Appendix C

GWLF/BATHTUB Modeling

Framework Water Quality Restoration Plan and Total Maximum Daily Loads (TMDLs) for the Lake Helena Watershed Planning Area:

Volume II – Final Report

August 31, 2006

Prepared for the Montana Department of Environmental Quality

Prepared by the U.S. Environmental Protection Agency,
Montana Operations Office
With Technical Support from Tetra Tech, Inc.
and PBS&J, Inc.

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1.0 INTRODUCTION

The Lake Helena Volume I report concluded that twenty stream reaches in the Lake Helena Watershed are impaired for sediment and/or nutrients (Figure 1, Table 1). To better understand the impairments, sediment and nutrients were modeled with the Generalized Watershed Loading Functions (GWLF) model (Haith et al., 1992). The primary purpose of the modeling effort was to determine the sediment and nutrient loads from each significant source category (e.g., point sources, roads, septic systems). The model was secondarily used to help answer the following questions:

- What is the extent to which sediment and nutrient loads in the watershed have been affected by anthropogenic activities (i.e., comparison of existing and natural scenarios)?
- How might loads change in the future with increased development of the watershed (i.e., comparison of existing and build out scenarios)?
- What are the allowable loads at various ungaged points in the watershed?

GWLF simulates runoff and stream flow by a water-balance method, based on measurements of daily precipitation and average temperature. The complexity of GWLF falls between that of detailed, process-based simulation models and simple export coefficient models which do not represent temporal variability. The application of a more detailed model was not warranted given the general lack of water quality data with which it could be calibrated (refer to Volume I). The GWLF model was determined to be appropriate because it simulates the important processes of concern, but does not require as much data for calibration. Loads from several sources (point sources, Helena Valley Irrigation District, abandoned mines, streambank erosion) were estimated separately and added to the GWLF output during post processing.

GWLF input parameters were assigned based on available monitoring data, default parameters suggested in the GWLF User's Manual (Haith et al., 1992), and local resource agency recommendations. Default values were used for many parameters due to a lack of local data and to ensure the modeling results are consistent with previously validated studies.

The U.S. Army Corps of Engineers' BATHTUB model was selected to simulate eutrophication in Lake Helena. BATHTUB predicts eutrophication-related water quality conditions (e.g., phosphorus, nitrogen, chlorophyll *a*, and transparency) using empirical relationships previously developed and tested for reservoir applications (Walker, 1987). Similar to GWLF, BATHTUB was chosen based on the lack of historic water quality data with which to calibrate a more detailed model. Simulated watershed loads from GWLF were used to drive the BATHTUB model to answer the following questions:

- What is the extent to which sediment and nutrient loads in the watershed have been affected by anthropogenic activities (i.e., comparison of existing and natural scenarios)?
- How might loads change in the future with increased development of the watershed (i.e., comparison of existing and build out scenarios)?

The following sections discuss the setup, calibration, and use of the GWLF and BATHTUB models.

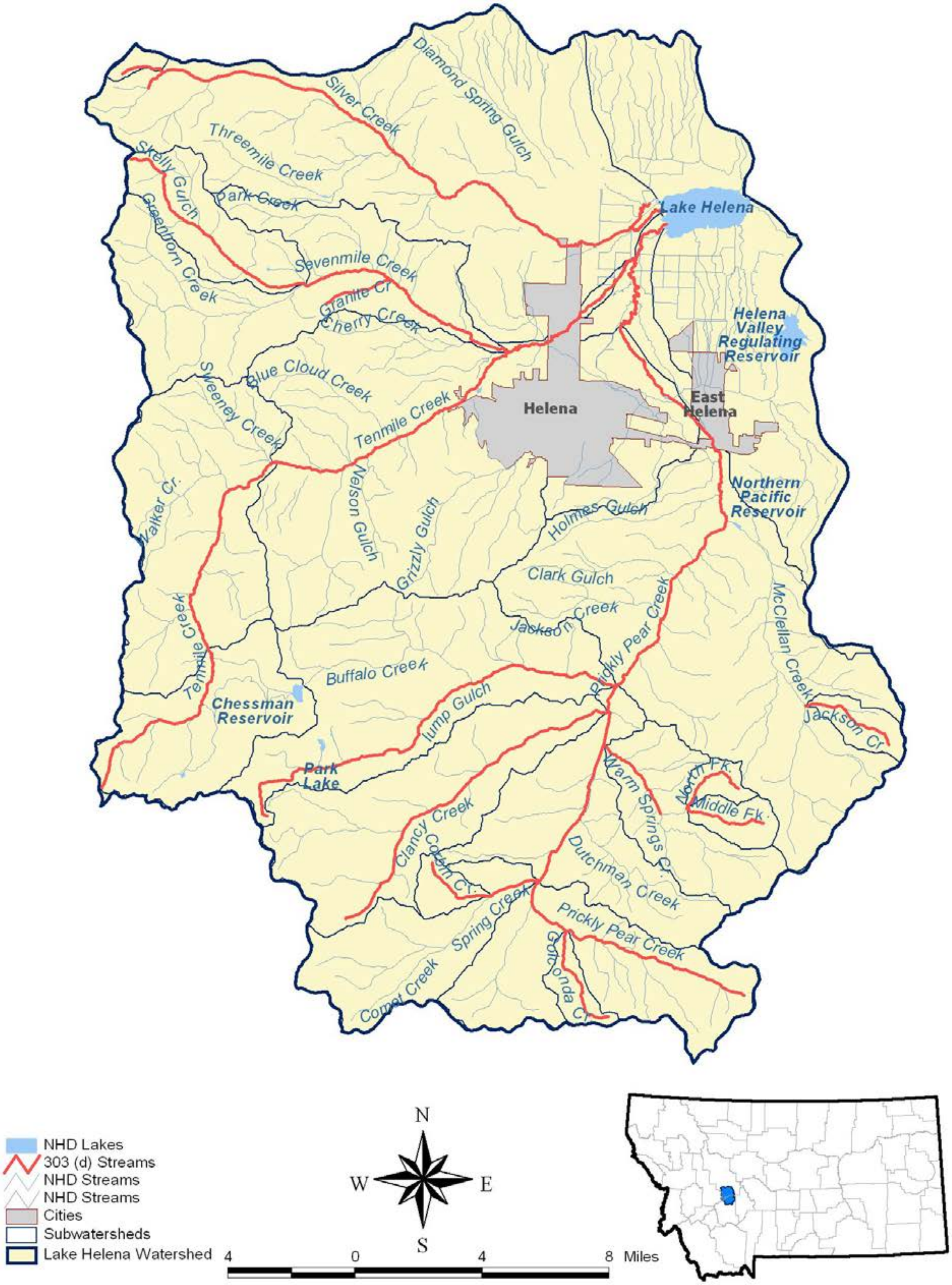

Figure 1. 303(d) Listed Segments in the Lake Helena Watershed

Table 1. Listed Reaches in the Lake Helena Watershed

WBKEY	Reach Description	Length (mile)	Impairment
MT41I006_180	North Fork Warm Springs Creek, Headwaters to mouth	2.50	Sediment
MT41I006_210	Jennies Fork from headwaters to mouth	1.41	Sediment
MT41I006_070	Golconda Creek, Headwaters to the mouth	3.71	Sediment
MT41I006_060	Prickly Pear Creek from headwaters to Spring Cr	8.65	Sediment
MT41I006_080	Spring Creek from Corbin Cr to the mouth	1.66	Sediment, nutrients
MT41I006_090	Corbin Creek from headwaters to the mouth	2.52	Sediment
MT41I006_100	Middle Fork Warm Springs Creek, Headwaters to mouth	2.68	Sediment
MT41I006_050	Prickly Pear Creek from Spring Cr to Lump Gulch	7.01	Sediment
MT41I006_110	Warm Springs Creek from the Middle Fork to the mouth	2.96	Sediment
MT41I006_120	Clancy Creek from headwaters to the mouth	11.56	Sediment, nutrients
MT41I006_130	Lump Gulch from headwaters to the mouth	14.47	Sediment
MT41I006_141	Tenmile Creek, headwaters to the Helena PWS intake above Rimini	6.82	Sediment
MT41I006_040	Prickly Pear Creek from Lump Gulch to Montana Highway 433 Crossing	10.43	Sediment
MT41I006_142	Tenmile Creek From the Helena PWS intake above Rimini to the Helena WT plant.	7.30	Sediment
MT41I006_143	Tenmile Creek from the Helena WT plant to the mouth	15.45	Sediment, nutrients
MT41I006_160	Sevenmile Creek from headwaters to the mouth	7.76	Sediment, nutrients
MT41I006_020	Prickly Pear Creek from Helena WWTP Discharge Ditch to Lake Helena	5.92	Sediment, nutrients
MT41I006_220	Skelly Gulch tributary of Greenhorn Cr-Sevenmile Cr T10N R5W Sec 2	7.71	Sediment
MT41I006_030	Prickly Pear Creek from Highway 433 Crossing to Helena WWTP Discharge	4.42	Sediment, nutrients
MT41I006_190	Jackson Creek from headwaters to the mouth	3.24	Sediment

2.0 GWLF MODEL DEVELOPMENT

GWLF provides a mechanistic, but simplified, simulation of precipitation-driven runoff and sediment delivery. Solids load, runoff, and ground water seepage are used to estimate particulate and dissolved-phase pollutant delivery to a stream, based on pollutant concentrations in soil, runoff, and ground water. GWLF simulates runoff and stream flow by a water-balance method, based on measurements of daily precipitation and average temperature. Precipitation is partitioned into direct runoff and infiltration using a form of the Natural Resources Conservation Service's (NRCS) Curve Number method (SCS, 1986). The Curve Number determines the amount of precipitation that runs off directly, adjusted for antecedent soil moisture based on total precipitation in the preceding 5 days.

Flow in streams may derive from surface runoff during precipitation events or from ground water pathways. The amount of water available to the shallow ground water zone is strongly affected by evapotranspiration, which GWLF estimates from available moisture in the unsaturated zone, potential evapotranspiration, and a cover coefficient. Potential evapotranspiration is estimated from a relationship to mean daily temperature and the number of daylight hours.

The user of the GWLF model must divide land uses into "rural" and "urban" categories, which determines how the model calculates loading of sediment and nutrients. For the purposes of modeling, "rural" land uses are those with predominantly pervious surfaces, while "urban" land uses are those with predominantly impervious surfaces. Monthly sediment delivery from each "rural" land use is computed from erosion and the transport capacity of runoff, whereas total erosion is based on the universal soil loss equation (USLE) (Wischmeier and Smith, 1978), with a modified rainfall erosivity coefficient that accounts for the precipitation energy available to detach soil particles (Haith and Merrill, 1987). Thus, erosion can occur when there is precipitation, but no surface runoff to the stream; delivery of sediment, however, depends on surface runoff volume. Sediment available for delivery is accumulated over a year, although excess sediment supply is not assumed to carry over from one year to the next. Nutrient loads from rural land uses may be dissolved (in runoff) or solid-phase (attached to sediment loading as calculated by the USLE).

For "urban" land uses, soil erosion is not calculated, and delivery of nutrients to the water bodies is based on an exponential accumulation and washoff formulation. All nutrients loaded from urban land uses are assumed to move in association with solids.

GWLF requires three input files to simulate runoff and pollutant loads from each subwatershed. The weather file contains daily values of precipitation and average temperature. The nutrient file contains nitrogen and phosphorus concentrations of groundwater and runoff as well as build-up wash off rates from urban areas. The transport file contains land use areas and parameters for estimating runoff, erosion, and evapotranspiration. This section of the report describes the modeling assumptions used to develop these three files for existing and natural conditions.

2.1 Transport Data

Land use areas, soil erodibility factors, and evapotranspiration rates were developed based on MRLC, STATSGO, and Agri-met datasets, respectively, and are described more fully below.

2.1.1 Subwatershed Delineation

The first step in developing the transport files was to delineate subwatersheds corresponding to the listed segments and major stream confluences. The Lake Helena Watershed was delineated into twenty-two subwatersheds based on a 30-meter digital elevation model of the watershed and the National Hydrography Dataset stream coverage as shown in Figure 2. Watershed area and mean elevation are listed in Table 2.

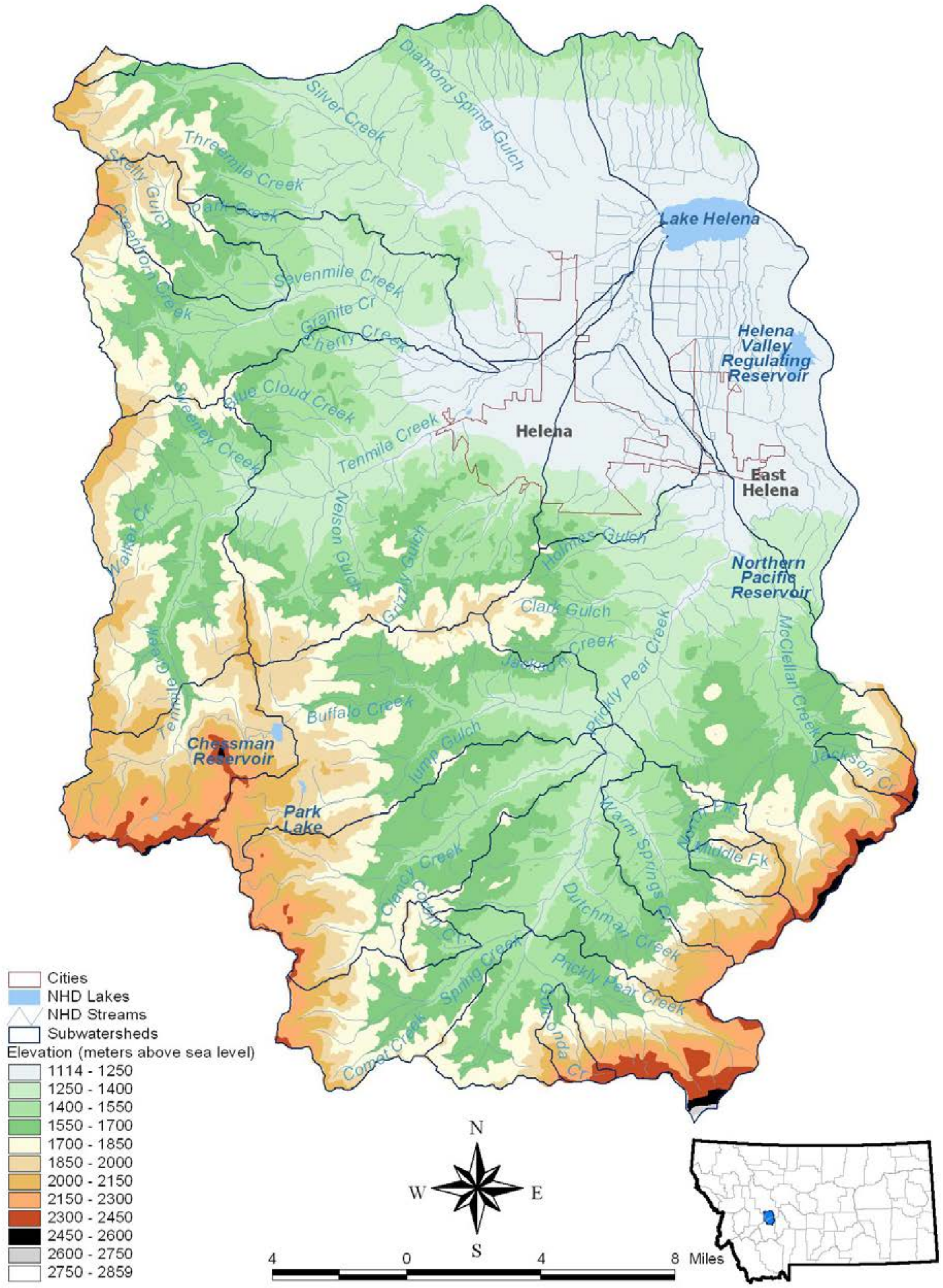

Figure 2. Lake Helena DEM, NHD Stream Coverage, and Subwatersheds

Table 2. Drainage Area and Mean Elevation of the Lake Helena Subwatersheds

Subwatershed	Watershed Area (ac)	Mean Elevation (m)	Corresponding Segment
Clancy Creek	21,140	1757.5	MT41I006_120
Corbin Creek	1,715	1685.2	MT41I006_090
Golconda Creek	1,887	1962.2	MT41I006_070
Jackson Creek	2,148	1924.2	MT41I006_190
Jennies Fork	670	1855.5	MT41I006_210
Overland flow to Lake Helena	38,330	1196.0	Overland flow
Lump Gulch	27,762	1722.3	MT41I006_130
Middle Fork Warm Springs	2,180	1796.9	MT41I006_100
Middle Tenmile Creek	24,701	1730.0	MT41I006_142
North Fork Warm Springs Creek	1,343	1721.7	MT41I006_180
Prickly Pear above Spring Creek	17,070	1866.7	MT41I006_060
Prickly Pear above Lake Helena	4,201	1134.6	MT41I006_020
Prickly Pear above Lump Gulch	16,275	1581.2	MT41I006_050
Prickly Pear above WWTP outfall	12,431	1294.0	MT41I006_030
Prickly Pear above Wylie Drive	47,176	1554.9	MT41I006_040
Sevenmile Creek	24,883	1527.6	MT41I006_160
Silver Creek	59,013	1355.4	MT41I006_150
Skelly Gulch	7,834	1700.6	MT41I006_220
Spring Creek	11,620	1758.4	MT41I006_080
Tenmile above Prickly Pear	48,786	1455.1	MT41I006_143
Upper Tenmile Creek	14,106	2068.3	MT41I006_141
Warm Springs Creek	9,670	1688.2	MT41I006_110
Total Watershed Area	393,445	na	na

2.1.2 Land Use in the Lake Helena Watershed

Existing land use and land cover in the Lake Helena Watershed were determined from satellite imagery, digital aerial photography, and geographic information system (GIS) layers. Digital land use/land cover data were obtained from the National Land Cover Dataset (NLCD). The NLCD is a consistent representation of land cover for the conterminous United States generated from classified 30-meter resolution Landsat thematic mapper satellite imagery data. The NLCD is classified into urban, agricultural, forested, water, and transitional land cover subclasses. The imagery was acquired by the Multi-Resolution Land Characterization (MRLC) Consortium, a partnership of federal agencies that produce or use land cover data. The imagery was acquired between 1991 and 1993.

MRLC data and corresponding land use classifications served as the primary basis for the GWLF modeling effort; however updates to the original data and refinements of land use categories were made to reflect current conditions in the Lake Helena watershed. 2004 high-resolution color orthophotos of the Helena Valley were used to manually classify a portion of the watershed using the land use definitions provided by the MRLC Consortium data description. Road areas and corresponding road surface materials in the watershed were distinguished based on GIS data layers acquired from Lewis and Clark and Jefferson counties and the Helena National Forest. Additionally, a new class of low-intensity residential development was added to reflect the low-density style of land development in the more rural areas of the Lake Helena Watershed. Figure 3 shows the final land use coverage and the data are summarized in Table 3.

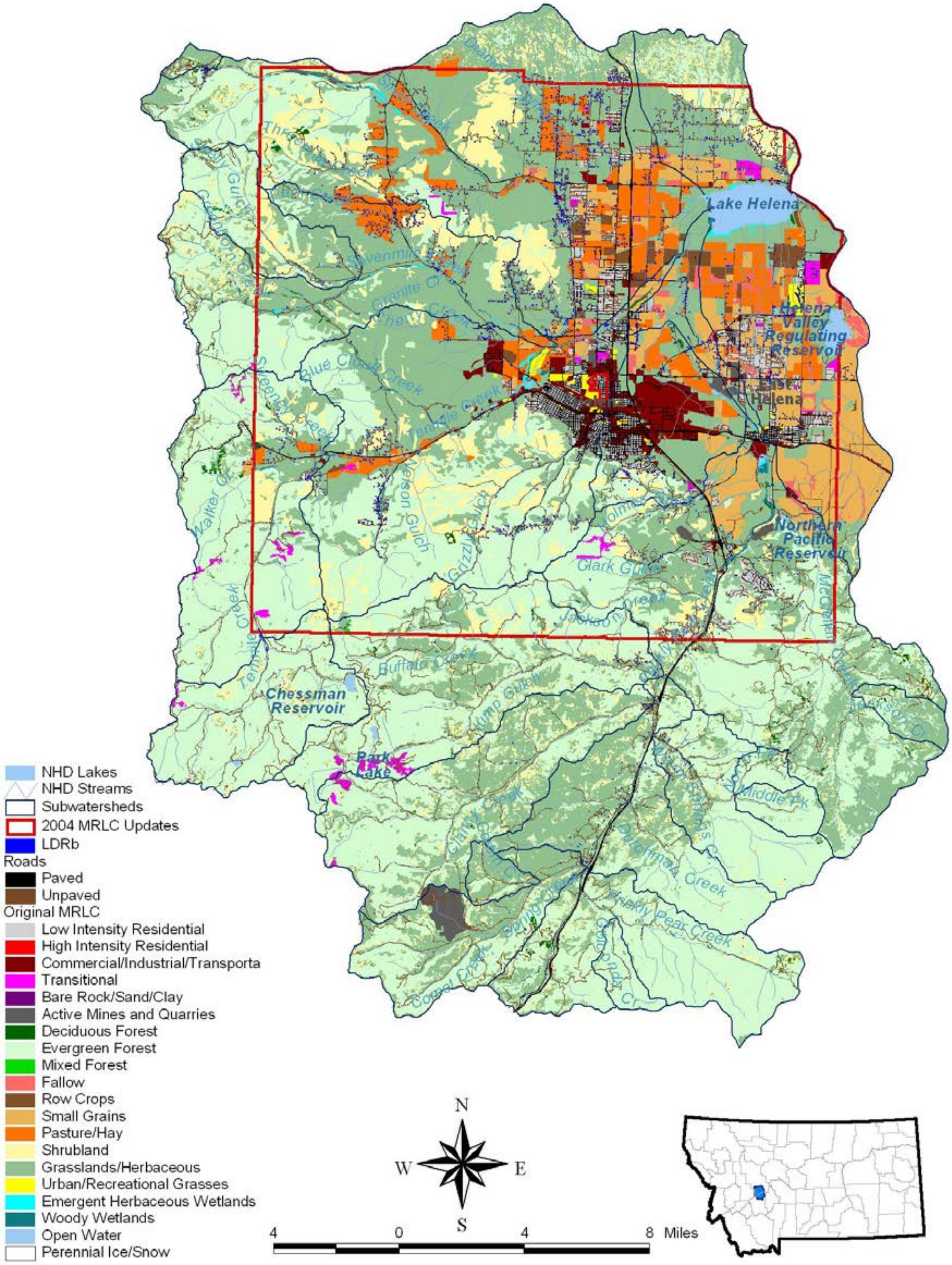

Figure 3. Land Use in the Lake Helena Watershed (Area Highlighted in Red was Updated Based on 2004 Aerial Photography)

Table 3. Land Use Areas for the Lake Helena Existing Conditions Modeling

Land Use	Existing (ac)
Bare Rock	84
LDRa	9,067
Quarries	234
Water	2,875
Transitional	1,853
Deciduous Forest	1,241
Evergreen Forest	154,204
Mixed Forest	36
Shrubland	37,014
Grassland	129,060
Pasture/Hay	14,892
Small Grains	16,925
Woody Wetland	1,270
Herbaceous Wetlands	421
Recent Clear-cut	522
Clear-cut Regrowth	3,571
Dirt Roads	3,326
Fallow	2,546
Row Crop	2,093
Non-system Roads	153
LDRb	2,950
Commercial/Industrial/Transportation	6,203
Urban/Recreational Grasses	1,001
Secondary Paved Roads	1,904
Total Watershed Area	393,445

All of the land use categories used for the modeling are standard MRLC classifications except for two low-intensity residential classifications, two silviculture classes, and three road classes, as described below.

