Hyrum Reservoir
TMDL
Cache County, Utah

Prepared by
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Hyrum Reservoir TMDL

Waterbody ID	**Hyrum Reservoir**
Location	**Cache County, Utah**
TMDL Pollutants of Concern	**Total Phosphorus** **Dissolved Oxygen**
Impaired Beneficial Uses	**Class 3A: Protected for cold water species of game fish and other cold water aquatic life, including the necessary aquatic organisms in their food chain.**
Loading Assessment ***(Based on 1998-1999 data)***	**Average daily TP load = 8.4 Kg/day** **Annual load = 3,066 Kg TP** **D.O. frequently = 4.0 mg/l**
Water Quality Targets/Endpoints ***(Based on 0.05-mg/l total phosphorus concentration inflow from LBR)***	**0.05 mg/l TP inflow concentration** **0.025 mg/l TP concentration in reservoir** **Average annual TP load = 6.3 kg/day** **Annual load = 2300 Kg TP** **Load reduction of 2.1 Kg/day TP** **D.O. = 4.0 mg/l for = 50% of water column**
Implementation Strategy	**Continue to implement BMP's on the Little Bear River as outlined in the Little Bear River TMDL.**
This document is identified as a TMDL for Hyrum Reservoir and is officially submitted to the U.S. EPA to act upon and approve as a TMDL.	

Introduction

Hyrum Dam and Reservoir are located on the Little Bear River just south of Hyrum City. The dam is a rolled earth and rockfill structure. The construction period was 1934 to 1935. The date of closure (first storage) was April 1, 1935, and the first water was made available in July 1935. The dam is operated and maintained by the South Cache Water Users Association. Irrigation of agriculture lands has greatly increased their productivity and has improved the general economy of the community. Alfalfa, wheat, barley, and pasture are the principal crops in the area. Many of the farms are small and are owned by part-time farmers. Table 1 shows the physical characteristics of Hyrum Reservoir.

Table 1 – Hyrum Reservoir Physical Description	
Watercourse – Little Bear River	USGS Cataloging Unit - # 16010203
Elevation – 4,664 feet	Depth – 82 feet
Surface Area – 438 acres	Length – 1.77 miles
Watershed Area – 116,480 acres	Width – 0.44 miles
Active Storage Volume – 15,280 acre-feet	Shoreline – 4.41 miles
Dead Storage Volume – 3,480 acre-feet	Latitude – 41 37' 14" N
Average Retention Time – 0.30 years	Longitude – 111 51' 28" W

The Utah Division of Parks and Recreation administer reservoir facilities. Recreational activities include boating, fishing, picnicking, swimming, and walking.

Water Quality Standards

Based on historical water quality data, water quality of the Hyrum Reservoir does not meet the standards set by the State of Utah for its 3A designated use classifications. It was originally listed on the 1998 303d list. The pollutants of concern include; total phosphorus (TP), and dissolved oxygen. The Little Bear drainage was listed due to water quality deterioration above Hyrum Reservoir. Point and nonpoint sources of TP above Hyrum Reservoir have been identified as significant sources of nutrient loading resulting in impairment of Hyrum Reservoir. Tables 2-4 show the TMDL status, pollutants of concern and the beneficial use classification of Hyrum Reservoir.

Table 2 – from Utah's 2002 List of Lakes and Reservoirs Identified as Needing TMDL Analyses.

Water Quality Management Unit	Waterbody Waterbody Name	HUC	Waterbody Size (Acres)	Beneficial Use Impaired	Pollutant or Stressor Of Concern	Priority For TMDL	Targeted For TMDL 2000-2002
Bear River	Hyrum Reservoir	16010203	438	3A	Total Phosphorus	High	Yes
Bear River	Hyrum Reservoir	16010203	438	3A	Dissolved Oxygen	High	Yes

Table 3 – Beneficial use class and pollutants causing impairment

Waterbody	Beneficial Use Classes (Impaired class shown in **bold**)	Impairment
Hyrum Reservoir	2A, 2B, **3A**, 4	Total Phosphorus Dissolved Oxygen

Table 4 – Explanation of beneficial use classifications for Hyrum Reservoir
Class 2 - Protected for recreational use and aesthetics.
Class 2A - Protected for primary contact recreation such as swimming.
Class 2B - Protected for secondary contact recreation such as boating, wading, or similar uses.
Class 3 - Protected for use by aquatic wildlife.
Class 3A - Protected for cold-water species of game fish and other cold-water aquatic life, including the necessary aquatic organisms in their food chain.
Class 4 - Protected for agricultural uses including irrigation of crops and stockwatering.

Public Law 92-500, the Federal Water Pollution Control Act (commonly referred to as the Clean Water Act), enacted by Congress in 1972 and amended in 1977, 1981 and 1987, provides a national framework for water quality protection. The Clean Water Act recognizes that it is the primary responsibility of the States to prevent, reduce and eliminate water pollution; to determine appropriate uses for their waters and to set water quality criteria to protect those uses. Section 303(d) of the Clean Water Act requires that each state reviews and, if necessary, revises its Water Quality Standards at least once every three years. This serves to ensure that the requirements of state and federal law are met and that water quality criteria are adequate to protect designated water uses.

