TONY GROVE RESERVOIR

LIMNOLOGICAL ASSESSMENT OF WATER QUALITY

November 2008

Tony Grove Reservoir Report
November 19, 2008

Tony Grove Lake is listed by the State of Utah as an impaired water body because dissolved oxygen and pH does not meet State water quality standards and total phosphorus does not meet the indicator level for Class 3A waters, protected for cold water species of game fish and other cold water aquatic species. In partnership with Utah Division of Water Quality (UDWQ), the Uinta-Wasatch-Cache National Forest (UWCNF) collected data from Tony Grove Lake from June 2007 to March 2008 to provide recent detailed water quality information to support an analysis of its beneficial use impairment. Dissolved oxygen impairment appears to be naturally occurring and not caused by man's activities within the Uinta-Wasatch-Cache National Forest. The results of the data and land management activities in the watershed indicate that natural processes are causing the dissolved oxygen impairment during the winter season. Since man-made activities have not caused the impairment, Tony Grove Lake is recommended to be placed in Category 4C of the State of Utah's List as not imparted by a pollutant.

This report contains information listed below.

- Section 1.0: Description of the water body and associated watershed.
- Section 2.0: Description of designated beneficial uses and relevant water quality standards for the parameters of concern.
- Section 3.0: Discussion of water quality targets and appropriate endpoints.
- Section 4.0: Assessment of causes and sources of impairment.
- Section 5.0: Assessment of pollution sources.
- Section 6.0: Technical analysis of water quality data in relationship to abiotic and biological processes.
- Section 7.0: Use Attainability Analysis.
- Section 8.0: Discussion of management options and practices.

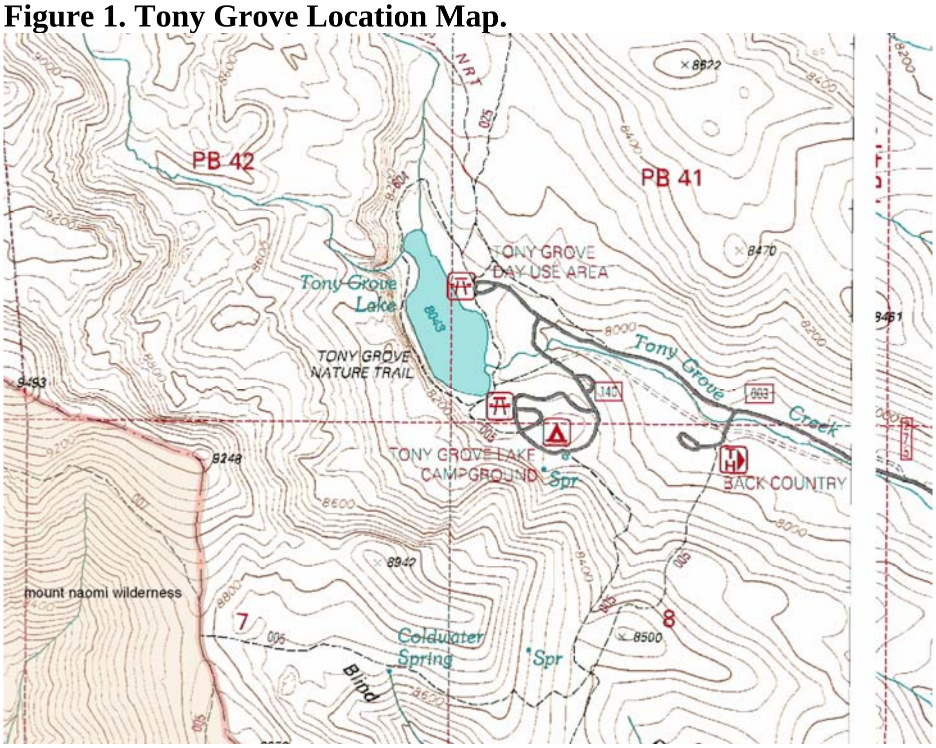
1.0 Introduction

Tony Grove Lake is a natural lake that was enlarged in 1939 when a dam was constructed to raise the water level of the lake. In 2005, the reservoir was drained to below the outlet works and work was done on the dam to meet State dam safety standards. Water filled the reservoir during the winter of 2006-7 and the reservoir was full in the spring of 2007 at which time lake and stream sampling was started for this study.

The lake is in a glacial cirque at the headwaters of Tony Grove Creek a tributary to the Logan River in northern Utah. It lies at an elevation of 8,043 feet and is 25 acres in size with a maximum depth of 11 meters. An ephemeral stream flows in and out of the lake. The watershed above the lake is rather small, about 1,330 acres in size. The watershed receives about 50 inches of precipitation annually with most in the form of snow that falls during the winter. Snow melt is the principal source of surface flow into the lake during the short summer season. The lake maintains a constant water depth throughout the year and no drawdown occurs. The predominant vegetation type in the drainage is subalpine fir and Douglas fir with some limber pine and spruce.

The ground cover in the watershed is in good to excellent condition. The shore surrounding Tony Grove Lake has grasses, forbs, and willows and a hiking trail that goes around the lake is well maintained. There is very little evidence of soil erosion around the lake and very little sediment reaching the lake. The streams flowing into and out of the lake have dense willow along the banks and are in good to excellent condition.

Figure 1. Tony Grove Location Map.



The drainage surrounding the lake is in entirely within federal ownership being part of the Wasatch-Cache National Forest. Tony Grove Lake is located next to the Naomi Peak Wilderness area that encompasses most of the watershed draining into the lake. The lake is used for recreation and cold water aquatic life. The water that passes through the lake is unregulated by man. A Forest Service campground with 37 units is located on the southeast side of the lake of which a few sites are in the drainage area of the lake. A parking lot, restroom, and trailhead are located on the east side of the lake and a hiking trail is located around the lake. A sheep grazing is allowed in the watershed above the lake, but no livestock is allowed around the lake or in the campground area.

