Otter Creek – East Fork Sevier TMDL Study

Prepared for:

Utah Department of Environmental Quality - Division of Water Quality

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Utah Department of Environmental Quality
Division of Water Quality
TMDL Section

Otter Creek – East Fork Sevier TMDL Study

Otter Creek Reservoir

Waterbody ID	16030002-004
Location	Piute County, Utah
Pollutants of Concern	Total Phosphorus
Impaired Beneficial Uses	Class 3A: Protected for cold water species of game fish and other cold water aquatic life, including the necessary aquatic organisms in their food chain.
Water Quality Assessment	In-Lake Total Phosphorus concentration exceeds 0.025 mg/l at reservoir monitoring sites from 25 percent to 100 percent.
Water Quality Targets/Endpoints	• 0.025 mg/l Total Phosphorus concentration in reservoir. • Average annual Total Phosphorus load = 2,037 kg/yr. • Load reduction = 6,651 kg/yr (77 %). • A shift from blue-green algal dominance to green algal dominance. • A TSI value in the reservoir not to exceed 50.
Implementation Strategy	• Reduce livestock access to water through fencing; stabilize channel banks and increase filtering capacity through implementation of riparian buffers. - Otter Creek: 13 miles - East Fork Sevier: 22 miles • Provide off-stream watering for livestock. • Implement rest-rotation grazing management on public allotments and private land areas. • Utilize low P feed at fish hatcheries and wetland treatment of effluent. • Conduct outreach programs to raise public awareness of proper maintenance and use of septic systems.

Utah Department of Environmental Quality
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Otter Creek – East Fork Sevier TMDL Study

Koosharem Reservoir

Waterbody ID	16030002-011
Location	Sevier County, Utah
Pollutants of Concern	Total Phosphorus
Impaired Beneficial Uses	Class 3A: Protected for cold water species of game fish and other cold water aquatic life, including the necessary aquatic organisms in their food chain.
Water Quality Assessment	In-Lake Total Phosphorus concentration exceeds 0.025 mg/l at reservoir monitoring sites from 50 percent to 100 percent.
Water Quality Targets/Endpoints	• 0.025 mg/l Total Phosphorus concentration in reservoir. • Average annual Total Phosphorus load = 629 kg/yr. • Load reduction = 582 kg/yr (48%). • A shift from blue-green algal dominance to green algal dominance. • A TSI value in the reservoir not to exceed 50.
Implementation Strategy	• Remove livestock access to areas below the reservoir high water mark by fencing 2 miles of shoreline. • Remove livestock access to critical stream segments through fencing 6 miles of stream channel. • Stabilize channel banks and increase filtering capacity through implementation of riparian buffers on 6 miles of stream channel. • Provide off-stream watering for livestock. • Implement rest-rotation grazing management on public allotments and private land areas. • Conduct outreach programs to raise public awareness of proper maintenance and use of septic systems.

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Otter Creek – East Fork Sevier TMDL Study

Lower Box Creek Reservoir

Waterbody ID	16030002-005
Location	Piute County, Utah
Pollutants of Concern	Total Phosphorus, Dissolved Oxygen
Impaired Beneficial Uses	Class 3A: Protected for cold water species of game fish and other cold water aquatic life, including the necessary aquatic organisms in their food chain.
Water Quality Assessment	100 percent of In-Lake Total Phosphorus samples exceed 0.025 mg/l at reservoir monitoring site. 50 percent of DO measurements < 4.0 mg/l on infrequent basis.
Water Quality Targets/Endpoints	• 0.025 mg/l Total Phosphorus concentration in reservoir. • Average annual Total Phosphorus load = 96 kg/yr. • Load reduction = 393 kg/yr (80 %). • A shift from blue-green algal dominance to green algal dominance. • A TSI value in the reservoir not to exceed 50. • DO concentration of 4.0 mg/l for greater than 50 percent of water column.
Implementation Strategy	• Stabilize channel banks and increase filtering capacity through implementation of riparian buffers on 1.5 miles of stream channel. • Provide off-stream watering for livestock. • Implement rest-rotation grazing management on Fish Lake National Forest grazing allotments.

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East Fork Sevier River

Waterbody ID	16030002-005
Location	Garfield County, Piute County, Utah
Pollutants of Concern	Total Phosphorus
Impaired Beneficial Uses	Class 3A: Protected for cold water species of game fish and other cold water aquatic life, including the necessary aquatic organisms in their food chain.
Water Quality Assessment	Total Phosphorus concentration exceeds 0.05 mg/l at stream monitoring sites from 33 percent to 82 percent.
Water Quality Targets/Endpoints	• 0.05 mg/l Total Phosphorus instream concentration. • Average annual Total Phosphorus load = 3,177 kg/yr. • Load reduction = 2,920 kg/yr (45 %).
Implementation Strategy	• Implement CNMPs on AFOs. • Stabilize channel banks and increase filtering capacity through implementation of riparian buffers on 22 miles of stream channel (15 miles associated with Otter Creek Reservoir TMDL). • Provide off-stream watering for livestock. • Conversion of brushland to herbaceous vegetation (70,000 acres). • Conduct outreach programs to raise public awareness of proper maintenance and use of septic systems.

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CHAPTER 1: INTRODUCTION

The Total Maximum Daily Load (TMDL) study for the Otter Creek/East Fork Sevier area has been completed under the direction of the Utah Department of Environmental Quality – Division of Water Quality (DWQ) for submittal to the U.S. Environmental Protection Agency (EPA) as specified by section 303(d) of the Clean Water Act (CWA). The water quality and flow assessment detailed within this document addresses impairment to all water bodies within the study area listed on the State of Utah 2002 303(d) list due to high concentrations of Total Phosphorus (TP) (Figure 1.1). An extensive field effort has accompanied this assessment in order to document existing conditions and verify model outputs. As a result, it is believed that this TMDL assessment provides an accurate picture of the important influences on water quality in the project area.

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

1.1 TMDL PROGRAM DESCRIPTION

The TMDL program is one part of a water quality-based approach to achieving the goals and objectives maintained by the Clean Water Act. After water bodies are identified as impaired, a TMDL is completed according to priority rankings and time schedules. Following approval of the TMDL assessment, actions are taken to control pollutant sources. Water quality conditions are also monitored over time to ensure progress toward water quality targets. The TMDL assessment includes a maximum amount of pollutant that a water body can assimilate and not violate water quality standards. This mass of pollutant is also referred to as the "loading capacity" for a water body and will be further described in this report.

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

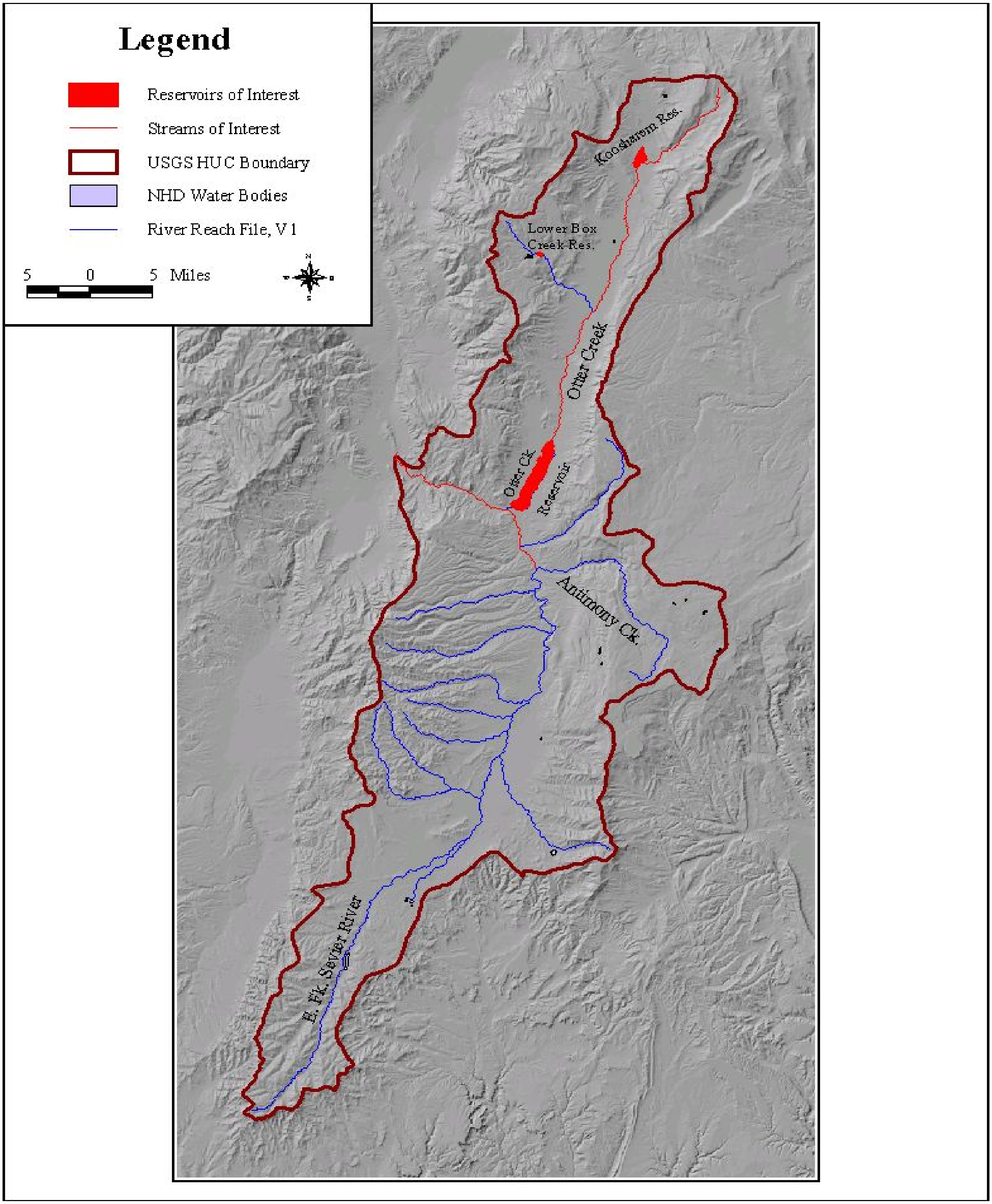

Figure 1.1 TMDL Study area including all of the East Fork Sevier River and otter Creek watersheds.

1.2 PREVIOUS STUDIES

Otter Creek Reservoir and the East Fork Sevier River have been periodically examined by federal and state agencies during the past 30 years. Many of these studies have examined water quality conditions and pollutant sources in only a portion of the TMDL study area. This TMDL assessment will attempt to provide a comprehensive view of the entire watershed along with an understanding of how the magnitude, seasonality, and location of pollutant sources contribute to impairment of reservoirs and stream segments. A comparison of existing conditions to findings reported in previous studies will also be made in order to examine changes in the water quality of the TMDL study area.

Many of the initial water quality and flow studies incorporated the TMDL study area as part of a larger assessment of the Sevier River Basin (Table 1.1). More recent studies have addressed specific water quality concerns within the East Fork Sevier/Otter Creek watershed as guided by state and federal legislation. Some of the more detailed studies include the Otter Creek/Koosharem Watershed Hydrologic Unit Plan (USDA-SCS 1992), Otter Creek Reservoir – Phase I Clean Lakes study (Merrit et al. 1996), and the Upper Sevier Watershed Management Plan (USFS 2004). A more detailed description of these studies is provided below. Other TMDL assessments have been completed within the past year on the Upper Sevier River (Utah DWQ 2004a), as well as the Middle and Lower Sevier River Watershed (Utah DWQ 2004b). These studies provided a limited description of some water quality conditions within the East Fork Sevier/Otter Creek watershed. However, they did not assign specific load allocations to the East Fork Sevier River or any water body within the TMDL study area.

Table 1.1. Selected water quality and flow investigations completed on the TMDL study area.

Year	Description/Title	Author
1966	Ground-Water Resources of Selected Basins in Southwestern Utah	USGS
1974	Comprehensive Water Quality Management Plan, Sevier River	Utah Water Research Lab
1977	National Eutrophication Survey (Working Paper 850)	EPA
1982	State of Utah Clean Lakes Inventory and Classification	Utah Department of Health (DWQ)
1988	State of Utah Nonpoint Assessment Report	Utah Department of Health (DWQ)
1991	Hydrologic inventory of the Sevier River Basin	Utah DNR/DWR
1992	Otter Creek/Koosharem Watershed Hydrologic Unit Plan	USDA – Soil Conservation Service (NRCS)
1993	Ground-water hydrology of the upper Sevier River Basin, south-central Utah, and simulation of ground-water flow in the valley-fill aquifer in Panguitch Valley	USGS
1996	Otter Creek Reservoir – Phase I EPA Clean Lakes study Diagnostic and Feasibility Report	Merrit et al. (as directed by Utah DWQ)
2004	Upper Sevier Watershed Management Plan	Upper Sevier River Community Watershed Project (USRC)

1.2.1 Otter Creek/Koosharem Watershed Hydrologic Unit Area Plan

In June 1990, the watershed area above Otter Creek Reservoir was submitted for approval to the USDA as a Hydrologic Unit Area (HUA). This submittal was accompanied by a request for funding to support nonpoint source water quality improvement projects in the area. Funding was subsequently approved for the HUA, officially described as the Otter Creek/Koosharem Watershed, and became the second HUA in Utah at that time. Initial efforts to locate water quality pollutant sources identified several processes contributing to water quality degradation including sedimentation, nutrient and coliform loading from agricultural lands, streambank erosion, elevated in-stream temperatures and degraded riparian conditions. Increasing algae growth and decreasing oxygen levels were also noted in both Koosharem Reservoir and Otter Creek Reservoirs. An inventory of conditions near the stream channel indicated that approximately 50 percent (3,000 acres) of the subirrigated pastures, wet meadows, and riparian areas located adjacent to 30 miles of Otter Creek were in poor to fair condition. A reconnaissance of sediment source areas in the Otter Creek/Koosharem watershed was also completed in the fall of 1990 to provide input data to a sediment yield model. The results from this effort were summarized in the HUA plan along with results from previous sediment yield studies completed on the East Fork Sevier/Otter Creek watershed (USDA-SCS 1992). This information indicated that Otter Creek Reservoir received about 26 acre-feet/year of sediment from Otter Creek and about 32 acre-feet/year of sediment from the East Fork Sevier River by way of the East Fork Canal.

A Coordinated Resource Management Plan (CRMP) was completed for the HUA in 1991. The plan identified specific water quality goals and expected results of implementing water quality improvement projects including:

1) Full support of designated uses and compliance with Utah Water Quality Standards in Otter Creek, Otter Creek Reservoir, and Koosharem Reservoir.
2) Reduce rangeland sediments loads by 70 percent.
3) Reduce excessive runoff flows caused by irrigation and intense precipitation events (including heavy rainstorms and snowmelt) thus reducing nutrient and coliform loading to streams and reservoirs.
4) Reduce streambank erosion by 70 percent on 20 miles of designated segments of Otter Creek.
5) Increase recreational use of streams and reservoirs.
6) Restoration of aquatic wildlife populations in streams and reservoirs to natural levels.

During 1991 through 1998, the HUA has obtained approximately $1.9 million in funding from federal, state, and private entities. These funds have been used to complete a number of practices that support resource management systems on private and federal land. A summary of these practices is included in Table1.2.

Table 1.2. Water quality improvement projects associated with the Otter Creek/ Koosharem HUA (1991 – 1998).

Practice	Completed	Practice	Completed
Brush management	13,359 acres	Water Catchments	2 locations
Range seeding	13,359 acres	Pasture Planting	1,500 acres
Fence	23 miles	Hayland Management	2,500 acres
Stock Water development	3 locations	Streambank Protection	3,800 feet.
Pipeline	32,200 feet.	Channel Vegetation	3,300 feet
Troughs	10 locations	Prescribed Grazing	96,944 acres

1.2.2 Otter Creek Reservoir – Phase I EPA Clean Lakes Study

Water quality conditions in Otter Creek Reservoir were addressed in 1996 as part of an EPA Phase I Clean Lakes Study (Merrit et al. 1996). Results from the study were submitted as a TMDL for the reservoir by Utah DWQ. The study examined all watershed areas adjacent to the main tributaries of the reservoir, including Otter Creek and the East Fork Canal. Water samples were collected from the reservoir and contributing streams from May 1993 through June 1994. A review of TP concentrations indicated that although the Otter Creek watershed had experienced some nutrient reduction (compared to data collected in 1977), actual improvements in water quality were countered by increased loads of sediment and nutrients delivered to the reservoir from the East Fork through the East Fork Canal. Many of the samples collected during 1993-94 exceeded the numeric criteria recommended for streams and lakes in Utah. Water quality conditions in the reservoir were described as eutrophic or "over-productive" resulting from high nutrient loads. An average Carlson's Trophic State Index of 55 was calculated for Otter Creek Reservoir during the summer 1993 monitoring period.

The major sources of pollution in the Otter Creek watershed were identified as "farm/ranch/rangeland" operations and erosion from stream channel segments in the East Fork Sevier River. Pollutant loads from agriculture areas were determined to occur through four processes including 1) direct drainage and storm runoff from dairy/feedlot operations; 2) direct stream access from animals grazing in pastures; 3) return flows from irrigated fields and stock watering; 4) general storm runoff from upslope areas. Distance from the reservoir and flowing tributaries was noted to have a direct influence on the magnitude of pollutant impacts to the reservoir. Grazing on vegetation growing from the exposed reservoir bed and pastures adjacent to the reservoir were noted to be of particular concern. No information was provided indicating the number of operations where animals could be kept in a concentrated area such as a dairy or feedlot operation. However, few operations were noted in the East Fork Sevier watershed. A rough estimate of the number of animals located within one-half mile of streams identified 1,000 animals in this corridor during the summer season (June – September) and 2,000 animals during the winter season (October – May). No specific description of stream channel erosion was identified in the report. It was noted that years with high runoff rates (including 1993), increased the level of erosion and channel instability and subsequent sediment and nutrient loads to the reservoir.

The results of this study recommended that TP loads be reduced by 45 percent and Nitrogen loads reduced by 23 percent. The study also recommended that during years of high runoff, flow from the East Fork Canal be diverted around Otter Creek Reservoir until the latter part of the runoff season. As a result, a large portion of the sediment loads would not enter the reservoir. Removal of livestock grazing on the exposed reservoir bed was also recommended. Projected water quality improvements from these measures included a lower Trophic status (from eutrophic to slightly eutrophic), significant reduction in algae blooms, healthier fish habitat and increased water transparency.

1.2.3 Upper Sevier Watershed Management Plan

The Upper Sevier Watershed Management Plan is the result of a collaborative effort between federal, state, and local entities to identify resource issues and concerns within the Upper Sevier Watershed. As defined in the plan, this watershed encompasses the Upper Sevier River and tributaries from the headwaters down to Panguitch Reservoir. Although water quality and meeting water quality standards was noted to be a major focus of the report, a variety of resource disciplines were utilized. Ensuring water quality and quantity for ranchers and farmers while providing for the needs of fish and wildlife was identified as a primary concern in the plan. The need to maintain and restore riparian and upland vegetation communities to a resilient and viable condition was also noted.

Pollutant sources and processes contributing to water quality impairment were identified within the Upper, Middle, and Lower segments of the East Fork Sevier. Some of the more significant concerns included the following:

- Accelerated erosion from unstable stream channels.
- Increased sediment transport from areas associated with dispersed camping and illegal ATV use.
- Poor road design and placement within stream corridors.
- Lack of vegetative diversity in riparian corridors. Many riparian areas are devoid of sedges, woody forbs and trees.
- Wildfire and livestock impacts to riparian areas.
- Pasture management in the Lower East Fork Sevier (below Otter Creek Reservoir).

No schedule of water quality improvement projects was provided in the plan. Information in the plan is intended to prioritize and rank watershed issues in an effort to guide future management decisions. The Upper East Fork Sevier River (above Johns Valley) and the Antimony Creek watershed were described as two priority treatment areas where restoration efforts should be focused.

1.3 PLAN OBJECTIVES

The goal of this TMDL assessment is to determine the pollutant sources and reductions necessary to support the beneficial uses assigned by the State of Utah to all impaired water bodies located within the TMDL study area. Some of these waterbodies have been included on the State 303(d) list of impaired water bodies since 1996. A summary of the 303(d) history for all waterbodies located in the TMDL study area is provided below in Table 1.3.

A review of Table 1.3 indicates that four waterbodies, including three reservoirs and one river segment are considered impaired by TP. A technical assessment of all pollutant sources contributing TP loads to these waterbodies is included in the remainder of this document. As mentioned previously, it is not the intent of this assessment to place blame or criticism on any individual or group within the watershed. Rather, the primary focus of this work is to define how waterbodies within the study area respond to both natural and human-created processes that are believed to influence water quality conditions. Once these processes have been defined, recommendations will be made to reduce or eliminate negative impacts to water quality and restore the beneficial use to a water body.

The success of this TMDL is dependent upon public involvement and support. An initial meeting was held in Richfield, Utah on June 11, 2003 to announce the beginning of this assessment. The meeting was held as part of the greater Sevier River Watershed Group and included representatives from the US Forest Service, US BLM, NRCS, Utah DWQ, and local Soil Conservation Districts. The proposed schedule for field assessment of stream channel conditions was provided and a request given for volunteer support to assist in this effort. A request was also made to obtain information on land management and irrigation practices in the TMDL study area. Full support was offered by those in attendance. It is noted here that throughout the initial phases of this TMDL assessment, a high level of cooperation and interest has been provided by private landowners. The Sevier River Watershed Group has gone through periods of inactivity since its initial formation. In September of 2005, Lynn Koyle was hired as the watershed coordinator for the middle and lower Sevier River in an effort to facilitate the formation of an active watershed group and complete a watershed management plan. Lynn has coordinated the formation of numerous work groups to identify issues and restoration opportunities in the watershed. These technical work groups include Hydrology/Water quality, Agriculture, Rangeland, Fisheries/Habitat, Human Uses/Recreation, and Information and Education. To date, two Sevier River Watershed Group meetings have been held on November 8th and December 14th at which details of these TMDLs have been presented to stakeholders.

In addition, the Upper Sevier River Steering Committee has been active for over 6 years in the development of a watershed plan and implementation strategies, as well the TMDL for the East Fork Sevier River portion of the watershed. The TMDL for the East Fork Sevier River has been presented to the Upper Sevier River Steering Committee on February 10, 2005. Implementation activities have begun on the East Fork as part of 319 PIPs developed by the watershed group and the Department of Wildlife Resources. In addition, the Division of Water Quality has received an EPA Targeted Watershed Grant for approximately 600,000 which will fund projects designed to improve fishery habitat on listed segments of the East Fork Sevier River.

The Division of Water Quality has also offered the TMDLs for public comment from February 15th to March 15th , 2006 and held an additional public meeting at the Junction Courthouse on February 24th, 2006.

Table 1.3. 303(d) history of impaired water bodies within the TMDL study area.

Year	Water body	Pollutant of Concern	Comments
1996	Otter Ck. from Otter Ck. Res. To Koosharem Res.	TP, DO, sediments, Coliforms	Otter Ck. targeted for Non Point Source Project
	Koosharem Res.	TP, DO	
	Lower Box Ck. Res.	DO, pH	
	Otter Ck. Res.	TP, DO, pH	
	Tropic Res.	DO	
1998	Otter Ck. from Otter Ck. Res. To Koosharem Res.		Removed from 1996 303(d) list, TMDL completed and approved by EPA.
	Koosharem Res.	TP, DO	
	Lower Box Ck. Res.	TP, DO, pH	
	Otter Ck. Res.	TP, DO	
	Tropic Res.	DO, pH	
2000	East Fork Sevier River and tributaries from confluence w/Sevier River to Antimony Creek confluence.	TP	
	Koosharem Res.	TP	DO impairment removed due to reevaluation and new data.
	Lower Box Ck. Res.	TP	DO and pH impairment removed due to reevaluation and new data.
	Otter Ck. Res.	TP, Temperature	DO impairment removed due to reevaluation and new data.
	Tropic Res.		Removed from 1998 303(d) list due to reevaluation and new data.
2002	East Fork Sevier River and tributaries from confluence w/Sevier River to Antimony Creek confluence excluding Otter Creek and tributaries.	TP	
	Koosharem Res.	TP	
	Lower Box Ck. Res.	TP	
	Otter Ck. Res.	TP	Temperature impairment removed due to the need for more data to determine if reservoir should be listed.
2004	East Fork Sevier River and tributaries from confluence w/Sevier River to Antimony Creek confluence excluding Otter Creek and tributaries.	TP	
	Koosharem Res.	TP	
	Lower Box Ck. Res.	TP	
	Otter Ck. Res.	TP, Temperature, pH	Heat budget analyses indicated that temperature violations were due to solar radiation. DWQ developing specific temperature criteria. Impairment for pH will not be listed until two consecutive cycles demonstrate impairment. TMDL reductions in TP should reduce pH.

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CHAPTER 2: PROJECT AREA DESCRIPTION

The TMDL study area (HUC 1603002) covers approximately 3,240 km^2 (1,250 mi^2 or 800,000 acres) in south central Utah, in the High Plateaus section of the Colorado Plateau Province. It encompasses the East Fork of the Sevier River (East Fork) and all the waters flowing into it, including Otter Creek and Otter Creek Reservoir (Figure 2.1), and constitutes the eastern part of the Upper Sevier River watershed. Portions of the project area fall within 4 counties: Sevier, Piute, Garfield, and Kane counties. Several small communities are found within the watershed including Burrville, Koosharem, Greenwich, Angle, Kingston, and Antimony (Figure 2.2). The traditional use of the study area has centered around livestock grazing although recreational use of public lands has experienced a steady increase over the past few decades. Representative photos of the watershed are shown in Figure 2.3.

2.1 PROJECT AREA HISTORY

Pioneers first settled Johns Valley in the 1870s. Early settlers tried to farm parts of the valley as nonirrigated cropland but the precipitation was too low and most of the farms were eventually abandoned. Some of the land was purchased and rehabilitated by the federal government. The historic pioneer town of Widstoe is located on the east side of Johns Valley, near the mouth of Escalante Canyon. In the early 1900s, the town had a school, a post office, and over 1,100 residents, which practiced dry farming and cattle ranching. Due to severe drought and unpredictable weather, the town was almost abandoned by 1935 and became a ghost town.

The town of Antimony is located just north of the confluence of Antimony Creek and the East Fork. The town and creek are named after the mineral stibnite, an ore of antimony, which was originally used by Navajo Indians to form arrowheads and bullets and later by white settlers as an alloy to strengthen other metals.

Irrigation needs for the first settlers to the Sevier Valley were met by simply diverting flow from the Sevier River. By the late 1800s, summer flow in the river was insufficient to meet the demand for irrigation water, with the greatest demand for water occurring when flow in the river was lowest. This caused serious conflicts between upstream and downstream settlers over water rights. Dry conditions during the 1890s made matters worse, as flow could scarcely meet one-fourth of the downstream demand. Elders John H. Smith and Anton H. Lund of the LDS Church advised the people to build a reservoir instead of quarrelling over the water but the idea was met with a lot of skepticism. Nevertheless, committees were appointed in 1895 to investigate potential reservoir sites and a company was formed. Otter Creek above the confluence with the East Fork was identified as a suitable location for the future dam in 1896 and Robert Dixon Young, a prominent citizen of Richfield, led the effort to get the dam constructed. However, State officials and the local population still had serious doubts about the project and no bank would provide funding for it. Robert Young refused to give up and volunteered his time and labor for one year on the project. Construction began on October 19, 1897 with a crew of three boys and one man. The level of interest in the project increased shortly thereafter, when crops were saved in the Sevier Valley from water that was stored by the partially completed dam and reservoir. The dam was mostly completed by 1901 and had a total width of 45 feet. Work on the spillway, outlet works, and diversion canals continued in the following years (Otter Creek Irrigation Company 2002).

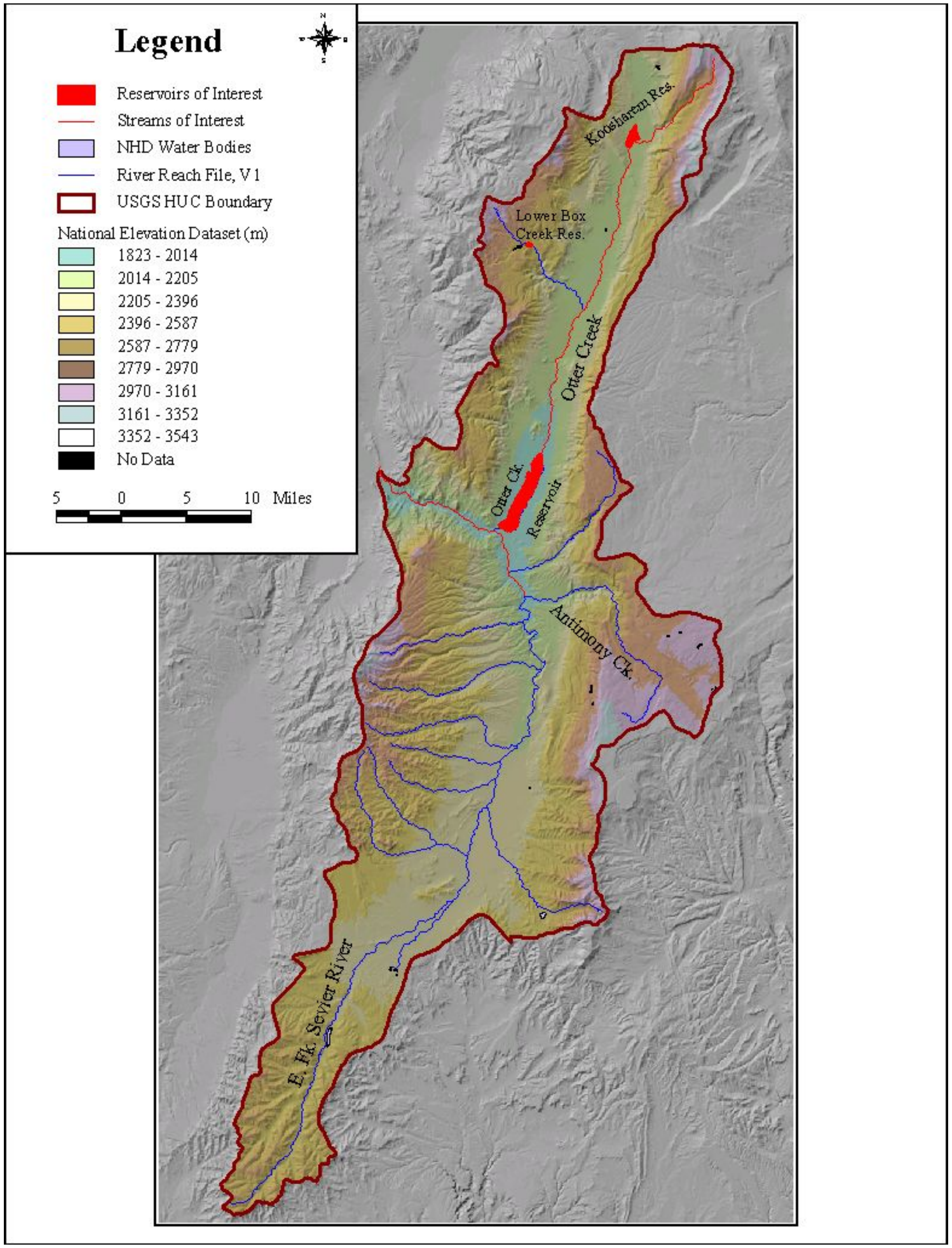

Figure 2.1. Topographic relief of TMDL study area.

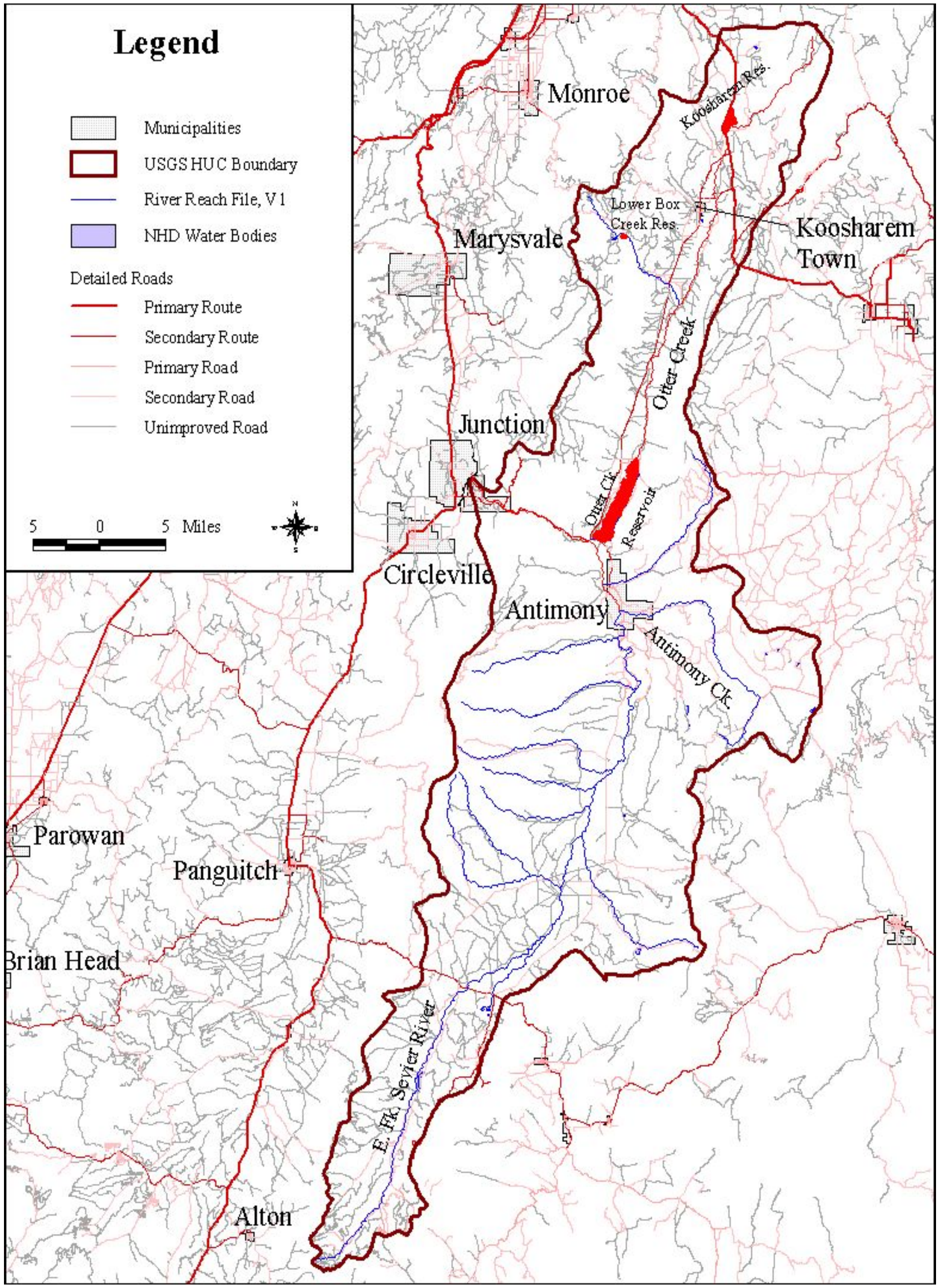

Figure 2.2. Major transportation routes and municipal areas located in the TMDL study area.

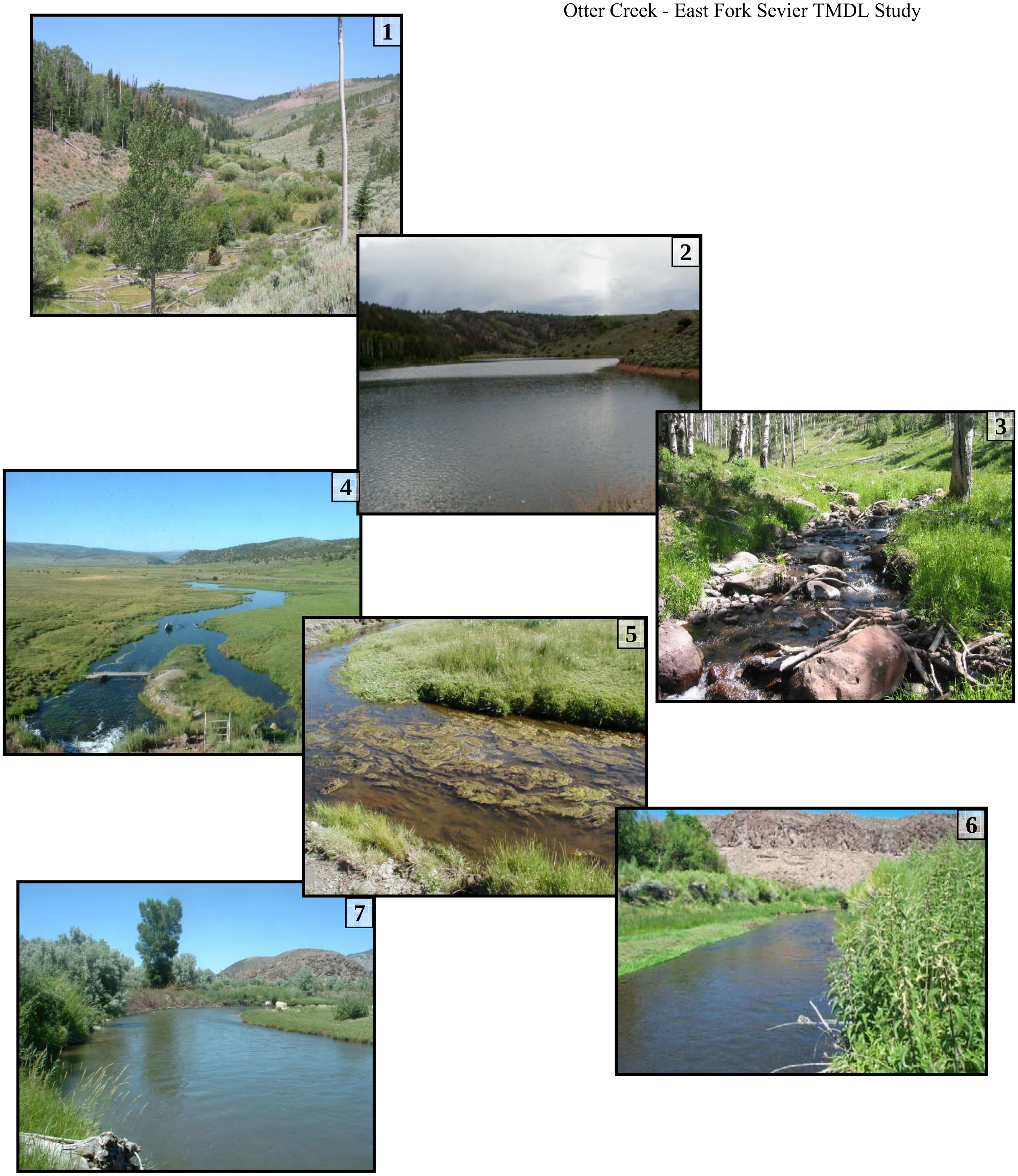

Figure 2.3. Representative photos of the TMDL study area including (1) Upper headwater area above Lower Box Creek Reservoir (2) Lower Box Creek Reservoir – May 2003 (3) Otter Creek in upper Daniels Canyon area (4) Otter Creek immediately below Koosharem Reservoir (5) Otter Creek above Narrows (6) East Fork Sevier near Antimony, Ut. (7) East Fork Sevier River near Kingston, Ut.

Although traditional use of the area has centered around livestock grazing, increased recreational use of National Forest System (NFS) lands has created some concern with regards to water quality. State Highway 12 and Highway 63 transports over 1.5 million visitors annually to Bryce Canyon National Park, located adjacent to the east boundary of the East Fork watershed. Dispersed camping, high traffic volumes on unpaved roads and stream crossings as well as illegal use of ATVs within riparian and upslope areas have impacted soil and vegetation resources within fragile stream corridors on NFS lands. Natural processes such as wildfire and periodic drought conditions have further increased the impact of these activities.

A significant impact to water quality in the East Fork watershed occurred during summer 2002 when two prescribed fires escaped their containment boundaries, eventually burning 78,000 acres in the Mt. Dutton area. The fire complex was eventually called the Sanford Fire but originally began as two prescribed burns near the headwaters of Deer Creek (Sanford prescribed fire) and along the upper portion of Hunt Creek (Adams Head prescribed fire). The vast majority of the burned area was located within the East Fork watershed. Roughly ten percent of the total burned area was determined to involve high intensity fire, much of which occurred within the Deep Creek drainage, a perennial tributary to the East Fork. Impacts resulting from the fire included high mortality counts within a Bonneville cutthroat trout fishery and downstream impacts to other high value recreation fisheries located along the East Fork. Additional impacts were experienced in the area due to a 100-year storm event that followed the fire. This storm event generated severe erosion and flooding and subsequently washed sediment and debris into the East Fork. Approximately $160,000 was spent on emergency rehabilitation to burned areas. Although recovery efforts have assisted in reducing water quality impacts to the East Fork, it is anticipated that sediment production from burned areas will occur at levels that exceed pre-fire conditions for several years.

2.2 CLIMATE

The study area has a semi-arid continental climate. Precipitation in the Sevier River Basin is influenced by two major storm patterns: frontal systems from the Pacific Northwest during winter and spring, and thunderstorms from the south and southwest during late summer and early fall (Utah Board of Water Resources 1999, DWQ 2003a). These thunderstorms develop as moist air from the Gulf of Mexico moves across the area (Swenson and Bayer 1984). Local topography influences these systems. As a result, precipitation and temperatures are highly variable and dependent upon location. Although heavy thunderstorms are common during the summer and cause increased sheet erosion, the majority of precipitation falls as snow over the mountains during the winter (USFS 2004). The higher mountains receive up to 30 inches annually along the East Fork drainage and up to 40 inches on the Fishlake Plateau, in the northeast corner of the Otter Creek drainage (Figure 2.4). Valley bottoms receive less precipitation (5-15 inches annually) and a larger proportion of it comes from summer and fall storms. The frost-free period (from the last spring frost to the first fall frost) typically lasts for 80-90 days in the valleys, with a growing season from June to September. The length of the growing season decreases almost linearly as elevation increases. In the higher mountains on the Sevier and Fishlake Plateaus, freezing temperatures can occur any day of the year and the growing season is extremely short (less than 20 days).

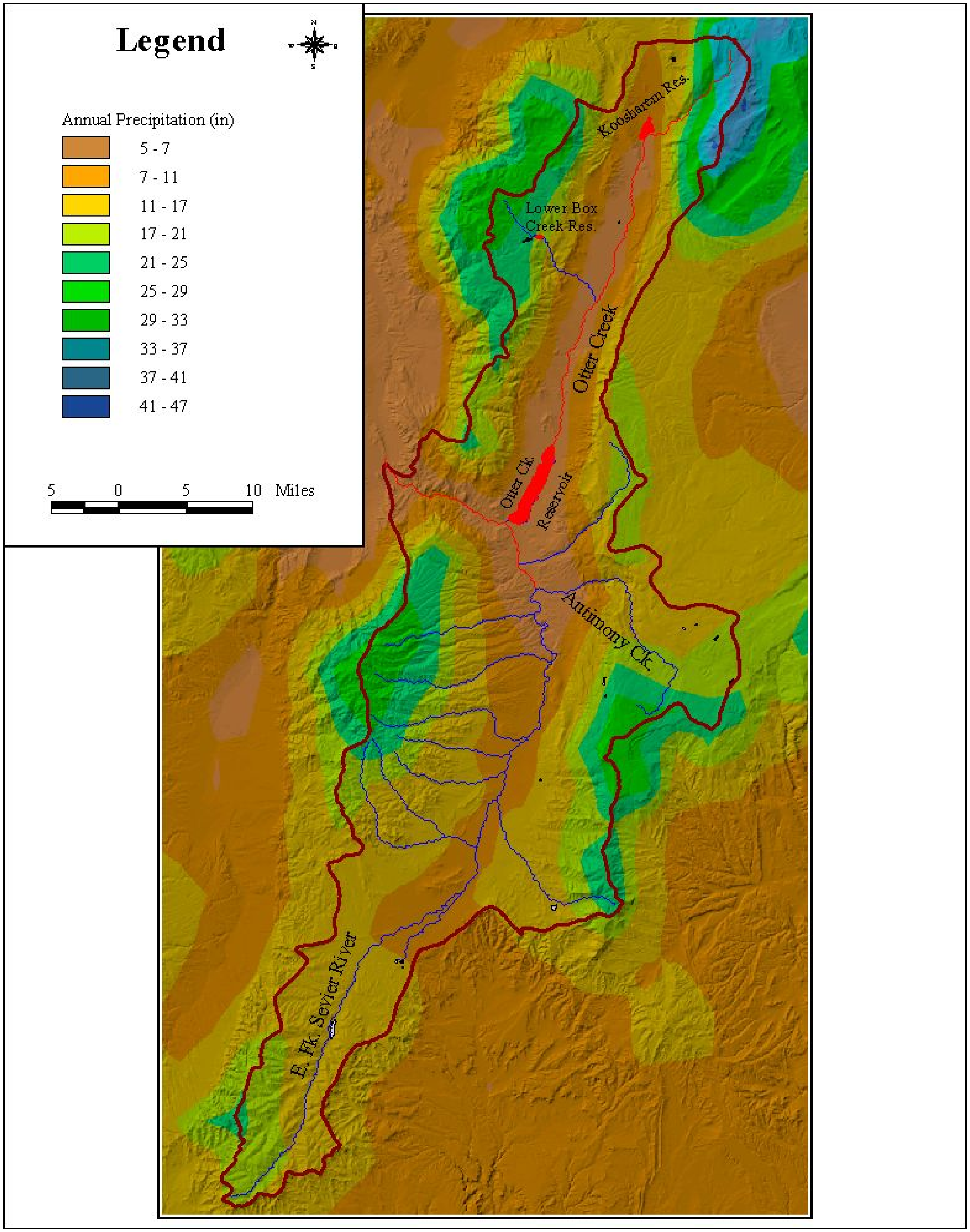

Figure 2.4. Average annual precipitation in the TMDL study area.

Detailed climatic data are available from the Western Regional Climate Center website for 4 locations within the study area: Koosharem, Angle, Antimony, and Bryce Canyon Airport (http://www.wrcc.dri.edu/summary/listut.html). These stations are representative of the valley areas. They are located in valley bottoms along Otter Creek, Otter Creek Reservoir, and the East Fork. Mean annual temperature for these stations ranges from 40°F at Bryce Canyon Airport to 45°F at Antimony and Angle and mean annual precipitation from 5 inches at Antimony to 12 inches at Bryce Canyon Airport. January is the coldest month with average lows ranging from 5°F at Bryce Canyon Airport to 10°F at Antimony and Koosharem and average highs ranging from 35°F at Bryce Canyon Airport to 42°F at Antimony. July is the warmest month with average lows ranging from 44°F at Bryce Canyon Airport to 48°F at Antimony and average highs ranging from 80°F at Bryce Canyon Airport to 86°F at Angle. The extreme minimum recorded temperature was –32°F at Koosharem, Angle, and Bryce Canyon Airport. The extreme maximum recorded temperature was 102 °F at Angle.

2.3 GEOLOGY/SOILS

The study area is located within the southeast corner of the Great Basin Region, characterized by north-south-trending fault-controlled mountain ranges and broad valleys. The Otter Creek and East Fork drainages are bounded by the Sevier and Paunsaugunt Plateaus on the west, the Fishlake Plateau on the northeast, and the Awapa and Aquarius Plateaus and Escalante Mountains on the east. Otter Creek originates at approximately 10,300 feet on the Fishlake Plateau and the East Fork Sevier River at approximately 9,000 feet at the south end of the Paunsaugunt Plateau. Elevation in the watershed ranges from 5,975 feet (1,821 m) at the confluence of the East Fork with the Sevier River, south of Piute Reservoir, to 11,633 feet (3,546 m) at the highest point on Fish Lake Hightop Plateau, in the northeast corner of the study area.

Most of the Otter Creek drainage consists of Tertiary volcanic rocks (extrusive igneous rocks), primarily from the Oligocene and Miocene. The East Fork drainage includes a mix of Tertiary volcanic rocks, primarily from the Miocene, and Tertiary sedimentary rocks (limestone and sandstone), primarily the colorful Claron Formation from the Paleocene. The Sevier Plateau is composed mainly of volcanic rocks while the Paunsaugunt Plateau is composed mainly of sedimentary rocks. Spectacular rock formations, resulting from erosion of the Claron Formation, occur along the edges of the Paunsaugunt Plateau and border the TMDL study area, including the Pink Cliffs in Bryce Canyon to the east and the Sunset Cliffs to the west. Unconsolidated Quaternary surface deposits (alluvium and colluvium) are found on valley floors in Johns Valley, Grass Valley, and Plateau Valley, and consolidated sedimentary rocks from the Cretaceous are found along the East Fork above Tropic Reservoir (Hintze et al. 2000).

Soils within the study area consist predominantly of loams in valley bottoms along streams (loam, silt loam, sandy loam, clay loam), grading to very gravelly and cobbly loams in foothills and lower mountains, then back to loams at higher elevations in the mountains. Figure 2.5 shows STATSGO soil mapping units in the Study area and Table 2.1 provides the soil group names corresponding to those mapping units. Most of these soils are well-drained. The soil types in the study area formed in parent material derived from the surrounding volcanic and sedimentary rocks (Swenson and Bayer, 1990). Climatic factors, topography, and vegetation also influenced the formation of these soils.

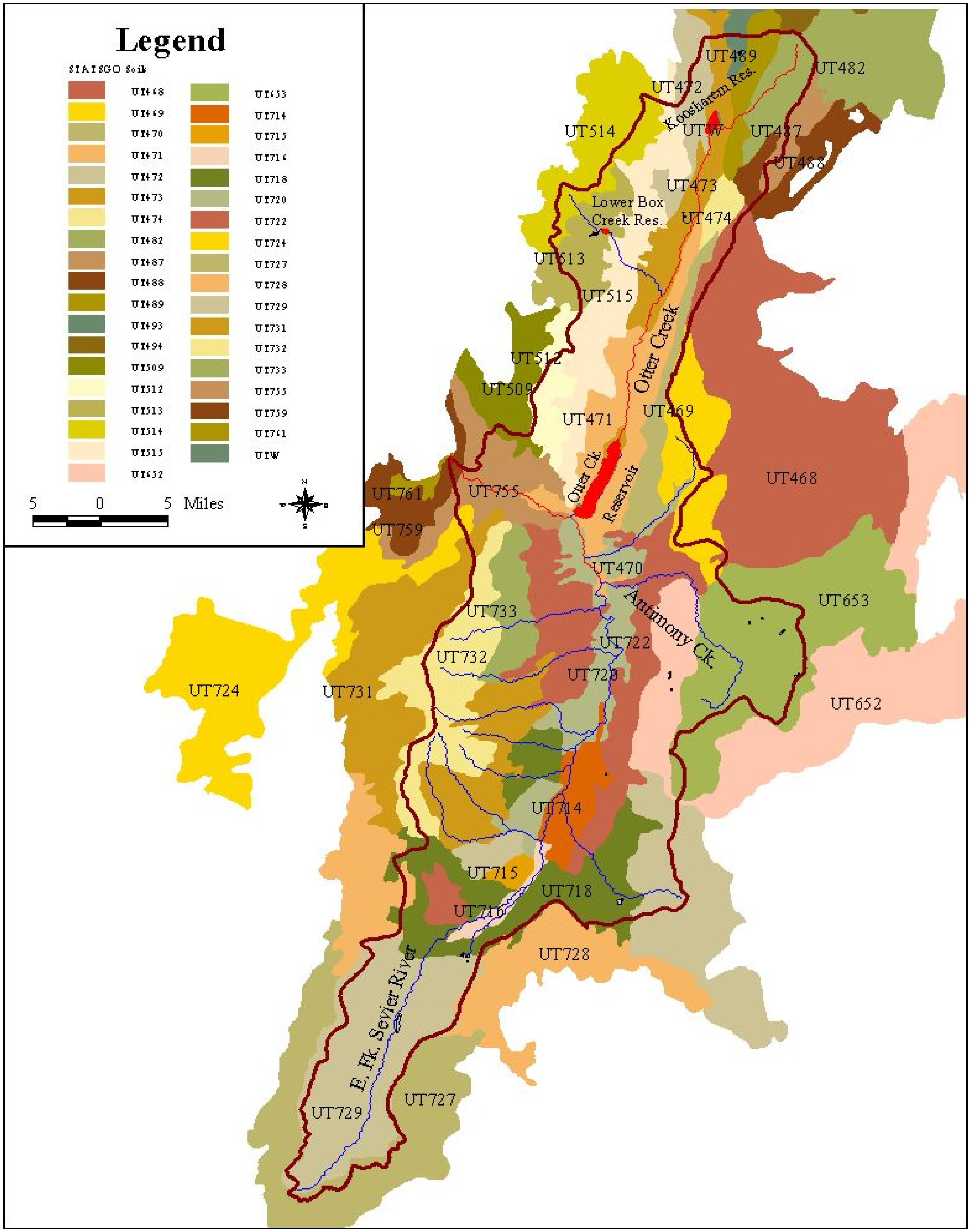

Figure 2.5. STATSGO Soils map of the TMDL study area. Descriptions of soil polygons are provided in Table 2.1 .

