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Rockport Reservoir and Echo Reservoir Total Maximum Daily Loads

Public Draft Report

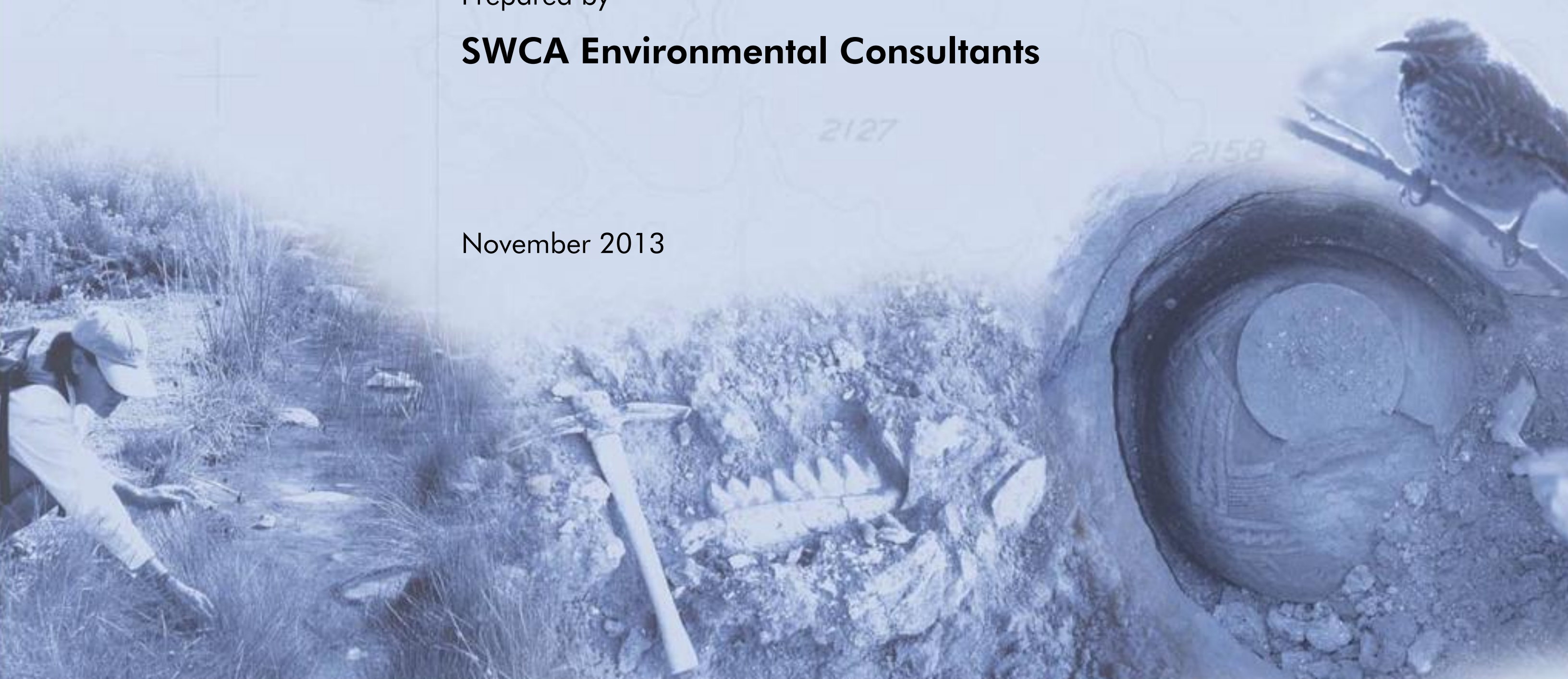
Prepared for

Utah Department of Environmental Quality, Division of Water Quality

Prepared by

SWCA Environmental Consultants

November 2013



Utah Department of Environmental Quality
Division of Water Quality

Rockport Reservoir TMDL
EPA Approval Date: TBD

Waterbody ID	UT-L-16020101-002_00
Location	Summit County, Utah
Pollutants of Concern	Total Nitrogen (TN) Total Phosphorus (TP)
Designated Beneficial Uses	Domestic water use (1C) Primary contact recreation (2A) Secondary contact recreation (2B) Cold water game fish (3A) Agricultural water supply (4)
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.
Current Load	2,337 kg TP/summer season (12.8 kg TP/day) 18,573 kg TN/summer season day (102 kg TN/day)
Loading Capacity (TMDL)	1,519 kg TP/summer season (8.3 kg TP/day) 12,072 kg TN/summer season (66.3 kg TN/day
Defined Targets/Endpoints	Nutrients - In-reservoir mean seasonal TP of 0.014 mg/L - In-reservoir mean seasonal TN of 0.26 mg/L Trophic Status and Algae - In-reservoir mean seasonal chlorophyll *a* of 3.5 µg/L - Algal dominance other than blue-green species Dissolved Oxygen (DO) - Mixed reservoir periods: 4.0 mg/L DO throughout at least 50% of the water column; 5.0 mg/L DO at surface on average over 7-day period; 6.5 mg/L DO at surface on average for 30-day period. - Stratified reservoir periods: 2-m layer throughout the reservoir in which DO is maintained above 4 mg/L and temperature below 20°C
Current Wasteload Allocation	495 kg TP/summer season (2.8 kg TP/day) (winter and summer) 4,504 kg TN/summer season (24.7 kg TN/day) (winter and summer)
Future Wasteload Allocation	72 kg TP/summer season (0.4 kg TP/day) 716 kg TN/summer season (3.9 kg TN/day)
Nonpoint source Wasteload Allocation	952 kg TP/summer season (5.2 kg TP/day) 6,853 kg TN/summer season (37.7 kg TN/day)
MOS	Implicit
Regulated Point Sources	Kamas Wastewater Treatment Plant (UPDES UT0020966) Oakley Wastewater Treatment Plant (UPDES UT0020061) UDWR Fish Hatchery near Kamas (General permit) Francis Wastewater Treatment Plant (UPDES in progress)
Watershed Nonpoint Sources	Agricultural land uses (grazing, fertilizer, and irrigation) Urban stormwater Septic systems discharges Landfill seepage Natural background sources including phosphatic shales

Utah Department of Environmental Quality
Division of Water Quality

Echo Reservoir TMDL

EPA Approval Date: TBD

Waterbody ID	UT-L-16020101-001_00
Location	Summit County, Utah
Pollutants of Concern	Total Nitrogen (TN) Total Phosphorus (TP)
Designated Beneficial Uses	Domestic water use (1C) Primary contact recreation (2A) Secondary contact recreation (2B) Cold water game fish (3A) Agricultural water supply (4)
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.
Current Load **Loading Capacity (TMDL)**	5,387 kg TP/summer season (29.6 kg TP/day) 42,709 kg TN/summer season (235 kg TN/day) 3,502 kg TP/summer season (19.2 kg TP/day) 27,761 kg TN/summer season (152.5 kg TN/day)
Defined Targets/Endpoints	Nutrients - In-reservoir mean seasonal TP of 0.018 mg/L - In-reservoir mean seasonal TN of 0.27 mg/L Trophic Status and Algae - In-reservoir mean seasonal chlorophyll *a* of 3.5 µg/L - Algal dominance other than blue-green species Dissolved Oxygen (DO) - Mixed reservoir periods: 4.0 mg/L DO throughout at least 50% of the water column; 5.0 mg/L DO at surface on average over 7-day period; 6.5 mg/L DO at surface on average for 30-day period. - Stratified reservoir periods: 2-m layer throughout the reservoir in which DO is maintained above 4 mg/L and temperature below 20°C
Current Wasteload Allocation **Future Wasteload Allocation** **Nonpoint source Load Allocation** **MOS**	1,237 kg TP/summer season (6.8 kg TP/day) 12,238 kg TN/summer season (67.2 kg TN/day) 485 kg TP/summer season (2.7 kg TP/day) 4,918 kg TN/summer season (27 kg TN/day) 1,779 kg TP/summer season (9.8 kg TP/day) 10,605 kg TN/summer season (58.3 kg TN/day) Implicit
Regulated Point Sources	Coalville Wastewater Treatment Plant (UPDES UT0021288) Silver Creek Water Reclamation Facility (UPDES UT0024414) Blue Sky Resort Wastewater Treatment Plant (UPDES UT0025763) Park City Tunnels (Permits pending)
Watershed Nonpoint Sources	Agricultural land uses (grazing, fertilizer, and irrigation) Urban stormwater Septic systems discharges Channel erosion Natural background sources including phosphatic shales

ROCKPORT RESERVOIR
AND ECHO RESERVOIR
TOTAL MAXIMUM DAILY LOADS

PUBLIC DRAFT REPORT

Prepared for

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ABBREVIATIONS

°C	degrees Celsius
°F	degrees Fahrenheit
µg/L	micrograms per liter
ac-ft	acre-feet or acre-foot
BLM	Bureau of Land Management
BMP	best management practices
BOD	biochemical oxygen demand
BOR	Bureau of Reclamation
cfs	cubic feet per second
CWA	Clean Water Act
DO	dissolved oxygen
DWQ	Division of Water Quality
DWR	Division of Wildlife Resources
EPA	Environmental Protection Agency
GOMB	Governor's Office of Management and Budget
kg	kilogram
m	meters
MGD	million gallons per day
mg/L	milligrams per liter
MOD	metalimnetic oxygen depletion
MOS	margin of safety
NRCS	Natural Resources Conservation Service
NTUs	nephelometric turbidity units
SWAT	Soil and Water Assessment Tool
SWCA	SWCA Environmental Consultants
TKN	total Kjeldhal nitrogen
TMDL	total maximum daily load
TN	total nitrogen
TP	total phosphorus
UDEQ	Utah Department of Environmental Quality
UPDES	Utah Pollutant Discharge Elimination System
USDA	U.S. Department of Agriculture
USFS	U.S. Forest Service
USGS	U.S. Geological Survey
WLA	Waste load allocations
WRCC	Western Regional Climate Center
WRF	Water Reclamation Facility
WWTP	wastewater treatment plant

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CHAPTER 1. INTRODUCTION

1.1 Purpose

This document presents the total maximum daily load (TMDL) study for the impaired waters of Rockport and Echo Reservoirs in the Weber River Watershed (UT16020102-022) in fulfillment of requirements of the Clean Water Act (CWA).

A TMDL study determines the amount of an identified pollutant (i.e., the load) that a waterbody can receive while preserving its designated uses and state water quality standards. Once the pollutant loads have been identified, controls are implemented to reduce those loads until the waterbody is brought back into compliance with water quality standards. Upon completion of the TMDL study, it is submitted to the Utah Water Quality Board and U.S. Environmental Protection Agency (EPA) for approval.

The Federal Water Pollution Control Act is the primary federal legislation that protects surface waters such as lakes and rivers. This legislation, originally enacted in 1948, was expanded in 1972 and became known as the Clean Water Act. The purpose of the CWA is to improve and protect the physical, chemical, and biological integrity of the nation's waters. The CWA requires EPA or delegated authorities such as states, tribes, and territories to evaluate the quality of waters, establish beneficial uses, and define water quality criteria to protect those uses. Section 303(d) of the CWA requires that each state submit a list of waterbodies that fail state water quality standards to the EPA every 2 years. This list is the "303(d) list," and waterbodies identified on the list are referred to as "impaired waters." For impaired waters, the CWA requires a TMDL study for each pollutant responsible for impairment of its designated use(s).

The Utah Department of Environmental Quality (UDEQ), Division of Water Quality (DWQ) collects biological and water quality data to assess its waters according to its designated beneficial uses and water quality standards (Utah State Administrative Code R317). Based on this assessment, Echo Reservoir was included on the State of Utah's 303(d) list in1996, and Rockport Reservoir was included in 2008.

1.2 Problem Statement

Rockport and Echo Reservoirs are listed as impaired due to violations of the cold-water fishery dissolved oxygen (DO) standards. Echo Reservoir was first listed in 1996 whereas Rockport Reservoir was first listed in 2008. Impairment occurs in the bottom layer (the hypolimnion) of the reservoirs, which does not mix with surface waters during the summer due to thermal stratification (Figure 1.1). Over the course of the summer, oxygen is depleted in this lower layer while surface temperatures become too warm for cold-water species of fish.-Rockport and Echo Reservoirs are also listed as impaired for exceedance of the temperature standard for cold-water fishery. DWQ is addressing this impairment in a separate document.

DO is important to the health and viability of the cold-water fishery. Concentrations of 6.0–8.0 milligrams per liter (mg/L) are necessary for the health and viability of fish and other aquatic life. Low DO concentrations (less than 4.0 mg/L) cause stress to fish species, promote disease, and ultimately result in stunted growth and/or death.

Low DO in the reservoirs is due in part to the decomposition of algae and other organic matter in the hypolimnion. Algal growth is fueled by excess nutrient loads of nitrogen and phosphorus to the reservoir. When algae die and settle to the bottom, decomposition of the dead algae and other detritus (nonliving organic matter) consumes the oxygen supply in the water. Reservoirs are especially sensitive to excess nutrient loads due to their high surface area to volume ratio and use as water storage facilities.

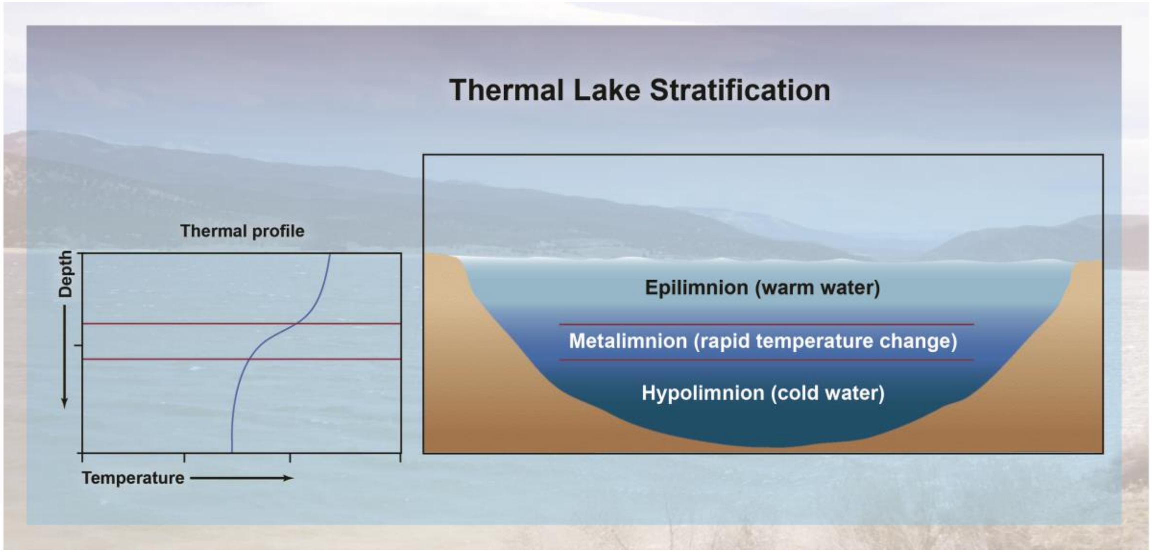

Figure 1.1. Profile view of thermal stratification in a typical lake or reservoir.

The shapes and settings of Rockport and Echo Reservoirs also contribute to low DO during summer months. Notably, the water levels at the inlet of each reservoir are shallow, whereas the water levels just upstream of the outlet are deep and the reservoir shape is long and narrow. As a result, the surface area of the reservoirs in the late-spring and early summer is quite large compared to the relatively small volume of hypolimnetic water near the outlet (i.e., the dam segment of reservoirs; Figure 1.2). As the reservoirs are drawn down, this small pool of hypolimnetic water ultimately receives all of the algal organic matter, and its associated oxygen demand, produced in the early spring and summer. The result of this phenomenon is that even at very low nutrient and algal concentrations, the hypolimnia of Rockport Reservoir and Echo Reservoir become depleted of oxygen over the course of the summer season.

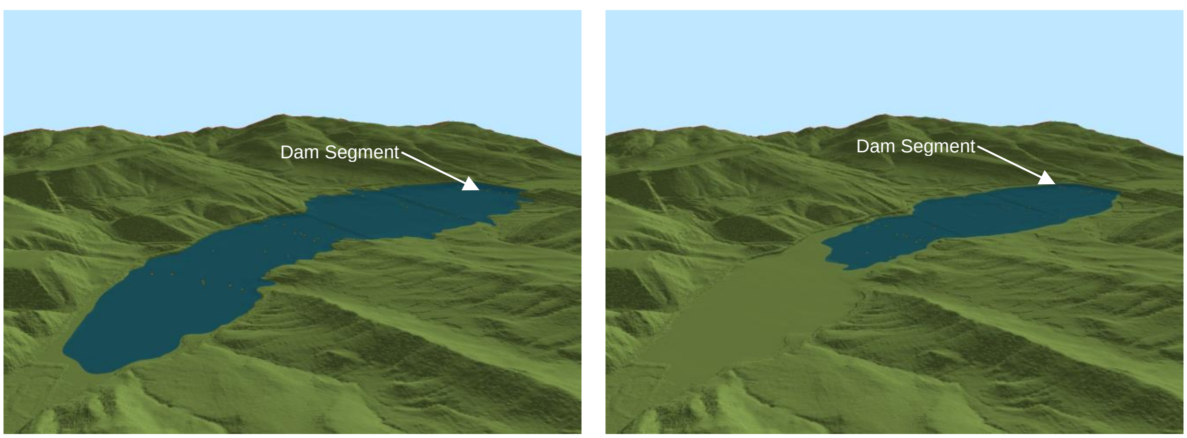

Figure 1.2. Change in Rockport Reservoir water level in 2007 from May 15 to September 30.

1.3 Regional Setting

1.3.1 History

Rockport and Echo Reservoirs are two of the seven reservoirs built by the Bureau of Reclamation (BOR) as part of the Weber River Project to store water and supply it to the northern Wasatch Front (Figure 1.3). Rockport Reservoir, located 1.5 miles south of Wanship, Utah, is contained by Wanship Dam, an earth-filled dam that was completed in 1957. When full, Rockport Reservoir maintains a surface elevation of 6,049 feet with a 62,100-acre-foot (ac-ft) storage capacity. The normal operating depth of the reservoir is 150 feet. The dam outlet has a capacity to release 1,000 cubic feet per second (cfs), and the spillway has the capacity to release 10,800 cfs.

Echo Reservoir is contained by Echo Dam, an earth-filled dam that was completed in 1931; it is located 6 miles north of Coalville, Utah. When full, Echo Reservoir maintains a surface elevation of 5,560 feet with a 91,156,000-ac-ft storage capacity. The normal operating depth of the reservoir is 110 feet. The dam outlet has a capacity to release 2,100 cfs, and the spillway has the capacity to release 15,000 cfs.

Water resources in the Weber River Watershed are well developed. It is estimated that water deliveries for municipal and agricultural needs make up 30% and 70% of use, respectively. In addition, Rockport Reservoir hosts a popular state park, and both reservoirs are used for recreational activities, including fishing and boating.

In the 1850s, Mormon Pioneers settled in the Weber River Basin, bounded by the Uinta Mountains to the east and the Wasatch Range to the west. Mountain-fed streams supported irrigation for small communities. In the 1860s, wagons moved coal from Coalville down to the Salt Lake Valley. In 1873, a line was built from Coalville to Echo Reservoir by the Utah Eastern Railroad, and it eventually became part of the Union Pacific Railroad. Discovery of lucrative metals such as lead, silver, and zinc resulted in mining and further expansion. Economic opportunity led to development of canals and eventually storage reservoirs capable of supporting the accompanying population growth (Utah State Historical Society 1988).

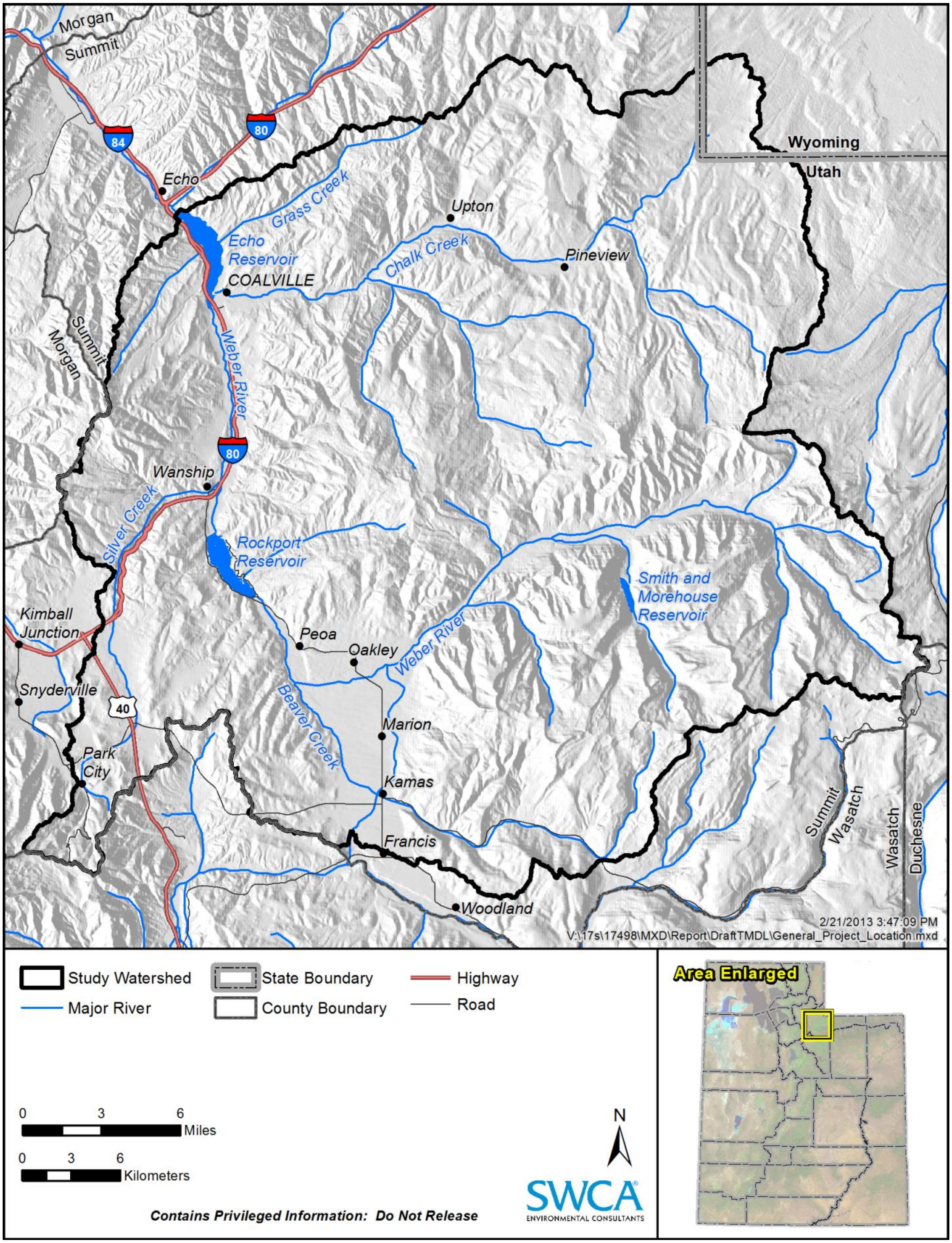

Figure 1.3. Map of study watershed, including state and county boundaries.

1.3.2 Population and Growth

Echo and Rockport Reservoirs are impoundments of the Weber River in the Upper Weber Watershed. The watershed covers approximately 464,000 acres, most (99%) of which is in Summit County, Utah. The remaining watershed area covers parts of Duchesne County, Utah; Morgan County, Utah; Wasatch County, Utah; and Uinta County, Wyoming. For this reason, most of the population using the water (an estimated 36,324 individuals in 2010) is found in Summit County, Utah. Summit County is made up of seven primary municipalities; their 2000 and 2010 populations are shown in Table 1.1. As of May 2012, the county had 13,103 non-primary residential structures versus 12,613 primary residential structures. These include cabins, condominiums, and mobile homes, as well as the standard home; these do not include commercial, vacant land, or exempt properties. The county as a whole is projected to grow by 56% by 2030, compared to a 42% projected growth for the entire State of Utah. Much of this growth is projected for small towns and rural areas in the county.

Table 1.1. Population of Weber River Watershed and Surrounding Areas

Area	Population 2000[1]	Population 2010[1]	Population 2030[2]
State of Utah	2,223,169	2,763,885	3,913,605
Summit County	29,736	36,324	56,890
Coalville City	1,382	1,363	1,859
Francis Town	698	1,077	2,415
Henefer Town	684	766	1,212
Kamas City	1,274	1,811	2,864
Oakley City	948	1,470	3,297
Park City	7,371	7,547	11,444
Balance of Summit County	17,374	22,290	33,799

[1] Data from Economic Report to the Governor (State of Utah 2011).

[2] Data from Governor's Office of Management & Budget (State of Utah 2012)

1.3.3 Socioeconomics

The economic base of the study watershed in Summit County is varied. The top three employment sectors in Summit County from 2007 to 2011 were arts, entertainment, accommodation and food services (18.6%); education, health, and social services (15%); and professional and administrative services (13.3%). The median and mean household incomes for Summit County are $84,752 and $112,646, respectively. Unemployment between 2007 and 2011 was estimated to be 4.9% (U.S. Census Bureau 2011).

Agriculture, forestry, fisheries, hunting, and mining represent 1.6% of industry in Summit County (U.S. Census Bureau 2011). The number of farms in Summit County increased from 557 in 2002 to 629 in 2007 with the average market value per farm production up 15% to $40,415 over this same time period. In 2007, livestock sales represented 94% of the total market value of agricultural production in Summit County (National Agricultural Statistics Service 2007).

1.3.4 Climate

Three active climate stations in the study watershed were used for the TMDL analysis. Climate data available for these three stations were obtained from the Western Regional Climate Center (WRCC 2012). Table 1.2 lists the climate station names and identification numbers, station locations, elevations, and data periods of record.

Table 1.2. Active Climate Stations in the Study Watershed

Station Name (Identification Number)	Location	Elevation	Period of Record
Kamas (424467)	40°39'N, 111°17'W	6,510 feet	1948–2011
Wanship Dam (429165)	40°48'N, 111°24'W	5,910 feet	1955–2012
Coalville (421590)	40°56'N, 111°10'W	6,420 feet	1974–2011

Figure 1.4 shows variation in average monthly precipitation for the three active climate stations in the study watershed. Tables 1.3, 1.4, and 1.5 show the monthly climate summaries for each of the three stations. The Kamas station (424467) represents climatic conditions in the upper reaches of the study watershed. The Wanship Dam (429165) and Coalville (421590) stations represent climate conditions at Rockport Reservoir and Echo Reservoir, respectively.

Average monthly high and low temperatures at these stations range from approximately 8 degrees Fahrenheit (°F) in January to 86°F in August. Average minimum temperatures at these stations are below freezing from October to May. Average annual precipitation is approximately 15–17 inches, with the greatest monthly precipitation averages occurring in April, May, and October.

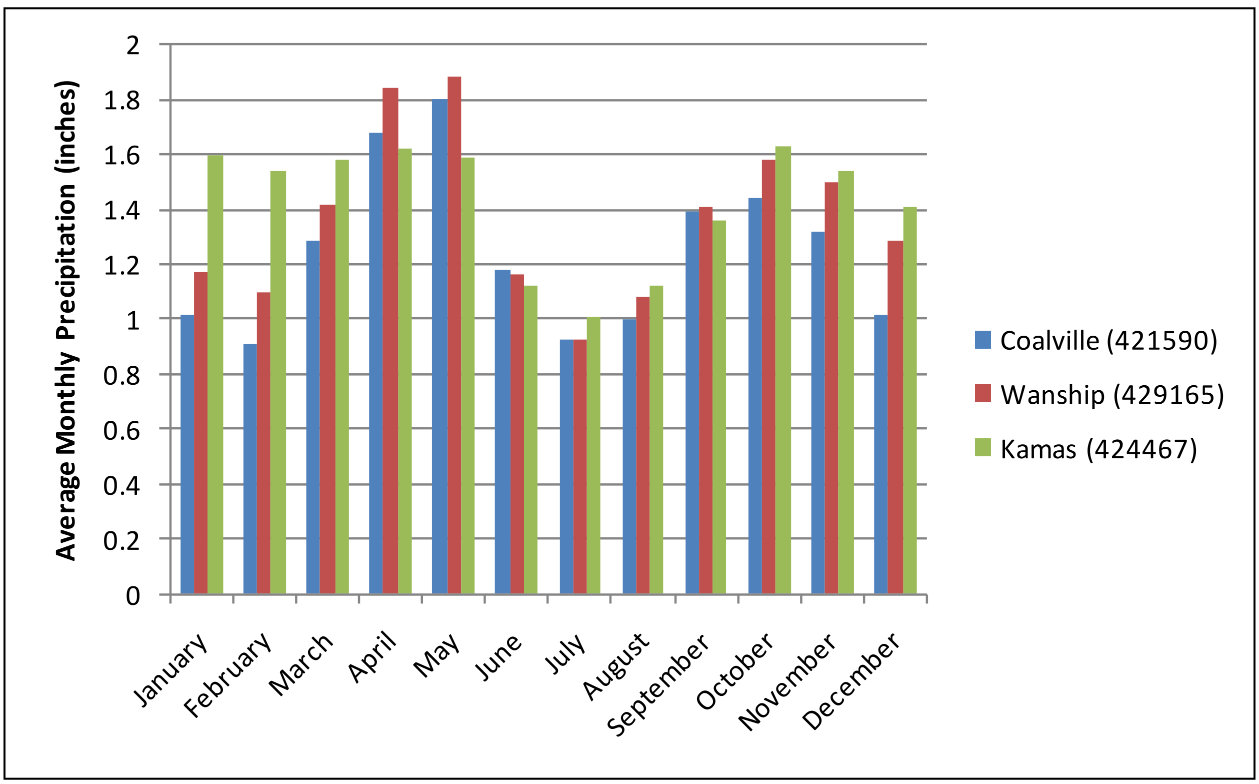

Figure 1.4. Average monthly precipitation at three climate stations in the study watershed.

Table 1.3. Monthly Climate Summary for Kamas Station (424467)

	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Average maximum temperature (°F)	36.0	39.8	46.5	55.6	66.1	76.0	85.3	83.5	74.7	62.0	46.1	37.3	**59.1**
Average minimum temperature (°F)	12.2	14.7	21.7	27.8	35.0	41.0	48.0	46.6	38.6	30.0	21.1	13.3	**29.2**
Average total precipitation (inches)	1.60	1.54	1.58	1.62	1.59	1.12	1.01	1.12	1.36	1.63	1.54	1.41	**17.12**
Average total snowfall (inches)	20.1	15.6	10.7	6.5	2.2	0.2	0	0	0.5	2.5	12.6	18.7	**89.5**
Average snow depth (inches)	9	10	3	0	0	0	0	0	0	0	1	5	**2**

Source: Kamas station (424467) from 10/1/1948 to 12/31/2011 (WRCC 2012)

Table 1.4. Monthly Climate Summary for Wanship Dam Station (429165)

	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Average maximum temperature (°F)	36.2	40.1	48.0	57.6	68.2	78.3	86.6	85.3	76.0	63.6	47.3	37.5	**60.4**
Average minimum temperature (°F)	11.7	14.8	21.9	28.5	35.3	41.3	47.2	45.7	37.4	28.9	20.9	13.5	**28.9**
Average total precipitation (inches)	1.17	1.10	1.42	1.84	1.88	1.16	0.93	1.08	1.41	1.58	1.50	1.29	**16.36**
Average total snowfall (inches)	15.2	13.9	10.7	6.4	0.9	0.1	0	0	0.3	1.9	10.2	13.9	**73.4**
Average snow depth (inches)	5	4	1	0	0	0	0	0	0	0	1	2	**1**

Source: Wanship Dam station (429165) from 8/1/1955 to 1/31/2012 (WRCC 2012)

Table 1.5. Monthly Climate Summary for Coalville Station (421590)

	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Average maximum temperature (°F)	35.8	39.0	44.7	53.7	62.9	73.7	82.8	80.4	72.0	60.4	45.8	36.9	**57.3**
Average minimum temperature (°F)	8.5	9.7	18.3	25.9	32.8	38.3	45.0	43.0	35.4	26.6	16.6	9.6	**25.8**
Average total precipitation (inches)	1.02	0.91	1.29	1.68	1.80	1.18	0.93	1.00	1.39	1.44	1.32	1.02	**14.98**
Average total snowfall (inches)	16.6	13.9	13.4	7.0	3.1	0.3	0	0	0.6	3.1	11.4	15.3	**84.7**
Average snow depth (inches)	8	9	5	1	0	0	0	0	0	0	2	6	**3**

Source: Coalville station (421590) from 10/11/1974 to 11/30/2011 (WRCC 2012)

CHAPTER 2. WATER QUALITY CONCERNS

2.1 Beneficial Uses and Impaired Waters

The purpose of the CWA is to improve and protect water quality through the restoration and maintenance of the physical, chemical, and biological integrity of the nation's waters. Protection of waters under the CWA consists of three main components: designating beneficial uses, establishing water quality criteria to protect those uses, and implementing anti-degradation policies and procedures.

Under Section 303(d) of the CWA, each state must submit a list to the EPA identifying waters that are not achieving water quality standards despite the application of technology-based controls in Utah Pollutant Discharge Elimination System (UPDES) permits. The waters identified on the 303(d) list are known as impaired waters.

The State of Utah designates beneficial uses to all surface waters in the state according to the classes outlined in Table 2.1. Recreational classifications are for waterbodies that are suitable, or are intended to be made suitable, for frequent and infrequent contact recreation.

Table 2.1. Summary of Use Designations for Rockport and Echo Reservoirs

Class	Designated Beneficial Use
1C	Protected for domestic purposes with prior treatment by treatment processes as required by the Utah Division of Drinking Water
2A	Protected for frequent contact recreation such as swimming
3A	Protected for cold-water species of game fish and other cold-water aquatic life, including the necessary aquatic organisms in their food chain
4	Protected for agricultural uses including irrigation of crops and stock watering

Source: Utah Administrative Code R317-2

The State of Utah has designated the beneficial uses for Rockport and Echo Reservoirs to be domestic water use (1C), frequent contact recreation (2A), cold-water game fish and the associated food chain (3A), and agricultural water supply (4). Rockport Reservoir was first listed on the State of Utah's 2008 303(d) list as impaired due to low DO and excess total phosphorus (TP) loading. Echo Reservoir was first listed on the State of Utah's 1996 303(d) list as impaired due to low DO and to pH measurements that exceeded state criteria; however, pH was removed from the list in 2003 and TP was added. Both reservoirs are currently listed as impaired due to violations of the cold-water fishery (3A) DO standards. Assessment of these uses and the level of support are discussed below.

2.2 Water Quality Standards Applicable to Rockport Reservoir and Echo Reservoir

Water quality criteria specific to designated beneficial uses consist of numeric limits for individual pollutants as well as narrative descriptions of desired conditions. Water quality standards applicable to the uses designated for Rockport and Echo Reservoirs are summarized in Table 2.2. The most applicable water quality standards for this TMDL are the standards associated with DO. Cold-water sport fish species are not known to reproduce in the reservoir; therefore, the early life-stage criteria do not apply.

The state DO criteria for all life stages of cold-water fish are 4.0 mg/L as a 1-day minimum, 5.0 mg/L as a 7-day average, and 6.5 mg/L as a 30-day average.

Table 2.2. Selected Water Quality Criteria for Designated Uses in Rockport and Echo Reservoirs

Parameter	Class 1C	Class 2B	Class 3A
Physical			
pH (range)	6.5–9.0	6.5–9.0	6.5–9.0
Turbidity increase (NTU)	N/A	10	10
Temperature (ºC)	N/A	N/A	20
Maximum temperature change (ºC)	N/A	N/A	2
DO[1]			
30-day average	N/A	N/A	6.5
7-day average	N/A	N/A	9.5/5.0
1-day minimum	N/A	N/A	8.0/4.0
Total dissolved gases (% saturation)	N/A	N/A	<110%
Inorganics (maximum)			
Nitrate as N (mg/L)	10	N/A	N/A
Total ammonia as N (mg/L)	See footnotes below		
Pollution Indicators[4]			
Biochemical oxygen demand (BOD) (mg/L)	N/A	5	5
Nitrate as N (mg/L)	N/A	4	4
Total phosphorus as P (mg/L)	N/A	0.025	0.025

Notes: NTU = nephelometric turbidity units; ºC = degrees Celsius

[1] These limits are not applicable to lower water levels in deep impoundments. First number in column details when early life stages are present; second number details when all other life stages are present.

[2] The 30-day average concentration of total ammonia nitrogen (in mg/L as N) does not exceed, more than once every 3 years on the average, the chronic criterion calculated using the following equations:

Fish Early Life Stages are Present:

mg/Las N (Chronic) = ((0.0577/(1+107.688-pH)) + (2.487/(1+10pH-7.688)) x MIN (2.85, 1.45*100.028*(25-T))

Fish Early Life Stages are Absent:

mg/L as N (Chronic) = ((0.0577/(1+107.688-pH)) + (2.487/(1+10pH-7.688)) * 1.45*100.028* (25-MAX(T,7))

[3] The 1-hour average concentration of total ammonia nitrogen (in mg/L as N) does not exceed, more than once every 3 years on the average, the acute criterion calculated using the following equation:

Class 3A:

mg/L as N (Acute) = (0.275/ (1+107.204-pH)) + (39.0/1+10pH-7.204))

[4] pH dependent criteria (Class 3A)

2.3 Reservoir Management

The manner in which water levels for the reservoirs under consideration are managed is of particular concern when addressing water quality issues. The timing of drawdown and the quantity of water present in a reservoir largely dictate water column processes and chemistry. Control and management of Rockport Reservoir and Echo Reservoir are under the jurisdiction of the Weber Basin Water Conservancy Districts and BOR, respectively.

