APPENDIX E – FLINT CREEK WATERSHED NUTRIENT ASSESSMENT

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACRONYMS

Acronym	Definition
AMSL	Above Mean Sea Level
BMP	Best Management Practices
BOD	Biochemical Oxygen Demand
DEQ	Department of Environmental Quality (Montana)
DNRC	Department of Natural Resources & Conservation (Montana)
FERC	Federal Energy Regulation Commission
GIS	Geographic Information System
GPS	Global Positioning System
GWIC	Groundwater Information Center
HRU	Hydrologic Response Units
MGWPCS	Montana Ground Water Pollution Control System
MPDES	Montana Pollutant Discharge Elimination System
msl	mean sea level
NHD	National Hydrography Dataset
NLCD	National Land Cover Dataset
NRCS	National Resources Conservation Service
SNOTEL	SNOw TELemetry
SWAT	Soil & Water Assessment Tool
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Solids
USFS	United States Forest Service
USGS	United States Geological Survey
USLE	Universal Soil Loss Equation

E1.0 Introduction

The Flint Creek watershed is located in southwestern Montana within the Clark Fork River watershed (**Figure E1-1**). Flint Creek and four tributaries are characterized as "water quality-limited" (Montana Department of Environmental Quality, Planning, Prevention and Assistance Division, Water Quality Planning Bureau, 2012b) from nutrients impairments (**Table E1-1** and **Figure E1-2**). To satisfy the Montana Water Quality Act and the Federal Clean Water Act requirements, Total Maximum Daily Loads (TMDLs) must be developed for these waterbodies so they can support beneficial uses. The Montana Department of Environmental Quality (DEQ) has determined that a modeling approach is the most effective way to identify existing nonpoint source loads in the watershed, and to complete equitable allocations between those sources as part of the TMDL. Therefore, a Soil & Water Assessment Tool (SWAT) model has been prepared to estimate watershed-scale loadings of nutrients, and to calculate associated fate and transport in the stream channel network. DEQ used the SWAT for this project. The model period chosen was October 1, 1989 through September 30, 2010. This time period was chosen to coincide with available water quality datasets, and to provide a sufficiently long modeling time that incorporates enough natural climatic variability to better predict future hydrology under several management scenarios.

The results of the SWAT model are used for several TMDL planning purposes including: (1) evaluating baseline conditions in the watershed; (2) partitioning pollutant loadings between nonpoint sources; (3) allocating nutrients for TMDL development; (4) formulating water quality restoration plans; and (5) prescribing management and land-use scenario changes to meet TMDL objectives.

Table E1-1. Nutrients Water Quality Limited Stream Segments in the Flint Creek Watershed

Waterbody Name	Reach Segment	Reach Length (mi)	TMDL Developed[1]
Flint Creek (upper)[2]	MT76E003_011	28.1	TP
Flint Creek (lower)[3]	MT76E003_012	16.9	TN/TP
Douglas Creek (lower)	MT76E003_020	7.1	Nitrate /TP
Barnes Creek	MT76E003_070	8.9	Nitrate/TN/TP
Princeton Gulch	MT76E003_090	3.9	Nitrate
Smart Creek	MT76E003_110	11.6	TN/TP

(1) TN = Total Nitrogen, TP = Total Phosphorus
(2) Flint Creek (upper) extends from Georgetown Lake to confluence with Boulder Creek
(3) Flint Creek (lower) extends from confluence with Boulder Creek to the mouth at Clark Fork River

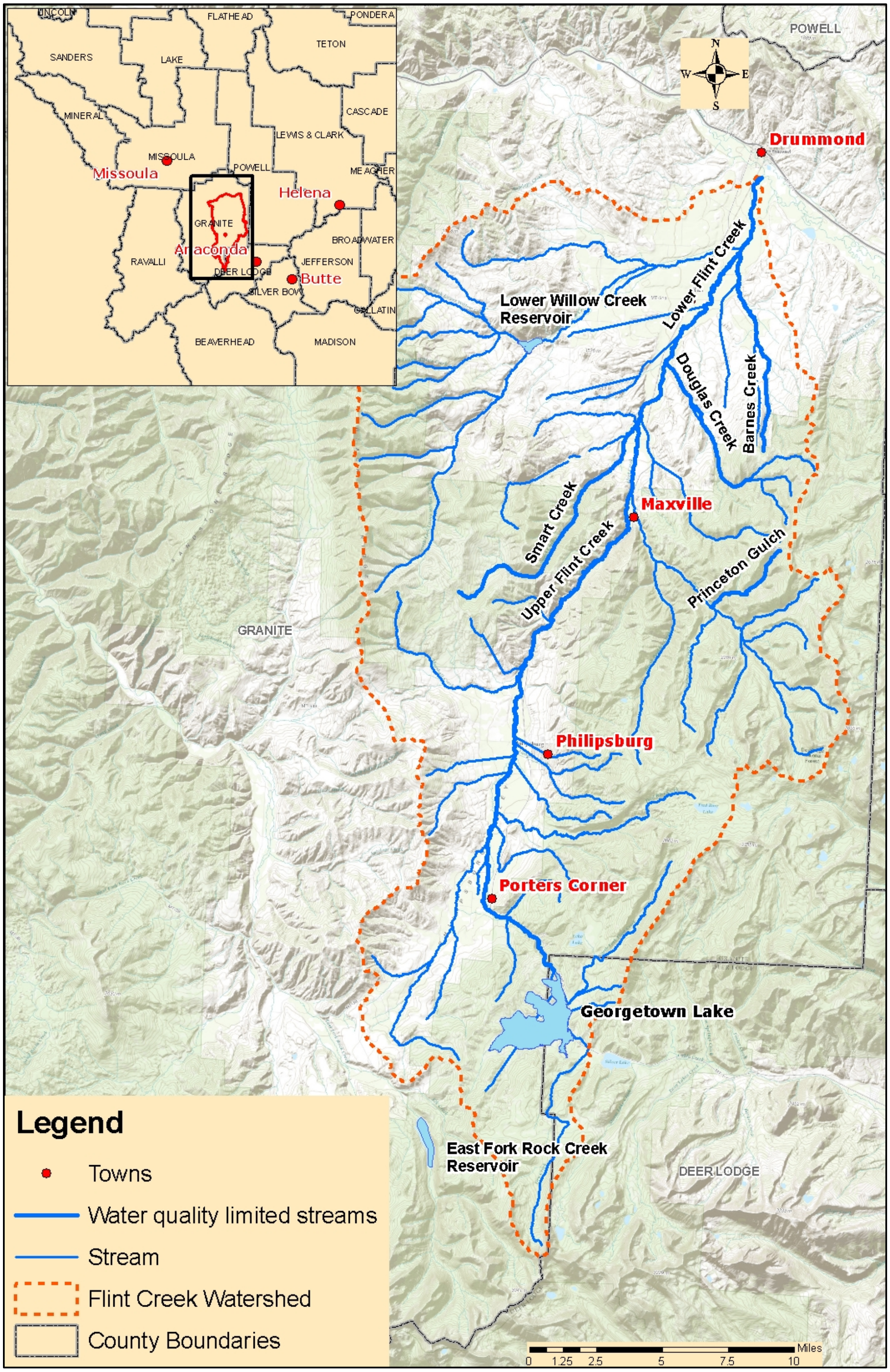

Figure E1-1. Location of the Flint Creek Watershed with 2010 Nutrient Water Quality Limited Stream Segments

Figure E1-2. The Flint Creek Watershed with 2012 Water Quality Limited Streams (303(d) Streams) Listed for Nutrients Impairments

E1.1 PRIOR STUDIES

There have been several prior studies specific to the Flint Creek watershed, all of which were reviewed for development of this model. These include:

- Georgetown Lake Clean Lakes Project (Garrett and Kahoe, 1984)
- Flint Creek Project Federal Energy Regulation Commission (FERC) No. 1473 Draft: Application to Surrender License (Montana Power Company, 1987)
- Flint Creek Return Flow Study (Voeller and Waren, 1997)
- Flint Creek Planning Area Watershed Characterization Report (Montana Department of Environmental Quality, Planning, Prevention and Assistance Division, Source Water Protection Program, 2007)
- Flint Creek Watershed Sediment Assessment: Upland Sediment Assessment and Modeling and BMP Effectiveness and Percent Reduction Potential (Water & Environmental Technologies, 2010)
- Flint Creek TMDL Planning Area Nutrient Source Review - Task 1: Discrete Source Characterization (Houston Engineering, 2011a)
- Flint Creek TMDL Planning Area Nutrient Source Review - Task 2: Non-Discrete Source Characterization (Houston Engineering, 2011b)
- Flint Creek TMDL Planning Area – Unpaved Roads Assessment: Sediment Load Estimates and Potential Reductions (Montana Department of Environmental Quality, Planning, Prevention and Assistance Division, Water Quality Planning Bureau, 2011)
- Flint Creek Planning Area Sediment and Metals TMDLs and Framework Water Quality Improvement Plan (Montana Department of Environmental Quality, Planning, Prevention and Assistance Division, Water Quality Planning Bureau, 2012a)

E1.2 NUTRIENTS CRITERIA IN MONTANA

Montana is currently governed by narrative nutrients criteria that requires surface waters to be free from municipal, industrial, and agricultural discharges that produce undesirable aquatic life [Administrative Rules of Montana 17.30.637(1)(e)]. Because narrative criteria are somewhat problematic for TMDL analysis, draft numeric criteria were used instead (Suplee et al., 2008; Suplee and Watson, 2013). Those applicable for the Flint Creek Watershed TMDL (e.g., the Middle Rockies Ecoregion) are shown in **Table E1-2** and **Figure E1-2**. These draft criteria are used as the target concentrations in management scenarios discussed in **Section E6.0**. DEQ anticipates these interim criteria will become final at or near their current concentrations by 2013. These criteria are applicable during the summer growing season which is defined as July 1 through September 30.

Table E1-2. Interim Nutrients Numeric Criteria (July 1–Sept 30) for the Flint Creek Watershed (Suplee and Watson, 2013)

Constituent	Watershed Concentration[(1)]	Upper Flint Creek Concentration[(2)]
Total Nitrogen (TN)	≤ 0.30 mg/L	≤ 0.50 mg/L
Nitrate	≤ 0.10 mg/L	≤ 0.10 mg/L
Total Phosphorus (TP)	≤ 0.03 mg/L	≤ 0.072 mg/L

[(1)] Concentrations apply everywhere in the watershed except for Upper Flint Creek
[(2)] Upper Flint Creek for purposes of the water quality standards extends from the outlet of Georgetown Lake (the Flint Creek dam) to the northern end of the Philipsburg valley approximately 4.2 miles north of the town of Philipsburg (see **Figure E1-2**)

E2.0 DATA COMPILATION AND ASSESSMENT

A variety of climatic, hydraulic, water quality, land-use, and geospatial data was reviewed and evaluated to populate the SWAT model with site-specific information. The details are described below.

