September 8, 2016

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Submitted via email: jamesharris@utah.gov

Mr. Harris:

On behalf of FRIENDS of Great Salt Lake, Wasatch Audubon, Great Salt Lake Audubon, Utah Audubon Council, Utah Waterfowl Association, League of Women Voters of Utah, South Shore Wildlife and Wetland Management, and Utah Chapter of the Sierra Club (collectively "Friends"), thank you for the opportunity to submit comments on the draft 2016 Integrated Report (2016 IR). We'd like to express our appreciation for all of the thought and hard work that has gone into this draft, and we view this document as a clear indication that the Utah Division of Water Quality (DWQ) is willing to take whatever actions it deems scientifically necessary to protect Utah water, and especially Utah Lake and Great Salt Lake, from the effects of excess nutrient loading. FRIENDS supports you in that effort. To that end, FRIENDS has asked Dr. Wayne Wurtsbaugh (report attached as Exhibit A) and Dr. Timothy Otten (report attached as Exhibit B) to comment on aspects of the draft 2016 IR. Additionally, we are including declarations from two Utah Airboat Association members that outline the extent of their recreational use of Farmington Bay and how that use is negatively influenced by the growing algal blooms in Farmington Bay.

Dr. Wurtsbaugh's Analysis of the 2016 IR

By way of executive summary, Dr. Wurtsbaugh's analysis of the draft 2016 IR suggests:

1) DWQ's approach for listing lakes as impaired due to toxic cyanobacterial blooms is appropriate.
2) Clarification is needed on how the manner of field collection (e.g. normal limnological sampling versus targeted collections of bloom scums) relates to the WHO guidelines that DWQ wishes to use. Additional information is needed in the report to clarify that it is "toxic" cyanobacteria, and not all cyanobacteria, that are of concern.
3) Although the use of toxic cyanobacterial cell densities is currently the most realistic metric to be used as a criterion for listing, DWQ needs to increase its capability to quickly and accurately measure toxin concentrations from these blooms, as this will provide a much more proximal measure of public health threat.

4) Although microcystin is one of the most widely occurring cyanotoxins, and is focused on in the 303d report, additional criteria need to be developed by DWQ for other cyanotoxins (e.g. anatoxins).
5) Toxic cyanobacterial blooms in both Utah Lake and Farmington Bay present threats to human health, and thus warrant 303(d) listing as impaired waters. The very high reported values in Farmington Bay are actually a conservative measure, because that sampling did not target cyanobacterial scums, which are the basis for the proposed criteria (following the WHO's protocols). Outflow waters from Farmington Bay also are a threat to bathers at a popular swimming beach at Antelope Island State Park.
6) Comparison of large algal concentrations in Farmington Bay with more moderate ones in Bear River Bay suggests that the extensive waste water discharges into Farmington are the cause of the cyanobacterial blooms there. More comparative studies on these two bays will be helpful for understanding the toxic cyanobacterial blooms, but such studies will need to be done after (or when), the lake rises and refills the bays with water.
7) More work is needed to understand the cyanobacteria produced in the benthic region of Farmington and Bear River Bays, and the importance of the biota in that region for fish and birds.
8) Although human health risk is the focus of the current Integrated Report, eutrophication in Farmington Bay also presents risks to aquatic biota. Additionally, eutrophication-related odor problems in Farmington Bay fail to meet DWQ's criteria for this parameter.

Outlined in detail below is a summary of the report by Dr. Wurtsbaugh:

Regarding the 2016 303(d) assessment methods, Dr. Wurtsbaugh notes that several clarifications of terms and statements found in Chapter 2 of the 2016 IR are warranted. Specifically, he:

1. Seeks clarification of terms "pollutants," "pollution impairments," (Wurtsbaugh at 1) and "conventionals." *Id*. at 3.
2. Notes the lack of clarity on how Farmington Bay is being assessed. *Id*. at 1.
3. Notes that the State should clarify that toxic cyanobacteria are the constituents of concern in these algae blooms and that the State should include more proximal measures of health threats than is supplied by raw densities of cyanobacteria alone. *Id*. at 1-2.
4. Notes that the standard used by State should specify the type of day that samples are collected and that the State should consider deploying recording sondes that can measure oxygen, temperature and pH at one-hour or less intervals in its sampling procedures. *Id*. at 2.
5. Notes that DWQ should clarify whether the TN:TP ration is in molar or weight units. *Id*. at 2.
6. Seeks clarification on the plot depicted in Figure 18. *Id*. at 2.
7. Seeks clarification of the type of cyanobacteria referred to on Page 71 of Chapter 2. *Id*. at 3
8. Requests that DWQ add language regarding the calibration of oxygen probes in hypersaline waters. *Id*. at 3.

9. And requests that the State add language regarding the percent recovery of internal spikes because of the potential interferences with sampling in Great Salt Lake. Id. at 3.

Regarding Chapter 5, Narrative Standard Assessment of Recreational Use Support in Lakes and Reservoirs and Application to Utah Lake, it is critical that the 2016 IR link the appropriate methodology of collection with the criteria being proposed. *Id*. at 3. Specifically, clarification is needed on how the manner of field collection (e.g. normal limnological sampling versus targeted collections of bloom scums) relates to the WHO guidelines that DWQ wishes to use. This is important because normal limnological sampling involves integrated water column samples – not just surface samples – and because the criteria outlined in Table 1 would not be appropriate with normal limnological sampling. *Id*.

Dr. Wurtsbaugh recommends that DWQ move towards greater use of direct measures of cyanotoxins to supplement cell count data, rather than depending on cell counts alone. *Id*. at 3-4. This is because measuring cyanotoxins provides a more definitive indication of human health threats. *Id*. To that end, additional information is needed in the report to clarify that it is "toxic" cyanobacteria, and not all cyanobacteria, that are of concern. *Id*. at 4.

Regarding the use of microcystin-LR concentrations as a secondary indicator of human health impairment, additional criteria for other cyanotoxins besides microcysin need to be developed by DWQ, especially neural toxins such as anatoxin. *Id*. As an example of why this is necessary, the genus of cyanobacteria found in Utah Lake in July 2016 – Aphanizomenon – is capable of producing anatoxins. *Id*.

Dr. Wurtsbaugh notes that the harmful algal bloom criteria established by the WHO (100,000 cells/ml; 20 µg/L microcystin and 50 µg/L chlorophyll) should be protective of most users, although the majority of states use lower criteria levels. *Id*. And although the use of toxic cyanobacterial cell densities is currently the most realistic metric to be used as a criterion for listing, DWQ should increase its capability to quickly and accurately measure toxin concentrations from these blooms, as this will provide a much more proximal measure of public health threat. *Id*.

Dr. Wurtsbaugh goes on to note that the data related to harmful blooms in Utah Lake is difficult to interpret because the locations where samples were collected are not well depicted. *Id*. These locations should either be depicted on a map, or GPS coordinates should be provided for each site. *Id*.

Dr. Wurtsbaugh states that toxic cyanobacterial blooms in both Utah Lake and Farmington Bay present threats to human health, and thus warrant 303(d) listing as impaired waters. *Id*. at 13. With regard to Utah Lake, the lake is located in one of the fastest growing urban centers in the State and nutrient loading to the lake will continue to increase unless reduction procedures are implemented. *Id*. at 5. While it is fortunate that a phosphorus reduction program is in place, DWQ should also consider nitrogen reduction as well. *Id*. at 6.

Regarding Chapter 6, Evaluation of Harmful Algal Bloom Data in Farmington Bay, Great Salt Lake, Dr. Wurtsbaugh notes that the very high reported values in Farmington Bay are actually a conservative measure, because that sampling did not target cyanobacterial scums, which are the basis for the proposed criteria (following the WHO's protocols). *Id*. at 13. This is because the samples were taken from about .25 meters in depth, along the center axis of the Lake, at routine sampling stations rather than specifically targeting cyanobacterial blooms. *Id*. at 6. Had the blooms been sampled, it is probable that the concentrations found would have been 100 to 1,000 times higher than measured, placing them in the "very high" risk category. *Id* at 7. Thus, he concludes, Farmington Bay has excessive concentrations of toxin producing cyanobacteria. *Id*. Because of these high concentrations, outflow waters from Farmington Bay also are a threat to bathers at a popular swimming beach at Antelope Island State Park. *Id*. at 6.

In comparing the algal concentrations of Bear River Bay with those of Farmington Bay, those in Bear River Bay have never exceeded the WHO criteria for human health effects. *Id*. at 7. Dr. Wurtsbaugh notes that comparative work between the two bays would be useful for understanding how nutrient loading relates to cyanobacterial blooms. *Id*. at 7-8. Regarding whether there have always been large cyanobacterial blooms in Farmington Bay, Dr. Wurtsbaugh concludes that the contrast between Bear River Bay and Farmington Bay suggests that it is the extreme nutrient loading in Farmington Bay that is a primary cause of the cyanobacterial blooms there. *Id*. at 7-8. He states that studies show that cyanobacterial blooms and eutrophication in Farmington Bay have increased substantially since European settlement, in some cases 7 to 12-fold. *Id*. at 9.

Dr. Wurtsbaugh notes that more work is needed to understand the cyanobacteria produced in the benthic region of Farmington and Bear River Bays, citing the importance of the biota in that region for fish and birds. *Id*. at 9-10. And, although human health risk is the focus of this Chapter in the 2016 Integrated Report, eutrophication in Farmington Bay also presents risks to aquatic biota, thus implicating a threat to the protection of "waterfowl, shore birds and other water-oriented wildlife including their necessary food chain." *Id*. at 11; *see also* R317-2-6.5(c) & (d). Finally, Dr. Wurtsbaugh cites the offensive eutrophication-related odor problems in Farmington Bay resulting from the production of hydrogen sulfide in the sediments and deep brine layer of the bay noting that this odor is specific to Farmington Bay. *Id*. at 12.

Dr. Otten's Analysis of the 2016 IR

By way of executive summary, Dr. Otten's analysis of the draft 2016 IR suggests:

1) A well thought out sampling methodology is of critical importance for making accurate assessments of CyanoHAB risks in Utah lakes. Results will be influenced by the time of day and location that samples are collected. As such, it is recommended that depth-integrated samples are collected, and from these the public health risks of a surface scum can be determined (*see* Appendix I of Dr. Otten's analysis).

2) The use of cell counts as a primary indicator is the most conservative approach, because even blooms that do not produce any recognized cyanotoxins would still result in the waterbody's listing on the 303(d). From a public health perspective, it can be argued that this is the safest course of action since cyanobacteria may produce other deleterious compounds besides the five recognized classes of cyanotoxins (anatoxin-a, cylindrospermopsin, microcystin, nodularin and saxitoxin); one example is the neurotoxin BMAA that has been linked to cyanobacteria.
3) The use of 50 µg/L chlorophyll *a* as a meaningful threshold for cyanobacterial bloom risks is arbitrary. In Utah Lake, up to 70% of samples from some regions of the lake would exceed this threshold, even though cyanobacterial blooms are not present 70% of the time based on cell counts. Therefore, in order for chl *a* to be a useful proxy for cyanobacterial biomass, an understanding of "normal" chl *a* concentrations for the waterbody is required. From these data, anomalous chl *a* concentrations (e.g., greater than two standard deviations above the average) could be used to indicate a cyanobacterial bloom event. Further, since all phytoplankton possess chlorophyll, but only cyanobacteria possess the photopigment phycocyanin, the latter is likely a more useful proxy for cyanobacterial biomass.
4) In addition to cell counts, water quality managers should have the option to use cyanotoxins or QPCR assessments of toxigenic cyanobacteria as primary indicators of water quality impairment. The latter two are desirable because they are amenable to high throughput processing and can generally return results in a more timely fashion (e.g., days as opposed to weeks).
5) Regarding cyanotoxin thresholds, the report needs to specify the concentrations for each of the five classes of cyanotoxins that would constitute an exceedance. The WHO criteria only says that 20 ppb is a suitable health threshold for microcystins, not the other toxins. Other states have developed thresholds for these other toxins and these could be used as a starting point for developing such standards in Utah.
6) The guidance document should clarify that only potential toxin-producing genera of cyanobacteria are to be included in the cell count assessments.

Outlined in detail below is a summary of the report by Dr. Otten:

Dr. Otten cites what he calls compelling evidence that Utah Lake has become increasingly eutrophic over the past 10-20 years. Otten at 1. The trophic indicators for Utah Lake during the summer months over the past two decades are all increasing and this trend is likely due to a combination of anthropogenic and climatic factors – both of which are expected to intensify in the future. *Id*. at 1-2. Prior to the massive cyanobacterial bloom in July 2016, June 2016 was the hottest June on record for the U.S., part of a growing pattern of 14 straight months of high record temperatures. *Id*. at 2. Dr. Otten states that it is likely that nitrogen plays an important role in controlling algal bloom proliferation in Utah Lake and that water temperatures and decreased snow pack due to climate change are likely to enhance cyanobacterial utilization of lake nutrients. *Id*. at 3. As a result, a dual nitrogen and phosphorus reduction strategy may be necessary in order to reach the water quality goals necessary to remove Utah Lake from the

303(d) list for cyanobacterial impairment and/or chlorophyll *a*. *Id*. In order to determine the appropriate nutrient reduction targets, nutrient dilution bioassays will be necessary. Id.

Dr. Otten states that cell counts as a primary indicator, as opposed to direct measurements of cyanotoxins, is a more conservative approach, because not all cyanobacteria are capable of producing toxins. *Id*. at 3-4. From a public health perspective, it can be argued that this is the safest course of action because cyanobacteria may produce other deleterious effects upon exposure. *Id*. at 4, 8. He therefore concurs with Utah DWQ's reliance on 100,000 cyanobacterial cells/mL as representative of a human health risk. *Id*. at 4. He points to health effects being linked to "nontoxic" blooms in Utah Lake, with over 100 people reporting common cyanobacterial exposure symptoms such as vomiting, diarrhea, headaches and rashes follow recreation contact. *Id*. In addition to cell counts, water quality managers should have the option to use cyanotoxins or QPCR assessments of toxigenic cyanobacteria as primary indicators of water quality impairment. *Id*. at 8. The latter two are desirable because they are amenable to high throughput processing and can generally return results in a more timely fashion (e.g., days as opposed to weeks). *Id*.