Table 2.1. STATSGO map unit numbers and soil group names for the Otter Creek and East Fork Sevier watersheds.

Map Unit	Soil Group Name
UT468	Forsey-Faim-Parkay
UT469	Parkay-Faim-Forsey
UT470	Dune Land-Bushvalley
UT471	Eldgin-Handy
UT472	Vicking-Watkins Ridge-Henefer
UT473	Krueger-Dacore-Haulings
UT474	Tolman Family-Circleville-Panguitch
UT482	Condie-Hoosan-Elwood
UT487	Scandard-Rogert Family-Elwood
UT488	Forsey-Parkay-Granile
UT489	Hourglass-Kamack-Elwood
UT493	Carstump-Eldgin-Eoj
UT494	Sessions-Skutum-Clayburn Family
UT509	Dacore-Bowen-Ellett
UT512	Sessions-Mortenson-Kamack
UT513	Bickmore Family-Embargo-Sessions
UT514	Condie-Cebone-Pando Family
UT515	Bowen-Dacore-Agassiz
UT652	Jemez Family-Parkay Family-Tatiyee Family
UT653	Scout Family-Namon Family-Tingey
UT714	Codley-Descot-Jodero
UT715	Mikim-Henrieville-Barx
UT716	Frandsen-Playas-Codley
UT718	Showalter-Guben-Panguitch
UT720	Notter-Bruman-Tridell
UT722	Ipson-Tridell-Guben
UT724	Tolman-Comodore-Waltershow
UT727	Ruko-Rock Outcrop-Swapps
UT728	Badland-Rock Outcrop-Syrett
UT729	Pahreah-Syrett-Badland
UT731	Castino-Rock Outcrop-Circleville
UT732	Callings-Behanin-Beardall
UT733	Winnemucca-Hoodle-Castino
UT755	Hiko Peak-Rock Outcrop-Red Butte
UT759	Monroe-Medburn-Green River
UT761	Poganeab-Kirkham-Manassa
UTW	Water

Five climatic zones, with associated soil characteristics, can be defined within the Sevier River Basin: high mountains, mountains, uplands, semi-desert, and desert (Utah Board of Water Resources 1999, State of Utah 2003). Mountain and high mountain soils are found on mountain slopes and in mountain valleys. These soils are highly developed, with organically enriched mollic horizons and a pH lower than 8 (6.0-7.5 for high mountain soils, 7.0-8.0 for mountain soils), due to higher precipitation levels that leach calcium carbonate from soil horizons. These two zones are used mostly for rangeland and timber production. Upland soils are found on alluvial fans and hills. They have moderate development with minimally expressed mollic horizons and a pH of 7.5 to 8 that is also influenced by leaching from precipitation. Most of this zone is used for rangeland, with a small amount of cropland. Semidesert soils are usually found in alluvial deposits and lake sediments. They are deep, with very little development and a pH higher than 8. Soils of this type exhibit subsurface accumulation of calcium carbonates and are found in cropland areas. Desert soils do not occur within the TMDL study area.

2.4 LAND USE / LAND OWNERSHIP

Land use in the TMDL study area is mostly comprised of forest and rangeland with some areas of agriculture associated with lower elevation areas. Table 2.2 and Figure 2.6 indicate the percent composition of land use categories and their associated acreage. Figures 2.7 and 2.8 illustrate the geographical distribution of these land use categories. A detailed description of how land use categories were developed is provided in the Appendix A – Modeling to this report. The agricultural industry in the study area centers on the raising of livestock, due to the short growing season which limits the growth of many commercial crops. In cultivated areas, the main crops are hay, alfalfa and small grains, used to feed livestock during the winter.

Table 2.2. Land use distribution in the Otter Creek/East Fork Sevier River watershed.

	Area		
Land Use Category	**Acres**	**Square Kilometers**	**Percent**
Urban/Residential	1,565	6.3	0.2
Forest Land	344,726	1,395	43.7
Range Land	399,341	1,616	50.6
Irrigated Agriculture	20,645	83.5	2.6
Non-Irrigated Agriculture	495	2.0	0.1
Animal Feeding Operations	127	0.5	0.02
Wetlands	338	1.4	0.04
Barren	20,851	84.4	2.6
Water	1,442	5.8	0.2
Total	789,531	3,195	100

Source: See Appendix A – Modeling for a description of the methods used to create the "Existing Conditions" land use dataset for the Otter Creek/East Fork Sevier River Watershed.

Figure 2.6 indicates that land use in the Otter Creek and East Fork Sevier River watersheds primarily consists of range land (50.6 %) and forest land (43.7 %), with less than 10 percent of the watershed area made up of agricultural, urban/residential, and other land use categories. This land use distribution is consistent with the land ownership in the watershed (Table 2.3, Figure 2.9 and Figure 2.10), which is primarily made up of NFS land (58.2 %), BLM (18.7 %), and State lands (10.5 %), with smaller areas of private land (10.1 %) that are primarily associated with the low-lying areas near existing water courses.

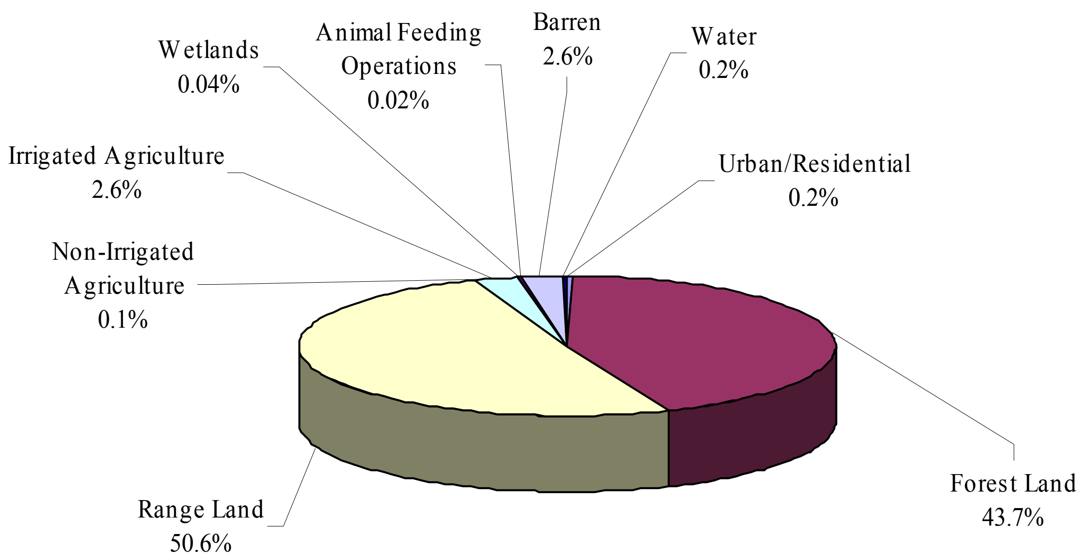

Figure 2.6. Land use distribution in the Otter Creek/East Fork Sevier River watershed.

Approximately 80 percent of land within the study area is federally owned, including 58 percent NFS land (parts of the Fishlake and Dixie National Forests), 19 percent Bureau of Land Management (BLM) land, 1 percent National Park land (part of Bryce Canyon National Park), and 1 percent Bankhead-Jones land (Figure 2.9). The Bankhead-Jones Farm Tenant Act of 1937 required the Secretary of Agriculture to develop a program of land conservation and utilization to correct maladjustments in land use. It authorized the federal government to acquire damaged land for rehabilitation purposes. Bankhead-Jones land within the project area is managed by the Forest Service. An additional 10 percent of the land is state-owned and 10 percent is private. A Native American reservation located near Koosharem Reservoir covers approximately 0.1 percent of the study area.

Table 2.3. Land ownership in the Otter Creek/East Fork Sevier River watershed.

	Area		
Ownership Category	**Acres**	**Square Kilometers**	**Percent**
BLM	147,785	598.1	18.7
Bankhead Jones	8,094	32.8	1.0
Forest Service	459,694	1860.3	58.2
Intermittent Water	42	0.2	0.01
National Park	7,933	32.1	1.0
Native American Reservation	669	2.7	0.1
Private	79,461	321.6	10.1
State	82,553	334.1	10.5
Water	3,293	13.3	0.4
Total	789,524	3,195	100

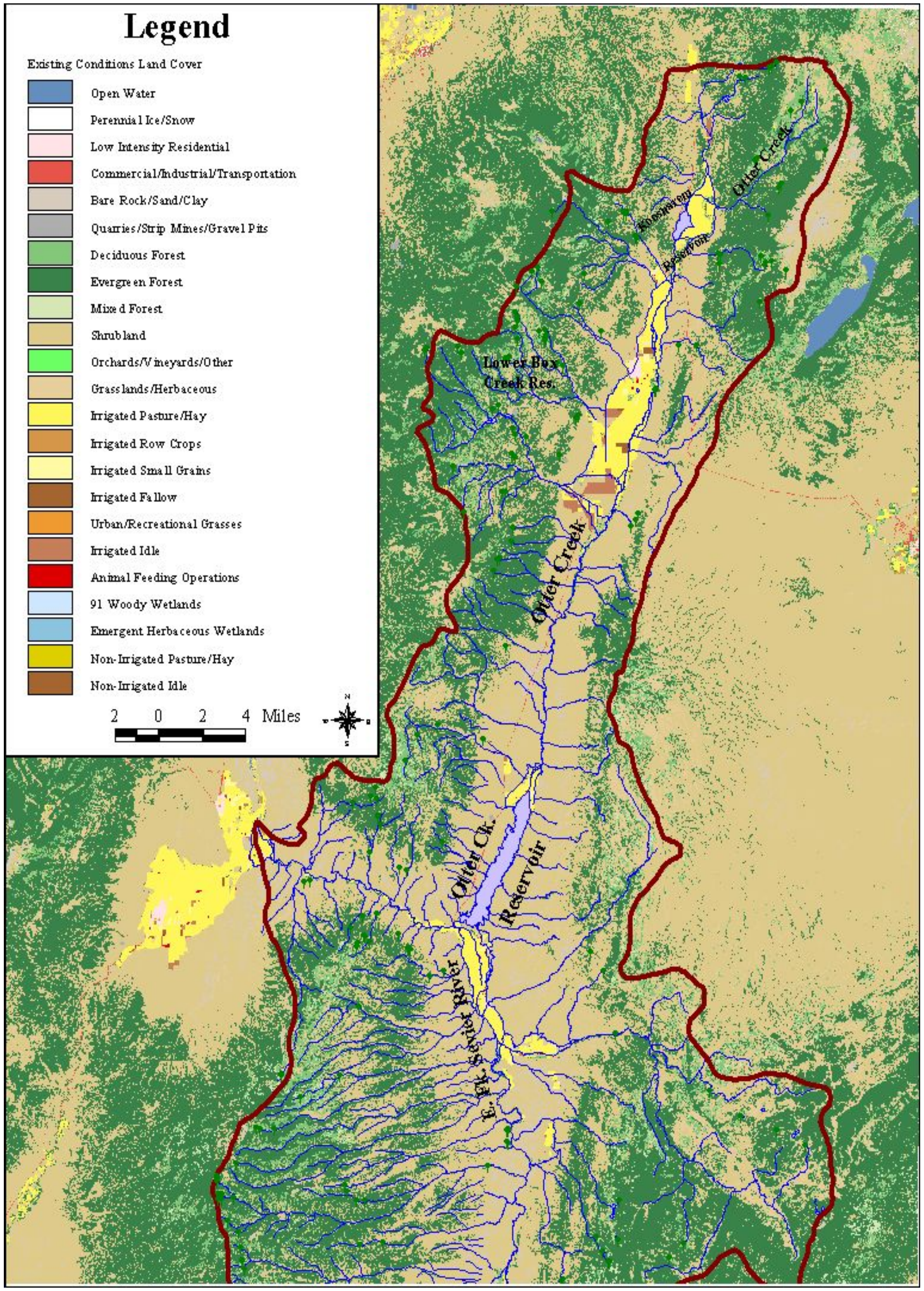

Figure 2.7. Existing land use / land cover conditions within the Otter Creek watershed.

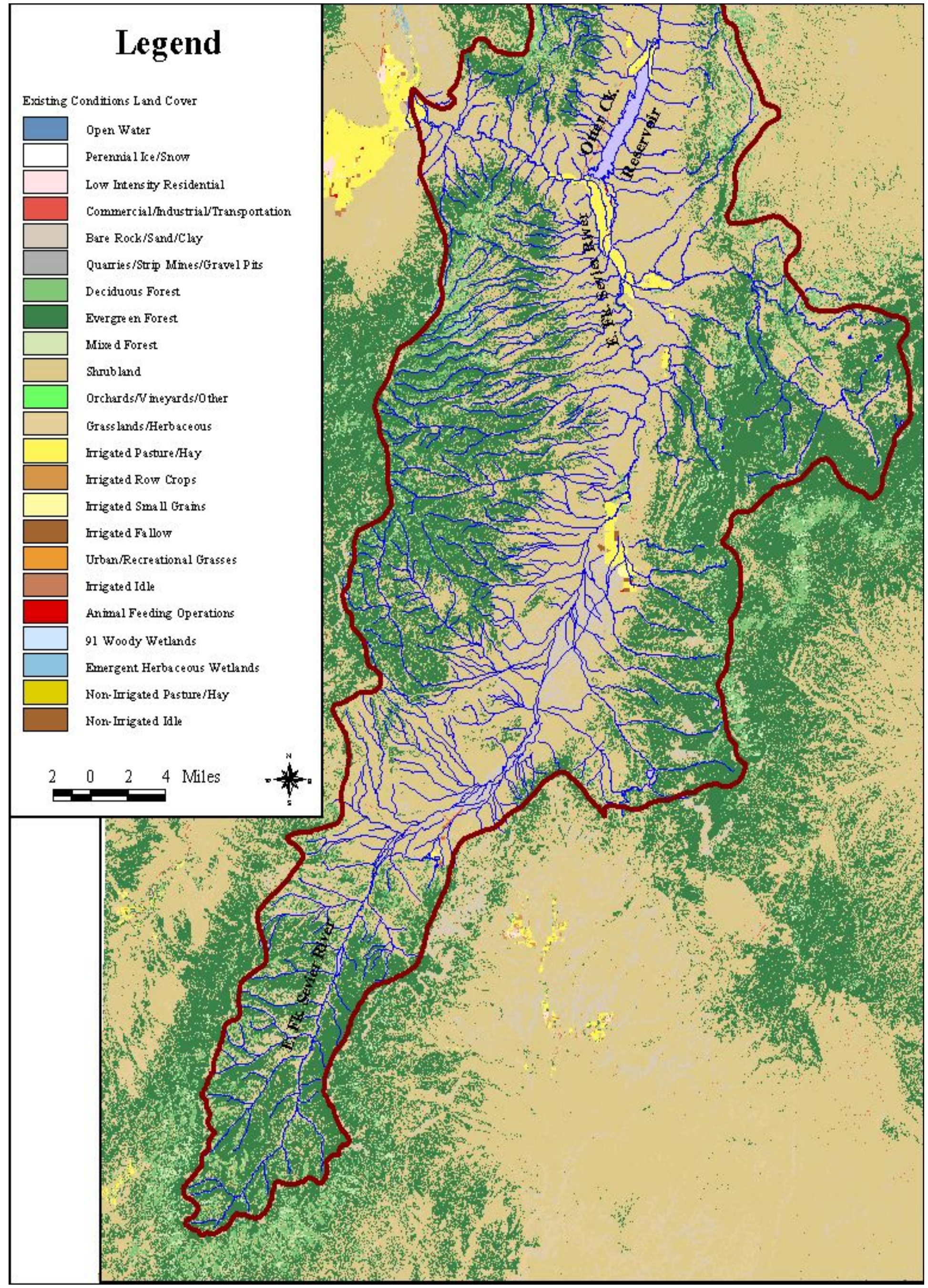

Figure 2.8. Existing land use / land cover conditions within the East Fork Sevier River watershed.

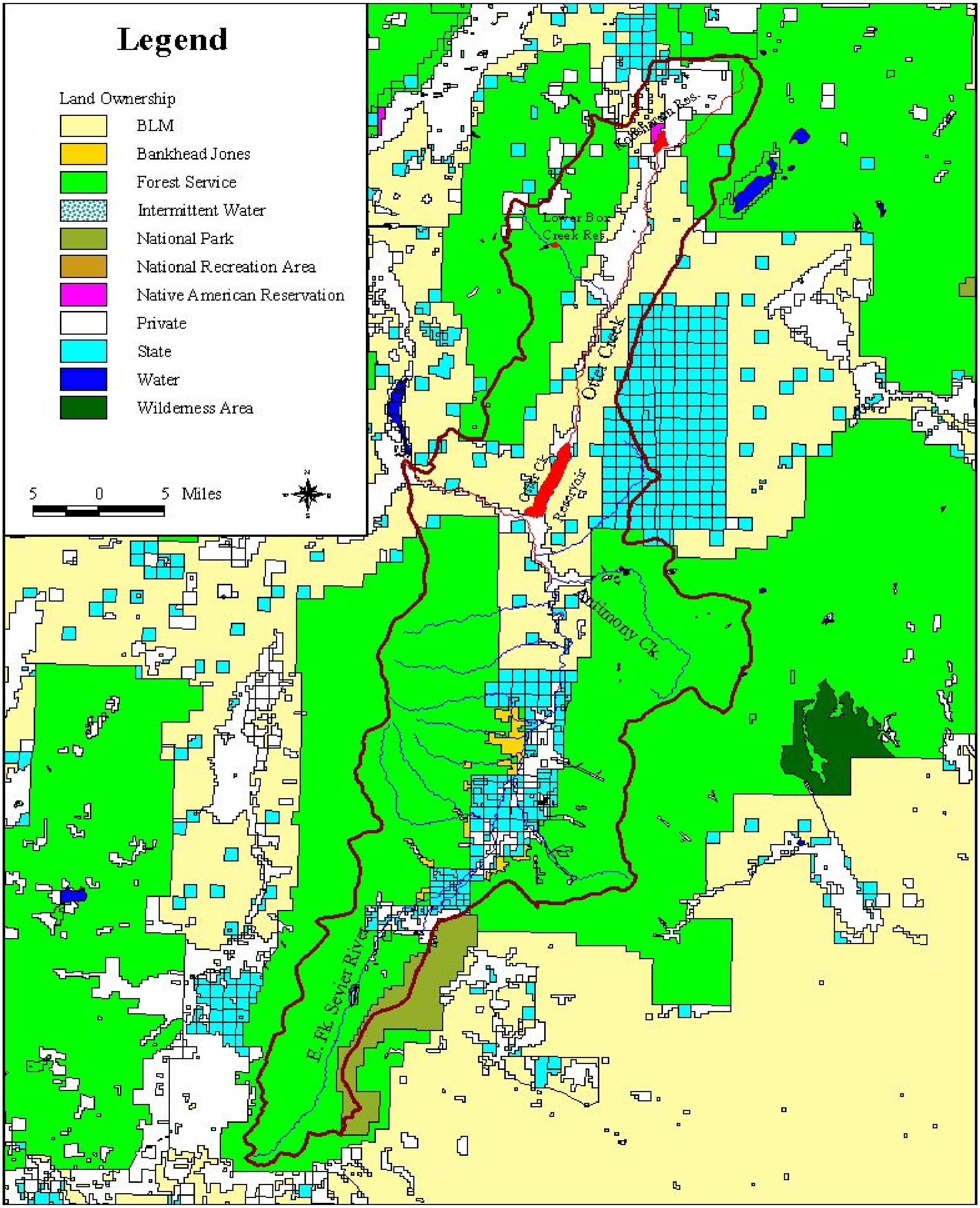

Figure 2.9. Land ownership within the TMDL study area.

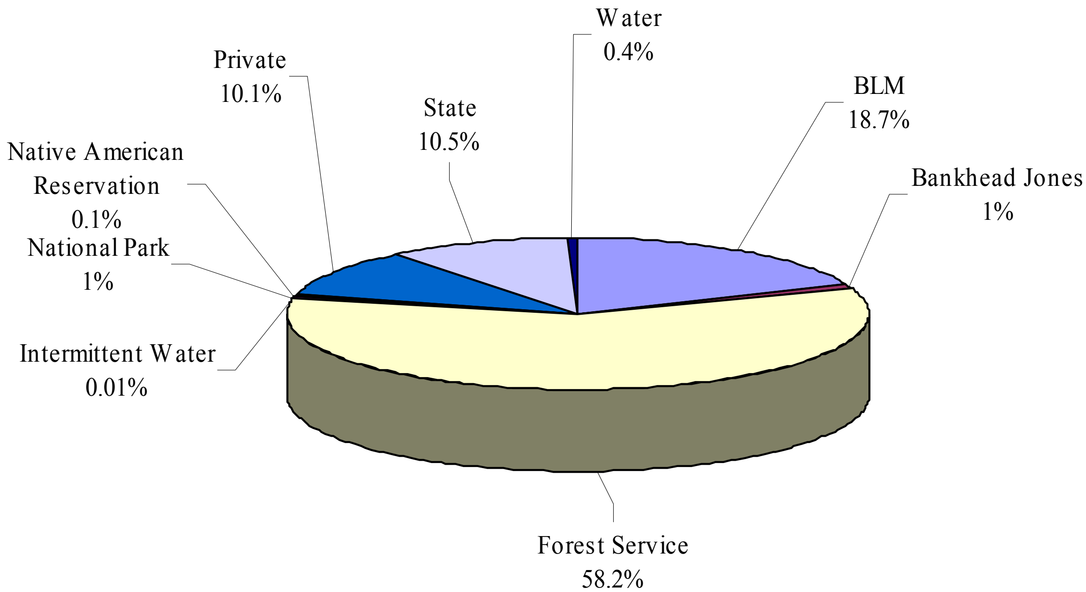

Figure 2.10. Land ownership in the Otter Creek/East Fork Sevier River watershed.

Recreational use of the watershed has been steadily increasing. Many remote areas that received very little use in the past are now being accessed by ATVs. Dispersed camping occurs throughout the watershed. Visitation rates at Bryce Canyon National Park are exceeding 1.5 million visitors per year. Other uses of the watershed include timber production, mining, and wildlife habitat. Additional information is provided below detailing land use and land cover within the East Fork and Otter Creek watersheds as lands immediately surrounding Otter Creek Reservoir.

2.4.1 East Fork

The upper portion of the East Fork drainage is mostly forested and includes areas of high recreational use, such as Bryce Canyon, Tropic Reservoir, Kings Creek Campground, and the East Fork ATV trail. At higher elevations, the forest consists mostly of mixed conifers. Ponderosa pine dominates at lower elevations, between Tropic Reservoir and Sevier Valley. Sagebrush and grasslands are also present. Most of the land is federally owned and part of the Dixie National Forest, with a belt of land along the eastern edge belonging to Bryce Canyon National Park. A few tracts of private land are also located adjacent to the East Fork below Tropic Reservoir.

Sevier Valley and Johns Valley include a mix of private, state, and federal lands. The mountain areas to the east and west of Johns Valley are part of the Dixie National Forest and include large stands of aspen, ponderosa pine, and mixed conifers. Most of the Bankhead-Jones land in the study area is located along the edges of Johns Valley, bordering the Dixie National Forest. State and private lands are found primarily at the bottom of Sevier and Johns Valleys, with some BLM land located at the north end of Johns Valley, around Black Canyon.

Grasslands, sagebrush, and pinyon-juniper are the dominant vegetation types in Sevier Valley and Johns Valley, with a small amount of agricultural lands in Johns Valley comprised of pastures, alfalfa, grass hay, and small grains. This part of the watershed is mostly used for livestock grazing. The lack of water and short growing season make the area unsuitable for most crops.

Some side-drainages of the East Fork receive heavy recreational use, particularly during hunting season. The recent paving of Highway 22 has increased traffic through John's Valley.

A shift in livestock use from sheep to cattle and better grazing management practices may help decrease upland erosion within the East Fork watershed. However, cattle access to riparian areas is still a problem and new issues are surfacing with the increased recreational use of the watershed. Road building and increased traffic on existing roads along stream channels, illegal off-road access by ATVs, and dispersed camping are further impacting vegetation, compacting soils, and causing increased sediment runoff. Improper waste management at developed and dispersed camping areas negatively impact water quality. Increased developments on private lands near Bryce Canyon National Park create a need for better waste disposal and long-term sewage management.

Located at the north end of Johns Valley, Black Canyon is a narrow rock canyon that provides valuable habitat for fish and waterfowl species, including trophy brown trout, in spite of historic impacts from overgrazing and road development. In an effort to extend conservation efforts, the Utah Division of Wildlife Resources (DWR) incorporated 600 acres of land into the Black Canyon Wildlife Management Area during the 1980s. As a result of this and additional efforts by the BLM and private landowners, wildlife habitat in the area showed steady improvement during the past several decades. However, the Sanford Fire has resulted in heavy impacts to game fish populations that were present in Deep Creek and the East Fork near Black Canyon.

The lower portion of the East Fork drainage includes the rural farming communities of Antimony and Kingston. Most of the land directly along the lower East Fork as well as the lower reaches of Antimony Creek is privately owned and used for agriculture. Pastures, alfalfa, and grass hay are the main crops, along with a few fields of small grain crops. Canals diverting water from the East Fork and Antimony Creek provide irrigation water to these lands. Grazing has been a major use of the area ever since the pioneers first settled along the East Fork. Although pasture management has improved over time, better practices are still needed to protect riparian areas and maintain vegetation diversity.

Private lands along the East Fork are bordered by BLM land intermixed with a few tracts of State land. Pinyon-juniper is the dominant vegetation cover in the foothills bordering this area. The higher mountains south of Kingston Canyon and most of the Antimony Creek watershed are part of the Dixie National Forest, whereas the Forshea Draw/Dry Wash drainage at the south end of Parker Mountain is mostly State owned. Dominant vegetation in the mountain areas includes conifers (mostly spruce-fir), aspen, sagebrush, and grasslands. These areas are used primarily for grazing and recreation. Antimony Creek and Pole Canyon support important wild trout fisheries. Due to fire suppression and historic overgrazing, pinyon-juniper cover has been encroaching on sagebrush grasslands. This has decreased the grass/forb understory and exposed greater amounts of soil surface, resulting in increased upland erosion. More recently, increased ATV use and dispersed camping have also created erosion and sediment transport in upland areas as well as degradation of riparian areas and aquatic habitats. Improper waste disposal is also an issue.

Below Otter Creek Reservoir, the narrow confines of Kingston Canyon inhibit agricultural development along the East Fork. The canyon primarily supports good riparian vegetation and wetland habitat, although streambank erosion is a concern in some areas. Highway 62, which runs parallel to the East Fork between Kingston and Otter Creek Reservoir, confining the stream channel in many areas. This highway receives a high level of recreational traffic during the summer season.

2.4.2 Otter Creek

The upper portion of the Otter Creek watershed primarily includes a mix of private, Forest Service, and BLM lands. Most of Plateau Valley and Boobe Hole Mountain are privately owned. The area to the west of Plateau Valley includes a mix of BLM and private lands, with some state lands to the northwest as well as Native American trust lands located near Koosharem Reservoir. The high mountain areas of the Fishlake Plateau in the northeastern portion of the watershed are part of the Fishlake National Forest, including the headwaters of Otter Creek.

Most of Plateau Valley consists of rangelands, with sagebrush grasslands covering the west side of the valley and pinyon-juniper covering the east side foothills. Agricultural lands supporting pastures are found in the lower parts of Plateau Valley, to the east and northeast of Koosharem Reservoir. Boobe Hole Mountain and the Fishlake Plateau are forested and support large stands of aspen and conifers, along with some sagebrush cover near the headwaters of Otter Creek.

From Koosharem Reservoir to Greenwich, a wide band of private agricultural land occupies the whole width of Grass Valley, between the Otter Creek stream channel and the Koosharem Canal. This band of private land becomes much narrower below Greenwich, where pinyon-juniper cover replaces agricultural lands on the valley floor. Most of this land is owned by the BLM, with a few tracts of State lands. The foothills on either side of Grass Valley, throughout most of its length, consist of BLM land covered with pinyon-juniper and occasional sagebrush. The mountains on the west side of the watershed are part of the Fishlake National Forest. The area is utilized for grazing purposes during the summer and fall seasons.

A small, open-pit clay mine is also located in the mountains west of Grass Valley, just below Lower Box Creek Reservoir. This mine is the only active mine site identified to date within the TMDL study area. The mine is locally known as the Koosharem Clay Pit and has been periodically used during the past several decades (Kunzler 2004). Active mining began during 1990 and continues on an infrequent basis. In 1999 the mine was expanded in order to increase production. At the present time the mine is not officially registered with the Utah Division of Oil, Gas, and Mining (DOGM). Operational procedures are currently being reviewed by DOGM (Kunzler 2004). Parker Mountain is located on the southeast side of the Grass Valley and is mostly State owned land. These mountain areas are covered with conifers, aspen, and sagebrush grasslands and utilized for grazing purposes.

The Otter Creek watershed includes four rural communities: Koosharem, Burrville, Greenwich, and Angle. The total population in the watershed is approximately 450 people. The major source of income in these communities is livestock production although many families obtain additional income from jobs in larger communities located nearby. Agricultural development in Grass Valley is concentrated within a one to four mile strip along Otter Creek for approximately 10 miles. The majority of this agricultural land consists of pastures. Alfalfa, grass hay, and small grains are also grown and used to support livestock operations. There are numerous irrigation canals and ditches in this area, in addition to tributaries with periodic flows that are often the result of irrigation return flows.

2.4.3 Otter Creek Reservoir

The shoreline of Otter Creek Reservoir is administered by the State of Utah, the BLM, and the Otter Creek Reservoir Company. The vegetation around the reservoir consists predominantly of pinyon-juniper, with agricultural lands at the northern tip of the reservoir being used to grow alfalfa as well as for pasture grazing. The main purpose of the reservoir is to supply irrigation water to the Sevier River Basin but it is also popular for recreation, including picnicking, camping, boating, and fishing. Otter Creek State Park is located at the south end of the reservoir and includes a campground, bathrooms, showers, drinking water, utility hookups, and a boat ramp (Merritt et al. 1996).

2.5 FISHERIES

Various native and non-native fish species are present in the TMDL study area. These include brown trout (*Salmo trutta*), rainbow trout (*Onchorycnchus mykiss*), cutthroat trout (*Oncorhynchus clarki*), brook trout (*Salvelinus fontinalis*), redside shiner (*Richardsonius balteatus*), leatherside chub (*Gila copey*), speckled dace (*Rhinichthys osculus*), mountain sucker (*Catostomus platyrhynchus*), Utah sucker (*Catostomus ardens*), Utah chub (*Gila atraria*), and mottled sculpin (*Cottus bairdi*).

Current fish density or relative abundance data is limited. Fish management plans for the impeded water bodies range from "Basic Yield" fisheries with annual stocking of fingerlings to "Wild" fishery maintained by natural recruitment with no supplemental stocking. Table 2.4 summarizes the available fisheries information.

Table 2.4. Relative abundance and management of fish species in the Echo TMDL study area.

Impaired Water body	Fish species	Density / Relative Abundance	Management / Comments
E. Fork Sevier River (From Antimony Cr. confluence to Sevier River)	Brown trout Rainbow trout Cutthroat trout Redside shiner Leatherside chub Speckled dace Mountain sucker Utah sucker Utah chub Mottled sculpin	Little data is available for the section from Antimony confluence to outlet of Otter Cr. Res. Density of trout in this section is suspected to be low due to seasonal dewatering below the Antimony diversion. Biomass estimates of trout for the section between the Otter Creek outlet to Kingston Diversion range from 33-98 lbs. per acre, with brown trout the predominant species of sport fish. Non-game fish species listed are abundant except for mottled sculpin. Trout densities are assumed to be low in the section between the Kingston Diversion and the Sevier River.	The sport fishery in this section is managed as a “Basic Yield” fishery with annual stocking of fingerling brown trout and cutthroat trout. In addition, rainbow trout migrate into this section from Otter Creek Reservoir. Management efforts include obtaining public access and improving/restoring riparian and aquatic habitats. The Division has recently acquired property in Kingston Canyon and has developed parking areas and access points. A multi-year stream restoration and wetland development project on the property will begin this fall. In addition to improving habitat for sport fish and increasing recreational opportunities, objectives include maintaining or improving habitat for non-game fish species, particularly leatherside chub that is listed as a Species of Concern on the Utah Sensitive Species List. Efforts are also underway to obtain conservation easements for public access and habitat improvement from other private landowners in Kingston Canyon. The management of water levels and releases from Otter Creek Reservoir can affect aquatic habitat and the fishery in the East Fork of the Sevier River downstream from the dam. Impacts are more pronounced during drought periods. Flows are typically reduced during late fall and winter months. Freezing and ice formation during harsh winters further limit habitat. Winter habitat is considered one of the limiting factors for the fishery in this stream section. In addition, during dry years the reservoir reaches almost dry levels that lead to increases in silt and turbidity downstream.
Otter Creek, headwaters to Koosharem Reservoir	Rainbow trout Cutthroat trout Brook trout Speckled dace Mountain sucker	There is no recent data for populations above Koosharem Reservoir. There is knowledge of a relatively dense population of small trout in this section, maintained by natural reproduction.	The sport fishery in this section is managed as a “Wild” fishery. Trout are maintained by natural recruitment with no supplemental stocking.
Otter Creek, Koosharem Reservoir to Angle Diversion	Brown trout Redside shiner Leatherside chub Utah chub Speckled dace Mountain sucker	Biomass estimates of brown trout have ranged from near 0 to 125 lbs. per acre. Utah chub and leatherside chub are abundant.	This section is managed as a “Basic Yield” fishery, with annual stocking of 5,000 fingerling brown trout. Recent surveys indicate that high summertime water temperatures may be a limiting factor for trout in this area.
Koosharem Reservoir	Rainbow trout Cutthroat trout Utah chub Redside shiner	No density estimates. Stocked annually with approximately 23,000 trout.	The reservoir is managed as a “Basic Yield” fishery, and is stocked annually with 13,000 6-inch cutthroat trout and 10,000 rainbow trout. It also receives a limited amount of natural recruitment from tributaries. Annual drawdown and competition between Utah chubs and stocked trout limits the sport fishery here at times. The reservoir has been treated with rotenone at varying intervals to reduce the number of Utah chubs.

Table 2.4. (cont'd) Relative abundance and management of fish species in the Echo TMDL study area.

Impaired Water body	Fish species	Density / Relative Abundance	Management / Comments
Lower Box Creek Reservoir	Rainbow trout Brook trout Redside shiner	No density estimates. Stocked annually with 3,500 trout.	The reservoir is managed as an "Intensive Yield" fishery, and is stocked annually with 2,000 10-inch rainbow trout and 1,500 3-inch brook trout. Annual drawdown and competition between redside shiners and stocked trout limits the sport fishery here at times.
Otter Creek Reservoir	Rainbow trout Cutthroat trout Smallmouth bass Utah chub	No density estimates. Stocked annually with 220,000 trout.	This reservoir is managed as a "Basic Yield" fishery, and stocked annually with 200,000 7-inch rainbow trout and 20,000 2-inch Bear Lake cutthroat trout. It has also been stocked annually for the past 4 yrs with adult and/or smallmouth bass fry in an effort to establish a self-sustaining population of that species. Otter Creek Reservoir is one of the most important sport fishing waters in southern Utah. The sport fishery is limited at times by drawdown, and competition between trout and Utah chubs. There is no conservation pool in the reservoir but typically, at least a small pool is left in the reservoir by the irrigation company to maintain the fishery. However, unscheduled fish kills have been experienced in Otter Creek Reservoir during drought years as a result of low reservoir levels. The reservoir has also received scheduled rotenone treatments during past years to reduce the numbers of Utah chubs. Other efforts to help control the numbers of Utah chubs include stocking Bear Lake cutthroat trout, a piscivorous strain of trout and trying to establish a population of smallmouth bass which will also feed on chubs.

Source: Utah Division of Wildlife Resources, Southern Region.

2.6 HYDROLOGY

The purpose of the hydrologic analysis provided in this section is to establish flow volumes and patterns found within the project area. This information will be used in conjunction with the water quality analysis to identify potential contamination sources and evaluate possible remediation strategies. The watershed comprising the TMDL study area incorporates the eastern portion of the Upper Sevier River watershed. It encompasses all water flowing into the East Fork Sevier River, including Otter Creek and Otter Creek Reservoir (Figure 2.11 and Figure 2.12). Relatively higher elevations are found in the north end of the watershed as compared to the south end. The average gradient for the East Fork is 37 ft/mile (0.70%) while Otter Creek maintains a slightly steeper gradient at 105 ft/mile (1.99%).

In general, the seasonal analysis of flow data in this report will be presented using box plots of the data. Figure 2.13 provides an illustration of a typical box plot. Box plots provide a means of illustrating the distribution of all data points for a particular time period or season rather than plotting or examining individual data points. Note that for all box plots contained in this report, box width corresponds to the number of observations and the shape of each box represents the distribution of the data. Note that the height of the "box" or hourglass shape indicates the inter-quartile range of the 25^{th} – 75^{th} quartiles with the middle of the box equal to the median value.

2.6.1 Irrigation

A total of 17 irrigation companies were identified within the TMDL study area (Table 2.5). Many of these organizations work closely with the owner/operators of the larger reservoirs in the study area to ensure proper delivery of water during the irrigation season. The locations of the major ditches and canals are shown in Figure 2.11 and Figure 2.12. Annual diversion amounts to canals have been estimated to be 16,000 acre-ft/yr in the Otter Creek watershed and 12,200 acre-ft/yr in the East Fork watershed (Thiros et al. 1993). The majority of canals and ditches used by irrigation companies in the TMDL study area are unlined and subject to a certain amount of seepage and loss to groundwater. Once the water is delivered to individual users, it is applied through flood irrigation or sprinkler irrigation. The majority of irrigation systems in the area rely upon pressurized irrigation systems. However, flood irrigation is typically preferred over pressurized systems on fields and pastures located near streams (Jarman 2004).

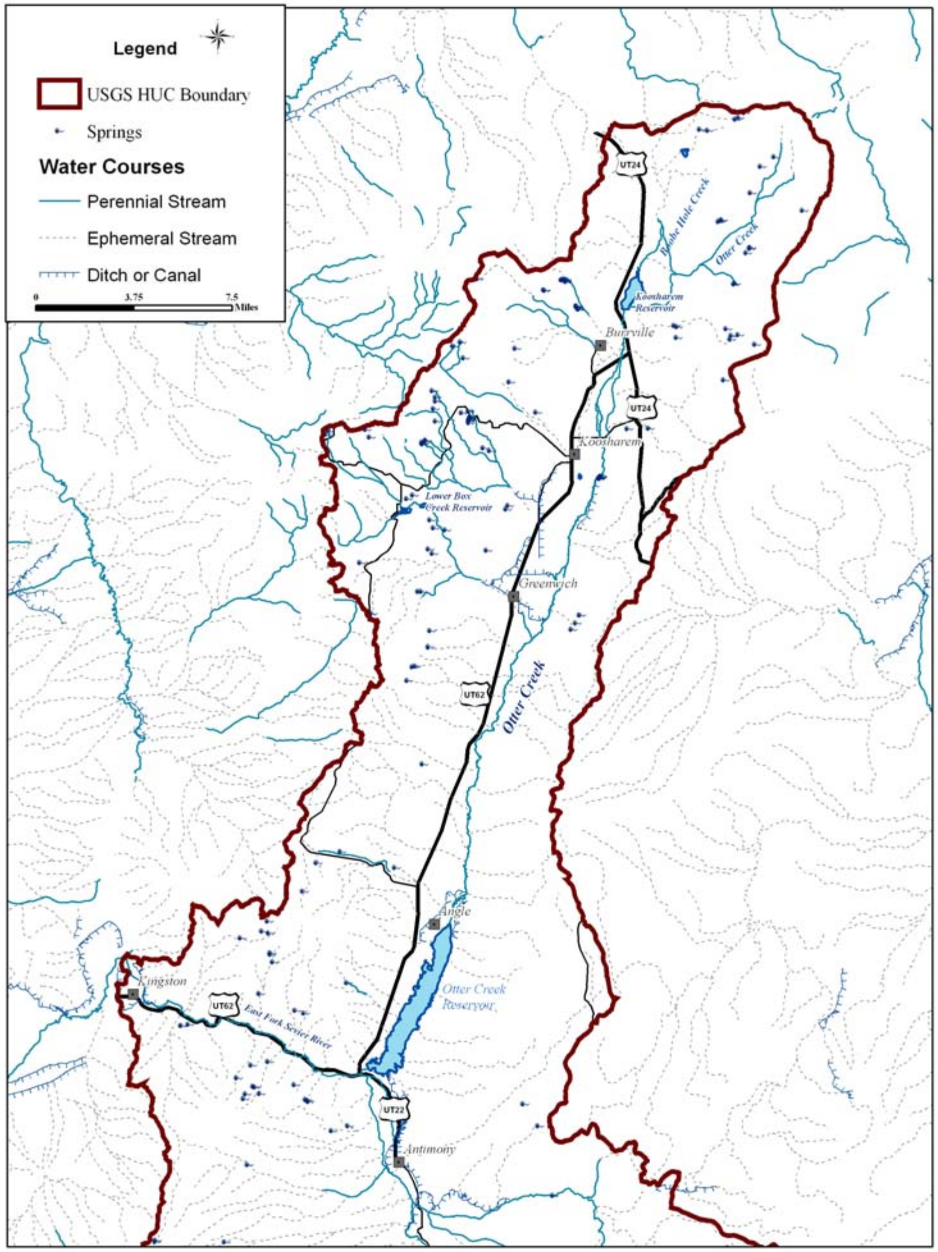

Figure 2.11. Hydrologic features located within the Otter Creek Watershed.

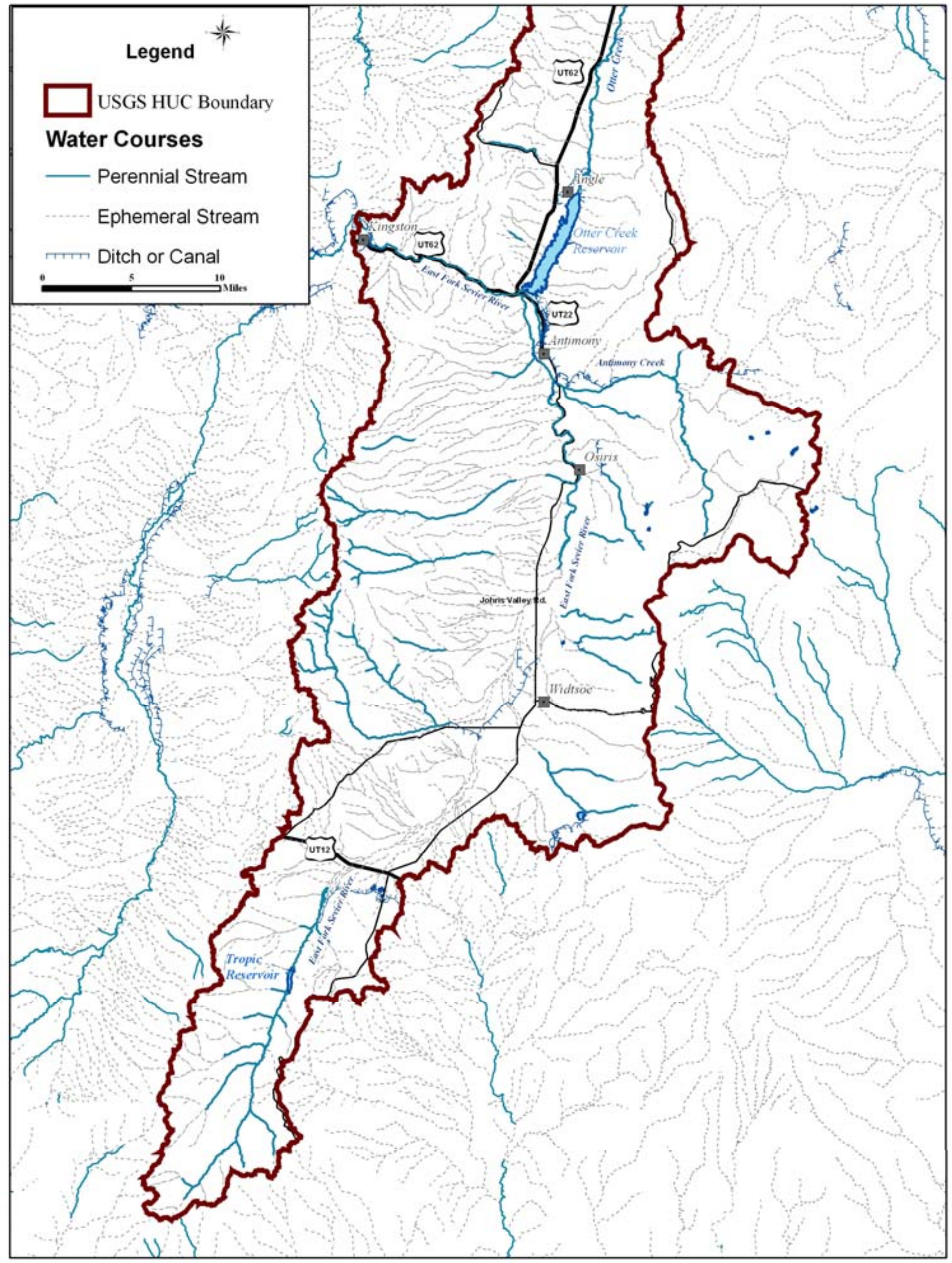

Figure 2.12. Hydrologic features located within the East Fork Sevier River watershed

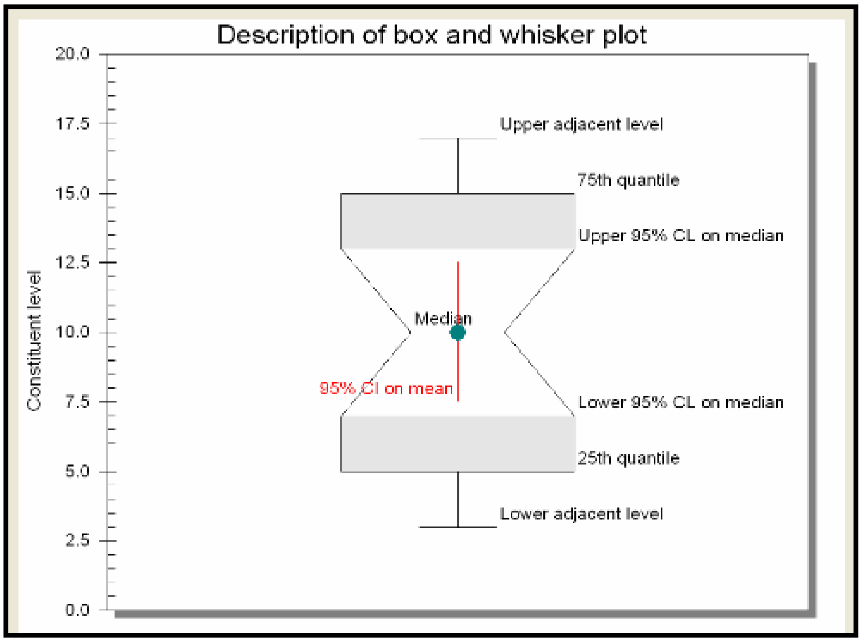

Figure 2.13. Box and whisker plot used to illustrate distribution of monthly average flow and water quality data.

Table 2.5. Irrigation companies located within the TMDL study area.	
County	**Irrigation company**
Sevier	Meridian Irrigation and Reservoir Company
	Otter Creek Reservoir Company
	Rosebud Irrigation Company
Piute	Angle Irrigation Company
	Antimony Creek Irrigation Company
	Beaver Creek Irrigation & Reservoir Company
	Beaver Creek Irrigation Company
	Burrville Irrigation Company
	Coyote & East Fork Irrigation Company
	Greenwich Creek Water Users Association
	Kingston Irrigation Company
	Koosharem Irrigation Company
Garfield	Antimony Bench Irrigation Company
	Antimony Creek (Coyote & East Fork) Irrigation Company
	Clover Flat Irrigation Co
	Coyote East Fork Irrigation Company
	Tropic & East Fork Irrigation Company (diverted Tropic)
Source: Utah Division of Water Rights.	

Water rights in the TMDL study area can be classified as primary (or streamflow) rights and storage rights. Storage rights are associated with water that is not used by direct diversion for irrigation purposes and includes winter runoff, flood events, and irrigation return flows (Otter Creek Irrigation Company 2002). The 1938 agreement to the Cox Decree provided the legal means to allow an irrigation company to store unused water at the end of an irrigation season. As a result of this agreement, water supplies are now more stable and used to support productive farmland areas during times of drought.

2.6.2 Reservoirs

The TMDL study area contains several reservoirs that are used primarily for storing water for irrigation. These reservoirs significantly influence the hydrology of downstream water bodies in terms of regulating peak runoff events and sustaining streamflow during drier parts of the year. Recreational use of the reservoirs occurs through fishing and boating activities. Table 2.6 lists some physical design characteristics for the reservoirs of interest within the study area.

Koosharem Reservoir is supported by two tributaries, including Otter Creek and Boobe Hole Creek. Figure 2.14 shows the monthly distribution of flow in Otter Creek above Koosharem Reservoir measured at USGS 10187300. No continuous streamflow data is available for Boobe Hole Creek above Koosharem Reservoir. The majority of tributary inflow to Koosharem Reservoir is provided by Otter Creek which is divided into a north ditch and a south ditch near the mouth of Daniels Canyon. Flow in the North Ditch is used completely and provides minimal return flow to Boobe Hole Creek. No irrigation diversions occur from Boobe Hole Creek (Burr 2004). A portion of the flow in the South Ditch is diverted again approximately one-mile from the east border of Koosharem Reservoir. The remaining flow in the South Ditch enters Koosharem Reservoir where it supplies water rights maintained by the Koosharem Irrigation Company and the Meridian Irrigation and Reservoir Company. The majority of storage within Koosharem Reservoir is obtained each spring by snowmelt runoff from fields surrounding the reservoir (Burr 2004). There are no diversions from tributaries to Koosharem Reservoir that send water around the reservoir.

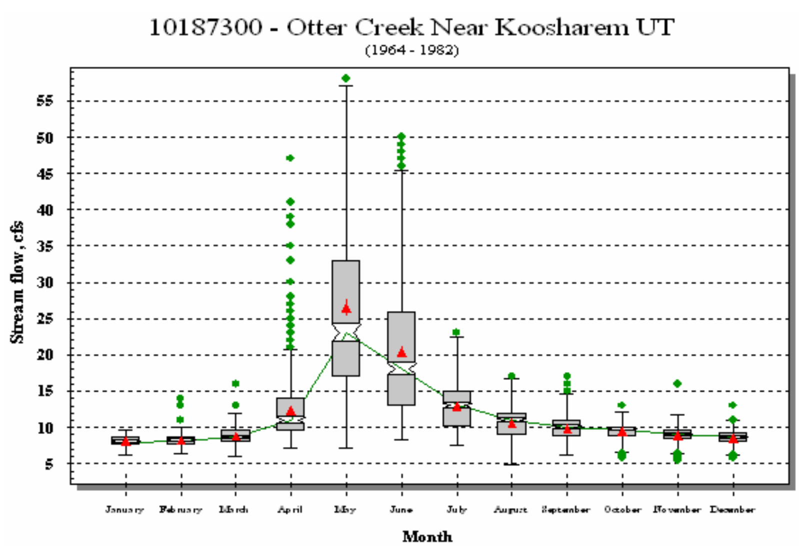

Figure 2.14. Monthly distribution of streamflow in Otter Creek above Koosharem Reservoir.

