Utah Department of Environmental Quality
Division of Water Quality
TMDL Section

Newcastle Reservoir TMDL

EPA Approval Date: August 22, 2008

Waterbody ID	Newcastle Reservoir Watershed UT-L-16030006-008
Location	Iron County, Southern Utah
Pollutants of Concern	Low dissolved oxygen Excess total phosphorus
Impaired Beneficial Uses	Class 3A: Protected for cold water fish species and their food chain.
Current Load **Loading Capacity (TMDL)** **Margin of Safety (MOS)**	26.53 kg of total phosphorus per day 12.01 kg of total phosphorus per day Margin of Safety incorporated using conservative assumptions
Wasteload Allocation **Load Allocation**	No Point Sources, 0 kg/day of total phosphorus 12.01 kg of total phosphorus per day (required load reduction of 75% total phosphorus)
Defined Targets/Endpoints	1. Water column dissolved oxygen concentration of at least 4.0 mg/L in at least 50% of the water column 2. Water column dissolved oxygen concentration of at least 6.5 mg/L as a 30-day average. 3. In-reservoir mean chlorophyll *a* concentration of 17 µg/L 4. In-reservoir mean total phosphorus concentration of no more than 0.022 mg/L
Implementation Plan	Reduce in-stream livestock use Rangeland and forest land management throughout watershed Manage roads to minimize soil erosion Manage irrigation water to minimize runoff

Table of Contents

List of Tables

List of Figures

List of Appendices

Foreword

This document represents the TMDL analysis for Newcastle Reservoir located in Southwestern Utah. The overall goal of the TMDL process is to restore and maintain water quality in Newcastle Reservoir and its watershed to a level that protects and supports the designated beneficial uses (secondary contact recreation, cold water game fish, and agricultural water supply).

The TMDL is composed of three components. The subbasin assessment (SBA) was the first step in the Total Maximum Daily Load (TMDL) process for Newcastle Reservoir watershed. The SBA characterizes the watershed (Chapter 2), identifies in-reservoir water quality concerns, applicable water quality criteria and standards, available data and data sources, potential sources of pollutant loading, indicators of impairment, and assesses impairments specific to the reservoir's designated uses (Chapter 3).

The load analysis component of the TMDL process quantifies current loading to the reservoir using the SWAT watershed model, and predicts reservoir response under varying climatic and reservoir management conditions using the BATHTUB reservoir model (Chapters 4 and 5). The load analysis also identifies water quality objectives for the reservoir and load allocations and reductions required to meet water quality standards (Chapter 6). It is important to note that even if water quality within Newcastle Reservoir is found to be impaired and steps are taken to improve it, correction of water quality problems will not happen overnight. Successful implementation of the final water quality management plan (Chapter 7) will require a coordinated effort of planning and implementation of best management practices between concerned government agencies and landowners in the watershed over the next several years.

This TMDL was developed by SWCA Environmental Consultants under the direction of the Utah Department of Environmental Quality (UDEQ), Division of Water Quality and is consistent with Utah Code Title 19, Chapter 5, Water Quality Act, 19-5-104 (powers and duties of board), which identifies the requirement for the development and implementation of TMDLs and/or equivalent processes.

Acknowledgments

Staff at SWCA gratefully acknowledge the time and effort dedicated by so many individuals and organizations, whose help and support have been indispensable. Their continuing support is very much appreciated and is, indeed, critical to the success of this project.

We would like to specifically acknowledge the efforts of the USDA Forest Service, Dixie National Forest, Newcastle Irrigation Company, Pinto Irrigation Company, Grass Valley Irrigation Company, Utah Division of Water Quality, Utah Division of Wildlife Resources, Utah Department of Agriculture, Utah Department of Water Resources, Utah Department of Water Rights, Utah Geological Survey, U.S. Geological Survey, USDA Natural Resources Conservation Service, and Iron County for their contributions of important background information and their assistance with data location and interpretation for this project.

Preparers and Contributors

Preparers

Doug Davidson, SWCA, Watershed Modeling and Implementation Plan

Tonya Dombrowski, SWCA, Water Quality Analysis and Impairment Assessment

Benjamin Gaddis, SWCA, Technical Writing and Editing

Erica Gaddis, SWCA, Water Quality Analysis, Reservoir Modeling, and Load Analysis

Eric McCulley, SWCA, Soils and Geology

Brian Nicholson, SWCA, Watershed Characteristics and Hydrology

Jan Reed, SWCA, Technical Writing

Tyson Schriener, SWCA, GIS

David Reinhart, SWCA, GIS

Contributors

Mason Jones

Mike Ottenbacher

1 INTRODUCTION

This document represents the TMDL analysis and implementation plan for the Newcastle Reservoir watershed as required by law.

The Federal Water Pollution Control Act (FWPCA) is the primary federal legislation that protects surface waters such as lakes and rivers. This legislation, originally enacted in 1948, was further expanded and enhanced in 1972; at this time it became known as the Clean Water Act (CWA). This act has been and continues to be subject to change as new information and a more complete understanding of the natural system and our impacts (both positive and negative) are identified. A more thorough discussion of the CWA can be found in *The Clean Water Act: An Owners Manual* (Elder et al. 1999).

The main purpose of the CWA is the improvement and protection of water quality through restoration and maintenance of the physical, chemical, and biological integrity of the nation's waterways. The CWA provides a mechanism to evaluate the status of the nation's waters, designate beneficial uses for specific waterbodies, and establish criteria for water quality to protect those uses.

In addition, section 303(d) of the CWA requires that every two years, each state submit a list to the U.S. Environmental Protection Agency (EPA) identifying waters throughout the state that are not achieving state water quality standards in spite of the application of technology-based controls required by National Pollutant Discharge Elimination System (NPDES) permits. The waters identified on the 303(d) list are known as **water quality limited**. For every waterbody that is water quality limited, the CWA requires development of a TMDL for all pollutants responsible for the impairment of its designated beneficial uses. Once the state has identified the pollutant load discharged from point and nonpoint source activities, controls can be implemented to reduce the daily load of pollutants until the waterbody is brought back into compliance with water quality standards. Once developed, TMDLs are submitted to the EPA for approval. The Utah Department of Environmental Quality (UDEQ) is directed by Utah Code Title 19, Chapter 5, Water Quality Act, 19-5-104 (powers and duties of board), to develop TMDLs.

1.1 THE TOTAL MAXIMUM DAILY LOAD PROCESS

Development of TMDLs to meet CWA standards involves scientific study of data from impaired waterbodies to determine existing pollution loads and to set maximum allowable pollution loads for each waterbody.

A pollution **load** is the amount of pollution contributed to a waterbody by a single source such as a wastewater treatment plant or by a group of sources such as pollution from all developments or agricultural fields in a watershed. **Load allocations** are developed to define an acceptable maximum pollution load that describes the amount of an identified pollutant that a specific stream, lake, river, or other waterbody can "accommodate" without violating state water quality standards.

When pollution loading reaches the maximum load allocation, it reaches the stream's **loading capacity**. The loading capacity takes into account seasonal variations, natural and background loading, and a margin of safety (MOS). Once loading capacity is determined, pollutant sources are considered, including both point sources and nonpoint sources, as described in the following section. Pollution that occurs in excess of the loading capacity violates CWA standards and initiates the development of a plan to reduce pollutant loads. This plan is called a TMDL.

A **TMDL** is a planning document that weighs existing loads of a particular pollutant in a watershed against allowable load allocations, creating a budget for pollutant loading. The **TMDL process** consists of two parts:

- Evaluating the available data from 303(d) listed waterbodies to determine point and nonpoint source pollution loads
- Using the data to set maximum allowable loads from each of these sources

Essentially, TMDLs comprise the basis for watershed-based plans to restore designated beneficial uses in water quality limited waterbodies. Designated beneficial uses may include domestic water supply, recreational use, fisheries and agricultural uses. The TMDL plans not only designate load allocations, but identify causes of impairment to designated beneficial uses and estimate reductions in pollutant loads necessary to meet water quality standards within a specified time. Ultimately, the responsibility for improving water quality lies with everyone who lives, works, and/or recreates in the watershed of an impaired waterbody.

1.1.1 Point Sources

Point sources of pollution such as wastewater treatment plants typically involve pipes that convey discharges directly into a waterbody. A point source is simply described as a discrete discharge of pollutants, as through a pipe or similar conveyance. A technical definition exists in federal regulation at 40 CFR 122.2. Point sources are grouped into a waste load allocation (WLA), which will become part of the TMDL equation.

1.1.2 Nonpoint Sources

Nonpoint sources such as roads, farmland, residential landscapes, and construction sites contribute pollution diffusely through runoff. Pollution may result from sources and activities such as livestock grazing, all-purpose forest roads, leaking underground storage tanks, septic systems, fertilizers and pesticides applied to residential yards and agricultural fields, construction sites, stream channel alteration and other diffuse sources. Nonpoint sources are grouped into a load allocation (LA), which will become part of the TMDL equation.

1.1.3 Margin of Safety

Nonpoint sources, grouped as LA, and point sources, grouped as WLA, are combined with a Margin of Safety (MOS) when designating the total pollutant load capacity or budget. The MOS accounts for uncertainty in the loading calculations. Combined, the loading capacity equation is:

Loading capacity: **TMDL = WLAs + LAs + Margin of Safety**

1.1.4 TMDL Scope

Once all point and nonpoint sources are accounted for, including the MOS, TMDLs are drafted to allocate the total pollutant loading among the various sources in a manner that meets water quality standards. The objective of TMDLs is to reduce loading from all point and nonpoint sources to restore the designated beneficial uses of a waterbody.

The TMDL does not specify how sources must attain their particular load allocation. The TMDL does not dictate best management practices for a source or otherwise tell the source how to meet the reduction goal.

1.1.5 Implementation Plan

Point source wasteload allocations (WLAs) are implemented through an existing regulatory program under the federal CWA called the National Pollutant Discharge Elimination System (NPDES) permit program (CWA Section 402). The Environmental Protection Agency has delegated authority to Utah to administer its own water quality regulatory permit program (UPDES permits). These permits set effluent quality limitations and require implementation of best available technologies that may include specific best management practices already established by the EPA through regulation.

The load allocation (LA) covers nonpoint sources and therefore is not covered by any specific regulatory program. Rather, the load allocation is usually implemented through incentive-based programs, volunteer efforts, or government-funded projects. Provided that a viable trading framework is in place, pollutant trading is allowed between or within the LA and the WLA categories, but the MOS cannot be traded.

In most cases, pollution load data already exists for most permitted point sources through the NPDES permitting process. A similar level of data density is seldom available for nonpoint sources. Therefore, the TMDL process must develop load calculations for nonpoint sources of pollution and for natural sources of pollution. In many circumstances, nonpoint source contributions are broken down into additional categories such as agriculture, development, forestry, or mining.

Because identifying specific nonpoint sources of pollution for an entire watershed is practically impossible, data are rarely collected on individual nonpoint sources that contribute pollutant loading to a waterbody. Instead, most TMDLs focus on estimating the cumulative or combined contribution of all nonpoint sources.

1.2 Why Should TMDLs Be Written?

The primary purpose of TMDLs is to accurately estimate the contribution of point and nonpoint sources to total pollutant loads in a waterbody. In Utah, as in many other states, the process of identifying waterbodies for TMDL plans, developing the proper methods to calculate loads from all pollutant sources, and implementing programs to reduce loads in order to meet water quality goals is ongoing. Completing TMDLs for all waterbodies may take years; some will be completed more quickly than others depending on the cause of impairment and the degree to which it is impaired.

Over the past 25 years, pollution control efforts under the CWA have focused on controlling point sources of pollution through the NPDES permitting process. While water quality has improved in many instances, the goals of the CWA have not been met in a number of waterbodies. Data from the EPA suggest that nonpoint sources are now the largest source of pollution in streams and lakes (EPA 2000a).

The implementation of TMDLs should help identify specific links between various sources of pollutants and their aggregate load in waterbodies. The EPA expects that the data collected as part of this process will help local, state, and federal agencies focus and improve their efforts to restore impaired waters.

1.3 WHO IS RESPONSIBLE FOR WRITING TMDLS?

The federal CWA grants individual states the first opportunity to establish TMDLs. In Utah, the bulk of the TMDL work is done by the Utah Department of Environmental Quality (UDEQ) and submitted to the EPA for their approval. However, if the states do not set TMDLs to the EPA's satisfaction, then the EPA is required to do so [CWA Section 303(d)].

Both federal and state statutes require the opportunity for public participation in the TMDL process. Participants may include permitted facilities, affected landowners, regulatory and other governmental agencies, local governments, public interest groups, and concerned citizens. Watershed associations and similar local organizations are encouraged to foster communication, planning, and consensus among those concerned.

1.4 WHAT SPECIFIC ELEMENTS SHOULD A TMDL INCLUDE?

Generally, TMDLs generally consist of three major sections:

- Subbasin assessment
- Loading analysis
- Implementation plan(s)

1.4.1 SUBBASIN ASSESSMENT

Subbasin assessments are usually conducted at the watershed scale. A subbasin assessment describes the affected area, the water quality concerns and status of designated beneficial uses of individual waterbodies, nature and location of pollution sources, and a summary of past and ongoing management activities.

1.4.2 LOADING ANALYSIS

A loading analysis provides an estimate of a waterbody's pollutant load capacity and outlines TMDL allocations in accordance with EPA regulations (40 CFR 130.2). The sum of LAs and WLAs must meet the load capacity; with a portion of the load reserved for the MOS. Minor nonpoint sources may receive a lumped allocation.

Generally, a loading analysis is required for each pollutant of concern. But it is recognized that some listed pollutants are really water quality problems that result from other pollutants. For example, habitat may be affected by sediment or by dissolved oxygen from nutrients that cause nuisance aquatic growths. In such cases, one listed stressor may be addressed by the loading analysis of another.

While loading analyses are intended to provide a quantitative assessment of pollutant loads, federal regulations allow that "loads may be expressed as mass per unit time, toxicity, or other appropriate measures" [(40 CFR 130.2(I)]. In many cases, less data will be available than may be considered optimal for loading analysis. This cannot delay TMDL development. Federal regulations also acknowledge that "load allocations are best estimates of the loading, which may vary from reasonably accurate estimates to gross allotments" [(40 CFR 130.2(g)].

A complete loading analysis lays out a general pollution control strategy and an expected time frame in which water quality standards will be met. For narrative criteria (criteria based on a qualitative description rather than quantifiable criteria), the measure of attainment of water quality standards is full support of the waterbody's designated beneficial uses. Long recovery periods (greater than five years) are expected for TMDLs dealing with nonpoint sediment or temperature sources. Interim water quality targets are recommended in these instances. Along with the load reductions, these targets set the sideboards within which specific actions are scheduled in the subsequent implementation plan.

1.4.3 Implementation Plan

The implementation plan is guided by the TMDL and provides details of actions needed to achieve load allocations, a schedule of those actions, and follow-up monitoring to document progress or provide other desired data. Implementation plans specify local actions that will lead to the goal of full support of designated beneficial uses. Important elements of these plans are:

- Implementation of actions based on the load allocations identified in the TMDL
- An estimated time by which water quality standards are expected to be met, including interim goals or milestones as deemed appropriate
- A schedule specifying, what, where, and when actions to reduce loads are to take place
- Identification of who will be responsible for undertaking each planned action
- A monitoring plan to refine the TMDL and/or document attainment of water quality standards

The exact pollutant load for nonpoint source pollutants is complex and can vary with weather conditions. Therefore, a TMDL with phased implementation that identifies interim milestones for a load allocation is necessary, with further monitoring to gauge the success of management actions in achieving load reduction goals and the effect of actual load reductions on the water quality in the watershed.

2 CHARACTERIZATION OF WATERSHED

Under section 303(d) of the CWA, Newcastle Reservoir has been identified as water quality limited due to low dissolved oxygen and excess phosphorus loading to the reservoir from the surrounding watershed. The State of Utah has designated the beneficial uses of the reservoir as secondary contact recreation (2B), cold water game fish and the associated food chain (3A), and agricultural water supply (4). The cold water game fish designated use (3A) was identified as partially impaired on the State of Utah's 2006 303(d) list. The secondary contact recreation and agricultural water supply designated uses were listed as being fully supported on this same list.

Newcastle Reservoir is located in the northern foothills of the Pine Valley Mountains in southwestern Utah, approximately two miles south of Newcastle and 30 miles west of Cedar City, at an elevation of 6,020 feet (Figure 2.1). The reservoir shoreline is privately owned by the Newcastle Irrigation Company with unrestricted public access. The watershed is predominately under federal management by the Bureau of Land Management (BLM) and U.S. Forest Service (USFS). A smaller proportion is in private property holdings in Pinto and dispersed "ranchettes" in the Little Pinto Creek drainage near Old Irontown. The watershed delineated in this subbasin assessment includes both the Newcastle Reservoir watershed and a portion of an adjacent subbasin in Grass Valley that has been hydrologically connected to the Newcastle Reservoir through a transbasin diversion. The characteristics of the Grass Valley subbasin were deemed to be important in characterizing pollutant loading into Newcastle Reservoir.

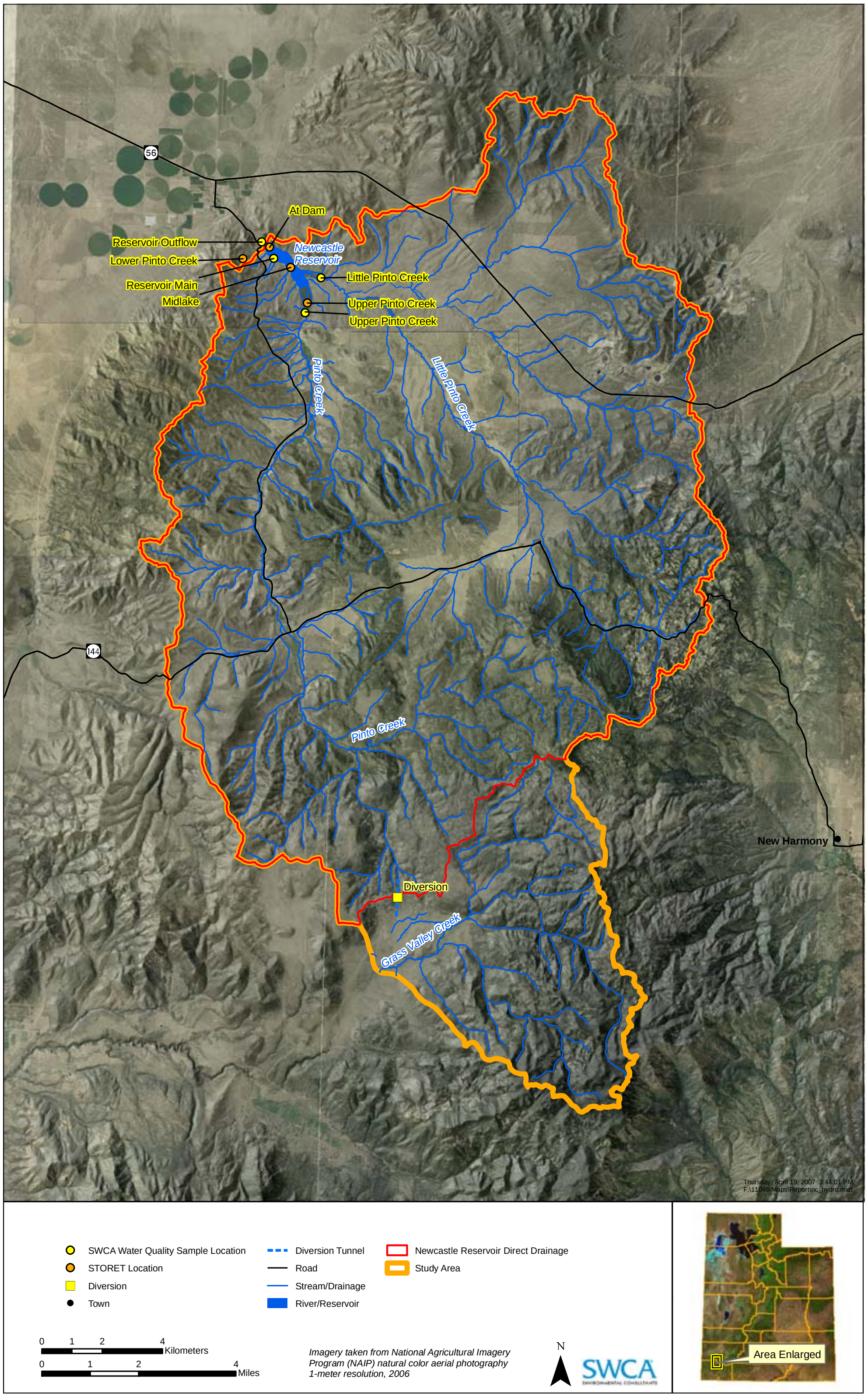


Figure 2.1. Watershed boundary and hydrologic features map.

The major land use in the watershed is livestock grazing. Sediments, nutrients, and heavy metals are the major pollutants. There are no point source pollution sources in the watershed. Major tributaries to the reservoir are Pinto Creek and Little Pinto Creek. The outlet of the dam is connected to a pipeline that delivers irrigation water to croplands in the summer months. The reservoir has seen increasing recreational usage in recent years due in part to the growing population of southern Utah. The Utah Division of Wildlife Resources stocks Newcastle Reservoir with Bear Lake cutthroat trout, wipers, and catchable rainbow trout. The reservoir also contains smallmouth bass, golden shiners, crappies, sunfish, and crayfish. A Fish Consumption Advisory was issued on April 23, 2007 due to elevated mercury levels for rainbow trout from the Newcastle Reservoir.

2.1 Physical and Biological Characteristics

At maximum volume the reservoir stores approximately 5,300 acre-feet of water and has a maximum depth of 23.5 m. Before the capacity of the reservoir was expanded in the 1970s, the maximum capacity of the reservoir was 3,839 acre-feet (personal communication, Mason Jones, March 26, 2007). The earth-fill dam that forms the reservoir was completed in 1956 and rises to a structural height of 83 feet (Utah Division of Water Rights 2006a). The reservoir is used for storing irrigation water and recreation. Anecdotal information indicates that Newcastle Reservoir has been filled to capacity (5,300 acre-feet) most years and has not been drawn down to the 500 acre-feet conservation pool in any of the last 10 years (personal communication, between Mason Jones, Newcastle, UT and Erica Gaddis, SWCA , March 26, 2007).

The Utah Division of Water Rights accumulated 18 reservoir elevation data points from April 22, 2003 to May 04, 2005 (Table 2.1). Reservoir elevation levels can be correlated to surface area and reservoir volume. The elevation data collected for Newcastle Reservoir from 2003–2004 reflects primarily low water conditions.

Augmenting the flow into Newcastle Reservoir are the Grass Valley Creek headwaters, connected to Pinto Creek via a transbasin diversion. Originally draining south into the Santa Clara River, this 15,043-acre (6,088 hectares [ha]) subbasin, at an elevation of over 8,000 feet (2,440 meters msl), is diverted through a mile-long tunnel completed in 1917, which discharges into the Pinto Creek drainage.

Reservoir water retention times vary widely due to limited control over inflow and dam spillover. During spring runoff in high flow years such as 2005, reservoir retention times may last three days or fewer. In low flow conditions (dry years and late summer seasons) retention times may extend to several months. The reservoir fills through inflows from Pinto Creek, Little Pinto Creek, and water diverted from Grass Valley during spring runoff. In most years the reservoir is filled by mid-March, when inflow volume decreases precipitously and may cease altogether in low water years. Outflow rates are determined by irrigation use and the associated water rights downstream of the reservoir.

The watershed that drains naturally into Newcastle Reservoir consists of approximately 85,159 acres (34,463 ha) of pinyon-juniper forest, an additional 15,043 acres (6,088 ha) is included in this characterization to account for the transbasin diversion from Grass Valley. Slopes within the entire watershed average 12 degrees and range from 0–84 degrees. Moderately steep terrain (slopes ranging from 8–15 degrees) comprises tertiary volcanics that descend to alluvium-filled floodplains and valleys (Figure 2.2). The reservoir spillway elevation is 6,020 feet (1,835 meters msl) (Utah Division of Water Rights 2006a); the highest point in the watershed is Rancher Peak, at 8,788 feet (2,679 meters msl).

Table 2.1. Newcastle Reservoir Elevation and Volume Data Summary

Date	Elevation (feet)	Volume (in acre-feet)	Acre-Feet Used	Notes
2001	--	--	3900	
2002	--	--	995	Kern River used 45.
4/22/2003	5993	1507	--	
5/28/2003	5993	1531	--	
6/25/2003	5990	1297	--	
7/14/2003	5988	1124	--	
2003	--	--	807	
3/6/2004	5989	1191	--	
5/15/2004	5998	1963	--	
7/3/2004	5994	1609	--	
2004	--	--	1109	
1/11/2005	6013	3892	--	
1/15/2005	6013	3892	--	
2/10/2005	6020	5301	--	
2/18/2005	6020	5301	--	
2/25/2005	6020	5301	--	
3/4/2005	6020	5301	--	
3/12/2005	6020	5301	--	
3/25/2005	6020	5301	--	
4/11/2005	6020	5301	--	
4/20/2005	6020	5301	--	
5/4/2005	6020	5301	--	
2005	--	--	3787	Dam ran over until 6/25/05.
2006	--	--	2769	Dam ran over until 5/13/06.
Source: Utah Division of Water Rights Data from the records of Mason Jones, 2001–2006.				

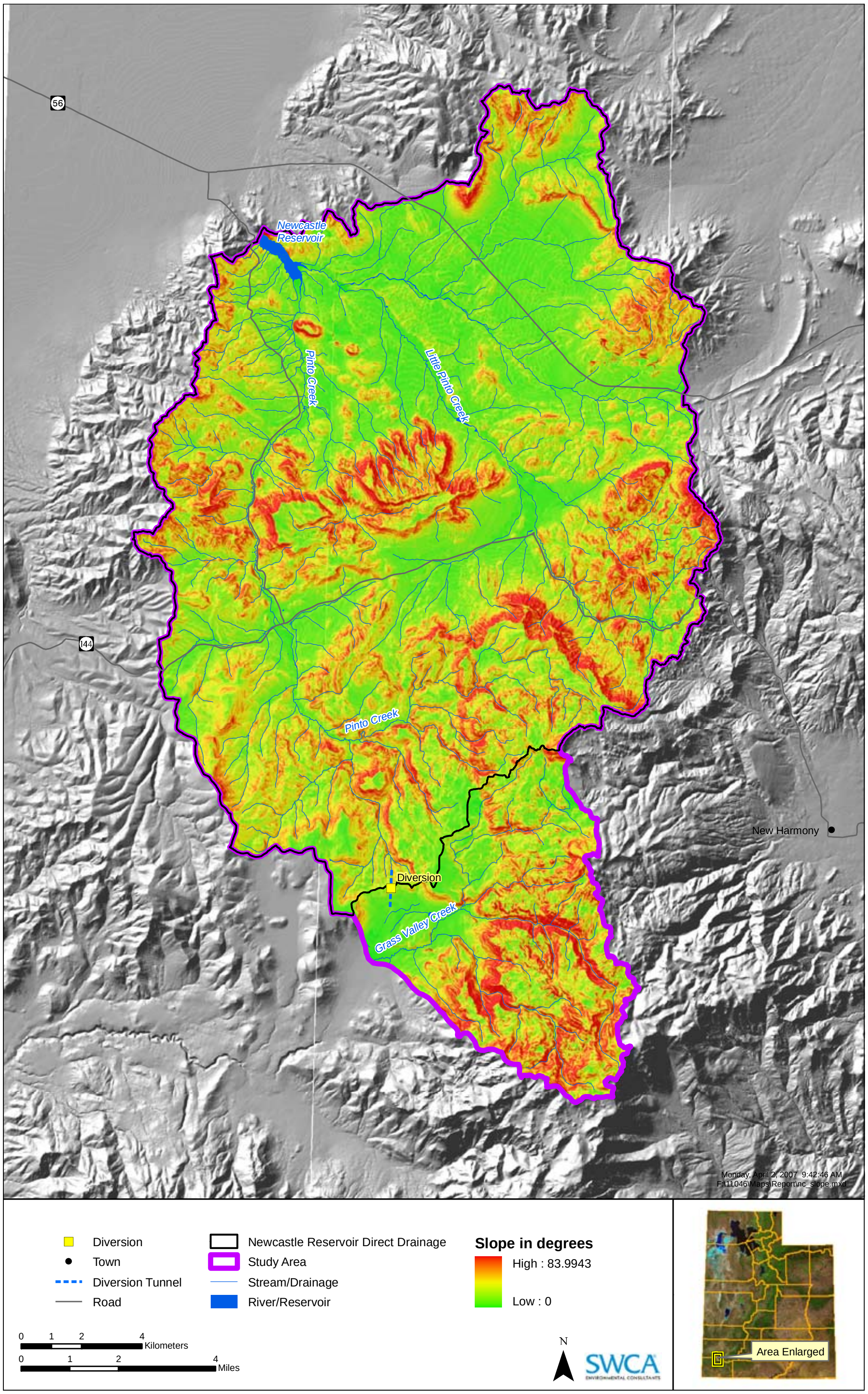


Figure 2.2. Slope map of Newcastle Reservoir watershed.

2.1.1 CLIMATE

The climate of the Newcastle Reservoir watershed study area is hot and dry in the summer and cold and dry in the winter. Precipitation is bimodal (peaking in March and August) with intense, brief summer storms and mild, enduring winter storms. Much of the water in the reservoir is derived from snowmelt runoff from high elevations and upstream reaches of tributaries.

Climate data are not available directly from the reservoir. However, two long-term climate sites maintained by the Western Regional Climate Center (WRCC) are available near the watershed boundaries, the Enterprise/ Beryl Junction site, and the New Harmony site.

The Enterprise/Beryl Junction WRCC site is located at an elevation of 5,170 feet (1,576 meters), approximately nine miles (14.5 km) west-northwest of the reservoir. Reported conditions at the site are assumed to accurately represent conditions at the reservoir site. The site has been in operation since July 1948 to the present, and data are available through December of 2005 (WRCC 2006). Average and extreme minimum and maximum temperatures recorded over the period of record for the Enterprise/Beryl Junction WRCC site are displayed in Table 2.2 and Figure 2.3. Average total monthly precipitation for this site is displayed in Table 2.3 and Figure 2.3.

Table 2.2. Enterprise/Beryl Junction Air Temperature Data Summary

	Monthly Average			Extreme High (°F)		Extreme Low (°F)	
	Max (°F)	Min (°F)	Average (°F)				
Annual	66	30	48	104	Jul 1960	-34	Dec 1990
Winter	44	15	30	77	Feb 1986	-34	Dec 1990
Spring	65	28	47	98	May 2003	-8	Jan 1962
Summer	87	47	67	104	Jul 1960	25	Jun 2001
Fall	67	30	48	98	Sep 1955	-13	Nov 1964
Winter = December, January, and February; Spring = March, April, and May; Summer = June, July, and August; Fall = September, October, and November. (WRCC data, period of record = 1948–2006)							

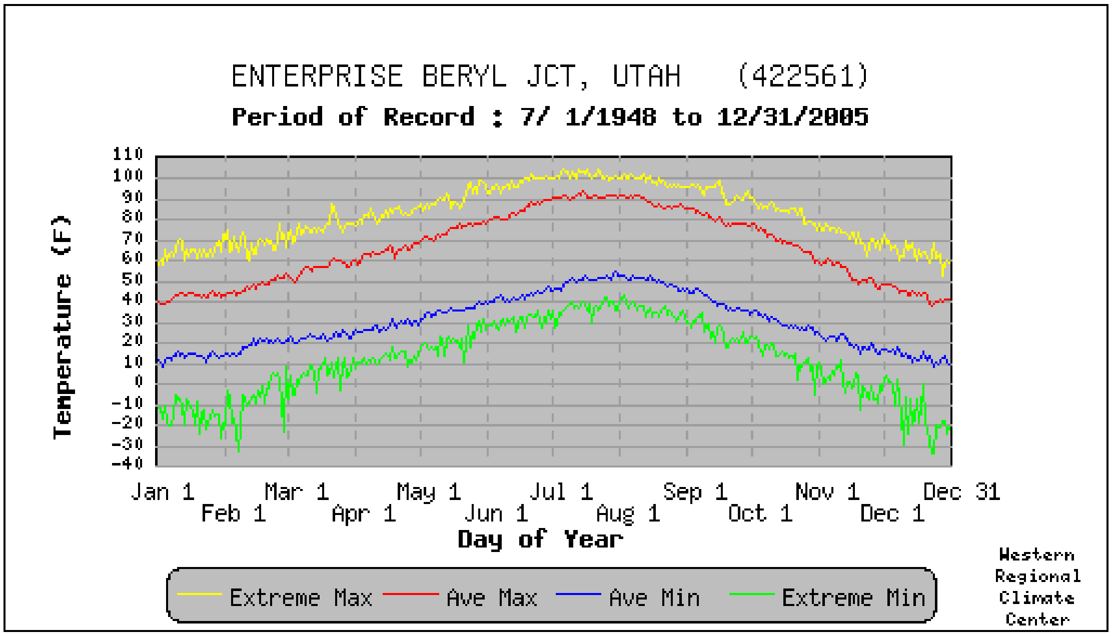
Table 2.3. Enterprise/Beryl Junction Precipitation Data Summary

	Average (inches)	High (inches)		Low (inches)	
Annual	9.9	16.0	1978	5.6	1966
Winter	2.2	7.0	1993	0.18	1977
Spring	2.6	6.9	1978	0.80	1972
Summer	2.6	6.9	1968	0.84	1978
Fall	2.5	5.0	1963	0.29	1995
Winter = December, January, and February; Spring = March, April, and May; Summer = June, July, and August; Fall =					

September, October, and November. (WRCC data, period of record = 1948–2006)

Data gathered from the Enterprise/Beryl Junction WRCC site represent the northwestern end of the watershed and may not compare fully with conditions in the southeastern areas, so additional data were collected from the WRCC site located near New Harmony.

The New Harmony WRCC site is located at an elevation of 5,306 feet (1,617 meters), approximately 17 miles (27.4 km) to the southeast of the reservoir; it is representative of the topography and elevation of much of the Newcastle Reservoir watershed. The site has been in operation since July 1948 to the present, and data are available through December 2005 (WRCC 2006). Average and extreme minimum and maximum temperatures recorded over the period of record for the New Harmony site are displayed in Table 2.4 and Figure 2.4. Average total monthly precipitation for the New Harmony site is displayed in Table 2.5 and Figure 2.4. While the observed temperatures for the Enterprise/Beryl Junction and New Harmony WRCC sites describe a similar range, annual precipitation is approximately twice as high at the New Harmony site, the majority of which occurs during the fall and winter months.



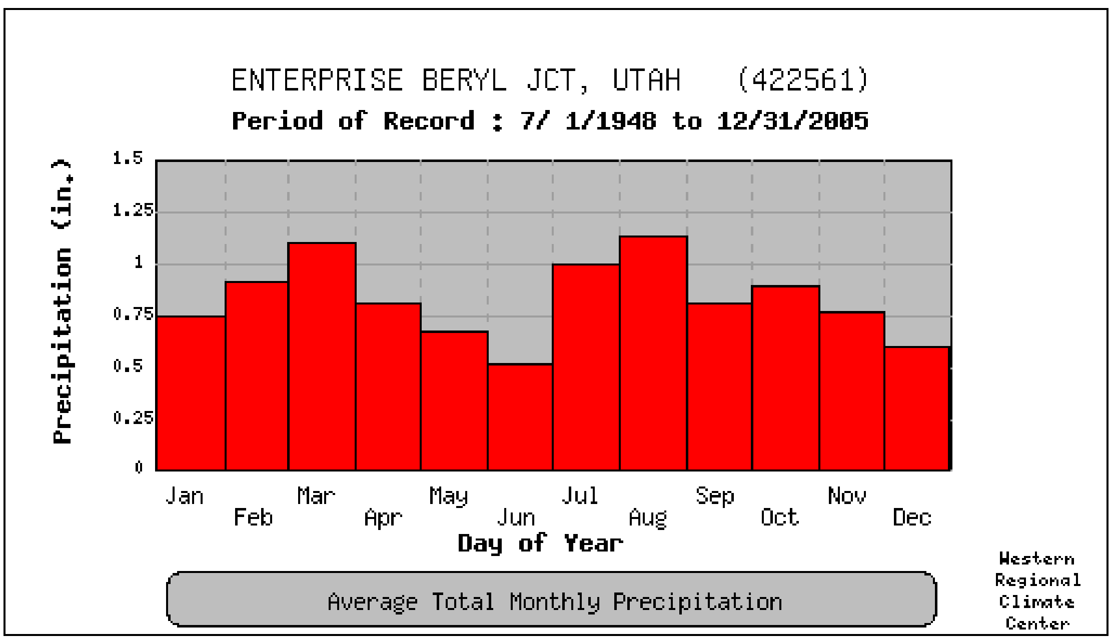


Figure 2.3. Average monthly air temperature conditions and precipitation data at the Enterprise/Beryl Junction meteorological site, Utah (data from WRCC 2006).

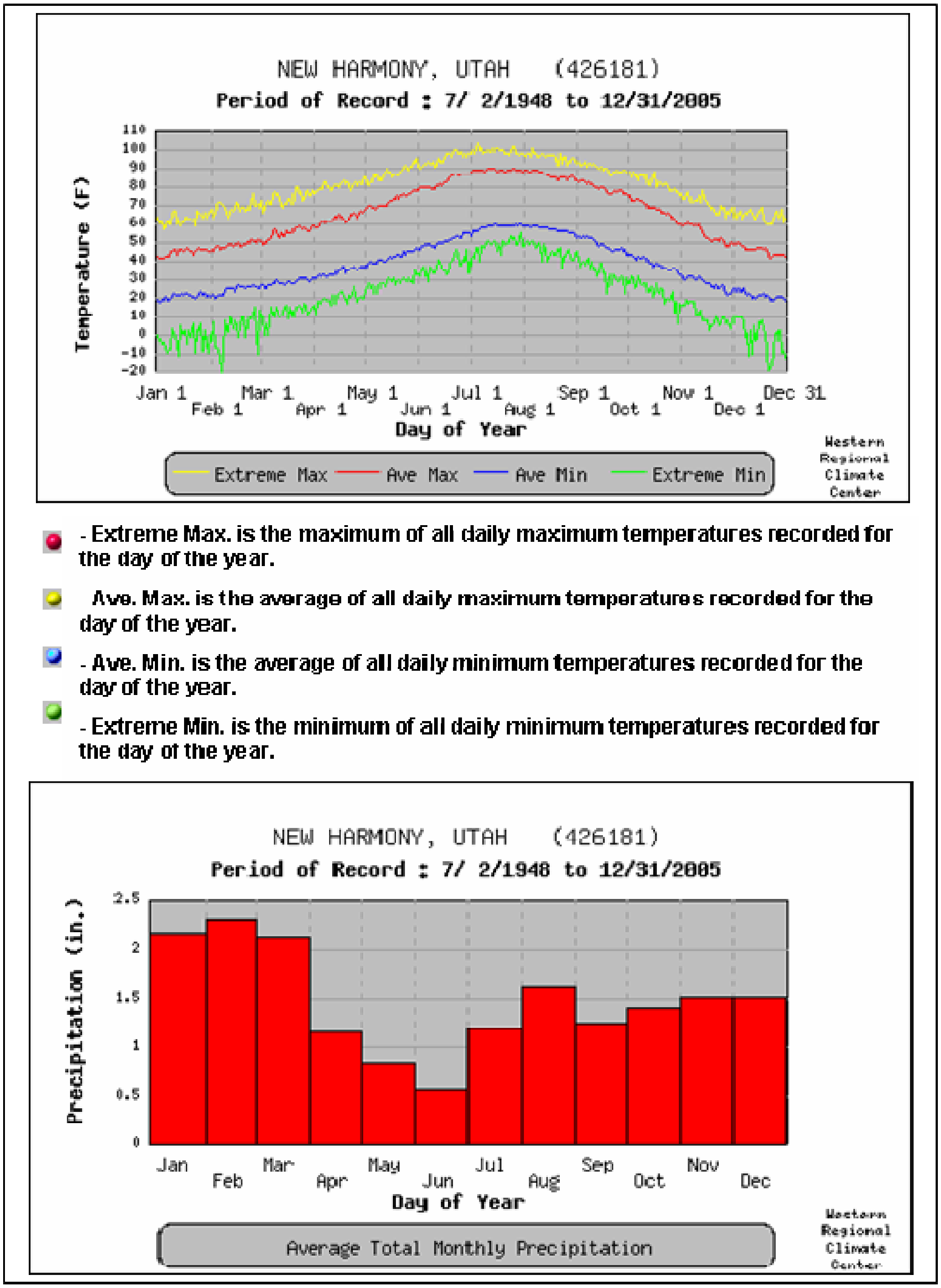


Figure 2.4. Average monthly air temperature conditions and precipitation data at the New Harmony meteorological site, Utah (data from WRCC 2006).

Table 2.4. New Harmony Air Temperature Data Summary

	Monthly Average			Extreme High (°F)		Extreme Low (°F)	
	Max (°F)	Min (°F)	Average (°F)				
Annual	66.0	37.9	51.9	104	July1985	-20	Feb 1989
Winter	46.6	22.4	34.5	76	Feb 1986	-20	Feb 1989
Spring	63.5	35.0	49.2	95	May2003	0	Mar 1966
Summer	86.2	55.4	70.8	104	July 1985	29	June1982
Fall	67.6	38.7	53.1	94	Sept 1955	3	Nov 1964

Winter = December, January, and February; Spring = March, April, and May; Summer = June, July, and August; Fall = September, October, and November (WRCC data, period of record = 1948–2006).

Table 2.5. New Harmony Precipitation Data Summary

	Average (inches)	High (inches)		Low (inches)	
Annual	17.6	36.6	1978	7.40	2002
Winter	5.9	18.1	1969	0.77	1961
Spring	4.2	11.3	1978	0.31	1955
Summer	3.3	9.0	2005	0.46	2002
Fall	4.2	15.6	2004	0.17	1959

Winter = December, January, and February; Spring = March, April, and May; Summer = June, July, and August; Fall = September, October, and November (WRCC 1948–2006).

High-elevation meteorological data are available from the Long Flat SNOTEL (snow telemetry) site located on the extreme eastern edge of the watershed, about 16 linear miles (25.8 km) from the reservoir. The SNOTEL site elevation is approximately 8,000 feet (2,438 meters) and is assumed to be characteristic of climate conditions in the higher elevations within the watershed.

Station data indicate that in the past 10 years, the average annual precipitation is 21.4 inches (53.6 cm) with a minimum of 8.9 inches (22.6 cm) recorded in 2002 and maximum of 38.5 inches (97.8 cm) falling in 2005 (NRCS 2006a). Most precipitation falls in the spring (March, April, and May) with periodic rain-on-snow events occurring in the early season (USFS 2005). The area is also subject to high-intensity thunderstorms in the summer. Mean monthly high temperatures at the SNOTEL station from 1997–2006 range from 40.6°F (4.8°C) in December to 75.7°F (24.3°C) in July, with a frost-free season between 120 and 140 days.

The Newcastle Reservoir watershed has experienced drought for much of the last five years, with extremely dry conditions occurring during the summer of 2002, when the Palmer Drought Severity Index (PDSI) reached near-record severity based on the last 100 years of instrumental data (NCDC 2004). These dry conditions have resulted in low flow conditions for the reservoir and adjacent areas.

2.1.2 HYDROLOGY

Watershed hydrology includes both surface and groundwater characterization, in relationship to natural precipitation patterns and management. The hydrology of the Newcastle Reservoir watershed has been modified by a transbasin diversion, the impoundment of water in the reservoir itself, and the diversion of water for irrigation both upstream and downstream of the reservoir.

2.1.2.1 Surface Water Hydrology

Limited hydrological data exist for this study area. The two perennial streams, Pinto Creek and Little Pinto Creek, do not currently have active stream gages. The only known stream gage, U.S. Geological Survey stream gage (09408500), was maintained on Pinto Creek between 1960–1995, approximately 500 yards (457 meters) downstream from the Grass Valley diversion tunnel outlet (USFS 2005; USGS 2007). Review of available flow records shows that the transbasin diversion typically contributes water to the south fork of Pinto Creek during runoff events, such as spring snowmelt or winter rain-on-snow events (USFS 2005).

While an estimate of the quantity of water diverted for irrigation is not available, diversions begin on March 15, after water from the transbasin diversion is impounded in the reservoir (personal communication, Mason Jones, March 26, 2007). Accordingly, upstream irrigators such as the Pinto Irrigation Company are free to utilize their water rights following this date. During low and medium water years, the diversion of water upstream of the reservoir can result in little or no inflow throughout the irrigation season and stagnant conditions in the reservoir.

The perennial flow of Pinto Creek begins downstream of the transbasin diversion from springs located in T38S, R14W, NW corner of Section 19 (USFS 2005). Within the watershed, surface water is diverted for irrigating grass hay and pasture in the valley bottom. Irrigation water either infiltrates into alluvium or becomes surface return flow returning to Pinto Creek down slope.

Within the higher elevations of the watershed, periodic spring rain-on-snow events result in high stream flows. Records maintained by USFS document one such event on December 24, 1971, when 3.49 inches (8.9 cm) of rain fell in a four-day period. Approximately 250 cfs flowed under Pinto Bridge near the town of Pinto, 74 cfs of that contributed by the transbasin diversion.

A hydrologic model has been developed to simulate flow in the Newcastle Reservoir watershed. The Soil and Water Assessment Tool (SWAT) model used in this study is described in Section 4, along with the water balance results.

2.1.2.2 Groundwater Hydrology

Groundwater within the Newcastle Reservoir watershed can be categorized as natural groundwater or irrigation associated recharge. Natural groundwater refers to groundwater that is present due to geological and hydrological processes. Irrigation associated recharge is irrigation water that percolates below the crop root zone or seeps below earthen ditches and canals to recharge the shallow groundwater aquifer.

Little information exists on the depth and extent of groundwater within the watershed. The limited information available comes from the Division of Water Rights online "point of diversion" database. Depth of water in wells associated with a water right and used for irrigation, stock watering, or domestic water range from 3–111 feet (0.9-34 meters) in the vicinity of Pinto.

Water pumped for irrigation and domestic use near Old Irontown in the Little Pinto drainage range in depth from 18–100 feet (5.5-30.5 meters). On a watershed scale, groundwater within the watershed is likely shallow and feeds Pinto Creek and other springs in the area. The majority of the groundwater likely flows as interflow and through-flow in shallow alluvial deposits (less than 30m deep). Irrigation recharge may raise local groundwater levels in the vicinity of irrigation ditches.

Topographic maps indicate the presence of springs within the watershed, and residents claim that a spring located immediately upstream of the dam was used as a source of drinking water before the dam was constructed. This spring was capped when dam construction began; water from the spring reportedly had a strong sulfur smell and taste and was not viewed as optimal drinking water. Extensive mineralization, exemplified by the Iron Mountain ore deposits, has presumably made groundwater development in the watershed untenable due to natural heavy metal content. Most of the watershed is composed of igneous deposits, which are known to be poor groundwater producers.

The Newcastle Reservoir watershed is in the recharge area of the principal basin-fill aquifer in the Beryl-Enterprise Area. The aquifer consists of lacustrine and interbedded alluvial-fan deposits. Groundwater exists in both the unconsolidated deposits and the fractured bedrock. Total dissolved solids in the aquifer below Newcastle Reservoir derive from bedrock and make up a component of the recharge area of the aquifer. The water table in this aquifer is declining due to large withdrawals compared with recharge rates (Thomas and Lowe 2007).

2.1.3 Geology and Soils

2.1.3.1 Geology

The Newcastle Reservoir watershed lies within the Tonoquints Volcanic Province of the Basin and Range-Colorado Plateau transition zone, a formation of crystalline igneous rocks of volcanic origin. Erosion results in deeply incised valleys that cut through the extrusive volcanic deposits to expose a preexisting topography of Paleozoic and Mesozoic sedimentary rocks.

The headwaters of Pinto Creek are located within the Pine Mountains, Harmony Mountains, and the eastern slope of Iron Mountain, all remnants of a large intrusive-extrusive body of monzonite porphyry (Stokes 1986). The Pinto Creek Basin is located entirely within this province, which covers approximately 7,500 square miles of southwestern Utah. Local lithology is predominantly composed of intrusive igneous rocks, extrusive igneous rocks, and hydrothermal mineral deposits, with some minor amounts of limestone and other sedimentary rocks. Major outcroppings are highly weathered decomposing material that is unstable, highly transportable, and easily eroded.

Soils tend to be course and occur along mountain fronts and in alluvial fans, grading into increasingly sandy and loamy soils in alluvial valleys. Typical soil types within the agricultural valleys are entisols and mollisols. Parent materials within the Little Pinto drainage area consist mostly of basic to intermediate igneous rocks, while parent materials within the Pinto drainage area consist mostly of igneous and calcareous sedimentary rocks. These parent materials weather relatively easily; exposed rocks are subjected to chemical breakdown, which in turn releases some of the natural background constituents inherent in the rocks, including phosphorus, potassium, calcium, magnesium, iron, and aluminum, making the soils within alluvial valleys prime farmland when irrigated. Many iron ore bodies have been mined in the upper reaches of the watershed.

The major erosional features that occur within the Newcastle subwatershed are alluvial fans formed by powerful sheet floods during the Pleistocene to Holocene epoch. Most materials worn away from mountain blocks in the Great Basin were carried by sheet flows, thus forming relatively even, cone-shaped fans. Soils that formed during the last glacial period cover the land surface in most valleys in the Great Basin. Subsequent erosion of these soils during drier recent (Holocene) times has caused lower rates of soil formation and higher rates of soil deposition in streams.

Increased cloudburst-type storms have also increased rates of surface layer erosion, resulting in "skeletonized" slopes, basically devoid of vegetation and soil (Stokes 1986). The lack of vegetation and soil has contributed to increased sedimentation of streams and has limited uptake of nutrients by soils and vegetation within the Newcastle Reservoir watershed.

The watershed is ecologically within the Central Basin and Range Level III Ecoregion. The upper watershed is located within the Woodland and Shrub-covered Low Mountains Level IV Ecoregion (Omernik and Gallant 1986), characterized by higher and wetter mountain slopes, hills, and alluvial fans, as compared to the area adjacent to the reservoir. The lower watershed is located within the Sagebrush Basins and Slopes Level IV Ecoregion (Omernik and Gallant 1986), characterized by sagebrush dominated valleys, alluvial fans, and mountain flanks. Soils are typically rockier and shallower at higher elevations and consist mostly of entisols and mollisols. Lower elevation soils are typically deeper and finer and consist of more aridisols.

2.1.3.2 Soils

Soil data for the Newcastle Reservoir watershed were collected from the USDA Soil Conservation Service (NRCS 2006b) and the State Soil Geographic (STATSGO) Database. Detailed soil maps within the Soil Survey of Iron County (USDA NRCS 1981) were also used as references. Soil locations and extents are detailed in the large map pictured in Figure 2.5. The dominant soil types in the Newcastle Reservoir watershed are detailed in Table 2.6. The majority of the soils are fine loamy to loamy, with relatively midlevel erodibility factors. Rock outcrops also make up a significant portion of the watershed, especially in the Grass Valley Creek watershed.

Table 2.6. Soil Types and Characteristics in the Newcastle Reservoir Watershed

Soil Name	Soil Texture	Soil Erodibility (K Factor)	Percent of Newcastle Reservoir Watershed	Percent of Grass Valley Creek Watershed
Wales–Taylorsflat–Sevy	Fine loamy	0.43	31%	0%
Red Butte–Pavant–Hiko Peak–Dixie–Checkett–Bamos	Loamy	0.37	0%	0%
Wye family–Sampson family–Pastorius family–Nehar family–Muzzler family–Mokiak family–Bernal family	Loamy	0.24	40%	0%
Pastura family–Magotsu–Curhollow	Clayey-skeletal	0.32	2%	1%
Rock outcrop–Motoqua family–Falcon family–Dotsero family–Bernal family	Rock outcrop	0	26%	64%

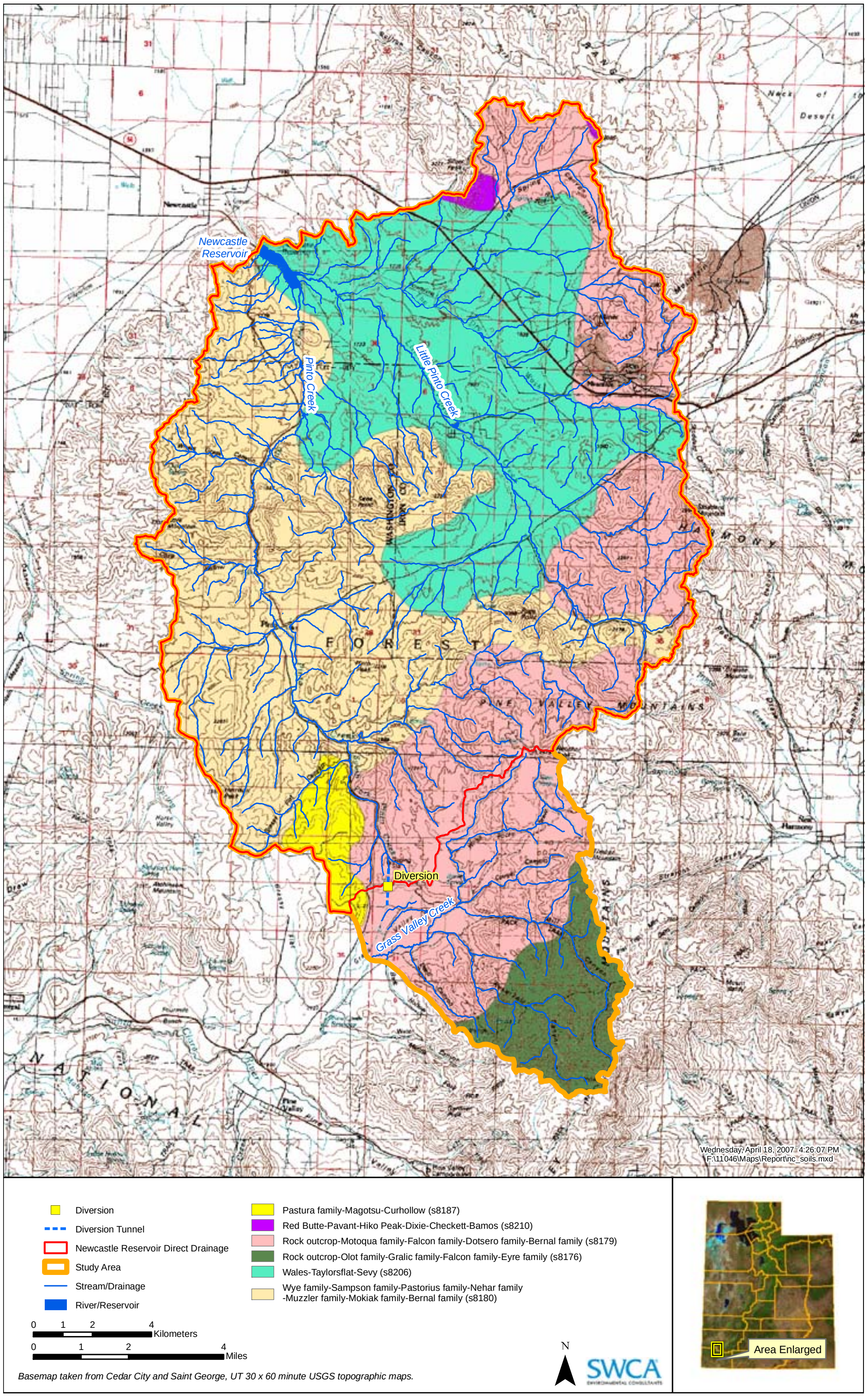


Figure 2.5. Soil map for the Newcastle Reservoir watershed.

2.1.4 Vegetation, Animals, and Fisheries

The health, diversity, and distribution of vegetation, wildlife, and fish in a watershed can be both an influence on and an indicator of habitat and water quality status. The state of the watershed often reflects the level of use, management, and short-term climate conditions that occur there.

2.1.4.1 Riparian Vegetation Community

The riparian community typical of this basin is characterized by yellow willow, whiplash willow, wild rose, Kentucky bluegrass, wiregrass, and Nebraska sedge (USFS 2005). Other associated riparian plant species include Douglas sedge, veronica, golden currant, redtop, clover, trefoil, and narrowleaf cottonwood. Yellow willow and wild rose comprise the dominant woody over story in the riparian area (USFS 2005).

Riparian areas constitute only a small portion of the overall study area but are ecologically important in terms of plant diversity, wildlife habitat, and erosion control along waterways. Riparian areas have reestablished over the past several decades following the end of a willow eradication program sponsored by the Soil Conservation Service in the 1950s.

2.1.4.2 Piñon-Juniper with Mountain Brush Vegetation Community

The dominant plant community found on hillside slopes is piñon-juniper. The vegetation over story is typically piñon pine, Utah juniper, and Gambel oak with intermixed big sagebrush, rabbitbrush, squawapple, and serviceberry. The dominant under story includes cheatgrass, mutton grass, blue grama, Sandberg bluegrass, galleta, junegrass, and sulfur buckwheat (Stokes 1986). The mixed brush components (Gambel oak) of this community are typically found intermixed on north and west aspects. No threatened, endangered, or sensitive plants are located within the Newcastle Reservoir watershed. Invasive weeds within the watershed include cheatgrass, noxious musk thistle and scotch thistle.

2.1.4.3 Wildlife

Wildlife found in the study area are indicative of piñon-juniper woodlands, mountain brush communities, willow/riparian communities, and rock habitats at middle elevations in southern Utah (USFS 2005). Game species include mule deer, Rocky Mountain elk, and wild turkey. Other mammals in the area include bobcat, coyote, red squirrel, and various smaller rodents. Several bat species can be observed at night flying along the roadway adjacent to Pinto Creek. Other nocturnal wildlife species include great-horned owls, striped skunks, and raccoons.

The most common birds found during the spring and summer months include western scrub jay, mourning dove, American robin, yellow warbler, spotted towhee, chipping sparrow, vesper sparrow, red-winged blackbird, western meadowlark, and less often, yellow-breasted chat and broad-tailed hummingbird. Turkey vultures and common ravens are also seen frequently. The most common reptiles are garter snakes and gopher snakes. Western rattlesnakes are also found at these elevations (USFS 2005).

2.1.4.4 Fisheries

Newcastle Reservoir supports stocked, self-sustaining, and introduced fisheries. Stocked fish species include Bear Lake cutthroat trout, wipers, and rainbow trout. The smallmouth bass population in the reservoir is self-sustaining. Golden shiner, crappie, and sunfish populations have been introduced.

Recent documented fish kills occurred in the reservoir in 2002 (recorded July 14, 2002) and 2006 (recorded August 17, 2006). Most fish involved were golden shiners. Another fish kill occurred in 1959 (recorded August 15, 1959) that included rainbow trout. This kill was associated with low water levels and occurred prior to establishment of the 500 acre-foot conservation pool, (personal communication, Mike Ottenbacher, Utah Division of Wildlife Resources, September 18, 2006).

Staff at Utah Division of Wildlife Resources have indicated that output from the trout fishery in Newcastle Reservoir has declined over the past 10 years, but the cause is not clear at this time. Many speculate that a combination of water quality, drought, predation, and competition (primarily due to the increase in shiner biomass over this time period) is causing the decline. Smallmouth bass feed on golden shiners, but they are unable to control the shiner population which lives primarily in the open water areas of the reservoir. Wipers (a sterile hybrid of white bass and striped bass) and Bear Lake cutthroat trout have recently been added to the reservoir stock in the hope that their predation on the golden shiner population will allow the trout fishery to rebound (personal communication, Mike Ottenbacher, Utah Division of Wildlife Resources, November 13, 2006). Golden shiners sampled in 2006 appear to be increasing to pre-drought levels, suggesting that wipers are not yet limiting the shiner population.

The end of the drought in 2005 restored water levels to the reservoir, resulting in an improved trout and smallmouth bass fishery. Increased populations of trophy-sized smallmouth bass were noted; however, smallmouth bass are also more difficult to catch due to the abundant shiner food supply, which reduces the appetite of the bass. The catch rate of trout in 2006 was the highest it had been in 30 years (Figure 2.6). In 2006, 153 trout were caught, representing both the seven-inch fingerlings stocked in fall 2005 (now age one) and other fish stocked prior to 2005. The current average size of rainbow trout is significantly greater than in recent years (Figure 2.7). Total length averages 245 mm and average weight is 160 grams. Other fish sampled in 2006 include Bear Lake cutthroat trout, smallmouth bass, and green sunfish.