Dr. Otten notes that while he supports DWQ's cell count criteria, the sampling methodology outlined in the 2016 IR is not clearly discussed. *Id*. at 5. He notes that a well thought out sampling methodology is of critical importance for making accurate assessments of CyanoHAB risks in Utah lakes and the results will be influenced by the time of day and location that samples are collected. *Id*. at 5, 8. For that reason, he recommends that depth-integrated samples be collected, and that from these samples the public health risks of surface scum be determined. *Id*. at 5-6, 8.

Dr. Otten goes on to note that the manner in which the secondary indicators of total cyanotoxin and total chlorophyll *a* are intended to be used is unclear, and he outlines a number of possible scenarios for DWQ to consider. *Id*. at 7. For instance, he feels that the use of 50 µg/L chlorophyll *a* as a meaningful threshold for cyanobacterial bloom risks is arbitrary. *Id* at 7-8. The reason for this is that in Utah Lake up to 70% of samples from some regions of the lake would exceed this threshold, even though cyanobacterial blooms are not present 70% of the time based on cell counts. *Id*. Therefore, in order for chlorophyll *a* to be a useful proxy for cyanobacterial biomass, an understanding of "normal" chlorophyll *a* concentrations for the waterbody is required. *Id*. From these data, anomalous chlorophyll *a* concentrations (e.g., greater than two standard deviations above the average) could be used to indicate a cyanobacterial bloom event. *Id*. Further, since all phytoplankton possess chlorophyll, but only cyanobacteria possess the photopigment phycocyanin, the latter is likely a more useful proxy for cyanobacterial biomass. *Id*.

Dr. Otten states that the 2016 IR should specify the concentrations for each of the five classes of cyanotoxins that would constitute an exceedance, noting that other states have developed thresholds for these toxins that might be used as a starting point for developing these

criteria. *Id*. He concludes by stating that the 2016 IR should clarify that only potential toxin-producing genera of cyanobacteria are to be included in the cell count assessments.

Comments regarding airboat use in Farmington Bay

Attached are declarations by R. Jefre Hicks (Exhibit C) and Kerry McCloud (Exhibit D) which outline in detail the extent of the recreational use of Farmington Bay. As is evidenced in these declarations, while there is some usage of Farmington Bay in the summer months, there is a great deal of airboat usage beginning in the middle of September each year. Both Mr. Hicks and Mr. McCloud are aware of significant algal blooms in the Bay, and their enjoyment of Farmington Bay is impacted because both are concerned about the possible health impacts of these blooms.

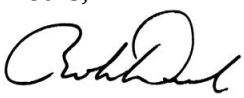
Mr. Hicks is a member of several organizations that are concerned about the health of the ecosystem of Great Salt Lake, including water quality. Those organizations are Utah Airboat Association, Friends of Great Salt Lake, Utah Waterfowl Association, and Delta Waterfowl. Hicks Decl. at ¶ 2. Mr. Hicks owns an airboat that he uses on a frequent basis in Farmington Bay, approximately 40 times annually. *Id*. at ¶ 3. While the majority of that usage occurs between September 15 and the end of March, he does go out in Farmington Bay during the summer months, including 5 trips so far this summer. *Id*. While access to Farmington Bay is limited during the summer months, the access gate is unlocked beginning September 15th of each year. *Id*. at ¶ 4. Once the gate is open, Mr. Hicks estimates that approximately 10 boats per day launch into Farmington Bay. *Id*. This summer, while out on Farmington Bay, Mr. Hicks has witnessed huge algal mats, covering multiple acres, especially near "stinky," the discharge point into Farmington Bay for the sewer treatment plant north of Salt Lake City. *Id*. at ¶ 5. Mr. Hicks notes that the algal blooms are not limited to summer months; these blooms sometimes linger well into October. *Id*. at ¶ 6. While much of the algae washes off as the boat goes through the water, some of the algae flies up onto the boat or becomes airborne as a fine mist. *Id*. at ¶ 7. Because of the recent publicity regarding algal blooms, Mr. Hicks has become concerned about the possible health impacts of the algae present in Farmington Bay. *Id*. at ¶ 8.

Mr. McCloud is President of the Utah Airboat Association and owns an airboat which he mainly uses in Farmington Bay. McCloud Decl. at ¶¶ 2-3. He estimates that he uses his airboat in Farmington Bay approximately 20 times annually, primarily between September 15 and the end of March each year. *Id*. at ¶ 3. Mr. McCloud does go out in the summer months in Farmington Bay, including twice so far this year. *Id*. Mr. McCloud agrees with Mr. Hicks that once the gates open during the middle of September, approximately 10 airboats per day use Farmington Bay. *Id*. at ¶ 4. He also agrees with Mr. Hicks that large algal blooms were evident this summer and that the blooms cover multiple acres. *Id*. at ¶ 5. These blooms are especially evident in the area of "stinky," as well as up close to Antelope Island. *Id*. After a ride in Farmington Bay in the summer, Mr. McCloud's propeller cage is typically covered with algae and he is also concerned about the toxicity and possible health impacts of these blooms. *Id*. at ¶ 6.

Conclusion

Again, thank you very much for the opportunity to comment on this draft. We appreciate the work that DWQ continues to put into addressing the nutrient issue in Utah waters and we look forward to seeing the final version of the 2016 IR.

Yours,



Rob Dubuc
Attorney for FRIENDS

Exhibit A

Comment on 2016 Integrated Report

Wayne Wurtsbaugh
LimnoVision
North Logan, Utah 84341
August 26, 2016

Mr. Rob Dubuc, Staff Attorney
Western Resource Advocates
Salt Lake City, Utah
rob.dubuc@westernresources.org

Dear Mr. Dubuc;

This letter constitutes my expert opinion regarding the Draft Integrated Report concerning the water quality status of the State's lakes and streams (Division of Water Quality 2016). I have studied eutrophication and toxic algae for over 40 years, and consequently feel qualified to comment on the parts of the document addressing this issue in Utah. Here I give particular emphasis to the assessment methodology proposed by the State for cyanobacterial blooms (Chapter 2), conditions in Utah Lake (Chapter 5), and the water quality conditions in Farmington Bay (Chapter 6) which I have studied extensively.

CHAPTER 2: 2016 303(D) ASSESSMENT METHODS

On pg. 4 of the document there is some confusing terminology that should be better defined: *"Clarification on reporting causes of impairment. EPA requires each impairment to identify a cause. Added additional language on determining cause and sources for pollutants and pollution impairments." Here, "pollutants" and "pollution impairments"* are used without definition. Subsequently (pg. 80), pollutants and pollution are indicated to mean different things ("*Where DWQ can identify that an impairment was not driven by a pollutant, DWQ may consider if the not-supporting assessment was driven solely by pollution versus a pollutant or by an unknown cause.*" (emphasis is mine). It would be good to clarify early on what is meant by these two quite similar terms.

On pg. 26-27 it is unclear here whether Farmington Bay is being assessed as a "lake or reservoir", or as "*Great Salt Lake and Associated Wetlands.*" Farmington Bay is clearly part of Great Salt Lake, but the wording suggests that standards for the lake are only under development. This is subsequently clarified, but the initial reference to the status of Farmington Bay is confusing.

On pg. 60 Table 10 (*World Health Organization thresholds of human health risk associated with potential exposure to cyanotoxins*) lists "cyanobacterial cell counts" for the various degrees of impairment of waters for humans, but what is really meant is "cyanobacteria taxa capable of producing toxins." This is dealt with cryptically on page 17 where it is clear that the document wants to address harmful algal blooms. This is important because bacterial-sized pico-cyanobacteria can be extremely abundant in lakes, yet they are not toxic and do not represent much of the biomass in most systems. For example,

Synechoccus sp., a common non-toxic cyanobacteria has reached 575,000 cells/ml in Farmington Bay, but each of these cells weighed only 0.27 picograms. This compares with the 330 picograms of a cell of the toxic cyanobacterium *Nodularia spumigena*. Consequently, *Synechoccus* weighs only 0.08% of the larger cell. Thus, raw cell counts for cyanobacteria should be clarified as to whether the taxa can be toxic, or non-toxic. Similarly, *Pseudoanabena*, sp. a toxic cyanobacterium weighs only 3 pg/cell, or less than 1% the weight of a *Nodularia* cell (Wurtsbaugh, unpublished information; 2009 data for all taxa). More integrative measures, such as biovolume, biomass, indicative pigments (e.g. phycocyanin), or toxin concentrations will provide a more reliable indication of potential impact or environmental importance than will cell counts alone. Fortunately, many cells of the toxic cyanobacteria (e.g. *Nodularia, Aphanizomenon, Microcystis, Anabaena*) have approximately the same cell size, so cell counts of non-picoplankton often provide relatively similar comparisons. Nevertheless, the State should: 1) clarify that toxic cyanobacteria are the issue of concern, and; 2) move to include more proximal measures of health threats than is supplied by raw densities of cyanobacteria alone.

On pg. 64 where *Oxygen/pH and temperature standards* are described, the standard needs to specify the time of day that samples are collected. This is because there is very high diel (24-hr) variability in oxygen dissolved in the water because of photosynthetic production of O_2 during the day and respiratory uptake at night. In hypereutrophic conditions, such as Farmington Bay, oxygen concentrations can range from 0 at night to supersaturated (>20 mg/L) during the day (Wurtsbaugh et al. 2012). Consequently, single measurements are almost meaningless because they are dependent on what time of the day the samples are collected. Since fish and other organisms live in a water body for 24 hours/day, they are susceptible to the lowest oxygen concentrations and this almost always occur at dawn before photosynthesis has resumed, and before technicians arrive to sample. Consequently, it is desirable to deploy recording sondes that can measure oxygen, temperature and pH at intervals of 1 hour or less in order to obtain useful data.

pH and temperature also can have wide diel fluctuations, and thus are susceptible to the same problem with sampling regimes. Deeper lakes such as shown in Figure 15 of the report are typically more stable than shallow, eutrophic lakes, and daytime measurements may provide a reasonable approximation of oxygen, pH and temperature conditions, but diel changes in these parameters would still be dependent on the trophic status of the system.

On pg. 70 (Table 11) the report should define whether the TN:TP ratio given is in molar or weight units. I believe you've given molar units here, yet the agency rarely works with molar units. Since most water quality data used in the State uses weight units, it would be preferable to use those units when defining the nitrogen:phosphorus ratio.

On pg. 71 (Fig. 18) the Trophic State Index (TSI) is described. I've seen this plot previously, but please verify if it is correct. My understanding of the concept is that the TSI for chlorophyll should equal the TSI for phosphorus IF phosphorus in limiting algal growth. The figure, however, is contrary to that.

On pg. 71 (Phytoplankton community) cyanobacteria are again referred to without clarification. As suggested earlier, the report should refer to "potentially-toxic cyanobacteria" rather than all cyanobacteria.

On pg. 73 please define "conventionals". This is not a common English word.

On pg. 107 where *Data Validation Criteria* (Appendix 6) are described, it would be desirable to add, "Oxygen probes should be calibrated under the full range of salinities expected in the water body." In my experience many probes, including those with membranes and optical sensors, must be calibrated very carefully in the hypersaline waters of Great Salt Lake.

On pg. 107 (Appendix 6) it would be appropriate to add something to the effect that "percent recovery of internal spikes on every xxth field sample ranges from 80 to 120%, and appropriate corrections are made for incomplete recovery." This is particularly important in Great Salt Lake where many interferences are possible. Many laboratories simply use spikes of their standards to determine the accuracy of their measurements, but this is insufficient for unusual waters like Great Salt Lake.

CHAPTER 5: NARRATIVE STANDARD ASSESSMENT OF RECREATIONAL USE SUPPORT IN LAKES AND RESERVOIRS AND APPLICATION TO UTAH LAKE

On pg. 5, Table 1 gives the *WHO recommended thresholds of human health risk for cyanobacteria, microcystin-LR, and chlorophyll a.* It is important to indicate here how the WHO suggests that samples be collected for this criteria. With the WHO's approach, all of the categories in the table would be from surface samples, including those with scums (that people could be exposed to). However, with normal limnological sampling, integrated water column samples, or samples taken below the surface, are usually taken. Consequently, densities measured with normal limnological methods are not appropriately compared with the criteria given in Table 1. It is critical that this report links the appropriate methodology with the criteria being proposed, since surface scums can contain several orders of magnitude higher cell densities than are encountered with integrated water column samples that do not target surface blooms.

Also, as mentioned earlier, "cyanobacteria" is too general of a term, since many taxa are small, very abundant, non-toxic, and beneficial for the food web. Use "toxin-producing taxa of cyanobacteria" instead.

On pg. 10 the use of cyanobacterial cell counts is recommended as the primary indicator of potential harm to human health. As suggested by the World Health Organization (2003), counts of toxic cyanobacteria represent a conservative approach, as high concentrations of these cells can cause skin rashes in a portion of the population, and the blooms may portend the development of more severe toxic situations if water is swallowed. As I suggested earlier, cell counts are not the best indicator of how harmful a bloom might be, and count data is laborious and expensive to obtain. Consequently, I recommend that the State move towards greater use of direct measures of cyanotoxins to routinely supplement count data, because cyanotoxins provide more definitive indications of human health threats. Adoption of either ELISA (enzyme-linked immunosorbent assay) ,HPLC, or molecular (Otten and

Paerl 2015) methodology in the State Laboratory or with collaborating universities or local private companies would provide a more definitive, rapid and economical way of assessing health risks from algal blooms.

On pg. 10 the use of *microcystin-LR concentrations*, a liver toxin, is described as a secondary indicator of human health impairment. Although the microcystin is one of the most widely occurring cyanotoxins, there are other toxins of equal concern. Consequently, additional criteria for these other cyanotoxins need to be developed for the State. In particular, neural toxins such as anatoxin, should be included in the criteria. For example, the genus of cyanobacteria in the July, 2016 HAB in Utah Lake, *Aphanizomenon*, can produce anatoxins, although not all strains are capable of doing so (Ballot et al. 2010; Cires and Ballot 2016; Pearson et al. 2010).

The harmful algal bloom criteria established by WHO (100,000 cells/ml; 20 µg/L microcystin and 50 µg/L chlorophyll) should adequately protect most users, even though most other states use lower levels for their thresholds. However, research on cyanotoxin links with cancer and neural diseases is ongoing, so the State should be prepared to revise these standards downward if additional research identifies and confirms important impacts on human health at lower concentrations.

