Echo Reservoir TMDL
Water Quality Study

Prepared for:

Utah Department of Environmental Quality -
Division of Water Quality

Kari Lundeen - Project Manager
Carl Adams - Project Supervisor
288 North 1460 West
Salt Lake City, Utah 84114-4870

Prepared by:

Cirrus Ecological Solutions, LC
965 South 100 West, Suite 200
Logan, Utah 84321

[EPA APPROVAL DATE]

Utah Department of Environmental Quality
Division of Water Quality
TMDL Section

Echo Reservoir TMDL

Waterbody ID	UT-L-16020101-001
Location	Summit County, Utah
Pollutants of Concern	Dissolved Oxygen, Total Phosphorus
Impaired Beneficial Uses	Class 3A: Protected for cold water species of game fish and other cold water aquatic life, including the necessary aquatic organisms in their food chain.
Loading Assessment	• More than 50% of water column < 4 mg/l dissolved oxygen in Echo Reservoir above Dam. • Percent of in-lake total phosphorus concentrations exceeding 0.025 mg/l ranging from 25% - 100%
Water Quality Targets/Endpoints	• Target Load of 19,800 kg/yr total phosphorus from all tributary sources to Echo Reservoir. • A shift away from blue-green algal dominance. • TSI values for Total Phosphorus, Chlorophyll A, and Secchi depth not to exceed 50.

Implementation Strategy	• Reduce Point Source loads through application of BATs
	• Implement Nonpoint Source BMPs
	  o CNMPs on all AFO facilities in study area.
	  o Remove livestock access to water and provide off-site watering sources along selected stream corridors.
	  o Implement riparian buffer strips on degraded stream segments and along other selected stream corridors.

This document is identified as a TMDL for Echo Reservoir and is submitted under §303d of the Clean Water Act to U.S. EPA for review and approval.	

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

CHAPTER 1: INTRODUCTION

The Total Maximum Daily Load (TMDL) study for the Echo Reservoir Watershed has been completed under the direction of the Utah Department of Environmental Quality – Division of Water Quality (DWQ) for submittal to the U.S. Environmental Protection Agency (EPA) as specified by section 303(d) of the Clean Water Act (CWA). The water quality and flow assessment detailed within this document addresses impairment to Echo Reservoir due to high concentrations of total phosphorus and low concentrations of dissolved oxygen. This assessment relies upon the most recent monitoring data collected in the study area, and as such provides an accurate picture of the important influences on water quality in the Echo Reservoir watershed.

In order for a TMDL to be effective, involvement by agencies and stakeholders at the local level is essential. Efforts have been made throughout this process to involve local agencies and stakeholders, and to inform them of the current status of water quality in the Echo Reservoir watershed. It is not the intent of this assessment to place blame or criticism on any individual or group within the watershed, but to try to provide an accurate characterization of **all** conditions that lead to water quality impairment in the study area.

1.1 TMDL Program Description

The TMDL program was one of several programs established in connection with the 1977 Clean Water Act to maintain and restore water quality to waters of the United States. A specific goal of the TMDL program is to ensure that water quality standards established by states are achieved and maintained. A critical element of the TMDL process identifies the maximum amount of pollutant that a water body can receive and still meet water quality standards. This amount is sometimes called the maximum allowable pollutant load or “permissible load.” If needed, the TMDL can associate the permissible load with a critical time-period, including months of low stream flow or seasons when lakes and reservoirs are prone to stratification.

The scientific assessment of water quality included as part of a TMDL incorporates the best information available to determine the nature and extent of impairment for a given water body. Pollutant loads are also defined for each significant pollutant source contributing to impairment. Following allocation of pollutant loads, an implementation plan is provided that will reduce existing pollutant loads and allow water quality standards to be achieved.

The TMDL process is a shift from the more generalized approaches employed in the past to implement the CWA. It demands a local focus on the target watershed, from both a scientific and an applied perspective. Water quality standards that are broadly applied can be carefully evaluated under this process in terms of restoring and maintaining beneficial uses under actual conditions that influence water quality in the Echo Reservoir watershed. Successful implementation of this assessment will require cooperation between federal, state, and local entities, including local stakeholders living within the study area.

1.2 Previous Studies

The greater Weber River Basin is located at the northern end of the Wasatch Front and incorporates a major portion of the Wasatch Mountain Range. Demand for water resources within the basin commenced with the development of agriculture and mining industries in the mid-1800s. Steady growth patterns along the Wasatch Front during the past century have been matched or exceeded in many areas of the

Weber River Basin. Currently, water resources in this area are considered to be among the most highly developed within the state and provide support to rural and urban economies within and outside of the basin. Because of the demand for good quality water from the Weber River and its tributaries, numerous studies of water quantity and water quality have been completed. A listing of some of the more significant studies completed within the Weber River Basin is included in Table 1.1 below. Two TMDL water quality studies have been previously completed in the study area, including the Chalk Creek CRMP and the Silver Creek TMDL (Figure 1.1). Information from these assessments will be used to supplement the Echo Reservoir TMDL where applicable.

1.3 PLAN OBJECTIVES

The goal of this TMDL assessment is to restore the beneficial uses assigned by the State of Utah to Echo Reservoir by meeting the applicable water quality standards for dissolved oxygen. Echo Reservoir has been included on the Utah 303(d) list since 1996 when it was listed as impaired due to low dissolved oxygen levels and pH measurements that exceeded State criteria. The 2000 303(d) list recommended that pH be removed for Echo Reservoir due to re-evaluation and assessment of new data. Low dissolved oxygen remained on the list of impairments to Echo Reservoir on the 2000 303(d) list, and total phosphorus was added. These two parameters are currently included on the 2004 303(d) list as pollutants of concern leading to impairment of Echo Reservoir.

The remainder of this document comprises a technical assessment of how pollutant sources in the study area influence dissolved oxygen levels in Echo Reservoir. As mentioned previously, it is not the intent of this assessment to place blame or criticism on any individual or group within the watershed. Rather, the primary focus of this work is to define where total phosphorus loads are generated and delivered to receiving waterbodies and how these loads influence dissolved oxygen levels in Echo Reservoir. As the loading process is defined, it is important that natural and anthropogenic (human-created) influences are defined. Once this objective has been met, recommendations will be made to reduce or eliminate negative impacts to water quality and restore the fisheries beneficial use of Echo Reservoir. A phased approach will be utilized to most effectively implement recommendations.

This phased approach to the TMDL will use the 4 mg/L dissolved oxygen standard as an interim goal while projects designed to reduce pollutant loads are implemented. EPA guidance recommends the development of a phased TMDL when water quality standards and assessment methodologies are expected to be revised in the near future.

The Division of Water Quality has used the 4 mg/L dissolved oxygen standard for cold water fisheries as the target and not the 7 or 30 day average values of 5 mg/L and 6.5 mg/L respectively due to the difficulty in interpreting average dissolved oxygen concentrations for lakes and reservoirs. Concurrently, the Division will commit to evaluating and revising, as appropriate, water quality standards and assessment methodologies for dissolved oxygen in lakes and reservoirs to simplify interpretation of standards and more accurately reflect the true potential of Echo Reservoir to attain and support water quality standards and its designated beneficial uses.

EPA guidance also recommends the use of a phased approach when there is uncertainty associated with the TMDL analysis. Uncertainty in the Echo Reservoir TMDL is associated with the linkage between total phosphorus and dissolved oxygen, the effectiveness of non-point source reductions and the time required to attain water quality standards.

EPA also recommends that phased TMDLs include implementation and monitoring plans as well as a scheduled time frame for revision of the TMDL. A project implementation plan (PIP) has been included as an appendix to the TMDL that includes recommendations and cost estimates for attainment of the required load reductions. The Division has also scheduled the Echo Reservoir TMDL to be re-evaluated in 2019. Ten years is an appropriate amount of time for revisiting to allow for implementation of non-point source management measures, for monitoring their effectiveness and to flush out or bury the majority of excess phosphorus in bottom sediments.

If water quality targets have not been achieved by 2019 the Division will re-evaluate the Echo Reservoir TMDL and consider use attainability analysis, site specific water quality standards, and examine other causative factors of low dissolved oxygen such as water management and loading of organic matter. These steps will only be taken after non-point source reduction projects have been fully implemented. At this point further phosphorus reductions would be difficult to obtain due to the high background load of phosphorus in the watershed associated with naturally occurring phosphatic shales. If non-point source projects have not been fully implemented by 2019, a formal water quality trading program would be considered.

The success of this TMDL is dependent upon public involvement and support. Five public meetings were held through the public draft phase of the Echo Reservoir TMDL assessment. The initial meeting was held on October 21, 2003 in Coalville, following a review of all available water quality and flow data. Attendees at the meeting included state and municipal agencies, representatives of permitted discharges, and private land owners. During the meeting, an overview of the TMDL process was given, followed by summary results from the data review. The proposed schedule for the remainder of the assessment was provided, including a description of the work effort associated with defining pollutant source categories. A request was made at that time for any information that would help characterize potential sources of total phosphorus. Additional meetings were held from November 2004 through January 2005 to provide information on calculated pollutant loads, load allocation, and the modeling process used to establish a linkage between total phosphorus and dissolved oxygen levels in Echo Reservoir. A more detailed discussion of the public involvement process is provided in Chapter 6.

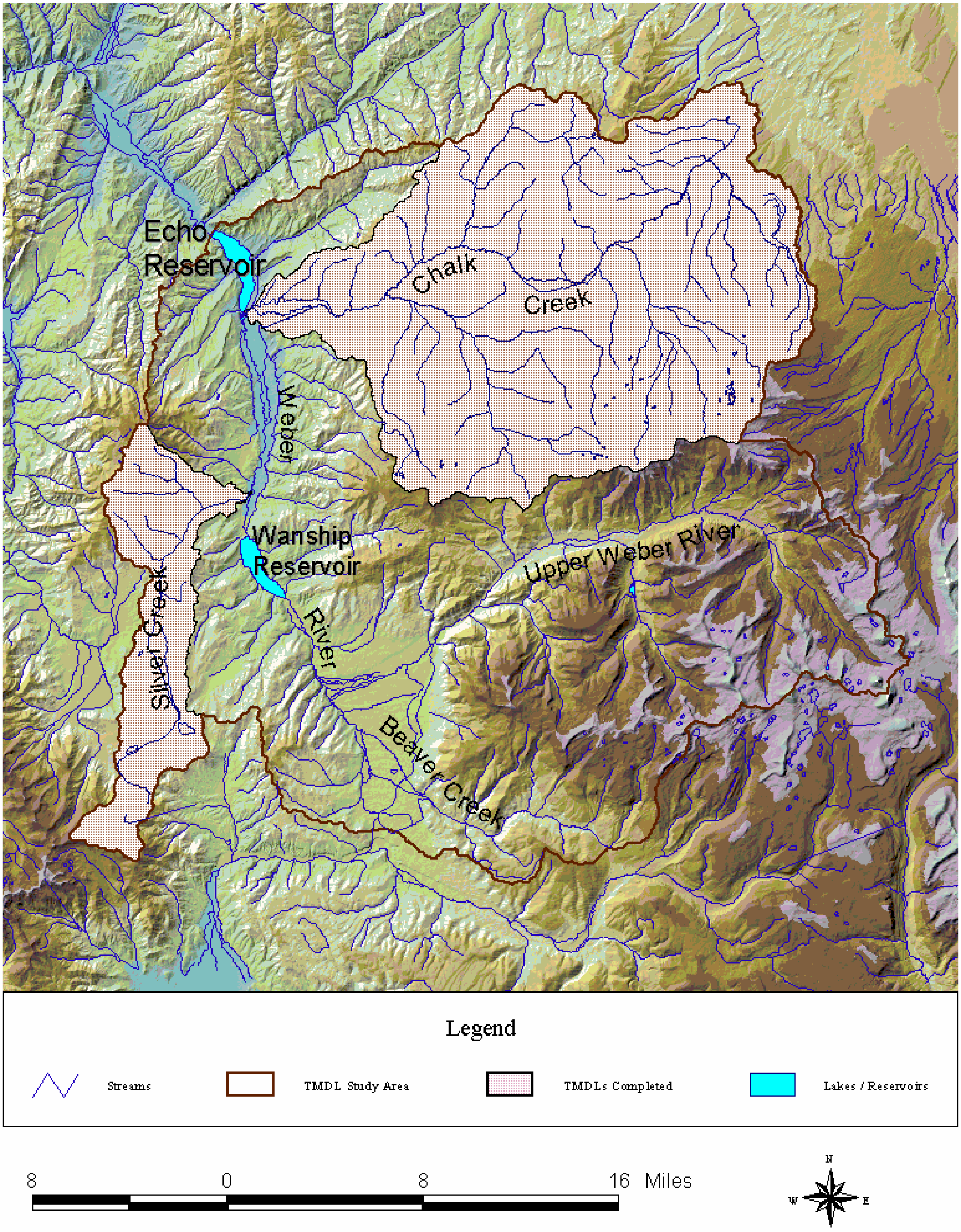

Figure 1.1. Map of study area indicating the location of all significant water bodies. Note highlighted areas indicating where TMDLs have previously been completed.

Table 1.1. Significant water investigations and planning documents completed for the greater Weber River Basin during the recent past (1983-2004). Note the specific reference to water bodies in the Echo Reservoir watershed, as they occur within each document.

Year	Title[a]	Author	Description
1983	Reconnaissance of the quality of surface water in the Weber River Basin.	USGS / Utah DWR	Assessment of data collected from July 1979-August 1980. Emphasis on dominant cation-anions in Weber River only. No assessment of Echo Reservoir. Seasonal dissolved oxygen readings on Weber River ranged from 5.5 mg/l (near outlet) to 14.7 mg/l.
1984	Ground-water reconnaissance of the Central Weber River area.	USGS / Utah DWR	Primary emphasis on groundwater hydrology. Brief review of groundwater quality near Coalville indicated high levels of dissolved iron and boron in some wells.
1986	Water Resources of the Park City area, Utah with emphasis on groundwater.	USGS / Utah DWR	Review of water resources for selected drainage basins in Park City area. Groundwater samples in Silver Creek drainage exceeded State standards for dissolved solids, manganese, cadmium and pH.
1993	Water Quality Assessment: Chalk Creek, Summit Co.	Utah DWQ	Established baseline water quality conditions prior to implementation of the Chalk Creek NPS Project Implementation Plan. Data collected from 1990 – 1992 indicated that total phosphorus concentrations were highly related to Total Suspended Solids, most of which are delivered by overland flow. Chalk Creek noted as greatest contributor of sediment in Weber River Basin. Roughly 50% of total load from Chalk Creek noted to pass through Echo Reservoir.
1995	Water Quality Assessment: Chalk Creek, Summit Co. Report No. 2.	Utah DWQ	Update of previous report, assessment of sediment and total phosphorus loading in watershed. S. Fk. Chalk Creek, Huff Creek, and mainstem Chalk Creek below Pine Cliff considered significant contributors of total phosphorus and sediment.
1995	Weber River Basin and Farmington Bay Area stream assessment.	Utah DWQ	Assessment of 1993-94 DWQ monitoring data in Weber River Basin. A total of 57% of perennial stream miles fully supporting Class 3 beneficial use; 40% partially supporting (including Chalk Creek and portions of Upper Weber R) and 3% not supporting (including Silver Creek). Total phosphorus loads in Chalk Creek noted to be associated with sediment loads. Silver Creek noted to maintain constant total phosphorus loads that were likely the result of point source discharge.
1997	Utah State Water Plan – Weber River Basin.	Utah DWR	Section 12 of this plan addresses general water quality issues in the Weber Basin, summarizes most of 1995 DWQ study.
1997	Chalk Creek Coordinated Resource Management Plan	Summit County Soil Conservation District	EPA approved TMDL (10/23/97). Published in 1994 and eventually submitted to the EPA in 1997. Major objectives of the Plan include the following: reduce sediment loads by 130,000 tons/yr, stabilize 10 miles of eroded streambank, restore riparian areas and floodplains and convert flood irrigation to sprinkler irrigation.
2000	East Canyon Reservoir TMDL.	Utah DWQ	EPA approved TMDL (5/23/00). Addresses impairment to Class 3A cold water fishery due to elevated total phosphorus and low dissolved oxygen concentrations. A 39% reduction of total phosphorus loads is recommended to meet desired endpoints.
2000	East Canyon Creek TMDL.	Utah DWQ	EPA approved TMDL (5/23/00). Pollutants of concern include total phosphorus and dissolved oxygen. Impairment due to nonpoint sources as well as the East Canyon WWTP. 58% reduction in total phosphorus recommended (from 0.12 mg/l to 0.05 mg/l) to meet desired endpoints.
2000	Weber River Watershed Management Water Quality Assessment Report.	Utah DWQ	Summarizes water quality data collected at 55 stream monitoring sites in the Weber River Basin during July 1998 – June 1999. No reservoir data collected as part of this study. Significant recent decrease in total phosphorus noted for Chalk Creek although sediment loads still a concern. Silver Creek noted to receive significant total phosphorus contributions from point sources. Streams noted for elevated levels of total phosphorus include Weber River from Echo Reservoir to Rockport Reservoir, Silver Creek, and Beaver Creek up to Kamas.

Table 1.1. (cont'd) Significant water investigations and planning documents completed for the greater Weber River Basin during the recent past (1983-2004). Note the specific reference to water bodies in the Echo Reservoir watershed, as they occur within each document.

Year	Title[a]	Author	Description
2001	Trace metal concentrations in sediment and water and health of aquatic macroinvertebrate communities of streams near Park City, UT.	USGS	Describes occurrence and spatial distribution of metals in bed sediment and surface water of Silver Creek. Does not assess total phosphorus or dissolved oxygen.
2001	Selected hydrologic and water quality data for Kamas Valley and vicinity, Summit County, UT 1997-2000.	USGS	Includes assessment of data collected in part from Kamas Valley, Upper Weber River (headwaters), and Beaver Creek near Samak. Identifies need for high quality groundwater to support municipal and domestic use. 5 of 37 wells sampled for Dissolved total phosphorus were > 0.05 mg/l.
2002	Geology of the Kamas- Coalville region and its relation to groundwater conditions.	Utah Geological Survey	Hydrostratigraphy of groundwater bearing units provided for Kamas-Coalville area. Hydraulic conductivity generally increases from east to west.
2002	Pineview Reservoir TMDL.	Utah DWQ	EPA approved TMDL (12/1/02). Addresses impairment to Class 3A coldwater fishery due to elevated total phosphorus, Temperature and low dissolved oxygen. Impairment noted to be the combined result of reservoir management, septic tanks and livestock manures. A 15% reduction in N and P loads was determined necessary to meet the desired endpoint.
2003	Hydrology and Simulation of Groundwater Flow in Kamas Valley.	USGS	Assessment of surface and groundwater data with intent to characterize general water quality and target potential contaminants. Nutrients were consistently less than State standards. Coliforms were identified in some surface waters and were anticipated to originate from livestock sources.
2003	Weber River Restoration Action Strategy	Utah Division of Water Quality	Planning document that describes progress of the Watershed Restoration Action Strategy (WRAS) for the Weber River Basin. The WRAS represents the strategy of the Weber River Coalition for restoring, protecting and maintaining water quality in the Weber River Basin.
2004	Silver Creek TMDL.	USGS	TMDL submitted to EPA (4/1/04). Defines impairment to Silver Creek from Zinc and Cadmium. Does not address total phosphorus, although some information regarding streamflow and development is provided.
2004	Weber River Basin: Planning for the future.	Utah DWR	Identifies major concerns to water quality in Weber River Basin including preservation of riparian corridors, storm water discharge permitting, nutrient loading, AFO/CAFO facilities and increasing septic tank densities.

[a] Full citation is included in the reference section of this document.

This page intentionally left blank.

CHAPTER 2: PROJECT AREA DESCRIPTION

The project area associated with this study is the watershed above Echo Reservoir. This land area contains much of the upper portion of the greater Weber River Basin. This basin is located in the north-central area of Utah. The Great Salt Lake defines the western boundary of the basin while the Wasatch Mountains form the northern, eastern, and southern boundaries. The Weber River Basin includes a significant portion of the Wasatch Range and receives runoff from these mountains as well as the northwest slopes of the Uinta Mountains. Total surface area of the basin is estimated at 1.5 million acres located within Weber, Davis, Morgan, and Summit counties. Mean elevation is approximately 6,700 feet and ranges from 4,200 feet to over 11,200 feet. Most of the upper basin above Echo Reservoir consists of high mountain valleys, mountain ranges, and high bench areas with limited agricultural potential. In contrast, the lower Weber River Basin is a fertile agricultural plain that is considered one of the largest producers of food and livestock in the state. The main tributaries to the Weber River are Beaver Creek, Chalk Creek, Lost Creek, East Canyon Creek, and the Ogden River. On average, the Weber River Basin has an annual water supply of 979,400 acre-feet from surface and ground water sources. The topographic relief of the watershed above Echo Reservoir is shown in Figure 2.1. The remainder of this chapter includes a detailed description of the study area.

2.1 HISTORY

Echo Reservoir is one of seven reservoirs built by the Bureau of Reclamation in the Weber River Basin to provide water to the northern Wasatch Front. Three of these reservoirs, including Smith-Morehouse, Wanship, and Echo, are located along the Weber River and within the project area. The towns of Coalville, Oakley and Kamas are also located in the project area (Figure 2.2). Created in 1931, Echo Reservoir is an earth-fill impoundment that inundates a valley approximately 0.8 miles wide and up to 800 feet deep. When full, Echo Reservoir maintains a surface elevation of 5560 feet above sea level and a capacity of 91,156,000 acre-feet. The average stream gradient above the reservoir is 3.7 percent (200 feet per mile). Primary inflows to the reservoir include the Weber River and Chalk Creek. Wanship Reservoir (referred to as Rockport Lake on Unite States Geological Survey [USGS] maps) and Smith and Morehouse Reservoir are located upstream roughly 10 miles and 30 miles, respectively. Smith-Morehouse Reservoir is an impoundment of a tributary of the upper Weber River.

Water resources in the Weber River Basin are considered among the most highly developed within the state of Utah. Inhabitants of this area depend on the water resources and associated habitat and wildlife to maintain their way of life. Agricultural irrigation is the primary use of water in the Weber River Basin, consuming almost 70 percent of the developed supply of water. Municipal and industrial uses consume the remaining 30 percent. Environmental and recreational water use are not quantified in these figures but are also considered an important use of the basin's water resources (Stonely 2004).

Significant use of water for irrigation began in the 1850s with the settlement of Mormon Pioneers in the Weber River Basin. Mormon settlements occurred near the mouths of streams flowing from the Wasatch Range toward the Great Salt Lake. Small communities were organized next to those streams with flows capable of sustaining irrigation. As pioneers became more familiar with irrigation practices, communities combined their resources to dig larger ditches and canals.

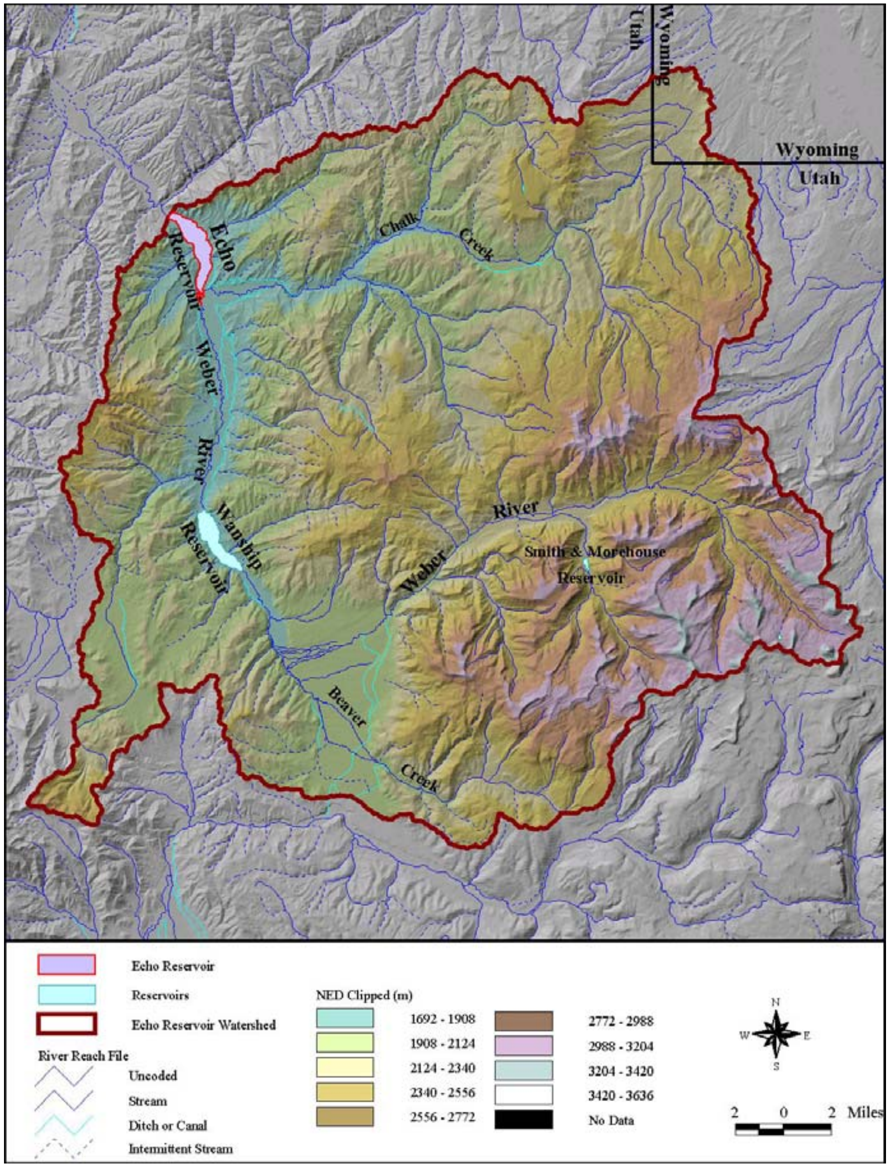

Figure 2.1. Topographic relief of the Echo Reservoir watershed.

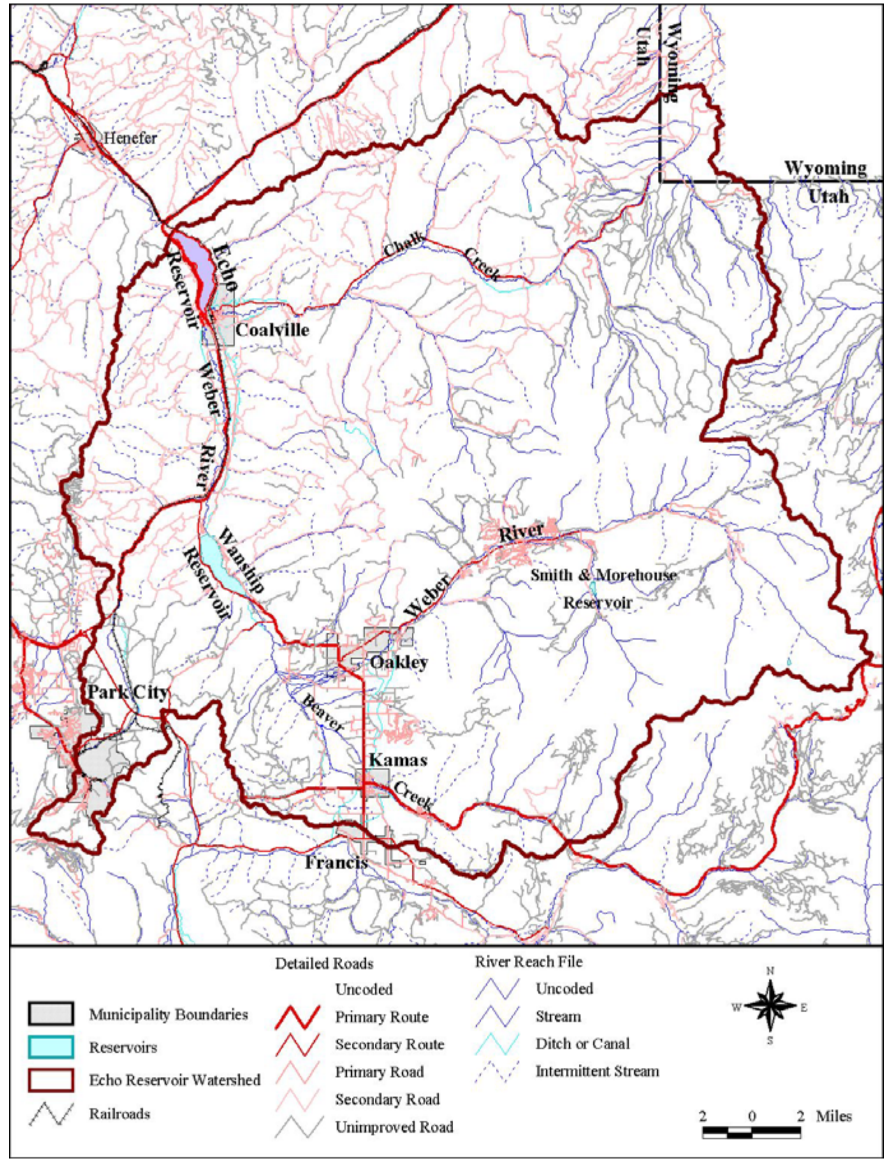

Figure 2.2. Municipal boundaries and transportation routes within the Echo Reservoir watershed.

Water soon became an integral part of developing communities and by 1860 the flow of many streams had become over-appropriated. The need for water storage to sustain yearlong crops led to the construction of storage reservoirs. The first reservoir in the area was built in 1852 on Holmes Creek (near Layton, Utah) and is believed to be the first irrigation storage reservoir in western America.

The communal model of water development worked well for many decades, but the growing water demand and the diversity of Utah's population drove this model to a more secular method. In 1880, the territorial government allowed the owners of water rights to use and dispose of them as personal property. This secular approach proved unsuccessful and the Utah Legislature passed several laws in the late 1800s and early 1900s to restore public control of the state's water. These laws led to the adjudication of water rights claims, which was a pre-requisite to the construction of large water development projects through the federal reclamation program. During the early 1900s, several local projects were completed including the Weber and Davis canal, East Canyon Dam, Pioneer Electric Power Plant, Bonneville Canal, Echo and Pineview Dams. The Bureau of Reclamation's Weber Basin Project started after the adjudication of the Weber River was completed in 1937.

Large investments on military infrastructure prior to and during World War II resulted in rapid growth in the Weber River Basin. Concerns about the growing water demand prompted the proposal of an ambitious water development by the Bureau of Reclamation. With the support of federal resources, the Weber Basin Project eventually captured much of the remaining surface water carried by the Weber River including water from excess spring runoff. The Weber Basin Water Conservancy District was created to pay back the Federal obligations and to operate and maintain project facilities. The Weber Basin Project, completed in the late 1960s, was the last major water development project within the basin.

Historic mining operations also contributed significantly to development in the project area. The Park City mining district was for many years one of the most productive sources of Gold, Silver, Lead, Zinc, Copper and Cadmium in the State of Utah. The Silver Creek drainage is part of the Park City mining district and the creek is known as a source of trace elements to the Weber River. Silver Creek enters the Weber River about 2.5 miles downstream from Wanship Reservoir and 6 miles above Echo Reservoir. After the completion of Wanship Reservoir in 1966, most of the sediments from the upper sections of the upper Weber River Basin most likely were deposited in the reservoir. There is no evidence that the completion of Wanship Reservoir affected the trend of trace element concentrations in sediments of Echo Reservoir. Further, studies have shown that drainage to the Weber River above Wanship Reservoir had very little effect on the enrichment of trace elements present downstream in Echo Reservoir (Waddell and Giddings 2004). Therefore, trace element enrichment in Echo Reservoir and sections of the Weber River below Silver Creek is primarily attributed to the wash-in of ore minerals from the inactive mining or mining processing sites of the Park City mining complex (Kada et al 1994). Wadell and Giddings (2004) suggested that most of these trace elements enter the Weber River and Echo Reservoir through Silver Creek. Mining activities in the drainage of Chalk Creek have been minimal. Chalk Creek directly enters Echo Reservoir and is believed to contribute a large amount of sediment to the reservoir, but the amount and chemical composition relative to that of the Weber River are unknown (Waddell and Giddings 2004).

2.2 SUBWATERSHED DESCRIPTION

The headwaters of the Echo Reservoir watershed include the Weber River and Beaver Creek in the western Uintas, Chalk Creek in the southwest corner of Wyoming, and Silver Creek that flows out of Park City and joins the Weber River below Wanship Reservoir. Prehistorically, the Provo River flowed through the Rhodes Valley and down the Weber River but now belongs to a different drainage. The source of the Weber River is west of U-150 at Pass Lake. This area contains the divide between the Duchesne River and the Weber River.

The watershed above Echo Reservoir can be divided into nine subwatersheds that roughly correspond to the confluence of major tributaries or areas where landuse/landtype change substantially (Figure 2.3). One subwatershed includes the area that drains directly to Echo Reservoir while the remaining eight subwatersheds are located above the reservoir. A list of the names and areas associated with each subwatershed are indicated in Table 2.1.

Table 2.1. Echo Reservoir Subwatersheds.

Sub-watershed	Name	Description	Total Area (km^2)
1	Upper Weber River	From headwaters of Weber River down to the confluence with Beaver Creek.	456
2	Beaver Creek	From headwaters of Beaver Creek down to the confluence with the Upper Weber River.	234
3	Weber River Below Beaver Creek	Weber River from confluence with Beaver Creek down to the inlet of Wanship Reservoir.	71
4	Wanship Reservoir	All land that drains directly into Wanship Reservoir, including all land below the reservoir inlet and above the reservoir outlet.	103
5	Weber River Below Wanship Reservoir	Weber River from Wanship Reservoir to the confluence with Silver Creek.	12
6	Silver Creek	From headwaters of Silver Creek to the confluence with the Weber River.	122
7	Weber River Below Silver Creek	Weber River from confluence with Silver Creek to the inlet of Echo Reservoir.	134
8	Chalk Creek	From headwaters of Chalk Creek down to Echo Reservoir.	646
9	Echo Reservoir	All land that drains directly into Echo Reservoir, including all land below the reservoir inlet and above the reservoir outlet.	101

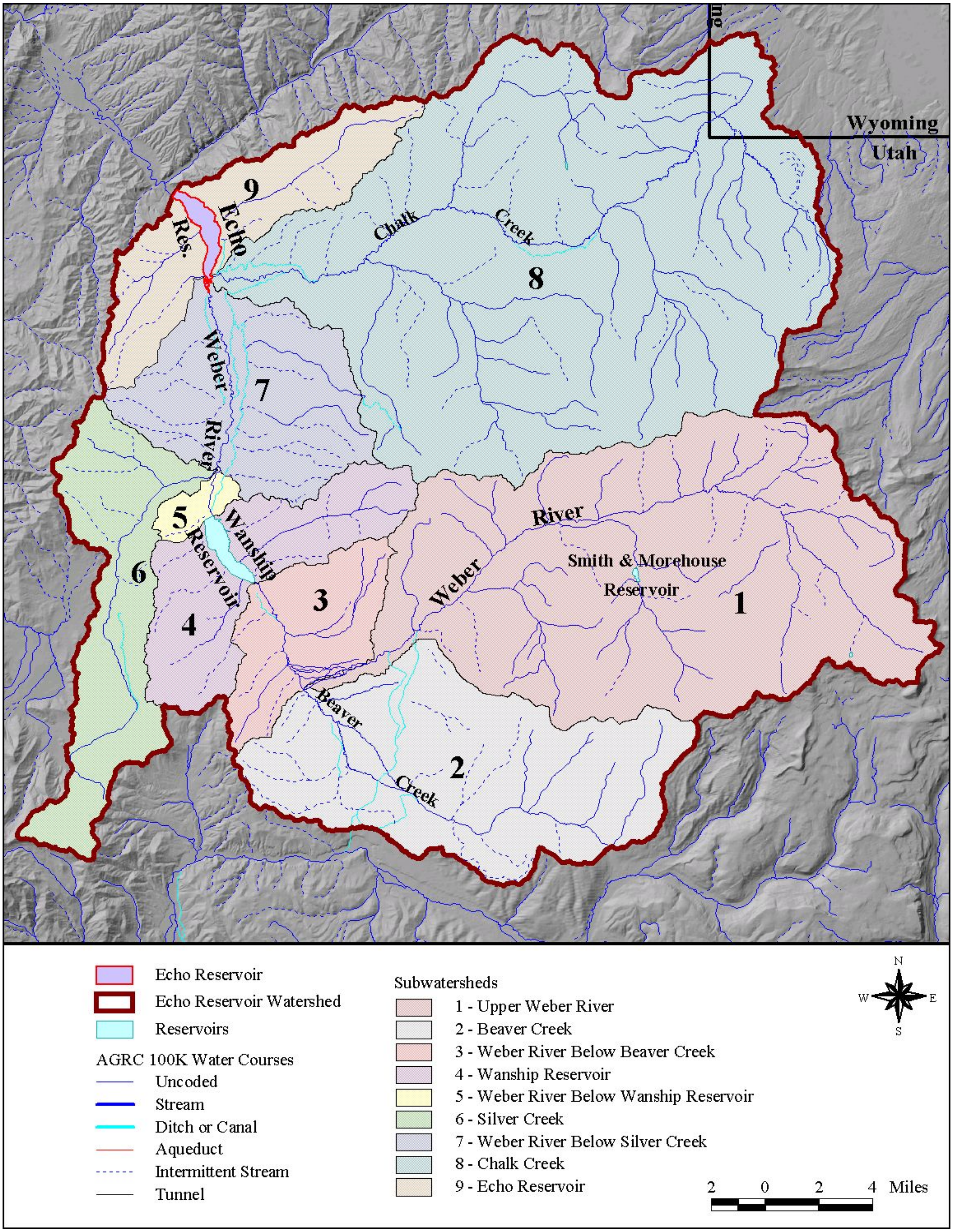

Figure 2.3. Subwatershed boundaries within the Echo Reservoir watershed.

The Upper Weber River subwatershed includes the headwaters, tributaries, and high elevation sections of the Weber River to the confluence with Beaver Creek. Smith and Morehouse Reservoir is located within this subwatershed. The highest lands to be irrigated in the Weber River Valley are located near the town of Oakley. Beaver Creek, the only large tributary within the Uintas, flows north through Kamas to join the Weber just south of Peoa. The Beaver Creek subwatershed includes the headwaters, mainstem, and tributaries of Beaver Creek to its confluence with the Upper Weber River. The headwater area of Beaver Creek contains many small glacial lakes that remain in fairly pristine condition. Water from the Upper Weber River is diverted into the Weber-Provo Diversion which flows through the Beaver Creek subwatershed. The section of the Weber River from the confluence of Beaver Creek to Wanship Reservoir corresponds to a third subwatershed in the project area. The Wanship Reservoir subwatershed includes Wanship Reservoir and several intermittent streams and springs that flow directly into the reservoir. The section of the Weber River below Wanship Reservoir, from Wanship Dam to the town of Wanship, corresponds to the smallest subwatershed in the study area.

The Silver Creek subwatershed encompasses the headwaters, mainstem, and tributaries of Silver Creek to its confluence with the Weber River. The headwaters of Silver Creek originate on the slopes of the Deer Valley Ski Resort near Park City. The Silver Creek subwatershed has experienced excessive vegetation loss and surface disturbance associated with construction of roads, parking lots and buildings. These developments reduce infiltration and contribute to instant runoff following storms. Additional discharge to Silver Creek includes the Silver Creek Water Reclamation Facility (WRF) which treats a portion of the municipal wastewater generated in the Park City area. The remaining subwatersheds in the project area include the area draining directly to Echo Reservoir and the Chalk Creek subwatershed. Much of the Chalk Creek drainage is considerably lower in elevation compared to the headwaters of the Weber River. The vegetation in this area is predominantly sage-grass with aspen and spruce-fir on the north facing slopes of some ridges. This land is privately owned and restricts public access. The headwaters of Chalk Creek are characterized by an unusual pattern of a southwest flowing main-stem with northeast flowing tributaries.

2.3 CLIMATE

The climate of the Weber River Basin is typical of the semiarid central and northern mountainous regions of Utah. Most of the precipitation that falls on the mountains and mountain valleys of the Weber River Basin is in the form of snow. This basin receives higher than normal precipitation due to the composition of mountain ranges and valleys at elevations greater than 5,000 feet. In addition, the proximity of the basin to the Great Salt Lake leads to a substantial amount of precipitation caused by the winter lake effect. This basin of 1,561,000 acres presents an average water yield of 1,091,000 acre-feet/year. As a result, the Weber River Basin has the second highest ratio of water yield to land area (0.70 acre-feet/acre) within the state of Utah (Stonely 2004). The upper Weber River subwatershed receives the highest precipitation (36 inch/year) within the Weber River Basin. Table 2.2 lists the average precipitation of the basin's major subwatersheds.

Spatially distributed precipitation values for the Echo Reservoir watershed were obtained from data contained in the Parameter-elevation Regressions on Independent Slopes Model (PRISM) dataset (Daly et al., 1994). PRISM is a modeling system that uses data collected at meteorological stations and a digital elevation model (DEM) to generate estimates of climatic parameters such as precipitation. The PRISM dataset captures spatial variability in precipitation due to elevation differences and other effects and aids in producing a more accurate estimate of annual average precipitation over the entire watershed area. Figure 2.4 shows the PRISM precipitation estimates for the Echo Reservoir watershed. The PRISM grid of spatial precipitation estimates was summarized using ArcView Spatial Analyst to calculate an average precipitation depth over the watershed area. The resulting average annual precipitation value for the Echo Reservoir watershed was equivalent to 24 inches/year.

Table 2.2. Average Precipitation by Subwatershed in the Weber River Basin.	
Name	**Average Annual Precipitation (in.)**
Upper Weber River[a]	36
Ogden Valley	33
East Canyon Creek	31
Morgan	30
Lost Creek	30
East Shore	23
Kamas Valley[a]	22
Chalk Creek[a]	22
Echo Creek[a]	18

[a] Subwatersheds located within the study area
Source: Utah Climate Center, Utah State University. Data based on the 1961-1990 period of record.

The high elevations of the Wasatch Range, within the Weber River Basin, lead to significant accumulations of precipitation in the high mountain watersheds as easterly migrating storm patterns encounter elevations of over 10,000 feet. However, due to the topography of the area, precipitation is considered erratic and varies drastically from location to location. Mean annual precipitation for the basin is 21 inches, ranging from 12 to 30 inches within 20 miles. In general, the climate is considered semiarid because evapotranspiration generally exceeds precipitation, except during the winter months.

Average annual temperatures in the Weber River Basin range from 36.0 to 51.2 °F depending on the elevation. High summer temperatures range from 80 to over 100° F. The average summer temperature in the mountain valleys is about six degrees cooler than at lower elevations west of the Wasatch Front. Cooler temperatures at high mountain valleys such as Ogden and Morgan have an average growing season of approximately 95 days. In contrast, the growing season in the lower valleys west of the Wasatch Range is over 160 days.

2.4 GEOLOGY/SOILS

Bedrock in the Weber Basin is primarily sedimentary. Paleozoic formations constitute a basal complex that includes massive limestone, dolomite, and shale with various mixtures of quartzite, sandstone and chert. The Mesozoic rocks are composed primarily of sandstone, siltstone, and shale (UDWR 1997).

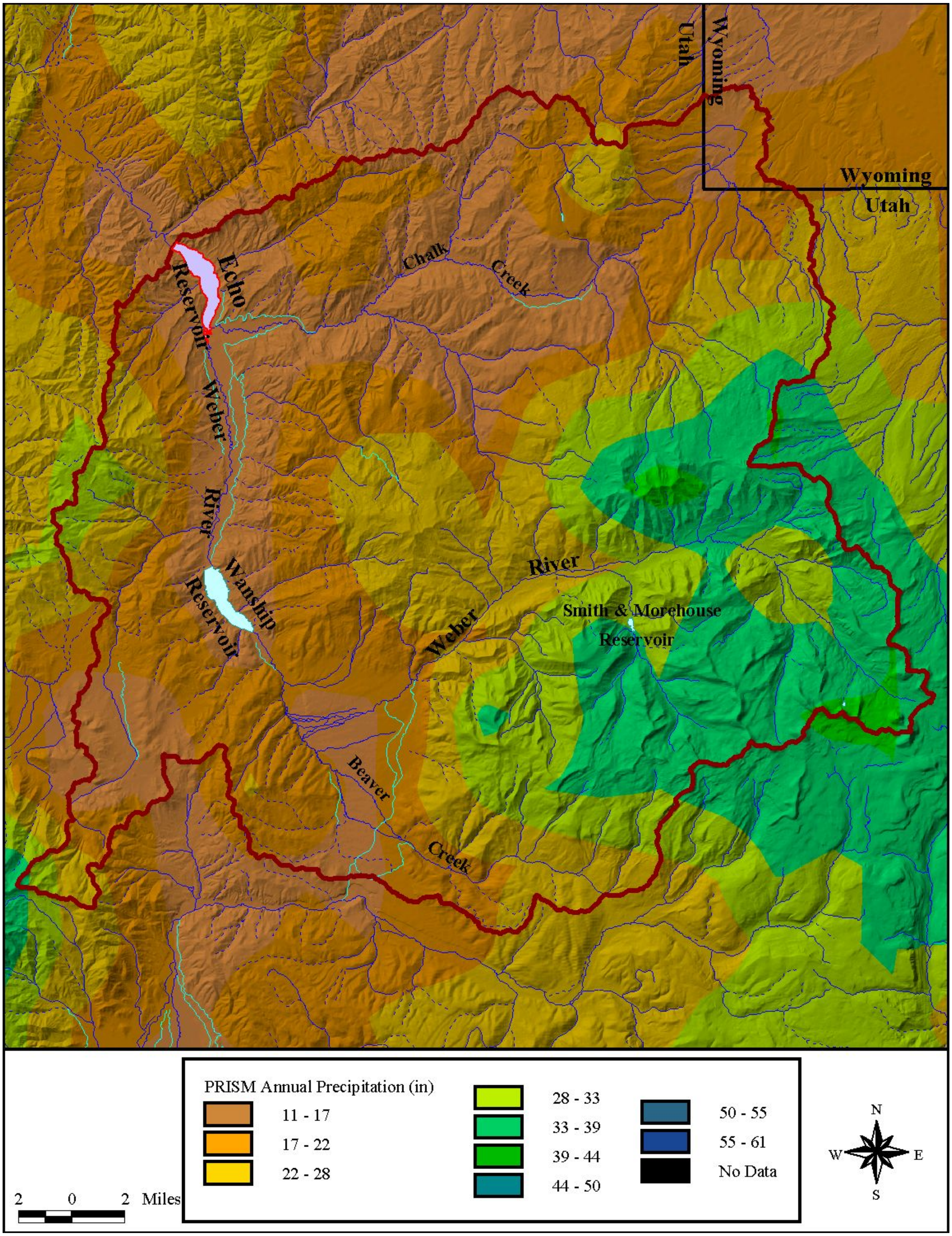

Figure 2.4. Annual average precipitation zones for the Echo Reservoir watershed.

