MILL HOLLOW RESERVOIR

LIMNOLOGICAL ASSESSMENT OF WATER QUALITY

March 2008

Mill Hollow Reservoir Report
March 6, 2008

Mill Hollow Reservoir is listed by the State of Utah as an impaired water body because of high total phosphorus concentrations and pH values that exceed State water quality standards (Utah, State of. 2006). In partnership with Utah Division of Water Quality (UDWQ), the Uinta National Forest (UNF) collected data from Mill Hollow Reservoir from March 2006 to August 2006 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, if not, what water quality targets and endpoints should be 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.

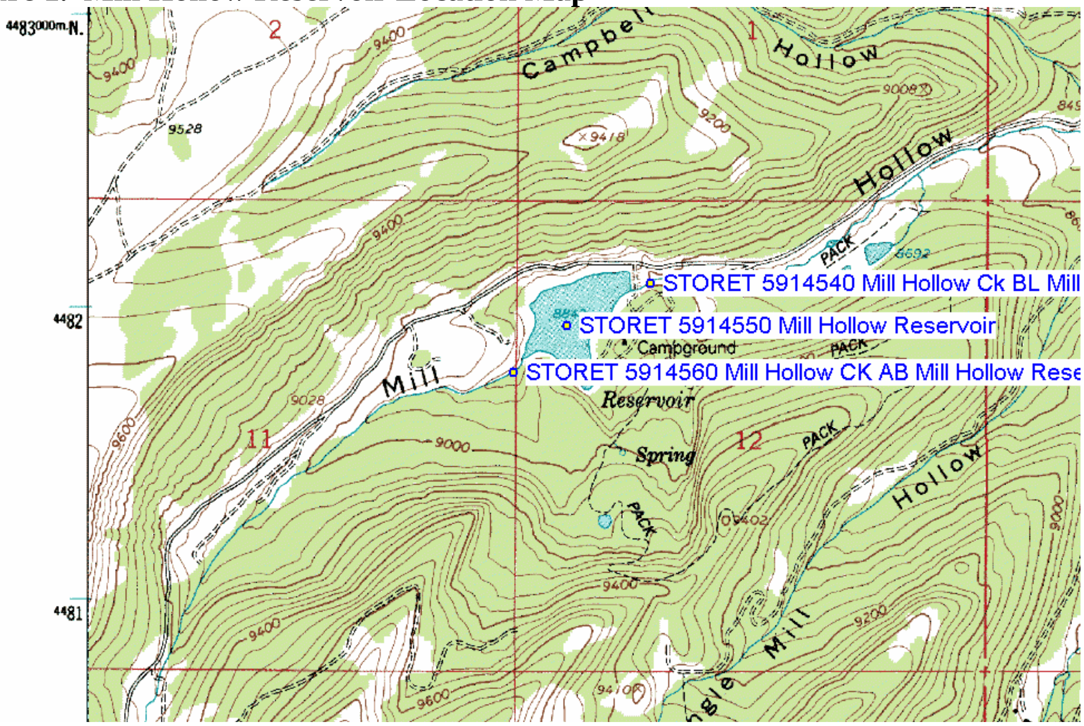
- Section 5.0: Identification of significant pollutant sources through use of existing information (maps, reports, inventories, and analyses) and new data.

- 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 water quality targets.

Figure 1. Mill Hollow Reservoir Location Map



1.0 Introduction

Mill Hollow Reservoir is an artificial stabilized lake maintained by the Utah Division of Wildlife Resources to provide angling opportunities for Utahns. The reservoir was created in 1962 by the construction of an earth-filled dam and has a surface area of 15 acres, volume of 315 acre-feet, and a mean depth of 5.4 meters (18 feet). It is located at an elevation of 8,843 feet above mean sea level (Judd 1997). In September 2006, the reservoir was drained to allow work to be done on the dam and is expected to be empty until work is completed, possibly in the fall of 2009.

Surface inflows to the reservoir consist of Mill Hollow Creek to the south, a small spring/wetland area to the east, and two small seeps on the north side of the reservoir. Water leaves the reservoir via Mill Hollow Creek which is about 6 feet wide above the reservoir and 10 feet wide below the reservoir. From data collected in 2006 and 2007, estimates of water flowing into Mill Hollow Reservoir range from 1.1 cubic feet per second (cfs) during low flows to 9.1 cfs during high flows. The average stream gradient on Mill Hollow Creek is 6.9 percent (Judd 1997).

The watershed above the lake is rather small, about 168 acres in size. The watershed receives 30 inches of precipitation annually with a frost-free season of 20-40 days. Most of the precipitation occurs in the form of snow that falls during the winter. The soil is of limestone origin and has good permeability and moderately slow erosion and runoff. The vegetation communities in the watershed are aspen, spruce-fir, and alpine meadows. The watershed is made up of high mountains with many rock outcroppings characteristic of the Wasatch Plateau (Judd 1997).

Many land uses occur within the watershed draining into the reservoir with grazing and recreation being the dominant uses. The shoreline around the reservoir is owned and managed by the Forest Service with unlimited public access. A 46-unit campground is located above Mill Hollow Reservoir and has a gravel road through it with restrooms south of the reservoir and drinking water from a spring nearby. Several dispersed campsites are located in the drainage above the reservoir. Other land uses include ATV riding and snowmobiling, camping, hunting and fishing (Judd 1997). Old timber harvest units are located in the watershed above the reservoir that have since re-vegetated with no evidence of accelerated erosion.

The ground cover in the watershed above the reservoir is in good condition. The main road through the canyon near the reservoir is gravel surfaced and well maintained. The shore surrounding the reservoir has dense vegetation in most areas. The riparian area along Mill Hollow Creek is in good condition and shows no sign of bank erosion. The dispersed campsites above the reservoir have user created two-track roads which lead to Mill Hollow Creek.

