# LOWER GOOSEBERRY RESERVOIR

## LIMNOLOGICAL ASSESSMENT OF WATER QUALITY

March 2008

# Lower Gooseberry Reservoir Report
## March 6, 2008

Lower Gooseberry Reservoir is listed by the State of Utah as an impaired water body because dissolved oxygen and pH do not meet State water quality standards. In partnership with Utah Division of Water Quality (UDWQ), the U.S. Forest Service collected data from Lower Gooseberry Reservoir from March 2006 to January 2007 to provide recent detailed water quality information to support a Total Maximum Daily Load (TMDL) analysis. This report contains information listed below.

- Sections 1.0 and 2.0: Description of the water body and associated watershed, the nature of the impairment and water quality standards for the parameters of concern for the water body.

- Section 3.0: Discussion of whether the impairments are naturally occurring and what water body targets and endpoints are recommended.

- Section 4.0: Discussion of which land management activities are contributing to the impairment, what practices may be recommended to reduce sources of impairment, and an estimate of the acceptable load or the degree to which the current pollutants (loads) need to be decreased to attain the defined endpoints.

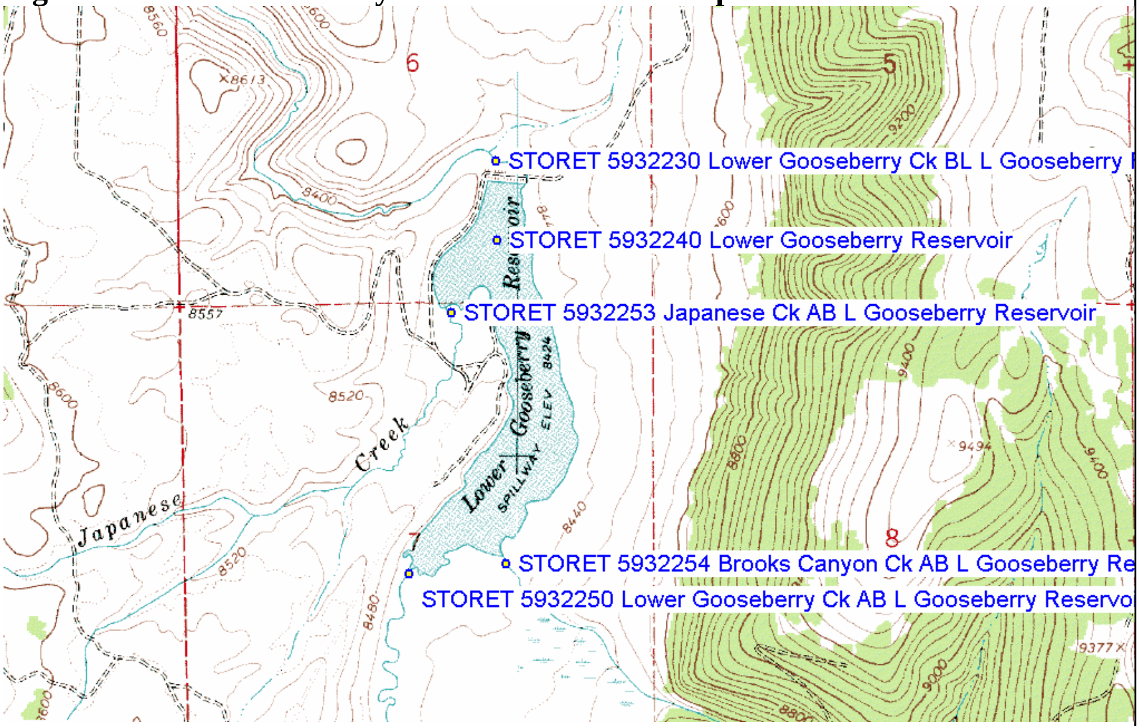
- Section 5.0: Identification of significant pollutant sources through use of existing information (maps, reports, inventories, and analyses) and new data.

- Section 6.0: Description of water quality data in relationship to abiotic and biological processes.

- Section 7.0: An evaluation of all sources contributing to impairment and a determination of beneficial use support.

- Section 8.0: The rationale for addressing all sources and causes that are significant for the attainment of the TMDL endpoints/targets.

**Figure 1. Lower Gooseberry Reservoir Location Map**



## 1.0 Introduction

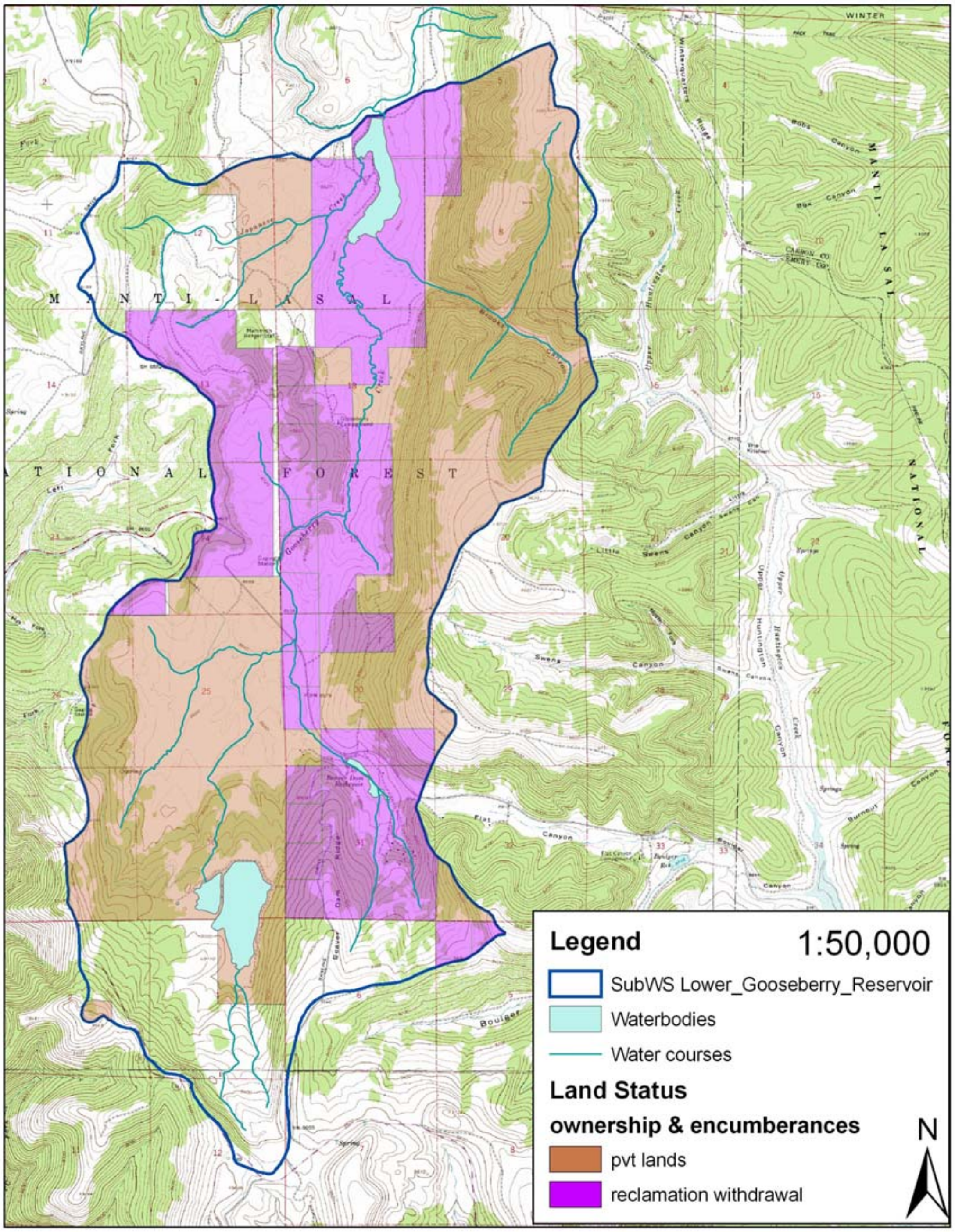
Lower Gooseberry Reservoir is an impoundment of a high mountain meadow by an earthen dam. The dam was constructed in 1939 and then reconstructed in 1990. The reconstruction included rock-facing the dam and enlarging it's footprint, renovating the spillway, and installing a hypolimnetic drain. The spillway renovation also resulted in a lowering of the lake level by approximately one foot. The reservoir has a surface area of 57 acres, volume of 212 acre-feet, a maximum depth of approximately 17 feet (5.2 meters) and a mean annual vertical fluctuation of 1.2 meters. It is located at an elevation of 9,706 feet above mean sea level (Judd 1997).

