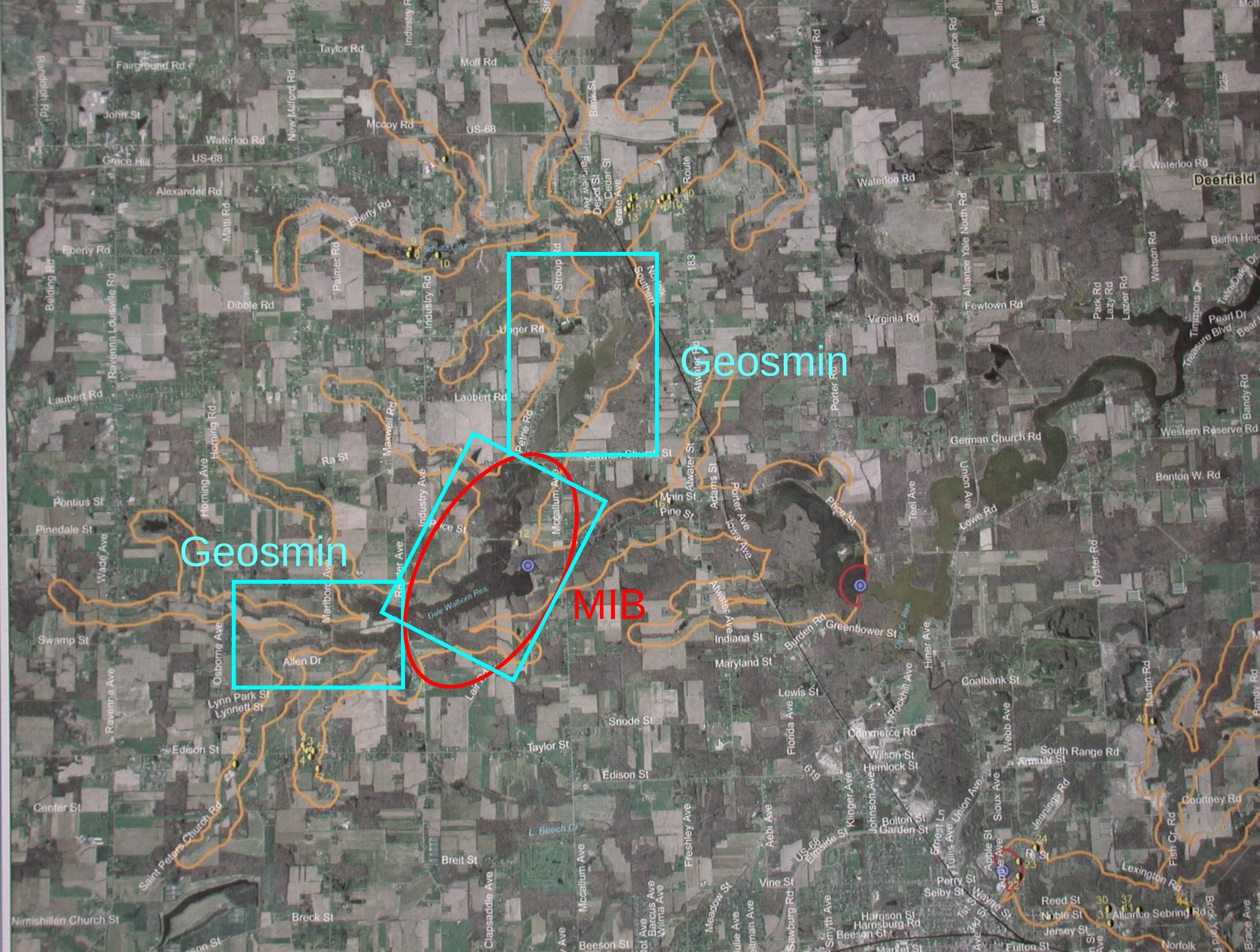

MIB
Deerfield
Taylor Rd
Fairground Rd
Moff Rd
Randolph Rd
John St
Waterloo Rd
New Milford Rd
Mccoy Rd
US-68
Grace Hill
Alexander Rd
Eberly Rd
Schultz Lake
Palmer Rd
Industry Rd
Stroup Rd
Bank St
Fairview Ave
Depot St
Cedar St
Grate Ave
Route 183
Norfolk Southern
Porter Rd
Alliance Rd
Notman Rd
Alliance Yale North Rd
Watson Rd
Fewtown Rd
Virginia Rd
Belding Rd
Ravenna Louisville Rd
Dibble Rd
Unger Rd
Laubert Rd
Atwater Rd
Park Rd
Lazy Rd
Lazier Rd
Timmons Dr
Twin Oaks Dr
Pearl Dr
Treasure Blvd
Bear
Bandy Rd
Western Reserve Rd
German Church Rd
German Church St
Horning Rd
Maxwell Rd
Ra St
Petrie Rd
Mccallum Ave
Atwater St
Adams St
Porter Ave
Main St
Pine St
Price St
Iowa Ave
Union Ave
Benton W. Rd
Lowe Rd
Teel Ave
Oyster Rd
Pontius St
Pinedale St
Wade Ave
Horning Ave
Industry Ave
Reeder Ave
Marlboro Ave
Dale Walborn Res.
Swamp St
Osborne Ave
Atwater Ave
Indiana St
Burden Rd
Greenbower St
Deer Cr. Res.
Himer Ave
Maryland St
Allen Dr
Lair Rd
Lewis St
Coalbank St
Martin Rd
Ravenna Ave
Lynn Park St
Lynnett St
Snode St
Florida Ave
Rockhill Ave
Commerce Rd
Webb Ave
South Range Rd
Edison St
Taylor St
Wilson St
Hemlock St
Armour St
Center St
Saint Peters Church Rd
L. Beech Cr
Freshley Ave
Aebi Ave
Klinger Ave
Johnson Ave
Bolton St
Garden St
Union Ave
Sioux Ave
Jennings Rd
Courtney Rd
Fish Cr. Rd
Lexington Rd
Breit St
Clapsaddle Ave
Mccallum Ave
US-68
Elmside St
Ernest Ln
Tullis Ave
Apple St
Perry St
Selby St
Wayne St
Reed St
Noble St
Jersey St
Alliance Sebring Rd
Nimishillen Church St
Breck St
Barcus Ave
Wilma Ave
Meadow St
Vine St
Sawburg Rd
Smyth Ave
Harrison St
Harrisburg Rd
Beeson St
Market St
Fulton St
Norfolk
Beeson St
Brace Ave



