CENTRAL DAVIS SEWER DISTRICT

July 25, 2016

James Harris
Utah Division of Water Quality
P.O. Box 144870
Salt Lake City, UT 84114-4870

Re: Comments on the 2016 Integrated Report

Dear Mr. Harris:

Central Davis Sewer District submits the attached comments for the 2016 Integrated Report.

Sincerely,

L Myers

Leland Myers P.E.
District Manager

CC: Walt Baker
Erica Gaddis
Leah Ann Lamb
CDSD Board

Utah 2016 Integrated Report
Comments Provided by Central Davis Sewer District
Leland Myers, P.E.

Thank you for the opportunity to comment. The 2016 Integrated Report represents a significant amount of effort to protect water quality in the State of Utah. We applaud the State Division of Water Quality for their effort in this important endeavor. The Staff and Board of Central Davis Sewer District provide these comments. We approach this in an effort to be collaborative and to improve the integrity of the integrated report.

Our comments will focus on the following areas of the report.

1. Listing and assessment methodology associated with harmful algal blooms, specifically cyanobacteria.
    a. Cell Count as a Basis for Listing
    b. Sampling Program Considerations
    c. Summary - Assessment
2. Assessment of Farmington Bay
3. Support for Adaptive Management

Harmful Algal Blooms Assessment Methodology

CELL COUNT AS A BASIS FOR LISTING

The IR focuses on information extracted from the WHO for assessment thresholds. Specifically, Table 10 (below) is used to determine support or non-support.

Table 10. World Health Organization thresholds of human health risk associated with potential exposure to cyanotoxins.

Indicator (units)	Low Risk	Moderate Risk	High Risk
Chlorophyll *a* (µg/l)	< 10	10–50	> 50
Cyanobacteria cell counts (cells/ml)	< 20,000	20,000–100,000	> 100,000

While we accept that this is one method used to assess a water body, many states use it primarily as a means to assess recreational use guidance, not for listing. We believe that the decision to list for impairment should be separate from the decision to post or provide warnings and restrictions for recreation. Protection of public health should be precautionary whereas listing has potential cost implications it should be based on a more rigorous standard. Virginia, for example uses essentially the same ranges for assessing recreational guidance as shown below (Virginia Recreational Guidance):

Table 1. Water Conditions and Corresponding Notification

Water Quality Condition	Public Health Response	Basis
5,000 to <20,000 *Microcystis* cells/mL	Notify local health district and DEQ; initiate bi-weekly water sampling.	WHO (2003)
20,000 to 100,000 *Microcystis* cells/mL	Notify public through press release and/or signage. Advise people and pet-owners that harmful algae are present. Initiate weekly water sampling.	Massachusetts and Washington Health Dept guidance, WHO (2003)
> 100,000 *Microcystis* cells /mL, or > 6 $\mu g/L$ microcystin concentration, or blue-green algal "scum" or "mats" on water surface	Notify public through press release and/or signage. Advise against any recreational activity that may involve water contact for people and pets; continue weekly monitoring until bloom and/or microcystin dissipates.	Washington Health Department guidance, WHO (2003)

The cell count process is used, but they also recommend the evaluation of toxin concentration as part of an effective sampling process. The guidance states:

> The Virginia Department of Health (VDH) recommends using a combination of cell counts and toxin concentrations to guide public health decision-making during harmful algal bloom events in recreational waters. When toxin results are not available, cell concentrations and other water quality parameters may be used to aid public health and environmental sampling decisions.

Based on our review of the literature, we believe that the assessment method based on cell count only, is the weakest method for assessing recreational impairment. Other states have spent considerable effort to evaluate the available literature and have concluded that toxin concentration or both cell counts and toxin concentration are needed to provide a reliable assessment for recreational safety. As can be seen in Table 1 above, Virginia uses both cell count and toxins to determine notification of a potential health threat.

The main reasons, we believe, that cell count alone is insufficient include the following:

1. Some cyanobacteria are non-toxin producing, and
2. The correlation between cell count and toxin concentration is poor. If cell count is the metric, then any cyanobacteria cells are the impairment if the total count exceeds 100,000. In our opinion, we believe toxins impair the use, not just cell counts. Specifically in Farmington Bay we reject the position that cyanobacteria are an impairment as they are an important part of the food chain. In a presentation given by Gary Belovsky of the Great Salt Lake Ecosystem

> Project, he explained through their research that the cyanobacteria Coccochloris improves the brine shrimp cysts yield. Farmington Bay cyanobacteria are also a food source for Gilbert Bay brine shrimp. In a 2012 study by Jaclyn Wright and edited by Wayne Wurtsbaugh it was reported that brine shrimp biomass more than doubled along the plume from Farmington Bay into Gilbert Bay. This occurred during a period of significant Nodularia bloom.

According to the U.S. Geological Survey in 2008 (Graham, et al):

> Most cyanobacterial taxa do not produce toxins or taste-and-odor compounds, but many of the common planktonic genera contain one or more toxin and/or taste-and odor producing strains. Whereas some strains may produce toxin and taste-and-odor compounds simultaneously, these compounds do not necessarily co-occur and the presence and concentration of one may not be reliably used to predict the presence and concentration of another (Chorus and Bartram, 1999). Because toxin and taste-and-odor production is strain dependent, algal identification alone cannot be used to determine whether or not these by-products will be present, although genera that contain strains producing these compounds can be identified.

The District has reviewed data collected by District employees and researchers from the period 2013 to 2015 in Farmington Bay of Great Salt Lake. The data was tabulated and evaluated by Dr. David Richards of Oreohelix in June 2016 (Report included in Appendix 1). The data collected was log(10) transformed and nodularian was regressed against cyanobacteria cell count. Below is a graph of the regression.

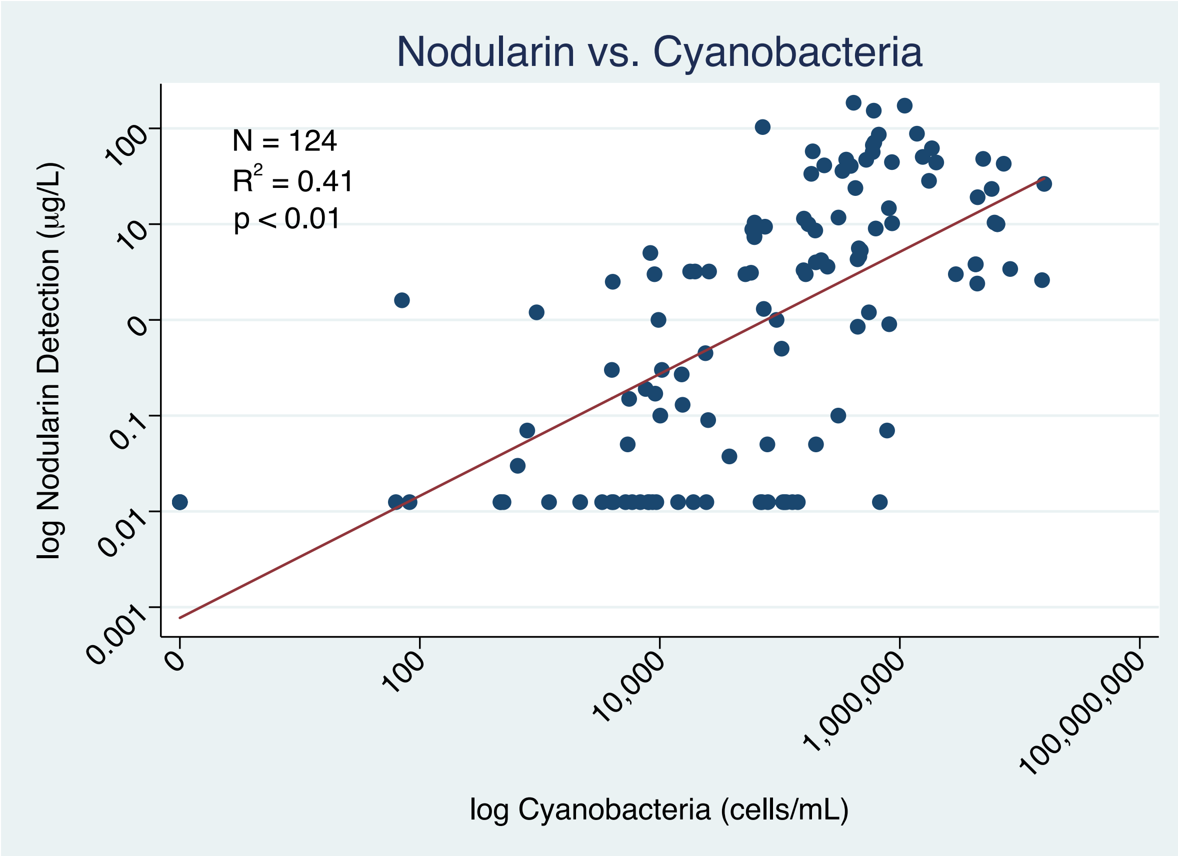


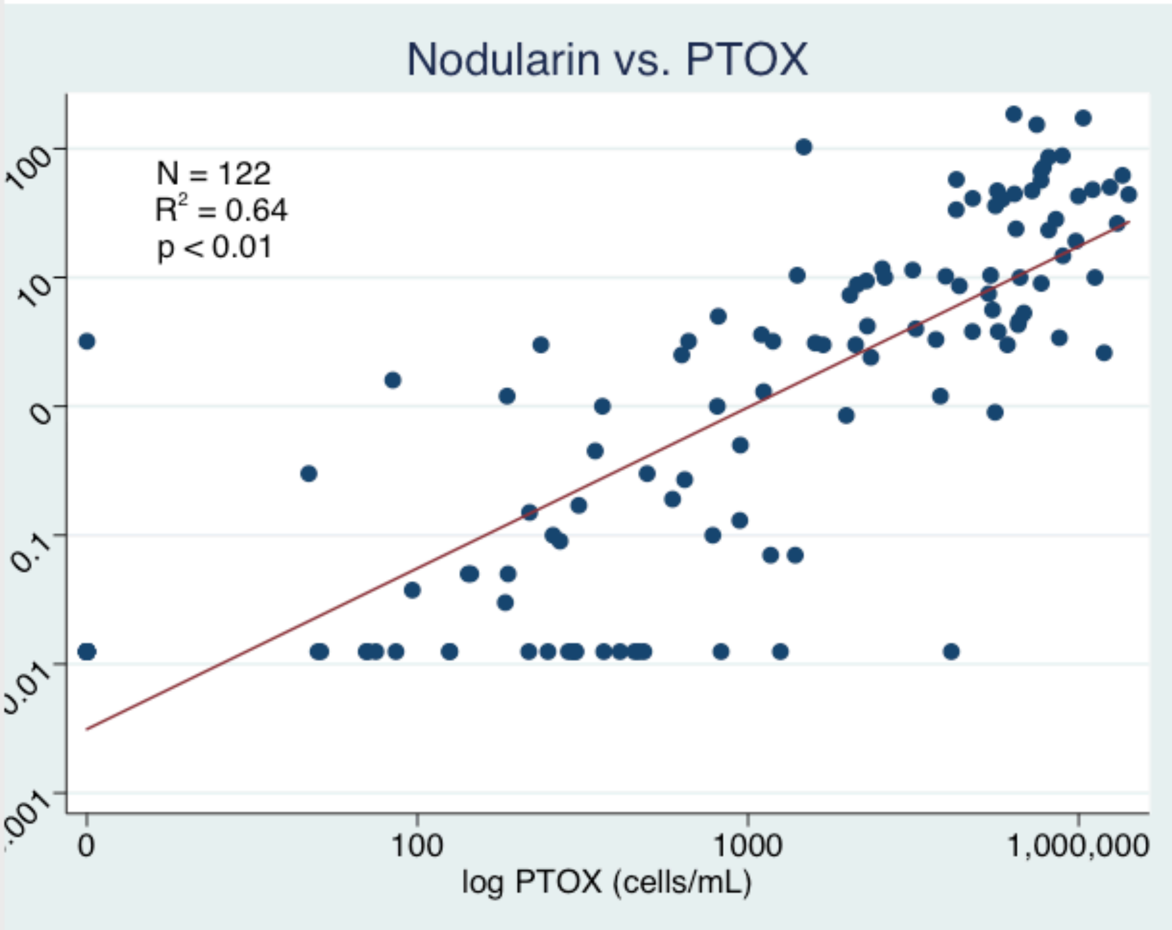
Figure 1. Relationship between nodularin (µg/L) and cyanobacteria (cells/mL) in Farmington Bay, Great Salt Lake.