On pages 12-17 the data for harmful algal bloom assessment in Utah Lake are described. Some of this is difficult to interpret because the sites where samples were collected are not well depicted. All of the sites given in the histogram of Figure 4 should be shown on the map in Fig. 3, or alternatively, GPS coordinates given for each site. In particular, Lindon Harbor with the highest cell densities should be shown on the figure. Also, the locations of the pictures shown in Fig. 5 should be given in the caption. This will be particularly helpful for readers that aren't intimately familiar with the geography of Utah Lake.

On pg. 15 in Ch. 5 the dominant cyanobacterial species shown in Figure 4 should be described in the text or in an appendix. It is important to try to relate the cell densities with the taxa, and finally with the toxin concentrations that are given in Table 2. As described earlier, not all cyanobacteria are equal in size and toxicity, or even with the toxins they produce. Table 2 only list microcystin toxins, so it is likely that *Microcystis* sp. was the dominant taxa, but not necessarily.

With regard to Table 2 (Pg. 17) showing the microcystin sample results from Utah Lake during the October 2014 bloom event it is noteworthy that only a single sample exceeded the WHO cyanotoxin criteria for high human health risk (20 µg/L microcystin) and one other sample exceeded the criteria for moderate risk. However, it is relevant that the revised Assessment Methodology allows for the *"… the evaluation of more recent data outside the period of record such that DWQ will reserve the discretion to integrate the newer information in the current cycle.*" Evaluation of cyanotoxin data from a large *Aphanizomenon* bloom in July 2016 in Utah Lake indicated another large exceedance of the WHO high health risk criteria, but concentrations at most stations were low:

Toxin concentration in Utah Lake during a July 2016 bloom of Aphanizomenon. Data without entries were below levels of detection. EPA Lab data, availabe at DWQ website

Location	Coordinates		Date	Cylindrospermopsin (ug/L)	Microcystin LR (ug/L)
Lindon Harbor			07/14/2016		0.1
Geneva Discharge	40.321	-111.778	07/14/2016		
Geneva Discharge	40.321	-111.778	07/15/2016		
1 MI EAST OF PELICAN POINT	40.268	-111.830	07/14/2016		
1 MI EAST OF PELICAN POINT	40.268	-111.830	07/15/2016		
1 MI WEST OF PROVO BOAT HARBOR	40.237	-111.765	07/14/2016		
1 MI WEST OF PROVO BOAT HARBOR	40.237	-111.765	07/15/2016		
1 MI WEST OF PROVO BOAT HARBOR	40.237	-111.765	07/15/2016		
2 MI E OF SARATOGA SPRINGS #12	40.342	-111.871	07/14/2016		0.1
2 MI E OF SARATOGA SPRINGS #13	40.342	-111.871	07/15/2016		
2.5 MI NE OF LINCOLN POINT #02	40.168	-111.760	07/14/2016		
3 MI WNW OF LINCOLN BEACH	40.170	-111.872	07/14/2016		
3 MI WNW OF LINCOLN BEACH	40.170	-111.872	07/15/2016		
AT MIDDLE OF PROVO BAY	40.189	-111.700	07/15/2016		
GOSHEN BAY MIDWAY OFF MAIN POINT ON EAST	40.085	-111.884	07/14/2016		0.1
OUTSIDE ENTRANCE TO PROVO BAY	40.189	-111.731	07/14/2016		
OUTSIDE ENTRANCE TO PROVO BAY	40.189	-111.731	07/15/2016		
1 MI WEST OF PROVO BOAT HARBOR			07/13/2016		0.2
1 mile W of Airport			07/15/2016		0.1
Lincoln beach			07/15/2016	0.06	1.6
Lincoln Harbor-integrated			07/15/2016		4.1
Lincoln Harbor-surface			07/15/2016		176.0
Lincoln Harbor-surface			07/15/2016		
mouth of Provo Harbor			07/15/2016		1.3
Provo Bay-ski park			07/14/2016		
Sandy Beach			07/15/2016		0.3
Saratorga Spring-private marina			07/15/2016		

Consequently, although blooms have had high cell densities, cyanotoxin concentrations are only serious when surface scums accumulate along the shoreline. However, given that the State has relatively little cyanotoxin data, it is possible that high cell densities and the very high chlorophyll concentrations at some sites on some dates had high toxin concentrations. As indicated above, more intensive and rapid cyanotoxin sampling and analysis is clearly warranted for Utah Lake and other water bodies in the State.

It is important to recognize that Utah Lake is located in one of the fastest growing urban centers in the State, so nutrient loading of nitrogen and phosphorus will continue to increase unless abatement procedures are implemented. This will likely increase cyanobacterial populations. The ongoing carp removal, if successful, will also result in less inorganic turbidity, which will allow more light through the water column, and thus combine with high nutrient levels to promote large harmful algal blooms.

On pg. 23 the immediate management implications of listing Utah Lake as impaired due to HABs is described: "N*o immediate changes to existing permits that discharge nitrogen and phosphorus to the Lake. Such changes would only be required if nutrients are identified as the cause of the impairment and after a TMDL is developed".* It is fortunate that a phosphorus TMDL is already in place and a reduction of phosphorus loading will likely decrease cyanobacterial populations.

Nitrogen reductions, however, should also be considered if wastewater treatment plants are required to re-tool their facilities. Dual nutrient control (P and N) is controversial (e.g. Lewis et al. 2011; Schindler et al. 2008), but there are two strong arguments for considering N reduction as well as P: 1) In a shallow lake such as Utah Lake, releases of residual phosphorus from the sediments will likely fuel cyanobacterial blooms for over a decade once abatement controls are in place, whereas nitrogen is lost from the sediments faster via denitrification and other processes (Jeppesen et al. 2007); 2) whereas some cyanobacteria such as *Aphanizomenon* can fix atmospheric nitrogen and thus partially relieve N-limitation, other important toxin producers such as *Microcystis*, cannot fix nitrogen. Consequently, controlling nitrogen loading along with phosphorus may more effectively control these harmful algal blooms. Research on dual control for Utah Lake would be warranted prior to implementation of nutrient controls for wastewater treatment plants or non-point sources.

CHAPTER 6: EVALUATION OF HARMFUL ALGAL BLOOM DATA IN FARMINGTON BAY, GREAT SALT LAKE

The beneficial use classification for Farmington Bay is: "Infrequent primary and secondary contact recreation, waterfowl, shore birds and other water-oriented wildlife including their necessary food chain," (UAC R317-2-6).

On pg. 7 in the section on Recreational Uses of Farmington Bay the report says: "*One of the primary access points to the waters of Great Salt Lake, Antelope Island Marina, is located on Gilbert Bay right outside the outlet from Farmington Bay and when water levels of Great Salt Lake are higher, the marina is accessible to boaters for airboating, kayaking, paddle boarding, and canoeing."* Although this is true, it is equally important that one of the primary swimming beaches at Great Salt Lake, Bridger Bay, is located just 2.5 miles from the outlet breach of Farmington Bay. I have observed a severe skin reaction of an elementary student who was netting brine shrimp there. It is likely that this reaction was from high concentrations of *Nodularia* that had lysed after flowing out of Farmington Bay. Because the water from Farmington Bay is less dense than that in Gilbert Bay, it forms a surface flow and can easily reach this popular swimming spot. Amoebae containing the potentially pathogenic *Legionella* sp. have also been found at Bridger Bay and in Farmington Bay (Gast et al. 2011). Consequently, the microbial blooms in the Bay should be considered in the wider context of the entire Great Salt Lake.

Comments on pg. 11-13. Cyanobacterial cell counts, chlorophyll and cyanotoxin concentrations

Very high concentrations of cyanobacteria (primarily the toxin-producing *Nodularia*), chlorophyll and cyanotoxins were encountered in the mid- to northern parts of Farmington Bay (Marden et al. 2015; McCulley et al. 2015). These frequently exceeded the World Health Organization's criteria for the probability of "High" public health effects. However, it is crucial to note here that the concentrations these investigators found were measured at 0.25 m depth (ca. 1 foot) along the center axis of the lake at routine sampling stations, and thus did not target cyanobacterial bloom scums that are the focus of the WHO guidelines. Had the researchers intentionally sampled in the surface scums, it is probable that the concentrations found would have been increased 100 to 1000-fold by the formation of surface scums and concentrations of these scums at the shore (World Health Organization 2003, Ch. 5). This would

place the blooms into the "very high" risk category of WHO. Farmington Bay consequently has excessive concentrations of toxin producing cyanobacteria.

Wurtsbaugh et al. (2012) also reported on cyanobacteria in Farmington Bay for four years spanning 2002-2009. These researchers also found very high concentrations of *Nodularia* and the toxin nodularin in the central- to northern parts of the bay even though they also sampled at 0.25-m depth and did not specifically target blooms (Figs. 2, 3). There were 44 exceedances (43%) of the WHO's cell count density criteria for High Health Risk, and 29 exceedances (52%) for cyanotoxins, including one measurement of 663 µg/L. Chlorophyll concentrations averaged 144 µg/L and exceed the WHO High Risk category (50 µg/L) 60 times (82%). These exceedances were more frequent in the Wurtsbaugh et al. (2012) study than in the studies by Marden and McCulley because Wurtsbaugh's group primarily sampled in the mid- to northern-sections of the bay. However, they did do limited transect sampling along the whole bay, and those results were consistent with those of Marden et al. (2015), McCulley et al. (2015) and Goel and Meyers (2009), showing low densities of cyanobacteria in the southern end of Farmington Bay, and high concentrations in the central and northern parts. Salinity was a primary determinant of *Nodularia* abundance, with high densities between 1 and 5%, and low densities outside this range. In fact, the low cyanobacterial and cyanotoxin concentrations in 2007 (Fig. 3) was due to the salinity in the northern part of the bay rising above 5% after May.

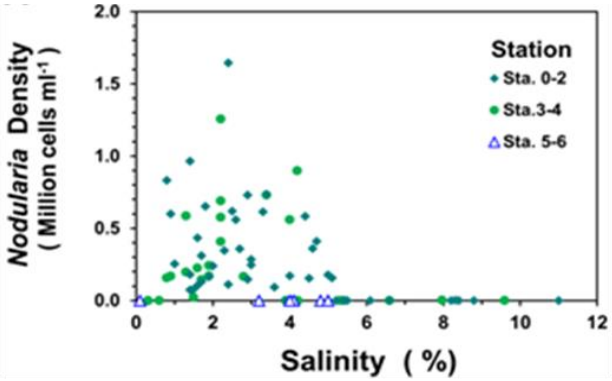


Figure 1. *Nodularia* cell densities in relation to salinity in Farmington Bay (Wurtsbaugh et al. 2012). Stations 0-2 are in the northern area, 3-4 in the central, and 5-6 in the southern part of the bay. Data from Wurtsbaugh et al. 2012.

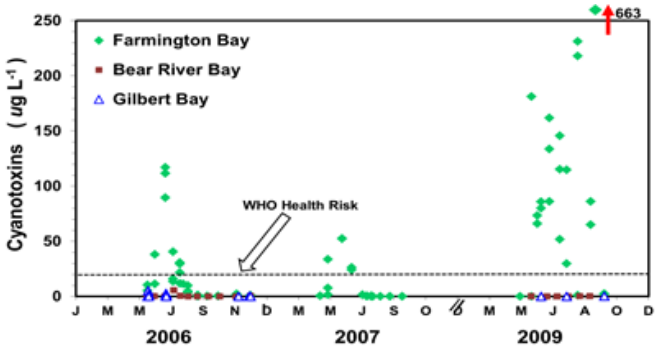


Figure 2. Cyanotoxins (nodularin) measured in three bays of Great Salt Lake in three years. Data from Wurtsbaugh et al. 2012.

It is also important to note that in Bear River Bay or Gilbert Bay cyanotoxin (or cell counts) never exceeded WHO's criteria for high human health effects (Fig. 3). In Gilbert Bay the low density of toxic cyanobacteria is consistent with the very high salinity there. In Bear River Bay, however, the low densities of cyanobacteria and toxins are more likely due to lower nutrient loading there than in Farmington Bay, because salinities in Bear River Bay were frequently in the range where cyanobacteria grow (Wurtsbaugh et al. 2012). More comparative work between Farmington Bay and Bear River Bay

would be useful for understanding the importance of nutrient loading in controlling cyanobacterial blooms.

An analysis of data in the thesis of McCulley (2014) demonstrated that there is a close link between *Nodularia* concentrations in Farmington Bay, and cyanotoxin concentrations (Figure 3). When cell concentrations rose above the World Health Organization's criteria for high public health risk (100,000/ml), microcystin LR equivalent toxin concentrations increased to 3-70 µg/L. Marden et al. (2015) also found a steep increase in cyanotoxin concentrations when *Nodularia* densities exceeded 100,000 cells/ml. Although more data are needed to improve the relationship shown in Figure 3, the information does suggest that using *Nodularia* cell densities is a reasonable alternative to actual measurements of toxin concentrations for assessing public health risk.

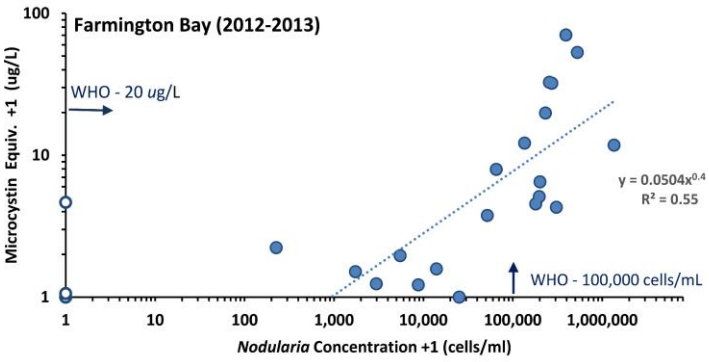


Figure 3. Relationship between *Nodularia* concentrations in Farmington Bay and microcystin equivalent toxin concentrations. HPLC analysis indicated that all of the toxin measured was nodularin. *Nodularia* concentrations of zero (+1 on graph) were not included in the regression. Concurrent *Nodularia* and toxin concentrations were not available for all dates and stations, so the sample size shown here is less than the individual numbers for each of these parameters. Data from McCulley (2014).

