Utah Department of Environmental Quality
Division of Water Quality
TMDL Section

Mantua Reservoir TMDL

Waterbody ID	**Mantua Reservoir and Tributaries**
Location	**Box Elder County, Northern Utah**
Pollutants of Concern	**Total Phosphorus** **Dissolved Oxygen** **pH**
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 **Current Load** **TMDL Target Load** **Load Reduction**	 **974.8 kg/yr** **629.3 kg/yr** **345.5 kg/yr**
Defined Targets/Endpoints	**25 ug/l in-lake total phosphorus** **Meet water quality standards for dissolved oxygen, and pH.**
Implementation Strategy	**Removal of point source (pump station)** **Agricultural BMP's** **Aquaculture BMP's**
This document is identified as a TMDL for Mantua Reservoir and is officially submitted to the U.S. EPA to act upon and approve as a TMDL	

INTRODUCTION

Under the Clean Water Act, every state must establish and maintain water quality standards designed to protect, restore, and preserve the quality of waters in the state. These standards consist of: narrative criteria that include designated uses; specific chemical and biological criteria necessary for protection of the designated uses; and antidegradation provisions. When a lake, river or stream fails to meet water quality standards, section 303(d) of the CWA requires that the state place the waterbody on a list of "impaired" waters and prepare an analysis called a Total Maximum Daily Load (TMDL).

Mantua Reservoir was listed on the 1998 Utah 303(d) list for exceedences of the pH, dissolved oxygen (DO) and total phosphorus (TP) criteria associated with the reservoir's 3A, or cold water fishery beneficial use classification.

In accordance with section 303(d) of the Clean Water Act, the Utah Department of Environmental Quality submits for EPA Region VIII review and approval, the phosphorus, pH and dissolved oxygen Total Maximum Daily Loads (TMDLs) for Mantua Reservoir as provided for in this summary and attached documents. These TMDLs have been established at levels necessary to meet applicable water quality standards for phosphorus, pH and dissolved oxygen with consideration of seasonal variation and a margin of safety. Implementation of this TMDL will protect the designated beneficial use classifications of the reservoir.

Background

Mantua Reservoir is a small reservoir located located within the community of Mantua in east Box Elder County, Utah (Figure 1.). The surface area of the reservoir is 224 ha (554 acres), with a length of approximately 1,910 meters and a width of 1,643 meters. The average depth is 4.3 meters.

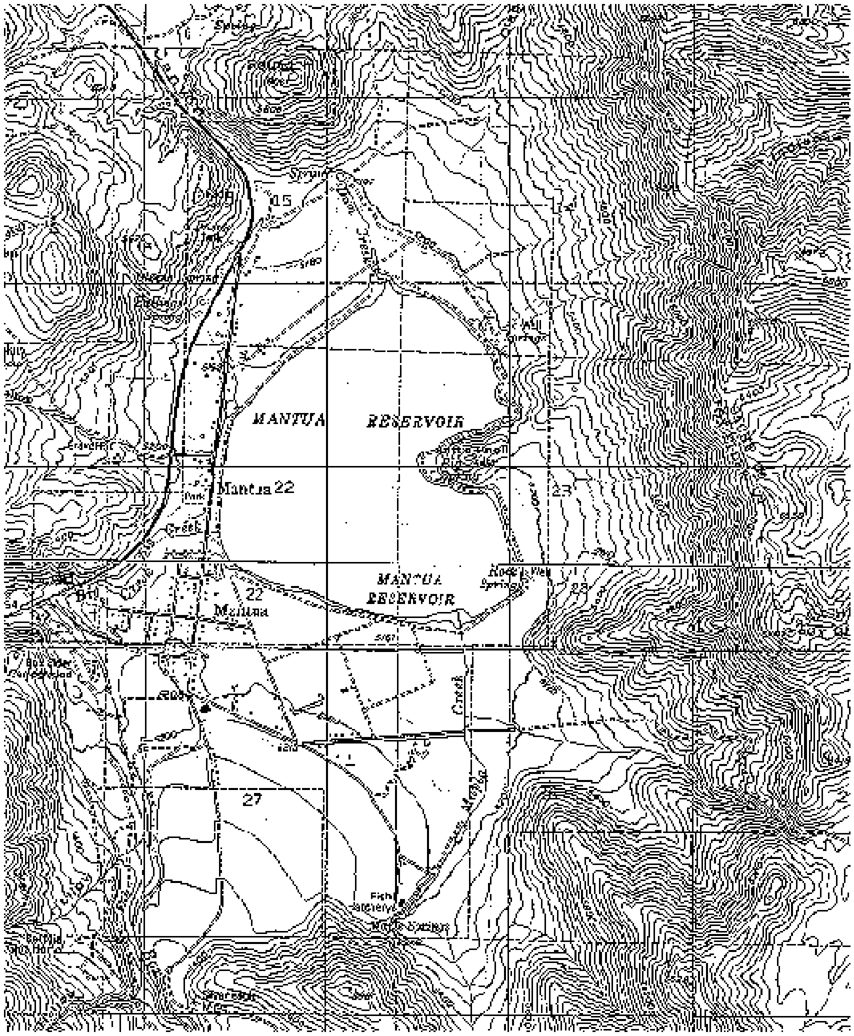
Brigham City is located about 5 miles west of Mantua and has rights to much of the water which originates near Mantua. The reservoir was created in 1962 by the construction of a dam across Big Creek.