Dr. Richards concluded that there was only a minor relationship between nodularian and cyanobacteria cell counts. In a report on cyanotoxins, Meriluoto and Spoof stated:

> In studies performed at the University of Helsinki, Finland, in the 1980s, about 50% of the cyanobacterial blooms tested contained toxins – the majority of them hepatotoxins (microcystins) (Sivonen et al. 1990). Later data from other countries corroborate these findings . . .

With only a poor relationship between cyanobacteria and cyanotoxins, why use the weakest metric to assess impairment in Utah? Finally, a study of cyanotoxin removal from five water treatment plants distributed across the United States included the general observation that "There was no correlation between numbers of toxin-producer cyanobacteria and levels of toxins found." (Szlag, et al)

If cell counts are determined to be the only viable method to assess narrative water quality attainment, it would be a better metric to count the potential toxin producing cyanobacteria (PTOX). From the Richards report, again using the data from Farmington Bay, the regression of PTOX cells against Nodularian toxin produces the following relationship:



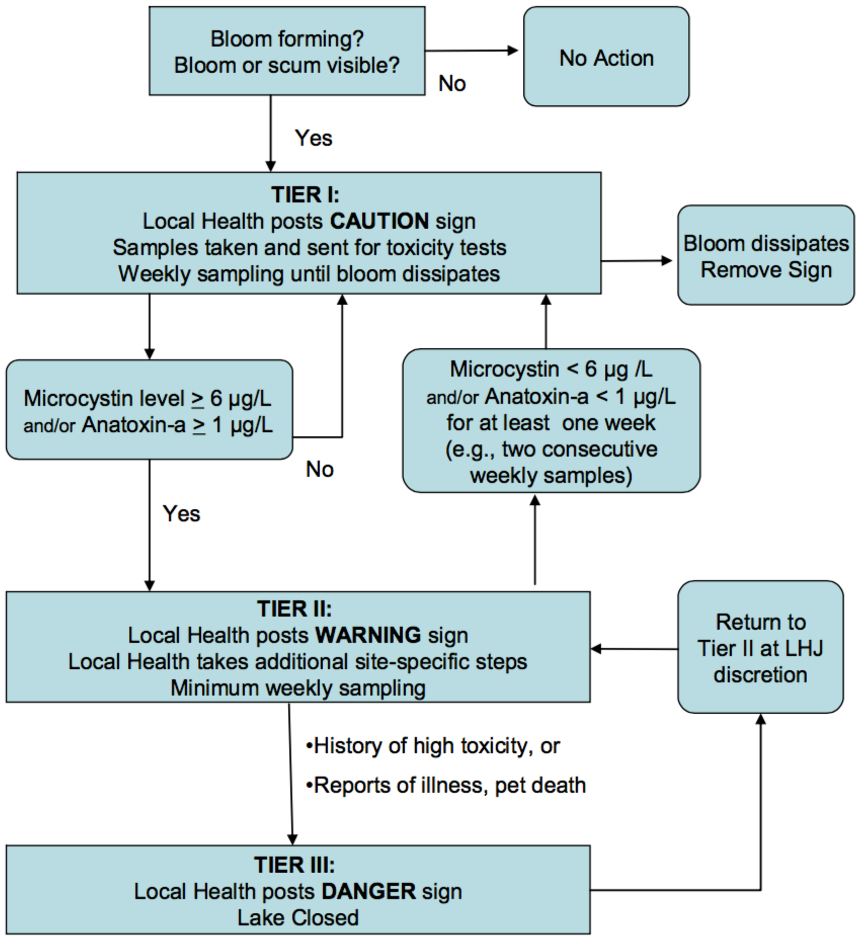
Relationship between nodularin (ug/L) and PTOX (cells/mL) in Farmington Bay, Great Salt Lake.

As can be seen, the R^2 for this relationship of 0.64 is better than using all cyanobacteria. For this reason, Washington State in their Recreational Guidance stated the following:

Washington State Department of Health (DOH) has identified a list of cyanobacteria genera and species of concern for lakes in Washington. If the following genera are identified in a water sample from an algal bloom, the sample should be tested for toxicity:

- *Microcystis*
- *Anabaena*
- *Aphanizomenon*
- *Gloeotrichia*
- *Oscillatoria/Planktothrix*
- *Cylindrospermopsis*
- *Lyngbya*
- *Nostoc.*

Washington uses the following flow chart to instruct local health departments about when to post an area for warning or danger.



As can be seen, Washington uses the presence of specific cyanobacteria to trigger sampling which then leads to posting for recreational areas if the toxin level exceeds the determined value. The above flow chart and genera and species screen demonstrates the use of PTOX cells to start the testing process rather than the presence of all cyanobacteria some variants of which may not be toxic formers.

Recognizing that all of the examples quoted are directly related to assessing and warning for potential health effects, we reiterate our recommendation that listing of a water body as impaired should require a more rigorous assessment method. We accept that when public health is a concern, using any available information is necessary to allow people to make an informed decision. However, listing and potential cost implications should be based on additional analysis to provide certainty that a problem exists. Nebraska recognized this in their assessment methodologies when they included the following:

3.1.2 Cyanobacteria Toxins

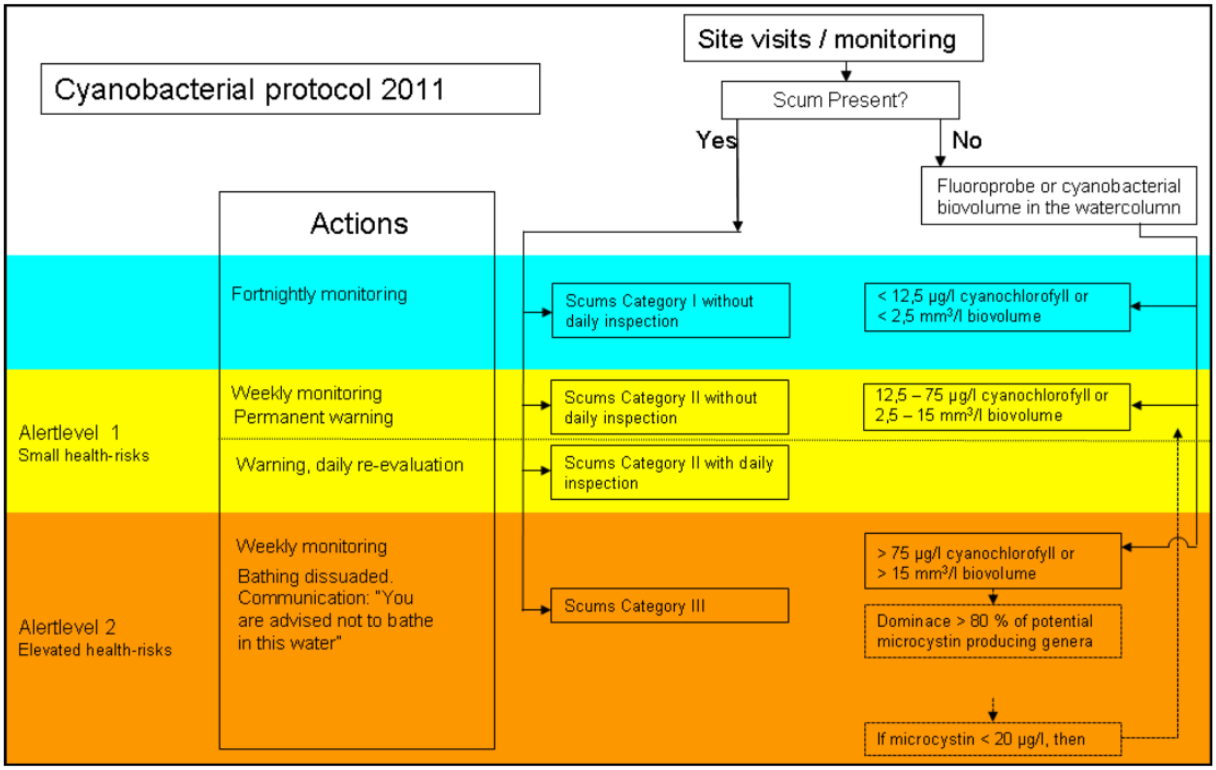
Cyanobacteria, or blue-green algae as it is commonly known, naturally occur in lakes and reservoirs throughout Nebraska. A few species of cyanobacteria found in Nebraska produce toxins that can be dangerous to humans and animals in high enough concentrations. On rare occasions, large scale cyanobacteria blooms occur in a lake or reservoir can produce enough toxin to make full contact recreation unsafe. Toxic substances are included in Title 117 as a water quality criterion for evaluating the recreation beneficial use (Title 117 Chapter 4, Section 002.02). Title 117 also designates the recreation season to be May 1– September 30, outside of which the criteria does not apply. NDEQ's cyanobacteria toxin limit was set at 20 μg/l, to correspond with the World Health Organization's recommendation. Recreation season data will be pooled independently for each stream segment, lake, and recreation season over the most recent 5-year monitoring period.

The established criteria and the assessment of toxin information are provided in Table 3.

Table 3: Assessment of Primary Contact Recreation Beneficial Use Using Toxin Data

Supported	Impaired
$\le$10% of Samples Exceed 20 μg/l	>10% of Samples Exceed 20 μg/l

Ingrid Chorus (2013) in a summary of different approaches to cyanotoxin risk management included the following flow chart for Cyanobacterial Protocol for the European Union:



Again, this approach uses toxin measurement to declare an elevated health risk and Alert Level 2. If toxin measurement is less than 20 µg/L the Alert Level 2 is not triggered, and a small health risk is the assessment conclusion.

Our recommendation is that the State of Utah should use toxin level as the metric for declaring a water body impaired. Some would suggest that toxin testing is cost prohibitive and cell count is adequate. California in their guidance about harmful algal blooms addresses this issue when they said:

> As most cyanobacteria produce some combination of cyanotoxins, and as the most commonly found cyanobacteria produce microcystins in particular, the trend in monitoring has often used cyanobacterial cell counts as a proxy for toxin concentrations. This stems from the higher cost for toxin analyses, the small number of laboratories performing the analyses, and the limitations in the research to be able to quantify all of the different cyanotoxins. However, enzyme-linked immunosorbent assay (ELISA)-based testing kits are now available that measure total microcystin concentration in water. These kits provide toxin results more rapidly than is possible for cell count analysis and are likely to become more affordable as this technology matures.

Paul Brakhage in an article “The Nebraska Experience” stated that by using the ELISA analysis in-house there were able to meet the following schedule for results publication:

> A weekly routine has been established in which water samples are collected and delivered to the laboratory on Monday and Tuesday, processed using freeze-thaw methods on Wednesday, and analyzed on Thursday. Sample results are reported on Thursday, and by Friday morning, NDEQ website information is updated and if necessary, warning signs are posted at lakes.