Surficial expressions of geologic features in the Echo Reservoir watershed were primarily formed during the Cenozoic era (Tertiary and Quaternary). These features are generally weathered bedrock including broken fragments, porous conglomerates, sand, or gravel. The principal Tertiary formation within the Weber River Basin is the Wasatch (Knight) Formation, which is composed of sandstone, conglomerate, siltstone, and mudstone (Bryant 1992). Quaternary formations consist mainly of alluvial deposits along the stream beds, lacustrine deposits in the valley (prehistorically occupied by Lake Bonneville), and glacial deposits in areas of highest elevation. These deposits generally include fine textured sands, silts, clays, and gravel.

The headwaters of the Weber River contain extensive deposits of Quaternary glacial material. These materials are highly permeable and therefore retain considerable amounts of water during the spring season. Retained water is subsequently discharged from this material throughout the year and contributes to the maintenance of base flows during the fall season.

Soil resources in the study area have been previously described by the Summit Area soil survey covering parts of Summit, Wasatch, and Salt Lake Counties (NRCS 2002). The spatial distribution of soils in the Upper Weber Basin is defined by the State Soil Geographic Database (STATSGO) shown in Figure 2.5. General descriptions of the soil associations displayed in Figure 2.5 are included below in Table 2.3. Development of soil resources in the Upper Weber River watershed are influenced by several factors including parent material, climate, topography, plant/animal life, and time. Parent material in the study area includes geologic formations located at the earth surface, some of which have been generally described above. Parent material can influence both physical and chemical properties of soil resources. Some geologic formations in the study area consist of material that is naturally high in phosphorus. Additional discussion on the location and extent of these formations is provided below. Soils formed from phosphorus-bearing parent material would likely maintain higher levels of phosphorus with respect to soils formed from other sources. It should be noted that this event would only occur in areas where phosphorus-bearing parent material is located at the earth surface. No information on soil nutrient levels is provided in the Summit Area soil survey.

The influences of climate, topography and plant and animal life on the development of soil resources are interrelated. Precipitation and temperature levels influence organic matter, growth of vegetation, and the rate of chemical reactions in soils. Climate in the Upper Weber Basin is typical of semiarid mountainous regions of Utah but is also influenced to a large degree by topography. The extent and growth patterns exhibited by vegetation are likewise related to precipitation levels and the range of diurnal and seasonal temperature cycles.

In general, soils located along drainage bottoms exhibit deep, well developed profiles that are sometimes subject to flooding and often have high water tables. These areas include portions of Kamas Valley and some areas between Wanship and Echo Reservoir. Soils found on lake and stream terraces are typically silt loam soils associated with lake sediments. These soils are typically well drained and somewhat susceptible to erosion if surface vegetation is not present. Soils located on mountain slopes, ridgelines and alluvial fans are highly variable due to differences in topography, climate and the underlying geology. Soil profiles range from shallow to deep while soil textures range from sandy loam to clay. Soils located on steep slopes are highly susceptible to erosion and sometimes slope failure if vegetation is not present.

Table 2.3. General soil properties for soil associations located in the Echo Reservoir watershed.

ID	Soil Association	General Description
20	TURNER-FLEUTSCH-GELKIE	Very deep, well drained, loam and sandy loam soils on alluvial fans, stream terraces, and mountain slopes.
104/ 349	KEARL-RISHSUM-THATCHER	Moderately deep to very deep, well drained, loam and silt loam soils on alluvial fans, terraces, and mountain and foothill slopes.
130	ANT FLAT-HADES-PICAYUNE FAMILY	Very deep to moderately deep, well drained, cobbly silt loam and loam soils on mountainsides, benches, stream terraces, and alluvial fans.
267	ROUNDY-DAYBELL-FITZGERALD	Deep to very deep, well drained and somewhat excessively drained, gravelly and cobbly loams and sandy loams soils on high mountainsides and plateaus.
273	BROADHEAD-AYOUB-LITTLE POLE	Deep to shallow, well drained, very cobbly loam and clay loam soils on mountainsides and alluvial fans
274	POLELINE-FITZGERALD-HAILMAN	Very deep and deep, somewhat excessively and well drained, loam and gravelly loam soils on mountainsides.
275	HENEFER-YEATESHOLLOW-MANILA	Very deep and deep, well drained, loam and stony or cobbly loam soils on mountain slopes and alluvial fans.
280	KOVICH-MOWEBA-MANILA	Very deep, poorly and well drained, loam and gravelly loam soils on alluvial fans, floodplains, and valley floors.
281	PRINGLE-SOWCAN-WATKINS RIDGE	Very deep, well and somewhat poorly drained, sandy loam, silt loam, and loam soils, on foothills, floodplains, stream terraces, and valley floors.
282	RICHSUM-AYOUB-CUTOFF FAMILY	Moderately deep to deep, well drained, gravelly or cobbly loam and silt loam soils on mountain slopes.
301	MIRROR LAKE-DUCHESNE-MARSELL	Very deep, somewhat excessively to well drained, very cobbly or gravelly sandy loam soils and areas of exposed bedrock on alpine ridges and mountainsides.
302	MIRROR-RUBBLE LAND-TEEWINOT	Moderately deep to shallow, well drained, silt loam and gravelly sandy loam soils and areas of exposed bedrock on alpine ridges and mountainsides.
309	SKUTUM-LUCKY STAR-UINTA	Deep to very deep, well drained, loam, gravelly loam, and cobbly sandy loam soils on mountain slopes and till plains.

2.4.1 Phosphate-Bearing Formations

At the watershed scale, phosphate (PO_4) is readily immobilized in the soil. Erosion of soil particles from steep slopes and disturbed areas following intense storms and flood events are known to contribute total phosphorus to receiving water bodies throughout the United States (US-EPA 1999). Most of the phosphorus eroded from continental rock (>90 percent) is carried to the sea or deep lakes or reservoirs in inert forms. Only a small percentage of total phosphorus delivered to streams occurs in a soluble form. It is unlikely that surface runoff from phosphate bearing rocks could increase the availability of soluble phosphorous for plant growth. Soluble phosphate, that leads to eutrophication, generally originates from domestic, industrial and agricultural sources (Horne and Goldman 1994).

Phosphate bearing rocks of the Park City Formation (Figure 2.6) are correlated with beds of the Phosphoria Formation that consist of deposits of the Permian Sea in the northern Rocky Mountains (Williams 1939). Phosphate-bearing Permian rocks extend from northern Utah through southeastern Idaho, western Wyoming, and central Montana. The Park City Formation underlies the Moenkopi Formation and overlies the massive Pennsylvanian Weber Sandstone (Garrand 1985).

Phosphate bearing rocks of the Park City Formation extend from Park City to the east boundary of the Echo Reservoir watershed along Weber Canyon (Figure 2.6). Generally, phosphate bearing rocks in the Park City Formation lie in depths ranging from 1500 ft in the southern portion to 300 ft in northern areas. However, phosphatic rocks can also be found in depths that range from 300 ft to outcrops at the ground surface in some areas (Garrand 1985). An outcrop of the Park City Formation partly encircles the town of Park City with a U-shaped configuration open to the south (Williams 1939). The phosphatic rock in this formation occurs in beds that vary from a few inches to several feet in thickness. Phosphate bearing rocks in Weber Canyon occur where the Weber River intersects the Phosphoria Formation. The topography of this area is somewhat moderate with the exception of steep canyon slopes. Surface exposures of the phosphatic rocks occur near the canyon bottom on either side of the river. Soil profiles are moderately deep in this area and support sagebrush on south facing slopes and oak brush on north facing slopes. Cottonwood, maple, and box elder tress are present in the canyon bottom (Hanson 1942).

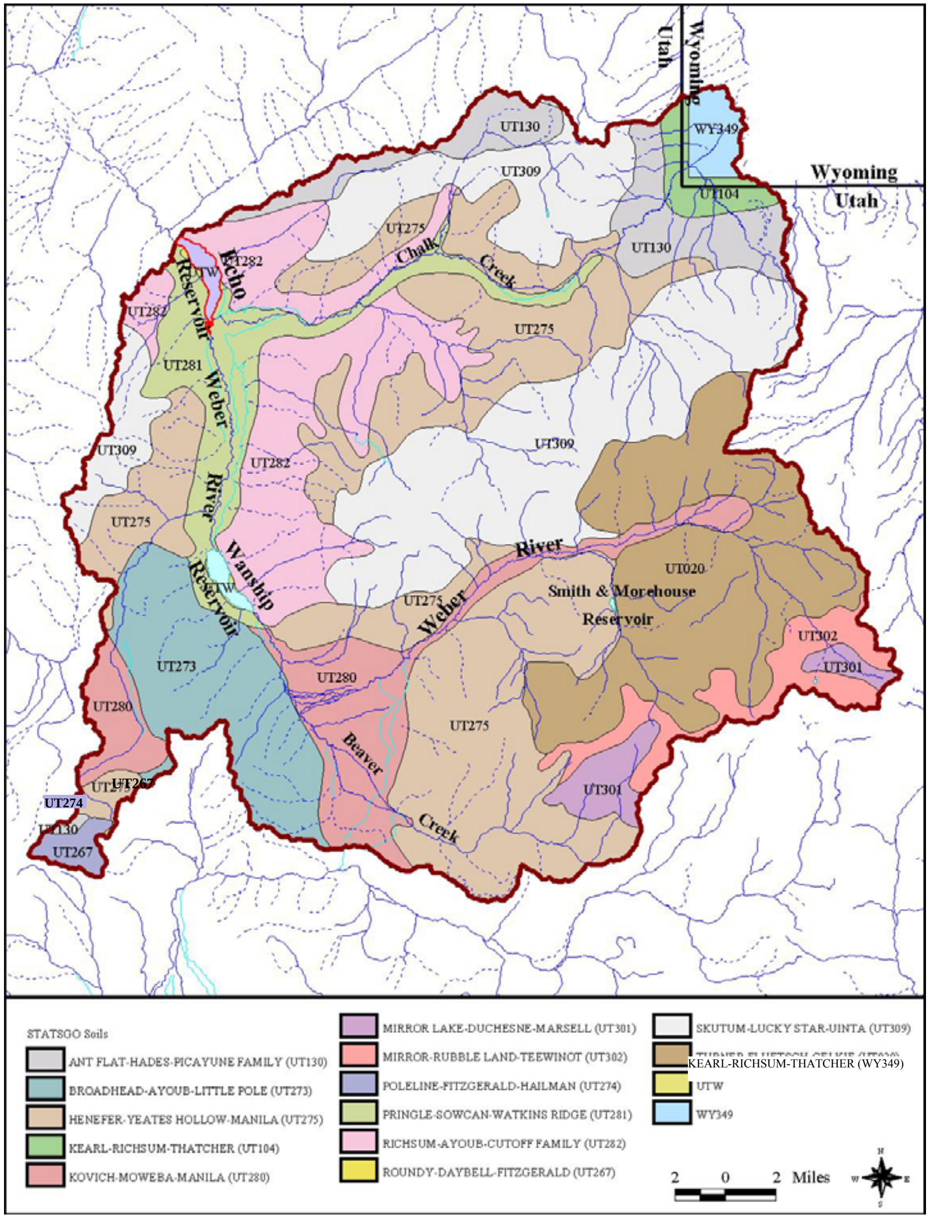

Figure 2.5. Soil property information within the Echo Reservoir Watershed.

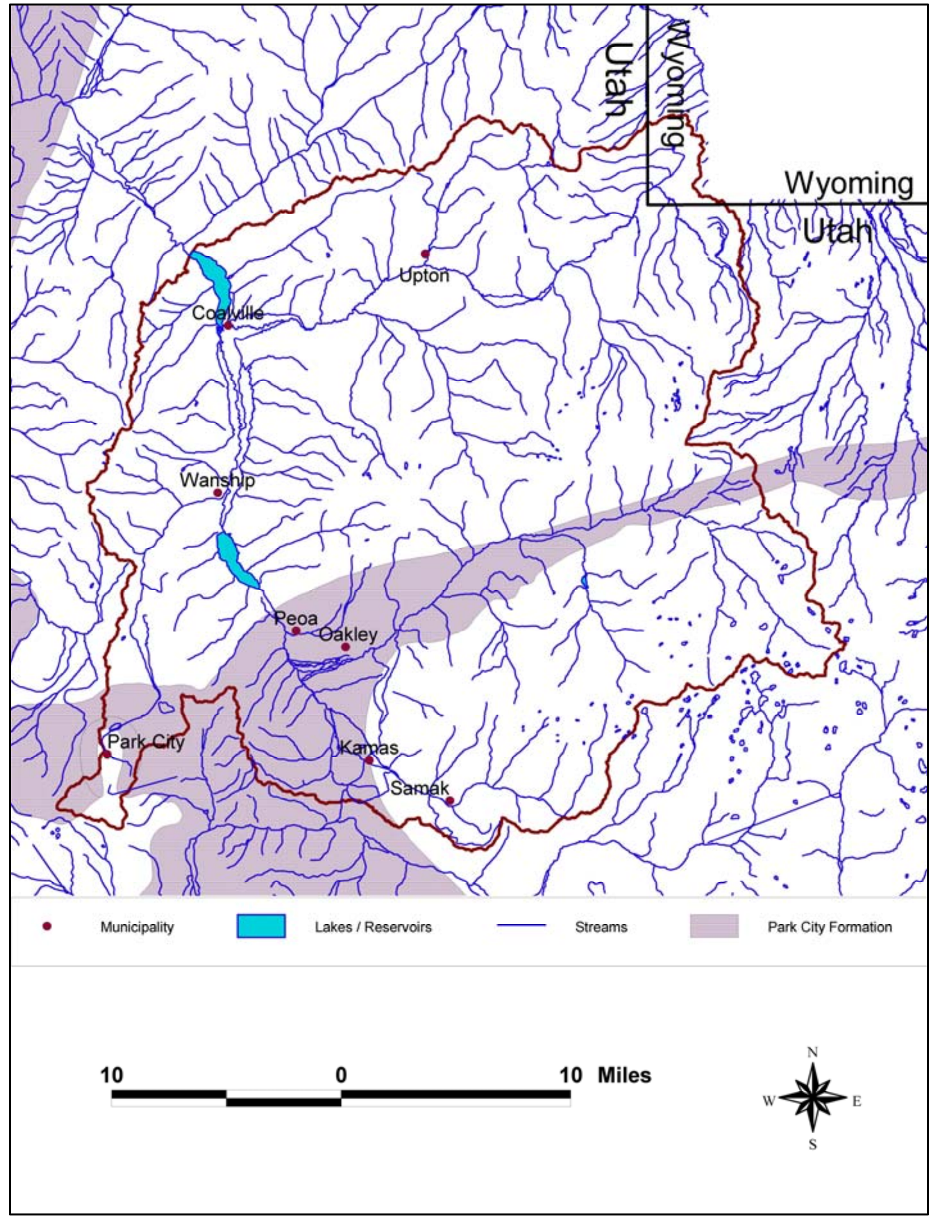

Figure 2.6. Phosphate bearing bedrock in the Echo Reservoir watershed.

2.5 LAND COVER

The Echo Reservoir watershed has a contributing area of approximately 1,876 km^2. Table 2.4 shows the land cover distribution for the Echo Reservoir watershed.

The majority of the land in the Echo Reservoir watershed is comprised of forest (approximately 56 percent) or rangeland (approximately 39 percent) which account for nearly 95 percent of the total watershed area. Although agricultural land represents a relatively minor percentage of land use within the watershed, these areas are likely very important to water quality as they are mainly located adjacent to streams (Figure 2.7).

Table 2.4. Land cover distribution in the Echo Reservoir watershed.

Land Cover Category	Area(km^2)	Percent of Watershed Area
Open Water	7.67	0.41
Perennial Snow/Ice	0.28	0.02
Low Intensity Residential	3.13	0.17
Commercial/Industrial/Transportation	4.43	0.24
Bare Rock/Sand/Clay	10.28	0.55
Quarries/Strip Mines/Gravel Pits	0.78	0.04
Deciduous Forest	381.79	20.35
Evergreen Forest	534.89	28.51
Mixed Forest	133.54	7.12
Shrubland	582.83	31.07
Orchards/Vineyards/Other	0.05	0.002
Grasslands/Herbaceous	146.49	7.81
Pasture/Hay	65.53	3.49
Small Grains	0.02	0.001
Urban/Recreational Grasses	2.05	0.11
Woody Wetlands	0.08	0.004
Emergent Herbaceous Wetlands	2.15	0.11
Total:	**1875.99**	

Source: USGS National Land Cover Dataset – http://landcover.usgs.gov.

2.6 LAND USE

The Echo Reservoir watershed supports a wide range of land uses. Figures 2.7 and 2.8 indicate the distribution of existing land use/land coverage and land ownership within the Echo Reservoir watershed, respectively. Land use in the Echo Reservoir watershed is primarily forest and range land, with smaller areas of irrigated agriculture associated with the low lying areas that are adjacent to stream channels. High mountain areas are used for diverse outdoor recreational activities, production of agricultural crops, livestock, and timber harvesting. The three major reservoirs, including Echo Reservoir, Wanship Reservoir, and Smith and Morehouse Reservoir are heavily used for fishing, boating and swimming. Hiking trails and streams provide additional opportunities to sports fishermen, rafters and kayakers. Livestock production in high mountain valleys is mainly for dairy and meat producing livestock. Irrigated agriculture includes a variety of pasture grasses, alfalfa, small grains, some orchard crops and a variety of vegetables. Populated areas of Summit County generally consist of small rural towns and commercial businesses with the exception of Snyderville Basin and Park City. These two areas are among the fastest growing areas in the state. A high percentage of the population in these residential developments work in the Salt Lake Valley.

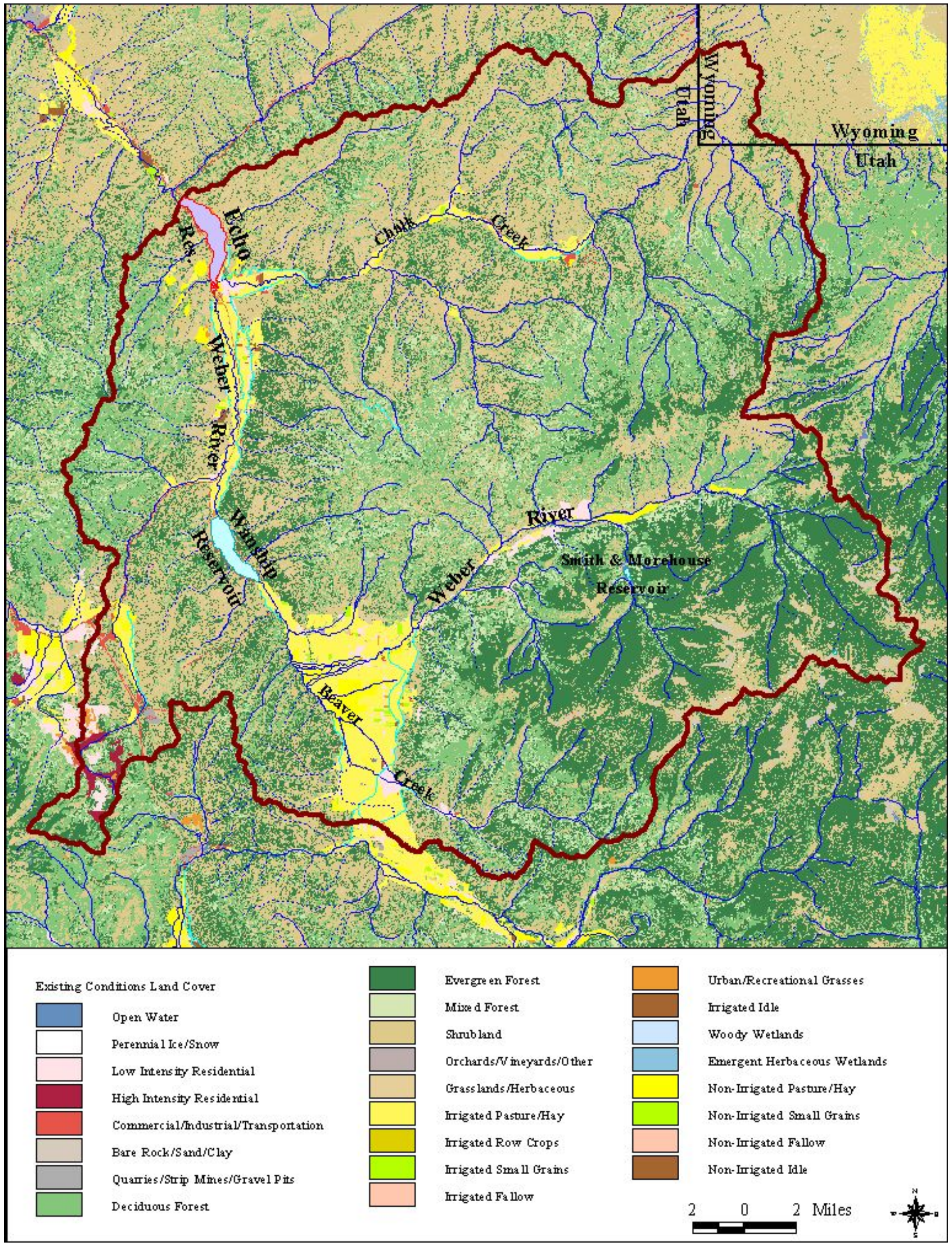

Figure 2.7. Land cover/land use within the Echo Reservoir watershed.

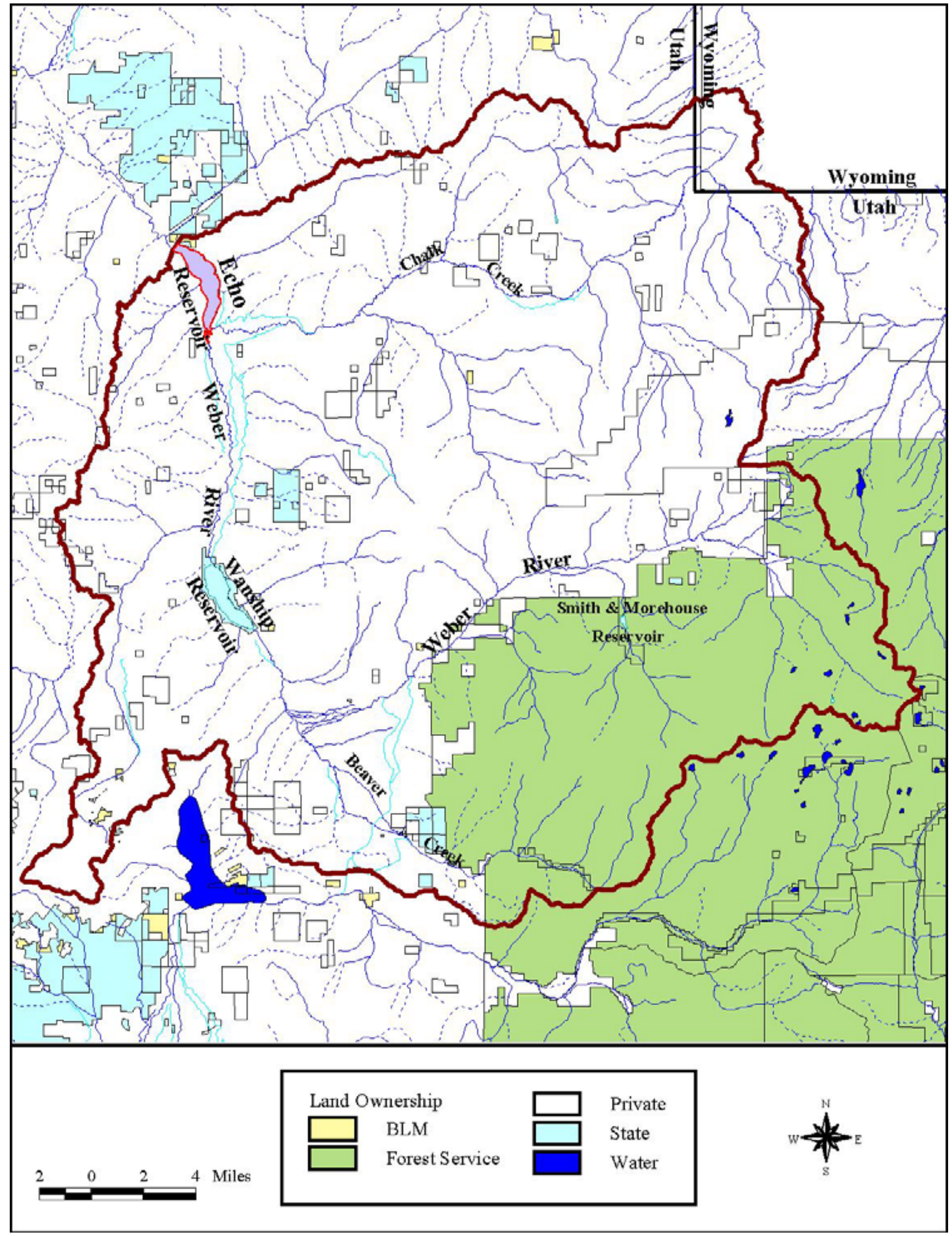

Figure 2.8. Land ownership within the Echo Reservoir watershed.

2.7 HYDROLOGY

The Echo Reservoir watershed comprises the southeastern and most upstream portion of the Weber River watershed and has a contributing area of approximately 725 mi^2. It encompasses all water flowing into Echo Reservoir, including Chalk Creek, Silver Creek, the Weber River, and Beaver Creek. The watershed contains three reservoirs that are managed primarily for irrigation and culinary water storage for downstream water users. Locations of all major water features in the study area are shown in Figure 2.9. The following sections detail the hydrology of the major subwatersheds and stream segments within the Echo Reservoir watershed.

2.7.1 Weber River

The headwaters of the Weber River originate on the western slopes of the Uinta Mountains. The high elevations in this area have precluded human settlement and as such, this area is in relatively pristine condition. The Weber River flows in a westerly direction from its headwaters for approximately 28 miles before it is joined by Beaver Creek. Around the midpoint of this segment, the Weber River is joined by Smith and Morehouse Creek, on which Smith and Morehouse Reservoir is located. This reservoir is the most upstream of several reservoirs located within the Weber River Basin that provide water for distribution purposes. Smith and Morehouse Reservoir is relatively small, with a surface area of around 44 acres and a storage capacity of approximately 1,360 acre-feet.

Also located on this section of the Weber River is a diversion located approximately 1 mile east of Oakley that diverts water from the Weber River across Rhodes Valley, out of the watershed, and down the Provo River. Stream flow in the Weber River above Beaver Creek and above the diversion is typically below 150 cubic feet per second (cfs) during the late summer, fall, and winter. Higher flows at this location are associated with spring runoff and are generally below 3,000 cfs but have been as high as 4,170 cfs (USGS 10128500 - Weber River Near Oakley 1904 - 2002).

After joining Beaver Creek, the Weber River then turns and flows north approximately 4 miles before flowing into Wanship Reservoir (also known as Rockport Lake). Stream flow in this section of the Weber River is similar to that of the Weber River above Beaver Creek. This is likely due to removal of water by the Weber-Provo diversion and the addition of Beaver Creek. Wanship Reservoir is the first of two large Bureau of Reclamation (BOR) impoundments on the Weber River. Water stored in Wanship Reservoir is consumed for both irrigation and culinary water use, and supports heavy recreational use during the late spring, summer and fall. Wanship Reservoir is large, with a surface area of nearly 1,189 acres and a storage capacity of 75,730 acre-feet.

Water released from Wanship Reservoir to the Weber River flows downstream approximately 2.2 miles before it is joined by Silver Creek. The Weber River eventually enters Echo Reservoir 7.5 miles north of this confluence. Stream flow in the section of the Weber River between Silver Creek and Echo Reservoir is generally less than 200 cfs in the summer, fall, and winter and is generally less than 600 cfs during the spring. Flows as high as 2,140 cfs have been observed and are associated with spring runoff (USGS 10130500 - Weber River Near Coalville 1927 - 2002).

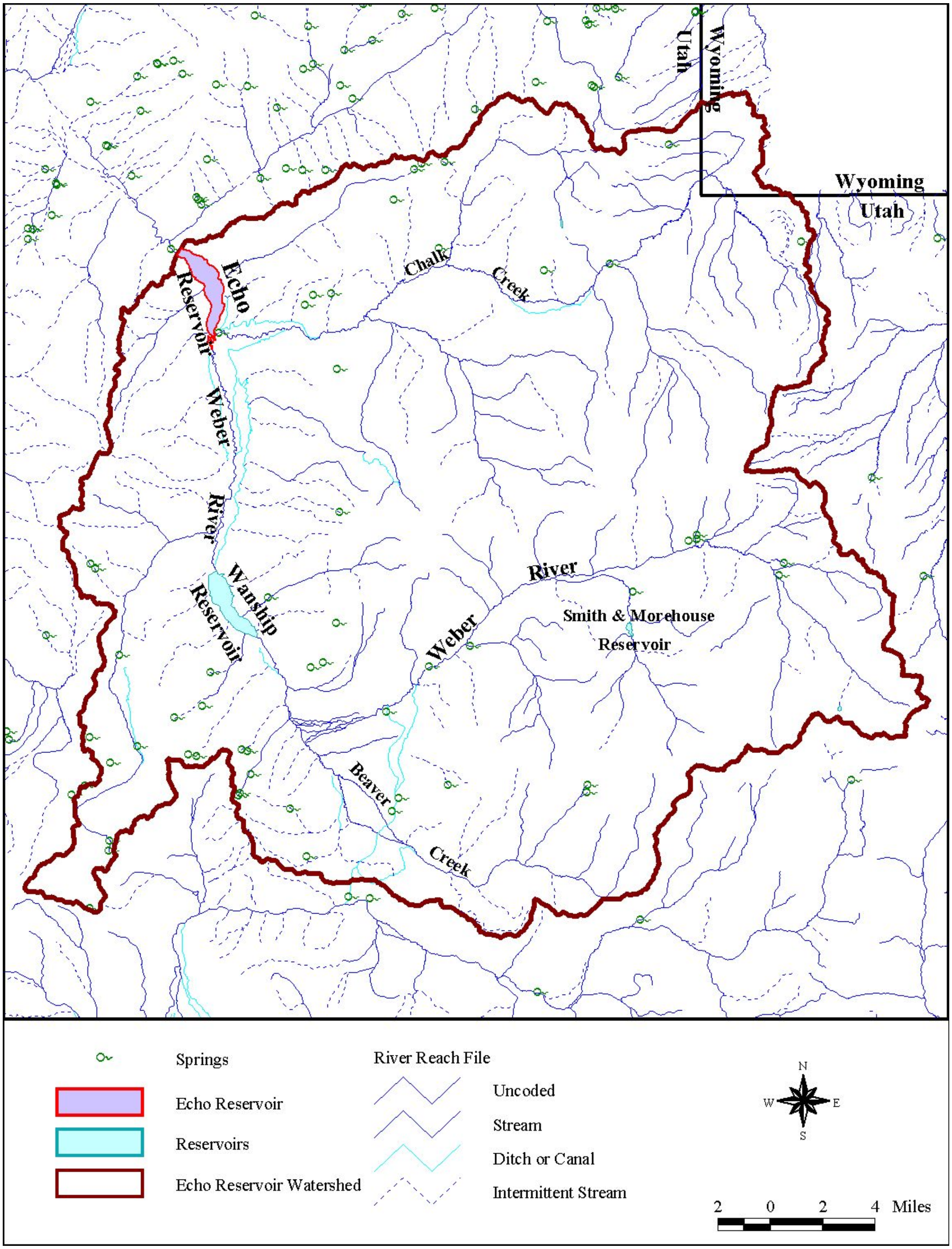

Figure 2.9. Water features in the Echo Reservoir watershed.

In times of low water levels in Echo Reservoir, Chalk Creek flows directly into the Weber River channel at the upper end of the dry lake bed. When water levels are higher, Chalk Creek flows directly into the reservoir. Several stream flow diversions are located on the segment of the Weber River between Wanship Reservoir and Echo Reservoir, primarily supplying irrigation water for agricultural lands located in the valley areas adjacent to the Weber River.

Echo Reservoir is the second of two large reservoirs in the watershed and is also located directly on the main stem of the Weber River. In comparison to Wanship Reservoir, Echo Reservoir has a larger surface area (1,394 acres) but a relatively smaller storage capacity (50,000 acre-feet). Echo Reservoir water is used for irrigation purposes downstream, in addition to the heavy recreational use at the reservoir itself. Releases from Echo Reservoir are generally less than 150 cfs during the fall and winter with no releases the last several years due to an extended drought. Releases are greatest during the months associated with spring runoff and usually peak between 500 to 1000 cfs. Discharge for irrigation purposes occurs throughout the summer and early fall and typically range from 200 to 600 cfs as water is delivered to downstream water users (USGS 10132000 Weber River at Echo 1927 – 1958 and 1989 - 2002).

2.7.2 Beaver Creek

Similar to the Weber River, Beaver Creek originates on the western slopes of the Uintas. It flows approximately 19 miles from its headwaters northwest through Kamas and then joins the Weber River just south of Peoa. Beaver Creek splits just above Kamas into two channels that flow together again approximately 3.4 miles downstream. A streamflow diversion is located on Beaver Creek above Kamas that diverts flow to the south and into the Weber – Provo Canal, which flows out of the watershed. Stream flows in Beaver Creek above the town of Kamas are typically below 20 cfs throughout the late summer, fall, and winter, with spring runoff flows that are generally below 150 cfs but have been observed as high as 308 cfs (UDWR 10129120 – Beaver Creek at Lind Bridge Above Kamas 1996 – 2001).

2.7.3 Silver Creek

This tributary to the Weber River originates on the slopes of the Deer Valley Ski Resort in Park City and carries with it storm water runoff from the Park City area and the effluent of the Silver Creek WRF, which treats much of the municipal wastewater generated in the Park City area. Stream flow in Silver Creek typically ranges from less than 10 cfs in the summer, fall, and winter, to higher flows associated with spring runoff that are typically less than 30 cfs but can be as high as 200 cfs (USGS 10130000 - Silver Creek Near Wanship).

2.7.4 Chalk Creek

The Chalk Creek drainage makes up a significant portion of the contributing area to Echo Reservoir. During times of low water in Echo Reservoir, Chalk Creek flows directly into the Weber River channel at the upper end of the dry lake bed. During times of higher water levels in the reservoir, Chalk Creek flows directly into the reservoir. Stream flow in Chalk Creek is typically less than 50 cfs for most of the year, with higher flows during the spring runoff period that are generally less than 400 cfs but can be as high as 1,400 cfs (USGS 10131000 - Chalk Creek at Coalville).

2.8 RESERVOIR OPERATIONS

Management of reservoir storage volumes in Echo, Wanship and Smith and Morehouse Reservoirs is controlled by the Weber Basin Water Conservancy District for flood control purposes. During the irrigation season however, Echo Reservoir is managed by Weber River Water Users. The timing of water discharge from these reservoirs will vary somewhat during any given year due to annual variations in water demand from entities below Echo Reservoir. Water rights held by individuals in the Lower Weber Basin can be met by delivering water through the Weber Basin river system from any upstream reservoir. In general, water storage is initially used from lower elevation reservoirs followed by upstream reservoirs at higher elevations. Water stored in upper reservoirs is held for as long as possible to provide for more delivery options during the latter part of the year. Mean monthly reservoir storage values for Echo Reservoir and Wanship Reservoir, discharge from Wanship Reservoir, and inflow to Echo Reservoir are shown below in Figure 2.10. The box plots shown in Figure 2.10 provide a means of illustrating the distribution of all data points for a particular month rather than plotting or examining individual data points. Note that the shape of each box indicates the distribution of the data. The height of the "box" or hourglass shape indicates the inter-quartile range of the 25^{th} – 75^{th} quantiles with the middle of the box equal to the median value.

Peak storage and monthly inflow to Echo Reservoir occur at roughly the same time during the year. It is noted that outside of the five-month period of March – July, combined inflow to Echo Reservoir is fairly consistent at about 150 cfs. This is in contrast to reservoir storage which decreases steadily from June through September, then continually increases during the rest of the year. Storage volumes in Echo Reservoir and inflow from the Weber River can be influenced by the Weber Basin Conservancy District. However, Chalk Creek exhibits seasonal trends in flow and water quality that are more typical of unregulated streams.

In general, reservoir discharge volumes exhibit dissolved oxygen concentrations that are lower than riverine waters due to the limited amount of mixing experienced by a reservoir pool in comparison to a river channel. It is currently believed that reservoir management influences water quality by affecting mixing rates between storage volumes and tributary inflow. Tributary inflow to Echo Reservoir is generally believed to increase reservoir dissolved oxygen concentrations. The percent of mixing that occurs at any given time depends on existing storage volumes and the rate of inflow. If no tributary inflow were occurring, dissolved oxygen concentrations in storage volumes would continue to be influenced to a much lesser degree by surface mixing (from wave action), algae photosynthesis, and chemical or biochemical reactions. If storage volumes are rapidly depleted, the influence of stratification would be removed.

If inflows to Echo Reservoir do not result in significant net storage gains, dissolved oxygen concentrations could increase or, at a minimum, stay unchanged. Total phosphorus loads under these conditions could pass through Echo Reservoir or add to existing loads in storage depending on the inflow concentration and settling rates. If inflow to Echo Reservoir is low, mixing rates will primarily depend on changes to reservoir storage (e.g. rapid discharge from the reservoir could contribute to some mixing of the reservoir pool as water elevations decrease). If high storage volumes are present, dissolved oxygen concentrations could remain in good condition if inflow rates provide adequate mixing of the reservoir pool.

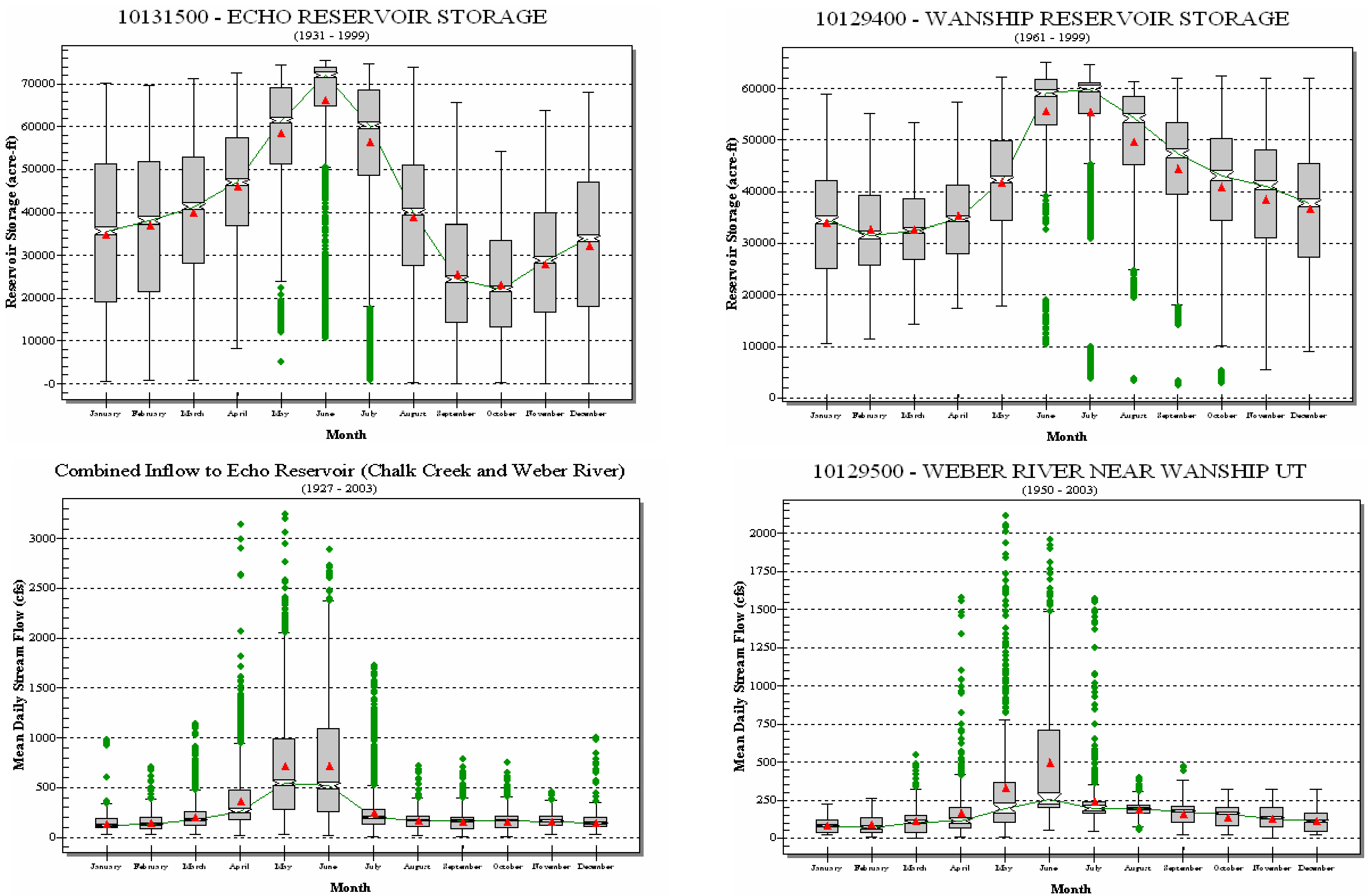

Figure 2.10. Mean monthly reservoir storage for Echo and Wanship Reservoirs. Tributary inflow to Echo Reservoir and streamflow in the Weber River immediately below Wanship Reservoir are shown in the bottom row.

2.9 ANNUAL WATER BUDGET

The overall water budget for the Echo Reservoir watershed was estimated under the assumption that inflows to the watershed are equal to outflows and based on available data using the following equation:

$$P + Q_{c,in} + Q_{g,in} = Q_{out} + Q_{c,out} + Q_{g,out} + CU \qquad (2.1)$$

Inflows = Outflows

Where:
P = Average annual precipitation
$Q_{c,in}$ = Average annual canal inflow
$Q_{g,in}$ = Average annual groundwater inflow
Q_{out} = Average annual discharge from the watershed
$Q_{c,out}$ = Average annual canal outflow
$Q_{g,out}$ = Average annual groundwater outflow
CU = Average annual consumptive use (includes evapotranspiration)

The following assumptions were made to facilitate the completion of the water balance calculations:

1. On average, inflows to the watershed are equal to outflows (the average yearly change in storage in the watershed is equal to 0).
2. The USGS gage near the watershed outlet (USGS 10132000) is characteristic of the watershed discharge. This gage is located on the Weber River just below Echo Dam.
3. There are no known canal inflows to the watershed.
4. Net groundwater flux equals zero ($Q_{g,in} = Q_{g,out}$).
5. The difference between inflows and outflows after all of the other terms in the water budget have been evaluated is attributed to consumptive use, which includes evapotranspiration.

Given these assumptions, Equation 2.1 reduces to:

$$P = Q_{out} + Q_{c,out} + CU \qquad (2.2)$$

The results of the water budget calculations for the Echo Reservoir watershed are shown in Table 2.5. These results have also been normalized by the watershed area and are presented in inches per year. The sections following Table 2.5 detail how the quantities in Equation 2.2 were calculated.

Table 2.5. Echo Reservoir watershed annual water budget results.

	Annual Average Volume (acre-ft)	Area Normalized Annual Average Volume (in)	Percent of Total
Inflows			
Precipitation (P)	928,275	24	100
Total:	928,275	24	100
Outflows			
Watershed Discharge to Weber River (Q_{out})	197,699	5.1	21
Canal Outflow ($Q_{c,out}$)	44,384	1.1	5
Consumptive Use (CU)	686,192	17.8	74
Total:	928,275	24	100

The largest outflow in the Echo Reservoir watershed is consumptive use, which accounts for approximately 74 percent of the total inflows to the watershed. Consumptive use is followed by the watershed discharge to the Weber River, which accounts for approximately 21 percent of the inflows to the watershed. Canal outflows are small comparatively, accounting for only approximately 5 percent of the inflows to the watershed.

2.9.1 Precipitation (P)

An annual average precipitation value was calculated for the Echo Reservoir watershed by summarizing the spatially explicit precipitation data contained in the Parameter-elevation Regressions on Independent Slopes Model (PRISM) dataset (Daly et al. 1994). A discussion of this dataset is included above in Section 2.2 Climate. Based on the PRISM dataset, the average annual precipitation value for the study area is 24 inches/year or 928,275 acre-feet.

In order to validate the PRISM precipitation estimate, annual average precipitation values for several climate stations within the watershed were calculated using data obtained from the Utah Climate Center (http://climate.usu.edu/). Table 2.2 above lists these annual average precipitation estimates and the average of all of the stations for which data was obtained. These stations represent a fairly good cross section of the variability in precipitation that would be expected within the watershed. The average annual precipitation across all six of the stations (23 in/yr) agrees with the PRISM estimate (24 in/yr).