Mantua Reservoir's watershed area is relatively small. The majority of the reservoir's inflow originate as springs. These springs are then used for irrigation, fish production and livestock watering. Two major springs surface away from the reservoir and form the headwaters of Maple Creek and Dam Creek. Other springs surface near the reservoir or they enter the bottom of the reservoir directly. The two major inflows to the reservoir are Dam Creek and Maple Creek. The outlet of the reservoir forms Big Creek. Big Creek is captured at the reservoir outlet and is piped to Brigham City where it is used for electrical power generation and for irrigation.

Mantua Reservoir is highly productive (i.e., has a large amount of nutrients such as nitrogen and phosphorus), creating problems that include dense beds of aquatic plants, algal blooms, low dissolved oxygen (DO), and high pH. The high productivity is primarily due to the lake's shallowness and excess loading of nutrients from the watershed.

In 1998, a Clean Lakes Phase I - Diagnostic/Feasibility study was completed for Mantua Reservoir (Loveless, 1998). The study included water quality and limnological testing of Mantua Reservoir and its watershed and recommended possible management practices for improving water quality. The Clean Lakes Study verified that Mantua Reservoir is eutrophic and phosphorus is the nutrient limiting algae and aquatic plant growth. The Clean Lakes Report (attached) and additional analysis by the Utah Division of Water Quality (DWQ) forms the basis for preparation of this TMDL.

Figure 1. Mantua Reservoir



WATER QUALITY STANDARDS

Utah's water quality standards are promulgated pursuant to the Utah Water Quality Act, Chapter 19-5 Utah Code Annotated (UCA). Authority to adopt rules and standards to protect water quality is vested with the Utah Water Quality Board. Utah's Water Quality Standards are found in R317-2, Utah Administrative Code (UAC).

Beneficial Uses

Mantua Reservoir holds the following beneficial use classifications (R317-2-13.12 UAC).

Class 2B - protected for secondary contact recreation such as boating, wading or similar 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.

Class 4 - protected for agricultural uses including irrigation of crops and stock watering.

Mantua Reservoir was listed on the 1998 Utah 303(d) list for exceedences of the pH, DO and TP criteria associated with the reservoir's 3A, or cold water fishery, beneficial use classification.

Applicable Criteria

Utah applies the following numeric criteria to the 3A beneficial use classes (R317-2-14 UAC) for the listed parameters.

Table 1. Applicable State Water Standards for pH, TP and DO for the 3A Classification.

Parameter	Standard
pH	6.5-9.0 (range)
Minimum Dissolved Oxygen (mg/l)[1]	
30 day average	6.5
7 day average	9.5/5.0
1 day average	8.0/4.0
Total Phosphorus (indicator)[2]	0.05 (mg/l) rivers and streams 0.025 (mg/l) for lakes and reservoirs.

[1] These limits are not applicable to lower water levels in deep impoundments. The first number in the column is for when early life stages are present; the second number is for when all other life stages present.