E2.1 WATERSHED DESCRIPTION

The Flint Creek watershed is located in southwestern Montana. It stretches from the continental divide south of Georgetown Lake to just south of Drummond (**Figure E1-1**). The watershed covers approximately 314,000 acres, and the continental divide runs along the southern tip. Flint Creek originates below Georgetown Lake and runs for 45 miles towards its confluence with the Clark Fork River near Drummond. Elevations in the watershed range from approximately 3,960 feet above mean sea level (AMSL) in the valley near Drummond to 9,848 feet AMSL at Mount Tiny along the southern boundary of the watershed.

The hydrology in the watershed is partially controlled via Flint Creek dam (which created Georgetown Lake in the late 1800s) and an inter-basin water transfer from the East Fork Rock Creek Reservoir. Management of the Flint Creek dam and East Fork Rock Creek Reservoir changes the natural hydrologic cycle in Flint Creek. Effects of the dam are visible in the United States Geological Survey (USGS) stream gage (Flint Creek near Southern Cross) that is less than 2 miles below the dam. Although less obvious than the upper USGS stream gage, effects of both the dam and the East Fork Rock Creek Reservoir are visible in the two stream gages on the lower Flint Creek at Maxville and near Drummond.

The Flint Creek dam was initially built for power generation, additional uses for irrigation and recreation evolved over time. For approximately the last 20 years it has not been used for power generation, but Granite County, the current dam owner, is preparing to begin power generation sometime in the near future. Part of the Federal Energy Regulatory Commission license (Federal Energy Regulating Commission, 2010) that controls operation of the dam includes several discharge requirements including a minimum flow of 30 cubic feet per second (cfs) from May 15 to September 15, and a minimum flow of 10 cfs at other times of the year to comply with an existing water rights decree. Some of the other requirements are maintaining the lake level within certain ranges, and capping maximum flows at 100 cfs except in times of emergencies. Discharge rates from the dam are not available, but the USGS gage located below the dam is used in the model to determine the hydrology in this upper portion of the watershed, and is described in **Section E2.5.5**.

The East Fork Rock Creek Reservoir is located in the Rock Creek watershed, which is near the southwest border of the Flint Creek watershed. Water is diverted into the Flint Creek watershed from the reservoir for irrigation use via a canal. The data and methods used to determine the amount of water diverted into the watershed from the East Fork Rock Creek Reservoir are described in **Section E2.5.5**.

A second dam that has only minor effects to the watershed hydrology is the Willow Creek dam located in the northern portion of the watershed. The data and methods used to determine the amount of water discharged from the Willow Creek dam are described in **Section E2.5.5**.

E2.2 CLIMATE

Climate in the Flint Creek watershed is inter-montane with distinct seasonality. Valleys tend to be moderately arid while mountainous regions are moderately wet. Annual average precipitation is estimated to range from under 12 inches near Drummond to over 40 inches in the mountains along the east side of the watershed (**Figure E2-1**). Seven weather stations were used in the SWAT model based on their distance to each sub-basin to distribute precipitation events across the watershed (**Table E2-1**). The eighth site in **Table E2-1**, Warm Springs SNOw TELemetry (or SNOTEL), located immediately east of the watershed may overestimate snowfall for its elevation as prevailing winds tend to deposit more snow east of topographic divides, therefore it was not used for estimating precipitation in the watershed. The maximum snow water equivalent generally occurs in April or May every year and comprises 47 to 60% of the total annual precipitation at four of the five the SNOTEL sites; at the Combination site, the snow water equivalent only comprises 24% of the total annual precipitation. The large amount of water contained as snow in the higher elevations creates a strong control on the stream hydrology, and will be discussed in **Section E2.3**

Maximum and minimum daily temperature values from all eight stations in **Table E2-1** were used to estimate daily temperatures across the watershed.

Table E2-1. Weather Station Data Used in the Flint Creek SWAT Model

Location	Station Type	Elevation (ft AMSL)	Average Annual Precipitation (in)	Average Annual Max Temp (F)	Average Annual Min Temp (F)	Avg. Max Snow Water Equiv. (in)
Time Period			1989–2010	1989–2010	1989–2010	1971–2000
Barker Lakes	SNOTEL(1)	8,248	34.4	44.2	25.2	16.2
Black Pine	SNOTEL(1)	7,212	25.5	46.6	29.9	12.8
Combination	SNOTEL(1)	5,601	20.5	52.0	28.6	4.9
Peterson Meadows	SNOTEL(1)	7,199	24.3	47.7	24.5	11.4
Warm Springs	SNOTEL(1)	7,799	41.0	44.6	25.2	24.2
Drummond Aviation	NCDC(2)	4,000	11.7	58.1	28.0	No data
Georgetown Lake	NCDC(2)	6,470	16.5	49.6	27.9	No data
Philipsburg Ranger Station	NCDC(2)	5,269	15.7	55.9	28.0	No data

(1) SNOTEL is a network of sensors operated by the Natural Resources Conservation Service to collect and disseminate mountain snowpack and climate data

(2) NCDC is the National Climatic Data Center, which collects and disseminates climate data

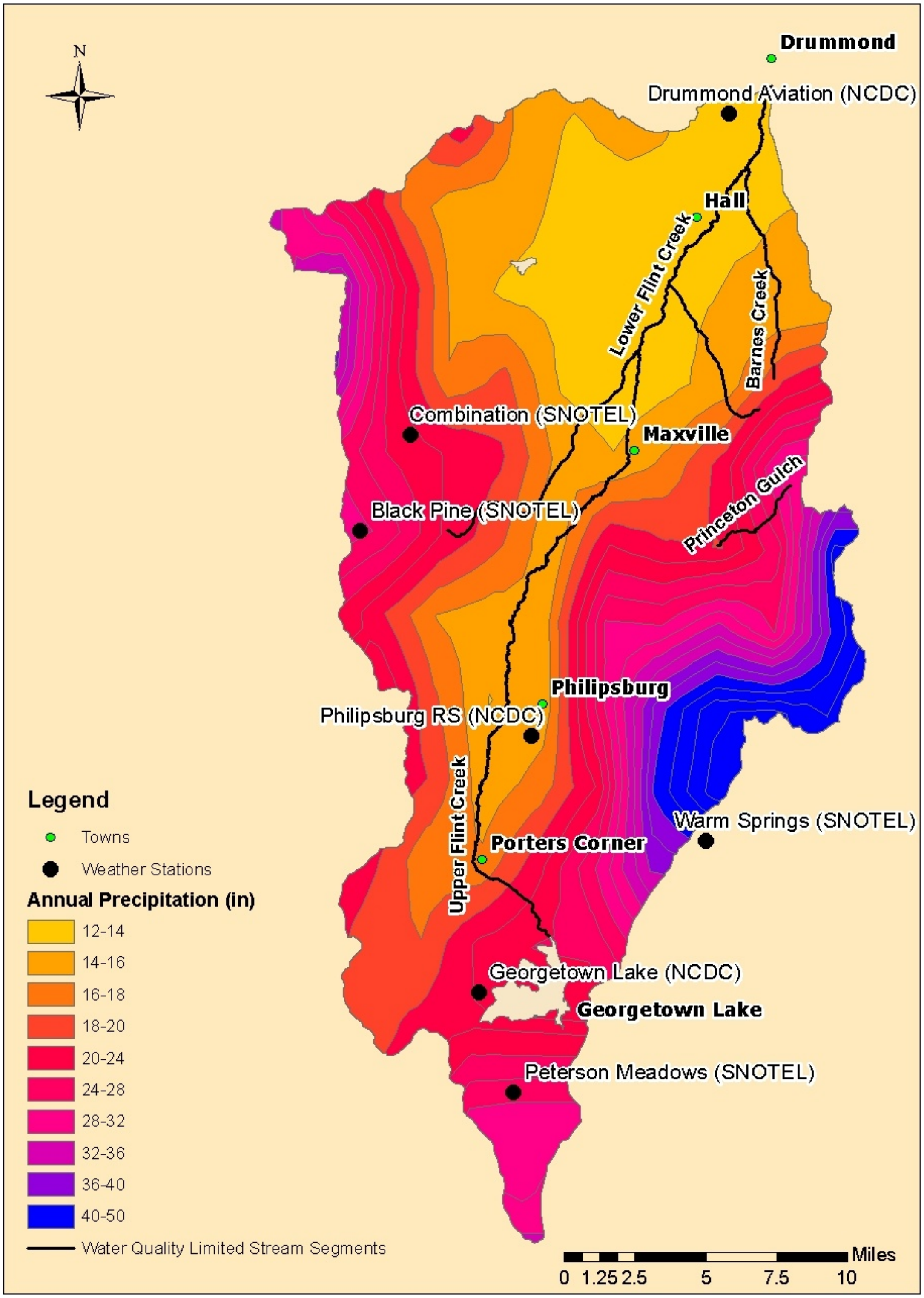

Figure E2-1. Precipitation Distribution and Location of Weather Stations Used in the Flint Creek SWAT Model

Daily wind speed, solar radiation, and relative humidity were obtained from various sources inside the watershed where available, and outside the watershed when there were no data available inside the watershed. Solar data were collected inside the watershed from Drummond Aviation (National Solar Radiation database) and from Philipsburg [Remote Automatic Weather Stations database]. Missing records in the solar radiation data were filled in through regression with two stations outside the basin, the Missoula Airport [Northern Research Station database] and Deer Lodge (AgriMet database). Humidity data were collected from the Philipsburg Remote Automatic Weather Stations site. Missing records in the humidity data were filled in through regression with the Missoula Airport Northern Research Station site and the Deer Lodge AgriMet site. Wind data were collected from the Philipsburg Remote Automatic Weather Stations site. Long periods of missing wind records (1989 through 2000 data were not available) could not be filled through regression with other stations (Missoula Airport or Deer Lodge) as the coefficient of determination (r^2) was very low between the sites. Therefore, a daily average of the 2001–2010 wind data from the Philipsburg site was used to populate the model from 1989 through 2000.

E2.3 Streamflow Hydrology

There are four active USGS streamflow gaging stations in the Flint Creek watershed with sufficient datasets within the modeling period (**Table E2-2** and see **Figure E1-2**). There have been several other short-term gaging stations in the watershed monitored by the USGS and the Montana Department of Natural Resources & Conservation (DNRC) (Voeller and Waren, 1997), but those stations did not have sufficient data for use in calibrating the model.