Surface inflows to the reservoir consist primarily of Gooseberry Creek, Japanese Creek, and Brooks Canyon Creek. Gooseberry Creek is the largest stream and is about 15 feet wide above the reservoir and 25 feet wide below the reservoir. Japanese Creek near the reservoir is about 3 feet wide and very entrenched with sedge-lined banks. Brooks Canyon Creek has a stream channel about the same size as Japanese Creek and has many beaver dams in the low gradient stream between the reservoir and the narrow canyon about 2000 feet to the east. Water leaves the reservoir via Gooseberry Creek. From data collected in 2006 and 2007, estimates of water flowing from the three streams into Lower Gooseberry Reservoir range from 5 cubic feet per second (cfs) during low flows to 23.1 cfs during high flows. The seasonal range of discharges for the streams flowing into the reservoir are 1.2 to 15.4 cfs for Gooseberry Creek, 0.7 to 8.4 cfs for Japanese Creek, and 0.8 to 2.7 cfs for Brooks Canyon Creek. The average stream gradient above the reservoir is 3 percent (Judd 1997).

The watershed including the reservoir is approximately 9955 acres in size. The watershed receives 30 to 40 inches of precipitation annually with a frost-free season of 40-60 days. Most of the precipitation occurs in the form of snow. The soil is of limestone origin and has good permeability and moderately slow erosion and runoff. The immediate area around the reservoir is sagebrush-grass with aspen and conifer forest growing within the watershed. The reservoir is in an area of rolling ridges and valleys characteristic of the Wasatch Plateau (Judd 1997).

Approximately one-half of the watershed is privately owned (4825 acres); the remainder (5130 acres) is National Forest System (NFS) lands. Approximately 3200 acres of the NFS lands are withdrawn by the Bureau of Reclamation for water development purposes (see Figure 1a). The withdrawn lands are managed by the Forest Service pending their use for the purposes of the withdrawal.

**Figure 1a. Land status within watershed above Lower Gooseberry Reservoir.**




Land uses in the watershed include private summer home subdivisions, cattle and sheep livestock grazing, ATV and snowmobiling, nordic skiing, camping, and hunting and fishing. Highway 264 and several Forest roads cross the watershed. A modified dispersed camping area is located on the west side of the reservoir and a 10-unit Forest Service campground is located about one mile south (upstream) of the reservoir; both have vault toilets. The modifications at the dispersed site include installation of toilets, graveling the loop access road and campsite spurs, installing log barriers to prevent vehicle access to the shoreline, and installation of firerings. The following photos display the modifications; the first was taken in 1990, the second in 2007.

The ground cover in the watershed above the reservoir is in good to excellent condition. The roads that access the reservoir and the summer homes south of the reservoir have gravel surfaces and the road drainage is well maintained. The shore surrounding the reservoir has dense vegetation in most areas and has a few areas where fisherman access-trails have bare soils. There are several stream banks about 50 feet long on Gooseberry Creek just above the reservoir that have steep, 6-foot high bare banks that are slowly eroding. These are features that slough-off occasionally and appear to be the main sediment sources that would reach the reservoir. The riparian area of Japanese Creek and Brooks Canyon Creek is in very good condition and no sign of accelerated erosion is seen.

## 2.0. Water Quality Standards

This section discusses the associated impairment with respect to state water quality standards related to beneficial uses, standards, and the parameters of concern on the 303(d) listing.

The beneficial uses for Lower Gooseberry Reservoir, as designated by the Utah Department of Environmental Quality, Division of Water Quality, are 1C – protected for drinking water with appropriate treatment; 2B – protected for non-contact recreation; 3A – protected for cold water species of game fish and other cold water aquatic species; and 4 – protected for agricultural uses (Utah, State of 2007).

Lower Gooseberry Reservoir is listed as impaired for dissolved oxygen and pH for Cold Water Species of Game Fish (Beneficial Use 3A). The methodologies for listing these parameters are described below.

**Listing methodology for Dissolved Oxygen –** The listing methodology employed by Utah for dissolved oxygen to assess Class 3A (aquatic life) beneficial use involves evaluating the dissolved oxygen profile data collected at the surface and at one meter intervals to see what percent of the water column falls below the one day average value of 4.0 milligrams per liter. For stratified lakes, the beneficial use is supported if the dissolved oxygen concentrations are greater than the dissolved oxygen standard for 50% of the water column depth. For non-stratified lakes, the beneficial use is supported if at least 90% of the oxygen measurements are greater than the dissolved oxygen standard for the entire water column depth. (Utah, State of 2007).

