Ocean Lake TMDL for Sediment

Fremont County, Wyoming

Prepared by

Wyoming Department of Environmental Quality – Water Quality Division

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WYOMING DEPARTMENT OF ENVIRONMENTAL QUALITY

WATER QUALITY DIVISION

OCEAN LAKE TMDL FOR SEDIMENT

TMDL QUICK SUMMARY

Waterbody ID	Ocean Lake, HUC 100800050202
303(d) Waterbody ID	WYBH100800050202_01
Waterbody Classification	Class 2ABww
Location	Fremont County, Wyoming
Pollutant(s) of Concern	Sediment
Impaired Designated Uses	Warm-water fisheries, non-game fisheries and aquatic life other than fish
Type of TMDL	Final
Targets	Annual geometric mean Trophic State Index of 60 (as determined by Secchi depth) Annual geometric mean Secchi depth equal to or greater than 1.00 meter Annual geometric mean total suspended solids (TSS) concentration as related to Secchi depth of 5.1 mg/L
Existing Condition	Annual geometric mean Trophic State Index of 62 (as determined by Secchi depth) Annual geometric mean Secchi depth of 0.86 meter Annual geometric mean total suspended solids concentration as related to Secchi depth of 6.2 mg/L
Existing Load	70,790 tons/yr of sediment
Target Load Capacity (TMDL)	58,230 tons/yr of sediment
Margin of Safety (MOS)	Explicit MOS at 29% (17,087 tons/yr)
Wasteload Allocation (WA)	11 tons/yr of sediment
Load Allocation (LA)	41,132 tons/yr of sediment
Reduction to achieve targets	29,647 tons/yr of sediment
Submittal to EPA	October 7, 2009
EPA Approval	December 3, 2009

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LIST OF ACRONYMS

BMP	Best Management Practices
CPUE	Catch Per Unit Effort
CWA	Clean Water Act
HUC	Hydrologic Unit Code
LA	Load Allocation
LWCD	Lower Wind Conservation District
MOS	Margin of Safety
NRCS	Natural Resource Conservation Service
OLWSC	Ocean Lake Watershed Steering Committee
SOL	Save Ocean Lake Committee
TE	Trap Efficiency
TMDL	Total Maximum Daily Load
TSI	Carlson Trophic State Index
TSI-Chla	Carlson Trophic State Index for Chlorophyll α
TSI-TP	Carlson Trophic State Index for Phosphorus
TSI-SD	Carlson Trophic State Index for Secchi Transparency
TSS	Total Suspended Solids
USACE	United States Army Corp of Engineers
USBOR	United States Bureau of Reclamation
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
WACD	Wyoming Association of Conservation Districts
WDEQ/WQD	Wyoming Department of Environmental Quality/Water Quality Division
WGFD	Wyoming Game and Fish Department
WLA	Wasteload Allocation
WWDC	Wyoming Water Development Commission
WYDOT	Wyoming Department of Transportation
WYPDES	Wyoming Pollutant Discharge Elimination System

EXECUTIVE SUMMARY

The Federal Clean Water Act requires the Wyoming Department of Environmental Quality – Water Quality Division to develop a total maximum daily load (TMDL) for waters that have been identified on the State's §303(d) list as impaired by a pollutant(s). Ocean Lake has been identified as impaired by sediment since 1996. Designated uses affected by the sediment have been identified as warm-water fisheries, non-game fisheries and aquatic life other than fish. The purpose of the TMDL for Ocean Lake is to calculate the allowable sediment load for the lake that will meet water quality standards and provide Ocean Lake with the water quality to support assigned designated uses.

The primary source of sediment that has caused the impaired condition is the re-suspension of lake bottom sediment by wind induced waves. A secondary source of sediment is contributions from the nine irrigation drains that flow into Ocean Lake.

The water quality goal of this TMDL is to reduce the sediment loading to acceptable levels consistent with the inherent characteristics of Ocean Lake. This reduced loading is predicted to resolve the sediment problem and maintain a loading rate and water clarity sufficient to allow Ocean Lake to support warm-water fisheries, non-game fisheries and aquatic life other than fish. The TMDL for sediment was primarily determined by development of an empirical-based model to calculate existing and predicted sediment loads to achieve the established TMDL targets.

According to Wyoming's TMDL Workplan (WDEQ/WQD 2008a), this TMDL will be reassessed at least every five years. Reassessments are an iterative approach that will allow for refinement of the TMDL as a result of new information or if the physical conditions of the watershed have changed significantly over time. In many instances, full restoration can take decades of implementation. TMDL reassessments are also important to determine progress towards attainment of TMDL goals and when designated uses are supported. Furthermore, TMDL reassessments are critical because a TMDL that no longer reflects actual conditions in the watershed will not be an acceptable guide to waterbody restoration. These reassessments are also critical for continued citizen involvement in waterbody restoration.

The average annual allocation of sediment for this TMDL is established at 58,230 tons/yr. The Town of Pavillion wastewater treatment facility is the only point source in the Ocean Lake watershed. Based on the design flow capacity and current limits for total suspended solids (TSS), the allocated load for this facility is 11 tons/yr. The remaining TMDL allocation is partitioned between non-point sources and the margin of safety. Non-point sources were identified as internal lake re-suspension and contributions from the nine irrigation drains that flow into Ocean Lake. For the TMDL, 69% or 40,078 tons/yr of the predicted load capacity was allocated to internal lake re-suspension whereas approximately 2% or 1,054 tons/yr was assigned to irrigation drain contributions. An explicit margin of safety at 29% or 17,098 tons/yr represented the remaining predicted load capacity for the TMDL.

Although the nine irrigation drains are currently a minor contributor to the sediment impairment in Ocean Lake, it has been estimated that approximately 56% of the historical sediment contributions from the irrigation drains have been reduced through implementation of BMPs in the 1980s and 1990s. The reduction in sediment from drains #4, #6 and #7, or those where the vast majority of BMPs were implemented, was 76% from historical sediment contributions. Prior to these proactive efforts, sediment

contributions from these drains were estimated at 5,519 tons/yr. The current estimated sediment contribution to Ocean Lake from the drains is 2,428 tons/yr, reflecting the progress that has been made in reducing sediment contributions to Ocean Lake.

INTRODUCTION

The Federal Clean Water Act (CWA) §303(d) and federal regulation 40 CFR 130.2 and 130.7 direct each State to develop a Total Maximum Daily Load (TMDL) for all waters that have been identified on their respective §303(d) list as impaired by a pollutant(s). A TMDL identifies maximum loading allocations for a pollutant that, when implemented, have a reasonable assurance that is expected to result in the attainment of applicable water quality standards. A TMDL incorporates elements which address the statutory and regulatory requirements for a TMDL along with documentation of the basis for the TMDL. These elements include an assessment of the pollutant problem and impacts to designated uses, development of numeric targets that interpret and apply the water quality standard(s), an assessment of the pollutant sources and estimation of loading capacity and associated load allocations, including a margin of safety, to meet the water quality standard(s). Ocean Lake was identified on Wyoming's 1996 §303(d) list as water quality limited due to physical habitat degradation from sediment. The level of sediment in Ocean Lake was determined to threaten the existing water quality standards supportive of warm-water fisheries, non-game fisheries and aquatic life other than fish designated uses. In 2008, recent information resulted in the update of Wyoming's §303(d) listing for Ocean Lake as non-supportive of existing water quality standards for support of warm-water fisheries, non-game fisheries and aquatic life other than fish due to sediment (WDEQ/WQD 2008b).

According to Wyoming's TMDL Workplan (WDEQ/WQD 2008a), this TMDL will be reassessed at least every five years. Reassessments are an iterative approach that will allow for refinement of the TMDL as a result of new information or if the physical conditions of the watershed have changed significantly over time. TMDL reassessments are also important to determine progress towards attainment of TMDL goals and when designated uses are supported. This approach also allows the WDEQ/WQD to utilize a feedback loop to determine if the initial sediment load target is effective in reaching the ultimate goal of having Ocean Lake meet water quality standards and fully support of designated uses. Furthermore, TMDL reassessments are critical because a TMDL that no longer reflects actual conditions in the watershed will not be an acceptable guide to waterbody restoration. These reassessments are also critical for continued citizen involvement in waterbody restoration. Significant revisions may warrant the recalculation of the TMDL which would require a public comment period and review by the USEPA.

This TMDL will consist of estimating the waterbody load capacity, existing pollutant load in excess of this capacity and source load allocations based on available information. Included with this TMDL is a recommended monitoring plan. Monitoring is a necessary component to TMDLs in order to assess the future designated use status, determine water quality trends, and evaluate the effectiveness of implemented best management practices (BMPs). Additional data collection can be used to determine if the TMDL and any developed implementation plan are effective in addressing the identified water quality impairment.

WATERBODY AND WATERSHED DESCRIPTION

Ocean Lake is a small, natural depression (formerly known as Dry Lake) located northwest of Riverton, Wyoming in central Fremont County where a control structure was installed in 1922. Ocean Lake currently has a mean depth of around 12 feet with a maximum depth of 26 feet and a storage volume of 71,635 acre-feet. The storage volume of Ocean Lake has decreased by 11% since its initial construction

(WGFD, personal communications). Total surface area of the lake is around 6,000 acres (9.4 mi^2). Ice-cover is present on Ocean Lake during the winter and spring months, though the lake does not freeze completely.

Total contributing watershed area to the lake is 168,320 acres (263 mi^2), of which 41,216 acres (64.4 mi^2) is irrigated cropland (Figure 1). Ocean Lake has a watershed-to-lake ratio of 28:1. Primary uses on Ocean Lake are storage of irrigation return flow water, recreation (predominantly angling) and wildlife habitat. Land uses and associated areas for the contributing Ocean Lake watershed are listed in Table 1. Residential subdivision development has seen some increase in the watershed in recent years, otherwise all other land uses have generally remained the same.

Table 1 – Land use in the contributing Ocean Lake watershed (University of Wyoming, Wyoming Geographic Information Center, December 1996). Urban/Residential refers to municipalities and concentrated residential areas.

Land Use	Area in Acres	Area in Square Miles	Percent of Total Area
Rangeland and pasture	120,672.8	188.6	70
Irrigated cropland	41,216	64.4	24
Open water	6,355	9.9	4
Urban/Residential	76.2	0.1	<0.1
Total	168,320	263	100

Inflows into Ocean Lake originate from nine irrigation canal return flow drains (Figure 2). Current annual inflows are estimated at 35,246 acre-feet. Based on an evaluation of all available information, three of the irrigation drains (#4, #6 and #7) contribute approximately 81% of the total inflow into Ocean Lake. An estimated annual outflow of 33,768 acre-feet from Ocean Lake enters irrigation drains that confluence with Five-Mile Creek which flows east and drains into Boysen Reservoir. The entire Ocean Lake watershed is located in the Wyoming Basin level III ecoregion (Omernik and Gallant 1987) and the Rolling Sagebrush Steppe level IV ecoregion (Chapman et al. 2003). The watershed is largely comprised of alluvium (Qa) and sedimentary materials from the Wind River Formation (Twdr) (USGS 1985). Table 2 summarizes selected general information for Ocean Lake.

Figure 1 – Ocean Lake watershed (red line) and associated municipalities (white dots), U.S. and State highways (orange lines). Imagery obtained from 2006 National Agricultural Imagery Program (NAIP).

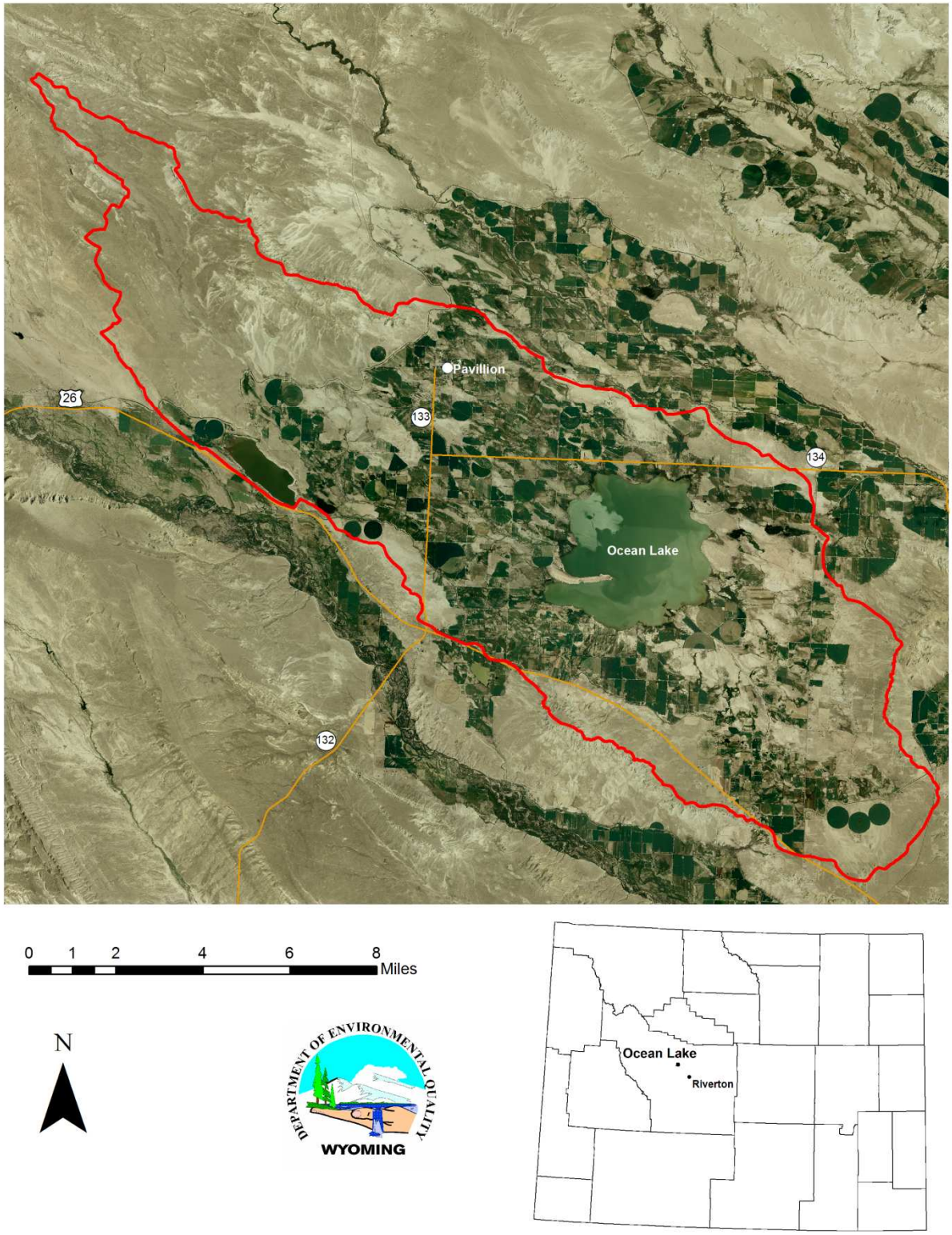


Figure 2 – Ocean Lake and associated inflows, outflow and roads.