Table 2.6. Physical dimensions of selected reservoirs in the TMDL study area.		
Name	**Description**	**Units**
Koosharem Reservoir	Surface area (acres) (At spillway crest)	340
	Capacity (acre-feet) (Storage at dam crest)	7,470
	Storage at spillway crest (acre-feet)	3,858
	Spillway maximum discharge (cfs)	570
	Maximum outlet discharge (cfs)	N/A
	Drainage basin area (square miles)	63
	Crest elevation of dam (feet)	6,995
Lower Box Creek Reservoir	Surface area (acres) (At spillway crest)	21
	Capacity (acre-feet) (Storage at dam crest)	382
	Storage at spillway crest (acre-feet)	231
	Spillway maximum discharge (cfs)	460
	Maximum outlet discharge (cfs)	21
	Drainage basin area (square miles)	13
	Crest elevation of dam (feet)	8,470
Otter Creek Reservoir	Surface area (acres) (At spillway crest)	2,440
	Capacity (acre-feet) (Storage at dam crest)	71,790
	Storage at spillway crest (acre-feet)	52,660
	Spillway maximum discharge (cfs)	2,500
	Maximum outlet discharge (cfs)	670
	Drainage basin area (square miles)	364
	Crest elevation of dam (feet)	6,381
Source: Utah Division of Water Rights (2003).		

The upper reaches of Box Creek are dammed in two places to create Upper and Lower Box Creek Reservoirs, located in the mountains to the northwest of Greenwich. These reservoirs were completed in 1925 and are currently owned and operated by the Beaver Creek and Reservoir Irrigation Company. No measurements of reservoir inflow to Upper Box Creek Reservoir and Lower Box Creek Reservoir are available. The operation of these reservoirs is usually based on the amount of precipitation received during the previous winter. Water is typically released from Lower Box Creek Reservoir first. Water from the upper reservoir is then used to maintain water levels in the lower reservoir. During a typical water year, the watermaster does not allow either one of the reservoirs to drain completely (Bagley 2004).

Otter Creek Reservoir, located at the lower end of Otter Creek, stores runoff from Otter Creek as well as the East Fork and is considered to be a significant storage reservoir within the Sevier River Basin. Otter Creek Reservoir is privately owned and operated by the Otter Creek Irrigation Company. All water used by the irrigation company is administered by the Upper Sevier River Commission who delivers water to the individual irrigation companies downstream of the reservoir. Many of these companies are located outside of the TMDL study area (Otter Creek Irrigation Company 2002). The two major inflows to the reservoir are Otter Creek and the East Fork Canal, contributing roughly one-fourth and three-fourths of the total annual inflow, respectively. A minor amount of water enters the reservoir as surface runoff from the area immediately adjacent to the shoreline. Water discharged from the reservoir flows through Kingston Canyon, eventually reaching Piute Reservoir.

Tributary inflow to Otter Creek Reservoir is characterized by high flow rates during the spring season. Seasonally high flow rates in tributaries to Otter Creek Reservoir are influenced by snowmelt runoff as well as discharge from upstream storage facilities such as Tropic Reservoir. Much of these flows also transport eroded sediment and chemical elements adsorbed to the sediment (including phosphorus). Figure 2.15 shows the distribution of monthly flows to Otter Creek Reservoir from Otter Creek and the East Fork Sevier.

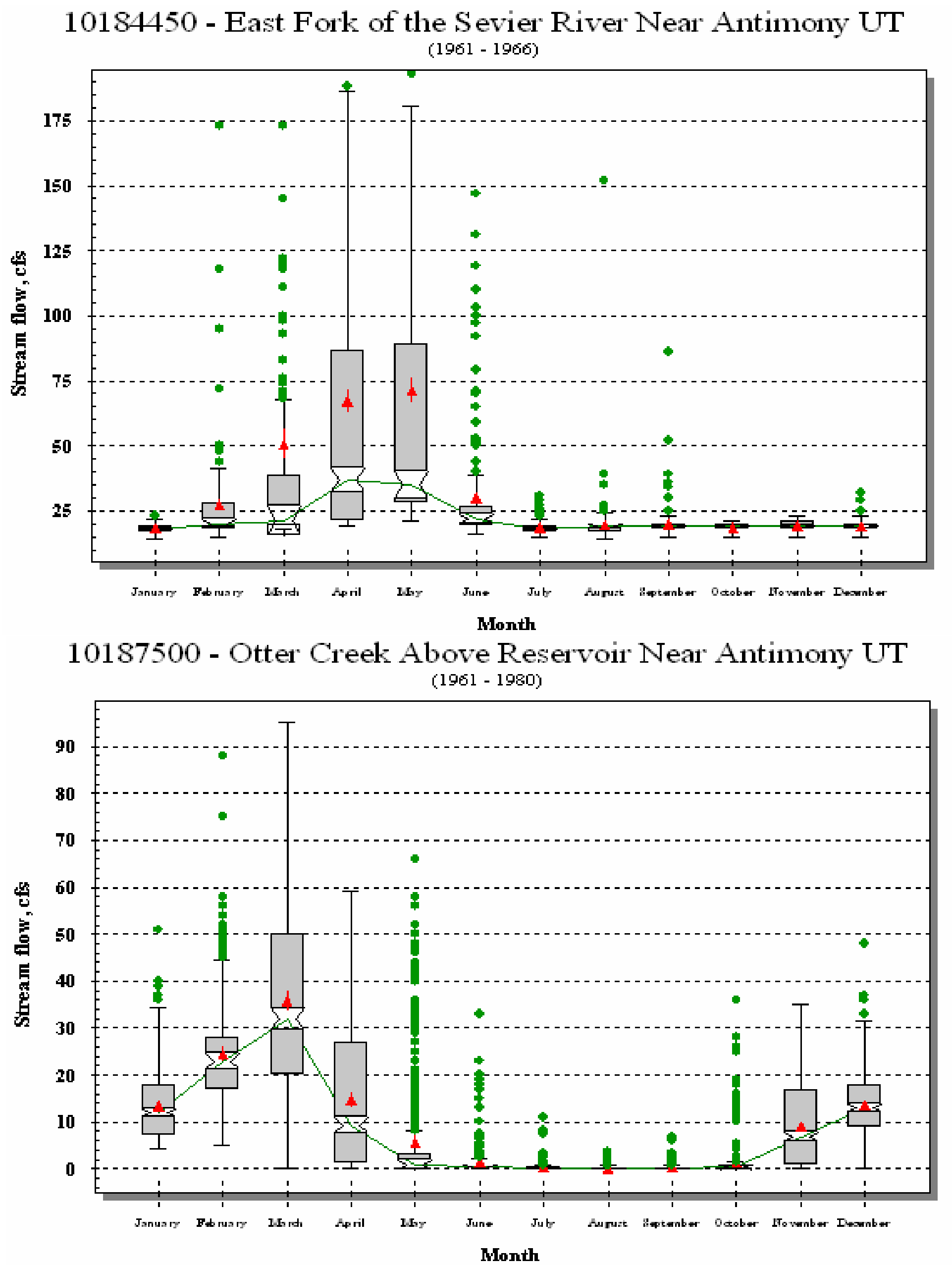

Figure 2.15. Monthly distribution of tributary inflow to Otter Creek Reservoir collected at USGS stream gage stations.

When Otter Creek Reservoir is full, it covers approximately 2,500 acres, with a length of six and a half miles and a width of three-fourths of a mile. The mean depth at full volume is 21 feet. Otter Creek Reservoir has been considered an excellent fishery in the past and is still heavily relied upon for fishing and other recreational purposes, as reservoirs and lakes in this area of Utah are relatively scarce.

Additional reservoirs in the watershed include Boobe Hole Reservoir (near the headwaters of Boobe Hole Creek above Koosharem Reservoir) and Tropic Reservoir (near the headwaters of the East Fork). Tropic Reservoir discharges water to the East Fork that is collected throughout the winter and early spring. During this time, the reservoir is allowed to fill completely to capacity. The water is then flushed into the East Fork to meet downstream water rights. Flow values during March and April shown for the East Fork Sevier in Figure 2.15 above indicate the influence of these releases. This flushing process is typically completed two or more times each year before water is diverted to the town of Tropic, located outside of the watershed, approximately ten miles to the east. As a result, the East Fork stream channel is typically dry from the Tropic Reservoir dam down to the north end of Johns Valley during the summer months.

2.6.3 East Fork Sevier River

The headwaters of the East Fork Sevier are on the Paunsaugunt Plateau within the Powell Ranger District of the Dixie National Forest. The East Fork is dammed at Tropic Reservoir and most of the water is diverted out of the watershed to the town of Tropic during summer months. As a result, the East Fork stream channel is typically dry during the summer from Tropic Reservoir down to the north end of John's Valley. Below Tropic Reservoir, the East Fork moves through Emery Valley and Johns Valley which provide a limited amount of flow from wetlands and perennial springs. At the north end of Johns Valley, the East Fork enters Black Canyon, where the river channel is confined to a narrow meander plain, roughly 0.1 mile wide and 5 miles long. Water enters the channel again from tributaries near Black Canyon, at the north end of Johns Valley.

Antimony Creek discharges into the East Fork approximately two miles below the mouth of Black Canyon and south of the town of Antimony. About a mile below the confluence with Antimony Creek, the entire flow from the East Fork is diverted to Otter Creek Reservoir during much of the year by way of the East Fork Canal. The canal also diverts flow from several intermittent streams prior to entering Otter Creek Reservoir. Flow in the East Fork Canal represents approximately 75 percent of annual inflow to the reservoir.

Monthly flows in the East Fork Sevier River are shown in Figure 2.16 below and previously in Figure 2.15 above. The seasonal pattern of flow in the East Fork Sevier River is influenced significantly by releases from Otter Creek Reservoir. The median peak flow for streamflow stations located above the reservoir occurs in May or April. Streamflow stations below Otter Creek Reservoir exhibit median peak flows in July during the time of maximum irrigation demand.

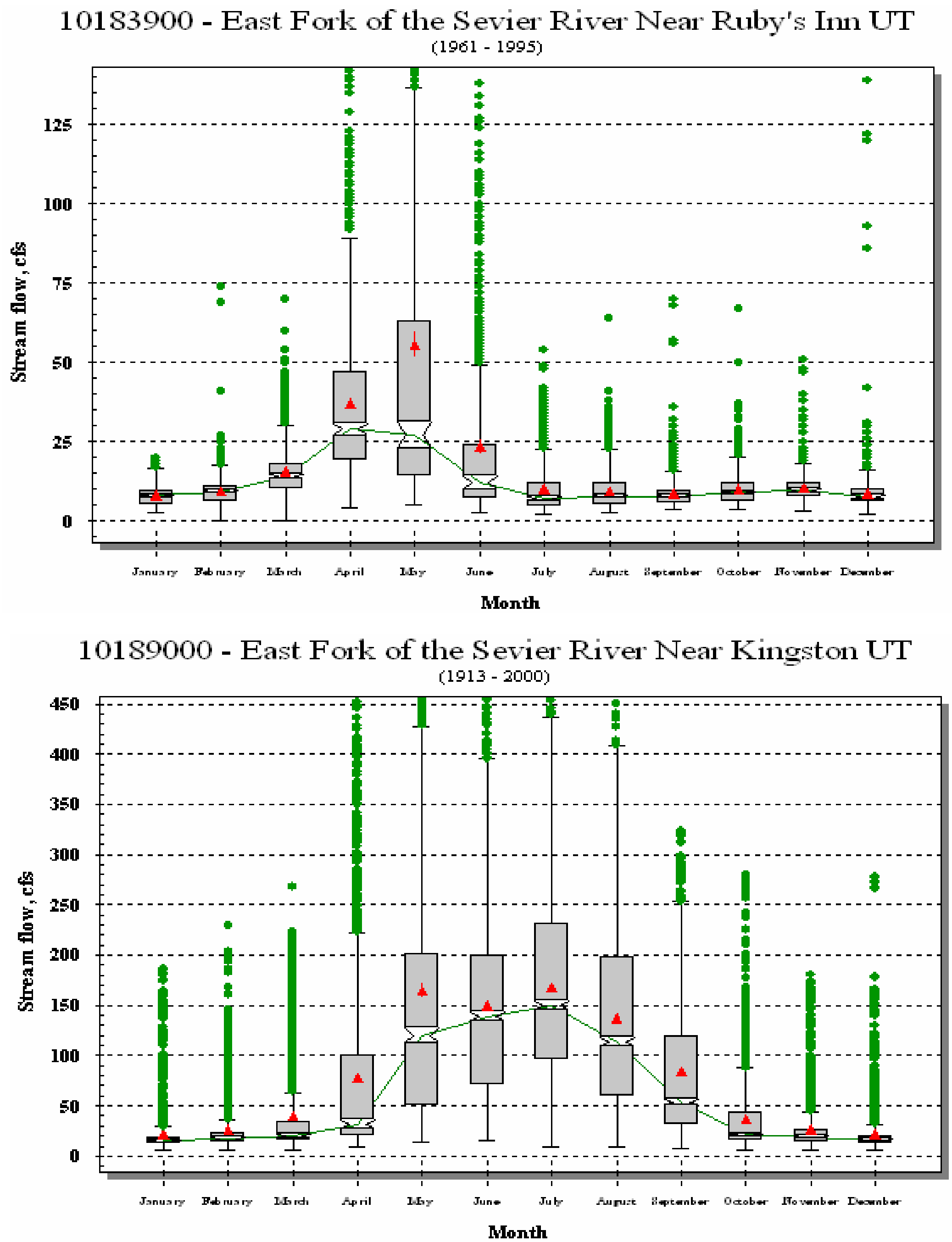

Figure 2.16. Monthly distribution of streamflow in the East Fork Sevier River. Note the temporal difference in median peak flow above and below Otter Creek Reservoir (East Fork near Ruby's Inn and East Fork near Kingston, respectively).

2.6.4 Otter Creek

The headwaters of the Otter Creek watershed are located in the north end of Plateau Valley. Surface flows are concentrated into three stream channels including Otter Creek, Daniels Creek, and Boobe Hole Creek (Figure 2.1). Koosharem Reservoir receives water from Boobe Hole Creek and Otter Creek. The headwaters of Boobe Hole Creek are stored in a reservoir and released throughout the spring and early summer season. Water stored in Koosharem Reservoir is delivered to Otter Creek, which flows south through Grass Valley for roughly 25 miles before entering Otter Creek Reservoir.

Agricultural development in the upper end of Grass Valley is concentrated within a one to four mile strip along Otter Creek for about approximately 15 miles. Multiple irrigation canals and ditches in this area cross natural side drainages, adding complexity to the hydrologic system. Many of the natural tributary drainages flowing to Otter Creek within Grass Valley are intermittent by nature. Flow that periodically occurs in the lower portion of these tributaries is oftentimes the result of irrigation return flows.

Monthly flows in Otter Creek have been shown previously in Figure 2.14 and Figure 2.15. Median peak flows for Otter Creek above Koosharem Reservoir and above Otter Creek Reservoir are different and likely are influenced by the timing of snowmelt and reservoir management. Otter Creek above Koosharem Reservoir receives flow from higher elevation watersheds which experience spring snowmelt in May and June. Flow in Otter Creek above Otter Creek Reservoir is regulated somewhat by management of Koosharem Reservoir and existing water rights. Median peak flows in Otter Creek above Otter Creek Reservoir occur in March and reflect seasonal inflow from tributaries below Koosharem Reservoir that are dry during other times of the year.

2.6.5 Lower East Fork Sevier River

The lower East Fork begins at the confluence with Antimony Creek and continues down to the main stem of the Sevier River. As mentioned previously, the East Fork Canal diversion is located below Antimony Creek and periodically routes the entire flow from the East Fork into Otter Creek Reservoir. Below the diversion, the East Fork continues for roughly five miles before receiving release flow from Otter Creek reservoir via Otter Creek. Below the confluence with Otter Creek, the East Fork runs west through Kingston Canyon to the town of Kingston then north to its confluence with the Sevier River, just south of Piute Reservoir. State Road 62 runs along the East Fork from Otter Creek Reservoir to Kingston through the canyon.

Hydrologic inputs to the lower East Fork are principally from Otter Creek Reservoir, which is the sum total flow produced by inflows from the upper East Fork and Otter Creek. Although several tributary streams do enter the East Fork within Kingston Canyon, the flows from these tributaries are typically intermittent in nature and are generally relatively minor contributions to the total flow in the East Fork. As a result, water quality impacts to the lower East Fork are highly dependent upon pollutant loads delivered to upstream water bodies, including Otter Creek, Otter Creek reservoir, and the upper East Fork.

2.6.6 Groundwater

Groundwater in the TMDL study area generally flows from recharge areas located at higher elevations near mountain fronts and valley heads down to discharge areas at lower elevations along Otter Creek and the East Fork (Thiros et al. 1993). The principal aquifer in the study area consists of saturated valley-fill deposits bordered by consolidated rock formations. These formations are also known to contain groundwater that is discharged in minor amounts through springs, particularly in the north and west portions of the Otter Creek watershed as well as along the east and west slopes of Johns Valley. Greater amounts of water are discharged through fractures in consolidated rock, some of which occur in the Black Canyon area (Thiros et al. 1993). Groundwater found within valley fill deposits is typically unconfined although finegrained lacustrine deposits form a confining layer in the northern end of the Otter Creek watershed.

Most of the aquifer recharge occurs from infiltrating surface water from streams and canals as well as from precipitation. Recharge from streams is dependent upon the rate of streamflow, physical properties of valley-fill deposits, and water table elevation with respect to the stream. An assessment of gaging station records within the TMDL study area has indicated that Otter Creek is a gaining stream along much of its length (Thiros et al. 1993). A gain-loss study of the East Fork was completed in August 1988 by the USGS. Results of the study indicated that the East Fork in the Black Canyon area exhibited an increase in base flow (Thiros et al. 1993). Aquifer recharge by streams is believed to occur primarily from losing tributaries in the higher elevations whose waters later discharge to the controlling stream (either Otter Creek or the East Fork). Seepage loss from streams has been estimated at 20 to 50 percent of annual streamflow amounts while loss from canals has been estimated to be approximately ten percent of the annual flow amount diverted into canals.

Five groundwater subbasins have been identified in the TMDL study area including 3 areas in the East Fork Sevier Valley between Tropic Reservoir and Kingston and 2 areas on Otter Creek (Utah DWR 1999). Subbasins in the East Fork Valley including Emery Valley, Johns Valley and Antimony subbasins are formed by bedrock restrictions that serve to bring water near the surface and into the East Fork Sevier River channel. Small volumes of streamflow in Emery Valley and Johns Valley tend to infiltrate into the groundwater reservoir. As a result, releases from Tropic Reservoir must be delivered in large volumes capable of reaching Otter Creek Reservoir. Groundwater outflows from Emery Valley are known to deliver 6,800 acre-feet of water into the Kanab Creek-Johnson Wash drainages (Utah DWR 1999). Groundwater withdrawals from the East Fork Valley remove 124 acre-feet of water for public drinking supplies, most of which are located in Emery Valley. Groundwater subbasins on Otter Creek include the Koosharem and Angle subbasins. No groundwater outflow is known to occur from these areas. The groundwater reservoir in this area contains about 150,000 acre-feet of water and supports an annual withdrawal of 1,700 acre-feet which is used for irrigation and livestock purposes (Utah DWR 1999).

Surface discharge of groundwater in the TMDL study area occurs in the form of springs, seeps, flowing wells and gaining stream segments. Numerous springs are located along the east and west slopes bordering Otter Creek and the East Fork. Spring discharge is used to support municipal water supplies for the towns of Kingston, Antimony, Greenwich, Koosharem, and Burrville (Thiros et al. 1993). Additional water is removed by phreatophytic plants in areas where the groundwater table is near the surface. Groundwater withdrawal from wells is generally considered to be a minor portion of the annual discharge. However, wells in the upper end of the Otter Creek watershed utilize approximately half of the total withdrawal amount for wells in the entire Upper Sevier watershed (Thiros et al. 1993). Most of this water is utilized for stock watering purposes, although a small percentage supports municipal water use. In contrast, almost 90 percent of water provided by wells in the East Fork watershed supports municipal use while the remainder is used for stockwatering and irrigation purposes (Thiros et al. 1993).

2.6.7 Annual Water Budget

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

$$P + Q_{c,in} + Q_{g,in} = Q_{out} + Q_{c,out} + ET + Q_{g,out} + CU \quad (1)$$

Inflows = Outflows

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

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

1. On average, inflows to the watershed are equal to outflows (the average yearly change in storage in the watershed is equal to 0).
2. The USGS gage near the watershed outlet (USGS 10189000) is characteristic of watershed discharge at the confluence to the mainstem Sevier River. .
3. There are no known canal inflows or significant groundwater inflows to the watershed.
4. Groundwater outflow equals 6,800 ac-ft, all of which leaves the East Fork Sevier groundwater aquifer in the upper reaches of the watershed and enters the Kanab Creek-Johnson Wash drainages (Utah DWR 1999).
5. Consumptive use is assumed to be negligible.
6. The difference between inflows and outflows after all terms in the water budget except evapotranspiration have been evaluated is attributed to evapotranspiration.

Given these assumptions, Equation 1 reduces to:

$$P = Q_{out} + Q_{c,out} + ET + Q_{g,out} \quad (2)$$

Table 2.7 shows the results of the water budget calculations for the TMDL study area. All flows were normalized by the watershed area and are presented in the units of inches per year. The sections following Table 2.7 detail how the quantities in Equation 2 were calculated.

Table 2.7. Water budget results for the TMDL study area including the East Fork Sevier River and Otter Creek watersheds.

	Annual Average Volume (acre-ft)	Area Normalized Annual Average Volume (in/yr)[1]	Percent of Total
Inflows			
Precipitation (P)	1,138,236	17.3	100
Total:	1,138,236	17.3	100
Outflows			
Watershed Discharge to Main Stem Sevier (Q_{out})	57,643	0.9	5.1
Canal Outflow ($Q_{c,out}$)	5,156	0.1	0.4
Evapotranspiration (ET)	1,068,637	16.2	93.9
Groundwater Outflow ($Q_{g,out}$)	6,800	0.1	0.6
Total:	1,138,236	17.3	100

[1] Total watershed area is 789,528 acres

Table 2.7 shows that the watershed discharge to the main stem of the Sevier River accounts for only about 5 percent of the total inputs to the watershed. The canal outflow via the Tropic & East Fork Canal that supplies water to the town of Tropic, UT accounts for less than ½ of one percent of the total inputs to the watershed. Nearly all of the outflows from the watershed are accounted for in the evapotranspiration term (93.9 %), which is consistent with the location and climate of the watershed.

Individual water budgets for 303(d)-listed water bodies in the project area are shown below in Table 2.8 through Table 2.10 with the exception of Lower Box Creek Reservoir. No water budget was calculated for Lower Box Reservoir due to a lack of flow data defining inflow and outflow to the reservoir. Water inflow and outflow volumes for Otter Creek Reservoir, Koosharem Reservoir and the East Fork Sevier were calculated from flow data collected by the USGS and local irrigation companies. Monthly evaporation and groundwater volumes for Otter Creek Reservoir were based on information included in Merritt et al. (1996). Evaporation measurements for Koosharem Reservoir were developed as part of the modeling effort used to characterize monthly pollutant loading. A detailed explanation of the modeling effort for Koosharem Reservoir is provided in Appendix A. Assumptions used to calculate the water budget for the East Fork Sevier were identical to those listed above, with the exception of groundwater outflow which occurs upstream of this river segment. Additional assumptions used to calculate water budget components for the East Fork Sevier include the following:

1. The sub-basin contributing flow to this segment of the East Fork Sevier extended from the confluence with Antimony Creek down to the confluence with the mainstem Sevier River. Total surface area of this sub-basin is 156,906 acres.

2. Monthly inflow volumes to the sub-basin can be characterized by flows from E. Fork Sevier above Antimony (USGS gage 10184450), Antimony Creek (USGS gage 10185000) and Otter Creek Reservoir releases (Otter Creek Irrigation Company).

3. Monthly outflow volumes can be characterized from East Fork near Kingston (USGS gage 10189000).

4. Annual precipitation volumes to the sub-basin can be characterized with PRISM data (see discussion below) equivalent to 16.5 inches/yr. Monthly distribution of precipitation can be calculated using the same distribution found at the Koosharem weather station.

5. All flow diverted for irrigation purposes re-enter the East Fork Sevier within the sub-basin through surface return flow or groundwater discharge.

Error for reservoir water budgets are indicated by the total change in storage. It is anticipated that some error is incorporated into the budget through estimates used to calculate reservoir evaporation and groundwater volumes.

Table 2.8. Otter Creek Reservoir Monthly Water Budget.						
Month	**Otter Creek inflow (ac-ft)**	**E. Fork Canal inflow (ac-ft)**	**Reservoir Discharge (ac-ft)**	**Evaporation (ac-ft)**	**Groundwater (ac-ft)**	**Change in Storage (ac-ft)**
October	79.9	1,088.3	-245.9	-197	20	745.3
November	535.5	2,225.4	-166.6	-62	20	2,552.4
December	836.2	2,619.4	-123.0	-34	9	3,307.6
January	823.9	2,551.7	-159.9	-37	-3	3,175.8
February	1,355.1	2,782.4	-266.6	-59	4	3,815.9
March	2,195.1	2,976.0	-239.8	-103	19	4,847.3
April	868.8	5,236.3	-2,921.6	-281	-47	2,855.5
May	356.6	6,917.3	-6,628.3	-605	-21	19.6
June	83.3	1,803.0	-7,568.9	-897	0	-6,579.6
July	24.6	534.9	-9,044.8	-1013	0	-9,498.3
August	12.3	983.8	-7,310.8	-749	0	-7,063.8
September	17.9	1,142.5	-4,076.0	-433	0	-3,348.7
Total	7,189.3	30,861.1	-38,752.3	-4,470	1	-5,170.9

Table 2.9. Koosharem Reservoir Monthly Water Budget.							
Month	**Otter Creek Inflow (ac-ft)**	**Boobe Hole Inflow (ac-ft)**	**Watershed inflow (ac-ft)**	**Precipitation (ac-ft)**	**Reservoir Discharge (ac-ft)**	**Evaporation (ac-ft)**	**Storage (ac-ft)**
January	500.4	346.2	59.5	12.8	-790.2	-19.4	109.2
February	458.6	317.3	54.5	13.0	-455.9	-26.8	360.8
March	537.5	371.9	63.9	15.5	-958.8	-49.3	-19.3
April	293.5	507.7	175.3	13.6	-1,006.1	-76.2	-92.2
May	650.9	1,126.0	388.8	18.5	-1,845.4	-118.8	220.1
June	485.3	839.5	289.9	11.1	-2,469.2	-124.1	-967.6
July	317.4	549.0	189.6	17.2	-1,295.4	-120.8	-343.0
August	261.4	452.1	156.1	19.1	-1,069.3	-95.6	-276.1
September	232.9	402.9	139.1	13.3	-740.1	-64.5	-16.3
October	411.6	403.4	103.6	11.7	-578.7	-43.5	308.0
November	530.4	367.0	63.1	10.2	-260.8	-27.2	682.7
December	521.0	360.5	62.0	12.0	-615.7	-18.5	321.4
Total	5,200.9	6,043.6	1,745.4	27.9	-12,085.6	-130.4	287.7

Table 2.10. East Fork Sevier monthly water budget from confluence with Antimony Creek downstream to confluence with Sevier River. - Assumption 2 - all irrigation diversions contribute return flow and groundwater recharge. Monthly ET volumes were normalized (in/yr) using a sub-basin area of 156,906 acres.

	Inflows	Precipitation	Outflow	ET	
Month	**(ac-ft)**	**(ac-ft)**	**(ac-ft)**	**(ac-ft)**	**(in/yr)**
October	2,394.9	17,480.5	4689.6	15,185.8	1.16
November	2,293.3	13,110.3	4218.8	11,184.8	0.86
December	2,329.8	14,030.4	4186.6	12,173.5	0.93
January	2,301.5	12,420.3	3960.2	10,761.6	0.82
February	2,696.3	11,730.3	4290.1	10,136.6	0.78
March	4,382.2	16,790.4	5653.5	15,519.2	1.19
April	8,428.7	14,030.4	10643.4	11,815.7	0.90
May	14,482.1	18,860.5	19112.4	14,230.3	1.09
June	10,664.3	13,800.4	13174.4	11,290.3	0.86
July	11,199.9	25,760.7	13094.2	23,866.4	1.83
August	9,528.1	33,580.9	11480.8	31,628.2	2.42
September	6,217.6	24,150.6	7836.1	22,532.1	1.72
Total	76,918.7	215,745.8	102,340.0	190,324.5	14.56

2.6.7.1 Precipitation (P)

An annual average precipitation value was calculated for the East Fork Sevier River watershed by summarizing the spatially explicit precipitation data contained in the **P**arameter-elevation **R**egressions on **I**ndependent **S**lopes **M**odel (PRISM) dataset (Daly et al., 1994). PRISM is a modeling system that uses data collected at meteorological stations and a digital elevation model (DEM) to generate gridded estimates of climate parameters such as precipitation. The PRISM dataset captures spatial variability in precipitation due to elevation differences and other effects and aids in producing a more accurate estimate of annual average precipitation over the entire watershed area. The PRISM grid of spatial precipitation estimates was summarized using ArcView Spatial Analyst to calculate an average precipitation depth over the watershed area. The resulting average annual precipitation value is 17.3 inches/year.

2.6.7.2 Watershed Discharge (Q_{out})

The East Fork of the Sevier River joins the main stem of the Sevier River near Kingston at the watershed outlet. The USGS gage located near the watershed outlet (USGS 10189000) was used to characterize watershed discharge via the East Fork Sevier River. Monthly average totals were summed to get an annual watershed discharge of 57,643 acre-feet. Normalized to the watershed area and converted to inches, the watershed discharge is equal to 0.9 in/yr.

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

Net canal flows were estimated using the following equation:

$$Q_{c,net} = Q_{c,in} - Q_{c,out} \qquad (3)$$

Where: $Q_{c,\ in}$ = Average annual canal inflows to the watershed
$Q_{c,\ out}$ = Average annual canal outflows from the watershed

It is assumed that there are no canal flows into the watershed ($Q_{c,in} = 0$). The only known canal outflow from the watershed is the Tropic & East Fork Canal, which delivers water from Tropic Reservoir to the town of Tropic, Utah. Available daily flow records spanning the period from 1961 to 2001 were obtained from the State of Utah Division of Water Rights and were used to estimate the annual average canal outflow volume. A daily average flow for each day of the year was first calculated using the available data, and then these period of record daily average flow values were summed to determine the annual average canal outflow volume. The following equations show these calculations.

$$Q_{i,avg} = \frac{\sum_{j=1}^{m} Q_{i,j}}{m} \tag{4}$$

$$Q_{c,out} = \sum_{i=1}^{n} Q_{i,avg} \tag{5}$$

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

Evaluating Equations 4 and 5 using the available data for the Tropic & East Fork Canal leads to an annual average canal outflow volume of 5,156 acre-feet. Normalized to the watershed area and converted to inches, the canal outflows are equal to 0.08 in/yr.

2.6.7.4 Groundwater Outflow ($Q_{g,out}$)

A brief review of groundwater in the Sevier River Basin is included in the Sevier River Basin Plan (Utah DWR 1999). No groundwater inflows were defined in this report for the TMDL study area. Groundwater outflows were noted to release 6,800 acre-feet of water from aquifers underlaying the East Fork Sevier River into the Kanab Creek-Johnson Wash. No other measurements were identified describing groundwater outflow from the East Fork Sevier River or Otter Creek.

2.6.7.5 Evapotranspiration (ET)

Evapotranspiration (ET) is the total evaporation from all free-water surfaces plus the transpiration of water vapor through plant tissues (Bedient and Huber, 1992). In order to estimate ET, the land cover distribution in the watershed must be known, along with ET rates for each land cover category. Table 2.2 provided the land use distribution in the East Fork Sevier River watershed.

Generally speaking, ET rates are available for most agricultural land cover types, but little information is available to characterize ET rates from non-agricultural land cover classes. Due to this fact, and since the majority of the land in the East Fork Sevier River watershed is not agricultural land (< 1 %), ET for the watershed was estimated by difference using the assumption that inflows to the watershed equal outflows. All of the inflows and outflows (except ET) in

Equation 2 were evaluated, including precipitation, canal flows, watershed discharge, and groundwater outflow, and then the difference between the inflows and outflows was attributed to ET. This was done by solving Equation 2 for ET and then evaluating the rest of the terms in the equation to get ET:

$$ET = P - Q_{c,out} - Q_{out} - Q_{g,out} \qquad (6)$$

Once all of the other terms in Equation 6 have been evaluated, the annual average ET volume in the East Fork Sevier River watershed works out to approximately 1,068,637 acre-feet. Normalized by area and converted to inches, the annual average ET in the East Fork Sevier River watershed is approximately 16.2 in/yr.

Table 2.11 shows annual ET estimates for different crop types at two National Weather Service stations in or near the project watershed (Koosharem and Tropic). These data are based on a Calibrated SCS Blaney-Criddle Equation and were adapted from Hill (1994).

Table 2.11. Annual ET estimates by crop type.

	Annual Average ET (in/yr)	
Crop Type	**Koosharem**	**Tropic**
Alfalfa	25.92	28.86
Pasture	21.20	23.31
Other Hay	21.15	
SP Grain	20.59	21.38
Turf	19.31	21.49
Garden	12.92	13.77

The values in Table 2.11 are for agricultural land cover classes and are, in general, somewhat higher than the ET estimate of 16.2 in/yr calculated above. This is, however, expected since agricultural lands typically transpire more water than rangeland or forestland vegetation, which make up the majority of the watershed. Given the information in Table 2.11, and the land cover distribution in the watershed, the calculated value for annual average ET over the entire watershed appears justified.

2.6.7.6 Consumptive Use (CU)

For the purposes of this water budget, consumptive use is defined as water use by residents of the watershed where the water does not return to the system via a septic system or some other pathway. Typically, consumptive use is a relatively small fraction of the total urban and residential water use (usually less than 10 %). There are several small towns in the East Fork Sevier River watershed. These include Burrville, Koosharem, Greenwich, Angle, Kingston, and Antimony. Water use estimates for the towns with public water supply systems were taken from data available on the State of Utah Division of Water Rights website (http://waterrights.utah.gov/cgi-bin/wuseview.exe?Startup). From these data it was determined that the population served by public water supply systems in the watershed is small (less than 650 individuals). This is consistent with the land ownership in the watershed, which is predominantly federal land.

Using the data from the Utah Division of Water Rights, it was determined that the total water use from those towns with public water supply systems was less than 300 acre feet, and the likely consumptive use amount would be approximately 10 percent of that amount or 30 acre ft. This small amount was determined to be insignificant to the overall water balance calculation because it represents such a small fraction of the total inputs to the watershed. As stated above, since the ET estimate is equal to the difference between watershed inflows and outflows after all other terms have been evaluated, the consumptive use is lumped with the ET estimate.

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CHAPTER 3: EXISTING WATER QUALITY CONDITONS

The Utah Division of Water Quality (DWQ) has monitored water quality parameters at several locations within the Otter Creek Watershed since 1975. Previous measurements of TP from Lower Box Creek, Koosharem, and Otter Creek Reservoirs as well as segments of the East Fork Sevier indicate that concentrations are in excess of desired levels. In addition, measurements of DO in Lower Box Creek Reservoir and pH and temperature in Otter Creek Reservoir do not meet the respective water quality criterion assigned to these water bodies. The *Utah 2004 303(d) List of Impaired Waters* included each of these water bodies (Utah DWQ 2004c). This chapter provides a detailed discussion of existing water quality conditions in support of this listing.

3.1 WATER QUALITY STANDARDS

The designated use of a body of water is based on the water quality standards and goals adopted by the state to protect public health or welfare, enhance water quality, and protect its assigned beneficial uses (e.g., aquatic life, recreation, and agricultural use). The beneficial uses and standards associated with impaired waterbodies in the Otter Creek TMDL study area are shown in Table 3.1. As stated in section 12 of R317-2 (Standards of Quality for Waters for the State), the East Fork Sevier River and tributaries are exempt from classification as High Quality Waters – Category 1, typically applied to all surface waters geographically located within the outer boundaries of U.S. National Forests whether on public or private lands.

Table 3.1. Beneficial use and associated water quality standards for waterbodies located in the Otter Creek TMDL study area.

Name	Impaired Beneficial Use	Level of Support	Standard
<u>Reservoirs/Lakes</u> Koosharem Lower Box Creek Otter Creek <u>Stream Segments</u> East Fork Sevier River Otter Creek	3A – Cold water aquatic life	Partial support	TP (reservoirs) ≥ 0.025 mg/l TP (streams) ≥ 0.05 mg/l DO (acute)$_a$ = 8.0/4.0 DO (chronic) = 6.5 mg/l Temperature = 20 °C pH = 6.5 – 9.0

$_a$ First number indicates acute DO standard applicable to adult-life stage aquatic species, second number is applicable to early-life stage aquatic species.

One method used to determine impairment to lakes and reservoirs is based on field-measurements of three water quality parameters including temperature, pH, and DO, which are collected by the State of Utah during routine monitoring efforts. Reservoir impairment can also be determined by exceedance of nutrient indicator values (including TP concentrations), evaluation of Trophic Status Index (TSI), winter season fish surveys, phytoplankton measurements, and a review of general water quality trends since 1989 (Utah DWQ 2004c).

In most cases, if less than 10 percent of water quality measurements exceed standards or indicator values, full support status is assigned to the water body. Partial support is assigned if exceedence is between 10 percent and 25 percent, while non-support status is assigned if more than 25 percent of measurements exceed desired levels. An exception to this rule is made for dissolved oxygen levels in deep lakes or reservoirs where low oxygen or anoxic conditions might exist. In these situations, if less than 50 percent of the water column is below 4.0 mg/l DO, the water body is considered to be fully supporting Class 3A beneficial use. If 50 percent to 75 percent of the water column is less than 4.0 mg/l DO, partial support status is assigned. If more than 75 percent of the water column is less than 4.0 mg/l DO the water body is considered non-supporting of the Class 3A beneficial use.

The TP value used by the State of Utah to determine impairment is an indicator value of nutrient enrichment and not a numeric criteria. Desired concentrations of TP associated with reservoirs and streams are 0.025 mg/l and 0.05 mg/l, respectively. These values have been determined to represent threshold values that prevent eutrophication and excessive algae growth. Excessive growth and decomposition of algae can deplete DO concentrations to levels that are harmful to fish. Excessive algal growth can also result in decreased water column transparency, growth of surface scum or heavy algal mats, noxious odors from algae decomposition, and shifts within the food web structure.

3.2 Water Quality and Flow Monitoring

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

Members of the Cirrus team contacted all pertinent agencies and stakeholders within the TMDL study area with the ability to provide water quality and flow data as well as additional information that was used to characterize pollutant sources. A list of individuals and their agency affiliation is provided below in Table 3.2.

3.2.1 Surface Water Quality monitoring stations

The analysis of water quality data indicated that the Utah Division of Water Quality (DWQ) has collected the majority of surface water quality samples to date, extending back to 1975. Surface water quality measurements have been collected by the DWQ at 81 different sites including streams, lakes/reservoirs, and facilities (Table 3.3). Other agencies that have been involved with water quality monitoring in the project area include the USGS, USFS, USEPA, National Park Service, and the Utah Department of Health. A total of 223 water quality monitoring stations have been identified to date measuring water quality parameters from both surface and groundwater sources (Table 3.3). The geographic location of all surface water quality monitoring stations within the TMDL study area can be seen in Figure 3.1. A more detailed view of the locations for all DWQ surface and groundwater monitoring stations is provided in Appendix B – Data.

Table 3.2. Individuals contacted during the search for water quality, flow, and other information used to characterize pollutant sources within the TMDL study area.

Name	Organization	Data Requested
Jim Harris	Utah Division of Water Quality	Water quality, flow, macroinvertebrate
Theron Miller	Utah Division of Water Quality	Reservoir profiles
Rich Jaros	Dixie NF	Water quality
Chris Butler	Dixie NF	Water quality
Phil Greenland	US DOI-BOR, Provo office	Bathymetry profile
Roger Hanson	US DOI-BOR, Provo, UT office	Reservoir discharge, reservoir area-capacity table
Dale Wilberg	USGS - Richfield, UT office	Flow data
Carvel Wayland	Utah Division of Water Rights, Price office	Flow data - irrigation canals and ditches.
Terry Monroe	Utah Division of Water Rights, Price office	Flow data
Ivan Cowley	Otter Creek Reservoir Company	Flow data- Otter Creek Reservoir
Charlie Bishop	Utah Geological Survey - DNR	Flow data, water quality data
Verl Bagley	Utah State University Extension	Animal numbers, grazing patterns
Ray Owens	Upper Sevier River Commission	Reservoir release data, canal locations.
Vince Pace	Richfield District, Fish Lake National Forest	Grazing allotment information
Kurt Robins	Teasdale District, Fish Lake National Forest	Grazing allotment information
Evan Boshell	Powell District, Dixie National Forest	Grazing allotment information
Kim Anderson	Escalante District, Dixie National Forest	Grazing allotment information
Tom Jarman	Richfield Office, Natural Resources Conservation Service	AFO/CAFO information, CNMP status, Otter Creek HUA
Monte Turner	Richfield Office, Utah Association of Conservation Districts	AFO/CAFO information, CNMP status
Ron Torgerson	State Trust Lands	Grazing allotment information
Sara Larsen	Division of Water Resources	GIS data – irrigation ditches and canals
Lina Hagaard	State Trust Lands	GIS data – grazing allotment coverage
Adam Bronson	Division of Wildlife Resources	Elk population data

Table 3.3. Water quality monitoring stations identified to date within the project area watershed.						
Agency	**Stream/ River**	**Groundwater/ Well**	**Groundwater/ Spring**	**Lake/ Reservoir**	**Facility**	**Total**
US Forest Service	12			3		15
US Geological Survey	11	24	13			48
Utah Dept. of Health		1	10			11
Utah Division of Water Quality	67	3	12	12	2	96
US Environmental Protection Agency	7			3		10
National Park Service	11	1	31			43
TOTAL	**108**	**29**	**66**	**18**	**2**	**223**

3.2.2 Groundwater Quality monitoring stations

A total of 95 groundwater monitoring stations were identified within the TMDL study area. Twenty-nine stations were associated with wells while 66 stations were associated with springs (Table 3.3). The majority of samples (24) collected from wells have been gathered by the USGS while most of the spring samples (31) have been collected by the National Park Service within Bryce Canyon National Park. Water quality monitoring at wells and points of groundwater discharge (springs) were typically limited to one or two samples. Thus, many of these sampling locations were not selected for plotting or data analysis. The locations of all groundwater monitoring stations are shown in Figure 3.2.

3.2.3 Flow Monitoring stations

Six continuous flow monitoring stations are located within the Otter Creek Watershed. The earliest record of continuous flow dates from 1913 through 2000 at a gauging station located at the East Fork of the Sevier River near Kingston UT (USGS 10189000). Continuous flow monitoring stations located within the project area are shown in Table 3.4 and Figure 3.3.

Table 3.4. USGS flow monitoring stations located in the Otter Creek project area.		
Station ID	**Name**	**Date Range**
10187300	Otter Creek near Koosharem	1964-1982
10187500	Otter Creek Above Reservoir near Antimony	1961-1980
10183900	East Fork of the Sevier River near Ruby's Inn UT	1961-1995
10184450	East Fork of the Sevier River near Antimony UT	1961-1966
10185000	Antimony Creek near Antimony	1946-1976
10189000	East Fork of the Sevier River near Kingston	1913-2000

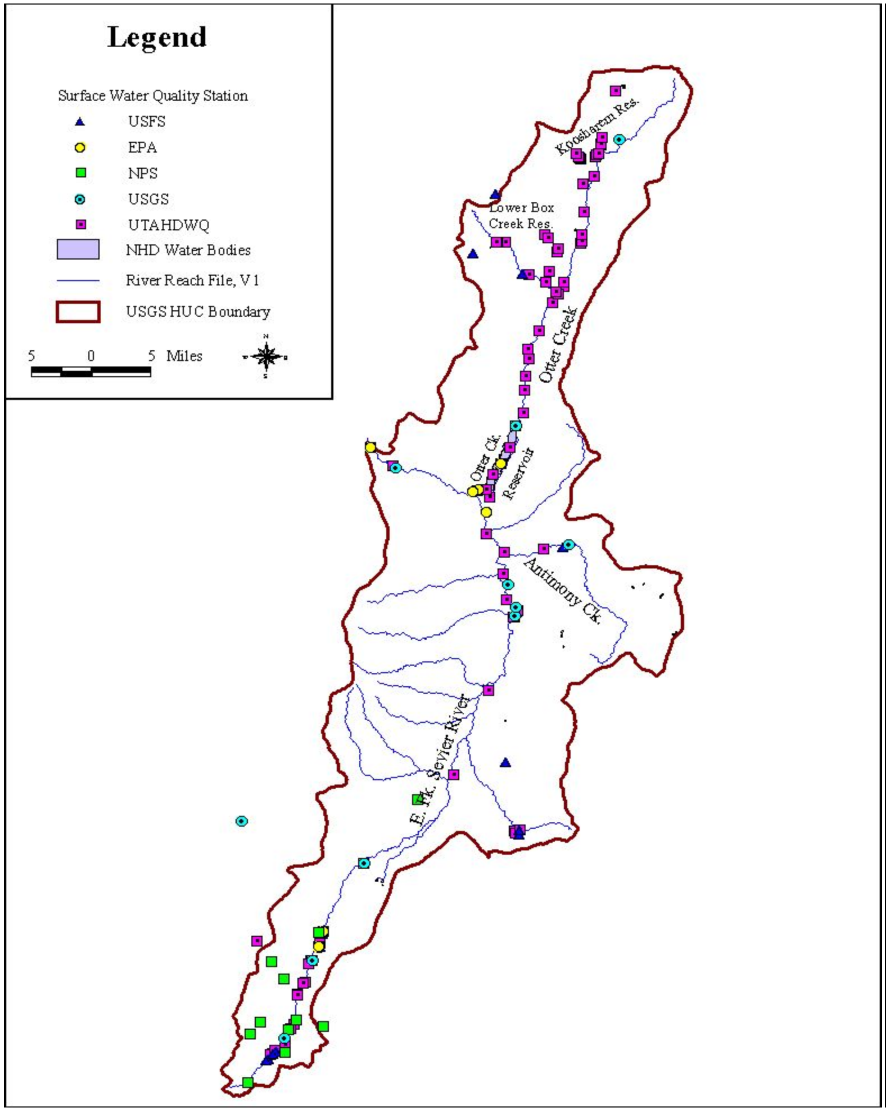

Figure 3.1. Surface water quality monitoring stations located in the TMDL study area.

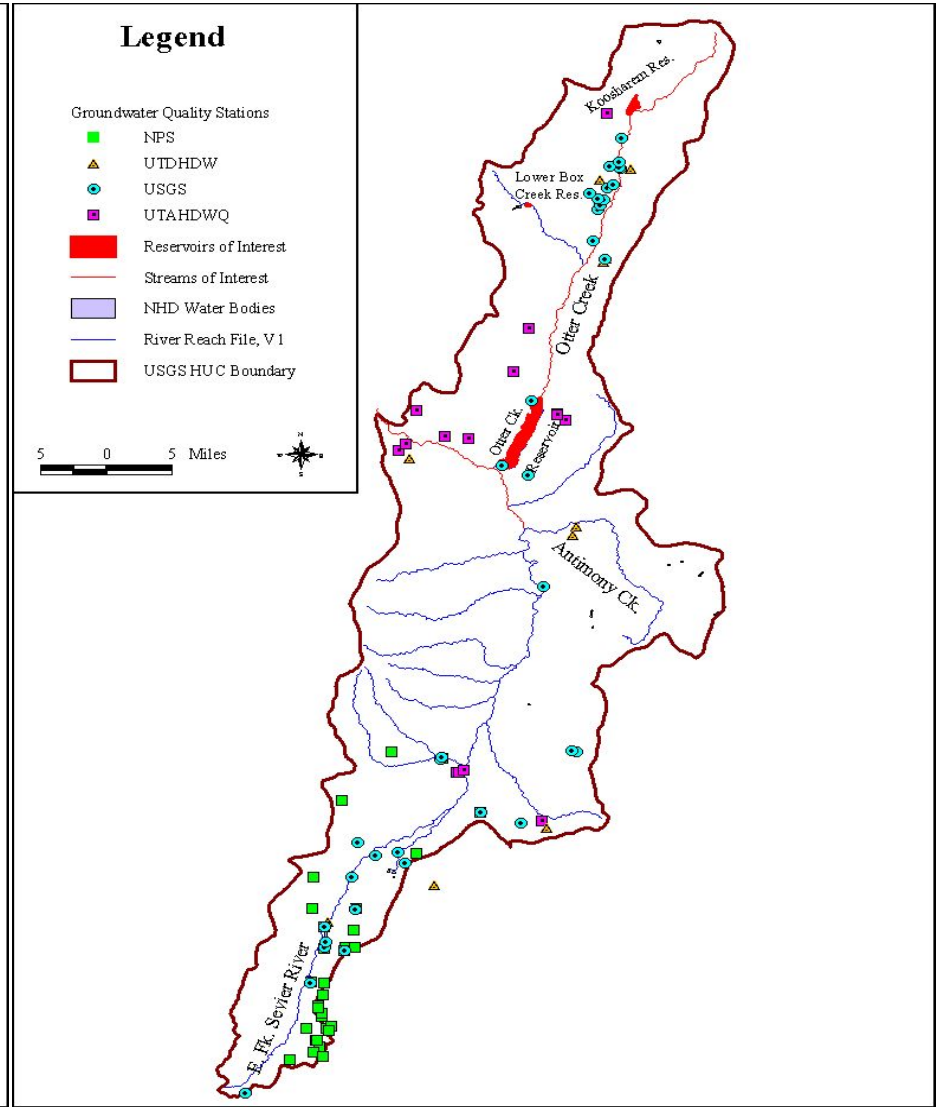

Figure 3.2. Ground water quality monitoring stations located in the TMDL study area.

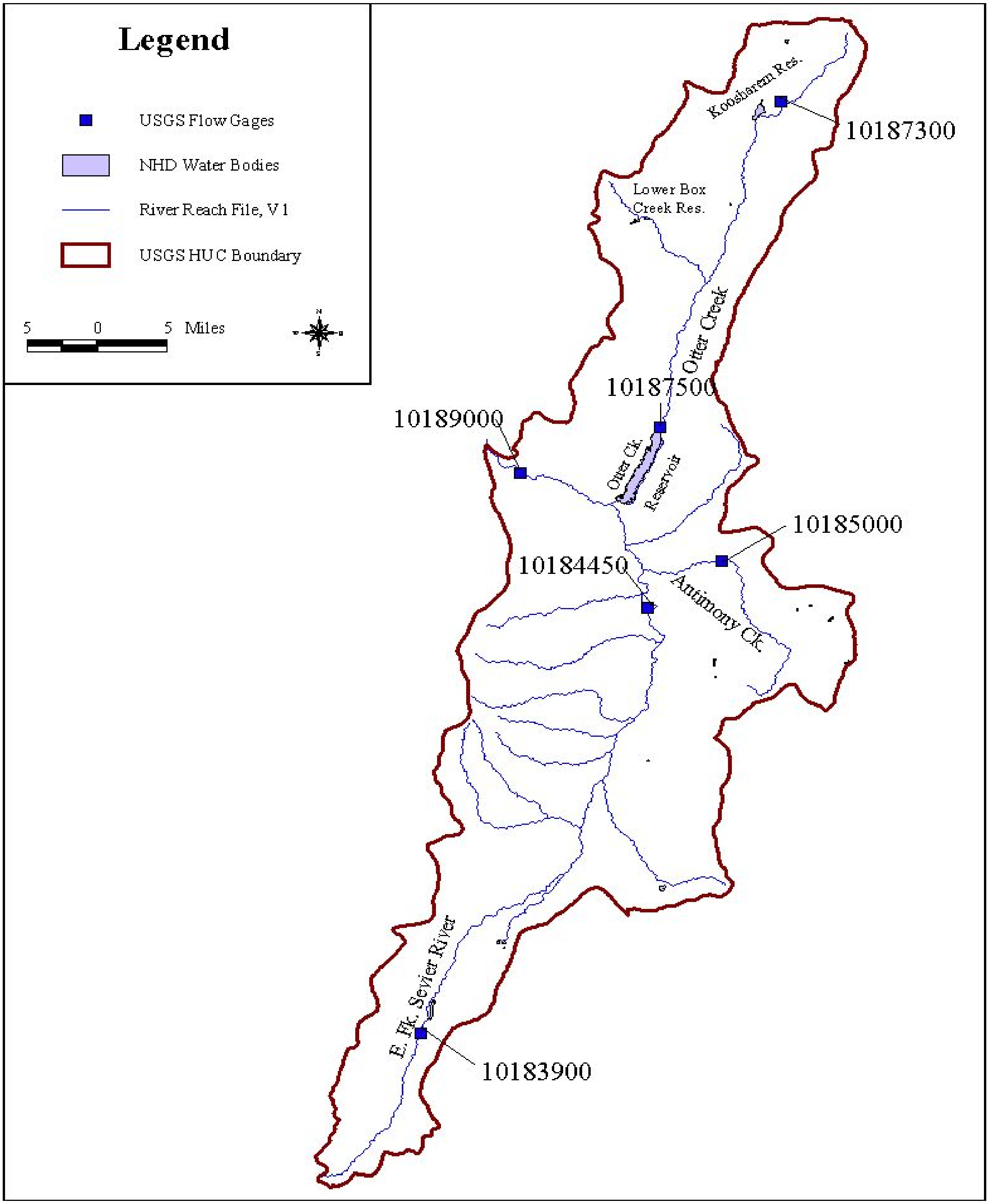

Figure 3.3. USGS flow monitoring stations located with the TMDL study area.