**Table 1. Utah's Dissolved Oxygen Criteria for Class 3A waters.(R317-2; Standards of Quality for Waters of the State)**

| **Timeframe** | **Minimum Dissolved Oxygen** | **Explanations** |
|---|---|---|
| 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 |

In addition, an evaluation is made 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. 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.

**Listing Methodology for pH –** The listing methodology employed by Utah for pH to assess Class 3A (aquatic life) beneficial use involves looking at pH profile data collected at the surface and at one meter intervals against the pH standard of greater than 6.5 and less than 9.0. For a given monitoring cycle, the beneficial use is supported if the number of violations are less than or equal to 10 percent (≤10%) of the measurements.

An assessment of the water quality conditions in Lower Gooseberry Reservoir in 1997 (Judd 1997) is described below.

The water quality of Lower Gooseberry Reservoir is good. It is considered to be moderately hard with a hardness concentration value of approximately 144 mg/L ($CaCO3$). The only parameters that have exceeded State water quality standards for defined beneficial uses are phosphorus, pH, and dissolved oxygen. The average concentration of total phosphorus in the water column has not exceeded the recommended pollution indicator for phosphorus of 25 ug/L, but on occasion values are reported at various depths in the water column. On occasion dissolved oxygen levels (2.3 mg/L) and pH values (10.2) have violated state standards near the bottom of the reservoir. The factor in the reservoir responsible for this phenomenon is the extensive macrophyte coverage of the bottom of the reservoir. The reservoir is shallow with good light penetration throughout the water column. The submerged plant material increases the dissolved oxygen concentration during the day and reduces the dissolved oxygen concentration during the night. It is evident from the August 29, 1991 profile that the reservoir is too shallow to produce stratification. Although the reservoir was reported in 1981 to be phosphorus limited, current data suggest that the reservoir is in fact a nitrogen limited system. TSI values indicate the reservoir is a fairly stable mesotrophic system.

According to DWR, fish kills have been reported during severe winter conditions. This is to be expected with the large amounts of organic material that accumulate from summer macrophyte growth. As this organic material decays and is decomposed oxygen is consumed. Because the reservoir is shallow and oxygen production is largely inhibited during the period of ice coverage the reservoir's dissolved oxygen content is reduced to the point that it cannot sustain a viable fishery. A profile conducted on March 5, 1992 indicates the severity of the depletion. At the surface the dissolved oxygen concentration was 1.1 mg/L, but quickly dropped to 0.4 mg/L throughout the majority of the water column.

The reservoir supports populations of rainbow trout (Oncorhynchus mykiss) and cutthroat trout (*Oncorhynchus clarki*). The lake has not been treated for rough fish competition, so populations of native fishes may still be present in the lake. According to recent stocking records Lower Gooseberry Reservoir is stocked with 12,000 catchable rainbow trout. A 1978 USFS limnological survey noted the existence of rainbow and cutthroat trout. Many species of macroinvertebrates were observed including Odonata, Hemiptera, Tricoptera, Coleoptera, Diptera, Amphipoda, Mollusca and Leeches. Zooplankton in the reservoir was composed almost entirely of Daphnia. In addition, the reservoir had large amounts of submerged macrophyte growth which reached the surface in about 40% of the reservoir’s total area.

Water quality data collected since 1999 indicate that the assessment described above is an accurate description of water quality conditions in Lower Gooseberry Reservoir, a water body with an unstratified water column. As seen in Figure 2, most of the dissolved oxygen values are within State standards but during part of the winter the DO values drop below standards. In 2006 and 2007, 5 out of 29 measurements (17% of samples) were below the 4.0 mg/l dissolved oxygen standard. As shown in Figure 3, all pH values are within State standards except those during August of 2001 and August 2003.

**Figure 2. Lower Gooseberry Lake - Percent of Water Column Supporting 4 mg/l D.O. Criteria**

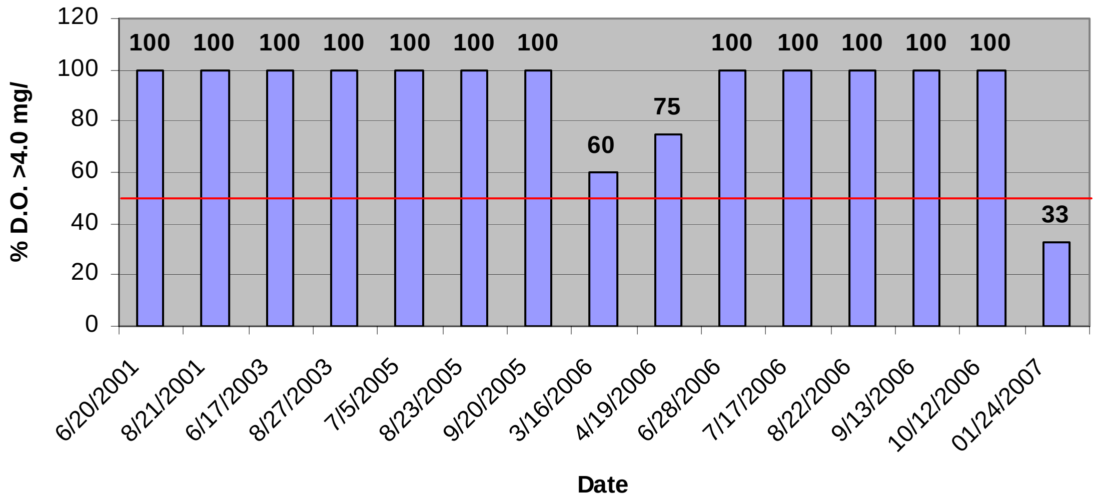
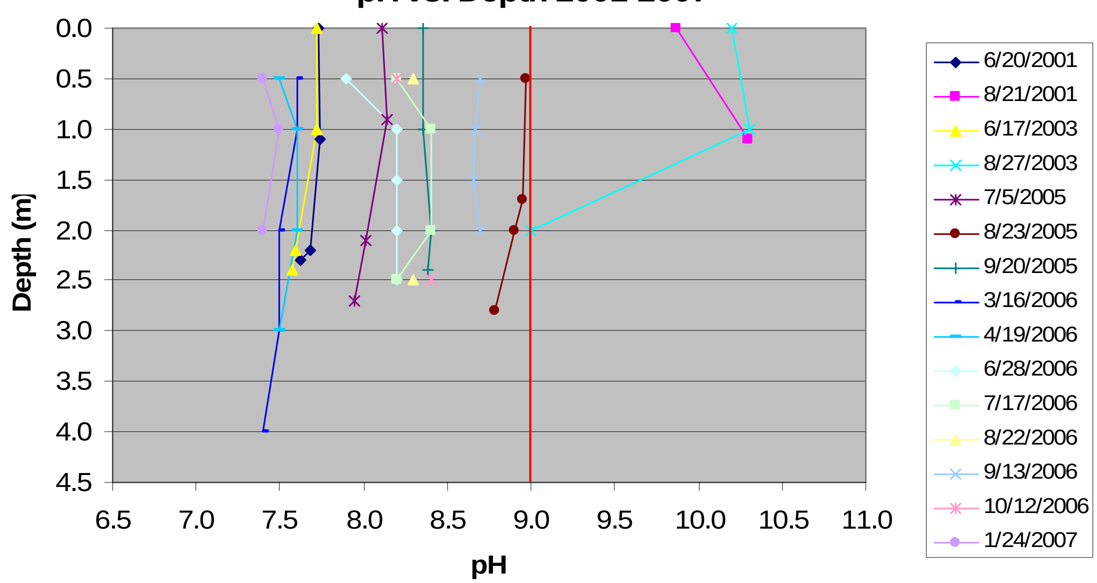



