Predicting Taste and Odor Events: Is it Possible?

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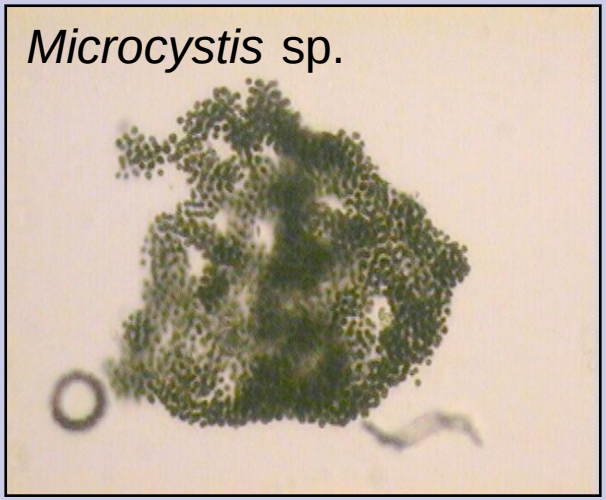
What is a taste and odor event?

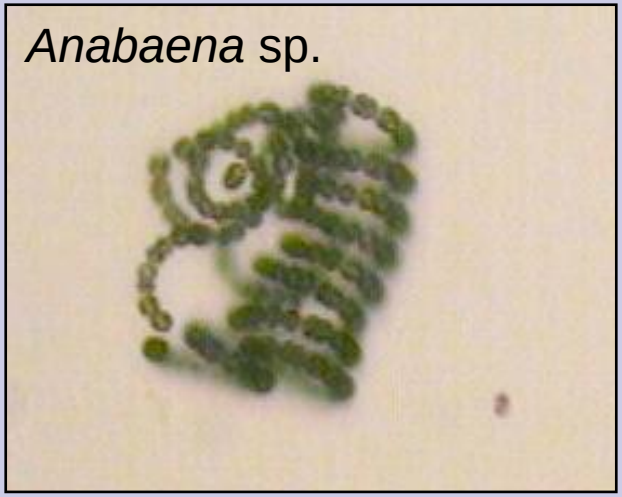
- Occurrence of organic compounds
  - Geosmin – “earth smell”
  - MIB (2-methylisoborneol)
- Low human detection limits
  - >5-10 parts per trillion (ng/L)
- No known effects on human health
  - Perceived effect on drinking water quality can be high
- Expensive to measure!

What are the main producers of T&O compounds?

- **Blue green algae**
  - ***Anabaena* sp.**
  - ***Aphanizomen* sp.**
  - ***Microcystis* sp.**
  - ***Oscillatoria* sp.**
- **Actinomycetes**
  - **Much less is known about their impact in Kansas Reservoirs**

Common cyanobacteria in Kansas reservoirs





Cyanobacteria

- Additional water quality concerns affecting reservoir water quality
  - Algal toxins
  - Low dissolved oxygen
  - Surface scums

Notice
An algae bloom has made
this area potentially
unsafe for water contact.
Avoid direct contact with
visible surface scum.

Cheney Reservoir, photos provided by KDHE

Cheney Reservoir, photos provided by KDHE

Cheney Reservoir, photos provided by KDHE

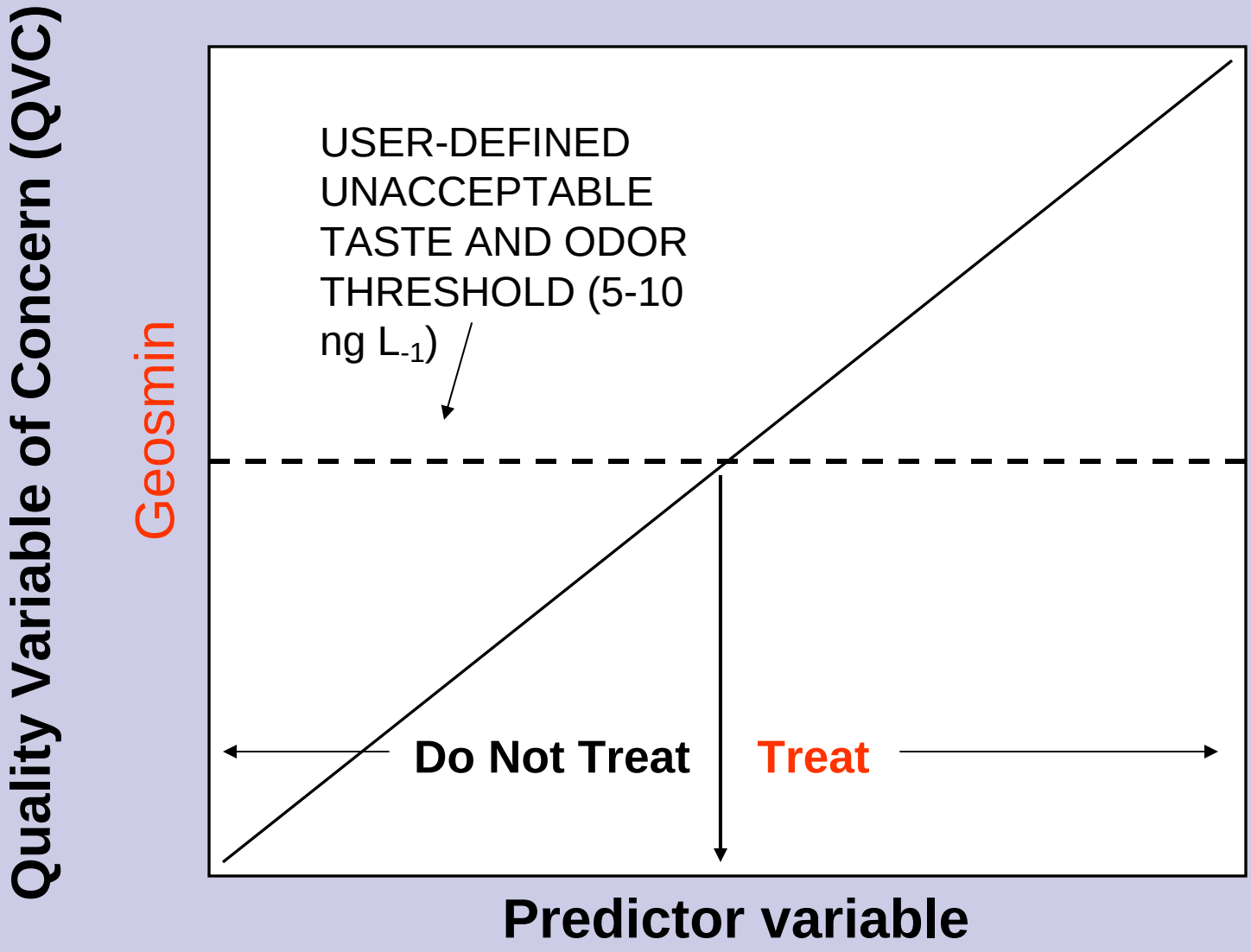
Early warning systems

- Short window of opportunity to detect and treat an event before complaints come in
- Can we use ecological and limnological principles to determine when T&O events are most likely to occur?
- How can these tools be implemented and used by water treatment personnel?