Water management in Rockport and Echo Reservoirs is governed largely by water rights and has a significant effect on the timing and quantity of flow in the Weber River. Rockport Reservoir is designed to hold two seasons' worth of irrigation water and maintains a more stable water level than Echo Reservoir. In the spring, Rockport Reservoir is filled before Echo Reservoir, reducing the natural springtime flow in the Weber River between Rockport and Echo Reservoirs. Echo Reservoir is a drain and fill reservoir designed to store the equivalent of 1 years' worth of water rights. In a given year, most of the water rights from Echo Reservoir have been fulfilled by September, resulting in a significantly lower reservoir volume in October. Approximately 25,000 ac-ft of Echo Reservoir water right allotments are stored in Rockport Reservoir (personal communication, Ivan Ray, Davis and Weber Counties Canal Company and Erica Gaddis, SWCA Environmental Consultants [SWCA], March 26, 2012). Daily pool elevation, storage, inflow, and discharge data are available from the BOR for both reservoirs from the late 1960s to the present (Figure 2.1) (BOR 2012).

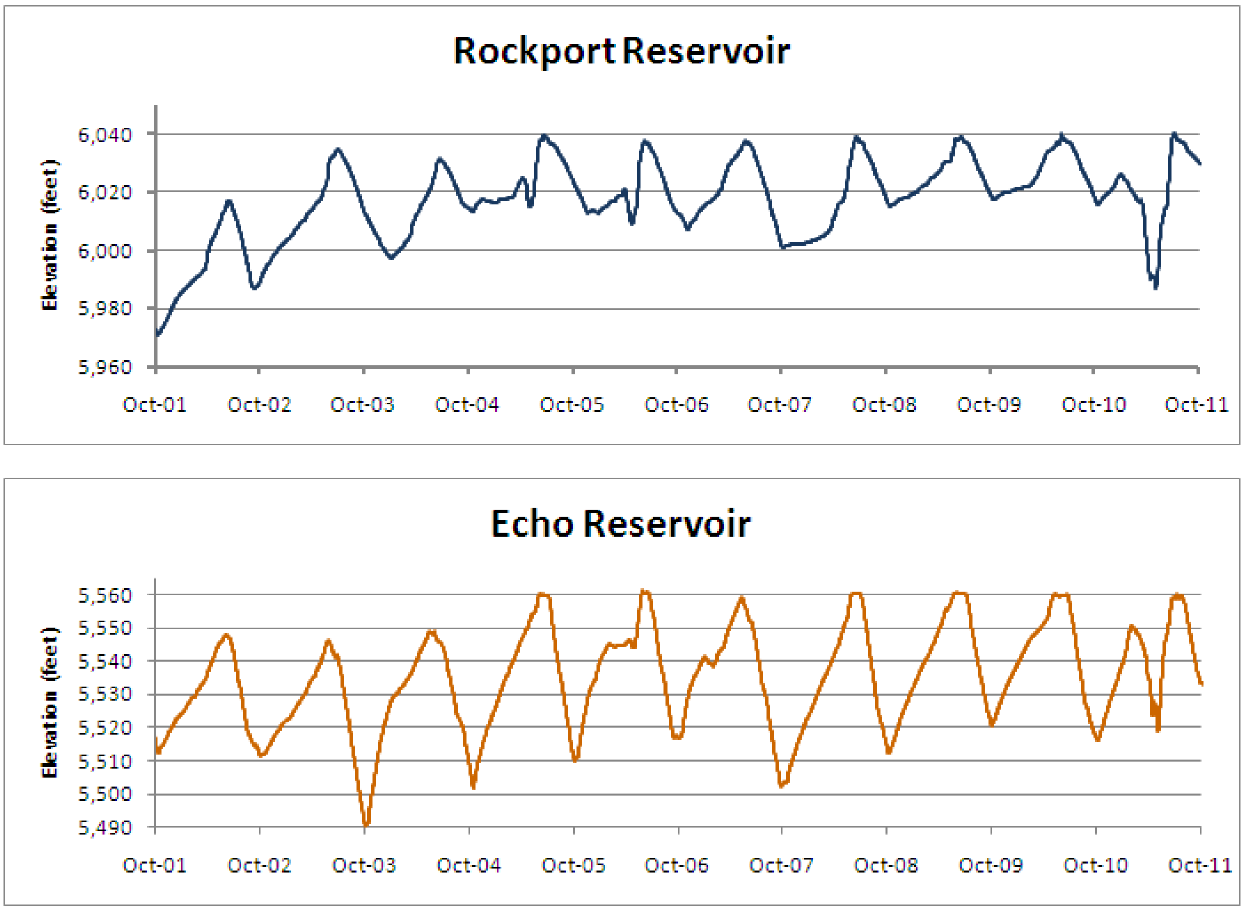

Figure 2.1. Reservoir pool elevation for Rockport and Echo Reservoirs from October 2001 through September 2011.

2.4 Beneficial Use Support Assessment for Rockport Reservoir and Echo Reservoir

This section summarizes reservoir profile data collected at the deepest sites near the dam of both reservoirs between 2002 and 2011 in order to validate the 303(d) listings for cold-water fishery DO standards. The impairment confirmation analyses were based on Utah's most recent *Water Quality Assessment Guidance* (DWQ 2008).

2.4.1 Echo Reservoir

In all, 48 profiles collected near Echo Dam during the typical stratification season (May–October) were included in this analysis. In addition, two profiles were available from February to evaluate winter stratification. On average, 28% of the water column is below the minimum DO criterion when all life stages of cold-water fish species are present (Table 2.3). This exceedance typically occurs in August at the end of the reservoir stratification period. The early life stage DO criteria are not applicable to Echo Reservoir because there are no cold-water reproducing fish species in the reservoir (personal communication, Craig Schaugaard, Utah Division of Wildlife Resources [DWR], and Erica Gaddis, SWCA, April 10, 2012).

Table 2.3. Average Percentage of Water Column below Dissolved Oxygen Criteria for the Cold Water Fishery Use (3A) for Data Collected near Echo Dam (2002–2011)

Month	Minimum All Life Stage DO Criteria (>4.0 mg/L)
February	6%
May	0%
June	11%
July	37%
August	47%
September	9%
October	0%
Overall average	**28%**

The *Water Quality Assessment Guidance* (DWQ 2008) provides for evaluation of the water column overlap in temperature and DO exceedances. Typically, by August there is no habitat with temperatures below 20^{o}C and DO greater than 4.0 mg/L (the minimum water quality criterion). In 69% of the profiles analyzed from 2002 through 2011, there was less than 2 meters (m) of such habitat in August (Table 2.4).

Table 2.4. Average Thickness of Habitat Layer that Meets the Cold Water Fishery Use (3A) for Temperature ($<20^{o}$C) and Dissolved Oxygen (>4.0 mg/L) Criteria at the Echo Dam Site (2002–2011)

Month	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Average
February		–	–	–	–	–	–	–	17.0	26.0	21.5
May	–	–	–	–	–	22.9	–	–	–	–	22.9
June	9.7	7.0	3.0	16.0	7.2	8.2	–	–	18.0	26.0	10.9
July	0	12.5	-	0	–	0.4	–	–	6.1	26.9	3.1
August	0	-	0	16.4	0	1.3	0	–	0	0	1.8
September	–	0	–	13.0	–	0	–	–	8.1	16.0	4.6
October	15.0	4.0	–	–	–	–	–	–	–	–	9.5

Figures 2.2, 2.3, and 2.4 show profiles of oxygen and temperature across the season for selected years for data collected by DWQ at the Echo Dam monitoring station (4926130).

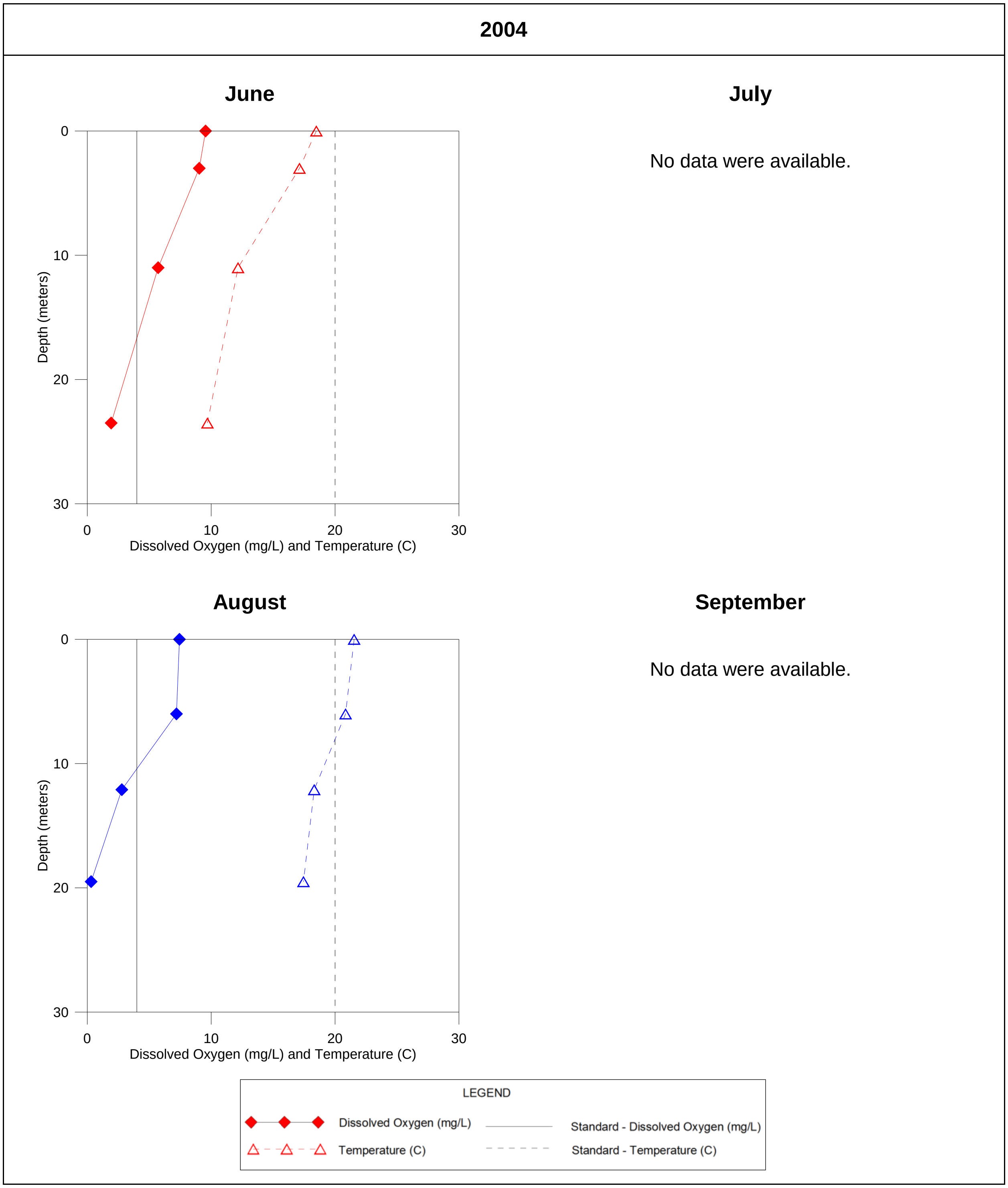

Figure 2.2. Dissolved oxygen and temperature graphs for the Echo Dam (DWQ station 4926130) in 2004.

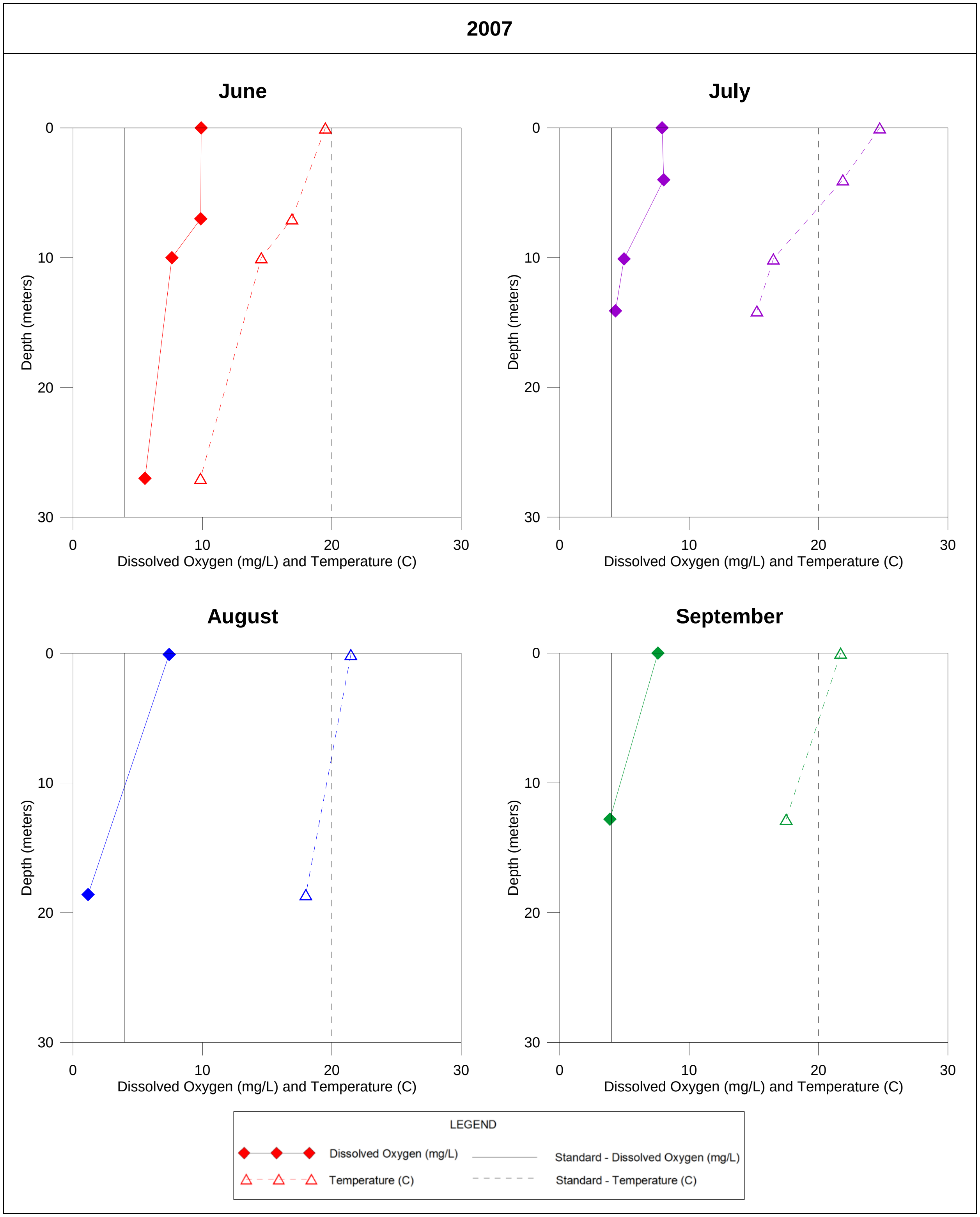

Figure 2.3. Dissolved oxygen and temperature graphs for the Echo Dam (DWQ station 4926130) in 2007.

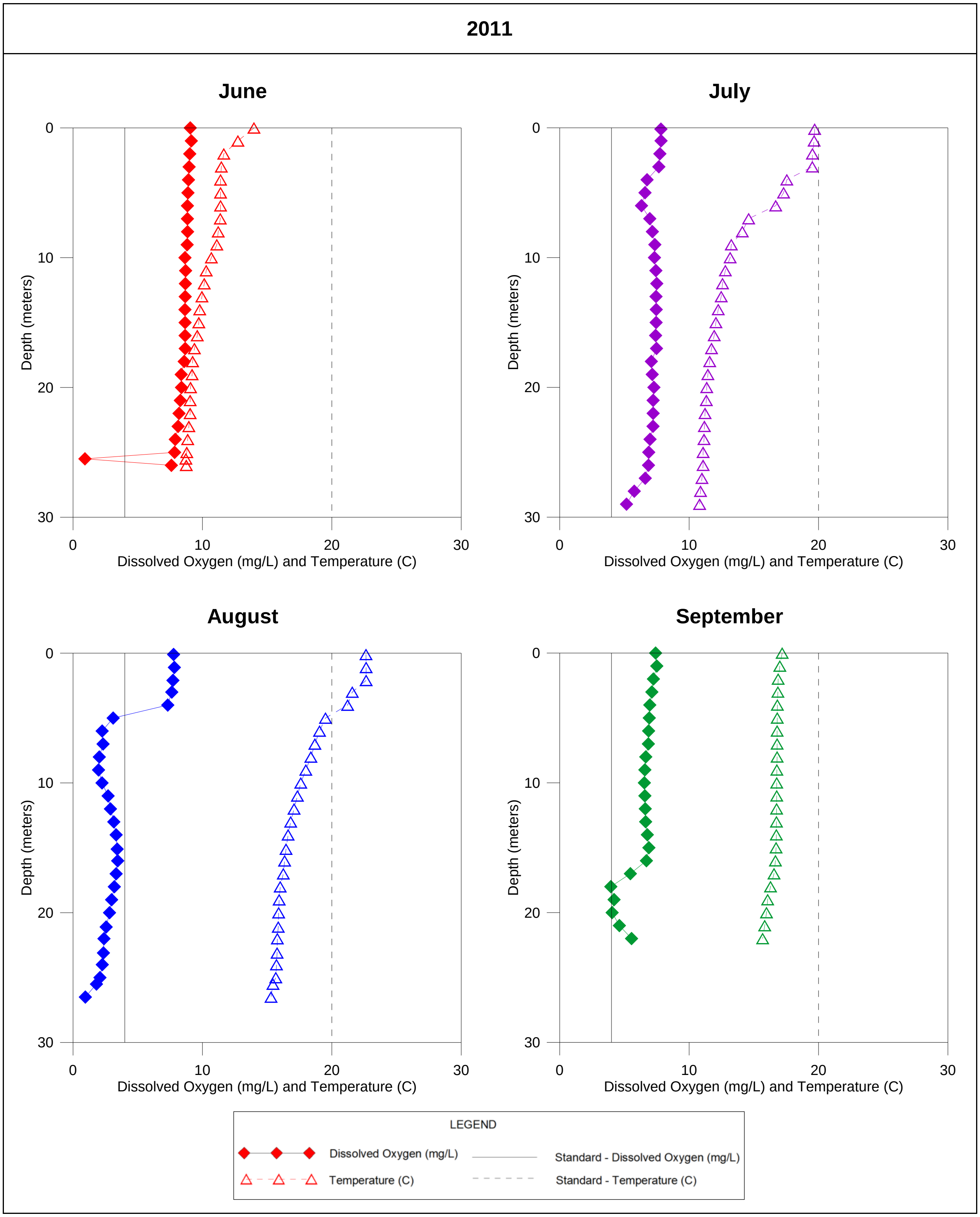

Figure 2.4 Dissolved oxygen and temperature graphs for the Echo Dam (DWQ station 4926130) in 2011.

2.4.2 Rockport Reservoir

In all, 32 profiles collected near Rockport Dam during the typical stratification season (May–October) were included in this analysis. In addition, one profile was available from February to evaluate winter stratification. On average, 29% of the water column is below the minimum water DO criteria when all life stages of cold-water fish species are present (Table 2.5). This exceedance typically occurs in August at the end of the reservoir stratification period. The early life stage DO criteria are not applicable to Echo Reservoir because there are no cold-water reproducing fish species in the reservoir (personal communication, Craig Schaugaard, DWR, and Erica Gaddis, SWCA, April 10, 2012).

Table 2.5. Average Percentage of Water Column below Dissolved Oxygen Criteria for the Cold Water Fishery Use (3A) at the Rockport Reservoir Dam Site (2002–2011)

Month	Minimum All Life Stage DO Criteria (>4.0 mg/L)
February	30%
June	14%
July	27%
August	51%
September	43%
Overall average	**29%**

On average, there is at least 2 m of habitat with temperatures below 20^{o}C and DO greater than 4.0 mg/L (the minimum water quality criterion) throughout the stratification season (Table 2.6). The worst-case condition occurred in Rockport Reservoir in 2008, during which time no habitat met the minimum temperature and DO criteria from July through September.

Table 2.6. Average Thickness of Habitat Layer that Meets the Cold Water Fishery Use (3A) Temperature (<20^{o}C) and Dissolved Oxygen (>4.0 mg/L) Criteria at the Rockport Reservoir Dam Site (2002–2011)

Month	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Average
February	–	–	–	–	–	–	–	–	19.0	21.0	20.0
June	10.8	–	11.0	–	6.0	65.2	3.0	0	34.9	32.5	25.4
July	–	–	–	–	–	8.8	0	0	6.1	–	5.9
August	0	–	0	–	0	–	0	9.1	0	0	1.3
September	–	–	–	–	–	–	0	0	16.9	12.0	7.2

Figures 2.5, 2.6, and 2.7 shows profiles of oxygen and temperature across the season for selected years for data collected by DWQ at the Rockport Reservoir Dam monitoring station (5923310).

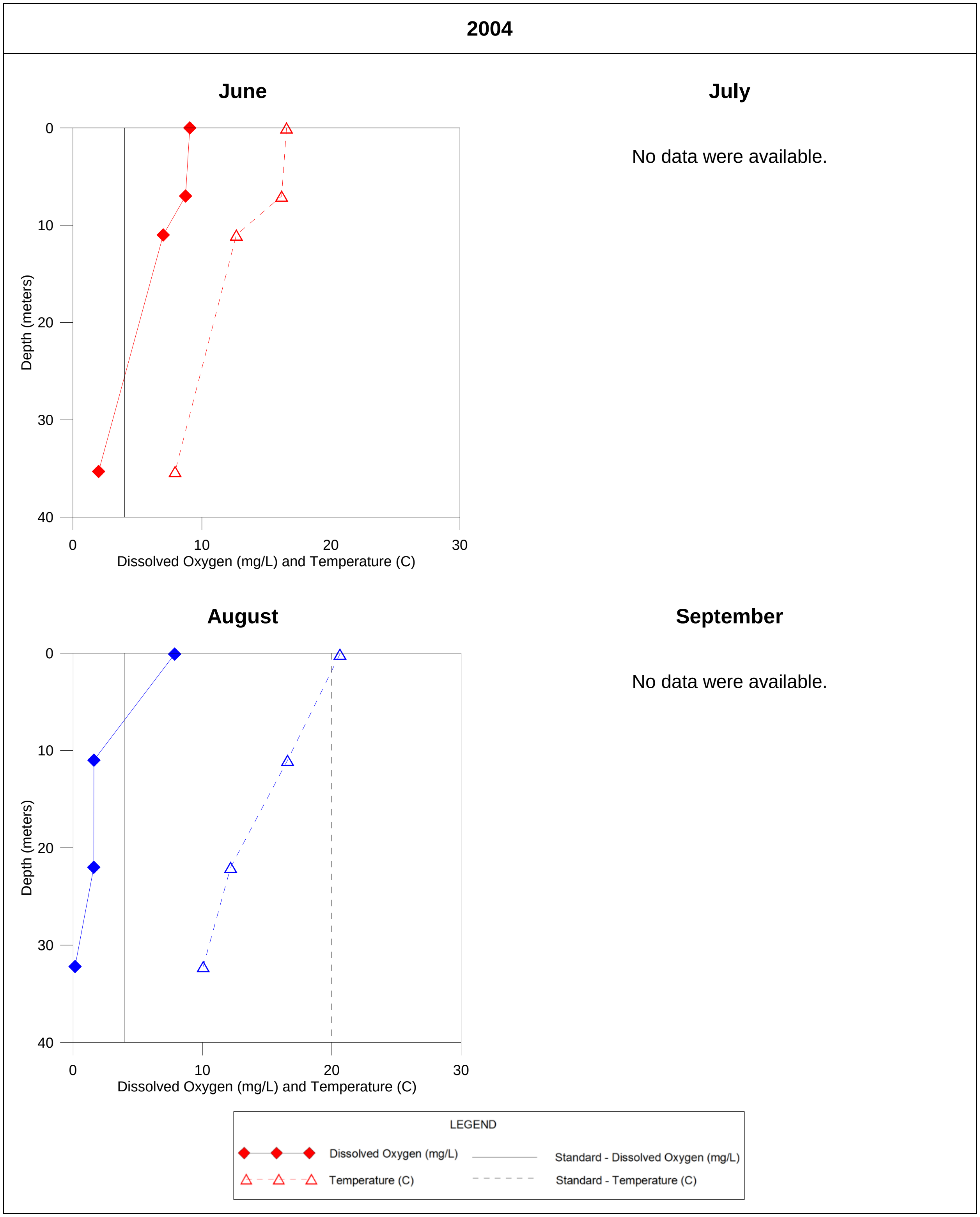

Figure 2.5. Dissolved oxygen and temperature graphs for the Rockport Reservoir Dam (DWQ station 5923310) in 2004.

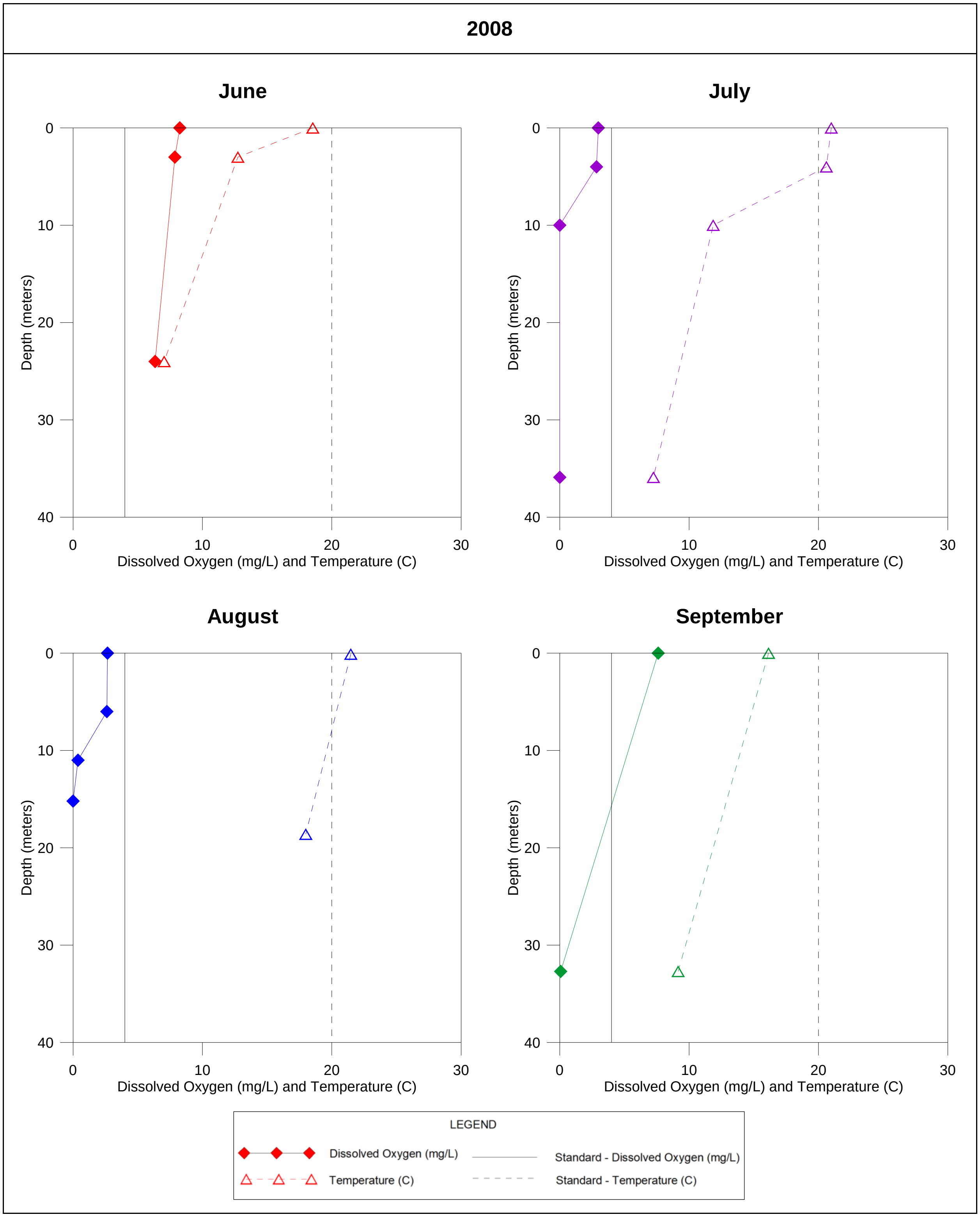

Figure 2.6. Dissolved oxygen and temperature graphs for the Rockport Reservoir Dam (DWQ station 5923310) in 2008.

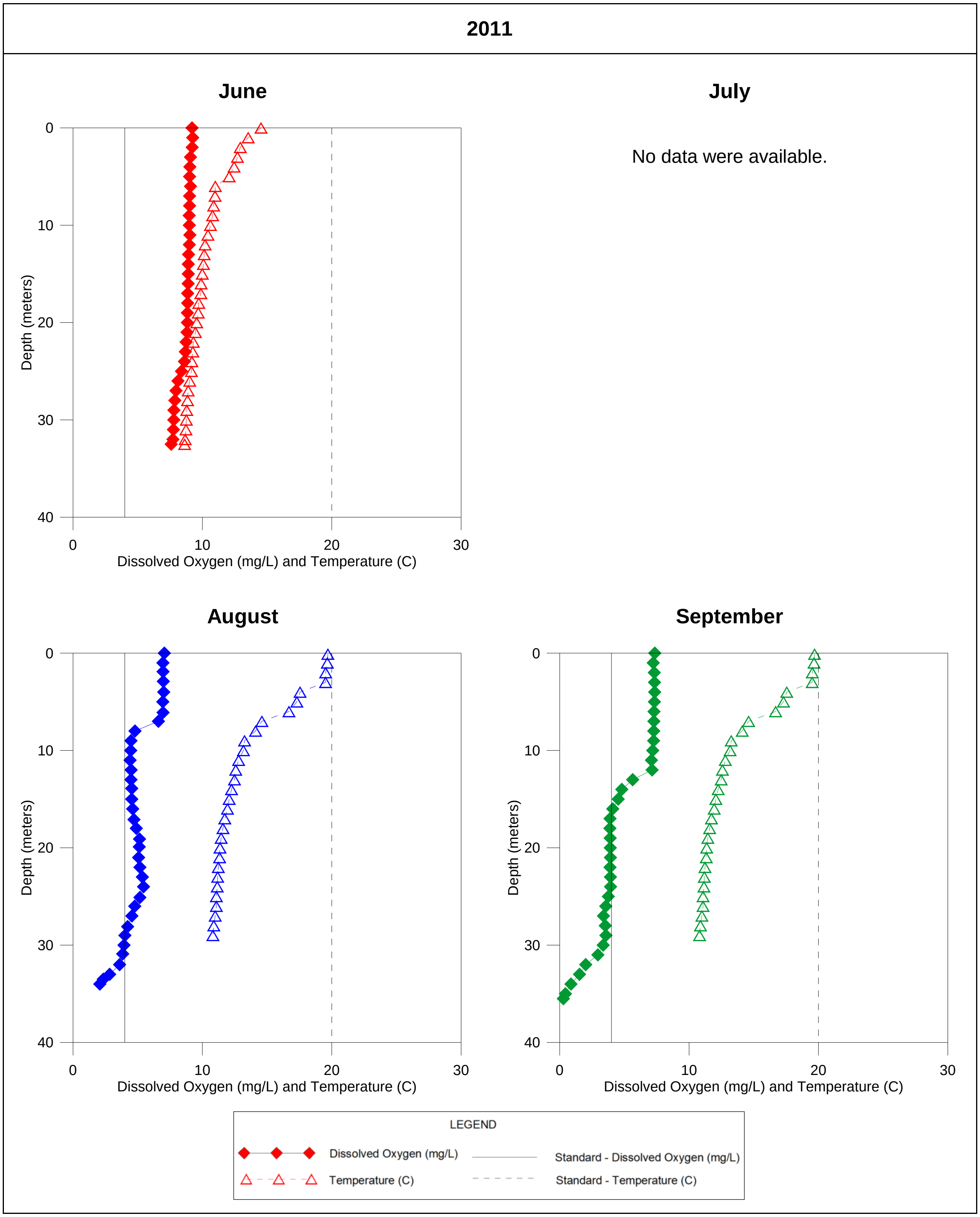

Figure 2.7. Dissolved oxygen and temperature graphs for the Rockport Reservoir Dam (DWQ station 5923310) in 2011.

2.5 History of TMDL Development and Watershed Planning in Echo Reservoir Basin

Local, state, and federal agencies have written scientific and resource management reports that provide data and information pertinent to the current TMDL process. Some reports, such as *Weber River Basin: Planning for the Future* (DWR 2009) and *Weber River Restoration Action Strategy* (Weber River Watershed Coalition 2003) provide background data on the setting and general conditions of the watershed. Other reports, such as the tributary TMDLs, have been completed and approved by the EPA (Table 2.7). Additional studies provide groundwater and surface water data that can be used in the modeling of historic conditions on the Weber River and Rockport and Echo Reservoirs (Table 2.8). Furthermore, although the Rockport and Echo Reservoir TMDL processes were initiated in 2003 (DWQ 2009), a TMDL for Echo Reservoir was completed in 2006 but was held in abeyance by the EPA until additional information was provided (EPA 2009).

Table 2.7. Lists of EPA-Approved TMDLs in the Upper Weber River Watershed Completed since 1995

Waterbody Name	Pollutant Listed	TMDL Date
Chalk Creek	Sediment, TP	October 1997
Silver Creek	Cadmium, zinc	August 2004

Note: Not all waterbodies have currently had assessments.

Table 2.8. Summary of Reports and Studies Relevant to the Echo and Rockport Reservoir TMDL Analysis and Implementation Planning

Topic	Year	Title	Author	Summary of Key Findings Relevant to TMDL Analysis
Tributary TMDL	2006	TMDL Water Quality Study of Echo Creek Watershed, Utah	UDEQ/DWQ	TMDL for sediment load reduction impairing cold-water fishery of Echo Creek, tributary to Weber River, downstream of Echo Reservoir. Contains watershed-wide source identification of sediment.
Tributary TMDL	2004	TMDL Water Quality Study of Silver Creek	UDEQ/DWQ	Defines impairment of Silver Creek for zinc and cadmium. Outlines hydrology of Silver Creek, a tributary to Weber River.
Groundwater hydrology	2003	Hydrology and Simulation of Groundwater Flow in Kamas Valley	U.S. Geological Survey (USGS)	Assesses groundwater and surface water data. Identified background nutrient data as well as sources of additional load.
Groundwater hydrology	2002	Geology of the Kamas-Coalville Region and Its Relation to Groundwater Conditions	Utah Geological Survey	Provides groundwater hydrology background for basin, including hydrostratigraphy and conductivity data.
Fishery	2008	Standard Electrofishing Surveys at East Canyon and Rockport Reservoirs during 2008	Benjamin K. Nadolski Craig J. Schaugaard (DWR)	Provides fisheries background information for beneficial use criteria.
Water quality	2001	Selected Hydrologic and Water Quality Data for Kamas Valley and Vicinity	USGS	Assesses water quality in Upper Weber River and Beaver Creek. Identifies high levels of phosphorous in groundwater.
Water management and planning	2003	Weber River Watershed Restoration Action Strategy	Weber River Watershed Coalition	Provides watershed background, description, and setting. Identifies sources of nutrient and sediment pollution and the strategy Weber River Coalition proposes for restoration and maintaining water quality in the basin.
Water management and planning	2009	Weber River Basin; Planning for the Future	DWR	Provides watershed background, description, and setting. Explains water management in watershed and source data including animal fee operations, stormwater discharges, and other sources of nutrient loading.
Groundwater hydrology	1984	Groundwater Reconnaissance of the Central Weber River area	USGS/DWR	Describes groundwater quality near Coalville.
Groundwater hydrology	1986	Water Resources of the Park City Area with Emphasis on Groundwater	USGS/DWR	Reviews water resources in the Park City area. Shows groundwater in the Silver Creek drainage exceeding state standards for several heavy metals and pH.
Source identification	2005	Clean Water Act Section 319 Nonpoint Source Pollution Control Program Watershed Project Final Report	Natural Resources Conservation Service (NRCS)	Identifies nonpoint source pollution to Chalk Creek, a tributary to Weber River. Identifies accomplished implementation projects to date, and identifies areas that still have room for adoption.
Source identification	1994	Chalk Creek Watershed; Coordinated Resource Management Plan	Soil Conservation Service–U.S. Department of Agriculture	Serves as a TMDL for sediment, phosphorous, and stream habitat impairment for cold-water fishery beneficial use. Provides proposed plan for sediment load reductions.