Geosmin
Geosmin
MIB
Deerfield
Dale Walborn Res
Deer Cr. Res.
L. Beech Cr
Schultz Lake
Taylor Rd
Fairground Rd
Moff Rd
Mccoy Rd
US-68
Waterloo Rd
Grace Hill
Alexander Rd
Eberly Rd
Dibble Rd
Laubert Rd
Unger Rd
Stroup Rd
Petrie Rd
Ra St
Pontius St
Pinedale St
Swamp St
Allen Dr
Lynn Park St
Lynnett St
Edison St
Center St
Saint Peters Church Rd
Nimishillen Church St
Breck St
Breit St
Taylor St
Snode St
Main St
Pine St
Indiana St
Maryland St
Lewis St
Greenbower St
Coalbank St
German Church Rd
Western Reserve Rd
Benton W. Rd
Fewtown Rd
Virginia Rd
South Range Rd
Commerce Rd
Courtney Rd
Lexington Rd
Alliance Sebring Rd
Reed St
Noble St
Jersey St
Fulton St
Norfolk
Beeson St
Harrison St
Harrisburg Rd
Vine St
Perry St
Selby St

Walborn Reservoir
Anabaena Population at Dam




Geosmin
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Pinedale St
Swamp St
Allen Dr
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Lynnett St
Edison St
Center St
Saint Peters Church Rd
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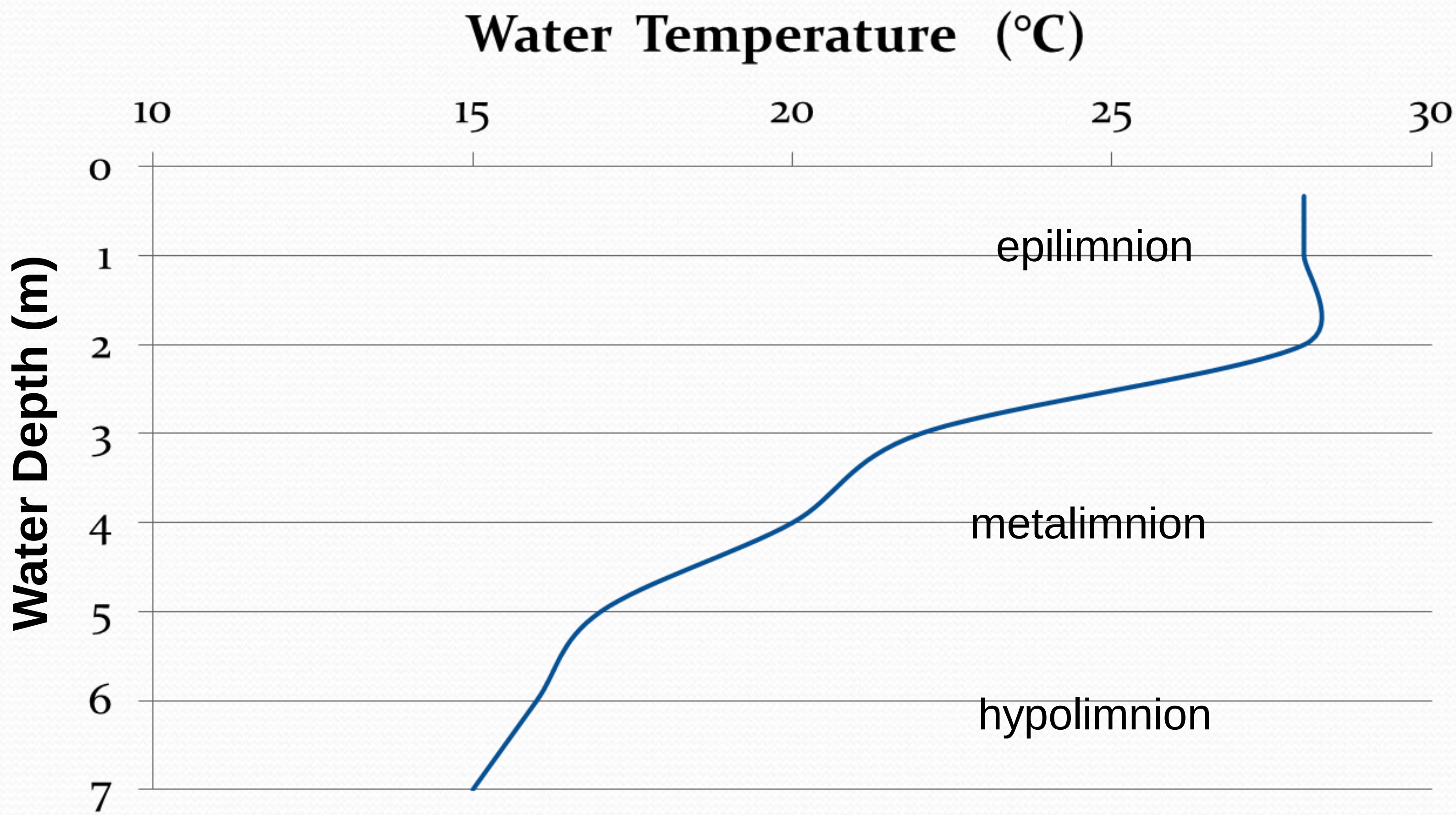
Taylor St
Edison St
Snode St
Main St
Pine St
Indiana St
Maryland St
Greenbower St
Burden Rd
Lewis St
Commerce Rd
Coalbank St
South Range Rd
Fewtown Rd
Virginia Rd
German Church Rd
Western Reserve Rd
Benton W. Rd
Lowe Rd
Lexington Rd
Alliance Sebring Rd
Courtney Rd
L. Beech Cr