Several non-numeric standards also exist to protect water quality. The anti-degradation policy states that when water quality is better than the state standard, it should be maintained at that higher quality unless there are compelling economic or social reasons to allow it to deteriorate, although at no time may water quality deteriorate to below the water quality standard. Narrative standards written into the code further state that no discharges may be made, which would result in deteriorated conditions or would adversely affect desirable aquatic life.

Water Quality Targets/Endpoints

The desired goal for the TMDL is to meet state water quality standards for the designated and beneficial uses of the waterbody. The target endpoint for total phosphorus is to obtain an inflow concentration of 0.05 mg/l into the reservoir. Endpoints identified to achieve the TMDL coincide with the goals and objectives associated with the Little Bear River Hydrologic Unit Area (see Margin of Safety section).

The endpoints are:

1. **Average total phosphorus load = 6.3 Kg/day (2,300 Kg/year). (Based on 0.05 mg/l TP concentration inflow)**
2. **In lake concentration of total phosphorus = 0.025 mg/l.**
3. **Dissolved oxygen concentration = 4.0 mg/l for = 50% of water column.**
4. **Algal shift away from Blue-green dominance.**

TMDL

The desired goal is to meet state water quality standards for the designated and beneficial uses of the waterbody. Based on this the following TMDLs will be established to assist in this effort.

Table 5 – TMDL for Hyrum Reservoir

TMDL		
Waterbody	**Dissolved Oxygen**	**Total Phosphorus**
Little Bear River load to Hyrum Reservoir *	N/A	Average 6.3 kg/day TP
Hyrum Reservoir	= 4 (mg/l) for = 50% of water column	Not to exceed 0.025 mg/l

*** TMDL for the Hyrum Reservoir is based in part on Little Bear River TMDL submitted to and approved by U.S.E.P.A.**

Significant Sources

A 1971 study by W. A. Luce (The Phosphorus Budget for the Upper Little Bear River, Hyrum Reservoir Watershed, 1974, Utah State University), showed that the Little Bear River contributed 97 percent of the phosphorus loadings, which entered Hyrum Reservoir. Effluent from a fish hatchery upstream of the reservoir accounted for approximately 40 percent of the inflow of total phosphorus and 60 percent of the inflow of dissolved total phosphorus. The study also noted significant loading contributions (50-60 percent) from agriculture.

Nonpoint Sources

Phosphorus is adsorbed to sediment particles and therefore by controlling the sediment production decreases in phosphorus will also be realized. Efforts to stabilize the channel and the streambanks are expected to have positive results on phosphorus reduction as sediment loads are decreased. Addressing sheet, rill, and gully erosion on rangeland will further decrease sediment loads. Sediment from this source is produced during heavy thunderstorms in late summer and early fall, and during periods of rapid snowmelt during the spring months.

Animal feed operations located next to the river are a major concern. However, the number of cattle and methods of manure application outside of the feedlots are also a major concern. In the past very few waste storage facilities existed and manure was spread year long except during the crop-growing season. Common practices included spreading manure on frozen, snow-covered ground during the winter months. This manure could then be carried to the stream when the snow melted or during early spring rains.

Point Sources

An important part of the state's water quality regulations is the UPDES program (see table 6). Point sources, which discharge into a waterbody are required to obtain a State of Utah discharge permit. The state determines the maximum allowable discharges of various pollutants from each source, and establishes a monitoring and reporting program for these different sources.

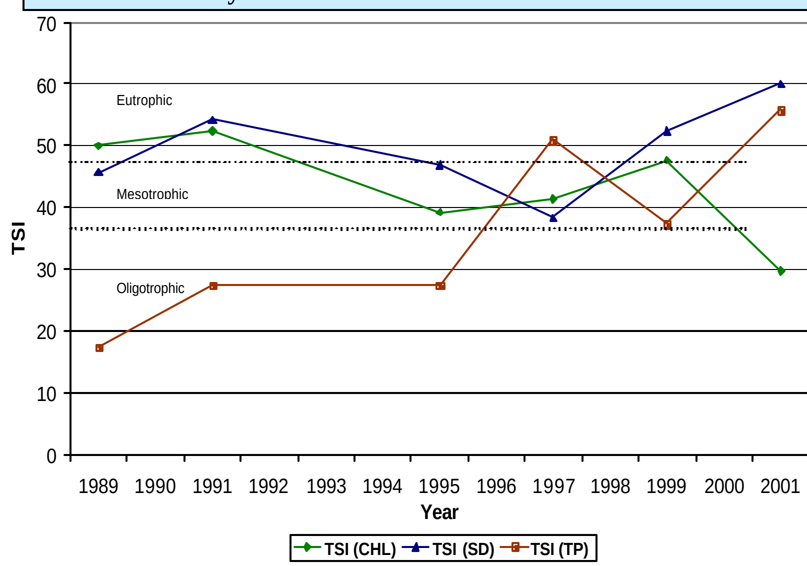
Table 6 - Summary of point sources that contribute pollutants of concern in the watershed.			
DISCHARGER	**UPDES #**	**STORET #**	**DISCHARGE LOCATION**
Trout of Paradise 001	UTG130015	490568	Little Bear River
Trout of Paradise 002	UTG130015	490571	Little Bear River