2.1.2.1. Residential Lands

Low-intensity development was classified as either LDRa or LDRb to differentiate between the concentration of low density housing in and around the municipalities and the low-density housing development in the remainder of the watershed. LDRa represents developments detected during the orthophoto analysis or present in the original MRLC data set, with approximately 40 percent impervious area and 60 percent lawn. LDRb was created by buffering the remaining residential areas outside of the LDRa area to 1.1-acre lots (represented by structures for Lewis and Clark County and wells for Jefferson County). A 1.1 acre buffer radius was chosen based on the median value of developed area for 100 randomly selected parcels outside of the LDRa areas. Based on the analysis of the 100 random parcels, LDRb lots were assigned 40 percent impervious (house, barn, sheds), 24 percent pasture with poor ground cover (animal paddocks), and 36 percent lawn in good condition.

2.1.2.2. Forest Lands

To account for harvesting activities in the watershed, forest was modeled in one of three categories: (1) clear-cut, (2) regrowth, or (3) full growth condition. Forestland in the Lake Helena Watershed is owned by private land owners, the Bureau of Reclamation, Department of Natural Resources, Bureau of Land Management, and the Helena National Forest (Figure 4). Databases were obtained from each agency to estimate average harvest acreages for the period between 1996 and 2000 (Table 4). The public agencies use selective cut techniques rather than clear cutting procedures, so harvest acres were assumed in the regrowth state after cutting. Cutting has not occurred on land owned by the Helena National Forest since 1996. No data were obtained from the Bureau of Reclamation despite numerous requests. Harvest data on private lands was not available, so a continuous 90-yr harvesting cycle (Stuart, 2004) was assumed (i.e., 1.1 percent of private forest land was assumed clear cut each year). To estimate the area of regrowth on private lands, we assumed a 5 year regrowth period to re-establish full growth ground cover. The curve numbers, cover factors, and nutrient runoff concentrations of these silvicultural land uses vary from typical forestland as described in Table 5, Table 7, and Table 9.

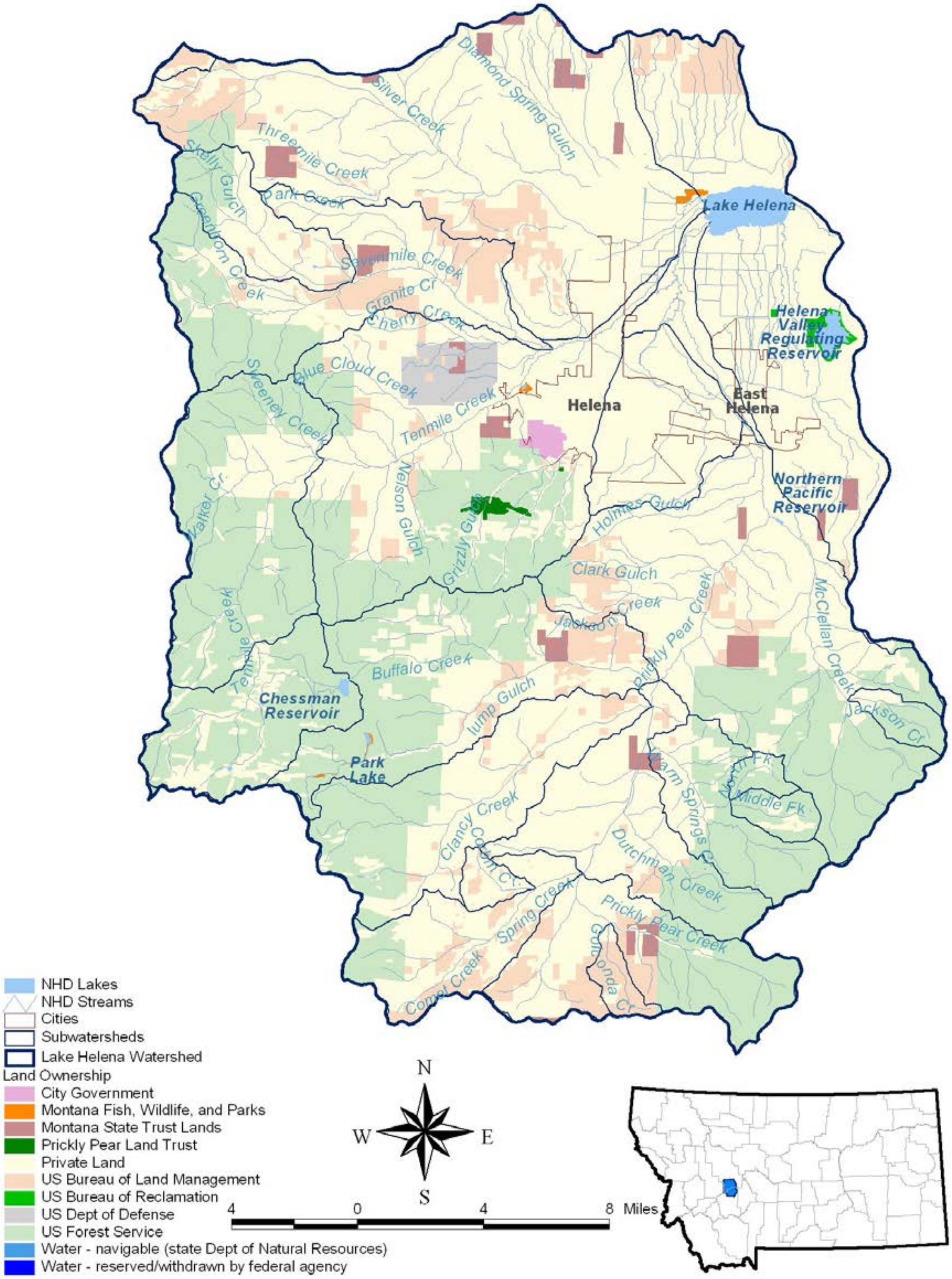

Figure 4. Land Ownership in the Lake Helena Watershed

Table 4. Harvest Data by Agency in the Lake Helena Watershed for the period 1996 to 2000.

Agency	Selective Harvest or Regrowth (ac)	Clear Cut (ac)
Bureau of Land Management	767	0
Bureau of Reclamation	0	0
Helena National Forest	0	0
Department of Natural Resource Conservation	195	0
Private	2,610	522

2.1.2.3. Roads

Road areas in the Lake Helena watershed were generated from current GIS data. The road polylines were converted into areas based on average widths from field data collected in 2005. Unpaved roads were buffered to a total width of 22 feet, and paved roads were buffered to a total width of 26 feet. Interstate 15 and Highway 12 are simulated with a width of 52 feet.

Non-system roads are those built for recreational purposes (dirt bikes, four wheelers, etc.) and are not built to approved specifications. Road slope is assumed to follow the land gradient rather than incorporate switch-backs. Ditches and cross drains are not present. In the Helena National Forest, non-system roads were estimated to comprise an additional 4.6 percent of the area of unpaved roads (Stuart, 2004). This value was extrapolated to the entire Lake Helena Watershed where unpaved roads are present.

2.1.2.4. Land Use Curve Numbers

The GWLF model uses the curve number method to estimate runoff from each land use area. Land uses with higher curve numbers are assumed to have more surface runoff than those with lower curve numbers. Table 5 lists the curve numbers by soil hydrologic group for land uses in the Lake Helena Watershed. Area weighted curve numbers were developed for each subwatershed and land use based on the reported NRCS soil hydrologic groups. Soil hydrologic groups were used to account for the different infiltration rates of different soil types (e.g., higher infiltration for sands compared to clays).

Table 5. SCS Curve Numbers for Land Uses in the Lake Helena Watershed

Land Use	CNa	CNb	CNc	CNd
Bare Rock	98	98	98	98
LDRa	63	76	84	87
Quarries	76	85	89	91
Water	100	100	100	100
Transitional	77	86	91	94
Deciduous Forest	30	55	70	77
Evergreen Forest	36	60	73	79
Mixed Forest	33	57	72	78
Shrubland	30	48	65	73
Grassland – Existing	49	69	79	84
Grassland - Natural	39	61	74	80
Pasture/Hay	30	58	71	78
Small Grains	63	75	83	87
Woody Wetland	98	98	98	98
Herbaceous Wetlands	98	98	98	98
Recent Clear-cut	77	86	91	94
Clear-cut Regrowth	57	73	82	87
Dirt Roads	72	82	87	89
Fallow	77	86	91	94
Row Crop	67	78	85	89
Non-system Roads	72	82	87	89
LDRb	69	39	39	39
Commercial/Industrial/Transportation	89	92	94	95
Urban/Recreational Grasses - fair condition	49	69	79	84
Secondary Paved Roads	98	98	98	98

2.1.3 USLE Parameters

GWLF uses the Universal Soil Loss Equation (USLE) to estimate soil erosion rates based on rainfall intensity, soil erodibility, slope length, gradient, and cover and management factors. Seasonal rainfall erosivity factors were developed based on regional values available from the GWLF User's Manual. The NRCS soils database (Figure 5) was used to estimate the average land slope in each subwatershed as well as area-weighted soil erodibility factors and length-slope factors (Table 6).

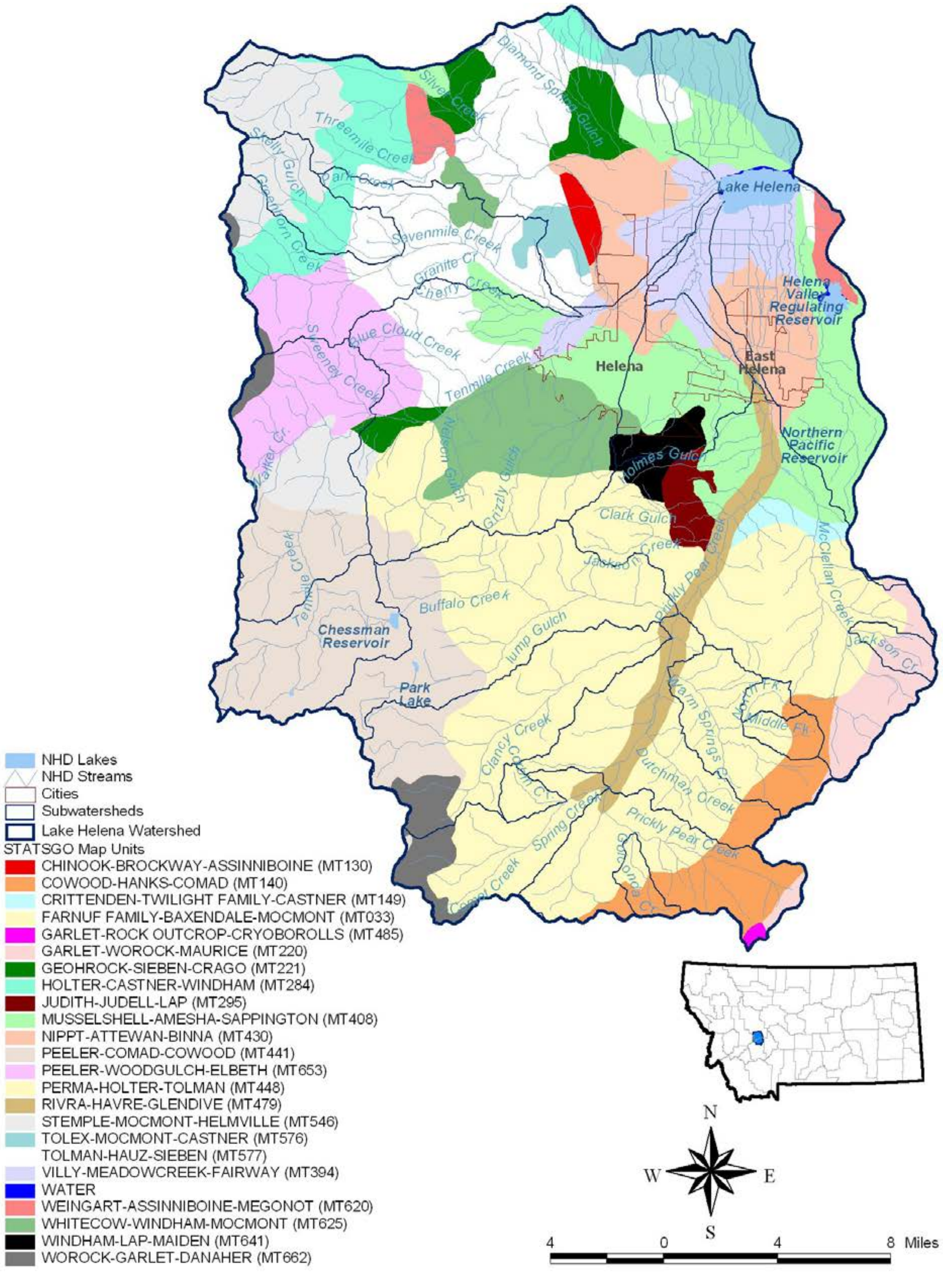

Figure 5. STATSGO Soil Types in the Lake Helena Watershed

Slope lengths were set to 30 meters, which is a general default value for GWLF. Length-slope factors were developed using the revised USLE approach (Schwab et al., 1993), which is preferred by the Montana NRCS (Tom Pick, Water Quality Specialist, NRCS Montana State Office, personal communications, August 9, 2005).

Table 6. Average Land Slopes, Soil Erodibility Factors, and Length-Slope Factors by Subwatershed

Subwatershed	Land Slope (%)	K	LS
Clancy Creek	31.3	0.154	5.547
Corbin Creek	27.6	0.152	4.855
Golconda Creek	31.5	0.133	5.582
Jackson Creek	44.6	0.148	7.866
Jennies Fork	45.0	0.134	7.927
Lake Helena overland flow	9.3	0.279	1.239
Lump Gulch	29.3	0.142	5.170
Middle Fork Warm Springs	31.0	0.134	5.494
Middle Tenmile Creek	33.3	0.143	5.914
North Fork Warm Springs Creek	26.9	0.147	4.721
Prickly Pear above Spring Creek	30.7	0.140	5.432
Prickly Pear above Lake Helena	1.0	0.313	0.145
Prickly Pear above Lump Gulch	21.1	0.184	3.596
Prickly Pear above WWTP outfall	13.9	0.280	2.152
Prickly Pear above Wylie Drive	23.6	0.194	4.080
Sevenmile Creek	25.8	0.186	4.520
Silver Creek	19.6	0.214	3.306
Skelly Gulch	34.6	0.165	6.152
Spring Creek	33.2	0.176	5.889
Tenmile above Prickly Pear	21.9	0.206	3.750
Upper Tenmile Creek	37.5	0.120	6.663
Warm Springs Creek	27.5	0.148	4.840

Most of the subwatersheds have relatively high land slopes that would not accommodate properly designed unpaved roads. An average of the land slope and measured road slope at stream crossings was therefore used to estimate average road slopes. Measured slopes at stream crossings were obtained from a stream-crossing sediment loading analysis performed with the WEPP model as a part of the TMDL study (see Appendix D). Non-system roads were modeled without accounting for switch-back reduction of slope.

Cover factors for each land use are based on values suggested in Agriculture Handbook 537 (Wischmeier and Smith, 1978) and are summarized in Table 7. Under natural conditions, only forest, wetlands, shrubland, grassland, barerock, and water are simulated. The Upper Yellowstone River Watershed Land Cover Assessment report (NRCS, 2003) was used to develop modeling parameters for these land uses under natural conditions. The report states that in this relatively undisturbed watershed, grassland has 20 percent bare ground cover, shrubland has 10 percent bare ground cover, and forest has 10 percent bare ground cover. Under existing conditions, the bare ground cover was assumed 30 percent for grassland and 20 percent for shrubland to reflect higher animal densities and human disturbance. Cover factors for grassland were increased from 0.013 to 0.0275 from natural to existing conditions; cover factors for shrubland were increased from 0.006 to 0.012. The percent bare ground cover in full-growth forest was not assumed to increase because human impacts are being simulated with the clear-cut and regrowth classifications.

The cover factor for dirt roads is based on a literature value (Sun and McNulty, 1998).

Table 7. Cover Factors by Land Use in the Lake Helena Watershed

Land Use	Cover Factor
Bare Rock	0.0001
LDRa	0.0078
Quarries	1.0000
Water	0.0000
Transitional	0.0910
Deciduous Forest	0.0030
Evergreen Forest	0.0030
Mixed Forest	0.0030
Shrubland - Existing	0.0120
Shrubland - Natural	0.0060
Grassland – Existing	0.0275
Grassland – Natural	0.0130
Pasture/Hay	0.0420
Small Grains	0.3800
Woody Wetland	0.0030
Herbaceous Wetlands	0.0030
Recent Clear-cut	0.4500
Clear-cut Regrowth	0.1500
Dirt Roads	0.7500
Fallow	1.0000
Row Crop	0.5400
Non-system Roads	0.7500
LDRb	0.0265
Commercial/Industrial/Transportation	0.1000
Urban/Recreational Grasses	0.0130
Secondary Paved Roads	0.2500

The USLE equation estimates average annual erosion rates. Delivered sediment is estimated by applying a sediment delivery ratio which is calculated for each subwatershed based on drainage area as suggested in Haith et al. (1992) and summarized in Table 8. Larger watersheds have smaller delivery ratios.

Table 8. Sediment Delivery Ratios for the Lake Helena Subwatersheds

Subwatershed	Sediment Delivery Ratio
Clancy Creek	0.1335
Corbin Creek	0.2386
Golconda Creek	0.2339
Jackson Creek	0.2277
Jennies Fork	0.2881
Lake Helena overland flow	0.1134
Lump Gulch	0.1241
Middle Fork Warm Springs	0.2270
Middle Tenmile Creek	0.1281
North Fork Warm Springs Creek	0.2509
Prickly Pear above Spring Creek	0.1411
Prickly Pear above Lake Helena	0.1970
Prickly Pear above Lump Gulch	0.1428
Prickly Pear above WWTP outfall	0.1528
Prickly Pear above Wylie Drive	0.1067
Sevenmile Creek	0.1278
Silver Creek	0.0998
Skelly Gulch	0.1708
Spring Creek	0.1554
Tenmile above Prickly Pear	0.1057
Upper Tenmile Creek	0.1481
Warm Springs Creek	0.1625

2.1.4 Soil Water Capacity and River Recession

Water stored in soil may evaporate, be transpired by plants, or percolate to ground water below the rooting zone. The amount of water that can be stored in soil (the soil water capacity) varies by soil type and rooting depth. Based on soil water capacities reported in the STATSGO database, soil types present in the watershed, and GWLF user’s manual recommendations, a GWLF soil water capacity of 10 cm was used.

The GWLF model has three subsurface zones: a shallow unsaturated zone, a shallow saturated zone, and a deep aquifer zone. Behavior of the second two stores is controlled by a ground water recession and a deep seepage coefficient. The recession coefficient was set to 0.01 per day and the deep seepage coefficient to 0, based on several calibration runs of the model.

2.2 Weather Data

The GWLF model uses daily estimates of precipitation and average temperature to estimate water inputs to the system as well as potential evapotranspiration rates. Weather data from the Helena Regional Airport (Coop ID 244055; elevation 1,167 m) was used to develop a 20-year input file from January 1980 through December 2003.

The mean elevation of each subwatershed was used to account for elevation effects on temperature and precipitation based on a comparison of mean annual precipitation and temperature at Austin, Montana

(Coop ID 240375; elevation 1,493 m). For each meter increase in elevation, 0.03 cm/yr of precipitation were added and 0.0038 ºC were subtracted from the daily average temperature.

SNOTEL data were not adequate to develop daily weather inputs for the high elevation subwatersheds because cumulative precipitation estimates showed losses due to sublimation, which would not occur over an entire modeling subwatershed. However, annual average precipitation at the Frohner station was used to validate the elevation adjustments cited above. In general, yearly precipitation at Frohner was more stable than at the airport. Even though elevation effects were accounted for, dry years at the airport (1994 and 1995) generally result in an underestimation of precipitation in the high elevation subwatersheds and an over prediction in extremely wet years (1993) (Figure 6).

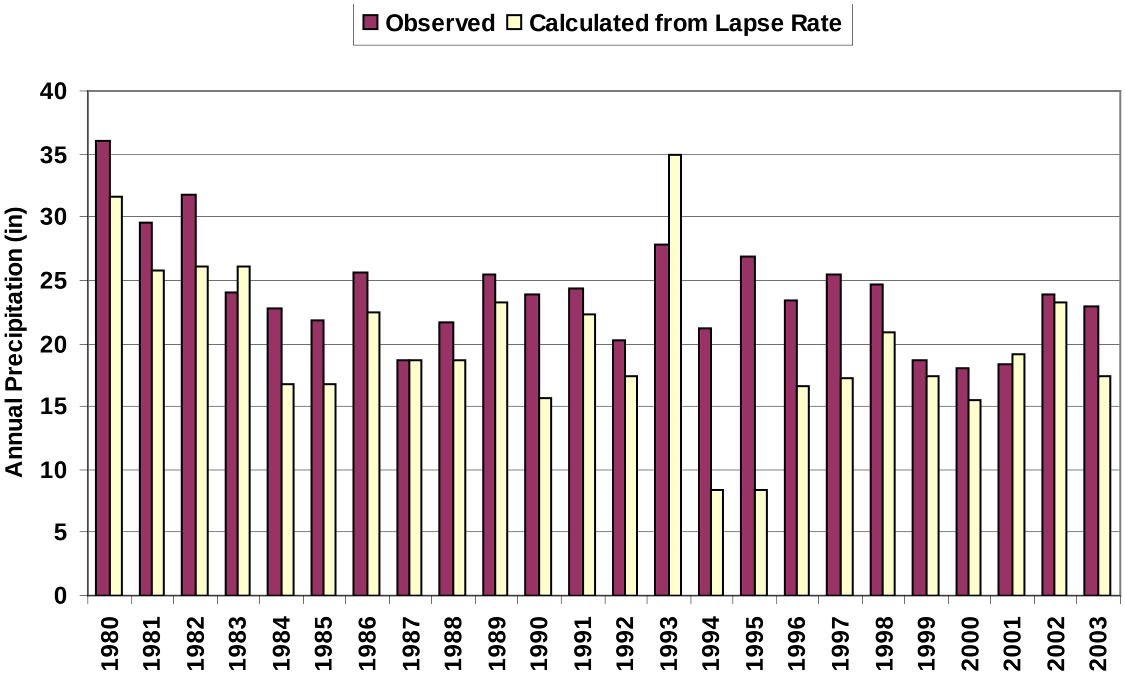

Figure 6. Comparison of Observed and Estimated Precipitation at the Frohner SNOTEL Station

2.3 Nutrient Data

The GWLF model simulates nutrient runoff from rural land uses and washoff from urban land uses. In addition, soil is assumed to carry sorbed nutrients; groundwater also serves as a component of the total load.

2.3.1 Soil Nutrient Concentrations

Because site-specific data were not available, soil nutrient concentrations are based on spatial distributions provided in the GWLF manual. Both the soil nitrogen and soil phosphorus concentrations were set to the lower end of the suggested range for the geographic area during model calibration (Section 2.6.2). The soil nitrogen concentration is estimated to be 2,000 mg/kg and the soil phosphorus concentration is estimated to be 440 mg/kg.

2.3.2 Runoff Concentrations from Rural Land Uses

Dissolved nutrient concentrations in runoff from each land use were set to GWLF default values and are summarized in Table 9. Because site-specific data were not available, default values were chosen to estimate relative contributions from the pollutant sources. Best professional judgment was used to estimate runoff concentrations from dirt roads.

Table 9. Nutrient Runoff Concentrations for Rural Land Uses in the Lake Helena Watershed

Land Use	Nitrogen (mg/L)	Phosphorus (mg/L)
Bare Rock	0.01	0.001
LDRa	1.72	0.094
Quarries	0.01	0.001
Water	0.07	0.012
Transitional	1.00	0.100
Deciduous Forest	0.07	0.012
Evergreen Forest	0.07	0.012
Mixed Forest	0.07	0.012
Shrubland	0.70	0.010
Grassland	0.60	0.070
Pasture/Hay	3.00	0.250
Small Grains	1.80	0.300
Woody Wetland	0.07	0.012
Herbaceous Wetlands	0.07	0.012
Recent Clear-cut	2.60	0.100
Clear-cut Regrowth	1.30	0.056
Dirt Roads	0.10	0.010
Fallow	2.60	0.100
Row Crop	2.90	0.260
Non-system Roads	0.10	0.010
LDRb	2.01	0.170

2.3.3 Buildup Washoff Rates from Urban Land Uses

GWLF simulates nutrient loads from developed land uses through a buildup/washoff formulation. Buildup rates for nitrogen and phosphorus are based on weighted averages of pervious and impervious default values suggested in the GWLF manual (Table 10).