The lake elevation has remained constant for the last 50 years. However, in the spring of 2004 the lake was drained in order to perform construction on the dam and outlet works as part of an effort to make the dam safer. The lake was drained to the elevation of the outlet works. Construction was completed and the lake began refilling in late fall 2006.

2.0 Water Quality Standards and Indicators

The State of Utah has categorized all the waters within the Uinta-Wasatch-Cache National Forest as High Quality Waters, Class 1 within the Antidegradation Policy (R317-2; Standards of Quality for Waters of the State) indicating that the existing water quality is better than the established standards for the designated beneficial uses and that water quality is required by state regulation to be maintained at this level. The designated beneficial uses of all waters within the Forest are Class 2B – protected for recreation; Class 3A – protected for cold water species of game fish and other cold water aquatic species; and Class 4 – protected for agricultural uses (Utah, State of 2006). The relevant water quality parameter associated with the lake's designation as impaired for their Class 3A beneficial use is dissolved oxygen. The following table shows Utah's dissolved oxygen criteria for class 3A waters.

Table 1. Utah's Dissolved Oxygen, pH, and Total Phosphorus Criteria for Class 3A waters.

Parameter	Timeframe	Criteria Value	Explanations
Dissolved Oxygen	30 day average	6.5 mg/L	
	7 day average	9.5/5.0 mg/L	Not to exceed 110% of saturation. 9.5 when early life stages are present. 5.0 when all other life stages present.
	1 day average	8.0/4.0 mg/L	Not to exceed 110% of saturation. 8.0 when early life stages are present. 4.0 when all other life stages present.
pH		6.6 – 9.0	
Total Phosphorus		0.025 mg/L	Phosphorus value is for lakes and is a pollution indicator and not a standard. Phosphorus pollution indicator value for streams is 0.05 mg/L.

(R317-2; Standards of Quality for Waters of the State):

The listing methodology employed by Utah for dissolved oxygen to assess Class 3 (aquatic life) beneficial use involves evaluating the dissolved oxygen profile data to see what percent of the water column falls below the one day average value of 4.0 milligrams per liter. When dissolved oxygen is greater than 4.0 milligrams per liter for greater than 50% of the water column, a fully supporting status is assigned. If 25-50% of the water column is less than 4.0 milligrams per liter, a partial support designation is assigned. If less than 25% of the water column is above 4.0 milligrams per liter or higher, a non-supporting designation is assigned (Utah 303(d) List of Waters, Utah DEQ 2000).

In addition, an evaluation of the trophic state index (TSI), winter dissolved oxygen conditions with reported fish kills, and the presence of significant blue green algal species in the phytoplankton community is made. If two of these three additional criteria indicate a problematic condition, the support status can be shifted downward.

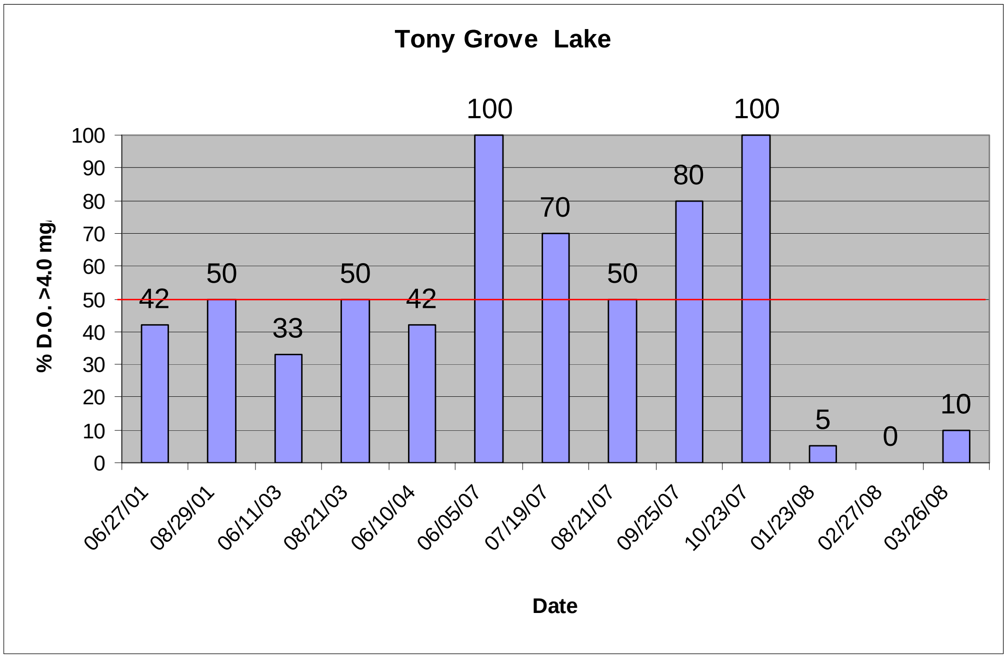
Lastly, the historical beneficial use support is evaluated for the water body in question. If a waterbody shows that beneficial use impairment consistently exists, the waterbody should be listed on the 303(d) list. However, if a waterbody exhibits a mixture of partially and fully supporting conditions over a period of years, the waterbody should continue to be evaluated. Table 2 presents the 303(d) listing for Tony Grove Lake.

Table 2. Utah 2006 303(d) listing for Tony Grove Lake.