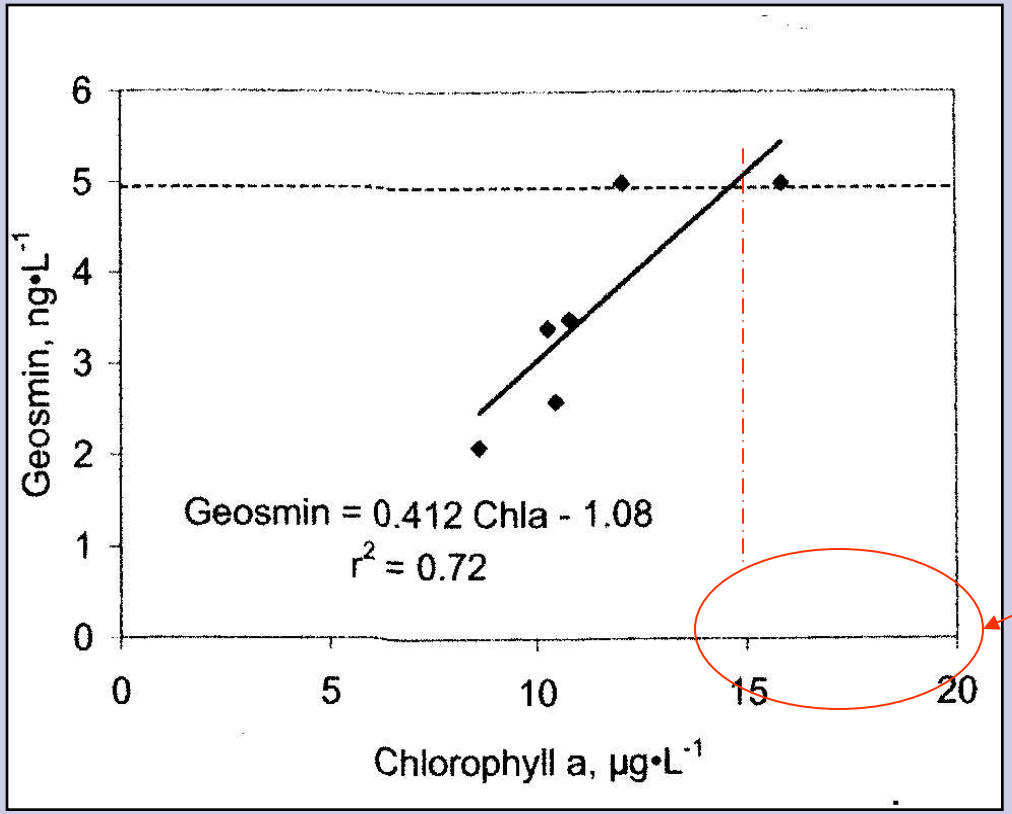
Why do cyanobacteria bloom?

- Factors affecting abundance
  - Temperature
  - Nutrient concentrations (nitrogen and phosphorus)
  - Water clarity
  - Reservoir mixing
- Can we use changes in these variables to predict blooms?

Predictive models



Example: **Chlorophyll *a* and geosmin in Cheney Reservoir**



Treat when Chl a levels exceed 15 ug/L

Data from Smith et al. 2002

Water quality model development

- Include variables that are relatively easy and cost effective to measure or collect
- “Universal model” for all reservoirs in the state?
- Models for individual reservoirs or groups of similar reservoirs?
- Models do not necessarily imply causation

Reservoir sampling

- Sampled five reservoirs of various sizes:

  Big Hill, Cheney, Clinton, Gardner, and Marion

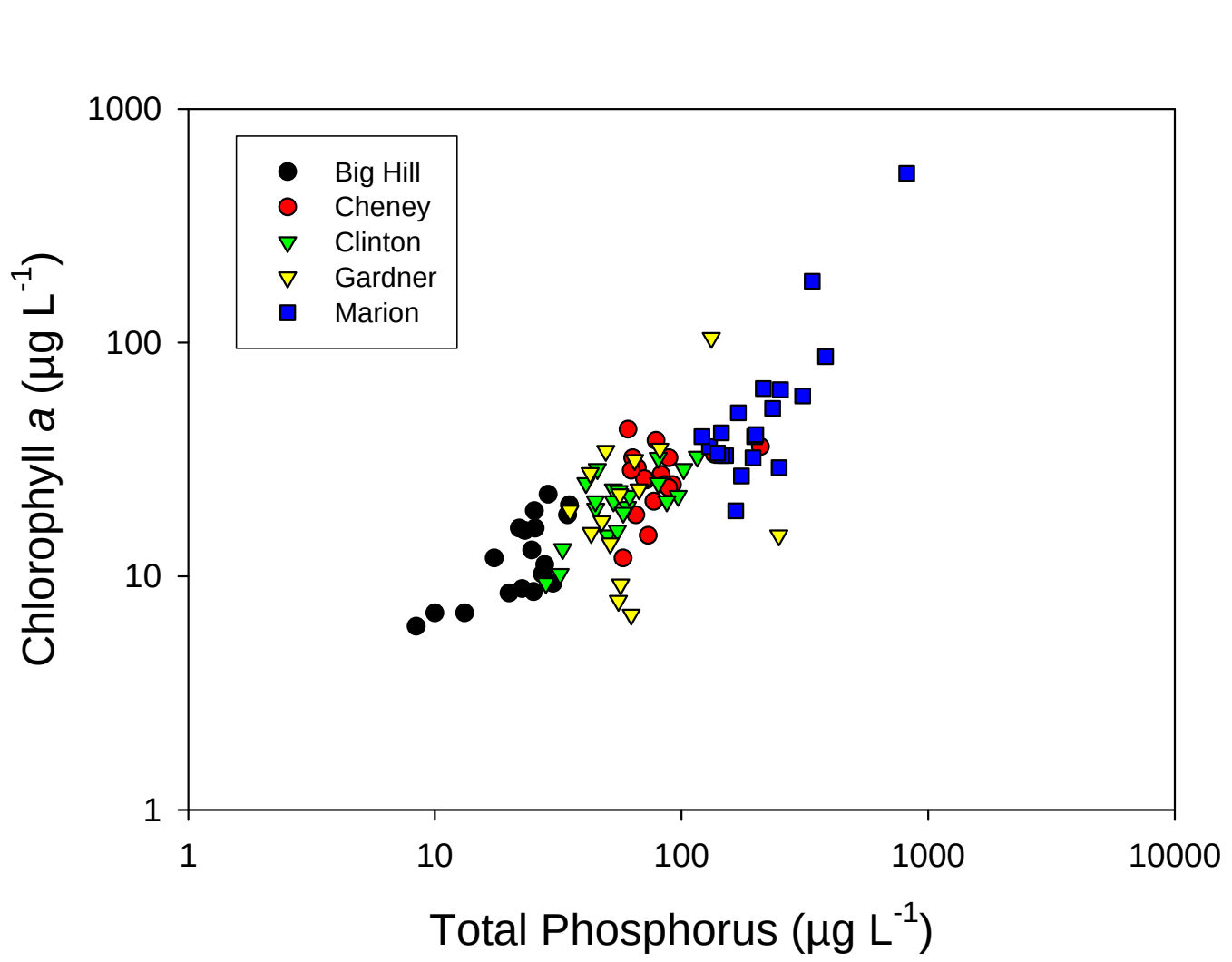
- Reservoirs sampled through the summer, and in some instances into the fall and winter

