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

UTAH DEPARTMENT of ENVIRONMENTAL QUALITY
WATER QUALITY

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ABBREVIATIONS

<	less than
>	greater then
AU	assessment unit
cell(s)/mL	cell(s) per milliliter
CFR	Code of Federal Regulations
DO	dissolved oxygen
DWQ	Division of Water Quality
EPA	U.S. Environmental Protection Agency
HAB(s)	harmful algal bloom(s)
IR	Integrated report
km2	square kilometer
mg/L	milligram per liter
TMDL	total maximum daily load
UAC	Utah Administrative Code
UDWQ	Utah Division of Water Quality
WHO	World Health Organization
µg/l	microgram per liter

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INTRODUCTION

UDWQ's criteria and assessment methods for recreational uses are designed to reduce risks to human health from exposure to potentially harmful water quality conditions while engaged in recreational activities. UDWQ uses parameters such as pH, E. coli bacteria concentrations, and the occurrence of harmful algal blooms (HABs) to assess recreational support. The occurrence of HABs is a growing water quality concern across the nation. In Utah, HABs usually consist of cyanobacteria (also known as blue green algae) that can produce dangerous toxins and pose a risk to human health through direct contact, inhalation or ingestion. HABs have occurred in some Utah lakes and reservoirs. However, until now, limited data and assessment methods have hindered UDWQ's ability to assess recreational use support in these waterbodies. In 2015, UDWQ developed assessment methods that included a new HAB assessment methodology for recreational uses (Chapter 2). The assessment methods were public noticed in March 2015 and adopted for the *2016 Integrated Report* as Chapter 2. This methodology reflects the potential for "*undesirable human health effects*" identified in the Narrative Standard and uses a cyanobacteria cell count exceeding 100,000 cells/mL as the indicator of HAB related impairments for recreational and drinking water uses.

Currently, few lakes or reservoirs have existing or readily available data collected during algal bloom events. One exception to this lack of HAB data is Utah Lake where several HAB targeted samples were collected through a series of HAB events in October 2014. Only one other lake, Big East Lake, had data collected during an HAB event available to assess for HABs. One sample exceeded the 100,000 cells/mL threshold in Big East Lake and is has been placed in category 3A (insufficient data with a single recorded exceedance of the HAB indicator) for the 2016 *Integrated Report*[1]. Farmington Bay, Great Salt Lake, also has a robust dataset related to HABs. This data is presented in Chapter 6 and was not assessed for 303(d) purposes in the 2016 *Integrated Report* because assessment methods are still in development for the Great Salt Lake. UDWQ's new HAB program has begun to collect more robust data for HAB assessment from waters around the state such that assessments of a wider group of waters will be possible in the 2018 *Integrated Report*.

Utah's Narrative Water Quality Standard

Utah's Narrative Water Quality Standard (R317-2-7.2) protects water quality from pollutants for which numeric criteria are not appropriate or have not yet been adopted. It states that,

> "*It shall be unlawful, and a violation of these rules, for any 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; or cause conditions which produce undesirable aquatic life or which produce objectionable tastes in edible aquatic organisms; or result in concentrations or combinations of substances which produce undesirable physiological responses in desirable resident fish, or other desirable aquatic life, or undesirable human health effects, as determined by bioassay or other tests performed in*

[1] Note: Big East Lake is listed overall as impaired (Category 5) in Chapter 4 for dissolved oxygen, temperature, and total phosphorus. This impairment overwrites the 3A assessment for harmful algal blooms.

accordance with standard procedures; or determined by biological assessments in Subsection R317-2-7.3."

The Narrative Standard is applicable to all of Utah's waters. Freshwater lakes are assessed under the narrative standard using the HAB assessment method and the Tier II lakes assessment methods (Chapter 2). The Narrative Standard is broadly applicable to multiple beneficial uses including recreational uses and aquatic life. UDWQ's HAB assessment method reflects the potential for "*undesirable human health effects*" identified in the Narrative Standard.

Harmful algal bloom indicators for recreational use attainment

UDWQ's HAB assessment method is based on an exceedance of 100,000 cyanobacteria cells per milliliter (cells/mL), an established indicator of human health risk. The assessment methods identify two exceedances of this indicator as a recreational use impairment. While cyanobacteria cell counts are the primary indicator for assessment purposes, two supplemental indicators are also used as confirmation of the primary indicator: cyanotoxin concentrations exceeding 20 ug/L and algal growth measured as chlorophyll a concentrations exceeding 50 ug/L (Figure 1). The World Health Organization has defined thresholds for all three indicators that are associated with a low, moderate, high, and very high relative probability of acute human health effects in recreational waters (Table 1). Exposure routes that may result in negative human health effects from HABs and cyanotoxins include dermal contact, inhalation, or ingestion of cyanobacteria or associated cyanotoxins. Additional literature supporting these thresholds and references of thresholds used in other states are provided in the sections that follow.

