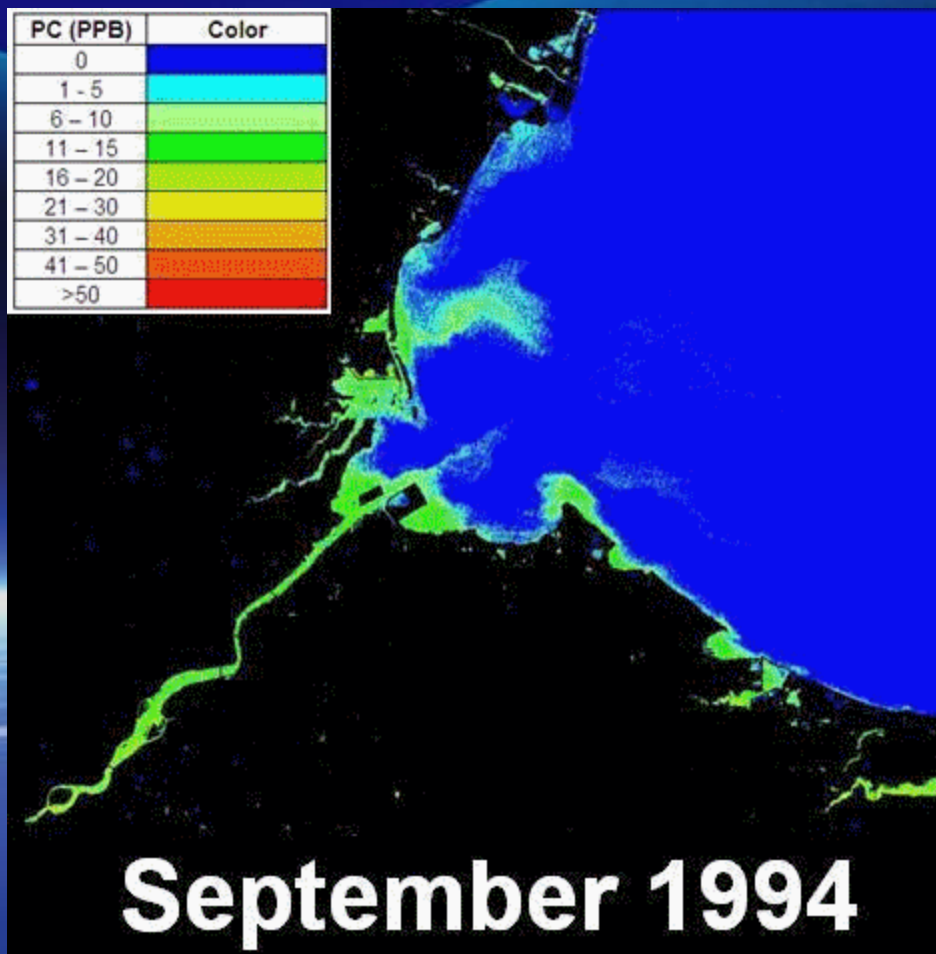


US EPA ARCHIVE DOCUMENT



PC (PPB)	Color
0	Blue
1 - 5	Cyan
6 - 10	Green
11 - 15	Yellow-Green
16 - 20	Yellow
21 - 30	Orange
31 - 40	Red-Orange
41 - 50	Red
>50	Dark Red



**September 1994**

# Blue Water Satellite

Using Satellite Imaging to Monitor the World's Land  
and Water Resources™

# What we do

- We use satellite images and patented image processing algorithms to monitor the world's land and water resources
- We provide you with images and data that allow you to
  - Determine land and water body quality
  - Spot problems areas
  - Develop cost effective remediation strategies (cost savings offset image costs)

# Some of our Customers

## Environmental Engineering



US Army Corps of Engineers

## Oil Companies



## Federal, State, Local Agencies, HOA's



## Power Companies

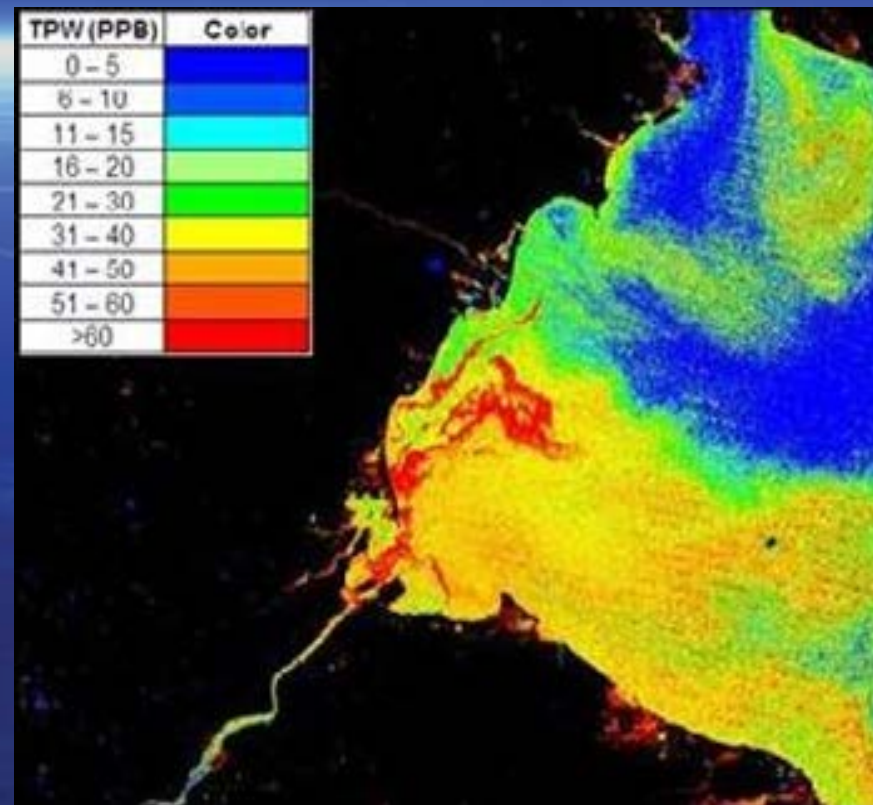




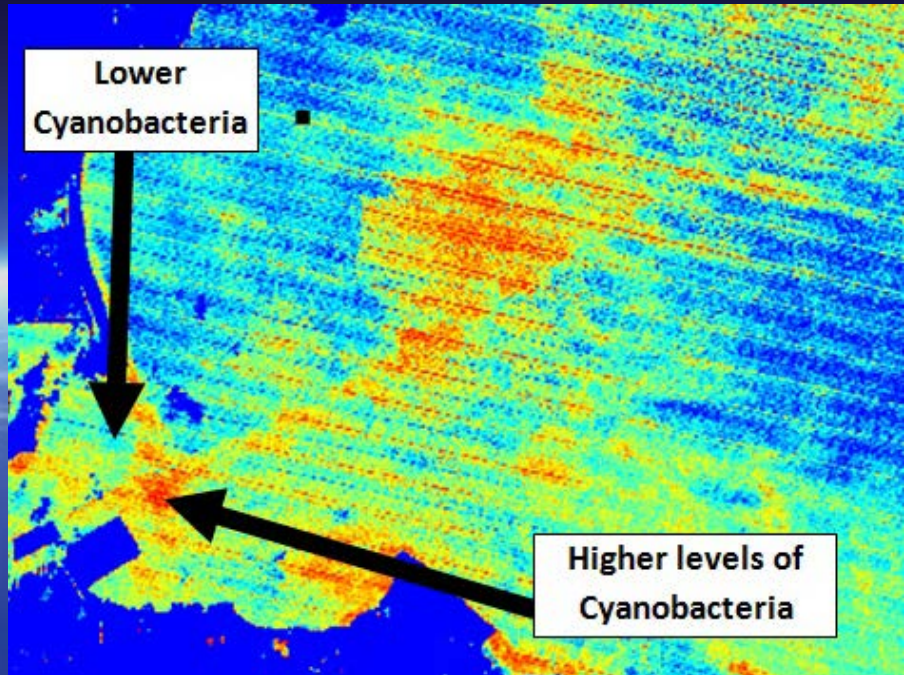
# Blue Water Satellite

Using Landsat and  
other satellites...

...to see where  
the problems are.