- Several reservoir locations were sampled to account for spatial variation in water quality conditions

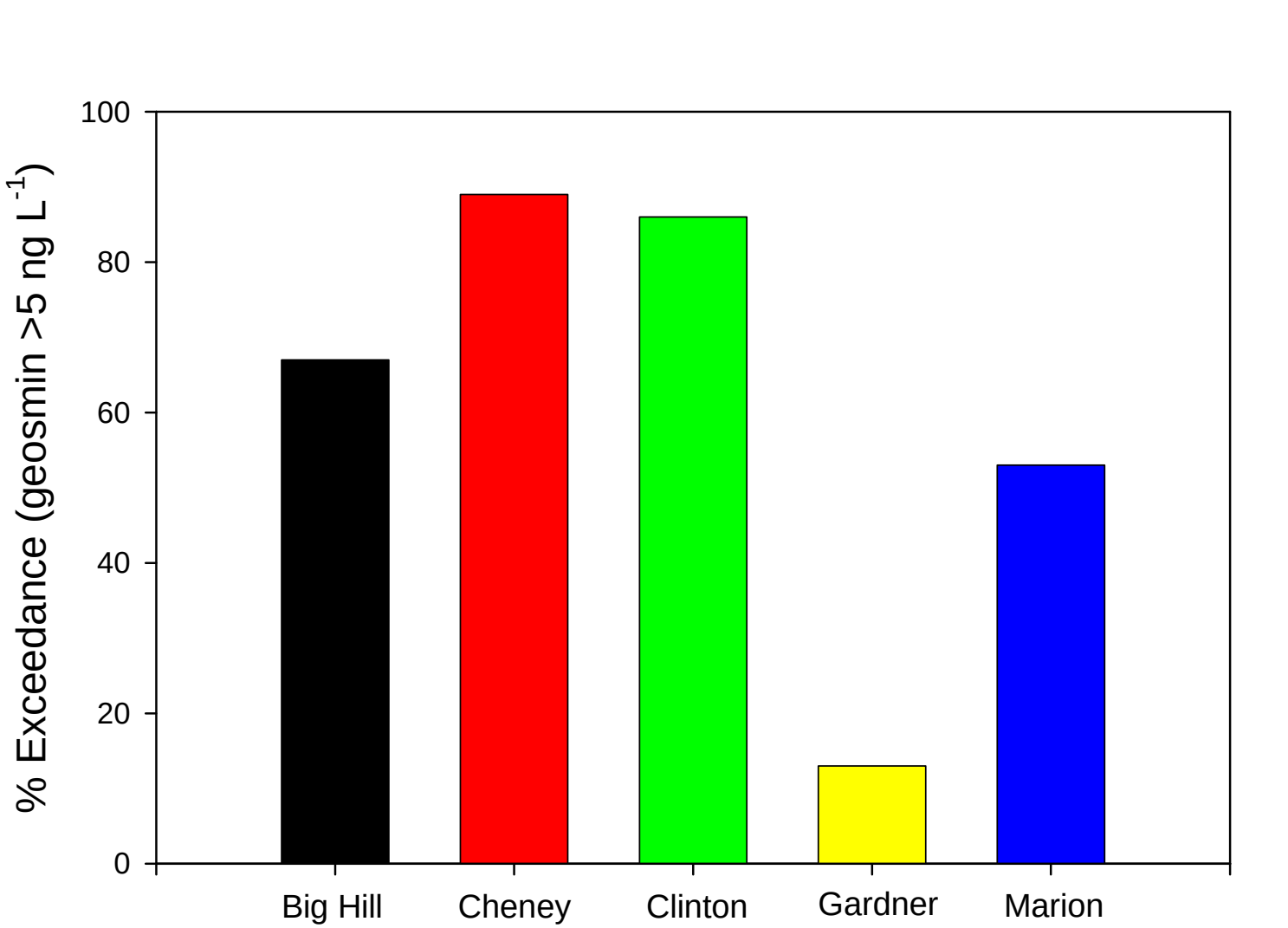
Water quality variables

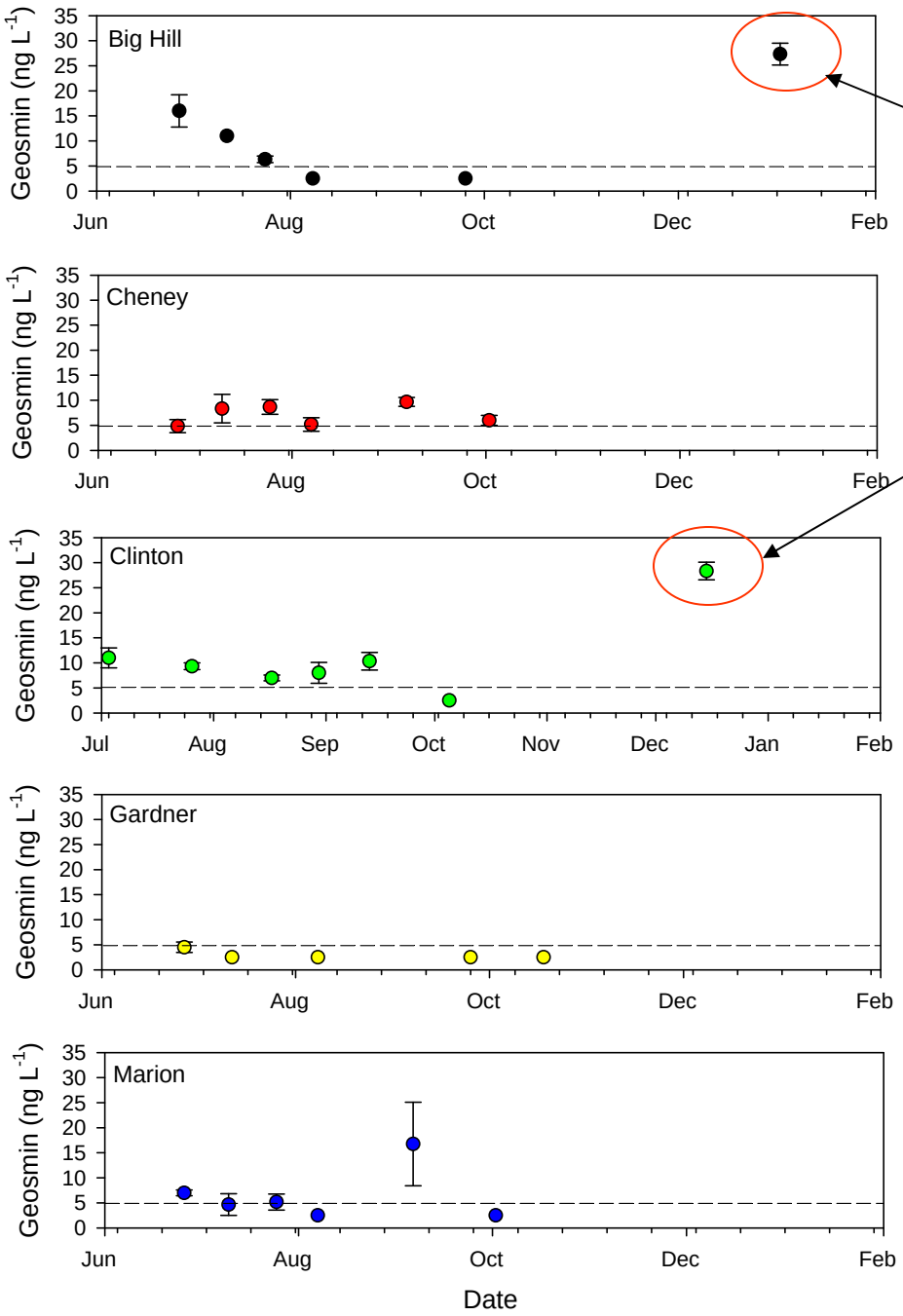
- Geosmin
- Dissolved Nutrients (nitrogen and phosphorus)
- Total Nutrients (nitrogen and phosphorus)
- Algal biomass (chlorophyll *a* and phaeophytin, relative fluorescence, cyanobacterial biomass)