Waterbody	**Waterbody Size**	**Beneficial Use Impaired**	**Pollutant or Stressor**
Tony Grove Lake	25 acres	3A Cold Water Species of Game Fish	Dissolved Oxygen, pH, Total Phosphorus

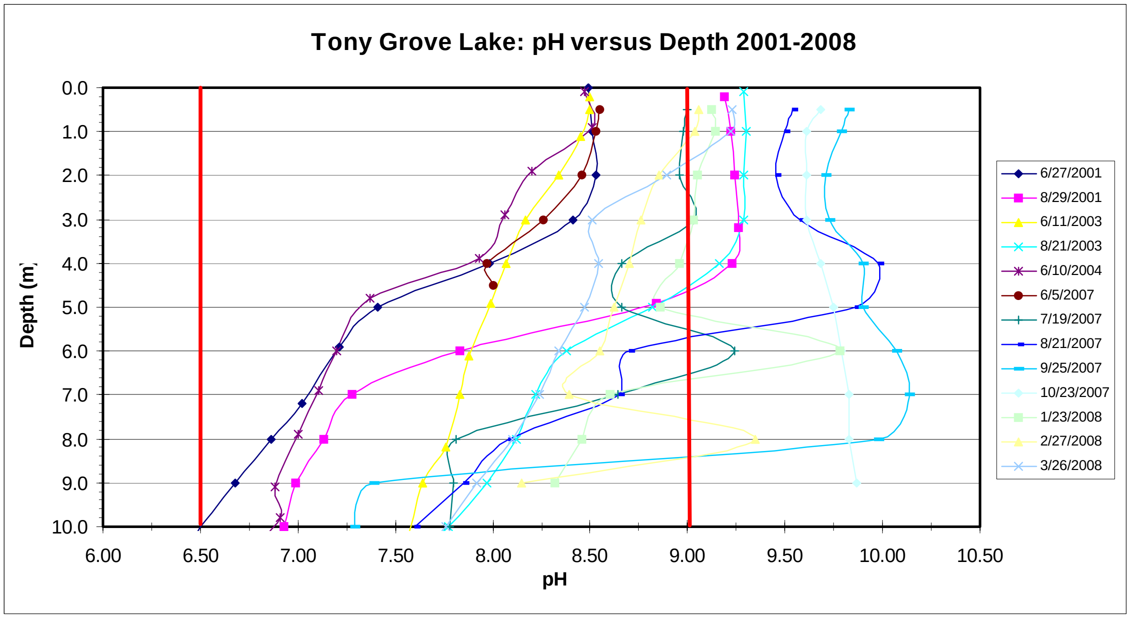
The percentage of the total water column above 4 mg/L dissolved oxygen in Tony Grove Lake is shown in Figure 2. Prior to the 2007-8 sampling events, dissolved oxygen profiles were taken in June and August and the percentage of the column greater tan 4mg/L were 33 to 50%. The monthly dissolved oxygen profile from June to October 2007 begins at 100% drops to 50% then returns to 100%. The June 2007 profile was only 5 meters deep and does not reflect the 10 meter profiles of the other months in 2007-8. Comparing the dissolved oxygen profiles to the secchi depth indicates that for the summer months the upper profile where light can penetrate has dissolved oxygen concentrations greater tan 4.0 mg/L. During the winter season, dissolved oxygen in almost the entire water column is less than 4 mg/L.

Figure 2. Percent of Water Column above 4 mg/L Dissolved Oxygen.



The pH levels in Tony Grove Lake exceed State Standards during several months of the year as shown in Figure 3. Nine of 13 months that were sampled exceeded the pH standard in some part of the water profile. For data collected in 2007-8, the only profile that did not exceed the pH standard in some part of the profile was June 2007. September and October 2007 profiles exceeded pH standards for the entire water column or almost all of the water column.

Figure 3. Tony Grove Lake pH profiles.



As shown in Table 3, total phosphorus exceeds the indicator value of 0.025 mg/L mostly in the water below the thermocline. Seven of 50 samples exceeded the indicator value above the thermocline while 28 of 49 samples exceeded the indicator value below the thermocline. Most of the samples at the bottom, 20 of 27 samples, exceeded the indicator value. Since, 2001, all samples collected above the thermocline had non-detection of total phosphorus. Samples collected in the winter that had non-detection for entire water profile except at the bottom in March 2008 which exceeded the indicator value.

Table 3. Tony Grove Lake - Nutrients by Depth Level and Date.

Date	Total Phosphorus as P (mg/l) Surface	Above Thermocline	Middle of Water Column	Below Thermocline	Bottom
7/8/1981	0.005	----	----	----	0.020
6/13/1989	0.005	----	0.015	----	0.081
8/24/1989	0.035	0.030	----	0.022	0.044
4/3/1990	0.033	----	----	----	0.057
6/11/1991	0.010	0.010	----	0.010	0.149
8/29/1991	0.010	0.010	----	0.014	0.028
6/23/1993	0.010	0.010	----	0.017	0.142
8/25/1993	0.011	0.010	----	0.026	0.028
7/12/1995	0.010	0.010	----	0.050	0.170
8/8/1995	0.010	0.010	----	0.010	0.020
7/15/1997	0.053	0.044	----	0.056	0.137
9/25/1997	----	----	----	----	----
7/7/1999	0.020	0.058	----	0.021	0.207
8/17/1999	0.026	0.020	----	0.038	0.081
6/27/2001	0.021	0.022	----	0.027	0.143
8/29/2001	0.020	0.020	----	----	0.048
6/11/2003	0.020	0.020	----	0.020	0.166
8/21/2003	0.020	0.020	----	0.029	0.042
10/22/2003	0.020	----	0.020	----	0.020
6/9/2004	0.020	0.020	----	0.020	0.186
6/5/2007	0.020	0.020	----	0.020	0.020
7/19/2007	0.020	0.020	----	0.028	0.047
8/21/2007	0.020	0.020	----	0.020	0.043
9/25/2007	0.020	0.020	----	0.029	0.028
10/23/2007	0.020	0.020	----	0.020	0.020
1/23/2008	0.020	0.020	----	0.020	0.020
2/27/2008	0.020	0.020	----	0.020	0.020
3/26/2008	0.020	0.020	----	0.024	0.055

Note: Blue means non-detect and minimum detection value for dates 1989 is 0.005 mg/L, 1991-1995 is 0.01 mg/L., and 1997-2008 is 0.02 mg/L.. Red highlighted values exceed pollution indicator limit of 0.025 mg/L. "----" indicates no data.