[2] Investigations should be conducted to develop more information where these levels are exceeded.

WATER QUALITY TARGETS/ENDPOINTS

The TMDL endpoints for Mantua Reservoir are: 1) to meet the applicable water quality standards (Table 1) for dissolved oxygen in the upper 50% of the reservoir's water column; 2) to meet the pH standard of 6.5-9.0 for at least 90% of in-lake measurements; and 3) to lower in-lake total phosphorus concentrations to 25 ug/l, expressed as an annual average of surface values.

The TMDL for Mantua Reservoir is expressed in terms of total phosphorous loading. Total phosphorous is the parameter which influences the trophic status of many Utah lakes. Phosphorus is a key water quality parameter, influencing algal and macrophyte production, and consequently, dissolved oxygen concentrations and lake pH.

DO and pH are altered by photosynthesis and respiration. During photosynthesis, as carbon dioxide (CO_2) concentrations decline, DO concentrations increase and the water becomes more alkaline (pH>7). At times when respiration exceeds photosynthesis, DO concentrations decline, CO_2 increases and pH declines (Cole, 1979).

Data collected for the Clean Lakes Study showed pH values ranging from 7.6 to 9.8 with a mean value of 8.6. Inflow pH values averaged 8.0. The highest pH was found near the surface due to photosythetic production of oxygen and consumption of carbon dioxide. The lowest pH was observed near the bottom, where low DO and high carbon dioxide levels are caused by microbial respiration.

A detailed phytoplankton assessment was conducted in conjunction with the Clean Lakes Study. Rushforth (1995) found that the flora of the reservoir was indicative of a eutrophic system. Rushforth noted that fully 58% of the phytoplankton was comprised of cyanobacteria (blue-green algae). He identified the blue-green algae *A. Flos-aquae, Anabaena circinalis* and *Microcystis aeruginosa* as the three most important species during the summer of 1994.

Reducing inflow concentrations of phosphorus will result in a lower ambient total phosphorus concentration in Mantua Reservoir. Lower phosphorus concentrations will result in a smaller standing crop of blue-green algae at any given time and will result in algal blooms of a lower intensity and shorter duration over time. This will improve both the average dissolved oxygen concentrations and pH levels in the reservoir and will therefore be beneficial to aquatic life.

Lee and Jones (1988) indicated that, independent of the trophic state of the waterbody, the algal -available P load to a waterbody must be changed by at least a 20% in order to perceive a change in water quality. They suggest that at least a 25 to 30% reduction in order to see a readily discernible change. The proposed TMDL load represents a 35.5% reduction in TP.

SIGNIFICANT SOURCES

Table 2 identifies TP loads in kg/day and kg/yr from each individual source of contribution to the Reservoir. Figure 2 gives a graphical representation of the percent load attributed to each major category.

Point Sources

The Mantua Fish Hatchery is the only permitted point source in the watershed. The hatchery is located at the point where Maple Springs originates. The water source is then used for fish production. The hatchery is owned and managed by the Utah Division of Wildlife Resources.

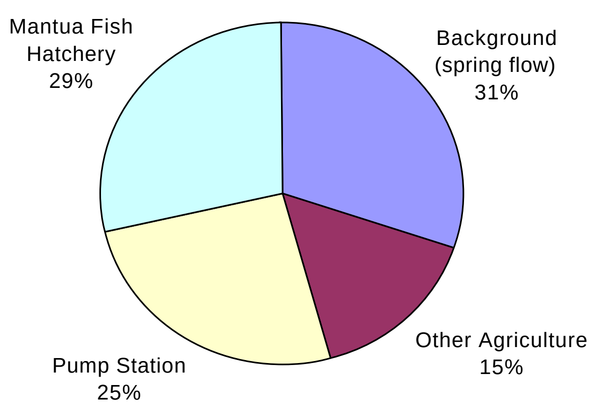
The Mantua Fish Hatchery is a significant contributor of nutrients to the Reservoir, adding an estimated 304.4 kg/y TP (31% of total load). Effluent from the hatchery is required to comply with the Utah Pollution Discharge Elimination System (UPDES) permit, administered by the Utah Division of Water Quality. Under the Hatchery's general permit, total suspended solids (TSS) concentrations are required to be maintained below 25 mg/l. As discussed previously, nitrogen and phosphorus are listed as pollution indicators in the state Water Quality Standards. As a result, the current UPDES permit does not include permit limits for these parameters.