2.0. Water Quality Standards

This section discusses the associated impairment and parameters of concern with respect to state water quality standards, antidegredation policies, and designated beneficial uses for Mill Hollow Reservoir.

The State of Utah has designated the waters within the lake as Antidegradation Segments indicating that the existing water quality is better than the established standards for the designated beneficial uses. Water quality is required by state regulation to be maintained at this level. The beneficial uses of streams within the Forest, as designated by the Utah Department of Environmental Quality, Division of Water Quality, 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 2005).

Mill Hollow Reservoir is listed as impaired for total phosphorus and pH for Cold Water Species of Game Fish (Beneficial Use Class 3A). The methodology for listing for these parameters is described below.

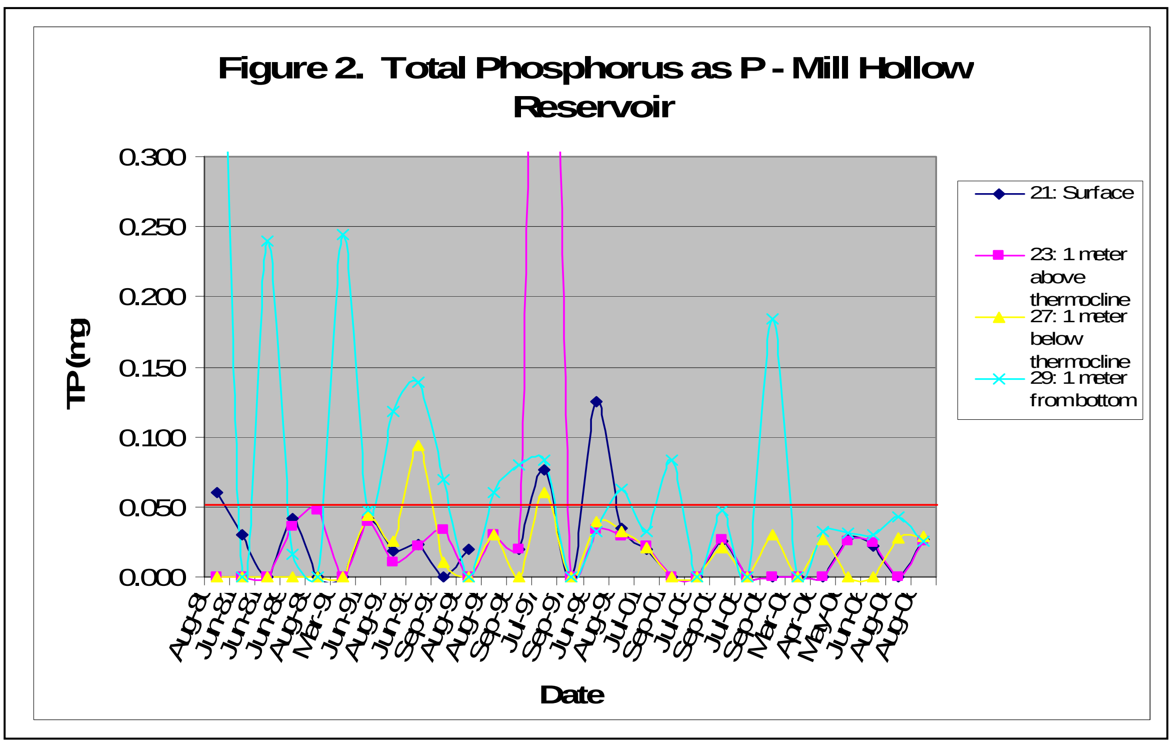
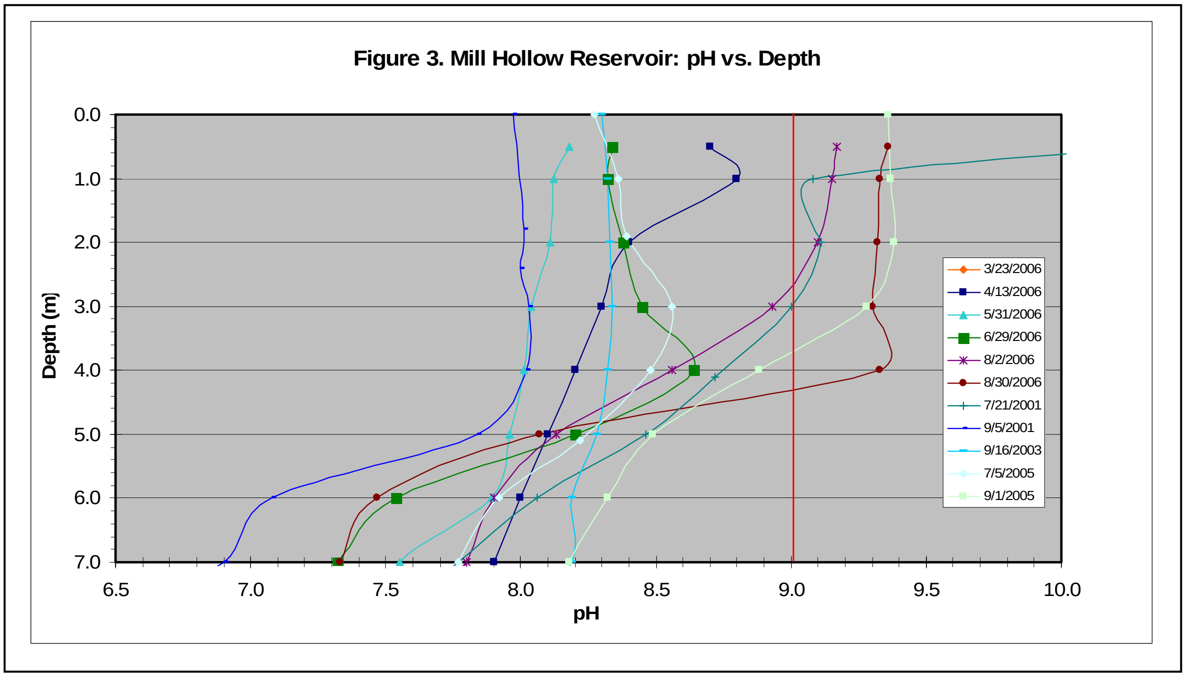