In addition to continuous flow monitoring stations, instantaneous flow is typically recorded at DWQ monitoring sites at the time when water samples are collected. Daily flow information was also obtained from the Division of Water Rights for irrigation ditches, canals, and reservoirs within the TMDL study area. These measurements were typically collected during the irrigation season (May – October) of a given year. A complete listing of all sources of flow data is included in Appendix B - Data of this report.

3.2.4 Sampling Frequency

Samples have been collected at different time intervals from each water quality and flow station. Surface water quality stations were typically sampled more often than groundwater stations. As mentioned previously, the sampling history at many of the groundwater quality stations is limited to one or two samples. Some of the surface water quality stations were included in a one-year intensive cycle of water quality sampling, completed by the DWQ during 1993-94, 1996-97 and again in 2001-02. Water quality samples were typically collected from each station at 4-6 week intervals during the intensive monitoring period. Reservoir monitoring sites in the TMDL study area were typically visited during even numbered years. Reservoir samples were collected approximately two times per year with the exception of 2002 when three or four visits were completed to each reservoir. A list of DWQ surface water quality stations visited during intensive monitoring cycles is provided in Table 3.5. The location of sample sites are shown in Figure 3.4. Although this assessment will emphasize DWQ water quality stations sampled during intensive monitoring cycles, all water quality data collected in the TMDL study area has been considered and reviewed during this assessment.

As mentioned previously, flow data has been collected at several different time scales. Instantaneous flow measurements were collected with water quality samples while flow measurements from irrigation ditches and canals were made on a daily basis or longer. Flow measurements from USGS sites were made on a continuous basis and thus provide the most accurate characterization of flow variability in the watershed.

Table 3.5. Surface water stations visited during DWQ intensive monitoring completed in the TMDL study area.

Station	Description	1993-1994	1996-97	2001-2002
	Facilities			
494875	Deans Fish Hatchery outfall			X
494876	Deans Fish Hatchery inflow	X		
494877	Road Ck. Burrville Fish Hatchery outfall	X		X
494878	Road Ck. Burrville Fish Hatchery inflow	X		
	Reservoirs			
494929	Otter Ck. Reservoir 03 1/3 way up lake	X		
494930	Otter Ck. Reservoir 04 near south inlet	X		
494931	Otter Ck. Reservoir 05 near upper end	X		X
494922	Otter Ck. Reservoir above Dam 01	X		X
494923	Otter Ck. Reservoir midway up lake 02	X		X
594562	Lower Box Ck. Reservoir 01	X		X
594577	Koosharem Reservoir above Dam 01	X		X
	Streams			
494887	Otter Ck. above diversion 1 mile north of Angle	X	X	X
494890	Greenwich Ck. above diversion at ATV Trailhead			X
494892	Box Ck. near canyon mouth 1 mile west of Greenwich			X
494894	Otter Ck. at the Narrows	X		X
494904	Otter Ck. at creek crossing north east of Koosharem	X		
494907	Otter Ck. at U62 crossing north of Koosharem			X
494908	Otter Ck. at U24 crossing – Outlet from Koosharem Reservoir	X		
494910	East Fork Sevier River at U62 crossing east of Kingston	X		X
494920	Otter Ck. near Angle at creek crossing	X		
494921	Otter Ck. below Otter Ck. Reservoir	X		
494924	E. Fork Sevier River Canal at inflow to Otter Ck. Reservoir	X		X
494926	E. Fork Sevier River above diversion at Antimony	X	X	X
494927	E. Fork Sevier River on Martinez property near home (DWR)	X		
494940	E. Fork Sevier River at USGS station (10183900) above Tropic Reservoir.		X	
494953	Pine Ck. above confluence with E. Fork Sevier River	X		
494954	Antimony Ck. above confluence with E. Fork Sevier Rver	X		X
494957	E. Fork Sevier River at county road crossing north of Widstoe Junction.		X	
494959	Antimony Ck. above diversion			X
494996	North Ck. above confluence with E. Fork Sevier River	X		
494997	E. Fork Sevier River above confluence with Deer Ck.	X	X	
494998	Deer Ck. above confluence with E. Fork Sevier River	X		
594563	Box Ck. below Upper Box Ck. Reservoir and above Lower Box Ck. Reservoir			X
594579	Otter Ck. above Koosharem Reservoir			X
594580	Boobe Hole Ck. above Koosharem Reservoir	X		X

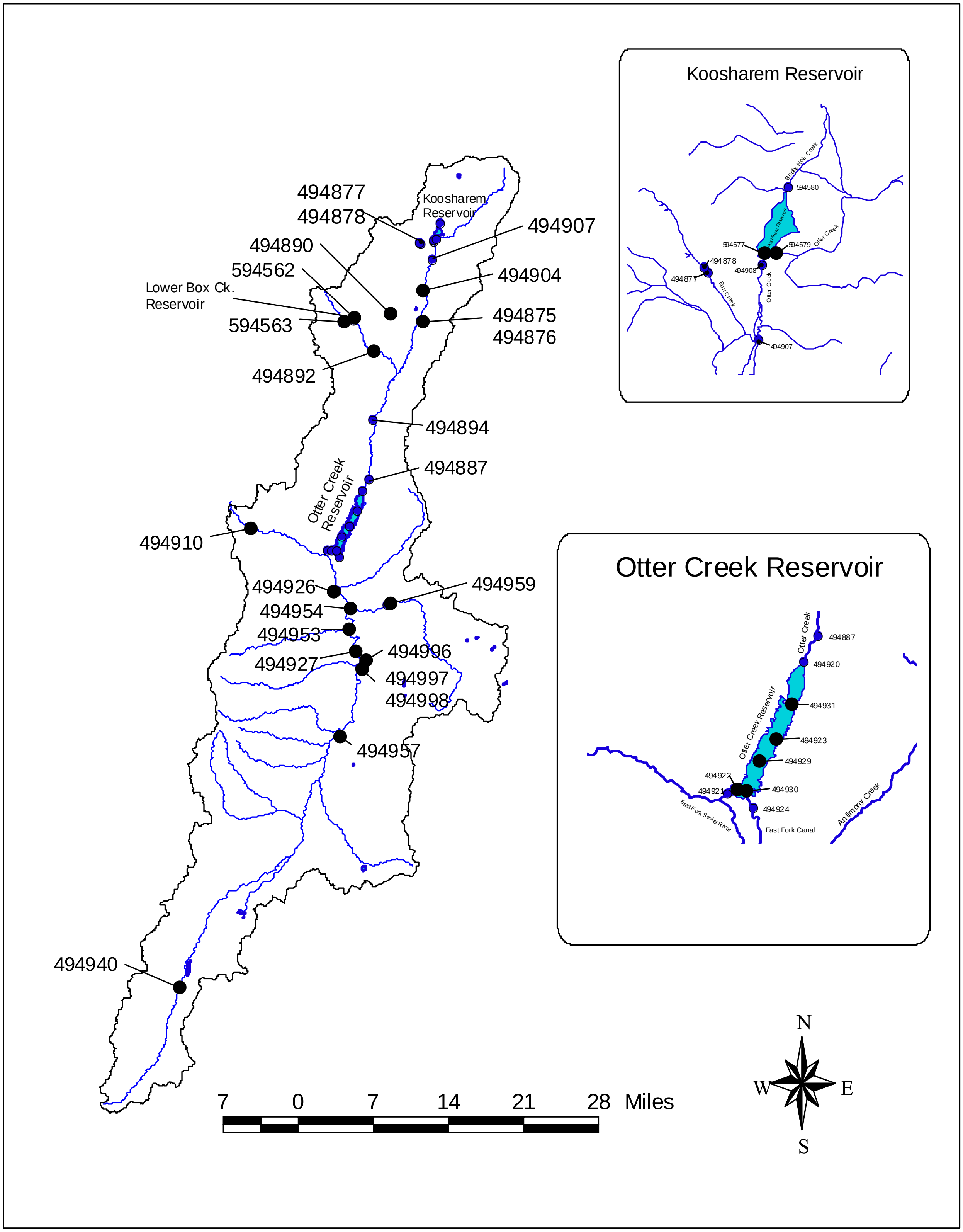

Figure 3.4. DWQ surface water quality monitoring sites visited during intensive monitoring cycles.

3.3 EXISTING WATER QUALITY

Water quality samples have been collected at surface and groundwater monitoring stations in the East Fork Sevier and Otter Creek watersheds since the early 1970s. The majority of monitoring stations are located on lower segments of the mainstem East Fork Sevier River and Otter Creek. A limited number of reservoir monitoring stations are found on Koosharem, Lower Box Creek and Otter Creek Reservoirs. As shown in Table 3.3, less than half of the water quality monitoring stations are associated with groundwater. An extensive water quality data record is available for a few stream monitoring stations. However, the data record is limited to a few years or less for a majority of sampling sites identified in this assessment. A comprehensive listing of water quality data collected by DWQ at stream and reservoir monitoring stations can be found in Appendix B – Data of this report. For discussion purposes, existing water quality is described below for a select number of DWQ monitoring stations. These stations have been chosen based on their location with respect to impaired water bodies as well as their sampling history. It is noted that all surface and groundwater quality data collected within the TMDL study area has been reviewed and considered during the assessment of water quality impairment. All water quality and flow data collected in the TMDL study area (including data collected by agencies other than DWQ) can be viewed in a companion document to this report (DWQ 2003).

3.3.1 Surface Water Quality

Water quality statistics for a select number of DWQ reservoir and stream monitoring stations are provided below in Table 3.6 and Table 3.7. Water quality data collected from reservoirs included profile measurements of the entire water column as well as water samples collected at specific depths within the column. Average profile measurements of water temperature, pH, DO, and TP collected from reservoirs are shown in Table 3.6. Mean values of water temperature, TP and DO measured during intensive monitoring periods are shown in Table 3.7 for selected reservoir and stream monitoring sites. In-lake TP concentration from reservoir monitoring stations during 1992 – 2003 as well as seasonal averages during this same time period are shown in Figure 3.5 for Koosharem, Lower Box Creek, and Otter Creek Reservoirs. Representative profiles of field measurements collected from each reservoir are shown in Figure 3.6. Monthly average TP concentrations are shown in Figure 3.7 for selected stream monitoring sites on the East Fork Sevier and Otter Creek. Although most of the assessment is based on recent water quality data (1992-2003), references are made to historic water quality conditions when sufficient data is available.

A select number of monitoring stations located in headwater areas were also assessed to help define water quality conditions that are assumed to be void of anthropogenic influence. Water quality at these selected stations will be used to determine natural background levels of TP delivered to impaired water bodies in the study area.

Table 3.6. Measurements of paired water quality samples and field parameters collected from Otter Creek Reservoir, Koosharem Reservoir, and Lower Box Creek Reservoir. Mean profile measurements include water temperature, pH, and dissolved oxygen. Mean Total Phosphorus (TP) measurements shown are typically calculated from one to four samples collected within the water column at the sample location.

Station 594577 - Koosharem Reservoir Above Dam 01															
			Temperature			**pH**			**DO**			**TP**			
Date	Depth (m)	Samples	Mean	**% > 20 C**	Status[a]	Mean	**6.5>%>9.0**	Status[a]	Mean	**% > 4.0 mg/l**	Status[a]	Mean	Samples	**% > .025 mg/l**	Status[a]
02-Jun-92	4.7	6	15.75	0	S	8.55	0	S	7.37	0	S	0.091	2	100	NS
18-Aug-92	2.6	4	19.63	25	NS	9.15	100	NS	6.78	0	S	0.125	2	100	NS
14-Jul-94	4.0	5	19.70	40	NS	8.80	0	S	5.54	20	S	0.195	2	100	NS
25-Jun-96	5.0	6	17.47	0	S	8.68	0	S	6.72	0	S	0.047	3	100	NS
05-Sep-96	2.8	4	17.73	0	S	8.50	0	S	7.03	0	S	0.055	2	100	NS
07-Jul-98	5.6	7	19.57	0	S	8.37	0	S	6.69	0	S	0.036	2	100	NS
09-Sep-98	3.8	5	16.52	0	S	7.78	0	S	4.26	20	S	0.212	2	100	NS
22-Jun-00	4.8	6	17.46	0	S	8.59	0	S	6.75	0	S	0.097	2	100	NS
16-Aug-00	3.4	5	18.24	0	S	8.43	0	S	7.27	0	S	0.104	2	50	NS
05-Jun-02	4.8	6	17.11	0	S	8.84	0	S	8.36	0	S	0.049	2	100	NS
18-Jul-02	3.0	4	19.55	0	S	9.30	100	NS				0.115	2	100	NS
14-Aug-02	4.0	4	25.60	100	NS	9.01	25	NS	6.30	0	S	0.281	2	100	NS
02-Oct-02	1.2	3	8.70	0	S	8.49	0	S	8.49	0	S	0.183	2	100	NS
Station 594562 - Lower Box Creek Reservoir 01															
			Temperature			**pH**			**DO**			**TP**			
Date	Depth (m)	Samples	Mean	**% > 20 C**	Status[a]	Mean	**6.5>%>9.0**	Status[a]	Mean	**% > 4.0 mg/l**	Status[a]	Mean	Samples	**% > .025 mg/l**	Status[a]
05-Aug-92	5.0	6	15.75	0	S	9.50	67	NS	9.77	0	S	0.1915	2	100	NS
06-Jul-94	5.0	6	17.15	0	S	9.12	67	NS	8.73	0	S	0.075	2	100	NS
02-Jul-96	4.4	6	14.47	0	S	8.60	17	PS	7.55	0	S	0.055	2	100	NS
21-Aug-96	4.6	6	15.40	0	S	9.92	100	NS	9.97	0	S	0.09	2	100	NS
08-Jul-98	5.0	5	14.42	0	S	7.90	0	S	8.52	0	S	0.072	2	100	NS
08-Sep-98	5.3	7	14.06	0	S	9.26	43	NS	6.64	0	S	0.131	2	100	NS
22-Jun-00	5.4	7	14.68	0	S	9.03	57	NS	9.09	0	S	0.042	4	100	NS
16-Aug-00	4.7	6	16.76	0	S	8.74	50	NS	5.12	50	PS	0.1065	2	100	NS
05-Jun-02	4.6	6	15.75	0	S	9.42	83	NS	9.60	0	S				
18-Jul-02	3.5	5	14.96	0	S	9.18	80	NS				0.074	2	100	NS
14-Aug-02	0.5	2	16.45	0	S	8.00	0	S	6.19	0	S	0.0955	2	100	NS
02-Oct-02	0.0	1	10.32	0	S	8.60	0	S	9.51	0	S	0.041	1	100	NS

Table 3.6. (cont'd) Measurements of paired water quality samples and field parameters collected from Otter Creek Reservoir, Koosharem Reservoir, and Lower Box Creek Reservoir.

Station 494922 - Otter Ck. Reservoir above Dam 01

			Temperature			**pH**			**DO**			**TP**			
Date	Depth (m)	Samples	Mean	**% > 20 C**	Status[a]	Mean	**6.5>%>9.0**	Status[a]	Mean	**% > 4.0 mg/l**	Status[a]	Mean	Samples	**% > .025 mg/l**	Status[a]
02-Jun-92	9.0	10	16.16	0	S	8.73	10	PS	6.78	10	S	0.067	4	75	NS
19-Aug-92	2.5	4	20.10	50	NS	9.48	100	NS	4.35	50	PS	0.068	2	100	NS
02-Jun-94	9.0	10	16.16	0	S	8.73	10	PS	6.73	10	S	0.028	1	100	NS
25-Jun-96	8.1	9	17.66	0	S	8.52	0	S	6.64	0	S	0.045	4	100	NS
05-Sep-96	3.9	5	17.66	0	S	8.14	0	S	5.46	0	S	0.060	2	100	NS
07-Jul-98	10.5	12	17.61	17	PS	8.35	0	S	5.92	42	S	0.061	4	100	NS
09-Sep-98	8.2	10	19.10	0	S	8.47	0	S	5.12	10	S	0.053	2	100	NS
22-Jun-00	5.2	7	18.33	0	S	8.55	0	S	6.63	14	S	0.039	2	100	NS
15-Aug-00	3.1	5	20.98	100	NS	8.31	0	S	5.90	0	S	0.073	2	100	NS
04-Jun-02	6.6	8	15.91	0	S	8.69	0	S	8.44	0	S	0.014	4	25	NS
17-Jul-02	3.8	5	20.72	100	NS	8.81	0	S	na	na		0.086	2	100	NS
14-Aug-02	3.6	5	19.37	20	PS	8.98	0	S	5.39	0	S	0.194	2	100	NS
02-Oct-02	2.7	4	11.26	0	S	8.27	0	S	6.51	0	S	0.192	2	100	NS

[a] Status: S = Fully supporting assigned beneficial use. NS = Not supporting assigned beneficial use. PS = Partially supporting assigned beneficial use.

Table 3.7. Summary of existing water quality parameters including dissolved oxygen, total phosphorous, and water temperature for selected reservoir and stream monitoring sites within the study area. Note that percent exceedance values for TP are compared to 0.025 mg/l for reservoir monitoring sites or 0.05 mg/l for stream monitoring sites.

Site	Water Temperature (°C)					Total Phosphorus (mg/L)					DO (mg/L)				
Date	**Samples**	**Mean**	**Min[a]**	**Max**	**% > 20 C**	**Samples**	**Mean**	**Min[a]**	**Max**	**% > .025 mg/l - % > 0.05 mg/l**	**Samples**	**Mean**	**Min[a]**	**Max**	**% > 4.0/8.0 mg/l**
494887 - OTTER CREEK ABOVE DIVERSION 1MILE NORTH OF ANGLE															
1993 - 1994	18	13	1	22	11	18	0.06	<BDL>	0.17	44	17	8.9	7.4	11.1	0/24
1996 - 1997	21	12	1	23	24	16	0.08	<BDL>	0.36	44	21	9.9	0.6	14.4	5/10
2001 - 2002	16	11	0	23	19	15	0.04	<BDL>	0.16	27	16	10.3	5.5	13.3	0/6
494890 – GREENWICH CREEK ABOVE DIVERSION AT ATV TRAILHEAD															
2001 - 2002	11	9.77	<BDL	20.11	9.1	11	0.09	0.03	0.39	63.6	11	8.7	7.06	11.66	0.00/36.4
494892 - BOX CREEK NEAR CANYON MOUTH 1 MILE WEST OF GREENWICH															
2001 - 2002	12	6.86	0.44	14.65	0	12	0.07	0.03	0.17	75	12	9.38	8	12.18	0.00/0.00
494875 - DEANS FISH HATCHERY OUTFALL															
1993 - 1994	13	11.99	5.90	15.5	0	1				100	13	9.19	6.10	13.80	0/30.8
2001 - 2002	15	11.73	8.62	16.7	0	12	0.05	0.02	0.08	58	15	7.35	5.16	9.67	0/73.3
494877 - ROAD CREEK BURRVILLE FISH HATCHERY OUTFALL															
1993 - 1994	13	11.48	6.20	16.0	0	10	0.13	0.03	0.22	90	13	7.60	6.40	8.80	0/77
2001 - 2002	16	11.64	5.66	20.8	6	12	0.05	0.03	0.07	67	16	7.42	3.86	9.59	6 / 69
494894 - OTTER CREEK AT THE NARROWS															
1993 - 1994	21	12	0	22	4	21	0.05	<BDL>	0.22	46	19	8.9	6.6	10.7	0/26
2001 - 2002	15	11	0	22	20	13	0.04	<BDL>	0.09	31	15	9.1	6.5	14.0	0/20
494907 - OTTER CREEK AT U62 CROSSING NORTH OF KOOSHAREM															
2001 - 2002	14	12.11	1.3	24.1	14.3	13	0.057	0.031	0.09	69.2	14	8.4	7.0	11.0	0/50
494908 - OTTER CREEK AT U24 CROSSING -OUTLET FROM KOOSHAREM RESERVOIR															
1993 - 1994	20	12	3	19	0	20	0.14	0.05	0.40	95	19	8.0	5.2	14.4	0/58
494910 - EAST FORK SEVIER RIVER AT U62 CROSSING EAST OF KINGSTON															
1993 - 1994	17	11	0	23	6	17	0.08	0.03	0.17	82	17	9.0	6.4	12.8	0/24
2001	17	12	0	22	18	16	0.07	0.03	0.15	69	17	9.4	6.8	14.2	0/18
494921 - OTTER CREEK BELOW OTTER CREEK RESERVOIR															
1993 - 1994	15	14.74	8.30	20.00	0	15	0.07	0.02	0.12	73	13	7.92	3.00	13.00	7.7/53.8
494922 - OTTER CREEK RESERVOIR ABOVE DAM 01															
1993 - 1994	59	16	2	20	14	43	0.07	0.02	0.27	86	59	7.1	3.4	10.6	24959
2002	22	17	11	21	27	10	0.10	<BDL>	0.23	70	17	7.1	2.7	8.5	19511
494923 - OTTER CREEK RESERVOIR MIDWAY UP LAKE 02															
1993 - 1994	25	18	11	22	12	24	0.09	0.02	0.18	92	23	7.4	3.9	10.9	4/70
2002	16	17	11	21	31	7	0.09	0.02	0.19	71	14	8.0	6.8	9.7	0/50

Table 3.7. (cont'd) Summary of existing water quality parameters including dissolved oxygen, total phosphorous, and water temperature for selected reservoir and stream monitoring sites within the study area.

Site	Water Temperature (°C)					Total Phosphorus (mg/L)					DO (mg/L)				
Date	Samples	Mean	Min[a]	Max	% > 20 C	Samples	Mean	Min[a]	Max	% > .025 mg/l - % > 0.05 mg/l	Samples	Mean	Min[a]	Max	% > 4.0/8.0 mg/l
494924 - EAST FORK SEVIER RIVER CANAL AT INFLOW TO OTTER CREEK RESERVOIR															
1993 - 1994	14	13	5	22	7	14	0.21	0.02	0.84	64	13	9.0	7.1	11.4	0/39
2002	5	14	3	22	20	4	0.14	0.03	0.30	50	5	8.4	6.5	10.2	0/40
494926 - EAST FORK SEVIER RIVER ABOVE DIVERSION AT ANTIMONY															
1993 - 1994	14	13.76	8.30	20.8	7	14	0.10	0.02	0.59	57	13	9.22	7.20	11.90	0/23.1
2001 - 2002	12	10.18	2.43	19.3	0	12	0.04	0.02	0.08	33	12	10.12	8.34	12.42	0/0
494931 - OTTER CREEK RESERVOIR 05 NEAR UPPER END															
1993 - 1994	21	17.78	10.80	21.30	14	22	0.10	0.02	0.25	96	19	7.14	3.20	9.90	10.5/57.9
2002 - 2002	6	18.62	16.80	20.67	17	2	0.05	0.04	0.07	100	5	9.62	8.67	10.40	0/0
494954 - ANTIMONY CREEK ABOVE CONFLUENCE WITH EAST FORK SEVIER RIVER															
1993 - 1994	9	13.48	8.70	21.0	11	10	0.06	0.02	0.19	30	9	7.30	5.50	9.10	0/66.7
2002 - 2003	6	10.24	0.29	24.4	17	4	0.05	0.03	0.06	50	6	9.16	6.74	11.65	0/50
594562 - LOWER BOX CREEK RESERVOIR 01															
1994 - 1994	8	17	15	18	0	4	0.15	0.05	0.26	100	8	8.2	1.8	11.4	13/38
2002	14	15	10	19	0	5	0.08	0.04	0.11	100	9	8.8	5.8	11.5	0/33
594563 - BOX CREEK BELOW UPPER BOX CREEK RESERVOIR AND ABOVE LOWER BOX CREEK RESERVOIR															
1994 - 1994	1				0	2	0.17	0.05	0.28	100	1				0/100
2002 - 2003	8	14.99	7.36	18.38	0	5	0.10	0.03	0.13	80	7	7.52	6.85	8.13	0/71.4
594577 - KOOSHAREM RESERVOIR ABOVE DAM 01															
1994 - 1994	7	19	19	20	29	4	0.21	0.16	0.24	100	7	5.6	3.7	6.7	14/100
2002	17	18	9	26	24	8	0.16	0.05	0.30	100	13	7.8	5.5	8.7	0/31
594578 - KOOSHAREM RESERVOIR MIDWAY UP LAKE															
1998 - 1998	2	19.20	18.40	20.00	0	2	0.04	0.03	0.04	100	2	5.75	4.20	7.30	0/100
594579 - OTTER CREEK ABOVE KOOSHAREM RESERVOIR															
1993 - 1994	1				0	2	0.12	0.07	0.17	100	1				0/100
2001 - 2002	13	11.50	0.69	24.90	15	13	0.16	<BDL>	1.02	46	12	8.59	6.27	11.35	0/33.3
594580 - BOOBE HOLE CREEK ABOVE KOOSHAREM RESERVOIR															
1993 - 1994	4	12.10	7.30	18.40	0	5	0.09	0.04	0.14	60	4	7.85	7.30	8.90	0/75
2001 - 2002	14	11.94	0.20	27.55	21	13	0.08	0.03	0.22	69	13	8.53	5.80	11.68	0/38.5

[a] <BDL> = below detection limit.

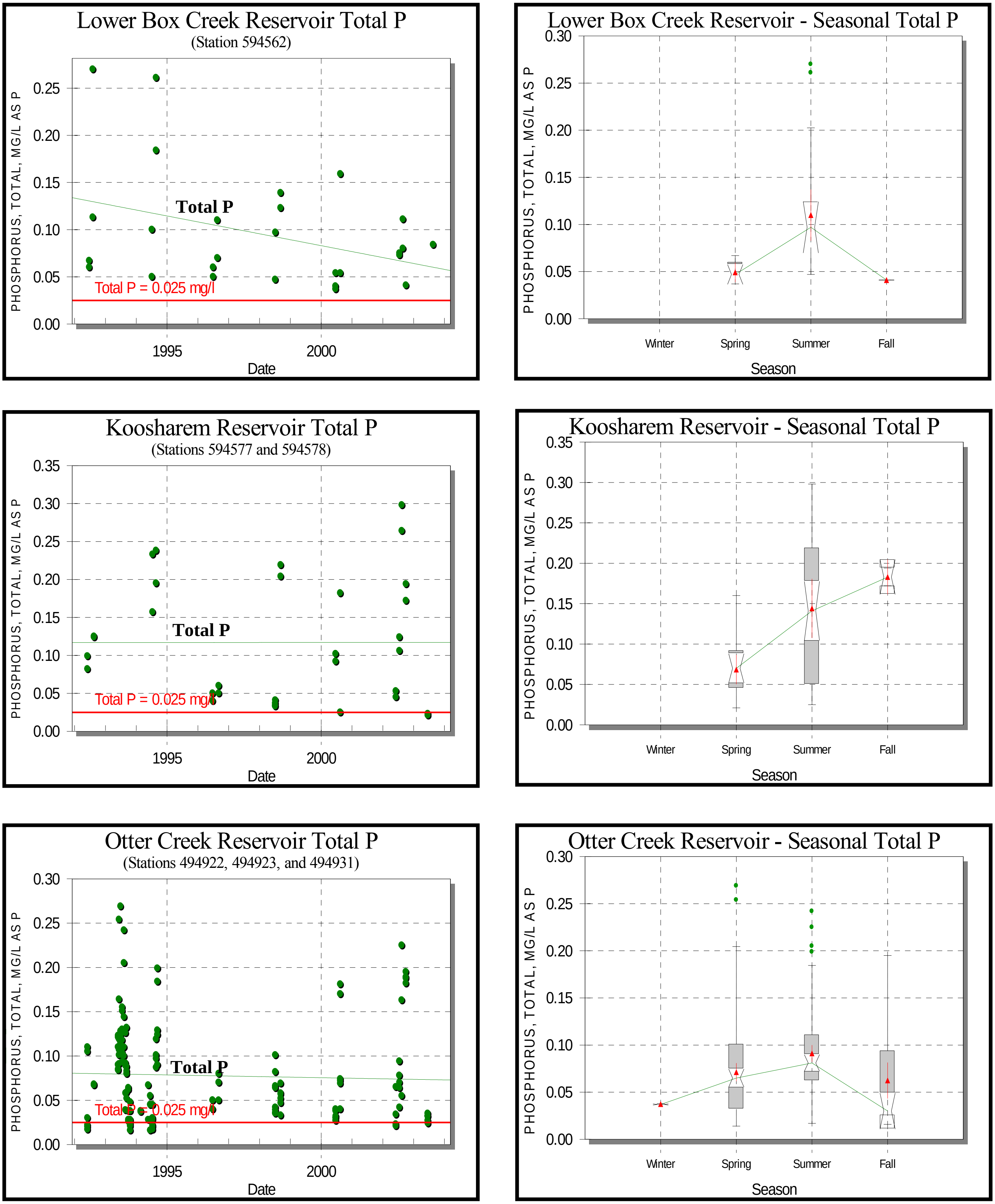

Figure 3.5. Reservoir Total P concentration for each sample date and seasonal period for Lower Box Creek, Koosharem, and Otter Creek Reservoirs (1992 – 2003). Data points shown in graphs on left represent all measurements collected from monitoring stations on each sample date. Note the best-fit line indicating Seasonal trends shown in graphs on right account for all Total P measurements during each 3-month seasonal period (e.g. winter season = January – March, spring season = April – June, etc.)

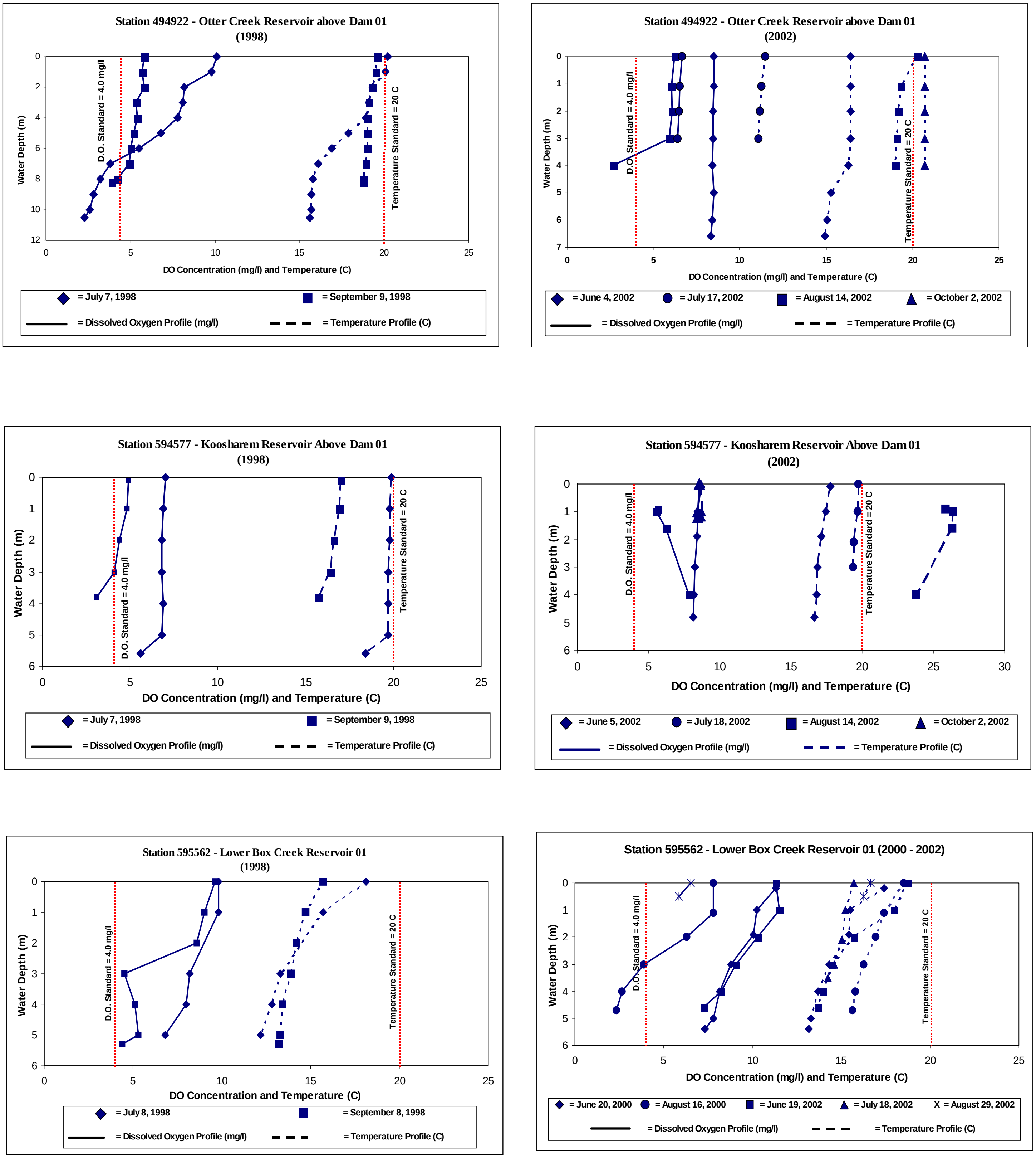

Figure 3.6. Water column profile measurements of Dissolved Oxygen (DO) and Temperature in Otter Creek Reservoir, Koosharem Reservoir, and Lower Box Creek Reservoir. Measurements shown were collected at the deepest monitoring site for each reservoir. Note the vertical dashed lines representing the Class 3A standards for DO and temperature.

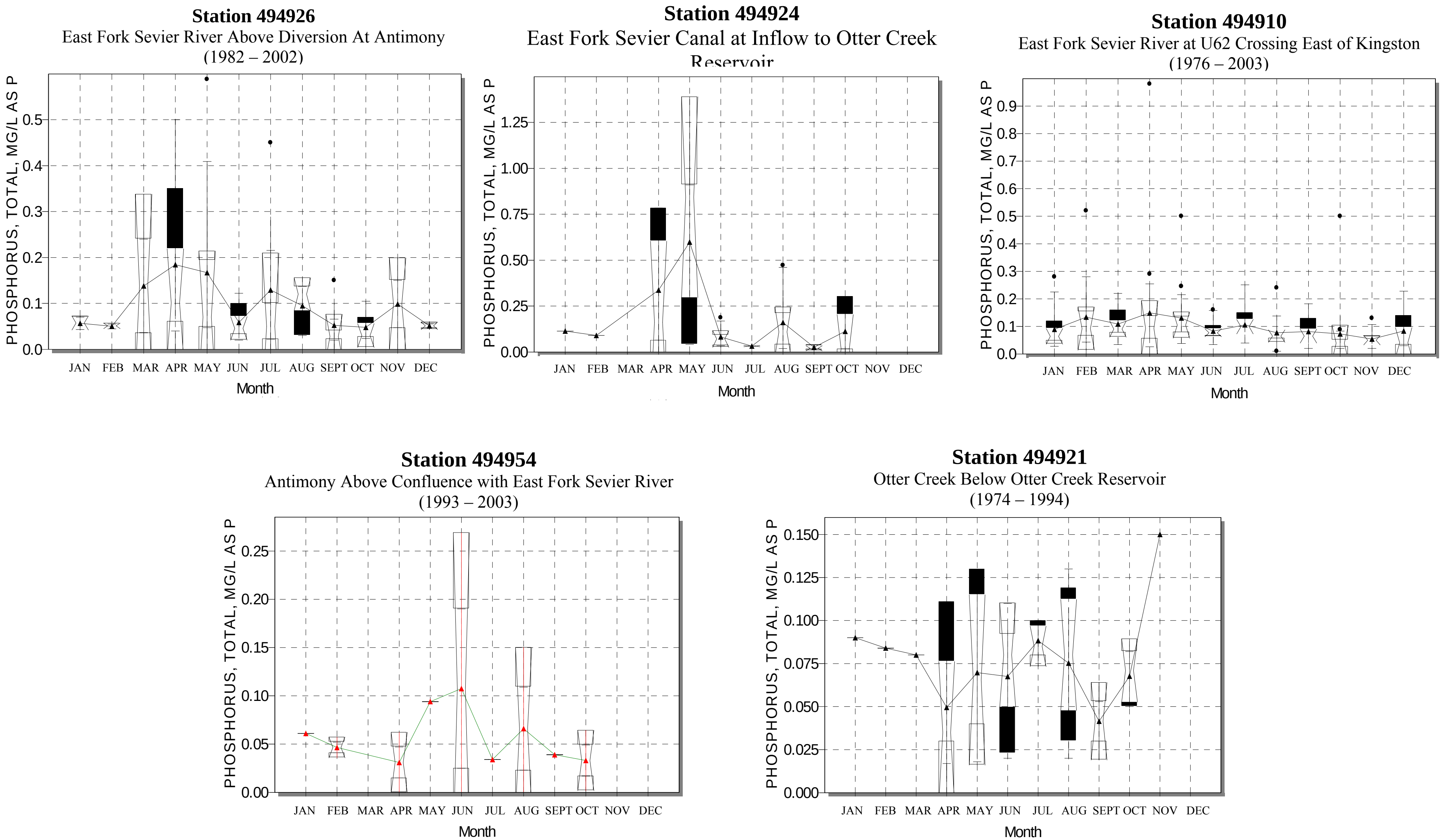

Figure 3.7. Monthly average Total Phosphorus concentration for selected stream monitoring stations on the mainstem and major tributaries to the East Fork Sevier. The data record used to calculate monthly averages is indicated in the title to each plot.

3.3.1.1 Koosharem Reservoir

Water quality has been monitored in Koosharem Reservoir at Station 594577 (Koosharem Reservoir Above Dam 01) and Station 594578 (Koosharem Reservoir Midway Up Lake). Measured TP concentrations from station 594577 during 1992 – 2003 indicated that all samples exceeded the 0.025 mg/l criterion with the exception of samples collected during late summer 2000 (Table 3.6). TP concentrations during this visit averaged 0.104 mg/l.

Historic WQ data for Koosharem Reservoir indicates that roughly half of TP samples are above the desired 0.025 mg/l concentration level (Figure 3.5). Maximum TP concentrations at this site were measured at several depths in the water column during August 2002. A trend assessment of TP measurements collected from 1992-2003 did not indicate if concentrations in Koosharem Reservoir are increasing or decreasing (Figure 3.5). However, mean TP concentration in 2002 measured 0.16 mg/l compared to 0.21 mg/l during 1994 (Table 3.7). Although it is difficult to determine if a decreasing trend actually exists, it is noted that three of the four monitoring visits to station 594577 during 2002 had measured TP concentrations that were roughly equal to or less than those observed during the two visits in 1994.

In general, TP concentrations in Koosharem Reservoir appear to increase through the summer and fall. Seasonal box-and-whisker plots indicated that mean TP concentrations in Koosharem Reservoir (station 594577) in the fall season are slightly higher than concentrations in the fall season (Figure 3.5). However, several of the highest TP concentrations were measured during summer 1998 and summer 2002 (Table 3.6). It is anticipated that irrigation demand and decreased inflow produce a smaller reservoir mixing volume for summer and fall season TP contributions to Koosharem Reservoir. As a result, concentrations gradually climb throughout the summer and fall.

An assessment of water quality conditions in the two major inflows to the reservoir including Otter Creek (station 594579) and Boobe Hole Creek (station 594580) indicate that the 0.05 mg/l TP criterion for streams was exceeded 46 percent and 69 percent of the time respectively (Table 3.7). Maximum TP concentrations for both streams occurred in the winter or early spring season of 2002. Water quality data collected in the upper areas of the Koosharem Reservoir watershed are very limited. Two samples have been collected from Boobe Hole Creek (station 594581) approximately one mile below Boobe Hole Reservoir. TP concentrations from these samples, collected during May 1990, measured 0.138 mg/l and 0.144 mg/l.

Water column profile measurements of DO and temperature in Koosharem Reservoir during the recent past have generally been in the desired range, even during periods when reservoir depths are shallow (Table 3.6 and Figure 3.6). DO concentrations generally descrease throughout the summer and into the fall season while temperatures generally increase. Maximum water temperatures were recorded in fall 2002 at 25.60 °C (Table 3.6). DO concentrations during this time were all above 4.0 mg/l (Figure 3.6).

3.3.1.2 Lower Box Creek Reservoir

Water quality samples at Lower Box Creek Reservoir were collected at station 594562 just above the dam. All TP measurements exceeded 0.025 mg/L during routine reservoir monitoring completed from 1990 though 2002 (Table 3.6). Average measured concentrations during this time ranged from 0.04 mg/l to 0.19 mg/l.

A review of historic WQ data for Lower Box Creek Reservoir indicates that although all measurements have exceeded the TP indicator value during the past decade, concentrations appear to be decreasing slightly (Table 3.7). The mean TP concentration in 1993-94 was 0.15 mg/l (4 observations) and 0.08 mg/l in 2001-2002 (5 observations). A trend assessment (multiple regression) of TP measurements for Station 595562 indicates that concentrations are exhibiting a decreasing trend during the past decade (Figure 3.5).

The seasonal distribution of TP measurements indicated that concentrations were highest during the summer (July – August) as compared to the spring and fall seasons (Figure 3.5). The summer season corresponds to those periods when irrigation demand is high, resulting in low water storage volumes in Lower Box Creek Reservoir.

The major tributary to Lower Box Creek Reservoir is Box Creek which is supported by discharge from Upper Box Creek Reservoir. DWQ monitoring of Box Creek between these reservoirs is located at Station 594563. Average TP concentrations during intensive monitoring cycles ranged from 0.10 mg/l in 2002 – 2003)to 0.17 mg/l in 1994 (Table 3.7). Percent exceedance during these same time periods were 80 percent and 100 percent, respectively.

All DO measurements in Lower Box Creek Reservoir during 1992-2003 were above 4.0 mg/l with the exception of measurements taken on August 16, 2000, when half of the measurements were below the DO standard (Table 3.6). Average water column DO concentrations ranged from roughly 10 mg/l to 5 mg/l and were generally in excess of 8.0 mg/l with the exception of samples collected during the latter part of the irrigation season. During these periods, water depths in the reservoir are typically at their lowest annual depths. Water temperature measurements were generally less than 20 °C and followed seasonal patterns similar to DO concentrations.

A review of DO and temperature profiles collected from Lower Box Creek Reservoir during 1998 and 2000 indicated that the water column is fairly well mixed with no evidence of stratification (Figure 3.6). This is typical of shallow reservoirs due to mixing processes such as surface turbulence, thermal influences, and reservoir drawdown that prevent stratification.

3.3.1.3 Otter Creek Reservoir

Monitoring data collected from 3 sites on Otter Creek Reservoir were used in this assessment including Station 494922 (Otter Creek Reservoir above Dam 01), Station 494923 (Otter Creek Reservoir Midway Up Lake 02) and Station 494931 (Otter Creek Reservoir 05 Near Upper End). All TP measurements collected from Station 494922 exceeded the 0.025 mg/l indicator value with the exception of 1 measurement in June 1992 and 3 measurements in June 2002 (Table 3.6).

TP concentrations in the reservoir appeared to increase slightly with distance from the dam, as shown by the percent of samples exceeding the 0.025 mg/l narrative standard (Table 3.7). This occurrence is likely due to the larger volume of water available at stations nearer the dam that subsequently dilute TP concentrations. Only three samples collected from the three reservoir monitoring stations during 2000 – 2003 had a measured TP concentration less than 0.025 mg/l (Figure 3.5).

A review of historic WQ data indicates that TP concentrations decreased slightly during 1996 – 2000 and then increased from 2000 – 2002 (Figure 3.5). No TP measurements during these years were below the 0.025 mg/l narrative standard. Although some fluctuation in mean annual TP concentration occurred, the overall trend slightly decreased from 1992 – 2003 (Figure 3.5). The sampling history for station 494922 indicated that a total of nine samples collected during four visits had measured TP concentrations below the 0.025 mg/l narrative standard. Roughly 70 percent of all samples measured at stations 494922 and 494923 exceeded 0.025 mg/l TP while nearly all samples collected at station 494931 exceeded this level (Table 3.7).

A seasonal assessment of Otter Creek Reservoir indicated that TP concentrations during the summer months are slightly higher than those observed during the spring, fall or winter (Figure 3.5). TP concentration measured at station 494922 during February 1994 was roughly 0.04 mg/l, and represents the only sample collected during the winter season.

An assessment of the two major inflows to Otter Creek Reservoir, including Otter Creek and the East Fork canal, indicated that annual average TP concentrations were generally higher in the East Fork canal than in Otter Creek. During the 1993-94 and 2001-02 intensive monitoring surveys, the mean TP concentrations at station 494887 (Otter Creek above Diversion 1 mile north of Angle) were 0.06 mg/l and 0.04 mg/l, respectively (Table 3.7). TP concentrations during these same time periods for station 494924 (East Fork Sevier Canal at inflow to Otter Creek Reservoir) were 0.21 mg/l and 0.14 mg/l, respectively (Table 3.7). The number of samples exceeding the 0.05 mg/l TP narrative standard ranged from 27-44 percent for Otter Creek and 50-64 percent for the East Fork Canal.

A comparison between TP concentration of inflows to Otter Creek Reservoir and TP concentration in the reservoir did not indicate any strong trends. Inflow TP concentrations decreased slightly between 1993-94 and 2001-2002 while reservoir TP concentrations increased slightly or remained the same (Table 3.7). It is difficult to complete a temporal assessment of TP concentrations due to the limited seasonal nature of reservoir data which generally consist of TP measurements collected during May through October. A more in-depth review of flow and concentration data for Otter Creek Reservoir is provided below in Chapter 4.

Profile measurements of DO and temperature from Otter Creek Reservoir indicated some violations of the Class 3A standards associated with these parameters. DO concentrations during 1992 – 2003 generally ranged between 4.0 mg/l – 8.0 mg/l, with only a few sample dates exhibiting measurements less than 4.0 mg/l (Table 3.6). In general, the DO profile at station 494922 appears fairly well mixed with only slight indications of stratification (Figure 3.6).

Shallow reservoir depths and summer season both appear to heavily influence water temperature. Maximum water temperatures were measured during two visits to station 494922 on August 15, 2000 and July 17, 2002. During these visits, all water column measurements of temperature exceeded 20 °C (Table 3.6). Reservoir depths measured 3.1 meters and 3.8 meters, respectively, on these measurement dates. In general, water temperature measurements ranged between 15 °C and 20 °C (Figure 3.6).

3.3.1.4 East Fork Sevier River

Measurements of TP on the East Fork Sevier River were collected at two primary locations during the 1993-94 and 2001-2002 intensive monitoring cycles. These two locations included Station 494910 (East Fork Sevier River at U62 Crossing East of Kingston) and Station 494926 (East Fork Sevier River above Diversion at Antimony). Water quality measurements collected at Station 494924 (East Fork Sevier River Canal at Inflow to Otter Creek Reservoir) provide a seasonal measurement for the upper portion of the East Fork Sevier as the entire flow from this segment is diverted into Otter Creek Reservoir during the early spring season.

Average annual TP concentration during 2001-2002 was slightly lower than during 1993-94 (Table 3.7). In general, annual TP concentrations show a limited increase with distance downstream on the mainstem East Fork Sevier. Average TP concentrations were typically lower on tributaries including Station 494954 (Antimony Creek above confluence with East Fork) and Station 494921 (Otter Creek below Otter Creek Reservoir). A substantial difference in average TP was noted between stations located on the mainstem East Fork Sevier and the East Fork Canal (Table 3.7). Annual average TP concentration on the East Fork Canal measured 0.21 mg/l and 0.14 mg/l during the 1993-94 and 2001-02 monitoring cycles respectively, and were roughly 0.10 mg/l higher than annual averages for the mainstem East Fork Sevier at Station 494926. Over two-thirds of TP samples collected at the watershed outlet from station 494910 exceeded the 0.05 mg/l narrative standard during the 1993-94 and 2001-2002 intensive monitoring cycles. This trend continued at upstream monitoring stations on the East Fork Sevier, although exceedance levels were less than those observed at Station 494910 (Table 3.7).

Monthly averages in water quality indicate that maximum monthly average TP concentrations generally occur in the spring season during the months of April and May (Figure 3.7). TP concentrations at Station 494926 range near 0.1 mg/l but are somewhat higher at Station 494924 with many monthly values above 0.2 mg/l. Average Monthly TP concentrations discharged from Otter Creek Reservoir are all below 0.1 mg/l (Station 494921) with maximum concentrations occurring in July. Monthly average TP concentrations vary minimally at 494910. It is anticipated that water quality dynamics at this site are influenced by discharge volumes released from upstream Otter Creek Reservoir, which serves to dilute the seasonal effects of spring runoff.

DO concentrations along the East Fork and Antimony Creek are generally good with no samples measured below 4.0 mg/l. However DO measurements were below 8.0 mg/l for 50 percent of samples at station 494954 (Antimony Creek above confluence with East Fork) and 18 percent of samples at station 494910 (East Fork near Kingston) (Table 3.7). Temperature measurements were good at all stations with the exception of 18 percent of the samples at station 494910 that exceeded 20 °C.

3.3.1.5 Otter Creek

Although Otter Creek is not listed on the 2004 303(d) list as impaired it is discussed here due to the significance of tributary inflow from this waterbody to Otter Creek Reservoir. Recent monitoring efforts within segments of Otter Creek included measurements at Station 494887 (north of Angle), Station 494894 (at Narrows), Station 494907 (north of Koosharem) and Station 494908 (outlet from Koosharem Reservoir). Samples were collected throughout all seasons of the year at these locations during intensive monitoring periods. TP concentrations appear to decrease with distance below Koosharem Reservoir. The proportion of samples exceeding the 0.05 mg/l TP narrative standard just below Koosharem Reservoir was 69 percent and 95 percent for Stations 494907 and 494908, respectively (Table 3.7). Roughly 45 percent of samples collected from monitoring stations on lower segments of Otter Creek, including Stations 494887 and 494894 exceeded 0.05 mg/l during intensive monitoring (Table 3.7).

Major tributaries to Otter Creek between Koosharem Reservoir and Otter Creek Reservoir include Burr Creek, Greenwich Creek, Box Creek and outflow from Koosharem Reservoir. The influence of tributaries to water quality in Otter Creek below Koosharem Reservoir is reduced due to irrigation diversions and intermittent stream flows. Measured TP concentrations in Box Creek (Station 494892) and Greenwich Creek (Station 494890) exceeded the 0.05 mg/l TP narrative standard in 75 percent and 64 percent of samples collected during 2001-2002, respectively (Table 3.7). The largest contribution to flow in Otter Creek within this segment is discharge from Koosharem Reservoir as represented by Stations 494907 and 494908. The percent of samples exceeding 0.05 mg/l TP at these stations were 70 percent and 95 percent, respectively (Table 3.7).

Two point sources are located in the watershed area between Koosharem Reservoir and Otter Creek Reservoir, including the Road Creek fish hatchery (Station 494877) and Deans fish hatchery (Station 494875). The Road Creek fish hatchery discharges directly to Burr Creek above the town of Burrville, while Deans fish hatchery discharges to a canal located along the east side above Otter Creek near Greenwich. TP concentration measured from these two facilities exceeded the 0.05 mg/l criterion from 58 percent to 100 percent in samples collected during intensive monitoring (Table 3.7).

Historical water quality data in Otter Creek indicate that TP concentrations have appeared to decrease slightly. A review of the mean TP concentrations measured at stations 494894 and 494887 indicate that concentrations have dropped slightly during the two intensive monitoring rounds completed during 1993-94 and 2001-02 (Table 3.7). Although the number of samples collected during these two time periods varies somewhat between stations, it is believed the samples adequately characterize annual variation in TP concentration at each site.