- Water Temperature
- pH
- Specific Conductance
- Dissolved Oxygen
- Turbidity
- Secchi Disk depth

Relationships between TP and chlorophyll *a* in 5 study reservoirs



Percentage of geosmin samples exceeding human detection in 5 reservoirs

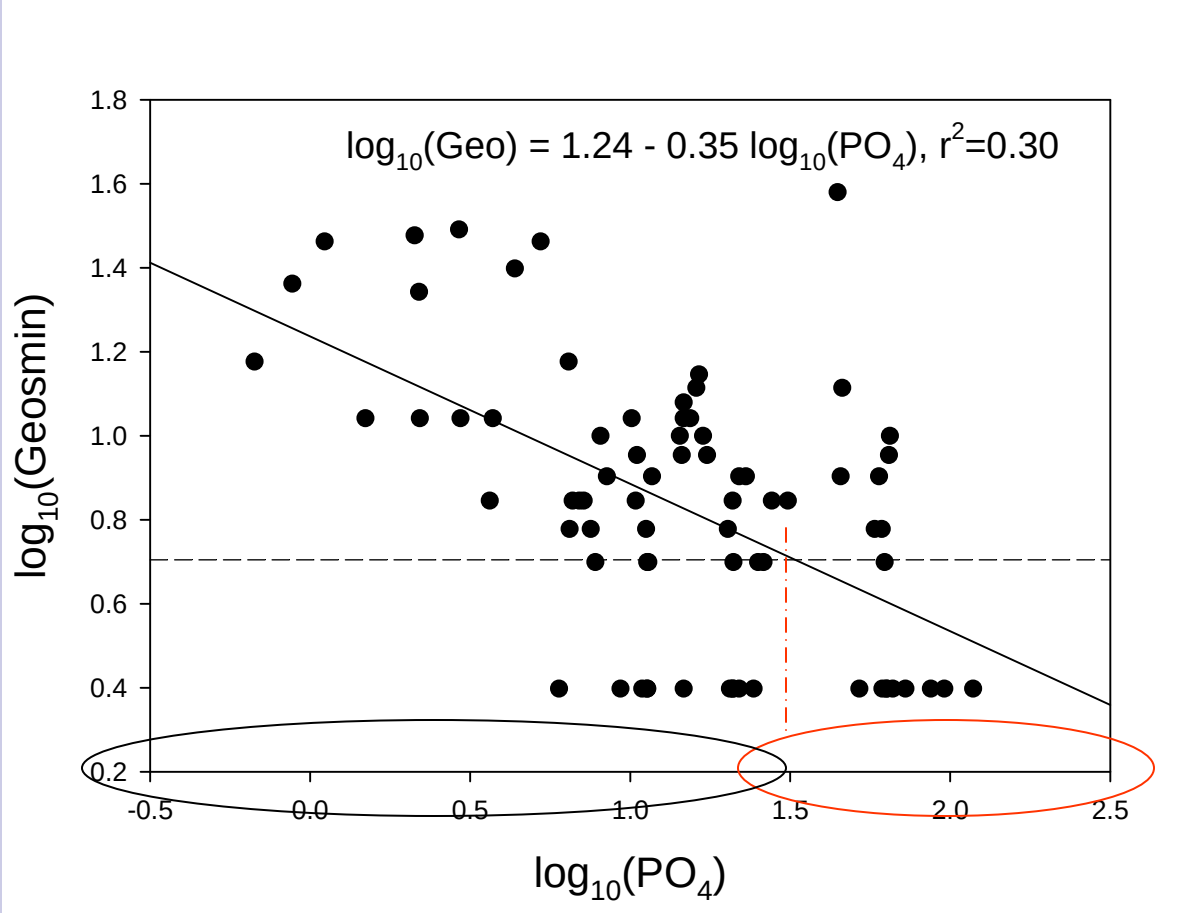




Winter T&O events

Temporal Patterns in Geosmin Concentrations

Can we develop a universal model to predict T&O events?