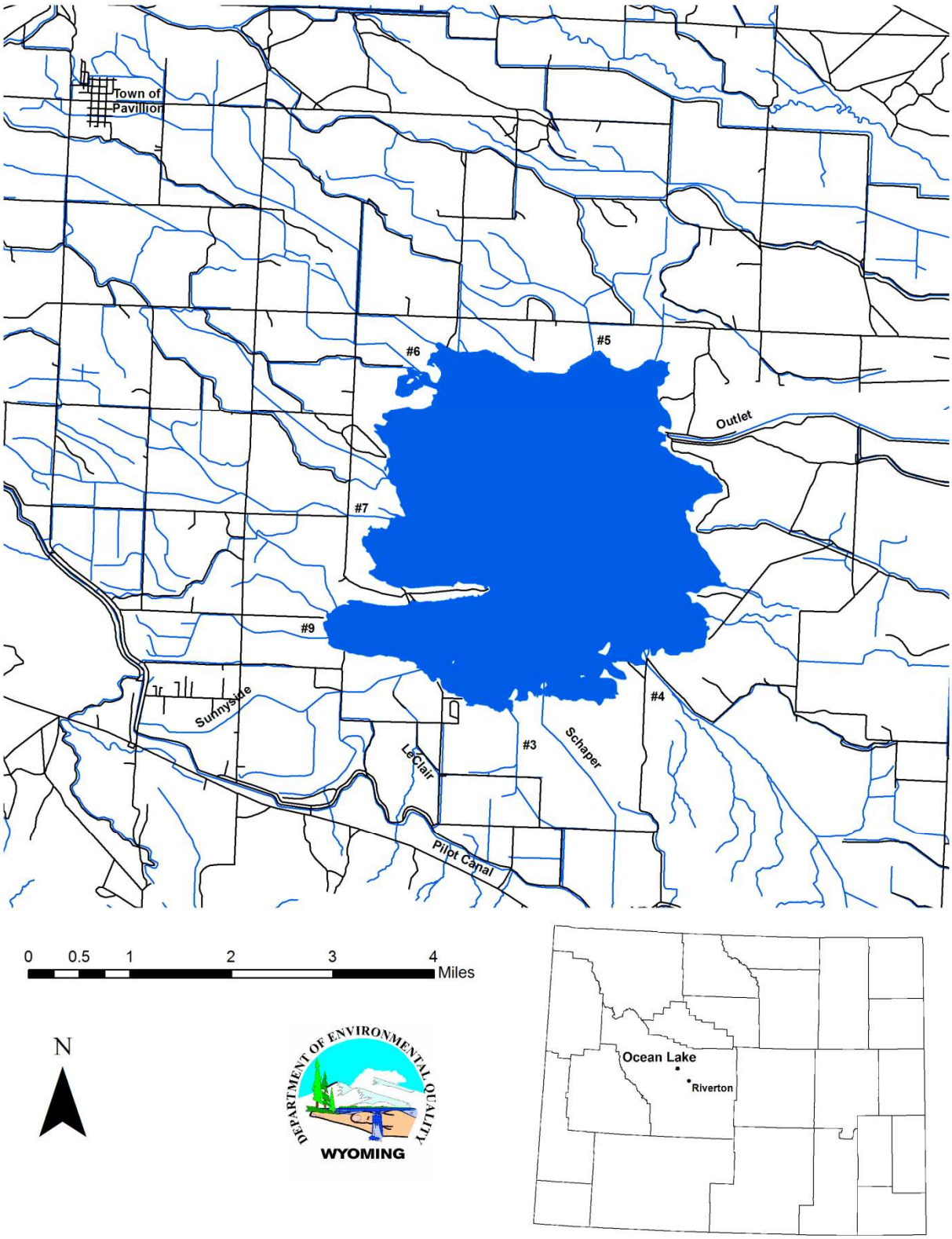


Table 2 – Selected general information for Ocean Lake.

Hydrologic Unit Code	100800050202
303(d) Waterbody ID	WYBH100800050202_01
Year Established	1922
Latitude (near center of lake)	43° 10' 49.89" N
Longitude (near center of lake)	-108° 35' 59.89" W
Normal Pool Elevation	5,234 feet
WDEQ/WQD Waterbody Classification	2ABww
Tributaries (i.e. irrigation drains)	#3, #4, #5, #6, #7, #9, LeClair, Schaper, and Sunnyside
Receiving Water	Irrigation drains to Five-Mile Creek
Lake Surface Area (normal pool)	6,000 acres (9.4 mi^2)
Maximum Depth (normal pool)	26 feet (7.9 m)
Mean Depth (normal pool)	12 feet (3.7 m)
Original Lake Volume (normal pool)	80,179 acre-feet
Current Lake Volume (normal pool)	71,635 acre-feet
Watershed Area	168,320 acres (263 mi^2)
Watershed/Lake Area Ratio	28:1
Estimated Annual Inflow to Lake*	35,246 acre-feet
Estimated Annual Outflow from Lake*	33,768 acre-feet
Estimated Hydraulic Residence Time	2.12 years

*Estimates were derived from the best available data.

The Town of Pavillion wastewater treatment facility (WWTF) constitutes the only point source of sediment contributions in the watershed. Pollutant discharges from this facility are managed under the Wyoming Pollutant Discharge Elimination System (WYPDES) program of the WDEQ/WQD. Effluent from this facility is discharged into an irrigation drain that confluences with drain #6. This facility is considered a minor source of sediment to Ocean Lake.

WATER QUALITY CONDITIONS, PROBLEM IDENTIFICATION AND PAST POLLUTANT CONTROL EFFORTS

Ocean Lake was considered a nationally famous black crappie (*Pomoxis nigromaculatus*) and largemouth bass (*Micropterus salmoides*) fishery from the 1940s to around the mid-1960s. Abundant burbot (*Lota lota*) were also present in the lake. An influx of nutrients from irrigation return ditches that increased the primary productivity and macrophyte growth within the lake, as well as a delicate balance between sediment and water inflows/outflows, were perhaps the main driving forces behind the high quality fishery. Since this period, the black crappie and largemouth bass fishery as well as populations of other fishes have declined. Since the mid-1950s, the increasingly turbid conditions of Ocean Lake have favored the introduction of walleye (*Stixostedion vetreum*) to offset the declining black crappie and largemouth bass fishery.

Continued decline in the fisheries and the disappearance of certain species of fishes from Ocean Lake prompted the Wyoming Game and Fish Department (WGFD) to conduct a study (Millis and Pedlar 1985) to evaluate causes of the fisheries decline. This study concluded that the primary cause of the decline in the fisheries of Ocean Lake was sediment from agricultural fields and irrigation return flow drains in the agricultural drainage area. Sediment entering the lake not only accelerated the natural reduction in volume and depth of the impoundment, but was increasing the turbidity of the waterbody. Increased turbidity was causing a reduction in primary productivity and macrophyte growth by reducing the depth to which light could penetrate. Depressed light conditions were limiting the ability of planktivorous fishes to detect and utilize the available food resource. Furthermore, increased turbidity may have upset the predator-prey balance by decreasing prey vulnerability to visually seeking piscivorous predators. Continued deposition of sediment would embed spawning areas and influence the diversity and abundance of both fishes and benthic macroinvertebrates. The study suggested that of the nine irrigation return drains that emptied into Ocean Lake, #6 and #7 were producing 78% of the sediment entering the lake. The third biggest contributor, #4, was contributing 12% of the sediment load to the lake.

Millis and Pedlar (1985) also concluded that Ocean Lake was in a mesotrophic state, however, lake phosphorus concentration and phosphorus loading from irrigation return ditches created a potential for eutrophic conditions. Though the potential for eutrophic conditions existed, such conditions have not developed since the elevated turbidity of the lake inhibits the full utilization of the nutrients by the phytoplankton community. The majority of turbidity in Ocean Lake is attributed to inorganic sediment. Similar conditions were noted in Ocean Lake in the early 1990s by Petty et al. (1993). Nutrients in the drains were considered to be largely the result of runoff from agricultural land in the drainage. Nutrients from the Town of Pavillion's wastewater treatment facility were considered negligible.

A study conducted by Petty et al. (1993) confirmed many of Millis and Pedlar's (1985) findings on sediment contributions and loading and nutrients to Ocean Lake. Petty et al. (1993) concluded that both sediment loading and turbidity had increased since the 1985 Millis and Pedlar study. Petty et al (1993) surmised that the increase in sediment loading (as measured by TSS) and turbidity was due in part to continual sediment loading from the nine irrigation drains. They also went on to suggest that factors such as high winds and to some degree boating, may contribute to turbidity through re-suspension of deposited lake sediment.

Additional studies by the Wyoming Water Development Commission (WWDC 1987, 1992 and 1993) and other parties concurred with the findings from Millis and Pedlar (1985) and Petty et al. (1993) that excessive sediment loading to Ocean Lake was largely the result of high flows of water channeled through the open irrigation return flow drain system. Much of the sediment entering Ocean Lake originated from bank erosion/failure within the irrigation drains. A small percentage likely originates from overland flows on agricultural land in the watershed, which subsequently intercepts nearby irrigation drains. Results from these studies verified that indeed the greatest percentage of sediment contributions to the lake originate from irrigation return flow drains #6, #7 and #4. The WWDC suggested that the most immediate and favorable impact to the fisheries of Ocean Lake would be to minimize sediment inputs into Ocean Lake through the implementation of BMPs on these three irrigation drains.

To address the sediment issue in Ocean Lake, representatives from the Lower Wind River Conservation District, Midvale Irrigation District, U.S. Bureau of Reclamation (USBOR), Natural Resource Conservation

Service (NRCS), WGFD, and local citizens formed the Save Ocean Lake (SOL) committee in 1986. The committee was formed to guide and coordinate efforts to reduce the sediment loading to Ocean Lake. Ocean Lake was eventually placed on Wyoming's §303(d) list of impaired waters in 1996 as threatened for warm-water fisheries and aquatic life designated uses due to sediment. The SOL committee received funds from several sources, including 319 funds administered by the WDEQ/WQD to address sediment loading to Ocean Lake. Based on available information at the time, the SOL committee recommended that BMPs would need to be implemented on the irrigated drains to reduce sediment inputs to Ocean Lake. Drains #6 and #7 were chosen as high priority for BMP implementation while #4 was considered a second priority. BMPs implemented on the drain systems included 1) drop structures to slow water velocities, prevent further downcutting and minimize bank erosion, 2) fencing along drains to minimize bank sheer and trampling, 3) installation of field drain culverts to minimize bank erosion and uncontrolled overland runoff, 4) re-seeding along drains to minimize bank erosion, 5) installation of water gaps along drains to provide water access for livestock, 6) installation of diversion dikes to return water from the field to the drain culverts and 7) bank sloping. BMPs were implemented between the mid-1980s through the mid-1990s. The WGFD conducted monitoring of TSS on drains #6, #7 and #4 from the late-1990s to the late-2000s to document trends in sediment contributions to the lake as a result of BMP implementation.

The WGFD in cooperation with the USBOR, U.S. Army Corp of Engineers (USACE), Wyoming Department of Transportation (WYDOT) and local citizens have placed numerous discarded Christmas trees and cleared trees from road right-a-ways in Ocean Lake since 1990. The trees are placed in groups on the ice, anchored to concrete cylinders and allowed to sink to the bottom during ice-off where it is hoped they will enhance fish habitat and encourage stabilization of lake sediments. No information exists to evaluate the effectiveness of this habitat improvement effort.

The WDEQ/WQD conducted an assessment of Ocean Lake and selected drains in 2003 to evaluate the effectiveness of BMPs along drains #6, #7 and #4 and sediment loading reduction efforts into Ocean Lake. This data combined with information from Millis and Pedlar (1985) and Petty et al. (1993) and TSS data collected by WGFD on drains #6, #7 and #4 were used to determine whether sediment reduction efforts in the drains were successful and whether warm-water fisheries and other aquatic life uses were supported in Ocean Lake. The available information indicated that sediment contributions to Ocean Lake have declined since the mid-1980s as a result of improvements along the drains, most notably drains #6 and #7 and to some degree drain #4 (WDEQ/WQD 2005). BMPs installed along drain #4 were not as successful compared to drains #6 and #7 presumably due to subdivision of land along the drain after sediment control efforts were initiated. Drain #4 functions as an emergency outlet from Pilot Canal. Channel instability associated with discharges of large volumes of water from Pilot Canal into drain #4 may have also contributed to the limited success of BMPs along this drain.

Despite the general improvements in sediment loading to Ocean Lake, a corresponding improvement in the water clarity and quality of Ocean Lake had not resulted (WDEQ/WQD 2005). Available information indicates Ocean Lake contains a legacy from its past in the form of fine sediment that had deposited on the lake bottom prior to sediment reduction efforts along the drains. In corroboration with findings from Petty et al. (1993), conclusions from WDEQ/WQD (2005) stated that the inherent shallowness of Ocean Lake combined with its limited protection from the wind and inadequate macrophyte beds for sediment stabilization continues to allow these historically deposited highly mobile fine sediments to be re-suspended during ice-free months. The limited water clarity along with an unstable lake bottom continues

to limit primary productivity and the suitability of the bottom for feeding, spawning and rearing areas for warm-water fisheries and other aquatic life. The combined effect of these factors has inhibited the development of a naturally sustainable warm-water fishery in Ocean Lake. In fact, there has been no appreciable change in geometric mean lake Secchi depth (lake transparency) TSS concentration since the 1980s. Historically, geometric mean Secchi depth and TSS in Ocean Lake prior to BMP implementation was 0.85 meters and 6.3 mg/L, respectively. Current geometric mean Secchi depth and TSS in Ocean Lake is 0.86 meters and 6.2 mg/L, respectively.

At present, the lake is still managed as a walleye fishery. However, according to the WGFD, walleye in Ocean Lake have little or no success in natural reproduction due to the lake bottom dominated by fine sediment. Walleye have been supplemented by annual stocking since 1972. Increased catch-per-unit-effort (CPUE) of walleye in recent years has not been linked to an improvement in water quality but rather increases in walleye stocking rates. The increased turbidity of the lake has produced favorable conditions for common carp (*Cyprinus carpio*) which are in abundance despite aggressive removal efforts. The WDEQ/WQD ultimately determined from the available information that Ocean Lake was non-supportive of its warm-water fisheries, non-game fisheries and aquatic life other than fish designated uses (WDEQ/WQD 2005). This determination resulted in a revision of the Ocean Lake §303(d) listing in 2008 from threatened to non-support of warm-water fisheries, non-game fisheries and aquatic life other than fish designated uses due to sediment (WDEQ/WQD 2008b).

IMPAIRED DESIGNATED USES AND APPLICABLE WATER QUALITY STANDARDS

Ocean Lake is classified as a Class 2ABww water. Designated uses assigned to Class 2ABww waters include warm-water fisheries, non-game fisheries, aquatic life other than fish, drinking water, fish consumption, agricultural, wildlife, industrial, recreational and aesthetic uses (WDEQ/WQD 2007).

In 1996 Ocean Lake was included on Wyoming's §303(d) list of impaired waters as threatened for support of warm-water fisheries, non-game fisheries and aquatic life other than fish due to sediment. In 2008, Ocean Lake continued to be listed for sediment but the level of impairment was changed to non-support to reflect the most recent evaluation of available information (WDEQ/WQD 2008b).