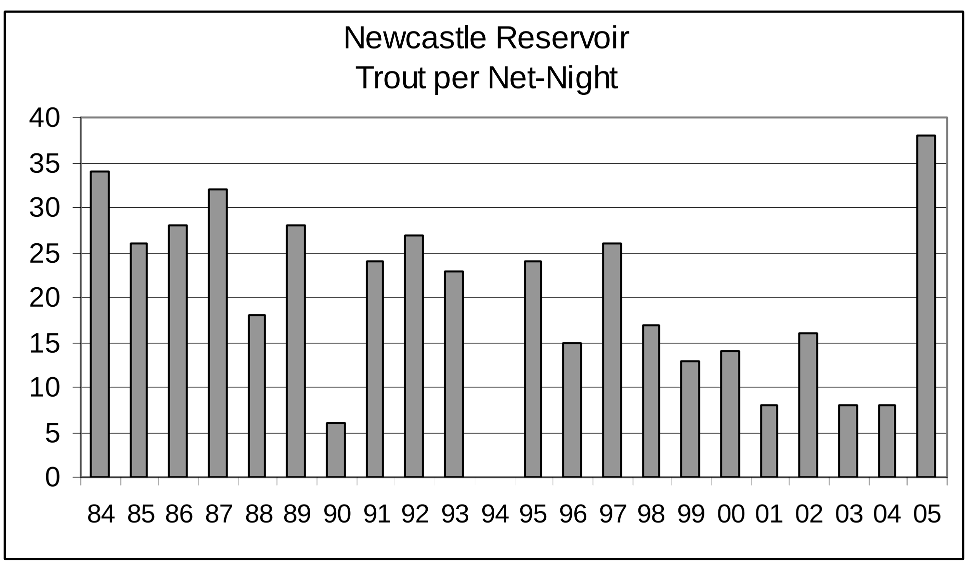


Figure 2.6. Historic trout catch in Newcastle Reservoir.

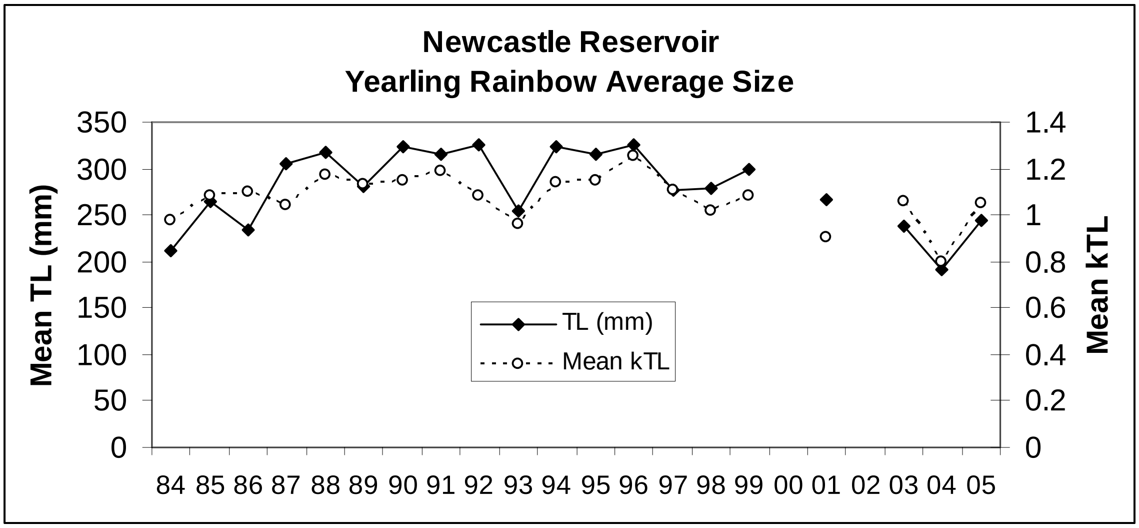


Figure 2.7. Historic trend in average size of Newcastle Reservoir rainbow trout.

Recently, the Utah Division of Wildlife Resources has set a goal to increase the population of catchable rainbow trout in Newcastle Reservoir. The Utah Division of Wildlife Resources is shifting its stocking of the reservoir from five- to seven-inch rainbow trout in accordance with this goal. Recommendations for improving the rainbow trout fishery include maintaining a stocking size of seven inches (17.8 cm), continuing to stock and monitor the progress of wipers in the reservoir, and including Newcastle Reservoir in a new sampling regime of monitoring the region's bass populations.

2.1.4.5 Special Designations

The Utah Division of Wildlife Resources (2006) has records of occurrence for American white pelican, Bonneville cutthroat trout, and burrowing owl within the Newcastle Reservoir watershed. In addition, records indicate the occurrence of the American three-toed woodpecker, ferruginous hawk, fringed myotis, and western toad in the vicinity. All of these species are included on the Utah Sensitive Species List.

2.2 Cultural Characteristics

2.2.1 Land Use and Ownership

The watershed (Newcastle Reservoir and Grass Valley) is predominantly forested (74%) and comprises both public and private lands. Landowners include:

- The USFS, which administers 63% of the watershed area as part of the Dixie National Forest and 8% of the watershed area as Wilderness Area
- The BLM, which administers 15% of the land area
- The Utah Trust Lands Administration, which owns 1.5% of the land area
- Private owners, who own a combined 12% of the drainage area

Small-acreage, privately owned land is commonly used for agricultural purposes—predominately for cattle ranching (Figure 2.8). A small amount of private land is used for crops, including alfalfa and grass hay. Both pasture/rangeland and cropland are divided into irrigated and nonirrigated categories (Table 2.7). Urban and residential areas make up roughly 1% of the total land area (Figure 2.9).

Table 2.7. Land Ownership Within the Newcastle Reservoir Watershed Study Area

Date	Grass Valley Watershed		Newcastle Reservoir Direct Drainage		Total Study Area
	Area (acres)	Percentage of Total Land	Area (acres)	Percentage of Total Land	Percentage of Total Land
USFS	6,263	41%	54,882	67%	63%
BLM	--	0.0%	14,142	17%	15%
Private	1,088	7.2%	10,938	13%	12%
USFS Wilderness Area	7,693	51%	--	0.0%	8.0%
Utah Trust Lands	--	0.0%	1,401	1.7%	1.5%
Water	--	0.0%	161	0.20%	0.20%
TOTAL	**15,044**		**81,524**		

Historically, land use in the watershed consisted primarily of livestock grazing and mining; very little land was used as residential property. Land use during the 1950s and 1960s was predominantly related to the mining of iron ore at Iron Mountain. Much of the surrounding area was used for livestock grazing and for growing feed to support livestock and the population of mining workers and residents living near Cedar City. Land-use trends since have shown a decrease in agricultural and mining land uses and an increase in the development of residential subdivisions and rural ranchettes.

Utah Automated Geographic Reference Center (AGRC) data were used to produce the current information on land ownership and land cover within the Newcastle Reservoir watershed area (Table 2.7 and Table 2.8).

Table 2.8. Land Use Within the Newcastle Reservoir Watershed Study Area

Date	Grass Valley Watershed		Newcastle Reservoir Direct Drainage		Total Study Area
	Area (acres)	Percentage of Total Land	Area (acres)	Percentage of Total Land	Percentage of Total Land
Evergreen Forest	12,215	81%	61,103	72%	74%
Shrub/Scrub	1,837	12%	21,054	25%	23%
Developed Uses	5.8	0.0%	699	0.8%	0.7%
Pasture/Hay	195	1.3%	417	0.5%	0.6%
Barren Land (Rock/Sand/Clay)	1.3	0.0%	574	0.7%	0.6%
Wetlands	88	0.6%	252	0.3%	0.3%
Grassland/ Herbaceous	--	0.0%	249	0.3%	0.3%
Deciduous Forest	88	0.6%	53	0.1%	0.1%
Open Water	--	0.0%	123	0.1%	0.1%
Mixed Forest	613	4.2%	--	0.0%	0.1%
TOTAL	**15,043.1**		**84,524**		

Geographic information system (GIS) coverage, satellite imagery, aerial photographs, and other cartographic resources were employed in the preparation of this document to determine accurate land-use values for the Newcastle Reservoir watershed study area on a subwatershed basis.

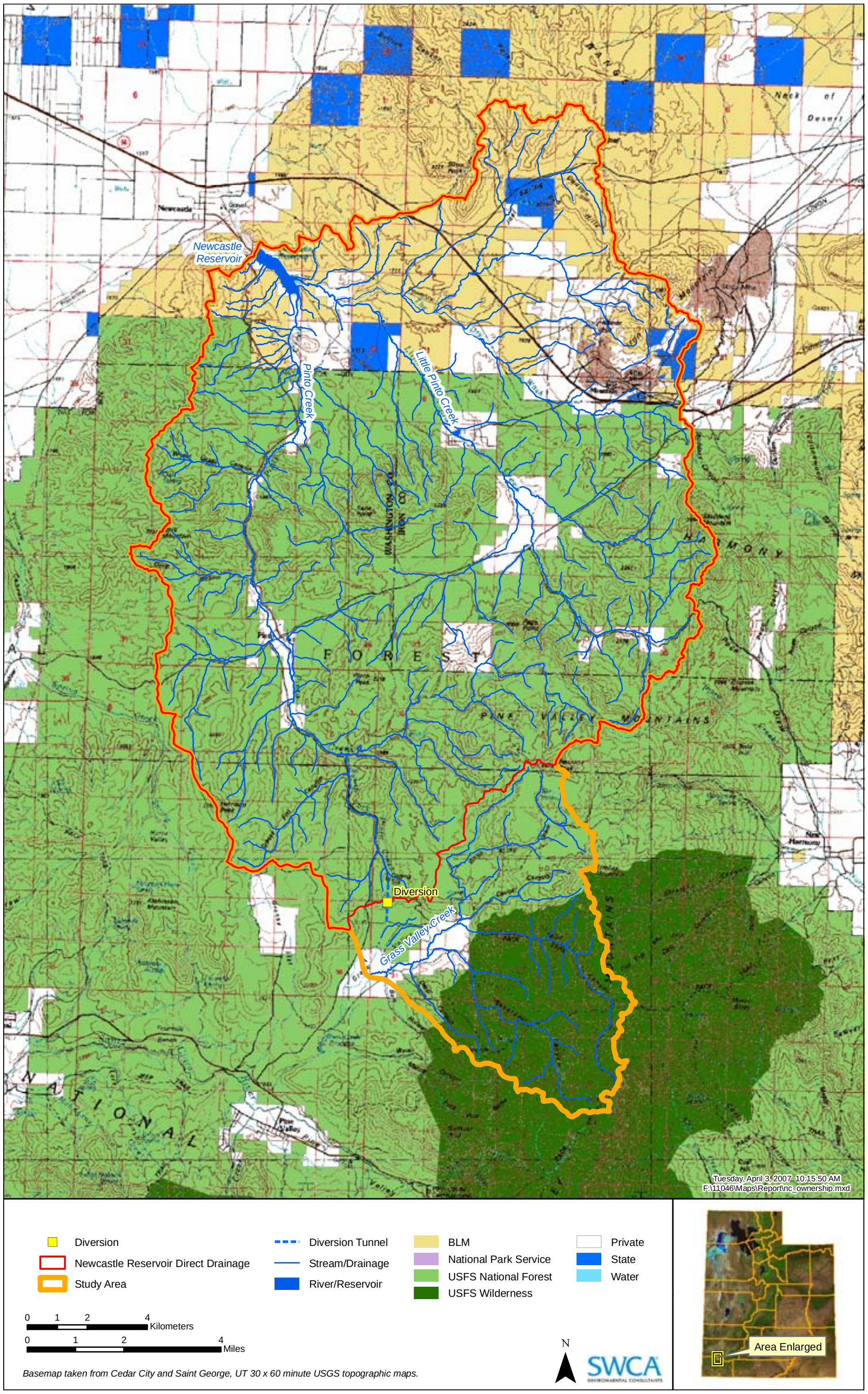


Figure 2.8. Newcastle Reservoir watershed land ownership and populations.

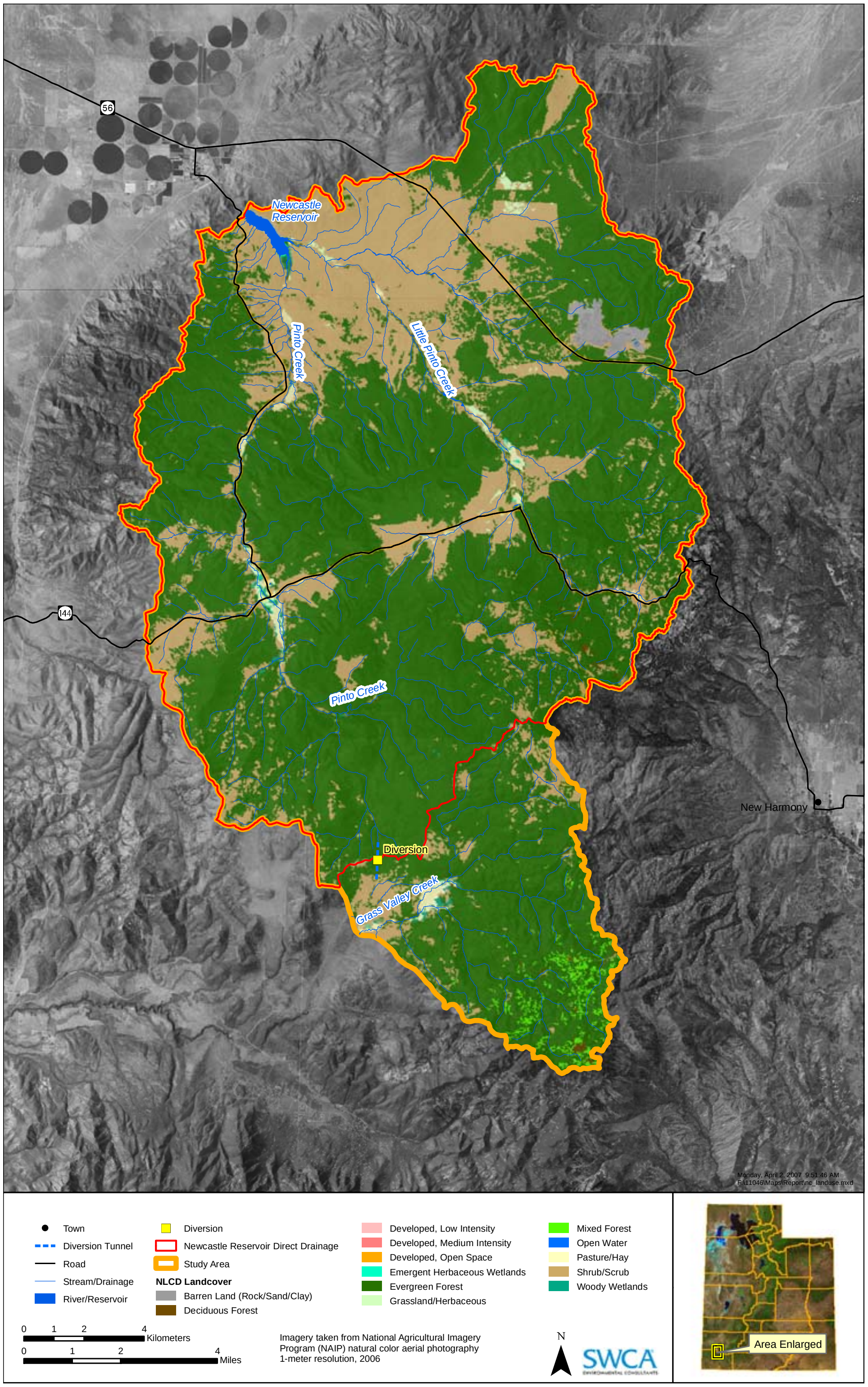


Figure 2.9. Newcastle Reservoir watershed land use.

2.2.2 Population

Population centers within the watershed boundaries are located in Pinto Creek Valley and Little Pinto Creek Valley and include Newcastle, Old Irontown, and Pinto. Total population for the Newcastle Reservoir watershed area is estimated at approximately 200 individuals, the majority of whom live in the town of Newcastle and adjacent unincorporated areas. The watershed is used not only by local residents, but by other individuals residing within and outside of the county who visit the watershed for tourism and recreational opportunities presented by the Newcastle Reservoir and surrounding areas.

2.2.3 History and Economics

Historically, the economy of the watershed was based almost solely on mining and agriculture. Lower prices for iron ore caused a reduction in mining within the Old Irontown District. The current economy of the region is based primarily on agricultural industries, with increasing revenue from tourism and recreation on public lands and wilderness areas. A small number of greenhouses have opened near Newcastle, which use the geothermal springs that occur along the Antelope Fault for heat generation. Livestock and crop production are currently the most common agricultural industries in the watershed.

2.2.4 Recreational Uses of Newcastle Reservoir

A variety of recreational opportunities are available on Newcastle Reservoir and within the surrounding watershed. Water-based recreational activities peak in the season between Memorial Day weekend and Labor Day weekend, when the reservoir is utilized by boaters, campers, and fishermen.

Most of these recreational opportunities are directly dependent on water quality. For example, fishing requires adequate water quality for the support of cold water aquatic life. Activities such as wading and boating depend on water quality for safety in contact recreation. Somewhat less obvious is the link between recreational activities such as hunting, hiking, or camping and water quality. However, wildlife habitat, and forest and riparian area health can also be directly affected by water quality. Water also provides an aesthetic component to many land-based activities that do not require a body of water but are generally enhanced by association with water. Further, operational and flow management conditions can significantly affect recreational uses. Both direct usage and local economies may be affected to a noticeable degree by water quality and water quantity management practices.

2.2.4.1 Boating and Related Activities

Boating is one of the most popular water-dependent recreation activities on Newcastle Reservoir. The reservoir also provides flat-water recreation opportunities that include water-skiing, cruising, and fishing. These activities are normally enjoyed early in the recreation season, when the reservoir is full. Reservoir drawdown and low inflows in the summer season often limit these activities, due to decreased boat access resulting from low water levels.

2.2.4.2 Fishing, Hunting, and Wildlife Observation

Fishing is a popular recreation activity on the reservoir. Fishing activity generally peaks in early summer after the spring runoff. Some anglers utilize the reservoir access for boat fishing, but there are also opportunities for shoreline fishing. Game fish species present in the reservoir include Bear Lake cutthroat trout and rainbow trout. Fishing on the reservoir can be affected directly by boat access issues cited above or indirectly by the effects of reservoir levels on reservoir fish populations.

As with fishing, hunting and viewing wildlife is a popular recreational activity in the watershed. Important wildlife that are hunted or trapped in the area include bear, coyote, deer, and game birds. There are established hunting seasons for a number of these animals as well as for various types of waterfowl and upland birds in the fall and winter months.

2.2.4.3 Camping

Camping use varies seasonally within the watershed. Many campers choose their destination based on proximity to other recreation activities, particularly boating and fishing.

2.2.5 Public Involvement

Throughout the TMDL process, local experience and participation were invaluable in identifying water quality issues and developing reduction strategies on a local scale. Because of the potential influence of the TMDL process on the local community and the dependence of any implementation plan on local participation, public involvement is viewed as critical for the entire TMDL process.

During the initiation of the TMDL process, a citizen's watershed advisory group was established to allow the community to provide direction and leadership in developing and implementing this plan. The watershed advisory group comprises local representatives from all major sectors of the local community, as follows:

- Agricultural interests
- Newcastle Irrigation Company
- Pinto Irrigation Company
- Citizens at large
- City of Pinto
- City of Newcastle
- Little Pinto Creek Development
- Environmental interests
- Sporting or recreational interests
- Timber interests
- Iron County Commissioners
- USFS Dixie National Forest
- BLM
- UDWR

Committee members are encouraged to work directly with their respective interest groups to provide direction to UDEQ in developing and implementing a watershed management plan. They may also help identify funding needs and sources of support for specific projects that may be implemented. The watershed advisory group is encouraged to assist in setting priorities for spending restoration funds and in periodically reviewing progress toward water quality improvement goals.

3 WATER QUALITY CONCERNS AND STATUS

This section defines water quality limited waterbodies and outlines designated beneficial uses for surface waters and the water quality standards that are necessary to facilitate those uses. In addition, this section provides water quality data on Newcastle Reservoir watershed waterbodies.

3.1 WATER QUALITY LIMITED WATERBODIES

As stated in the opening sections of this document, the main purpose of the CWA is to improve and protect water quality through restoration and maintenance of the physical, chemical, and biological integrity of the nation's waters.

Under section 303(d) of the CWA, states must submit to the EPA a list of waters that are not achieving state water quality standards. The waters identified on the 303(d) list are known as water quality limited.

Newcastle Reservoir has been identified under section 303(d) of the CWA as water quality limited due to low dissolved oxygen and excess phosphorus loading to the reservoir from the surrounding watershed.

3.2 BENEFICIAL USE CLASSIFICATIONS FOR SURFACE WATERS

The State of Utah has designated the following beneficial uses for Newcastle Reservoir:

- Secondary contact recreation (2B)
- Cold water game fish and associated food chains (3A)
- Agricultural water supply (4)

The cold water game fish designated use was identified on the State of Utah's 2006 303(d) list as **partially impaired**, while secondary contact recreation and agricultural water supply uses were listed as **fully supported**.

Recreation classifications designate waterbodies that are suitable or are intended to be made suitable for primary and secondary contact recreation. Swimming is an example of a primary contact recreational use. Secondary contact recreation refers only to uses where intimate human contact and ingestion of water is expected to occur to a lesser degree, such as boating and wading.

Waters designated for protection of cold water game fish and their associated food chain are required to exhibit appropriate temperature and levels of dissolved oxygen, pH, and ammonia, among other parameters for cold water aquatic life support.

Waters designated for agricultural water supply (including irrigation water and livestock watering) are required to be suitable for the irrigation of crops or as drinking water for livestock. These waters are required to meet general surface water quality criteria for toxic materials and total dissolved solids criteria.

3.3 APPLICABLE WATER QUALITY STANDARDS

Water quality standards under the CWA consist of three main components: designated beneficial uses, water quality criteria established to protect designated beneficial uses, and antidegradation policies and procedures.

Water quality criteria may be presented either by numeric limits for individual pollutants and conditions or by narrative descriptions of desired conditions. Table 3.1 summarizes the applicable Utah water quality criteria and lists specific citations where the full code language can be found.

3.4 SUMMARY AND ANALYSIS OF EXISTING WATER QUALITY DATA

Primary information sources for water quality data include the EPA STORET website, Utah Division of Water Quality (UDWQ), Utah Division of Water Resources (UDWR), Utah Geological Survey (UGS), U.S. Geological Survey (USGS), USFS, BLM, Natural Resources Conservation Service (NRCS), Newcastle Irrigation Company, Iron County, state and local colleges and universities, state and local soil and water conservation services, irrigation districts and their associated databases, and others. Groundwater flow and volume information is general in nature and is available almost exclusively from USGS, UGS, and county studies and reports. Climate information was obtained from WRCC and SNOTEL sites.

The UDWQ, USGS, EPA, and others have been monitoring water quality at a number of sites in the Newcastle Reservoir watershed since the late 1970s. Locations for which water quality information is available include reservoir monitoring sites, major tributary streams, and reservoir outflow, as well as other sites such as groundwater wells. These include four intensive water quality monitoring sites identified as appropriate for TMDL analysis efforts— one site on Pinto Creek upstream of the reservoir, two in-reservoir sites, and one location downstream of the reservoir. A listing of these sites, their geographical locations, and a summary of the data available for each is presented in Tables 3.2–3.3.

In total, over 4,300 data points were identified and assessed for the Newcastle Reservoir watershed, covering the 1979–2006 time period.

Early monitoring consisted primarily of assessing field parameters, nutrients, oxygen demand, dissolved ions and metals, and groundwater. This work was followed in the 1990s with pesticide analyses, more in-depth nutrient and organic carbon studies, bacterial analysis, and some trophic status-related parameters. Recent and current data indicate a variety of field parameters as well as occurrence of nutrients, sediment, dissolved ions, and metals (Table 3.4).

Table 3.1. Water Quality Criteria Specific to Newcastle Reservoir TMDLs (2B, 3A, 4)

Parameter and Designated Beneficial Use	Criterion	Utah State Code	Comments
Bacteria			
2B	Less than 206 *E. coli* organisms per 100 ml as a 30-day geometric mean **AND** less than 940 *E. coli* organisms per 100 ml as a maximum	RS317-2-14 Table 2.14.1	
3A	N/A		
4	N/A	RS317-2-14 Table 2.14.1	
Dissolved Oxygen (DO)			
2B	N/A		
3A	No less than 6.5 mg/L (30-day average), 9.5 early life stages / 5.0 all life stages (7-day average), 8.0 early life stages / 4.0 all life stages (1-day average)	RS317-2-14 Table 2.14.2	Footnote #2: These limits are not applicable to lower water levels in deep impoundments.
4	N/A		
Biological Oxygen Demand (BOD)			
2B	No greater than 5 mg/L	RS317-2-14 Table 2.14.1	
3A	No greater than 5 mg/L	RS317-2-14 Table 2.14.2	
4	No greater than 5 mg/L	RS317-2-14 Table 2.14.1	

Table 3.1. Water Quality Criteria Specific to Newcastle Reservoir TMDLs (2B, 3A, 4)

Parameter and Designated Beneficial Use	Criterion	Utah State Code	Comments
Nuisance Algae and Related Materials			
	It shall be unlawful, and a violation of these regulations, for any person to discharge or place any waste or other substance in such a way as will be or may become offensive such as unnatural deposits, floating debris, oil, scum, or other nuisances such as color, odor, or taste; or cause conditions which produce undesirable aquatic life or which produce objectionable tastes in edible aquatic organisms; or result in concentrations or combinations of substances which produce undesirable physiological responses in desirable resident fish, or other desirable aquatic life, or undesirable human health effects, as determined by bioassay or other tests performed in accordance with standard procedures.	RS317-2-14	Footnote #5: Investigations shall be conducted to develop more information where these pollution indicator levels are exceeded.
Nutrients, Ammonia as N			
	The 30-day average concentration of total ammonia nitrogen (in mg/l as N) does not exceed, more than once every 3 years on the average, the chronic criterion calculated using the following equations. Fish Early Life Stages are Present: mg/l as N (Chronic) = ((0.0577/1+10 E7.688-pH)+ (2.487/1+10 EpH-7.688)) * MIN (2.85, 1.45*10 E0.028*(25-T)). Fish Early Life Stages are Absent: mg/1 as N (Chronic) = ((0.0577/1+10 E7.688-pH) + (2.487/1+10 EpH-7.688)) * 1.45*10 E0.028* (25-MAX(T-7))). The 1-hour average concentration of total ammonia nitrogen (in mg/l as N) does not exceed, more than once every three years on the average the acute criterion.		Early life stages include the pre-hatch embryonic stage, the post-hatch free embryo or yolk-sac fry stage, and the larval stage for the species of fish expected to occur at the site. In addition, the highest four-day average within the 30-day period should not exceed 2.5 times the chronic criterion. The "Fish Early Life Stages are Present" 30-day average total ammonia criterion will be applied by default unless it is determined by the Division, on a site-specific basis, that it is appropriate

Table 3.1. Water Quality Criteria Specific to Newcastle Reservoir TMDLs (2B, 3A, 4)

Parameter and Designated Beneficial Use	Criterion	Utah State Code	Comments
2B	N/A		Applies to the "Fish Early Life "Stages are Absent" 30-day average criterion for all or some portion of the year. At a minimum, the "Fish Early Life Stages are Present" criterion will apply from the beginning of spawning through the end of the early life stages. The Division will consult with the Division of Wildlife Resources in making such determinations. The Division will maintain information regarding the waterbodies and time periods where application of the "Early Life Stages are Absent" criterion is determined to be appropriate.
3A	mg/l as N (Acute) = 0.275/(1+10 E7.204-pH)) + (39.0/(1+10 EpH-7.204))	RS317-2-14 Table 2.14.2	
4	N/A		
Nutrients, Nitrate as N			
2B	No greater than 4 mg/L	RS317-2-14 Table 2.14.1	Footnote 5: Investigations shall be conducted to develop more information where these pollution indicator levels are exceeded.
3A	No greater than 4 mg/L	RS317-2-14 Table 2.14.2	
4	N/A		
Nutrients, Total Phosphate as P			
2B	No greater than 0.05 mg/L	RS317-2-14 Table 2.14.1	Footnote 6 and Footnote 12: Total phosphorus as P (mg/L) threshold for lakes and reservoirs shall be 0.025 mg/L.
3A	No greater than 0.05 mg/L	RS317-2-14 Table 2.14.2	

Table 3.1. Water Quality Criteria Specific to Newcastle Reservoir TMDLs (2B, 3A, 4)

Parameter and Designated Beneficial Use	Criterion	Utah State Code	Comments
4	N/A		
pH			
2B	No less than 6.5 **AND** no greater than 9.0 pH units	RS317-2-14 Table 2.14.1	
3A	No less than 6.5 **AND** no greater than 9.0 pH units	RS317-2-14 Table 2.14.2	
4	No less than 6.5 **AND** no greater than 9.0 pH units	RS317-2-14 Table 2.14.1	
Turbidity			
2B	No greater than 10 NTU increase	RS317-2-14 Table 2.14.1	
3A	No greater than 10 NTU increase	RS317-2-14 Table 2.14.2	
4	N/A		
Total Dissolved Gas			
2B	N/A		
3A	Not to exceed 110% of saturation	RS317-2-14 Table 2.14.2	
4	N/A		

Table 3.1. Water Quality Criteria Specific to Newcastle Reservoir TMDLs (2B, 3A, 4)

Parameter and Designated Beneficial Use	Criterion	Utah State Code	Comments
Total Dissolved Solids			
2B	N/A		Footnote 4: TDS limits may be adjusted if such adjustment does not impair the designated beneficial use of the receiving water. The total dissolved solids (TDS) standards shall be at background where it can be shown that natural or unalterable conditions prevent its attainment. In such cases rulemaking will be undertaken to modify the standard accordingly.
3A	N/A		
4	No greater than 1,200 mg/L (irrigation), no greater than 2,000 (stock watering)	RS317-2-14 Table 2.14.1	
Temperature			
2B	N/A		Footnote 3: The temperature standard shall be at background where it can be shown that natural or un-alterable conditions prevent its attainment. In such cases rulemaking will be undertaken to modify the standard accordingly.
3A	No greater than 20 ^{o}C, no greater than 2 ^{o}C change	RS317-2-14 Table 2.14.2	
4	N/A		

Table 3.2. Water Quality Monitoring Site Information for the Newcastle Reservoir Watershed

Org Name	Station ID	Station Name	State	County	HUC	Station Latitude	Station Longitude	Station Horizontal Datum
UDEQ/SWCA	4940600	PINTO CK BL NEWCASTLE RES	UTAH	IRON	16030006	37.64889	-113.537	UNKWN
UDEQ/SWCA	4940650	PINTO CK AB NEWCASTLE RES	UTAH	IRON	16030006	37.63611	-113.513	UNKWN
SWCA		LITTLE PINTO CK AB NEWCASTLE RES	UTAH	IRON	16030006	37.64377	-113.508	NAD83
UDEQ	4940610	NEWCASTLE RES AB DAM 01	UTAH	IRON	16030006	37.65250	-113.527	UNKWN
UDEQ	4940620	NEWCASTLE RES MIDWAY UP LAKE 02	UTAH	IRON	16030006	37.64667	-113.519	UNKWN

In-reservoir monitoring by UDEQ includes both grab (instantaneous) samples and depth-integrated profile data for some parameters.

Table 3.3. Newcastle Reservoir Water Quality Summary from Intensive Monitoring Efforts

	Characteristic	N	Start	Stop	Max	Min	Mean	Median
Inflow	**4940650 PINTO CK AB NEWCASTLE RES**							
	Alkalinity, Carbonate as CaCO3	3	9/15/82	8/2/90	298	277	286	284
	Chlorophyll *a*, uncorrected for pheophytin	--	--	--	--	--	--	--
	Dissolved oxygen (DO)	9	9/15/82	11/15/05	9.0	6.0	7.7	7.8
	Dissolved Solids	9	9/15/82	11/15/05	612	302	444	436
	Flow	15	9/15/82	9/14/05	7.8	0.0	1.2	0.20
	Nitrogen, Ammonia as N	9	9/15/82	8/9/05	0.05	0.05	0.05	0.05
	Nitrogen, Total Kjeldahl	5	9/15/82	11/15/05	1.8	0.20	0.63	0.35
	Nitrogen, Nitrite (NO2) + Nitrate (NO3) as N	7	9/15/82	7/31/06	0.05	0.024	0.035	0.032
	pH	10	9/15/82	7/31/06	8.2	7.7	8.0	8.1
	Phosphorus as P, Total	9	9/15/82	9/14/05	0.99	0.077	0.24	0.12
	Phosphorus as P, Dissolved	7	8/2/90	7/31/06	0.15	0.059	0.091	0.085
	Secchi disk depth	--	--	--	--	--	--	--
	Specific conductance	10	9/15/82	7/31/06	773	259	620	654
	Temperature, water	9	9/15/82	11/15/05	29	14	20	18
	Total Suspended Solids (TSS)	9	9/15/82	7/31/06	856	10	164	32
	Turbidity	3	9/15/82	9/14/05	125	7.6	47	7.7
	Volatile Solids	5	5/20/92	11/15/05	21	4	13	15
Outflow	**4940600 PINTO CK BL NEWCASTLE RES**							
	Alkalinity, Carbonate as CaCO3	5	5/24/79	6/22/83	244	102	171	139
	Chlorophyll *a*, uncorrected for pheophytin	--	--	--	--	--	--	--
	Dissolved oxygen (DO)	4	5/24/79	6/22/83	9.3	7.0	8.3	8.4
	Dissolved Solids	5	5/24/79	8/17/06	466	7.0	266	239
	Flow	2	1/6/83	8/17/06	107	0.0	53	53
	Nitrogen, Ammonia as N	5	5/24/79	6/22/83	0.10	0.10	0.10	0.10
	Nitrogen, Total Kjeldahl	5	5/24/79	6/22/83	0.40	0.10	0.32	0.40

Table 3.3. Newcastle Reservoir Water Quality Summary from Intensive Monitoring Efforts

	Characteristic	N	Start	Stop	Max	Min	Mean	Median
Outflow (cont.)	Nitrogen, Nitrite (NO2) + Nitrate (NO3) as N	5	5/24/79	8/17/06	0.10	0.050	0.077	0.080
	pH	6	5/24/79	8/17/06	8.6	8.1	8.3	8.4
	Phosphorus as P, Total	5	5/24/79	4/27/83	0.15	0.030	0.076	0.070
	Phosphorus as P, Dissolved	--	--	--	--	--	--	--
	Secchi disk depth	--	--	--	--	--	--	--
	Specific conductance	10	5/24/79	6/22/83	820	260	507	385
	Temperature, water	5	5/24/79	8/17/06	18	6.4	12	10
	Total Suspended Solids (TSS)	4	11/9/82	8/17/06	29	4	14	12
	Turbidity	5	5/24/79	6/22/83	17	6.4	10	9.7
	Volatile Solids	--	--	--	--	--	--	--
Depth Integrated	**4940610 NEWCASTLE RES AB DAM 01** (Dam Site)							
	Alkalinity, Carbonate as CaCO3	27	5/24/79	9/14/04	257	133	186	182
	Chlorophyll *a*, uncorrected for pheophytin	20	5/30/90	8/4/04	224	0.50	29	9.1
	Dissolved oxygen (DO)	147	5/24/79	9/14/05	12	0.10	5.1	5.8
	Dissolved Solids	27	5/24/79	7/27/05	538	214	363	358
	Flow							
	Nitrogen, Ammonia as N	73	5/24/79	8/17/06	0.80	0.04	0.19	0.10
	Nitrogen, Total Kjeldahl	23	5/24/79	6/25/98	0.90	0.14	0.44	0.50
	Nitrogen, Nitrite (NO2) + Nitrate (NO3) as N	67	5/24/79	9/14/05	0.43	0.030	0.155	0.10
	pH	163	5/24/79	9/14/05	9.0	4.0	8.2	8.3
	Phosphorus as P, Total	73	5/24/79	8/17/06	0.31	0.010	0.062	0.050
	Phosphorus as P, Dissolved	60	8/2/90	8/17/06	0.26	0.010	0.057	0.038
	Secchi disk depth	20	5/24/79	5/29/02	4.2	0.30	2.0	2.0
	Specific conductance	160	5/24/79	8/17/06	935	333	633	632
	Temperature, water	147	5/24/79	9/14/05	25	8.5	19	19
	Total Suspended Solids (TSS)	9	9/2/80	9/14/05	40	4.0	17	17

Table 3.3. Newcastle Reservoir Water Quality Summary from Intensive Monitoring Efforts

	Characteristic	N	Start	Stop	Max	Min	Mean	Median
	Turbidity	25	5/24/79	5/20/92	48	0.5	8.8	4.6
	Volatile Solids	4	5/20/92	8/16/94	3.0	1.0	1.8	1.5
Depth Integrated	**4940620 NEWCASTLE RES MIDWAY UP LAKE 02** (Mid-lake)							
	Alkalinity, carbonate as CaCO3	2	5/30/90	8/2/90	256	234	245	245
	Chlorophyll *a*, uncorrected for pheophytin	18	8/2/90	8/4/04	72	1.2	17	5.2
	Dissolved oxygen (DO)	98	5/24/79	9/14/05	13	0.10	6.9	7.3
	Dissolved solids	3	5/24/79	9/14/05	540	226	425	510
	Flow							
	Nitrogen, ammonia as N	34	5/24/79	7/27/05	0.20	0.005	0.05	0.025
	Nitrogen, Kjeldahl Total	11	5/24/79	9/14/05	0.90	0.25	0.41	0.30
	Nitrogen, nitrite (NO2) + nitrate (NO3) as N	33	5/24/79	8/7/02	0.01	0.025	0.029	0.025
	pH	98	5/24/79	9/14/05	9.4	7.4	8.4	8.5
	Phosphorus as P, Total	40	5/24/79	9/14/05	0.24	0.005	0.05	0.036
	Phosphorus as P, Dissolved	35	8/2/90	7/25/00	0.120	0.005	0.03	0.02
	Secchi disk depth	14	5/30/90	6/7/05	4.7	0.40	2.2	2.4
	Specific conductance	98	5/24/79	9/14/05	926	234	531	598
	Temperature, water	84	5/24/79	9/14/05	25	14	20	20
	Total Suspended Solids (TSS)	18	5/30/90	6/9/04	27	2.0	5.1	3
	Turbidity	2	5/30/90	7/21/04	3.0	1.5	2.3	2.3
	Volatile Solids	8	6/15/94	8/4/04	3.0	0	0.62	0

Table 3.4. Water Quality Constituent Information for Newcastle Reservoir TMDLs

Analyte	Form/Fraction	Units	Total Number of Data Points
Alkalinity, Carbonate as $CaCO_3$	Total	mg/L	40
Chlorophyll *a*, uncorrected for pheophytin	Total	µg/L	44
Chemical Oxygen Demand (COD)	Total	mg/L	20
Dissolved Solids	Dissolved	mg/L	37
Dissolved Oxygen (DO)	Dissolved	mg/L	340
Dissolved Oxygen saturation (DO)	Dissolved	% saturation	259
Fecal Coliform	Total	#/100 mL	7
Fecal Streptococcus Group Bacteria	Total	#/100 mL	4
Fixed Solids		mg/L	27
Flow	Measured	cfs	14
Flow	estimated	cfs	14
Nitrogen, Ammonia (NH_3) as NH_3	Total	mg/L	21
Nitrogen, Total Kjeldahl	Total	mg/L	49
Nitrogen, Nitrate (NO_3) as NO_3	Total	mg/L	2
Nitrogen, Nitrate (NO_3) as NO_3	Dissolved	mg/L	10
Nitrogen, Nitrite (NO_2) + Nitrate (NO_3) as N	Total	mg/L	23
Nitrogen, Nitrite (NO_2) + Nitrate (NO_3) as N	Dissolved	mg/L	114
Nitrogen, Nitrite (NO_2) as NO_2	Total	mg/L	12
Nitrogen, Nitrite (NO_2) as NO_2	Dissolved	mg/L	10
pH		units	366
Phosphorus as P	Total	mg/L	144
Phosphorus as P	Dissolved	mg/L	119
Phosphorus, Orthophosphate as P	Total	mg/L	12
Phosphorus, Orthophosphate as P	Dissolved	mg/L	10
Salinity		ppt	65
Secchi Depth		meters	37
Specific Conductance		umho/cm	369
Temperature, air		degrees C	5
Temperature, water		degrees C	288
Total Organic Carbon (TOC)	total	mg/L	11
Total Coliform	total	#/100 mL	13
Total Suspended Solids (TSS)	total	mg/L	48
Turbidity	total	NTU	42
Volatile Solids		mg/L	26

Note: Not all parameters are available for all sites or dates.

Quantitative data were not available for stream channel stability, riparian corridor health, or stream morphology for tributary sites. Biological data primarily represents benthic macroinvertebrate identification, with a very small dataset representing algal identification information. Overall determination of algal population types or speciation is not possible from this dataset.

3.4.1 STATISTICAL OVERVIEW

A statistical overview of all recent and current water quality data available is presented in Table 3.3. The maximum and minimum concentrations measured that are displayed in Table 3.3 provide a range of observed conditions within the watershed and critical monitoring stations. Mean concentration data are provided for reference, although most of the parameter-specific datasets do not occupy a normal distribution. Median values are also presented to allow some level of interpretation of the skew or bias observed within the datasets, as is the number of data points included in the statistical analysis.

3.4.1.1 Analytical Methods

Data collected and assessed for Newcastle Reservoir TMDLs consist of samples evaluated by four primary categories of analytical methodology: APHA, EPA, UDWQ generic, and UDWQ field methods.

3.4.1.1.1 APHA Methods

"APHA methods" refers to methods of the American Public Health Association (APHA), *Standard Methods for the Examination of Water and Wastewater*, 18th edition (1992). More information can be obtained on APHA by writing to the American Public Health Association; 1015 15th Street, NW; Washington DC 20005. Access the APHA website at http://www.epa.gov/STORET/metadata.html).

The APHA-approved methods specific to the available database for Newcastle Reservoir TMDLs include analytical procedures for measuring alkalinity, chemical oxygen demand, chloride, chlorophyll *a*, dissolved solids, fecal coliform bacteria, fecal streptococcus group bacteria, fixed solids, pH, total coliform bacteria, total organic carbon, total suspended solids, volatile solids, and others not pertinent to this TMDL effort.

3.4.1.1.2 EPA Methods

"EPA methods" refers to methods developed by the U.S. Environmental Protection Agency (EPA). See the EPA's *Methods for Chemical Analysis of Water and Wastes* (1983, 600/4-79-020) for further details; the material is accessible on the internet at http://www.epa.gov/STORET/metadata.html.

The EPA-approved methods specific to the available database for the Newcastle Reservoir TMDL includes analytical procedures for measuring ammonia, biochemical oxygen demand, chloride, nitrate + nitrite, phosphorus, specific conductance, total suspended solids, turbidity, volatile solids, and others not pertinent to this TMDL effort.

3.4.1.1.3 UDWQ Generic Methods (Generic Method and Generic Method 2)

"UDWQ generic methods," also called "generic method and generic method 2," refers to methods that the Utah Division of Water Quality (UDWQ) has entered in the STORET database; where historical methodology may not be available, method is listed as *unknown, no cite, method not cited*, or other similar listings.

The UDWQ generic methods specific to the available database for the Newcastle Reservoir TMDL includes measurements of alkalinity, ammonia, biochemical oxygen demand, chemical oxygen demand, chloride, chlorophyll *a*, nitrate, nitrate + nitrite, nitrite, pH, orthophosphate, phosphorus, specific conductance, total Kjeldahl nitrogen, total organic carbon turbidity, and others not pertinent to this TMDL effort.

Due to the fact that the data in this analysis category were collected, reviewed, and submitted to the STORET database by UDWQ, it was assumed that all sampling protocols and analytical methods employed were carried out in a fashion approved by UDWQ and contained and attained a UDWQ-approved level of quality assurance and quality control.

3.4.1.1.4 UDWQ Field Measures

"UDWQ Field Measures" refers to standards listed in UDWQ's *Quality Assurance/Quality Control Manual* (1996).

The UDWQ Field Measures–approved methods that are specific to the available database for Newcastle Reservoir TMDLs include analytical procedures for measuring chlorine, dissolved oxygen, flow, pH, salinity, Secchi depth, specific conductance, and temperature (of air and water).

3.4.2 QUALITY ASSURANCE AND QUALITY CONTROL

The collected data were assessed to ensure that those data points included in the TMDL process met an appropriate level of quality assurance and quality control. Basic statistical analyses were used to characterize data range and quality. Statistical parameters assessed included the number of data points and the determination of mean, median, maximum, and minimum values, as well as assessment of variance and analysis of seasonality. The completeness of the dataset was also evaluated in a spatial, temporal, and parameter-specific fashion, and critical data gaps were identified. Further evaluation is discussed in the following sections.

3.4.2.1 Treatment of Nondetects

Many of the data points (14% of total data points) collected in this dataset are concentration values identified as "below detection limits", "greater than quantitation limits," or "too numerous to count." For the purpose of analyzing the data, a method must be developed to statistically interpret these values. This is generally accomplished by assigning a numeric value that is one-half of the detection limit (in the case of concentrations identified as below detection limits) or a value that represents the quantitation limit (in the case of concentrations identified as greater than quantitation limits).

Detection limits applied to those data points, where specific analytical methods were identified, were extracted from available method summaries. Much of the data available from UDWQ monitoring efforts does not identify a specific analytical method; identifying the analytical procedure as "generic method" or "generic method 2." However, detection limits were reported in the STORET database for most data points and provided a specific nondetect values for most data. Arne Hultquist of the Utah Division of Water Quality, Monitoring Section provided method numbers and detection limits for nondetect data for which no detection limits were reported in the STORET database.

In the case of bacteriological data, where numerous dilutions are used to determine the total counts, an upper quantitation limit cannot be identified directly from the method summary. In cases where total concentrations were listed as being greater than the quantitation limits or "too numerous to count", a value of 1.5 times the highest quantified concentration was substituted.

This provides a numeric value that will allow statistical analyses to be performed. Such a substitution most likely represents an underestimation of the total bacteria count present. However, as the quantitation limits for the analysis of total coliform and fecal coliform bacteria are rarely lower than the state criteria for contact recreation, the recommended substitution is not expected to result in a situation where risk to recreationists is unidentified (no false negatives) but at the same time is not likely to result in a situation where bacterial loading is grossly overestimated within the watershed.

3.4.2.2 Treatment of Errors

An initial assessment of the data was performed to identify transcription and other errors such as inappropriate values (e.g., a pH value of 90), inaccurate sample information (e.g., units of mg/L for specific conductivity data), and errors in physical information (e.g., incorrect county or latitude information for a known sample site). A small number of such errors were identified and corrective action was taken as outlined below.

A number of sample sites included data points of zero. Zero values represented 5% (or 187) of the data points. It was not immediately obvious what these values represented. Possible interpretations include:

- Misentry of an analytical nondetect
- An error in a spreadsheet used to enter data to STORET or an error within the STORET database that did not allow display of appropriate decimal places and resulted in values of "less than one" being displayed and recorded as zero
- Direct transcription errors
- A combination of the above and other unknown errors

Because of this uncertainty, zero values were removed from all datasets, with the exception of measured or estimated flow and measurements of water and air temperature, where a zero value is possible. Zero values occurred in datasets for total suspended solids and volatile solids. The total number of zero values removed from the Newcastle Reservoir dataset was 26 (~1.6% of the dataset). Zero values occurred in this dataset for total suspended solids (16 points) and volatile solids (10 points).

A listed value of 26.1 mg/L for dissolved oxygen was removed form the dataset for site #4940650 (PINTO CK AB NEWCASTLE RES, 6/15/1994), with a listed analytical method of FIELD MEASURES; as the value was impossible to attain under natural atmospheric conditions, the value was determined to be a transcription or entry error and was removed.

3.4.2.3 Treatment of Outliers

To identify a final dataset representative of water quality conditions within the Newcastle Reservoir watershed, a threshold of plus or minus three standard deviations from the mean was applied to the available datasets. This resulted in the removal of approximately 50 data points from the Newcastle Reservoir dataset (less than 3% of the dataset. This mechanism for identifying nonrepresentative data was approved by UDWQ. Those values identified as being outside of the range were removed from the dataset.

3.4.2.4 Treatment of Duplicate Measures

In the case of pH and specific conductivity data, several sites included both measurements made in the field and measurements made in the laboratory. As field measures provide in-stream data and laboratory measures provide in-bottle conditions, field measures were used preferentially over laboratory measures for these two constituents. In those cases where field measures were not available (well less than 1% of the dataset), laboratory measures were substituted.

A comparison of a subset of matched field values and laboratory values identified only a moderate level of difference. A set of 191 data points were evaluated where both field and laboratory values were available for pH and showed a mean difference of 0.46%, in field-measured pH to laboratory-measured pH, and a median difference of 0.24% in median field-measured pH to laboratory-measured pH. A similar evaluation of a set of 214 data points, where both field and laboratory values were available for specific conductance, showed a mean difference of 3.25% in field-measured specific conductance to laboratory-measured specific conductance, and a difference of 0.76% in median field-measured specific conductance to laboratory-measured specific conductance. It was therefore concluded that substitution was appropriate for laboratory values in those few cases where laboratory values were available but field values were not.

3.5 Water Quality Data Coverage

The available dataset covers a range of water years and a variety of physical, chemical, and biological water quality constituents. To better evaluate the existing dataset, available data were divided into several subsets to allow identification of temporal, spatial, and constituent coverage and completeness in both a general and a specific fashion.

Identified water quality concerns in the Newcastle Reservoir system were used as the primary basis for data collection and delineation. Therefore, while additional data exist (such as metal and pesticide concentration information), they have not been included in this data summary.

3.5.1 Temporal Coverage

Monitoring data included in this data summary are available from the late 1970s through early 2006, covering a wide range of water years and flow scenarios. As detailed in Table 3.3, some monitoring locations have consistent data throughout this time period while others have experienced only intermittent, single-year, or single-event data collection.

Data collected prior to 1982 were excluded from the water quality assessment database as they were assumed not to be representative of current conditions in the watershed; further, use of non-representative data may have inherent liabilities (such as false conclusions drawn from outdated sampling or poor comparisons that fail to account for differences between old and current measurements). Additionally, flow, diversion, and land use and management within the watershed has changed considerably in some cases since the early 1980s and transport and delivery relationships derived from early data are not likely to reflect current conditions.

Data available to the TMDL process has been divided into the following three categories: 1982–1992 (historic), 1993–1998 (recent), and 1999-2006 (current). Data collected prior to 1982 will be categorized as "legacy" data and use will be restricted to trend analysis within the TMDL process. Data to be used for the TMDL process have been restricted to 1999–2006 data.

It should be noted that much of the data from the early 1990s to 2004 were collected under moderate to extreme drought conditions. Physical water quality characteristics such as temperature and dissolved oxygen concentrations measured during these water years represent critical watershed conditions, as drought generally exacerbates such conditions within the watershed. The most current data have been used for assessment of criteria or threshold exceedance, pollutant transport and processing, and pollutant loading analyses.

Current data will be the primary source of information used to develop pollutant loading calculations and coefficients within the ongoing TMDL process. It has been used to determine the support level of designated beneficial uses and will be employed to help define appropriate endpoints or thresholds (if applicable) for the Newcastle Reservoir system.

3.5.2 HYDROLOGICAL COVERAGE

Data were collected over a wide range of hydrological conditions. As gaged flows were not available for the Newcastle Reservoir watershed, nearby drainages with continuous gage information were used as a surrogate measure of relative flow volume and intensity.

Annual total flow volumes calculated from gaged flows in the Santa Clara River near Pine Valley, Utah (USGS gage #09408400), and Coal Creek near Cedar City, Utah (USGS gage #10242000), are displayed in Figures 3.1–3.2. Annual flow volumes and ranking relative to the 30-year average for USGS gages #09408400 and #10242000 are displayed in Tables 3.5–3.6.

While absolute flow volumes in these two systems are not equivalent, the same flow trends are observed in both systems; this similarity is a good indication that basin-wide flows follow relatively similar trends from year to year. This correlation also lends confidence to the application of the observed flow scenarios to the ungaged flows entering Newcastle Reservoir.

Based on the assumption that ungaged flows in the Newcastle Reservoir watershed are similar in trend volume and flow to gaged flows in nearby drainages (Santa Clara River and Coal Creek), early water years (1982–1992) represent low to average, to much-above average, water years.

More recent water years (1993–1998) represent a wide range of water years from low to high flows. Current water years (1999–2006) are generally well below average, with the exception of 2005, which was a high-water year. Water years 2002–2004 represent years with less than 60% of the 30-year average flow values.

Current water quality data collected in the Newcastle Reservoir watershed are representative of a wide range of flow values and describe both very low (in 2002, 18–26% of the 30-year average flow volume) and very high (in 2005, 317–636% of the 30-year average flow volume) flows. Therefore, data collected during the period 1999–2006 are expected to be representative of high flow and low flow (critical) conditions within the watershed.

Annual flow distributions for high, low, and medium water years in the Santa Clara River and Coal Creek are displayed as monthly flow volumes in Tables 3.5–3.6.

Table 3.5. Annual Flow Volumes and Ranking for the Santa Clara River

Water Year	Flow (cfs)	Percent of 30-year Average Flow
1975	8.7	135%
1976	5.5	85%
1977	2.3	36%
1978	19	301%
1979	22	343%
1980	20	317%
1981	6.4	100%
1982	8.2	129%
1983	29	459%
1984	6.4	100%
1985	6.7	104%
1986	6.3	99%
1987	6.1	96%
1988	14	226%
1989	3.7	59%
1990	3.0	46%
1991	4.9	77%
1992	10	164%
1993	19	306%
1994	6.5	102%
1995	23	359%
1996	3.4	54%
1997	5.5	86%
1998	18	276%
1999	5.6	88%
2000	6.1	95%
2001	10	159%
2002	1.2	18%
2003	2.9	46%
2004	5.9	92%
2005	41	638%
30-year average	10.3	100%

Annual flow volumes and ranking relative to the 30-year average for the Santa Clara River near Pine Valley, Utah (USGS gage #09408400).

Table 3.6. Annual Flow Volumes and Ranking for Coal Creek

Water Year	Flow (cfs)	Percent of 30-year Average Flow
1975	28	77%
1976	20	55%
1977	11	31%
1978	40	110%
1979	53	144%
1980	49	132%
1981	31	85%
1982	40	110%
1983	86	234%
1984	42	116%
1985	42	115%
1986	35	95%
1987	30	82%
1988	39	107%
1989	14	39%
1990	17	45%
1991	19	53%
1992	24	67%
1993	68	185%
1994	23	64%
1995	61	166%
1996	16	45%
1997	26	72%
1998	63	171%
1999	32	88%
2000	24	65%
2001	33	90%
2002	9.6	26%
2003	20	55%
2004	21	58%
2005	116	317%
30-year average	36.8	100%

Annual flow volumes and ranking relative to the 30-year average for Coal Creek near Cedar City, Utah (USGS gage #10242000).

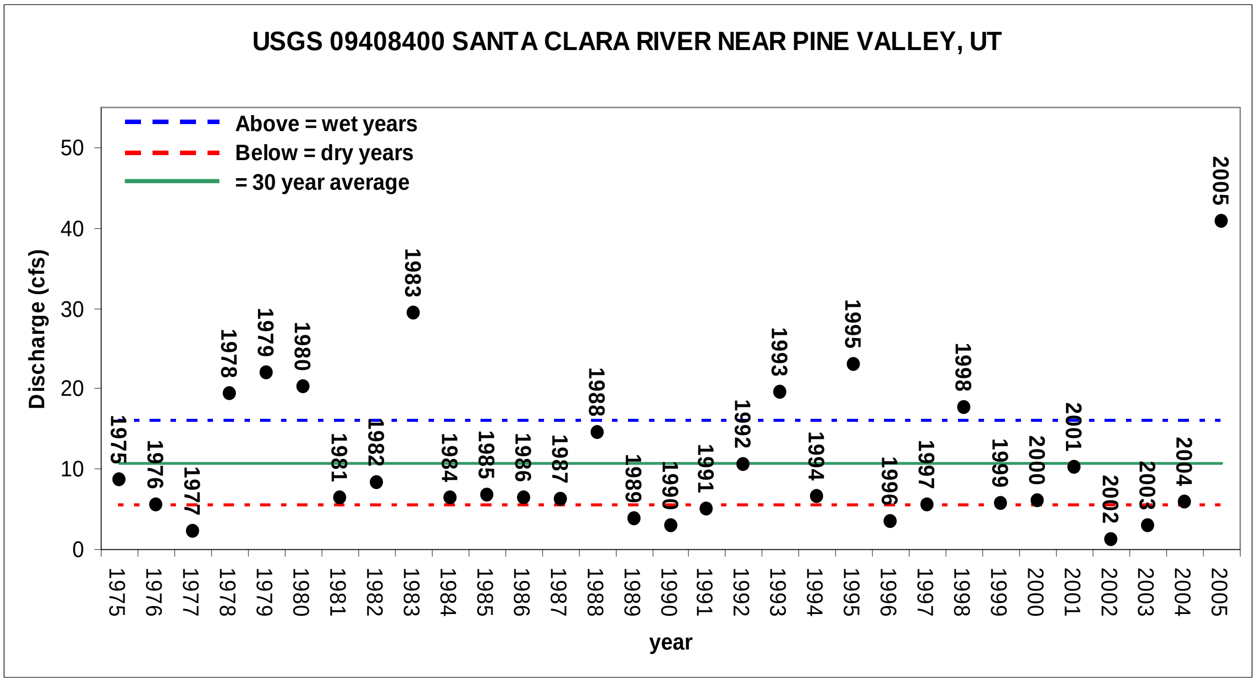


Figure 3.1. Annual discharge volumes for the Santa Clara River near Pine Valley, Utah, 1975–2005 (USGS Gage #09408400).

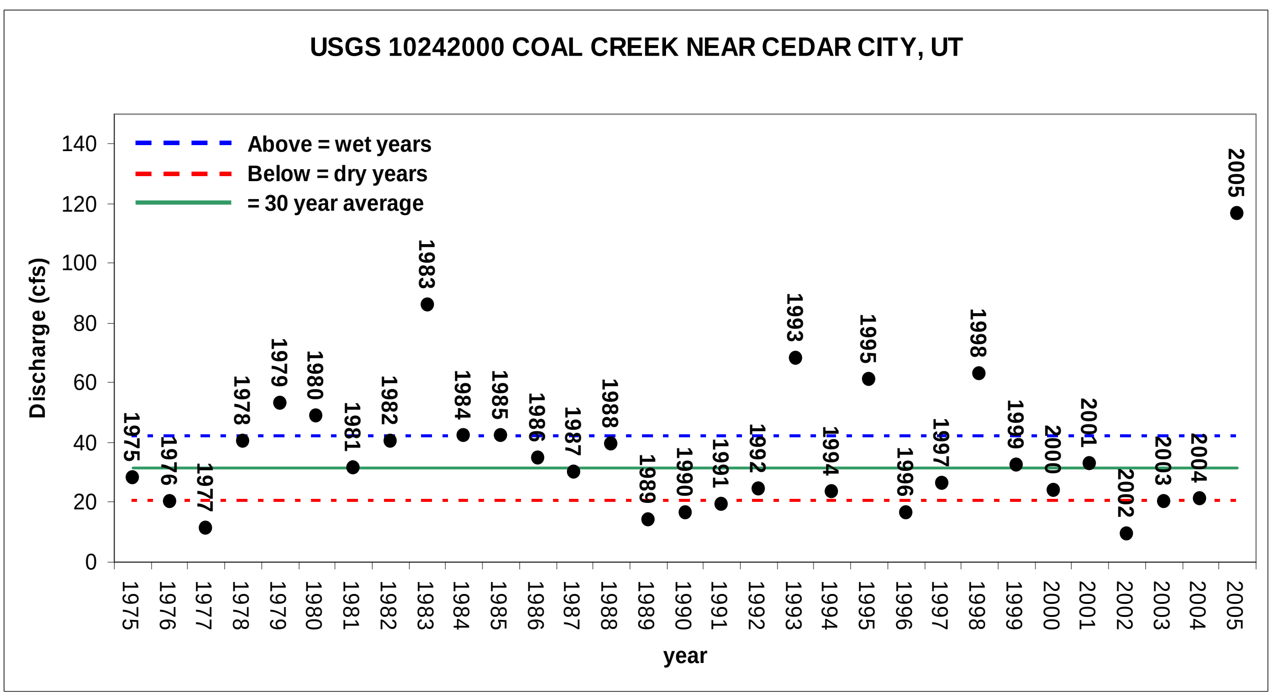


Figure 3.2. Annual discharge volumes for Coal Creek near Cedar City, Utah, 1975–2005 (USGS Gage #10242000).