3.0 Water Quality Targets/Endpoints

This section discusses whether the impairments are naturally occurring and if not, what quantifiable targets or endpoints will achieve water quality standards.

Pollution from point sources and nonpoint sources can enter a lake and cause water quality problems. The USEPA (Olem and Flock 1990, 94) states that point source wastewater from industrial, municipal, and household sources can be high in organic matter, bacteria, and nutrients. Discharge of wastewater into a lake can be assessed by looking for indicators of pollution such as algae blooms or turbid water. Non-point sources of pollution can also contaminate lakes through runoff and groundwater. Runoff can carry sediment and fertilizers from roads, lawns, agricultural wastes such as livestock manure. Nutrients and bacteria can enter a lake through malfunctioning septic systems. When bacteria consume nutrients, dissolved oxygen is consumed, particularly in the hypolimnetic zone. This can result in low dissolved oxygen levels, fish kills, odors, and noxious conditions. In addition nutrients act as a fertilizer and can stimulate excessive growth of algae and macrophytes that may contribute to additional loss of dissolved oxygen.

Point source and nonpoint source pollution is not occurring in Tony Grove Lake. The watershed that drains into Tony Grove Lake does not have point sources of pollution because there are no industrial, municipal, or household discrete points of wastewater discharges. Runoff carrying sediment is the only nonpoint source of pollution that could cause pollution to enter Tony Grove Lake because human waste is contained in vault toilets that are functioning and maintained properly. Land conditions around the lake indicate that runoff is controlled and sediment above naturally occurring amounts is not entering Tony Grove Lake. A review of possible sediment sources along the shoreline surrounding Tony Grove Lake was conducted during field visits in the summer of 2007 and no sediment deposition was noted in the lake along the shoreline.

Tony Grove Lake appears to be acting under natural processes. The trophic state is what is expected from a lake that has low nutrient inputs in a coniferous forest environment. As shown in Table 6, man-made inputs of phosphorus and nitrogen are not detected in the stream above Tony Grove Lake and it appears that dissolved oxygen is used up in the winter as a result of low photosynthesis due to low light conditions because of ice and snow covering the entire lake surface, from macrophyte respiration, and bacteria respiration that uses up oxygen during the decay of dead plants and animals.

4.0 Source Assessment

Land management activities do not appear to be contributing to dissolved oxygen impairment that occurs during the winter season. Ground cover, which is an indicator of how well soil is protected from erosion, is good to excellent in the watershed, there is very little evidence of soil erosion around the lake, and nutrients are not detected in samples taken from the stream entering the lake. As discussed in Section 8.0, several projects to aerate water in lakes nearby have not been successful. No management actions are recommended at this time because the lake is functioning under natural processes, impairment occurs during the winter when snow depths are high, respiration from macrophytes and bacterial decay would naturally use the oxygen in the shallow lake water.

5.0 Significant Sources

In order to identify sources of pollution, maps were reviewed to determine where surface water drains into Tony Grove Lake, what and where man-made activities occur within the watershed, and field visits during the summer of 2007 looked at land conditions such as the amount as ground cover, sediment deposition, rills and gullies, and other indicators of erosion and sedimentation. As result of this review, no significant sources of pollution were identified.

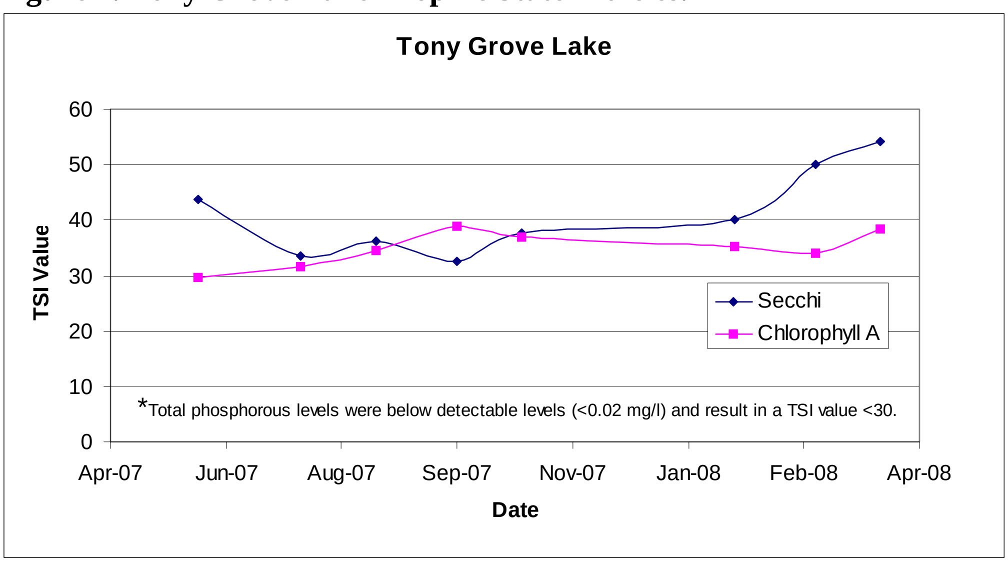
6.0 Technical Analysis

This section contains a description of water quality data conditions at Bridger Lake and at the end, a discussion containing a summary by Bronmark and Hansson (2005) of abiotic and biological processes that occur in lakes and ponds and a comparison of these concepts with the water quality conditions of Bridger Lake.