Table 10. Buildup Washoff Rates for Urban Land Uses in the Lake Helena Watershed

Land Use	Nitrogen (kg/ha-d)	Phosphorus (kg/ha-d)
Commercial/Industrial/Transportation	0.05	0.005
Urban/Recreational Grasses	0.012	0.0016
Secondary Paved Roads	0.1	0.01

2.3.4 Groundwater Nutrient Concentrations

Groundwater nutrient concentrations were based on baseflow measurements reported in the GWLF manual for various levels of forested and agriculturally developed watersheds. Completely forested watersheds have values of 0.07 mg-N/L and 0.012 mg-P/L. Primarily agricultural watersheds have values of 0.71 mg-N/L and 0.104 mg-P/L. Intermediary values are also reported. Values for each subwatershed were assigned based on the percent forest and agricultural land use in the watershed (Table 11). For the natural scenario, all subwatersheds were assumed to have concentrations reported for primarily forested watersheds. Groundwater loads from the Helena Valley Irrigation District were modeled separately as discussed in Section 2.4.4.

Table 11. Estimated Groundwater Nutrient Concentrations for the Lake Helena Subwatersheds Under Existing Conditions

Subwatershed	Groundwater Nitrogen Concentration (mg-N/L)	Groundwater Phosphorus Concentration (mg-P/L)
Clancy Creek	0.18	0.015
Corbin Creek	0.18	0.015
Golconda Creek	0.07	0.012
Jackson Creek	0.18	0.015
Jennies Fork	0.18	0.015
Lake Helena overland flow	0.83	0.083
Lump Gulch	0.18	0.015
Middle Fork Warm Springs	0.07	0.015
Middle Tenmile Creek	0.07	0.015
North Fork Warm Springs Creek	0.07	0.015
Prickly Pear above Spring Creek	0.07	0.015
Prickly Pear above Lake Helena	0.83	0.083
Prickly Pear above Lump Gulch	0.18	0.015
Prickly Pear above WWTP outfall	0.83	0.083
Prickly Pear above Wylie Drive	0.18	0.015
Sevenmile Creek	0.18	0.015
Silver Creek	0.18	0.015
Skelly Gulch	0.18	0.015
Spring Creek	0.18	0.015
Tenmile above Prickly Pear	0.18	0.015
Upper Tenmile Creek	0.07	0.015
Warm Springs Creek	0.18	0.015

2.3.5 Septic System Loading Data

The GWLF model requires an estimation of population served by septic systems to generate septic system nutrient loading rates. Lewis and Clark County maintains a GIS coverage of permitted septic systems and reports that permitted systems are approximately 63 percent of the total number of systems in the watershed (LCCHD, 2002). The number of permitted systems within Lewis and Clark County was scaled up accordingly to estimate the total number of systems in each subwatershed for the existing scenario.

A GIS coverage of permitted septic systems was not available for Jefferson County. However, both Lewis and Clark and Jefferson Counties maintain geographic databases of wells that were available to the project team. The average ratio of septic systems to wells in Lewis and Clark County was determined to be 0.86 by comparing the two databases. Based on the assumption that most houses with wells will also have a septic system, this ratio was applied to the number of wells on record for each subwatershed in Jefferson County to estimate the total number of septic systems. Figure 7 shows the permitted septic systems in Lewis & Clark County and the wells coverage for the entire watershed.

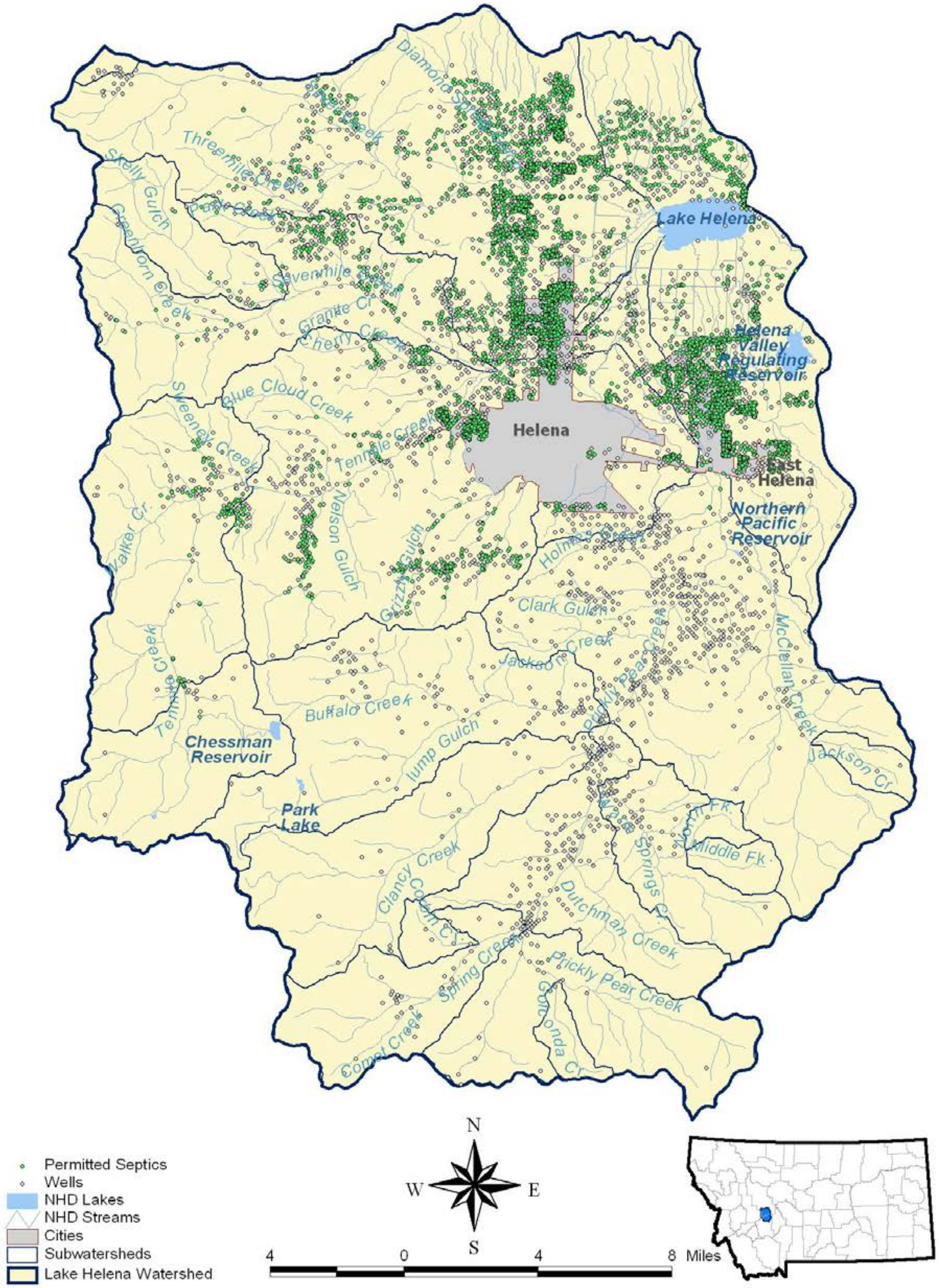

Figure 7. Permitted Septic Systems in Lewis & Clark County and Wells Coverage for the Watershed

To convert the number of septic systems to population served, an average household size of 2.5 people per dwelling was used based on Census data. GWLF also requires an estimate of the number of normal and failing septic systems. This information was requested of the county health departments but was not available. It was therefore assumed that 7 percent of all systems were failing based on the reported national average (USEPA, 2002b). A failing system is assumed to short circuit the drainfield and plant uptake zones and discharge directly to the groundwater. The population served by normal and failing systems is summarized by subwatershed in Table 12.

Table 12. Population Served by Septic Systems in the Lake Helena Watershed

Subwatershed	Normally Functioning	Failing[a]	Total
Clancy Creek	88	7	94
Corbin Creek	12	1	13
Golconda Creek	4	0	4
Jackson Creek	4	0	4
Jennies Fork	20	2	21
Lake Helena overland flow	4875	367	5,242
Lump Gulch	245	18	264
Middle Fork Warm Springs	0	0	-
Middle Tenmile Creek	207	16	222
North Fork Warm Springs Creek	2	0	2
Prickly Pear above Spring Creek	90	7	96
Prickly Pear above Lake Helena	513	39	552
Prickly Pear above Lump Gulch	474	36	510
Prickly Pear above WWTP outfall	447	34	480
Prickly Pear above Wylie Drive	1605	121	1,725
Sevenmile Creek	517	39	556
Silver Creek	8340	628	8,968
Skelly Gulch	48	4	52
Spring Creek	161	12	174
Tenmile above Prickly Pear	3004	226	3,230
Upper Tenmile Creek	26	2	28
Warm Springs Creek	157	12	169
Total	20,839	1,568	22,407

[a] Assumed 7 percent of onsite systems are failing based on national average (USEPA, 2002b).

Daily per capita mass loading rates and plant uptake rates for normal and failing systems were set to GWLF default values and are summarized in Table 13. Using the default parameters suggested by the manual allows for an estimation of pollutant loading relative to other sources in the watershed.

Table 13. Septic System Loading Rates and Plant Uptake Rates

Parameter	Nitrogen	Phosphorus
Loading Rate from Septic Tank Prior to Drainfield Treatment and Plant Uptake (grams/capita/day)	12	1.5
Growing Season Plant Uptake Rate (grams/capita/day)	1.6	0.4
Dormant Season Plant Uptake Rate (grams/capita/day)	0	0
Percent Additional Treatment in Soil Adsorption Field of Normal System (%)	0	100
Percent Additional Treatment in Soil Adsorption Field of Failing System (%)	0	0

Note that normal and failing systems are assumed to have the same tank effluent loading rates. In a normally functioning system, tank effluent is distributed over a soil drainfield. Phosphorus is assumed completely adsorbed to the soil particles and some nitrogen is taken up by plant roots during the growing season. The failing system bypasses both of these treatment mechanisms and is assumed to discharge pollutants at rates equivalent to the tank effluent values. Appendix K gives a more thorough description of septic system design and water quality impacts as well as a comparison of loading rates from conventional septic systems, Level 2 treatment systems, and wastewater treatment plants.

Current estimated septic system loading rates by major subwatershed are presented in Table 14. The table also shows the impacts of 1) updating all failing systems to properly functioning conventional septic systems, 2) replacing all failing systems with a Level 2 treatment system (Appendix K), or 3) diverting the wastewater from households served by a failing system to the City of Helena WWTP. The diversion scenario is shown only for illustrative purposes and is not meant to infer a viable management strategy for failing onsite systems.

At the Lake Helena watershed scale, repairing or replacing failing systems with properly functioning onsite wastewater treatment systems (conventional or Level 2) will reduce the septic system nitrogen load by less than 2 percent and the cumulative nitrogen load by less than 1 percent. Diverting the flow from the failing systems to the City of Helena WWTP would result in a net reduction in nitrogen loading of approximately 2 percent. Phosphorus loads from septic systems would be reduced to zero in all three scenarios because the drainfields of normally functioning onsite systems are assumed to retain all phosphorus. At the Lake Helena watershed scale, phosphorus loads would decrease by approximately one-half a percent. The diversion scenario assumes that only failing systems are diverted to the plant. If normally functioning systems are assumed diverted, the net phosphorus load would increase because wastewater treatment plants discharge higher loads of phosphorus per person compared to properly functioning onsite systems.

Table 14. Comparison of Loading Rates from Septic Systems in the Lake Helena Watershed Under Four Failure Scenarios

Watershed	Current Septic System Loading Rate with 7 Percent Failure (mt/yr)	Load if Failing Systems are Updated to Properly Functioning Conventional Systems (mt/yr)	Load if Failing Systems are Replaced with Level 2 Systems (mt/yr)	Load if Failing Systems are Diverted to City of Helena WWTP (mt/yr)
Nitrogen				
Prickly Pear Creek	33.59	33.42	33.01	31.08
Sevenmile Creek	2.49	2.48	2.45	2.31
Spring Creek	0.77	0.76	0.75	0.71
Tenmile Creek	16.79	16.71	16.50	15.54
Lake Helena	92.06	91.60	90.46	85.19
Phosphorus				
Prickly Pear Creek	0.31	0.00	0.00	0.00
Sevenmile Creek	0.02	0.00	0.00	0.00
Spring Creek	0.01	0.00	0.00	0.00
Tenmile Creek	0.16	0.00	0.00	0.00
Lake Helena	0.86	0.00	0.00	0.00

Note: Diverting loads from failing systems to the City of Helena WWTP would result in an average annual increase in total nitrogen loading from the plant of 1.55 mt/yr and an increase in total phosphorus loading of 0.69 mt/yr.

2.3.6 Point Sources

There are nine centralized wastewater treatment systems in the Lake Helena Watershed (See Appendix E for information about each facility). The EPA point source database was used to obtain average flows and nutrient loads for the City of Helena, City of East Helena, and Evergreen Nursing facilities. Loads from the smaller systems were estimated by applying suggested nutrient concentrations reported in the 1997 USEPA publication, Technical Guidance Manual for Developing Total Maximum Daily Loads, Book 2: Streams and Rivers, which provides total nitrogen and total phosphorus concentrations from several studies following various treatment methods (Table 15). General facility information was obtained from the 1998 Helena Area Wastewater Treatment Facility Plan (Damschen & Associates, Inc., 1998).

As stated in Appendix E, three of the lagoon systems in the Lake Helena watershed (Tenmile/Pleasant Valley, Treasure State, and Leisure Village) appear to be functioning improperly, mostly because of excessive seepage from the system or insufficient storage capacity. Based on information in the Facility Plan, it was assumed that 75 percent of the stored water from the Tenmile/Pleasant Valley subdivision and the Leisure Village Mobile Home Park is seeping into the groundwater, and that the systems should only be seeping a maximum of 25 percent. The report did not state that Treasure State has excessive seepage, but rather insufficient storage capacity. Concentrations from Treasure State were simulated at “after sedimentation” concentrations rather than stabilized values. For TMDL allocations and reductions, these three systems were assumed to function as designed (Appendix A).

Table 15. Typical Nutrient Concentrations Reported in USEPA, 1997

Nutrient	Before Sedimentation	After Sedimentation	Stabilization Pond Effluent
Total Nitrogen (mg/L)	35	25	12-17
Total Phosphorus (mg/L)	10	8	5
Inorganic Nitrogen (mg/L)	16	8	5

Table 16 summarizes the average flows and nutrient loads from each facility for the existing scenario. Loads from the City of Helena WWTP are presented pre- and post-plant upgrades, which occurred in June 2001.

Table 16. Average Flow Rates and Annual Nutrient Loads from Centralized Wastewater Treatment Systems in the Lake Helena Watershed

Facility	Flow (MGD)	TN (mt/yr)	TP (mt/yr)
City of Helena: pre-upgrades	3.5	65.801	8.910
City of Helena: post-upgrades	3.5	28.801	12.230
East Helena: pre-upgrades	0.096	2.890	0.475
East Helena: post-upgrades	0.096	5.920	0.910
Evergreen Nursing Home	0.007	0.090	0.034
Eastgate Subdivision	0.15	0.060	0.104
Treasure State Acres subdivision	0.10	0.070	0.111
Tenmile and Pleasant Valley subdivisions	0.09	0.680	0.068
Leisure Village mobile home park	0.10	0.750	0.075
Mountain View law enforcement academy	0.007	0.140	0.048
Fort Harrison, national guard, VA center and hospital pre-closure	0.07	0.310	0.031

Flow volumes and nutrient loads from the City of Helena, City of East Helena, Treasure State Acres, Tenmile/Pleasant Valley, and Mountain View Academy are discharged to the Prickly Pear Creek above Lake Helena subwatershed. The Evergreen Nursing Home discharges to the Prickly Pear Creek above Lump Gulch subwatershed. East Gate Subdivision and Leisure Village discharge to the Lake Helena overland flow subwatershed. Facility locations are shown in Figure 8.

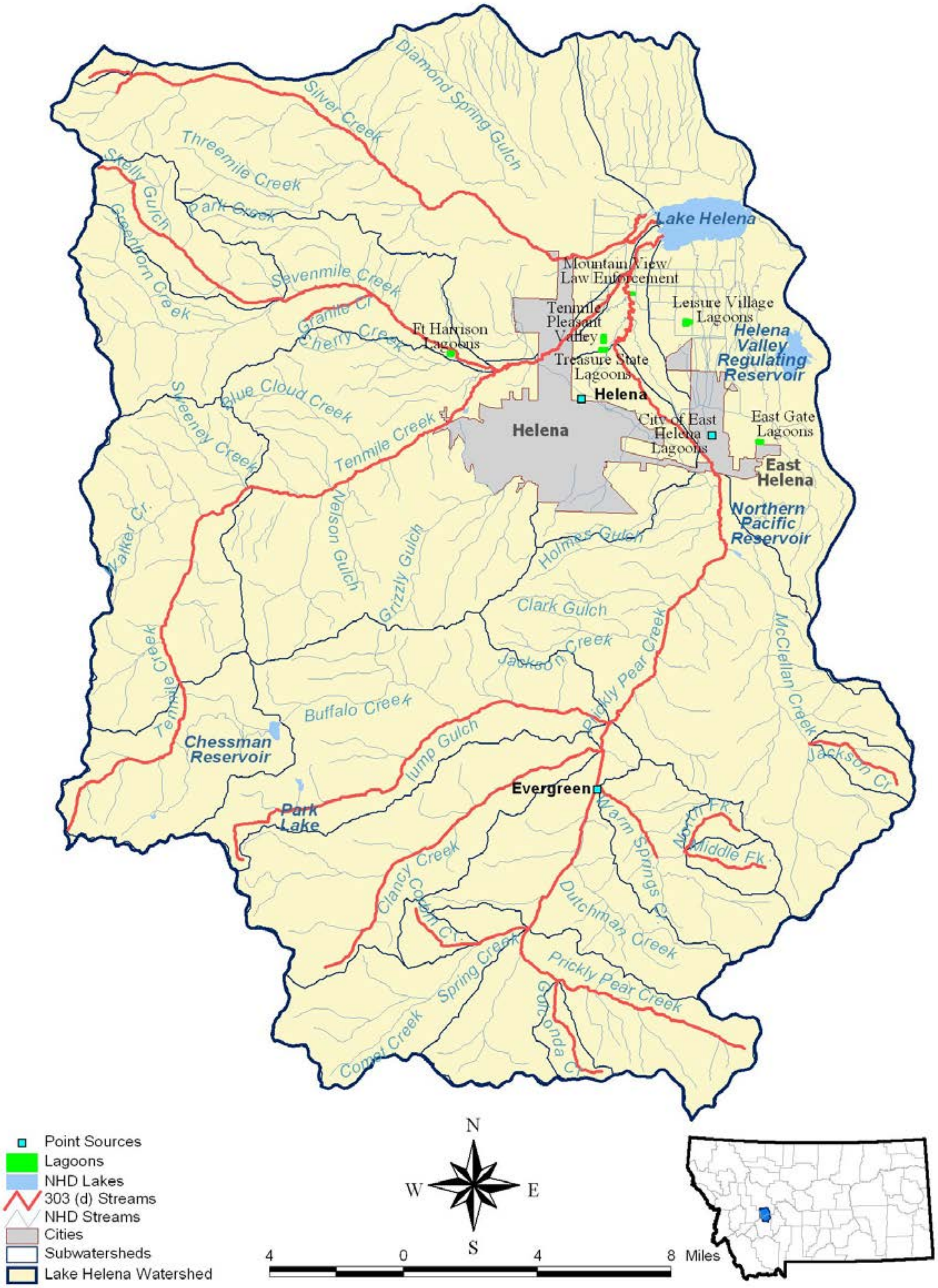

Figure 8. Location of Centralized Wastewater Facilities in the Lake Helena Watershed

2.4 Additional Considerations

The Lake Helena Watershed has several additional considerations that were accounted for in post-processing steps separate from the GWLF modeling. Assumptions regarding streambank erosion, drinking water plant diversions, abandoned mines, the Helena Valley Irrigation District, the City of Helena Stormwater System, and the existing sewer system are discussed in this section.

2.4.1 Streambank Erosion

Streambank erosion is an inherent part of channel evolution and can contribute significant quantities of sediment to stream systems based on a combination of climatic and physiographic features. However, anthropogenic impacts, such as grazing, mining, timber harvest, road encroachment, riparian vegetation removal, and/or channel alterations can result in elevated rates of streambank erosion. The intent of this analysis was to provide a sediment load estimate from streambank erosion within the listed watersheds. Modeled sediment load was allocated into two source categories: anthropogenic and natural.

Due to the size of the Lake Helena Watershed and the large number of listed stream miles, a coarse filter approach was used to estimate the sediment load related to streambank instability (See Appendix D). Bank Erosion Hazard Index (BEHI) assessments were conducted on intra-segment reaches to assess streambank erosion. Results from sampled reaches were averaged and extrapolated to the full perennial stream length within a listed stream segment's watershed. The BEHI assessments were based on a slightly modified version of the Rosgen (1996) method to characterize streambank conditions into numerical indices of bank erosion potential.

The modified BEHI methodology evaluated a streambank's inherent susceptibility to erosion as a function of six factors, including

- The ratio of streambank height to bankfull stage.
- The ratio of riparian vegetation rooting depth to streambank height.
- The degree of rooting density.
- The composition of streambank materials.
- Streambank angle (i.e., slope).
- Bank surface protection afforded by debris and vegetation.

To determine annual sediment load from eroding streambanks in each BEHI category, bank retreat rates developed by Rosgen (2001) were used (Table 17). The rate of erosion was then multiplied by the area of eroding bank (square feet) to obtain a volume of sediment per year, and then multiplied by the sediment density (average bulk densities were 1.41 g/cm^3 within granitic parent material, and 1.31 g/cm^3 outside of the batholith, U.S. Forest Service, 1998) to obtain a mass of sediment per year.

Table 17. Bank Retreat Rates Used for Banks of Varying Severity of Erosion

Bank Erosion Hazard Condition	Retreat Rate from Rosgen 2001 (ft/yr) – used for A and B channels	Retreat Rate from Rosgen 2001 (ft/yr) – used for C channels
Low	0.045	0.09
Moderate	0.17	0.34
High	0.46	0.7
Severe	0.82	1.2

Note: A, B, and C channels refer to Rosgen Stream Types.

Total sediment load from eroding streambanks of each sediment-listed stream was generated by averaging intra-segment (reach) sediment loads, and applying this value to the entire perennial segment length. For this purpose, each listed segment was divided into approximately 5 assessment reaches (actual number of reaches varied from 2 to 10) based on homogeneity of land use, vegetation and geomorphic character. Each listed reach outside the Helena National Forest boundary was visited, and BEHI measurements were conducted where eroding streambanks were observed.

In the reaches where bank instability was determined to be a significant source of sediment, a representative eroding streambank was surveyed using the BEHI methodology; the surveyors then extrapolated this bank configuration/condition for an identified percentage of the reach (or segment) length, which was observed through aerial photo assessment or direct visual assessment.

For example, if the BEHI analysis resulted in an average segment sediment load of 0.02 tons/foot/year from a segment's surveyed eroding streambank, the total channel length is 3 miles, and the condition of the surveyed eroding streambank represented 20 percent of the total channel length. (This 20 percent example relates to total eroding streambanks from river right and river left.) The 0.02 tons/foot/year is extrapolated to the entire eroding perennial streambank length of the segment; i.e., 20 percent of 3 miles (15,840 ft.) of streambank is 3,168 feet; applying the unit based sediment load of 0.02 tons (0.02 x 3168 ft) results in a total sediment load from eroding streambanks from this theorized segment of 63.4 tons/yr.