Experience with Traditional Watershed Management

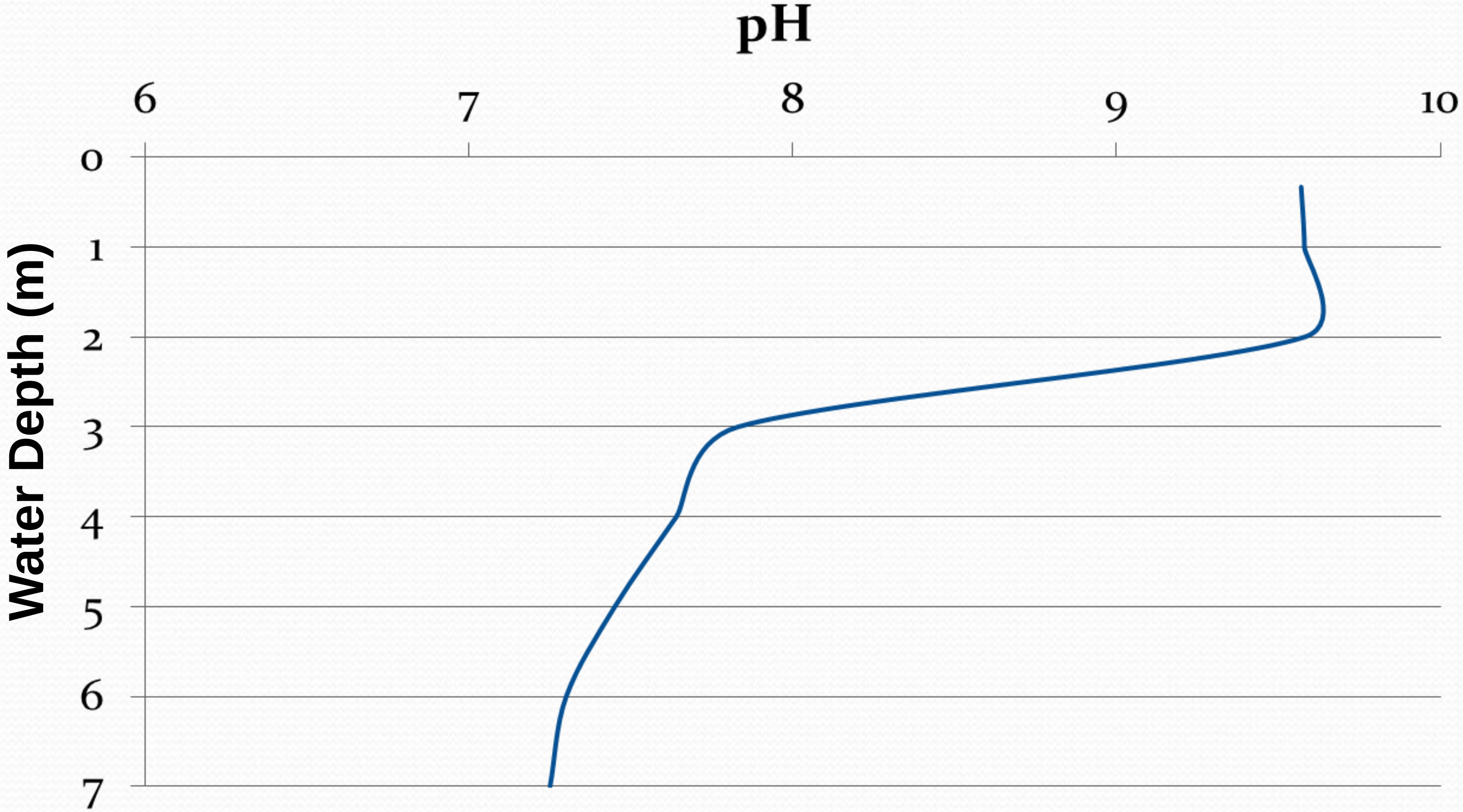
- Algicide
  - Did not help because biggest problem with T&O was in winter
  - Algae population very low in late fall and winter
  - Most of the MIB was extracellular
- Artificial destratification and aeration
- Alum coagulation (using alum sludge - potential)
  - Internal vs external sources of nutrients
- Intake port - depth modification
  - Stratification
  - Manganese


DEER CREEK RESERVOIR INTAKE
INTAKE PORTS
3’ (1m)
10’ (3m)
17’ (5m)
23’ (7m)

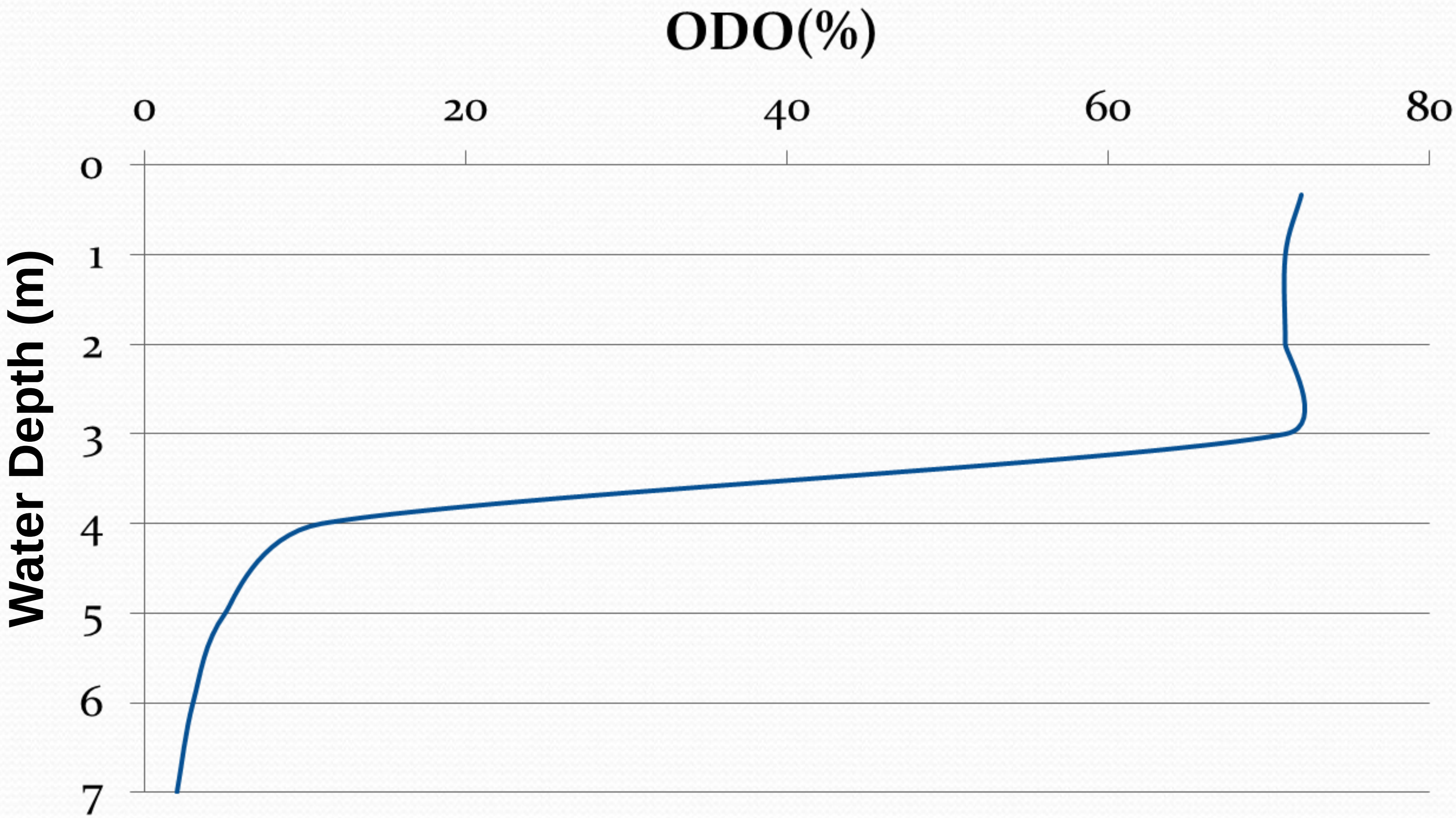
Deer Creek Water Temperature on 7/30/2015