Cyanobacterial blooms and recreation in Farmington Bay

Prior to 2008, Farmington Bay was classified for "frequent primary and secondary contact recreation". Subsequent to the documentation of large toxic cyanobacterial blooms in Farmington Bay, it was reclassified to "infrequent contact recreation." In part, this was due to the lack of suitable beaches for swimming in Farmington Bay. Consequently, the degree of impairment for humans rests largely with the amount of use of the bay by the public. I have seen people swimming in Farmington Bay off of the automobile causeway to Antelope Island, despite the signs posted to warn bathers of the danger. However, this use is infrequent. A more frequent use is by air boaters for sightseeing and for hunting. The waterfowl hunting season begins in early October, and thus overlaps with blooms of toxic cyanobacteria in Farmington Bay (Marden et al. 2015). Consequently, hunters and their dogs may be exposed to cyanotoxins in the bay. As noted previously, the outflow of Farmington Bay can also impact bathers at the popular swimming beach at Bridger Bay on Antelope Island State Park.

Paleolimnological and historical analyses of cyanobacteria in Farmington Bay

"Estuaries" such as Farmington Bay are frequently naturally productive, so the question arises whether there have always been large cyanobacterial blooms in the bay. The contrast between Bear River and Farmington Bays suggests, however, that the extreme nutrient loading in Farmington is a primary cause of blooms there.

Paleolimnological analyses of pigments deposited at different depths (i.e. different decades) also suggests that blooms are much more prevalent now than prior to European settlement in the Salt Lake Valley. Sediment core analyses by Leavitt et al. (2012) and (Wurtsbaugh 2012), and a reanalysis of the lead-210 dating of those reports by Cerling (2014) indicate that cyanobacterial blooms and eutrophication in the bay has increased substantially since European settlement. Cyanobacteria pigments characteristic of *Nodularia* have increased 7-fold, and pigments characteristic of all algae have increased 12-fold since settlement (Leavitt et al. 2012). The exact magnitude of the increase in cyanobacteria and other algae is difficult to determine because preservation of these pigments is not complete, but it is clear that Farmington Bay has experienced extensive eutrophication since wastewaters from greater metropolitan Salt Lake City and non-point sources have been discharged there.

The Benthic and Bird Communities in Farmington Bay

Nearly all of the research on the limnology and cyanobacteria in Farmington Bay has focused on the organisms in the water column. However, the benthic (bottom) community of the lake is also extremely important for the functioning of the ecosystem, particularly in a shallow water body like the bay (Vadeboncoeur et al. 2002). For example, in the southern reaches of Farmington Bay where depths in recent years have generally been less than one foot, the abundance of filamentous, benthic algae is striking (Figure 4). It is likely that these benthic periphyton compete for nutrients with the phytoplankton in the water column, and this may be a reason for the lower planktonic chlorophyll and cyanobacteria concentrations there.

Figure 4. Filamentous algae in southern Farmington Bay on July 8, 2010.

The benthic periphyton can also contain cyanotoxins. Although sampling has been very limited, Wurtsbaugh (2011) found a neurotoxin produced by cyanobacteria (anatoxin), in these benthic organisms. One frequently sees plates of benthic biofilm floating in the water column as a consequence of trapped oxygen lifting them off the bottom, so they may also impact swimmers and other biota in the water column. Consequently, much more work needs to be done to sample these benthic habitats.

In a study of Willard Spur (NE Bear River Bay), Hoven et al. (2014) found that it had an order of magnitude lower N and P concentrations than in Farmington Bay, and that submerged aquatic vegetation (macrophytes) were abundant. In experimental studies they also found that the submerged aquatic vegetation in the Spur was negatively impacted by high nutrient additions. High variability in their experimental replicates precluded definitive conclusions about the impact on the macrophytes, but eutrophication is known to severely diminish these important plants (Wetzel 2001), and it may impact them in Farmington Bay as well.

Benthic invertebrates—The production of benthic invertebrates in Farmington and Bear River Bays is also very important, but barely studied. Roberts (2013) found that most of the shorebirds in Great Salt Lake feed on benthic invertebrates, not on the zooplankton that has been extensively studied in Farmington Bay and Gilbert Bay. In a small, preliminary survey, S. Miller of the BLM found that densities of benthic invertebrates in Farmington Bay and Bear River Bays were high, and did not differ substantially, suggesting that the excessive productivity in Farmington Bay is not necessary to produce large quantities of benthic invertebrates. A 2014 transect study of Farmington Bay also showed high densities of benthic invertebrates, but extremely low diversity (Wurtsbaugh et al. 2015). The low diversity of the benthic invertebrates in the bay is another indicator of the severe eutrophication there. However, these studies were very limited, so the influence of eutrophication on the benthic invertebrates needs to be evaluated more extensively.

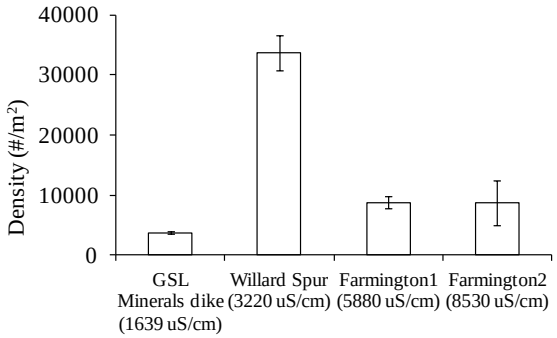


Figure 5. Average macroinvertebrate densities (± SE) at four sites sampled via Ekman grabs in 2010. Three replicates were taken within a ~4 m^2 area. The GSL Minerals sample and Willard Spur sample were from Bear River Bay. Data of Scott Miller, BLM/USU National Aquatic Monitoring Center, Utah State University.

Farmington Bay hosts high densities of shorebirds and waterfowl and the hyper-productivity of the bay has been cited as a reason for this (e.g. Marden et al. 2015). However, Bear River Bay, which has far lower productivity in the plankton community (Wurtsbaugh et al. 2012), has equal or higher numbers of birds than does Farmington Bay (Paul and Manning 2002). Additionally, Wurtsbaugh et al. (2012) found very low densities of birds in the northern part of Farmington Bay underlain by a deep brine layer that contained no oxygen and high concentrations of toxic hydrogen sulfide. These conditions would preclude benthic invertebrates from living there, and this may partially explain the low numbers of birds observed in this region of the bay during that study. The formation of an anoxic deep-brine layer is caused by the intrusion of high-density salt water from Gilbert Bay, and the decomposition of the abundant phytoplankton that sediments into that layer. In another hypereutrophic salt lake (Salton Sea) the release of toxic hydrogen sulfide from the deep layers during windstorms kills plankton and fish (Tiffany et al. 2007) and the same phenomenon may impact organisms in Farmington Bay (Wurtsbaugh et al. 2012).

Effects of eutrophication and cyanobacterial blooms on the aquatic community

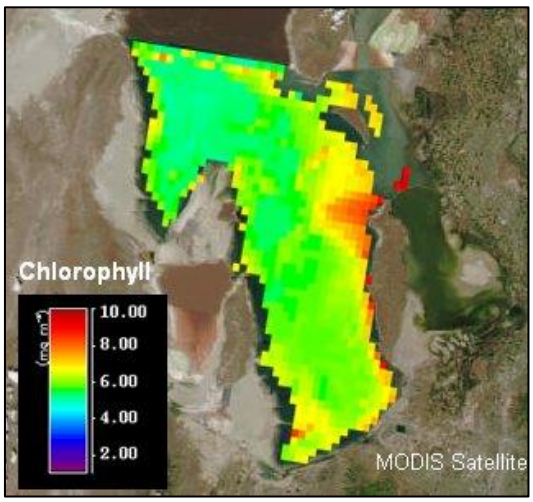


Figure 7. MODIS satellite imagery showing algal bloom (false-red color) extending out of Farmington Bay into Gilbert Bay in May, 2006 (Wurtsbaugh et al. 2008).

Although the current Integrated Report suggests that Farmington Bay should be listed on the 303d list because of human health issues, there is also reason to address the impact of eutrophication and cyanobacterial blooms on the aquatic community. The hypereutrophic nature of the bay causes the entire water column to go anoxic (no oxygen) much of the time (Wurtsbaugh and Marcarelli 2006; Wurtsbaugh et al. 2012), and this likely stresses or kills fish and other aquatic organisms in the bay. Although Farmington Bay is treated as a special case, oxygen criteria for other warm waters requires a minimum of 3.0 mg/L, well above the nighttime minima in Farmington Bay. The high algal growth in Farmington Bay also strips the water of carbon dioxide, causing the pH to rise above the warm water criteria of 9.0 (Marden et al. 2015; Wurtsbaugh et al. 2012). Finally, cyanobacteria densities and cyanotoxin concentrations are frequently far above the range shown to kill birds elsewhere (Alonso-Andicoberry et al. 2002; Bidigare et al. 2009; Matsunaga et al. 1999; Stewart et al. 2008; Wilde et al. 2005). Cyanobacterial blooms have also been implicated in the initiation of avian botulism outbreaks (Murphy et al. 2000; Murphy et al. 2003). Botulism outbreaks in Farmington Bay and Bear River Bay are common (Figure 6). A preliminary study on the cyanotoxin-botulism link in Farmington Bay failed because high salinities in the bay halted cyanobacterial blooms during the year of investigation (2007; Wurtsbaugh 2011). Additional work on the effects of *Nodularia* and other cyanobacteria on the birds in Farmington Bay is thus needed.

Effects of nutrient and algal outflow from Farmington Bay on Gilbert Bay brine shrimp

Phytoplankton and nutrients flowing out of Farmington Bay may enrich the water in Gilbert Bay and contribute to the production of brine shrimp there. Satellite imagery sometimes shows plumes of algal-rich overflow water extending into Gilbert Bay (Figure 7), and Naftz (2008) found isotopic evidence of Farmington Bay nitrogen in brine shrimp at a distant location from the outflow. However, subsequent synoptic studies throughout Gilbert Bay failed to show this isotopic effect (Wurtsbaugh et al. 2008). However, the same study estimated that Farmington Bay contributed 45% of the limiting nutrient (nitrogen) to Gilbert Bay. Another study showed that the effects of the outflow plume diminished rapidly a few miles into Gilbert Bay and that algal concentrations were highest in just the surface waters due to the higher buoyancy of the fresher water from Farmington Bay (Wurtsbaugh and Epstein 2011). As part of that study Montrone (2011) showed that particulate nitrogen and carbon from Farmington Bay was quickly diluted within a few miles of the outlet, and isotopic ratios in brine shrimp indicated that the effect of Farmington Bay diminished rapidly within 3-6 miles, depending on what isotope was

used to estimate the diet of the shrimp. Nutrients and algae from Farmington Bay undoubtedly contribute to the productivity and brine shrimp production in Gilbert Bay, but the magnitude of this effect remains to be determined due to the conflicting data that has been obtained.

Table **1.** Odor survey of residents, workers and visitors to the Great Salt Lake, August-December, 2003. Participants were asked to rate the odor level for each day on the following scale: 1-None; 2-Mild; 3-Moderate; 4-Strong; 5-Unbearable. Average, minimum (Min.) and maximum (Max.) scores are shown. Data from Wurtsbaugh et al. 2012.

		Score		
Location	Responses	Average	Min.	Max.
Farmington/Ogden Bays: Responses of people driving to Antelope Is.	109	3.3	1	5
Farmington/Ogden Bays: Gate for Antelope Island State Park	94	1.6	1	5
Farmington Bay: Farmington Bay Refuge	92	1.2	1	3
Bear River Bay: Bear River Migratory Bird Refuge	17	1.2	1	3
Gilbert Bay/Farmington Bay: Antelope Island	12	1.7	1	3
Gilbert Bay: Great Salt Lake State Park - Saltair	97	1.1	1	4*
Gilbert Bay: Promentory Point	84	1.5	1	3

* Wind from east (i.e. Farmington Bay)

Odor issues

Utah's water quality regulations state that *"It shall be unlawful, and a violation of these rules, for a person to discharge or place any waste or other substance in such a way as will be or may become offensive such as unnatural deposits, floating debris, oil, scum, or other nuisances such as color, odor or taste;…* (emphasis mine)." In a prominent national magazine Great Salt Lake has been derided as a "putrid, fly-infested sump…" (LaRoe 2002), but an analysis of those odors suggests that the primary culprit is not the lake as a whole, but rather Farmington Bay (Table 1; Wurtsbaugh et al. 2012). This survey of 505 respondents from around the lake indicated that all of the "Strong" and "Unbearable" odor reports were derived from Farmington Bay, and none from Gilbert or Bear River Bays. Trentelman (2009; unpublished data) also found a higher incidence of people reporting objectionable odors who lived in Davis County, which is closer to Farmington Bay, than in those living in Weber County. Researchers and Antelope Island employees also report that Gilbert Bay does not have strong odors, but that Farmington Bay often does. The odors emanating from Farmington Bay consequently convey a negative impression of the entire Great Salt Lake and very likely reduce the recreational use of this important resource. The odors from Farmington Bay are the result of the decomposition of organic matter derived from eutrophication (Arruda and Fromm 1989) and the production of hydrogen sulfide in the sediments and deep brine layer of the bay (Wurtsbaugh 2012).

Drought and Hydrological Effects on Farmington Bay

Utah's Integrated Report allows that: *"Additional information on the process of integrating information regarding extreme conditions such as drought or flood that may come to light during the review of the 303(d) list and its associated datasets (see section on Representative Data)."* This is very relevant to the current condition in Farmington Bay, as drought, and particularly water diversions, have dried up over 80% of the bay (Wurtsbaugh et al. 2016), and have largely prevented salt water from entering from Gilbert Bay. Consequently, in the last 2-3 years, Farmington Bay has essentially become a very wide, shallow river with relatively low salinity and short water residence times (Wurtsbaugh et al. 2015). With low salinities, the dominant cyanobacteria, *Nodularia*, does not grow, and it is likely that in the very shallow water the bottom benthic periphyton are the dominant algae. Consequently, recent studies and

those done in the near future will not address the normal functioning of the bay, but they may portend the fate of the bay if water diversions continue to increase.