Table E2-2. USGS Streamflow Gaging Station Information (McCarthy et al., 2004)

USGS Station Name	Period of Record	Drainage Area (sq. miles)	Mean Annual Flow (cfs)	Mean High Monthly Flow for June (cfs)	Mean Low Monthly Flow (cfs) [month]
Flint Creek near Drummond	1990–present	490	125	280	49 [Aug]
Boulder Creek at Maxville	1939–present	71.3	45	174	18 [Feb/Mar/Sept]
Flint Creek at Maxville	1941–present	208	97	188	54 [Jan]
Flint Creek near Southern Cross	1940–1998 and 2000–present	52.6	30	57	19 [Jan]

The typical hydrograph for this type of snowmelt-controlled watershed consists of spring snowmelt runoff beginning in mid to late March (or April for higher elevation basins), peaking in June and then declining rapidly in July and August towards base flow. However, due to dams, diversions, irrigation withdrawals, and irrigation return flows only one of the USGS gages in this watershed (Boulder Creek at Maxville) has a typical hydrograph (**Figure E2-2**). The Flint Creek near Drummond gage shows the effects of irrigation withdrawals in late summer which causes the annual low flows at this gage to occur in late summer rather than in winter. At the same gage the streamflows rise from late summer through mid-October due to irrigation return flows and the reduction of irrigation. This atypical hydrograph pattern due to irrigation withdrawals and returns has been described in other Montana valleys (Kendy and Bredehoeft, 2006). The Flint Creek at Maxville gage shows a slightly more typical hydrograph, but still shows effects of upstream irrigation return flows with an earlier than anticipated flattening of the hydrograph slope during the irrigation season. The Flint Creek at Southern Cross gage shows a late-summer rising hydrograph, similar to the Flint Creek at Maxville gage, most likely due to increased dam releases. The Flint Creek at Southern Cross gage is controlled by releases from Flint Creek dam with only a small spring time peak as the dam has minimum (30 cfs) and maximum (100 cfs) discharge limitations during the summer growing season as described earlier. The SWAT model was less accurate predicting streamflow at gages heavily influenced by human activities, as discussed in **Section E4.4**. These less accurate predictions are primarily due to a lack of available information regarding irrigation schedules, irrigation diversions, and difficulty estimating return flow rates in the groundwater.

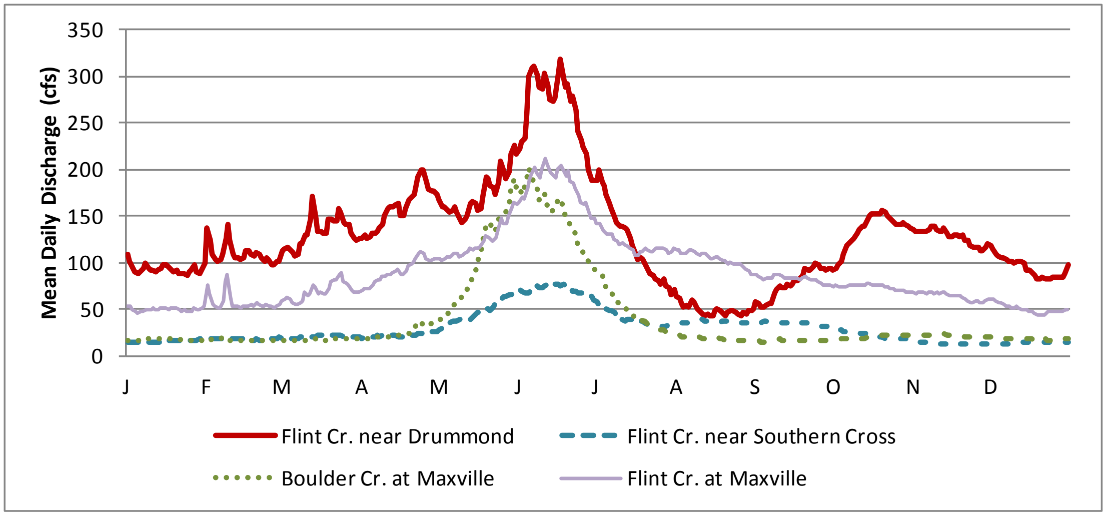

Figure E2-2. Average Annual Streamflow Hydrographs at USGS Gages (1990–2010)

The Flint Creek watershed lies within the Upper Clark Fork basin that is closed to new surface water rights appropriations (with a few limited exceptions) per a legislative closure on April 14, 1995 (Montana Department of Natural Resources and Conservation, 2003). The closure is due to over-appropriation as there is not always sufficient water in the watershed to satisfy every water right. There are approximately 1,400 recorded surface water diversions in the basin; only two of the largest ones have available data associated with them and are the only ones specifically accounted for in the model with location-specific diversions to a canal. However, based on DNRC mapped irrigation units (Buck, 1959) the SWAT model is able to indirectly account for diversions by withdrawing water from the representative stream within the sub-basin that the irrigated area is in. In some cases, a diversion for irrigation may be located in an upstream sub-basin, which could create a minor error in simulated streamflow if a hydrology calibration point is located between the actual diversion and the sub-basin that the irrigated land is located. A detailed discussion of how irrigation was simulated in the model is included in **Section E2.5.1.1**.

E2.4 Water Quality

Streamflow and water quality data are required components for sediment and nutrients model calibration. Those available to DEQ in 2011 were used in the modeling process. Data were reviewed with particular focus on recent data (1990 through 2010) for model construction and development. These data are considered most relevant as they are coincident with the land cover that will be used for the model (the 2001 National Land Cover Dataset [NLCD]). Key data included the following:

- Flow
- Sediment
- Nutrients
    - Total Phosphorus (TP)
    - Total Nitrogen (TN)

- o Nitrate+Nitrite (NO_3+NO_2)

Instream data for model calibration were acquired from several sources including the USGS, Philipsburg Department of Public Works, Tri-State Water Quality Council, the University of Montana, Missoula Valley Local Water Quality District, Craig Stafford, and the DEQ. Other than streamflow at the four USGS gages, data collection was sporadic in the watershed. The longest and most regular water quality data were collected monthly at three sites on Flint Creek from July 2005 through October 2009 by the Philipsburg Department of Public Works (**Table E2-3**).

Table E2-3. Available Data for Calibration and Validation of SWAT Model in the Flint Creek Watershed

Location [Model Sub-Basin]	Parameter	Period of Record	Sampling Frequency	Number of Samples
USGS gage – Flint Creek near Drummond [2]	Flow Sediment Nutrients Nutrients	1990–1991 1985–2004 1990–1991 1998–2002	Daily Seasonal Monthly Monthly Seasonal Monthly	4,201 139 23 38
USGS gage – Boulder Creek at Maxville [19]	Flow Sediment Nutrients	1939–2010 2007–2009 2007–2009	Daily Seasonal Intermittent Seasonal Intermittent	4,901 5 5
USGS gage – Flint Creek at Maxville [24]	Flow Sediment Nutrients	1941–2010 1991–92/2007–08 2007–2009	Daily Intermittent Seasonal Intermittent	4,870 15 5
Flint Creek above and below Philipsburg Wastewater Discharge [32]	Sediment Nutrients	2007–2009 2005–2009	Seasonal Intermittent Monthly	5 59
USGS gage – Flint Creek near Southern Cross [38]	Flow Sediment Nutrients	1940–2010 2007–2009 2005–2009	Daily/Seasonal Daily Seasonal Intermittent Monthly	5,725 5 52
North Fork Flint Creek [40]	Sediment Nutrients	2009–2010 2009–2010	Monthly Monthly	15 15
Seven sites on Flint Creek [multiple]	Sediment Nutrients	2007–2009 2007–2009	Seasonal Intermittent Seasonal Intermittent	4–5 4–5
Barnes Ck; Boulder Ck; Douglass Cr; Lower Willow Cr; Princeton Gulch; Smart Cr; Trout Cr [multiple]	Sediment Nutrients	2007–2009 2007–2009	Seasonal Intermittent Seasonal Intermittent	4–5 4–5

The calibration point nearest the mouth of Flint Creek (Flint Creek near Drummond) is approximately 1.7 miles upstream from the mouth of Flint Creek. The mouth of Flint Creek only has 6 months of daily streamflow measurements and five water quality samples, so the upstream site with better data was used as the final downstream calibration point in the model. However, the model boundary does extend completely to the mouth of Flint Creek.

Where the sampling frequency is described as seasonal, the samples collection times are predominately during the summer season or the late spring/early fall seasons. Much of the nutrients and sediment data was collected during the summer which is the time of year that nutrients have a greater effect on water quality.

Numerous additional sites on Flint Creek and its tributaries have water quality data, but the amount of data at those sites was typically five dates or less over 1- to 3-year periods and was determined to not be sufficient for numerical calibration as is described in **Sections E4.6** and **E4.7**.

Groundwater monitoring was not conducted for the TMDL development. However, the SWAT model requires the user to specify a background groundwater phosphorus concentration. The concentration used in the model, 0.01 mg/L, is based on groundwater well data from the Montana Bureau of Mines and Geology well database, the Groundwater Information Center (GWIC). That database contained orthophosphorus sample data from 54 wells. Forty-eight of those wells reported orthophosphorus concentrations below the detection limit, which ranged from 0.05 to 0.25 mg/L. Assuming that all those samples below the detection limit are equal to zero, the average of all 54 wells is 0.01 mg/L. Therefore, the groundwater phosphorus concentration in the model was set at 0.01 mg/L. Although background phosphorus levels vary from region to region this value for background phosphorus is consistent with other published values. One study showed the average background orthophosphorus (also referred to as mineral phosphorus) at 0.02 mg/L in 47 wells across the country in undeveloped areas (Fuhrer et al., 1999). A local study in the Kalispell area sampled 10 residential wells and 4 monitoring wells that showed mean Total Phosphorus (TP) and orthophosphorus concentrations were 0.008 and 0.003 mg/L, respectively (Tappenbeck and Ellis, 2010).

E2.5 Land Use

Land uses in the model were based on the NLCD 2001 dataset (**Table E2-4**) but were modified where necessary. Estimations of land uses and land-use practices are described in the following sub-sections, and are also summarized for easier reference in **Attachment EA**.

Eighty-seven percent of the watershed is categorized as either forest or rangeland. Another 10% is categorized as agriculture and livestock uses. The remaining 3% is categorized as water/wetlands and developed. The Hay/Pasture acreage is primarily comprised of alfalfa and alfalfa-hay mixes. The land listed as cultivated crop was significantly overestimated in the NLCD data; this was corrected in the SWAT model delineation and is discussed in the next section. Developed lands, particularly medium and high density, are increased in the final SWAT discretization land-use percentages due to the high growth rates near Georgetown Lake that were not captured in the 2001 NLCD. Each of the major land uses with temporal changes that may have occurred naturally or by human activity over the course of the modeling period is discussed in **Sections E2.5.1** through **E2.5.5**.