The State of Wyoming does not have numeric water quality criteria for sediment but does have narrative standards that are applicable to Ocean Lake that can be found in Chapter 1 of the Wyoming Water Quality Division Rules and Regulations (WDEQ/WQD 2007).

> Section 15 (Settleable Solids) – "*In all Wyoming surface waters, substances attributable to or influenced by the activities of man that will settle to form sludge, bank or bottom deposits shall not be present in quantities which could result in significant aesthetic degradation, significant degradation of habitat for aquatic life or adversely affect public water supplies, agricultural or industrial water use, plant life or wildlife.*"
>
> Section 16 (Floating or Suspended Solids) – "*In all Wyoming surface waters, floating and suspended solids attributable to or influenced by the activities of man shall not be present in quantities which could result in significant aesthetic degradation, significant degradation of habitat*

for aquatic life, or adversely affect public water supplies, agricultural or industrial water use, plant life or wildlife."

Section 32 (Biological Criteria) - "*Class 1, 2 and 3 waters of the state must be free from substances, whether attributable to human-induced point source discharges or nonpoint source activities, in concentrations or combinations which will adversely alter the structure and function of indigenous or intentionally introduced aquatic communities.*"

Ocean Lake has continued to be included on Wyoming's §303(d) list of impaired waters since 1996 based on information from studies conducted by Millis and Pedlar (1985), Petty et al. (1993), and WWDC (1987, 1992 and 1993), fisheries and TSS data collected by WGFD and data collections and evaluations made by WDEQ/WQD (2005). The WDEQ/WQD has determined that all available information indicated Ocean Lake does not support warm-water fisheries, non-game fisheries and aquatic life other than fish due to continued poor water clarity caused by the constant re-suspension of fine sediment on the lake bed and its effects on primary productivity, macrophyte growth and fish and other aquatic life production.

POLLUTANT SOURCES

Point Sources: The Town of Pavillion wastewater treatment facility represents the only point source in the watershed. Based on the design flow capacity and current limits for TSS, the estimated sediment load from this facility is minor at 11 tons/yr.

Non-Point Source: The sediment impairment to Ocean Lake is primarily caused by internal re-suspension of sediment from the lake bottom. The re-suspension of lake sediments is caused by the inherent shallowness of the lake combined with wind action and inadequate macrophyte beds for sediment stabilization. Though total annual sediment loads to Ocean Lake from the nine irrigation drains have been reduced, sediment from the drains remains a minor contributor to the suspended sediment load in Ocean Lake.

Natural Background Sources: Because an extensive drain network exists in the Ocean Lake watershed, the majority of surface runoff of sediment from natural sheet and rill erosion intercepts the irrigation drains and is therefore an implicit part of the non-point source sediment load. Wind-blown sediment and shoreline erosion from wave and wind action contributes to the internal sediment load of Ocean Lake. However, sediment contributions from these factors are considered minimal and are therefore an implicit part of the non-point source sediment load associated with internal sediment re-suspension.

UNCERTAINTIES IN DEVELOPING THE SEDIMENT TMDL

The analyses used to develop the Ocean Lake sediment TMDL presented in the remainder of this document are based on the best available information. While a basic understanding of the most important sources of sediment loading to Ocean Lake have been identified, insufficient monitoring data exists to accurately quantify sediment loading to and within Ocean Lake. Much of the analyses presented below are based on several single point-in-time measurements of total suspended solids and flow. Assumptions were also applied where appropriate. Unless otherwise noted, annual and monthly estimates of Secchi depth, TSS, water budgets and sediment loads were calculated as geometric means.

Geometric means are commonly calculated on limited, non-continuous datasets that are represented by highly variable values. A geometric mean reduces the skewness of the data and provides a more accurate mean of the parameters compared to a conventional arithmetic mean. Additional sediment and flow data are necessary to more accurately define the spatial and temporal characteristics of sediment loading to and within Ocean Lake. The analysis of current and targeted sediment loadings by source category are 'best estimates' based on extrapolations from available monitoring data. As discussed in the Introduction, TMDL targets and source allocations will be modified as more information becomes available. If future data indicate the TMDL or targets are unachievable, the targets and/or TMDL can be revised to achieve applicable water quality standards.

DATA SOURCES AND TMDL TARGETS

The ultimate goal of this TMDL is to achieve Wyoming water quality standards to fully support warm-water fisheries, non-game fisheries and aquatic life other than fish for Ocean Lake through a reduction in sediment loading. This section covers the data sources, methods and analysis that were utilized to determine the water quality targets that will guide sediment load reductions and watershed management practices to achieve full support of warm-water fisheries, non-game fisheries and aquatic life other than fish in Ocean Lake.

Data Sources

As part of the study conducted by Millis and Pedlar (1985), several water quality parameters that include Secchi depth and TSS were collected at two locations on Ocean Lake during 1980, 1981 and 1982. Samples were collected at least once per month during the ice-free season (April through November).

Discharge measurements collected by the United States Geological Survey (USGS) gage 06246500 at the Ocean Lake outflow between 1979 and 1982, were used to estimate mean annual outflow from Ocean Lake.

Petty et al. (1993) analyzed water quality parameters that included TSS and Secchi depth at two locations on Ocean Lake in 1992. Samples were collected once monthly from April to September. Some TSS and Secchi depth samples were not used in the analysis due to their outlier status and/or erroneous values. In addition, Petty et al. (1993) collected TSS and measured flow on all nine irrigation drains to Ocean Lake at least once per month from April to November in 1992. This information contains the most representative estimates of flow and sediment loading from the irrigation drains prior to BMP implementation in the watershed. Ocean Lake outflow was also measured at least once per month from April to November in 1992.

TSS data were collected by the WGFD on irrigation drains #4, #6 and #7 from 1989 to 2008. Samples were collected once monthly from April to October. A small set of flow data on drains #4 and #7 and Ocean Lake Secchi depth measurements were also collected during the sample period. TSS and Secchi depth were collected by the WDEQ/WQD at three locations on Ocean Lake in 2003. The WGFD and WDEQ/WQD data are considered the most representative estimates of these parameters during the post-BMP implementation period.

TMDL Targets

Because re-suspension of lake bottom sediment has been determined the primary cause of the impairment in Ocean Lake, a TMDL target aimed at reducing sediment re-suspension (and consequently sediment load) through the use of a water transparency indicator will be used. This TMDL will use Carlson's Trophic State Index (TSI) as the water transparency indicator. Carlson (1977) developed Trophic State Indices (TSI) to categorize and evaluate lakes based on their responses to different ecological factors. Changes in trophic status or 'biological productivity' are based on changes in the interrelationships between nutrient concentrations (measured by total phosphorus), algal biomoass (measured by chlorophyll a) and water transparency (measured by Secchi depth). TSI index values range from 0 (ultraoligotrophic) to 100 (hypereutrophic). TSI value for Secchi depth (SD), chlorophyll a concentration (Chla) and total phosphorus concentration (TP) are calculated using the following formulae:

$$TSI\text{-}Chla = 30.6 + 9.81 * \ln(Chla)$$

$$TSI\text{-}TP = 4.15 + 14.42 * \ln(TP)$$

$$TSI\text{-}SD = 60 - 14.41 * \ln(SD)$$

Carlson defined general categories of biological expectations for lakes and reservoirs based on the ranges of TSI values for the three independent variables (Table 3).

Table 3 – Carlson's Trophic States and biological expectations.

TSI < 30	Classic oligotrophy: clear water, many algal species, oxygen throughout the year in bottom water, cold water, oxygen-sensitive fishes in deep lakes
TSI 30 - 40	Deeper lakes still oligotrophic, but bottom water of some shallower lakes will become oxygen-depleted during the summer.
TSI 40 - 50	Water moderately clear, but increasing chance of low dissolved oxygen in deep water during the summer.
TSI 50 - 60	Lakes becoming eutrophic: decreased clarity, fewer algal species, oxygen-depleted bottom waters during the summer, plant overgrowth evident, warm-water fisheries only.
TSI 60 - 70	Blue-green algae become dominant and algal scums are possible, extensive plant overgrowth problems possible.
TSI 70 - 80	Becoming hypereutrophic, heavy algal blooms possible throughout summer, dense plant beds, but extent limited by light penetration (blue-green algae).
TSI >80	Algal scums, summer fishkills, few plants, rough fish dominant.

Thus, a change in any of these three independent measures and corresponding TSI values can cause a change in trophic status. Because the three index variables of total phosphorus, chlorophyll a and Secchi depth are interrelated, any of the three variables can be used to assess trophic state. In the case of Ocean Lake, reduced water transparency caused by re-suspension of lake sediments has caused a change in trophic state via a reduction in primary productivity and macrophyte growth by reducing the

depth to which light can penetrate. Depressed light conditions limit the ability of planktivorous fishes to detect and utilize the available food resource. Furthermore, increased turbidity has likely upset the predator-prey balance by decreasing prey vulnerability to visually seeking piscivorous predators and inhibiting reproductive success of warm-water game fishes.

To more accurately reflect biological expectations for temperate lakes, some Midwestern States have modified Carlson's original biological expectations while retaining the same TSI categories using information obtained from Carlson and Simpson (1995), Oglesby et al. (1987) and USEPA (2000). The modified biological expectations for temperate warm-water lakes and reservoirs are listed in Table 4.

Table 4 – Changes in temperate lake attributes according to trophic state.

TSI 50 - 60	Eutrophy: anoxic hypolimnia, macrophyte problems possible. Warm-water fisheries only; percid fishery; bass may be dominant
TSI 60 -70	Blue-green algae dominate; algal scums and macrophyte problems may occur. Weeds, algal scums and low transparency discourage swimming and boating. Centrarchid fishery
TSI 70 - 80	Hyper-eutrophy (light limited), dense algae and macrophytes. Weeds, algal scums and low transparency discourage swimming and boating. Cyprinid fishery (e.g. common carp and other rough fish).
TSI >80	Algal scums, few macrophytes. Algal scums and low transparency discourage swimming and boating. Rough fish dominate, summer fish kills possible.

It seems reasonable to conclude that a Carlson TSI based on Secchi depth (TSI-SD) can be used as a simple yet effective method for establishing a desirable TMDL target for re-suspended sediment. Indeed, TSI-SD targets have been used in other States with narrative sediment criteria such as Iowa, Kansas, Minnesota, Missouri, Nebraska and North Dakota to establish appropriate sediment TMDLs for lakes and reservoirs. TSI-SD targets for lake/reservoir sediment TMDLs supportive of warm-water fisheries in these States have generally ranged from 0.7 to 1.0 meter, dependent on the characteristics and potential of the waterbody.

The TSI-SD method is advantageous for a number of reasons: it is based on empirical data from a wide range of lakes; its application is conceptually simple and does not require the assumptions of many unknown parameters; it is recognized by the scientific community as a reasonable method for predicting lake trophic status and it is recognized by other States as a reasonable method for establishing TMDL targets in the absence of numeric criteria for not only sediment, but also nutrients. Absent approved criteria or policies and considering the similarities of Ocean Lake with other temperate lakes in North America, the modified trophic state biological expectations in Table 4 could be used as a reasonable guide to establish an appropriate TSI-SD target for Ocean Lake.

Therefore, the target for the Ocean Lake sediment TMDL is defined by a mean water transparency measured by Secchi depth equal to or greater than 1.0 meters. This target is equivalent to a TSI-SD value of 60 which is the minimum water transparency considered supportive of a self-sustaining warm-water fishery where percids dominate. Because maintenance of the warm-water game fisheries in Ocean Lake is entirely dependent on stocking, a reasonable goal for this TMDL would be to effectively address

the sediment impairment so that conditions in Ocean Lake are conducive to support self-sustaining populations of warm-water game fishes. This target also seems reasonable for this TMDL since it is within the general range of existing sediment TMDLs for warm-water fisheries. Finally, this target is reasonable considering that Ocean Lake is currently managed as a warm-water walleye fishery and formerly had a self-sustaining black crappie and bass fishery (walleye and crappie are both members of the percid family).

CRITICAL CONDITION AND TEMPORAL VARIATION

According to the federal regulations 40 CFR 130.7(c)(1), the 'critical condition' must be taken into account when developing TMDLs. The 'critical condition' is generally defined as the condition when the physical, chemical and biological characteristics of the receiving water environment interact with the pollutant to produce the greatest potential adverse impact on the existing designated uses. The intent of this requirement is to ensure that the water quality of the receiving water is protected during times when it is most vulnerable.

The critical condition for this TMDL is during the ice-free months (typically the growing season) (April through November) when sediment and flow contributions, sediment re-suspension and low transparency in Ocean Lake are most likely to occur. Annual averages therefore incorporate only the months April to November.

The TMDL target/endpoint is expressed as the annual average. The existing and target sediment loads for Ocean Lake are expressed primary as annual averages. The models used to calculate the existing and target sediment loads utilize monthly flow, TSS concentrations and Secchi depth measurements to calculate average annual sediment loading.

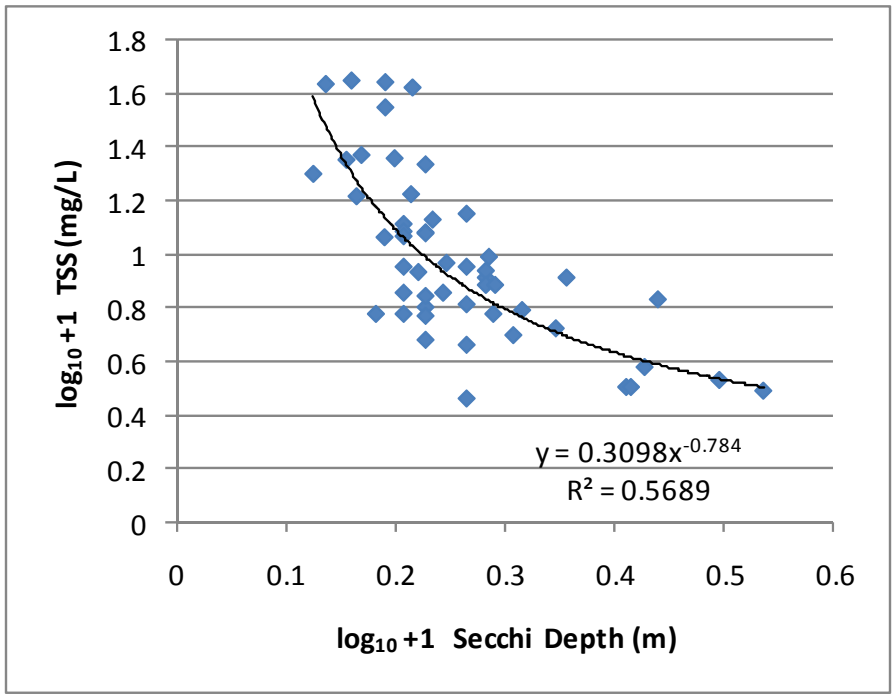
LINKAGE BETWEEN TMDL TARGETS AND SEDIMENT LOADS

One component of a TMDL is to establish a link between predicted pollutant loads and the numeric indicator(s) or targets that have been chosen to measure attainment of uses. Once this link has been established, it is possible to determine the total capacity of the waterbody to assimilate pollutant loadings while still supporting its designated uses. Allowable loads can then be allocated among the various pollutant sources.