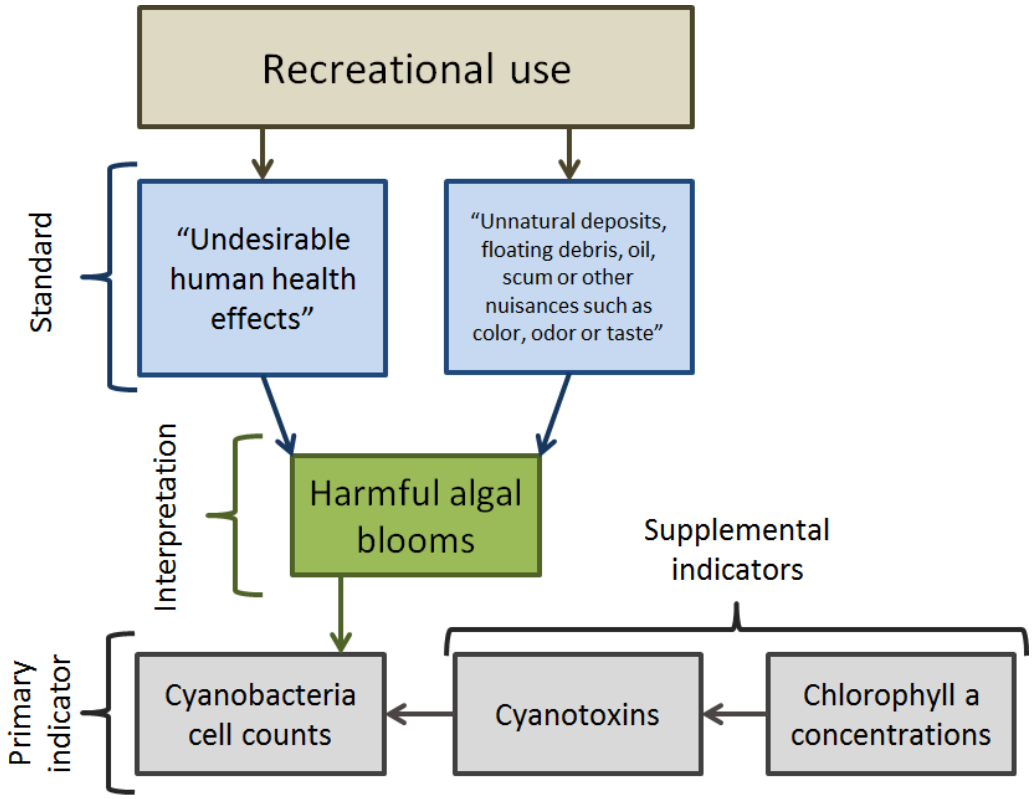

Figure 1. Conceptual diagram of UDWQ's recreational use assessment for HABs under the Narrative standard.

Utah protects water quality for both frequent and infrequent primary contact recreational beneficial uses. Frequent contact recreation includes activities such as swimming or waterskiing where dermal contact, inhalation, and ingestion are all potential exposure routes. Infrequent contact recreation includes activities such as wading or boating where occasional dermal contact or inhalation is the most likely exposure routes. In addition, domestic animals accompanying recreationists may experience higher levels of exposure to HABs than humans, particularly in waters where people generally don't swim.

Table 1. WHO recommended thresholds of human health risk for cyanobacteria, microcystin-LR, and chlorophyll a.

Health Effects Threshold	Cyanobacteria (cells/mL)	Microcystin-LR (µg/L)	Chlorophyll-a (µg/L)
Low	< 20,000	<10	<10
Moderate	20,000-100,000	10-20	10-50
High	100,000-10,000,000	20-2,000	50-5,000
Very High	> 10,000,000	>2,000	>5,000

Primary indicator: Cyanobacteria cell concentrations

The 100,000 cell/mL cyanobacteria indicator is a well-supported indicator of human health risk and negative impacts on recreational uses in a waterbody. The World Health Organization (WHO) first identified 100,000 cells/mL as a threshold representing high human health risk in 1999. WHO identifies possible health effects including potential acute poisoning, long-term illness, skin irritation, and gastrointestinal illness associated with exposure to cyanobacteria at these levels. Review of the studies underlying the WHO recommendations as well as additional research provides further evidence of the link between cyanobacteria and human health issues. Prominent studies on the human health effects of recreation exposure to cyanobacteria consistently identify human health issues such as gastrointestinal distress, headaches and earaches, skin or eye irritation, and temporary respiratory illness occurring at cyanobacteria cell counts at or below 100,000 cells/mL (Pilotto et al. 1997, Stewart et al. 2006, Levesque et al. 2014, Lin et al. 2016). For example, Pilotto et al. 1997 identify a significantly higher occurrence of these types of symptoms at a threshold of only 5,000 cells/mL. Levesque et al. 2014 identified increased gastrointestinal illness associated with limited contact activities such as fishing and boating at cyanobacteria cell counts exceeding 20,000 cells/mL, demonstrating that even limited recreational contact with water containing greater than 100,000 cells/mL of cyanobacteria may result in adverse health effects for recreational users. Stewart et al. 2006 and Lin et al. 2016 also both identify similar negative human health effects associated with recreational contact to cyanobacteria cell counts at or below 100,000 cells/mL. Importantly, the negative health effects observed in several of these studies (Pilotto et al. 1997, Stewart et al. 2006, Lin et al. 2015) were not necessarily associated with cyanotoxin concentrations, suggesting cyanotoxin concentrations alone are not sufficient for determining health risk associated with HABs. The 100,000 cell/mL cyanobacteria cell count indicator used in this assessment is a benchmark that represents a clear potential risk for human health issues.