Table 2.8. Summary of Reports and Studies Relevant to the Echo and Rockport Reservoir TMDL Analysis and Implementation Planning

Topic	Year	Title	Author	Summary of Key Findings Relevant to TMDL Analysis
Source identification	1997–2011	Summit County Three Mile Landfill Monitoring Report	Five Star Engineers	Summarizes groundwater monitoring data, including nitrate measurements, up-gradient and down-gradient of landfill. The close proximity to Rockport Reservoir suggests that landfill leachage could reach Rockport Reservoir.
Echo Reservoir TMDL	2006	Echo Reservoir TMDL Water Quality Study	Cirrus Ecological Solutions, DWQ	Is the draft TMDL for Echo Reservoir. Contains source identification and watershed background data.
Echo Reservoir TMDL	2009	EPA Region VIII TMDL Review of Echo TMDL	EPA	Identifies additional information needed in draft TMDL.
Fishery	1998/ 2006	Revised Fish Hatchery Production Plan Final Environmental Assessment	U.S. Fish and Wildlife Service	Provides regulations for fish hatcheries in Utah, including the Kamas Fish Hatchery in Kamas. Assists in identifying load from point source pollution in the watershed.
Fishery	2008	Fish Population Surveys at Lost Creek, Echo, Smith and Morehouse, Woodruff, and Birch Creek Reservoirs during 2008	Benjamin K. Nadolski Craig J. Schaugaard (DWR)	Provides fisheries background information for beneficial use criteria.
Fishery	1994	Emigration of Juvenile Rainbow Trout from a Mid-Elevation Utah Reservoir	Brad Schmitz, Utah State University, Master's Thesis	Identifies potential behavior of trout in Echo and Rockport Reservoirs. This document will assist in evaluating the spawning potential of rainbow trout, which will help identify degree of impairment as a cold-water fishery.

CHAPTER 3. WATERSHED CHARACTERIZATION

3.1 Geology and Soils

3.1.1 Geology

Most surficial geologic features in the study watershed were formed in the Cretaceous and Eocene eras (from 145 to 34 million years ago) and include the Wasatch, Cotton, Flagstaff, Claron, and White Sage Formations. The Quaternary (most recent) formations consist of alluvial deposits along streams, lacustrine deposits in the valley, and glacial deposits at higher elevations. A summary of geologic formations in the study watershed is shown in Figure 3.1. Permian phosphatic (containing phosphorus) shales, found in the Park City Formation, also occur in the watershed (Figure 3.2). Erosion of these shales contributes phosphorus loading to surrounding surface waters.

3.1.2 Soils

Impacts to water quality from soils are due to stream bank erosion and excess nutrients associated with runoff and sediments washed into the stream. The soil groups that affect water quality at Rockport and Echo Reservoirs are generally the nutrient-rich loamy farmland soils near tributary streams. Soils in the watershed are not naturally high in phosphorus, with the exception of soils derived from the Park City Formation (Figure 3.3). As noted above, recent development in the subbasins where the phosphoric formation occurs has likely caused the erosion of phosphatic soils and increased phosphorus loading in East Canyon Creek (Olsen and Stamp 2000a).

The U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) has collected soils data for the Rockport Reservoir and Echo Reservoir watersheds. The dominant soil types in the watersheds are shown in Figure 3.3, and soil texture and erodibility (K factor) are shown in Figures 3.4 and 3.5, respectively. Soil texture and erodibility are important characteristics for determining agricultural viability and soil stability. The erodibility of soils increases with its representative K factor, which is a function of soil organic matter, soil structure, particle size, soil permeability to water, and clay content. For example, soils high in clay content have a low K factor (0.05–0.15), whereas soils high in silt content generally have a high K factor (greater than 0.4) and are the most erodible type of soil. Soil textures and K factors by acre are presented in Tables 3.1 and 3.2, respectively. Most soils found in the watershed are loamy (i.e., a combination of sand, silt, and clay) and relatively erodible—the average K factor is greater than 0.25. This implies that sediment loads from tributaries to reservoirs should be relatively common.

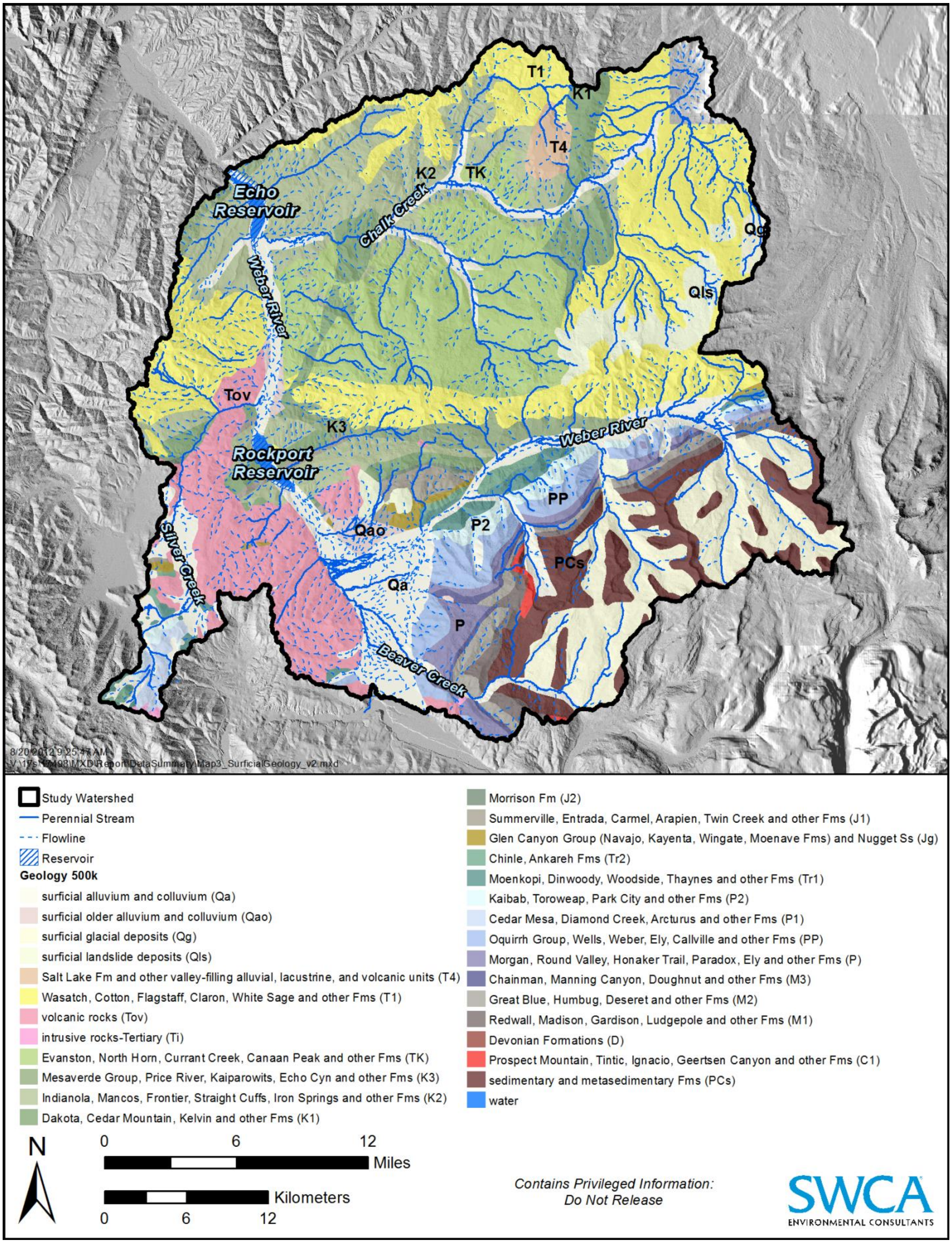

Figure 3.1 Map of geologic formations in the study watershed. (Utah Geologic Survey 2000).

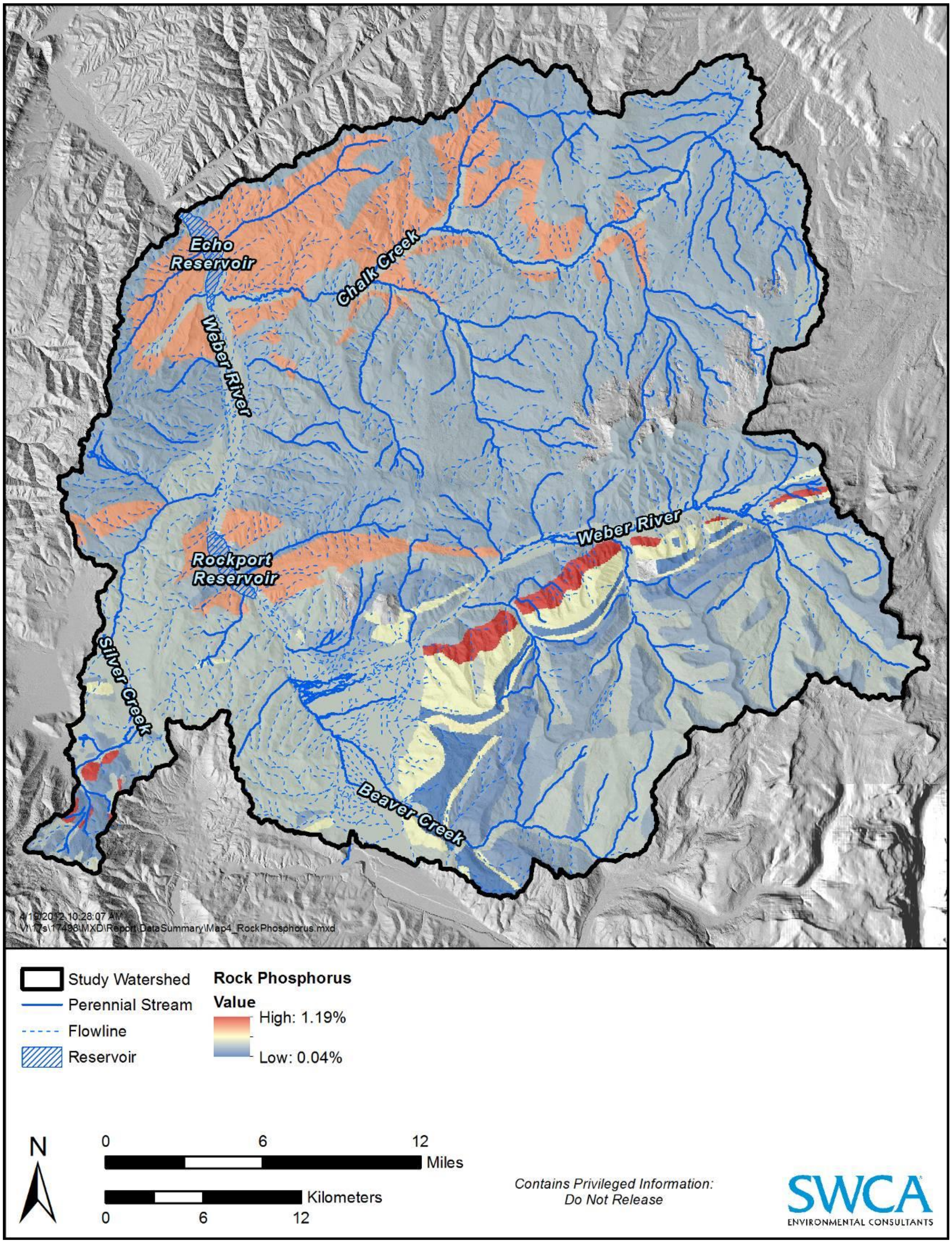

Figure 3.2. Map of rock phosphorus value in the study watershed.

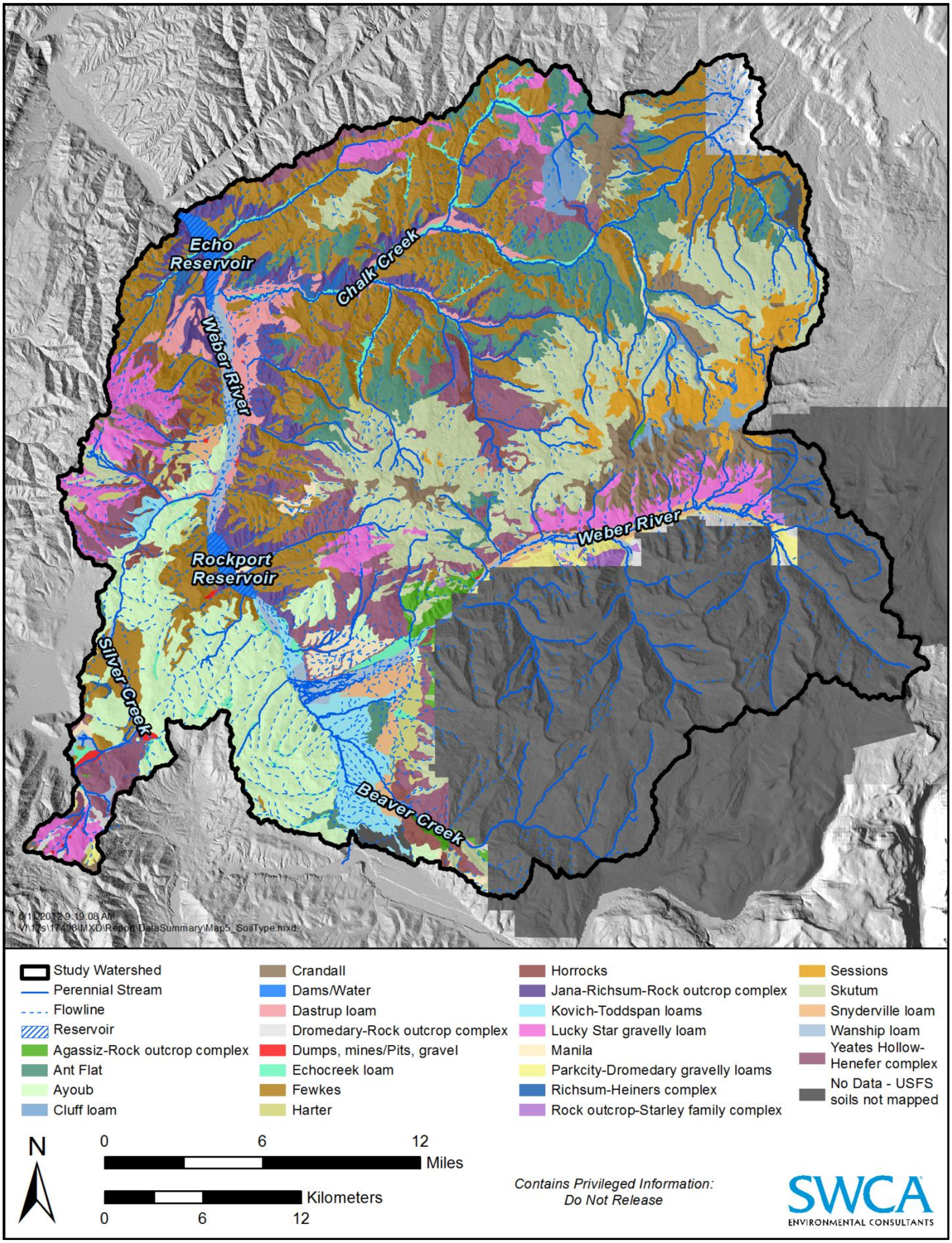

Figure 3.3. Soil types found throughout the study watershed.

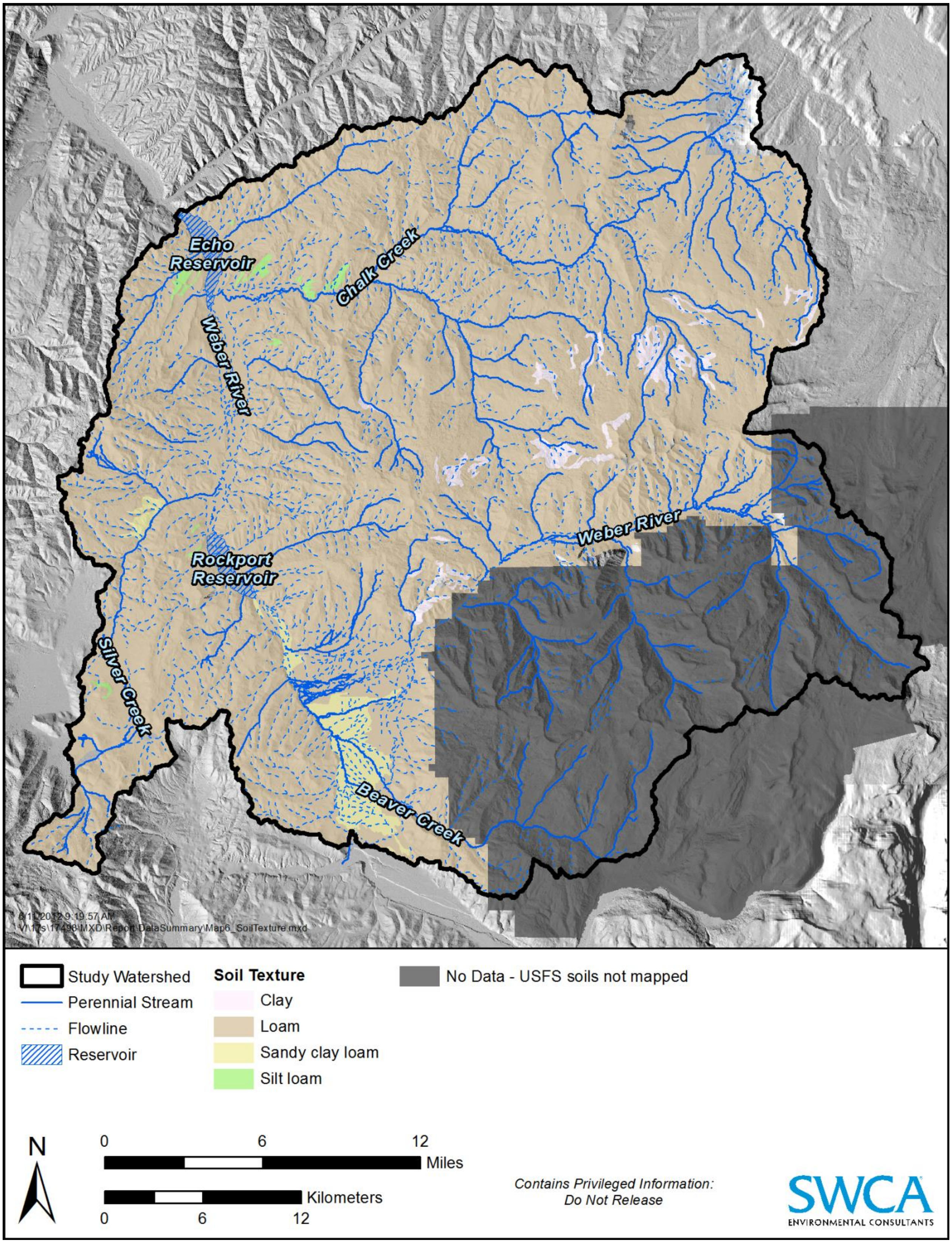

Figure 3.4. Map of soil textures in the study watershed.

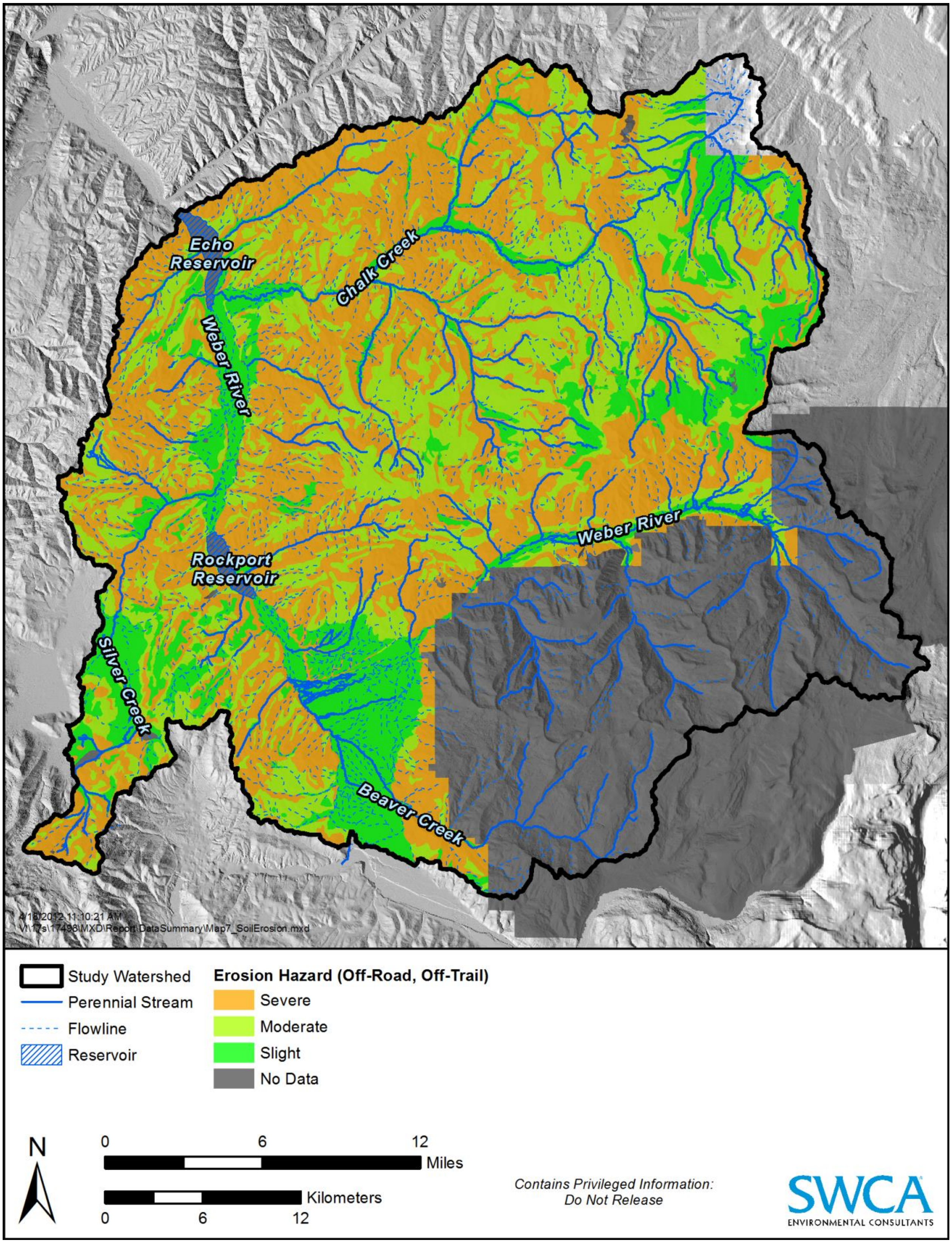

Figure 3.5. Map of erosive soil potential in the study watershed.

Table 3.1. Soil Textures in the Study Watershed by Total Acres

Watershed	Cobbly Loam	Gravelly Loam	Loam	Sandy Loam	Silt Loam	Not Mapped
Echo Reservoir Watershed	6,264	2,507	201,783	N/A	39,816	852
Rockport Reservoir Watershed	24,437	N/A	157,749	20,179	9,265	1,031

Table 3.2. Whole Soil K Factor by Acre for Rockport and Echo Reservoir Watersheds

Whole Soil K Factor	Echo Reservoir Watershed	Percentage of Echo Reservoir Watershed	Rockport Reservoir Watershed	Percentage of Rockport Reservoir Watershed
0.02	N/A	N/A	7,407	3.48%
0.10	N/A	N/A	12,772	6.01%
0.15	2,507	1.00%	N/A	N/A
0.17	6,264	2.49%	24,437	11.49%
0.24	55,726	22.18%	28,260	13.29%
0.28	84,201	33.52%	17,621	8.29%
0.32	5,715	2.27%	53,686	25.24%
0.37	56,140	22.35%	58,182	27.36%
0.43	39,816	15.85%	9,265	4.36%
Not mapped	852	0.34%	1,031	0.48%

3.2 Land Cover and Land Use

Land use is an important parameter to consider when determining nutrient and sediment loads to receiving waterbodies. For example, if the majority of a watershed were covered by agricultural operations, it would be expected that fertilizer-derived nutrients would make up an important component of the total nutrient load. Land cover data for the Rockport Reservoir and Echo Reservoir watersheds were obtained from the 2006 National Land Cover Data program (Fry et al. 2011). Results indicate that for the watersheds under consideration, land cover is dominated by forests and rangeland, while parks, agriculture, and highways represent the least amount of land cover (Table 3.3 and Figure 3.6). These results would imply that nutrient loads from agricultural sources should be minimal when compared to loads from other sources.

Table 3.3. Land Cover Categories for Rockport Reservoir and Echo Reservoir Watersheds

Category	Echo Reservoir Watershed (acres)	Percentage of Echo Reservoir Watershed	Rockport Reservoir Watershed (acres)	Percentage of Rockport Reservoir Watershed
Agricultural	668	0.27%	218	0.10%
Alfalfa	1,659	0.66%	1,420	0.67%
Barren	459	0.18%	4,766	2.24%

Table 3.3. Land Cover Categories for Rockport Reservoir and Echo Reservoir Watersheds

Category	Echo Reservoir Watershed (acres)	Percentage of Echo Reservoir Watershed	Rockport Reservoir Watershed (acres)	Percentage of Rockport Reservoir Watershed
Forest	133,487	53.14%	143,074	67.28%
Hay	2,288	0.91%	2,959	1.39%
Highway	257	0.10%	0	0%
Park	344	0.14%	95	0.04%
Pasture	5,417	2.16%	12,394	5.83%
Rangeland	91,219	36.31%	38,271	18.00%
Urban	8,671	3.45%	4,952	2.33%
Urban low density	2,523	1.00%	1,109	0.52%
Water and wetlands	4,231	1.68%	3,405	1.60%

3.3 Fisheries and Wildlife

The areas surrounding Rockport and Echo Reservoirs are home to various wildlife species, and both reservoirs are popular fishing and recreational destinations. Fish species in the reservoirs include rainbow trout, brown trout, and small mouth bass. The DWR has managed these reservoirs as a “put-grow-and-take” trout fishery since the 1960s and stocks them annually (Schmitz 1994). The reservoirs are managed as “two-story” fisheries in which warm-water species are supported in the upper layers of the reservoirs and cold-water species are supported in the lower layers (personal communication, Chris Penne, DWR, and Erica Gaddis, SWCA, July 3, 2013).

Big-game species in the watershed include mule deer (*Odocoileus hemionus*), elk (*Cervus canadensis)*, and moose (*Alces alces*). Common mammals in the area include yellow-bellied marmot (*Marmota falviventris*), gophers (*Thomomys spp.*), coyotes (*Canis latrans*), porcupines (*Erethizon dorsatum*), striped skunks (*Mephitis mephitis*), and raccoons (*Procyon lotor*). Common waterfowl and shorebird species in and around the reservoirs include mallard (*Anas platyrhynchos*), gadwall (*Anas strepera*), northern pintail (*Anas acuta*), teal (*Anas spp.*), redhead (*Aythya americana*), Canada goose (*Branta Canadensis*), sandhill crane (*Grus Canadensis*), killdeer (*Charadrius vociferous*), great blue heron (*Ardea alba*), Clark's grebe (*Aechmorphorus clarkia*), western grebe (*Aechmorphorus occidentalis*), gulls (*Larus spp.*), and plovers (*Pluvialis spp*.). It is likely that some of these waterfowl and shorebird species use riparian habitats along tributary streams, as well.

3.4 Landownership

Landownership in the Echo Reservoir and Rockport Reservoir watersheds is split among private, federal lands, and state-owned lands (Figure 3.7). Private landownership makes up the largest portion (77.0%), whereas federal lands (U.S. Forest Service [USFS] and Bureau of Land Management [BLM]) and state lands (state parks, trust lands, and wildlife management areas) make up the remaining 22% and 1%, respectively (Table 3.4).

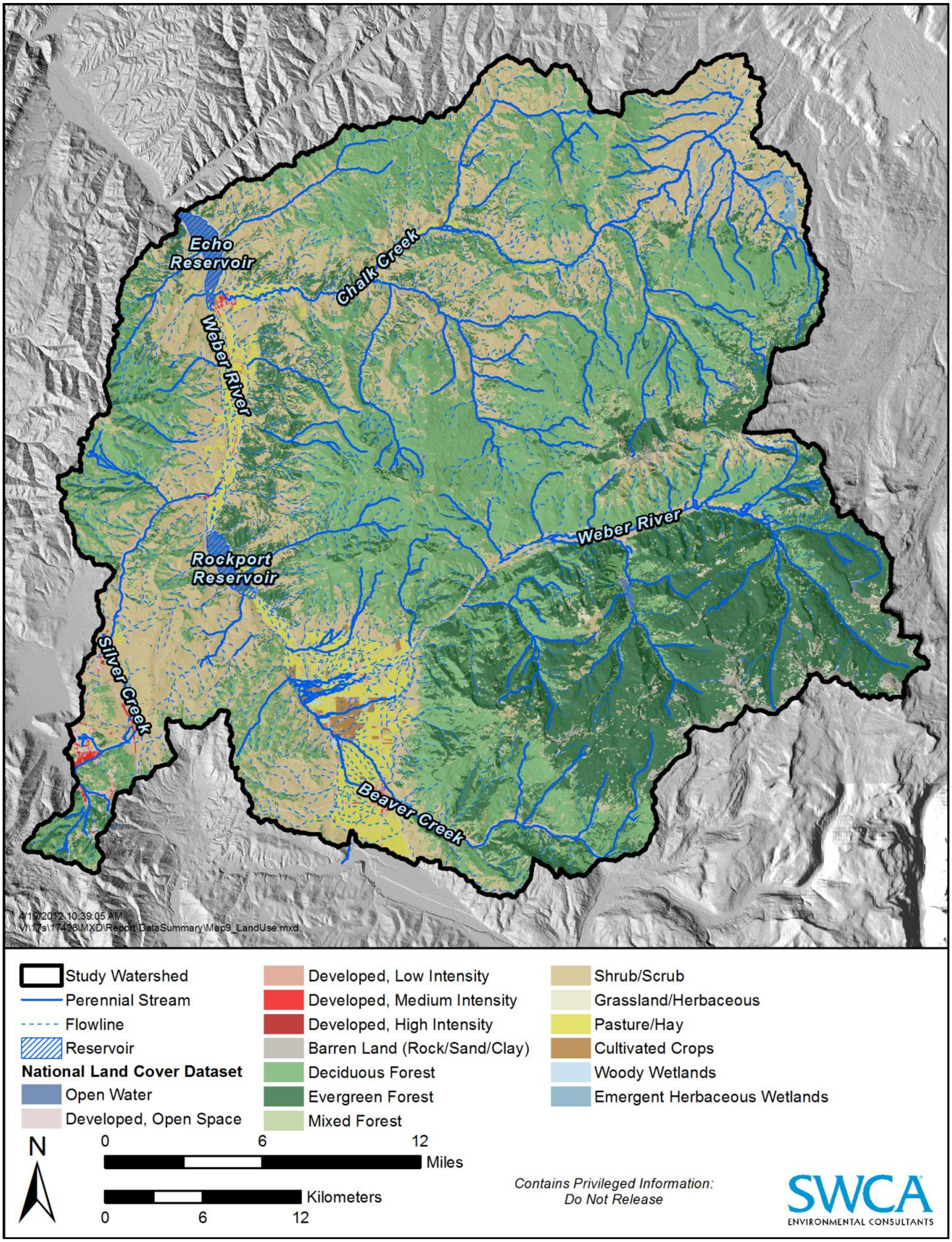

Figure 3.6. Map of land use and land cover in the study watershed.

As discussed previously, agriculture in Summit County makes up relatively small part of the economy, joining forestry, fisheries, hunting, and mining to total only1.6% of industry in Summit County (U.S. Census Bureau). However, the social connection to historic land use is important in the local communities. While the proportion of land used for agriculture has decreased, agriculture has contributed and continues to contribute to the area's sense of place and visual quality. Between 2002 and 2007, the area of land used for agriculture in Summit County increased 10% from 375,689 acres to 414,928 acres. Agricultural land uses in Summit County are dominated by grazing or pasture land (92%), followed by cropland (7%) and other uses (1%) (National Agricultural Statistics Service 2007).

Table 3.4. Landownership for Rockport Reservoir and Echo Reservoir Watersheds

Category	Echo Reservoir Watershed (acres)	Percentage of Echo Reservoir Watershed	Rockport Reservoir Watershed (acres)	Percentage of Rockport Reservoir Watershed
BLM	294	<1%	156	<1%
USFS	0	0%	100,254	47%
Private	249,315	99%	108,969	51%
State parks and recreation	125	<1%	1,736	<1%
State trust lands	1	<1%	280	<1%
State wildlife reserve/management area	1,487	<1%	1,268	<1%
Total	251,222	100%	212,663	100%

3.5 Stream Hydrology

In order to determine a TMDL for the reservoirs under consideration, it is crucial to understand how and where loads are delivered. Therefore, a stream hydrology assessment is needed. The main pathway through which loads are delivered to the reservoirs is the Weber River. In the watershed addressed in this TMDL, the Weber River drains 725 square miles of the western slope of the Uinta Mountains and connects Rockport and Echo Reservoirs. Its major tributaries are Smith and Morehouse Creek, the South Fork of the Weber River, Beaver Creek, Silver Creek, and Chalk Creek. For clarity in this report, the Weber River is divided into two segments: the stream network above Rockport Reservoir and the stream network above Echo Reservoir (i.e., below Rockport Reservoir).

3.5.1 Stream Network above Rockport Reservoir

The first major tributary to enter the Weber River is Smith and Morehouse Creek at river mile 21.3 (measured upstream from the Wanship Dam at river mile 0.0). The Smith and Morehouse Reservoir is approximately 6.0 miles upstream from the confluence of Smith and Morehouse Creek and the Weber River. The Smith and Morehouse Reservoir has a storage capacity of approximately 1,360 ac-ft.

Below the Smith and Morehouse Creek confluence, the Weber River flows west, receiving flows from several smaller tributaries from the north. At river mile 16.5, the South Fork of the Weber River joins the Weber River. The Weber River then turns north and is joined by Beaver Creek, the largest tributary in this segment of the river, at river mile 7.9. The Weber River then flows into Rockport Reservoir, which at full capacity has a surface area of 1,189 acres and storage capacity of approximately 75,000 ac-ft. Figure 3.8 is a stem diagram of the Weber River from its headwaters to Rockport Reservoir, including major tributaries and diversions.

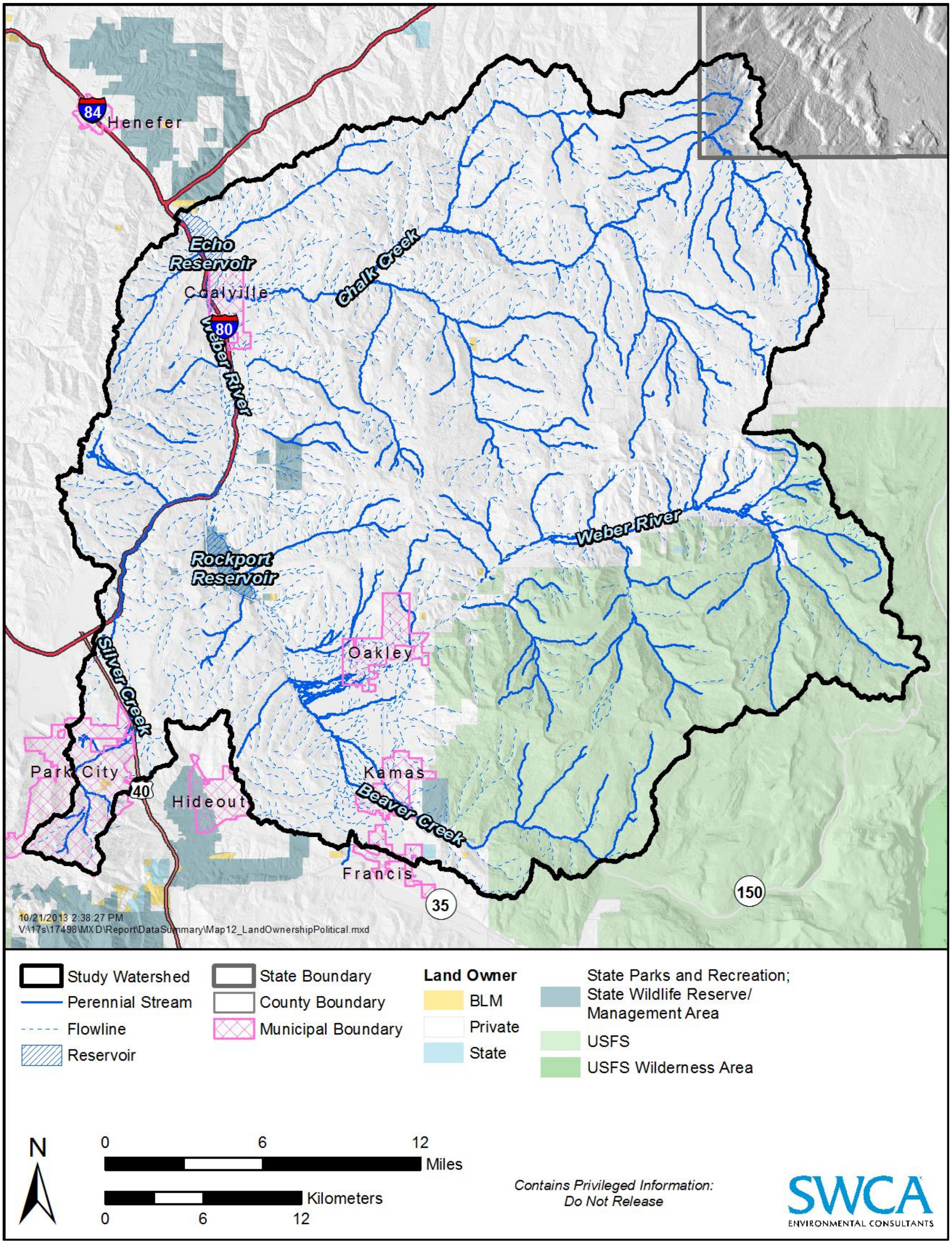

Figure 3.7. Map of landownership in the study watershed.

3.5.2 Stream Network above Echo Reservoir

Water released from the Wanship Dam at Rockport Reservoir flows north for approximately 2 miles before it is joined by Silver Creek at river mile 13.6 (measured upstream from Echo Dam). The Weber River then flows north through agricultural lands for another 8.0 miles before entering Echo Reservoir, which is a shallower reservoir having a surface area of 1,394 acres and a storage capacity of approximately 50,000 ac-ft. The largest tributary to this segment of the river is Chalk Creek, which flows directly into Echo Reservoir when the reservoir is at full capacity; otherwise, it flows into the Weber River at river mile 5.0. Figure 3.9 illustrates a stem diagram of the Weber River from Rockport Reservoir to Echo Reservoir, including major tributaries and diversions.