2.9.2 Watershed Discharge (Q_{out})

The outlet of the Echo Reservoir watershed is characterized by releases from the Echo Reservoir dam. The USGS maintains a gage immediately downstream of the dam (USGS 10132000 - Weber River Near Echo) that was used to characterize the watershed discharge via Echo Reservoir releases. The period of record for this gage is from 1927 - 1958 and 1989 - 2002. Figure 2.11 shows annual average flows for the period of record at this gage. In general, Figure 2.11 shows that annual stream flow trends at this gage follow drought cycles, and the data do not show any obvious shifts in management that would affect the average magnitude of the watershed discharge calculated from this data set.

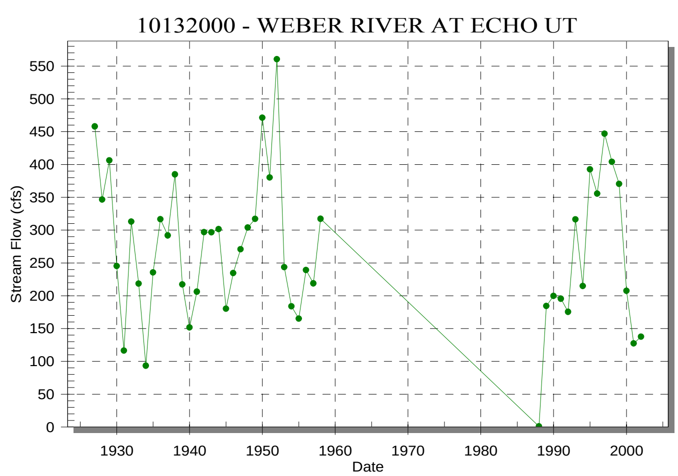

Figure 2.11 Annual average flows for the Weber River below Echo Dam (USGS 10132000).

Equations 2.3 and 2.4 below were used to calculate the annual average watershed discharge. In these equations, an average watershed discharge volume is calculated for each day of the year using existing flow records. Average daily values were then summed to get an annual average watershed discharge volume. This method was chosen because there are times within the period of record where there are gaps in the stream flow data. Daily average flow values can be calculated using all of the available data rather than restricting the analysis to years for which flow data are available on every single day of the year.

$$Q_{i,avg} = \frac{\sum_{j=1}^{m} Q_{i,j}}{m} \quad (2.3)$$

$$Q_{out} = \sum_{i=1}^{n} Q_{i,avg} \quad (2.4)$$

Where: $Q_{i,avg}$ = Period of record average watershed discharge volume for day i of the year
$Q_{i,j}$ = Observed watershed discharge flow volume for day i in year j
m = Number of years for which data are available in the period of record
Q_{out} = Annual average watershed discharge volume
n = Number of days in the year (365)

Evaluating these equations using the USGS stream flow data leads to an annual average watershed discharge of 197,699 acre-feet. Normalized to the watershed area and converted to millimeters, the watershed discharge is equal to 5.1 in/yr.

2.9.3 Canal Outflows ($Q_{c,out}$)

There are no canal flows into the Echo Reservoir watershed ($Q_{c,in}$ = 0). The only canal outflow from the watershed is the Weber - Provo Diversion Canal, which delivers water from the Weber River watershed to the Provo River. Available daily flow records spanning the period from 1932 - 1969 and 1988 - 1998 were obtained from the USGS (USGS 10154500 - Weber - Provo Diversion Canal Near Woodland). These flow measurements; which were made near the watershed boundary and are assumed to be representative of the outflows from the watershed via the Weber - Provo Canal; show that water is delivered to the Provo River via this diversion year-round. Figure 2.12 shows annual average flows for the period of record at this gage.

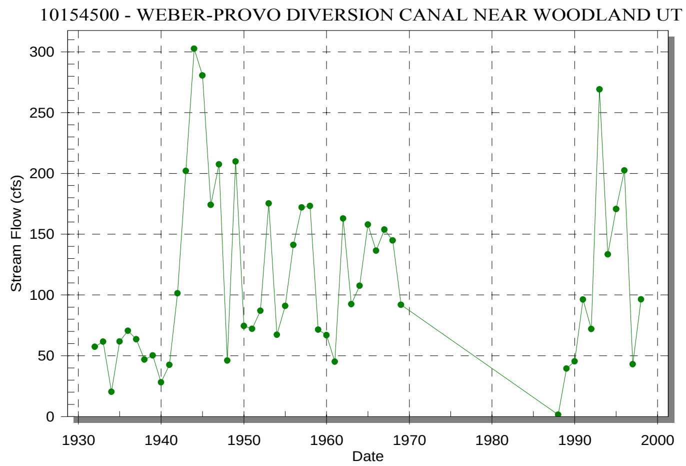

Figure 2.12. Annual average flows for the Weber - Provo Diversion Canal near Woodland (USGS 10154500).

Similar to the calculation of the annual average watershed discharge volume, a daily average flow for each day of the year was first calculated using the available data, and then these periods of record daily average flow values were summed to determine the annual average canal outflow volume. Evaluating Equations 2.3 and 2.4, but substituting the available data for the Weber - Provo Diversion Canal, leads to an annual average canal outflow volume of 44,384 acre-feet. Normalized to the watershed area and converted to millimeters, the canal outflows are equal to 1.1 in/yr.

2.9.4 Consumptive Use (CU)

For the purposes of this water budget, consumptive use has been divided into two components. The first is defined as urban and residential water use, where the water does not return to the system via a septic system or some other pathway and excludes irrigation. The second is water that is consumptively used through evapotranspiration (ET) and includes water used for irrigation. Typically, consumptive use by residents of the watershed is a relatively small fraction of the total urban and residential water use (usually less than 10 percent). There are several municipalities in the Echo Reservoir watershed, which include all of Coalville, Oakley, and Kamas and portions of Park City and Francis. Water use estimates for these towns with public water supply systems were available from the State of Utah Division of Water Rights website (http://waterrights.utah.gov/cgi-bin/wuseview.exe). A review of these data, however, indicated that the magnitude of the water that is consumptively used via urban and residential use (excluding irrigation) is relatively small and was subsequently grouped with evapotranspiration.

It should be noted here that Park City does import water from outside the watershed for its public water supply. However, return flows from urban and residential water use in Park City are split between the East Canyon WRF and Silver Creek WRF. Although flow delivered to the East Canyon WRF leaves the watershed, it is believed that the import and export of water from Park City has little effect on the overall water balance of the basin due to the relatively small magnitude of the net flows.

Evapotranspiration (ET) is defined as the total evaporation from all free-water surfaces plus the transpiration of water vapor through plant tissues (Bedient and Huber 1992). In order to estimate ET separately, the land cover distribution in the watershed must be known along with ET rates for each land cover category. Table 2.4 above shows the land cover distribution in the Echo Reservoir watershed according to the existing conditions land use/land cover dataset that was produced to support modeling and analysis in the watershed.

Generally speaking, ET rates are available for most agricultural land cover types due to research on irrigation requirements of agricultural crops. However, little information is available to characterize ET rates from non-agricultural land cover classes (i.e., evergreen forest, shrubland, etc.). Annual ET estimates at three different National Weather Service stations within the watershed and for several different crop types were available from the Utah Division of Water Rights' website (http://waterrights.utah.gov/cgi-bin/libview.exe). These data are based on a Calibrated SCS Blaney-Criddle Equation and were adapted from Hill (1994). Table 2.6 lists the ET estimates for each of the three locations and the average of all three locations.

The values in Table 2.6 are for agricultural land cover classes and are, in general, somewhat higher than would be expected for the average ET rate for the watershed as a whole. This is expected since agricultural lands typically transpire more water than rangeland or forestland vegetation, which make up the majority of the area within the watershed.

Table 2.6. Annual ET estimates by crop type.			
		Annual Average ET	
Location	**Crop Type**	**mm**	**in**
Echo Dam	Alfalfa	660	26.0
	Pasture	516	20.3
	Other Hay	579	22.8
	SP Grain	518	20.4
	Turf	485	19.1
Wanship Dam	Alfalfa	620	24.4
	Pasture	485	19.1
	Other Hay	546	21.5
	SP Grain	483	19.0
	Turf	457	18.0
Kamas	Alfalfa	625	24.6
	Pasture	505	19.9
	Other Hay	544	21.4
	SP Grain	521	20.5
	Turf	472	18.6
Average	Alfalfa	635	25.0
	Pasture	502	19.8
	Other Hay	556	21.9
	SP Grain	507	20.0
	Turf	471	18.6

Since approximately 94 percent of the land in the Echo Reservoir watershed is not agricultural, and since reasonable ET rates are unavailable for these areas, ET for the watershed was not specifically calculated. Instead, as stated above, ET was lumped with the rest of the consumptive water use in the watershed and was estimated by difference. Under the assumption that inflows to the watershed equal outflows, all of the inflows and outflows (except consumptive use) in Equation 2 were evaluated. These include precipitation, canal flows, and watershed discharge. Next, the difference between the inflows and outflows was attributed to consumptive use. This was done by solving Equation 2 for consumptive use and then evaluating the terms on the right side of equation 5:

$$CU = P - Q_{c,out} - Q_{out} \tag{2.5}$$

Once all of the other terms in Equation 2.5 have been evaluated, the annual average consumptive use volume in the Echo Reservoir watershed works out to approximately 686,192 acre-feet. Normalized by area and converted to millimeters, the annual average consumptive use in the Echo Reservoir watershed is approximately 17.8 in/yr. It is expected that the vast majority of consumptive use within the Echo watershed is due to evapotranspiration and that consumptive use by urban and residential water users is relatively minor.

CHAPTER 3: EXISTING WATER QUALITY CONDITIONS

Various agencies including the Utah Division of Water Quality (DWQ), USFS, USGS, and the EPA have been involved with water quality monitoring in the project area. The record of water quality monitoring data reviewed in this assessment begins in the early 1970s through much of 2003. The exact length of the data record varies depending on the monitoring site and the agency responsible for data collection. Following a review of available water quality data, it was evident that total phosphorus and dissolved oxygen concentrations at Echo Reservoir exceeded the water quality criterion for the designated beneficial use. This chapter provides a detailed assessment of the available water quality, streamflow, and reservoir level data collected within the TMDL study area.

3.1 WATER QUALITY STANDARDS

The designated use of a body of water is based on the water quality standards and goals adopted by the state to protect public health or welfare, enhance water quality, and protect its assigned beneficial uses (e.g. aquatic life, recreation, and agricultural use). The Echo Reservoir Watershed includes two water bodies that are listed on the Utah 2004 303(d) list including Echo Reservoir and Silver Creek. As mentioned previously, the Silver Creek TMDL was submitted to the EPA in April 2004. The impaired beneficial use included on the Utah 2004 303(d) list for Echo Reservoir is shown below in Table 3.1.

Table 3.1. Beneficial use and associated water quality standards for Dissolved Oxygen (DO) and Total Phosphorus (TP) associated with impaired waterbodies located in the Echo Reservoir TMDL study area.

Name	Pollutant of concern	Beneficial Use Class	Beneficial Use Support	Standard / Indicator Value
Echo Reservoir	Total phosphorus Dissolved oxygen	3A – Cold water aquatic life	Partial Support	DO (acute) ≥ 8.0/4.0 [a] DO (chronic) ≥ 6.5 mg/l TP (reservoirs) ≤ 0.025 mg/l TP (streams) ≤ 0.05 mg/l Temperature ≤ 20 °C

[a] First number indicates acute DO standard applicable to early-life stage aquatic species, second number is applicable to adult-life stage aquatic species.

Impairment to lakes and reservoirs is based on three parameters including temperature, pH, and dissolved oxygen, which are collected during routine monitoring of these water bodies by the State of Utah. In most cases, if less than 10 percent of measurements for any of these parameters exceed standards, then full support status is assigned to the water body. Partial support is assigned if exceedance is between 10 percent and 25 percent, while non-support status is assigned if exceedance is more than 25 percent. An exception to this rule is made for dissolved oxygen levels in deep lakes or reservoirs where low oxygen or anoxic conditions might exist. In these situations, if less than 50 percent of the water column is below 4.0 mg/l, the water body is considered to be fully supporting Class 3A beneficial use. If 50 percent to 75 percent of the water column is less than 4.0 mg/l, partial support status is assigned. If more than 75 percent of the water column is less than 4.0 mg/l the water body is considered non-supporting of the Class 3A beneficial use.

The total phosphorus value used by the State of Utah to determine impairment is an indicator value and not a numeric criterion. Desired concentrations of total phosphorus applied to reservoirs and streams are

0.025 mg/l and 0.05 mg/l respectively. These values have been determined to represent threshold values that prevent eutrophication and excessive algae growth. Excessive growth and decomposition of algae and many forms of zooplankton can deplete dissolved oxygen concentrations to levels that are harmful to fish.

In addition to the dissolved oxygen criteria and total phosphorus indicator, other measures of water quality health can be used to add support to a beneficial use assessment. Some of these measures include a Trophic State Index (TSI) evaluation, winter season fish surveys, phytoplankton measurements, and a review of assessment trend since 1989. As mentioned in Chapter 1, Echo Reservoir has been included on the Utah 303(d) list since 1996. The Utah 2002 305(b) report indicated that Echo Reservoir has been classified as partially supporting the Class 3A beneficial use for dissolved oxygen and temperature since 1994. A detailed review of existing water quality and flow conditions for all water bodies in the Echo Reservoir watershed is included below.

3.2 WATER QUALITY AND FLOW MONITORING

A critical part of a TMDL assessment relies upon obtaining and accurately interpreting water quality and flow data. The product of these two parameters can be used to calculate pollutant loads equivalent to a mass per unit time (kg/yr). If paired measurements of flow and water quality are collected at regular intervals and at the appropriate locations, these measurements can be used to validate loads allocated to different pollutant sources.

Members of the Cirrus team obtained the majority of data from publicly accessible repositories including the EPA-STORET database and the USGS data archives. In addition, Cirrus contacted all pertinent agencies and stakeholders within the TMDL study area with the ability to provide water quality, flow, and additional data and information that was used to characterize pollutant sources.

This water quality assessment has reviewed all available water quality data for the study area, including samples collected by agencies other than the DWQ. Some of the assessment relies primarily upon water quality collected by the DWQ during intensive monitoring cycles and flow/reservoir level data collected by the USGS, BOR, and DWQ at selected monitoring sites. As this information was collected on a regular basis, it provides a comprehensive review of water quality and flow conditions in the study area. The most recent data generally considered in this assessment was collected during 2003, although data from UPDES discharges measured in 2004 has also been included.

3.2.1 Surface Water Quality Monitoring Stations

A total of 297 water quality monitoring stations have been identified to date measuring water quality parameters from both surface and groundwater sources within the watershed. The DWQ has collected the majority of surface water quality samples to date, extending back to the early 1970s. Surface water quality measurements have been collected by the DWQ at 86 different sites including streams, lakes/reservoirs, and facilities (Table 3.2). Other agencies that have been involved with water quality monitoring in the project area include the USGS, USFS, and the USEPA. In general, water quality samples from streams have been collected from early spring to early fall, while measurements from reservoirs typically occurred during the summer season. The geographic locations of DWQ water quality monitoring stations in the study area are shown in Figure 3.1. Detailed maps showing the location of all water quality monitoring stations in the study area, including agencies other than DWQ are shown in the Appendix – Maps to this document.

Table 3.2. Water quality monitoring stations identified to date within the Echo Reservoir TMDL project area.						
Agency	**Stream/ River**	**Groundwater/ Well**	**Groundwater/ Spring**	**Lake/ Reservoir**	**Facility**	**Total**
US Forest Service	18			3		21
US Geological Survey	58	76	13			147
Utah Dept. of Health		10	19			29
Utah Division of Water Quality	71	2	2	6	9	90
US Environmental Protection Agency	4			2		6
US EPA Environmental Research Laboratory				1		1
US EPA Region 8					3	3
TOTAL	**151**	**88**	**34**	**12**	**12**	**297**

3.2.2 Ground Water Quality Monitoring Stations

A total of 122 ground water monitoring stations were identified within the TMDL study area. Of these stations, 88 stations were associated with wells while 34 stations were associated with springs (Table 3.2). The majority of well samples (76) have been collected by the USGS while most of the spring samples (19) have been collected by the Utah Department of Health. In general, water quality monitoring at wells and springs were limited to one or two samples.

3.2.3 Flow Monitoring Stations

The USGS monitors continuous flow at eighteen stations located within the Echo Reservoir Watershed. The longest record of continuous flow dates from 1904 through 2002 at a gauging station located at the Weber River near Oakley, Utah (USGS 10128500). Of the flow monitoring stations identified within the study area, six have a data record that extends through 2002. Continuous flow monitoring stations located within the project area are shown in Table 3.3 and Figure 3.2.

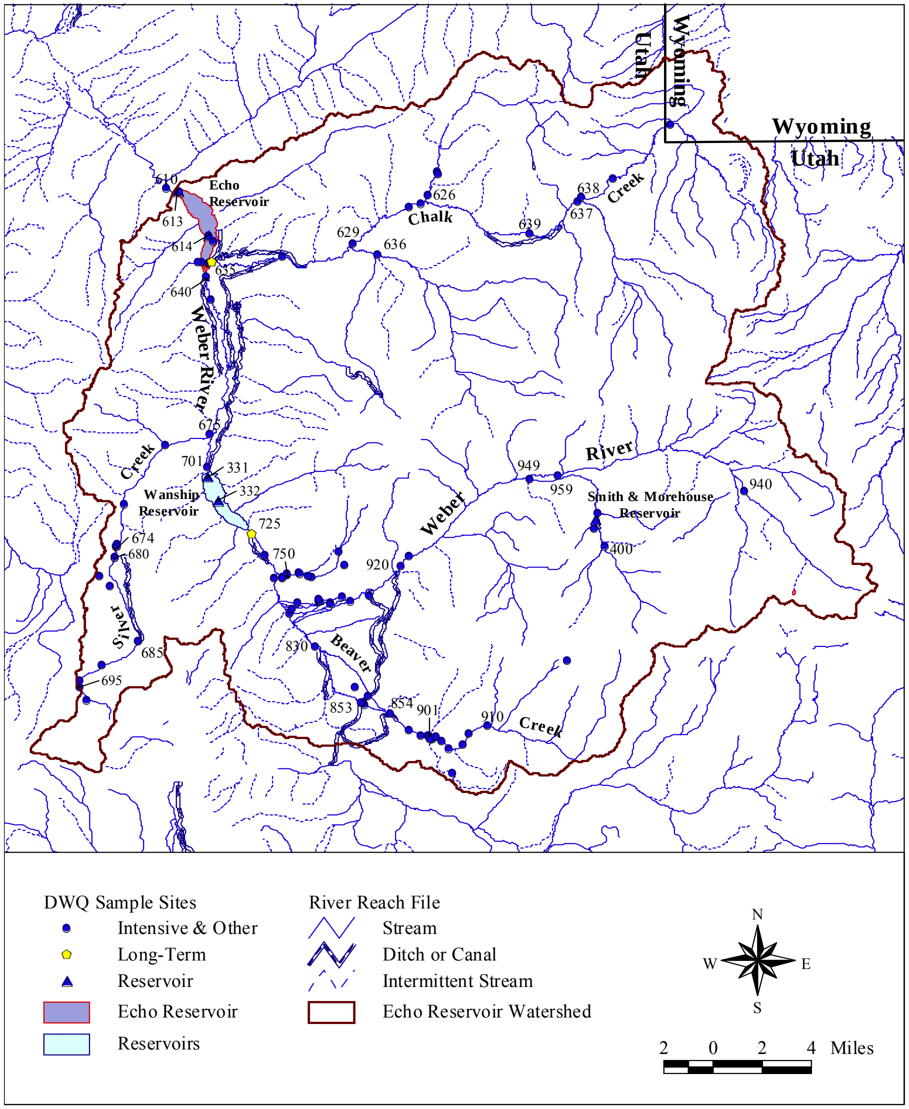

Figure 3.1. DWQ surface water monitoring sites in the Echo Reservoir watershed. The labeled sites shown in this figure indicate those sites included in the intensive and long term monitoring programs. Note that station ID labels shown include the last three numbers only.

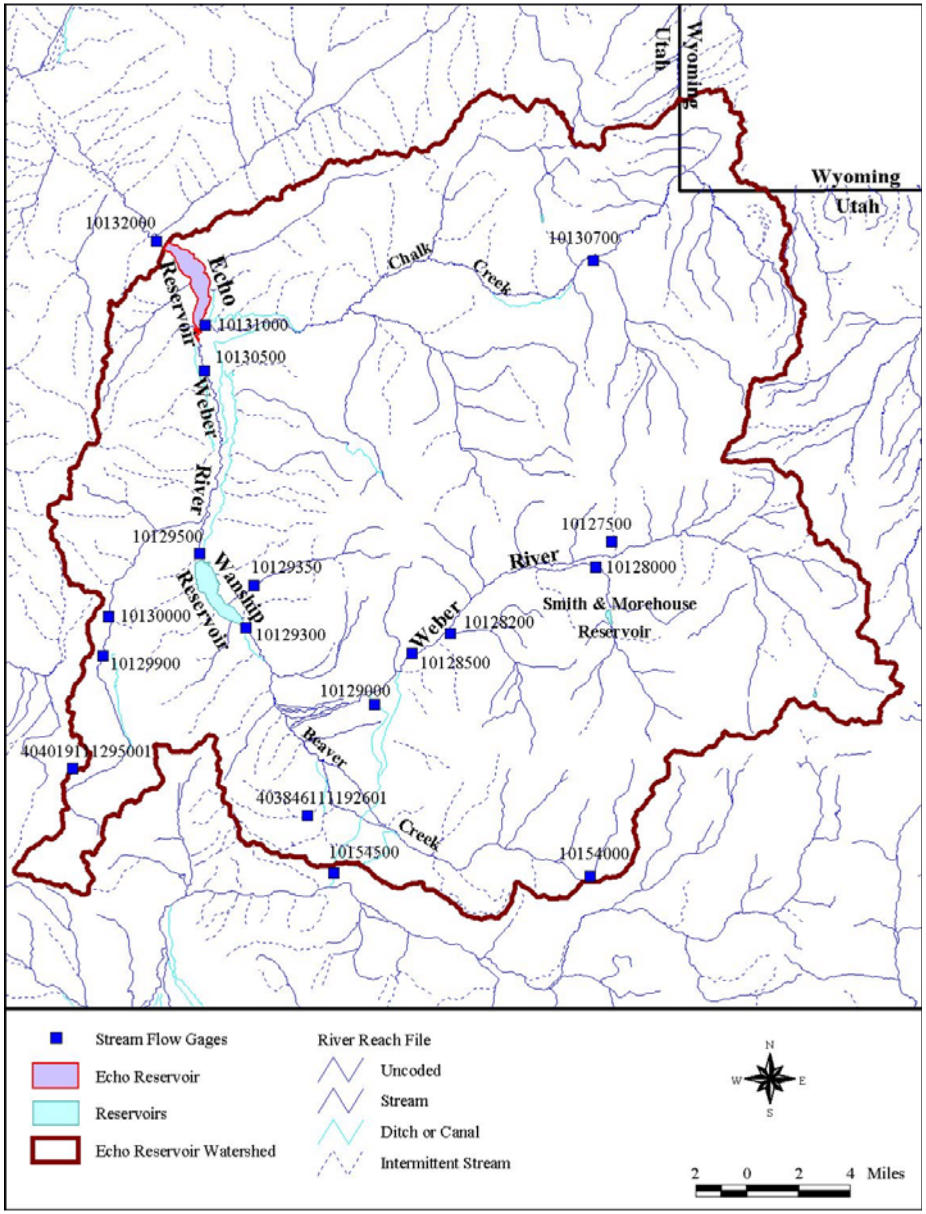

Figure 3.2 USGS flow gage stations located within the Echo Reservoir watershed.

Table 3.3. USGS flow monitoring stations located in the Echo Reservoir project area.		
Station ID	**Station Name**	**Date Range**
10127500	Weber River Above Smith and Morehouse Creek Near Oakley	1946 – 1947
10128000	Smith and Morehouse Creek Near Oakley UT	1946 – 1974
10128200	South Fork Weber River Near Oakley UT	1964 – 1974
10128500	Weber River Near Oakley UT	1904 – 2002
10129000	Weber-Provo Diversion Canal at Oakley UT	1938 – 1969
10129300	Weber River Near Peoa UT	1957 – 1977
10129350	Crandall Creek Near Peoa UT	1963 – 1973
10129500	Weber River Near Wanship UT	1950 – 2002
10129900	Silver Creek Near Silver Creek Junction, UT	2001 – 2002
10130000	Silver Creek Near Wanship UT	1941 – 1996
10130500	Weber River Near Coalville UT	1927 – 2002
10130700	East Fork Chalk Creek Near Coalville UT	1964 – 1974
10131000	Chalk Creek at Coalville UT	1927 – 2002
10132000	Weber River at Echo UT	1927 – 2002
10154000	Shingle Creek Near Kamas UT	1963 – 1973
10154500	Weber-Provo Diversion Canal Near Woodland UT	1932 – 1998
403846111192601	Indian Hollow Near Kamas	1998 – 1999
404019111295001	Dority Spring Weir Near Park City UT	1988 – 1988

In addition to these continuous flow-gauging stations, instantaneous flow is typically recorded at DWQ monitoring sites at the time when water samples are collected, thus providing additional records of stream discharge. Daily flow information was also obtained from the Division of Water Rights for irrigation ditches, canals, and reservoirs within the TMDL study area.

3.2.4 Sampling Frequency

Streams in the Weber River Basin are monitored for water quality and flow by the DWQ at two different sample frequencies. A select number of sites are continually sampled each year as part of a long term monitoring program. Additional sites are sampled every fifth year approximately every month during an intensive monitoring cycle. The locations of these sites are shown in Figure 3.1. Water quality monitoring sites included as part of the 1993-94 and 1998-99 intensive monitoring cycles are included in Table 3.4. An indication of sites that were measured during the long-term monitoring completed in 2001-2002 is also included in Table 3.4, as this data was used to support trend assessments and reflect the most recent water quality conditions in the study area.

Reservoirs and lakes in the Weber River Basin are typically monitored every other year by the DWQ. At the present time, Echo Reservoir and Smith and Morehouse Reservoir are monitored during even years, while Smith and Morehouse Reservoir is also monitored on odd years. In order to provide greater support to this TMDL assessment, additional measurements were collected from Echo Reservoir on four dates during 2002 and again during 2003. Profile measurements of dissolved oxygen, temperature, pH and other field parameters were collected during all site visits from two locations on Echo Reservoir and Wanship Reservoir and from one location on Smith and Morehouse Reservoir. The number of water samples collected from the water column at each monitoring site was determined by the presence or absence of a thermocline. If a thermocline was not observed during measurement of field parameters, water samples were collected from just below the water surface, at mid-depth, and within 0.5 m of the bottom. If a thermocline was noted, the mid-depth sample was replaced by two samples collected 1 meter above and 1 meter below the thermocline.

Continuous flow monitoring of streams has been completed by the USGS at selected locations shown above in Table 3.3. Measurements of water surface elevation and discharge from Echo Reservoir have been completed on a daily basis by the Bureau of Reclamation and the Weber Basin Water Conservancy District.

Table 3.4. Surface water stations visited during DWQ monitoring completed in the TMDL study area.

Station	Site Description	1993-94	1998-99	2001-02
Facilities				
492632	COALVILLE WWTP	X	X	X
492679	SILVER CREEK WWTP	X	X	X
492802	OAKLEY LAGOONS	X	X	X
492850	KAMAS LAGOONS	X	X	X
492900	KAMAS FISH HATCHERY EFFLUENT	X	X	X
Reservoirs[a]				
492613	ECHO RES AB DAM 01	X	X	X
492614	ECHO RES 2/3 WAY UP LAKE 02	X	X	X
592331	WANSHIP RES AB DAM 01	X	X	X
592332	WANSHIP RES MIDLAKE 02	X	X	X
592396	SMITH AND MOREHOUSE RES AB DAM 01	X	X	X
Streams				
492610	WEBER R BL ECHO RES	X	X	
492626	HUFF CK AB CNFL/ CHALK CK	X	X	
492628	CHALK CREEK AT UT/WYO STATELINE		X	
492629	CHALK CREEK AB CNFL/ SOUTH FORK	X	X	
492635	CHALK CK AT US189 XING	X	X	X
492636	CHALK CK S FK 1 MI AB CHALK CK	X	X	
492637	CHALK CK EAST FK AB CNFL/ CHALK CK	X	X	
492638	CHALK CK AT CULVERT 0.8MI AB PINE CLIFF CAMPGROUND	X	X	
492639	CHALK CREEK 4 MILES EAST OF UPTON	X	X	
492640	WEBER R AB ECHO RES	X	X	X
492674	SILVER CK AT FARM XING IN ATKINSON		X	X
492675	SILVER CK AT WANSHIP AB CNFL / WEBER R	X	X	X
492680	SILVER CK AB ATKINSON		X	X
492685	SILVER CK AT US40 XING E OF PARK CITY		X	X
492695	SILVER CK @ CITY PARK AB PROSPECTOR SQUARE		X	X
492697	PARK MEADOW DRAIN CK FROM GOLF COURSE AB SILVER CK		X	
492701	WEBER R BL WANSHIP RES	X	X	
492725	WEBER R AB WANSHIP RES	X	X	X
492830	BEAVER CK AB CROOKED CK	X	X	
492853	BEAVER CREEK AB0VE WEBER-PROVO CANAL		X	
492854	BEAVER CK AT BRIDGE TO LUMBER MILL 1MI AB KAMAS 19	X	X	
492910	BEAVER CK AT USFS BOUNDARY 10	X	X	
492920	WEBER R AB WEBER/PROVO DIVERSION	X	X	
492940	WEBER R AB HOLIDAY PARK DEVELOPMENT	X	X	
492949	SMITH MOREHOUSE CK AB CNFL/ WEBER R	X	X	
492959	WEBER R AB CNFL/ SMITH MOREHOUSE CK		X	
592400	SMITH AND MOREHOUSE CK AB SMITH AND MOREHOUSE RES	X	X	X

[a] Reservoir sites were sampled on even years only (e.g. 1994, 1998, 2002).

3.3 Existing Water Quality

As discussed above, the assessment of water quality conditions in the Echo Reservoir watershed indicated that concentrations of dissolved oxygen and total phosphorus in Echo Reservoir do not fully support the established standards for aquatic life. Both dissolved oxygen and total phosphorus participate in important chemical and biological reactions that support viable aquatic habitat. The main source of oxygen is the atmosphere. Oxygen is consumed in respiration by plants and animals but is only produced by plants under appropriate light and nutrient conditions. In the water column, respiration and decomposition can deplete oxygen unless it is continually replenished by the atmosphere. Oxygen depletion causes changes in the solubility of many metals and some nutrients. Organic matter from natural, domestic, and industrial sources can also contribute to the depletion of oxygen concentrations. Under low oxygen, or anoxic conditions, most aquatic organisms die and are replaced by few specialized organisms that can tolerate these conditions.

Dissolved oxygen is regulated primarily by temperature, but photosynthesis, respiration, aeration of the water, and the presence of other gases can also affect dissolved oxygen concentrations. In general, the concentration of dissolved oxygen is inversely proportional to the water temperature. In productive reservoirs, depth oxygen profiles vary at short and long time intervals. The ranges of diel (diurnal-nocturnal) variations increase with higher lake productivity. During the winter or spring mixing period, oxygen concentrations reach equilibrium with the atmosphere. As temperatures increase, thermal stratification will occur. Thermal stratification in a reservoir generally creates horizontal layers with distinct temperature and dissolved oxygen conditions. Upper layers near the water surface are considered part of the epilimnion while lower layers are part of the hypolimnion. Between the upper and lower layers is a transitional zone of temperature and dissolved oxygen concentration called the metalimnion. This zone usually exhibits a temperature gradient or thermocline of at least 1° F per 1.5 ft. In lakes where thermal stratification occurs, oxygen levels can decrease below the metalimnion until much of the hypolimnion water is anoxic. During fall, as water temperatures decrease, the resistance to mixing is lowered and oxygen levels tend to approach equilibrium with the atmosphere. In the hypolimnion of productive lakes, dissolved oxygen is reduced by the oxygen demand of decaying phytoplankton. Low dissolved oxygen in the hypolimnion affects the survival of fish and invertebrates and increases the recycling of nutrients (Horne and Goldman 1994).

Organic pollution of rivers and streams lead to high fluctuations of dissolved oxygen concentrations. Modern sewage treatment plants reduce the biological oxygen demand of the effluent, but where only primary treatment is provided, permanent oxygen depletion can occur. Further, the oxygen demand generated by nonpoint source pollution also reduces oxygen concentrations in streams (Horne and Goldman 1994).

Phosphorus is a common limiting factor for phytoplankton growth in lakes and reservoirs. Most of the phosphorus in the water column is biologically unavailable in the particulate form. The phosphorus cycle in lakes involves organic, inorganic, soluble, and particulate forms. Of these forms, algae can only use soluble phosphate (PO_4) for growth. Phosphates generally accumulate over winter and are reduced to lower concentrations by late spring. During the rest of the year, the remaining phosphorous compounds and the phosphorus taken up phytoplankton are recycled by the excretion of fish, zooplankton, and bacterial activity. In general, recycling is likely to be the main source of phosphorous for phytoplankton during summer and fall. In shallow lakes, or in shallow waters of deep lakes, phosphates from the sediments replenish the water column in a process known as internal loading. In deeper lakes however, winter or spring mixing is a more significant factor for returning phosphorous to the epilimnion (Horne and Goldman 1994).

In a watershed, phosphate is rapidly immobilized in the soil. Ground water does not easily transport phosphate during recharge to surface streams. Inflows of total phosphorus to streams and lakes results primarily from erosion of soil particles from steep slopes and disturbed areas. Most of the phosphorous detached from rocks from weathering is transported to waterbodies in an inert form. Only a portion of the total phosphorus in streams is present in soluble form. Domestic, agricultural, and industrial wastes are sources of soluble phosphate and have led to eutrophication in many lakes and reservoirs. In phosphorus limited lakes the amount of algal growth during summer is proportional to phosphorus loads received from the surrounding watershed.

At the bottom of the water column, the sediment-water interface is the barrier to free interchange of phosphorous between sediment and water. Phosphate ions can enter the water column at this location if anoxic conditions are present. However, if sufficient oxygen is available, phosphate ions are scavenged and do not pass freely to the water column (Horne and Goldman 1994).

3.3.1 Surface Water Quality

The assessment of current water quality conditions in the Echo Reservoir watershed included the compilation and summary of available data. The stations included in this assessment were selected based on their location with respect to impaired water bodies and length of data record. It is noted that although Wanship Reservoir and Smith and Morehouse Reservoir are not included on the 2004 303(d) list, they are discussed here for comparison purposes.

Table 3.5 and Table 3.6 show mean values for selected stream and reservoir monitoring sites during intensive monitoring periods (1993-94 and 1998-99) as well as during the recent past (2001 – present). A statistical summary of water quality parameters for all stream and reservoir monitoring stations included in the DWQ intensive monitoring program for the Echo Reservoir watershed is provided in the Appendix – Data. Figure 3.3 shows mean concentrations of total phosphorus and dissolved oxygen from 1993 – 2003 for selected monitoring sites on the mainstream Weber River, major tributaries to the river and all three reservoirs in the study area. A comprehensive review of all available water quality and flow data can be found in the data investigation completed prior to this TMDL assessment (DWQ 2003).

<u>3.3.1.1 Streams</u>

Dissolved Oxygen- Average dissolved oxygen concentrations on the main stem of the Weber River ranged from 6.03 mg/l at a station located below Wanship Reservoir (Station 492701) to 11.21 mg/l above Echo Reservoir (Station 492640) (Table 3.5). The concentration of dissolved oxygen in streams generally exceeded the applicable acute standard for early aquatic life stage (8 mg/l) and adult aquatic life stage (4 mg/l). A decrease in dissolved oxygen concentration was observed at stations located above and below Wanship Reservoir. A similar pattern was observed at stations located above and below Echo Reservoir (Figure 3.3(a)).

Total Phosphorous- No strong longitudinal trends are evident for total phosphorus concentrations between upstream and downstream stations along the mainstem of the Weber River. However, upper headwater stations in the upper Weber and Silver Creek subwatersheds have low average total phosphorus concentrations, ranging from 0.02 mg/l to 0.03 mg/l. Total phosphorus concentrations in the Weber River above Echo Reservoir appear slightly higher than below the reservoir with the exception of samples collected during 2003 (Table 3.5). Wanship Reservoir appears to have a slight influence on instream total phosphorus concentrations. The total phosphorus indicator value for streams (0.05 mg/L) was exceeded roughly half of the time at stations located above and below Echo Reservoir (Stations 492640, 492610). Total phosphorus concentrations measured at the mouth of Beaver Creek (Station 492830) and Chalk Creek (Station 492635) also exceeded 0.05 mg/l for roughly 40 – 60 percent of all samples during the 1993-93 and 1998-99 intensive monitoring cycles. The long-term average total phosphorus concentration for selected stream sites is shown in Figure 3.3(c). Total phosphorus concentrations for all stream monitoring sites visited during the 1998-99 intensive monitoring cycle are shown in Figure 3.4.

Table 3.5. Summary water quality statistics for selected DWQ stream monitoring sites in the Echo Reservoir watershed.

		DO (mg/l)			**pH**			**Temperature (°C)**			**Total Phosphorus (mg/l)**		
	Dates	**Samples**	**Mean**	**Exceedance (%)a**	**Samples**	**Mean**	**Exceedance (%)**	**Samples**	**Mean**	**Exceedance (%)**	**Samples**	**Mean**	**Exceedance (%)**
492610 - WEBER R BL ECHO RES													
	1993 - 94	18	8.48	0/44.4	18	8.33	0	18	9.14	0	18	0.05	44.4
	1998 - 99	13	8.28	7.7/38.5				13	8.52	0	13	0.04	38.5
	2003	5	8.29	0/20	10	8.12	0	5	10.88	0	5	0.16	40.0
492635 - CHALK CK AT US189 XING													
	1993 - 94	30	9.28	0/23.3	30	8.13	0	30	8.13	0	30	0.14	40.0
	1998 - 99	18	9.65	0/16.7	18	8.28	0	18	7.62	0	18	0.11	38.9
	2003	8	9.529	0/12.5	15	8.05	0	8	7.87	0	8	0.10	25.0
492640 - WEBER R AB ECHO RES													
	1993 – 94	22	9.76	0/9.1	23	8.49	0	23	9.26	0	23	0.07	82.6
	1998 – 99	15	9.80	0/0	15	8.54	6.7	15	10.36	0	15	0.09	60.0
	2003	20	11.21	0/0	30	8.49	0	20	10.31	0	20	0.07	50.0
492701 - WEBER R BL WANSHIP RES													
	1993 - 94	19	7.94	5.3/42.1	19	8.34	0	19	8.23	0	19	0.05	31.6
	1998 - 99	13	8.37	0/38.5	12	8.33	0	13	8.02	0	13	0.04	15.4
	2003	5	6.03	20/60	10	7.97	0	5	9.42	0	5	0.04	20.0
492725 - WEBER R AB WANSHIP RES													
	1993 - 94	25	9.34	0/8	25	8.40	4	25	8.76	0	25	0.04	28.0
	1998 - 99	19	10.44	0/0	18	8.57	5.6	19	7.05	0	19	0.05	47.4
	2003	16	9.99	0/18.8	31	8.48	0	16	9.27	6.2	16	0.04	18.8
492920 - WEBER R AB WEBER/PROVO DIVERSION													
	1993 -94	19	8.84	0/26.3	19	8.39	0	19	7.20	0	19	0.03	10.5
	1998 – 99	12	9.97	0/8.3	12	8.52	0	12	5.34	0	12	0.02	0
492830 - BEAVER CK AB CROOKED CK													
	1993 – 94	18	9.29	0/16.7	19	8.23	0	19	8.82	5.3	19	0.06	52.6
	1998 – 99	12	10.13	0/0	12	8.30	8.3	12	8.69	0	12	0.07	58.3
492680 - SILVER CK AB ATKINSON													
	2001 - 02	11	9.04	0/18.2	11	7.76	0	11	6.98	0	9	0.03	22.2

a First value indicates percent samples less than the 4.0 mg/l minimum DO criteria associated with presence of adult life-stage aquatic species. The second value indicates the percent samples less than the 8.0 mg/l minimum DO criteria associated with early life-stage aquatic species.

Table 3.6. Measurements of water quality collected from Echo Reservoir. Mean profile measurements include water temperature, pH, and dissolved oxygen. Mean total phosphorus measurements shown are typically calculated from four column samples collected at station 492613 or two water column samples at station 492614 on each date.

					Temperature (°C)			pH			DO (mg/l)			Total Phosphorus (mg/l)		
Date	Depth (m)	Inflow (cfs)	Storage (ac-ft)	Samples	Mean	% > 20 C	Status[a]	Mean	6.5>%>9.0	Status[a]	Mean	% > 4.0 mg/l	Status[a]	Mean	% > .025 mg/l	Status[a]
Reservoir Station 492613 - ECHO RES AB DAM 01																
28-Jun-94	24.9	238	54090	26	15.70	0	S	8.23	0	S	5.41	85	S	0.014	25	NS
02-Aug-94	19.0	273	31830	20	19.62	30	NS	8.18	0	S	4.84	70	S	0.028	25	NS
18-Jun-96	28.5	1292	73250	22	13.76	0	FS	8.33	0	S	7.35	100	S	0.019	25	NS
06-Aug-96	24.4	316	49900	26	18.19	19	PS	7.98	0	S	4.70	46	PS	0.024	25	NS
02-June-98	29.0	713	67350	30	13.53	3	S	8.22	0	S	6.90	100	S	0.013	0	S
01-Sep-98	23.7	247	47640	26	18.35	4	S	7.96	0	S	4.03	42	PS	0.043	25	NS
07-Jun-00	25.6	261	59274	25	13.69	8	S	8.13	0	S	6.86	96	S	0.023	25	NS
01-Aug-00	18.6	169	30006	20	20.20	45	NS	7.88	0	S	5.05	60	S	0.030	25	NS
12-Jun-02	25.9	228	56561	27	12.29	0	S	8.25	0	S	6.38	100	S	0.020	25	NS
16-Jul-02	21.4	182.6	41112	23	18.73	35	NS	7.90	0	S	4.26	39	PS	0.041	25	NS
21-Aug-02	17.6	166.2	25213	19	18.96	0	S	8.26	0	S	5.08	53	S	0.050	100	NS
02-Oct-02	15.0	134	19637	16	14.47	0	S	8.26	0	S	6.84	100	S	0.066	100	NS
12-Jun-03	24.4	176	50990	25	13.16	0	S	8.12	0	S	6.46	88	S	0.010	0	S
23-Jul-03	20.0	158.6	36308	22	18.54	32	NS	7.88	0	S	10.51	95	S	0.049	100	NS
04-Sep-03	12.7	148.4	15318	14	19.47	29	NS	8.17	0	S	5.92	64	S	0.037	50	NS
01-Oct-03	6.5	201.5	7317	8	14.42	0	S	8.19	0	S	7.99	100	S	0.044	100	NS
Reservoir Station 492614 - ECHO RES 2/3 WAY UP LAKE 02																
18-Jun-96	20.6	1292	73250	21	14.47	9	S	8.34	0	S	6.92	100	S	0.020	50	NS
06-Aug-96	15.5	316	49900	17	18.92	47	NS	8.21	0	S	6.10	100	S	0.053	50	NS
01-Sep-98	6.7	247	47640	8	19.09	50	NS	8.29	0	S	6.37	100	S	0.068	50	NS
07-Jun-00	8.5	261	59274	10	16.41	0	S	8.22	0	S	7.63	100	S	0.020	50	NS
01-Aug-00	6.0	169	30006	7	22.18	100	NS	8.27	0	S	7.08	100	S	0.054	50	NS
12-Jun-02	7.2	228	56561	9	16.22	0	S	8.16	0	S	7.81	100	S	0.018	0	S
16-Jul-02	2.1	182.6	41112	4	22.71	75	NS	8.43	0	S	8.78	100	S	0.054	100	NS
21-Aug-02	4.0	166.2	25213	5	18.98	0	S	8.49	0	S	8.52	100	S	0.047	100	NS
12-Jun-03	6.1	176	50990	7	17.05	0	S	8.47	0	S	8.52	100	S	0.010	0	S
23-Jul-03	2.5	158.6	36308	4	23.63	100	NS	8.41	0	S	8.37	100	S	0.045	100	NS

[a]S= Fully supporting beneficial use, PS=Partially supporting beneficial use, and NS=Not supporting beneficial use.