3.3.2 Groundwater Quality

Groundwater quality measurements can be used to determine natural concentrations of TP delivered to surface water bodies through discharge from springs and high water tables. Data characterizing groundwater quality has been collected by the USGS and DWQ through periodic measurements of wells and surface locations of groundwater discharge (springs). A review of all water quality data collected from well and spring monitoring stations was completed for this assessment in order to determine the range of collection dates and the number and type of water quality parameters measured at each station. Those stations maintaining phosphorus measurements were selected for further review. Outliers from this data set were identified and removed based on exceedence of 1.5 x inter-quartile range (Moore and McCabe 1993) and best professional judgement of factors that may have influenced the data point. A grouped statistical summary of data collected from these sites are shown in Table 3.8.

A formal monitoring program of groundwater quality in Utah was commenced in 1957 by the USGS. This program included 4 monitoring wells located within the TMDL study area. A summary of data collected during 1962 – 1984 for these wells is provided by Price and Arnow (1986). The report indicated that dissolved solids concentration of groundwater in the TMDL study area is 224 mg/L and much less than the 1,000 mg/L threshold used by the USGS to classify fresh water. Price and Arnow (1986) indicated that no significant trends in groundwater quality were observed during the monitoring period (1962 – 1984). However, no measurements of phosphorus were included in the study. In order to locate phosphorus data, a review of all well monitoring stations in the TMDL study area was conducted. Four stations with phosphorus data were located, including three of four wells assessed previously by Price and Arnow (1986). The mean DTP concentration of the 20 well samples identified was 0.04 mg/L, including 3 samples that were below the measured limit of detection. Total well depth for these four stations ranged from 90 ft. to 200 ft.

Water quality from all monitored springs was reviewed in order to identify those springs with phosphorus measurements (Table 3.8). Phosphorus data was identified from a total of ten springs, all of which were monitored by the DWQ. Data from three springs were identified as outliers and removed from the statistical assessment of water quality. Mean TP concentration for the remaining seven springs was 0.035 mg/L including four samples that were below the measured limit of detection.

Table 3.8 Grouped statistical assessment of water quality parameters measured from USGS well monitoring stations and DWQ springs located in the TMDL study area.

Wells[1]										
Parameter	**Dates**	**Samples**	**Number BDL**	**Mean**	**Median**	**SD**	**Variance**	**Geometric Mean**	**Min.**	**Max.**
Temperature (ºC)	1959 - 2001	97	0	13.97	13	2.79	7.81	13.72	8.5	24
Total Hardness as $CaCO_3$ (mg/L)	1959 - 1982	27	0	168.70	210	72.20	5212.84	149.1	62	250
Total Dissolved Solids (mg/L)	1962 - 1982	16	0	244.30	289.5	81.02	6564.24	229.2	127	332
Nitrite plus Nitrate, Dissolved (mg/L)	1980 - 2000	21	0	0.44	0.384	0.21	0.04	0.3931	0.1	0.76
pH	1959 - 2001	65	0	7.77	7.6	0.43	0.19	7.758	7	9.9
DTP (mg/L)	1980 - 2000	20	3	0.04	0.03	0.02	0.00	0.0322	<BDL>	0.09
Specific Conductance (μmhos/cm)	1959 - 2001	97	0	360.00	430	136.60	18659.56	329.5	150	560
Total Alkalinity as $CaCO_3$ (mg/L)	1962 - 1981	17	0	154.00	178	58.26	3394.23	141.7	76	236
Total depth of well (ft)	1962 - 1981	42	0	172.70	197	46.79	2189.30	164.4	90	200
Springs[2]										
Parameters	**Dates**	**Samples**	**Number BDL**	**Mean**	**Median**	**SD**	**Variance**	**Geometric Mean**	**Min.**	**Max.**
Dissolved Oxygen (mg/l)	1989 - 2003	14	0	8.84	8.83	1.15	1.33	8.76	6.87	10.59
PH	1989 - 2003	15	0	8.19	8.19	0.56	0.32	8.16	7	8.85
Specific Conductance (μmhos/cm)	1989 - 2003	15	0	284.40	249	119.50	14280.25	262.30	144	486
Temperature (ºC)	1989 - 2003	15	0	9.25	10.1	3.27	10.66	8.64	3.48	14.1
Total Alkalinity as $CaCO_3$ (mg/l)	1983 - 1994	10	0	150.40	105.2	85.96	7389.12	128.40	59.14	253
Total Nitrogen Ammonia (mg/L)	1983 - 2003	19	17	0.01	0.00026	0.02	0.001	0.00	<BDL>	0.101
Nitrite plus Nitrate, Dissolved (mg/L)	1991 - 2003	10	4	0.14	0.0815	0.15	0.02	0.08	<BDL>	0.42
DTP (mg/l)	1991 - 2003	10	6	0.02	0.018	0.004	0.00	0.02	<BDL>	0.026
TP (mg/L)	1983 - 2003	18	4	0.04	0.036	0.03	0.001	0.03	<BDL>	0.081

[1] The four wells included in this assessment are: (C-26-1) 23ddb-1, (C-29-2) 35bad-1, (C-30-2) 28bdc-1, and (C-31-2) 23bcd-2.

[2] Stations used in this assessment include the following:

494879 – Osiris Spring; 594612 – Spring at discharge pipe in Pine Lake; 599131 – Root Spring; 599132 – King Spring; 599134 – Nick's Spring; 599135 – Pole Canyon Spring; 599140 – Birch Springs

3.3.3 Existing Flow Conditions

A statistical summary of flow data collected at USGS monitoring stations is shown below in Table 3.9. The location of these monitoring stations is shown in Figure 3.3. Time series plots and monthly box and whisker plots of stream flow for each site are presented in Appendix B - Data. A review of the monthly distribution of streamflow at each station indicates that peak median monthly flows are found during April through June with the exception of station 10187500 (Otter Creek above Reservoir near Antimony) and station 10189000 (East Fork Sevier River near Kingston). Station 10187500 exhibits peak median monthly flow in March with a rapid decrease to nearly zero in June as a result of upstream irrigation diversions. Stream flow at station 10189000 is influenced in a large part by discharge from Otter Creek Reservoir. This influence is reflected in the pattern of median monthly discharge at this site. Median monthly flows at this site are roughly equivalent during the months of May through August indicating the moderating influence of Otter Creek Reservoir.

3.4 STREAM CHANNEL ASSESSMENT

A measure of stream health and overall channel stability can identify conditions that contribute to pollutant loading. A total of 79.9 miles of stream channels and near-channel areas along Otter Creek and the impaired section of the East Fork Sevier River were evaluated using the Stream Visual Assessment Protocol (SVAP) developed by the Natural Resource Conservation Service (NRCS 1998). This method quantifies the health of stream channels using several categories that can be rapidly scored during field efforts. Streambank erosion potential was also assessed using the Streambank Erosion Control Index (SECI) method. Major categories used to evaluate stream channels by the SVAP and SECI methods are provided below in Table 3.10.

The SVAP assessment method indicated that most of the stream reaches surveyed were in poor condition (64.3 miles), while smaller sections of the stream were in fair (7.5 miles), good (4.2 miles), and excellent (3.8 miles) condition. Summary results from the SVAP assessment are shown in Table 3.11. Stream reaches classified as excellent or good condition were observed in the upper headwater areas of Otter Creek in Daniels Canyon or along Antimony Creek. Stream reaches in fair condition were found on Otter Creek immediately below Koosharem Reservoir and just below the Narrows as well as several locations along the lower East Fork Sevier. The remaining stream segments were identified to be in poor condition according to the SVAP protocol.

Table 3.9. Statistical summary of flow data (cfs) from USGS and DWQ monitoring stations in the Otter Creek project area.

Station	# of Observations	Range of Dates	Mean	Geometric Mean	Median	SD	Variance	Min	Max
10183900 – E. Fork Sevier near Ruby's Inn UT	12,418	1961 - 1995	17.3	11.1	9.9	27.5	754.7	0	418
494940 – E. Fork Sevier above Tropic Reservoir	31	1990 - 2003	39.8	9.1	9	92.9	8,621.1	0	500
10184450 – E. Fork Sevier near Antimony UT	9,590	1961 - 1966	31.0	23.8	20	41.0	1,680.2	14	542
494926 – E. Fork Sevier above diversion at Antimony	48	1983 - 2002	56.8	37.2	33.5	78.7	6,198.4	5.8	500
10185000 – Antimony Creek near Antimony	7,732	1946 - 1976	21.0	18.3	17	21.0	437.9	12	314
494954 – Antimony Creek above confluence with E. Fork Sevier	20	1993 - 2003	10.3	6.5	7.45	8.4	70.9	0	25
10187300 – Otter Creek near Koosharem	6,635	1964 - 1982	12.0	10.8	9.6	7.6	57.0	4.8	91
594579 – Otter Creek above Koosharem Reservoir	50	1990 - 2003	2.1	0.5	0.8	3.2	10.4	0	17.5
10187500 – Otter Creek above Reservoir near Antimony	4,629	1961 - 1980	9.5	2.1	1.2	14.5	211.3	0	123
494887 – Otter Creek above diversion 1 mile N of Angle	97	1979 - 2003	17.1	12.8	14.4	13.3	176.4	0.1	80
10189000 – E. Fork Sevier near Kingston	31,963	1913 - 2000	80.2	44.0	34	101.0	10,191.5	5.5	1,740
494910 – E. Fork Sevier at U62 crossing E. of Kingston	177	1976 - 2001	96.2	58.5	58.8	110.0	12,100.0	9.1	1030

Table 3.10. Categories used to evaluate stream channel conditions in the TMDL study area.

SVAP method	SECI method
Channel condition	Bank erosion evidence
Hydrologic alteration	Bank stability condition
Riparian zone	Bank cover/vegetation
Bank stability	Lateral channel stability
Water appearance	Channel bottom stability
Nutrient enrichment	In-channel deposition
Barriers to fish movement	
Instream fish cover	
Pools	
Invertebrate habitat	

Table 3.11. SVAP and SECI summary for surveys conducted in June 2003.

SVAP						
Stream Condition	**Average SVAP Score**	**SD**	**Number of reaches (n)**	**Average length (miles)**	**Total length (miles)**	**Percent of stream surveyed (%)**
Poor	4.2	1.2	39	1.4	64.3	81%
Fair	6.5	0.5	7	1.1	7.5	9%
Good	8.3	0.5	3	1.4	4.2	5%
Excellent	9.6	0.0	1	3.8	3.8	5%
SECI						
Erosion Severity	**Average SECI Score**	**SD**	**Number of reaches (n)**	**Average length (miles)**	**Total length (miles)**	**Percent of stream surveyed (%)**
Slight	2.0	1.6	34	0.97	50.6	63%
Moderate	7.0	1.2	13	0.41	26.9	34%
Severe	10.0	1.7	3	0.81	2.4	3%
Total length of stream surveyed (miles)						**79.9 miles**

SECI scores indicated that of the nearly 80 miles surveyed, approximately 48 miles presented slight erosion, 21 miles presented moderate erosion, and extreme erosion was evident in approximately 2.4 miles (Table 3.11). Stream reaches exhibiting severe erosion were located in reaches immediately below Otter Creek Reservoir. Reaches with moderate erosion were observed on the East Fork Sevier River along reaches between Otter Creek Reservoir and the confluence of Antimony Creek, as well as in the middle section of Otter Creek near the confluence of Box Creek.

The combined score from SVAP and SECI measures may provide a means for organizing stream segments into groups that require similar measures to rehabilitate or restore a group of channel segments. A description of each of these groups is provided in Appendix C - SVAP (Table C.6) and shown in Figure C.3. A detailed assessment of each stream channel segment is also provided in Appendix C - SVAP.

3.5 MACROINVERTEBRATE ASSESSMENT

Macroinvertebrates are beginning to be widely accepted as a surrogate measure of water quality due to their ability to reflect biological health of a water body. Some species of macroinvertebrates are very sensitive to water quality and will only exist in streams and lakes where water quality is high. Other species are somewhat tolerant or highly tolerant to pollution and can exist under a wide range of water quality conditions. The available macroinvertebrate data was collected by the DWQ and includes measurements of invertebrate abundance from 1990 to 1998. Samples have been collected during all seasons at monitoring stations located in Otter Creek and the East Fork.

The most current data (collected in 1998) was used to calculate the Family Level Biotic Index (FBI) (Hilsenhoff 1988). This index represent the average weighted pollution tolerance value for all arthropods present in a sample, with the exemption of organisms that are too immature or damaged to be identified, as well as organisms that have not yet been assigned a pollution tolerance value. The FBI is an index of organic pollution and is based on the response of a community to the combination of high organic loading and decreased dissolved oxygen levels. Pollution tolerance values were assigned to the family level of each one of the organisms identified with lower values representing pollution intolerant families. The dominant taxa, abundance, tolerance values of organisms identified, and FBI values are shown in Table 3.12.

Table 3.12. Macroinvertebrates identified at stream monitoring sites on Otter Creek and the East Fork Sevier River (1998).

Stream	Station	Date	Genus or specie	Family	Abundance (#/m^2)	%[1]	Tolerance Value [2]	FBI [3]
Otter Creek	Otter Creek above Narrows (494873)	July-98	*Baetis*	Baetidae	5034	57	4	**4.8**
		July-98	*Orthocladiinae*	Chironomidae	1091	12	8	
		July-98	*Zaitzevia*	Elmidae	1453	16	4	
	Otter Creek ½ mile above Narrows (494874)	July-98	*Baetis*	Baetidae	2153	19	4	**6.9**
		July-98	*Chironomini*	Chironomidae	8066	69	8	
		July-98	*Tricorythodes minutus*	Leptohyphidae	402	3	4	
	Otter Creek above diversion 1 mi. North of Angle (494887)	April-98	*Orthocladiinae*	Chironomidae	6071	23	8	**5.2**
		April-98	*Zaitzevia*	Elmidae	13886	53	4	
	Otter Creek at the Narrows (494894)	April-98	*Baetis*	Baetidae	5253	43	4	**5.1**
		April-98	*Orthocladiinae*	Chironomidae	1819	15	8	
		April-98	*Simuliidae*	Simuniidae	2723	22	6	
	Otter Creek at U62 xing North of Koosharem (494907)	April-98	*Baetis*	Baetidae	6897	53	4	**4.8**
		April-98	*Simuliidae*	Simuniidae	2452	19	6	
	Otter Creek near Angle at CR xing (494920)	July-98	*Orthocladiinae*	Chironomidae	82725	96	8	**7.9**
East Fork Sevier	East Fork Sevier River at USGS station 10183900 above Tropic Res. (494940)	May-97	*Baetis*	Baetidae	218	15	4	**6.8**
			Orthocladiinae	Chironomidae	915	63	8	

[1] Percent composition in sample.
[2] Tolerance values based on Hilsenhoff (1988).
[3] Hilsenhoff Family Biotic Index.

Hilsenhoff's FBI water quality rating system is shown in Table 3.13. This index is seasonally dependent; higher values occur during the summer because the organisms present during this month generally tend to be more tolerant to pollution than the organisms that are present during spring. The FBI values calculated for stations in Otter Creek ranged from 4.8 to 7.9, suggesting that some sections of the stream present some degree of pollution while in others, the degree of pollution is severe. The FBI value for the station sampled in the East Fork Sevier River suggested that the degree of pollution in this location was very substantial.

Table 3.13. Water quality ratings for the Family-level HBI (from Hilsenhoff 1988).

FBI Value	Water Quality Rating	Degree of Organic Pollution
≤3.75	Excellent	Unlikely
3.76-4.25	Very good	Possible - slight
4.26-5.00	Good	Some - probable
5.01-5.75	Fair	Fairly substantial
5.76-6.50	Fairly poor	Substantial - likely
6.51-7.25	Poor	Very substantial
7.26-10.00	Very poor	Severe

3.6 TROPHIC STATE ASSESSMENT

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

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

Carlson's TSI values typically range from 0 to 100, although theoretically, the range of values could exceed these bounds (Carlson and Simpson 1996). An increase of 10 units in the TSI scale is equivalent to doubling the concentration of TP or halving water transparency as measured by sechi disk depth. Calculations for determining TSI values based on TP, chl-a, and SD depth are provided below. Information relating Carlson TSI values to trophic state characteristics is provided in Table 3.14. TSI values calculated for Koosharem, Otter Creek, and Lower Box Creek Reservoirs are displayed in Figure 3.8 and in Table 3.15.

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

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

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

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

Table 3.14. Description of lake trophic status based on Carlson TSI values (Carlson and Simpson 1996).

TSI	Trophic status[1]	Description
< 35	Oligotrophic	Clear water, high oxygen levels throughout the year although shallow lakes/reservoirs may develop low DO concentrations in the hypolimnion. Salmonid fisheries dominate aquatic populations. Water may be suitable for unfiltered drinking in some cases.
35 - 50	Mesotrophic	Water is moderately clear, greater chance of low DO concentrations in the hypolimnion during the summer season. Low DO levels result in salmonid losses, walleye may predominate. Water requires filtration for drinking purposes.
50 - 70	Eutrophic	Low DO levels predominate, heavy algal growth dominated by blue-green algae. Warm water fisheries only. High biomass may discourage boating, swimming.
> 70	Hypereutrophic	Dense algal growth, heavy algal scums present at surface. Rough fish dominate; summer fish kills possible.

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

TSI calculations for Koosharem, Lower Box Creek, and Otter Creek Reservoirs resulted in similar index values for some years but noticeably different for others (Figure 3.8). It should be noted that some variation of index values is obtained because the relationships between variables were originally derived from regression relationships and the correlations are not perfect (Carlson and Simpson 1996). The drop in TSI values for all reservoirs during 2003 is possibly the result of seasonal influences. The only measurements available for 2003 were recorded during the month of June and do not include values measured during the late summer and fall when concentrations are typically higher.

A second method used to assess TSI parameters relies on the difference between TSI(chl-a) and TSI(TP) or TSI(SD). Results from this assessment are shown in Figure 3.9 where TSI(chl-a) – TSI(TP) is plotted on the vertical axis and TSI(chl-a) – TSI(SD) is plotted on the horizontal axis. As indicated by Figure 3.9 most of the values fall below the horizontal axis for Koosharem and Otter Creek Reservoirs, suggesting that under most situations, algal growth in these water bodies is limited by nitrogen or something other than phosphorus. Points shown in Figure 3.9 located to the right of the vertical axis indicate situations where transparency is more influenced by larger particulate matter including algal growths such as blue-green algae (Cyanobacteria) and less affected by small particulate matter. Data points located to the right of the vertical axis may also be the result of zooplankton grazing that removes smaller particles and leaves larger forms of algal matter. Points located to the left of the vertical axis are situations where small, non-algal particles influence water clarity, such as suspended sediment or water color.

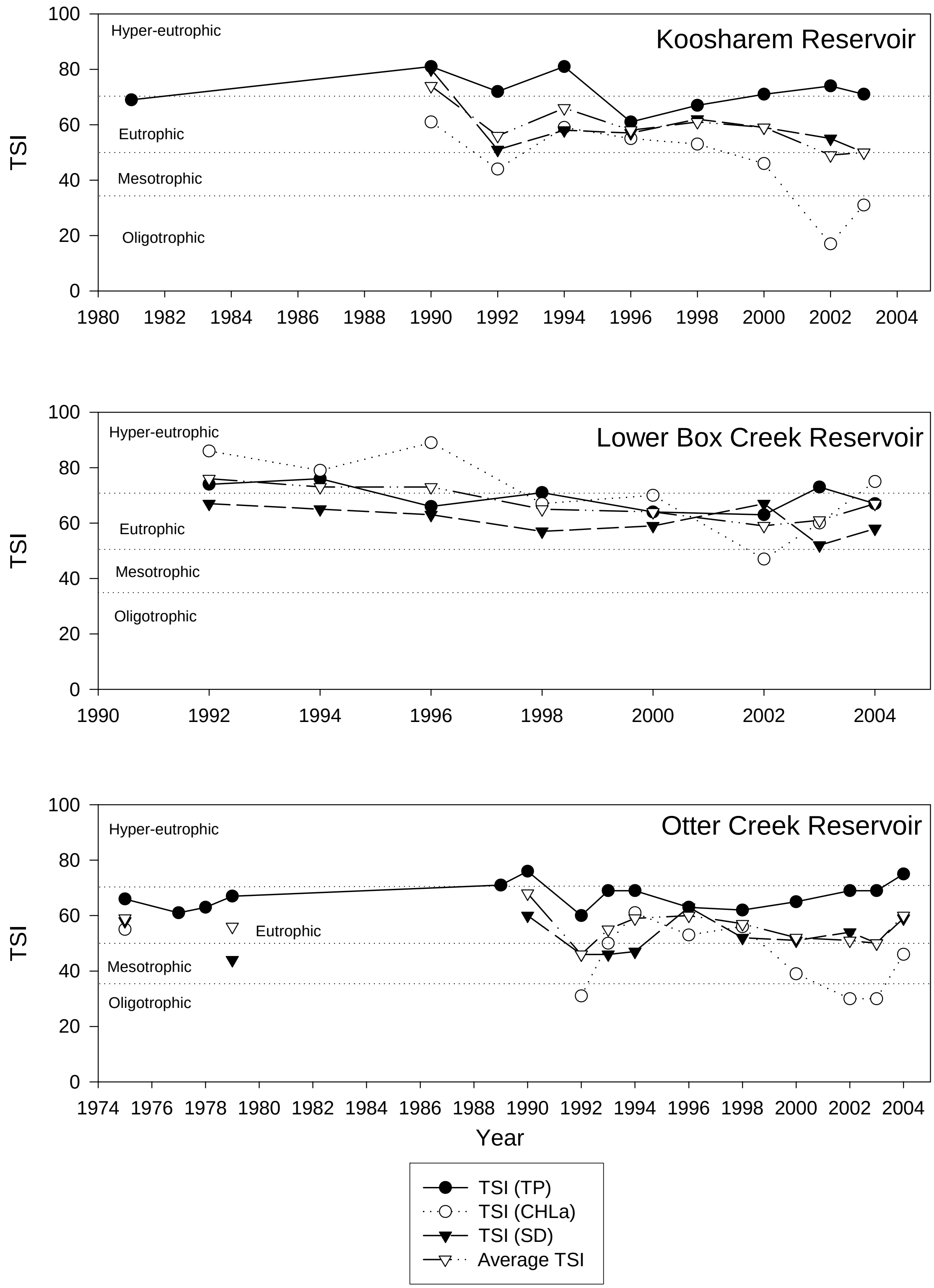

Figure 3.8. TSI values calculated for Koosharem Reservoir (Stations 594577 and 594578), Lower Box Creek Reservoir (Station 594562), and Otter Creek Reservoir (Stations 491031, 491302, 494929, 494930, 494931, 494922, and 494923).

Table 3.15. TSI parameters for Koosharem, Otter Creek, and Lower Box Creek Reservoirs.							
Reservoir	Year	TSI				TSI deviations	
		TSI (TP)	TSI (Chla)	TSI (SD)	Average TSI	TSI(CHLa)-TSI (TP)	TSI(CHLa)-TSI (SD)
KOOSHAREM	1981	69	n/a	n/a	n/a	n/a	n/a
	1990	81	61	80	74	-21	-19
	1992	72	44	51	56	-27	-7
	1994	81	59	58	66	-22	1
	1996	61	55	57	58	-5	-2
	1998	67	53	62	61	-15	-9
	2000	71	46	59	59	-24	-13
	2002	74	17	55	49	-57	-39
	2003	71	31	60	38	-40	-19
LOWER BOX	1992	74	86	67	76	12	19
	1994	76	79	65	73	2	14
	1996	66	89	63	73	23	25
	1998	71	67	57	65	-4	10
	2000	64	70	59	64	6	11
	2002	63	47	67	63	-16	-19
	2003	73	60	52	37	-13	8
	2004	67	75	58	76	8	17
OTTER CREEK	1975	66	55	58	59	-11	-3
	1977	61	n/a	n/a	n/a	n/a	n/a
	1978	63	n/a	n/a	n/a	n/a	n/a
	1979	67	n/a	44	56	n/a	n/a
	1989	71	n/a	n/a	n/a	n/a	n/a
	1990	76	n/a	60	68	n/a	n/a
	1992	60	31	46	46	-29	-14
	1993	69	50	46	55	-19	4
	1994	69	61	47	59	-8	14
	1996	63	53	63	60	-10	-11
	1998	62	56	52	57	-6	4
	2000	65	39	51	52	-25	-12
	2002	69	30	54	52	-39	-24
	2003	69	30	50	37	-39	-20
	2004	75	46	59	59	-29	-14

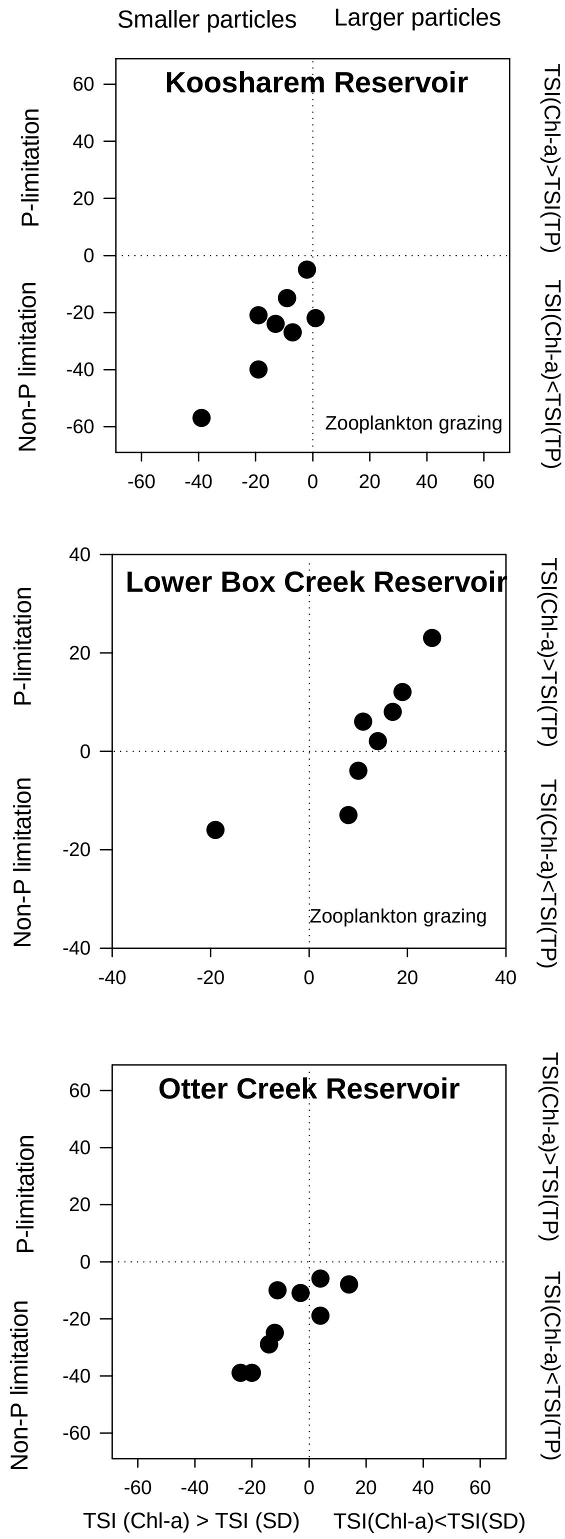

Figure 3.9. Assessment of annual TSI differences calculated for Koosharem, Lower Box Creek, and Otter Creek Reservoir.

The average annual TSI values calculated for Koosharem Reservoir indicated that eutrophic to hyper-eutrophic conditions were present during the 1990s. In 2002, the TSI(chl-a) value dropped from 53 to 15 units, while TSI(TP) and TSI(SD) remained above 50 units. This difference may be due to an increase in turbidity from less than 25 Nephelometric Turbidity Units (NTU) before year 2000 to approximately 45 NTUs in 2002. In turbid lakes or reservoirs, it is common to observe similar TSI values for TP and Secchi depth, while the chl-a index measures several units lower. Carlson and Simpson (1996) suggested that this difference is caused by particles containing phosphorus that are not readily available for algae. In other words, algae are not able to use the phosphorous trapped in clay or other particles suspended in the water column that do not contribute significantly to light attenuation. The increase in the TSI index for TP from 1996 to 2002 also supports this hypothesis. TSI deviations for Koosharem Reservoir are almost exclusively located in the lower left quadrant of Figure 3.9. This pattern suggests that phosphorus is not a limiting factor for algae growth in Koosharem Reservoir and that smaller particles (non-algal) likely contribute to light attenuation in the water column.

Lower Box Creek Reservoir is generally characterized by eutrophic conditions (Figure 3.8). The similar TSI index trend for all parameters at Lower Box Creek Reservoir suggest that phosphorous may be a limiting factor for algal growth, and that most of the attenuation of light is by algae. The TSI deviations shown in Figure 3.9 suggest that TP may be trapped in larger particles, as indicated by the data points located in the top-right quadrant. Observations located in the bottom-left quadrant of the plot correspond to the 2002 TSI deviation. This observation suggested that during this time period, non-algal factors or the presence of very small particles dominated transparency in Lower Box Creek Reservoir.

TSI values for Otter Creek Reservoir have typically remained in the eutrophic to mesotrophic range during the past 30 years (Figure 3.8) although some large variations in TSI (chl-a) have occurred in 1992 and from 2000 through 2004. The pattern of these variations is similar to those observed for Koosharem Reservoir and may likewise be due in part to increased turbidity levels. As mentioned previously, turbid lakes and reservoirs will commonly have similar values of TSI(TP) and TSI(SD) while maintaining relatively lower values of TSI(chl-a) due to an unavailable form of phosphorus that is trapped to sediment particles. This hypothesis is supported by increasing TSI(TP) values observed in Otter Creek Reservoir during 1998 – 2004. The majority of TSI deviations for Otter Creek Reservoir shown in Figure 3.9 are located in the lower left quadrant, suggesting that algal growth is limited by nitrogen or other factors but not by phosphorous. TSI deviations located in the lower right quadrant of Figure 3.9 correspond to the years 1993, 1994, and 1998. TSI(chl-a) values for these years include three of five TSI(chl-a) index values for Otter Creek Reservoir that measured in the eutrophic range. Levels of chl-a in the eutrophic range are likely indicative of large algal formations in Otter Creek Reservoir during this time period.

3.7 PHYTOPLANKTON ASSESSMENT

Phytoplankton samples have been collected every other year at sampling stations located on Koosharem, Lower Box Creek, and Otter Creek Reservoirs. A summary of the phytoplankton data, including Shannon-Weaver index, species evenness, species richness, number of species, total abundance and percent relative density of dominant species is provided in Table 3.16. These metrics or ecological summaries are used to assess the structure of the phytoplankton community and are considered a surrogate measure of water quality, similar to the presence and extent of macroinvertebrate populations, discussed above. The Shannon-Weaver diversity index is a measure of phytoplankton community structure defined by the relationship between the number of distinct taxa and their relative abundance. The species evenness index is a measure of the distribution of taxa within a community; a single taxa becomes more dominant as evenness values approach zero. In general, species richness and the number of families present in a water column will decrease with decreasing water quality conditions.

The highest Shannon-Weaver diversity index and species richness calculated for Otter Creek Reservoir were observed in 1998 and 2002. Since 2002, values have decreased slightly and the number of species has dropped from 8 to 3. The reduction in the number of species and total abundance is consistent with the low TSI-Chla values observed since 1998 (Figure 3.8). The species observed in this reservoir (i.e., Ceratium hirudinella, Aphanizomenon flos-aquae, Fragilaria crotonensis) typically occur in eutrophic lakes and their abundances change seasonally in response to changes in habitat characteristics (Reynolds 1984). Because samples were collected in August, September, and/or October, the apparent annual shifts in species composition may only be a reflection the particular physical and chemical conditions of the reservoir at the time it was sampled.

Similar indices of species evenness and total number of species were observed at Koosharem Reservoir from 1994 to 1998. A decrease in the total number of species was observed 2000 and a subsequent increase was observed in the first sampling event in 2002 (i.e., August). The high species richness index and number of species observed may be associated to relatively good water quality during this sampling event (Table 3.16). These values correspond to the low TSI-Chla observed in 2002 (Figure 3.8). However, the species observed during all sampling events (i.e., Anabaena species, Volvox spp, Stephanodiscus spp, and Aphanizomenon flos-aquae), including 2002, generally occur in eutrophic systems (Reynolds 1984). Seasonal variations in community structure, such as those observed in August and October of 2002, are related to changes in physical and chemical characteristics in the water column (Harris 1986, Reynolds 1984).

At Lower Box Creek Reservoir both the number of species and the indices calculated increased in 2002 and 2003. However, this likely does not represent an improvement in water quality, as the dominant species in the reservoir consist of blue-green algae *Aphanizomenon* and *Microcystis*, which are known to be common in eutrophic lakes (Horne and Goldman 1994).

Table 3.16. Summary of phytoplankton data for Koosharem, Lower Box Creek, and Otter Creek Reservoirs (1992-2003).

Site	Station	Month/Year	Shannon Weaver Index	Species Evenness	Species Richness	Number of Species	Total Abundance (# cells/ml)	Dominant species	Relative density (%)
Koosharem	594577	August 1992	0.45	0.22	0.32	8	5199	Anabaena species	91
	594577	August 1994	0.25	0.12	0.27	8	400	Gloeotrichia echinulata	93
	594577	September 1996	0.84	0.43	0.28	7	161	Volvox areus Aphanizomenon flos-aquae	66 26
	594577	September 1998	1.10	0.50	1.70	9	733	Stephanodiscus niagarae *Total Bacillariophyta*	63 81
	594557	August 2000	0.68	0.98	0.27	2	135	Pennate diatoms Centric diatoms *Total Bacillariophyta*	61 39 100
	594557	August 2002	1.61	0.65	2.15	12	3136	Stephanodiscus niagarae *Total Bacillariophyta*	68 85
	594557	October 2002	0.29	0.41	0.31	2	150	Pennate diatoms	93
Lower Box Creek	594562	August 1992	0.02	0.02	0.04	2	6127	Aphanizomenon flos-aquae	99
	594562	August 1994	0.46	0.33	0.12	4	4370	Aphanizomenon flos-aquae	83
	594362	August 1996	0.09	0.07	0.12	4	5037	Aphanizomenon flos-aquae	98
	594562	September 1998	0.09	0.08	0.32	3	2728	Aphanizomenon flos-aquae	99
	594562	August 2000	0.64	0.46	0.61	4	423	Aphanizomenon flos-aquae Microcystins aeruginosa	90 8
	594562	August 2002	1.92	0.8	2.23	11	551	Microcystins incerta Microcystins aeruginosa	75 15
	594562	August 2003	1.84	0.80	2.26	10	169	Aphanizomenon flos-aquae Microcystins aeruginosa	38 33

Table 3.16. (cont'd) Summary of phytoplankton data for Koosharem, Lower Box Creek, and Otter Creek Reservoirs (1992-2003).									
Site	**Station**	**Month/Year**	**Shannon Weaver Index**	**Species Evenness**	**Species Richness**	**Number of Species**	**Total Abundance (# cells/ml)**	**Dominant species**	**Relative density (%)**
Otter Creek	494922	August 1992	0.71	0.40	0.24	6	183	Ceratium hirudinella Pennate diatoms	74 23
	494922	August 1994	1.47	0.61	0.45	11	417	Aphanizomenon flos-aquae Stephanodiscus niagarae Gleocystis species	35 29 20
	494922	September 1994	0.43	0.16	0.54	14	1451	Stephanodiscus niagarae Fragilaria crotonensis	92 3
	494922	September 1996	1.38	0.52	0.58	14	1190	Fragilaria crotonensis Stephanodiscus niagarae	59 20
	494922	September 1998	1.97	0.86	2.36	10	248	Ceratium hirudinella Aphanizomenon flos-aquae	43 30
	494922	August 2000	0.78	0.71	0.69	3	56	Aphanizomenon flos-aquae Shroederia setigera	49 38
	494922	August 2002	1.78	0.86	2	8	103	Fragilaria crotonensis Aphanizomenon flos-aquae	42 39
	494922	October 2002	0.63	0.57	0.74	3	94	Pennate diatoms Chlorophyta species	83 17
	494933	August 2003	0.69	1.00	1.44	2	13	Euglena species	94
	494922	August 2003	0.85	0.77	0.91	3	28	Pennate diatoms *Total Bacillariophyta*	76 87

CHAPTER 4 : POLLUTANT SOURCE ASSESSMENT

4.1 SIGNIFICANT SOURCES OF TOTAL PHOSPHORUS LOADING

Based on the review of the SVAP data, other field observations, and discussions with various state and local agencies, the following pollutant categories contributing to water quality impairment in the Otter Creek/East Fork Sevier River watershed have been identified.

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

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

4.1.1 Animal Feeding Operations

Recognition of animal feeding operations (AFO) as a contributor to water quality impairment has been recently addressed by the Utah CAFO Advisory Committee (2001). The strategy proposed by the State reflects a desire to implement responsible management techniques while maintaining a local decision-making process. A voluntary incentive-based approach is emphasized that reverts to a regulatory approach only for larger facilities or situations where voluntary methods have failed. The deadline for correction of unacceptable conditions at AFO/CAFO facilities is June 2007. A critical element of this program is to maintain open communication between stakeholders and agencies. An effort has been made throughout this assessment to maintain the level of confidence previously established between these two groups in the TMDL study area. No site-specific information is provided in this assessment. An estimation of the total contribution from all operations within a specific watershed or subwatershed are provided where necessary in the sections below.

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

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

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

Thirteen locations where animals appear to be contained for 45 days or longer were identified in the TMDL study area during several field reconnaissance surveys conducted in 2002. The approximate location of these facilities is shown in Figure 4.1 and Figure 4.2. These figures indicate that only two of these facilities are within the East Fork Sevier River watershed, one located along Antimony Creek and one located on the East Fork near Otter Creek Reservoir. The remaining eleven operations are located in the Otter Creek watershed, most of them near the town of Koosharem. Additional discussions with NRCS personnel in the Richfield, Utah field office indicated that two of the operations are currently inactive (Jarman 2004).

Animal feeding operations in the TMDL study area watershed have varying degrees of nutrient management practices in place. Of the 11 active operations, eight are currently working with, or have previously worked with state agencies to develop nutrient management plans in an effort to minimize pollutant loading (Jarman 2004). Three of the active operations do not have nutrient management plans in place, although two of these facilities are currently working with the NRCS to develop plans. The remaining operator does not want federal assistance, but has maintained open communication with the NRCS and agreed to voluntarily move forward with nutrient management efforts including development of off-site watering, and runoff containment. Many of the beef-feedlot operations scrape and haul manure annually while dairy operations stockpile manure on a daily basis and haul it to the surrounding fields during the spring and fall seasons. Land application of manure generally occurs to fields within a five-mile radius of each facility. Most of the manure is applied as a nutrient supplement to fields managed in a rest-rotation system alternating between small grain crops and alfalfa. As a result, land areas supporting alfalfa will typically not receive manure applications until these areas are returned to small grain crops (Turner 2004).

4.1.2 Grazing

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

Extensive grazing occurs in the Otter Creek and East Fork Sevier River watersheds. Figures 4.3 and 4.4 show the grazing allotment boundaries associated with public and private lands in these two watershed areas. Allotment names and annual permitted grazing levels for all public and private land grazing allotments are shown in Appendix B. Grazing allotments are found on nearly all of the public land within the TMDL study area. It is estimated that over 90 percent of the Otter Creek and East Fork Sevier River watersheds are contained within grazing allotments permitted by the Forest Service, the Bureau of Land Management, or operated by private land owners. These allotments have varying numbers of permitted animals and seasons of use, and these factors influence the potential for loading from the grazed areas in the watershed. Annual use of public land grazing allotments in the TMDL study area has varied substantially over the past decade as a result of drought conditions (Boshell 2003, Pace 2003). The annual use of some grazing allotments has been as low as 10 percent of the permitted level, while most allotments ranged between 100 percent to 50 percent of the permitted level.

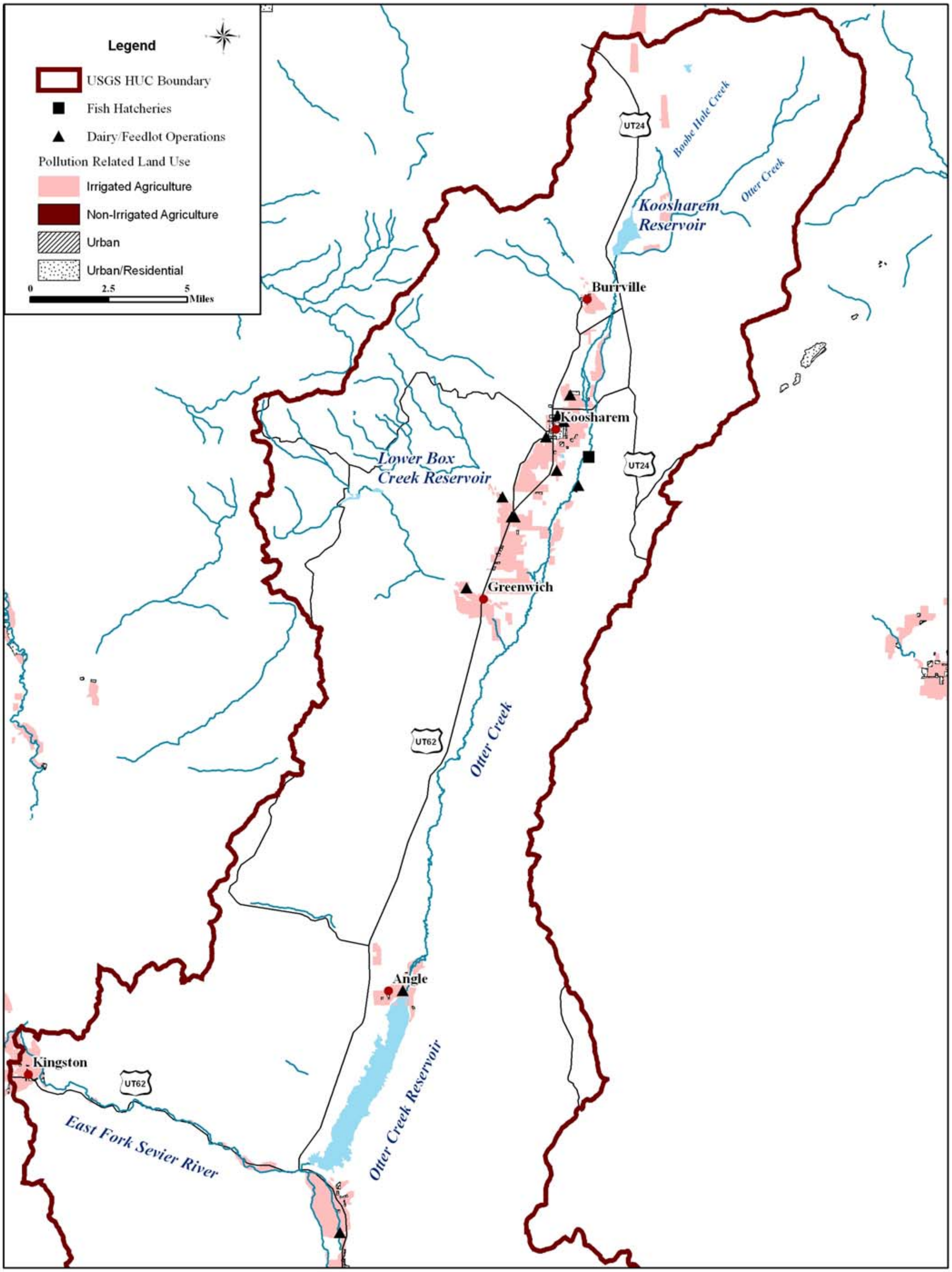

Figure 4.1. Pollution related land use in the Otter Creek Watershed.

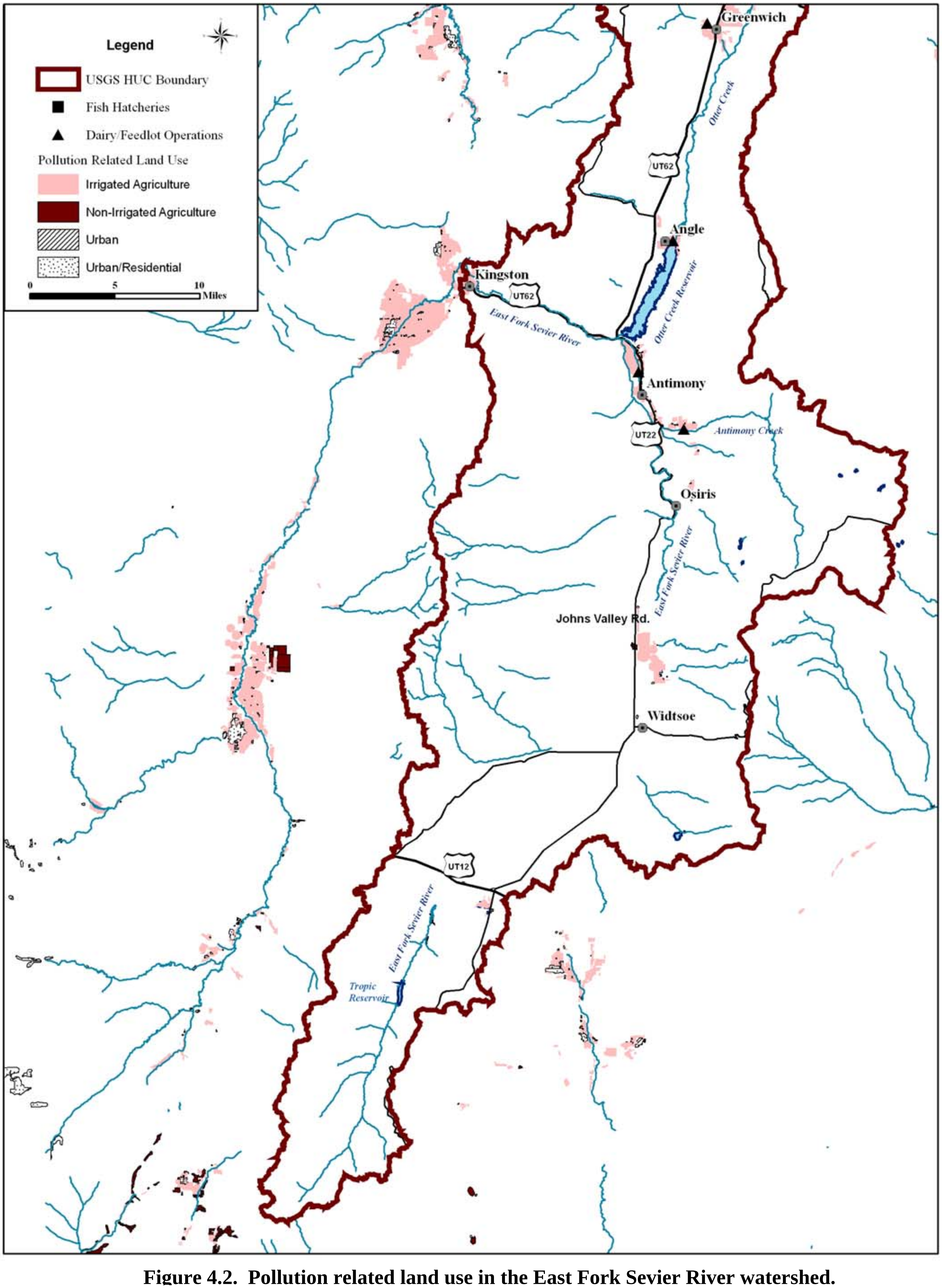

Figure 4.2. Pollution related land use in the East Fork Sevier River watershed.

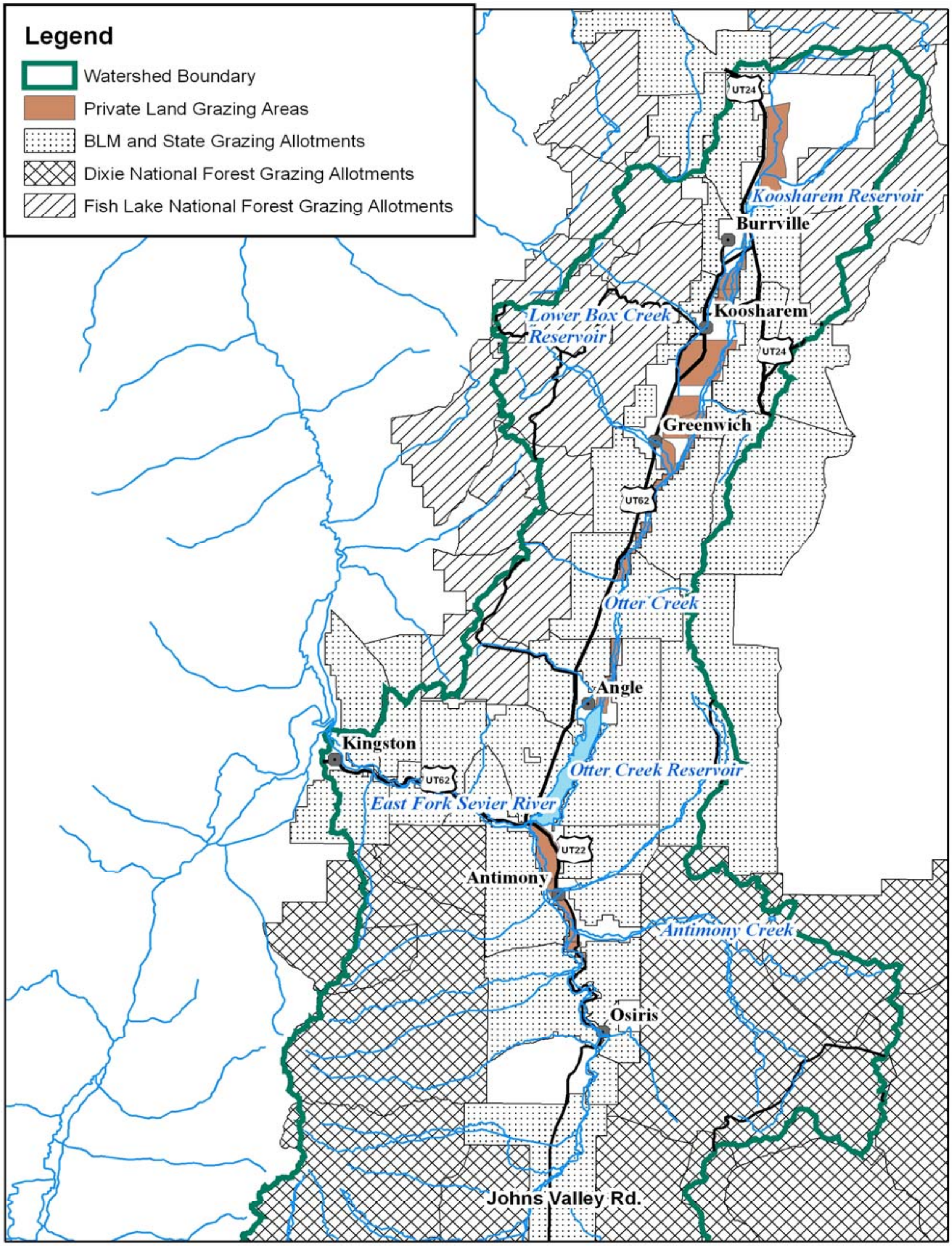

Figure 4.3. Grazed areas in the Otter Creek

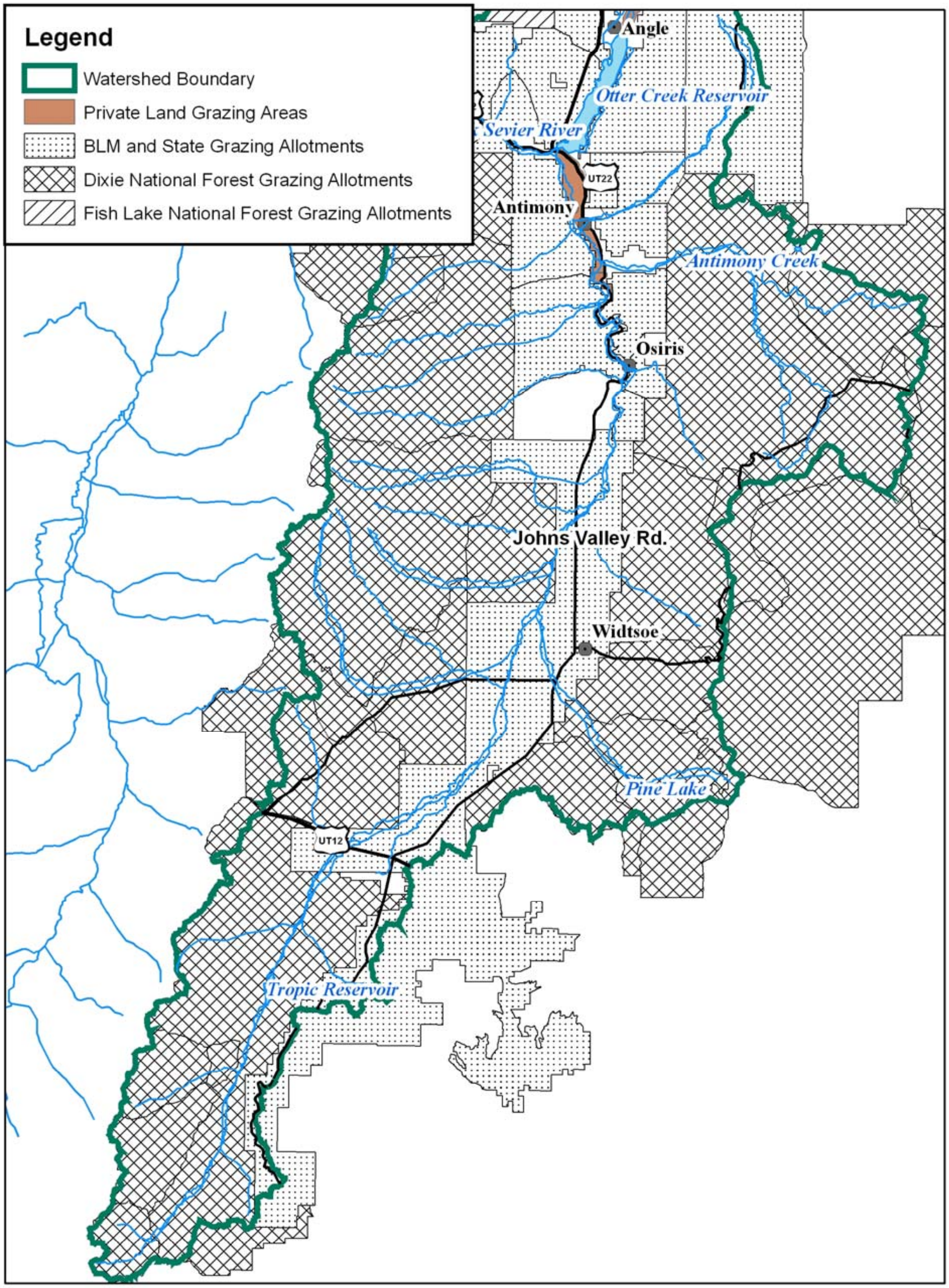

Figure 4.4. Grazed areas in the East Fork Sevier River watershed.

