Recapture Reservoir
Limnological Assessment of Water Quality

Prepared for:

Utah Department of Environmental Quality -
Division of Water Quality

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Prepared by:

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TMDL Section

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Utah Department of Environmental Quality
Division of Water Quality
Watershed Protection Section

Recapture Reservoir

Waterbody ID	UT-L-14080201-007
Location	San Juan County, Utah
Pollutants of Concern	Dissolved Oxygen
Impaired Beneficial Uses	Class 3A: Protected for cold water species of game fish and other cold water aquatic life, including the necessary aquatic organisms in their food chain.
Water Quality Assessment	Average in-lake Total Phosphorus concentrations are 0.023–0.033 mg/L and do not appear to significantly impact Dissolved Oxygen concentrations. Reservoir profiles of Dissolved Oxygen in the spring season are influenced by runoff volumes. Low Dissolved Oxygen (<4 mg/l) is evident at depth from June-October during years of average-low precipitation. Impairment of Class 3A fishery is evident based on reservoir profiles that maintain low DO (< 4 mg/L) and elevated temperature (> 20°C).
Water Quality Targets/Endpoints	Maintain 0.025 mg/l In-Lake Total P. Maintain 0.05 mg/l Total P concentration in Recapture Creek, Johnson Creek, Bulldog Creek, and Bullpup Creek. Average annual TP load = 225 kg/year Change fisheries beneficial use of reservoir from Class 3A (cold water) to Class 3B (warm water). Seasonal site specific reservoir DO standard during July and August of 100 percent of DO measurements in the epilimnion of greater than 3 mg/L.
Implementation Strategy	Implement CNMPs on agricultural lands adjacent to reservoir tributaries. Implement and maintain livestock grazing BMPs on public land grazing allotments. Eliminate and/or maintain exclusion of livestock grazing below high water line.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1.0 INTRODUCTION

The Total Maximum Daily Load (TMDL) study for Recapture Reservoir in San Juan County, Utah has been completed under the direction of the Utah Department of Environmental Quality – Division of Water Quality (DWQ). This report will be submitted to the U.S. Environmental Protection Agency (EPA) as specified by section 303(d) of the Clean Water Act (CWA). The assessment of water quality and flow defines conditions leading to low concentrations of Dissolved Oxygen (DO) in the reservoir, located in the eastern portion of San Juan County. This assessment relies upon recent and historic monitoring data collected in the study area and as such, provides an accurate picture of existing water quality conditions while incorporating the longer-term climatic influences that affect the greater Recapture Reservoir watershed.

There are many factors influencing water quality in Recapture Reservoir. It is not the intent of this assessment to place blame or criticism on any individual or group, but to try and provide an accurate characterization of **all** conditions that lead to water quality impairment in the study area.

1.1 TMDL PROGRAM DESCRIPTION

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

The scientific assessment of water quality included as part of a TMDL incorporates the best information available to determine the nature and extent of impairment for a given water body. Pollutant loads are also defined for each significant pollutant source contributing to impairment. Pollutants can come from point sources, such as water treatment plants and concentrated animal feeding operations, and nonpoint sources, such as agricultural areas and eroding streambanks. Following source identification and allocation of pollutant loads, an implementation plan is provided that will reduce existing pollutant loads and allow water quality standards to be achieved.

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

1.2 PREVIOUS STUDIES

Water quality and streamflow in the Recapture Reservoir project area were regularly monitored by federal and state agencies from 1957-1980 for the Indian Creek Tunnel, from 1965-2006 for a site on upper Recapture Creek, and from 1975-1993 for a site on lower Recapture Creek (below the confluence with Johnson Creek). Routine water quality measurements have been made from 1997 to present at a site on Johnson Creek approximately 5.5 miles upstream from the reservoir, in 1978 where Route 163 crossed Recapture Creek prior to construction of the reservoir, from 1988 to 2000 on Bulldog Creek just above its outfall to the reservoir, and from 1989 to 2006 for three sites within the reservoir.

Two studies have focused specifically on Recapture Reservoir, including a flow assessment that was completed on the upper Recapture Creek watershed to fulfill Army Corp of Engineer permitting requirements prior to construction of the reservoir (UDWR 1981). The other local study was completed by DWQ on Recapture Reservoir as part of an EPA sponsored Clean Lakes study that reviewed water quality in all reservoirs and lakes in Utah. (Judd 1997.) Published studies have more typically incorporated the watershed above Recapture Reservoir as part of research that examined all or portions of larger river basins including the San Juan River or Colorado River. A brief review of studies completed to date is included below.

1.2.1 RECAPTURE CREEK FLOW ASSESSMENT 1982

The Utah Division of Water Resources prepared a report in 1982 to support their request to include the construction of Recapture Reservoir within the category of Nationwide Permits with respect to Section 404 requirements of the Clean Water Act, as administered by the U.S. Army Corps of Engineers. In this report, UDWR developed a model for predicting runoff to the Recapture Reservoir watershed. It included a calculation of "natural flow" to a stream gage on Recapture Creek Below Johnson Creek that was only three years old by correlating its flows to those at other, older gage sites on Recapture Creek (within the reservoir's watershed) and Indian Creek 15 miles to the north (and outside the reservoir's watershed). UDWR used an "Elevation-Precipitation Curve for Abajo Mountain Area" and then a "Precipitation-Runoff Curve for South and East Colorado Area" to develop "Unit Runoff" factors in acre-feet per square mile for each 1,000 foot elevation band. The result was an estimate of average annual natural flow to the gage at Recapture Creek Below Johnson Creek of 4,402 acre-feet per year, and flow to the reservoir site (after accounting for diversions and other tributaries) of 2.3 cfs, or 1,616 acre-feet per year. New calculations for the watershed indicate that UDWR's calculations of national flow to the reservoir site may have underestimated flows by as much as 4,500 acre-feet per year.

1.2.2 RECAPTURE RESERVOIR CLEAN LAKES STUDY

This study provides a brief overview of the history and geology of Recapture Reservoir, and discusses its characteristics such as area, volume, and retention time. Beneficial uses of the reservoir are also detailed, as well as recreational opportunities in the area. Some information on fisheries management in the reservoir is also provided.

STORET water quality data from 1989 and 1991 from the three water quality stations in the reservoir are summarized. Profile measurements for DO and temperature are also given. DO results show concentrations of <4 mg/l at depths below 4 meters. Slight exceedances of the total phosphorus (TP) indicator value were recorded in 1991. Phytoplankton data shows that green algae are predominant.

Pollution sources were identified, and sedimentation and nutrient loading from grazing and feed yards and wastes or litter from recreation were listed. No point sources were identified.

1.2.3 Utah State Water Plan – Southeast Colorado River Basin (2000)

As part of the State of Utah's goal of providing a framework for state water policy planning, a detailed water plan was prepared for the Southeast Colorado River Basin, which includes the Recapture River watershed. This plan discusses the Basin's water-related resources and the problems, needs, issues and alternatives for conservation and development measures. While the plan covers a wide area, useful information on Recapture Reservoir and its tributaries is found within this document. The main focus of the plan is the conservation and development of water supplies within the Basin.

The plan declared surface water quality in the Basin to be "generally of suitable chemical quality for agricultural, municipal and industrial uses." Total dissolved solids (TDS) were said to increase with distance downstream due to lower quality groundwater inflow and return flows from irrigation. Data for TDS and conductivity were provided for selected stations.

1.3 PUBLIC PARTICIPATION

Federal and local agencies were contacted during April 2007 to provide notification that a TMDL assessment was being completed for Recapture Reservoir. Personnel from each agency were invited to participate in a stakeholder review process at that time.

Public review of the Draft TMDL report will commence in February 2008. Comments will be accepted from the public following a 30-day review period and incorporated into the final TMDL report submitted to the EPA on April 1, 2008.

2.0 PROJECT AREA DESCRIPTION

2.1 HISTORY

The area around Recapture Reservoir was settled by Mormon pioneers in the late 1800s. Blanding, two and a half miles southwest of the reservoir, is the closest town and was the last to be established in San Juan County when it was founded in 1897.

Large-scale cattle ranching came to the area when the LC Cattle Company was established around 1880. The company grazed about 17,000 head of cattle near the confluence of Recapture and Johnson Creeks in the south end of the Recapture Reservoir watershed. Several other large companies also brought cattle to the area. Most of these companies were gone by the late 1890s as a result of low cattle prices, drought, rustlers, and other factors. (UDWR 2000)

Early settlers used water from streams from the Abajo Mountains north of Blanding for agricultural irrigation. As the town grew and water demand increased an irrigation company began a tunnel project to divert yet more water from Indian Creek on the north side of the Abajo Mountains to Johnson Creek on the south side. Started in 1921, the tunnel was completed in 1952. Another interbasin diversion now part of the Recapture Reservoir watershed includes a catchment and canal from Dry Wash on the west into Johnson Creek.

Recapture Creek was impounded in the early 1980's with an earthen dam, which is crossed by Highway 191 north of Blanding. Most of the water stored in the reservoir is used for agriculture, although the city of Blanding occasionally withdraws water for municipal use. (Judd 1997, Thorton 2007)

2.2 WATERSHED DESCRIPTION

The Recapture Reservoir watershed is entirely within the area designated by the USGS as the Upper Colorado Region, Hydrologic Unit Code (HUC) 14, which eventually flows into the San Juan River, and thence into the Colorado River. For the purposes of this project, the Recapture Reservoir watershed is drawn to include two smaller watersheds outside of its natural drainage to accommodate diversions from Indian Creek to the north and Dry Wash to the west. Other minor subdivisions within the Recapture Reservoir watershed that feed diversions or stream confluences were also identified and named for reference in this project. The entire watershed is 64.29 square miles (41,143 acres) in size. See Figure 2.1 for a map of the watershed and Table 2.1 for descriptions of the smaller subdivisions.

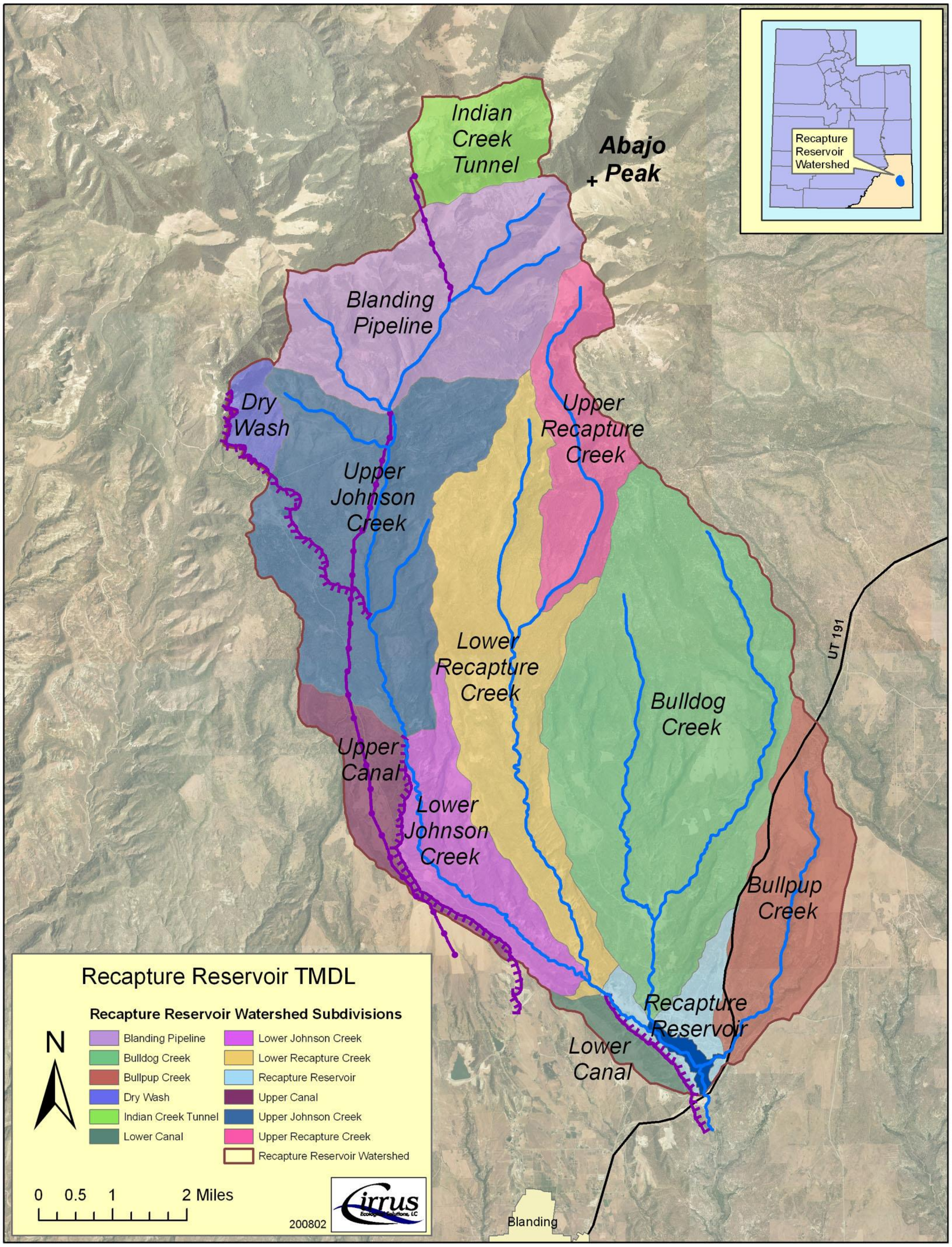


Figure 2.1. Watershed subdivisions within the Recapture Reservoir TMDL project area.

The Recapture Reservoir watershed is drained by four streams flowing north to south. The largest stream is Johnson Creek, which forms at approximately 11,000 feet in elevation just west of Abajo Peak. Flow from Indian Creek Tunnel comes from a diversion in the upper Indian Creek watershed at about 9,100 feet above sea level and brings water approximately 1-3/4 mile through a tunnel in the mountain to enter Johnson Creek at about 8,200 feet elevation. At about 7,700 feet elevation, a diversion from Johnson Creek feeds the Blanding municipal pipeline. The canal from Dry Wash enters the western boundary of the watershed at about 8,000 feet elevation and is collected in a small reservoir at about 7,700 feet before being drained via a natural watercourse to reach Johnson Creek at about 7,100 feet elevation. At about 6,800 feet elevation, the Upper Canal diverts Johnson Creek water during the late spring, summer, and early fall. This canal leaves the southwest corner of the watershed roughly parallel to and 200 feet below the Blanding Pipeline to feed two small surface reservoirs approximately two miles north of Blanding. Below the Upper Canal diversion, Johnson Creek flows unimpeded to the confluence with Recapture Creek at approximately 6,100 feet elevation.

Recapture Creek rises at approximately 10,000 feet elevation from the south side of the Abajo Mountains as two parallel drainages that form the northeast corner of the watershed. It is not diverted by canals or pipelines and is joined by Johnson Creek at approximately 6,100 feet elevation. About 0.3 miles and 50 feet of elevation below the confluence with Johnson Creek, a diversion to feed the Lower Canal had been built, but is now abandoned. Recapture Creek enters Recapture Reservoir between the reservoir's design elevations of 5,940 (0 acre-feet volume) and 6,080 (17,500 acre-feet volume) feet above sea level.

The eastern third of the watershed is drained by two named tributaries, Bulldog and Bullpup Creeks. Bulldog rises at about 8,000 feet elevation and drains most of the east side of the watershed. A much smaller Bullpup Creek forms the southeast portion of the watershed. Both tributaries drain directly into Recapture Reservoir.

Table 2.1. Subdivisions in Recapture Reservoir Watershed.

Subwatershed	Area (ac)	Watershed Subdivision	Area (ac)	8 Digit HUC[1]
Johnson Creek	17,649	Indian Creek Tunnel[2]	1,547	14030005
		Blanding pipeline	5,275	14080201
		Dry Wash[2]	560	14080201
		Upper Johnson Creek	6,546	14080201
		Upper canal	1,312	14080201
		Lower Johnson Creek	2,408	14080201
Recapture Creek	8,285	Upper Recapture Creek	2,404	14080201
		Lower Recapture Creek	5,881	14080201
Recapture Reservoir	14,700	Bulldog Creek	10,507	14080201
		Bullpup Creek	3,167	14080201
		Recapture Reservoir	1,026	14080201
Other	509	Lower canal[3]	509	14080201
Total	**41,143 (64.29 sq mi)**			

[1] May be partial Hydrologic Unit Code.
[2] Drainages for interbasin transfers from adjacent watersheds.
[3] Assumed entire area drains outside of Recapture Reservoir watershed.

2.3 CLIMATE

The climate in southeast Utah is arid to semi-arid. Average monthly maximum temperatures in summer are in the high 90s (^{o}F) and average monthly minimum temperatures in December and January winter are 3-10^{o}F. Annual average precipitation is approximately 13.3 inches in Blanding. The average precipitation for 2001-2007, the years of most data on surface water flows, was 12.95 inches, although rainfall was below average in 2002 (8.0 inches) and above average in 2005 (16.7 inches).

The watershed spans a broad range of precipitation bands, however, from 13 inches per year near Blanding to over 39 inches at the top of the Abajo Mountains. Precipitation from these higher elevations generate much of the runoff that feeds into Recapture Reservoir (UDWR 2000).

The monthly Palmer Drought Indices in 2007 put all of southeastern Utah in the mid-range of moisture (through October), indicating that available moisture in the area is neither deficient nor abundant.

2.4 GEOLOGY/SOILS

Recapture Reservoir lies within the Paradox Basin, a large depression on the southwest flank of the Uncompahgre uplift. This basin was repeatedly filled with seawater 300 million years ago, which deposited carbonate-rich sediments that became limestone and dolomite strata. The Paradox basin covers approximately 20,000 square miles, including most of San Juan County. As seawater receded, salt and other saline deposits were left behind and now underlie the Paradox Basin. Eroded material was transported by prehistoric rivers flowing into the basin, creating alluvial fans, deltas, and tidal flats that are rich in clay, copper, uranium, vanadium, gold, and silver as well as oil and gas deposits that formed from decomposed organic matter. The Abajo Mountains located to the north of Blanding were formed by igneous intrusions nearly 25 million years ago and exceed 11,000 feet in elevation. This isolated mountain range is comprised of dramatic granite features that are visible from many miles away. The highest elevation in the Recapture Reservoir watershed is found along the ridges near Abajo Peak at 11,295 feet above sea level. The reservoir itself is approximately 6,080 feet above sea level at is inlet, resulting in a mean surface gradient of approximately 9 percent.

Soils in the Recapture Reservoir drainage are generally very stony and well-drained. These soils are mainly formed by aeolian deposits or colluvium derived from sandstone. Approximately 2 percent of watershed soils are considered farmland of statewide importance. Such soils typically consist of very fine sandy loam.

2.5 LAND COVER AND LAND USE

Land cover in the project area was mapped from the dataset provided by the Southwest Regional Gap Analysis Project, completed in 2005 by the Remote Sensing/Geographic Information Systems Laboratory at Utah State University (USURS/GISL). Land cover types were then combined into broader categories for which data was available for phosphorus export coefficients (Figure 2.2). The land cover types, analysis categories and acreages within the Recapture Reservoir watershed are summarized in Table 2.2. Forest land covers 18,673 acres, or 45.4 percent of the watershed. Pinyon-juniper was the next largest, covering 16,713 acres, or 40.6 percent of the watershed.

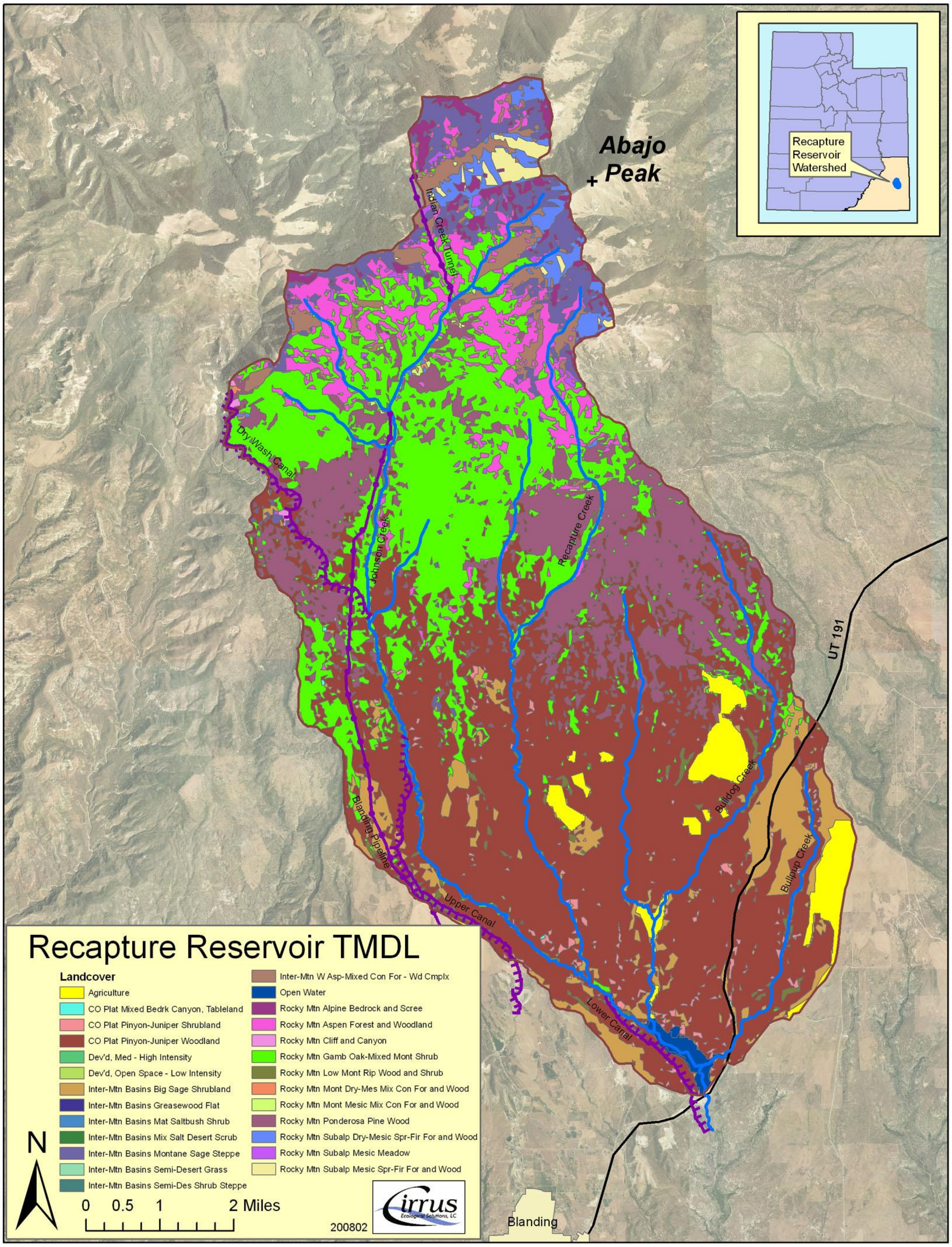


Figure 2.2. Land cover types within the Recapture Reservoir TMDL project area.

Table 2.2. Landcover types in the Recapture Reservoir watershed.				
Analysis Category	**Area (ac)**	**% of Total**	**SWReGap Landcover Type**	**Area (ac)**
Forest Land	18,673	45.4	Inter-Mountain West Aspen-Mixed Conifer Forest and Woodland Complex	9,578
			Rocky Mountain Aspen Forest and Woodland	2,250
			Rocky Mountain Gambel Oak-Mixed Montane Shrubland	8,294
			Rocky Mountain Lower Montane Riparian Woodland and Shrubland	567
			Rocky Mountain Montane Dry-Mesic Mixed Conifer Forest and Woodland	38
			Rocky Mountain Montane Mesic Mixed Conifer Forest and Woodland	30
			Rocky Mountain Ponderosa Pine Woodland	5,674
			Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland	607
			Rocky Mountain Subalpine Mesic Spruce-Fir Forest and Woodland	256
Pinyon-Juniper	16,713	40.6	Colorado Plateau Pinyon-Juniper Shrubland	327
			Colorado Plateau Pinyon-Juniper Woodland	16,385
Range Land	3,802	9.2	Inter-Mountain Basins Big Sagebrush Shrubland	2,104
			Inter-Mountain Basins Greasewood Flat	0.2
			Inter-Mountain Basins Mat Saltbush Shrubland	1
			Inter-Mountain Basins Mixed Salt Desert Scrub	0.1
			Inter-Mountain Basins Montane Sagebrush Steppe	1,523
			Inter-Mountain Basins Semi-Desert Grassland	6
			Inter-Mountain Basins Semi-Desert Shrub Steppe	0.8
			Rocky Mountain Subalpine Mesic Meadow	167
Agriculture	1,142	2.8	Agriculture	1,142
Barren	611	1.5	Colorado Plateau Mixed Bedrock Canyon and Tableland	6
			Rocky Mountain Alpine Bedrock and Scree	574
			Rocky Mountain Cliff and Canyon	31
Water	201	0.5	Open Water	201
Urban	2	0.01	Developed, Medium - High Intensity	1
			Developed, Open Space - Low Intensity	1
Total	**41,143**			**41,143**

Landownership within the watershed is dominated by federal holdings. The largest landowner is the US Forest Service, which administers 26,644 acres (65 percent of the watershed). The BLM administers 7,332 acres (18 percent of the watershed). Only 5,838 acres (14 percent of the watershed) is privately owned. The primary land use in the watershed is livestock grazing. Other common uses include agriculture, energy development, and dispersed recreation. Figure 2.3 and Table 2.3 show land ownership in the Recapture Reservoir watershed.

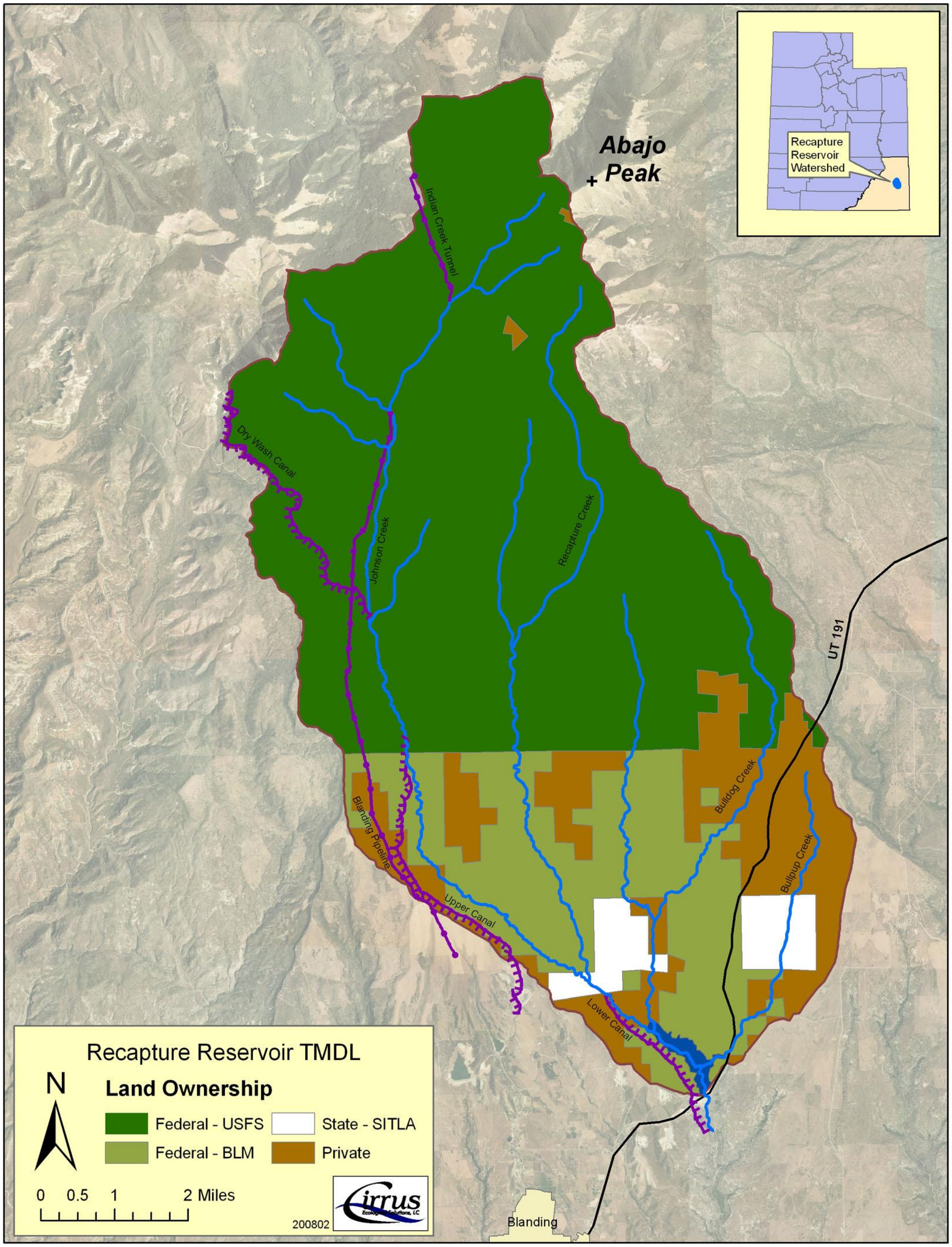


Figure 2.3. Land ownership within the Recapture Reservoir TMDL project area.

Table 2.3. Land ownership within the Recapture Reservoir watershed.		
Land Ownership	**Area (ac)**	**Percent of Total**
US Forest Service (USFS)	26,644	65
Bureau of Land Management (BLM)	7,332	18
State	1,329	3
Private	5,838	14
Total	**41,143**	**100**

2.6 HYDROLOGY

Table 2.4 lists sites where reasonably long term measurements of stream flow have been made in the Recapture Reservoir watershed. Figure 2.4 shows the locations of these stations.

Table 2.4. Stream Flow Monitoring Stations in the Recapture TMDL project area.				
Station	**Station Name**	**Agency**	**Type**	**Period of Record**
9185800	Indian Creek Tunnel near Monticello, Utah[1]	USGS	Stream	October 1957-September 1980
9378630	Recapture Creek near Blanding, Utah	USGS	Stream	October 1965-September 2006
9378650	Recapture Creek below Johnson Creek near Blanding, Utah	USGS	Stream	October 1975-October 1993
N/A	Blanding Pipeline	Blanding City	Pipeline	January 2002-December 2007
N/A	Recapture Reservoir Discharge	San Juan Water Conservancy District	Stream	2001 - present
[1] Station located outside of the natural watershed of Recapture Reservoir but included because entire runoff of this watershed subdivision is assumed to be diverted into the watershed via a tunnel.				

Stream flows in the Recapture Reservoir watershed have been reported by various entities. The USGS has monitored three sites on a daily basis: Indian Creek Tunnel Station 9185800, Recapture Creek Near Blanding Station 9378630, and Recapture Creek Below Johnson Creek Station 9378650. Blanding City reports flows into their pipeline from the diversion on Johnson Creek. The San Juan Water Conservancy District (SJWCD) reports flows at the Recapture Reservoir discharge and measures the elevation of the reservoir occasionally during the spring, summer, and fall, from which a volume can be calculated.

No flow gages are known to exist for interbasin transfers from Dry Wash, nor for diversions into the Upper Canal. Anecdotal reports on the latter, however, claim a maximum capacity of 10 cfs, and that seasonal flows are typically 7-9 cfs (Palmer 2008).

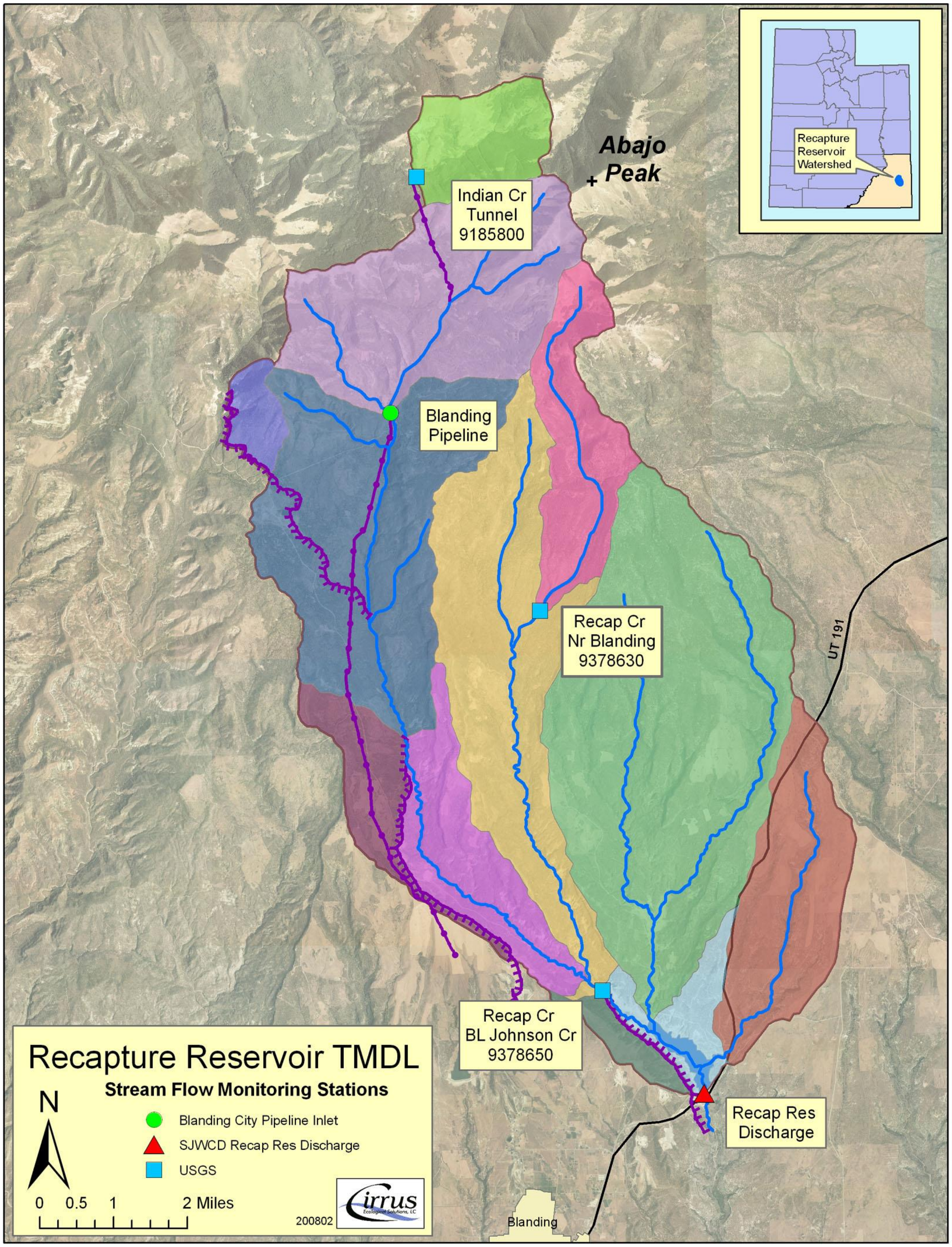


Figure 2.4. Stream flow monitoring stations within the Recapture Reservoir TMDL project area.

Stream flows are also measured by the Utah Division of Water Quality when taking water quality measurements, but these are infrequent and were therefore not used for determining temporal patterns of stream flow in the watershed.

Anecdotal reports are that Bulldog and Bullpup Creeks provide flows to the reservoir only during runoff events.

Table 2.5 shows a summary of daily stream flows by month for long term gages in the Recapture Reservoir watershed. All three of the gauged streams are seasonal in nature, with peak flows between April and June, and lowest (or no) flows from August through February. Indian Creek peaks slightly earlier than Recapture or Johnson Creeks as expected due to the influence of snowmelt at higher elevations. Average monthly flows for upper Recapture Creek (Station 9378630) are typically less than 10 cfs, while downstream after the confluence with Johnson Creek, the gage shows average monthly flows above 30 cfs in late spring. The latter flows would be even higher if not for the diversions into the Blanding Pipeline and the Upper Canal in the upper reaches of Johnson Creek. The maximum flow of 57 cfs in Recapture Creek was evidently due to a major storm that occurred October 19-20, 1972. Maximum flows at the lower Recapture Creek Below Johnson Creek have peaked at over 212 cfs.

Table 2.5. Recapture reservoir project area daily stream flow by month (cfs).