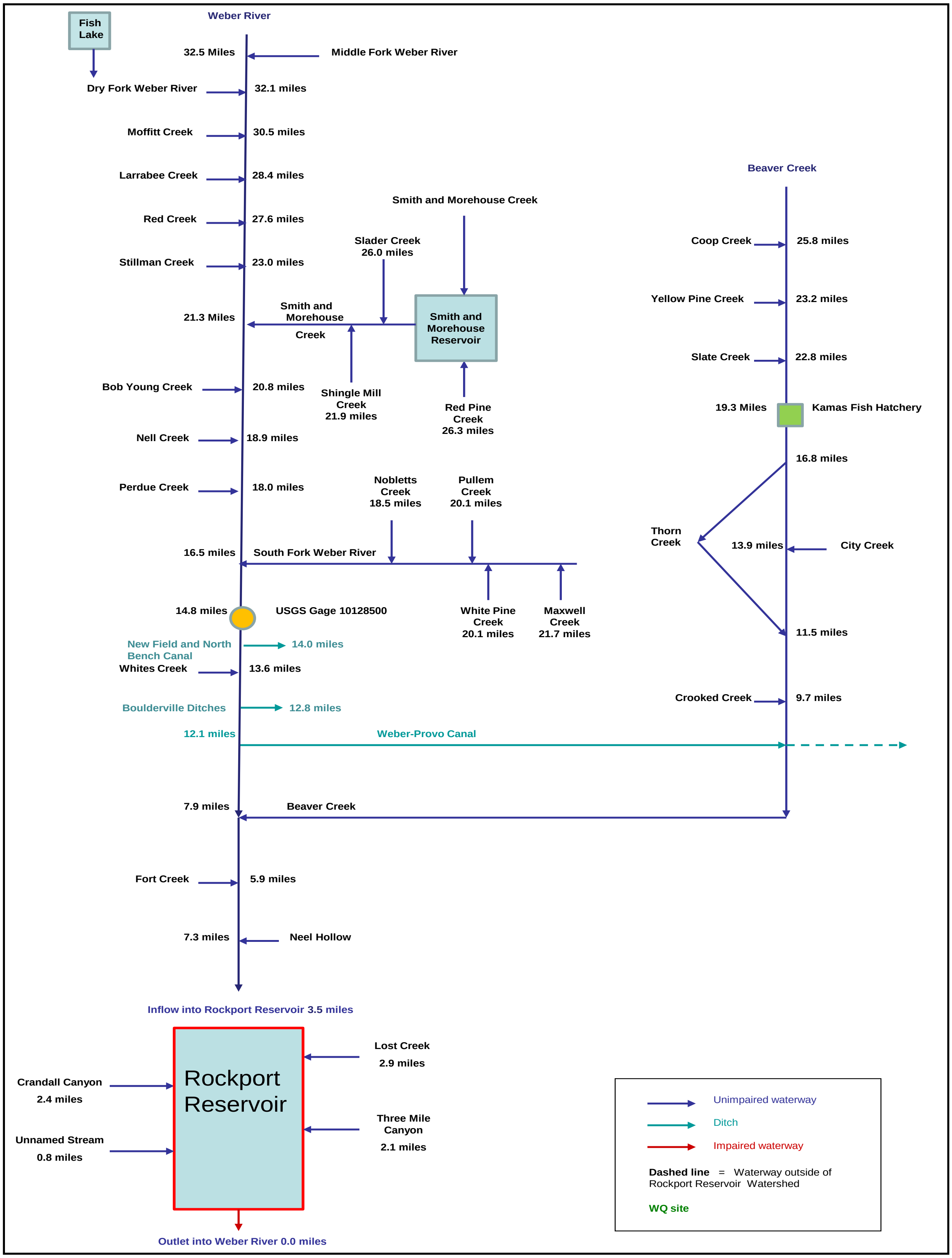

Figure 3.8. Stream network from Weber River headwaters to Rockport Reservoir (not to scale).

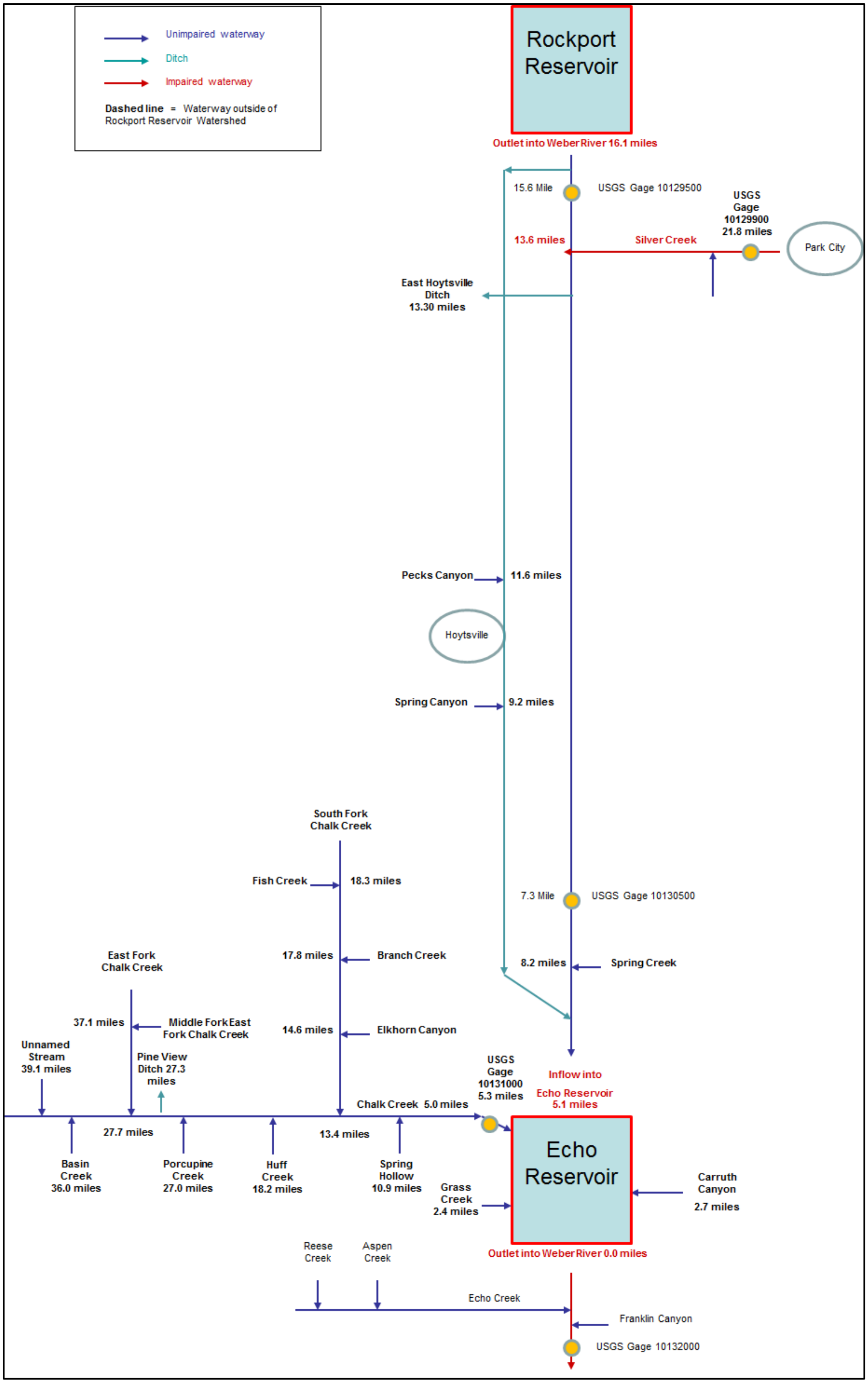

Figure 3.9. Stream network from Rockport Reservoir to Echo Reservoir (not to scale).

CHAPTER 4. WATERSHED AND RESERVOIR MODELING

4.1 Model Goals and Objectives

Developing the TMDL for the Rockport and Echo Reservoirs involved using two models: BATHTUB and the Soil and Water Assessment Tool (SWAT). BATHTUB is an empirical reservoir model based on data from over 500 reservoirs across the United States. BATHTUB models nitrogen and phosphorus loads for reservoirs to determine algal growth and DO depletion rates during stratification. It is also used to model reservoir management scenarios and to determine load reductions required to achieve water quality targets. SWAT is a spatially distributed watershed model that simulates hydrology, plant growth, and nutrient and sediment transport processes in a watershed. Simply put, SWAT was used to model relative contribution of nutrient loads to the reservoirs associated with watershed sources, and BATHTUB was used to model load effects within reservoirs.

For modeling purposes, separate watershed and reservoir models were created for the Rockport Reservoir Watershed and the Echo Reservoir Watershed (Figure 4.1). The Rockport Reservoir Watershed includes the headwaters of the mainstem of the Weber River and Beaver Creek, a major tributary to the Weber River. The watershed area between the dam at Echo Reservoir and the dam at Rockport Reservoir is considered the Echo Reservoir Watershed for SWAT modeling. Silver Creek and Chalk Creek are major tributaries that drain the Echo Reservoir Watershed and flow into the Weber River above the Echo Reservoir.

There are two reasons for creating the two SWAT models for the TMDL. First, the split allows the BATHTUB model results for Rockport Reservoir to be easily incorporated into the Echo Reservoir Watershed SWAT model as a release from Rockport Reservoir into the downstream watershed. Second, measured outflow data exist for Rockport, which eliminates the need to model and calibrate Rockport Reservoir releases as part of the hydrology in SWAT, thereby removing the uncertainty associated with simulating reservoir releases.

Baseline BATHTUB reservoir models were developed for several different conditions: dry weather and low reservoir level conditions, average weather and average reservoir level conditions, and wet weather and high reservoir level conditions. Each of these conditions has occurred since 2000. BATHTUB scenarios with varying levels of nutrient input from the watershed (as modeled from SWAT) as well as changes in reservoir operation were run and compared to the baseline model to determine the nutrient load reduction needed to meet water quality standards for DO.

4.2 Modeled Conditions

BATHTUB was set up to model representative dry (2004), average or expected normal (2007), and wet (2011) hydrologic conditions (Figure 4.2). Note that although 2004 was a dry year for most of the Weber River Basin, the flows above Rockport Reservoir are higher than in 2007. The SWAT models were set up to run from January 1, 1998, to December 31, 2011. The years 1998 through 2001 are considered warm-up years. Warm-up years are the first years in a model run that allow the model to initiate plant growth and other watershed processes. However, the output for these years is not used in the analysis to reduce the effects of initial model conditions on results. The year 2007 is considered an average year for stream flow and reservoir level, and is used for modeling average conditions in the study watershed.

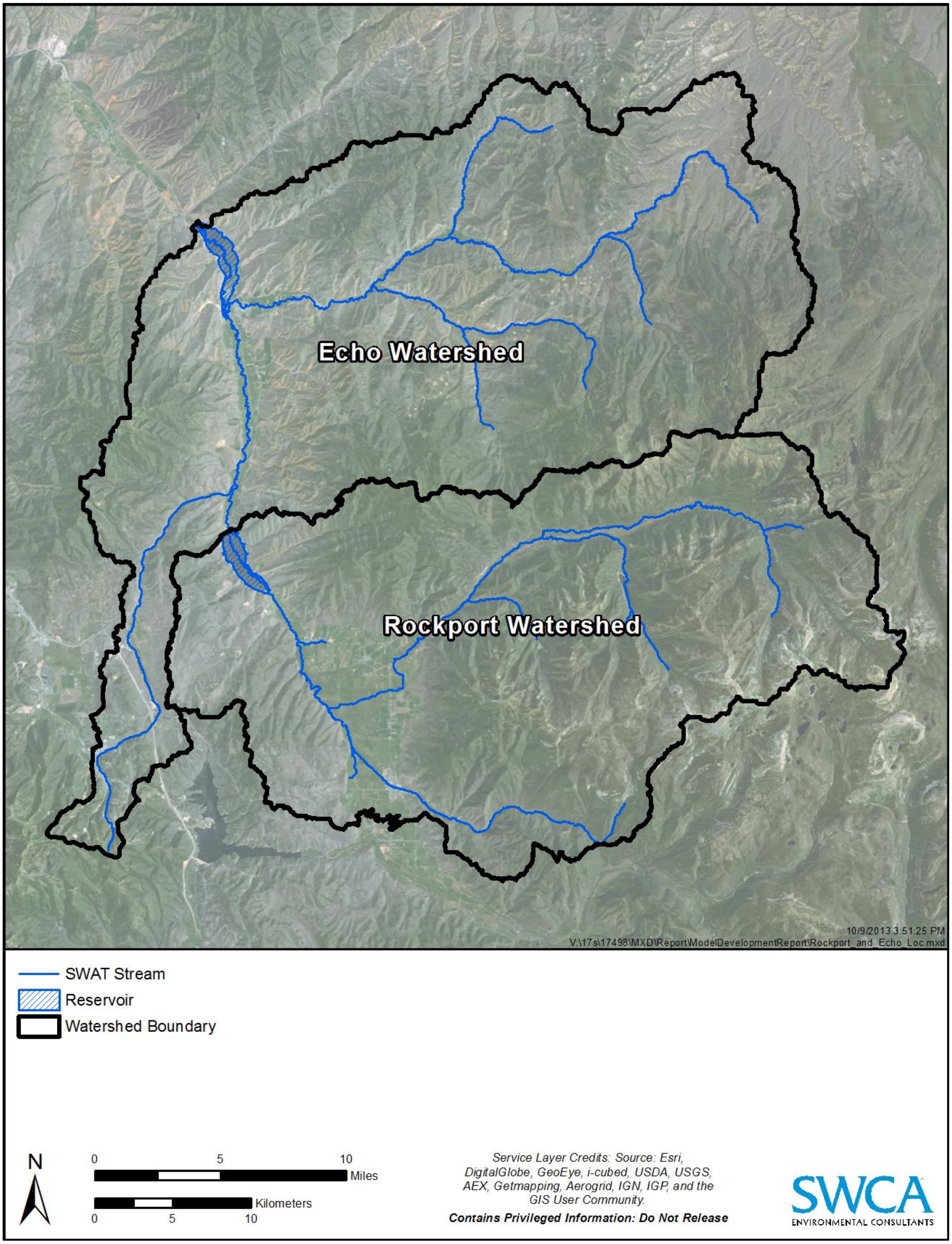

Figure 4.1. Subwatersheds in the study watershed.

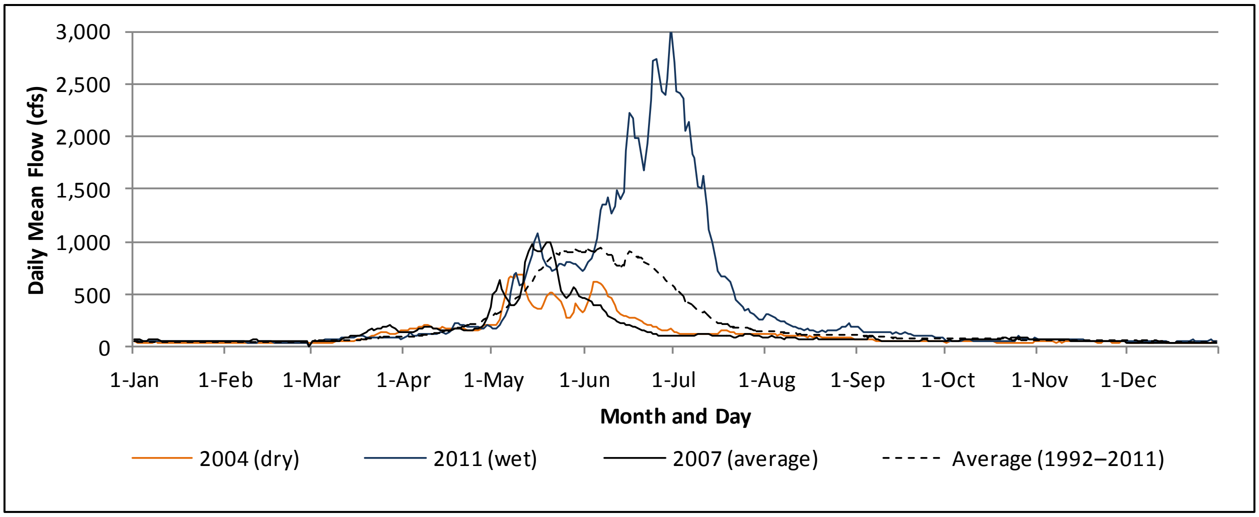

Figure 4.2. Dry, wet, and average year hydrographs for Weber River near Oakley, Utah (USGS gage number 10128500).

4.3 Watershed Model: Soil and Water Assessment Tool

SWAT is used to predict the effect of management decisions on water, sediment, nutrient, and pesticide yields with reasonable accuracy on large, ungaged river basins (Gassman et al. 2007). SWAT is an interdisciplinary watershed modeling tool that has been used to conduct a variety of analyses, including hydrologic studies, pollutant load assessments, climate change impacts, and TMDLs (Gassman et al. 2007). The USDA's Agricultural Research Service created the SWAT model and continues to update the model and provide technical support for users. For the TMDL analysis, SWAT 2012 Version 591 was run using ArcGIS 10.0 SP5.

SWAT models watershed processes at a subbasin scale (see Figure A-1 in Appendix A). Each watershed was split into subbasins based on the stream network, locations of gages for calibration, and locations of known point sources. Because SWAT estimates discharge and nutrient loads on a subbasin level within the overall watershed, the SWAT model outputs can be used to identify subbasins with high nutrient loads, which is useful in developing a practicable and targeted implementation plan. The modeling was conducted at the subbasin scale and then aggregated up to larger subwatersheds for the source identification portion of the analysis (Chapter 5).

The SWAT model incorporates data on climate, land cover and land use, soils and topography, and known point sources to simulate hydrology, nutrients (nitrogen and phosphorus), plant growth, and erosion. SWAT allows users to apply watershed-specific information about fertilization practices, grazing practices, irrigation, and septic systems to model nutrient loading from the watershed. The SWAT model also incorporates monitoring data from point sources in the watershed such as the Silver Creek and Coalville City wastewater treatment plants (WWTPs).

In SWAT, hydrology is generated using weather data. Default weather station data are available in SWAT for the United States. However, the model is improved if precipitation and temperature data are provided from weather stations in or near the watershed. Six data stations in and around the watershed were used for the SWAT models developed for Rockport Reservoir and Echo Reservoir Watersheds. SWAT also accounts for snowmelt and snowfall effects with snow parameters, and scales precipitation amount and type (snow versus rain) based on elevation. Snow parameters were important in calibrating the timing of the snowmelt in the watershed and subsequent peaks and baseflows. SWAT also uses weather data to estimate evapotranspiration from the watershed.

SWAT generates surface water hydrology using a digital elevation model and weather data from weather stations in or near the watershed. The curve number approach was chosen to estimate runoff volume from the watershed, whereas a modified rational method was used to calculate a peak flow. Groundwater and soil water are also components in the SWAT model, with input tables to adjust those portions of the hydrologic cycle. The USGS gage data and the USGS Baseflow Program algorithms were used to estimate baseflow, which is the contribution of water from groundwater to streams.

Changes in hydrology from human actions are also simulated in SWAT either through its point source feature or as a management operation. In SWAT, a point source is a way to add or subtract flow, sediment, and nutrients to a subbasin from a source that is not included in the land use or soil layers. Additional flow from a WWTP is one example. The Weber-Provo diversion, which removes water from the watershed, is an example of a point source that subtracts flow. Irrigation was also simulated using the management features in SWAT.

Reservoirs can be included in SWAT to simulate the effects of storage and release on the hydrology of the watershed. Only the Smith and Morehouse Reservoir was included in the Rockport Reservoir Watershed SWAT model because its effects on flow in the Weber River are important. Rockport Reservoir and Echo Reservoir were intentionally left out because large reservoirs are not well modeled in SWAT for water quality. Instead, reservoir water quality was modeled using BATHTUB.

SWAT models nutrient transport and transformations in the watershed through soil, groundwater, and surface water. SWAT estimates the loads of nitrogen and phosphorus from nonpoint sources described by specific soil and land use combinations (e.g., urban or agricultural runoff) including parameters associated with land management. Management activities include grazing and fertilizer application as well as planting and harvesting of crops. Point sources can represent any type of additional nutrient load. The Rockport Reservoir and Echo Reservoir Watersheds include point sources for WWTPs, a fish hatchery, and tunnels carrying stormwater and groundwater to Silver Creek. The point source inputs include loads for organic nitrogen, nitrite, and ammonia as well as mineral and organic forms of phosphorus. SWAT generates output for these nutrient forms on a reach scale.

4.4 Reservoir Model: BATHTUB

The BATHTUB reservoir model was developed by the U.S. Army Corps of Engineers as a sophisticated empirical model for predicting eutrophication in reservoirs. The model predicts nutrient concentrations, chlorophyll *a*, Secchi depth, and other eutrophication indices in a spatially segmented reservoir under steady-state conditions (Walker 1999). Model inputs include reservoir shape (mean depth, length, width, and mixed-layer depth), hydraulic connectivity (between reservoir segments and tributaries), tributary water quality (total nutrients, dissolved nutrients, and flow), climatic parameters (precipitation and evapotranspiration), definition of the stratification season, and atmospheric deposition of nutrients. The model uses empirical equations for physical processes, including advective transport, diffuse transport, and nutrient sedimentation to predict nutrient concentrations and reservoir water quality.

Each set of inputs used specific sources and required individual assumptions which are discussed in detail in Appendix A. The model predicts average water quality in the reservoirs for the defined stratification season. The summer stratified period is the most critical for DO concerns because stratification prevents the mixing of oxygen rich waters at the surface into the lower parts of the reservoir (hypolimnion). Algal growth also occurs during the summer season, the decomposition of which leads to low DO in the hypolimnion. Calibration of the BATHTUB model also requires estimates of reservoir water quality parameters, which are discussed in Appendix A.

4.4.1 Stratification Season

The reservoirs were assumed to be thermally stratified for 137 days from May 15 to September 30. These dates were selected based on evaluation of all temperature and DO profile data available for the reservoirs. Temperature and DO profile data from the years 2004, 2007, and 2011 were used to further validate the use of this stratification season assumption for all of the conditions modeled (see Figures 2.2 through 2.7). These dates were used to determine reservoir elevation at the beginning and ending of stratification using data available from the BOR (2012). Elevations at both reservoirs are significantly lower at the end of the season for 2004 and 2007. In 2007, the water level in Rockport Reservoir began at 1,839.4 m and ended at 1,829.6 m. The year 2011 was wet, and end-of-season elevation was slightly higher than at the beginning for Echo Reservoir and significantly higher for Rockport Reservoir.

4.4.2 Reservoir Shape and Segmentation

Rockport Reservoir and Echo Reservoir were each divided into a mid-upper pool segment and a dam segment (Figures 4.3 and 4.4). Chalk Creek and Weber River are tributaries to the Echo Reservoir mid-upper pool segment; Weber River is the only tributary to the mid-upper pool for Rockport Reservoir. Tributary inputs for each of the dam segments are based on direct discharge into the reservoirs. Reservoir shape includes seasonal starting and ending elevations; average length, width, and depth; surface area; depth at stratification of mixed layer and hypolimnion; and volume. An updated (2007) bathymetry dataset was available for Rockport Reservoir, but no bathymetry data were available for Echo Reservoir. Depth measurements collected throughout Echo Reservoir in summer 2007 by the Weber Basin Water Conservancy District were used, together with contour data available at the surface of the reservoir, to generate a simplistic bathymetry dataset for purposes of estimating reservoir shape at varying elevations. Spatial analysis tools in ArcGIS, including volumetric estimation, were used to calculate all reservoir dimensions except hypolimnetic depth. Hypolimnetic depth was determined through examination of depth profiles of temperature and DO collected during each year at various times during the stratification season. From these data, the percentage of the total depth that is represented by the hypolimnion and metalimnion was determined for both the mid-upper pool and dam segments.

4.5 Model Results

Modeling results from SWAT were used to determine the total nutrient loads to each reservoir under three conditions (dry, wet, and average). Loads are summarized in the current load section of Chapter 6. The SWAT model was also used to differentiate the sources generated by each nonpoint source at the subwatershed scale, the results of which are presented in Chapter 5. In addition, the SWAT model was used to derive delivery ratios for nitrogen and phosphorus from each subwatershed to the reservoir of interest. Delivery ratios represent nutrient processing between a source and the receiving waterbody. These delivery ratios are incorporated into the load analysis and source identification components of the TMDL (Chapters 5 and 6).

Modeling results from BATHTUB were used to derive water quality targets for the TMDL and to determine the necessary nutrient load reductions for the reservoirs (see Chapter 6). A summary of model calibration and results is also provided in Appendix A.

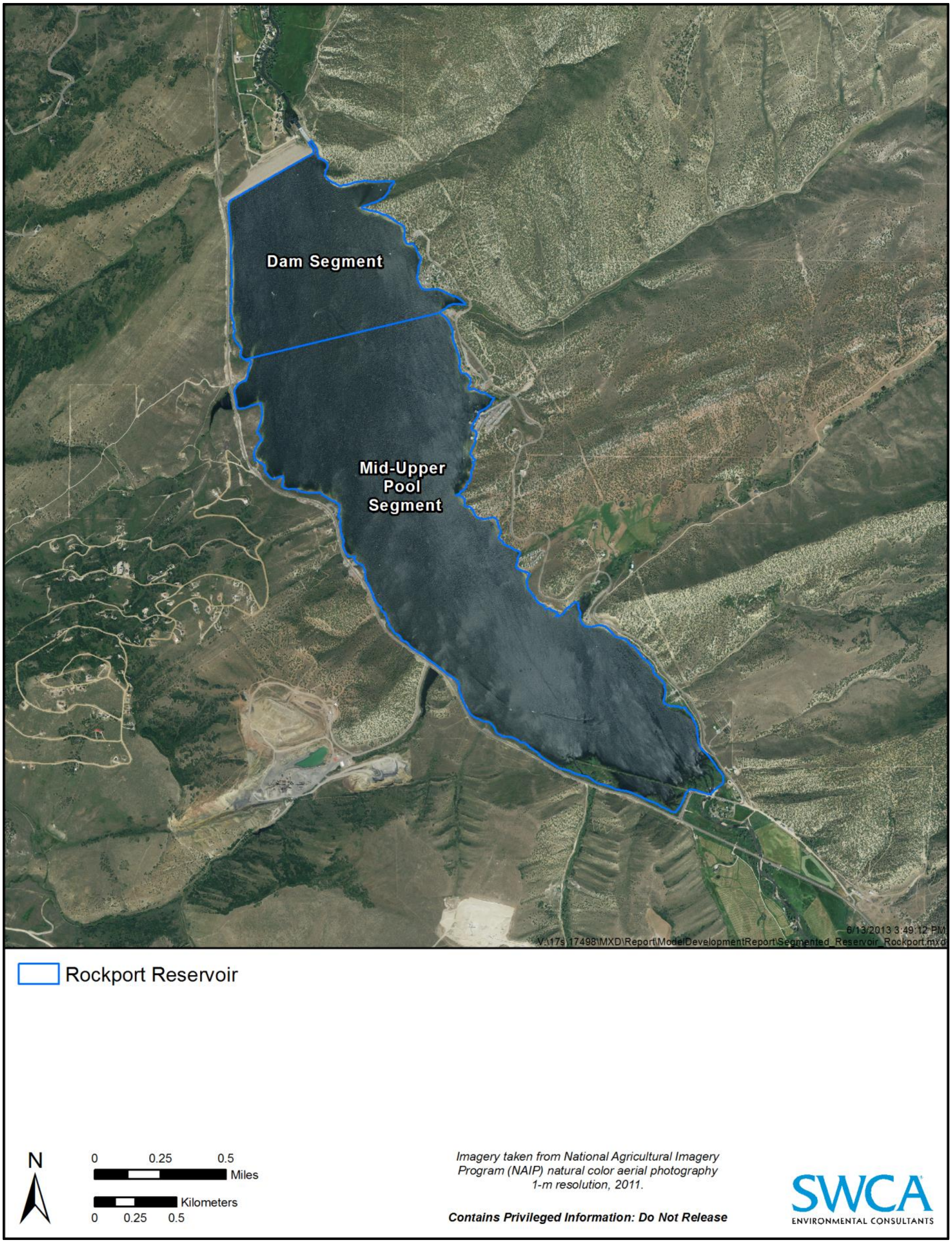

Figure 4.3. Rockport Reservoir model segments.

Figure 4.4. Echo Reservoir model segments.

CHAPTER 5. SOURCE IDENTIFICATION

This section discusses nutrient sources that contribute to the DO impairment of Rockport and Echo Reservoirs. The Weber River and its major tributaries Silver Creek, Chalk Creek, and Beaver Creek transport nutrients from point sources and nonpoint sources in the watershed to the reservoirs. The point sources consist of four existing WWTPs, a fish hatchery, and a series of mine tunnels originating in the Park City area. Blue Sky Ranch is a new point source with planned discharge into the watershed. Francis WWTP is an existing non-discharging lagoon system that may convert to a discharging system in the near future. Nonpoint sources of nutrients in the watershed include stormwater runoff, agricultural activities, channel erosion, septic systems, and channel erosion. The Summit County landfill is also known to contribute nitrate to Rockport Reservoir. In addition, releases from Rockport Reservoir represent an upstream load to the Echo Reservoir Watershed. Agricultural activities consist of irrigation and fertilizer applications to support crops, crop harvesting, and grazing of sheep and cows. Grazing occurs on public and private land. Contributions from individual nonpoint sources vary throughout the year and by location within the watershed. These sources are difficult to monitor and are not regulated; however, their impacts can be mitigated through best management practices (BMPs), reservoir management, and channel stabilization.

Rockport Reservoir Watershed and Echo Reservoir Watershed are divided into subwatersheds (Figure 5.1) for purposes of source identification. Characterizing sources at the subwatershed level contributes to a more meaningful implementation plan that is based on prioritization of BMPs for specific sources and areas of the watershed. Characteristics for each subwatershed that illustrate the relative importance of specific sources are summarized in Table 5.1. All of the nutrient loads discussed in this section are seasonal, representing the period of April 1–September 30, the critical period for DO impairment in the reservoirs. Loads are derived based on data and model output for the year 2007, a year that represents an average climatic condition and for which there are sufficient water quality data in the tributaries and reservoirs to develop and calibrate watershed and reservoir water quality models (see Appendix A).

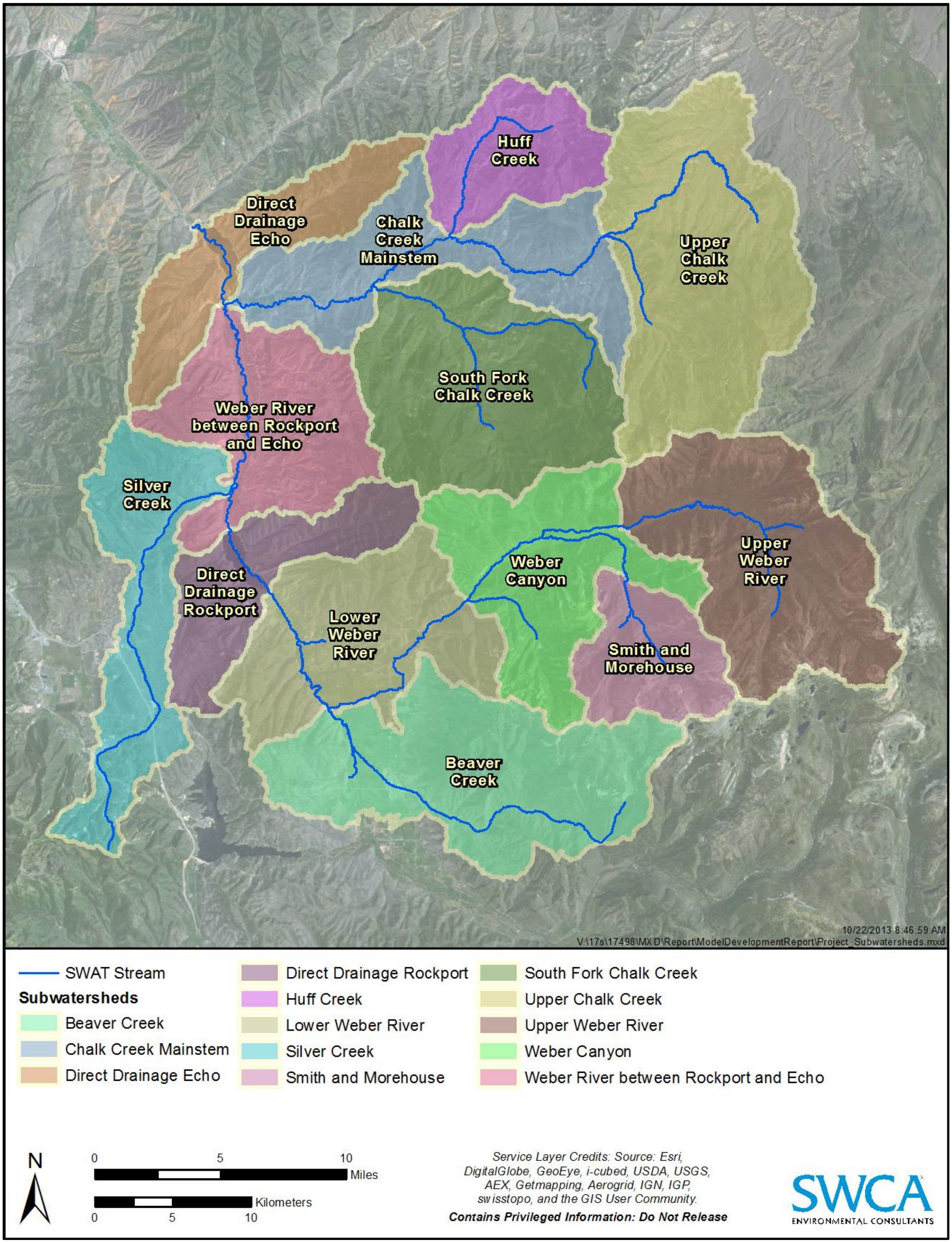

Figure 5.1. Subwatersheds used for source identification and characterization in the Rockport Reservoir Watershed and Echo Reservoir Watershed.

Table 5.1. Characteristics of Subwatersheds in the Rockport Reservoir and Echo Reservoir Watersheds

Subwatershed	Total Acreage	Percentage Agricultural	Percentage Urban	Percentage Forest, Shrub, and Wetland	Point Sources	Nitrogen Delivery Ratio	Phosphorus Delivery Ratio	TN Load to Reservoir	TP Load to Reservoir
Rockport Reservoir Watershed									
Beaver Creek	53,549	13.5%	3.9%	82.6%	Kamas WWTP and DWR fish hatchery	79%	83%	2,981	687
Direct Drainage Rockport	22,584	0.5%	5.0%	94.5%	None	100%	100%	2,948	306
Lower Weber River	36,572	21.1%	3.8%	75.2%	Oakley WWTP	100%	100%	3,434	814
Smith and Morehouse	17,627	<0.1%	0.4%	99.6%	None	55%	56%	1,596	126
Upper Weber River	47,514	1.5%	0.4%	98.1%	None	45%	56%	3,453	225
Weber Canyon	34,817	3.5%	3.7%	92.8%	None	67%	56%	4,161	180
Total	**212,663**	**8.0%**	**2.9%**	**89.1%**	**N/A**	**N/A**	**N/A**	**18,573**	**2,337**
Echo Reservoir Watershed									
Chalk Creek Mainstem	36,181	7.9%	2.7%	89.4%	Coalville WWTP	100%	100%	6,076	547
Direct Drainage Echo	23,793	3.8%	2.2%	94.0%	None	100%	100%	416	187
Huff Creek	19,767	1.6%	0.7%	97.8%	None	71%	70%	1,001	444
Silver Creek	32,556	4.1%	25.0%	70.9%	Silver Creek Water Reclamation Facility; Park City tunnels; Blue Sky Ranch	75%	72%	13,841	2,246
South Fork Chalk Creek	47,863	0.6%	0.8%	98.5%	None	84%	84%	2,317	310
Upper Chalk Creek	56,876	0.2%	0.3%	99.5%	None	82%	83%	2,332	53
Weber River between Rockport and Echo	34,186	12.3%	4.3%	83.4%	None	100%	100%	16,727	1,599
Total	**251,222**	**4.0%**	**4.7%**	**91.3%**	**N/A**	**N/A**	**N/A**	**42,709**	**5,387**

5.1 Point Sources

Point sources of nutrients have the potential to affect water quality year-round in the Weber River Basin. During periods of low flow, point sources represent a larger portion of the load to streams. Currently, four municipal WWTPs discharge treated effluent at seven outfalls in the watershed (Figure 5.2). The outfalls discharge nutrients, organic matter, and sediment, among other pollutants commonly found in wastewater, and have the potential to affect DO concentrations. The UPDES program regulates WWTPs and monitors their discharges to ensure compliance with their permit.

The Kamas WWTP and Oakley WWTP discharge in the Rockport Reservoir Watershed. The Kamas Fish Hatchery is permitted to discharge to the Weber River in the Rockport Reservoir Watershed but was closed in 2010 (personal communication between Wes Pearce, DWR, and Andrew Myers, SWCA, on September 18, 2013). Francis WWTP is an existing, non-discharging lagoon system in the Rockport Reservoir Watershed that may convert to a discharging system in the near future. The Silver Creek Water Reclamation Facility (WRF) and the Coalville WWTP are in the Echo Reservoir Watershed. Park City discharges water from several mine tunnels to Silver Creek in the Echo Reservoir Watershed. Currently, the mine tunnels do not have UPDES permits, but the tunnels will be issued permits in the near future. Park City has monitored these sources in the past. Finally, Blue Sky Ranch will treat industrial and municipal wastewater and recently received a permit to discharge to Silver Creek in the Echo Reservoir Watershed. The treatment system has not yet been constructed.