The timing of grazing activities within the watershed is also important. Animal concentrations near the stream courses in the low-lying areas of the watershed are higher during the late fall, winter, and spring months, as these are the areas where the animals spend the winter. The exact location of animal herds during this time period will vary depending on available forage and weather extremes that make it difficult for grazing to occur. A typical grazing pattern during this time will find animals in the lower valley pastures until late November through mid-December or when snow depths make grazing difficult. Animal herds are then moved into smaller pastures that are easily accessible or sometimes feedlots where hay can be distributed to them. Animal herds are moved away from hay feed areas as soon as grass forage is available in the spring season, typically during March or early April. Some herds are transported out of the watershed entirely to other locations within the Sevier Valley (Bagley 2004).

During the summer months, many herds are moved away from actively flowing streams located in the low to mid-elevation pastures and on to higher elevation grazing allotments located on public lands. Many of the grazing allotments managed by the BLM and SITLA provide early or late season grazing opportunities (eg. March and April or November through January) while FS allotments are primarily used during the late spring through early fall. BLM and SITLA grazing allotments may not be used consistently in the watershed on an annual basis. These allotments typically receive greater use during periods of drought, when management of FS allotments requires a shorter grazing season or lower grazing density (Torgerson 2003). In general, many animal herds are moved to public lands during May or June and return to private lands in late October. However, some herds continue to be rotated through privately owned pastures in the lower valley areas throughout the spring, summer and fall. Many of these pastures provide open access to Otter Creek and the East Fork. This pattern has resulted in degradation to streambanks and riparian areas in some locations. Intense use of these areas has resulted in heavy manure deposits, streambank degradation, and surface and channel erosion that subsequently contribute to pollutant loading. Specific information on areas exhibiting erosion and other characteristics contributing to water quality degradation are contained in Appendix C of this report.

4.1.3 Onsite Wastewater Treatment Systems

Less than 1 percent of the study area watershed is classified as urban or urban/residential. None of these areas are sewered, and consequently all of the residences in the watershed rely on onsite wastewater treatment systems. The main concentrations of these systems are found in the municipal areas of Burrville, Koosharem, Greenwich, Antimony, and the part of Kingston that lies within the watershed (Figure 2.2). Onsite wastewater treatment systems located in all other areas of the watershed, including the contributing areas for Koosharem and Lower Box Creek Reservoirs, are assumed to be so diffuse that their loading to the system is negligible.

4.1.4 Fish Hatcheries

Two privately-owned fish hatcheries are located within the watershed. Due to the operational size of these facilities and their subsequent discharge volumes they are permitted under a statewide general permit and are not required to have a more specific permit containing discharge limitation. The approximate location of these facilities is shown in Figure 4.1. The Road Creek fish hatchery is supported by flow from Burr Creek. Water from the fish hatchery is directly discharged to Burr Creek approximately 800 feet below the point of diversion. It was noted in Fall 2002 that all flow in Burr Creek passed through the Road Creek fish hatchery. It is anticipated that during the spring season and other periods of high flow, much of the streamflow in Burr Creek bypasses the Road Creek fish hatchery. Burr Creek eventually discharges into Otter Creek below Koosharem Reservoir. At the present time, it is known that the Road Creek fish hatchery has not been active for the past two years (Archer 2005). Measurements used to calculate loads for the Road Creek fish hatchery were collected during the period when the facility was active.

Deans Fish hatchery is supported by a series of springs located nearby. Discharge from the hatchery enters a series of ponds which eventually flow into a canal located immediately to the west of the facility. The canal is supported by additional flow from multiple springs and seeps located on west facing slopes for one to three miles upstream of the hatchery. Discharge from the canal provides flood irrigation flows to several pastures on the east side of Otter Creek. It is anticipated that a very limited amount of discharge from Deans Fish hatchery reaches Otter Creek. This assumption is based on field observations of this facility and the surrounding area including discharge rate, slope, surface cover, and distance to Otter Creek. Both fish hatcheries in the Otter Creek Watershed are supported by stock from by the Road Creek Ranch, located outside of the TMDL study area. Several efforts have been made at these facilities during the recent past to improve the quality of discharge water, including aeration structures and settling ponds (Jarman 2004).

4.1.5 Diffuse Loads from Runoff

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

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

Most runoff in the TMDL study area is associated with spring snowmelt and a few summer thunderstorms that pass through the area. In general, pollutant loading associated with runoff is essentially related to land use, although other physical factors such as soil type, vegetative cover, slope, riparian conditions, etc. are also important. The proximity of each land use category to existing streams is also of consideration in evaluating pollutant loads associated with runoff. In the Otter Creek and East Fork Sevier River watersheds, nearly all of the agricultural lands lie within a narrow one to two mile wide strip along the existing stream courses. The condition of these lands is also of importance, as it is generally accepted that areas in close proximity to existing water courses have a greater likelihood of contributing pollutant loads, especially when poor conditions exist (trampled stream banks, lack of vegetative cover, disturbed soils, etc.). Field surveys conducted along impaired stream channels revealed many areas in close proximity to existing streams where poor conditions exist. A more detailed description of these areas is included in Appendix C.

4.1.6 Natural Background

Background pollutant loads are loads assumed to occur under "natural" or undisturbed conditions and are generally considered to be uncontrollable. Background loads can be associated with any natural process that is not man-enhanced or man-induced. Sources of background loading can include surficial geologic formations, atmospheric deposition (through rain or snow), wildlife species, and naturally occurring levels of soil erosion and stream channel dynamics. Background loadings are not insignificant in the Otter Creek and East Fork Sevier River watersheds. Merritt et al. (1996) estimate that background concentrations of TP in the East Fork of the Sevier River watershed are approximately 0.06 mg/L and approximately 0.04 mg/L in the Otter Creek watershed. These concentrations are close to if not exceeding the 0.05 mg/L State of Utah pollution indicator value for TP in streams and rivers.

In an effort to provide more information on which to base background concentrations, a review was completed of water quality parameters measured in areas where minimal anthropogenic influence is assumed, including springs, and upper headwater streams, tributaries and reservoirs/lakes in the TMDL study area. This is a typical approach to determining natural or background levels of water quality constituents. Water quality samples from springs and upper tributary streams have been collected on an infrequent basis during the past 30 years. Data from this assessment are included in Table 4.1 through Table 4.3 below.

TP concentrations from springs located throughout the TMDL study area ranged from below the detection limit (<0.01 mg/l) to 0.081 mg/l. TP concentrations on the mainstem East Fork above Tropic Reservoir ranged from <0.01 mg/l to 0.14 mg/l. Measurements from tributaries to the East Fork indicated TP concentrations from <0.01 mg/l to 0.68 mg/l. It is noted here that some areas of the East Fork watershed have been impacted through recreational use including dispersed camping and user-created ATV trails as well as historic mining, recent forest fires, and grazing. No stream monitoring data was available for upper watershed areas above Koosharem Reservoir or Lower Box Creek Reservoir with the exception of a limited number of measurements discussed above in Chapter 3. Mean TP concentrations measured from Tropic Reservoir and Pine Lake range from <0.01 mg/l to 0.15 mg/l and increased slightly from 0.01 mg/l in 1993 to 0.03 mg/l during 1997-99. As mentioned previously, Tropic Reservoir is hydrologically isolated from the rest of the TMDL study area for much of the year due to seasonal irrigation diversions. Use of TP measurements in and above Tropic Reservoir are used to establish water quality conditions in less-disturbed areas and is not meant to imply these areas contribute significant background loads.

Based on the estimates of Merritt et al. (1996) and the above review of water quality data from sites high in the watershed, it is estimated that natural background concentrations of TP in the East Fork Sevier River and Otter Creek watersheds are approximately 0.03 mg/L. This concentration will be used to estimate natural background loadings for the purposes of this TMDL.

4.1.7 Internal Reservoir Loading

Bottom sediments have long been acknowledged as a potential source of phosphorus to the overlying waters of lakes and reservoirs (Chapra 1997). In many cases, bottom sediments serve as a sink for phosphorus as phosphorus laden suspended solids enter the reservoir and settle out and as organic phosphorus in the form of dead and decaying algae and plant material settle to the bottom and are buried in the sediments. However, in some cases phosphorus associated with the bottom sediments can become re-entrained in the overlying water column. In general, flux of phosphorus from sediments to the overlying water column takes place only during periods of very low dissolved oxygen concentrations (less than 0.5 mg/L) and/or low pH that last long enough for the interaction to be significant. These conditions are most common in deeper impoundments with significant periods of stratification that limit mixing and related oxygen transfer. When conditions such as these occur, phosphorus released to the overlying water column from the sediments can be carried into the photic zone by subsequent mixing and turnover following stratification making the now dissolved phosphorus available for use by algae and other aquatic organisms.

Table 4.1. Measurements of Total Phosphorus collected from DWQ spring monitoring stations in the TMDL study area.

Station	Dates	Observations	Number BDL	Mean	Median	SD	Variance	Geometric Mean	Min.	Max.	Exceedance (%)
Osiris Spring - 494879	2002 - 2003	5	0	0.044	0.036	0.016	0.0003	0.042	0.032	0.071	
599131 - Root Spring	1985 - 1985	1	0	**0.050**							0
599132 - King Spring	1985 - 1985	1	0	**0.080**							100
599134 - Nick's Spring	1983 - 1983	1	0	**0.058**							100
599135 - Pole Canyon Spring	1983 - 1983	1	0	**0.081**							100
599140 - Birch Springs	1987 - 1987	1	0	**0.040**							0
594612 - Spring at discharge pipe in Pine Lake	1989 - 1995	6	3	0.007	0.006	0.007	0.0000	0.005	<BDL>	0.020	0

Bold text signifies only one sample above detection limit.

Table 4.2. Measurements of Total Phosphorus collected from DWQ stream monitoring stations located on tributaries to the East Fork Sevier River.

Station	Range Of Dates	Observations	Number BDL	Mean	Median	SD	Variance	Geometric Mean	Min.	Max.	Exceedance (%)
4923B1 - Badger Creek	1974 - 1975	7	1	0.015	0.010	0.008	0.0001	0.013	<BDL>	0.030	0
4923C1 - King Creek	1974 - 1975	10	4	0.012	0.010	0.009	0.0001	0.010	<BDL>	0.030	0
494937 - King Creek	1977 - 1988	5	2	0.012	0.006	0.012	0.0001	0.007	<BDL>	0.030	0
494938 - Badger Creek	1977 - 1988	5	2	0.142	0.008	0.301	0.0906	0.006	<BDL>	0.680	20
494941 - Skunk Creek	1987 - 1988	3	2	**0.007**							0
494944 - Blubber Creek	1987 - 1990	4	2	0.006	0.005	0.003	0.0000	0.005	<BDL>	0.010	0
494946 - Upper Kanab Creek	1987 - 1990	4	2	0.006	0.006	0.001	0.0000	0.006	<BDL>	0.007	0
494948 - Podunk Creek	1987 - 1990	4	3	**0.010**							0
494951 - Crawford Creek	1987 - 1990	4	3	**0.008**							0
494952 - Sieler Creek	1987 - 1987	2	1	**0.010**							0

Bold text signifies only one sample above detection limit.

Table 4.3. Measurements of Total Phosphorus collected from DWQ reservoir monitoring stations located on Tropic Reservoir and Pine Lake.

Station	Date	Observations	Number BDL	Mean	Median	SD	Variance	Geometric Mean	Min.	Max.	Exceedance (%)
494934 - Tropic Reservoir above Dam 01	1977 - 2001	64	38	0.012	0.007	0.015	0.0002	0.007	<BDL>	0.080	3.1
494935 - Tropic Reservoir midway up Lake 02	1977 - 1993	18	7	0.016	0.009	0.015	0.0002	0.009	<BDL>	0.050	0
594609 - Pine Lake 001	1980 - 2001	42	23	0.016	0.006	0.029	0.0008	0.006	<BDL>	0.150	7.1

4.2 POLLUTANT LOAD CALCULATION – EXISTING DATA

Pollutant loads can be calculated at monitoring locations where flow and water quality concentrations have been measured. Loads calculated in this manner are considered to be most accurate if measurements are collected at the same time (i.e. paired measurements) and represent the full range of flow conditions at a given monitoring location. Error can be introduced into the calculation of pollutant loads when measurements of flow and water quality are measured independent of each other. In some instances, only paired measurements are used and the remaining data not considered. One method of supplementing the simple average approach is to utilize continuous flow data recorded from a nearby stream flow monitoring station. Calculated average flow values from these sites incorporate the full magnitude of discharge rates. As a result, the monthly or annual averages for these locations may better represent streamflow conditions than an average of a limited number of instantaneous flow measurements. This method was used in the assessment of loading to Koosharem Reservoir, Otter Creek Reservoir and the East Fork Sevier. A description of the flow and water quality stations used for load calculations is included below in tables associated with each water body.

Pollutant loads calculated from continuous flow data do not always match up with load calculations that rely on instantaneous flow measurements. However, loads based on instantaneous water quality and flow monitoring data can provide supporting information in determining pollutant load contributions. A review of the original data set, including the number of samples and sample dates should accompany any assessment of pollutant load calculations. This is particularly important when attempting to characterize loads from nonpoint pollutant sources, which are highly dependent upon surface runoff generated during storm events or rapid snowmelt. Pollutant loads should be based on measurements collected across a representative time period that include both drought and high flow conditions as well as all seasons of the year.

Figure 4.5 indicates mean annual TP loads calculated for the entire period of record at DWQ stream monitoring sites within the project area using the simple average approach. Data used in the simple average approach only included measurements of flow and water quality that were collected on the same date (paired measurements). This information provides a rough estimate of TP loading throughout the watershed. The total number of samples and years when samples were collected varies between station. A direct comparison of TP loads between locations shown in Figure 4.5 does not fully account for these differences. For instance, some stations were measured consistently on a year round basis, including periods of higher flow. Other stations were measured on a limited basis and do not include winter or spring season measurements. In general, it is apparent that the greatest average TP loads are delivered by segments of the East Fork, above Otter Creek reservoir.

A complete listing of all data used in load calculations can be found in Appendix B - Data. Table B-2 in Appendix B provides TP loads calculated during intensive monitoring periods including 1993-94, 1996-97, and 2001-02. TP loads in Table B-2 were based solely upon paired measurements of instantaneous flow and TP concentration measured at DWQ stream monitoring sites.

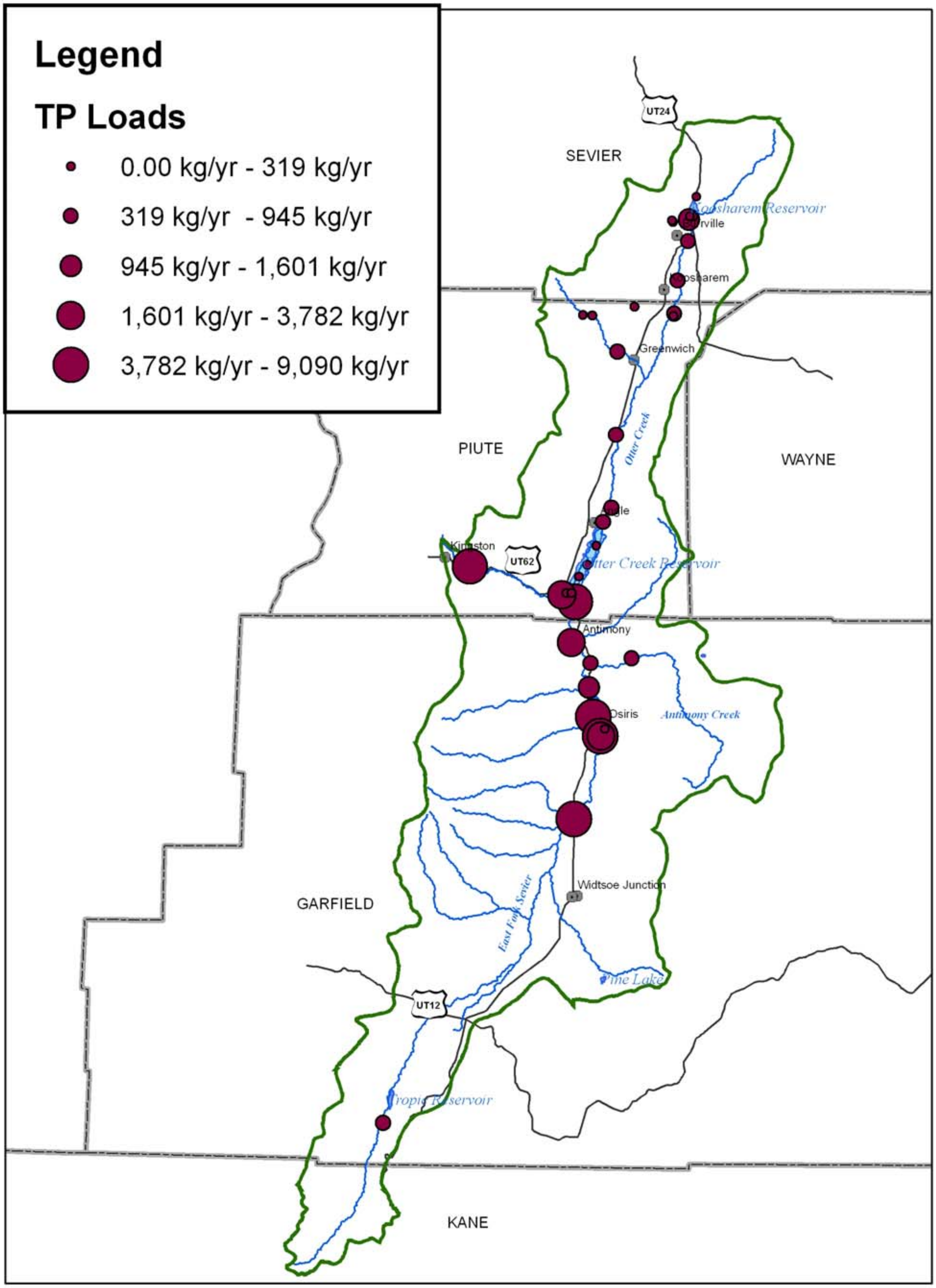

Figure 4.5. Annual average TP loads in the TMDL study area. TP loads were calculated with the simple average approach using only paired measurements of flow and TP concentration collected at DWQ monitoring stations for the entire period of record.

The increase in annual loads shown in Table B-2 between Stations 494926 (East Fork Canal at inflow to Otter Creek Reservoir) and 494924 (East Fork Sevier above diversion at Antimony) is not entirely due to physical conditions along the East Fork Canal. This conclusion is based upon discussion with local stakeholders and site visits to this area in fall 2005. The limited number of samples collected during April and May at Station 494926 indicates that concentrations during the spring runoff season may not be as well defined as those at Station 494924. In addition, no samples have been collected during November, December and March at Station 49496. Further discussion of existing loads from the East Fork Canal is provided below in Section 4.5.

In addition, inflow loads shown in Appendix B – Table B-2 for Deans Fish Hatchery are greater than outflow loads. An examination of individual monitoring data indicate that mean TP concentration in the inflow stream is similar to that of the outflow stream, as would be expected (Appendix B - Table B-1). However, mean flow is much greater at the inflow station when compared to the outflow station. It is believed that existing streamflow measurements do not adequately characterize the seasonal nature of inflows and outflows at Deans Fish Hatchery.

The remaining sections in this chapter describe TP loads from major pollutant sources that contribute to each of the impaired water bodies in the Otter Creek/East Fork Sevier River watershed. The impaired water bodies include Koosharem Reservoir, Lower Box Creek Reservoir, Otter Creek Reservoir, and the East Fork of the Sevier River from its confluence with the Sevier River upstream to the Antimony Creek confluence.

4.3 TOTAL PHOSPHORUS LOADS - KOOSHAREM RESERVOIR

Existing loads to Koosharem Reservoir were calculated using available streamflow and water quality sampling information. It is assumed that Otter Creek and Boobe Hole Creek are the major inflows to Koosharem Reservoir and that loadings associated with all other inflows are relatively minor. It should be noted, however, that in this watershed there is significant grazing that occurs adjacent to and below the high water line of the reservoir. Loading from animals grazing in these areas would not be accounted for in the loads calculated using existing data for the tributary inflows.

Few direct measurements are available to characterize the inflows to the reservoir. Due to this, anecdotal information obtained from the Koosharem Irrigation Company (Burr 2004) was used along with all available streamflow data (1964 – 1982) from the USGS gage in Otter Creek at the mouth of Daniels Canyon (USGS 10187300) to estimate monthly average inflows to the reservoir from Otter Creek. This data set was also used to generate an artificial time series of flow for Boobe Hole Creek. The procedure used to estimate these flows is described in Appendix A – Section A2 Koosharem Reservoir Permissible Loadings. In summary, this method involved calculating unit area flows for the Daniels Canyon watershed. These flows were then multiplied by the area of the Boobe Hole Creek watershed and the average annual precipitation for the watershed. This method provided an artificial time series of flow from 1964-1982 which was used to estimate monthly average flows for Boobe Hole Creek.

Monthly average TP concentrations were estimated using available water quality sampling information in Boobe Hole Creek and were multiplied by the estimated monthly average flows and a units conversion factor to calculate monthly loads. Table 4.4 lists the results of these calculations. No TP observations are available during the months of January, February, or March at the Otter Creek sampling site. As a result, monthly or seasonal loadings could not be determined so an annual average load using all of the available data was calculated. An annual average flow was determined for Otter Creek using all available streamflow data from USGS 10187300 and was multiplied by an annual average TP concentration to produce the annual load shown in Table 4.4. It should be noted that a single TP observation was made in December at the Otter Creek site, with a resulting concentration of 1.02 mg/L. This measurement is considered an outlier and not representative of average conditions because it was made at a time that there was very little flow in the creek and it is much greater than all of the other observations at this site. This value was excluded from the analysis.

Table 4.4. Existing loads to Koosharem Reservoir calculated using all available streamflow data (1964-1982) from USGS 10187300 and DWQ water quality sampling data (1990 – 2003).

Boobe Hole Creek[1]				
Month	**Average Flow (cfs)**	**Number of TP Observations**	**Average TP Concentration (mg/L)**	**Total Load (kg)**
January	5.6	2	0.059	25.2
February	5.7	1	0.069	26.8
March	6.0	4	0.139	63.8
April	8.5	8	0.055	34.4
May	18.3	7	0.068	94.4
June	14.1	8	0.061	63.2
July	8.9	8	0.213	144.2
August	7.4	6	0.087	48.5
September	6.8	4	0.066	32.8
October	6.6	4	0.064	31.8
November	6.2	3	0.035	15.8
December	5.9	1	0.064	28.5
Annual Total:				**610**
Otter Creek[2]				
	Annual Average Flow (cfs)	**Number of TP Observations**	**Annual Average TP Concentration (mg/L)**	**Total Annual Load (kg)**
	6.3	33	0.077	**433**
Annual Total to Reservoir				**1,043**

[1] Flow: Estimated using Daniels Canyon Unit Area Flows (see Appendix A). Water Quality: Station 594580 - Boobe Hole Creek above Koosharem Reservoir.
[2] Flow: USGS 10187300 Otter Creek at mouth of Daniels Canyon. Water Quality: Station 594579 - Otter Creek above Koosharem Reservoir.

The calculations based on the monitoring data and detailed in Table 4.4 show that the annual loading to Koosharem Reservoir is approximately 1,043 kg/yr with approximately 610 kg/yr (58 %) coming from Boobe Hole Creek and 433 kg/yr (42 %) from Otter Creek.

Koosharem Reservoir is located at the extreme north end of the Otter Creek watershed. The contributing area for the reservoir is relatively small at approximately 63 mi^2 (163 km^2), and consists of a mix of NFS, BLM, and private land (Figure 4.6). There is also a small amount of Native American Reservation land adjacent to the west side of the reservoir. There are no municipal or urban areas in the watershed, and consequently there is no significant loading associated with urban or residential land. The following pollutant sources are present in the Koosharem Reservoir watershed and are addressed in the following sections:

1. Grazing
2. Natural Background
3. Internal Reservoir Loading
4. Diffuse Loads from Runoff

4.3.1 Grazing

Much of the contributing area to Koosharem Reservoir is grazed. Nearly all of the BLM and NFS land in the watershed is grazed, and important grazing areas in the low-lying private lands on the north and east of the reservoir have also been identified. Field visits to the watershed have determined that during portions of the year animals grazing on allotments and pastures adjacent to the reservoir are given unrestricted access to the reservoir bed below the high water line. Manure deposited below the high water line represents a direct contribution to the reservoir as these areas become inundated as the water level in the reservoir rises in the spring. Figure 4.7 shows the grazed areas in the Koosharem Reservoir watershed. The following assumptions have been made so that loads from grazing animals to existing water bodies in the Koosharem Reservoir watershed can be calculated:

1. Grazing allotments are used at their maximum permitted levels (except for those allotments where actual use information was available).

2. The animals are distributed equally over the areas of the allotments.

3. Only area within 100 meters of an existing water body contributes to loading.

4. A delivery ratio of 100 percent is assumed for animal waste deposited within 10 meters of an existing water body and a delivery ratio of 10 percent is assumed for animal waste deposited between 10 and 90 meters of an existing water body.

5. A delivery ratio of 100 percent is assumed for animal waste deposited below the high water line of Koohsarem Reservoir.

Table 4.5 lists those grazing allotments that are within the Koosharem Reservoir watershed and have area within 100 meters of an existing water body. The table also provides some descriptive information such as the number of permitted animals and season of use. The permitted animals are grouped by their allotment, animal type, and season of use (Animal Group) to facilitate the analysis that follows.

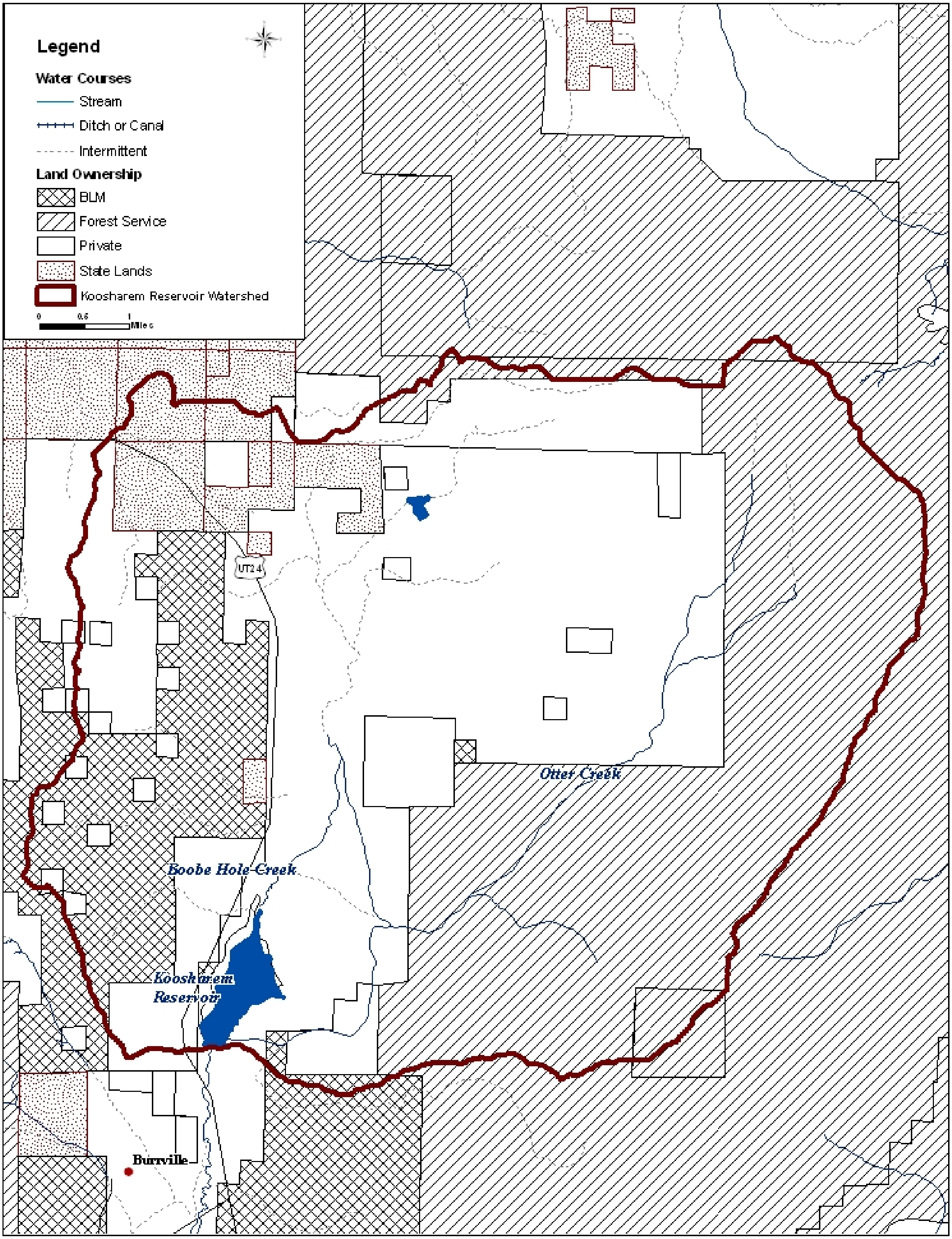

Figure 4.6. Land ownership in the Koosharem Reservoir watershed.

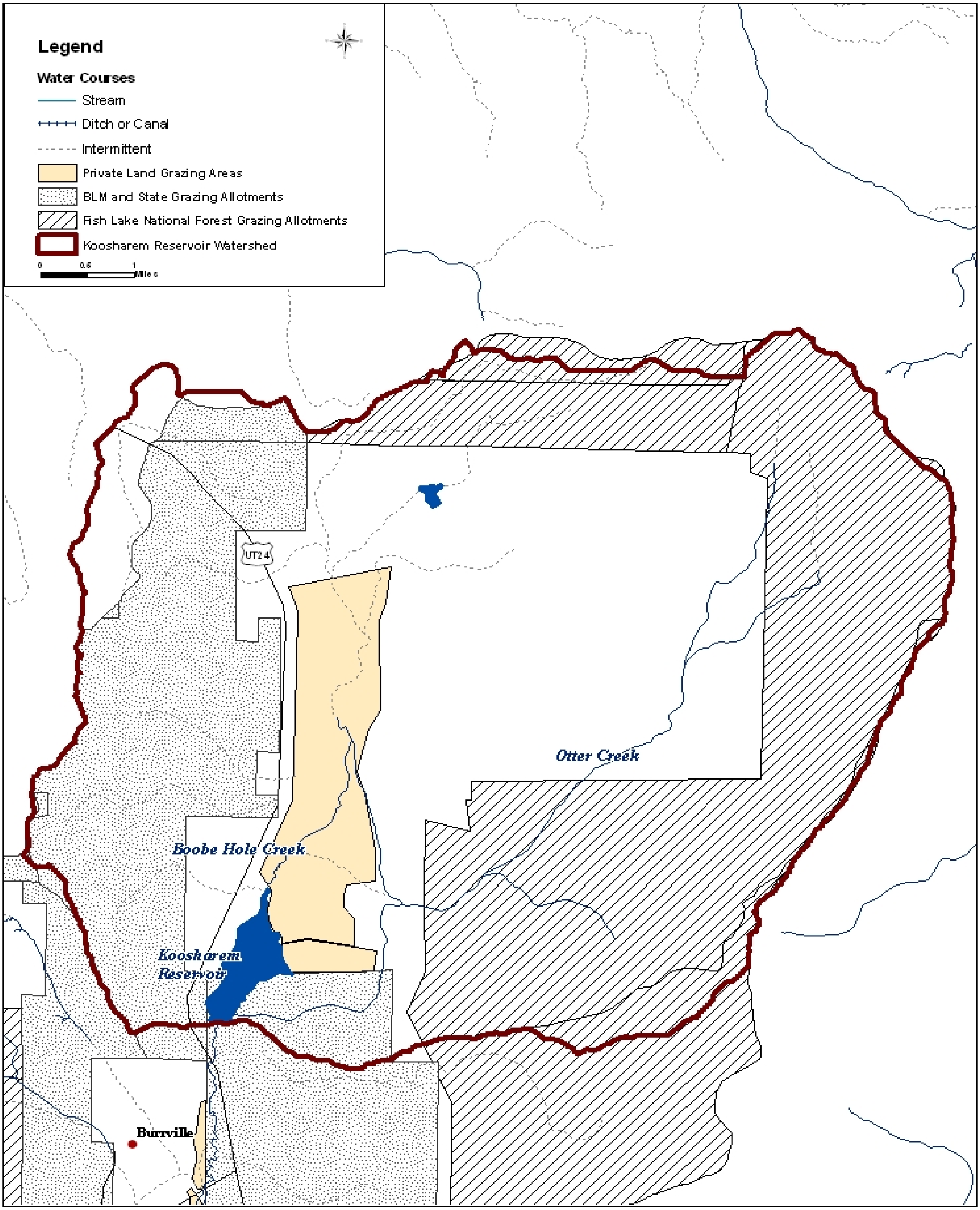

Figure 4.7. Grazed areas in the Koosharem Reservoir watershed.

Table 4.5. Grazing allotments in the Koosharem Reservoir watershed[a].					
Allotment Name	**Responsible Organization**	**Animal Group**	**Animal Type**	**Permitted Animals**	**Season of Use**
Daniels	USFS	1	Cattle	400	Jul-1 to Sept-30 (91 days)
Lost Creek-Boobe Hole	USFS	2	Cattle	1,225	Jun-12 to Oct-11 (121 days)
Plateau	BLM	3	Sheep	236	Jun-1 to Jul-10 (39 days)
		4	Sheep	800	Jun-10 to Jul-15 (35 days)
Fishlake	BLM	5	Sheep	1,822	Jun-11 to Nov-30 (172 days)
Private Land 1001	Private	6	Cattle	300	Jun-1 to Oct-31 (152 days)
Private Land 1002	Private	7	Cattle	150	Jul-1 to Jan-1 (183 days)
		8	Sheep	350	Jun-1 to Aug-1 (61 days)
[a]The information in this table is for the entire allotment and not just the area of the allotment within the Koosharem Reservoir watershed.					

In the absence of more detailed information and as stated above, it is assumed that the animals on the grazing allotments are distributed equally over the entire area of the allotments. Given this assumption, Table 4.6 lists the distribution of livestock in the grazing allotments identified in Table 4.5 by Animal Group.

Table 4.6. Grazing Livestock distribution in the grazing allotments within the Koosharem Reservoir watershed.					
Allotment Name	**Total Land Area (mi^2)**	**Animal Group**	**Animal Type**	**Permitted Animals**	**Animals Per mi^2**
Daniels	21.7	1	Cattle	400	18
Lost Creek-Boobe Hole	52.9	2	Cattle	1,225	23
Plateau	12	3	Sheep	236	20
		4	Sheep	800	67
Fishlake[a]	27	5	Sheep	1,822	67
Private Land 1001[a]	3.7	6	Cattle pairs	300	81
Private Land 1002[a]	0.36	7	Cattle pairs	150	417
		8	Sheep	350	972
[a]These allotments have area that is adjacent to the reservoir and this area would change to a small degree as the water level declines and area below the high water line becomes available for grazing.					

In general, the primary mechanisms by which loading from grazing animals occurs are direct deposition in existing water bodies and surface runoff from areas where cattle have grazed. In this watershed, an additional mechanism for phosphorus loading is from animals grazing below the high water line of the reservoir. Given the dispersed nature of grazing activities, it is assumed that only animal waste deposited in the area within 100 meters of an existing water body (either a stream or the reservoir) contributes to loading. In considering the mechanisms by which loading occurs, it is also assumed that 100 percent of the TP associated with manure deposited within 10 meters of an existing water body contributes to loading (delivery ratio = 100 %) and that approximately 10 percent of manure deposited between 10 and 100 meters from an existing water body contributes to loading (delivery ratio = 10 %). A delivery ratio of 100 % is assumed for manure deposited below the high water line of the reservoir as these areas are inundated as water levels rise in the reservoir. Tables 4.7 and 4.8 list the contributing areas associated with the zones contributing loads from grazing to existing water bodies in the Koosharem Reservoir watershed. Table 4.7 lists the contributing areas for existing stream courses in the watershed, and Table 4.8 lists those areas that contribute loading directly to the reservoir (i.e., they are not drained by an existing stream). The areas listed in these two tables were calculated by buffering the streams and reservoir using a GIS.

Table 4.7. Areas of zones contributing loading to stream courses in the Koosharem Reservoir watershed from grazing.

Allotment	Contributing Zone	Contributing Area (mi^2)
Daniels	0-10 meters	0.112
	10-100 meters	1.0
Lost Creek-Boobe Hole	0-10 meters	0.029
	10-100 meters	0.259
Plateau	0-10 meters	0.011
	10-100 meters	0.108
Fishlake	0-10 meters	0.025
	10-100 meters	0.220
Private Land 1001	0-10 meters	0.084
	10-100 meters	0.714
Private Land 1002	0-10 meters	0
	10-100 meters	0

Table 4.8. Areas of zones contributing loads directly to Koosharem Reservoir from grazing.

Allotment	Contributing Zone	Contributing Area (mi^2)
Fishlake	0-10 meters Outside Reservoir	0.012
	10-100 meters Outside Reservoir	0.094
	Below High Water Line[a]	0.104
Private Land 1001	0-10 meters Outside Reservoir	0.0048
	10-100 meters Outside Reservoir	0.045
	Below High Water Line[a]	0.046
Private Land 1002	0-10 meters Outside Reservoir	0.0023
	10-100 meters Outside Reservoir	0.021
	Below High Water Line[a]	0.025

[a]The area below the high water line was estimated by creating a 100 meter buffer *inside the reservoir* and adjacent to the allotment boundaries. No data are available to determine the area exposed to grazing below the high water line of the reservoir and so a conservative assumption of 100 meters has been used.

According to the Agricultural Waste Management Handbook (NRCS 1992) the average weight of a grazing cow is approximately 1,000 pounds and the average TP production rate is approximately 0.12 lbs of TP/1,000 pound animal/day. It is assumed that approximately five sheep are equivalent to one cow, so the TP production rate for sheep is 0.024 lbs TP/sheep/day. Given these numbers, Table 4.9 lists the unit area loads for each animal group that were calculated by multiplying the animal density (number of animals per square mile) from Table 4.6 by the TP production rate. The unit area loads were then adjusted based on information regarding actual use of each allotment versus the permitted animal numbers. Where no actual use information was available, the estimated permit usage percent (the percent of the permitted animals that have actually used the allotment over approximately the past ten years) was assumed to be equal to 100 percent. Tables 4.10 and 4.11 show the annual TP loads contributed by grazing to streams in the Koosharem Reservoir watershed and directly to Koosharem Reservoir, respectively.

Table 4.9. Calculation of unit area loads.

Animal Group	Animals per mi^2	Total Phosphorus Production Rate (lbs TP/animal/day)	Unit Area Load (lbs TP/mi^2/day)	Estimated Permit Usage Percent	Adjusted Unit Area Load (lbs TP/mi^2/day)
1	18	0.12	2.2	100	2.2
2	23	0.12	2.8	100	2.8
3	20	0.024	0.5	40	0.2
4	67	0.024	1.6	40	0.6
5	67	0.024	1.6	33	0.5
6	81	0.12	10	100	9.7
7	417	0.12	50	100	50
8	972	0.024	23	100	23

Table 4.10. Annual Total Phosphorus loading to existing streams in the Koosharem Reservoir watershed from grazing.

Animal Group	Contributing Zone	Area Within Zone (mi^2)	Days on Allotment	Adjusted Unit Area Load (lbs TP/mi^2/day)	Delivery Ratio (%)	Total Phosphorus Loading (kg/yr)
1	0-10 meters		91	2.2	100	10.2
	10-100 meters				10	9.1
2	0-10 meters		121	2.8	100	4.5
	10-100 meters				10	4.0
3	0-10 meters		39	0.2	100	0.04
	10-100 meters				10	0.04
4	0-10 meters		35	0.6	100	0.1
	10-100 meters				10	0.1
5	0-10 meters		172	0.5	100	1.0
	10-100 meters				10	0.9
6	0-10 meters		152	10	100	57.9
	10-100 meters				10	49.2
7	0-10 meters		183	50	100	0.0
	10-100 meters				10	0.0
8	0-10 meters		61	23	100	0.0
	10-100 meters				10	0.0
Total						**137**

Table 4.11. Annual Total Phosphorus loading directly to Koosharem Reservoir from grazing.						
Animal Group	**Contributing Zone**	**Area Within Zone (mi^2)**	**Days on Allotment**	**Adjusted Unit Area Load (lbs TP/mi^2/day)**	**Delivery Ratio (%)**	**Total Phosphorus Loading (kg/yr)**
5	0-10 meters	0.012	172	0.5	100	0.5
	10-100 meters	0.094			10	0.4
	Below High Water Line	0.104			100	4.1
6	0-10 meters	0.005	152	10	100	3.3
	10-100 meters	0.045			10	3.1
	Below High Water Line	0.046			100	31.7
7	0-10 meters	0.002	183	50	100	9.5
	10-100 meters	0.021			10	8.7
	Below High Water Line	0.025			100	103.8
8	0-10 meters	0.002	61	23	100	1.5
	10-100 meters	0.021			10	1.3
	Below High Water Line	0.025			100	15.9
Total						**168**

4.3.2 Natural Background

In order to estimate natural background loading, data characterizing the amount of flow contributed to the reservoir and the "natural" or pre-human influence concentration of that flow are needed. As mentioned above, few direct measurements are available to characterize the inflows to the reservoir. Because of this, the same streamflow estimates for Otter Creek and Boobe Hole Creek used to estimate the loads from existing sampling data were used to estimate the loading from natural background.

To calculate the magnitude of the natural background loading, the estimates of the average daily flows were multiplied by the estimated historical background concentration of 0.03 mg/L and a conversion factor to produce estimates of the average daily loads. The average daily loads within each month were then summed to produce monthly loads that were then averaged across the 1965 to 1981 time period to create average monthly loads. Table 4.12 lists the results of these calculations, including the sum of the average monthly loads, which totals approximately 394 kg/yr.

Table 4.12. Average monthly and total annual natural background loading in the Koosharem Reservoir watershed (1965 – 1981).			
	Total Phosphorus Load (kg)		
Month	**Boobe Hole Creek**	**Otter Creek**	**Total to Reservoir**
January	18	13	31
February	17	12	29
March	20	14	34
April	8	19	27
May	18	41	59
June	13	31	45
July	9	20	29
August	7	17	24
September	7	15	21
October	14	15	29
November	20	14	33
December	19	13	33
Annual Total:	**171**	**224**	**394**

4.3.3 Diffuse Loads from Runoff

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

Land use in the Koosharem Reservoir watershed is primarily forest and range land, with smaller areas of irrigated agriculture associated with the east side of the reservoir. Table 4.13 lists the land use distribution in the Koosharem Reservoir watershed in terms of acres and percent. This information is displayed visually in Figure 4.8. A detailed explanation of the procedure used to generate the existing conditions land use coverage is included in Appendix A.

Table 4.13. Land use distribution in the Koosharem Reservoir watershed.			
	Area		
Land Use Category	**Acres**	**Square Kilometers**	**Percent**
Urban/Residential/Transportation	121	0.5	0.3
Forest Land	21,701	87.8	53.9
Range Land	15,421	62.4	38.3
Irrigated Agriculture	1,919	7.8	4.8
Wetlands	20	0.1	0.05
Barren	879	3.6	2.2
Water	220	0.9	0.5
Total	**40,281**	**163**	**100**

The amount of urban/residential/transportation land is small and mainly associated with transportation corridors that travel through the watershed. Loading from these areas is assumed to be minimal. In addition, loading associated with the small amount of wetlands and open water in the watershed is assumed to be negligible. Barren lands in the watershed are associated with high elevation areas that are not expected to contribute significantly to loading. This leaves the forest land, range land, and irrigated agricultural lands in the watershed.

The irrigated agricultural lands in the Koosharem Reservoir watershed are primarily located adjacent to the east and north sides of the reservoir (Figure 4.8) and make up less than five percent of the total watershed area. These lands are primarily irrigated pastures used for forage cropping. Although the irrigated agricultural lands make up a small percentage of the watershed, their proximity to the reservoir increases the likelihood that they are contributing significantly to loading. Since most of these lands are irrigated, return flows from these areas flow into the reservoir, likely carrying with them elevated levels of TP.

As discussed above, nearly all of the forest and range lands in the watershed are grazed, and this has led to increased sediment loads in the watershed and impacted riparian conditions. Phosphorus associated with eroded sediment is carried into the streams and down to the reservoir as runoff events occur. As there are no other identified sources of loading in the watershed, it is assumed that the magnitude of diffuse loadings from runoff is equal to the difference between the measured loads reported in Table 4.2 and the sum of the natural background loads and grazing loads calculated in Sections 4.3.2 and 4.3.3 above (approximately 512 kg/yr). The Koosharem Reservoir source summary in the following section presents the results of the loading assessment for Koosharem Reservoir.

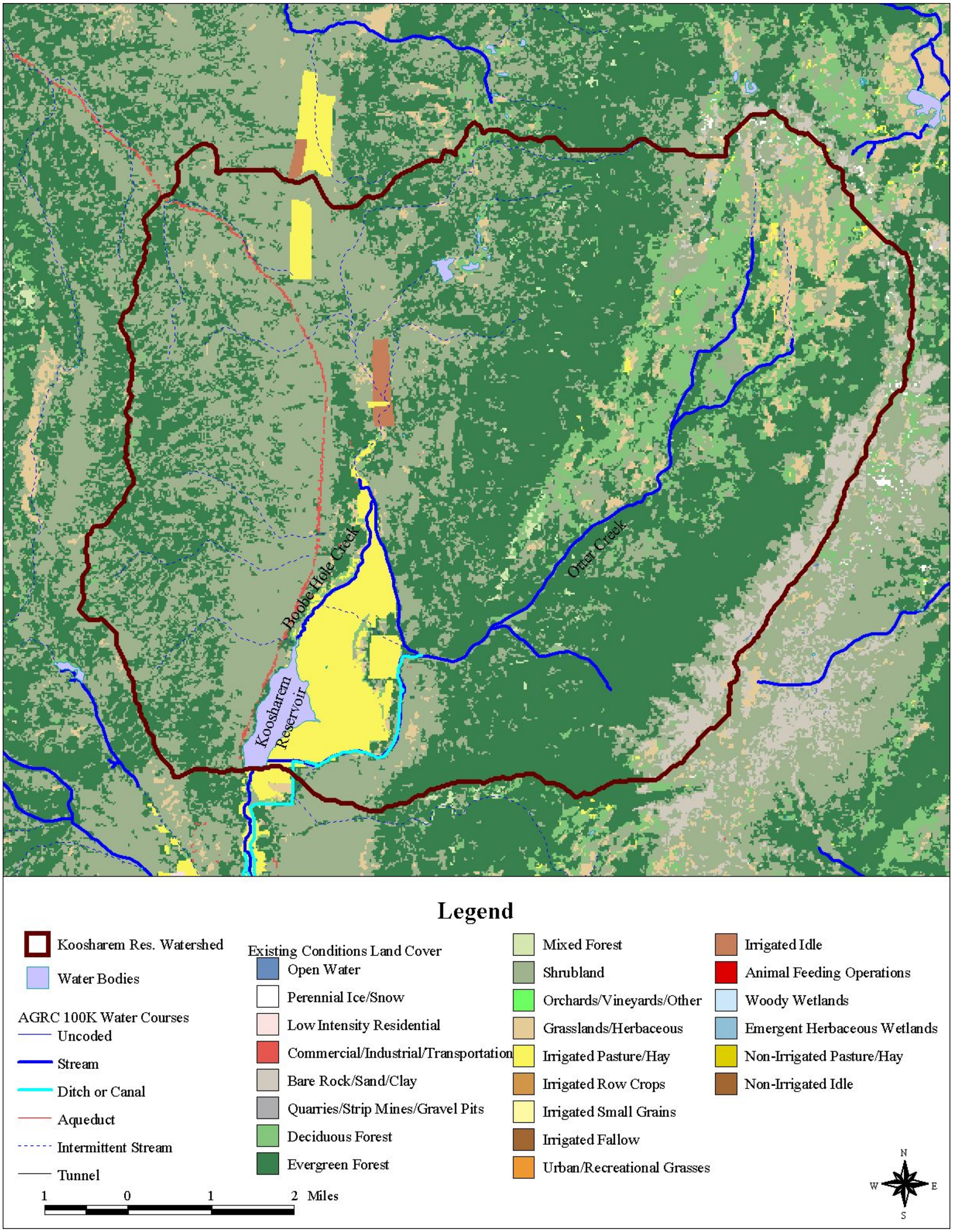

Figure 4.8. Land use in the Koosharem Reservoir watershed.

4.3.4 Koosharem Reservoir Source Summary

Table 4.14 summarizes the significant loadings to Koosharem Reservoir by source category. Approximately 38 percent of the total measured load can be attributed to natural background loading, with grazing loads contributed to the existing streams and diffuse loads from runoff making up approximately 13 and 49 percent of the measured loading respectively. In addition to the measured loading, it is approximated that 168 kg/yr of loading is contributed directly to the reservoir from grazing within and adjacent to the reservoir. These loads would not be measured in the tributary inflows, and so they are added to the total measured loading to generate an estimate of the total loading to the reservoir.

Table 4.14. Summary of annual loads to Koosharem Reservoir by source category.

Estimated Loads by Source	Annual Total Phosphorus Load (kg)
Grazing – Loading to Streams	137
Grazing – Loading Directly to Reservoir	168[a]
Natural Background	394
Diffuse Loads from Runoff	512
Total Measured Loading to Reservoir	**1,043**
Total Estimated Loading to Reservoir	**1,211**

[a]Loading in this category would not be included in the total measured loading because it does not enter the reservoir via an existing stream course.