The targets for the Ocean Lake sediment TMDL have been established using a TSI-SD of 60 which is equivalent to a targeted Secchi depth of 1.0 meter. These targets have been chosen as the numeric indicators to measure the attainment of designated uses in Ocean Lake. In order to quantify the predicted sediment loads required to attain the numeric targets, the WDEQ/WQD developed a model to predict TSS concentration based on Secchi depth in Ocean Lake. Log (X+1) transformations of paired TSS and Secchi depth data collected on Ocean Lake between 1980 and 2003 from Millis and Pedlar (1985), Petty et al. (1993), WGFD and WDEQ/WQD were used to generate a power curve model to back-calculate the sediment load for the TSI-SD target Secchi depth value of 1.0 meter as well as the existing sediment load. A small portion of the available data were designated as outliers and not used in development of the power curve model or in the calculation of existing and target sediment loads. Figure 3 shows the log (X+1) transformed TSS and Secchi depth power curve model. Variability in the data

resulted in a modest model accuracy with a coefficient of correlation (r^2) of 0.57. Use of this and other types of models to back-calculate existing and target sediment loads for a TMDL is common throughout the United States. Examples of States where similar approaches have been used to establish links between TMDL targets and pollutant loads include Iowa, Kansas, Minnesota, Missouri, Nebraska, New Mexico and North Dakota. Mentioned outliers and data used to develop the power curve model can be found in Appendix A.

Figure 3 – Log (X+1) transformed Secchi depth and TSS power curve model for Ocean Lake.



The power curve model in Figure 3 in addition to calculations of a water budget and TSS concentrations were used to calculate the predicted and existing sediment loads for Ocean Lake. Analyses were also performed specifically for the irrigation drains for both the pre and post-BMP periods to determine past sediment load reductions from BMPs implemented in the drains. A description of the analyses and a summary of findings for these budgets are described below.

WATER BUDGET AND TSS CONCENTRATIONS

Water Budget

The calculation of sediment loads for Ocean Lake is highly dependent on reservoir outflows and inflows from the nine irrigation drains. Therefore, it is important that the annual water budget for Ocean Lake be as accurate as possible so that resulting sediment loads are reasonable. Flow monitoring into and out of Ocean Lake has been extremely limited and thus inaccuracies exist in the water budget calculation.

Based on daily discharge data measured at USGS gage 06246500 from 1979 to 1983, average annual outflow from Ocean Lake was calculated at 33,768 acre-feet. Average daily reservoir outflow calculated from Petty et al. (1993) data was 40.2 cfs or 29,104 acre-feet per year. Average annual reservoir outflow based on Petty et al. (1993) measurements was 86% similar to outflow measured at the USGS gage. Because of the paucity of recent reservoir outflow information, the more conservative average annual outflow estimate of 33,768 acre-feet based on the USGS data was used for the Ocean Lake TMDL. Data used to calculate reservoir outflow can be found in Appendix B.

Mean monthly flows to Ocean Lake from the nine irrigation drains were calculated for both the pre and post-BMP (current) implementation periods. For the pre-BMP period, daily discharge measurements collected by Petty et al. (1993) were used to calculate mean monthly inflows. For the post-BMP period, mean monthly inflows for selected months on drains #7 and #4 were calculated with WGFD data collected from 1997 to 2003. The absence of recent flow information on the remaining drains required the assumption that post-BMP monthly flow conditions on these six drains were unchanged from the pre-BMP period. Petty et al. (1993) and Millis and Pedlar (1985) indicated the irrigation drains generally contribute flows to Ocean Lake during the ice-free months of April to November, therefore, mean monthly and total annual inflows for both periods were based only on those eight months. Estimated mean monthly and total annual inflows to Ocean Lake for the pre-BMP period are shown in Table 5. Estimated post-BMP mean monthly and total annual inflows to Ocean Lake based on the combination of Petty et al. (1993) and WGFD data are shown in Table 6.

Table 5 – Estimated pre-BMP mean monthly and total annual flow contributions in acre-feet from Ocean Lake's nine irrigation drains.

Month	#7	#6	#4	Sunnyside	#5	Schaper	#9	#3	LeClair
April	320.7	221.4	274.3	64.9	45.8	193.4	11.9	23.8	69.6
May	1357.6	1660.8	1221.8	453.2	402.1	199.8	121.1	54.7	89.8
June	1068.7	720.6	870.5	188.6	170.2	141.0	38.7	42.8	28.6
July	1405.6	1044.7	1213.2	246.0	346.8	218.3	48.6	68.3	68.9
August	1896.9	1288.8	1502.8	352.9	275.5	202.3	90.4	101.5	62.7
September	1888.7	1944.0	991.9	362.4	223.7	224.9	129.7	81.5	92.8
October	1460.9	1179.9	1100.6	188.2	143.9	216.4	81.8	65.2	68.3
November	938.4	339.8	1065.1	1.2	54.7	193.4	28.6	63.1	66.0
Average total inflow (acre-feet) (April - November):	10337.6	8399.9	8240.2	1857.3	1662.7	1589.6	550.7	500.8	546.7
Total annual inflow (acre-feet) from all drains (April - November):	33685.5								
Percent of total inflow:	30.7	24.9	24.5	5.5	4.9	4.7	1.6	1.5	1.6

Flows for October were generally not measured. Monthly October values were interpolated by averaging September and November flows.
Where data were missing for an entire month with no data from the prior or following month, the average of all monthly values was used

Table 6 – Estimated post-BMP mean monthly and total annual flow contributions in acre-feet from Ocean Lake's nine irrigation drains. Highlighted values were calculated from data collected by WGFD.

Month	#7	#6	#4	Sunnyside	#5	Schaper	#9	#3	LeClair
April	320.7	221.4	274.3	64.9	45.8	193.4	11.9	23.8	69.6
May	1242.7	1660.8	447.0	453.2	402.1	199.8	121.1	54.7	89.8
June	1406.1	720.6	1157.4	188.6	170.2	141.0	38.7	42.8	28.6
July	2115.8	1044.7	1548.3	246.0	346.8	218.3	48.6	68.3	68.9
August	2794.6	1288.8	2369.7	352.9	275.5	202.3	90.4	101.5	62.7
September	1888.7	1944.0	1854.1	362.4	223.7	224.9	129.7	81.5	92.8
October	1460.9	1179.9	291.5	188.2	143.9	216.4	81.8	65.2	68.3
November	938.4	339.8	28.6	1.2	54.7	193.4	28.6	63.1	66.0
Average total inflow (acre-feet) (April - November):	12167.9	8399.9	7970.8	1857.3	1662.7	1589.6	550.7	500.8	546.7
Total annual inflow (acre-feet) from all drains (April - November):	35246.4								
Percent of total inflow:	34.5	23.8	22.6	5.3	4.7	4.5	1.6	1.4	1.6

Flows for October were generally not measured. Monthly October values were interpolated by averaging September and November flows.
Where data were missing for an entire month with no data from the prior or following month, the average of all monthly values was used

As indicated in past studies, the largest contribution of inflows to Ocean Lake during both the pre and post-BMP periods originate from drains #7, #6 and #4. The total annual inflow to Ocean Lake from all nine irrigation drains was marginally greater in the post-BMP period (35,246 acre-feet) compared to the pre-BMP period (33,686 acre-feet). Data used to calculate mean monthly irrigation drain inflows can be found in Appendices C and D.

Total estimated inflows from the Town of Pavillion WWTF was estimated at 28 acre-feet/yr based on a design flow capacity of 0.025 million gallons/day.

TSS Concentrations

Mean monthly TSS concentrations from the nine irrigation drains were calculated for both the pre and post-BMP implementation periods. This analysis was necessary to quantitatively determine sediment loads into Ocean Lake and the reduction in sediment load from drains #7, #6 and #4, where sediment BMP's have been implemented. Data collected by Petty et al. (1993) were used to calculate mean monthly TSS concentrations for the pre-BMP period. WGFD data collected between 1997 and 2003 were used to calculate mean monthly TSS concentrations for drains #7, #6 and #4 for the post-BMP period. Similar to the water budget analysis, the absence of recent TSS data and the fact that sediment BMPs were not implemented on the remaining six drains required the assumption that post-BMP mean monthly TSS concentrations on these drains were unchanged from the pre-BMP period. Mean monthly TSS concentrations were only calculated for the ice-free months of April to November. Estimated mean monthly TSS concentrations on the nine irrigation drains for both the pre and post-BMP periods are shown in Tables 7 and 8, respectively. Data used to calculate mean monthly TSS concentrations can be found in Appendices C and D.

Table 7 – Estimated pre-BMP mean monthly TSS concentrations in mg/L from Ocean Lake's nine irrigation drains.

Month	#7	#6	#4	Sunnyside	#5	Schaper	#9	#3	LeClair
April	25.4	24.7	44.5	46.6	43.6	77.6	71.3	22.2	168.2
May	186.2	185.8	188.7	100.0	171.9	77.6	74.8	85.8	368.1
June	236.2	60.3	654.8	85.5	127.6	122.8	100.5	78.6	160.4
July	247.6	47.3	96.0	21.6	21.6	32.0	44.0	110.4	52.2
August	67.8	72.6	129.4	125.1	143.5	68.3	221.7	191.4	127.8
September	47.5	21.8	85.2	89.6	22.0	87.3	43.3	65.0	64.5
October	106.2	72.1	79.3	91.0	75.5	77.6	76.5	111.1	78.4
November	164.8	122.4	73.4	92.3	129.0	77.6	109.6	111.1	92.3

TSS for October interpolated by averaging September and November values.

Where data were missing for an entire month with no data from the prior or following month, the average of all monthly values was used

Table 8 – Estimated post-BMP mean monthly TSS concentrations in mg/L from Ocean Lake's nine irrigation drains. Highlighted values were calculated from data collected by WGFD.

Month	#7	#6	#4	Sunnyside	#5	Schaper	#9	#3	LeClair
April	9.7	49.6	30.8	46.6	43.6	77.6	71.3	22.2	168.2
May	40.5	68.3	90.4	100.0	171.9	77.6	74.8	85.8	368.1
June	42.1	27.6	96.9	85.5	127.6	122.8	100.5	78.6	160.4
July	42.7	19.0	83.4	21.6	21.6	32.0	44.0	110.4	52.2
August	35.0	25.8	44.0	125.1	143.5	68.3	221.7	191.4	127.8
September	17.4	25.1	37.0	89.6	22.0	87.3	43.3	65.0	64.5
October	22.3	29.0	19.8	91.0	75.5	77.6	76.5	111.1	78.4
November	30.0	34.9	57.5	92.3	129.0	77.6	109.6	111.1	92.3

TSS for October interpolated by averaging September and November values.

Where data were missing for an entire month with no data from the prior or following month, the average of all monthly values was used

TSS values for #6 are averages calculated from WGFD data collected on both Drains 6A and 6B

The estimated TSS concentration from the Town of Pavillion WWTF is based on the facility's current daily maximum effluent limit of 300 mg/L.

EXISTING SEDIMENT LOADS

Irrigation Drains

Estimates of sediment loading to Ocean Lake from the nine irrigation drains were calculated for the pre and post-BMP periods. For the nine irrigation drains, sediment loads in tons per month were estimated by multiplying the mean monthly flows in Tables 5 and 6 by the mean monthly TSS concentrations in Tables 7 and 8, respectively with the appropriate conversion factors. The estimated sediment load in tons per month into Ocean Lake for each of the nine irrigation drains for both the pre and post-BMP periods is shown in Tables 9 and 10, respectively.

Table 9 – Estimated pre-BMP mean monthly and total annual sediment contributions in tons from Ocean Lake's nine irrigation drains.

Month	#7	#6	#4	Sunnyside	#5	Schaper	#9	#3	LeClair
April	11.1	7.4	16.6	4.1	2.7	20.4	1.2	0.7	15.9
May	343.4	419.1	313.1	61.6	93.9	21.1	12.3	6.4	44.9
June	342.8	59.0	774.3	21.9	29.5	23.5	5.3	4.6	6.2
July	472.8	67.0	158.2	7.2	10.2	9.5	2.9	10.2	4.9
August	174.7	127.1	264.1	60.0	53.7	18.8	27.2	26.4	10.9
September	121.8	57.6	114.8	44.1	6.7	26.7	7.6	7.2	8.1
October	210.7	115.6	118.6	23.2	14.8	22.8	8.5	9.8	7.3
November	210.1	56.5	106.1	0.1	9.6	20.4	4.3	9.5	8.3
Average total tons (April - November):	1887.3	909.4	1865.8	222.2	221.0	163.1	69.2	74.8	106.5
Total tons to Ocean Lake from all drains (April - November):	5519.3								
Percent of total sediment load:	34.2	16.5	33.8	4.0	4.0	3.0	1.3	1.4	1.9

Table 10 – Estimated post-BMP mean monthly and total annual sediment contributions in tons from Ocean Lake's nine irrigation drains.

Month	#7	#6	#4	Sunnyside	#5	Schaper	#9	#3	LeClair
April	4.2	14.9	11.5	4.1	2.7	20.4	1.2	0.7	15.9
May	68.4	154.1	54.9	61.6	93.9	21.1	12.3	6.4	44.9
June	80.3	27.0	152.3	21.9	29.5	23.5	5.3	4.6	6.2
July	122.8	27.0	175.3	7.2	10.2	9.5	2.9	10.2	4.9
August	132.9	45.2	141.5	60.0	53.7	18.8	27.2	26.4	10.9
September	44.6	66.3	93.2	44.1	6.7	26.7	7.6	7.2	8.1
October	44.2	46.5	7.8	23.2	14.8	22.8	8.5	9.8	7.3
November	38.2	16.1	2.2	0.1	9.6	20.4	4.3	9.5	8.3
Average total tons (April - November):	535.6	397.1	638.7	222.2	221.0	163.1	69.2	74.8	106.5
Total tons to Ocean Lake from all drains (April - November):	2428.3								
Percent of total sediment load:	22.1	16.4	26.3	9.2	9.1	6.7	2.9	3.1	4.4

The estimated reduction in total annual sediment load to Ocean Lake from the nine irrigation drains was 3,091 tons from the pre to post-BMP period. This equates to a 56% decrease in annual sediment load to Ocean Lake from the BMP's implemented on drains #7, #6 and to some extent #4. Considering only drains #4, #6, and #7, the annual sediment load reduction from the pre to post-BMP periods was 76%. Current estimated sediment load to Ocean Lake from the irrigation drains is 2,428 tons per year.

Town of Pavillion WWTF

Estimated sediment loading to Ocean Lake from the Town of Pavillion WWTF was estimated at 11 tons/yr based on the estimated annual inflow of 28 acre-feet/yr and the facility's current daily maximum effluent limit for TSS of 300 mg/L.