Technical Analysis

The water quality of Hyrum Reservoir is good, but there have been concerns since the 1950's. According to the Hyrum Reservoir Clean Lakes Phase I study (1994) the issue of degraded water quality conditions are evidenced by extensive late summer blooms of the blue-green *Aphanizomenon flos-aqua*. Phosphorus concentrations frequently exceeded the state indicator value of 25 ug/l. These conditions resulted in decreased transparency, surface scum and algal mats, noxious odors from these decaying algal mats and changes in the food web structure. Low hypolimnetic dissolved oxygen concentrations have occurred resulting in increased internal phosphorus loading. These conditions compromised beneficial uses of the reservoir.

The 1994 Clean Lakes Phase I Report showed improvements in several water quality indicators relative to prior conditions. Although algal concentrations were high in summer, blooms of *Aphanizomenon flos-aqua* were not present. Improvements could be attributed to a reduction in dissolved total phosphorus output from the fish hatchery above the reservoir. Production at the hatchery decreased significantly between 1972 and 1993.

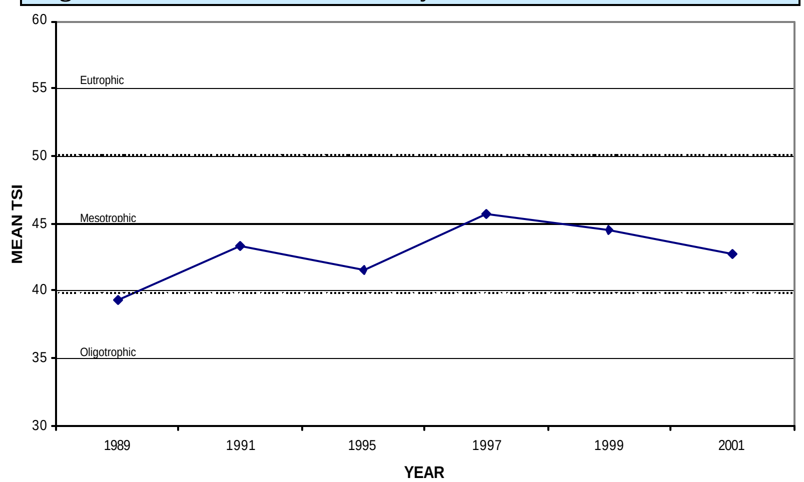
Figure 1 – Summer Chlorophyll, Secchi Depth & Total Phosphorus TSI values for Hyrum Reservoir 1989-2001



Carlson (1977,1997) has developed Trophic State Indices (TSI) to classify lakes based on their biological response to factors such as nutrient concentrations. Trophic states are defined as the total weight of living biological material at a given time, which is estimated independently by measurements of chlorophyl-a, total phosphorus, and secchi depth. Calculating the mean TSI of each of these parameters for Hyrum Reservoir indicates that between 1989-2001, the reservoir was mesotrophic. This state is noted by probable anoxic hypolimnia in summer, moderate water clarity, and stress and possible loss of salmonids due to hypolymnetic anoxia. TSI values for chlorophyl-a, secchi depth, and total phosphorus are shown in figure 1. The average values for all indices are shown in figure 2. This data represents monitoring for the summer sampling period only, which is the time of year that lakes generally stratify, reach maximum biomass production, and demonstrate hypolymnetic anoxia. The summer period represents the critical period to evaluate productivity. Since TSIs are a measure of lake biomass and chlorophyl-a is the best measure of the biological material in lakes, the chlorophyl-a TSI value is optimal for gauging the biological response of lakes over time. The chlorophyl-a TSI line shows a general decline over time particularly since 1991. With the exception of 2001, secchi TSI indicates similar improvement. The 2001 values for secchi and total phosphorus TSI both demonstrate a sharp increase, suggesting that light attenuation was not due to algae but other factors such as turbidity with phosphorus possibly bound to suspended sediment.

Species composition of algae samples taken from Hyrum Reservoir in 1995, 1997, and 1999 were analyzed by Dr. Sam Rushforth of BYU and are presented in Tables 1-3. Additional analysis was also completed in 1972-73 (Drury et al. 1975) during a period when blue-green algae blooms of *Aphanizomenon flos-aqua* were occurring. Characteristic of eutrophic systems, blue-green algae dominate in lakes and reservoirs when excessive phosphorus is available and nitrogen becomes the limiting nutrient since they possesses the ability to fix atmospheric nitrogen. In addition to causing hypolimnetic oxygen depletion, blooms of *Aphanizomenon flos-aqua* can produce hepatotoxins harmful to fish, wildlife, and humans. Recent analysis of species composition has demonstrated a shift from dominance of blue-green to species indicative of eutrophic systems. For example, samples collected in 1995 were dominated by the green algae, *Sphaerocystis schroeteri* commonly found in mesotrophic lakes and reservoirs. In addition, *Ceratium hirundinella*, a clean water species of dinoflagellate, dominated the taxa collected in 1997. Its dominance in Hyrum Reservoir could be explained by the fact that *Ceratium hirundinella* is flagellated and thus able to migrate into lower, more phosphorus-rich strata to acquire nutrients.