Brakhage reported that Nebraska saved over $77,000 annually by using this test methodology. US EPA has recommended testing results using the ELISA in the Fourth Unregulated Contaminant Monitoring Rule (https://www.epa.gov/dwucmr/fourth-unregulated-contaminant-monitoring-rule). This method for monitoring can be performed by the Division of Water Quality and delays associated with cell counts can be eliminated. Hence, allowing for more accurate assessment of risk. In addition, USGS has reported this method to be comparable to samples measured by LC/MS/MS (Loftin, 2010). As a side note, Abraxis, Inc. has ELISA testing systems available for under $10,000. Such systems would greatly aid the Division of Water Quality to secure lower costs and additional information.

By shifting to a methodology that incorporates testing, the state can then create risk assessment levels allowing for accurate impairment assessment. Ohio has created such a tiered approach in their recent Harmful Algal Response Strategy for Recreational Waters that includes the following table:

Table 2. Numeric Thresholds for Cyantoxins in Recreational Water.

Threshold (μg/L)	Microcystins*	Anatoxin-a	Cylindrospermopsin	Saxitoxins*
Informational Sign	<6	<80	<5	<0.8
Recreational Public Health Advisory	6	80	5	0.8
Elevated Recreational Public Health Advisory	20	300	20	3

*Microcystins and saxitoxin thresholds are intended to be applied to total concentrations of all reported congeners of those cyanotoxins.

In the Ohio 2014 integrated report, listing was based on measured concentration in finished drinking water (Ohio 2014 Integrated Report Section H). If two or more excursions above 1 μg/L for microcystins are measured, the water body is listed as impaired. In Section I of the same integrated report, Ohio outlines proposed action to reduce cyanotoxins and includes an excessive nutrient strategy. We believe that Utah should continue addressing nutrients and cyanobacteria on an adaptive management program rather than through listing and TMDL's. While the listing in Ohio in 2014 was based on drinking water concentration, it is our recommendation that Utah adopt the public advisory level of 20 μg/L as a concentration for impairment listing. With appropriate sampling methodologies, this concentration would represent an acceptable threshold for action, including the preparation of a TMDL.

SAMPLING PROGRAM CONSIDERATIONS

After reviewing Section 5 of the integrated report, the selective use of sampling appears to be a significant basis for the impairment declaration for Utah Lake. There are several issues that the Utah Lake sample collection sites raise. First, the assessment methodology does not address sampling philosophy. Specifically, Chapter 2: 2016 303(D) Assessment Methods do not address how sampling should be conducted and where samples are obtained. Sampling on any water body does where cyanobacteria occurs can be biased based on where the sample is obtained. Following is an illustration from a WHO document that demonstrates the varying concentration at different locations.

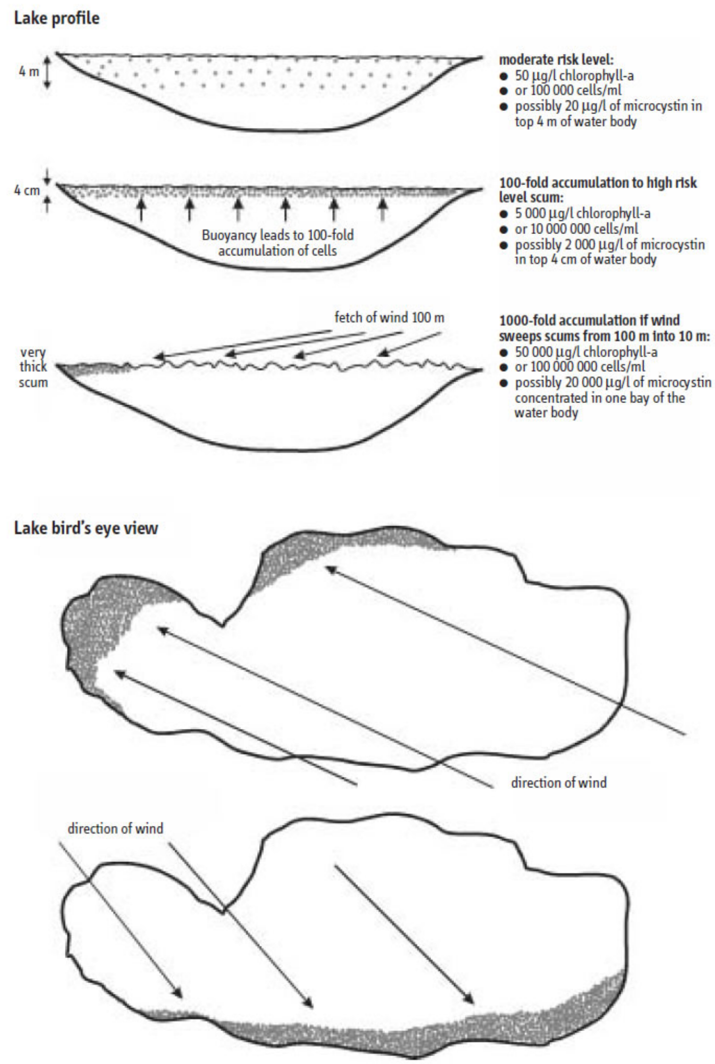
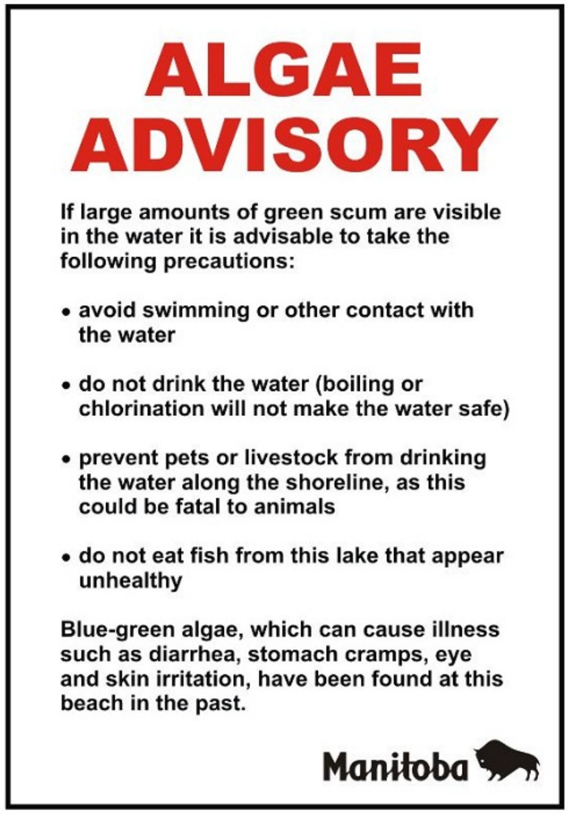


FIGURE 8.1. SCHEMATIC ILLUSTRATION OF SCUM FORMATION CHANGING THE CYANOTOXIN RISK FROM MODERATE TO HIGH (CHORUS & BARTRAM, 1999)

This illustration demonstrates the accumulative affect that a buoyant cyanobacteria and wind can have on the sampling results. In Figure 4 and Figure 5 of Chapter 5 of the IR it can be seen that all sites where values exceeded 100,000 cells /ml are in locations where accumulation can occur. Indeed, samples collected in the open water in general had toxin concentrations below the concentration considered acceptable for finished drinking water (Table 2 from the IR). We have concerns with the decision to list based on these samples for the following two reasons.

1. The sample results are not uniform and it appears an attempt was made to collect samples with high values for the assessment. This approach paints the whole Lake with the tainted paintbrush that exists only in the accumulated areas. If a segment of the Lake, say Lindon Marina is impaired, list Lindon Marina not the entire lake. Further, if

the tainted areas are of concern, place signs in these areas, rather than listing the entire lake. Below is such a sign from Manitoba.



2. The second and even more disconcerting fact is the lack of public input to the determination by DWQ to accept and use worst-case scenario sampling results. We believe that there should be a State management determination as to whether sampling should be representative of the entire lake or only the accumulation locations. Further, once a management determination has been made as to worst case or representative sampling, that determination should be subject to public comment. We do not believe this occurred for the listing of Utah Lake. We accept that the IR comment period allows for public comments, but we still maintain that before the draft IR was issued, representative or worst case sampling issues should have been explicitly included in the Assessment Methodology. As a result of its exclusion from that document, we assumed that sampling would have been representative for the entire lake rather than biased by worst case location samples as actually used by DWQ.

The US Geological Survey (Graham, et al) has developed sampling methodologies in their guidelines for sampling cyanobacteria. Appendix Two of this document has a sampling design approach that includes ankle, knee and chest deep samples at 0.15

and 0.30 below the surface. Dense surface samples may also be collected. The intended use of sample results should be discussed in the sampling methodology prepared by DWQ and should also be available for public comment before being used in the integrated report.

Based on the above-identified deficiencies in the sampling program used for Utah Lake, it is our recommendation that listing of the lake should be postponed until the deficiencies discussed previously in this section are corrected.

SUMMARY – ASSESSMENT METHODOLOGY

In summary, we recommend the following changes or actions be taken by DWQ in the current 2016 Integrated Report and/or for future assessment methodologies.

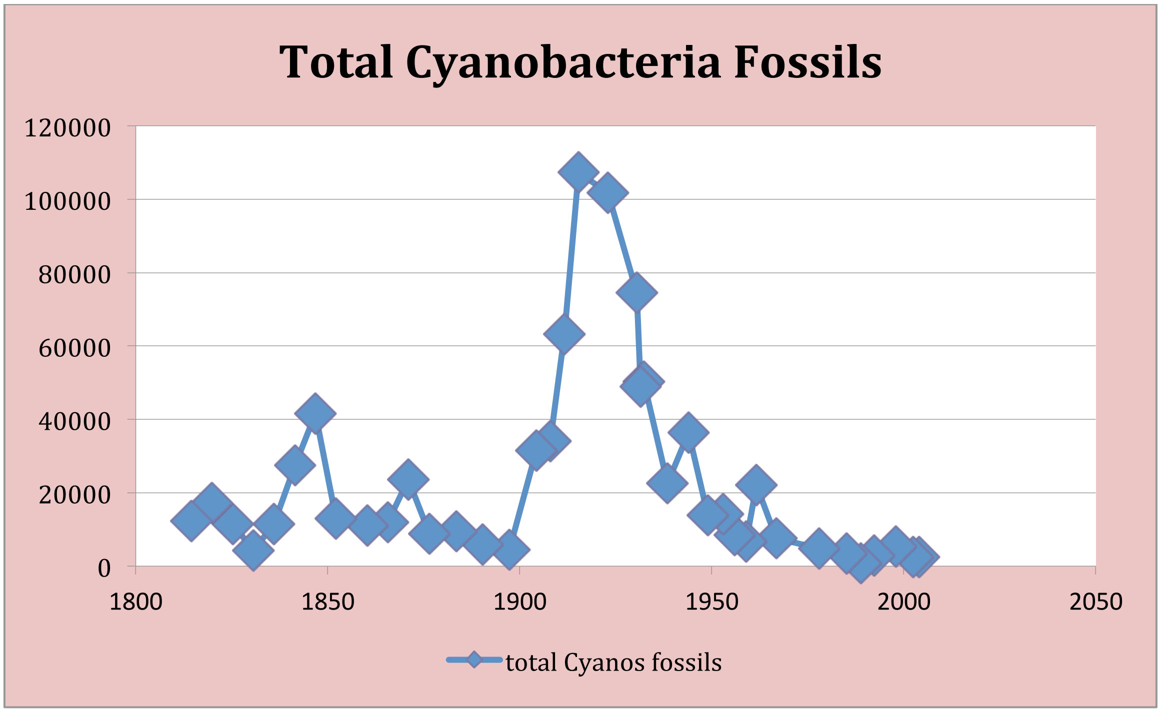
1. Separate public health notice methodologies from listing methodologies for cyanobacteria/cyanotoxins.
2. Establish a listing metric of 20 μg/L for cyanotoxins. Alternatively, establish a numeric value, based on the most exposed individual, in a policy or as a standard subject to public comment and review.
3. Although not directly related to the IR, we recommend DWQ begin an in-house ELISA testing program to provide reliable data for listing decisions in the future.
4. Develop a sampling policy that clearly delineates protocols for sampling location and uses in the integrated report for listing.
5. Allow for public comment on the proposed sampling policy and any sampling plans associated with said policy.
6. For Utah Lake we recommend the State delay listing until a sampling policy is available and a more robust data set is available.