Utah's use of the 100,000 cells/mL threshold for recreational use assessments is also consistent with those of other states. Wisconsin assesses recreational use support using a 100,000 cell/mL cyanobacteria threshold (WDNR 2015), and New Hampshire uses a threshold of 70,000 cells/mL to assess waters as impaired for cyanobacteria scum (NHDES 2015). Arizona also identifies mean blue green algae counts greater than 20,000 cells/mL in conjunction with elevated chlorophyll a as a violation of the state's Narrative Nutrient Criteria for Lakes and Reservoirs (AZDEQ 2009). At least 12 other states including Indiana, Kentucky, Oklahoma, Wisconsin, Kansas, Arizona, Connecticut, Massachusetts, Rhode Island, Idaho, Oregon, and Virginia have identified cyanobacteria or toxigenic algae taxa cell counts at or below 100,000 cells/mL as an appropriate benchmark for issuing public health watches or warnings or closing recreational areas. No other states that have adopted recreational guidelines for cyanobacteria have established a higher benchmark as indicative of human health risks. In addition, other countries including Canada, New Zealand, and several European countries have also issued human health guidelines for recreational waters based on the WHO cyanobacteria cell count indicators (Chorus 2012).

Supplemental indicator: Cyanotoxin concentration indicators

For recreational waters, WHO identifies microcystin-LR concentrations greater than 20 µg/L as a human health risk. The WHO guideline for microcystin in recreational waters is based on a tolerable daily intake calculated from a microcystin exposure study (Fawell et al. 1994) and the expected

incidental consumption of water of a 60 kilogram adult. However, several states and countries have set lower thresholds for human health advisories based on studies that have identified lower values for microcystin toxicity based on expected recreational exposure of small children. Microcystin concentrations are used in Utah's HAB assessment as confirmatory evidence of toxin producing algae that pose a human health risk to recreational uses.

Supplemental indicator: Chlorophyll *a* concentration indicators

For recreational waters, WHO also recommends 50 ug/L of chlorophyll *a* as a threshold indicative of human health risk. Several scientific studies identify a pattern of increasing cyanobacterial dominance (as either density or biovolume) with increasing chlorophyll *a* concentrations in lakes and reservoirs (e.g. Downing et al. 2001, Rogalus and Watzin 2007, Pokaine et al.2014). Similarly, the likelihood of occurrence of cyanotoxins has also been shown to increase with elevated chlorophyll *a* concentrations (WHO 2003, Rogalus and Watzin 2007, Lindon and Heiskary 2009, Yuan et al. 2014). This pattern of a positive relationship between cyanotoxins and chlorophyll *a* concentrations is consistent both within single lakes as demonstrated by Rogalus and Watzin (2007) in Lake Champlain and across lakes at a national scale as demonstrated by Yuan et al. 2007 using the EPA's National Lakes Assessment dataset. Chlorophyll *a* data from open water samples are used in Utah's assessment to provide context and supplemental information regarding the probability and extent of HAB occurrences.

HARMFUL ALGAL BLOOM ASSESSMENT FOR UTAH LAKE

Utah Lake is a shallow, generally well-mixed lake with relatively large surface area (about 380 km^2). It is currently protected for the designated beneficial uses of infrequent primary contact recreation (2B), warm water fish (3B), waterfowl and shore birds (3D), and agricultural uses including irrigation and stock watering (4) (UAC 317-2-13.5). However, Utah Lake is currently being used for recreational activities that are better characterized as frequent primary contact recreation (2A) and this constitutes an existing use of Utah Lake. The aquatic wildlife uses in Utah Lake were previously listed as impaired due to total phosphorus concentrations (1994) and polychlorinated biphenyls in fish tissue (2010), and the agricultural uses were listed as impaired due to total dissolved solids concentrations (2006). Due to water quality differences between Provo Bay and the rest of Utah Lake, DWQ has split Provo Bay into a separate assessment unit and it is assessed separately.

Recreational Uses in Utah Lake

Utah Lake is an important recreational resource for the State of Utah. Popular activities include fishing, boating, water skiing, and more recently, swimming and wading. Developed recreational facilities include Utah Lake State Park, American Fork Boat Harbor, Lindon Marina and Boat Harbor, Vineyard Beach, Pelican Bay Marina, and Lincoln Beach Park and Marina. There are numerous other points of access for recreational use surrounding the lake identified on the Utah Division of Wildlife Resources' website at http://wildlife.utah.gov/utah_lake_acess.

Recreational use on Utah Lake is high. According to Utah Lake State Parks' visitation data (UDNR 2016) the average number of visitors to this facility since 2006 is 253,599 per year. In addition, the Utah Lake Commission is actively working to increase public access and recreational opportunities on Utah Lake including the development of new recreation facilities (Utah Lake Commission 2009). As the population in Utah County grows, the number of people recreating on Utah Lake is expected to increase.

