APPENDIX G
BIG HOLE RIVER WATERSHED NUTRIENT TMDL
GWLF MODELING DOCUMENTATION

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DOCUMENT PURPOSE

This document has been prepared to support nutrient source assessments and loading estimates for the Big Hole River Watershed Nutrient TMDL. It is intended to provide a brief synopsis of the project and substantiate numerical estimates of nitrogen and phosphorus delivery in the watershed. Work has been completed cooperatively by the Water Quality Modeling and Planning Sections of the Montana Department of Environmental Quality.

LIST OF ACRONYMS

ACRONYM

AMC	Antecedent Moisture Condition
AU	Animal Units
AUM	Animal Units per Month
ARM	Administrative Rules of Montana
AWC	Available Water Capacity
BMPs	Best Management Practices
CN	Curve Number
CMPPCT	Composition Percentage
CN	Curve Number
COOP	Cooperative Observer
CWA	Clean Water Act
CWAIC	Clean Water Act Information Center
DEQ	Montana Department of Environmental Quality
EMC	Event Mean Concentration
EPA	Environmental Protection Agency
GIS	Geographic Information System
GRTS	Grants Reporting and Tracking System
GWLF	Generalized Watershed Loading Functions
HUC	Hydrologic Unit Code
K	Soil Erodibility Factor
LULC	Land Use/Land Cover
MOS	Margin of Safety
MUID	Map Unit ID
N	Nitrogen
NRCS	Natural Resource Conservation Service
NED	National Elevation Datum
NHD	National Hydrography Dataset
NLCD	National Land Cover Dataset
NO2+NO3	Nitrate plus Nitrite
NPS	Nonpoint Source
NURP	Nationwide Urban Runoff Program
NWIS	National Water Information System
P	Phosphorus
SCS	Soil Conservation Service
SDR	Sediment Delivery Ratio
SNOTEL	Snow Telemetry System
SRP	Soluble Reactive Phosphorus
SSC	Suspended Sediment Concentration
STATSGO	State Soil Geographic Database
STORET	Storage and Retrieval Water Quality Database
TN	Total Nitrogen
TP	Total Phosphorus

TMDL	Total Maximum Daily Load
TPA	TMDL Planning Area
USGS	U.S. Geological Survey
USLE	Universal Soil Loss Equation

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SECTION 1.0
INTRODUCTION

Nineteen tributaries are characterized as “water quality-limited” in the Big Hole River watershed due to nutrient impairment (Table 1; CWAIC, 2008). To satisfy Federal Clean Water Act requirements, Total Maximum Daily Loads (TMDLs) must be developed for these water bodies such that they support beneficial uses. As part of this effort, a low-detail modeling study was completed by Montana Department of Environmental Quality (DEQ) to estimate nutrient source contributions and seasonal loadings of nitrogen and phosphorus from various land uses. The Generalized Watershed Loading Functions (GWLF) model was selected for the analysis due to its relative simplicity in model application and usefulness in simulating hydrology and mass loadings of pollutants on a monthly time-scale. Due to current TMDL scheduling priorities, only a subset of the impaired water bodies in each TMDL Planning Area (TPA) were evaluated as part of the current TMDL effort. The remaining tributaries will be addressed according to the scheduling timeframes outlined in the consent decree. A map of the 303(d) listed reaches evaluated as part of this project are shown in **Figure 1.**

Table 1. Water quality limited reaches in the Big Hole River watershed impaired from nutrients.

Water body ID1,2	Reach Segment	Probable Cause
	Upper TPA[3]	
Francis Creek	MT41D004_200	Nitrogen/Phosphorus (total)
Steel Creek	MT41D004_190	Phosphorus (total)
McVey Creek	MT41D004_210	Nitrogen/Phosphorus (total)
Rock Creek	MT41D004_120	Nitrogen/Phosphorus (total)
Swamp Creek	MT41D004_110	Nitrogen/Phosphorus (total)
Fox Creek	MT41D004_170	Phosphorus (total)
Pine Creek	MT41D004_160	Phosphorus (total)
Warm Springs Creek	MT41D004_180	TKN/Phosphorus (total)
	Middle TPA[3]	
Jerry Creek	MT41D003_020	Excess algal growth
Charcoal Creek	MT41D002_150	Nitrogen/Phosphorus (total)
Fishtrap Creek	MT41D003_160	Phosphorus (Total)
Gold Creek	MT41D003_230	Phosphorus (Total)
Sawlog Creek	MT41D004_230	Phosphorus (Total)
	Lower TPA[3]	
Camp Creek	MT41D002_020	Phosphorus (Total)
Divide Creek	MT41D002_040	TKN/Phosphorus (Total)
Grose Creek	MT41D002_060	Phosphorus (Total)
Lost Creek	MT41D002_180	Nitrogen/Phosphorus (total)
Soap Creek	MT41D002_140	Phosphorus (Total)
Wickiup Creek	MT41D002_120	Phosphorus (Total)

[1] Source: 2006 303(d) List.
[2] Items shown in white are being addressed as part of the current TMDL effort. Greyed items will be addressed at a later date.
[3] TPA (TMDL Planning Area) segments are subsets of the overall Big Hole River Watershed used to divide the project area into manageable units for TMDL planning.

1.1 Previous Studies

A literature review was completed prior to the initiation of the project to identify if previous studies would be of use in modeling. Those of interest to DEQ are shown below:

1. **USGS bi-weekly monitoring** – USGS collected bi-weekly nitrate (NO3-) and daily sediment samples in the lower portion of the Big Hole River watershed from 1960-1964. Sediment is of interest due to its affinity for nutrient sorption.
2. **Statewide water quality monitoring network monitoring** – DEQ conducted nutrient sampling at multiple locations in the watershed from 2003-2005 as part of the statewide monitoring network. Sampling was limited to a frequency of once per year, in the growing season.
3. **TMDL source assessment monitoring** – DEQ monitored nutrients at multiple sites from 2003 and 2005 as part of TMDL source assessment activities. Data collection was limited to the growing season, with a frequency of one to two samples per summer.

The pertinence of these studies toward the modeling is detailed further in subsequent sections. Applicability toward nutrient criteria is described below.

1.2 Nutrient Criteria in Montana (ARM 17.30.637)

Montana is currently governed by narrative nutrient criteria, specifically, that surface waters must be free from municipal, industrial, and agricultural discharges that produce undesirable aquatic life [ARM 17.30.637 (1)(e)]. In instances where water bodies do not support beneficial uses, TMDLs and associated water quality restoration plans must be developed. Nineteen such tributaries were identified as impaired on the 2006 303(d) List. Nine are being addressed as part of the Big Hole River watershed TMDL (**Table 1**). Because narrative criteria are somewhat problematic for total maximum daily load analysis, interim numeric criteria were used as a surrogate instead. Those applicable for the Big Hole River TMDL (e.g. the Middle Rockies Ecoregion) are shown in **Table 2**. Modeling will be conducted to assess strategies that can be implemented such that these interim criteria are achieved.

Table 2. Interim numeric criteria for the Big Hole River Watershed (Suplee et al., 2007).

Constituent	Target Value
Total nitrogen (TN)	≤ 0.39 mg/L (winter) ≤ 0.52 mg/L (runoff) ≤ 0.32 mg/L (growing season)
Total phosphorus (TP)	≤ 0.03 mg/L (winter) ≤ 0.05 mg/L (runoff) ≤ 0.049 mg/L (growing season)
Chlorophyll a	≤ 150 mg/m² for Foothill/Valley

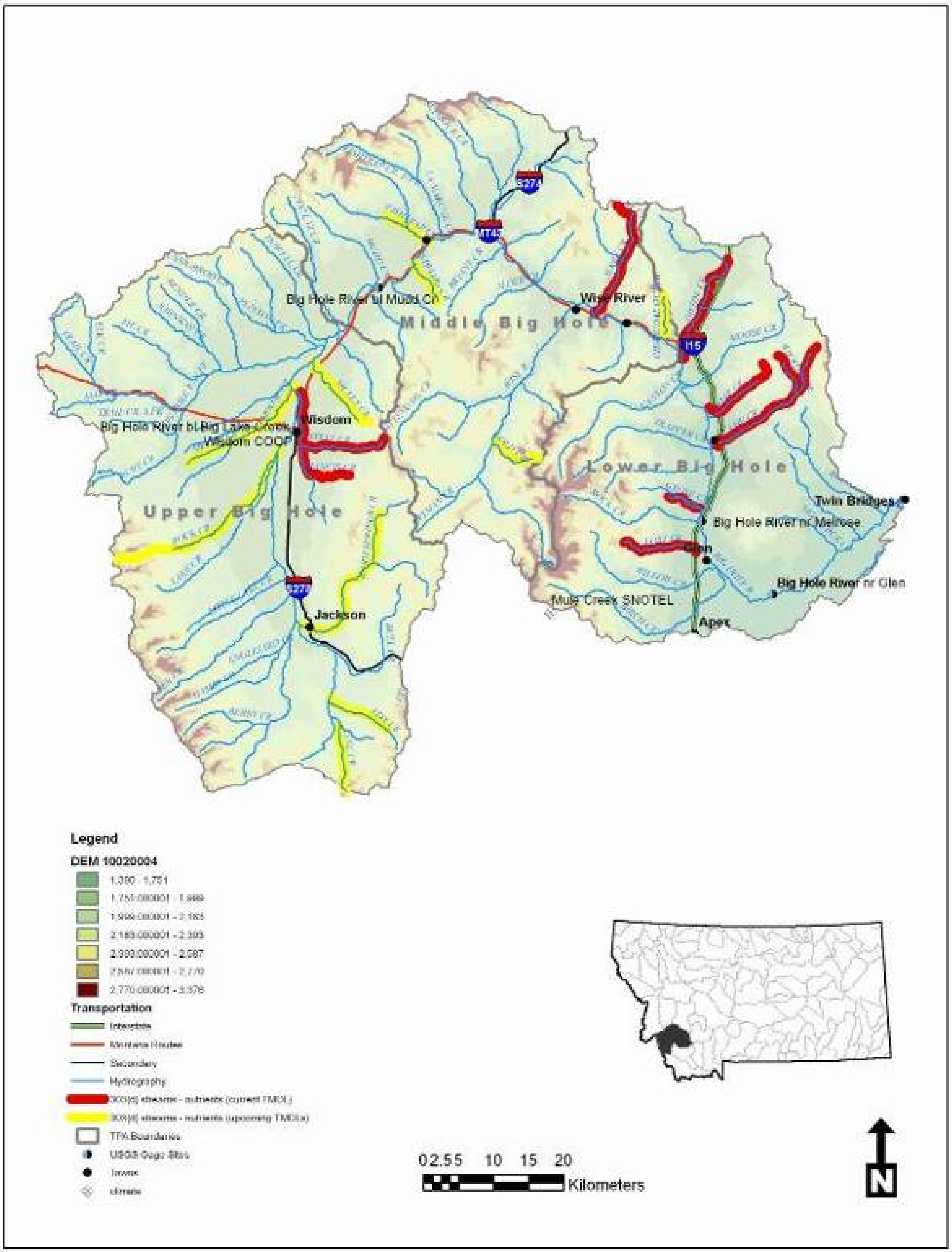


Figure 1. Study of map showing 303(d) listed stream segments, elevation and terrain (DEM), streamflow gaging stations, climate stations, and transportation network. Stream segments highlighted in red are being addressed in the current TMDL. The remaining listings will be completed at a later date.

SECTION 2.0
STUDY AREA

The Big Hole River drains approximately 7,250-km2 (2,800-mi2) of high- and mid-elevation mountainous topography in southwestern Montana. Originating from the continental divide, the river flows 247-km past the towns of Jackson, Wisdom, Wise River, Melrose, and Glen before reaching its endpoint near Twin Bridges (**Figure 1**). Elevations in the watershed range from 1,399 to 3,388 meters (4,590 to 11,115 feet), and mean basin elevation is 2,149 meters (7,050 feet). The entire watershed is part of United States Geological Survey (USGS) Hydrologic Unit Code (HUC) 10020004. Three distinct planning segments are being addressed by DEQ as part of the TMDL. These include: (1) the upper TPA which extends from the headwaters to Pintlar Creek, (2) middle TPA which extends from Pintlar Creek to Divide Creek, and (3) lower TPA which extends from Divide Creek to the Beaverhead River.

2.1 Climate

Climate in the Big Hole River watershed is inter-montane continental, with marked seasonality. Wisdom cooperative observer (COOP) station 249067 and the Mule Creek SNOTEL station provide representative information regarding the basin (**Table 3**, **Figure 2a**). Valleys are predominantly arid, and the mountains wet, with a 30-year average annual precipitation at Wisdom of 30.2 centimeters (11.9 inches) (1971-2000). The Mule Creek SNOTEL receives nearly double this amount; 76.6 centimeters annually (30.2 inches). The observed variation in precipitation is typical of climates in mountainous regions and has been described previously by Farnes (1975) and Marvin and Voller (2000). Temperatures are also consistent with mountainous climates with warmer valleys and cooler uplands, the exception being during the winter months when inversions occur. Mean monthly temperature at Wisdom is 2.0ºC (35.6ºF) while the Mule Creek SNOTEL site is 0.8ºC (33.4ºF).

Table 3. Representative climate stations for the Big Hole River Watershed (1971-2000).

Station ID	Agency	Elevation	Mean Annual Precipitation	Mean Annual Temperature[1]
Wisdom COOP 249067 (valley)	NOAA	1847 m (6060 ft)	30.2 cm (11.9 inches)	2.0ºC (35.6ºF)
Mule Creek SNOTEL (mountain)	NRCS	2530 m (8300 ft)	76.6 cm (30.2 inches)	0.8ºC (33.4ºF)

[1] Mean annual temperature statistics not compiled by NRCS for 1971-2000. Entire period of record used instead.

2.2 Streamflow

There are four operational USGS gaging stations in the Big Hole River watershed: (1) USGS 06024450 Big Hole River below Big Lake Creek at Wisdom, MT, (2) USGS 06016000 Big Hole River below Mudd Creek, (3) USGS 06017000 Big Hole River nr Melrose, and (4) USGS 06018500 Big Hole River nr Glen. Based on review of their hydrographs, surface water hydrology is predominately snowmelt driven, with spring snowmelt beginning in mid to late March, peaking in June, and then rapidly declining in July and August toward baseflow (**Figure b**). Baseflow and/or low flow conditions then persist to the following spring when winter snow accumulation once again begins to melt.

2.3 Land Use

Land use in the Big Hole River consists primarily of agriculture, with cow-calf operations being the dominant production practice. Many stock owners pasture their livestock on National Forest range during the summer months and grow irrigated grass or alfalfa hay for winter feed. In the headwaters, logging and associated activities, such as road construction, have been known to occur, but only to a minor extent. The same goes for urban encroachment and residential development. No point source discharges or wastewater discharges were identified in the watershed and the towns of Jackson, Wisdom, Wise River, Melrose, and Glen all have relatively low septic densities, all under 200 people (U.S. Census, 2000).

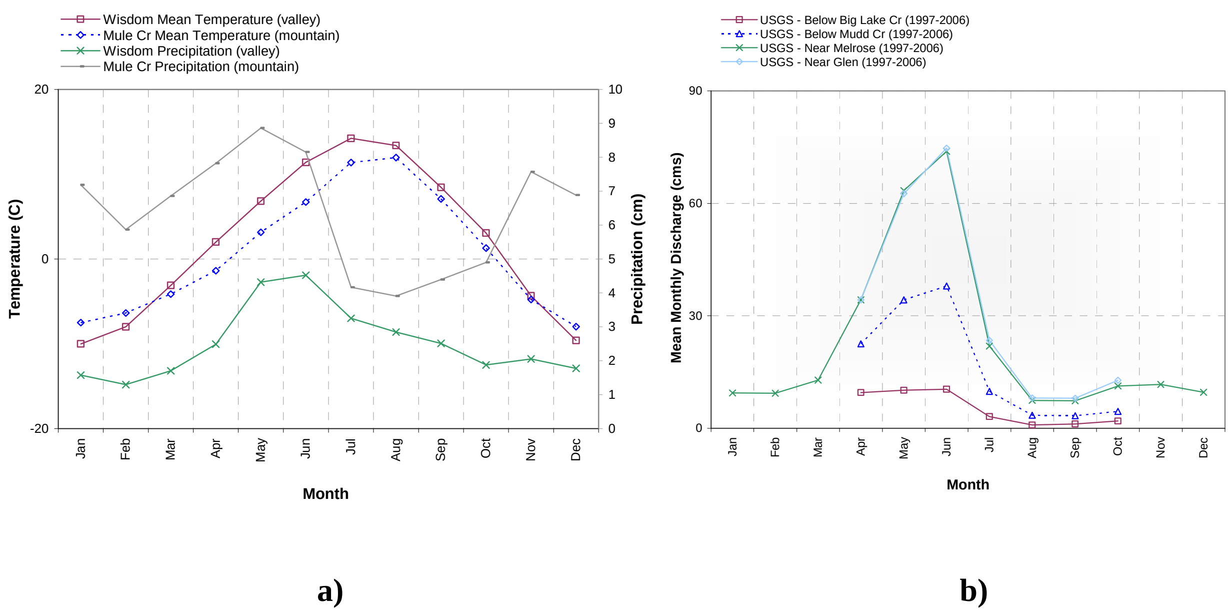


Figure 2. a) Climate at Wisdom COOP 249067 (valley) and Mule Creek SNOTEL (mountainous) sites (1971-2000); b) hydrology at the four operational USGS gages in the watershed (1997-2006).

2.4 Soil

Soils in the Big Hole River watershed are highly variable and depend on location. In general they have moderate infiltration rates and consist mainly of deep well drained soils with fine to coarse textures. The Maurice-Phillipsburg-Thayne loam is the predominant soil series in the Upper Big Hole River TPA. It is found at the lower elevations between Jackson and Wisdom. The Ovando-Elkner-Shadow is a gravelly-silt-loam found at mid elevations of the Pintler and Pioneer Mountains, and dominates the Middle Big Hole River Planning Area. Finally, the Trimad-Kalsted-Crago is a silt-loam found throughout much of the Lower Big Hole River Planning Area

(DEQ, 2007). Soils information was acquired from the State Soil Geographic (STATSGO) database (NRCS, 1994).

SECTION 3.0
DATA COMPILATION & ASSESSMENT

A data compilation and assessment was initially completed to identify available information for modeling. Two types of data were assessed: (1) flow data and (2) water chemistry data. Both the USGS National Water Information System (NWIS, 2008) and the U.S. Environmental Protection Agency's (EPA) STORET databases (STORET, 2008) were queried. Results are briefly described below.

3.1 Flow

Observed streamflow is a required component for hydrologic calibration and was obtained directly from the USGS. Gaging stations that have historically operated in the Big Hole River watershed are shown in **Table 4**, and most contain suitable observational data for modeling (e.g. daily streamflow). Periods of record and associated water quality observations are also indicated.

Table 4. USGS streamflow and water quality stations in the Big Hole River Watershed.

USGS No.	Site Name	Begin Date	End Date	# of Nutrient Observ.	# of SSC Observ.
6025270	Moose Cr ab Maclean Cr nr Divide MT	10/1/1997	9/30/1999	0	0
6025480	Rock Cr bl Brownes Lake nr Glen MT	9/1/1997	10/31/1999	0	0
6025700	Willow Cr Diversions to Birch Cr nr Glen MT	4/21/1946	9/30/1966	0	0
6026206	Upper Raffety Ditch near Glen MT	4/24/1998	10/31/1999	0	0
6024510	West Fork Ruby Creek near Wisdom MT	4/1/1995	9/30/1996	0	0
6024000	Miner Creek near Jackson MT	5/24/1948	10/31/1953	0	0
6025800	Willow Creek near Glen MT	8/1/1962	10/31/1999	36	21
6026000	Birch Creek near Glen MT	5/1/1946	10/6/1976	21	15
6023500	Big Hole River near Jackson MT	4/29/1948	10/31/1953	0	0
6024470	Swamp Creek near Wisdom MT	3/28/1995	9/30/1996	0	0
6024500	Trail Creek near Wisdom MT	6/29/1948	7/20/1972	2	0
6024590	Wise River near Wise River MT	9/28/1972	9/30/1985	0	0

Table 4. USGS streamflow and water quality stations in the Big Hole River Watershed.

USGS No.	Site Name	Begin Date	End Date	# of Nutrient Observ.	# of SSC Observ.
6024450	Big Hole River bl Big Lake Cr at Wisdom MT	5/1/1988	5/11/2008	0	0
6024540	Big Hole River bl Mudd Cr nr Wisdom MT	10/1/1997	5/11/2008	0	0
6024580	Big Hole River near Wise River MT	6/1/1979	10/2/1981	0	0
6025000	Big Hole River near Dewey MT	9/1/1910	9/30/1913	0	0
6025250	Big Hole River at Maiden Rock nr Divide MT	10/1/1997	5/11/2008	0	0
6025500	Big Hole River near Melrose MT	10/1/1923	5/11/2008	102	1465
6026210	Big Hole River near Glen MT	9/11/1997	5/11/2008	0	0
6026400	Big Hole River near Twin Bridges MT	7/25/1979	10/1/1981	50	0
6026420	Big Hole R bl Hamilton Ditch nr Twin Bridges, MT	7/1/2007	9/30/2007	0	0

3.2 Chemistry

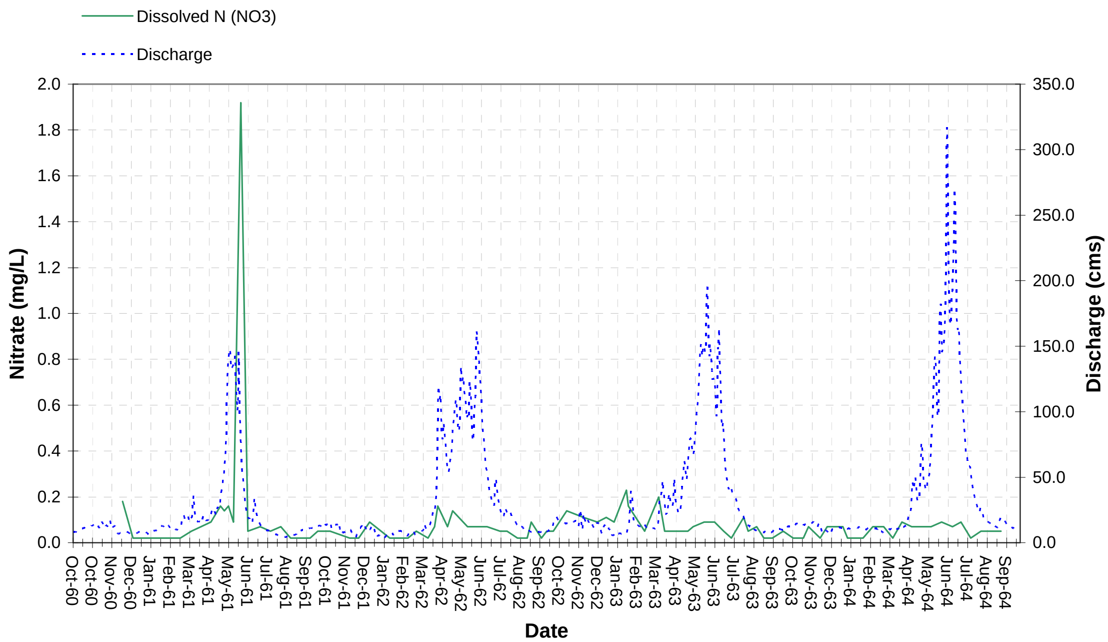
Water chemistry data are necessary for quality calibration. As such, the USGS and STORET records were evaluated to ensure suitability for modeling. Based on this reconnaissance, only a handful of sites have adequate sediment and nutrient observations for modeling. This includes USGS 6025800 Willow Creek near Glen and USGS 6025500 Big Hole River near Melrose, MT. No suitable data were found in STORET. Thus a calibration and validation approach was formulated around those stations. This is described in **Section 3.6**. An assessment of this data is provided in the following section.