Additionally, the total sediment load related to eroding streambanks was allocated between naturally occurring and anthropogenically induced. This allocation was determined through observations during field reconnaissance and by aerial photo assessments. Land uses adjacent to, or in some cases upstream from, eroding streambanks were surveyed. The majority of land uses found to contribute to eroding streambanks included channel encroachment or sinuosity reductions related to transportation infrastructure, which includes interstate highways, city/county roads, forest roads, and rail-roads; riparian vegetation reduction caused by grazing in or near the riparian zones; and historic mining activities. Based on these assessment results, percentages of eroding bank lengths were generated and allocated to natural or anthropogenic sources within each segment.

Average BEHI ratings for all sediment listed segments varied between "moderate" and "high" for all the listed segments, however intra-segment reach BEHI ratings varied between "low" and "very high". Intra-segment variability was a product of heterogeneous land ownership and land use. BEHI rating and reach location were well correlated. Segments with BEHI ratings of "high" were largely confined to higher order stream segments lower in the watershed. Higher ordered segments tend to have finer substrate, and a greater intensity of land use, both, of which result in decreased streambank stability.

Sediment load from streambank erosion for the Lake Helena Watershed was estimated to be 6,162 metric tons/year. Of this total, 4,815 tons/year were generated within the Prickly Pear watershed, and the remaining 1,347 tons/year were generated within the Tenmile/Sevenmile watershed.

Streambank erosion was allocated between natural and anthropogenic sources by field and aerial assessment. Of the total sediment load (6,162 tons), 4,725 tons (approximately 77 percent) was related to anthropogenic activities; the remaining 1,438 tons (approximately 23 percent) was related to naturally occurring streambank erosion. The results of this analysis on a subwatershed basis are summarized below in Table 18.

Table 18. Sediment Loads from Eroding Streambanks by Source

Reach ID	Anthropogenic Related Eroding Banks (%)	Anthropogenic Sediment Load (mt/yr)	Natural Sediment Load (mt/yr)	Total Sediment Load (mt/yr)
Prickly Pear above Lake Helena	85%	516.6	91.2	607.8
Prickly Pear above WWTP	85%	20.5	3.6	24.1
Prickly Pear above Lump Gulch	100%	142.4	0.0	142.4
Prickly Pear above Spring Creek	55%	1134.7	928.4	2,063.1
Corbin Creek	90%	24.9	2.8	27.7
Spring Creek	95%	76.8	4.0	80.8
Clancy Creek	85%	1193.1	210.5	1,403.6
Warm Springs Creek	60%	35.1	23.4	58.5
Lump Gulch	80%	325.4	81.3	406.7
Middle Tenmile Creek	95%	296.8	15.6	312.4
Tenmile above Prickly Pear	95%	281.7	14.8	296.5
Skelly Gulch	45%	21.6	26.4	47.9
Sevenmile Creek	95%	652.2	34.3	686.5
Jennies Fork	70%	2.7	1.2	3.9

2.4.2 Upper Tenmile Creek Diversions

Drinking water for the City of Helena is processed at the City of Helena Tenmile Water Plant. During the summer months, the plant receives supplemental flows from the Missouri River Water Plant. The plant gets the majority of its water from head gates on Tenmile Creek, Beaver Creek, Minnehaha Creek, Moose Creek, and Walker Creek, which are all located in the Upper Tenmile subwatershed. Daily head gate flows were provided from the Tenmile Plant for January 1990 through June 2005. Flows and associated nutrient loads were subtracted from GWLF results on a monthly basis to account for these diversions.

2.4.3 Abandoned Mines

Sediment loads associated with abandoned mining were calculated for sites throughout the Lake Helena watershed. Potential sediment source locations were delineated from the High Priority Abandoned Hardrock Mine Sites, and Abandoned and Inactive Mines of Montana, as well as the National Hydrography Dataset GIS data layers. Potential sediment source delineation criteria were as follows: mine sites within 300 feet of a stream, or mines within 1,000 feet of a stream in areas where slopes are greater than 30 percent.

This GIS exercise generated 223 mines deemed to be potential sediment sources. These mines were cross-referenced with Montana Bureau of Mines and Geology (MBMG) reports, and the Montana State Bureau of Abandoned Mines. Available MBMG documents reported that 12 of the Abandoned-Inactive mines were probable sediment sources. Additionally, records of High Priority Abandoned Hardrock Mine Sites from the Montana State Bureau of Abandoned Mines indicated that 18 additional mine sites were probable sediment sources. Locations of sediment producing mines are shown in Figure 9. The

MBMG and Bureau of Abandoned Mine reports contained CAD drawings of the mine sites with areas and volumes of tailings and waste rock piles.

Area-based sediment loads for waste rock piles were obtained from a report produced by CDM, for USEPA, for use in the Upper Tenmile Creek Mining Area Superfund site. CDM used RUSLE version 1.06 to generate a sediment yield of 27 tons/acre/year from nose slopes, and 16 tons/acre/year from side slopes of waste rock piles in loamy-sand textured soil. Sediment delivery ratios were generated based on methodology described in *Guidelines for the Use of the Revised Universal Soil Loss Equation (RUSLE) Version 1.06 on Mined Lands, Construction Sites, and Reclaimed Lands* (Toy and Galetovic, 1999).

Five of the High Priority Abandoned Mine sites were reported to be reclaimed. The level of reclamation, and associated reduction in sediment production was assessed at each of the five sites. Of the five mine sites, only one (Alta) was not fully vegetated and continued to generate sediment. Pre- and post-reclamation sediment loads were calculated for reclaimed mine scenarios.

Table 19 and Table 20 describe the sediment loads associated with each mine site determined to be a sediment source. Five of the mines (Gregory, Alta, Bertha, Nellie Grant, and Corbin Flats) have been reclaimed in recent years, and correspondingly the associated sediment yield has decreased. The total pre-reclamation sediment load from abandoned mines was 1,098 tons/year, or 0.03 percent of the total Lake Helena sediment load; total post reclamation sediment load was 456 tons/yr, or 0.01 percent of total Lake Helena sediment load. Watershed wide, reclamation activities reduced abandoned mine related sediment yield by 642 ton/year, or 59 percent.

Sediment and nutrient loads were added to the appropriate watershed as described in Table 21. Nutrient loads were derived by applying the sediment nutrient concentrations discussed in Section 2.3.1.

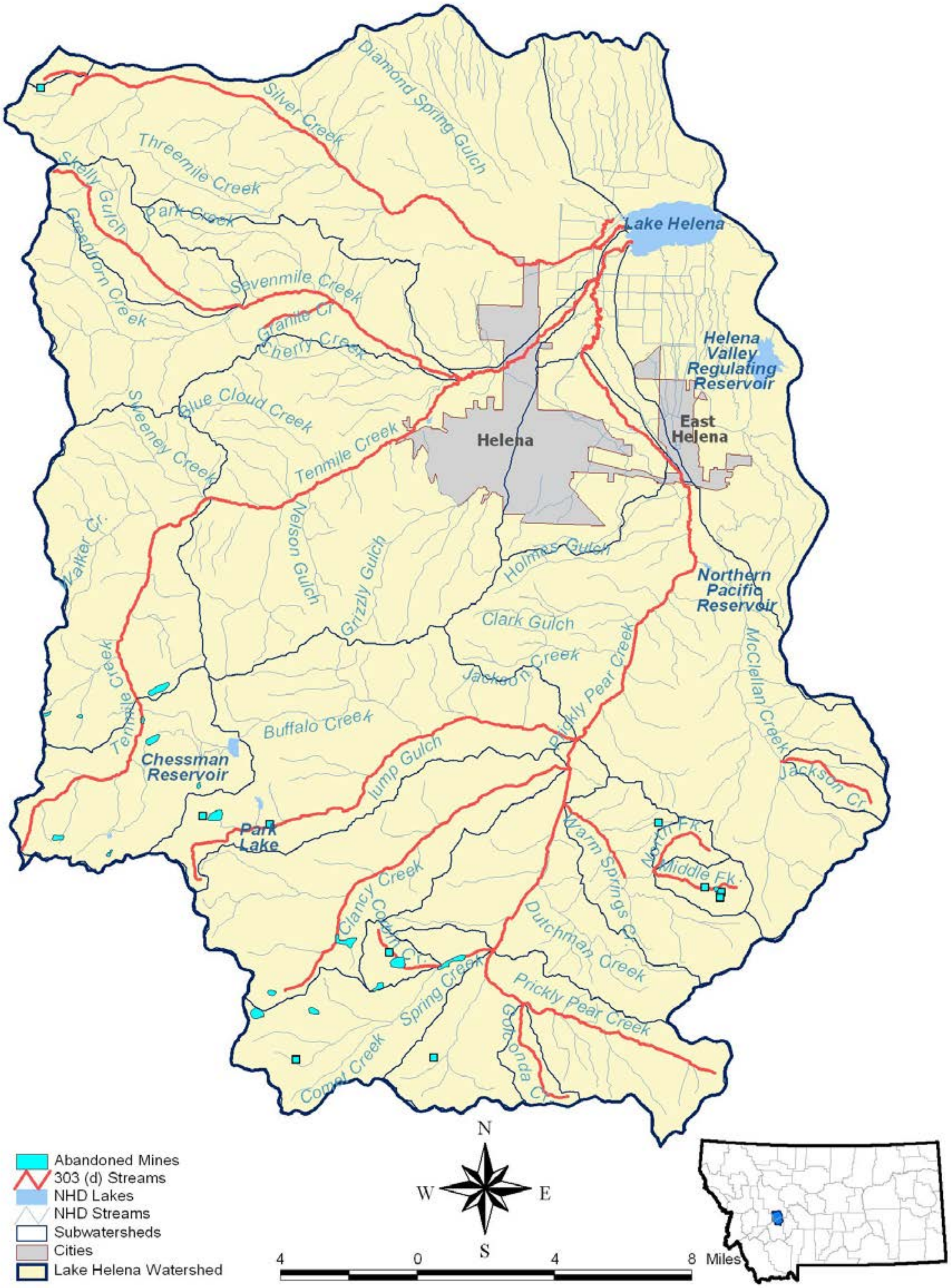

Figure 9. Location of Sediment-Producing Abandoned Mines in the Lake Helena Watershed

Table 19. Sediment Loads from Abandoned Mine Sites

Mine	Watershed	Total Sediment Producing Area (ft^2)	Pre-reclamation Sediment Load (mt/yr)	Post-reclamation Sediment Load (mt/yr)
Crawley Camp	Clancy Creek	No data	No data	No data
Gregory	Clancy Creek	77,235	32.8	0.0
Alta	Corbin Creek	39,000	16.1	16.1
Bertha	Corbin Creek	12,510	4.4	0.06
Black Jack Mine	Corbin Creek	11,769	4.6	N/A
Nellie Grant	Lump Gulch	5,040	1.0	0.01
Frohner Mine And Mill	Lump Gulch	87,120	44.1	N/A
Yama Group Mine	Lump Gulch	33,750	6.2	N/A
Middle Fork Warm Springs	Middle Fork Warm Springs	27,300	8.8	N/A
Solar Silver	Middle Fork Warm Springs	12,000	4.9	N/A
Newburgh Mine / Fleming Mine	Middle Fork Warm Springs	205,921	81.1	N/A
Warm Springs Tailings Adit	Middle Fork Warm Springs	369,453	98.7	N/A
White Pine Mine	Middle Fork Warm Springs	70,639	31.9	N/A
Armstrong Mine	Middle Tenmile Creek	46,475	13.8	N/A
Beatrice	Middle Tenmile Creek	7,695	2.3	N/A
Upper Valley Forge	Middle Tenmile Creek	7,590	2.2	N/A
Copper Gulch	Prickly Pear above Spring Creek	19,602	3.9	N/A
Bluebird	Spring Creek	8,7915	47.0	N/A
Corbin Flats	Spring Creek	1,742,400	587.9	0.0
Washington	Spring Creek	61,440	31.5	N/A
Salvai / Mt Washington Mine	Spring Creek	32,065	10.9	N/A
Monitor Creek Tailings	Upper Tenmile Creek	10,500	5.3	N/A
National Extension	Upper Tenmile Creek	12,000	6.1	N/A
Peter	Upper Tenmile Creek	1,150	0.6	N/A
Red Mountain	Upper Tenmile Creek	15,675	6.2	N/A
Red Water	Upper Tenmile Creek	4,500	2.3	N/A
Valley Forge/Susie	Upper Tenmile Creek	26,700	10.4	N/A
Woodrow Wilson	Upper Tenmile Creek	600	0.3	N/A
Badger	Warm Springs Creek	43,877	19.7	N/A

Table 20. Sediment Loads from Abandoned Mine Sites by Sub-Watershed

Sub-watershed	Pre-reclamation Delivered Sediment Load (mt/yr)	Post-reclamation Delivered Sediment Load (mt/yr)	Reduction in Sediment Load from reclamation activities (%)
Clancy Creek	32.8	0.0	100%
Corbin Creek	25.1	4.7	81.3%
Spring Creek	677.4	89.5	86.8%
Lump Gulch	51.3	50.3	1.9%
Middle Fork Warm Springs	225.4	N/A	0.0%
Warm Springs Creek	19.7	N/A	0.0%
Prickly Pear above Spring Creek	3.9	N/A	0.0%
Silver Creek	12.5	N/A	0.0%
Middle Tenmile Creek	18.3	N/A	0.0%
Upper Tenmile Creek	31.2	N/A	0.0%
Total	1,098	N/A	0.0%

Table 21. Sediment and Nutrient Loads from Abandoned Mines in the Lake Helena Watershed

Subwatershed	Delivered Sediment Load (mt/yr)	Total Nitrogen Load (mt/yr)	Total Phosphorus Load (mt/yr)
Corbin Creek	20.78	0.06	0.009
Lump Gulch	50.29	0.15	0.022
Middle Fork Warm Springs	151.27	0.45	0.067
Middle Tenmile Creek	18.30	0.05	0.008
Prickly Pear above Spring Creek	3.94	0.01	0.002
Silver Creek	12.53	0.04	0.006
Spring Creek	89.41	0.27	0.039
Upper Tenmile Creek	31.21	0.09	0.014
Warm Springs Creek	19.74	0.06	0.009

2.4.4 Loads from the Helena Valley Irrigation District

The GWLF model calculates nutrient loads resulting from precipitation induced runoff and erosion and does not consider any water or loading inputs from irrigation. Irrigation loading is therefore considered separately in the model. The Helena Valley Irrigation District provides approximately 350 cfs of water pumped from the Missouri River to the Lake Helena Watershed from mid-April through September each year (Jim Foster, Helena Valley Irrigation District, personal communications, October 6, 2004). A water balance based on weir measurements of canal and drain flows, crop water use, and evaporation from the open conduits was used to apportion flows into groundwater recharge and drain overflow fractions. The results are presented in Table 22 for a typical water year (2003).

Nutrient loads were estimated by applying appropriate concentrations to each source of flow from the irrigation district. Groundwater-recharge nutrient concentrations were based on suggested GWLF values for primarily agricultural watersheds: 0.71 mg-N/L and 0.104 mg-P/L. The nutrient concentrations in overflow drains were estimated by averaging values observed in three overflow drains during the summer of 2004 (0.71 mg-N/L and 0.037 mg-P/L). Resulting loads are 52 metric tons of total nitrogen and 6.6 metric tons of total phosphorus for 2003.

Table 22. Water Balance for the Helena Valley Irrigation District for 2003

Month	Groundwater Recharge (cfs)	Drain Overflow (cfs)	Evaporation (cfs)	Total Flow to Lake Helena (cfs)
April	25.0	56.0	0.25	80.75
May	36.5	39.5	0.39	75.61
June	178.0	41.0	0.45	218.55
July	200.3	29.7	0.63	229.37
August	210.9	51.1	0.53	261.47
September	129.7	34.3	0.31	163.69

Detailed water balance data were not available for the other modeling years. However, the Bureau of Reclamation provided water supply records for the years 1993 through 1996, 1999 through 2001, and 2003. A regression of net supply versus annual precipitation allowed for an estimation of net supply for years that records are not available. The estimated or observed net supply was then compared with that of 2003 to scale loads and flow volumes from the irrigation district. Table 23 shows the flows and loads for each modeling year.

Table 23. Additional Flow Volumes and Loads from the Helena Valley Irrigation District

Year	Scale Factor	Flow (MG)	TN (mt)	TP (mt)
1993	0.878	17,160	45.6	5.78
1994	0.988	19,311	51.3	6.51
1995	0.893	17,459	46.4	5.88
1996	1.053	20,572	54.7	6.93
1997	1.076	21,039	55.9	7.09
1998	1.130	22,092	58.7	7.45
1999	1.117	21,834	58.0	7.36
2000	1.130	22,082	58.7	7.44
2001	1.100	21,505	57.2	7.25
2002	1.164	22,755	60.5	7.67
2003	1.000	19,546	52.0	6.59

2.4.5 City of Helena Stormwater System

The City of Helena currently has a stormwater drainage system that eventually drains into several tributaries of the Lake Helena watershed. The City has applied for a permit under the Small Municipal Separate Storm Sewer System (MS4), but at the time of this report, the permit has not yet been granted. A detailed description of the system is provided in Appendix E and Appendix J.

2.4.6 Sewer System Expansion – Hypothetical Scenario

The City of Helena provides sewer service to areas in the Tenmile and Prickly Pear Creek watersheds. The City of East Helena also provides sewer service to portions of the Prickly Pear Creek watershed as well as the overland flow subwatershed. The existing sewer area covers approximately 15.8 square miles. Two hypothetical sewer system expansion scenarios were created to illustrate the impacts of sewer expansion. The first scenario (Scenario 1) assumes a 5.3 sq. mi. annexation area adjacent to existing sewer infrastructure. The second scenario (Scenario 2) assumes an additional 15.9 sq. mi. area where there is a fairly high density of subdivisions on septic systems. Figure 10 shows the areas currently served by sewer and the two hypothetical expansion areas.

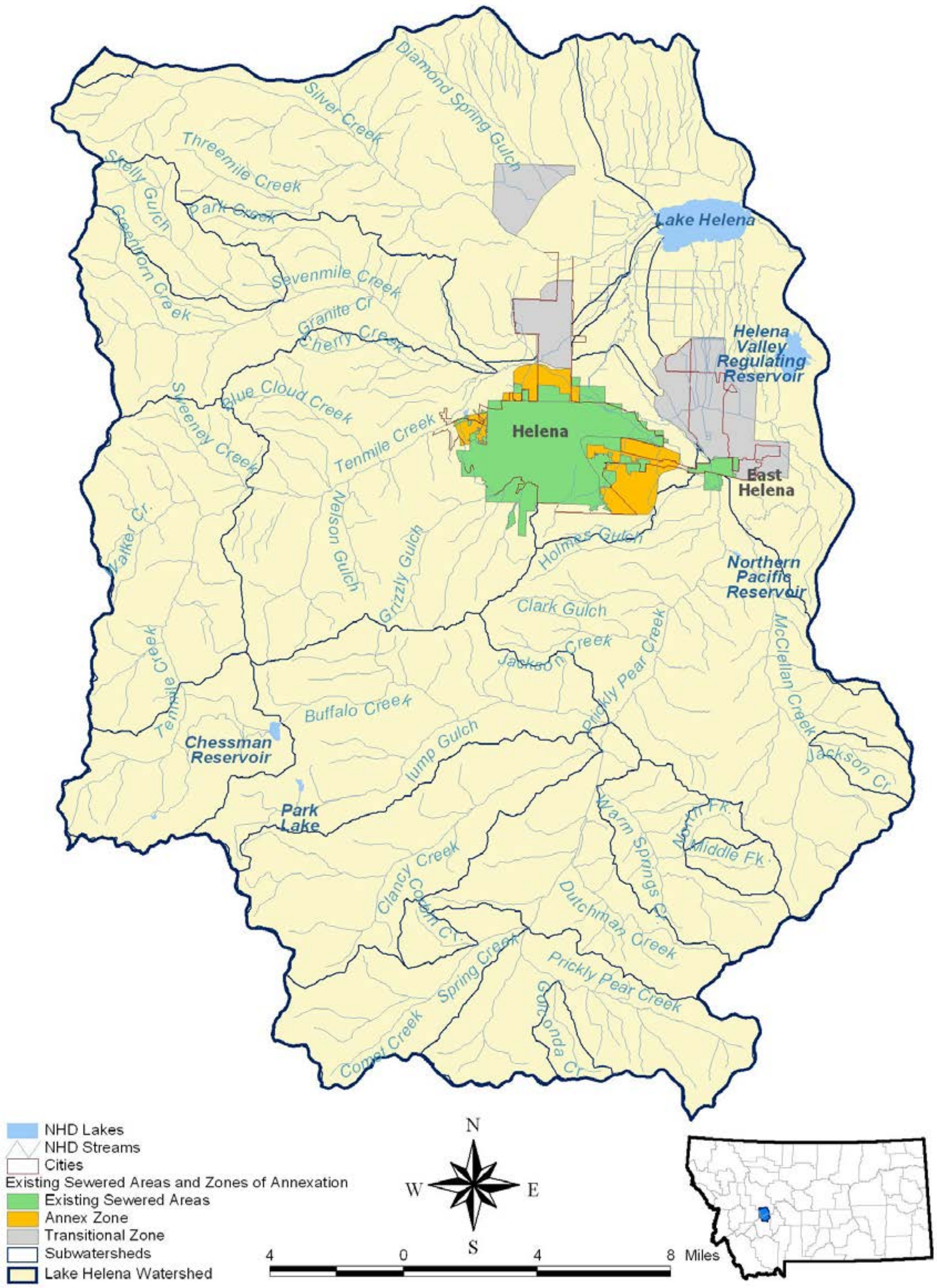

Figure 10. Sewer Service and Hypothetical Sewer System Expansion Zones in the Lake Helena Watershed

The GWLF model was used to estimate the potential impacts of sewer system expansion on total nitrogen and total phosphorus loading in each watershed. Table 24 and Table 25 show the simulation results. Scenario 1 would replace a total of 466 septic systems serving approximately 1,165 people and Scenario 2 would replace an additional 3,718 septic systems serving approximately 9,295 people.

The predicted net impact (i.e., at the Lake Helena watershed scale) of the hypothetical annexations is a decrease in nitrogen loads (-24%) and an increase in phosphorus loads (30%). Note that these values are based on the assumption that 7 percent of septic systems in the annexation areas are currently failing. Due to the smaller lot sizes in the City limits, the failure rate in this area is likely higher, and annexation may provide more reduction than assumed here. Also, estimated increases in loading from the City of Helena WWTP are based on current average plant effluent nutrient concentrations (7.7 mg-N/L and 5.0 mg-P/L). Enhanced WWTP treatment efficiency could improve the results substantially.

For Demonstration Purposes Only

It should be noted that this analysis of sewer system expansion has been conducted and presented for demonstration purposes only. It may not reflect details about specific expansion projects that may be pursued by the Cities of Helena or East Helena as well as the surrounding communities. However, it has been presented to demonstrate that the resulting water quality impacts of sewer system expansion may not be as expected, intuitively (i.e., they may not necessarily result in improved water quality). Future sewer system expansion projects should be accompanied by a water quality impact analysis conducted at the watershed scale, such that the overall affects (positive or negative) can be viewed in the proper context.