# You CAN'T tell this.....



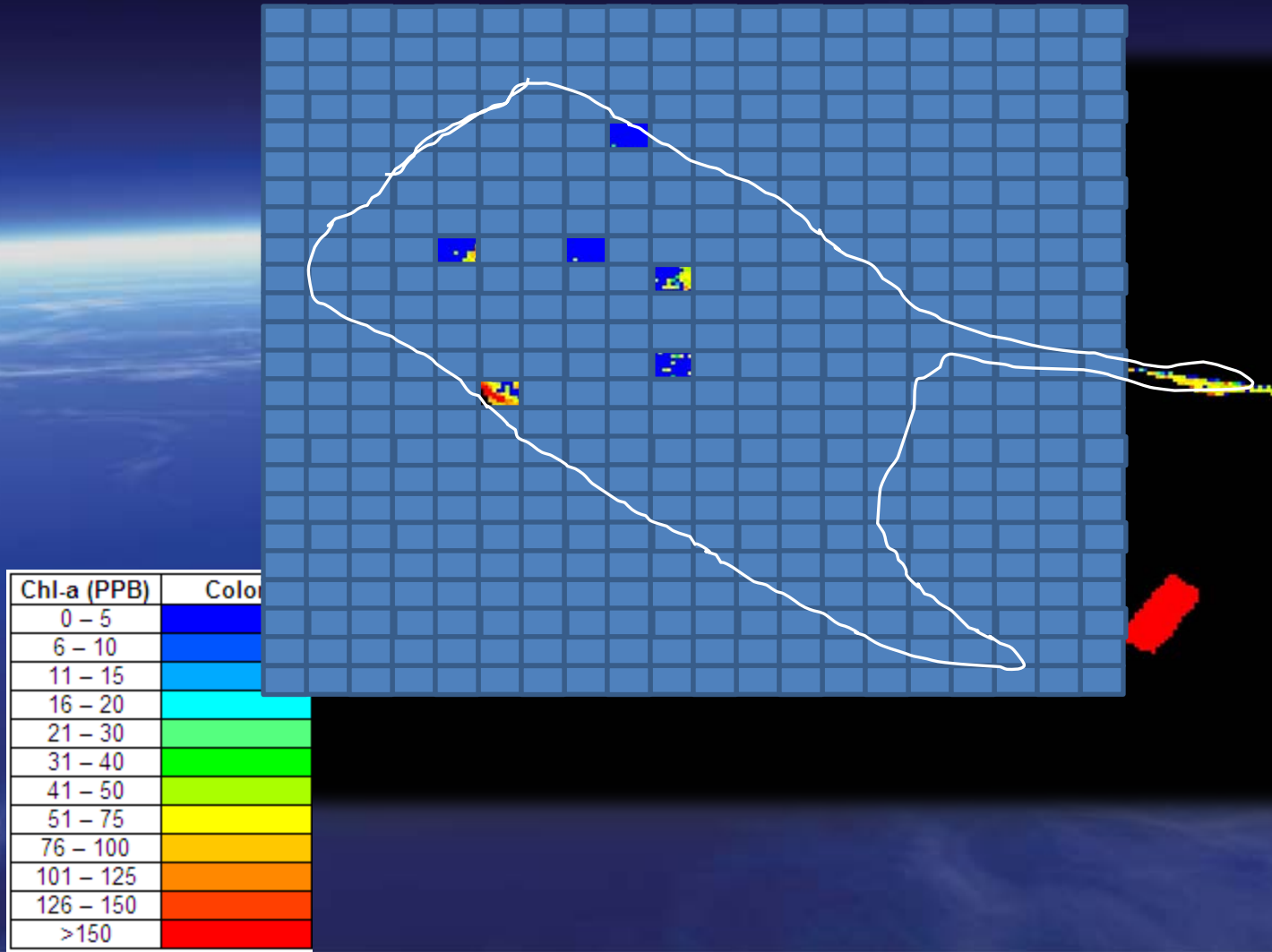
## From this.



To make intelligent decisions,

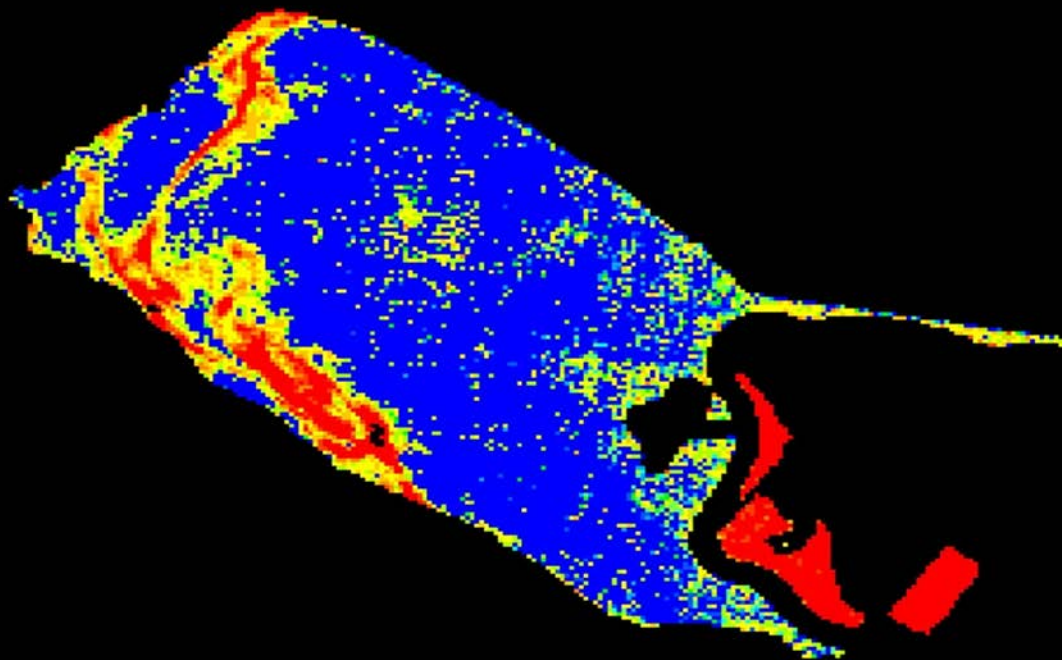
you need more data. BWS=5 samples/acre

# Lake Elsinore 10/01/1997 Chl-a Scan





# Lake Elsinore 10/01/1997 Chl-a Scan



Chl-a (PPB)	Color
0 - 5	Dark Blue
6 - 10	Blue
11 - 15	Light Blue
16 - 20	Cyan
21 - 30	Light Green
31 - 40	Green
41 - 50	Yellow-Green
51 - 75	Yellow
76 - 100	Orange-Yellow
101 - 125	Orange
126 - 150	Red-Orange
>150	Red

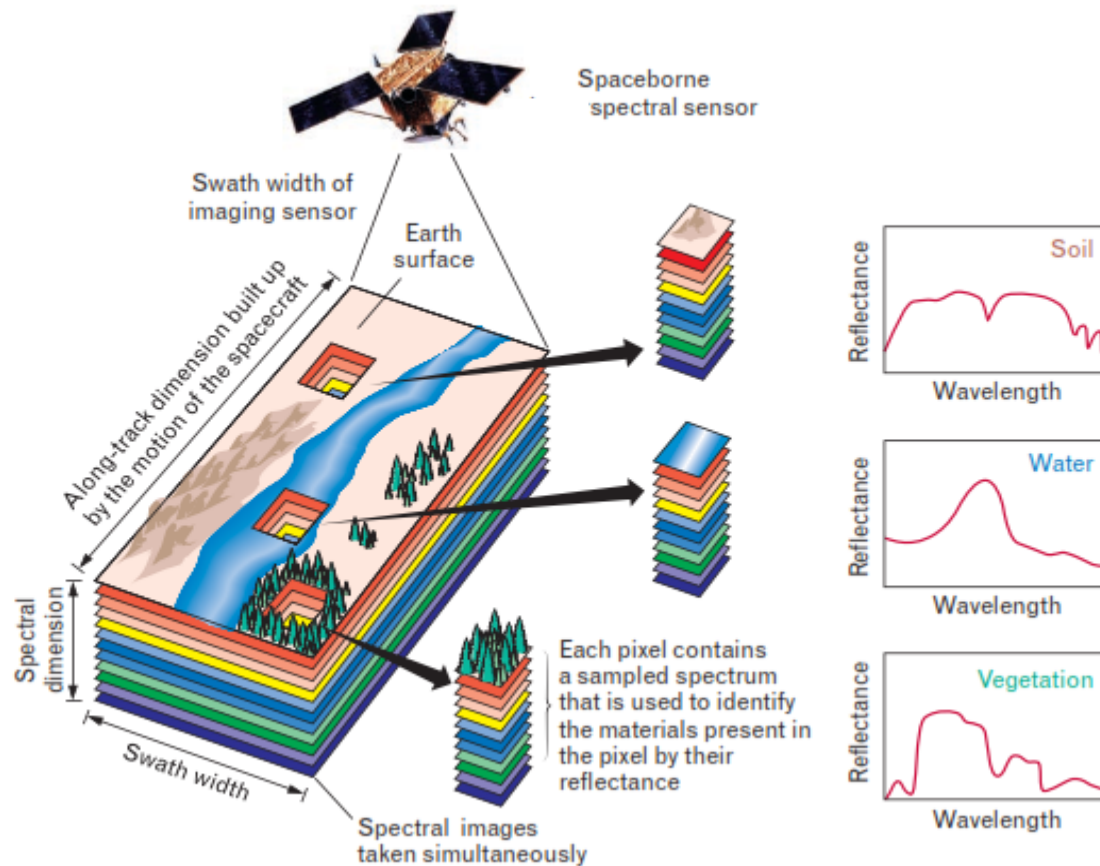


# Most Water Bodies are not Homogeneous!

Station	Station	Mean	Mean
		Chl a	PC
ST 196	1	187.825	143.5
ST 197	2	371.225	309.225
ST 198	3	122.675	137.625
ST 199	4	616.775	568.525
ST 200	5	106.075	108.975
ST 201	6	65.775	60.625
ST 202	7	42.375	33.2
ST 203	8	51.65	39.7
ST 204	9	52.725	44.225
ST 205	10	32.675	23.1
ST 206	11	53.975	57.05
ST 207	12	52.375	45.05
ST 208	13	35.175	30.45
ST 209	14	30.175	23.6
ST 210	15	28.425	20.675
ST 606	16	26.75	23.55
ST 607	17	31.975	33.7
ST 608	18	33.2	37.275
ST 609	19	71.575	49.175
ST 610	20	143.125	69.55