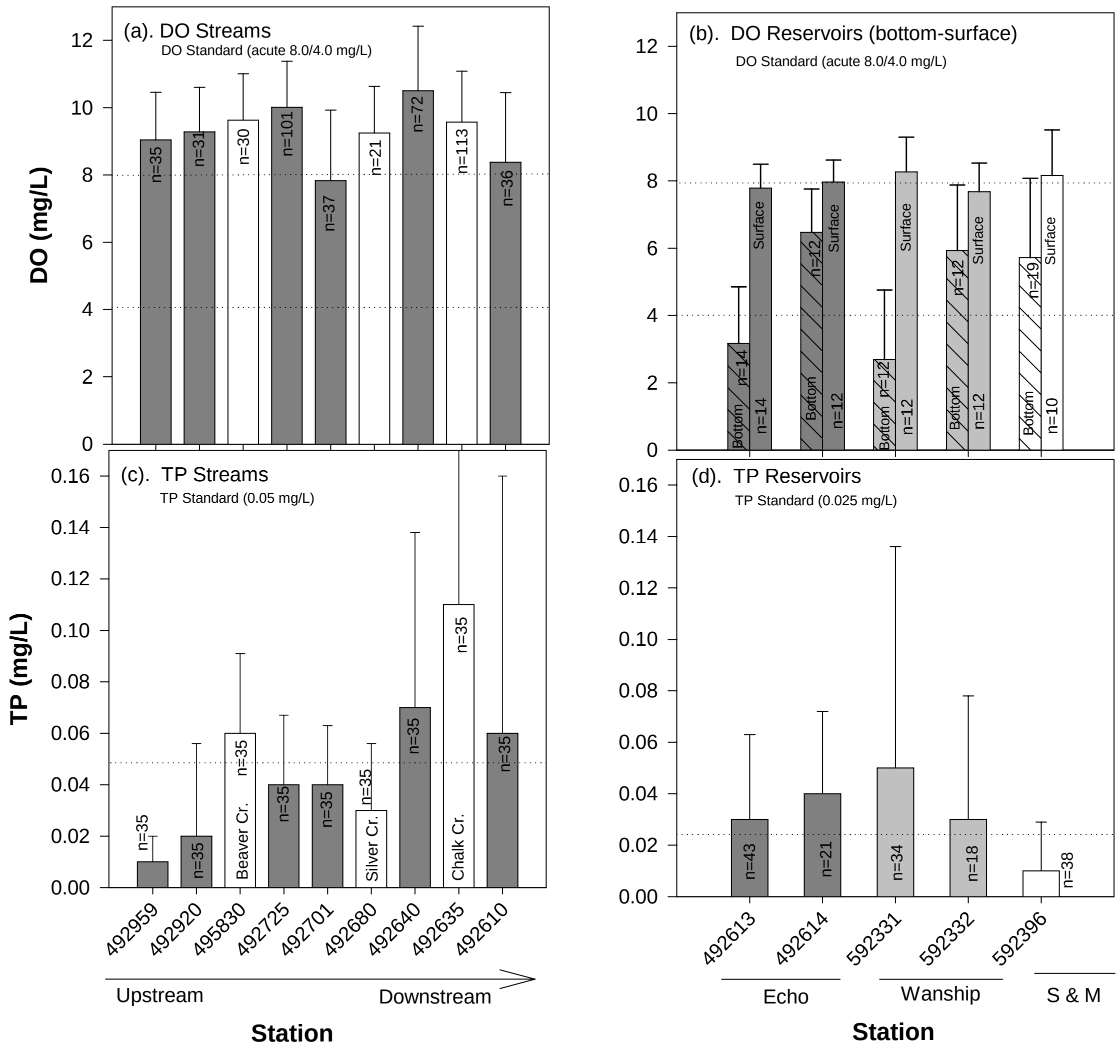

Figure 3.3. Mean concentration of DO (top) and total phosphorus (TP - bottom) in streams and reservoirs within the Echo Reservoir Watershed (1993 – 2003). Grey bars on left figures indicate mainstem sites, clear bars indicate tributaries. On the right figures, dark gray bars correspond to Echo Reservoir, light gray to Wanship Reservoir, and clear to Smith and Morehouse Reservoir. Whiskers represent the standard deviation; n indicates the number of samples.

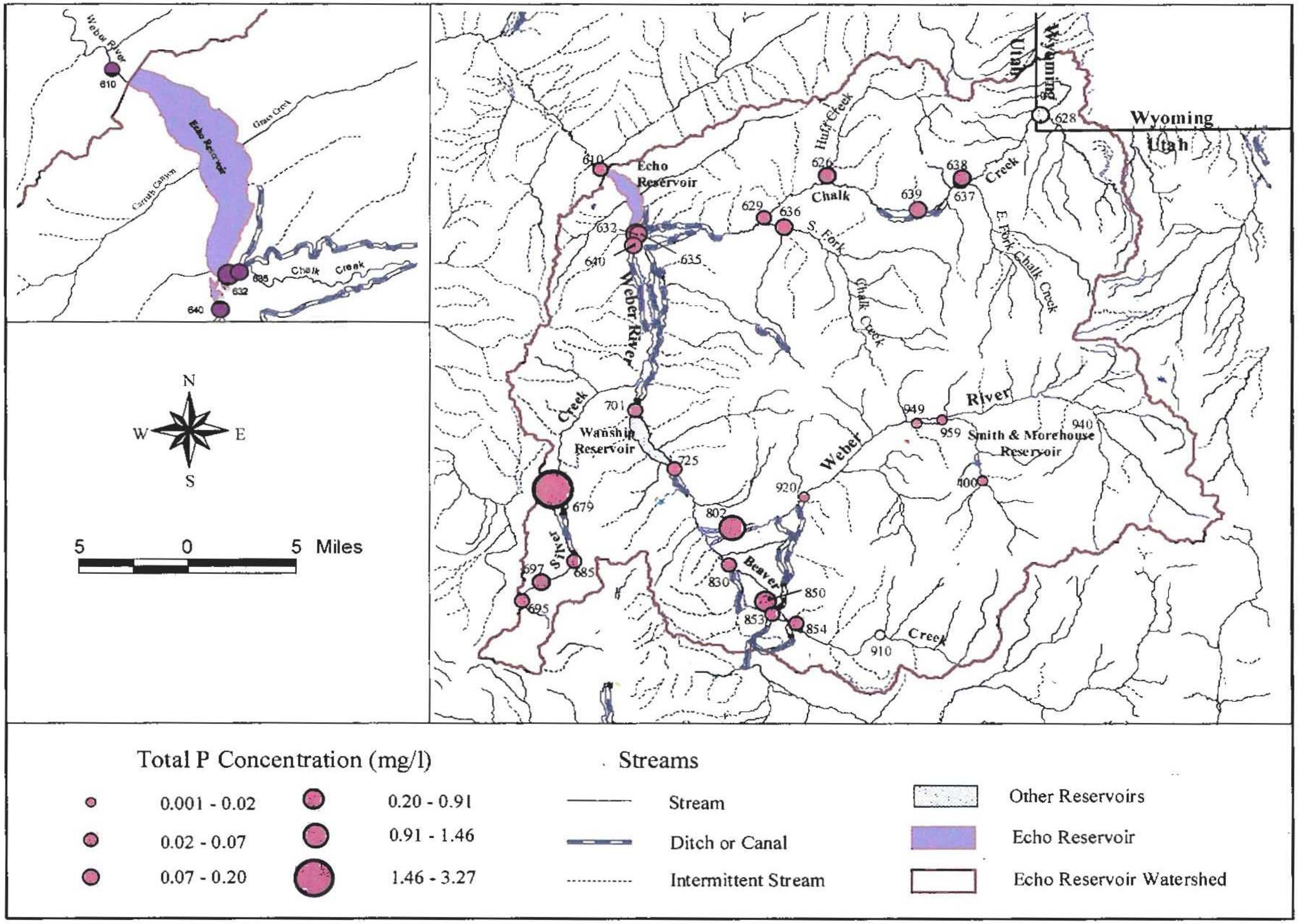

Figure 3.4. Annual mean total phosphorus (Total P) concentrations for monitoring stations visited during the 1998-99 intensive monitoring cycle. Note that station labels shown indicate the last three station ID numbers.

3.3.1.2 Reservoirs

Dissolved oxygen- Profile measurements during individual site visits to station 492613 were reviewed for compliance to the 4.0 mg/l acute standard (Table 3.6). Results from this assessment indicate that less than 50 percent of profile measurements were above the 4.0 mg/l acute standard during the fall season of 1996, 1998 and 2002. In addition, several monitoring dates approached the 50 percent threshold, including some dates where reservoir depths were relatively shallow. As an example, the water column at station 492313 measured only 12.7 meters on September 4, 2003. However, 35 percent of the measurements on this date were below 4.0 mg/l. In general, tributary inflow rates and storage volumes were relatively low on dates where less than 50 percent of samples were above 4.0 mg/l (Table 3.6). These results indicate that tributary inflow likely provides an influx of dissolved oxygen to Echo Reservoir.

Long-term mean dissolved oxygen concentrations in the epilimnion and hypolimnion of Echo Reservoir were calculated from measurements recorded during 1994 – 2002 for each of these portions of the water column (Figure 3.3(b) and Figure 3.3(d)). At Echo Reservoir, dissolved oxygen concentrations in the hypolimnion ranged from 3.17 mg/L near the dam (Station 492613) to 6.47 mg/L at a mid-lake station (Station 492614). The average dissolved oxygen concentration in the hypolimnion for station 492613 did not meet the applicable dissolved oxygen standard for adult aquatic life stages (dissolved oxygen ≥ 4 mg/L). In addition, average epilimnion dissolved oxygen concentrations at both stations were slightly below the applicable acute dissolved oxygen standard for early aquatic life stages (dissolved oxygen ≥ 8 mg/L).

A similar pattern of dissolved oxygen concentrations for stations located at mid-lake (Station 592332) and near the dam (Station592331) of Wanship Reservoir was observed (Figure 3.3(b) and Figure 3.3(d)). The acute dissolved oxygen standard for early aquatic life stages was not met with the exception of the average epilimnion dissolved oxygen concentration at the station located near the dam. Similarly, the average epilimnion dissolved oxygen concentration at Smith and Morehouse Reservoir was above the acute dissolved oxygen standard for early aquatic life stages (Figure 3.3(b)).

Depth profiles at Echo Reservoir indicated that dissolved oxygen concentrations at the hypolimnion typically declined to concentrations below 4 mg/L between July and August. The concentration of dissolved oxygen in the water column then moves towards equilibrium starting in October. In general, the concentration of dissolved oxygen in surface water was near 8 mg/L. A profile of hypolimnetic dissolved oxygen concentrations over the last decade indicated that very low oxygen concentrations often occur at the deeper layers of the water column (Figure 3.5). Further, low dissolved oxygen concentrations at the microzone suggested that near anoxic conditions often occur during summer (Table 3.7).

At Wanship Reservoir, typical depth dissolved oxygen profiles indicated that concentrations drop quickly with depth during June and August. Generally, summer concentrations of dissolved oxygen in the hypolimnion were below 4 mg/L (Figure 3.6). In addition, low dissolved oxygen concentrations at the microzone of this reservoir also suggested that near anoxic conditions occur during summer (Table 3.7)

Figure 3.7 shows the summer profiles of dissolved oxygen concentration measured at Smith and Morehouse Reservoir, located in the upper portion of the Echo Reservoir watershed. These profiles indicate that water column dissolved oxygen levels are generally good, yet slightly below the 8.0 mg/l dissolved oxygen standard for early life aquatic species. Concentrations of dissolved oxygen generally exceeded the standard for adult life stages. The concentrations of dissolved oxygen in the microzone of this reservoir were typically higher than at the sediment-water interface of Echo and Wanship Reservoirs (Table 3.7)

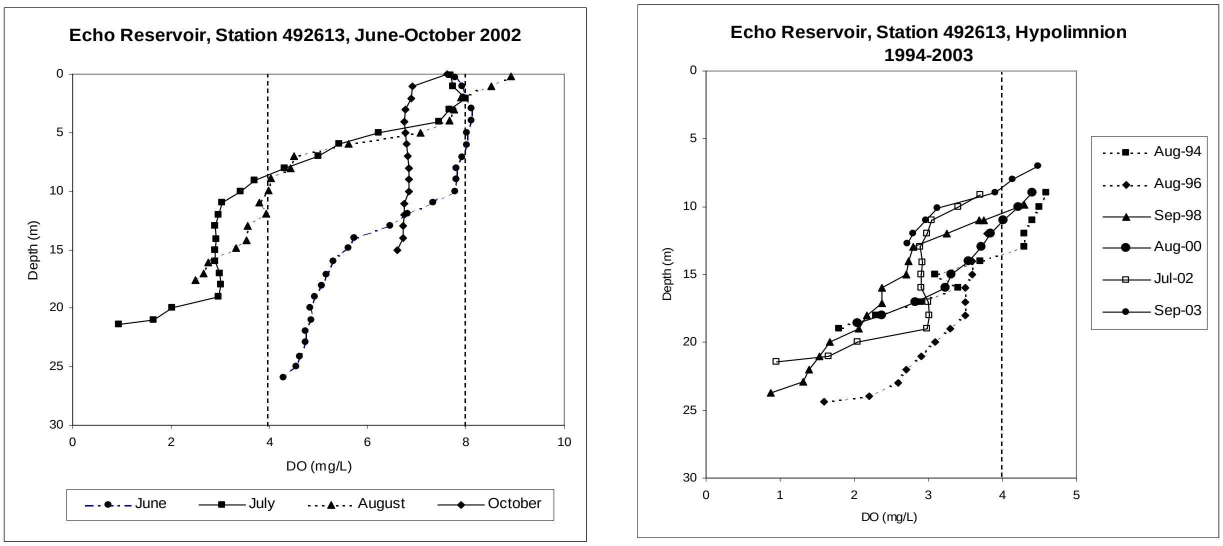

Figure 3.5. DO depth profiles for Echo Reservoir. Left: Typical profile (June-October, 2002). Right: Hypolimnion profiles (1994-2003). The dotted lines indicate the standard DO for adult aquatic life stages (DO≥ 4 mg/L) and early aquatic life stages (DO≥ 8 mg/L).

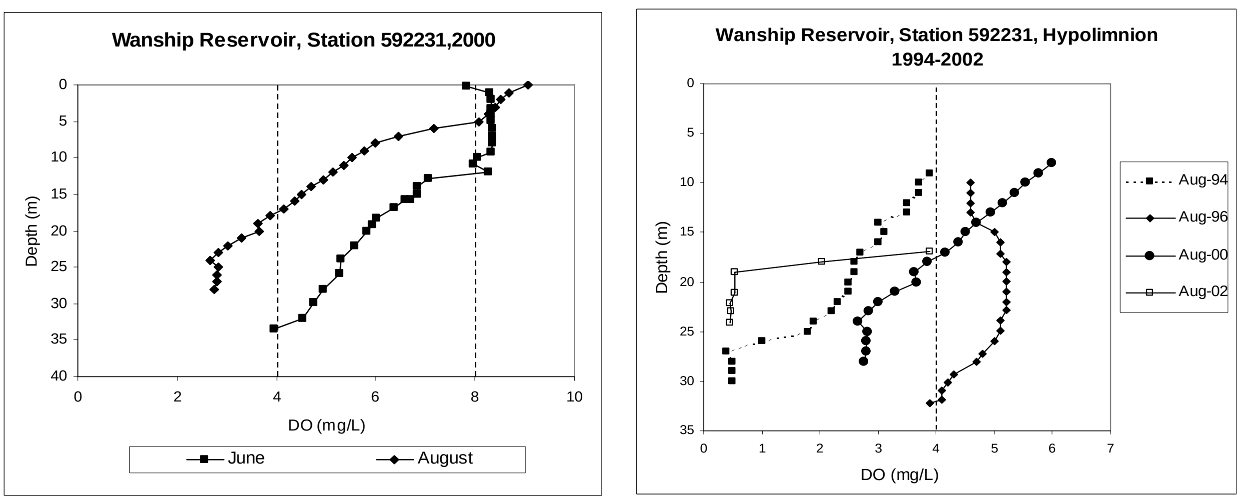

Figure 3.6. DO depth profiles for Wanship Reservoir. Left: Typical profile (June, August 2000). Right: Hypolimnion profiles (1994-2002). The dotted lines indicate the standard DO for adult aquatic life stages (DO≥ 4 mg/L) and early aquatic life stages (DO≥ 8 mg/L).

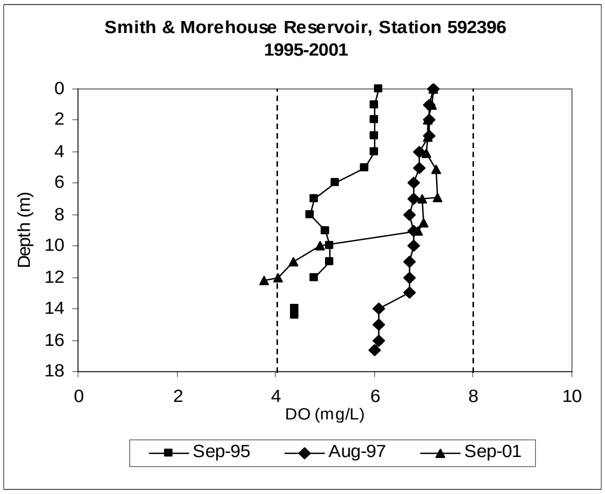

Figure 3.7. DO depth profiles for Smith and Morehouse Reservoir (1995-2001). The dotted lines indicate the standard DO for adult aquatic life stages (DO≥ 4 mg/L) and early aquatic life stages (DO≥ 8 mg/L).

Table 3.7. Concentration of dissolved oxygen (DO) at the sediment-water interface at Echo, Wanship, and Smith and Morehouse Reservoirs.

Station	Station ID	Year	Month	Depth (m)	DO (mg/L)
Echo Reservoir above dam	492613	1994	June	24.9	2.7
			August	19.0	1.8
		1996	June	28.5	4.4
			August	24.4	1.6
		1998	June	29.0	5.4
			September	23.7	0.9
		2000	June	25.6	3.8
			August	18.6	2.1
		2002	June	25.9	4.3
			July	21.4	1.0
			August	17.6	2.5
			October	15	6.6
		2003	June	24.4	2.9
			July	20	2.3
			September	12.7	2.7
			October	6.5	4.7
Wanship Reservoir above dam	592331	2000	June	33.5	4.0
			August	28	2.8
		2002	June	28.3	3.7
			August	24.1	0.5
Smith and Morehouse above dam	592396	1995	July	18.5	9.0
			September	14.4	4.4
		1997	June	18.9	8.6
			August	16.6	6.0
		1999	May	18.4	1.1
		2001	June	17.9	7.3
			September	12.2	3.8

Temperature- Temperature levels measured at stream monitoring sites appear to be fully supporting the Class 3A cold water standard (Table 3.5). Profile measurements of water temperature at Echo Reservoir monitoring sites were not supporting or partially supporting the Class 3A cold water standard on several sample dates. It is anticipated that water temperature in Echo Reservoir is primarily determined by incoming solar radiation levels. A radiation budget assessment will be completed prior to submitting this TMDL assessment to EPA to determine if this assumption is correct.

Total phosphorous- The applicable total phosphorus standard for reservoirs (≤ 0.025 mg/L) was exceeded at Echo (Stations 492613, 492614) and Wanship (Stations 592331, 592332) reservoirs. Average concentrations of total phosphorus at Echo Reservoir ranged from 0.03 mg/L near the dam to 0.04 mg/L at a mid-lake station. At Wanship Reservoir, the highest average total phosphorus concentration was observed near the dam (total phosphorus = 0.05 mg/L, station 592331), while a lower average concentration was estimated at a mid-lake station (total phosphorus=0.03 mg/L, station 592332). Conversely, the average total phosphorus concentration at Smith and Morehouse Reservoir (total phosphorus = 0.01 mg/L, station 592396) meet the applicable standard. See Figure 3.3(d) above.

3.3.2 Ground Water Quality

Periodic assessments of groundwater quality in the Echo Reservoir watershed have been completed by the USGS and the DWQ during the past two decades. Groundwater quality has also been monitored on an infrequent basis from both wells and points of groundwater discharge (springs). As mentioned previously, most samples collected from well and spring monitoring sites are limited to one or two measurements.

Two of the more significant groundwater assessments have focused on the Kamas Valley and the Park City area. A summary of water samples collected by the USGS from 37 wells and 2 springs in Kamas Valley and from the upper reaches of the Beaver Creek drainage from 1997 to 2000 indicated that groundwater quality is generally good (Haraden et al. 2001). Total depth of each well ranged from 10 feet to 450 ft. Parameters that were tested included major ions, dissolved metals, nutrients and other constituents necessary to characterize the suitability of groundwater for drinking purposes. Results of the study indicated that, based on TDS concentrations alone, most groundwater in the Kamas Valley area could be classified as Class 1A – Pristine Ground Water according to Utah Division of Drinking Water standards (Brooks et al. 2003). Major-ion chemistry indicated that most groundwater in the area is a calcium-bicarbonate type although slight differences were noted due to local geologic variations. Of the 37 wells sampled, only seven were noted to have concentrations of dissolved total phosphorus that were greater than the 0.05 mg/l indicator value used to assess surface waters. No total phosphorus measurements were identified for the groundwater sample sites identified in this study.

Maintaining groundwater quality in the Park City area is of particular concern to local municipalities and developers as well as the Division of Water Rights due to the need for an adequate water source capable of supporting the growing population. Developed land areas present additional potential for groundwater contamination due to the presence of bacteria and chemicals such as hydrocarbons, nutrients, and dissolved metals. Increased use of groundwater resources may also reduce discharge from springs and cause downward movement of poor quality groundwater located near the surface with underlying fresh water aquifers. A USGS study summarizing 30 years of groundwater data collected in the headwaters of Silver Creek, East Canyon Creek, Drain Tunnel Creek and portions of the Provo River indicated that groundwater quality in this area is generally suitable for all uses (Holmes et al. 1986). Measurements of dissolved total phosphorus reported in the study indicated that seven of the 27 springs sampled had concentrations that exceeded the 0.05 mg/l indicator value. Fourteen wells were also sampled for dissolved total phosphorus in the study area, all of which had measured concentrations below the 0.05 mg/l indicator value.

3.3.3 Existing Flow Conditions

A statistical summary of flow data collected at USGS monitoring stations is shown below in Table 3.8. Time series as well as monthly box and whisker plots of selected stream flow stations are presented in Appendix – Data. These stations were selected based on the availability of current data. The monthly distributions of stream flow at these stations indicated that at the Weber River median monthly flows peak during April through June (Stations 10132000, 10130500, and 10128500). Flows at Chalk Creek (Station 10131000) peak during April and May, while at Silver Creek (Station 10130000) peak flows are observed from March though April.

Table 3.8. Statistical Summaries for Stream Flow Gages.

Station	# of observations	Range of Dates	Mean (cfs)	Variance (cfs)	SD (cfs)	Median (cfs)	Min. (cfs)	Max. (cfs)
10127500	365	1946 - 1947	107	18656	137	42.5	28.0	612
10128000	4,748	1946 - 1974	62	11213	106	19.0	7.1	747
10128200	3,652	1964 - 1974	26	1142	34	12.0	6.5	242
10128500	35,794	1904 - 2002	219	120109	347	80.0	20.0	4170
10129000	11,323	1938 - 1969	51	15925	126	0	0	918
10129300	7,458	1957 - 1977	180	58588	242	104.0	23.0	2030
10129350	3,653	1963 - 1973	5	99	10	1.0	0	81
10129500	7,487	1950 - 2002	194	53241	231	152.0	0.1	2120
10129900	365	2001 - 2002	4	26	5	2.7	1.6	46
10130000	5,574	1941 - 1996	9	157	13	5.0	0	206
10130500	27,577	1927 - 2002	213	61474	248	151.0	7.0	2140
10130700	3,652	1964 - 1974	35	2085	46	13.0	5.5	367
10131000	27,394	1927 - 2002	69	13625	117	26.0	1.0	1420
10132000	16,619	1927 - 2002	274	106724	327	166.0	0.2	3010
10154000	3,692	1963 - 1973	16	848	29	3.5	1.6	176
10154500	6,926	1932 - 1998	112	25883	161	38.0	0	870
403846111192601	365	1998 - 1999	1	3	2	0.1	0	13
404019111295001	11	1988 - 1988	0	0	0	0.1	0	0.4

3.4 MACROINVERTEBRATE ASSESSMENT

The relationship between the biological health of a water body and the composition of the macroinvertebrate community it supports has led to the use of macroinvertebrates as a surrogate measure of water quality. While some species of macroinvertebrates are very sensitive to water quality and will only exist in streams and lakes where water quality is high, other species are somewhat tolerant or highly tolerant to pollution and can exist under a wide range of water quality conditions. The water quality rating system based on Hilsenhoff (1988) uses the Family Level Biotic Index (FBI) and is shown in Table 3.9. This index is seasonally dependent; higher values may occur during the summer because the organisms present during this month generally tend to be more tolerant to pollution than the organisms that are present during spring.

Table 3.9. Water quality ratings for the Family Level Biotic Index (FBI) (from Hilsenhoff 1988).		
FBI Value	**Water Quality Rating**	**Degree of Organic Pollution**
≤ 3.75	Excellent	Unlikely
3.76-4.25	Very good	Possible - slight
4.26-5.00	Good	Some - probable
5.01-5.75	Fair	Fairly substantial
5.76-6.50	Fairly poor	Substantial - likely
6.51-7.25	Poor	Very substantial
7.26-10.00	Very poor	Severe

The available macroinvertebrate data was collected by the Utah DWQ and includes measurements of invertebrate abundance from 1990 to 2002. Samples have been collected during spring and fall at monitoring stations located in Chalk Creek and the Weber River. The most current data (collected in 2001 and 2002) was used to calculate the FBI (Hilsenhoff 1988). This index represents the average weighted pollution tolerance value for all arthropods present in a sample, with the exemption of organisms that are too immature or damaged to be identified, as well as organisms that have not yet been assigned a pollution tolerance value. The FBI is an index of organic pollution and is based on the response of a community to the combination of high organic loading and decreased dissolved oxygen levels. Pollution tolerance values were assigned to the family level of each one of the organisms identified with lower values representing pollution intolerant families. The dominant taxa, abundance, tolerance values of organisms identified, and FBI values are shown in Table 3.10.

Table 3.10. Macroinvertebrates identified at stream monitoring sites on the Echo Reservoir study area.

Stream/Station #	Date	Taxa (Family)	Tolerance	Abundance		FBI
				(#/m2)	%	
Chalk Creek AB CNFL/South Fork. Station 492629	April-01	Ephemerallidae	1	3158	10	3.52
		Helicopsychidae	3	3154	10	
		Hydropsychidae	4	7358	24	
		Chironomidae	8	3502	11	
	October-01	Ephemerallidae	1	2141	23	3.10
		Leptohyphidae	4	2906	31	
Chalk Creek at US189 crossing. Station 492635	April-02	Baetidae	4	695	6	7.30
		Chironomidae	8	9573	79	
Chalk Creek East Fork AB CNFL/Chalk Creek. Station 492637	April-02	Chironomidae	8	784	16	5.50
		Helicopsychidae	3	634	13	
		Chironomidae	8	1203	25	
	October-02	Hydropsychidae	4	583	30	4.10
		Psychodidae	10	210	11	
		Ceratopogonidae	6	153	8	
Chalk Creek 4 miles East of Upton. Station 492639	April-02	Ephemerallidae	1	1928	14	3.91
		Chironomidae	8	1950	14	
		Leptohyphidae	4	3900	27	
Weber River AB Wanship Reservoir. Station 492725	April-02	Baetidae	4	4593	24	5.31
		Elmidae	4	1911	10	
		Chironomidae	8	6228	33	

The FBI values calculated for stations in Chalk Creek ranged from 3.1 to 7.3, suggesting that some sections of the stream present a small degree of pollution while in others, the degree of pollution is severe. The FBI value for the station sampled in the Weber River suggested that the degree of organic pollution in this location was fairly substantial.

3.5 TROPHIC STATE ASSESSMENT

The trophic state of a lake or reservoir can be considered a measure of the total weight of all living biological material or biomass found within the waterbody at a given point in time (Carlson and Simpson 1996). The specific trophic state of a water body can be influenced by nutrient additions, as well as other factors such as season, zooplankton grazing, mixing depth, etc. (Carlson and Simpson 1996). Trophic status is generally considered to respond to nutrient inputs over time, and will reflect the biological condition of a waterbody. The trophic state index (TSI) is based on measurements of nutrient-related parameters that are believed to characterize biomass. Carlson (1977) has developed trophic state indices based on measurements of chlorophyll a (Chl-a), total phosphorus, and Secchi disk (SD) depth, each of which can independently provide an estimate of algal biomass. For the purpose of classification, priority is given to chlorophyll because this variable is generally considered to be the most accurate of the three indicators at predicting algal biomass. According to Carlson (1977), total phosphorus may be better than chlorophyll at predicting summer trophic state from winter samples, and transparency should only be used if there are no better methods available.

Carlson's TSI values typically range from 0 to 100, although theoretically, the range of values could exceed these bounds (Carlson and Simpson 1996). An increase of 10 units in the TSI scale is equivalent to doubling the concentration of total phosphorus or halving water transparency as measured by SD depth. Calculations for determining TSI values based on total phosphorus, Chl-a, and SD depth are provided below.

$$TSI\ (TP) = 14.42 \ln (TP - \mu g/l) + 4.15 \qquad (3\text{-}1)$$

$$TSI\ (Chl\text{–}a) = 9.81 \ln (\text{chlorophyll a} - \mu g/l) + 30.6 \qquad (3\text{-}2)$$

$$TSI\ (SD) = 60 - 14.41 \ln (\text{Secchi disk} - \text{meters}) \qquad (3\text{-}3)$$

where:
TSI = Carlson trophic state index
ln = natural logarithm

Information relating Carlson TSI values to trophic state characteristics is provided in Table 3.11. TSI values calculated for Echo Reservoir, Wanship Reservoir and Smith and Morehouse Reservoir are included in Table 3.12. TSI calculations showed good correlation between TSI index values for most years. It should be noted that the relationships between variables were originally derived from regression relationships and the correlations are not perfect (Carlson and Simpson 1996).

As shown in Figure 3.8, the TSI index for Chl-a indicated that all reservoirs in the study area could be classified as mesotrophic. An increase in the TSI (Chl-a) value during 2003 for Echo Reservoir suggested the presence of eutrophic conditions. TSI index values for total phosphorus at Smith and Morehouse Reservoir were generally lower that those of Chl-a and SD, suggesting phosphorus is strongly limiting algal biomass in this water body (Carlson and Simpson 1996).

A second method used to assess TSI parameters relies on the difference between TSI (Chl-a) and TSI (TP) or TSI (SD). Results from this assessment are shown in Figure 3.9 where TSI (Chl-a) – TSI (TP) is plotted on the vertical axis and TSI (Chl-a) – TSI (SD) is plotted on the horizontal axis.

Table 3.11. Description of lake trophic status based on Carlson TSI values (Carlson and Simpson 1996).

TSI	Trophic status[a]	Description
< 35	Oligotrophic	Clear water, high oxygen levels throughout the year although shallow lakes/reservoirs may develop low dissolved oxygen concentrations in the hypolimnion. Salmonid fisheries dominate aquatic populations. Water may be suitable for unfiltered drinking in some cases.
35 - 50	Mesotrophic	Water is moderately clear, greater chance of low dissolved oxygen concentrations in the hypolimnion during the summer season. Low dissolved oxygen levels result in salmonid losses, walleye may predominate. Water requires filtration for drinking purposes.
50 - 70	Eutrophic	Low dissolved oxygen levels predominate, heavy algal growth dominated by blue-green algae. Warm water fisheries only. High biomass may discourage boating, swimming.
> 70	Hypereutrophic	Dense algal growth, heavy algal scums present at surface. Rough fish dominate; summer fish kills possible.

[a] Oligotrophy, mesotrophy, and eutrophy are used in the context of the amount of algae in the water, not hypolimnetic oxygen concentrations.

Table 3.12. TSI parameters for Smith and Morehouse, Wanship, and Echo Reservoirs.

Reservoir	Year	TSI		
		TP	Chl a	SD
Smith and Morehouse	1991	30	45	57
	1993	30	29	47
	1995	31	43	42
	1997	54	44	47
	1999	34	34	43
	2001	27	39	52
Wanship	1994	51	38	47
	1996	47	43	50
	1998	54	38	43
	2000	63	30	42
	2002	59	43	48
Echo	1994	45	37	44
	1996	47	42	43
	1998	50	38	43
	2000	49	37	46
	2002	52	38	50
	2003	45	54	55

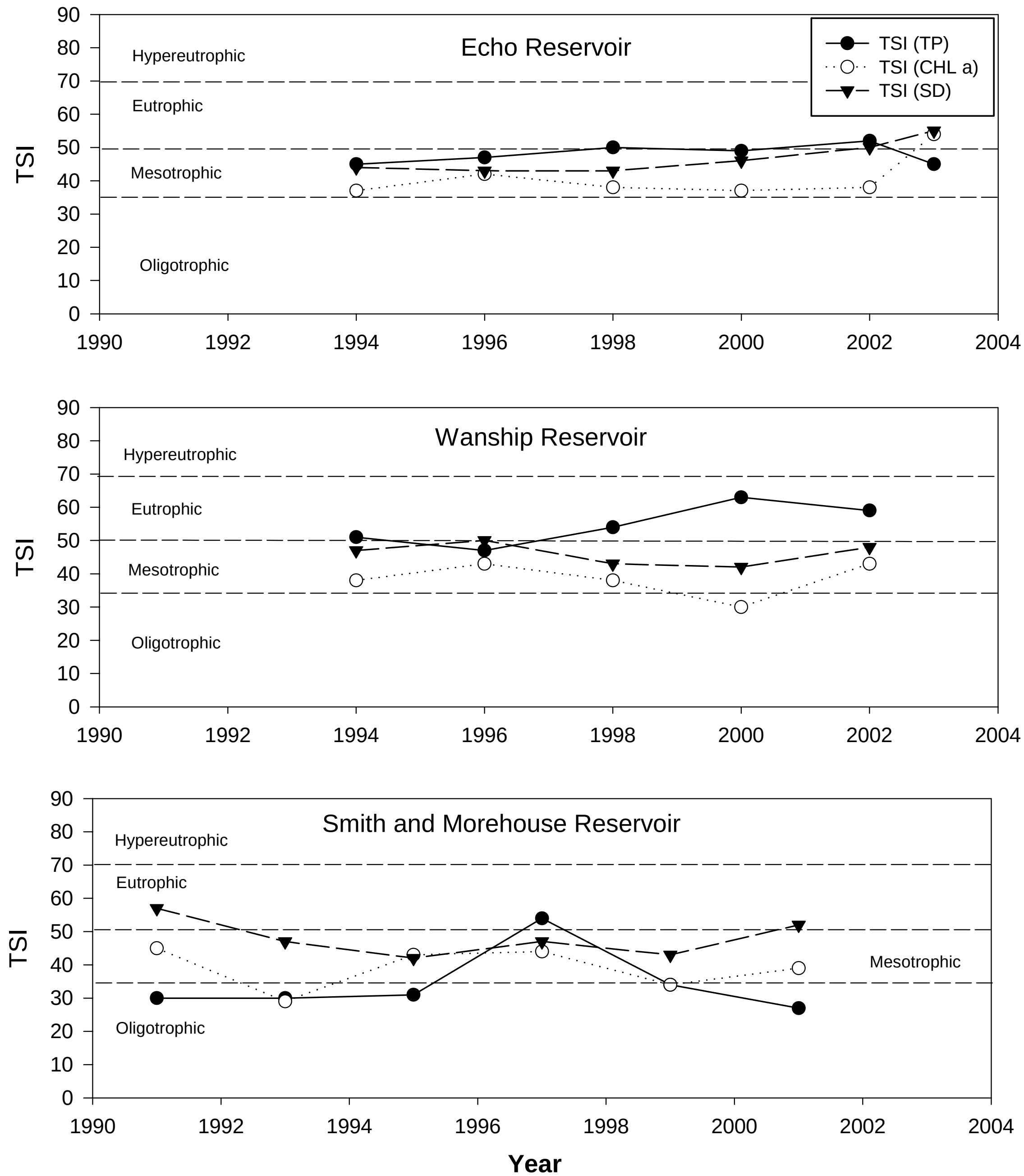

Figure 3.8. TSI values calculated for Echo, Wanship, and Smith and Morehouse Reservoirs. TSI parameters shown include Total Phosphorus (TP), Chlorophyll a (CHL-a), and Secchi depth (SD).

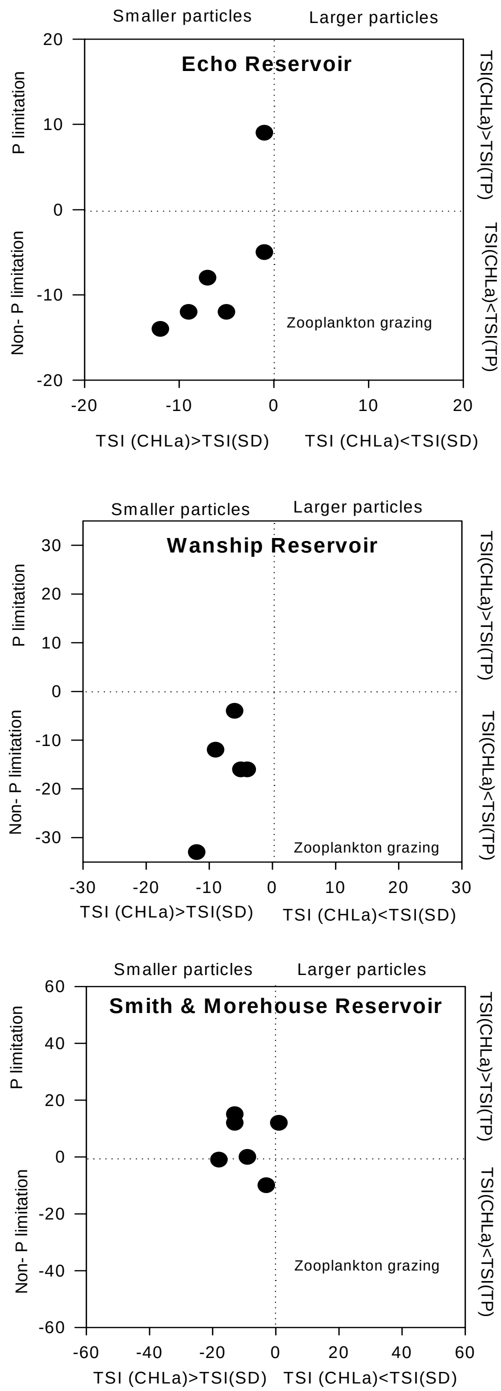

Figure 3.9. Assessment of annual TSI differences calculated for Echo, Wanship, and Smith and Morehouse, Reservoirs. Based on Carlson and Simpson (1996).

The overall location of TSI differences for Wanship and Echo Reservoirs below the horizontal axis, indicate that Chl-a may be under-predicted by total phosphorus, and suggest that algal growth in these water bodies is limited by factors other than phosphorus such as turbidity caused by clay particulates (Figure 3.9). Conversely, data points above the horizontal axis provide evidence of potential phosphorus limitation, as shown for Smith and Morehouse Reservoir (Figure 3.9). The point located above the horizontal axis on Figure 3.9 (top graph) is associated with deviations for Echo Reservoir during 2003 when total phosphorus was below the detection limit for most of the water samples collected.

TSI deviation values, located in quadrants on the left side of the vertical axis, suggest that non-algal factors such as watercolor or turbidity (suspended sediment) may influence the transparency of all reservoirs. The lack of deviations to the right of the vertical axis suggests that transparency values were as expected based on the Chl-a index.

Another means of evaluating nutrient limitation for algal growth in reservoirs is to calculate the ratio of total nitrogen (N) to phosphorus (P). According to Chapra (1997), an N:P ratio in water that is less than 7.2 suggests that nitrogen is limiting. Conversely, higher levels (N:P > 7.2) imply that phosphorus will limit growth of algae and aquatic plants. This is because the ratio of nitrogen to phosphorus in biomass is approximately 7.2. The following Table 3.13 shows that for the monitoring station near Echo Reservoir's dam (492613), the ratio of nitrogen to phosphorus varies throughout the spring and summer; however, all the ratios are above 7.2, indicating phosphorus limitation.

Table 3.13. Average nitrogen to phosphorus ratios for Echo Reservoir above dam (Station 492613).

Month	Average Monthly N:P Ratio
April	10.95
May	11.37
June	34.38
July	98.97
August	12.62
September	10.98

3.6 PHYTOPLANKTON ASSESSMENT

Phytoplankton assessments at Echo Reservoir were conducted from 1998 to 2003. A summary of the phytoplankton data, including the Shannon-Weaver index, species evenness, species richness, and number of species is provided in Table 3.14. These metrics or ecological summaries are used to assess the structure of the phytoplankton community and are considered a surrogate measure of water quality, similar to the presence and extent of macroinvertebrate populations, discussed above. The Shannon-Weaver diversity index is a measure of phytoplankton community structure defined by the relationship between the number of distinct taxa and their relative abundance. The species evenness index is a measure of the distribution of taxa within a community; evenness values approach zero as a single taxa becomes more dominant. In general, species richness and the number of families present in a water column will decrease with decreasing water quality conditions.

Table 3.14. Summary of phytoplankton data for Echo and Wanship Reservoirs.

Reservoir	Station	Date	Shannon Weaver Index[a]	Species Evenness[b]	Species Richness[c]	Number of Species[d]
Echo	492613	September-98	1.28	0.58	1.85	9
	492613	August-00	1.96	0.85	2.73	10
	492613	August-02	1.44	0.65	1.67	9
	492613	October-02	0.73	0.32	1.79	10
	492613	September-03	1.62	0.61	2.33	14

[a] Shannon Diversity Index is a measure of community structure defined by the relationship between the number of distinct taxa and their relative abundances. Diversity generally increases with increasing water quality.
[b] Evenness is a measure of the distribution of taxa within a community. Values range from 0-1 and approach zero as a single taxa becomes more dominant.
[c] Taxa richness is a component and estimate of community structure and stream health based on the number of distinct taxa. Taxa richness normally decreases with decreasing water quality.
[d] Number of species: number of species normally decreases with decreasing water quality.

The phytoplankton assessments conducted at Echo Reservoir from 1998 to 2003 did not reveal a trend of increasing or decreasing diversity or species evenness. The Shannon-Weaver diversity index ranged from 0.73 in October of 2003 to 1.96 in August of 2000. These dates also generally correspond to the lowest and highest species evenness and richness values at Echo Reservoir (Table 3.14). An increase in the number of species was observed at Echo Reservoir in 2003. However, this likely does not represent an improvement in water quality, as the dominant species in the reservoir consists of blue-green algae *Aphanizomenon*, which is known to be dominant in eutrophic lakes (Horne and Goldman 1994).

CHAPTER 4: POLLUTANT SOURCE ASSESSMENT

4.1 SIGNIFICANT SOURCES OF TOTAL PHOSPHORUS LOADING

Based on field observations, discussions with the Natural Resources Conservation Service (NRCS), Utah Association of Conservation Districts (UACD), Utah Department of Water Quality (Utah DWQ), and Utah State University (USU) extension, the following pollutant categories contributing to water quality impairment in the Echo Reservoir watershed have been identified:

1. Animal Feeding Operations
2. Grazing
3. Onsite Wastewater Treatment Systems
4. Point Sources
5. Diffuse Loads from Runoff
6. Natural Background
7. Internal Reservoir Loading

The following sections describe each of the significant pollutant sources in more detail.

4.1.1 Animal Feeding Operations

Recognition of animal feeding operations (AFO) as a contributor to water quality impairment has been recently addressed by the Utah AFO/CAFO Advisory Committee (2001). The strategy proposed by the State reflects a desire to implement responsible management techniques while maintaining a local decision making process. A voluntary incentive-based approach is emphasized that reverts to a regulatory approach only for larger facilities or situations where voluntary methods have failed. A critical element of this program is to maintain open communication between stakeholders and agencies. An effort has been made throughout this assessment to maintain the level of confidence previously established between these two groups in the TMDL study area. No site-specific information is provided in this assessment. An estimation of the total contribution from all operations within a specific watershed or subwatershed is provided where necessary in the sections below.

AFOs have been defined in the Code of Federal Regulations 40 CFR 122.23(b)(1) as an area where animals “have been, are, or will be stabled or confined and fed or maintained for a total of 45 days or more in any 12 month period and crops, vegetation forage growth, or post-harvest residues are not sustained in the normal growing season over any portion of the lot or facility.” Furthermore, an AFO is considered to be a concentrated animal feeding operation (CAFO) if it meets the regulatory definition of a CAFO or is designated as such by the regulating agency. CAFOs are defined in 40 CFR 122.23 Appendix B based on the following parameters:

- Any AFO with more than 1,000 animal units.
- A facility with more than 300 animal units where discharge occurs to navigable waters through a man-made conveyance system (e.g., ditch, pipe or other flushing system).
- A facility with more than 300 animal units where discharge occurs directly to waters of the United States.

- An AFO of any size that is determined to be a significant contributor or pollution to waters of the United States, following a site visit. Such facilities must be discharging to a man-made conveyance or directly to waters of the United States.

In general, there are two components of loading from animal wastes generated at animal feeding operations. The first is direct runoff of animal waste that enters adjacent water bodies. The second is loading from animal waste generated at animal feeding operations but that is scraped, hauled, and land applied elsewhere in the watershed. According to Ray Loveless of the UACD, there are a total of 18 animal feeding operations in the Echo Reservoir watershed that meet the definition above. However, the runoff generated at eight of these facilities enters irrigation ditches that do not return to the streams or Echo Reservoir. The UACD considers the impact on water quality of runoff from these eight operations negligible.

It is assumed that animal feeding operations in the watershed have varying degrees of nutrient management practices in place, but little information is available to characterize conditions at these sites. In general, little is known about these sites, including their locations.

4.1.2 Grazing

Cattle grazing can be a significant pollutant source in many watersheds where historic grazing has taken place. This is especially true when cattle are concentrated in or near the riparian zone surrounding existing streams, water courses, and water bodies. This is quite often the case and has been observed in the Echo Reservoir watershed during fieldwork and watershed visits. Livestock prefer these areas because they provide shade, the best source of forage, and often the only source of drinking water.

Grazing animals are located throughout the Echo Reservoir watershed on both public and private lands. Figure 4.1 shows the U.S. Forest Service grazing allotment boundaries associated with public lands in the watershed and locations at which grazing on private lands has been observed during two separate field visits to the watershed. Estimates of the number of animals grazing on private lands in the watershed were obtained using manual counts of visible animals during the field visits. These numbers are assumed to be low due to the fact that field personnel did not have access to much of the private land in the watershed and were limited to what could be seen from public roads.