**Figure 3. Lower Gooseberry Reservoir - pH vs. Depth 2001-2007**




## 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.

Based on the dissolved oxygen profiles recorded in March and April of 2006 and January of 2007 Lower Gooseberry Reservoir is not meeting the cold water fisheries criteria for dissolved oxygen. However, based on the source loading assessment the primary cause for these exceedences appear to be a result of the shallowness of the reservoir coupled with natural processes including a long period of snow and ice cover.

For pH, since 2003 and particularly during the sample collection period in 2006 and 2007, no pH measurements were outside of the State standard of 6.0 to 9.0. Lower Gooseberry reservoir currently is meeting State standards for pH.

## 4.0 Beneficial Use Assessment

This section discusses which land management activities are potentially contributing to the impairment, what practices may be recommended to reduce sources of impairment, and, if applicable, an estimate of the acceptable load or the degree to which the current pollutants (loads) need to be decreased to attain the defined endpoints.

Land management activities appear to contribute to a negligible amount of the dissolved oxygen deficit during the winter season. This deficit is instead attributable to natural conditions including the reservoir's shallow depth coupled with several months of snow and ice cover. The pH measured in 2005 and 2006 was within State standards throughout the water column and man-made activities in the watershed do not appear to be causing pollution problems affecting pH or dissolved oxygen.

## 5.0 Significant Sources

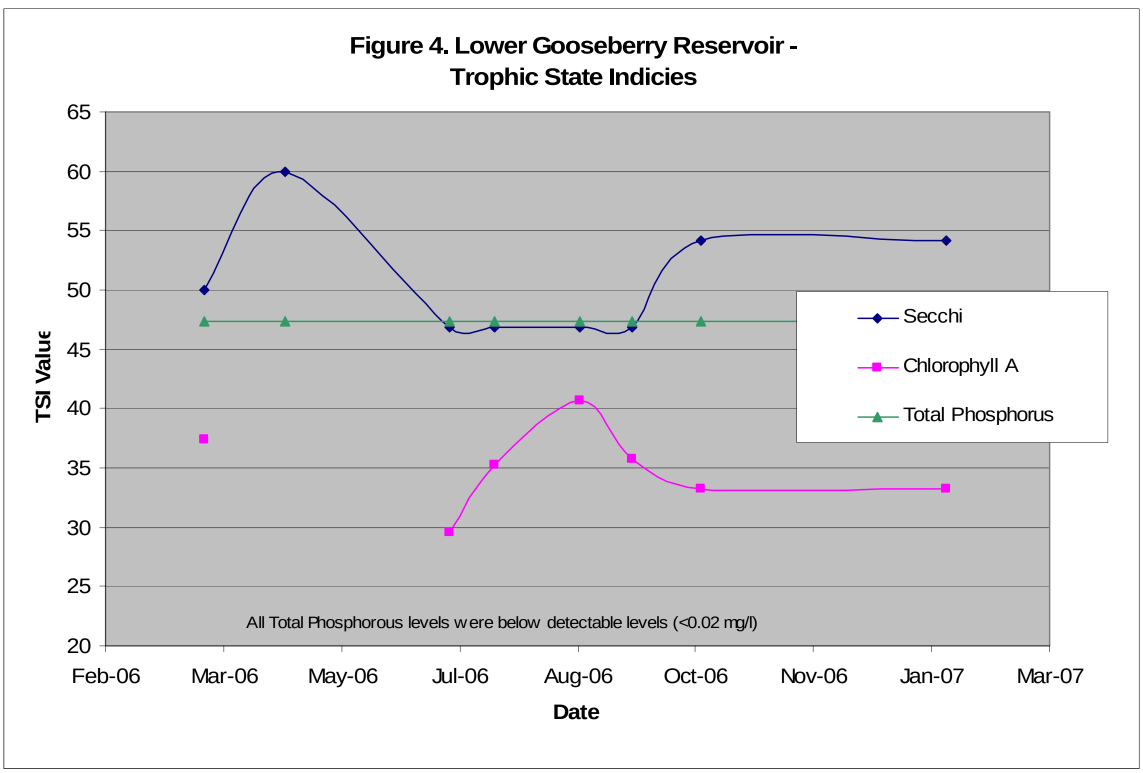
In order to identify sources of pollution, maps were reviewed to determine where surface water drains into Lower Gooseberry Reservoir, as well as what and where man-made activities occur within the watershed. Field visits during the summer of 2006 looked at land conditions such as the amount as ground cover, sediment deposition, rills and gullies, and other indicators of erosion and sedimentation. As a result of this review, no significant sources of pollution were identified. Human waste is contained in vault toilets that are functioning and maintained properly. Nutrient loads from streams flowing into the reservoir are very low as seen in Table 3. For streams flowing into the reservoir since 2001, total phosphorus as P was above the detection limit only twice and dissolved nitrate and nitrite values were well below the State standard. The ground cover in the watershed that drains into the reservoir is in good to excellent condition and there is very little evidence of soil erosion around the reservoir and no sign of upland sediment reaching the lake. The shore surrounding the reservoir has dense vegetation in most areas although there are a few small areas where bare soil occurs at fisherman access trails that lead to the reservoir shoreline. The roads in the watershed above the reservoir are well maintained. The low gradient meandering streams flowing into and out of the lake have good ground cover such as willows and sedges along the banks. Stream bank rehabilitation work consisting of large rock rip-rap has been placed along Gooseberry

Creek above the reservoir and willows are growing in these areas. Although sheep and cattle livestock are allowed to graze in the watershed above the reservoir, no sign of accelerated erosion was noted from grazing during the field review in 2006.

## 6.0 Technical Analysis

This section contains a description of water quality data conditions at Lower Gooseberry Reservoir 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 Lower Gooseberry Reservoir.

**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 measured values for chlorophyll a, secchi depth, and 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).