Trophic State – Carlson's Trophic State Index (TSI) is used to determine the living biological material or biomass of a lake and uses a continuum of states to indicate the amount of biomass of the lake. The TSI for a lake can be determined using regression equations and values for chlorophyll a, secchi depth, or total phosphorus. Carlson states that the best parameter to use for the index is chlorophyll a and transparency should be used only if no other parameter is available (Kent State 2005).

Using chlorophyll-a for samples collected in 2007-8, the TSI for Tony Grove Lake is between 30 and 40 indicating oligotrophic conditions as seen in Figure 4. A characteristic of oligotrophy is the hypolimnia of shallower lakes may become anoxic. The hypolimnia is the part of a lake below the thermocline made up of water that is stagnant and of essentially uniform temperature except during the period of overturn. Using the secchi depth as an indicator of TSI, it is similar to TSI conditions using chlorophyll-a but also shows the lack of light penetration during the winter months resulting in TSI of 40 to 55 indicating mesotrophic to eutrophic conditions. This appears to reflect conditions in Tony Grove Lake where anoxic conditions occur throughout the water column during the winter months.

Figure 4. Tony Grove Lake Trophic State Indicies.



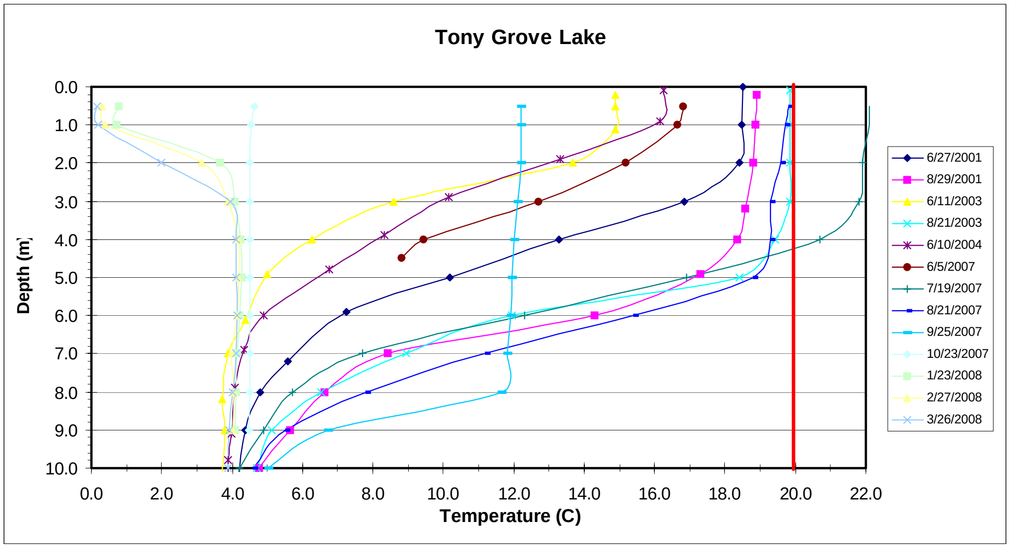
Carlson presents characteristics of north temperate lakes based on the trophic state and says that when lakes become mesotrophic, the hypolimnia of shallow lakes is likely to become anoxic that may result in a loss of salmonids and when lakes are eutrophic, the hypolimnia is anoxic and macrophyte problems are possible (Kent State 2005). Bridger Lake has these characteristics throughout most of the year when the lake is mesotrophic and eutrophic.

A possible reason that the algae biomass is in a eutrophic state during the warmer periods of the year is that those organisms that would limit the amount of algae, such as zooplankton that would feed on the phytoplankton, may be absent or in low populations in the lake water. Since phosphorus and nitrogen nutrients are very limited in the lake and in the source water entering the lake, phytoplankton would increase during the warmer periods of the year without being fed upon by upper levels of the food chain.

Lake Morphology – Tony Grove lake is an oval shaped, small glacial lake with a surface area of 25 acres and a maximum depth of 11 meters. The lake is at an elevation of 8,043 feet (Judd 1997).

Temperature – Temperature versus depth is shown in Figure 5. During the summer months, a thermocline was present between four and seven meters deep. In October 2007, turnover occurred and the temperature was about nine degrees C in the entire water profile. No thermocline was present during the winter months of 2008. Between June and August ,the upper level of the water column in Tony Grove Lake warms up from 14 to 16 degrees C to in the upper two meters in June to 18 to 20 degrees C in the upper four meters in August. Below these levels, the water temperature drops rapidly to six degrees C between four and eight meters in depth. At about 10 meters, the bottom of the lake stays at a relatively constant temperature of four to five degrees C. In July 2007, the upper four meters were above the temperature standard of 20 degrees C.

Figure 5. Tony Grove Lake Temperature vs. Depth Profiles.



Light (secchi depth, chlorophyll concentration) – Based on 2007-8 data, the greatest light penetration occurs during the summer months. Chlorophyll-a concentrations range from 0.9 to 2.2 ug/L and no particular trend can be seen in the data shown in Table 4.

Table 4. Secchi depth and chlorophyll concentration for Tony Grove Lake.

Date	Secchi Depth (m)	Chlorophyll –a (ug/L)
06/05/2007	3.1	0.9
07/19/2007	6.3	1.1
08/21/2007	5.3	1.5
09/25/2007	6.8	2.3
10/23/2007	4.8	1.9
01/23/2008	4.0	1.6
02/27/2008	2.0	1.4
03/26/2008	1.5	2.2

Catchment Area - The watershed draining into Tony Grove Lake is about 1,330 acres in size and the lake was formed in a depression left from glaciers. The watershed high point is Naomi Peak at an elevation of 9,979 feet. Soil in the watershed is glacial till and alluvium. Much of the upland area of the watershed is bare rock and sedges and willows grow along the small stream flowing into Tony Grove Lake (Judd 1997). A small catchment area, particularly within conifer forest, is likely to have low nutrients since soils have low productivity and rainwater has a short distance to reach the lake (Bronmark and Hansson 2005).

pH – pH values versus depth is shown in Figure 3. The pH values within the water column in Tony Grove Lake from 2007 to 2008 ranged between 7.3 and 10.1. The pH trend in the upper part of the water column is the water is alkaline (9.0 to 10.0) in the summer and becomes less alkaline during the winter(pH 8.5 to 9.0). The lower part of the water column becomes less alkaline to almost neutral at the bottom. The pH of the inflow water ranged from 7.3 to 8.6. No outflow occurred form the lake during the sample events. The pH of Tony Grove Lake is alkaline and is typical of most lakes of the earth. According to Bronmark and Hansson (2005), the majority of lakes on earth have a pH between 6 and 9.