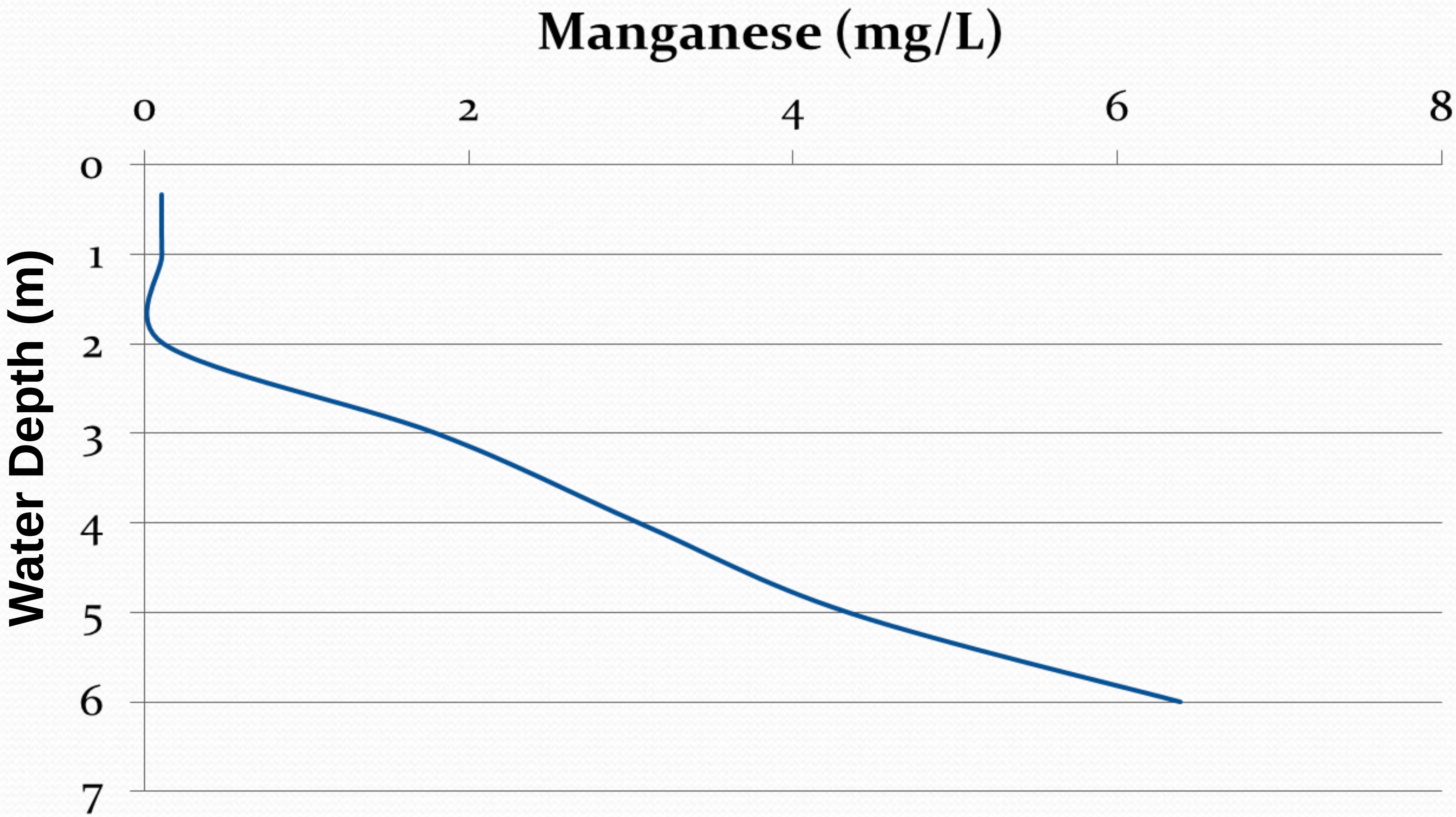
Deer Creek pH on 7/30/2015



Deer Creek Dissolved Oxygen on 7/30/2015

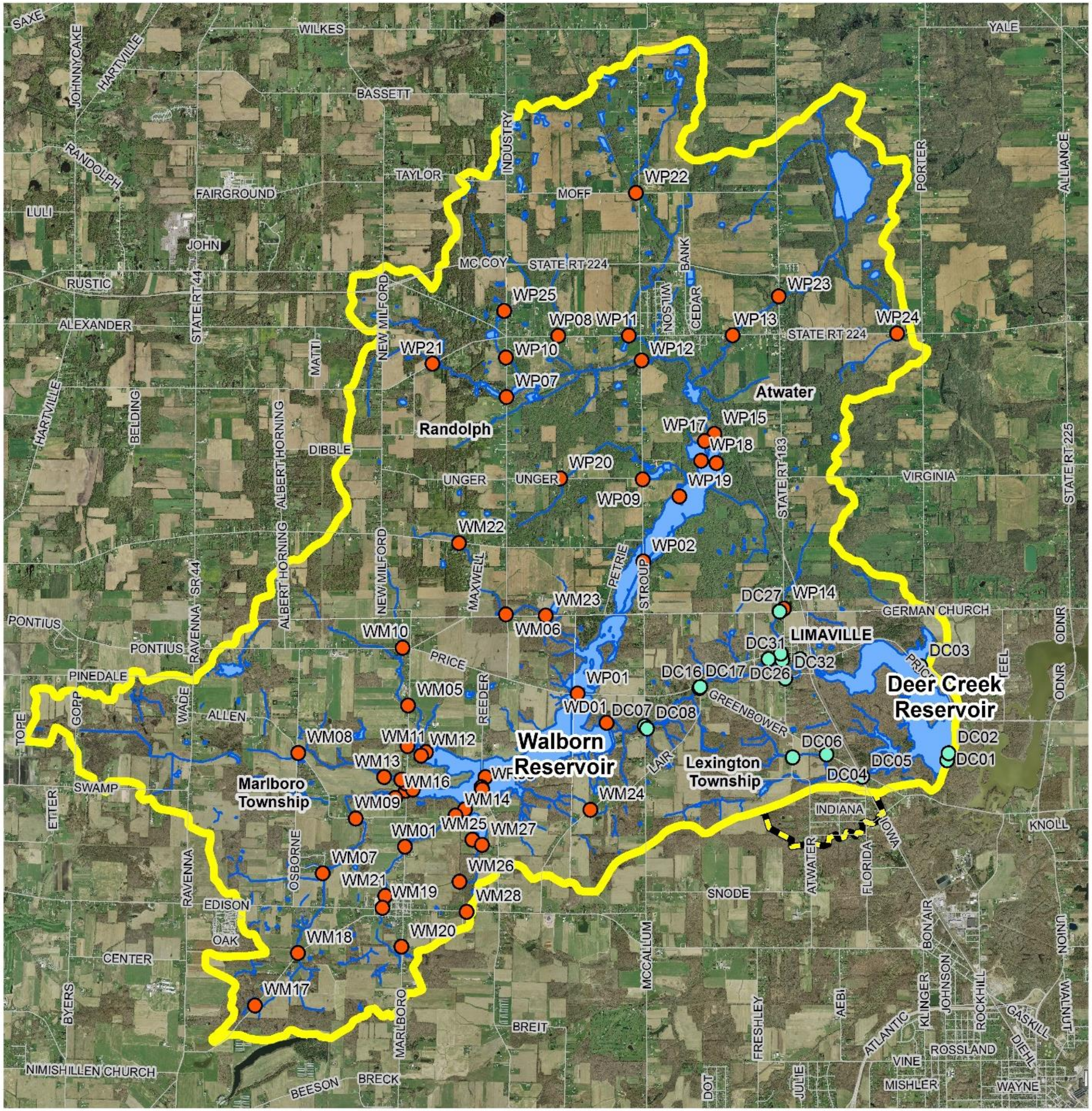


Deer Creek Manganese Concentrations on 7/30/2015



Deer Creek Watershed

Sampling Locations



Deer Creek Reservoir Sampling Locations

Sampling Locations

Deer Creek Watershed

Deer Creek Watershed Fixed

N
W E
S

0 1 2 Miles

Northeast Ohio Four County Regional Planning and Development Organization, 2015.

Watershed Sampling

- >60 sites in the watershed
    - Tributaries
    - Reservoirs
- Field and laboratory analyses

Analyses

Nitrogen: Ammonia, Nitrate, Nitrite and Total Kjeldahl Nitrogen

Phosphorus: Total and Ortho

Chloride

Water Clarity

Temperature

Dissolved oxygen

MIB and Geosmin (9 sampling sites)

Nutrient Contaminant Ranges (mg/L)

Area	NO_3	NH_3	TKN	Total P	Chloride
<u>Stark Co.</u> Marlboro and Lexington Areas	<0.4 – 13.03	<0.1 – 11.26	<0.1 – 27.4	<0.2 – 23.42	<0.2 – >641