3.3 Data Assessment

3.3.1 Time Series

Bi-weekly nutrient samples (NO3-) and daily suspended sediment samples were collected at USGS 06017000 Big Hole River near Melrose from 1960-1964. Monthly nutrient and SSC samples were collected at USGS 6025800 Willow Creek near Glen from 1962-1965. Based on the data, pollutant loading is consistently correlated with early season hydrograph response (**Figure 3** and **Figure 4**). Fluctuations in nitrate appear to be infrequent short duration events which presumably are associated with overland flow from agricultural landscapes. Sediment peaks are more prolonged and are believed to occur primarily from bank erosion during sustained snowmelt (rather than rainfall induced upland erosion).
3.3.2 Graphical and statistical analysis

STORET contains a wealth of standalone water chemistry data. A population based approach was used to estimate cursory statistical information from STORET, such as mean and median concentrations, upper and lower quartiles, and ranges for total nitrogen (TN), nitrate (NO3-), total phosphorus (TP), and soluble reactive phosphorus (SRP) (**Figure 5**). In general, nutrient concentrations appear to have remained relatively consistent over time, with dissolved nitrogen (e.g. NO3-) exhibiting the most variability. This largely is consistent with the hypothesis that overland flow infrequently contributes dissolved loadings during the runoff period.



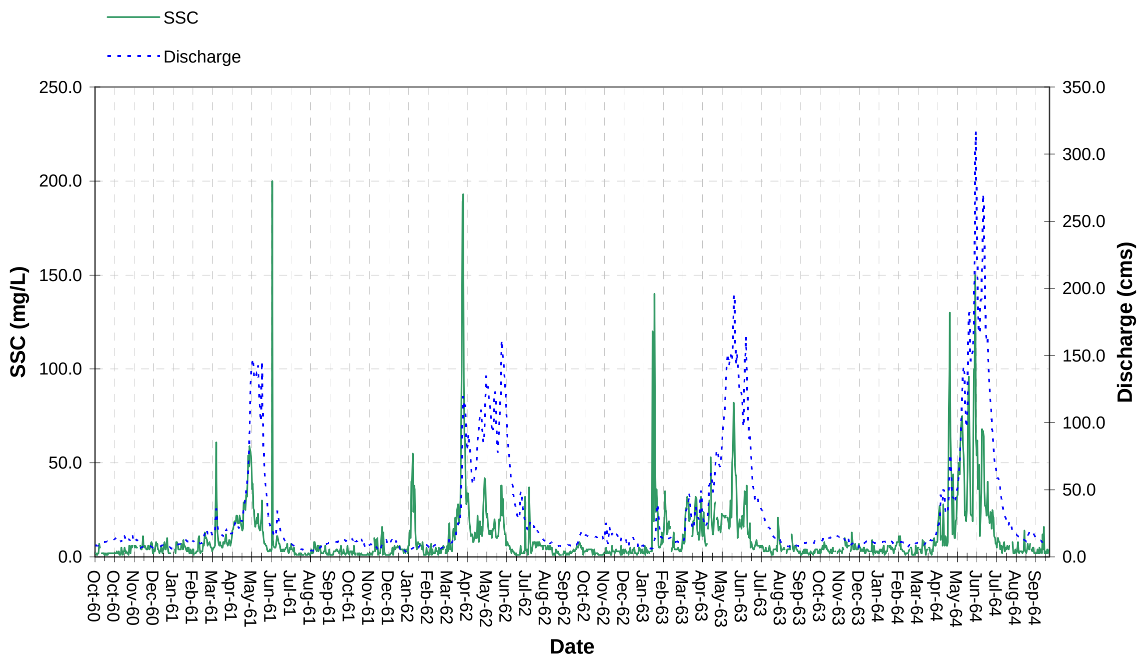
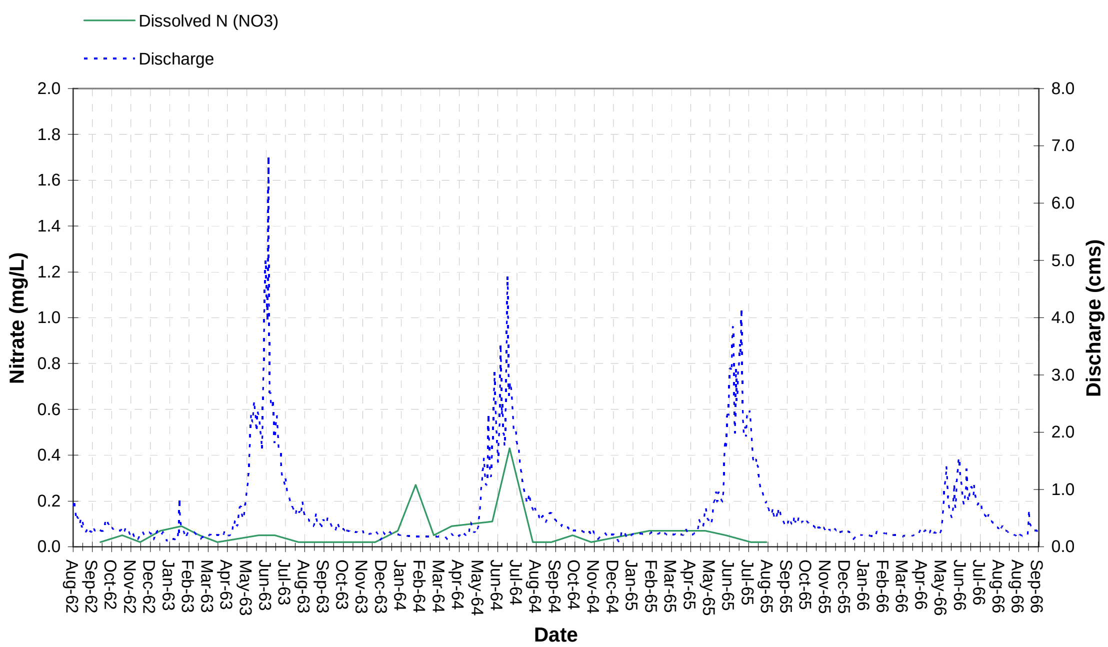


Figure 3. Biweekly nitrate concentrations (NO3--), daily suspended sediment concentration (SSC), and daily flow at USGS 06017000 Big Hole River near Melrose.



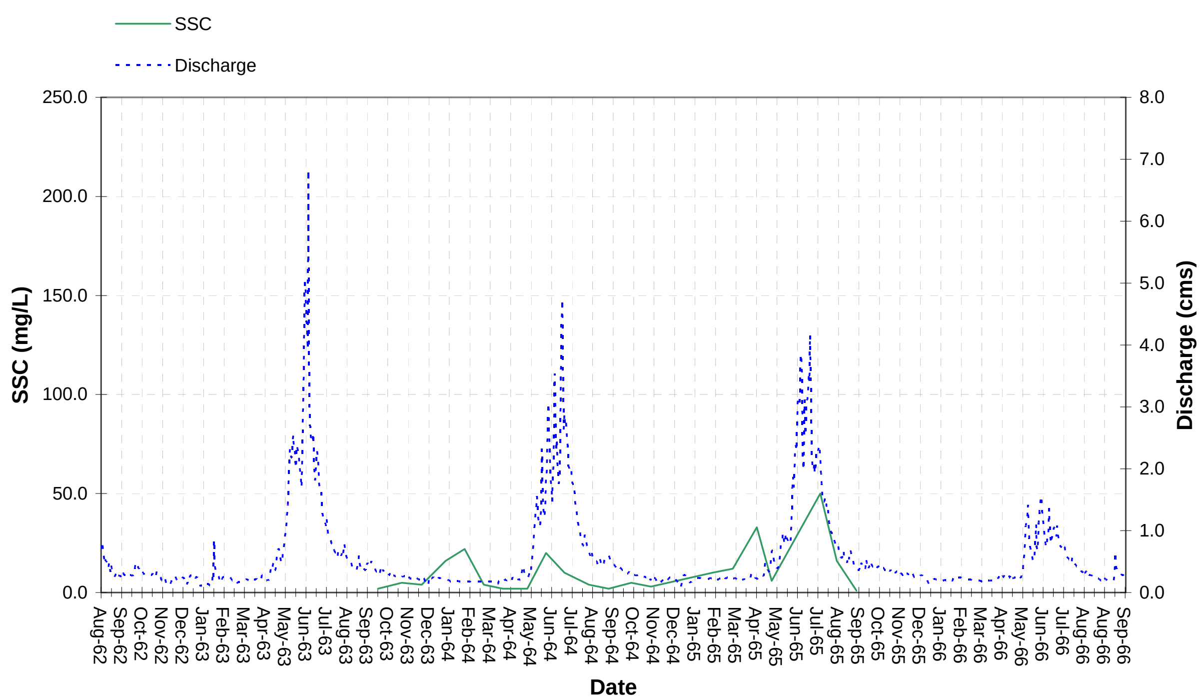


Figure 4. Monthly nitrate (NO3-) and suspended sediment (SSC) concentration, and daily flow at USGS 6025800 Willow Creek near Glen.

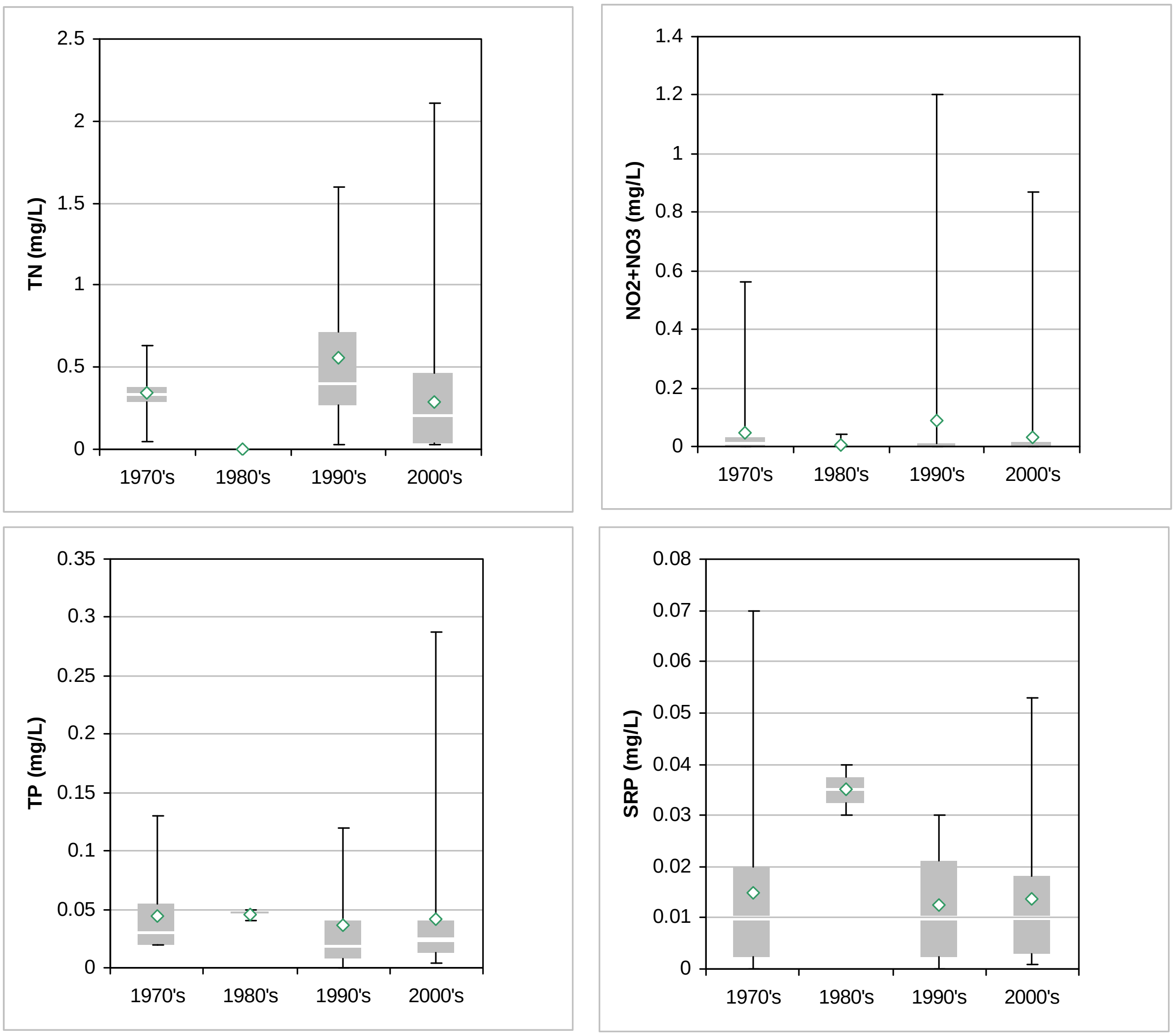


Figure 5. Box and whisker plots showing mean (e.g. green dot), median, quartiles, and ranges of total nitrogen (TN), dissolved nitrogen (NO2+NO3), total phosphorus (TP), and dissolved phosphorus (SRP) data collected in the Big Hole River watershed from 1970-current. Information originates from the STORET database.

Note: Number of observations during each decade shown below

Species	1970's	1980's	1990's	2000's
TN	10	0	11	219
NO2+NO3	18	62	15	189
TP	11	2	15	188
SRP	50	2	6	57

SECTION 4.0
MODELING APPROACH

From review of the data assessment, it was found that suitable data are available for development of a GWLF model of the Big Hole River watershed. The USGS database contains the necessary paired flow and chemistry data for calibration and validation, while observations from STORET can be used to fill data gaps (such as dissolved to total nutrient ratios and anticipated mean concentrations for TP, SRP, TN, and NO2+NO3). Thus the modeling project was initiated. A parameter transfer approach was used in the model development phase where calibration was completed on USGS 0601000 Big Hole River near Melrose, while a separate validation model was developed for a watershed similar in size to the TMDL watersheds, e.g. USGS 6025800 Willow Creek near Melrose. Attributes of each of the simulated watersheds are shown in **Table 5.**

Table 5. Characteristics of calibration and validation sites for GWLF modeling effort.

USGS No.	Site Name	Area (km2)	Forested Area (%)	Mean Elev. (m)	Mean Prcp (cm)
6025800	Willow Creek near Glen MT	92.8	74.7	2,224	71.3
6025500	Big Hole River near Melrose MT	6,384	57.3	2,149	63.1

The location of the proposed calibration and validation watersheds, along with the nine watersheds where TMDL analysis will be completed are shown in **Figure 6**. GWLF model input development activities are described in the following section.

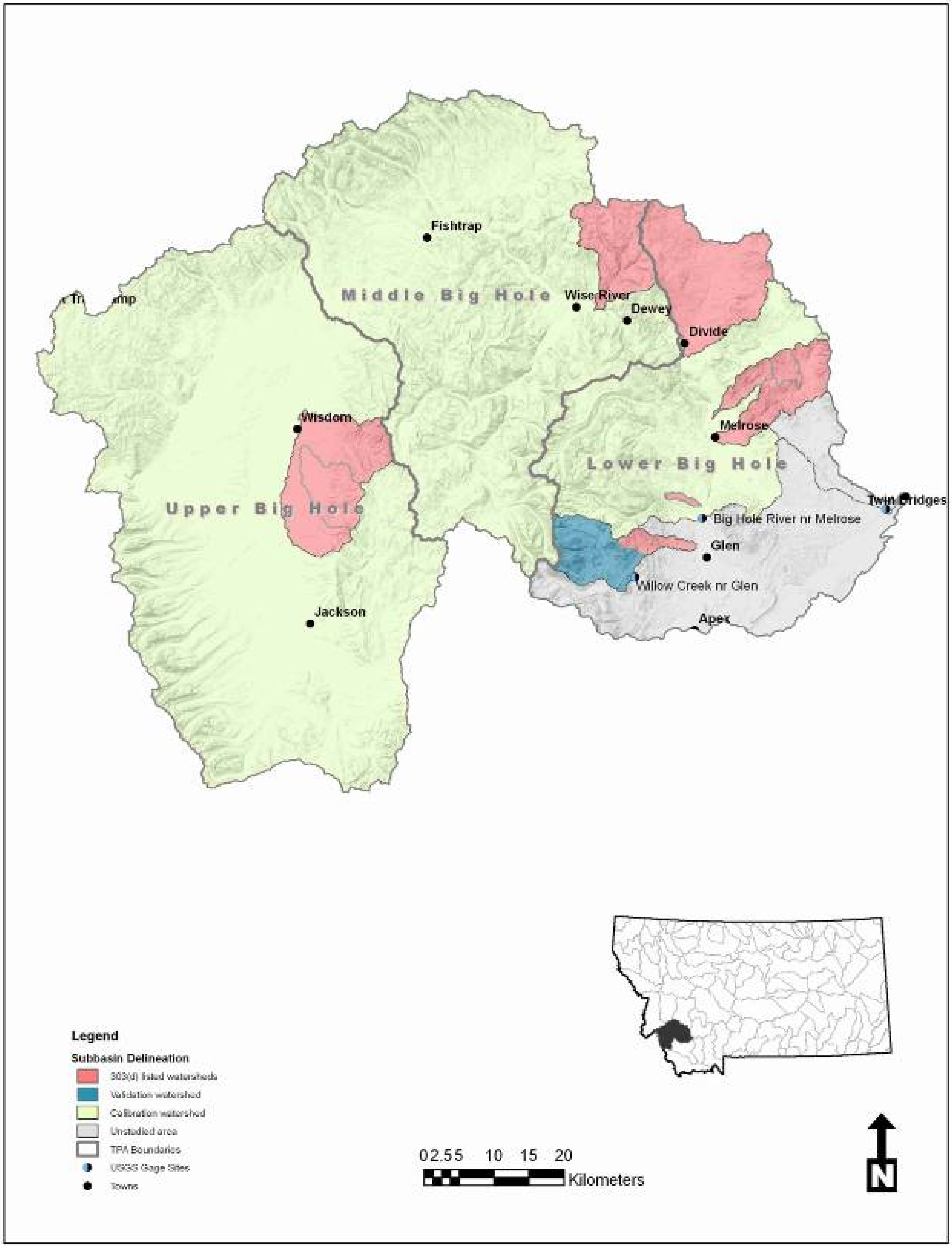


Figure 6. Map showing calibration and validation watersheds and 303(d) listed subbasins. The area in grey was not evaluated as part of the TMDL effort.

SECTION 5.0
GWLF MODEL DEVELOPMENT

5.1 GWLF Model Description

The Generalized Watershed Loading Functions model (GWLF) is a daily time-step model used in prediction of runoff, sediment, nitrogen, and phosphorus loads in variable sized watersheds. Rainfall, snowmelt, evapotranspiration, infiltration, dissolved and solid phase nutrient loading, and streambank erosion are all simulated as part of the model. It was written with the express purpose of requiring no calibration, and the model simply aggregates loads from each of the source areas in the watershed to form the overall pollutant load. The model is not spatially explicit and contains no routing component, therefore the complexity falls between that of detailed, process based simulation models and simple export coefficient models. GWLF has been endorsed by the U.S. EPA as a good "mid-level" model for simulating most of the key mechanisms controlling nutrient fluxes within a watershed (U.S. EPA, 1999).

5.2 GIS Pre-processing

The ArcView3.2 AVGWLF Geographic Information System (GIS) interface (Evans et al., 2002) was used to expedite the initial model setup and parameterization of GWLF. Fundamental input data for AVGWLF are topography (e.g. digital elevation model; DEM), land use/landcover (LULC), soils information, and climate. GIS data sources used in the Big Hole River GWLF model include:

- National Elevation Dataset (NED) – The USGS NED is a 1:24,000 scale DEM is used in calculation the slope length/steepness for the Universal Soil Loss Equation (USLE.) The BASINS version of the NED was used (USEPA, 2004).
- National Hydrography Dataset (NHD) – NHD is a 1:24,000 scale vector coverage of stream topology and was also taken from BASINS (USEPA, 2004). It was used as a definition of the channel network subject to bank erosion in the model.
- National Land Cover Dataset (NLDC) –NLCD (Homer et al., 2001) is a 29- category land cover classification (30-m grid) available over the conterminous U.S. It was used to develop gridded landcover inputs for runoff and erosion computations. (**Figure 7**)
- STATSGO Soils – The STATSGO soil map (NRCS, 1994) is a 1:250,000 scale generalization of detailed soil survey data that was used to develop soil erosion properties and associated information for runoff and erosion calculations.

5.3 Climate Input

Climate input for GWLF was based on Wisdom cooperative observer (COOP) station 249067, with adjustment for orographic precipitation and temperature variation using the Parameter-elevation Regressions on Independent Slopes Model (PRISM) (Daily et al., 2000), and environmental lapse rate. The annual ratio between the site data, and that of the watershed being modeled, was used in this adjustment. PRISM data was taken directly from the Montana Natural

Resource Information System (NRIS, 2008), and the environmental lapse rate from the International Civil Aviation Organization (ICAO, 2008) was used.

5.4 Water Balance/Hydrologic Input

Hydrology in GWLF is partitioned into surface water and groundwater components using the SCS-curve number (CN) methodology. Curve number estimation procedures are described below.

5.4.1 Curve Number Estimation

Curve number was estimated using the combination of the National Land Cover Dataset (NLCD; Homer et al., 2001) and STATSO soil database (NRCS, 1994). Six aggregated source categories were used in facilitating the modeling including: water, developed, forest, grassland, shrub/scrub (e.g. sagebrush), and pasture/hay. They are shown in **Table 6**. Of these, forest, grassland, and shrubland comprise over 90 percent of the total watershed area (43.9 percent, 34.3 percent, and 14.0 percent respectively). The remaining portions include open water (0.3 percent), developed lands (1.5 percent), and pasture/hay (5.8 percent). Curve numbers derived for each of these land classes are shown in **Table 7**.

Table 6. Landcover and aggregated land classes used in the GWLF modeling (original source, NLCD 2001).

NLCD 2001 Landcover	Area (hectares)[2]	Percentage (%)	GWLF-E Re-classified Landcover
Open Water	1,141	0.2%	Open Water
Perennial Ice, Snow	49	0.0%	
Developed, Open Space	4,604	0.6%	Developed
Developed, Low Intensity	1,235	0.2%	
Developed, Medium Intensity	190	0.0%	
Developed, High Intensity	4	0.0%	
Barren Land, Rock	3,739	0.5%	Forest
Deciduous Forest	341	0.0%	
Evergreen Forest	378,881	52.1%	
Mixed Forest	98	0.0%	
Woody Wetlands	1,942	0.3%	
Emergent Herbaceous Wetlands	43	0.0%	
Shrub, Scrub	37,888	5.2%	Shrub, Scrub
Grassland, Herbaceous	273,009	37.5%	Grassland, Herbaceous
Pasture/Hay	21,157	2.9%	Pasture/Hay
Cultivated Crops (1)	2,963	0.4%	

[1] Review of aerial photographs and NLCD 2001 indicate that cultivated crops typically consist of alfalfa and/ or hay.
[2] Areas for entire watershed; not be confused with areas used in modeling.