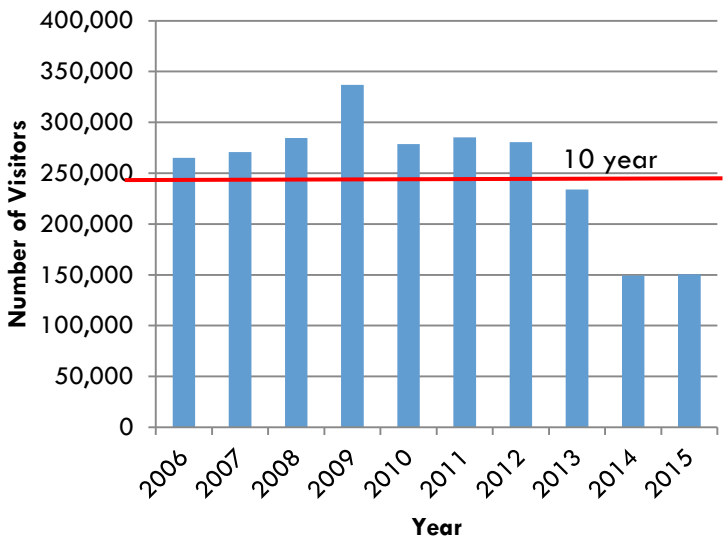

Figure 2. Number of visitors to Utah Lake State Park from 2006 to 2015 (UDNR, 2016)

Relevant Data

UDWQ collected two types of water quality samples in Utah Lake that are used in this analysis: (1) targeted HAB samples and (2) routine open water monitoring samples. The targeted HAB samples were collected at times and locations when observed potential HABs occurred in fall 2014. HAB-targeted samples are essential for assessing water quality that is protective of potential human health in locations where recreational contact with HABs is most likely, including marinas, inlets, and shorelines. These samples were collected to obtain cyanobacteria cell counts and cyanotoxin quantification and are the primary sample type assessed in this chapter. Given the sporadic nature of HAB occurrences, infrequent and routine water quality samples collected from open water monitoring locations are unlikely to detect HABs in most water bodies. Open water chlorophyll *a* samples are used to characterize the potential frequency and extent of HAB occurrence in Utah Lake.

A total of 18 HAB-targeted phytoplankton and cyanotoxin samples were collected in several locations throughout the lake during October 2014 when suspected HABs were observed. An additional three cyanotoxin samples were collected in the Jordan River immediately below the outlet from Utah Lake during and after the October 2014 bloom.

UDWQ also collected over 150 open water samples at eight monitoring locations in Utah Lake during the 2016 IR cycle (May-November, 2008-2014, Figure 3). These samples include full water chemistry analyses, but only the chlorophyll *a* data were used as a supporting indicator in this HAB assessment. An additional 45 phytoplankton samples were also collected during routine monitoring events but none of them exceeded the 100,000 cells/mL threshold and they are not indicative of HAB events.