Comments on IR Chapter 6 – Farmington Bay Assessment

FARMINGTON BAY AND CYANOBACTERIA

The following rationale is suggests that before any listing actions are taken relative to Farmington Bay, significant additional research is needed to determine the appropriate action relative to Famington Bay and nutrients.

1. Cyanobacteria in Farmington Bay are a naturally occurring condition. Listing Farmington Bay for cyanobacteria would be like listing Great Salt Lake for high TDS. The figures below were extracted from the paleo-limnology reports prepared by consultants to DWQ (Leavitt, et al).



The above figure of Total Cyanobacteria Fossils, demonstrates from the sediment core, that current fossils are consistent with fossils from the pre-settlement days. The significant rise and then drop in fossils could be explained by the raw sewage that was sent to GSL that was curtailed by secondary treatment in the beginning of the 1950's. As can be seen, the cyanobacteria fossils demonstrate that cyanobacteria have always been present in the lake. In addition, recent concentrations are similar to those prior to settlement of the area. Clearly, any existing use of Farmington Bay would include a use consistent with the inclusion of cyanobacteria. During the preparation of the paleo-limnology report it was argued that the dating on the core is fuzzy. For this reason the state had a third party expert review the dating component of the report. Their expert, Dr. Thure Cerling stated that:

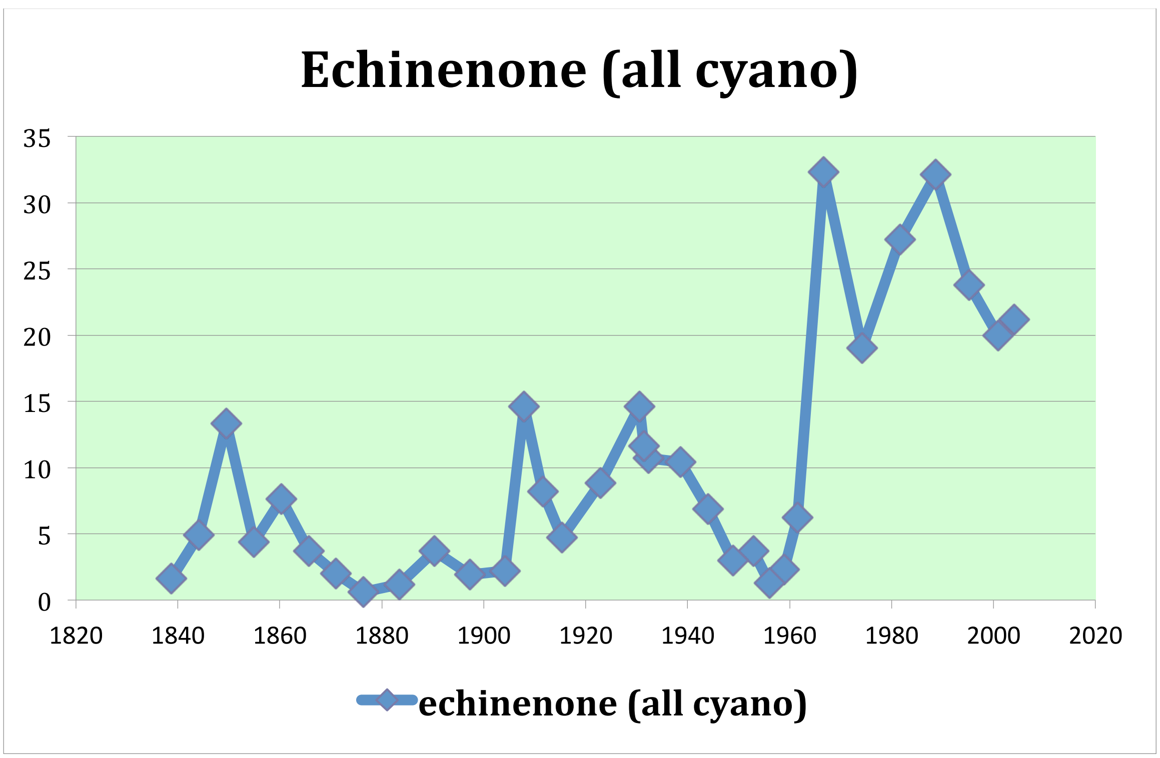
> It is likely that these cores can provide information on metal concentrations and ecological indicators in the discrete periods including pre-European settlement (ca. prior to 1850), the early metal extraction period (ca. 1860 ca. 1960), and the post-causeway era (ca. 1960 to present). Within each of those periods the stratigraphic rules of superposition give a chronological order, and within each of those periods some consistent historical inferences will be able to be made (Cerling).

In 40 CFR Part 130.10(g) there is a provision that removes a beneficial use designation if it is naturally occurring. Assuming a recreational use in the narrative standard includes a requirement for cyanobacteria density, we believe that the narrative standard does not apply to Farmington Bay based in the following code citation:

> (g) States may remove a designated use which is not an existing use, as defined in § 131.3, or establish sub-categories of a use if the State can demonstrate that attaining the designated use is not feasible because:
>
> (1) Naturally occurring pollutant concentrations prevent the attainment of the use;

Hence, the existing uses of Farmington Bay for recreational purposes or as a part of the narrative standard should not include any condition relating to cyanobacteria. We again reiterate if warning of potential health concerns is separated from impairment listing, protections of public health can readily be accomplished without 303(d) listing considerations.

A second consideration relates to increases in the pigment echinenone. Below is a graph prepared from the Levitt data.



This figure of Echinenone (all cyano) above shows a marked increase of pigments about the time the causeways were constructed. Again, the DWQ's paleo report states

> Instead, causeway construction appears to have constrained the most severe eutrophication to Farmington Bay and may have reduced the degree of eutrophication at some Gilbert Bay locations (Leavitt).

In 40 CFR Part 131.10(g) it states that if an existing use is not attainable because of one of six factors, an existing use may be modified. In paragraph 40 CFR Part 131.10(g)(4) it states

> Dams, diversions or other types of hydrologic modifications preclude the attainment of the use, and it is not feasible to restore the water body to its original condition or to operate such modification in a way that would result in the attainment of the use; . . .

If an existing use of Farmington included cyanobacteria, which we believe is not the case, the construction of the dikes would justify the existing use being modified. The presence of cyanobacteria is historic and not just recent. The causeways were constructed prior to the existing use date of November 28, 1975 and cyanobacteria has always been present. An impairment for primary and secondary contact recreation should be removed from the beneficial use since it is not, nor has it been an existing use. We reiterate that protection of public health demands that health officials should post signage as shown following to protect public health and to inform the public of the potential natural risks that exist. Such signage allows the attenuation of public health risks while conforming to the current and past existing use of Farmington Bay.

2. The designated beneficial use for Farmington Bay is:

> d. Class 5D Farmington Bay
> Geographical Boundary -- All open waters at or below approximately 4,208-foot elevation east of Antelope Island and south of the Antelope Island Causeway, excluding salt evaporation ponds.
> Beneficial Uses -- Protected for infrequent primary and secondary contact recreation, waterfowl, shore birds and other water-oriented wildlife including their necessary food chain (Utah Administrative Rules).

The existing use as a food source for birds and their necessary food chain may conflict with the desire to have infrequent primary and secondary contact as a beneficial use including a cyanobacteria limitation, also. Again, citing the Paleo report, it states:

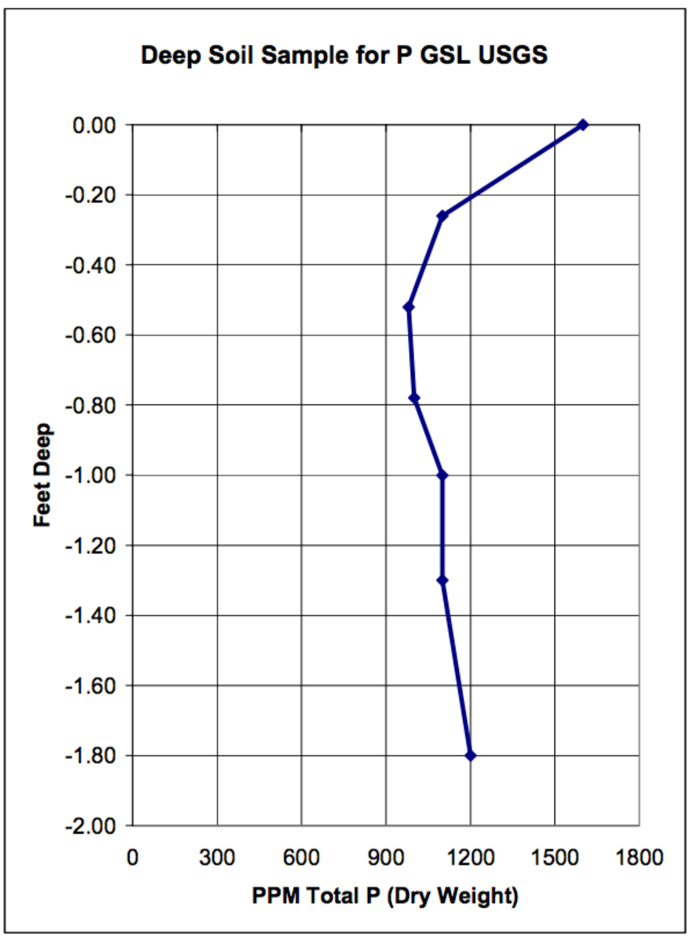
> On the other hand, eutrophication can also increase ecosystem productivity and favor production of commercially-important organisms such as fish or invertebrates, including brine shrimp and flies, which support avian production. This issue is of particular interest with regard to Farmington and Bear River bays of Great Salt Lake (GSL), Utah, both of which host large populations of shorebirds, waterfowl and other avian taxa which rely on high production of invertebrates (Paul and Manning 2002) (Leavitt).

Reports on gulls generated during the selenium studies by Conover, et.al. during 2006-2007 demonstrated that a vast majority of the birds depended on brine shrimp as a primary diet. Reduction in Farmington Bay productivity could significantly reduce brine shrimp concentrations and thus food availability. In addition, John Cavitt reported that primary food sources for shorebirds such as corixidae were dependent on adequate productivity to support the existing populations of birds. Hence, if a reduction in productivity occurs as a result of an attempt to reduce cyanobacteria through nutrient control, the unintended byproduct would be a loss of food mass to support the existing use that involves birds.