Ocean Lake

The TSI-SD values for the period 1980 to 2007 indicate Ocean Lake is generally mesotrophic, though trending toward eutrophy with time. The mean TSI-SD for this period of record is 62. The mean TSI-SD for the most recent data available (2007) is 61. Because of annual variability in TSI-SD, the TSI-SD value of 62 was selected to represent the existing trophic condition of Ocean Lake. Using the power curve model in Figure 2, a mean TSS of 6.2 mg/L was back-calculated from the TSI-SD of 62 – representing the existing mean TSS concentration in Ocean Lake. The existing sediment load (E_{ISL}) in Ocean Lake in tons/yr begins with the calculation of how much sediment is current existing Ocean Lake annual using equation 1:

$$E_{ISL} = V * E_{TSS} * \tau * C_1 * C_2 * C_3$$

Where:

V = Reservoir volume in acre-feet

E_{TSS} = Existing TSS concentration in mg/L

T = Hydraulic Residence Time

C_1 = Conversion Factor 1 of 1,233,482 L/acre-feet

C_2 = Conversion Factor 2 of 0.00000220462262 lbs/mg

C_3 = Conversion Factor 3 of 0.0005 tons/lb

The calculation for the existing annual sediment load exiting Ocean Lake is as follows:

71,635 acre-feet * 6.2 mg/L * 2.12138 * 1,233,482 L/acre-feet * 0.00000220462262 lbs/mg * 0.0005 tons/lb

This equates to 1,281 tons of sediment exiting Ocean Lake annually. However, to calculate the existing load capacity of Ocean Lake, a reservoir trap efficiency coefficient must be applied. Trap efficiency (TE) is the percent of inflowing sediment that remains in a lake or reservoir. Some proportion of the inflowing sediment leaves the reservoir through the outlet. The proportion remaining in the reservoir is typically estimated based on the TE. Because available data are extremely limited, calculation of a TE with available data did not seem appropriate considering that sediment loads to and within Ocean Lake is based on an extremely limited dataset and thus may not adequately quantify sediment inputs, outputs and retention. There are several methods to calculate TE, though most provide a similar result. Brune's Curve (Brune 1953) is a common method for calculating TE for small reservoirs. Brune's Curve is based on the ratio of reservoir capacity (C) and mean annual inflow (I) as show in equation 2:

$$TE = 0.97^{[0.19^{(LOG\ C/I)}]}$$

The calculation for the Ocean Lake TE is as follows using the estimated total annual existing inflow from Table 6:

TE = 0.97^[0.19^(LOG 71,635 acre-feet/35,246 acre-feet)]

The TE for Ocean Lake is 0.981903. Utilizing the TE for Ocean Lake results in an existing sediment load (E_{SL}) of 70,790 tons/yr using equation 3:

E_{SL} = 1,281 tons/(1 - TE)

TARGET SEDIMENT LOAD CAPACITY

The target sediment load capacity of Ocean Lake is determined by using the TMDL target TSI-SD of 60 which is equivalent to a Secchi depth of 1.0 meter. Using the power curve model between Secchi depth and TSS from Figure 2, the target TSS concentration is 5.1 mg/L based on a Secchi depth of 1.0 meter. Using equation 1 above, the target sediment load capacity for Ocean Lake is calculated as:

71,635 acre-feet * 5.1 mg/L * 2.12138 * 1,233,482 L/acre-feet * 0.00000220462262 lbs/mg * 0.0005 tons/lb

This equates to 1,054 tons of sediment expected to exit Ocean Lake annually. This value and Ocean Lake's TE of 0.981903 is then applied to equation 3 to calculate the target sediment load (T_{SL}):

T_{SL} = 1,054 tons/(1 - TE)

The result is a target sediment load capacity of 58,230 tons/yr.

LINKAGE OF SOURCES AND SEDIMENT LOADS

The existing total annual sediment load from the nine irrigation drains was estimated at 2,428 tons/yr. Sediment contributions from the Town of Pavillion WWTF was estimated at 11 tons/yr. Ocean Lake's current sediment load is 70,790 tons/yr. Assuming the sediment loads from the nine irrigation drains and the Town of Pavillion WWTF contribute to the existing sediment load capacity of Ocean Lake, the estimated sediment loading due to internal re-suspension of sediment within the lake is 68,361 tons/yr. To put it another way, 97% of the existing sediment load in Ocean Lake is due to internal sediment re-suspension. This estimate compliments the findings by Petty et al. (1993) and WDEQ/WQD (2005) that internal sediment re-suspension is the primary reason for the Ocean Lake sediment impairment.

DEPARTURE FROM TARGET SEDIMENT LOAD CAPACITY

The target sediment load capacity for Ocean Lake is 58,230 tons/yr. The existing sediment load to and within Ocean Lake is 70,790 tons/yr. Excluding the margin of safety, this results in a departure from the target sediment load capacity of 12,560 tons/yr or an 18% reduction in the existing sediment load. Based on the linkage of sources and sediment loads, approximately 81% of the departure or 10,121 tons/yr is due to re-suspension of lake sediment. The nine irrigation drains contribute 2,428 tons/yr of sediment or approximately 2% of the departure. The Town of Pavillion WWTF contributes 11 tons/yr of sediment or less than 1% of the departure.

POLLUTANT ALLOCATION

A TMDL allocates pollutant loads to all sources including point (wasteload allocations or WLA) and non-point and background sources (load allocations or LA). In addition, a margin of safety (MOS) is included to account for the uncertainty inherent in the analysis and ensure that designated uses are protected in the future. Conceptually a TMDL can be defined as:

$$TMDL = WLAs + LAs + MOS$$

The MOS is a required part of the TMDL development process. There are two basic methods for incorporating the MOS. The first is an implicit method where the MOS is incorporated into conservative model assumptions when developing load allocations. The second is explicit where a specific portion of the TMDL load allocation is assigned to the MOS. The TMDL for Ocean Lake includes an explicitly established MOS. The TMDL for Ocean Lake equals the target sediment load capacity of 58,230 tons/yr.

Wasteload Allocation

The Town of Pavillion wastewater treatment facility is the sole point source in the Ocean Lake watershed. It has been determined that this facility contributes a negligible quantity of sediment to Ocean Lake of only 11 tons/yr. Therefore, the wasteload allocation (WLA) for this TMDL is set at 11 tons/yr.

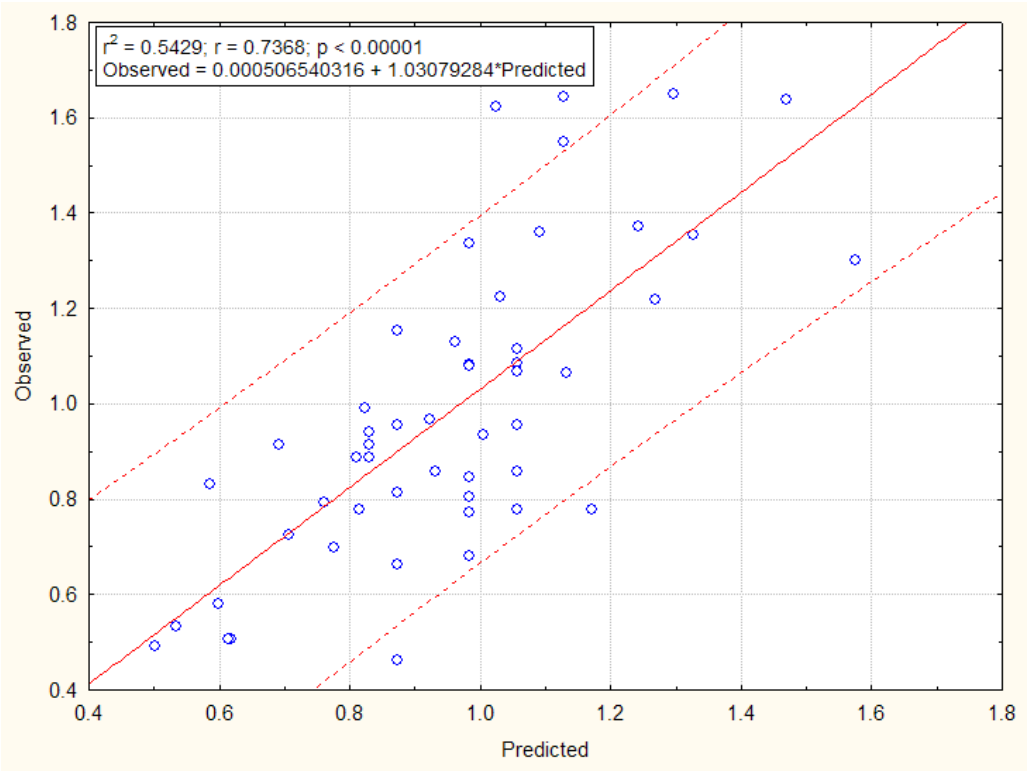
Load Allocation

Non-point sources of sediment in Ocean Lake come predominantly from internal re-suspension of bottom sediments and a small percentage from the nine irrigation drains. The desired target is to reduce the current level of excess sediment in the lake primarily through effective controls that reduce internal sediment re-suspension. Accounting for the explicit MOS, the load allocation (LA) established for Ocean Lake is 41,132 tons/yr of sediment.

Margin of Safety

The margin of safety (MOS) for the Ocean Lake TMDL is explicit. The 90% prediction interval was calculated from a linear regression model based on the measured TSS concentrations used to develop the power curve model in Figure 3 and the predicted TSS values derived from this same model using measured Secchi depth for the same data points. Figure 4 shows the results of this analysis.

Figure 4 – Linear regression of predicted versus measured TSS concentrations used to develop the power regression model in Figure 3. Note values are log (X+1) transformed. The 90% prediction limits are represented by the dashed red lines.



The overall difference between the upper 90% predicted limit and the best fit linear regression line was 0.37 units. This difference of 0.37 units was then added to each of the predicted TSS concentration values to develop error-adjusted predicted TSS concentrations (i.e., predicted TSS concentrations at the 90% predicted limit). The error-adjusted predicted TSS concentrations represented an overall 29% margin of error from the predicted TSS values. This 29% margin of error represents the MOS for the target sediment load capacity or 17,087 tons/yr.

Summary of Load Allocations

Approximately 2% of the predicted load capacity of Ocean Lake or 1,054 tons/yr of sediment was allocated to the nine irrigation drains. This allocation was based on the predicted sediment load that would exit Ocean Lake once the lake is at the target load capacity as previously described. The irrigation drains' allocation was set equal to the predicted sediment load exiting Ocean Lake to maintain a no net change in sediment contribution to the lake from the irrigation drains. Less than 1% of the predicted sediment load capacity of Ocean Lake or 11 tons/yr of sediment was allocated to the Town of Pavillion WWTF based on the existing design flow capacity and current maximum daily TSS limit. The majority of the needed sediment load reduction will come from stabilization of re-suspended sediments in Ocean Lake of which 40,078 tons/yr were allocated. Because of inherent error in the model used to predict the target sediment load capacity of Ocean Lake, an allocation of 17,087 tons/yr was applied to the MOS. Table 11 summarizes the current, allocated and needed reduction in sediment loads to achieve

designated use support for Ocean Lake. According to EPA, a daily load expression is a required element in all TMDL documents. Table 12 describes the current, allocated and needed reduction in sediment loads as a daily load expression considering both a 365 day year and the 244 day 'critical condition' period.

Table 11 – Ocean Lake sediment TMDL load allocations in tons/yr.

Source	Current	Allocation	Reduction
Internal sediment re-suspension	68,351	40,078	28,273
Nine irrigation drains	2,428	1,054	1,374
Town of Pavillion WWTF	11	11	
Margin of Safety		17,087	
Total	70,790	58,230	29,647

Table 12 – Ocean Lake sediment TMDL load allocations in tons/day. Values are expressed as a 365 day year (left value) and the 244 day 'critical condition' period (right value) for internal sediment re-suspension, the nine irrigation drains and the margin of safety. The 244 day period does not apply to the Town of Pavillion WWTF since effluent from this facility can be discharged throughout a 365 day year.

Source	Current	Allocation	Reduction
Internal sediment re-suspension	187 / 280	110 / 164	78 / 116
Nine irrigation drains	7 / 10	3 / 4	4 / 6
Town of Pavillion WWTF	< 1	< 1	
Margin of Safety		47 / 70	
Total	194 / 290	160 / 239	81 / 122

MONITORING

Further monitoring is needed to evaluate the effectiveness of maintaining existing BMPs in addition to implementation of future BMPs that control sediment inputs and internal sediment re-suspension in Ocean Lake. Additional monitoring will also provide the necessary information to determine progress towards attainment of the TMDL and when designated uses are supported in Ocean Lake. Monitoring recommendations include but are not limited to:

1) Monthly monitoring (April through November) of TSS and Secchi depth at one or more historically sampled locations in Ocean Lake.
2) Monthly measurements (April through November) of flow and TSS on irrigation drains #7, #6 and #4. Monitoring should be conducted at historical monitoring sites on these three drains that are closest to their confluences with Ocean Lake.
3) Conduct periodic measurements of flow and TSS on the remaining six drains to more accurately quantify sediment loading to Ocean Lake.

4) Conduct a complete chemical, physical and biological evaluation of Ocean Lake to establish existing baseline conditions for comparison to future data collections to evaluate trends in these attributes over time.
5) Monthly measurements (April through November) of flow and TSS from Ocean Lake outflows at the historical monitoring location.
6) Wyoming Game and Fish Department should continue to conduct periodic fish population surveys of Ocean Lake to evaluate success and recruitment of walleye and other warm-water fishes.

PUBLIC PARTICIPATION

The draft Ocean Lake Sediment TMDL was submitted to the Ocean Lake Steering Committee for input on February 13, 2009. A meeting was held on March 18, 2009 in Riverton, Wyoming with the Ocean Lake Steering Committee to discuss comments on the draft Ocean Lake Sediment TMDL.

The revised draft Ocean Lake Sediment TMDL was submitted for public notice on May 1, 2009. Public comments on the draft TMDL were received up to May 30, 2009. The received public comments and WDEQ/WQD's responses are provided in the Responses to Public Comments section. Following the public notice period, a public meeting was held at the Fremont County Library in Riverton, Wyoming on June 10, 2009 to present the draft Ocean Lake Sediment TMDL for public comment. Comments received at the public meeting were considered and where appropriate, incorporated into the TMDL.

RESPONSES TO PUBLIC COMMENTS

The received public comments and WDEQ/WQD's responses on the draft Ocean Lake Sediment TMDL follow.

Comment 1 - "The first concern of the Steering Committee and the Conservation District is related to the age of the data used in the TMDL development and the assumptions that were developed based on this data.".

Response 1 - As noted in the Ocean Lake TMDL, the analyses of current and targeted sediment loadings by source category are 'best estimates' based on extrapolations from the best available data and professional assumptions. However, TMDL targets and source allocations can be modified as more information becomes available. If future data indicate the TMDL or targets are unachievable, the targets and/or TMDL can be revised to achieve applicable water quality standards. Keep in mind that according to Wyoming's TMDL Workplan, this TMDL would be reassessed at least every five years. Reassessments allow for refinement of the TMDL as a result of new information or if the conditions in the watershed have changed appreciably over time.

Comment 2 - "We also understand that more recent TSS data was included in Appendix D but it does not appear to have been included in the power curve model.".

Response 2 - The power curve model was developed from paired TSS and Secchi depth data collected within Ocean Lake. While recent Secchi depth data on Ocean Lake was provided, unfortunately, there

was no accompanying paired TSS data collected on Ocean Lake. Consequently, the power curve model could not be updated.

Comment 3 - "Additionally, the group feels that the noted 56% decrease in sediment load is misleading since data pre-BMP and post-BMP is the same for six of the nine drains. The reduction in sediment from drains #7, #6 and #4 (using data in Tables 9 and 10) was 76%.".