	USGS 9378630 – Recapture Creek near Blanding			USGS 9378650 - Recapture Creek Below Johnson Creek Near Blanding			USGS 9185800 - Indian Creek Tunnel near Monticello			SJWCD - Recapture Reservoir Discharge		
Month	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**
Jan	0.1	0.0	6.9	0.1	0.0	2.9	0.3	0.0	1.0	0.4	N/A	N/A
Feb	0.1	0.0	3.5	1.4	0.0	26.0	0.3	0.0	1.0	0.8	N/A	N/A
Mar	1.7	0.0	26.0	10.5	0.0	128.0	0.4	0.0	5.0	0.9	N/A	N/A
Apr	4.7	0.0	50.0	35.1	0.0	200.0	1.3	0.0	13.0	2.3	N/A	N/A
May	6.0	0.0	46.0	37.9	0.0	212.0	4.7	0.0	21.0	5.7	N/A	N/A
Jun	2.0	0.0	31.0	15.3	0.0	129.0	5.9	0.0	18.0	5.4	N/A	N/A
Jul	0.2	0.0	4.2	1.5	0.0	27.0	2.2	0.1	18.0	4.8	N/A	N/A
Aug	0.1	0.0	6.0	0.2	0.0	18.0	0.9	0.0	7.3	4.3	N/A	N/A
Sep	0.0	0.0	1.2	0.2	0.0	15.0	0.6	0.0	3.2	3.0	N/A	N/A
Oct	0.1	0.0	57.0	0.4	0.0	24.0	0.8	0.0	7.1	1.7	N/A	N/A
Nov	0.1	0.0	19.0	1.0	0.0	80.0	0.6	0.0	5.9	0.4	N/A	N/A
Dec	0.0	0.0	7.1	0.1	0.0	2.6	0.3	0.0	3.2	0.3	N/A	N/A
Summary	**1.3**	**0.0**	**57.0**	**8.6**	**0.0**	**212.0**	**1.5**	**0.0**	**21.0**	**2.5**	**N/A**	**N/A**

Available measurements of Recapture Reservoir discharges were limited to a six year period since 2001 and generally included one or more measurements per month with the exception of mid-winter. Monthly discharge from the reservoir is managed, so flows are more even through the year than the flows in the tributaries, with monthly average flows ranging from 0.3 cfs in December to 5.7 cfs in May. Since measurements are not made on a daily basis, daily minimum and maximums are not available.

Water in Recapture Reservoir is managed by the San Juan County Water Conservancy District. Most water stored in the reservoir is ultimately used for agricultural purposes. The city of Blanding owns a right to 800 acre-feet of the reservoir for municipal use, but only withdraws water during years of low precipitation. The most recent municipal use of reservoir storage by Blanding occurred in 2002 when 284 acre-feet were withdrawn during July and August. Blanding City and the Blanding Irrigation Company also divert water from Recapture Creek and Johnson Creek before flows can reach Recapture Reservoir. Blanding City has a 1 cfs water right from Johnson Creek and a 2 cfs water right from Indian Creek which is diverted through the Abajo Peak tunnel.

2.6.1 ANNUAL WATER BUDGET

In order to understand long term patterns of flow and nutrient loads to Recapture Reservoir, a model was constructed to estimate present day runoff to the reservoir. This model was based on an area-altitude approach described in a letter and accompanying analysis produced by the Utah Division of Water Resources (UDWR) dated January 27, 1982 in support of their request to include the Recapture Dam construction project under the Nationwide Permits provisions of Section 404 of the Clean Water Act, administered by the U.S. Environmental Protection Agency.

A present day model faces similar challenges as those encountered by UDWR in 1981. Specifically, there are few monitoring stations and limited periods of data and, while the lower Recapture Creek Below Johnson Creek gage has now produced 18 years of data, those data ended in 1993. The upper Recapture Creek Near Blanding gage also has a longer period of record, although the most recent data available were recorded in September 2006. Moreover, diversion flows to the Upper Canal and the contributions of Dry Wash, Bulldog Creek, and Bullpup Creeks are only anecdotal. On the other hand, actual flow data is now available for the Blanding Pipeline for the last 7 years, and there is a record of discharge from the reservoir itself back to at least mid-2001. New Geographic Information Systems (GIS) mapping analysis and spreadsheet tools cannot recreate actual data on flows, but they help improve the speed and resolution of analysis.

A variation on the area-altitude approach used by UDWR was used for this TMDL analysis (see Appendix B). The watershed for the Recapture Reservoir was first delineated using GIS layers of streams superimposed on USGS topographic maps. The watershed subdivisions contributing interbasin transfers from Indian Creek and Dry Wash were included, as were those areas draining directly into the reservoir near the dam. The result was a layer of 12 watershed subdivisions (see Figure 2.1 and Table 2.1).

The original UDWR values for runoff as a function of precipitation were reproduced in a table and similar normalization steps were taken to generate new "Unit Runoff" values, yielding a formula for calculating acre-feet per year per square mile as a function of precipitation. These unit runoff values were then fit to an exponential function which was adjusted by successive approximation to get the best fit for the upper Recapture Creek Near Blanding watershed because that smaller watershed has the longest and most recent period of record and no diversions. It was then adjusted once more to minimize error when applied to the gages at Recapture Creek Below Johnson Creek and Recapture Reservoir itself. The resulting model still produced some error due to the limited data available, but proved a more accurate predictor of flows to Recapture Reservoir than did the earlier work.

3.0 WATER QUALITY

The Utah Division of Water Quality (UDWQ) and the United States Geological Survey (USGS) have been involved with water quality monitoring in the Recapture Reservoir basin. Water quality data have also been collected by the US Forest Service and the Utah Department of Health. The record of water quality monitoring data reviewed in this assessment extends from 1950 through 2007. The exact length of the data record varies depending on the monitoring site and the agency responsible for data collection. Where possible, water quality data collected in the past 10 years (1998-2007) is used to represent existing conditions. An assessment of existing conditions has indicated that water quality measurements in the study area violate water quality criteria designed to protect the beneficial use of Recapture Reservoir and tributaries that flow to the reservoir. This chapter is a detailed assessment of these measurements and provides the basis for the Recapture Reservoir TMDL that is presented in Chapter 5.

3.1 WATER QUALITY STANDARDS

The water quality standards and goals are based on the designated use of water bodies adopted by the state to protect public health and welfare, enhance water quality, and protect those assigned beneficial uses (e.g. aquatic life, recreation, and agricultural use). The Utah 2006 303(d) list indicated Recapture Reservoir is impaired for low dissolved oxygen (DO) concentrations. The beneficial use and associated water quality standards for impaired conditions at Recapture Reservoir are shown in Table 3.1.

Table 3.1. Beneficial use and associated water quality standards for impaired waterbodies located in the Recapture Reservoir TMDL study area.

Name	Pollutant of concern	Beneficial Use Class	Beneficial Use Support	Standard / Indicator Value
Recapture Reservoir	Dissolved oxygen (DO)	3A – Cold water aquatic life	Non-supporting	DO $\geq$ 4.0 mg/L

In general, impairment to water bodies is based on water quality parameters including temperature, pH, and DO (Table 3.2). Measurements of these parameters are collected during routine monitoring by the State of Utah. At stream monitoring stations, full support status is assigned to the water body if less than 10 percent of measurements for any of these water quality parameters exceed the established criteria. Non-support status is assigned when exceedance is greater than 10 percent. Exceptions to these thresholds are made for DO in lakes and reservoirs where water quality is modified in deep impoundments due to stratification. In these situations, non-support status is determined if 50 percent of profile measurements are less than 4.0 mg/L.

The total phosphorus (TP) value used by the State of Utah to determine impairment is an indicator of pollution and is not a numeric criterion or water quality standard. As a result, Utah does not consider a water body to be impaired based solely on exceedances of the TP indicator value alone. Desired concentrations of TP applied to reservoirs and streams are 0.025 mg/l and 0.05 mg/l, respectively. These values have been shown to represent threshold values that prevent eutrophication and excessive algae growth. Excessive growth and decomposition of algae and zooplankton can deplete DO concentrations to levels that are harmful to fish. The acute DO criteria for early and adult life stages in streams are greater than or equal to 8 mg/L and 4 mg/L, respectively. The chronic, 30-day average DO criterion is greater than or equal to 6.5 mg/L. In addition to these parameters, other measures of water quality health are used to support a beneficial use assessment. Some of these measures include fish surveys, phytoplankton, and macroinvertebrate assessments. A detailed review of existing water quality measurements in the project area as well as measurements of fish, algae and macroinvertebrate populations are provided below.

Table 3.2. Water quality parameters associated with Class 3A reservoirs and streams.

Parameter	Standard/Indicator Level
Ammonia	pH dependent criteria calculated for individual data points as per Utah Code R317-2.
Dissolved Oxygen (DO)	4.0 mg/L acute criterion for adult coldwater aquatic species.
pH	6.5 - 9.0
Total Dissolved Solids (TDS)	1,200 mg/L
Total Phosphorus (TP)*	0.05 mg/L
Water Temperature	20 ^{o}C

* Pollution indicator value.

3.2 WATER QUALITY MONITORING

Compiling and accurately interpreting water quality and flow data are critical elements of a TMDL assessment. The concentration of a particular pollutant and flow can be used to calculate its load equivalent as mass per unit time (e.g., kg/yr). If paired measurements of flow and water quality are collected at regular intervals and at the appropriate locations, these measurements can be used to validate loads allocated to different pollutant sources. Available measurements of flow were presented earlier in Section 2.

Members of the Cirrus team obtained the majority of data from publicly accessible repositories including the EPA-STORET database, the Utah DWQ database, and the USGS National Water Information System (NWIS) data archives. In addition, Cirrus contacted all pertinent agencies and stakeholders within the TMDL study area with the ability to provide additional data and information that could be used to characterize pollutant sources.

This water quality assessment reviews all available water quality data for the study area. The assessment relies primarily upon water quality data collected by the Utah DWQ during intensive monitoring cycles. As this information was collected on a regular basis, it provides a comprehensive review of water quality conditions in the study area. The most recent data considered in this assessment was collected during 2007.

3.2.1 WATER QUALITY MONITORING STATIONS

Water quality measurements have been collected at 15 monitoring sites in the project area (Figure 3.1). Summary details for each station are provided in Table 3.3. Information on the period of record and frequency of water quality measurements collected at each station are provided in Table A1 (Appendix A). Although the USGS has consistently monitored water quality at stream gage sites dating back to 1971, this data set is primarily limited to measurements of temperature and specific conductivity. The Utah DWQ has collected a much wider range of surface water quality measurements to date, extending back to the mid-1970s. The USGS has collected the only measurements of groundwater quality, including 2 locations near Recapture Reservoir.

Only two stream stations have long-term records that also include recent measurements of water quality. Station 4953460 is located on Johnson Creek above the upper canal diversion and about 5.5 miles upstream of the reservoir. This station has data from 1997 – 2006. The other station with a comprehensive data record is Bulldog Canyon Creek above Recapture Reservoir (Station 4953510), near the reservoir high water mark. This station has data from 1988 – 2001.

Table 3.3. Water quality monitoring stations identified in the Recapture TMDL project area.

Station	Station Name	Agency	Type	Period of Record	Number of sample visits
5958010	Recapture Reservoir above dam 001.	DWQ	Lake	1989 - 2005	19
5958020	Recapture Reservoir 1/4 way up reservoir 02.	DWQ	Lake	1989 - 2005	18
5958030	Recapture Reservoir 1/2 way up reservoir 03.	DWQ	Lake	1989 - 2005	19
4953460	Johnson Creek above Recapture Reservoir above diversion.	DWQ	Stream	1997 - 2005	23
4953500	Recapture Creek wash at U163(191) crossing below reservoir.	DWQ	Stream	1978 - 2000	3
4953510	Bulldog Canyon Creek above Recapture Reservoir.	DWQ	Stream	1998 - 2001	42
1900101	Blanding-Johnson Creek 1.	Dept. of Health	Stream	1977 - 1989	7
1900102	Blanding-Indian Creek.	Dept. of Health	Stream	1981 - 1987	3
100501052251[1]	Upper Indian Creek.	USFS	Stream	1980	4
100501251351	Johnson Creek at Blanding Pipeline inlet.	USFS	Stream	1980	3
9185800	Indian Creek Tunnel near Monticello, Utah	USGS		1971 - 1980	64
9378630	Recapture Creek near Blanding, Utah	USGS		1971 – 1991	128
9378650	Recapture Creek below Johnson Creek near Blanding, Utah	USGS		1977 - 1994	104
373954109270001	(D-36-22)12ccd-1	USGS	Well	1982	1
374726109303001	(D-34-22)28caa-1	USGS	Well	1977	1

[1] Station located outside of the Recapture Reservoir watershed on upper Indian Creek upstream of the Indian Creek tunnel inlet.

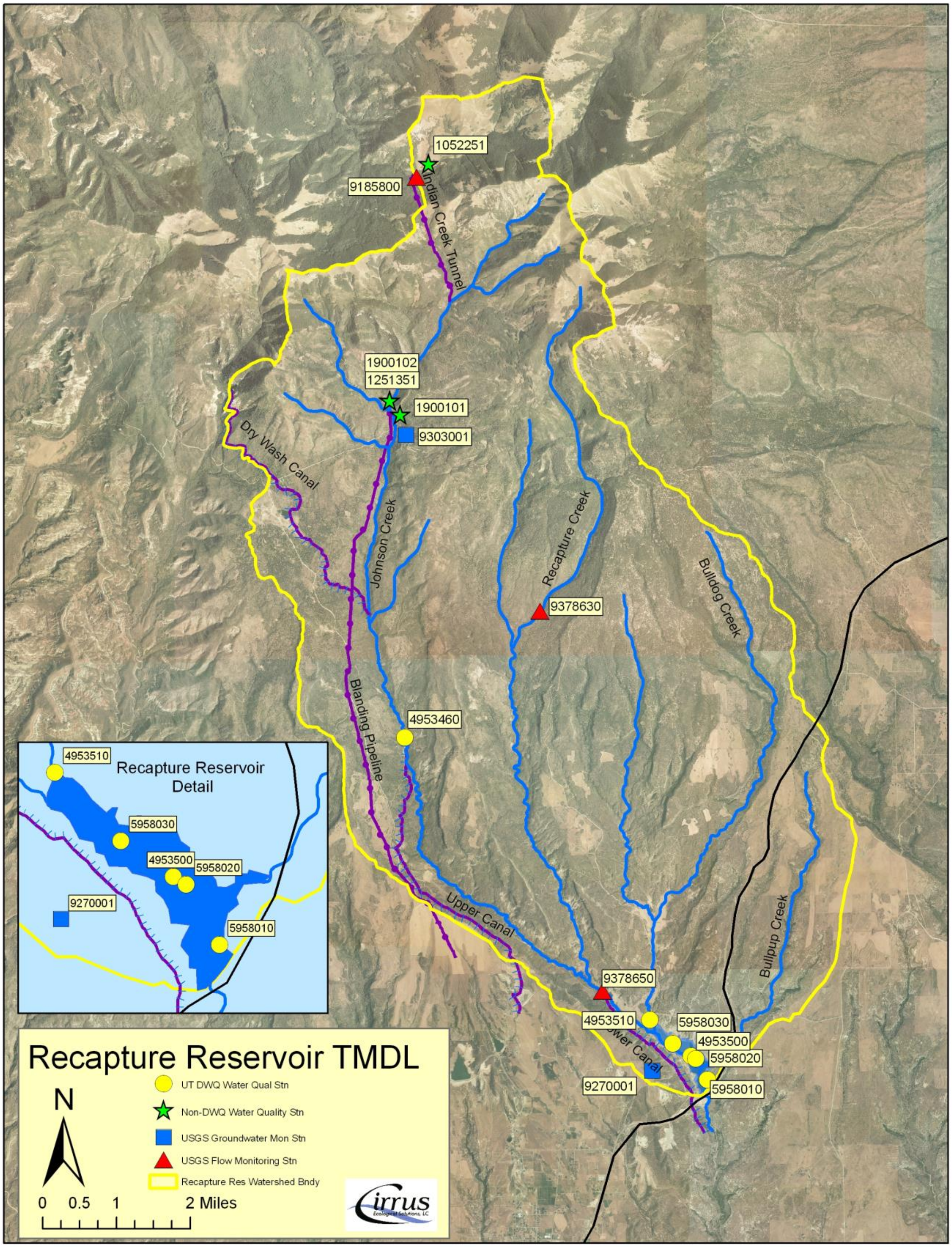


Figure 3.1. Water quality monitoring stations within the Recapture Reservoir TMDL project area.

Three monitoring stations are located on the reservoir itself including Station 5958010 – Recapture Reservoir above dam 001, Station 5958020 – Recapture Reservoir 1/4 way up reservoir 02, and Station 5958030 – Recapture Reservoir 1/2 way up reservoir 03. For discussion purposes these stations will be referred to as Station 01, Station 02, and Station 03, respectively. Water quality records from these stations extend from 1989-2006 with consistent summer season profile measurements beginning in 2001. All reservoir measurements of water quality were collected by DWQ and include the parameters of concern addressed in this TMDL. The most intensely studied year of reservoir monitoring occurred in 2005 when each station was visited once per month during June, July, August, and October.

3.3 EXISTING WATER QUALITY

An assessment of water quality conditions in the Recapture Reservoir watershed has indicated that concentrations of DO and TP in the study area generally meet the criteria for the aquatic wildlife beneficial use (Class 3A), with the exception of some profile measurements of DO at reservoir monitoring stations. Both DO and TP drive important chemical and biological processes that support viable aquatic habitat. Dissolved oxygen can be heavily influenced by temperature, as well as surface reaeration, mixing of the water column, plant photosynthesis and respiration, and high concentrations of nutrients and organic matter.

In general, the concentration of DO is inversely related to water temperature. Cold water temperatures increase the solubility of DO and allow a given water volume to contain greater DO concentrations. Atmospheric oxygen influences aquatic systems through surface reaeration. This process is induced by turbulence created as water flows across roughened channel surfaces or from wind moving across the water surface of lakes and reservoirs. Mixing of stratified water volumes can occur as tributary streams flow into lakes and reservoirs. Additional mixing can occur when thermal profiles shift during the fall season as reservoir surface layers become colder, denser and ultimately settle to the bottom to force deep water volumes back to the surface. This process is commonly referred to as fall turnover.

Oxygen is also introduced to the water column by photosynthesis of aquatic plants. However, if high levels of light and nutrients are present, algae populations will rapidly increase, resulting in large diurnal swings of DO concentrations. These diurnal cycles caused by photosynthesis can exceed saturation levels during daylight hours.

Dissolved oxygen is lost to the atmosphere when water temperatures increase and the solubility of DO in water is reduced. Dissolved oxygen is also consumed by respiration of animals and plants. Nighttime respiration, particularly by high concentrations of algae, may reduce DO levels below the water quality criterion in some water bodies.

Phosphorus and nitrogen provide essential nutrients for plant and animal life. If nutrients are present in excessive amounts, the growth of algae and other waterborne plants is accelerated. Nutrient rich water bodies that experience rapid growth of algae are considered eutrophic. Decay of algae through bacterial decomposition can significantly reduce DO levels. Additional organic material can be carried into streams and reservoirs through point source discharges or in the form of nonpoint source runoff. No effluent discharges from point sources have been identified in the project area.

3.3.1 Surface Water Quality

The assessment of current water quality conditions in the Recapture Reservoir watershed included the compilation and summary of available measurements of water quality data that have the potential to influence reservoir DO concentrations. Stream monitoring stations included in this assessment were selected based on their location with respect to Recapture Reservoir and length of data record. In most instances, only water quality measurements collected since 1998 were considered.

Summary statistics for parameters including DO, TP, Dissolved Phosphorus (DP), Total Ammonia, Total Suspended Solids (TSS), pH, and Water Temperature (Temperature) for selected stream monitoring sites are shown in Tables A2 - A13 (Appendix A). These tables provide a summary of current and historical data collected at each site within the last decade. A complete statistical summary of water quality parameters is provided in Appendix A. Time series and seasonal box-and-whisker plots for the selected parameters are also included in Appendix A for selected monitoring sites in the project area.

3.3.1.1 Dissolved Oxygen

Minimum DO concentration measured in tributary streams to Recapture Reservoir is 2.4 mg/L (June 2001) above the reservoir in Bulldog Canyon Creek and 5.0 mg/L (August 2005) five miles upstream of the reservoir in Johnson Creek. Maximum stream DO concentrations are 5.8 mg/L at Bulldog Canyon Creek and 12.6 mg/L at Johnson Creek. All other stream stations have no DO data, or have it only for the year 1980. Mean DO in Bulldog Canyon Creek is 4.4 mg/L, and 8.7 mg/L upstream in Johnson Creek. Figure 3.2 shows available DO measurements collected from each site including 19 measurements (1988-2001) collected from Bulldog Canyon Creek and 20 measurements from Johnson Creek (1998-2006).

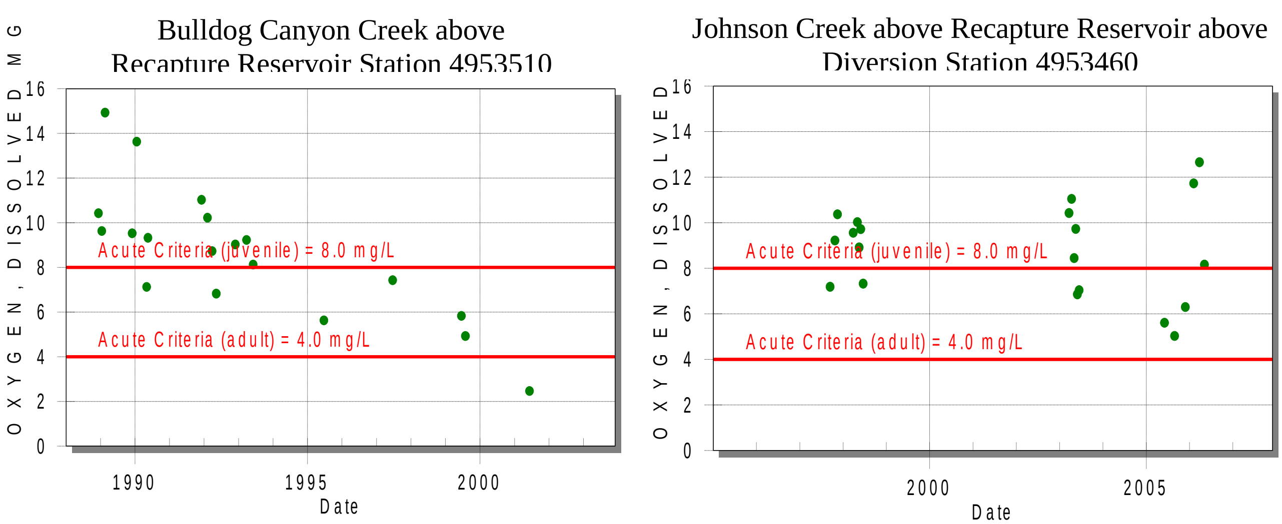


Figure 3.2. Available DO measurements collected from tributary streams to Recapture Reservoir including Bulldog Canyon Creek and Johnson Creek.

Recapture Creek and its tributary streams are classified as 3A streams (cold-water aquatic life beneficial use) with an acute DO standard for juvenile and adult life stages of 8.0 mg/L and 4.0 mg/L, respectively. This standard also applies to the Reservoir itself. All DO measurements collected from Johnson Creek and all but one DO measurement from Bulldog Creek met the 4 mg/L criterion.

During the past ten years, minimum DO concentrations in Recapture Reservoir have been consistently below 0.5 mg/L in the lower portions of the water column. Maximum DO levels in Recapture Reservoir range from 8.4 to 8.9 mg/L. Recent (1998-2007) mean DO concentrations observed at reservoir monitoring stations ranged from 4.6 to 6.0 mg/L. DO levels generally increased with distance upstream from the dam.

Table 3.4 provides water quality information on reservoir profile measurements. Reservoir profiles have been consistently measured at three monitoring stations since 2001. Greatest water depths typically occur nearest the Dam and decrease toward the inlet. The percent of DO profile measurements that violated the 4.0 mg/L criterion in Recapture Reservoir at Stations 01 and 02 ranged from 0 to 75 percent, with many sample dates indicating more than 50 percent of DO profile measurements below this level. The greatest number of samples violating DO criteria occur in August of most years when more than 50 percent of the column is below 4 mg/L. The lowest concentrations were observed on August 14, 2003 when 75 percent of DO profile measurements were less than 4.0 mg/L. An exception to this seasonal pattern occurred in 2006 when less than 50% of the water column was above 4.0 mg/L in June and July, all of the water column was above 4.0 mg/L in August, and 26% of the water column was below 4.0 mg/L in September. However, the number of measurements collected in August 2006 at Station 01 (above Recapture Dam) are very limited and do not appear to represent the entire profile. Average DO concentrations during August of most years were less than 4.0 mg/L at Station 01 and Station 02 (1/4 way up the reservoir). During July 2005 DO profiles at the two upper-reservoir locations were low, with most measurements less than 5.0 mg/l.

Full support of DO criteria was typically observed at reservoir monitoring stations in June and July of each year as well as September and October when measurements were available for these months. Although water is deepest at Station 01, based on the consistency of violations it does not appear that support of DO criterion is strongly correlated with water depth at reservoir monitoring stations.

Figure 3.3 displays profile measurements of DO and temperature at all three reservoir monitoring stations during June and October of 2005. Note that although the total depth varies at each station, the shape of the profiles at depth is very similar, even during different times of the year. These plots indicate a pattern that is typical of other years and provide evidence that stratified layers are consistent between the three monitoring locations with respect to distance (approximately 0.4 miles between each station), and season. It is likely these stratified layers continue upstream of Station 03 (1/2 way up the reservoir). The similarity between profiles at each station indicates the presence of stratified layers throughout a large portion of the reservoir. A probable cause for this condition is a lack of mixing due to the absence of tributary inflow during the summer and fall months, as described above in Section 2.

Most profile measurements show that Recapture Reservoir is stratified in June and continues throughout the summer and fall season. Figure 3.4 includes reservoir profiles measured at Station 01 during a wet (2005) and relatively dry year (2006), as indicated by monthly precipitation values shown near the bottom of each plot. Note that total precipitation during January through June for 2005 was roughly 3 times as great as total precipitation measured during the same period in 2006. DO profile measurements in June 2005 indicate complete mixing to a depth of nearly 30 meters. Stratification was evident for approximately 4 weeks later in July. Water column depth had decreased substantially over this period, although only 15 percent of measurements were below 4.0 mg/L. DO concentrations continued to decrease in August to below 2 mg/L at depths below approximately 7 m. This pattern was reversed in October in the upper water column when concentrations increased to more than 6 mg/L at depths of nearly 10 m below the water surface. Note that total precipitation during the winter and spring seasons prior to June 2005 totaled nearly 16 inches. Spring runoff associated with precipitation levels of this magnitude appear to be capable of complete water column mixing as shown by the June 2005 profile.

Profiles from 2006 indicate the presence of stratified water layers during the measurement period of June through September. Similar to 2005, upper column DO concentrations increase between July and September. These increases could be the result of mixing from runoff volumes generated by intense thunderstorms capable of generating surface runoff and tributary inflow, or in response to increased DO solubility and thermal mixing as surface water layers begin to cool. Note that total precipitation (November-May) prior to June 2006 was slightly more than 4 inches and roughly 25 percent of the total shown for the same time period in 2005. Profile measurements from both years do not indicate a fall turnover by the time measurements are taken in October.

3.3.1.2 Total Phosphorus

Within the past eight years, minimum TP concentrations in Recapture Reservoir and its tributaries have been below detection limits (typically 0.02 mg/L). Maximum TP on stream sites was 0.36 mg/L at Bulldog Canyon Creek and 0.19 mg/L at Johnson Creek. These measures are at or above the pollution indicator value of 0.05 mg/L TP for streams. Figure 3.5 shows available TP concentrations measured at each stream monitoring site, including 29 samples (1988-2001) from Bulldog Canyon Creek and 22 samples (1998-2006) from Johnson Creek. It is noted that 2 samples from Bulldog Canyon Creek and 14 samples from Johnson Creek were below the method detection limits for TP measurements. Average TP concentration (1998-2007) at stream sites are 0.02 mg/L at the Johnson Creek station and 0.03 mg/L at the Bulldog Canyon Creek station. In general, TP concentrations were highest during the winter season (January-March) at each stream station (including Johnson Creek and Bulldog Canyon Creek) but were still below the 0.05 mg/l indicator value. Exceedance of the TP indicator value at stream stations during 1998-2007 was 4.8 percent at Johnson Creek. All samples from Bulldog Canyon Creek during this time period were at or below 0.05 mg/L.

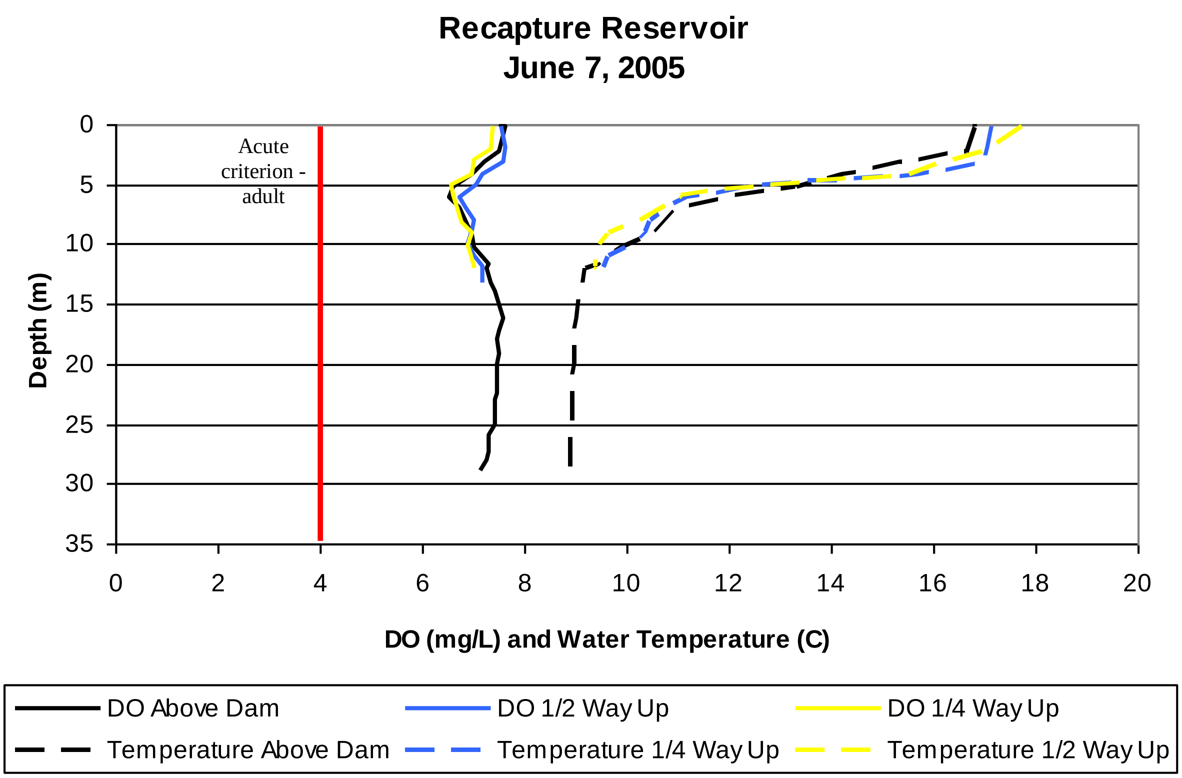
Measurements of TP were typically collected from Recapture Reservoir in June through October during visits when reservoir profiles were measured. Maximum TP concentrations at reservoir stations ranged from 0.23 mg/L at Station 01 to 0.05 mg/L at Station 03. Mean reservoir TP concentrations based on available data (1998-2007) were 0.033 mg/L at Station 01, 0.032 mg/L at Station 02, and 0.023 mg/L at Station 03.

Recapture Reservoir was considered to be in non-support of the TP indicator value in 1996 and 1998, but it has been considered in full support of this parameter since that time. Data from reservoir stations indicate that 17-44 percent of available TP measurements measured during 1998-2007 have exceeded the 0.025 mg/l indicator value (Table A11-Table A13, Appendix A). Exceedance of the indicator value is highest at Station 02 and lowest at Station 03.

Table 3.4. Water quality at three Recapture Reservoir monitoring sites.

			DO			pH			Temperature		
Date	**Depth (m)**	**Samples**	**Mean (mg/L)**	**% <4.0 mg/l**	**Status[1]**	**Mean**	**6.5>%>9.0**	**Status[1]**	**Mean (°C)**	**% >20 C**	**Status[1]**
Reservoir Station 5958010 – Recapture Reservoir Above Dam 01											
6/13/2001	21.8	23	5.37	34.78	FS	7.72	0	FS	12.39	0	FS
8/14/2001	20.4	22	2.52	68.18	NS	7.67	0	FS	15.39	31.81	NS
6/4/2003	15.5	17	5.26	35.29	FS	7.78	0	FS	13.93	29.41	NS
8/14/2003	11.8	12	2.12	75	NS	7.52	0	FS	17.23	41.67	NS
6/7/2005	28.9	28	7.28	0	FS	7.88	0	FS	10.66	0	FS
7/13/2005	18.4	20	4.84	15	FS	8.24	0	FS	13.84	25	NS
8/31/2005	14.6	17	2.91	58.82	NS	7.42	0	FS	15.93	35.29	NS
10/5/2005	14.7	16	4.46	37.5	FS	7.63	0	FS	14.08	0	FS
6/22/2006	21.1	23	5.07	52.17	NS	7.9	0	FS	13.72	21.74	NS
7/19/2006	18.2	19	2.79	52.63	NS	7.58	0	FS	16.6	42.11	NS
8/24/2006	3.5	5	6.19	0	FS	8.14	0	FS	22.42	100	NS
9/22/2006	18	19	6.02	26.32	FS	8.23	0	FS	14.22	0	FS
Reservoir Station 5958020 – Recapture Reservoir ¼ Way Up Reservoir 02											
6/13/2001	3.3	5	7.97	0	FS	8.49	0	FS	18.94	0	FS
8/14/2001	14.1	15	3.58	53.33	NS	7.8	0	FS	18.06	46.66	NS
6/4/2003	14	15	5.56	33.33	FS	7.83	0	FS	14.44	26.66	NS
6/7/2005	13.3	14	7.18	0	FS	7.8	0	FS	12.72	0	FS
7/13/2005	20.6	22	4.02	68.18	NS	8.02	0	FS	13.5	22.73	NS
8/31/2005	9.5	11	4.1	36.36	FS	7.57	0	FS	18.67	63.64	NS
10/5/2005	17	18	4.02	38.89	FS	7.61	0	FS	13.49	0	FS
6/22/2006	14.7	17	5.62	29.41	FS	8.1	0	FS	16.27	29.41	NS
7/19/2006	11.8	13	3.66	46.15	FS	7.71	0	FS	20	53.85	NS
8/24/2006	6.2	8	5.06	25.00	FS	8.01	0	FS	22.08	100	NS
Reservoir Station 5958030 – Recapture Reservoir ½ Way Up Reservoir 03											
6/13/2001	7	8	7.76	0	FS	8.35	0	FS	17.52	0	FS
8/14/2001	5.2	7	6.70	0	FS	8.41	0	FS	22.65	100	NS
6/4/2003	9.4	11	6.81	18.2	FS	8.02	0	FS	16.50	36.4	NS
6/7/2005	12.1	12	6.96	0	FS	7.89	0	FS	12.57	0	FS
7/13/2005	12.0	14	3.71	66.6	NS	7.90	0	FS	16.35	41.7	NS
8/31/2005	4.1	6	6.11	0	FS	7.84	0	FS	21.78	100	NS
10/5/2005	7.1	9	6.83	0	FS	7.92	0	FS	15.62	0	FS
6/22/2006	9.1	11	6.69	18.2	FS	8.33	0	FS	18.51	45.5	NS
7/19/2006	6.8	8	5.43	25.0	FS	8.00	0	FS	22.88	87.5	NS
8/24/2006	5.3	7	5.51	14.3	FS	8.06	0	FS	22.12	100	NS

FS= full support of beneficial use, NS= non-support of beneficial use.