Table E2-4. Land Uses within the Flint Creek Watershed (2001 NLCD)

NLCD Land Use	Area (acres)	Watershed Area (%)
Cultivated Crops	16,422	5.23
Hay/Pasture	14,949	4.76
Evergreen Forest	166,921	53.12
Shrub/Scrub [Range - Brush]	53,575	17.05
Herbaceous [Range - Grass]	53,085	16.89
Deciduous Forest	16	0.01
Developed - Low Density/Open Space	4,209	1.34
Developed - Medium Density	53	0.02
Developed - High Density	5	<0.01
Open Water	3,353	1.07
Wetlands	1,516	0.48
Barren Land	118	0.04
Totals	**314,224**	**100.0%**

E2.5.1 Agriculture

Two datasets, the 2001 NLCD and the National Agricultural Statistics Service, were used to establish an estimate of typical crop production in the watershed. An average of the available National Agricultural Statistics Service Cropland Data Layer data from 2003 to 2009 was used in the analysis [**Attachment EB**]. The 2003–2009 National Agricultural Statistics Service data are published on a county basis, but because the Flint Creek watershed contains over 95% of the agricultural lands in Granite County (2001 NLCD), using the county values was determined to be an acceptable approximation. Over 96% of the crops in the watershed are hay, alfalfa and pasture, the remaining amount is used for spring wheat and barley. The amount of hay, alfalfa, pasture and other row crops was estimated from the 2001 NLCD and National Agricultural Statistics Service data to differentiate these land uses in SWAT because the irrigation, fertilizer and harvesting needs for each of those crops can be different. The 2001 NLCD lists 31,371 acres of crops/hay-alfalfa/pasture but does not distinguish which fraction of the crops code (AGRR) is alfalfa. The National Agricultural Statistics Service 2003–2009 database does differentiate alfalfa and hay, it lists 15,857 acres of hay and 9,000 acres of alfalfa. Accounting for the differences in the NLCD and National Agricultural Statistics Service datasets, and due to the methods SWAT uses to partition the watershed into land uses (referred to as Hydrologic Response Units [HRUs]) based on land use, soil type, and slope, the final land-use areas in the SWAT model are provided in **Table E2-5** and **Figure E2-3**. The HRUs are described in more detail in **Section E3.5**.

Table E2-5. SWAT Land Uses within the Flint Creek Watershed

SWAT Land Use	Area (acres)	Watershed Area (%)
Alfalfa	9,958	3.17
Hay	15,031	4.78
Pasture	4,473	1.42
Spring Wheat	479	0.15
Spring Barley	479	0.15
Forest – Evergreen	169,184	53.82
Range – Brush	54,039	17.19
Range – Grass	52,851	16.81
Residential – Low Density	3,761	1.20
Residential – Medium Density	775	0.25
Residential – High Density	21	0.02
Water	2,966	0.94
Wetlands	306	0.10
Totals	**314,323**	**100.0%**

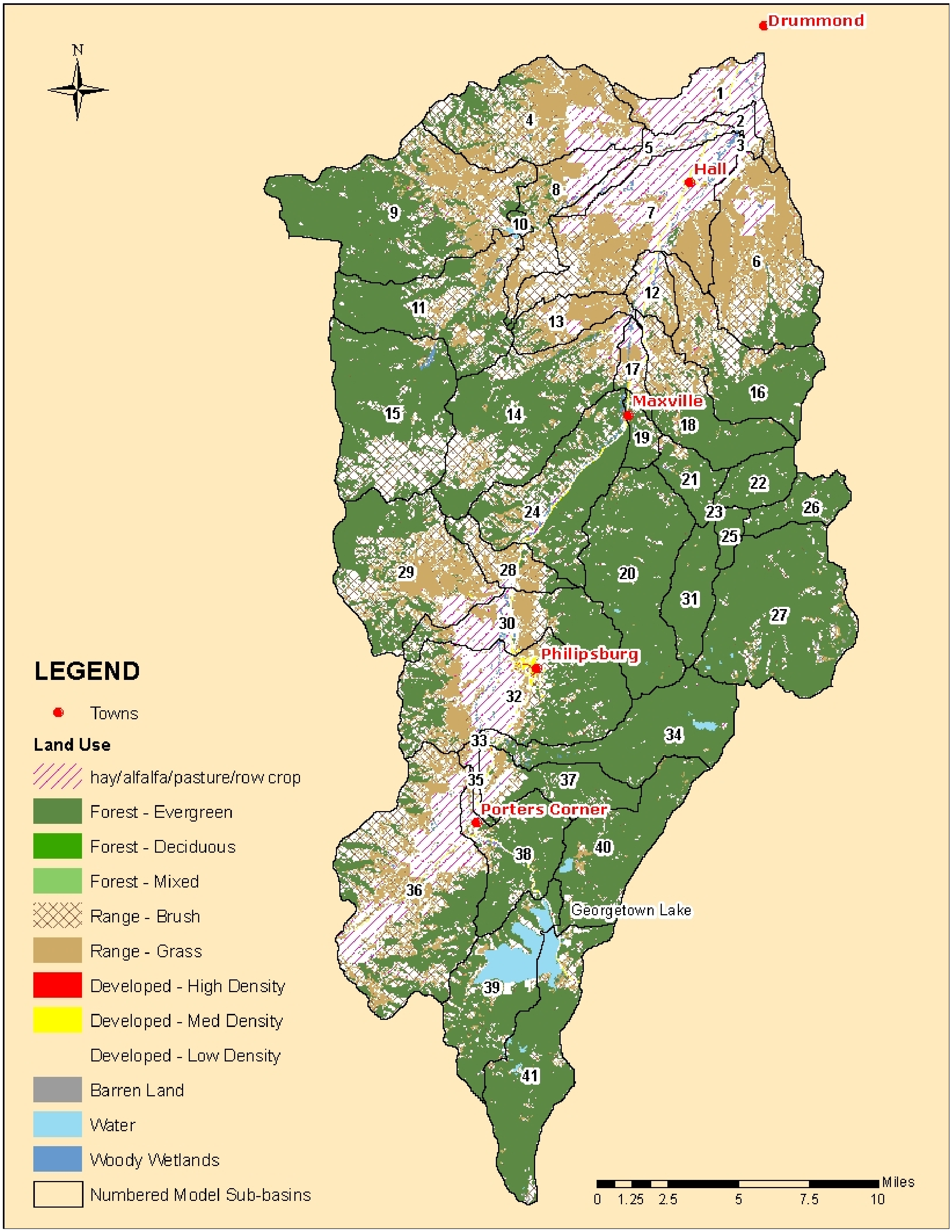

Figure E2-3. SWAT Land Use

Crop harvesting can vary year to year based on climatic factors. However, without detailed data on those variations the agriculture practices for planting, irrigating, fertilizing, and harvesting were set for the same date every year. Due to the higher elevation and shorter growing season, the irrigated land in the Philipsburg valley only gets a single hay/alfalfa cutting(Montana State University County Extension Agent, Lucas, Dan, personal communication 4/23/2013), which is set at July 4 in the model. The Drummond-Hall valley gets two alfalfa/hay cuttings, which are set at July 4 and September 30 in the model. Barley and spring wheat are harvested once annually on September 15 and 30 in the Philipsburg and Drummond-Hall valleys, respectively. For purposes of discussing crops and irrigation (see **Figure E2-3**), the Philipsburg valley is the agricultural area that begins approximately 5 miles south of the town of Maxville and extends to the southwest corner of the watershed, and the Drummond-Hall valley is the agricultural area immediately north of Maxville that extends to Drummond.

E2.5.1.1 Irrigation

The irrigation needs were primarily based on a report (Voeller and Waren, 1997) that indicated flood irrigation accounts for approximately 60–90% of the irrigation and sprinkler accounts for the remainder of irrigation in the watershed. Irrigation efficiency is the percent of water applied to crops that is actually used by the crop, it does not include applied water that flows past the root zone and enters the groundwater and/or surface water; the USGS (U.S. Geological Survey, 2000) estimates flood irrigation is about 50% efficient and sprinkler is about 90% efficient. From these values a watershed average irrigation efficiency of 58% was estimated for use in the SWAT model. However, to better match the measured streamflow trends at the USGS gages, and particularly higher than predicted streamflows in the fall and winter partially due to irrigation return flows, the efficiency was changed to 50% in the final SWAT simulations. The reported annual consumptive use of irrigation water (Voeller and Waren, 1997) averaged between 1.5 and 1.75 acre-feet per acre in the Drummond-Hall area (1.7 acre-feet per acre was used in the SWAT model), and averaged 0.75 acre-feet per acre in the Philipsburg area (0.74 acre-feet per acre was used in the SWAT model). Without specific irrigation rates for different crops, the same irrigation rate was used for hay, alfalfa, pasture, spring wheat and barley. The difference in irrigation rates and schedules (described below) for the two primary agricultural areas in the watershed (Philipsburg area and Drummond-Hall area) is primarily due to the higher elevations and colder temperatures in the Philipsburg area.

The irrigation season for the Drummond-Hall area was estimated to occur from May 1 through September 15 of each year (except for hay and pasture, where irrigation began on June 1 to allow for spring grazing on those lands). The start and end dates of the irrigation season were based on information from four sources and are summarized in **Table E2-6**:

- Using the 1990–2010 average of the USGS Flint Creek gage near Drummond, a distinct drop in streamflow occurs around May 1 and a distinct rise occurs approximately between September 1 and October 1 (see **Figure E2-2**);
- Data from the Allendale Ditch (**Figure E2-4a**) show it was flowing in mid-May or late May in 1994, 1995 and 1996 (Voeller and Waren, 1997). That report shows that it went dry between September 29 and October 25 in 1994, and went dry between September 26 and October 19 in 1995;
- A DNRC groundwater monitoring well (GWIC Id M:154595) with daily water level measurements since 2000 that is located approximately 4,000 feet downgradient from the Allendale Ditch, has a steeply rising hydrograph due to irrigation starting in late May or early June, and then a steeply falling hydrograph in late September or early October. Other wells monitored by DNRC (Voeller and Waren, 1997) during 1996 and 1997 showed similar trends. Due to the lag-time for

the canal water or irrigation water to effect the well, it is assumed irrigation begins and ends sometime before water level changes in the well; and

- A discussion between DEQ employees and the Willow Creek Reservoir manager on May 19, 2011 indicated that the Allendale Ditch is flowing in early May most years for flood irrigation which typically begins earlier than sprinkler irrigation due to freezing issues.

The irrigation season for the Philipsburg area was estimated to occur from June 1 through August 30 of each year. The start and end dates of the irrigation season were based on information from three sources:

- Using the 1990–2010 average of the USGS Flint Creek gage at Maxville, a subtle rise in streamflow occurs near September 1 (see **Figure E2-2**). This trend is not as distinct as the trends described above for the lower gage on Flint Creek, because this gage is several miles below the irrigated areas around Philipsburg and other influences are likely muting the effects from irrigation practices;
- Data from the Marshall Canal diversion (**Figure E2-4b**), which diverts some of the water supplied by the East Fork Rock Creek Reservoir diversion (Voeller and Waren, 1997), show it started flowing between May 17 and May 25 in 1994, and started flowing sometime before June 8 in 1995. That report shows that it went dry between September 15 and 29 in 1994, and went dry sometime between August 30 and September 27 in 1995; and
- Data from the East Fork Rock Creek Reservoir Diversion (Norberg Matthew, personal communication, 5/2011), show that for the 8 years with available data between 2000 and 2010 the median date that the diversion began was on May 24 and the median date that the diversion stopped was on September 17.