Figure 2. Total Phosphorus as P - Mill Hollow Reservoir

Listing Methodology for Total Phosphorus – Total phosphorus does not directly affect aquatic life, but as a nutrient it can stimulate growth of aquatic algae and emergent plants. Nuisance blooms of algae and other aquatic plants can have an effect on the amount of dissolved oxygen and habitat that fish and macroinvertebrates occupy. The assessment methodology employed by Utah for total phosphorus in lakes and reservoirs states that an assessment unit needs further study if more than 10% of the phosphorus concentration measurements at given depths (21,23, 27, 29) exceed 0.025mg/l. If further study is needed, other factors such as fish kills, low dissolved oxygen, amount of blue-green algae, and the Trophic State Index (TSI) are considered in the evaluation (Utah, State of. 2007).

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 Mill Hollow Reservoir in 1997 (Judd 1997) is described below.

> The water quality of Mill Hollow Reservoir is good. It is considered to be soft with a recent hardness concentration value of approximately 68 mg/L (CaCO3). The only parameters that have exceeded State water quality standards for defined beneficial uses are phosphorus and dissolved oxygen. On occasion pH values will exceed the criteria of 9.0 when a heavy algal bloom is in progress. The average concentration of total phosphorus in the water column in 1981 and 1991 was 135 and 43 ug/L which exceeds the recommended pollution indicator for phosphorus of 25 ug/L. The phosphorus concentration in the hypolimnion in September, 1991 reached a level of 118 ug/L. This increased concentration occurred when the reservoir was stratified, and low dissolved oxygen was present near the bottom. Dissolved oxygen concentrations in late summer substantiate the fact that water quality impairments do exist. Concentrations dropped dramatically below the thermocline to approximately 1.4 mg/L during the summer. A review of a reservoir profile obtained on March 28, 1990 indicates that anoxic conditions are prevalent throughout the winter. Concentrations of dissolved oxygen were 1.8 mg/L at 1 meter, 1.2 mg/L at 2 meters and virtually 0.0 down to a depth of 9 meters. These conditions are deleterious to the fishery rendering approximately the entire reservoir unsuitable for a fishery. It is apparent that the only carryover of fish would be in the inlet area where oxygen supplies are sufficient to maintain a limited fishery. Current data suggest that the

reservoir is a nitrogen limited system. TSI values indicate the reservoir is mesotrophic approaching the eutrophic range with fairly high productivity.

The reservoir was stratified during a summer monitoring trip on August 21, 1991. The profile indicates that a thermocline developed at a depth of 3-7 meters. This is consistent with a noticeable decline in the concentration of dissolved oxygen in the water column.

According to DWR no fish kills have been reported in recent years, however it is evident that some winter kills may occur. The reservoir supports populations of brook trout (Salvelinus fontinalis), rainbow trout and albino rainbow trout (Oncorhynchus mykiss). The lake has not been treated for rough fish competition, so populations of native fishes may still be present in the lake. According to the Utah State Division of Wildlife Resources, Mill Hollow Reservoir is regularly stocked with 8,000 catchable rainbow trout, 4,200 catchable albino rainbow trout, and 7,500 fingerling brook trout. DWR also reports that the water flea, Daphnia, is also present in the reservoir.

The phytoplankton community is dominated by flagellates, diatoms and blue-green algae. This supports the water quality analysis of the reservoir with moderate productivity and generally good water quality.

Pollution Assessment
Nonpoint pollution sources include the following: sedimentation and nutrient loading from grazing and litter or waste from recreation. Grazing takes place throughout the watershed.
There are no point sources of pollution in the watershed.

Water quality data collected since 2001 indicate that the assessment described above is an accurate description of water quality conditions in Mill Hollow Reservoir. Total phosphorus exceeded the State pollution indicator value in 42 of 76 samples (55.3 % of samples) between 1980 and 2005 and exceeded State standards in 12 of 20 samples (60% of samples) in 2006. Since 2001, Mill Hollow Reservoir exceeded the pH State standard of 9.0 in 17 out of 90 samples (19% of the samples). In 2006, Mill Hollow Reservoir exceeded the pH State standard of 9.0 in 9 out of 45 samples (20% of the samples).

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.

A review of potential pollution sources have identified a few sources of man-made pollution that may be contributing to elevated total phosphorus and pH in the reservoir. These are discussed in Sections 4.0 and 5.0. The primary recommended endpoints for Mill Hollow Reservoir based on standards are at least 90% of mean in-lake concentrations of total phosphorus are less than or equal to 0.025 mg/l, and for pH, at least 90% of the pH measurements are within the pH standard range of 6.0 to 9.0.

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.

There area no point sources of pollution within the Mill Hollow Reservoir watershed. The primary man-made non-point sources of total phosphorus are likely to be from sediment that enters the reservoir and a few sources have been identified in the drainage above the reservoir. Dispersed camping is occurring along the drainage bottom above the reservoir and dirt access roads are located near the drainage bottom. These roads are causing erosion and the close proximity of the dispersed sites and dirt roads to the drainage bottom are likely to be causing sediment to enter the stream that flows into the reservoir. Other potential sources do not appear to contribute to phosphorus entering the reservoir. Human waste is contained in vault toilets that are functioning and maintained properly. Timber harvest activities are not contributing sediment because the land surface is well-vegetated and trees in the harvest units have grown back.