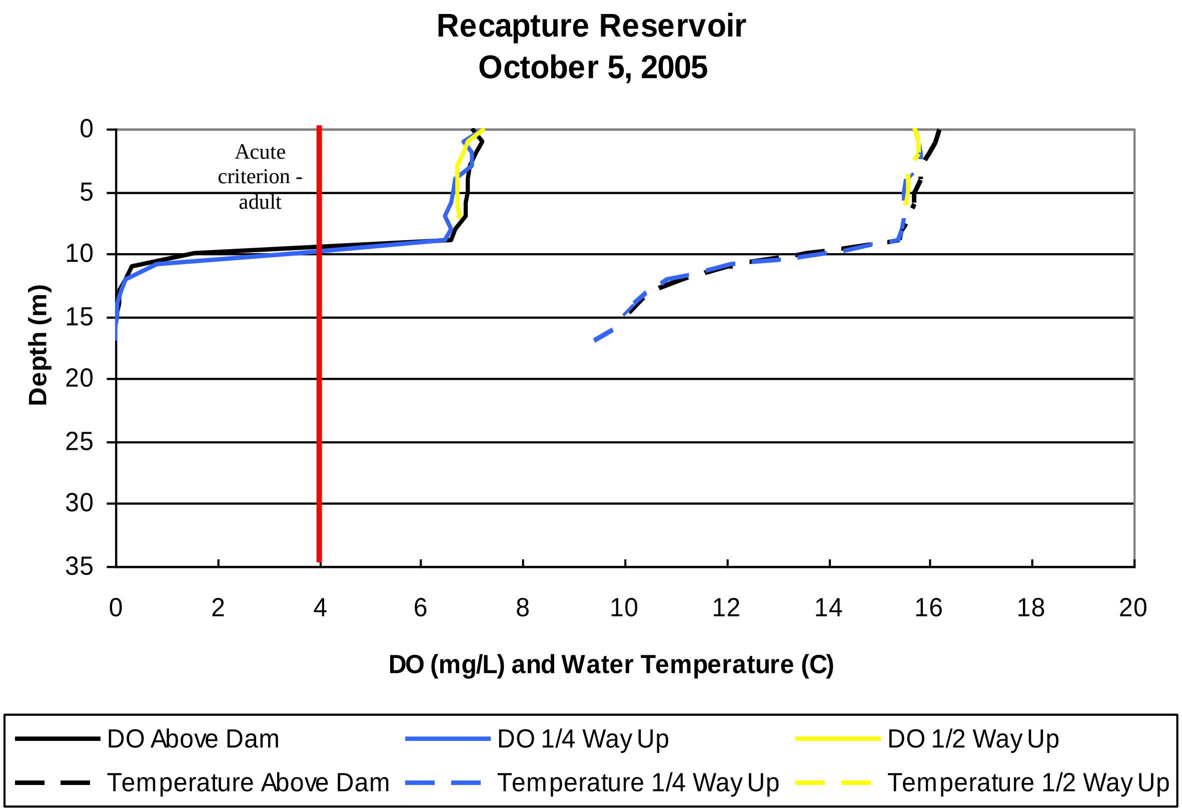


Figure 3.3. Selected reservoir DO and temperature profiles measured from monitoring stations on Recapture Reservoir during 2005.

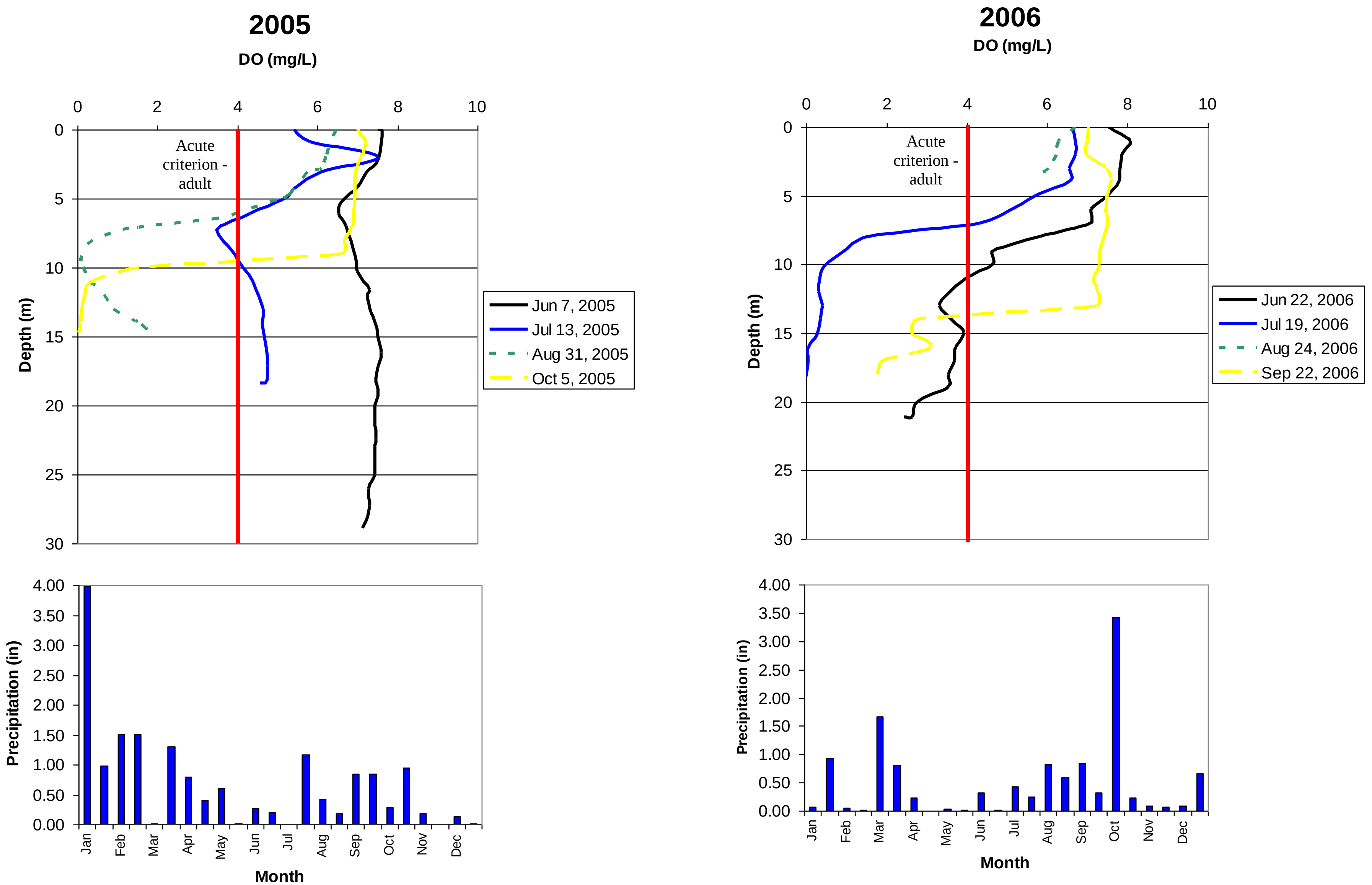


Figure 3.4. DO profiles observed at Recapture Reservoir Above Dam during 2005 and 2006.

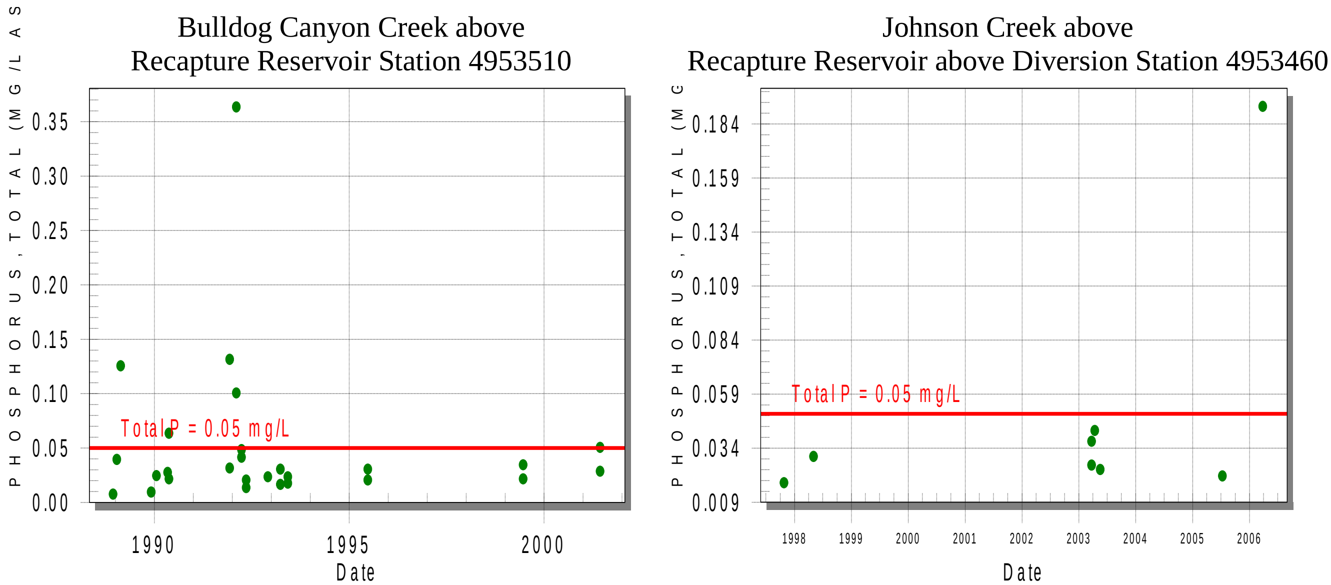


Figure 3.5. Available TP measurements collected from tributary streams to Recapture Reservoir including Johnson Creek and Bulldog Canyon Creek.

Table 3.5 provides information on profile measurements of TP. These measurements are generally collected at 4 different depths that are representative of the entire water column. Note that although most dates include samples that exceed 0.025 mg/L, most dates also include samples that were below the detection limit. Samples with concentrations less than the detection limit were represented by a value of one-half the detection limit. For each sample date, the highest TP concentrations were consistently measured from the lowest profile sample which is collected roughly 1 meter above the reservoir bottom. Figure 3.6 displays all TP measurements collected during periods when reservoir elevation data is available (2001-2007) and indicates that higher concentrations are present during times when reservoir levels have increased rapidly. These time periods are typically associated with the spring runoff period.

3.3.1.3 Dissolved Phosphorus

The availability of phosphorus for growth of algal species is indicated by measurements of DP. A high DP/TP ratio indicates that much of the phosphorus in water bodies is potentially available for use by algae and other plant species. Only one measurement of DP is available from stream monitoring locations in the project area. It was collected in March 2006 at Johnson Creek. The DP value at this station was 0.030 mg/L, which is below the pollution indicator value of 0.05 mg/L.

Measurements of DP have been routinely collected from reservoir monitoring stations. Table 3.5 indicates mean DP concentrations calculated from reservoir profile samples. Similar to TP measurements, many of the DP samples had concentrations that were below detection limits as well as high concentrations collected from samples near the reservoir bottom. Nearly all mean DP concentrations were below 0.30 mg/L and most were below 0.025 mg/L. DP/TP ratios were consistently greater than 0.50, indicating that most of the phosphorus is available for plant growth. Note that for some dates all DP samples had concentrations below detection limits and a value of 0.020 mg/L was assumed. In these instances, the actual DP/TP ratio is likely overestimated.

Figure 3.6 displays all DP measurements collected during periods when reservoir elevation data is available (2001-2007). DP concentrations generally follow a pattern similar to TP although the large increases observed during early 2005 are limited in their range. The highest concentrations were observed in late 2006 on a date when reservoir elevations were not available. It is not known if the increased concentrations in both TP and DP sample were in response to loading from tributaries or resuspension of bottom sediments. The highest measured concentration on this date was collected at the bottom of the water column.

3.3.1.4 pH

Minimum pH measurements throughout the Recapture Reservoir watershed since 1999 have been essentially neutral, ranging from 6.9 at Station 02 to 7.4 at Bulldog Creek. Maximum values are neutral to slightly basic, ranging from 8.3 at Bulldog Canyon Creek to 9.6 at Johnson Creek. Mean pH values were slightly basic and ranged from 7.8 at Stations 01 and 02 to 8.3 at Johnson Creek.

The pH standard for Class 3A water bodies including Recapture Reservoir and its tributaries is 6.5 - 9.0. This standard was not exceeded in Recapture Reservoir in the past eight years or in Bulldog Canyon Creek during the entire period of record. The standard was exceeded in 7.1 percent of samples at Johnson Creek. Seasonal patterns of pH levels were not observed in streams in the project area.

As with other parameters, pH measurements in the reservoir were only taken in June through October. Table 3.4 provides a summary of pH profile measurements collected during each sample date. As indicated in this table, no violations of the pH standard were observed in profile measurements.

3.3.1.5 Total Suspended Solids

Minimum TSS concentrations were below detection limits throughout the watershed including stream and reservoir sites. Maximum TSS readings in project area streams were 32 mg/L in Bulldog Canyon Creek and 92.7 mg/L at Johnson Creek. Mean TSS values at these stations were 19.2 and 16.4 mg/L, respectively.

All reservoir TSS readings since 1999 have been below detection limits. This indicates that suspended material brought into the reservoir by inflowing tributaries settles quickly. It also provides additional evidence that little or no water column mixing occurs during the summer and early fall that would resuspend material.

3.3.1.6 Nitrogen - Ammonia

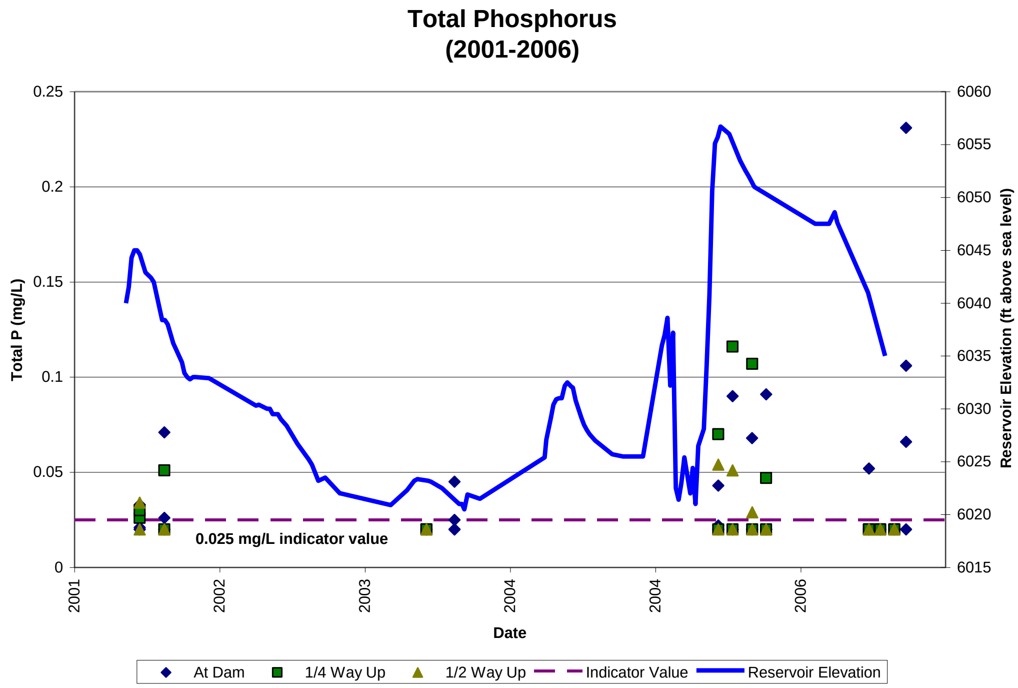
Most ammonia measurements taken in the project area since 1999 were below the detection limit. The only stream with ammonia concentrations above the detection limit was Johnson Creek which had a mean concentration of 0.04 mg/L and a maximum value of 0.06 mg/L. No exceedance of the pH-dependent ammonia standard occurred.

More than 40 percent of reservoir measurements of ammonia were below the detection limit. Mean concentrations of reservoir measurements above the detection limit ranged from 0.047 to 0.054 mg/L. Maximum values ranged from 0.23 mg/L at Station 01 to 0.08 mg/L at Station 03 While mean values show little variance, maximum values are generally higher at Station 01 and Station 02. Similar to stream monitoring stations, no exceedance of the ammonia standard was observed at reservoir monitoring stations.

Table 3.5. Water quality at two Recapture Reservoir monitoring sites.

		Total P (mg/L)				Dissolved P (mg/L)				
Date	Depth (m)	Samples	Below Detection Limit	Mean	Samples >0.025 mg/l	Samples	Below Detection Limit	Mean	Samples >0.025 mg/l	DP/TP Ratio
Reservoir Station 5958010 - RECAPTURE RES AB DAM 001										
6/13/2001	21.8	4	1	0.024	1	4	3	0.021	0	0.88
8/14/2001	20.4	4	2	0.034	2	4	2	0.029	1	0.85
6/4/2003	15.5	4	4	0.020	0	4	4	0.020	0	1.00
8/14/2003	11.8	4	1	0.028	1	4	3	0.024	1	0.86
6/7/2005	28.9	4	2	0.026	1	4	4	0.020	0	0.77
7/13/2005	18.4	4	3	0.038	1	4	3	0.023	1	0.61
8/31/2005	14.6	4	3	0.032	1	4	3	0.023	1	0.72
10/5/2005	14.7	4	3	0.038	1	4	3	0.025	1	0.66
6/22/2006	21.1	4	3	0.028	1	4	4	0.020	0	0.71
7/19/2006	18.2	4	4	0.020	0	4	4	0.020	0	1.00
8/24/2006	3.5	2	2	0.020	0	2	2	0.020	0	1.00
9/22/2006	18	4	1	0.106	3	4	1	0.108	3	1.02
Reservoir Station 5958020 - RECAPTURE RES 1/4 WAY UP RES 02										
6/13/2001	3.3	2	0	0.028	2	2	2	0.020	0	0.71
8/14/2001	14.1	2	1	0.036	1	2	0	0.046	2	1.28
6/4/2003	14	2	2	0.020	0	2	1	0.016	0	0.80
6/7/2005	13.3	2	1	0.045	1	2	1	0.024	1	0.53
7/13/2005	20.6	2	1	0.068	1	2	1	0.026	1	0.38
8/31/2005	9.5	2	1	0.064	1	2	1	0.023	0	0.36
10/5/2005	17	2	1	0.034	1	2	1	0.030	1	0.88
6/22/2006	14.7	2	2	0.020	0	2	2	0.020	0	1.00
7/19/2006	11.8	2	2	0.020	0	2	2	0.020	0	1.00
8/24/2006	6.2	2	2	0.020	0	2	2	0.020	0	1.00
Reservoir Station 5958030 - RECAPTURE RES 1/2WAY UP RES 03										
6/13/2001	7	2	1	0.027	1	2	2	0.020	0	0.74
8/14/2001	5.2	2	2	0.020	0	2	2	0.020	0	1.00

Table 3.5. (cont'd) Water quality at two Recapture Reservoir monitoring sites.										
		TP (mg/L)				DP (mg/L)				
Date	Depth (m)	Samples	Below Detection Limit	Mean	Samples >0.025 mg/l	Samples	Below Detection Limit	Mean	Samples >0.025 mg/l	DP/TP Ratio
6/4/2003	9.4	2	2	0.020	0	2	2	0.020	0	1.00
6/7/2005	12.1	2	1	0.037	1	2	1	0.020	0	0.54
7/13/2005	12.0	2	1	0.036	1	2	1	0.021	0	0.57
8/31/2005	4.1	2	1	0.025	1	2	2	0.020	0	0.80
10/5/2005	7.1	2	2	0.020	0	2	2	0.020	0	1.00
6/22/2006	9.1	2	2	0.020	0	2	2	0.020	0	1.00
7/19/2006	6.8	2	2	0.020	0	2	2	0.020	0	1.00
8/24/2006	5.3	2	2	0.020	0	2	2	0.020	0	1.00



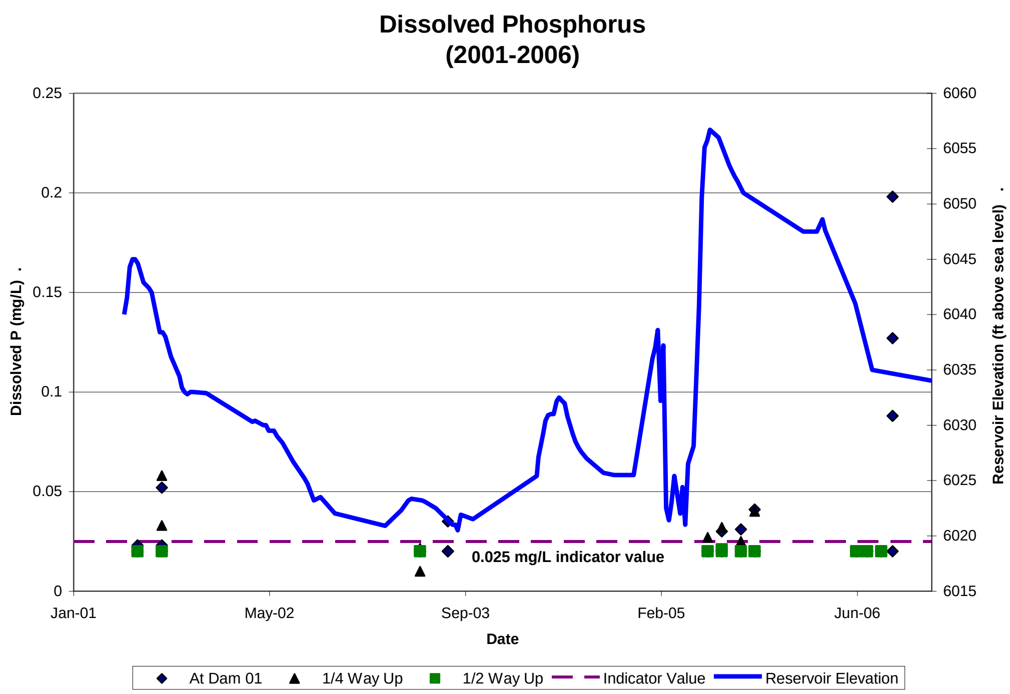


Figure 3.6. Total and Dissolved Phosphorus concentrations measured at Recapture Reservoir monitoring locations during 2001-2006. Data points represent individual measurements collected at approximately 2-4 depths in the water column for a given sample date.

3.3.1.7 Water Temperature

Since 1999, maximum stream temperatures were 23.5 °C on Johnson Creek, upstream of the reservoir, and 27.5 °C at Bulldog Canyon Creek, just above the reservoir. Mean temperature at Johnson Creek was 9.9 °C, and much higher at 23.2 °C on Bulldog Canyon Creek which exceeds the 20 °C Class 3A standard. Exceedance of the temperature standard was recorded in 20 percent of measurements from Johnson Creek samples and 33.3 percent of samples collected from Bulldog Canyon Creek.

Maximum temperatures in reservoir profiles ranged from 24.7 to 24.9 °C. Mean temperatures increased with distance from the dam, ranging from 14.1 °C at Station 01 to 16.9 °C at Station 03. The criterion for supporting the 3A beneficial use in reservoirs is based on the same temperature threshold of 20 °C as in streams, but the standard is in terms of the percentage of samples taken from a single location on the reservoir that exceed that criterion temperature. Table 3.4 shows the results of water temperature measurements for the three monitoring sites in the reservoir between early June and October for several of the last six years. Until early June and after early September, temperature does not exceed 20 °C. However, some percentage of the samples always exceed the 20 °C standard during late June through August.

The percentage of reservoir samples that exceed the standard is substantially higher at the Station 03 site because it is much shallower. Figure 3.7 shows temperature profiles of all three sites on a typical day in August. All three profiles were measured from the surface to the bottom. Note first that the site immediately above the dam is deepest (~15 m) and the site half way up the reservoir is much shallower (~4 m). Surface water temperatures are slightly lower at the dam where the water is deepest. However, all three sites show a similar temperature profile with respect to actual depth. At the site furthest from the dam, and the shallowest location, all of the profile measurements exceed the 20 °C criterion. Since the same number of measurements is spread out through the entire water column, deeper sites, such as near the dam, will register a smaller percentage of samples that fail the temperature criterion. As with DO, this suggests that water quality in the reservoir needs to be assessed with respect to actual depths of habitable water by the designated fishery.

3.3.2 GROUNDWATER QUALITY

Two groundwater monitoring stations were identified in the watershed, with one visit to each station. One station is 10 miles upstream of Recapture Reservoir (374726109303001), and one is near the reservoir (373954109270001). Table 3.6 contains a summary of parameters at each station. No measurements of nutrients were identified at these locations. Measurements of temperature and TDS appeared to be representative of good groundwater quality conditions.

Table 3.6. Groundwater quality data from well stations.

Station	Station Name	Year	Specific Conductance (umhos/cm @ 25°C)	pH	Solids, Dissolved (mg/l)	Water Temperature (°C)
373954109270001	(D-36-22)12ccd-1	1982	510	9.2	130	16.5
374726109303001	(D-34-22)28caa-1	1977	-	7.6	251	-

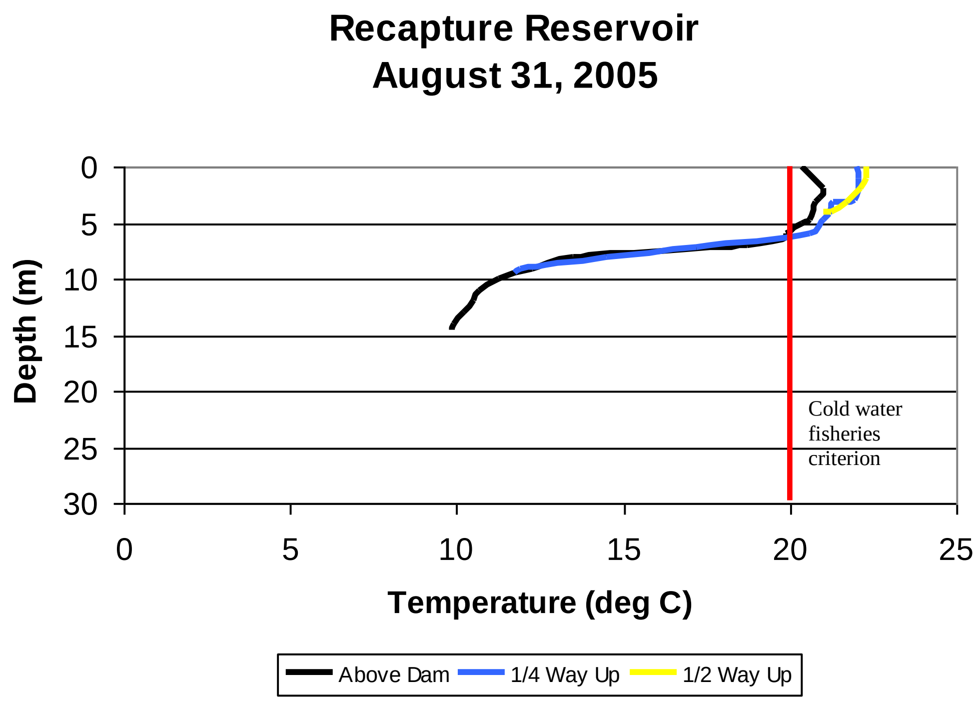


Figure 3.7. Temperature profiles at three sites in Recapture Reservoir.

3.3.3 BIOLOGICAL DATA

The available measurements of algae in the Recapture Reservoir watershed were limited to the period 1995-2001 at Station 01 (Recapture Reservoir Above Dam). Phytoplankton data collected about 15 years ago showed one species of green algae, *Sphaerocystis schroeteri*, to be highly dominant, representing almost 98 percent of algal cell volume (Judd 1997). A review of the DWQ algae monitoring data from STORET shows a more balanced species distribution. Sixteen different species were identified from samples collected during this time period, with no species representing more than 21 percent of the total composition. Most of these species are green algae species, which are indicative of good water quality and moderate production. Table 3.7 shows algae data from Recapture Reservoir.

Macroinvertebrate data was also collected on Johnson Creek above Recapture Reservoir in October 2004. An O:E score of 0.881 was recorded. An O:E score is the ratio of observed over expected for macroinvertebrate populations. Therefore, a score of 1.0 would indicate that all species expected were observed. Anything above the threshold value of 0.74 is considered to be in full support. Based on macroinvertebrate samples, Johnson Creek was found to be in full support of its beneficial uses.

Recapture Reservoir is reported to have supported populations of cold water fish including brook trout, rainbow trout, and bullheads (Judd 1997). The reservoir was initially treated in the fall of 1983 for elimination of non-game fish prior to filling the impoundment to capacity level. A limnological assessment completed by Utah DWR at that time indicated the reservoir could support a cold water fishery. As a result, rainbow trout were initially stocked by DWR to establish in the reservoir. Fish stocking was discontinued in 2001 because illegally introduced northern pike were found to be eating the fingerlings.

A recent gillnetting survey was conducted on Recapture Reservoir by DWR on April 26, 2007. This survey collected numerous pike that were 18-24 inches and one large 8 lb, 31 inch adult. Other fish that were identified included many robust 11-14 inch largemouth bass as well as good numbers of black bullhead roughly 2 lbs each (DWR 2007). Most of these species are considered warmwater fish and likely have adapted to higher temperatures and low DO conditions that are sometimes observed in the reservoir. All warmwater species have been illegally stocked. No coldwater species were identified in the survey results.

Table 3.7. Algae measurements collected from Recapture Reservoir.[1]

Species	Value[2]	% of Total	Type
August 23, 1995			
Chlorophyta sp. 1	5,560	11.10	Green
Melosira granulate	5,560	11.10	Diatom
Oocystis sp. 1	16,680	33.30	Green
Phacus	5,560	11.10	Green
Sphaerocystis schroeteri	11,120	22.20	Green
Bacillariophyta sp. 1	5,560	11.10	Green
TOTAL	**50,040**	**100**	
August 4, 1999			
Pteromonas	16,700	15.80	Green
Chlorophyta sp. 1	22,200	21.00	Green
Ceratium hirundinella	5,600	5.30	Dinoflagellate
Ankistrodesmus falcatus	50,000	47.30	Green
Oocystis sp. 1	11,100	10.5	Green
TOTAL	**105,600**	**100**	
August 14, 2001			
Bacillariophyta sp. 1	31,300	31.20	Diatom
Fragilaria crotonensis	18,800	18.80	Diatom
Bacillariophyta sp. 2	3,100	3.10	Diatom
Tabellaria fenestrata	18,800	18.80	Diatom
Oocystis borgei	6,300	6.30	Green
Pteromonas	21,900	21.90	Green
TOTAL	**100,200**	**100**	

[1] Biological data included algae measurements at Station 5958010 Recapture Reservoir above Dam 01.
[2] Units #/L.

Table 3.8 indicates habitat needs of fish species stocked by DWR following reservoir construction as well as those species later identified in surveys of Recapture Reservoir.

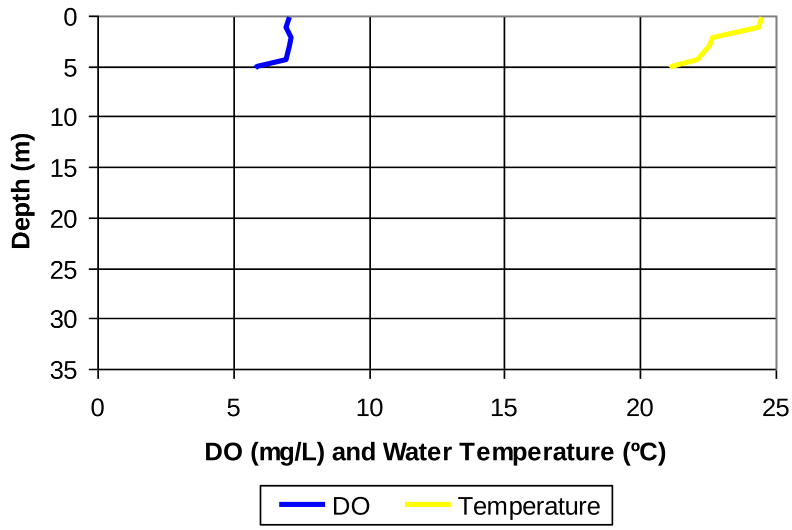
Based on the available data, it is quite likely that every summer cold water species of fish would be under severe stress. Figure 3.8 shows a condition in August of 2001 where the entire water column at Station 03 is warmer than 20 °C, and at Station 01, water below 20 °C is only present where DO levels are less than 4.0 mg/L. This situation may occur in most of the reservoir every year, for even in a year of very high precipitation, such as 2005, Figure 3.9 shows that fish would have encountered the same situation. Based on 2007 gill netting, it appears there are no cold water species that survived. Warm water fish, are much less constrained by temperature and DO levels in comparison to cold water species. Water temperatures have never exceeded the Class 3B warm water criterion of 27 °C during monitoring visits to Recapture Reservoir.

Table 3.8. Summary of habitat needs of Recapture Reservoir fish.

Species	Optimum Temperatures (deg C)			DO Requirements (mg/L)*	Habitat Type	Diet	Spawning Season	Substrate
	Egg	Adult	Spawning					
Black Bullhead	22.2 - 23.9	21–24	18.9–22.2	Optimum > 7, Lethal <3 (summer), 0.3 (winter)	50–80% of total stream area with low velocity pools or backwaters and also riffle-run areas.	Omnivores, mainly crustaceans	Late spring–summer	Silt
Bluegill	20.0	15–25	19.4–20.0	Optimum >5, Lethal <1	Weedy, shallow, clear, warm water.	Insects, small fishes, frogs, crayfish, and snails, plankton	Spring	Sand or gravel
Cutthroat Trout	10.0	12–15	5.5–8.9	Optimum >9	Clear, cold lakes and streams.	Adults carnivorous, young eat plankton and insects	Early spring	Silt-free, rocky
Brook Trout	4.5-11.5	11-16	4.5-10.0	Optimum >7	Clear, cold water with 1:1 pool:riffle ratio and stable flow and vegetated banks.	Macroinvertebrates, terrestrial insects	Fall	Silt-free, rocky
Green Sunfish	23.3	18–32	18.9–27.7	Optimum >5, Lethal <1.5	Small, warm, streams, ponds, and shallow areas of lakes.	Insects, mollusks, and small fish	Spring	
Largemouth Bass	16.7–18.3	26.7	14.4–15.0	Optimum >8, Lethal <1	Small, shallow lakes and ponds and large, slow rivers.	Fish and small mammals; plankton, insects	Spring	
Rainbow Trout	>5.6	12–18	10.0	Optimum >9, Lethal <3	Clear, cold lakes and streams with 1:1 pool:riffle ratio.	Fish, invertebrates, algae, vascular plants	Early spring	Silt-free rocky substrate
Northern Pike	16-20	19-21	8-12	Optimum >4, Lethal <1.5	Shallow, vegetated areas in lakes and reservoirs	Fish, insects	Spring	Dense vegetation

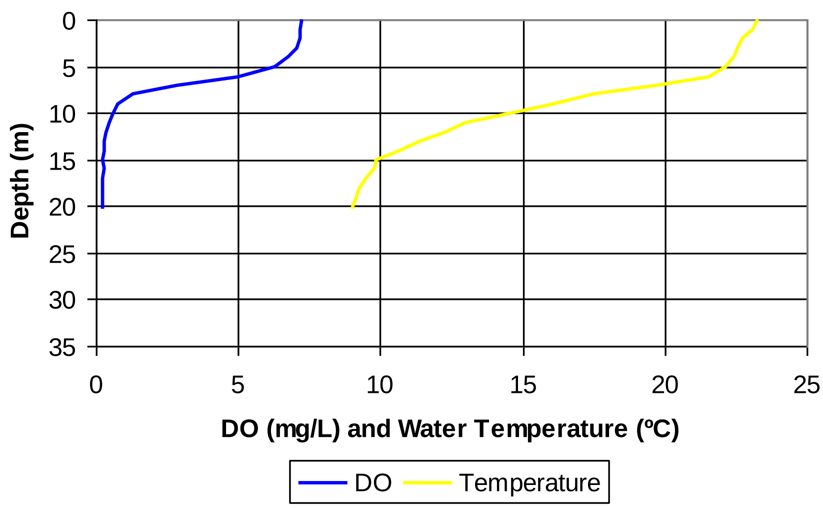
*The term "optimum" can be misleading, as some species can survive DO levels well below their optimum, while others are more sensitive. When considered with the lethal limit, this information provides an indication of the relative ranges of requirements across species.
Sources: Petrovsky and Magnuson 1973, Matthews and Berg 1997, Stuber et. al 1982a, Hickman and Raleigh 1982, Stuber et. al 1982b, Sigler and Sigler 1996, Inskip 1982, Raleigh 1982, Casselman and Lewis 1996.