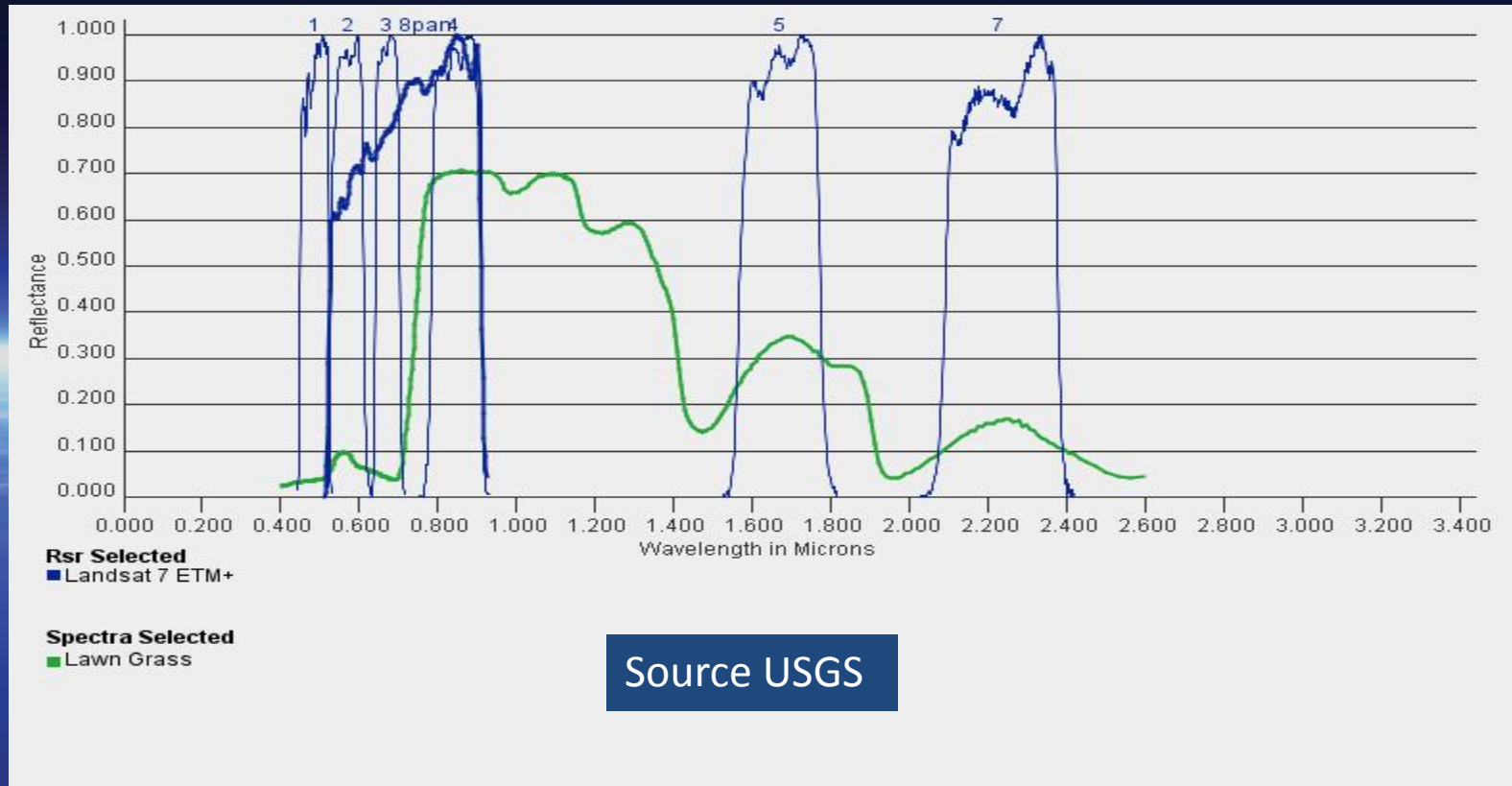
All data from EPA method certified labs in ppb

# How it works



Many chemical and biological constituents produce a unique spectral reflectance signature  
(Courtesy MIT Lincoln Labs)

# How Blue Water Satellite Works

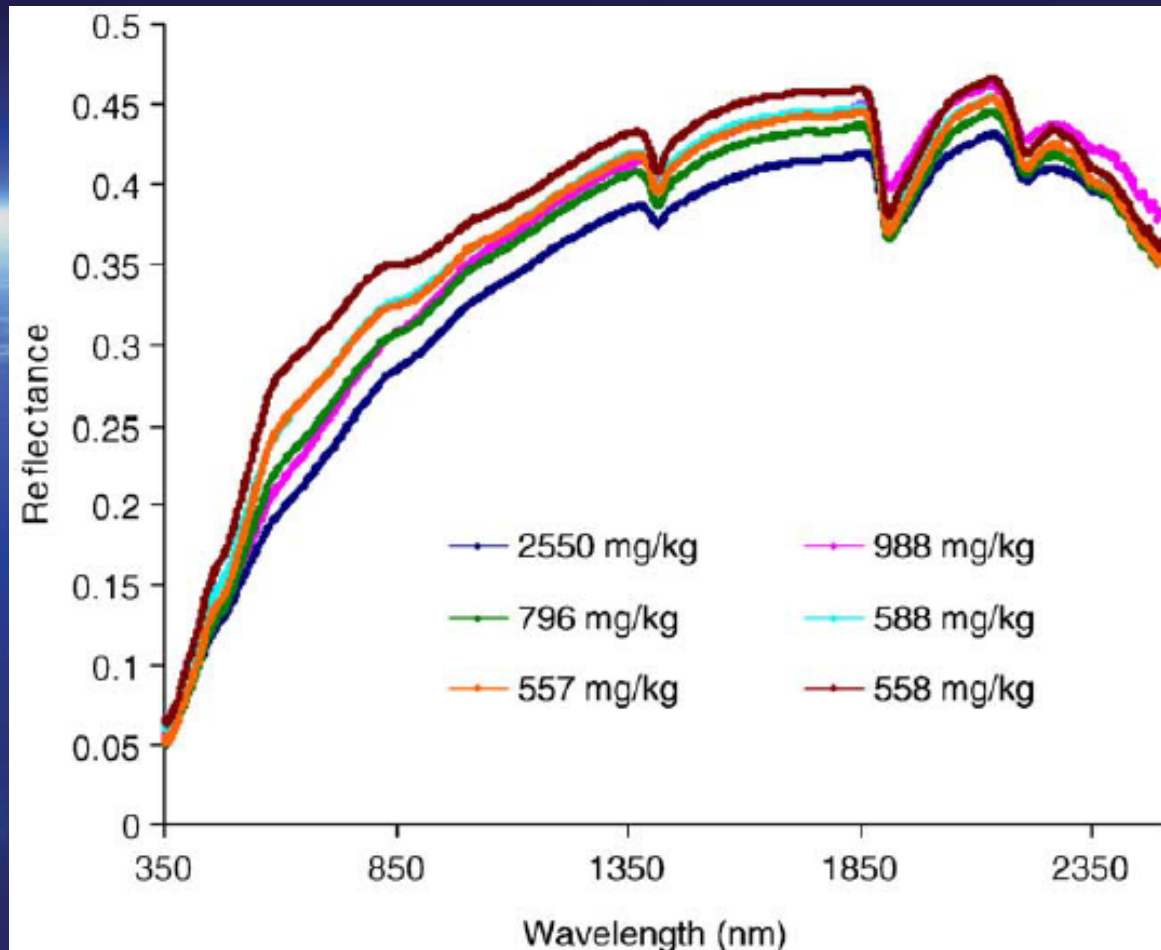


The ratios between the 7 bands of reflected light is a “fingerprint “ for each constituent

# Spectral Reflectance Curve Phosphorus on Land

## Phosphorus in Soils

Spectra of Soil at Various Phosphorus Levels used in BWSI Algorithm







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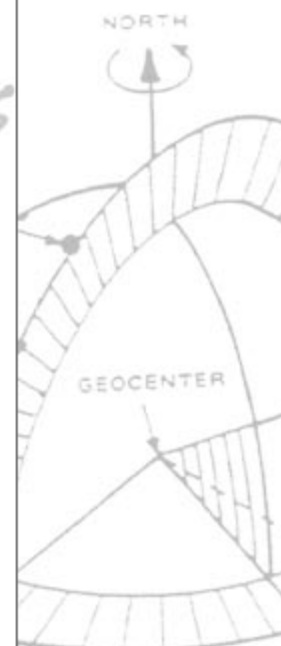
landsat news

## Landsat Enables Remote Detection of Dangerous Water Pollutants

Nov. 12 • A young Ohio business, Blue Water Satellite, Inc., is using Landsat 5 and 7 data to detect potentially harmful pollutants in water bodies across the U.S. used for recreation and for drinking water supplies. Using Landsat and algorithms developed at Ohio's Bowling Green State University, Blue Water can detect E. Coli, cyanobacteria, phosphorus, and Red Tide. Dr. Robert K. Vincent, a geology professor at BGSU, used NASA and NOAA grant money to help develop the pollutant-detection algorithms.

More information:

+ [Bowling Green business goes global](#) [external link]



# Years of Research & Peer Review



## Total Phosphorus Water Monitoring Using Satellite Imagery

Figure 1: BWSI Total Phosphorus Processed Image Example, Lake Washington

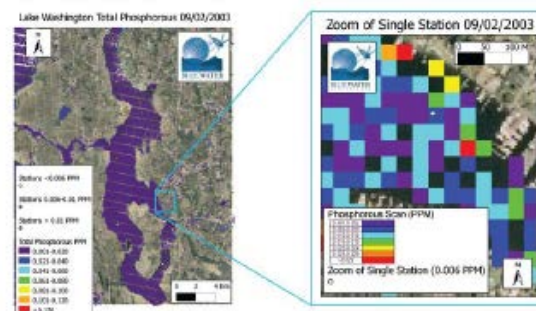
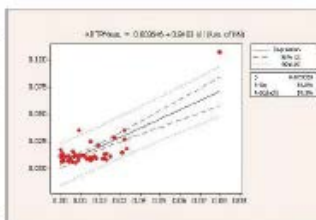


Figure 1: BWSI Total Phosphorus Processed Image Example, Lake Washington

Remote Sensing of Environment

www.elsevier.com/locate/rse



show that using the BWSI processed images for Phosphorus monitoring is certainly a historical and future monitoring efforts. The next evaluation shows how the data line of field sample collection and satellite overpass are closer together.