Response 3 - In order to calculate a reasonable pre- and post-BMP sediment load from the nine irrigation drains, assumptions had to be incorporated with the best available data. Only post-BMP flow and/or sediment data were available for selected months on drains #7, #6 and #4. These data were incorporated into the calculations of post-BMP sediment load from the nine irrigation drains. Because no post-BMP flow or sediment data was available for the remaining six drains, a reasonable assumption was made that these parameters were similar between the pre- and post-BMP periods. This assumption is clearly described within the Ocean Lake TMDL. This assumption was also supported by information that indicated no sediment reduction efforts were implemented on the remaining six drains. However, the Ocean Lake TMDL will note that a 76% reduction in sediment load was realized from drains #7, #6 and #4 between the pre- and post-BMP periods.

Comment 4 - "We also question the in-flow data in Tables 5 and 6 which indicate that more water flowed to Ocean Lake after BMPs were implemented than before. Using the same in-flow information (much of which was extrapolated from "single point-in-time measurements") for six of the nine drains for pre- and post-BMPS is misleading.".

Response 4 - The Ocean Lake TMDL was developed using the most recent data available. Similar to the previous response, post-BMP flow data on the nine irrigation drains were only available for selected months on drains #7 and #4. These data were incorporated into the calculations of the post-BMP water budget for the nine irrigation drains. Because no post-BMP flow data were available for the remaining six drains, a reasonable assumption was made that flow for these six drains was similar between the pre- and post-BMP periods. This assumption is clearly described within the Ocean Lake TMDL. While it is accurate that estimated total flow from the nine irrigation drains was greater during the post-BMP (35,246.4 acre-feet) relative to the pre-BMP (33,685.5 acre-feet) periods, the difference is statistically insignificant. Therefore for all practical purposes, the water budget from the nine irrigation drains was similar between the pre- and post-BMP periods.

Comment 5 - "Give the importance of having an accurate TMDL, and the need to reflect changes that increased irrigation efficiency and other Best Management Practices (BMPs) (along all drains) have brought to the watershed, it is the opinion of this group that WDEQ should work with local, state and federal agencies to gather existing information and to develop new data on which to base future decisions and TMDL related actions.".

Response 5 - WDEQ/WQD concurs that it is important that the Ocean Lake TMDL be as accurate as possible. The Ocean Lake TMDL is as accurate as it can be given the limited information that was available from local, state and federal agencies. WDEQ/WQD is committed and advocates continued

cooperation with local, state and federal agencies to collect additional data that may be used during periodic reassessments of the TMDL.

Comment 6 - "The calculations and work put into the TMDL may seem mathematically logical given the goal of reducing sedimentation in Ocean Lake in order to meet the criteria necessary given its designated use. However, there is a very serious concern as to the capacity to meet the TMDL developed or if it is even practical or reasonable to imagine that it can be done in an economic fashion. As currently written, the TMDL requires a significant reduction in the sediment input (< 2,000 tons per year). The group has considerable concern over the possibility of meeting this number. Upon reviewing the TMDL and looking at expected and acceptable erosion rates within the agricultural areas (using United States Department of Agriculture Natural Resources Conservation Service soil maps and soil loss prediction equations), it appears very unlikely that the sediment budget can be met without introducing significant sediment capture structures and related BMPs within the irrigation return flow system. Tolerable soil loss rates, as outlined in NRCS policy, are well in excess of the numbers that would need to be met if the TMDL, as written, were to be implemented. It appears highly unlikely that the goals outlined in the TMDL can be met without considerable economic investment in the system.".

Response 6 - It is important to recognize that the sum of all pollutant allocations in a TMDL must result in attainment of the water quality standard(s) throughout the waterbody. Given the possibility of considerable economic investment to meet the Ocean Lake TMDL target allocations, the group may want to consider an economic analysis in the TMDL implementation plan for Ocean Lake. The economic analysis could not only determine the net impact of implementing the TMDL on state and local resources, but provide reasonable suggestions for dedication of resources to implement the corrective actions prescribed in the implementation plan that will be developed for Ocean Lake. In any event, economic and social conditions as well as resource use should be considered prior to implementation of corrective actions to meet the TMDL target allocations.

Comment 7 - "Although the TMDL gave considerable credence to the effect that existing sediment has on the lake, there was no associated solution for this problem. The desired target (page 22) is "to reduce the current level of excess sediment in the lake primarily through effective controls that reduce internal sediment re-suspension". What are the "effective controls"? How does WDEQ plan to stabilize the "re-suspended sediments" (page 23)?"...."The Steering Committee and the Conservation District would like to see WDEQ suggestions for solutions to the issue of re-suspension of existing sediment (the primary source of the impairment) and for the removal of excess sediment."

Response 7 - The Federal Clean Water Act §303(d) does not require the development of TMDL implementation plans. While implementation planning is optional within TMDLs from the federal perspective, States may have requirements and expectations for necessary follow-up in implementing the TMDL. Simply stated, the sole purpose of the TMDL is to specify the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards. The total target load or "loading capacity" of a waterbody is set at a level necessary to achieve the applicable water quality standards. The State of Wyoming and WDEQ does not require the inclusion of an implementation plan in a TMDL. WDEQ has however, incorporated descriptions of the existing watershed plans and possible recommendations (at the request of the Steering Committee) for attaining the target sediment load for Ocean Lake. Ultimately, it is

up to the local community and interested parties to develop a reasonable implementation plan that will serve as the vehicle for addressing the sediment issue in Ocean Lake while also considering the economic and social realities.

Comment 8 - "The TMDL indicates in several places that Ocean Lake was man-made. Ocean Lake (formerly known as Dry Lake) is NOT a man made lake.".

Response 8 - WDEQ has provided clarification in the Ocean Lake TMDL that Ocean Lake is not a man-made lake.

Comment 9 - "Ocean Lake receives water from irrigation return flows and from underground tile drains which flow into the nine drains which, in turn, flow into Ocean Lake. The water in Ocean Lake is NOT stored for irrigation use.".

Response 9 - WDEQ has incorporated language into the Ocean Lake TMDL to reflect this information.

Comment 10 - "Table 1 indicates the presence of subdivisions, but the data is quite dated. Numerous subdivisions have been proposed and developed since 2002. There was also little definition given to the explanation of urban/rural areas. The group would like to see a map of what you consider the "contributing watershed" and the data source cited.".

Response 10 - The most recent landscape data we were able to obtain on urban/residential development in the Ocean Lake area was from 1996. WDEQ has incorporated language into the Ocean Lake TMDL to recognize new subdivision development in the area since 2002. Further description of urban areas and a map that illustrates the contributing watershed to Ocean Lake has been inserted into the Ocean Lake TMDL.

Comment 11 - "Ocean Lake has been on the Wyoming 305(b) report since 1992 and was listed as threatened in 1996 on the Wyoming DEQ 303(d) list. Throughout the document the listed date is 1998 which is incorrect.".

Response 11 - The Ocean Lake TMDL has been revised to reflect the 1996 listing.

Comment 12 - "Since only the months of April through November were considered when calculating averages, the Steering Committee and Conservation District suggest the titles be "seasonal" rather than "annual". This will avoid confusion when examining the data.".

Response 12 - Clarification is provided under the Critical Condition and Temporal Variation section of the TMDL.

Comment 13 - "The Steering Committee and the Conservation District feel that it is important to note that Drain #4 had considerably less work put into it when compared to Drains #6 and #7. This was primarily due to the fact that Drain #4 contributed less sediment (12%). It is also important to recognize that the soil type is significantly different. The soil types on the eastern part of the lake are more susceptible to

erosion than are their counterparts on the western side of the lake. Additionally, Drain #4 is designed by the Midvale Irrigation District as an emergency outlet should a structural failure occur in the system. There is concern about an emergency discharge, how it would impact existing and future BMPs and if it has been considered in the TMDL development.".

Response 13 - Additional clarification has been incorporated into the Ocean Lake TMDL to reflect this information. Concerns on how existing and future BMPs on Drain #4 would be impacted by emergency discharges should be incorporated into the implementation plan developed for Ocean Lake.

Comment 14 - "We appreciate your acknowledgement of the plan [Ocean Lake Watershed Water Quality Management Plan – February 18, 2009] but do not feel that it is necessary to quote the goals and objectives (five pages in the final document) of the plan. We also feel that it would be more productive for agencies to work together to implement this existing plan rather than write another plan as suggested on page 28.".

Response 14 - WDEQ minimized the description of the Ocean Lake Watershed Water Quality Management Plan within the Ocean Lake TMDL and maintained the reference for the reader. If desired by the Steering Committee and local community, the watershed plan can serve as the basis or template for development of an implementation plan to address sediment to Ocean Lake.

Comment 15 - "Landowners in the area are very concerned about the development of the TMDL, the timeframe for meeting the goals, who will determine compliance with the TMDL and what the consequences are if the goals of the TMDL are not met. This is especially a concern if the TMDL realistically cannot be achieved.".

Response 15 - It is the responsibility of the stakeholders in development of the implementation plan, to decide the most reasonable approach(s) for meeting the TMDL target goals. This includes development of a reasonable timeline for the implementation plan that includes a voluntary compliance schedule (for non-point source pollutants) to meet interim and final target goals and may also include additional monitoring and of course re-evaluation of the TMDL when new information becomes available. The timeframe for compliance with TMDLs varies and may take many years, though it is determined during development of the implementation plan. If it is determined in the future that the existing TMDL goals can not be achieved due to legitimate reasons, the TMDL can be re-opened to re-evaluate and/or adjust the TMDL goals. As stated previously, to ensure that the TMDL goals are reasonably achievable, the TMDL may be revaluated every five years (if new information is available) according to Wyoming's TMDL Workplan.

IMPLEMENTATION PLAN

Many of the concerns expressed in the public meeting for the draft TMDL centered on the uncertainty for implementing successful sediment reduction strategies that could significantly reduce the existing sediment load within Ocean Lake. Since approximately 3% of the annual load originates from the drains that discharge into Ocean Lake, the primary and obvious load to address is from internal re-suspension. However, the question remains on whether any implementation method(s) can provide "reasonable

assurance" that the needed load reduction is achievable. Addressing this problem will likely be an iterative process and, for success, needs a coordinated effort with all parties involved with this waterbody. As mentioned earlier in this document, a handful of studies defined the past conditions on Ocean Lake, the most recent of which occurred in 1993. However, an accurate and detailed description of current conditions on Ocean Lake has not been conducted. Furthermore, these past studies were limited in information and suggestions that could be used to improve, if possible, the water quality conditions of Ocean Lake. WDEQ/WQD and WGFD staff present at the Ocean Lake public meeting agreed that a coordinated effort to define the existing conditions, with clear goals and objectives, is needed.

The Ocean Lake TMDL can act as a springboard for the cooperative development of an implementation plan which should include, but is not limited to: a detailed study that looks at existing water quality conditions including fishery trends, potential action items to address internal loading, and, ultimately, clear and defined goals and objectives to address the sediment impairment in Ocean Lake. Several organizations and citizen groups are concerned with the current and future condition of this resource. Therefore, these organizations should be included at the earliest stages of implementation plan development. Development of an implementation plan for Ocean Lake should consider the local residents, resource users as well as economic and social conditions.

The Lower Wind River Conservation District (LWRCD), Ocean Lake Watershed Steering Committee (OLWSC), Ocean Lake landowners along with assistance provided by the United States Department of Agriculture (USDA) Conservation Service and Wyoming Association of Conservation Districts (WACD) developed a water quality management plan to address the sediment impairment in Ocean Lake (LWRCD 2009). The plan describes goals and objectives that range from additional monitoring to managing sediment from roads, shoreline and streambanks to address Ocean Lake's sediment impairment. Readers are encouraged to review the goals and objectives that address sediment and other potential pollutants in more depth by requesting a copy of the plan from the Lower Wind Conservation District, 508 N. Broadway, Riverton, Wyoming, 82501, phone: 307-856-7524. This plan could be used as a framework for development of the implementation plan, with the approval of the authors.

Possible implementation action items that address the internal re-suspension could be investigated concurrent to the coordinated effort to define the current conditions of Ocean Lake. One suggestion to revive some semblance of the historic fisheries may lie in a draw-down of the lake. Draw-down over several years may allow vegetation to establish and stabilize the bottom sediments. Once lake sediments become stabilized, the established vegetation could provide the necessary cover and forage base for fishes and other aquatic life once the lake is refilled. Another benefit of this measure could be improved water clarity and an enhancement in primary productivity and macrophyte growth which in turn could help improve the fishery. Lake draw-down has been considered a viable method to address sediment and nutrient impacts for some shallow lakes in the United States. Such a management strategy would likely require a substantial period of time to realize any benefits and of course would need to be carefully examined and planned by trained fisheries and aquatic habitat biologists familiar with Ocean Lake. The impact on local economic, recreational and other associated factors would also need to be fully evaluated if lake draw-down is considered a viable option.

The abundance of common carp in Ocean Lake may also contribute to sediment re-suspension through bottom disturbance that limits establishment of new aquatic vegetation and removal of existing aquatic

vegetation. Strategies for control must not only reduce overall biomass of the population but also reduce recruitment or reproduction. Prior to implementing common carp control, cost and benefits of removal, disposal and utilization should be considered by trained fisheries and aquatic habitat biologists. Control measures that could be implemented that include but are not limited to are:

- Limiting common carp access to adjacent wetlands and sloughs that provide habitat for reproduction.
- Mechanical barriers designed to prevent common carp from entering Ocean Lake.
- Biological controls to reduce common carp numbers.
- Removal should be targeted during times when common carp are concentrated.

As mentioned previously in this document, approximately 56% of the historical sediment contributions from the irrigation drains (primarily drains #6, #7 and to some extent #4) have been reduced through implementation of BMPs in the 1980s and 1990s. Efforts should be made to maintain the existing BMPs and consider implementing similar BMPs on reaches of irrigation drains that are currently contributing excess sediment to Ocean Lake, such as drain #4. These BMPs include but are not limited to:

- Drop and Grade Control Structures – These structures slow water velocities, minimizing channel incision (downcutting) and accelerated bank erosion. These are particularly effective to stabilize portions of channels that experience highly variable flows with elevated water velocities.
- Fencing – Installation of fences along drains minimizes intensive grazing of the riparian zone that could result in bank destabilization through hoof shear/trampling and loss of vegetative biomass. Adequate healthy riparian vegetation protects banks from accelerated erosion and limits lateral channel movement.
- Field Drain Culverts – These structures return water from irrigation fields to the drains in a controlled manner which minimizes accelerated bank erosion and excess sediment contributions.
- Reseeding – Reestablishment of riparian vegetation along banks would protect the banks during high flows and minimize accelerated bank erosion.
- Water Gaps – This BMP would provide water to private landowner(s) livestock yearlong while maintaining existing BMPs along the riparian zone throughout the rest of the drain(s).
- Diversion Dikes – These return water from irrigation fields to drain culverts in a controlled manner that minimizes accelerated bank erosion and excess sediment contributions. This has the added benefit of allowing Midvale Irrigation District access to maintain the drains.
- Limited Bank Sloping – When properly done, this BMP would adjust bank slopes that minimizes accelerated bank erosion and facilitates reseeding of the banks to establish adequate riparian vegetation to stabilize banks.