Recapture Reservoir Profile
Station 03 1/2 Way - August 14, 2001



Depth	DO	Temp
0.1	7.05	24.52
1.2	6.98	24.35
2.2	7.15	22.71
3.1	7.05	22.53
4.3	6.94	22.14
5	5.88	21.2
5.2	5.84	21.13

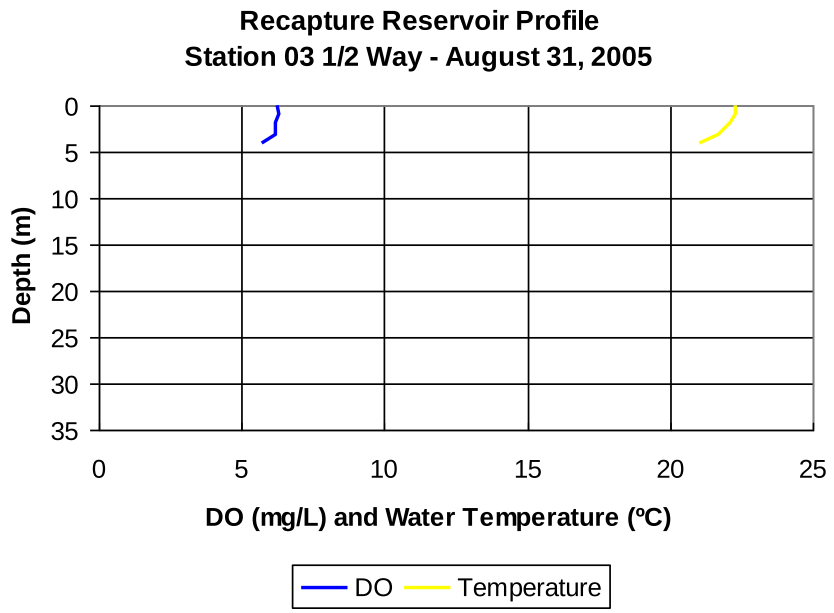
Recapture Reservoir Profile
Station 01 at Dam - August 14, 2001



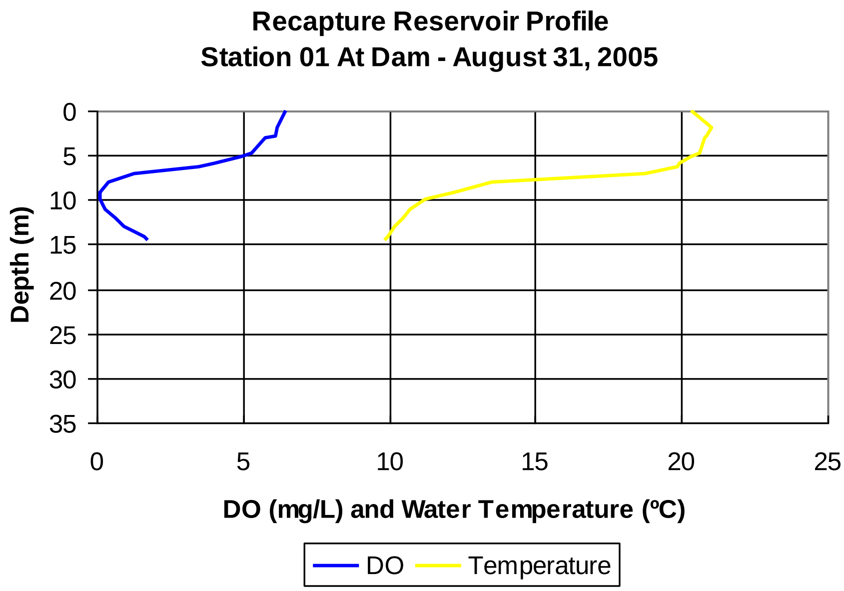
Depth	DO	Temp
0	7.24	23.26
1.1	7.18	23.1
2	7.16	22.76
3	7.07	22.58
4	6.75	22.46
5	6.32	22.12
6.1	5.01	21.55
7	2.85	19.71
7.9	1.33	17.49
9.1	0.8	16.09
10.1	0.58	14.44
11.1	0.45	12.99
12.1	0.38	12.25

13.1	0.32	11.38
14.1	0.3	10.63
15	0.26	9.86
16	0.27	9.77
17	0.26	9.5
18.1	0.25	9.28
19.3	0.25	9.16
20.2	0.24	9.05
20.4	0.23	9.05

Figure 3.8. Recapture Reservoir profiles measured August 14, 2001. Shaded cells in tables indicate measurements that comply with Class 3A criterion for DO (> 4 mg/L) or temperature (20 ºC). Note that both criterion are never met at the same depth.



Depth	DO	Temp
0	6.24	22.31
1	6.33	22.31
1.9	6.16	22.12
3.1	6.2	21.69
4	5.72	21.02
4.1	5.99	21.23



Depth	DO	Temp
0	6.45	20.36
1.9	6.19	21.03
2.8	6.1	20.89
3.1	5.76	20.79
4.7	5.31	20.62
5.1	4.95	20.34
6	4.01	19.92
6.4	3.52	19.88
7.1	1.28	18.74
8	0.39	13.52
9.1	0.1	12.25
10	0.12	11.27
11	0.31	10.7
12	0.66	10.48
13	0.91	10.19
14.1	1.61	9.94
14.6	1.75	9.85

Figure 3.9. Recapture Reservoir profiles measured August 31, 2005. Shaded cells in tables indicate measurements that comply with Class 3A criterion for DO (> 4 mg/L) or temperature (20 ºC). Note that both criterion are met at a depth of 6 m.

3.3.4 TROPHIC STATE INDEX

The trophic state of a lake or reservoir is an indicator of the total weight of all living biological material or biomass found within the waterbody at a given point in time (Carlson and Simpson 1996). The specific trophic state of a water body can be influenced by nutrient additions, as well as other factors such as season, zooplankton grazing, mixing depth, etc. (Carlson and Simpson 1996). Trophic status is generally considered to respond to nutrient inputs over time, and will reflect the biological condition of a waterbody. The trophic state index (TSI) is based on measurements of nutrient-related parameters that are believed to characterize biomass. Carlson (1977) has developed trophic state indices based on measurements of chlorophyll a (Chl-a), TP, and Sechi disk (SD) depth, each of which can independently provide an estimate of algal biomass.

Chlorophyll a is a green pigment produced by all plants (including algae) during photosynthesis and generally accounts for 1-2% of total algal biomass. Concentrations of nutrients such as phosphorus and nitrogen greatly influence the growth and production of algal species. Measurements of water clarity are represented by SD depth and indicate the maximum depth that a 8-inch diameter disk can be observed from the water surface. High levels of turbidity would result in low SD readings and indicate high amounts of suspended material, such as algae.

For the purpose of classification, priority is given to chlorophyll because this variable is generally considered to be the most accurate of the three indicators at predicting algal biomass. According to Carlson (1977), TP may be better than Chl-a at predicting summer trophic state from winter samples, and transparency should only be used if there are no better methods available.

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

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

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

$$\text{TSI (SD)} = 60 - 14.41 \ln (\text{Sechi disk in meters}) \quad (3\text{-}3)$$

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

Information relating Carlson TSI values to trophic state characteristics is provided in Table 3.9. Lakes and reservoirs that exhibit an oligotrophic state are considered to have good water quality. While a mesotrophic state is considered good for some aquatic species, it can include seasonal conditions that are detrimental to salmonids and other cold water aquatic species. A trophic status of eutrophic or hypereutrophic is considered to represent poor water quality conditions. TSI values calculated for three monitoring sites on Recapture Reservoir are included in Table 3.10. Most TSI values at each site were associated with a mesotrophic state although some TSI values for Chl-a and SD were in the oligotrophic or eutrophic state, respectively. In general, TSI values for Chl-a and TP increased with distance above the dam and were typically observed in the upper range of the mesotrophic state. A few TSI values for TP and SD at upper reservoir sites were observed at levels considered to represent eutrophic conditions.

TSI values calculated for the site above Recapture Dam are displayed in Figure 3.10 and indicate that trophic status degrades slightly over the summer with the poorest conditions observed in September. TSI values for Chl-a, which are considered to best represent algal populations, were near the threshold between an oligotrophic and mesotrophic state. Annual average TSI values were generally mesotrophic and indicated that TSI values for Chl-a were not well correlated with TP. TSI values for SD were consistently higher than values for Chl-a and TP. High TSI values for SD likely reflect the lack of mixing observed in Recapture Reservoir.

Based on the TSI assessment, Recapture Reservoir is generally mesotrophic, although TSI values for SD and TP are in the eutrophic range during some time periods. TSI values for TP are generally higher than Chl-a and therefore do not appear to limit algal growth. However, this could be a response to typical differences in sampling depth including surface measurements of Chl-a while TP samples were collected at 2-4 depths in the water column.

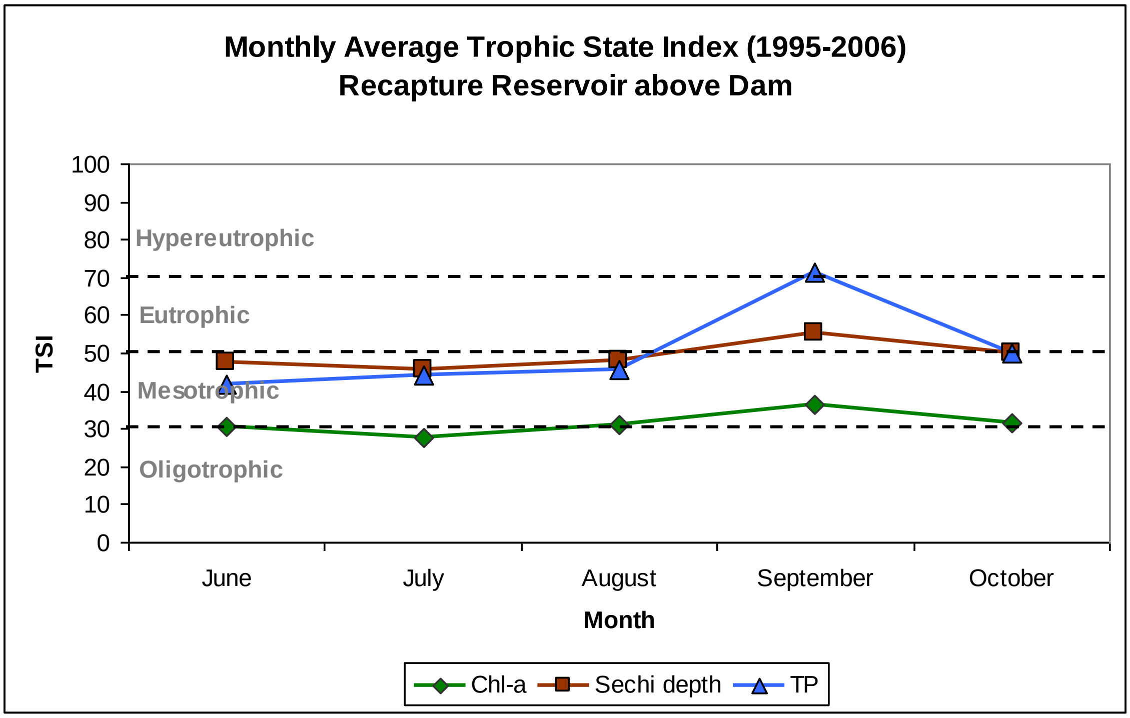
Table 3.9. Description of lake trophic status based on Carlson TSI values (Carlson and Simpson 1996).

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

[a] Oligotrophy, mesotrophy, and eutrophy are used in the context of the amount of algae in the entire water column and are not based on oxygen concentrations observed at depth.

Table 3.10. Trophic State Index (TSI) values for monitoring sites located on Recapture Reservoir. Values shown are based on averages of measured parameters collected in each year.

Station	Year	TSI Chl-a	TSI TP	TSI SD
Recapture Reservoir Above Dam	1989	36	49	56
	1991	38	49	54
	1993	35	46	55
	1995	34	34	45
	1997	35	-	48
	1999	34	45	48
	2001	15	49	46
	2003	19	43	47
	2005	31	48	52
	2006	32	57	49
Recapture Reservoir 1/4 way up	1989	38	48	55
	1991	38	43	54
	1993	38	46	58
	1995	31	40	44
	1997	37	-	49
	1999	35	42	49
	2001	15	52	47
	2003	15	41	47
	2005	34	55	49
	2006	30	37	50
Recapture Reservoir 1/2 way up	1989	42	41	62
	1991	45	47	66
	1993	31	47	58
	1995	32	34	46
	1997	31	-	48
	1999	33	42	50
	2001	15	42	50
	2003	15	37	48
	2005	31	46	52
	2006	35	37	50



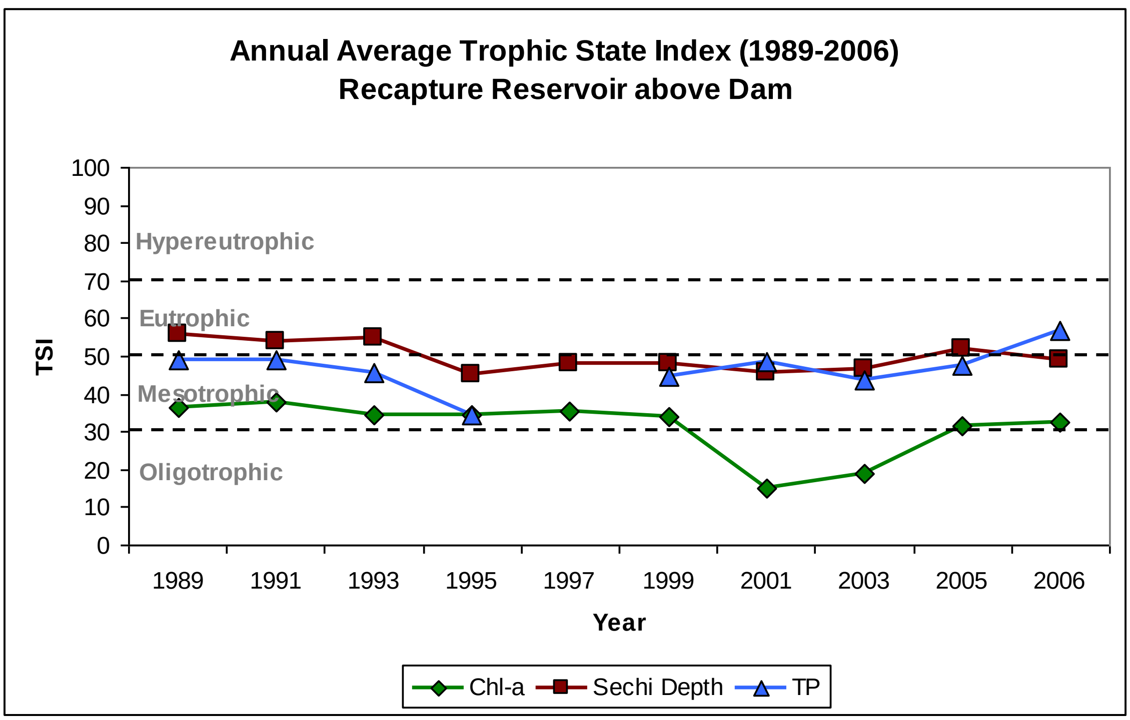


Figure 3.10. Trophic State Index values calculated for Recapture Reservoir including Chlorophyll a (Chl-a), Sechi Depth, and Total Phosphorus (TP).

3.4 SUMMARY

This water quality assessment reviewed data collected from both streams and reservoirs located in the project area. Concentrations measured at stream monitoring locations generally represented good water quality. Additional information defining loading from tributaries to Recapture Reservoir will be reviewed in Chapter 4.

Water column measurements collected at three reservoir monitoring sites were only available between June through October. A comparison of profiles at all sampling locations indicates similar patterns and indicates that a majority of the reservoir is stratified. Profile measurements from late June through early September show that DO concentrations in the reservoir generally fall to a non-supporting status (DO is above 4.0 mg/L in less than 50% of the water column). The reservoir fails to reach a fully-supporting status every year. The duration and timing of DO impairment appears related most closely to periods of low surface water inflows observed during the summer and fall months in the project area.

Complete mixing of the water column appears to occur following periods of high precipitation that produce heavy spring snowmelt or short-term runoff during summer and fall storm events. Restratification occurs within weeks during periods of low precipitation.

Mean reservoir TP concentrations based on available data (1998-2007) were 0.033 mg/L at Station 01, 0.032 mg/L at Station 02, and 0.023 mg/L at Station 03. Each of these mean values exceed the 0.025 mg/L pollution indicator value. Although some individual measurements of TP and DP exceed the pollution indicator value, these samples are typically collected from the bottom of the reservoir. Based on the phosphorus measurements reviewed in this assessment, it is likely that existing concentrations **do not** produce excessive growth of algae that subsequently decompose and consume DO to the low levels observed in reservoir profiles.

Temperatures during the warmest months of the summer result in portions of the reservoir where no part of the water column is below the 20 °C criterion recommended for a Class 3A cold water fishery. Measured profile temperatures have all been below the 27 °C criterion recommended for Class 3B warm water fisheries.

4.0 POLLUTANT SOURCE CHARACTERIZATION

Based on observations made during two field surveys conducted in the spring and fall of 2007, a review of GIS information, and discussions with various state and local agencies, the following pollutant categories have been identified in the Recapture Reservoir watershed.

1. Livestock Grazing
2. Diffuse Loads from Runoff

The human population in the watershed is relatively small and dispersed in nature. There are point sources of pollution within the watershed. There is very limited industry in the watershed, and agricultural activities are predominantly related to ranching with the majority of crops in the watershed being raised for animal forage. Because of this, the pollutant contributions from sources such as urban runoff, industrial activity, and agricultural chemicals (pesticides and fertilizers) are nonexistent or insignificant. The following sections describe each of the significant pollutant sources in more detail.

4.1 LIVESTOCK GRAZING

Cattle grazing can be a significant pollutant source in many western watersheds where historic grazing has taken place. This is especially true when cattle are concentrated in or near the riparian zone surrounding streams, water courses, and other water bodies. This is quite often the case in watersheds where perennial streams provide a water source on a year-round basis. Although this does happen to a limited degree in the project area, field observations indicate that many corridors of tributary streams to Recapture Reservoir do not support abundant riparian vegetation or the opportunities for shade, forage, and livestock watering. As a result, watering needs for livestock in the project area are met by dispersed developed water sources including troughs and pipeline systems fed by spring boxes or wells.

Review of grazing allotment information obtained from the U.S. Forest Service and BLM indicates the potential for livestock grazing throughout the watershed. Figure 4.1 shows the grazing allotment boundaries associated with public lands in the project area. Grazing allotments are found on nearly all public land within the TMDL study area. It is estimated that over 64 percent of the Recapture Reservoir watershed is within grazing allotments permitted by the Forest Service or the BLM. These allotments have varying numbers of permitted animals and seasons of use which have changed substantially from year to year as a result of drought conditions (High 2007). Some grazing allotments are rested entirely during some years, while most allotments have ranged between 100 percent and 50 percent of the permitted level. Table 4.1 indicates the level of authorized and actual use associated with livestock grazing on federal lands.

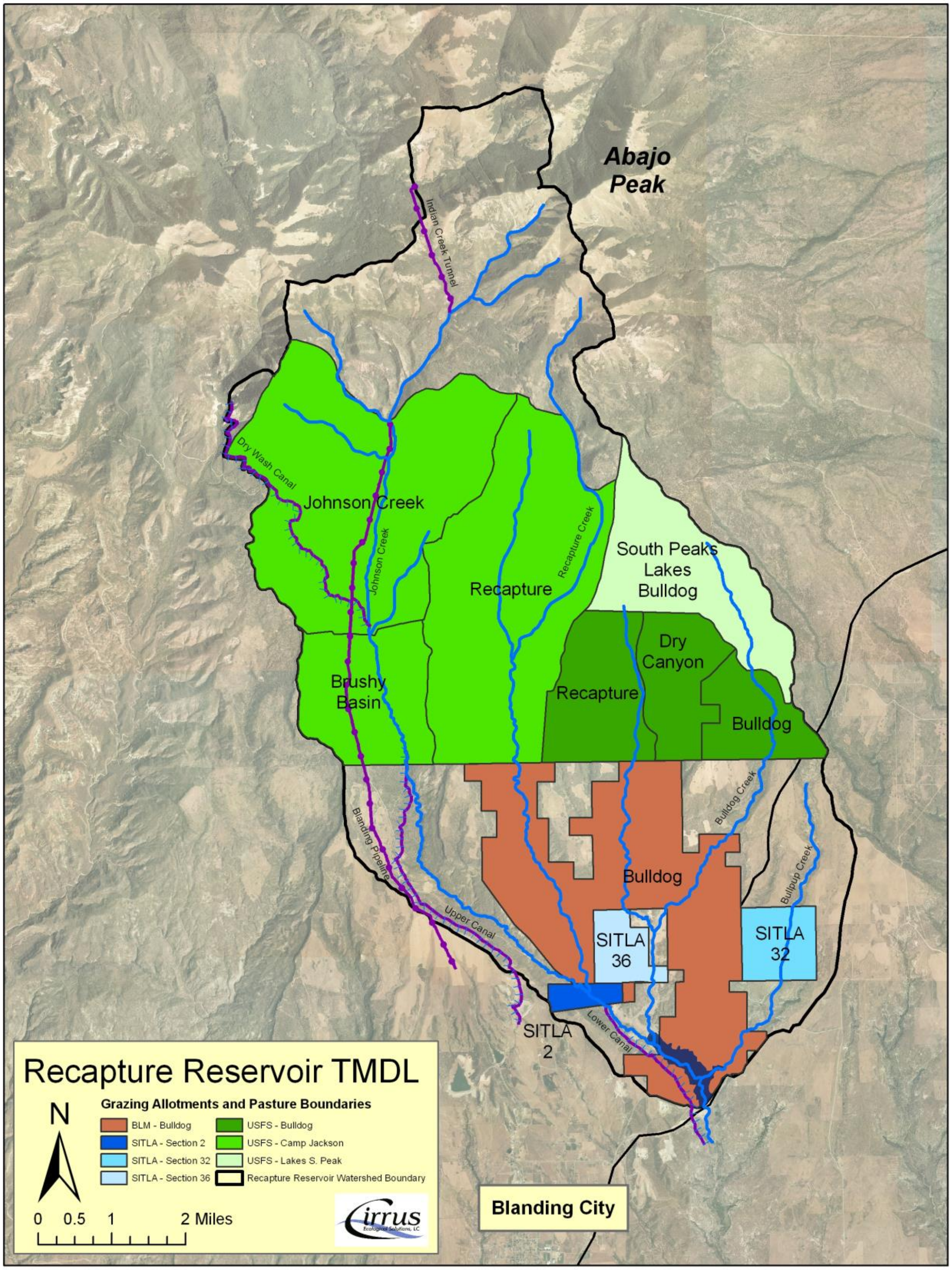


Figure 4.1. Livestock grazing allotments in the Recapture Reservoir TMDL project area.

Table 4.1. Livestock grazing information associated with public lands in the Recapture Reservoir TMDL project area.							
Agency	**Allotment**	**Pasture**	**Total Pasture Area (ac)**	**Authorized (AU)**	**Actual (AU)**	**AU/ac**	**Unit area load (kg/ac/day)**
BLM	Bulldog		5,621	62	62	0.011	0.0006
BLM				300	300	0.053	0.0029
SITLA	SITLA-2	SITLA-2	204	15	15	0.074	0.0040
SITLA	SITLA-32	SITLA-32	644	23	23	0.036	0.0019
SITLA	SITLA-36	SITLA-36	468	30	30	0.064	0.0035
USFS	Bulldog	Bulldog	1,016	26	26	0.026	0.0014
USFS	Bulldog	Dry Canyon	1,166	28	31	0.027	0.0014
USFS	Bulldog	Recapture	1,571	26	29	0.018	0.0010
USFS	Camp Jackson	Brushy Basin	1,942	215	237	0.122	0.0066
USFS	Camp Jackson	Johnson Creek	6,007	219	181	0.030	0.0016
USFS	Camp Jackson	Recapture	5,398	270	232	0.043	0.0023
USFS	Lakes-S Peak	Bulldog	2,376	87	87	0.037	0.0020
USFS	Lakes-S Peak	Lakes		220	197	0.083	0.0045
USFS	Lakes-S Peak	South Peak		84	95	0.040	0.0022
TOTAL			26,414	1,605	1,546		

Livestock grazing also occurs on state and privately-owned land. Grazing allotments on state land are managed by SITLA and are located primarily at lower elevations of the watershed. Authorized grazing levels were obtained from SITLA personnel. No records of actual use are currently maintained for these allotments.

Periodic livestock grazing also occurs on private land. However, no information on livestock numbers was obtained for these areas. Field surveys completed in April 2007 observed no livestock on private lands, and less than 10 animals were identified on private land areas during October 2007.

The timing of grazing activities within the watershed is also important. Grazing allotment information has indicated that grazing practices occur on high elevation public lands during the summer and fall seasons. In some areas of the state, livestock numbers in lower elevations of the watershed can increase during the late fall, winter, and spring months as animals are moved from public lands to privately owned pastures. Field surveys confirm that little or no animals were held on private lands during 2007. Therefore, it is anticipated that actual use numbers of livestock grazing on federal and state allotments represent annual loads associated with this source.

The following assumptions were made so that loads from livestock grazing could be calculated.

1. Grazing allotments are used at the average actual use reported from 1997-2006. Allotment data provided by federal agencies included some years where only the authorized or actual number was reported. During these years the same number was used to represent both categories and incorporated into the mean value.

2. Livestock are distributed equally over the area of each grazing allotment and can be accounted for in a density of animal units/acre and translated into a unit area load of TP/acre/day.

Table 4.1 lists all grazing allotments that intersect the project area. Additional descriptive information such as the number of permitted animals and the days of use in each allotment is also provided. Animal densities were calculated by dividing the total allotment area by the average actual use reported for each allotment by federal and state agencies. Grazing allotments were then clipped to the project area using a GIS. The total number of cattle were determined by multiplying animal density by the acreage of livestock grazing areas.

The process that delivers loading due to livestock grazing includes direct deposition in existing water bodies and surface runoff from areas where cattle have grazed. Given the dispersed nature of grazing activities, it is assumed that only animal waste deposited in the area within 100 meters (about 300 feet) of an existing water body contributes to loading.

In considering the two mechanisms by which loading occurs, it is also assumed that 100 percent of the TP associated with manure deposited within 10 meters (about 30 feet) of an existing water body contributes to loading (delivery ratio = 100 percent simulating direct deposition) and that approximately 10 percent of manure deposited between 10 and 100 meters from an existing water body contributes to loading (delivery ratio = 10 percent). Table 4.2 lists the contributing area associated with these two zones. These areas were calculated by buffering the streams and reservoirs using GIS.

According to the Agricultural Waste Management Handbook (NRCS 1992) the average weight of a grazing cow is approximately 1,000 pounds and the average TP production rate is approximately 0.12 pounds of TP/1,000 pound animal/day. Based on these numbers, the unit area loads were calculated for each allotment by multiplying the animal density (number of animals per square mile) by the TP production rate. The unit area loads were then adjusted based on information regarding actual use of each allotment. Table 4.2 indicates the total loads associated with each grazing allotment, as well as for the entire watershed and the portion of that load delivered to Recapture Reservoir. The load to the reservoir has been adjusted to account for diversions that remove flow and loading from the study area. Table 4.3 indicates the annual TP loads generated by livestock grazing in each major tributary watershed flowing to Recapture Reservoir and how this load is distributed among federal and state agencies.

As mentioned previously, no information is recorded on the exact distribution of livestock grazing. Field observations indicate the lack of riparian corridors that would typically serve to concentrate animals seeking forage, shade, and water. It is not certain at this time exactly how much of the TP load generated by livestock grazing is delivered to Recapture Reservoir by tributary streams. The assumptions used to calculate loads have been conservative and reflect some indication of the relative magnitude this source could contribute to project area streams and ultimately to Recapture Reservoir. Loads from livestock grazing do not account for processes that remove TP from flowing waters in streams such as adsorption, settling, and uptake by aquatic vegetation.

Table 4.2. Total phosphorus loads associated with livestock grazing in the Recapture Reservoir TMDL project area.

Agency	Allotment	Pasture	Area 0-10m (ac)	Area 10-100m (ac)	Days of use	Unit area load (kg/ac/day)	TP Load 0-10m (kg/yr)	TP Load 10-100m (kg/yr)	Total Load (kg/yr)
USFS	Camp Jackson	Brushy Basin	91	717	32	0.0066	19.2	15.2	34.4
USFS	Bulldog	Dry Canyon	59	541	26	0.0014	2.3	2.1	4.3
USFS	Camp Jackson	Johnson Creek	264	2196	28	0.0016	12.2	10.2	22.4
USFS	Lakes-S Peak	Bulldog	91	836	32	0.0020	5.8	5.3	11.2
USFS	Lakes-S Peak	South Peak	91	836	100	0.0022	19.7	18.1	37.8
USFS	Lakes-S Peak	Lakes	91	836	107	0.0045	43.6	40.2	83.7
SITLA	SITLA	SITLA-2	8	63	57	0.0040	1.9	1.4	3.3
SITLA	SITLA	SITLA-32	31	272	57	0.0019	3.4	3.0	6.4
SITLA	SITLA	SITLA-36	13	112	57	0.0035	2.7	2.2	4.9
USFS	Bulldog	Bulldog	54	476	26	0.0014	2.0	1.7	3.7
BLM	Bulldog-BLM	Bulldog	317	2462	122	0.0006	23.2	18.0	41.2
BLM	Bulldog-BLM	Bulldog	317	2462	23	0.0029	21.1	16.4	37.6
USFS	Camp Jackson	Recapture	281	2326	48	0.0023	31.8	26.3	58.1
USFS	Bulldog	Recapture	96	810	27	0.0010	2.6	2.2	4.8
					Total Load to Stream (kg/yr)		**191.5**	**162.4**	**353.9**
					Total Load to Reservoir (kg/yr)		**171.6**	**145.6**	**317.3**

Pollutant loads from diffuse runoff are discussed below and include a detailed discussion of the methodology used to calculate loads. Diffuse runoff loads account for the effect of surface runoff by landcover type and are assumed to incorporate loading from livestock grazing.

Table 4.3. Total phosphorus loads from grazing to Recapture Reservoir defined by watershed or by land owner.

Watershed	BLM	SITLA	USFS	Total (kg/yr)
Johnson Creek	5.8	0.8	24.8	**31.5**
Recapture Creek	16.1	1.8	61.9	**79.7**
Bulldog Creek	36.7	4.9	138.8	**180.5**
Bullpup Creek	5.2	6.4	0.4	**12.1**
Recapture Reservoir	12.9	0.6	-	**13.5**
Total	**76.8**	**14.5**	**225.9**	**317.3**

4.2 DIFFUSE RUNOFF

In the Recapture Reservoir watershed, the major source of pollutant loading to surface water is runoff of precipitation moving phosphorus from diffuse sources into streams and reservoirs. Examples of diffuse sources include the following:

- Phosphorus in compounds bound to naturally occurring soils and minerals running off from different landcover (vegetation) types.
- Nutrients and other constituents associated with erosion from upslope areas disturbed by grazing or forestry activities.
- Surface runoff from developed agricultural and urban areas that contains agricultural chemicals including fertilizers and pesticides.
- Nutrients and other constituents associated with erosion from other human disturbed areas (including trails, roads, and dispersed camping sites).

All of these sources are related to land use. Urban and intensive agricultural land uses make up a small percentage of the land uses in the watershed. Because the region experiences relatively low precipitation – 13.3 inches annually in nearby Blanding – the more intensive agricultural uses are thought to be a minor contributor to phosphorus runoff to surface water. The only agricultural use existing over substantial portions of the watershed is dispersed livestock grazing, on both private and public lands. Low precipitation results in generally low stream flows, which in turn concentrates animals around artificial water sources and away from natural streams. This gives vegetation and soils an opportunity to reabsorb any phosphorus in surface runoff.

Factors such as soil type, slope, and riparian conditions, also influence the amount of nutrient loading to surface waters but given that phosphorus does not seem to be a major pollutant in the watershed's streams or the reservoir itself, it was felt that an adequate TP runoff model could be developed based on just a few characteristics, including: patterns of hydrologic flow based on precipitation; spatial runoff patterns based on relationships between subwatersheds, diversions and interbasin transfers; and spatial patterns and types of land uses and their associated phosphorus loads.

Flow for the TP runoff model was taken from stream flow estimates that were developed in the water budget model (see Section 2.6.1). Near the top of the watershed (see Figure 2.1), an interbasin transfer brings water from Indian Creek north of the natural Recapture Reservoir watershed via a tunnel through the Abajo Mountains into Johnson Creek. Blanding City takes advantage of the increased flow in Johnson Creek and diverts some of that water via a pipeline. Further downstream a canal transfers water from the adjacent Dry Wash watershed west of the natural Recapture Reservoir watershed to Johnson Creek, after holding back the first 185 acre-feet for livestock in a small reservoir. Several miles below, a Utah DWQ water quality station monitors phosphorus and other parameters on Johnson Creek just above a point where most of the creek is diverted in the summer into the Upper Canal for transfer out of the basin into two reservoirs above Blanding City for irrigation. Johnson Creek then joins Recapture Creek, which has collected water from high altitude areas to the east. The combined streams then flow unimpeded into Recapture Reservoir. (Johnson Creek is no longer diverted into the Lower Canal.) Further to the east two other tributaries, Bulldog Creek and Bullpup Creek drain lower elevations into the reservoir directly. Lands immediately around the reservoir drain into the reservoir directly.

The water budget model calculated runoff by first determining the 12 watershed subdivisions within the Recapture Reservoir drainage based on the locations of stream gages, water quality monitoring stations, and diversion points. These were then further divided based on bands of annual precipitation to yield a total of 61 areas for analysis. The water budget model then calculated runoff as acre-feet per square mile using an exponential function that was fit initially to the upper Recapture Creek watershed, which has no diversions, and then adjusted slightly to minimize error when applied to the only other two subwatersheds within the watershed where some long-term stream gage data was available for calibration, Recapture Creek Below Johnson Creek and Recapture Reservoirs' discharge itself.

Different land uses generate different loads of phosphorus for transport by runoff. Export coefficients, in the form of kilograms/hectare/year, have been successfully applied to these different land uses in other TMDL studies. Table 4.4 lists the land use distributions in the Recapture Reservoir watershed in terms of acres and percent. Over 95 percent of the land use in the Recapture Reservoir watershed is forest and range land, with smaller areas of agriculture in the south and southeast portions of the watershed. The spatial distribution of these land uses is displayed visually in Figure 2.3. Based on results in basins with similar landcover and hydrology, a table of initial loading coefficients was developed, shown in Table 4.5.

Table 4.4. Land use distribution in the Recapture Reservoir watershed.

	Area		
Land Use Category	**Acres**	**Square Miles**	**Percent**
Agriculture	1,142	1.78	2.78
Urban	2	0.00	0.01
Forest Land	18,673	29.18	45.38
Pinyon-Juniper	16,713	26.11	40.62
Range Land	3,802	5.94	9.24
Barren	611	0.95	1.48
Water	201	0.31	0.49
Total	**41,143**	**64.29**	**100**

Table 4.5. Initial coefficients for phosphorus load runoff from land uses used in total phosphorus runoff model.	
Land Use Category	**Export Coefficients (kg/ha/yr)**
Agriculture	1.00
Urban	1.00
Forest Land	0.05
Pinyon-Juniper	0.25
Range Land	0.10
Barren	0.20
Water	0.00

In order to calculate diffuse runoff loads, a map of landcover, acquired from the Southwest ReGap project (USURS/GISL), was overlain on the 61 areas from the water budget model to create a table of almost 3,100 polygons. Twenty-six detailed landcover types were summarized into the seven land uses above. Each polygon therefore had properties of runoff (based on the area within a particular polygon and the exponential function of precipitation), phosphorus loads (based on the export coefficient for each land use), as well as ownership (BLM, USFS, Utah SITLA, and private) and subwatershed location for purposes of summary for the load calculations. The mass load of phosphorus was then calculated by finding the ratio of modeled precipitation runoff to total expected precipitation for each polygon and applying this ratio to the loads determined by multiplying the phosphorus export coefficient by the area of each polygon. These load values could then be summed in various combinations to yield loads for each landowner, land use, and subwatershed.

Calculating the load expected to enter Recapture Reservoir required processing these flows and loads from the top of the watershed to the reservoir itself, taking into consideration the contributions of flows and loads from each watershed subdivision, and the diversions of flows and loads out of the watershed via a pipeline or canal. This incremental approach was necessary because concentrations of phosphorus varied as precipitation and patterns of land use changed through the watershed.

An application of this model is shown in Table 4.6 for average annual TP loads to Recapture Reservoir that illustrates how each tributary or diversion contributes or removes different combinations of flow and phosphorus load. The model was calibrated by increasing the export coefficients by a factor of 3.0 to achieve a TP concentration similar to that measured at the UDWQ Water Quality Station 4953460 on Johnson Creek of approximately 0.025 mg/L (see Residual in Johnson Creek - at UDWQ monitoring station value of 0.029 mg/L in the table below). The model predicted a concentration of 0.046 mg/L which is very similar to the value at the monitoring site 1/4 way up the reservoir (0.030 mg/L at Station 5958020; see Section 3, Table 11). The 0.046 value of TP would be expected to drop significantly as phosphorus settles out, so it was considered a reasonable estimate for reservoir concentrations measured at the dam (0.024 mg/L at Station 5958010).