Nutrients – Total phosphorus and nitrogen values for Tony Grove Lake and the stream above Tony Grove Lake are shown in Tables 5 and 6. According to Bronmark and Hansson (2005), most lakes unaffected by man have phosphorus concentrations between 0.001 to 0.1 mg/l and total nitrogen concentrations between .004 and 1.5 mg/L. The phosphorus and total nitrogen concentrations of Tony Grove Lake are typical of most lakes unaffected by man. All samples of total phosphorus as P taken throughout that water column are below 0.1 mg/l except eight bottom samples. Almost all dissolved nitrate + nitrite concentrations are below detection and all values that have been detected are below 0.1 mg/L except one that has a value of 2.87 mg/L from a surface sample in August 2001.

Table 5. Tony Grove Lake - Nutrients by depth level in lake.

	Dissolved Total Phosphorus as P (mg/l)				Total Phosphorus as P (mg/l)					D-NO2+NO3, N (mg/l)			
Date	21	23	27	29	21	23	25	27	29	21	23	27	29
7/8/1981	----	----	----	----	ND	----	----	----	0.020	----	----	----	----
6/13/1989	----	----	----	----	ND	----	0.015	----	0.081	----	----	----	----
8/24/1989	----	----	----	----	0.035	0.030	----	0.022	0.044	----	----	----	----
4/3/1990	----	----	----	----	0.033	----	----	----	0.057	----	----	----	----
6/11/1991	ND	ND	ND	0.067	ND	ND	----	ND	0.149	0.028	0.021	ND	ND
8/29/1991	ND	ND	0.012	ND	ND	ND	----	0.014	0.028	ND	0.034	ND	ND
6/23/1993	ND	ND	ND	0.012	ND	ND	----	0.017	0.142	0.027	ND	ND	ND
8/25/1993	ND	ND	0.011	0.010	0.011	ND	----	0.026	0.028	ND	ND	ND	ND
7/12/1995	ND	ND	ND	0.060	ND	ND	----	0.050	0.170	ND	ND	ND	ND
8/8/1995	ND	ND	ND	ND	ND	0.010	----	ND	ND	ND	ND	ND	ND
7/15/1997	----	----	----	----	0.053	0.044	----	0.056	0.137	ND	ND	ND	ND
9/25/1997	----	----	----	----	----	----	----	----	----	ND	ND	ND	ND
7/7/1999	ND	0.020	0.013	0.023	0.020	0.058	----	0.021	0.207	ND	ND	ND	0.100
8/17/1999	ND	ND	ND	ND	0.026	ND	----	0.038	0.081	ND	ND	ND	ND
6/27/2001	ND	ND	ND	0.041	0.021	0.022	----	0.027	0.143	ND	ND	ND	ND
8/29/2001	ND	ND	ND	0.021	ND	ND	----	----	0.048	2.870	ND	ND	ND
6/11/2003	ND	ND	ND	0.083	ND	ND	----	ND	0.166	ND	ND	ND	ND
8/21/2003	ND	ND	ND	ND	ND	ND	----	0.029	0.042	ND	ND	ND	ND
10/22/2003	----	----	----	----	ND	----	ND	----	ND	----	----	----	----
6/9/2004	ND	ND	ND	0.066	ND	ND	----	ND	0.186	ND	ND	ND	ND
6/5/2007	ND	ND	ND	ND	ND	ND	----	ND	ND	ND	ND	ND	ND
7/19/2007	ND	ND	ND	ND	ND	ND	----	0.028	0.047	ND	ND	ND	0.029
8/21/2007	ND	ND	ND	ND	ND	ND	----	ND	0.043	ND	ND	ND	0.027
9/25/2007	ND	ND	ND	ND	ND	ND	----	0.029	0.028	ND	ND	ND	ND
10/23/2007	ND	ND	ND	ND	ND	ND	----	ND	ND	ND	ND	ND	ND
1/23/2008	ND	ND	ND	ND	ND	ND	----	ND	ND	ND	ND	ND	ND
2/27/2008	ND	ND	ND	ND	ND	ND	----	ND	ND	ND	ND	ND	ND
3/26/2008	ND	ND	ND	ND	ND	ND	----	0.024	0.055	ND	ND	ND	ND

Note: ND means Non-detect. Red highlighted values exceed pollution indicator limit (0.025 mg/l for phosphorus and 4.0 mg/l for NO3+NO2). "----" indicates no data. 21 indicates surface sample, 23 above thermocline when present, 25 midpoint of water column when no thermocline is present, 27 below thermocline when present, and 29 indicates bottom sample.