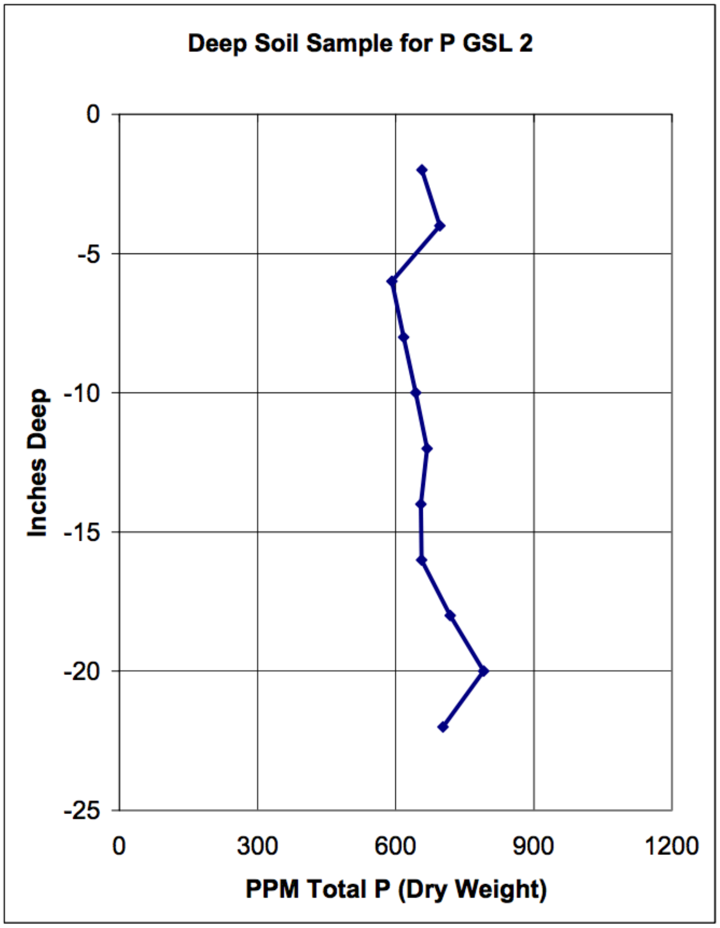
3. It is impractical to control phosphorus in Farmington Bay such that phosphorus control will reduce or eliminate cyanobacteria in this water body. One of the principal purposes for listing is to eliminate the condition(s) that creates impairment. If GSL is listed due to cyanotoxins, the conclusion would be there is a need to reduce or eliminate cyanobacteria from the ecosystem. Numerous sources suggest that to eliminate cyanobacteria, the in-water phosphorus needs to be below 20 μg/L. To achieve such a concentration, reductions would be needed in multiple areas. Current Salt Lake County Storm Water reports indicate a phosphorus concentration exceeding 0.5 mg/L to 0.6

mg/L (Salt Lake County, 2014) or 50 time more phosphorus than necessary to support cyanobacteria. Sampling done by Central Davis Sewer District demonstrated that phosphorus concentration in snow in the valley areas had about 0.5 mg/L of phosphorus. In high mountain areas the snow phosphorus was 0.07 to 0.15 mg/L phosphorus concentration. Again much more than required to support cyanobacteria. While anthropogenic concentrations from wastewater treatment plants range from about 1 to 3 mg/L, 100% removal of wastewater phosphorus will not nearly be sufficient to reduce water concentration to below 20 μg/L. Because of these inputs and the natural presence of cyanobacteria in Farmington Bay, the Division of Water Quality and the Core Nutrient Team recognized that an adaptive approach to phosphorus in this water body was best (Technology Based Limit Document). As such, a 1 mg/L phosphorus standard has been approved by the Water Quality Board.

In addition to natural and/or anthropogenic sources of phosphorus being sufficient to support cyanobacteria, the Farmington Bay sediments have been evaluated and found to have significant concentrations of phosphorus. Sediment concentrations range from 200 mg/L to 1900 mg/L. Some of the core samples taken show that concentrations of phosphorus have increased over time (Myers, et al) as seen in the graph following.



Other samples have shown consistent phosphorus concentrations throughout the core as shown in the next graph. In either case, however, the sediment concentration of phosphorus is significant and would allow for mineralization to return phosphorus to the water column for the foreseeable future.



This 2006 study also demonstrated that when sediment was mixed with a low phosphorus water source, it released phosphorus to the water. Conversely, when the sediment was mixed with high phosphorus water the sediment acquired phosphorus from the water. The significant sink of phosphorus in the sediment will continue to exchange phosphorus with the overlying water. Also, vegetation growing in the lakebed will mobilize phosphorus from the sediment, which could be released to water when the vegetation senesces. It is highly likely that phosphorus in the sediment will continuously recycle into the water column making the possibility of reducing to 20 μg/L concentration phosphorus in the water column nearly impossible.

4. The final rationale for not listing is the altered state of the Lake due to the construction of causeways through the Lake. These causeways have altered the function of the different segments of the Lake created by the separation. Utah DWQ recognized this when they created separate use designations for the different bays in

R317-2-6 in the Utah Administrative Code. At the time of this change the beneficial uses for each bay remained the same, but discussions at the time suggested the beneficial uses may change for each bay as the differences created by the causeways were better understood. In the invertebrates paleo report Mosier stated:

> Eutrophication processes in the Great Salt Lake (GSL) may be particularly complex as the lake is divided by several causeways, which restrict natural hydrologic circulation (Figure 1; Table 1). In particular, impoundment of individual embayments may influence eutrophication by reducing circulation, isolating contaminants, and altering natural salinities in individual sub-basins. For example, Farmington and Bear River bays are shallow and receive substantial river inflows that dilute salts to near-freshwater levels during spring runoff. However, as those flows subside, evaporation and intrusion of salts from adjoining bays can increase salinities (Mosier, et al).

While it is well understood that changes between the bays has occurred, how those changes relate to the beneficial uses of the bays has not been determined. As such, before listing of Farmington Bay for recreational uses occurs, the actual changes created by the causeways should be defined and beneficial uses adjusted accordingly. Mosier further stated:

> Eutrophication and salinity interact to control the organisms that survive in GSL, and this interaction may add complexity to the mechanisms degrading water quality in individual embayments. For example, Gilbert Bay has a limited diversity of phytoplankton (algae in the water column) and periphytic (bottom-dwelling) algae, and includes only two metazoans— brine shrimp (Artemia) and brine flies (Ephydra). Similarly, the salt-saturated waters of Gunnison Bay support only a few types of algae, bacteria and Archaea (a bacteria-like organism), and presently includes very few invertebrates. In addition, the high spatial and temporal variability of salinities in Farmington and Bear River bays may cause significant changes in the biotic composition throughout the year.

As stated previously, the information presented explains why an understanding of Lake division and the effects on ecosystem function should be defined and the beneficial uses adjusted accordingly before being declared impaired.

In summary, Central Davis Sewer District maintains the four following items discussed above demonstrate that cyanobacteria and phosphorus in Farmington Bay are not and should not be considered impairments:

1. Because of the nature of a terminal water body, Farmington Bay has naturally occurring cyanobacteria and is naturally high in phosphorus.
2. The bird designated beneficial use of Farmington Bay requires the Lake be highly productive, such that algal or cyanobacteria growth is beneficial and not a detriment.
3. It is impractical to control cyanobacteria with phosphorus because of the historic and current inputs to the system.
4. The lake is a sink for phosphorus and mineralization and recycling will always occur.

Adaptive Management

Central Davis Sewer District supports the continued use of adaptive management as a tool for managing water quality in Farmington Bay. The District believes that any changes in Farmington Bay should be done on a measured basis so as not to destroy the beneficial uses or cause undue expenditures on dischargers to the Bay. The Utah Nutrient Strategy: Technology Limits Document states:

> Monitoring following implementation of TBLs will provide valuable data with regard to potential ecological improvements downstream of treatment facilities. However, it must be understood that recovery can take years or decades given legacy accumulation, particularly for phosphorus. Whether or not immediate improvements to downstream conditions are observed, the proposed strategy helps reduce the risk that increasing levels of nutrients from ongoing growth will cause or exacerbate nutrient problems. This adaptive logic behind these reductions applies to both N and P for all water bodies except for GSL. The GSL is unique because N reductions have the potential to harm the ecosystem because N may limit the abundance of brine shrimp, and potentially brine flies, that are of critical importance as food to the millions of birds that depend on the GSL ecosystem.

In the case of Farmington Bay, the reduction to 1 mg/L phosphorus should be monitored and evaluated before any further changes are considered. In addition, further changes in nutrient control should not be triggered by the mere presence of cyanobacteria in Farmington Bay. Additional changes should be based on sound science that justifies that changes should be made.

The Division of Water Quality's web page on nutrients supports this adaptive management approach, also when it states:

> The Division's goal is to protect Utah's waters for their beneficial uses while taking into consideration the respective characteristics and potential of these waters. Given the wide diversity of streams and lakes throughout Utah, the levels of nutrients protective of the beneficial uses in one type of stream will be different in another type of stream.

In addition, the December 2013 EPA Long Term Vision for Assessment, Restoration, and Protection under the Clean Water Act Section 303(d) Program also provides support for the use of adaptive management as an alternative approach. This document states:

> By 2018, States use alternative approaches, in addition to TMDLs, that incorporate adaptive management and are tailored to specific circumstances where such approaches are better suited to implement priority watershed or water actions that achieve the water quality goals of each state, including identifying and reducing nonpoint sources of pollution The purpose of this Goal is to encourage the use of the most effective tool(s) to address water quality protection and restoration efforts. For the past two decades, many TMDLs have been developed in response to litigation. As a result, States and EPA have not always had the opportunity to objectively evaluate whether a TMDL would be the most effective tool to promote and expedite attainment of State water quality standards. With most of their consent decree and settlement agreement TMDLs completed, States and EPA are using their program experience to make more informed decisions about selecting and using the tools that have the best opportunity to restore and protect water quality.

While we do not believe or support the notion that Farmington Bay should be listed on the 303(d) list, we do believe that EPA is correct in calling for adaptive management especially when the water body is as complex as Great Salt Lake or the Farmington Bay component.

Finally, Central Davis supports and has been heavily involved in research on Farmington Bay to better understand the ecosystem and to allow for possible development of water body specific standards when the information available warrants such action. We firmly believe that a thorough understanding of Farmington Bay will answer the questions about appropriate nutrient levels or whether cyanobacteria needs to or can be controlled. While this research is taking place, we believe the adaptive step of 1 mg/L phosphorus is sufficient to protect the Bay and eliminate any further degradation in the next 10-20 years.

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Attachment 1
David Richards Report
“Relationships between Cyanobacteria cell counts, PTOX cell counts, and Nodularin”

Version 1.0

Relationships between Cyanobacteria cell counts, PTOX cell counts, and Nodularin

Technical Memo

June 29, 2016

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Methods

Statistical analyses were conducted to help understand relationships between nodularin concentrations and cyanobacteria and PTOX cell counts from data collected between 2013 and 2105 from Farmington Bay, Great Salt Lake. Several data values needed adjustment. Non-detect nodularin values (N = 30) were assigned values of 0.0125, which was ½ the lowest detected value of 0.025. One raw nodularin value was recorded at 0 and reassigned to a value of 0.0125. An additional nodularin value was recorded as 0.025-0.05 and reassigned to a value of 0.0375. This is a common adjustment procedure but can be more biased than other computationally intensive methods when there are a large number of non-detects. Therefore, results presented are accurate but may not be precise.

The second step was to examine data normality (Gaussian distribution) and then transform, if necessary (Figure 1). Data were not normally distributed and were log(10) transformed (Figure 1).