A single variable, PO_4, explained 30% of the variation in geosmin concentration

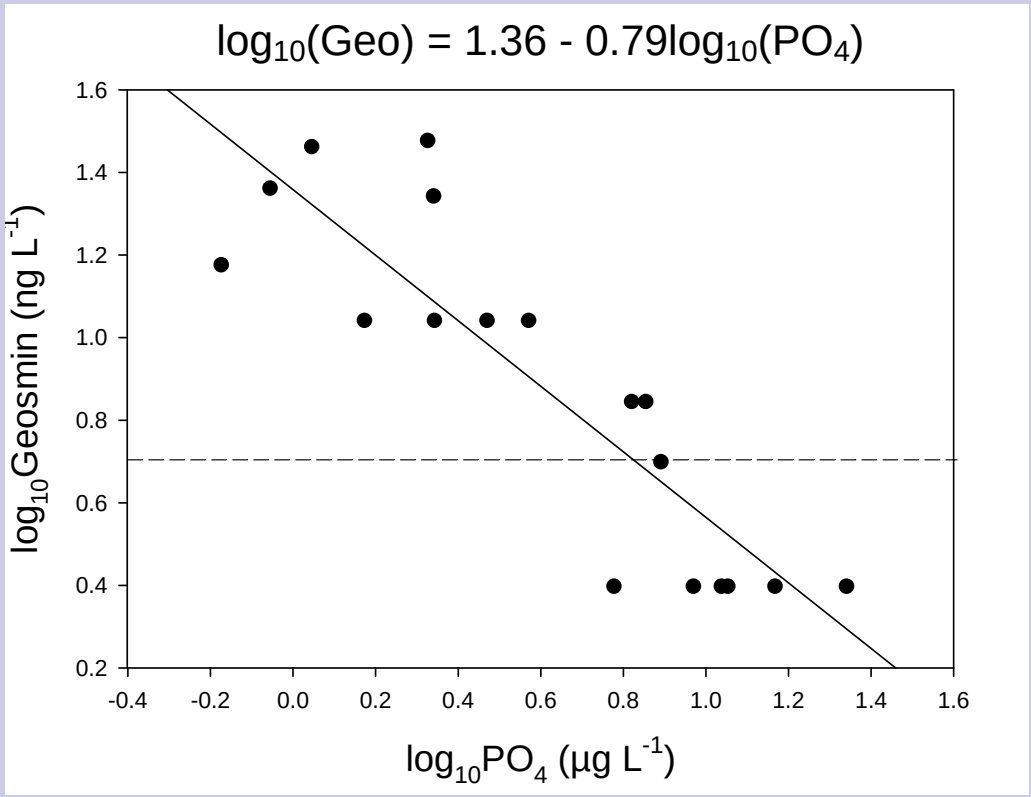
Treat when PO_4 is less than 1.5

Do not treat when PO_4 is greater than 1.5

Universal models

- Could be used to predict geosmin, but may not be accurate enough to make treatment decisions
- What about individual reservoir models?

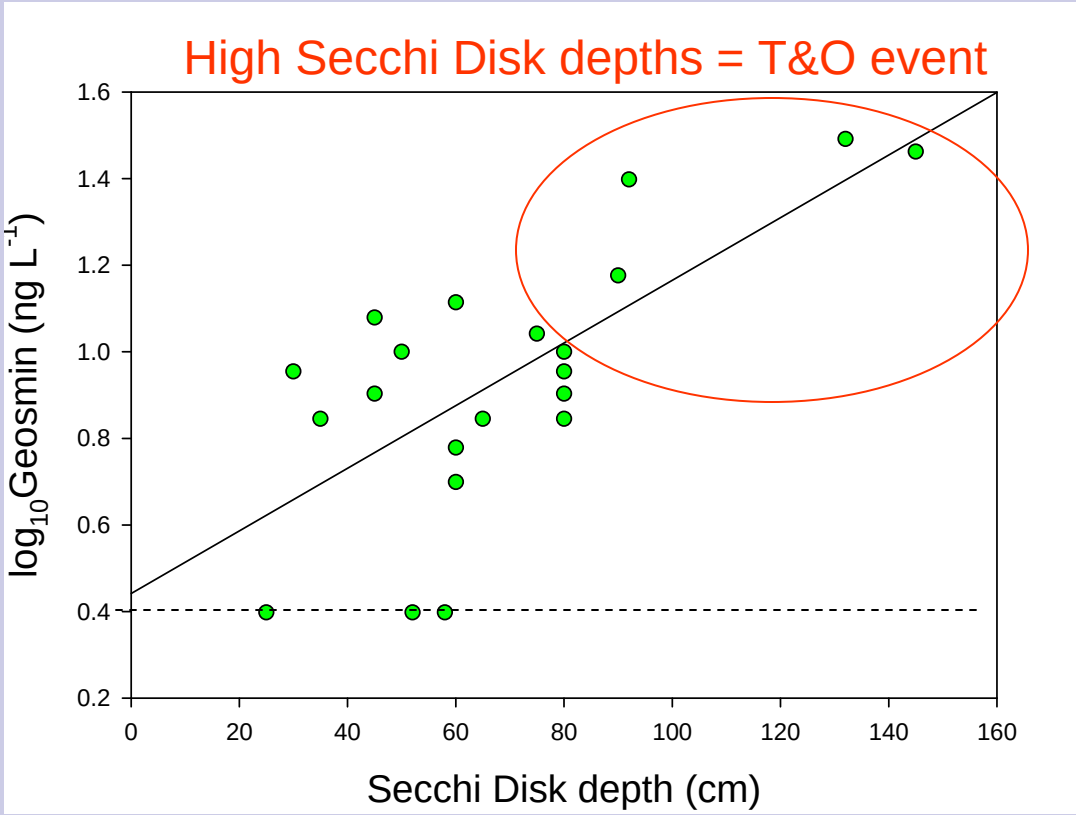
Big Hill Reservoir



- **PO_4 explained 77 percent of the variation in geosmin.**
- **Individual reservoir model has much greater predictive ability!**