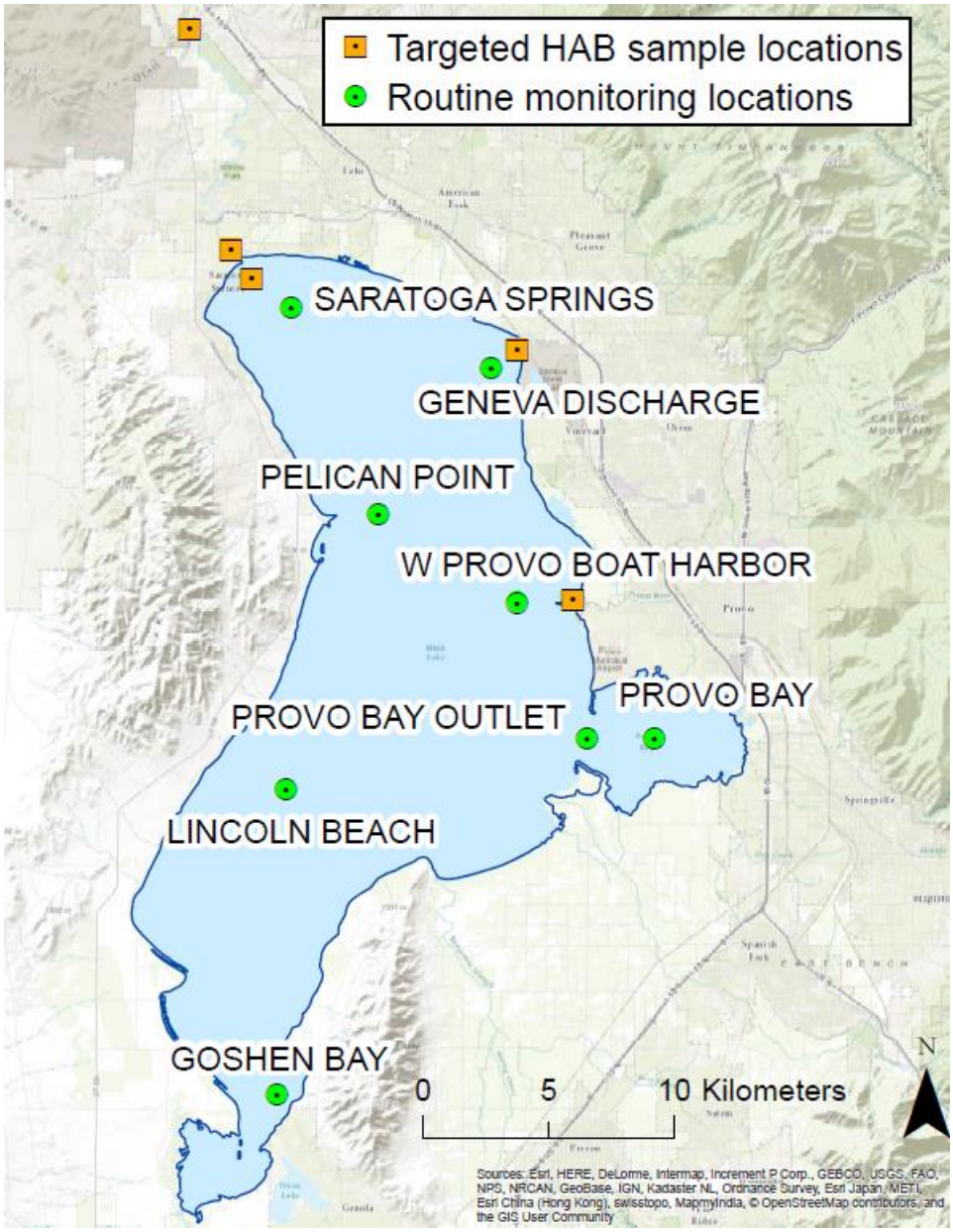

Figure 3. Map of UDWQ monitoring locations in Utah Lake and Jordan River. Routine water quality and profile monitoring locations as green circles. Targeted HAB and cyanotoxin samples as orange squares.

Exceedances of Primary Indicator: Cyanobacteria cell counts

Phytoplankton assemblage monitoring by UDWQ and partners during October, 2014 identified five exceedances of the cyanobacteria cell count indicator of 100,000 cells/mL at three locations on two separate days (Figure 4). These samples were collected in Lindon Harbor, Utah Lake State Park Harbor, and near the lake outlet. Two of these samples exceeded 200,000 cells/mL of cyanobacteria and one exceeded 750,000 cells/mL. Samples collected in Provo Bay did not exceed the 100,000 cell/mL indicator.

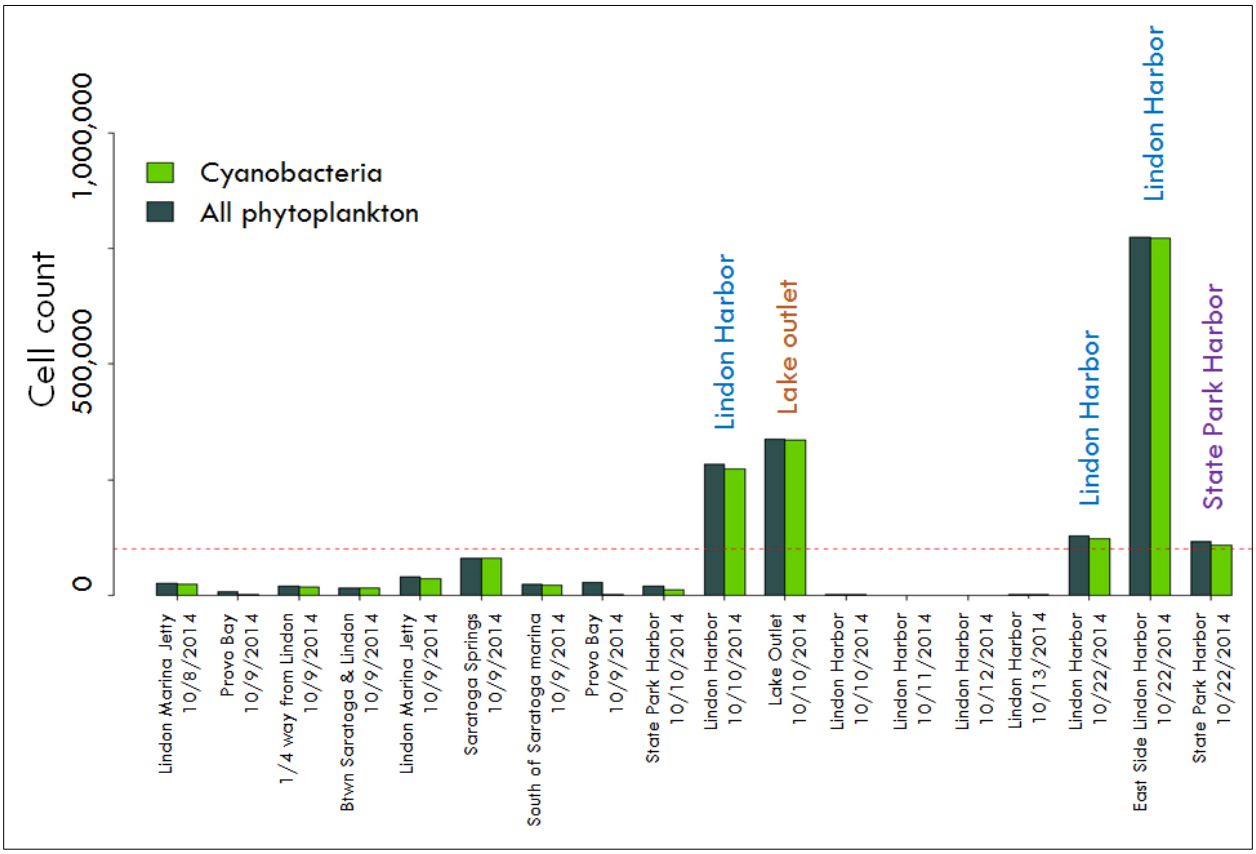

Figure 4 . Harmful algal bloom events in Utah Lake during October, 2014. Total phytoplankton counts for each sample are drawn in dark green with cyanobacteria counts beside in light green. The 100,000 cell/mL indicator is identified by a red dashed line.