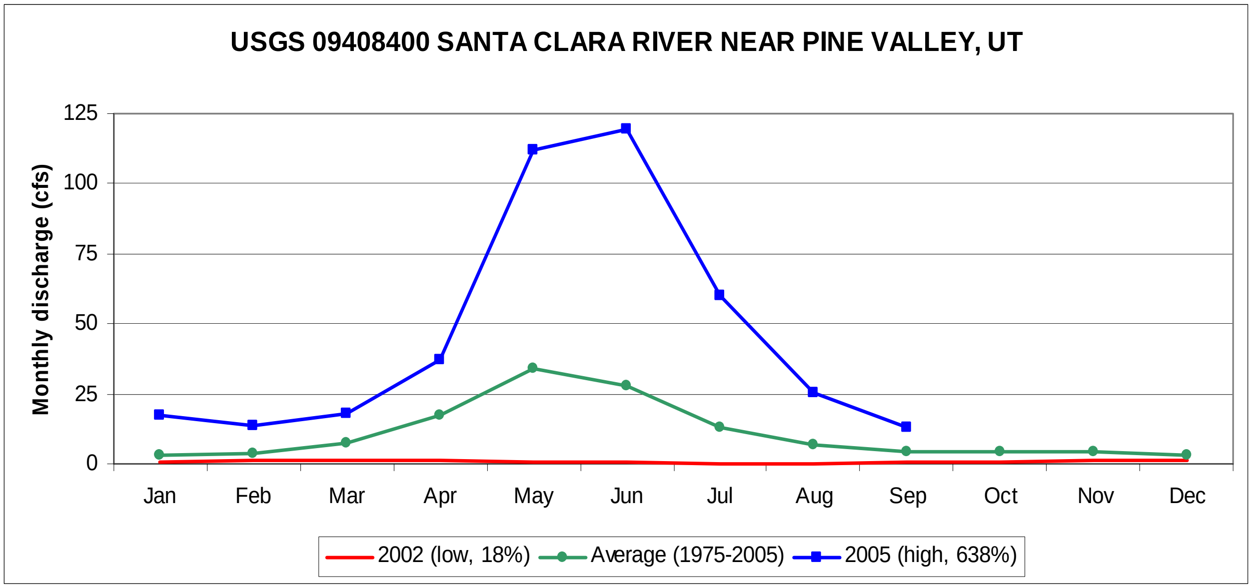


Figure 3.3. Monthly average discharge volumes for the Santa Clara River near Pine Valley, Utah, for 2002 (low), 2005 (high), and the 30-year average (USGS Gage #094084).

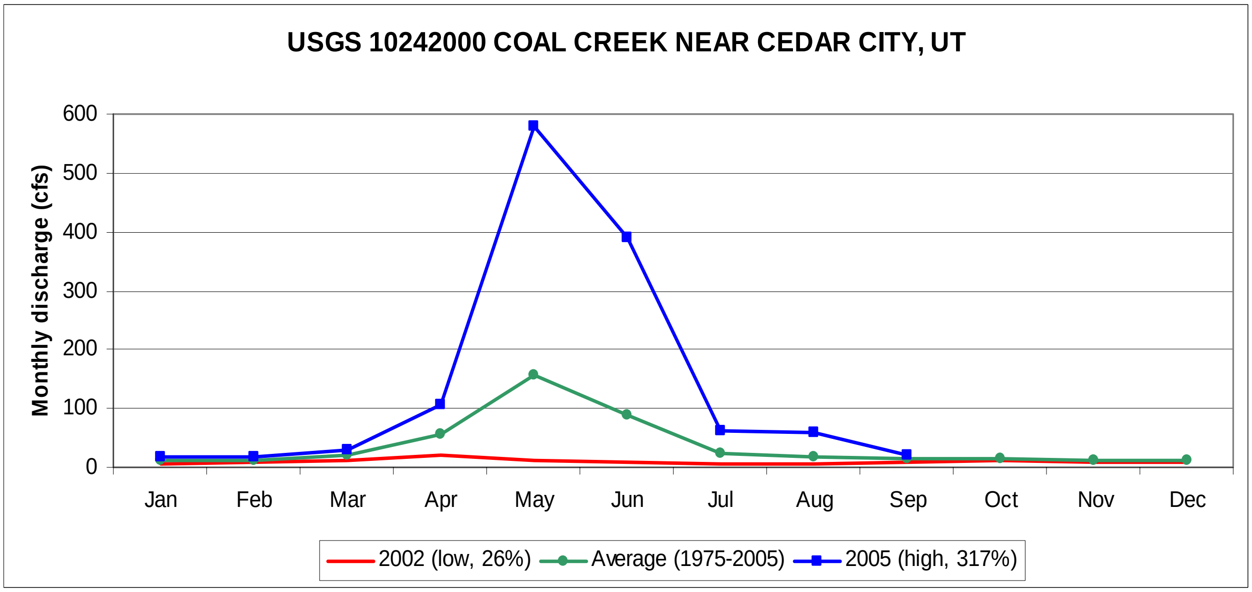


Figure 3.4. Monthly average discharge volumes for Coal Creek near Cedar City, Utah, for 2002 (low), 2005 (high), and the 30-year average (USGS Gage #10242000).

Data collection is somewhat weighted toward the late spring to late fall months, with fewer winter data points in most datasets. Assuming that ungaged flows in the Newcastle Reservoir watershed are similar in trend volume and flow to gaged flows in nearby drainages (Santa Clara River and Coal Creek), seasonal data collection are assumed to cover the range of high (spring runoff in May and June) and low (August and September) seasonal flows over the course of a year.

On both a water-year and a seasonal basis, available data collection times were compared with representative precipitation indices for high, average, and low water years. Data collection generally occurred over the critical range of flow and precipitation regimes, indicating (to the extent possible) that data coverage is representative of an adequate variety of flow and precipitation events.

3.5.3 SPATIAL COVERAGE

Surface water quality data are available for the Newcastle Reservoir watershed at the following locations (water quality monitoring sites are identified on the full-sized maps accompanying this summary):

- 4940650 PINTO CK AB NEWCASTLE RES (Historic and current, 1982–2006)
- 4940600 PINTO CK BL NEWCASTLE RES (Historic, some current, 1982–1983, 2006)
- 4940610 NEWCASTLE RES AB DAM 01 (Historic and current, 1982–2006)
- 4940620 NEWCASTLE RES MIDWAY UP LAKE 02 (Historic and current, 1982–2006)

These sites represent inflow, in-reservoir, and outflow conditions (water quality parameters are detailed in Table 3.3). While all sites do not share the same level of data density, cumulatively, these monitoring sites represent good spatial coverage of the reservoir system.

While the sites identified provide inflow, in-reservoir, and outflow information for the reservoir system, the majority of outflow information available is from historic or legacy monitoring only (1982–1983). The reservoir outlet is piped and is not exposed to daylight in the immediate vicinity of the dam, making sample collection impossible. A single suite of data was collected in August 2006 that may be used to calculate outflowing loads and assist in the calculation of in-reservoir pollutant loading.

3.5.4 DATA GAPS

Several data gaps were identified through the analysis of data available to this effort. These include lack of gaged flows (inflows and outflows); lack of current comprehensive outflow water quality data, and lack of diurnal dissolved oxygen and temperature data.

3.5.4.1 Flow and Nutrient Load

Flowing water represents the primary means by which materials such as soil and pollutants are transported from place to place within the Newcastle Reservoir watershed. Available measured flow data for inflow systems and downstream sites are sparse. The majority of the flow data provided are estimated and the potential error associated with the estimation method is unknown. Because the calculation of pollutant loading is dependant on both concentration and flow data, a model has been developed to estimate appropriate, representative flows where measured flow data are unavailable. This mechanism combines data about flow relationships from measured or gaged flows within the watershed and using the SWAT watershed modeling suite. Conservative assumptions have been applied in the calculation of representative flows in order to minimize error.

Hydrologic models are simplified representations of certain portions of the water cycle that are generally used for predicting and understanding hydrologic processes and for characterizing the water balance of a region or watershed. These models can be used to better understand water movement as a significant means by which other material, such as soil or pollutants, are transported from place to place. Initial input to receiving waters may arise from a point source discharge or a diffuse source, such as surface runoff. Since the 1960s, researchers have developed rather complex mechanistic mathematical models (facilitated by the availability of high-speed computers) that couple temporal dynamics and spatial relationships of water movement, both of which are key to understanding how water moves within the landscape. The most common pollutant classes analyzed are nutrients, pesticides, total dissolved solids, and sediment.

The model proposed for estimating watershed flow budgets is the Soil and Water Assessment Tool (SWAT) developed by the USDA Agricultural Research Service (USDA-ARS) to predict the impact of management practices on water, sediment, and agricultural chemical yields in watersheds that possess different soils, land uses and management conditions over long durations (Neitsch et al. 2002). This vector-based model links spatial and process models by dividing the landscape into hydrologic response units (HRUs), which are similar in soil type, slope, and land use. The model is described in more detail in Chapter 4.

The SWAT model will be used in the Newcastle TMDL process to simulate daily tributary flow to the reservoir; it combines empirical water quality data with calculations associated with annual nutrient and sediment loads to the reservoir and has been configured to include the diversion from Grass Valley.

3.5.4.2 Outflow Monitoring

Recent water quality data available to this effort consist of the single suite of data collected through a break in the outflow pipe in August 2006. While these data will be helpful to inform the process, it represents only a snapshot in time and cannot be applied to the wide range of conditions identified by the in-reservoir monitoring conducted over several years. Land and water management within both watersheds have changed since the available data were collected for Newcastle Reservoir (1983 and 1982, respectively) and the water quality trends and indicators described by the available data may not be representative of current conditions. The reservoir flow patterns, transport, and processing mechanisms appear to be consistent with those of other small, nutrient-enriched systems. Thus, the current suite of data, along with accepted literature references will be used to determine the outflow component of reservoir loading. Due to the nonmeasured status of the outflow, conservative assumptions will be applied in the calculation of loading to minimize error.

3.5.4.3 Reservoir Volume Data

Reservoir elevation, overflow, and volume data do not exist for the entire temporal range of water quality sampling activities, nor have specific elevation measurements been taken on the same day water quality sampling occurred. Reservoir bathymetry was determined, to the extent possible, from existing volume and elevation information. A correlation between water depth at dam (derived from elevation data and known maximum dam capacity) and reservoir volume has been constructed using data available from UDWR (Figure 3.5).

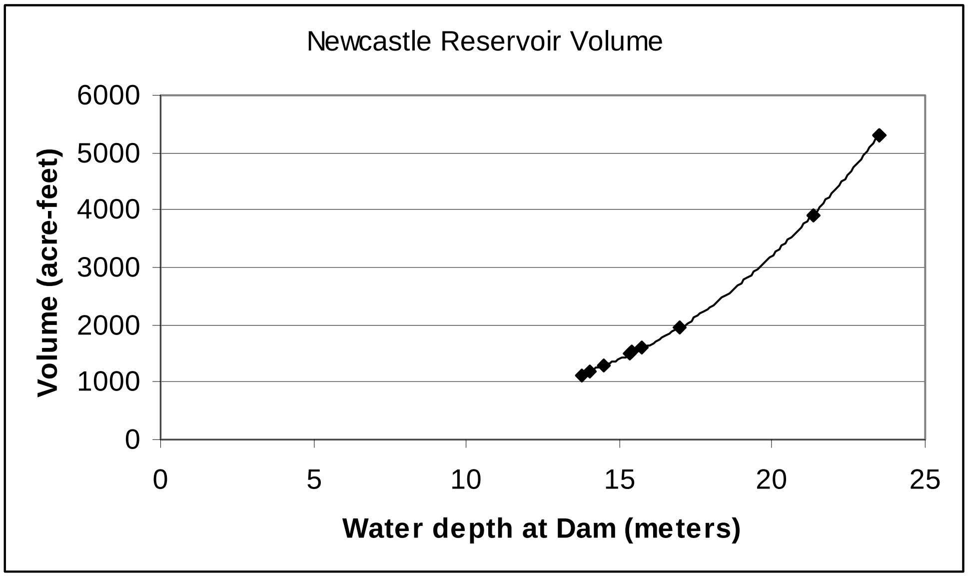


Figure 3.5. Correlation between reservoir volume and reservoir depth at the Dam Site.

3.5.4.4 Temperature

Temperature data collected in the late spring and summer months in the Newcastle Reservoir watershed are instantaneous grab samples and therefore cannot be compared directly to the state cold water criteria of a 20^{o}C daily maximum. Though grab samples cannot characterize the magnitude of the criteria exceedance, they do indicate that an exceedance has occurred.

To better characterize the potential for temperature excursions in the absence of diurnal data, water quality sample times were assessed to determine whether water temperatures were likely to rise or fall following the sampling event. The results of this analysis showed that in most cases (85% at the Mid-lake Site and 88% at the Dam Site) the water temperature measured was either indicative of the highest daily temperature conditions or cooler than the expected daily maximum (e.g., measurements were taken prior to when the daily maximum air temperature occurred). Therefore, the temperature data are representative of a conservative (low) condition and do not reflect the maximum daily water temperature in the majority of cases. In the State of Utah's 2006 303(d) list, violations of temperature criteria that were related to solar radiation, calculated through a heat budget analysis, were not deemed cause for listing a waterbody on the impaired-waters list.

3.5.4.5 Summary

Guidance by the CWA indicates that states are to use the best available data in the TMDL process, and in those cases where data gaps exist (such as the availability of concentration data and the lack of concurrent flow information mentioned above), each TMDL is to include a MOS to account for unknown factors. In most cases, the Newcastle Reservoir system has a reasonably complete set of available data for the evaluation of water quality impairment.

It should be noted that both recent and current data have been collected during low water years. Therefore, physical water quality characteristics such as temperature and dissolved oxygen concentration measured during these water years will be representative of critical watershed conditions. However, loading estimates that are calculated exclusively from low water years will underestimate total pollutant loading, since both runoff and in-stream water volumes are decreased during drought conditions. It is therefore recommended that total loading calculations incorporate, to the extent possible, all water years in the current dataset rather than only the most recent water year or years. In summary, there is a reasonably robust dataset available to the TMDL process. Identified data gaps can be filled either by additional monitoring or methods for interpolating missing data. Table 3.7 summarizes the identified data gaps and the proposed mechanisms for accommodating the identified gaps within the TMDL process.

Table 3.7. Status of Data Gaps Identified in the Newcastle Reservoir Phase I Watershed Management Plan

Data Gap	Description	Proposed Mechanism to Accommodate Gap
Lack of measured flow data	Flow data are lacking for tributaries and reservoir outflow. Anecdotal information of overflows of the dam during high spring flows.	Apply the SWAT model.
Lack of water quality monitoring in reservoir outflow	Water quality data are dated (1982–1983) for the reservoir outflow and do not represent current conditions.	Collect a suite of outflow data in summer 2006 (completed), apply accepted literature references, and apply BATHTUB model to predict reservoir water quality.
Lack of reservoir information specific to physical characteristics (flow, volume, elevation, bathymetry)	Reservoir elevation, overflow, and volume data do not exist for the range of water years. Available data (2003–2004) do not correlate temporally with water quality monitoring.	Correlate reservoir elevation (water level) with depth, volume, length and area based on Utah Division of Water Rights data.
Lack of diurnal temperature data	Grab samples cannot be assumed to represent the critical period for temperature excursions.	Perform impairment assessment with available data and identify locations and time periods of concern.

3.6 Assessment of Beneficial Use Impairment/Support

The State of Utah determined that secondary contact recreation and agricultural water supplies at Newcastle Reservoir are fully supported. However, designated beneficial uses specific to cold water game fish are impaired; assessment of these uses and the level of support being given to restore conditions for cold water game fish will be discussed here.

3.6.1 Key Indicators of Impairment

The following sections identify the key indicators and causes of impairment within the Newcastle Reservoir watershed. Table 3.8 summarizes these indicators and the designated beneficial uses to which they correspond, specific to the 303(d) listing concerns.

Table 3.8. Indicators of Impairment and Corresponding Designated Beneficial Uses

Key Indicators of Impairment	Potential Pollutant Sources
Low dissolved oxygen concentrations Elevated nutrient concentrations Elevated water temperatures Elevated pH (above 9.0)	Plant/algal growth and decay of organic matter Agricultural fertilizers in irrigation runoff Riparian grazing within the watershed Runoff from all-purpose forest roads Unstable stream banks Leaking septic/sewer Natural sources Near-stagnant summer flow conditions

When water quality in a waterbody is impaired, the problem is seldom blamed on a single or simple cause. In most cases, impairment results from a combination of circumstances or conditions. For example, low dissolved oxygen in a lake or reservoir commonly results from elevated nutrient inputs, warm water temperatures, and summer light levels. When these elements occur simultaneously, they produce conditions in the reservoir that are favorable to algae growth and decay, both of which remove oxygen from the water column. All three conditions are necessary for this result. If only one or two were present (nutrients, warmth, or light), the algae would not grow in sufficient quantities to cause low dissolved oxygen levels (anoxia). A more detailed explanation of each potential cause of impairment, as well as common sources of those causes, follows.

3.6.1.1 Low Dissolved Oxygen

Dissolved oxygen (DO) is important to the health and viability of fish and other aquatic life. Aquatic life depends on high concentrations of dissolved oxygen (from 6–8 mg/L or greater); low dissolved oxygen (concentrations below 5 mg/L) can result in stress, reduced resistance to other environmental stressors, and even death at very low levels (less than 2 mg/L).

In addition to direct effects on aquatic life, low dissolved oxygen concentrations can lead to changes in water and sediment chemistry that can influence the concentration and mobility of nutrients and toxins—e.g., changes in phosphorus, ammonia, and mercury levels in the water column. Low dissolved oxygen at the sediment-water interface can result in substantial release of sorbed phosphorus in the water column, which in turn can lead to increased algal growth and decreased dissolved oxygen concentration. Anoxic conditions, combined with available organic matter, can result in higher rates of methylmercury production. Methylmercury represents a significantly greater threat for bioconcentration and accumulation than elemental or mineralized mercury compounds. Finally, increased water column concentrations of ammonia can result from the chemical changes caused by anoxic conditions. Elevated ammonia levels threaten the health of aquatic life forms and, at extreme concentrations, can result in death.

Low dissolved oxygen often results from high nutrient, organic, or algal loading to a surface water system. Nutrients promote algae growth, which in turn consumes oxygen from the water column during periods when respiration is the dominant process (generally at night). In addition, dying algae in lakes and reservoirs settle to the bottom of the waterbody and decompose; aerobic decomposition of the dead algae and other detritus (nonliving organic material) depletes the oxygen supply in the overlying water and sediment. In systems where suspended solids are primarily organic in origin, low dissolved oxygen levels may be correlated with sediment inputs as well.

Dissolved oxygen concentrations are also reduced by pollutants that require oxygen in oxidation processes. Biochemical oxygen demand (BOD) is a measure of the dissolved oxygen required to oxidize material (usually organic), whether the material is naturally occurring, the result of increased natural material, or contained in municipal, agricultural, or industrial wastes. Some of the delivered organic material is algae and some is detritus. Both of these organic matter components produce a certain amount of BOD. A substantial organic load may be delivered to the reservoir during high volume and high velocity spring flow events.

Fish use gill respiration to extract oxygen from the water column. As the temperature of the water increases, oxygen can be more easily extracted from it. However, cold-blooded organisms also have increased metabolic rates and higher oxygen requirements at elevated water temperatures, so the additional oxygen gained at higher temperatures is offset and does not benefit the fish. Further, oxygen dissolves more readily in colder water. As water temperatures increase, oxygen comes out of solution and the amount of dissolved oxygen in the water decreases.

Developing embryos and young emergent fish are especially sensitive to dissolved oxygen concentrations. Small fish often shelter near the shoreline (littoral) areas that represent the best opportunity for vegetative cover. As these areas experience the changeover from photosynthesis to respiration, the shallow water column can quickly become depleted of oxygen and young fish can be stressed or die due to the low concentrations. Low dissolved oxygen levels at the sediment/water interface also represent a food-chain related concern. Anoxia can have adverse effects on benthic organisms (lower life forms that live in the bottom sediments) and other macroinvertebrates which are a food source for many fish and bird species.

While some diurnal variations in dissolved oxygen is natural and fish species are adapted to them, substantial variations (identified by some researchers as swings of 3 mg/L or more) are detrimental to aquatic life. These substantial diurnal fluctuations in dissolved oxygen, even when concentration remains within the range described by the water quality criteria, are likely to be stressful and damaging to fish health. Such fluctuations cause stress in fish, resulting in reduced fish growth rates, poor feed conversion, and reduced resistance to disease (Nebeker et al. 1992; Whitworth 1968; and Seager et al. 2000).

A recent literature review by Breitburg (2002) summarized field research on the effect of declining dissolved oxygen concentrations on fisheries. The collected works show that as oxygen concentrations decrease, the abundance and diversity of fish species decline. Total fish abundance and fish species richness were observed to decline with a decrease in dissolved oxygen concentrations. These patterns were documented in the fish study conducted by Utah State University in 2005 and 2006.

Longer exposure to low oxygen and more severe hypoxia led to avoidance of and migration from the affected area. All larval, juvenile, and adult fish in the surveyed studies responded to low dissolved oxygen by moving upward or laterally away from waters with low dissolved oxygen concentrations. Studies have shown that not only do fish avoid lethal conditions, but they also avoid conditions that require greater energy expenditures for ventilation (i.e., conditions that would result in reduced growth). Field and laboratory studies have documented that dissolved oxygen concentrations routinely avoided are 2 to 3 times higher than those that would lead to 50% mortality in a population (Breitburg 1990, 1992; Breitburg et al. 1997, 1999; Breitburg and Riedel 2005; Nebeker et al. 1992; Whitworth 1968; and Seager et al. 2000). According to the studies referenced in the literature review, the net result of depressed dissolved oxygen is reduced species diversity and lower abundance and production of fish within the affected area.

Growth and reproduction can be negatively affected by dissolved oxygen concentrations that are outside of the range to which local fish species are adapted. This is especially true for early life stages. Growth and survival of young fish and embryos is dependant on both adequate dissolved oxygen and appropriate water temperatures. Like adult fish, the detrimental effects of low dissolved oxygen concentrations on young fish and embryos are generally greater when they occur at water temperatures approaching the upper limit for a fish species (20 ºC in the case of cold water game fish) (EPA 2003). High water temperatures often occur near the shoreline in the shallow littoral zones. Young fish preferentially inhabit near-shore areas due to the presence of adequate cover in these areas. Due to the larger percentage of the water column in direct contact with aquatic plants in these areas, low dissolved oxygen conditions occur more frequently and to a greater magnitude in littoral areas. Young fish cannot avoid the warmer water temperatures and low dissolved oxygen conditions that occur during the summer season and may succumb to diurnal swings in dissolved oxygen, coupled with elevated water temperatures, leading to poor recruitment and young of the year survival.

Additional dissolved oxygen is necessary for the support of spawning and early life stages. The State of Utah water quality criteria recognize this and provide for no less than 9.5 mg/L dissolved oxygen as a seven-day average when early life stages are present and no less than 8.0 mg/L as a one-day average when early life stages are present. While 303(d) listing and beneficial use support status are not specific to spawning and early life stage criteria, reservoir conditions were evaluated for early life stage criteria in an assessment of biological and habitat conditions for the cold water game fishery and are summarized in the SBA portion of this TMDL.

3.6.1.2 pH

A key indicator of acidity or alkalinity of a system is pH, as measured by the hydrogen ion activity in the water. A pH value of 7.0 is neutral, with values from 0–7 indicating acidic water and values from 7–14 indicating alkaline water. Extremely acid or alkaline waters can be toxic to aquatic life. Even at less extreme levels, acidic or alkaline conditions can cause chemical shifts in a system; acidic conditions can release metallic compounds from sediments while alkaline conditions can increase ammonia toxicity and release sorbed phosphorus.

Both living and dead (decomposing) algae can affect the pH of the water due to the release of various acid and base compounds during respiration and photosynthesis. Additionally, low dissolved oxygen levels caused by decomposing organic matter can lead to changes in water chemistry and release of sorbed phosphorus to the water column where water and sediment interface. These same conditions are conducive to methylmercury production in areas where inorganic mercury is present in the system.

In the Newcastle Reservoir watershed, pH could be altered to a small degree or in a localized area by ammonia production during organic matter decomposition, by agricultural runoff, or by excessive algal growth due to the carbon dioxide released during respiration. However, given the alkaline soils present in the watershed, pH is likely buffered by sodium, calcium, and magnesium salts (carbonates), which are dissolved or eroded from the landscape and delivered as sediment and bed load; therefore, changes are usually small when they occur.

3.6.1.3 Temperature

Appropriate temperature is key to water quality and support of aquatic habitat. Temperature determines whether or not a waterbody can support warm or cold water aquatic species. High water temperatures can be harmful to fish at all life stages, especially when high temperatures combine with other habitat limitations such as low dissolved oxygen or poor food supply. As a stressor to adult fish, elevated temperatures can lower body weight, reduce oxygen exchange, and diminish reproductive capacity. Extremely high temperatures can result in death if they persist for an extended length of time. Juvenile fish are more sensitive to temperature variations and duration than adult fish; they tend to experience negative impacts at a lower threshold value than the adults.

Acceptable temperature ranges vary for different species of fish; warm water species adapt better to rising water temperatures than cold water fish. Newcastle Reservoir contains a wide variety of fish species and requires system management to ensure appropriate habitat and support of designated beneficial uses wherever and whenever use occurs. Protective criteria have been established to serve the needs of important cold- and warm water species of aquatic life. The temperature criteria are usually built around a maximum allowable value that relates to critical life-stage requirements.

Temperature increases in Newcastle Reservoir are influenced by natural heat exchange through high air temperatures and the effects of direct solar radiation on the water surface, especially during the summer. In addition, inflowing tributaries in hot climates can contribute to temperature increases particularly in the summer. Other influences may affect water temperature, including agricultural return flows, flow diversions, loss of riparian vegetation, and other anthropogenic modifications to both Little Pinto Creek and Pinto Creek; however, these factors most likely have a minor effect on water temperatures in the reservoir relative to natural factors.

3.6.1.4 Nutrients

General concerns associated with excessive nutrient concentrations relate to both direct and indirect effects. Direct effects are nuisance algae and periphyton growth. Indirect effects include low dissolved oxygen, increased methylmercury production, elevated pH, cyanotoxins from cyanobacteria (blue-green algae) production, trihalomethane production in drinking water systems, and maintenance issues associated with domestic water supplies.

Nuisance aquatic growth, both algae (phytoplankton, or water column algae, and periphyton, or attached algae) and rooted plants (macrophytes) can adversely affect both aquatic life and recreational water uses. Algal blooms occur where nutrient concentrations (nitrogen and phosphorus) are sufficient to encourage excessive growth. Levels necessary for growth may occur at concentrations well below the identified water quality thresholds and criteria. Available nutrient concentrations, flow rates, velocities, water temperatures, and sunlight penetration in the water column are all factors that influence algae (and macrophyte) growth. When conditions are appropriate and nutrient concentrations exceed the quantities needed to support algal growth, excessive blooms may develop. Commonly, these blooms appear as extensive layers or algal mats on the surface of the water.

Algal blooms often create objectionable odors in water used for recreation and can produce intense coloration of both the water and shorelines. Waterbodies demonstrating sufficient nutrient concentrations to cause excessive algal growth are said to be eutrophic. Algae is not always damaging to water quality, however. The extent of the effect is dependent on both the type(s) of algae present and the size, extent, and timing of the bloom. In many systems algae provide a critical food source for many aquatic insects, which in turn serve as food for fish.

Algae growth also has indirect effects on water quality. When algae die, they sink slowly through the water column, eventually collecting on the bottom sediments. The biochemical processes that occur as the algae decompose remove oxygen from the surrounding water. Because most of the decomposition occurs within the lower levels of the water column, dissolved oxygen concentrations near the bottom of lakes and reservoirs can be substantially depleted by a large algal bloom. Low dissolved oxygen in these areas can lead to decreased fish habitat and even fish kills if there are not other areas of water with sufficient dissolved oxygen available where the fish can take refuge.

Both nitrogen and phosphorus represent nutrients that can contribute to eutrophication. Either nutrient may be the limiting factor for algal growth depending on algal species. Cyanobacteria (blue-green algae) can dominate in nitrogen-limited systems as they are able to fix nitrogen from the atmosphere (where air and water interface) and from the water column. In systems where cyanobacteria (blue-green algae) are the dominant population, nitrogen is not a limiting agent based on this ability to fix nitrogen. Therefore, these organisms can grow where low nitrogen concentrations may inhibit the growth of other algal species (Sharpley et al. 1995 and 1984; Tiessen 1995). These systems are thus P-limited. Freshwater systems are usually thought to be phosphorus limited; however, there is a large body of recent literature concerning the impact of the nitrogen-to-phosphorus ratio (N:P) in freshwater systems, indicating a co-limited system. Typically N:P ratios of less than 10:1 suggest a nitrogen-limited system, whereas higher ratios suggest that nitrogen and phosphorus are either co-limiting or that the system is P-limited. However, the cut off for an N:P ratio below which nitrogen is likely the limiting agent ranges from 7:1 to 15:1 (EPA 2000).

The N:P ratio in Newcastle Reservoir averages 14:1 at the Dam Site and 7.9:1 at the Mid-lake Site (Table 3.9). The ratios range from a low of 0.6:1 to a high of 21:1. However, these estimates are based on a very narrow dataset because there are very few dates for which total phosphorus and total nitrogen data are available. Many data points do not come from the recent or current dataset (defined as 1992 and later). Nonetheless, the N:P data suggest that Newcastle Reservoir could be co-limited by nitrogen and phosphorus. Therefore, strategies aimed to improve water quality by reducing chlorophyll *a* and improving dissolved oxygen levels should be targeted at both nutrients. Most best management practices for agriculture and forestry reduce phosphorus and nitrogen simultaneously.

Table 3.9. N:P Ratios in Newcastle Reservoir

	N:P Mid-lake	N:P Dam
5/24/1979	--	19:1
8/29/1979	11:1	21:1
9/2/1980	13:1	17:1

Table 3.9. N:P Ratios in Newcastle Reservoir

	N:P Mid-lake	N:P Dam
5/30/1990	13:1	
8/2/1990	14:1	14:1
5/20/1992	2.7:1	1.6:1
9/9/1992	4.0:1	4.3:1
6/25/1998	0.60:1	--
6/6/2000	3.6:1	--
7/31/2006	--	18:1
8/17/2006	--	19:1
Overall Average	7.9:1	14:1
Overall Maximum	14:1	21:1
Overall Minimum	0.6:1	1.6:1
Current Average (1999–2006)	3.6:1	18:1

Phosphorus can be present in a waterbody in a variety of forms. The most common forms monitored in the Newcastle Reservoir watershed are total phosphorus (TP), which includes all phosphorus (dissolved and particulate-bound) in a sample and dissolved phosphorus (primarily orthophosphate), which includes highly soluble, oxidized phosphorus. Because of its solubility, orthophosphate is commonly more available for biological uptake and leads more rapidly to algal growth than particulate phosphorus. The relative amount of each form measured can provide information on the potential for algal growth within the system. If a high percentage of TP is present as soluble orthophosphate, as it is in Newcastle Reservoir, rapid algal growth is more likely to occur than if the majority of the TP were mineral phosphorus incorporated in sediment (provided other conditions such as light and temperature are adequate). Due to phosphorus cycling, or conversion between forms, TP concentrations must be considered in the evaluation of nutrient loading.

Excess nutrient loading causes water quality problems due to the direct effect of high phosphorus concentrations on excess algal growth within the water column, combined with the direct effect of the algal life cycle on dissolved oxygen and pH within aquatic systems. As TP includes both dissolved and particulate-bound phosphorus, it represents the phosphorus that is currently available for growth as well as that which has the potential to become available over time.

Consideration of flow is important in the evaluation of nutrients and phytoplankton, periphyton, and rooted macrophyte concentrations. In a riverine system, flow transports phytoplankton and nutrients from upstream to downstream in an advective or dispersive transport mode. In other words, the riverine system is a dynamic system in which nutrients are being continually cycled as the water moves downstream. The flow regimen is important in determining the result of this combination of component concentrations. High flows can flush dissolved constituents like nutrients downstream. High flows can also scour periphyton and rooted macrophytes, reducing their concentrations considerably in-stream and concentrating them in the receiving waterbody. Finally, when high flows scour sediments and sediment is moved downstream, sediment-bound nutrient concentrations also increase as buried sediment is exposed.

High total phosphorus concentrations can lead to increases in the rate of algal growth and in overall productivity, up to the saturation point. The increased algal biomass production and transport increases biological oxygen demand (BOD) and decreases dissolved oxygen levels. Reservoir systems that experience low flow-through rates during the growing season, such as the Newcastle Reservoir system, can experience conditions that are optimal to algae growth and decomposition.

A separate consideration is the difference between algae concentrations and the rate of algal growth. Algal concentrations are determined by the availability of nutrients on a continuing basis, the availability of adequate light, and the presence of flows (velocities) that will permit continued growth without losses due to flushing (of phytoplankton), sloughing (of attached algae or periphyton), or mechanical breakage and scouring (of rooted macrophytes). In quiescent systems like Newcastle Reservoir, algal concentrations during summer seasons are dependent on nutrient availability, and only if nutrient concentrations have been depleted by algal uptake does the growth rate approach zero and phytoplankton begin to die.

In streams and rivers, the nutrients also cycle between the water, sediment, living organisms, and detritus; this is called nutrient spiraling. Generally, high velocities occur often enough to scour attached and rooted vegetation and to keep concentrations of aquatic vegetation low. Under low velocities, however, attached and rooted vegetation may increase to noticeable levels. As long as nutrients continue to be available and flows are inadequate to cause losses of algae mass, the algae will continue to grow and may reach levels that cause algal mats on the bottom or at the surface. This is often the case in shallow lakes or ponds or in pools found in intermittent streams. However, the presence of algal mats or attached algae does not necessarily indicate an excess of nutrients.

Where depth-integrated total phosphorus data are available for 1996 and 1998, concentrations are observed to increase with depth during summer months. Concentrations in deeper water generally average about three times greater than concentrations at the water's surface Mid-lake, and about six times greater than concentrations at the water's surface at the dam. Increases in total phosphorus with depth are generally correlated with low dissolved oxygen (less than 3 mg/L) in the lower layers of the reservoir and most likely indicate dissolution from sediment-bound phosphorus delivered during spring inflow.

Many sources and conditions in the environment add nutrients to waterbodies. Phosphorus can be present as a constituent of certain rock types (siliceous igneous rock) and in the mineral apatite. Nitrogen is a major component of the atmosphere and enters biological systems through nitrogen fixation and rock weatherization.

The environment itself can also be a factor in the phosphorus levels occurring within a region, since the climate, pH of natural waters, and the presence of other substances that may adsorb or release phosphorus (Hedley et al. 1995) can all potentially affect phosphorus levels. In addition, soil chemistry, redox potential, and nutrient ratios affect the cycling of nitrogen in natural systems.

There are also anthropogenic (manmade) nutrient sources. Applied fertilizers in farming, landscaping and pasture management, manure treatment, the duration and density of livestock grazing, the creation of artificial waterways and water levels through irrigation and water management practices, as well as the presence of sewage and septic waste (treated and untreated) in the surface, subsurface, and groundwater of a region often represent significant contributions to the phosphorus concentration in an area. All of these sources exist to one extent or another in the Newcastle Reservoir watershed and the Grass Valley watershed.

Natural sources of nutrients include the indigenous wildlife and wildfowl that utilize the watershed. While these populations are relatively stable throughout much of the year, substantial increases in some populations are observed with spring and fall migration patterns.

Nitrogen occurs in the environment in a variety of sources and forms. It can be present as a mineral constituent of certain rock types, as a result of the decomposition of plant and other organic material; in rainfall, as a component of agricultural or urban/suburban runoff; and as a constituent in septic discharges.

It is likely that both physical and chemical processes impact the transport and availability of phosphorus and nitrogen in the Newcastle Reservoir watershed. Physical processes (wind and water movement) dominate in the transport of phosphorus contained within or adsorbed into sediment and particulates. Chemical processes (changes in water chemistry such as dissolved oxygen, pH levels, or redox) dominate in the transport of dissolved phosphorus to the system and in the transformation of phosphorus from one form or state (i.e., free or adsorbed) to another, within both the transport pathway and the water column.

3.6.1.5 Secchi Depth

Secchi depth is a measurement of the clarity or transparency of surface waters. Secchi depths are measured using a disk with alternating black and white sections that is lowered into the water. When the disk is no longer visible, the "Secchi depth" is recorded. For example, a Secchi depth of three feet (0.9 meters) indicates that the disk was last visible at three feet below the surface. High Secchi depth readings indicate that the water is relatively clear and will allow sunlight to penetrate to greater depths. Low readings indicate turbid water (due to algae growth, suspended sediment, or other causes), which can reduce the depth to which sunlight can penetrate. Limited light at lower depths can result in decreased growth of aquatic plants.

The Secchi depths recorded for Newcastle Reservoir (Figures 3.6 and 3.7) show a decreasing trend over time during the summer growing season, in most cases. This trend is most likely related to the increasing trend noted over the summer season in chlorophyll *a* concentrations and generally indicates an increase in algal growth.

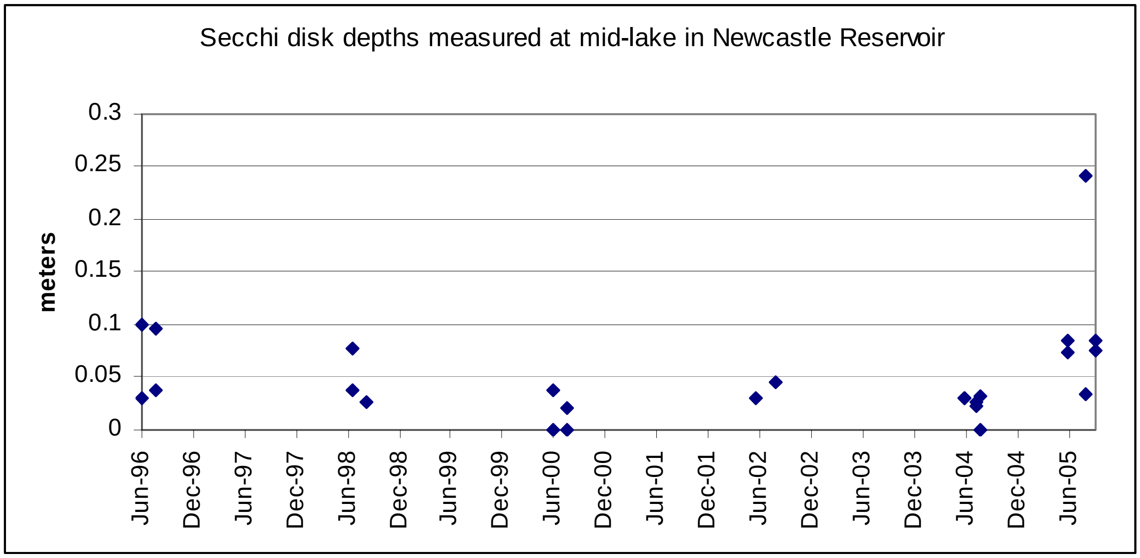


Figure 3.6. Secchi depths measured during routine monitoring at the Mid-lake Site in Newcastle Reservoir.

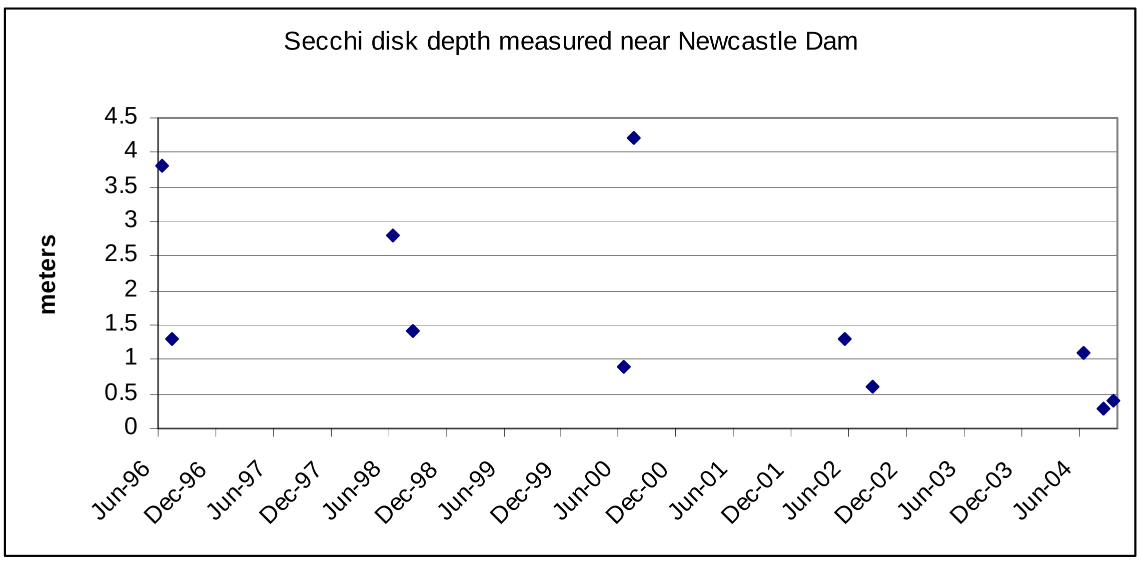


Figure 3.7. Secchi depths measured during routine monitoring near the Dam Site in Newcastle Reservoir.

3.6.1.6 Trophic State

The health and support status of a waterbody can be assessed using a trophic state index (TSI), a measurement of the biological productivity or growth potential of a body of water. The basis for trophic state classification is algal biomass (estimation of how much algae is present in the waterbody). The calculation of a TSI generally includes the relationship between chlorophyll *a*(the green pigment in algae, where chlorophyll *a* is used as a surrogate measure of algal biomass), transparency using Secchi depth measurements, and total phosphorus (commonly the nutrient in shortest supply for algal growth) as follows (Carlson and Simpson 1996):

- Chlorophyll *a*: $TSI_{CHL} = 9.81 \ln(\text{Chl a}) + 30.6$
- Secchi depth: $TSI_{SD} = 60 - 14.41 \ln(\text{SD})$
- Total Phosphorus: $TSI_{TP} = 14.42 \ln(\text{TP}) + 4.15$

An equation for calculating a TSI based on total nitrogen has also been defined:

- Total Nitrogen: $TSI_{TN} = 54.45 - 14.43 \ln(\text{TN})$ in mg/L

However, the equation is not as commonly applied (Carlson and Simpson 1996).

Waterbodies with very low TSI values (less than 30) and low TSI values (30–40) are generally transparent, have low algal population densities, and have adequate dissolved oxygen throughout the water column. Waterbodies with these characteristics are generally supportive of cold water fisheries and are identified as **oligotrophic**.

Waterbodies with low to midrange TSI values (40-50) are moderately clear, and have an increasing chance of hypolimnetic anoxia in summer. Waterbodies with these characteristics are generally supportive of warm water fisheries and are identified as **mesotrophic**.

Waterbodies with midrange TSI values (50–70) commonly experience more turbidity (the water is not as clear) and higher algal population densities than oligotrophic waterbodies. These waterbodies often exhibit low dissolved oxygen levels in mid- to late-summer, with the most extreme conditions observed in the hypolimnetic (deeper) water column. Waterbodies with these characteristics often experience some macrophyte problems (excessive growth) and are generally supportive of warm water fisheries only. These waterbodies are identified as being **eutrophic**.

Waterbodies with high TSI values (70 and greater) are generally observed to have heavy algal blooms, dense macrophyte growth, and extensive dissolved oxygen problems that often occur throughout the water column. Fish kills are often common and recreation is limited under such conditions. Fish populations are generally confined to rough fish species. Such waterbodies are identified as **hypereutrophic**.

Table 3.10 identifies generally accepted trophic state values derived from this relationship. In most cases, the greater the TSI value a waterbody has, based on collected data, the more eutrophic the waterbody is said to be.

Table 3.10. TSI Values and Status Indicators

TSI	Trophic Status and Water Quality Indicators
< 30	Oligotrophic; clear water; high DO throughout the year in the entire hypolimnion
30–40	Oligotrophic; clear water; possible periods of limited hypolimnetic anoxia (DO =0)
40–50	Mesotrophic; moderately clear water; increasing chance of hypolimnetic anoxia in summer; cold water fisheries "threatened"; supportive of warm water fisheries
50–60	Mildly eutrophic; decreased transparency; anoxic hypolimnion; macrophyte problems; generally supportive of warm water fisheries only
60–70	Blue-green algae dominance; scums possible; extensive macrophyte problems
70–80	Heavy algal blooms possible throughout summer; dense macrophyte beds; hypereutrophic
> 80	Algal scums; summer fish kills; few macrophytes due to algal shading; rough fish dominance
Source: From Carlson and Simpson, 1996.	

The trophic scale outlined in Table 3.10 illustrates these general classifications, as well as the midrange conditions that occur between each major category. However, each waterbody is unique and will exhibit site-specific characteristics based on the water quality conditions identified within the lake or reservoir and over specific time periods, seasons, or water flow conditions. The identification of TSI values for a specific waterbody allows a general classification and may provide insight into overall water quality trends and seasonality.

Summer TSI values for Newcastle Reservoir have been calculated using the data available for chlorophyll *a* concentrations, Secchi depth, and total phosphorus concentrations. The resulting values are displayed in Figures 3.8–3.13. Mean TSI values for Newcastle Reservoir are listed in Table 3.11.

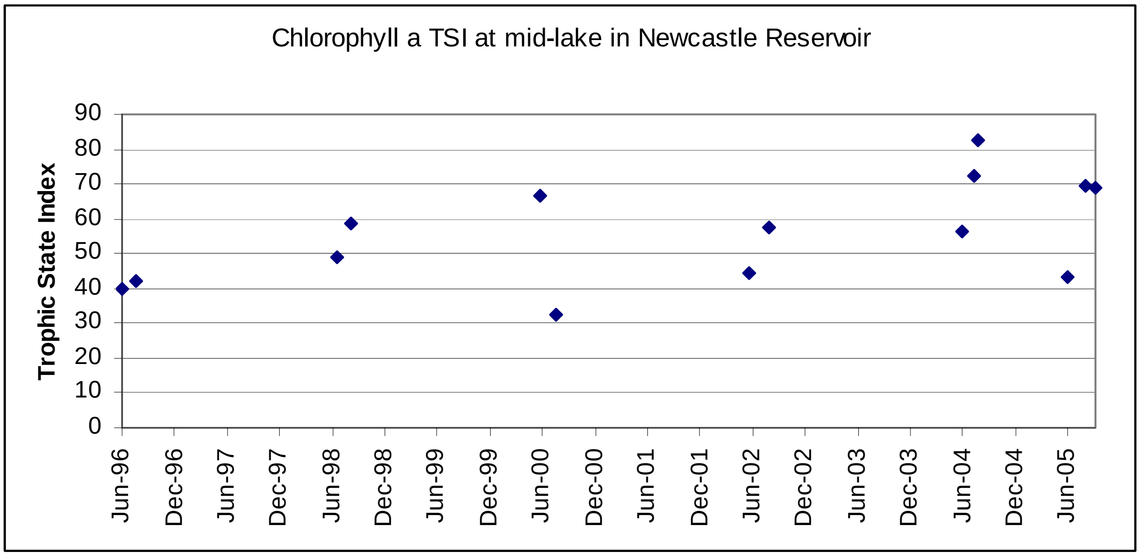


Figure 3.8. TSI values calculated for chlorophyll *a* at the Mid-lake Site.

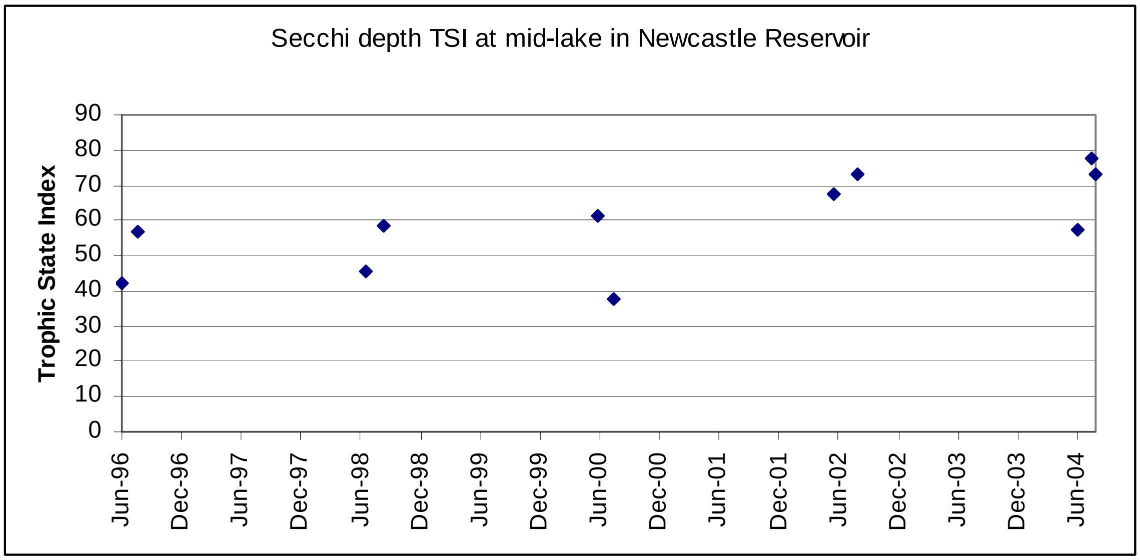


Figure 3.9. TSI values calculated for Secchi depth at the Mid-lake Site.

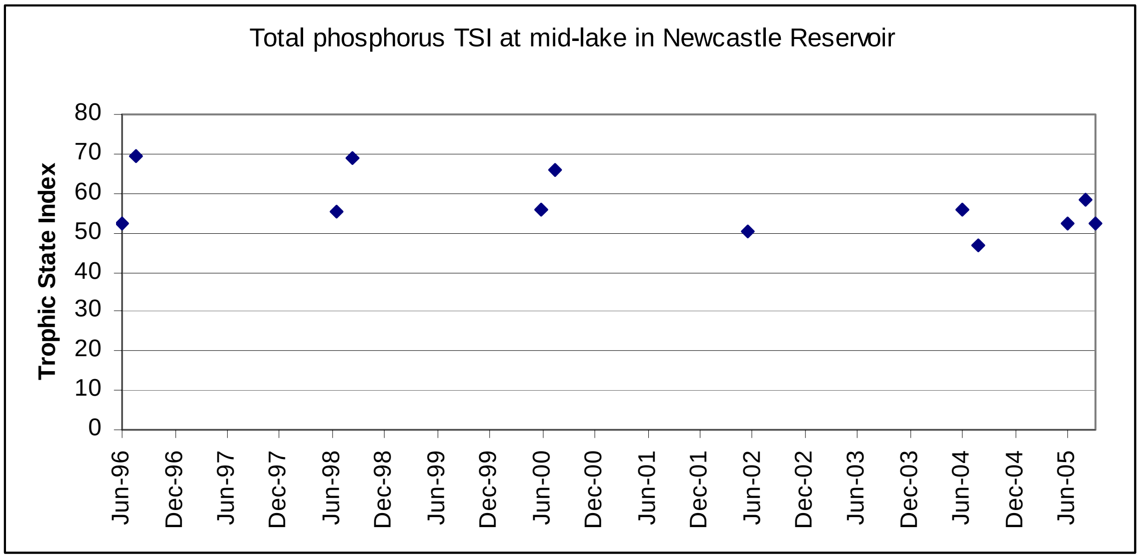


Figure 3.10. TSI values calculated for total phosphorus at the Mid-lake Site.

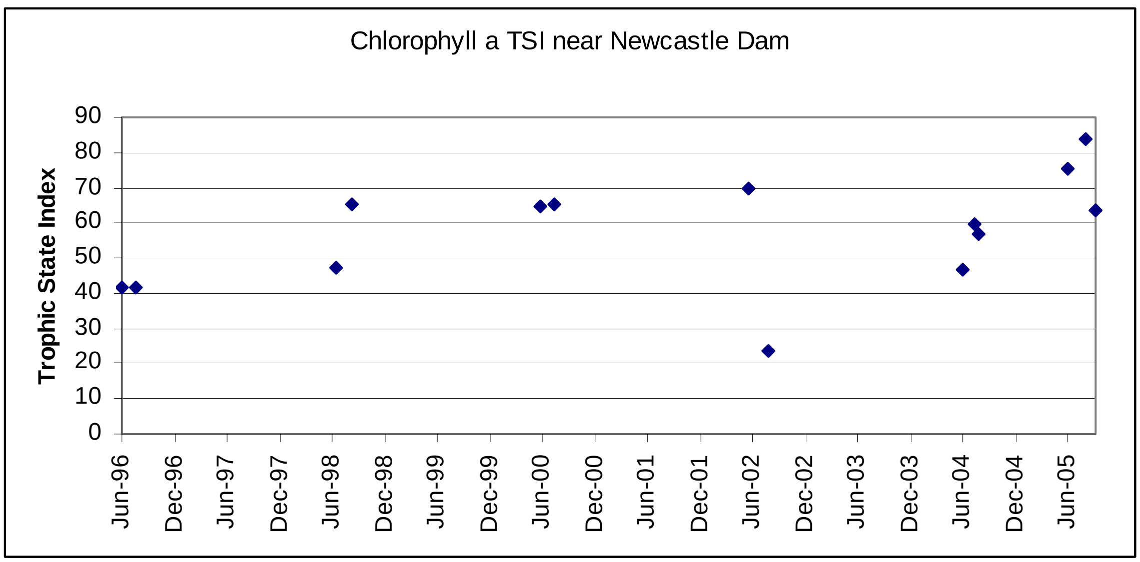


Figure 3.11. TSI values calculated for chlorophyll *a* near the Dam Site.

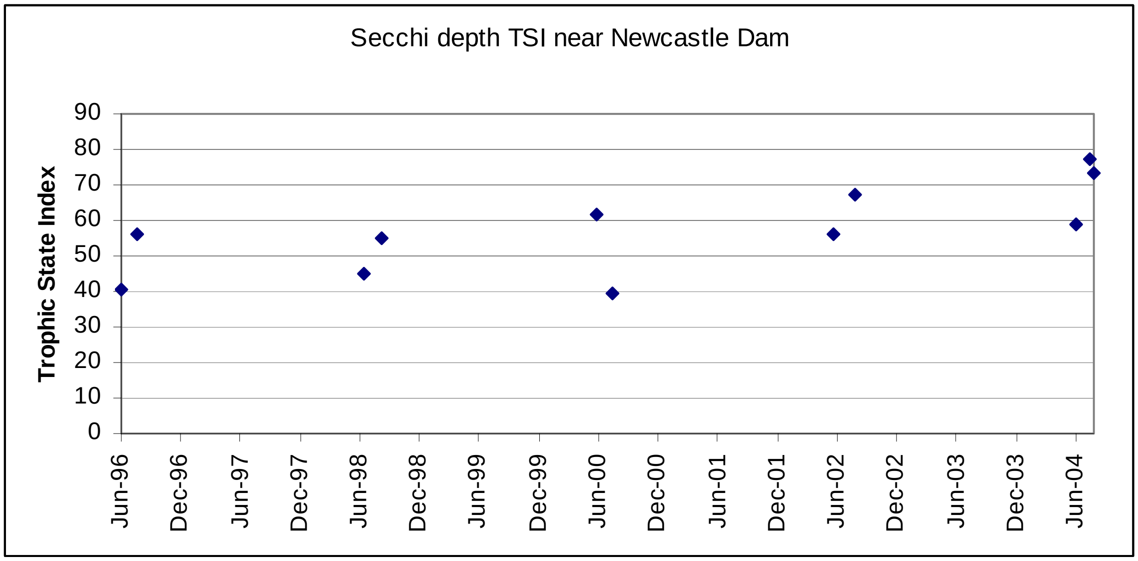


Figure 3.12. TSI values calculated for Secchi depth near the Dam Site.

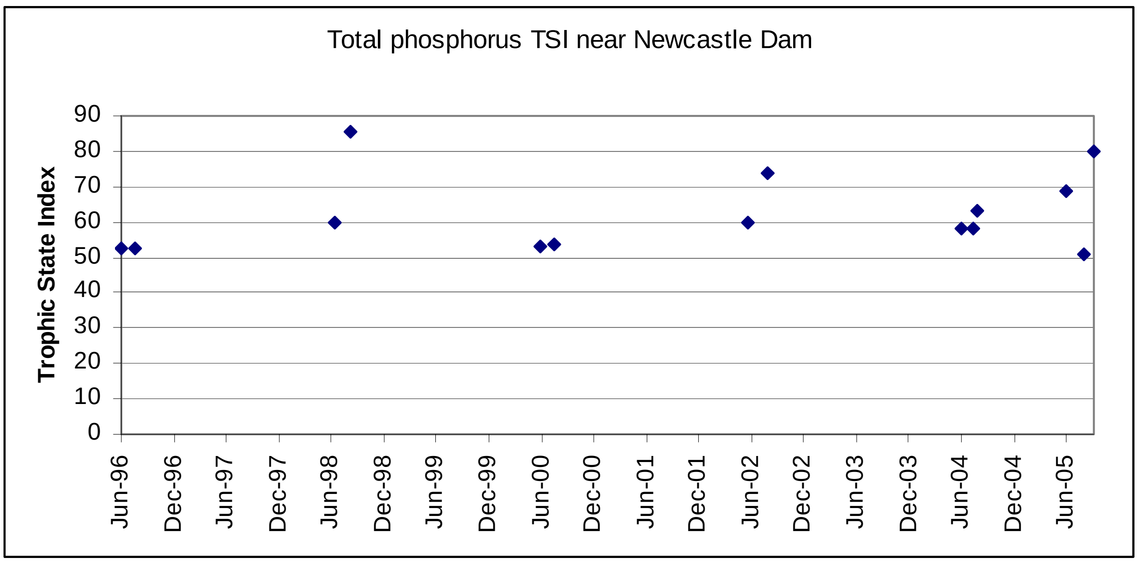


Figure 3.13. TSI values calculated for TP near the Dam Site.

Table 3.11. Average TSI Values Calculated for Newcastle Reservoir

TSI Parameter			
Monitoring Site	**Secchi Depth**	**Chlorophyll *a***	**Total Phosphorus**
Mid-lake	59	56	59
Dam Site	58	61	57
Trend over Time			
Mid-lake	Increasing	Increasing	Decreasing
Dam Site	Increasing	Increasing	Stable

The TSI values calculated indicate that Newcastle Reservoir experiences eutrophic conditions over the summer season and that the magnitude of the eutrophic effects (outlined in Table 3.11) are observed to be increasing over time. This may be in part due to the recent low water years experienced throughout the watershed as drought conditions tend to exacerbate algal growth and decomposition.

Determining the relationship between TSI values calculated for a specific waterbody is also helpful in identifying factors that limit algal biomass and/or affect the measured water quality parameters. Although every waterbody is unique, a number of common relationships between Secchi depth, chlorophyll *a*, and total phosphorus have been identified (Carlson and Simpson 1996). The following relationships may apply to Newcastle Reservoir:

- TSI(CHL) = TSI(TP) = TSI(SD): Algae dominate light attenuation
- TSI(CHL) > TSI(SD): Large particulates, such as *Aphanizomenon* flakes, dominate

For data from both monitoring locations, all three TSI values are closely grouped. No single parameter substantially differs from the other two. This close agreement in the TSI values indicates excessive algal growth, which blocks light penetration, and the formation of algal scums during the late spring and summer growing seasons. At the Dam Site, the mean chlorophyll *a* TSI is slightly higher than the TSI for Secchi depth and total phosphorus; this suggests large particulate or algal clumping, which occurs in slack water near the dam. However, the difference is relatively small and therefore does not substantiate a strong trend.

3.6.2 Direct Exceedance of Numeric Criteria and/or Threshold Values

Exceedances of water quality criteria and thresholds specific to eutrophication and designated beneficial use support are evident within the Newcastle Reservoir watershed. A direct assessment of the available data (grab samples and depth-integrated data) for exceedance of numeric criteria and identified pollutant thresholds was completed for the Newcastle Reservoir watershed. A cursory discussion of the level of exceedance observed for pertinent water quality standards and threshold values on a watershed level is presented in the following parameter-specific sections.