Clinton Reservoir

- **Secchi disk depth explained 50% of the variation in geosmin**



Cheney Reservoir

- **We were unable to develop a significant model for Cheney Reservoir**
- **However, both the USGS (2006) and Smith *et al*. (2002) were able to develop models**
- **These results indicate that the factors affecting T&O events vary spatially even within reservoirs**
  - **Need multiple years of data to develop accurate models**

Predictive geosmin models

- Measure predictor variable (e.g. chlorophyll *a*)
- Insert value into spreadsheet formulas
- Obtain estimate of geosmin
- Make treatment decisions

Microsoft Excel - tandomodels2007(2).xls

PRELIMINARY GEOSMIN PREDICTION MODELS

Predicting Taste and Odor Events in Kansas Reservoirs – Phase 1
(Dzialowski et al., 2007)
Prepared for the Kansas Water Office
in fulfillment of KWO Contract No. 06-121

Preliminary models were developed for the Kansas Water Office to estimate Geosmin in five reservoirs in Kansas: Big Hill Reservoir, Cheney Reservoir, Marion Lake, Clinton Lake, and Gardner Lake. Each worksheet in this file corresponds to one of these reservoirs.

Models require the input of measured parameters. These parameters must be measured accurately and recorded in the proper units (as specified in the ***Model Inputs*** section of each worksheet). After entering the observed or measured values for these parameters, the predicted values for geosmin will appear in the ***Model Results*** section of the worksheet. The ***Model Design*** section of each sheet describes which models (Model I, Model II, Model III, etc.) use which parameters (Orthophosphate, Water Temperature, Total Phosphorus, etc.) and whether the model is Universal (i.e., applies to all 5 reservoirs) or specific to a particular reservoir (e.g., Big Hill specific). The two universal models (Models I and II) were developed using all available data from the study period, and therefore represent the most regionally comprehensive predictions. These universal models are also included on every sheet for comparison with reservoir-specific predictions. The R^2 values shown are the proportions of variance explained by each model. The Model Design section also defines the model factors and their units, the model equations, and the specific model coefficients used for each equation.

Explanation | Big Hill | Cheney | Marion | Clinton | Gardner

CLINTON LAKE

Geosmin Model - August 2007

Model Inputs

	Observed Value
Orthophosphate, PO_4 (µg/L)	13.7
Temperature (deg. C)	22.7
Total Phosphate, TP (µg/L)	61
Secchi Disk Depth (cm)	69
Total Nitrogen, TN (mg/L)	0.655
Cyanobacterial Biovolume (%)	50

Model Results

	Model I	Model II	Model III	Model IV	Model V
log (Geosmin)	0.818046	0.808529	0.926	0.9427	1.079663
Predicted Geosmin (ng/L)	**6.6**	**6.4**	**8.4**	**8.8**	**12.0**
Overall Model R^2	0.36	0.53	0.50	0.43	0.82

Model Design

Model Extents

Model	Extent	R^2
I	Universal Model	0.36
II	Universal Model	0.53
III	Clinton specific	0.50
IV	Clinton specific	0.43
V	Clinton specific	0.82

Model Equations

Model	Model Equation
I	log(Geosmin) = a + b log(PO_4)
II	log(Geosmin) = a + b log(PO_4) + c log(TEMP) + d log(TP)
III	log(Geosmin) = a + b (SECC)
IV	log(Geosmin) = a + b (PO_4)
V	log(Geosmin) = a + b (TN) + c log(TEMP) + d (%CYAN)

Model Input Factors

Factor	Measured Compound
PO_4	Orthophosphate (µg/L)
TEMP	Temperature (deg. C)
TP	Total Phosphate (µg/L)
SECC	Secchi Disk Depth (cm)
TN	Total Nitrogen, TN (mg/L)
%CYAN	Cyanobacterial Biovolume (%)

Model Coefficients

Coefficient	Model I	Model II	Model III	Model IV	Model V
a	1.25	1.45	0.443	1.34	1.38
b	-0.38	-0.61	0.007	-0.029	1.78
c		-0.62			-1.45
d		0.50			0.01

Water Quality Modeling: Conclusions

- **Significant models could be developed to estimate geosmin concentrations for most reservoirs**
- **Individual reservoir models appear to be better than universal model for most reservoirs**
- **T&O events were common in reservoirs regardless of <u>nutrient concentrations</u> and <u>throughout the year</u>**