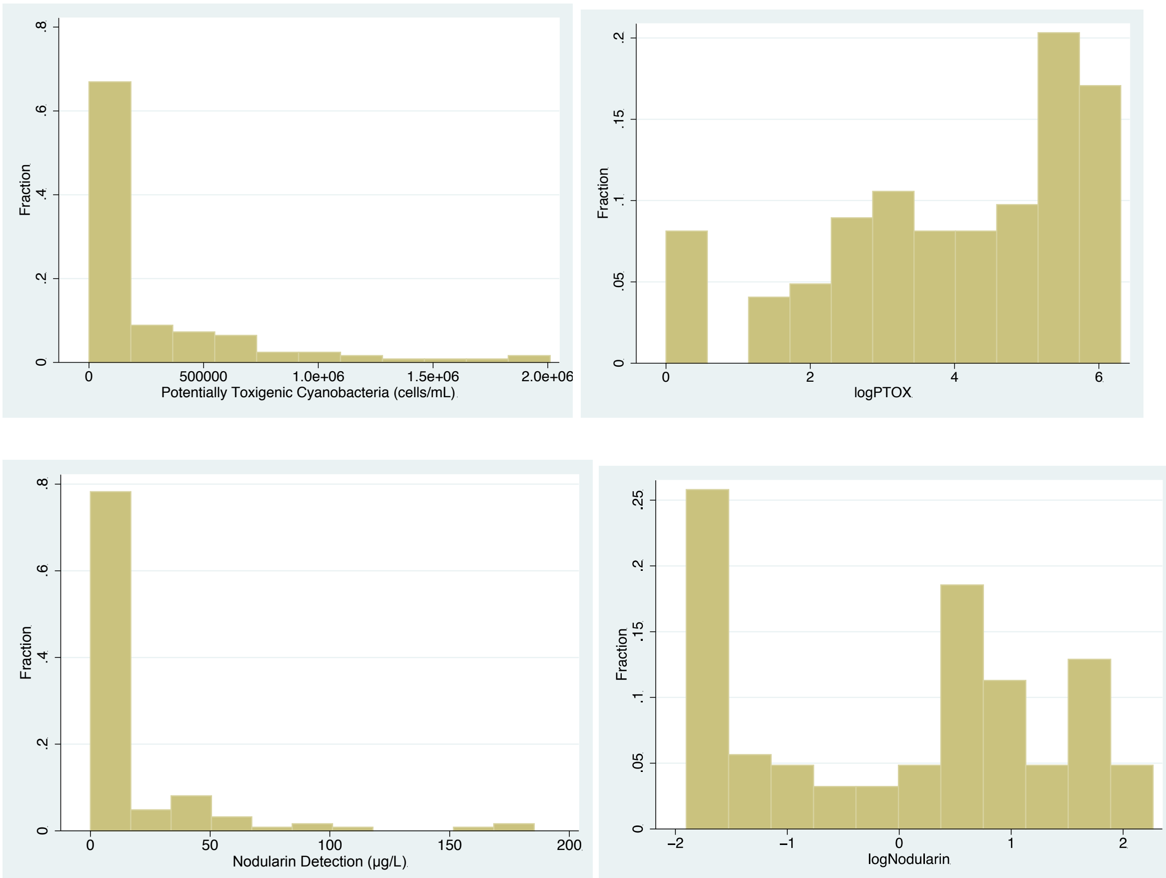

Figure 1.. Data log (10) transformations for Nodularin and Cyanobacteria. Log transformations were also made for PTOX but not illustrated in this figure.

Log transformed data were more normalized than raw data but still not quite normal. Therefore, both ordinary least squares (OLS) regression and simultaneous quantile regressions were performed on the log transformed data. Quantiles regressed were 25th, 50th, and 75th. Simultaneous quantile regression standard errors and 95% CIs for coefficients were estimated by bootstrapping the variance-covariance matrix 1000 times. All statistics were performed in Stata 4.1 for Mac (StataCorp, College Station, TX).

Results

Ordinary Least Squares Regression

There were small to moderate significant relationships between: nodularin concentration vs. PTOX cell counts (Figure 2); nodularin concentration vs. cyanobacteria cell counts (Figure 3); and PTOX cell counts vs. cyanobacteria cell counts (Figure 4).

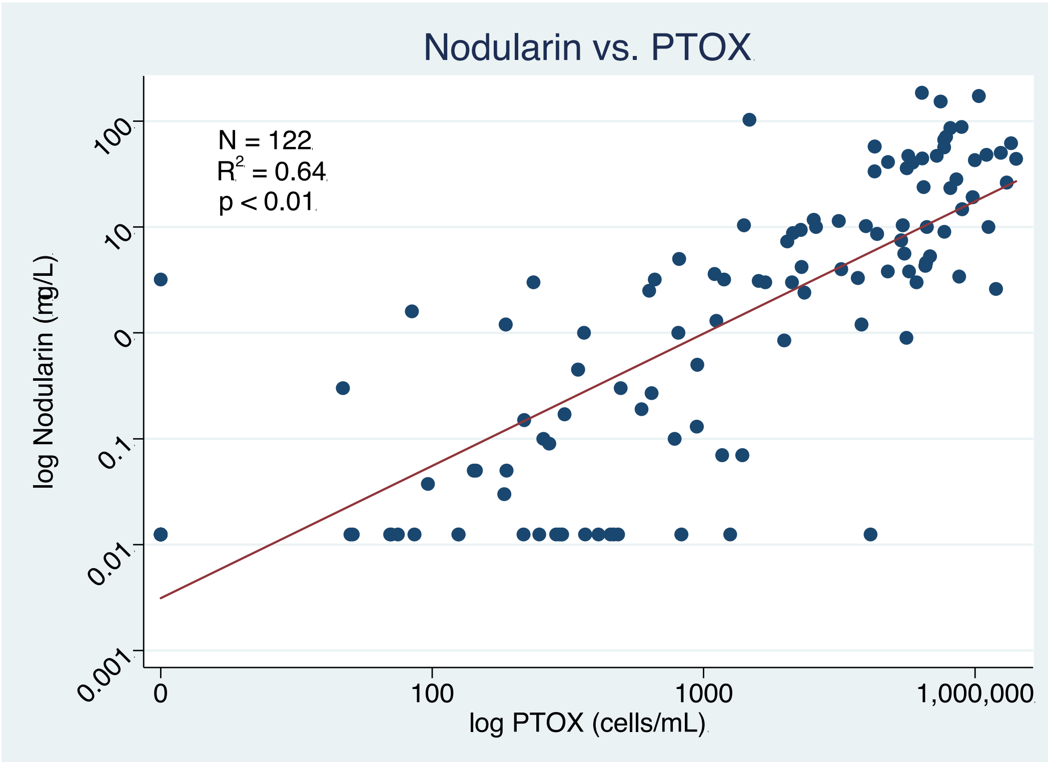

Figure 2. Relationship between nodularin (ug/L) and PTOX (cells/mL) in Farmington Bay, Great Salt Lake.

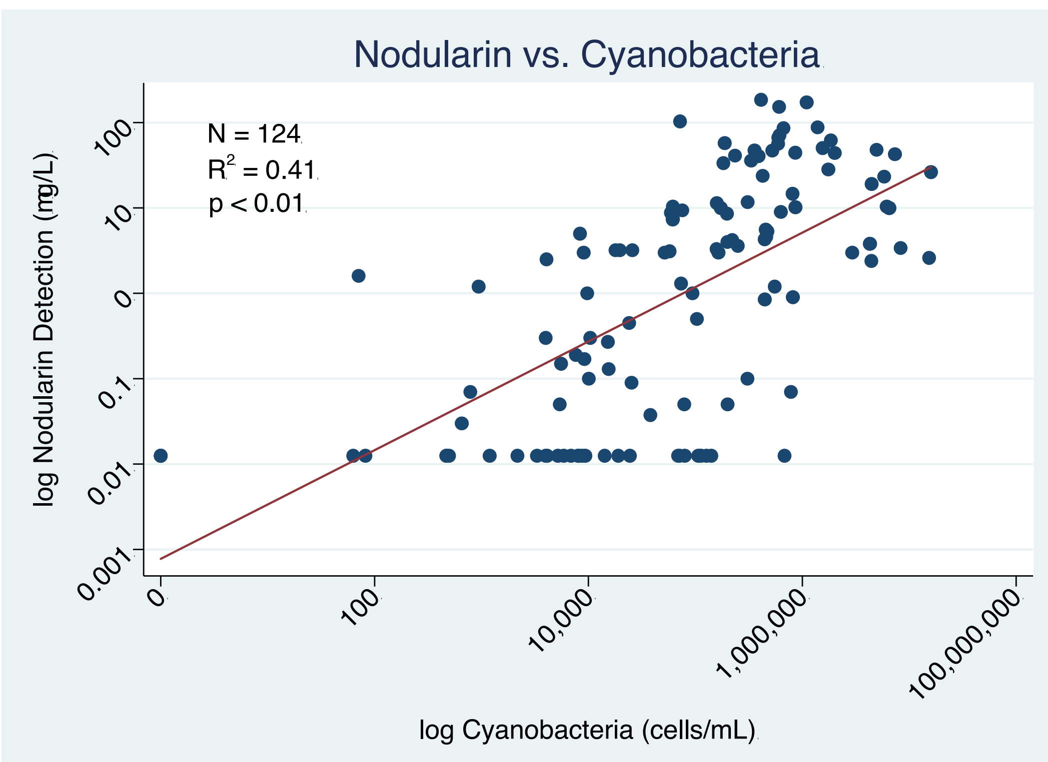

Figure 3. Relationship between nodularin (ug/L) and cyanobacteria (cells/mL) in Farmington Bay, Great Salt Lake.

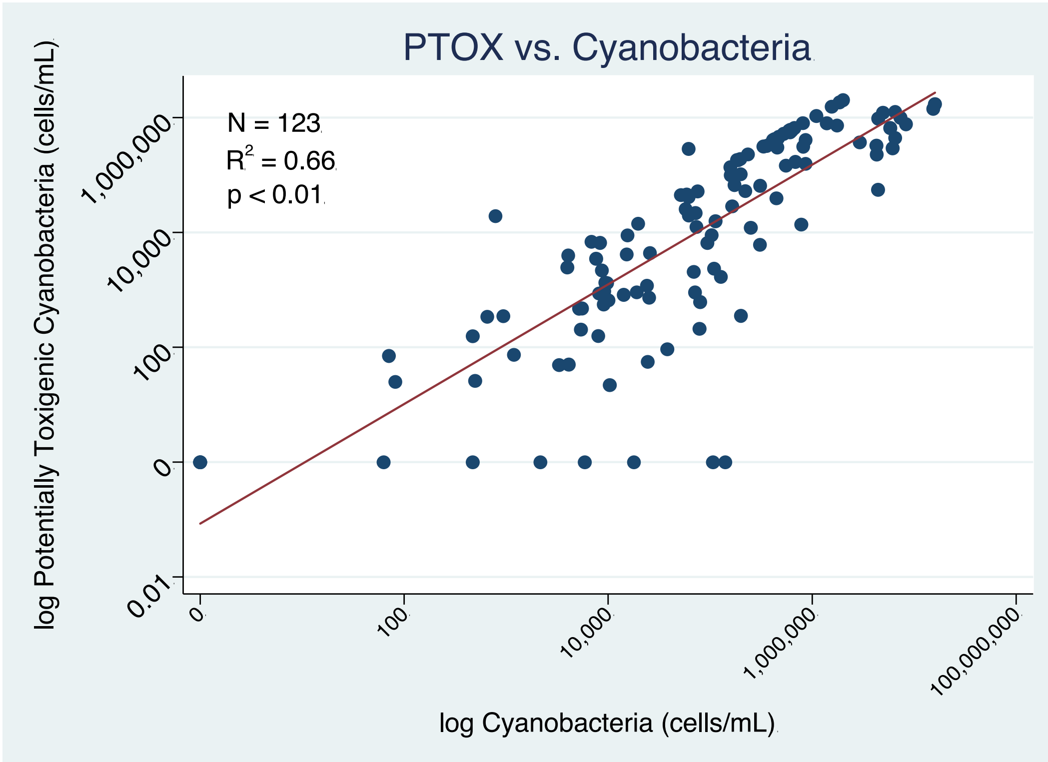

Figure 4. Relationship between PTOX (cells/mL) and cyanobacteria (cells/mL) in Farmington Bay, Great Salt Lake.