3.6.2.1 Ammonia

Data applicable to the (3A) fisheries designated beneficial use show no criteria exceedances for ammonia.

3.6.2.2 Chlorophyll *a*

Data applicable for the (2B) designated beneficial use for secondary contact recreation and for the (3A) fisheries designated beneficial use reveal information about concentrations of chlorophyll *a*. The mean value for the Newcastle Reservoir dataset is 28 µg/L. While the state does not publish criteria for acceptable levels of chlorophyll *a*, one review regarding nuisance thresholds and chlorophyll *a* standards reported that chlorophyll *a* concentrations of 10–15 µg/L protect waters inhabited by salmonids (Pilgrim et al. 2001). Several states in the U.S. and Canada have stated that a range of 15–50 µg/L maximum chlorophyll *a* concentrations is ideal for protecting aesthetic value and recreational uses. Data on water discoloration (Rashke 1994) show that a level of discoloration deemed acceptable to the average recreational user commonly occurs at chlorophyll *a* concentrations between 10–15 µg/L. Above this concentration, deep discoloration is observed to occur, along with the formation of algal scum, reducing aesthetics and recreational use. Median in-reservoir chlorophyll *a* concentrations range from 17 µg/L (Mid-lake Site) to 29 µg/L (Dam Site), based on data collected in 1996–2006 (Figures 3.14 and 3.15). The chlorophyll *a* concentrations observed in Newcastle Reservoir (STORET) are above the literature threshold identified as being protective for salmonid species and above the lower end of the range identified as being protective of recreational activities, but these concentrations do not appear to represent a consistent concern to recreational users.

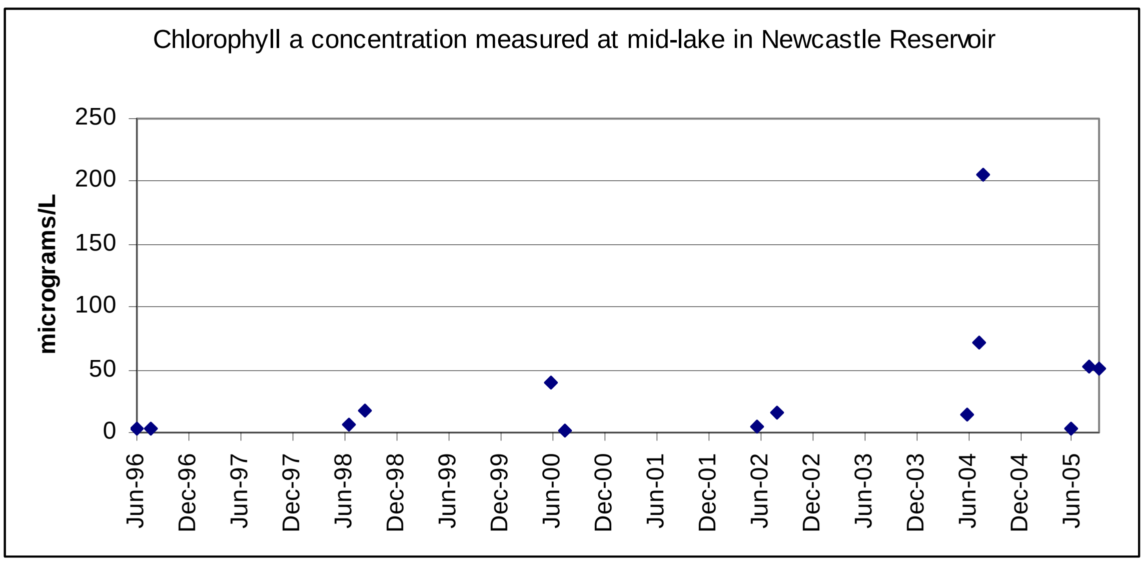


Figure 3.14. Chlorophyll *a* concentrations observed during routine monitoring at the Mid-lake Site in Newcastle Reservoir.

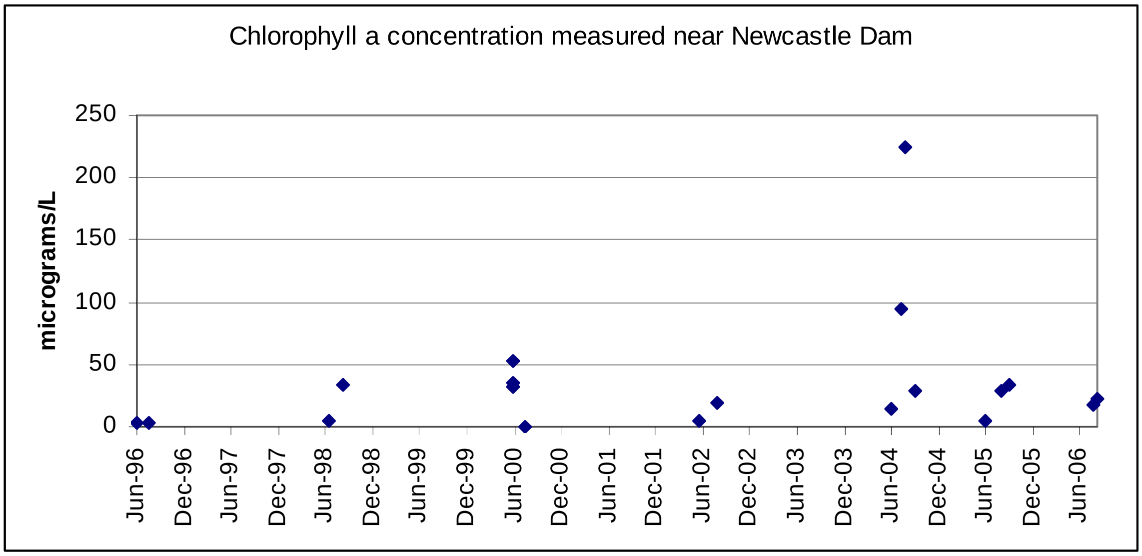


Figure 3.15. Chlorophyll *a* concentrations observed during routine monitoring near the Dam Site in Newcastle Reservoir.

Available data suggest that chlorophyll *a* concentrations of greater than 15 µg/L occur routinely in Newcastle Reservoir (36% of data reveal concentrations of greater than 15 µg/L). All of the highest observed chlorophyll *a* concentrations in Newcastle Reservoir occurred during or after 1998, indicating that a change in use or water level/inflow (drought) may be exacerbating the problem. The observably higher concentrations of chlorophyll *a* identified in Newcastle Reservoir may contribute to degraded dissolved oxygen concentrations in the reservoir.

3.6.2.3 Dissolved Oxygen

Dissolved oxygen concentrations related to the cold water fishery designated beneficial use (less than 4.0 mg/L) occur routinely in Newcastle Reservoir, with 28% of data showing dissolved oxygen concentrations of less than 4 mg/L. The observed minimum value (0.1 mg/L) shows that exceedances of the criteria are occurring at a magnitude of concern. A more detailed discussion of dissolved oxygen exceedances and plots of dissolved oxygen concentrations that were observed within the water column are available in the Section 3.6.3.

3.6.2.4 Nitrate

There are no exceedances of the nitrate criteria of 4 mg/L for the (3A) fisheries designated beneficial use. The available nitrate dataset is small, and most of the data is outdated. Recent monitoring of nitrate + nitrite concentrations reveals mean and median values that are well below desired concentrations of less than 4 mg/L.

3.6.2.5 pH

Data applicable to the (2B) designated beneficial use for secondary contact recreation and for the (3A) fisheries designated beneficial use indicate some criteria exceedances in regard to pH. Data show only very isolated exceedances (~6% of the data) of the water quality criteria (no greater than 9.0, and no less than 6.5). All observed exceedances were greater than 9.0. A more detailed discussion of pH exceedances and plots of pH values observed within the water column are available in Section 3.6.3.

3.6.2.6 Temperature

Data applicable to the (3A) fisheries designated beneficial use indicate routine exceedances of the less than 20 ^{o}C criteria (Figures 3.16–3.17). However, data are essentially grab samples and do not necessarily represent the most critical portion of the day (noon to early afternoon) where the highest water temperatures are most likely to occur. Maximum measured summertime water temperatures were 24.7 ^{o}C in the reservoir and 21.6 ^{o}C in inflowing Pinto Creek. In total, 43% of the available data showed water temperatures over 20 ^{o}C. A more detailed discussion of temperature exceedances and plots of temperature values observed within the water column are available in Section 3.6.3.

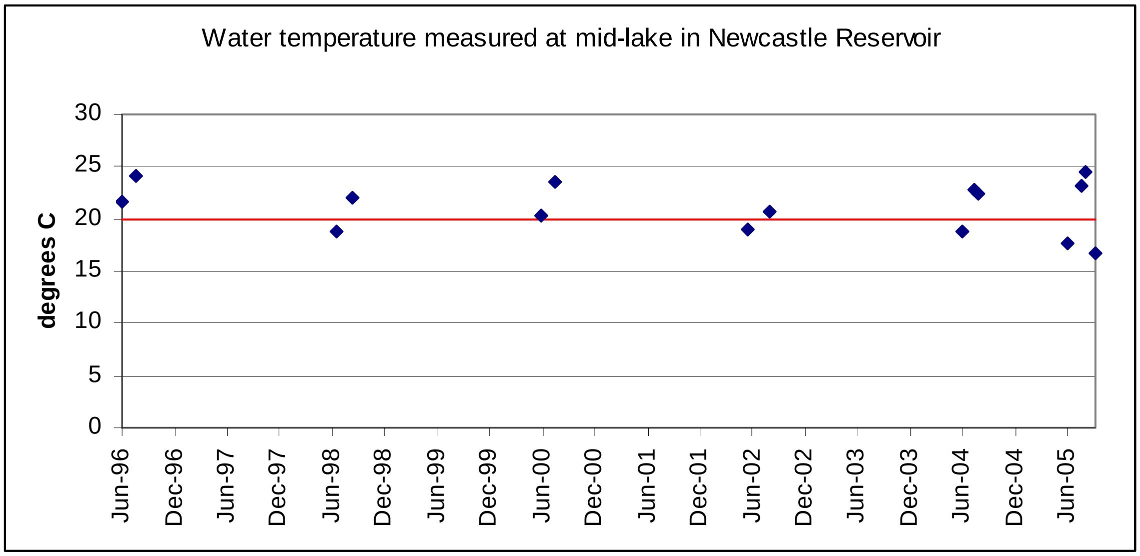


Figure 3.16. Water temperatures observed during routine monitoring at the Mid-lake Site in Newcastle Reservoir (the solid line represents the State of Utah criteria for cold water game fish of 20^{o}C).

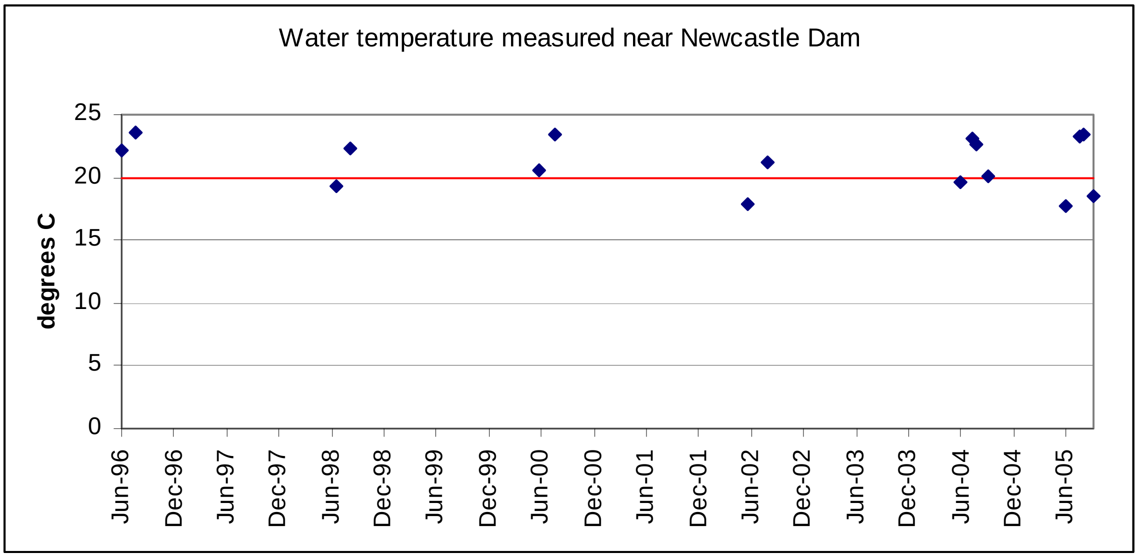


Figure 3.17. Water temperatures observed during routine monitoring near the Dam Site in Newcastle Reservoir (the solid line represents the State of Utah criteria for cold water game fish of 20^{o}C).

3.6.2.7 Total Dissolved Solids

Data applicable to the agricultural water supply designated beneficial use shows no exceedance of the total dissolved solids criteria of 1,200 mg/L criteria. All concentrations are well below 1,000 mg/L.

3.6.2.8 Total Phosphorus

Total phosphorus data reveal routine exceedances of the 0.025 mg/L threshold value for reservoirs (Figures 3.18 and 3.19). Both the mean and median values for the Newcastle Reservoir dataset illustrated in Table 3.3 are in exceedance of the threshold value. Recent and current TP concentrations in Newcastle Reservoir (STORET) show that concentrations of greater than 0.025 mg/L occur in more than 90% of data. In-reservoir monitoring shows that between 70–90% of the phosphorus in Newcastle Reservoir is dissolved.

Median in-reservoir total phosphorus concentrations range from 0.005 mg/L (Mid-lake Site) to 0.027 mg/L (Dam Site), based on data collected between 1996 and 2006. Mean in-reservoir total phosphorus concentrations are 0.021 mg/L (Mid-lake Site) and 0.035 mg/L (Dam Site). Where depth-integrated data are available, total phosphorus concentrations tend to increase with depth. This is most likely due to dissolution of sediment-bound phosphorus under anaerobic conditions.

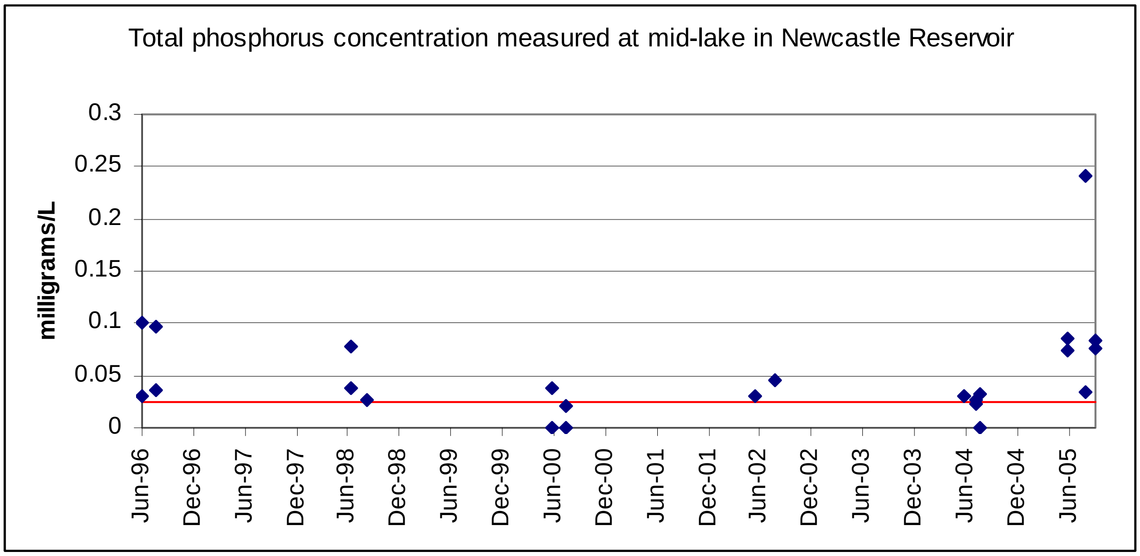


Figure 3.18. Total phosphorus concentrations observed during routine monitoring at the Mid-lake Site in Newcastle Reservoir (the solid line represents the State of Utah threshold value for lakes and reservoirs of 0.025 mg/L).

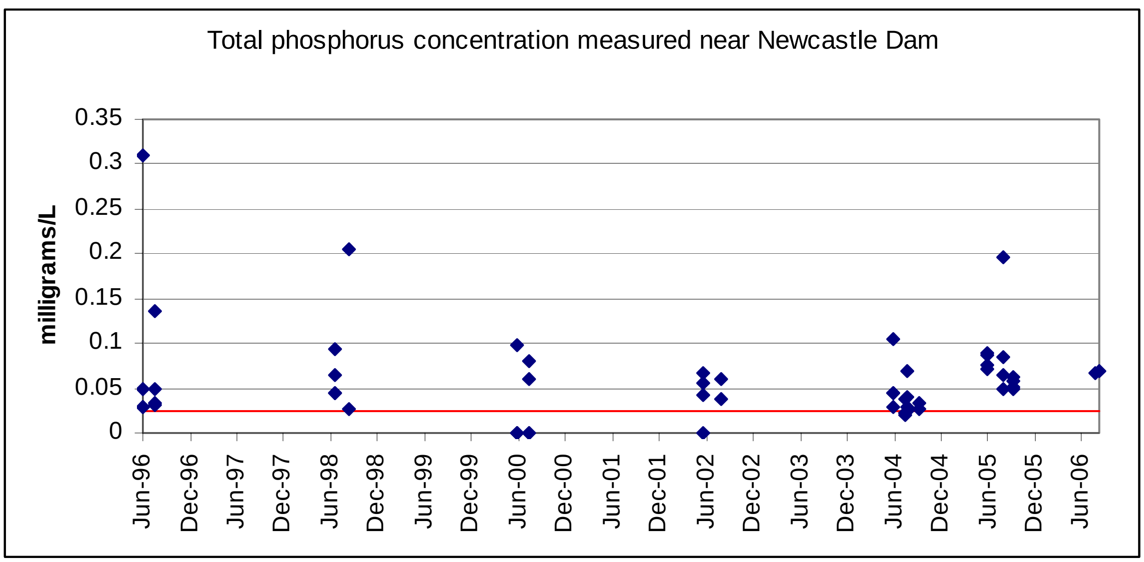


Figure 3.19. Total phosphorus concentrations observed during routine monitoring near the Dam Site in Newcastle Reservoir (the solid line represents the State of Utah threshold value for lakes and reservoirs of 0.025 mg/L).

3.6.3 WATER COLUMN-BASED IMPAIRMENT STATUS ASSESSMENT

As fish and most other aquatic life species are mobile and can relocate to areas of suitable habitat in the event of a localized criteria exceedance, the State of Utah has defined the support status of game fish populations relative to the percentage of the total water column experiencing depressed dissolved oxygen concentrations.

In terms of dissolved oxygen, a waterbody is given nonsupporting status for cold water game fish when less than 25% of the water column depth exhibits dissolved oxygen concentrations of 4.0 mg/L or greater. If 25–50% of the water column depth exhibits dissolved oxygen concentrations of 4.0 mg/L or greater, the waterbody is given a partial-support status. Full-support status is given where greater than 50% of the water column depth exhibits dissolved oxygen concentrations of 4.0 mg/L or greater.

In terms of pH, a waterbody is given full-support status if pH is no less than 6.5 and no greater than 9.0 pH units. In terms of temperature, a waterbody is given full-support status for cold water game fish as long as temperatures are less than 20 ºC.

Depth-integrated data were evaluated using the percentage-based criteria for dissolved oxygen critical for supporting the cold water game fish designated use. Depth-integrated data were also used to assess temperature and pH water quality parameters for support of cold water game fish. Depth-integrated data were available for both a Mid-lake Site and Dam Site for the time periods shown in Table 3.12.

Table 3.12. Depth Integrated Reservoir Monitoring

	Mid-lake Site						**In-reservoir Dam Site**				
	2000	2002	2004	2005	2006		2000	2002	2004	2005	2006
May		✓						✓			
June	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓
July	✓	✓	✓	✓			✓	✓	✓	✓	
August		✓	✓	✓	✓			✓	✓	✓	✓
September			✓	✓					✓	✓	

Representative depth-profile plots of dissolved oxygen, temperature, and pH are displayed for spring, summer, and fall conditions (2005) observed in Newcastle Reservoir at the Mid-lake Site and the Dam Site (Figures 3.20–3.23). A complete set of profile plots for all available depth-integrated data is presented in Appendix A.

Depth increases down the vertical axis of each of the plots displayed. To read the plots, assume that the lower horizontal axis represents the bottom or floor of the reservoir and the top of the plot represents the water surface. Total water depth differs for each monitoring site and date, depending on the water level of the reservoir at the time the data were collected. Dissolved oxygen, temperature, and pH data are plotted in separate curves on each of the Figures. Data are displayed for both the Mid-lake Site and the Dam Site. Depths at the Mid-lake Site are generally shallower than those at the Dam Site. Depth-integrated data from 2005 were selected for display here because they represent the year with the best overall seasonal coverage and relatively average flow conditions (see Table 3.12).

The 2005 water year followed an extended period of drought in the watershed and southwestern Utah. Data gathered for 2005 may reflect in-channel purge/flush conditions; these conditions occur when sedimentation and deposition processes intensify upstream in lower flow (drought) conditions or in higher flow events, which occur when average water conditions cause a surge of deposited material that is delivered to downstream waterbodies over a short period of time. These data cannot therefore be considered completely representative of average water year conditions in the Newcastle Reservoir watershed but provide a good illustration of seasonal changes in dissolved oxygen, temperature and pH within the reservoir.

Drought or conditions in low water years can generally be assumed to result in warmer water temperatures and lower dissolved oxygen levels, while high-water years often result in deeper water levels and lower water temperatures. Water withdrawals during critical summer months accentuate this pattern, especially during low water years. Year-to-year variations in a managed system are usually not as noticeable as they are in a free-flowing, non-impounded system such as a natural lake.

Figure 3.20 illustrates June 2005 depth-integrated data, which reveals some stratification occurring within the reservoir. Stratification occurs when dissolved oxygen and temperature change specific to depth; lower water layers are generally cooler while upper water layers experience higher temperatures. Stratification is noticeably stronger at the Mid-lake Site, with a marked thermocline occurring between 3–5 m depth. A thermocline is a location in the waterbody where temperature changes by more than 1 ^{o}C over less than a 1-meter change in depth. When strongly established, thermoclines can resist mixing and lead to low dissolved oxygen in the lower layers of a reservoir, since decomposition removes oxygen from the water column and thermal inertia discourages mixing of the better aerated surface layers.

On average, dissolved oxygen concentrations and water temperatures at the Mid-lake Site are not in exceedance of water quality criteria, while dissolved oxygen at the Dam Site (between depths of 4–8 m) show concentrations below 4.0 mg/L.

Figure 3.21 displays July 2005 conditions and presents a marked contrast to the June profiles. Stratification is noticeably stronger at the Dam Site, with a marked thermocline between depths of 4–5 m, while the Mid-lake Site is mixed. Dissolved oxygen concentrations at the Mid-lake Site (down to about 2 m depth) indicate in-reservoir algal growth, and water temperatures are noticeably higher than the cold water criteria throughout the water column. Dissolved oxygen in the lower depths at the Dam Site (below 4 m) show concentrations that are detrimental to cold water game fish. Low levels of dissolved oxygen are directly correlated with high water temperatures (above 20^{o}C) in the overlying water column and reduce viable habitat. Fish trying to escape warm water temperatures will encounter decreasing dissolved oxygen concentrations as they move to deeper waters in the reservoir. While the water column at the Mid-lake Site contains sufficient dissolved oxygen, the waters are not deep enough to support cold water species. Minor pH exceedances are observed in the upper water layer at the Dam Site.

Figure 3.22 illustrates August 2005 water column conditions for the reservoir. Similar to data recorded for July, August data indicates that low dissolved oxygen concentrations in the deeper reservoir depths correlate with high water temperatures in the overlying layers; these factors cumulatively reduce viable habitat for cold water species. Minor pH exceedances occurred in the upper water layer at both the Mid-lake Site and the Dam Site; these exceedances indicate in-reservoir growth and photosynthesis.

Figure 3.23 illustrates conditions for September 2005; substantial mixing and cooling within the water column occurred at both the Mid-lake Site and the Dam Site. Water temperatures and pH values were nearly static from surface to depth and show that the shorter daylight hours and cooler air temperatures affect both reservoir waters and inflows. Dissolved oxygen concentrations at the Dam Site show a gradual decrease with depth (possibly a product of ongoing decomposition), but adequate levels were maintained, except at the very lowest layers of the reservoir (below 10 m in depth).

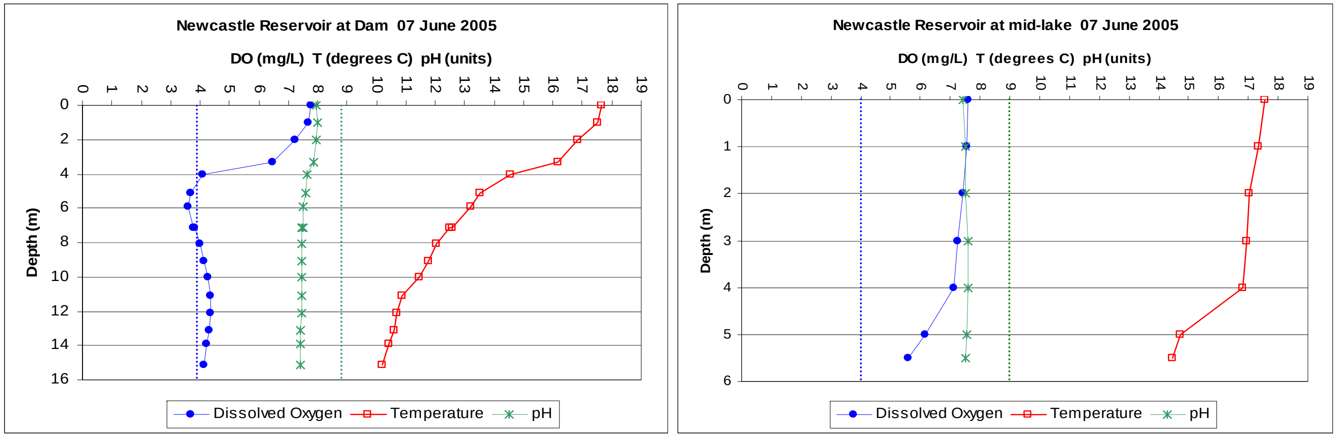


Figure 3.20. Spring (07 June 2005) depth profile plots for dissolved oxygen, temperature, and pH observed in Newcastle Reservoir (UDEQ).

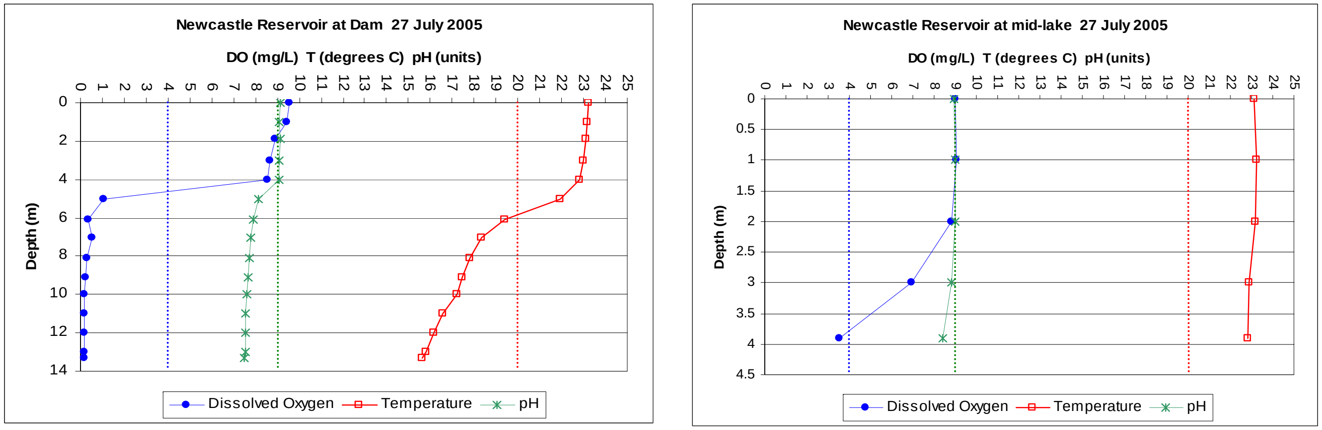
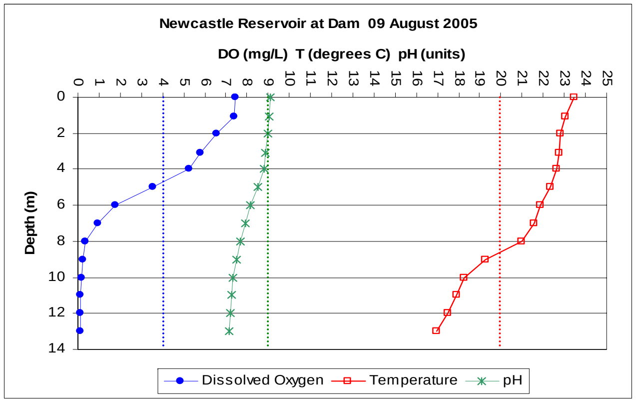


Figure 3.21. Summer (27 July 2005) depth profile plots for dissolved oxygen, temperature, and pH observed in Newcastle Reservoir (UDEQ).



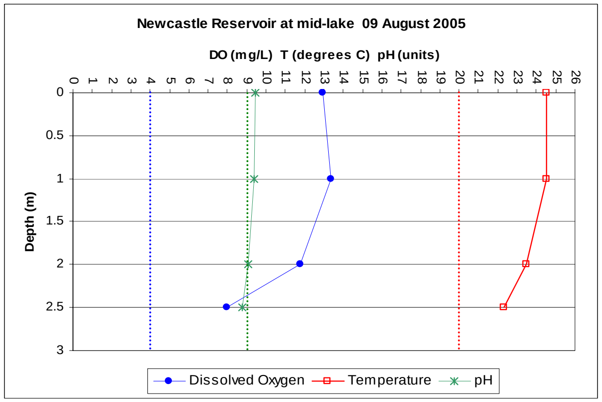
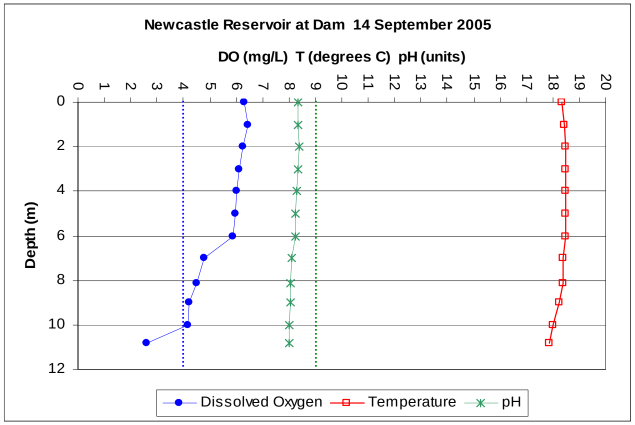


Figure 3.22. Summer (09 August 2005) depth profile plots for dissolved oxygen, temperature, and pH observed in Newcastle Reservoir (UDEQ).



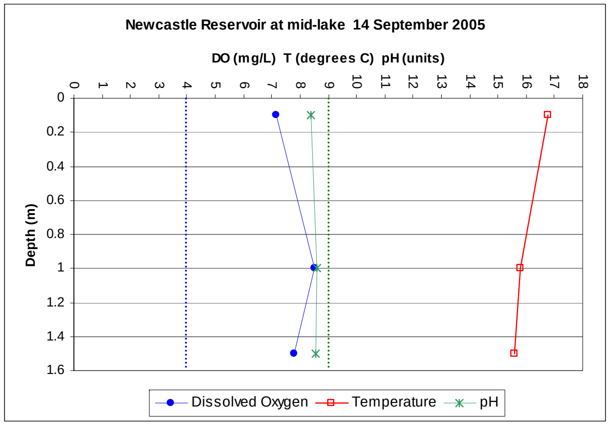


Figure 3.23. Fall (14 September 2005) depth profile plots for dissolved oxygen, temperature, and pH observed in Newcastle Reservoir (UDEQ).

3.6.3.1 Mid-lake Site Compliance

Tables 3.13–3.17 contain representative depth profiles. Dissolved oxygen, temperature, pH, and viable habitat data are displayed for spring, summer, and fall conditions (2005) observed in Newcastle Reservoir at the Mid-lake Site and the Dam Site.

Depth-integrated data collected at the Mid-lake Site in Newcastle Reservoir showed that none of the water column, from surface to depth, was in full compliance with water quality criteria for the months of July 2000, August 2002, July–August 2004, July–August 2005, and August 2006. Data collected at this site reveal that 100% of the water column experienced at least one parameter out of compliance during these months. Annual average conditions compiled using available profile data show that 100% of the water column experiences at least one parameter out of compliance during the months of July and August (Table 3.14).

On average, low dissolved oxygen (less than 4.0 mg/L) was experienced in 0% of the water column at the Mid-lake Site in May, 2% of the water column in June, 24% of the water column in July, 22% of the water column in August, and 0% of the water column in September (Table 3.13). In one instance, 88% of the water column was below 4.0 mg/L (nonsupport). In July 2000, the Mid-lake Site at Newcastle Reservoir was shown to have less than 50% but more than 25% of the water column in compliance (partial support).

Supersaturation (dissolved oxygen concentrations greater that 110% of saturation) was experienced in 100% of the water column at this site in May, 24% of the water column in June, 25% of the water column in July, 27% of the water column in August, and 0% of the water column in September, under average annual conditions calculated from available profile data (Table 3.14).

On average, elevated water temperature (greater than 20 ^{o}C) was experienced in 0% of the water column at this site in May, 19% of the water column in June, 92% of the water column in July, 97% of the water column in August, and 0% of the water column in September (Table 3.15). These values are assumed to be conservative (low) as the majority of the water temperature data were collected in the morning or early afternoon, prior to when daily maximum water temperatures generally occur.

On average, elevated pH (greater than 9.0) was experienced in 0% of the water column at this site in all months except August, in which 20% of the water column exhibited elevated pH (Table 3.16).

All three TSI values (Secchi depth, chlorophyll *a*, and total phosphorus) calculated for the Mid-lake Site in Newcastle Reservoir indicate that this area of the reservoir is at least moderately eutrophic during the summer growing season. The magnitude of eutrophic effects as defined by TSI values appears to be increasing over time (1996–2006) at this location. This may be in part due to the recent low water years experienced throughout the watershed, since drought conditions tend to exacerbate algal growth and decomposition.

Table 3.13. Newcastle Exceedance, DO < 4.0 mg/L (percent of water column)

ID#	Site Name	Month	2000	2001	2002	2003	2004	2005	2006	Average
4940610	NEWCASTLE RES AB DAM 01	May			35%					35%
4940610	NEWCASTLE RES AB DAM 01	June	11%				55%	13%	58%	34%
4940610	NEWCASTLE RES AB DAM 01	July	63%				57%	62%		61%
4940610	NEWCASTLE RES AB DAM 01	August			7%		42%	62%	67%	44%
4940610	NEWCASTLE RES AB DAM 01	September					17%	7%		12%
4940620	NEWCASTLE RES MIDWAY UP LAKE 02	May			0%					0%
4940620	NEWCASTLE RES MIDWAY UP LAKE 02	June	0%				0%	0%	9%	2%
4940620	NEWCASTLE RES MIDWAY UP LAKE 02	July	37%				11%	23%		24%
4940620	NEWCASTLE RES MIDWAY UP LAKE 02	August			0%		0%	0%	88%	22%
4940620	NEWCASTLE RES MIDWAY UP LAKE 02	September						0%		0%

Table 3.14. Newcastle Exceedance, DO > 110% (percent of water column)

ID#	Site Name	Month	2000	2001	2002	2003	2004	2005	2006	Average
4940610	NEWCASTLE RES AB DAM 01	May			13%					13%
4940610	NEWCASTLE RES AB DAM 01	June	33%				0%	0%	14%	12%
4940610	NEWCASTLE RES AB DAM 01	July	0%				14%	30%		15%
4940610	NEWCASTLE RES AB DAM 01	August			0%		1%	0%	0%	0%
4940610	NEWCASTLE RES AB DAM 01	September					2%	0%		1%
4940620	NEWCASTLE RES MIDWAY UP LAKE 02	May			100%					100%
4940620	NEWCASTLE RES MIDWAY UP LAKE 02	June	41%				0%	0%	56%	24%
4940620	NEWCASTLE RES MIDWAY UP LAKE 02	July	0%				22%	51%		25%
4940620	NEWCASTLE RES MIDWAY UP LAKE 02	August			0%		27%	80%	0%	27%
4940620	NEWCASTLE RES MIDWAY UP LAKE 02	September						0%		0%

Table 3.15. Newcastle Exceedance, Temperature > 20 (percent of water column)

ID#	Site Name	Month	2000	2001	2002	2003	2004	2005	2006	Average
4940610	NEWCASTLE RES AB DAM 01	May			0%					0%
4940610	NEWCASTLE RES AB DAM 01	June	33%				0%	0%	7%	10%
4940610	NEWCASTLE RES AB DAM 01	July	56%				43%	38%		46%
4940610	NEWCASTLE RES AB DAM 01	August			100%		58%	62%	51%	68%
4940610	NEWCASTLE RES AB DAM 01	September					2%	0%		1%
4940620	NEWCASTLE RES MIDWAY UP LAKE 02	May			0%					0%
4940620	NEWCASTLE RES MIDWAY UP LAKE 02	June	41%				0%	0%	35%	19%
4940620	NEWCASTLE RES MIDWAY UP LAKE 02	July	89%				89%	100%		92%
4940620	NEWCASTLE RES MIDWAY UP LAKE 02	August			100%		100%	100%	89%	97%
4940620	NEWCASTLE RES MIDWAY UP LAKE 02	September						0%		0%

Table 3.16. Newcastle Exceedance, pH > 9.0 (percent of water column)

ID#	Site Name	Month	2000	2001	2002	2003	2004	2005	2006	Average
4940610	NEWCASTLE RES AB DAM 01	May			0%					0%
4940610	NEWCASTLE RES AB DAM 01	June	0%				0%	0%	0%	0%
4940610	NEWCASTLE RES AB DAM 01	July	0%				0%	30%		10%
4940610	NEWCASTLE RES AB DAM 01	August			0%		1%	15%	0%	4%
4940610	NEWCASTLE RES AB DAM 01	September					0%	0%		0%
4940620	NEWCASTLE RES MIDWAY UP LAKE 02	May			0%					0%
4940620	NEWCASTLE RES MIDWAY UP LAKE 02	June	0%				0%	0%	0%	0%
4940620	NEWCASTLE RES MIDWAY UP LAKE 02	July	0%				0%	0%		0%
4940620	NEWCASTLE RES MIDWAY UP LAKE 02	August			0%		0%	80%	0%	20%
4940620	NEWCASTLE RES MIDWAY UP LAKE 02	September						0%		0%

Table 3.17. Newcastle Viable Habitat (percent of water column)

ID#	Site Name	Month	2000	2001	2002	2003	2004	2005	2006	Average
4940610	NEWCASTLE RES AB DAM 01	May			67%					67%
4940610	NEWCASTLE RES AB DAM 01	June	57%				45%	87%	35%	56%
4940610	NEWCASTLE RES AB DAM 01	July	0%				0%	8%		3%
4940610	NEWCASTLE RES AB DAM 01	August			0%		0%	0%	0%	0%
4940610	NEWCASTLE RES AB DAM 01	September					81%	93%		87%
4940620	NEWCASTLE RES MIDWAY UP LAKE 02	May			100%					100%
4940620	NEWCASTLE RES MIDWAY UP LAKE 02	June	59%				100%	100%	56%	79%
4940620	NEWCASTLE RES MIDWAY UP LAKE 02	July	0%				0%	0%		0%
4940620	NEWCASTLE RES MIDWAY UP LAKE 02	August			0%		0%	0%	0%	0%
4940620	NEWCASTLE RES MIDWAY UP LAKE 02	September						100%		100%

3.6.3.2 Dam Site Compliance

Applying the same techniques at the Dam Site, and assuming that viable habitat is defined as having no exceedances of dissolved oxygen, temperature, or pH criteria, data collected at the Dam Site showed that more than 50% of the water column was in compliance (full support) 39% of the time under average annual conditions.

Depth-integrated data collected at the Dam Site in Newcastle Reservoir showed that none of the water column, from surface to depth, was in full compliance with water quality criteria for the months of July 2000, August 2002, July–August 2004, and August 2006. Data collected at this site show 100% of the water column experienced at least one parameter out of compliance during these months. Annual average conditions compiled using available profile data show that 100% of the water column experiences at least one parameter out of compliance during the month of August in any of the years observed.

On average, low dissolved oxygen (less than 4.0 mg/L) was experienced in 35% of the water column at this site in May, 34% of the water column in June, 61% of the water column in July, 44% of the water column in August, and 12% of the water column in September.

Supersaturation (dissolved oxygen concentrations greater that 110% of saturation) was experienced in 13% of the water column at this site in May, 12% of the water column in June, 15% of the water column in July, 0% of the water column in August, and 1% of the water column in September, under average annual conditions calculated from available profile data.

On average, elevated water temperature (greater than 20^{o}C) was experienced in 0% of the water column at this site in May, 10% of the water column in June, 46% of the water column in July, 68% of the water column in August, and 1% of the water column in September. These values are assumed to be conservative (low), since the majority of the water temperature data were collected in the morning or early afternoon, prior to when daily maximum water temperatures generally occur.

On average, elevated pH (greater than 9.0) was experienced in 0% of the water column at this site in May, 0% of the water column in June, 10% of the water column in July, 4% of the water column in August, and 0% of the water column in September.

All three TSI values (Secchi depth, chlorophyll *a*, and total phosphorus) calculated for the Dam Site in Newcastle Reservoir indicate that this area of the reservoir is at least moderately eutrophic during the summer growing season. The magnitude of eutrophic effects as defined by TSI values appears to be increasing over time (1996–2006) at this location. This may be in part due to the recent low water years experienced throughout the watershed, since drought conditions tend to exacerbate algal growth and decomposition.

3.6.3.3 Correlated Criteria Exceedance Assessment

Due to the fact that multiple stressors can intensify detrimental impacts on aquatic life (e.g., temperature and dissolved oxygen in exceedance simultaneously), an additional assessment also examined the occurrence of two or more water quality exceedances measured in the water column at the same time and place.

The water column at this site showed full support of the cold water game fish designated use during the months of May 2002, June 2000, and June 2005, as well as during September in all years for which profiles were available. The water column at this site showed 100% of the water column experiencing at least one parameter out of compliance during the months of July and/or August for every year for which profiles were available.

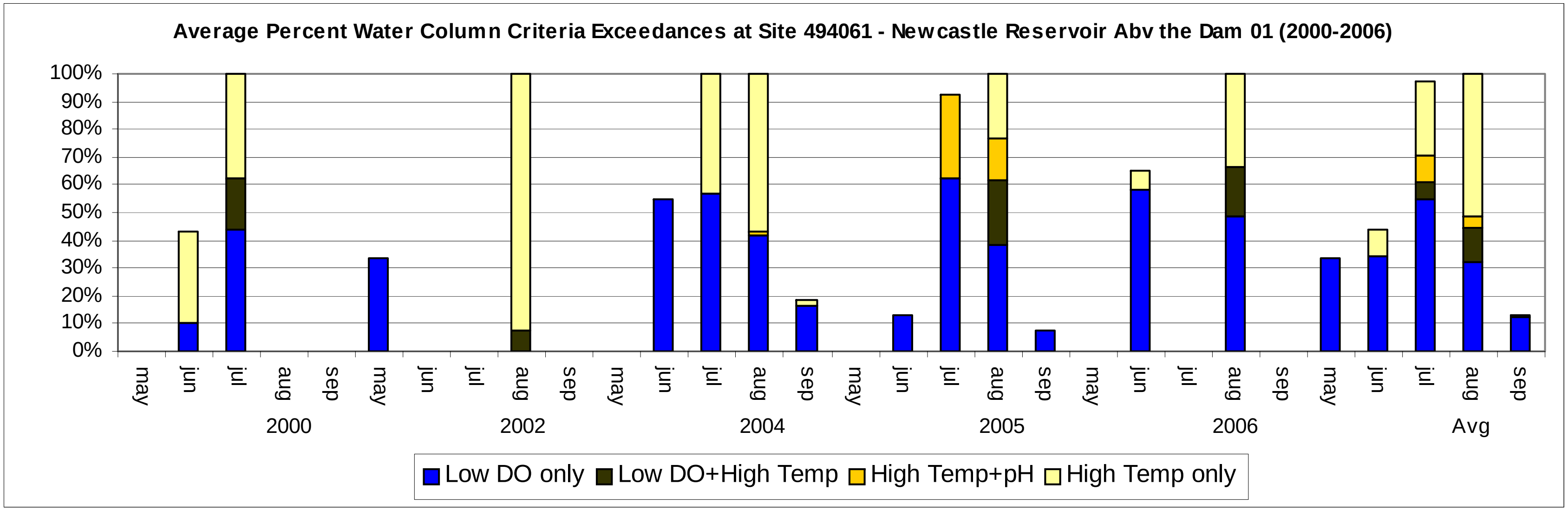
Figure 3.24 displays a plot of the relative percent of the water column experiencing a single exceedance, as well as multiple criteria observed during summertime in 2000, 2002, 2004, 2005, and 2006 (monitoring is detailed in Table 3.12). Figure 3.25 shows the relative percent of the water column that is viable habitat for cold water fish species during the same time period.

During July and August of all years for which there are profile data, nearly 100% of the water column at both sites is in exceedance of at least one criterion. While measured dissolved oxygen concentrations alone cannot be identified as impairing the cold water game fishery in the reservoir, co-located exceedances of dissolved oxygen and temperature criteria, especially in the months of July and August, combine to reduce viable habitat within the water column to less than 3%. This circumstance is most likely exacerbated by the nearly stagnant conditions that occur in the reservoir following diversion of the majority of the inflowing waters. The reservoir appears to experience little turnover during the summer months; anoxia at the sediment interface layer most likely contributes to the chemical release of sediment-bound nutrients and creates a cycle of growth and decay that further deplete dissolved oxygen and results in a condition of environmental stress for the resident fish population. Of great concern is the observed lack of apparent refuge for cold water species in the reservoir during summer months. On average, 92%–100% of the water column at both sites is void of viable habitat.

As discussed earlier, instantaneous sampling of dissolved oxygen does not generally capture the critical time frame for dissolved oxygen sags. The potential for these sags to occur during nighttime hours is directly related to the magnitude of algal growth occurring in the waterbody. Because growth and photosynthesis increase dissolved oxygen in the water during daylight hours, the potential for a nighttime dissolved oxygen sag to occur is proportional to the occurrence of supersaturation during daylight hours.

On average, supersaturation (dissolved oxygen saturation of greater than 110%) was experienced in 100% of the water column at Mid-lake Site in May, 24% of the water column in June, 25% of the water column in July, and 27% of the water column in August (Table 3.14). Supersaturation at the Dam Site occurred to a lesser extent. At the Dam Site location, supersaturation at the Mid-lake Site was observed in 13% of the water column in May, 12% of the water column in June, 15% of the water column in July, 0% of the water column in August, and 1% of the water column in September.

These trends indicate aquatic growth occurring within the reservoir and further suggest the potential for accumulation and decomposition of excessive biomass in the reservoir, especially over the summer, when low flow-through conditions, increased light and elevated temperatures are common. Recent documented fish kills in Newcastle Reservoir coincide directly with late summer periods shown to have no available viable habitat in the reservoir—July 2002 and August 2006 (Mike Ottenbacher, Utah Division of Wildlife Resources, September 18, 2006).



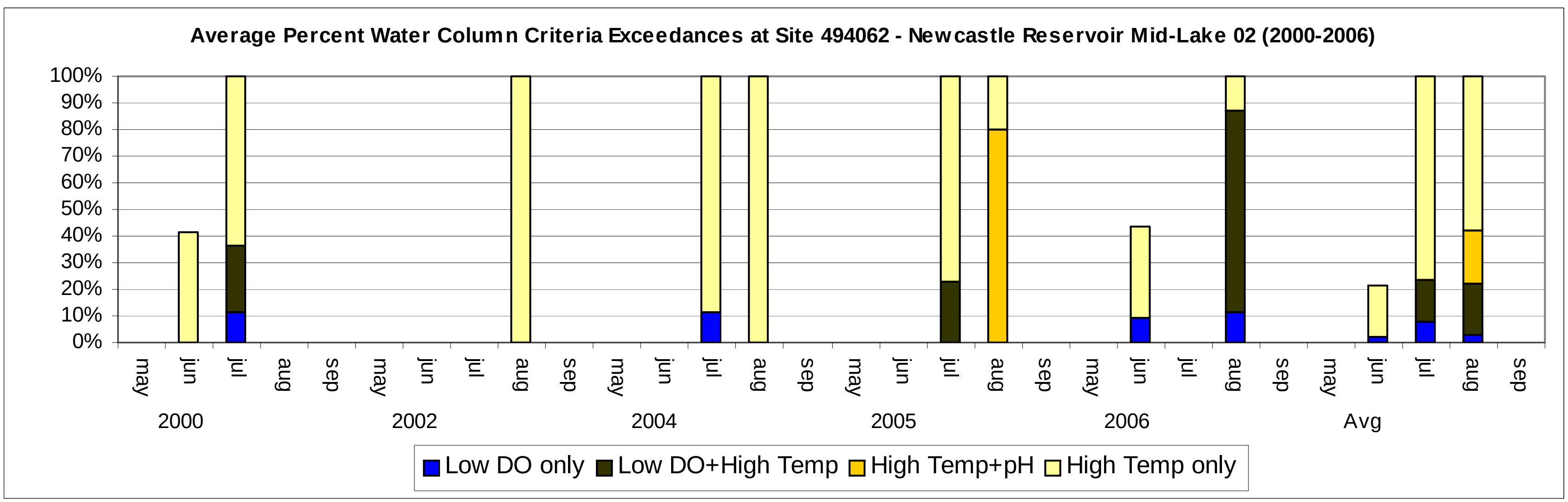


Figure 3.24. Relative percent of the water column at Mid-lake Site (lower plot) and near the Dam Site (upper plot) experiencing one or more exceedances of water quality criteria.

3.6.3.4 Phytoplankton

Detailed plankton data are available for the Dam Site at Newcastle Reservoir for August 7, 2002, and August 4, 2004 (Rushforth and Rushforth 2003 and 2005). Algal taxa present at these times were identified and grouped by taxon to show green algae (chlorophyta), blue-green algae (cyanophyta), diatoms (bacillariophyta), and others.

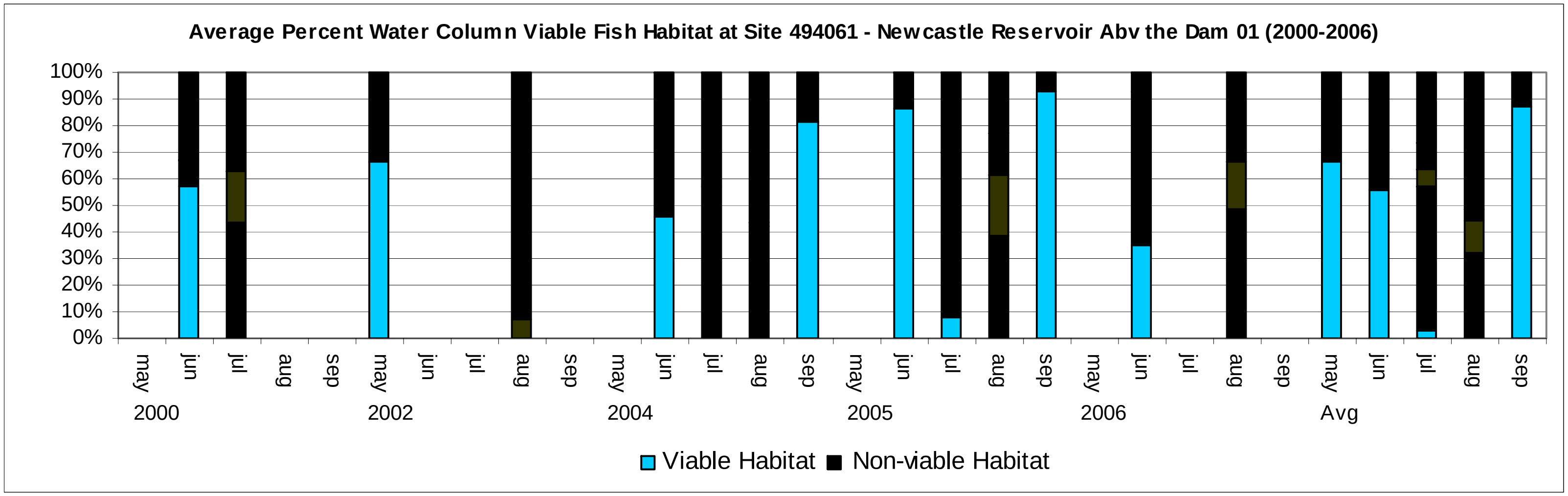
In the 2002 sampling, green algae dominated at 66.5% of the total algal population, and blue-green algae and diatoms represented much smaller population segments at 8.7–14.6% (respectively) of the total. The 2004 sampling showed a dominant blue-green algae bloom occurring with a single blue-green species (*Aphanizomenon flosaquae*), representing 81.6% of the total algal population. Green algae and diatom populations were substantially smaller, at 1.9% and 0.7% (respectively) of the total population.

Surface water temperatures were warmer (approximately $2^{o}C$) during the 2004 sampling event and dissolved oxygen concentrations at depth were substantially lower (less than 1.0 mg/L [2004], 2.95 mg/L [2002]) than observed during the 2002 sampling event. The maximum depth during the 2004 sampling event was 6.9 feet (2.1 meters), compared to 5.4 feet (1.6 meters) in 2002. Elevated water temperatures, low dissolved oxygen concentrations, and blue-green dominance were most likely exacerbated by drought conditions occurring throughout southern Utah.

3.6.3.5 Support Status Summary

The State of Utah determined that designated beneficial uses of secondary contact recreation and agricultural water supplies at Newcastle Reservoir are supported. However, designated beneficial uses specific to cold water game fish are threatened; assessment of these uses and the level of support being given to restore conditions for cold water game fish will be discussed here.

The cold water game fish beneficial use in Newcastle Reservoir was assessed using the standards described for deep reservoirs (UDWQ 2006). A fully supporting status is assigned when greater than 50% of the water column is in compliance with the minimum dissolved oxygen criteria of not less than 4.0 mg/L. A partial supporting status is designated in cases when less than 50% but greater that 25% of the water column is in compliance with the dissolved oxygen criteria. The reservoir was considered to be not supporting when less than 25% of the water column is in compliance with the dissolved oxygen criteria. Water column habitat viability was assessed using the same percent water column thresholds for temperature and pH (Figure 3.25). In Figure 3.25, “viable habitat” is defined as that portion of the water column where no exceedances of water quality criteria, joint or single, are observed.



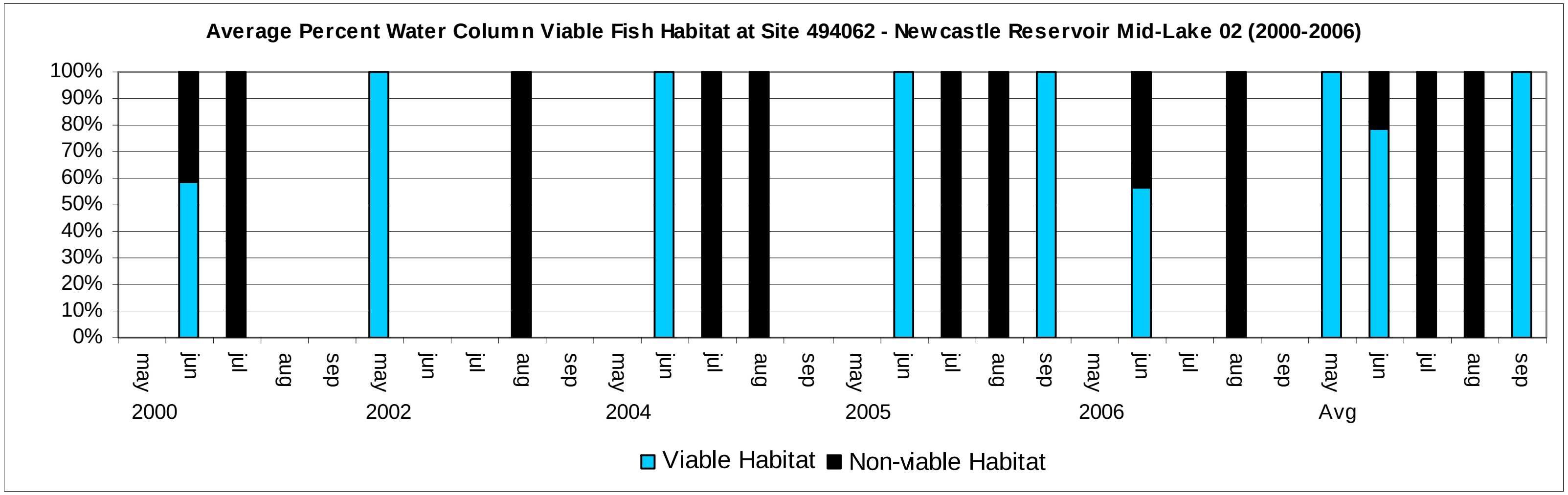


Figure 3.25. Relative percent of the water column at Mid-lake Site (lower plot) and near the Dam Site (upper plot) exhibiting viable habitat conditions.

This assessment finds that the impairment in Newcastle Reservoir during July and August is due to low dissolved oxygen concentrations in the lower water column and elevated water temperatures in the upper water column. In the State of Utah's 2006 303(d) list, violations of temperature criteria that were related to solar radiation, calculated through a heat budget analysis, were not deemed cause for listing a waterbody on the impaired-waters list. Newcastle Reservoir is not listed for temperature impairment; therefore, temperature exceedances identified in this TMDL are assumed to be related to solar radiation and no temperature endpoint has been selected for this TMDL.

3.7 Summary of Past and Present Pollution Control Efforts

3.7.1 Point Source Efforts

No point sources exist within the watershed boundary.

3.7.2 Nonpoint Source Efforts

Efforts to reduce the nonpoint source load of sediment and phosphorus to Newcastle Reservoir include road upgrades in the forested area of the watershed, trail management, and stream channel modification.

3.7.2.1 Road Upgrades

Throughout the area, the forestry industry at private, state, federal, and commercial levels has made a concerted effort to limit erosion and sediment transport from logging roads within the watershed. Over time, roads within the watershed have been upgraded by hard-surfacing, culvert replacement, and drainage improvement measures. Other roads have been obliterated and re-seeded to establish natural vegetation.

The USFS has relocated a portion of the South Fork Pinto Creek Road (Forest Road 30011) and the Grassy Flat Canyon Road (Forest Road 30915). In 2006 approximately 3.1 miles of the existing road was relocated to an upland location on the west side of South Fork Pinto Creek. The previous road ran through the riparian area of South Fork Pinto Creek and Grassy Flat Canyon Creek. These road sections were obliterated and the natural vegetation was restored, as well as the contour of the land. The new road has a gravel surface, designed for safety and drainage.

Erosion from the existing roadway contributed sediment to the stream and led to the loss of vegetation along the stream channels (USFS 2005). This road improvement project was intended to:

- Restore the riparian areas on South Fork Pinto Creek and Grassy Canyon Creek to desired conditions
- Improve water quality, fisheries and aquatic habitats, and associated riparian vegetation
- Support other safety-related benefits

In conjunction with the reclamation of the roadway, the USFS made improvements to riparian zone vegetation and other conditions. Woody plant species, grasses, and forbs were planted to restore disturbed and reclaimed areas. Restoration should reestablish natural energy flow through the system and floodplain. Over time, surface erosion rates should decrease, and sediment influx into the stream system should return to natural levels.

3.7.2.2 Recreation and Trail Management

The USFS has planned for trail redesign and reroutes up Mill Canyon to reduce erosion from trail crossings and to move the trail out of the immediate floodplain of Mill Creek, to the extent possible (personal communication between Joni Brazier, USFS and Brian Nicholson, SWCA, March 16, 2007).

An emergency off-highway vehicle (OHV) closure was also implemented by the Dixie National Forest to reduce erosion in the area west of the old South Fork Pinto Road (personal communication between Joni Brazier, USFS and Brian Nicholson, SWCA, March 16, 2007).