<u>Portage Co</u>. Atwater Area	<0.4 – 2.04	<0.1 – 0.8	<0.1 – 1.94	<0.2 – 1.30	<0.2 – >641

Point Sources of Nutrient Contaminants

- One dairy farm
  - Stark County Soil and Water Conservation District
- Town of Marlboro ~110 homes
  - Army Corps of Engineers, SC Sanitary Engineers, Township Trustees
  - Wastewater facility completed June 2013
- Village of Limaville
  - Work starting Winter 2016
- Home septic systems (many sites)
  - Stark County Health Department
    - Lacking any system
    - Compromised home septic system





Other Potential Sources

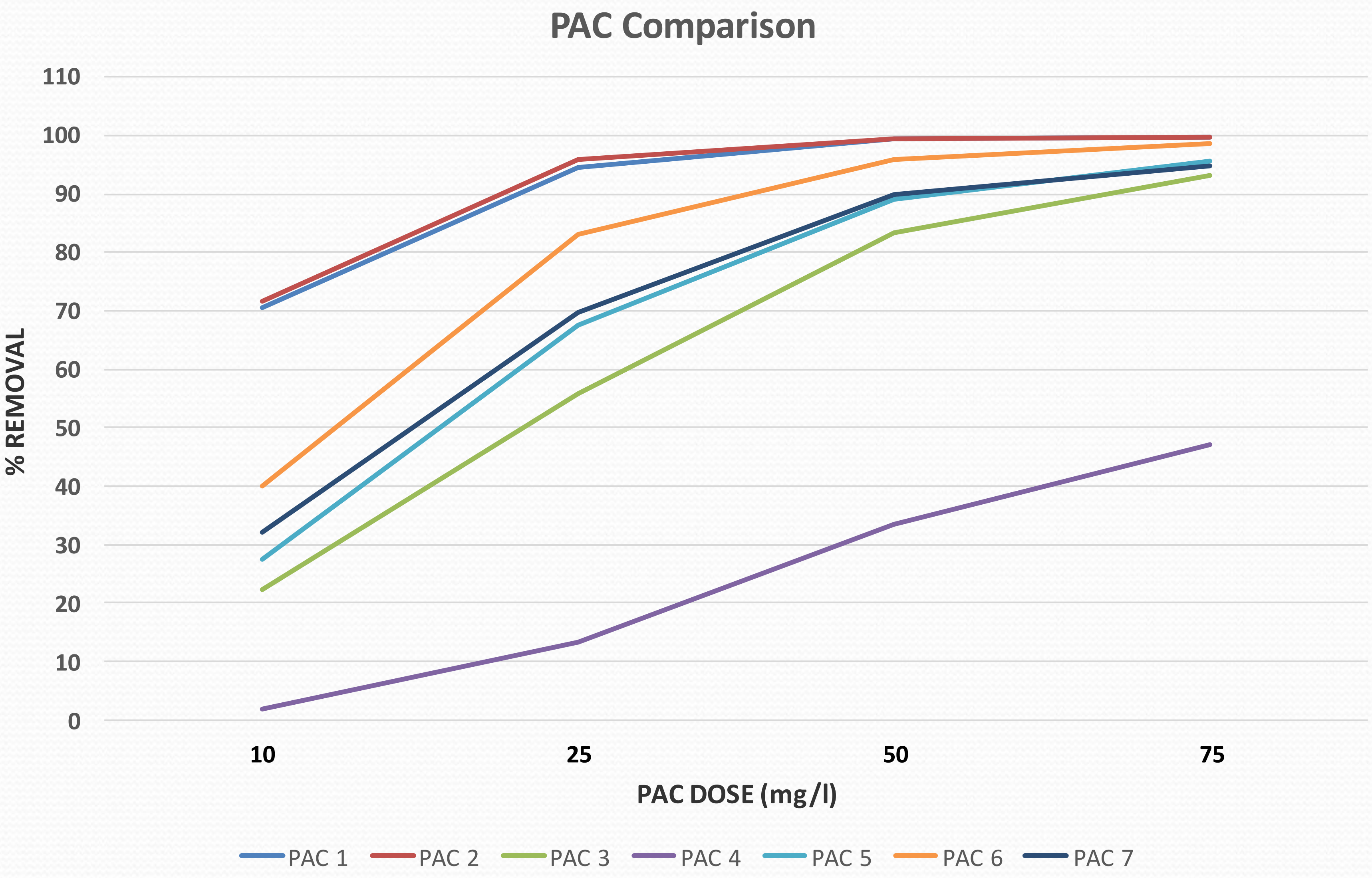
- Agriculture non-point sources
  - Animal manure
  - Fertilizers
- Atwater Treatment Plant in Portage County
- Five Wastewater Utilities have OEPA approved fields for sludge application
  - Rules for application have changed recently
  - Require more monitoring of any runoff
  - Liquid vs. solid applications