## Phycocyanin detection from LANDSAT TM data for mapping cyanobacterial blooms in Lake Erie

Robert K. Vincent<sup>a,\*</sup>, Xiaomeng Qin<sup>a</sup>, R. Michael L. McKay<sup>b</sup>, Jeffrey Miner<sup>b</sup>, Kevin Czajkowski<sup>c</sup>, Jeffrey Savino<sup>d</sup>, Thomas Bridgeman<sup>d</sup>

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<sup>b</sup> Department of Biological Sciences, Bowling Green State University, 190 Sherman Hall, Bowling Green, OH 43403-0218, USA

<sup>c</sup> Department of Geography and Planning, University of Toledo, University Hall, 4190A, 2800 New Concord Road, Toledo, OH 43606, USA

<sup>d</sup> University of Toledo Lake Erie Campus, 6280 Bayshore Rd., Oregon, OH 43616, USA

Received 1 May 2003; received in revised form 14 October 2003; accepted 28 October 2003



US007132254B2

## United States Patent Vincent

(10) Patent No.: US 7,132,254 B2  
(45) Date of Patent: Nov. 7, 2006

- (54) **METHOD AND APPARATUS FOR DETECTING PHYCOCYANIN-PIGMENTED ALGAL AND BACTERIA FROM REFLECTED LIGHT**
- (75) Inventor: Robert Vincent, Bowling Green, OH (US)
- (73) Assignee: Bowling Green State University, Bowling Green, OH (US)
- (\*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.
- (21) Appl. No.: 10/763,138
- (22) Filed: Jan. 22, 2004

## OTHER PUBLICATIONS

Richardson, Laurie, Remote sensing of algal bloom dynamics, *J. Great Lakes Res.*, vol. 46, No. 7, pp. 492-501, 2000.

Gitelson, A., et al., Optical properties of dense algal cultures outdoors and their application to remote estimation of biomass and pigment concentration in *Spirulina platensis* (Cyanobacteria), 1995, *J. Appl. Phys.*, vol. 31, No. 5, pp. 828-834, abstract.

Green, S., 2003, <http://www.usd.edu/~sage/phys/strat/MODEL.HTM>, The effect of chlorophyll concentration on airborne hyperspectral reflectance.

LandSat 7 Science Data Users Handbook, <http://ftpwww.gsfc.nasa.gov/LAS/handbook.html#chapter8.html>, last updated Aug. 7, 2001; accessed Dec. 16, 2004.

Gitelson, A. et al., Optical properties of dense algal cultures outdoors and their application to remote estimation of biomass and pigment concentration in *Spirulina platensis* (cyanobacteria), 1995, *J. Physiol.*, 31: 825-834.



## Science of the Total Environment

journal homepage: [www.elsevier.com/locate/scitotenv](http://www.elsevier.com/locate/scitotenv)

## Mapping the total phosphorus concentration of biosolid amended surface soils using LANDSAT TM data

B.B. Maruthi Sridhar<sup>a,\*</sup>, Robert K. Vincent<sup>a</sup>, Jason D. Witter<sup>b</sup>, Alison L. Spongberg<sup>b</sup>

<sup>a</sup> Department of Geology, Bowling Green State University, Bowling Green, OH 43403, United States

<sup>b</sup> Department of Environmental Sciences, University of Toledo, Toledo, OH 43606, United States

## ARTICLE INFO

Article history:

## ABSTRACT

Conventional methods for soil sampling and analysis for soil variability in chemical characteristics are too



## Mapping the total phosphorus concentration of biosolid amended surface soils using LANDSAT TM data

B.B. Maruthi Sridhar<sup>a,\*</sup>, Robert K. Vincent<sup>a</sup>, Jason D. Witter<sup>b</sup>, Alison L. Spongberg<sup>b</sup>

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Remote sensing

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# BWS to Laboratory Data Comparison

Data comparison Blue Water Satellite, Heidelberg National Center for Water Quality, UNH						
Phosphorus in water ppb data from samples taken at Moultonborough NH						
#	Date	Lat	Long	Landsat TP (Averaged) ppb	Heidelberg Data ppb	UNH Data ppb
1	7/16/2011	43 40' 29.9"	71 20' 45.3"	4.7	9.8	5.6
2	7/16/2011	43 42' 23.0"	71 21' 16.1"	11.3	11.6	6.9
3	7/16/2011	43 43' 07.8"	71 24 33.7"	9.3	11.6	8.5
4	7/16/2011	43 43' 34.2"	71 22 32.6"	6.5	12.5	8.6
5	7/16/2011	43 42' 57.4"	71 22' 08.7"	2.6	14.8	9
6	7/16/2011	43 43' 03.2"	71 24' 37.3"	13.4	12.4	11
7	7/16/2011	43 43' 26.0"	71 24' 37.3"	*	16	8.4
8	7/16/2011	43 43' 14.7"	71 22' 58.7"	8.8	11.6	8.5
*In an area where satellite measurement could not be made						
				Δ Landsat to Heidelberg (ppb)	Δ Landsat to UNH (ppb)	Δ Heidelberg to UNH (ppb)
				5.1	0.9	4.2
				0.3	4.4	4.7
				2.3	0.8	3.1
				6.0	2.1	3.9
				12.2	6.4	5.8
				1.0	2.4	1.4
						7.6
				2.8	0.3	3.1
Average of Absolute Value delta (ppb)				4.3	2.5	4.2

# Technology

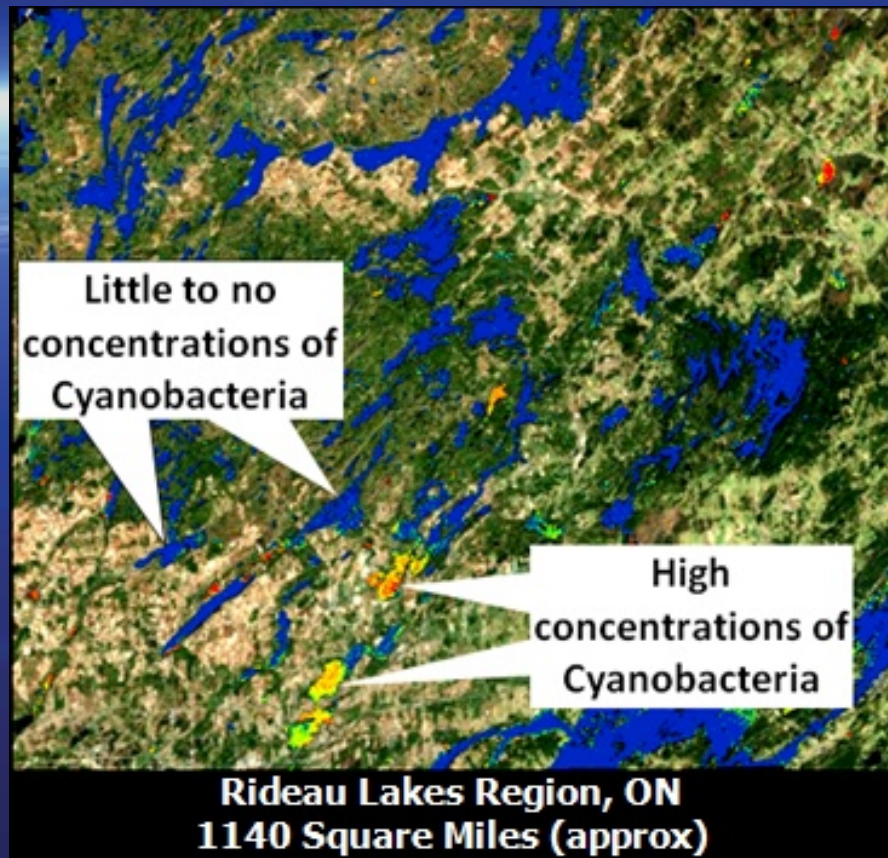
- Uses Landsat and commercial satellites
- Technology Bowling Green State University (BGSU).
- \$1 million in funding from NASA and NOAA over 2 ½ years for validation.
- 3 issued patents and 8 pending patents
- Peer reviewed science
- Ability to go back in time to 1984
- 5 samples/acre
- Worldwide China, Australia, Canada, US, Etc.