Figure 2 – Mean TSI values for Hyrum Reservoir 1989-2001



The linkage between lake/reservoir oxygen depletion and nutrients

There is a definitive linkage between nutrient loads to Utah lakes/reservoirs and indirect oxygen depletions that occur as a result of excess algae blooms. This linkage will be used to support approval for the 2002 submitted TMDL for Hyrum Reservoir for dissolved oxygen endpoints.

In a review of scientific literature, Carpenter et al. (1998), has shown that non-point sources of phosphorous (P) have lead to eutrophic conditions for many lake/reservoirs across the U.S. One consequence of eutrophication is oxygen depletions caused by decomposition of algae and aquatic plants. They also document that a reduction in nutrients will eventually lead to the reversal of eutrophication and attainment designated beneficial uses. Rates of recovery vary among lakes/reservoirs. This supports the Division of Water Quality’s (DWQ) viewpoint that decreased nutrient loads at the watershed level will result in improved oxygen levels, the concern is that this process takes a significant amount of time (5-15 years).

In Lake Erie, heavy loadings of phosphorous have impacted the lake severely. Monitoring and research from the 1960's has shown that depressed hypolimnetic DO levels were responsible for large fish kills and large mats of decaying algae. Binational programs to reduce nutrients into the lake have resulted in a downward trend of the oxygen depletion rate since monitoring began in the 1970's. The trend of oxygen depletion has lagged behind that of P reduction, but this was expected
(See http://www.epa.gov/glnpo/lakeeerie/dostory).

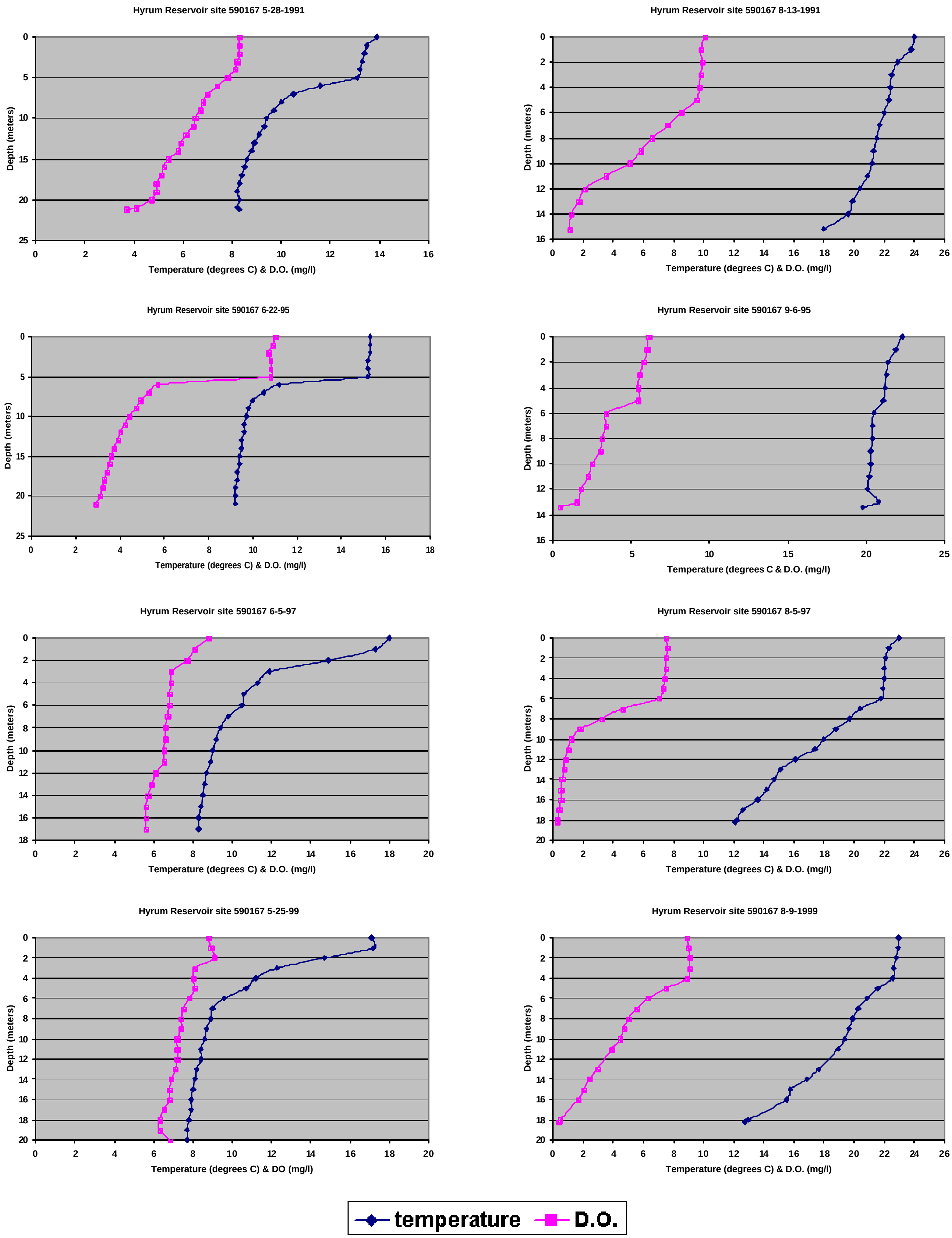
Nurnberg (1995, 1995a, 1996, 1997), developed a model that quantified duration (days) and extent of lake oxygen depletion, referred to as an anoxic factor (AF). This model showed that AF is positively correlated with average annual total phosphorous (TP) concentrations. The AF may also be used to quantify response to watershed restoration measures, which makes it very useful for TMDL development. Nurnberg (1996), developed several regression models that show nutrients (P and N) control all trophic state indicators related to oxygen and phytoplankton in lakes/reservoirs. These models were developed from water quality characteristics using a suite of North American lakes. The DWQ has calculated morphometric parameters such as surface area (A_o), mean depth (z), and the ratio of mean depth to surface area ($z/A_o^{0.5}$) for the concerned lakes and reservoirs in Utah (see Table 1). The results show that these parameters are within the range of lakes used by Nurnberg. Because of this we feel confident that Nurnberg's empirical nutrient-oxygen relationship holds true for Utah lakes and reservoirs. We are also convinced that prescribed BMP's will reduce external loading of nutrients to the lakes/reservoirs, which will reduce algae blooms and therefore increase oxygen levels over time. In addition Nurnberg rejects absolute DO_{min} as a trophic state metric (e.g., see page 442, Nurnberg (1996) in particular for an observation that there are many oligotrophic lakes with zero DO). Nurnberg presents other variables and metrics that would predict trophic status, which we are relying on, besides DO, itself. It is the compilation of all these indicators that will allow for complete evaluation of the lake health and achievement of water quality standards. Included with this document are other papers by Nurnberg to support our rationale.