Two Pronged Attack

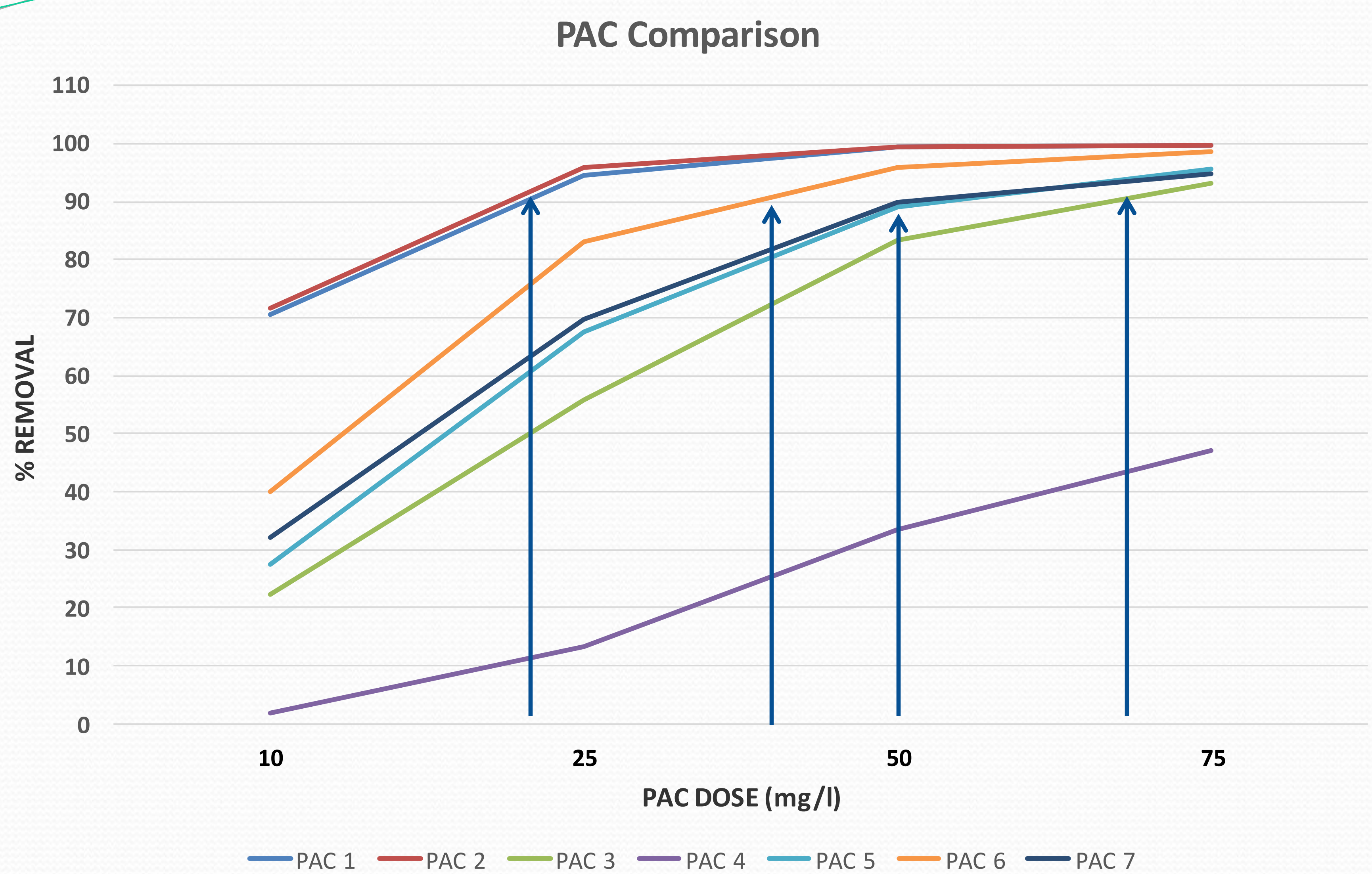
- Finding and eliminating nutrient contamination in watershed
- Treatment in Plant – Multi-barrier
  - ClO_2 oxidation – releases T&O and toxins
  - Coagulation – removes cells
  - PAC
  - Filter GAC biologically active mid June-mid October
  - UV Advanced Oxidation Process
  - CT - 20 times or more than needed in clearwell

Treatment Tools for Taste and Odor Removal

- Powdered Activated Carbon
  - $247,000 January 2008-June 2009
  - $170,000 Winter of 2009-2010
  - $280,000 Winter of 2010-2011
  - $245,000 Winter of 2011-2012
  - $300,428 Spring 2012 – Winter 2013
- Granulated Activated Carbon
  - Not biologically active when water is cold
  - Adsorptive removal of MIB limited to first year
  - $250,000 to reactivate GAC in all 8 filters
- UV Advanced Oxidation using H_2O_2



PAC Comparison
110
100
90
80
70
60
50
40
30
20
10
0
% REMOVAL
10
25
50
75
PAC DOSE (mg/l)
PAC 1
PAC 2
PAC 3
PAC 4
PAC 5
PAC 6
PAC 7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PAC DOSE (mg/l)
PAC 1
PAC 2
PAC 3
PAC 4
PAC 5
PAC 6
PAC 7

Treatment Tools for Taste and Odor Removal

- UV Advanced Oxidation using H_2O_2
  - 2-30" TrojanUV Swift™ECT reactors
    - Medium pressure lamps
  - Installed October 2014
  - Tests in Fall 2014
  - Running 2015