Regardless of what sediment reduction strategies are incorporated into the implementation plan, the plan needs to clearly define the desired short and long-term goals and outcomes, and what subsequent actions will occur if the goals and outcomes are not met. These and other possible implementation action items should be evaluated during the coordinated process to define the existing conditions of Ocean Lake.

REFERENCES

Brune, G.M. 1953. Trap efficiency of reservoirs. Transactions of the American Geophyical Union 34:407-418.

Carlson, R.E. 1977. A trophic state index for lakes. Limnology and Oceanography 25:378-382.

Carlson, R.E. and J. Simpson. 1995. A coordinator's guide to volunteer lake monitoring methods. North American Lake Management Society. 96 pp.

Chapman, S.S., S.A. Bryce, J.M. Omernik, D.G. Despain, J. Zumberge, and M. Conrad. 2003. Ecoregions of Wyoming (color poster with map, descriptive text, summary tables and photographs). Reston, Virginia. U.S. Geological Survey (map scale 1:1,400,000).

LWRCD. 2009. Ocean Lake Watershed Water Quality Management Plan. Lower Wind Conservation District, Ocean Lake Watershed Steering Committee and Ocean Lake Watershed Landowners.

Millis, R. L. and D. E. Pedlar. 1985. Ocean Lake Eutrophication and Water Quality Study. Wyoming Game and Fish Department, Fish Division.

Oglesby, R.T., J.H. Leach and J. Forney. 1987. Potential Stizostedion yield as a function of chlorophyll concentration with special reference to Lake Erie. Canadian Journal of Fisheries and Aquatic Sciences 44:166-170.

Omernik, J. M. and A. L. Gallant. 1987. Ecoregions of the west-central United States (map). United States Environmental Protection Agency, Corvallis, OR.

Petty, J.C., T.A. Wesche, Q.D. Skinner, and J.G. Hiller. 1993. Evaluation of Water Quality Associated with the Ocean Lake Hydrologic Unit Area. Masters Thesis. University of Wyoming Cooperative Extension Service. Laramie, Wyoming.

U.S. Environmental Protection Agency (USEPA). 2000. Nutrient criteria technical guidance manual: lakes and reservoirs. Report No. EPA-822-B00-001. Office of Water, Washington D.C.

U.S. Geological Survey (USGS). 1985. Geologic map of Wyoming. Compiled by J.D. Love and A.C. Christansen. Sheets 1,2, and 3. Reston, VA. G85135.

WDEQ/WQD. 2008a. Wyoming Department of Environmental Quality Total Maximum Daily Load (TMDL) Workplan Update. Water Quality Division, Cheyenne, WY.

WDEQ/WQD. 2008b. Wyoming's 2008 305(b) Integrated State Water Quality Assessment Report and 2008 303(d) List of Waters Requiring TMDLs. Water Quality Division, Cheyenne, WY.

WDEQ/WQD. 2007. Wyoming Water Quality Rules and Regulations, Chapter 1, Wyoming Surface Water Quality Standards. Water Quality Division, Cheyenne, WY.

WDEQ/WQD. 2005. Wyoming Department of Environmental Quality, Water Quality Division, Monitoring and Assessment Report – Ocean Lake. Water Quality Division, Cheyenne, WY.

WWDC. 1987. Erosion and Sediment Transport in the No. 7 "PILOT" Drain, Midvale. Irrigation District. Wyoming Water Development Commission.

WWDC. 1992. Drain No. 4 Sediment Transport Study. Wyoming Water Development Commission.

WWDC. 1993. Follow-up Report on Erosion and Sediment Transport in the No. 7 “PILOT” Drain, Midvale Irrigation District. Wyoming Water Development Commission.

APPENDIX

Appendix A – Secchi depth and TSS data used to develop the power curve model in Figure 1. Data obtained from Millis and Pedlar (1985), Petty et al. (1993), WDEQ/WQD (2003) and WGFD (1997-2007).

Site	Collection Date	Secchi Disk (m)	TSS (mg/L)	TSI (SD)	Secchi Disk (log_{10}+1)	TSS (log_{10}+1)
Ocean Lake Long Point	Jun-80	1.68	2.8	52.6	0.43	0.58
Ocean Lake Long Point	Jul-80	1.07	5.2	59.1	0.32	0.79
Ocean Lake Long Point	Aug-80	0.33	19.0	76.0	0.12	1.30
Ocean Lake Long Point	Sep-80	0.61	12.0	67.1	0.21	1.11
Ocean Lake Long Point	Oct-80	0.61	6.2	67.1	0.21	0.86
Ocean Lake East Shore	Jun-80	0.91	7.2	61.3	0.28	0.91
Ocean Lake East Shore	Jul-80	0.91	7.7	61.3	0.28	0.94
Ocean Lake East Shore	Aug-80	0.46	15.5	71.3	0.16	1.22
Ocean Lake East Shore	Sep-80	0.76	8.3	63.9	0.25	0.97
Ocean Lake East Shore	Oct-80	0.61	8.0	67.1	0.21	0.95
Ocean Lake Long Point	Apr-81	0.91	6.7	61.3	0.28	0.89
Ocean Lake Long Point	May-81	1.27	7.2	56.6	0.36	0.91
Ocean Lake Long Point	Jun-81	0.84	8.0	62.5	0.26	0.95
Ocean Lake Long Point	Jul-81	0.84	5.5	62.5	0.26	0.81
Ocean Lake Long Point	Aug-81	0.69	5.4	65.4	0.23	0.80
Ocean Lake Long Point	Sep-81	0.69	4.9	65.4	0.23	0.77
Ocean Lake Long Point	Oct-81	0.61	11.2	67.1	0.21	1.09
Ocean Lake East Shore	Apr-81	0.66	7.6	66.0	0.22	0.93
Ocean Lake East Shore	May-81	1.57	2.2	53.5	0.41	0.51
Ocean Lake East Shore	Jun-81	0.84	13.2	62.5	0.26	1.15
Ocean Lake East Shore	Jul-81	0.69	11.1	65.4	0.23	1.08
Ocean Lake East Shore	Aug-81	0.69	3.8	65.4	0.23	0.68
Ocean Lake East Shore	Sep-81	0.69	6.0	65.4	0.23	0.85
Ocean Lake East Shore	Oct-81	0.61	10.7	67.1	0.21	1.07
Ocean Lake Long Point	Jan-82	2.44	2.1	47.2	0.54	0.49
Ocean Lake Long Point	Apr-82	0.69	20.7	65.4	0.23	1.34
Ocean Lake Long Point	May-82	0.84	3.6	62.5	0.26	0.66
Ocean Lake Long Point	Jun-82	1.75	5.8	51.9	0.44	0.83
Ocean Lake Long Point	Jul-82	0.75	6.2	64.2	0.24	0.86
Ocean Lake Long Point	Aug-82	0.71	12.5	64.9	0.23	1.13
Ocean Lake Long Point	Sep-82	1.03	4.0	59.6	0.31	0.70
Ocean Lake Long Point	Oct-82	1.22	4.3	57.1	0.35	0.72
Ocean Lake East Shore	Jan-82	2.13	2.4	49.1	0.50	0.53
Ocean Lake East Shore	Apr-82	0.69	11.0	65.4	0.23	1.08
Ocean Lake East Shore	May-82	0.84	1.9	62.5	0.26	0.46
Ocean Lake East Shore	Jun-82	1.60	2.2	53.2	0.42	0.51
Ocean Lake East Shore	Jul-82	0.55	10.6	68.7	0.19	1.06
Ocean Lake East Shore	Aug-82	0.64	15.8	66.5	0.21	1.23
Ocean Lake East Shore	Sep-82	0.93	8.8	61.1	0.28	0.99
Ocean Lake East Shore	Oct-82	0.95	6.7	60.7	0.29	0.89
Ocean Lake Long Point	Apr-92	0.43	21.6	72.3	0.15	1.35
Ocean Lake Long Point	May-92	0.55	34.4	68.7	0.19	1.55
Ocean Lake Long Point	Jun-92	0.15	64.1	87.7	0.06	1.81
Ocean Lake Long Point	Jul-92	0.55	92.2	68.7	0.19	1.97
Ocean Lake Long Point	Jul-92	0.55	0.0	68.7	0.19	0.00
Ocean Lake Long Point	Jul-92	0.52	0.0	69.5	0.18	0.00
Ocean Lake Long Point	Aug-92	0.55	43.0	68.7	0.19	1.64
Ocean Lake Long Point	Sep-92	0.37	42.3	74.5	0.14	1.64
Ocean Lake Middle	Apr-92	0.44	43.6	71.8	0.16	1.65
Ocean Lake Middle	May-92	0.64	41.0	66.4	0.21	1.62
Ocean Lake Middle	Jun-92	1.58	93.8	53.4	0.41	1.98
Ocean Lake Middle	Jul-92	0.47	22.5	70.8	0.17	1.37
Ocean Lake Middle	Jul-92	0.58	21.9	67.9	0.20	1.36
Ocean Lake Middle	Jul-92	0.56	0.0	68.3	0.19	0.00
Ocean Lake Middle	Aug-92	0.47	65.4	70.8	0.17	1.82

Highlighted values were considered outliers and not used in development of the TMDL.

Appendix A – Secchi depth and TSS data used to develop the power curve model in Figure 1. Data obtained from Millis and Pedlar (1985), Petty et al. (1993), WDEQ/WQD (2003) and WGFD (1997-2007).

Site	Collection Date	Secchi Disk (m)	TSS (mg/L)	TSI (SD)	Secchi Disk (log_{10}+1)	TSS (log_{10}+1)
Ocean Lake	May-97	1.02	-	59.8	0.30	-
Ocean Lake	Jun-97	0.66	-	66.0	0.22	-
Ocean Lake	Jul-97	0.61	-	67.1	0.21	-
Ocean Lake	Aug-97	0.66	-	66.0	0.22	-
Ocean Lake	Sep-97	0.57	-	68.1	0.20	-
Ocean Lake	Oct-97	0.76	-	63.9	0.25	-
Ocean Lake	May-98	0.89	-	61.7	0.28	-
Ocean Lake	Jul-98	1.57	-	53.5	0.41	-
Ocean Lake	Aug-98	0.64	-	66.5	0.21	-
Ocean Lake	Oct-98	0.85	-	62.3	0.27	-
Ocean Lake Pelagic	Jul-03	0.61	5.0	67.1	0.21	0.78
Ocean Lake-Mills Pt.	Jul-03	0.52	5.0	69.5	0.18	0.78
Ocean Lake-Drain 6 Littoral	Jul-03	0.94	5.0	60.8	0.29	0.78
Ocean Lake NW	May-07	0.66	-	66.0	0.22	-
Ocean Lake NW	Jun-07	0.58	-	67.7	0.20	-
Ocean Lake NW	Jun-07	1.35	-	55.7	0.37	-
Ocean Lake NW	Jun-07	1.30	-	56.3	0.36	-
Ocean Lake NW	Jul-07	1.55	-	53.7	0.41	-
Ocean Lake NW	Aug-07	0.71	-	64.9	0.23	-
Ocean Lake NW	Aug-07	0.94	-	60.9	0.29	-
Ocean Lake NW	Sep-07	0.84	-	62.5	0.26	-
Ocean Lake NW	Oct-07	0.58	-	67.7	0.20	-
Ocean Lake NW	Oct-07	0.70	-	65.1	0.23	-
Ocean Lake NW	Oct-07	0.50	-	70.0	0.18	-
Ocean Lake NW	Nov-07	1.57	-	53.5	0.41	-
Ocean Lake Mid	May-07	0.76	-	63.9	0.25	-
Ocean Lake Mid	Jun-07	0.66	-	66.0	0.22	-
Ocean Lake Mid	Jun-07	1.14	-	58.1	0.33	-
Ocean Lake Mid	Jun-07	1.68	-	52.6	0.43	-
Ocean Lake Mid	Jul-07	1.98	-	50.1	0.47	-
Ocean Lake Mid	Aug-07	0.66	-	66.0	0.22	-
Ocean Lake Mid	Aug-07	0.89	-	61.7	0.28	-
Ocean Lake Mid	Sep-07	0.64	-	66.5	0.21	-
Ocean Lake Mid	Oct-07	0.64	-	66.5	0.21	-
Ocean Lake Mid	Oct-07	0.75	-	64.1	0.24	-
Ocean Lake Mid	Oct-07	0.80	-	63.2	0.25	-
Ocean Lake Mid	Nov-07	1.85	-	51.1	0.46	-
Ocean Lake SE	May-07	0.71	-	64.9	0.23	-
Ocean Lake SE	Jun-07	0.69	-	65.4	0.23	-
Ocean Lake SE	Jun-07	1.30	-	56.3	0.36	-
Ocean Lake SE	Jun-07	0.89	-	61.7	0.28	-
Ocean Lake SE	Jul-07	0.99	-	60.1	0.30	-
Ocean Lake SE	Aug-07	0.71	-	64.9	0.23	-
Ocean Lake SE	Aug-07	0.46	-	71.3	0.16	-
Ocean Lake SE	Sep-07	0.66	-	66.0	0.22	-
Ocean Lake SE	Oct-07	0.61	-	67.1	0.21	-
Ocean Lake SE	Oct-07	0.75	-	64.1	0.24	-
Ocean Lake SE	Oct-07	0.80	-	63.2	0.25	-
Ocean Lake SE	Nov-07	2.01	-	50.0	0.48	-

Appendix B – Data obtained from USGS gage 06246500 and by Petty et al. (2003) to calculate Ocean Lake outflows.

USGS Gage 06246500

Water Year	Annual Outflow (m^3)	Geometric Average Annual Outflow (m^3)	Geometric Average Annual Outflow (acre-feet)
1979	44800000		
1980	36800000		
1981	34600000	41652446	**33768**
1982	40700000		
1983	54001550		

Ocean Lake outflows measured by Petty et al. (1993)

Date	CFS
4/18/1992	22.9
5/19/1992	26.2
5/26/1992	31.7
6/3/1992	38.8
6/21/1992	61.7
7/8/1992	54.8
7/30/1992	60.5
8/18/1992	67.0
8/26/1992	61.6
9/19/1992	18.6
11/25/1992	38.2

Geometric Average Daily Outflow (cfs)	40.2
Geometric Average Daily Outflow (m^3/day)	98352.3
Geometric Average Annual Outflow (m^3)	35898603.0
Geometric Average Annual Outflow (acre-feet)	**29103.5**

Appendix C – Measured discharge (cfs) and TSS (mg/L) from Ocean Lake drains (Petty et al. (1993).