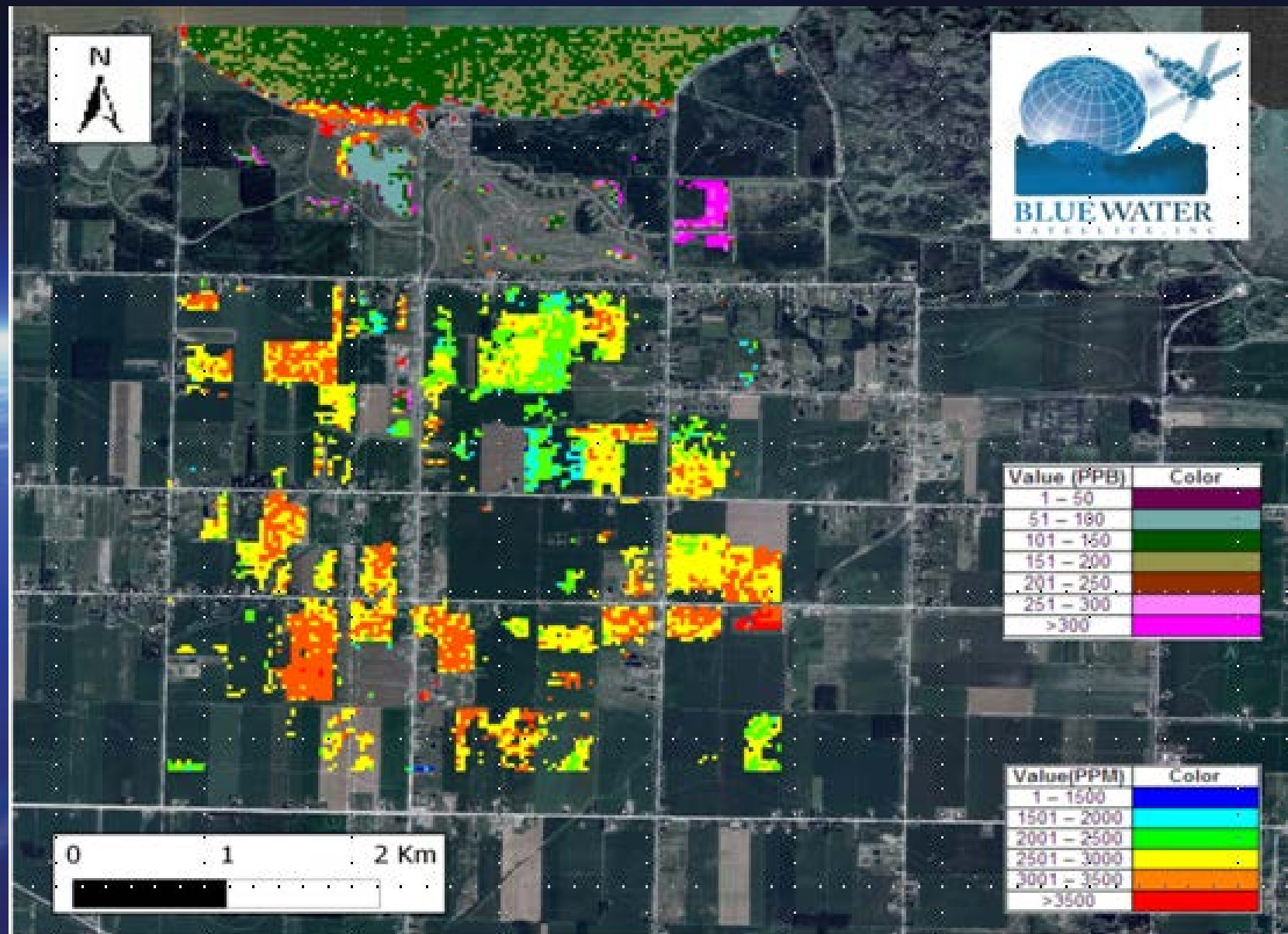
# Case Study #1

## Identifying where the problems are

### Area with 106 Lakes



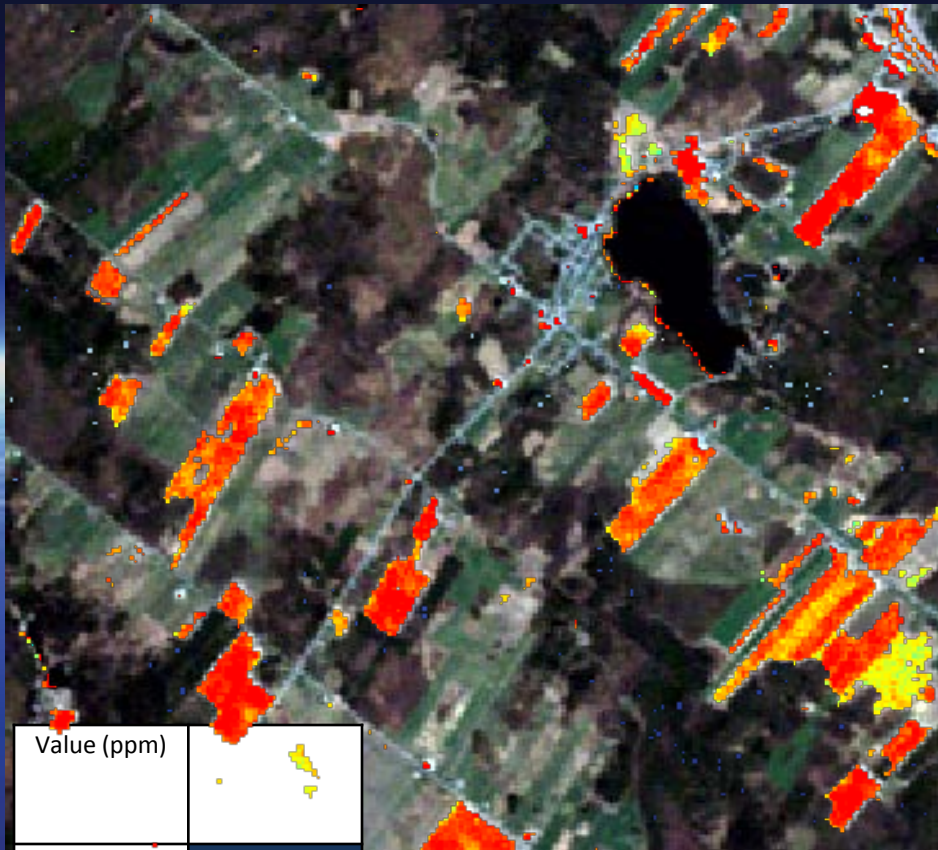
# Case Study #2 Sources Phosphorus Land



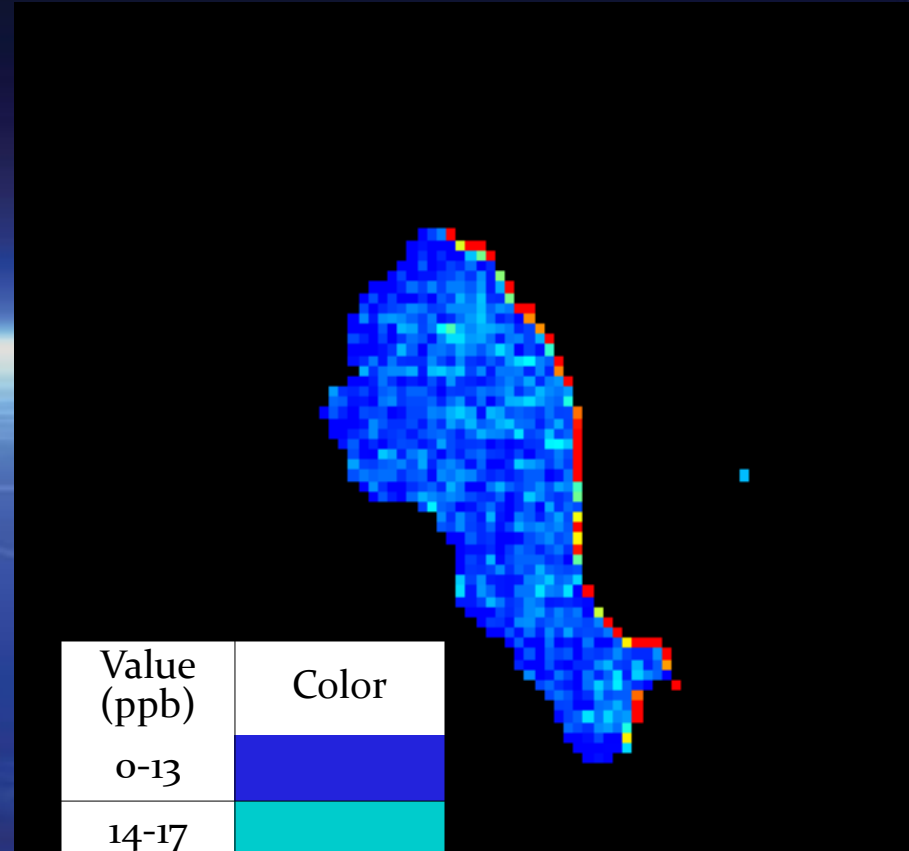
# Case Study #3

## Identifying Point Source Problems on Land

The image below details Total Phosphorus on Land (TPL) in an agricultural area



Value (ppm)	
0	
1900	
2400	
2700	
3800	



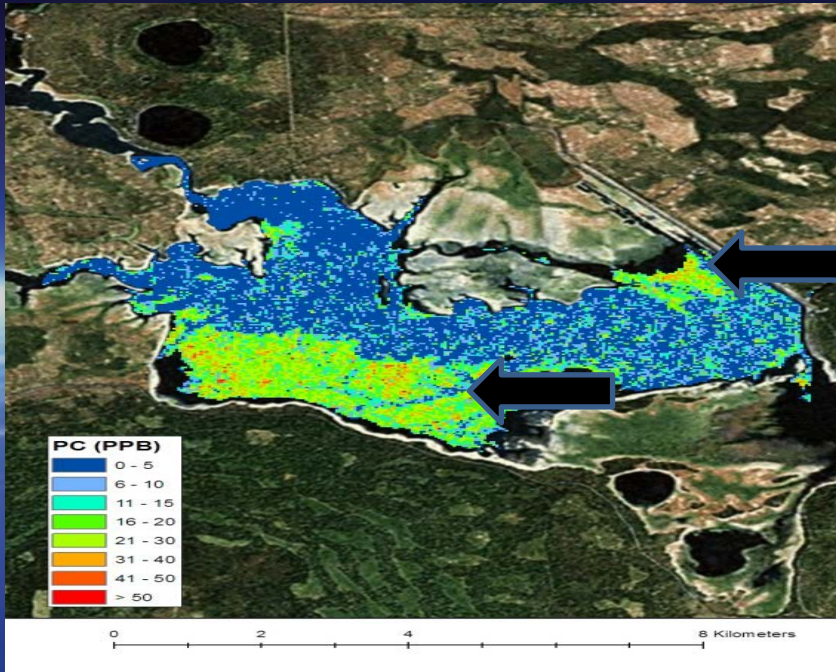
Value (ppb)	Color
0-13	
14-17	
18-21	
22-26	
27-49	
>50	



# Case Study #4

## Reducing Treatment Cost

BWSI is the only technology that enables significant savings in treatment costs!