3.7.2.3 Stream Channel Modifications

In 2006, the Dixie National Forest removed some old log-drop fish structures that were causing channel widening (personal communication between Joni Brazier, USFS and Brian Nicholson, SWCA, March 16, 2007).

3.7.2.4 Irrigation Management

A few of the points of diversion that deliver irrigation water have been improved with screw gates. In the past, temporary check dams of dirt and other in-channel materials were created with heavy equipment to divert water into these ditches.

3.7.2.5 Livestock and Grazing Management

Grass seeding from rangeland improvement occurred in the 1960s on Page Ranch and in the 1980s and 1990s in other parts of the watershed.

3.7.2.6 Riparian Enhancement

Several large riparian exclosures have been created in the Dixie National Forest to reduce direct impact on riparian areas from livestock. One section, completed in 2002, extends from the confluence of the north fork and south fork of Pinto Creek to the private land boundary along the stream. Another exclosure encompasses the majority of the Little Pinto Creek within the USFS boundary (personal communication between Joni Brazier, USFS and Brian Nicholson, SWCA, March 16, 2007).

4 WATERSHED AND RESERVOIR MODELING

The watershed and reservoir modeling approach applied to Newcastle Reservoir and its watershed was chosen to quantify nutrient loads in watershed streams, predict reservoir loading capacity, and reservoir response to phosphorus load reductions. The SWAT model was used to simulate hydrologic and nutrient load output during varying hydrologic and reservoir management conditions. The linked SWAT and BATHTUB modeling scheme provides a systematic method for modeling nutrient sources, transport, delivery, and assimilation in a watershed-reservoir system.

4.1 MODELED CONDITIONS: VARIABILITY AND UNCERTAINTY

Multiple SWAT simulations were executed to account for variability in annual and seasonal climatic patterns, as well as for input to the BATHTUB model. The SWAT simulations were paired with simulations of different reservoir management patterns (Table 4.1). The 2002 hydrologic year was selected to represent a dry year in the region, whereas 2005 was selected to represent a high flow year. The years 1996–2006 were used to estimate average flow and runoff patterns. Average climatic conditions represent the worst case condition in terms of water quality in the reservoir. During a wet high-flow year, sufficient flow is available to flush the reservoir of algae as they begin to grow. In a low-flow year, very little nutrient load is delivered to the reservoir from the watershed due to reduced precipitation and associated runoff. Stagnant conditions in the reservoir, under this condition, are related to water quantity rather than nutrient loads from the watershed. Output from the SWAT simulation was evaluated with existing water quality monitoring data collected within the watershed at numerous spatial points.

Table 4.1. Summary of the Climatic and Reservoir Management Conditions

Condition	Water Year (SWAT)	Reservoir Level (BATHTUB)
Condition A	Average	Mid-level
Condition B	Average	Low
Condition C	Low	Mid-level
Condition D	Low	Low
Condition E	High	Mid-level

For the average hydrologic year simulation, BATHTUB was used to predict nutrient concentrations, chlorophyll *a*, oxygen depletion, eutrophication in Newcastle Reservoir across the algal growth season as well as during the critical part of the season (August), when the reservoir is drawn down to its lowest point. For the high-water year, the average reservoir condition was assumed to represent the entire season, since draw down to lower levels would not occur during a high water year. For the low water year, BATHTUB was used again to simulate both the average condition in the reservoir during that season as well as during the critical period.

4.2 WATERSHED MODEL: SWAT

4.2.1 GENERAL MODEL DESCRIPTION

The USDA-ARS developed SWAT to predict the effects of management practices on water, sediment, nutrient, and pesticide yields at the watershed scale. The tool uses a GIS environment to subdivide watersheds into smaller, spatially linked units with Digital Elevation Models (DEMs). To further divide subwatersheds into Hydrologic Response Units (HRUs), the tool breaks units by land use, management practices, and soil-type GIS coverages. An HRU is not a spatial subdivision but a total area within a subwatershed that possesses similar land uses and soils. Within SWAT, all HRUs are assumed to be homogenous. The HRUs simplify model simulations by combining land uses and soil types that overlie each other in the GIS environment.

4.2.1.1 Model Components and Operation

The SWAT modeling tool incorporates climatic and physical watershed data and stream reach routing to simulate hydrologic dynamics, including surface runoff, return flow, percolation, evapotranspiration (ET), transmission losses, reservoir storage, crop growth and irrigation, groundwater flow, water transfer, snow accumulation, and snowmelt. The tool also simulates nutrient and pesticide loading. Overall, the SWAT modeling tool provides the modeling environment necessary to simulate groundwater and surface water hydrology and water quality at the watershed scale.

The model makes use of long-term continuous time period simulations using readily available data for inputs. These data inputs include regional hydrology, DEMs, climatic data, soils, and land uses. Most of these data are available from regional or national natural-resource agencies without cost. Figure 4.1 summarizes the physical processes that SWAT simulates. The tool simulates the hydrology of the watershed using several different physical processes, including ET and canopy storage for water that is intercepted by vegetation, infiltration, and redistribution. The tool uses rainfall amounts to calculate surface runoff volumes, infiltration, and peak runoff rates for each HRU. The model is capable of using either the STATSGO or the Soil Survey Geographic (SSURGO) database for soils data. The model allows up to 10 soil layers where infiltration and water holding capacity, among other things, may be modified. Water held within the soil profile is moved through the matrix by the storage routing method.

Not all areas within the state have complete SSURGO data coverage at this time, so STATSGO data is applied. Land use and land cover (LULC) information is also used for a data layer. The LULC coverage is overlaid with the soils to facilitate HRU development for the application of the physical-based equations applied throughout the modeled watershed.

The model accounts for both saturated and unsaturated flows. Saturated flow is driven by gravity and the movement is characterized by a storage routine method, which calculates the amount of soil water percolating to an underlying soil layer on a given day. Water in excess of the permanent wilting point or soil field capacity is available for plant growth or infiltration within the soil profile. For unsaturated flow, movement occurs in any direction based on energy gradients from areas of high to low water content. Only saturated flow is simulated; however, water consumed by the plant during growth is simulated indirectly by the ET process associated with the plants.

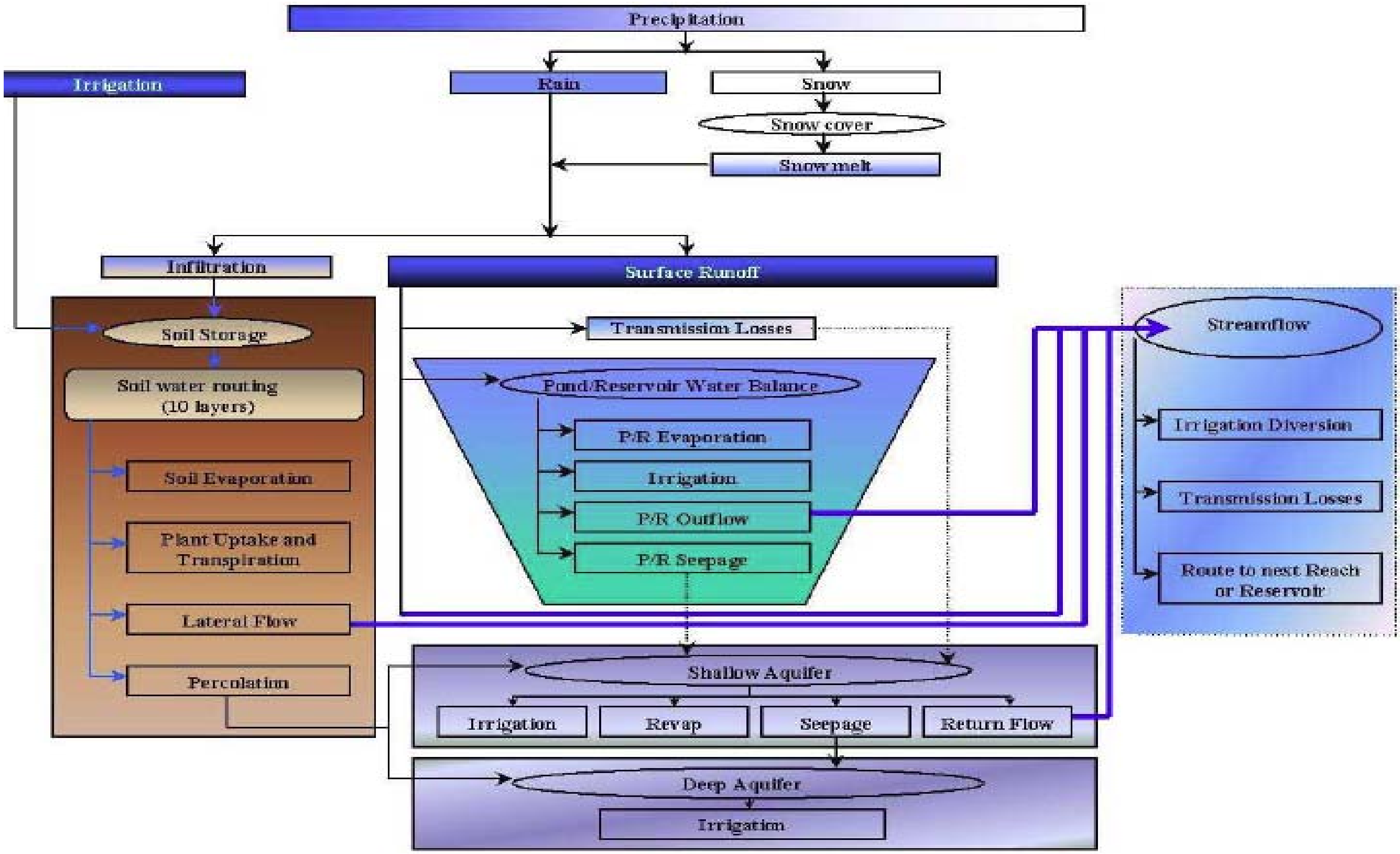


Figure 4.1. SWAT model schematic of water routing and processes (Neitsch 2002).

The model relies on climatic data for computer simulations and makes use of many different sources of climatic data in equations associated with physical processes within the watershed. The model also has a built-in weather generator that employs a network of weather stations throughout the country to develop a climatic record. This climatic record is based on average values, which demonstrate weather extremes that may have occurred within the watershed being modeled during the simulation period.

Two climatic datasets (including daily minimum and maximum temperature and precipitation), in most cases, should be included using local weather station data. The model will associate the local climate station dataset to each subbasin within the watershed boundary and apply the climate data for the simulation. Any missing climate data during the simulations are interpolated by the model to provide for a complete dataset. Other climate data required by the model, such as wind speed, relative humidity, and daily solar radiation are usually simulated by the model. On rare occasions when actual measured data are available on a daily time step, these data are used in lieu of simulated data.

The model has two methods for infiltration and runoff. The first method is the Green-Ampt method, where water infiltration occurs through a wetted front routine. This method requires subhourly precipitation data, which is not available in this watershed and will therefore not be discussed further. The other runoff method is the SCS curve number (CN), which is based on a rainfall-runoff relationship where overland flow will not occur until all depressional storage (surface storage, canopy interception, and infiltration) has occurred. The equation also looks at soil permeability, land use, and antecedent soil moisture conditions to determine runoff. The runoff rate is dependant upon empirical values that have been developed across the U.S. for cover types associated with land uses present within the watershed. The CN influences the runoff values and is accounted for by a CN value applied within model parameter settings. This number is set initially within the model but may be changed to adjust runoff values during model simulations.

The SWAT model also simulates shallow and deep groundwater aquifers. Shallow aquifers contribute flow to the stream reach in the watershed and also reinfiltrate water into the soil profile. The remaining infiltrated water may also be pumped out or may recharge the deeper aquifer. The deep aquifer is confined and contributes water outside of the watershed. Waters of the deep confined aquifer that are not pumped for irrigation purposes are considered lost to the watershed.

To simulate erosion and sediment yield, SWAT uses the Modified Universal Soil Loss Equation (MUSLE), which employs the amount of runoff derived from the runoff methods listed above to calculate sediment yield. The sediment is delivered to the surface water system by overland flow. The model uses two versions of the kinematic wave approximation (variable storage and Muskingum approximation) to route waters through the stream channels. In-stream sediment transport and channel erosion are also included. In-stream water quality processes are modeled using built-in modified QUAL-2E mathematical methods.

For nutrient simulation processes, SWAT models the water flow through the natural system to determine the amount of nutrients transported from one source to another. For nitrogen simulation, the basic nitrogen cycle and transformations are used. The SWAT tool monitors five different pools of nitrogen in the soil (two inorganic and three organic). The loading function estimates daily organic N loss based on the organic N concentration in the uppermost layer of soil, the sediment yield, and the N-enrichment ratio. Soluble and organic phosphorus are also removed by the transport with the water movement described above. Soluble phosphorus runoff is calculated using the solution phosphorus values in the upper 10 mm present in the soil, the runoff volume, a soil-partitioning factor, as well as an enrichment ratio. The tool monitors six different pools of phosphorus in the soil (three inorganic and three organic) and these pools are further divided by rate of decay and mineralization into active-to-stabile pools. Nutrient loads and water flow rates will be used as inputs into a one-dimensional reservoir model (Neitsch et al. 2002).

4.2.2 Model Development for the Newcastle Reservoir Watershed

Newcastle Reservoir is located along the lower slopes of the Pine Valley Mountains of southwest Utah, where Pinto Creek emerges from the mountains into the Escalante Desert. The Newcastle Reservoir watershed is a relatively large (approximately 80,000 acres [32,375 ha]), diverse watershed comprising a mountainous forested upper watershed (with a watershed high point at 9,900 feet [3,017 meters]) and a lower watershed featuring foothills and plains. It has a large natural drainage basin extended by the Grass Creek Diversion Tunnel through the ridge at the headwaters of the south fork of Pinto Creek. This area is a substantial part of the highest portion of the Pine Valley Mountains and greatly increases the water entering Newcastle Reservoir. The main inflows are Pinto Creek and Little Pinto Creek. The reservoir outflow is primarily diverted into a pipeline for downstream sprinkler irrigation. The vegetation of the study area consists primarily of a variety of arid and semiarid plant communities, including piñon-juniper, sage-grass, shadscale, bitterroot-mahogany, spruce-fir, pine, aspen, and associated grasses and forbs (Spence 2001). The soil is of limestone origin with rapid permeability and erosion. The watershed comprises multiple land uses, including recreation and livestock grazing. Livestock grazing is currently the dominant land use.

A SWAT watershed model was implemented to represent the Newcastle Reservoir watershed (Figure 4.1). Numerous GIS steps were required to derive and build the spatial inputs to SWAT. Data for climatic data, DEMs, hydrography, soils, and LULC were also preprocessed to match the format required as an input to the SWAT watershed model.

4.2.2.1 Digital Elevation Data for the Newcastle Reservoir Watershed

The elevation gradient for the Newcastle Reservoir watershed was obtained from the USGS National Elevation Dataset (NED) website (http://ned.usgs.gov/). The NED is a 1:24,000-scale DEM for the conterminous U.S.; it has a geographic projection with a one-arc second resolution and elevation units in meters (m). The horizontal datum is NAD83, with a vertical datum of NAVD88. The coverage, a continuous grid, overlays the entire watershed.

4.2.2.2 Hydrology Data for the Newcastle Reservoir Watershed

Hydrology for the Newcastle Reservoir watershed was obtained from the USGS National Hydrography (NHD) website (http://nhd.usgs.gov/data.html). Within the NHD, surface water reaches link the surface water drainage network. The NHD is based on digital line graph (DLG) hydrography, with reach-related information from the EPA Reach File Version 3.0 (RF3). Included within the NHD are the Pinto and Little Pinto creeks of the Newcastle Reservoir watershed and Grass Creek of the Santa Clara River watershed.

The SWAT model was developed with the knowledge of a transbasin diversion constructed in 1910, which transfers water from the Grass Creek drainage, located south of the watershed, to the Pinto Creek drainage. This diversion is supported by a tunnel dug through the topographic divide that diverts water from Grass Creek directly into Pinto Creek for the support of irrigation within the Newcastle Reservoir watershed.

The USGS measured the Grass Creek diversion rates for approximately 35 years until the end of the 1995 water year. No data are available for years following 1995. The diversion flow data are available at the USGS web site (http://waterdata.usgs.gov/ut/nwis/sw). Because the model is used to evaluate the watershed for present-day conditions and output, the Grass Creek diversion flows are needed as input for the most recent years. Specific data related to the Grass Creek diversion were developed to allow for the inclusion of the Grass Creek diversion as a model input. The following describes how the model hydrology was set up.

The Grass Creek diversion was added to the Pinto Creek drainage when a draining watershed was added to the model (Subbasin 73). Given the need to model recent periods and the absence of measured flow data since 1995, flow data for the Grass Creek diversion were evaluated by plotting data from the early 1960s, late 1980s, and early 1990s to determine possible temporal/volume patterns within the measured data. Since diversions are under the control of regional water masters and are subject to agricultural needs, statistical evaluation required accounting for water management practices that were in place when diversions occurred. Water was usually diverted at the beginning of March and turned off by the first days of July. Using the log values of the flow data to reduce variation in the plotted data, a best-fitting curve was empirically drawn through the log plots to define the outflow. By taking the antilog, these data were then used as Grass Creek diversion model inputs for the unmeasured years 1996–2006. This estimation method successfully produced representative results for the Grass Creek diversion based on historical data. However, this method does not produce any yearly variations in the Grass Creek diversion flow. The monthly results of the estimated Grass Creek diversion (in acre-feet) are shown in Table 4.2. Estimated volumes for the Grass Creek diversion were then converted in units (m^3/day) that were required by the SWAT model for input as a draining watershed.

Table 4.2. Grass Creek Diversion Measured and Estimated Flows into Pinto Creek

	Average Measured Flow 1960–1995		Modeled Flow (1995–2005
Month	**Cubic Feet per Second (cfs)**	**Acre-Feet**	**Acre-Feet**
January	0.10	6.1	0.00
February	0.50	28	0.14
March	4.0	245	201
April	18	1069	1189
May	21	1289	1229
June	7.8	463	124
July	0.41	25	0.60
August	0.38	23	0.00
September	0.00	0.00	0.00
October	0.56	34	0.00
November	1.1	65	0.00
December	0.20	12	0.00
TOTAL		**3259.1**	**2743.7**

4.2.2.3 LULC and Soils Data for the Newcastle Reservoir Watershed

The Southwest Regional Gap Analysis Project (SWReGAP) LULC dataset was originally used in the setup of the Newcastle Reservoir model. Coverage for SWReGAP is on a regional, multiple-state scale (Arizona, Colorado, Nevada, New Mexico, and Utah); the project focuses on mapping land cover for large geographic areas. A 2005 report on land cover mapping methods can be found online (http://earth.gis.usu.edu/swgap/swregap_landcover_report.pdf). The SWReGAP LULC dataset, though very detailed in land coverage description, is not compatible with SWAT. The SWReGAP land use descriptions were therefore converted to Multi-Resolution Land Characteristics Consortium (MRLC) National Land Cover Dataset (NLCD) descriptions. These land cover data are based on land cover classes including various forest types, urban land uses, surface water, wetlands, and agricultural lands, among others (see Table in Appendix B).

The SWAT model uses MRLC NLCD land cover descriptions to assign plant growth properties and land runoff potential based on a built-in database of physical properties associated with each of the land uses. Together with the STATSGO data on soils coverage properties, available online from the National Resource Conservation Service (http://soildatamart.nrcs.usda.gov), the model developed the watershed HRUs, calculated by setting a threshold level of minor land use areas, with land use areas less than the threshold level being ignored and reapportioned among the major land uses and soil types. The default values for the threshold are usually set at 10% for land use and 20% for soil type. This means that any land use taking place in an area of less than 10% within the watershed would be reassigned by the model to the most similar land use type. The same would occur for soil coverages, which have an area of less than 20% within the watershed. Because of the detailed coverage supplied by the SWReGAP data, the threshold levels for the HRU determination were set at 2% for land use and 4% for soils. This allowed for more detailed assessment associated with land use near Pinto and Little Pinto Creek for the application of irrigation events and grazing activity.

Land uses assigned within the model, including acreage and percent area within the watershed, are listed in Table 4.3. Forested lands and rangelands make up approximately 77% and 22% of the watershed, respectively. Agriculture, open water, wetlands-mixed, and low-density residential land uses make up less than 2% of the watershed.

Table 4.3. Watershed Land Use and Area Breakdown for SWAT Model

SWAT Land Use	Area (ha)	Watershed Percentage
Range	7,392	22.1
Agriculture	294	0.80
Water	59	0.17
Wetlands, Mixed	45	0.13
Forest, Deciduous	129	0.39
Forest, Evergreen	25,551	76.3
Residential, Low Density	36	0.11
TOTAL	**33,506**	**100**

4.2.2.4 Management Practices for the Newcastle Reservoir Watershed

The SWAT model accommodates input for management practices associated with land uses. These practices are added within the model at the HRU level, facilitating input of spatial scale land management data and, in turn, facilitating output results that may be evaluated within specific areas within the watershed. The model simulation includes the addition of Pinto Creek irrigation water to nearby lands.

Grazing of cattle within the watershed occurs throughout the summer growing season. Though the boundaries of the grazing allotments are known in the watershed and an estimate of stocking densities on private lands, what is not known is the specific number of cattle that are present within each subbasin for any specified amount of time. The SWAT model accommodates data for grazing within a subbasin but evaluates the grazing within each subbasin based on daily food uptake, animal pressure on the range, and manure deposition. Other grazing controls allow grazing days to be set within a subbasin along with the establishment of a crop residual amount; grazing controls preclude animals from overgrazing the grassland to levels below actual growth potential. This factor forces the model to eliminate grazing from any subbasin before simulated overgrazing occurs. The average grazing animal criteria have been set with the following parameters:

Daily forage uptake (dry weight)	80.1 lb/ac/day
Grazing time limit/subbasin	45 days
Trampling impact from hooves (dry weight)	0.9 lb/ac/day
Manure deposition (dry weight)	0.22 lb/ac/day
Biomass residual	356 lb/acre

The management inputs may be scheduled within the simulation by using heat units (Neitsch 2002). Use of heat units is necessary to reflect the fact that any crop needs specific temperatures to start production within a growing period. Any temperature value above the baseline minimum temperature for a crop goes into the plant for growth. Specific management practices can be scheduled in SWAT based on a percentage of the total heat units required for the crop to actually grow and be harvested, with a value of 1 indicating when actual growth is completed for the year. Based on that information, irrigation events were scheduled at the fractional values 0.3 and 0.75 heat units for the crop, while grazing was scheduled at a fractional value of 0.5 heat units.

Table 4.4 defines locations within the watershed where irrigation water has been applied and specifies the amount used. Irrigation water is applied to specific HRUs located within the subbasin to limit the water application to defined land use areas. Because all HRUs within SWAT are assumed to be homogenous, distinction between irrigation of individual fields or exclusive areas within an HRU is not possible.

Table 4.4. Irrigation of Agricultural Lands of Pinto Creek

Subbasin	HRU	Area (km^2)	Area (acres)	Input (mm)	Input (inches)	Volume (acre-feet)
4	13	0.03	7.4	126.3	5.0	3.1
9	33	0.01	2.5	148.5	5.8	1.2
45	143	0.05	12.4	12.6	0.49	0.51
50	160	0,12	29.6	33.0	1.3	3.2
51	164	0.54	133.4	9.8	0.39	4.3
57	183	0.04	9.9	55.9	2.2	1.8
TOTAL		**0.79**	**195.2**	**386.1**	**15.2**	**14.1**

4.2.2.5 Climatic Data Inputs for the Newcastle Reservoir Watershed

Climatic data for the watershed are required by SWAT. A built-in weather generator within the model uses climatic averages from nearby climatic stations to generate data. Data generated from stations located in the watershed or within close proximity more closely represent existing watershed conditions than data generated elsewhere. The Newcastle Reservoir watershed is in an isolated area with no climatic stations. The SWAT model assigned the New Harmony climatic station using a "nearest subbasin-centroid" algorithm. In situations where no climatic stations are present within the watershed being studied, interpolating between datasets from two nearby climatic stations is ideal. However, in the case of the Newcastle Reservoir watershed, only one nearby climatic station is present. Minimum and maximum daily temperatures and precipitation levels from the New Harmony climatic station were used as significant driving factors in the model.

4.2.3 Simulation Period for the Newcastle Reservoir Watershed

For the purposes of this analysis, the SWAT 2005 model simulation period was October 1995 through September 2006 (water year 1996 through water year 2006). The first water year of the simulation output is considered a model "warm-up" period, with the water levels and content within the hydrologic system reaching equilibrium by filling the soil profile with water, supplying water to the reservoir, and starting the physical processes occurring within the watershed. Flow and nutrient concentrations from the model are used to evaluate model output for the Newcastle Reservoir watershed. The yearly and monthly model output for the Little Pinto Creek subbasin (Subbasin 4) and Pinto Creek subbasin (Subbasin 9) reflect the cumulative stream reach outputs for each drainage basin within the watershed.

4.3 Reservoir Model: BATHTUB

4.3.1 General Model Description

The BATHTUB reservoir model was developed by the U.S. Army Corps of Engineers (USACE) as a sophisticated empirical model for predicting eutrophication in reservoirs. The model predicts nutrient concentrations, chlorophyll *a*, Secchi depth (transparency), and other eutrophication indices in a spatially segmented reservoir under steady-state conditions.

Model inputs include reservoir morphometry (mean depth, length, width, mixed-layer depth), hydraulic connectivity (between reservoir segments and tributaries), tributary water quality (total nutrients, dissolved nutrients, and flow), and climatic parameters (precipitation and ET). The model uses empirical equations for physical processes—advective transport, diffusive transport, and nutrient sedimentation—to predict nutrient concentrations and reservoir water quality.

Within the BATHTUB model, various empirical models predict total phosphorus, total nitrogen, and chlorophyll *a* concentrations and Secchi depth. The models summarized in Table 4.5 were found to best fit Newcastle Reservoir system conditions.

Table 4.5. Empirical Models Selected for Reservoir BATHTUB Model of Newcastle Reservoir

Parameter	Model Selected	Justification
Conservative Substance	Not computed	Default and no data
Total Phosphorus	2nd order, available TP	Default
Total Nitrogen	2nd order, available N	
Chlorophyll *a*	TP, N, Low turbidity (Conditions A, B, E)	Reservoir has low turbidity except during algal blooms. TP is limiting in the reservoir on average. N could be limiting during some events.
Chlorophyll *a*	TP, N, Light, T (Conditions C, D)	Default. No longer can expect low turbidity during low flow conditions. Less likely to have N limitation.
Transparency	Chl-a and turbidity	Default
Longitudinal Dispersion	Fischer-numeric	Default
Phosphorus Calibration	Decay rates (1) Decay rates (0.25)	Default (Conditions A, E) Conditions B, C, D as recommended in manual to account for stagnant water in reservoir during low flow.
Nitrogen Calibration	Decay rates (1) Decay rates (0.25)	Default (Conditions A, E) Conditions B, C, D as recommended in manual to account for stagnant water in reservoir during low flow.

4.3.2 MODEL INPUTS FOR NEWCASTLE RESERVOIR

4.3.2.1 Reservoir Morphometry

Model inputs were developed for each of the five baseline conditions (Section 4.1) that describe various climatic and reservoir management conditions. The physical description of the reservoir morphometry was calculated by correlating reservoir volume with average depth profiles throughout the reservoir and to area and length calculations. Data for dam elevation and calculated reservoir volume were available from the Utah Division of Water Rights. From this dataset, dam depth was calculated and compared to the maximum depth at the dam. From these data a polynomial regression equation (R^2 = 0.99) was developed to correlate water depth (m) at the dam with reservoir volume in acre-feet (Figure 4.2). In addition, mean reservoir depth and reservoir area were correlated with depth at dam for each data point so that the regression equation could be used to predict these variables from a given reservoir volume. Length of the reservoir was assumed to change by an equal percentage to area with changing volume.

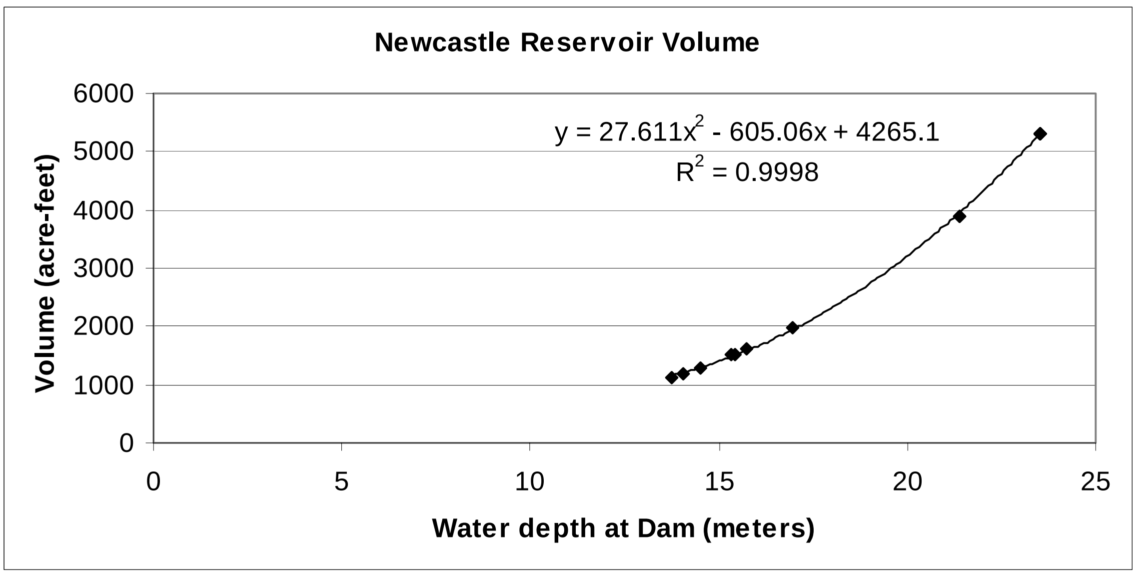


Figure 4.2. Volume (acre-feet) and regression of water depth at the Dam Site.

Volume estimates were determined for each of the five conditions as described below. From these volume estimates, mean depth, area and length of the reservoir were predicted using the methods described above (Table 4.6).

- **Condition A**: Average reservoir volume during an average flow year was calculated to be 3,250 acre-feet, based on the average between the maximum (5,300 acre-feet) and minimum (1,200 acre-feet) volume for an average flow year.
- **Condition B**: Reservoir volume of 1,200 acre-feet was assumed to represent the lowest reservoir volume during an average flow year, based on review of the volume dataset provided by Utah Division of Water Rights.
- **Condition C**: Reservoir volume was calculated to be 1,015 acre-feet by averaging the conservation pool volume (500 acre-feet) with the maximum recorded volume during a low flow year (1,530 acre-feet).

- **Condition D**: Low reservoir volume during a dry year was assumed to be the volume of a conservation pool of 500 acre-feet.
- **Condition E**: Reservoir volume during a wet, high flow year was assumed to be 5,300 acre-feet, which represents maximum storage capacity.

Hypolimnetic depth was determined through examination of depth profiles of temperature and dissolved oxygen collected from 2000–2005 at various times of the year, for various reservoir volumes. From these data the percent of the total depth that is represented by the hypolimnion and metalimnion was determined for both the Mid-lake Site and Dam Site. Thresholds for percent hypolimnetic depth were also determined for various depth ranges, as shown in Table 4.7; these were applied to representative conditions. It was assumed that the reservoir was fully mixed and thus there was no hypolimnion during critical low conditions (Conditions B and D).

Table 4.6. Reservoir Morphometry Input Data for Various BATHTUB Modeling Conditions

Condition			Area		Mean Depth	Mixed Depth	Hypo-limnetic Depth	Length
	Water Year	Reservoir Level	Acres	km^2	Meters	Meters	Meters	km
Condition A	Average	Mid-level	167	0.68	5.9	1.9	1.8	1.8
Condition B	Average	Low	96	0.39	3.8	3.8	-	1.0
Condition C	Low	Mid-level	97	0.39	3.8	2.0	0.70	1.0
Condition D	Low	Low	70	0.28	2.2	2.2	-	0.74
Condition E	High	Mid-level	230	0.93	7.0	1.7	4.1	2.5

Table 4.7. Calculation of Hypolimnetic Depth for Newcastle Reservoir Conditions

Reservoir Total Depth (meters)	Percent Mixed Depth	Percent Hypolimnetic Depth	Condition
4–5.5 m	52%	18%	C
7–11 m	33%	31%	A
12+ m	24%	58%	E
12+ m	100%	0%	B, D

4.3.2.2 Tributary Inputs

Inputs for water quality and flow for each condition were taken directly from the SWAT model for Little Pinto Creek and Pinto Creek. The miscellaneous nutrient load input (Section 5.2.8), calculated separately, is processed as an additional load to the reservoir in BATHTUB. Added together the load from Pinto Creek plus the miscellaneous nutrient load in Pinto Creek are equivalent to a load calculated by multiplying the median measured nutrient concentrations in

Pinto Creek (TP = 0.11 mg/L; Orthophosphate = 0.067 mg/L; TN = 1.1 mg/L) by the mean flows predicted by SWAT (Table 4.8). This served to validate the estimated loads for the entire watershed. Insufficient data was available for Little Pinto Creek to perform a separate validation for this tributary. It was assumed that watershed processes are similar in both tributaries and that validation of Pinto Creek was sufficient for the entire watershed. Data from May–October were used to simulate the critical period of interest in Newcastle Reservoir.

Table 4.8. Summary of Phosphorus Loads to Newcastle Reservoir During the Algal Growth Season for Each Condition (kgTP/day)

	Condition A	Condition B	Condition C	Condition D	Condition E
Little Pinto	10.90	10.90	0.73	0.73	12.38
Pinto Creek	11.51	11.51	1.63	1.63	16.39
Miscellaneous	4.07	4.07	0.30	0.30	4.44
Atmospheric	0.05	0.05	0.03	0.02	0.08
TOTAL	26.53	26.53	2.69	2.68	33.28

The BATHTUB model simulated conditions for an average water year and a critical dry year within the 1995–2006 modeling period. Water quality model inputs consist of flow (cfs), total nitrogen (mg/L), inorganic nitrogen (mg/L), total phosphorus (mg/L), and dissolved phosphorus (mg/L). The inorganic nitrogen and the dissolved phosphorus are readily available fractions of the total nutrient load, which contribute directly to reservoir productivity.

4.4 Model Calibration and Validation

The SWAT model was configured with actual climatic data inputs. Assumptions made regarding land use management, specifically grazing, were based on allotment information obtained from USFS and BLM and an estimated stocking rate of 4 AUM/acre for private land. The hydrologic portion of the SWAT model was checked against average flow rates into Newcastle Reservoir, providing reasonable assurance that this component of the model is representative of the hydrology in the watershed. The flow values obtained from SWAT were combined with available monitoring concentration data for nutrients in Little Pinto Creek and Pinto Creek for the May–October season to estimate the total nutrient load into Newcastle Reservoir. These data were collected between 1999 and 2006. The total load input for Newcastle Reservoir produced reservoir modeling results within BATHTUB that represent observed conditions in the reservoir. Nutrient concentrations in tributary streams, predicted using SWAT, account for the majority of diffuse sources in the watershed, including grazing, agricultural production, forestry management, and stormwater from developed areas. However, SWAT does not have the spatial or temporal resolution to account for several known sources in the watershed such as erosion of stream banks denuded by grazing and erosion from roads in the forested and rangeland areas of the watershed. Thus, the modeled concentrations were slightly below monitored concentrations in the streams. The difference between modeled and monitored nutrient concentrations was assumed to be representative of loads not calculated by SWAT, including erosion of stream banks and runoff and erosion from roads in the watershed.

Reservoir water quality data are not used directly in the BATHTUB model but are used to validate the model assumptions and tributary input loads used to configure the reservoir model. Water quality data for Newcastle Reservoir are only available for an average water year. There were not enough data to differentiate low and high water years. However, the data were separated for the mixed and stratified time periods of the year. It was assumed that the low water level is represented by the mixed period (Condition B), whereas the average reservoir water level was characterized by the average across the entire season (Condition A). Water quality data were summarized separately for these two periods, based on known stratification dates determined using the depth-profile data available for dissolved oxygen, temperature, and pH. Critical conditions, as simulated in Condition B, were assumed to occur in August. Thus, Condition A was validated using average water quality data across the May–October season (Figure 4.3) and Condition B was calibrated based on stratified data collected during the month of August (Figure 4.4).

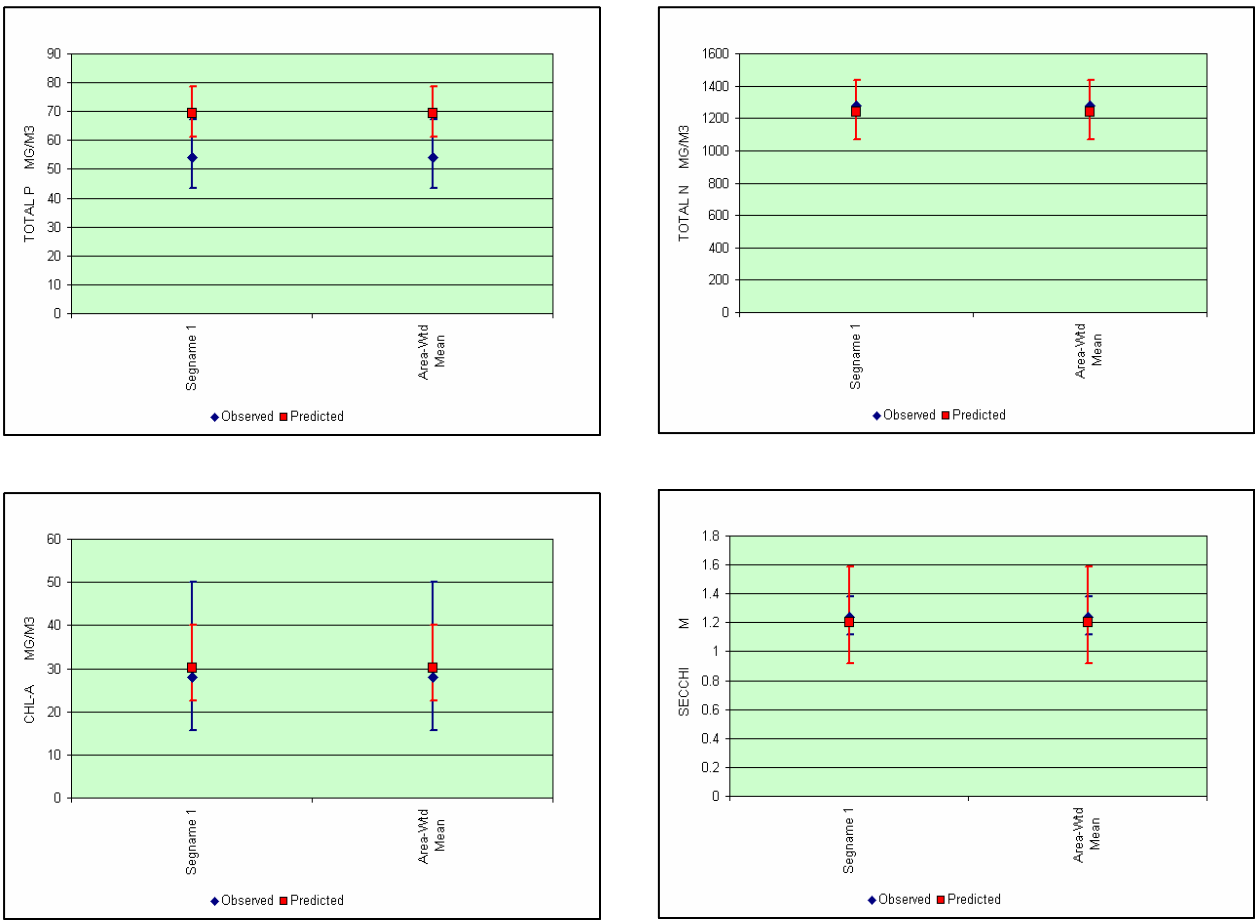


Figure 4.3. Model validation graphs for BATHTUB Condition A.

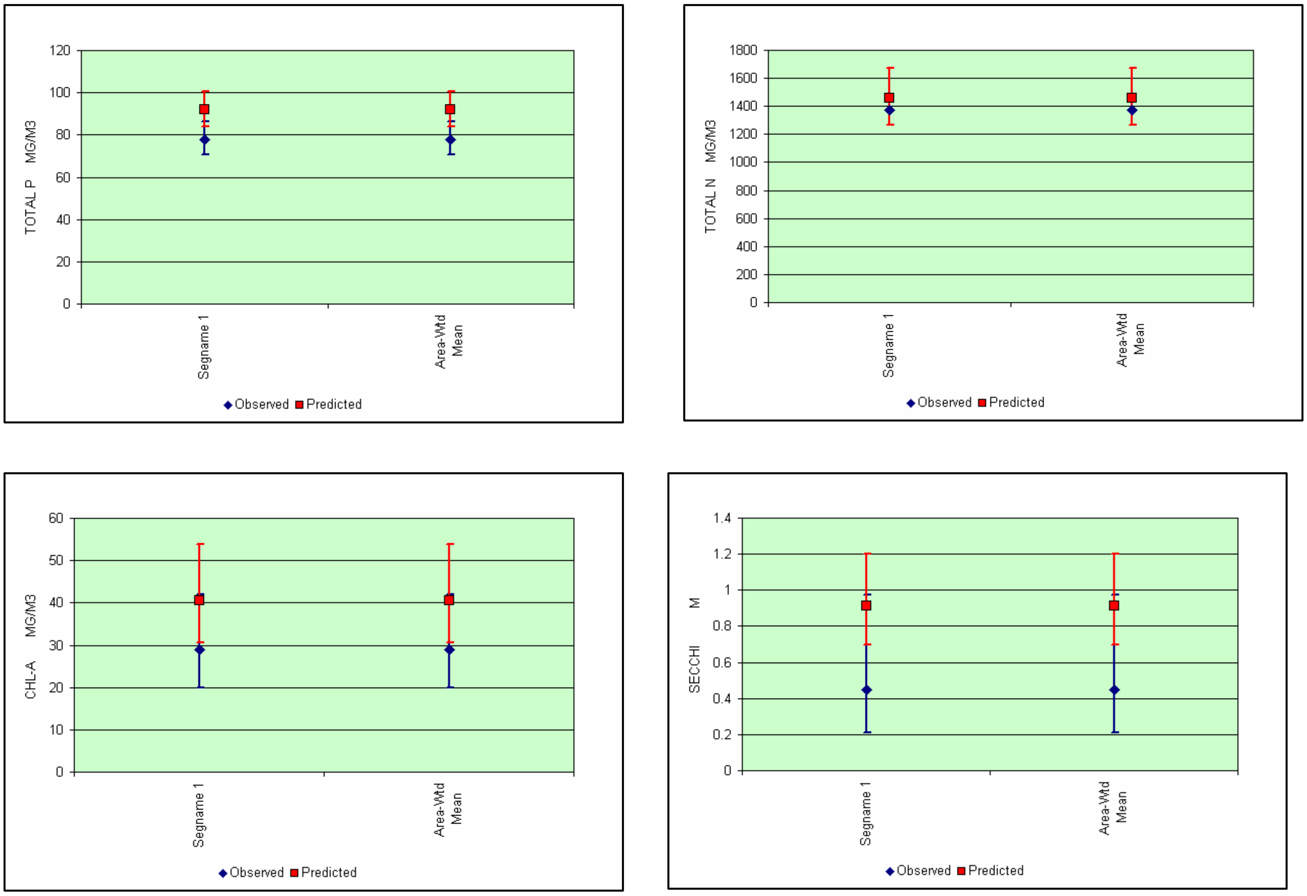


Figure 4.4. Model validation graphs for BATHTUB Condition B.

4.5 MODEL UNCERTAINTY

Watershed models are simplified abstractions of a natural system. No measurement within nature can be made without error, and the developed models cannot represent true spatial and temporal variability. Model outputs therefore present some level of uncertainty. Specific causes of uncertainty include lack of appropriate data pertaining to watershed output, conflicting data, data ambiguity, and measurement uncertainty. Uncertainty in estimating nutrient loads produced within the watershed comes primarily from:

1. Errors in weather station data
2. Errors related to weather station location
3. Errors in nutrient parameter adjustments
4. Errors associated with the SWAT or BATHTUB models themselves
5. Errors that result from combining the SWAT and BATHTUB models

Since the SWAT model is a spatially distributed, physically based model, output modification is accomplished by parameter adjustment. Because of the lack of physical data available for the watershed, computer parameter sensitivity methods are not available and manual parameter modification and measurement become very tedious and time-consuming, with limited complexity. Uncertainty in model output is increased with the use of arbitrary parameter-estimation methods. However, recent studies have demonstrated that a direct comparison of model output for a complete dataset versus an incomplete dataset did not produce large discrepancies in model performance (Wainwright 2004). Since SWAT produced results meeting acceptable calibration measurement performance, the SWAT model outputs were determined to be appropriate for use in this watershed analysis. The observed concentrations are generally lower than the predicted values, thus adding an additional conservative element to the analysis.

4.6 Annual Water Budget

The USGS defines a water budget as an estimate of the water resources of a geographical region. The water budget includes an evaluation of all sources of supply or recharge in comparison with all known discharges or extractions.

The Newcastle Reservoir watershed water budget was constructed using results from the SWAT hydrologic model. The water budget incorporates all the gains and losses of water that constitute the hydrologic cycle in the watershed. The SWAT model quantifies watershed inputs as precipitation and diversion from Grass Valley Creek. Hydrologic losses include annual discharge from the watershed (including surface runoff, lateral flow, and groundwater recharge of streams), ET, and loss to deep aquifers.

The Newcastle Reservoir watershed is not a closed system; it has a variety of water features that complicate precise determination of gains and losses. These include:

- Grass Creek is diverted via a transbasin diversion into the watershed at the upper portion of Pinto Creek.
- Water usage for irrigation is not accurately measured within the drainage.
- The total outflow of Pinto Creek is not measured. The transbasin diversion was measured up to the 1995 water year, but measurements have since been discontinued.
- No weather recording stations are located within the watershed; the nearest station is located at New Harmony.

The water budget demonstrates the assumption that total water inputs equal total water outputs. The SWAT model uses all of the inputs to calculate the output for the watershed, based on a simple water budget equation:

$$P + D = Q_{out} + ET + Q_{gw}$$

Where:

P = precipitation

D = diversion inputs

ET = evapotranspiration

$\mathbf{Q_{out}}$ = surface water outflow from watershed into reservoir

$\mathbf{Q_{gw}}$ = loss to deep aquifers

The annual water budget, derived from SWAT, is summarized in Table 4.9 and described in the sections that follow.

Table 4.9. Newcastle Reservoir Watershed Annual Water Budget

	Area Weighted Annual Average (mm)	Annual Average Volume (acre-feet)	Percent of Total
Inflows			
Precipitation (P)	578	155,017	98%
Diversion from Grass Valley (D)	10	2,744	2%
TOTAL	**588**	**157,761**	**100%**
Outputs			
Watershed Discharge (Qout)	276	74,084	47%
Evapotranspiration (ET)	311	83,495	53%
Loss to Groundwater (Qgw)	1	182	0.1%
TOTAL	**588**	**157,761**	**100%**

4.6.1 PRECIPITATION (P)

The climate of the Newcastle Reservoir watershed is semiarid; summers are hot and dry and winters are cold and moist, with significant snow accumulations in the upper reaches of the watershed. Precipitation generally declines as elevation decreases in the watershed. Most of the precipitation in the watershed occurs from November–March as snow (Figure 4.5). The immediate watershed receives 12–16 inches (30.5-40.6 cm) of precipitation annually, with a frost-free season of 120–140 days at the reservoir. Figure 4.6 illustrates the streamflow output and precipitation patterns of the Newcastle Reservoir watershed region. The stream outflow is highly dependent upon precipitation events that occur throughout the year. Figure 4.6 demonstrates that the precipitation events are seasonal, with little precipitation occurring during the heat of the summer and most of the precipitation occurring during the fall or winter months as temperatures decline.

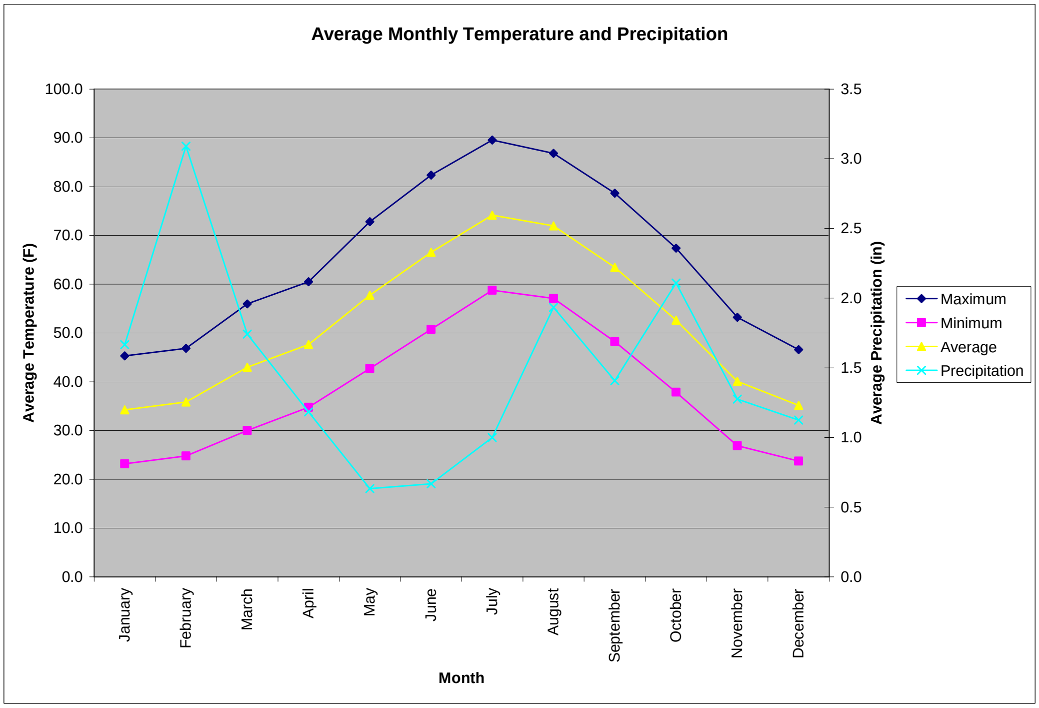


Figure 4.5. Monthly temperature and precipitation values for Newcastle Watershed.

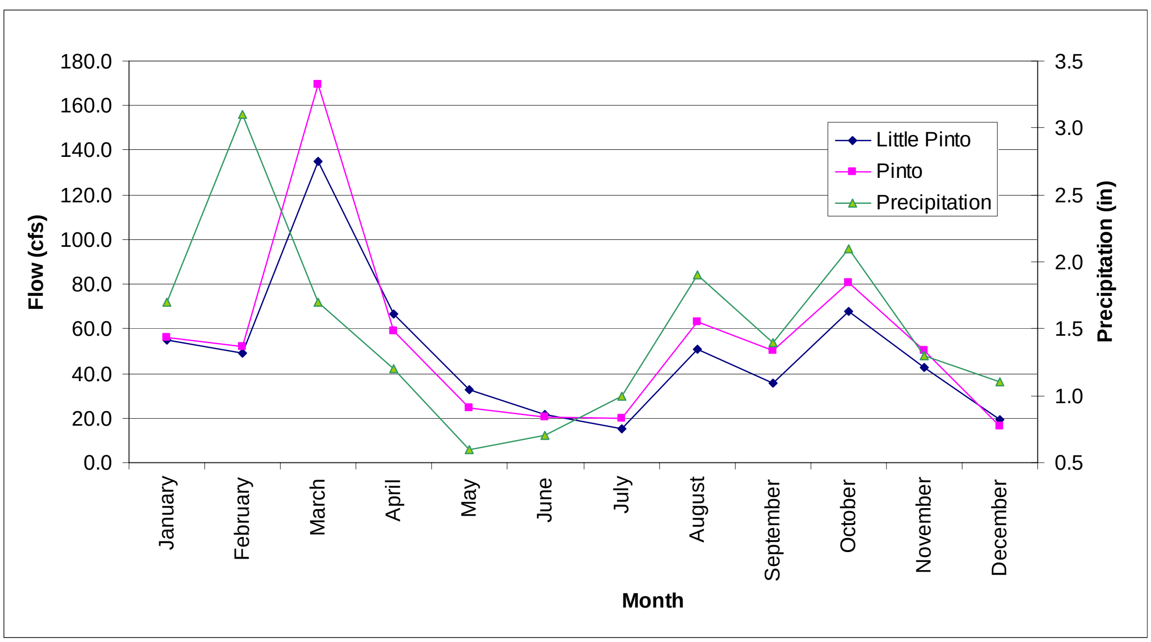


Figure 4.6. Monthly flow rates and precipitation for Pinto and Little Pinto Creek.

4.6.2 Diversion Inputs (D)

Water from Grass Creek is diverted into Pinto Creek to provide irrigation water for agricultural lands in the watershed. This input is approximately 2,744 acre-feet per year. Most of this water is lost by ET, but some of the water returns to the stream via irrigation return flow and is captured in the watershed discharge estimate (Q_{out}).

4.6.2.1 Watershed Discharge (Q_{out})

Discharge from the Newcastle Reservoir watershed is computed where Pinto Creek and Little Pinto Creek discharge into Newcastle Reservoir. The net surface discharge from these tributary streams (74,084 acre-feet per year) includes surface water runoff (45% of streamflow), lateral flow contributions to streamflow (51% of streamflow), and groundwater contributions to streamflow (4% of streamflow).

4.6.2.2 Evapotranspiration (ET)

A large part of the water that enters the Newcastle Reservoir watershed is consumed by evaporation and plant transpiration, known collectively as evapotranspiration (ET). These processes represent the water loss from the plant-soil system due to evaporative demand of the atmosphere. This loss equals a total of 83,495 acre-feet per year, which occurs mostly during the warm summer months, when plants are actively growing, humidity is low, and temperature is high. A limited amount of ET occurs during the winter months.

In the arid Southwest, water is the limiting factor within the ET calculation. Based on local temperature and precipitation, the potential ET (PET) is much greater than the available water supply (PET is a measure of the ability of the atmosphere to remove water from the surface through the processes of evaporation and transpiration, assuming no limit of water supply). This would actually not occur under normal arid conditions that are present within this watershed unless supplemental irrigation water met the PET demand. Climatic data show that PET for the New Harmony area is 91.8 inches (2,331 mm). Given limited precipitation within the watershed, the amount of actual ET is approximately 12.3 inches (311.36 mm).

4.6.2.3 Loss to Groundwater (Q_{GW})

Another fraction of water that is lost from the watershed water budget is the infiltration water that percolates past the root zone of the vegetation within the area and eventually enters the deep groundwater aquifer as recharge water. This recharge loss accounts for 182 acre-feet per year (less than 1%).

4.7 Baseline Model Results

4.7.1 Stream Load Calculations Using SWAT Model Output

The SWAT model developed for and applied to the Newcastle Reservoir watershed is described in detail in Section 4.2. The water balance output from the model is summarized in Section 4.6. In this section, current phosphorus loads are summarized for the two tributaries.

The contribution of nutrients to Newcastle Reservoir is calculated based on average tributary flows out of the watershed and into the reservoir, as well as on median in-stream nutrient concentrations for Pinto Creek (TP = 0.11 mg/L; Orthophosphate = 0.067 mg/L; TN = 1.1 mg/L). The difference between miscellaneous load and SWAT model load determined for Pinto Creek was used to determine inflow concentrations in Little Pinto Creek based on the SWAT model output results (TP = 0.09 mg/L; Orthophosphate = 0.06 mg/L; TN = 1.4 mg/L). It is assumed that these "average" conditions exist from year to year, with variances ranging from very dry to very wet. Limnetic conditions within the reservoir vary based on water availability. These inputs can be classified by high flow conditions, average conditions, and critical dry conditions. Because high flow conditions result in high-quality limnetic conditions, the outputs for these years are not evaluated; water quality conditions during these years are assumed to meet all water quality standards. Reservoir evaluations are generated for average climatic conditions and critical dry conditions.

Average climatic and flow conditions occur during the simulation period (1996–2006). The average year is based on watershed flow output for the model simulation period. The critical dry period (2002) is the low flow condition. A simulation year could have a very low flow condition but have one or two months where low flow conditions did not exist and therefore load conditions of nutrients were skewed by the high monthly flow output. The year 2002 was chosen based on conditions throughout the critical seasonal low flow conditions during the May–October period. Average and low flow concentration results for Little Pinto and Pinto Creeks from SWAT are shown in Table 4.10.

Table 4.10. Summary of SWAT Output Data for Average, Low, and High Water Climatic Conditions

Output Data for Average, Low, and High Water Climatic Conditions									
Average Water Year Output									
Pinto Creek		**MAY**	**JUNE**	**JULY**	**AUGUST**	**SEPTEMBER**	**OCTOBER**	**Average Daily Load**	**Average Seasonal Conc. (mg/L)**
	Total Nitrogen (kg)	5.81	7.00	12.92	31.93	26.66	41.11	125.43	1.18
	Organic Nitrogen (kg)	0.07	0.13	0.10	0.40	0.27	0.62	1.58	1.11
	Total Phosphorus (kg)	0.14	0.58	0.23	2.93	3.14	5.04	11.51	0.091
	Orthophosphate (kg)	0.05	0.21	0.08	1.08	1.16	1.87	4.46	0.034
Little Pinto Creek		**MAY**	**JUNE**	**JULY**	**AUGUST**	**SEPTEMBER**	**OCTOBER**	**Average Daily Load**	**Average Seasonal Conc. (mg/L)**
	Total Nitrogen (kg)	6.89	9.00	13.95	40.35	33.88	58.60	162.68	1.41
	Organic Nitrogen (kg)	0.08	0.65	0.12	0.91	0.57	4.32	6.64	1.36
	Total Phosphorus (kg)	0.11	0.81	0.27	2.87	1.39	6.07	10.90	0.083
	Orthophosphate (kg)	0.04	0.30	0.10	1.06	0.51	2.25	4.27	0.031
Dry Water Year Output									
Pinto Creek		**MAY**	**JUNE**	**JULY**	**AUGUST**	**SEPTEMBER**	**OCTOBER**	**Average Daily Load**	**Average Seasonal Conc. (mg/L)**
	Total Nitrogen (kg)	0.33	0.41	5.01	0.21	46.00	18.08	70.05	0.99
	Organic Nitrogen (kg)	0.00	0.00	0.00	0.00	0.39	0.14	0.54	0.99
	Total Phosphorus (kg)	0.04	0.04	0.06	0.02	1.19	0.26	1.62	0.048
	Orthophosphate (kg)	0.02	0.02	0.02	0.01	0.44	0.10	0.60	0.018

Table 4.10. Summary of SWAT Output Data for Average, Low, and High Water Climatic Conditions

Output Data for Average, Low, and High Water Climatic Conditions									
Little Pinto Creek		**MAY**	**JUNE**	**JULY**	**AUGUST**	**SEPTEMBER**	**OCTOBER**	**Average Daily Load**	**Average Seasonal Conc. (mg/L)**
	Total Nitrogen (kg)	0.36	0.67	3.99	0.36	53.24	22.88	81.50	0.98
	Organic Nitrogen (kg)	0.00	0.00	0.00	0.00	0.25	0.05	0.30	0.98
	Total Phosphorus (kg)	0.04	0.05	0.06	0.03	0.43	0.13	0.73	0.031
	Orthophosphate (kg)	0.02	0.02	0.02	0.01	0.16	0.05	0.27	0.012
Wet Water Year Output									
Pinto Creek		**MAY**	**JUNE**	**JULY**	**AUGUST**	**SEPTEMBER**	**OCTOBER**	**Average Daily Load**	**Average Seasonal Conc. (mg/L)**
	Total Nitrogen (kg)	10.94	22.80	31.02	116.03	10.70	41.26	232.76	1.30
	Organic Nitrogen (kg)	0.34	0.72	0.41	2.63	0.00	0.60	4.70	1.28
	Total Phosphorus (kg)	0.31	0.51	0.56	13.93	0.18	0.88	16.36	0.044
	Orthophosphate (kg)	0.12	0.19	0.21	5.15	0.07	0.32	6.05	0.016
Little Pinto Creek		**MAY**	**JUNE**	**JULY**	**AUGUST**	**SEPTEMBER**	**OCTOBER**	**Average Daily Load**	**Average Seasonal Conc. (mg/L)**
	Total Nitrogen (kg)	12.10	26.08	25.06	149.77	13.70	46.97	273.68	1.52
	Organic Nitrogen (kg)	0.45	1.85	0.50	4.38	0.00	0.79	7.96	1.49
	Total Phosphorus (kg)	0.25	1.57	0.56	9.37	0.15	0.53	12.43	0.041
	Orthophosphate (kg)	0.09	0.58	0.21	3.47	0.05	0.20	4.60	0.015

4.7.2 RESERVOIR WATER QUALITY

The BATHTUB model was used to predict current water quality in Newcastle Reservoir under several different climatic conditions and reservoir levels. These results provide the model baseline used to analyze the impact of reduced nutrient loads on reservoir water quality. Results are presented for all five conditions, though only Condition A (average climatic conditions and average reservoir volume) is used to estimate load reduction requirements to meet target water quality endpoints. The poor water quality expected during times when the reservoir is stagnant is believed to result more from water quantity management than from tributary nutrient loads.