Table 5.2. Nutrient Loads from Point Sources in the Rockport Reservoir and Echo Reservoir Watersheds

Subwatershed	Point Source	Load to Receiving Waterbody (kg/season)[1]		Load to Reservoir (kg/season)[2]		Percentage of Load Reaching the Reservoir (delivery ratio)	
		TN	TP	TN	TP	TN	TP
Rockport Reservoir Watershed							
Beaver Creek	Kamas WWTP	1,587	348	1,051	231	66%	66%
	DWR Fish Hatchery[3]	1,162	177	802	124	69%	70%
	Francis WWTP	N/A	N/A	N/A	N/A	69%	70%
Lower Weber River	Oakley WWTP	1,016	152	703	106	69%	70%
Total	**3**	**3,765**	**677**	**2,556**	**461**	**N/A**	**N/A**
Echo Reservoir Watershed							
Chalk Creek Mainstem	Coalville WWTP	946	193	715	165	76%	86%
Silver Creek	Silver Creek WRF	15,976	1,797	11,343	1,258	71%	70%
	Park City tunnels total	830	67	53	4	6%	6%
	Judge Tunnel	*89*	*7*	*6*	*0*	*6%*	*6%*
	Spiro Tunnel	*620*	*24*	*40*	*1*	*6%*	*6%*
	Prospector Drain/Biocell	*121*	*37*	*8*	*2*	*6%*	*6%*
	Blue Sky Ranch and Resort (future discharge)[3]	N/A	N/A	N/A	N/A	71%	70%
Total	**6**	**16,323**	**1,897**	**11,098**	**1,317**	**N/A**	**N/A**

[1] Calculated based on DMR data.

[2] Calculated based on results from SWAT.

[3] Not currently discharging, delivery ratios based on subbasin delivery ratio.

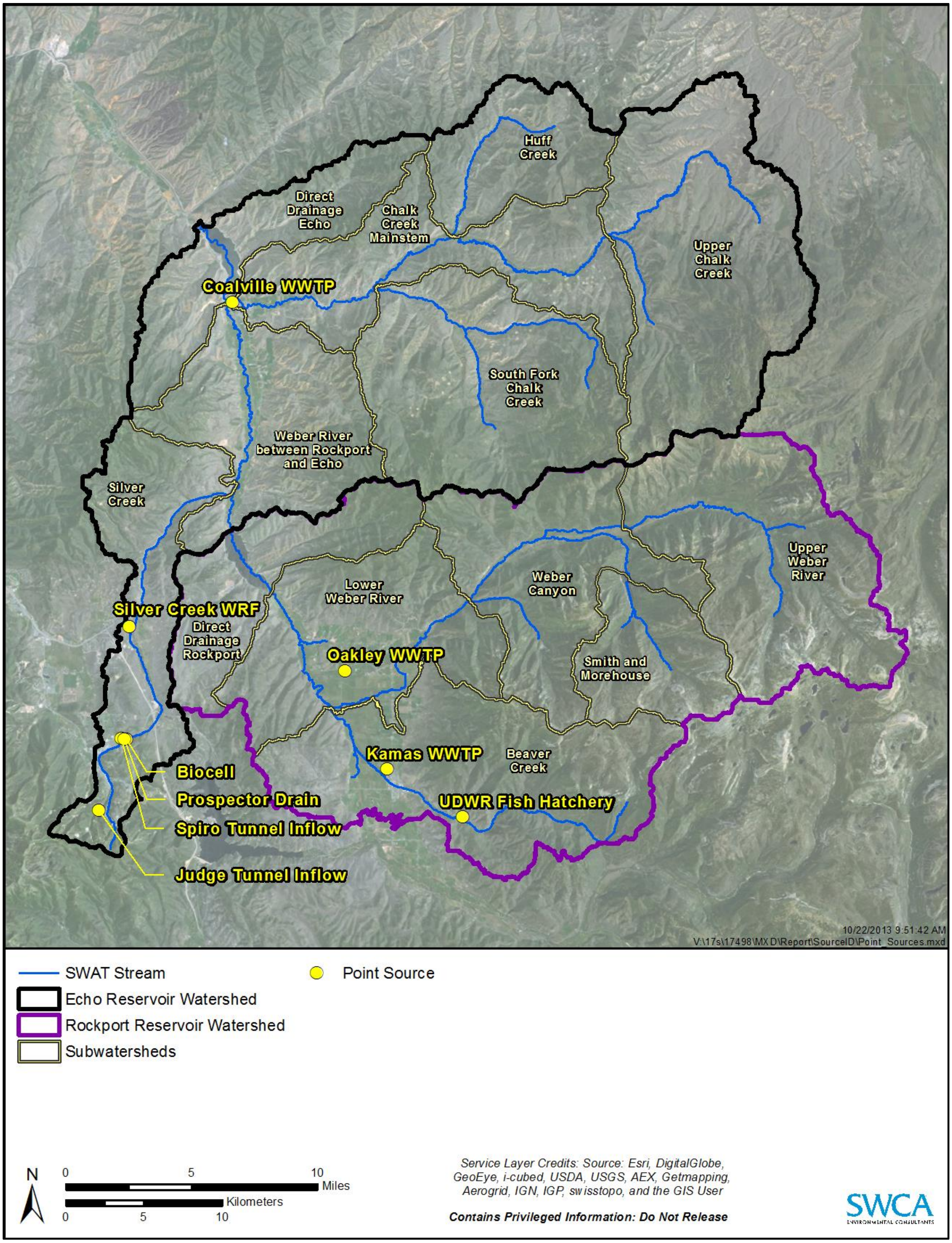

Figure 5.2. Point source outfall locations in the study watershed.

5.1.1 Rockport Reservoir Watershed Point Sources

5.1.1.1 KAMAS CITY WASTEWATER TREATMENT PLANT

The Kamas City WWTP (UPDES UT0020966) serves a population of approximately 1,500 people. The Kamas plant was most recently upgraded in 1991. Current design includes an 18-inch inlet pipe leading to five waste stabilization ponds (the first three of which are aerated), ultraviolet light disinfection, an effluent flow meter, a 10-kilowatt generator, and seven 20-horsepower aerators. The five lagoons cover approximately 18.8 acres. No nutrient data were available for the Kamas plant, except for flow (Table 5.3). Averages used for load calculations were based on input from DWQ (see Appendix A for details). The total average nutrient loads to Beaver Creek are 1,587 kilograms (kg) TN/season and 348 kg TP/season. Based on the delivery ratio for this point source (see Table 5.2), the total load delivered to Rockport Reservoir is 1,051 kg TN/season and 231 kg TP/season.

Table 5.3. Summary of Nutrient Data Reported on Discharge Monitoring Reports for Kamas City Wastewater Treatment Plant from 2004 through 2012

	Flow (MGD)	Nitrate + Nitrite (mg/L)	Ammonia (mg/L)	TKN (mg/L)	Organic N (mg/L)	TN (mg/L)	Dissolved P (mg/L)	TP (mg/L)
Monthly average	0.17[1]	–	–	–	–	–	–	–
Summer monthly average	0.22[1]	–	–	–	–	–	–	–
Maximum monthly average	0.83[1]	–	–	–	–	–	–	–
Minimum monthly average	0.04[1]	–	–	–	–	–	–	–
Value used for current load calculation	0.14	8.41	2.80	7.60	4.80	16.00	3.51	3.50
Total load (kg/season)	N/A	N/A	N/A	N/A	N/A	1,587	N/A	348
Load delivered to Rockport Reservoir (kg/season)	N/A	N/A	N/A	N/A	N/A	1,051	N/A	231

Note: TKN = total Kjeldhal nitrogen. MGD = million gallons per day.

[1] Based on monthly average data from discharge monitoring reports.

5.1.1.2 OAKLEY CITY WASTEWATER TREATMENT PLANT

The Oakley City WWTP (UPDES UT0020061) was designed for daily flows of 0.25 million gallons per day (MGD). The plant processes wastewater using the following methods. First, influent wastewater is run through a 2-millimeter screen followed by compaction and grit removal. Next, wastewater enters an aeration basin and then into a membrane bioreactor for additional filtration. Finally, wastewater is treated using an ultraviolet disinfection system before being discharged into the Weber River.

No nutrient data were available for the Oakley City plant, although flow data was available (Table 5.4). Refer to Appendix A for averages used to calculate seasonal TN and TP loads. The total average nutrient loads to the Lower Weber River are 1,016 kg TN/season and 152 kg TP/season. Based on the delivery ratio for this point source (see Table 5.2), the total load delivered to Rockport Reservoir is 703 kg TN/season and 106 kg TP/season.

Table 5.4. Summary of Nutrient Data Reported on Discharge Monitoring Reports for Oakley City Wastewater Treatment Plant from 2004 through 2012

	Flow (MGD)	Nitrate + Nitrite (mg/L)	Ammonia (mg/L)	TKN (mg/L)	Organic N (mg/L)	TN (mg/L)	Dissolved P (mg/L)	TP (mg/L)
Monthly average	0.38[1]	–	–	–	–	–	–	–
Summer monthly average	0.29[1]	–	–	–	–	–	–	–
Maximum monthly average	0.96[1]	–	–	–	–	–	–	–
Minimum monthly average	0.07[1]	–	–	–	–	–	–	–
Value used for current load calculation	0.15	5.25	1.75	4.75	3.00	10.00	1.50	1.50
Total load (kg/season)	N/A	N/A	N/A	N/A	N/A	1,016	N/A	152
Load delivered to Rockport Reservoir (kg/season)	N/A	N/A	N/A	N/A	N/A	703	N/A	106

Note: TKN = total Kjeldhal nitrogen.

[1] Based on monthly average data from discharge monitoring reports.

5.1.1.3 KAMAS FISH HATCHERY

The DWR operates a fish hatchery near Kamas that discharges to Beaver Creek. A UPDES general permit regulates these discharges. The hatchery was rebuilt in 2000, but has operated only intermittently over the last 10 years. The recent closure in 2010 was related to whirling disease (personal communication between Wes Pearce, DWR, and Andrew Myers, SWCA, on September 18, 2013). The hatchery operates as a flow-through system, and discharges range from 2.13 to 4.47 MGD between April and September according to DMR data. BMPs to reduce nutrient loads in the effluent were implemented in 2003 (personal communication, Lonnie Shull, UDEQ, and Erica Gaddis, SWCA, July 19, 2013). The nutrient loads discharged are estimated to be 177 kg TP/season and 1,162 kg TN/season. Rockport Reservoir receives 69%–70% of the load discharged to Beaver Creek. The facility is not expected to expand and therefore the nutrient loads discharged should remain at existing levels.

5.1.1.4 TOWN OF FRANCIS WASTEWATER

The Town of Francis currently manages wastewater in a lagoon system without discharging to surface waters. Francis is currently discussing the possibility of expanding the wastewater treatment system, which could include discharging to the Weber River. Such a system would operate at an average daily flow of 0.14 MGD with the potential to expand to 0.36 MGD by 2035. Based on current wastewater characterization data, the total phosphorus concentration in the influent is 7 mg/L. Total Nitrogen estimates were not available but current ammonia-N concentrations in the influent are 25 mg/L (Carollo Engineers 2012).

5.1.2 Echo Reservoir Watershed Point Sources

5.1.2.1 COALVILLE CITY CORPORATION WASTEWATER PLANT

The Coalville City Corporation WWTP (UPDES UT0021288) serves a population of approximately 1,470 people. It was originally designed as a trickling filter plant in 1964. Since then, three upgrades have been completed. First, in 1985, the plant was modified to an extended aeration/activated sludge plant. Subsequent additions include two biosolids drying beds in 1992, the addition of a Somat screw press for dewatering, a composting pad, and alterations to existing drying beds in 1995. Plant design allows for an average daily flow of 0.35 MGD and peak flow of 0.42 MGD. Coalville City is currently in the process of moving the WWTP. The newly designed WWTP accounts for growth through 2035. Monthly data were available for flow, ammonia, and TP (Table 5.6). Weekly and instantaneous data were used to generate average values for nitrate + nitrite and total Kjeldhal nitrogen (TKN). Organic N was calculated by subtracting ammonia from TKN, and TN was calculated as the sum of TKN and nitrate + nitrite. All of the TP was assumed to be in dissolved form. The total average nutrient loads to Chalk Creek are 946 kg TN/season and 193 kg TP/season. Based on the delivery ratio for this point source (see Table 5.2), the total load delivered to Echo Reservoir is 715 kg TN/season and 165 kg TP/season.

Table 5.6. Summary of Nutrient Data Reported on Discharge Monitoring Reports for Coalville City Wastewater Treatment Plant from 2004 through 2012

	Flow (MGD)	Nitrate + Nitrite (mg/L)	Ammonia (mg/L)	TKN (mg/L)	Organic N (mg/L)	TN (mg/L)	Dissolved P (mg/L)	TP (mg/L)
Monthly average	0.20[1]	5.53[2]	0.44[1]	1.34[2]	0.90[3]	6.87[3]	–	0.87[1]
Summer monthly average	0.21[1]	5.22[2]	0.46[1]	1.29[2]	0.83[3]	6.51[3]	–	0.90[1]
Maximum monthly average	0.30[1]	10.35[2]	1.70[1]	4.00[2]	2.30[3]	14.35[3]	–	1.80[1]
Minimum monthly average	0.15[1]	2.20[2]	0.40[1]	1.00[2]	0.60[3]	3.20[3]	–	0.10[1]
Value used for current load calculation	0.21	5.22	0.40	1.09	0.69	6.31	1.39	1.39
Total load (kg/season)	N/A	N/A	N/A	N/A	N/A	946	N/A	193
Load delivered to Echo Reservoir (kg/season)	N/A	N/A	N/A	N/A	N/A	715	N/A	165

Note: TKN = total Kjeldhal nitrogen.

[1] Based on monthly average data from discharge monitoring reports.

[2] Based on 7-day average and/or instantaneous values.

[3] Calculated.

5.1.2.2 SILVER CREEK WATER RECLAMATION FACILITY

The Snyderville Basin Water Reclamation District operates the Silver Creek WRF (UPDES UT0024414), a conventional, secondary treatment plant that services residential areas and permitted significant industrial users in portions of the watershed, including areas of Park City. Constituents with specific effluent limitations are DO, BOD, total suspended solids, ammonia, *E. coli*, oil and grease, and pH (UPDES UT0024414). Phosphorus is not regulated with a specific effluent limitation, but is sampled on a monthly basis under the existing permit, which is currently in the process of being renewed. No flow is indicated in the UPDES permit, but the current facility has a capacity of 2.0 MGD and average monthly summer flow is 1.23 MGD. Upgrades are currently being planned, with final designs based on a discharge of 4.0 MGD. The designs and technology included in the upgrades depend in part on the effluent concentrations identified in the UPDES permit.

Monthly data were available for flow, ammonia, and TP (Table 5.7). Weekly and instantaneous data were used to generate average values for nitrate + nitrite, TKN, and dissolved P. Organic N was calculated by subtracting ammonia from TKN, and TN was calculated as the sum of TKN and nitrate + nitrite. The total average nutrient loads to Silver Creek are 15,976 kg TN/season and 1,797 kg TP/season. Based on the delivery ratio for this point source (see Table 5.2), the total load delivered to Echo Reservoir is 11,343 kg TN/season and 1,258 kg TP/season.

Table 5.7. Summary of Nutrient Data Reported on Discharge Monitoring Reports for Silver Creek Wastewater Treatment Plant from 2004 through 2012

	Flow (MGD)	Nitrate + Nitrite (mg/L)	Ammonia (mg/L)	TKN (mg/L)	Organic N (mg/L)	TN (mg/L)	Dissolved P (mg/L)	TP (mg/L)
Monthly average	1.21[1]	17.14[2]	0.33[1]	1.57[2]	1.24[3]	18.71[3]	2.28[2]	2.51[1]
Summer monthly average	1.23[1]	16.19[2]	0.21[1]	1.43[2]	1.22[3]	17.62[3]	2.09[2]	2.14[1]
Maximum monthly average	2.00[1]	21.68[2]	1.71[1]	2.60[2]	0.89[3]	24.28[3]	3.42[2]	4.20[1]
Minimum monthly average	0.56[1]	8.35[2]	0.30[1]	1.00[2]	0.98[3]	9.35[3]	1.03[2]	1.10[1]
Value used for current load calculation	1.23	17.49	0.22	1.42	1.20	18.90	2.12	2.12
Total load (kg/season)	N/A	N/A	N/A	N/A	N/A	15,976	N/A	1,797
Load delivered to Echo Reservoir (kg/season)	N/A	N/A	N/A	N/A	N/A	11,343	N/A	1,258

Note: TKN = total Kjeldhal nitrogen.

[1] Based on monthly average data from discharge monitoring reports.

[2] Based on 7-day average and/or instantaneous values.

[3] Calculated.

5.1.2.3 JUDGE TUNNEL

Judge Tunnel carries groundwater from a series of mine tunnels to a chlorination vault where the flow is treated and becomes drinking water for Park City (see Figure 5.2). If the turbidity is too high the water bypasses the vault and is released into Empire Creek, a tributary to Silver Creek (Park City Municipal Corporation 2012). Judge Tunnel's average monthly flow is somewhat variable, but generally small compared to mainstem flows. The average monthly discharge is 0.4 cfs. The state will be issuing a UPDES permit for Judge Tunnel to regulate discharges from the tunnel.

Instantaneous data were used to generate average values for flow, nitrite + nitrate, and TP (Table 5.8). It was assumed that all of the phosphorus was in the dissolved form. The total average nutrient loads to Silver Creek are 89 kg TN/season and 7 kg TP/season. Based on the delivery ratio for this point source (see Table 5.2), the total load delivered to Echo Reservoir is 6 kg TN/season and 0 kg TP/season.

Table 5.8. Summary of Nutrient Data Reported on Discharge Monitoring Reports for Judge Tunnel from 2004 through 2012

	Flow (MGD)	Nitrate + Nitrite (mg/L)	Ammonia (mg/L)	TKN (mg/L)	Organic N (mg/L)	TN (mg/L)	Dissolved P (mg/L)	TP (mg/L)
Monthly average	0.41	0.13	–	–	–	–	–	0.04
Summer monthly average	0.52	0.17	–	–	–	–	–	0.03
Maximum monthly average	4.40	0.30	–	–	–	–	–	0.05
Minimum monthly average	–	0.01	–	–	–	–	–	0.02
Value used for current load calculation	0.52	0.13	0.09[1]	–	0.30[1]	0.52[1]	0.04[2]	0.04
Total load (kg/season)	N/A	N/A	N/A	N/A	N/A	89	N/A	7
Load delivered to Echo Reservoir (kg/season)	N/A	N/A	N/A	N/A	N/A	6	N/A	0

Note: TKN = total Kjeldhal nitrogen.

[1] Based on data from Spiro Tunnel.

5.1.2.4 SPIRO TUNNEL

Like Judge Tunnel, Spiro Tunnel collects groundwater from mine tunnels (Figure 5.3). Spiro Tunnel discharges water into two irrigation ditches in the Silver Creek watershed: 1) the Bates, Snyder, Dority Ditch and 2) the Pace Homer Ditch. Spiro Tunnel discharges directly into Silver Creek at the Pace Homer Ditch (Park City Municipal Corporation 2012). Spiro Tunnel average discharge is approximately 1.5 cfs.

Instantaneous data were used to generate average values for flow, nitrite + nitrate, dissolved P, and TP (Table 5.9). Organic N was calculated by subtracting ammonia from TKN, and TN was calculated as the sum of TKN and nitrate + nitrite. Only one data sample was available for ammonia and TKN, taken in October. The total average nutrient loads to Silver Creek are 620 kg TN/season and 24 kg TP/season. Based on the delivery ratio for this point source (see Table 5.2), the total load delivered to Echo Reservoir is 40 kg TN/season and 1 kg TP/season.

Table 5.9. Summary of Nutrient Data Reported on Discharge Monitoring Reports for Silver Spiro Tunnel from 2004 through 2012

	Flow (MGD)	Nitrate + Nitrite (mg/L)	Ammonia (mg/L)	TKN (mg/L)	Organic N (mg/L)	TN (mg/L)	Dissolved P (mg/L)	TP (mg/L)
Monthly average	1.50	0.12	0.10	0.40	0.30[1]	0.52[1]	0.02	0.02
Summer monthly average	2.30	0.14	–	–	–	–	0.02	0.03
Maximum monthly average	3.90	0.20	0.10	0.40	0.30[1]	0.52[1]	0.03	0.03
Minimum monthly average	0.03	0.01	0.10	0.40	0.30[1]	0.52[1]	0.01	0.02
Value used for current load calculation	2.30	0.12	0.10	–	0.30	0.52	0.02	0.02
Total load (kg/season)	N/A	N/A	N/A	N/A	N/A	620	N/A	24
Load delivered to Echo Reservoir (kg/season)	N/A	N/A	N/A	N/A	N/A	40	N/A	1

[1] Calculated.

5.1.2.5 PROSPECTOR DRAIN AND BIOCELL

Prospector Drain collects shallow groundwater impacted by mine tailings. This drain also collected stormwater until 2012 when Park City eliminated cross-connection from stormwater sources.

A portion of flow from Prospector Drain goes into the biocell, which treats the water for metal contamination. The biocell contains organic matter in the form of manure, which may explain the high nutrient concentrations in the biocell discharge, which goes to Silver Creek. The remaining water in Prospector Drain flows untreated to Silver Creek (Park City Municipal Corporation 2012). These sources contribute a relatively small quantity of flow to Silver Creek. The Prospector Drain discharges an estimated 0.07 cfs, and the biocell may contribute 0.04 cfs.

The biocell and Prospector Drain are expected to be part of an EPA-directed Comprehensive Environmental Response, Compensation, and Liability Act removal action in the foreseeable future. The discharges from these sources will be addressed, pending EPA approval of a removal action. Therefore, no UPDES permit will be issued for these point sources until the EPA-directed removal action is complete (Park City Municipal Corporation 2012).

Instantaneous data were used to generate average values for flow, nitrite + nitrate, and TP (Table 5.10). It was assumed that all of the phosphorus was in the dissolved form. The total average nutrient loads to

Silver Creek from Prospector Drain and the biocell combined are 121 kg TN/season and 37 kg TP/season. Based on the delivery ratio for this point source (see Table 5.2), the combined total load delivered to Echo Reservoir is 8 kg TN/season and 2 kg TP/season

Table 5.10. Summary of Nutrient Data Reported on Discharge Monitoring Reports for Prospector Drain and Biocell from 2004 through 2012

	Flow (MGD)	Nitrate + Nitrite (mg/L)	Ammonia (mg/L)	TKN (mg/L)	Organic N (mg/L)	TN (mg/L)	Dissolved P (mg/L)	TP (mg/L)
Prospector Drain								
Monthly average	0.07	3.03	–	–	–	–	–	0.06
Summer monthly average	0.07	3.32	–	–	–	–	–	–
Maximum monthly average	0.22	4.60	–	–	–	–	–	–
Minimum monthly average	0.03	1.50	–	–	–	–	–	–
Value used for current load calculation	0.07	3.03	0.10[1]	0.10[1]	0	4.00	0.06	0.06
Biocell								
Monthly average	0.04	0.09	–	–	–	–	–	2.29
Summer monthly average	0.04	0.08	–	–	–	–	–	0.61
Maximum monthly average	0.06	0.30	–	–	–	–	–	28.30
Minimum monthly average	0.01	0.01	–	–	–	–	–	0.08
Value used for current load calculation	0.04	0.08	0.10[1]	0.90[2]	1.00[2]	1.20	2.30	2.30
Prospector Drain and Biocell								
Total load (kg/season)	N/A	N/A	N/A	N/A	N/A	121	N/A	37
Load delivered to Echo Reservoir (kg/season)	N/A	N/A	N/A	N/A	N/A	8	N/A	2

[1] Based on background in Silver Creek.

[2] Based on typical concentration of TKN in high phosphorous effluents.

5.1.2.6 BLUE SKY RANCH AND RESORT

Blue Sky Ranch and Resort is a proposed resort development in the lower part of the Silver Creek Watershed. The state has issued a UPDES discharge permit (UT0025763) for the on-site WWTP, designed to treat 30,000 gallons per day. This WWTP is not yet operational and has no discharge. When the development is complete, the plant will discharge directly into Alexander Creek, a tributary to Silver Creek. Under the permit, Blue Sky Ranch and Resort will receive offsets for phosphorus because the developers plan to remove all cattle grazing on the property. The Blue Sky Ranch and Resort WWTP will be allowed to discharge 0.03 MGD with 1.0 mg/L TP, reflecting the phosphorus offset, and 1.0 mg/L total ammonia as N as monthly averages. Based on this design the total seasonal load would be 21 kg TP/season and 208 kg TN/season.

5.2 Nonpoint Sources

5.2.1 Stormwater

Residential and commercial development has increased the amount of impervious surface area (roads, parking lots, etc.) in the Rockport and Echo Reservoir Watersheds, which contributes to an increase in stormwater runoff (Figure 5.3). Figure 5.4 shows a number of outfalls in Park City. Additional outfalls likely exist in the watershed, but have not been mapped. Stormwater transports nutrients that have accumulated on surfaces during dry periods. The runoff generally begins as diffuse flow (e.g., off a parking lot), which is then directed to curb and gutters and storm drains. These drains direct stormwater into canals and other drainages, where it eventually reaches a stream. There is usually no treatment associated with stormwater unless BMPs are installed and maintained. Stormwater can be problematic at active construction sites because of sediment loading. Construction in areas with soils of severe erosion potential underlain by a rock formation with elevated phosphorus concentrations may generate excess loads of phosphorus if proper BMPs are not used.

Because of its more rural nature, stormwater generates a smaller nutrient load in the Rockport Reservoir Watershed compared to the Echo Reservoir Watershed. Stormwater in the Rockport Reservoir Watershed generates 278 kg TP/season and 601 kg TN/season. Within the Rockport Reservoir Watershed, the Direct Drainage subwatershed contains the highest percentage of impervious cover and generates the highest loads from stormwater, 123 kg TP/season 226 kg TN/season. The Lower Weber River, Weber Canyon, and Beaver Creek subwatersheds are similar in the amount of development that has occurred and they generate similar amounts of nutrient loads from stormwater, 42–54 kg TP/season and 106–130 kg TN/season. The subwatersheds with the least amount of impervious surface—Upper Weber River and Smith and Morehouse subwatersheds—are higher in the drainage and generate very little nutrient load from stormwater. These subwatersheds generate less than 10 kg TP/season and 20 or less kg TN/season (Table 5.11). The Echo Reservoir Watershed contains areas that have seen increased urbanization in the last decade, including portions of Park City as well as the I-80 corridor and US-40 corridor. Stormwater accounts for 1,290 kg TP/season and 1,893 kg TN/season to the Echo Reservoir.

The Silver Creek subwatershed contributes the most load in the Echo Reservoir Watershed (719 kg TP/season and 1,063 kg TN/season). It contains nearly 5% impervious cover, and 25% of the subwatershed is low to medium density development. The I-80 and US-40 road corridors are also primarily within the Silver Creek subwatershed. Chalk Creek contributes 236 kg TP/season and 242 kg TN/season, reflecting the development of 2.7% of the watershed and the 0.4% impervious cover. Upper Chalk Creek generates the least stormwater, having the least amount of development and impervious cover (Table 5.11).

The acreages from the land use datasets were used to calculate the percentage of low to medium density development and the percentage of high density development and roads. The percentage of impervious cover was calculated using proportions of low, medium, and high density development that would be impervious cover provided in the SWAT databases.

Table 5.11. Summary of Stormwater Related Subwatershed Characteristics and Loads to Reservoirs

Subwatershed	Total Acres	TP Load[1] (kg/season)	TN Load[1] (kg/season)	Low to Medium Density Development (% of watershed)	High Density Development and Roads (% of watershed)	Impervious Cover (% of subwatershed)
Rockport Reservoir Watershed						
Beaver Creek	53,549	47	106	3.9%	<0.1%	0.7%
Direct Drainage Rockport	22,584	123	226	5.0%	<0.1%	0.8%
Lower Weber River	36,572	54	130	3.8%	<0.1%	0.7%
Smith and Morehouse	17,627	3	4	0.4%	<0.1%	0.1%
Upper Weber River	47,514	9	20	0.4%	<0.1%	0.1%
Weber Canyon	34,817	42	115	3.7%	<0.1%	0.7%
Total	**212,663**	**278**	**601**	**2.9%**	<0.1%	**0.5%**
Echo Reservoir Watershed						
Chalk Creek mainstem	36,181	236	242	2.7%	<0.1%	0.4%
Direct Drainage Echo	23,793	101	174	2.2%	0.2%	0.3%
Huff Creek	19,767	41	45	0.7%	<0.1%	0.1%
Silver Creek	32,556	719	1,063	25.0%	0.7%	4.7%
South Fork Chalk Creek	47,863	76	67	0.8%	<0.1%	0.1%
Upper Chalk Creek	56,876	32	47	0.3%	<0.1%	<0.1%
Weber River between Rockport and Echo	34,186	84	255	4.3%	0.4%	0.8%
Total	**251,222**	**1,290**	**1,893**	**4.7%**	**0.2%**	**0.8%**

[1] Load delivered to reservoir from each subwatershed for summer season (April 1–September 30).

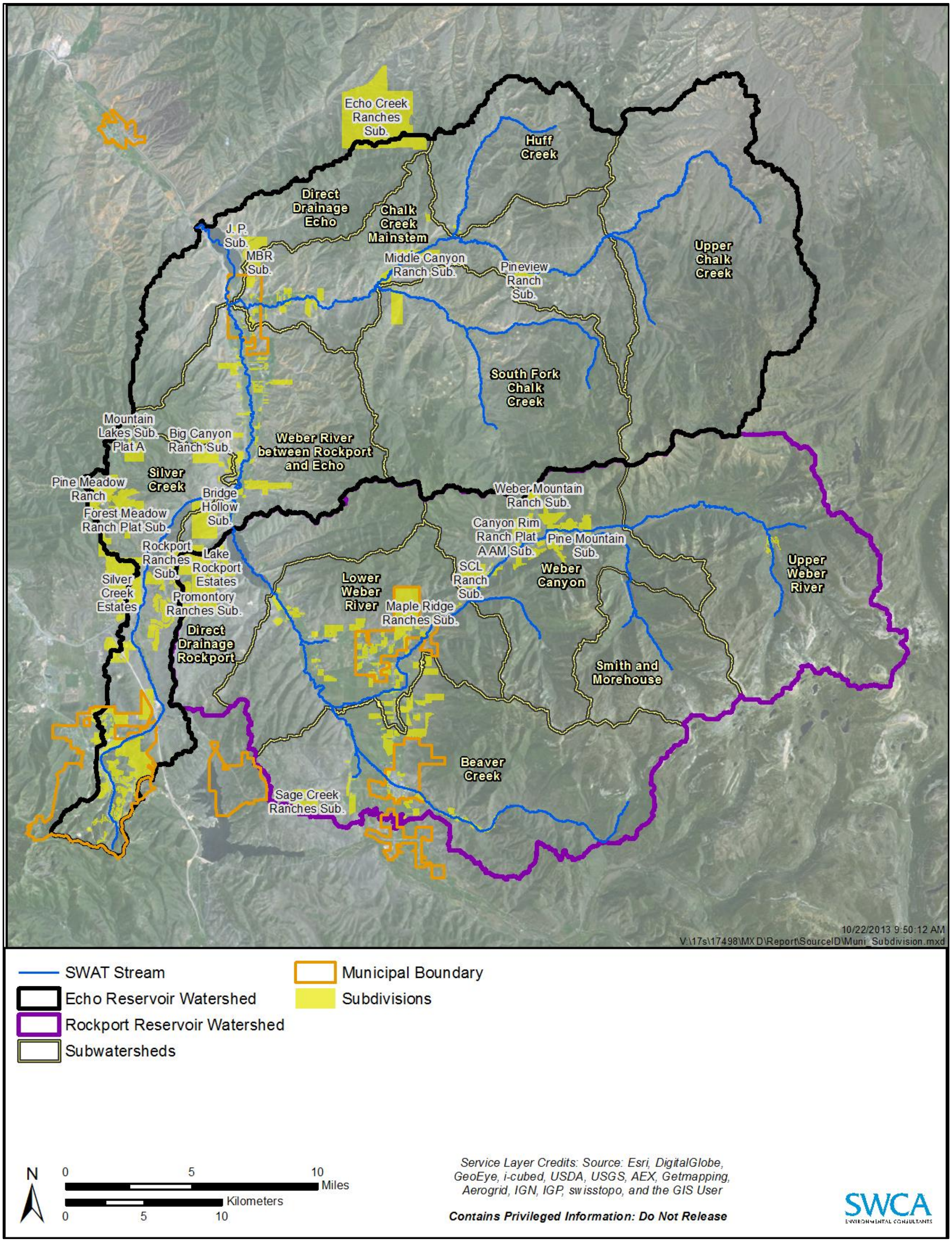

Figure 5.3 Municipalities and subdivisions in the study watershed.

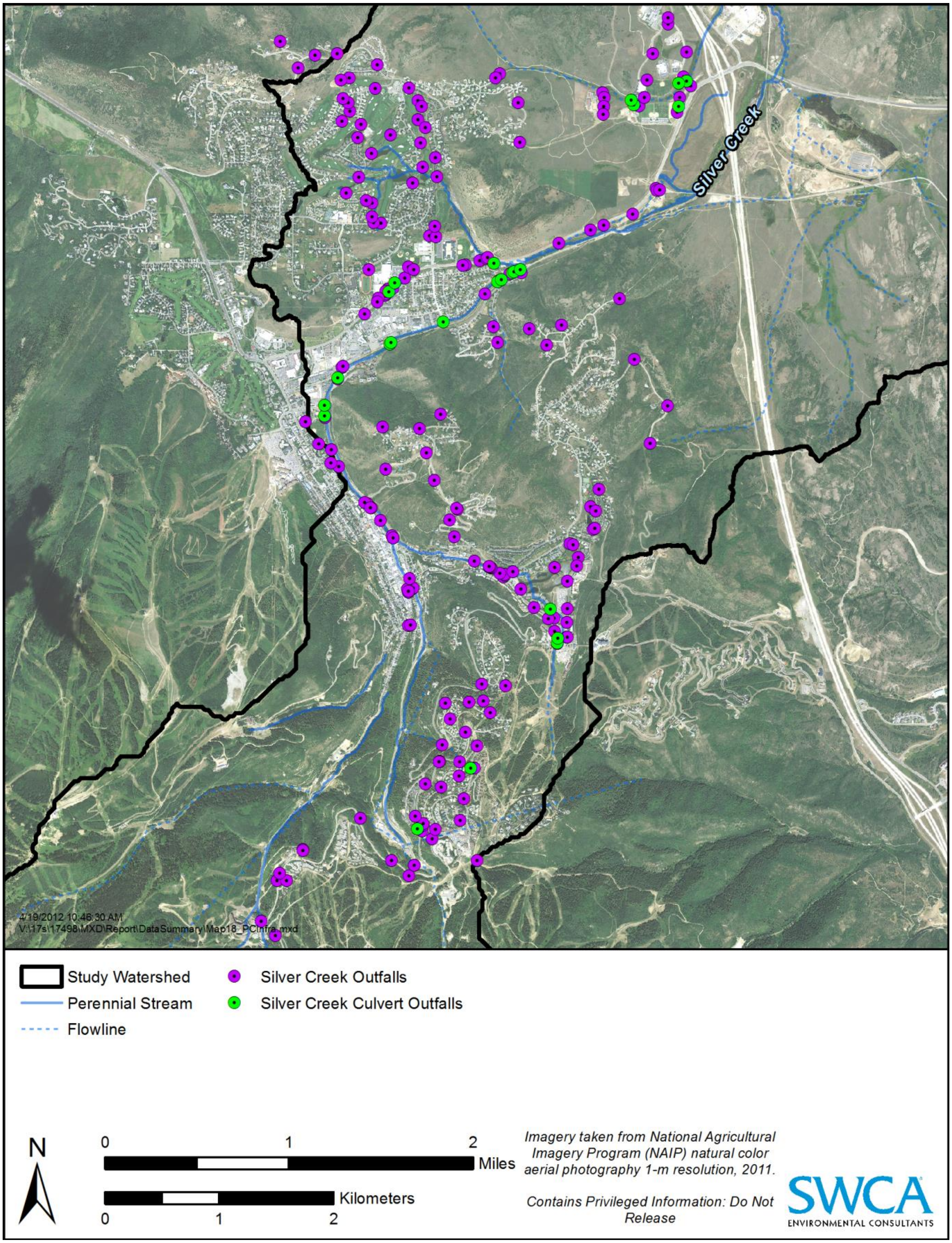

Figure 5.4 Locations of stormwater outfalls in the Silver Creek subwatershed.

5.2.2 Agricultural Sources

Grazing, hay, and alfalfa production, as well as other crop production are examples of agricultural activities that occur in the Rockport and Echo Reservoir Watersheds (Figure 5.5). These activities involve use of fertilizers and irrigation in some areas of the watersheds. Agriculture is considered a nonpoint source, and it generates sediment and nutrients through active grazing, application of fertilizers, and irrigation.