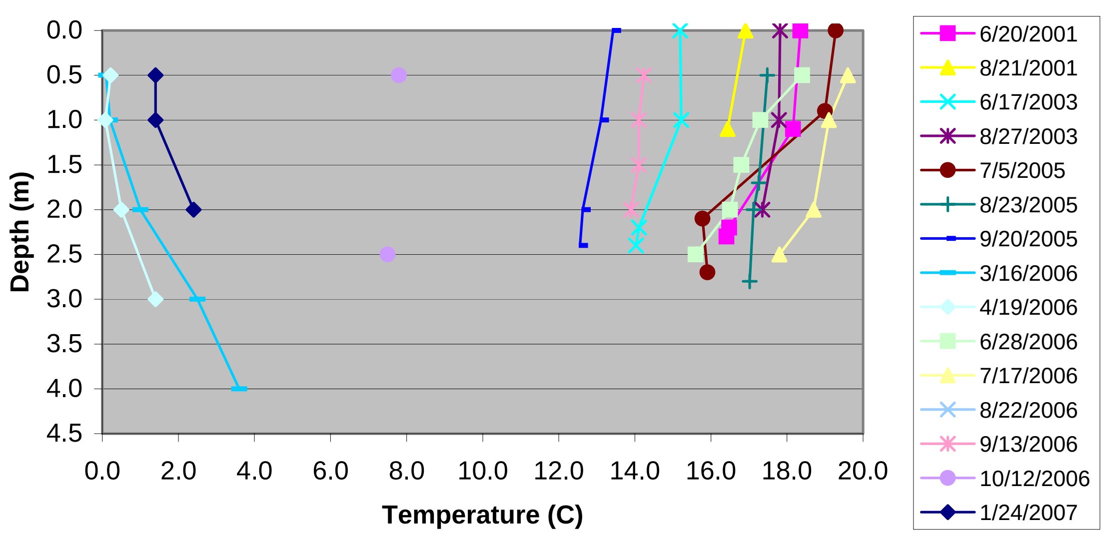
Based on water sampling of Lower Gooseberry Reservoir in 2006 and 2007, the trophic state using chlorophyll-a is mainly oligotrophic (TSI (Chl) of <40) throughout the year. The clarity of the water as indicated by the secchi depth is the reverse of this pattern where the water clarity is generally higher during the summer months than during the winter months. The trophic state using secchi depth gave values that were between upper mesotrophic and eutrophic. Phosphorus could not be used for comparison because all of the samples were below the detection limit.

Carlson presents characteristics of northern temperate lakes based on the trophic state and provides the generalized observation that when lakes become mesotrophic, the hypolimnia of shallow lakes is likely to become anoxic and that may result in a loss of salmonids. When lakes are eutrophic, the hypolimnia is typically anoxic and macrophyte problems are possible (Kent State 2005). Although the secchi depth data indicate that Lower Gooseberry Reservoir cycles between mesotrophy and eutrophy the more definitive indicator of chlorophyll-a strongly indicates oligotrophy.

**Lake Morphology –** Lower Gooseberry Reservoir is somewhat rectangular in shape and is about 845 feet wide, 4,500 feet long, and has a mean depth of 3.7 feet (1.1 meters).

**Temperature –** The temperature of Lower Gooseberry Reservoir ranges in winter from 0ºC at the surface to 3.5ºC at the bottom and in summer from 15.2 to 19.5ºC at the surface and from 14 to 17.8ºC near the bottom at a depth of 2.5 to 3.0 meters. The temperature profile indicates that the reservoir is unstratified throughout the year.

**Figure 5. Lower Gooseberry Reservoir - Temperature vs. Depth 2001-2007**




**Light (secchi depth, chlorophyll concentration) –** The secchi depth in Lower Gooseberry Reservoir in 2006 and 2007 ranged from 1.0 to 2.5 meters with most of the measurements being 2.0 to 2.5 meters. During the winter of 2006, ice was in three layers about 2 meters thick and snow was over one-foot deep and lay upon the entire surface of the ice. On January 24, 2007, the ice was a solid 0.36 meters thick with 0.75 feet of snow.

**Catchment Area (size of catchment, type of geology) –** The watershed contributing to Lower Gooseberry Reservoir is about 9955 acres in size and is located within the Wasatch Plateau, a high elevation tract capped entirely by sedimentary rocks (Stokes 1986). The reservoir is located in a north-south oriented valley that is about 3 miles wide and the distance from the reservoir to the south end of the valley (watershed divide) is 6.2 miles. The valley has steep side slopes off of the ridges to the east and west and between them is a broad, rolling valley. The predominant vegetation type in the valley bottom is sagebrush/mountain brush with pockets of aspen and on the steep sideslopes are aspen and conifer. According to Bronmark and Hansson (2005), 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.

**pH –** The pH values for water samples collected in Lower Gooseberry Reservoir are between 7.4 and 10.3. As seen in Table 2, pH tends to become less alkaline in the summer and returns to more alkaline conditions in the winter. From 2001 to 2005, the number of pH exceedances of State standards was 2 of 13 measurements (15%). In 2006 and 2007, no exceedances were found in 17 measurements. The pH of the streams flowing into the reservoir is fairly constant throughout the year and range between 7.8 and 8.5. The pH of the water flowing in Gooseberry Creek just below the reservoir is very close to the pH of the reservoir water at the time of measurement. Lower Gooseberry Reservoir 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.

**Table 2. Lower Gooseberry Reservoir (STORET 5932240) pH field data.**

| | Depth (m) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Date** | **0** | **0.5** | **1** | **1.5** | **2** | **2.5** | **3** | **3.5** | **4** |
| 06/20/2001 | 7.7 | | 7.7 | | 7.7 | | | | |
| 08/21/2001 | 9.9 | | 10.3 | | | | | | |
| 06/17/2003 | 7.7 | | 7.7 | | 7.6 | 7.6 | | | |
| 08/27/2003 | 10.2 | | 10.3 | | 9.0 | | | | |
| 07/05/2005 | 8.1 | | 8.1 | | 8.0 | 7.9 | | | |
| 08/23/2005 | | 9.0 | | 9.0 | 8.9 | | 8.8 | | |
| 09/20/2005 | 8.4 | | 8.4 | | 8.4 | 8.4 | | | |
| 03/16/2006 | | 7.6 | 7.6 | | 7.5 | | 7.5 | | 7.4 |
| 04/19/2006 | | 7.5 | 7.6 | | 7.6 | | 7.5 | | |
| 06/28/2006 | | 7.9 | 8.2 | | 8.2 | | 8.2 | | 8.2 |
| 07/17/2006 | | 8.2 | 8.4 | | 8.4 | 8.2 | | | |
| 08/22/2006 | | 8.3 | | | | 8.3 | | | |
| 09/13/2006 | | 8.7 | 8.7 | 8.7 | 8.7 | | | | |
| 10/12/2006 | | 8.2 | | | | 8.4 | | | |
| 01/24/2007 | | 7.4 | 7.5 | 7.4 | | | | | |

Note: Values were rounded off to the nearest depth. Red highlighted values indicate pH exceeds standard.