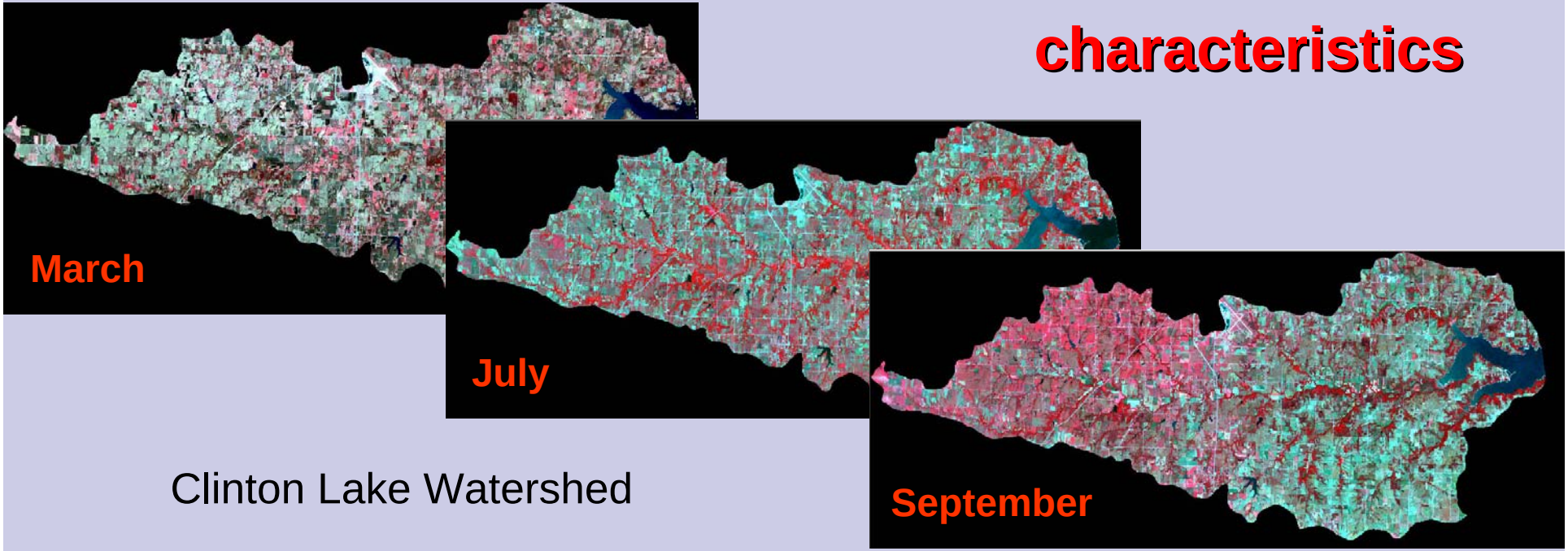
Future Water Quality Model Development

- Include additional variables in the models
- Include water quality data from other investigators
- Continue to collect data to improve and refine models
- Test the accuracy of models in each reservoir and additional reservoirs

Can we use remotely sensed data to predict T&O events?

- **Use <u>satellite imagery</u> to monitor the development of algal blooms and T&O events?**

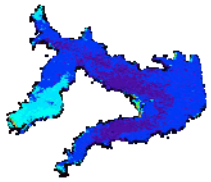
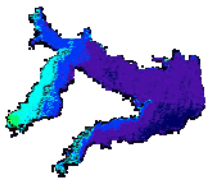
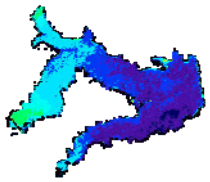
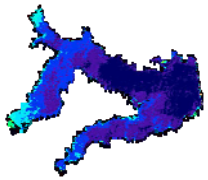
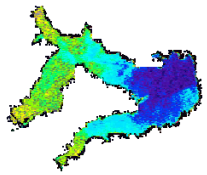
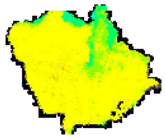
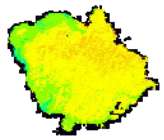
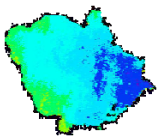
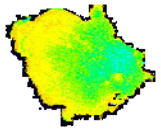
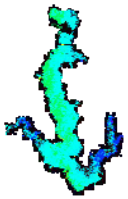
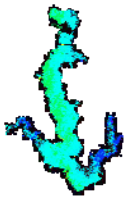
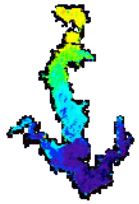
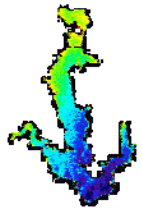
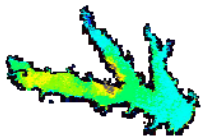
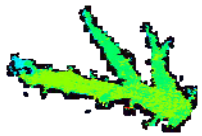
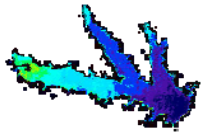
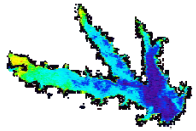
1. **Landscape characteristics**



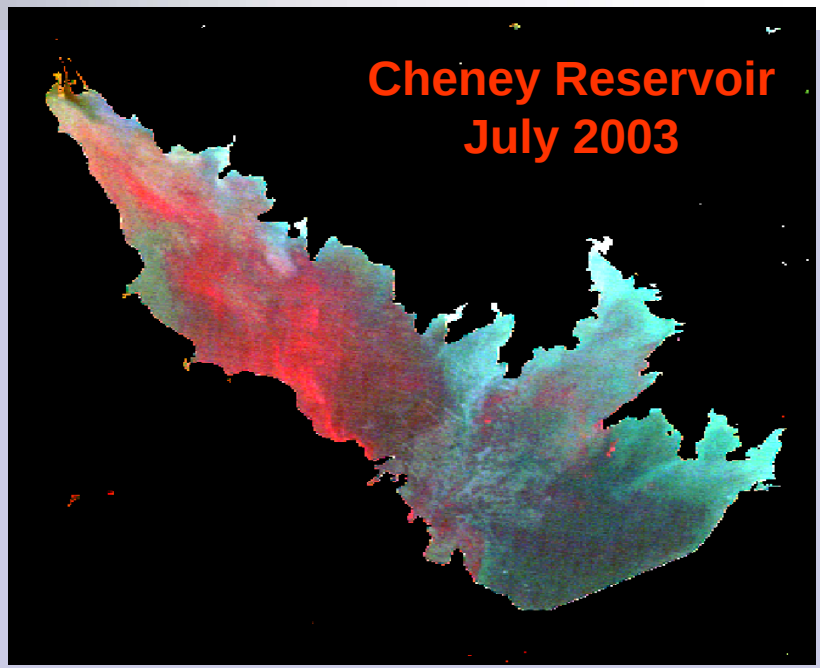
Clinton Lake Watershed

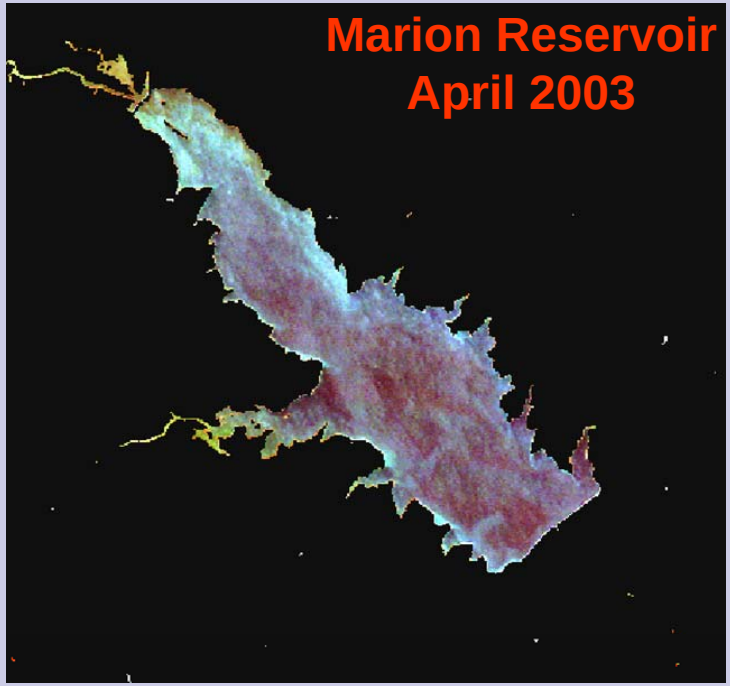
2. Monitor spatial and temporal patterns