PTOX and Cyanobacteria varied seasonally and there was a slight but significant decreasing trend from 2013 to 2015 (Figure 5).

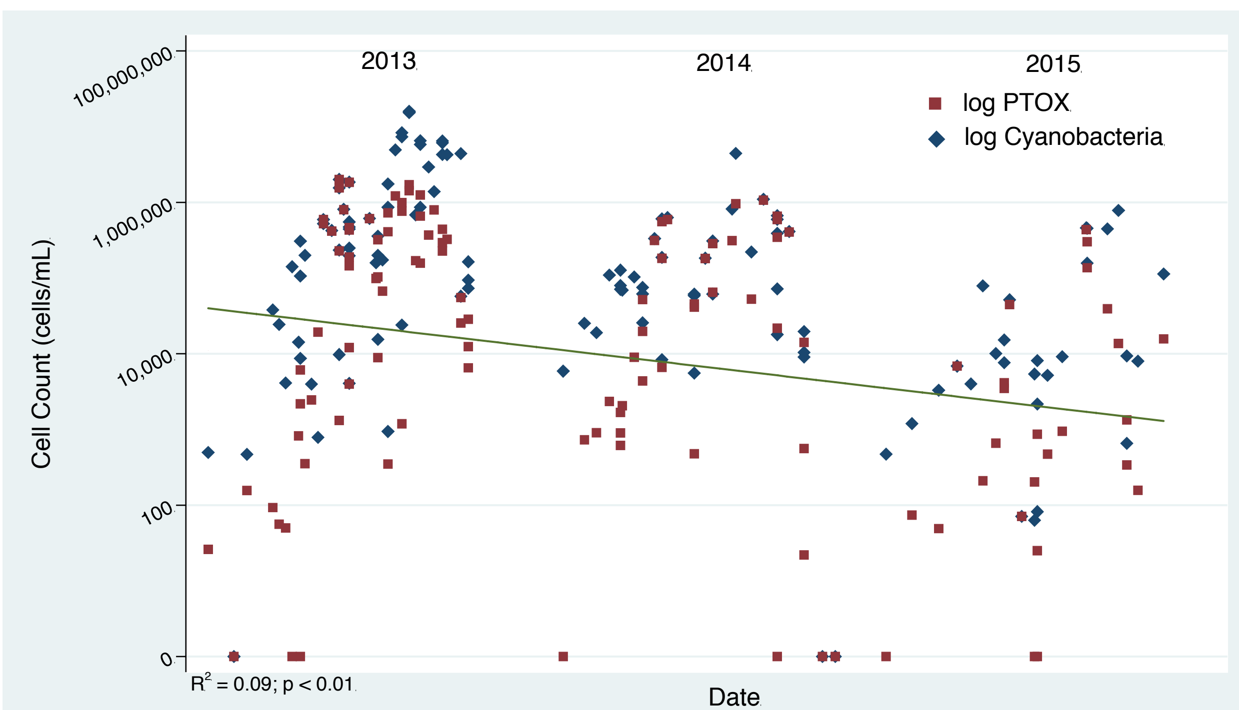

Figure 5. Changes in PTOX and cyanobacteria over time (2013-2015) in Farmington Bay, Great Salt Lake.

Nodularin non-detect values

Nodularin non-detect values (< 0.025ug/L) (N = 30 or 24% of data) occurred under a wide range of cyanobacteria and PTOX values (Figures 6 and 7). Therefore, in many instances nodularin concentration was not related to cyanobacteria or PTOX cell counts.

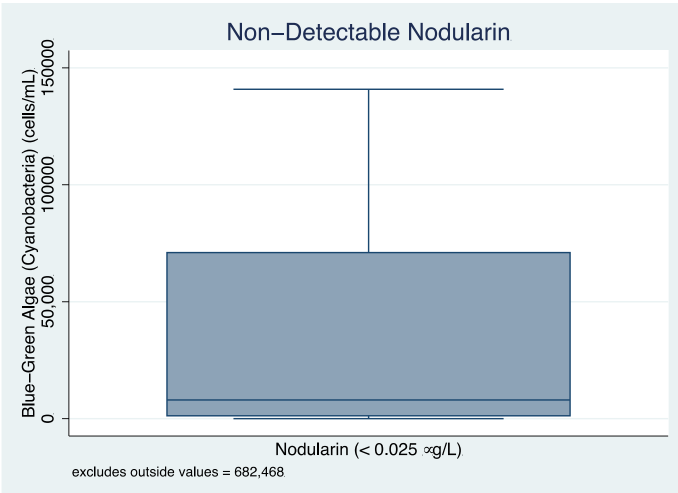

Figure 6. Range of cyanobacteria cell counts to non-detectable nodularin concentrations (< 0.025 ug/L).

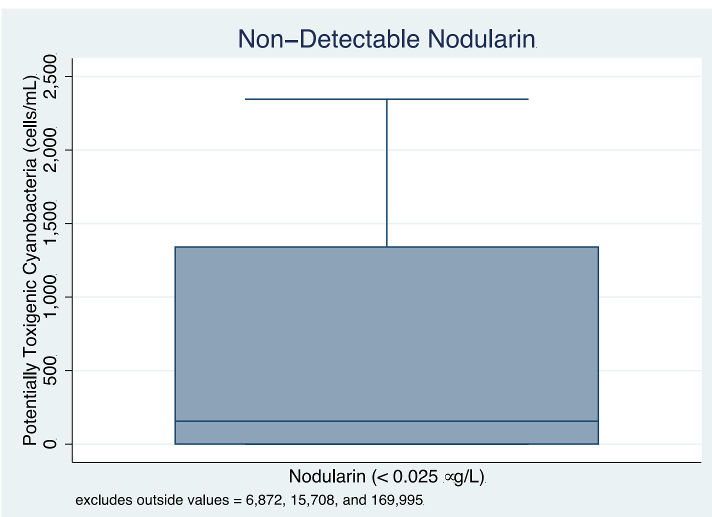

Figure 7. Range of PTOX cell counts to non-detectable nodularin concentrations (< 0.025 ug/L).

Nodularin values recorded as non-detect suggests a poor relationship between nodularin and the other variables at low levels and likely contributed to the relatively fair to poor OLS regression fits.

Quantile Regression

Nodularin vs. Cyanobacteria

There were no significant differences between OLS regression model and any of the three quantile regressions for log Nodularin vs. log Cyanobacteria (Table 1). The OLS regression model was not useful for predicting the intercept at low and high quantiles and nodularin concentrations near the non- detect levels (Figure 9).

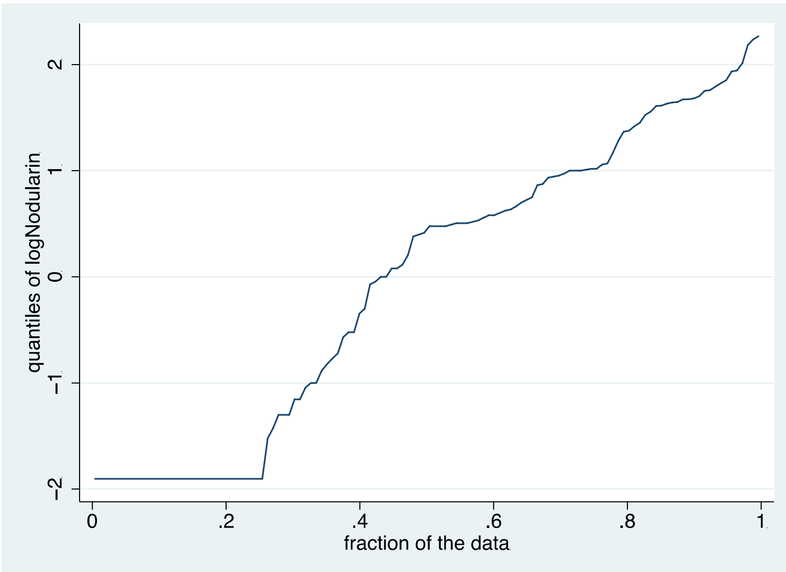

Figure 8. Quantile regression plot for log Nodularin vs. log cyanobacteria

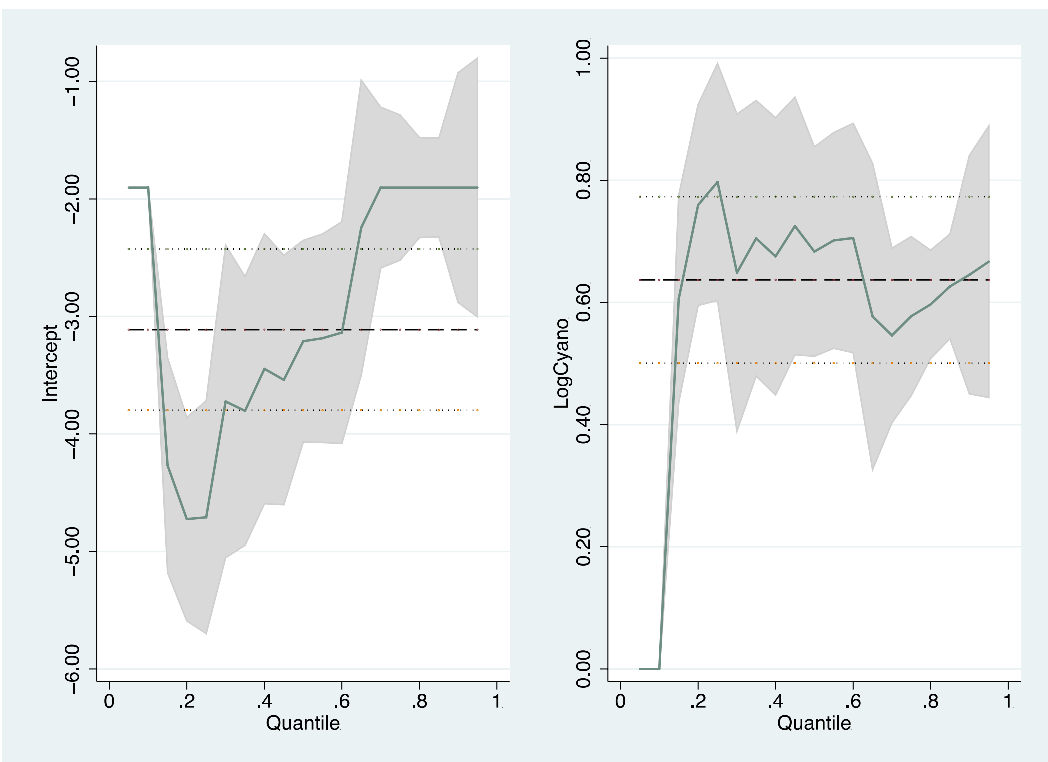

Figure 9. Quantile regression diagnostic plots for log Nodularin vs. log Cyanobacteria. Dashed parallel lines are OLS fit line with 95% CIs and solid line with gray shading is quantile regression fit lines and 95% CIs.

Table 1.