**Nutrients –** Table 3 contains a summary of exceedances and Table 4 contains the dissolved and total phosphorus and nitrogen concentrations in Lower Gooseberry Reservoir for samples collected primarily at the surface and bottom. In 2006, 2 samples out of 16 (12.5% of the samples) exceeded the indicator value for total phosphorus as P. These two samples were bottom samples taken in September and October and the concentration of total phosphorus for all the other samples collected in 2006 were below the detection limit of 0.02 mg/L. For surface and bottom samples collected in Lower Gooseberry Reservoir since 2001, dissolved total phosphorus was below the detection limit for all samples except for the bottom sample in June 2006 which had a value of 0.023 mg/l. For all samples collected, nitrogen as dissolved nitrite+nitrate was well below the standard of 4.0 mg/l and most of the samples did not detect nitrogen.

**Table 3. Summary of Total Phosphorus exceedances and concentrations.**

| Time Period | Number of Exceedances | Number of Samples | Percent of Exceedances | Average Concentration (mg/l) |
|---|---|---|---|---|
| 1980 – 2005 | 6 | 37 | 16.2 | 0.014 |
| 2006 | 2 | 16 | 12.5 | 0.009 |
| 1980 - 2006 | 8 | 53 | 15.1 | 0.012 |

**Table 4. Lower Gooseberry Reservoir - Dissolved and Total Phosphorus as P and Nitrogen by depth.**

| | Diss. 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** | **27** | **29** | **21** | **23** | **27** | **29** |
| 10/31/1980 | | | | | 0.050 | | | | | | | |
| 06/11/1981 | | | | | ND | | | ND | | | | |
| 06/13/1990 | | | | | 0.029 | | | 0.027 | | | | |
| 08/01/1990 | 0.044 | | | 0.017 | 0.016 | | | 0.024 | | | | |
| 06/06/1991 | 0.011 | | | 0.013 | 0.036 | | | 0.017 | 0.125 | | | 0.128 |
| 08/29/1991 | ND | | | ND | 0.021 | | | ND | ND | | | ND |
| 06/16/1993 | ND | | | ND | 0.019 | | | 0.016 | ND | | | ND |
| 08/11/1993 | ND | | | ND | 0.014 | | | ND | 0.034 | | | ND |
| 07/01/1995 | | | | ND | | | | 0.010 | | | | 0.030 |
| 07/05/1995 | ND | | | | 0.010 | | | | 0.030 | | | |
| 10/03/1995 | ND | ND | | ND | 0.010 | 0.010 | 0.010 | 0.010 | ND | ND | | ND |
| 06/18/1997 | 0.110 | | | 0.083 | | | | | 0.020 | | | 0.030 |
| 08/12/1997 | | | | | | | | | ND | | | 0.270 |
| 06/02/1999 | ND | | | ND | 0.021 | | | 0.067 | 0.200 | | | 0.200 |
| 08/11/1999 | 0.021 | | | 0.021 | 0.020 | | | ND | ND | | | ND |
| 06/20/2001 | ND | | | ND | ND | | | 0.024 | ND | | | ND |
| 08/22/2001 | ND | | | | ND | | | | ND | | | |
| 06/17/2003 | ND | | | ND | ND | | | ND | 0.200 | | | ND |
| 08/27/2003 | ND | | | | 0.020 | | | | ND | | | |
| 07/05/2005 | ND | | | ND | ND | | | 0.025 | ND | | | ND |
| 08/23/2005 | ND | | | ND | ND | | | ND | ND | | | 0.480 |
| 09/20/2005 | ND | | | ND | ND | | | ND | ND | | | ND |
| 03/16/2006 | ND | | | ND | ND | | | ND | 0.140 | | | ND |
| 04/19/2006 | ND | | | ND | ND | | | ND | 0.240 | | | 0.240 |
| 06/28/2006 | ND | | | 0.023 | ND | | | ND | ND | | | ND |

| | | | | | | |
|---|---|---|---|---|---|---|
| 07/17/2006 | ND | ND | ND | ND | ND | ND |
| 08/22/2006 | ND | ND | ND | ND | ND | ND |
| 09/13/2006 | ND | ND | ND | 0.037 | ND | ND |
| 10/12/2006 | ND | ND | ND | 0.103 | ND | ND |
| 01/24/2007 | ND | ND | ND | ND | 0.140 | 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).

Dissolved and total phosphorus and nitrogen concentrations in water samples collected in streams flowing into and out of Lower Gooseberry Reservoir are shown in Table 4. For all samples collected, total phosphorus as P did not exceed the indicator value of 0.05 mg/l. A surface sample collected in June 1997 that was analyzed for dissolved total phosphorus as P exceeded the indicator value of 0.05 mg/l. Most of the samples collected at these sites were below the detection limit for dissolved and total phosphorus. The phosphorus that is detected in the stream is almost entirely in the dissolved fraction as indicated by phosphorus samples collected in August 1990 and June 1999. For all samples collected, nitrogen as dissolved nitrite+nitrate was well below the standard of 4.0 mg/l although nitrogen was detected in most samples.