The timing of grazing activities within the watershed is also important. Animal concentrations near the stream courses in the low-lying areas of the watershed are higher during the late fall, winter, and spring months, as these are the areas where the animals spend the winter. The exact location of animal herds during this time period will vary depending on available forage and weather extremes that make it difficult for grazing to occur. A typical grazing pattern during this time will find animals in the lower valley pastures until late November through mid-December or when snow depths make grazing difficult. Animal herds are then moved into smaller pastures that are easily accessible or sometimes feedlots where hay can be distributed to them. Animal herds are moved away from hay feed areas as soon as grass forage is available in the spring season, which can occur as early as March or early April.

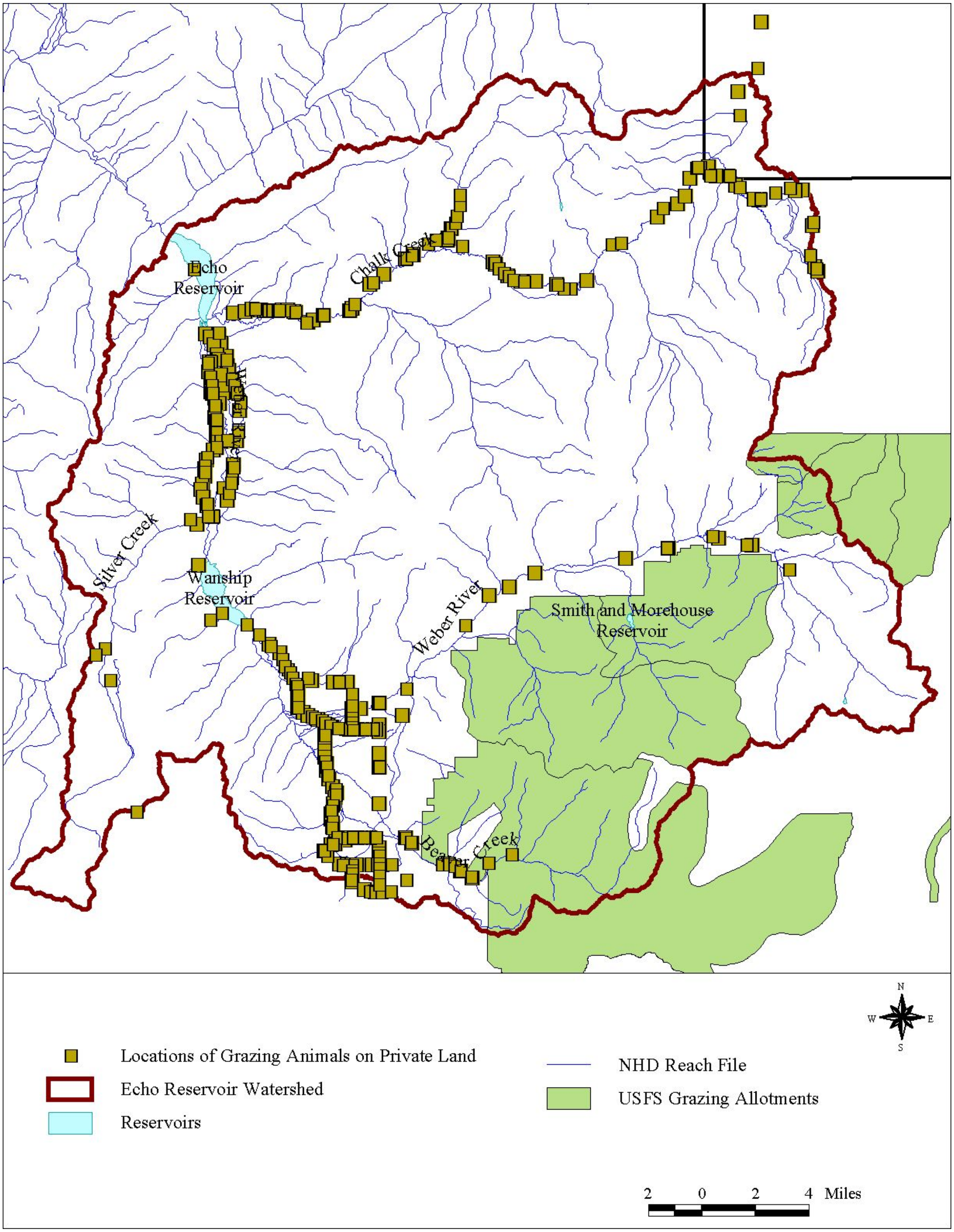

Figure 4.1. U.S. Forest Service grazing allotments and locations at which grazing on private lands have been observed in the Echo Reservoir watershed.

During the summer months, many herds are moved away from actively flowing streams located in the low to mid-elevation pastures and on to higher elevation grazing allotments located on public and private lands. The grazing allotments managed by the Forest Service are primarily used during the late spring through early fall. In general, animals are moved onto the Forest Service allotments during May or June and return to private lands in late October. The pattern is similar for higher elevation private lands that are grazed within the watershed.

Many of the pastures in the low-lying areas of the watershed provide open access to actively flowing streams. This has resulted in degradation to stream banks and riparian areas in some locations. In some cases, intense use of these areas has resulted in heavy manure deposits, stream bank degradation, and surface and channel erosion that subsequently contribute to pollutant loading.

4.1.3 Onsite Wastewater Treatment Systems

Relatively extensive urban and residential development has occurred within some areas of the watershed over the past 10 years. Most of this development is associated with the Park City area where the majority of urban and residential developments have access to sewer hookups. However, a significant number of residences and summer homes have been built within the watershed that rely on onsite wastewater treatment systems. These onsite wastewater treatment systems have the potential for contributing nutrient loading to streams within the watershed, especially where they are installed in close proximity to existing waterways, where they are installed incorrectly, or where they fail.

4.1.4 Point Sources

Several point sources of pollution have been identified in the Echo Reservoir watershed and are listed in Table 4.1. These facilities all contribute total phosphorus loading to streams within the Echo Reservoir watershed. These facilities are described in more detail in the paragraphs following Table 4.1, and their locations are shown in Figure 4.2.

Table 4.1. Point sources of pollution in the Echo Reservoir Watershed.

Facility	UPDES Permit No.	Receiving Water
UDWR Kamas Fish Hatchery	UTG130006	Beaver Creek
Kamas Lagoons	UT0020966	Beaver Creek
Snyderville Basin Silver Creek WRF	UTR000626	Silver Creek
Oakley Wastewater Treatment Plant (WWTP)	UT0020061	Weber River
Coalville WWTP	UT0021288	Chalk Creek[a]

[a]In times of high water levels in Echo Reservoir, the Coalville WWTP discharges directly to the reservoir.

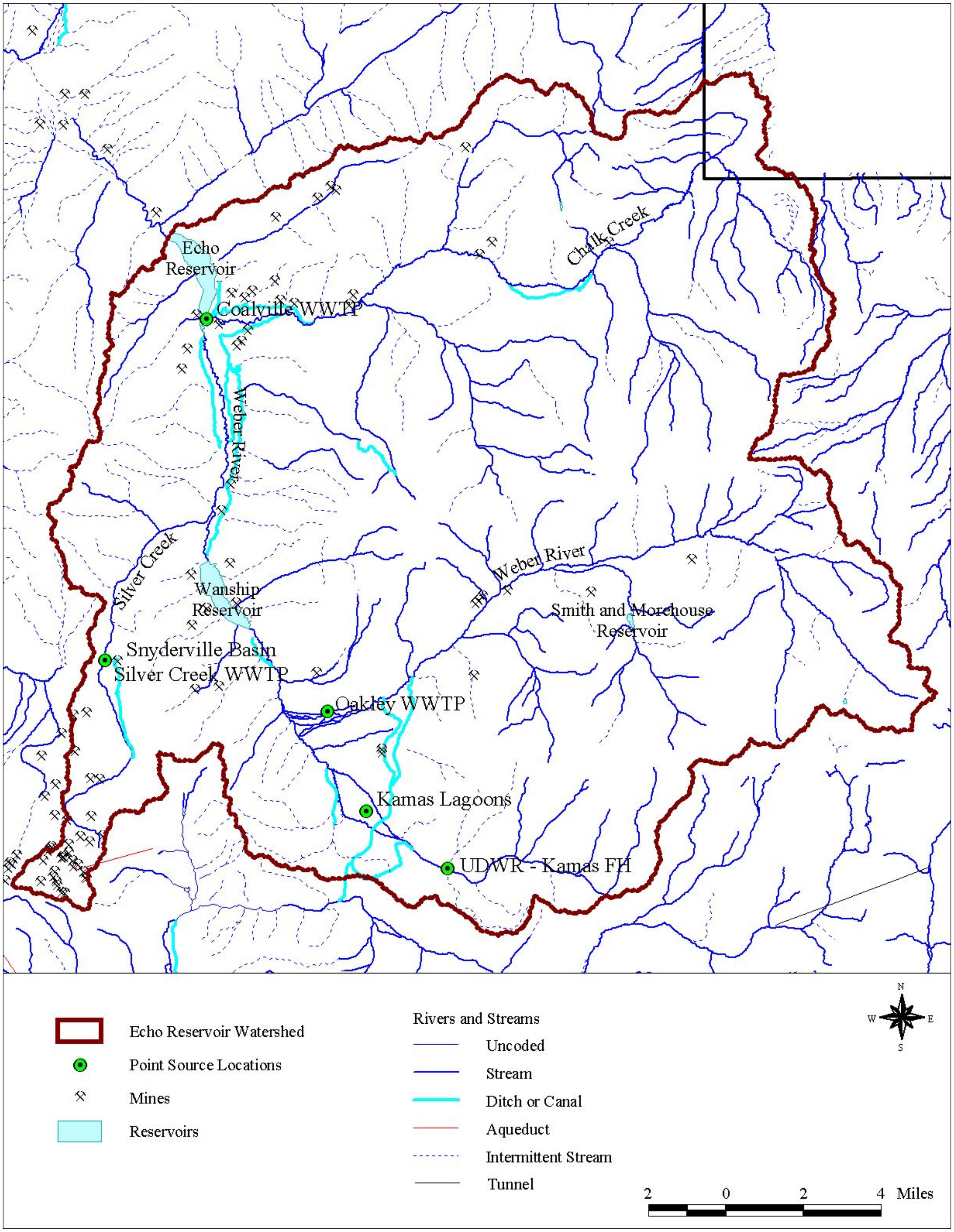

Figure 4.2. Locations of point sources of pollution in the Echo Reservoir watershed.

The Kamas Fish Hatchery (Kamas FH) is located near the town of Kamas and is owned and operated by the Utah Division of Wildlife Resources. This fish hatchery has been completely redesigned and updated in the past two years. A UPDES permit does exist for this point source, but it is not currently regulated for nutrients. Kamas FH discharges to Beaver Creek.

The Kamas Lagoons serve as the wastewater treatment plant for the town of Kamas and will generally be referred to as the Kamas WWTP in this assessment. Recent improvements have been made to this facility, including the installation of two new mixers and two new aerators. Future plans call for further improvements to this facility. A UPDES permit does exist for the lagoons, but they are not currently regulated for nutrient discharges. Kamas WWTP discharges to Beaver Creek.

The Snyderville Basin Silver Creek WRF serves Park City as one of two wastewater treatment facilities. (The other facility is located near Jeremy Ranch in the East Canyon drainage and is outside the Echo Reservoir watershed). Silver Creek WRF is a mechanical plant and has a current design capacity of 1.5 million gallons per day (MGD), with expansion plans slated for 2012 - 2013. Silver Creek WRF has a UPDES permit, but it is not currently regulated for phosphorus discharges. The facility discharges to Silver Creek, approximately 8 miles upstream from its confluence with the Weber River.

The Oakley WWTP has recently been upgraded to a microfiltration unit. A UPDES permit exists for this facility, but it is not currently regulated for nutrient discharges. Oakley WWTP has a continuous discharge to the Weber River above its confluence with Beaver Creek.

The Coalville WWTP serves the town of Coalville and is located on Chalk Creek, just upstream of Echo Reservoir. The current design capacity of this facility is 0.4 MGD. There are no immediate plans for expansion, but the need will likely arise in the near future. A UPDES permit exists for the facility, but it is not currently regulated for nutrient discharges. Coalville WWTP has one discharge point on Chalk Creek. However, the channel of Chalk Creek is inundated by Echo Reservoir during times of high water storage. As such, Coalville WWTP discharges directly to the reservoir when the water is high. When the reservoir is lower, the facility discharges to Chalk Creek.

4.1.5 Diffuse Loads from Runoff

Diffuse loads from runoff are defined for the purposes of this TMDL study as anthropogenic loads associated with surface runoff that are not the result of manure produced by grazing animals or one of the other loading sources already specifically accounted for. Some examples of diffuse loads include the following:

- Surface runoff that contains agricultural chemicals including fertilizers and pesticides.
- Nutrients and other constituents associated with erosion from human disturbed areas (including trails, roads, and dispersed camping sites).
- Nutrients and other constituents associated with erosion from upslope areas disturbed by managed grazing activities. This does not include direct manure loading described above in Section 4.1.2 – Grazing.

Most runoff in the TMDL study area is associated with spring snowmelt and a few summer thunderstorms that pass through the area. In general, pollutant loading associated with runoff is essentially related to land use, although other physical factors such as geology, soil type, vegetative cover, slope, riparian conditions, etc. are also important. The proximity of each land use category to existing streams is also of consideration in evaluating pollutant loads associated with runoff. In the Echo Reservoir watershed, nearly all of the agricultural lands lie within a narrow one to two mile wide strip along the existing stream courses. The condition of these lands is also of importance, as it is generally accepted that areas in close proximity to existing water courses have a greater likelihood of contributing pollutant loads, especially when poor conditions exist (trampled stream banks, lack of vegetative cover, disturbed soils, etc.).

4.1.6 Internal Reservoir Loading

Bottom sediments have long been acknowledged as a potential source of phosphorus to the overlying waters of lakes and reservoirs (Chapra 1997). In many cases, bottom sediments serve as a sink for phosphorus as phosphorus laden suspended solids enter the reservoir and settle out, and as organic phosphorus in the form of dead and decaying algae and plant material settle to the bottom and are buried in the sediments. However, in some cases phosphorus associated with the bottom sediments can become re-entrained in the overlying water column. In general, flux of phosphorus from sediments to the overlying water column takes place only during periods of very low dissolved oxygen concentrations (less than 1 mg/L) and/or low pH that last long enough for the interaction to be significant. These conditions are most common in deeper impoundments with significant periods of stratification that limit mixing and related oxygen transfer. When conditions such as these occur, phosphorus released to the overlying water column from the sediments can be carried into the photic zone by subsequent mixing and turnover following stratification making the now dissolved phosphorus available for use by algae and other aquatic organisms.

An additional mechanism that may be of concern for Echo Reservoir is re-suspension of phosphorus-laden sediment as draw down of the reservoir occurs. As the reservoir is drawn down in the late summer and fall, the tributary streams flow through the newly exposed lake bed picking up sediment that was previously deposited on the bottom of the reservoir and re-suspending it in the water column of the reservoir. The phosphorus associated with these sediments is likely in mostly biologically unavailable forms. The extent to which this mechanism is involved in the overall phosphorus budget for the reservoir is further discussed below.

4.1.7 Natural Background

Background pollutant loads are those that are assumed to occur under "natural" or undisturbed conditions and are generally considered to be uncontrollable. Background loads can be associated with any natural process that is not man-enhanced or man-induced. Sources of background loading can include weathering and erosion of surficial geologic formations, atmospheric deposition (through rain or snow), wildlife species, and naturally occurring levels of soil erosion and stream channel dynamics. Background loadings are likely not insignificant in the Echo Reservoir watershed.

Geologic parent material that is naturally high in phosphorus content is present in the watershed and has likely contributed to background phosphorus loading. Figure 2.6 shows the location of the phosphorus rich deposits in the Echo Reservoir watershed. The dataset shown in Figure 2.6 was obtained from the Utah Automated Geographic Reference Center (AGRC), and according to the metadata was prepared for the Bureau of Mines Special Report: "Availability of Federally Owned Minerals for Exploration and Development in Western States: Utah, 1988." The areas shown on the map are referred to as "Known Mineral Deposit Areas" or "KMDAs." The resolution of the data is not such that one can distinguish whether these deposits are present in outcrops or buried formations, but outcrops of this formation do occur in the Park City area.

One approach for determining natural or background levels of water quality constituents is to complete a review of water quality data collected in areas where minimal anthropogenic influence can be assumed. These areas include springs and upper headwater streams, tributaries and reservoirs/lakes within the TMDL study area. Such a review was completed for the TMDL study area, and data from this assessment are summarized in subsequent sections of this report.

It is noted here that some of the upper areas in the Echo Reservoir watershed have been impacted through recreational use, including dispersed camping, user-created ATV trails, and grazing, but in the absence of pre- human influence information, these data are considered the best information to characterize potential background loading in the TMDL study area.

4.2 POLLUTANT LOAD CALCULATION FROM EXISTING DATA

Pollutant load calculations based on water quality and flow monitoring data can provide supporting information in determining pollutant load contributions. A review of the original data set, including the number of samples and sample dates should accompany any assessment of pollutant load calculations. This is particularly important when attempting to characterize loads from nonpoint pollutant sources, which are highly dependent upon surface runoff generated during storm events or rapid snowmelt. Pollutant loads should be based on measurements collected across a representative time period that include both drought and high flow conditions as well as all seasons of the year.

Pollutant loads can be calculated at monitoring locations where both flow and water quality concentrations have been measured. Loads calculated from sampling data are considered to be most accurate if measurements of flow and concentration are collected simultaneously (i.e. paired measurements) and over a range of conditions that are believed to be representative of the full range of flow and water quality conditions at a given monitoring location. Uncertainty can be introduced into the calculation of pollutant loads when using observations of flow and water quality that were measured independently of each other.

A simple average approach is often used in the calculation of pollutant loads, wherein the average of all flow measurements is multiplied by the average of all water quality measurements. Loads calculated using this method can be misleading if most flow readings were taken during a different season than water quality measurements (spring vs. fall), or if measurements for each parameter were taken during different years (e.g., flow data from a drought year used with water quality data from a high flow year). Care must be exercised in the selection of data for use in loading calculations.

One way to address the above complexities is to use only paired measurements and not consider the remaining data. In most cases, however, this is not feasible because of the small number of paired observations. Another method of supplementing the simple average approach is to use continuous flow data recorded from a nearby stream flow gage. Calculated average flow values from these sites better represent the variability in streamflow because flow measurements are generally made at a much higher frequency. As a result, monthly or annual averages for these locations may better represent streamflow conditions than an average of a limited number of instantaneous flow measurements.

For the purposes of this analysis, annual total phosphorus loads were calculated at several locations throughout the Echo Reservoir watershed where flow and water quality data are available. These loads were estimated by first calculating average monthly flows and concentrations from available sampling data. Where USGS streamflow gages exist, the associated data were used in place of instantaneous observations of flow made at DWQ monitoring sites. Flow monitoring records for the wastewater treatment facilities obtained from DWQ were used to estimate the flows from these facilities. Average monthly concentrations were calculated from DWQ sampling data at each location. In general, concentration data were limited to the time period between 1992 and 2003 because it is believed that this period best represents existing water quality conditions within the watershed.

The average monthly flows and concentrations were multiplied, together with the appropriate unit conversion factor, to produce monthly load estimates. Finally, the monthly load estimates were summed to produce an annual load estimate for each location. Annual total phosphorus loads calculated at DWQ stream monitoring sites within the project area are shown in Figure 4.3 and Table 4.2. Appendix – Data details the calculation of these loads and lists the data used.

Table 4.2 indicates that total phosphorus loads delivered to Echo Reservoir through Chalk Creek (492635 - 10,544 kg/yr) and the Weber River (492640 - 13,657 kg/yr) are on the same order of magnitude. Although flows in the Weber River are generally about 6 times greater, Chalk Creek has been observed to carry a much higher sediment load that originates from erosive uplands and unstable streambanks. The Coalville WWTP (492632) contributes an additional 149 kg/yr for a total loading to Echo Reservoir of approximately 24,350 kg/yr based on the loads calculated from the sampling data.

The data indicate that the majority of the total phosphorus loading contributed to Echo Reservoir via the Weber River is from upstream loading from Wanship Reservoir releases (492701 - 7,162 kg/yr) and sources along the Weber River between Wanship Reservoir and Echo Reservoir. Silver Creek (492675) contributes approximately 4,945 kg/yr to this section of the Weber River. In the Silver Creek drainage, the Silver Creek WRF (492679) contributes approximately 4,070 kg/yr of loading to the creek.

The total loading to Wanship Reservoir from the Weber River (492725) is approximately 7,550 kg/yr. A good portion of this loading is from Beaver Creek (492830), which contributes approximately 4,552 kg/yr to the Weber River above Wanship Reservoir. In the Beaver Creek drainage, the Kamas Lagoons (492850) contribute approximately 1,322 kg/yr to Beaver Creek, and the Kamas Fish Hatchery (492900) contributes a much smaller 434 kg/yr. In the Weber River above its confluence with Beaver Creek, the Oakley wastewater treatment facility contributes approximately 475 kg/yr.

4.3 Assessment of Existing Total Phosphorus Loads by Source

As reported in Section 4.2 above, the total loading to Echo Reservoir as calculated from existing flow and concentration observations is approximately 24,350 kg/yr. The total loading to the reservoir is indicative of the combined effects of all of the upstream sources of total phosphorus. The following sections provide detail regarding the magnitude of loading from each of the major sources that have been identified in the Echo Reservoir watershed. The loads reported in this section represent loads generated at their respective locations throughout the watershed. The linkage analysis provided below in Section 4.4 of this report analyzes the relative contribution of each of these loads to Echo Reservoir.

4.3.1 Animal Feeding Operations

According to the UACD, eighteen animal feeding operations that meet the definition contained in Section 4.1.1 above are located in the Echo Reservoir watershed (Loveless 2004). Although scattered throughout the watershed, it is assumed that these operations are generally located in the low-lying agricultural areas within a couple of miles of existing stream courses. Some of the operations in the Echo Reservoir watershed are seasonal in nature, and others have confined animals year round. It is assumed that varying levels of nutrient management practices have been implemented at these operations, although little information is available to characterize the animal feeding operations within the watershed.

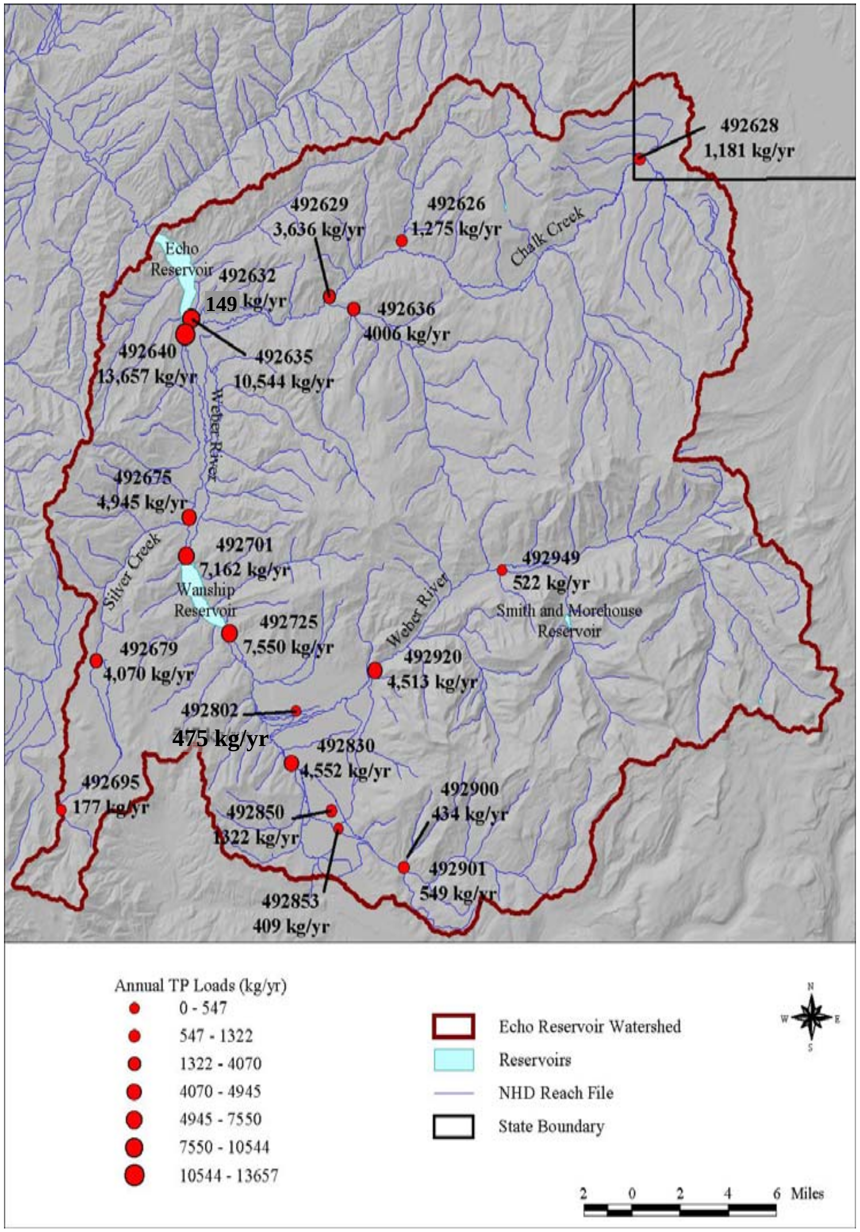

Figure 4.3. Location of calculated total phosphorus loads shown at right in Table 4.2 for selected monitoring locations in the Echo Reservoir Watershed.

Table 4.2. Annual total phosphorus (TP) loads calculated at selected monitoring locations in the Echo Reservoir Watershed using available streamflow and water quality monitoring data. In general total phosphorus loads relied on concentration data collected during 1992 – 2003. Appendix Data contains a detailed list of all calculated loads.

Station	Station Name	TP Load (kg/yr)
Stream Stations		
492626	Huff Creek Above Confluence with Chalk Creek	1,275
492628	Chalk Creek at Utah/Wyoming State Line	1,181
492629	Chalk Creek above Confluence with the South Fork	3,636
492635	Chalk Creek at US 189 Crossing	10,544
492636	South Fork Chalk Creek 1 Mile Above Chalk Creek	4,006
492640	Weber River Above Echo Reservoir	13,657
492675	Silver Creek at Wanship Above Confluence with the Weber River	4,945
492695	Silver Creek at City Park Above Prospector Square	177
492701	Weber River Below Wanship Reservoir	7,162
492725	Weber River Above Wanship Reservoir	7,550
492830	Beaver Creek Above Crooked Creek	4,552
492853	Beaver Creek Above Weber-Provo Canal	409
492901	Beaver Creek above Kamas Fish Hatchery	549
492920	Weber River above Weber-Provo Diversion	4,513
492949	Smith and Morehouse Creek above Confluence with the Weber River	522
Point Sources		
492632	Coalville WWTP	149
492679	Silver Creek WWTP	4,070
492802	Oakley Lagoons	475
492850	Kamas Lagoons	1,322
492900	Kamas Fish Hatchery Effluent	434

Loading from animal feeding operations has essentially two components. The first component is direct stream loading caused by runoff generated at each operation. Precipitation falls on the surface of the operation and picks up and carries animal waste with it as it flows overland and into an adjacent water body. The second component is loading generated from the land application of animal waste. Periodically, animal waste is scraped from the surface of animal feeding operations. This waste is stored onsite until the storage capacity is exceeded or until conditions are right for land application. The waste is then hauled offsite and applied on adjacent agricultural fields as fertilizer. Animal wastes that are not immediately incorporated with the soil are available to be carried into adjacent streams with runoff generated by precipitation events. The following sections describe these loadings in the Echo Reservoir watershed.

4.3.1.1 Loading from Animal Feeding Operation Runoff

Of the 18 animal feeding operations, 8 are isolated such that any runoff generated on the property leaves only through irrigation ditches that do not return to the streams or reservoirs in the watershed (Loveless 2004). The UACD does not consider the runoff from these 8 operations to be a significant source of total phosphorus loading to streams in the watershed. Annual loads from the 10 remaining animal feeding operations in the watershed were calculated by the UACD using the NRCS Utah Animal Feedlot Runoff Risk Index (UAFRRI) model (Goodrich 2004). This model estimates, on an annual basis, the amount of phosphorus that leaves an animal feeding operation and enters nearby water courses based on the physical characteristics of the feeding operation, the number of animals onsite, distance to an existing water course, etc. Table 4.3 lists the results of the UAFRRI model by subwatershed.

Table 4.3. Annual total phosphorus loads generated by runoff from animal feeding operations to adjacent water bodies reported by subwatershed in which they occur.

Subwatershed	Number of Confined Animals	Total Phosphorus Loading (kg)
Upper Weber River	162[a]	417
Beaver Creek	110	165
Weber River below Beaver Creek	233[a]	599
Wanship Reservoir	0	0
Weber River below Wanship Reservoir	0	0
Silver Creek	90	66
Weber River Below Silver Creek	0	0
Chalk Creek	150	248
Echo Reservoir	0	0
Total of all Subwatersheds[b]	**745**	**1495**

[a]These values were reported as a single value for the Weber River above Wanship Reservoir. The number of confined animals and the direct stream loading was divided between the two subwatersheds according to the percentage of the total area of agricultural land within both subwatersheds that lies within each.
[b]This is the total for the 10 animal feeding operations with a direct stream loading component and does not include the 8 operations for which no information was received from the UACD.

4.3.1.2 Loading from Land Applied Animal Waste

Little information is available to characterize loadings from land applied animal waste in the Echo Reservoir watershed, and as such, there is considerable uncertainty associated with the estimates of loading from this source. Although information on the number of confined animals in each subwatershed for the ten animal feeding operations with a direct runoff loading component was provided by the UACD, no animal numbers were provided for the 8 operations considered to have no direct runoff loading. In addition, no information regarding the amount of time that these animals are confined was provided. Therefore, the following assumptions were made so that loading from this source could be estimated.

1. Animals are confined on all 18 operations all year long. This is considered a worst-case scenario, as it will maximize the amount of manure production.
2. The difference between total phosphorus production from an animal feeding operation (based on animal numbers) and direct runoff loading is considered to be the amount of manure (and total phosphorus) that is land applied. For those operations with no direct runoff loading component, it is assumed that 100 percent of the manure (and total phosphorus) produced at each facility is land applied. The method used to determine the fraction of land applied manure (and total phosphorus) that washes into streams is described below.
3. Total phosphorus production at the 8 operations with no direct runoff loading component and for which no animal number estimates have been provided is assumed to be the average of the operations for which information is available.
4. Land application of animal waste takes place in the subwatershed in which the facility is located. Land application of waste from the 8 operations with unknown locations is assumed to be distributed across all subwatersheds according to the amount of agricultural land within each subwatershed.

Given these assumptions, the amount of land-applied phosphorus is estimated below. The first step is to estimate the amount of total phosphorus that is land applied as manure in each subwatershed on an annual basis. Table 4.4 lists the necessary calculations needed to estimate the annual land application amounts.

Table 4.4. Calculation of the amount of total phosphorus (TP) land applied as manure using animal numbers reported by the UACD.

Subwatershed	Number of Confined Animals	TP Production Rate[a] (kg TP/day)	Annual TP Production (kg/yr)	Annual TP Lost to Runoff (kg/yr)	Annual TP Land Applied (kg/yr)
Chalk Creek	150	0.054	2,957	248	2,709
Beaver Creek	110	0.054	2,168	165	2,003
Silver Creek	90	0.054	1,774	66	1,708
Weber River above Wanship Reservoir	395	0.054	7,785	1,016	6,769
Remaining 8 Facilities	596[b]	0.054	11,747	0	11,747
Total of all Facilities	**1,341**		**26,431**	**1,495**	**24,936**

[a]Phosphorus production rate is for "as excreted" beef manure. An average 1000 pound animal size is assumed (NRCS 1992).
[b]The number of confined animals for the 8 facilities with no information was calculated by taking the total number of animals for the 10 facilities for which information exists and dividing by 10 to calculate an average facility size (745/10 = 74.5). This average facility size was then multiplied by 8 to determine the total number of animals at the 8 facilities for which no information is available (8 X 74.5 = 596).

Since no information is available on the location of 8 out of the 18 facilities, the manure produced at these 8 facilities is assumed to be divided among all of the subwatersheds according to the area of agricultural land within each (assumption 4 above). Table 4.5 lists the distribution of the land applied total phosphorus by subwatershed.

Table 4.5. Calculation of annual land applied total phosphorus (TP) by subwatershed.					
Subwatershed	**Area of Agriculture (km^2)**	**Percent of Total Agricultural Area in Watershed**	**Land Applied TP from 8 Facilities with no Location Info (kg/yr)[a]**	**Land Applied TP from 10 facilities with Location Info (kg/yr)**	**Total Land Applied TP (kg/yr)**
Upper Weber River	12	10.6	1244	2763[a]	4007
Beaver Creek	40.4	35.7	4189	2003	6192
Weber River below Beaver Creek	17.4	15.4	1804	4006[a]	5810
Wanship Reservoir	0.1	0.1	10		10
Weber River below Wanship Reservoir	1.6	1.4	166		166
Silver Creek	5.9	5.2	612	1708	2320
Weber River Below Silver Creek	16.9	14.9	1752		1752
Chalk Creek	15.6	13.8	1617	2709	4326
Echo Reservoir	3.4	3.0	353		353
Total of all Subwatersheds	**113.3**	**100**	**11747**	**13189**	**24936**

[a]It is unknown whether the facilities in the Weber River watershed above Wanship Reservoir are above or below Beaver Creek. Because of this, the land applied total phosphorus reported in Table 3.2 was divided between these two subwatersheds according to the area of agricultural land within each.

A mass balance approach was adapted from Bicknell et al. (1993) to simulate the accumulation of total phosphorus from land applied animal wastes on land surfaces and removal by overland flow causing loadings to stream reaches. Equation 4.1 below shows this mass balance:

$$\left\{\begin{array}{l}\text{Change in the mass of}\\ \text{total phosphorus}\\ \text{available for wash of,}\\ \text{plant uptake, etc.}\end{array}\right\} = \left\{\begin{array}{l}\text{Total phosphorus}\\ \text{loading from}\\ \text{manure application}\end{array}\right\} - \left\{\begin{array}{l}\text{Total phosphorus}\\ \text{removal by immediate}\\ \text{incorporation with}\\ \text{soil}\end{array}\right\} - \left\{\begin{array}{l}\text{Total phosphorus}\\ \text{removal by plant}\\ \text{uptake, etc.}\end{array}\right\} - \left\{\begin{array}{l}\text{Total phosphorus}\\ \text{removal by surface}\\ \text{runoff}\end{array}\right\} \quad (4.1)$$

Equation 4.1 can be rewritten as:

$$\frac{dP}{dt} = A - fA - U - W \quad (4.2)$$

Where: P = Mass of total phosphorus in storage on the land and available for wash off, plant uptake, etc. (kg)
t = Time (day)
A = Total phosphorus application rate from manure application (kg/day)
f = Fraction of total phosphorus lost through immediate incorporation with the soil
U = Total phosphorus removal rate from plant uptake, etc. (kg/day)
W = Rate of total phosphorus wash off from overland flow (kg/day)

Annual total phosphorus application rates (A) have been calculated (Table 4.5), but little information exists regarding the schedule of the manure application in the Echo Reservoir watershed. Information obtained from the NRCS indicates that Figure 4.4 is typical of the manure application schedule in the Echo Reservoir watershed (Broadbent 2004; Warnick 2004).

August September October	Approximately 85 percent of all land-applied manure is incorporated into the soil. Some surface erosion may occur during precipitation events, depending on the field, transporting non-soluble P to the stream channel with soil particles. Roughly 70 percent of fall-season manure is applied during this time period.
November December	Land-applied manure is not typically incorporated into the soil during these time periods due to high soil moisture content or frozen soil. Remaining fall-season manure (30 percent) is applied during this time period.
January February	No manure application based on past observations. More runoff occurs from feedlots, depending on the feedlot. No scraping or land application. Some dairies scrape corrals daily or weekly year round. Manure is either stored in bunkers or staging areas.
March	Land application of spring-season manure begins. No manure is incorporated into the soil at this time due to high soil moisture content or frozen soil. Roughly 25% of spring-season manure is applied during this period.
April	Approximately 85 percent of all land-applied manure is incorporated into the soil. Some surface erosion may occur during precipitation events, depending on the field, transporting non-soluble P to the stream channel with soil particles. Remaining spring-season manure (75 percent) is applied during this time period.
May	No land application. Active growing season. Some dairies scrape corrals daily or weekly.
June	Manure is either stored in bunkers or staging areas.
July	Harvest.

Figure 4.4. Calendar of typical manure application occurring in the Echo Reservoir watershed.

The fraction of land applied total phosphorus lost through immediate incorporation with the soil (*f*) is dependent on whether incorporation is occurring, what percentage of the total phosphorus applied is incorporated with the soil, and the fraction of the total phosphorus incorporated that would be expected to become unavailable as a result. According to Tabbara (2003), immediate incorporation of land-applied manure with the soil can reduce total phosphorus losses associated with subsequent surface runoff events by 30 to 60 percent (i.e., approximately 30 to 60 percent of the applied total phosphorus would immediately become unavailable to surface runoff if it is immediately incorporated with the soil). Given this, it is assumed that 50 percent reduction is reasonable and *f* can be modeled as:

$$f = 0.5 I_p \qquad (4.3)$$

Where: I_p = The fraction of land applied total phosphorus that is incorporated with the soil

In addition to the immediate removal of total phosphorus that occurs through incorporation with the soil, the amount of available total phosphorus continues to decrease with time since application as phosphorus uptake by plants and further adsorption with the soil occurs. A single term (U) in Equation 4.2 accounts for total phosphorus removal by plant uptake, adsorption of total phosphorus into the soil, and any other physical, chemical, or biological processes that contribute to the reduction of the amount of available total phosphorus. This term is expressed as a first order loss rate and is given by Equation 4.4:

$$U = -kP \tag{4.4}$$

Where: k = First order removal rate of total phosphorus (day^{-1})

The rate of total phosphorus wash off from overland flow (W) is given by Equation 4.5 which is a standard build up/wash off function adapted from the HSPF model (Bicknell et al. 1993). Wash off is a function of the magnitude of the surface runoff that occurs, the amount of total phosphorus available for wash off, and a single parameter, $Q_{s,90}$, representing the amount of surface runoff that results in 90 percent wash off of the available total phosphorus.

$$W = P\left(1 - e^{\frac{-2.3 \cdot Q_s}{Q_{s,90}}}\right) \tag{4.5}$$

Where: Q_s = Surface runoff rate per unit watershed area (m/day)
$Q_{s,90}$ = Surface runoff rate per unit watershed area that results in 90 percent wash off (m/day)

The daily surface runoff values used to simulate wash off of total phosphorus with overland flow were estimated by doing a base flow separation on the flow data at USGS gage station 10128500 (Weber River near Oakley, UT). This station is representative of unregulated natural flows in the Weber River, and it is assumed that surface flows at this station are representative of surface flows throughout the watershed. The Hysep program produced by USGS was used to do the base flow separation (USGS 1996).

Substituting in Equations 4.3, 4.4, and 4.5, Equation 4.2 can be rewritten as:

$$\frac{dP}{dt} = A - 0.5I_p A - kP - P\left(1 - e^{\frac{-2.3 \cdot Q_s}{Q_{s,90}}}\right) \tag{4.6}$$

The amount of total phosphorus associated with surface runoff was calculated by evaluating the mass balance for total phosphorus on a daily time step. Parameter values in Equation 4.6 (k and $Q_{s,90}$) were set based on available information and professional judgment. Equation 4.7 shows how the mass balance in Equation 6 is implemented to calculate the amount of total phosphorus available on a daily time step.

$$P_t = P_{t-1} + A_t - 0.5I_{p,t} A_t - k_t P_{t-1} - P_{t-1}\left(1 - e^{\frac{-2.3 \cdot Q_{s,t}}{Q_{s,90}}}\right) \tag{4.7}$$

Where: P_t = Mass of total phosphorus in storage on the land and available for wash off, plant uptake, etc. at time t (kg)
P_{t-1} = Mass of total phosphorus in storage on the land and available for wash off, plant uptake, etc. at time t-1 (kg)
A_t = Total phosphorus loading from manure application at time t (kg)
$I_{p,t}$ = Fraction of manure that is incorporated with the soil at time t
k_t = First order removal rate of total phosphorus at time t (day^{-1})
$Q_{s,t}$ = Surface runoff rate at time t (m/day)

Table 4.6 lists the amount of total phosphorus applied to agricultural land within each subwatershed on an annual basis and the amount of the land applied total phosphorus that is expected to reach the streams as loading from overland flow as calculated using the above modeling approach. Loadings to the streams were evaluated on a daily basis for the time period of flows between 1980 and 2002. The daily results for each year were summed to produce a total annual loading for each year. Annual loadings for all of the years were then averaged to generate the values in Table 4.6. The percent distribution of these loadings between subwatersheds is shown in Figure 4.5.

Table 4.6. Average annual total phosphorus loading from land applied animal wastes by subwatershed (1980-2002).

Subwatershed	Total Phosphorus Applied to Land (kg)	Total Phosphorus Loading to Stream (kg)
Upper Weber River	4,007	891
Beaver Creek	6,192	1,376
Weber River below Beaver Creek	5,810	1,291
Wanship Reservoir	10	2
Weber River below Wanship Reservoir	166	37
Silver Creek	2,320	516
Weber River Below Silver Creek	1,752	389
Chalk Creek	4,326	961
Echo Reservoir	353	78
Total of all Subwatersheds	**24,936**	**5,542**

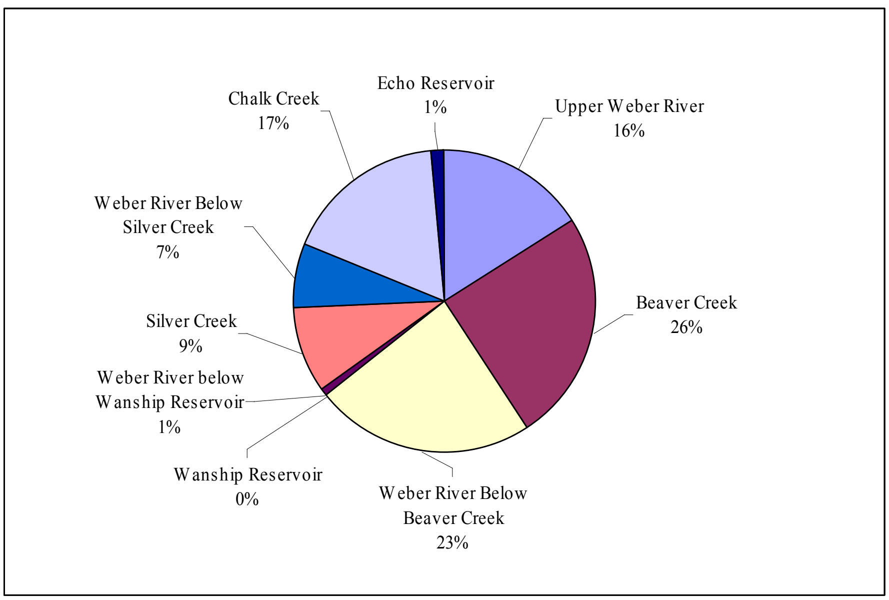

Figure 4.5. Average annual total phosphorus loading from land applied animal wastes by subwatershed (1980-2002).

The above results indicate that approximately 22 percent of the total phosphorus applied to the land as manure in the Echo Reservoir watershed is washed into the streams. This is somewhat lower than similar results reported in other TMDLs (Tetra Tech Inc. 2002) where approximately 50 percent of the total phosphorus produced as animal waste within the basin was transported to the streams and subsequently to the reservoir. In this TMDL, however, no differentiation was made between land applied animal wastes and direct runoff to stream from animal feeding operations, which may be responsible for the difference between the delivery rates. A relatively high rate of wash off is to be expected in a watershed where manure application takes place year round, including during the winter on top of frozen and potentially snow covered ground.

4.3.2 Grazing

Grazing animals are present throughout many of the low-lying, privately owned areas in the watershed. In addition, all or portions of five USFS grazing allotments are present in the watershed, mainly in the upper Weber River and Beaver Creek drainages. The following sections describe the loading contributed to streams in the TMDL study area from grazing on public and private lands within the watershed.

4.3.2.1 Grazing on Public Lands

The following assumptions have been made so that loads from grazing animals on public lands to existing water bodies in the Echo Reservoir watershed can be calculated:

1. Animal numbers within the USFS grazing allotments are based on actual use information provided by the Wasatch-Cache National Forest.
2. The animals are distributed equally over the areas of the USFS allotments.
3. Only animal waste deposited within the area within 100 meters of an existing water body contributes to loading.
4. A delivery ratio of 100 percent is assumed for animal waste deposited within 10 meters of an existing water body and a delivery ratio of 10 percent is assumed for animal waste deposited between 10 and 90 meters of an existing water body.

Table 4.7 lists the USFS grazing allotments that are within the Echo Reservoir watershed. The table also provides some descriptive information such as the number of animals using the allotment and season of use. The animals are grouped by their allotment, animal type, and season of use (Animal Group) to facilitate the analysis that follows. Actual use animal numbers were provided by the Wasatch-Cache National Forest (Holland 2004).

Table 4.7. USFS grazing allotments in the Echo Reservoir watershed[a].

Allotment Name	Animal Group	Animal Type	Number of Animals	Season of Use
Kamas Valley	1	Cow	594	June 10 - October 15 (127 days)
	2	Cow	190	July 1 - September 15 (76 days)
	3	Cow	23	June 10 - June 30 (20 days)
Weber River	4	Cow	186	June 21 - September 30 (101 days)
Smith-Morehouse[b]				
Moffit	5	Sheep	1,050	July 11 - September 29 (80 days)
Humpy Creek	6	Sheep	851	July 25 - September 24 (61 days)

[a]The information in this table is for the entire allotment and not just the area of the allotment within the Echo Reservoir watershed.
[b]This allotment is vacant.