Table 7. Curve numbers used in GWLF modeling.

GWLF-E Re-classified Land Class	Dominant Hydrologic Soil Group	Curve Number AMC II
Developed	B	70
Evergreen Forest	A	45
Shrub, Scrub	B	49
Grassland, Herbaceous	B	62
Pasture/Hay	B	58

5.4.2 Irrigation

Irrigation was accounted for in GWLF using crop evapotranspiration (ET) from the Dillon (DLNM) AGRIMET site and associated crop area. Losses of 25 percent were assumed to occur in the distribution system. Estimated withdrawls were then directly subtracted from the overall "streamflow" component of the water balance with the provision that the diverted value did not exceed simulated streamflow (e.g. no negative streamflow calculations). The calculation procedure for this methodology is shown in the **Appendix A1**.

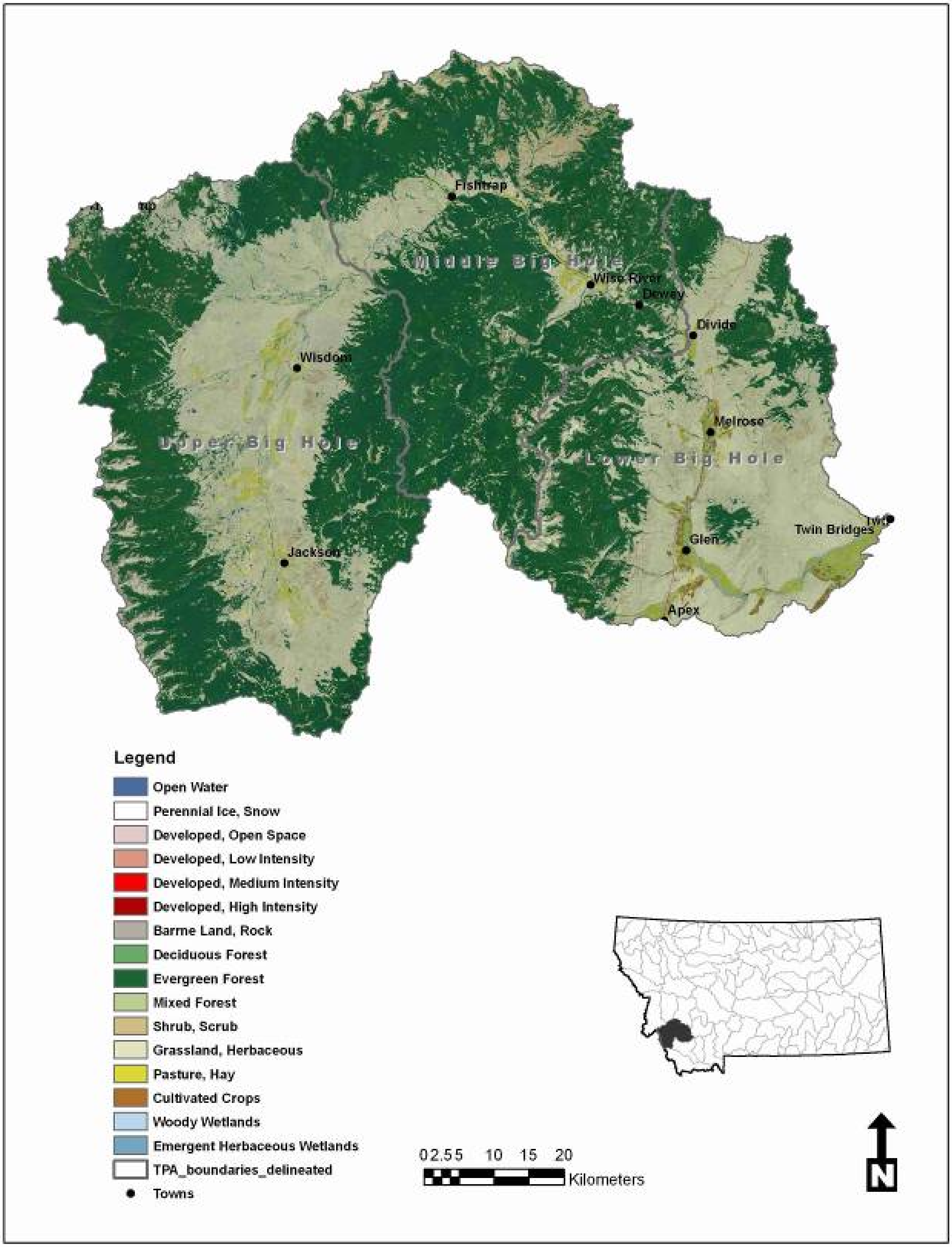


Figure 7. Landcover of the Big Hole River watershed (Homer, et al., 2001).

5.5 Sediment Input

5.5.1 Hillslope Erosion

Erosion and sedimentation are computed in GWLF using the Universal Soil Loss equation (USLE). Input parameters used in the GWLF modeling are shown in **Table 8** and are consistent with studies conducted elsewhere by DEQ.

Table 8. USLE parameter assignment for GWLF modeling.

USLE Assignment[1,2]						Assignment Details	
GWLF-E Re-classified Land Class	**[3]K-Factor**	**[4]LS-Factor**	**[5]C-factor**	**[6]P-factor**	**Ground or canopy Cover**	**Canopy Type**	**Cover Type**
Developed	WS	WS	0.09	1	---	none	G/W
Evergreen Forest	WS	WS	0.003	1	---	forest	60% duff
Shrub, Scrub	WS	WS	0.05	1	---	20" brush	G
Grassland, Herbaceous	WS	WS	0.07	1	---	none	G
Pasture/Hay	WS	WS	0.02	1	---	none	G

[1] WS = Watershed specific; computed from GIS layers
[2] Rainfall erosivity factor calculated from daily precipitation
[3] Soil erodibility factor from NRCS STATSGO grid
[4] Topographic factor calculated from Basins DEM
[5] Cover management factor from Brooks, 1999 and MCcuen, 1998
[6] P-factor of unity applied (e.g. no conservation practices)

5.5.1 Streambank Erosion

Streambank erosion is computed within GWLF using a rating curve approach. Parameterization of the lateral bank erosion "a" coefficient was completed solely through model calibration. In order to properly scale parameters for watersheds with differing streamflow conditions, "a" was adjusted to maintain a consistent lateral erosion rate for each watershed (e.g. to maintain the rate determined in the calibration). Coefficients used in the modeling are shown in the model input in the **Appendix A3**.

5.6 Nutrient Input

5.6.1 Dissolved Nutrients

Dissolved nutrients in GWLF are simulated using event mean concentrations (EMCs). Those coefficients used in the modeling were fine-tuned through model calibration (**Table 9**) and were in agreement with the literature (see Haith et al., 1992; USEPA, 1983; USEPA, 2001). Dissolved nutrient concentrations in groundwater were based on the land use with the most subsurface water yield, which for the most part, was from forested areas. Thus the EMC for forest surface runoff was applied to dissolved groundwater (e.g. 0.05 and 0.02 mg/L N and P) and appeared to yield the best results during model calibration.

Table 9. EMC parameters used in GWLF model.

Land Use	Dissolved Nitrogen (mg/L)	Dissolved Phosphorus (mg/L)
Developed (kg/ha/day)	0.012	0.002
Evergreen Forest	0.05	0.02
Shrub, Scrub	0.5	0.1
Grassland, Herbaceous	0.5	0.1
Pasture/Hay	3.5	0.25

5.6.2 Organic/Solid Phase Nutrients

Solid phase nutrients in GWLF originate from landscape and streambank based soil erosion. Since watershed specific information was not available regarding soil nutrient concentrations, values were taken from the national map provided in the GWLF user's manual. A value of 1500 mg/kg was used for nitrogen and 620 mg/kg for phosphorus. During calibration, it was found that GWLF was unable to account a large organic load from forested environments. Therefore, an organic load component was added to the model using the computed forest water yield and an associated concentration of organic nitrogen and phosphorus observed in forest surface runoff (0.24 and 0.017 mg/L of nitrogen and phosphorus respectively). This modification brought the balance of dissolved nutrient to total nutrient ratios into much closer alignment.

5.6.3 Non-Recoverable Animal Manure

Non-recoverable animal manure loads were estimated in GWLF using livestock density data from the U.S. Agricultural Statistics Service (NASS, 2008) and an associated delivery ratio to surface waters. Manure composition taken directly from the Animal Waste Management, National Engineering Handbook (NRCS, 1999) and an adjustment procedure was used to correct the number of reported animals to actual animal units (AU). Delivery ratio of nutrient loads from animal manure was based entirely on the literature (see Pieterse et al., 2003; Johnes, 1996; De Wite, 2000; Johnson et al., 1976; and Olness et al., 1980) and a value of 5 percent for nitrogen, and 0.01 percent for phosphorus were used in the modeling. More information on the farm animal manure calculations can be found in the Appendix.

5.6.4 Septic Systems

Septic system loads were crudely estimated using aerial imagery (2005 NAIP) and data from the STEPL Model Input Data Server which provides coarse, regional level information about per capita tank use and failure rates from the National Environmental Service Center (1992). Estimated septic densities for each of the watersheds are shown in the Appendix, and are considered approximations only.

5.7 Model Calibration-Validation

The general approach toward GWLF calibration and validation, was typical of that of any watershed modeling endeavor: (1) calibration of monthly streamflow, (2) sediment calibration, and then (3) nutrient calibration. Calibrated reach parameters are shown in Attachment-A, and are based on user experience, knowledge of the watershed, and recommendations from the GWLF user's manual. Those used in the calibration include SCS curve number, evapotranspiration coefficient, saturated and unsaturated aquifer parameters, groundwater recession constant, deep aquifer/seepage coefficient, monthly rainfall erosivity coefficient, streambank sediment coefficient, event mean concentrations (EMCs), and groundwater nutrient EMCs.

5.8 Model Evaluation Criteria

Performance statistics were selected prior to model development to assess monthly and seasonal streamflow, sediment, and nutrient predictions from GWLF. The first criterion used in the project was percent bias (PBIAS), which is a measure of the average tendency of the simulated temperatures to be larger or smaller than an observed value. Optimal PBIAS is 0.0 while a positive value indicates a model bias toward overestimation. A negative value indicates bias toward underestimation. PBIAS is calculated as follows:

$$PBIAS = \frac{\sum_{i=1}^{n}(O_{isim} - O_{iobs})}{\sum_{i=1}^{n}(O_{iobs})} \times 100$$

Equation 1

where

PBIAS = deviation in percent
Tiobs = observed value
Tisim = simulated value

DEQ defined acceptable model bias for the Big Hole River GWLF model as ±15 percent, similar to that reported in the literature by Van Liew et al. (2005) and Donigian et al. (1983). The second evaluation criterion was the Nash-Sutcliffe coefficient of efficiency (NSE; Nash and Sutcliffe, 1970). NSE expresses the fraction of the measured variance that is reproduced by the model. As error in the model is reduced, the NSE coefficient is inherently increased. Simulation results are considered to be good for NSE > 0.75, while values between 0.36 and 0.75 are considered satisfactory (Motovilov et al. 1999). NSE is calculated as:

$$NS_E = 1 - \frac{\sum_{i=1}^{n}(O_{iobs} - O_{isim})^2}{\sum_{i=1}^{n}(O_{iobs} - O_{avg})^2}$$

Equation 2

where

NSE = coefficient of efficiency
Tavg = average simulated value

Reported statistics for calibration and validation of each of the measures shown previously are shown in **Section 6.0**.

5.9 Model Sensitivity/Uncertainty

Given the "limited-detail" nature of this study, model sensitivity and uncertainty were not addressed as part of this project. To some extent, model uncertainty can be characterized by review of the results and discussion section. It is recommended that a margin of safety (MOS) be built into the TMDL to account for this inherent error.

SECTION 6.0
RESULTS AND DISCUSSION

6.1 Water Balance/Hydrology

6.1.1 Calibration

Monthly streamflow for the calibration is shown in **Figure 8**. Inspection of the observed and predicted values shows satisfactory agreement. In general, the model predicts growing season streamflow values very well (May-September), while predictions during the winter months are poor. This largely is due to the inability to lag groundwater from month to month. Snowmelt appears to be accurately represented based on the rising limb of the hydrograph, and the falling limb is also well simulated. PBIAS and NSE were +1.1 percent and 0.69 respectively (**Table 10**).

6.1.2 Validation

Results of the hydrologic validation on Willow Creek (a gaged tributary similar in size to the TMDL watersheds) are only slightly different from the calibration. PBIAS and NSE were +8.9 percent and 0.58 (**Figure 9**) which largely demonstrates that the parameter transfer approach is effective for hydrologic predictions for the remaining TMDL watersheds.

Table 10. Summary of calibration and validation statistics from Big Hole River GWLF model.

Watershed	Hydrology		Sediment[1]		Nutrients	
	NSE	PBIAS	NSE	PBIAS	NSE	PBIAS
Big Hole River near Melrose, MT (calibration)	0.69	+1.1%	0.54	+0.4%	0.56	+0.7%
Willow Creek near Glen, MT (validation)	0.58	+8.9%	-4.61	+145.6%	0.39	-8.7%

[1]Validation much better than reported if two outlier peaks removed; NSE = 0.54 and PBIAS = +21.2%.

6.2 Sediment

6.2.1 Calibration

PBIAS and NSE for the sediment calibration were +0.4 percent and 0.54 respectively (**Figure 8**). Sediment peaks generally follow hydrograph response, and a majority of the sediment load in the watershed occurs during the months of May, June, and July. Based on the modeling results, the source of this load is primarily streambank erosion. Several false peaks do occur, and are likely a result of spatial variability in precipitation. Overpredictions are consistent with oversimulated peaks in hydrology.

6.2.2 Validation

Analysis of the validation model show very poor results. PBIAS and NSE were +145.6 percent and 4.61 (**Figure 9**). This is largely as a result of two vastly over-simulated sediment peaks in the months of 10/1963 and 6/1964. Again, these are likely a function of precipitation variability in the watershed and predictions would be much better in the absence of these peaks (i.e. PBIAS of +21.2 percent and NSE of 0.54). Fortunately, errors in sediment simulation have only minor impacts on simulated organic nitrogen and phosphorus loads. Thus it is believed that the use of GWLF for TMDL planning is still valid.

6.3 Nutrients

6.3.1 Calibration

Calibration of the nutrients was inherently uncertain, as many of the nutrient species were not measured at the USGS gage sites. Because of this, the model was first calibrated to observed USGS dissolved nitrogen data (e.g. measured NO3-), and then a quasi-calibration was completed to fit the remaining species to mean concentration and dissolved to total nutrients ratios observed in STORET. PBIAS and NSE for the NO3- calibration was +0.7 percent and 0.56 (**Table 10**) while simulated and observed dissolved nitrogen and phosphorus concentrations and ratios are shown in **Table 11**.

6.3.2 Validation

The validation performed similar to the calibration, with PBIAS and NSE of -8.7 percent and 0.39. Validation concentrations and statistics are shown in **Table 11**. Clearly, nutrient simulations are adequate for low certainty TMDL planning.

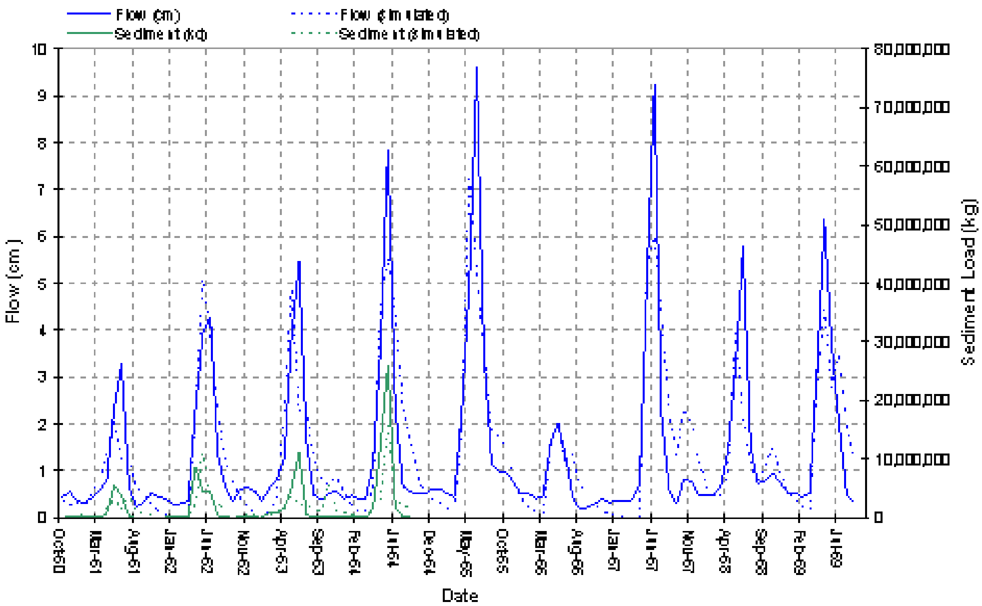
Table 11. Summary of observed and simulated mean concentrations and dissolved nutrient ratios in the Big Hole River GWLF model.

Watershed	Nitrogen			Phosphorus		
	TN (mg/L)	NO2+ NO3 (mg/L)	Dissolved: Total ratio	TP (mg/L)	SRP (mg/L)	Dissolved : Total ratio
STORET – all observations	0.31	0.03	0.10	0.041	0.014	0.34
Big Hole River near Melrose, MT (calibration)	0.28	0.08	0.29	0.049	0.026	0.53
Willow Creek near Glen, MT (validation)	0.27	0.06	0.22	0.046	0.022	0.48
Reference Non-reference from Suplee et al. (2007)	0.22 0.40	0.02 0.10	0.09 0.25	0.01 0.04	0.005 0.020	0.50 0.50

6.4 Summary

Given that hydrology, sediment, and nutrients are adequately simulated in GWLF, TMDL development activities for impaired water bodies in the Big Hole River watershed were initiated and area detailed in subsequent sections.

a) Calibration



b) Validation

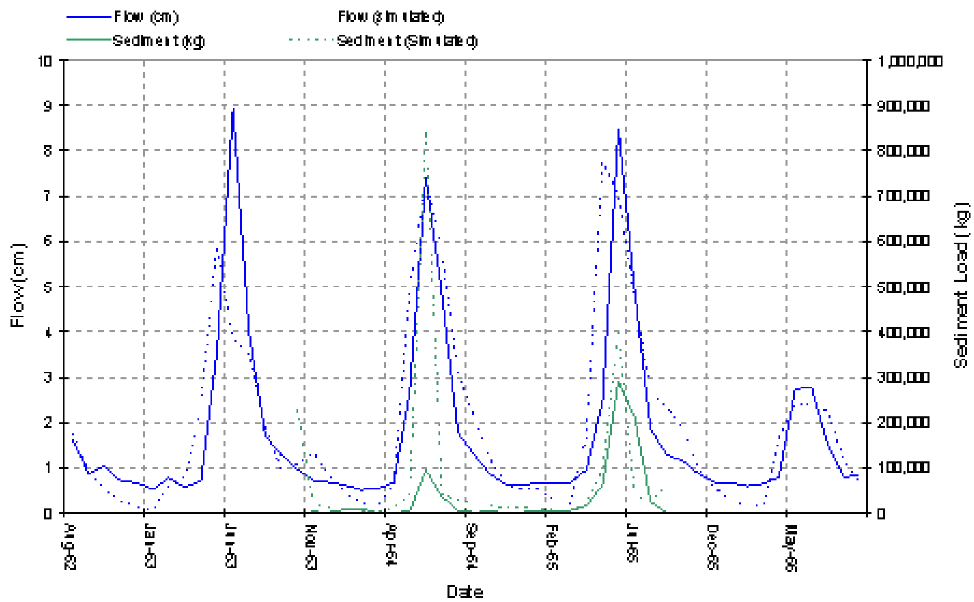
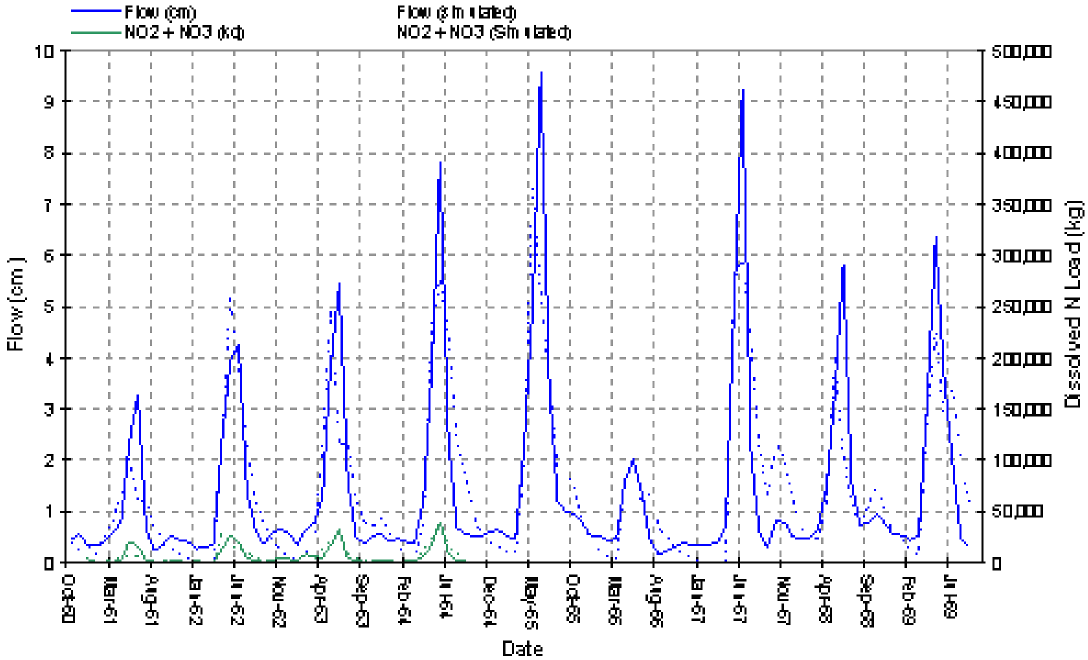


Figure 8. Calibration and validation plots for sediment and hydrology for a) USGS gage 6025500 Big Hole River near Melrose, MT and b) USGS gage 6025800 Willow Creek near Glen MT.

a) Calibration



b) Validation

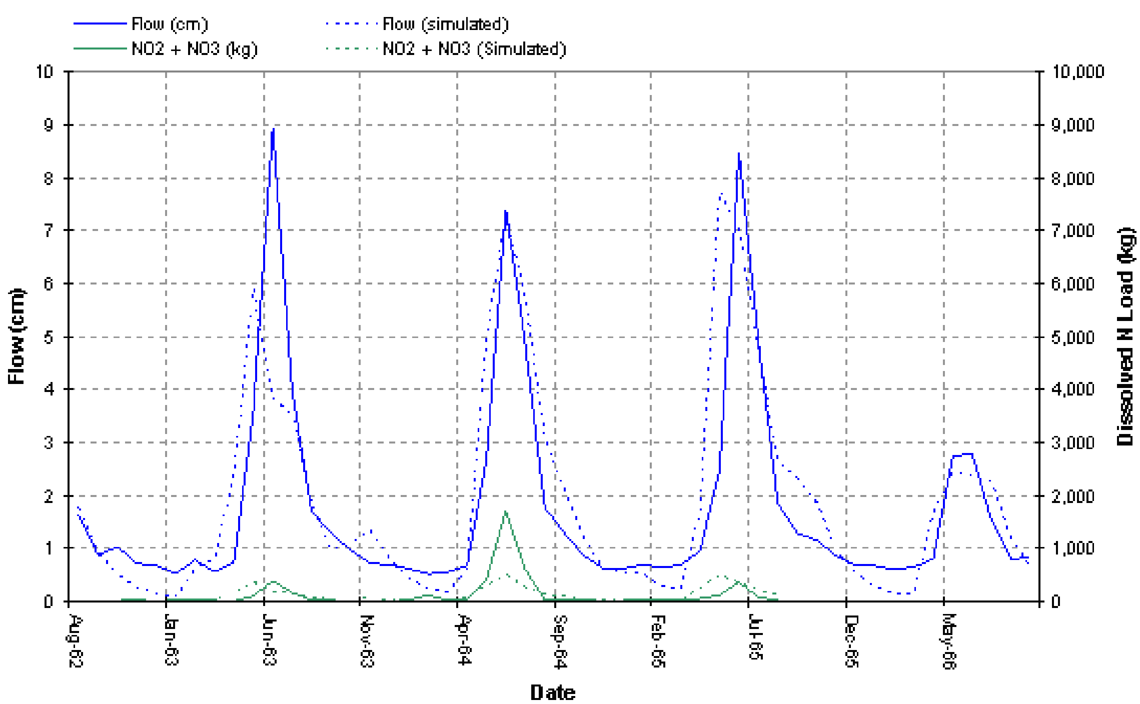


Figure 9. Calibration and validation plots for nutrients and hydrology for a) USGS gage 6025500 Big Hole River near Melrose, MT and b) USGS gage 6025800 Willow Creek near Glen MT.