OLS regression

```
. regress logNodularin LogCyano
```

Source	SS	df	MS
Model	98.1189224	1	98.1189224
Residual	139.978228	122	1.14736252
Total	238.09715	123	1.93574919

Number of obs	=	124
F(1, 122)	=	85.52
Prob > F	=	0.0000
R-squared	=	0.4121
Adj R-squared	=	0.4073
Root MSE	=	1.0712

logNodularin	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
LogCyano	.6370475	.0688883	9.25	0.000	.5006761	.7734188
_cons	-3.112014	.3463567	-8.98	0.000	-3.797662	-2.426366

Simultaneous quantile regression

Simultaneous quantile regression
bootstrap(1000) SEs

Number of obs	=	124
.25 Pseudo R2	=	0.2182
.50 Pseudo R2	=	0.2710
.75 Pseudo R2	=	0.2463

logNodularin	Coef.	Bootstrap Std. Err.	t	P>|t|	[95% Conf.	Interval]
q25						
LogCyano	.7973322	.1083959	7.36	0.000	.5827517	1.011913
_cons	-4.708829	.5723678	-8.23	0.000	-5.841888	-3.57577
q50						
LogCyano	.6833206	.1046454	6.53	0.000	.4761646	.8904766
_cons	-3.210838	.5498299	-5.84	0.000	-4.299282	-2.122395
q75						
LogCyano	.5776766	.0959882	6.02	0.000	.3876584	.7676948
_cons	-1.90309	.4980563	-3.82	0.000	-2.889042	-.9171377

Nodularin vs. PTOX

There were no significant differences between OLS regression model and any of the three quantile regression models for log nodularin vs. log PTOX (Table 2). The OLS regression model over predicted the intercept up to about the 0.4 quantile and underestimated the intercept above approximately the 0.6 quantile (Figure 10). The OLS model also was a poor fit for nodularin values below the 0.2 quantile (Figure 10).

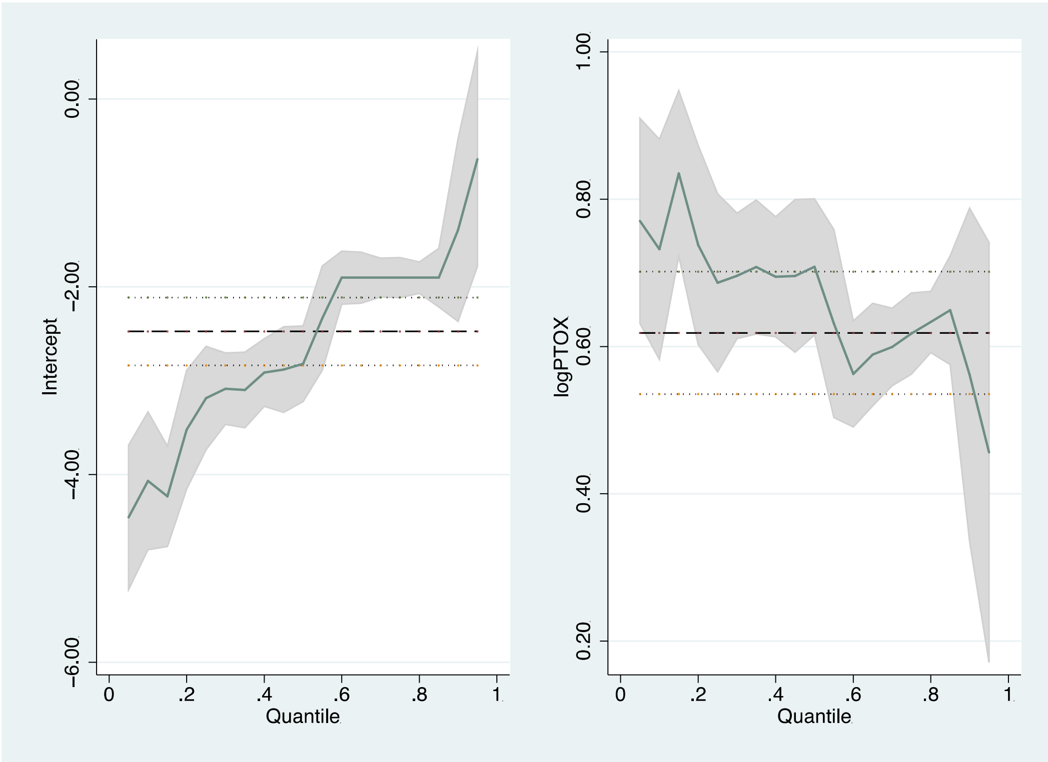

Figure 10. Quantile regression diagnostic plots for log Nodularin vs. log PTOX. Dashed parallel lines are OLS fit line with 95% CIs and solid line with gray shading is quantile regression fit lines and 95% CIs.

Table 2. OLS and quantile regression results for log Nodularin vs. log PTOX

OLS regression

```
. regress logNodularin logPTOX

      Source |       SS           df       MS      Number of obs   =       123
-------------+----------------------------------   F(1, 121)       =    216.98
       Model |  150.598808         1  150.598808   Prob > F        =    0.0000
    Residual |   83.980474       121  .694053504   R-squared       =    0.6420
-------------+----------------------------------   Adj R-squared   =    0.6390
       Total |  234.579282       122    1.922781   Root MSE        =     .8331

------------------------------------------------------------------------------
logNodularin |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
     logPTOX |   .6184521   .0419848    14.73   0.000     .5353321     .701572
       _cons |  -2.476271   .1828946   -13.54   0.000    -2.838359   -2.114183
------------------------------------------------------------------------------
```

Simultaneous quantile regression results.

```
Simultaneous quantile regression                    Number of obs =        123
  bootstrap(1000) SEs                               .25 Pseudo R2 =     0.4312
                                                    .50 Pseudo R2 =     0.4670
                                                    .75 Pseudo R2 =     0.4454
```

logNodularin	Coef.	Bootstrap Std. Err.	t	P>|t|	[95% Conf.	Interval]
q25						
logPTOX	.6863908	.07956	8.63	0.000	.5288808	.8439008
_cons	-3.186113	.4128743	-7.72	0.000	-4.003507	-2.36872
q50						
logPTOX	.7080812	.0849294	8.34	0.000	.539941	.8762215
_cons	-2.819815	.4242681	-6.65	0.000	-3.659765	-1.979864
q75						
logPTOX	.6175137	.0241815	25.54	0.000	.5696402	.6653873
_cons	-1.90309	.0955353	-19.92	0.000	-2.092227	-1.713953

PTOX vs. Cyanobacteria

There were no significant differences between OLS regression model and any of the three quantile regressions for log PTOX and log cyanobacteria (Table 3). The OLS regression model over predicted the intercept up to about the 0.2 quantile Figure 12). The OLS model also underestimated PTOX values below the 0.2 quantile (Figure 12).

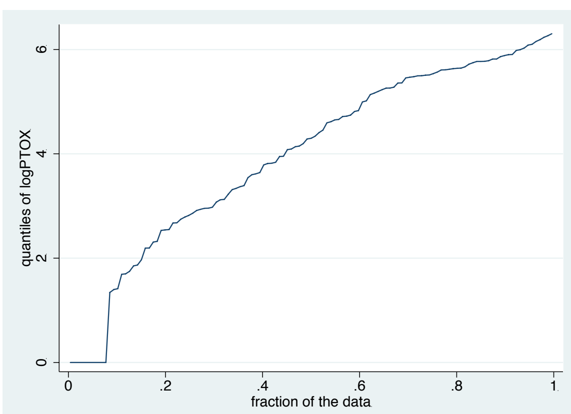

Figure 11. Quantile regression plot for log PTOX vs log cyanobacteria

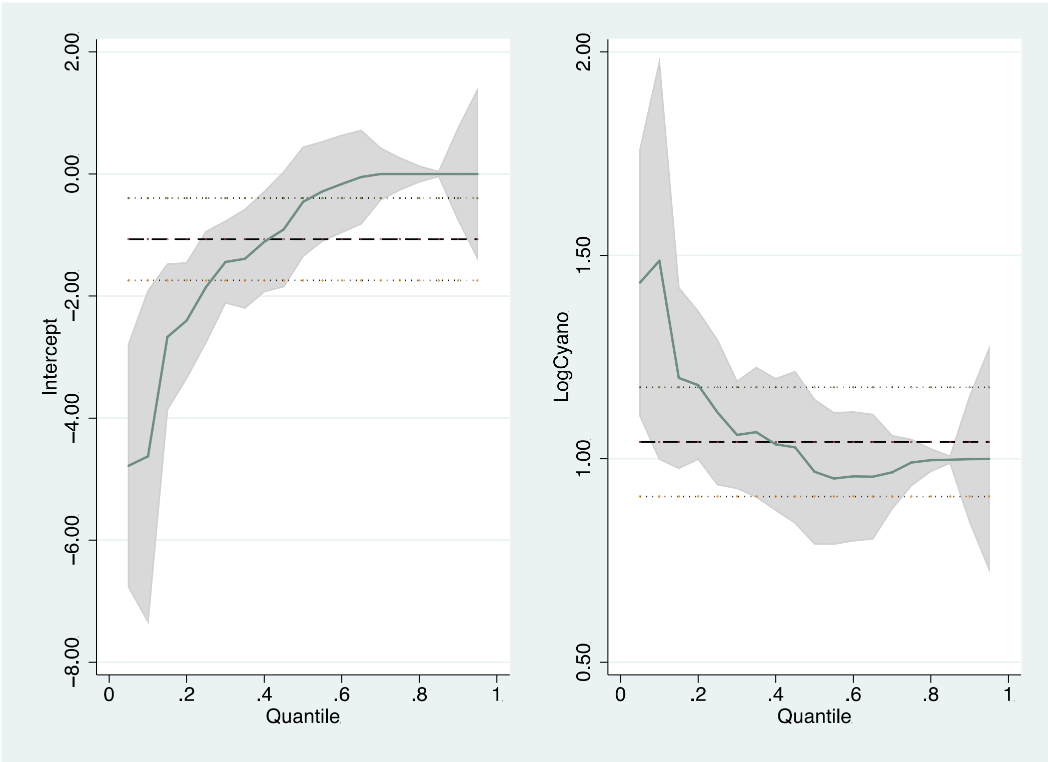

Figure 12. Quantile regression diagnostic plots for log PTOX vs. log cyanobacteria. Dashed parallel lines are OLS fit line with 95% CIs and solid line with gray shading is quantile regression fit lines and 95% CIs.

Table 3.

```
. regress logPTOX LogCyano
```

Source	SS	df	MS
Model	260.610081	1	260.610081
Residual	133.129849	121	1.10024669
Total	393.739931	122	3.22737648

Number of obs	=	123
F(1, 121)	=	236.87
Prob > F	=	0.0000
R-squared	=	0.6619
Adj R-squared	=	0.6591
Root MSE	=	1.0489

logPTOX	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
LogCyano	1.04151	.0676726	15.39	0.000	.9075339	1.175485
_cons	-1.069074	.3409171	-3.14	0.002	-1.744009	-.3941388

```
Simultaneous quantile regression                    Number of obs =        123
  bootstrap(1000) SEs                               .25 Pseudo R2 =     0.4532
                                                    .50 Pseudo R2 =     0.5015
                                                    .75 Pseudo R2 =     0.5100
```

logPTOX	Coef.	Bootstrap Std. Err.	t	P>|t|	[95% Conf. Interval]	
q25						
LogCyano	1.113839	.0783115	14.22	0.000	.9588007	1.268877
_cons	-1.849789	.4858849	-3.81	0.000	-2.811727	-.8878521
q50						
LogCyano	.9684	.1116398	8.67	0.000	.7473796	1.18942
_cons	-.4553972	.5930191	-0.77	0.444	-1.629435	.7186405
q75						
LogCyano	.9909636	.0494586	20.04	0.000	.8930473	1.08888
_cons	-8.88e-16	.259706	-0.00	1.000	-.5141564	.5141564

Conclusion

Given the relatively poor fit of the OLS model and diagnostics, it appears that cyanobacteria cell counts are a mediocre, at best, metric for estimating nodularin concentrations, especially at lower and upper nodularin concentrations. This was also the mostly the case for PTOX as a predictor of nodularin concentration and for cyanobacteria as a predictor of PTOX, particularly at lower concentrations and cell counts.