Table 4.6. Incremental contributions and diversions of flow and phosphorus loads from diffuse sources in the watersheds feeding Recapture Reservoir during an average precipitation year.				
Source of Flow and Load and Diversion	**Modeled Runoff (acre-feet)**	**Modeled Load (pounds)**	**Modeled Load (kg)**	**TP (mg/L)**
Interbasin Transfer from upper Indian Creek watershed	2,047	155.8	70.7	0.028
Upper Johnson Creek watershed above the Blanding Pipeline	4,019	284.9	129.2	0.026
Less diversion to the Blanding Pipeline	(976)	(71.7)	(32.5)	0.027
Residual in Johnson Creek	**5,091**	**369.0**	**167.4**	**0.027**
Dry Wash runoff	133	9.3	4.2	0.026
Dry Wash flow held back in small reservoir (first 185 acre-feet)	(133)	(9.3)	(4.2)	0.026
Residual in Johnson Creek	**5,091**	**369.0**	**167.4**	**0.027**
Johnson Creek watershed below the Blanding Pipeline diversion but above the UDWQ water quality monitoring station	907	97.8	44.4	0.040
Residual in Johnson Creek	**5,998**	**466.8**	**211.7**	**0.029**
Upper Canal diversion		-	-	
Provided by the watershed captured by canal	31	9.6	4.4	0.113
Diversion from Johnson Creek to supply balance of canal flow estimated at 9 cfs for 6 months	(3,227)	(251.1)	(113.9)	0.029
Residual in Johnson Creek - at UDWQ monitoring station	**2,771**	**215.7**	**97.8**	**0.029**
Add in other watersheds		-	-	
Lower Johnson Creek (low elevation runoff pattern)	35	15.7	7.1	0.164
Upper Recapture Creek above USGS gage	908	68.6	31.1	0.028
Upper Recapture Creek below USGS gage	412	51.0	23.1	0.045
Lower Recapture Creek (low elevation runoff pattern)	32	14.9	6.8	0.172
Upper Bulldog Creek	287	47.0	21.3	0.060
Lower Bulldog Creek (low elevation runoff pattern)	96	60.9	27.6	0.232
Bullpup Creek	30	19.9	9.0	0.245
Watershed flowing directly into Recapture Reservoir	6	2.9	1.3	0.169
Total Flow into Recapture Reservoir	**4,577**	**496.5**	**225.2**	**0.040**
Evaporative effects on phosphorus concentrations	(606)	-	-	0.000
Effective balance of flows and loads into Recapture Reservoir	**3,972**	**496.5**	**225.2**	**0.046**

These annual flows and loads can also be distributed monthly for different water years. The tables below apply the monthly pattern of the USGS stream gage in upper Recapture Creek Near Blanding to flows from the higher elevation subdivisions of the watershed. The monthly pattern of the USGS stream gage on lower Recapture Creek Below Johnson Creek was used to calculate flows from lower elevation subdivisions of the watershed. Table 4.7 shows monthly flows and loads for an average year, before evaporation effects at the reservoir, based on flows of 2001-2007 (when average annual precipitation was 12.95 inches at Blanding, compared with the long-term precipitation average of 13.3 inches).

Table 4.7. Modeled monthly runoff flows and total phosphorus loads to Recapture Reservoir for average annual precipitation year.

Month	Flow (acre-feet)	TP Load (pounds)	TP Load (kg)
Jan	4	0.4	0.2
Feb	55	6.0	2.7
Mar	471	51.1	23.2
Apr	1,528	165.8	75.2
May	1,704	184.9	83.9
Jun	666	72.3	32.8
Jul	66	7.2	3.3
Aug	10	1.1	0.5
Sep	7	0.8	0.4
Oct	18	1.9	0.9
Nov	44	4.7	2.1
Dec	3	0.3	0.1
Total	**4,576**	**496.5**	**225.2**

The model also allows estimates for flows and TP loads to the reservoir based on years of greater or lesser precipitation. Table 4.8 shows estimates of flows and loads for 2002 and 2005, respectively dry and wet years in Blanding. These were obtained by adjusting average annual runoff as a ratio of that year's precipitation to the average precipitation of 2001-2007, and then applying monthly patterns to the annual results as above.

Table 4.8. Modeled monthly runoff flows and total phosphorus loads to Recapture Reservoir for 2002 and 2005.

	2002 - Dry		2005 - Wet	
Month	**Flow (acre-feet)**	**TP Load (kg)**	**Flow (acre-feet)**	**TP Load (kg)**
Jan	1	0.1	5	0.2
Feb	23	1.3	76	3.7
Mar	199	11.1	647	31.4
Apr	647	35.9	2,102	101.9
May	722	40.1	2,344	113.7
Jun	282	15.7	916	44.4
Jul	28	1.6	91	4.4
Aug	4	0.2	14	0.7
Sep	3	0.2	10	0.5
Oct	7	0.4	24	1.2
Nov	18	1.0	60	2.9
Dec	1	0.1	3	0.2
Total	**1,937**	**107.6**	**6,293**	**305.2**

Tables 4.9 and 4.10 show modeled TP loads for the Recapture Reservoir watershed by landowner, land use, and subwatershed. The largest loads to the reservoir are contributed by USFS lands, as expected because these account for the largest areal extent of the watershed. For similar reasons, forest, pinyon-juniper, and range land uses account for the largest loads to the reservoir. Among the tributaries, Johnson Creek contributes the highest loads.

Table 4.9. Annual total phosphorus loads (kg/year) by land use and landowner to Recapture Reservoir for average annual precipitation year.

	Landowner					
Land Use	**BLM**	**USFS**	**SITLA**	**Private**	**Total**	**Percent of Total**
Agriculture	0.2	0.2	0.3	14.3	**15.0**	**7**
Urban	0.0	0.0	0.0	0.0	**0.0**	**0**
Forest Land	0.1	76.4	0.0	0.4	**76.9**	**34**
Range Land	0.2	34.9	0.0	1.8	**37.0**	**16**
Pinyon-Juniper	15.6	46.6	2.0	7.1	**71.4**	**32**
Barren	0.0	24.8	0.0	0.1	**24.9**	**11**
Water	0.0	0.0	0.0	0.0	**0.0**	**0**
Total	**16.2**	**182.9**	**2.3**	**23.8**	**225.2**	**100**
Percent of total	**7%**	**81%**	**1%**	**11%**	**100%**	

Table 4.10. Annual total phosphorus loads (kg/year) by subwatershed and landowner to Recapture Reservoir for average annual precipitation year.

	Landowner					
Subwatershed	**BLM**	**USFS**	**SITLA**	**Private**	**Total**	**Percent of Total**
Johnson Creek	4.3	98.6	0.1	2.0	**104.9**	**47**
Recapture Creek	3.9	56.3	0.2	0.6	**61.0**	**27**
Bulldog Creek	6.2	27.8	0.7	14.3	**48.9**	**22**
Bullpup Creek	0.8	0.2	1.2	6.8	**9.0**	**4**
Recapture Reservoir Direct	1.1	0.0	0.1	0.1	**1.3**	**1**
Total	**16.2**	**182.9**	**2.3**	**23.8**	**225.2**	**100**
Percent of Total	**7%**	**81%**	**1%**	**11%**	**100%**	

4.3 IN-STREAM POLLUTANT LOAD CALCULATION

Based on the data available for the Recapture Reservoir watershed, pollutant loads can be calculated at two monitoring locations where flow and water quality concentrations have been measured. Loads calculated in this manner are considered to be most accurate if measurements are collected at the same time (i.e. paired measurements) and represent the full range of flow conditions at a given monitoring location. Error can be introduced into the calculation of pollutant loads when measurements of flow and water quality are measured independent of each other.

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

A review of the data available at stream monitoring stations in the Recapture Reservoir watershed indicated that measurements were insufficient to calculate more than daily loads. Table 4.11 shows the few actual measurements of tributary TP loads in the Recapture Reservoir watershed. In each case, a flow (in cfs) was measured at the same time as a concentration of TP ("non-detect" values were assigned a concentration of 0.01 mg/L). The daily load is calculated from these two values. Of interest are the concentrations for Johnson Creek that help to validate the concentrations generated by the TP runoff model.

4.4 LOADING SOURCE SUMMARY

Pollutant loads were calculated for livestock grazing and diffuse runoff. Loads from livestock grazing indicate the relative contributions to Recapture Reservoir from tributary watersheds and, based on management responsibility for these watersheds, relative contributions by land management agencies. The loads resulting from this calculation were not calibrated with monitoring data and likely overestimate actual loads delivered to the reservoir (because they do not account for the processes of adsorption, settling, and other factors that are present and serve to remove phosphorus loads as they are transported through stream systems). To account for other sources including grazing, and to more accurately project loads delivered to the Reservoir, a diffuse runoff model was developed.

Pollutant loads from diffuse runoff were adjusted to meet a concentration measured at the stream monitoring station on Johnson Creek. Loads shown for Recapture Reservoir from diffuse runoff were adjusted for diversions on Johnson Creek that remove flow and pollutant loads from the study area. As indicated in Table 4.7, the annual average TP load to Recapture Reservoir is 225.2 kg/yr. This load is significantly less than the load indicated by the livestock-based calculation discussed above, for the reasons indicated. Therefore, the results of the diffuse runoff model provide the most accurate indicator of actual load, and the results of the livestock based calculation provide the most accurate breakdown of livestock's contribution by watershed and land ownership. Similarities between the two profiles indicate that livestock is an important contributor; differences indicate that other loading processes are also at work.

Using available data, daily loads were calculated at the two stream monitoring stations in the area including Johnson Creek and Bulldog Creek. Annual and monthly loads were not calculated for these sites due to the high seasonal variability in flow that occurs at these locations which was not reflected in the limited data available. TP concentrations measured at Johnson Creek helped to validate the TP runoff model.

Table 4.11. Measured daily total phosphorus loads from tributaries of Recapture Reservoir.			
Activity Start	**TP Concentration (mg/L)**	**Stream Flow (cfs)**	**Daily Load (kg)**
Bulldog Creek UDWQ Station 4953510			
12/14/1988	0.034	0.1	0.002
2/22/1989	0.030	0.4	0.122
12/6/1989	0.017	0.1	0.002
1/24/1990	0.030	0.1	0.006
2/12/1992	0.020	0.3	0.266
4/1/1992	0.048	6.2	0.728
5/14/1992	0.363	0.1	0.005
3/31/1993	0.024	32.8	2.407
6/9/1993	0.009	0.4	0.017
6/28/1995	0.125	0.3	0.022
6/23/1999	0.007	5	0.416
Johnson Creek Above Recapture Reservoir UDWQ Station 4953460			
4/1/1998	0.010	11	0.269
5/20/1998	0.010	28	0.685
6/3/1998	0.010	25	0.611
6/23/1998	0.010	13	0.318
3/26/2003	0.037	2.4	0.217
4/16/2003	0.042	7.9	0.812
5/7/2003	0.010	11.6	0.284
5/21/2003	0.024	3.5	0.205
6/4/2003	0.010	3	0.073
6/18/2003	0.010	1	0.024
6/7/2005	0.010	5	0.122
8/31/2005	0.010	5	0.122
11/30/2005	0.010	1	0.024
3/29/2006	0.010	3.5	0.086
5/10/2006	0.192	3	1.409
7/19/2006	0.010	0	0.000

5.0 TMDL ANALYSIS

Recapture Reservoir is included on the Utah 2006 303(d) list as impaired for low dissolved oxygen (DO). The level of impairment is defined by minimum DO requirements designed to protect cold water fish species. The purpose of this TMDL is to restore full support to the beneficial uses assigned to the reservoir. A standard approach to completing a TMDL is to recommend a water quality endpoint that will support designated beneficial uses followed by a target load for the pollutant of concern that will allow the endpoint to be met. The target load and necessary load reductions are allocated among the pollutant sources.

This TMDL assessment has gone through the process of defining existing water quality conditions as well as processes that might contribute to low DO in Recapture Reservoir. The results indicate that the typical approach of defining and implementing load reductions would likely not restore support to assigned beneficial uses of Recapture Reservoir. The reasons for this argument are outlined below, followed by recommendations to preserve water quality in the reservoir.

As discussed previously, DO is known to be consumed following oxidation of organic matter which can include algal material in eutrophic reservoirs. Measurements of Chl-a in Recapture Reservoir have been used in a TSI assessment that was presented in Chapter 3. The results of this assessment indicate that Chl-a concentrations are generally at levels representing oligotrophic to mestrophic conditions. Growth of algae is influenced by the presence of nutrients including phosphorus and nitrogen. TSI results indicate that TP concentrations are primarily mesotrophic but sometimes observed at levels representing eutrophic conditions. A threshold used to prevent excessive algae growth in reservoirs is a TP concentration of less than 0.025 mg/L. Average levels of TP since 1999 in Recapture Reservoir are around 0.030 mg/L, only marginally higher than the 0.025 pollution indicator level. The highest TP concentrations were consistently measured at greater depths with less light penetration, making it unlikely that TP levels are a major contributor to an algal problem, if it exists, and thus the cause of DO impairment.

The existing data indicate that the major factor in low DO levels is a low mixing rate from inflowing oxygenated water. The reservoir is located in a region of low annual rainfall (13.3 inches in nearby Blanding). Although part of the reservoir's watershed is found in the Abajo Mountains, with summits over 11,000 feet, much of the runoff from the mountain streams is diverted into pipelines or canals for culinary or irrigation use. Low tributary inflows therefore reduce the opportunity for high-oxygen runoff to mix into the reservoir layers.

The reservoir is capable of becoming well mixed with respect to DO after periods of abnormally high precipitation, however. The last time the reservoir is known to have been thoroughly mixed was in early summer of 2005, after more than 11 inches of precipitation fell after January 1 in Blanding. Most of this precipitation likely occurred in the form of snow and probably didn't contribute runoff until March or April (no stream gage information was available for Johnson Creek, the main tributary to the Reservoir). Within weeks of being fully mixed, however, the reservoir returned to a stratified pattern. Other periods of reduced stratification documented in the 4 years for which data is available also seem to follow months of above average precipitation.

Reservoir depth profiles measured in 2001, 2003, 2005, and 2006 show that the surface layers of the reservoir are typically higher in DO than deeper layers. In late summer the reservoir routinely exhibits a clear and sharply stratified boundary between layers of high and low concentrations of DO. Water temperatures in the reservoir also show a gradient during those periods of critically low DO, with surface temperatures in the upper 2 meters of the reservoir as high as 25°C and decreasing to less than 10°C in 10–15 meters of depth.

As indicated in Table 3.8, cold water fish need temperatures less than 20°C. In the shallower upper reaches of the reservoir there is no depth with temperatures less than 20°C, so cold water species are forced to migrate to areas of the reservoir near the dam where the water is deeper and colder. However, at depths with sufficiently low water temperatures, DO concentrations are only marginally above 4.0 mg/L. During some years profile measurements indicate no water depths at any of the three monitoring sites in the reservoir with temperatures less than 20°C and DO concentrations above 4.0 mg/L, which are needed to support a viable cold water fishery.

Beneficial use of Recapture Reservoir was initially defined following consultation with Utah DWR and a review of information that characterized the physical, chemical, and biological properties of the water body. Following this assessment it was determined that the reservoir would be capable of supporting cold water fish species. As indicated in Section 3.3.3, Biological Data, Utah DWR discontinued stocking the reservoir with cold water fish species in 2001 due to predation by invasive warm water species including Northern Pike. Utah DWR has indicated that they plan to continue to manage the reservoir as suitable habitat for warm water fish (Birdsey 2008).

Based on the analysis of existing data and knowledge of local reservoir conditions, it is unlikely that DO levels can be restored through lowering nutrient concentrations. However, it is important that nutrient concentrations do not increase beyond existing levels. Increased tributary inflow would improve mixing of stratified layers and provide a source of DO that is higher than concentrations observed at depth for the three reservoir monitoring stations. However, implementation of TMDLs in Utah does not rely upon flow modification. Mechanical reaeration of the reservoir would also serve to restore DO to the necessary levels but would be cost-prohibitive.

Monitoring data indicate that it is possible for the reservoir to support a beneficial use associated with Class 3B criteria. Late summer DO concentrations are typically greater than 4 mg/L for at least 5–7 meters of depth as shown by reservoir profiles, and maximum temperatures are all less than 27°C. Table 5.1 indicates the percent of samples that violate Class 3B criteria for DO, temperature, and pH as shown by measurements of reservoir profiles from 2001 through 2006.

Table 5.1. Water quality at Recapture Reservoir monitoring sites.											
			DO			pH			Temperature		
Date	**Depth (m)**	**Samples**	**Mean (mg/L)**	**Total column % <3.0 mg/l**	**Status[1]**	**Mean**	**6.5>%>9.0**	**Status[1]**	**Mean (°C)**	**% >27 C**	**Status[1]**
Reservoir Station 5958010 – Recapture Reservoir Above Dam 01											
6/13/2001	21.8	23	5.37	4.34	FS	7.72	0	FS	12.39	0	FS
8/14/2001	20.4	22	2.52	68.18	**NS**	7.67	0	FS	15.39	0	FS
6/4/2003	15.5	17	5.26	29.41	FS	7.78	0	FS	13.93	0	FS
8/14/2003	11.8	12	2.12	75	**NS**	7.52	0	FS	17.23	0	FS
6/7/2005	28.9	28	7.28	0	FS	7.88	0	FS	10.66	0	FS
7/13/2005	18.4	20	4.84	0	FS	8.24	0	FS	13.84	0	FS
8/31/2005	14.6	17	2.91	52.94	**NS**	7.42	0	FS	15.93	0	FS
10/5/2005	14.7	16	4.46	37.5	FS	7.63	0	FS	14.08	0	FS
6/22/2006	21.1	23	5.07	13.04	FS	7.9	0	FS	13.72	0	FS
7/19/2006	18.2	19	2.79	57.89	**NS**	7.58	0	FS	16.6	0	FS
8/24/2006	3.5	5	6.19	0	FS	8.14	0	FS	22.42	0	FS
9/22/2006	18	19	6.02	21.05	FS	8.23	0	FS	14.22	0	FS
Reservoir Station 5958020 – Recapture Reservoir ¼ Way Up Reservoir 02											
6/13/2001	3.3	5	7.97	0	FS	8.49	0	FS	18.94	0	FS
8/14/2001	14.1	15	3.58	53.33	**NS**	7.8	0	FS	18.06	0	FS
6/4/2003	14	15	5.56	26.67	FS	7.83	0	FS	14.44	0	FS
6/7/2005	13.3	14	7.18	0	FS	7.8	0	FS	12.72	0	FS
7/13/2005	20.6	22	4.02	0	FS	8.02	0	FS	13.5	0	FS
8/31/2005	9.5	11	4.1	36.36	FS	7.57	0	FS	18.67	0	FS
10/5/2005	17	18	4.02	38.89	FS	7.61	0	FS	13.49	0	FS
6/22/2006	14.7	17	5.62	15.79	FS	8.1	0	FS	16.27	0	FS

Table 5.1. (cont'd) Water quality at Recapture Reservoir monitoring sites.											
			DO			pH			Temperature		
Date	Depth (m)	Samples	Mean (mg/L)	Total column % <3.0 mg/l	Status[1]	Mean	6.5>%>9.0	Status[1]	Mean (°C)	% >27 C	Status[1]
7/19/2006	11.8	13	3.66	46.15	FS	7.71	0	FS	20	0	FS
8/24/2006	6.2	8	5.06	12.50	FS	8.01	0	FS	22.08	0	FS
Reservoir Station 5958030 – Recapture Reservoir ½ Way Up Reservoir 03											
6/13/2001	7	8	7.76	0	FS	8.35	0	FS	17.52	0	FS
8/14/2001	5.2	7	6.70	0	FS	8.41	0	FS	22.65	0	FS
6/4/2003	9.4	11	6.81	0	FS	8.02	0	FS	16.50	0	FS
6/7/2005	12.1	12	6.96	0	FS	7.89	0	FS	12.57	0	FS
7/13/2005	12.0	14	3.71	30.77	FS	7.90	0	FS	16.35	0	FS
8/31/2005	4.1	6	6.11	0	FS	7.84	0	FS	21.78	0	FS
10/5/2005	7.1	9	6.83	0	FS	7.92	0	FS	15.62	0	FS
6/22/2006	9.1	11	6.69	12.5	FS	8.33	0	FS	18.51	0	FS
7/19/2006	6.8	8	5.43	14.29	FS	8.00	0	FS	22.88	0	FS
8/24/2006	5.3	7	5.51	14.3	FS	8.06	0	FS	22.12	0	FS
1 FS= full support of beneficial use, NS= non-support of beneficial use.											

5.1 WATER QUALITY TARGETS

The water quality targets selected by this TMDL assessment include the following:

- Average TP concentration calculated from TP profile measurements at three reservoir monitoring stations not to exceed 0.025 mg/L.
- TP concentration not to exceed 0.05 mg/L at tributary inflow monitoring stations.
- Change beneficial use of reservoir from Class 3A, cold water aquatic life, to Class 3B, warm water aquatic life, including recommended criteria for DO (3 mg/L) and temperature (27°C).
- Site specific reservoir DO standard during July and August of 100 percent of DO measurements in the water column epilimnion greater than 3 mg/L.

5.2 PERMISSIBLE LOADINGS

Permissible loadings are typically used to represent a mass that will produce a desired water quality concentration. Recommendations can then be made to reduce existing loads to meet the permissible load. The monitoring data presented in Chapter 3 indicate low concentrations of TP that are close to the threshold of 0.025 mg/L used to limit algae growth and subsequent decomposition and consumption of DO. Based on the measured concentrations of TP, the low DO conditions observed in Recapture Reservoir are not a response to excessive algae growth and decomposition. Low DO conditions are more likely due to a lack of tributary inflow and mixing observed in reservoir profiles. Therefore no recommendations are provided for decreasing the existing TP loading. However, it is recognized that TP loads and concentrations should not be permitted to increase above existing levels.

5.3 SEASONALITY

The Clean Water Act requires that TMDLs include seasonality. Seasonality is addressed in this TMDL by modeled loads to Recapture Reservoir on an annual and monthly basis. The distribution of modeled loads was based on available data records that incorporate periods of wet and dry years as well as months during which there is little or no tributary inflow to the reservoir. Although reservoir water quality data is primarily limited to 1989–2006, monthly loads to the reservoir are based on the distribution of monthly average flows shown by gage records that span longer time periods including lower Johnson Creek (1975–1993) and upper Recapture Creek (1965–2006). Annual variation in loading was based on annual precipitation records and the long-term annual average for Blanding. The long-term average precipitation value is based on the entire period of record that spans 1957-2006.

5.4 MARGIN OF SAFETY

The Clean Water Act also requires that TMDLs include a Margin of Safety (MOS). Generally, the MOS is incorporated into the TMDL through the use of conservative assumptions or is specified explicitly by reserving a particular amount of the permissible loading. This TMDL uses conservative assumptions to address the MOS.

Conservative assumptions have been made in some of the loading calculations and are discussed, where applicable, in the text of this report. It should be noted that some degree of uncertainty is associated with using the State of Utah's TP pollution indicator values of 0.05 mg/L for streams and 0.025 mg/L for the reservoirs as the endpoints for this TMDL analysis. It is believed these values are conservative, and future monitoring of the reservoir may show that TP endpoint values could be higher than pollution indicator values. The loads specified in this report will be evaluated in the future as additional water quality data is acquired. Follow-up monitoring will be executed to ensure that the reservoirs appropriate beneficial uses as a warm water fishery are being supported.

5.5 TMDL TARGET LOAD

The TMDL target load is defined by the existing TP load to Recapture Reservoir of 225 kg/yr based on an annual average precipitation year. The method used to calculate loading to the reservoir is described in detail in Section 4.2 and was calibrated using available monitoring data from Johnson Creek. This load incorporates contributions from all pollutant sources including livestock grazing. As additional monitoring data becomes available through future monitoring efforts, this target load may be adjusted. However, without additional information, the TP water quality endpoints of 0.025 mg/L and 0.05 mg/L should remain in place. Any change to the target load must continue to meet these endpoints unless they are changed.

5.6 FUTURE GROWTH

It is estimated at this time that minimal change will occur in the tributary watersheds to Recapture Reservoir in the future. Information obtained from population census as well as anecdotal information from local agencies and stakeholders indicates that rural populations and land use practices in the TMDL study area will remain fairly constant. However, recreational use of the public lands managed by the Manti-LaSal National Forest will likely continue to increase. Recreational use of the reservoir will likely mirror long-term statewide trends in use of resources of this type and show slight increases over time. It is not anticipated that these changes will result in significant load increases to the reservoir.

5.7 ALLOCATION OF POLLUTANT LOADS

It is recommended that pollutant loads remain allocated by land ownership, as the vast majority of land contributing flow to Recapture Reservoir is managed by federal and state agencies. Agricultural land practices that occur on private land are also significant due to their proximity to tributary streams as well as the reservoir. Table 5.2 summarizes TP loading. The distribution of loads by land ownership is presented in Table 5.3.

The TMDL allocation of pollutant loads is defined by modeled loads reflecting current conditions. TP concentrations observed in reservoir profiles are low and very close to the desired level of 0.025 mg/L used to control algal growth. Therefore, this TMDL will not include a reduction in existing loads but will require that loads not increase beyond the current levels defined in this assessment. BMPs that can be used to maintain existing loads are presented in

Appendix C. It is recommended that these practices be implemented and maintained in order to ensure that the TP water quality endpoint is met.

Table 5.2. Total phosphorus loading summary for Recapture Reservoir.

Loading Category	Annual load (kg/yr)
Existing Loads	225
Permissible Loads	225
Reserve for Future Growth	0
Load Allocation	225
Necessary Reduction	0
Total	**225**

Table 5.3. Allocation of permissible total phosphorus loadings to Recapture Reservoir by land ownership.

Agency	Annual load (kg/yr)	Percent of total
BLM	16	7
USFS	183	81
SITLA	2	1
Private	24	11
Total	**225**	**100**

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APPENDIX A - DATA

LIST OF TABLES

LIST OF FIGURES

TABLE A1. MEASUREMENT FREQUENCY OF WATER QUALITY STATIONS IN THE RECAPTURE RESERVOIR WATERSHED. Shaded cells indicate years during which monitoring occurred and numbers within shaded cells indicate the number of visits to each site that occurred during a given year.

	Type	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
100501052251	River/Stream													4																									
100501052451	River/Stream													5																									
100501251351	River/Stream													3																									
1900101	River/Stream										1		1		2	1			1				1																
1900102	River/Stream														1	1					1																		
373954109270001	Well															1																							
374726109303001	Well										1																												
4953440	River/Stream										1	2		1					6	7	4	4									1			1					
4953460	River/Stream																														3	5				3	8		4
4953500	River/Stream											1											1											1					
4953510	River/Stream																					1	10	7	6	7	3		2		3		2		1				
5958010	Lake																						2		2		2		2		1		2		2		2		4
5958020	Lake																						2		2		2		2		1		2		2		1		4
5958030	Lake																						2		2		2		2		2		2		2		1		4
9185800	River/Stream				1	6	4	6	6	9	9	8	9	6																									
9378630	River/Stream				3	9	6	4	5	2	3	12	10	6	7	7	9	5	3	8		5	9	9	6														
9378650	River/Stream										3	11	3	9	7	9	13	6	3	8		5	10	9	7			1											
9378700	River/Stream	12	15	10	9	9	8	7	9	7	6	9	3	8	7	8	11	4	3	8																			

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TABLE A2. SUMMARY STATISTICS FOR STATION 4953440 - RECAPTURE CREEK AT U262 CROSSING.

Parameter	n	BDL[1]	Date	Mean	Median	SD	Geo. Mean	Min	Max	Exceedance[2] (%)
Ammonia (mgN/L)	5	4	1980 - 1997	-	-	-	-	-	-	
BOD (mg/L)	2	0	1977 - 1980	2.5	2.5	2.1	2	1	4	0
DO (mg/L)	5	0	1980 - 1997	7.8	7.7	1.4	7.7	6.6	10.2	0
	1	0	2000-2000	7.7[3]	-	-	-	-	-	
Fecal Coliform (#/100 mL)	3	0	1977 - 1980	4,547	4,300	4,635	1,170	40	9,300	66.7
pH	11	0	1977 - 1997	8.3	8	0.6	8.2	7.7	9.5	18.2
	2	0	2000 - 2000	8.4	8.4	0.1	8.4	8.4	8.5	0
Total Coliform (#/100 mL)	3	0	1977 - 1980	6,550	4,500	7,634	2,163	150	15,000	33.3
TDS (mg/L)	7	0	1977 - 1997	1,659	1,160	2,408	746.2	126	6,966	50
TP (mg/L)	4	0	1980 - 1988	0.12	0.06	0.17	0.04	0.01	0.37	50
TSS (mg/L)	7	2	1977 - 1997	3,122	2376	3679	1,247	<BDL>	9999	75
Water Temperature (^{o}C)	8	0	1977 - 1997	14.7	14.4	7.8	12.7	5.5	24.5	0
Flow (cfs)	25	18	1977 - 1997	2.4	0.2	8.0	0.16	<BDL>	40	-
Specific Conductivity (umhos/cm@25^{o}C)	12	0	1977 - 1997	1,033	1,011	718.7	746.1	180	1,870	-
	2	0	2000 - 2000	419	419	31.1	418.4	397	441	-

[1] Number of samples below detection limit (BDL).
[2] Percent exceedance values calculated using the following numeric criteria and narrative standards associated with Class 2B and 3A streams:
Ammonia: pH dependent criteria calculated for individual data points as per Utah Code R317-2; **Biochemical Oxygen Demand (BOD):** <5 mg/L; **Dissolved Oxygen (DO):** (3a) >4.0; **Fecal Coliform:** <200 colonies/100 mL; **pH:** >6.5 and <9.0; **Total Coliform:** <5,000 colonies/100 mL; **Total Dissolved Solids (TDS):** <1,200 mg/L; **Total Phosphorus (TP):** <0.05 mg/L; **Total Suspended Solids (TSS):** <35 mg/L; **Water Temperature:** (3a) <20.
[3] Value of the single sample.

TABLE A3. SUMMARY STATISTICS FOR STATION 4953460 - JOHNSON CREEK ABOVE RECAPTURE RESERVOIR ABOVE DIVERSION.

Parameter	n	BDL[1]	Date	Mean	Median	SD	Geo. Mean	Min	Max	Exceedance[2] (%)
Ammonia (mgN/l)	3	3	1997 - 1997	-	-	-	-	-	-	
	17	14	1998 - 2006	0.04	0.04	0.01	0.04	<BDL>	0.06	
DO (mg/L)	3	0	1997 - 1997	8.9	9.2	1.6	8.8	7.16	10.3	0
	17	0	1998 - 2006	8.7	8.9	2.2	8.4	5	12.6	0
DP (mg/L)	1	0	2006 - 2006	0.03[3]	-	-	-	-	-	
pH	6	0	1997 - 1997	8.2	8.2	0.2	8.2	8.04	8.6	0
	28	0	1998 - 2006	8.3	8.3	0.5	8.2	7.14	9.6	7.1
TDS (mg/L)	3	0	1997 - 1997	255.3	262	24.7	254.5	228	276	0
	15	0	1998 - 2005	155.6	144	41.3	151.1	110	242	0
TP (mg/L)	1	0	1997 - 1997	0.018[3]	-	-	-	-	-	
	21	14	1998 - 2006	0.022	0.009	0.041	0.009	<BDL>	0.19	4.8
TSS (mg/L)	3	0	1997 - 1997	9.5	6	7.8	7.6	4	18.4	0
	15	4	1998 - 2005	16.4	8.4	23.2	8.7	<BDL>	92.7	6.7
Water Temperature (^oC)	3	0	1997 - 1997	9.5	10	8.4	5.3	0.86	17.7	0
	15	1	1998 - 2006	9.9	6.79	8.6	4.6	<BDL>	23.5	20
Flow (cfs)	3	0	1997 - 1997	1.1	1	0.9	0.8	0.3	2	
	18	5	1998 - 2005	6.7	3.3	8.3	2.9	<BDL>	28	
Salinity (mg/l@ 25^oC)	12	1	2003 - 2006	0.14	0.14	0.04	0.13	<BDL>	0.2	
Specific Conductivity (umhos/cm@25^oC)	6	0	1997 - 1997	426.3	427	35.9	425.1	369	479	
	26	0	1998 - 2006	238.1	226	79.6	225.3	95	391	

[1] Number of samples below detection limit (BDL).
[2] Percent exceedance values calculated using the following numeric criteria and narrative standards associated with Class 2B and 3A streams:
Ammonia: pH dependent criteria calculated for individual data points as per Utah Code R317-2; **Dissolved Oxygen (DO):** (3a) >4.0; **Dissolved Phosphorus (DP):** <0.05 mg/L; **pH:** >6.5 and <9.0; **Total Dissolved Solids (TDS):** <1,200 mg/L; **Total Phosphorus (TP):** <0.05 mg/L; **Total Suspended Solids (TSS):** <35 mg/L; **Water Temperature:** (3a) <20 ^oC.
[3] Value of the single sample.

TABLE A4. SUMMARY STATISTICS FOR STATION 4953500 - RECAPTURE CREEK WASH AT U163(191) CROSSING BELOW RESERVOIR.

Parameter	n	BDL[1]	Date	Mean	Median	SD	Geo. Mean	Min	Max	Exceedance[2] (%)
Fecal Coliform (#/100 mL)	1	0	1978 - 1978	2,400[3]	-	-	-	-	-	100
pH	1	0	1978 - 1978	8.3[3]	-	-	-	-	-	0
Total Coliform (#/100 mL)	1	0	1978 - 1978	90[3]	-	-	-	-	-	0
TDS (mg/L)	1	0	1978 - 1978	210[3]	-	-	-	-	-	0
TSS (mg/L)	1	0	1978 - 1978	2,000[3]	-	-	-	-	-	100
Water Temperature (^{o}C)	1	0	1978 - 1978	6.5[3]	-	-	-	-	-	0
Specific Conductivity (umhos/cm@25^{o}C)	1	0	1978 - 1978	250[3]	-	-	-	-	-	-

[1] Number of samples below detection limit (BDL).
[2] Percent exceedance values calculated using the following numeric criteria and narrative standards associated with Class 2B and 3A streams:
Fecal Coliform: <200 colonies/100 mL; **pH:** >6.5 and <9.0; **Total Coliform:** <5,000 colonies/100 mL; **Total Dissolved Solids (TDS):** <1,200 mg/L; **Total Suspended Solids (TSS):** <35 mg/L; **Water Temperature:** (3a) <20 ^{o}C.
[3] Value of the single sample.

TABLE A5. SUMMARY STATISTICS FOR STATION 4953510 - BULLDOG CANYON CREEK ABOVE RECAPTURE RESERVOIR.										
Parameter	**n**	**BDL[1]**	**Date**	**Mean**	**Median**	**SD**	**Geo. Mean**	**Min**	**Max**	**Exceedance[2] (%)**
Ammonia (mgN/l)	16	16	1988 - 1997	-	-	-	-	-	-	
	2	2	1999 - 2001	-	-	-	-	-	-	
DO (mg/L)	16	0	1988 - 1997	9.4	9.3	2.4	9.1	5.6	14.9	0
	3	0	1999 - 2001	4.4	4.9	1.7	4.1	2.4	5.8	33.3
Fecal Coliform (#/100 mL)	1	1	1990 - 1990							
pH	26	0	1988 - 1997	8.0	8.1	0.29	8.0	7.4	8.5	0
	3	0	1999 - 2001	7.9	7.9	0.46	7.9	7.4	8.3	0
Total Coliform (#/100 mL)	1	0	1990 - 1990	240,000[3]	-	-	-	-	-	100
TDS (mg/L)	15	0	1988 - 1997	411.2	472	157.1	364.2	82	562	0
	3	0	1999 - 2001	513.3	360	434.8	399.2	176	1004	0
TP (mg/L)	24	1	1988 - 1995	0.05	0.03	0.07	0.030	<BDL>	0.36	20.8
	5	1	1999 - 2001	0.03	0.03	0.013	0.027	<BDL>	0.05	0
TSS (mg/L)	15	2	1988 - 1997	203.3	29	453.2	30.4	<BDL>	1700	40
	3	1	1999 - 2001	19.2	16.8	11.8	16.8	<BDL>	32	0
Water Temperature (°C)	15	1	1988 - 1997	10.5	9.8	8.4	6.2	<BDL>	23.5	20
	3	0	1999 - 2001	23.2	24.6	4.9	22.9	17.8	27.3	66.6
Fecal Strep (#/100 mL)	1	0	1990 - 1990	500[3]	-	-	-	-	-	
Flow (cfs)	36	25	1988 - 1997	1.1	0.0	5.5	0.01	<BDL>	32.8	
	2	0	1999 - 1999	2.6	2.6	3.5	0.7	0.1	5	
Salinity (mg/l@ 25°C)	1	0	2001 - 2001	0.1[3]	-	-	-	-	-	
Specific Conductivity (umhos/cm@25°C)	26	0	1988 - 1997	764.7	770	445.2	664.5	125	2690	
	3	0	1999 - 2001	721.7	538	560.5	585.4	276	1351	

[1] Number of samples below detection limit (BDL).
[2] Percent exceedance values calculated using the following numeric criteria and narrative standards associated with Class 2B and 3A streams:
Ammonia: pH dependent criteria calculated for individual data points as per Utah Code R317-2; **Dissolved Oxygen (DO):** (3a) >4.0; **Fecal Coliform:** <200 colonies/100 mL; **pH:** >6.5 and <9.0; **Total Coliform:** <5,000 colonies/100 mL; **Total Dissolved Solids (TDS):** <1,200 mg/L; **Total Phosphorus (TP):** <0.05 mg/L; **Total Suspended Solids (TSS):** <35 mg/L; **Water Temperature:** (3a) <20 °C.
[3] Value of the single sample.