### Planned Treatment :

Apply Alum in entire lake	\$2,200,000
---------------------------	-------------

### BWSI Solution:

Target Alum to affected areas	\$1,300,000
Cost of Satellite Images	\$ 40,000
Total	\$1,340,000

### Customer Savings:

**\$860,000!**

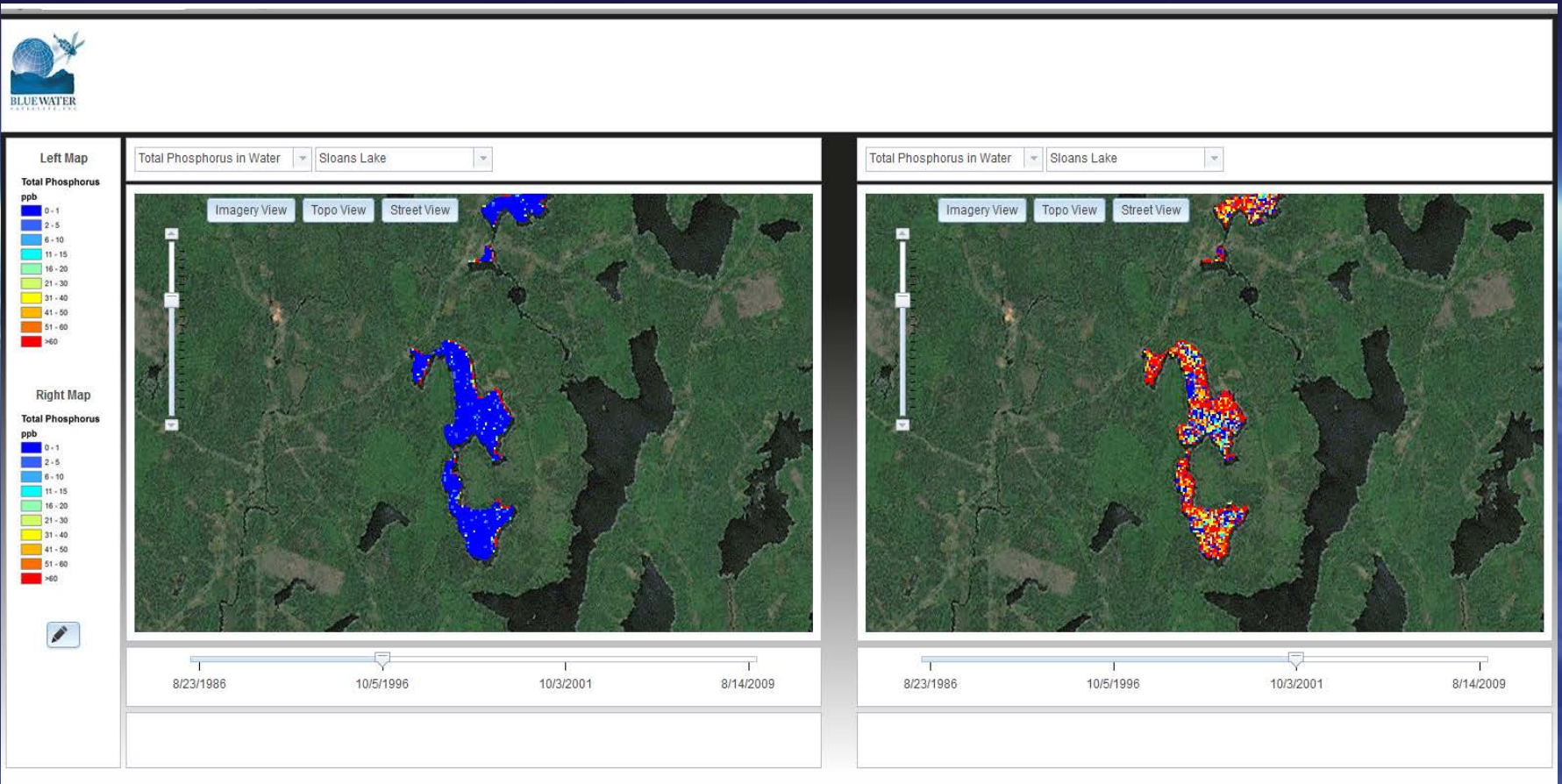
*"You really can't get this information in a cost-effective manner any other way. It's a real bargain if you're trying to do comprehensive sampling of the lake. It's the only way to get the information we want in a cost effective manner because it's lake wide and it's a big lake. – Frank Pickett PPL Montana*



# Case study #5 Risk Mitigation

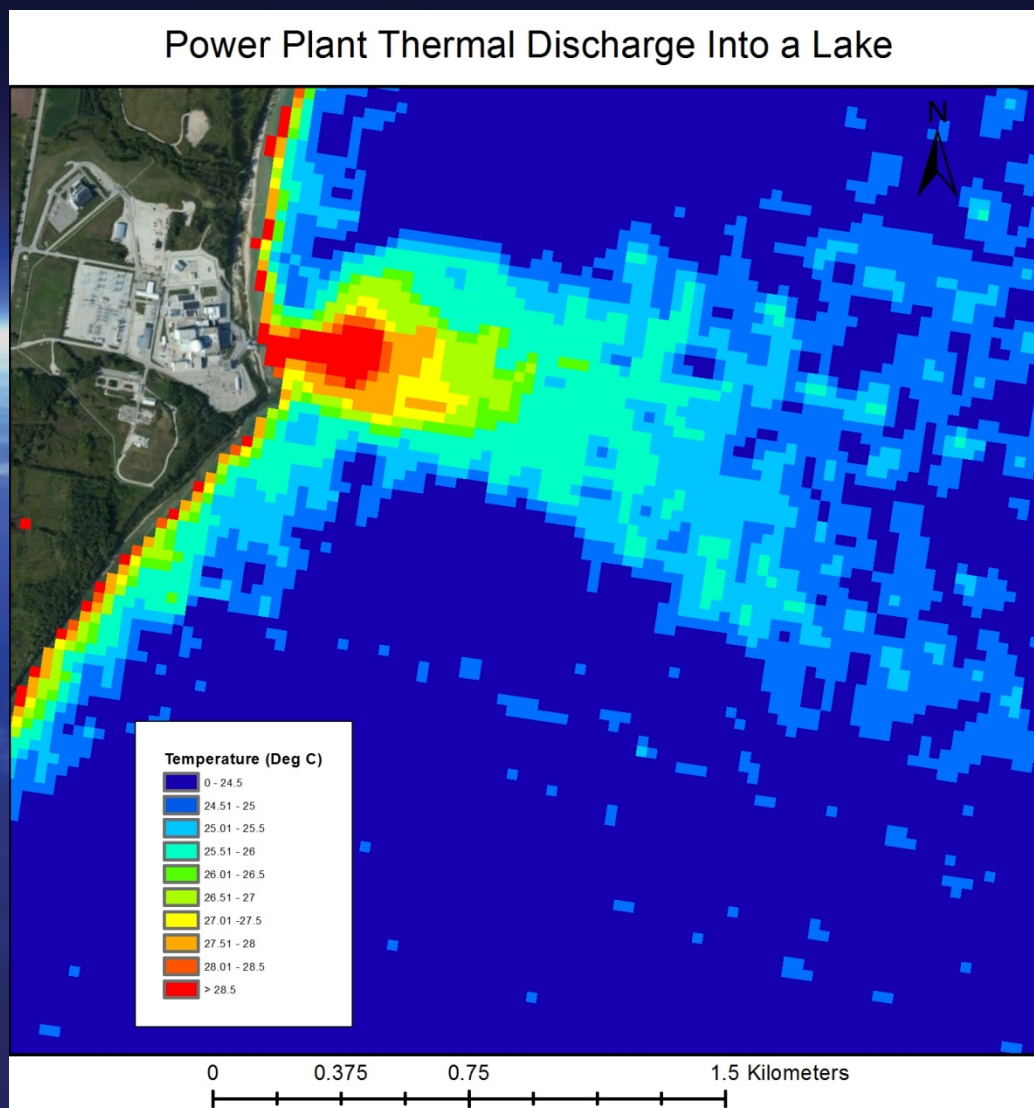
The Blue Water Satellite Viewer (BWS Viewer™) enables clients to:

Compare water bodies and constituents  
Quickly evaluate current and historic trends



# Case Study #6 Temperature Plumes

The image below details temperature in water (Deg C)