Summary

In conclusion, my analysis suggests:

1) The State's approach for listing lakes as impaired due to toxic cyanobacterial blooms is appropriate.
2) Clarification is needed on how the manner of field collection (e.g. normal limnological sampling versus targeted collections of bloom scums) relates to the WHO guidelines that the State wishes to use. Additional information is needed in the report to clarify that it is "toxic" cyanobacteria, and not all cyanobacteria, that are of concern.
3) Although the use of toxic cyanobacterial cell densities is currently the most realistic metric to be used as a criterion for listing, the State needs to increase its capability to quickly and accurately measure toxin concentrations from these blooms, as this will provide a much more proximal measure of public health threat.
4) Although microcystin is one of the most widely occurring cyanotoxins, and is focused on in the 303d report, additional criteria need to be developed by the State for other cyanotoxins (e.g. anatoxins).
5) Toxic cyanobacterial blooms in both Utah Lake and Farmington Bay present threats to human health, and thus warrant 303d listing as impaired waters. The very high reported values in Farmington Bay are actually a conservative measure, because that sampling did not target cyanobacterial scums, which are the basis for the proposed criteria (following the WHO's protocols). Outflow waters from Farmington Bay also are a threat to bathers at a popular swimming beach at Antelope Island State Park.
6) Comparison of large algal concentrations in Farmington Bay with more moderate ones in Bear River Bay suggests that the extensive waste water discharges into Farmington are the cause of the cyanobacterial blooms there. More comparative studies on these two bays will be helpful for understanding the toxic cyanobacterial blooms, but such studies will need to be done after (or when), the lake rises and refills the bays with water.
7) More work is needed to understand the cyanobacteria produced in the benthic region of Farmington and Bear River Bays, and the importance of the biota in that region for fish and birds.
8) Although human health risk is the focus of the current Integrated Report, eutrophication in Farmington Bay also presents risks to aquatic biota. Additionally, eutrophication-related odor problems in Farmington Bay fail to meet the State's criteria for this parameter.

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WAYNE A. WURTSBAUGH

LimnoVision

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EDUCATION

Ph.D. University of California at Davis, in Ecology (1983) Dissertation: Internal and external controls on plankton abundance in a large eutrophic lake.

M.S. Oregon State University, in Fisheries, with minor in Water Resources (1973). Thesis: Effects of temperature and ration level on the growth of steelhead trout.

B.S. University of California at Davis, in Fisheries & Wildlife (1970). Thesis: Food and distribution of underyearling brook and rainbow trout in Castle Lake, California.

PROFESSIONAL EXPERIENCE

Professor (July 1996 to present), Watershed Sciences Department (Formerly Aquatic, Watershed & Earth Resources Department), Utah State University, Logan, Utah.

Fulbright Lecturing/Research Fellowship (March-May 2011), Universidad de Cordoba, Argentina.

Gastprofessor (Sept 2005-Apr 2006) ETH University and Swiss Federal Institute for Environmental Science and Technology (EAWAG), Zurich, Switzerland. (sabbatic)

Associate Professor (July 1989-1996), Dept. of Fisheries and Wildlife, Utah State U. Logan, Utah.

Assistant Professor (July 1983 - 1989), Department of Fisheries and Wildlife, Utah State University.

Fulbright Senior Research Scholar (Sep. 1997-Apr. 1998), Universidad De Valencia, Spain.

Visiting Scientist (May-July 1991), Max-Planck-Institut fuer Limnologie, Ploen, Germany (sabbatic)

Visiting Scientist (Oct. 1990 - April 1991), Center for Limnology, Madison, Wisconsin. (sabbatic)

Staff Research Scientist (1980-1983), Div. of Environmental Studies, U. of California, Davis. Duty station: Lake Titicaca, Peru.

Post-graduate Researcher and RA (1975-1980), Dept of Wildlife and Fisheries/Inst. of Ecology, University of California, Davis.

Biologist (1973 and 1975), Clear Lake Algal Research Unit, Lakeport, California.

Fishery Biologist & Volunteer (1973-1974), U.S. Peace Corps, Puno, Peru.

Water Pollution Trainee (1970-1973), Department of Fisheries and Wildlife, Oregon State University. Corvallis, OR.

Seasonal Aide (1968-1969, summers), California Fish and Game. Sacramento, CA.

CURRENT RESEARCH INTERESTS:

- Saline lake limnology
- Algal-nutrient relationships
- Fish ecology
- Stable isotopes and food webs
- deep-chlorophyll maxima
- Landscape limnology

RECENT RESEARCH AND FUNDING

Wurtsbaugh, W.A. and D. Rosenberg. Integrated Natural Resource Management for Urmia Lake Restoration: A Collaborative Program Between the Iranian Lake Urmia Restoration Program (ULRP) & Utah State University. Koshrow Semnani Foundation (2016; $23,000).

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Wurtsbaugh, W.A. Relations between mercury, nutrients and plankton along the Farmington Bay-

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McCulley, E. and Wurtsbaugh, WA. Great Salt Lake Research: nutrients, metals, and plankton in Farmington Bay, Utah. Utah Division of Water Quality and ENVIRON. (2012-13; $64,378)

Wurtsbaugh, W.A. Factors affecting the spatial and temporal variability of *Nodularia* blooms in Farmington Bay (Great Salt Lake). Central Davis County Sewage Improvement District. (2012; $14,974)

Wurtsbaugh, W. Great Salt Lake Student Research Projects-2010. Utah Division of Water Quality. Salt Lake City, Utah (2011; $1,067).

Wurtsbaugh, W. Undergraduate research student support: mercury fractions and transfer from the Great Salt Lake's Deep Brine Layer. Utah State Division of Forestry, Fire and Lands. (2011; $1000)

Wurtsbaugh, W., M. Baker, and B. McGwynn. National Science Foundation. Landscape limnology of mountain watersheds: Nutrient retention and ecosystem stability in complex aquatic ecosystems. (2006-09; $1,297,193).

Wurtsbaugh, W., P. Leavitt and K. Moser. Paleolimnological evaluation of eutrophication and metal deposition in bays of the Great Salt Lake using multi-proxy sediment records. Utah Division of Water Quality. Salt Lake City, Utah (2009-10; $154,108).

Wurtsbaugh, W. Importance of the Great Salt Lake=s deep brine layer for mercury transfer and nutrition of brine shrimp. Utah State Division of Forestry, Fire and Lands. (2009-10; $46,675).

Wurtsbaugh, W. Monitoring of water quality in three bays of the Great Salt Lake. Utah Division of Water Quality, Salt Lake City. (2009; $74,853)

Wurtsbaugh, W. Relationships between eutrophication, cyanobacteria blooms and avian botulism mortalities in the Great Salt Lake, Utah. Utah Wetlands Foundation. (2006, $10,000).

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RECENT TEACHING EXPERIENCE (I have taught 3-4 classes/year from 1983-present)

- Limnologie	ETH Switzerland (2005)
- Limnology	WATS 4500 (3 credit; 1983-2016, USU)
- Aquatic Ecology Pract.	WATS 4510 (3 credits; 1983-2015, USU)
- Water Pollution	WATS 4530/6530 (3 credits; 1989, 1994-2008 USU)
- Graduate Induction	WATS 6260 (1 credit, team-taught; 2014-2016 USU)

SELECTED AWARDS AND HONORS

- Graduate Student Mentor of the Year, Dept. of Fisheries & Wildlife, USU (1995)
- Advisor of the Year, College of Natural Resources, USU (2005)
- Honorary Recognition for Education & Human Resources Development, American Society of Limnology & Oceanography (2005)
- Undergraduate Research Mentor of the Year, College of Natural Resources, Utah State Univ. (2007)
- Teacher of the Year, College of Natural Resources, Utah State University (2009)

STUDENT RESEARCH MENTORING

- 20 M.S. and 2 Ph.D. students
- 8 post-doctoral associates & visiting scholars
- 5 NSF Research Experience for Undergrad. students
- 2 Undergraduate Research Scholars at USU

PROFESSIONAL SOCIETIES

-Am. Fisheries Soc. (AFS)
-Soc. Limnology & Oceanography (ASLO)
-Ecological Soc. of America (ESA)
-Int. Soc. for Salt Lake Research (ISSLR)
-Int. Soc. of Theor. & Applied Limnol. (SIL)
-Iberian Limnological Society

RECENT PROFESSIONAL ACTIVITIES & AWARDS

- Sustaining Fellow, Association for the Advancement of Limnology and Oceanography (ASLO; 2016)
- National Representative, U.S. Section of the Inter. Soc. of Limnology (2004-2010)
- Associate Editor, Limnologica (2006-)
- Am. Soc. Limnology & Oceanography Board member (2007-2010)
- Chairperson, Image Library Committee, Am. Soc. Limnology & Oceanography (2007-2010)
- Board Member, International Society for Salt Lake Research
- Co-Chair, 10th Conf. Int. Society for Salt Lake Research, Salt Lake City, Utah (2008)
- Fellow, Association for the Advancement of Limnology and Oceanography (ASLO)

SELECTED PEER-REVIEWED PUBLICATIONS (of 150 total publications; Google Scholar H-Index 33)

Ogata, E.M., W.A. Wurtsbaugh, T.N. Smith and S. Durham. 2016. Bioassay analysis of nutrient and Artemia effects on trophic interactions in the Great Salt Lake, USA. Can. J. Fish. Aquatic Sci. doi:10.1007/s10750-016-2881-9

Barnes, B.D. and W.A. Wurtsbaugh. 2015. The effects of salinity on plankton and benthic communities in the Great Salt Lake, Utah, USA: a microcosm experiment. Can. J. Fish. Aquatic Sci. DOI: 10.1139/cjfas-2014-0396.

Jones, E.F. and W.A. Wurtsbaugh. 2014. The Great Salt Lake's monimolimnion and its importance for mercury bioaccumulation in brine shrimp (*Artemia franciscana*). Limnol. Oceanography 59 (1): 141-155.

Epstein, D.M., W.A. Wurtsbaugh, and M.A. Baker. 2012. Nitrogen partitioning and transport through a subalpine lake measured with an isotope tracer. Limnology and Oceanography 57(5): 1503-1516.

Lewis, W.M., Jr., W.A. Wurtsbaugh and H. Pearl. 2012. Rationale for control of anthropogenic nitrogen and phosphorus in inland waters. Environmental Science and Technology 45 (24): 10300-10305 DOI: 10.1021/es202401p.

Wurtsbaugh, W.A., J. Gardberg and C. Izdepski. 2011. Biostrome communities and mercury and selenium bioaccumulation in the Great Salt Lake (Utah, USA). Science of the Total Environment 409: 4425–4434.

Wurtsbaugh, W.A. 2009. Biostromes, brine flies, birds and the bioaccumulation of selenium in Great Salt Lake, Utah. Pp. 1-15 In: A. Oren, et al. (eds). Saline Lakes Around the World: Unique Systems with Unique Values. Natural Resources and Environmental Issues, volume XV. URL: /www.cnr.usu.edu/quinney/files/uploads/NREI2009online.pdf

Marcarelli, A.M. and W.A. Wurtsbaugh. 2009. Nitrogen fixation varies spatially and seasonally in linked stream-lake ecosystems. Biogeochemistry. 94:95B110.

Wurtsbaugh, W.A. and Z. M. Gliwicz. 2001. Limnological control of brine shrimp population dynamics in the Great Salt Lake, Utah. Hydrobiologia. 466: 119-132.

Wurtsbaugh, W.A. 1992. Food-web modification by an invertebrate predator in the Great Salt Lake (USA). Oecologia 89:168-175.

Wurtsbaugh, W.A. and T.S. Berry. 1990. Cascading effects of decreased salinity on the plankton, chemistry and physics of the Great Salt Lake (Utah). Can. J. Fish. Aquat. Sci. 47:100-109.

Exhibit B

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8/26/2016

Mr. Rob Dubuc
Staff Attorney, Western Resource Advocates
150 South 600 East, Ste 2A
Salt Lake City, UT 84102

Greetings Mr. Dubuc,

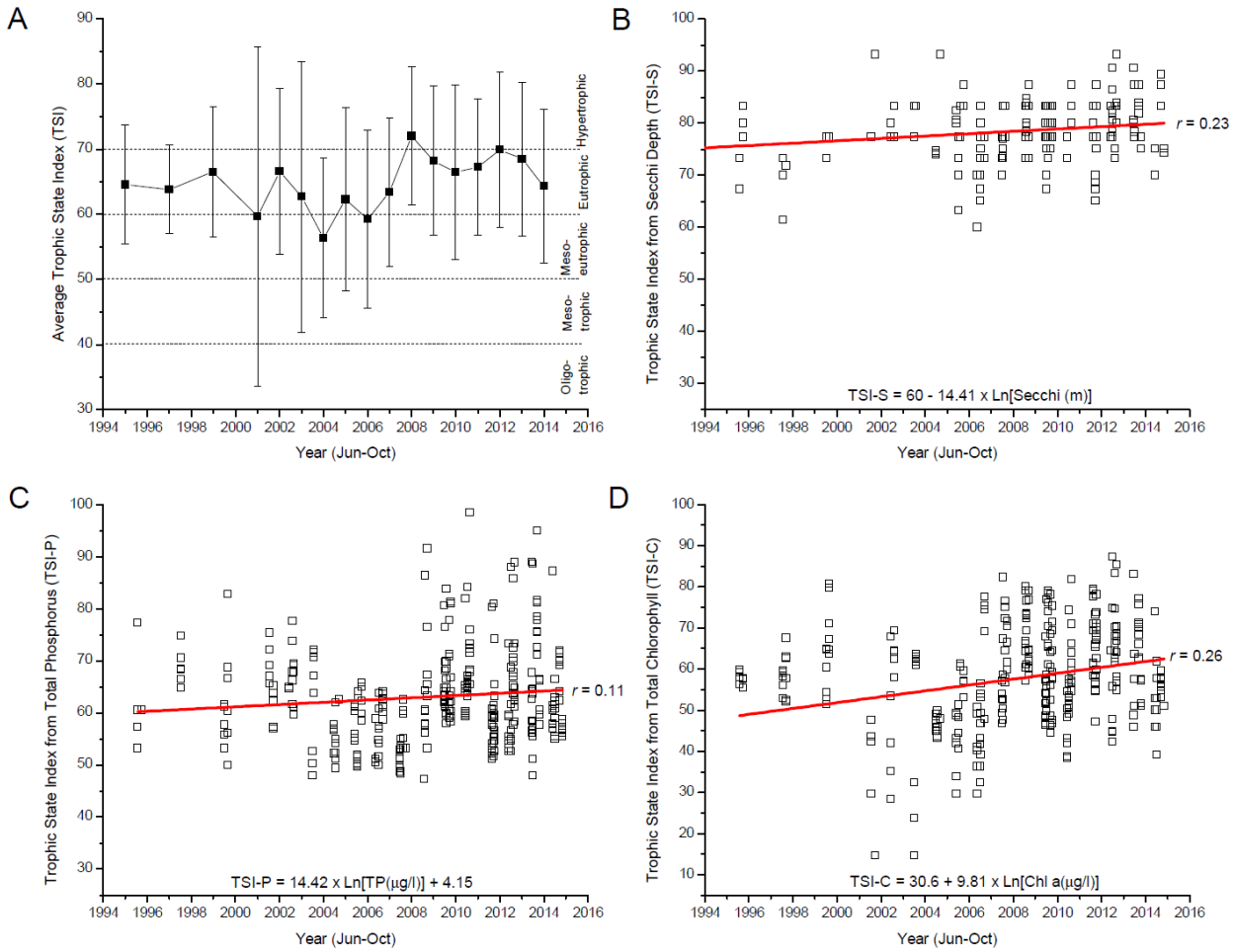
Drawing upon my extensive research experience pertaining to environmental drivers of toxin-producing cyanobacterial harmful algal blooms (CyanoHABs), I offer the following comments regarding the proposed narrative standard assessment criteria for recreational use support in lakes and reservoirs and their specific application to Utah Lake (DWQ 2016 Draft IR: Chapter 5). This chapter acknowledges the growing threat that harmful algal blooms (or HABs) may present to beneficial recreational uses and public health of Utah lakes and reservoirs. Due to the paucity of data, only Utah Lake–for which long-term monitoring data are available–is discussed in the context of the proposed assessment criteria. Because DWQ intends to expand its HAB monitoring program in the future, with new listings possible in the 2018 *Integrated Report*, it is important that proper guidelines are developed before the next monitoring cycle commences.