4.7.2.1 Nutrients

Average in-reservoir nutrient concentrations for Condition A (the condition used for the TMDL load analysis) are 0.07 mg/L total phosphorus and 1.2 mg/L total nitrogen. The majority of the phosphorus is predicted to be orthophosphate (0.05 mg/L) and the bulk of the nitrogen is predicted as organic nitrogen (0.85 mg/L). The highest nutrient concentrations occur in Condition B with 0.09 mg/L total phosphorus and 1.45 mg/L total nitrogen when the reservoir water level is maintained at a low level, such that nutrient flushing is reduced and internal loading from reservoir sediments is enhanced. Nutrient concentrations under low flow conditions (conditions C and D) are low due to the reduced nutrient inputs from tributary streams (Table 4.11).

The BATHTUB model also predicts total N:P ratios and dissolved N:P ratios. Values greater than 7–10 generally indicate a phosphorus-limited system. Based on total nutrient ratios, all conditions point to a phosphorus-limited system.

Table 4.11. Predicted Nutrient Concentrations in Newcastle Reservoir Based on the BATHTUB Model

	Units	Condition				
		A	B	C	D	E
Water Year		Average	Average	Low	Low	High
Reservoir Level		Average	Low	Average	Low	Average
Total Phosphorus	mg/L	0.07	0.09	0.04	0.05	0.04
Orthophosphate	mg/L	0.05	0.07	0.04	0.03	0.03
Total Nitrogen	mg/L	1.24	1.45	1.09	1.12	1.38
Organic Nitrogen	mg/L	0.85	1.09	0.67	0.62	0.60
Indicator of Limiting Nutrient (N:P)	unitless	16	14	21	21	29
Inorganic Nitrogen:Orthophosphate	unitless	22	17	66	42	81

4.7.2.2 Chlorophyll *a* and Secchi Depth

Predicted mean chlorophyll *a* concentrations range from 19 µg/L under Condition E to 41 µg/L under Condition B. The mean concentration under Condition A, the condition used for the TMDL load analysis, is 30 µg/L. Predicted percent exceedance of various chlorophyll *a* concentrations indicate the frequency at which nuisance algal levels are expected to occur in the reservoir under each condition. Exceedance of a nuisance threshold of 30 µg/L ranges from 17% under Condition D to a high of 57% under Condition B (Figure 4.7).

Predicted Secchi depth ranges from a low of 0.9 m under Condition B to a high of 1.8 m under Condition E, closely following predicted chlorophyll *a* for each Condition Table 4.12).

Table 4.12. BATHTUB Model Output for Newcastle Reservoir Baseline Conditions Related to Algal Growth

	Units	Condition					Interpretation
		A	B	C	D	E	
Water Year		Average	Average	Low	Low	High	
Reservoir Level		Average	Low	Average	Low	Average	
Chlorophyll *a*	µg/L	30	40	22	20	19	
Secchi Depth	meters	1.2	0.90	1.6	1.7	1.8	
2nd Principal Component of Reservoir Response Variables	index	15	16	16	15	15	> 10, algae dominated, light unimportant, high nutrient response
Non-algal Turbidity	1/meter	0.10	0.10	0.10	0.10	0.10	< 0.4 is low turbidity; high algal response to nutrients
Mixed-layer Depth/Secchi Depth	unitless	1.6	4.2	1.3	1.3	2.3	< 3 high algal response to nutrients; > 6 low algal response to nutrients
Chlorophyll *a* * Transparency	mg/m2	36	37	35	34	34	> 16 algae dominated, nutrient-limited
Mean Chlorophyll *a*/Mean TP	unitless	0.40	0.40	0.50	0.40	0.50	> 0.4 P-limited; <0.13 algae-limited by other factors

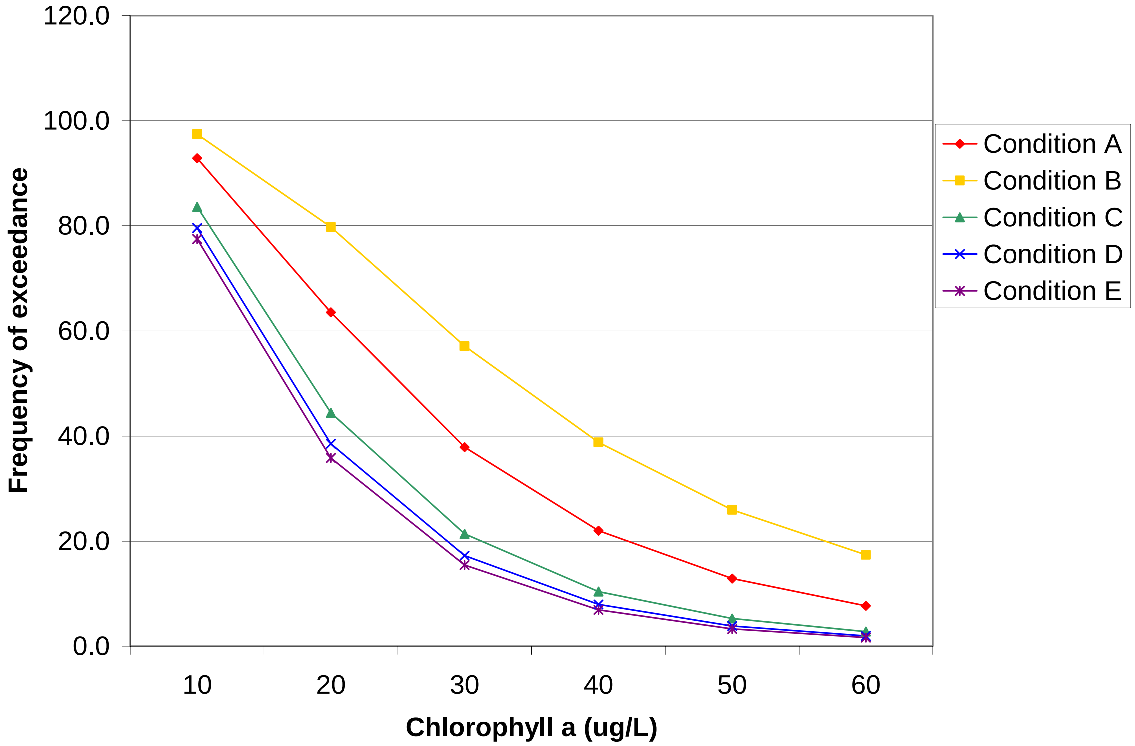


Figure 4.7. Predicted percent exceedance of nuisance algal thresholds under each baseline condition.

Several model outputs are metrics that indicate the extent to which algal growth in the reservoir is nutrient-limited. Most of these metrics indicate high algal response to nutrients under all conditions. One metric, mixed-layer depth/Secchi depth, suggests that Condition B is less responsive to nutrient reduction than the other conditions (see Table 4.12).

4.7.2.3 Eutrophication Potential and Oxygen Depletion

The BATHTUB model outputs several metrics of eutrophication potential and oxygen depletion that can also be used to assess the suitability of the reservoir for cold water fish. The initial results from a principal component analysis of reservoir response variables are expressed as an index value. Values greater than 500 (Conditions A and B) are believed to indicate high eutrophication potential (Walker 1999). All of the predicted total phosphorus, chlorophyll *a*, and Secchi depth concentrations indicate a eutrophic system for all five conditions. According to the TSI for Secchi depth, Conditions D and E border on a mesotrophic state.

The hypolimnetic oxygen depletion (HOD) rate predicts oxygen depletion below the thermocline and is related to the supply of organic matter from settling algae as well as to external organic sediment loads and hypolimnetic depth. The metalimnetic oxygen depletion rate (MOD) predicts oxygen depletion in the metalimnion. When HOD is above 0.10 mg/L/day, the oxygen supply in the hypolimnion is usually depleted within 120 days (4 months) after stratification. Dissolved oxygen depth profiles collected at the Dam Site on June 7, 2005 and July 27, 2005 were compared and used to calculate actual oxygen depletion rates throughout the hypolimnion and metalimnion during the period of stratification. The calculation is based on guidance from the PROFILE and BATHTUB user manual (Walker 1999). Based on this analysis, HOD rates in Newcastle Reservoir ranged in summer 2005 from 0.072 mg/L/day at the thermocline to 0.083 mg/L/day at the sediment-water interface, with a mean HOD of 0.080 mg/L/day. Metalimnetic oxygen depletion rates ranged from 0.052 mg/L/day at the boundary between the epilimnion and metalimnion to 0.060 mg/L/day at the boundary between the metalimnion and the hypolimnion. The mean MOD in Newcastle Reservoir was estimated to be 0.056 mg/L/day. These calculated values incorporate summer sediment oxygen demand associated with algal growth in the previous fall and winter seasons and/or previous years. They were used to calibrate predicted HOD and MOD rates in Condition A of the BATHTUB model. The calibration coefficients were carried over to the other conditions as well as per the reduction scenarios (Table 4.13). Newcastle Reservoir appears to stratify in mid-May and mix again in early August (2.5 months of stratification). Following calibration of this parameter, HOD rates were predicted to range from 0.07 mg/L/day (Condition E) to 0.181 mg/L/day (Condition C). Oxygen depletion rates in the metalimnion range from 0.048 mg/L/day (Condition E) to 0.89 mg/L/day (Condition C). No oxygen depletion rates are calculated for Conditions B and D because the reservoir is assumed to be mixed under these conditions.

Table 4.13. BATHTUB Model Results for Model Baseline Conditions Related to Average Seasonal Eutrophication and Oxygen Depletion

	Units	Condition					Interpretation
		A	B	C	D	E	
Water Year		Average	Average	Low	Low	High	
Reservoir Level		Average	Low	Average	Low	Average	
HOD Rate	mg/L	0.08		0.18		0.070	
MOD Rate	mg/L	0.057		0.89		0.048	
1st Principal Component of Reservoir Response Variables	index	703	1194	389	354	331	> 500 = high eutrophication potential
TSI TP	index	65.3	69	59	59	58	51–70 = eutrophic; 41–50 = mesotrophic; < 40 = oligotrophic
TSI Chlorophyll *a*	index	64	67	61	60	60	52–70 = eutrophic; 41–50 = mesotrophic; < 40 = oligotrophic
TSI Secchi Depth	index	57.3	61	54	52	52	53–70 = eutrophic; 41–50 = mesotrophic; < 40 = oligotrophic

Using the HOD rates for Condition A across the entire hypolimnion, as observed in June of 2005 (higher oxygen depletion rates at the sediment-water interface), and assuming an initial oxygen concentration of 8.5 mg/L at stratification, a dissolved oxygen profile at the Dam Site for the end of the stratification period (August 1) was developed for Newcastle Reservoir (Figure 4.8). This Figure indicates that the dissolved oxygen concentration is below 4 mg/L in more than 50% of the water column under current average conditions, a conclusion supported by observed dissolved oxygen profiles in August.

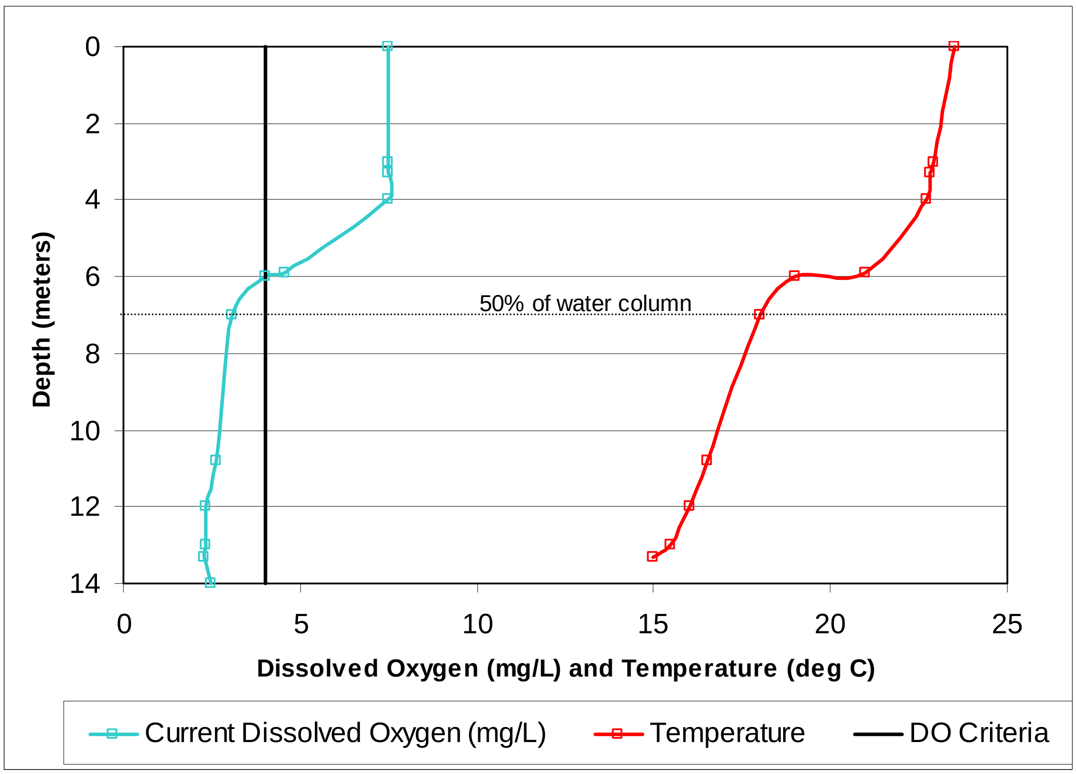


Figure 4.8. Predicted dissolved oxygen profile for average conditions at the end of stratification period (assumed to be August 1 on average) based on oxygen depletion rates calculated June 2005.

5 LOAD ANALYSIS

5.1 MAJOR SOURCES OF NUTRIENT LOADING TO NEWCASTLE RESERVOIR

This section discusses pollutant sources that contribute to the impairment of Newcastle Reservoir. Because Newcastle Reservoir is primarily phosphorus limited, phosphorus is the primary focus of this analysis. Numerous potential nonpoint sources of pollution exist within the Newcastle Reservoir watershed. Tributary loadings from Pinto and Little Pinto Creeks are related to land use activities occurring within the watershed. Phosphorus loads are reported for the algal growth season (May-October). All loads expressed in the load analysis refer to total phosphorus (TP) in kg per day during the algal growth season. Significant sources of nutrient loading in the Newcastle Reservoir watershed include:

- Cattle in riparian areas and stream channels
- Forest land management
- Rangeland management
- Agricultural land management sources
- Stormwater runoff from rural subdivisions
- On-site wastewater treatment systems (septic systems)
- Internal reservoir sources
- Miscellaneous sources (roads, stream erosion, etc.)
- Atmospheric sources
- Natural background sources

Although references to numerous pollutants are given in this background section, only assumptions relevant to calculation of phosphorus loads are included.

5.1.1 CATTLE IN RIPARIAN AREAS AND STREAM CHANNELS

Cattle grazing along stream banks and within the channel may, if improperly managed, exacerbate erosion in two major ways. The shearing action of hooves on stream banks destabilizes the soil and increases the potential for significant erosion as loose sediments are rapidly removed by flowing water. Grazing cattle may also remove or substantially reduce riparian vegetation (Platts and Nelson 1995).

Cattle impact riparian areas and stream channels through increased sediment and nutrient loading when stream banks are destabilized and eroded by animals and when animals deposit manure and urine into surface waters (Mosely et al. 1997). Bank erosion is accelerated where riparian vegetation has been removed or heavily grazed. Stream-bank vegetation serves to stabilize bank sediments and reduce the erosional force of flowing water. It also serves as a depositional area for sediment already in the stream. Water entering vegetated reaches slows down because of the resistance plant stems create within the flow path. As flow velocity decreases, larger sediment particles settle out within the riparian areas. Reduction or removal of riparian vegetation decreases bank stability through the loss of root mass within the soil profile and decreases settling and sedimentation at the edges of the stream channel. As a result, stream banks have become unstable in many stream reaches. Related impacts include increased water temperatures in the tributaries due to removal of stream side vegetation, allowing greater dissolution of adsorbed phosphorus and other nutrients from sediment-bound forms. Cattle within a grazed pasture rarely spread out and cover the entire acreage evenly; rather, they tend to congregate around areas where water is readily available (riparian areas and stream channels) and forage is plentiful.

Consequently, a greater proportion of the manure is deposited in or nearby stream channels and riparian areas.

The majority of grazing on USFS and BLM lands within the watershed occurs from May–November. Grazing allotments in the Newcastle Reservoir watershed are summarized in Table 5.1 and Table 5.2. The methodology used to determine stocking rates on private pastures in the watershed is described in Section 5.1.3. Impacts of grazing on water quality are discussed in greater detail in Sections 5.1.2, 5.1.3, and 5.1.4.

5.1.2 Forest Lands Management

Grazing practices impact forested lands through soil compaction, manure deposition, and increased sediment and nutrient loading due to destabilization and erosion of forest soils. While a small portion of the available phosphorus in plant material is used by grazing animals to grow and maintain bones and teeth, between 60–95% of the phosphorus intake returns to the environment as manure (Magdoff et al. 1997). Manure has a slower physical decomposition rate than plant material on the surface. This results in increased accumulation of soluble phosphorus in a physically unstable form within the grazed area. Such deposition is especially noticeable when correlated with the spatial distribution of animals in grazing and bedding routines.

Four USFS grazing allotments are found within the Grass Valley and Pinto Creek watersheds. These include the West Pinto, Iron Town, East Pinto, and Pine Valley allotments. Grazing intensity and duration information, provided by the Dixie National Forest, Pine Valley Ranger District are presented in Table 5.1. It is important to note that allotments do not coincide with subwatershed boundaries and may only be partially contained within a watershed, and that the cattle are not dispersed evenly across the landscape. An environmental assessment conducted for the South Pinto Creek Road relocation found that grazing impacts to the south fork of Pinto Creek and Grassy Flat Canyon were not appreciably affecting the quality of aquatic habitat (USFS 2005).

Table 5.1. Identified Grazing Permits on USFS Lands within the Newcastle Reservoir Watershed

	2006		2005	
West Pinto Allotment				
Lower Pinto	5/21–6/22	123 head	Rest	
Cove Mountain	6/23–8/24	257 head	8/11–10/10	257 head
Iron Town Allotment				
Kane Point	6/1–7/1	93 head	6/1–6/30	65 head
East Pinto Allotment				
Pinto	7/16–9/15	146 head	7/6–9/15	146 head
North Richie	9/16–10/15	146 head	6/1–7/5	146 head
South Richie	6/1–7/15	100 head	9/6–10/15	146 head
Pine Valley Allotment				
Mountain	8/1–10/15	786 head	8/1–9/7	707 head
Grass Valley	7/20–8/1	650 head	7/25–7/31	707 head
Pine Valley (Burgess)	6/1–10/15	5 head	6/1–10/15	5 head
Black Bench	6/26–7/25	700 head	6/21–7/25	707 head

Total phosphorous loads generated by other forestry management practices (including road construction and use and in-stream erosion) are discussed in Section 5.1.8, Miscellaneous Sources.

5.1.3 Rangeland Management

Within the study area, BLM land is broken into five grazing allotments. These include Joel Spring, Reservoir, Lower Meadow, Pinto Creek, and Iron Mountain. Grazing permit information provided by the BLM's Cedar City Field Office is presented in Table 5.2.

Private in-holdings also support livestock within the watershed area. Estimates from the local NRCS office identified five producers in the watershed. Production on rangeland in the watershed is estimated at four acres per Animal Unit Month (AUM).

The effects on water quality from rangeland management are similar to those from forest land management. See Section 5.1.2 for a complete discussion.

Table 5.2. Identified Grazing Permits on BLM Lands within the Newcastle Reservoir Watershed

Allotment	Number of Cattle	Date	Percent Public Land	AUMs
Joel Spring	164	11/01–05/31	100%	1134
Reservoir	39	11/01–05/31	78%	218
Lower Meadow	47	05/0–09/30	5%	12
Iron Mountain	No grazing privileges remain.			
Pinto Creek	Unknown			

5.1.4 Agricultural Land Management Sources

Primary sources of pollutants associated with agriculture are sediment and nutrients present in both dissolved and sediment-bound forms resulting from irrigation, cropping, pasturing, and ranchettes (Table 5.3). Related impacts are alteration of stream flows and temperatures from activities that directly influence the riparian area. The generation and transport of pollutants from agricultural nonpoint sources are influenced by:

- The health of riparian areas through which water is transported to the reservoir.
- Overland flow from runoff and snowmelt.
- Irrigation practices.
- Pasture and rangeland management.
- Fertilizer application.

Table 5.3. Potential Pollutant Loading from Agricultural Management Practices

Management Practices	Resulting Status of Sediment Loads	Resulting Status of Nutrient Loads	Resulting Status of Other Pollutants
Over-utilization of Pasture	Increased erosion sheet and rill Increased transport of sediment Decreased stubble height Soil compaction, leading to reduced water infiltration	Increased nutrient load from animal waste deposition Soil compaction and decreased stubble height, leading to increased nutrient transport from overland flow	Increased bacterial levels
Flood Irrigation	Removal of soil fines from surface and subsurface Increased bank erosion from subsurface drainage and recharge Subsurface saturation, decreased permeability, and increased erosion from surface runoff	Prolonged saturation, leading to anaerobic soil conditions and decreased capacity for phosphorus sorption Removal of soil fines, leading to decreased surface area of soils and available capacity for phosphorus sorption	
Ranchettes	High road and livestock density, leading to increased sediment transport	Increased animal waste deposition and transport, leading to increased nutrient loads	Increased bacterial levels Increased storm-water pollutants

Stocking rates on private pastures were used in both the SWAT model and in estimating the impact cattle on private pastures have on streams and riparian areas. The number of animals that graze dry land or irrigated pasture is measured as a standard of forage production used or an animal unit month (AUM). An AUM is the amount of forage required by one animal unit (AU) for one month. The Natural Resources Conservation Service (NRCS) uses 30 pounds of air-dry forage per day as the standard forage demand for a 1,000-pound cow and her calf (one AU). To establish appropriate stocking rates, adjustments must be made to this basic definition of an AUM to establish reasonable forage usage rates, which include consumption levels, trampling, and wastage by cattle. Cattle of different weights will consume different amounts of forage. The term Animal Unit Equivalent (AUE) is the forage requirements of an animal relative to the requirements of an AU.

In order to obtain proper pasture utilization, the number of AUMs within a given grazing period may need to be adjusted. If a pasture has 4 AUMs of forage, that forage may be utilized as either 4 AUs on the pasture for 1 month, 1 AU on the pasture for 4 months, or any other combination totaling 4 AUMs. According to the NRCS in Utah, the average forage production on irrigated pasture and hay land is about 7,200 lbs dry weight/acre. Based on the AUM forage production used, 7,200 lbs/acre equates to 4 AUMs/acre. To calculate the carrying capacity of an irrigated pasture based on total forage production, the AU is applied to the total irrigated acreage to equate total production to the total amount of animals that may be grazed for a season. Based upon the calculations, the private irrigated hay and pasture land located within the Newcastle Reservoir watershed can graze 366 AUs for the grazing period. This is equivalent to a total of 67,399 animal unit days.

5.1.4.1 Irrigation

Limited irrigation occurs within the watershed on the floodplain near Pinto. To irrigate pastures, surface water is either diverted from Pinto Creek or groundwater is pumped from shallow aquifers. Irrigation practices that substantially alter the water Table can lead to changes in the mobility of phosphorus within the shallow subsurface. Phosphorus has been observed to move more easily through soils that are consistently waterlogged because the majority of the iron present in these soils is reduced and sorption potential is decreased (Sharpley et al. 1995). Such irrigation practices create a substantially increased subsurface flow, which facilitates transport. In addition, movement of water in subsurface layers results in the preferential loss and transport of fine, lightweight soil fractions, which represent the primary phosphorus sorption sites in the soil. These particles carry a significant amount of sorbed phosphorus with them when they are removed and leave the remaining soil deficient in sorption sites. Therefore, not only is the subsurface water enriched directly through the sorbed phosphorus on the particulate, but further runoff from the original soils will be enriched due to the decrease in phosphorus sorption capacity (Hedley et al. 1995). In addition, phosphorus sorption-desorption characteristics, buffer capacity, and the sorption index of the transported sediments are altered, and the equilibrium phosphorus content is usually enriched (Sharpley et al. 1995).

The fine, lightweight soil fractions preferentially removed from the subsurface through some irrigation practices are deposited within the flow channel after subsurface flows discharge to streams and tributaries. Material deposited in this fashion can function as a nutrient source to the receiving water. Natural processes maintain equilibrium between nutrient concentrations in the streambed sediment and the flowing water. Thus, if nutrient concentrations in overlying water are less than nutrient concentrations occurring within the deposited sediments, sorbed nutrients will be more readily dissolved by the flowing water. This process enriches tributary inflow concentrations to the reservoir and extends the peak nutrient-input period to the reservoir beyond the traditional irrigation season (Sonzongi 1982).

Irrigation recharge and surface runoff created by subflood irrigation practices are diverted to local streams or return as shallow groundwater. These waters generally contain high concentrations of phosphorus and nitrogen compared to ambient concentrations of local streams (Omernik et al. 1981; Shewmaker 1997). In addition, inefficient irrigation water management practices can reduce stream flows unnecessarily, resulting in increased water temperatures.

5.1.4.2 Cropping

Information from the UDWR water-related land use database indicates small areas of pasture and limited grass hay production along Pinto Creek between the town of Pinto and Newcastle Reservoir.

Impacts from cropping within the watershed are projected to be relatively minor due to the small acreages dedicated to crop production. These impacts may include those detailed for irrigation in the section above and the impacts of fertilizers to establish growth in newly seeded fields.

5.1.4.3 Pasturing

Production by pasture operators in the Pinto vicinity is estimated at approximately 4 AUMs per acre due to the benefits of irrigation. Manure concentration per unit of land is relatively small but the total grazed-land area can be relatively large and correlates well with major waterbodies, resulting in a greater potential for direct transport. The phosphorus contained within manure is in a highly soluble, readily bioavailable form. Because of the high solubility, phosphorus loading and transport from a manured field can exceed those from a field that is not exposed to manure by as much as 67 times (Khaleel et al. 1980; Olness et al. 1975; Omernik et al. 1981; Reddell et al. 1971; Hedley et al. 1995; Sharpley et al. 1992). Erosional processes occurring within an ungrazed or forested watershed would require a significantly greater amount of time and transport to produce the same effect on bioavailable phosphorus loading as direct deposition of phosphorus -rich animal wastes into the channel or floodplain of a stream.

Reduced vegetation from improper forest and rangelands management and sheet and rill erosion from storm events result in increased sediment transport to streams and channels. In a related fashion, overuse of pasture land can result in subsurface compaction of soil as hoof action and animal weight create a pressure wave that compresses the soil profile, resulting in the formation of a dense layer of low permeability 12–15 inches below the upper soil horizon. During storm events and spring melt, water cannot penetrate this compacted layer, and the volume and velocity of overland flow are increased, as is the total suspended sediment and nutrient load. Vegetation in overutilized pasture areas is commonly insufficient to retain sediment within overland flow and deposited manure is easily transported directly into water or downstream within existing stream and irrigation channels (NRCE 1996).

5.1.4.4 Ranchettes

Certain aspects of rural ranchettes have been included in the agricultural land use designation because the pollutant reduction strategies most closely approximate those of agricultural practices. These properties may contribute high nutrient loading and bacteria from hobby livestock such as horses, mules, llamas, and other domestic animals. Because best management practices (BMPs) are not regularly implemented in many cases, animal densities (particularly of horses and mules) are often greater than the available land can support, exhausting existing vegetation and causing problems with waste management, which in turn increase erosion and nutrient transport. In addition to contributing common agricultural pollutants, these properties represent a significant source of urban pollutants as well. Development of ranchettes leads to increased road density. This aspect of loading and the management practices recommended are addressed through both the agricultural and urban/suburban land use designations, as poor drainage within these developments and runoff from snowmelt can wash urban stormwater pollutants and animal waste materials into local streams. Much of the private land within the Little Pinto Creek watershed is zone A-20 and could therefore support one residence per 20 acres (8 ha).

5.1.5 Stormwater Runoff from Rural Subdivisions

Primary sources of pollutants associated with rural subdivisions are sediment and nutrients in both dissolved and sediment-bound forms from roadway and impervious surface runoff and snowmelt, irrigation practices, and yard and vehicle maintenance. In the vicinity of Old Irontown (Little Pinto Creek drainage), three subdivisions are divided into lots of approximately 0.5–1.4 acres (0.2-0.6 ha) each but lack many of the impervious surfaces typical of subdivisions. Old Irontown Phase I, Old Irontown Phase II, and Pinto Creek Ranchos have 21, 2, and 16 developed lots out of 132, 64, and 65 plotted lots, respectively, according to the 2006 Iron County tax roll. Far West, located at the junction of Route 56 and Pinto Road, as well as property on the north and south side of Route 56 at Old Iron Town Road, is subdivided into five-acre (2 ha) lots (Iron County Information Systems Department 2007). Of 30 plotted lots, 16 are developed with single-family houses and occur on the 2006 Iron County tax roll. In addition, one out of nine lots has been developed in the adjacent Williams subdivision. In northern Washington County, the small town of Pinto is located along Pinto Creek approximately eight miles upstream of Newcastle Reservoir and is accessible by dirt road. Through interpretation of aerial photography, this rural agricultural community contains approximately 17 single-family residences, in addition to numerous outbuildings such as barns. Limited sources of anthropogenic stormwater exist within the Newcastle Reservoir watershed.

5.1.6 On-site Wastewater Treatment Systems (Septic Systems)

Residences identified in the Newcastle Reservoir watershed are all served by septic systems. The subdivisions located in the Little Pinto drainage are not located near areas of perennial surface water. However, some homes in Pinto are adjacent to the Pinto Creek floodplain. Septic systems have the potential to contribute nutrient loads to surface waters in the watershed via leachfield contamination of groundwater that recharges streams or to contribute nutrient loads directly when leachfields fail.

The most important mechanisms responsible for immobilizing phosphorus are, first, the formation of insoluble iron and aluminum phosphate compounds and, second, the adsorption of phosphate ions onto clay particles (Tilstra 1972). It generally appears that surface soils in the vicinity of Newcastle Reservoir and its tributaries have good binding capacity, but with depth, phosphorus sorption declines (McGeehan 1996). In addition, where home sites are located in close proximity to each other and there is the potential for seasonal high groundwater Tables, the mobilization of phosphorus may increase, ultimately transporting all phosphorus from septic tank effluent to the reservoir.

5.1.7 Internal Reservoir Sources

Phosphorus contained in reservoir bed sediments could represent a significant loading source to the water column. The deposition, release, and dissolution of this phosphorus are dependent on both physical and chemical processes within the watershed and reservoir. Physical processes dominate in the transport of phosphorus contained within or adsorbed to sediment and particulate matter. Chemical processes dominate in the transport of dissolved phosphorus and in the transformation of phosphorus from one form or state (i.e., free or adsorbed) to another, within both the transport pathway to the reservoir and the water column.

Phosphorus within the water column can be divided into two major sources: suspended sediment-bound phosphorus and dissolved phosphorus. Suspended matter can be colloidal in nature (under 0.45 um in diameter) and resist settling forces because the ratio of surface area to mass is high enough that internal buoyancy counteracts gravitational forces. Sediment and organic matter that has settled to the reservoir bed may also become resuspended and act as a source of dissolved phosphorus as the chemical environment within the water column changes with proximity to the surface. Dissolved phosphorus may be present in tributary inflow or phosphorus released from bed sediments. Significant phosphorus release from bed sediments has been observed under anaerobic conditions. Phosphorus sorption sites are related to the charge state and concentration of iron and aluminum within sediment particles. Under anaerobic conditions, the charge state of these metals is changed, resulting in the release of bound phosphorus to the overlying water column as sorption potential is decreased (Sharpely et al.

1995). Low dissolved oxygen levels lead to sediment release of bound phosphorus in this manner.

Operational conditions that control water depth over reservoir sediments may affect availability of sediment-bound phosphorus and potential leaching into surface water. Fluctuating water levels that periodically expose lake sediments or alter the aerobic/anaerobic conditions at the sediment/water interface affect the sink/source characteristics of these sediments. Under annual drawdown conditions, more sediment phosphorus may be available, further contributing to the enrichment of the water column and increased algal productivity.

5.1.8 Miscellaneous Sources (Roads, Stream Erosion, Lakeshore Erosion, Etc.)

Miscellaneous sources of phosphorus loading consist of road construction and use, runoff from roads, streamflow alterations, urban runoff, sewage effluent, and recreational uses such as OHVs (off-highway vehicles) around the reservoir and in the watershed (Table 5.4).

Road construction and use on forested allotments contribute to dissolved and sediment-bound phosphorus associated with forestry management. Pollutants from all-purpose forest roads (sediment) and natural processes (sediment) deposited in streams during low flow can be rapidly resuspended and transported to the reservoir during high flow events (Megahan 1972 and 1979; Mahoney and Erman 1984; Whiting 1997). If not properly managed, these factors may result in increased sediment and TP loading within the watershed. Careful management and BMPs are likely able to minimize the impact and duration of weather-related complications, including increased sediment loading that occurs periodically due to high flow or fire events. Restriction of OHV use to designated routes away from waterways and drainage areas would reduce sediment loading due to soil erosion and bank destabilization.

Table 5.4. Potential Pollutant Loading from Miscellaneous Sources

Management Practices/Pollutant Sources	Resulting Status of Sediment Loads	Resulting Status of Nutrient Loads	Resulting Status of Other Pollutants
Road Building and Use	Increased sediment load	Increased nutrient load from sediment-bound phosphorus	
Runoff from Forest Roads	Destabilization of slopes and increased sediment transport in storm events and runoff	Increased nutrient load from sediment-bound phosphorus	
Fire Events	Destabilization of slopes and increased sediment transport in storm events and runoff; release of elemental phosphorus from burned vegetation	Increased nutrient load from sediment-bound phosphorus and released phosphorus from burned biomass	Release of atmospheric mercury trapped in soils and vegetation
Streamflow Alterations	Increased velocity, resulting in increased erosion and sediment transport	Increased nutrient load from sediment-bound phosphorus	
Urban Runoff	Increased sediment	Increased sediment-	Increased petroleum

Table 5.4. Potential Pollutant Loading from Miscellaneous Sources

Management Practices/Pollutant Sources	Resulting Status of Sediment Loads	Resulting Status of Nutrient Loads	Resulting Status of Other Pollutants
	from roads and construction practices	bound nutrients from runoff and construction	products and chemicals used for road use and home and lawn care
Recreational Users	Increased sediment from OHV use and irresponsible camping vehicle use	Increased nutrient load from improperly disposed wastes, bank destabilization and soil erosion.	Increased bacterial levels from improperly disposed human, fishing, and hunting wastes, as well as increased petroleum products in the water column from use, maintenance, and fueling of watercraft and OHVs.

Nearly all forested areas within the watershed, excluding wilderness areas, have an extensive network of roads, which increases sediment yields. If forest management practices are developed to minimize the sediment transport that results from sources other than road-related factors, and if those practices avoid removal of riparian vegetation near the stream channel, then impacts associated with removal of overhanging vegetation (such as increased water temperatures in tributaries, which leads to greater dissolution of adsorbed phosphorus and other nutrients from sediment-bound forms) are unlikely to occur.

The geology of forested lands within the Newcastle Reservoir watershed is conducive to erosion and sediment production. Predominant lithology comprises intrusive igneous rocks, extrusive igneous rocks, and hydrothermal mineral deposits, with some minor amounts of limestone and other sedimentary rocks that are decomposing to unstable, easily transportable sediments. Local lithology also contributes to landslides. Most slides are due to natural causes, but some are management-induced (such as destabilization caused by cutting and filling a road or OHV use).

Typical of many USFS lands, the watershed is interconnected by a series of transportation corridors. Research on roads throughout the West suggests that they are a source of sediment input to surface waters. Water that would naturally flow downslope or infiltrate into the ground instead flows on or adjacent to the roads due to soil compaction and rutting, transporting sediment downgradient with the overland flow. Runoff that is intercepted by the roads becomes concentrated and channelized in drainage ditches or ruts. This can reduce the amount of water that would normally infiltrate into the ground. Roads that are located in close proximity of streams become a direct conduit of flow and sediment to the stream channel and can increase peak flows (USFS 2005) as well as sediment loads. In addition, maintenance activities (i.e., blading) and cross-drain culverts can directly input sediment into the active stream channel when roads are close to aquatic resources.

As irrigation water is released from the reservoir impoundment and as water levels decrease within the reservoir, the bed sediment becomes exposed to surface activities. Erosive forces such as wave action within the reservoir can cause banks to recede, resulting in loss of land and loss of vegetation cover of exposed soils. Sediment inputs from reservoir shorelines may alter water chemistry and aquatic habitats and reduce water storage capability. Nutrients, such as nitrogen and phosphorus, from eroded soils could also contribute to water quality impairments.

Potential impacts from recreational uses are varied, ranging from increased erosion potential caused by irresponsible forest road and OHV use, to direct contamination of surface water by personal watercraft or accidental fuel spills. Pollutants of concern generated by recreational use of the watershed include (but are not limited to) hydrocarbons from outboard motors, organic material from fish cleaning, potential bacterial contamination from human waste (improper sanitary disposal) and addition of nutrients, grease, and oils from parking lot runoff at campgrounds and boat ramps. Sediments are also contributed by erosion of banks around popular beach areas and camping sites and heavy use of forested roads, particularly during the wet season. Nutrient load from recreational sources is assumed to be minimal in Newcastle Reservoir and is not calculated as a separate source.

5.1.9 Atmospheric Sources

Phosphorus does not have a gaseous state; however, phosphorus contained in dust particles in the atmosphere can contribute a small load of phosphorus to the landscape and directly to waterbodies.

5.1.10 Natural Background Sources

Natural background loads are those nutrient loads that would naturally occur under undisturbed conditions. Natural processes that contribute to background sources consist of weathering of bedrock and surficial geologic formations, atmospheric deposition, mobilization via wildlife deposition, natural sheet and rill erosion of soils, and stream channel formation.

Local lithology contributes to the possibility of natural landslides in the watershed. Predominant lithology consists of intrusive igneous rocks, extrusive igneous rocks, and hydrothermal mineral deposits, with some minor amounts of limestone and other sedimentary rocks. Most landslides result from natural causes, but some are induced by management practices that lead to conditions such as a destabilized road cut and fill.

Typically, natural background nutrient concentrations are estimated by sampling a pristine stream in the vicinity of the watershed. No appropriate reference stream could be identified for Newcastle Reservoir. To determine natural background loads, the SWAT model was run without anthropogenic impact conditions.

5.2 Calculation of Existing Phosphorus Load by Source

Phosphorus loads within the watershed were calculated for existing conditions based on water quality data collected in Pinto Creek and modeled discharge and diffuse nutrient runoff using the SWAT watershed model. The SWAT model is a physically based model that uses readily available spatial data and standard referenced equations to derive output for the watershed. Detailed descriptions of calculations and methods used by SWAT are described in Neitsch (2002) and Section 4 of this document. Loads that are not captured by the SWAT model were calculated separately for the watershed. Several loads were calculated separately for the watershed based on outside of the SWAT software. Nutrients deposited on the landscape during the winter season (November–April) are tracked in the SWAT model which accounts for runoff of these nutrients from the landscape throughout the year. Only those nutrients that runoff during the May–October season (regardless of when they were deposited on the landscape) are used to predict eutrophication in the reservoir. Loads throughout this section and the loading analysis are reported in units of kg of total phosphorus per day (kgTP/day). Since the reservoir is highly managed and has a short hydraulic retention time, this approach provides the best estimate of actual nutrient loads during the critical algal season.

5.2.1 Loads From Cattle in Riparian Areas and Stream Channels

The majority of the Newcastle Reservoir watershed is public land (USFS and BLM). Grazing occurs on the BLM land primarily in the winter and on the USFS land in the summer. Grazing animals spend most of their time in the low-lying areas of the watershed. To estimate the load from deposition of manure in streams and riparian areas, the following assumptions were made:

- Animal units in the Newcastle Reservoir watershed were derived by multiplying the total animal units in the grazing allotment (as provided by the USFS and BLM) by the proportion of the allotment that is in the watershed.
- Cattle spend approximately 11% of their time in streams and 54% of their time in the riparian area (Gary et al. 1983).
- The average beef cow (1,000-pound animal) excretes 0.05 kgTP/day (USDA 1992).
- A delivery ratio of 100% is assumed for animal waste deposited directly in the stream, and a delivery ratio of 10% is assumed for waste deposited in the riparian area (within 300 feet [91.4 meters] of a stream).

Seasonal total phosphorus loading to streams and riparian areas in the Newcastle Reservoir watershed was calculated for each grazing allotment by multiplying the equivalent animal unit days by the percentage of time the cows spend in the watershed during each season, the percentage of the allotment that is in the watershed, the delivery ratios for in-stream and riparian deposition, the percentage of time cows spend in streams (11%) and riparian areas (54%), the nutrient volatilization rate, and the per-animal loading estimated using the Agricultural Waste Management Field Handbook (USDA 1992). Daily loads were calculated by dividing by the number of days in the algal growth season (May–October). Loads for each allotment and for private lands are summarized in Table 5.6.

Characteristics of the grazing allotments and private pastured areas in the Newcastle Reservoir are summarized in Table 5.5. Of the estimated 6.62 kgTP/day that results from cattle grazing in streams and riparian areas in the watershed, approximately 45% of this occurs on privately owned pastures. This represents a disproportionate amount of load from private lands considering that only 17.4% of all stream channels in the watershed run through private lands, compared to 82.6% that run through federal and state lands (Table 5.7). The majority of the cattle in streams and riparian areas likely occur in 4% of the total number of streams that run adjacent to privately owned pasture lands in the watershed.

From May to October, total cattle in streams and total grazing in riparian areas account for 4.44 kgTP/day and 2.18 kgTP/day, respectively. Total grazing in streams is 17% of the total load to the reservoir (26.53 kgTP/day), while total grazing in riparian areas is 8% of the total load.

Table 5.5. Summary of Grazing Allotment Information in the Newcastle Reservoir Watershed

Allotment Name	Unit	No of Animals	Season of Use	Equivalent Days	Percent of Time November–April	Percent of Time May–October	Percent of Allotment in Watershed	Animal Unit Days in Watershed
Forest Service Allotments								
West Pinto	Lower Pinto	123	5/21–6/22	33	0%	100%	99%	4,023
	Cove Mountain	257	8/21–9/15	25	0%	100%	97%	6,262
	Cove Mountain	157	9/16–10/10	25	0%	100%		--
Iron Town	Kane Point	Rest	--	--	0%	100%	100%	--
East Pinto	Pinto	Rest	--	--	0%	100%	100%	--
	North Richie	146	6/1–7/15	45	0%	100%	100%	6,570
	South Richie	100	7/16–8/30	45	0%	100%	100%	4,500
Pine Valley	Mountain	786	7/10–9/8	60	0%	100%	65%	30,597
	Grass Valley	100	9/8–10/15	37	0%	100%	32%	1,167
	Pine Valley	100	9/18–10/15	28	0%	100%	0%	--
	Black Bench	786	6/1–7/9	37	0%	100%	47%	13,555
New Harmony	Grants Ranch	25	7/1–9/30	92	0%	100%	45%	1,036
East Pinto	Little Pinto Creek	46	7/16–8/30	45	0%	100%	100%	2,070
Iron Town	Stoddard Mountain	93	8/1–10/15	76	0%	100%	81%	5,726
BLM Allotments								
Joel Spring	--	164	11/01–05/31	212	85%	15%	66%	23,111
Reservoir	--	39	11/01–05/31	212	85%	15%	70%	5,756
Lower Mead	--	47	05/01–09/30	153	100%	0%	100%	7,191
Pinto Creek *	--	164	11/01–05/31	212	85%	15%	23%	8,031
Private Pasture								
Private land			5/1–10/31	184				67,521

* Information on the Pinto Creek allotment could not be obtained from the BLM field office. A conservative estimate was made based on other allotments in the area.

Table 5.6. Summary of Phosphorus Loads (kg/day) from Cattle in Streams and Riparian Areas

		Daily TP Load (kg)	
Forest Service Allotment Name	**Unit**	**Grazing in Streams**	**Grazing in Riparian Areas**
West Pinto Allotment	Lower Pinto	0.12	0.059
West Pinto Allotment	Cove Mountain	0.18	0.092
West Pinto Allotment	Cove Mountain	--	--
Iron Town Allotment	Kane Point	--	--
East Pinto Allotment	Pinto	--	--
East Pinto Allotment	North Richie	0.19	0.097
East Pinto Allotment	South Richie	0.13	0.066
Pine Valley Allotment	Mountain	0.92	0.45
Pine Valley Allotment	Grass Valley	0.04	0.017
Pine Valley Allotment	Pine Valley	-	-
Pine Valley Allotment	Black Bench	0.40	0.20
New Harmony Allotment	Grants Ranch	0.03	0.015
East Pinto Allotment	Little Pinto Creek	0.06	0.030
Iron Town Allotment	Stoddard Mountain	0.17	0.082
Subtotal Forest Service		**2.24**	**1.11**
BLM Grazing Allotment Name			
Joel Spring	--	0.11	0.049
Reservoir	--	0.03	0.013
Lower Mead	--	--	--
Pinto Creek *	--	0.04	0.020
Subtotal BLM allotments		**0.18**	**0.082**
Private Land		**2.02**	**0.99**
TOTAL		**4.44**	**2.18**
*Estimated based on typical BLM allotment size, still trying to obtain actual information for this allotment.			

Table 5.7. Summary of ownership and land cover along streams in the Newcastle Reservoir watershed.

Ownership/Land Cover	Stream Length feet (meters)	Percent of stream length
State Trust Land	**1,725.02 (525.8)**	**1.1%**
Pasture/Hay	592.87 (180.7)	0.4%
Shrub/Scrub	1,132.15 (345.1)	0.7%
Bureau of Land Management (BLM)	**4,731.61 (1,442.2)**	**3.1%**
Evergreen Forest	314.85 (96.0)	0.2%
Shrub/Scrub	4,416.76 (1,346.2)	2.9%
Private	**26,372.82 (8.038.4)**	**17.4%**
Developed, Low Intensity	103.19 (31.5)	0.1%
Developed, Open Space	1,367.56 (416.8)	0.9%
Emergent Herbaceous Wetlands	2,057.17 (627.0)	1.3%
Evergreen Forest	4,053.86 (1,235.6)	2.7%
Grassland/Herbaceous	455.00 (138.7)	0.3%
Pasture/Hay	5,903.79 (1,799.5)	3.9%
Shrub/Scrub	11,070.96 (3,374.4)	7.3%
Woody Wetlands	1,361.28 (414.9)	0.9%
USFS Wilderness Area	**34,286.23 (10,450.4)**	**22.5%**
Deciduous Forest	906.57 (276.3)	0.6%
Evergreen Forest	27,246.40 (8,304.7)	17.9%
Mixed Forest	5,927.30 (1,806.6)	3.9%
Shrub/Scrub	205.96 (62.8)	0.1%
US Forest Service (USFS)	**85,478.35 (26,053.8)**	**56.0%**
Developed, Low Intensity	328.12 (100.0)	0.2%
Developed, Open Space	1,597.96 (487.1)	1.0%
Evergreen Forest	57,372.20 (17,487.1)	37.6%
Grassland/Herbaceous	414.25 (126.3)	0.3%
Shrub/Scrub	25,765.82 (7,853.4)	16.9%
TOTAL	**152,594.02 (46,510.7)**	**100.0%**

5.2.2 LOAD FROM FOREST LANDS MANAGEMENT

The SWAT model, described in Section 4.2, was used to estimate the diffuse TP load from forest lands management in the watershed. The SWAT model was set up to incorporate specific grazing and natural background information in the watershed. These assumptions and input variables are summarized in Section 4.2. Other known nutrient sources in the forested areas of the watershed are calculated elsewhere, since their spatial and/or temporal resolution could not be incorporated into SWAT. These include the impact of cattle in riparian areas and streams (Section 5.2.1) and miscellaneous sources, including the impact of erosion from roads and mass wasting of stream banks (Section 5.2.8). Background loads are presented in Section 5.2.10. Table 5.8 presents grazing loads of TP by subwatershed and in total.

From May to October, grazing on forest lands in the Newcastle Reservoir watershed accounts for a daily load of 6.32 kgTP/day of load to the reservoir, or 24% of the total daily load (26.53 kgTP/day).

Table 5.8. Diffuse Forestry Grazing Loads of TP

Subwatershed	Daily TP Load (kg)
Pinto Creek	3.74
Little Pinto Creek	2.58
TOTAL	**6.32**

5.2.3 Load From Rangeland Management

The SWAT model was also used to estimate the diffuse TP load from rangeland management in the watershed (see Section 4.2). Other known nutrient sources in the range land use of the watershed are calculated elsewhere as their spatial and/or temporal resolution could not be incorporated into SWAT. These include the impact of cattle in riparian areas and streams (Section 5.2.1), and miscellaneous sources such as erosion resulting from roads and mass wasting of stream banks (Section 5.2.8). Background loads are presented in Section 5.2.10. Table 5.9 presents grazing loads of TP by sub-watershed and in total.

From May to October, grazing on rangelands in the Newcastle Reservoir watershed accounts for a daily load of 6.33 kgTP/day loading to the reservoir, or 24% of the total daily load (26.53 kgTP/day).

Table 5.9. Diffuse Rangeland Grazing Loads of TP

Subwatershed	Daily TP Load (kg)
Pinto Creek	2.89
Little Pinto Creek	3.44
TOTAL	**6.33**

5.2.4 Agricultural Land Management Load

The SWAT model was used to estimate the diffuse TP load from agricultural land use in the watershed as well (see Section 4.2). The agricultural management source loads determined by SWAT can be separated into two sources: grazing management and irrigation management (Table 5.10). Background loads are presented in Section 5.2.10.

Table 5.10. Agricultural Management Loads of TP

Subwatershed	Component	Daily TP Load (kg)
Pinto Creek	Grazing	0.15
	Irrigation	0.07
Little Pinto Creek	Grazing	0.004
	Irrigation	0.001
Subtotal	**Grazing**	**0.15**
	Irrigation	**0.07**
Total Agricultural Sources		**0.22**

The total daily TP load of 0.22 kg from agricultural sources represents less than 1% of the total phosphorus load (26.53 kgTP/day) to Newcastle Reservoir during the algal growth season.

5.2.5 Stormwater Runoff from Rural Subdivisions Load

The SWAT model was used to estimate the diffuse TP load from the developed land uses in the watershed (see Section 4.2). The other known phosphorus source in the developed land use is septic tank effluent, which could not be incorporated into SWAT and was calculated separately in Section 5.2.6.

The total daily TP load of 0.04 kg from suburban stormwater runoff represents less than 1% of the total TP load (26.53 kgTP/day) to Newcastle Reservoir during the algal growth season (Table 5.11).

Table 5.11. Developed Land Use Loads of TP (kgTP/day)

Subwatershed	Component	Daily TP Load (kg)
Pinto Creek	Suburban	0.01
Little Pinto Creek	Suburban	0.03
TOTAL		**0.04**

5.2.6 On-site Wastewater Treatment Systems (Septic Systems) Load

Minor development of suburban areas within the watershed has occurred. Developments including the areas of Old Irontown, located in the Little Pinto Creek drainage, have 39 developed sites ranging in size from 0.5–1.4 acres (0.2-0.6 ha). The area has the potential for 261 developed lots at full build out. An additional 16 of 30 platted five-acre (2 ha) lots within the upper Little Pinto Creek drainage have been developed. The small town of Pinto, located along Pinto Creek, contains approximately 17 single-family residences (Table 5.12). These developed areas all rely on on-site wastewater treatment (septic) systems for their waste treatment. Nutrient loading from on-site wastewater treatment systems can be influenced by poor design and inadequate sizing, improper maintenance, installation in close proximity to surface waters, and high groundwater levels.

Table 5.12. Summary of Residential Development in the Newcastle Reservoir Watershed

Subwatershed	Residence Location	Residences within 500 feet of Stream	Residences beyond 500 feet of Stream	Total Lots
Little Pinto	Old Irontown	12	27	39
Little Pinto	Far West	2	14	16
Pinto	Pinto	2	15	17
TOTALS	Irrigation	16	56	72

To calculate the load from these on-site wastewater systems the following assumptions were made based on data from the area and literature values:

- The average household size in Iron County is 3.11 person equivalents (pe) per household (USCB 2007).
- The average phosphorous effluent per day per person is 1.5 gTP/pe/day.
- Phosphorous reduction in septic tanks is assumed to be 90% (Echo Reservoir TMDL, pending EPA approval).
- For septic tanks located within 500 feet (152.4 meters) of a stream, it was assumed that all septic effluent was loaded to streams via percolation to shallow groundwater Tables (Brown 2003).
- For systems located more than 500 feet from a stream, it was assumed that half of the phosphorus load was captured in soil or groundwater prior to contact with the stream (Brown 2003). This is an especially conservative assumption for phosphorus that, depending on soil characteristics, may easily bind to soil.

These assumptions provide a conservative (high-end) estimate of total nutrient loads to streams from septic tanks and should be viewed as a worst-case load. No reductions have been assumed for part-time residences, although it is known that many of the ranchettes in the area are only occupied for a portion of the year. The estimated load from septic tanks of 0.02 kgTP/day represents less than 1% of the total load to the reservoir (Table 5.13).

Table 5.13. Estimated TP Loads from On-site Wastewater Systems in the Newcastle Reservoir Watershed

Subwatershed	Residence Location	Daily Loads within 500 feet of Stream	Daily Loads beyond 500 feet of Stream	Total Daily Loads from On-site Wastewater Systems
Phosphorus		0.01	0.01	0.02

5.2.7 INTERNAL RESERVOIR LOAD

A mass balance model completed for Newcastle Reservoir shows that the reservoir is a net sink for phosphorus. To calculate the net internal daily load over the algal growth season (May–October), the daily load into the reservoir (26.53 kgTP/day) was subtracted from the calculated daily load out of the reservoir (21.08 kgTP/day). The load out of the reservoir was estimated by assuming that the flow *out* of the reservoir for the season was equivalent to the flow *in* the reservoir for the season and multiplying that number by the average total phosphorus concentration in Pinto Creek below the dam (0.077 mg/L). Based on this calculation, the reservoir absorbs on average 5.45 kgTP/day, also expressed as a negative internal load (Table 5.14). Although the reservoir is a net sink during the season, phosphorus is likely to be released from sediments during periods of anoxia at the sediment-water interface. However, this release does not represent a new load or a source of phosphorus to the reservoir. The phosphorus released from sediments is derived from the watershed and is only mobilized into the water column during anoxic periods. The rate of anoxia in the reservoir was calibrated to observed oxygen depletion rates. The empirical equations used in the BATHTUB model account for this process, which is common for the deep reservoirs used to build the empirical equations. In order to add a conservative assumption in predicting chlorophyll *a* concentrations, an internal load of 0 kg/day (rather than the negative load associated with the reservoir acting as a net sink) was assumed for reservoir modeling.

Table 5.14. Calculation of Net Internal TP Load

Parameter	Calculation
Total TP Load IN (kg/day)	26.53
Total TP Load OUT (kg/day)[1]	21.08
Total Internal Load (kg/day)	-5.45
Reservoir Area (m2)	676,414
Area Internal Load (mg/m2/day)[2]	-4.1

1 Total TP load out is calculated by multiplying the total flow out (100.08 nm3/season) by the concentration out (77.5 µg/L) and dividing by the days in the season (184 days).
2 Area internal load (mg/m2/day) are the units required by the BATHTUB model.

5.2.8 MISCELLANEOUS LOADS (ROADS, STREAM EROSION, ETC.)

Phosphorous concentrations predicted using SWAT account for the majority of diffuse sources in the watershed, including forestry and rangeland management, agricultural production, and stormwater from developed areas. However, SWAT does not have the spatial or temporal resolution to account for several known sources in the watershed such as erosion of stream banks denuded by grazing and erosion from roads in the forested and rangeland areas of the watershed. Modeling of these two sources is difficult, especially without detailed spatial information on stream bank health and the drainage and grade of roads in the area. Therefore, these two sources are grouped with other miscellaneous sources into a final load. This load was calculated as the difference between the loads calculated using the SWAT model and the total load calculated using median measured concentration and modeled flow. The total miscellaneous daily load is 1.07 kg during the May–October season which represents 4% of the total daily load (26.53 kgTP/day) to the reservoir.

5.2.9 Atmospheric Load

Atmospheric phosphorus load is assumed to be 0.082 mg/m^2 per day, the default value used in BATHTUB. The atmospheric load is multiplied by the total area of the reservoir under each condition. Therefore, when reservoir volume is low, the net atmospheric load is reduced. The atmospheric load of 0.05 kgTP/day for the average reservoir level (Condition A) represents less than 1% of the total load to the reservoir.

5.2.10 Natural Background Load

The SWAT model was used to estimate the diffuse nutrient load from the watershed (Section 4.2).

Background sources account for 5.87 kgTP/day, or 22%, of the daily phosphorus load (26.53 kgTP/day) to Newcastle Reservoir during the May–October algal growth season (Table 5.15).

Table 5.15. Background TP Load in the Newcastle Reservoir Watershed

		Daily TP Load (kg)
Pinto Creek		
	Forestry Lands	0.72
	Rangelands	1.89
	Agricultural Lands	0.13
Little Pinto Creek		
	Forestry Lands	1.05
	Rangelands	2.08
	Agricultural Lands	< 0.01
TOTAL Background Load		**5.87**

5.3 Summary of Existing Loads

The greatest contribution of TP to the reservoir comes from forested lands and rangeland (Table 5.16, Figure 5.1). This is attributed directly to the fact that these land uses are by far the most prevalent within the watershed and because their primary use is grazing. Natural background loads also represent an important contribution (22%). Miscellaneous sources contribute significantly to the TP loading in the surface water system as well. The other land uses do contribute to the final load but the actual percentage of the total load is small.