Figure 5. Photographs of the HAB events and targeted sample collections in Utah Lake, October 2014.

Exceedances of supplemental indicators

Cyanotoxin concentrations in Utah Lake

Three cyanotoxins (microcystin, anatoxin-a, and cylindrospermopsin) were detected in Utah Lake during the October 2014 algal bloom. One sample collected on October 10, 2014 along the Lindon Marina shoreline, identified a microcystin-LR concentration of 730 µg/L, greatly exceeding the WHO health risk indicator of 20 µg/L. This sample was collected from a targeted location along the shoreline as recommended by Utah's HAB guidance to assess the highest risk of exposure at a point of potential recreational contact (Figure 5, bottom photos). A second sample collected north of the Lindon Marina jetty on October 6, 2014 showed a microcystin-LR concentration of 11.2 µg/L (Table 2).

Table 2. Microcystin samples collected on Utah Lake and the Jordan River during October 2014. ND = non-detect.

Waterbody	Location	Date	Microcystin (µg/L)
Utah Lake	Lindon Marina Interior	10/6/2014	4.50
Utah Lake	Lindon Marina N of Jetty	10/6/2014	11.20
Utah Lake	Lindon Boat Harbor	10/8/2014	0.18
Utah Lake	State Park Harbor	10/8/2014	0.30
Utah Lake	Outlet to Jordan River	10/8/2014	0.21
Jordan River	Utah Lake outlet	10/8/2014	0.19
Jordan River	Narrows Pump Station	10/8/2014	0.20
Utah Lake	Lindon Boat Harbor/Marina	10/10/2014	0.80
Utah Lake	State Park Harbor	10/10/2014	ND
Utah Lake	Outlet to Jordan River	10/10/2014	0.23
Utah Lake	Target (Lindon Harbor Shoreline)	10/10/2014	730
Jordan River	Utah Lake Outlet	10/10/2014	0.17
Jordan River	Narrows Pump Station	10/10/2014	1.39

Chlorophyll *a* concentrations

Chlorophyll *a* concentrations measured during routine lake monitoring demonstrate consistently high algal growth in Utah Lake throughout the entire 2016 *Integrated Report* data period (2008-2014), identifying a recurring risk for HAB occurrence. Throughout the main body of Utah Lake, the chlorophyll *a* indicator for human health risk (50 µg/L) was exceeded in 19 out of 154 samples (12%) from 2008 through 2014 (Table 3). Exceedances were observed at all routine monitoring locations except Pelican Point. In Provo Bay, the chlorophyll *a* indicator was exceeded in 14 of 19 samples (74%).

Table 3. Chlorophyll *a* sample size and exceedances of the 50 µg/L chlorophyll *a* threshold by monitoring location.

Monitoring Location	Sample size	Exceedances
Geneva Discharge	23	3
Pelican Point	23	0
W Provo Boat Harbor	20	6
Lincoln Beach	23	1
Saratoga Springs	23	1
Goshen Bay	20	6
Provo Bay Outlet	22	2
Provo Bay	19	14
Total	173	33

Other issues related to HAB occurrences in Utah Lake

There are several other issues related to the occurrence of HABs in Utah Lake that are not captured by the HAB assessment methodology but may be important to Utah Lake stakeholders. These include the potential for HABs to trigger public health advisories for recreational areas, negative effects on the health of domestic animals including pets, and impacts to downstream uses of the Jordan River.

Utah Lake recreational use advisories

The HAB events in October 2014 caused the Utah County Health Department to issue a public health advisory for recreational areas including Lindon Marina. In addition, the following summer of 2015, observed algal blooms again triggered public health advisories. Based on visual observations, local health department officials strongly suspected a cyanobacteria bloom. Subsequent phytoplankton monitoring did not identify exceedances of the 100,000 cell/mL cyanobacteria threshold, but photographs and personal communication from the sampling events suggest that the bloom was largely dissipated by the time of sample collection, and may have missed a HAB occurrence (Figure 6). Although there is uncertainty in identifying this event as a HAB, it did result in a public health advisory for recreational uses in Lindon Harbor (8/20/2015).

Figure 6. Photographs of the 2015 algal blooms that triggered a recreational advisory at Utah Lake.

Utah Lake dog deaths

Dogs and other animals can be especially susceptible to the harmful health effects of cyanotoxins while swimming and playing in water with HABs. They tend to ingest larger quantities of scum while swimming and when grooming, by licking the scum off their fur. Two dog deaths were potentially linked to algal toxins during the October 2014 HAB events in Utah Lake. UDWQ recognizes the uncertainty associated with diagnosing the causes of these deaths and directly linking them to algal toxins, and initial reports for the first reported death did not identify a conclusive cause of death. However, veterinarian investigations into the second reported death did conclude ingestion of cyanobacteria or cyanotoxins to be the cause of death. This finding was based on the dog's symptoms including rapid breathing, the veterinarian's past experience dealing with cyanotoxin poisonings in another state, and clear signs of exposure to cyanobacteria including the presence of cyanobacteria on the dog's nose. Despite the lack of confirmation that cyanobacteria poisoning was the cause of the death for the dog that died on October 5, 2014, UDWQ and Utah Department of Health scientists still suspect cyanobacteria as the sole or a contributing cause of death for both dogs. Both dogs died within hours of being in the water where toxin-producing cyanobacteria were present. The symptoms exhibited were consistent with cyanotoxin poisoning, specifically neurotoxins. Even though cyanobacteria were not detected in the dog's stomach during necropsy, the dog's owner reported that the dog was drinking the water where "algae" had accumulated and vomited bright green "algae." Cyanotoxins were not detected in the tissues of the necropsied dog, but the analytical methods that were used only identify a limited number of the known cyanotoxins, and additional unidentified toxins are suspected to exist.