Pursuant to Utah's narrative water quality standard (R317-2-7.2), freshwater lakes and reservoirs are assessed using the HAB assessment method and the Tier II lakes assessment methods described in Chapter 2 of the 2016 Draft *Integrated Report*. The proposed primary indicator criteria calls for a water body to be listed as impaired if two or more HAB events, defined by cyanobacteria cell counts exceeding 100,000 cells/mL, are observed within a single sampling season (generally May or June through October for temperate systems). Additionally, two supplemental indicators are proposed for use in confirming the primary indicator: these are cyanotoxin concentrations in excess of 20 µg/L and chlorophyll *a* concentrations in excess of 50 µg/L. The scientific merit of each of these three indicators will be discussed in the following paragraphs.

However, before discussing those criteria, it is worth first discussing the compelling evidence that **Utah Lake has become increasingly eutrophic over the past 10-20 years**. These data are based on long-term monitoring efforts of water samples collected from diverse sites across the lake, but are not specifically discussed within the context of the 2016 Draft *Integrated Report*, which only focuses on the period 2012-2014. Although there is no universal definition, the trophic state of a lake is often defined using criteria first developed by Carlson, 1977. These criteria, or trophic state indices (TSI), are based on one or more of the following variables: Secchi depth measurements as a measure of water clarity (Fig 1B; TSI-S), total phosphorus (Fig 1C; TSI-P), chlorophyll *a* (TSI-C) or an average of the three measurements. Figure 1A displays the combined average (±1 standard deviation) of the three trophic indicators for Utah Lake during the summer months (June-October) over the past two decades. The trend lines in Fig. 1B-D are all positive, indicating that the trophic state is increasing. This pattern is likely due to a combination of anthropogenic (i.e., nutrient loading and basin land use practices) and climatic (e.g., warmer

temperatures, less snow pack, drought conditions, etc.) factors–both of which are expected to intensify in the years to come due to increased population growth around the lake and climate models. What is missing from these data, but of central importance, is if cyanobacteria are specifically becoming more dominant in Utah Lake.

Figure 1. Utah Lake Trophic State Indices (TSI) over a 20-year period (data from Utah AWQMS).

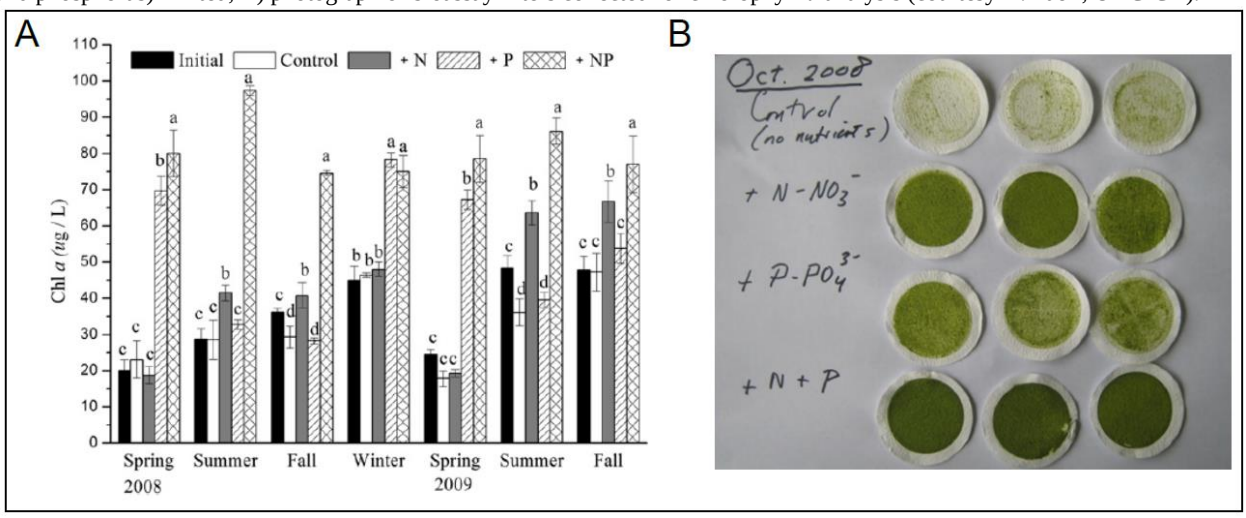


The 2016 Draft Integrated Report describes in detail a cyanobacterial bloom event that occurred in Utah Lake in Oct. 2014, and also provides some details pertaining to another CyanoHAB event that occurred in 2015. Presently, in July 2016, a massive cyanobacterial bloom comprised primarily of *Aphanizomenon flos-aquae* has continued to spread across Utah Lake. Prior to this latest bloom event, June (2016) was already declared the hottest June on record for the United States (https://www.ncdc.noaa.gov/sotc/global/201606), part of a growing pattern of 14 straight months of high temperature records. It is well established that cyanobacteria are adapted to warmer temperatures where they are able to outcompete other phytoplankton groups (e.g, diatoms, cryptophytes, etc.) (Paerl & Otten, 2013). *A. flos-aquae* belongs to the order Nostocales, which is comprised of filamentous, atmospheric nitrogen (N_2) fixing cyanobacteria that tend to thrive in high phosphorus and low nitrogen waters (low TN:TP ratio) since they can augment their nitrogen needs internally. Upper Klamath Lake (Oregon) shares many similar characteristics with Utah Lake, both are large, shallow, heavily mixed, eutrophic systems (high P, high chl *a* & low clarity) that are prone to massive blooms of *A. flos-aquae*. Fortunately, these blooms appear to be nontoxic. However, in recent years in Upper Klamath Lake there has been a marked increase in the abundance of another cyanobacterium, *Microcystis aeruginosa*, which is a

common and prolific producer of the hepatotoxin microcystin. *Microcystis* cannot fix its own nitrogen and therefore relies upon dissolved inorganic/organic nitrogen from the water column. In Upper Klamath Lake, it is thought that much of the nitrogen which sustains these *Microcystis* blooms is recycled from the senescence of *A. flos-aquae* blooms (Eldridge et al., 2012). In addition to nitrogen, warmer temperatures are believed to select for potentially toxic *Microcystis* sp. over typically nontoxic *Aphanizomenon* populations (Paerl and Otten, 2016). Based on these comparisons, and the fact that the TSI-chlorophyll tends to lag that of TSI-S and TSI-P in Utah Lake suggests that factors in addition to P (e.g., temperature, light or nitrogen) effect bloom magnitude and persistence. Since CyanoHABs are positively buoyant, water clarity, and therefore light availability, is less likely to constrain growth. Instead, it is more likely that nitrogen plays an important role in controlling algal bloom proliferation in Utah Lake and that warmer water temperatures due to climate change and decreased snow pack are likely to enhance cyanobacterial utilization of lake nutrients, increase growth rates and inter-species competitiveness (Paerl and Huisman, 2008).

The role of nitrogen in controlling phytoplankton biomass has been thoroughly investigated in Lake Taihu, China; a lake that is also large, shallow, constantly mixed, hypertrophic and dominated by cyanobacterial blooms several months out of the year. In that system, nutrient amendment bioassays indicate that both N and P stimulate phytoplankton growth, with N having a slightly stronger effect than P–but less so than the combined addition of both N & P (Figure 2). Thus, the "P only" paradigm for CyanoHAB control is not applicable to all freshwater lakes as was once believed (Schindler, 1977), and there is a growing body of evidence to support this (e.g., Elser et al., 2007; Lewis and Wurtsbaugh, 2008). Additionally, numerous studies have demonstrated that N_2-fixing cyanobacteria, while able to support a portion of their nitrogen needs, cannot fix enough to meet ecosystem N demands (Horne, A.J., Goldman, C.R., 1972; Halm et al., 2009; Marcarelli and Wurtsbaugh, 2009; Scott and McCarthy, 2010). Therefore the addition of N will further stimulate phytoplankton growth in many systems, including those with prevalent N_2-fixing taxa. This topic is only discussed because the inclusion of Utah Lake on the 303(d) list for cyanobacterial impairment and/or chlorophyll *a* may ultimately require a dual N & P reduction strategy before water quality goals will be attainable. Nutrient dilution bioassays will be necessary to determine appropriate nutrient reduction targets.

Figure 2. A) Nutrient addition bioassays in Lake Taihu, China, indicate that summer cyanobacteria blooms are dual (nitrogen and phosphorus) limited; B) photograph of bioassay filters collected for chlorophyll *a* analysis (courtesy H. Paerl, UNC-CH).



Regarding the DWQ proposed guideline values for 303(d) listing due to cyanobacterial impairment, the primary criterion is based on the assumption that samples exceeding 100,000 cyanobacterial cells/mL represent a condition capable of negatively influencing human health and therefore are not supportive of recreational activities. In my opinion, the use of cells/mL as the primary

indicator, as opposed to direct measurements of cyanotoxins, is a more conservative management approach. The reason that this is more conservative is because not all cyanobacteria are capable of producing toxins. This is an extremely important point to convey, cyanotoxin production is largely believed to be a constitutive process, meaning that if a cell possesses the genes for toxin biosynthesis, it will actively produce the toxin (Paerl et al., 2016). There is evidence for a degree of cyanotoxin gene regulation in response to intracellular and/or extracellular conditions, but in most cases toxigenic cell abundances are highly correlated with toxin concentrations (Otten et al., 2015a). Since many strains of cyanobacteria lack the genes necessary for cyanotoxin biosynthesis, these strains would be considered nontoxic under the pretense that only cyanobacteria which produce microcystin, nodularin, cylindrospermopsin, anatoxin-a, saxitoxin may exert toxic effects. However, there are numerous lines of evidence that support the conclusion that cyanobacteria are often broadly toxic from environmental or human health perspectives. As such, I concur with the WHO and Utah DWQ that **100,000 cyanobacterial cells/mL represents a potential human health risk, even if these cells are found to be "nontoxic" since they may still exert deleterious effects (e.g., respiratory or dermal responses) upon exposure**. This conclusion is well supported in the literature by animal toxicological studies where exposures to crude extracts, which include known toxins and whatever other metabolites are within the cyanobacteria, routinely produce more adverse health outcomes than purified toxin alone (Oberemm et al., 1999; Pietsch et al., 2001; Burỳsková et al., 2006). Additionally, a very contemporary example of adverse health effects being linked to "nontoxic" blooms is presently ongoing in Utah Lake, where a massive bloom of *A. flos-aquae* coincides with over 100 people reporting common cyanobacterial exposure symptoms such as: vomiting, diarrhea, headaches and rashes following recreational contact with the bloom. Notably, only one of the dozens of samples analyzed for cyanotoxins exceeded the recreational guideline value of 20 µg/L for microcystin (Lincoln Harbor; http://deq.utah.gov/locations/U/utahlake/algal-bloom.htm).

Table 1. Cyanobacterial secondary metabolites that may be produced by common bloom-forming taxa.

Metabolite Class	Biosynthesis	APHA	CYL	DOL	FISCH	GLO	LYNG	MIC	NOD	NOST	OSCIL	PLANK	RAPH
Aeruginosin	NRPS							X	X				
Anabaenopeptin	NRPS	X		X				X	X			X	
Anatoxin-a	NRPS/PKS	X	X	X							X	X	X
Anatoxin-a(s)	Unknown			X									
Aplysiatoxins	PKS						X				X		
Bacteriocins	Ribosomal		X	X				X	X	X			X
BMAA	Unknown									X			
Cyanobactins	Ribosomal	X		X			X	X	X	X	X	X	
Cyanopeptolin	NRPS			X			X	X	X			X	
Cyclamides	Ribosomal			X			X	X		X	X		
Cylindrospermopsin	NRPS/PKS	X	X	X									X
Fischerellin	PKS				X								
Lyngbyatoxin-a	NRPS						X				X		
Microcystin	NRPS/PKS			X	X	X		X		X	X	X	
Microviridin	Ribosomal			X				X	X	X		X	
Microginin	NRPS							X		X		X	
Nodularin	NRPS/PKS								X				
Saxitoxin	NRPS/PKS	X	X	X			X					X	X

*Where: APHA=*Aphanizomenon* ; CYL=*Cylindrospermopsis* ; DOL=*Dolichospermum* (formerly *Anabaena*); FISCH=*Fischerella* ; GLO=*Gloeotrichia* ; LYNG=*Lyngbya* ; MIC=*Microcystis* ; NOD=*Nodularia* ; NOST=*Nostoc* ; OSCIL=*Oscillatoria* ; PLANK=*Planktothrix* ; RAPH=*Raphidiopsis*