In the absence of more detailed information and as stated above, it is assumed that the animals on the grazing allotments are distributed equally over the entire area of the allotments. Given this assumption, Table 4.8 lists the distribution (density) of livestock in the grazing allotments identified in Table 4.7 above by Animal Group.

Table 4.8. Grazing livestock distribution in the USFS grazing allotments within the Echo Reservoir watershed.					
Allotment Name	**Total Land Area (mi^2)**	**Animal Group**	**Animal Type**	**Number of Animals**	**Animals Per mi^2**
Kamas Valley	85.8	1	Cow	594	6.9
		2	Cow	190	2.2
		3	Cow	23	0.27
Weber River	45.3	4	Cow	186	4.1
Smith-Morehouse[a]	23.9				
Moffit	4.49	5	Sheep	1,050	234
Humpy Creek	4.62	6	Sheep	851	184

[a]This allotment is vacant.

In general, the primary mechanisms by which loading from grazing animals occur are direct deposition in existing water bodies and surface runoff from areas where cattle have grazed. Given the dispersed nature of grazing activities, it is assumed that only animal waste deposited in the area within 100 meters of an existing water body contributes to loading. In considering the two mechanisms by which loading occurs, it is also assumed that 100 percent of the total phosphorus associated with manure deposited within 10 meters of an existing water body contributes to loading (delivery ratio = 100 percent simulating direct deposition) and that approximately 10 percent of manure deposited between 10 and 100 meters from an existing water body contributes to loading (delivery ratio = 10 percent). Table 4.9 lists the contributing area associated with these two zones. These areas were calculated by buffering the streams and reservoirs using GIS.

Table 4.9. Areas of zones contributing to loading from grazing in the Echo Reservoir watershed.		
Allotment	**Contributing Zone**	**Contributing Area (mi^2)**
Kamas Valley	0-10 meters	0.353
	10-100 meters	3.216
Weber River	0-10 meters	0.402
	10-100 meters	3.649
Smith-Morehouse	0-10 meters	0.233
	10-100 meters	2.083
Moffit	0-10 meters	0.073
	10-100 meters	0.641
Humpy Creek	0-10 meters	0.036
	10-100 meters	0.323

According to the Agricultural Waste Management Handbook (NRCS 1992) the average weight of a grazing cow is approximately 454 kg and the average total phosphorus production rate is approximately 0.05 kg of total phosphorus/454 kg animal/day. In addition, it is assumed that approximately 5 sheep are equivalent to one cow, so the total phosphorus production rate for sheep is 0.01 kg of total phosphorus/sheep/day. Given these numbers, Table 4.10 lists the unit area loads for each animal group that were calculated by multiplying the animal density (number of animals per square mile) from Table 4.8 by the total phosphorus production rate.

Table 4.10. Calculation of unit area total phosphorus (TP) loads.					
Allotment	**Animal Group**	**Animal Type**	**Animals per mi^2**	**Total Phosphorus Production Rate (kg TP/animal/day)**	**Unit Area Load (kg TP/mi^2/day)**
Kamas Valley	1	Cow	6.9	0.05	0.345
	2	Cow	2.2	0.05	0.110
	3	Cow	0.27	0.05	0..014
Weber River	4	Cow	4.1	0.05	0.205
Moffit	5	Sheep	234	0.01	2.34
Humpy Creek	6	Sheep	184	0.01	1.84

Annual total phosphorus loading to the existing water bodies in the Echo Reservoir watershed was calculated for each animal group by multiplying the unit area loads in the last column of Table 4.10 by the areas of the deposition zones, the assumed delivery ratios associated with these zones where manure is deposited, and the number of days that the animals in each animal group spend on the allotment. The loadings from each animal group were then summed to produce a total annual loading of approximately 196 kg/yr for the entire watershed. Table 4.11 shows these calculations by grazing allotment, and Table 4.12 summarizes them by the subwatersheds in which the allotments fall.

Table 4.11. Annual total phosphorus (TP) loading to water bodies in the Echo Reservoir watershed from grazing on public land summarized by allotment.							
Allotment	**Animal Group**	**Contributing Zone (meters)**	**Area Within Zone (mi^2)**	**Days on Allotment**	**Unit Area Load (kg TP/mi^2/day)**	**Delivery Ratio (%)**	**Total Phosphorus Loading (kg/yr)**
Kamas Valley	1	0-10	0.353	127	0.376	100	37.1
		10-100	3.216			10	33.8
	2	0-10	0.353	76	0..120	100	7.1
		10-100	3.216			10	6.5
	3	0-10	0.353	20	0.015	100	0.2
		10-100	3.216			10	0.2
Allotment Total							**84.9**
Weber River	4	0-10	0.402	101	0.223	100	20.0
		10-100	3.649			10	18.1
Allotment Total							**38.1**
Moffit	5	0-10	0.073	80	2.65	100	34.1
		10-100	0.641			10	29.9
Allotment Total							**64**
Humpy Creek	6	0-10	0.036	61	0.996	100	4.8
		10-100	0.323			10	4.3
Allotment Total							**9.1**
Total of all Allotments							**196**

Table 4.12. Annual total phosphorus loading to water bodies in the Echo Reservoir watershed from grazing on public land summarized by subwatershed.	
Subwatershed	**Annual Load (kg/yr)**
Upper Weber River (Weber River, Moffit, and Humpy Creek Allotments)	111.2
Beaver Creek (Kamas Valley Allotment)	84.9
Weber River below Beaver Creek	0
Wanship Reservoir	0
Weber River below Wanship Reservoir	0
Silver Creek	0
Weber River Below Silver Creek	0
Chalk Creek	0
Echo Reservoir	0
Total of all Subwatersheds	**196**

4.3.2.2 Grazing on Private Lands

During field visits to the TMDL study area, animals were observed grazing throughout the watershed on private lands. Efforts were made to manually count these animals where they were observed, and the locations along with the number and type of animals were recorded. These field observations provide a snapshot of the number of animals grazing on private lands, but field personnel were limited to public transportation routes, and so the animal counts may not be inclusive of all animals grazing on private lands in the watershed. The manual animal counts were conducted on two separate occasions in 2004 and are summarized in Table 4.13. Due to the diversity in the types of animals that were observed, the summaries are presented in terms of equivalent animal units where 1 cow = 1 horse = 5 sheep = 5 goats. Animals observed at known animal feeding operations were excluded from these summaries to avoid double counting of potential loading (the loads associated with animal feeding operations are accounted for in Section 4.3.1 of this report).

Table 4.13. Summary of manual animal counts in the TMDL study area by subwatershed.		
Subwatershed	**Total Observed Animal Units**	
	April 2004	**June 2004**
Upper Weber River	262	680
Beaver Creek	1,647	2,678
Weber River below Beaver Creek	432	227
Wanship Reservoir	0	0
Weber River below Wanship Reservoir	63	30
Silver Creek	34	10
Weber River Below Silver Creek	1,093	718
Chalk Creek	533	1,349
Echo Reservoir	0	0
Total of all Subwatersheds	**4,064**	**5,692**

The animals were divided into three groups associated with their distance from water including the following;

Group 1: Animals observed to have direct access to an existing stream channel.
Group 2: Animals observed within 100 meters of an existing stream channel.
Group 3: Animals observed at distances greater than 100 meters from an existing stream.

Again it is assumed that manure generated by animals located greater than 100 meters from an existing stream channel does not contribute appreciably to loading. Delivery ratios of 25 percent and 10 percent are assumed for animal groups 1 and 2, respectively. The higher delivery ratio associated with those animals in group 1 is intended to account for the fact that these animals have direct access to the stream and therefore likely deposit some manure directly in the stream. The same phosphorus production rate used to calculate loads from public lands grazing was used in these calculations (total phosphorus production rate = 0.054 kg TP/animal unit/day) (NRCS 1992). To be conservative, it is assumed that livestock on private land remain in the watershed on a year-round basis. Table 4.14 summarizes the results.

4.3.3 Onsite Wastewater Treatment Systems

As stated above, significant development has occurred within the Echo Reservoir watershed in the past 10 to 15 years. The municipal area of Park City is expanding, and the surrounding urban and residential area has increased. Much of the new development within the watershed has occurred in areas that are connected to the sewer systems of Park City and the other smaller municipalities in the watershed. However, a significant number of cabins, summer homes, and other residences have been built within the watershed in areas that are not sewered. These residences use onsite wastewater treatment systems as their primary means of wastewater treatment.

Data indicating the number of septic tanks located within each of the subwatersheds in the TMDL study area were obtained from the Summit County Health Department (Ovard 2004). Summit County Health Department records were also used to estimate the number of full time residences versus those that are used on a recreational basis (cabins, summer homes, etc). These data, along with the following assumptions, were used to estimate annual loads from onsite wastewater treatment systems by subwatershed.

1. All septic tanks in the Echo Reservoir watershed service residential dwellings.
2. Each residential dwelling has a single septic tank.
3. Discharge from septic tanks associated with recreational dwellings is approximately 5 percent of full time septic effluent discharge based on roughly 2.5 weeks residence per year.
4. Average household size in Summit County is 2.87 persons (U.S. Census Bureau 2000).
5. Full time indoor per capita water use is approximately 70 gallons/person/day (UDWR 2001).
6. All indoor water use is discharged via the septic systems.
7. Average total phosphorus concentration of septic system discharge is 9 mg/L (US-EPA 2002).
8. On average, 90 percent of the phosphorus in the effluent from onsite wastewater treatment systems is retained onsite or a 90 percent treatment rate (Canter and Knox 1985).

Loads for onsite wastewater treatments systems are reported in Table 4.15. These loads represent the amount of phosphorus that is likely to reach water courses adjacent to the septic systems.

Table 4.14. Calculation of total phosphorus (TP) loading from private land grazing.

Subwatershed	Animal Group	Number of Animal Units April 2004	Number of Animal Units June 2004	Average Number of Animal Units	TP Production Rate (kg TP/animal unit/day)	Delivery Ratio (%)	TP Loading (kg/yr)
Upper Weber River							
	1	111	100	106	0.054	25	520
	2	75	382	229	0.054	10	450
	3	76	198	137	0.054	0	0
Subwatershed Total		**262**	**680**	**471**			**970**
Beaver Creek							
	1	20	123	72	0.054	25	352
	2	662	1,312	987	0.054	10	1,945
	3	965	1,243	1,104	0.054	0	0
Subwatershed Total		**1,647**	**2,678**	**2,163**			**2,298**
Weber River below Beaver Creek							
	1	25	0	13	0.054	25	62
	2	337	57	197	0.054	10	388
	3	70	170	120	0.054	0	0
Subwatershed Total		**432**	**227**	**330**			**450**
Wanship Reservoir							
	1	0	0	0	0.054	25	0
	2	0	0	0	0.054	10	0
	3	0	0	0	0.054	0	0
Subwatershed Total		**0**	**0**	**0**			**0**
Weber River below Wanship Reservoir							
	1	0	0	0	0.054	25	0
	2	63	10	37	0.054	10	72
	3	0	20	10	0.054	0	0
Subwatershed Total		**63**	**30**	**47**			**72**
Silver Creek							
	1	0	0	0	0.054	25	0
	2	10	0	5	0.054	10	10
	3	24	10	17	0.054	0	0
Subwatershed Total		**34**	**10**	**22**			**10**
Weber River Below Silver Creek							
	1	113	34	74	0.054	25	362
	2	798	324	561	0.054	10	1,106
	3	182	360	271	0.054	0	0
Subwatershed Total		**1,093**	**718**	**906**			**1,468**
Chalk Creek							
	1	188	1,110	649	0.054	25	3,198
	2	226	116	171	0.054	10	337
	3	119	123	121	0.054	0	0
Subwatershed Total		**533**	**1,349**	**941**			**3,535**
Echo Reservoir							
	1	0	0	0	0.054	25	0
	2	0	0	0	0.054	10	0
	3	0	0	0	0.054	0	0
Subwatershed Total		**0**	**0**	**0**			0
Total of all Subwatersheds		**4,064**	**5,692**	**4,878**			**8,803**

Table 4.15. Estimated annual loads from onsite wastewater treatment systems by subwatershed.	
Subwatershed	**Annual Load (kg/yr)**
Upper Weber River	92
Beaver Creek	81
Weber River below Beaver Creek	33
Wanship Reservoir	15
Weber River below Wanship Reservoir	36
Silver Creek	65
Weber River Below Silver Creek	34
Chalk Creek	24
Echo Reservoir	0
Total of all Subwatersheds	**380**

4.3.4 Point Sources

Loads from the point sources within the watershed were calculated using existing flow and concentration data obtained from DWQ. Discussion with discharge permittees indicated that recent improvements have occurred to several facilities including those located in Coalville, Oakley, and Kamas. Repairs to the collection system in 2000 at the Coalville WWTP significantly decreased flow and concentrations of total phosphorus. The Kamas FH was re-built in 2001 and began utilizing a low-phosphorus feed at that time. The Oakley WWTP changed from a lagoon treatment system to a micro filtration process in 2003. Improvements were also made to the Kamas WWTP in 2004. A pre-and post-improvement assessment for each of these facilities indicated that effluent water quality had improved substantially for Coalville WWTP. Slight improvements were observed at the Oakley WWTP although the data set was extremely limited. The limited data set following improvements in 2004 to the Kamas WWTP was insufficient to calculate a meaningful annual load. No differences were noted at the Kamas FH following facility improvements.

Existing load calculations for the Coalville WWTP utilized total phosphorus concentrations following improvements to the facility. Limited data sets for the Oakley WWTP and Kamas WWTP required that the entire water quality monitoring data set (1975 – 2004) be used to develop monthly and annual loads. Load calculations for the Silver Creek WRF and the Kamas FH were based upon the most recent water quality monitoring data (1992 – 2003). A detailed description of the monthly flow and total phosphorus concentrations used to calculate monthly and annual loads is contained in Appendix – Data of this report.

Table 4.16 lists the estimated annual loads associated with each of the point sources that have been identified within the watershed. Also indicated in the table are the receiving waters for each point source discharge. Table 4.17 summarizes the point source loads by the subwatersheds in which they are located.

Table 4.16. Annual loads from point sources in the Echo Reservoir watershed.		
Point Source Name	**Receiving Water**	**Annual Total Phosphorus Loading (kg)**
UDWR Kamas Fish Hatchery	Beaver Creek	434
Kamas WWTP	Beaver Creek	1,322
Snyderville Basin Silver Creek WRF	Silver Creek	4,070
Oakley WWTP	Weber River	475
Coalville WWTP	Chalk Creek	149
Total of all Point Sources		**6,450**

Table 4.17. Annual loads from point sources summarized by subwatershed.	
Subwatershed	**Annual Load (kg/yr)**
Upper Weber River (Oakley WWTP)	475
Beaver Creek (Kamas WWTP and Kamas Fish Hatchery)	1,756
Weber River below Beaver Creek	0
Wanship Reservoir	0
Weber River below Wanship Reservoir	0
Silver Creek (Snyderville Basin Silver Creek WRF)	4,070
Weber River Below Silver Creek	0
Chalk Creek (Coalville WWTP)	149
Echo Reservoir	0
Total of all Subwatersheds	**6,450**

4.3.5 Diffuse Loads from Runoff

Natural background loads are those that are expected in the absence of human influence in the watershed and are related to the natural distribution of flow and land cover in the watershed. Diffuse loads from runoff can be considered the current background loads that occur in the watershed given that the land cover distribution has been changed from natural conditions. In other words, diffuse loads from runoff are the current background loads that have replaced the natural background loads in the watershed.

Loading in this category is related to land use, and specific sources within this category include fertilizers and pesticides in agricultural return flows and runoff from agricultural lands. Sediment related phosphorus loading from erosion processes accelerated by grazing and other agricultural practices are also included in this category. It is important to note that while these loads may be related to grazing activities, phosphorus loads associated with animal waste deposited by grazing animals are accounted for above and are not part of this loading.

Land use in the Echo Reservoir watershed is primarily forest and range land, with smaller areas of irrigated agriculture associated with the low lying areas of the watershed adjacent to the stream channels. Table 4.18 lists the land use distribution in each of the subwatersheds in the Echo Reservoir watershed in terms of acres and percent, and Figure 4.6 shows it visually (see Appendix – Modeling for procedures used to generate the existing conditions land use coverage).

Diffuse loads from runoff associated with each of the land use categories were calculated using annual export coefficients selected from the literature. These export coefficients represent the amount of total phosphorus loading that would be exported from each land use on an annual basis. Table 4.19 lists ranges of export coefficients for each of the land use categories taken from the literature and the values selected for estimating loading from land use in the Echo Reservoir watershed. Appendix – Modeling contains the literature values from which the ranges and selected values were compiled.

In general, the selected values for the export coefficients in Table 4.19 are in the lower part of the ranges found in the literature. These values were selected using professional judgment, but were confirmed by comparing the loads estimated using these values to the measured loads in Section 4.2 of this report to make sure that they are reasonable. In addition, it is believed that the selected values are consistent with the processes controlling diffuse loading in the Echo Reservoir watershed - little surface runoff is generated in the watershed, except for snowmelt runoff in the spring, and so it is expected that the export coefficients would be lower.

Table 4.18. Land use distribution in the Echo Reservoir watershed by subwatershed.			
	Area		
Land Use Category	**Acres**	**Square Kilometers**	**Percent**
Upper Weber River Subwatershed			
Urban/Residential/Transportation	1,558	6.3	1.4
Forest Land	79,190	320.5	70.3
Range Land	26,492	107.2	23.5
Agriculture	2,963	12.0	2.6
Wetlands	30	0.1	0.0
Barren	2,167	8.8	1.9
Water	196	0.8	0.2
Total for Subwatershed	112,595	455.7	100
Beaver Creek Subwatershed			
Urban/Residential/Transportation	1,233	5.0	2.1
Forest Land	34,268	138.7	59.3
Range Land	12,141	49.1	21.0
Agriculture	9,991	40.4	17.3
Wetlands	12	0.0	0.0
Barren	172	0.7	0.3
Water	9	0.0	0.0
Total for Subwatershed	57,826	234.0	100
Weber River Below Beaver Creek Subwatershed			
Urban/Residential/Transportation	404	1.6	2.3
Forest Land	7,127	28.8	40.8
Range Land	5,645	22.8	32.3
Agriculture	4,292	17.4	24.5
Wetlands	0	0.0	0.0
Barren	19	0.1	0.1
Water	0	0.0	0.0
Total for Subwatershed	17,489	70.8	100
Wanship Reservoir Subwatershed			
Urban/Residential/Transportation	160	0.6	0.6
Forest Land	11,915	48.2	46.7
Range Land	12,437	50.3	48.8
Agriculture	35	0.1	0.1
Wetlands	56	0.2	0.2
Barren	36	0.1	0.1
Water	872	3.5	3.4
Total for Subwatershed	25,512	103.2	100
Weber River Below Wanship Reservoir Subwatershed			
Urban/Residential/Transportation	73	0.3	2.6
Forest Land	1,259	5.1	44.0
Range Land	1,124	4.5	39.3
Agriculture	401	1.6	14.0
Wetlands	1	0.0	0.0
Barren	0	0.0	0.0
Water	0	0.0	0.0
Total for Subwatershed	2,859	11.6	100

Table 4.18. (cont'd) Land use distribution in the Echo Reservoir watershed by subwatershed.

	Area		
Land Use Category	**Acres**	**Square Kilometers**	**Percent**
Silver Creek Subwatershed			
Urban/Residential/Transportation	2798	11.3	9.3
Forest Land	16,121	65.2	53.4
Range Land	9,626	39.0	31.9
Agriculture	1,457	5.9	4.8
Wetlands	2	0.0	0.0
Barren	165	0.7	0.5
Water	5	0.0	0.0
Total for Subwatershed	30,174	122.1	100
Weber River Below Silver Creek Subwatershed			
Urban/Residential/Transportation	654	2.6	2.0
Forest Land	15,318	62.0	46.4
Range Land	12,808	51.8	38.8
Agriculture	4,181	16.9	12.7
Wetlands	12	0.0	0.0
Barren	48	0.2	0.1
Water	0	0.0	0.0
Total for Subwatershed	33,021	133.6	100
Chalk Creek Subwatershed			
Urban/Residential/Transportation	666	2.7	0.4
Forest Land	77,817	314.9	48.7
Range Land	77,053	311.8	48.3
Agriculture	3852	15.6	2.4
Wetlands	22	0.1	0.0
Barren	181	0.7	0.1
Water	39	0.2	0.0
Total for Subwatershed	159,629	646.0	100
Echo Reservoir Subwatershed			
Urban/Residential/Transportation	174	0.7	0.7
Forest Land	9,890	40.0	39.5
Range Land	12,833	51.9	51.3
Agriculture	851	3.4	3.4
Wetlands	401	1.6	1.6
Barren	47	0.2	0.2
Water	837	3.4	3.3
Total for Subwatershed	25,032	101.3	100
All Subwatersheds Combined			
Urban/Residential/Transportation	7,720	31.2	1.7
Forest Land	252,905	1,023.5	54.5
Range Land	170,159	688.6	36.7
Agriculture	28,024	113.4	6.0
Wetlands	536	2.2	0.1
Barren	2,836	11.5	0.6
Water	1,958	7.9	0.4
Total of all Subwatersheds	464,138	1,878.3	100

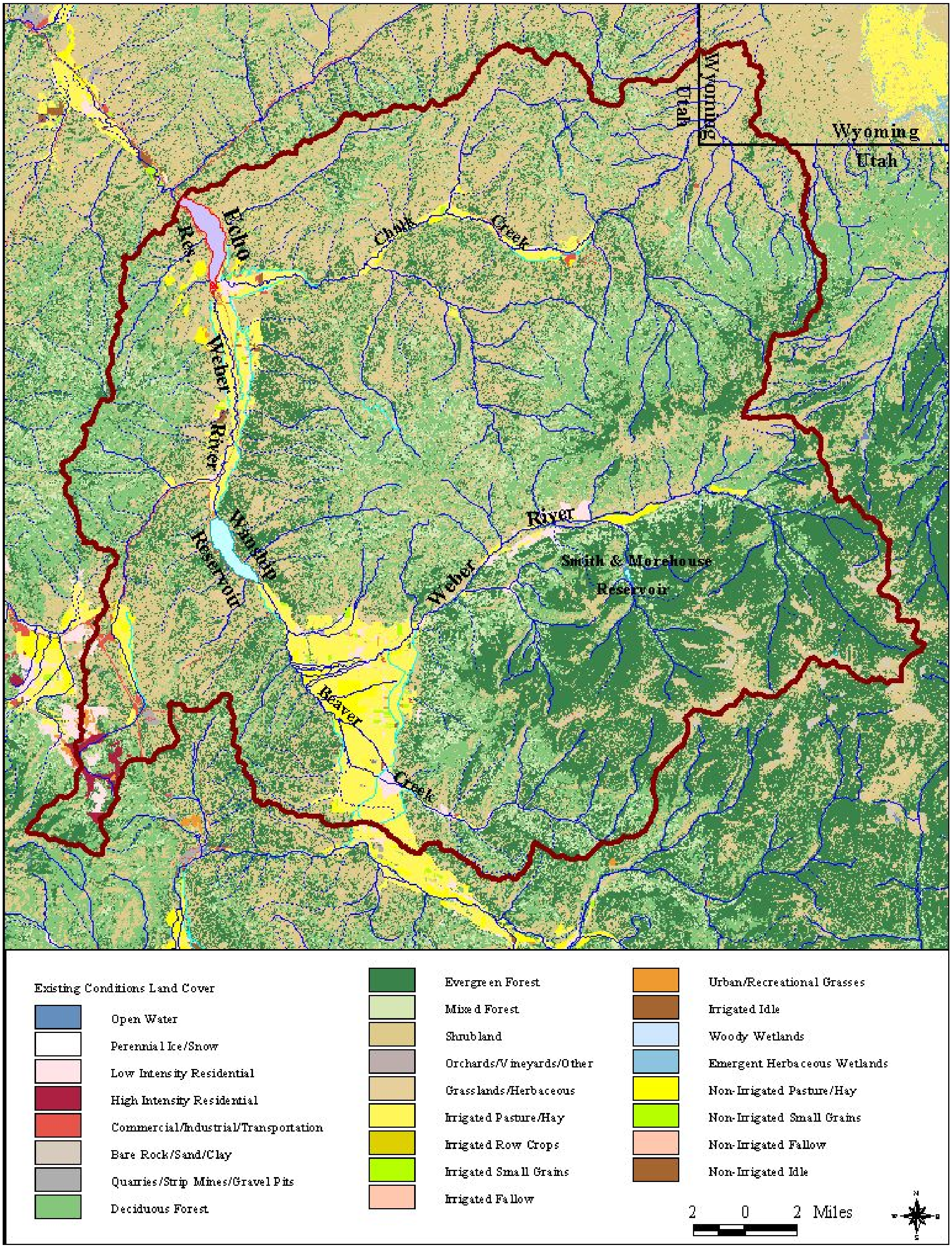

Figure 4.6. Land use distribution in the Echo Reservoir watershed.

Table 4.19. Export coefficients for total phosphorus (TP).		
Land Use Category	Literature Range (kg TP/ha/yr)	Selected Value (kg TP/ha/yr)
Urban/Residential/Transportation	0.1 - 30	1
Forest Land	0.01 - 0.9	0.05
Range Land	0.08 - 0.74	0.1
Agriculture	0.1 - 5	1
Wetlands	[a]	0.25
Barren	0.1 - 0.74	0.2
Water		0[b]
[a]Only a single value was found in the literature [b]Open water is assumed to have negligible phosphorus export.		

Loads for each subwatershed were calculated by multiplying the selected export coefficient values by the area of each land use in each subwatershed. These loads are listed in Table 4.20. Table 4.21 indicates the distribution of loads summarized by subwatershed while Table 4.22 displays loads by land use category.

Table 4.20. Estimated annual total phosphorus (TP) loading to streams in the Echo Reservoir watershed from diffuse loads associated with runoff.			
Land Use Category	**Area (km^2)**	**Export Coefficient (kg TP/ha/yr)**	**TP Loading (kg/yr)**
Upper Weber River Subwatershed			
Urban/Residential/Transportation	6.3	1	630
Forest Land	320.5	0.05	1,603
Range Land	107.2	0.1	1,072
Agriculture	12	1	1,200
Wetlands	0.1	0.25	3
Barren	8.8	0.2	176
Water	0.8	0	0
Total for Subwatershed	455.7		**4,684**
Beaver Creek Subwatershed			
Urban/Residential/Transportation	5	1	500
Forest Land	138.7	0.05	694
Range Land	49.1	0.1	491
Agriculture	40.4	1	4,040
Wetlands	0	0.25	0
Barren	0.7	0.2	14
Water	0	0	0
Total for Subwatershed	234		**5,739**
Weber River Below Beaver Creek Subwatershed			
Urban/Residential/Transportation	1.6	1	160
Forest Land	28.8	0.05	144
Range Land	22.8	0.1	228
Agriculture	17.4	1	1,740
Wetlands	0	0.25	0
Barren	0.1	0.2	2
Water	0	0	0
Total for Subwatershed	70.8		**2,274**

Table 4.20. (cont'd) Estimated annual total phosphorus (TP) loading to streams in the Echo Reservoir watershed from diffuse loads associated with runoff.			
Land Use Category	**Area (km^2)**	**Export Coefficient (kg TP/ha/yr)**	**TP Loading (kg TP/yr)**
Wanship Reservoir Subwatershed			
Urban/Residential/Transportation	0.6	1	60
Forest Land	48.2	0.05	241
Range Land	50.3	0.1	503
Agriculture	0.1	1	10
Wetlands	0.2	0.25	5
Barren	0.1	0.2	2
Water	3.5	0	0
Total for Subwatershed	103.2		**821**
Weber River Below Wanship Reservoir Subwatershed			
Urban/Residential/Transportation	0.3	1	30
Forest Land	5.1	0.05	26
Range Land	4.5	0.1	45
Agriculture	1.6	1	160
Wetlands	0	0.25	0
Barren	0	0.2	0
Water	0	0	0
Total for Subwatershed	11.6		**261**
Silver Creek Subwatershed			
Urban/Residential/Transportation	11.3	1	,1130
Forest Land	65.2	0.05	326
Range Land	39	0.1	390
Agriculture	5.9	1	590
Wetlands	0	0.25	0
Barren	0.7	0.2	14
Water	0	0	0
Total for Subwatershed	122.1		**2,450**
Weber River Below Silver Creek Subwatershed			
Urban/Residential/Transportation	2.6	1	260
Forest Land	62	0.05	310
Range Land	51.8	0.1	518
Agriculture	16.9	1	1,690
Wetlands	0	0.25	0
Barren	0.2	0.2	4
Water	0	0	0
Total for Subwatershed	133.6		**2,782**
Chalk Creek Subwatershed			
Urban/Residential/Transportation	2.7	1	270
Forest Land	314.9	0.05	1,575
Range Land	311.8	0.1	3,118
Agriculture	15.6	1	1,560
Wetlands	0.1	0.25	3
Barren	0.7	0.2	14
Water	0.2	0	0
Total for Subwatershed	646		**6,540**

Table 4.20. (cont'd) Estimated annual total phosphorus (TP) loading to streams in the Echo Reservoir watershed from diffuse loads associated with runoff.

Land Use Category	Area (km^2)	Export Coefficient (kg TP/ha/yr)	TP Loading (kg TP/yr)
Echo Reservoir Subwatershed			
Urban/Residential/Transportation	0.7	1	70
Forest Land	40	0.05	200
Range Land	51.9	0.1	519
Agriculture	3.4	1	340
Wetlands	1.6	0.25	40
Barren	0.2	0.2	4
Water	3.4	0	0
Total for Subwatershed	101.3		**1,173**
Total for Echo Reservoir Watershed	1,878.3		**26,724**

Table 4.21. Estimated annual total phosphorus loading to streams in the Echo Reservoir watershed from diffuse loads associated with runoff summarized by land use.

Land Use Category	Total Phosphorus Loading (kg/yr)
Urban/Residential/Transportation	3,110
Forest Land	5,119
Range Land	6,884
Agriculture	11,330
Wetlands	51
Barren	230
Water	0
Total of all Land Use Categories	**26,724**

Table 4.22 Estimated annual total phosphorus loading to streams in the Echo Reservoir watershed from diffuse loads associated with runoff summarized by subwatershed.

Subwatershed	Total Phosphorus Loading (kg/yr)
Upper Weber River	4,684
Beaver Creek	5,739
Weber River Below Beaver Creek	2,274
Wanship Reservoir	821
Weber River Below Wanship Reservoir	261
Silver Creek	2,450
Weber River Below Silver Creek	2,782
Chalk Creek	6,539
Echo Reservoir	1,173
Total of all Subwatersheds	**26,724**

4.3.6 Internal Reservoir Loading

Little information is available on the extent to which internal phosphorus loading is important in reservoirs in the Intermountain West, or on the factors controlling phosphorus uptake or release in these sediments (Messer and Ihnat 1983). In general, the uptake or release of phosphorus by bottom sediments is related to the chemistry of the sediments and the amount of dissolved oxygen present at the sediment water interface. In many cases, phosphorus release from sediments is controlled by iron redox chemistry and which is to a large degree related to dissolved oxygen concentrations at the sediment/water interface. When this is the case, dissolved oxygen concentrations above approximately 1 mg/L generally prohibit significant release of phosphorus from the sediments.

Echo Reservoir is relatively large and generally has sufficient depth early in the summer to support stratification. An extended period of stratification is inhibited, however, due to the large irrigation demand downstream that leads to the extensive draw down of the reservoir throughout the summer. This draw down may reduce productivity and cause a premature turnover in the reservoir. Dissolved oxygen concentrations at depth in the reservoir are typically above those required for anaerobic phosphorus release from bottom sediments to occur (usually less than 1 mg/L), although concentrations less than 1 mg/L have been observed. These periods are assumed to be associated with stratified conditions, which are relatively short lived in this reservoir due to its draw down.

No information is available regarding the phosphorus content or potential phosphorus release rates of the sediments in Echo Reservoir. However, phosphorus release studies have been done on other reservoirs in Utah and the Intermountain West (Messer and Ihnat 1983; Messer et al. 1984). Table 4.23 provides a comparison of aerobic and anaerobic phosphorus release rates from sediment cores collected in some Intermountain reservoirs. As expected, the aerobic release rates are quite low. The anaerobic release rates are somewhat higher, which is also to be expected, but are still relatively low when compared to anaerobic release rates from eutrophic lakes that can be in the range of 10 - 50 mg P/m^2 - day (Messer et al. 1984).

Table 4.23. Comparison of aerobic and anaerobic phosphorus release rates from sediment cores collected from some Intermountain reservoirs and incubated in the laboratory (adapted from Messer et al. (1984)).

	Phosphorus Release Rate (mg P/m^2-day ± 1 SD)	
	Aerobic Rate	**Anaerobic Rate**
Flaming Gorge Reservoir	0.8 ± 0.8 (5)	4.6 ± 4.7 (5)
Deer Creek Reservoir	0.3 ± 0.4 (12)	4.6 ± 3.5
Panguitch Reservoir	0.2 (11)	1.4 (1)
Scofield Reservoir	0.1 ± 0.1 (3)	0.4 ± 0.4 (4)
Strawberry Reservoir	0.0 ± 0.0 (7)	0.2 ± 0.4 (9)

Note: the number in parentheses represents the number of cores tested.

Although it is uncertain whether the conditions in any of these reservoirs are representative of the conditions in Echo Reservoir, the information in Table 4.23 was used to generate an estimate of the potential internal phosphorus loading from the sediments. In order to make the estimate, several assumptions had to be made. First, it is assumed that the rates of phosphorus release from the sediments (both aerobic and anaerobic) are equal to the average of the mean release rates in Table 4.23. Under this assumption, the aerobic release rate is equal to 0.28 mg P/m^2-day and the anaerobic release rate is equal to 2.24 mg P/m^2-day.

Next, it is assumed that the area of the sediments exposed to the overlying water column is equal to the surface area of the reservoir. Given that the surface area of Echo Reservoir changes as it fills and drains, an estimate of reservoir surface area as a function of time is needed. Operational data obtained from the United States Bureau of Reclamation (BOR) and morphometry information derived from a bathymetric map of the reservoir were used to estimate average monthly surface areas for the reservoir. The bathymetry of Echo Reservoir is shown in Figure 4.7. The bathymetric data were first used to derive a relationship between reservoir water surface elevation and surface area (Figure 4.8), and then this relationship was used along with water surface elevation data for the period between 1984 and 2004 from BOR to determine the average monthly reservoir areas (Figure 4.9).

It is assumed that the reservoir stratifies twice yearly (summer and winter) with a spring and fall turnover event. Under this assumption the reservoir would be stratified approximately 7 months out of the year, with a summer stratification period of June through August (with an early turnover in the fall due to the draw-down) and a winter stratification period of December through March. This leaves approximately 5 months of mixed conditions associated with spring and fall turnover. In addition, it is assumed that during turnover, oxygen from the surface is mixed rapidly; and that it takes approximately 1 month after a stratification is in place for the oxygen at the sediment/water interface to be depleted. Under these assumptions, the sediments in the reservoir are anaerobic approximately 5 months out of the year and aerobic approximately 7 months out of the year. This rudimentary stratification schedule is shown in Table 4.24 below.

Table 4.24. Assumed stratification schedule for Echo Reservoir.

Month	Sediment Condition	Description
January	Anaerobic	Winter stratification, oxygen depleted at sediment/water interface.
February	Anaerobic	Winter stratification, oxygen depleted at sediment/water interface.
March	Anaerobic	Winter stratification, oxygen depleted at sediment/water interface.
April	Aerobic	Ice-off and spring turn over occurs, mixed conditions.
May	Aerobic	Mixed conditions.
June	Aerobic	Summer stratification sets up, oxygen not yet depleted at sediment/water interface.
July	Anaerobic	Summer stratification, oxygen depleted at sediment/water interface.
August	Anaerobic	Summer stratification, oxygen depleted at sediment/water interface.
September	Aerobic	Summer stratification ends with early fall turn over due to draw down, mixed conditions.
October	Aerobic	Mixed conditions.
November	Aerobic	Mixed conditions.
December	Aerobic	Winter ice up occurs, winter stratification sets up, oxygen not yet depleted at sediment/water interface.

Given the above assumptions, the monthly and annual loadings to the water column from the sediments in Echo Reservoir were estimated and are reported in Table 4.25. Approximately 1,701 kg/yr of phosphorus may be contributed to the water column in Echo Reservoir from its sediments. It should be noted, however, that since the internal loading estimates are based on sediment release rates and assumptions that may not be entirely characteristic of Echo Reservoir, the load estimates should be considered as having a relatively high degree of uncertainty. This uncertainty could be remedied to some degree if site specific data characterizing the sediments in Echo Reservoir were collected.

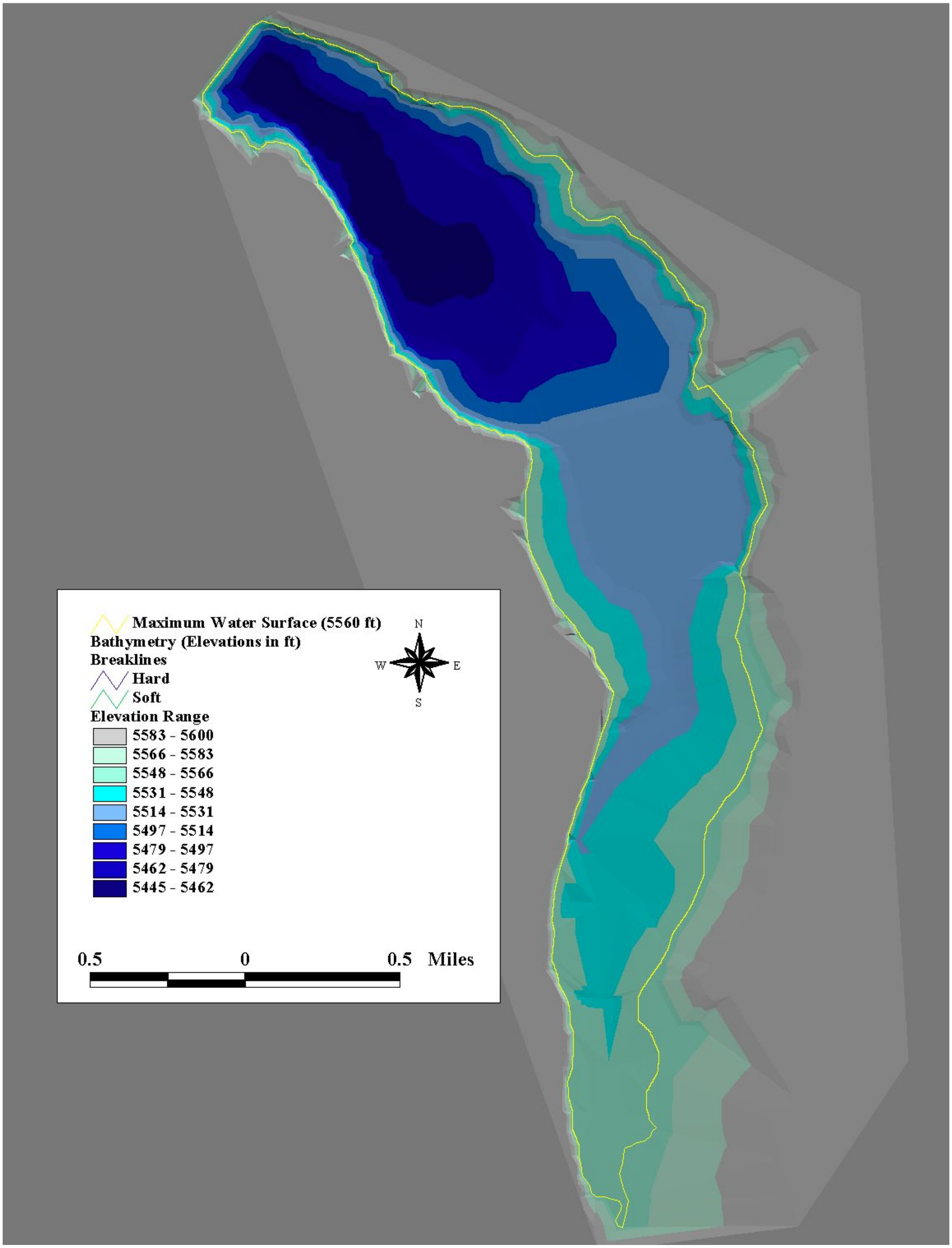

Figure 4.7. Bathymetric elevation map of Echo Reservoir.

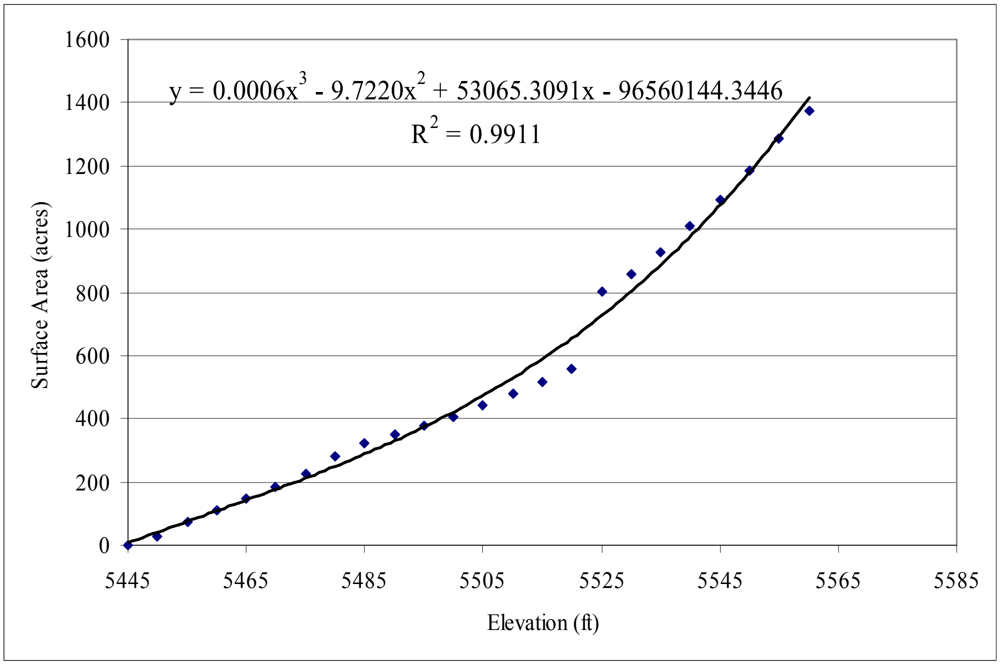

Figure 4.8. Relationship between water surface elevation and reservoir surface area for Echo Reservoir derived from a contour map of the reservoir.

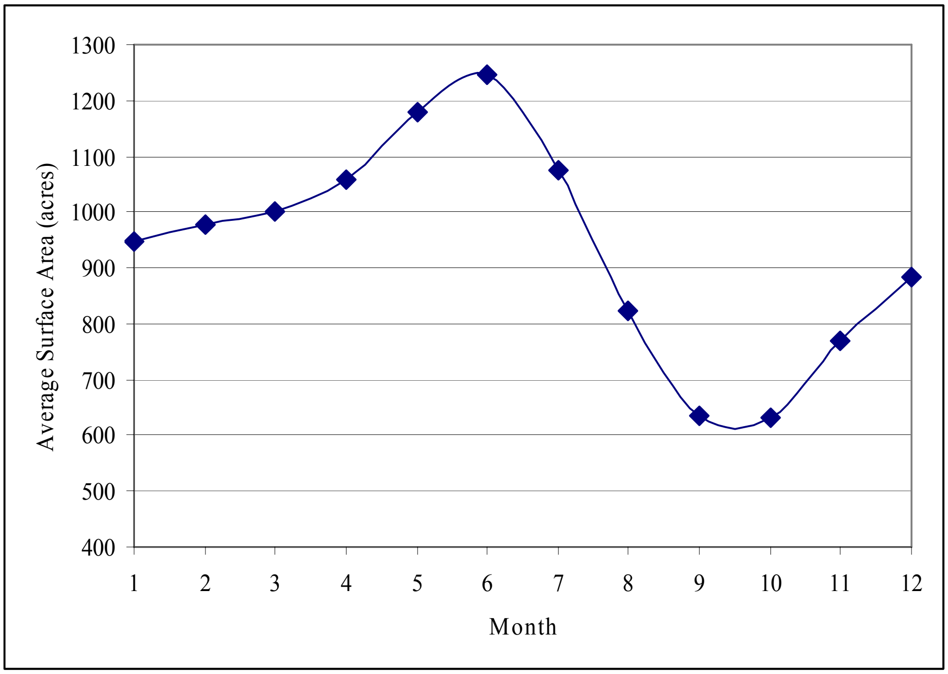

Figure 4.9. Average monthly surface area of Echo Reservoir based on BOR operational data from the period 1984 - 2004.

Table 4.25. Estimated internal phosphorus loading from sediments in Echo Reservoir.			
Month	**Average Surface Area (acres)**	**Sediment Release Rate (mg/m^2-day)**	**Internal Loading (kg)**
January	949	2.24	267
February	977	2.24	248
March	1,000	2.24	281
April	1,058	0.28	36
May	1,177	0.28	41
June	1,248	0.28	42
July	1,073	2.24	302
August	825	2.24	232
September	635	2.24	173
October	631	0.28	22
November	770	0.28	26
December	885	0.28	31
Annual Total			**1,701**

4.3.7 Assessment of Natural Background Loading

In order to estimate natural background loading, information characterizing the amount of flow contributed to Echo Reservoir and the "natural" or pre-human influence concentration of that flow are needed. Since no observations are available to characterize pre-human influence conditions in the watershed, a review of water quality data collected in areas where minimal anthropogenic influence can be assumed was conducted. These areas include springs and upper headwater streams and tributaries within the TMDL study area. The data from this assessment are summarized in Appendix – Data of this report. In the absence of more detailed information, these measurements will be used to provide a reasonable estimate of potential natural background concentrations in the watershed. Actual background concentrations may be lower or higher than the measurements shown in Appendix – Data.