Utah's approach to treat the sources of nutrients and reduce/eliminate nutrient loads to impaired waterbodies is consistent with accepted watershed strategies to treat sources rather than symptoms (low dissolved oxygen). However, if after treatment of sources and a sufficient period for recovery, (10+ years) dissolved oxygen concentrations are not improving, then in-lake treatments may be investigated and implemented. However, in-lake treatments should not be implemented without control of nutrient sources within the watershed. This view is also supported by Carpenter et al. (1998).

Table 7 - Morphometry data for Utah lakes and reservoirs.

Lake	Nurnberg Range	Mantua	Scofield	East Canyon	Minersville	Kents Lake	Lebaron	Puffer
z (m)	1.8-200	4.27	7.9	23	8.1	6.2	3.23	4.5
A_o	5-8.2 10^6	224	1139	277	400	19.4	9.47	26.3
z/A_o	0.14-48.1	2.85	2.34	13.81	4.05	8.77	10.49	8.77

Figure 3 - Temperature & dissolved oxygen profiles 1991 - 2001



Margin of Safety

As indicated from the plots contained in figure 3 dissolved oxygen exceedences are near the endpoint value in recent years. There has been a general improvement in dissolved oxygen concentrations in the reservoir and we expect that trend to continue. Consistency in meeting the TMDL endpoint should be achieved as further load reductions are achieved.

At the time of the 98-99 surveys approximately half of the Little Bear River BMPs had been implemented. In addition some of the TMDL endpoints have been attained. For example the current inflow concentration has continued to decrease (0.04 mg/l) below the concentration for the 1999 loading calculations and the inflow target endpoint of 0.05 mg/l. The algal dominance is at green. The reasonable assurance for this TMDL includes a margin of safety provided by attainment of the Little Bear River TMDL endpoints from the implementation of the animal waste facilities and the streambank restoration practices, coupled with the implementation of practices associated with cropland, pasture and range areas. In addition the reservoir and inflow will continue to be monitored to assure compliance with endpoints or reevaluation of the TMDL based upon data obtained.

Allocation of Load Reductions or Management Practices

The point sources contribute substantially to nutrient loading. Each nonpoint source area was evaluated separately and sources of nutrients and sediments were identified. Manure management is a critical issue. Runoff from fields spread with manure during the winter and direct runoff from feedlots are also serious problems.

The potential for reducing pollutant loading by various remediation activities was evaluated and the Technical Advisory Committee made specific recommendations. It was predicted that with a medium to high level of remediation effort in the targeted areas, TP loads can be reduced substantially, and the TMDL can be met in Hyrum Reservoir.

Table 8 synthesizes various practices shown in table 9 and their effectiveness at pollution reduction (both tables 8 & 9 were taken from the Lower Bear River Water Quality Management Plan). These levels of effort are then used in table 10 to determine pollution reduction potential.

Table 8 - Percent reductions in predicting phosphorus loads in this report.