Recommended practices that may reduce total phosphorus and pH levels in the reservoir are:

- Identify dispersed camping areas that are authorized under Forest Plan Travel Management, but may need to be closed or need to use best management practices to control soil erosion.
- Limit vehicle access in the drainage above the reservoir by decommissioning and rehabilitating unauthorized dirt roads above the reservoir.

It is likely that these practices will reduce some of the total phosphorus in the reservoir but it is not known whether that these practices will result in meeting the endpoints (meeting State water quality standards).

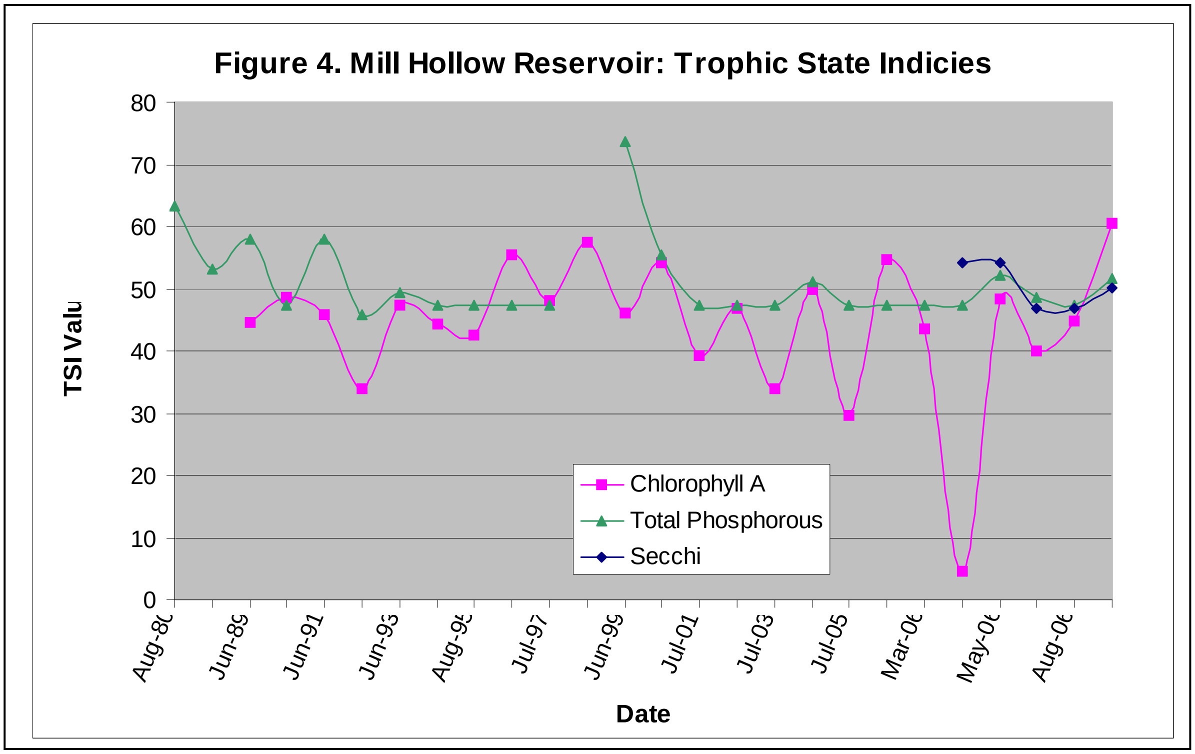
5.0 Significant Sources

The main sources of man-made pollution are from soil erosion and sedimentation including dispersed camping areas and dirt roads located in the drainage bottom in the area above the reservoir.

6.0 Technical Analysis

This section contains a description of water quality data conditions at Mill Hollow 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 Mill Hollow 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 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).



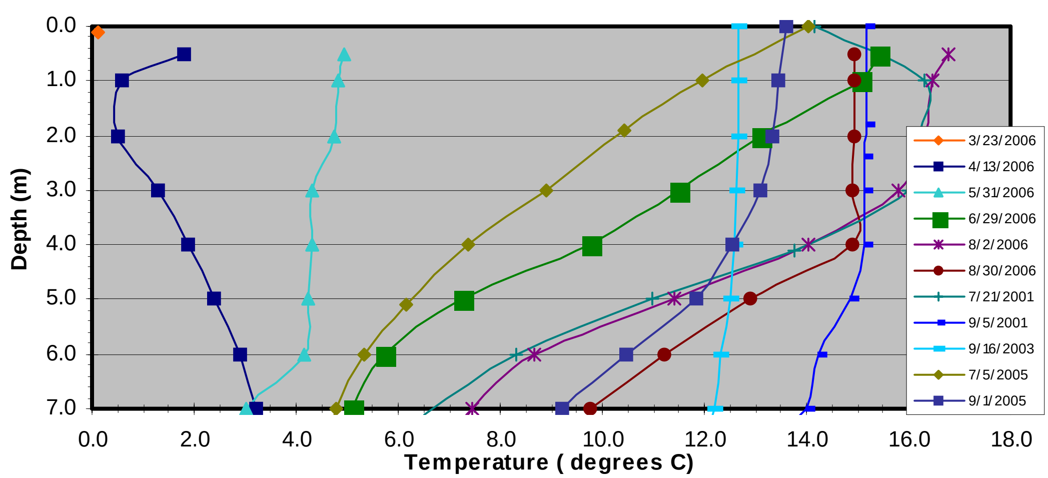
Based on sampling from 1989, the trophic states using chlorophyll-a are oligotrophic to mesotrophic (TSI (Chl) of 30-45) during winter and spring seasons and are mesotrophic to eutrophic (TSI (Chl) of 45-55) in the summer and fall seasons. The clarity of the water reflects the chlorophyll-a pattern but indicates a slightly higher trophic level. The trophic state using secchi depth and total phosphorus gave trophic levels that were between upper mesotrophic and eutrophic. Total phosphorus samples were near or below the detection limit.