The statistical assessment of selected background stations in Chalk Creek shows mean total phosphorus concentrations in the range of 0.03 mg/L to 0.19 mg/L with an overall mean for all background stations of 0.1 mg/L. In general, total phosphorus concentrations at most locations in the Chalk Creek drainage (including the background stations) are relatively high, and a large percentage of the observations are in exceedance of the 0.05 mg/L pollution indicator value for total phosphorus. Mean total phosphorus concentrations at background stations in the upper parts of the Weber River drainage are much lower than those of Chalk Creek, ranging from less than 0.01 mg/L to 0.011 mg/L with an overall mean for all stations of 0.01 mg/L. Concentrations at background stations in the Beaver Creek Drainage are slightly higher than those in the Upper Weber River, with mean concentrations ranging from 0.012 mg/L to 0.018 mg/L and an overall mean of 0.016 mg/L. Background concentrations in the Silver Creek drainage are similar to those of Chalk Creek, with an overall mean concentration of 0.1 mg/L.

The results of the statistical assessment above provide mixed indications of whether the phosphorus rich geological deposits within the watershed have had a significant effect on background loading. In the upper Weber River, there is little evidence of significant background loading from this source, as concentrations are typically less than 0.01 mg/L at the stations that were assessed. The same is generally true of those stations assessed in Beaver Creek. The stations assessed in Silver Creek, however, do show elevated background concentrations, which may be attributable to this source. The difference may be because the Park City Formation, shown in Figure 2.6, has been exposed in the Silver Creek drainage but not in the Beaver Creek or Upper Weber River drainages. However, further study, which is beyond the scope of this TMDL study, would be required to confirm this theory.

Irrespective of the potential sources of natural background loading, the grouped statistical assessments in each of the drainages were used to estimate mean monthly natural background concentrations, which were then used to estimate natural background loads at several locations in the Echo Reservoir watershed. Mean monthly flows at each of the selected locations were estimated from available streamflow sampling data. Appendix – Data details the calculations, the streamflow datasets used, and the assumed background concentrations for each location at which background loading was estimated. Table 4.26 lists the results of the background loading calculations.

Table 4.26. Estimated annual background total phosphorus loading at several locations in the Echo Reservoir watershed.

Subwatershed	Annual Background Loading (kg)
Upper Weber River above Weber-Provo Diversion	2,914
Beaver Creek near Mouth	1,231
Weber River above Wanship Reservoir	2,465
Weber River below Wanship Reservoir	2,540
Silver Creek near Mouth	1,578
Weber River above Echo Reservoir	4,859
Chalk Creek near Mouth	7,399

It should be noted that the monthly estimates of "natural" background loading likely bear little resemblance to truly natural conditions in the watershed since flows in the Weber River above Echo Reservoir are regulated by the dam at Wanship Reservoir and since there is some uncertainty in the selected background concentrations. However, it is believed that the annual estimates are reasonable approximations of background loadings to Echo Reservoir.

4.3.8 Loading Source Summary

The significant loadings in the Echo Reservoir watershed are summarized in Table 4.27 by source category and in Table 4.28 by subwatershed. Again, these loads represent loading to water bodies within the watershed and not necessarily to the reservoir. The linkage analysis provided below in Section 4.4 of this report will examine the effects of loads from each of the sources on Echo Reservoir.

4.4 LINKAGE ANALYSIS

A critical component of the TMDL process is to determine the cause-and-effect relationship between pollutant sources and the desired water quality target. In a review of scientific literature, Carpenter et al. (1998), has shown that non-point sources of phosphorus has lead to eutrophic conditions for many lakes and reservoirs across the U.S. One consequence of eutrophication is oxygen depletion caused by decomposition of algae and aquatic plants. They also document that a reduction in nutrients will eventually lead to the reversal of eutrophication and attainment of designated beneficial uses. Nurnberg (1995, 1995a, 1996, 1997), developed a model that quantified duration (days) and extent of lake oxygen depletion, referred to as an anoxic factor (AF). This model showed that AF is positively correlated with average annual total phosphorus concentrations. Nurnberg (1996) developed several regression models that show nutrients (P and N) control all trophic state indicators related to oxygen and phytoplankton in lakes and reservoirs. These models were developed from water quality characteristics using a suite of North American lakes. The morphometric parameters of Echo Reservoir, such as mean depth and surface area, fall within the range of lakes used by Nurnberg (1996). As a result, the empirical nutrient-oxygen relationship provided by Nurnberg (1996) should be applicable to Echo Reservoir.

Utah's approach to reduce nutrient loads to impaired waterbodies is consistent with accepted watershed strategies to address the sources of impairment rather than the symptoms (low dissolved oxygen). However; if after practicable treatment of all nutrient sources, and allowing for a sufficient period for recovery (at least 10 years), dissolved oxygen concentrations still do not improve; in-lake treatments may be investigated and implemented.

Another critical component in this analysis is that calculated watershed loads must be linked to measured loads at the watershed outlet. Information contained in Table 4.27 provides calculated watershed loads for each significant source of total phosphorus in the study area. After this link has been defined, the amount of total phosphorus that Echo Reservoir can assimilate (permissible loading) and still support desired dissolved oxygen concentrations will be determined. The permissible load to Echo Reservoir can then be allocated between the different pollutant source categories in the watershed using the linkage assessment. Calculation of permissible loads and load allocations will be completed in Chapter 5 of this report.

Calculated pollutant loads were linked to measured watershed outlet loads at three locations including Chalk Creek, the Weber River below Wanship Reservoir (including Silver Creek), and the Weber River above Wanship Reservoir. The linkage was established by assuming that the percent contribution from each pollutant source category to the total watershed load (all sources) comprised the same percent contribution at the watershed outlet. For instance, diffuse loads from runoff for Chalk Creek contributed 6,539 kg or approximately 58 percent of the 11,307 kg total watershed load reported for all nonpoint sources in Table 4.28. It is therefore assumed that diffuse loads from runoff also contribute roughly 58 percent (or 6,097 kg) of the 10,544 kg load measured at station 492635. It is noted here that although a 149 kg load is reported in Table 4.28 for point sources in Chalk Creek, this value is not used to determine watershed outlet loads. This is due to the fact that Station 492635 is located above the Coalville WWTP. Loads from the plant are considered a direct load to Echo Reservoir. The total watershed outlet load for Chalk Creek is considered to be the sum of measured loading from Station 492635 – Chalk Creek at US 189 Crossing and Station 492632 – Coalville WWTP.

Monthly values for each pollutant source were also determined in order to assess the seasonal distribution of watershed outlet loads. Sufficient monitoring data was available to directly calculate monthly loads for point sources. Due to the limited information characterizing non-point pollutant sources, several assumptions were made. The monthly distribution of loads from septic tanks were assumed to be equal throughout the year and calculated by dividing the annual load by 12. Monthly loads from land applied manure were determined based on the assumptions and method previously described in section 4.3.1.2.

Monthly loads from AFOs, diffuse runoff, and grazing on public and private lands were determined using the HYSEP baseflow separation procedure (Sloto and Crouse 1996) on the 1903-2003 streamflow record for USGS Gage 10128500 (Weber River at Oakley). This method partitions streamflow volume into base-flow and surface-flow components. The base-flow portion of stream discharge is typically associated with groundwater contributions while the surface-flow portion is attributed to overland flow contributions from rain or snowmelt events. It is assumed that the flow record at this station (1904 – 2003) is representative of unregulated natural flows in the Weber River and that the percent of flow contributed by surface runoff at this station is representative of surface flows throughout the study area. The monthly distribution of surface flows at USGS Gage 10128500 is provided below in Table 4.29.

Table 4.27. Summary of annual total watershed loads in the Echo Reservoir TMDL study area by source category.	
Source	**Annual Total Phosphorus Load (kg)**
Animal Feeding Operations	
Direct Stream Loading	1,495
Land Applied Animal Waste	5,542
Grazing	
Public Lands	196
Private Lands	8,803
Onsite Wastewater Treatment Systems	380
Point Sources	6,450
Diffuse Loads from Runoff	26,724
Internal Reservoir Loading	1,701
Total of all Sources	**51,290**

Table 4.28. Summary of annual total watershed loads by subwatershed.

	Annual Total Phosphorus Loading to Streams (kg/yr)								
Subwatershed	**Direct Stream Loading from Animal Feeding Operations**	**Land Applied Animal Wastes**	**Public Land Grazing**	**Private Land Grazing**	**Onsite WWTS**	**Point Sources**	**Diffuse Loads from Runoff**	**Internal Reservoir Loading**	**Total of all Sources**
Upper Weber River	417	891	111	970	92	475	4,683		7,639
Beaver Creek	165	1,376	85	2,298	81	1,756	5,739		11,500
Weber River Below Beaver Creek	599	1,291	0	450	33	0	2,274		4,647
Wanship Reservoir	0	2	0	0	15	0	821		838
Weber River Below Wanship Reservoir	0	37	0	72	36	0	261		406
Silver Creek	66	516	0	10	65	4,070	2,450		7,177
Weber River Below Silver Creek	0	389	0	1,468	34	0	2,782		4,673
Chalk Creek	248	962	0	3,535	24	149	6,541		11,458
Echo Reservoir	0	78	0	0	0	0	1,173	1,701	2,952
Total of all Subwatersheds	**1,495**	**5,542**	**196**	**8,803**	**380**	**6,450**	**26,724**	**1,701**	**51,290**

Monthly loads for AFOs, diffuse runoff, and grazing on public and private lands were then determined by simply multiplying the fraction of surface flow volume by the annual watershed loads for these pollutants. The monthly distribution of watershed outlet loads for Chalk Creek, Weber River below Wanship, and the Weber River above Wanship Reservoir are provided in Table 4.30 through Table 4.32 respectively. Note that loads provided in Table 4.30 for Chalk Creek represent the sum of measured loads at Station 492635 (Chalk Creek at US 189 Crossing) and Station 492632 (Coalville WWTP). Table 4.31 indicates the reach gain in loading between the outlet of Wanship Reservoir (Station 492701) and the inlet to Echo Reservoir (Station 492640) as well as contributions made from the subwatershed surrounding Echo Reservoir. Table 4.32 indicates the watershed outlet loads at the inlet to Wanship Reservoir as well as the reservoir outlet. Total annual loads passing through Wanship Reservoir are decreased by approximately 388 kg or 5.14 percent. Information in Table 4.32 indicates this reduction to the annual watershed outlet load for each pollutant source.

Table 4.29. Baseflow separation completed on USGS 10128500 Weber River at Oakley. Values indicate the fraction of total monthly streamflow that can be attributed to surface runoff volumes.

Month	Fraction of Surface Flow
January	0.003
February	0.003
March	0.008
April	0.069
May	0.392
June	0.429
July	0.048
August	0.017
September	0.012
October	0.008
November	0.006
December	0.005

Table 4.30. Existing Pollutant Loads – Chalk Creek. Note that Monthly Total Watershed Loads are shown in the upper portion of the table and Annual Watershed Outlet Loads are shown in the lower portion of the table. Values shown for Annual Percent of Total Load are based on the annual total load of 11,307 kg which does not include the point source load from Coalville WWTP. This load is considered a direct load to Echo Reservoir and as a result, does not need to be adjusted to an equivalent watershed outlet load. Annual Watershed Outlet Loads for each source (point and non-point sources) are shown at the bottom of the table.

Monthly Total Pollutant Loads – Chalk Creek Watershed									
Month	**Fraction of Surface Flow Volume**	**AFOs (kg)**	**Land Applied Manure (kg)**	**Public Land Grazing (kg)**	**Private Land Grazing (kg)**	**Septic Tanks (kg)**	**Point Source(kg)**	**Diffuse Runoff (kg)**	**Total (kg)**
January	0.003	0.7	42.8	0.0	10.6	2.0	18.6	19.6	94.3
February	0.003	0.7	23.7	0.0	10.6	2.0	11.9	19.6	68.5
March	0.008	2.0	123.2	0.0	28.3	2.0	11.4	52.3	219.2
April	0.069	17.1	417.5	0.0	243.9	2.0	10.8	451.2	1142.5
May	0.392	97.2	102.8	0.0	1385.7	2.0	5.7	2563.3	4156.7
June	0.429	106.4	0.2	0.0	1516.5	2.0	14.7	2805.2	4445
July	0.048	11.9	0.1	0.0	169.7	2.0	12.6	313.9	510.2
August	0.017	4.2	26.5	0.0	60.1	2.0	15.7	111.2	219.7
September	0.012	3.0	49.3	0.0	42.4	2.0	12.4	78.5	187.6
October	0.008	2.0	43.6	0.0	28.3	2.0	1.0	52.3	129.2
November	0.006	1.5	60.7	0.0	21.2	2.0	19.2	39.2	143.8
December	0.005	1.2	71.1	0.0	17.7	2.0	14.5	32.7	139.2
Annual Total Load (kg)		**247.9**	**961.5**	**0.0**	**3,535.0**	**24.0**	**148.5**	**6,539.0**	**11,455.9**
Annual Watershed Outlet Loads – Chalk Creek Watershed									
Annual Percent of Total Load (Non-point sources only)		2.2	8.5	0.0	31.3	0.2	0.0	57.8	100
Annual Watershed Outlet Load (kg) by Pollutant Source (Total is sum of Station 492635 and Station 492632)		231	897	0.0	3,296	22	149	6,098	10,693

Table 4.31. Existing Pollutant Loads – Weber River Below Wanship Reservoir. Note that Monthly Total Watershed Loads are shown in the upper portion of the table and Annual Watershed Outlet Loads are shown in the lower portion of the table. Annual Watershed Outlet Loads shown in the bottom row of this table indicate the reach gain of total phosphorus loads between 492701-Weber River Below Wanship Reservoir and 492640 – Weber River Above Echo Reservoir as well as loads contributed from the subwatershed draining directly to Echo Reservoir.

Monthly Total Pollutant Loads – Weber River Below Wanship Reservoir									
Month	**Fraction of Surface Flow Volume**	**AFOs (kg)**	**Land Applied Manure (kg)**	**Public Land Grazing (kg)**	**Private Land Grazing(kg)**	**Septic Tanks (kg)**	**Point Source(kg)**	**Diffuse Runoff (kg)**	**Total (kg)**
January	0.003	0.2	42.0	0.0	4.7	11.3	283.2	16.5	357.7
February	0.003	0.2	23.2	0.0	4.7	11.3	338.4	16.5	394.1
March	0.008	0.5	120.7	0.0	12.4	11.3	405.3	43.9	594.1
April	0.069	4.6	409.0	0.0	107.0	11.3	267.8	379.0	1,178.5
May	0.392	25.9	100.7	0.0	607.6	11.3	265.9	2153.3	3,164.6
June	0.429	28.3	0.1	0.0	665.0	11.3	319.7	2356.5	3,380.9
July	0.048	3.2	0.1	0.0	74.4	11.3	468.1	263.7	820.6
August	0.017	1.1	25.9	0.0	26.4	11.3	341.1	93.4	499.1
September	0.012	0.8	48.3	0.0	18.6	11.3	371.8	65.9	516.6
October	0.008	0.5	42.7	0.0	12.4	11.3	291.3	43.9	402.2
November	0.006	0.4	59.4	0.0	9.3	11.3	320.3	33.0	433.6
December	0.005	0.3	69.6	0.0	7.8	11.3	396.8	27.5	513.2
Annual Total Load (kg)		**66.0**	**941.8**	**0.0**	**1,550.0**	**135.0**	**4,069.5**	**5,493.0**	**12,255.3**
Annual Watershed Outlet Loads – Weber River Below Wanship Reservoir									
Annual Percent of Total Load		0.5	7.7	0.0	12.6	1.1	33.2	44.8	100
Annual Watershed Outlet Load (kg) for Weber River Below Wanship (Reach Gain)		35	499	0.0	821	72	2,157	2,911	6,495

Table 4.32. Existing Pollutant Loads – Weber River Above Wanship Reservoir. Note that Monthly Total Watershed Loads are shown in the upper portion of the table and Annual Watershed Outlet Loads are shown in the lower portion of the table. Annual Watershed Outlet Loads shown for Station 492725 – Weber Above Wanship are based on the measured average total of 7,550 kg. Loads shown in the bottom row of the table indicate a 5.14 percent decrease that occurs due to in-lake processes that remove total phosphorus as the Weber River flows through Wanship Reservoir.

Monthly Total Pollutant Loads – Weber River Above Wanship Reservoir									
Month	**Fraction of Surface Flow Volume**	**AFOs (kg)**	**Land Applied Manure (kg)**	**Public Land Grazing (kg)**	**Private Land Grazing (kg)**	**Septic Tanks (kg)**	**Point Source(kg)**	**Diffuse Runoff (kg)**	**Total (kg)**
January	0.003	3.5	158.6	0.6	11.2	18.4	219.2	40.6	452.0
February	0.003	3.5	87.7	0.6	11.2	18.4	183.9	40.6	345.9
March	0.008	9.4	456.2	1.6	29.7	18.4	240.7	108.1	864.2
April	0.069	81.5	1,546.0	13.5	256.5	18.4	160.4	932.7	3,009.1
May	0.392	463.0	380.6	76.8	1,457.5	18.4	319.7	5,298.7	8,014.7
June	0.429	506.6	0.6	84.1	1,595.0	18.4	434.2	5,798.8	8,437.7
July	0.048	56.7	0.3	9.4	178.5	18.4	159.7	648.8	1,071.8
August	0.017	20.1	98.1	3.3	63.2	18.4	161.6	229.8	594.5
September	0.012	14.2	182.6	2.4	44.6	18.4	99.8	162.2	524.1
October	0.008	9.4	161.5	1.6	29.7	18.4	84.3	108.1	413.1
November	0.006	7.1	224.7	1.2	22.3	18.4	64.3	81.1	419.1
December	0.005	5.9	263.2	1.0	18.6	18.4	103.3	67.6	477.9
Annual Total Load (kg)		**1,181.0**	**3,560.0**	**196.0**	**3,718.0**	**220.8**	**2,231.3**	**13,517.0**	**24,624.10**
Annual Watershed Outlet Loads – Weber River Above Wanship Reservoir									
Annual Percent of Total Load		4.8	14.5	0.8	15.1	0.9	9.1	54.9	100
Annual Watershed Outlet Load (kg) for Weber Above Wanship Reservoir at Station 492725		362.1	1091.5	60.1	1140.0	67.7	684.1	4144.5	7550.0
Annual Watershed Outlet Load (kg) Weber River Above Wanship Reservoir at Station 492701		343.5	1,035.4	57.0	1,081.4	64.2	649.0	3,931.5	7,162.0

CHAPTER 5: TMDL ANALYSIS

5.1 WATER QUALITY TARGETS

In order to determine the permissible loadings to Echo Reservoir, acceptable water quality targets or TMDL endpoints must be set. These endpoints define the conditions under which the beneficial use of the reservoir will be protected, and allow the evaluation of management options in terms of their overall effect on water quality. In general, TMDL endpoints are defined in terms of existing numeric water quality criteria. Although in some cases these numeric criteria are over or under protective of the beneficial use, they have been set at levels that have historically been observed to protect the beneficial use of the waters for which they are specified.

Echo Reservoir is designated as Class 3A - protected for cold-water species of game fish and other cold-water aquatic life. Impairment to lakes and reservoirs is generally based on three parameters including temperature, pH, and dissolved oxygen, which are collected during routine monitoring of these water bodies by the State of Utah. In most cases, if less than 10 percent of measurements for any of these parameters exceed standards, full support status is assigned to the water body. Partial support is assigned if exceedance is between 10 percent and 25 percent, while non-support status is assigned if exceedance is more than 25 percent. An exception to this rule is made for dissolved oxygen levels in deep lakes or reservoirs where low oxygen or anoxic conditions might exist. In these situations, if less than 50 percent of the water column is below 4.0 mg/l, the water body is considered to be fully supporting Class 3A beneficial use. If 50 to 75 percent of the water column is less than 4.0 mg/l, partial support status is assigned. If more than 75 percent of the water column is less than 4.0 mg/l the water body is considered non-supporting of the Class 3A beneficial use.

The dissolved oxygen criteria for Class 3A waters described above will be used as the primary endpoint for this TMDL. Specifically, loadings to Echo Reservoir will be evaluated under the requirement that at least 50 percent of the water column at all locations within the reservoir remain above the 4 mg/L dissolved oxygen criterion value. Load reductions will be specified such that it is expected that dissolved oxygen concentrations in at least 50 percent of water column will be above the 4 mg/L criterion. An estimation of the load reduction required for 100 percent of the water column dissolved oxygen to be above 4 mg/L is also evaluated.

In addition to the dissolved oxygen numeric criteria, the water quality standards for the State of Utah specify a pollution indicator value for total phosphorus concentrations in lakes and reservoirs of 0.025 mg/L and 0.05 mg/L for streams and rivers. In general, it is believed that concentrations below these indicator values will result in the beneficial use being met; however, the dissolved oxygen criteria will serve as the primary endpoint for the TMDL.

The following endpoints will also be used to evaluate attainment of water quality standards in Echo Reservoir:

1. An annual load of 19,800 kg/yr from all tributary sources to Echo Reservoir.
2. A shift away from blue-green algal dominance.
3. TSI values for total phosphorus, Chlorophyll A, and Secchi depth not to exceed 50.

5.2 PERMISSIBLE TOTAL PHOSPHORUS LOADINGS

The permissible loading represents the maximum amount of phosphorus that can be assimilated by Echo Reservoir while still meeting the TMDL endpoints that have been established above. Permissible loadings were evaluated using a model of Echo Reservoir that simulates the major physical, chemical, and biological processes affecting total phosphorus and dissolved oxygen concentrations within the reservoir. A detailed description of this model is provided in Appendix – Modeling of this report.

It should be noted here that monitoring station 492613 (Echo Reservoir Above Dam 01) was selected as the compliance point to be used in determining the permissible loading to Echo Reservoir. This sampling location is in the deepest part of the reservoir and is representative of the worst conditions that occur within the reservoir (lowest dissolved oxygen concentrations). Violations of the dissolved oxygen endpoint have been observed at this location. It is expected that if load reductions are prescribed such that the dissolved oxygen endpoint is met at the location near the dam, the rest of the reservoir will be in compliance as well. This approach is conservative.

Measured dissolved oxygen profiles at DWQ monitoring station 492613 indicate that low dissolved oxygen concentrations exist in the lower depths of the reservoir during the late summer months. The reservoir model was used to run simulations for the months of June – September under a variety of flow and storage conditions in order to capture the onset of stratified conditions, the subsequent draw down of the reservoir in the late summer and fall, and the differences between wet, average, and dry hydrologic periods. The flow and storage scenarios were constructed by identifying representative wet, average, and dry periods from the time series of reservoir storage and streamflow. Average monthly storage and flow values were calculated for these periods to provide the model input values. Table 5.1 lists the scenario conditions that were run through the model.

Table 5.1. Echo Reservoir model scenarios.

Scenario	Representative Years	Month	Average Monthly Storage (acre-ft)	Average Monthly Flow (cfs)
High Flow/Storage	1983 – 1986	June	71,639	1,666
		July	69,937	521
		August	57,919	316
		September	44,202	321
Medium Flow/Storage	1996 – 1999	June	71,937	1,073
		July	65,139	339
		August	52,835	252
		September	40,571	247
Low Flow/Storage	1988 – 1992	June	63,297	323
		July	47,249	258
		August	28,225	244
		September	15,115	185

These scenarios listed above were used to identify the conditions under which the dissolved oxygen endpoint is likely to be exceeded in the reservoir. Table 5.2 summarizes the results of the scenarios that were run using the model. Each month within each storage/flow condition was evaluated using the model to determine the expected percent of the water column at station 492613 with dissolved oxygen above 4 mg/L. This is reported in the second to last column. In the last column, the percent reduction in total P loading required to ensure that 100 percent of the water column is above 4 mg/L is reported. These numbers were estimated by re-running each simulation, reducing the total phosphorus loading each time, until the entire water column was above the 4 mg/L criterion.

Table 5.2. Model simulation results for station 492613 Echo Reservoir Above Dam 01.

Scenario	Month	Average Storage (acre-ft)	Average Flow (cfs)	Percent of Water Column with DO Above 4 mg/L	Required Percent Reduction in P Loading for 50% of Water Column DO Above 4 mg/L	Required Percent Reduction in P Loading for 100% of Water Column DO Above 4 mg/L
High Flow/Storage 1983 -1986	June	71,639	1,666	100	0	0
	July	69,937	521	100	0	0
	August	57,919	316	100	0	0
	September	44,202	321	100	0	0
Medium Flow/Storage 1996 - 1999	June	71,937	1,073	100	0	0
	July	65,139	339	100	0	0
	August	52,835	252	32	60	84
	September	40,571	247	21	60	80
Low Flow/Storage 1988 - 1992	June	63,297	323	100	0	0
	July	47,249	258	100	0	0
	August	28,225	244	55	0	80
	September	15,115	185	69	0	81

Of the scenarios tested, the worst dissolved oxygen conditions were identified under the Medium Flow/Storage scenario during the months of August and September. It is estimated that approximately 60 percent reduction in total phosphorus loading during these months will result in 50 percent of the water column remaining above the 4 mg/L criterion value and the endpoint will be met. It is estimated that with approximately 80 percent reduction in loading during these months, the entire water column (100 percent) will remain above 4 mg/L. Additional modeling was conducted during 2007 to further analyze these conclusions based on a "worst case scenario." The supplemental modeling supported the conclusion that the medium flow/medium storage scenario yields water quality impairments. A detailed discussion of this modeling is presented in Appendix – Modeling.

The average monthly total phosphorus loads for August and September during the Medium Flow/Storage time period were 1,213 kg and 1,041 kg respectively. These numbers represent the sum of the loading to Echo Reservoir from Chalk Creek (including the Coalville WWTP) and the Weber River over the 1996 – 1999 period, and were calculated using available streamflow and water quality data during that period. On a mass basis, the required load reduction to Echo Reservoir under the medium flow/storage scenario to achieve 50 percent of water column dissolved oxygen concentrations above 4 mg/L is 1,353 kg (728 kg for August – 60 percent and 625 kg for September – 60 percent). Similarly, on a mass basis, the required load reduction to Echo Reservoir under the medium flow/storage scenario to achieve 100 percent of water column dissolved oxygen concentrations above 4 mg/L is 1,852 kg (1,019 kg for August – 84 percent and 833 kg for September – 80 percent).

The mass reductions reported above associated with the Medium Flow/Storage scenario will serve as the basis for this TMDL because they are conservative. Under higher flow and storage conditions, it is anticipated that a lower reduction in loading would be required (as evidenced by the results of the High Storage/Flow scenario where no load reduction is required). Under the Low Flow/Storage scenario in Table 5.2, no load reductions are required during August and September because greater than 50 percent of the water column was above 4 mg/L during both of those months. Approximately 80 percent reduction in loading would be required to bring 100 percent of the water column above 4 mg/L for this scenario, which is slightly lower than the Medium Flow/Storage scenario. Given that the loading for the Low Flow/Storage scenario is very similar to the Medium Flow/Storage scenario, the required mass reduction would be very similar to get 100 percent of the water column above 4 mg/L. In other words, if the load reductions associated with the Medium Flow/Storage scenario are realized, compliance will be assured for the other two scenario conditions as well.

The mass reduction reported above to achieve at least 50 percent of the water column with dissolved oxygen concentrations above 4 mg/L (1,353 kg) represents approximately 5.5 percent of the average annual loading to Echo Reservoir (the sum of the annual average loading from the Weber River, Chalk Creek, and the Coalville WWTP – 24,636 kg/yr). The mass reduction required to achieve 100 percent of the water column above 4 mg/L (1,852 kg) represents approximately 7.5 percent of the average annual loading to the reservoir, but over 80 percent of the monthly loading during August and September which is not realistically achievable. A more temporally discrete approach would involve simulating the dynamic cycles of dissolved oxygen and total phosphorus on a daily basis over a period of years that represent the range of water quality and flow conditions typically found in Echo Reservoir. The information could then be used to determine average total phosphorus reductions necessary on a monthly or annual basis that would be needed to maintain the desired concentration of dissolved oxygen in Echo Reservoir. Such a model could also provide information on water quality discharged from Echo Reservoir to downstream reaches of the Weber River. However, the assumptions needed to provide daily input data to a model of this type would possibly create levels of uncertainty that would render the model output meaningless. Due to the limitations of existing data (i.e. reservoir monitoring data is limited or unavailable October through May) a steady-state model was selected as the best method for assessing water quality in Echo Reservoir. A model of this type cannot provide information on daily fluctuations in flow and water quality but it can provide an accurate definition of average conditions for a designated time period. As a result of the temporal limitations of the steady-state model used for Echo Reservoir, other less empirical factors were considered to develop an annual TMDL Target Load that is accurate in terms of magnitude and timing.

5.3 SEASONALITY

The Clean Water Act requires that TMDLs include seasonality. Seasonality is addressed in this TMDL through the calculation of actual and permissible loadings to the impaired water bodies on an annual and monthly basis, where possible. The calculations were completed using data that in most cases incorporates the past 10 – 12 years of stream and reservoir monitoring. It is anticipated this data set is sufficiently long enough to reflect seasonal and interannual changes in precipitation and streamflow as well as represent water quality improvement projects that have occurred during this time (e.g. Chalk Creek CNMP). In addition, the scenarios used to determine the permissible loading to Echo Reservoir were selected to represent a variety of climatic and hydrologic conditions to ensure that the resulting load reductions are protective of water quality in the reservoir.

5.4 MARGIN OF SAFETY

The Clean Water Act Also requires that TMDLs include a Margin of Safety (MOS). Generally, this MOS is incorporated into the TMDL via the use of conservative assumptions or is specified explicitly by reserving a particular amount of the permissible loading as a MOS. This TMDL uses a combination of both conservative assumptions and explicit measures to address the MOS.

Conservative assumptions have been made during this assessment and are associated with loading calculations, computer modeling, and selection of the compliance point for water quality in Echo Reservoir. A discussion of load calculations is included above in Chapter 4. The worst case scenario was used in computer modeling of Echo Reservoir to determine a permissible load that would meet the desired water quality endpoint. The load reductions prescribed based on the results of the worst case scenario are such that the endpoint would be met under the worst conditions and so it is expected that the endpoint would be met under all other conditions. It is expected that this will contribute an additional MOS in the specified load reductions

As discussed above, the endpoint is based on the percent of the depth at sampling location 492613 (Echo Reservoir Above Dam 01) with dissolved oxygen concentration greater than 4 mg/L. This location represents the deepest part of the reservoir at which the worst dissolved oxygen conditions occur. By specifying load reductions that ensure that the dissolved oxygen endpoint is met at this location, it will ensure that the endpoint is met throughout the reservoir. In addition, since most of the reservoir is shallow, compliance with the endpoint at the station near the dam will ensure that the majority of the reservoir volume, which is more important than depth in terms of aquatic life, is above 4 mg/L.

An explicit MOS of 10 percent of the annual permissible load to Echo Reservoir will also be used to ensure that the desired water quality endpoint is met. This amount accounts for uncertainty associated with (1) BMP/BAT effectiveness, (2) the assessment linking pollutant sources to water quality in Echo Reservoir and (3) internal reservoir dynamics during the late fall, winter and early spring season. It is anticipated that the combination of conservative assumptions and the explicit MOS provide reasonable assurance the TMDL will achieve the dissolved oxygen endpoint for Echo Reservoir as well as protect the beneficial use assigned to the downstream Weber River.

In addition to the conservative assumptions listed above and throughout this document, the TMDL recommended for Echo Reservoir will be evaluated in the future as BMPs/BATs are implemented and additional water quality data is acquired. Follow-up monitoring will be executed to ensure that water quality is improving and water quality standards are being met upon implementation of this TMDL.

5.5 TMDL TARGET LOAD

The recommended TMDL Target Load for Echo Reservoir will need to meet the desired endpoint in terms of water quality but should also consider the influence that reservoir discharge has on water quality conditions in downstream segments of the Weber River. It should also achieve a balance between the known level of monitoring data, model output, and cost of BMPs/BATs needed to achieve the target load. This assessment recognizes the need to apply concentration limits to pollutant sources that are not overly stringent but still achieve the desired endpoints

It is anticipated that if the load reduction of 1,852 kg total phosphorus were spread across the period of algae growth in Echo Reservoir (generally believed to occur from April through September), 100 percent of all water column measurements of dissolved oxygen in Echo Reservoir would likely be greater than 4 mg/l throughout the year which is more stringent than the 50 percent compliance standard used by DWQ. This is based on (1) an extensive review of reservoir monitoring data (including dissolved oxygen and nutrient measurements), (2) knowledge of the algae growth cycle, (3) use of conservative assumptions, and (4) best professional judgment.

In terms of data review, Figure 5.1 shows substantial accumulations of total phosphorus occurring April through July. It is widely accepted that total phosphorus quantities are correlated with algae growth, and dissolved oxygen concentrations are reduced when algae die off and decay. Figure 5.2 indicates the total watershed loads for point and nonpoint sources reflecting analysis of the monitoring data, indicate that the majority of total phosphorus loads from nonpoint sources are generated during April through June, while total phosphorus loads from point sources are much more consistent across the year. More specifically, 92 percent of the annual watershed load from nonpoint sources is produced during the months of April through September (Table 5.3). As a result, application of BMPs to nonpoint pollutant sources across a 6-month period, from April through September, could significantly decrease nutrient availability and reduce the potential for algae growth. In contrast, the annual load from point sources is distributed somewhat evenly throughout the year with 47 percent of annual loads discharged from October through March, and

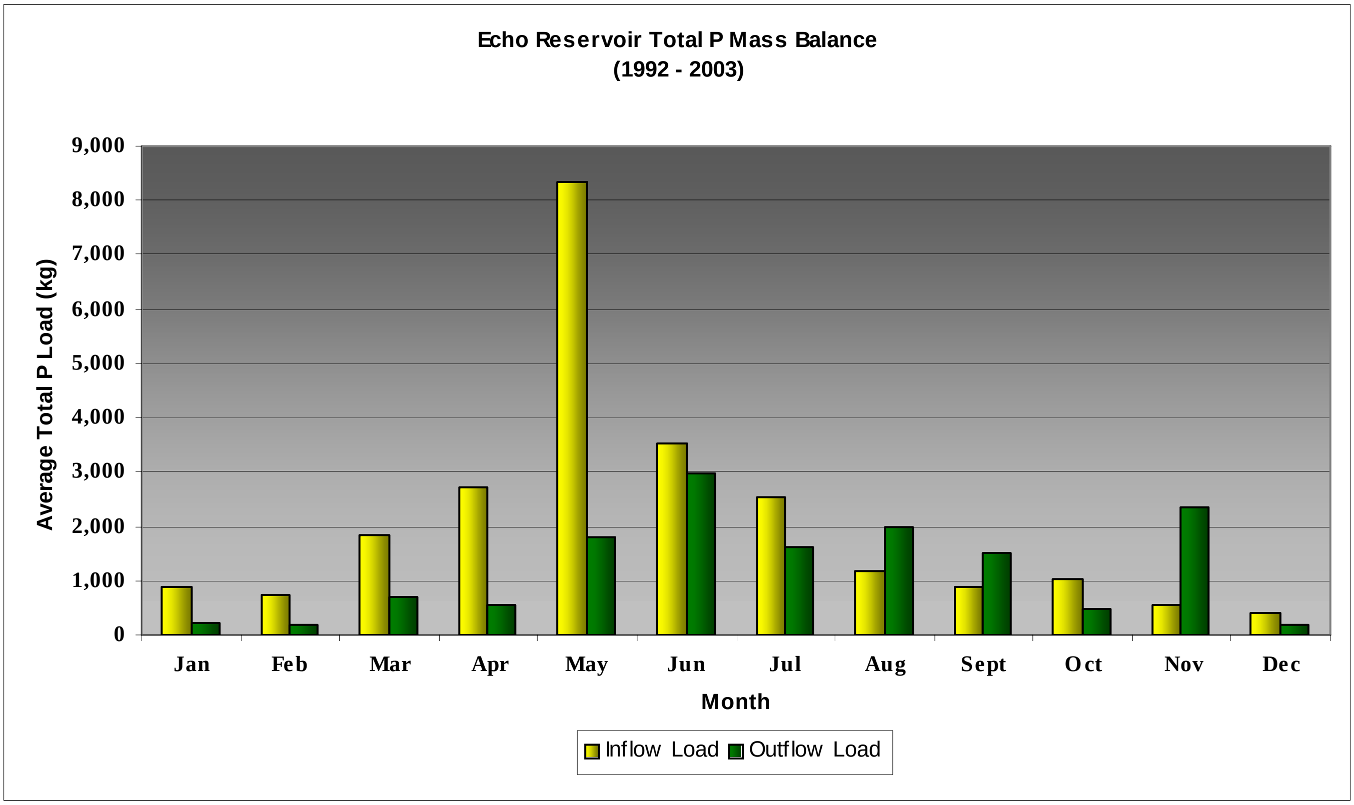

Figure 5.1. Echo Reservoir Total P mass balance 1992 – 2003.

53 percent discharged from April through September. As a result, a seasonal TMDL for point sources would not address significant loading that occurs during the rest of the year.

Table 5.3. Seasonal distribution of Total Watershed loads.			
	Apr-Sept Total Load (kg)	**Oct-Mar Total Load (kg)**	**Annual Total Load (kg)**
AFOs (kg)	1,446	49	1,495
Land Applied Manure (kg)	3,464	2,078	5,542
Public Land Grazing (kg)	190	6	196
Private Land Grazing (kg)	8,513	290	8,803
Septic Tanks (kg)	190	190	380
Point Source (kg)	3,442	3,008	6,449
Diffuse Runoff (kg)	25,841	882	26,724
Non-point Source Load (kg)	39,644	3,495	43,139
Point Source Load (kg)	3,442	3,008	6,450
Internal Reservoir Load (kg)	826	875	1,701
Total Watershed Load (kg)	43,912	7,378	51,290

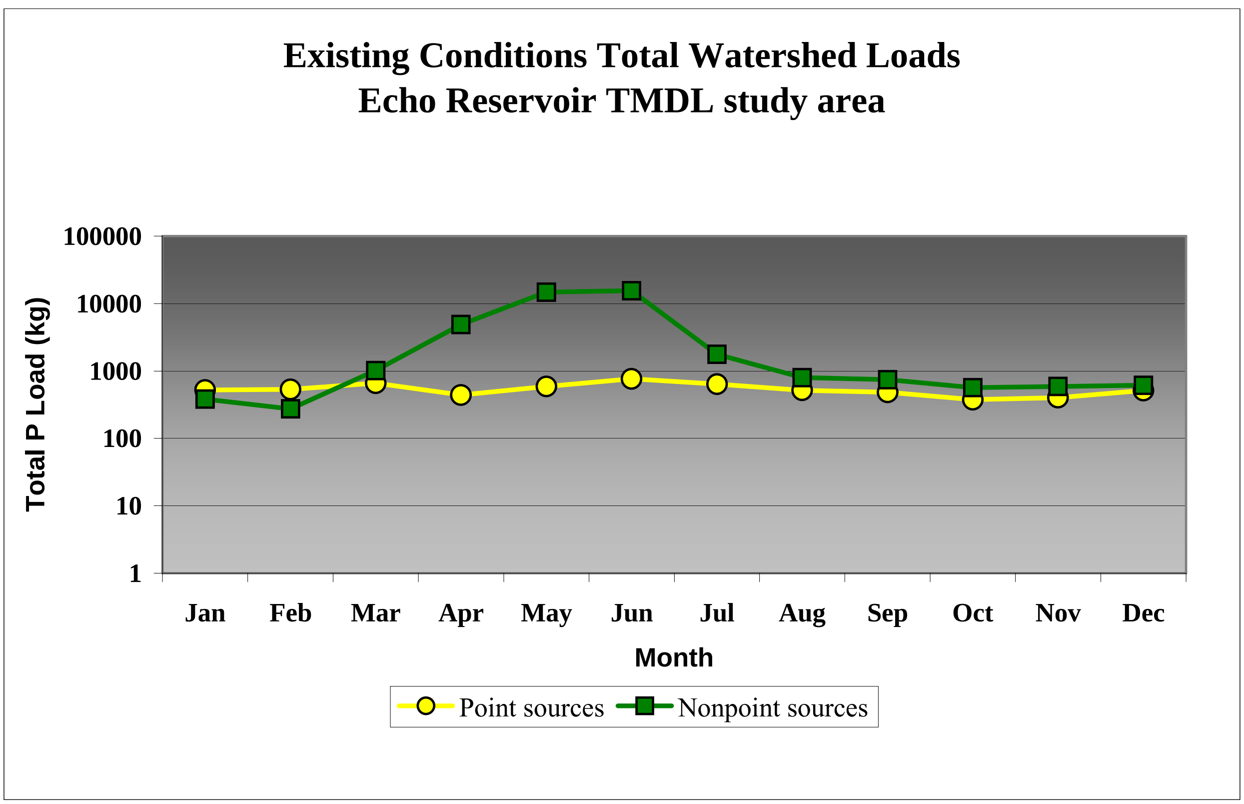

Figure 5.2 Existing Conditions Total Watershed Loads.

In regard to algae growth, the growth period is a function of several factors including diurnal length, available nutrients, and residence time. The growth period for algae in Echo Reservoir generally occurs during the months of April through September when these factors are optimal for biomass production. Although conditions outside of this period are less conducive to algae growth, accumulation of total phosphorus loads in the reservoir during October through March, primarily from point sources, make significant contributions to nutrient availability during the rest of the year and should be considered.

Use of conservative assumptions in the modeling assessment increase the Target Load reduction for total phosphorus needed to meet the dissolved oxygen endpoint, adding assurance that the Target Load would achieve the desired dissolved oxygen endpoint. Conservative assumptions have been discussed previously as they were incorporated into modeling of Echo Reservoir, selection of the monitoring site used to determine compliance with the TMDL, and during calculation of pollutant loads.

In summary, while the 6-month, April – September Target Load would meet the dissolved oxygen endpoint for Echo Reservoir, it may not be most effective for several reasons. First, it would not address the late fall through early spring period when point source contributions contribute roughly half of their annual load to Echo Reservoir. Second, annual Target Loads are easier to incorporate into permitting processes for point sources than 6-month targets. Finally, the 6-month Target Load for Echo Reservoir may not adequately address downstream water quality concerns on the Weber River.

One approach to meeting limitations associated with the 6-month Target Load is to convert this amount to an annual load based on the assumption that BMPs/BATs identified to meet the 6-month Target Load will remain functional throughout the year (which is anticipated would happen). It is noted that the relationship between 6-month and annual loads for each pollutant source is not constant due to the seasonal nature of the loading process. Therefore, a 6-month Target Load achieved through reductions to non-point sources would have an equivalent annual load that would be different when compared to what would occur if reductions were obtained from point sources only.

If BMPs/BATs required to meet the 1,852 kg reduction from April through September were left in place year round, the annual reduction in current conditions loading would be the 1,852 kg from April through September plus an additional 341 kg for a total annual load reduction to existing loads of 2,193 kg total phosphorus or an annual load 22,158 kg/yr. Total phosphorus concentrations in the Weber River below Echo Reservoir are currently being reviewed. In order to mitigate the influence of loading to this river segment from Echo Reservoir, total phosphorus concentrations in reservoir discharge should be equal to or less than 0.05 mg/l. The existing mean annual reservoir discharge and total phosphorus concentration is 268 cfs and 0.062 mg/l, respectively. Based on these numbers, the annual total phosphorus load from Echo Reservoir is 14,792 kg/yr. If reservoir discharge concentrations were equal to or less than 0.05 mg/l the load from Echo Reservoir would be 11,994 kg/yr or a difference of 2,798.

Accounting for the 10 percent margin of safety (2,200 kg/yr) and some minor seasonal variation in loading, the recommended TMDL Target Load for Echo Reservoir is 19,800 kg/yr. It is anticipated this target load will meet all water quality endpoints detailed in section 5.1 above as well as provide support to maintaining the beneficial use in downstream segments of the Weber River.

5.6 Future Growth

The TMDL process must account for the influence of future growth on pollutant loading. The impact of future growth patterns and trends on water quality in the study area was completed through the year 2025. This assessment was based primarily on population growth projections established by the Utah Governors

Office of Planning and Budget (GOPB), the Snyderville Growth Management Report (EPS 2000) and discussions with Summit County Community Development.

A review of existing information indicated that future load increases from Point Sources, Onsite Wastewater Systems (Septic Tanks), and Diffuse Runoff are likely. Future load decreases from sources associated with agriculture are also expected including AFOs, land applied manure, and private land grazing. No change in loading was anticipated to occur from public land grazing. A brief summary of the anticipated future trends associated with the change in total watershed loading from each source is provided below. A summary of the future watershed outlet loads is provided at the end of section 5.5.

5.6.1 Future Loading – Point Sources

Increased population growth within existing municipal boundaries and other sewered areas will result in increased discharge and loading from the four wastewater treatment plants in the study area. Future loads from each of these sources were generally based on the assumption that existing per capita water use will not change, therefore increased discharge can be directly correlated with population growth. Future discharge from the Silver Creek WRF was determined from information contained in the Snyderville Growth Management Report and estimates provided by the Snyderville Basin Water Reclamation District (Boyle 2005). Increased future discharge from the Kamas FH is anticipated following development of inflowing springs to provide additional inflow of roughly 3 cfs to the facility (Dewey 2004). Future total phosphorus concentration was held constant for all five facilities under the assumption that existing methods to treat discharge would not change. Therefore, flow rates were the only variable that was adjusted in order to calculate future loads from point sources in the TMDL study area.