	LEVEL OF EFFORT		
SOURCE	**LOW**	**MEDIUM**	**HIGH**
Nonpoint	40	50	90
Point	50	**	90
Feedlots	50	75	90

Table 9 – Literature review of remediation and effectiveness

Potential Sources of Pollution	Remediation	Percent Reduction	Cost	Impact
Feedlots (manure management)	**Structural**			Reduce runoff of nutrients, fecal coliform and total suspended solids from animal waste into adjacent waterways
	Holding Ponds	50-70%	$25,000	
	Lagoons	75-100%	$25,000-$85,000	
	Bunkers	*	$10,000-$50,000	
	Tanks	*		
	Composting			
	Operational			
	Total animal waste management			
	Hook into MWWTF	*		
Agriculture	**Structural**			These practices reduce soil erosion and therefore, decrease the transport of sediments and associated nutrients (soluble and insoluble) into adjacent waterways.
	Sprinkler Systems			
	Operational			
	conservation tillage	full strip 40-90% *(1)*		
		wide strip 40-60% *(1)*		
		narrow strip 50-95% *(1)*		
	Contour farming	50% max *(1)*		
	Strip Cropping	75% max *(1)*		
	Cover Crops	40-60% *(1)*		
	Terrace	95-98% *(1)*		
	Grade Stabilization	75-90% *(1)*		
	Water Sediment Control	40-60% *(1)*		
	Filter strips	35-40% (general) *(2)*	0.18-1.92/m^2 *(2)*	
	(10-25 m width)	70% (nutrients) *(1)*		
	Nutrient Management			
	Livestock Management			Reduce streambank erosion, reduce the transport of animal waste and associated pollutants (nutrients, fecal coliform and total suspended solids) into adjacent waterways.
	Exclusion	*		
	Rest-rotation	*		
	Mgmt + reveg	groundcover>30% *(1)*		
	Mgmt w/o reveg	groundcover >10% *(1)*		
	Fencing	*	$2.00-$2.50/ft	
	Constructed wetlands	?	$5,000 and up	
Streambank	**Non-structural**			These practices stabilize streambanks and reduce soil and streambank erosion.
	Revegetation			
	Trees	15-50%	$1-$2/ft for willows *(1)*	
	Brush	50-60%	0.18-1.92/m^2 *(2)*	
	Grass	up to 90% *(2)*	$55 and up/acre *(1)*	
	Snag removal and clearing	*	$1/ft *(1)*	
	Structural			
	Flow regulation			
	Drop structures	*	Up to $5,000 based on size, length, etc.	
	Rock Pools	*	Up to $20-placed rock	
	Wire structures		$500/ea.	
	Revetments			
	Conifer	** *(1)*	$12/ft	
	Rock	** *(1)*	$200-400/ft	
	Deflectors			
	Single	75% *(1)*	$500/ea.	
	Irrigation management (offsite watering, pipelines)	25-75% *(1)*	$400/trough + $?/pump + $2/ft for pipe *(1)*	
Open Channel	**Meander reconstruction**	** *(1)*	$50/ft *(2)*	Reduce streambank erosion

Table 9 (continued) – Literature review of remediation and effectiveness					
			Cost per MGD Construction (4)	**Maintenance (4)**	
Wastewater	Hook into MWWTF	80-90% *(3)*	$980,000-1,200,000	$44,000-64,000	Reduce total Phosphorus
	Land treatment option	80-90% *(3)*	$34,000-44,000	$25,000-47,000	
	Rapid infiltration	30-60% *(3)*			
	Overland flow	>90% *(3)*	$160,000-820,000	$10,000-64,000	
	Activated sludge	94% *(3)*	$18,000-48,000	$40,000-55,000	
	Alum	56-97% *(3)*	$16,000-46,000	$28,000-40,000	
	Ferric chloride				
	Primary treatment	60-75% *(3)*			
	with mineral addition	40-70%			
	without mineral addition				
	Secondary treatment				
	trickling filter	85-95% *(3)*			
	with mineral addition	70-92%			
	without mineral addition				
	Activated sludge	85-95% *(3)*			
	with mineral addition	85-95%			
	without mineral addition				

(1) Utah Little Bear River Hydrologic Unit Plan 1992
(2) Water Quality Investigations - Lower Bear River and Hyrum Reservoir; ERI 1991
(3) Process Design Manual fo Phosphorus Removal; 625/1-76-0019
(4) Barker et al. 1989

Using information from Reckhow in table 10 for feedlots and nonpoint sources, and the monitoring data collected during the intensive monitoring period in 1998-99 for point sources, annual loadings of total phosphorus were determined for the various areas throughout the watershed (table 11).

Table10 - Phosphorus loading coefficients for different landuse. Rates used in loading calculations compiled from Reckhow et al. 1980.