SECTION 7.0
TMDL SOURCE ASSESSMENT

Following validation of the modeling approach, source estimates for the TMDL watersheds were completed over a representative period for which the data were compiled (24 years). A summary of the predicted annual nitrogen and phosphorus source contributions for each of the TMDL watersheds are shown in **Figure 10** and **Figure 11**. Simulated sources include: (1) hay/pasture (including fertilizer application and grazing), (2) shrub and grassland (with effects of grazing), (3) forested areas (including grazing), (4) developed areas (including both urban runoff and septic effluent), and (5) streambanks. Non-recoverable animal manure from each land use was lumped into its specific source category based on the estimated percentage cattle were on each land cover type (e.g. on hay/pasture 20 percent of the time, grassland/shrub 60 percent, and forest 20 percent). Individual source assessments for each of the TMDL watersheds are shown in **Figures 12-20** and **Tables 10-18**.

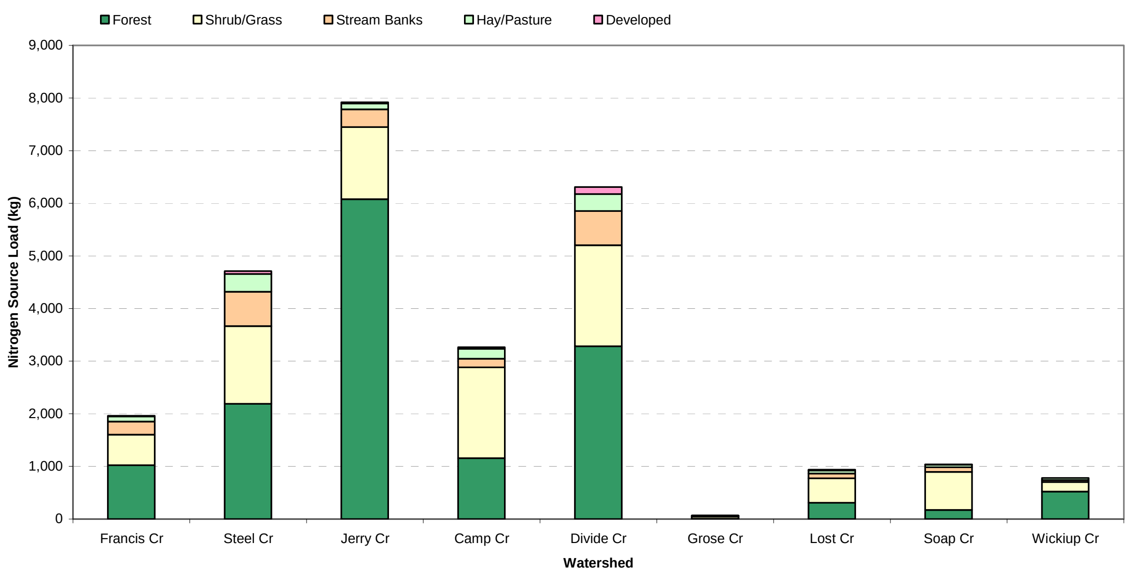


Figure 10. Summary of estimated nitrogen sources in each TMDL watershed.

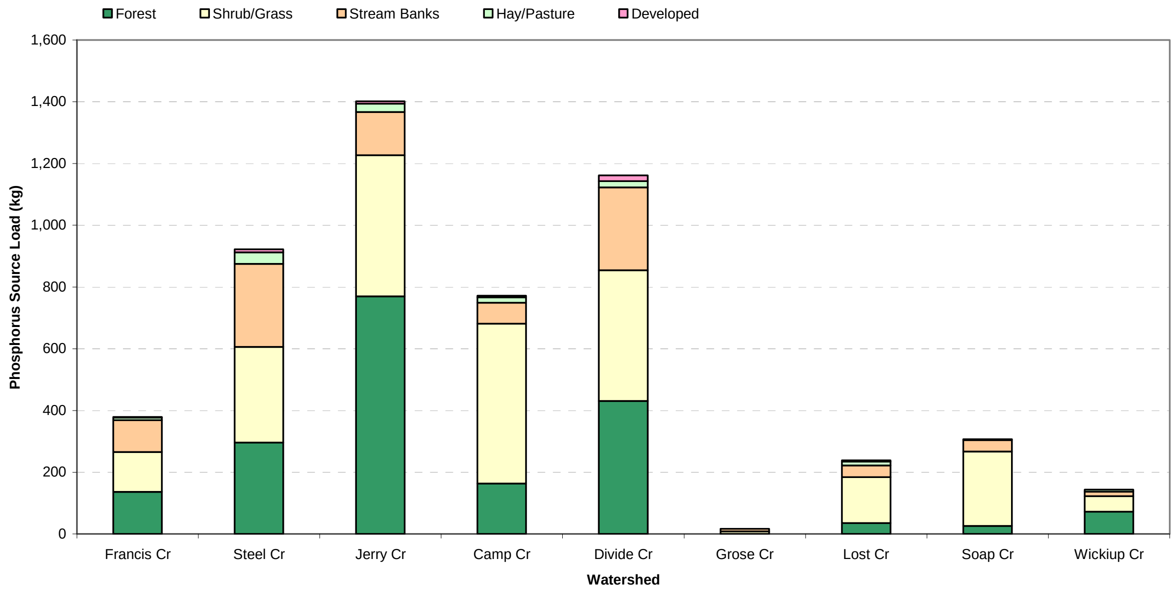
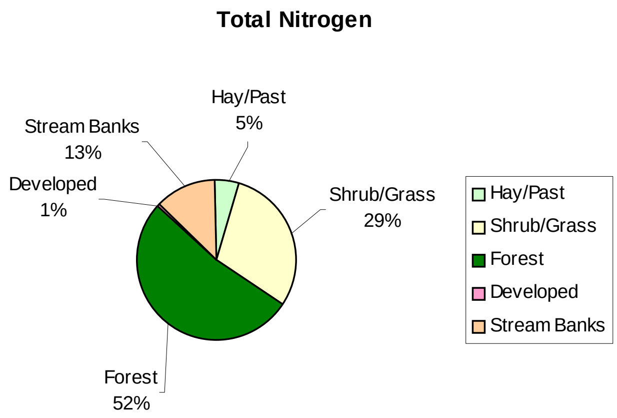


Figure 11. Summary of estimated phosphorus sources in each TMDL watershed.

7.1 Francis Creek

The existing condition source assessment for Francis Creek is shown below (**Figure 12**, **Table 12**).



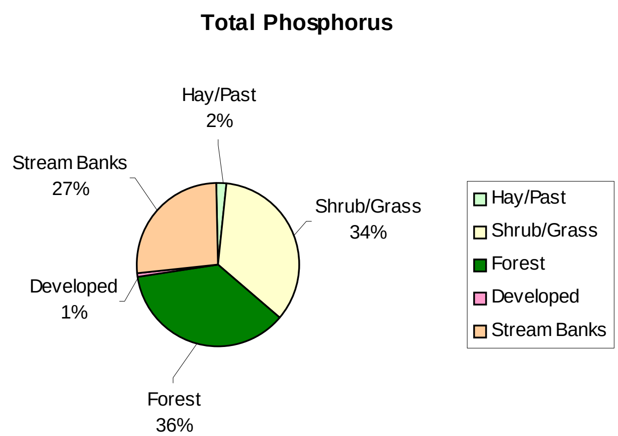


Figure 12. Graphical Nutrient Source Assessment for Francis Creek.

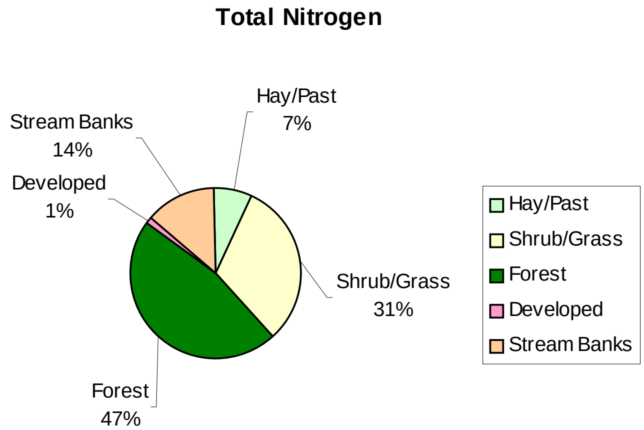
Table 12. Tabular Nutrient Source Assessment for Francis Creek.

Source	**Area (ha)**	**Runoff (cm)**	**Sediment (kg x 1000)**	**Dis N (kg)**	**Tot N (kg)**	**Dis P (kg)**	**Tot P (kg)**
Hay/Past	130	0.39	0.40	13.7	99.3	1.8	8.4
Shrub/Grass	3311	0.76	86.36	104.6	578.2	69.2	129.1
Forest	3036	0.05	20.75	0.8	1024.5	13.2	136.5
Developed	35	1.59	0.56	0.0	11.1	0.0	2.3
Stream Banks			166.06	0.0	249.1	0.0	103.0
Point Source			0.00	0.0	0.0	0.0	0.0
Groundwater[1]			0.00	0.0	0.0	0.0	0.0

[1]Groundwater load integrated into landscape source categories based on computed runoff (e.g. surrogate for infiltration/groundwater recharge)

7.2 Steel Creek

The existing condition source assessment for Steel Creek is shown below (**Figure 13**, **Table 13**).



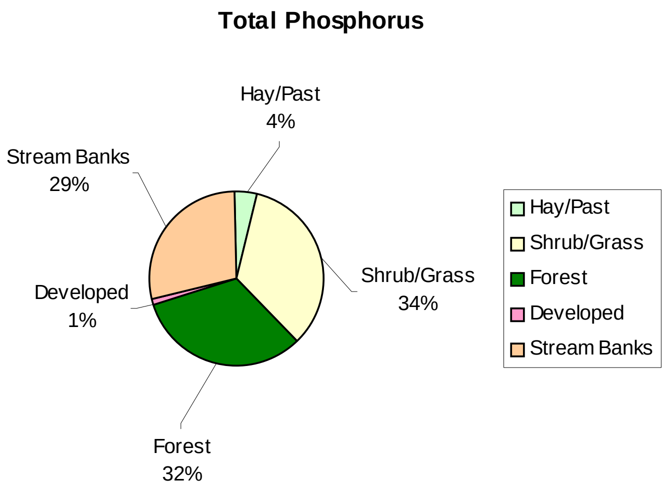


Figure 13. Graphical Nutrient Source Assessment for Steel Creek.

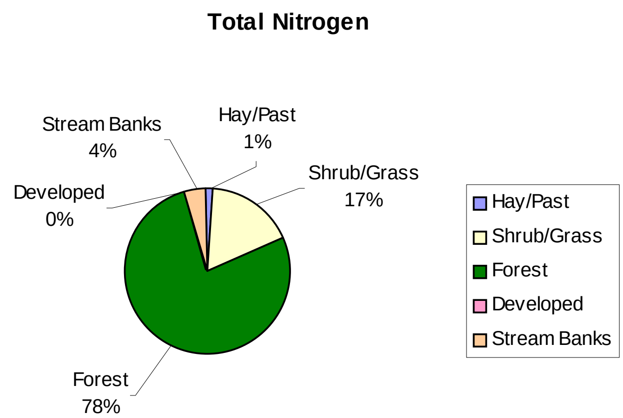
Table 13. Tabular Nutrient Source Assessment for Steel Creek.

Source	Area (ha)	Runoff (cm)	Sediment (kg x 1000)	Dis N (kg)	Tot N (kg)	Dis P (kg)	Tot P (kg)
Hay/Past	828	0.52	1.75	108.6	338.7	15.7	37.2
Shrub/Grass	8610	0.97	152.76	352.1	1474.0	148.5	309.8
Forest	6008	0.06	34.87	1.7	2192.4	22.3	296.3
Developed	192	1.97	2.02	0.0	57.5	0.0	9.5
Stream Banks			434.22	0.0	651.3	0.0	269.2
Point Source			0.00	0.0	0.0	0.0	0.0
Groundwater[1]			0.00	0.0	0.0	0.0	0.0

[1]Groundwater load integrated into landscape source categories based on computed runoff (e.g. surrogate for infiltration/groundwater recharge)

7.3 Jerry Creek

The existing condition source assessment for Jerry Creek is shown below (**Figure 14**, **Table 14**).



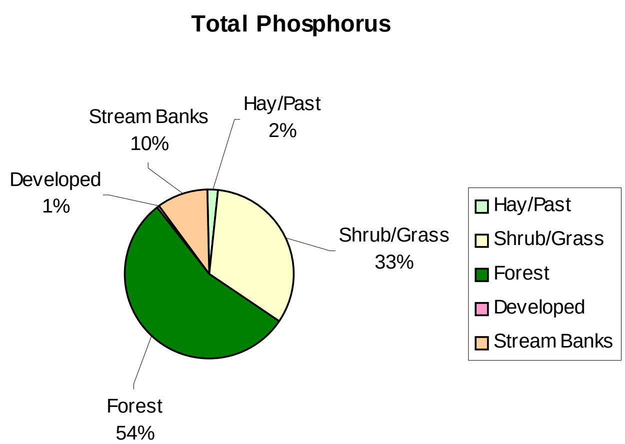


Figure 14. Graphical Nutrient Source Assessment for Jerry Creek.

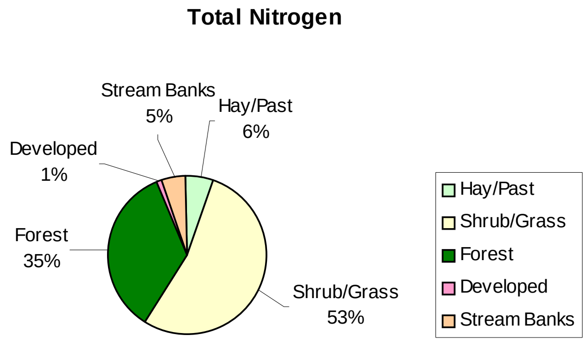
Table 14. Tabular Nutrient Source Assessment for Jerry Creek.

Source	Area (ha)	Runoff (cm)	Sediment (kg x 1000)	Dis N (kg)	Tot N (kg)	Dis P (kg)	Tot P (kg)
Hay/Past	29	1.68	0.07	13.0	114.5	1.7	27.0
Shrub/Grass	2106	3.08	447.67	250.8	1370.6	130.7	457.0
Forest	9741	0.32	121.02	15.6	6076.3	81.3	770.2
Developed	1	5.09	0.01	0.0	21.2	0.0	8.2
Stream Banks			224.97	0.0	337.5	0.0	139.5
Point Source			0.00	0.0	0.0	0.0	0.0
Groundwater[1]			0.00	0.0	0.0	0.0	0.0

[1]Groundwater load integrated into landscape source categories based on computed runoff (e.g. surrogate for infiltration/groundwater recharge)

7.4 Camp Creek

The existing condition source assessment for Camp Creek is shown below (**Figure 15**, **Table 15**).



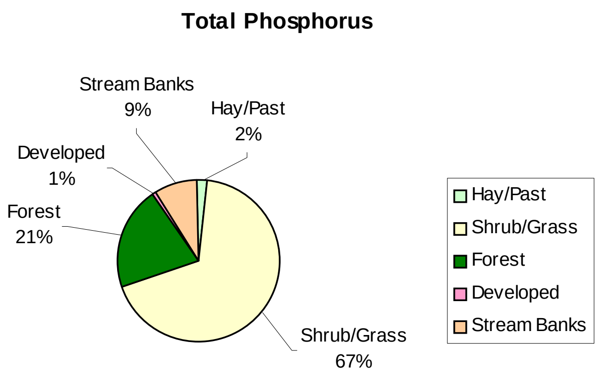


Figure 15. Graphical Nutrient Source Assessment for Camp Creek.

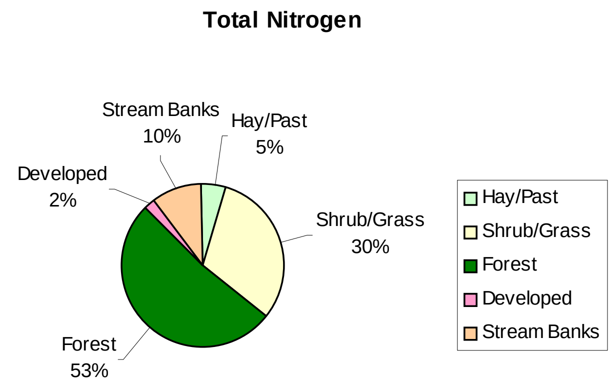
Table 15. Tabular Nutrient Source Assessment for Camp Creek.

Source	**Area (ha)**	**Runoff (cm)**	**Sediment (kg x 1000)**	**Dis N (kg)**	**Tot N (kg)**	**Dis P (kg)**	**Tot P (kg)**
Hay/Past	315	0.53	0.52	43.4	186.9	6.0	17.7
Shrub/Grass	5684	0.99	601.92	230.8	1725.5	300.7	517.9
Forest	2784	0.07	28.46	0.9	1157.4	18.0	163.3
Developed	95	1.99	0.80	0.0	31.3	0.0	5.4
Stream Banks			109.54	0.0	164.3	0.0	67.9
Point Source			0.00	0.0	0.0	0.0	0.0
Groundwater[1]			0.00	0.0	0.0	0.0	0.0

[1]Groundwater load integrated into landscape source categories based on computed runoff (e.g. surrogate for infiltration/groundwater recharge).

7.5 Divide Creek

The existing condition source assessment for Divide Creek is shown below (**Figure 16**, **Table 16**).



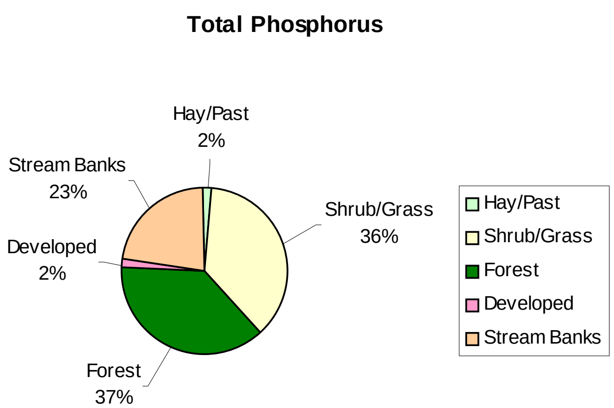


Figure 16. Graphical Nutrient Source Assessment for Divide Creek.

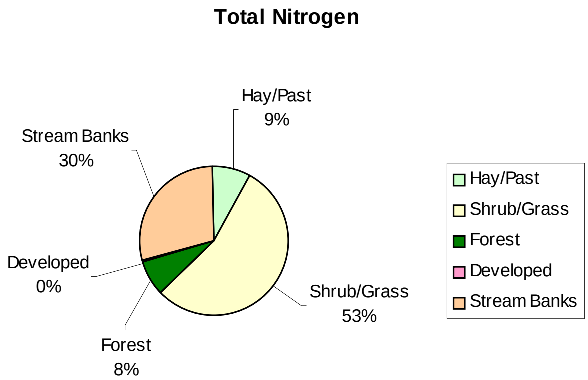
Table 16. Tabular Nutrient Source Assessment for Divide Creek.

Source	Area (ha)	Runoff (cm)	Sediment (kg x 1000)	Dis N (kg)	Tot N (kg)	Dis P (kg)	Tot P (kg)
Hay/Past	496	0.24	0.58	33.6	324.0	4.1	20.0
Shrub/Grass	11845	0.48	341.79	250.0	1918.1	255.2	423.4
Forest	11622	0.02	44.09	1.3	3283.6	27.9	430.7
Developed	598	1.18	8.08	0.0	130.6	0.0	18.3
Stream Banks			433.73	0.0	650.6	0.0	268.9
Point Source			0.00	0.0	0.0	0.0	0.0
Groundwater[1]			0.00	0.0	0.0	0.0	0.0

[1]Groundwater load integrated into landscape source categories based on computed runoff (e.g. surrogate for infiltration/groundwater recharge)

7.6 Grose Creek

The existing condition source assessment for Grose Creek is shown below (**Figure 17**, **Table 17**).



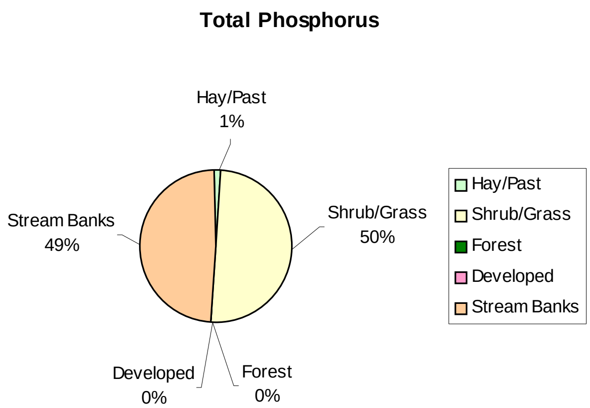


Figure 17. Graphical Nutrient Source Assessment for Grose Creek.

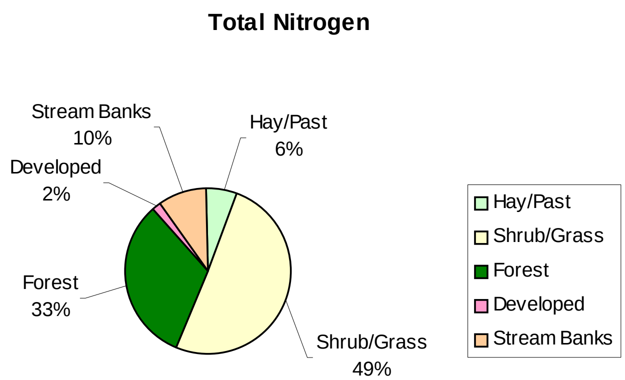
Table 17. Tabular Nutrient Source Assessment for Grose Creek.