TASTE & ODOR INSTALLATION - CORNWALL, ONTARIO

UV-OXIDATION – OPERATIONAL PHILOSOPHY

More UV is required for T&O control than for disinfection

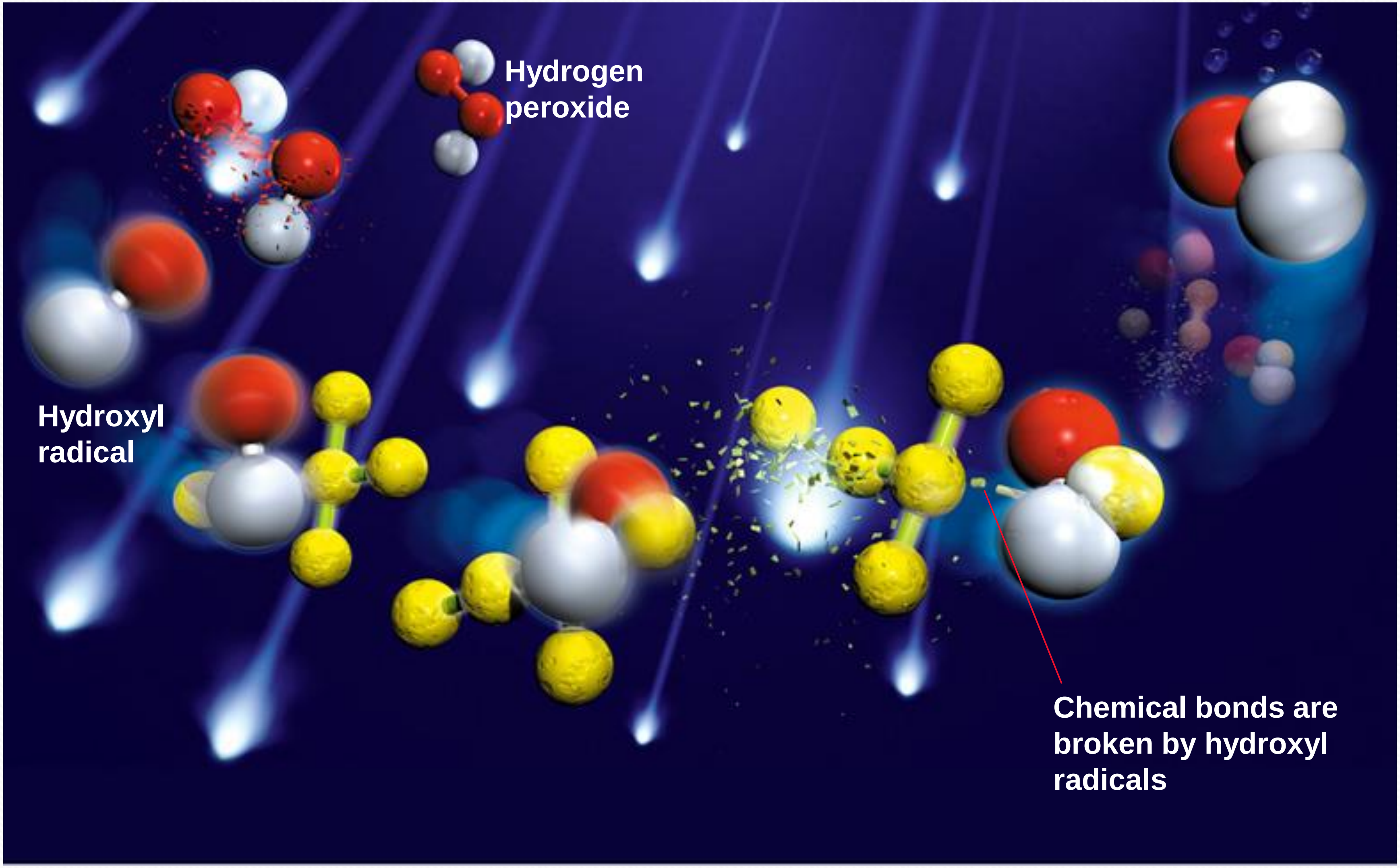
For T&O events, more UV lamps are turned on and H_2O_2 is injected upstream

UV system located post-filtration

Treatment occurs nearly instantaneously inside the reactor

$$H_2O_2 + \text{high energy UV light} \longrightarrow 2OH\bullet$$

UV-OXIDATION



Total Cost for T&O

PAC (average/yr)	$250,000/yr
GAC	$ 83,000/yr
Sampling, shipping	$ 56,000/yr
Algal ID	$ 6,240/yr
Sludge removal	$ 5,000/yr
Safety equipment	$ 3,500/yr
Operator time($32,000/yr)	

Total cost/year $403,740 (20%)