Table 24. Comparison of Cumulative Nitrogen Loading Under Two Hypothetical Annexation Scenarios

Watershed Component	Current Nitrogen Load mt/yr	Nitrogen Load Scenario 1 mt/yr	Net Percent Change	Nitrogen Load Scenarios 1 and 2 Combined mt/yr	Net Percent Change
Tenmile Creek: Septic Systems	16.8	12.7	-24.3%	11.3	-32.9%
Prickly Pear Creek: Septic Systems	33.6	28.8	-14.3%	25.5	-24.2%
Silver Creek: Septic Systems	36.9	36.9	0.0%	17.5	-52.7%
Overland Flow: Septic Systems	21.5	21.5	0.0%	6.2	-71.4%
WWTPs	36.5	37.8	3.6%	48.2	32.1%
Entire Lake Helena Watershed: Septic Systems and WWTP	128.6	125.1	-2.7%	97.3	-24.3%

Table 25. Comparison of Cumulative Phosphorus Loading Under Two Hypothetical Annexation Scenarios

Watershed Component	Current Phosphorus Load mt/yr	Phosphorus Load Scenario 1 mt/yr	Net Percent Change	Phosphorus Load Scenarios 1 and 2 Combined mt/yr	Net Percent Change
Tenmile Creek: Septic Systems	0.2	0.1	-24.3%	0.1	-32.9%
Prickly Pear Creek: Septic Systems	0.3	0.3	-14.3%	0.2	-24.2%
Silver Creek: Septic Systems	0.3	0.3	0.0%	0.2	-52.7%
Overland Flow: Septic Systems	0.2	0.2	0.0%	0.1	-71.4%
WWTPs	13.6	14.1	3.9%	18.3	34.7%
Entire Lake Helena Watershed: Septic Systems and WWTP	14.5	14.9	3.3%	18.8	29.9%

2.5 Summary of Pollutant Loading Sources

The GWLF modeling and additional analyses incorporate all known point and nonpoint sources of pollutant loading in the watershed. Table 26 summarizes each source category and the assumptions used to estimate pollutant loading.

Table 26.Summary of Pollutant Loading Sources in the Lake Helena Watershed

Source Category	Source	Summary/Description/Assumptions
Anthropogenic Nonpoint Sources	Timber Harvest	To account for harvesting activities in the watershed, forest was modeled by GWLF in one of three categories: (1) clear-cut, (2) regrowth, or (3) full growth condition. Forestland in the Lake Helena Watershed is owned by private land owners, the Bureau of Reclamation, Department of Natural Resources, Bureau of Land Management, and the Helena National Forest. Databases were obtained from each agency to estimate average harvest acreages. Harvest data on private lands was not available, so a continuous 90-yr harvesting cycle (Stuart, 2004) was assumed. To estimate the area of regrowth on private lands, a 5 year regrowth period (to re-establish full growth ground cover) was assumed. The curve numbers, cover factors, and nutrient runoff concentrations for each silvicultural land use category vary from typical forestland as described in Table 5, Table 7, and Table 9.
	Unpaved Roads	Road areas and corresponding road surface materials in the watershed were distinguished based on GIS data layers acquired from Lewis and Clark and Jefferson Counties and the Helena National Forest. The road polylines were converted into areas based on average widths from field data collected in 2005. Unpaved roads were buffered to a total width of 22 feet. The curve numbers, cover factors, and nutrient runoff concentrations of unpaved roads are described in Table 5, Table 7, and Table 9.
	Non-system Roads	Non-system roads are those built for recreational purposes (dirt bikes, four wheelers, etc.) and are not built to approved specifications. Road slope is assumed to follow the land gradient rather than incorporate switch-backs. Ditches and cross drains are not present. In the Helena National Forest, non-system roads were estimated to comprise an additional 4.6 percent of the area of unpaved roads (Stuart, 2004). This value was extrapolated to the entire Lake Helena Watershed where unpaved roads are present. The curve numbers, cover factors, and nutrient runoff concentrations of non-system roads are described in Table 5, Table 7, and Table 9.
	Paved Roads	Road areas and corresponding road surface materials in the watershed were distinguished based on GIS data layers acquired from Lewis and Clark and Jefferson Counties and the Helena National Forest. The road polylines were converted into areas based on average widths from field data collected in 2005. Paved roads were buffered to a total width of 26 feet. The curve numbers, cover factors, and nutrient runoff concentrations of paved roads are described in Table 5, Table 7, and Table 9.
	Active Mines and Quarries	Identification of active mines and quarries is based on the Multi-Resolution Land Characterization (MRLC) dataset acquired between 1991 and 1993. Updates to the data based on 2004 high-resolution color orthophotos of the Helena Valley were made to reflect current conditions in the Lake Helena watershed. Only areas draining offsite, based on topographic data, were included in the pollutant loading estimates. The curve numbers, cover factors, and nutrient runoff concentrations for active mines and quarries are described in Table 5, Table 7, and Table 9.
	Abandoned Mines	Sediment loads associated with abandoned mining were calculated for sites throughout the Lake Helena watershed. Potential sediment source locations were delineated from the High Priority Abandoned Hardrock Mine Sites, and Abandoned and Inactive Mines of Montana, as well as the National Hydrography Dataset GIS data layers. Potential sediment source delineation criteria were as follows: mine sites within 300 feet of a stream, or mines within 1,000 feet of a stream in areas where slopes are greater than 30 percent. This GIS exercise generated 223 mines deemed to be potential sediment sources. These mines were cross-referenced with Montana Bureau of Mines and Geology (MBMG) reports, and the Montana State Bureau of Abandoned Mines. Available MBMG documents reported that 12 of the Abandoned-Inactive mines were probable sediment sources. Additionally, records of High Priority Abandoned Hardrock Mine Sites from the Montana State Bureau of Abandoned Mines indicated that 18 additional mine sites were probable sediment sources. Area-based sediment loads for waste rock piles were obtained from a report produced by CDM, for USEPA, for use in the Upper Tenmile Creek Mining Area Superfund site. CDM used RUSLE version 1.06 to generate a sediment yield of 27 tons/acre/year from nose slopes, and 16 tons/acre/year from side slopes of waste rock piles in loamy-sand textured soil. Sediment delivery ratios were generated based on methodology described in *Guidelines for the Use of the Revised Universal Soil Loss Equation (RUSLE) Version 1.06 on Mined Lands, Construction Sites, and Reclaimed Lands* (Toy and Galetovic, 1999). Five of the High Priority Abandoned Mine sites were reported to be reclaimed. The level of reclamation, and associated reduction in sediment production was assessed at each of the five sites. Sediment and nutrient loads from abandoned mines are summarized in Table 18, Table 19, and Table 20.
	Agriculture	Identification of agricultural areas (pasture/hay, small grains, row crops, fallow fields) is based on the Multi-Resolution Land Characterization (MRLC) dataset acquired between 1991 and 1993. Updates to the data based on 2004 high-resolution color orthophotos of the Helena Valley were made to reflect current conditions in the Lake Helena watershed. The curve numbers, cover factors, and nutrient runoff concentrations for each agricultural land use are described in Table 5, Table 7, and Table 9.
	Urban Areas	Identification of urban areas (low and high intensity residential, commercial, industrial, transportation, etc.) is based on the Multi-Resolution Land Characterization (MRLC) dataset acquired between 1991 and 1993. Updates to the original data and refinements of land use categories were made to reflect current conditions in the Lake Helena watershed based on 2004 high-resolution color orthophotos of the Helena Valley. Additionally, a new class of low-intensity residential development was added to reflect the low-density style of land development in the more rural areas of the Lake Helena Watershed. The curve numbers, cover factors, and nutrient build-up washoff rates for each urban land use are described in Table 5, Table 7, and Table 9.

Table 26.Summary of Pollutant Loading Sources in the Lake Helena Watershed

Source Category	Source	Summary/Description/Assumptions
	Anthropogenic Streambank Erosion	Bank Erosion Hazard Index (BEHI) assessments were conducted on intra-segment reaches of streams in the Lake Helena watershed to assess streambank erosion. Results from sampled reaches were averaged and extrapolated to the full perennial stream length within a listed stream segment's watershed. To determine annual sediment load from eroding streambanks in each BEHI category (low, moderate, high, severe), bank retreat rates developed by Rosgen (2001) were used (Table 16). The rate of erosion was then multiplied by the area of eroding bank to obtain a volume of sediment per year, and then multiplied by the average bulk sediment density to estimate mass. Additionally, the total sediment load related to eroding streambanks was allocated between naturally occurring and anthropogenically induced erosion. This allocation was determined through observations during field reconnaissance and by aerial photo assessments. Land uses adjacent to, or in some cases upstream from, eroding streambanks were surveyed and correlated to natural or anthropogenic erosion conditions.
	Helena Valley Irrigation System	The Helena Valley Irrigation District provides approximately 350 cfs of water pumped from the Missouri River to the Lake Helena Watershed from mid-April through September each year (Foster, 2004). A water balance for year 2003 based on weir measurements of canal and drain flows, crop water use, and evaporation from the open conduits was used to apportion flows into groundwater recharge and drain overflow fractions during a typical water year. Nutrient loads were estimated by applying appropriate concentrations to each source of flow from the irrigation district. Groundwater-recharge nutrient concentrations were based on suggested GWLF values for primarily agricultural watersheds: 0.71 mg-N/L and 0.104 mg-P/L. The nutrient concentrations in overflow drains were estimated by averaging values observed in three overflow drains during the summer of 2004 (0.71 mg-N/L and 0.037 mg-P/L). Detailed water balance data were not available for the other modeling years. However, the Bureau of Reclamation provided water supply records for the years 1993 through 1996, 1999, 2000, 2001, and 2003. A regression of net supply and annual precipitation allowed for an estimation of net supply for years that records were not available.
	Septic Systems	The population served by septic systems in the Lake Helena watershed (Table 12) is based on the Lewis and Clark County GIS database of permitted systems, the ratio of permitted systems to total systems reported in the Lewis and Clark County Inventory of Onsite Wastewater Treatment Systems (2001), the ratio of total systems to wells, and well data collected in Lewis and Clark and Jefferson Counties. Based on national average failure rates, it was assumed that 7 percent of all systems were failing such that tank effluent bypassed treatment by soil adsorption and plant uptake. Tank effluent loading rates and plant uptake rates are shown in Table 13.
Natural Nonpoint Sources	Fullgrowth Forest	Identification of forest areas (deciduous, evergreen, and mixed) is based on the Multi-Resolution Land Characterization (MRLC) acquired between 1991 and 1993. Updates to the original data and refinements of land use categories were made to reflect current conditions in the Lake Helena watershed based on 2004 high-resolution color orthophotos of the Helena Valley. The curve numbers, cover factors, and nutrient concentrations for each forest land use are described in Table 5, Table 7, and Table 9.
	Wetlands	Identification of wetland areas (woody and herbaceous) is based on the Multi-Resolution Land Characterization (MRLC) acquired between 1991 and 1993. Updates to the original data and refinements of land use categories were made to reflect current conditions in the Lake Helena watershed based on 2004 high-resolution color orthophotos of the Helena Valley. The curve numbers, cover factors, and nutrient concentrations for each wetland land use are described in Table 5, Table 7, and Table 9.
	Shrubland	Identification of shrubland areas is based on the Multi-Resolution Land Characterization (MRLC) acquired between 1991 and 1993. Updates to the original data and refinements of land use categories were made to reflect current conditions in the Lake Helena watershed based on 2004 high-resolution color orthophotos of the Helena Valley. The curve numbers, cover factors, and nutrient concentrations for shrubland are described in Table 5, Table 7, and Table 9.
	Grassland	Identification of grassland areas is based on the Multi-Resolution Land Characterization (MRLC) acquired between 1991 and 1993. Updates to the original data and refinements of land use categories were made to reflect current conditions in the Lake Helena watershed based on 2004 high-resolution color orthophotos of the Helena Valley. The curve numbers, cover factors, and nutrient concentrations for grassland are described in Table 5, Table 7, and Table 9.
	Natural Streambank Erosion	Bank Erosion Hazard Index (BEHI) assessments were conducted on intra-segment reaches of streams in the Lake Helena watershed to assess streambank erosion. Results from sampled reaches were averaged and extrapolated to the full perennial stream length within a listed stream segment's watershed. To determine annual sediment load from eroding streambanks in each BEHI category (low, moderate, high, severe), bank retreat rates developed by Rosgen (2001) were used (Table 16). The rate of erosion was then multiplied by the area of eroding bank to obtain a volume of sediment per year, and then multiplied by the average bulk sediment density to estimate mass. Additionally, the total sediment load related to eroding streambanks was allocated between naturally occurring and anthropogenically induced erosion. This allocation was determined through observations during field reconnaissance and by aerial photo assessments. Land uses adjacent to, or in some cases upstream from, eroding streambanks were surveyed and correlated to natural or anthropogenic erosion conditions.

Table 26.Summary of Pollutant Loading Sources in the Lake Helena Watershed

Source Category	Source	Summary/Description/Assumptions
	Groundwater	The GWLF model has three subsurface zones: a shallow unsaturated zone, a shallow saturated zone, and a deep aquifer zone. Behavior of the second two stores is controlled by a groundwater recession and a deep seepage coefficient. The recession coefficient was set to 0.01 per day and the deep seepage coefficient to 0, based on several calibration runs of the model. Groundwater nutrient concentrations were based on baseflow measurements reported in the GWLF manual for various levels of forested and agriculturally developed watersheds. Completely forested watersheds have values of 0.07 mg-N/L and 0.012 mg-P/L. Primarily agricultural watersheds have values of 0.71 mg-N/L and 0.104 mg-P/L. Intermediary values are also reported. Values for each subwatershed were assigned based on the percent forest and agricultural land use in the watershed.
Anthropogenic Point Sources	City of Helena: post-upgrades	The City of Helena wastewater treatment facility is located in the northeast section of Helena, Montana in the Prickly Pear Creek watershed. Prior to 2001, the facility operated a secondary treatment bio-tower system. In June of 2001, an advanced secondary treatment wastewater system with nitrification/denitrification went online. Under Montana DEQ Permit MT0022641, the facility has a permitted discharge of 6.2 MGD, and permitted ammonia limits that vary by month. Discharge from the Helena treatment plant enters an unnamed irrigation ditch that originates near the facility and eventually flows into Prickly Pear Creek. However, during the irrigation season (April-October), irrigators withdraw water from the ditch, and discharge flows from the plant rarely reach Prickly Pear Creek. Losses due to irrigation of wastewater were applied from April through October. The nitrate present in the irrigated effluent (5.32 mg/L average post-upgrade value reported in DMRs) is assumed to pass through the system. Ninety percent of phosphorus is assumed removed by the irrigated fields.
	East Helena: post-upgrades	The City of East Helena wastewater treatment facility is located approximately 0.5 miles north of the city in the Prickly Pear Creek watershed. Prior to 2003, the facility operated three partially mixed ponds with a designed retention time of 30 days. In 2003, the plant was renovated and now operates an advanced secondary treatment activated sludge system with nitrification. Under Montana DEQ Permit #MT0022560, the facility has a permitted discharge of 0.43 MGD, permitted TP load of 20 lb/day, and a permitted TN load of 80 lb/day. At the time of the permit application, the system served approximately 1,673 people from East Helena and the surrounding area. The average observed flow rate from January 2003 to July 2005 was 0.20 MGD, with an average TN concentration of 23.2 mg/L, an average TP concentration of 3.6 mg/L, and an average NO_2+NO_3 concentration of 14.3 mg/L. Ammonia concentrations were non-detectable for most sampling events (less than 0.1 mg/L). Prior to the plant upgrade, ammonia concentrations were much higher (average of 4.1 mg/L) and NO_2+NO_3 concentrations much lower (average of 1.0 mg/L). The current values reflect the facility's new nitrification system, which converts ammonia to nitrate and nitrite.
	Evergreen Nursing Home	The Evergreen Nursing Facility is located in Clancy, Montana in the Prickly Pear Creek watershed. The facility operates a secondary treatment activated sludge wastewater system. Under Montana DEQ Permit MT0023566, the facility has a permitted discharge of 15,000 GPD, and does not currently have permit limits for any species of nitrogen or phosphorus. Thirty-four occupants along with all support staff for the Evergreen Nursing facility are served by this system. The average observed flow rate from January 1998 to April 2005 was 6,876 GPD, with an average TN concentration of 11.9 mg/L, an average TP concentration of 2.9 mg/L, and an average NO_2+NO_3 concentration of 8.4 mg/L.
	Treasure State Acres Subdivision	The Treasure State Acres subdivision is located approximately 1.5 miles north of the city of Helena in the Prickly Pear Creek watershed. Montana DEQ does not require a permit from this facility. There is currently a wastewater treatment system consisting of two storage ponds treating 0.1 MGD. Effluent is applied to cropland. There is insufficient pond storage capacity for the population served (Damschen & Associates, 1998), so full treatment is unlikely. Applied concentrations are based on USEPA (1997) values for post-sedimentation values, not stabilization values, of 25 mg-N/L and 8 mg-P/L (Table 14). The nitrate present in irrigated effluent is assumed to pass through the system, and the USEPA guidance suggests a value of 2 percent of the total nitrogen concentration to estimate nitrate concentrations in primary or secondary treatment effluent. Ninety percent of phosphorus is assumed removed by the irrigated fields.
	Tenmile and Pleasant Valley Subdivisions	The Tenmile and Pleasant Valley subdivisions are located approximately 1.5 miles north of the City of Helena (Helena Valley) in the Prickly Pear Creek subwatershed, and just north of the Treasure State Acres subdivision. Tenmile and Pleasant Valley are served by a 0.09 MGD wastewater treatment system consisting of four ponds designed for total retention with disposal via evaporation. Montana DEQ does not require a permit from this facility. Though current wastewater flows should fill all four ponds, only one pond currently fills. Water balance calculations performed by the authors of the Helena Valley Facility Plan conclude that excessive seepage is occurring from the ponds (Damschen & Associates, 1998). Because of this, Montana DEQ is currently pursuing enforcement action against the subdivision (Jim Lloyd, Personal Communications, September 27, 2005). It is assumed that 25 percent of the flow is discharged to the subsurface with concentrations typical of "stabilization pond effluent" and that 75 percent of the effluent is discharged to the subsurface at "after sedimentation" concentrations (Table 14). Phosphorus adsorption is assumed to uptake 90 percent of total phosphorus; however, all inorganic nitrogen is assumed to pass through to groundwater.
	Mountain View Law Enforcement Academy	The Mountain View Law Enforcement Academy is located approximately 3.5 miles north of the city of Helena in the subwatershed draining directly to Lake Helena. The academy currently possesses two small, facultative treatment ponds that treat 0.007 MGD. Montana DEQ does not require a permit from this facility. Effluent discharge occurs by evaporation, seepage, and direct discharge to Prickly Pear Creek. There is no evidence that the system is not operating as designed, so it is assumed that 100 percent of the flow discharges to Prickly Pear Creek with stabilization pond effluent values (Table 14). No surface area information or actual flow measurements are available to account for evaporative losses.

Table 26.Summary of Pollutant Loading Sources in the Lake Helena Watershed

Source Category	Source	Summary/Description/Assumptions
	Eastgate Subdivision	The Eastgate Subdivision Homeowners Association is located approximately one mile northeast of the city of East Helena. The subdivision currently operates a wastewater treatment system consisting of two mechanically aerated ponds that are designed to treat 0.15 million gallons per day (MGD). Montana DEQ does not require a permit for this facility. Final effluent is disposed via irrigation to cropland, and this system is currently in compliance and meeting design specifications. The concentrations reported for total nitrogen and total phosphorus after stabilization (USEPA, 1997) are 14.5 mg-N/L and 5 mg-P/L (Table 14). While no groundwater monitoring data are available, the nitrate present in irrigated effluent is assumed to pass through the system, and the USEPA guidance suggests a value of 2 percent of the total nitrogen concentration to estimate nitrate concentrations in primary or secondary treatment effluent. Ninety percent of phosphorus is assumed removed by the irrigated fields.
	Leisure Village Mobile Home Park	The Leisure Village Mobile Home Park is located approximately 1.5 miles northeast of the city of Helena in the subwatershed draining directly to Lake Helena. Four treatment/storage ponds receiving 0.1 MGD serve the Leisure Village Mobile Home Park. Montana DEQ does not require a permit from this facility. Only one pond currently fills, but waste flows are sufficient to fill all four ponds. It is assumed that 25 percent of the flow is discharged to the subsurface with concentrations typical of “stabilization pond effluent” and that 75 percent of the effluent is discharged to the subsurface at “after sedimentation” concentrations (Table 14). Phosphorus adsorption is assumed to uptake 90 percent of total phosphorus; however, all inorganic nitrogen is assumed to pass through to groundwater.
Total	Totals	All known point and non-point sources currently active in the Lake Helena watershed were included in the TMDLs. In general, MRLC data collected around 1992 were used to estimate the land use types in each watershed. Orthophotos of Helena Valley taken in 2004 were used to update the land use data to reflect current conditions. Road data were obtained from GIS data layers acquired from Lewis and Clark and Jefferson Counties and the Helena National Forest. Literature values were used for curve numbers, cover factors, and nutrient parameters for each land use. Septic system loading rates were based on GWLF default values for normal and failing systems and population estimates based on data collected in Lewis and Clark and Jefferson Counties. Separate loading analyses were performed for the Helena Valley Irrigation District, streambank erosion, abandoned mines, and centralized wastewater treatment systems.

2.6 GWLF Calibration

Calibration refers to the adjustment or fine-tuning of modeling parameters to reproduce observations. Hydrologic calibration precedes water quality calibration because runoff is the transport mechanism by which nonpoint pollution occurs. In an ideal situation, calibration is an iterative procedure of parameter evaluation and refinement as a result of comparing simulated and observed values of interest and is based on several years of simulation to evaluate parameters under a variety of climatic conditions. Unfortunately, limited flow and water quality data were available to perform this sort of a calibration for the Lake Helena watershed. Therefore, default values were used for most modeling parameters with limited adjustment during the calibration process. A comparison of the simulated and observed data is presented below and the implications of the limited available data and calibration are described further in Section 5.0.

2.6.1 Hydrologic Calibration

The GWLF model predicts flow volumes from runoff at monthly intervals. Flows from the Helena Valley Irrigation District and wastewater treatment plants were added during post-processing. Simulated flows were compared to observed flows at USGS Gage 06061500 (Prickly Pear Creek near Clancy, MT) during model calibration. Daily flows reported from January 1980 through September 2002 were summed by month for comparison with the GWLF simulation. As shown in Figure 11 the period from 1980 to 2002 includes years with low, average, and high annual flows.

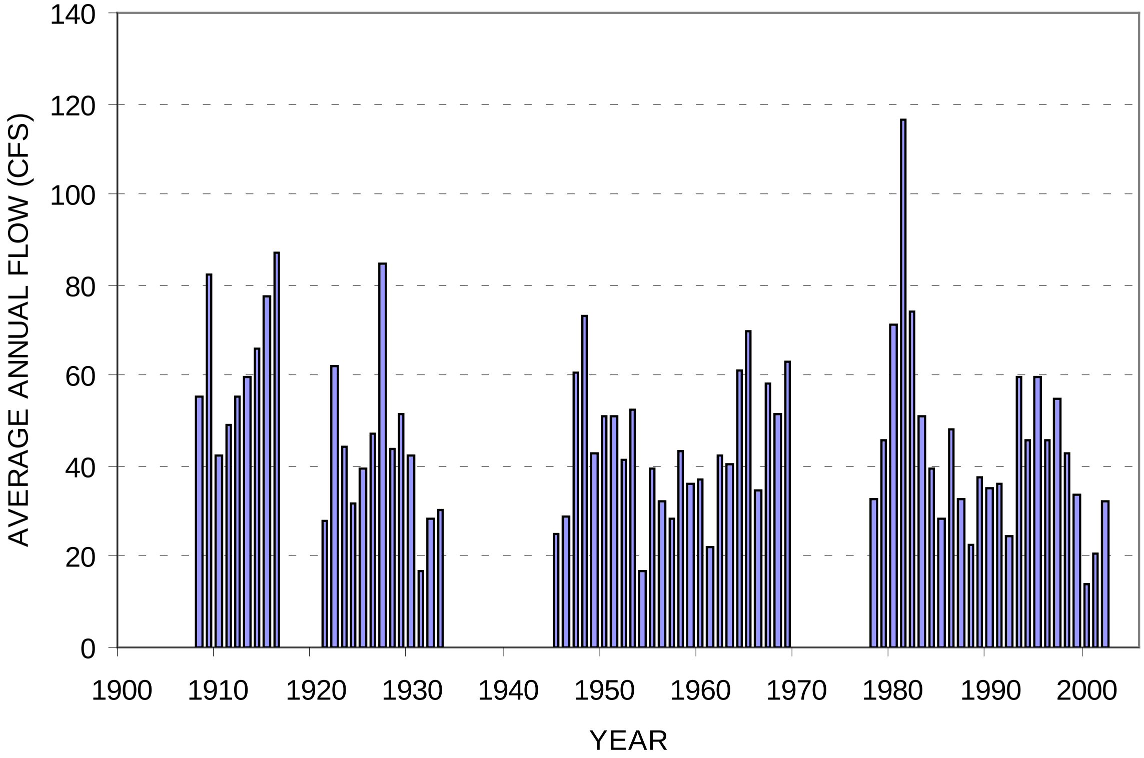

Figure 11. Average Annual Flows Over the Period of Record for Prickly Pear Creek Near Clancy (USGS Gage 06061500)

Figure 12 compares the monthly flow volumes observed at the gage to GWLF estimates and indicates that the model matches certain months better than others. In general the observed monthly flows appear to be less variable than the simulated monthly flows. This might be related to the use of only one weather station to represent precipitation throughout the watershed (see Section 2.2). Monthly flows are often over-estimated when high precipitation values (e.g., greater than 20 cm/month) are recorded at the Helena airport and are under-estimated when low precipitation values are recorded (e.g., less than 10 cm/month). Figure 12 also indicates that the model reasonably simulates runoff volumes during the typically wetter months of April through June. For example, Figure 13 compares the monthly flow volumes observed at the gage to GWLF estimates over a shorter time period (January 1998 through December 2000). GWLF matches the volume of the spring snowmelt period fairly well, although the timing is slightly late. Summer and fall flows are slightly over-estimated in 1998 and 1999 and under-estimated in 2000, possibly due to an inadequate representation in the model of flow withdrawals and other anthropogenic impacts.