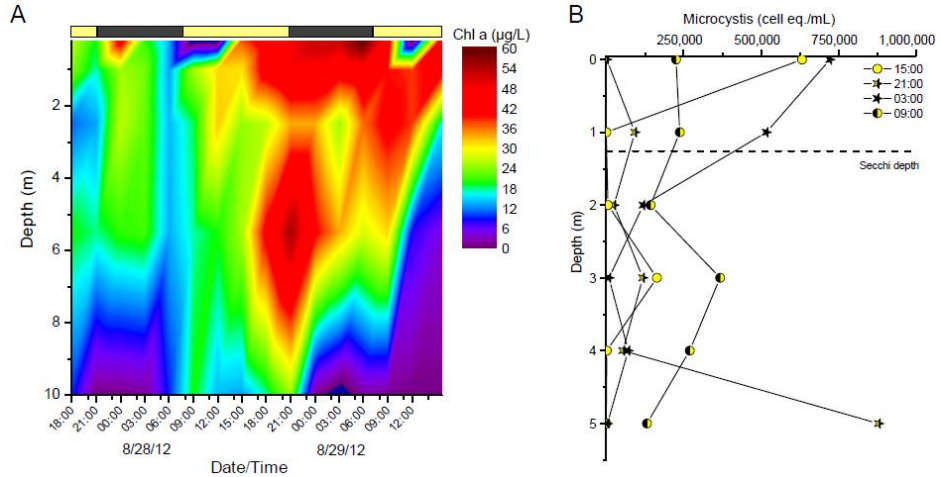
Cyanobacteria have existed for over 2.7 billion years, yet we have only identified cyanotoxins within the past ~40 years (with the last one being cylindrospermopsin in 1992 [Ohtani et al., 1992]); it would not be unexpected if additional toxic metabolites are identified in the future. One example of this may be beta-N-methylamino-L-alanine (BMAA), identified in 2003 (Cox et al., 2003), and linked with neurodegenerative disease (Holtcamp, 2013), although the scientific consensus is still out on whether or

not this is as prevalent across cyanobacterial lineages as originally described (Cox et al., 2005; Faassen et al., 2014; Marler et al., 2010). What we do know is that in addition to cyanotoxins, all cyanobacteria sequenced to date have the ability to produce multiple secondary metabolites using similar molecular machinery as that involved in cyanotoxin production (Otten and Paerl, 2015). Due to their natural bioactivity, novel cyanobacterial metabolites are actively sought after for use in pharmacological applications (i.e., bioprospecting), although at present most of the functions/potential health effects of these metabolites remain unresolved (Otten and Paerl, 2015). Table 1 displays the secondary metabolite classes that have been observed in the most common bloom-forming cyanobacteria genera, recognized cyanotoxin classes are indicated in bold.

While I do support the DWQ conclusion that cyanobacteria concentrations exceeding 100,000 cells/mL represent a potential environmental and/or human health risk–even when recognized cyanotoxins are low/absent, the sampling methodology will be of critical importance for making accurate assessments of cyanobacterial risks. However, **sampling methodology is not clearly discussed in the proposed guidance** (i.e., surface grab samples versus depth-integrated sampling). Many cyanobacterial HAB taxa are positively buoyant due to intracellular gas vesicles that allow them to regulate their position in the water column based on their physiological needs. However, their position in the water column is not static, instead varying based on their physiological needs and in response to physical factors such as light intensity, wind and wave mixing. Additionally, not all bloom-forming cyanobacteria form surface scums. For example, *Planktothrix rubescens* and *Cylindrospermopsis raciborskii*, both of which are potential toxin producers, can reach high cell densities below the water's surface with little visual indication that a bloom is present. They are able to do this because they are enriched with a photopigment (phycoerythrin) which absorbs red light–the main wavelength of light at depth. If an environmental monitoring sonde is available, metalimnetic blooms can be identified by lowering the sonde through the water column while looking for a sharp increase in chlorophyll *a*, phyocyanin or dissolved oxygen.

Depth-integrated samples are traditionally collected to assess environmental water quality conditions (e.g., baseline monitoring), whereas public health grab samples are intended to represent maximum exposure risks. However, there are several problems with the public health sampling methodology: 1) the data are not meaningful for assessing the ecological condition of the lake, 2) the data are not useful for comparisons across sites or systems, 3) even when cells are visible at the surface, there are likely others below the surface because the entire bloom does not undergo diel migration in sync (e.g., Figure 3), and 4) high cell concentrations present at depth will be missed by surface grab samples.

Figure 3. Diel migration patterns of a *Microcystis* sp. bloom in Copco Reservoir (CA). A) Water column profiles of chlorophyll *a* across a time-series, B) QPCR estimates of total *Microcystis* across depth at four different times.



To ensure that sampling efforts adequately estimate cyanobacterial risks, and to increase uniformity of data collection thereby facilitating direct comparisons across different sites/lakes, it is suggested that a depth integrated sampling methodology be used. For shallow sites, the water column from the surface down to ~0.25 m above the sediments should be sampled. In stratified lakes, integrated samples should be collected from the surface down to the metalimnion (thermocline). The reason to not simply sample through the photic zone is that cyanobacteria may drop below the photic zone and into the metalimnion in order to access nutrients and ferrous iron (Fe^{2+}) (Molot et al., 2014), and because not all cells move in unison during diel migration. Figure 3B illustrates this point whereby a percentage of *Microcystis* cells (determined by real-time quantitative PCR; qPCR) are distributed throughout the water column at all times, even though local maxima typically occur at a specific depth depending on the time of day. Accordingly, a near surface grab sample collected between 9AM-12PM would grossly underestimate total *Microcystis* abundance since at that time the majority of cells were at 3 m depth on 8/29/12. Since redox gradients are generally absent in mixed waters, nutrients will be distributed throughout the water column. Therefore, unstratified lakes should be sampled from the surface to the bottom of the photic zone. This rationale is based on the fact that light attenuates as it moves through the water column, therefore even taxa that do not form surface scums will still need to maintain a position within or near the photic zone. If a PAR (photosynthetic active radiation) sensor is unavailable, a factor of the Secchi depth measurement (which represents ~10% of incident light) can be used as a suitable replacement to estimate the depth in which incident light is ~1%. However, photic depth is not a constant function of Secchi depth, instead it has been reported to range from 1.16 to 2.3 times the Secchi depth depending on the optical properties of the lake (Davies-Colley and Vant, 1988). Since the goal is to inclusively sample all cyanobacteria, using 2.3X-Secchi depth for sample collection should provide a reasonably conservative estimate of total cyanobacteria throughout the photic zone in unstratified waters.

Appendix I illustrates how public health risks can be estimated from depth integrated samples, providing a "best of both worlds" approach. Under this framework, the maximum possible surface cell concentration ($Cell_{max}$) is predicted under the pretense of a perfectly calm water column where all cells are located as a scum within the top 2-cm of the water column. The proposed methodology should minimize errors associated with cell abundance estimates by greatly reducing the impacts of mixing and bloom motility throughout the water column. As such, factors such as the time of day that samples are collected or weather conditions (e.g., wind or rain events) will have little effect on estimates of $Cell_{max}$. In the 2016 Draft IR Chapter 5 discussion of Relevant Data collected from Utah Lake, it is noted that none of the 45+ routine water quality monitoring phytoplankton samples exceeded 100,000 cells/mL. This is not surprising since in a shallow, well mixed lake the only likely way for a grab sample to exceed this threshold is for the conditions to be very calm and mixing to be minimal. However, if any of these samples were depth integrated, it may be possible to back calculate the $Cell_{max}$, which may in fact have exceeded the proposed action limit.

Lastly, regarding the cell concentration primary indicator, it is worth mentioning the drawbacks of this approach. Microscope-based estimates of cyanobacterial community composition and abundance are influenced by the methodology employed (e.g., volume analyzed, natural units counted, etc.) and the subjectivity of the taxonomist. Microscope estimates also come at a considerable cost and a relatively slow turnaround time. **For public health decision making, there are faster options for assessing cyanobacterial risks than microscopy.** Quantitative polymerase chain reaction, or qPCR, is a high throughput method that can quantify the total number of cyanobacteria present in up to 40 samples in only a few hours. Similarly, flow imaging algal counting instruments are now available and toxin measurements can be conducted in parallel in order to produce estimates of risk for dozens of samples at a time. Acknowledging that new methods have the potential to supplant traditional approaches, I would encourage DWQ to include the possibility these other methods in the 2016 Draft IR.

The secondary indicators, total cyanotoxin and total chlorophyll *a* will be discussed next. It is my opinion that the manner in which these secondary indicators are intended to be used is unclear. Of the two, the concept of cyanotoxin indicators make the most sense as these are already in place in numerous states. However, there are several aspects of this that DWQ does not adequately explain. **Is the cyanotoxin threshold of 20 µg/L intended for all cyanotoxins or just for microcystins?** The WHO guidance that is referenced specifically equates 100,000 cells/mL to potential microcystin concentrations up to 20 µg/L, but it makes no reference to anatoxin-a, cylindrospermopsin or saxitoxin (Chorus and Bartram, 1999). Note that the microcystin estimate is based on average cell toxin quotas of ~0.2 pg/cell; however, there is much less information on cell quotas for the other cyanotoxins and the 100,000 cells/mL correlation may therefore be inaccurate for other cyanotoxins. For example, anatoxin-a quotas up to 0.35 pg cell^{-1} for *Tychonema* sp. (Shams et al., 2015) and 0.55 pg cell^{-1} for *Phormidium* sp. (Harland et al., 2013) have been reported, and saxitoxin cell quotas of up to 0.45 pg cell^{-1} have been reported for *Anabaena* (Llewellyn et al., 2001). Thus, toxin concentrations for these taxa could potentially exceed 20 µg/L at cell concentrations below 50,000 cells/mL. The second point requiring clarification is, **under what conditions will cyanotoxins be collected and/or is there a specific cell concentration that triggers cyanotoxin testing?** Based on the above referenced studies, it would be prudent if cyanobacterial cell concentrations in exceedance of a specific threshold (e.g., 20,000 cells/mL) triggered toxin testing or toxin gene screening (e.g., by qPCR) for the relevant toxins that may be produced by the taxa present (see Table 1 for a list of cyanobacteria and the toxins they may produce). Thirdly, how is the cyanotoxin indicator applied/interpreted if cell counts exceed 100,000 cells/mL but cyanotoxin concentrations are below 20 µg/L? The guidance suggests that even nontoxic blooms exceeding the threshold would count towards impairment listing. This approach is contrary to that of other states (e.g., Oregon) that use a tiered framework that considers cyanotoxin measurements as the "gold standard" for making a posting decision (i.e., if a lake exceeds 100,000 cells/mL but is below the toxin threshold, it would not be posted). Conversely, under the proposed secondary indicators, **what happens if cell counts are below 100,000 cells/mL but cyanotoxin concentrations exceed 20 µg/L?** What happens if one sample exceeds 100,000 cells/mL with toxins < 20 µg/L, while a different sample has less than 100,000 cells/mL but exceeds 20 µg/L toxin? These would both be cyanobacterial-related impairments above the proposed guideline values, but not two of the same type of exceedance. Would this lake then be placed on the 303(d) list? Lastly, what is the management outcome if two cyanotoxins are detected in a sample that are individually below 20 µg/L, but combined (e.g., 10 µg/L MC + 10 µg/L ANTX) they exceed the limit for total cyanotoxins? Presumably this would not produce an exceedance, but since the guidelines only say cyanotoxins instead of specifically naming them individually, this outcome is unclear. These scenarios are offered in order to convey some of the uncertainties surrounding the proposed cyanotoxin secondary indicator. As such, it would be helpful if the guidance included more clarity on how the criteria will be applied under various scenarios likely to be encountered.

The use of chlorophyll a as a secondary indicator is even more ambiguous. To begin with, the threshold of 50 µg/L chlorophyll *a* seems to be rather arbitrary. Under the Carlson Trophic State Index for chlorophyll (TSI-C), a concentration of 50 µg/L equates to an index value of 69, which is on the high end of still being considered eutrophic. If this concentration were to occur during the summer months in an oligotrophic or mesotrophic lake, there would likely be a high probability of a cyanobacterial bloom present. However, in highly productive systems, such as Utah Lake, where ~20% of summer-time samples from across the lake over the past 20 years exceed 50 µg/L (or greater than 70% of samples from Provo Bay) chlorophyll *a*, but cyanobacteria counts rarely exceed 100,000 cells/mL, this criteria is not very useful for assessing cyanobacterial bloom risks in this lake. As with the 20 µg/L threshold for cyanotoxins, this 50 µg/L threshold for chlorophyll *a* comes from the WHO guidance document (Chorus and Bartram, 1999). In the WHO guidance, the stated assumption is that samples **dominated by cyanobacteria**–that also exceed 50 µg/L chl *a*–have an increased probability of microcystin concentrations above 20 µg/L. As such, a more accurate methodology would be to use probability statistics to set the chl *a* threshold for each lake based on knowledge of the phytoplankton community

present in relation to chl *a* (i.e., **what is the probability of cyanobacterial dominance for a given chl *a* concentration in the summer?)**. In the absence of phycological data, the seasonal chl a average for the lake could be used to set chl *a* concentration limits. Under this scenario, samples containing chl *a* concentrations statistically above the lake's mean summer concentration would be considered to have an above average risk of cyanobacterial impairment. For normally distributed data, the statistical definition of an abnormal value is that which exceeds two standard deviations above the mean (i.e., in exceedance of the 95th percentile of normal). For chl *a* data that does not exhibit a Gaussian distribution, normality may be achieved after applying a suitable transformation (e.g., natural log), then the mean and standard deviations can be calculated and back-transformed (after accounting for Taylor expansion) into the original units.

Summary of major points

1) A well thought out sampling methodology is of critical importance for making accurate assessments of CyanoHAB risks in Utah lakes. Results will be influenced by the time of day and location that samples are collected. As such, it is recommended that depth-integrated samples are collected, and from these the public health risks of a surface scum can be determined (see Appendix I).

2) The use of cell counts as a primary indicator is the most conservative approach, because even blooms that do not produce any recognized cyanotoxins would still result in the waterbody's listing on the 303(d). From a public health perspective, it can be argued that this is the safest course of action since cyanobacteria may produce other deleterious compounds besides the five recognized classes of cyanotoxins (anatoxin-a, cylindrospermopsin, microcystin, nodularin and saxitoxin); one example is the neurotoxin BMAA that has been linked to cyanobacteria.

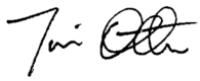
3) The use of 50 µg/L chlorophyll *a* as a meaningful threshold for cyanobacterial bloom risks is arbitrary. In Utah Lake, up to 70% of samples from some regions of the lake would exceed this threshold, even though cyanobacterial blooms are not present 70% of the time based on cell counts. Therefore, in order for chl *a* to be a useful proxy for cyanobacterial biomass, an understanding of "normal" chl *a* concentrations for the waterbody is required. From these data, anomalous chl *a* concentrations (e.g., greater than two standard deviations above the average) could be used to indicate a cyanobacterial bloom event. Further, since all phytoplankton possess chlorophyll, but only cyanobacteria possess the photopigment phycocyanin, the latter is likely a more useful proxy for cyanobacterial biomass.