Table E2-6. Summary of Irrigation Information

Crop Type	Start Date	End Date	Irrigation Rate (feet/season)	Harvest Dates
DRUMMOND-HALL AREA				
Alfalfa	May 1	September 15	1.7	July 4, Sept 30
Hay	June 1	September 15	1.7	July 4, Sept. 30
Pasture	June 1	September 15	1.7	Not Applicable
Barley/Spring Wheat	May 1	September 15	1.7	September 30
PHILIPSBURG AREA				
Hay/Alfalfa	June 1	August 30	0.74	July 4
Pasture	June 1	August 30	0.74	Not Applicable
Barley/Spring Wheat	June 1	August 30	0.74	September 15

There are three irrigation diversions in the watershed that are accounted for in the SWAT model, the East Fork Rock Creek Reservoir, Marshall Canal and the Allendale Ditch (**Figures E2-4a** and **E2-4b**). The East Fork Rock Creek Reservoir water is diverted from the adjacent Rock Creek watershed into Trout Creek (sub-basin 36 in the SWAT model). Daily discharge rates for that water transfer were available for 2000, 2002–2004, and 2007–2010 from the monitoring point called East Fork Rock Creek Main Canal below Head Gate (#76E 2000) and provided by DNRC. Measured flows (Voeller and Waren, 1997) indicate that approximately only about 76% of the water diverted at this station actually makes it into the Flint Creek basin due to conveyance losses – those losses were accounted for in the SWAT model. Some of the water from the East Fork Rock Creek Reservoir is diverted into the Marshall Canal (in model sub-basin 36), where it is used to irrigate lands on the west side of Philipsburg valley before entering Flint Creek via Marshall Creek downstream of Philipsburg. The other diversion is at the Allendale Ditch (in model sub-basin 12) that diverts water from Flint Creek to irrigate lands on the west side of the

Drummond-Hall valley. Both the Marshall Canal and Allendale Ditch have a limited number of instantaneous flow measurements (Voeller and Waren, 1997) but are not sufficient to extrapolate over the model period. The volume of water moved into these two diversions is estimated by determining the amount of land that is irrigated from the diversion based on DNRC water rights maps (Buck, 1959) and described below.

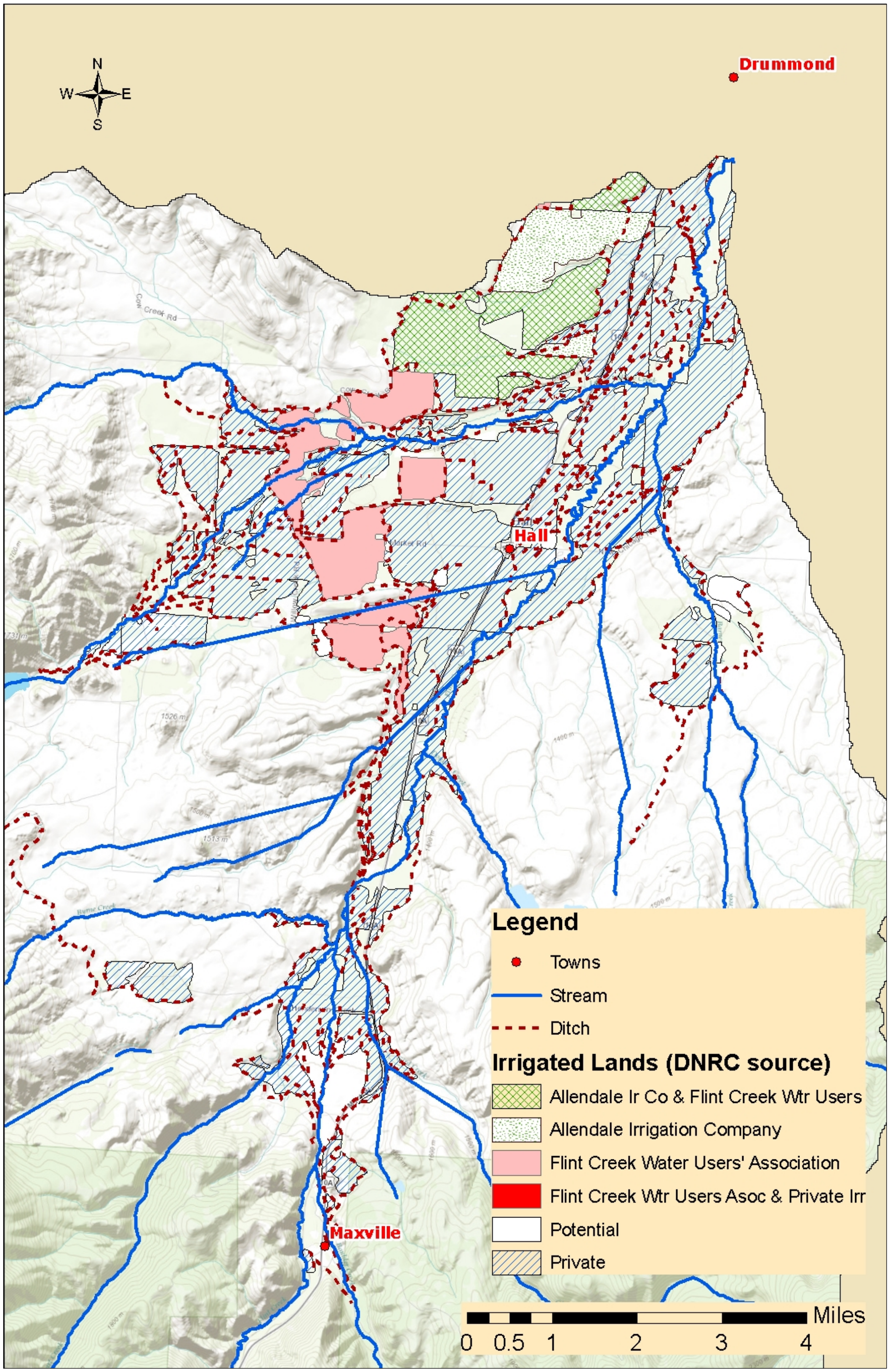

Figure E2-4a. Irrigation Canals, Diversions, and Dams in the Northern Flint Creek Watershed

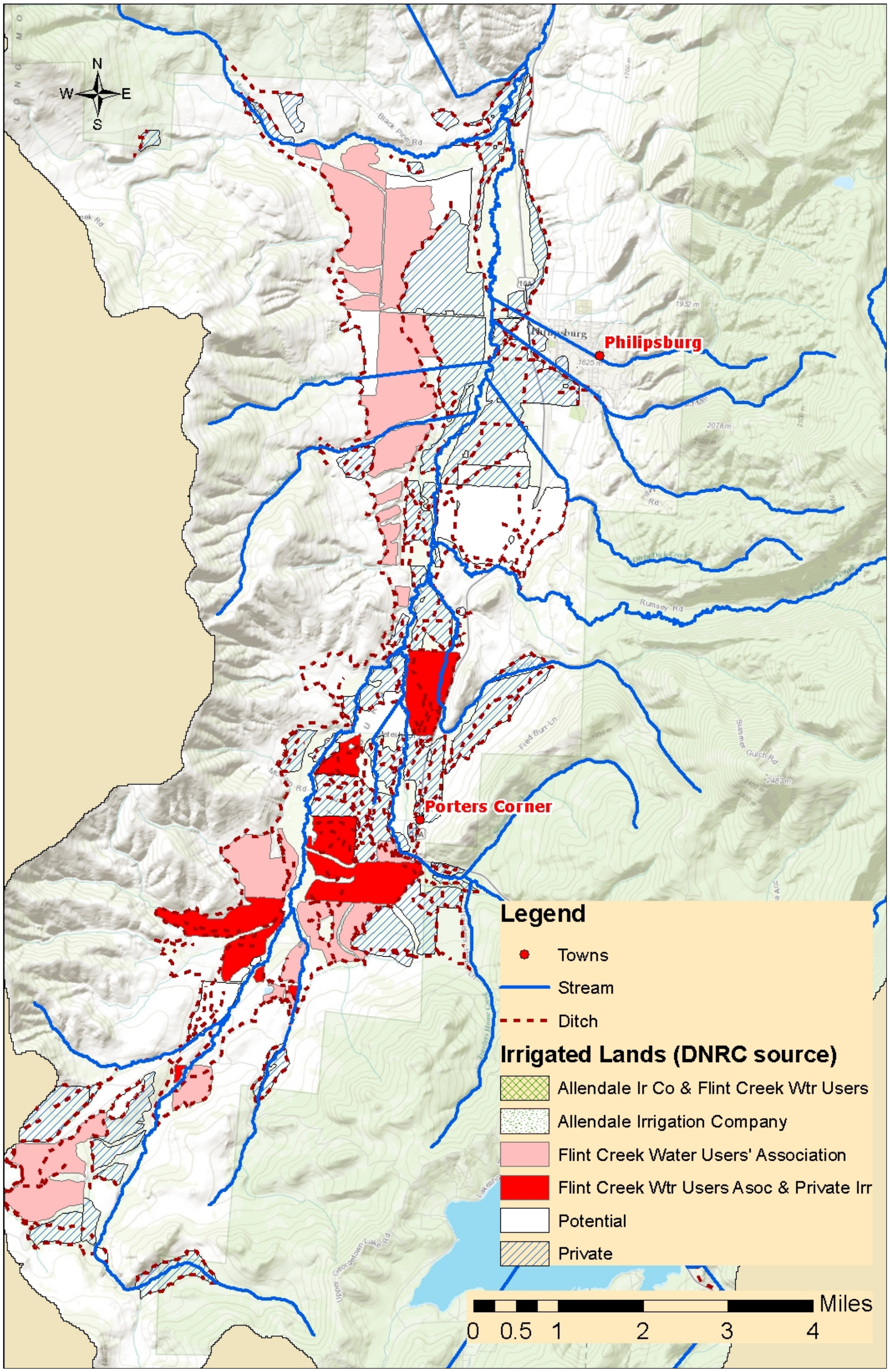

Figure E2-4b. Irrigation Canals, Diversions, and Dams in the Southern Flint Creek Watershed

Using the 16 dates of flow measurement between 1994 and 1996 at the Allendale Ditch Head Gate (Voeller and Waren, 1997), the average flow rate was 67.8 cfs when there was water in the ditch. Using the 1.7 acre-feet per acre value of consumptive use described above, the annual irrigation need from the Allendale Ditch was only 29.7 cfs (based on the estimated acreage of irrigated land served by the ditch from DNRC records (Buck, 1959)) (see **Figure E2-4a**). Because the irrigation needs of 29.7 cfs are less than half of the average measured values, and to account for the 0.5 irrigation efficiency (which indicates twice the water that the crops will consume must be diverted to account for irrigation inefficiency), the diversion amount and irrigation use was doubled to 59.4 cfs at this diversion, which roughly approximates the average measured diversion of 67.8 cfs.

Similarly for the Marshall Canal diversion, the 13 dates of flow measurement between 1994 and 1996 at the Allendale Canal (Voeller and Waren, 1997) showed an average flow rate of 30 cfs when there was water in the canal. Using the 0.74 acre-feet per acre value of consumptive use described above, the annual irrigation need from the Marshall Canal was only 5.9 cfs (based on estimated acreage of irrigated land served by the canal from DNRC records (Buck, 1959)) (see **Figure E2-4b**). Because the irrigation needs of 5.9 cfs are 20% of the average measured values, and to account for the 0.5 irrigation efficiency, the diversion amount and irrigation use was also doubled to 11.8 cfs at this diversion. At 11.8 cfs there is still a significant discrepancy from the measured diversions of 30 cfs, the cause for this discrepancy is uncertain but could be related to issues such as high rates of ditch losses to groundwater, additional irrigated lands not accounted for in the DNRC database, or higher irrigation rates than were estimated (Voeller and Waren, 1997).