Carlson presents characteristics of northern temperate lakes based on the trophic state and says that when lakes become mesotrophic, the hypolimnia of shallow lakes is likely to become anoxic and 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). Mill Hollow Reservoir has these characteristics throughout most of the year when the lake is mesotrophic and eutrophic.

Lake Morphology – Mill Hollow is somewhat square-shaped and is about 1,162 feet wide, 1,426 feet long, and has a mean depth of 18 feet (5.4 meters).

Temperature – The temperature of Mill Hollow Reservoir ranges in winter from 0ºC to 4.9 at the surface to 3.2ºC at the bottom and in summer from 12.7 to 16.8ºC at the surface and from 4.8 to 14.0ºC near the bottom at a depth of about 7.0 meters. The temperature profile indicates that the reservoir is weakly stratified during the summer season.

Figure 5. Mill Hollow Reservoir: Temperature vs. Depth



Light (secchi depth, chlorophyll concentration) –The secchi depth in Mill Hollow Reservoir in 2006 ranged from 1.5 to 2.5 meters. In April 2006, ice was 1.5 meters thick with one foot of slush and 0.5 feet of snow covering the slush. From May to August the reservoir was ice-free.

Catchment Area (size of catchment, type of geology) – The watershed draining into Mill Hollow Reservoir is about 168 acres in size and is located within the Wasatch Montane Zone of the Wasatch and Uinta Mountains Level III ecoregion. This zone is partially glaciated with surficial Quaternary glacial till, collovium and alluvium. (Woods et al. 2001). The reservoir is located within a phosphate deposit zone identified by the Bureau of Mines Special Report "Availability of Federally Owned Minerals for Exploration and Development in Western States: Utah, 1988." These deposits, depending on their proximity to the surface, may contribute phosphorus loading into the reservoir.

The reservoir is located in a northeast-southwest oriented valley that is about 0.7 mile wide and the distance from the reservoir to the southwest end of the valley is 2.8 miles. The valley is v-shaped and has steep side slopes off of the ridges that are 1,000 higher than the valley bottom. The predominant vegetation type in the valley bottom is sagebrush/mountain brush and on the steep sideslopes are aspen and conifer.

pH – The pH values for water samples collected in Mill Hollow Reservoir are between 6.6 and 12.0. As seen in Table 1, pH is more alkaline in the upper half of the water column during summer/fall and generally returns to less alkaline conditions in the winter. Since 2001, Mill Hollow Reservoir exceeded the pH State standard of 9.0 in 17 out of 90 samples (19% of the samples). In 2006, Mill Hollow Reservoir exceeded the pH standard of 9.0 in 9 out of 45 samples (20% of the samples). The pH of the streams flowing into the reservoir was measured in 2006 and values are fairly constant throughout the year and range between 7.8 and 8.5. As shown in Table 2, the pH of the water flowing into the reservoir is alkaline but does not exceed State standards for pH. On August 3, 2006, the water flowing out of the reservoir is at the upper limit of the pH standards (9.0). All other samples collected below the reservoir are below the pH standard. Mill Hollow Reservoir is alkaline and most of the pH values are 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 1. Mill Hollow Reservoir pH field data.

	Depth (m)											
Date	**0.5**	**1.0**	**2.0**	**3.0**	**4.0**	**5.0**	**6.0**	**7.0**	**7.4**	**8.0**	**8.3**	**8.6**
07/21/2001	12.0	9.1	9.1	9.0	8.7	8.5	8.1	7.7	----	----	----	----
09/05/2001	8.0	8.0	8.0	8.0	8.0	7.8	7.1	6.9	6.6	----	----	----
09/16/2003	8.3	8.3	8.3	8.3	8.3	8.3	8.2	8.2	----	8.0	8.0	----
07/05/2005	8.3	8.4	8.4	8.6	8.5	8.2	7.9	7.8	----	7.7	----	----
09/01/2005	9.4	9.4	9.4	9.3	8.9	8.5	8.3	8.2	----	8.1	----	8.0
03/23/2006	8.1	----	----	----	----	----	----	----	----	----	----	----
04/13/2006	8.7	8.8	8.4	8.3	8.2	8.1	8.0	7.9	----	7.9	----	----
05/31/2006	8.2	8.1	8.1	8.0	8.0	8.0	7.9	7.6	----	7.5	----	----
06/29/2006	8.3	8.3	8.4	8.5	8.6	8.2	7.5	7.3	----	7.1	----	----
08/02/2006	9.2	9.2	9.1	9.1	8.6	8.1	7.9	7.8	----	7.7	----	----
08/30/2006	9.4	9.3	9.3	9.3	9.3	8.1	7.5	7.3	----	----	----	----

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

Nutrients – Table 2 contains a summary of exceedances and Table 4 contains the dissolved and total phosphorus and nitrogen concentrations in Mill Hollow Reservoir for samples collected since 1980. For calculating the following averages, the assumption is made that a sample that had a non-detect was given a value 0.01 mg/L, one half the detection limit. Since 2001, most of the total phosphorus is in the dissolved fraction. For all sampling events, the average concentration of total phosphorus as P at the surface (21) is 0.028 mg/l, above the thermocline (23) is 0.023 mg/l (excluding a suspiciously high value of 0.765 mg/L collected on 7/17/1997), below the thermocline (27) is 0.03 mg/l, and just above the bottom (29) is 0.098 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 (68%) did not detect nitrogen.

Table 2. Summary of Total Phosphorus exceedances and concentrations.

Time Period	Number of Exceedances	Number of Samples	Percent of Exceedances	Average Concentration (mg/l)
1980 – 2005	42	76	55.3	0.056
2006	12	20	60.0	0.020
1980 - 2006	54	96	56.3	0.048

Table 3. Mill Hollow Reservoir - Nutrients by depth level.