Drain	Date	Discharge	TSS	Drain	Date	Discharge	TSS	Drain	Date	Discharge	TSS
Sunnyside	4/18/1992	1.09	46.56	LeClair	4/18/1992	1.17		#3	4/18/1992	0.40	22.22
Sunnyside	5/20/1992	6.03	41.82	LeClair	5/20/1992	1.38	356.57	#3	5/20/1992	0.97	81.87
Sunnyside	5/27/1992	9.01	239.19	LeClair	5/27/1992	1.54	379.95	#3	5/27/1992	0.81	89.83
Sunnyside	6/3/1992	3.42	67.73	LeClair	6/3/1992	0.39	113.82	#3	6/3/1992	0.57	64.47
Sunnyside	6/22/1992	2.93	108.04	LeClair	6/22/1992	0.59	225.99	#3	6/22/1992	0.91	95.76
Sunnyside	7/8/1992	2.65		LeClair	7/8/1992	0.79	117.50	#3	7/8/1992	1.25	46.47
Sunnyside	7/28/1992	6.05	21.55	LeClair	7/28/1992	1.58	23.21	#3	7/28/1992	0.98	262.05
Sunnyside	8/18/1992	5.74	130.29	LeClair	8/18/1992		239.86	#3	8/18/1992	1.32	196.69
Sunnyside	8/27/1992	5.74	120.06	LeClair	8/27/1992	1.02	68.07	#3	8/27/1992	2.06	186.19
Sunnyside	9/20/1992	6.09	89.56	LeClair	9/20/1992	1.56	64.52	#3	9/20/1992	1.37	65.01
Sunnyside	11/25/1992	0.02	92.34	LeClair	11/25/1992		92.34	#3	11/25/1992		

Drain	Date	Discharge	TSS	Drain	Date	Discharge	TSS	Drain	Date	Discharge	TSS
#4	4/18/1992	4.61	44.47	#5	4/18/1992	0.77	43.61	#6	4/18/1992	3.72	24.72
#4	5/20/1992	20.40	183.28	#5	5/20/1992	8.39	205.08	#6	5/20/1992	27.47	459.24
#4	5/27/1992	19.36	194.23	#5	5/27/1992	5.09	144.09	#6	5/27/1992	26.55	75.15
#4	6/3/1992	15.33	1833.00	#5	6/3/1992	3.11	164.13	#6	6/3/1992	16.79	52.49
#4	6/22/1992	13.97	233.93	#5	6/22/1992	2.62	99.18	#6	6/22/1992	8.74	69.30
#4	7/8/1992	17.42	142.21	#5	7/8/1992	5.23	21.49	#6	7/8/1992	20.36	47.25
#4	7/28/1992	22.35	64.80	#5	7/28/1992	6.09	21.79	#6	7/28/1992	14.17	
#4	8/18/1992	24.55	175.47	#5	8/18/1992	3.47	88.16	#6	8/18/1992	25.56	
#4	8/27/1992	24.33	95.40	#5	8/27/1992	5.79	233.43	#6	8/27/1992	17.18	72.61
#4	9/20/1992	16.67	85.23	#5	9/20/1992	3.76	22.02	#6	9/20/1992	32.67	21.83
#4	11/25/1992		73.36	#5	11/25/1992	0.92	129.02	#6	11/25/1992	5.71	122.41

Drain	Date	Discharge	TSS	Drain	Date	Discharge	TSS	Drain	Date	Discharge	TSS
#9	4/18/1992	0.20	71.34	#7	4/18/1992	5.39	25.42	Schaper	4/18/1992		
#9	5/20/1992	2.24	40.61	#7	5/20/1992	18.83	161.31	Schaper	5/20/1992		
#9	5/27/1992	1.74	137.75	#7	5/27/1992	25.88	214.92	Schaper	5/27/1992		
#9	6/3/1992	0.69	64.66	#7	6/3/1992	19.13	117.26	Schaper	6/3/1992	2.66	142.34
#9	6/22/1992	0.61	156.05	#7	6/22/1992	16.87	475.57	Schaper	6/22/1992	2.12	105.98
#9	7/8/1992	0.65	90.30	#7	7/8/1992	17.76	107.29	Schaper	7/8/1992	2.98	23.81
#9	7/28/1992	0.97	21.48	#7	7/28/1992	29.42	571.55	Schaper	7/28/1992	4.23	43.10
#9	8/18/1992	1.21	352.78	#7	8/18/1992	38.80	65.80	Schaper	8/18/1992	3.65	65.42
#9	8/27/1992	1.79	139.27	#7	8/27/1992	24.53	69.83	Schaper	8/27/1992	2.97	71.31
#9	9/20/1992	2.18	43.34	#7	9/20/1992	31.74	47.48	Schaper	9/20/1992	3.78	87.26
#9	11/25/1992	0.48	109.60	#7	11/25/1992	15.77	164.83	Schaper	11/25/1992		

Appendix D – WGFD measured discharge (cfs) and TSS (mg/L) from the most downstream locations on Ocean Lake drains prior to entering Ocean Lake, 1997-2008.

Drain	Date	CFS	TSS
#4 100YDS Abv Lake	Jul-97	30.40	
#4 100YDS Abv Lake	Aug-97	45.00	
#4 100YDS Abv Lake	Sep-98	36.60	
#4 100YDS Abv Lake	Jun-99	21.88	
#4 100YDS Abv Lake	Jul-99	27.28	
#4 100YDS Abv Lake	Aug-99	33.00	
#4 100YDS Abv Lake	Sep-99	28.59	
#4 100YDS Abv Lake	May-00		48.00
#4 100YDS Abv Lake	Jun-00	17.29	51.00
#4 100YDS Abv Lake	Jul-00	15.16	46.00
#4 100YDS Abv Lake	Aug-00		55.00
#4 100YDS Abv Lake	Sep-00	27.75	46.00
#4 100YDS Abv Lake	Oct-00	4.74	21.00
#4 100YDS Abv Lake	May-01	3.26	62.00
#4 100YDS Abv Lake	Jun-01		72.00
#4 100YDS Abv Lake	Jul-01		82.00
#4 100YDS Abv Lake	Aug-01		7.90
#4 100YDS Abv Lake	Sep-01		29.30
#4 100YDS Abv Lake	Oct-01		16.40
#4 100YDS Abv Lake	Apr-02		28.80
#4 100YDS Abv Lake	Jun-02		44.70
#4 100YDS Abv Lake	Jul-02		47.30
#4 100YDS Abv Lake	Aug-02		50.70
#4 100YDS Abv Lake	Sep-02		66.00
#4 100YDS Abv Lake	May-03		35.60
#4 100YDS Abv Lake	Jun-03		80.00
#4 100YDS Abv Lake	Jul-03	31.95	105.00
#4 100YDS Abv Lake	Aug-03		67.00
#4 100YDS Abv Lake	Sep-03	32.47	34.00
#4 100YDS Abv Lake	Jun-04		70.00
#4 100YDS Abv Lake	Jul-04		69.00
#4 100YDS Abv Lake	Aug-04		39.00
#4 100YDS Abv Lake	Oct-04		22.00
#4 100YDS Abv Lake	May-05	16.21	90.00
#4 100YDS Abv Lake	Jun-05		300.00
#4 100YDS Abv Lake	Jul-05		100.00
#4 100YDS Abv Lake	Aug-05		84.00
#4 100YDS Abv Lake	Apr-06		33.00
#4 100YDS Abv Lake	May-06		440.00
#4 100YDS Abv Lake	Jul-06		130.00
#4 100YDS Abv Lake	Aug-06		46.00
#4 100YDS Abv Lake	Sep-06		30.00
#4 100YDS Abv Lake	Oct-06		21.00
#4 100YDS Abv Lake	May-07		130.00
#4 100YDS Abv Lake	Jun-07		97.00
#4 100YDS Abv Lake	Jul-07		110.00
#4 100YDS Abv Lake	Aug-07		86.00
#4 100YDS Abv Lake	Sep-07		35.00
#4 100YDS Abv Lake	Oct-07		19.00
#4 100YDS Abv Lake	Jun-08		290.00
#4 100YDS Abv Lake	Jul-08		105.00
#4 100YDS Abv Lake	Aug-08		32.00
#4 100YDS Abv Lake	Sep-08		30.00

Drain	Date	CFS	TSS
#6A Shady Lane	May-00		95.00
#6A Shady Lane	Jun-00		18.00
#6A Shady Lane	Jul-00		27.00
#6A Shady Lane	Aug-00		46.00
#6A Shady Lane	Sep-00		37.00
#6A Shady Lane	Oct-00		25.00
#6A Shady Lane	May-01		12.00
#6A Shady Lane	Jun-01		49.00
#6A Shady Lane	Jul-01		8.00
#6A Shady Lane	Aug-01		31.50
#6A Shady Lane	Sep-01		27.70
#6A Shady Lane	Oct-01		6.47
#6A Shady Lane	Apr-02		4.00
#6A Shady Lane	Jun-02		19.60
#6A Shady Lane	Jul-02		4.00
#6A Shady Lane	Aug-02		35.60
#6A Shady Lane	Sep-02		68.80
#6A Shady Lane	May-03		16.00
#6A Shady Lane	Jun-03		5.20
#6A Shady Lane	Jul-03		26.80
#6A Shady Lane	Aug-03		43.30
#6A Shady Lane	Sep-03		22.50
#6A Shady Lane	Jun-04		49.00
#6A Shady Lane	Jul-04		63.00
#6A Shady Lane	Aug-04		38.00
#6A Shady Lane	Oct-04		72.00
#6A Shady Lane	May-05		140.00
#6A Shady Lane	Jun-05		62.00
#6A Shady Lane	Jul-05		84.00
#6A Shady Lane	Aug-05		40.00
#6A Shady Lane	Apr-06		190.00
#6A Shady Lane	May-06		100.00
#6A Shady Lane	Jul-06		54.00
#6A Shady Lane	Aug-06		46.00
#6A Shady Lane	Sep-06		37.00
#6A Shady Lane	Oct-06		27.00
#6A Shady Lane	May-07		23.00
#6A Shady Lane	Jun-07		62.00
#6A Shady Lane	Jul-07		52.00
#6A Shady Lane	Aug-07		190.00
#6A Shady Lane	Sep-07		43.00
#6A Shady Lane	Oct-07		7.20
#6A Shady Lane	May-08		470.00
#6A Shady Lane	Jun-08		140.00
#6A Shady Lane	Jul-08		67.00
#6A Shady Lane	Aug-08		66.00
#6A Shady Lane	Sep-08		36.00
#6A Shady Lane	Oct-08		8.60

Appendix D – WGFD measured discharge (cfs) and TSS (mg/L) from the most downstream locations on Ocean Lake drains prior to entering Ocean Lake, 1997-2003.

Drain	Date	Discharge	TSS
#7 Shady Lane	May-97	17.20	
#7 Shady Lane	Jun-97	37.40	
#7 Shady Lane	Jul-97	37.00	
#7 Shady Lane	Aug-97	45.45	
#7 Shady Lane	Jun-98	28.87	
#7 Shady Lane	Jul-99	32.00	
#7 Shady Lane	May-00	23.75	81.00
#7 Shady Lane	Jun-00	12.22	10.00
#7 Shady Lane	Jul-00		87.00
#7 Shady Lane	Aug-00		31.00
#7 Shady Lane	Sep-00		17.00
#7 Shady Lane	Oct-00		34.00
#7 Shady Lane	May-01		214.00
#7 Shady Lane	Jun-01		33.00
#7 Shady Lane	Jul-01		30.00
#7 Shady Lane	Aug-01		12.80
#7 Shady Lane	Sep-01		9.60
#7 Shady Lane	Oct-01		16.00
#7 Shady Lane	Apr-02		3.60
#7 Shady Lane	Jun-02		44.00
#7 Shady Lane	Jul-02		12.40
#7 Shady Lane	Aug-02		29.00
#7 Shady Lane	Sep-02		4.00
#7 Shady Lane	May-03		11.20
#7 Shady Lane	Jun-03		26.20
#7 Shady Lane	Jul-03		34.10
#7 Shady Lane	Aug-03		48.50
#7 Shady Lane	Sep-03		37.80
#7 Shady Lane	Jun-04		93.00
#7 Shady Lane	Jul-04		36.00
#7 Shady Lane	Aug-04		74.00
#7 Shady Lane	Oct-04		71.00
#7 Shady Lane	May-05		110.00
#7 Shady Lane	Jun-05		63.00
#7 Shady Lane	Jul-05		150.00
#7 Shady Lane	Aug-05		18.00
#7 Shady Lane	Apr-06		26.00
#7 Shady Lane	May-06		150.00
#7 Shady Lane	Jul-06		52.00
#7 Shady Lane	Aug-06		49.00
#7 Shady Lane	Sep-06		34.00
#7 Shady Lane	Oct-06		30.00
#7 Shady Lane	May-07		56.00
#7 Shady Lane	Jun-07		53.00
#7 Shady Lane	Jul-07		32.00
#7 Shady Lane	Aug-07		47.00
#7 Shady Lane	Sep-07		26.00
#7 Shady Lane	Oct-07		9.10
#7 Shady Lane	May-08		470.00
#7 Shady Lane	Jun-08		83.00
#7 Shady Lane	Jul-08		48.00
#7 Shady Lane	Aug-08		46.00
#7 Shady Lane	Sep-08		22.00
#7 Shady Lane	Oct-08		11.60

Drain	Date	Discharge	TSS
#6B Missour Valley Rd	May-00	12.02	67.00
#6B Missour Valley Rd	Jun-00	18.25	23.00
#6B Missour Valley Rd	Jul-00		6.40
#6B Missour Valley Rd	Aug-00	29.40	21.00
#6B Missour Valley Rd	Sep-00	23.75	2.00
#6B Missour Valley Rd	Oct-00	9.90	48.00
#6B Missour Valley Rd	Apr-01	3.83	
#6B Missour Valley Rd	May-01	6.35	58.00
#6B Missour Valley Rd	Jun-01		22.00
#6B Missour Valley Rd	Jul-01		6.00
#6B Missour Valley Rd	Aug-01	16.49	3.60
#6B Missour Valley Rd	Sep-01		5.00
#6B Missour Valley Rd	Oct-01		28.90
#6B Missour Valley Rd	Apr-02		21.00
#6B Missour Valley Rd	Jun-02		24.40
#6B Missour Valley Rd	Jul-02		7.20
#6B Missour Valley Rd	Aug-02		1.00
#6B Missour Valley Rd	Sep-02		15.50
#6B Missour Valley Rd	May-03	10.63	54.00
#6B Missour Valley Rd	Jun-03		9.20
#6B Missour Valley Rd	Jul-03		6.80
#6B Missour Valley Rd	Aug-03		9.60
#6B Missour Valley Rd	Sep-03		16.30
#6B Missour Valley Rd	Jun-04		9.10
#6B Missour Valley Rd	Jul-04		10.00
#6B Missour Valley Rd	Aug-04		39.00
#6B Missour Valley Rd	Jun-05		15.00
#6B Missour Valley Rd	Jul-05		51.00
#6B Missour Valley Rd	Aug-05		15.00
#6B Missour Valley Rd	Apr-06		380.00
#6B Missour Valley Rd	May-06		61.00
#6B Missour Valley Rd	Jul-06		8.60
#6B Missour Valley Rd	Aug-06		10.00
#6B Missour Valley Rd	Sep-06		30.00
#6B Missour Valley Rd	Oct-06		36.00
#6B Missour Valley Rd	May-07		69.00
#6B Missour Valley Rd	Jun-07		36.00
#6B Missour Valley Rd	Jul-07		15.00
#6B Missour Valley Rd	Aug-07		120.00
#6B Missour Valley Rd	Sep-07		25.00
#6B Missour Valley Rd	Oct-07		750.00
#6B Missour Valley Rd	May-08		290.00
#6B Missour Valley Rd	Jun-08		85.00
#6B Missour Valley Rd	Jul-08		37.00
#6B Missour Valley Rd	Aug-08		26.00
#6B Missour Valley Rd	Sep-08		230.00
#6B Missour Valley Rd	Oct-08		16.80