Negative results from the toxin analyses are not uncommon in dog deaths attributed to cyanotoxin poisonings. Other causes not related to cyanobacteria are plausible as the cause of one or both of the deaths, but these were judged to be less likely given the weight of environmental evidence and that two dogs died within 24 hours of one another after ingesting Utah Lake water.

Cyanotoxins in Jordan River below Utah Lake outlet

Four samples taken in the Jordan River downstream from Utah Lake identified levels of microcystin-LR above detection limits during the October 2014 algal bloom. This section of the Jordan River is protected as a class 1C drinking water source (UAC R317-2.6). UDWQ will monitor for cyanotoxins at this site during future HAB blooms to ensure there is no threat to drinking water uses. The Jordan River is also protected as class 4 for agricultural uses. Numerous diversions from the Jordan River are used for stock watering and as secondary sources of water for residential properties in the south Salt Lake Valley. These data demonstrate the potential for negative impacts on downstream uses from HAB occurrences in Utah Lake.

Summary

Five unique exceedances of the primary HAB indicator for human health risk (100,000 cyanobacteria cells/mL) occurred at three locations in Utah Lake on two separate days in October 2014 (Table 4). Of these blooms, UDWQ measured cyanotoxin microcystin concentrations that pose a threat to human health. In addition, open water chlorophyll a concentrations from 2008-2014 exceeded the human health risk threshold of 50 µg/L representing 19% of total samples collected and demonstrating a risk for HAB occurrence (Table 4). Together, these indicators identify an impairment of the recreational use

under the Narrative Standards in Utah Lake for the occurrence of HABs. Exceedances of the primary cyanobacteria indicator were not detected in Provo Bay, and recreational use in Provo Bay has therefore not been identified as impaired for HAB occurrences. However, chlorophyll a samples in Provo Bay do identify consistently high algal growth.

Table 4. Number and percent of exceedances in Utah Lake for all three indicators at human health risk thresholds as defined by WHO.

	HAB-targeted/harbor samples		Open water samples
Parameter	Cyanobacteria	Microcystin	Chlorophyll a
Threshold	(100,000 cells/mL)	(20 µg/L)	(50 µg/L)
Sample size	18	12	173
Exceedances	5	1	33
Percent exceedance	28	8.3	19

FREQUENTLY ASKED QUESTIONS

Aren't cyanobacteria naturally occurring in Utah Lake?

Cyanobacteria are among the oldest known photosynthetic organisms and their persistence over the last 3.5 billion years has allowed these organisms to evolve into a diverse group of organisms that are well adapted to a variety of conditions (Pearl and Huisman 2009). They occur naturally in both freshwater and marine waters, and in conditions that range from hot springs to the arctic. The diversity and tolerance of these organisms allows then to take advantage of alterations to aquatic ecosystems, which may explain the increasing dominance of the organism in aquatic ecosystems worldwide (Taranu et al. 2015).

Although cyanobacteria are naturally present in many temperate waters, including Utah Lake, the concentrations of cyanobacteria in large blooms in Utah Lake appear to have increased. These blooms are a concern especially when they involve species that are known to produce toxins, because exposure during these blooms is more likely to result in detrimental health effects (Pilotto et al. 1997). It is not the presence of these species that resulted in the impairment decision for these waters, but the magnitude of blooms and presence of toxins.

Paleolimnology investigations have been conducted on Utah Lake (Macharia 2012; Bolland 1974) that describe a general increase in algal production following European settlement. Data from these investigations suggest that Utah Lake has become increasingly eutrophic over time. Macharia (2012) was primarily interested in the effects of land use patterns, so the Utah Lake study emphasized indicators of sediment and pollen characteristics over temporal patterns in lake algae. This investigation demonstrated an increase in sediment nutrient concentrations corresponding to increasing population growth. Reductions in the carbon:nitrogen ratio were also observed in Utah Lake indicating an increase in algal productivity over time. This observation was bolstered with increases in the isotope ^{13}C, which suggests an increasing importance of algal organic matter over other carbon sources. Using a similar coring technique to that in Macharia (2012), Bolland (1974) analyzed changes in diatom assemblage over time in Utah Lake cores. This study found that pre-settlement diatoms in the lake reflected a greater representation of oligo/meso-trophic diatom taxa and benthic taxa. This means that historic conditions were very likely less turbid and typified by lower nutrient conditions.

How does the relative importance of natural and human-caused algal blooms play into impairment decisions?

UDWQ, under delegated federal Clean Water Act authority, is required to report any observed water quality problems to EPA on a biennial basis, including "*those water quality standards established under section 303 of the Act, including numeric criteria, narrative criteria, waterbody uses and antidegradation requirements*" (40 CFR §130.7(b)(3)). Reporting observed violations in water quality standards means that initial impairment listings are often made in situations where there is uncertainty about the cause, source or extent of the impairment. The decision to list a water body as impaired is only the first step in a series of steps aimed at addressing the problem. Additional investigations are required before remediation plans can be proposed and implemented. In this case, the investigations

will need to include a better characterization of algal blooms in Utah Lake, including the relative importance of natural and human-caused sources, and linkages with aquatic life uses.