Population growth projections used in calculating future discharge from point sources are included below in Table 5.4. A summary of the calculated future annual loads for point sources is provided in Table 5.5. A detailed listing of all data used to calculate future point source loads is included in Appendix – Data.

Table 5.4. Projected municipal and county growth associated with the study area.

	2000[a]	2003[b]	2005[c]	2020[d]	2025[e]	Average % annual increase	20 year % increase (2005 - 2025)
Summit County Total	29,736	33,020	36,417	52,806	75,450	10.36	107
Coalville	1,382	1,426	1,573	3,306	4,724	15.02	200
Henefer	684	723	797	1,604	2,292	14.37	187
Kamas	1,274	1,429	1,576	2,984	4,264	13.53	171
Oakley	948	1,125	1,241	2,981	4,259	17.16	243
Park City	7,371	7,854	8,662	17,634	25,196	14.54	191
Balance of County	18,077	20,463	22,568	24,297	34,716	7.69	54

[a] Year 2000 population numbers taken from United States Census Bureau (2000), Census 2000.
[b] Year 2003 population numbers taken from Economic Report to the Governor 2005 p.45.
[c] Year 2005 County population taken from Utah GOPB population estimates 2000-2050, city estimates adjusted from 2003 data based on increase to county total.
[d] Year 2020 population numbers taken from 2002 Baseline City Population Projections (Salt Lake City April 2003).
[e] Year 2025 County population taken from Utah GOPB population estimates 2000-2050, city estimates adjusted from 2020 data based on increase to county total.

Table 5.5. Future watershed total phosphorus (TP) loads in year 2025 from all permitted point source discharges in the Echo Reservoir TMDL study area.

Source	Existing Annual Mean Flow (cfs)	Future Annual Mean Flow – Year 2025 (cfs)	Annual Mean TP Concentration (mg/L)	Existing TP Load (kg)	Future TP Load (kg)	Percent Increase
Coalville WWTP	0.31	0.92	0.54	149	446	200.0
Silver Creek WRF	1.72	6.42	2.67	4,070	15,305	276.1
Oakley WWTP	0.26	0.89	2.16	475.4	1,630.7	243.0
Kamas WWTP	0.68	1.85	2.21	1,322	3,583	171.0
Kamas FH	4.84	7.52	0.09	434	675	55.5
Total Load				6,351	21,094	

5.6.2 Future Loading – Septic Tanks

Additional loading from septic tanks was based on population growth projections for areas outside of municipal boundaries. It is anticipated that new subdivisions would likely be constructed in Summit County during the next 20 years. The number and location of potential new subdivisions is not known at this time. Therefore it is assumed that the existing distribution of septic tanks between subwatersheds will remain consistent in the future. Table 5.6 indicates the future loads anticipated from each subwatershed in the year 2025. Future loads were determined by increasing existing subwatershed loads by the projected growth rate of 54 percent for non-municipal areas of Summit County. This projected increase accounts for growth within existing subdivisions as well as development of new subdivisions in the study area.

Table 5.6. Future watershed total phosphorus loads (Year 2025) from septic tanks located in the Echo Reservoir TMDL study area. Increased loads are based on the percent population growth of approximately 54 percent projected from 2005 - 2025 for areas outside of municipal towns in Summit County.

Subwatershed	Existing Load (kg)	Future Load (kg)
Upper Weber River	212.7	327.6
Beaver Creek	117.5	181.0
Weber River below Beaver Creek	92.4	142.3
Wanship Reservoir	19.5	30.0
Weber River below Wanship Reservoir	75.7	116.6
Silver Creek	64.3	99.0
Weber River below Silver Creek	100.7	155.0
Chalk Creek	26.7	41.2
TOTAL	709.5	1092.7

5.6.3 Future Loading - Diffuse Runoff

Projections of future land use patterns and trends within the study area indicate that urban development will continue to expand. This trend will result in a loss of land currently associated with agriculture, forest, rangeland and other land cover types. Increased population growth within existing municipal areas is expected to occur as well. A brief description of the anticipated changes is provided below followed by a summary of future loads from Diffuse Runoff. A more detailed explanation of this procedure is included in Appendix – Modeling.

5.6.3.1 Agriculture

Non-point source pollution associated with crop production in Echo Reservoir watershed is influenced by the amount of land dedicated to farming, the type of crop grown, and cropping practices used during production including tillage and irrigation methods. Existing loads from Diffuse Runoff associated with agricultural lands indicate that over 11,000 kg/yr of total phosphorus are currently delivered to streams (Table 4.21). The total acreage of agricultural lands is currently declining, and is expected to continue during the next 20 years (Stonely 2004). The loss of irrigated farmland and associated water diversions are shown below in Table 5.7. It is anticipated that a portion of the land involved in this process will be used for urban/rural development.

Table 5.7. Past, present, and projected irrigated cropland and agricultural water use/diversions in Summit County and the Weber River Basin.

Irrigated acres					
Area	**1987**	**1999**	**2003**	**2020**	**2050**
Summit County	29373	30780	28631	24300	16600
Weber River Basin	142126	125467	111218	85600	57100
Estimated Diversion (acre-feet)					
Summit County	90500	102400	96500	82600	56400
Weber River Basin	472700	398700	359800	291000	194100

Source: Todd Stonely (2004). Weber River Basin- Planning for the future. Public draft.

In general, the Weber River Basin has experienced a decreasing trend in irrigated croplands and agricultural water use. In Summit County, agricultural acres have remained somewhat constant from 1987 through 2003. However, due to the growing population and conversion of farms into residential and commercial areas, is likely that the recent decreasing trend will continue in the future. Water use for irrigation purposes is also expected to decrease as the transition from agricultural to urban land use occurs over the next several decades (Stonely 2004).

5.6.3.2 Range and Forest Land

Existing trends defining use of range and forest land areas are nearly static and indicate that minimal change should occur through 2025. Most rural areas that maintain conditions suitable for urban development are currently used for agricultural purposes. A small amount of forest or rangeland will likely be developed for summer recreation homes or a limited number of single-family dwellings near existing subdivisions.

5.6.3.3 Residential Development

General patterns of urban and residential development in Summit County can be estimated from the number of building permits issued since 1991. This information is organized in Table 5.8 into three general areas including Snyderville Basin, South Summit County and North Summit County (Summit County 2004). The border between North and South Summit County is located at Wanship Reservoir with areas upstream of the reservoir located in South Summit County. Permits issues for New Dwelling represent single-family dwellings only. Total Permits issued include single and multiple family dwellings, business structures, schools, hospitals, etc. The mean number of permits issued indicates that most of the residential development in Summit County has occurred in the Snyderville Basin, followed by South Summit County.

Table 5.8. Community development in Summit County. Building permit and new construction (1991-2004).														
Total Permits per year															
Area	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**AVG**
Snyderville Basin	313	491	530	495	507	487	627	640	662	544	649	516	562	517	516
South Summit Co.	82	109	115	102	113	135	125	120	139	186	172	155	229	162	124
North Summit Co.	51	86	99	133	116	94	100	97	91	60	66	83	64	90	72
Total	446	686	744	730	736	716	852	857	892	790	887	754	855	769	712
New Dwellings per year															
Snyderville Basin	261	456	435	361	369	519	553	460	393	205	426	226	447	267	407
South Summit Co.	36	54	57	50	50	64	46	49	57	94	78	60	99	87	78
North Summit Co.	18	41	49	45	67	47	41	47	43	19	20	31	35	45	55
Total	315	551	541	456	486	630	640	556	493	318	524	317	581	399	539
Source: Summit County Community Development.															

Information defining the specific geographic location of building development in the study area was not available. In order to predict where future development might occur, the distribution of future populations were estimated using the 2000 census blocks as a base distribution and the GOPB projections for Summit County in year 2025.

A coarse-level screening was completed in order to define land areas unsuitable for urban use and development. These areas were then removed from the acres of potential land that could ultimately be developed. The land areas that were removed included public lands, existing urban/residential and transportation lands, wetlands and open water, and all areas with slopes > 10 degrees. Conversion to urban land use was removed proportionally from all other land use types in the TMDL study area including agricultural, rangeland, and forest using estimates of typical per capita housing rates (2.5 persons per house), average lot size (1 acre), and fraction of development associated with new development versus growth within existing urban/residential land. After the new land use coverage was calculated for each subwatershed, the anticipated future loads from each land use type were then calculated using the same export coefficients used to determine existing loads from Diffuse Runoff. A detailed description of this process is included in Appendix – Modeling.

5.6.3.4 Summary – Future Loading – Diffuse Runoff

A review of available information indicates that existing trends in urban development will continue in the study area. It is anticipated these trends will produce an increase in urban/residential land areas and a subsequent decrease in developable land associated with agricultural, rangeland, and forested lands. This shift in land use would result in a change to loading rates from Diffuse Runoff due to the increased total phosphorus loads that are typically produced from urban/residential land cover types compared to other land cover types including rangeland and forested lands. The methods used to quantify this change in loading has been described above and are detailed in Appendix – Modeling. The estimated future loads from Diffuse Runoff are included below in Table 5.9. The percent change between existing and projected future loads range from approximately 2 percent to 24 percent. The Silver Creek subwatershed experienced a 24 percent increase in loads while the Upper Weber River, Wanship Reservoir and Echo Reservoir subwatersheds exhibited an increase of roughly 2 percent.

Table 5.9. Future watershed total phosphorus loads (Year 2025) from Diffuse Runoff in the Echo Reservoir TMDL study area.			
Subwatershed	**Existing Load (kg/yr)**	**Projected Future Load (kg/yr)**	**Percent change (%)**
Upper Weber River	4,683	4,786	2.2
Beaver Creek	5,739	5,924	3.2
Weber River Below Beaver Creek	2,274	2,349	3.3
Wanship Reservoir	821	840	2.3
Weber River Below Wanship Reservoir	261	280	7.3
Silver Creek	2,450	3,042	24.2
Weber River Below Silver Creek	2,782	2,958	6.3
Chalk Creek	6,539	6,798	4.0
Echo Reservoir	1,173	1,202	2.5
Total of all subwatersheds	**26,722**	28,177	5.4

5.6.4 Future Loading – AFOs, Land Applied Manure and Private Land Grazing

Future loads from AFOs, land areas receiving manure applications and privately grazed land were calculated using similar assumptions regarding the shift in land use from rural to urban/residential. An assumption was made that loads from these sources are proportional to the area of land use on which they occur. For AFOs and land applied manure, the only land use affected is agriculture, so a change in the area of available agricultural land translated to an equivalent reduction in loading from these sources (i.e. a 5 percent less agricultural area in a subwatershed resulted in 5 percent less loading from AFOs and land applied manure). Grazing on private land could occur on privately owned agricultural, range and forest land areas. As a result the change in loading from this source was proportional to the change in the sum of the areas of these land use categories. The Weber River above Wanship Reservoir subwatershed only considered the area of agriculture, rangeland and forest that was privately owned and did not include areas of national forest land.

In order to provide future loads that were consistent with load allocation information, loads from these sources were determined using land use summaries for the three regions discussed earlier in Chapter 4. These regions included the Weber River above Wanship, Weber River below Wanship, and the Chalk Creek watershed. Future anticipated loading from AFOs, land applied manure and private land grazing are included below in Table 5.10. Note the percent change is equal for subwatersheds contained within the same region as discussed earlier in Chapter 4.

Table 5.10. Future watershed total phosphorus loads (Year 2025) from AFOs, areas receiving land applied manure and private land grazing.

	AFOs			Land Applied Manure			Private Land Grazing		
	Existing Load	Future Load	% change	Existing Load	Future Load	% change	Existing Load	Future Load	% change
Upper Weber River	417	388.7	-6.8	891	830.5	-6.8	970	950.3	-2.0
Beaver Creek	165	153.8	-6.8	1,376	1,282.5	-6.8	2298	2,251.4	-2.0
Weber River below Beaver Creek	599	558.3	-6.8	1,291	1,203.3	-6.8	450	440.9	-2.0
Wanship Reservoir	0	0.0	0.0	2	1.9	-6.8	0	0.0	0.0
Weber River below Wanship Reservoir	0	0.0	0.0	37	34.0	-8.0	72	69.1	-4.1
Silver Creek	66	60.7	-8.0	516	474.6	-8.0	10	9.6	-4.1
Weber River below Silver Creek	0	0.0	0.0	389	357.8	-8.0	1,468	1,408.4	-4.1
Chalk Creek	248	244.8	-1.3	961	948.7	-1.3	3,535	3,518.5	-0.5
Echo Reservoir	0	0.0	0.0	78	71.7	-8.0	0	0.0	0.0

5.6.5 Potential Future Loadings from Grazing on Public Lands

Based on historic trends of grazing in allotments on U.S. Forest Service and BLM lands, it is anticipated that grazing in public lands will remain relatively constant or decline in the coming years (Niels Hansen, NRCS, personal communication). Therefore, a conservative assumption was made to hold future total phosphorus loads constant through 2025 from grazing on public lands.

5.6.6 Summary – Future loads

The total watershed loads and watershed outlet loads to Echo Reservoir for each known pollutant source are summarized in Table 5.11 for three general regions in the Echo Reservoir TMDL study area. These areas include the Weber River above Wanship, Weber River below Wanship, and Chalk Creek. A comparison of the percent contribution by pollutant source for existing and future conditions is shown in Figures 5.3 and 5.4. The largest projected increase for any pollutant source is exhibited by point sources which increased from an existing load of 2,954 kg/yr to a projected 10,270 kg/yr in the year 2025.

If future loads are accounted for, the reduction in total phosphorus loading required to meet the TMDL Target Load for Echo Reservoir is 12,688 kg/yr.

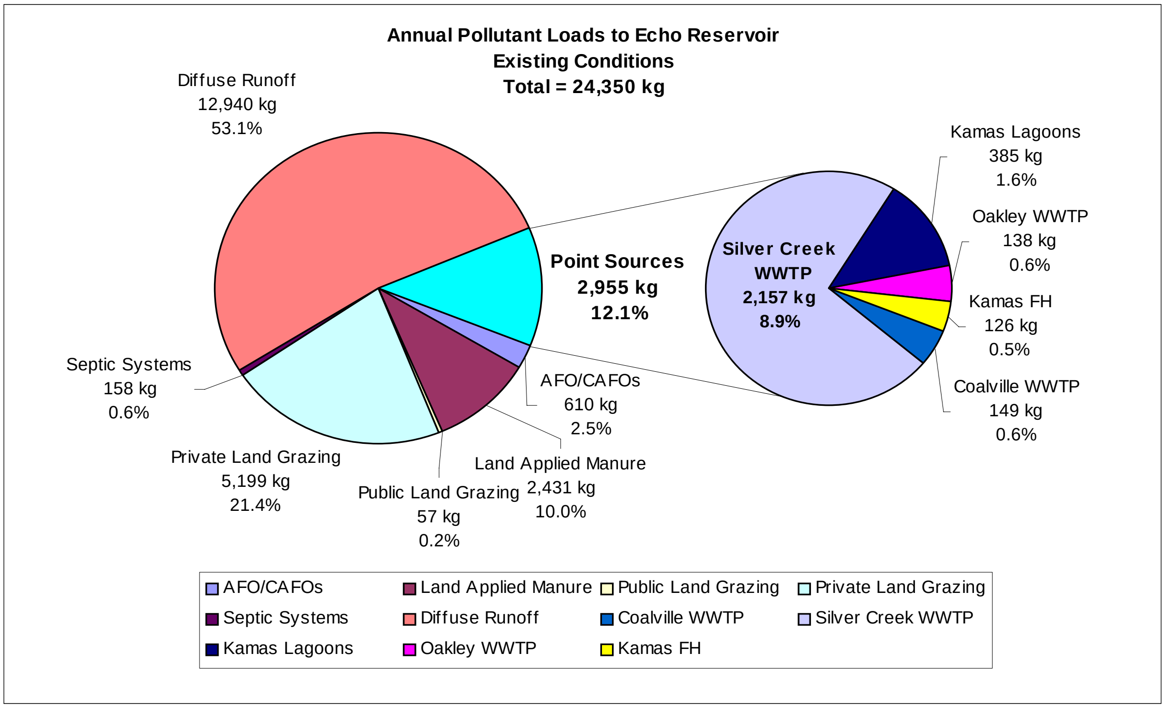

Figure 5.3. Existing annual pollutant loads to Echo Reservoir. These loads are based on existing monitoring data collected from 1992 – 2003 on Chalk Creek, Coalville WWTP, and the

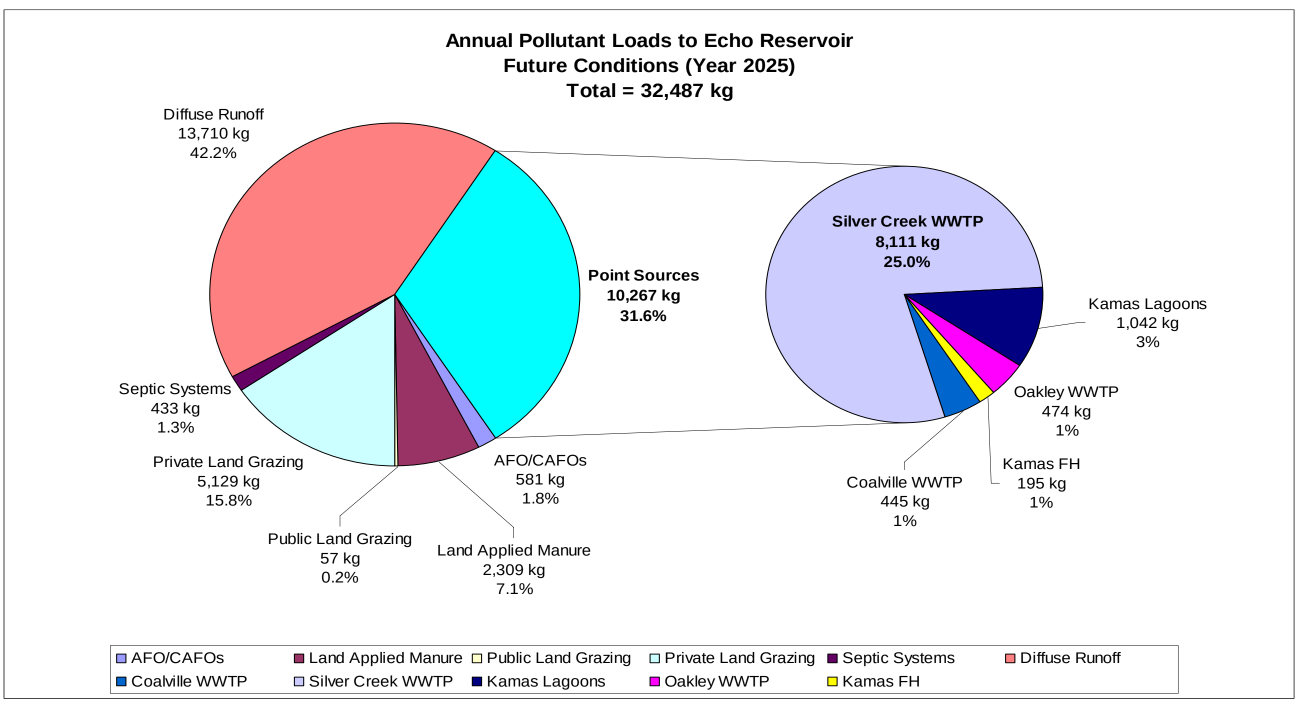

Figure 5.4. Projected future annual loads to Echo Reservoir in year 2025.

Table 5.11. Annual total phosphorus watershed outlet loads for three regions within the Echo Reservoir TMDL study area including Chalk Creek, Weber Above Wanship, and Weber Below Wanship. All loads shown in this table indicate existing and future conditions without TMDL reductions.

	Chalk Creek			Weber Above Wanship[a]			Weber Below Wanship			Total Loads without TMDL reductions		
Source	**Existing Conditions (kg/yr)**	**Future Conditions (kg/yr)**	**Percent change (%)**	**Existing Conditions (kg/yr)**	**Future Conditions (kg/yr)**	**Percent change (%)**	**Existing Conditions (kg/yr)**	**Future Conditions (kg/yr)**	**Percent change (%)**	**Existing Conditions (kg/yr)**	**Future Conditions (kg/yr)**	**Percent change (%)**
Direct Stream Loads from AFOs	231	228	-1.3	343	320	-6.8	35	32	-8.0	610	581	-4.8
Land Applied Manure	897	885	-1.3	1,035	965	-6.8	499	459	-8.0	2,431	2,309	-5.0
Public Land Grazing	0	0	0.0	57	57	0.0	0	0	0.0	57	57	0.0
Private Land Grazing	3,296	3,281	-0.5	1,081	1,059	-2.0	821	788	-4.1	5,199	5,129	-1.4
Septic Systems	22	38	71.5	64	198	208.2	72	197	174.7	158	433	173.7
Point Sources	149	446	200.0	649	1,713	163.9	2,157	8,111	276.1	2,954	10,270	247.6
Diffuse Runoff	6,098	6,339	4.0	3,931	4,043	2.8	2,911	3,328	14.3	12,940	13,710	5.9
TOTAL	10,693	11,218	4.9	7,162	8,355	16.7	6,495	12,916	98.9	24,350	32,489	33.4

[a] Annual Loads for Weber Above Wanship have been adjusted for the 5.14 % annual decrease that occurs as the Weber River flows through Wanship Reservoir

5.7 ALLOCATION OF POLLUTANT LOADS

The process used to allocate pollutant loads between sources in the TMDL study area has considered many factors. Some of these include public involvement, existing plans for implementing BMP/BATs in the study area, cost, projected future load from pollutant sources, and effectiveness of BMPs. The proposed TMDL allocation is included in Table 5.12 below and displayed graphically in Figure 5.5. Note these amounts represent loading to Echo Reservoir only. The allocation of Watershed Outlet loads and Total Watershed Loads that would meet the TMDL for Echo Reservoir under existing and future conditions are shown in Table 5.13 and Table 5.14 respectively. The measures needed to meet these load reductions are discussed in Appendix – PIP including a description of proposed water quality improvement projects. On-going monitoring will be needed in order to measure whether load reductions are being achieved. Based on the measured outcomes, changes will be made to the TMDL allocations as appropriate.

Table 5.12. Proposed allocation of total phosphorus loads for the Echo Reservoir TMDL. Wasteload allocation and Load allocation shown in this table represent loads to the Echo Reservoir inlet. Load allocations assigned at the point of origin are included at the end of this chapter.

Category	Allocation (kg/yr)
Existing Load to Echo Reservoir	24,350
Permissible Load to Echo Reservoir	22,000
Explicit Margin of Safety (10%)	2,200
TMDL Target Load for Echo Reservoir	19,800
Reserve for future growth[1]	8,138
Wasteload allocation	4,810
Load allocation	14,990

Based on a projected future total phosphorus load to Echo Reservoir of 32,488 kg/yr.

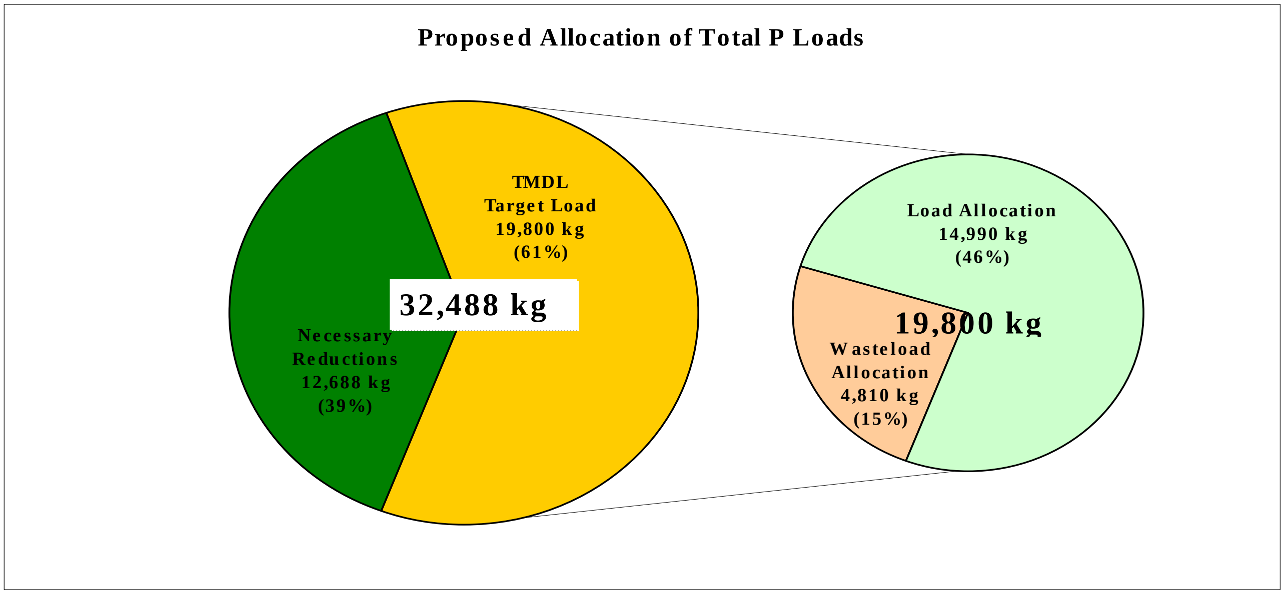

Figure 5.5. Proposed Allocation of Total Phosphorus (Total P) Loads for Echo Reservoir. Load allocation is based on a TMDL Target Load of 19,800 kg/yr Total P. Pie chart on left indicates the future (2025) estimated Total P load to Echo Reservoir of 32,488 kg/yr Total P.

Table 5.13. Allocation of Watershed Outlet Loads to Echo Reservoir. Load allocations shown are based on obtaining the TMDL Target Load of 19,800 kg/yr.

	Existing Watershed Outlet Load (kg/yr)	Existing Watershed Outlet Load Allocation per TMDL (kg/yr)	Future Watershed Outlet Load (kg/yr)	Future Watershed Outlet Load Allocation per TMDL (kg/yr)
Point Sources				
Coalville WWTP	149	149	446	823
Silver Creek WRF	2,157	2,157	8,111	3,042
Oakley WWTP	138	138	475	243
Kamas WWTP	385	385	1,043	561
Kamas FH	126	126	195	144
Total Point Source	**2,955**	**2,955**	**10,270**	**4,810**
Non-point Sources				
Chalk Creek				
AFOs	231	23	228	23
Land applied manure	897	179	885	177
Public land grazing	0	0	0	0
Private land grazing	3,296	2,966	3,281	2,297
Septic Systems	22	22	38	38
Diffuse Runoff	6,098	5,244	6,339	4,862
Weber River below Wanship				
AFOs	35	4	32	3
Land applied manure	499	100	459	92
Public land grazing	0	0	0	0
Private land grazing	821	739	788	552
Septic Systems	72	72	197	197
Diffuse Runoff	2,911	2,620	3,328	2,496
Weber River above Wanship				
AFOs	343	34	320	32
Land applied manure	1,035	207	965	193
Public land grazing	57	57	57	57
Private land grazing	1,081	973	1,059	742
Septic Systems	64	64	198	198
Diffuse Runoff	3,931	3,538	4,043	3,032
Total Nonpoint Source	**21,393**	**16,842**	**22,217**	**14,992**
Grand Total	**24,348**	**19,797**	**32,488**	**19,802**

[a] Watershed outlet loads describe the phosphorus load delivered by a particular source to Echo Reservoir. Watershed outlet loads account for losses that occur as a result of irrigation diversion, adsorption to soil particles, algal uptake and any other process that removes phosphorus from a receiving water body before it is delivered to Echo Reservoir. Watershed outlet loads are typically less than Total Watershed Loads.

Table 5.14. Allocation of Total Watershed Loads. Based on the TMDL assessment, the existing and future Total Watershed Load allocations shown below will result in meeting the TMDL Target Load of 19,800 kg/yr to Echo Reservoir.

	Existing Total Watershed Load (kg/yr)	Existing Total Watershed Load Allocation per TMDL (kg/yr)	Percent Reduction (%)	Future Total Watershed Load (kg/yr)	Future Total Watershed Load Allocation per TMDL (kg/yr)
Point Sources					
Coalville WWTP	149	149	0	446	823
Silver Creek WRF	4,070	4,070	0	15,305	5,733
Oakley WWTP	475	475	0	1,631	798
Kamas WWTP	1,322	1,322	0	3,583	1,656
Kamas FH	434	434	0	675	805
Total Point Source	**6,450**	**6,450**	**0.0**	**21,640**	**9,815**
Non-point Sources					
Chalk Creek					
AFOs	248	25	90	245	25
Land applied manure	961	192	80	949	190
Public land grazing	0	0	0	0	0
Private land grazing	3,535	3,182	10	3,518	2,463
Septic Systems	24	24	0	41	41
Diffuse Runoff	6,539	5,624	14	6,798	5,214
Weber River below Wanship					
AFOs	66	7	90	61	6
Land applied manure	942	188	80	866	173
Public land grazing	0	0	0	0	0
Private land grazing	1,550	1,395	10	1,487	1,041
Septic Systems	135	135	0	371	371
Diffuse Runoff	5,493	4,944	10	6,280	4,710
Weber River above Wanship					
AFOs	1,181	118	90	1,101	110
Land applied manure	3,560	712	80	3,318	664
Public land grazing	196	196	0	196	196
Private land grazing	3,718	3,346	10	3,643	2,550
Septic Systems	221	221	0	680	680
Diffuse Runoff	13,517	12,165	10	13,899	10,424
Total Nonpoint Source	**41,886**	**32,473**	**22.5**	**43,453**	**28,858**
Grand Total	**48,336**	**38,923**	**19.5**	**65,093**	**38,672**

Total watershed loads describe the phosphorus load that is delivered to receiving water bodies above Echo Reservoir. They do not account for phosphorus loss as loads are transferred through the watershed to Echo Reservoir. Total watershed loads are typically greater than watershed outlet loads. The method used to convert total watershed loads to watershed outlet loads is described above in Section 4.4 Linkage Analysis.

5.8 PHASED TMDL APPROACH AND RATIONALE

USEPA Guidance (1991, 2006) recommends a phased TMDL approach when certain conditions apply.

1. When there is uncertainty with respect to load reductions from nonpoint sources, such as uncertain loadings from the major land uses or when the available data only allow for estimates of necessary load reductions;
2. When the TMDL involves both point sources and nonpoint sources and the point source wasteload allocation is based on a load allocation for which nonpoint source controls need to be implemented; and/or
3. For TMDLs that need to be established for scheduling reasons despite significant data uncertainty and where the State expects that the loading capacity and allocation will be revised in the near future as additional information is collected.

The Echo Reservoir TMDL meets these conditions in the following ways.

1. Significant uncertainty exists with respect to the loading calculations – the TMDL used future loads which were determined using assumptions based on growth and predicted land use changes.
2. Nonpoint source controls are a significant part of the overall load reduction, and increased loading allocations in the future for the Coalville Wastewater Treatment Plant rely on nonpoint source offsets.
3. Because of the original TMDL development schedule, DWQ must finalize the Echo Reservoir TMDL. However, DWQ will re-evaluate the Echo Reservoir TMDL in conjunction with the TMDL for Rockport Reservoir scheduled for completion in 2016. Rockport Reservoir is directly upstream of Echo Reservoir and has been added to the 2008 303(d) list of impaired waters. DWQ plans to collect additional information on both reservoirs and develop a TMDL for the entire watershed that will also address the interrelationship of the two reservoirs. This interrelationship has been an ongoing concern for stakeholders in the watershed: further study and modeling will address their concerns as well as provide a more accurate and thorough understanding of this watershed.

In addition to revised wasteload allocations, the new TMDL study will include 1) revisions to the source assessment that provide more detailed loading information, and 2) a more comprehensive implementation plan.

CHAPTER 6: PUBLIC PARTICIPATION

6.1 PUBLIC PARTICIPATION MEETINGS

Public participation stakeholder meetings for the Echo Reservoir TMDL were begun in 2003. Stakeholders were informed of each of the meetings through e-mails and letters of invitation. Announcements were also made to the public via the local radio station and newspaper. All meetings were held at Coalville City Hall. A summary is provided below.

October 21, 2003 (13 attendees): During the first public participation meeting, John Whitehead presented an overview of the TMDL process. Discussion at this meeting included the purpose and objectives of the Echo Reservoir TMDL, available data and data trends, potential sources of pollution, and additional data needs.

November 9, 2004 (22 attendees): The meeting focus was a presentation by Cirrus consulting firm on loading calculations for the watershed. Cirrus described the sources of pollution, loading calculations for each source, and how those loads would be utilized in the development of a TMDL. The role of the Upper Weber Technical Advisory Committee (TAC) was also defined.

December 15, 2004 (17 attendees): The four agenda items discussed at this meeting were: updated information for pollutant sources in the watershed, including septic systems, land application of manure, and municipal treatment facilities data; an overview of impairment data for Echo Reservoir; the modeling approach utilized for the TMDL; and the next steps for the TMDL process.

January 19, 2005 (18 attendees): The two agenda items discussed during the meeting were: an overview of the reservoir model, including a discussion of inputs, seasonal variability, and the relationship between flow and storage conditions; and load allocations, including several conceptual approaches. It was also noted that a draft version of chapters 1-3 of the TMDL report had been distributed via e-mail. Contact information and a deadline for input, changes or corrections were established.

March 10, 2005 (26 attendees): Load allocations under existing and future conditions were presented at this meeting, including a cost per pound assessment. The agenda items for the meeting were: review permissible loading to Echo Reservoir; linkage between upstream sources and watershed outlet loads; future loading calculations based on projected growth; target load reductions needed to achieve the permissible load; and load allocation scenarios.

February 2, 2006 (16 attendees): John Whitehead presented an overview of the Draft Echo Reservoir TMDL to the Upper Weber River Watershed meeting. The public comment period dates were discussed. Copies of the draft TMDL were mailed out to all stakeholders on January 13, 2006.

6.2 ADDITIONAL PUBLIC INVOLVEMENT

October 19, 2005: John Whitehead presented an overview of the allocation portion of the Draft Echo Reservoir TMDL to the point source dischargers in the Echo Reservoir watershed. Representatives from Kamas Lagoons, Kamas Fish Hatchery, Coalville WWTP, and Silver Creek WRF attended.

November 17, 2005: John Whitehead presented an overview of the Draft Echo Reservoir TMDL to the Oakley City Council.

December 7, 2005: John Whitehead presented an overview of the Draft Echo Reservoir TMDL to the Summit County Commission.

The formal 30-day public comment period for the draft TMDL concluded on March 6, 2006. The 30 day comment period was advertised in the Salt Lake Tribune, Deseret Morning News, and the Summit County Bee newspapers. The draft TMDL was also posted on the Division of Water Quality's web site beginning January 13, 2006 for ease in accessing the draft document. Comments received and the corresponding responses are provided in Appendix – Public Comments.

In response to stakeholder comments, revisions to the TMDL were completed in 2008. A public meeting was held December 3, 2008 to present an overview of the revised TMDL. A formal 30-day comment period for the revised TMDL ended January 15, 2009. Both the public meeting and the formal 30-day comment period were advertised in the Salt Lake Tribune, Deseret Morning News, and the Summit County News (formerly the Summit County Bee) newspapers. No comments were received during the public meeting or during the formal comment period.

REFERENCES

Bedient, P.B., and W.C. Huber. 1992. *Hydrology and Floodplain Analysis*. Addison-Wesley Publishing Company. Reading, MA. Second Edition.

Bicknell, B.R., J.C. Imhoff, J.L. Kittle, Jr., A.S. Donigian, Jr., and R.C. Johanson. 1993. Hydrological Simulation Program – Fortran: Users Manual for Release 10. United States EPA. Environmental Research Laboratory. Office of Research and Development. Athens, GA. EPA/600/R-93/174.

Boyle, M. 2005. Operations Manager, Snyderville Basin Water Reclamation District, Park City, UT. Personal communication with E. Duffin, Watershed Scientist, Cirrus Ecological Solutions, Logan, UT re. Future growth of Silver Creek Water Reclamation Facility.

Broadbent L. 2004. Rangeland Management Specialist, Coalville Field Office, Natural Resources Conservation Service. Personal communication with E. Duffin, Watershed Scientist, Cirrus Ecological Solutions, Logan, Utah re. Agricultural practices in the Upper Weber Basin.

Brooks, L.E. B.J. Stolp, L.E. Spangler. 2003. Hydrology and simulation of ground-water flow in Kamas Valley, Summit County, Utah. State of Utah Department of Natural Resources. Technical Publication 117. Prepared by the United States Geological Survey in cooperation with the Utah Department of Natural Resources, Division of Water Rights.

Bryant, B. 1992. Geologic and structure maps of the Salt Lake City 1^{o} x 2^{o} Quadrangle, Utah and Wyoming: U.S. Geological Survey Map I-1997, scale 1:125,000.

Canter, L.W. and R. C. Knox. 1985. Septic tank systems effects on ground water quality. Lewis Publishers. Chelsea, MI.

Carlson, R.E. 1977. A trophic state index for lakes. Limnology and Oceanography. 22:361-369.

Carlson, R.E. and J. Simpson. 1996. A coordinator's guide to volunteer lake monitoring methods. North American lake Management Society. 96pp.

Carpenter, S.R., N.F. Caraco, D.L. Correll, R.W. Howarth, A.N. Sharpley, and V.H. Smith. 1998. Nonpoint pollution of surface waters with phosphorus and nitrogen. Ecol. Appl. 8:559-568

Chapra, S.C. 1997. Surface Water Quality Modeling. McGraw-Hill Companies, Inc. Boston, MA.

Daly, C., R.P. Neilson, and D.L. Phillips. 1994. A statistical-topographic model for mapping climatological precipitation over mountainous terrain. Journal of Applied Meteorology, 33, 140-158. http://www.ocs.orst.edu/prism/prism_new.html.

Dewey, D. Fisheries Biologist, Utah Department of Natural Resources, Division of Wildlife Resources, Kamas, UT. Personal communication with E. Duffin, Watershed Scientist, Cirrus Ecological Solutions, Logan, UT re. Kamas Fish Hatchery.

DWQ 2003. Utah Division of Water Quality (DWQ). 2003. Echo Reservoir TMDL Water Quality Study - Work Element 1. Prepared for DWQ by Cirrus Ecological Solutions, Logan, Utah.

Economic and Planning Systems (EPS). 2000. Snyderville Basin Growth Management Report. Prepared for Summit County by Economic Planning Systems, Inc. March 2000. EPS #8091.

Garrand, L. 1985. Phosphate in the Uinta Basin, Northeast Utah. Pages 263- 270 *in* Geology and energy resources, Uinta basin of Utah. Picard, M.D. Editor. Utah Geological Association. Salt Lake City, Utah.

Goodrich K. 2004. Utah Feedlot Runoff Model, version 1.4 (UAFFRI_1.4.xls). USDA-Natural Resources Conservation Service, 125 S. State St. Suite 4402, Salt Lake City, Utah.

Hanson, A. M. 1942. Phosphate deposits in western Summit, Wasatch, Salt Lake, Morgan, and Weber Counties, Utah. Thesis. Utah State University. 44 p.

Haraden, P. L., L.E. Spangler, L.E. Brooks, B.J. Stolp. 2001. Selected hydrologic and water-quality data for Kamas Valley and vicinity, Summit County, Utah, 1997-2000. U.S. Geological Survey. Open-File Report 01-155.

Helsel, D.R. 1990. Less than obvious: statistical treatment of data below the detection limit. Environ. Sci. Technol. Vol. 24, No.12.

Hill, 1994. Consumptive Use of Irrigated Crops in Utah. Utah Agricultural Experiment Station

Hilsenhoff, W.L., 1988. Rapid field assessment of organic pollution with a family-level biotic index. Journal of the North American Benthological Society 7:65-68.

Holland J. 2004. Resource Specialist, Wasatch Cache National Forest. Personal communication with E. de la Hoz, Aquatic Ecologist, Cirrus Ecological Solutions, Logan, Utah re. Grazing allotment information in the Upper Weber Basin.

Holmes, W.F, K.R. Thompson, M. Enright. 1986. Water Resources of the Park City Area, Utah with emphasis on ground water. State of Utah Department of Natural Resources. Technical Publication No. 85. Prepared by the United States Geological Survey in cooperation with the Utah Department of Natural Resources, Division of Water Rights.

Horne, A.J., and C.R. Goldman. 1994. Limnology. 2nd Edition. McGraw-Hill. 575 pp.

Kada, J., Heit, M., and K. Miller. 1994. Chronology of anthropogenic trace element input to four Utah lakes reconstructed using sediment cores. Water, Air and Soil Production. 75: 353-369.

Loveless R. 2004. Zone 3 Coordinator Utah Area Conservation Districts. Information submitted to J. Whitehead, Environmental Scientist, Utah Division of Water Quality re. AFO/CAFO inventory in the Upper Weber Basin. July 19, 2004.

Messer, J.J. and J.M. Ihnat. 1983. Reconnaissance of Sediment-Phosphorus Relationships in some Utah Reservoirs. Utah Water Research Laboratory. Utah State University. Logan, UT. UWRL/Q-83/03.

Messer, J.J., Hardy, T.B., and J.M. Ihnat. 1984. Sediment-Phosphorus Relationships in Deer Creek Reservoir. Utah Water Research Laboratory. Utah State Univeristy. Logan, UT. UWRL/Q-84/01.

Moore, D.S. and G.P. McCabe. 1993. Introduction to the practice of statistics. W.H. Freeman and Co. New York, N.Y.

Natural Resource Conservation Service (NRCS). 1992. Agricultural waste management field handbook. National Engineering Handbook. 210-AWMFH. United States Department of Agriculture. National Resources Conservation Service. Washington, D.C.

Nurnberg, G.K. 1995. Quantifying anoxia in lakes. Limnol. Oceanogr. 40:1100-1111

Nurnberg, G.K. 1995a. The Anoxic Factor, a Quantitative Measure of Anoxia and Fish Species Richness in Central Ontario Lakes. Transactions of the American Fisheries Society. 124:677-686.

Nurnberg, G.K. 1996. Trophic state of clear and colored, soft- and hardwater lakes with special consideration of nutrients, anoxia, phytoplankton and fish. J. of Lake and Reservoir Management. 12:432-447.

Nurnberg, G.K. 1997. Coping with water quality problems due to hypolimnetic anoxia in Central Ontario lakes. Water Quality. Res. J. Canada. 32:391-405.

NRCS. 2002. Soil Survey of Summit Area, Utah. Parts of Summit, Salt Lake and Wasatch Counties.

Ovard B. 2004. Deputy Director, Summit County Health Department, Summit County, Utah. Personal communication with E. Duffin, Watershed Scientist, Cirrus Ecological Solutions, Logan, Utah re. Septic tank information in the Echo Reservoir watershed.

Res. Report #145 Utah State University. Logan, UT.

Sloto R. and M. Crouse. 1996. HYSEP: A computer program for streamflow hydrograph separation and analysis. U.S. Geological Survey Water-Resources Investigations Report 96-4040.

Stonely, T. 2004. Weber River Basin – Planning for the future. Utah Division of Water Resources. Public review draft. 137 p.

Summit County Department of Community Development. 2004. Summit County Department of Community Development - Building Division Reports (1991 – 2003).

Tabbara, H. 2003. Phosphorus loss to runoff water twenty-four hours after application of liquid swine manure of fertilizer. J. Environ. Qual. 32:1044-1052.

Tetra Tech, Inc. 2002. Pineview Reservoir TMDL. Final report prepared for the Utah Department of Environmental Quality, Division of Water Quality.

Utah Division of Water Resources (UDWR). 1997. Utah State water plan - Weber River Basin. Utah Division of water resources. Department of natural Resources. 178 p.

UDWR. 2001. Utah's Water Resources, Planning for the Future. Utah State Water Plan.

United States Census Bureau. 2000. Table DP-1. Profile of general demographic characteristics: 2000. Summit County, Utah.

United States Environmental Protection Agency (USEPA). 1991. Guidance for water quality based decisions: the TMDL process. EPA 440/4-91-001. Office of Water, United States Environmental Protection Agency, Washington, D.C. 63 p.

USEPA. 1999. Protocol for Developing Nutrient TMDLs. First Edition. Office of Water, United States Environmental Protection Agency, Washington D.C.

USEPA. 2002. Onsite Wastewater Treatment Systems Manual. EPA/625/r-00/008.

USEPA. 2006. Clarification regarding "phased" total maximum daily loads. Memorandum. http://www.epa.gov/owow/tmdl/tmdl_clarification_letter.html

USGS. 1996. Hysep: A Computer Program for Streamflow Hydrograph Separation and Analysis. Water Resources Investigations Report 96-4040. Lemoyne, PA.

Utah AFO/CAFO Committee. 2001. A Utah Strategy to Address Water Pollution from Animal Feeding Operations. http://www.waterquality.utah.gov/documents/AFO_CAFO_strat_2001.pdf.

Utah AGRC. 2001. Phosphate deposit areas of Utah - SGID250.PhosphateDeposits1988. Salt Lake City, UT. http://agrc.its.state.ut.us/.

Utah Division of Water Resources. 2001. Utah's Water Resources Planning for the Future. Utah State Water Plan.

Utah Governors Office of Planning and Budget. 2004.

Waddell, K. M., and Giddings, E.M. 2004. Trace elements and organic compounds in sediment and fish tissue from the Great Salt Lake Basins, Utah, Idaho, and Wyoming, 1998-1999. Water-Resources Investigations Report 03-4283. Unites States Geological Survey. National Water-Quality Assessment Program. Salt Lake City, Utah. 44p.

Warnick V. 2004. Utah Area Conservation Districts, Heber, Utah. Personal communication with E. Duffin, Watershed Scientist, Cirrus Ecological Solutions, Logan, Utah re. Agricultural practices in the Upper Weber Basin.

Williams, J.S. 1939. Phosphate in Utah. Utah Experiment Station Bulletin No. 290. 44 p.