A minimum flow was specified for each stream reach (each sub-basin has one stream reach) in the model to avoid dewatering streams. If the stream reached this value in the SWAT simulation it would not remove additional water for irrigation until the flow exceeded the pre-set minimum value. For larger streams (Flint Creek, Boulder Creek, Trout Creek, and Lower Willow Creek) the minimum value was set at 3.5 cfs. The USGS gages on Flint Creek and Boulder Creek showed that measured flow rates fell below 3.5 cfs on only a few dates at the gage near Drummond during the modeling period. For all other stream reaches the minimum value was set at 1.0 cfs. These minimum flow rates did limit some irrigation particularly in the late summer.

E2.5.1.2 Fertilizer

Local fertilizing application rates were unavailable from suppliers due to privacy concerns (Houston Engineering, 2011b). Therefore, typical crop-specific fertilizer rates for nitrogen, phosphorus and potassium were based upon a Montana State University Extension Service publication titled “Fertilizer Guidelines for Montana Crops” (Jacobsen et al., 2005). Fertilizer was used on alfalfa, spring wheat and barley. The alfalfa rates recommended in Jacobsen et al. (2005) were reduced in half based on communication with the Technical Advisory Group that indicated roughly half of the land owners use fertilizer on alfalfa fields (this was simulated in the model by reducing fertilizer use in half on all alfalfa fields rather than removing fertilizer from half of the alfalfa acreage in the watershed). Hay and pasture land uses were assigned winter grazing periods and fertilized through animal waste.

Fertilizer rates for alfalfa were based on estimated average soil conditions for phosphorus, and an estimated yield of 1 ton/acre (Houston Engineering, 2011b) for a 60/40 mix of alfalfa/grass. Fertilizer rates for Barley and Spring Wheat were based on average yields in Granite County based on National Agricultural Statistics Service Quick Stats (Houston Engineering, 2011b), and Montana fertilizer guidelines (Jacobsen et al., 2005). All fertilizer was applied on June 3 of each year as based on communication with the Technical Advisory Group. Fertilizer application rates are summarized in **Table E2-7**.

Table E2-7. Annual Fertilizer Rates in Flint Creek Watershed

Crop Type	Nitrogen load (lb/acre)	Phosphorus load (lb/acre)	Potassium load (lb/acre)
Alfalfa/Hay (60/40)[(1)]	5	20	20
Barley	90	0	0
Spring Wheat	247	35	0

[(1)] The rates used are half of the values suggested in Jacobsen (2005) to account for landowners that do not use fertilizer in the watershed

E2.5.2 Grazing

National Agricultural Statistics Service statistics show an average of 17,350 beef cattle in Granite County between 1980 and 2010. Through personal conversation, the National Resources Conservation Service (NRCS) estimates 65–75% of those are in the Flint Creek basin (Houston Engineering, 2011b), therefore a value of 12,000 was used in the SWAT model. There are also approximately 650 lamb/sheep in the watershed, primarily located in the Smart Creek drainage based on a 2011 site visit. Because grazing information for sheep was not available through the Montana State University extension service and there are relatively few sheep in the watershed, the 650 sheep were incorporated into the cattle values by estimating that an adult sheep is about 1/10 the weight (Kott, 2005) of a typical 1,400 lb beef cattle. The Environmental Protection Agency Spreadsheet Tool for the Estimation of Pollutant Load uses a similar ratio for Total Nitrogen (TN) and TP production for sheep as compared to cattle (Michigan Department of Environmental Quality, 1999). Therefore, the 650 sheep are equivalent to 65 beef cattle and are added to the 12,000 value discussed previously for a total value of 12,065.

Grazing was assumed to occur only in lands classified as range land (either grass range or brush range), which largely occurs on private land in the watershed. The United States Forest Service (USFS) has 15 grazing allotments in the watershed, but they are mostly in evergreen forest and except for one allotment located west of Maxville in range land are not suitable for grazing (Houston Engineering, 2011b). The USFS grazing allotment located west of Maxville (in sub-basins 14 and 15) does contain about 5,000 acres of range land and was used for summer grazing land in the SWAT model. All other land classified as range land that is located on USFS property (approximately 12,350 acres) was not included in the grazing acreage. The majority of summer grazing (about 95% of the total grazing area) was therefore located on privately owned range land. Privately owned evergreen forest areas, which account for approximately 37,000 acres in the watershed, were not included in the grazing area to remain consistent with the lack of grazing on government owned evergreen forest. Using those assumptions the total available summer grazing land for the 12,065 cattle is approximately 94,500 acres. To better represent grazing rotations the amount of grazing was varied between rangeland HRUs by allowing more grazing on lands that grow more vegetation (as based on biomass estimations in the model). Grazing lands were thus divided into 4 categories: no grazing, low grazing, moderate grazing and heavy grazing. Moderately grazed HRUs had 2 times as much grazing as low grazing HRUs, and heavily grazed HRUs had 3 times as much grazing as low grazing HRUs. Rangeland HRUs with no grazing only comprised 300 acres which reduced the total summer grazing area to approximately 94,200 acres. This tiered system provided more consistent rates of rangeland biomass growth in the watershed and attempted to simulate good grazing rotation practices. Over a 5 month grazing season (June 1 through October 31), that is approximately 1.6 acres/animal-unit-month. For reference, according to a Montana State University Extension Service publication (Lacey and Taylor, 2005) the range of acres/animal-unit-month is between 0.6 and 50 in Montana. During the winter months, it is assumed that the cattle feed on the hay (15,031 acres) and pasture (4,473 acres) lands in the watershed (Houston Engineering, 2011b). Based on discussions with the Technical Advisory Group winter grazing used existing field vegetation in November and May, and used feed transported into the grazing areas from December through April.

A 1,400 lb cow/calf pair eats approximately 35 pounds per day (dry weight) (Paterson, 2009). In this watershed the average cow/calf pair is roughly 1,200 lbs (based on communication with the Technical Advisory Group). Daily trampling was estimated equal to their consumption based on recommended SWAT values and previous studies (Montana Department of Environmental Quality and U.S. Environmental Protection Agency, Region 8, 2011). Based on NRCS (Natural Resources Conservation Service, 2008) a 1,000 lb beef cow produces 125 lb/day of manure, 88% of that is water weight, which provides a dry weight of 15 lb/day/cow. Converting that to a 1,200 lb cow/calf pair provides a dry weight manure of 18 lb/day/cow. That manure is applied across the summer and winter grazing ranges for all 12,065 livestock in the watershed, for a watershed-wide summer load of 2.3 lb/acre/day and a winter load of 11.1 lb/acre/day. The nutrients composition of the dry manure used in the model was based on NRCS (Natural Resources Conservation Service, 2008) that estimates it contains 2.8% nitrogen and 0.66% phosphorus. SWAT allows the manure applied to break down, percolate into the subsurface, or runoff towards streams. In addition, to simulate the time that livestock spend in the local streams 1% of the livestock waste is applied directly into the surface waters (Sheffield et al., 1997).

E2.5.3 Urban Land Use and Septic Systems

Urban density was initially based on the 2001 NLCD. However, the 2001 NLCD did not capture some of the significant growth of single family homes in the area surrounding Georgetown Lake in the 1990s and 2000s. To account for that growth, the land use surrounding Georgetown Lake was updated using visual inspection of 2009 air photos. The land-use update was only conducted once during the model period because there is insufficient information available to warrant a more frequent land-use update. The update was included halfway through the modeling period, January 1, 2000. This date is also approximately halfway through the increase in development rates that began in the early 1990s and ended in the late 2000s. Updating the urban land use to correctly identify areas of low, medium or high density is reflected in the SWAT model with increased percentages of impervious ground as the residential (i.e., urban) density increases.

To simulate typical residential land use, the model includes information for irrigation, cutting and disposal of grass for urban development. To determine the amount of land used for lawns, the number of septic systems for the watershed in 2009 was estimated at 1,613 from a county Geographic Information System (GIS) layer described below; based on the population in Philipsburg of 825 and an average household of 2.2 persons/home an additional 370 lawns were included. This provided approximately 2,000 lawns to include in the model. Without any available statistics, the average size of the lawn was estimated as ¼ acre (roughly 10,000 square feet) for a total lawn area in the watershed of 500 acres. Irrigation from groundwater was applied automatically by SWAT based on the soil moisture content, 10% of the irrigation water was assumed to runoff. Grass was harvested on the same seven dates every year (June 1, June 15, July 1, July 15, August 1, September 1, and October 1), and each harvest removed 50% of the grass. Fertilizer application was estimated from recommended application rates (Rosen et al., 2006) and from commercial lawn fertilizer bags. It was assumed that only half of the 2,000 lawns use commercial fertilizer, which provided 250 fertilized acres. Current fertilizer recommendations (Rosen et al., 2006) and commercial fertilizers do not use significant amounts of phosphorus, therefore only nitrogen was added to the lawns. The application rate on the 250 acres was set at 71.6 lb/ac/yr, for a total watershed application of 17,900 lb/yr.

For the purposes of estimating septic system locations a 2009 GIS layer created for Granite and Deer Lodge counties to assist emergency responders was used. The GIS layer was reduced to those parcels described as an apartment, cabin, house, or mobile home. A septic system was assigned to each of those parcels except for parcels served by the city of Philipsburg as determined from the city's sewer system map. Based on the GIS layer there were approximately 1,613 septic systems in the watershed in 2009, approximately half of those (875) are located in the immediate vicinity of Georgetown Lake and the other half spread around the rest of the watershed (**Figure E2-5**).