Source	Area (ha)	Runoff (cm)	Sediment (kg x 1000)	Dis N (kg)	Tot N (kg)	Dis P (kg)	Tot P (kg)
Hay/Past	21	0.02	0.04	0.1	5.9	0.0	0.2
Shrub/Grass	393	0.05	12.61	0.9	36.3	8.0	8.3
Forest	1	0.00	0.00	0.0	5.3	0.0	0.0
Developed	4	0.20	0.04	0.0	0.2	0.0	0.0
Stream Banks			13.43	0.0	20.1	0.0	8.3
Point Source			0.00	0.0	0.0	0.0	0.0
Groundwater[1]			0.00	0.0	0.0	0.0	0.0

[1]Groundwater load integrated into landscape source categories based on computed runoff (e.g. surrogate for infiltration/groundwater recharge)

7.7 Lost Creek

The existing condition source assessment for Lost Creek is shown below (**Figure 18**, **Table 18**).



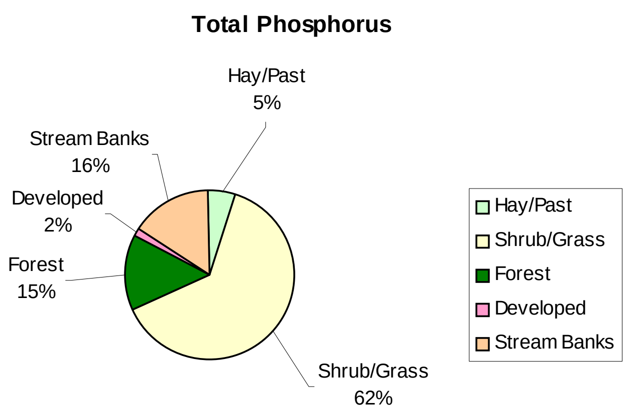


Figure 18. Graphical Nutrient Source Assessment for Lost Creek.

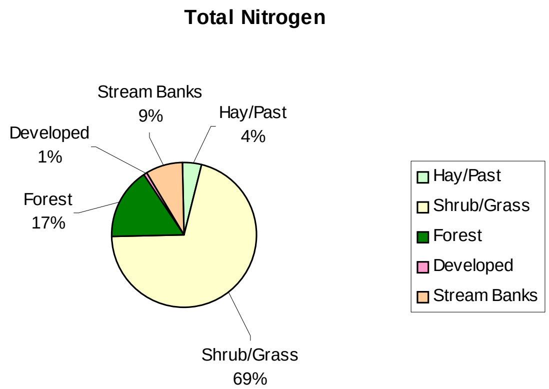
Table 18. Tabular Nutrient Source Assessment for Lost Creek.

Source	**Area (ha)**	**Runoff (cm)**	**Sediment (kg x 1000)**	**Dis N (kg)**	**Tot N (kg)**	**Dis P (kg)**	**Tot P (kg)**
Hay/Past	10	0.47	0.04	1.2	58.7	0.2	12.6
Shrub/Grass	1243	0.89	192.82	45.7	465.3	115.8	149.1
Forest	949	0.06	13.27	0.3	309.0	8.3	35.1
Developed	29	1.77	1.48	0.0	15.6	0.0	4.2
Stream Banks			60.58	0.0	90.9	0.0	37.6
Point Source			0.00	0.0	0.0	0.0	0.0
Groundwater1			0.00	0.0	0.0	0.0	0.0

[1]Groundwater load integrated into landscape source categories based on computed runoff (e.g. surrogate for infiltration/groundwater recharge).

7.8 Soap Creek

The existing condition source assessment for Soap Creek is shown below (**Figure 19, Table 19**).



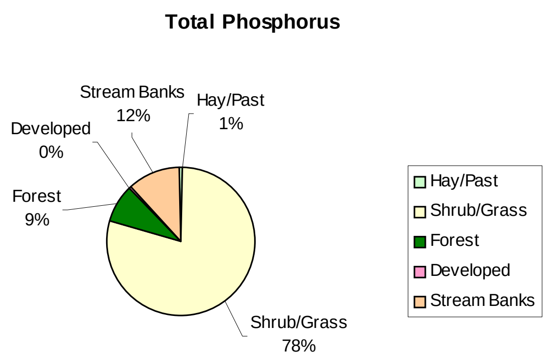


Figure 19. Graphical Nutrient Source Assessment for Soap Creek.

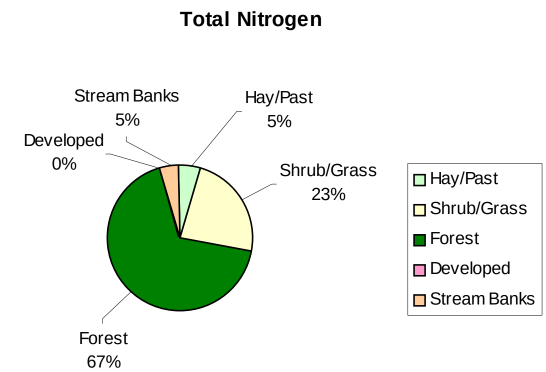
Table 19. Tabular Nutrient Source Assessment for Soap Creek.

Source	Area (ha)	Runoff (cm)	Sediment (kg x 1000)	Dis N (kg)	Tot N (kg)	Dis P (kg)	Tot P (kg)
Hay/Past	42	0.35	0.02	3.9	46.3	0.5	2.5
Shrub/Grass	1981	0.67	329.82	54.0	725.3	175.6	240.8
Forest	365	0.04	5.33	0.1	171.2	3.3	26.4
Developed	22	1.46	0.28	0.0	5.8	0.0	1.0
Stream Banks			58.93	0.0	88.4	0.0	36.5
Point Source			0.00	0.0	0.0	0.0	0.0
Groundwater[1]			0.00	0.0	0.0	0.0	0.0

[1]Groundwater load integrated into landscape source categories based on computed runoff (e.g. surrogate for infiltration/groundwater recharge)

7.9 Wickiup Creek

The existing condition source assessment for Wickiup Creek is shown below (**Figure 20, Table 20**).



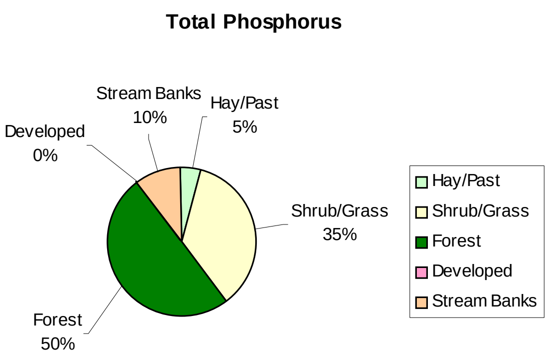


Figure 20. Graphical Nutrient Source Assessment for Wickiup Creek.

Table 20. Tabular Nutrient Source Assessment for Wickiup Creek.

Source	Area (ha)	Runoff (cm)	Sediment (kg x 1000)	Dis N (kg)	Tot N (kg)	Dis P (kg)	Tot P (kg)
Hay/Past	56	0.95	2.08	13.9	38.2	1.9	6.6
Shrub/Grass	505	1.50	53.39	37.9	180.4	40.7	50.4
Forest	1034	0.11	8.16	0.6	523.0	5.3	72.0
Developed	0	0.00	0.00	0.0	0.0	0.0	0.0
Stream Banks			23.54	0.0	35.3	0.0	14.6
Point Source			0.00	0.0	0.0	0.0	0.0
Groundwater[1]			0.00	0.0	0.0	0.0	0.0

[1]Groundwater load integrated into landscape source categories based on computed runoff (e.g. surrogate for infiltration/groundwater recharge).

7.10 Summary of TMDL Source Assessment Results

In review of the existing condition source assessment, nitrogen and phosphorus loads are a function of land cover type, soils, topography, and associated land management practices. For the most part, forest and shrub/grassland provide the largest natural loads in the TMDL watersheds while anthropogenic sources are primarily of agricultural origin. Those loads consist of non-recoverable animal manure, grazing, and fertilization of hay/pasture, along with minor contributions from developed lands. Streambanks were also found to contribute a moderate amount of nitrogen and phosphorus to TMDL watersheds. In any case, existing loads for each of the impaired watersheds were estimated. **Section 8.0** details scenarios that evaluate mitigation measures for significant and controllable sources.

SECTION 8.0
SCENARIO ANALYSIS

Following the estimation of existing condition sources, a number of scenarios were evaluated so that watershed managers can provide reasonable recommendations for meeting water quality criteria in the river. Specifically, modeling scenarios were formulated to address the following: (1) baseline conditions, (2) a fertilizer reduction scenario, (3) streambank erosion reduction scenario, (4) upland erosion reduction scenario, (5) riparian buffer scenario, and (6) a livestock density reduction scenario.

8.1 Baseline Scenario

The baseline scenario describes existing conditions in the watershed and has been described previously (**Section 7.0**). Simulated values from this scenario form the basis for which all other scenarios will be compared.

8.2 Fertilizer Reduction Scenario

Agricultural fertilizer management was identified as a potential methodology for reducing nutrient loads in the Big Hole River. It is a common perception among watershed managers that fertilizer application rates could be decreased without affecting crop yield. This is most likely true, and for all intents and purposes, has already occurred due to prohibitive costs of fertilizer and through conservation strategies such as the Candidate Conservation Agreement with Assurances (CCAA) program. Reported cutbacks in the watershed are estimated at a change in application rate of 90.9 kg (200 lbs) of 29-6-6 mix application (nitrogen, phosphorus, potassium) to 45.5-68.2 kg/acre (100-150 lbs/acre) of 29-0-0 (personal communication, Erik Kalsta/Big Hole River Watershed Committee). Since DEQ considers this a reasonable BMP, the fertilizer reduction scenario was designed to estimate this nutrient reduction. Results are shown in **Table 20**. In general, very little change was observed in the watershed nutrient yield. This is due to the fact that hay/pasture is only a minor land use in most watersheds, as well as that some believe a greater amount of land is fertilized than characterized as hay/pasture in the NLCD (e.g. thus underestimating the actual influence fertilizer reduction). No investigations were completed to confirm this assertion.

Table 20. Nutrient reductions for fertilizer reduction scenario in the Big Hole River watershed.

Watershed	TN Reduction (kg)	Watershed Reduction (%)	TP Reduction (kg)	Watershed Reduction (%)
Francis	7.4	0.4%	4.9	1.3%
Steel	39.8	0.8%	21.6	2.3%
Jerry	19.0	0.4%	16.1	1.8%
Camp	17.9	0.5%	10.4	1.3%
Divide	18.1	0.3%	11.7	1.0%
Grose	0.1	0.2%	0.1	0.7%
Lost	2.2	0.2%	1.5	0.5%
Soap	2.2	0.2%	1.5	0.5%
Wickiup	5.6	0.7%	3.2	2.2%

The nitrogen EMC was reduced by 25 percent or 68.2/90.9 to reflect the change in application rate.

Phosphorus was adjusted to that of natural conditions (e.g. grassland), which totaled a 60 percent reduction.

8.2 Stream Bank Erosion Scenario

Stream bank erosion was identified as a nutrient source in many of the TMDL watersheds, therefore, a scenario was developed to address achievable pollutant reductions via stabilization of eroding or trampled stream banks. Relative reductions in bank erosion (in percent) were taken directly from the sediment TMDL, and then were applied to the computed streambank erosion load in GWLF to estimate the net change in nutrient load. Based on results of this scenario, watershed loads can be reduced by approximately 1-18 percent for nitrogen and 1-30 percent for phosphorus (**Table 21**).

Table 21. Nutrient reductions for the bank erosion scenario.

Watershed	GWLF Bank Load (kg x 1000)	Assumed Reduction (%)	TN Reduction (kg)	Watershed Reduction (%)	TP Reduction (kg)	Watershed Reduction (%)
Francis	166.06	26%	64.8	3.3%	26.8	7.1%
Steel	434.22	48%	312.6	6.6%	129.2	14.0%
Jerry	224.97	26%	87.7	1.1%	36.3	2.6%
Camp	109.54	43%	70.7	2.2%	29.2	3.8%
Divide	433.73	7%	45.5	0.7%	18.8	1.6%
Grose	13.43	62%	12.5	18.4%	5.2	30.5%
Lost	60.58	32%	29.1	3.1%	12.0	5.0%
Soap	58.93	11%	9.7	0.9%	4.0	1.3%
Wickiup	23.54	12%	4.2	0.5%	1.8	1.2%

8.3 Upland Erosion Scenario

Upland erosion was also considered for its underlying effect on nitrogen and phosphorus loads in TMDL watersheds. A similar procedure to the bank erosion scenario was completed, whereby results of the sediment TMDL were applied directly to computed values in GWLF (e.g. through changes in the cover management factor). Estimated reductions are shown in **Table 22**. Again, phosphorus was the nutrient most strongly associated with reductions in sedimentation.

Table 22. Nutrient reductions for the upland erosion scenario.

Watershed	**GWLF Upland Load (kg x 1000)**	**Assumed Reduction (%)**	**TN Reduction (kg)**	**Watershed Reduction (%)**	**TP Reduction (kg)**	**Watershed Reduction (%)**
Francis	108.07	14%	40.5	2.1%	16.7	4.4%
Steel	191.40	15%	69.5	1.5%	28.7	3.1%
Jerry	568.77	17%	144.7	1.8%	59.8	4.3%
Camp	631.70	20%	249.4	7.6%	103.1	13.3%
Divide	394.54	17%	164.9	2.6%	68.2	5.9%
Grose	12.69	19%	6.2	9.1%	2.6	15.1%
Lost	207.61	20%	89.4	9.5%	36.9	15.5%
Soap	335.45	21%	146.1	14.1%	60.4	19.7%
Wickiup	63.63	19%	27.2	3.5%	11.2	7.8%

8.4 Riparian Filter Strip Scenario

Riparian filter strips have been shown to be effective in removing phosphorus and nitrogen from surface water runoff and groundwater (Wegner, 1999; Peterjohn and Correll, 1985; Evans et al., 2001). In the case of the Big Hole River, it is believed riparian enhancement could have some utility in reducing nutrient loads in impaired watersheds. Filtering/uptake capacity is dependent on the condition of the riparian filter strip and associated width. Evans et al. (2001) provides filtering efficiencies for use in GWLF (**Table 23**).

Table 23. Assumed filtering efficiency of fully-functioning 10-m (30-ft) riparian buffer strip.

Phosphorus	Nitrogen	Sediment
54%	52%	58%

GWLF user's manual (Evans et al., 2001.)

Because certain locations in the watershed may already contain a functional buffer, DEQ derived four general conditions to provide an estimate of the current filtering capacity potential. These include non-functioning, partially-functioning, nearly-functioning, and functioning buffer strips as described below (determined from air photo assessment and greenline monitoring as):

1. Non-functioning – areas with severely degraded riparian zones having a very high proportion of bare banks, high lateral erosion rates, higher bare ground rates, and largely devoid of woody vegetation.

2. Partially-functioning – areas that have patchy riparian zones and could use more grazing management or setbacks from active hay production operations.
3. Nearly-functioning – areas that are in fair condition overall but have patchy areas that could use grazing BMPs.
4. Fully-functioning – well vegetated area with minimal impact and functioning as desired.

Using this information, the following assumptions regarding reduction attainability were made for each of the TMDL watersheds in the scenario:

- Francis Creek: 50 percent reduction potential for grassland, shrub, hay; 15 percent for forest
- Steel Creek: 50 percent reduction potential for grassland, shrub, hay
- Jerry Creek: 25 percent reduction potential in all areas
- Camp Creek: 25 percent reduction potential for hay; 15 percent for grassland, shrub, and forest
- Divide Creek: 15 percent reduction potential for grassland, shrub, hay
- Grose Creek: 25 percent reduction potential for hay; 15 percent for grassland, shrub, and forest
- Lost Creek: 25 percent reduction potential for hay; 15 percent for grassland, shrub, and forest
- Soap Creek: 25 percent reduction potential for hay; 15 percent for grassland, shrub, and forest
- Wickiup Creek: 15 percent reduction potential in all areas

The cumulative estimated effect of riparian filer strips is shown in **Table 24**.

Table 24. Nutrient reductions for the riparian filter strip scenario.

Watershed	TN Reduction	Watershed Reduction (%)	TP Reduction	Watershed Reduction (%)
Francis	468.4	23.9%	78.4	20.7%
Steel	851.7	18.1%	148.3	16.1%
Jerry	1849.4	23.4%	294.5	21.0%
Camp	437.3	13.4%	88.5	11.5%
Divide	308.9	4.9%	54.5	4.7%
Grose	6.7	9.9%	0.9	5.3%
Lost	116.8	12.4%	24.9	10.4%
Soap	123.6	11.9%	31.3	10.2%
Wickiup	106.3	13.7%	17.2	12.0%

Net filtering efficiency includes filtering of non-recoverable animal manure

8.5 Animal Stocking Density Scenario

Since animals are an anthropogenic source in many of the TMDL watersheds, a scenario was developed to assess relative stocking densities in the watershed (e.g. whether reductions in livestock should be recommended by DEQ). Forage biomass was used as the primary indicator of approximate maximum stocking rates, and recommended values from Dryland Pastures in Montana and Wyoming Species and Cultivars, Seeding Techniques and Grazing Management (MSU, 2003) were used as a general guideline for this estimate (**Table 25**). With conservative assumptions, such as a precipitation zone of 10-14 inches, and crested wheatgrass as the primary grassland forage, 0.61 hectares (1.5 acres) are required per animal unit per month (AUM). Assuming a six-month grazing period from May-October, 3.6 ha (9.0) acres would be required per animal unit (AU). Thus, the overall calculated carrying capacity of the study area upstream of Melrose is approximately 70,430 AU (using grassland as a surrogate for grazing area). When compared with the National Agricultural Statistics Service (NASS), current stocking density is 39,669 AU, which indicates that no reductions are necessary (**Table 26**). It should be noted, this is an estimate only (not considering available winter feed), and does not constitute a recommendation for increased livestock production in the watershed. Stocking density calculations are shown in **Appendix A4**.

Table 25. Stocking rate guidelines for dryland pastures and crop aftermath (MSU, 2003).

Pasture	Precipitation Zone (inches)	AUM Per Acre	Acre Per AUM
Crested wheatgrass	10–14	0.67	1.5
	15–18	1.00	1.0
Russian wildrye	10–14	0.50	2.0
	15–18	1.00	1.0
Pubescent wheatgrass	13–14	0.75	1.3
	15–18	1.25	0.8
Intermediate wheatgrass	14–18	1.50	0.7
Meadow bromegrass	16–18	1.50	0.7
Timothy	16–18	1.25	0.8
Orchardgrass	16–18	1.50	0.7
Grain aftermath	10-14 15-18	0.20 0.30	5.0 3.3
Hay aftermath	10-14 15-18	0.40 0.50	2.5 2.0

AUM = 1,000 lb cow/calf pair

Table 26. Nutrient reductions for the livestock density scenario.

Watershed	TN Reduction	Watershed Reduction (%)	TP Reduction	Watershed Reduction (%)
Francis	0.0	0.0%	0.0	0.0%
Steel	0.0	0.0%	0.0	0.0%
Jerry	0.0	0.0%	0.0	0.0%
Camp	0.0	0.0%	0.0	0.0%
Divide	0.0	0.0%	0.0	0.0%
Grose	0.0	0.0%	0.0	0.0%
Lost	0.0	0.0%	0.0	0.0%
Soap	0.0	0.0%	0.0	0.0%
Wickiup	0.0	0.0%	0.0	0.0%

SECTION 9.0 TMDL SCENARIO

A final scenario was formulated to assess the integrated effects of previous scenarios, e.g. effectively all reasonable soil and water conservation practices as outlined in ARM 17.30.602. Results were then compared to proposed interim nutrient criteria as outlined in **Section 1.2**. A summary of individual scenario results, combined nutrient reductions, and associated reduction percentages for each TMDL watershed is shown in **Table 27**, **Table 28**, and **Figure 21**. Individual results are detailed in **Figures 23-31** and **Tables 31-56**.

Table 27. Nitrogen reduction summary table.

Watershed	Fertilizer Scenario (kg)	Stream-bank Scenario (kg)	Upland Scenario (kg)	Filter Strip Scenario (kg)	Animal Scenario (kg)	Overall Reduction (kg)	Total Load (kg)	% Red.
Francis Cr	7.4	64.8	40.5	468.4	0.0	581.1	1,962.1	30%
Steel Cr	39.8	312.6	69.5	851.7	0.0	1,273.7	4,713.9	27%
Jerry Cr	19.0	87.7	144.7	1,849.4	0.0	2,100.9	7,920.0	27%
Camp Cr	17.9	70.7	249.4	437.3	0.0	775.2	3,265.5	24%
Divide Cr	18.1	45.5	164.9	308.9	0.0	537.4	6,306.9	9%
Grose Cr	0.1	12.5	6.2	6.7	0.0	25.6	67.9	38%
Lost Cr	2.2	29.1	89.4	116.8	0.0	237.5	939.4	25%
Soap Cr	2.2	9.7	146.1	123.6	0.0	281.6	1,037.0	27%
Wickiup Cr	5.6	4.2	27.2	106.3	0.0	143.3	776.9	18%

Table 28. Phosphorus reduction summary table

Watershed	Fertilizer Scenario (kg)	Stream-bank Scenario (kg)	Upland Scenario (kg)	Filter Strip Scenario (kg)	Animal Scenario (kg)	Overall Reduction (kg)	Total Load (kg)	% Red.
Francis Cr	4.9	26.8	16.7	78.4	0.0	126.8	379.3	33%
Steel Cr	21.6	129.2	28.7	148.3	0.0	327.9	922.1	36%
Jerry Cr	16.1	36.3	59.8	294.5	0.0	406.8	1,401.7	29%
Camp Cr	10.4	29.2	103.1	88.5	0.0	231.2	772.1	30%
Divide Cr	11.7	18.8	68.2	54.5	0.0	153.2	1,161.4	13%
Grose Cr	0.1	5.2	2.6	0.9	0.0	8.7	16.9	52%
Lost Cr	1.5	12.0	36.9	24.9	0.0	75.3	238.5	32%
Soap Cr	1.5	4.0	60.4	31.3	0.0	97.2	307.2	32%
Wickiup Cr	3.2	1.8	11.2	17.2	0.0	33.4	143.6	23%

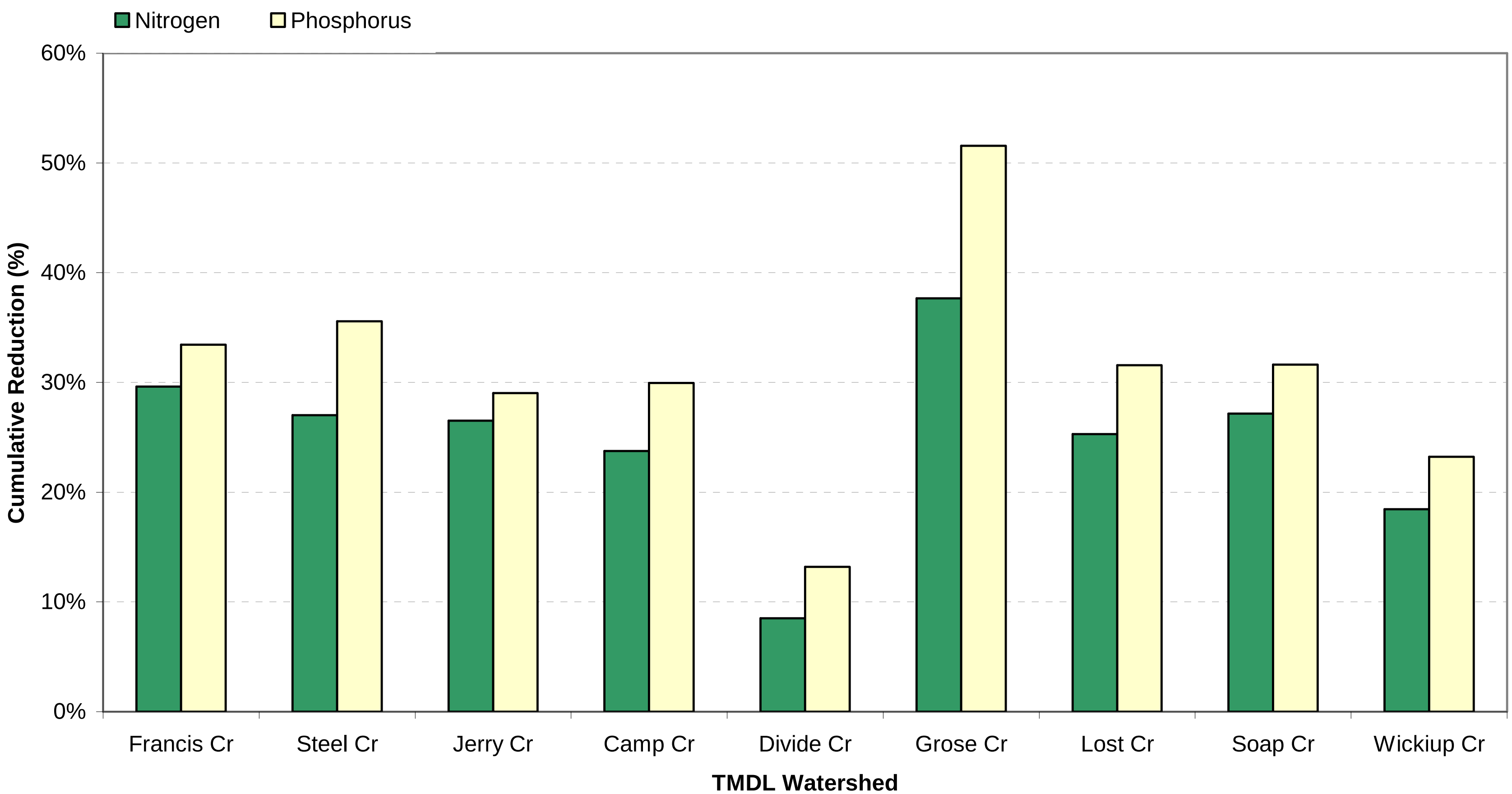


Figure 21. Summary of estimated nitrogen and phosphorus reductions in TMDL watersheds from implementation of all reasonable land, soil and water conservation practices (ARM 17.30.602).