**Table 5. Selected Data for unnamed streams above and below Lower Gooseberry Reservoir.**

| Location | Date | Dissolved - Total Phosphorus (mg/l) | Total Phosphorus (mg/l) | Dissolved - NO2+NO3 as N (mg/l) |
|---|---|---|---|---|
| Gooseberry Ck below Lower Gooseberry Res | 06/11/1981 | | 0.010 | |
| Gooseberry Ck below Lower Gooseberry Res | 07/22/1983 | | ND | |
| Gooseberry Ck below Lower Gooseberry Res | 03/16/2006 | ND | 0.021 | ND |
| Gooseberry Ck below Lower Gooseberry Res | 04/19/2006 | ND | ND | 0.230 |
| Gooseberry Ck below Lower Gooseberry Res | 06/28/2006 | ND | ND | ND |
| Gooseberry Ck below Lower Gooseberry Res | 07/17/2006 | ND | ND | ND |
| Gooseberry Ck below Lower Gooseberry Res | 08/22/2006 | ND | ND | ND |
| Gooseberry Ck below Lower Gooseberry Res | 09/13/2006 | ND | ND | ND |
| Gooseberry Ck below Lower Gooseberry Res | 10/12/2006 | ND | ND | ND |
| Gooseberry Ck below Lower Gooseberry Res | 01/24/2007 | ND | ND | 0.120 |
| | | | | |
| Gooseberry Ck above Lower Gooseberry Res | 06/11/1981 | | ND | |
| Gooseberry Ck above Lower Gooseberry Res | 07/22/1983 | | ND | |
| Gooseberry Ck above Lower Gooseberry Res | 06/13/1990 | | 0.019 | |
| Gooseberry Ck above Lower Gooseberry Res | 08/01/1990 | 0.010 | 0.014 | |
| Gooseberry Ck above Lower Gooseberry Res | 06/06/1991 | ND | 0.019 | 0.119 |
| Gooseberry Ck above Lower Gooseberry Res | 08/29/1991 | ND | ND | 0.087 |
| Gooseberry Ck above Lower Gooseberry Res | 06/16/1993 | ND | 0.015 | ND |
| Gooseberry Ck above Lower Gooseberry Res | 08/11/1993 | ND | ND | 0.119 |
| Gooseberry Ck above Lower Gooseberry Res | 07/05/1995 | ND | ND | 0.020 |
| Gooseberry Ck above Lower Gooseberry Res | 10/03/1995 | ND | ND | 0.150 |
| Gooseberry Ck above Lower Gooseberry Res | 06/18/1997 | 0.095 | | 0.110 |
| Gooseberry Ck above Lower Gooseberry Res | 08/12/1997 | | | 0.110 |

| | | | | |
|---|---|---|---|---|
| Gooseberry Ck above Lower Gooseberry Res | 06/02/1999 | 0.024 | 0.023 | 0.200 |
| Gooseberry Ck above Lower Gooseberry Res | 08/11/1999 | ND | 0.025 | ND |
| Gooseberry Ck above Lower Gooseberry Res | 06/20/2001 | ND | ND | ND |
| Gooseberry Ck above Lower Gooseberry Res | 08/22/2001 | ND | ND | 0.100 |
| Gooseberry Ck above Lower Gooseberry Res | 06/17/2003 | ND | ND | 0.210 |
| Gooseberry Ck above Lower Gooseberry Res | 08/27/2003 | ND | ND | ND |
| Gooseberry Ck above Lower Gooseberry Res | 07/05/2005 | ND | ND | ND |
| Gooseberry Ck above Lower Gooseberry Res | 08/23/2005 | ND | ND | 0.180 |
| Gooseberry Ck above Lower Gooseberry Res | 09/20/2005 | ND | ND | 0.110 |
| Gooseberry Ck above Lower Gooseberry Res | 03/16/2006 | ND | ND | 0.300 |
| Gooseberry Ck above Lower Gooseberry Res | 04/19/2006 | ND | 0.020 | 0.360 |
| Gooseberry Ck above Lower Gooseberry Res | 06/28/2006 | ND | ND | 0.140 |
| Gooseberry Ck above Lower Gooseberry Res | 07/17/2006 | ND | 0.022 | 0.180 |
| Gooseberry Ck above Lower Gooseberry Res | 08/22/2006 | ND | ND | 0.100 |
| Gooseberry Ck above Lower Gooseberry Res | 09/13/2006 | ND | ND | ND |
| Gooseberry Ck above Lower Gooseberry Res | 10/12/2006 | ND | ND | ND |
| Gooseberry Ck above Lower Gooseberry Res | 01/24/2007 | ND | ND | 0.310 |
| | | | | |
| Japanese Ck above Lower Gooseberry Res | 04/19/2006 | ND | ND | 0.350 |
| Japanese Ck above Lower Gooseberry Res | 06/28/2006 | ND | ND | 0.170 |
| Japanese Ck above Lower Gooseberry Res | 07/17/2006 | ND | ND | 0.230 |
| Japanese Ck above Lower Gooseberry Res | 08/22/2006 | ND | ND | 0.180 |
| Japanese Ck above Lower Gooseberry Res | 09/13/2006 | ND | ND | 0.160 |
| Japanese Ck above Lower Gooseberry Res | 10/12/2006 | ND | ND | 0.130 |
| Japanese Ck above Lower Gooseberry Res | 01/24/2007 | ND | ND | 0.260 |
| | | | | |
| Brooks Canyon Ck above Lower Gooseberry Res | 04/19/2006 | ND | ND | 0.180 |
| Brooks Canyon Ck above Lower Gooseberry Res | 06/28/2006 | ND | ND | ND |
| Brooks Canyon Ck above Lower Gooseberry Res | 07/17/2006 | ND | ND | ND |
| Brooks Canyon Ck above Lower Gooseberry Res | 08/22/2006 | ND | ND | ND |
| Brooks Canyon Ck above Lower Gooseberry Res | 09/13/2006 | ND | ND | ND |
| Brooks Canyon Ck above Lower Gooseberry Res | 10/12/2006 | ND | ND | ND |
| Brooks Canyon Ck above Lower Gooseberry Res | 01/24/2007 | ND | ND | 0.110 |

Note: ND means Non-detect. Red highlighted values exceed pollution indicator limit (0.05 mg/l for phosphorus and 4.0 mg/l for NO3+NO2).

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 concentration of Lower Gooseberry Reservoir is typical of most lakes unaffected by man since almost all samples of total phosphorus as P taken throughout that water column are below 0.1 mg/l and almost all dissolved nitrate + nitrite concentrations are below detection and those that have been detected have a highest value of 0.48 mg/l taken as a bottom sample.

**Oxygen –** From measurements collected in 2006 and 2007, the dissolved oxygen profile shows no stratification occurring throughout the year. The lowest dissolved oxygen concentrations and the period when State standards are exceeded occur during the winter months as indicated by the three samples that were taken March and April 2006 and January 2007. The dissolved oxygen concentrations of these winter samples are above the State standard to a depth of 1 to 2 meters at which point the dissolved oxygen concentration drops rapidly. Dissolved oxygen concentrations in the entire profile are above State standards for the remainder of the year. For the one-year period when samples were taken between March 2006 and January 2007, the number of exceedances of dissolved oxygen in the depth profile was 5 out of 29 samples taken (17% of the samples).