TABLE A6. SUMMARY STATISTICS FOR STATION 1900101 - BLANDING-JOHNSON CREEK 1.										
Parameter	**n**	**BDL[1]**	**Range of Dates**	**Mean**	**Median**	**SD**	**Geo. Mean**	**Min**	**Max**	**Exceedance[2] (%)**
Ammonia (mgN/l)	3	0	1981 - 1989	0.10	0.10	0.00	0.10	0.1	0.1	0
pH, lab	5	0	1977 - 1989	7.82	7.80	0.19	7.82	7.6	8.1	0

[1] Number of samples below detection limit (BDL).
[2] Percent exceedance values calculated using the following numeric criteria and narrative standards associated with Class 2B and 3A streams: **Ammonia:** pH dependent criteria calculated for individual data points as per Utah Code R317-2; **pH:** >6.5 and <9.0.

TABLE A7. SUMMARY STATISTICS FOR STATION 1900102 - BLANDING-INDIAN CREEK.										
Parameter	**n**	**BDL[1]**	**Range of Dates**	**Mean**	**Median**	**SD**	**Geo. Mean**	**Min**	**Max**	**Exceedance[2] (%)**
Ammonia (mgN/l)	1	0	1987 - 1987	0.2[3]	-	-	-	-	-	
pH, lab	1	0	1987 - 1987	8.2[3]	-	-	-	-	-	
Specific Conductivity (umhos/cm@25^{o}C)	1	0	1987 - 1987	230[3]	-	-	-	-	-	

[1] Number of samples below detection limit (BDL).
[2] Percent exceedance values calculated using the following numeric criteria and narrative standards associated with Class 2B and 3A streams: **Ammonia:** pH dependent criteria calculated for individual data points as per Utah Code R317-2; **pH:** >6.5 and <9.0.
[3] Value of the single sample.

TABLE A8. SUMMARY STATISTICS FOR STATION 100501052251 - UPPER INDIAN CREEK.										
Parameter	**n**	**BDL[1]**	**Range of Dates**	**Mean**	**Median**	**SD**	**Geo. Mean**	**Min**	**Max**	**Exceedance[2] (%)**
DO (mg/L)	4	0	1980 - 1980	8.75	9.5	1.89	8.57	6	10	0
pH	4	0	1980 - 1980	7.88	7.4	1.1	7.82	7.2	9.5	25
TSS (mg/L)	4	0	1980 - 1980	1	1	0	1	1	1	0
Water Temperature (^{o}C)	4	0	1980 - 1980	4.72	4.44	2.29	4.29	2.22	7.77	0

[1] Number of samples below detection limit (BDL).
[2] Percent exceedance values calculated using the following numeric criteria and narrative standards associated with Class 2B and 3A streams:
Dissolved Oxygen (DO): [standard used is dependent upon the respective site specific criteria] (3a) >4.0; **pH:** >6.5 and <9.0; **Total Suspended Solids (TSS):** <35 mg/L**; Water Temperature:** (3a) <20 ^{o}C.

TABLE A9. SUMMARY STATISTICS FOR STATION 100501052451 - LOWER INDIAN CREEK.										
Parameter	**n**	**BDL[1]**	**Range of Dates**	**Mean**	**Median**	**SD**	**Geo. Mean**	**Min**	**Max**	**Exceedance[2] (%)**
DO (mg/L)	6	0	1980 - 1980	9.00	9.00	1.10	8.94	7	10	0
pH	4	0	1980 - 1980	8.03	7.60	0.99	7.98	7.4	9.5	25
TSS (mg/L)	5	0	1980 - 1980	23.30	14.00	23.94	12.33	3	56.5	40
Water Temperature (^{o}C)	6	0	1980 - 1980	12.13	10.83	6.30	10.84	6.11	22.22	6.3

[1] Number of samples below detection limit (BDL).
[2] Percent exceedance values calculated using the following numeric criteria and narrative standards associated with Class 2B and 3A streams:
Dissolved Oxygen (DO): [standard used is dependent upon the respective site specific criteria] (3a) >4.0; **pH:** >6.5 and <9.0; **Total Suspended Solids (TSS):** <35 mg/L;**Water Temperature:** (3a) <20 ^{o}C.

TABLE A10. SUMMARY STATISTICS FOR STATION 100501251351 - JOHNSON CREEK AT BLANDING PIPELINE INLET.										
Parameter	**n**	**BDL[1]**	**Range of Dates**	**Mean**	**Median**	**SD**	**Geo. Mean**	**Min**	**Max**	**Exceedance[2] (%)**
DO (mg/L)	3	0	1980 - 1980	8.67	9.00	0.58	8.65	8	9	0
pH	2	0	1980 - 1980	9.50	9.50	0.00	9.50	9.5	9.5	100
TSS (mg/L)	3	0	1980 - 1980	5.33	3.00	4.93	4.04	2	11	0
Water Temperature (^{o}C)	3	0	1980 - 1980	10.18	11.11	4.24	9.49	5.55	13.88	0

[1] Number of samples below detection limit (BDL).
[2] Percent exceedance values calculated using the following numeric criteria and narrative standards associated with Class 2B and 3A streams:
Dissolved Oxygen (DO): [standard used is dependent upon the respective site specific criteria] (3a) >4.0; **pH:** >6.5 and <9.0; **Total Suspended Solids (TSS):** <35 mg/L; **Water Temperature:** (3a) <20 ^{o}C.

TABLE A11. SUMMARY STATISTICS FOR STATION 5958010 - RECAPTURE RESERVOIR ABOVE DAM 01.

Parameter	n	BDL[1]	Date	Mean	Median	SD	Geo. Mean	Min	Max	Exceedance[2] (%)
Ammonia (mgN/l)	36	28	1989 - 1997	0.042	0.016	0.07	0.016	<BDL>	0.33	0
	39	24	1999 - 2006	0.054	0.043	0.04	0.043	<BDL>	0.23	0
DP (mg/L)	24	13	1991 - 1995	0.012	0.005	0.010	0.009	<BDL>	0.041	12.5
	54	42	1999 - 2006	0.028	0.020	0.030	0.022	<BDL>	0.198	14.8
DO (mg/L)	36	0	1989 - 1997	4.8	5.8	2.7	3.4	0.1	8.4	44.4
	189	1	1999 - 2006	4.6	5.1	2.8	2.8	<BDL>	8.9	37.0
Fecal Coliform (#/100 mL)	2	2	1991 - 1991	-	-	-	-	-	-	0
pH	46	0	1989 - 1997	8.0	8	0.52	8.0	7.1	9.3	4.3
	175	0	1999 - 2006	7.8	7.8	0.48	7.8	7.0	8.7	0
Total Coliform (#/100 mL)	2	1	1991 - 1991	-	-	-	-	-	-	50
TDS (mg/L)	12	0	1989 - 1997	211.8	225	53.5	205.2	124	282	0
	10	0	1999 - 2005	169.6	162	52.7	162.3	86	280	0
TP (mg/L)	32	0	1989 - 1995	0.020	0.018	0.012	0.017	0.005	0.048	37.5
	54	32	1999 - 2006	0.033	0.020	0.035	0.025	<BDL>	0.231	25.9
TSS (mg/L)	11	7	1989 - 1997	3.5	2.5	3.0	2.5	<BDL>	10	0
	10	9	1999 - 2005	-	-	-	-	-	-	0
Water Temperature (°C)	36	0	1989 - 1997	14.3	13.8	5.4	13.3	7.3	23.2	22.2
	181	0	1999 - 2005	14.1	11.8	5.2	13.2	8.2	24.8	22.1
Fecal Strep (#/100 mL)	1	1	1991 - 1991	-	-	-	-	-	-	
Salinity (mg/l@ 25°C)	19	0	2001 - 2006	0.12	0.11	0.05	0.11	0.01	0.2	
Specific Conductivity (umhos/cm@25°C)	36	0	1989 - 1997	322.3	325.5	82.9	311.4	190	452	
	139	0	1999 - 2005	269.6	276	67.9	260.8	173	374	

[1] Number of samples below detection limit (BDL).
[2] Percent exceedance values calculated using the following numeric criteria and narrative standards associated with Class 2B and 3A streams:
Ammonia: pH dependent criteria calculated for individual data points as per Utah Code R317-2; **Dissolved Phosphorus (DP):** <0.025 mg/L; **Dissolved Oxygen (DO):** (3a) >4.0; **Fecal Coliform:** <200 colonies/100 mL; **pH:** >6.5 and <9.0; **Total Coliform:** <5,000 colonies/100 mL; **Total Dissolved Solids (TDS):** <1,200 mg/L; **Total Phosphorus (TP):** <0.025 mg/L; **Total Suspended Solids (TSS):** <35 mg/L; **Water Temperature:** (3a) <20 °C.

TABLE A12. SUMMARY STATISTICS FOR STATION 5958020 - RECAPTURE RESERVOIR 1/4 WAY UP RESERVOIR 02.

Parameter	n	BDL[1]	Date	Mean	Median	SD	Geo. Mean	Min	Max	Exceedance[2] (%)
Ammonia (mgN/l)	18	16	1989 - 1997	0.065	0.06	0.03	0.06	<BDL>	0.13	0
	18	13	1999 - 2005	0.047	0.04	0.03	0.04	<BDL>	0.11	0
DP (mg/L)	12	10	1991 - 1995	0.009	0.005	0.006	0.007	<BDL>	0.02	0
	24	17	1999 - 2006	0.022	0.020	0.011	0.020	<BDL>	0.058	20.8
DO (mg/L)	16	0	1989 - 1997	4.76	6.0	3.1	3.0	0.1	8.5	43.8
	114	0	1999 - 2006	4.83	6.1	2.7	2.8	0.01	8.5	39.5
Fecal Coliform (#/100 mL)	2	1	1991 - 1991	-	-	-	-	-	-	0
pH	16	0	1989 - 1997	8.0	8.1	0.56	8.0	7.1	8.9	0
	107	0	1999 - 2006	7.8	7.8	0.44	7.8	6.9	8.6	0
Total Coliform (#/100 mL)	2	1	1991 - 1991							50
TP (mg/L)	16	0	1989 - 1995	0.021	0.015	0.015	0.016	0.005	0.052	37.5
	24	13	1999 - 2005	0.032	0.020	0.028	0.026	<BDL>	0.116	33.3
TSS (mg/L)	5	4	1993 - 1997	-	-	-	-	-	-	0
	9	9	1999 - 2005	-	-	-	-	-	-	0
Water Temperature (^{o}C)	16	0	1989 - 1997	14.8	14	6.2	13.6	7.3	23.6	37.5
	114	0	1999 - 2005	15.1	15.4	5.0	14.3	8.4	24.9	24.6
Fecal Strep (#/100 mL)	2	1	1991 - 1991	-	-	-	-	-	-	
Salinity (mg/l@ 25^{o}C)	15	0	2001 - 2006	0.13	0.12	0.04	0.12	0.08	0.21	
Specific Conductivity (umhos/cm@25^{o}C)	16	0	1989 - 1997	320.9	308.5	87.1	309.6	190	448	
	68	0	1999 - 2005	251.6	222.5	65.2	243.6	175	376	

[1] Number of samples below detection limit (BDL).
[2] Percent exceedance values calculated using the following numeric criteria and narrative standards associated with Class 2B and 3A streams:
Ammonia: pH dependent criteria calculated for individual data points as per Utah Code R317-2; **Dissolved Phosphorus (DP):** <0.025 mg/L; **Dissolved Oxygen (DO):** (3a) >4.0; **Fecal Coliform:** <200 colonies/100 mL; **pH:** >6.5 and <9.0; **Total Coliform:** <5,000 colonies/100 mL; **Total Phosphorus (TP):** <0.025 mg/L; **Total Suspended Solids (TSS):** <35 mg/L; **Water Temperature:** (3a) <20 ^{o}C.
[3] Value of the single sample.

TABLE A13. SUMMARY STATISTICS FOR STATION 5958030 - RECAPTURE RESERVOIR 1/2 WAY UP RESERVOIR 03.

Parameter	n	BDL[1]	Date	Mean	Median	SD	Geo. Mean	Min	Max	Exceedance[2] (%)
Ammonia (mgN/l)	20	19	1989 - 1997	-	-	-	-	-	-	
	16	7	1999 - 2005	0.05	0.05	0.012	0.05	<BDL>	0.08	0
DP (mg/L)	12	9	1991 – 1995	0.019	0.020	0.003	0.018	<BDL>	0.02	0
	24	23	1999 - 2006	0.020	0.020	0.000	0.020	<BDL>	0.021	0
DO (mg/L)	20	0	1989 - 1997	5.4	6.4	2.6	4.2	0.4	8.2	30
	79	0	1999 - 2006	6.0	6.7	1.8	5.6	0.5	8.4	20.3
Fecal Coliform (#/100 mL)	2	2	1991 - 1991	-	-	-	-	-	-	0
pH	20	0	1989 - 1997	8.1	8.3	0.49	8.1	7.1	8.7	0
	73	0	1999 - 2006	8.0	7.9	0.33	8.0	7.1	8.6	0
Total Coliform (#/100 mL)	2	0	1991 - 1991	120000	120000	169700	3464	50	240000	50
TP (mg/L)	16	0	1989 - 1995	0.020	0.016	0.014	0.015	0.005	0.049	31.3
	24	18	1999 - 2005	0.023	0.020	0.010	0.022	<BDL>	0.054	16.7
TSS (mg/L)	6	6	1993 - 1997	-	-	-	-	-	-	0
	9	9	1999 - 2005	-	-	-	-	-	-	0
Water Temperature (^oC)	20	0	1989 - 1997	16.9	17.3	5.5	15.9	7.5	23.7	40
	76	0	1999 - 2005	16.9	16.7	4.8	16.2	9.3	24.7	35.5
Fecal Strep (#/100 mL)	2	0	1991 - 1991	30	30	14.14	28.28	20	40	
Salinity (mg/l@ 25^oC)	10	0	2001 - 2006	0.12	0.11	0.034	0.12	0.08	0.2	
Specific Conductivity (umhos/cm@25^oC)	19	0	1989 - 1997	311.1	288	77.5	301.9	192	437	
	55	0	1999 - 2005	247.2	222	60.4	240.3	176	368	

[1] Number of samples below detection limit (BDL).
[2] Percent exceedance values calculated using the following numeric criteria and narrative standards associated with Class 2B and 3A streams:
Ammonia: pH dependent criteria calculated for individual data points as per Utah Code R317-2; **Dissolved Phosphorus (DP):** <0.025 mg/L; **Dissolved Oxygen (DO):** (3a) >4.0; **Fecal Coliform:** <200 colonies/100 mL; **pH:** >6.5 and <9.0; **Total Coliform:** <5,000 colonies/100 mL; **Total Dissolved Solids (TDS):** <1,200 mg/L; **Total Phosphorus (TP):** <0.025 mg/L; **Total Suspended Solids (TSS):** <35 mg/L; **Water Temperature:** (3a) <20 ^oC.
[3] Value of the single sample.

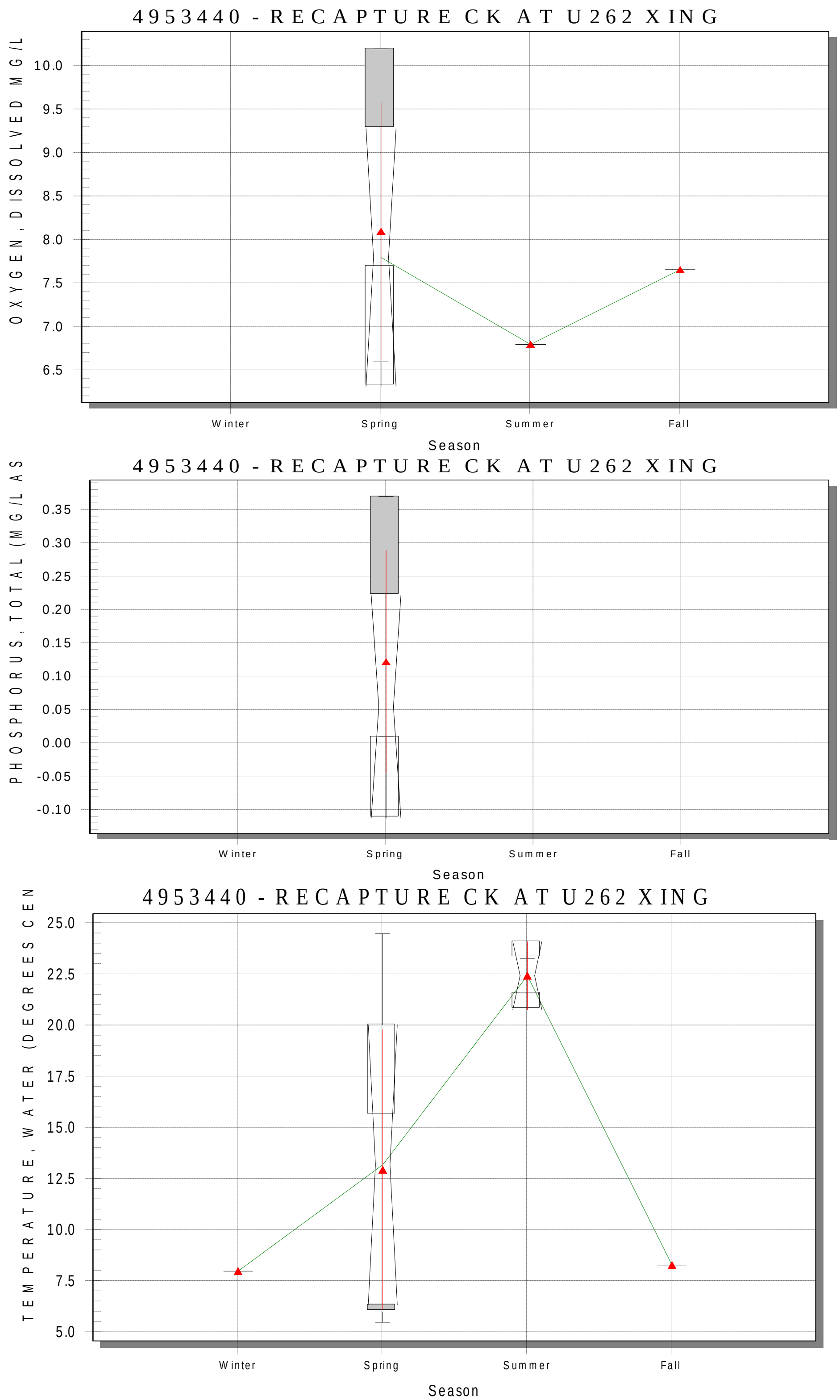


Figure A1. Seasonal parameter plots for station 4953440 from 1977-2000, including dissolved oxygen (6 samples), total phosphorus (4 samples), and water temperature (9 samples).

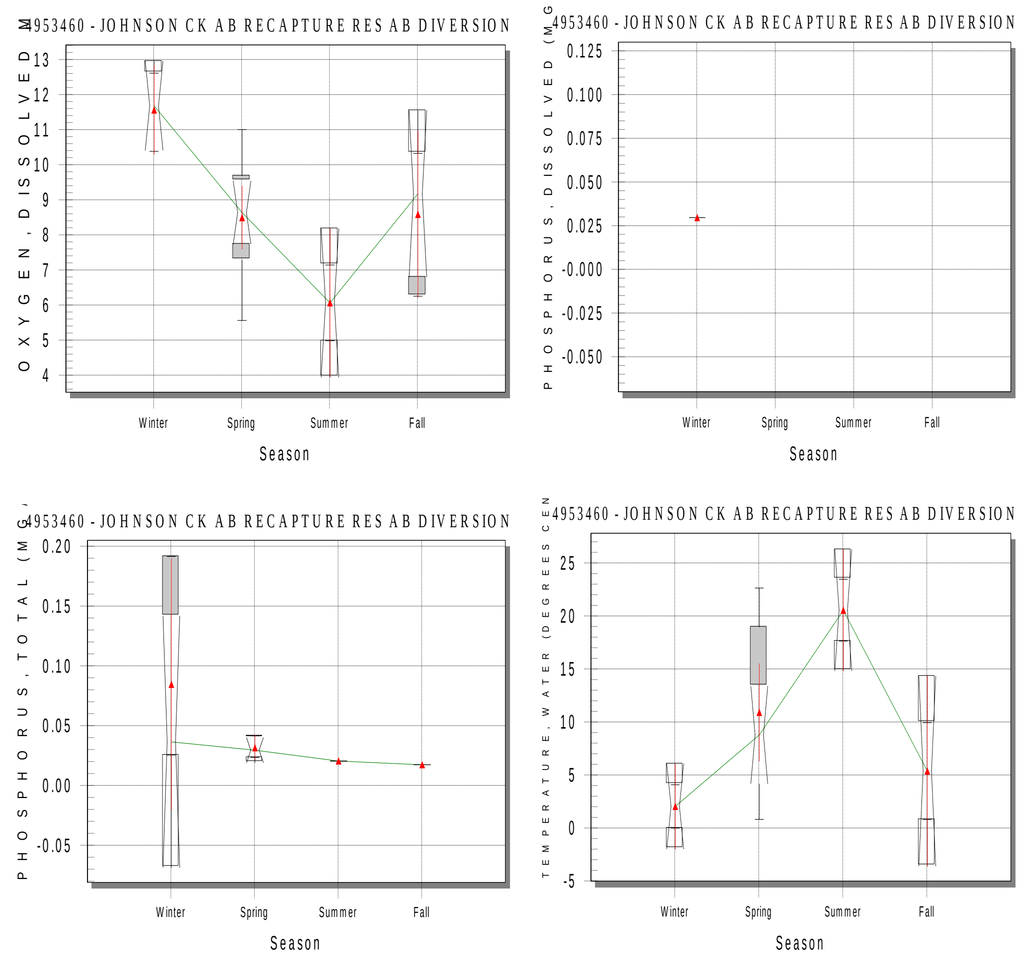


Figure A2. Seasonal parameter plots for station 4953460 from 1997-2006, including dissolved oxygen (20 samples), total phosphorus (22 samples), and water temperature (18 samples).

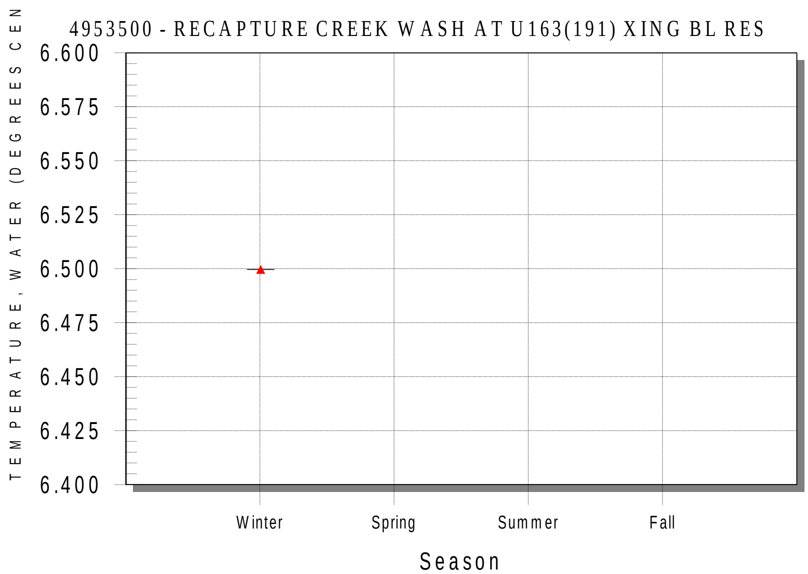
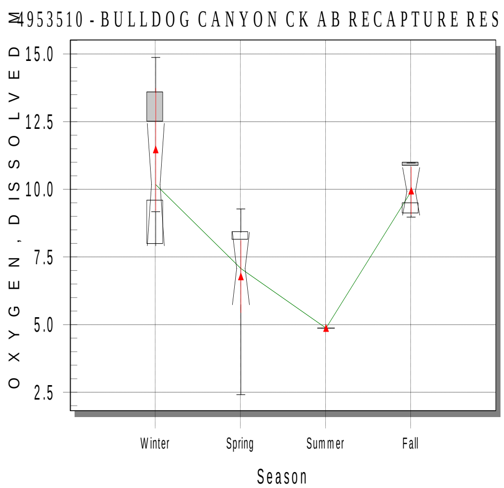
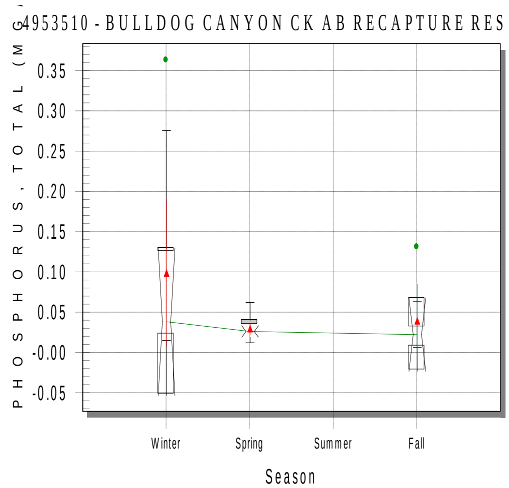


Figure A3. Seasonal parameter plots for station 4953500 from 1978, including water temperature (1 sample).





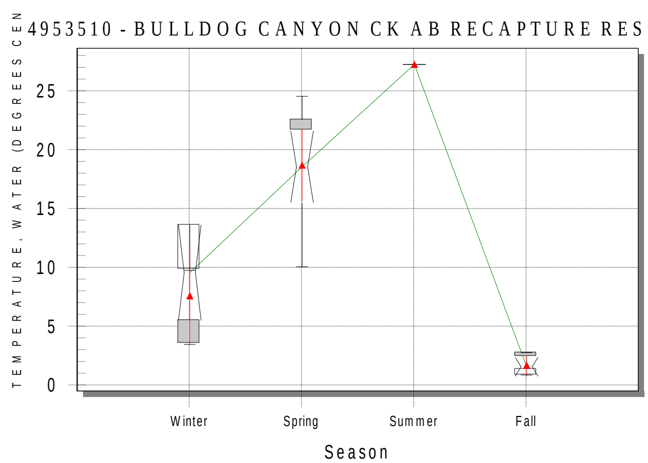
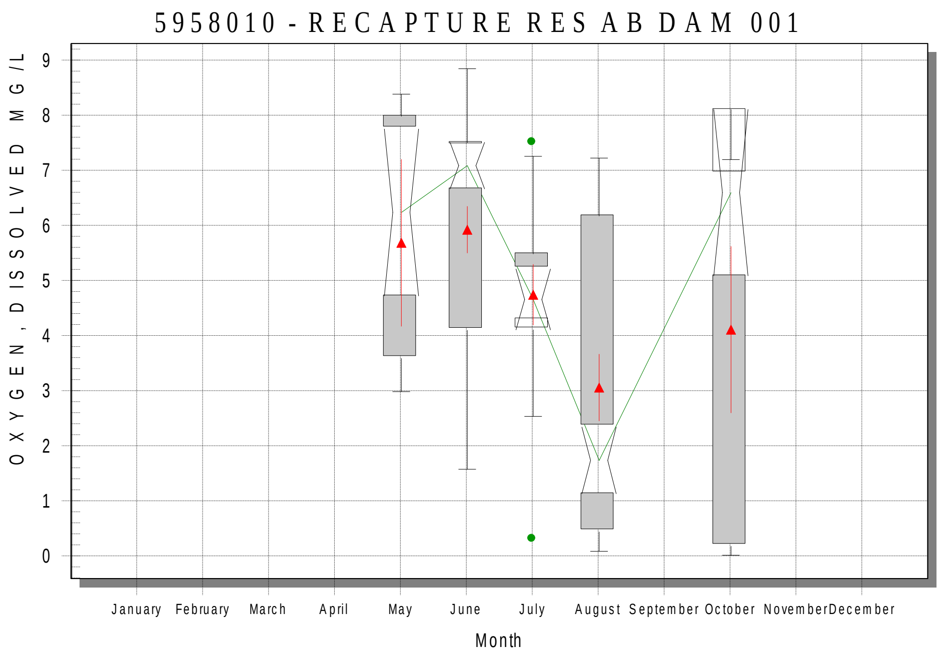


Figure A4. Seasonal parameter plots for station 4953510 from 1988-2001, including dissolved oxygen (19 samples), total phosphorus (29 samples), and water temperature (18 samples).



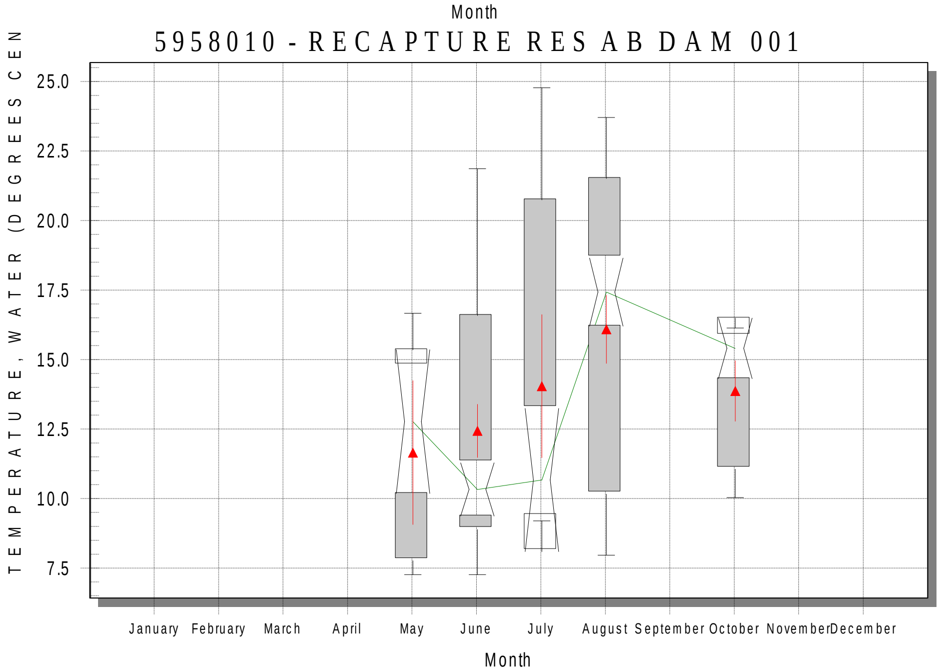
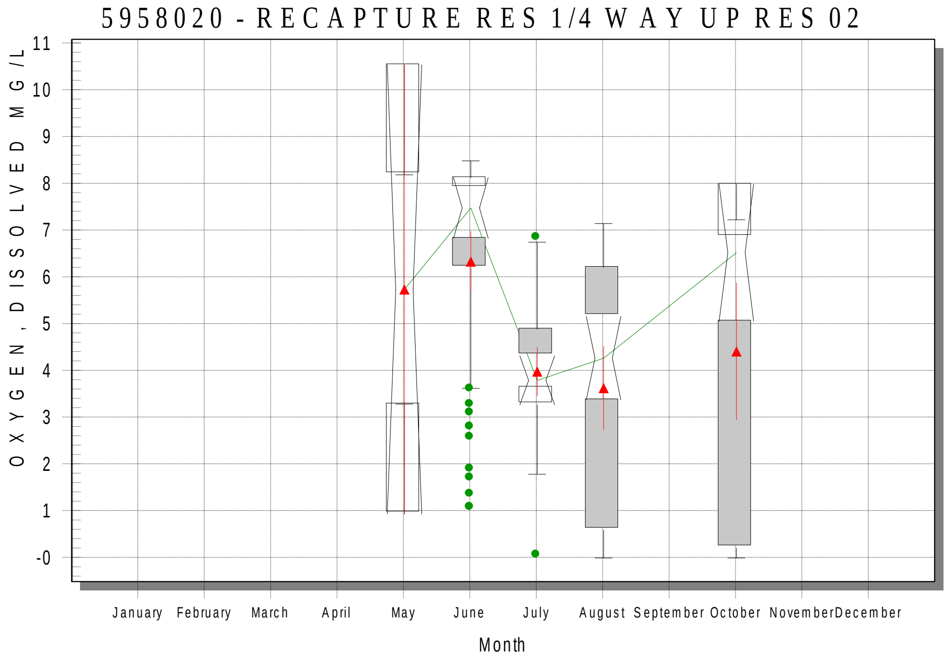


Figure A5. Monthly parameter plots for station 5958010 from 1989-2006, including dissolved oxygen (225 samples) and water temperature (217 samples).



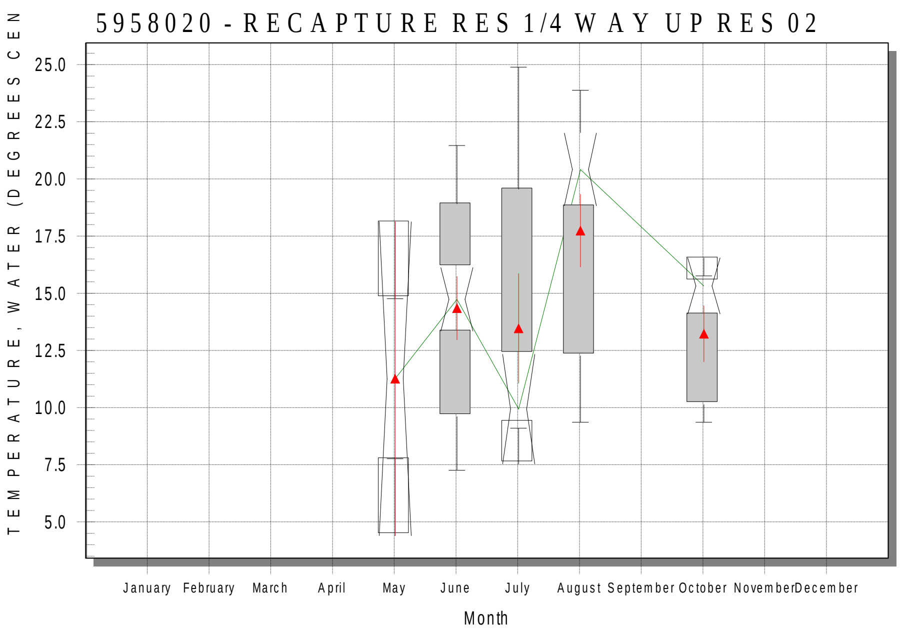
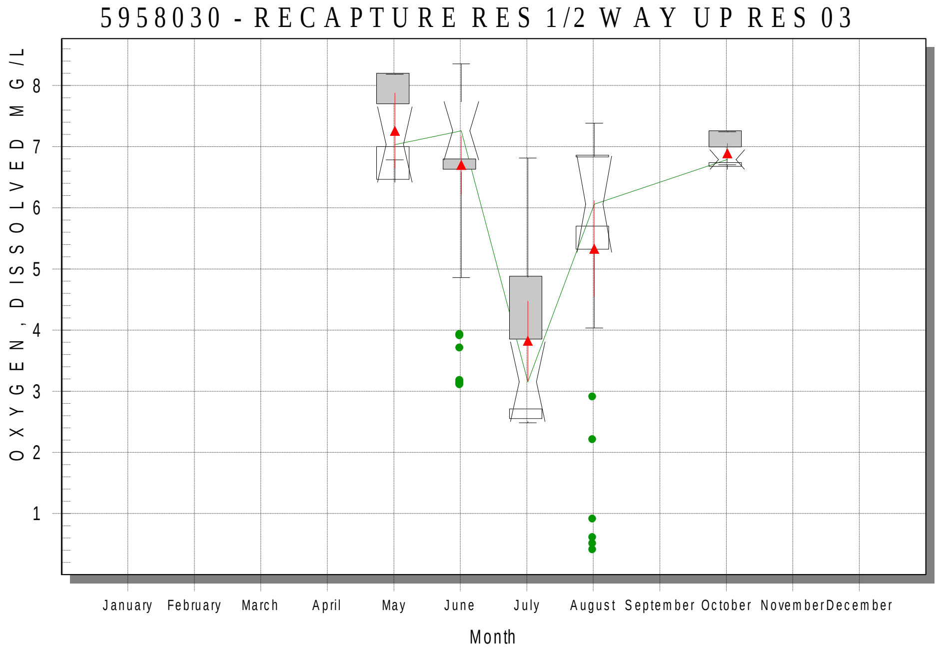


Figure A6. Monthly parameter plots for station 5958020 from 1989-2006, including dissolved oxygen (130 samples) and water temperature (130 samples).