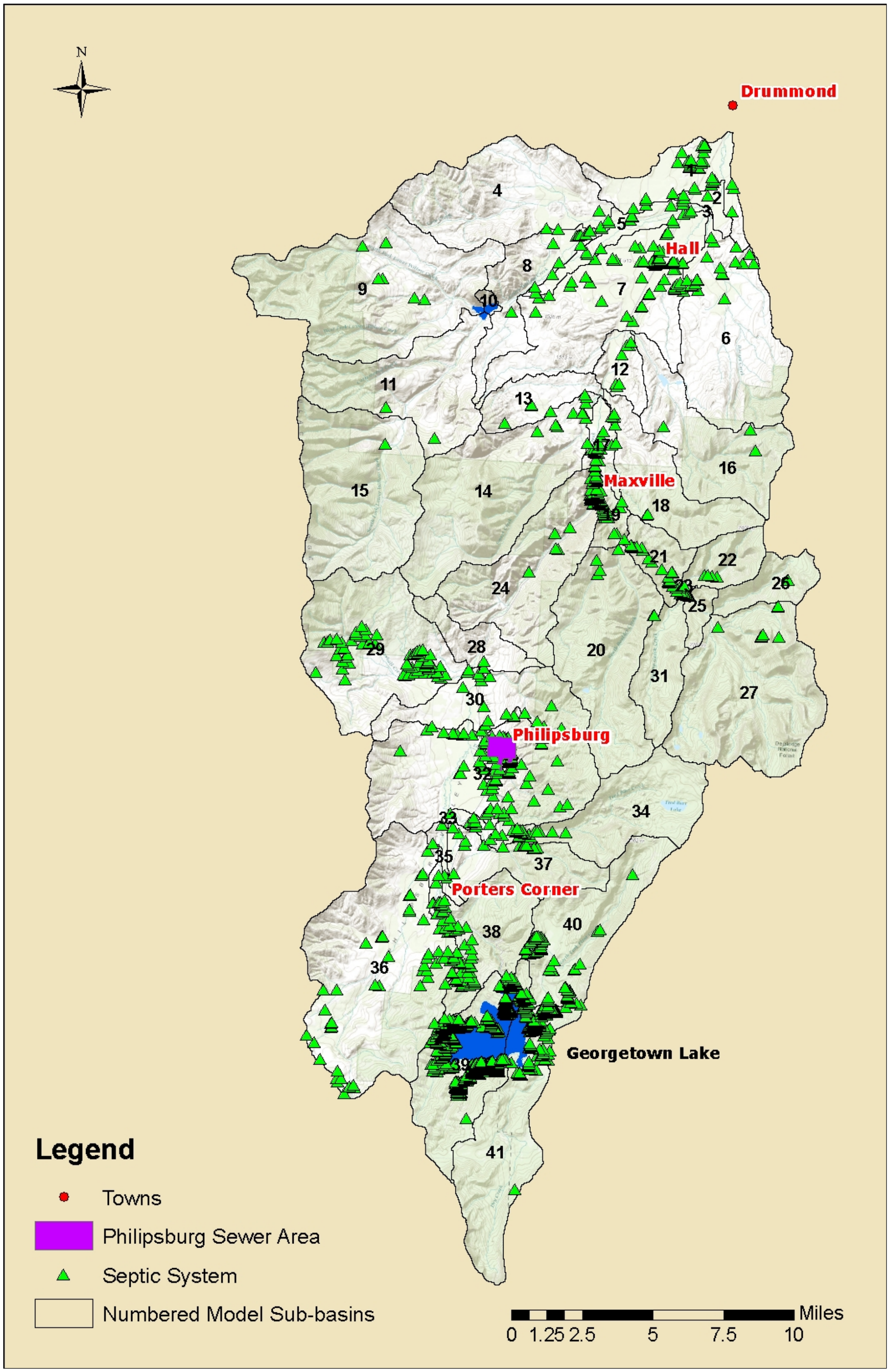

Figure E2-5. Approximate Septic System Location (2009)

The septic density land use designation in SWAT does not add a nitrogen or phosphorus load to the watershed that is specific to septic discharges (it only changes the runoff characteristics of the land by increasing impervious area with increased development density). Specific loading of nutrients from septic systems must be completed with a separate septic module within SWAT or via an external calculation that is then added to the model via a point source at the upstream end of the reach in each sub-basin. The latter option was used for this watershed. Using the locations of septic systems from the GIS layer, the nitrogen and phosphorus loading to surface waters from the 1,613 septic systems was estimated using a simple spreadsheet method as described in **Appendix F**. The number of septic systems in **Appendix F** is slightly different than described here due to minor differences in the watershed boundary delineated by SWAT versus the GIS information originally supplied with the 2009 county septic layer.

To account for the increase of septic systems in the vicinity of Georgetown Lake during the model simulation period, the point source loadings from septic systems were updated on an annual basis during the modeling period. Between 1990 and 1999, the number of septic system permits issued in the Flint Creek watershed was approximately 202 (Granite County Sanitarian, Lanes, Chad, personal communication 2013). Between 2000 and 2010, the rate of septic permits issued remained similar to the previous 10 years at 188 (Granite County Sanitarian, Lanes, Chad, personal communication 2013). A septic permit is issued when a new septic system is installed, and thus is an accurate measure of the increase of development. Because the rate of development in the watershed below Georgetown Lake has been relatively stagnant (as seen in the constant or slightly declining population in Philipsburg – see **Section E2.7.1** for additional detail), all of the increased development is assumed to occur in the vicinity of Georgetown Lake. Based on the 2009 estimate of 875 septic systems near Georgetown Lake and the 390 septic permits issued during the model period, the number of septic systems in the Georgetown Lake area was increased annually at a constant rate from 485 (875 minus 390) in 1990 to 875 in 2010, or 19.5 systems per year.

Each septic system was assumed to be a conventional system that produces an average of 200 gallons per day with a nitrate concentration of 50 mg/L and a mineral phosphorus concentration of 10.6 mg/L (U.S. Environmental Protection Agency, 2002; Montana Department of Environmental Quality, 2009) (see **Appendix F** for additional details). Those concentrations equate to loading values of 0.0836 lb/day and 0.0176 lbs/day/system for nitrate and mineral phosphorus, respectively. While there are some level 2 systems (septic systems that reduce nitrogen concentrations) in the county, it is a small percentage of the septic systems and without any available database to determine how many level 2 systems exist they were not accounted for in the SWAT model. For reference, the nitrate and mineral phosphorus loads applied as point sources from septic systems in 2000 after the attenuation rates calculated in **Appendix F** are incorporated are provided in **Table E2-8**.

Table E2-8. Nitrate and Mineral Phosphorus Loading Rates from Septic Systems in 2000

Sub-Basin	Nitrate Load (lbs/day)	Mineral Phos. Load (lbs/day)	Sub-Basin	Nitrate Load (lbs/day)	Mineral Phos. Load (lbs/day)	Sub-Basin	Nitrate Load (lbs/day)	Mineral Phos. Load (lbs/day)
1	1.053	0.093	15	0.030	0.003	29	1.835	0.161
2	0.180	0.016	16	0.090	0.008	30	0.481	0.042
3	0.000	0.000	17	0.572	0.050	31	0.000	0.000
4	0.120	0.011	18	0.241	0.021	32	3.640	0.320
5	0.451	0.040	19	1.594	0.140	33	0.000	0.000

Table E2-8. Nitrate and Mineral Phosphorus Loading Rates from Septic Systems in 2000

Sub-Basin	Nitrate Load (lbs/day)	Mineral Phos. Load (lbs/day)	Sub-Basin	Nitrate Load (lbs/day)	Mineral Phos. Load (lbs/day)	Sub-Basin	Nitrate Load (lbs/day)	Mineral Phos. Load (lbs/day)
6	0.572	0.050	20	0.180	0.016	34	0.963	0.085
7	2.557	0.225	21	0.692	0.061	35	0.120	0.011
8	0.421	0.037	22	0.150	0.013	36	1.745	0.154
9	0.180	0.016	23	0.211	0.019	37	0.451	0.040
10	0.000	0.000	24	0.602	0.053	38	1.745	0.154
11	0.060	0.005	25	0.211	0.019	39	14.605	1.285
12	0.211	0.019	26	0.060	0.005	40	2.009	0.177
13	0.090	0.008	27	0.271	0.024	41	4.442	0.391
14	0.361	0.032	28	0.060	0.005			

E2.5.4 Fires/Timber Harvest/Beetle Kill

More than 87% of the model area is classified as forest or rangeland (see **Figure E2-3**). Timber harvest, fire, and beetle kill effects were examined to determine whether temporal land-use changes should be incorporated into the SWAT model. Locations discussed are shown on **Figure E2-6**.

Fire effects were researched via discussion with USFS personnel (Houston Engineering, 2011b). Between 1985 and 2009 there was only one significant wildfire on USFS land which was in 1988. The fire consumed 8,200 acres near the headwaters of the Smart Creek drainage on the west side of the watershed in sub-basins 14 and 15. The high density of roads in this area suggest it was likely also harvested for timber pre or post fire. This area was accounted for in the 2001 NLCD as a rangeland-brush land use instead of forest as it would have been before the fire. Since 1994, the DNRC database showed several small fires that were all less than 15 acres in size. The smaller wildfires are minor and were not accounted for in the watershed discretization. Additional information is available on the DNRC website (Montana Department of Natural Resources and Conservation,2012).

Timber harvests were incorporated as land-use updates in the SWAT model. Harvested areas were identified through visual interpretation of the air photos that are available from 1990 through the present, which included 1990, 1991, 1995, 2003, 2005, and 2009. Three areas were identified. The first area is in sub-basin 29 and covers approximately 1,300 acres; it appears to have been harvested between 1995 and 2001. The 2001 NLCD classified it as rangeland-brush as a result of the logging, it was modified to be forest from 1989 through 1997 and then set to rangeland-brush for the remainder of the model period. The second area is in sub-basin 16 and covers approximately 640 acres; it appears to have been harvested between 2003 and 2005. The 2001 NLCD classified it as forest; therefore the land use was changed in the SWAT model in 2004 from forest to rangeland-brush to match the land-use classification for harvested areas. The third area is in sub-basins 9 and 11 and covers approximately 1,500 acres, it was harvested before 1990, but in the 1995 air photo the effects are still visible. By 2001, the effects were low enough that the NLCD classified the area as forest. The land use for this area was changed to rangeland-brush from 1989 through 1999 and then reverted back to forest in 2000.

The scope of mountain pine beetle effects was examined using information from the USFS (U.S. Department of Agriculture, Forest Service,2013) includes maps based on aerial surveys showing the location and number of affected trees. Based on those maps there are tens of thousands of forested acres in the watershed that have been affected by beetle kill. However, the effects of beetle kill on the hydrology of the watershed are not clear at this time. Therefore, the SWAT model was not altered to account for the beetle kill effects, if any had occurred during the modeling period. This may be an area to re-assess in the model in the future if additional information and studies about the effects of beetle kill on hydrology and/or nutrient migration become available.