	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
08/07/1980	-----	-----	-----	-----	0.060	-----	-----	-----	0.620	0.10	-----	-----	1.00
06/10/1981	-----	-----	-----	-----	0.030	-----	-----	-----	-----	0.10	-----	-----	-----
06/16/1981	-----	-----	-----	-----	-----	-----	-----	-----	0.240	-----	-----	-----	-----
06/14/1989	-----	-----	-----	-----	0.042	0.036	0.020	-----	0.016	-----	-----	-----	-----
08/30/1989	-----	-----	-----	-----	ND	0.048	ND	-----	ND	-----	-----	-----	-----
03/28/1990	ND	-----	-----	-----	-----	-----	-----	-----	0.244	-----	-----	-----	-----
06/12/1991	0.019	0.021	0.022	0.024	0.042	0.039	-----	0.044	0.047	0.22	0.21	0.25	0.22
08/21/1991	ND	0.040	0.025	0.083	0.018	0.011	-----	0.025	0.118	ND	0.04	ND	ND
06/30/1993	0.024	0.021	0.055	0.062	0.023	0.022	-----	0.094	0.139	0.05	0.03	0.03	0.10
09/06/1993	ND	ND	ND	0.037	ND	0.034	-----	0.011	0.070	ND	ND	ND	ND
08/01/1995	0.010	-----	-----	-----	0.020	-----	-----	-----	-----	ND	-----		-----
08/02/1995	-----	0.010	ND	0.030		0.030	-----	0.030	0.060	-----	ND	ND	ND
09/21/1995	-----	0.010	-----	0.060	0.020	0.020	-----	-----	0.080	ND	ND	-----	0.03
07/17/1997	-----	-----	-----	-----	0.077	0.765	-----	0.060	0.083	ND	ND	ND	ND
09/05/1997	-----	-----	-----	-----	-----	-----	-----	-----	-----	ND	0.02	-----	ND
06/15/1999	0.024	0.022	0.039	0.028	0.125	0.034	-----	0.039	0.033	ND	0.10	0.20	0.10
08/11/1999	ND	ND	ND	0.026	0.035	0.029	-----	0.032	0.062	ND	ND	ND	ND
07/17/2001	ND	ND	ND	0.024	0.020	0.022	-----	0.021	0.032	ND	ND	ND	ND
09/05/2001	ND	ND	ND	0.047	ND	ND	-----	ND	0.083	ND	ND	ND	ND
07/09/2003	ND	ND	ND	ND	ND	ND	-----	ND	ND	ND	ND	ND	ND
09/16/2003	ND	ND	ND	0.022	0.026	0.027	-----	0.021	0.047	0.19	ND	ND	ND
07/06/2005	ND	ND	ND	ND	ND	ND	-----	ND	ND	ND	1.15	ND	ND
09/01/2005	ND	ND	0.026	0.129	ND	ND	-----	0.030	0.184	ND	ND	ND	ND

03/23/2006	ND	-----	-----	-----	ND	-----	-----	-----	-----	1.20	-----	-----	-----
04/13/2006	ND	0.022	0.023	0.022	ND	ND	-----	0.027	0.033	0.40	0.32	0.33	0.17
05/31/2006	ND	ND	-----	0.020	0.028	0.025	-----	-----	0.031	ND	ND	-----	0.22
06/29/2006	ND	ND	ND	ND	0.022	0.024	-----	ND	0.030	ND	ND	ND	ND
08/02/2006	ND	ND	0.024	0.031	ND	ND	-----	0.028	0.043	0.35	ND	ND	ND
08/30/2006	0.024	0.023	0.023	ND	0.027	0.025	-----	0.029	0.026	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).

Dissolved and total phosphorus and nitrogen concentrations in water samples collected in Mill Hollow Creek flowing into and out the reservoir are shown in Tables 4 and 5. For all samples collected, total phosphorus as P did not exceed the indicator value of 0.05 mg/l above the reservoir and exceeded it below the reservoir two times, once in April and once in August. Only a few samples collected at these sites were below the detection limit for dissolved and total phosphorus and these were all from samples collected below the reservoir. For all samples collected, nitrogen as dissolved nitrite+nitrate was well below the standard of 4.0 mg/l although nitrogen was detected in the majority of samples (64%).

Table 4. Mill Hollow Creek field data above reservoir.

Date	Time	Water Temp (C)	pH	DO (mg/l)	Spec. Cond. (S/cm^2)	Discharge (cfs)	Units of flow	Total Phosphorus as P (mg/l)	Dissolved Total Phosphorus as P (mg/l)	Dissolved Nitrogen NO2+NO3
03/23/06	1230	0.4	8.6	6.90	----	----	cfs	0.027	0.025	0.280
04/13/06	1430	2.0	8.8	10.40	205	1.20	cfs	0.029	0.024	0.264
05/31/06	1225	5.5	7.9	7.93	95	9.12	cfs	0.031	0.020	ND
06/29/06	1205	8.9	8.1	8.10	130	2.61	cfs	0.027	0.024	0.120
08/02/06	1200	7.9	8.5	6.46	184	1.51	cfs	0.026	0.027	0.130
08/30/06	1240	10.2	8.5	6.66	192	1.09	cfs	0.037	0.042	0.120

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).

Table 5. Mill Hollow Creek field data below reservoir.