In the Rockport Reservoir Watershed, agricultural activities generate 1,131 kg TP/season and 5,660 kg TN/season. Grazing occurs on up to 56% of the total watershed area, depending on the season and individual operations, whereas crops occur on 2% of the watershed area. The Lower Weber River subwatershed generates the most nutrient load from agricultural activities in the Rockport Reservoir Watershed (532 kg TP/season and 1,425 kg TN/season). In this subwatershed, 33% of the land may be used for private grazing, and over 7% is used to cultivate crops. Although 47% of the area in the Beaver Creek subwatershed is used for public grazing and 20% for private grazing, it generates a smaller nutrient load (305 kg TP/season and 387 kg TN/season). Weber Canyon generates 1,941 kg TN/season but only 41 kg TP/season. Agricultural activities in this subwatershed consist primarily of grazing on public lands (Table 5.12).

Agricultural activities in the Echo Reservoir Watershed generate 825 kg TP/season and 10,838 kg TN/season. The “Weber River between Rockport and Echo” subwatershed contributes the most TP from agriculture to Echo Reservoir (277 kg/season). Huff Creek accounts for 240 kg TP/season, whereas Silver Creek contributes 166 kg TP/season. South Fork, Chalk Creek, and Upper Chalk Creek generate less than 20 kg TP/season (Table 5.12). The “Weber River between Rockport and Echo” subwatershed generates 4,520 kg TN/season, over 40% of the TN load from agriculture in the Echo Reservoir Watershed. The Chalk Creek mainstem and South Fork Chalk Creek subwatersheds contribute high amounts of TN, as well (3,108 kg/ season and 1,172 kg/season, respectively). Direct drainage to Echo Reservoir accounts for less than 20 kg TN/season. No public grazing allotments are present in the Echo Reservoir Watershed, but private grazing occurs in each subwatershed. Crop cultivation, if present, occurs on less than 5% of the subwatershed area.

The percentage of subwatershed within public grazing allotments was calculated assuming that USFS lands identified as an allotment within the subwatershed were grazed. The Smith and Morehouse allotment is not currently an active allotment and, although included in the area percentage, is not included in load calculations. The percentage of watershed coinciding with private grazing-land uses is assumed to be proportional to the acreage of forest, pasture, and range that is privately owned. The percentage of watershed as crop is calculated as the proportion of subwatershed area that is identified as agriculture, alfalfa, hay, or orchard on the land use map.

Table 5.12. Summary of Agricultural-Related Subwatershed Characteristics and Loads to Reservoirs

Subwatershed	Total Acres	Percentage of Subwatershed within Public Grazing Allotments	Percentage of Watershed Coinciding with Private Grazing Land Uses	Percentage of Watershed as Crop	TP Load[1] (kg/season)	TN Load[1] (kg/season)
Rockport Reservoir Watershed						
Beaver Creek	53,549	47%	20%	2.9%	305	387
Direct Drainage Rockport	22,584	0%	20%	<0.1%	138	506
Lower Weber River	36,572	7%	33%	7.2%	532	1,425
Smith and Morehouse	17,627	100%[2]	0%	<0.1%	60	685
Upper Weber River	47,514	25%	20%	0.2%	55	717
Weber Canyon	34,817	46%	13%	0.1%	41	1,941
Total	**212,663**	**35%**	**21%**	**2.1%**	**1,131**	**5,660**
Echo Reservoir Watershed						
Chalk Creek Mainstem	36,181	0%	34%	2.24%	57	3,108
Direct Drainage Echo	23,793	0%	24%	3.39%	57	19
Huff Creek	19,767	0%	34%	<0.1%	240	495
Silver Creek	32,556	0%	32%	0.44%	166	619
South Fork Chalk Creek	47,863	0%	41%	<0.1%	12	1,172
Upper Chalk Creek	56,876	<0.1%	55%	<0.1%	15	905
Weber River between Rockport and Echo	34,186	0%	29%	3.73%	277	4,520
Total	**251,222**	**<1%**	**38%**	1.2%	**825**	**10,838**

[1] Load delivered to reservoir from each subwatershed for summer season (April 1–September 30).

[2] The Smith and Morehouse allotment is not currently active.

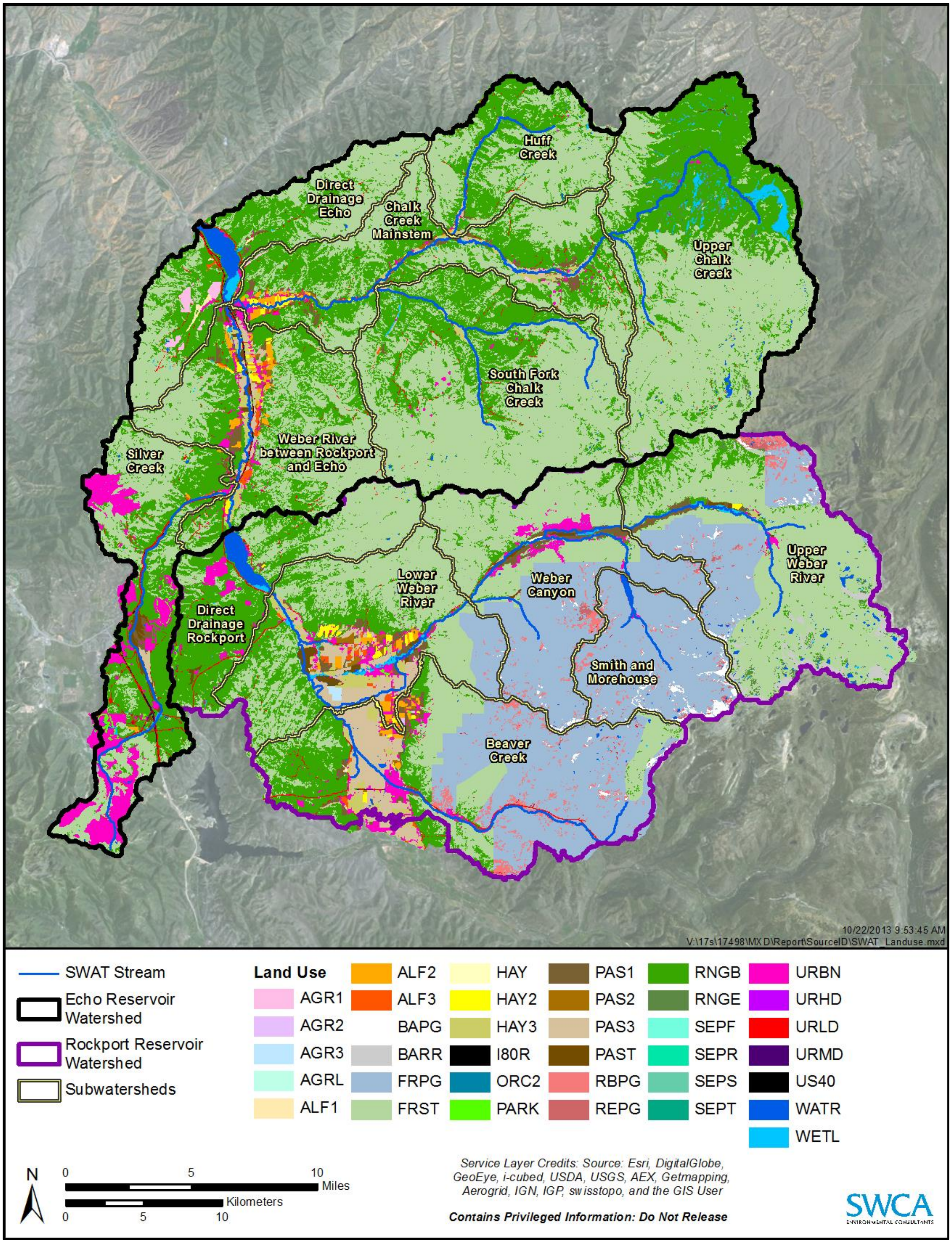

Figure 5.5. Land use by subwatershed in Rockport Reservoir and Echo Reservoir Watersheds.

Note: The light blue areas dominating Rockport Reservoir Watershed represent public grazing allotments, whereas privately owned areas potentially grazed are PAS1-PAST, FRST, RNGB, and RNGE. Crops are considered AGRL, AGR1-3, ALFA, ALF1-3, and HAY-HAY3.

5.2.2.1 GRAZING ON PUBLIC LAND

Five USFS allotments occur in the study watershed (see Figure 5.6). Among benefits such as clean water, wildlife protection, recreation, and others, "forage for livestock" on public forest land is protected under the Multiple Use Sustained-Yield Act of 1960 (Swank 1998). It is important to note that a) allotments do not coincide with subwatershed boundaries and may only be partially contained in a watershed and b) cattle are not dispersed evenly across the landscape. Allotment data were used to estimate the number of livestock that graze within the watershed (Table 5.13). USFS allotments are exclusively high-elevation, with use restricted to the summer season. Cattle graze on USFS land primarily in July, August, and September, although some grazing occurs as early as June and as late as October. Generally, cattle that graze on public lands are pastured on private lands in the valley during the rest of the year.

Table 5.13. Identified Grazing Permits on USFS Lands in Rockport Reservoir and Echo Reservoir Watersheds

Allotment Name	Allotment Area in Watershed (acres)	Typical Dates	Average Animals in Watershed (acres)	Animal Type
Rockport Reservoir Watershed				
Humpy Creek	973	July 25–September 24	382	Ewe/lamb pairs
Kamas Valley	25,299	June 10–October 15	336	Cows
Moffit	2,747	July 11–September 29	1,048	Ewe/lamb pairs
Weber River	28,975	June 21–September 30	186	Cows
Total	**57,994**		**1,952**	
Echo Reservoir Watershed				
Humpy Creek	5	July 25–September 24	2	Ewe/lamb pairs
Total	**5**		**2**	

5.2.2.2 GRAZING ON PRIVATE LAND

Rangeland and pasturelands in the watershed are typically adjacent to local streams. Cattle within a grazed pasture rarely spread out and cover the entire acreage evenly; rather, they tend to congregate around areas where water is readily available (riparian areas and stream channels) and forage is plentiful. Consequently, a greater proportion of the manure is deposited in or nearby stream channels and riparian areas, resulting in a greater potential for direct transport of nutrients and pathogens.

Grazing within the watershed occurs on public USFS-managed allotments as well as on private land. Employees from the NRCS at the Coalville office supplied information on private grazing, including estimates of the animal units by season in the watershed zones (Figure 5.6) for both Rockport Reservoir and Echo Reservoir Watersheds.

Typically, cattle graze in the valleys in the fall and spring. In the hot summer months, they are taken to the higher elevation forests, and in the winter, they are relocated to the West Desert. Table 5.14 provides the estimated number of cattle grazing seasonally on private lands in the study watershed. For the Weber River Watershed, cattle density is greatest during summer and fall seasons. The Beaver Creek subwatershed is the exception; here, approximately 2,000 cattle graze year-round.

Table 5.14. Number of Grazing Cattle per Season on Private Land

NRCS Zone	Spring (March 21–June 21)	Summer (June 22–September 21)	Fall (September 22–December 22)	Winter (December 23–March 21)
Rockport Reservoir Watershed				
Beaver Creek	2,000	2,000	2,000	2,000
Weber River between Rockport and Weber-Provo Diversion	1,000	1,500	1,500	1,000
Weber River Canyon	1,000	3,000	1,500	500
Total	**4,000**	**6,500**	**5,000**	**3,500**
Echo Reservoir Watershed				
Chalk Creek	500	3,500	3,500	500
Silver Creek	100	1,100	500	100
Weber River between Echo and Rockport	1,500	1,500	2,500	1,500
Total	**2,100**	**6,100**	**6,500**	**2,100**

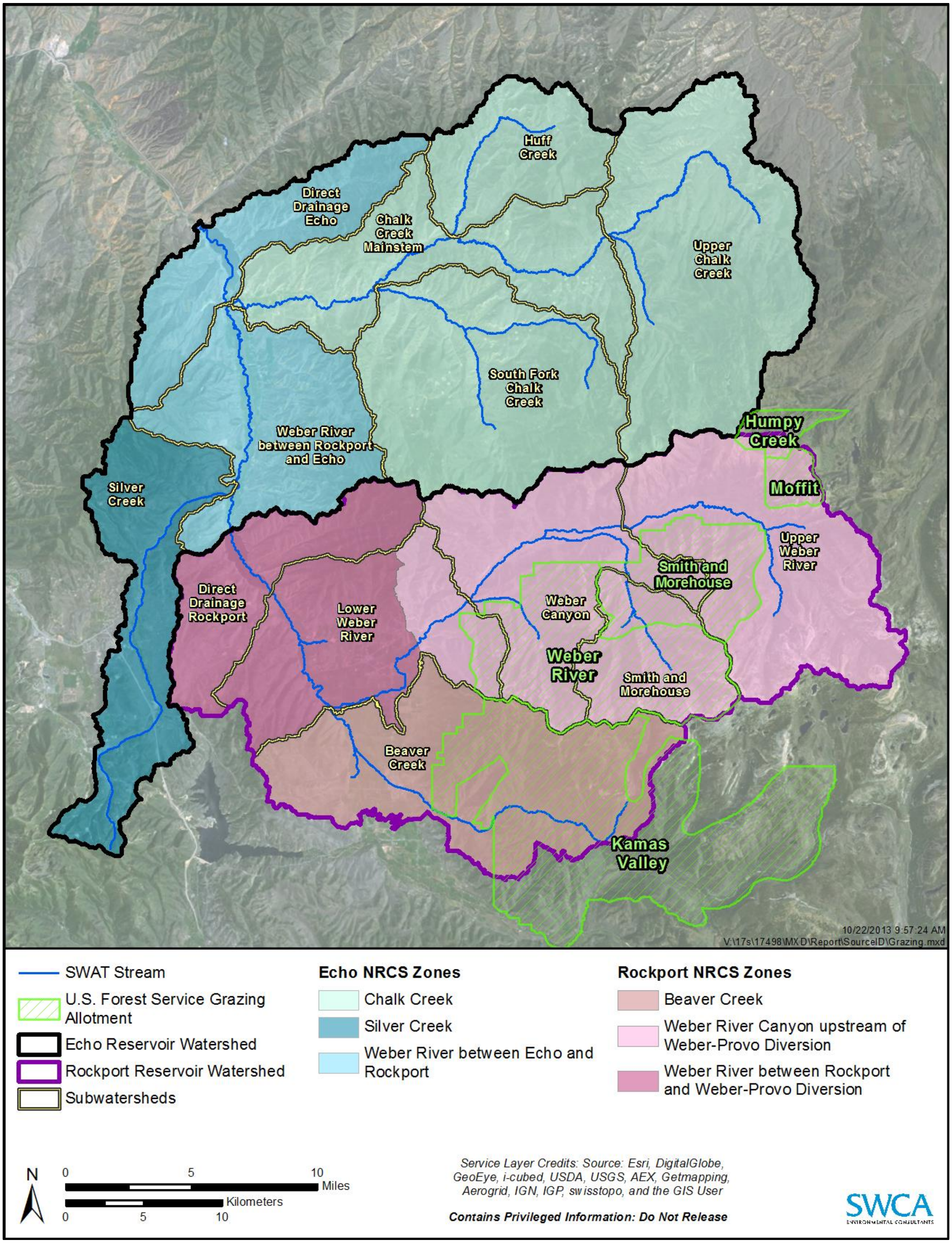

Figure 5.6. Zones used to broadly quantify the number of grazing animals on private property (NRCS zones) and the locations of USFS allotments in the Rockport Reservoir and Echo Reservoir Watersheds.

5.2.2.3 FERTILIZER AND MANURE APPLICATION

Fertilizer and manure are applied to fields to improve crop yields on agricultural lands. Fertilizer is also used in urban areas, generally on lawns, landscaping, and turf on golf courses and recreational sports fields. Applied fertilizer may wash off during storm events or during irrigation, particularly flood irrigation. Water flowing off fields may drain directly back to the stream or to irrigation or drainage ditches. Runoff from urban landscapes directly adjacent to a stream may transport fertilizer directly to that stream. For example, a stream may run through a golf course that has been landscaped to the stream banks. Storm drains may also conduct flow off urban areas and transport fertilizer to streams.

The NRCS provided broad estimates of fertilizer application types and rates for the entire watershed. They indicated that most of the fertilizer used in both the Rockport Reservoir and Echo Reservoir Watersheds is a commercial type with 11:52:11 (N:P:K) applied at a rate of 35 kg/year. Areas within 1 mile of a dairy operation were assumed to use manure in place of commercial fertilizers, using the same application rate. Urban areas are likely to be fertilized to keep grass and turf alive, but they are also likely to be more water efficient. These areas were assigned a lower application rate of 5kg/hectare. It was assumed fertilizer was not applied to high-density urban areas.

Nutrient loads from fertilizer application are included in the total loads from agriculture described in section 5.2.2. The characteristics of fertilizer application will affect the amount of nutrients washed off, with surface runoff generated by storm events, spring runoff, or irrigation return flow. In the Rockport Reservoir Watershed, the Lower Weber River subwatershed contains the highest percentage of fertilized area, with agricultural and urban areas being fertilized. Beaver Creek fertilizer application is about half that of the Lower Weber River Watershed, whereas essentially no fertilizer application occurs in the Smith and Morehouse subwatershed. In the Upper Weber River and Weber Canyon subwatersheds, fertilizer application occurs mostly in urban areas, with little application to agricultural areas (Table 5.15).

Table 5.15. Fertilizer Characteristics

Subwatershed	Total Acres	Percentage of Watershed Fertilized	Acres of Fertilized Agricultural Areas (using 35 kg/ha)	Acres of Fertilized Urban Areas (using 5 kg/ha)
Rockport Reservoir Watershed				
Beaver Creek	53,549	6.0%	1,575	1,566
Direct Drainage Rockport	22,584	3.0%	10	654
Lower Weber River	36,572	11.0%	2,640	1,238
Smith and Morehouse	17,627	0.3%	0	49
Upper Weber River	47,514	0.5%	80	153
Weber Canyon	34,817	2.0%	40	746
Total	**212,663**	**4.0%**	**4,345**	**4,407**
Echo Reservoir Watershed				
Chalk Creek mainstem	36,181	5.7%	1,263	816
Direct Drainage Echo	23,793	4.5%	754	311
Huff Creek	19,767	1.0%	105	100
Silver Creek	32,556	14.3%	143	4,516
South Fork Chalk Creek	47,863	1.0%	155	319
Upper Chalk Creek	56,876	0.2%	0	125
Weber River between Rockport and Echo	34,186	9.5%	2,063	1,187
Total	**251,222**	**5.0%**	**4,483**	**7,375**

5.2.2.4 IRRIGATION RETURN FLOW

Irrigation return flow is runoff from agricultural fields (such as pasture and hay fields) that is generated by irrigating the field. The runoff either returns to the irrigation ditch or the stream directly down-gradient from the field. Irrigation return flow is primarily associated with flood irrigation practices and less so with sprinkler irrigation. Flood irrigation allows water to flow from a ditch or stream onto the fields directly through a head gate or other diverting works. This method effectively flushes soil, biomass, manure, and fertilizer off the field and into the ditch or stream. Sprinkler systems apply less water at rates that allow water to infiltrate the soil, thereby reducing irrigation return flow generated from surface runoff.

Over-irrigation of pasture and hayland will also raise the water table and lead to changes in the mobility of phosphorus in soils. Phosphorus has been observed to move more easily through soils that are consistently waterlogged because most of the iron present in these soils is reduced, and sorption potential is decreased (Sharpley 1995). Waterlogged soils are also prone to the loss and transport of fine, lightweight soil particles (such as silt and clay) to receiving waters. These fine particles represent the primary phosphorus sorption sites in the soil. These particles carry a significant amount of phosphorus with them when they are removed and leave the remaining soil deficient in phosphorus holding capacity (Hedley et al. 1995). Nitrogen is highly mobile in soils, and over-irrigation would promote leaching through the soil layers. Return flow also easily transports nitrogen to irrigation canals and streams from irrigated fields.

Flood irrigation efficiency was assumed to be 30%, and sprinkler irrigation was assumed to be 70%. The surface runoff was assumed to be 40% from flood-irrigated land and 5% for sprinkler-irrigated lands (personal communication, Thomas Hoskins, NRCS, and Erica Gaddis, SWCA, December 12, 2012). These values reflect the difference in the amount and quality of irrigation return flow generated from flood irrigation compared to sprinkler irrigation.

Nutrient loads from irrigation return flows are included with the total loads from agriculture described in section 5.2.2. Irrigation methods will affect the quantity of nutrients transported by irrigation return flow. Sprinkler irrigation generates less return flow; compared to flood irrigation, it transports less fertilizer, sediment, and other debris from agricultural fields that contain nutrients. Based on the Water Related Land Use data, flood irrigation is the primary form of irrigation in the Rockport Reservoir Watershed. Sprinkler and flood irrigation are almost equivalent in Echo Reservoir Watershed, with flood irrigation being slightly higher.

In the Rockport Reservoir Watershed, 5.6% of the total area is irrigated, primarily with flood irrigation. Sprinkler irrigation is applied to 2,102 acres across the Rockport Reservoir Watershed. The Lower Weber River subwatershed has the highest proportion of irrigated land (16%). In this subwatershed, 1,383 acres are sprinkler irrigated and 4,799 acres are flood irrigated. Irrigation occurs on 10% of the Beaver Creek subwatershed, with nearly 5,000 acres as flood irrigation and only 656 acres irrigated with sprinklers. Very little irrigation occurs in the Weber Canyon subwatershed, and no irrigation occurs in the Smith and Morehouse subwatershed (Table 5.16; Figure 5.7).

Irrigation occurs on 3% of the Echo Reservoir Watershed, with sprinkler irrigation occurring on 2,467 acres and 3,672 acres being flood irrigated. Irrigation occurs on almost 10% of the Weber-River-between-Rockport-and-Echo subwatershed. In this subwatershed, 1,185 acres are sprinkler irrigated and 1,947 acres are flood irrigated. No irrigation occurs in the Upper Chalk Creek subwatershed. In Silver Creek and the Direct Drainage Echo subwatershed, sprinkler irrigation occurs on more acreage than does flood irrigation. All irrigation in the South Fork Chalk Creek subwatershed is under flood irrigation (Table 5.16; Figure 5.7).

Table 5.16. Irrigation Return Flow

Subwatershed	Total Acres	Percentage of Subwatershed Irrigated	Acres with Sprinkler Irrigation	Acres with Flood Irrigation
Rockport Reservoir Watershed				
Beaver Creek	53,549	10.5%	656	4,960
Direct Drainage Rockport	22,584	<0.1%	12	1
Lower Weber River	36,572	16.9%	1,383	4,799
Smith and Morehouse	17,627	<0.1%	0	0
Upper Weber River	47,514	0.2%	45	35
Weber Canyon	34,817	0.1%	5	29
Total	**212,663**	5.6%	**2,102**	**9,823**
Echo Reservoir Watershed				
Chalk Creek Mainstem	36,181	5.8%	906	1,182
Direct Drainage Echo	23,793	0.3%	54	28
Huff Creek	19,767	1.0%	11	192
Silver Creek	32,556	1.2%	310	89
South Fork Chalk Creek	47,863	<0.1%	1	234
Upper Chalk Creek	56,876	0%	0	0
Weber River between Rockport and Echo	34,186	9.16%	1,185	1,947
Total	**251,222**	**3.0%**	**2,467**	**3,672**

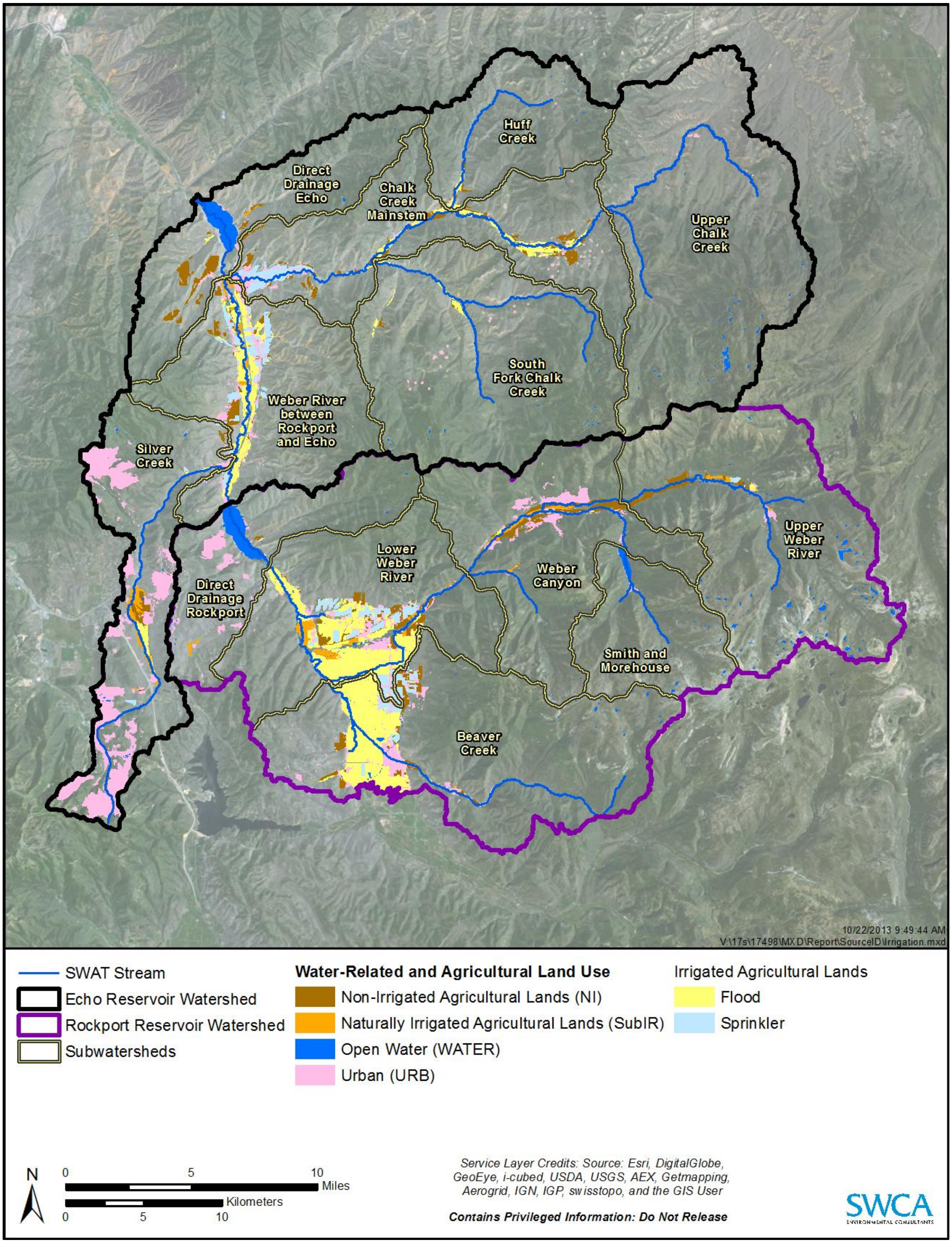

Figure 5.7. Areas of sprinkler and flood-irrigated lands in each subwatershed.

5.2.3 Septic Systems

Although the WWTPs discussed above serve a large portion of the Rockport Reservoir and Echo Reservoir Watersheds, there are an estimated 3,764 septic systems in the study watershed (Table 5.17; Figure 5.8). Septic system failure, improper design, and poor location of a leach field can increase the nutrient loads and BOD from these systems. A properly operating septic system treats wastewater and disposes of the water through an underground leach field. Soils beneath the leach field remove most pathogens by filtering, adsorption, and biological processes. However, where soils or groundwater conditions are marginally suitable, or where septic densities are too high, conventional septic systems fail and removal rates are reduced or no treatment occurs at all. A septic system can affect surface waters when soils below the leach field become clogged or flooded and when effluent reaches the surface where it can be washed off into a stream. An associated problem occurs when a septic system is flooded by groundwater or the depth-to-groundwater is near the base of the leach field and effluent is released to shallow groundwater, which discharges into nearby streams. Therefore, the proximity of septic systems to surface waters (Table 5.17) and the type and depth of the system (Table 5.18) are important factors that have the potential to affect water quality. Septic systems have been categorized based on their level of use. The Primary category contains buildings known to be primary residences and other buildings that are likely operating all year. Buildings listed as other or unknown, including those identified as Farmland Assessment Act buildings, were included in the Primary category to maintain a conservative estimate of septic systems and their operations within the watershed. Secondary septic systems are based on a county classification of the residence of 6 months or less. Buildings that the county considers recreational have less than 3 months of occupancy over the year.

Table 5.17. Number of Septic Tanks for Primary Residences, Secondary Residences, and Recreational Residences by Subwatershed

Subwatershed	Primary	Secondary	Recreational	Distance to Water (m)	TP Load[1] (kg/season)	TN Load[1] (kg/season)
Rockport Reservoir Watershed						
Beaver Creek	414	41	50	114	18	450
Direct Drainage Rockport	50	13	50	268	2	779
Lower Weber River	400	43	26	110	20	544
Upper Weber River	27	–	75	98	6	509
Weber Canyon	92	10	779	173	34	1,214
Total	**983**	**107**	**1,045**	**146**	**79**	**3,496**
Echo Reservoir Watershed						
Chalk Creek Mainstem	162	6	2	95	5	199
Direct Drainage Echo	6	–	21	192	0	44
Huff Creek	8	1	–	98	0	2
Silver Creek	212	40	310	189	4	302
South Fork Chalk Creek	6	–	–	47	1	6
Upper Chalk Creek	2	–	–	63	–	1
Weber River between Rockport and Echo	394	24	–	133	10	539
Total	**790**	**71**	**333**	**154**	**19**	**1,093**

[1] Load delivered to reservoir from each subwatershed for summer season (April 1–September 30).

Septic systems contribute 79 kg TP/season and 3,496 kg TN/season to Rockport Reservoir. The Weber Canyon subwatershed contributes the largest nutrients load from septic systems (34 kg TP/season and 1,214 kg TN /season). The Weber Canyon subwatershed contains 779 recreational septic systems and only 92 primary septic systems. The Lower Weber River subwatershed and the Beaver Creek subwatershed contribute just over 100 kg TP/season and 450–500 kg TN/season. These subwatersheds have over 400 primary septic systems and fewer than 100 recreational septic systems. The Direct Drainage subwatershed contributes 779 kg TN/season and only 2 kg TP/season. There are fewer than 200 septic systems in the subwatershed, and most are far from a waterbody. However, most are deep trench septic systems (Table 5.18).

Septic systems contribute 19 kg TP/season and 1,093 kg TN/season to Echo Reservoir. The Weber-River-between-Rockport-and-Echo subwatershed contributes the most nutrients, accounting for about half (10 kg/season) of the TP and almost half (539 kg/season) of the TN load with mostly primary septic systems. The Silver Creek subwatershed, with 212 primary septic systems and 310 recreational septic systems, contributes 4 kg TP/season and 302 kg TN/season. Upper Chalk Creek contains almost no septic systems and does not contribute to nutrient loads from septic systems (Table 5.17).

Table 5.18. Number of Septic Systems by Type and Depth

Subwatershed	Chamber	Deep Trench	Seepage Pit	Shallow
Rockport Reservoir Watershed				
Beaver Creek	15	109	1	69
Direct Drainage Rockport	–	48	–	9
Lower Weber River	7	69	–	61
Upper Weber River	2	15	–	25
Weber Canyon	4	271	1	29
Total	**28**	**512**	**2**	**193**
Echo Watershed				
Chalk Creek Mainstem	–	32	–	11
Direct Drainage Echo	–	2	–	3
Huff Creek	–	1	–	–
Silver Creek	10	205	3	34
South Fork Chalk Creek	1	–	–	–
Upper Chalk Creek	–	–	–	–
Weber River between Rockport and Echo	2	103	1	41
Total	**13**	**343**	**4**	**89**

[1] Within the study watershed, fewer than five systems of the following types occur: 50 trench, 750 trench, chamber/shallow, drainfield, infiltrated-deep, infiltrated-shallow, and shallow-infiltrated.

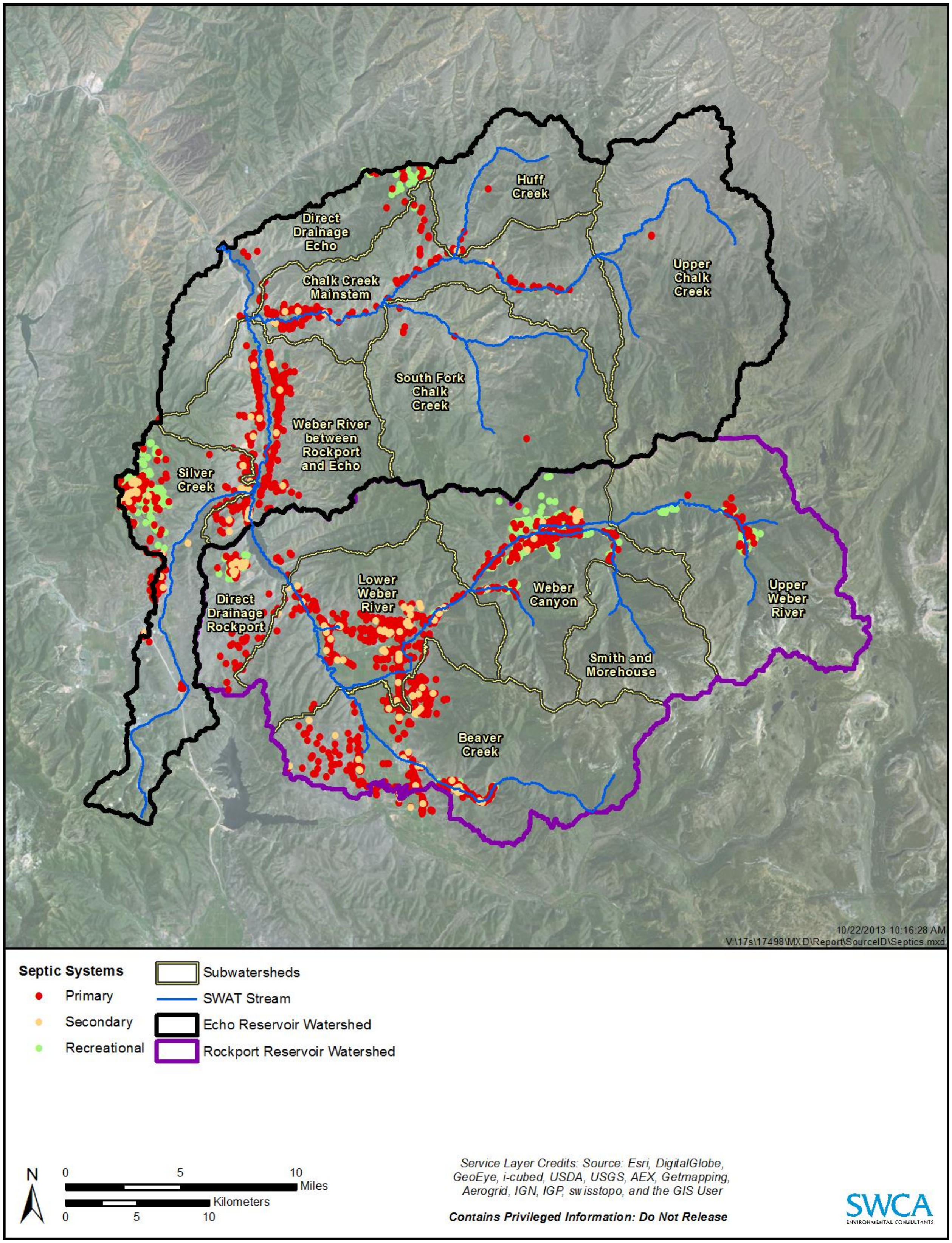

Figure 5.8. Location of septic systems in each subwatershed.

5.2.4 Streambank Erosion

Population growth has led to a rise in development in the watershed. The increase in impermeable surface area associated with residential and commercial development in the watershed can result in flashy peak flows that contribute to streambank erosion and inputs of organic matter, nitrogen, and phosphorus to receiving waters. Figure 5.9 shows an example of streambank erosion occurring in the watershed. Sources of sediment and pollutants include stormwater runoff from paved areas, erosion from construction sites, and sediment and nutrients from roads and livestock. Ski areas, golf courses, and livestock grazing also contribute to the potential of increased runoff and the transport of nutrients and sediment as discussed previously. Developments bordering streams have resulted in the removal and disruption of riparian vegetation, and peak storm flows have caused stream down cutting in some areas and widening in others (Bell et al. 2004). This portion of the total load is associated with the increase in channel erosion beyond natural background. The nutrient load from channel erosion is considered negligible in the Rockport Reservoir Watershed. In the Echo Reservoir Watershed, channel erosion is generally negligible except for the Huff Creek and South Fork Chalk Creek subwatersheds (Table 5.21 and Table 5.22). Channel erosion adds 125 kg TP/season in Huff Creek and 132 kg TP/season in South Fork Chalk Creek (Table 5.22).

Figure 5.9. Streambank erosion occurring in the South Fork Chalk Creek subwatershed.

5.2.5 Landfill

The Three Mile Canyon Landfill, operated by Summit County, is 600 m west and up-gradient of the Rockport Reservoir. The unlined landfill has been in operation since the late 1980s and collects non-hazardous solid waste from municipal, commercial, industrial, and construction/demolition sources. Groundwater well data are available for one well up-gradient of the landfill and two wells down-gradient of the landfill. Nitrate concentrations up-gradient of the landfill are typically below detection limits (<0.01 mg/L). Nitrate concentrations down-gradient of the landfill range from 1 to 44 mg/L. This increase indicates that landfill leachate is a significant source of nitrate to groundwater. Given the proximity of the landfill to Rockport Reservoir, there is a high probability that some of the groundwater with high nitrogen concentrations is delivered to the reservoir by subsurface flow. Data on groundwater flow into the reservoir are not available. Therefore, SWAT model estimates of groundwater flow were used to estimate a nitrogen load from the landfill that is transported through groundwater. The proportion of the total groundwater flow in the Direct Drainage subwatershed that flows beneath the landfill was assumed to be 1% of the total groundwater flow to the reservoir. This value was calibrated as part of the reservoir modeling to account for a missing nitrogen source that was indicated by reservoir nitrogen data but not by tributary data. The average nitrate concentrations were assumed to be 25 mg/L, based on data collected in 2007, the year used for model calibration. The total estimated nitrate load from the landfill to Rockport Reservoir is 922 kg/season.