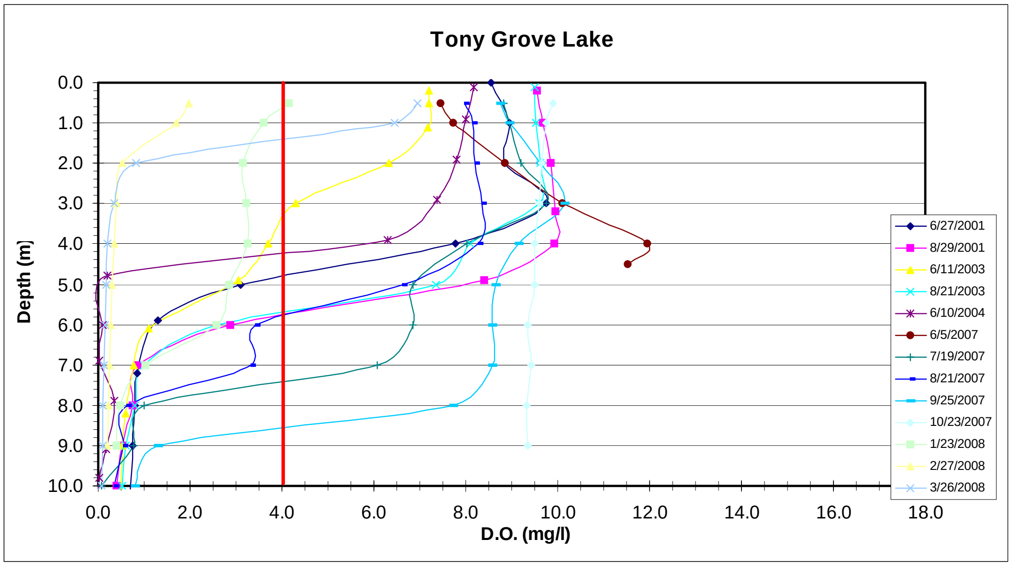
For samples collected in 2007-8, dissolved total phosphorous was below the detection limit for the entire water column, total phosphorous was not detected at the surface or above the thermocline, total phosphorous was just above the indicator limit of 0.025 mg/L on two samples during the summer months just below the thermocline, and was above the indicator value on four of eight samples on the bottom. For samples collected in 2007-8, nitrogen as nitrate+nitrite was below the detection limit for the entire water column except for two bottom samples that were just above the detection limit but were far below the indicator value of 4.0 mg/L. For samples collected from 1981 through 1994, the phosphorous and nitrogen values are fairly consistent with the values for samples collected in 2007-8, although between 1981 and 1994 some samples at the surface and above the thermocline exceeded indicator values for total phosphorous. For the stream above Tony Grove Lake, phosphorous and nitrogen as nitrate+nitrite for all samples collected between 1989 and 2008 were either below diction or below the indicator values with the exception of total phosphorous in July 1997 which was just above the indicator value of 0.05 mg/L. Phosphorous and nitrogen was not detected in any stream sample above Tony Grove Lake since August 2003.

Table 6. Selected data for stream above Tony Grove Lake.

Date	Dissolved Phosphorus as P (mg/l)	Total Phosphorus as P (mg/l)	Dissolved Nitrogen NO2+NO3
6/13/1989	----	ND	----
6/11/1991	ND	ND	----
8/29/1991	ND	ND	----
6/23/1993	ND	ND	----
8/25/1993	0.010	ND	----
7/12/1995	0.020	0.010	----
8/8/1995	ND	ND	----
7/15/1997	----	0.058	----
9/25/1997	----	----	----
7/7/1999	0.026	0.036	----
8/17/1999	----	0.034	----
6/26/2001	ND	ND	ND
8/29/2001	ND	ND	ND
6/11/2003	0.024	0.021	ND
8/21/2003	ND	ND	ND
6/10/2004	ND	ND	ND
6/5/2007	ND	ND	ND
7/19/2007	ND	ND	ND
8/21/2007	ND	ND	ND
9/25/2007	ND	ND	ND
10/23/2007	ND	ND	ND
1/23/2008	No stream flow data was collected because of deep snow cover.		
2/27/2008	No stream flow data was collected because of deep snow cover.		
3/26/2008	No stream flow data was collected because of deep snow cover.		

Oxygen – Dissolved oxygen versus depth is shown in Figure 6. Between 2001 and 2008, dissolved oxygen is above the State standard of 4 mg/L in the upper 4 meters of the water profile except during the winter when the entire water profile is anoxic. The lower part of the water profile for almost all the sampling events was below the State standard except in October 2007 when the dissolved oxygen in entire profile was about 9 mg/L. The temperature profile in October 2007 was similar to the dissolved oxygen profile in that the entire water profile was about 4 degrees C.

Figure 6. Tony Grove Lake Dissolved Oxygen vs. Depth Profiles.



Macrophytes - Macrophytes and algae are the only aquatic organisms that need light as their energy source. Since light intensity decreases with depth, the depth at which macrophytes grow is dependent upon the amount of light that penetrates through the water. Angiosperms need about 15% of the amount of light at the surface and have been found only at depths of less than 12 meters (Bronmark and Hansson 2005). In Tony Grove Lake macrophytes grow on most of the bottom of the lake. Plants can overcome the depth requirements by growing tall and reaching light near the surface while the roots are in the lake bottom below the area of minimum light requirements (Bronmark and Hansson 2005).

Algae – Samples were collected and sent to the lab but no results have been received at this time.

Discussion – In the following discussion, Branmark and Hansson (2005) describe dissolved oxygen conditions in autumn and winter that are typical of shallow lakes.

> "In autumn, the amount of solar energy reaching the lake is reduced and water temperatures will decrease. Eventually, the lake water will overturn and oxygenated water circulates down to the deeper strata (Fig. 2.5). At the formation of an ice cover during winter, the exchange of oxygen with the atmosphere will be blocked. If the ice is transparent, there will be a considerable production of oxygen by photosynthesizing algae immediately under the ice, whereas in deeper layers oxygen-consuming decomposition processes will dominate. The amount of dissolved oxygen will thus decrease with increasing depth during the winter and be particularly low close to the bottom (Fig. 2.5). If the ice is covered by a thick layer of snow, photosynthesis and oxygen production will be almost completely suppressed because of the lack of light. If this continues for a long period the

oxygen in the lake may be completely depleted, resulting in massive fish mortality. This is called '*winterkill*' and is especially common in shallow, productive ponds and lakes where decomposition of large quantities of dead organisms consumes a lot of oxygen."