4.4 Total Phosphorus Loads - Lower Box Creek Reservoir

Lower Box Creek Reservoir is located on the west side of Otter Creek approximately midway between Koosharem Reservoir and Otter Creek Reservoir. The contributing area for the reservoir is much smaller than Koosharem Reservoir at approximately 13 mi^2 (33.5 km^2), and consists of a mix of NFS land and private land (Figure 4.9). There are no municipal or urban areas in the watershed, and consequently there is no significant loading associated with urban or residential land. The following pollutant sources are present in the Lower Box Creek Reservoir watershed and are addressed in the following sections:

1. Grazing
2. Natural Background
3. Internal Reservoir Loading
4. Diffuse Loads from Runoff

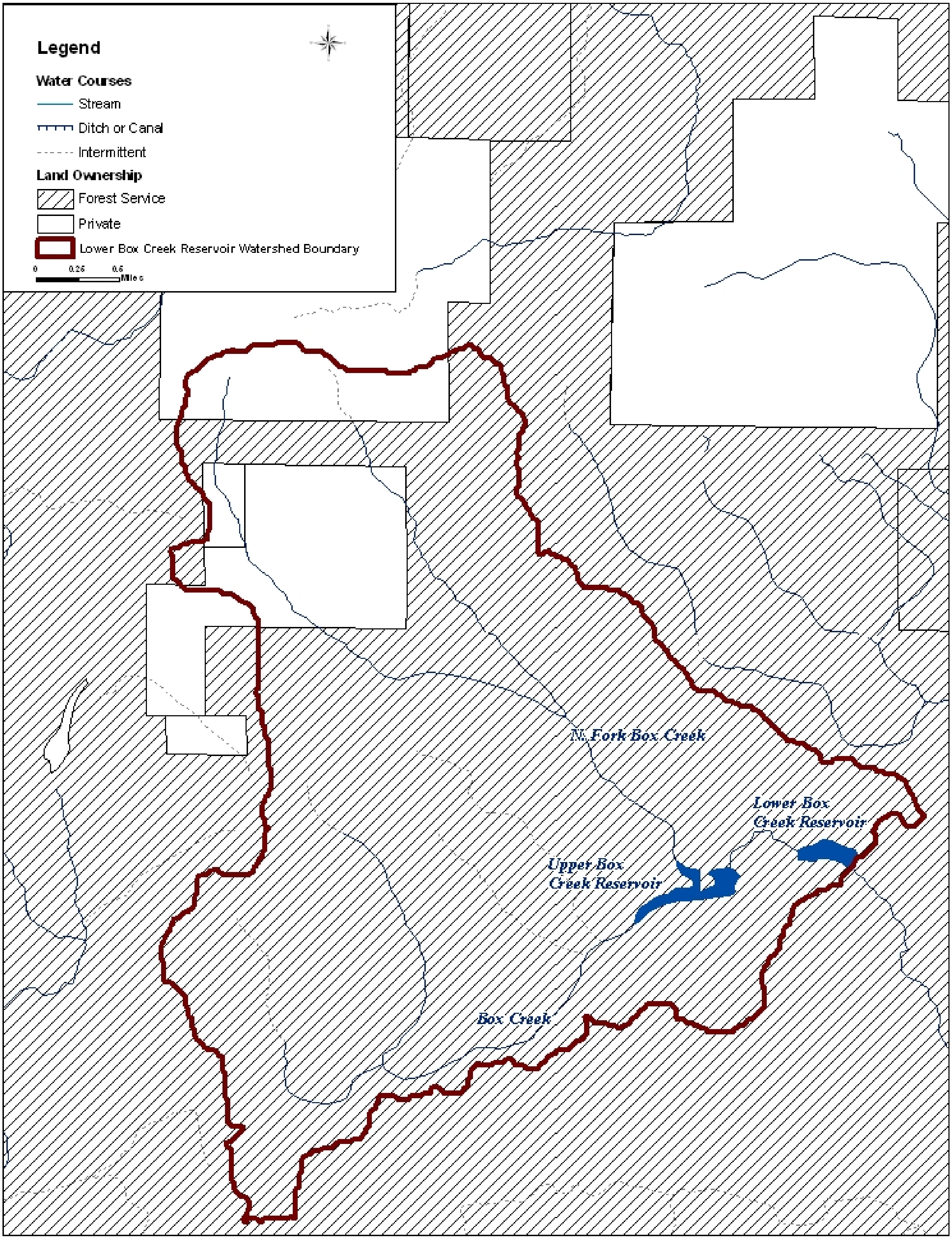

Figure 4.9. Land ownership in the Lower Box Creek Reservoir watershed.

Data to characterize existing loads to Lower Box Creek Reservoir are very limited. There are a few water quality observations made by the Forest Service in the late 1970s in the upper watershed above the upper reservoir, but these observations are likely not representative of current conditions. There is also one water quality station on Box Creek between the two reservoirs (station 594653), at which 13 observations of TP concentration have been made during the months of June – October over the past 10 years (1992 – 2003). There are no data available during the other months of the year. In addition, this station characterizes releases from the upper reservoir and may not characterize loadings in the watershed since there is likely some phosphorus loss to settling in the upper reservoir. Due to the paucity of data, no load calculations using existing streamflow and concentration data were done.

4.4.1 Grazing

All of the contributing area to Lower Box Creek Reservoir lies within the National Forest Service Koosharem – Monroe Creek grazing allotment. Figure 4.10 shows the allotment boundaries associated with the Lower Box Creek Reservoir watershed. Table 4.15 provides some descriptive information about the allotment, including the number of permitted animals and season of use.

The permitted animals are grouped by their season of use (Animal Group) to facilitate the analysis that follows.

Table 4.15. Characteristics of the Koosharem – Monroe Creek grazing allotment.[a]

Allotment Name	Responsible Organization	Animal Group	Animal Type	Permitted Animals	Season of Use
Koosharem- Monroe Creek Total Area = 71.9 mi^2	USFS	1	Cow	654	June 1 – October 15 (137 days)
		2	Cow	106	July 1 – October 15 (107 days)
		3	Cow	27	July 6 – October 15 (102 days)

[a]The information in this table is for the entire allotment and not just the area of the allotment within the Lower Box Creek Reservoir watershed.

In the absence of more detailed information, it is assumed that the animals on the grazing allotment are distributed equally over the entire area of the allotment. Given this assumption, Table 4.16 lists the distribution of livestock in the Koosharem-Monroe Creek Allotment by Animal Group. In general, livestock that are not part of a managed grazing system show preference to meadows and pastures adjacent to a water source compared to areas located further away from water. No measurements of grazing density were available for the Lower Box Creek Reservoir watershed. Recommendations for removing direct livestock access to water are addressed in the Project Implementation Plan associated with the TMDL proposed for Lower Box Creek Reservoir.

Table 4.16. Grazing livestock distribution in the Koosharem – Monroe Creek Grazing allotment.

Allotment	Land Area (mi^2)	Animal Group	Animal Type	Number of Animals	Animals Per mi^2
Koosharem – Monroe Creek	71.9	1	Cow	654	9.1
		2	Cow	106	1.5
		3	Cow	27	0.4

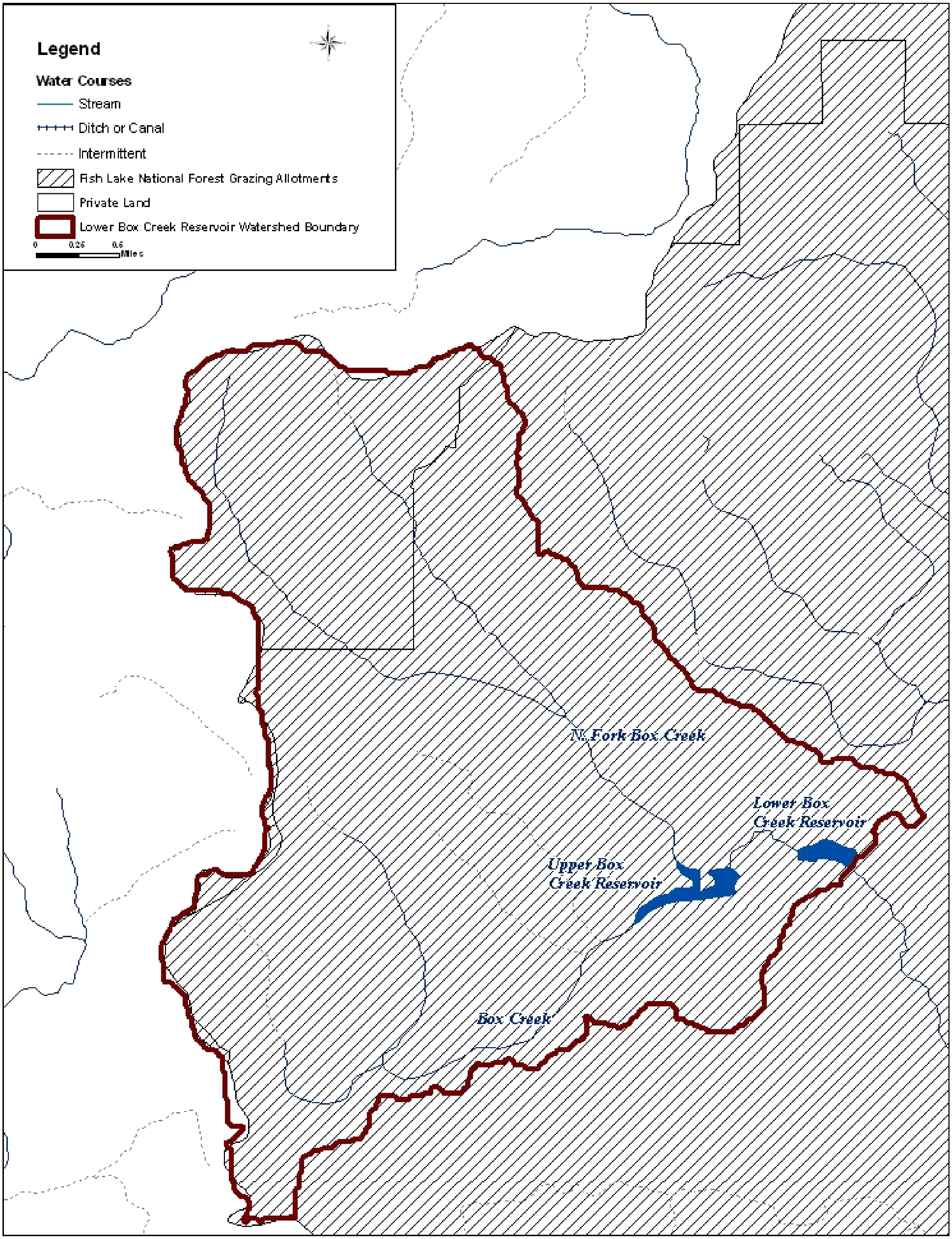

Figure 4.10. Grazed areas in the Lower Box Creek Reservoir watershed.

The same assumptions made above in the Koosharem Reservoir loading assessment regarding the deposition areas within 10 and 100 meters of an existing water body contributing to loading and the associated delivery ratios are used again here to calculate loadings in the Lower Box Creek Reservoir watershed. Table 4.17 lists the contributing area associated with the two assumed depositional zones that contribute to loading. These areas were calculated by buffering the streams and reservoirs using a GIS.

Table 4.17. Areas of zones contributing to loading from grazing in the Lower Box Creek watershed.

Contributing Zone	Contributing Area (mi^2)
Within 10 meters of an existing water body	0.231
10 – 100 meters from an existing water body	2.05

Again, according to the Agricultural Waste Management Handbook (NRCS 1992) the average weight of a grazing cow is approximately 1,000 pounds and the average TP production rate is approximately 0.12 lbs of TP/1,000 pound animal/day. Given these numbers, Table 4.18 lists the unit area loads for each animal group that were calculated by multiplying the animal density (number of animals per square mile) from Table 4.16 by the TP production rate.

Table 4.18. Calculation of unit area loads.

Animal Group	Animals per mi^2	TP Production Rate (lbs TP/animal/day)	Unit Area Load (lbs TP/mi^2/day)
1	9.1	0.12	1.1
2	1.5	0.12	0.18
3	0.4	0.12	0.05

Annual TP loading to the existing water bodies in the Lower Box Creek Reservoir watershed was calculated for each animal group by multiplying the unit area loads in Table 4.18 by the areas of the deposition zones, the delivery ratios associated with these zones where manure is deposited, and the number of days that the animals in each animal group spend on the allotment. Table 4.19 shows these calculations. No adjustments in the unit area loads were made for actual versus permitted use of this allotment since no information was available. The total annual loading of 76.3 kg/yr estimated in Table 4.19 represents the combined loading to all of the water bodies in the watershed.

Table 4.19. Total Phosphorus loading to water bodies in the Lower Box Creek Reservoir watershed from grazing.

Animal Group	Contributing Zone	Area Within Zone (mi^2)	Days on Allotment	Unit Area Load (lbs TP/mi^2/day)	Delivery Ratio (%)	Total Phosphorus Loading (kg/yr)
1	0-10 meters	0.231	137	1.1	100	34.8
	10-100 meters	2.05			10	30.9
2	0-10 meters	0.231	107	0.18	100	4.45
	10-100 meters	2.05			10	3.95
3	0-10 meters	0.231	102	0.05	100	1.18
	10-100 meters	2.05			10	1.05
Total						**76.3**

4.4.2 Natural Background Loading

No measurements are available to characterize the amount of flow generated in the Lower Box Creek Reservoir watershed (i.e., inflow to the reservoirs). The only flow data available were collected below both of the reservoirs and represent the regulated releases from both of the reservoirs. Given that the outflow data are the only information available characterizing flow in the Lower Box Creek Reservoir watershed, they will be used to estimate the natural background loadings. Given the following assumptions, the outflows from the reservoir can be assumed to be approximately equal to the inflows on an annual basis:

1. The net groundwater flow to the reservoir is equal to zero (groundwater flow in is equal to groundwater flow out).
2. Precipitation input to the reservoir is approximately equal to the evaporation.
3. The average change in storage on an annual basis is equal to zero.

To calculate the magnitude of the natural background loading in the Lower Box Creek Reservoir watershed, the estimated historical background concentration of 0.03 mg/L was multiplied by the daily average outflow from the reservoir and a conversion factor to generate an average daily load. The daily average outflow values were generated by averaging the flow values for each day of the year across all years for which data are available. The average daily loads were then summed to get a total annual load from natural background of approximately 95 kg/yr. Daily or monthly results are not presented here because the timing of the inflows to the reservoir and the outflows from the reservoir is different.

4.4.3 Internal Reservoir Loading

Similar to Koosharem Reservoir, Lower Box Creek reservoir is small, relatively shallow, and is regularly drawn down. These factors generally prevent the reservoir from stratifying and would typically prevent the conditions required for release of phosphorus from the sediments in the reservoir. Oxygen concentrations within the reservoir are typically above 5 mg/L for the entire water column, although a concentration of 1.8 mg/L was recorded in August of 1994. Internal loading from sediments is not considered a significant source of TP to Lower Box Creek Reservoir.

It should be noted, however that a significant amount of grazing takes place in the immediate vicinity of the reservoir, including areas below the high water line. Phosphorus deposited in these areas by grazing animals is readily transported to the lake via runoff or when the lake level rises and inundates these areas. Pollutant loadings from this source have been discussed previously in Section 4.4.1 above.

4.4.4 Diffuse Loads from Runoff

There are no agricultural lands in the Lower Box Creek Reservoir watershed (Figure 4.11), so there is no loading associated with the use of agricultural chemicals. There is, however, potential in this watershed for loading caused by increased sedimentation and erosion caused by grazing animals in and near existing streams and reservoirs, erosion from forest roads, ATV trails and dispersed camping sites, as well as bank erosion from inflowing streams to the reservoir. Field surveys of Box Creek above Upper Box Creek Reservoir indicated that many channel segments were experiencing moderate to severe levels of bank erosion, particularly on North Fork Box Creek. Additional sediment loading appeared to be produced from failed beaver dams and channel segments behind these dams that were downcutting through large sediment deposits.

Based on the results of the field survey, annual sediment loads from Box Creek and the North Fork of Box Creek were estimated at 1,085 tons/year.

There are no direct measurements of surface runoff and erosion available within the watershed and little information in general is available to quantify the diffuse loads from runoff. Because of this, a mass balance approach was used to estimate the diffuse loading from runoff in the Lower Box Creek Reservoir watershed. The following equation was developed for the TP loading to Lower Box Creek Reservoir.

$$L_T = L_G + L_{NB} + L_{DL} - S \tag{4.1}$$

Where: L_T = Total loading *to Lower Box Creek Reservoir* (kg/yr)
L_G = Total loading from grazing *in the watershed* (kg/yr)
L_{NB} = Total natural background loading *in the watershed* (kg/yr)
L_{DL} = Total diffuse loads from runoff *in the watershed* (kg/yr)
S = Total phosphorus lost to settling *in Upper Box Creek Reservoir* (kg/yr)

Equation 4.1 can be rearranged to solve for the diffuse loads from runoff term:

$$L_{DL} = L_T + S - L_G - L_{NB} \tag{4.2}$$

The total loads from grazing (L_G) and natural background (L_{NB}) in the watershed were calculated above, and are equal to 76.3 kg/yr and 95 kg/yr respectively. It is estimated that the total loading to Lower Box Creek Reservoir (L_T) is equal to 262 kg/yr and that the phosphorus loss to settling in Upper Box Creek Reservoir (S) is approximately equal to 227 kg/yr. Given these numbers, Equation 4.2 can be evaluated giving an estimate of 318 kg/yr of loading from diffuse loads from runoff. The following sections describe how the phosphorus loss to settling in Upper Box Creek Reservoir and the total loading to Lower Box Creek Reservoir were estimated.

4.4.4.1 Phosphorus Loss to Settling in Upper Box Creek Reservoir (S)

The phosphorus budget for Lower Box Creek Reservoir is complicated by the presence of an upstream reservoir. Most of the contributing area in the Lower Box Creek Reservoir watershed is above Upper Box Creek Reservoir, and the sources of pollution are entirely nonpoint source in nature. Therefore, most of the loading also occurs above Upper Box Creek Reservoir. As flow in the watershed passes through Upper Box Creek Reservoir, it is likely that some of the TP loading is lost to algal uptake and settling and does not pass on to Lower Box Creek Reservoir. An estimate of this loss is required so that the results of the phosphorus budget calculations can be used to estimate the diffuse loading from runoff. Chapra (1997) describes this mechanism for phosphorus loss using the following equation:

$$S = vA_sP \tag{4.3}$$

Where: S = Total phosphorus lost to settling (kg/yr)
v = Total phosphorus settling velocity (m/day)
A_s = Reservoir surface area (m^2)
P = Total phosphorus concentration (kg/m^3)

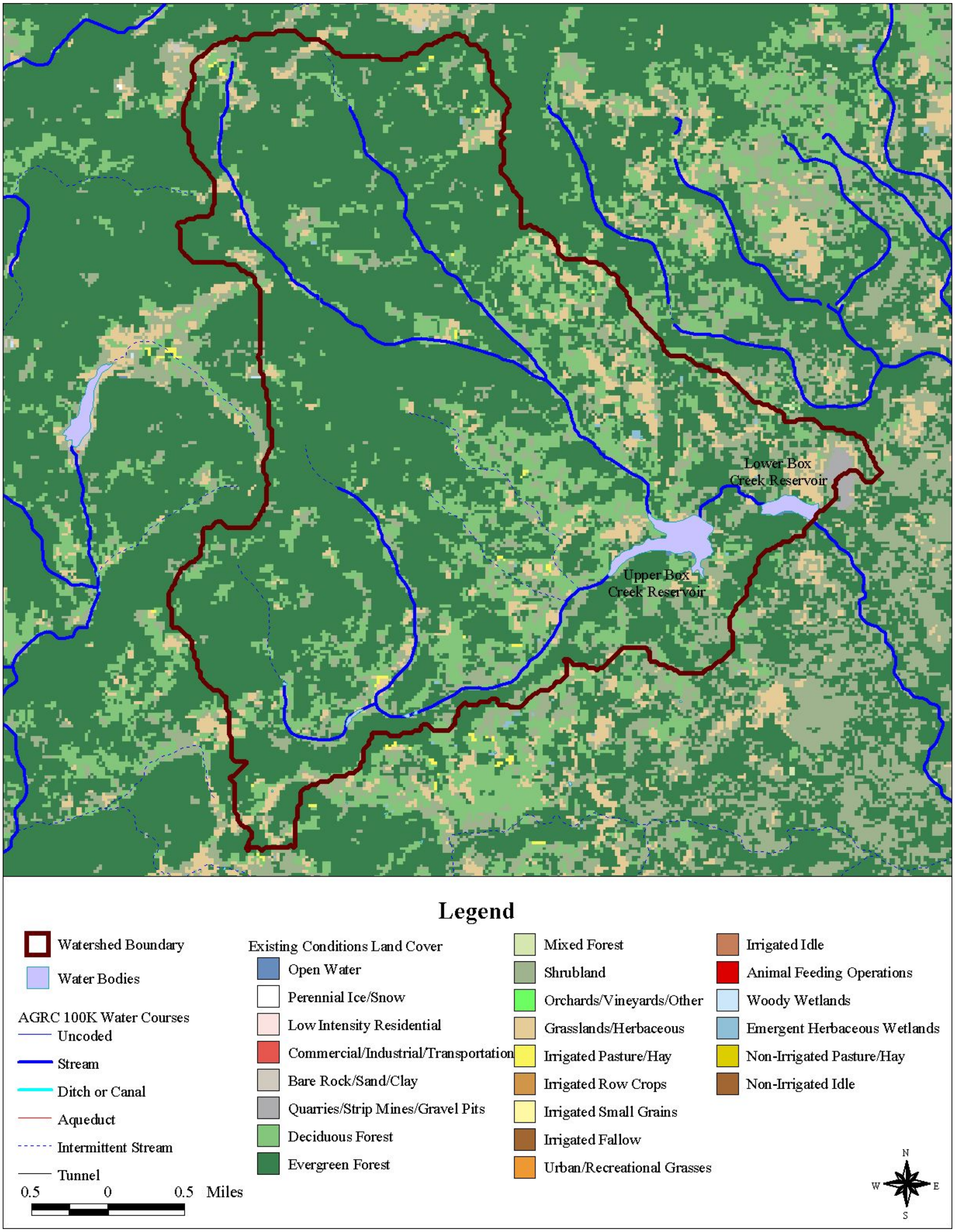

Figure 4.11. Land use in the Lower Box Creek Reservoir watershed.

To estimate the TP loss to settling on an annual basis, estimates of the parameters in Equation 4.3 are needed. According to Chapra (1997), the TP settling velocity (*v*) typically ranges from 5 to 20 m/yr (0.0137 to 0.0548 m/day). The actual settling velocity is a function of phosphorus uptake by algae and their subsequent growth, death, and settling. Settling velocity is also influenced by settling velocity of phosphorus attached to particulate matter. In general, the higher the value of the settling rate, the more TP is lost via settling and the higher the permissible loading to a reservoir or lake. The midpoint of the range suggested by Chapra (12.5 m/yr or 0.0342 m/day) was selected as an estimate of the TP settling velocity (*v*) for this area. There are no available records of water levels or surface areas within Upper Box Creek Reservoir, so information available from the Division of Water Rights' DAMVIEW/Dam Safety database (Utah DWR 2003) and anecdotal information from the reservoir operator were used to estimate average water levels and surface areas as a function of the day of year.

It is assumed that the reservoir generally fills by around the beginning of May and then is drawn down during the irrigation season until it reaches its lowest levels around the beginning of October. Otter Creek Reservoir, for which there are water level and volume measurements available, follows a similar trend. Figure 4.12 shows the estimated daily average volumes, and Figure 4.13 shows the estimated daily average surface area of Upper Box Creek Reservoir. The relationship between volume and surface area was derived using information from the Division of Water Rights Dam Safety Database (Utah DWR 2003).

There are only two sampling dates, which occurred during the summer of 1992, for which TP data are available in Upper Box Creek Reservoir. Due to the small number of observations (n = 6), the available data were averaged to get an estimate of the mean TP concentration in the upper reservoir (*P*). The resulting estimate (*P* = 0.158 mg/L) is not considered to be a particularly good estimate of the average TP concentration in the reservoir because it is based on a small number of observations collected over the course of one summer. However, in the absence of any other information, it will be used here.

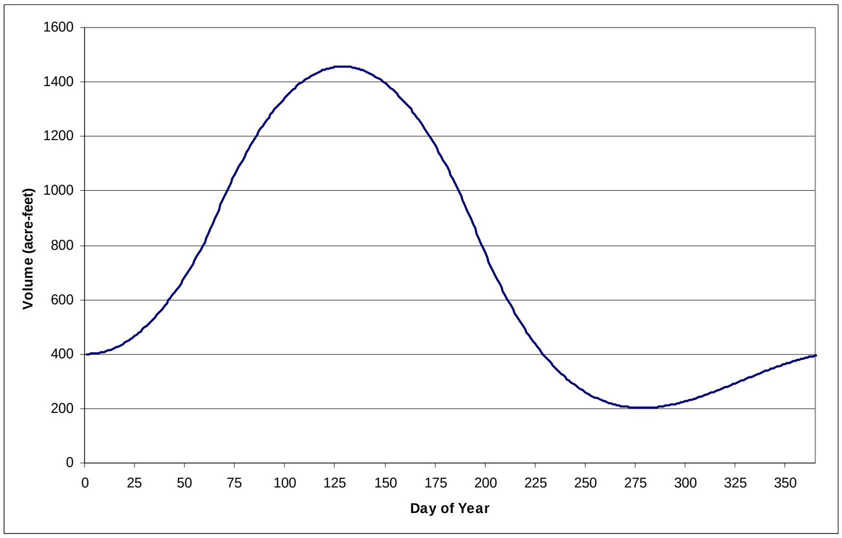

Figure 4.12. Estimated daily average volume in Upper Box Creek Reservoir.

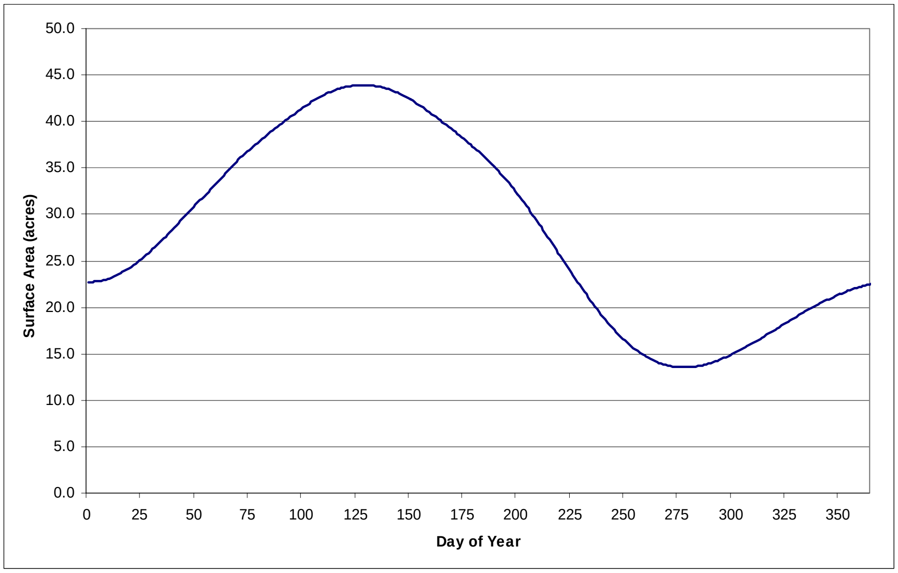

Figure 4.13. Estimated daily average surface area of Upper Box Creek Reservoir.

Given the settling rate, the estimates of the surface area of the reservoir, and the average TP concentration of the reservoir, an estimate of the phosphorus lost to settling in the upper reservoir can be made by evaluating Equation 4.3. The resulting estimate of phosphorus lost to settling in the upper reservoir is approximately 227 kg per year.

4.4.4.2 Total Loading to Lower Box Creek Reservoir (L_T)

The total loading to Lower Box Creek Reservoir (L_T) was calculated using an estimate of the permissible loading to Lower Box Creek Reservoir given a 0.025 mg/L endpoint concentration and an estimate of the average percent reduction in mass within the reservoir required to meet the permissible loading. The average annual permissible loading to Lower Box Creek Reservoir as calculated in Chapter 5 is approximately 96.4 kg/yr. This estimate is based on a phosphorus budget model for the reservoir and an assumed endpoint concentration of 0.025 mg/L TP (i.e., it represents the total amount of phosphorus that can be loaded to the reservoir while maintaining TP concentrations at or below 0.025 mg/L). Table 4.20 lists the average TP concentrations measured in Lower Box Creek Reservoir by sampling date and the percent reduction in phosphorus mass within the reservoir that would be required to meet the water quality criterion of 0.025 mg/L.

Given that the average permissible loading to Lower Box Creek Reservoir is 96.4 kg/yr (based on a 0.025 mg/L endpoint concentration) and the average percent reduction in TP mass within the reservoir required to meet this goal is approximately 63.2 percent, the estimated annual loading to the reservoir is approximately 262 kg/yr.

Table 4.20. Average Total Phosphorus concentrations and percent reduction in mass required to meet the 0.025 mg/L water quality criterion.		
Date	**Average Total Phosphorus Concentration (mg/L)**	**Mass Percent Reduction Required**
6/24/1992	0.0635	60.6
8/5/1992	0.1915	86.9
7/6/1994	0.075	66.7
8/24/1994	0.2225	88.8
7/1/1996	0.055	54.5
8/20/1996	0.09	72.2
7/6/1998	0.072	65.3
9/8/1998	0.131	80.9
6/20/2000	0.046	45.7
8/16/2000	0.1065	76.5
7/18/2002	0.074	66.2
8/28/2002	0.0955	73.8
10/2/2002	0.041	39.0
6/19/2003	< 0.02	0
8/20/2003	0.084	70.2
Average:		**63.2**

4.4.5 Lower Box Creek Reservoir Source Summary

Table 4.21 summarizes the TP loading in the Lower Box Creek Reservoir from each of the major sources that have been identified. Of the total loading in the Lower Box Creek Reservoir watershed, approximately 16 percent is from grazing, 19 percent is from natural background, and approximately 65 percent is from diffuse loads from runoff. An estimated 227 kg of the total loading in the watershed is lost to settling in Upper Box Creek Reservoir, leading to an estimated 262 kg/yr TP loading to Lower Box Creek Reservoir. It is noted here that this value is different than the average annual load of approximately 184 kg/yr shown in Appendix B – Table B-2 for Station 594563 (Box Creek above Lower Box Creek Reservoir). Differences between these two values are likely the result of the approach and assumptions used in each method. The higher value will be selected at this time as the existing annual load to the reservoir.

Table 4.21. Summary of annual average Total Phosphorus loads to Lower Box Creek Reservoir by source.	
Estimated Loads by Source	**Annual Total Phosphorus Load (kg)**
Grazing	76.3
Natural Background	95
Diffuse Loads from Runoff	318
Total Loading in Watershed	**489**
Losses to settling in Upper Box Creek Reservoir	-227[a]
Total Loading to Lower Box Creek Reservoir	262
[a] This number is negative because it represents a loss to the system.	

4.5 TOTAL PHOSPHORUS LOADS - OTTER CREEK RESERVOIR

Existing loads to Otter Creek Reservoir from its tributaries were calculated using available streamflow and water quality sampling information. It is assumed that Otter Creek and the East Fork Canal are the major inflows to Otter Creek Reservoir and that loadings associated with all other inflows are minor. Data characterizing water quality in Otter Creek upstream of the reservoir are generally good. Fewer flow and water quality measurements are available to characterize loading to the reservoir from the East Fork Canal, despite the fact that the majority of the flow to the reservoir is from this source.

Monthly average TP concentrations were calculated using available water quality sampling information in Otter Creek (Station 494920) and the East Fork Canal (Station 494924) immediately upstream of the reservoir. Data used in the calculation of the monthly average concentrations were limited to the period of 1990 to 2003. In the case of the East Fork Canal, no TP observations are available for the months of March, November, and December. Average concentrations for these months from station 494926 (East Fork Sevier River Above Diversion Near Antimony) were substituted. It is noted that mean annual TP concentrations at station 494926 are somewhat lower than those calculated on the downstream East Fork Canal station (494924). Although changes in water quality may occur along the length of the canal, Station 494926 represents the upstream source of the water in the East Fork Canal and will reflect monthly trends in water quality.

Streamflow data from USGS gage 10187500 (Otter Creek Above Reservoir Near Antimony, UT) were used to characterize monthly average flows in Otter Creek above the reservoir. These data do not correspond with the time period of the water quality data, but they do represent a variety of conditions within Otter Creek (over ten years of mean daily flows are available from 1961 to 1980) and should be representative of the monthly average flows that occur in Otter Creek. Flow data (1963 – 1990 and 2001) obtained from the Utah Division of Water Rights (Utah DWR Otter Creek Reservoir Inlet) were used to characterize the monthly average flows in the East Fork Canal. Again, these data do not correspond completely in time with the water quality observations, but, similar to the USGS gage on Otter Creek, there is a long period of record available and it is assumed that the available data are representative of the flows in the East Fork Canal.

Table 4.22 lists the results of the monthly load calculations. The results show that the annual loading to Otter Creek Reservoir is approximately 8,688 kg/yr with approximately 1,059 kg/yr (12 %) coming from Otter Creek and 7,629 kg/yr (88 %) from the East Fork Canal. These loads are similar to the long term total annual loads reported by Merritt et al. (1996), which are 1,071 kg/yr for Otter Creek and 7,331 kg/yr for the East Fork Canal.

The following sections describe the loading from the major sources that have been identified to Otter Creek Reservoir. Sources of TP loading to Otter Creek Reservoir that have been identified and that are summarized in the following sections are listed below. Loading from the East Fork Canal will also be addressed.

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

Table 4.22. Existing loads to Otter Creek Reservoir calculated using available streamflow and water quality sampling data.

Month	Average Flow (cfs)	Number of TP Observations	Average TP Concentration (mg/L)	Total Load (kg)
Otter Creek[1]				
January	13.4	3	0.134	136.7
February	24.4	3	0.155	259.3
March	35.7	5	0.144	390.8
April	14.6	9	0.089	95.5
May	5.8	10	0.084	37.0
June	1.4	12	0.074	7.5
July	0.4	9	0.129	3.5
August	0.2	10	0.110	1.4
September	0.3	7	0.089	1.8
October	1.3	6	0.096	9.8
November	9.0	4	0.045	29.8
December	13.6	2	0.084	86.3
Annual Total:				1,059
East Fork Canal[2]				
January	41.5	1	0.114	358.7
February	50.1	1	0.090	308.9
March	48.4	1	0.036	132.2
April	88.0	3	0.337	2,177.7
May	112.5	2	0.442	3,771.6
June	30.3	6	0.082	182.6
July	8.7	2	0.032	21.1
August	16.0	6	0.161	195.1
September	19.2	3	0.026	36.1
October	17.7	3	0.112	150.7
November	37.4	1	0.047	129.0
December	42.6	2	0.051	165.0
Annual Total:				7,629
Annual Total to Reservoir				**8,688**

[1]Flow: USGS 10187500 - Otter Creek Above Reservoir Near Antimony, UT (1961-1980); Water Quality: 494920 – Otter Creek Near Angle at Creek Crossing (1990-2003).
[2] Flow: Utah DWR – Otter Creek Reservoir Inlet (1963 – 1990, 2001); Water Quality: 494924 – East Fork Sevier River Canal at Inflow to Otter Creek Reservoir.

4.5.1 Animal Feeding Operations

Several animal feeding operations have been identified in the Otter Creek watershed. They are primarily clustered in and around the town of Koosharem. There is one dairy located immediately upstream of Otter Creek Reservoir, near Otter Creek, but it has been inactive for approximately three years and is not expected to contribute loading. Two of the operations near Koosharem are also inactive and not expected to contribute to loading. Two animal feeding operations have been identified within the East Fork Sevier River watershed, but one is located downstream of the East Fork Canal diversion, and one has been inactive for approximately six years. It is assumed that neither of these operations contribute loading to Otter Creek Reservoir.

Some of the active operations in the Otter Creek watershed are seasonal in nature and others have confined animals year round. Annual loads from each of the animal feeding operations in the

Otter Creek watershed were calculated using the NRCS Utah Animal Feedlot Runoff Risk Index (UAFRRI) model (Goodrich 2004). This model estimates, on an annual basis, the amount of phosphorus that leaves an animal feeding operation and enters nearby water courses based on the physical characteristics of the feeding operation, the number of animals, distance to an existing water course, etc.

The total estimated loading from active animal feeding operations in the Otter Creek watershed to nearby water courses is approximately 2,804 kg/yr. The receiving bodies for these loads are primarily intermittent tributaries and/or irrigation canals and ditches. It is anticipated that much of the loading associated with the animal feeding operations does not reach Otter Creek (or Otter Creek Reservoir) due to the fact that for the most part the runoff from these operations would be used for irrigation and little would return to Otter Creek. Given the low probability of this load reaching Otter Creek Reservoir, a zero net contribution from animal feeding operations could be assumed. However, to ensure adequate conservative assumptions in support of the ultimate margin of safety for this TMDL, it is assumed that a full 5 percent of the load (140 kg/yr) contributes to the total annual load in Otter Creek Reservoir.

4.5.2 Onsite Wastewater Treatment Systems

Onsite wastewater treatment systems represent a very small contribution of loading to Otter Creek Reservoir. There are three small municipalities in the contributing area for the reservoir, Koosharem and Greenwich in the Otter Creek Drainage and Antimony in the East Fork Sevier River watershed, which may contribute loading to Otter Creek Reservoir from onsite wastewater treatment systems. Annual loads from onsite wastewater treatment systems were calculated using the following information:

1. The number of septic tanks was estimated by using population estimates from the 2000 census (assuming 5 people per structure) or from a manual count of buildings that appeared to be inhabited.
2. The average effluent flow rate was assumed to be 227 gallons/day with a concentration of 18 mg/L TP (Lowe et al. 2003).
3. It is assumed that approximately 90 percent of the phosphorus in the effluent is retained onsite (a 90 percent treatment rate).

Table 4.23 lists the estimated annual loads from onsite wastewater treatment systems from each municipal area. These loads represent the amount of phosphorus that is likely to reach nearby water courses. It is anticipated that the relatively small amount of loading from onsite wastewater treatment systems has little potential for reaching or influencing water quality conditions within Otter Creek Reservoir, especially considering that the towns of Koosharem and Greenwich are located in the upper portion of the Otter Creek watershed, far from the reservoir. Therefore it is assumed that 25 kg/yr is a reasonable upper bound on the loading from onsite wastewater treatment systems to Otter Creek Reservoir.

Table 4.23. Potential loads from onsite wastewater treatment systems.

Municipality	Population	Number of Septic Tanks	Daily Load (kg/yr)	Annual Load (kg/yr)
Koosharem	276	55	0.085	31
Greenwich		18	0.028	10
Antimony	122	24	0.038	14

4.5.3 Fish Hatcheries

There are two fish hatcheries located in the Otter Creek watershed in the area below Koosharem Reservoir. Neither of these fish hatcheries discharges directly to Otter Creek. The Road Creek Burrville fish hatchery discharges to Burr Creek, which is an intermittent tributary that is intercepted by an irrigation canal prior to flowing into Otter Creek from the west. The Deans fish hatchery effluent flows directly into an irrigation canal on the east side of Otter Creek, and the flows are further split into several ditches and used for irrigation. Any flow from the two fish hatcheries that reaches Otter Creek does so in the form of agricultural return flows in the summer and tributary flows in the winter.

Effluent loadings from the two fish hatcheries were estimated using available flow and water quality sampling information from the Division of Water Quality. Monthly average flows were multiplied by monthly average TP concentrations (in many cases, only a single observation of TP was available in each month) to generate estimates of monthly effluent loadings, and the monthly estimates were summed to provide an annual estimate. Table 4.24 shows the results of these calculations.

Even though the two fish hatcheries have a combined effluent loading of approximately 375 kg/yr, it is likely that much of this loading does not reach Otter Creek Reservoir. The Road Creek Burrville hatchery is located roughly 25 miles upstream of Otter Creek Reservoir, and the Deans hatchery is located approximately 17 miles upstream. As stated above, neither of these hatcheries discharges directly to Otter Creek, and most of the effluent is likely used for irrigation during the irrigation season (April – October). During the remainder of the year, the effluent likely does reach Otter Creek and would be transported downstream. If it is assumed that none of the effluent reaches Otter Creek during the irrigation season (April – October), that 100 percent of the effluent from these two hatcheries reaches Otter Creek during the irrigation off season (November – March), and that 100 percent of the loading that does reach Otter Creek is transported downstream to Otter Creek Reservoir, the total loading to Otter Creek and subsequently to Otter Creek Reservoir from these two sources would be approximately 172 kg/yr (73 kg/yr from Deans hatchery and 99 kg/yr from the Road Creek Burrville hatchery). This is considered to be a conservative upper bound on the potential loading to Otter Creek Reservoir from the two fish hatcheries within the Otter Creek watershed.

Table 4.24. Estimated discharge loading from the Road Creek Burrville and Deans fish hatcheries.

Month	Average Flow (cfs)	Number of TP Observations	Average TP Concentration (mg/L)	Total Load (kg)
494877 – Road Creek Burrville Fish Hatchery Outfall				
January	2.48	3	0.099	18.5
February	2.89	1	0.051	10.1
March	2.59	3	0.138	27.1
April	2.48	2	0.108	19.6
May	2.14	1	0.036	5.9
June	2.65	3	0.123	24.0
July	2.70	2	0.116	23.7
August	2.66	2	0.045	9.1
September	2.94	3	0.105	22.6
October	2.45	1	0.056	10.4

Table 4.24. (cont'd) Estimated discharge loading from the Road Creek Burrville and Deans fish hatcheries.

Month	Average Flow (cfs)	Number of TP Observations	Average TP Concentration (mg/L)	Total Load (kg)
November	3.12	3	0.093	21.4
December	8.00	1	0.036	21.8
Annual Total:				**214**
494875 – Deans Fish Hatchery Outfall				
January	2.50	1	0.055	10.4
February	3.77	1	0.059	15.2
March	2.86	2	0.077	16.7
April	3.63	1	0.044	11.7
May	3.54	1	0.082	22.0
June	2.80	1	0.058	11.9
July	3.11	1	0.041	9.7
August	3.44	1	0.044	11.5
September	2.93	1	0.024	5.2
October	3.30	1	0.063	15.8
November	4.44	1	0.069	22.5
December	3.00	1	0.036	8.2
Annual Total:				**161**

4.5.4 Natural Background

Natural background loads in the inflows to the reservoir were calculated using the same flow information that was used to calculate the existing loads to Otter Creek Reservoir, but substituting in the estimated natural background concentration of 0.03 mg/L. These values were used to generate the estimates of natural background loading in Table 4.25.

The calculations above suggest that under the current hydrologic regime the natural background loading to Otter Creek Reservoir may be as high as 1,408 kg/yr, with approximately 19 percent coming from Otter Creek and 81 percent coming from the East Fork Canal.

Table 4.25. Estimated natural background loading to Otter Creek Reservoir from Otter Creek and the East Fork Canal.

Month	Average Flow (cfs)	Average TP Concentration (mg/L)	Total Load (kg)
Otter Creek			
January	13.4	0.03	30.5
February	24.4	0.03	50.1
March	35.7	0.03	81.2
April	14.6	0.03	32.2
May	5.8	0.03	13.2
June	1.4	0.03	3.0
July	0.4	0.03	0.8
August	0.2	0.03	0.4
September	0.3	0.03	0.6
October	1.3	0.03	3.1

Table 4.25. (cont'd) Estimated natural background loading to Otter Creek Reservoir from Otter Creek and the East Fork Canal.

Month	Average Flow (cfs)	Average TP Concentration (mg/L)	Total Load (kg)
November	9.0	0.03	19.8
December	13.6	0.03	31.0
Annual Total:			266
East Fork Canal			
January	41.5	0.03	94.4
February	50.1	0.03	103.0
March	48.4	0.03	110.2
April	88.0	0.03	193.9
May	112.5	0.03	256.0
June	30.3	0.03	66.7
July	8.7	0.03	19.8
August	16.0	0.03	36.5
September	19.2	0.03	42.2
October	17.7	0.03	40.2
November	37.4	0.03	82.3
December	42.6	0.03	97.0
Annual Total:			1,142
Annual Total to Reservoir			**1,408**

4.5.5 Internal Reservoir Loading

Even when Otter Creek Reservoir is full, nearly the entire reservoir is less than 11 meters (36 feet) deep. In addition, the reservoir is nearly always drawn down to a depth of 3 - 5 meters (10 - 16 feet) by mid August, which is normally the most critical period for stratification to occur. According to Merritt et al. (1996) Otter Creek Reservoir does not develop a persistent summer stratification for these reasons. Recent profile data collected by the Division of Water Quality support these conclusions. In the deepest part of Otter Creek Reservoir (station 494922 - Otter Creek Reservoir Above Dam), dissolved oxygen concentrations rarely fall below 3 mg/L, with a minimum observed concentration of 2.3 mg/L. In addition, pH values are high, with a minimum value of 7.8. It is unlikely that under these conditions significant exchange of phosphorus between the reservoir sediments and the water column takes place, and because of this, internal loading to Otter Creek Reservoir is assumed to be negligible.

4.5.6 Grazing and Diffuse Loads from Runoff

The hydrology of the Otter Creek and East Fork Sevier River watersheds is complex. Many diversions occur along the length of Otter Creek and the East Fork that carry flow and loading out of the main water courses and reduce the downstream loadings. In many cases, loadings from upland areas are intercepted by these diversion ditches and canals before they reach Otter Creek or the East Fork. When this is the case, loads from upland sources are spread with the irrigation water on agricultural land and the subsequent loads to the main water courses are reduced to the small amount that returns to the main water courses via return flows. The complicated hydrology, along with the dispersed nature of the loading from grazing animals and diffuse loads from runoff make the estimation of loadings from these sources difficult at best.

For the purposes of estimating the loading to Otter Creek Reservoir from these two sources, they have been grouped into a single category. Loads in this category originating in the East Fork watershed and entering the reservoir are accounted for in Section 4.5.7 and subsequent sections of this report. The magnitude of the loading to Otter Creek Reservoir in this category that originates in the Otter Creek watershed is estimated as the difference between the measured loads just upstream of the reservoir and the magnitude of all of the other sources after they have been evaluated. This difference is approximately 456 kg/yr, which seems like a relatively small contribution to the reservoir given the magnitude of the grazing that is occurring in the Otter Creek watershed. However, given that much of the loading from these two sources never makes it to the reservoir and the fact that Otter Creek only contributes approximately 19 percent of the total annual flow to the reservoir on a volumetric basis, this number seems much more reasonable in the context of the other loadings calculated in this section.

The following section provides an analysis of the grazing allotments within the Otter Creek watershed. This analysis is designed to provide an indication of the relative potential for loading from grazing in different areas within the watershed. This information will be particularly useful in targeting areas for management to reduce loadings. It is important to note that the loads reported in the following section represent loadings to water courses within the Otter Creek watershed. As stated above, much of the flow associated with these water courses is diverted or intercepted prior to reaching Otter Creek Reservoir and would not contribute to loading to the reservoir.

4.5.6.1 Grazing

Extensive grazing has occurred in both the Otter Creek and East Fork Sevier River watersheds, and, as such, Otter Creek Reservoir receives loading associated with grazing animals from both watersheds. This section will address the loading from grazing animals in the Otter Creek watershed, while loads associated with grazing in the East Fork watershed will be addressed below in section 4.6.6. Several factors affect the contribution of different grazing allotments to loads in Otter Creek Reservoir. These factors include:

1. The density of animals on the allotment
2. The area of the allotment
3. The season of use of the allotment
4. The proximity of grazing animals to receiving streams
5. The proximity of the allotment to the reservoir

Given the complexity associated with grazing programs that are in place in the Otter Creek and East Fork Sevier River watersheds, several simplifying assumptions had to be made so that loads from grazing animals could be estimated. The assumptions and the methods used to calculate the loads from grazing in the Otter Creek and East Fork Sevier River watersheds are those that were used to estimate the loadings from grazing to Koosharem and Lower Box Creek Reservoirs. Loads from grazing were calculated on a subwatershed basis and are tabulated below in Table 4.26. The USGS 12-digit Hydrologic Unit Boundaries were used as the subwatershed units in this analysis. Figure 4.14 shows a map of the subwatersheds within the Otter Creek drainage colored by their relative loading.

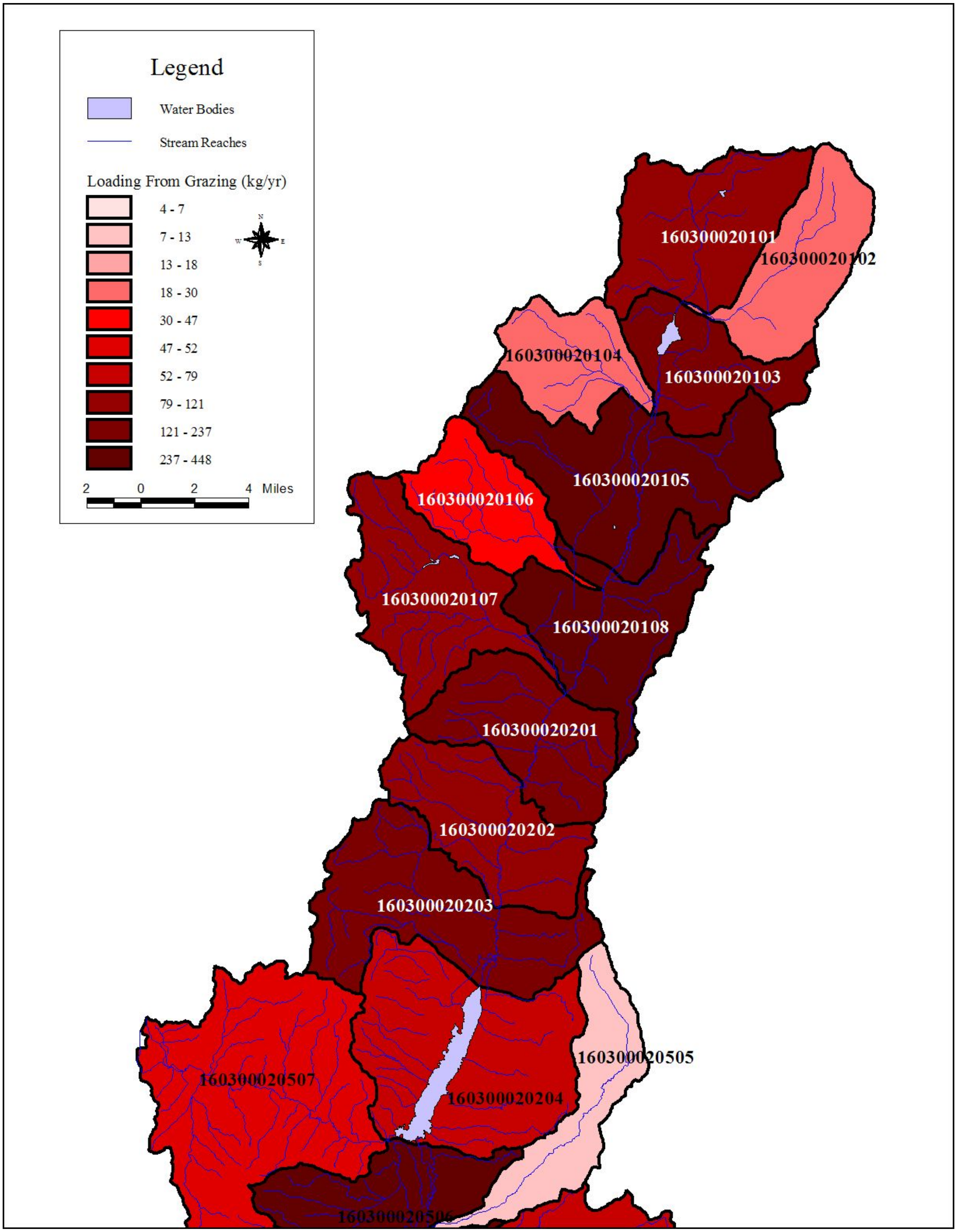

Figure 4.14. Grazing loads to water courses in the Otter Creek drainage by subwatershed.

Table 4.26. Grazing loads to water courses in the Otter Creek drainage by subwatershed.