5.2.6 Natural Background

Background loads represent what would exist in the stream without human interaction in the watershed. The soils and geology of the watershed contribute to the natural or background nutrient loads to the Weber River and its tributaries through soil and bedrock erosion and weathering. Most of the watershed consists of a loam-type soil (Figure 5.10). Soils rated as having severe erosion hazard cover most of the watershed and are generally located in steeply sloped areas (see Figure 3.5). A phosphatic shale layer with concentrations of rock phosphorus between 0.04% and 1.19% (Figure 5.11) is also present in the watershed. The areas of higher concentrations coincide with some areas of severe erosion hazard, indicating potential for higher natural phosphorus concentrations, particularly from easily eroded areas. These areas of higher phosphorus include Chalk Creek. Terrestrial and aquatic wildlife also contribute to the natural background load of nutrients.

Some limestone and sandstone formations are present in parts of the watershed, particularly the Silver Creek subwatershed. These rock types are commonly associated with karst topography. The sinkholes that developed in 1982 and 2008 along Silver Creek occurred close to each other in a limestone formation (Loughlin Water Associates, LLC. 2009). Although such formations do not contribute phosphorus, they will affect the total streamflow, thereby affecting the total nutrient load reaching a reservoir.

Dust particles in the atmosphere can contribute phosphorus loads to the landscape and directly to waterbodies, although the amount depends on long-term climatic and short-term weather patterns and therefore varies greatly from year to year.

Natural background load accounts for 512 kg TP/season and 6,141 kg TN/season in Rockport Reservoir Watershed. The Upper Weber subwatershed generates the most natural background load, whereas the Direct Drainage subwatershed generates the least (Table 5.19). In the Echo Reservoir Watershed, background loads contribute 638 kg TP/season and 7,158 kg TN/season. The Weber-River-between-Rockport-and-Echo subwatershed generates the most background load (297 kg TP/season and 1,197 kg TN/season). The Direct Drainage subwatershed generates the least background load (28 kg TP/season and 180 kg TN/season).

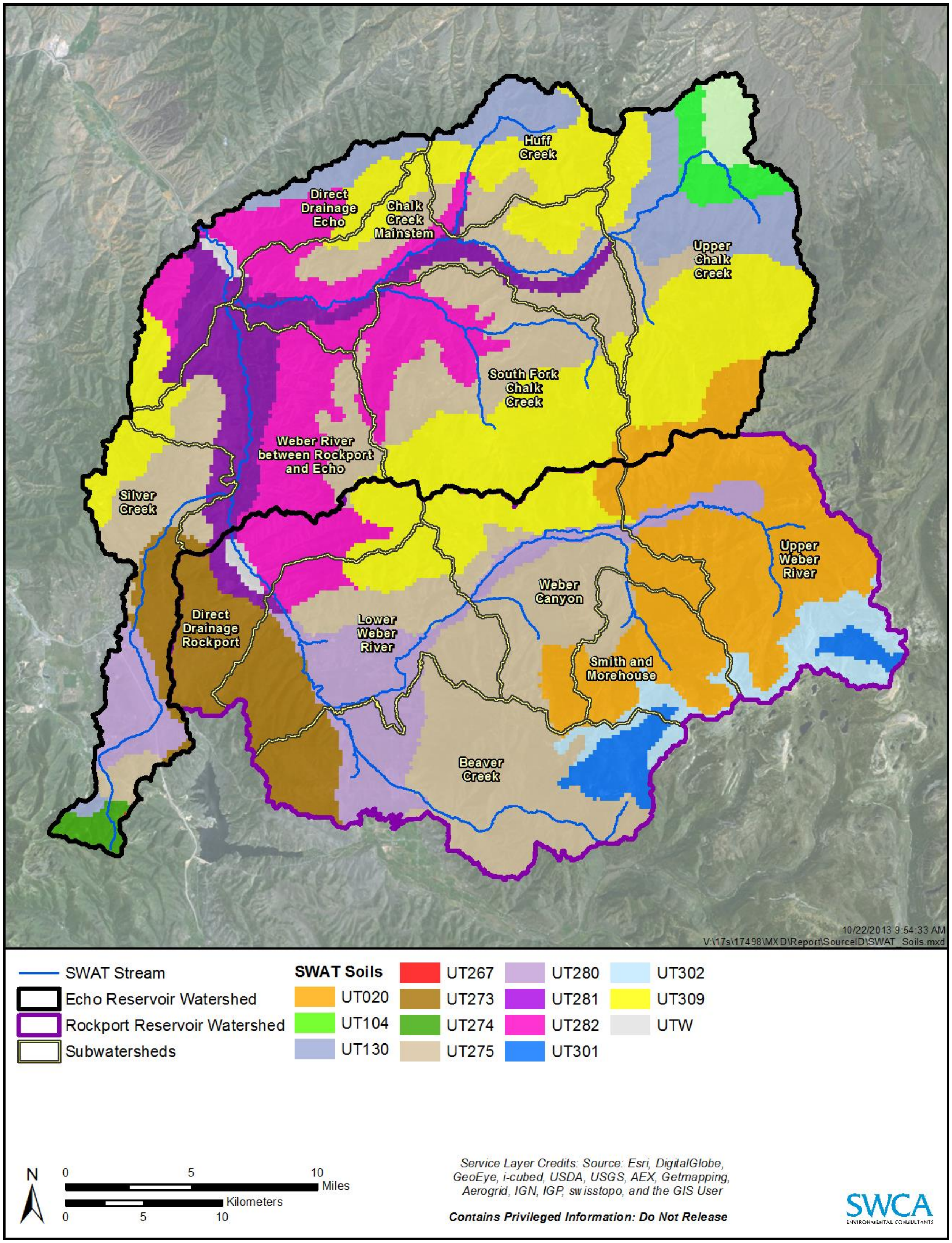

Figure 5.10. Soil types in each subwatershed.

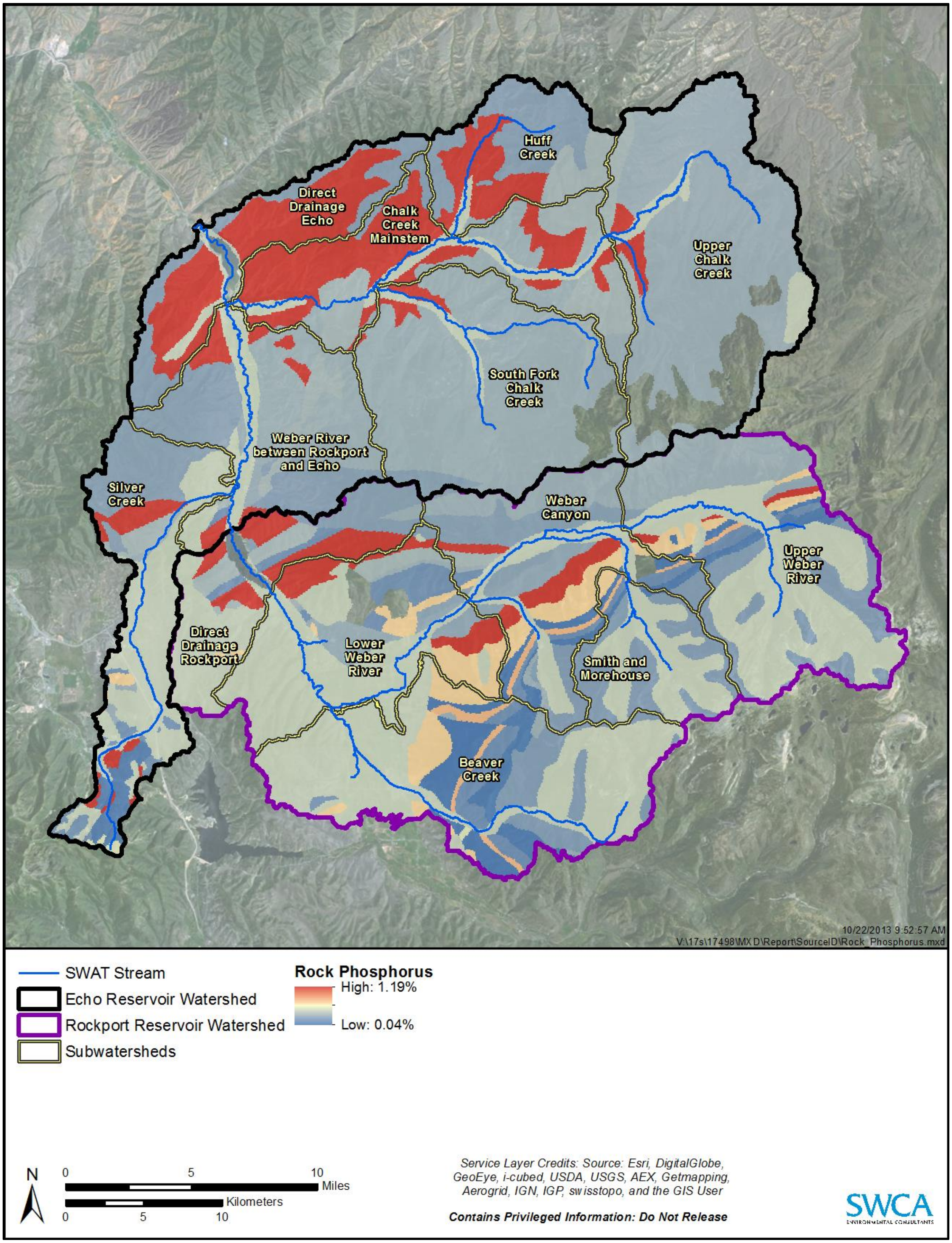

Figure 5.11. Rock phosphorus percentage in each subwatershed.

The natural background nutrient loads were calculated using measured flows from USGS data for all subwatersheds except for the Direct Drainage subwatershed in the Echo Reservoir Watershed. Those flows were calculated using SWAT-generated inflow estimates. Values for background concentrations of TN and TP were taken from the EPA reference conditions for level III, ecoregion 9 (EPA 2000). The aggregate values for spring and summer at the 25th percentile were used for TP. The values classified as the 25th percentile for all seasons were used for TN because of a lack of data to generate aggregate values. The total amount of natural background load is tied to the size of the subwatershed and the flows generated in the subwatershed.

Table 5.19. Natural Background Nutrient Loads by Subwatershed

Subwatershed	TP Load[1] (kg/season)	TN Load[1] (kg/season)
Rockport Reservoir Watershed		
Beaver Creek	86	986
Direct Drainage Rockport	43	516
Lower Weber River	102	632
Smith and Morehouse	64	907
Upper Weber River	155	2,208
Weber Canyon	63	892
Total	**512**	**6,141**
Echo Reservoir Watershed		
Chalk Creek Mainstem	84	1,811
Direct Drainage Echo	28	180
Huff Creek	38	459
Silver Creek	37	461
South Fork Chalk Creek	89	1,072
Upper Chalk Creek	64	1,378
Weber River between Rockport and Echo	297	1,797
Total	**638**	**7,158**

[1] Load delivered to reservoir from each subwatershed for summer season (April 1–September 30).

5.3 Internal Load

Internal pollutant loads are an important consideration when attempting to reverse the eutrophication of lakes. While some lakes may respond rapidly to reductions in external loading of phosphorus, other lakes may experience a delay in recovery due to internal phosphorus loading. This is because the phosphorus in the bottom sediment needs time to equilibrate with the new loading level (Sondergaard et al. 2003; Wetzel 2001). Furthermore, the hypoxic (low oxygen) conditions that occur in the hypolimnion (see Figure 1.1) of stratified lakes can cause phosphorus bound to iron and other elements to be released into the water column (Nurnberg 2009; Sorrano et al. 1997). Therefore, in some stratified lakes internal loading of phosphorus can represent a significant phosphorus load in late summer and early fall. Decomposition of organic matter on the bottom also releases phosphorus in lakes and reservoirs.

Reservoir TP mass balances were calculated for both Rockport and Echo Reservoirs for the years 2002, 2004, 2007, 2008 (Table 5.20). Both reservoirs exhibited similar seasonal trends in TP mass balances as well: In the springtime, both reservoirs were net retainers of TP (more in than out) but became net exporters of TP in the summertime (more out than in). Overall, the reservoirs exhibited net retention of TP. As such, internal load has not been included as an important source in the source identification for either reservoir.

Table 5.20. Reservoir internal load estimates for spring and summer seasons (kg/season).

	2004	2007	2011
Rockport Reservoir			
In	3,229	2,337	15,190
Out	1,694	2,375	8,297
Net Internal Load (Out – In)	-1,535	38	-6,893
Echo Reservoir			
In	5,099	7,436	26,559
Out	2,124	2,206	12,639
Net Internal Load (Out – In)	-2,975	-5,230	-13,920

5.4 Source Summary

The average TP and TN loads to Echo Reservoir are 5,387 kg/season and 42,709 kg/season, respectively (Tables 5.20 and 5.21). Point sources represent approximately 26% of the TP load and 29% of the TN load into Echo Reservoir (Figures 5.12 and 5.13). Releases from Rockport Reservoir make up 17% of the TP load and 22% of the TN load. Background sources account for 12% of the TP and 17% of the TN load to Echo Reservoir. Stormwater, agricultural sources, and channel erosion are all significant sources of nonpoint sources in the Echo Reservoir Watershed for phosphorus. Agricultural nonpoint sources comprise the largest nonpoint source in the watershed for nitrogen. In total, nonpoint sources (excluding background sources and releases from Rockport Reservoir) account for 45% of the TP load and 32% of the TN load to Echo Reservoir.

The average TP and TN loads to Rockport Reservoir are 2,337 kg/season and 18,573 kg/season, respectively (Tables 5.20 and 5.21). Point sources represent approximately 14% of the TP load and 10% of the TN load into Rockport Reservoir (Figures 5.14 and 5.15). Background sources account for 22% of the TP and 33% of the TN load to Echo Reservoir. Agricultural nonpoint sources comprise the largest nonpoint source in the watershed for both nitrogen and phosphorus. Stormwater is also a significant source of both nutrients to Rockport Reservoir. The landfill and septic systems, primarily in Weber Canyon and the Lower Weber subwatersheds, are also significant sources of nitrogen to Rockport Reservoir. In total, nonpoint sources (excluding background sources) account for 64% of the TP load and 57% of the TN load to Rockport Reservoir.

Table 5.21.Summary of Nonpoint Source Total Phosphorous Loads (kg per summer season [April – September])

Subwatershed	Stormwater	Agriculture	Septic Systems	Channel Erosion	Natural Background	Upstream	Total Nonpoint Source	Point Source Load	Total
Rockport Reservoir Watershed									
Beaver Creek	47	305	18	0	86	0	456	0	687
Direct Drainage Rockport	123	138	2	0	43	0	306	231	306
Lower Weber River	54	532	20	0	102	0	708	0	814
Smith and Morehouse	3	60	–	0	64	0	126	106	126
Upper Weber River	9	55	6	0	155	0	225	0	225
Weber Canyon	42	41	34	0	63	0	180	0	180
Total	**278**	**1,131**	**79**	**0**	**512**	**0**	**2,000**	**337**	**2,337**
Echo Reservoir Watershed									
Chalk Creek mainstem	236	57	5	0	84	0	382	165	547
Direct Drainage Echo	101	57	0	0	28	0	187	0	187
Huff Creek	41	240	0	125	38	0	444	0	444
Silver Creek	719	166	4	0	37	0	926	1,262	2,188
South Fork Chalk Creek	76	12	1	132	89	0	310	0	310
Upper Chalk Creek	32	15	0	0	64	0	111	0	111
Weber River between Rockport and Echo	84	277	10	0	297	931	1,599	0	1,599
Total	**1,290**	**825**	**19**	**257**	**638**	**931**	**3,960**	**1,427**	**5,387**

Table 5.22. Summary of Nonpoint Source Total Nitrogen Loads (kg per summer season [April – September])

Subwatershed	Stormwater	Agriculture	Septic Systems	Channel Erosion	Landfill	Natural Background	Upstream	Total Nonpoint Source	Point Source Load	Total
Rockport Reservoir Watershed										
Beaver Creek	106	387	450	–	–	986	–	1,930	1,051	2,981
Direct Drainage Rockport	226	506	779	–	922	516	–	2,948	–	2,948
Lower Weber River	130	1,425	544	–	–	632	–	2,731	703	3,434
Smith and Morehouse	4	685	–	–	–	907	–	1,596	–	1,596
Upper Weber River	20	717	509	–	–	2,208	–	3,453	–	3,453
Weber Canyon	115	1,941	1,214	–	–	892	–	4,161	–	4,161
Total	**601**	**5,660**	**3,496**	**–**	**922**	**6,141**	**–**	**16,819**	**1,754**	**18,573**
Echo Reservoir Watershed										
Chalk Creek mainstem	242	3,108	199	–	–	1,811	–	4,929	715	6,076
Direct Drainage Echo	174	19	44	–	–	180	–	416	–	416
Huff Creek	45	495	2	–	–	459	–	1,001	–	1,001
Silver Creek	1,063	619	302	–	–	461	–	2,445	11,396	13,841
South Fork Chalk Creek	67	1,172	6	–	–	1,072	–	2,748	–	2,317
Upper Chalk Creek	47	905	1	–	–	1,378	–	2,332	–	2,332
Weber River between Rockport and Echo	255	4,520	539	–	–	1,797	–	16,727	–	16,727
Total	**1,893**	**10,838**	**1,093**	**–**	**–**	**7,158**	**–**	**30,598**	**12,111**	**42,709**

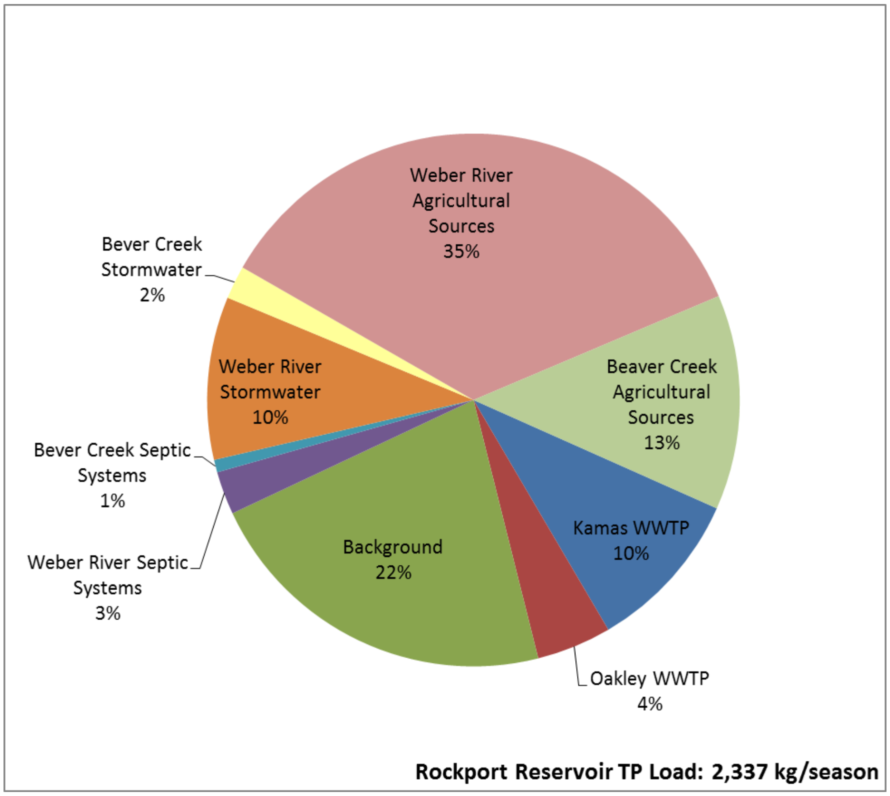

Figure 5.12. Proportion of summer season total phosphorus load associated with significant sources in the Rockport Reservoir Watershed.

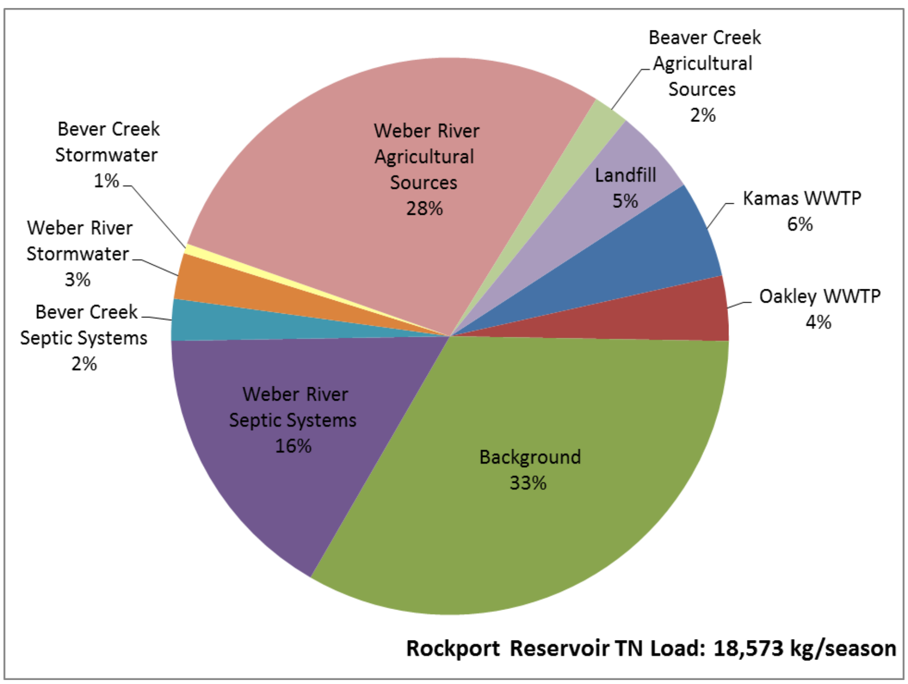

Figure 5.13. Proportion of summer season total nitrogen load associated with significant sources in the Rockport Reservoir Watershed.

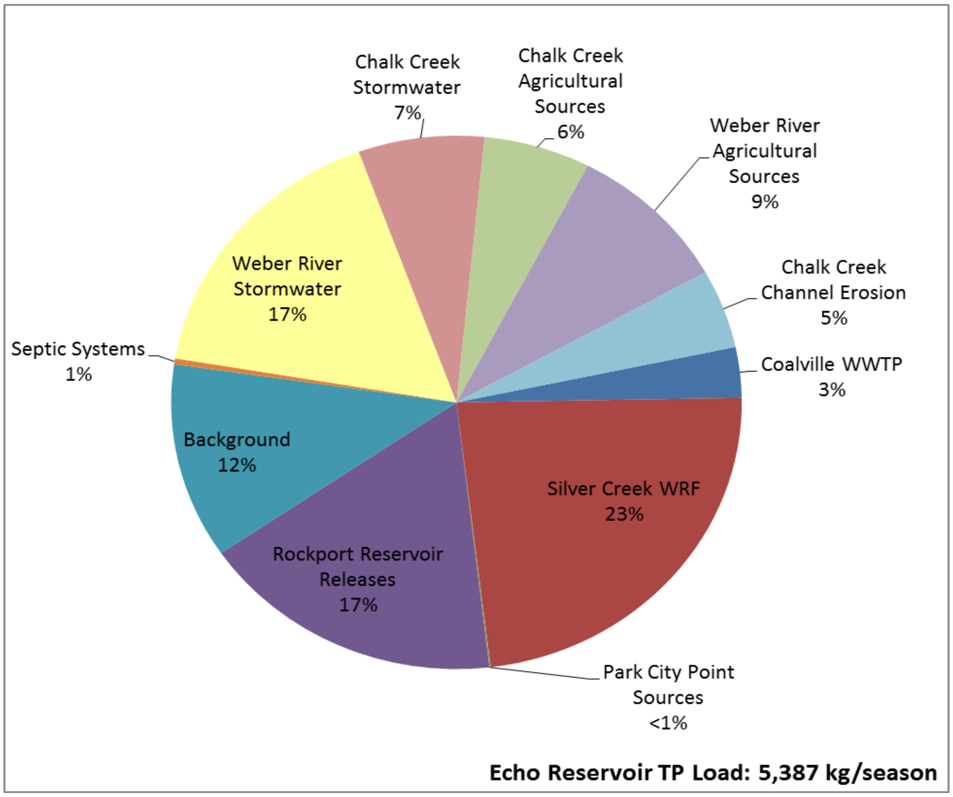

Figure 5.14. Proportion of spring–summer season total phosphorus load associated with significant sources in the Echo Reservoir Watershed.

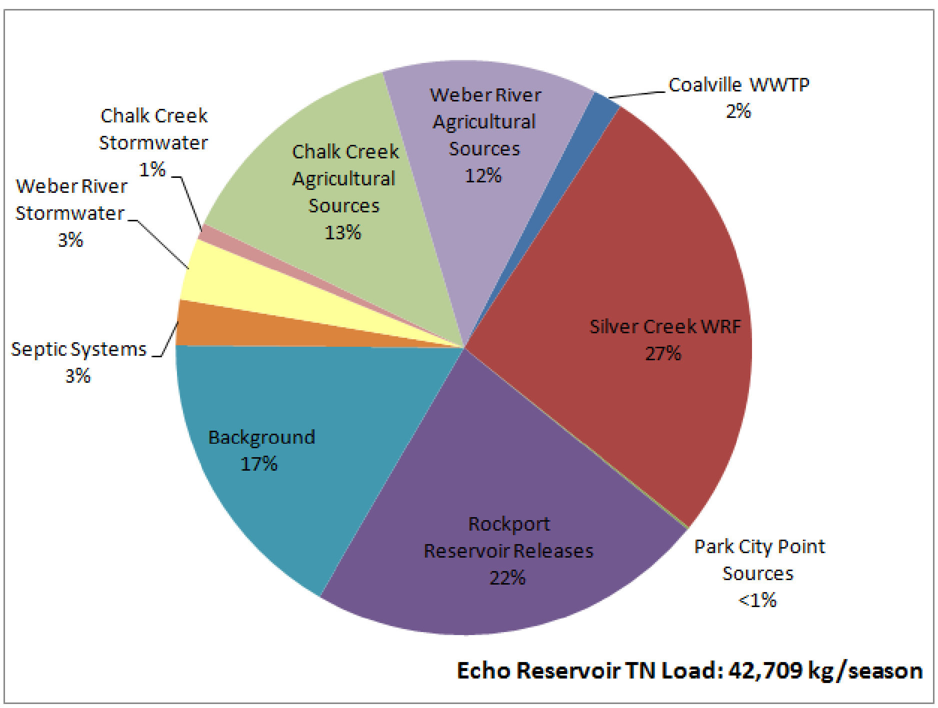

Figure 5.15. Proportion of summer season total nitrogen load associated with significant sources in the Echo Reservoir Watershed

CHAPTER 6. TOTAL MAXIMUM DAILY LOAD SUMMARY

6.1 Water Quality Targets and Linkage Analysis

Setting water quality endpoints is critical in the TMDL development process. The goal of the Rockport Reservoir and Echo Reservoir TMDLs is to achieve state water quality criteria to bring designated beneficial uses into full support as quickly as possible. Setting appropriate water quality endpoints is a key prerequisite to the calculation and apportionment of current pollutant loads and the necessary load reductions to support designated beneficial uses. Several methods were employed to derive water quality endpoints for Rockport Reservoir and Echo Reservoir.

The State of Utah has designated Rockport Reservoir and Echo Reservoir as protected for cold-water game fish (Class 3A). This designated beneficial use was identified as impaired on the State of Utah 1996 303(d) list for Echo Reservoir and the 2008 303(d) list for Rockport Reservoir. DO endpoints are based on State Water Quality criteria and, together with warm temperatures, are the direct cause of the impairment of cold-water fisheries (3A) in the reservoir. Low DO in the reservoirs is related to the decomposition of algae and subsequent depletion of DO in the bottom layer (hypolimnion) that does not mix with surface waters during the summer (see Figure 1.1). Oxygen-, nutrient-, and algae-related endpoints were selected based on the direct and indirect influence of algal growth on DO concentrations in both waterbodies. These endpoints were based on a review of relevant scientific literature and results from the BATHTUB models developed for both reservoirs for three reservoir and climatic conditions (dry, wet, and average). Nutrient and algal targets for the reservoirs are based on the correlation between target oxygen depletion rates, associated DO concentrations in the middle layer (metalimnion) of the reservoir, and mean seasonal chlorophyll *a*, TP, and TN concentrations derived from the BATHTUB modeling results.

The primary contributor to low DO in Rockport and Echo Reservoirs is sediment oxygen demand related to annual algal blooms, legacy organic matter, and annual organic matter washed into the system. An increase in nutrients, primarily nitrogen and phosphorus, increases algal growth in the reservoirs, and the subsequent increased amount of decaying organic matter reduces the amount of DO remaining in the water column. Algal blooms, reflected in increases in chlorophyll *a* concentrations, contribute to sediment oxygen demand and oxygen depletion in the reservoir throughout the year. Sediment carrying organic matter can also affect DO concentrations through use of DO in decomposition of the organic matter. Reduction of nutrients is required to reduce the trophic state of the reservoir, reduce algal growth, and improve DO profiles especially during stratification. Decomposition of watershed-derived organic matter represents an unknown component of oxygen depletion in the hypolimnion. Impairment occurs during the spring and summer because the reservoirs stratify during warmer seasons, which creates an upper layer of warm water with sufficient DO and a lower layer of cold water with low DO. It is the low DO concentrations that impair the reservoirs' ability to support a cold-water fishery during the spring and summer, when these reservoirs are likely to be stratified and surface temperatures become too warm for cold-water species.

The BATHTUB model was used to correlate DO endpoints and chlorophyll *a* endpoints with mean seasonal nutrient concentrations. Attainment of the DO endpoints specific to Rockport and Echo Reservoirs correlate with mean seasonal TP and TN concentrations of 0.014 mg/L and 0.26 mg/L, respectively, for Rockport Reservoir and 0.018 mg/L and 0.27 mg/L, respectively, for Echo Reservoir. These nutrient concentrations will result in attainment of the mean seasonal chlorophyll *a* target of 3.5 ug/L for each reservoir. These concentrations will therefore serve as the nutrient endpoints for Rockport and Echo Reservoirs.

6.1.1 Dissolved Oxygen Targets

DO is important to the health and viability of the cold-water fishery beneficial use (3A) designated by the State of Utah for Rockport Reservoir and Echo Reservoir. High concentrations of DO (6.0–8.0 mg/L or greater) are necessary for the health and viability of fish and other aquatic life. Low DO concentrations (less than 4.0 mg/L) cause increased stress to fish species, lower resistance to environmental stress and disease, and result in mortality at extreme levels (less than 2.0 mg/L). Low DO in the reservoir is related to the decomposition of algae and other organic matter and subsequent depletion of DO in the hypolimnion.

The goal of the Rockport Reservoir and Echo Reservoir TMDLs is to increase concentrations of oxygen in the reservoir such that the designated beneficial uses are fully supported. Cold-water sport fish species are not known to reproduce in the reservoir; therefore, the early life-stage criteria do not apply. The state DO criteria for all life stages of cold-water fish are 4.0 mg/L as a 1-day minimum, 5.0 mg/L as a 7-day average, and 6.5 mg/L as a 30-day average.

All of these criteria are currently attained in the epilimnion of the reservoirs and typically violated in the hypolimnion of the reservoirs at the end of the summer stratification season. The State of Utah applies the 4.0 mg/L standard to a minimum of 50% of the water column in assessing attainability of this standard in deep stratified lakes and reservoirs. In addition, the epilimnion in each reservoir routinely exceeds temperature criteria during the summer season due to solar radiation. To protect the fishery from the intersecting pressures of high temperature in the epilimnion and low DO in the hypolimnion, the following site-specific assessment methodology was implemented for the Rockport and Echo Reservoir TMDLs.

During periods of thermal stratification, the minimum DO criteria of 4.0 mg/L and maximum temperature of 20^{o}C shall be maintained in a 2-m layer across the reservoir to provide adequate refuge for cold-water game fish. This layer is represented by the metalimnion. These criteria were determined to provide sufficient support for the cold-water game fish beneficial use (3A) designated by the State of Utah for the East Canyon Reservoir TMDL approved by the EPA in 2010. During periods of complete mixing in the reservoir, all life-stage water quality criteria identified by the State of Utah will be maintained across the reservoir and throughout at least 50% of the water column.

The DO endpoints for Rockport and Echo Reservoirs are consistent with existing Utah water quality criteria and are based on similar endpoints derived for the East Canyon Reservoir, a similar upper-elevation reservoir the Weber River Basin. The East Canyon endpoints, as well as those for Rockport and Echo Reservoirs, were developed in collaboration with the Utah DWR and determined to be protective of the fish species found in the reservoirs. The UDEQ and DWR will have an opportunity to review and comment on this approach for these reservoirs prior to completing the final TMDL.

6.1.1.1 METALIMNETIC OXYGEN DEPLETION RATE TARGETS

The goal of attaining a DO concentration of at least 4 mg/L in the metalimnion is correlated with a target metalimnetic oxygen depletion (MOD) rate, a parameter that has been calculated for current reservoir conditions and that can be predicted using the BATHTUB model. The target MOD rate (mg/m^3/day) is calculated by comparing the oxygen concentration below the thermocline at stratification with the target of 4 mg/L to determine how much oxygen can be depleted from the metalimnion and still meet water quality criteria. This value is then divided by the total number of days in the stratification season to determine an acceptable target MOD rate. The target MOD rate is therefore related to the starting oxygen concentration in the reservoir and the number of days in the stratification season. A higher initial oxygen concentration and/or a shorter stratification season would result in a higher target MOD rate (Figure 6.1).

The MOD target for Echo Reservoir and Rockport Reservoir is 36.5 mg/m^3/day based on an assumed initial DO concentration of 9.0 mg/L. This target was used to derive TP and nitrogen targets for the reservoir as well as algal-related targets.

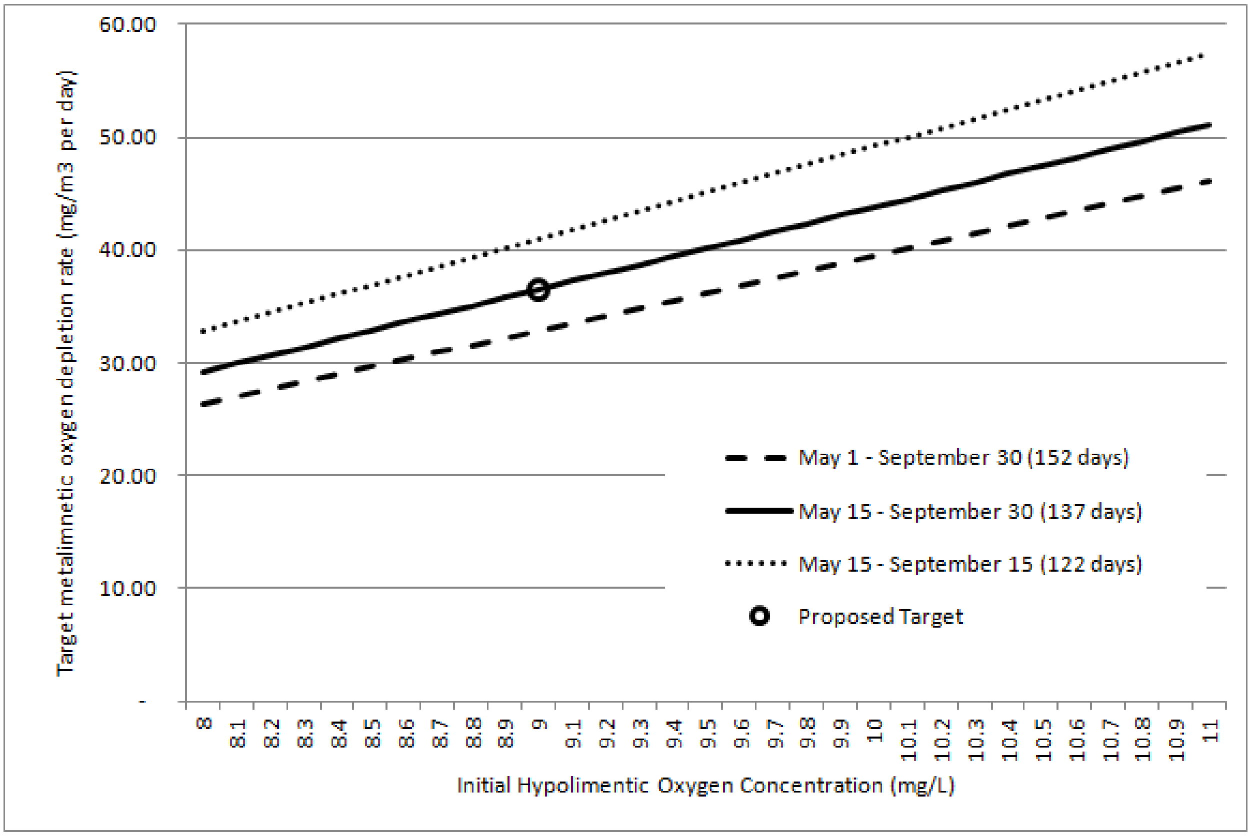

Figure 6.1. Relationship between metalimnetic oxygen depletion rate targets and initial hypolimnetic oxygen concentration for three different assumed stratification seasons and selected target for Rockport Reservoir and Echo Reservoir.