9.1 Francis Creek

Estimated monthly streamflow, existing nutrient loads, interim criteria, BMP implementation loads, recommended restoration approaches, and proposed source allocations for Francis Creek are shown in **Figure 22**, **Table 29**, **Table 30**, and **Table 31**.

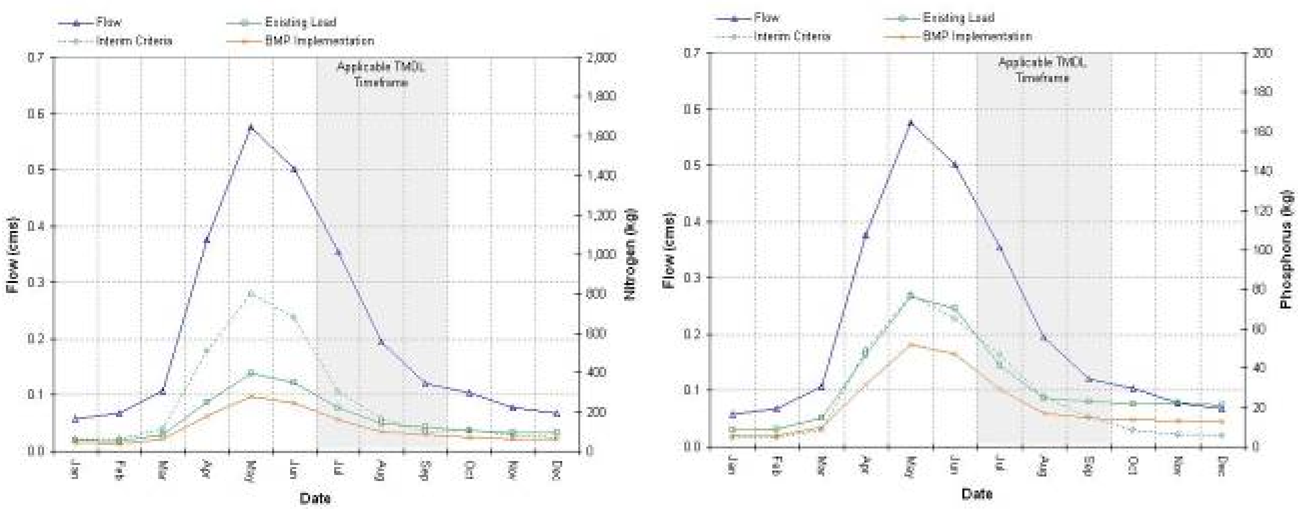


Figure 22. Estimated existing and proposed monthly loads of nitrogen and phosphorus in Francis Creek.

Table 29. Monthly tabular data of estimated monthly streamflow and pollutant loads for Francis Creek.

Month	Streamflow (cms)	Existing Condition Nitrogen Load (kg)	Nitrogen Criteria Load (kg)	BMP Nitrogen Load (kg)	Existing Condition Phosphorus Load (kg)	Phosphorus Criteria Load (kg)	BMP Phosphorus Load (kg)
Jan	0.06	57.2	61.0	41.2	8.4	4.7	5.7
Feb	0.07	52.2	63.5	37.1	8.7	4.9	5.9
Mar	0.11	84.8	111.7	60.5	14.9	8.6	10.0
Apr	0.38	248.0	507.9	177.9	46.5	48.8	31.8
May	0.58	394.0	802.5	280.6	76.6	77.2	52.1
Jun	0.50	350.4	677.2	246.1	70.1	65.1	47.0
Jul	0.35	220.9	304.2	158.7	41.6	46.6	29.1
Aug	0.19	140.6	166.7	100.8	24.5	25.5	16.9
Sep	0.12	122.4	100.0	84.5	23.0	15.3	14.7
Oct	0.10	103.3	109.2	70.1	21.7	8.4	13.5
Nov	0.08	96.3	78.7	63.2	22.0	6.1	13.2
Dec	0.07	92.0	71.1	60.2	21.1	5.5	12.6

Table 30. Nitrogen sources and loads, recommended restoration approaches, and proposed source allocations for Francis Creek.

Source Area	*Associated Human Activities*	*Existing Tot. N (kg)*	*Source Area Restoration Approach (reduction in kg)*	*Source Area Allocated Tot. N (kg)*	*Pollutant Filtering via Riparian Vegetation Improvement (reduction in kg)*	*Total Allocated Load From Source (kg)*
Hay/Past	Grazing Hay Production Fertilizer	99.3	Fertilizer/Grazing Management 7.6	91.7	50% 45.8	45.8
Shrub and Grassland	Grazing	578.2	Upland grazing management 40.3	537.9	50% 268.9	268.9
Forest	Grazing Timber Harvest	1024.5	NA	1024.5	15% 153.7	870.8
Developed	Urban	11.1	NA	11.1	0	11.1
Stream Banks	Grazing Hay encroachment	249.1	Riparian Vegetation restoration and grazing management 64.8	184.3	NA	184.3
Point Sources	Waste Load Allocation	0.0	NA	0.0	0	0.0
Future Sources	All	0.0	NA	0.0	0	0.0
Total Estimated Annual Load		1962.1	112.7	1849.4	468.4	1381.0
Estimated overall % reduction			6%		25%	30%

Table 31. Phosphorus sources and loads, recommended restoration approaches, and proposed source allocations for Francis Creek.

Source Area	*Associated Human Activities*	*Existing Tot. P (lbs)*	*Source Area Restoration Approach (reduction in lbs)*	*Source Area Allocated Tot. P (lbs)*	*Pollutant Filtering via Riparian Vegetation Improvement (reduction in lbs)*	*Total Allocated Load From Source (lbs)*
Hay/Past	Grazing Hay Production Fertilizer	8.4	Fertilizer/Grazing Management 5.0	3.5	50% 1.7	1.7
Shrub and Grassland	Grazing	129.1	Upland grazing management 16.7	112.4	50% 56.2	56.2
Forest	Grazing Timber Harvest	136.5	NA	136.5	15% 20.5	116.0
Developed	Urban	2.3	NA	2.3	0	2.3
Stream Banks	Grazing Hay encroachment	103.0	Riparian Vegetation restoration and grazing management 26.8	76.2	NA	76.2
Point Sources	Waste Load Allocation	0.0	NA	0.0	0	0.0
Future Sources	All	0.0	NA	0.0	0	0.0
Total Estimated Annual Load		379.3	48.4	330.8	78.4	252.4
Estimated overall % reduction			13%		24%	33%

9.2 Steel Creek

Estimated monthly streamflow, existing nutrient loads, interim criteria, BMP implementation loads, recommended restoration approaches, and proposed source allocations for Steel Creek are shown in **Figure 23**, **Table 32**, **Table 33**, and **Table 34**.

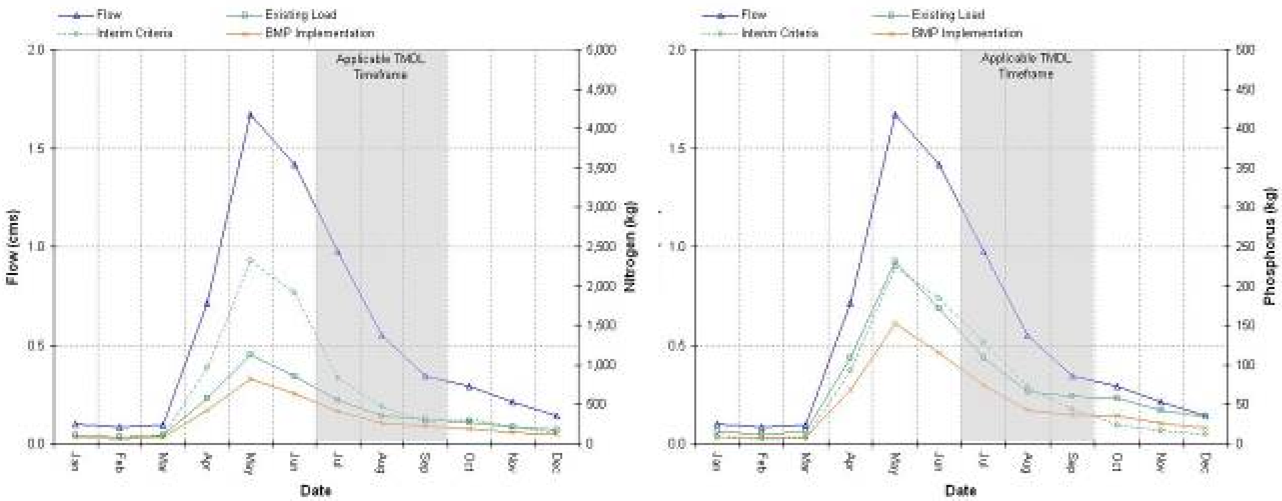


Figure 23. Estimated monthly loads of nitrogen and phosphorus in Steel Creek; including existing conditions, interim criteria, and BMP implementation results.

Table 32. Monthly tabular data of estimated monthly streamflow and pollutant loads for Steel Creek.

Month	Streamflow (cms)	Existing Condition Nitrogen Load (kg)	Nitrogen Criteria Load (kg)	BMP Nitrogen Load (kg)	Existing Condition Phosphorus Load (kg)	Phosphorus Criteria Load (kg)	BMP Phosphorus Load (kg)
Jan	0.10	111.1	103.7	82.0	14.9	8.0	8.8
Feb	0.08	84.7	79.3	61.4	12.2	6.1	7.0
Mar	0.09	104.5	97.6	76.7	14.7	7.5	8.6
Apr	0.71	574.7	959.5	419.8	109.1	92.3	68.1
May	1.67	1125.3	2325.7	827.2	231.5	223.6	152.7
Jun	1.42	854.2	1911.0	630.7	171.2	183.7	114.9
Jul	0.98	548.4	835.7	405.9	108.9	128.0	73.4
Aug	0.55	354.3	470.4	259.9	65.4	72.0	42.3
Sep	0.34	310.8	285.2	222.7	59.7	43.7	36.9
Oct	0.29	266.9	304.9	187.2	57.9	23.5	35.3
Nov	0.21	206.1	213.5	145.0	42.3	16.4	25.6
Dec	0.14	172.9	146.4	121.9	34.1	11.3	20.5

Table 33. Nitrogen sources and loads, recommended restoration approaches, and proposed source allocations for Steel Creek.

Source Area	*Associated Human Activities*	*Existing Tot. N (kg)*	*Source Area Restoration Approach (reduction in kg)*	*Source Area Allocated Tot. N (kg)*	*Pollutant Filtering via Riparian Vegetation Improvement (reduction in kg)*	*Total Allocated Load From Source (kg)*
Hay/Past	Grazing Hay Production Fertilizer	338.7	Fertilizer/Grazing Management 40.8	297.9	50% 149.0	149.0
Shrub and Grassland	Grazing	1474.0	Upland grazing management 68.6	1405.4	50% 702.7	702.7
Forest	Grazing Timber Harvest	2192.4	NA	2192.4	0% 0.0	2192.4
Developed	Urban	57.5	NA	57.5	0	57.5
Stream Banks	Grazing Hay encroachment	651.3	Riparian Vegetation restoration and grazing management 312.6	338.7	NA	338.7
Point Sources	Waste Load Allocation	0.0	NA	0.0	0	0.0
Future Sources	All	0.0	NA	0.0	0	0.0
Total Estimated Annual Load		4713.9	422.0	4291.9	851.7	3440.3
Estimated overall % reduction			9%		20%	27%

Table 34. Phosphorus sources and loads, recommended restoration approaches, and proposed source allocations for Steel Creek.

Source Area	*Associated Human Activities*	*Existing Tot. P (lbs)*	*Source Area Restoration Approach (reduction in lbs)*	*Source Area Allocated Tot. P (lbs)*	*Pollutant Filtering via Riparian Vegetation Improvement (reduction in lbs)*	*Total Allocated Load From Source (lbs)*
Hay/Past	Grazing Hay Production Fertilizer	37.2	Fertilizer/Grazing Management 22.0	15.2	50% 7.6	7.6
Shrub and Grassland	Grazing	309.8	Upland grazing management 28.4	281.5	50% 140.7	140.7
Forest	Grazing Timber Harvest	296.3	NA	296.3	0% 0.0	296.3
Developed	Urban	9.5	NA	9.5	0	9.5
Stream Banks	Grazing Hay encroachment	269.2	Riparian Vegetation restoration and grazing management 129.2	140.0	NA	140.0
Point Sources	Waste Load Allocation	0.0	NA	0.0	0	0.0
Future Sources	All	0.0	NA	0.0	0	0.0
Total Estimated Annual Load		922.1	179.6	742.5	148.3	594.1
Estimated overall % reduction			19%		20%	36%

9.3 Jerry Creek

Estimated monthly streamflow, existing nutrient loads, interim criteria, BMP implementation loads, recommended restoration approaches, and proposed source allocations for Jerry Creek are shown in **Figure 24**, **Table 35**, **Table 36**, and **Table 37**.

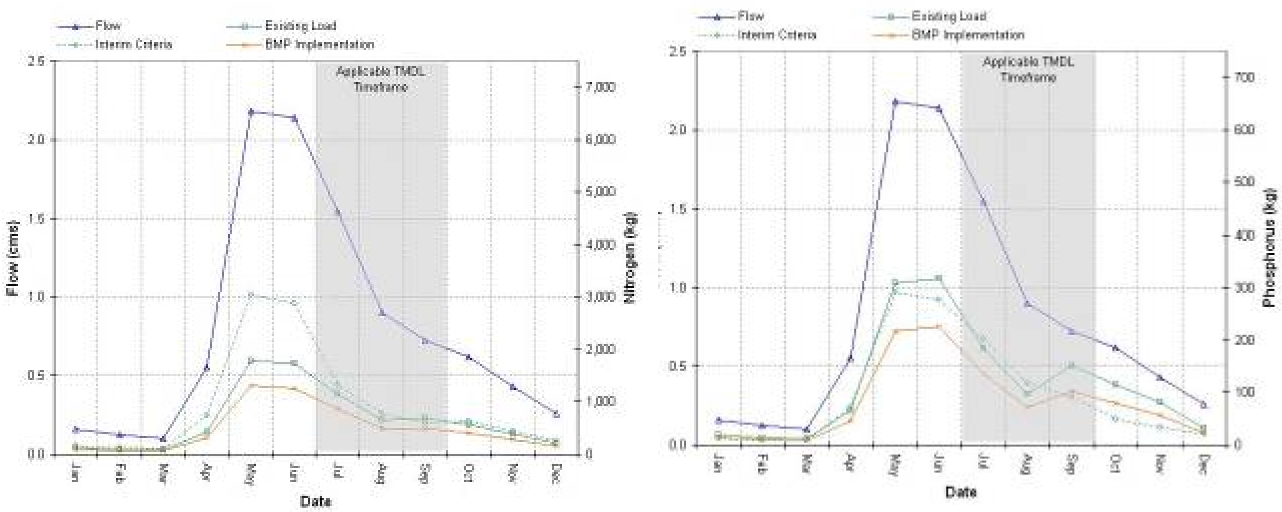


Figure 24. Estimated monthly loads of nitrogen and phosphorus in Jerry Creek; including existing conditions, interim criteria, and BMP implementation results.

Table 35. Monthly tabular data of estimated monthly streamflow and pollutant loads for Jerry Creek.

Month	Streamflow (cms)	Existing Condition Nitrogen Load (kg)	Nitrogen Criteria Load (kg)	BMP Nitrogen Load (kg)	Existing Condition Phosphorus Load (kg)	Phosphorus Criteria Load (kg)	BMP Phosphorus Load (kg)
Jan	0.16	129.3	166.8	96.2	19.0	12.8	13.9
Feb	0.12	91.8	115.8	67.9	13.9	8.9	10.0
Mar	0.10	87.2	106.5	64.6	12.9	8.2	9.3
Apr	0.55	426.2	747.3	317.1	66.1	71.9	46.8
May	2.18	1782.2	3038.6	1313.6	309.5	292.2	218.1
Jun	2.14	1726.6	2884.2	1264.5	318.5	277.3	226.6
Jul	1.54	1152.9	1322.6	861.7	184.2	202.5	136.3
Aug	0.90	658.8	775.3	496.1	97.3	118.7	73.2
Sep	0.72	697.1	600.5	494.4	151.3	92.0	102.1
Oct	0.62	562.6	643.9	404.2	114.6	49.5	78.9
Nov	0.43	397.3	435.4	284.3	82.1	33.5	56.3
Dec	0.26	208.0	273.3	154.7	32.3	21.0	23.5

Table 36. Nitrogen sources and loads, recommended restoration approaches, and proposed source allocations for Jerry Creek.

Source Area	*Associated Human Activities*	*Existing Tot. N (kg)*	*Source Area Restoration Approach (reduction in kg)*	*Source Area Allocated Tot. N (kg)*	*Pollutant Filtering via Riparian Vegetation Improvement (reduction in kg)*	*Total Allocated Load From Source (kg)*
Hay/Past	Grazing Hay Production Fertilizer	114.5	Fertilizer/Grazing Management 19.0	95.5	25% 23.9	71.6
Shrub and Grassland	Grazing	1370.6	Upland grazing management 144.7	1225.9	25% 306.5	919.4
Forest	Grazing Timber Harvest	6076.3	NA	6076.3	25% 1519.1	4557.3
Developed	Urban	21.2	NA	21.2	0	21.2
Stream Banks	Grazing Hay encroachment	337.5	Riparian Vegetation restoration and grazing management 87.7	249.7	NA	249.7
Point Sources	Waste Load Allocation	0.0	NA	0.0	0	0.0
Future Sources	All	0.0	NA	0.0	0	0.0
Total Estimated Annual Load		7920.0	251.4	7668.6	1849.4	5819.2
Estimated overall % reduction			3%		24%	27%

Table 37. Phosphorus sources and loads, recommended restoration approaches, and proposed source allocations for Jerry Creek.

Source Area	*Associated Human Activities*	*Existing Tot. P (lbs)*	*Source Area Restoration Approach (reduction in lbs)*	*Source Area Allocated Tot. P (lbs)*	*Pollutant Filtering via Riparian Vegetation Improvement (reduction in lbs)*	*Total Allocated Load From Source (lbs)*
Hay/Past	Grazing Hay Production Fertilizer	27.0	Fertilizer/Grazing Management 16.2	10.8	25% 2.7	8.1
Shrub and Grassland	Grazing	457.0	Upland grazing management 59.8	397.1	25% 99.3	297.9
Forest	Grazing Timber Harvest	770.2	NA	770.2	25% 192.5	577.6
Developed	Urban	8.2	NA	8.2	0	8.2
Stream Banks	Grazing Hay encroachment	139.5	Riparian Vegetation restoration and grazing management 36.3	103.2	NA	103.2
Point Sources	Waste Load Allocation	0.0	NA	0.0	0	0.0
Future Sources	All	0.0	NA	0.0	0	0.0
Total Estimated Annual Load		1401.7	112.2	1289.5	294.5	995.0
Estimated overall % reduction			8%		23%	29%

9.4 Camp Creek

Estimated monthly streamflow, existing nutrient loads, interim criteria, BMP implementation loads, recommended restoration approaches, and proposed source allocations for Camp Creek are shown in **Figure 26**, **Table 38**, **Table 39, and Table 40**.

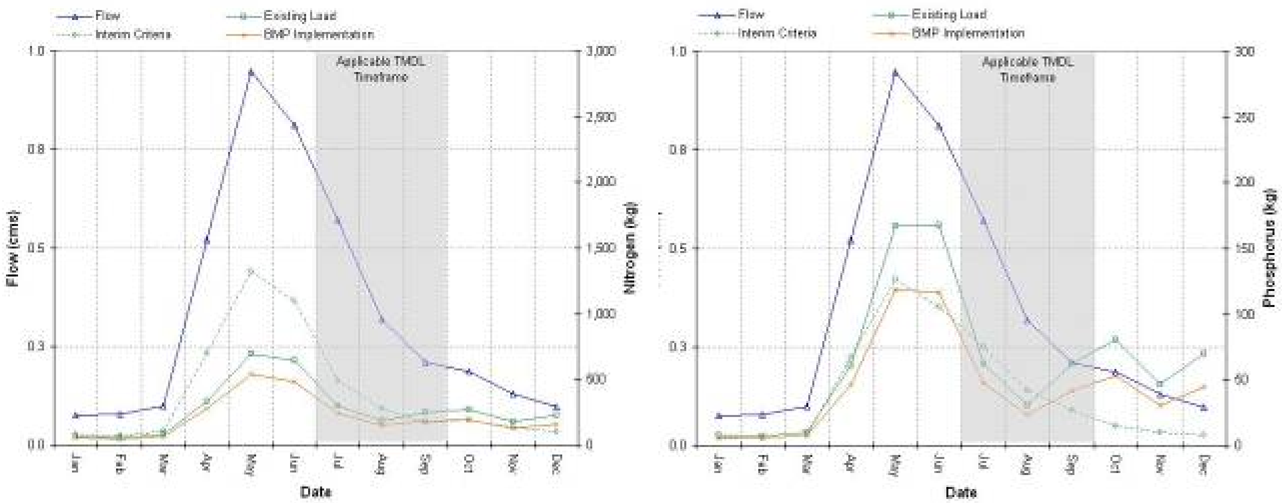


Figure 25. Estimated monthly loads of nitrogen and phosphorus in Camp Creek; including existing conditions, interim criteria, and BMP implementation results.