An additional point source was located on the northeast end of the reservoir. A pump was installed by Brigham City to pump agricultural runoff water, which typically ponded on the inland side of the lake dike, into the lake. The TP Load associated with the Pump Station is 267.9 kg/yr (27.5% of total load)

Table 2. Summary of Total Phosphorous Loads to Mantua Reservoir

Description	TP Load lbs/day	TP Load kg/y	Source Category	% Load Contb.
Maple Spring	0.47	**77.43**	Background	7.94
Mantua Fish Hatchery	1.84	**304.38**	Hatchery	31.23
Spring Flow to Hatchery	0.44	**73.20**	Background	7.51
West flow from Maple Springs	0.06	**9.75**	Background	1.00
Outflow loss	-0.47	**-78.40**	Loss	-8.04
Box Elder Creek Diversion	0.83	**137.91**	Agriculture	14.15
Total Box Elder Creek		524.27		
Additional spring flow to reservoir	0.62	**102.61**	Background	10.53
Pump Station	1.62	**267.89**	pump	27.48
Bunderson Spring	0.12	**19.64**	Background	2.01
Bunderson Spring	0.12	**19.64**	Agriculture	2.01
Dam Creek	0.21	**35.14**	Background	3.61
Dam Creek	0.03	**5.56**	Agriculture	0.57
	5.89	**974.74**		100.00

Figure 2. Percent Contribution of Total Phosphorus Loading by Category



Nonpoint Sources

The majority of inflow water to the reservoir is from springs. Springs contribute the largest single input of TP to the reservoir, approximately 31% of the TP load. Springs in the area represent a background or natural source of pollutants.

Box Elder Creek diversion contributes an estimated 137.9 kg/yr (14.2 % of total load) to the reservoir. The diversion is also the largest contributor of sediment.

Additional agricultural activities along dam creek and the eastern side of the reservoir contribute approximately 25.2 kg/yr TP.

TECHNICAL ANALYSIS

Data Sources

As part of the Clean Lakes Study, water quality and limnological water samples were collected from 11 watershed monitoring stations and 3 in-lake sites during 1994 and 1995. Samples were taken every two weeks during spring and summer (April through August), and monthly from September through March. Watershed monitoring sites were strategically placed to maximize the benefit of the sampling program.

Water quality samples were obtained by qualified staff of Mountainlands Association of Governments. Sample collection, preservation and analysis was conducted in accordance with the Division of Water Quality's Quality Control/Quality Assurance (QA/QC) Program. Chemical Analysis was conducted by the EPA-certified State Health Laboratory in accordance with their approved QA/QC plan.

A detailed phytoplankton assessment (Rushforth, 1995) and macrophyte study (Allen, 1995) were also conducted in conjunction with the Clean Lakes Study.

Additional lake water quality data collected by the Division of Water Quality in 1980, 1990, 1991, 1998 and 1999 were also used in this analysis.

Watershed phosphorus loads presented in the Clean Lakes Report were based on annual means and did not differentiate sources to the level required for a TMDL analysis. Phosphorous loads used for this TMDL analysis were recalculated to identify discrete sources and were calculated on a flow weighted basis from the Clean Lakes Study data set for each of the sampling stations. As a result, loads presented in this analysis differ slightly from those presented in the Clean Lakes Study.

Loveless (1998) indicated that flows and nutrient concentrations were highly variable during the Clean Lakes study period. Difficulties were encountered due to the fact that during the study period, construction occurred at the outlet to put Big Creek into a pipe to better allow use of the water at the downstream electric generation plant in Brigham City. Flows were higher than average during some periods and very low at others to accommodate construction. When the construction was completed, outlet samples were taken several mile downstream below the hydro-electric plant. As a result outflow flows and concentrations obtained during the Clean Lakes Study contain a high degree of uncertainty.