	TOTAL PHOSPHORUS (KG/ACRE/DAY)		
	LOW	**MEDIUM**	**HIGH**
Nonpoint Source:			
Irrigated agriculture	**0.00100**	**0.00243**	**0.00588**
Non-irrigated agriculture	**0.00011**	**0.000832**	**0.00177**
Open/unknown	**0.00011**	**0.000889**	**0.00294**
Urban	**0.00011**	**0.00122**	**0.00299**
Public lands	**0.00011**	**0.00022**	**0.00033**
Feedlots	**0.177**	**0.277**	**0.471**
Cows (kg/cow/day)	**0.0008**	**0.018**	**0.032**

Since the inception of implementation activities in the Hyrum Reservoir watershed (contained in the Little Bear River TMDL) approximately 50% of the identified BMP's have been implemented. These activities have focused primarily on agricultural lands related to controlling animal wastes, runoff from irrigated agriculture lands and riparian restoration on public and private lands. In addition the "Trout of Paradise" fish hatchery, a UPDES permitted facility, has changed from an active fish production facility to a recreational fishery with some production to maintain the fishery. The original potential reduction of total phosphorus in the watershed of 23.72 Kg/day was based on landsat imagery for land use and Reckhow's coefficients for estimate of nonpoint sources for landuses.

Table 11 - Total phosphorus loads for sources in the Little Bear River drainage.			
	Current	**1998-99**	
Point Sources	**Average Kg/day**	**Average Kg/day**	**Average Kg/year**
Trout of Paradise 001	**2.5**	**2.5**	**766.2**
Trout of Paradise 002	**0.33**	**0.33**	**115.5**
Nonpoint Source *			
Irrigated agriculture	**3.92**	**7.83**	**2859**
Non-irrigated agriculture	**.88**	**1.76**	**644**
Open/unknown	**1.24**	**2.48**	**904**
Urban	**.23**	**0.46**	**167**
Public Lands	**2.06**	**4.11**	**1501**
Feedlots	**2.13**	**4.25**	**1550**
Total estimated load (PS and NPS) using Reckhow's coefficients for NPS.	**13.29**	**23.72**	
Total estimated NPS load from Reckhow		**20.89**	
Current estimated NPS load with a projected 50% reductions of Reckhow's NPS estimate	**10.46**		
Total 1999 Load above Hyrum		**8.4**	
TMDL Target Load above Hyrum		**6.3**	

** Based on acreage times coefficients from table 10.*

A review of the information in table 11 provides the reasonable assurances that the TMDL endpoints will be achieved and beneficial uses as defined for Hyrum Reservoir protected. Based on the projection that 50% of the identified BMP's have been implemented a general assumption can be made that there is a 50% reduction in Reckhow's estimated NPS loading (from 20.89 to 10.46). This remaining NPS load (10.46 Kg/day) plus the current loading from 'Trout of Paradise' (2.83 Kg/day based on 1998-99 dataset) provides an estimate of 13.29 Kg/day available total phosphorus that could be controlled. The focus of this analysis will be on further reductions from the identified nonpoint sources. Table 12 represents load reductions that can be expected based on the level of effort to control nonpoint sources. Note the current loading for 'Trout of Paradise' remains unchanged in this analysis. With a low level effort a further reduction of 4.4 Kg/day can be achieved. A medium effort would yield a 5.0 Kg/day reduction. Based on the current loading (1998-99) of 8.4 Kg/day it is evident that even the low level effort will result in achievement of the TMDL loading endpoint of 6.3 Kg/day. As indicated earlier in this report using recent data (2000-01), which is limited, it has been estimated that the current load is 5.5 Kg/day. It is only reasonable considering all available data that ongoing implementation activities directed towards controlling nonpoint sources will achieve the goals of the TMDL and in addition provide a significant reduction below the TMDL target of 6.3 Kg/day.

Table 12 – Potential phosphorus loads in the Little Bear River given different levels of remediation intensity. Reductions are applied to average loads in Table 11.						
	Potential Total Phosphorus Loads (Kg/day)					
	Level of Remediation effort					
	LOW		MEDIUM		HIGH	
	Existing Load	(%) and load reduction kg/day	Existing Load	(%) and load reduction kg/day	Existing Load	(%) and load reduction kg/day
Point Source:						
Trout of Paradise 001	**2.5**	**0**	**2.5**	**0**	**2.5**	**0**
Trout of Paradise 002	**0.33**	**0**	**0.33**	**0**	**0.33**	**0**
Nonpoint Source:						
Irrigated agriculture	**3.92**	**(40) 1.57**	**3.92**	**(50) 1.96**	**3.92**	**(90) 3.53**
Non-irrigated agriculture	**0.88**	**(40) 0.35**	**0.88**	**(50) 0.44**	**0.88**	**(90) 0.79**
Open/unknown	**1.24**	**(40) 0.5**	**1.24**	**(50) 0.62**	**1.24**	**(90) 1.12**
Urban	**0.23**	**(40) 0.09**	**0.23**	**(50) 0.12**	**0.23**	**(90) 0.21**
Public lands	**2.06**	**(40) 0.82**	**2.06**	**(50) 1.03**	**2.06**	**(90) 1.85**
Feedlots	**2.13**	**(50) 1.07**	**2.13**	**(75) 1.60**	**2.13**	**(90) 1.92**
Total estimated load reduction		**4.4**		**5.77**		**9.42**
Total current load	**13.29**	**--**	**13.29**	**--**	**13.29**	**--**
Projected load using Reckhow's NPS coefficients.	**--**	**8.89**	**--**	**7.52**	**--**	**3.87**
TMDL Target Load Hyrum Reservoir = 6.3 Kg/day, a medium to high effort required to meet TMDL.						