Table 38. Monthly tabular data of estimated monthly streamflow and pollutant load for Camp Creek.

Month	Streamflow (cms)	Existing Condition Nitrogen Load (kg)	Nitrogen Criteria Load (kg)	BMP Nitrogen Load (kg)	Existing Condition Phosphorus Load (kg)	Phosphorus Criteria Load (kg)	BMP Phosphorus Load (kg)
Jan	0.08	67.0	79.6	55.7	7.6	6.1	5.8
Feb	0.08	54.4	72.7	44.8	7.1	5.6	5.3
Mar	0.10	75.2	103.9	61.9	10.3	8.0	7.7
Apr	0.52	335.2	701.7	274.3	60.6	67.5	45.8
May	0.95	694.5	1320.3	535.3	166.8	127.0	119.2
Jun	0.81	640.6	1094.1	478.0	167.9	105.2	116.7
Jul	0.57	298.9	488.6	240.7	62.0	74.8	47.4
Aug	0.32	180.8	272.7	148.7	30.1	41.8	23.4
Sep	0.21	248.3	173.3	182.1	62.4	26.5	41.6
Oct	0.19	269.6	193.9	188.5	80.8	14.9	52.8
Nov	0.13	175.0	131.6	125.9	46.6	10.1	30.6
Dec	0.10	225.8	100.4	154.2	69.9	7.7	44.7

Table 39. Nitrogen sources and loads, recommended restoration approaches, and proposed source allocations for Camp Creek.

Source Area	Associated Human Activities	Existing Tot. N (kg)	Source Area Restoration Approach (reduction in kg)	Source Area Allocated Tot. N (kg)	Pollutant Filtering via Riparian Vegetation Improvement (reduction in kg)	Total Allocated Load From Source (kg)
Hay/Past	Grazing Hay Production Fertilizer	186.9	Fertilizer/Grazing Management 18.2	168.8	25% 42.2	126.6
Shrub and Grassland	Grazing	1725.5	Upland grazing management 249.1	1476.4	15% 221.5	1254.9
Forest	Grazing Timber Harvest	1157.4	NA	1157.4	15% 173.6	983.8
Developed	Urban	31.3	NA	31.3	0	31.3
Stream Banks	Grazing Hay encroachment	164.3	Riparian Vegetation restoration and grazing management 70.7	93.7	NA	93.7
Point Sources	Waste Load Allocation	0.0	NA	0.0	0	0.0
Future Sources	All	0.0	NA	0.0	0	0.0
Total Estimated Annual Load		3265.5	337.9	2927.5	437.3	2490.3
Estimated overall % reduction			10%		15%	24%

Table 40. Phosphorus sources and loads, recommended restoration approaches, and proposed source allocations for Camp Creek.

Source Area	*Associated Human Activities*	*Existing Tot. P (lbs)*	*Source Area Restoration Approach (reduction in lbs)*	*Source Area Allocated Tot. P (lbs)*	*Pollutant Filtering via Riparian Vegetation Improvement (reduction in lbs)*	*Total Allocated Load From Source (lbs)*
Hay/Past	Grazing Hay Production Fertilizer	17.7	Fertilizer/Grazing Management 10.5	7.2	25% 1.8	5.4
Shrub and Grassland	Grazing	517.9	Upland grazing management 103.0	414.9	15% 62.2	352.7
Forest	Grazing Timber Harvest	163.3	NA	163.3	15% 24.5	138.8
Developed	Urban	5.4	NA	5.4	0	5.4
Stream Banks	Grazing Hay encroachment	67.9	Riparian Vegetation restoration and grazing management 29.2	38.7	NA	38.7
Point Sources	Waste Load Allocation	0.0	NA	0.0	0	0.0
Future Sources	All	0.0	NA	0.0	0	0.0
Total Estimated Annual Load		772.1	142.7	629.5	88.5	541.0
Estimated overall % reduction			18%		14%	30%

9.5 Divide Creek

Estimated monthly streamflow, existing nutrient loads, interim criteria, BMP implementation loads, recommended restoration approaches, and proposed source allocations for Divide Creek are shown in **Figure 26**, **Table 41**, **Table 42** and **Table 43**.

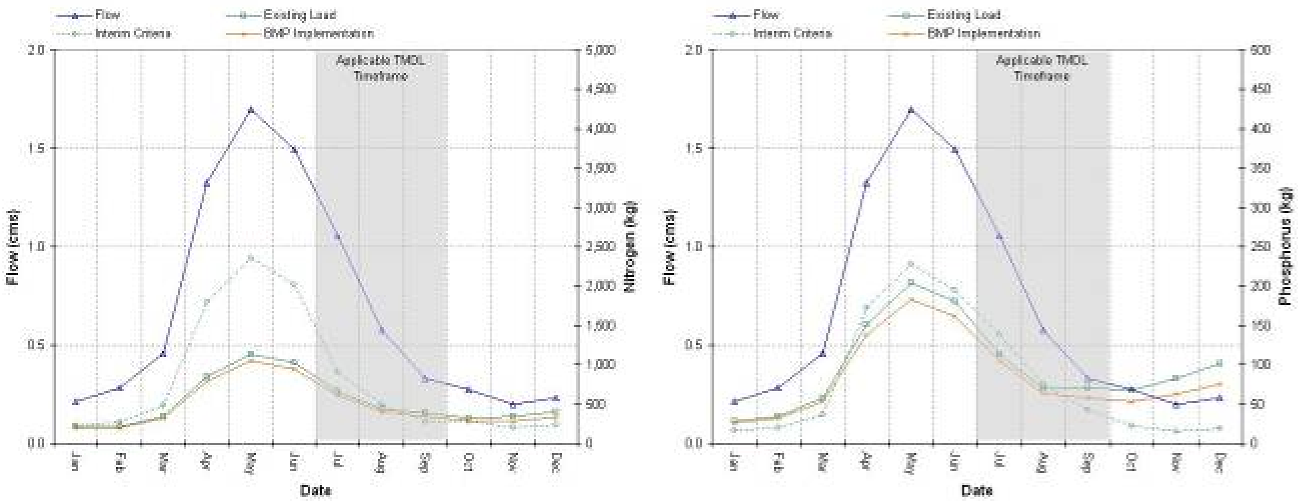


Figure 26. Estimated monthly loads of nitrogen and phosphorus in Divide Creek; including existing conditions, interim criteria, and BMP implementation results.

Table 41. Monthly tabular data of estimated monthly streamflow and pollutant load for Divide Creek.

Month	Streamflow (cms)	Existing Condition Nitrogen Load (kg)	Nitrogen Criteria Load (kg)	BMP Nitrogen Load (kg)	Existing Condition Phosphorus Load (kg)	Phosphorus Criteria Load (kg)	BMP Phosphorus Load (kg)
Jan	0.21	208.0	220.3	195.1	28.5	16.9	25.9
Feb	0.28	215.2	268.2	201.5	34.5	20.6	31.4
Mar	0.46	342.5	478.9	320.7	57.6	36.8	52.5
Apr	1.33	849.1	1788.0	794.5	151.3	171.9	137.5
May	1.70	1127.1	2362.8	1046.7	203.5	227.2	182.5
Jun	1.50	1020.8	2017.9	944.2	180.7	194.0	161.0
Jul	1.05	655.4	903.8	617.1	112.9	138.4	105.0
Aug	0.58	431.1	495.1	403.3	69.7	75.8	63.7
Sep	0.33	389.9	275.1	347.4	70.9	42.1	57.8
Oct	0.28	323.4	287.4	283.1	67.3	22.1	53.6
Nov	0.20	343.1	201.2	285.4	83.1	15.5	62.1
Dec	0.23	401.2	239.5	330.5	101.4	18.4	75.2

Table 42. Nitrogen sources and loads, recommended restoration approaches, and proposed source allocations for Divide Creek.

Source Area	Associated Human Activities	Existing Tot. N (kg)	Source Area Restoration Approach (reduction in kg)	Source Area Allocated Tot. N (kg)	Pollutant Filtering via Riparian Vegetation Improvement (reduction in kg)	Total Allocated Load From Source (kg)
Hay/Past	Grazing Hay Production Fertilizer	324.0	Fertilizer/Grazing Management 18.4	305.6	15% 45.8	259.8
Shrub and Grassland	Grazing	1918.1	Upland grazing management 164.6	1753.5	15% 263.0	1490.5
Forest	Grazing Timber Harvest	3283.6	NA	3283.6	0% 0.0	3283.6
Developed	Urban	130.6	NA	130.6	0	130.6
Stream Banks	Grazing Hay encroachment	650.6	Riparian Vegetation restoration and grazing management 45.5	605.1	NA	605.1
Point Sources	Waste Load Allocation	0.0	NA	0.0	0	0.0
Future Sources	All	0.0	NA	0.0	0	0.0
Total Estimated Annual Load		6306.9	228.5	6078.4	308.9	5769.5
Estimated overall % reduction			4%		5%	9%

Table 43. Phosphorus sources and loads, recommended restoration approaches, and proposed source allocations for Divide Creek.

Source Area	Associated Human Activities	Existing Tot. P (lbs)	Source Area Restoration Approach (reduction in lbs)	Source Area Allocated Tot. P (lbs)	Pollutant Filtering via Riparian Vegetation Improvement (reduction in lbs)	Total Allocated Load From Source (lbs)
Hay/Past	Grazing Hay Production Fertilizer	20.0	Fertilizer/Grazing Management 11.8	8.2	15% 1.2	7.0
Shrub and Grassland	Grazing	423.4	Upland grazing management 68.0	355.4	15% 53.3	302.1
Forest	Grazing Timber Harvest	430.7	NA	430.7	0% 0.0	430.7
Developed	Urban	18.3	NA	18.3	0	18.3
Stream Banks	Grazing Hay encroachment	268.9	Riparian Vegetation restoration and grazing management 18.8	250.1	NA	250.1
Point Sources	Waste Load Allocation	0.0	NA	0.0	0	0.0
Future Sources	All	0.0	NA	0.0	0	0.0
Total Estimated Annual Load		1161.4	98.7	1062.7	54.5	1008.2
Estimated overall % reduction			8%		5%	13%

9.6 Grose Creek

Estimated monthly streamflow, existing nutrient loads, interim criteria, BMP implementation loads, recommended restoration approaches, and proposed source allocations for Grose Creek are shown in **Figure 27**, **Table 44**, **Table 45** and **Table 46**.

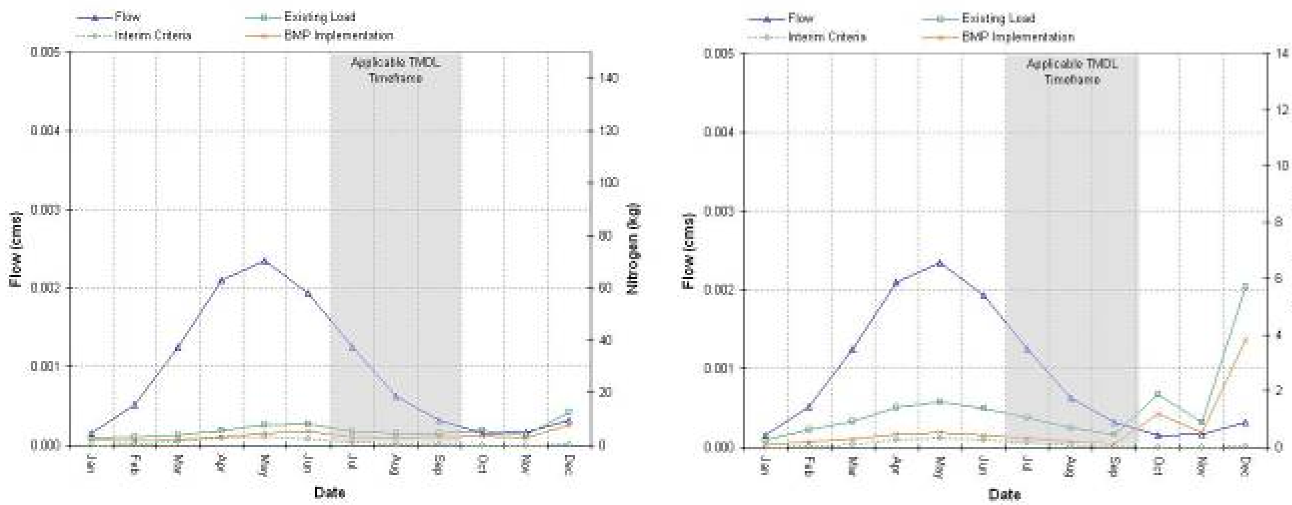


Figure 27. Estimated monthly loads of nitrogen and phosphorus in Grose Creek; including existing conditions, interim criteria, and BMP implementation results.

Table 44. Monthly tabular data of estimated monthly streamflow and pollutant load for Grose Creek.

Month	Streamflow (cms)	Existing Condition Nitrogen Load (kg)	Nitrogen Criteria Load (kg)	BMP Nitrogen Load (kg)	Existing Condition Phosphorus Load (kg)	Phosphorus Criteria Load (kg)	BMP Phosphorus Load (kg)
Jan	0.00	2.7	0.2	2.0	0.3	0.0	0.1
Feb	0.00	3.0	0.5	1.8	0.6	0.0	0.2
Mar	0.00	3.9	1.3	2.1	0.9	0.1	0.3
Apr	0.00	5.8	2.8	3.1	1.4	0.3	0.5
May	0.00	7.8	3.3	4.6	1.6	0.3	0.5
Jun	0.00	8.2	2.6	5.3	1.4	0.3	0.4
Jul	0.00	5.2	1.1	3.1	1.0	0.2	0.3
Aug	0.00	4.5	0.5	3.0	0.7	0.1	0.2
Sep	0.00	4.4	0.3	3.2	0.5	0.0	0.1
Oct	0.00	5.5	0.2	3.5	1.9	0.0	1.2
Nov	0.00	3.8	0.2	2.7	0.9	0.0	0.5
Dec	0.00	12.9	0.3	7.8	5.7	0.0	3.8

Table 45. Nitrogen sources and loads, recommended restoration approaches, and proposed source allocations for Grose Creek.

Source Area	*Associated Human Activities*	*Existing Tot. N (kg)*	*Source Area Restoration Approach (reduction in kg)*	*Source Area Allocated Tot. N (kg)*	*Pollutant Filtering via Riparian Vegetation Improvement (reduction in kg)*	*Total Allocated Load From Source (kg)*
Hay/Past	Grazing Hay Production Fertilizer	5.9	Fertilizer/Grazing Management 0.2	5.7	25% 1.4	4.3
Shrub and Grassland	Grazing	36.3	Upland grazing management 6.2	30.2	15% 4.5	25.7
Forest	Grazing Timber Harvest	5.3	NA	5.3	15% 0.8	4.5
Developed	Urban	0.2	NA	0.2	0	0.2
Stream Banks	Grazing Hay encroachment	20.1	Riparian Vegetation restoration and grazing management 12.5	7.7	NA	7.7
Point Sources	Waste Load Allocation	0.0	NA	0.0	0	0.0
Future Sources	All	0.0	NA	0.0	0	0.0
Total Estimated Annual Load		67.9	18.8	49.1	6.7	42.3
Estimated overall % reduction			28%		14%	38%

Table 46. Phosphorus sources and loads, recommended restoration approaches, and proposed source allocations for Grose Creek.

Source Area	*Associated Human Activities*	*Existing Tot. P (lbs)*	*Source Area Restoration Approach (reduction in lbs)*	*Source Area Allocated Tot. P (lbs)*	*Pollutant Filtering via Riparian Vegetation Improvement (reduction in lbs)*	*Total Allocated Load From Source (lbs)*
Hay/Past	Grazing Hay Production Fertilizer	0.2	Fertilizer/Grazing Management 0.1	0.1	25% 0.0	0.1
Shrub and Grassland	Grazing	8.3	Upland grazing management 2.5	5.8	15% 0.9	4.9
Forest	Grazing Timber Harvest	0.0	NA	0.0	15% 0.0	0.0
Developed	Urban	0.0	NA	0.0	0	0.0
Stream Banks	Grazing Hay encroachment	8.3	Riparian Vegetation restoration and grazing management 5.2	3.2	NA	3.2
Point Sources	Waste Load Allocation	0.0	NA	0.0	0	0.0
Future Sources	All	0.0	NA	0.0	0	0.0
Total Estimated Annual Load		16.9	7.8	9.1	0.9	8.2
Estimated overall % reduction			46%		10%	52%

9.7 Lost Creek

Estimated monthly streamflow, existing nutrient loads, interim criteria, BMP implementation loads, recommended restoration approaches, and proposed source allocations for Lost Creek are shown in **Figure 28**, **Table 47**, **Table 48**, and **Table 49**.

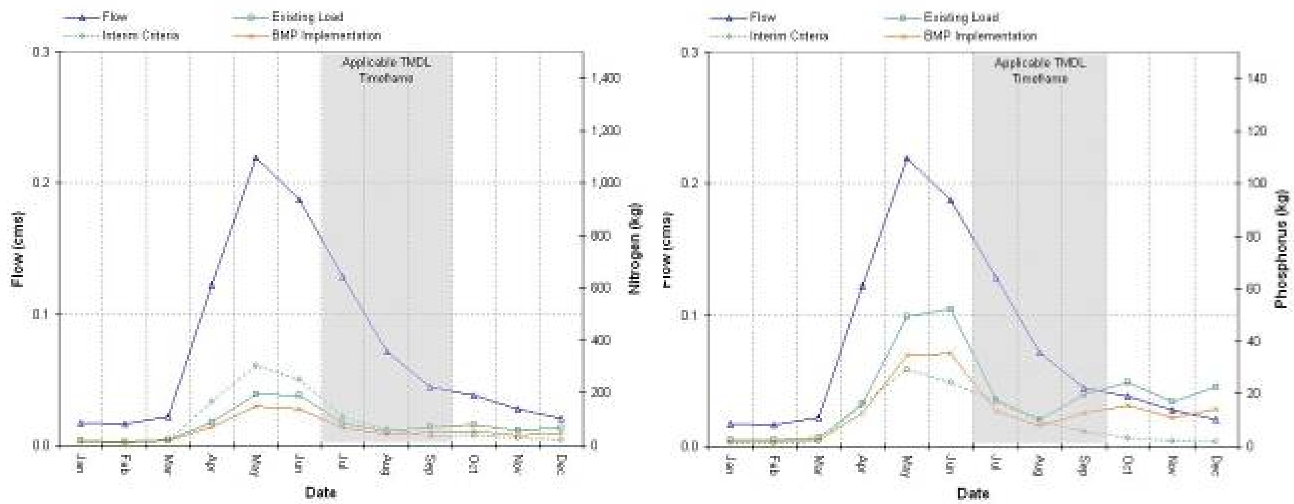


Figure 28. Estimated monthly loads of nitrogen and phosphorus in Lost Creek; including existing conditions, interim criteria, and BMP implementation results.

Table 47. Monthly tabular data of estimated monthly streamflow and pollutant load for Lost Creek.

Month	Streamflow (cms)	Existing Condition Nitrogen Load (kg)	Nitrogen Criteria Load (kg)	BMP Nitrogen Load (kg)	Existing Condition Phosphorus Load (kg)	Phosphorus Criteria Load (kg)	BMP Phosphorus Load (kg)
Jan	0.02	18.1	17.4	14.9	2.5	1.3	1.8
Feb	0.02	15.1	15.7	12.3	2.3	1.2	1.7
Mar	0.02	20.5	22.6	16.7	3.2	1.7	2.4
Apr	0.12	86.9	164.7	71.5	16.4	15.8	12.6
May	0.22	195.0	305.1	148.0	49.4	29.3	34.6
Jun	0.19	190.9	252.9	139.4	52.5	24.3	35.5
Jul	0.13	84.5	110.7	67.8	17.8	16.9	13.3
Aug	0.07	54.1	61.4	43.4	10.4	9.4	7.7
Sep	0.04	71.7	37.1	51.1	19.7	5.7	12.8
Oct	0.04	76.9	40.0	52.2	24.4	3.1	15.6
Nov	0.03	56.7	27.8	38.9	17.2	2.1	10.9
Dec	0.02	69.0	21.8	45.5	22.8	1.7	14.2

Table 48. Nitrogen sources and loads, recommended restoration approaches, and proposed source allocations for Lost Creek.

Source Area	*Associated Human Activities*	*Existing Tot. N (kg)*	*Source Area Restoration Approach (reduction in kg)*	*Source Area Allocated Tot. N (kg)*	*Pollutant Filtering via Riparian Vegetation Improvement (reduction in kg)*	*Total Allocated Load From Source (kg)*
Hay/Past	Grazing Hay Production Fertilizer	58.7	Fertilizer/Grazing Management 2.2	56.4	25% 14.1	42.3
Shrub and Grassland	Grazing	465.3	Upland grazing management 89.4	375.9	15% 56.4	319.5
Forest	Grazing Timber Harvest	309.0	NA	309.0	15% 46.3	262.6
Developed	Urban	15.6	NA	15.6	0	15.6
Stream Banks	Grazing Hay encroachment	90.9	Riparian Vegetation restoration and grazing management 29.1	61.8	NA	61.8
Point Sources	Waste Load Allocation	0.0	NA	0.0	0	0.0
Future Sources	All	0.0	NA	0.0	0	0.0
Total Estimated Annual Load		939.4	120.7	818.7	116.8	701.9
Estimated overall % reduction			13%		14%	25%

Table 49. Phosphorus sources and loads, recommended restoration approaches, and proposed source allocations for Lost Creek.

Source Area	*Associated Human Activities*	*Existing Tot. P (lbs)*	*Source Area Restoration Approach (reduction in lbs)*	*Source Area Allocated Tot. P (lbs)*	*Pollutant Filtering via Riparian Vegetation Improvement (reduction in lbs)*	*Total Allocated Load From Source (lbs)*
Hay/Past	Grazing Hay Production Fertilizer	12.6	Fertilizer/Grazing Management 1.5	11.1	25% 2.8	8.3
Shrub and Grassland	Grazing	149.1	Upland grazing management 36.9	112.2	15% 16.8	95.3
Forest	Grazing Timber Harvest	35.1	NA	35.1	15% 5.3	29.8
Developed	Urban	4.2	NA	4.2	0	4.2
Stream Banks	Grazing Hay encroachment	37.6	Riparian Vegetation restoration and grazing management 12.0	25.5	NA	25.5
Point Sources	Waste Load Allocation	0.0	NA	0.0	0	0.0
Future Sources	All	0.0	NA	0.0	0	0.0
Total Estimated Annual Load		238.5	50.5	188.1	24.9	163.2
Estimated overall % reduction			21%		13%	32%

9.8 Soap Creek

Estimated monthly streamflow, existing nutrient loads, interim criteria, BMP implementation loads, recommended restoration approaches, and proposed source allocations for Soap Creek are shown in **Figure 29**, **Table 50**, **Table 51**, and **Table 52**.