Reduction Response Models

Lake phosphorus response was estimated by the use of a steady-state phosphorus mass balance model (Figure 3) described by Vollenweider (1976), Reckhow (1979), EPA (1983).

Figure 3. Phosphorous Response Model

$$P = \frac{W'}{\bar{z}\rho + v_s}$$

P = inlake TP concentration (mg / l)

W' = areal loading rate (g / m^2 - yr)

$\bar{z}$ = mean lake depth (m)

$Q / V = \rho$ where: Q = lake outflow (m^3 / yr)

V = lake volume (m^3)

$k_s = \rho^{0.5}$

$v_s = k_s \bar{z}$ where v_s is net settling velocity (m / yr)

TMDL

This model was used to estimate the inflow TP load reduction required to meet the TMDL endpoint of 0.025 mg/l mean annual in-lake TP. The model estimated that a loading reduction of **345.5 kg/year** or **0.95 kg/day** is required to achieve this goal. This corresponds to a allowable TMDL of **629.3 kg/yr or 1.72 kg/day**.

The Carlson Trophic State Index (TSI) (Carlson, 1977) was developed to estimate the algal production in lakes and to determine trophic state based on chlorophyl pigments, secchi depth, and total phosphorus. The TSI is a logarithmic scale that ranges from approximately 0 to 100. The three index values, chlorophyll pigments (CLA), Secchi depth (SD) and total phosphorus (TP), use regression equations to estimate the index value and algal production. The three index values are interrelated and should produce similar index values for a given combination of input values. The regression equations used to calculate these values are shown in Figure 4.

Figure 4. Carlson's TSI Relationships

TSI (SD)=60 -14.41 ln(SD)

TSI (CLA)=9.81 ln(CHL)+30.6

TSI(TP)=14.42 ln(TP)+4.15

A *chlorophyll-a* and secchi depth response model (Carlson, 1977) was used to predict the expected trophic condition of the reservoir with a TP concentration of 0.025 mg/l. Carlson's model used the equations shown in Figure 5 (EPA, 1988).

Figure 5. Prediction Equations for *Chlorophyll-a* and Secchi Depth

Chlorophyll-a (ug/l) = $0.068\ P^{1.46}$

Secchi Depth (m) = 7.7 *chlorophyll-a* $^{-0.68}$

Table 3 shows TSI values for Mantua Reservoir from data collected during the Clean Lakes study and predicted values for the TMDL endpoint of 0.025 mg/l TP, using the above relationships. The reduction in TP loading moves the TSI values from the mid to high eutrophic range to the low eutrophic/high mesotrophic range.

Table 3. Observed and Predicted TSI Values for Mantua Reservoir

	Observed TSI during Clean Lakes Study	Predicted TSI values with TP = 0.025 mg/l
Total Phosphorous TSI	63.4	50.6
Chlorophyll-a TSI	62.1	50.3
Secchi Depth TSI	51.8	50.3
Average TSI	59.1	50.4

Seasonal Variation

The evaluation of nutrient impacts in the reservoir was considered for the average annual conditions representing the response to long-term, cumulative nutrient loading. The TMDL and load allocation are presented as annual average loading consistent with the type of impairment (eutrophication) and the waterbody type (reservoir). Reduction of the average annual load of TP is expected to result in achievement of water quality standards.

Margin of Safety

Conservative estimates of percent reduction were used for calculating load reductions. Additionally, lake water quality data collected in 1998 and 1999 (9 samples) indicates the an average in-lake TP concentration of .022 mg/l, compared to the TMDL goal of 0.025 mg/l. The mean *chlorophyll-a* concentration was 2.53 ug/l and Secchi depth averaged 3.66 m. These values translate into average TSI values of 48.7 (TP), 39.7 (CHL) and 41.3 (SD), firmly in the mesotrophic range. Although these results are based on limited data, it is reasonable to assume that this response was realized by removal of loads associated with the pump station (267.9 kg/yr), a 27.5% decrease in TP load to the reservoir. Additional load reductions have also been achieved by changes in management practices at the fish hatchery, such as changing from a low-efficiency sinking feed to a high-efficiency floating feed. Mantua Reservoir will continue to be monitored on a biannual basis in order to track changes in trophic state.