Figure 14 displays the range of the monthly observed and simulated flows and also indicates greater variability in the simulated flows compared to the observed flows. The simulated maximum monthly flow is similar to the observed, although the minimum is considerably less.

Figure 15 compares the annual simulated and observed totals for the period 1980 to 2002 and indicates relatively close agreement for most years. The error in total stream flow for this period is 32 percent but only 20 percent if 1993 is excluded.

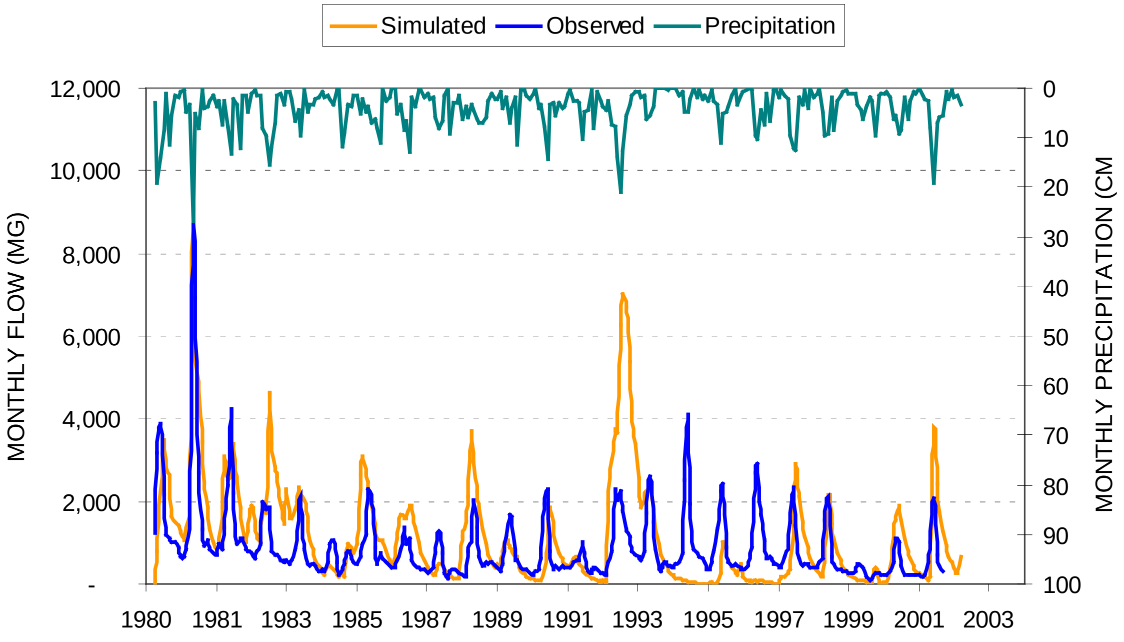

Figure 12. Comparison of Simulated and Observed Monthly Flow Volumes at USGS Gage 06061500, Along with Monthly Precipitation at the Helena Airport

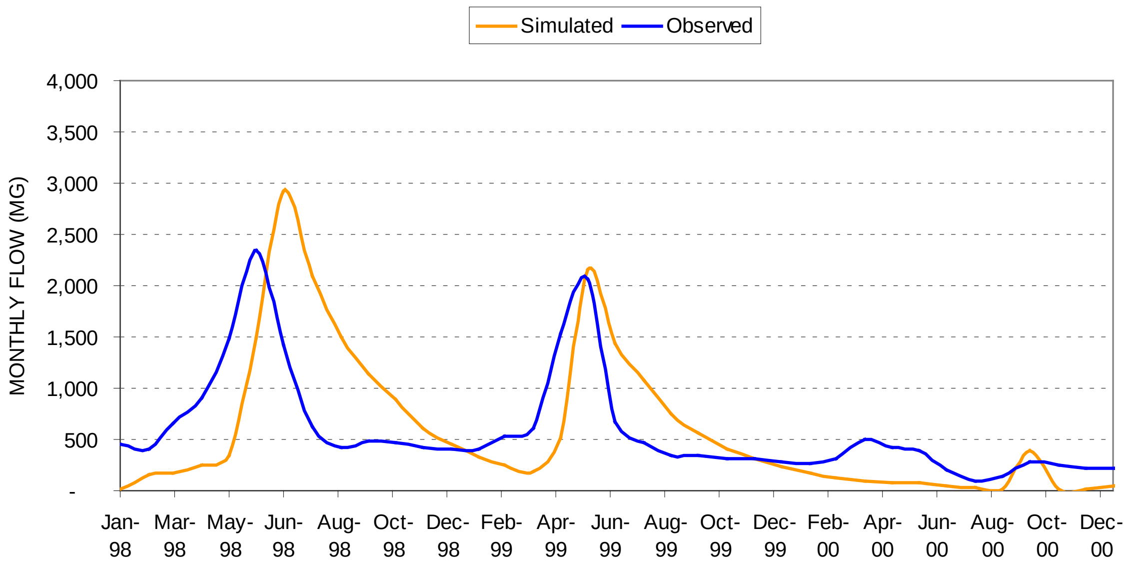

Figure 13. **Comparison of Simulated and Observed Monthly Flow Volumes at USGS Gage 06061500 for the Period January 1, 1998 through December 31, 2000**

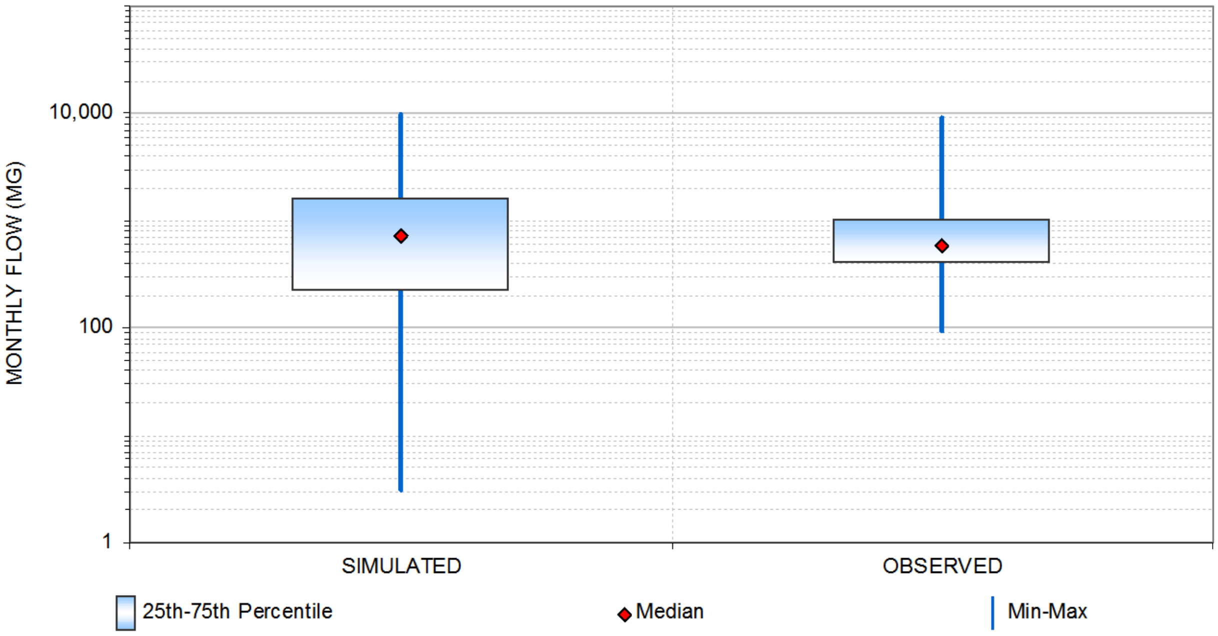

Figure 14. **Range of Simulated and Observed Monthly Flows at USGS Gage 06061500 for the period 1980 to 2002**

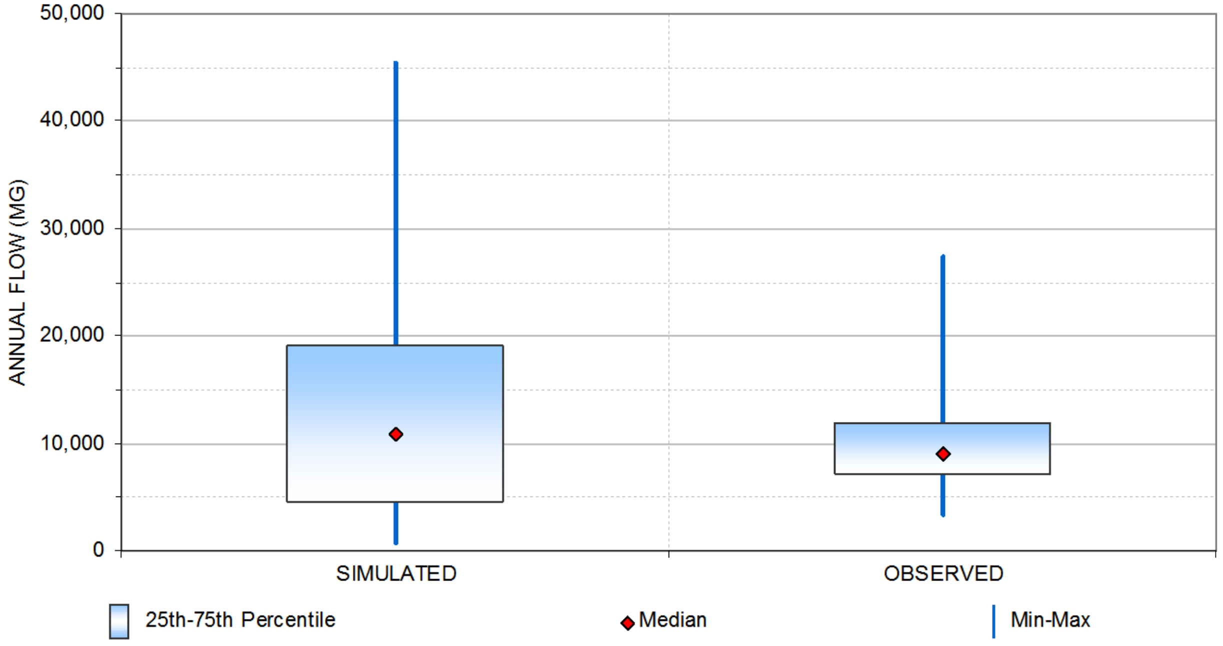

Figure 15. **Comparison of Simulated and Observed Annual Flow Volumes at USGS Gage 06061500 for the Period 1980 to 2002**

2.6.2 Nutrient Calibration

Two USGS gages were chosen for the comparison of simulated nutrient loads to represent the two major tributaries to Lake Helena: Tenmile Creek and Prickly Pear Creek. The USGS has not collected more than two water quality samples at any gage along Silver Creek with which to develop a meaningful comparison. Water quality data collected by other agencies in the watershed were not used because instantaneous flow measurements are required to extrapolate a daily load.

The USGS Gage along Tenmile Creek (Gage 06063000) is located in the “Tenmile above Prickly Pear Creek” GWLF subwatershed. The drainage area to the USGS gage is 96.5 square miles whereas the drainage area of the modeling subwatershed is 136.9 square miles. Very limited data (8 sampling events from 2002 and 2003) were available for comparison to simulated loads (Table 27). The average annual simulated load at the outlet of the modeling subwatershed was converted to a daily load and scaled down by the ratio of the drainage areas to estimate the simulated load at the gage. The minimum, average, and maximum daily observed and simulated loads are shown in Figure 16 (for total nitrogen) and Figure 17 (for phosphorus). In both cases the average simulated loads are greater than the average observed loads. There are several possible reasons for the difference including modeling assumptions used to simulate diversions in the Upper Tenmile reaches or the small number of sampling events (eight) used to generate the comparison. It should also be noted that the simulated loads are annual average loads from a twenty year model run converted to a daily load (tons/day) whereas the observed USGS loads are instantaneous loads converted to the same daily units. The observed and simulated loads are therefore not directly comparable and the observed loads might be biased due to only being collected during one season (typically summer) or one flow condition (typically low flows). Both 2002 and 2003 were relatively dry years and therefore it is reasonable to assume that long-term daily loading rates are greater than those represented by the limited sampling data.

Table 27. Observations of Stream Flow, Total Phosphorus, and Total Nitrogen at USGS Gage 06063000 on Tenmile Creek

Site Number	Date	Flow (cfs)	Total Phosphorus (mg/L)	Total Nitrogen (mg/L)
06063000	4/17/02	8.8	0.029	0.434
06063000	5/28/02	97.0	0.043	0.362
06063000	7/29/02	1.1	0.019	0.352
06063000	10/9/02	0.4	0.009	0.286
06063000	3/13/03	1.0	0.210	1.058
06063000	5/27/03	164.0	0.059	0.350
06063000	7/23/03	0.5	0.022	0.668
06063000	12/4/03	0.5	0.008	0.331
	Average	34.2	0.050	0.480

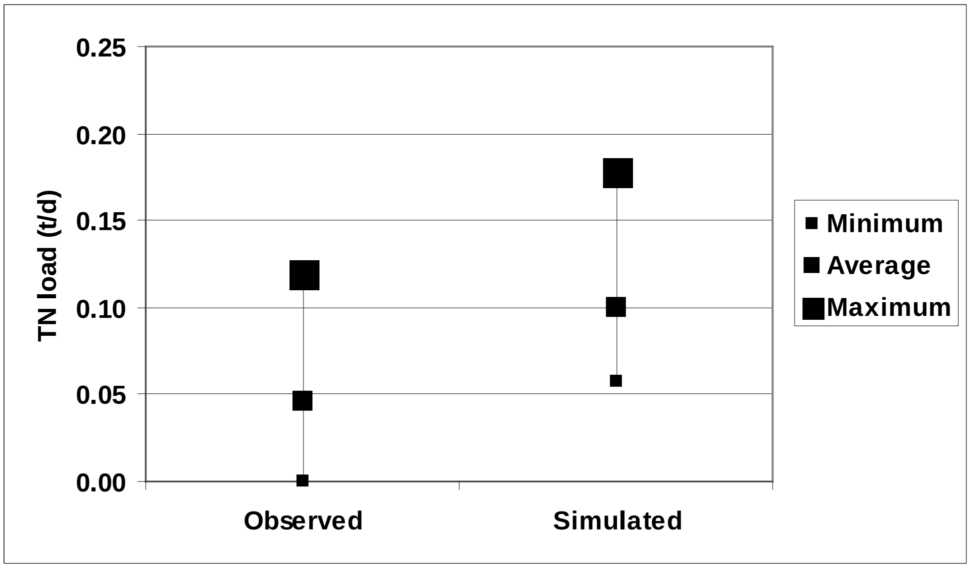

Figure 16. Comparison of Observed and Simulated Daily Total Nitrogen Load at USGS Gage 06063000 Along Tenmile Creek (Observed Loads Based on 8 Samples; Simulated Loads Based on Twenty Years of Model Output)

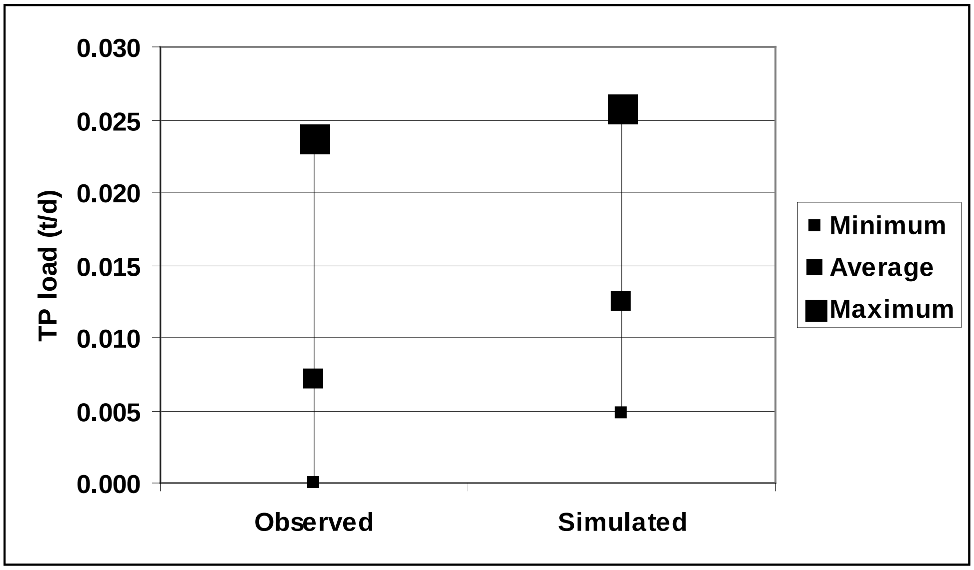

Figure 17. Comparison of Observed and Simulated Daily Total Phosphorus Load at USGS Gage 06063000 Along Tenmile Creek (Observed Loads Based on 8 Samples; Simulated Loads Based on Twenty Years of Model Output)

USGS Gage 06061500 was chosen to represent the loads for Prickly Pear Creek and 20 sampling events were available for the comparison (Table 28). The drainage area of this gage is 192 square miles, and it is located in the "Prickly Pear Creek above Wylie Drive" subwatershed. Simulated loads for this subwatershed represent a drainage area of 250 square miles so loads were scaled down for comparison with the gage data. Figure 18 shows the comparison of daily total nitrogen loads from observed instantaneous loads and simulated annual average loads. Figure 19 shows the same comparison for total phosphorus. At this gage, simulated total nitrogen loads and simulated total phosphorus loads are within the range observed at the gage with average simulated loads slightly greater than the observed loads. This could be due to model limitations or could be due to potential bias in the observed data as discussed above.

Table 28. Observations of Stream Flow, Total Phosphorus, and Total Nitrogen at USGS Gage 06061500 on Prickly Pear Creek

Site Number	Date	Stream flow (cfs)	Total Phosphorus (mg/L)	Total Nitrogen (mg/L)
06061500	5/19/1999	71	0.075	0.479
06061500	5/25/1999	109	0.132	0.541
06061500	6/4/1999	201	0.128	0.570
06061500	8/18/1999	22	0.024	0.319
06061500	11/5/1999	17	0.013	0.251
06061500	3/21/2000	14	0.014	0.354
06061500	6/1/2000	33	0.040	0.381
06061500	8/7/2000	4.7	0.015	0.232
06061500	4/25/2001	35	0.039	0.435
06061500	5/16/2001	71	0.041	0.344
06061500	7/19/2001	32	0.021	0.274
06061500	8/22/2001	8	0.008	0.220
06061500	10/23/2001	12	0.006	0.211
06061500	4/5/2002	17	0.015	0.374
06061500	5/20/2002	82	0.124	0.787
06061500	7/29/2002	22	0.013	0.216
06061500	4/17/2003	43	0.024	0.325
06061500	5/20/2003	64	0.025	0.338
06061500	6/2/2003	98	0.045	0.429
06061500	7/22/2003	12	0.017	0.401
	Average	48	0.041	0.374

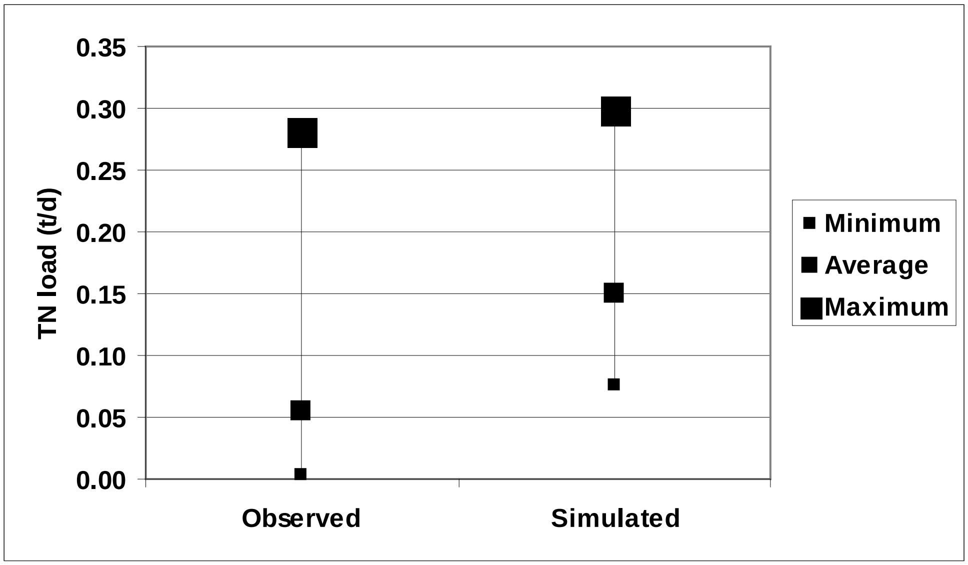

Figure 18. Comparison of Observed and Simulated Daily Total Nitrogen Load at USGS Gage 06061500 Along Prickly Pear Creek (Observed Loads Based on 20 Samples; Simulated Loads Based on Twenty Years of Model Output)

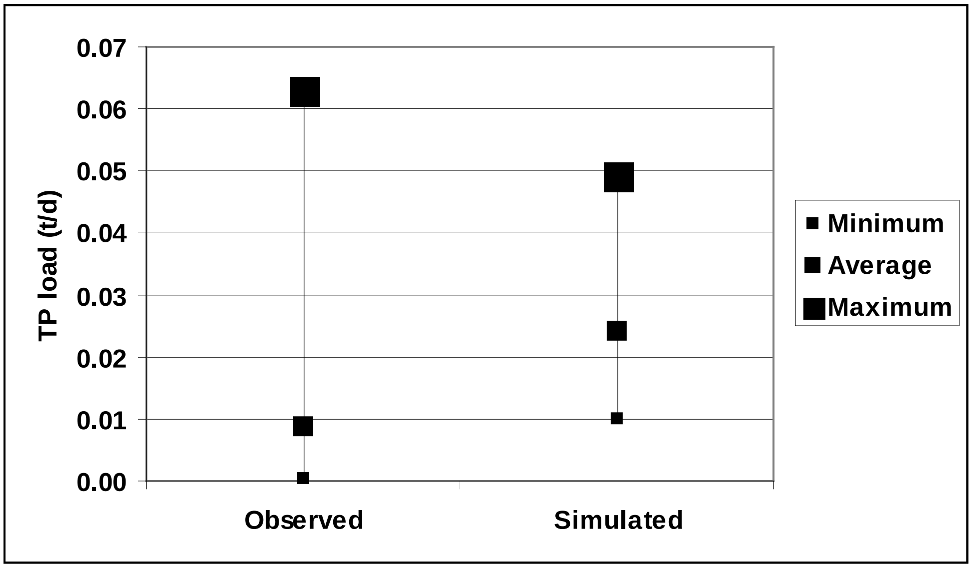

Figure 19. Comparison of Observed and Simulated Daily Total Phosphorus Load at USGS Gage 06061500 Along Prickly Pear Creek (Observed Loads Based on 20 Samples; Simulated Loads Based on Twenty Years of Model Output)

3.0 BATHTUB MODEL SETUP

The USACE BATHTUB model (Walker, 1987) was set up to simulate nutrient response in Lake Helena based on input from the GWLF model for the various scenarios. BATHTUB performs steady-state water and nutrient balance calculations in a spatially segmented hydraulic network, which accounts for pollutant transport and sedimentation. Eutrophication-related water quality conditions (e.g., phosphorus, nitrogen, chlorophyll *a*, and transparency) are predicted using empirical relationships previously developed and tested for reservoir applications (Walker, 1987). BATHTUB was determined to be appropriate because it addresses the parameters of concern and has been used previously for reservoir TMDL applications. The use of more sophisticated lake models was not warranted based on the very limited water quality data with which they could be calibrated.