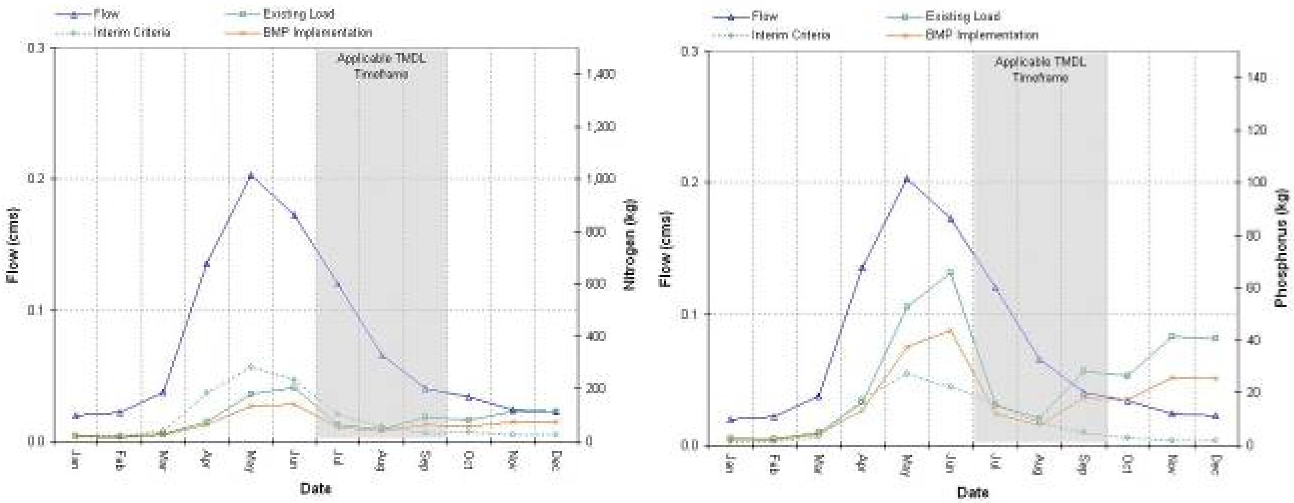


Figure 29. Estimated monthly loads of nitrogen and phosphorus in Soap Creek; including existing conditions, interim criteria, and BMP implementation results.

Table 50. Monthly tabular data of estimated monthly streamflow and pollutant load for Soap Creek.

Month	Streamflow (cms)	Existing Condition Nitrogen Load (kg)	Nitrogen Criteria Load (kg)	BMP Nitrogen Load (kg)	Existing Condition Phosphorus Load (kg)	Phosphorus Criteria Load (kg)	BMP Phosphorus Load (kg)
Jan	0.02	20.3	20.7	17.5	2.7	1.6	2.2
Feb	0.02	16.6	20.7	14.3	2.6	1.6	2.2
Mar	0.04	27.4	39.5	23.4	4.9	3.0	4.1
Apr	0.14	75.7	183.0	64.6	16.1	17.6	13.4
May	0.20	181.8	283.2	136.1	52.9	27.2	37.4
Jun	0.17	203.9	233.1	143.2	65.7	22.4	44.0
Jul	0.12	63.7	103.3	52.4	15.2	15.8	12.2
Aug	0.07	47.5	56.3	38.8	10.2	8.6	7.9
Sep	0.04	91.3	33.2	63.3	28.1	5.1	18.2
Oct	0.03	80.9	35.7	55.0	26.7	2.7	17.3
Nov	0.02	114.9	24.4	74.0	41.3	1.9	25.9
Dec	0.02	113.1	23.5	72.7	40.7	1.8	25.4

Table 51. Nitrogen sources and loads, recommended restoration approaches, and proposed source allocations for Soap Creek.

Source Area	Associated Human Activities	Existing Tot. N (kg)	Source Area Restoration Approach (reduction in kg)	Source Area Allocated Tot. N (kg)	Pollutant Filtering via Riparian Vegetation Improvement (reduction in kg)	Total Allocated Load From Source (kg)
Hay/Past	Grazing Hay Production Fertilizer	46.3	Fertilizer/Grazing Management 2.2	44.1	25% 11.0	33.1
Shrub and Grassland	Grazing	725.3	Upland grazing management 146.1	579.2	15% 86.9	492.3
Forest	Grazing Timber Harvest	171.2	NA	171.2	15% 25.7	145.5
Developed	Urban	5.8	NA	5.8	0	5.8
Stream Banks	Grazing Hay encroachment	88.4	Riparian Vegetation restoration and grazing management 9.7	78.7	NA	78.7
Point Sources	Waste Load Allocation	0.0	NA	0.0	0	0.0
Future Sources	All	0.0	NA	0.0	0	0.0
Total Estimated Annual Load		1037.0	158.0	878.9	123.6	755.4
Estimated overall % reduction			15%		14%	27%

Table 52. Phosphorus sources and loads, recommended restoration approaches, and proposed source allocations for Soap Creek.

Source Area	*Associated Human Activities*	*Existing Tot. P (lbs)*	*Source Area Restoration Approach (reduction in lbs)*	*Source Area Allocated Tot. P (lbs)*	*Pollutant Filtering via Riparian Vegetation Improvement (reduction in lbs)*	*Total Allocated Load From Source (lbs)*
Hay/Past	Grazing Hay Production Fertilizer	2.5	Fertilizer/Grazing Management 1.5	1.0	25% 0.3	0.8
Shrub and Grassland	Grazing	240.8	Upland grazing management 60.4	180.4	15% 27.1	153.3
Forest	Grazing Timber Harvest	26.4	NA	26.4	15% 3.9	22.4
Developed	Urban	1.0	NA	1.0	0	1.0
Stream Banks	Grazing Hay encroachment	36.5	Riparian Vegetation restoration and grazing management 4.0	32.5	NA	32.5
Point Sources	Waste Load Allocation	0.0	NA	0.0	0	0.0
Future Sources	All	0.0	NA	0.0	0	0.0
Total Estimated Annual Load		307.2	65.9	241.3	31.3	210.0
Estimated overall % reduction			21%		13%	32%

9.9 Wickiup Creek

Estimated monthly streamflow, existing nutrient loads, interim criteria, BMP implementation loads, recommended restoration approaches, and proposed source allocations for Wickiup Creek are shown in **Figure 30**, **Table 53**, **Table 54**, and **Table 55**.

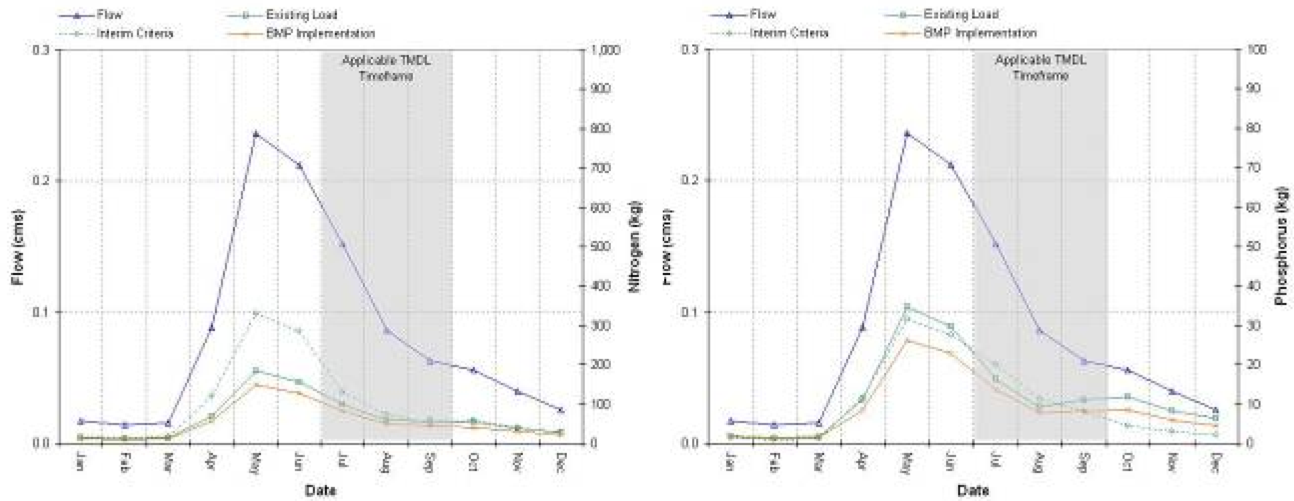


Figure 30. Estimated monthly loads of nitrogen and phosphorus in Wickiup Creek; including existing conditions, interim criteria, and BMP implementation results.

Table 53. Monthly tabular data of estimated monthly streamflow and pollutant load for Wickiup Creek.

Month	Streamflow (cms)	Existing Condition Nitrogen Load (kg)	Nitrogen Criteria Load (kg)	BMP Nitrogen Load (kg)	Existing Condition Phosphorus Load (kg)	Phosphorus Criteria Load (kg)	BMP Phosphorus Load (kg)
Jan	0.02	14.3	17.4	12.2	1.9	1.3	1.6
Feb	0.01	10.8	13.1	9.2	1.5	1.0	1.2
Mar	0.02	13.2	16.2	11.3	1.8	1.2	1.5
Apr	0.09	67.7	119.4	56.0	11.2	11.5	8.5
May	0.24	182.9	329.3	148.4	34.6	31.7	26.1
Jun	0.21	155.7	286.1	126.4	29.8	27.5	22.9
Jul	0.15	98.4	130.2	83.4	16.2	19.9	13.6
Aug	0.09	58.5	74.0	49.8	9.1	11.3	7.7
Sep	0.06	55.5	52.1	44.2	11.0	8.0	8.1
Oct	0.06	53.1	58.5	41.1	11.9	4.5	8.5
Nov	0.04	38.1	39.8	29.6	8.3	3.1	6.0
Dec	0.03	28.6	26.7	21.9	6.4	2.1	4.5

Table 54. Nitrogen sources and loads, recommended restoration approaches, and proposed source allocations for Wickiup Creek.

Source Area	Associated Human Activities	Existing Tot. N (kg)	Source Area Restoration Approach (reduction in kg)	Source Area Allocated Tot. N (kg)	Pollutant Filtering via Riparian Vegetation Improvement (reduction in kg)	Total Allocated Load From Source (kg)
Hay/Past	Grazing Hay Production Fertilizer	38.2	Fertilizer/Grazing Management 6.7	31.5	15% 4.7	26.8
Shrub and Grassland	Grazing	180.4	Upland grazing management 26.1	154.3	15% 23.1	131.2
Forest	Grazing Timber Harvest	523.0	NA	523.0	15% 78.4	444.5
Developed	Urban	0.0	NA	0.0	0	0.0
Stream Banks	Grazing Hay encroachment	35.3	Riparian Vegetation restoration and grazing management 4.2	31.1	NA	31.1
Point Sources	Waste Load Allocation	0.0	NA	0.0	0	0.0
Future Sources	All	0.0	NA	0.0	0	0.0
Total Estimated Annual Load		776.9	37.0	739.9	106.3	633.6
Estimated overall % reduction			5%		14%	18%

Table 55. Phosphorus sources and loads, recommended restoration approaches, and proposed source allocations for Wickiup Creek.

Source Area	*Associated Human Activities*	*Existing Tot. P (lbs)*	*Source Area Restoration Approach (reduction in lbs)*	*Source Area Allocated Tot. P (lbs)*	*Pollutant Filtering via Riparian Vegetation Improvement (reduction in lbs)*	*Total Allocated Load From Source (lbs)*
Hay/Past	Grazing Hay Production Fertilizer	6.6	Fertilizer/Grazing Management 3.6	3.0	15% 0.4	2.5
Shrub and Grassland	Grazing	50.4	Upland grazing management 10.8	39.6	15% 5.9	33.7
Forest	Grazing Timber Harvest	72.0	NA	72.0	15% 10.8	61.2
Developed	Urban	0.0	NA	0.0	0	0.0
Stream Banks	Grazing Hay encroachment	14.6	Riparian Vegetation restoration and grazing management 1.8	12.8	NA	12.8
Point Sources	Waste Load Allocation	0.0	NA	0.0	0	0.0
Future Sources	All	0.0	NA	0.0	0	0.0
Total Estimated Annual Load		143.6	16.2	127.4	17.2	110.2
Estimated overall % reduction			11%		13%	23%

9.10 TMDL Scenario Summary

Clearly, the combined benefit of BMP implementation is a general reduction of nutrient loading in the watersheds which closely approximates interim numeric criteria (in most cases). Thus it is believed that upland and streambank erosion mitigation, riparian buffer enhancement, and reductions in fertilizer application are appropriate BMP recommendations for the upcoming TMDL. Ultimately, it will be up to the discretion of the watershed managers on which options are recommended for future action.

SECTION 10.0
CONCLUSION

GWLF was used to simulate monthly nitrogen and phosphorous loads for the upcoming Big Hole River nutrient TMDL. Through modeling, it was found that forest, grassland, and shrub/scrub provide a large natural background load in most watersheds, and that a majority of the anthropogenic load is of agricultural origin. Sources identified during the project include non-recoverable animal manure, grazing, fertilization, and urban lands. Streambanks were also found to contribute a substantial nitrogen and phosphorus load. Following the source assessment, scenarios were formulated to assess the relative effectiveness of BMP treatments in each of the impaired watersheds. Riparian buffer strip enhancement was shown to be the most effective treatment and anthropogenic pollutant removal ranged from approximately 5-25 percent. When combined with other implementation practices such as streambank and upland erosion mitigation and fertilizer application decreases, reductions ranged from approximately 10-50 percent in each watershed. In most cases, the computed load following BMP implementation load very much approximated interim numeric nutrient criteria. As a result, the primary recommendation is establishment of functioning riparian buffers, followed by streambank and upland erosion reductions. Finally, a reminder should be made that the modeling was relatively low-certainty, and for all intensive purposes, computed loads and associated reductions used in the TMDL development are estimates only.

SECTION 11.0
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Appendix – A1 Irrigation Calculations

ET values for pasture/hay from Dillon AGRIMET site (1997-2006)

```
***************************************************************************
*     *   DAILY    *  *  *  *  *  *  *
*     * CROP WATER USE-(IN) * DAILY*   *   *   * 7 * 14 *
* CROP START* PENMAN ET - SEP * FORE *COVER* TERM* SUM * DAY* DAY *
*   DATE*---------------------* CAST * DATE* DATE* ET * USE* USE *
*     * 27  28  29  30 *   *   *   *   *  *   *
*-----------*---------------------*------*------------------*----------*-----
* PAST 420 * 0.00 0.00 0.00 0.00 * 0.00 * 530 * 920 * 18.4 * 0.0* 0.2  1997
* PAST 420 * 0.00 0.00 0.00 0.00 * 0.00 * 530 * 920 * 20.9 * 0.0* 0.2  1998
* PAST 420 * 0.00 0.00 0.00 0.00 * 0.00 * 530 * 920 * 20.9 * 0.0* 0.2  1999
* PAST 420 * 0.08 0.07 0.07 0.00 * 0.00 * 530 * 930 * 24.1 * 0.4* 1.0  2000
* PAST 420 * 0.09 0.06 0.07 0.00 * 0.00 * 530 * 930 * 24.6 * 0.5* 1.2  2001
* PAST 420 * 0.04 0.05 0.06 0.00 * 0.00 * 530 * 930 * 23.0 * 0.3* 0.9  2002
* PAST 420 * 0.08 0.06 0.08 0.00 * 0.00 * 530 * 930 * 25.6 * 0.5* 1.2  2003
* PAST 420 * 0.06 0.06 0.05 0.00 * 0.00 * 530 * 930 * 23.0 * 0.4* 0.7  2004
* PAST 420 * 0.08 0.06 0.08 0.00 * 0.00 * 530 * 930 * 22.9 * 0.4* 1.0  2005
* PAST 420 * 0.07 0.08 0.06 0.00 * 0.00 * 530 * 930 * 24.3 * 0.4* 0.8  2006
* PAST 420 * 0.08 0.05 0.02 0.00 * 0.00 * 530 * 930 * 25.2 * 0.4* 0.8  2007
*-----------*---------------------*------*------------------*----------*-----
                    AVG  22.7
```

Example irrigation calculation used in GWLF model of USGS Big Hole River nr Melrose, MT:

Irrigated area (pasture/hay) = 14,750 ha
Total watershed area = 636,522 ha
AGRIMET crop water use = 57.8 cm/yr (pasture) (22.7 inches)

$$= \frac{14,750ha}{636,522ha} \times 57.8cm / yr$$

Crop water use requirement = 1.4 cm/yr
Distribution losses = 25%

Net diversion value = 1.7 cm/yr (distribute over summer months)

APPENDIX – A2 LIVESTOCK CALCULATIONS

Livestock calculations used in GWLF modeling are detailed below.

Available Data:

National Agricultural Statistics Service data from 1998-2007 (NASS, 2008)

106,900 cows and calves
12,600 ewes and lambs
750 horses (estimated)

Convert to AUM (NRCS, 2003)
Assume: cow/calf pair = 1 AUM
ewe/lamb = 0.3 AUM
horse = 1.25 AUM

Livestock estimate for grazing season (May-October; 6 months)
53,450 pair cattle x 1 AUM x 6 = 320,700 AUM
6,300 pair sheep x 0.3 AUM x 6 = 11,340 AUM
750 horses x 6 = 5,625 AUM
= 337,665 AUM

Carrying capacity estimate

221,830 ha of grassland in watershed
0.61 ha (1.5 acres) per AUM

= 363,656 AUM

Stocking rate less than carrying capacity

APPENDIX – A3 NON-RECOVERABLE ANIMAL MANURE CALCULATIONS

Table A3-1: 1950 CENSUS OF AGRICULTURE (USDA, 1952)						
MONTANA COUNTY DATA INVENTORY						
County	**Cattle**	**Hogs**	**Sheep**	**Horses**	**Poultry**	
Beaverhead	95,819	2,813	101,047	6,745	15,384	
Deer Lodge	5,611	1,015	9,668	560	8,402	
Granite	22,032	892	3,713	881	5,832	
Madison	60,990	5,972	89,918	4,549	27,655	
Ravalli	35,912	6,804	14,637	3,200	59,808	
Silver Bow	7,405	614	4,117	772	6,008	
Correct for percentage of area in each county contained in Big Hole Watershed						
	County Area[1]					
County	**Correction**	**Cattle**	**Hogs**	**Sheep**	**Horses**	**Poultry**
Beaverhead	35.19%	33,719	990	35,558	2,374	5,414
Deer Lodge	43.70%	2,452	444	4,225	245	3,672
Granite	0.39%	86	3	14	3	23
Madison	5.65%	3,446	337	5,080	257	1,563
Ravalli	0.63%	226	43	92	20	377
Silver Bow	39.03%	2,890	240	1,607	301	2,345
	TOTAL	**42,819**	**2,057**	**46,577**	**3,200**	**13,392**
	Adjust for Watershed Area[2]	38,537	1,851	41,920	2,880	12,053
	Convert to GWLF Animal Units[3]	27,297	1,311	29,693	2,040	8,538
	Round	**27,300**	**1,310**	**29,690**	**2,040**	**8,540**

[1]County percentages taken from STEPL model data server
[2]Big Hole Watershed area = 2,762 mi^2; Melrose gage area = 2,476 mi^2 (e.g. 0.90 conversion)
[3]Assume 1/2 of animals are offspring
each count as 1/4 mature animal (0 at birth 1/2 at weaning)
on landscape 1/2 year (March-September)

Table A3-2: 2002 CENSUS OF AGRICULTURE (USDA, 2004)

MONTANA COUNTY DATA INVENTORY						
County	**Cattle**	**Hogs[1]**	**Sheep**	**Horses**	**Poultry**	
Beaverhead	135,926	15	15,823	2,679	295	
Deer Lodge	8,739	0	1,065	378	0	
Granite	21,737	100	457	881	396	
Madison	70,892	0	4,803	2,526	947	
Ravalli	33,846	854	4,473	4,927	2,319	
Silver Bow	5,937	40	291	758	68	
Correct for percentage of area in each county contained in Big Hole Watershed						
	County Area[2]					
County	**Correction**	**Cattle**	**Hogs**	**Sheep**	**Horses**	**Poultry**
Beaverhead	35.19%	47,832	5	5,568	943	104
Deer Lodge	43.70%	3,819	0	465	165	0
Granite	0.39%	85	0	2	3	2
Madison	5.65%	4,005	0	271	143	54
Ravalli	0.63%	213	5	28	31	15
Silver Bow	39.03%	2,317	16	114	296	27
	TOTAL	**58,272**	**27**	**6,448**	**1,581**	**200**
	Adjust for Watershed Area[3]	52,445	24	5,804	1,423	180
	Convert to GWLF Animal Units[4]	37,148	17	4,111	1,008	128
	Round	**37,150**	**20**	**4,110**	**1,010**	**130**

[1]Values in grey estimated; data withheld to avoid disclosing information for individual farms
[2]County percentages taken from STEPL model data server
[3]Big Hole Watershed area = 2,762 mi^2; Melrose gage area = 2,476 mi^2 (e.g. 0.90 conversion)
[4]Assume 1/2 of animals are offspring
each count as 1/4 mature animal (0 at birth 1/2 at weaning)
on landscape 1/2 year (March-September)

Table A3-3: Estimated Livestock Distributions of TMDL Watersheds

Use area of grassland in watershed to distribute farm animals							
Watershed		**Grassland area (ha)**	**Cattle**	**Hogs**	**Sheep**	**Horses**	**Poultry**
Melrose gage		221830	37150	20	4110	1010	130
Willow Cr		1187	200	0	20	10	0
Lost Cr		1132	190	0	20	10	0
Camp		4822	810	0	90	20	0
Wickuip		505	80	0	10	0	0
Soap		1650	280	0	30	10	0
Divide		11500	1930	0	210	50	10
Jerry		1210	200	0	20	10	0
Steel		7902	1320	0	150	40	0
Francis		3041	510	0	60	10	0
Grose		389	70	0	10	0	0

APPENDIX – A4 MODEL INPUT AND OUTPUT

A4-1 SEPTIC DENSITY ESTIMATES

Septic density estimates were completed using NAIP aerial imagery. Approximate numbers of buildings (and associated septic fields) are shown below.

Watershed	Area (ha)
Melrose	495
Willow	0
Wickiup	0
Francis	0
Steel	10
Jerry	5
Camp	10
Divide	30
Grose	0
Lost	5
Soap	2

A4-2 Stocking Density Calculations

Livestock calculations used in GWLF modeling are detailed below.

Available Data:

National Agricultural Statistics Service data from 1998-2007 (NASS, 2008)

106,900 cows and calves
12,600 ewes and lambs
750 horses (estimated)

Convert to AUM (NRCS, 2003)

Assume:	cow/calf pair	= 1 AUM
	ewe/lamb	= 0.3 AUM
	horse	= 1.25 AUM

Livestock estimate for grazing season (May-October; 6 months)

53,450 pair cattle x 1 AUM x 6	= 320,700 AUM
6,300 pair sheep x 0.3 AUM x 6	= 11,340 AUM
750 horses x 1.25 x 6 =	= 5,625 AUM
	= 337,665 AUM

Carrying capacity estimate

221,830 ha of grassland in watershed
0.61 ha (1.5 acres) per AUM
= 363,656 AUM

Stocking rate less than carrying capacity ☑

A4-3 – Modeling Input and Output Tables

Due to large content DEQ will provide model input and tables upon request.