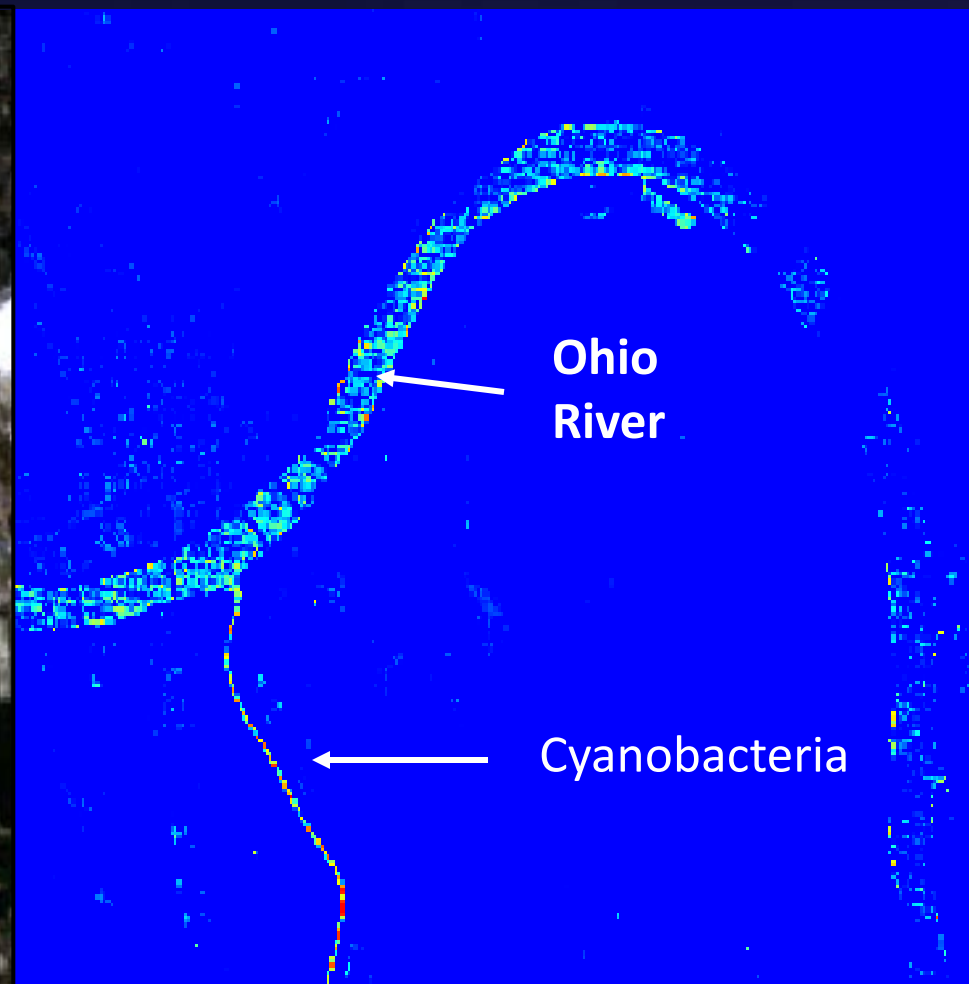




# Case Study #7 Aid in Determining Problem Sources Ohio River 2008



Landsat Natural Color Image



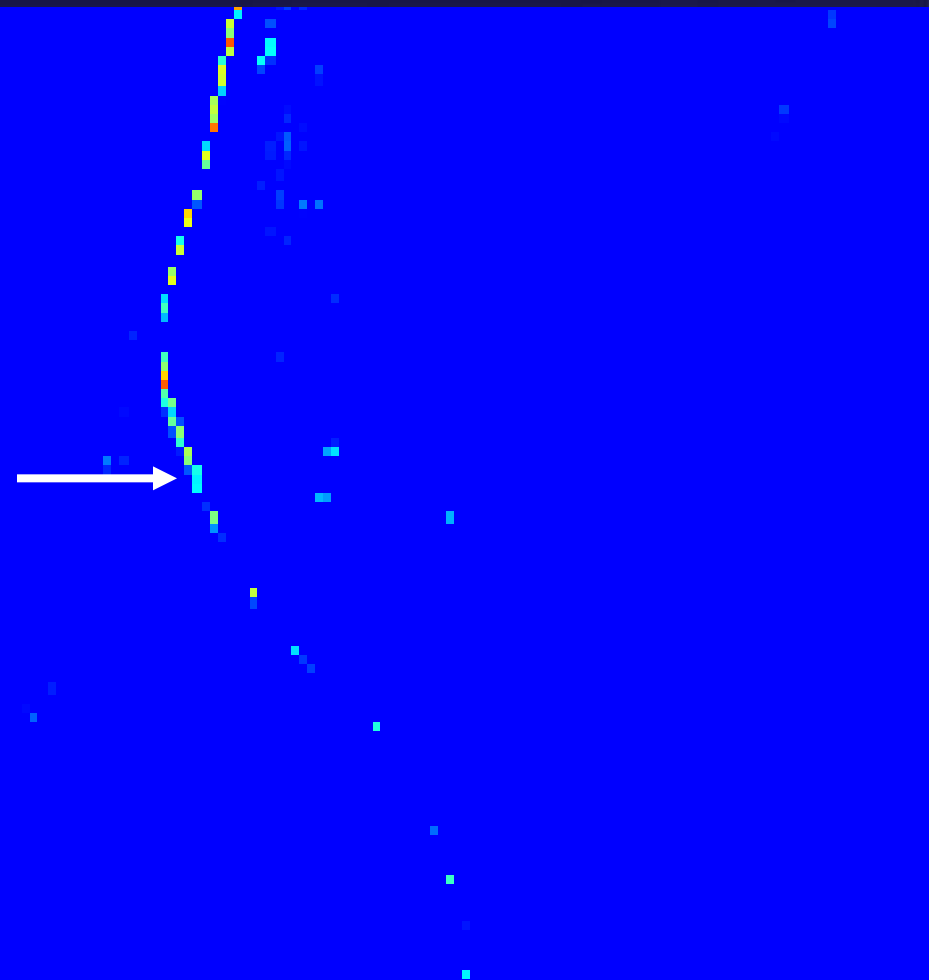
Landsat processed Image

# Case Study #7 Aid in Determining Problem Sources

## Licking River 2008



Landsat Natural Color Image



Landsat Processed image

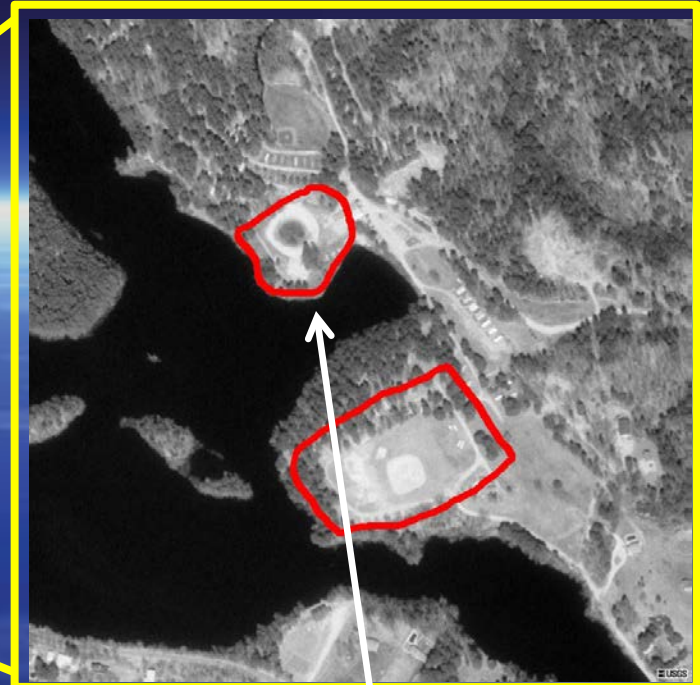
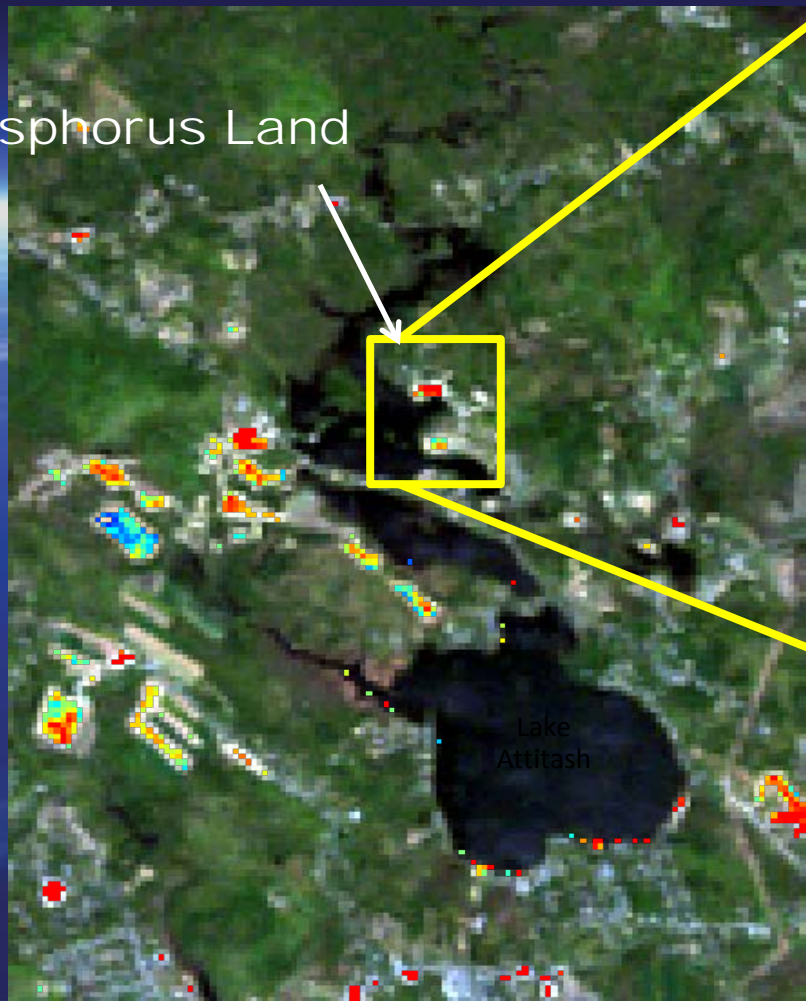