3.1 Lake Morphology

The BATHTUB model requires basic lake morphometric data (Table 29) to assess residence time, net flow rate, and potential euphotic depth. Morphometric data are based on information provided by Montana DEQ (Mike Suplee, Montana DEQ, personal communications, November 10, 2004). Because the lake is fairly uniform and no ponding occurs along the downstream reaches of the tributaries, segmentation is not required.

Table 29. Lake Helena Morphology

Lake Volume (10^6 m^3)	13.45
Average Depth (m)	1.6
Surface area (km^2)	8.41

3.2 Atmospheric Deposition to Lake Helena

Atmospheric deposition can contribute a significant proportion of nitrogen loads directly to a lake surface, particularly when the ratio of watershed area to lake surface area is low. The Lake Helena watershed to lake area ratio is relatively high (192) so atmospheric deposition is not likely a major source of nutrient loading.

Total wet and dry nitrogen deposition rates to the lake surface (1.5 kg/ha) were based on CASTNET monitoring at Glacier National Park (GLR468) for 1997. Phosphorus deposition rates (primarily from wind blown dust) are generalized estimates (0.1 kg/ha).

3.3 Inorganic Nutrient Fractions

BATHTUB requires an estimate of inorganic nutrient fractions for all loads to the lake. The inorganic nutrient fractions for the watershed loads were approximated from the ratios of dissolved nutrient load to total nutrient load predicted by GWLF for each year. Atmospheric and groundwater recharge loads from the irrigation system were assumed 100 percent inorganic; loads in the irrigation system drains were assumed 25 percent inorganic due to algal synthesis. Table 30 summarizes the inorganic fractions of nutrient loads to Lake Helena for each modeling year.

Table 30. Inorganic Nutrient Fractions to Lake Helena

Year	Fraction Inorganic Nitrogen	Fraction Inorganic Phosphorus
1993	0.58	0.37
1994	0.83	0.70
1995	0.77	0.61
1996	0.68	0.51
1997	0.65	0.45
1998	0.56	0.36
1999	0.63	0.43
2000	0.69	0.52
2001	0.55	0.39
2002	0.48	0.38
2003	0.63	0.53

3.4 Light Penetration in Lake Helena

The BATHTUB model requires average Secchi depth to determine the nonalgal turbidity in the lake. Eight separate Secchi depth readings were collected in Lake Helena by Montana Fish Wildlife and Parks personnel during the summer of 2003. The readings ranged from 0.15 meters to 1.07 meters. Because data are only available for 2003, the average value of 0.41 meters was applied to all modeling years.

3.5 BATHTUB Calibration

The BATHTUB model for Lake Helena is currently not calibrated because of the limited water quality data available (one sampling event in 2002 and two events in 2003). The proposed water quality sampling plan for Lake Helena (Appendix H) will provide the necessary data to better understand nutrient response. However, to ensure the BATHTUB results are reasonable, the model output for the existing scenario was compared to the conditions observed in Lake Helena in 2002 and 2003, which are represented by DEQ data collected on 8/9/2002 and EPA data collected on 6/26/2003 and 8/29/2003.

The BATHTUB model offers the user several choices for nutrient sedimentation models, which determine the predicted in-lake concentrations from loading rates and residence time. Since insufficient historic lake water quality data are available to calibrate the model, the nutrient and chlorophyll *a* calibration factors were left at the default values of 1.0.

Table 31 and Table 32 show the average annual predicted total nitrogen and total phosphorus concentrations in Lake Helena under the existing scenario with a comparison to water quality observations collected in 2002 and 2003. The simulated total nitrogen average for 2002 is very close to the average observed concentration; the simulated average for 2003 is higher than the observed 2003 average. The simulated total phosphorus concentration for 2002 is very close to the average observed concentration; the simulated average for 2003 is less than the observed 2003 average.

Table 33 shows the yearly, predicted chlorophyll *a* concentrations in Lake Helena under the existing scenario with a comparison to water quality observations collected in 2002 and 2003. The BATHTUB model predicts an average chlorophyll *a* concentration of 53 µg/L, which is almost the same as the average of all samples collected in both 2002 and 2003 (52 µg/L). However, there is a greater variation in the observed data compared to the simulated concentrations. Thus, the model may be accurately depicting general eutrophication of the lake, rather than day-to-day variation detected by limited sampling data.

Table 31. Comparison of Observed and Simulated Total Nitrogen Concentrations (mg-N/L) in Lake Helena

Year	Simulated Total Nitrogen Concentration	Average Observed Total Nitrogen Concentration	Minimum Observed Total Nitrogen Concentration	Maximum Observed Total Nitrogen Concentration
1993	0.94	NA	NA	NA
1994	1.42	NA	NA	NA
1995	2.14	NA	NA	NA
1996	1.89	NA	NA	NA
1997	2.09	NA	NA	NA
1998	1.69	NA	NA	NA
1999	1.79	NA	NA	NA
2000	2.03	NA	NA	NA
2001	1.62	NA	NA	NA
2002	1.53	1.48	1.37	1.56
2003	1.49	0.82	0.65	0.99

NA: No nutrient water quality data were collected in Lake Helena from 1993 through 2001.

Table 32. Comparison of Observed and Simulated Total Phosphorus Concentrations (mg-P/L) in Lake Helena

Year	Simulated Total Phosphorus Concentration	Average Observed Total Phosphorus Concentration	Minimum Observed Total Phosphorus Concentration	Maximum Observed Total Phosphorus Concentration
1993	0.102	NA	NA	NA
1994	0.128	NA	NA	NA
1995	0.172	NA	NA	NA
1996	0.157	NA	NA	NA
1997	0.171	NA	NA	NA
1998	0.146	NA	NA	NA
1999	0.151	NA	NA	NA
2000	0.166	NA	NA	NA
2001	0.153	NA	NA	NA
2002	0.158	0.155	0.14	0.174
2003	0.157	0.226	0.19	0.377

NA: No nutrient water quality data were collected in Lake Helena from 1993 through 2001.

Table 33. Comparison of Observed and Simulated Chlorophyll *a* Concentrations (μg-N/L) in Lake Helena

Year	Simulated Chlorophyll *a* Concentration	Average Observed Chlorophyll *a* Concentration	Minimum Observed Chlorophyll *a* Concentration	Maximum Observed Chlorophyll *a* Concentration
1993	27	NA	NA	NA
1994	48	NA	NA	NA
1995	73	NA	NA	NA
1996	64	NA	NA	NA
1997	71	NA	NA	NA
1998	56	NA	NA	NA
1999	60	NA	NA	NA
2000	69	NA	NA	NA
2001	56	NA	NA	NA
2002	61	89	57	114
2003	45	14	5	26
Average for 2002 and 2003	53	52	31	70

NA: No nutrient water quality data were collected in Lake Helena from 1993 through 2001.

4.0 APPLICATION OF THE GWLF/BATHTUB MODELS

This section of the document discusses the various applications of the GWLF and BATHTUB models in support of TMDL development in the Lake Helena watershed.

4.1 Required Nutrient Reductions for Each TMDL Watershed

Nutrient TMDLs are required for four stream segments in the Lake Helena Watershed, representing Prickly Pear Creek, Sevenmile Creek, Tenmile Creek, and Spring Creek. The TMDLs are based on meeting the proposed interim water quality targets of 0.33 mg-N/L and 0.04 mg-P/L. As discussed in the main TMDL document, these targets are based on the best available data and provide the best means by which to ensure protection of beneficial uses until such time as they can be revised following an adaptive management approach.

The load reductions needed to achieve the TMDL target concentrations are determined by comparing current loads to allowable loads. For example, if the current load in a segment is 10 tons/year and the allowable load is 4 tons/year, a 60 percent reduction in loads is needed. Unfortunately, the current load is unknown in all segments due to a lack of water quality and/or flow data. The allowable load is also unknown in those segments without flow data. Simulated nutrient loads are therefore used to estimate the required reductions with some refinement based on available water quality and flow data. The necessary reductions should be revised in the future following additional sampling as described in Appendix H. This section summarizes the methods used to calculate the required loading reduction for each of the segments.

4.1.1 Prickly Pear Creek

The most downstream USGS Gage on Prickly Pear Creek (Number 06061500) has continuous flow monitoring and was used to estimate allowable nutrient loads. Daily flows recorded at this gage were scaled up by the ratio of the drainage areas of the listed segment and the gage (464/192) and added to the average daily flows released by wastewater treatment facilities. Total daily flows were then used with the nutrient water quality targets to estimate allowable loads at the mouth of Prickly Pear Creek. The average allowable loads were 33.7 mt/yr total nitrogen and 4.1 mt/yr total phosphorus.

Average, yearly simulated loads from the GWLF model (using weather data from 1993 through 2003) were 167.4 mt/yr and 32.1 mt/yr for nitrogen and phosphorus, respectively. Based on a comparison of the simulated and allowable loads, reductions of 80 percent total nitrogen and 87 percent total phosphorus are required to reduce loads to the allowable levels.

Very limited data are available from one water quality station (M09PKPRC02) located in this segment of Prickly Pear Creek (Table 34). The average observed total nitrogen concentration at this site is 2.03 mg-N/L, which would require an 84 percent reduction to meet the water quality target of 0.33 mg-N/L. The average observed total phosphorus concentration is 0.56 mg-P/L, which would require a 93 percent reduction to meet the water quality target of 0.04 mg-P/L.

Table 34. Observed Nutrient Data in Prickly Pear Creek Segment MT41I006_020

Sampling Site ID	Location	Date	TP (mg/L)	TN (mg/L)
M09PKPRC02	Prickly Pear Creek above Tenmile Creek	7/17/2003	0.797	2.660
		8/12/2003	0.522	1.940
		7/27/2004	0.736	2.600
		8/27/2004	0.458	1.900
		9/9/2004	0.492	1.690
		9/24/2004	0.345	1.370
		Average	0.558	2.027

For this listed segment, the reductions based on simulated loads are slightly lower than those estimated from observed water quality data. Because such limited observed water quality are available, the average annual simulated loads will be used to set the reductions of 80 percent total nitrogen and 87 percent total phosphorus.

To verify the accuracy of using an average annual allowable load to set the targets rather than the results from each modeling year, the gage data on Prickly Pear Creek were used to estimate allowable loads for each modeling year. These loads were then compared to the simulated yearly loads to calculate a reduction for each year (Table 35). The average reductions over the modeling period are 79 percent for total nitrogen and 87 percent for total phosphorus, which are almost identical to the reductions estimated from the average of the allowable and simulated loads. This comparison shows that loads simulated during extreme wet and dry years are not biasing the proposed reductions.

Table 35. Comparison of Annual and Average Annual Nutrient Load Reductions

Modeling Year	Allowable Load		Simulated Load		Required Reduction (%)	
	TN (mt)	TP (mt)	TN (mt)	TP (mt)	TN	TP
1993	44.0	5.33	291.0	52.29	85%	90%
1994	34.1	4.13	110.9	20.66	69%	80%
1995	44.0	5.33	106.4	21.08	59%	75%
1996	34.1	4.14	136.8	26.10	75%	84%
1997	40.4	4.90	145.2	29.23	72%	83%
1998	31.9	3.86	200.9	39.12	84%	90%
1999	25.6	3.11	163.0	31.89	84%	90%
2000	11.6	1.41	130.9	25.22	91%	94%
2001	16.3	1.98	189.3	36.94	91%	95%
2002	Incomplete flow data		226.3	42.56	Target loads could not be calculated due to incomplete flow data	
2003	No flow data available		149.4	28.14		
Average[1]	33.7	4.1	168.2	32.11	80	87
Average of reductions calculated for each year					79	87

[1] The average allowable loads are for all years with complete flow data (1980 through 2001), not just the modeling years presented in the table.

4.1.2 Tenmile Creek

Tenmile Creek is listed for nutrient impairment from the Helena water treatment plant to the mouth at Prickly Pear Creek. There is a USGS flow gage located in the most downstream segment (06063000), but only summer flows have been measured during a few sampling years. The average observed flow (36.6 cfs) was scaled up by drainage area (188/96.5) to estimate the average flow rate at the outlet of the subwatershed. Water quality targets were then applied to estimate an allowable nutrient load from this segment of Tenmile Creek.

The average estimated allowable total nitrogen and total phosphorus loads are 21.0 and 2.6 mt/yr, respectively. Average simulated total nitrogen load is 51.7 mt/yr, which would require a 59 percent reduction. Average simulated total phosphorus load is 6.47 mt/yr, which would require a 61 percent reduction.

Several water quality stations are located in this subwatershed with observed nutrient concentration data (Table 36). Water quality decreases below the confluence with Sevenmile Creek though it is impaired along the entire segment length. Average conditions throughout the segment result in estimated reductions of 46 for nitrogen and 49 percent for phosphorus.

In this segment, percent reductions based on simulated loads are slightly greater than reductions based on the water quality observations. To remain consistent with the other segments, reductions will be based on simulated loads and are 59 percent for total nitrogen and 61 percent for total phosphorus. It is acknowledged that this is possibly an over-estimate and contributes toward the TMDL’s margin of safety (i.e., 13 and 12 percent for TN and TP, respectively).

Table 36. Observed Nutrient Data in Tenmile Creek Segment MT41I006_143

Sampling Site ID	Location	Date	Total Phosphorus (mg/L)	Total Nitrogen (mg/L)
06063000	Tenmile Creek near Helena	6/5/1997	0.030	
		8/28/1997	0.020	
		10/9/1997	0.020	
		4/17/2002	0.029	0.434
		5/28/2002	0.043	0.362
		7/29/2002	0.019	0.352
		10/9/2002	0.009	0.286
		3/13/2003	0.210	1.058
		5/27/2003	0.059	0.350
		7/23/2003	0.022	0.668
		12/4/2003	0.008	0.331
06064100	Tenmile Creek at Green Meadow Drive	6/5/1997	0.050	
		8/28/1997	0.030	
		10/9/1997	0.010	
		4/17/2002	0.031	0.438
		5/28/2002	0.060	0.442
		7/29/2002	0.037	0.263
		10/9/2002	0.021	0.202
		3/13/2003	1.490	4.896
		5/27/2003	0.105	0.480
		7/24/2003	0.047	0.332
		12/4/2003	0.019	0.303
06064150	Tenmile Creek above Prickly Pear Creek	6/5/1997	0.060	
		8/28/1997	0.040	
		10/9/1997	0.030	
463438112091801	Tenmile Creek below Colorado Gulch	6/4/1997	0.030	
		8/28/1997	0.030	
		10/9/1997	0.030	
		4/17/2002	0.032	0.434
		5/28/2002	0.040	0.310
		7/29/2002	0.027	0.193
		10/9/2002	0.013	0.332
		3/13/2003	0.220	1.069
		5/27/2003	0.052	0.452
		7/23/2003	0.019	0.399
		12/4/2003	0.016	0.440
M09TENMC01	Tenmile Creek downstream of Green Meadow Golf Course	7/30/2001	0.029	0.410
M09TENMC02	Tenmile Creek upstream of Green Meadow Drive	7/31/2001	0.048	0.610
M09TENMC03	Tenmile Creek 3/4 mile upstream of Rimini	7/31/2001	0.005	0.710
		Average	0.079	0.613

4.1.3 Sevenmile Creek

Sevenmile Creek is listed for nutrients from its headwaters to the mouth at Tenmile Creek. There is no USGS flow gage on this stream with which to estimate allowable nutrient loads. Simulated flows in year 2003 are used to estimate the allowable load because the simulated concentrations that year are within the range of observed values. Thus, the relationship between flow and load is believed accurate. The simulated average total nitrogen concentration is 1.98 mg-N/L while observed values range from 0.33 to 5.16 with an average of 1.58 mg-N/L. Average simulated total phosphorus in 2003 is 0.28 mg-P/L. Observed values range from 0.03 to 1.61 with an average of 0.44 mg-P/L.

The allowable loads estimated from simulated flows in 2003 and the water quality targets are 1.99 mt/y of nitrogen and 0.24 mt/yr of phosphorus. The average simulated nitrogen load over the modeling period is 14.0 mt/y, which would require a reduction of 86 percent. The average simulated phosphorus load over the modeling period is 2.1 mt/y, which would require a reduction of 89 percent.

Water quality sampling with nutrient observations occurred at three locations (M09SVNMC01, M09SVNMC02, and USGS 463747112033801) from 1997 to 2003 with a total of 13 sampling events for phosphorus and 10 for nitrogen (Table 37). The average observed total nitrogen concentration is 0.93 mg-N/L, which would require a 65 percent reduction to meet the water quality target. The average total phosphorus concentration is 0.19 mg-P/L, which requires a 79 percent reduction to meet the water quality target.

In this segment, the simulated loads require a slightly higher reduction than observed water quality data. However, the allowable loads are based on simulated flow volumes and there is no available flow data from this creek to verify the flow results. The load reductions required in the receiving stream (Tenmile Creek) were approximately 60 percent for both total nitrogen and total phosphorus. These reductions are similar to those indicated by the water quality observations in Sevenmile Creek. Therefore, for Sevenmile Creek, the water quality observations will be used to set the reductions: 65 percent for total nitrogen and 79 for total phosphorus.

Table 37. Observed Nutrient Data in Sevenmile Creek Segment MT41I006_160

Sampling Site ID	Location	Date	Total Phosphorus (mg/L)	Total Nitrogen (mg/L)
463747112033801	Sevenmile Creek at Mouth	6/5/97	0.150	
		8/28/97	0.080	
		10/9/97	0.070	
		4/17/02	0.038	0.462
		5/28/02	0.065	0.373
		7/29/02	0.049	0.243
		10/9/02	0.046	0.264
		3/13/03	1.610	5.163
		5/27/03	0.053	0.336
		7/24/03	0.068	0.382
		12/4/03	0.030	0.442
M09SVNMC01	Sevenmile Creek upstream of Green Meadow Drive	7/30/01	0.163	1.210
M09SVNMC02	Sevenmile Creek upstream of bridge, 150 feet north of railroad tracks	7/31/01	0.054	0.410
		Average	0.190	0.929

4.1.4 Spring Creek

Spring Creek is listed for nutrients from Corbin Creek to the mouth at Prickly Pear Creek. There is no USGS flow gage on this stream with which to estimate allowable nutrient loads. Simulated flows in year 2003 are used to estimate the allowable load because the simulated concentrations that year are within the range of values observed during 2003. The simulated average total nitrogen concentration in 2003 is 1.03 mg-N/L while observed values range from 0.37 to 1.05 with an average of 0.71 mg-N/L. Average simulated total phosphorus in 2003 is 0.17 mg-P/L. Observed values range from 0.04 to 0.21 with an average of 0.13 mg-P/L.

Table 38. Observed Nutrient Data in Spring Creek Segment MT41I006_080

Sampling Site ID	Location	Date	Total Phosphorus (mg/L)	Total Nitrogen (mg/L)
M09SPRGC01	Spring Creek near Jefferson City	7/14/2003	0.039	0.370
		8/11/2003	0.205	1.050
		7/27/2004	0.050	0.240
		8/27/2004	0.010	0.280
		9/9/2004	0.009	0.110
		9/24/2004	0.007	0.200
		Average	0.053	0.375

Reductions based on simulated loads are 75 percent for total nitrogen and 83 percent for total phosphorus. Reductions based on observed 2003 concentrations are 54 percent for total nitrogen and 69 percent for total phosphorus. Reductions based on the average of all concentrations are 12 percent for total nitrogen and 25 percent for total phosphorus. The TMDL is based on the reductions estimated by the simulated loads based on the limited water quality data. It is acknowledged that this is possibly an over-estimate and contributes toward the TMDL’s margin of safety. Table 39 summarizes the proposed load reductions for each subwatershed.

Table 39. Cumulative Nutrient Load Reductions for Listed Segments in the Lake Helena Watershed as Determined Using Observed Concentrations and Simulated Loads (Proposed Load Reductions Shown in Bold)

	Reductions Based on Observed Concentrations			Reductions Based on Simulated Loads		
Reach Description	**# Samples**	**TN**	**TP**	**TN**	**TP**	**Notes**
Spring Creek	6	54	69	**75**	**83**	Reductions based on simulated loads due to limited water quality data.
Tenmile Creek	39[A]	46	49	**59**	**61**	Reductions based on simulated loads to remain consistent with the other segments.
Sevenmile Creek	13[B]	**65**	**79**	86	89	Reductions based on observed concentrations due to limited available flow data and to be consistent with Tenmile reductions.
Prickly Pear Creek	6	84	93	**80**	**87**	Reductions based on simulated loads due to limited water quality data.

[A] 39 samples for TP and 27 for TN.

[B] 13 samples for TP and 10 for TN.

4.2 Natural Scenario

To provide a starting point for evaluating the magnitude of potential nutrient impairments, the GWLF model was also used to estimate nutrient loading in the Lake Helena watershed under “natural” conditions. It should be noted that the results from this scenario have not been used to derive nutrient concentration targets or load reductions. This scenario has been developed and evaluated for informational purposes. The existing scenario includes current land use conditions, wastewater treatment plant operations, septic systems, and the Helena Valley Irrigation District. The natural scenario models the watershed in its pre-disturbed condition. Septic systems, point sources, and the irrigation system are removed from the loading and all urban, agricultural, and silvicultural land uses are converted proportionally back to evergreen forest, shrubland, or grassland. Table 40 summarizes the land use areas for the two modeling scenarios.

Table 40. Land Use Areas for the Lake Helena Existing and Natural Conditions Modeling

Land Use	Existing (ac)	Natural (ac)
Bare Rock	84	84
LDRa	9,067	-
Quarries	234	-
Water	2,875	2,875
Transitional	1,853	-
Deciduous Forest	1,241	1,454
Evergreen Forest	154,204	171,484
Mixed Forest	36	36
Shrubland	37,014	46,787
Grassland	129,060	169,037
Pasture/Hay	14,892	-
Small Grains	16,925	-
Woody Wetland	1,270	1,270
Herbaceous Wetlands	421	421
Recent Clear-cut	522	-
Clear-cut Regrowth	3,571	-
Dirt Roads	3,326	-
Fallow	2,546	-
Row Crop	2,093	-
Non-system Roads	153	-
LDRb	2,950	-
Commercial/Industrial/Transportation	6,203	-
Urban/Recreational Grasses	1,001	-
Secondary Paved Roads	1,904	-
Total Watershed Area	393,445	393,445

Under natural conditions, grassland areas are assumed to have lower animal densities compared to grassland under existing conditions, which is often used for organized grazing. Soil compaction is therefore expected to be lower under natural conditions. Curve numbers for natural grassland area correspond to good condition, while under existing conditions, the curve numbers correspond to fair conditions.

Table 41 through Table 43 summarize the predicted increases in sediment, nitrogen, and phosphorus loads that have occurred from the natural condition to the existing condition. Very significant increases are projected to have occurred for all three pollutants in almost every subwatershed.