The changes in dissolved oxygen described above are similar to the lake processes in Tony Grove Lake. During the autumn turnover, the entire water column becomes oxygenated. Ice forms on Tony Grove Lake and snow covers the lake at least 3 feet deep. The lake then develops very low dissolved oxygen throughout the water profile. This is likely caused by the respiration of plants due to lack of light when the ice is covered by snow and also no atmospheric oxygen enters the water because of the ice covered water surface during the long winter season.

7.0 Use Attainability Analysis

As discussed in Section 2.1, dissolved oxygen impairment appears to be naturally occurring and not caused by man's activities within the Uinta-Wasatch-Cache National Forest. The results of the data and land management activities in the watershed indicate that natural processes are causing the dissolved oxygen impairment during the winter season. Since man-made activities have not caused the impairment, Tony Grove Lake is recommended to be placed in Category 4C of the State of Utah's List as not imparted by a pollutant.

8.0 Management Options and Practices

Several approaches for increasing dissolved oxygen in lakes are described in Baker et al. 1993). Low levels of dissolved oxygen can occur in natural and culturally-altered lake conditions primarily in the hypolimnion during long periods of ice or snow and in dense macrophyte beds at night or following long periods of cloud cover. Approaches to alleviating low dissolved oxygen problems include decreasing the quantity of organic matter decomposing in the lake, increasing photosynthesis, destratifying the lake, and directly aerating the lake.

Several techniques can been used to increase dissolved oxygen and each has their limitations. Pump and baffle systems, consisting of water pumped on shore through a set of baffles, are effective at increasing dissolved oxygen but freeze-up during the winter can cause ice buildup that may in turn cause the baffles to be ineffective or become top heavy and fall over. The system must be checked daily to ensure proper operation. Artificial circulation eliminates thermal stratification and produces lake-wide mixing. The technique is best used in lakes that are not nutrient limited because nutrient concentrations are often higher in the hypolimnion and mixing can stimulate increased algae growth. In addition, artificial circulation is not a viable option for coldwater fish species that use the hypolimnion as a thermal refuge during summer. Hypolimnetic aerators may be used to increase dissolved oxygen in the hypolimnion without disturbing thermal stratification. However, hypolimnetic aerators require a large hypolimnion to work properly and are generally ineffective in shallow lakes or ponds. Direct oxygen injection into the hypolimnion has been effective at raising dissolved oxygen levels. Snowplowing that removes at least 30 percent of the snow is effective in preventing winterkill in shallow lakes with abundant rooted macrophytes. It has been noted that even thin layers of snow can greatly decrease light penetration which decreases primary productivity and can lead to dissolved oxygen depletion. An important option for lakes with dissolved oxygen problems is to mange the fisheries for species that tolerate relatively low levels of dissolved oxygen or that do not inhabit areas of the lake that experience oxygen depletion such as the hypolimnion (Baker et al.).

In the late 1970s through the early 1990s, the Wasatch-Cache National Forest installed mechanical circulation devices, bottled oxygen and air diffusers on Tony Grove Lake and several other lakes in the Uinta Mountains to try to break down the summer thermal stratification and to decrease the amount of time that the lower lake depths are devoid of dissolved oxygen, or to directly oxygenate the lake water. In 1984, aerators were installed on Tony Grove Lake to pump oxygen into the water. Since no electric power is available at Tony Grove lake, solar panels were installed to provide power to the aerator pumps. Problems occurred with the operation of the aerators due to seal breakages on the motors from poor electrical connection, blockage of the air delivery line, pump malfunctions, damage to solar panel structure and cover of the solar panels by snow. Normal snow depths are 7 to 8 feet deep. A Forest Service memo in February 1987 stated that the aerators were working properly but Tony Grove Lake was essentially anoxic because the diffusion of oxygen in the water was not sufficient to equal the oxygen demand. Recommendations were to not circulate the lake from the bottom because of the very high oxygen demand of the bottom waters, but to aerate waters at or near the surface. The project was abandoned some time after 1987.

Also in the Uinta Mountains, aerators powered by solar panels were installed on Marsh Lake; barrel-type wind aerators were installed on Sargent Lake, an unnamed lake east of Stateline Reservoir, Graham Reservoir, and Teapot Lake; bottled oxygen was hauled into a couple small lakes near Stateline Reservoir and diffused into the lake; and in partnership with Phillips Petroleum, air was diffused throughout Quarter Corner Lake using air hoses attached to the compressor plant located at a nearby oil pad. At Quarter Corner Lake, a fishing pier was installed in anticipation of a year-round fishery but oxygen was still limited in the lake. The Utah Division of Wildlife Resources still stocks trout in the lake for a put-and-take fishery.

Oxygen monitoring in the lakes showed mixed results. The ability of the wind powered circulators to bring about a complete mixing of the lakes that otherwise would be thermally stratified has not been realized on these lakes. The effect on Sargent Lake and Teapot Lake is that circulation had little effect on the oxygen/temperature profile yet had a significant effect on the dissolved oxygen during the summer. However, Teapot Lake has never been able to overwinter fish. Marsh Lake had a significant change in the summer temperature profile but little change in the dissolved oxygen profile. The winter dissolved oxygen in Marsh Lake increased after the first year but is most likely the result of the breaching of the irrigation dam at the same time that the circulators were running and the aquatic vegetation in the lake decreased by about one-half. These efforts were abandoned in the early 1990s because of the very difficult environmental conditions for operation and maintenance, the marginal results of the efforts, and the high costs to the low benefits that were realized from the projects.

Since no man-made pollution has been found to contribute to dissolved oxygen impairment during the winter season, no allocation of loads, controls applied to them, or additional land management is recommended.

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