Table 5.16. Summary of Existing Loads of TP in Newcastle Reservoir Watershed

Component	Daily TP Load (kg)	Percent of Total Daily Load
Grazing in riparian areas and stream channels	6.62	25%
Forest land management	6.32	24%
Rangeland management	6.33	24%
Agricultural land management	0.22	1%
Suburban stormwater runoff	0.04	< 1%

Table 5.16. Summary of Existing Loads of TP in Newcastle Reservoir Watershed

Component	Daily TP Load (kg)	Percent of Total Daily Load
On-site wastewater treatment systems	0.02	< 1%
Internal reservoir	-	0%
Miscellaneous sources	1.07	4%
Atmospheric deposition	0.05	< 1%
Natural background sources	5.87	22%
TOTAL LOAD	**26.53**	**100%**

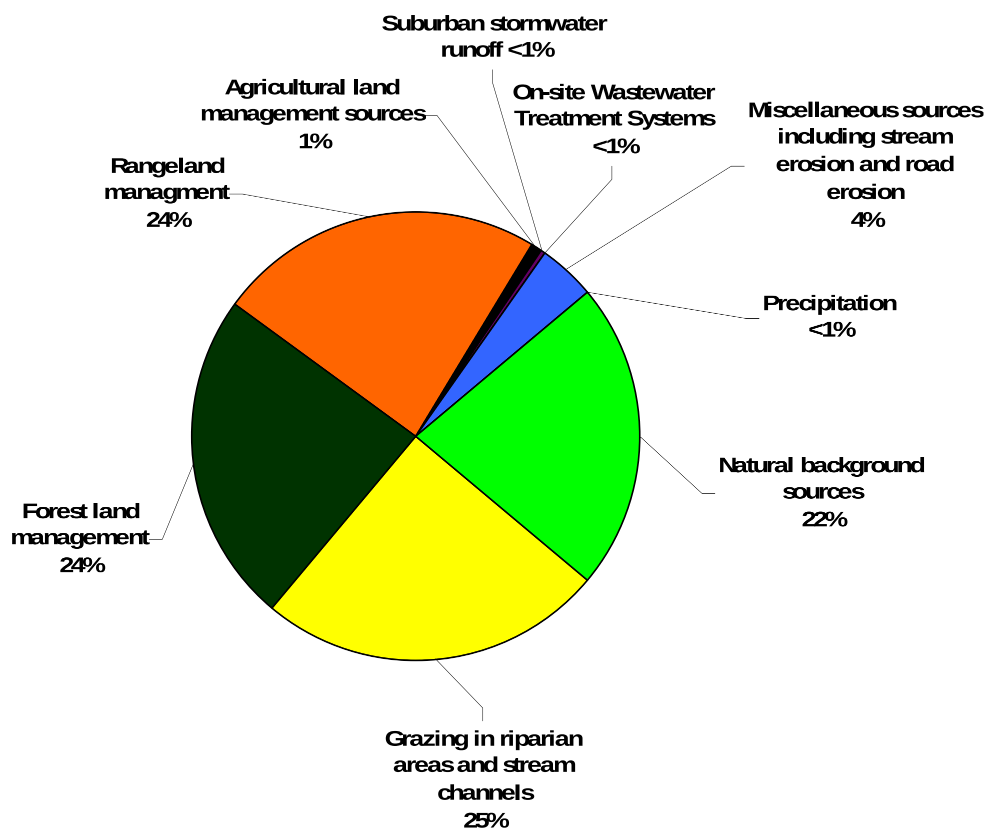


Figure 5.1. Source apportionment summary of TP loads to Newcastle Reservoir.

6 TOTAL MAXIMUM DAILY LOAD ANALYSIS

6.1 WATER QUALITY TARGETS AND LINKAGE ANALYSIS

Setting water quality endpoints is an important step in the TMDL process. The final goal for the Newcastle Reservoir TMDL is to achieve state water quality criteria so that the designated beneficial uses are being fully supported as quickly as possible.

Several methods were employed to evaluate possible water quality endpoints for Newcastle Reservoir. The dissolved oxygen endpoints were selected based on State Water Quality criteria as the primary water quality endpoints for Newcastle Reservoir as low dissolved oxygen is intricately linked with the identified impairment of the cold water fishery in the reservoir. In addition, a chlorophyll *a* endpoint was selected for protection of the recreational beneficial uses in the reservoir. To identify this endpoint, a literature review was conducted to examine the use of chlorophyll *a* as a water quality target in other states and to explore the range of chlorophyll *a* targets that are protective of recreational uses established for Newcastle Reservoir. Finally, a target total phosphorus concentration was identified, based on predicted chlorophyll *a* concentrations and oxygen depletion rates for the May–October season using that BATHTUB reservoir model. Results from the model provide reasonable assurance that the identified nutrient targets will lead to attainment of the dissolved oxygen and chlorophyll a endpoints.

6.1.1 DISSOLVED OXYGEN ENDPOINT

Dissolved oxygen (DO) is important to the health and viability of fish and other aquatic life. Low dissolved oxygen (concentrations below 4 mg/L) can result in stress to aquatic species, lower resistance to environmental stressors, and even death at very low levels (less than 2 mg/L).

The State of Utah has designated Newcastle Reservoir as Class 3A–protected for cold water game fish and their associated food chain. This designated beneficial use was identified as partially impaired on the State of Utah 2006 303(d) list. This impairment has been confirmed in the impairment assessment section of this TMDL (see Section 3.6). Impairment to this beneficial use is based on the percentage of water column exceedances of dissolved oxygen. The dissolved oxygen criteria identified for deep reservoirs, such as Newcastle Reservoir, require that more than 50% of the water column be maintained above 4.0 mg/L dissolved oxygen to be in full-support status. For the 3A cold water fishery beneficial use, the State of Utah has also identified a 30-day average (chronic) standard for dissolved oxygen of 6.5 mg/L. Thus, attainment of these water quality criteria is used as the primary endpoints for this TMDL.

6.1.2 CHLOROPHYLL *A* ENDPOINT

A review of other state approaches to setting chlorophyll *a* endpoints revealed that chlorophyll *a* standards are typically expressed as mean seasonal concentrations that are set to minimize the occurrence of extreme or nuisance conditions. Nuisance algal concentrations, related to recreational beneficial uses, range from 25 µg/L (Walker 1985; Raschke 1994) to 40 µg/L, with recognized severe nuisance concentrations occurring above 60 µg/L (Heiskary and Walker 1995).

Human perceptions of aesthetics and swimability are subjective and dependent on the expectations and tolerances of the public. One way to quantify the effect of chlorophyll *a* on these uses is to survey users of a waterbody and correlate their responses to water quality variables (e.g., chlorophyll *a*, Secchi disk depth, and phosphorus). This method has been used by several authors. Heiskary and Walker (1988) collected user-perception data from three groups of lake monitors in Minnesota. User survey responses were used to assign four support levels of the "swimmable" designated use (Smeltzer and Heiskary 1990). The four support levels are presented below in Table 6.1.

Table 6.1. Summary of Support of Swimming Designated Use at Varying Frequencies of High Algal Levels

Frequency of High Algal Levels	Support Levels of the Recreation Designated Uses
< 10%	Fully supporting
11–25%	Fully supporting–threatened
26–50%	Partial support–impaired
> 50%	Nonsupport–impaired
From Smeltzer and Heiskary 1990	

The nuisance threshold recommended for Newcastle Reservoir is 30 µg/L of chlorophyll *a*. This nuisance threshold chlorophyll *a* value was correlated with mean chlorophyll *a* concentration in the reservoir based on the BATHTUB model and relevant literature from other Utah reservoirs. Maximum summer chlorophyll *a* concentrations have been assumed to be 1.7 times mean summer chlorophyll *a* concentrations in other Utah reservoirs (Oldham 2001). Thus, a 30 µg/L nuisance threshold corresponds with a 17 µg/L mean chlorophyll *a* concentration. Mean chlorophyll *a* concentration is an output of the BATHTUB model and thus can be used to simulate the effects of various load reduction scenarios. These targets are slightly higher than estimated reference conditions for the watershed and recognize achievable targets for the multiple uses in the watershed.

A summary of chlorophyll *a* data for the Subecoregion 13 (Central Basin and Range) in Ecoregion 3 (Xeric West) is provided below in Table 6.2. The statistical summaries are based on data from 50 lakes and reservoirs and include 637 records for chlorophyll *a*. Data were collected between 1990 and 1999. The nutrient criteria technical guidance manual (EPA 2000) suggests that the lower 25th percentile of ecoregional data is representative of the reference condition, when not all lakes and reservoirs are considered to be in the reference condition. The 25th percentile data for the subecoregion range from a low of 2.4 µg/L in the spring to a high of 12.5 µg/L in the winter. These values are below the range of the chlorophyll *a* endpoints recommended for Newcastle Reservoir and provide assurance that the targets are achievable and are not excessively low.

Table 6.2. Summary Statistics for Chlorophyll *a* (µg/L) Data from Lakes and Reservoirs in the Central Basin and Range Subecoregion of the Xeric West Ecoregion

Season	25th Percentile	Median	75th Percentile
Fall	4.5	7.7	13
Spring	2.4	3.5	11
Summer	2.4	5.2	14
Winter	12	27	30

The Idaho Department of Environmental Quality surveyed lakes and reservoirs throughout Idaho as part of the Beneficial Use Reconnaissance Project (BURP). Chlorophyll *a* concentration data from these regional water studies are related to Idaho Department of Fish and Game's fishery management objectives in Figure 6.1. It does not appear that a mean growing season chlorophyll *a* concentration of 17 µg/L would negatively affect a cold water fishery.

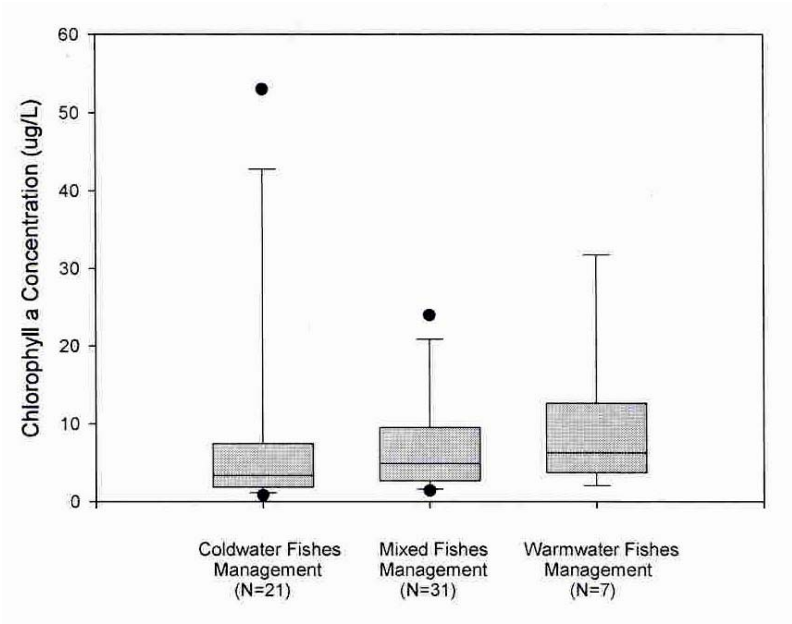


Figure 6.1. Summer chlorophyll *a* concentration distributions for Idaho lakes and reservoirs related to the Idaho Department of Fish and Game's fisheries management designations (circular symbols represent the 5th and 95th percentiles described by the collected data).

6.1.3 Linkage Analysis: Nutrient Targets and Water Quality Endpoints

The loading capacity represents the maximum amount of phosphorus that can be assimilated by Newcastle Reservoir while meeting the TMDL endpoints discussed above. The loading capacity was calculated using a BATHTUB model of Newcastle Reservoir simulating water quality and eutrophication (see Section 4 for the model and associated assumptions). Based on iterative reservoir modeling with BATHTUB, the dissolved oxygen and chlorophyll *a* endpoints would be achieved with a mean in-reservoir total phosphorus concentration of 0.022 mg/L. Achieving this in-reservoir concentration requires a 75% reduction of phosphorus load to the reservoir.

A mean in-reservoir total phosphorus concentration of 0.022 mg/L was used to predict oxygen depletion rates in the hypolimnion and metalimnion under Condition A (average climatic conditions and reservoir water level). These predicted oxygen depletion rates were used to develop a dissolved oxygen profile at the Dam Site for the end of the stratification period in an average year (Figure 6.3). The hypolimnetic and metalimnetic oxygen depletion (HOD and MOD) rates were calibrated in the BATHTUB model using observed data collected in the summer of 2005 in Newcastle Reservoir (Section 4.7.2.3). The BATHTUB model predicts that at a total phosphorous concentration of 0.022 mg/L, HOD rates under Condition A will be reduced to 0.044 mg/L/day from the current rate of 0.08 mg/L/day, and MOD rates will be reduced to

0.031 mg/L/day from the current rate of 0.057 mg/L/day. It was assumed that in an average year, the dissolved oxygen concentration in the water column at stratification is 8.5 mg/L, and that stratification begins on May 15 and ends on August 1. This profile, compared to a similar profile developed based on current measured oxygen depletion rates, indicates that by August 1 more than 50% of the water column would be in compliance with the State of Utah's dissolved oxygen criteria of 4 mg/L (Figure 6.2). August 1 represents the worst case water column dissolved oxygen scenario for a single day in an average water year. The 30-day period prior to August 1 (month of July) represents the worst month of the year in terms of dissolved oxygen profiles as it represents the end of the stratification period. Predicted dissolved oxygen concentrations for the month of (Figure 6.3) indicate that on average during this month, more than 50% of the water column will be maintained above the 6.5 mg/l chronic criteria established by the State of Utah. Therefore, the recommended nutrient load reductions provide reasonable assurance that during an average flow year, when the reservoir water level is managed at mid-level, Newcastle Reservoir will come into compliance for all dissolved oxygen criteria.

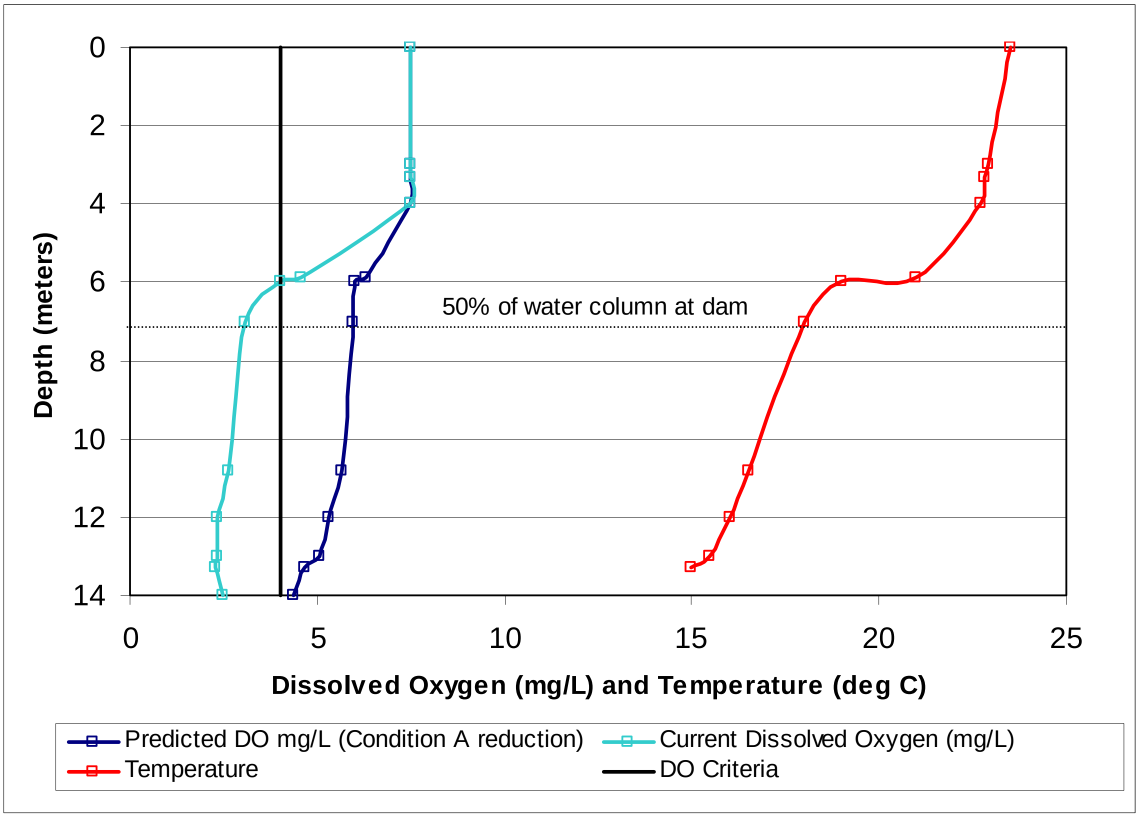


Figure 6.2. Predicted and existing (current) dissolved oxygen profile for average conditions (Condition A) at the end of the stratification period (August 1) compared to the acute dissolved oxygen standard of 4.0 mg/l.

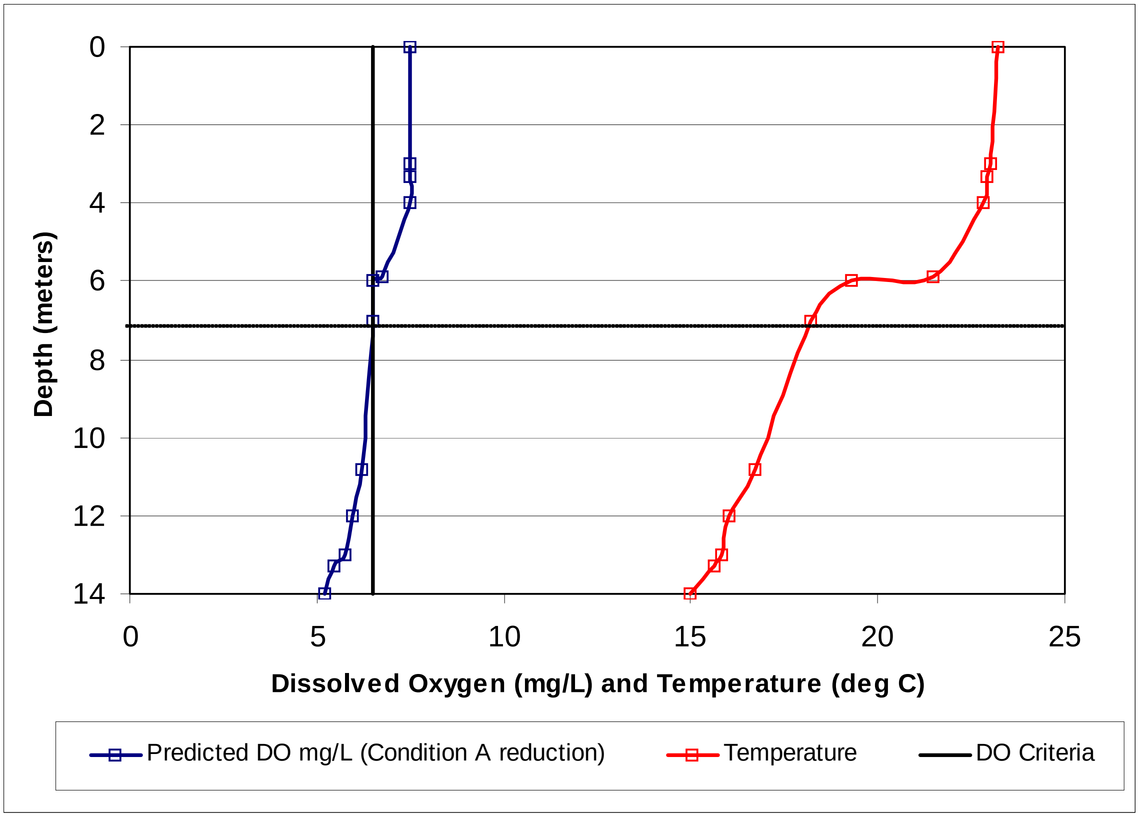


Figure 6.3. Average 30-day predicted dissolved oxygen profile for the month of July, assumed to experience the lowest average dissolved oxygen levels in the hypolimnion, under Condition A, compared to the chronic dissolved oxygen standard of 6.5 mg/l over 30 days.

Elevated nutrient concentrations, primarily phosphorus concentrations, are responsible for algal growth. Because the linkage between nutrients and low dissolved oxygen is through algal growth and decay (primarily in late July/August through early October), chlorophyll *a* is the best available surrogate measure of algal biomass in the current dataset for Newcastle Reservoir. Using the BATHTUB model, the chlorophyll *a* target of 17 µg/L is also numerically related to a total phosphorus concentration of 0.040 mg/L. The nutrient target (0.022 mg/L) associated with oxygen depletion rates is therefore sufficient to attain both the dissolved oxygen and chlorophyll *a* endpoints.

6.2 Future Growth

An analysis of potentially developed lots in the Newcastle Reservoir watershed show that loading to the reservoir from additional on-site wastewater treatment systems could increase in the future. Of the 261 undeveloped lots identified in the Newcastle Reservoir watershed, 37 are within 500 feet of a stream. Using the same methods described in Section 5.2.6, the development of all potential lots in the watershed could result in an additional 28 kg/year of total phosphorus load, half of which would be loaded during the algal growth season. Therefore, a load of 0.08 kg/day total phosphorus will be allocated to future growth.

6.3 ALLOCATION OF LOAD REDUCTIONS

The 75% phosphorous reduction, 14.52 kg TP/day, identified in the TMDL analysis will ensure watershed loads that meet water quality endpoints and restore all beneficial uses to Newcastle Reservoir. Load allocations (Table 6.3) are distributed across sources based on effectiveness (attainability), BMP cost, and the goal of spreading the responsibility for water quality improvement among all users of the watershed. The implementation plan discussed in Section 7 identifies BMPs appropriate for each source that provide reasonable assurance that required load reductions are attainable. The implementation of BMPs will follow a phased approach with a focus on areas where recommended BMPs are not currently in place and maintaining areas where BMPs are currently in place. Additional monitoring of water quality can be used to determine if additional BMPs are needed above the level described in this document.

Table 6.3 Daily phosphorus Load Allocations for Sources in the Newcastle Reservoir Watershed

	Current Load (kg/day)	Load Allocation (kg/day)	Required Load Reduction (kg/day)
Grazing in riparian areas and stream channels	6.62	0.20	6.42
Forest land management (diffuse load)	6.32	0.20	6.11
Rangeland management (diffuse load)	6.33	0.20	6.14
Agricultural land management sources	0.22	0.01	0.21
Suburban stormwater runoff	0.04	0.04	0
On-site wastewater treatment systems (including future growth)	0.02	0.02 +0.04	-0.04
Internal reservoir loading	0	0	0
Miscellaneous sources including erosion from streams and roads	1.07	0.04	1.02
Precipitation	0.05	0.05	0
Natural background sources	5.86	5.86	0
TOTAL	**26.53**	**6.63**	**19.86**

6.4 RESERVOIR RESPONSE TO LOAD REDUCTION UNDER VARYING CONDITIONS

The targeted TP load reduction of 75% was assumed for all of the conditions (Table 6.4). The BATHTUB model was used to predict response based on this assumed reduction. This assumes that the watershed will respond proportionally during wet and dry climatic conditions to BMPs designed around the average climatic condition. As discussed in Section 4.1, the load analysis is based on Condition A, accounting for average climatic conditions and maintenance of the reservoir at an average water level. However, the BATHTUB model was used to simulate other conditions such as wet and dry climatic conditions, as well as drawdown of the reservoir to a critically low level during the average season (Table 6.5). This section summarizes the model predictions for all of these conditions.

Table 6.4. Load Inputs to BATHTUB Model under Load Reduction Scenario Proposed to Attain Beneficial Uses

Condition	Total Phosphorus Load (kgTP/day)
Condition A	6.63
Condition B	6.63
Condition C	0.70
Condition D	0.70
Condition E	8.38

Table 6.5. Predicted Reservoir Response to Target Phosphorus Load Reduction

		Condition A		Condition B		Condition C		Condition D		Condition E	
		Base-line	Reduction Scenario	Base-line	Reduction Scenario	Base-line	Reduction Scenario	Base-line	Reduction Scenario	Base-line	Reduction Scenario
Total phosphorus	mg/L	0.069	0.022	0.092	0.025	0.044	0.012	0.046	0.012	0.042	0.012
Total nitrogen	mg/L	1.24	1.24	1.46	1.46	1.09	1.09	1.12	1.12	1.38	1.38
Composite nutrient concentration		55.1	21.5	70.2	24.0	38.2	12.0	39.6	11.9	38.8	11.7
Chlorophyll *a*	µg/L	30.0	9.2	40.6	10.6	22.2	5.8	20.2	5.5	19.4	4.4
Secchi depth	Meters	1.2	3.2	0.9	2.9	1.6	4.4	1.7	4.6	1.8	5.3
Organic nitrogen	mg/L	0.85	0.37	1.09	0.41	0.67	0.30	0.62	0.29	0.60	0.26
Orthophosphate	mg/L	0.051	0.014	0.070	0.017	0.037	0.008	0.034	0.008	0.032	0.006
HOD rate	mg/L/day	0.080	0.044	--	--	0.181	0.093	--	--	0.070	0.033
MOD rate	mg/L/day	0.057	0.031	--	--	0.089	0.045	--	--	0.048	0.023
1st principal component of reservoir response variables	Index	702.9	98.6	1,193.8	123.0	388.6	42.9	353.9	40.4	330.8	31.8
2nd principal component of reservoir response variables	Index	15.5	14.2	15.7	14.4	15.7	13.9	15.2	13.7	15.1	12.6
Indicator of limiting nutrient (N:TP)	Unitless	15.7	49.4	14.2	53.1	21.5	77.0	21.2	80.0	29.4	104.2
Inorganic	Unitless	21.8	110.6	16.8	133.1	65.7	195.3	42.1	183.4	80.7	178.1

Table 6.5. Predicted Reservoir Response to Target Phosphorus Load Reduction

		Condition A		Condition B		Condition C		Condition D		Condition E	
		Base-line	Reduction Scenario	Base-line	Reduction Scenario	Base-line	Reduction Scenario	Base-line	Reduction Scenario	Base-line	Reduction Scenario
nitrogen: orthophosphate											
Nonalgal turbidity	1/meter	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Mixed-layer depth* turbidity	Unitless	0.2	0.2	0.3	0.3	0.2	0.2	0.2	0.2	0.3	0.3
Mixed-layer depth/Secchi depth	Unitless	1.6	0.6	4.2	1.3	1.3	0.5	1.3	0.5	2.3	0.8
Chlorophyll *a** transparency	mg/m2	36.1	29.7	37.1	30.7	35.0	25.8	34.5	25.3	34.3	23.0
Mean chlorophyll *a*/ mean total phosphorus	Unitless	0.4	0.4	0.4	0.4	0.5	0.5	0.4	0.5	0.5	0.4
Trophic state index TP	index	65.3	48.8	69.3	50.3	58.6	40.2	59.2	40.1	58.0	39.8
TSI chlorophyll *a*	index	64.0	52.4	66.9	53.8	61.0	47.8	60.1	47.3	59.7	45.0
TSI Secchi depth	index	57.3	43.2	61.3	44.7	53.5	38.5	52.3	38.0	51.7	36.0

6.4.1 PHOSPHOROUS

Under the proposed TP reduction scenario, average in-reservoir TP concentrations for Condition A would be 0.022 mg/L. Under Condition B, representative of low water conditions in the reservoir during an average water year, mean TP concentrations would be reduced to 0.025 mg/L. Under all other conditions TP concentrations would be 0.012 mg/L, less than those described for Condition A. Under the reduction scenario, N: P ratios still indicate a phosphorus limited system.

6.4.2 CHLOROPHYLL *A* AND SECCHI DEPTH

With reduced nutrients, the mean seasonal chlorophyll *a* concentration in Condition A is reduced to 9.2 µg/L, a value slightly below the water quality endpoint identified for the reservoir. Under Condition B, chlorophyll *a* concentrations are reduced to 10.6 µg/L, from 40.6 µg/L predicted in the baseline model run. Under all other conditions, chlorophyll *a* concentrations would be even less than those described for Condition A, ranging from 4.4 to 5.8 µg/L. Most importantly, exceedance of nuisance threshold conditions (identified as 30 µg/L) has been reduced to 1.4% under Condition A (Figure 6.4), a significant reduction from the baseline value of 38%. In addition, under Condition B chlorophyll *a* values would only exceed nuisance concentrations 2.4% of the time. Based on Smeltzer and Heiskary (1990) this would still maintain a fully supporting status for recreational use; however, under these conditions, the use would be considered threatened. Under all other conditions, nuisance algal concentrations are exceeded less than 2.4% of the time.

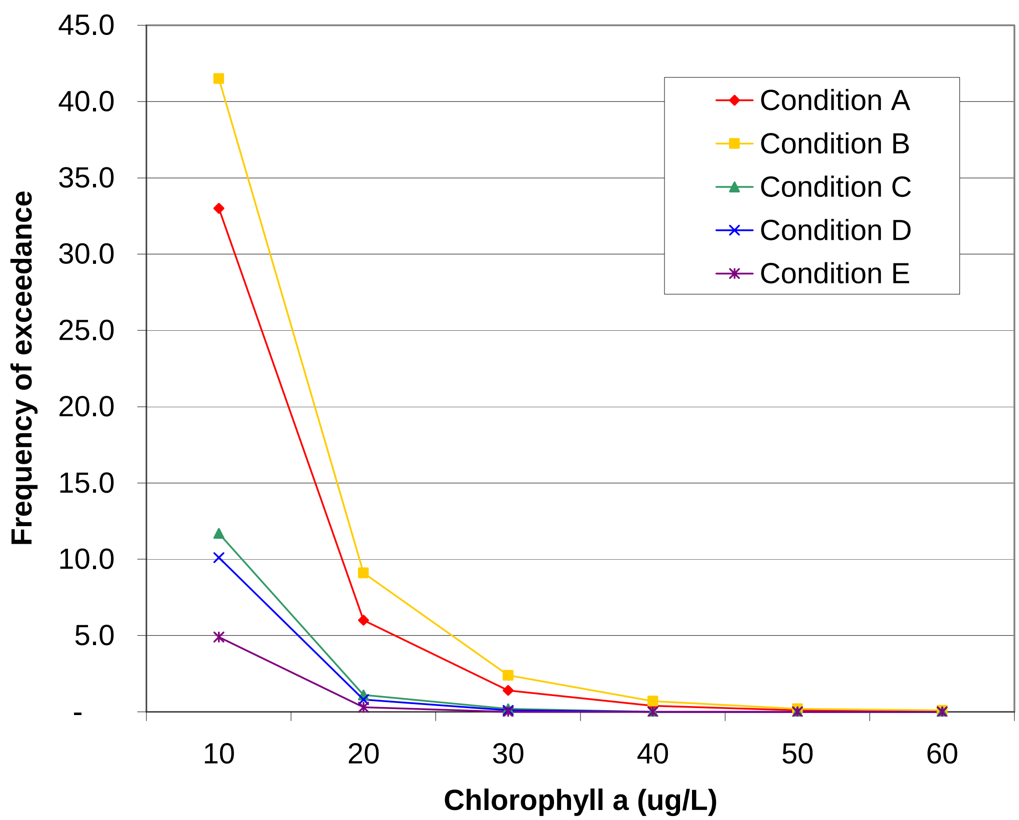


Figure 6.4. Predicted percent exceedance of nuisance algal thresholds under each reduction scenario condition.

Several model outputs indicate the extent to which algal growth in the reservoir is nutrient-limited. All of these metrics still indicate high algal response to nutrients under all conditions.

6.4.3 Eutrophication Potential

The BATHTUB model outputs several metrics of eutrophication potential that can also be used to assess reservoir health. The first results from a principal component analysis of reservoir response variables, which is expressed as an index value. Values greater than 500 (conditions A, B, C, and E) are considered to be indicative of high eutrophication potential. Although all of the scenarios were over 500 during the baseline run, none of them are above this threshold under the reduction scenario run. The predicted total phosphorus and chlorophyll *a* concentrations and Secchi depth indicate that the reservoir system would border between oligotrophic to mildly eutrophic for conditions A and B, and oligotrophic to mesotrophic for conditions C, D and E.

6.5 Seasonality

The seasonality requirement for TMDLs as described in the CWA is inherent in this TMDL study, which has focused on the algal growth season (May–October) as the critical season for nutrient reductions to the reservoir. Since the reservoir is drawn down to a minimal pool each year and very little reservoir data is available outside of the algal growth season, no predictions of water quality have been made outside of the identified critical season. Nonetheless, monthly load estimates have been determined using the SWAT model for average, wet, and dry hydrologic years during the algal growth season. These data are presented in Tables 6.6, 6.7, and 6.8. In addition, the data analysis and model simulations encompassed a 10-year period of stream and reservoir monitoring and climatic data inputs, a period sufficiently long to capture seasonal and interannual variation. Model runs under various climatic and reservoir management conditions further depict seasonal changes in reservoir water level and interannual variations in precipitation. Nutrients deposited on the landscape during the winter season (November–April) are tracked in the SWAT model which accounts for runoff of these nutrients from the landscape throughout the year. Only those nutrients that runoff during the May–October season (regardless of when they were deposited on the landscape) are used to predict eutrophication in the reservoir. Baseline model results are presented in Section 4.7 and scenario model results based on targeted load reductions are presented in Section 6.3. The highest phosphorus loads were predicted for the month of October result from several large storms during this month during the 10 year simulation period selected for the study.

Table 6.6. Monthly Summary of Phosphorus Loads (kg/day) under Average Climatic Conditions

	Pinto Creek	Little Pinto Creek
May	0.81	0.68
June	3.50	4.90
July	1.40	1.60
August	17.4	17.1
September	19.2	8.50
October	29.9	36.0

Table 6.7. Monthly Summary of Phosphorus Loads (kg/day) under Wet Climatic Conditions

	Pinto Creek	Little Pinto Creek
May	1.80	1.50
June	3.10	9.60
July	3.30	3.40
August	82.7	55.6
September	1.10	0.90
October	5.20	3.20

Table 6.8. Monthly Summary of Phosphorus Loads (kg/day) under Dry Climatic Conditions

	Pinto Creek	Little Pinto Creek
May	0.23	0.23
June	0.27	0.30
July	0.39	0.35
August	0.13	0.19
September	7.30	2.60
October	1.50	0.74

6.6 MARGIN OF SAFETY

The CWA requires that the total load capacity "budget" calculated in TMDLs must also include a margin of safety (MOS). The MOS accounts for uncertainty in the loading calculation. The MOS may not be the same for different waterbodies due to differences in the availability and strength of data used in the calculations. The MOS can be incorporated into TMDLs via the use of conservative assumptions in the load calculation or be specified explicitly as a proportion of the total load. This TMDL uses conservative assumptions to meet the MOS requirement.

Conservative assumptions have been incorporated into the watershed modeling, reservoir modeling, load analysis, and selection of water quality endpoints for Newcastle Reservoir. Among these assumptions are the following:

- Selection of 17 µg/L as a mean chlorophyll *a* concentration which is less than the mean concentration selected in many other states and waterbodies.
- Assumptions relevant to the calculation of load from the on-site wastewater treatment systems lead to a calculation of worst-case scenario.
- Assumptions used in calculating the load from grazing animals in streams and riparian areas were selected at the upper conservative end of literature values (i.e., assuming cattle spend 11% of their time in streams).
- Nitrogen reductions, related to BMPs selected for phosphorus reduction, could further reduce algal concentrations during periods of co-limitation. However, since nitrogen

reduction is not counted on to meet chlorophyll *a* water quality endpoints, this provides an additional conservative assumption.

- The assimilative capacity of the sediments in Newcastle Reservoir was not included in the load assessment, such that meeting the TMDL endpoints is not dependent on the sediments acting as a sink into the future.

However, it should be noted that the worst-case condition (Condition B) was not selected as the condition for which targeted loads would be defined because it is understood that water rights in the watershed allow the reservoir to be drawn down to a conservation pool of 500 acre-feet. During these conditions, due to stagnant water and low reservoir volume, it is expected that water quality criteria will be exceeded regardless of load reduction efforts throughout the watershed.

7 PROJECT IMPLEMENTATION PROPOSAL

7.1 INTRODUCTION

The Newcastle Reservoir Watershed Implementation Proposal outlines a strategy for applying BMPs to achieve water quality endpoints identified in the TMDL analysis (Chapter 6) for total phosphorus (TP). The implementation plan has been developed based on a 55% phosphorus reduction, which is a reduction level identified to be sufficient to achieve the acute dissolved oxygen criteria of 4 mg/l even at the end of the reservoir stratification period. This level of reduction represents a phased-in approach to implementing the TMDL described for Newcastle Reservoir, which identified a 75% reduction to meet all water quality criteria. It also recognizes the uncertainty inherent in modeling water quality in a reservoir managed under various climatic and irrigation demand conditions. Following implementation of the 55% phosphorus reduction target, the reservoir will be reassessed to determine if all beneficial uses are being supported and whether or not the reservoir is meeting all water quality standards. A 55% phosphorus load reduction to the reservoir is equivalent to 14.52 kgTP/day during the algal growth season (May–October).

Best management practices (BMPs) comprise the primary means for achieving phosphorus load reductions. The implementation proposal is based on a review of other TMDLs written for watersheds in the intermountain west, watershed characteristics, and consideration of implementation actions determined to be efficient and effective. The proposal also describes regulatory and voluntary management measures needed to achieve pollutant reductions specified by the TMDL. A schedule of BMP implementation, measurements, and milestones will be defined in the implementation proposal, but the plan is not static. It is a dynamic document subject to implementation changes and modification as new data and documentation become available throughout the life of the management proposal. This implementation proposal is designed to be a flexible tool for BMP implementation guidance and management.

Actual BMP implementation will be accomplished through the assistance of natural resource agencies and local conservation activities. The implementation proposal includes:

- A description of actions and management measures to be implemented to achieve TMDL endpoints
- A schedule for implementing activities to achieve TMDL objectives
- A follow-up plan for monitoring surface water quality to determine the effectiveness of the management measures undertaken
- Identified measurable outcomes, which will be reviewed to assess the execution of the implementation proposal and achievement of water quality standards

The organizations that will be involved in the implementation of the proposal include the Natural Resources Conservation Service (NRCS), the Utah Department of Agriculture and Food (UDAF), USFS Dixie National Forest, and BLM Cedar City Field Office, as well as individual landowners and land managers for lands located within the watershed.

7.2 STATEMENT OF NEED

The Federal Water Pollution Control Act (FWPCA) is the primary federal legislation that protects surface waters such as lakes and rivers. This legislation, originally enacted in 1948, was further expanded and enhanced in 1972; at this time it became known as the Clean Water Act (CWA). The main purpose of the CWA is the improvement and protection of water quality through restoration and maintenance of the physical, chemical, and biological integrity of the nation's waterways. The CWA provides a mechanism to evaluate the status of the nation's waters, designate beneficial uses for specific waterbodies, and establish criteria for water quality to protect those uses.

Under Section 303(d) of the CWA, Newcastle Reservoir has been identified by the State of Utah as water quality limited due to low dissolved oxygen and excess phosphorus loading to the reservoir from the surrounding watershed. The State of Utah has designated the beneficial uses of the reservoir as secondary contact recreation (2B), cold water game fish and the associated food chain (3A), and agricultural water supply (4). The cold water game fish designated use (3A) was identified as partially impaired on the State of Utah 2006 303(d) list. The secondary contact recreation and agricultural water supply designated uses were listed as being fully supported on this same list.

7.2.1 Summary of Load Analysis

The completed load analysis was used to identify and quantify pollutant sources that have contributed to the impairment of Newcastle Reservoir. A combination of modeling tools and data analysis for the watershed and reservoir were employed in the estimation of existing phosphorus loads. The SWAT modeling tool simulated loads of nutrients entering Newcastle Reservoir from a variety of nonpoint sources. SWAT incorporates digital elevation data (DEM), hydrology data, LULC data, soils data, management practice data, and climatic data over a specified simulation period (1996–2006). The BATHTUB modeling tool predicted nutrient concentrations, chlorophyll *a*, Secchi depth (transparency), and other eutrophication indices within Newcastle Reservoir. This tool incorporated reservoir morphometry data, hydraulic connectivity data, precipitation and evapotranspiration (ET) data, and tributary input data produced from the SWAT modeling tool. In other words, the SWAT modeling tool was used to predict nutrient loading to Newcastle Reservoir while the BATHTUB modeling tool was used to predict reservoir responses to nutrient loading in terms of water quality.

Multiple SWAT simulations were executed to account for variability in annual and seasonal climatic patterns, as well as for input to the BATHTUB model. The SWAT simulations were paired with simulations of different reservoir management patterns using the BATHTUB model. The years 1996–2006 were used to estimate average flow and runoff patterns. The load analysis focused on the algal growth season (May–October) which is considered to be the critical season for nutrient reductions and improved dissolved oxygen in the reservoir. Average climatic conditions and an average reservoir level were used in determining required load reductions. However, reservoir response to recommended reductions was simulated for other climatic and reservoir management conditions.

Water quality endpoints established for Newcastle Reservoir identify a mean chlorophyll *a* value of 17 µg/L during the algal growth season (May–October) and water column dissolved oxygen concentration of 4.0 mg/L not to exceed in more than 50% of the water column. These endpoints could be achieved with a mean in-reservoir total phosphorus concentration of 0.037 mg/L. Achieving these endpoints requires a 55% reduction of total phosphorus load from the surrounding watershed.

7.2.2 Description of Sources

The load analysis determined that sources of phosphorus loading to Newcastle Reservoir in detailed in Table 7.1 and includes the following:

***Cattle in riparian areas and stream channels*:** A direct impact of grazing on nutrient loads to surface water is the direct deposition of manure and urine into streams and riparian areas.

***Forest land management*:** Impacts from grazing practices on forested lands include soil compaction, manure deposition, and increased sediment and nutrient loading due to erosion resulting from loss of vegetation and hoof action associated with grazing. Four USFS grazing allotments (West Pinto, Iron Town, East Pinto, and Pine Valley) are found within the Newcastle Reservoir watershed, including the Grass Valley watershed from which water is diverted into Pinto Creek, a tributary to Newcastle Reservoir.

***Rangeland management*:** BLM land within the study area is broken into four grazing allotments (Joel Spring, Reservoir, Lower Meadow, and Iron Mountain). Private in holdings also support livestock within the watershed area. Estimates from the local NRCS office identified five producers in the watershed. Production on rangeland in the watershed is estimated at four acres per AUM (support for a cow/calf pair for one month). The effects on water quality from rangeland management are similar to those from forest land management.

***Agricultural land management sources*:** Primary sources of pollutants associated with agriculture are sediment and nutrients present in both dissolved and sediment-bound forms resulting from irrigation, cropping, and pasturing. The generation and transport of pollutants from agricultural nonpoint sources are influenced by: a) the health of riparian areas through which water is transported to the reservoir, b) overland flow from runoff and snowmelt, c) irrigation practices (flood irrigation v. sprinkler irrigation), d) pasture and rangeland management including rotation of animals, grazing density, and watering facilities, and e) fertilizer application.

***Stormwater runoff from rural subdivisions*:** Primary sources of pollutants associated with rural subdivisions are sediment and nutrients present in both dissolved and sediment-bound forms from roadway and impervious surface runoff and snowmelt, irrigation practices, and yard and vehicle maintenance. Limited sources of anthropogenic stormwater exist within the Newcastle Reservoir watershed.

***On-site wastewater treatment systems (septic systems)*:** Residences identified in the Newcastle Reservoir watershed are all served by septic systems. The subdivisions located in the Little Pinto drainage are not located near areas of perennial surface water. However, some homes in Pinto are adjacent to the Pinto Creek floodplain. Septic systems have the potential to contribute nutrient loads indirectly to surface waters in the watershed via leachfield contamination of groundwater that recharges streams or directly when leachfields fail. Where homesites are located in close proximity to each other and there is the potential for seasonal high ground-water Tables, the mobilization of phosphorus may increase, ultimately transporting all phosphorus from septic tank effluent to the reservoir.

***Internal reservoir loading*:** Phosphorus contained in reservoir bed sediments represent a legacy of tributary phosphorus loading to the reservoir originating from both natural and anthropogenic sources. The deposition, release, and dissolution of this phosphorus are dependent on both physical and chemical processes within the watershed and reservoir. Physical processes are most responsible for the transport of phosphorus contained within or adsorbed to sediment and particulate matter. Chemical processes are most responsible for the transport of dissolved phosphorus and in the transformation of phosphorus from one form or state (i.e., free or adsorbed) to another, within both the transport pathway to the reservoir and the water column.

***Miscellaneous sources (roads, stream erosion, etc.)*:** Miscellaneous sources of TP loading include road construction and use, runoff from all-purpose forest roads, in-stream and lakeshore erosion, and recreational uses. Road erosion associated with forestry management was determined to contribute to dissolved and sediment-bound phosphorus. Pollutants in streams—specifically, sediments deposited from road runoff and natural processes—can be rapidly resuspended during periods of low flow and transported to the reservoir during high flow events (Megahan 1972 and 1979, Mahoney and Erman 1984, Whiting 1997). In-stream erosion associated with grazing in riparian areas is also captured as a miscellaneous load. Grazing impacts stream banks through hoof action on banks, stream channels and riparian areas as well as destabilization of soil due to the removal of vegetation by grazing animals (Mosely et al. 1997). Lakeshore erosion around Newcastle Reservoir is primarily associated with OHV use.

***Atmospheric load*:** Phosphorus does not exist in a gaseous state; however, phosphorus contained in dust particles in the atmosphere can contribute a small load of TP to the landscape and directly to waterbodies.

***Natural and legacy background loads*:** Background loads are those nutrient loads that would naturally occur under undisturbed conditions. Natural processes that contribute to background sources include weathering of bedrock and surficial geologic formations, mobilization via wildlife deposition, natural sheet and rill erosion of soils, and stream channel formation. Typically, natural background nutrient concentrations are estimated by sampling a pristine stream in the vicinity of the watershed. No appropriate reference stream could be identified for Newcastle Reservoir. To determine natural background loads, the SWAT model was run under conditions of no anthropogenic impacts.

Table 7.1. Summary of Loads by Source in the Newcastle Reservoir Watershed

Component	TP Load (kg/day)
Grazing in riparian areas and stream channels	6.62
Forest land management (diffuse load)	6.32
Rangeland management (diffuse load)	6.33
Agricultural land management sources	0.22
Suburban stormwater runoff	0.04
On-site Wastewater Treatment Systems (including future growth)	0.02
Internal Reservoir Loading	--
Miscellaneous sources including erosion from streams and roads	1.07
Precipitation	0.05
Natural background sources	5.86
TOTAL LOAD	**26.53**

7.3 PROJECT DESCRIPTION

7.3.1 PROJECT GOALS AND OBJECTIVES

The implementation proposal is determined by the TMDL and provides a plan that is required to achieve load allocations and follow-up monitoring to document progress toward the essential goal of full support of the designated beneficial uses. During the implementation phase, action taken within the watershed should be measured and reported to determine the effect of actual load reductions on the water quality in the watershed.

The Newcastle Watershed Implementation Proposal has been developed to assist in defining the means and methods employed to achieve water quality endpoints within the watershed. The proposal includes the following:

- Implementation of BMPs
- Reduction of nutrient loading
- Projected costs for implementation
- Funding mechanisms and schedule of implementation
- Reasonable assurances
- Monitoring and progress reporting
- Interagency coordination

7.3.2 Overview of Best Management Practices (BMPs)

7.3.2.1 Types of BMPs

Implementation and maintenance of BMPs within the Newcastle Reservoir watershed is necessary to achieve water quality targets and TMDL endpoints. Installed BMPs are either structural or nonstructural practices used to protect the physical and biological integrity of waterbodies. These practices are most effective when installed in combination as a system of BMPs rather than in isolation. All BMPs should follow standards established by the USDA NRCS Field Office Technical Guide (NRCS 2007).

Structural BMPs applied to the Newcastle Reservoir watershed may include practices such as resurfacing roads, stabilizing slopes, installing vegetative buffer strips along stream channels, reestablishing vegetation in critical riparian areas, restricting cattle access to stream channels and reservoir banks, and reinforcing or stabilizing eroded areas along these same waterbodies. Nonstructural techniques include improving timing of grazing operations or implementing irrigation water management. Structural and nonstructural BMPs are discussed in greater detail later in association with where and to what extent they are recommended to be applied.

7.3.2.2 Existing BMPs

Several BMPs suggested in this implementation plan are already being implemented within the Newcastle Reservoir watershed. The implemented BMPs are included in the calculated load reductions required for each source. These include riparian exclosures, road relocation, brush management, and livestock management prescriptions.

7.3.2.2.1 Riparian Exclosures

A 1.53-mile riparian exclosure located in the Pinto Creek subbasin extends from the confluence of the north and south forks of Pinto Creek to the Dixie National Forest boundary. A 0.77-mile riparian exclosure in the Little Pinto Creek subbasin covers the majority of the stream length extending from the private land boundary of Old Irontown to the USFS boundary. The total existing riparian exclosure within the Newcastle Reservoir watershed is approximately 2.3 miles in length and was installed between 2003 and 2004 (personal communication between Joni Brazier, USFS and Brian Nicholson, SWCA, March 16, 2007).

7.3.2.2.2 Road Relocation

In 2007 the USFS Dixie National Forest removed 3.1 miles of road along the south fork of Pinto Creek to reestablish the floodplain and vegetation along the creek. A new road was constructed on the uplands, about 0.25 miles to the west side of the south fork of Pinto Creek.

7.3.2.2.3 Brush Management

In the last two years, the USFS has removed piñon and juniper trees from approximately 1,264 acres (511 ha) in the Pinto Creek subbasin using mechanical equipment. Pinyon and juniper removal from this area is expected to improve upland forage available to livestock and wildlife. Improvement of upland forage reduces the time cattle spend in riparian areas and improves upland soil stability through improvement of vegetation condition, thereby reducing erosion from uplands.

7.3.2.2.4 Livestock Management Prescriptions

Grazing allotments are distributed across the watershed, but these allotments also overlap the boundaries of the watershed. Permit holders for the five livestock grazing allotments on USFS land in the Newcastle Reservoir watershed are required to abide by livestock management prescriptions outlined by the USFS in the Allotment Annual Operating Instructions (USFS 2007).

For the 2007 grazing season, these livestock management prescriptions include:

- Distribution of cattle throughout each allotment unit
- Regular herding to keep cattle from concentrating at water troughs, ponds, springs, and riparian areas
- Location of salt a quarter-mile from water troughs, springs, and riparian areas

The Allotment Annual Operating Instructions (USFS 2007) document also includes some planned development work that may have beneficial effects on water quality. Planned development work by allotment is described in Table 7.2.

Table 7.2. Planned Development Work by USFS Allotment in the Newcastle Reservoir Watershed

Allotment	Planned Development Work
Pine Valley	Maintain fence between Pine Valley and East Pinto up to Paradise.
	Replace 500 feet (152.4 meters) of pipeline on four-mile spring pipeline in bottom.
Iron Town	Install cattle guard at Rye Patch and possibly behind Iron Town Reservoir.
West Pinto	Construct wings for cattle guards.

7.3.2.2.5 Irrigation Improvements

Agricultural producers within the Pinto Creek drainage have installed sprinkler irrigation on approximately 50 acres (20 ha) of pasture/hayland. Sprinklers are more efficient than flood irrigation for supplementing crops with additional water. Sprinklers also reduce the possibility of sediment loss from overland flow while reducing nutrient release, which occurs from the oxidation-reduction process during subsurface saturation.

7.3.2.2.6 OHV

The Dixie National Forest Management Plan restricts OHV use to designated roads and trails and prohibits operation of vehicles "in manner damaging to the land, wildlife, or vegetation" (CFR 261).

7.3.2.3 Estimating Expected BMP Effectiveness

All land uses within the Newcastle Reservoir watershed contribute sediment and nutrient loads to the surface waters of the watershed. The implementation proposal details how BMPs could be implemented on all lands, public or private, for the purpose of reducing phosphorus and sediment loading to Newcastle Reservoir. Both high and low estimates of BMP effectiveness were determined based on literature values. If BMPs for load reduction are designed, installed, and maintained properly, the greatest possible phosphorus reduction will be achieved at the least cost. Further, the systemization of individual BMPs (i.e., the designing of BMPs in cohesive systems rather than as stand-alone practices) further facilitates watershed planning and phosphorus reduction. Estimated reductions from BMP implementation were determined from percent reduction estimates obtained from the literature and will be used to attain the final **55% reduction goal** for meeting the TMDL endpoint and restoring all currently impaired beneficial uses.

7.3.2.4 Constraints

Implementation of all recommended BMPs would result in the greatest water quality improvement in Newcastle Reservoir. However, due to a variety of possible constraints, implementing some BMPs in certain areas of the watershed might not be possible. Structural BMPs may result in disturbances that are not in conformance with land uses and plans as established by law and/or policy for the watershed. Possible constraints include:

- Limitations on actions in federally designated wilderness areas within the watershed.
- Limitations on actions based upon the BLM Cedar City Field Office's current resource management plan and the Dixie National Forest's current forest management plan.
- Limitations on actions based on local and county land use planning laws and regulations.

The degree to which any of these constraints may curtail the ability of land managers to implement recommended BMPs will need to be investigated definitively prior to BMP implementation. At this time the USFS wilderness area occupying approximately 7,692 acres (3,113 ha) of the Grass Valley watershed represents the only known constraint on implementation of BMPs. Any BMP recommended for this area would require USFS approval and would need to be consistent with the wilderness designation.

The listed BMP component practices are general guidelines for achieving the TP load reductions outlined in the TMDL. The NRCS and Conservation District for the Newcastle Watershed will make the final determination of appropriate BMPs after completing a resource management system (RMS) plan with individual landowners. Federal and state resource managers for the USFS, BLM, and State of Utah will plan and implement BMPs that meet their resource goals.

According to the Utah Department of Natural Resources, Division of Water Rights, a water right is required in order to add a point of diversion within the drainage of a stream. A water right is not required in order to allow cattle to drink directly from a stream flowing within the property. However, a water right is required in order to divert water from the stream to a tank, even though cattle will not consume more water from a tank than directly from the stream. Because water rights for off-site watering may be very difficult to obtain in southwestern Utah, other methods of stock water are available to producers and landowners, such as the installation of water gap structures within riparian fencing. A water gap does not exclude cattle from the stream, but limits access to controlled areas of the stream bank. The riparian corridor is protected by the installation of a hardened (rock) entry point to the water with remaining access areas fenced to protect them from trampling and grazing pressure. Assistance with water gap designs can be obtained from the local NRCS field office in Cedar City.

7.3.3 Cattle in Riparian Areas and Stream Channels

7.3.3.1 Pollutant Sources and Load

With limited management practices installed, grazing animals will gather in riparian areas where water is readily available. A direct impact from grazing in riparian areas is the deposition of manure in the stream and riparian area. Cattle spend 65% of their time in streams and riparian areas with 11% of manure deposited directly into streams (Gary et al. 1983). Only 5–40% of the phosphorus in plant materials consumed by grazers is utilized, the rest (60–95%) exits the animal in the form of manure (Magdoff et al. 1997). In addition, increased water temperatures often result from increased sedimentation and decreased vegetation cover, which result in greater dissolution of adsorbed phosphorus and other nutrients from sediment-bound forms. Consequently, soluble phosphorus accumulates in a physically unstable form within the watershed.

7.3.3.2 Recommended BMPs

Livestock exclusion from streams and riparian areas (NRCS code 472), off-site watering (NRCS code 614), stream crossings and channel bank revegetation (NRCS code 578), and prescribed grazing (NRCS code 528) are recommended BMPs to be used in managing grazing in riparian areas and streams. All of these BMPS have proven effective in reducing phosphorus and sediment loading due to riparian area grazing in other watersheds (Line et al. 2000, Osmond et al. 2007, Miner et al. 1992). A comprehensive assessment of stream health throughout the watershed is critical in identifying the most degraded stream reaches which should be prioritized for stream and riparian restoration.

A heavily stocked dairy loafing pasture demonstrated a 79% reduction of TP (Line et al. 2000), and an 82% reduction in total suspended sediment in a stream after cattle were fenced out of a riparian area and a buffer was established (Osmond et al. 2007). Pollutant loads from cattle using streams as water sources were also significantly reduced when alternative water systems were provided (Miner et al. 1992). Cattle preferred to drink from a trough 92% of the time when alternative water systems were installed; this suggests that installation of troughs reduces the time that cattle spend in riparian areas and the overall impact they have on the stream. In this study, streambank erosion was reduced by 77%, total suspended solid concentrations in grab samples were reduced by 54%, and average concentrations of TP were reduced by 81%. Montana State University (2000) applied prescribed grazing BMPs, including pasture rotation, reduced grazing rates, and riparian management or exclusion, to a managed pasture system in Montana with results monitored downstream. The researchers noted that prescribed grazing management practices that were installed together as a system had a positive impact on the water quality of a nearby stream.

Included within the prescribed grazing practices are management techniques, such as fencing and hardened crossings, which encourage animals to drink or cross at specified points. Hardened crossings may be installed in riparian areas where cattle show a tendency to enter the stream to cross to areas in the nearby vicinity. Crossings may also be developed to protect the stream bank and bed from tire damage from all-terrain vehicles and 4-wheel vehicles when they attempt to cross the stream. Hardened crossings create a layer of rock within the stream bed and provide protection directly from any contact, and thereby protect and stream reach from sediment and nutrient releases. The hardened crossing may also be developed in conjunction with watering structures and facilities such as riparian fencing and water gaps, providing livestock with watering areas which have easy access with limited sediment entering into the stream flow. Livestock have been shown to prefer watering sites where ease of access is provided, and these BMPs have been shown to reduce trampling of stream banks. According to research (Hoorman and McCutcheon, nd), monitored streams responded favorably to stream-bank fencing, bank stabilization, and the installation of rock-lined hardened crossings.

Approximately 45% of the load from cattle in streams and riparian areas is associated with privately owned pastures which represent only 17.4% of the total stream length in the watershed (see Table 5.7). The disproportionate amount of the load from privately owned pastures, compared to stream length, indicates that these areas are the most intensively used streams in the watershed, and should therefore be the first priority for reducing the impact of cattle in streams and riparian areas by using the BMPs described in the implementation plan.

7.3.3.3 Calculation of Load Reduction

Livestock exclusion from streams (NRCS code 472), which includes fencing (NRCS code 382) and off-site watering (NRCS code 614), is recommended for 4.4 miles (15%) of streams, 2.3 miles of which have already been completed on USFS land. Considering the intensive use of streams and riparian areas by private landowners, the remaining exclusion is recommended for private lands. The NRCS is best placed to prioritize specific locations where exclusion would be effective and appropriate. As this management practice was assumed to be 100% effective at reducing manure deposited in the riparian area and stream, a 0.99 kg/day reduction in TP loading is expected after the total 4.4 miles of exclusions have been implemented. Off-site watering alone (NRCS code 614), which has been determined to be between 50–81% effective in reducing phosphorus loading (Miner et al. 1992), is recommended for 11.6 miles (40%) of streams in the watershed. This leads to an expected reduction of 1.32–2.14 kg per day. Stream crossings (NRCS code 578) combined with channel bank revegetation (NRCS code 322) are recommended for 5.8 miles (20%) of streams. This includes 3.9 miles on USFS land and 1 mile on private lands based on the percent of stream length under each ownership (see Table 5.7). With an estimated effectiveness of 50–75% (Montana State University 2000), a seasonal load reduction of 0.66–0.99 kgTP/day is expected. Prescribed grazing (NRCS code 528), which has been shown to be 70–90% effective in the removal of phosphorus (Osmond et al. 2007), is recommended for 7.2 miles (25%) of stream areas. This would reduce TP loading by 1.16–1.49 kgTP/day.

The current TP load due to grazing in riparian areas and streams is 6.62 kgTP/day. Implementation of these management actions would result in an estimated reduction of 4.13–5.61 kgTP/day, which leaves an estimated 1.01–2.49 kgTP/day remaining due to the grazing of livestock in riparian areas. This information is summarized in Table 7.3.

Table 7.3. Estimated Load Reduction for Grazing in Riparian Areas and Cattle in Streams

Recommended BMP	Current Estimated Load from Source (kg/day)	Percent of Stream Recommended for Treatment	Recommended Application	Estimated Effectiveness	Load Reduction (kg/day)
Livestock exclusion from streams*	6.62	15%**	4.4 stream miles (2.3 completed already on USFS land)	100%	0.99
Off-site watering		40%	11.6 stream miles	50–81%	1.32–2.14
Stream crossings and channel bank vegetation		20%	5.8 stream miles	50–75%	0.66–0.99
Prescribed grazing		25%	7.2 stream miles†	70–90%	1.16–1.49
Total Load Reduction (kg/day)					4.13–5.61
Current Load from Source (kg/day)					6.62
Percent Reduction					62–85%
Load from Source after Reduction (kg/day)					1.01–2.49

*Includes fencing and off-site watering and would result in natural reestablishment of riparian buffer.
** Includes the 2.3 length of stream already treated with livestock exclusion.
† This recommendation has already been completed by the USFS.

7.3.4 Forest Land Management

7.3.4.1 Pollutant Sources and Load

Impacts from grazing practices on forested lands include soil compaction, manure deposition, and increased sediment and nutrient loading due to erosion resulting from loss of vegetation and hoof action associated with grazing. (Mosley et al. 1997). Grazing within the upland areas can be a significant source of sediment and nutrient loads if the timing and intensity of the grazing are not controlled (Osmond et al. 2007). Manure deposition from the livestock subsequently delivers phosphorus from the forested areas to stream channels which is ultimately then transported to the reservoir.

7.3.4.2 Recommended BMPs

Prescribed grazing (NRCS code 528), brush management (NRCS code 314), and riparian forest buffer (NRCS code 391), are recommended in order to reduce the amount of phosphorus loading into the watershed as a result of forest land management.