# Case Study # 8 Total Phosphorus Land Finding a leaky septic system in abandoned summer camp

Total Phosphorus Land

1998 Aerial Photograph

High Phosphorus Land



Abandoned Summer  
Camp with leaky  
Septic system



# BWS Range and Accuracy

## Blue Water Satellite Constituent Accuracy and Range Data

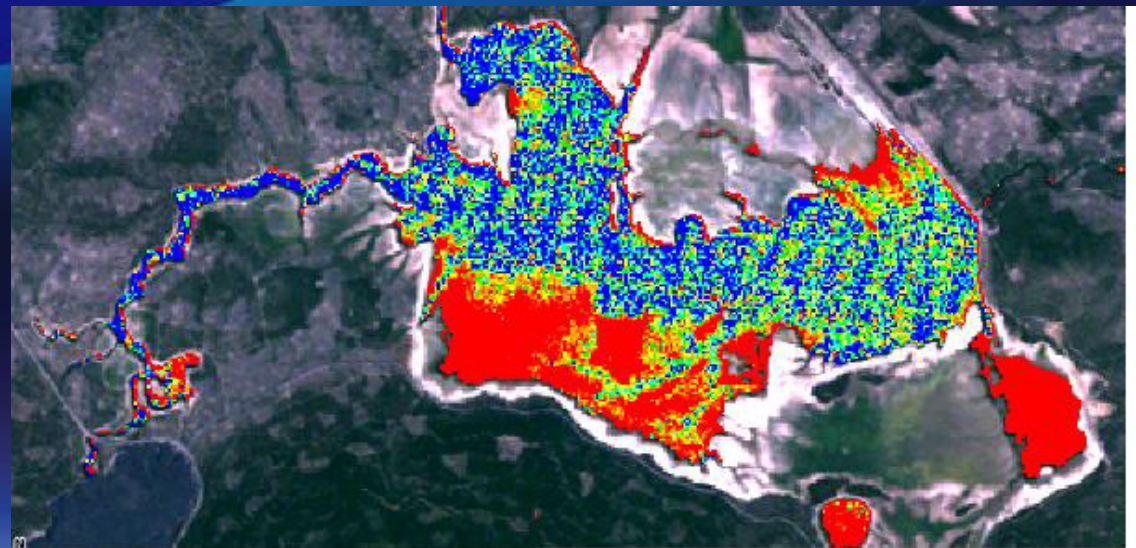
Constituent	Range	Accuracy
Cyanobacteria (Phycocyanin)	0-17 ppb	±2 ppb
Cyanobacteria (Phycocyanin)	17-60 ppb <sup>A</sup>	±17 ppb
Total Phosphorus Water (TPW)	0-20 ppb	±6 ppb
Total Phosphorus Water (TPW)	20-100 ppb	±11 ppb
Total Phosphorus Land (TPL)	0-4000 ppm	±530 ppm
Chlorophyll-a	1-155 ppb	±22 ppb
Temperature	1.9 - 27.6°C	± 1.52°C
Aquatic Vegetation	Relative	Presence/ Absence
Note: ppb = parts per billion		
Note: ppm = parts per million		

<sup>A</sup> Above 60 ppb will measure 60 ppb



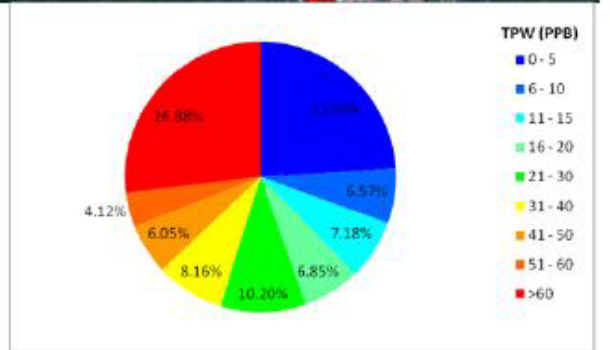
# Blue Water Satellite Deliverables

- Geo TIFF file for each image (for ArcGIS)
- Processed images (pdf, tiff, or jpeg)
- Custom report (sample page as shown)
- Accuracy data
- BWS Viewer™ (optional)



TPW (PPB)	Color
0 - 5	Blue
6 - 10	Light Blue
11 - 15	Cyan
16 - 20	Light Green
21 - 30	Green
31 - 40	Yellow-Green
41 - 50	Yellow
51 - 60	Orange
>60	Red

TPW (PPB)	Area (Acres)	Percent of Lake
0 - 5	1174.24	23.99
6 - 10	321.81	6.57
11 - 15	351.38	7.18
16 - 20	335.15	6.85
21 - 30	499.78	10.20
31 - 40	399.64	8.16
41 - 50	296.23	6.05
51 - 60	201.93	4.12
>60	1315.91	26.88

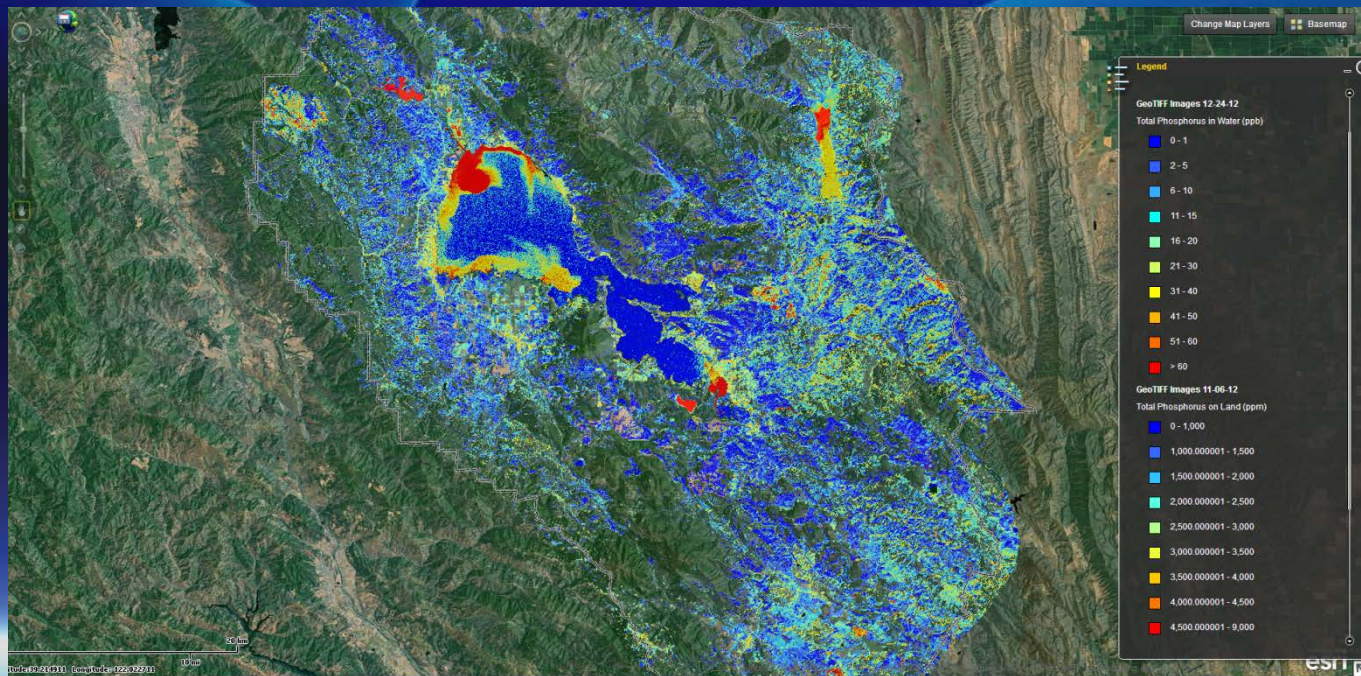


Color scale (above left) indicates ranges of concentration of phosphorus in parts per billion as represented in scan image (top).

Pie chart histogram (above) indicates percentage of water within view delineated by concentration ranges.

Table (left) indicates actual acreage falling within each range of concentration of phosphorus.



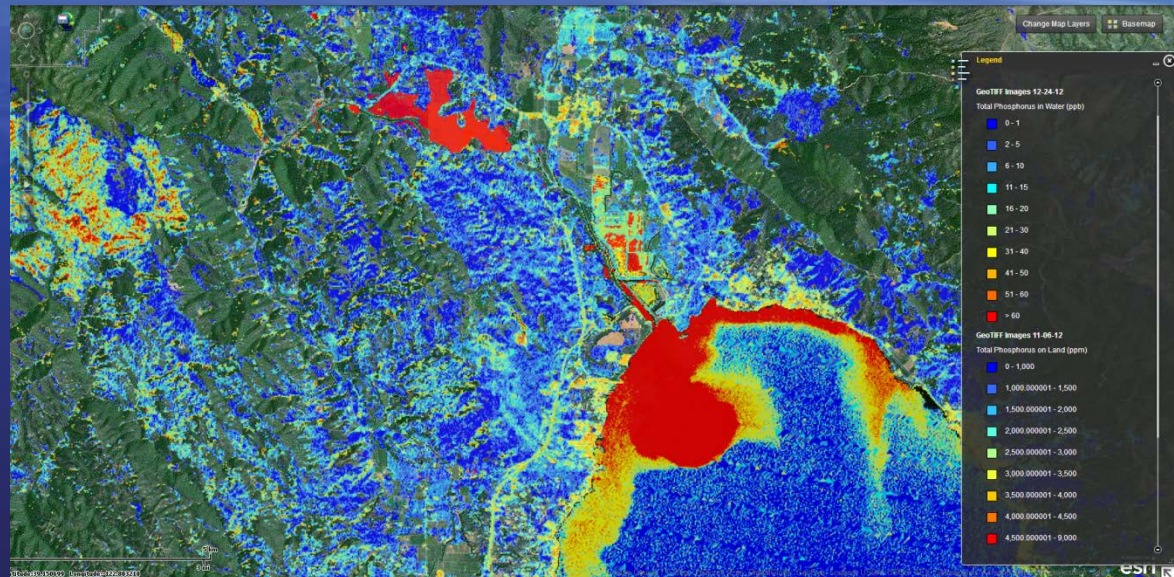


Phosphorus on land  
and in water analysis

<http://gispublic.co.lake.ca.us/BWS/>

Blue Water Satellite  
Customer Example:  
Clear Lake, California

Lake County makes  
BWS data available  
online for public  
outreach



zoom



# Blue Water Satellite



**No one sees it like Blue Water Satellite.  
No one.**

**For additional information 855-885-5648 ext 1**