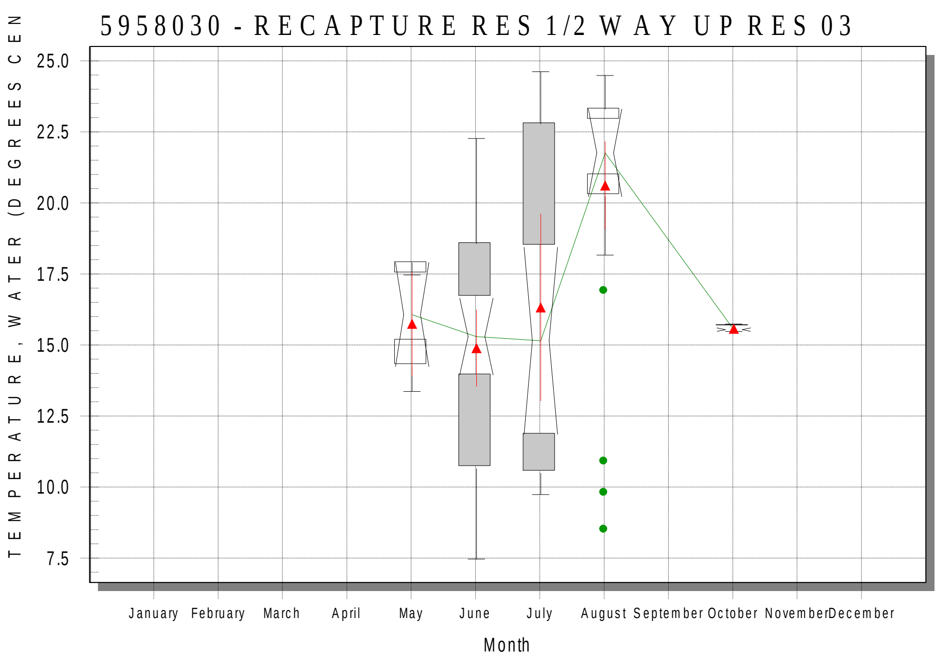


Figure A7. Monthly parameter plots for station 5958030 from 1989-2006, including dissolved oxygen (99 samples) and water temperature (96 samples).

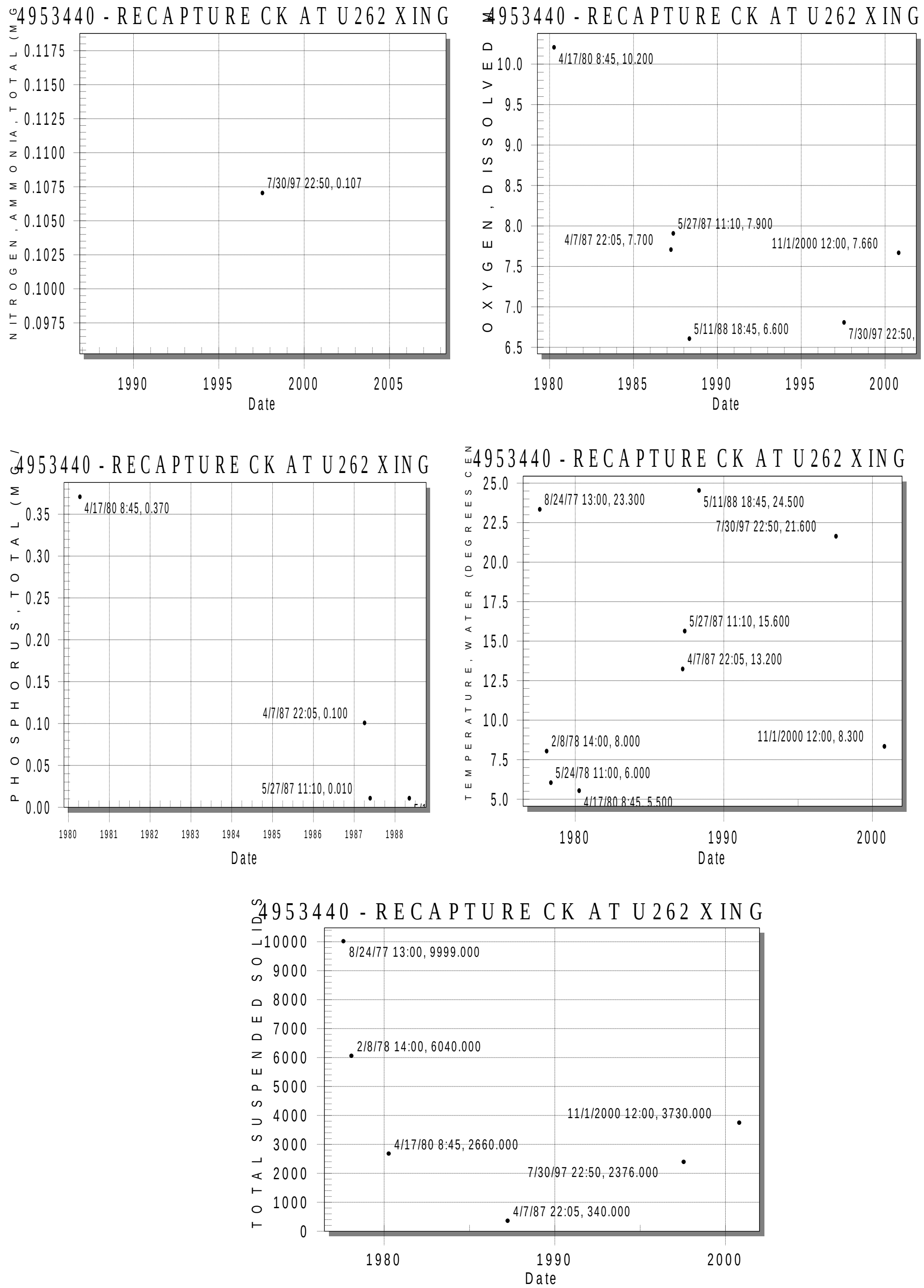


Figure A8. Time series plots for station 4953440.

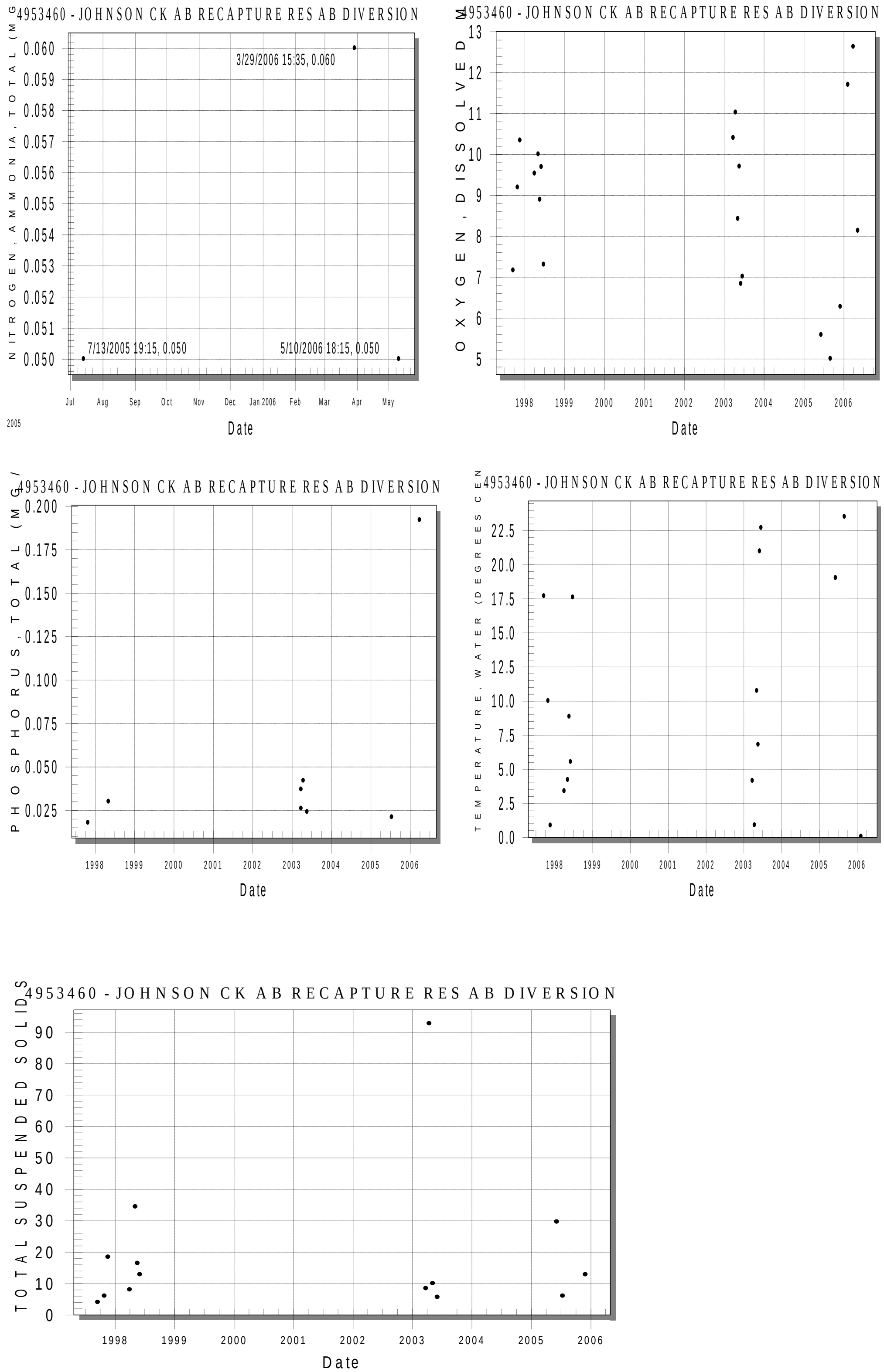


Figure A9. Time series plots for station 4953460.

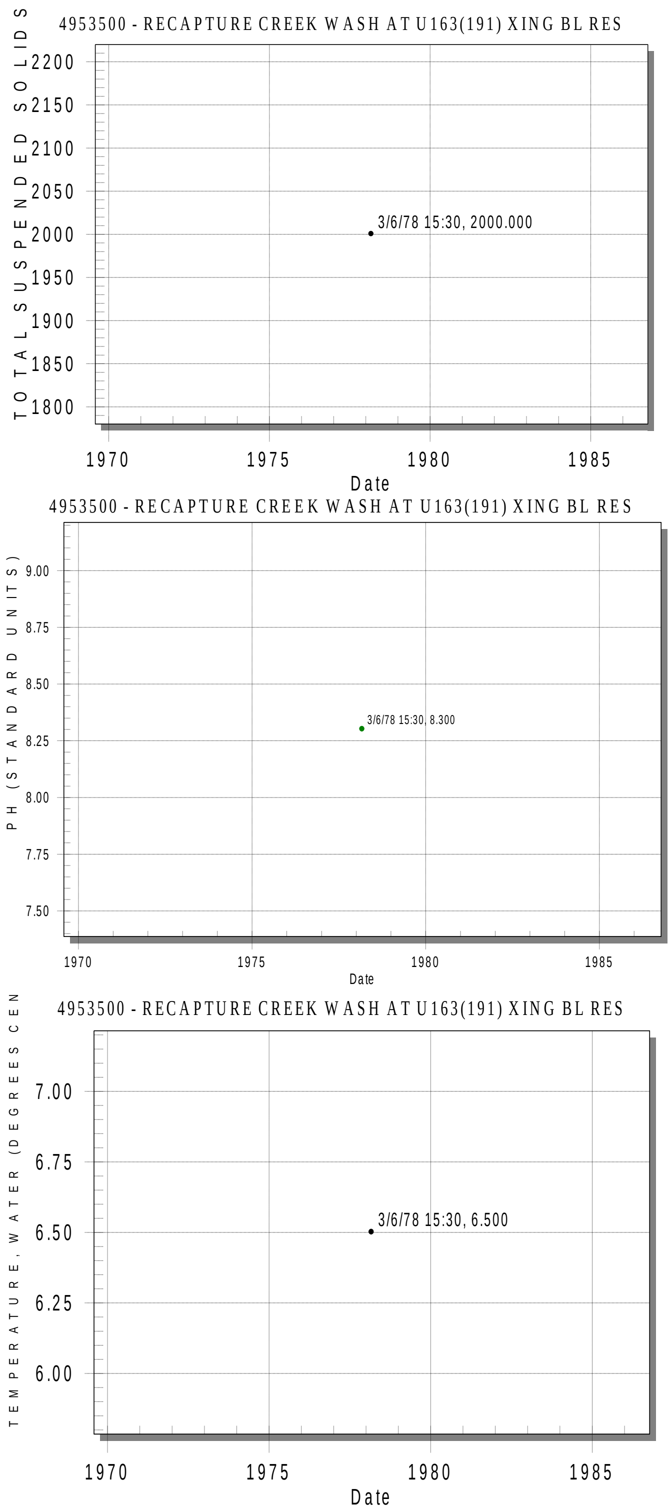


Figure A10. Time series plots for station 4953500.

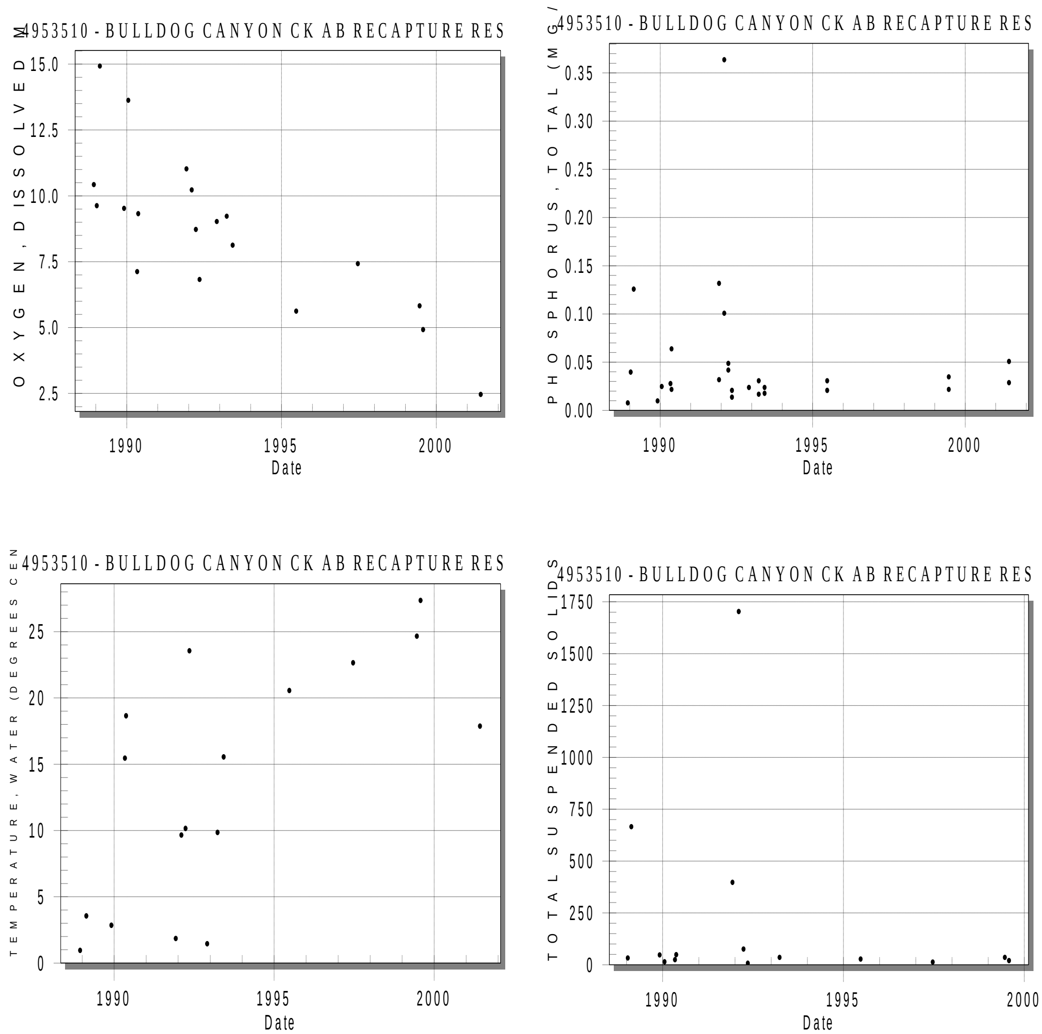


Figure A11. Time series plots for station 4953510.

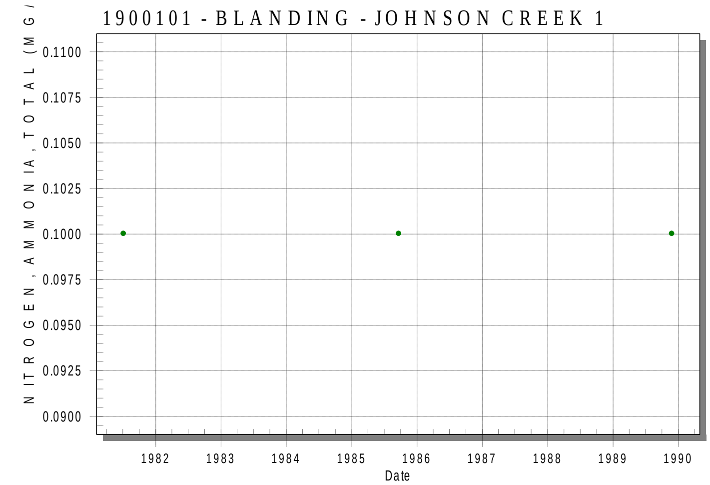


Figure A12. Time series plots for station 1900101.

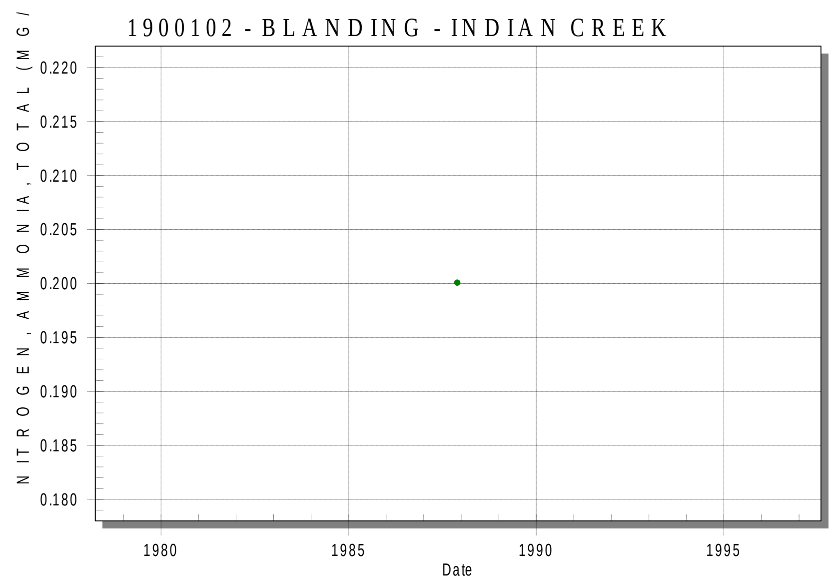


Figure A13. Time series plots for station 1900102.

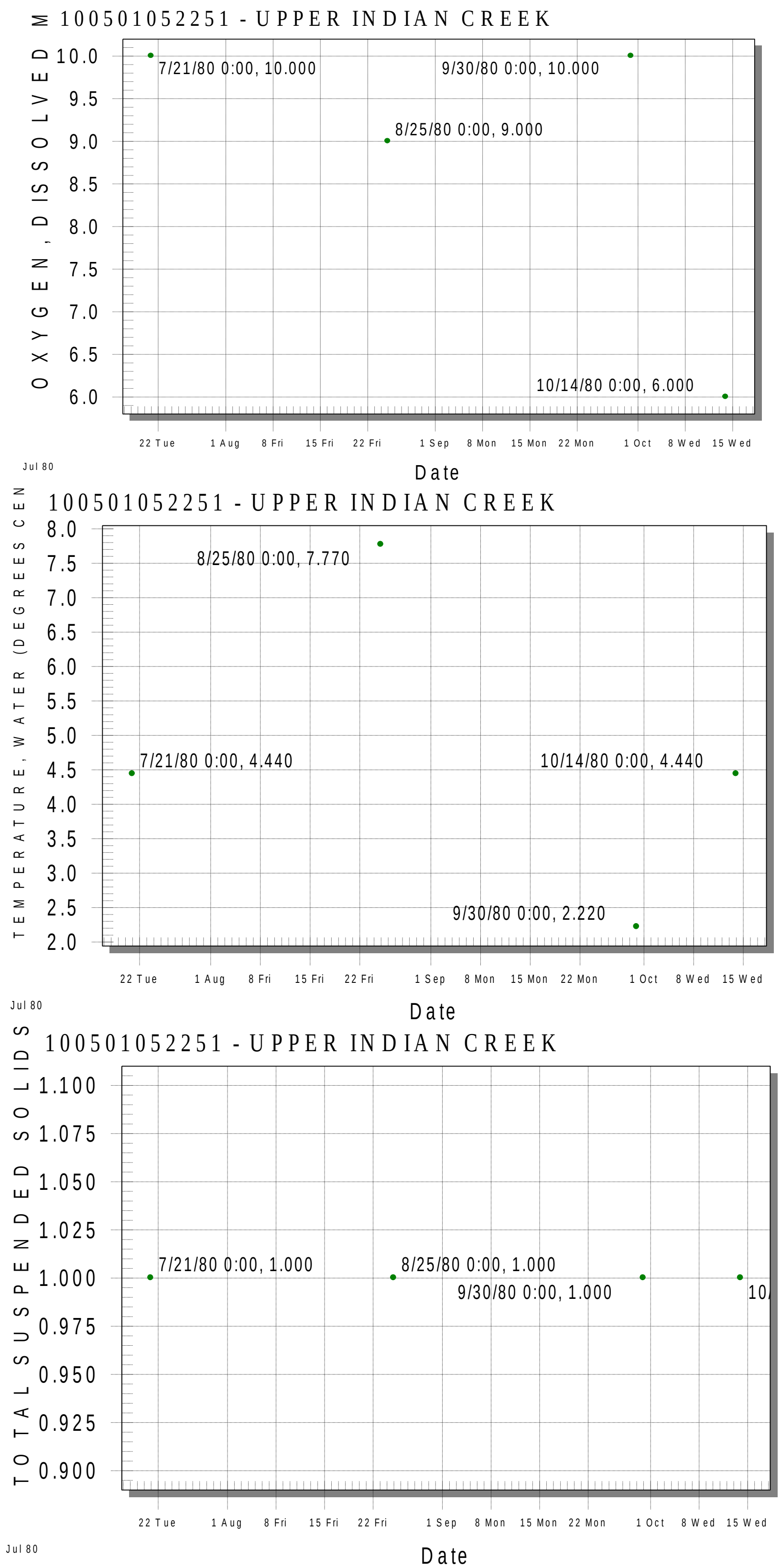
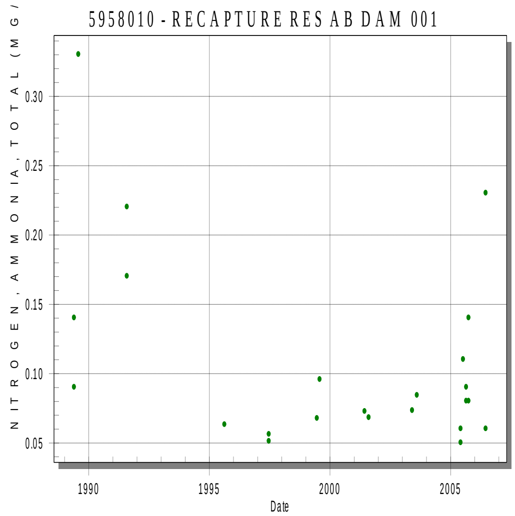
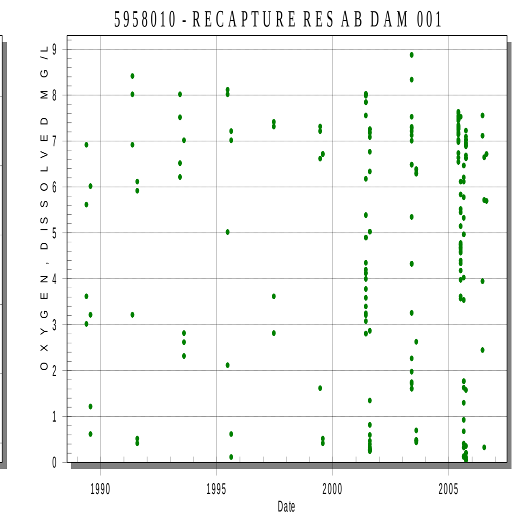
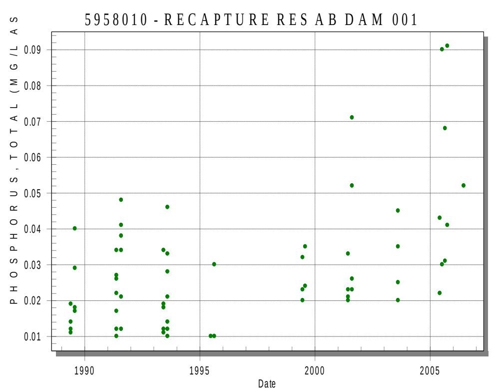
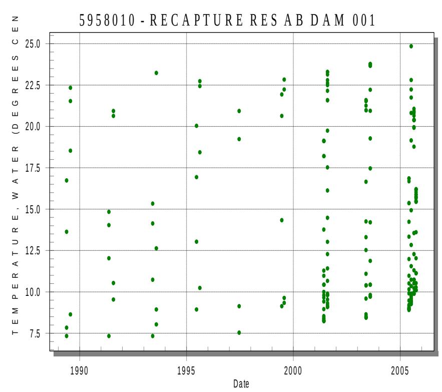


Figure A14. Time series plots for station 100501052251.









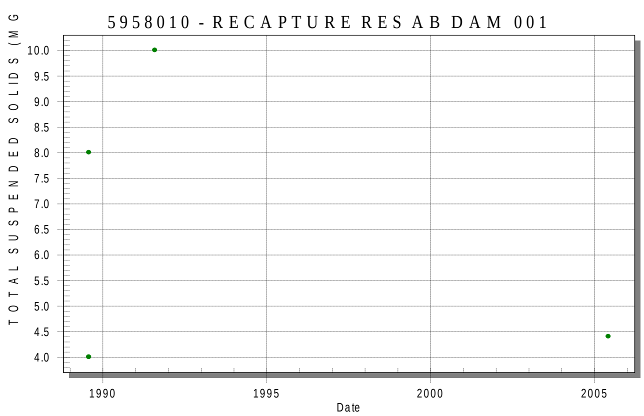


Figure A15. Time series plots for station 5958010.

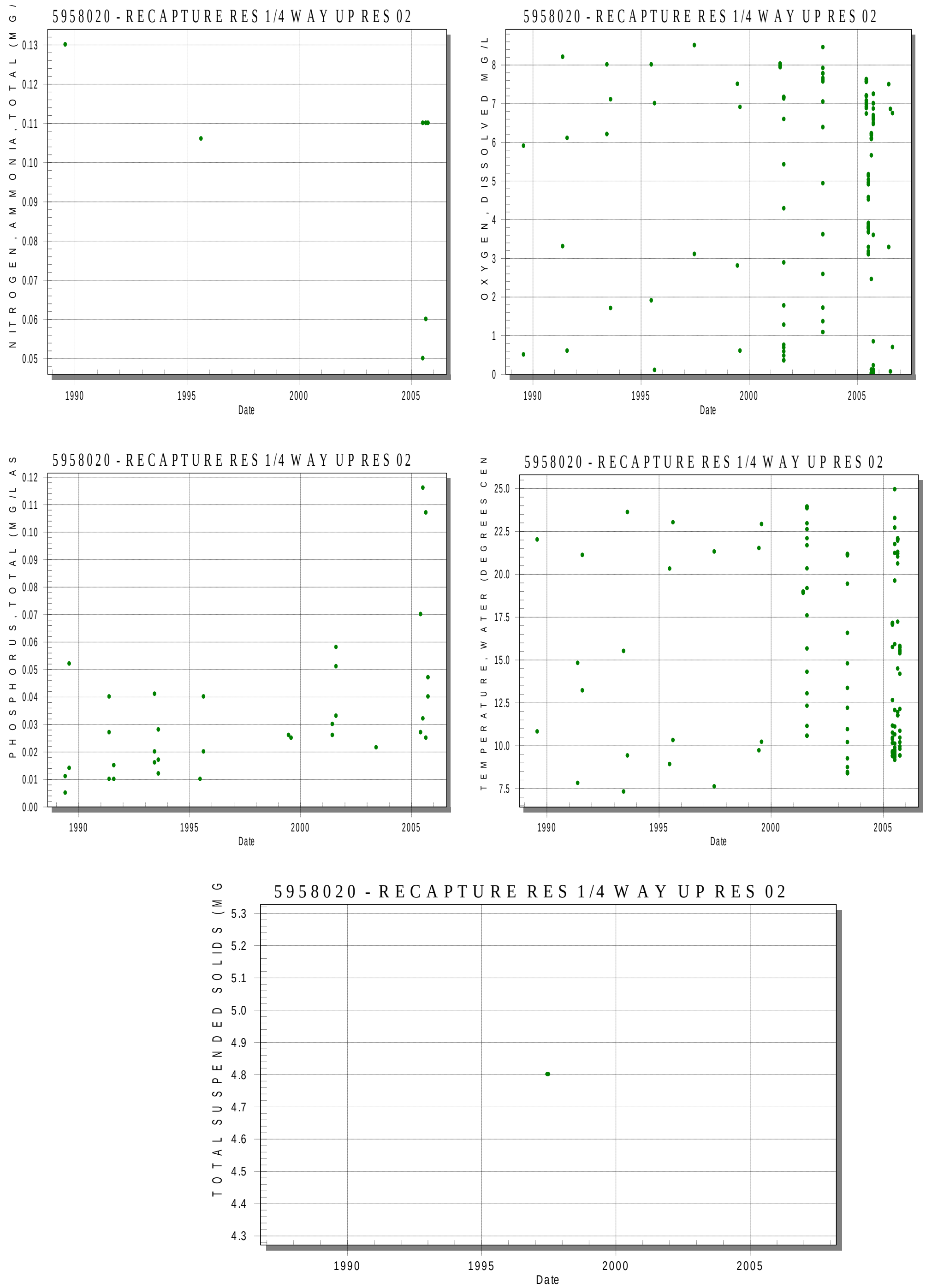


Figure A16. Time series plots for station 5958020.

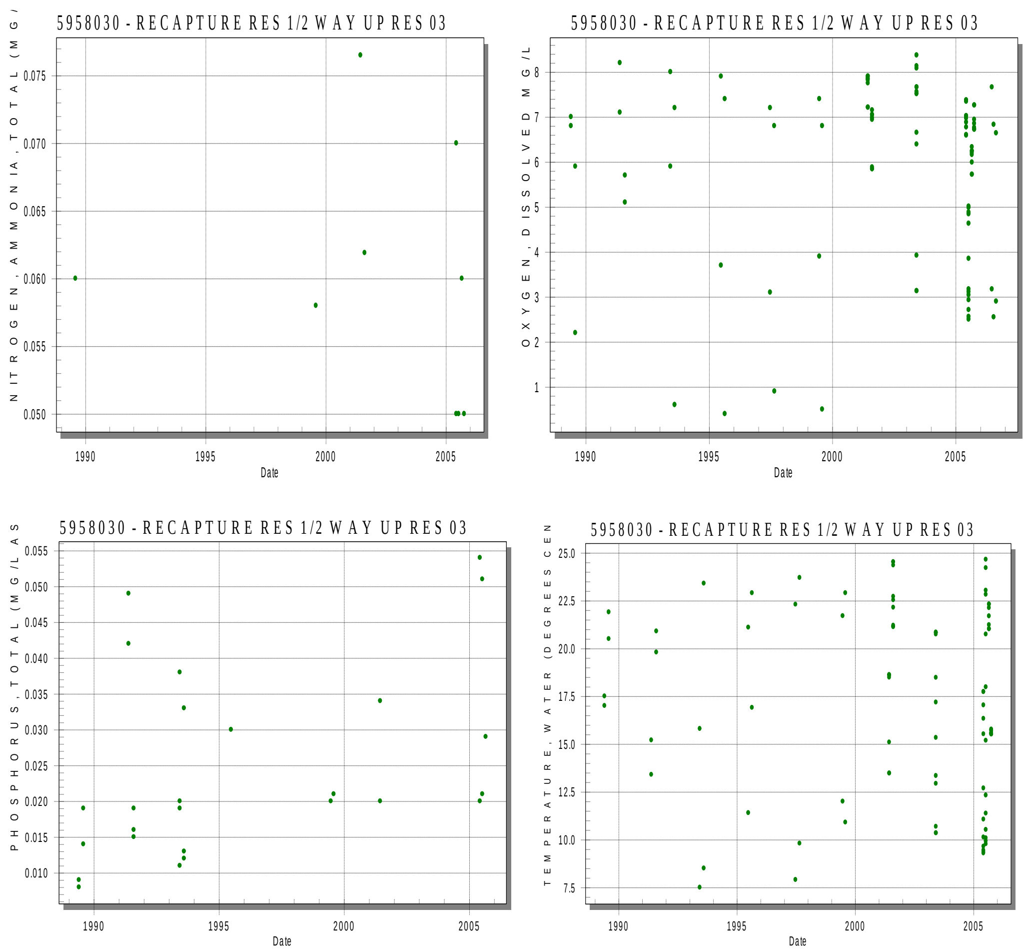


Figure A17. Time series plots for station 5958030.

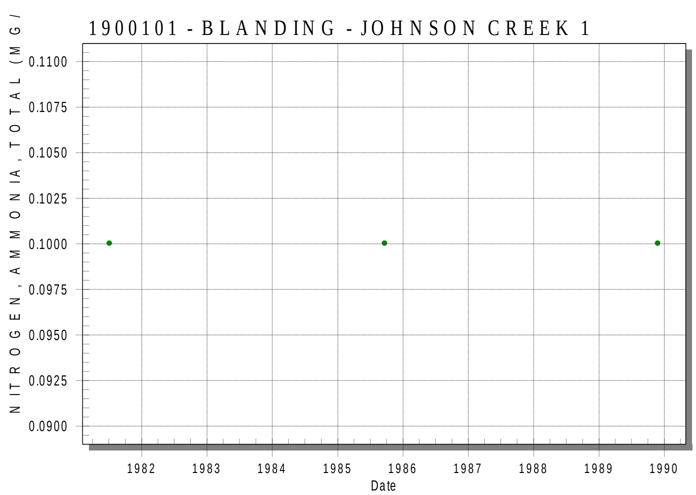


Figure A18. Time series plots for station 1900101.

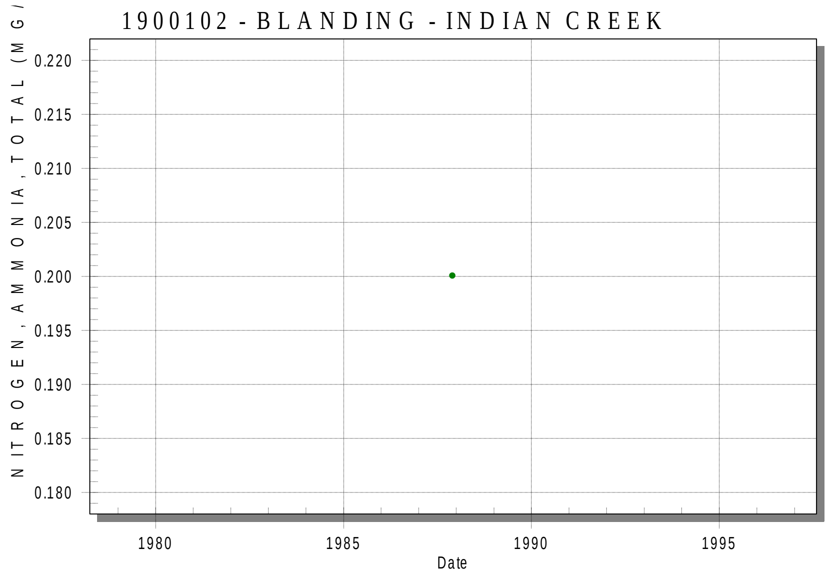


Figure A19. Time series plots for station 1900102.