4) In addition to cell counts, water quality managers should have the option to use cyanotoxins or QPCR assessments of toxigenic cyanobacteria as primary indicators of water quality impairment. The latter two are desirable because they are amenable to high throughput processing and can generally return results in a more timely fashion (e.g., days as opposed to weeks).

5) Regarding cyanotoxin thresholds, the report needs to specify the concentrations for each of the five classes of cyanotoxins that would constitute an exceedance. The WHO criteria only says that 20 ppb is a suitable health threshold for microcystins, not the other toxins. Other states have developed thresholds for these other toxins and these could be used as a starting point for developing such standards in Utah.

6) The guidance document should clarify that only potential toxin-producing genera of cyanobacteria are to be included in the cell count assessments.

The preceding comments were specifically drafted in response to the Utah Department of Water Quality's proposal to include cyanobacterial water quality impairment indicators in its 2016 Draft Integrated Report used to place/remove water bodies from the EPA Clean Water Act 303(d) list of impaired waters and total maximum daily loads. The opinions expressed in this document are solely those of the author.



Timothy G. Otten, PhD, MPH

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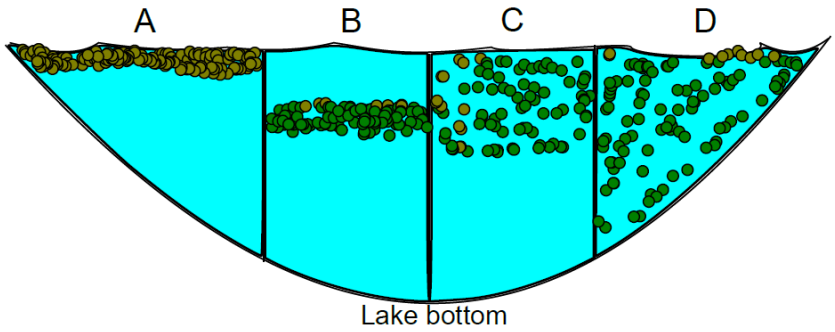
Appendix I

An improved sampling methodology for cyanobacterial monitoring

1. Understanding common cyanobacterial distribution patterns within lakes/reservoirs



A. Surface scum, often occurring near-shore or in calm waters, more common in the morning before winds pick up

B. Cells concentrated within a specific area of the photic zone or above the thermocline, common in the evening/night

C. Cells evenly distributed above the thermocline, found in moderately mixed, but thermally stratified lakes

D. Cells evenly distributed throughout the water column, typical of shallow, well mixed lakes

2. Sample collection for cyanobacterial risk assessment

1. Collect depth-integrated sample from water's surface to 0.25 m above the sediment (for shallow lakes) or to the bottom of the photic zone (2.3-times Secchi disk transparency) in unstratified lakes or to the metalimnion (thermocline) in stratified lakes.

2. Record the depth sampled and the volume collected.

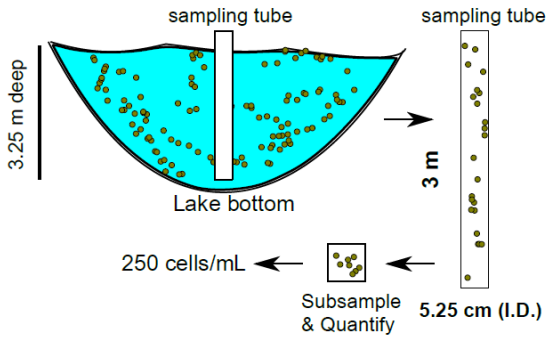
3. Mix the collected water thoroughly, then subsample (ideally using a churn splitter) and preserve accordingly.

4. Determine total cyanobacteria by microscopy or real-time quantitative PCR (qPCR).

5. Estimate the maximum possible surface cell concentration ($Cell_{max}$) by multiplying the measured cell concentration by the total volume sampled, then dividing by the volume comprised by the top 2 cm of the collection apparatus.

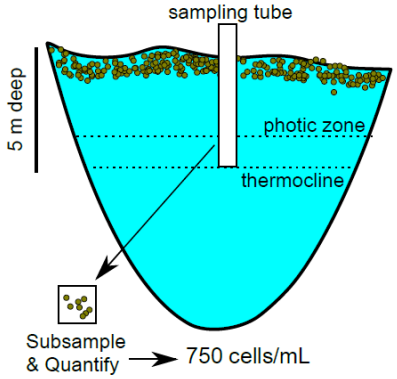
3. Example using a cylindrical PVC pipe to collect samples (cylinder vol.= $\pi r^2 h$)

1. Shallow, well-mixed lake



Sample vol. = π x 3,000 (mm) x 27.5^2 (mm^2) / 1,000 (mm^3/mL) =7,127.5 mL
Total cells = 250 cells/mL x 7127.4 mL = 1,781,872 cells
Vol. top 2 cm = π x 20 (mm) x 27.5^2 (mm^2) / 1,000 (mm^3/mL) = 47.51 mL
Max cell conc. possible in top 2 cm = 1,781,872 cells / 47.51 mL = **37,505 cells/mL**

2. Deep, stratified lake



Sample vol. = 11,879.2 mL
Total cells = 8,909,361 cells
Vol. top 2 cm = 47.51 mL
$Cell_{max}$ = **187,526 cells/mL**

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Aug., 2007 - Aug. 2012	Graduate Research Assistant - Univ. of North Carolina-Chapel Hill
May, 2006 - Aug. 2007	Research Assistant - Washington DC Water & Sewer Authority
Aug., 2005 - Aug. 2007	Graduate Research Assistant - George Washington University
May, 2003 - Aug. 2004	Research Assistant - Michigan Dept. of Ag., Div. Plant Pathology

RESEARCH INTERESTS

I am broadly interested in all aspects of molecular microbial ecology. In particular, I study microbial community succession patterns in order to better discern selection pressures favoring certain species or strains over others. Most of my research has pertained to environmental health microbiology and harmful algal blooms in drinking water reservoirs. My work incorporates

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Otten TG, Dreher TW. The molecular ecology of Klamath *Microcystis* blooms. Oregon Lakes Association. Klamath Falls, OR. October 29, 2015.

Otten TG. Case studies in harmful algal bloom monitoring and risk assessment: New tools for an old problem. Siuslaw Water Shed Council Meeting. Florence, OR. July 29, 2015.

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Otten TG. Effects of cyanobacterial toxins and routes of exposure. Harmful Algal Bloom Technical Workshop. Corvallis, OR. March 25, 2015.

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Otten TG. Webinar: Environmental drivers of microcystin-producing cyanobacteria. EPA Western Ecology Division. Corvallis, OR. February 20, 2014.

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Otten TG. Molecular methods for identifying toxin-producing cyanobacteria. *Invited talk.* Nanjing Institute of Geography and Limnology, Chinese Academy of Sciences. Nanjing, China. June 3, 2011.

Otten TG. The green monster of China's Lake Taihu: Insights into the microbial ecology of its toxin producing genera. *In-house seminar*, University of North Carolina, Chapel Hill, NC. March 2, 2011.

Otten TG, Paerl HW. Bloom Dynamics and Controlling Factors of Perennial Toxin-Producing *Microcystis* Blooms in China's Lake Taihu. Association for the Sciences of Limnology and Oceanography (ASLO). San Juan, Puerto Rico. Feb. 18, 2011.

Otten TG, Paerl HW. A Long PCR Assay for Improved Screening of Toxic and Non-Toxic Strains of the Bloom Forming Cyanobacterium: *Microcystis aeruginosa*. American Society for Microbiology (ASM). San Diego, CA. May 26, 2010.

Student mentorship:

Mr. Joshua Jackson (2013-2014) Microbiology undergraduate student at Oregon State Univ.
Ms. Amy Pflaumer (2011-2012) Marine science REU then graduate student at UNC Chapel Hill

Synergistic activities:

- California CyanHAB Network (CCHAB) member
- National HAB Committee member and steering member for 8th Symposium on Harmful Algae in the U.S. (Long Beach, CA - Nov. 2015).
- HAB Science Advisory Committee Member (2012-Present) Oregon Health Authority
- Session chair (2012) 8th National Water Quality Monitoring Conference, Portland, OR
- *Ad hoc* reviewer for the journals: Applied and Environmental Microbiology, Applied Microbiology, Aquatic Ecology, Aquatic Microbial Ecology, Environmental Management, Environmental Microbiology, Environmental Microbiology Reports, Environmental Science

and Pollution Research, Environmental Science & Technology, Harmful Algae, Hydrobiologia, The ISME Journal, Journal of the American Water Works Association, Journal of Applied Phycology, Limnology, Marine Biology, Marine Drugs, Microbial Ecology, Phycologia, PLoS One, Toxicon, Water Research

PROFESSIONAL MEMBERSHIPS

Association for the Sciences of Limnology and Oceanography
American Society for Microbiology
HAB Science Advisory Committee - Oregon Health Authority
International Society for the Study of Harmful Algae
North American Lake Management Society
Oregon Lakes Association

MEDIA & OUTREACH

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GRANTS

Proposal to continue multiyear analysis of *Microcystis* population structure and toxigenicity in Copco and Iron Gate Reservoir, PacifiCorp, $59,829, T. Otten (PI) and T. Dreher.

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Study to assess the utility and efficacy of various management strategies targeting benthic, *Microcystis* spp. cells in shallow areas of Klamath Reservoirs, PacifiCorp, $48,704. T. Otten (PI) and T. Dreher.

Investigation of diel migration patterns and niche adaptation strategies of toxigenic and nontoxic *Microcystis* ecotypes within the euphotic zone of Copco Reservoir, Klamath River, PacifiCorp, $2,885. T. Otten (PI), T. Dreher and S. Mackey.

Comparison of *Microcystis* populations in Copco/Iron Gate Reservoirs and in the Klamath system upstream and downstream: Are the populations linked or largely independent? PacifiCorp, $74,367. T. Dreher (PI) and T. Otten.

The role of *Microcystis* blooms in the Delta food web: A functional approach, Delta Science Program, $900,000. A. Parker (PI), F. Wilkerson, W. Kimmerer, R. Kudela, C. Mioni and H. Paerl and T. Otten.

Succession patterns of the toxic cyanobacterium- *Microcystis* sp. - in China's Lake Taihu, National Science Foundation East Asia and Pacific Summer Institutes (EAPSI) for U.S. graduate students, $10,000. T. Otten (PI).

REFERENCES

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Exhibit C

DECLARATION OF R. JEFRE HICKS

I, R. Jefre Hicks, based on my personal knowledge and belief, state:

1. My name is R. Jefre Hicks. I am of sound mind and body and competent to make this Declaration.
2. I live in Davis County, Utah and am a member of several organizations that are concerned with the health of the ecosystem of Great Salt Lake, including water quality. Those organizations include the Utah Airboat Association, Friends of Great Salt Lake, Utah Waterfowl Association, and Delta Waterfowl.
3. I am the owner of an airboat that I use on a frequent basis out in Farmington Bay. I estimate that I use my airboat in Farmington Bay approximately 40 times annually, with most of the usage between September 15th and the end of March. However, I do go out on Farmington Bay during the summer months, including 5 times so far this year. I anticipate that I will make one additional trip out in Farmington Bay this summer.
4. Access to Farmington Bay during the summer months is limited to those airboaters that obtain permission, because the access gate is locked from February through mid-September and requires a key or combination to access the boat ramp. However, in mid-September, the access gate is left unlocked and approximately 10 boats per day use Farmington Bay in order to prepare for the upcoming waterfowl hunting season.
5. Each time I have been out on Farmington Bay this summer, I have seen and had to ride through algal blooms. These blooms are huge mats of algae, covering multiple acres. The algal blooms are especially evident in the area near what airboaters call “stinky” which is the discharge point into Farmington Bay for the sewer treatment plant north of Salt Lake City.

6. The algal blooms are not limited to the summer months. The blooms are prevalent during late summer days in September and I have seen algal blooms linger well into October.
7. While much of the algae washes off as I ride through the water, some of the algae flies up onto the boat, and the propeller cage. The propeller can turn the wet algae into a fine mist and it becomes airborne for a short distance.
8. These blooms have recently become a concern for me as I understand more about the toxicity and possible health impacts of the blue-green algae that is present in Farmington Bay.

I declare, under penalty of perjury, that the foregoing is true and correct.

/s/ R. Jefre Hicks (with permission)
R. Jefre Hicks
September 1, 2016

Exhibit D

DECLARATION OF KERRY H. McCLOUD

I, Kerry Harris McCloud, based on my personal knowledge and belief, state:

1. My name is Kerry H. McCloud. I am of sound mind and body and competent to make this Declaration.
2. I live in Davis County, Utah and am a member of the Utah Airboat Association of which I am President.
3. I am the owner of an airboat that I use on a frequent basis out in Farmington Bay, which is where I mainly use my boat. I estimate that I use my airboat in Farmington Bay approximately 20 times annually, with most of the usage between September 15th and the end of March. However, I do go out on Farmington Bay during the summer months, including 2 times so far this year.
4. Access to Farmington Bay during the summer months is limited to those airboaters that obtain permission, because the access gate is locked from February through mid-September and requires a key or combination to access the boat ramp. However, in mid-September, the access gate is left unlocked and approximately 10 boats per day use Farmington Bay in order to prepare for the upcoming waterfowl hunting season.
5. Each time I have been out on Farmington Bay this summer, I have seen and had to ride through what appear to be algal blooms. These blooms are large mats of algae, covering multiple acres. The algal blooms are especially evident in the area near what airboaters call “stinky” which is the discharge point into Farmington Bay for the sewer treatment plant north of Salt Lake City, as well as up close to Antelope Island which is downstream of the sewer discharge.

6. After a ride through Farmington Bay during the summer, my propeller cage is typically covered with algae. With the recent toxic algae blooms in Utah Lake, the algae blooms in Farmington Bay have become a concern for me as I understand more about the toxicity and possible health impacts of these blooms.

I declare, under penalty of perjury, that the foregoing is true and correct.

/s/ Kerry H. McCloud (with permission)
Kerry H. McCloud
September 1, 2016