Table 41. Change in Annual Sediment Load from Existing to Natural Conditions in Lake Helena Modeling Subwatersheds

Subwatershed	Current Average Annual Sediment Load (mt)	Natural Average Annual Sediment Load (mt)	Percent Increase
Clancy Creek	3,774	1,427	164.5%
Corbin Creek	432	155	179.2%
Golconda Creek	228	116	95.8%
Jackson Creek	701	328	114.0%
Jennies Fork	378	121	212.9%
Lake Helena Overland Flow	5,614	326	1620.4%
Lump Gulch	2,953	1,013	191.4%
Middle Fork Warm Springs	365	119	207.2%
Middle Tenmile Creek	2,238	926	141.6%
North Fork Warm Springs Creek	168	75	123.9%
Prickly Pear above Spring Creek	1,929	977	97.4%
Prickly Pear above Lake Helena	765	150	411.4%
Prickly Pear above Lump Gulch	1,495	565	164.5%
Prickly Pear above WWTP outfall	1,829	318	474.4%
Prickly Pear above Wylie Drive	6,239	1,328	369.9%
Sevenmile Creek	2,874	967	197.3%
Silver Creek	6,525	1,183	451.3%
Skelly Gulch	1,277	561	127.5%
Spring Creek	2,083	739	181.9%
Tenmile above Prickly Pear	3,861	1,161	232.6%
Upper Tenmile Creek	1,522	659	130.8%
Warm Springs Creek	818	396	106.4%
Total Watershed Load	48,067	13,611	253.2%

Table 42.Change in Annual Nitrogen Load from Existing to Natural Conditions in Lake Helena Modeling Subwatersheds

Subwatershed	Current Average Annual Nitrogen Load (mt)	Natural Average Annual Nitrogen Load (mt)	Percent Increase
Clancy Creek	9.6	3.5	179.0%
Corbin Creek	1.0	0.4	191.5%
Golconda Creek	0.6	0.3	97.7%
Jackson Creek	1.7	0.8	121.5%
Jennies Fork	1.0	0.3	265.9%
Lake Helena Overland Flow	35.9	0.9	4030.3%
Lump Gulch	9.0	2.6	242.1%
Middle Fork Warm Springs	0.8	0.3	170.7%
Middle Tenmile Creek	6.7	2.4	181.0%
North Fork Warm Springs Creek	0.4	0.2	109.2%
Prickly Pear above Spring Creek	5.5	2.5	118.9%
Prickly Pear above Lake Helena	39.9	0.3	12762.8%
Prickly Pear above Lump Gulch	6.8	1.4	378.4%
Prickly Pear above WWTP outfall	9.5	0.7	1250.5%
Prickly Pear above Wylie Drive	23.3	3.3	599.6%
Sevenmile Creek	10.5	2.3	355.7%
Silver Creek	59.9	2.9	1979.9%
Skelly Gulch	3.5	1.3	167.0%
Spring Creek	5.8	1.8	224.1%
Tenmile above Prickly Pear	26.9	2.8	860.0%
Upper Tenmile Creek	3.9	2.0	98.8%
Warm Springs Creek	2.9	1.0	191.4%
To Lake Helena from Irrigation System	54.5	0	N/A
Total Watershed Load	319.4	33.8	845.4%

Table 43. Change in Annual Phosphorus Load from Existing to Natural Conditions in Lake Helena Modeling Subwatersheds

Subwatershed	Current Average Annual Phosphorus Load (mt)	Natural Average Annual Phosphorus Load (mt)	Percent Increase
Clancy Creek	1.81	0.73	148.1%
Corbin Creek	0.20	0.08	164.6%
Golconda Creek	0.12	0.06	85.4%
Jackson Creek	0.33	0.16	105.6%
Jennies Fork	0.18	0.06	209.4%
Lake Helena Overland Flow	3.08	0.17	1728.3%
Lump Gulch	1.48	0.55	169.4%
Middle Fork Warm Springs	0.17	0.06	180.6%
Middle Tenmile Creek	1.18	0.50	136.5%
North Fork Warm Springs Creek	0.08	0.04	111.0%
Prickly Pear above Spring Creek	1.03	0.52	97.1%
Prickly Pear above Lake Helena	13.79	0.07	20320.0%
Prickly Pear above Lump Gulch	0.85	0.29	189.0%
Prickly Pear above WWTP outfall	1.20	0.15	697.1%
Prickly Pear above Wylie Drive	3.14	0.70	351.8%
Sevenmile Creek	1.50	0.48	208.3%
Silver Creek	4.12	0.60	586.4%
Skelly Gulch	0.63	0.28	124.3%
Spring Creek	1.00	0.38	165.6%
Tenmile above Prickly Pear	2.36	0.59	300.6%
Upper Tenmile Creek	0.79	0.40	99.3%
Warm Springs Creek	0.44	0.21	111.1%
To Lake Helena from Irrigation System	6.90	0	N/A
Total Watershed Load	46.4	7.1	555.9%

4.3 Reduced Scenario

To determine the potential load reductions that may be achievable in the Lake Helena Watershed, a “reduced” scenario was run in GWLF. The following load reductions were assumed for the reduced scenario:

- Dirt Roads: BMPs will remove 60 percent of sediment as well as sediment-associated nutrients.
- Urban areas: BMPs will remove 80 percent sediment, 50 percent TP, and 30 percent TN based on typical ranges available in the literature (e.g., CWP, 2000).
- Abandoned Mines: BMPs will remove 79 percent of sediment as well as sediment-associated nutrients based on an evaluation of reclaimed mines in the Lake Helena watershed.
- Streambank Erosion: Anthropogenic loads have been reduced to reference conditions.
- Non-system roads are assumed closed and reclaimed, loads are zero.
- All septic systems are simulated as performing normally (i.e., no failing septic systems). Normally functions systems are assumed to discharge no phosphorus but nitrogen loads are only reduced due to preliminary treatment in the tank and plant uptake.
- Agriculture: Under existing conditions, agriculture is simulated with no BMPs. Under the reduced scenario, small grains are assumed in a wheat-grass rotation rather than a wheat-fallow rotation. For row crops, residuals are left on the field; disk turning in the spring replaces turn plowing in the fall. All fallow fields are assumed planted with alfalfa. Buffer strips are assumed to remove an additional 60 percent of sediment and 50 percent of nitrogen and phosphorus based on typical ranges available in the literature (e.g., Dillaha et al., 1989).
- Timber harvest land uses (recent clear cut and clear cut regrowth) are simulated as full-growth forest.
- Major point sources are assumed to discharge at instream nutrient target concentrations. All malfunctioning lagoons are simulated as properly functioning.
- Nutrient loads from the Helena Valley Irrigation District are assumed reduced by 50 percent based on best professional judgment.

In general, most of the load reductions proposed above are conservative (i.e., on the high end of the range of potential values) and assume that BMPs will be applied to each individual source (e.g., all of the dirt roads) within each of the broader source categories (e.g., dirt roads). These load reductions are also assumed to equate to application of “all reasonable land, soil, and water conservation practices.” It is acknowledged that achieving the proposed level of reductions may not be possible, but in the absence of site-specific data for each individual source this approach provides the only means to estimate the maximum load reductions that may be technologically achievable/feasible.

The results of the reduced scenario are presented in Appendix A by TMDL subwatershed.

4.4 Simplistic Build-out Scenario

Since the 1950's, population growth in the Lake Helena Watershed has averaged approximately 18 percent per decade. According to EPA's "Onsite Wastewater Treatment Systems Manual" (2002b), each person contributes 4.8 to 13.7 pounds of nitrogen and 0.8 and 1.6 pounds of phosphorus per year. As a result, there is a direct link between population growth/development and increased nutrient loading. While the extent to which population growth might lead to increased nutrient loading is dependant upon how and where domestic wastewater is treated and how and where the resulting development occurs, some incremental increase in nutrient loading is inevitable with a population increase.

A simplistic "build-out" scenario has been developed and modeled to demonstrate the extent to which nutrient loading might increase in the future. This scenario assumes that population growth will occur such that the municipal wastewater discharge facilities in the Cities of Helena and East Helena attain their design flow capacity, and the level of treatment at each of these facilities remains as it is today. Helena and East Helena are currently at approximately 50 percent and 47 percent of their design flow capacity, respectively. This scenario further assumes that all of the parcels currently platted and shown on the 2004 cadastral data base (i.e., a database of all legally defined pieces of land) will be developed.

The modified MRLC land use classification layers were used to select private parcels that are currently not classified as residential, commercial/industrial/transportation, or an active mine or quarry. 4,534 parcels were selected as a result of this analysis.

For this scenario, it was assumed that only one lot per parcel would be developed. This resulted in adding an additional 4,534 septic systems to the entire watershed. Because approximately 80 percent of the parcels are larger than 2 acres, this scenario is likely an underestimate of the number of lots that may actually be developed and the loading that may occur under full buildout.

The assumptions for the low intensity residential category, LDRb, were chosen to add 1.1 acres of new development for each of the 4,534 parcels, resulting in 4,987 acres of new development in the Lake Helena Watershed. The majority of the current land use categories converted were grasslands (50 percent), evergreen forest (30 percent), and shrubland (15 percent). To reflect additional road areas associated with the projected development, the current ratios of LDRb to unpaved roads were analyzed. This ratio was used as a multiplier to increase the unpaved road areas in each subwatershed proportionally to the new area of LDRb development. For those areas where the ratio resulted in a 0 percent increase in road area, a 15 percent increase in current road area was estimated based on similar subwatersheds (headwater subwatersheds). For those areas where the ratio resulted in more than a 100 percent increase in road area, a 100 percent increase in current road area was calculated.

It is acknowledged that this scenario represents a simplistic view of the future. However, the purpose of this scenario is to demonstrate what might happen in the future when the two largest wastewater discharge facilities attain their design capacity and much of the developable land in the watershed is developed.

Table 44 through Table 46 compare the sediment, nitrogen, and phosphorus loading under the existing and build-out scenarios. The subwatersheds with the greatest projected increases in nutrient loadings are Corbin Creek, Prickly Pear Creek, Middle Fork. Warm Springs Creek, and Upper Tenmile Creek. At the watershed scale there is a small net increase in sediment loading and fairly significant increases in nitrogen and phosphorus loading.

Table 44. Change in Annual Sediment Load from Existing to Buildout Conditions in Lake Helena Modeling Subwatersheds

Subwatershed	Current Average Annual Sediment Load (mt)	Buildout Average Annual Sediment Load (mt)	Percent Increase
Clancy Creek	3,774	3,776	0.1%
Corbin Creek	432	418	-3.3%
Golconda Creek	228	237	3.9%
Jackson Creek	701	706	0.7%
Jennies Fork	378	421	11.2%
Lake Helena Overland Flow	5,614	5,720	1.9%
Lump Gulch	2,953	2,995	1.4%
Middle Fork Warm Springs	365	366	0.1%
Middle Tenmile Creek	2,238	2,325	3.9%
North Fork Warm Springs Creek	168	174	3.8%
Prickly Pear above Spring Creek	1,929	1,971	2.2%
Prickly Pear above Lake Helena	765	767	0.3%
Prickly Pear above Lump Gulch	1,495	1,657	10.8%
Prickly Pear above WWTP outfall	1,829	1,894	3.5%
Prickly Pear above Wylie Drive	6,239	6,445	3.3%
Sevenmile Creek	2,874	3,119	8.6%
Silver Creek	6,525	7,030	7.7%
Skelly Gulch	1,277	1,415	10.8%
Spring Creek	2,083	2,098	0.7%
Tenmile above Prickly Pear	3,861	4,113	6.5%
Upper Tenmile Creek	1,522	1,590	4.5%
Warm Springs Creek	818	936	14.4%
To Lake Helena from Irrigation System			
Total Watershed Load	48,067	50,171	4.4%

Note: The negative percent increase in Corbin Creek is due to conversion of land uses with low vegetative cover to urban land uses, which are assumed to have established lawns.

Table 45. Change in Annual Nitrogen Load from Existing to Buildout Conditions in Lake Helena Modeling Subwatersheds

Subwatershed	Current Average Annual Nitrogen Load (mt)	Buildout Average Annual Nitrogen Load (mt)	Percent Increase
Clancy Creek	9.6	14.7	53.1%
Corbin Creek	1.0	3.2	207.7%
Golconda Creek	0.6	1.0	72.7%
Jackson Creek	1.7	1.8	9.8%
Jennies Fork	1.0	1.7	75.6%
Lake Helena Overland Flow	35.9	40.4	12.5%
Lump Gulch	9.0	14.6	61.3%
Middle Fork Warm Springs	0.8	1.7	117.1%
Middle Tenmile Creek	6.7	8.0	19.7%
North Fork Warm Springs Creek	0.4	0.6	53.5%
Prickly Pear above Spring Creek	5.5	9.5	72.3%
Prickly Pear above Lake Helena	39.9	90.1	125.8%
Prickly Pear above Lump Gulch	6.8	13.4	98.7%
Prickly Pear above WWTP outfall	9.5	12.9	36.2%
Prickly Pear above Wylie Drive	23.3	35.5	52.3%
Sevenmile Creek	10.5	14.6	39.0%
Silver Creek	59.9	71.4	19.3%
Skelly Gulch	3.5	6.3	77.8%
Spring Creek	5.8	11.4	97.2%
Tenmile above Prickly Pear	26.9	35.0	30.3%
Upper Tenmile Creek	3.9	7.9	104.0%
Warm Springs Creek	2.9	5.1	76.6%
To Lake Helena from Irrigation System	54.5	54.5	0.0%
Total Watershed Load	319	455	42.6%

Table 46. Change in Annual Phosphorus Load from Existing to Buildout Conditions in Lake Helena Modeling Subwatersheds

Subwatershed	Current Average Annual Phosphorus Load (mt)	Buildout Average Annual Phosphorus Load (mt)	Percent Increase
Clancy Creek	1.81	2.06	13.8%
Corbin Creek	0.20	0.29	44.0%
Golconda Creek	0.12	0.15	25.3%
Jackson Creek	0.33	0.34	3.1%
Jennies Fork	0.18	0.23	30.1%
Lake Helena Overland Flow	3.08	3.20	4.1%
Lump Gulch	1.48	1.75	18.4%
Middle Fork Warm Springs	0.17	0.23	31.9%
Middle Tenmile Creek	1.18	1.26	7.0%
North Fork Warm Springs Creek	0.08	0.09	15.6%
Prickly Pear above Spring Creek	1.03	1.28	24.3%
Prickly Pear above Lake Helena	13.79	45.40	229.2%
Prickly Pear above Lump Gulch	0.85	1.24	45.7%
Prickly Pear above WWTP outfall	1.20	1.33	10.4%
Prickly Pear above Wylie Drive	3.14	3.69	17.4%
Sevenmile Creek	1.50	1.75	16.7%
Silver Creek	4.12	4.74	15.1%
Skelly Gulch	0.63	0.81	28.9%
Spring Creek	1.00	1.28	28.0%
Tenmile above Prickly Pear	2.36	2.74	15.9%
Upper Tenmile Creek	0.79	1.07	34.5%
Warm Springs Creek	0.44	0.59	34.5%
To Lake Helena from Irrigation System	6.90	6.90	0.0%
Total Watershed Load	46	82	77.7%

4.5 Lake Helena Response to Scenarios

The BATHTUB model was used to simulate the potential impacts of the natural, reduced, and buildout scenarios on Lake Helena. The results are summarized in Table 47. Model results indicate that lake water quality is significantly worse today, under the existing condition, compared to the natural condition, and is projected to deteriorate further under the simplistic full build-out scenario. The results of the reduced scenario indicate slightly improved conditions compared to the existing condition.

Table 47. Comparison of Simulated Average Total Nitrogen, Total Phosphorus, and Chlorophyll *a* Concentrations in Lake Helena Under Four Modeling Scenarios

Parameter	Natural	Existing	Reduced	Buildout
Total Nitrogen (mg-N/L)	0.41	1.67	1.51	2.00
Total Phosphorus (mg-P/L)	0.115	0.149	0.136	0.263
Chlorophyll *a* (μg/L)	12.11	56.3	51.3	72.8

5.0 UNCERTAINTY OF THE GWLF/BATHTUB MODELING

There were several goals of the Lake Helena nutrient and sediment modeling effort:

- To determine the relative significance of each of the sediment and nutrient source categories within each TMDL subwatershed.
- To determine how sediment and nutrient loads in the watershed have been affected by anthropogenic activities (i.e., comparison of existing and natural scenarios) and the resulting impact to Lake Helena.
- To determine how loads might change in the future with increased development of the watershed and the resulting impact to Lake Helena.
- To determine allowable and existing loads at various points in the watershed that lack observed flow and/or water quality data.

Relatively simple models were chose to accomplish these goals because of the lack of data with which to calibrate more complex models. The models were set up using the best available data and output was compared to the limited observed data set. Output from the models was also reviewed by the project team to ensure that it was reasonable compared to local knowledge of the watershed. Errors in the model output are present and expected, and are primarily governed by errors and uncertainty with the following model inputs:

- Only one weather station was available to represent an area of greater than 600 square miles with extreme variations in elevation.
- Limited information was available on the timing or location of water withdrawals and other anthropogenic impacts to flows.
- No information was available on the extent of timber harvest on private land. We assumed that harvesting occurs at a continuous rate allowing for a 90-year harvest cycle (1/90 of private land is harvested each year). However, it is more likely that large cuts occur sporadically.
- Only limited data were available on the extent of failing septic systems in the watershed. We assumed that 7 percent of the systems were failing, but this is likely an under-estimate in certain parts of the watershed and an over-estimate in others.
- Applying constant monthly loads from the Helena Valley Irrigation District, point sources, and septic systems may oversimplify the loading from these sources.
- There is a general lack of understanding about the interaction between surface water and groundwater in the Helena Valley.

Despite these limitations, the GWLF and BATHTUB models are believed to be useful tools to help further the understanding of water quality in the Lake Helena watershed. They were used, **in combination with all other available information**, to identify those waterbodies that are impaired and to develop all necessary TMDLs. The limitations of the models were taken into consideration during their application as follows:

- The primary purpose of the GWLF modeling effort was to determine the relative difference in sediment and nutrient loads from each significant source category (e.g., point sources, roads, septic systems). These loads are most sensitive to annual flow volumes, which are largely driven by the runoff that occurs during the wettest months. GWLF performs reasonably well at matching annual flows as well as spring snowmelt volumes (refer to Section 2.6.1). Default values were used for most of the loading parameters (e.g., runoff concentrations, soil nutrient concentrations) due to a lack of local data and to ensure the modeling results are consistent with previously validated studies. The relative difference between the various source categories is therefore believed reasonable, even though the magnitude of the loads might be in error.

- Another purpose of the modeling effort was to evaluate the extent to which sediment and nutrient loads in the watershed have been affected or might be affected by anthropogenic activities. This was done by comparing the results of the existing scenario to artificial “natural” and “build out” scenarios. The results of the GWLF/BATHTUB model under natural conditions are considered reasonable because transport parameters for undisturbed land uses are well established. The results of the GWLF/BATHTUB model for the build-out scenario likely have a high degree of uncertainty due to the simplifying assumptions that were made. However, the results are believed to provide a reasonable estimate of the potential increase in loads.
- The GWLF model was also used to estimate the nutrient load reductions required to meet the proposed interim water quality targets. Accurate estimates of these reductions require the model to correctly simulate both existing flows (to calculate the allowable loads in streams without flow data) and existing loads. It is acknowledged that there is a fair amount of uncertainty in these values due to the limitations identified above. The reductions simulated by the model were therefore tempered by a comparison to the available data; however, the available data are also limited (i.e., few samples, little seasonal variability). The proposed reductions should therefore be viewed as preliminary goals to be refined during an adaptive management process.
- Finally, the modeled loads presented in Appendix A have purposefully been rounded to a minimum of significant figures so that the loads do not appear to be more accurate than they are.

6.0 REFERENCES

Canfield, D.E. and R.W. Bachmann. 1981. Prediction of total phosphorus concentrations, chlorophyll-*a* and Secchi disc in natural and artificial lakes. *Can. J. Fish. Aq. Sci.*, 38, 414-423.

Center for Watershed Protection. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Prepared by Winer, Rebecca. Prepared for U.S. EPA Office of Science and Technology.

Clark, Don. 2004. Personal communication to Julie Tsatsaros via email dated November 8, 2004 concerning the City of Helena WWTP.

Damschen & Associates. 1998. Helena Area Wastewater Treatment (HAWT) Facility Plan. Damschen & Associates, Inc.

Dillaha, T.A., R.B. Renear, S. Mostaghimi, and D. Lee. 1989a. Vegetative filter strips for agricultural nonpoint source pollution control. *Transactions of the American Society of Agricultural Engineers* 32(2):513-519.

Haith, D.A., R. Mandel, and R.S. Wu. 1992. GWLF, Generalized Watershed Loading Functions, Version 2.0, User’s Manual. Dept. of Agricultural & Biological Engineering, Cornell University, Ithaca, NY.

Ingman, G. 2004. Personal communication during conference call dated November 4, 2004 concerning the City of Helena WWTP.

LCCHD. 2002. Inventory of On-Site Wastewater Treatment Systems. Lewis and Clark County Health Department, Helena, MT, April 2002.

Moore, K. 2005. Personal communication with Julie Tsatsaros, May 2005. Lewis and Clark County.

Musket, J. 2005. Personal communication with Julie Tsatsaros, August 2005. City of East Helena.

NRCS. 2003. Upper Yellowstone River Watershed Land Cover Assessment, Final Report. Natural Resources Conservation Service, Montana, August 2003.

Rosgen, D.L. 1996. Applied River Morphology. Wildland Hydrology, Pagosa Springs, CO.

Rosgen, D.L. 2001. A Practical Method of Computing Streambank Erosion Rate. Proceedings of the Seventh Federal Interagency Sedimentation Conference, Vol. 2, pp. II - 9-15, March 25-29, 2001, Reno, NV

Schwab, G.O., D.D. Fangmeier, W.J. Elliot, and R.K. Frevert. 1993. Soil and Water Conservation Engineering, Fourth Edition, John Wiley & Sons, Inc, NY.

SCS. 1986. Urban Hydrology for Small Watersheds. Technical Release 55, U.S. Department of Agriculture, Soil Conservation Service, Engineering Division, Washington, DC.

Sun, G. and S. G. McNulty. 1998. Modeling soil erosion and transport on forest landscape. In: Winning solutions for risky problems: Proceedings of conference 29; 1998 February 16-20; Reno, NV. Steamboat Springs, CO: International Erosion Control Association: 189-198.

Stuart, Bo. 2004. Personal communication to Taylor Greenup via email dated November 8, 2004 concerning the Helena National Forest.

Tetra Tech. 2000. Watershed Characterization System User's Guide, Version 1.1. Developed for the Environmental Protection Agency, Region 4.

Toy, T.J., G.R. Foster, and J.R. Galetovic. 1998. Guidelines for the Use of the Revised Universal Soil Loss Equation (RUSLE) Version 1.06 on Mined Lands, Construction Sites, and Reclaimed Lands. Office of Technology Transfer, Western Regional Coordinating Center, Office of Surface Mining. Available at http://www.ott.wrcc.osmre.gov/library/hbmanual/rusle/frontmatter.pdf

USEPA. 1997. Technical Guidance Manual for Developing Total Maximum Daily Loads, Book 2: Streams and River. EPA 823-B-97-002.

USEPA. 2002a. Wastewater Technology Fact Sheet, Slow Rate Land Treatment. EPA 832-F-02-012, September 2002.

USEPA. 2002b. *Onsite Wastewater Treatment Systems Manual.* EPA/625/R-00/008. February 2002.

USEPA. 2004. Water Quality Restoration Plan and Total Maximum Daily Loads (TMDLs) for the Lake Helena Watershed Planning Area.

U.S. Forest Service. 1998. Soil Survey of Flathead National Forest Area, Montana, in cooperation with Montana Agricultural Experiment Station, Natural Resources Conservation Service, and U.S. Forest Service.

Walker, W.W., Jr. 1987. Empirical Methods for Predicting Eutrophication in Impoundments. Report 4–Phase III: Applications Manual. Technical Report E-81-9. U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, MS.

Wischmeier, W.H., and Smith, D.D., 1978. Predicting Rainfall Erosion Losses — A Guide to Conservation, Agricultural Handbook 537. Planning, Science and Education Administration. US Department of Agriculture, Washington, DC, 58 pp.