Subwatershed	Name	Total Loading (kg/yr)
160300020101	Boobe Hole Creek	95
160300020102	Daniels Canyon-Otter Creek	30
160300020103	Koosharem Reservoir	164
160300020104	Mill Creek	25
160300020105	Koosharem Creek-Otter Creek	448
160300020106	Greenwich Creek	47
160300020107	Box Creek	98
160300020108	Hatch Canyon-Otter Creek	317
160300020201	Browns Canyon-Otter Creek	237
160300020202	Pine Canyon-Otter Creek	121
160300020203	Pole Canyon-Otter Creek	196
160300020204	Otter Creek Reservoir	63

4.5.7 Anthropogenic Loading from the East Fork Canal

As calculated above, the East Fork Canal currently contributes approximately 7,629 kg/yr of TP loading to Otter Creek Reservoir. This loading is a result of pollutant sources in the East Fork Sevier River watershed, which will be addressed individually in following sections. However, in Section 4.5.4 above, the natural background loading associated with the East Fork Canal flows was estimated to be approximately 1,142 kg/yr. This means that the anthropogenic portion of the TP loading to Otter Creek Reservoir from the East Fork Canal is approximately 6,487 kg/yr.

4.5.8 Otter Creek Reservoir Source Summary

Annual loads to Otter Creek Reservoir are summarized in Table 4.27. Natural background loads and anthropogenic loading from the East Fork canal contribute the bulk of the loading and make up approximately 16 and 75 percent of the loading to Otter Creek Reservoir, respectively. Loads from sources in the Otter Creek watershed are relatively small compared to those from the East Fork watershed due largely to the relative differences in flow.

Table 4.27. Summary of annual average Total Phosphorus loads to Otter Creek Reservoir by source.

	Annual Total Phosphorus Load (kg)	
Estimated Loads by Source	**Otter Creek**	**East Fork Sevier**
Animal Feeding Operations	140	0
Onsite Wastewater Treatment Systems[1]	19	6
Fish Hatcheries	172	0
Natural Background	266	1,142
Grazing and Diffuse Loads from Runoff	456	6,487
Total	1,053 (12%)	7,635 (88%)
Total Measured Loading to Otter Creek Reservoir	8,688	

[1] Based on distribution of existing loads from this source and total of 25 kg/yr contributed to Otter Creek Reservoir.

4.6 TOTAL PHOSPHORUS LOADS - EAST FORK SEVIER RIVER

The East Fork of the Sevier River is listed from its confluence with Antimony Creek downstream to its confluence with the Sevier River at the watershed outlet. This reach receives upstream flows from the East Fork and Antimony Creek. Downstream of the confluence of the East Fork and Antimony Creek, water is diverted into the East Fork Canal, which feeds Otter Creek Reservoir and represents a loss of flow and loading from the listed reach. Further downstream, the releases from Otter Creek Reservoir enter the East Fork via Otter Creek, representing another loading contribution. In addition, there are several small tributaries along the length of the reach that are ephemeral in nature.

The magnitude of the existing loading at the outlet of the listed reach of the East Fork of the Sevier River was calculated using existing streamflow and water quality sampling data. Monthly average TP concentrations were calculated using available water quality sampling information at station 494910 (East Fork Sevier River at U62 Crossing East of Kingston). This station is located near the end of the listed reach and will be used for compliance purposes in the future. Data used in the calculation of the monthly average concentrations were limited to the period 1990 to the present. Streamflow data from USGS gage 10189000 (East Fork of the Sevier River Near Kingston, UT), which is located just upstream of station 494910, were used to characterize the monthly average flows at this location. These streamflow data represent a very long period of record and are believed to be representative of the variety of streamflow conditions that occur within the East Fork.

Table 4.28 lists the results of the monthly load calculations for station 494910. The results show that the annual loading near the end of this reach is approximately 6,105 kg/yr, with a large portion of the loading occurring during the months of May through August.

Table 4.28. Existing loading in the East Fork Sevier River calculated using available streamflow and water quality sampling data near the end of the listed reach.

Month	Average Flow (cfs)	Number of TP Observations	Average TP Concentration (mg/L)	Total Load (kg)
January	21.8	9	0.079	131
February	26.2	9	0.089	159
March	39.4	6	0.072	216
April	76.9	11	0.077	436
May	164.3	10	0.110	1365
June	150.8	11	0.072	792
July	167.5	11	0.117	1,482
August	135.6	10	0.075	772
September	83.0	8	0.077	469
October	36.5	7	0.037	103
November	26.8	5	0.060	118
December	22.1	4	0.037	62.1
Annual Total:				**6,105**

Flow: USGS 10189000 - East Fork of the Sevier River Near Kingston, UT (1913 - 2002).
Water Quality: 494910 – East Fork Sevier River at U62 Crossing East of Kingston (1990 - 2003).

The following sections describe the loading from the major sources that have been identified to the listed reach of the East Fork of the Sevier River. Sources of TP loading to the East Fork Sevier River that have been identified and that are summarized in the following sections include:

1. Animal Feeding Operations
2. Onsite Wastewater Treatment Systems
3. Natural Background
4. Loading from Otter Creek Reservoir Releases
5. Grazing and Diffuse Loads from Runoff

4.6.1 Animal Feeding Operations

There is a single active animal feeding operation that contributes loading to the East Fork of the Sevier River. It is located on a tributary to the East Fork downstream of the East Fork Canal diversion. The estimated annual loading from this animal feeding operation as calculated using the NRCS UAFRRI model is approximately 280 kg/yr. Due to the proximity of this feeding operation to the water course that receives its loading and the relatively short stream length prior to its confluence with the East Fork of the Sevier River, it is assumed that 100 percent of this loading is delivered to the listed reach of the East Fork.

4.6.2 Onsite Wastewater Treatment Systems

There are two areas that may contribute loading to the listed segment of the East Fork from onsite wastewater treatment systems, Antimony and Kingston. The potential loading from Antimony was estimated in Section 4.5.2 above to be approximately 14 kg/yr. Table 4.27 indicates that roughly 6 kg/yr of the load from Antimony reaches the East Fork Sevier and Otter Creek Reservoir. Most of the area of Kingston lies outside of the watershed, and loadings from onsite wastewater treatment systems associated with Kingston to the listed segment of the East Fork are assumed to be insignificant. The 6 kg/yr from Antimony is transported into the East Fork, but most of it would be diverted into the East Fork Canal and into Otter Creek Reservoir.

4.6.3 Natural Background

Calculation of natural background loading in the East Fork is complicated by the fact that the hydrologic regime of the listed reach has been modified to a great degree by the presence of an off line reservoir. Much of the flow at the upper end of this reach is diverted via the East Fork Canal into Otter Creek Reservoir, where it combines with flow from Otter Creek and then is released back into the East Fork below the reservoir. Therefore, the flow in the East Fork near the end of the reach is a combination of flow from Otter Creek (after passing through the reservoir) and flow from the East Fork (only part of which flows through the reservoir).

Table 4.29 lists the average monthly flows in the East Fork at USGS gage 10189000, the average monthly releases from Otter Creek Reservoir, and the percentage of the flow in the East Fork that the reservoir releases represent. During the months of April through September, 60 – 80 percent of the flow in the East Fork at the USGS gage is released from Otter Creek Reservoir. Volumetrically, this is approximately 67 percent of the flow on an annual basis.

It makes little sense to apply the estimated natural background concentration (0.03 mg/L) to the outflow from Otter Creek Reservoir, since the outflow reflects a mixture of flow from the East Fork and Otter Creek, the quality of which is controlled by the hydrodynamics of the reservoir and the chemical and biological processes that occur within the reservoir (i.e., even if the inflows to the reservoir were at their background levels, we would not expect the reservoir outflow concentration to be the same as the inflow concentrations). Since this is the case, the natural background associated with the *outflow* from Otter Creek reservoir will not be specifically evaluated here. Rather, the total loading (including natural background) from Otter Creek Reservoir to the East Fork of the Sevier River will be calculated in the next section using existing sampling data. It should, however, be noted that in Section 4.5.4 above the natural background loadings from Otter Creek and the East Fork Canal *into* Otter Creek Reservoir are estimated, with an estimated 1,142 kg/yr of natural background loading being diverted out of the East Fork watershed via the East Fork Canal and into Otter Creek Reservoir.

Table 4.29. Average monthly flows in the East Fork at USGS gage 10189000 and Otter Creek Reservoir releases.

	Monthly Average Flow (cfs)		
Month	**USGS 10189000**	**Otter Creek Reservoir Releases**	**Percent of East Fork Flow Represented by Releases from Otter Creek Reservoir**
January	21.8	2.6	12
February	26.2	4.8	18
March	39.4	3.9	10
April	76.9	49.1	64
May	164.3	107.8	66
June	150.8	127.2	84
July	167.5	147.1	88
August	135.6	118.9	88
September	83	68.5	83
October	36.5	4.0	11
November	26.8	2.8	10
December	22.1	2.0	9

The remaining component of natural background loading in the East Fork is associated with that portion of the flow in the East Fork that bypasses the East Fork Canal Diversion or is generated downstream of the diversion. This flow can be approximated by subtracting the reservoir release flows from the measured flows near the end of the reach. Table 4.30 lists the monthly average flows at gage 10189000 (near the end of the reach), the monthly average release flows from the reservoir, and the estimated monthly average flows in the East Fork that do not pass through Otter Creek Reservoir.

Table 4.30. Estimated monthly flows contributing to the East Fork Sevier River at USGS gage 10189000.

Month	Total Flow in East Fork at USGS Gage 10189000 (cfs)	Total Releases from Otter Creek Reservoir[a] (cfs)	East Fork Flows that Do Not Pass Through Otter Creek Reservoir (cfs)
January	21.8	2.6	19.2
February	26.2	4.8	21.4
March	39.4	3.9	35.5
April	76.9	49.1	27.8
May	164.3	107.8	56.5
June	150.8	127.2	23.6
July	167.5	147.1	20.4
August	135.6	118.9	16.7

Table 4.30. (cont'd) Estimated monthly flows contributing to the East Fork Sevier River at USGS gage 10189000.

Month	Total Flow in East Fork at USGS Gage 10189000 (cfs)	Total Releases from Otter Creek Reservoir[a] (cfs)	East Fork Flows that Do Not Pass Through Otter Creek Reservoir (cfs)
September	83	68.5	14.5
October	36.5	4.0	32.5
November	26.8	2.8	24.0
December	22.1	2.0	20.1

[a]Flow data from the Utah division of Water Rights and the Sevier River Water User's Association.

Table 4.31 lists the monthly average and annual natural background loadings that would be expected in the East Fork flows bypassing the reservoir given the estimated natural background concentration of 0.03 mg/L. The calculations suggest that under the current hydrologic regime the natural background loading from this portion of the flow near the end of the listed reach of the East Fork may be as high as 699 kg/yr, which represents approximately 11 percent of the total measured loading at station 490910.

4.6.4 Loading from Otter Creek Reservoir Releases

The releases from Otter Creek Reservoir serve as a source of TP loading to the East Fork of the Sevier River. The magnitude of these loadings was evaluated on a monthly basis using existing streamflow and water quality sampling data. Monthly average streamflow values were estimated using available data from the Division of Water Rights and the Sevier River Water User's Association, and monthly average TP concentrations were estimated using data at station 494921 (Otter Creek Below Otter Creek Reservoir). Table 4.32 lists the monthly loads calculated using these data. The resulting annual loading estimate from Otter Creek Reservoir is approximately 3,391 kg/yr, which is approximately 56 percent of the measured load near the end of the listed reach. This loading estimate is similar to that of Merritt et al. (1996), who calculated an outflow loading of 3,499 kg/yr. As stated above, it is important to note that some of this loading could be considered natural background (i.e., the natural background loading carried into the reservoir from Otter Creek and the East Fork Canal).

Table 4.31. Estimated natural background loading in the East Fork Sevier River from flows that bypass Otter Creek Reservoir.

Month	Average Flow (cfs)	Average TP Concentration (mg/L)	Total Load (kg)
January	19.2	0.03	43.7
February	21.4	0.03	44.0
March	35.5	0.03	80.8
April	27.8	0.03	61.2
May	56.5	0.03	128.6
June	23.6	0.03	52.0
July	20.4	0.03	46.4
August	16.7	0.03	38.0
September	14.5	0.03	31.9
October	32.5	0.03	73.9
November	24	0.03	52.8
December	20.1	0.03	45.7
Annual Total:			**699**

Table 4.32. Existing monthly Total Phosphorus (TP) loading in Otter Creek below Otter Creek Reservoir.

Month	Average Flow (cfs)[1]	Number of TP Observations	Average TP Concentration (mg/L)[2]	Total Load (kg)
January	2.6	1	0.09	18
February	4.8	1	0.08	28
March	3.9	1	0.08	24
April	49.1	4	0.05	178
May	107.8	4	0.07	570
June	127.2	6	0.07	630
July	147.1	3	0.09	986
August	118.9	7	0.08	679
September	68.5	2	0.04	209
October	4.0	3	0.07	21
November	2.8	1	0.15	31
December	2.0	0	0.12[3]	18.2
Annual Total:				**3,391**

[1] UWR-OCRO - Otter Creek Reservoir Outlet.
[2] 494921 - Otter Creek Below Otter Creek Reservoir.
[3]No concentration data are available in the month of December, so the average of November and January was used.

4.6.5 Loading Diverted into Otter Creek Reservoir

In Section 4.5 above, the total loading to Otter Creek Reservoir from the East Fork Canal was calculated using existing water quality and flow measurements. The total load to Otter Creek Reservoir from the East Fork Canal was estimated to be approximately 7,629 kg/yr, with 1,142 kg/yr of that being from natural background and 6,487 kg/yr being from anthropogenic sources. This loading represents a loss from the East Fork Sevier River.

The anthropogenic loading in the East Fork canal is from a combination of sources. The East Fork Canal receives most of its flow from the East Fork Canal Diversion on the East Fork; however, there is at least one diversion from the East Fork above the East Fork Canal Diversion (Coyote East Fork Canal) and at least one diversion from Antimony Creek (Antimony Bench Ditch) that likely contribute some return flows to the East Fork Canal before it flows into Otter Creek Reservoir. Anthropogenic loading in the East Fork Canal flows is expected to be primarily due to grazing and diffuse loads from runoff as the other sources within the watershed are either located below the diversion or are small enough that they are insignificant.

4.6.6 Grazing and Diffuse Loads from Runoff

As stated above, the hydrology of the Otter Creek and East Fork Sevier River watersheds is complex. The complicated hydrology, along with the dispersed nature of the loading from grazing animals and diffuse loads from runoff make the estimation of loadings from these sources difficult at best. Again, for the purposes of estimating the loading to the East Fork Sevier River watershed from these two sources, they have been grouped. The total loading from these two sources in the East Fork Sevier River watershed has two components: 1) the upstream load of which the majority is diverted into Otter Creek Reservoir via the East Fork Canal, and 2) loading that bypasses the diversion or is generated below the diversion.

The first component was estimated in the previous section. Since the total loading to Otter Creek Reservoir is approximately 7,629 kg/yr, approximately 1,142 of which is attributable to natural background, it is estimated that 6,487 kg/yr of loading from grazing and diffuse runoff is diverted into Otter Creek Reservoir via the East Fork Canal.

The second component of the loading from grazing and diffuse loads from runoff was estimated by subtracting all of the other sources from the total measured load at the end of the listed reach. It is estimated that approximately 1,721 kg/yr of loading from grazing and diffuse loads from runoff either bypasses the diversion or is generated below the diversion. This is the portion of the loading that would be measured directly in the flow at the end of reach monitoring location.

The following section provides an analysis of the grazing allotments within the East Fork Sevier River watershed. This analysis is designed to provide an indication of the relative potential for loading from grazing in different areas within the watershed. This information will be particularly useful in targeting areas for management to reduce loadings. It is important to note that the loads reported in the following section represent loadings to water courses within the East Fork Sevier River watershed. As stated above, much of the flow associated with these water courses is diverted or intercepted and would not contribute to loading to Otter Creek Reservoir or the downstream reaches of the East Fork.

4.6.6.1 Grazing

The same methods used to estimate potential loads from grazing in the Otter Creek watershed were used to evaluate grazing allotments by subwatersheds within the East Fork. The results are tabulated below in Table 4.33 and are shown visually in Figure 4.15. Again, it is important to remember that the loads in the table are estimates of the loading to the water courses within each subwatershed and do not represent the total loading to downstream reaches of the East Fork or Otter Creek Reservoir.

Table 4.33. Grazing loads to water courses in the East Fork Sevier River drainage by subwatershed.

Subwatershed	Name	Total Loading (kg/yr)
160300020301	East Fork Sevier River Headwaters	18
160300020302	Tropic Reservoir	13
160300020303	Mud Spring Creek-East Fork Sevier River	69
160300020304	Showalter Creek-East Fork Sevier River	72
160300020305	Hunt Creek	47
160300020306	Cameron Wash-East Fork Sevier River	40
160300020401	Clay Creek	7
160300020402	South Creek	25
160300020403	Sweetwater Creek	12
160300020404	Prospect Creek	79
160300020405	Ranch Creek-Sevier River	52
160300020406	Cottonwood Creek	6
160300020407	Cow Creek-Sevier River	4

Table 4.33. (cont'd) Grazing loads to water courses in the East Fork Sevier River drainage by subwatershed.

Subwatershed	Name	Total Loading (kg/yr)
160300020408	Deer Creek	13
160300020409	North Creek	24
160300020410	Deep Creek	17
160300020411	Forest Creek	16
160300020412	Pacer Lake	214
160300020501	Coyote Hollow-Antimony Creek	71
160300020502	Lost Spring Draw	27
160300020503	Antimony Creek	66
160300020505	Dry Wash	12
160300020506	Antimony-East Fork Sevier River	388
160300020507	East Fork Sevier River Outlet	51

4.6.7 East Fork Sevier River Source Summary

Table 4.34 summarizes the loadings to the East Fork of the Sevier River by source category. In this table positive loadings indicate those loadings that would be measured near the end of the listed reach. The negative loadings represent phosphorus that is loaded to the listed reach but that is lost from the system by diversion (via the East Fork Canal). These loads would not be measured at the end of the listed reach. The largest portion of the measured loading (approximately 56 percent) at the end of the reach is associated with releases from Otter Creek Reservoir. Loads from onsite wastewater treatment systems and animal feeding operations are relatively minor, and approximately 28 percent of the measured loading is likely attributable to natural background in the East Fork flows that bypass Otter Creek Reservoir. Grazing and diffuse loads represent a large loading to the upstream end of the reach, but much of this loading is diverted into Otter Creek Reservoir via the East Fork Canal (approximately 6,487 ky/yr). In addition, it is estimated that approximately 1,142 kg/yr of the total loading diverted to Otter Creek Reservoir is due to natural background, leaving approximately 1,721 kg/yr from grazing and diffuse loads from runoff that either bypasses the diversion or is generated below the diversion and would be measured downstream.

Table 4.34. Summary of annual average Total Phosphorus loads to the East Fork of the Sevier River by source.

Estimated Loads by Source	Annual Total Phosphorus Load (kg)
Animal Feeding Operations	280
Onsite Wastewater Treatment Systems	6
Grazing and Diffuse Loads from Runoff	
Diverted into East Fork Canal	-6,487
Bypass or generated below the East Fork Diversion	1,721
Loading from Otter Creek Reservoir Releases	3,391
Natural Background	
Diverted into the East Fork Canal	-1,142
Bypass or generated below the East Fork Diversion	699
Total Loading Diverted into Otter Creek Reservoir	-7,629
Total Measured Loading in the East Fork of the Sevier River	6,097

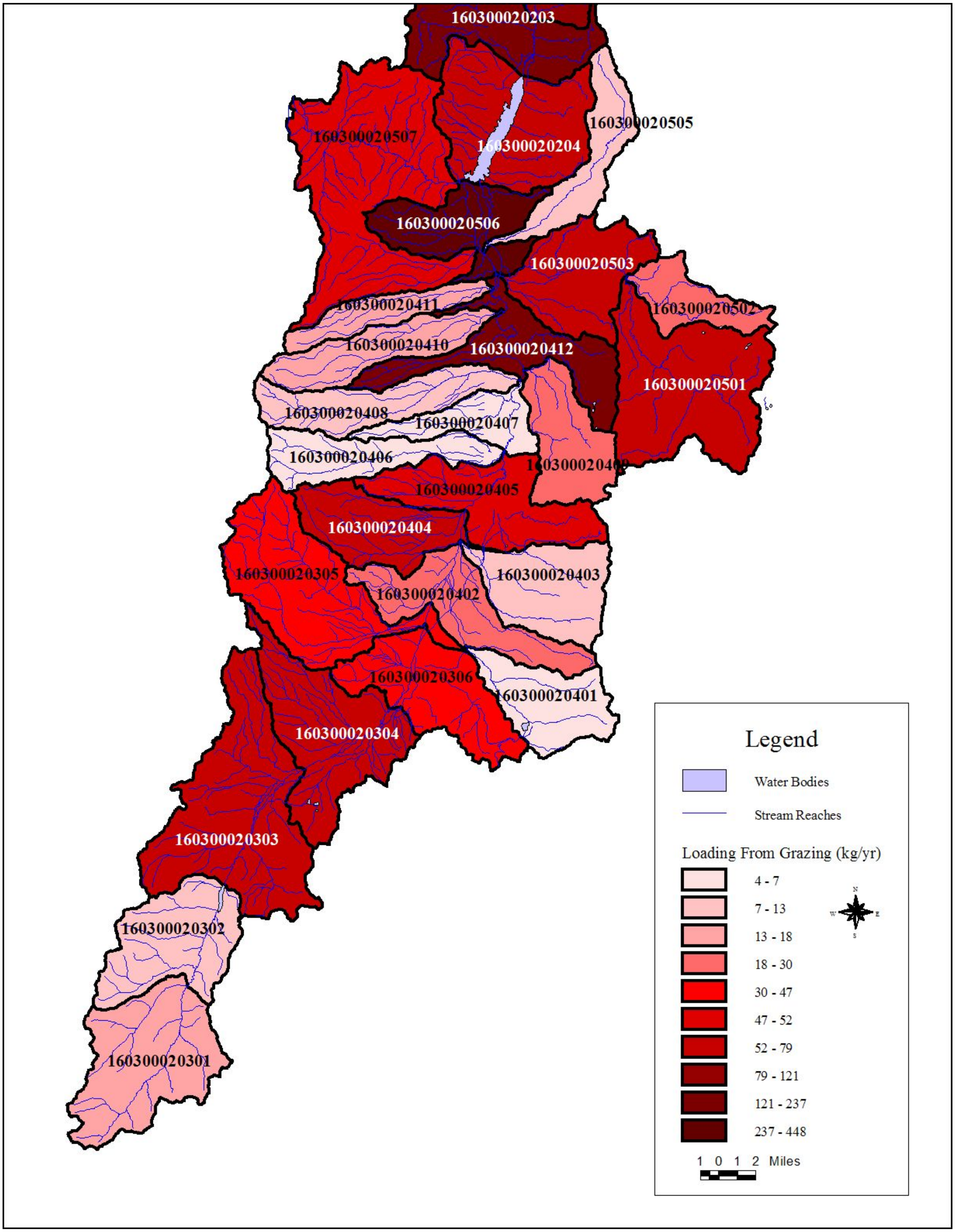

Figure 4.15. Grazing loads to water courses in the East Fork Sevier River drainage by watershed.

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CHAPTER 5: TMDL ANALYSIS

5.1 WATER QUALITY TARGETS

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

5.1.1 Reservoirs

All three impaired reservoirs in the watershed are designated as Class 3A - protected for cold water species of game fish and other cold water aquatic life. Existing numeric water quality criteria for the State of Utah specify that for lakes and reservoirs designated as Class 3A waters the TP concentration must be below 0.025 mg/L. The criterion of 0.025 mg/L will be used as the primary endpoint for the TMDLs for the impaired reservoirs. In addition, the water quality criteria for Class 3A lakes and reservoirs require that DO concentrations not fall below 4.0 mg/L in 50 percent of the water column depth for adult aquatic life or 8 mg/L in 50 percent of the water column depth for early life stage aquatic life. It is believed that the attainment of the 0.025 mg/L TP criterion will result in the DO criteria being met, and so it will serve as the primary water quality target for the reservoir TMDLs. Existing and potential future loadings to the impaired reservoirs in the watershed will be evaluated in terms of the requirement that TP concentrations be maintained below 0.025 mg/L.

In addition to the TP concentration endpoints, the following endpoints were selected to evaluate attainment of water quality standards in the impaired reservoirs:

1. A 0.05 mg/l TP inflow concentration from all tributary streams.
2. A shift away from blue-green algal dominance.
3. TSI values for TP, CHLa, and SD in the impaired reservoirs not to exceed 50.
4. Dissolved oxygen concentration of 4.0 mg/L or greater for at least 50 percent of the water column.

5.1.2 East Fork Sevier River

The East Fork of the Sevier River is also classified as Class 3A. For streams and rivers classified as Class 3A waters, State of Utah indicator criteria state that TP concentrations must be below 0.05 mg/L and DO concentrations must be above 4.0 mg/L for adult aquatic life and 8.0 mg/L for early stage aquatic life. A TP concentration of 0.05 mg/L will be used as the endpoint for the TMDL for the East Fork Sevier River. The linkage between DO concentrations and TP concentrations have been well documented through scientific research. It is anticipated that as the TP endpoint of 0.05 mg/L is met the DO criteria will also be met. Existing and potential future TP loads to the East Fork of the Sevier River will be evaluated in terms of the requirement that TP concentrations in the East Fork be maintained below 0.05 mg/L.

5.2 PERMISSIBLE TOTAL PHOSPHORUS LOADINGS

In order to determine the load reductions required to meet the TMDL endpoints discussed above, the permissible loadings to each of the impaired water bodies must be estimated. The following sections detail the calculation of the permissible loadings to each of the impaired water bodies in the study area watershed.

5.2.1 Koosharem Reservoir

Assuming a TP endpoint concentration of 0.025 mg/L for Koosharem Reservoir, the magnitude of the permissible loadings to the reservoir were calculated so that reductions to existing loadings could be specified in efforts to meet the TP endpoint. Permissible loadings were calculated using a TP budget model for Koosharem Reservoir. This mass balance model, suggested by Chapra (1997) and first formulated by Vollenweider (1976), simulates the TP concentration in the reservoir by accounting for TP in the reservoir inflow, TP in the reservoir outflow, and the loss of TP due to settling and is given by the following equation:

$$V\frac{dP}{dt} = W - QP - vA_s P \tag{5.1}$$

Where: V = Reservoir volume (m^3)
P = Total phosphorus concentration (kg/m^3)
t = time (day)
W = Total phosphorus inflow loading rate (kg/day)
Q = Outflow (m^3/day)
v = Total phosphorus settling velocity (m/day)
A_s = Reservoir surface area (m^2)

The maximum permissible loadings to the reservoir were calculated by determining the magnitude of loadings that will maintain a constant, maximum concentration of 0.025 mg/L in the reservoir (i.e., steady state with respect to concentration). To accomplish this, the TP in the reservoir (P) was held at 0.025 mg/L and was not allowed to change with time. Therefore, dP/dt = 0 and Equation 5.1 reduces to:

$$0 = W - QP - vA_s P \tag{5.2}$$

Now, Equation 5.2 can be rearranged to solve for the loading rate (W):

$$W = P\left(Q + vA_s\right) \tag{5.3}$$

The TP concentration can be held constant, but the nature of Koosharem Reservoir is that the inflows, outflows, volume, and surface area fluctuate throughout the year as the reservoir is drawn down by releases to Otter Creek. Because of this, it is important to account for permissible loadings on a daily basis. The permissible annual loading to the reservoir, then, is the sum of the daily loadings for the entire year. Equation 5.4 shows how the total annual permissible loading is calculated.

$$W_{Ann} = P\sum_{i=1}^{365}\left(Q_i + vA_{s,i}\right) \tag{5.4}$$

Where: W_{Ann} = Permissible annual loading rate (kg/yr)
P = 0.000025 kg/m^3 (0.025 mg/L)
Q_i = Outflow rate on day i (m^3/day)
$A_{s,i}$ = Reservoir surface area on day i (m^2)

It should be noted that the simple phosphorus budget model used here is subject to the following assumptions:

1. The reservoir is well mixed.

   This is likely true of Koosharem Reservoir for most of the year. The reservoir is relatively shallow, and the rates of drawdown and filling in the reservoir are relatively quick due to the small size of the reservoir. The applicability of this assumption is based on anectdotal information provided by the Koosharem Reservoir Irrigation Company. Given these conditions, the reservoir has little chance to develop a stable stratification that would lead to incomplete mixing. In addition, the reservoir is small enough and shallow enough that significant wind storms would cause mixing to occur.

2. The interaction of the water column with the sediments is neglected.

   Although potentially significant, little information is available about potential internal loading to the reservoir from phosphorus released from the bottom sediments. Flux of phosphorus from sediments only occurs during times of very low dissolved oxygen concentration (less than 1 mg/L) and is affected by pH and the character of the sediments. Although lower dissolved oxygen concentrations have been observed at depth in Koosharem Reservoir, all observations have been above 3.0 mg/L, and pH is typically above 7. Based on available data and information, conditions resulting in phosphorus release from the sediments have not been observed, and if present would be short lived when they do occur due to the lack of a stable stratification that lasts for long periods of time. Currently available data, however, are inadequate to determine the duration and extent of low dissolved oxygen concentrations at depth in the reservoir. Given the above discussion, the magnitude of loading from phosphorus releases from the sediments is likely much smaller than the terms that are accounted for in the budget model and will be neglected.

In order to evaluate Equation 5.4, the reservoir outflow rate and surface area must be known on a daily basis. A simple water budget model for the reservoir was developed for this and other purposes. Equation 5.5 (Chapra 1997) shows the water balance model for the reservoir:

$$\frac{dV}{dt} = Q_{in} - Q_{out} + G + pA_s - EA_s \tag{5.5}$$

Where: Q_{in} = Inflow (m^3/day)
Q_{out} = Outflow (m^3/day)
G = Groundwater flow (m^3/day)
p = Precipitation (m/day)

E = Evaporation (m/day)

Equation 5.6 shows how equation 5.5 was evaluated on a daily basis to solve for the reservoir volume.

$$V_t = V_{t-1} + V_{in,t} - V_{out,t} + V_{G,t} + p_t A_{s,t-1} - E_t A_{s,t-1} \quad (5.6)$$

Where:
V_t = Reservoir volume at the end of time interval t (m^3)
V_{t-1} = Reservoir volume at the end of time interval t-1 (m^3)
$V_{in,t}$ = Inflow volume in time interval t (m^3)
$V_{out,t}$ = Outflow volume in time interval t (m^3)
$V_{G,t}$ = Groundwater flow in time interval t (m^3)
p_t = Precipitation in time interval t (m)
$A_{s,t-1}$ = Reservoir surface area at the end of time interval t-1 (m^2)
E_t = Evaporation in time interval t (m)

The reservoir surface area is solved for as a function of reservoir elevation (*H*) and volume (*V*) according to the following regression equations that were derived from an area/elevation/capacity table reported by the State of Utah Division of Water Rights (Utah Division of Water Rights 2003).

$$H_t = (2E-11)\cdot V_t^3 - (7E-7)\cdot V_t^2 + 0.0072\cdot V_t \quad (5.7)$$

$$A_{s,t} = -0.0047\cdot H_t^4 + 0.3516\cdot H_t^3 - 7.5289\cdot H_t^2 + 66.214\cdot H_t \quad (5.8)$$

Few direct measurements of inflow to Koosharem Reservoir are available, and only limited data are available to characterize releases from the reservoir. Appendix A provides details on how inflows to the reservoir were estimated and on how the available release data were used to estimate outflows. Net groundwater flows (*G*) are assumed to be zero (groundwater inflow = groundwater outflow). Precipitation (*p*) and evaporation (*E*) were estimated based on data downloaded from the Utah Climate Center for a weather station at Koosharem, located to the south and west of Koosharem Reservoir.

Daily input time series of inflow, outflow, precipitation, and evaporation were constructed for the time period between 1965 and 1981 using available data, and the reservoir water budget model was run on a daily time step to produce a daily output time series of reservoir volume and surface area. The results of the water budget model (reservoir outflow and surface area) were then used on a daily basis to evaluate Equation 5.4. The result of the evaluation of Equation 5.4 is a daily time series of permissible loadings to Koosharem Reservoir based on a desired endpoint concentration of 0.025 mg/L TP in the reservoir.

According to Chapra (1997), the TP settling velocity (*v*) typically ranges from 5 to 20 m/yr (0.0137 to 0.0548 m/day). This settling velocity is related to the uptake of phosphorus by algae and their subsequent growth, death, and settling. The settling velocity is also related to the settling velocity of phosphorus attached to particulate matter. In general, the higher the value of the settling rate, the more TP is lost via settling and the higher the permissible loading to the reservoir. If the endpoint of 0.025 mg/l is used, the permissible loading to Koosharem Reservoir is approximately 629 kg/yr.

Table 5.1 lists the permissible monthly average loadings to the reservoir calculated using the different values for the settling velocity. Monthly loading values were generated by summing the daily loading values to get total monthly loadings for each month, and then averaging each month across the 1965 - 1981 period. The midpoint of the range suggested by Chapra (12.5 m/yr or 0.0342 m/day) was used to calculate permissible loadings to Koosharem Reservoir.

Table 5.1. Monthly average permissible loadings to Koosharem Reservoir (1965 – 1981).

	Permissible Load (kg)			
Month	***v* = 5 m/yr**	***v* = 10 m/yr**	***v* = 12.5 m/yr**	***v* = 20 m/yr**
January	34	44	**50**	65
February	24	34	**39**	53
March	41	51	**57**	73
April	41	51	**56**	72
May	70	81	**86**	102
June	83	91	**95**	108
July	47	54	**58**	69
August	38	44	**47**	56
September	27	33	**35**	44
October	24	31	**34**	43
November	17	25	**29**	42
December	29	38	**43**	58
Total:	**475**	**578**	**629**	**784**

5.2.2 Lower Box Creek Reservoir

The same model used to calculate permissible loadings to Koosharem Reservoir was used to estimate the permissible loadings to Lower Box Creek Reservoir. Appendix A describes the construction of the input datasets that were required to model permissible loadings in Lower Box Creek Reservoir. Table 5.2 lists the permissible monthly average loadings to the reservoir based on the 0.025 mg/L TP endpoint calculated using the different values for the settling velocity. Monthly values were generated by summing the daily values within each month to get total monthly loadings.

Table 5.2. Monthly average permissible loadings to Lower Box Creek Reservoir.

	Permissible Load (kg)			
Month	***v* = 5 m/yr**	***v* = 10 m/yr**	***v* = 12.5 m/yr**	***v* = 20 m/yr**
January	2.3	2.9	**3.2**	4.0
February	2.1	2.7	**3.0**	4.0
March	2.5	3.3	**3.7**	4.8
April	2.3	3.1	**3.5**	4.8
May	11.4	12.2	**12.6**	13.9
June	21.8	22.4	**22.7**	23.6
July	16.7	17.2	**17.4**	18.1
August	13.4	13.9	**14.1**	14.8
September	6.2	6.7	**6.9**	7.5
October	2.5	2.9	**3.2**	3.8
November	2.4	2.8	**3.1**	3.7
December	2.4	2.9	**3.2**	4.0
Total:	**85.9**	**92.9**	**96.4**	**107.0**

As stated above, the midpoint of the range of settling velocities suggested by Chapra (1997) is recommended for use in this area. If the endpoint of 0.025 mg/L is used, the permissible loading to Lower Box Creek Reservoir is approximately 96.4 kg/yr.

5.2.3 Otter Creek Reservoir

Three different endpoints were considered for calculating the required percent reduction in loading to Otter Creek Reservoir. They are as follows:

1. An expected 90th percentile mean water column concentration that is below the 0.025 mg/L reservoir water quality criterion value.

2. Expected 90th percentile inflow concentrations that are below the 0.05 mg/L stream water quality criterion value.

3. Substituting 0.05 mg/L for all reservoir inflow total phosphorus concentrations above 0.05 mg/L and then recalculating monthly average concentrations, multiplying them by monthly average flows to generate estimates of monthly average permissible loads, and then summing the monthly average permissible loads to get an estimate of the average annual permissible load to the reservoir.

The statistical rollback procedure proposed by Ott (1995) describes a way to use the statistical characteristics of the existing set of water quality measurements to estimate the distribution of future concentrations after management practices have been implemented to control pollutant loadings. This method was used to estimate the required percent reductions in loading to Otter Creek Reservoir from its tributaries and the associated permissible loadings for endpoints 1 and 2. This method relies on basic dispersion and dilution assumptions and their effect on the distribution of TP sampling results at monitoring locations. Appendix A - Modeling provides a more detailed explanation of the statistical theory of rollback.

For the first endpoint, the mean water column concentration was selected as representative of the entire water column at each sampling location. Due to the shallow nature of Otter Creek Reservoir and the fact that the reservoir does not support a prolonged, stable stratification, this is a reasonable assumption. The 90th percentile represents the level above which 10 percent of the observations lie. If the 90th percentile of the mean water column concentrations within the reservoir is relocated to the 0.025 mg/L level using the statistical rollback procedure, the resulting shifted distribution will be such that 90 percent of the future (post management) mean water column concentrations will be below the 0.025 mg/L criterion value and 10 percent will be above. A similar statement is true for endpoint 2, except that the metric by which compliance is judged is the in stream concentration and the criterion value is the one for streams (0.05 mg/L).

Table 5.3 lists the 90th percentile mean water column TP concentrations at each of the sampling locations within the reservoir. The 90th percentile values are similar at all of the locations within the reservoir, and all are well above the criterion. The last column in Table 5.3 lists the percent reduction in the 90th percentile values required to relocate them to the 0.025 mg/L level. Due to the similarity of the 90th percentile concentration values at each location and the associated percent reductions, no efforts were made to volume weight these values. Rather, a simple arithmetic average of the percent reduction values was calculated. The resulting average percent reduction in TP loading required to reduce the 90th percentile mean water column concentrations below the 0.025 mg/L criterion (alternative endpoint one above) is approximately 82 percent.

Table 5.3. 90th Percentile mean water column Total Phosphorus concentrations by location and percent reductions required to reduce the 90th percentile values to 0.025 mg/L.

Sampling Station	Station Name	90th Percentile Mean Water Column Total Phosphorus Concentration (mg/L)	Required % Reduction
494922	Otter Creek Reservoir Above Dam 01	0.13	80.8
494930	Otter Creek Reservoir 04 Near South Inlet	0.12	79.2
494929	Otter Creek Reservoir 03 1/3 Way Up Lake	0.13	80.8
494923	Otter Creek Reservoir Midway Up Lake 02	0.14	82.1
494931	Otter Creek Reservoir 05 Near Upper End	0.18	86.1
Average:			81.8

For alternative endpoint 2, a rollback analysis was conducted to determine the percent reduction in loading in Otter Creek and the East Fork Canal required to reduce the 90th percentile of the sampling distributions at the sampling locations representing these inflows to the reservoir to the 0.05 mg/L in stream water quality criterion. For alternative endpoint 3, the permissible loading to the reservoir was estimated by substituting 0.05 mg/L for all total phosphorus concentrations in the reservoir inflows (Otter Creek and East Fork Canal) that are above the 0.05 mg/L stream criterion value and then recalculating average monthly and average annual loads to the reservoir using the modified sampling data. It is assumed that the load reductions associated with alternative endpoint 3 represent a lower bound on the load reductions needed to assure that water quality standards are met in Otter Creek Reservoir.

Table 5.4 summarizes the percent reduction in the total loading to Otter Creek Reservoir required by each of the alternative endpoints listed above and the magnitude of the permissible loading under each alternative. In addition, Table 5.4 lists the expected percentage of the time that the post management water quality will be in compliance with the water quality criterion for each of the alternative endpoints. As calculated in Section 4.5 above, the total loading to Otter Creek Reservoir from its tributaries is approximately 8,688 kg/yr (1,059 kg/yr from Otter Creek and 7,629 kg/yr from the East Fork Canal).

Endpoint 3 was selected for the Otter TMDL based on the nature of pollutant loading to the reservoir and the uncertainty that is associated with inflowing loads and in-lake TP concentrations. In addition, linkage between the TP criterion of 0.25 mg/l and dissolved oxygen in the reservoir is not well established. Otter Creek exhibits low dissolved oxygen in portions of its profile, however, the reservoir is not currently listed for low dissolved oxygen. If the desired in-lake water quality concentrations have not been met once endpoint 3 is achieved, it is recommended that endpoint 1 be used.

Table 5.4. Average percent reduction and permissible loading to Otter Creek Reservoir by alternative endpoint.

Alternative Endpoint	Endpoint Description	Required Reduction in Loading % / (kg)	Permissible Loading (kg/yr)	Estimated Compliance Percentage
1	Expected 90th percentile mean water column concentration in reservoir below the 0.025 mg/L reservoir criterion	82 / (7,124)	Total to Reservoir = 1,564	90
2	Expected 90th percentile inflow concentrations below the 0.05 mg/L stream criterion	69 / (731) (Otter Creek 494920) 89 / (6790) (East Fork Canal 494924)	Otter Creek = 328 East Fork Canal = 839 Total to Reservoir = 1,167	[a]
3	0.05 mg/L substituted for all total phosphorus observations above 0.05 mg/L in tributary flows	59 / (622) (Otter Creek 494920) 78 / (5922) (East Fork Canal 494924)	Otter Creek = 437 East Fork Canal = 1,707 Total to Reservoir = 2,144	[a]

[a]As these calculations are based on in stream concentrations and the stream criterion, it is unknown what the compliance percentage would be for concentrations in the reservoir.

5.2.4 East Fork Sevier River

The permissible loading to the listed reach of the East Fork Sevier River was estimated using the existing sampling data near the end of the listed reach (USGS gage 10189000 and DWQ station 494910). This end-of-reach approach is conservative because it does not allow for potential decay or loss of TP that may occur along the length of the listed reach. Essentially, each of the tributary flows to the listed reach of the East Fork must have concentrations less than the 0.05 mg/L endpoint so that the endpoint is not exceeded anywhere along the length of the listed reach. Two endpoints were explored for estimating the magnitude of the permissible loading in the East Fork Sevier River. It is:

- Using the statistical rollback procedure to estimate the percent reduction in loading required to reduce the 90th percentile of the stream concentrations below the 0.05 mg/L stream criterion value.
- Substituting 0.05 mg/L for all total phosphorus concentrations above 0.05 mg/L at station 494910 and then recalculating monthly average concentrations, multiplying them by monthly average flows to generate estimates of monthly average permissible loads, and then summing the monthly average permissible loads to get an estimate of the average annual permissible load.

If the 90th percentile of the sampling distribution is shifted down to the criterion using the rollback procedure, the East Fork would be in compliance 90 percent of the time (i.e., nine out of ten samples would be below the 0.05 mg/L criterion) and, according to the rollback procedure, this corresponds to a 69 percent reduction in loading to the listed reach. For comparison, if the second endpoint is considered, a 45 percent reduction in loading is needed in the listed reach, although, using this method the estimated compliance percentage cannot be determined. Table

5.5 details the reductions in loading required in the East Fork of the Sevier River. In addition, Table 5.5 lists the expected percentage of the time that the post management water quality will be in compliance with the water quality criterion for each of the alternative endpoints.

Table 5.5. Average percent reduction and permissible loading in the East Fork of the Sevier River by alternative endpoint.

Alternative Endpoint	Endpoint Description	Required Reduction in Loading % / (kg)	Permissible Loading (kg/yr)	Estimated Compliance Percentage
1	Expected 90th percentile concentration below the 0.05 mg/L criterion	69 / (4,212)	1,893	90
2	0.05 mg/L substituted for all total phosphorus observations above 0.05 mg/L	45 / (2,752)	3,353	[1]

[1] It is unknown what the compliance percentage would be for this alternative endpoint.

5.3 SEASONALITY

The Clean Water Act requires that TMDLs include seasonality. Seasonality is addressed in this TMDL through the calculation of actual and permissible loadings to the impaired water bodies on an annual and monthly basis, where possible. The calculations were completed using data representing time periods extending as long as possible in efforts to generate results that reflect seasonal changes in weather, streamflow, and other conditions that may change from year to year. However, the annual loads associated with the impaired water bodies will be the primary values used in determining compliance.

5.4 MARGIN OF SAFETY

The Clean Water Act Also requires that TMDLs include a margin of safety. Generally, this margin of safety is incorporated into the TMDL via the use of conservative assumptions or is specified explicitly by reserving a particular amount of the permissible loading as a margin of safety. In general, this TMDL uses conservative assumptions to address the margin of safety. Conservative assumptions have been made in some of the loading calculations and are discussed, where applicable, in the text of this report. It should be noted that some degree of uncertainty is associated with using the State of Utah's TP pollution indicator values of 0.05 mg/L for streams and 0.025 mg/L for the reservoirs as the endpoints for this TMDL analysis. It is believed that these values are conservative, and future monitoring of the water bodies for which TMDLs are specified in this report may show that the TP endpoint values could be higher than the pollution indicator values. The TMDLs specified in this report will be evaluated in the future as BMPs are implemented and additional water quality data is acquired. Follow-up monitoring will be executed to ensure that water quality is improving and water quality standards are being met upon implementation of this TMDL.

5.5 FUTURE GROWTH

It is estimated at this time that minimal change will occur in Koosharem and Lower Box Creek Reservoirs. Information obtained from population census as well as anecdotal information from local agencies and stakeholders indicates that rural populations and land use practices in the TMDL study area will remain fairly constant. However, recreational use of Dixie NFS lands in the Upper East Fork Sevier watershed will likely continue to increase, as well as developed recreation facilities adjacent to Otter Creek Reservoir.

5.6 TMDL LOAD ALLOCATIONS

5.6.1 Koosharem Reservoir

The loading summary for Koosharem Reservoir is shown below in Table 5.6. The necessary reduction of TP loading to Koosharem Reservoir is approximately 48 percent. Table 5.7 shows the allocation of the remaining permissible loadings to the different major source categories identified above and the required reductions in loading.

Table 5.6. Loading Summary for Koosharem Reservoir.

Loading Category	Total Phosphorus Loading (kg/yr)
Existing Loads	1,211
Permissible Loads (Loading Capacity)	629
Reserve for Future Growth	0
Load Allocation	629
Necessary Reduction	582 (48 %)

Table 5.7. Allocation of permissible loadings to Koosharem Reservoir by major source category.

Loading Source	Existing Total Phosphorus Loading (kg/yr)	Required Load Reduction (kg/yr)	Load Allocation (kg/yr)
Grazing – Loads to Stream	137	62 (45.3%)	75
Grazing – Loads to Reservoir	168	168 (100%)	0
Natural Background	394	0 (0 %)	394
Diffuse Loads from Runoff	512	352 (68.8 %)	160
Total	1,043	582 (48 %)	629

5.6.2 Lower Box Creek Reservoir

The loading summary for Lower Box Creek Reservoir is shown in Table 5.8. The overall reduction of TP loading to Lower Box Creek Reservoir necessary to meet the TMDL endpoint is approximately 80 percent. Table 5.9 shows the allocation of the permissible loadings to the different major source categories identified above and the required reductions in loading. Since the natural background loading is being used as the permissible loading for Lower Box Creek

Reservoir, all other loadings within the watershed must be eliminated to meet the endpoint of the TMDL.

Table 5.8. Loading Summary for Lower Box Creek Reservoir.

Loading Category	Total Phosphorus Loading (kg/yr)
Existing Loads	489.3[1]
Permissible Loads (Loading Capacity)	96.4
Reserve for Future Growth	0
Load Allocation	96.4
Necessary Reduction	392.9 (80.3 %)

1 Total loading within watershed (does not account for settling losses in upper reservoir).

Table 5.9. Allocation of permissible loadings to Lower Box Creek Reservoir by major source category.

Loading Source	Existing Total Phosphorus Loading (kg/yr)	Required Load Reduction (kg/yr)	Load Allocation (kg/yr)
Grazing	76.3[1]	76.3 (100%)	0
Natural Background	95[1]	0 (0 %)	95
Diffuse Loads from Runoff	318[1]	316.6 (99.6 %)	1.4
Total	489[1]	392.9	96.4

1 Total loading within watershed (does not account for settling losses in upper reservoir).

5.6.3 Otter Creek Reservoir

The loading summary for Otter Creek Reservoir is shown in Table 5.10. The necessary reduction of TP loading to Otter Creek Reservoir ranges from approximately 82 percent for endpoint one and 69 percent to 89 percent for endpoint two. A comparison of the permissible load associated with endpoint 2 in Table 5.10 to the natural background loads shown in Table 4.26 indicate that Endpoint 2 cannot be met. Table 5.11 shows the allocation of the remaining permissible loadings to the different major source categories identified above and the required reductions in loading associated with endpoint 3. All water quality endpoints associated with the Otter Creek Reservoir TMDL recommend a high level of reduction to TP loads. Endpoint 3 was selected for the Otter TMDL based on the nature of pollutant loading to the reservoir and the uncertainty that is associated with inflowing loads and in-lake TP concentrations. If the desired in-lake water quality concentrations have not been met once endpoint 3 is achieved, it is recommended that endpoint 1 be used.

Table 5.10. Loading Summary for Otter Creek Reservoir.			
Loading Category	**Total Phosphorus Loading (kg/yr)**		
	Endpoint 1[1]	**Endpoint 2[2]**	**Endpoint 3[3]**
Existing Loads	8,688	8,688	8,688
Permissible Loads (Loading Capacity)	1,564	1,167	2,144
Reserve for Future Growth (5%)	78.2	58.4	107.2
Load Allocation	1,486	1,109	2,037
Necessary Reduction (%)	7,202 (82.9 %)	7,576 (87.2 %)	6,651 (76.6%)

[1] Endpoint 1: 90th percentile mean water column concentration in reservoir below the 0.025 mg/L indicator level recommended for reservoirs.
[2] Endpoint 2: Expected 90th percentile inflow concentrations below the 0.05 mg/L indicator level recommended for streams.
[3] Endpoint 3*:* Substituting 0.05 mg/L for all inflow concentrations exceeding the 0.05 mg/L indicator level recommended for streams.

Table 5.11. Allocation of permissible loadings to Otter Creek Reservoir by major source category.

	Otter Creek			**East Fork Sevier**		
Loading Source	**Existing TP Load (kg/yr)**	**Required Reduction (kg/yr)**	**Load Allocation (kg/yr)**	**Existing TP Load (kg/yr)**	**Required Reduction (kg/yr)**	**Load Allocation (kg/yr)**
Animal Feeding Operations	140	126 (90%)	14	0		
Onsite Wastewater Treatment Systems[1]	19	13 (68%)	6	6	5 (83%)	1
Fish Hatcheries	NA	NA	TBD	0		
Natural Background	435	0	435	1,142	0	1,142
Grazing and Diffuse Loads from Runoff	456	385 (84%)	71	6,487	6,123 (92%)	364

5.6.4 East Fork Sevier River

The loading summary for the East Fork Sevier River is shown in Table 5.12. The necessary reduction of TP loading to the listed section of the East Fork ranges from approximately 34 percent to 71 percent. Table 5.13 shows the allocation of the remaining permissible loadings to the different major source categories identified above and the required reductions in loading. Load allocations shown in Table 5.13 are based on achieving Endpoint 2. It is recognized that in order to meet the TMDL associated with Otter Creek Reservoir (Table 5.11), the TMDL proposed in Table 5.13 below for the East Fork Sevier will also be met.

Table 5.12. Loading Summary for the East Fork of the Sevier River.	
Loading Category	**Total Phosphorus Loading (kg/yr)**
Existing Loads	6,105
Permissible Loads (Loading Capacity)	3353
Reserve for Future Growth (5%)	167
Load Allocation	3185
Percent Necessary Reduction	**2,920 (47.8%)**
Substituting 0.05 mg/L for all stream concentrations exceeding the 0.05 mg/L indicator level recommended for streams.	

Table 5.13. Allocation of permissible loadings to the East Fork Sevier River by major source category. [1]

Loading Source	Existing Total Phosphorus Loading (kg/yr)	Required Load Reduction (kg/yr)	Load Allocation (kg/yr)
Animal Feeding Operations	280	252 (90%)	28
Onsite Wastewater Treatment Systems	6	3 (50%)	3
Grazing and Diffuse Loads[2]	1,721	909 (53%)	812
Loading from Otter Creek Reservoir releases	3,391	1,756 (52%)	1,635
Natural Background[a]	699	0	699
Total:	**6,097**	**2,920 (45%)**	**3,177**

[1]Endpoint 2: Substituting 0.05 mg/L for all stream concentrations exceeding the 0.05 mg/L indicator level recommended for streams.

[2] Grazing and Diffuse Loads shown here do not include the amount diverted via the East Fork Canal as shown in Table 4.35.

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