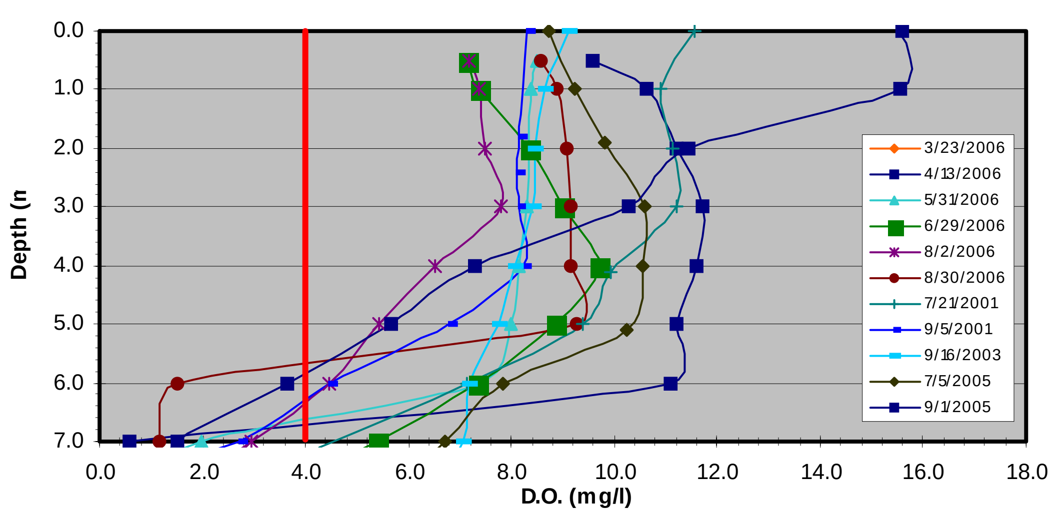
Date	Time	Water Temp (C)	pH	DO (mg/l)	Spec. Cond. (S/cm^2)	Discharge (cfs)	Units of flow	Total Phosphorus as P (mg/l)	Dissolved Total Phosphorus as P (mg/l)	Dissolved Nitrogen NO2+NO3
03/23/06	----	----	----	----	----	----	cfs	----	----	----
04/13/06	1400	2.1	8.1	10.50	231	----	cfs	0.059	0.033	0.246
05/31/06	1315	5.9	8.0	8.07	119	10.90	cfs	0.028	ND	ND
06/29/06	1245	15.4	8.2	6.04	130	4.24	cfs	ND	ND	ND
08/02/06	1300	15.0	9.0	4.96	131	2.39	cfs	0.046	0.035	0.120
08/30/06	1240	12.0	8.7	4.81	144	1.33	cfs	0.180	0.152	ND

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).

Phosphorus in the inflow stream is primarily in the dissolved fraction. It is interesting to note that although in-lake phosphorus concentrations regularly exceed the pollution indicator value of 0.025 mg/L none of the tributary stream data exceed the 0.05 mg/L indicator value possibly indicating another source of phosphorus loading into the reservoir. In reviewing the profile data it appears the additional phosphorus loading may originate from the bottom sediments (internal loading). Given that Mill Hollow Reservoir is located within a zone identified as rich in phosphate by the Bureau of Mines much of this internal phosphorus load may originate from the native soils and bedrock on which the reservoir is located.

Oxygen – From measurements collected since 2001, the dissolved oxygen profile shows very little stratification at any time of the year. The only month where stratification appears below the first meter in depth is in September 2005. Almost all of the profiles show a pronounced drop in oxygen in the bottom two meters. For all the profiles, the percent of the water column supporting the 4 mg/l dissolved oxygen criteria range from 60 to 100 percent. Before 2006, Mill Hollow Reservoir exceeded the dissolved oxygen standard of 4 mg/l in 5 out of 46 samples (11% of the samples). In 2006, Mill Hollow Reservoir exceeded the dissolved oxygen standard of 4 mg/l in 9 out of 45 samples (20% of the samples). For all samples collected, Mill Hollow Reservoir exceeded the dissolved oxygen standard of 4 mg/l in 14 out of 91 samples (15% of the samples). All of the exceedances of the State dissolved oxygen standard occurred in the bottom 2 meters of the reservoir.

Figure 6. Mill Hollow Reservoir: Dissolved Oxygen vs. Depth 2006



Macrophytes – Macrophytes cover about 50% of the bottom of the reservoir as indicated in photos of the reservoir bottom when the reservoir was drained in September 2006.

Algae –For all samples collected from 2001, chlorophyll a, uncorrected for pheophytin ranges from <0.07 to 21.0 ug/l with the largest value in August 2006 and the lowest value in April 2006. No seasonal trends were observed in the data. No algal masses were seen during any sample event.

A taxonomic survey of phytoplankton was conducted on Mill Hollow 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.

Table 6. Diversity measurements for Mill Hollow Reservoir.

Diversity Measure	**Judd (1997)**	**2006 Sample**
Shannon-Weiner Index	1.57	1.14
Species Evenness	0.68	0.71
Species Richness	0.40	1.13

Discussion – Non-point sources of pollution can contaminate lakes through runoff and groundwater. Runoff can carry sediment and nutrients from roads, bare soil, and 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. Excessive algae and macrophyte growth can create supersaturated oxygen conditions from photosynthesis during the day, which then plunges to low levels of dissolved oxygen at night from high levels of respiration and lack of photosynthesis, creating dramatic diel fluctuations.

pH is a measure of the acidity or alkalinity of water, and determines the solubility and biological availability of chemical constituents such as nutrients and heavy metals. When pollution results in higher algal and plant growth, pH levels may increase. This is because photosynthesis uses up dissolved carbon dioxide, which disassociates into carbonic acid in water. As carbon dioxide is decreased, the alkalinity of the water increases. These changes in pH can increase the solubility and aggravate nutrient problems of phosphorus, making it more available for plant growth.

Researchers of the U. S. Geological Survey (Winter et al.1998) summarized ground water and surface water processes affecting chemicals in lakes and wetlands and an excerpt from their discussion that applies to nutrients is presented below.