ALLOCATION OF LOAD REDUCTIONS OR MANAGEMENT PRACTICES

Sources of TP load were allocated (Table 4) based on conservative, best professional judgement that the individual reductions could be met.

Table 4. Total Phosphorous Load Allocations

Source	Current TP Load (kg/yr)	TMDL Load (kg/yr)	TP Load Reduction (kg/yr)	Percent Load Reduction of Source	% of Total Load Reduction (%)
Pump Station	267.9	0	267.9	100	77.3
Box Elder Diversion	137.91	110.33	27.58	20	8.0
Bunderson & Dam Creek	25.17	20.13	5.04	20	1.5
Mantua Fish Hatchery	304.38	258.72	45.66	15	13.2
			346.18		

The 1998 Clean Lakes Study recommended the following activities for restoration of Mantua Reservoir:

- elimination of pumping station
- implement low phosphorus/high efficiency fish food at Mantua Fish hatchery
- annual maintenance of sediment basin at Mantua Fish Hatchery
- explore the constructed wetland alternative for the Mantua Fish Hatchery
- Introduction of Grass Carp to the Reservoir
- implement the agricultural nonpoint source plan
- adopt zoning ordinances to limit development on the east side of Manuta Reservoir
- provide public education

Pump Station

The pump Station located on the west side of the reservoir contributed 267.9 kg/yr, or 27.5% of the TP load to the reservoir. A reconstruction of US Highway 89 west of Mantua provided for wetland construction to mitigation wetlands lost during construction. As a result, the water being pumped back into the reservoir was piped to the constructed wetlands to provide a permanent source of water for that project.

Mantua Fish Hatchery

Use of floating, high-efficiency, low-phosphorous feeds can reduce the concentration of phosphorous discharged from the hatchery. Since the time of the Clean Lakes report, the Hatchery has converted from traditional low-efficiency sinking feed to high-efficiency floating feed. High-efficiency feeds are formulated so that a reduced proportion of the feed is converted to metabolic waste products (discharged as organic nutrients), and more of the feed is incorporated as body mass in the growing fish.

The hatchery has constructed a sedimentation basin at the lower end of the hatchery. That basin should be cleaned on an annual basis. During the cleaning process, water should be diverted around the basin. Efficient solids removal, both fish feces and uneaten food, will reduce the load of phosphorus which would otherwise be discharged.

There are several acres of land below the hatchery raceways, owned by the Division of Wildlife Resources. Loveless (1998) suggested that a large constructed wetland could be built to provide biological treatment of the effluent before it returns to Maple Creek. The wetland could also serve as a wetland nature park for outdoor education. The development of this wetland may be needed if after the implementation of recommended BMP's beneficial uses are not restored.

Nonpoint Source Control

The existing sediment retention basin located upstream from the Box Elder Creek diversion should be reconstructed and maintained yearly.

Other activities would reduce agricultural nonpoint source loads include removal of animals from the lake shoreline; farming practices on the east side of the reservoir should avoid the application of manure at times of the year when the ground is frozen; and the use of minimum tillage practices should be encouraged as well as maintaining a buffer strip between farm land and live water bodies.

PUBLIC PARTICIPATION

The Bear River Association of Governments (BRAG) coordinated the public participation component of the Clean Lakes Study. A Mantua Reservoir Water Quality Technical Advisory Committee was formed and had their initial meeting on January 18, 1994. The Committee was made up of interested and affected parties representing a diverse set of interests in the reservoir, its watershed and downstream uses. The Technical Advisory Committee met regularly during the project to provide input and review the findings of the study. Members of the committee represented the following groups:

Mantua Town Council
Mantua Citizens
Brigham City
West Field Irrigation Co.
Northern Utah SCD
Box Elder Water Conservancy District
NRCS
Box Elder County Commission
Bear River Association of Governments
Box Elder Creek Water Users
Facer Dairy
Division of Wildlife Resources
Mountainlands Association of Governments
Utah Division of Water Quality
North Field Irrigation Co.
Perry Water Company
Bear River District Health Department

The Draft TMDL was noticed in a paper with statewide distribution, the Salt Lake Tribune, and was available on the Division of Water Quality's Internet Web Site. No comments were received.

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