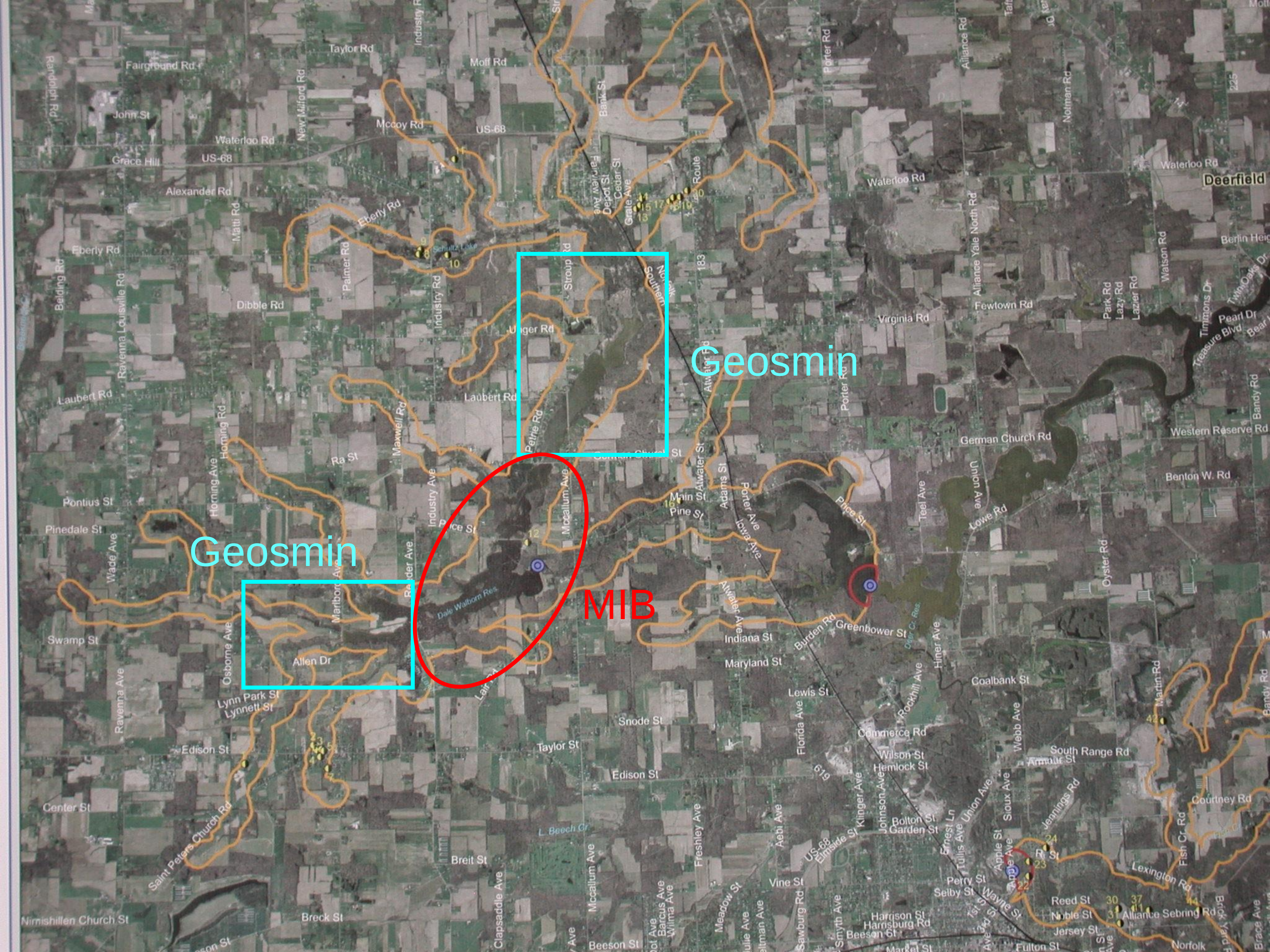
Operating Budget $2,000,000/yr

Alliance Water Treatment

- Four years with very little presence
  - Microcystin at 0.2 µg/L (ppb) occasionally in raw water.
    - Below Detectable Limit in finished water
    - Health Advisory Levels set in 2015 by U.S. EPA
    - "DO NOT DRINK"
      - 0.3 µg/L (ppb) children 6 yr or younger
      - 1.6 µg/L (ppb) older than 6 yr
  - Anatoxin-a at one sampling
  - Saxitoxin at one sampling
  - Cylindrospermopsin not found
  - Routine sampling for all four toxins
    - ELISA Analysis 2 times/year at cost of $3,000
      - 2010, 2011, 2012, 2013

Alliance Water Treatment

- 2014 Increased sampling frequency
  - All four toxins at four locations $1,600
    - Saxitoxin - one location just above the MDL
    - Microcystin at 150ug/L (ppb) in Walborn
  - Microcystin - multiple samplings $4,625
  - PAC at 15 mg/L $45,000
- 2015 Sampled weekly throughout summer
  - Microcystin only
  - $250/wk for test reagents


Geosmin
Geosmin
MIB
Deerfield
Dale Walborn Res
Deer Cr. Res.
L. Beech Cr

Indirect Costs to the Alliance Utility

- 64 years since first reservoir was built
- Image or reputation
  - "Their water is terrible."
- Several Taste & Odor events
  - 5 of the last 7 years
- Complaint calls

Cost of Treatment Tools for Taste and Odor Removal

- Powdered Activated Carbon
  - $247,000 January 2008-June 2009
  - $170,000 Winter of 2009-2010
  - $280,000 Winter of 2010-2011
  - $245,000 Winter of 2011-2012
  - $300,428 Spring 2012 – Winter 2013
- Granulated Activated Carbon
  - Not biologically active when water is cold
  - Adsorptive removal of MIB limited to first year
  - $250,000/3 yrs to reactivate GAC in all 8 filters
- UV Advanced Oxidation using H_2O
  - $2.2 million
  - Cutting edge technology – currently ~12 in U.S.

Alliance Treatment Costs for Taste and Odor Removal

- Granulated Activated Carbon
  - Not biologically active when water is cold
  - Adsorptive removal of MIB limited to first year
  - $250,000 to reactivate GAC in all 8 filters/3 yrs
    - $6,944/mo.

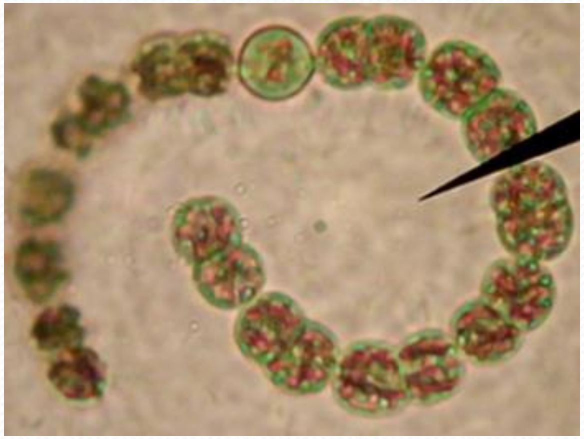
- UV Advanced Oxidation using H_2O_2
  - Construction costs - $2.2 million Project
  - Power and chemical costs vary

Sampling Costs

- MIB and Geosmin samples GC-MS
  - $200 per sample
  - Shipping 4-8 sample locations
  - $110/week overnight to Florida (**$3,000 +/yr**)
  - Timely results are important
  - 1,375 samples x $200 =$275,000 /6 yrs
    - **~$46,000/yr**
  - 4.5 hrs/wk sampling time x $30/hr = $135/wk
  - $135/wk x 52 wk/yr = **~$7,000/yr**
  - **Total $56,000/yr**

Algal Identification

- Weekly species ID and enumeration
- Collection 1hr x 2 locations/week
- Scope time 1hr x 2 locations/week
- Cost for ID/wk:4 hr/wk x $30/hr = $120/wk
- **Total $6,240 /yr**



PAC Additional Costs

- Additional sludge created by addition of PAC
  - ~$5,000/yr
- Quarter of operators shift spent loading PAC into the equipment = $180/day
- Safety equipment - masks, gloves and Tyvek Suits
  - $3,500 /yr
- Employee injury
  - 6 weeks time off after hand surgery
  - Hospital costs $24,000

Cyanotoxins

- Most common in Ohio
  - Microcystin - >100 congeners - LR
  - Anatoxin-a
  - Cylindrospermopsin
  - Saxitoxin
- Others
  - Nodularins
  - Lyngbyatoxin
  - BMAA
  - Lipopolysaccharides


Walborn Dam


Deer Creek Spillway