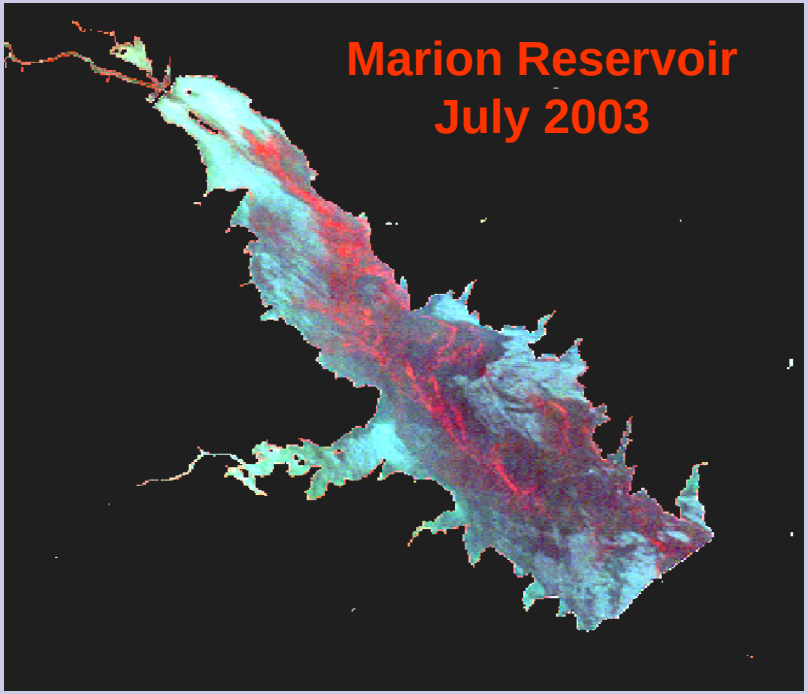
Example: Differences in turbidity concentrations shown by differences in satellite reflectance values

	1982	1987	1990	1994	2002
Clinton					
John Redmond					
Perry					
Pomona					

Red areas indicate high chlorophyll (blue-green algae) concentrations in the water.





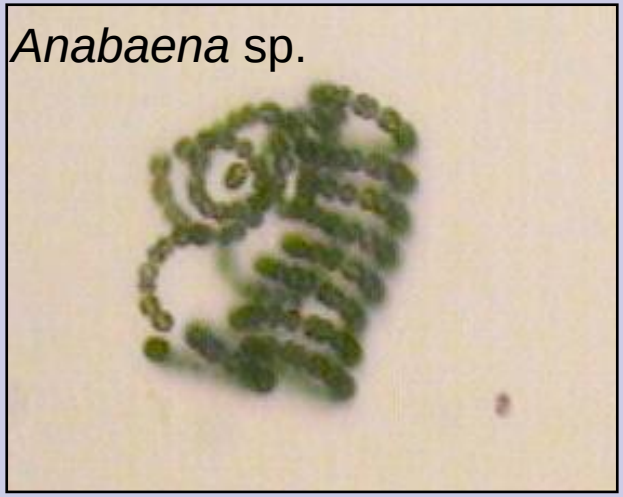


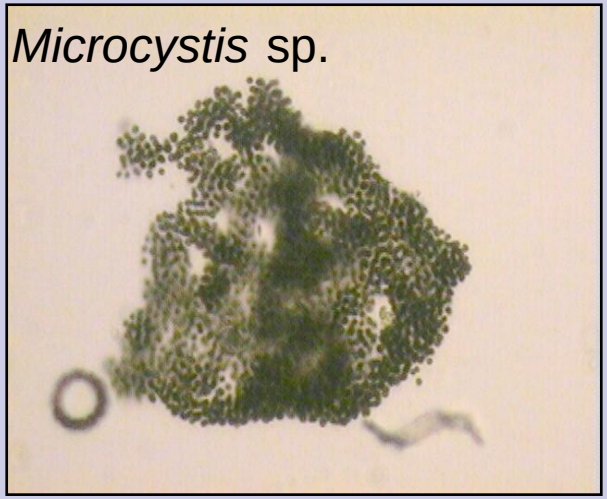
Implementation of Models

- Drinking Water T&O Workgroup created to help translate research findings into usable treatment strategies
  - Variable measurement must be rapid (0-5 days)
  - Data collection and analysis must be cost effective
  - Test the accuracy of the models
  - User friendly model structure and data input
  - Will the reservoir models work with raw water

Implementation (continued)

- **Algal identification training**
  - Workshops to help distinguish between main T & O producers





Implementation (continued)

- **Water quality kits**
  - **Provide "kits" that can be used to sample water that is then sent for immediate analysis of water quality conditions**
    - **Collect water quality sample**
    - **Overnight to laboratory for processing**
    - **Plug values into predictive models to get estimate of geosmin concentrations**

Implementation (continued)

- **Standardized T&O Event Form**
  - **Used by all treatment plants in the state**
  - **Better understand temporal and spatial dynamics**
  - **Compile associated water quality data from state and federal agencies**
  - **Determine how big a problem T&O events are in the state (number of plants affected, frequency of events, duration of events)**

Future Needs

- Documentation of T&O events
- More ecological and limnological data associated with T&O events
- Extent of the role of Actinomycetes
- Assessment of the relationships between remotely sensed watershed and reservoir conditions and measured WQ and T&O variables

In summary

After almost 100 years of data collection and analysis, it is clear that both the decay of plant matter as well as release of metabolites and storage products of living microbiota contribute to tastes and odors in water supplies (Sigworth, 1957).

“In that same 100 years we seem to have made only limited progress in predicting the when and where taste and odor events will occur but we need to make the research investment” (Huggins and Dzialowski, 2008).

Acknowledgements

- Drinking Water Taste and Odor Workgroup
  - USGS, KDHE, KBS, KGS, KU, USACE
  - Water managers and others
- Kansas Water Office
  - Tom Lowe, Deb Baker, Kerry Wedel, and Earl Lewis
- CPCB researchers
  - Jason Beury, Niang Choo Lim, Jerry deNoyelles, Debbie Baker

This presentation as well as other works on Taste and Odor can be found at www.cpcb.ku.edu under the heading Taste and Odor Workgroup.