Is the very high microcystin concentration recorded at Lindon Harbor on October 10, 2014 representative of bloom conditions and risk?

Phytoplankton and cyanotoxin samples taken during the HAB events in Utah Lake included both composite water column samples from relatively open water and targeted surface scum samples located at recreational access points. Taking both types of samples helps quantify both the spatial extent and overall human health risk of a HAB event. Utah's HAB sampling guidance recommends sampling areas of a waterbody where algae cells tend to accumulate and where recreationists are most likely to contact harmful algae including along shorelines and within protected areas such as harbors. A targeted sample collected along the Lindon Harbor Shoreline on October 10, 2014 resulted in cyanobacteria cell counts exceeding 750,000 cells/mL and a microcystin concentration of 730 µg/L (Figure 5, bottom). This type of sample helps to quantify the total human health risk of HAB events.

Doesn't Utah require two IR cycles to make a listing decision?

UDWQ's assessment methods for lakes and reservoirs previously required two IR cycles of equivalent support status to change the use support designation. These methods were developed when monitoring data was collected every other year for each lake (e.g., see **DWQ 2008 Assessment Methods**). When UDWQ began monitoring using a rotating basin approach, commenters questioned whether the two consecutive monitoring cycle requirement was appropriate because instead of a lake being sampled every other year, a lake would be sampled every six years (see response to comments for both the **2008** and **2010** *Integrated Reports*). UDWQ determined that the two consecutive cycle methodology could not be supported if the consecutive cycles were six years apart under the rotating basin monitoring approach. An impairment could go undetected for up to 13 years if for instance, a lake was newly impaired the year following the last monitoring, it would be five years to the next monitoring, another six years until the second monitoring, and two years until that data would be assessed in the *Integrated Report*. Therefore, the assessment methods were revised and two consecutive monitoring cycles are no longer required. This change ensures that lakes with impaired water quality are identified and a plan for resolving the impairment is implemented as soon as practical.

Why use the 100,000 cells/mL cyanobacteria threshold?

UDWQ's use of the 100,000 cell/mL cyanobacteria threshold for HAB assessment seeks an appropriate balance between the high priority of protecting human health and the uncertainty inherent in the assessment process. Given the human health risks associated with HABs and cyanotoxins, a significant level of caution is appropriate. Although the presence of cyanotoxins is the clearest sign of immediate health risk, toxins can be formed, degraded, and dissipated rapidly. In addition, current tests for cyanotoxin concentrations only account for a subset of potentially occurring toxins. This means that the presence of cyanotoxins can serve as confirmation of human health risk, but the absence of cyanotoxins is not necessarily indicative of safe recreational waters. Therefore, the presence of cyanobacteria in concentrations sufficient to produce toxins is a more reliable indicator of overall

human health risk than the concentrations of cyanotoxins themselves. In addition, several scientific studies demonstrate risks to human health at cyanobacteria concentrations at or below100,000 cells/mL. Finally, UDWQ is confident in the use of this threshold and the findings in this chapter for several reasons including:

- The occurrence of toxin producing cyanobacteria was confirmed through taxonomic identifications.
- Concentrations of cyanotoxins exceeded thresholds for human health risk which confirms the risk indicated by the cyanobacteria cell counts.
- The high frequency and magnitude of exceedances of the cyanobacteria cell count indicator reduces the uncertainty in assessing the recreational uses as impaired. In Utah Lake, two samples more than doubled the 100,000 cell/mL threshold, and one sample produced cell counts over 750,000 cells/mL, more than seven times the threshold.

How can you be sure that there is a health risk when not all cyanobacteria produce toxins?

The presence of high concentrations of cyanobacteria indicate that environmental conditions are favorable for both toxin and non-toxin producing cyanobacteria. The number and types of cyanobacteria can rapidly change due to causes that are not currently well understood. High concentrations of cyanobacteria are not a definitive indicator of the presence of a health risk but they do indicate a high potential for health risks (WHO 2003). This potential increases with increasing concentrations of cyanobacteria, if the cyanobacteria are known to be toxin producing, and if toxins are actually detected. These risks are potentially serious and a proactive response is warranted to protect human health.

What are the implications of potential HAB listings for other UDWQ initiatives?

The identification of recreational use impairment for the occurrence of HABs will not alter existing timelines for studying the effects of nutrients on Utah Lake.

The following initiatives and timelines will remain on track:

- Implementation of Utah's Technology Based Phosphorus Effluent Limit rule (UAC R317-1-3.3) requiring all mechanical publically owned treatment works to meet a phosphorus effluent limit of 1 mg/L by January 1, 2020.
- Phase 1 of the Utah Lake Water Quality Study that includes beneficial use assessments for aquatic life; additional monitoring; and a refined load analysis.
- No 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.

New initiatives to follow the 2016 assessment will include:

- Evaluation of additional indicators to determine if any are appropriate for inclusion as formal assessment methods used to interpret the Narrative Standard in future *Integrated Reports*.
- Increased monitoring of harmful algal blooms and nuisance algal growth in popular recreational waters and drinking water sources across Utah.
- Additional research on Utah Lake to determine the causes of harmful algal blooms.

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