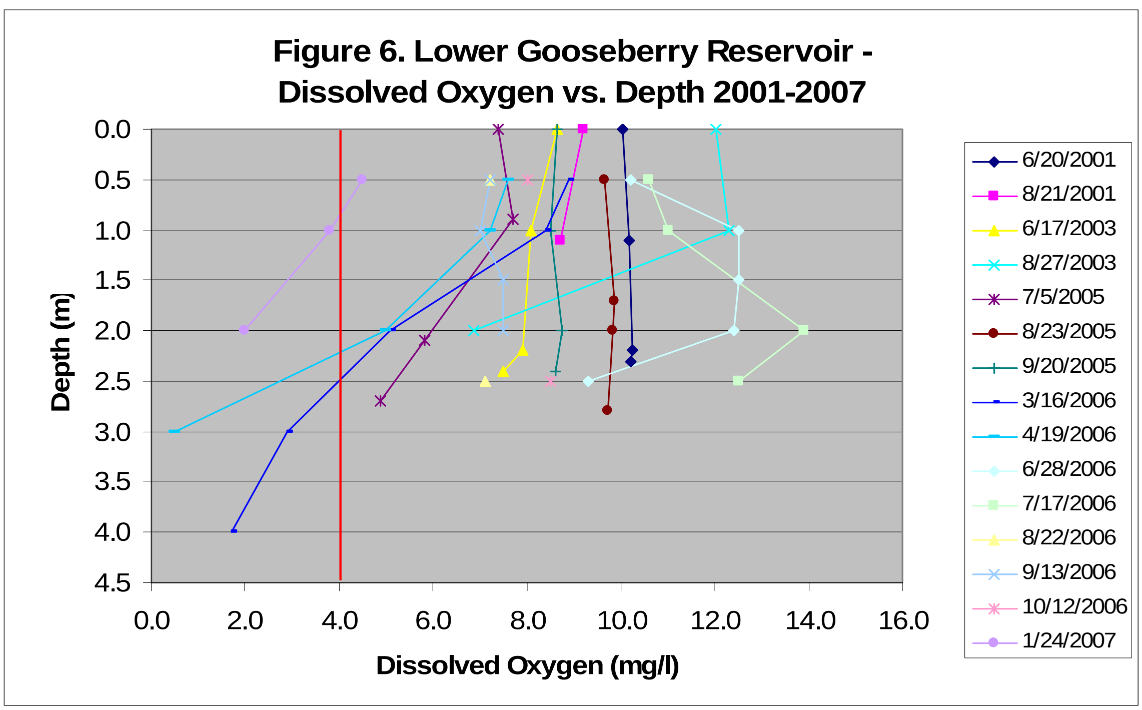


**Figure 6. Lower Gooseberry Reservoir - Dissolved Oxygen vs. Depth 2001-2007**

**Macrophytes –** Judd (1997) stated that Lower Gooseberry Reservoir had large amounts of submerged macrophyte growth which reached the surface in about 40% of the reservoir's total area. From field observations in 2006, macrophytes appear to grow on most of the bottom of the reservoir.

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 which is about 12 meters deep in clear water (Bronmark and Hansson 2005). Lower Gooseberry Reservoir has an average depth of 1.1 meters and a maximum depth of 5 meters. For this reservoir, most of the reservoir bottom is conducive for macrophyte growth based on the relationship between secchi depth and maximum depth of growth of angiosperms by Chambers and Kaiff (1985) as shown in Bronmark and Hansson (2005). The relationship indicates that at a secchi depth of 2.5 meters the maximum depth of angiosperm growth would be 3 meters. 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 –** During the 2006 and 2007 sampling rounds, chlorophyll a, uncorrected for pheophytin ranged from <0.07 to 2.8 ug/l with the largest value in August and the lowest value in April. No seasonal trends were observed in the data. No algal masses were seen during any of the sampling events.

A taxonomic survey of phytoplankton was conducted on Lower Gooseberry Reservoir from a sample of the water column collected in August 2006. The results of this sample compared to those in the Judd (1997) inventory is presented in Table 6. These results indicate an increase in diversity and richness of the phytoplankton community which is indicative of improving water quality conditions.

**Table 6. Phytoplankton diversity indices for Lower Gooseberry Reservoir.**

| **Diversity Measure** | **Judd (1997)** | **2006 Sample** |
|---|---|---|
| Shannon-Weiner Index | 0.75 | 1.21 |
| Species Evenness | 0.24 | 0.88 |
| Species Richness | 0.82 | 1.44 |

**Discussion –**Non-point sources of pollution can also contaminate lakes through runoff and groundwater. There are no point sources of pollution into Lower Gooseberry Reservoir. Runoff can carry sediment and nutrients from roads, bare soil and agricultural wastes such as livestock manure. As noted above, no evidence of non-point pollution was noted during field reconnaissance of the watershed. 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. However, nutrient data for the tributary streams were at acceptable levels.

The pH values within a lake may vary due to several factors. The geology and hydrology of a catchment area will determine the regional differences in pH. Within a lake or pond, variations in pH are strongly affected by biological processes such as photosynthesis and respiration. The pH will increase when plants consume carbon dioxide during photosynthesis and will decrease when plants decay and respire (Branmark and Hansson 2005).

Since 2005, the pH in Lower Gooseberry Reservoir has met State water quality standards. During the 2006 and 2007 sampling events, the pH of the streams flowing into the reservoir have also met State water quality standards.

In the following discussion, Bronmark 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 not the same as in Lower Gooseberry Reservoir because the reservoir does not stratify. The shallowness of the lake, the short summer season, the lack of light below 2 to 2.5 meters, and the amount of macrophytes throughout the lake bottom consumes oxygen below the 2-meter depth, which is the depth where the submerged macrophytes grow. A decrease in dissolved oxygen during the winter season is most likely caused by the respiration of plants due to lack of light when the ice is covered by snow and also because no atmospheric oxygen has entered the water for an extended period of time because of the long winter season.

## 7.0 Source Assessment

This section identifies whether load reductions are necessary, and if so, what would be an appropriate margin of safety for limits on sources of pollution while considering the seasonal changes of the parameters of concern.

Since anthropogenic activities have not caused the impairment, Lower Gooseberry Reservoir is recommended to be placed in Category 4C of the State of Utah's 303d List as not impaired by a pollutant.

## 8.0 Best Management Practices

This section discusses the rationale for the means of addressing all sources and causes that are significant in the attainment of the water quality endpoints/targets; the allocation of loads to those significant sources; a description of what controls will be applied and who will be responsible for applying them, and where and when they will be applied. In addition, this section discusses whether land management activities are contributing to the impairment and what practices may be recommended to reduce sources of impairment.

Since the pH of the reservoir and streams flowing into the reservoir are meeting State standards, no management practices are recommended for reducing pH levels. Because the control for the hypolimnetic drain is not tamper-proof, the Manti-La Sal National Forest proposes that the control mechanism be re-engineered to ensure that it is operated only by a limited number of authorized individuals (Forest Service or Division of Wildlife Resources).

There are other means of addressing the dissolved oxygen deficit, including decreasing the quantity of organic matter decomposing in the lake, increasing photosynthesis, destratifying the lake, and directly aerating the lake. They are not recommended for this reservoir.

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