> "Lakes and wetlands also have distinctive biogeochemical characteristics with respect to their interaction with ground water. The chemistry of ground water and the direction and magnitude of exchange with surface water significantly affect

> the input of dissolved chemicals to lakes and wetlands. In general, if lakes and wetlands have little interaction with streams or with ground water, input of dissolved chemicals is mostly from precipitation; therefore, the input of chemicals is minimal. Lakes and wetlands that have a considerable amount of ground-water inflow generally have large inputs of dissolved chemicals. In cases where the input of dissolved nutrients such as phosphorus and nitrogen exceeds the output, primary production by algae and wetland plants is large. When this large amount of plant material dies, oxygen is used in the process of decomposition. In some cases the loss of oxygen from lake water can be large enough to kill fish and other aquatic organisms.
>
> The magnitude of surface-water inflow and outflow also affects the retention of nutrients in wetlands. If lakes or wetlands have no stream outflow, retention of chemicals is high. The tendency to retain nutrients usually is less in wetlands that are flushed substantially by throughflow of surface water. In general, as surface-water inputs increase, wetlands vary from those that strongly retain nutrients to those that both import and export large amounts of nutrients. Furthermore, wetlands commonly have a significant role in altering the chemical form of dissolved constituents. For example, wetlands that have throughflow of surface water tend to retain the chemically oxidized forms and release the chemically reduced forms of metals and nutrients."

Most of the surface water flowing into the reservoir is from spring sources and from Mill Hollow Creek. Total phosphorus concentrations in the creek primarily consisted of the dissolved fraction. This indicates that ground water is the most likely source of this inflow water. Although there are some man-made sources of sediment that may be contributing to the reservoir, it is likely that most of the phosphorus entering the lake is from natural geological sources and ground water.

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 (Bronmark and Hansson 2005).

The pH of water in Mill Hollow Reservoir appears to reflect the ground water chemistry of the drainage and the biochemical reactions occurring in the reservoir. Inflow water to the reservoir is alkaline (between 8.0 and 9.0) and the pH of the lake increases during the summer season as a result of photosynthesis that results in pH levels that exceed 9.0 for part of the year.

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.

The results of the data and land management activities in the watershed indicate that natural processes are primarily causing exceedances of the total phosphorus pollution indicator value and pH standards although there appears to be some man-made activities that are contributing to the amount of total phosphorus that is entering the reservoir.

Most of the anthropogenic sources could be mitigated through development and implementation of appropriate best management practices. Natural inputs of phosphorus due to the phosphate geology of the watershed might also be able to be reduced through BMPs that reduce sediment inputs. Since anthropogenic activities have not caused the impairment, Mill Hollow Reservoir is recommended to be placed in Category 4C of the State of Utah's 303d List as not impaired by a pollutant.

Although Mill Hollow Reservoir is likely to not be impaired due to anthropogenic causes several recommended projects are included to help guide land management efforts to preserve and improve current water quality conditions

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. 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 most of the total phosphorus is in the dissolved fraction, the main contributor of total phosphorus is likely to be from the spring sources entering the reservoir. Soil erosion is not likely to be a major cause of the phosphorus impairment. The spring sources around the reservoir are in very good condition and no management practices are recommended for these.

Recommended practices that may reduce total phosphorus and pH levels in the reservoir are:

- Identify dispersed camping areas that are authorized under Forest Plan Travel Management, but may need to be closed or need to use best management practices to control soil erosion.
- Limit vehicle access in the drainage above the reservoir by decommissioning and rehabilitating unauthorized dirt roads above the reservoir.

It is likely that these practices will reduce some of the total phosphorus in the reservoir and may reduce the pH levels as a result of the reduced phosphorus. It is not known whether these practices will result in meeting the endpoints (meeting State water quality standards). The Forest Service would be responsible for implementing work on National

Forest lands but when implementation would occur would depend upon available funding and Forest Service priorities.

REFERENCES

Baker, J.P., H. Olem, C.S. Creager, M.D. Marcus, and B.R. Parkhurst. 1993. Fish and Fisheries Management in Lakes and Reservoirs. EPA 841-R-93-002. Terrene Institute and U.S. Environmental Protection Agency, Washington, D.C.

Bronmark, Christer and Lars-Anders Hansson. 2005. The Biology of Lakes and Ponds. Oxford University Press.

Bureau of Mines Special Report "Availability of Federally Owned Minerals for Exploration and Development in Western States: Utah, 1988."

Judd, H.J. 1997. Utah's Lakes and Reservoirs, An Inventory and Classification of Utah's Priority Lake and Reservoirs. Utah Department of Environmental Quality, Division of Water Quality.

Kent State. 2005. Internet site http://dipin.kent.edu.tsi.htm, The Great North American Secchi Dip-In. excerpted and modified from Carlson, R.E. and J. Simpson. 1996. A Coordinators Guide to Volunteer Lake Monitoring Methods. North American Lake Management Society. 96 pp.

Olem, H. and G. Flock, eds. 1990. Lake and Reservoir Restoration Guidance Manual, 2nd edition. EPA -440/4-90-006. Prep. by N. Am. Lake Manage. Soc. for U.S. Environ. Prot. Agency, Washington DC.

Utah, State of. 2005. Standards of Quality for the Waters of the State. R317-2, Utah Administrative Code. Utah Department of Environmental Quality, Division of Water Quality, Revised December 1, 2005.

Utah, State of. 2006. Utah's 2004 303(d) List of Impaired Waters. Utah Department of Environmental Quality, Division of Water Quality.

Utah, State of. 2007. Draft Water Quality Assessment Guidance. Utah Department of Environmental Quality, Division of Water Quality, August 31, 2007.

Woods, A.J., Lammers, D.A., Bryce, S.A., Omernik, J.M., Denton, R.L., Domeier, M., and Comstock, J.A. 2001, Ecoregions of Utah (color poster with map, descriptive text, summary tables, and photographs): Reston, Virginia, U.S. Geological Survey (map scale 1:1,175,000).