The stratification season for both reservoirs is assumed to be 137 days in length extending from May 15 to September 30. The concentration of DO at the start of stratification, as opposed to during the stratification period, is more difficult to estimate. There are no DO data in early spring, prior to stratification. The earliest spring measurements were taken in Echo Reservoir on May 22, 2007, and on May 29, 2007 for Rockport Reservoir. The average and maximum surface DO concentrations on those dates were 9.10 mg/L and 9.45 mg/L for Echo Reservoir and 7.9 and 8.0 mg/L for Rockport Reservoir, respectively. Although there are very few DO data for either reservoir at stratification, there are more DO data available for the tributaries into and out of the reservoirs in early spring, and these concentrations also provide some perspective on hypolimnetic oxygen depletion rates, especially the concentrations in the Weber River directly downstream of each dam, recognizing that some aeration of the water will occur upstream of the monitoring site. A summary of these data is provided in Table 6.1 and indicates the initial concentration of oxygen in the hypolimnion could be as high as 10 mg/L in Echo Reservoir. The use of 9.0 mg/L in deriving the MOD rate target is a conservative assumption for the TMDL analysis.

Table 6.1. Summary of Early Spring Dissolved Oxygen Data in Tributaries to and from Rockport Reservoir and Echo Reservoir

	Chalk Creek	Weber River above Rockport Reservoir	Weber River below Rockport Reservoir	Weber River above Echo Reservoir	Weber River below Echo Reservoir
April					
2004	9.6	10.9	9.8	9.8	12.8
2005	9.5	10.0	–	–	–
2006	9.8	10.2	–	–	–
2008	11.0	10.3	–	–	–
2009	1.8	10.0	9.8	11.4	9.4
Average	**8.3**	**10.3**	**9.8**	**10.6**	**11.1**
May					
2001	10.8	11.1	–	–	–
2002	8.8	8.9	–	–	–
2003	8.7	7.9	–	10.3	–
2004	8.9	9.5	10.8	10.6	11.3
2006	15.2	12.0	–	–	–
2007	11.2	10.6	11.0	12.0	9.2
2009	9.8	9.8	9.1	11.5	9.4
Average	**10.3**	**10.0**	**10.4**	**11.0**	**10.3**

6.1.2 Nutrient Targets

Average seasonal water quality in the reservoirs, based on a 35% nutrient reduction scenario for each condition, are presented in Tables 6.2 and 6.3. The target TP and TN concentrations in Rockport Reservoir are 0.014 mg/L and 0.26 mg/L under average conditions, respectively. The target TP and TN concentrations in Echo Reservoir are 0.018 mg/L and 0.27 mg/L, respectively. The average condition concentrations are used in the TMDL analysis to determine the quantity of nutrient reductions.

Table 6.2. Predicted Rockport Reservoir Nutrient Concentrations under Proposed Nutrient Load Reductions of 35%

	Dry	Average	Wet
Current			
Total phosphorus (mg/L)	0.043	0.021	0.034
Total nitrogen (mg/L)	0.409	0.392	0.381
Organic nitrogen (mg/L)	0.347	0.295	0.312
Orthophosphate (mg/L)	0.012	0.0081	0.0094
Target Water Quality			
Total phosphorus (mg/L)	0.027	0.014	0.023

Table 6.2. Predicted Rockport Reservoir Nutrient Concentrations under Proposed Nutrient Load Reductions of 35%

	Dry	Average	Wet
Total nitrogen (mg/L)	0.268	0.257	0.260
Secchi depth (m)	6.2	6.1	5.7
Organic nitrogen (mg/L)	0.236	0.239	0.251
Orthophosphate (mg/L)	0.004	0.004	0.005

Table 6.3. Predicted Echo Reservoir Nutrient Concentrations under Proposed Nutrient Load Reductions of 35%

	Dry	Average	Wet
Current			
Total phosphorus (mg/L)	0.019	0.023	0.036
Total nitrogen (mg/L)	0.353	0.414	0.407
Organic nitrogen (mg/L)	0.274	0.295	0.318
Orthophosphate (mg/L)	0.006	0.008	0.010
Target Water Quality			
Total phosphorus (mg/L)	0.014	0.018	0.025
Total nitrogen (mg/L)	0.246	0.266	0.274
Secchi depth (m)	6.7	5.9	5.3
Organic nitrogen (mg/L)	0.227	0.244	0.264
Orthophosphate (mg/L)	0.003	0.004	0.006

6.1.3 Algal Targets

Algae-related endpoints were selected to 1) reduce the direct and indirect effects of plant overgrowth on DO concentrations, 2) address the periodic overgrowth of algae that violates the narrative standard for waters established by the State of Utah, 3) prevent conversion to dominance of blue-green algae, and 4) maintain a food supply for the fishery. Overgrowth of algae violates the narrative standard for waters established by the State of Utah, which requires waters to be maintained such that they do not become offensive by "unnatural deposits, floating debris, oil, scum, or other nuisances such as color, odor or taste…or result in concentrations or combinations of substances which produce undesirable human health effects…" (Utah State Code R317). In addition to algal overgrowth, prevention of blue-green algal dominance is important for protection of beneficial uses in Rockport and Echo Reservoirs. Blue-green algae blooms can cause the formation of surface scums and the potential release of toxins harmful to humans, livestock, and pets. There are no known reports of toxic cyanobacteria blooms in Rockport Reservoir or Echo Reservoir, a condition that must be maintained. Each reservoir supports a fishery that relies on algae as a part of the food web and as habitat; however, low DO in the deeper portions of the reservoirs related to decomposition and plant respiration are stressful to fish, particularly when surface water temperatures increase during the summer. High surface water temperatures force fish to deeper parts of the reservoir to avoid the warmer water, but deeper waters during the summer periods are more likely to be low in DO or anoxic and therefore of limited use as refugia for fish.

Two algal-related endpoints were identified for Rockport and Echo Reservoirs:

1. Mean seasonal chlorophyll *a* values of 3.5 µg/L
2. Dominance by algal species other than blue-green algae

The mean seasonal chlorophyll *a* endpoint of 3.5 µg/L was derived from the BATHTUB model results, which are in the range of median values for reservoirs in western forested mountains (Table 6.4). A summary of chlorophyll *a* data from 1990 to 1998 in Ecoregion 2 (Western Forested Mountains) is provided below (Table 6.4). The statistical summaries are based on data from 441 lakes and reservoirs and include 3,931 records for chlorophyll *a*. The nutrient criteria technical guidance manual (EPA 2000) suggests that the lower 25th percentile of ecoregional data is representative of the reference condition, when not all lakes and reservoirs are considered to be in the reference condition. However, the target value of 3.5 µg/L is more protective of Echo Reservoir during average conditions (Table 6.5).

Table 6.4. Summary Statistics for Chlorophyll *a* (µg/L) Data from Lakes and Reservoirs in the Western Forested Mountains Ecoregion

Season	25th Percentile	Median	75th Percentile
Fall	1.8	3.1	6.7
Spring	2.1	4.4	8.6
Summer	1.4	2.9	5.9
Winter	3.5	5.8	6.2

Table 6.5. Predicted Rockport Reservoir Chlorophyll *a* (µg/L) Concentrations under Proposed Nutrient Load Reductions

	Dry	Average	Wet
Current (predicted)			
Rockport Reservoir	8.1	5.8	6.5
Echo Reservoir	4.9	5.6	6.8
Target Water Quality			
Rockport Reservoir	3.2	3.3	3.9
Echo Reservoir	2.8	3.6	4.4

6.2 Future Growth

The combined Rockport Reservoir and Echo Reservoir Watershed is approximately 464,000 acres with over 99% of the land in Summit County, Utah. The population of Summit County was estimated at 36,324 in 2010. Summit County is made up of seven primary municipalities; their 2000 and 2010 populations are shown in Table 1.1. As of May 2012, the county had 13,103 non-primary residential structures versus 12,613 primary residential structures. These include cabins, condominiums, mobile homes, and standard homes; these do not include commercial, vacant land, or exempt properties.

The county as a whole is projected to grow by 56% by 2030, compared to a 42% projected growth for the entire State of Utah (Table 6.6). Much of this growth is projected for small towns and rural areas in the county, outside of Park City (State of Utah 2012). A large portion of the population growth in the watershed is expected to occur in the Echo Reservoir Watershed. The population in the Synderville Basin is expected to more than double by 2030. Population estimate reports show Park City growing from 7,497 in 2005 to 16,312 in 2030, a 54% increase. Summit County lands in the Snyderville Basin are expected to accommodate 31,887 people by 2030; a 51% increase from 15,734 people in 2005 (see section 2.2.2 for population projections). The majority of new residential development is likely to occur on the basin floor and on hillsides with less than a 25% slope. Commercial development will be concentrated along Interstate 80 and Highways 224, 40, and 248. A large portion of the Snyderville Basin is zoned for residential development. The Rural Residential zone (Figure 6.2) allows existing residential uses to continue and allows for the construction of new single family dwelling units. The base density is 1 unit/per 20 acres on developable lands and 1 unit/40 acres on sensitive lands. The Hillside Stewardship zone accommodates residential development in areas that contain slopes ranging from 15% to 25% with a base density of 1 unit/30 acres on developable lands and 1 unit/40 acres on sensitive lands. Lands in this zone are more susceptible to erosion, and development in these areas may negatively affect water quality. Residential development in the Mountain Remote zone is minimal (1 unit/120 acres on developable and sensitive lands) because the location and terrain do not allow for easy access to local service providers. Development in the Mountain Remote Zone is also minimized in order to protect the natural environment and water quality, to lessen fire danger, to minimize viewshed disturbances, and to promote the open space values of the Snyderville Basin (Summit County 2008). Commercial development and light industry are concentrated along I-80 and Highways 224, 40, and 248. Densities for the Community Commercial zone and Service Commercial/Light Industrial zone are not specified. In the Neighborhood Commercial zone, no single structure will contain more than 5,000 square feet.

Table 6.6. Population of Rockport Reservoir and Echo Reservoir Watersheds

Area	Population 2000[1]	Population 2010[1]	Population 2030[2]	Percentage Growth 2010–2030
State of Utah	2,223,169	2,763,885	3,913,605	42%
Summit County	29,736	36,324	56,890	56%
Echo Reservoir Watershed				
Park City	7,371	7,547	11,444	52%
Coalville City	1,382	1,363	1,859	36%
Subtotal	**8,753**	**8,910**	**13,303**	**49%**
Rockport Reservoir Watershed				
Kamas City	1,274	1,811	2,864	58%
Oakley City	948	1,470	3,297	124%
Subtotal Population with Wastewater Treatment	**2,222**	**3,281**	**5,981**	**82%**

[1] Data from Economic Report to the Governor (State of Utah 2011).

[2] Data from Governor’s Office of Management & Budget, 2012 Baseline Projections(State of Utah 2012)

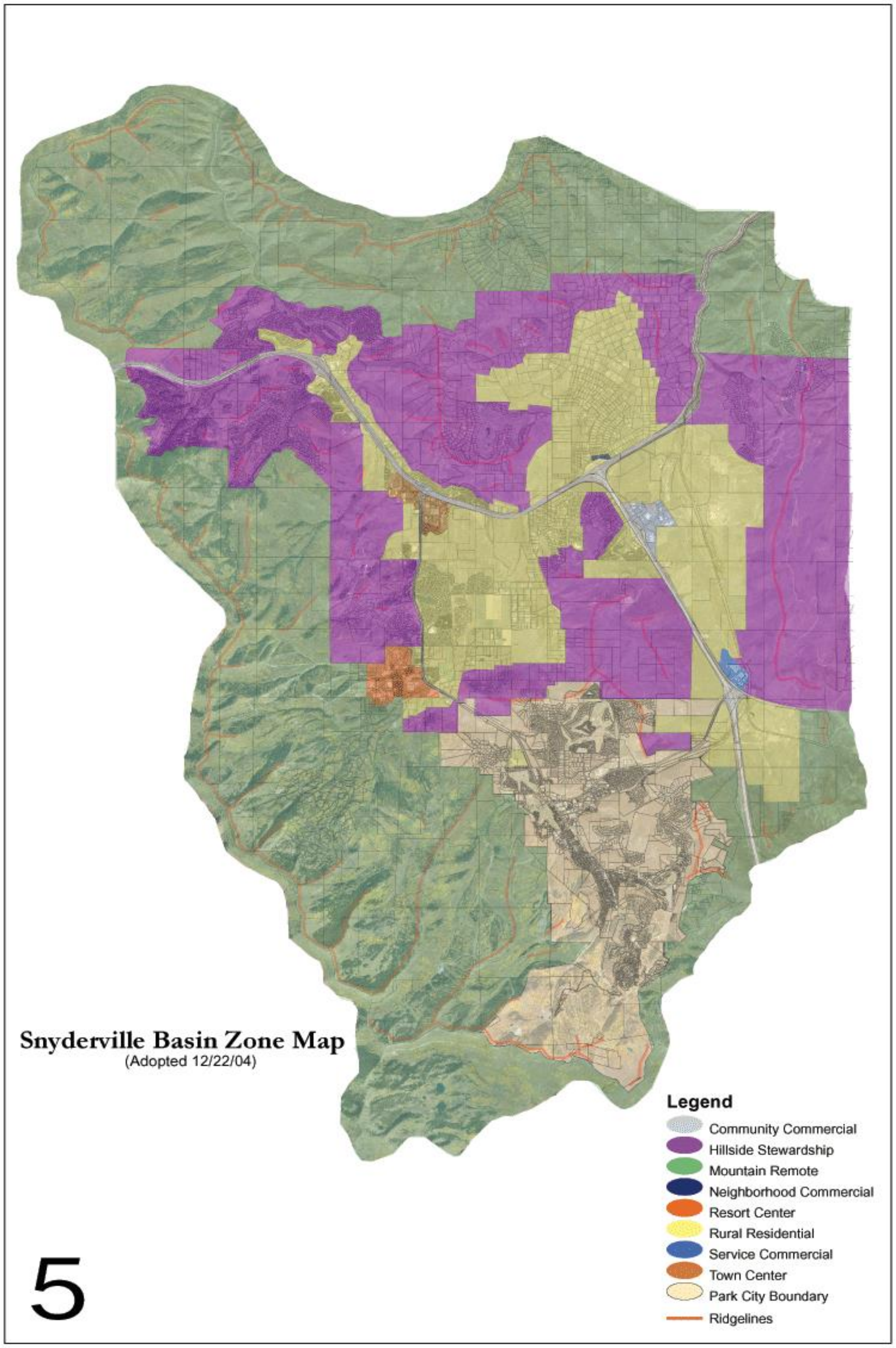

Figure 6.2. Snyderville Basin zoning map (Summit County 2008).

Assuming no new WWTPs are planned, new residential and commercial development in the watersheds will require additional connections to an existing WWTP. As evidenced by the land use map (see Figure 5.5), the majority of undeveloped land is shrub/scrub, agricultural land, open space, or forest, with significant low-density urban land uses already present in the Silver Creek subwatershed and the Weber Canyon subwatershed.

The Coalville WWTP is currently in the process of upgrading. Their current summer flow is 0.21 MGD, but they are projecting a future flow of 0.291 MGD. The Oakley WWTP flow of 0.15 MGD is currently well below their capacity flow of 0.25 MGD and less than half the projected future flow. The Snyderville Basin Water Reclamation District, which operates the Silver Creek WRF, has already determined that anticipated growth in their service district will require expansion of the Silver Creek WRF. Current average daily flow from the Silver Creek WRF is 1.23 MGD with capacity flows of approximately 2.0 MGD. Accommodation of the expected population growth in the Silver Creek subwatershed basin will require expansion of the treatment system with an average discharge of 4.0 MGD, twice the current capacity flow (Table 6.7).

The Blue Sky Resort WWTP is included as a future source because it is currently permitted to discharge, but the facility has not been constructed and is therefore not currently discharging. This future source is permitted with an offset for phosphorus related to removing the grazing operations on the Blue Sky Resort property. Similarly, the Francis WWTP is currently negotiating a discharge permit with UDWQ and growth expectations in that area will be reflected in that permit. The DWR fish hatchery in Kamas and the Park City tunnels are not affected by growth in the watershed. The loads from these sources are expected to remain at current levels over the next 10 years (Table 6.7).

Table 6.7. Projected Increase in Wastewater Discharges Resulting From Projected Population Growth

Point Source	Current Summer Flow (MGD)	Capacity Flow (MGD)	Future Flow 2030 (MGD)	Capacity Source	Future Flow Source
Rockport Reservoir Watershed					
Kamas WWTP	0.14	0.40	–	Permit	$\%growth \times current\ flow$
Oakley WWTP	0.15	0.25	0.330	Permit	$\%growth \times current\ flow$
DWR fish hatchery	–	3.41	3.410	Current	No growth
Francis WWTP	–	0.14	0.36	DWQ staff	DWQ staff
Echo Reservoir Watershed					
Coalville WWTP	0.21	0.42	0.291	Permit[1]	Design
Silver Creek WRF	1.23	2.00	4.000	Self-reported	Design
Park City tunnels total	2.02	2.02	2.020	Current	No growth
Blue Sky	–	0.03	0.040	Permit	Design

[1] No capacity listed for peak flow; design flow assumed 0.60 in statement of basis analysis.

Future growth in the watershed also affects the nonpoint source loads. Conversion from agricultural to low-density urban areas has two main effects: 1) increases in impervious surface cover resulting in increased stormwater runoff and 2) reduction in nutrient loads from agricultural activities. These effects are not necessarily equivalent, meaning that nutrient loads may or may not be reduced under a scenario of urbanization. Moreover, increased urbanization generally changes the hydrology of the area to a more flashy system that will generate more erosion from storm events.

6.3 Total Maximum Daily Load Analysis

6.3.1 Current Load Summary and Total Maximum Daily Loads

Current loads and TMDL loads, expressed as daily and seasonal (April 1–September 30) averages, are summarized for Rockport and Echo Reservoirs in Table 6.8. Although daily loads are presented, seasonal loads are considered to be the most appropriate averaging period for this TMDL. The seasonal loads, rather than daily total maximum loads, are the most appropriate for establishing discharge UPDES permits associated with this TMDL.

The current TP load to Rockport Reservoir is 2,337 kg TP/season (12.8 kg TP/day), including a point source load of 337 kg TP/season (1.9 kg TP/day) and a nonpoint source load of 2,000 kg TP/season (1.1 kg TP/day). The current TN load to Rockport Reservoir is 18,573 kg TN/season (102 kg TN/day). The point source contribution is 1,754 kg TN/season (9.6 kg TN/day), and the nonpoint sources contribute 16,819 kg TN/season (92 kg TN/day).

Results from the BATHTUB model (see Appendix A) indicate that attainment of water quality endpoints identified for the waterbody requires a reduction of the TP load to Rockport Reservoir of 818 kg TP/season, which represents an overall reduction of 35% and a total seasonal load of 1,519 kg TP/season. The target seasonal load corresponds to an average daily load of 8.3 kg TP/day. However, daily average could vary with hydrology over the season and is expected to be attained only on average over the course of the season. The target reduction for TN is 6,501 kg TN/season, also a 35% reduction. This reduction corresponds to a total seasonal load of 12,072 kg TN/season, or an average daily load of 66.3 kg TN/day during the season. As with TP, the daily value will vary and is expected to be attained as an average over the season (Table 6.9).

The current load of TP and TN to Echo Reservoir is 5,387 kg TP/season (29.6 kg/day) and 42,709 kg TN/season (235 kg TN/day). Point sources contribute 1,427 kg TP/day (8 kg TP/day) and 12,111 kg TN/season (66.5 kg TN/day), whereas nonpoint sources contribute 3,960 kg TP/season (21.7 kg TP/day) and 30,598 kg TN/season (168 kg TN/day). BATHTUB results indicate that attainment of water quality endpoints identified for Echo Reservoir requires a 35% reduction for both TP and TN. This reduction is 1,885 kg TP/season (10.4 kg TP/day), resulting in a load of 3,502 kg TP/season (19.2 kg TP/day). Total nitrogen must be reduced by 14,948 kg TN/season (82 kg TP/day) with a resulting load of 27,761 kg TN/season (141 kg TN/day). Again, the daily value will vary and is expected to be attained as an average over the season (Table 6.9).

Table 6.8. Summary of Current Loads to Receiving Waters and Resulting Loads to the Rockport and Echo Reservoirs

	Total Phosphorus		**Total Nitrogen**	
	Current Load to Receiving Waters (kg/season)	**Current Load to Reservoir (kg/season)**	**Current Load to Receiving Waters (kg/season)**	**Current Load to Reservoir (kg/season)**
Rockport Reservoir				
Point source load	500	337	2,603	1,754
Nonpoint source load	N/A	2,000	N/A	16,819
Total load	**N/A**	**2,337**	**N/A**	**18,573**
Echo Reservoir				

Table 6.8. Summary of Current Loads to Receiving Waters and Resulting Loads to the Rockport and Echo Reservoirs

	Total Phosphorus		Total Nitrogen	
	Current Load to Receiving Waters (kg/season)	**Current Load to Reservoir (kg/season)**	**Current Load to Receiving Waters (kg/season)**	**Current Load to Reservoir (kg/season)**
Point source load	2,057	1,427	17,751	12,111
Nonpoint source load	N/A	3,960	N/A	30,598
Total load	**N/A**	**5,387**	**N/A**	**42,709**

Table 6.9. Summary of Maximum Total Phosphorus and Total Nitrogen Seasonal and Daily Loads for Attainment of Water Quality Standards in Rockport and Echo Reservoirs

	Total Phosphorus		Total Nitrogen	
	Average Season (kg/season)	**Average Daily (kg/day)**	**Average Season (kg/season)**	**Average Daily (kg/day)**
Rockport Reservoir				
Nonpoint source load allocation	952	5.2	6,853	37.7
Waste load allocation for point sources at current capacity	495	2.8	4,504	24.7
Waste load allocation for point sources future growth	72	0.4	716	3.9
MOS	0	0	0	–
Total load to reservoir	**1,519**	**8.3**	**12,072**	**66.3**
Echo Reservoir				
Nonpoint source load allocation	1,779	9.8	10,605	58.3
Waste load allocation for point sources at current capacity	1,237	6.8	12,238	67.2
Waste load allocation for point sources future growth	485	2.7	4,918	27.0
MOS	0	0	0	0
Total load to reservoir	**3,502**	**19.2**	**27,761**	**152.5**

6.3.2 Margin of Safety

The CWA requires that the total load capacity "budget" calculated in TMDLs must also include a margin of safety (MOS). The MOS accounts for uncertainty in the loading calculation. The MOS can differ for each waterbody due to variation in the availability and strength of data used in the calculations. The MOS can be incorporated into TMDLs via the use of conservative assumptions in the load calculation, or it can be specified explicitly as a proportion of the total load. The Rockport Reservoir and Echo Reservoir TMDLs rely on conservative assumptions to meet the MOS requirement. These include the following:

1. **Organic matter loading to reservoirs was not accounted for in oxygen depletion rate predictions.** The BATHTUB models were calibrated to oxygen depletion rates assumed to be driven by algal growth and nutrients in the reservoirs. However, organic matter loading to the hypolimnia from the watersheds could also contribute to oxygen depletion. Thermal stratification may confine these effects to the hypolimnion during the spring-summer season. The water temperature of the Weber River is lower than the surface temperature of the reservoirs in the summer. Accordingly, much of the water delivered to the reservoirs in the summer may bypass the surface and sink to the hypolimnion directly. While the effect of this phenomenon on nutrient loads to the epilimnion has been accounted for through calibration of nutrient sedimentation rates in the reservoir, the BATHTUB model does not account for additional oxygen depletion associated with organic matter. Further, there are very few data related to organic matter loading from the Weber River to the reservoirs that could be used in any analysis of this potential driver. Thus, contribution to oxygen depletion from organic matter is not accounted for in the current analysis. This is a protective assumption, in that all of the improvement in oxygen depletion will be achieved through nutrient reductions. Any BMPs implemented to reduce nutrients in the watershed would likely also reduce organic matter loading as both nutrient and organic matter transport are associated with soil erosion and sediment transport from the watershed.

2. **Selection of conservative MOD rate target.** The concentration of oxygen in the hypolimnion at stratification is a critical assumption in calculating an acceptable oxygen depletion rate for each reservoir. No hypolimnetic oxygen data are available for either reservoir in April or early May. DO data from reservoir surfaces in late May and in the Weber River below each reservoir in April and May were used to develop an assumed initial DO concentration for the reservoirs. In addition, calculated MOD rates based on profile data were used to backcast initial DO rates. Although the initial DO concentrations could be as high as 10.0 mg/L, 9.0 mg/L was assumed for the analysis as a conservative assumption.

3. **Selection of very low nutrient targets indicative of reference lakes in the Ecoregion.** The target water quality for nutrients, based on the BATHTUB modeling, results in very low nutrient concentrations in the surface of both reservoirs. It should be further noted that the average seasonal phosphorus concentrations in some years in which DO impairments have been observed are already below the threshold value (0.025 mg/L) identified by the State of Utah to indicate a nutrient concern. These targets are sufficiently protective of the uses designated to Rockport Reservoir and Echo Reservoir. Further reductions could threaten the fishery by reducing the available algae for food.

4. **Conservative assumptions in modeling.** Sources of uncertainty and variability associated with all models including SWAT and BATHTUB relate to data representativeness or the uncertainty and variability for data used for calibration, uncertainty and variability in the values used to characterize parameters, and uncertainty in the understanding of the processes occurring and the equations and parameters used in the model to simulate processes. Conservative assumptions were made in each case to ensure the final TMDL is protective of water quality, and these assumptions are included in the model development discussion (Appendix A).

6.3.3 Load Allocation and Rationale

The EPA provides guidance in allocating loads to point and nonpoint sources in TMDLs (EPA 1999). The *Protocol for Developing Nutrient TMDLs* states that dividing the assimilative capacity of a given waterbody among sources should consider the following issues: economics, political considerations, feasibility, equitability, types of sources and management options, public involvement, implementation, limits of technology, and variability in loads and effectiveness of BMPs (EPA 1999). All of these have been considered in determining load allocations for Rockport Reservoir and Echo Reservoir.

To achieve equity among point sources in the watershed, waste load allocations (WLAs) are based on assigning the same TP (1.0 mg/L) and TN concentrations (10.0 mg/L) to the current capacity flows for each point source in the watershed. These values are consistent with the technology-based nutrient criteria currently proposed for the State of Utah (1.0 mg/L TP and 10.0 mg/L of total inorganic nitrogen). WLAs are generally greater than current loads because current loads are based on current flows and WLAs are based on capacity flows. In almost every case, the WLAs will require nutrient reductions from current concentrations in point sources. The exception to this is Coalville City, which has been achieving lower nutrient concentrations in their effluent than the treatment plant is designed to achieve. Coalville City is currently in the process of constructing a new WWTP, and it is unlikely that the lower nutrient concentrations can be achieved with the new facility designed to meet nutrient concentrations of 1.0 mg/L TP and 10 mg/L total inorganic nitrogen. Due to the large projected growth in the watershed, two treatment plants will need to be expanded above current capacity flows in the future (Silver Creek WRF in the Echo Reservoir Watershed and Oakley WWTP in the Rockport Reservoir Watershed). WLAs associated with the expanded flow are based on lower nutrient concentrations of 0.5 mg/L TP and 5.0 mg/L TN. In addition, WLAs are included for two permitted point sources that are not currently operating. The Kamas Fish Hatchery, operated by the Utah DWR, has been offline for several years for facility upgrades. The Blue Sky Ranch is preparing to construct a small permitted WWTP that will discharge to the lower reaches of Silver Creek.

Summer season WLAs for currently permitted point sources in the Rockport Reservoir Watershed are 495 kg TP/season and 4,504 kg TN/season (Table 6.10). Additional WLAs for future growth were assigned to the Oakley WWTP for 19 kg TP/season and 190 kg TN/season and to the Francis WWTP for 53 kg TP/season and 526 kg TN/season. The nonpoint source load allocation for the watershed is 952 kg TP/season and 6,853 kg TN/season, requiring a 52% and 59% reduction, respectively, from current nonpoint source loads. Summer season WLAs for currently permitted point sources in the Echo Reservoir Watershed are 1,237 kg TP/season and 12,238 kg TN/season (Table 6.11). An additional WLA for future growth was assigned to the Silver Creek WRF for 485 kg TP/season and 4,918 kg TN/season. The nonpoint source load allocation for the watershed is 1,779 kg TP/season and 10,605 kg TN/season, requiring a 55% and 65% reduction, respectively, from current nonpoint source loads. Load allocations will be further differentiated for both reservoirs in the implementation plan.

Although summer is the critical season for DO exceedances in the reservoirs, winter WLAs were develop to be protective of the reservoir all year. Because internal nutrient loading during the summer, associated with winter loads of nutrients, is not a major concern in the reservoirs, the WLAs are slightly higher than the summer WLAs. The winter WLAs are based on the capacity flow for each point source and target effluent concentrations of 1.0 mg/L TP and 10.0 mg/L TN. This is identical to the WLAs for the summer season. The WLAs for future growth are based on the added flow projected to be associated with growth and target effluent concentrations of 1.0 mg/L TP and 10.0 mg/L TN, a higher effluent target than the future growth targets identified for the summer season. Tables 6.12 and 6.13 summarize the WLAs for the winter and summer seasons.

Table 6.10. Summary of Maximum Total Phosphorus and Total Nitrogen Summer (April–September) Seasonal and Daily Loads for Attainment of Water Quality Standards in Rockport Reservoir

	Total Phosphorus				**Total Nitrogen**			
	Current Load to Reservoir (kg/season)	**Allocated Load to Reservoir[1] (kg/season)**	**Equivalent Average Daily Load (kg/day)**	**Percentage Change**	**Current Load to Reservoir (kg/season)**	**Allocated Load to Reservoir (kg/season)**	**Equivalent Average Daily Load (kg/day)**	**Percentage Change**
Waste Load Allocations, Current								
Kamas WWTP (UPDES UT0020966)	231	183	1.0	-21%	1,051	1,835	10.1	+75%
Oakley WWTP (UPDES UT0020061)	106	120	0.7	+13%	703	1,198	6.6	+70%
Kamas Fish Hatchery (general permit)	N/A	124	0.7	N/A	N/A	802	4.4	N/A
Francis WWTP	N/A	*68*	0.4	N/A	*N/A*	*669*	*3.7*	*N/A*
Subtotal	*337*	*495*	*2.8*	*+46.9%*	*1,754*	*4,504*	*24.7*	*+157%*
Waste Load Allocations, Reserved for Future Growth								
Oakley WWTP (UPDES UT0020061)	N/A	19	0.1	N/A	N/A	190	1.0	N/A
Francis WWTP	*N/A*	*53*	*0.3*	*N/A*	*N/A*	*526*	*2.9*	*N/A*
Subtotal	*N/A*	*72*	*0.4*	*N/A*	*N/A*	*716*	*3.9*	*N/A*
MOS	–	0	–	–	–	0	–	–
Nonpoint source load allocation	2,000	952	5.2	-52%	16,819	6,853	37.7	-59%
Total load to reservoir	**2,337**	**1,519**	**8.3**	**-35%**	**18,573**	**12,072**	**66.3**	**-35%**

[1] Allocated loads are to the reservoir and account for the delivery ratios modeled for each point source (see Table 5.2). Permitted loads to receiving waters will account for delivery ratios and therefore be higher than the loads shown here.

Table 6.11. Summary of Maximum Total Phosphorus and Total Nitrogen Summer (April–September) Seasonal and Daily Loads for Attainment of Water Quality Standards in Echo Reservoir

	Total Phosphorus				Total Nitrogen			
	Current Load to Reservoir (kg/season)	**Allocated Load to Reservoir[1] (kg/season)**	**Equivalent Average Daily Load (kg/day)**	**Percentage Change**	**Current Load to Reservoir (kg/season)**	**Allocated Load to Reservoir (kg/season)**	**Equivalent Average Daily Load (kg/day)**	**Percentage Change**
Waste Load Allocations, Current								
Coalville WWTP (UPDES UT0021288)	165	249	1.4	51%	715	2,200	12.1	208%
Silver Creek WRF (UPDES UT0024414)	1,258	970	5.3	-23%	11,343	9,837	54.0	-13%
Park City tunnels (permits pending)	4	4	0	0%	53	53	0.3	0%
Blue Sky Ranch (UPDES UT0025763)	N/A	15	0.1	N/A	N/A	148	0.8	N/A
Subtotal	*1,427*	*1,237*	*6.8*	*-13%*	*12,111*	*12,238*	*67.2*	*1%*
Waste Load Allocations, Reserved for Future Growth								
Silver Creek WRF (UPDES UT0024414)	–	485	2.7	–	–	4,918	27.0	–
Subtotal	–	*485*	*2.7*	–	–	*4,918*	*27.0*	–
MOS	–	**0**	–	–	–	**0**	–	–
Nonpoint source load allocation	**3,960**	**1,779**	**9.8**	**-55%**	**30,598**	**10,605**	**58.3**	**-65%**
Total load to reservoir	**5,387**	**3,502**	**19.2**	**-35%**	**42,709**	**27,761**	**152.5**	**-35%**

[1] Allocated loads are to the reservoir and account for the delivery ratios modeled for each point source (see Table 5.2). Permitted loads to receiving waters will account for delivery ratios and therefore be higher than the loads shown here.

Table 6.12. Waste Load Allocations at Discharge Point for Wastewater Treatment Plants in the Rockport Reservoir during Summer and Winter Seasons

	Total Phosphorus (kg/season)			Total Nitrogen (kg/season)		
	Summer Allocated Load to Reservoir[1]	**Summer WLA at Discharge Location**	**Winter WLA at Discharge Location**	**Summer Allocated Load to Reservoir[1]**	**Summer WLA at Discharge Location**	**Winter WLA at Discharge Location**
Waste Load Allocations, Current						
Kamas WWTP (UPDES UT0020966)	183	277	277	1,835	2,771	2,771
Oakley WWTP (UPDES UT0020061)	120	173	173	1,198	1,732	1,732
Kamas Fish Hatchery (general permit)	124	177	177	802	1,162	1,162
Francis WWTP	68	97	97	669	970	970
Waste Load Allocations, Reserved for Future Growth						
Oakley WWTP (UPDES UT0020061)	19	27	55	190	275	549
Francis WWTP	53	76	152	526	762	1,524

[1] Allocated loads are to the reservoir and account for the delivery ratios modeled for each point source (see Table 5.2). Permitted loads to receiving waters will account for delivery ratios and therefore be higher than the loads shown here.

Table 6.13. Waste Load Allocations at Discharge Point for Wastewater Treatment Plants in the Echo Reservoir during Summer and Winter Seasons

	Total Phosphorus			Total Nitrogen		
	Summer Allocated Load to Reservoir[1]	**Summer WLA at discharge location**	**Winter WLA at discharge location**	**Summer Allocated Load to Reservoir[1]**	**Summer WLA at discharge location**	**Winter WLA at discharge location**
Waste Load Allocations, Current						
Coalville WWTP (UPDES UT0021288)	249	291	291	2,200	2,909	2,909
Silver Creek WRF (UPDES UT0024414)	970	1,385	1,385	9,837	13,855	13,855
Park City tunnels (permits pending)	4	67	67	53	830	830
Blue Sky Ranch (UPDES UT0025763)	15	21	21	148	208	208
Waste Load Allocations, Reserved for Future Growth						
Silver Creek WRF (UPDES UT0024414)	485	693	1,385	4,918	6,927	13,855

[1] Allocated loads are to the reservoir and account for the delivery ratios modeled for each point source (see Table 5.2). Permitted loads to receiving waters will account for delivery ratios and therefore be higher than the loads shown here.

6.5 Seasonality

There are two important seasonal aspects to the Rockport Reservoir and Echo Reservoir TMDLs: 1) the critical season for oxygen depletion in the hypolimnia of the reservoirs and 2) the distribution of nutrient loads across seasons.

The critical season for oxygen depletion in the hypolimnia is the period in which the reservoirs are thermally stratified. It was assumed that the reservoirs are thermally stratified from May 15 to September 30. These dates were selected based on evaluation of all of temperature and DO profile data available for the reservoirs. DO and temperature profile data from the years 2004, 2007, and 2011 were used to further validate the use of this stratification season assumption for all of the conditions modeled.

Although the stratification period lasts for 137 days (May 15 through September 30), the critical season for nutrient loading to the reservoirs begins with the spring melt period, assumed to begin on April 1. Nutrient loads to the reservoir for the summer season used in the TMDL analysis extends from April 1 through September 30. The seasonal loads are important because spring runoff and summer storm events tend to generate the majority of sediment and nutrients from these watersheds. The reservoirs are drawn down significantly each fall and fill again in the spring. Nutrient loads from the watershed are minimal during the winter, which is not a critical period for algal growth or oxygen depletion in the reservoirs. Internal load typically represents load from previous years or seasons (e.g., winter) that is re-suspended and that contributes to summer nutrient concentrations at the surface. However, the inlet and outlet data from both reservoirs indicate that the reservoirs are a net sink for nutrients during the critical summer season. Therefore, no internal loading of nutrients to the reservoir surface is assumed for the summer stratification season.

The summer season used in the TMDL load analysis (April 1–September 30) is further divided into spring (April 1–July 15) and summer (July 15–September 30) components. Identifying when loads are delivered to the reservoir during the TMDL season is helpful in targeting implementation measures for nonpoint sources.

The nutrient load to Echo Reservoir is split relatively evenly between spring (April–mid July) and summer (mid July–September); however, the source of loads during these two seasons is significantly different (see Tables A-42 and A-43 in Appendix A). The majority of the Chalk Creek load occurs during the spring whereas the majority of the Weber River load occurs during the summer. This reflects the snow melt–dominated hydrology characterizing the Chalk Creek watershed in the spring and the release of water from Rockport Reservoir into the Weber River primarily during the summer season. While there is significant flow into Rockport Reservoir during the spring period, this flow is mostly being retained in Rockport Reservoir for release later in the summer season. The majority of the load to Rockport Reservoir is delivered during the spring melt period (see Tables A-44 and A-45 in Appendix A).

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