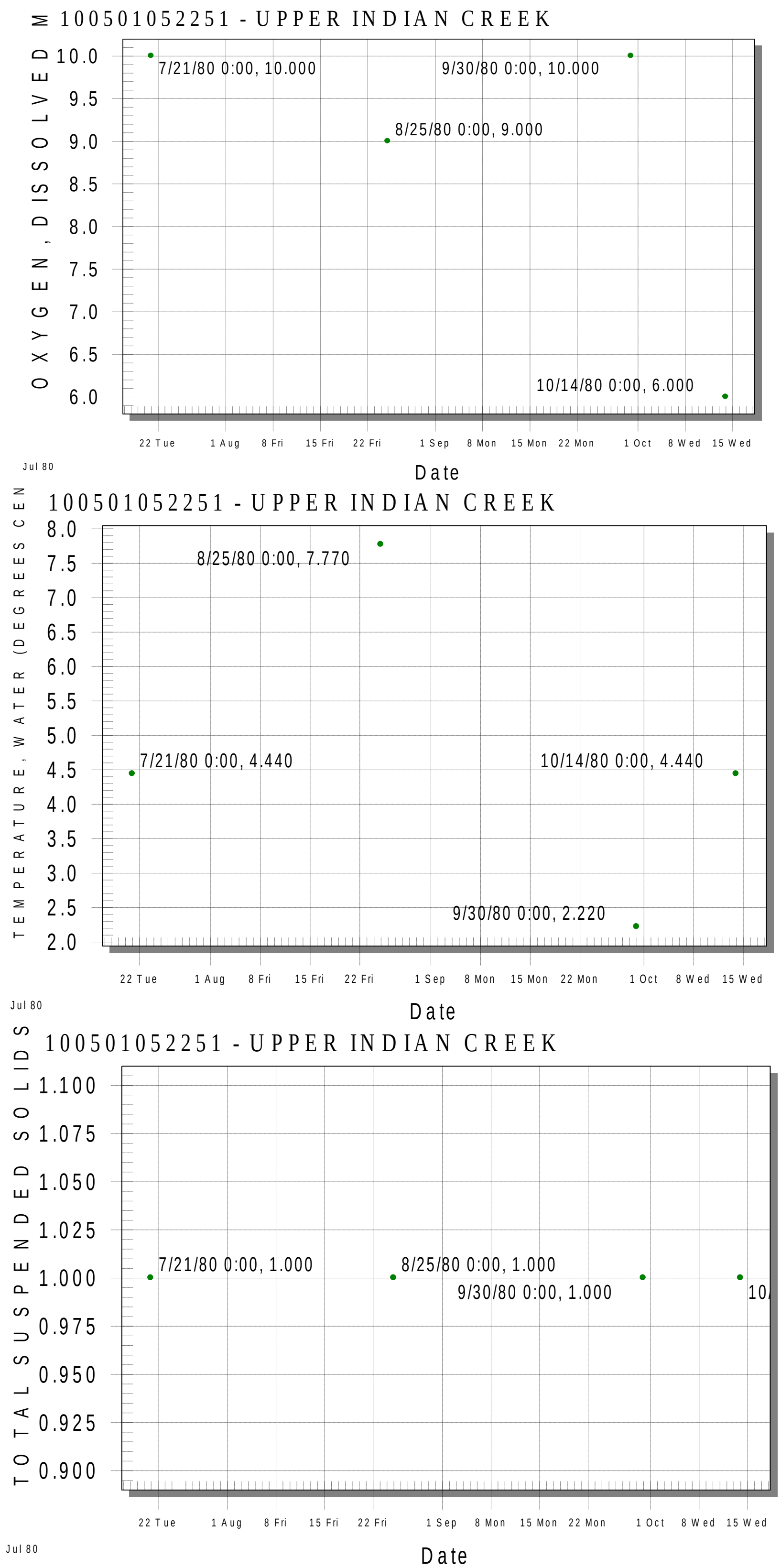


Figure A20. Time series plots for station 100501052251.

APPENDIX B –

WATERSHED BUDGET MODEL

Table of Contents

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

A new model was needed to estimate present day runoff and pollutant loads to the reservoir. This model was based on the area-altitude approach described in a letter and accompanying analysis produced by the Utah Division of Water Resources (UDWR) dated January 27, 1982 in support of their request to include the Recapture Dam construction project under the Nationwide Permits provisions of Section 404 of the Clean Water Act, administered by the U.S. Environmental Protection Agency.

UDWR 1981 MODEL

UDWR faced the challenge of forecasting “natural” runoff to the reservoir site from only two stream gages in the watershed and limited data on flows into diversions. Their data were even more limited than today, however, because the lower Recapture Creek Below Johnson Creek gage was only three years old, and the watershed at the time was subject to three diversions (Blanding Pipeline, Upper Canal, and Lower Canal). UDWR therefore initially had to construct a theoretical historical flow for the lower Recapture Creek gage by correlating the available data, first to the upper – and non-diverted – Recapture Creek Near Blanding gage (for which data had been collected for 13 years), and then to a gage on Indian Creek 15 miles to the north (USGS Indian Creek Above Cottonwood Creek, Near Monticello, UT, Station 9186500) for which data had been collected for 22 years (but not entirely overlapping in time and from which diversions existed above the gage). They concluded that the average annual flow at the Recapture Creek Below Johnson Creek gage was 4,402 acre-feet.

Having constructed a model of annual and monthly average flow at the lower Recapture Creek Below Johnson Creek gage, UDWR then constructed a model to predict runoff to the proposed reservoir site. They approached this task by developing coefficients of acre-feet of runoff per year per square mile for 1,000 foot elevation bands in the watershed. They first used an “Elevation-Precipitation Curve for Abajo Mountain Area” and then a “Precipitation-Runoff Curve for South and East Colorado Area” to predict runoff in inches from each elevation band. They then produced a “Runoff Factor” for each elevation band by normalizing the resulting theoretical runoff amounts (in inches) to the runoff in the highest elevation band. Applying this normalized Runoff Factor to the measured area in each elevation band yielded an “Equivalent Area” in each elevation band. Each Equivalent Area was then taken as a percent of the total Equivalent Area, and the resulting fraction was multiplied by the total annual runoff for the lower Recapture Creek Below Johnson Creek calculated from their correlations with other gages. The result was a list of “Unit Runoff” factors in acre-feet per square mile for each elevation band. Their table showing their calculations is reproduced below in Table B.1 (with some very small errors due to rounding).

Table B.1. UDWR 1981 Area altitude method based on natural flow of Recapture Creek Below Johnson Creek - based on mean annual runoff of 4,400 acre-feet calculated from correlations to other gages.							
Elevation (feet above sea level)	**Area (sq mi)**	**Precip (in)**	**Runoff (in)**	**Runoff Factor**	**Equiv Area (sq mi)**	**Unit Runoff (ac-ft/sq-mi)**	**Runoff (ac-ft)**
10-11,000	1.547	32.5	14.5	1.000	1.547	**433**	669
9-10,000	4.828	27.0	8.5	0.586	2.830	**254**	1,225
8-9,000	7.672	22.5	5.0	0.345	2.646	**149**	1,145
7-8,000	14.719	17.5	2.4	0.166	2.436	**72**	1,054
6-7,000	7.953	14.0	1.3	0.090	0.713	**39**	309
Total	36.719				10.172		4,402

UDWR attempted to validate this approach to modeling watersheds by developing new unit runoff factors for the smaller watershed feeding the upper Recapture Creek Near Blanding gage, above which there were no diversions. This yielded slightly different Unit Runoff coefficients which, when applied back to the larger watershed above the Recapture Creek Below Johnson Creek gage produced an estimate of 4,650 acre-feet of "natural flow", only slightly higher than their value of 4,402 acre-feet from their correlations.

From this point, UDWR made assumptions in calculating the flow expected at the Recapture Reservoir Dam site. These included:

1. Applying the original Unit Runoff Factors to the rest of the watershed, including Bulldog and Bullpup Creeks to generate a modeled "natural flow" to the reservoir;

2. Blanding would always divert up to, but no more than, 30 acre-feet per month;

3. The Upper Canal would divert up to, but no more than, 20 cfs (~1,200 acre-feet per month) from April through October; and

4. The Lower Canal would divert whatever was available (up to 1,130 acre-feet per month in their summary) from April through October.

UDWR thus calculated that the average annual flow to the Recapture Reservoir Dam site would be 2.3 cfs, or 1,616 acre-feet (See UDWR 1981, Article C).

Table B.2 compares UDWR's 1981 calculations of the natural flow at the gage at Recapture Creek Below Johnson Creek, based on correlations with other gauges, to the longer period of record now available from this gage, adjusted for diversions and interbasin inflows. Between 1976 and 1993, this gage measured an annual mean of 6,260 acre-feet (median of 4,168 acre-feet). Assuming that the mean annual flow now is similar to the flow in the years of record, and calculating a "natural flow" by adding back flows measured by Blanding City for the Blanding Pipeline of 976 acre-feet per year (average 2002-2007) and the Upper Canal diversion of 2,715 acre-feet (assuming average of 9 cfs for 5 months) as well as the net flows from Dry Wash, and deducting the annual average interbasin contribution from Indian Creek Tunnel, we would expect the natural flow at this gage to be approximately 8,917 acre-feet per year. UDWR's correlations for this gage yielded 4,402 acre-feet per year, a discrepancy of approximately 4,500 acre-feet per year.

Table B.2. Comparison of 1981 DWR Correlations and Current Data for Recapture Creek Below Johnson Creek Gage (Adjusted) (all values in acre-feet).		
UDWR 1981 Calculation of "Natural Flow" (no diversions or interbasin transfers) based on correlations to other stations		**4,402**
Present Day Estimates		
Actual mean annual flow at gage		6,260
Add back average annual upstream diversions		
Blanding Pipeline	976	
Upper Canal	2,715	
Deduct average annual upstream inflow Indian Creek Tunnel	(1,034)	
Dry Wash flow net of 185 acre-feet held back (flow net of “hold back” is typically zero)	-	
Total adjustments		2,657
Present day "Natural Flow"		**8,917**
UDWR 1981 Underestimate		**(4,515)**

The longer period of record for the stream gage on Recapture Creek Below Johnson Creek would probably have resulted in different conclusions with respect to the USEPA Section 404 Permit process in 1981. The underestimated stream flow at the stream gage on Recapture Creek Below Johnson Creek would have flowed to Recapture Reservoir site, adding to UDWR’s estimate of 1,616 acre-feet per year at that site, for an annual total of 6,116 acre-feet, or an average of 8.44 cfs, well above the limit of 5 cfs for a Nationwide Permit at the time.

CURRENT WATER BUDGET MODEL

Not only are there more years of gage data today, but newer information is available for precipitation bands at different elevations in the Recapture Reservoir watershed. A data layer of average annual precipitation for 1961-1990, in two inch precipitation bands, was acquired from the U.S. Department of Agriculture, Service Center Agencies, NRCS - National Cartography & Geospatial Center (based on data from PRISM, Parameter-elevation Regressions on Independent Slopes Model, at Oregon State University, http://www.prismclimate.org, created August 2006). Using GIS software, this precipitation data was clipped to the watershed boundaries, and a “union” operation produced 61 separate polygons for the unique combinations of watershed subdivision and precipitation value. These polygons were then grouped for flow modeling purposes based on where they came together at a diversion or major confluence. Areal extents for each precipitation-watershed subdivision were exported to spreadsheets for further analysis.

The first new adjusted exponential function was then tested on the watersheds of the other two gage sites, Recapture Creek Below Johnson Creek and the Recapture Reservoir itself based on the following assumptions:

1. The equation for unit runoff as a function of precipitation is exponential with zero offset (i.e., some runoff occurs at every precipitation amount).

2. Average annual flow at the upper Recapture Creek Near Blanding gage is 895 acre-feet per year (from actual gage data).

3. Diversions to the Blanding Pipeline for 2002-2007 equaled 976 acre-feet per year, as reported by Blanding City officials.

4. Diversions to the Upper Canal averaged 9 cfs for 6 months, based on personal communications with personnel from the SJWCD.

5. The first 185 acre-feet from the Dry Wash subdivision is retained in the Dry Wash reservoir, based on personal communications with personnel from the SJWCD.

6. Reservoir losses to evaporation are 48.5 inches of water per year, less 13 inches of average annual precipitation, times the average areal extent of the reservoir, yielding evaporative losses of 500-870 acre-feet per year.

This first approximation yielded significant errors when applied to these two other watersheds, so the coefficient and exponent of the model were adjusted once more to minimize the total error among all three gage sites. A graph of the unit runoff equation is reproduced in Figure B.1.

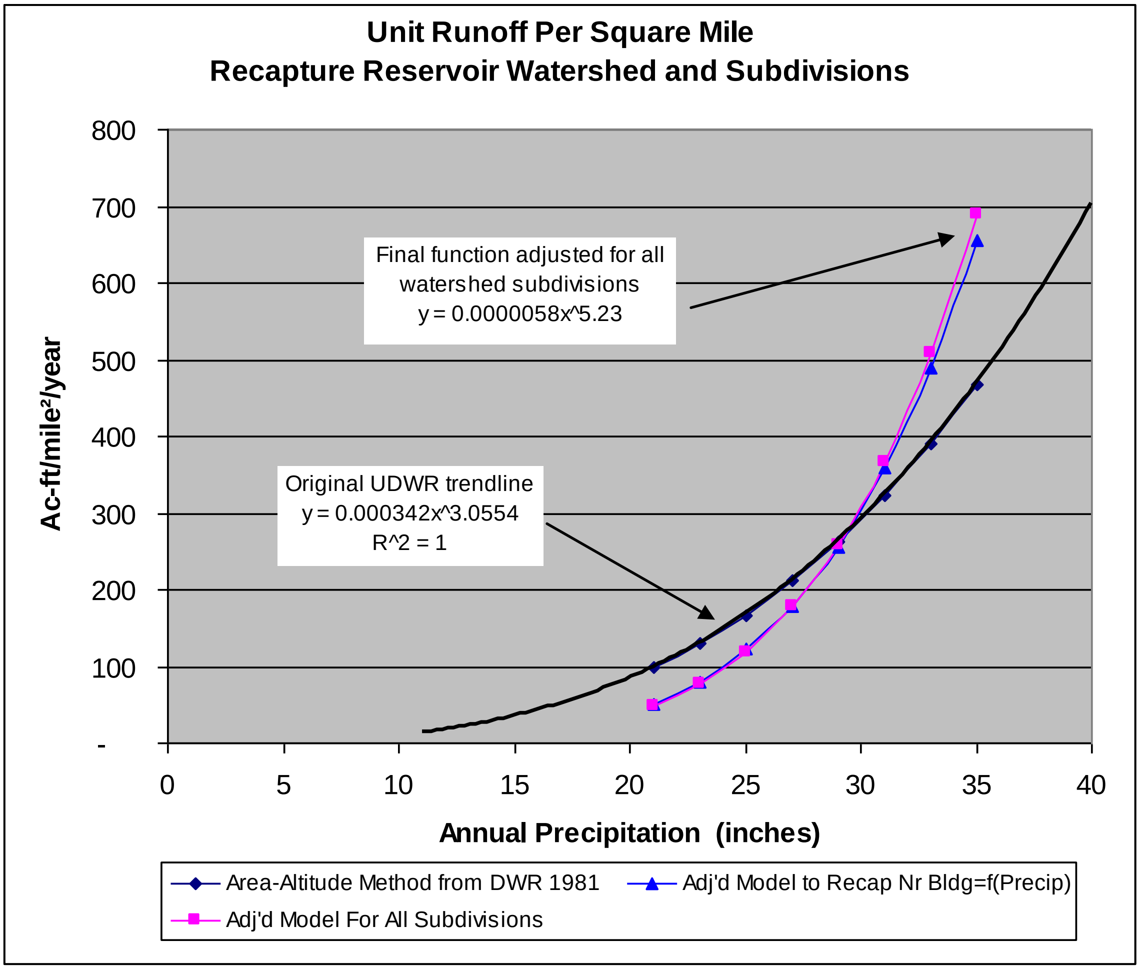
A reconciliation of the modeled flows against the flows actually measured at the stream gages is presented in Table B.3. The model was used to calculate annual average flows for the watershed areas that fed each of the stream or reservoir discharge gages. Deductions were made for diversions, based on estimates from local sources, and evaporation from Recapture Reservoir, based on estimates relying on average evaporation in the region and the average areal extent of the reservoir each year. Deductions were not made for water withdrawn by Blanding City or the SJWCD from the reservoir itself.

5.

Table B.3. Reconciliation of average annual flows predicted by model with actual gage data.

	Recapture Creek Near Blanding (ac-ft)	**Recapture Creek Below Johnson Creek (ac-ft)**	**Recapture Reservoir At Dam (ac-ft)**
Modeled Natural Runoff	**907**	**8,332**	**8,913**
Deduct Blanding Pipeline diversion	N/A	(976)	(976)[1]
Deduct Upper Canal diversion[2]	N/A	(2,715)	(2,715)
Deduct Dry Wash held water	N/A	(185)	(185)
Deduct evaporation losses[3]	N/A	N/A	(605)
Actual Average Annual Gage Flows	**895**	**6,260**	**1,668**
"Error" - Other unknown inflows (losses)	**(13)**	**1,804**	**(2,763)**

[1]From average measurements from Blanding 2002-2007.
[2]Assumes 9 cfs for 5 months.
[3]Assumes evaporative loss of 47.5" per year for free water surfaces, from UWRL Water Atlas for Utah, and based on the average areal extent of the reservoir for that year, based on reservoir capacity tables provided by UDWR.



6. Figure B.1. Modeled functions for unit runoff in acre-feet per square mile per year as a function of precipitation in the Recapture Reservoir watershed.

The error for Recapture Creek Near Blanding is the smallest, because the model was originally created based on data from that station and because that watershed is relatively small with no diversions within it. The positive error for Recapture Creek Below Johnson Creek implies that the model has either underestimated runoff from lower elevations or not adequately accounted for ground water discharge to the stream. The negative unknown discrepancy for Recapture Reservoir implies that the model has overestimated flows from lower elevation land areas, or underestimated other losses, such as withdrawals from canals, Blanding City, or the SJWCD, or not adequately taken into account losses of natural seepage to ground water. With respect to this latter error, representatives from the SJWCD have confirmed that a clay layer was incorporated into the bottom of the reservoir during construction to minimize seepage. An independent assessment of the underlying geology and hydrogeology was not undertaken for this report.

In all, however, this model predicts flows better than the area-altitude model used in 1981 by UDWR. It would benefit by taking into consideration additional factors such as slope, vegetation cover, and soil characteristics. More stream gaging stations, especially at diversions and closer to the reservoir, would help with future studies.

APPENDIX C - PIP

PROJECT IMPLEMENTATION PLAN

TABLE OF CONTENTS

LIST OF TABLES

INTRODUCTION

To achieve water quality targets and TMDL endpoints, it is necessary to implement practices that are commonly known as Best Management Practices (BMPs) or Best Available Technologies (BATs). BMPs are practices used to protect the physical and biological integrity of surface and groundwater, primarily from nonpoint sources of pollution. BMPs are most effective when combined to create a BMP system that will comprehensively reduce or eliminate pollution from a single source. It should be noted that no single BMP system is considered to be the most effective way of controlling a particular pollutant in all situations. Rather, the design of a BMP system should consider local conditions that are known to influence the production and delivery of nonpoint source pollutants. The design of a BMP system should not only account for the type and source of pollutant, but should also consider background factors such as the physical, climatic, biological, social, and economic setting. BATs are used to treat effluent from a facility or operation before it is discharged through a single location to a receiving water body. Since no point sources of pollution have been identified in the project area, no BATs will be recommended.

The following pollutant loading sources were identified during the assessment of water quality conditions in the TMDL study area:

- Livestock grazing
- Diffuse loads from runoff

Although recreational use of public lands was not defined specifically as a pollutant source in the TMDL assessment, this Project Implementation Plan (PIP) also includes recommendations for minimizing impacts from recreational activities. Given the long-term trends observed on public lands, it is recognized that these activities are an integral part of land use and should be addressed with regards to the potential for generating nonpoint source pollution.

Recapture Reservoir is currently impaired for Dissolved Oxygen (DO), and has been listed as such as far back as 1996. Recapture Reservoir was also listed as impaired for Temperature, pH, and Total Phosphorus (TP) in 1996 and 1998. The TP listing was removed in 1998 when the state determined that TP data could not be used by itself as a means for determining beneficial use support.

Existing total watershed loads, and the recommended pollutant load allocations by land owner and watershed are provided below in Table C1. The target load associated with the TMDL is reflected by existing conditions. The selection of the target load was based on an assessment of existing reservoir TP concentrations and a review of potential impacts to reservoir DO levels. It was determined that existing reservoir TP concentrations are marginally above the 0.025 mg/L pollution indicator value and likely not responsible for the low DO levels observed in Recapture Reservoir. Therefore the existing loading to Recapture Reservoir was selected as the target load. However, all sources identified in the TMDL assessment and those discussed in this PIP are considered significant in terms of their influence on water quality conditions in Recapture Reservoir. The remainder of this document will include recommendations for maintaining existing loads from each source and the unit cost associated activities that can be used to maintain or reduce loading.

As pollutant loads are transferred through the TMDL study area, they are influenced by a number of different processes that reduce the mass of TP delivered to the Recapture Reservoir. Some of these processes can include adsorption, algal uptake, settling, and flow diversion for municipal or irrigation purposes. The exact level that each of these processes influence TP loading to the reservoir is not known at this time. Therefore it is recommended that implementation of BMPs follow a phased approach that focuses on areas where recommended BMPs are not currently in place as well as maintaining those areas where BMPs are in place. Additional monitoring of water quality can then be used to determine if additional BMPs are needed above the level described in this document.

Table C1. Allocation of permissible total phosphorus loadings to Recapture Reservoir by land ownership.

Agency	Annual TP load (kg/yr)	Percent of total
BLM	16	7
USFS	183	81
SITLA	2	1
Private	24	11
Total	**225**	**100**

LIVESTOCK GRAZING AND DIFFUSE RUNOFF

Loads included in this category are related primarily to manure loading from livestock grazing on public and private lands. Also included are loads from diffuse runoff, which are related to land use. Specific sources within this category including runoff from agricultural lands, urban/residential areas, rangeland, forest land, and other land cover types. The TMDL recommends that total loads from livestock grazing and diffuse runoff be maintained at their existing level or reduced where possible as opportunities arise to improve management practices.

Livestock grazing is one of the primary land uses in the Recapture Reservoir watershed and as a result, occurs on many of the areas that contribute seasonal runoff to tributaries of the reservoir. Nearly all of the BLM and National Forest System lands in the watershed are associated with public grazing allotments. BLM lands, located in the southern portion of the watershed, are primarily grazed from mid-May through late September each year. Forest Service allotments are located in the northern part of the watershed and are grazed slightly later in the season. Areas of private and state owned lands are also scattered throughout the southern part of the watershed. Although no animals were observed grazing on private lands during field visits to the TMDL study area, it is likely that periodic grazing of private land does occur. There are no AFO/CAFO operations in the watershed. The primary loading mechanisms from grazing animals include the direct deposition of manure to water bodies and surface runoff from areas where livestock have grazed. TP loads to Recapture Reservoir resulting from livestock grazing are shown in Table C2.

Table C2. Total phosphorus loads (kg/yr) from grazing to Recapture Reservoir defined by watershed or by land owner.				
Watershed	**BLM**	**SITLA**	**USFS**	**Total (kg/yr)**
Johnson Creek	5.8	0.8	24.8	**31.5**
Recapture Creek	16.1	1.8	61.9	**79.7**
Bulldog Creek	36.7	4.9	138.8	**180.5**
Bullpup Creek	5.2	6.4	0.4	**12.1**
Recapture Reservoir	12.9	0.6	-	**13.5**
Total	**76.8**	**14.5**	**225.9**	**317.3**

Land cover in the Recapture Reservoir watershed is primarily pinyon-juniper (approximately 43 percent), followed by rangeland (approximately 29 percent) and forest (24 percent). The amount of agriculture areas are small (3 percent), but are located near tributary streams on private land in the lower-elevation part of the watershed. Although agricultural lands comprise only a small portion of the watershed, they are believed to be significant due to their location as well as practices that occur in these areas which may include land application of manure or chemical fertilizers, and tillage of cropped areas. Barren lands are located mostly in the upper elevations of the watershed are generally considered to have minimal impacts to reservoir loads. TP loads to Recapture Reservoir from diffuse runoff are shown in Table C3.

Table C3. Total phosphorus loads (kg/yr) by land use and landowner to Recapture Reservoir for average annual precipitation year.						
	Landowner					
Land Use	**BLM**	**USFS**	**SITLA**	**Private**	**Total Load (kg/yr)**	**Percent of Total**
Agriculture	0.2	0.2	0.3	14.3	**15.0**	**7**
Urban	0.0	0.0	0.0	0.0	**0.0**	**0**
Forest Land	0.1	76.4	0.0	0.4	**76.9**	**34**
Range Land	0.2	34.9	0.0	1.8	**37.0**	**16**
Pinyon-Juniper	15.6	46.6	2.0	7.1	**71.4**	**32**
Barren	0.0	24.8	0.0	0.1	**24.9**	**11**
Water	0.0	0.0	0.0	0.0	**0.0**	**0**
Total Load (kg/yr)	**16.2**	**182.9**	**2.3**	**23.8**	**225.2**	**100**
Percent of total	**7%**	**81%**	**1%**	**11%**	**100%**	

The following discussion will address BMP recommendations to reduce loading contributed to streams in the Recapture Reservoir watershed from grazing and diffuse runoff.

RECOMMENDATIONS

A list of BMPs that are appropriate for reducing loads from grazing and diffuse runoff are included in Table C4. Recommended management practices include exclusion of cattle from streams (via the installation of fences), filter strips, range planting, and revegetation of stream banks.

Table C4. Recommended BMPs for reducing loads from grazing and diffuse runoff.

NRCS Conservation Practice ID (where applicable)	Description	Cost
382	Fence	$2 / linear foot
614	Offsite watering system	$1.50 / gallon
393	Filter Strip	$250/acre
390	Riparian Herbaceous Cover	$160/acre
550	Range Planting	$170/acre
	Maintain a minimum herbage stubble height of 4-6 inches within riparian areas. Allow adequate time for regrowth of plants in these areas before reuse.	Non-structural
	Limit springtime grazing of herbaceous vegetation to not exceed 60 percent. Limit livestock use from riparian areas when primary forage plants are still in the vegetative state (early growth stage).	Non-structural
	Rest-Rotation grazing. Allow adequate rest for vegetation recovery in pastures and allotments. Consider limiting grazing in pastures containing riparian areas during hot periods when livestock use of riparian areas typically increases.	Non-structural
	Ensure all livestock are removed from each pasture at the end of the specified use period. Recovery of riparian areas is reduced if some animals remain following use period.	Non-structural
	Implement streambank disturbance standards that require a percentage of stream channels to be in a stable condition before grazing is allowed within pastures adjacent to water.	Non-structural
	Manage winter feeding to avoid pastures that contribute direct snowmelt runoff to streams.	Non-structural

Along with direct deposition of manure, cattle can damage streams by trampling and eroding the banks, which serve to widen stream channels, and by removing bank vegetation. This damage leads to shallower flows, increased water temperature, and poorer water quality. Exclusion of cattle from streams prevents such damage. Sheffield et al. (1997) and Line et al. (2000) indicated measured reductions in TP loading of 98 percent and 75 percent, respectively, when livestock were excluded from streams. Line et al. (2000) indicated that some of the reduction in TP loading was likely due to reduced erosion from channel banks and upslope areas as well as filtering of surface runoff by vegetation. Similar conclusions were reached by Sheffield et al (1997) and Owens et al. (1996) who observed reductions in sediment loss of 70 percent and 40 percent, respectively, following livestock exclusion from channel corridors. Exclusion of cattle from streams would require the installation of alternate watering systems, if they are not already in place.

Filter strips, or buffer strips, allow TP loads contributed from runoff to be reduced as it flows though surface vegetation. The amount of TP removed by vegetation is dependent upon the density of vegetation, time of travel, infiltration capacity, and size of soil particles transported by runoff (Allaway 2003). Higher density vegetation (e.g. grass and forb species) serve to increase the time required for surface flows to pass through buffer strips. The infiltration capacity of buffer strips is dependent on vegetation type. Lee et al. (2000) reported that buffers consisting of forbs and large woody plants trapped 21 percent more TP than did buffers comprised of grass species alone. It was assumed that woody plant species provided a greater infiltration capacity than grass species due to their relatively deeper root structure. The larger biomass of woody species in comparison to grass covers is also thought to maintain a greater capacity for uptake of TP. However, Schmitt et al. (1999) found few differences between grass and woody species buffer strips.

It is difficult to make a meaningful comparison between different types of buffer strips due to the many factors that influence removal efficiency, including slope, strip width, and runoff volume. Allaway (2003) presented a summary of buffer strip efficiency and found that one of the most significant factors is buffer strip width. His review noted that buffer strips between 18 feet and 30 feet trap roughly 67 percent of TP and buffers greater than 33 feet or more remove 74 percent TP, on average, from surface runoff volumes.

Closely related to these two practices is restoration of riparian herbaceous cover. Trampling by cattle and removal of riparian vegetation can lead to erosion of stream banks. Estimates of the contribution of stream bank erosion to phosphorus loads vary from 2 percent for non-incised streams (Sonzogni et al. 1980) to 55 percent for incised streams (Zaimes et al. 2004). Excluding cattle, planting buffer strips, and restoring riparian vegetation can stabilize banks, thus reducing phosphorus loads and reducing erosion. As indicated above, some of the TP load reductions realized from exclusion of cattle from streams is likely due to reduced erosion from channel banks.

Diffuse loads from surface runoff can also be reduced by completing activities that promote infiltration and decrease runoff volumes. Vegetation that provides good ground cover, such as bunchgrasses, slows down runoff water, allowing more of it to infiltrate into the ground. Overgrazed land also allows more runoff than properly managed rangeland. Overstocking of grazing allotments can lead to increased soil compaction, which impedes infiltration (McGinty et al. 2000). Consequently managing livestock use in the Recapture Reservoir TMDL study area is important. A Manti-La Sal Forest Plan amendment (US Forest Service 1990) defines Proper Use Criteria for percent use of key species. Meeting these criteria, shown in Table C5, would help maintain adequate vegetative cover on Forest Service allotments in the watershed.

Range planting would allow for the reintroduction or increase of native and desired forage species in grazing allotments. Species that are adapted to grazing, as well as the dry conditions prevalent in San Juan County and much of southern Utah, would be good candidates for this method. A proper mix of forage species would satisfy the needs of cattle while helping to increase infiltration of runoff and filtration of sediments while maintaining adequate ground cover.

Table C5. Proper Use Criteria for grazing in the Manti-La Sal National Forest.	
Uplands (Management System)	**Percent Use of Key Species**
Season Long Use	40-55
Deferred Rotation	45-60
Rest Rotation	55-65
Riparian Areas (Season)	
Spring	50-60
Summer	45-50
Fall	30-40
Source: 1990 Manti-La Sal Forest Plan Amendment.	

It is anticipated that implementation of BMPs designed to remove TP loads from grazing and diffuse runoff (Table C5), will help to maintain or possibly reduce nonpoint source loading. If some of these practices are currently in place, they should maintained. It is recommended that additional efforts be made to apply these practices in all areas of the watershed. Areas that are known to contribute direct surface runoff to Recapture Reservoir as well as segments near the reservoir should be emphasized. In general, the TP removal rate of BMPs listed in Table C4 is considered to be 60 percent from areas where they are not currently in effect , if BMPs are properly implemented and maintained.

Current practices used by the Forest Service which reduce the amount of TP loading caused by grazing include (1) the use of deferred rotation, through which areas are prevented from being grazed in consecutive years, and (2) the creation of a Watershed Protection Area in the northern part of the watershed, above the grazing allotments where Johnson and Recapture Creeks, as well as several of their tributaries, originate. In addition, tree planting activities have taken place in the area affected by the Nizhoni fire in 2002. These efforts will help to reduce processes that contribute TP loads to Recapture Reservoir.

RECREATION

There are several types of recreation that are common in the Recapture Reservoir project area. The reservoir itself offers swimming, boating, and fishing. Other locations in the project area offer camping, hunting, and off-road vehicle use. There is a network of gravel and dirt roads throughout the area. Primitive camping is available, and a USFS campground, Devil's Canyon, is on the eastern boundary of the watershed off of Highway 191. Since most of the land in the project area is publicly owned, access for recreational purposes is open in many places.

There are many road crossings of streams in the watershed, providing an avenue for runoff from roads to enter the system. Road networks serve to concentrate sediment from a large area into one place and can result in a large amount of sediment entering a small, seasonal tributary. Recreation can also decrease vegetation density and diversity, decrease soil infiltration, and increase erosion through dispersed camping and ATV use.

RECOMMENDATIONS

A list of BMPs that are appropriate for maintaining or reducing loading from recreational activities are included in Table C6. Recommended management practices include constructing proper crossings where roads intersect streams and upgrading access roads according to USFS and NRCS standards.

Properly constructed stream crossings would provide for travel needs while not impeding stream flow. Such crossings, with the proper dimensions of width and slope, could reduce erosion and sediment deposition. Since stream crossings are already in place throughout the watershed, this BMP would consist mainly of modifying existing crossings where it is determined to be feasible and beneficial. Runoff water can also be diverted away from streams using diversion ditches. In conjunction with improving stream crossings, upgrading roads in the watershed to meet federal standards for access roads can reduce loading by minimizing erosion and providing proper drainage. Road upgrade methods include building water bars and roadside ditches.

It has been estimated in some watersheds that roads and stream crossings are responsible for 5 – 90 percent of all sediment from forest lands (Sheridan and Noske 2007)(Chang 2006). The ultimate level of sediment loading is dependent upon local factors including flow, soil type, intensity of use. Forest lands comprise about 45 percent of major land cover types in the Recapture Reservoir project area. Few evaluations of the effects of road restoration on TP loading have been published, but it has been determined that increasing the thickness of surface material can reduce surface erosion, as can reducing the amount of road surface draining directly to streams (Roni et al. 2002). Since phosphorus is carried in sediment, reducing the amount of erosion at and near stream crossings can reduce the amount of TP introduced into streams from roads.

Table C6. Recommended BMPs for reducing loads from grazing and diffuse runoff.

NRCS Conservation Practice ID	Description	Cost
578	Stream Crossing	$7/sq. yd.
560	Access Roads	$8/sq. yd.

SUMMARY

The objective of the BMPs recommended in this plan is to reduce or remove those processes that contribute TP loading to Recapture Reservoir. Unit costs have been provided for BMP measures that are applicable to each pollutant source. The total cost of implementation will be dependent upon site specific factors that can be obtained through communication with individual stakeholders. The results of this TMDL assessment indicate that existing loads are marginally above the 0.025 mg/L TP threshold that limits algae growth. Therefore, no load reductions are recommended at this time. However, it is critical that loadings do not increase in order to maintain the existing TP concentrations observed in the Reservoir. It is recommended that a coordinated effort between local stakeholders and agencies responsible for managing public lands take place. This effort should focus on identifying locations where existing BMPS are in place and extend efforts to maintain these practices. It is reasonable to assume that pollutant sources with the most direct influence on existing water quality conditions should be addressed first, followed by those with a lesser influence. A prioritized list of BMPs and water quality improvement measures includes the following:

- Eliminate any existing routes providing direct animal access to the area immediately surrounding Recapture Reservoir including areas below the high water mark. Livestock access to degraded segments of tributary streams should also be eliminated or restricted until viable riparian vegetation communities are established. Utilize offsite watering structures where necessary, to satisfy livestock water demand.

- Implement riparian buffer strips along portions of Recapture Reservoir tributaries. Emphasis should be placed on those areas where grazing and winter feeding has occurred.

- Conduct range planting in sensitive areas to promote forage plants that intercept runoff and promote infiltration. This method should focus on grazed areas where vegetative cover is low and areas of bare ground exist.

This list of BMPs is designed to eliminate or reduce TP loading from areas that significantly contribute direct surface runoff to Recapture Reservoir. Other BMPs recommended in this PIP but not included on this list need to be implemented as well in order to support TMDL endpoints. It is anticipated that by maintaining or implementing the BMPs recommended in this document, that TP loads to Recapture Reservoir will not increase and provide a means for achieving the water quality endpoint and load allocations established by the TMDL for Recapture Reservoir.

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