Prescribed grazing includes manipulating the seasonality, duration, or location of grazing in order to minimize the impact of livestock on an area. Decreases in grazing intensity correlate with lower levels of total suspended sediment production and decreased soil loss and runoff (Osmond et al. 2007). In conjunction with the application of prescribed grazing, brush management can provide increases in forage availability within the allotment. This serves to improve vegetation condition such that overland flow is reduced and soil infiltration is increased. One study demonstrated that vegetation cover is the dominant factor influencing erosion and runoff (Hofmann et al. 1983); the study showed that soil loss in heavily grazed areas was around 1,054 kilograms per hectare, while only 64 kilograms per hectare of soil in lightly grazed areas was lost (Osmond et al. 2007). Critical area planting involves reestablishing vegetation on sites that have had high erosion rates and exhibit conditions that prevent establishment of vegetation with normal practices. This practice would also decrease the amount of soil loss from the uplands and should be applied as needed. The riparian forest buffer established as a result of practices used to reduce cattle presence in riparian areas would filter and assimilate sediment and nutrients that are delivered directly to the riparian area (Rashin et al. 1999).

7.3.4.3 Calculation of Load Reduction

Prescribed grazing is recommended for 51,872 acres (20,992 hectares or 70%) of forested land. Combined with brush management, which is recommended for 1,000 acres (405 ha or 1%) of forested land, an estimated effectiveness of 55–82% is reached (Osmond et al. 2007). The current TP load during the algal growth season due to grazing in forested areas is 6.32 kgTP/day. Implementation of these management practices are expected to result in a decrease of 2.43–3.62 kgTP/day. In addition, riparian forest buffers, with an estimated effectiveness of 50–82%, are recommended for 23 miles (80%) of stream length within the watershed. Since this same BMP recommendation is also made in regards to grazing in riparian and stream areas, the load reduction for this land use is only applied to the remaining 2.43–3.62 kgTP/day in order to avoid double counting load reduction. The BMP installation results in an estimated load reduction of 1.28–1.91 kgTP/day. Combined with the load reduction of the other management actions, this results in a total reduction of 3.71–5.53 kgTP/day, leaving approximately 0.79–2.61 kg/day after reduction. This information is summarized in Table 7.4.

Table 7.4. Summary of Load Reduction Expected for Forest Land Management

Recommended BMP	Current Estimated Load from Source (kg/day)	Percent of Forested land Recommended for Treatment	Recommended Application	Estimated Effectiveness	Load Reduction (kg/day)
Prescribed grazing	6.32	70%	51,872 acres of forested land†	55–82%	2.43–3.62
Brush management		1%	1,000 acres of forested land†		
Riparian buffer	2.43–3.62*	80%**	23 miles (37 km) of stream	50–82%	1.28–1.91
Total Load Reduction (kg/day)					3.71–5.53
Current Load from Source (kg/day)					6.32
Percent Reduction					59–88%
Load from Source after Reduction (kg/day)					0.79–2.61

† This recommendation has already been completed by the USFS.

*Note that the filtration function of the riparian forest buffer is calculated on the remaining load after BMPs are implemented in the upland part of the watershed. This avoids double counting of load reduction.

**The 80% recommendation is based on the recommended treatments of riparian areas in the previous section. It is assumed that livestock exclusion, off-site watering, and prescribed grazing will all result in the reestablishment of the riparian area and its ability to filter sediment and nutrients from upland diffuse sources.

7.3.5 Rangeland Management

7.3.5.1 Pollutant Sources and Load

Pollutant loading from rangeland management is influenced by the intensity, timing, duration of grazing, proximity to the riparian vegetation community, and location of watering and salt/mineral block areas. Overgrazing in the upland regions of the watershed may result in increases of sheet and rill erosion from storm events. Combined with reduced vegetation from improper rangeland management, this results in increased sediment transport to streams and channels. Vegetation in overutilized range pasture areas is commonly insufficient to retain sediment from overland flow, and deposited manure is easily transported into existing stream and irrigation channels.

7.3.5.2 Recommended BMPs

Prescribed grazing (NRCS code 528), brush management (NRCS code 314), and installation of riparian forest buffer (NRCS code 391) are recommended in order to reduce the amount of phosphorus loading into the watershed as a result of rangeland grazing. Justification for these selections is shown in Section 7.3.4 above, as management recommendations are the same for both rangeland and forest land management.

7.3.5.3 Calculation of Load Reduction

Prescribed grazing is recommended on 16,589 acres (6,713 ha or 70%) of rangeland. Brush management has already been completed on 800 acres (324 ha or 3%) of rangeland. The load reduction achieved from this action is calculated in Table 7.5. The current TP load due to grazing in range areas is 6.33 kgTP/day. These combined management actions have an estimated effectiveness of 55–82% (Osmond et al. 2007) and lead to a load reduction of 2.44–3.63 kgTP/day. Riparian forest buffers, which are recommended for 1,682 miles (2,707 km or 80%) of streams within the watershed, are expected to be 50–82% effective and reduce the load by 1.29–1.92 kgTP/day. This results in a total reduction of 3.73–5.55 kgTP/day, leaving approximately 0.78–2.6 kg/day after reduction. This information is summarized in Table 7.5.

Table 7.5. Summary of Load Reduction Expected from Rangeland Management

Recommended BMP	Current Estimated Load from Source (kg/day)	Percent of Rangeland Recommended for Treatment	Recommended Application	Estimated Effectiveness	Load Reduction (kg/day)
Prescribed grazing	6.33	70%	16,589 acres of rangeland	55–82%	2.44–3.63
Brush management		3%	800 acres of rangeland		
Riparian forest buffer	2.44–3.63*	80%**	23 miles (37 km) of stream	50–82%	1.29–1.92
Total Load Reduction (kg/day)					3.73–5.55
Current Load from Source (kg/day)					6.33
Percent Reduction					64–95%
Load from Source after Reduction (kg/day)					0.78–2.6

*Note that the filtration function of the riparian forest buffer is calculated on the remaining load after BMPs are implemented in the upland part of the watershed. This avoids double counting of load reduction.

**The 80% recommendation is based on the recommended treatments of riparian areas in the previous section. It is assumed that livestock exclusion, off-site watering, and prescribed grazing will all result in the reestablishment of the riparian area and its ability to filter sediment and nutrients from upland diffuse sources.

7.3.6 Agricultural Management Sources

7.3.6.1 Irrigated Land

7.3.6.1.1 Pollutant Sources and Load

Land within the Pinto Creek watershed managed for agricultural production includes areas that are irrigated from Pinto Creek water. Approximately 200 acres (81 ha) located near the stream are flood or sprinkler irrigated. This acreage is considered to be some of the most productive lands within the watershed. Lands that are irrigated using water diverted from surface waters have the potential to carry sediment as well as nutrients from multiple sources. When irrigation water is diverted via an earthen canal, the erosion that results leads to the transport of sediment and nutrients across the landscape. Some of this water may be directly deposited into the surface water canal system, delivering a load of sediment and nutrients directly to the stream.

As the flood waters erode the landscape, the possibility for loss of soil increases. The sediments and nutrients that comprise the soil may be delivered directly to the stream or may accumulate in a topographical low and become entrained when sufficient water or wind energy is present to deliver to the stream. Waters that infiltrate the subsurface will move downward by gravity until they meet a confining boundary, where they will move laterally toward the stream. If the subsurface waters accumulate and replace the existing oxygen within the soil pore spaces, a complex oxygen-reduction reaction may occur, and phosphorus may be released from the negatively charged soil particles. This can increase the soil delivery rate of phosphorus to the stream from subsurface baseflow. Nitrogen present as nitrate in the subsurface has the highest mobility rate of any nitrogen form. When excess irrigation water is introduced into the subsurface, the nitrate has the potential to flow with the water as it moves as baseflow.

If these agricultural areas are grazed, cattle manure can be transported by irrigation waters or storm runoff directly to the streams. Most of these lands are located near the riparian area and the loads may not receive any significant treatment before reaching the surface water if the riparian area is not properly functioning.

7.3.6.1.2 Recommended BMPs

Most of the irrigated lands within the Newcastle Reservoir watershed are used as pasture. Recommended BMPs for irrigated lands include filter strips, sprinkler irrigation, pasture and hayland planting, and prescribed grazing. Together these BMPs will reduce water use, increase pasture productivity, and reduce animal pressure on the grazing lands. When sediment and nutrients are transported overland, the filter strips that are installed at the field border will reduce the sediment and nutrient inputs. Research reveals that vegetative buffers have been effective in reducing nutrients. TP was reported to be reduced by 85%, total organic carbon by approximately 50%, total Kjeldahl nitrogen (TKN) by approximately 60%, and nitrate (NO_3) by more than 90% (Osmond et al. 2007).

7.3.6.1.3 Calculation of Load Reduction

With the implementation of the recommended BMPs applied to this land use, the estimated load reduction ranges from approximately 0.06 to 0.08 kgTP/day (see Table 7.6). The irrigated land use BMPs are applied based upon the implementation of a system of BMPs. Though any single BMP may be applied, greater reductions are achieved when BMPs are implemented in conjunction with others.

7.3.6.2 Nonirrigated Land

Nonirrigated acreages within the Pinto and Little Pinto Creek watershed include areas that are considered grazing pastures and are not dominated by forest or rangeland. These lands, even though they are not irrigated, have vegetative cover with greater production capacity than forested or range-dominated pastures. Some areas may lie close enough to riparian areas to receive subsurface water flow that may act as a water source.

7.3.6.2.1 Pollutant Sources and Load

As these acres are not irrigated, the significance of nutrient availability from oxidation-reduction reactions is not considered. Overland flow may still occur from storm events and may exceed the infiltration capacity of the soils. Sediment may be eroded from bare exposed surfaces. If these agricultural areas are grazed, the cattle manure can be transported by storm runoff directly to the streams. Some of these lands may be located near the riparian area and the loads may not receive any significant treatment before reaching the surface water if the riparian is also not properly functioning.

7.3.6.2.2 Recommended BMPs

Prescribed grazing and installation of filter strips are recommended for nonirrigated lands in the watershed. Prescribed grazing is expected to increase pasture productivity, reduce animal pressure on the grazing lands, and improve forage stands. When sediment and nutrients are transported overland from runoff events, the filter strips installed at the field border will reduce the sediment and nutrient inputs into the riparian and the surface water system.

7.3.6.3 Calculation of Load Reduction

Implementation of recommended BMPs applied to this the agricultural land use will reduce load by an estimated 0.02–0.03 kgTP/day removed (Table 7.6). Nutrient reductions, when applied with irrigated land reductions and filter strips, reduce phosphorus loads by 36–50% from agricultural sources.

Table 7.6 Load Reduction Expected from Agricultural Management Sources

Recommended BMP	Current Estimated Load from Source (kg/day)	Percent of Stream Recommended for Treatment	Recommended Application	Estimated Effectiveness	Load Reduction (kg/day)
Prescribed grazing	0.22	30%*	411 acres (166 ha)	55-82%	0.02–0.03
Irrigation systems**		35%	200 acres (81 ha)	70-90%	0.03–0.04
Pasture and hayland planting**					
Prescribed grazing**					
Filter strip		55%	611 acres (247 ha)	55-95%	0.03–0.04
Total Load Reduction (kg/season)					0.08–0.11
Current Load from Source (kg/season)					0.22
Percent Reduction					36–50%
Load from Source after Reduction (kg)					0.11–0.14

*Includes non-irrigated lands.
**Implemented as a system of listed BMPs on irrigated agricultural lands.

7.3.7 STORMWATER RUNOFF AND ON-SITE WASTEWATER TREATMENT

7.3.7.1 Pollutant Sources and Load

Primary sources of pollutants from rural, developed properties are sediment and nutrients present in both dissolved and sediment-bound forms. The developed areas have limited sources of stormwater because the developments are low-density in nature, resulting in relatively little impervious cover. The total load from stormwater runoff on developed lands in the watershed was estimated to be 0.04 kgTP/day.

Potential nutrient contributions from septic tank effluent can be influenced by poor design, inadequate sizing, improper maintenance, and a high water Table. The current contribution of phosphorus from septic effluent to Newcastle Reservoir is estimated to be 0.02 kgTP/day. An additional 0.08 kgTP/day has been allocated for septic tank load associated with future growth in the watershed (see Section 6.2).

7.3.7.2 Recommended BMPs

The phosphorus load estimates for septic tanks were based on the assumption that systems and leachfields were fully functioning. Septic tanks are designed to leach water and nutrients into the ground, thereby removing bacteria and other pathogens of greatest concern for public health. The BMPs that are designed to reduce pollutant loads from on-site wastewater treatment systems include repair of existing systems, addition of sand or recirculating filters, regular maintenance of systems, or the complete removal and new installation of a properly functioning system. Such systems were found to be prohibitively expensive and led to very little progress in load reduction. Therefore, there are no recommended structural BMPs for improving phosphorus treatment in septic tanks or leachfields. However, tanks and drainfields that are not installed correctly or not operating as designed should be modified, repaired, or fixed.

With the potential for some growth within the regions of the watershed, an information and educational program (I&E) concerning the design, installation, and maintenance of on-site wastewater treatment systems should be initiated by the agency responsible for overseeing the permitting of new or replaced systems. This I&E program could include the development of an information pamphlet that is given out to all septic owners, as well as all new applicants for septic permits.

7.3.7.3 Calculation of Load Reduction

No load reduction is calculated for stormwater or on-site wastewater treatment systems because the cost of BMPs was found to be very expensive when compared to the load reduction achieved for the watershed.

7.3.8 MISCELLANEOUS SOURCES

7.3.8.1 Road Erosion

7.3.8.1.1 Pollutant Sources and Load

The watershed is interconnected by an extensive network of roads, which increase sediment and nutrient yields. The geology of forested lands within the Newcastle Reservoir watershed is conducive to erosion and sediment production (Stokes 1986). Water that would naturally flow downslope or infiltrate into the ground instead flows on or adjacent to the roads due to soil compaction and rutting. As a result, sediment is transported downgradient as overland flow. Runoff intercepted by roads becomes concentrated and channelized in drainage ditches or ruts. Roads near streams become a direct conduit of flow and sediment to the stream channel and can increase peak flows (USFS 2005) as well as sediment and nutrient loads. The magnitude of sediment load delivered to streams is determined by a large number of parameters, including road gradient, road width, delivery length (length of road surface draining to a stream), surface type, traffic, cutslope height and gradient, fillslope length and gradient, vegetation density on cut and fill slopes, locations of culverts and other drainage control structures, and ditch type and conditions.

The phosphorus load from road erosion in the watershed could not be directly quantified. Over 166 kilometers (102 miles) of road were found to be within 300 feet (91.4 meters) of a stream or wash. It was assumed that 60% of the miscellaneous load in the watershed, or 0.64 kgTP/day, comes from this source. This estimate is believed to be conservative, considering that up to 90% of the sediment load to streams in forested lands around the country may come from road erosion (Daniels et al. 2004).

7.3.8.1.2 Recommended BMPs

Significant reductions of phosphorus load resulting from road-related erosion can be achieved through access road treatment. In some cases, road realignment may be required to protect the stream channel and permanently reduce sediment loading.

Applying gravel to native surface roads best mitigates road sediment production, as well as treating the cut and fill slope areas adjacent to the road surface. These BMPs are expected to decrease sediment transport capacity by improving and maintaining drainage and by protecting (i.e., avoiding) sites where unusual soil characteristics increase road surface or ditch runoff. Sediment production rates from native surface roads were 12–25 times greater than from rocked roads (Rogers 2006). Road treatments may also include slash filter and hydro mulch on road cuts, graveled water bars and ditch linings, rolling dips, diversion ditches, and cross culverts (State of Utah, no date). It is recommended that 70% of the roads within 300 feet of a stream (116 kilometers or 72 miles) should be treated. The prioritization of road segments and selection of the most appropriate treatment for each segment is left up to the USFS and BLM.

Regrading road surfaces is not recommended as a BMP because recently graded roads have historically produced twice as much sediment per unit of storm erosivity as roads that had not been recently graded (Rogers 2006). This is most likely due to the disruption of the road surface armor layer—a period of a couple of years is required to reestablish the armor layer (Luce et al. 2001). Grading within the ditch also affects sediment delivery from runoff. The destruction of vegetation that protects the soil surface from direct runoff energy leads to increased sediment transport.

The realignment of a road moves road surfaces near riparian areas to areas where sediment is less likely to be deposited directly into surface waters. The realignment process includes both the destruction of the original road and the construction of a new road. Additional BMPs for realigning road segments are in place during construction of the new segment. Road realignment is recommended for 10% of the roads (10.2 miles [16.5 kilometers]) within 300 feet (91.4 meters) of a stream in the watershed. The recent road realignment project along the south fork of Pinto Creek accounts for 2.5 miles (4 kilometers) of this recommendation, leaving an additional 7.7 miles (12.5 kilometers) of roads recommended for future realignment in the watershed. This realignment could be substituted with road closure as an effective alternative to realignment. The majority of these roads are on USFS and BLM managed lands.

Off-highway vehicles should be restricted to designated routes away from waterways to prevent bank destabilization and soil erosion along tributaries and within reservoir shorelines.

7.3.8.1.3 Calculation of Load Reduction

Load reductions associated with road treatment were calculated based on average BMP efficiencies applied to 70% of the roads within 300 feet (91.4 meters) of a stream. Sediment reduction associated with slash filter and hydro mulch range from 80–95% (Burroughs and King 1989). The BMP efficiencies for road surface treatment are also high, ranging from 85% for dust abatement to 92% for armor ditch lining and graveled water bar. Load reductions are summarized in Table 7.7. Load reductions resulting from road realignment range from 50–75% (Burroughs and King 1989). In total, road realignment and access road treatment would result in a total phosphorus load reduction ranging from 0.27 kgTP/day to 0.32 kgTP/day accounting for a 36% to 43% reduction of phosphorus load from this source.

Table 7.7. Summary of Road Erosion Load Reduction Expected from Implementation of Recommended BMPs

Recommended BMP	Current Estimated Load from Source (kg/day)	Percent of Watershed Recommended for Treatment	Recommended Application in Watershed Units	Estimated Effectiveness	Load Reduction (kg/day)
Access road treatment	0.64	50%	51.6 miles (83 km) of roads w/in 300 feet (91.4 m) of stream	80–95%	0.26–0.31
Road realignment		5%*	5.2 miles (8.3 km) of roads w/in 300 feet of stream	50–75%	0.01
Total Load Reduction (kg/day)					0.27–0.32
Current Load from Road Erosion (kg/day)					0.75
Percent Reduction					36–43%
Load after Reduction (kg/day)					0.43–0.48

* Includes the 2.5% already treated in the recent road realignment (2.5 miles or 4 kilometers of road).

7.3.8.2 In-stream and Lakeshore Erosion

7.3.8.2.1 Pollutant Sources and Load

Impacts from grazing practices in riparian areas include increased sediment and nutrient loading due to erosion of stream bank areas destabilized by grazing animals (Mosely et al. 1997). Cattle grazing along stream banks and within the channel may, if improperly managed, exacerbate erosion in two major ways. The shearing action of hooves on stream banks destabilizes the soil and increases the potential for significant erosion as loose sediments are rapidly removed by flowing water. Grazing cattle may also remove or substantially reduce riparian vegetation (Platts and Nelson 1995). Erosion of stream banks denuded by cattle is considered to be a component of the miscellaneous load that was not captured by the SWAT model or the riparian grazing load. Off-highway vehicle use in drainages and along streambanks and shorelines also increases the potential for reduced riparian vegetation cover and significant soil erosion into the waterway. It was assumed that in-stream and lakeshore erosion accounted for 25% of the miscellaneous load, or 1.02 kgTP/day.

7.3.8.2.2 Recommended BMPs

Removal of cattle from riparian areas and stream channels will result in a reduction of in-stream erosion. It is recommended that cattle be removed from 55% of the stream length in the watershed through the combination of livestock exclusion, fencing, and off-site watering. It is also recommended that OHV use be restricted to existing trails and excluded from the lakeshore and riparian areas. Exclusion of OHVs from riparian and drainage areas would similarly reduce in-stream erosion and lakeshore erosion as well as reduce the loss of riparian cover. Such exclusions are already incorporated into the Dixie National Forest Management Plan, but should also be included in BLM Resource Management Plans, especially regarding OHV use around the Newcastle Reservoir shoreline. These BMPs and recommended implementation strategies are described in more detail in Section 7.3.2.

Treatment techniques to counter erosive actions around the reservoir should focus on the use of live and dead vegetation for reinforcement and protection of soil or intensive treatment techniques, such as riprap, or a combination of riprap and live vegetation to protect exposed soils and shorelines. Limiting the amount of exposed soils by controlling and limiting the reservoir drawdown can also be used, if possible.

7.3.8.2.3 Calculation of Load Reduction

Livestock exclusion from streams (NRCS code 472), consisting of fencing (NRCS code 382) and off-site watering (NRCS code 614), is recommended for 4.4 miles (15%) of streams, 2.3 miles of which have already been completed. Off-site watering alone (NRCS code 614), which has been determined to be between 50–81% effective in reducing phosphorus loading (Miner et al. 1992), is recommended for 11.6 miles (40%) of streams in the watershed. According to research, these BMPs have an effectiveness ranging from 70–95% (Sheffield et al. 1997). This leads to an estimated load reduction of 0.10–0.14 kgTP/day (Table 7.8).

Table 7.8. Summary of Load Reduction Expected from Implementation of Recommended BMPs for In-stream and Lakeshore Erosion

Recommended BMP	Current Estimated Load from Source (kg/day)	Percent of Stream/Reservoir Recommended for Treatment	Recommended Application	Estimated Effectiveness	Load Reduction (kg/day)
Livestock exclusion from streams*	0.27	15%**	4.4 stream miles (2.3 completed already)	70–95%	0.10–0.14
Off-site watering		40%	11.6 stream miles		
Restrict OHV use around reservoir		100% of lakeshore	3 miles of lakeshore		
Total Load Reduction (kg/day)					0.10–0.14
Current Load from Source (kg/day)					0.27
Percent Reduction					38–52%
Load from Source after Reduction (kg/day)					0.13–0.17

*Includes fencing and off-site watering and would result in natural reestablishment of riparian buffer
** Includes the 2.3 miles of stream already treated with livestock exclusion.

7.3.9 SUMMARY OF IMPLEMENTATION PROPOSAL

Installation of BMPs recommended in this implementation proposal is expected to result in a total load reduction of between 12.39–16.47 kgTP/day (average of 14.76 kgTP/day). This estimate assumes that all recommended BMPs will be implemented in accordance with the BMP descriptions specified in the preceding sections. Load reductions resulting from BMPs implemented by loading sources are summarized in Table 7.9.

Table 7.9. Summary of Load Reductions Resulting from BMPs Implemented by Loading Source

Loading Source	Current Estimated Load from Source (kg/day)	Recommended BMPs	Percent of Application Units Recommended for Treatment	Recommended Application Units	Estimated Effectiveness	Load Reduction (kg/day)
Grazing in Riparian Areas and Stream Channels	6.62	Livestock exclusion from streams [1]	15% [2]	4.4 stream miles	100%	0.99
		Off-site watering	40%	11.6 stream miles	50–81%	1.32–2.14
		Stream crossings and channel bank vegetation	20%	5.8 stream miles	50–75%	0.66–0.99
		Prescribed grazing	25%	7.2 stream miles†	70–90%	1.16–1.49
Forest Land Management	6.32	Prescribed grazing	70%	51,872 acres†	55–82%	2.43–3.62
		Brush management	1%	1,000 acres†		
	2.43–3.62 [3]	Riparian buffer	80% [4]	23 miles	50–82%	1.28–1.91
Rangeland Management	6.33	Prescribed grazing	70%	16,589 acres	55–82%	2.44–3.63
		Brush management	3%	800 acres		
	2.44–3.63 [3]	Riparian buffer	80% [4]	23 miles	50–82%	1.29–1.92
Agricultural Land Management Sources	0.22	Nonirrigated lands prescribed grazing	30%	411 acres of nonirrigated land	55-82%	0.02–0.03
		Pasture and hayland planting on irrigated lands	35%	200 acres of irrigated land	70-90%	0.03–0.04
		Irrigated lands prescribed grazing				
		Filter strip	55%	Along ditches and canals on all 611 acres of irrigated and nonirrigated land	55-95%	0.03–0.04
Miscellaneous Sources (Roads, In-	0.64	Access road treatment	50%	52 miles (83 km) of roads w/in 300 feet (91.4 m) of stream	80–95%	0.26–0.31

Table 7.9. Summary of Load Reductions Resulting from BMPs Implemented by Loading Source

Loading Source	Current Estimated Load from Source (kg/day)	Recommended BMPs	Percent of Application Units Recommended for Treatment	Recommended Application Units	Estimated Effectiveness	Load Reduction (kg/day)
stream, and Lakeshore Erosion)		Road realignment	5% [5]	5.2 miles (8.3 km) of roads w/in 300 feet (91.4 m) of stream	50–75%	0.01
	0.27	Livestock exclusion from streams [1]	15% [2]	4.4 stream miles (7.1 km) - 2.3 miles (3.7 km) completed already	70–95%	0.10–0.14
		Off-site watering	40%	11.6 stream miles (18.7 km)		
		Restrict OHV use around reservoir	100% of lakeshore	3 mile(4.8 km) lakeshore		
TOTALS	Total Load Reduction from All Sources (kg/day)					12.02–17.26
	Total Average Load Reduction from All Sources (kg/day)					14.64
	Target Load Reduction (kg/day)					14.59
	Current Estimated Load from All Sources (kg/day)					26.53
	Percent Reduction from All Sources					55%

[1] Includes fencing and off-site watering and would result in natural reestablishment of riparian buffers.
[2] Includes the 2.3 miles of stream already treated with livestock exclusion.
[3] The filtration function of the riparian forest buffer is calculated on the remaining load after BMPs are implemented in the upland part of the watershed. This avoids double counting of load reduction.
[4] The 80% recommendation is based on the recommended treatments of riparian areas in the previous section. It is assumed that livestock exclusion, off-site watering, and prescribed grazing will all result in the reestablishment of the riparian area and its ability to filter sediment and nutrients from upland diffuse sources.
[5] This includes the 2.5% already treated in the recent road realignment on USFS land (2.5 miles or 4 kilometers of road).
[6] Calculated using total average load reduction from all sources (14.59 kgTP/day).

7.3.10 Timeframe for Implementation

The Newcastle Reservoir Watershed Implementation Proposal will be initiated as projects secure funding. Completion of BMP implementation is estimated to take 10 years. Detailed implementation documentation should be used to track installation of BMPs and costs associated with construction and implementation. Nutrient reductions will be estimated based on available literature or monitoring results. Reduction goals and watershed conditions will be evaluated near the five-year mark to assess current watershed conditions and determine whether modifications are necessary in the implementation schedule.

7.3.11 Reasonable Assurance

Load reductions for the Newcastle Reservoir Watershed Implementation proposal rely on nonpoint source reductions to achieve desired water quality and protect designated beneficial uses. Estimated percent reduction values, and therefore estimated load reductions, are based on values from the peer-reviewed literature. Implementation of a suite of BMPs, as described in this implementation proposal, provides reasonable assurance that load reductions will be achieved and designated beneficial uses will be restored. Monitoring and reporting will be conducted to determine effectiveness of implemented BMPs. If monitoring shows that load reductions are not occurring to the extent necessary, BMPs should be modified accordingly. This monitoring and modification "feedback loop" provides further assurance that estimated load reductions will be achieved by implementing a suite of BMPs as described here.

7.4 Interagency Coordination

Interagency coordination is an integral part of the Newcastle Reservoir Watershed Implementation Proposal. Coordination between the State of Utah, the USFS and BLM to ensure implementation of BMPs on federal land managed by these agencies is critical. A recent memorandum of understanding between the USFS and the EPA (http://www.epa.gov/owow/tmdl/usfsepamoa/) regarding impaired waters on forest service managed lands should help to facilitate this partnership. Further, the NRCS will assist in coordination between the State of Utah and private landowners regarding available funding to implement BMPs on private land.

Implementation of BMPs for publicly owned forested lands is mandated by federal legislation. For agriculture, BMP implementation is a voluntary incentive-based program. Federal cost-share incentives are available to agricultural producers. These programs include the Conservation Reserve Program (CRP), Wetland Reserve Program (WRP), Wildlife Habitat Incentives Program (WHIP), and the Environmental Quality Incentive Program (EQIP). The State of Utah also offers some loan and grant programs to agricultural producers for the installation of conservation BMPs. The programs for federal and state conservation can have a positive impact on the land and surrounding water quality.

7.5 Monitoring

A watershed monitoring program is needed to estimate and monitor the capability of each BMP to reduce phosphorus or sediment loads and to ensure that BMPs are operating properly. Assessments will document progress toward improved water quality conditions. Success in reducing annual load of sediment and phosphorus will be measured by contributions monitored at or near the mouths of major tributary points, as well as by noted visual observations of sediment movement, erosion and stream bank loss and overgrazed areas. Additionally, managers of forested land should monitor implementation and effectiveness of activities conducted to reduce sediment/phosphorus loading. Potential indicators may be quantitative (e.g., laboratory analysis of phosphorus concentrations in water exiting a riparian area) or qualitative (e.g., visual observation of sediment reduction in the water passing through a fenced riparian area), depending on the BMP implemented and the overall scope of the project. In-stream monitoring is scheduled to occur periodically throughout the year by UDEQ and includes physical, chemical, and biological parameters. In-reservoir monitoring is scheduled to occur periodically during the algal growth season and includes physical, chemical, and biological parameters.

7.5.1 Sampling Design and Parameters

The basic monitoring plan requires monitoring of sites located throughout the watershed that contribute directly to the annual phosphorus load. To assist in achieving the water quality goals, the initial monitoring plan should include:

- Seasonal monitoring throughout the year at reservoir monitoring sites and tributaries into the reservoir selected sites for phosphorus, nitrogen, chlorophyll *a*, temperature, and total suspended sediment
- Monitoring streams above and below large BMP installation projects in order to determine effectiveness of individual projects
- Annual surveys of the extent or number of sites experiencing nuisance algae growth and/or violations of water quality targets
- Visual inspections of implemented BMPs for effectiveness and operation

Objectives of the monitoring plan consist of:

- Obtaining information necessary for ensuring that water quality target loading and concentration targets for TP are met
- Obtaining a detailed record of water quality data to assess whether the established target levels and threshold values are protective of beneficial uses
- Evaluating BMP effectiveness and loading reductions resulting from implementation efforts.

Successful development and implementation of the monitoring plan will provide flexibility for adapting changes to the implementation proposal as the need arises.

7.5.2 Progress Reporting

Annual reports will provide details about sediment and phosphorus reduction measures, operation efficiencies, and projected load reductions; reports will be submitted to the appropriate organization and agencies for their review. A database for offering all stakeholders internet access to available information is recommended. The database would initially include water quality data gathered as part of this implementation proposal but could be expanded to incorporate other types of data generated within the watershed.

7.6 BUDGET

7.6.1 PROJECTED COSTS FOR IMPLEMENTATION

Implementation of the BMPs necessary to meet the water quality goals outlined within the TMDL will require a significant allocation of financial resources from multiple sources. Cost-benefit studies are recommended as a tool for identifying the most cost-effective strategies to prioritize throughout the reservoir. As stated previously, the implementation plan outlined here is a general guide. Final decisions on project implementation will be made by land managers and owners based on their intricate knowledge of the watershed. The total estimated costs for each recommendation's total estimated costs for the entire watershed are listed in Table 7.10. The sources of potential funds are described below in Section 7.6.2.

Unit-cost estimates listed for each BMP are based on two separate sources. The agricultural costs were obtained from the NRCS EFOTG cost sheet located at the Utah NRCS website (http://efotg.nrcs.usda.gov/efotg_locator.aspx?map=UT). The forestry costs were obtained from an online U.S. Forest Service bid history sheet from the cost-estimate guide for road construction (http://www.fs.fed.us/r1/projects/costguide_index.shtml). There may also be additional costs associated with compliance with the National Environmental Policy Act (NEPA).

The BMP costs are listed by total quantities recommended for implementation within each land use type. In some cases the units required to calculate cost differ slightly from those used in the preceding sections to estimate load reduction. Linear stream miles are converted to riparian acres based on an assumed riparian buffer width of 300 feet (91.4 meters) on each side of the stream. The number of crossings on streams in the watershed is unknown. Restoration of five stream crossings was assumed to account for 20% of the linear stream miles. Off-site watering costs are determined based on the gallons of water storage provided off-site. Off-site water facilities were assumed to hold 1,000 gallons of water each. It was assumed that one off-site watering facility would be required for each of the allotments in the watershed. Since this recommendation is applied to 55% of stream linear miles, it was assumed that 8 allotments (55% of the allotments) would require treatment. Indirect costs associated with land set-aside costs or annual maintenance have not been calculated. The BMPs that have already been completed within the watershed have also not been calculated. Estimated costs include the cost of additional required BMPs only. The total cost estimated for the Newcastle Reservoir Watershed Implementation Proposal is approximately $0.87 million, with additional costs for required annual maintenance of structural BMPs and NEPA.

Table 7.10. Summary of Costs Associated with Project Implementation Proposal

BMP name	Loads†	Percent Treated	Units	Units in Watershed	Units Treated	Unit Cost (dollars)	Total Cost (dollars)
Livestock Exclusion from Streams and riparian (472)	1,2,3,5,7	15%	Acres of riparian	2,102	148*	$15.00	$2,225
Fencing (382)	1,2,3,5,7	15%	Linear feet of stream (both sides)	305,188	45,778	$2.65	$121,312
Off-site Watering (614)	1,2,3,7	55%	Allotments	14	8	$1,650.00	$13,200
Channel Bank Vegetation (322)	1	20%	Acres of riparian	2,102	420	$750.00	$315,300
Stream Crossing (578)	1	20%	Crossings	Unknown	5	$2,000.00	$10,000
Prescribed Grazing (528) Riparian	1,2,3,7	25%	Acres of riparian	2,102	0‡	$4.00	$0
Prescribed Grazing (528) Forest	2	70%	Acres of forest	74,060	0‡	$4.00	$0
Brush Management (314) Forest	2	1%	Acres of forest	74,060	0‡	$200.00	$0
Prescribed Grazing (528) Range	3	70%	Acres of rangeland	23,698	16,589	$4.00	$66,354
Range Planting (550)	3	2%	Acres of rangeland	23,698	500	$20.00	$10,000
Brush Management (314) Range	3	2%	Acres of rangeland	23,698	800	$200.00	$160,000
Prescribed Grazing (528) Nonirrigated	4	30%	Acres of nonirrigated land use	411	123	$4.00	$492
Prescribed Grazing (528) Irrigated	4	100%	Acres of irrigated land	200	200	$4.00	$800
Irrigation System (442)	4	35%	Acres of irrigated land	200	20††	$1,000.00	$20,000
Pasture and Hayland Planting (512)	4	35%	Acres of irrigated land	200	70	$110.00	$7,700
Filter Strip (393)	4	55%	Acre of agricultural land	611	336	$275.00	$92,414
Road Treatment (560)	6	50%	Linear miles of roads	103	52	$500.00	$25,841

Table 7.10. Summary of Costs Associated with Project Implementation Proposal

BMP name	Loads[†]	Percent Treated	Units	Units in Watershed	Units Treated	Unit Cost (dollars)	Total Cost (dollars)
Road Realignment and Decommissioning	6	5%	Linear miles of roads	103	2.7**	$9,500.00	$25,349
Total Costs							**$870,987**

[†] 1 – Cattle in riparian areas and streams; 2 – Forest land management; 3 – Rangeland management; 4 – Agricultural management sources; 5 – In-stream erosion (miscellaneous source); 6 – Erosion from roads, trails, and landings (miscellaneous source); 7 – Natural and legacy background sources.

* Excludes 167 acres of riparian area covered in existing exclosure projects.

** Excludes 2.5 miles of road already realigned.

‡ Brush management on 1,000 acres of forest land, prescribed grazing on 51,000 acres of upland forest land, and 7.2 stream miles has already been completed by the USFS, which was included in load reduction estimates but not in cost estimates.

†† Irrigation management on 50 acres of agricultural land has already been completed and thus is not included in remaining cost estimates.

7.6.2 Financial and Legal Vehicles for Implementation

Various programs are available for private landowners to assist with the implementation of BMPs through cost-share incentive programs, grants, or low-interest loans. The program funds come from multiple sources such as the EPA, the NRCS, and the State of Utah. All programs require voluntary signup for participation, while some require eligible lands to qualify, based on program requirements.

The NRCS administers a number of programs for funding to assist agricultural producers in installing BMPs on their privately owned lands. One program is the Environmental Quality Incentive Program (EQIP), which is a federal Farm Bill program that offers assistance in the installation or implementation of conservation practices; cost-sharing incentives pay for 50–75% of the costs.

Other federal cost-share programs administered by the NRCS are the Wildlife Habitat Incentives Program (WHIP) and the Wetland Reserve Program (WRP). They are designed to establish habitat for wildlife and fish and to restore wetlands, respectively. Another federal cost-share program is the Conservation Reserve Program (CRP), which encourages farmers to convert highly erodable farmland or other highly sensitive acreages to vegetative cover. The CRP is administered by the Farm Service Agency (FSA). All of the federal programs require landowners to voluntarily sign up and all land enrolled must qualify based on rules associated with the respective programs.

The State of Utah offers a low-interest loan program titled the Agriculture Resource Development Loan (ARDL), which is administered under the Utah Department of Agriculture and Food (UDAF). The programs offer loans for projects that conserve soil and water resources and maintain and improve water quality. Another UDAF program is the Grazing Improvement Program (GIP), which offers a competitive grant for fence repairs, reseeding of grazing land, and the replacement or development of water projects.

The State of Utah Section 319 grant program is another financial program which may be employed by agricultural producers or conservation districts to implement nonpoint source projects for the protection or improvement of water quality. The 319 program is a cost-share program that requires a 60:40 grant-to-cost share match. The program is administered by the UDAF and funded through the UDWQ from a national EPA Clean Water Act grant program.

List of Acronyms and Abbreviations

Acronym	Definition
§303(d)	Refers to Section 303 subsection (d) of the Clean Water Act, or a list of impaired waterbodies required by this section
µ	micro, one-one thousandth
§	Section (usually a section of federal or state rules or statutes)
AUM	Animal Unit Month
AWS	agricultural water supply
BAG	Basin Advisory Group
BLM	United States Bureau of Land Management
BMP	best management practice
BOD	biochemical oxygen demand
BOR	United States Bureau of Reclamation
BURP	Beneficial Use Reconnaissance Program
C	Celsius
CFR	Code of Federal Regulations (refers to citations in the federal administrative rules)
cfs	cubic feet per second
cm	centimeters
CN	curve number
CWA	Clean Water Act
CWAL	cold water aquatic life
DEM	digital elevation model
DEQ	Department of Environmental Quality
DGL	digital graph line
DO	dissolved oxygen
DOI	U.S. Department of the Interior
DWS	domestic water supply
EPA	United States Environmental Protection Agency
ESA	Endangered Species Act
ET	Evapotranspiration rate
F	Fahrenheit
FWS	U.S. Fish and Wildlife Service
GIS	Geographical Information Systems
HOD	hypolimnetic oxygen depletion
HRU	hydrologic response unit
HUC	Hydrologic Unit Code
INFISH	The federal Inland Native Fish Strategy
km	Kilometer
km2	square kilometer
LA	load allocation
LC	load capacity

Acronym	**Definition**
m	meter
m3	cubic meter
mi	mile
mi2	square miles
MBI	macroinvertebrate index
MGD	million gallons per day
mg/L	milligrams per liter
mm	millimeter
MOD	metalimnetic oxygen depletion rate
MOS	margin of safety
MRLC	Multi-Resolution Land Characteristics Consortium
MUSLE	Modified Universal Soil Loss Equation
MWMT	maximum weekly maximum temperature
n.a.	not applicable
N	Nitrogen
NA	not assessed
NB	natural background
nd	no data (data not available)
NED	National Elevation Dataset
NEPA	National Environmental Policy Act of 1969
NFS	not fully supporting
NHD	National Hydrography Dataset
N:P	nitrogen to phosphorus ratio
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
NTU	nephlometric turbidity unit
ORW	Outstanding Resource Water
P	Phosphorus
PCR	primary contact recreation
PFC	proper functioning condition
ppm	part(s) per million
QA	quality assurance
QC	quality control
RHCA	riparian habitat conservation area
SBA	subbasin assessment
SCR	secondary contact recreation
SCS	Soil Conservation Service
SNOTEL	snow telemetry
SRP	soluble reactive phosphorus
SS	salmonid spawning
SSOC	stream segment of concern
SSURGO	Soil Survey Geographic (SSURGO) Database
STATSGO	State Soil Geographic (STATSGO) Database

Acronym	**Definition**
STORET	EPA water quality database
SWReGAP	Southwest Regional Gap Analysis Project
TDG	total dissolved gas
TDS	total dissolved solids
T&E	threatened and/or endangered species
TIN	total inorganic nitrogen
TKN	total Kjeldahl nitrogen
TMDL	total maximum daily load
TP	total phosphorus
TS	total solids
TSI	Trophic State Index
TSS	total suspended solids
t/y	tons per year
UDEQ	Utah Department of Environmental Quality
UDNR	Utah Department of Natural Resources
UDWQ	Utah Division of Water Quality
UDWR	Utah Department of Water Resources
UGS	Utah Geological Survey
U.S.	United States
U.S.C.	United States Code
USACE	United States Army Corps of Engineers
USDA	United States Department of Agriculture
USDI	United States Department of the Interior
USFS	United States Forest Service
USGS	United States Geological Survey
WAG	Watershed Advisory Group
WBID	waterbody identification number
WLA	wasteload allocation
WQLS	water quality limited segment
WQMP	water quality management plan
WQS	water quality standard
WRCC	Western Regional Climate Center

Abbreviation	**Meaning**
~	approximate
ac	acre
acre-ft	acre foot
cfs	cubic feet per second
cts	counts
ft	foot
ft^3	cubic foot
h	hectare
kg	kilogram
km	kilometer
L	liter
m	meter
MGD	million gallons per day
mi	mile
mL	milliliter
pH	measure of acidity: pH 1-6 = acidic, pH 7 = neutral, pH 8-14 = basic
SU	standard units
T	ton
Tier 1	all land within 150 feet of either side of a stream
Tier 2	low land, mostly irrigated crop and pastureland
Tier 3	upland mostly non-irrigated pasture
mg	milligram
µg	microgram
yr	year
^oC	degrees Celsius

Bibliography

Breitburg, D. L. 1992. Episodic hypoxia in the Chesapeake Bay: interacting effects of recruitment, behavior and a physical disturbance. *Ecological Monographs* 62:525-546.

Breitburg, D.L. 2002. Effects of hypoxia, and the balance between hypoxia and enrichment, on coastal fishes and fisheries. *Estuaries* 25:767-781.

Breitburg, D. L. 1990. Nearshore hypoxia in the Chesapeake Bay: patterns and relationships among physical factors. *Estuarine Coastal and Shelf Science* 30:593-610.

Breitburg, D.L, T. Loher, C.A. Pacey, A. Gerstein. 1997. Varying effects of low dissolved oxygen on trophic interactions in an estuarine food web. *Ecological Monographs* 67:489-507.

Breitburg, D.L. and G.F. Riedel. 2005. Multiple stressors in marine systems. Pp 167-182 *In* E. Norse and L. Crowder, eds. *Marine Conservation Biology: The Science of Maintaining the Sea's Biodiversity.* Island Press, Washington

Breitburg, D.L., S.TP. Seitzinger and J.G. Sanders (eds.). 1999. The effects of multiple stressors in marine and freshwater systems. *Limnology and Oceanography* (Special issue) 44 (issue 3, part 2): 233.

Brown, R.B. 2003. *Soils and Septic Systems*. Soil and Water Science Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida.

Burroughs, E. R., Jr., King, J. G. 1989. *Reduction of soil erosion on forest roads*. General Technical Report INT-264. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, Utah, 21 pp.

Carlson, R.E. and J. Simpson. 1996. *A Coordinator's Guide to Volunteer Lake Monitoring Methods*. North American Lake Management Society. 96 pp.

Daniels, B., D. McAvoy, M. Kuhns, R. Gropp. 2004. *Managing Forest for Water Quality: Forest Roads*. Utah Forest Facts. Utah State University Extension Service. NR/FF/010.

D'Avanzo, C. and Kremer, J.N. 1994. Diel oxygen dynamics and anoxic events in an eutrophic estuary of Waquoit Bay, Massachusetts. *Estuaries* 17: 131-139.

Elder, D., Killam, G., and TP. Koberstein. 1999. *The Clean Water Act: An owner's manual*. Portland Oregon. River Network.

Environmental Protection Agency (EPA). 2000a. *Progress in Water Quality: An Evaluation of the National Investment in Municipal Wastewater Treatment*. United States Environmental Protection Agency, Washington D.C.

Environmental Protection Agency (EPA). 2000b. EPA 822-B00-001. Nutrient Criteria Technical Guidance Manual: Lakes and Reservoirs, and 822-B-00-002. First Edition. United States Environmental Protection Agency Office of Water, Washington DC. July 2000. URL: www.epa.gov/ost/standards/nutrient.html.

Environmental Protection Agency (EPA). 2003. *Ambient Water Quality Criteria for Dissolved Oxygen, Water Clarity and Chlorophyll a for Chesapeake Bay and Its Tributaries*. EPA-903-R-03-002 April 2003. U. S. Environmental Protection Agency, Region III, Chesapeake Bay Program Office, Annapolis, Maryland and Region III Water Protection Division, Philadelphia, Pennsylvania in coordination with Office of Water, Office of Science and Technology, Washington, D.C.

Gary, H. L., S. R. Johnson, and S.L. Ponce.1983. Cattle grazing impact on surface water quality in a Colorado Front Range stream. *Journal of Soil and Water Conservation* 38: 124 - 128.

Hedley, M.J.; Mortvedt, J.J.; Bolan, N.S.; Syers, J.K.. 1995. *Phosphorus Fertility Management in Agrosystems*; Chapter 5 In: Phosphorus in the Global Environment: Transfers, Cycles and Management. Tiessen, H.; (ed.); John Wiley and Sons, Chichester.

Heiskary, S. A. and W. W. J. Walker.1988. Developing phosphorus criteria for Minnesota lakes. *Lake and Reservoir Management* 4(1): 1-9.

Heiskary, S. A. and W. W. J. Walker.1995. Establishing a chlorophyll *a* goal for a run-of-the-river reservoir. *Lake and Reservoir Management* 1(1): 67-76.

Hofmann, L., R.E. Ries, and J.E. Gilley. 1983. Relationship of runoff and soil loss to groundcover of native and reclaimed grazing land. *Agronomy Journal* 75:599-602.

Hoorman, J.J. and J. McCutcheon, No Date, *Best Management Practices to Control the Effects of Livestock Grazing Riparian Areas Fact Sheet LS-4-05*. The Ohio State University Extension Fact Sheet. School of Environment and Natural Resources, 2021 Coffey Road, Columbus, Ohio 43210.

Iron County Information Systems Department. 2007. *Iron County Zoning Map*. Available at:http://www.ironcounty.net/departments/Information%20Systems%20 Department/gis/maps/zoning_noparcels.pdf. Accessed on January 22, 2007

Khaleel, R.; Reddy, K.R.; Overcash, M.R.. 1980. Transport of Potential Pollutants in Runoff Water from Land Areas Receiving Animal Wastes: A Review. *Water Research* 14: 421–436.

Line, D. E., W. A. Harman, G. D. Jennings, E. J., Thompson, and D. L. Osmond. 2000. Nonpoint source pollutant load reductions associated with livestock exclusion. *J. Environ. Qual*. 29:1882-1890.

Lowry, J. H, Jr., R. D. Ramsey, K. Boykin, D. Bradford, TP. Comer, S. Falzarano, W. Kepner, J. Kirby, L. Langs, J. Prior-Magee, G. Manis, L. O'Brien, T. Sajwaj, K. A. Thomas, W. Rieth, S. Schrader, D. Schrupp, K. Schulz, B. Thompson, C. Velasquez, C. Wallace, E. Waller and B. Wolk. 2005. *Southwest Regional Gap Analysis Project: Final Report on Land Cover Mapping Methods, RS/GIS Laboratory, Utah State University, Logan, Utah*. Available at : http://earth.gis.usu.edu/swgap/swregap_landcover_report.

Luce, C.H. and T.A. Black. 2001. *Effects of Traffic and Ditch Maintenance on Forest Road Sediment Production.* Proceedings of the Seventh Federal Interagency Sedimentation Conference, March 25-29, 2001, Reno, Nevada. pp. V67–V74.

Magdoff, F., Lanyon, L., and Liebhardt, B. 1997. Nutrient cycling, transformations, and flows: Implications for a more sustainable agriculture. *Advances in Agronomy*. 60: p. 1-73

Mahoney, D.; Erman, D.C. 1984. An Index of Stored Fine Sediment in Gravel Bedded Streams. *Water Resources Bulletin* 20 (3): 343–348.

McGeehan, S.L.. 1996. *Phosphorus Retention in Seasonally Saturated Soils Near McCall, Idaho (Final Report).* University of Idaho, Division of Soil Science, Moscow, Idaho; 54 p + appendix. December.

Megahan, W.F. 1972. *Volume Weight of Reservoir Sediment in Forested Areas*; Journal of the Hydraulics Division, Proceedings of the American Society of Civil Engineers; Volume 98; Number HY8. August. pp. 1335–1342.

Megahan, W.F. 1979. *Channel Stability and Channel Erosion Processes*. Workshop Proceedings: Scheduling Timber Harvest for Hydraulic Concerns; Portland, Oregon; November 27–29; p. 18.

Miner, J. R., J. C. Buckhouse, and J.A. Moore. 1992. Will a water trough reduce the amount of time hay-fed livestock spend in the stream (and therefore improve water quality)? *Rangelands* 14(1): 35-38.

Montana State University. 2000. *Montana Grazing Best Management Practices for Water Quality Demonstration Project.* Online document, accessed 12/5/07. http://www.homepage.montana.edu/~harries/#Recommendations

Mosley, J.C., TP.S. Cook, A.J. Griffis, and J. O'Laughlin. 1997. *Guidelines for Managing Cattle Grazing in Riparian Areas to Protect Water Quality: Review of Research and Best Management Practices Policy*. University of Idaho.

NCDC. 2004. Daily Climate Data [internet website]. National Climatic Data Center, National Oceanic and Atmospheric Administration. Available at http://www.ncdc.noaa.gov/paleo/pdsi.html

Natural Resources Conservation Service (NRCS). 2006a. Utah SNOTEL sites. [October 20, 2006] Available at http://www.wcc.nrcs.usda.gov/snotel/Utah/utah.html

Natural Resources Conservation Service (NRCS). 2006b. Soil Data Mart. Auburn, AL. Available http://soildatamart.nrcs.usda.gov [accessed May 23, 2006].

Natural Resources Conservation Service (NRCS). 2007. *NRCS Field Office Technical Guide*. www.nrcs.usda.gov/TECHNICAL/efotg/

Natural Resources Consulting Engineers, Inc. (NRCE). 1996. *Analysis Summary Report: Cascade Reservoir Irrigation Management Plan*. Fort Collins, Colorado. September. TP. 51.

Nebeker, A.V., S.T. Onjukka, D.G. Stevens, G.A. Chapman and S.E. Dominguez. 1992. Effects of low dissolved oxygen on survival, growth and reproduction of Daphnia, Hyalella and Gammarus. *Environmental Toxicology and Chemistry* 11(3): 373-379.

Neitsch, S.L., Arnold, J.G., Kiniry, J.R., Williams, J.R., King, K.W. 2002. *Soil and Water Assessment Tool, Theoretical Documentation*. Grassland, Soil, and Water Research Laboratory, Agricultural Research Service. Temple, Texas.

Oldham, J. H. 2001. *Evaluating the trophic status and setting nutrient protection endpoints in Utah lakes and reservoirs*. Civil and Environmental Engineering. Logan, UT, Utah State University. Master of Science: 138.

Olness, A.; Smith, S.J.; Rhoades, E.D.; Menzel, R.D. 1975. Nutrient and Sediment Discharge from Agricultural Watersheds in Oklahoma. Journal of Environmental Quality 4(3): 331–336.

Omernik, J.M.; Abernathy, A.R.; Male, L.M.. 1981. Stream Nutrient Levels and Proximity of Agricultural and Forest Land to Streams: Some Relationships. *Journal of Soil and Water Conservation* July-August: 227–231

Omernik, J.M.; Gallant, A.L. 1986. *Ecoregions of the Northwest*; EPA/600/3-86/033; p. 39.

Osmond, D.L., D.M. Butler, N.N. Ranells, M.H. Poore, A. Wossink, and J.T. Green. 2007. *Grazing Practices: A Review of the Literature*. Technical Bulletin 325-W, North Carolina Agricultural Research Service, North Carolina State University, Raleigh, North Carolina.

Pilgrim, K., D. Sanders, and T. Dupuis. 2001. *Relationship between chlorophyll a and beneficial uses*. CH2M Hill, Boise, Idaho. 10 p.

Platts, W.S. and Nelson, R.L. 1995. Streamside and Upland Vegetation Use by Cattle. *Rangelands* 7(1): 5–7.

Raschke, R. L. 1994. Phytoplankton bloom frequencies in a population of small southeastern impoundments. *Lake and Reservoir Management* 8(2): 205-210.

Rashin, E., C. Clishe, A. Loch, J. Bell. 1999. *Effectiveness of Forest Road and Timber Harvest Best Management Practices with Respect to Sediment-Related Water Quality Impacts*. Washington State Department of Ecology, Environmental Assessment Program, Watershed Ecology Section, Olympia, WA.

Reddell, D.L., Johnson, W.H., Lyerly, TP.J., and Hobgood, TP. 1971. Disposal of Beef Manure by Deep Plowing. *Livestock Waste Management and Pollution Abatement*; ASAE Publication, Proceedings -271, ASAE; St. Joseph, Michigan; pp. 235–238.

Rogers Coe, D.B., 2006. *Sediment Production and Delivery from Forest Roads in the Sierra Nevada, California*. Masters Thesis, Department of Forest, Rangeland, and Watershed Stewardship, Colorado State University, Colorado

Rushforth, S. R., and S. J. Rushforth. 2003. *A study of phytoplankton floras from Utah lakes and reservoirs collected late summer 2002.* Report to the Utah Division of Water Quality.

Rushforth, S. R., and S. J. Rushforth. 2005. *A study of phytoplankton floras from Utah lakes and reservoirs collected late summer 2004.* Report to the Utah Division of Water Quality.

Seager, J., Milne, I., Mallett, M. and I. Sims. 2000. Effects of short-term oxygen depletion on fish. *Environmental Toxicology and Chemistry* 19(12): 2937–2942.

Sharpley, A.N.; Hedley, M.J.; Sibbesen, E.; Hillbricht-Ilkowska, A.; House, W.A.; Ryszkowski, L.. 1995. *Phosphorus transfers from terrestrial to aquatic ecosystems*; Chapter 11, In Phosphorus in the Global Environment: transfers, cycles and management; Tiessen, H.(ed.); John Wiley and Sons, Chichester.

Sharpley, A.N.; Jones, C.A.; Grey, C.; Cole, C.V. 1984. A simplified soil and plant phosphorus model II: Prediction of labile, organic and sorbed phosphorus. *Soil Science Society of America Journal* 48: 805–809.

Sharpley, A.N.; Smith, S.J.; Jones, O.R.; Berg, W.A.; Coleman, G.A.. 1992. The Transport of Bioavailable Phosphorus in Agricultural Runoff. *Journal of Environmental Quality* 21: 30–35.

Sheffield, R.E., S. Mostaghimi, D.H. Vaughan, E.R. Collins, Jr., and V.G. Allen. 1997. Off-stream water sources for grazing cattle as a streambank stabilization and water quality BMP. *Transactions of American Society of Agricultural Engineers* 40: 595-604.

Shewmaker, G.E.. 1997. Livestock Grazing Effects on Phosphorus Cycling in Watersheds. *Proceedings: Watershed and Riparian Workshop*. LeGrand, Oregon; September 11–13; p. 25.

Smeltzer, E. and S. A. Heiskary .1990. Analysis and applications of lake user survey data. *Lake and Reservoir Management* 6(1): 109-118.

Sonzongi, W.C.; Chapra, S.C.; Armstrong, D.E.; Logan, T.J.1982. Bioavailability of Phosphorus Inputs to Lakes. *Journal of Environmental Quality* 11(4): 555–563.

Spence, J.R. 2001. *Climate of the Central Colorado Plateau, Utah and Arizona: Characterization and Recent Trends.* National Park Service, Resource Management Division, Glen Canyon National Recreation Area, Page, AZ.

Stokes, W.L. 1986. *Geology of Utah.* Utah Geological and Mineral Survey Department of Natural Resources.

Tiessen, H. (ed.). 1995. *Phosphorus in the Global Environment: Transfers, Cycles and Management*; Scientific Committee on Problems of the Environment (SCOPE) 54; John Wiley and Sons, Chichester.

Thomas, K. and M. Lowe. 2007. *Recharge and Discharge Areas for the Principal Basin-Fill Aquifer, Beryl-Enterprise Area, Iron, Washington, and Beaver Counties, Utah*. Utah Department of Natural Resources, Utah Geological survey, ISBN 1-55791-770-1.

Tilstra, J.R.; Malueg, K.W.; Larson, W.C. 1972. Removal of phosphorus and nitrogen from wastewater effluent by induced soil percolation. *J. Water Pollution Control Federation* 44(5): 796–805.

U.S. Census Bureau: State and County. 2007. *QuickFacts: Data derived from Population Estimates, Census of Population and Housing, Small Area Income and Poverty Estimates, State and County Housing Unit Estimates, County Business Patterns, Nonemployer Statistics, Economic Census, Survey of Business Owners, Building Permits*. Consolidated Federal Funds Report

U. S. Department of Agriculture (USDA). 1992. Agricultural Wastes and Water, Air and Animal Resources. *Agricultural Waste Management Field Handbook*: *Part 651, Chapter 3*. Washington, DC (April); pp. 3–8 to 4–11.

U. S. Forest Service (USFS). 2005. *Environmental Assessment: South Fork Pinto Creek road relocation and riparian restoration*. Dixie National Forest Cedar City, UT.

U. S. Forest Service (USFS). 2007. *Range Allotment Annual Operating Instructions. Dixie National Forest Cedar City, UT*. Available at: http://www.fs.fed.us/r4/dixie/resources/rangemgt.shtml

US Geological Survey (USGS). 2007. *Surface-Water Data for Utah*. Available at http://waterdata.usgs.gov/ut/nwis/sw.

Utah Division of Water Rights. 2006a. *DAMVIEW dam safety database*. http://nrwrt1.nr.state.ut.us/cgi-bin/damview.exe [viewed October 20, 2006]

Utah Division of Water Quality (UDWQ). 1996. *Quality Assurance/Quality Control Manual*. Utah Department of Environmental Quality, Division of Water Quality, Salt Lake City, Utah (from http://www.epa.gov/STORET/metadata.html).

Utah Division of Water Quality, Department of Environmental Quality (UDEQ). EPA Review Pending. *Echo Reservoir TMDL Water Quality Study*. Salt Lake City, Utah.

Utah Division of Water Quality (UDWQ), Department of Environmental Quality. 2006. *Utah's 2006 Integrated Report. Volume II – 303(d) List of Impaired Waters*.

Utah Division of Wildlife Resources. 2006. *Utah Natural Heritage Program database*. Written communication with Sarah Lindsey October 16, 2006.

Wainwright, J., Mulligan, M. 2004. *Environmental Modeling: Finding Simplicity in Complexity*. John Wiley and Sons, Ltd. London, UK., Part 1, pages 56-58.

Walker, W.W. 1985. Water quality criteria and standards. *Lake and Reservoir Management: practical applications*. Proceedings of the 4th Annual Conference and International Symposium. October 16-19. pp. 57-62.

Walker, W. W. 1999. *Simplified procedures for eutrophication assessment and prediction: User manual.* Vicksburg, MS, U.S. Army Corps of Engineers, Waterways Experiment Station.

Walmsley, R. D. 1984. Chlorophyll *a* trophic status classification system for South African impoundments. *Journal of Environmental Quality* 13(1): 97-104.

Western Regional Climate Center (WRCC). 2006. *Western Regional Climate Center web-sites for Utah* Available at: www.wrcc.sage.dri.edu/summary/climsmut.html

Whiting, TP.J.; Matisoff, G.; Bonniwell, E.C. 1997. *Phosphorus Radionuclide Tracing of Fine Sediment in Forested Watersheds*. Case Western Reserve University, Department of Geological Sciences, Cleveland, Ohio; July; 39 p + appendices.

Whitworth, W.R. 1968. Effects of diurnal fluctuations of dissolved oxygen on the growth of brook trout. *J. Fish. Res. Board Canada* 25: 579-584.

Western Regional Climate Center (WRCC). 2006. *Western Regional Climate Center web-sites for Utah.* Available at: www.wrcc.sage.dri.edu/summary/climsmut.html