Public Participation

Hyrum Reservoir is part of the Little Bear River Watershed. USDA designated the Little Bear River as a Hydrologic Unit Area in 1990. Since then a Steering Committee and a Technical Advisory Committee were formed. Little Bear River Committees assist landowners and area decision makers to address water quality concerns throughout the watershed. Through a cooperative effort a broad array of partners provide guidance and input into project priorities and activities.

The main audience is the LBR agriculture landowners. Efforts have also been made to educate local community groups and the youth. Public awareness and support to improve water quality in Hyrum Reservoir is a major area of emphasis.

This document was posted on the Utah Division of Water Quality web site and available to the public for download. Two newspaper articles announced the public comment period that extended for 30 days. A public meeting was also held to solicit public input and comments.

Little Bear River HUA Partners

U.S. Department of Agriculture
NRCS, CSREES, FSA
U.S. Department of Interior
USFWS, USACE
Utah Department of Environmental Quality
Division of Water Quality
Utah Department of Natural Resources
Wildlife Resources, DFFSL,
Water Rights, Water Resources

Bear River RC&D
South Cache Freshman Center
U.S. Environmental Protection Agency
Boy Scouts of America
Audubon Society
South Cache Middle School
Utah State University
Utah Association of Conservation Districts
Cache Society of Fisheries/Cache Valley Anglers

References

Hyrum Reservoir Clean Lakes Phase I Report, 1994
Lower Bear River Water Quality Management Plan, 1995
Little Bear River TMDL, 2000

Appendix 1

Algal taxa present in a total plankton sample collected from Hyrum Reservoir (site 590167) September 6, 1995. The percent relative density, species rank in the sample, number of cells per liter, and the volume of cells (in cubic micrometers/liter) are also provided. Descriptive statistics are also provided at the end of the list of taxa.

Taxon	Relative Density	Rank	Number Per Liter	Cell Volume (μ^3 / liter)
ANKISTRODESMUS FALCATUS	0.00	12	11120	22240
ASTERIONELLA FORMOSA	0.05	5	38920	66164000
CENTRIC DIATOMS	0.03	6	77840	46704000
CHLAMYDOMONAS SPECIES	0.00	11	5560	2224000
COSMARIUM SPECIES	0.11	4	11120	155680000
DINOBRYON DIVERGENS	0.01	8	5560	12232000
FRAGILARIA CROTONENSIS	6.29	2	216840	8933808000
OOCYSTIS SPECIES	0.46	3	439240	658860000
OOCYSTIS SPECIES 2	0.01	9	5560	8340000
PENNATE DIATOMS	0.02	7	38920	27244000
SPHAEROCYSTIS SCHROETERI	93.01	1	278000	132050000000
UNKNOWN SPHERICAL CHLOROPHYTA	0.00	10	11120	6672000

Shannon-Weaver Index [H'] = 0.28
Species Evenness = 0.11
Species Richness [d] = 0.43
Number of species = 12

$$H' = -\sum_{i=1}^{S} P_i \text{ LOG } P_i$$

Where: P_i = porportion of the total number of individuals in the i^{th} species; S = the number of species.

Species Evenness = H' / log S
Where: S = the number of species; H' = Shannon-Weaver Index.

Species Richness = S-1 / log N
Where: S = the number of species; N = the number of individuals.

Appendix 2

Algal taxa present in a total plankton sample collected from Hyrum Reservoir, 590167, August 5, 1997. The percent relative density, species rank in the sample, number of cells per milliliter, and the volume of cells (in cubic micrometers/milliliter) are also provided. Descriptive statistics are also provided at the end of the list of taxa.

Taxon	Relative Density	Rank	Number Per Milliliter	Cell Volume (μ^3/ml)
ANKISTRODESMUS FALCATUS	0.1	8	11.1	8729
CENTRIC DIATOMS	0.1	9	11.1	7784
CERATIUM HIRUNDINELLA	91.1	1	77.8	13232800
DINOBRYON DIVERGENS	0.3	5	16.7	36696
FRAGILARIA CROTONENSIS	3.2	3	11.1	458144
OOCYSTIS GIGAS	0.2	6	5.6	33360
PENNATE DIATOMS	0.0	10	5.6	4448
PHACOTUS SPECIES	0.8	4	11.1	111200
SPHAEROCYSTIS SCHROETERI	4.2	2	5.6	611600
UNKNOWN SPHERICAL CHRYSOPHYTA	0.1	7	38.9	15568

Shannon-Weaver Index [H']	= 1.86
Species Evenness	= 0.19
Species Richness	= 2.53
Number of Species	= 10

$H' = -\sum_{i=1}^{s} P_i \log P_i$

Where: P_i = proportion of the total number of individuals in the i^{th} species; S = the number of species

Species Evenness = H' / log S
Where: S = the number of species; H' = Shannon-Weaver Index

Species Richness = S-1 / log N
Where: S = the number of species; N= the number of individuals