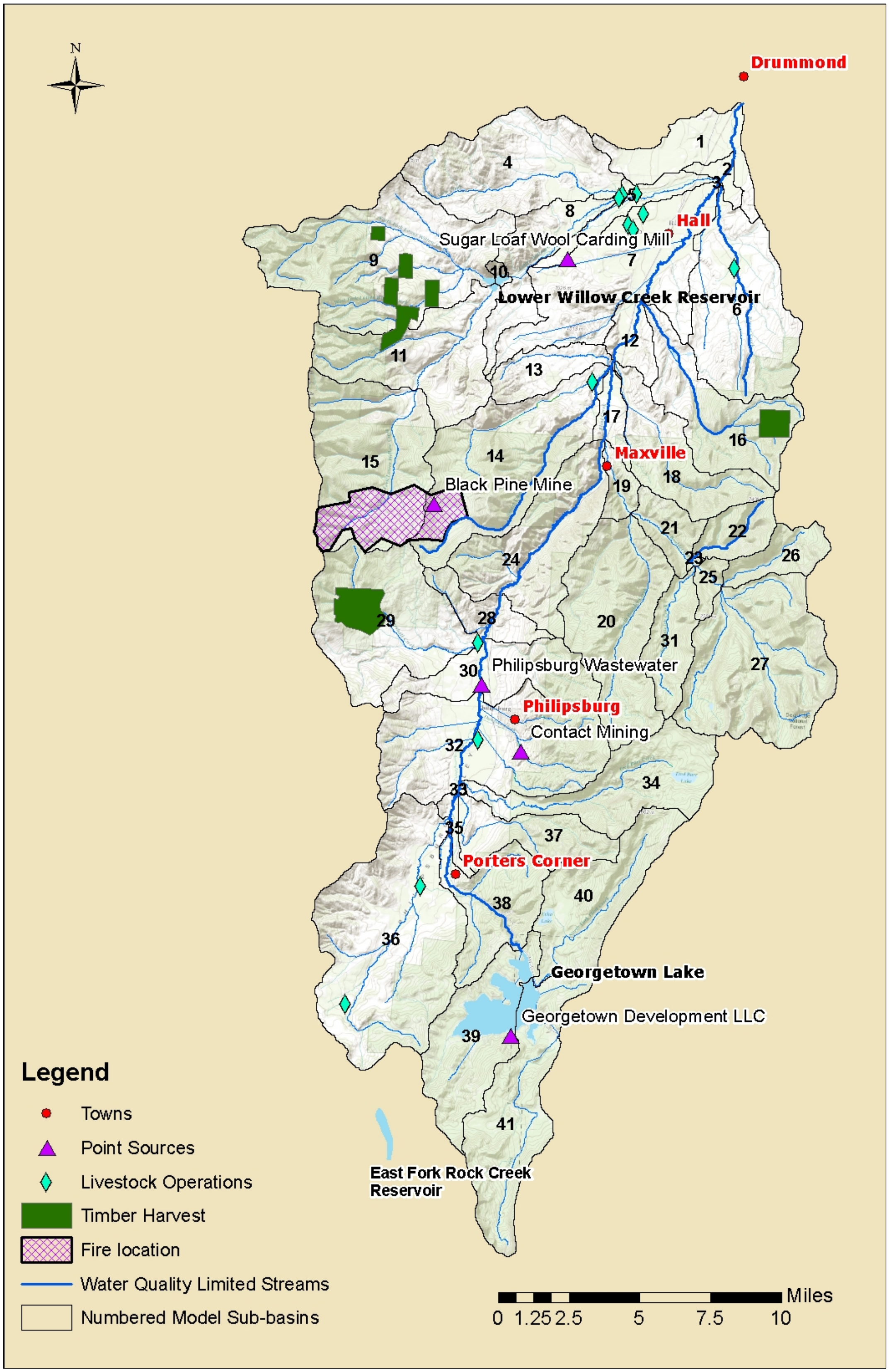

Figure E2-6. Timber Harvest, Fire, Livestock Confinement, and Point Source Locations

E2.5.5 Water/Wetlands/Reservoirs

In addition to the main and tributary stream channels that route the water through the watershed, SWAT also incorporates four different types of impoundments: ponds, wetlands, depressions/potholes, and reservoirs. Reservoirs are located on the main channel network and receive water from all sub-basins upstream of the waterbody. Ponds, wetlands, and depressions/potholes are located within a sub-basin off of the main channel and only receive runoff from a portion of the sub-basin in which they are located. As simulated in SWAT, no distinction is made between naturally occurring and man-made waterbodies. Daily calculations of surface area, precipitation, evaporation, and seepage are completed in SWAT based on user-provided information on the reservoir outflow or storage-operational curves. Ponds, wetlands, or depressions/potholes were not included in the model, but three reservoirs were included. The three reservoirs include Georgetown Lake (sub-basin 39), Lower Willow Creek Reservoir (sub-basin 10), and the East Fork Rock Creek Reservoir (sub-basin 36) (see **Figure E2-6**).

The history of the Flint Creek dam which created Georgetown Lake was described previously in **Section E2.1**. The lake area is 2,900 acre, and the lake volume at full pool is approximately 31,000 acre-feet (Garrett and Kahoe, 1984). Full pool is estimated as the noncontrolled spillway at 6,429.5 feet above mean sea level (msl) (Montana Power Company, 1987). Discharges from the dam are controlled by the dam operator, and are not directly related to reservoir water elevation (Stafford and Ahl, 2011). Records of dam releases are not available; therefore the amount of water released from the dam was based on the daily readings from the USGS gage station (Flint Creek near Southern Cross) located approximately 9,400 feet downstream of the dam. Because there is only one unnamed small stream (its drainage area is approximately 1.3 square miles) that enters Flint Creek between the dam and that USGS gage station, the USGS streamflow values should be representative of the dam releases from Georgetown Lake. Daily year-round flow data collection at the USGS gage has been reduced since 2004 to daily collection from April 1 to October 31 of each year. The missing winter data in that time period were based on the average daily flow for each day from November 1 through March 31 measured at the gage between 1990 and 2003 (**Attachment EC**).

Information for the Lower Willow Creek Reservoir was obtained from the Granite Conservation District (Houston Engineering, 2011b). It was constructed in 1962 with a maximum capacity of 6,230 acre-feet and a normal storage of 4,800 acre-feet. Average monthly discharge data when the dam releases water for irrigation (April through October) are only available from 1965 through 1983. Normal operation of the dam has not changed over its life span, therefore the monthly averages of the historic data were used as the daily discharge during the model period (**Attachment EC**). From November through March there are no releases from the dam, but normal runoff is directed through the reservoir in sub-basin 10.

The East Fork Rock Creek Reservoir is located in the adjacent Rock Creek watershed. It transfers water into the Flint Creek watershed via siphon into Trout Creek to meet water rights obligations for irrigation. Because the reservoir is outside the watershed it is treated as a point source of water in the SWAT model. The DNRC monitors the flow from the reservoir – daily data for water diverted into the Flint Creek watershed were available for 8 years of the model period (2000, 2002–2004, and 2007–2010). For the years without data, the median daily value for each of the years with data was used to estimate the daily diversion values (**Attachment EC**). The median was used instead of the average because there were only eight or fewer values (the diversion started and stopped on different dates each year so some dates had less than eight discharge volumes) for each date; with so few data points one anomalously low or high value could skew the extrapolated value.

E2.6 ROADS

Sediment runoff from unpaved roads contributes sediment to surface water and was estimated based on the Water Erosion Prediction Project model (Montana Department of Environmental Quality, Planning, Prevention and Assistance Division, Water Quality Planning Bureau, 2011). That project divided the Flint Creek watershed into 13 sub-watersheds and estimated sediment loads for each sub-watershed. The sediment loads in each of the 13 sub-watersheds were divided proportionally by the miles of gravel or native material roads within each of the 41 sub-basins in the SWAT model (paved roads were not included in determining the sediment loads). Those sediment loads were added as a constant daily point source load to each sub-basin (**Table E2-9**). Although there may be some seasonal variation in sediment loading from streams there was not enough information to vary the sediment loading seasonally. Additional details on methods used to measure and extrapolate the sediment loads are available in the report (Montana Department of Environmental Quality, Planning, Prevention and Assistance Division, Water Quality Planning Bureau, 2011).

Although paved roads may contribute some sediment loading (from traction sand in winter months, for example), the comparative load to unpaved roads is small and not significant on the watershed scale.

Table E2-9. Sediment Loading Rates from Roads

Sub-Basin	Sediment Load (lbs/day)	Sub-Basin	Sediment Load (lbs/day)	Sub-Basin	Sediment Load (lbs/day)
1	7.50	15	19.84	29	25.35
2	2.65	16	39.24	30	12.13
3	0.00	17	1.10	31	4.19
4	15.65	18	10.36	32	33.73
5	3.53	19	2.87	33	0.44
6	15.65	20	18.08	34	5.95
7	18.30	21	5.51	35	1.10
8	5.29	22	5.51	36	20.94
9	31.31	23	0.66	37	7.94
10	0.22	24	23.59	38	17.64
11	10.80	25	2.87	39	16.98
12	0.00	26	5.29	40	18.08
13	6.61	27	13.01	41	13.67
14	69.67	28	0.00		

E2.7 POINT SOURCES

There are several permitted discharges in Flint Creek watershed (**Figure E2-6**). Most are intermittent with no predictable discharge or too small to be included in the model, except for the wastewater discharge from the city of Philipsburg. Each discharge is described below. There can be a few construction stormwater permits active at any time in the watershed; due to the lack of monitoring typically required for such activities and their transient nature they were not included in the SWAT model. The description and identification numbers for these permitted discharges may have changed since the model was initially parameterized in 2010, the permits described may have lapsed, been re-issued with different conditions, or new permits may have been issued in the interim. The model inputs were maintained under the conditions that existed in 2010.

E2.7.1 City of Philipsburg Wastewater Discharge

Discharge from the Philipsburg wastewater treatment plant was simulated as a point source to Flint Creek in sub-basin 30 of the SWAT model. Flow and water quality data were not available for the entire modeling period, therefore, some interpolation and extrapolation of the data that have been collected were used to estimate the monthly constituent loadings from the wastewater treatment plant as described below. Based on the available wastewater treatment plant effluent data monthly loads of sediment, organic nitrogen, nitrate, ammonia, organic nitrogen, organic phosphorus, and orthophosphorus were included in the loads applied to Flint Creek from the wastewater treatment plant.

The city of Philipsburg's wastewater treatment plant was constructed in 1961, it was upgraded in the early 1990s, and the city is currently evaluating plans for further upgrades. Treatment is via a 2-cell facultative lagoon with continuous discharge into Flint Creek near the northwest corner of the treatment lagoons. It currently operates under a Montana Pollutant Discharge Elimination System (MPDES) permit (MT0031500) with a permitted design flow of 160,000 gallons per day. As required in the MPDES permit the effluent flow rate has been measured since 2000. TN and TP have been measured in the effluent since 2005. Biochemical Oxygen Demand (BOD) and Total Suspended Solids (TSS) have been measured in the effluent since 2007. For periods when effluent quality data and flow rates were not available, values from the discharge monitoring reports submitted to the DEQ were used to estimate average monthly flow and loadings. Effluent dissolved oxygen has not been measured in the past therefore the concentration was estimated at 2.0 mg/L. However, since July 2012, the MPDES permit has required dissolved oxygen monitoring. The current estimate of 2.0 mg/L can be adjusted in the future if necessary based on the data collected. Effluent rate data from November 2004 through October 2006 showed the flow nearly doubling for that time period without any known increase in population or usage. The rapid increase and then decrease in flow is likely due to one or a combination of two events: the first event was the replacement of a corroded outflow flume in November 2004 which may have resulted in incorrect manual readings from the new flume; the second event was a broken sewer line (repaired in December 2006) that was allowing water from Camp Creek to enter the wastewater collection system (Houston Engineering, 2011a). For this time period of uncertain flow rate records, average values of wastewater treatment plant loading from other years with data were used. The population of Philipsburg has ranged from 925 in 1990 to 914 in 2000 to 825 in 2010. There were no noticeable changes in measured effluent rates for the period of available data in the MPDES file (2000 through 2010); therefore the extrapolated effluent and loading rates between 1989 and 2000 were not adjusted for the population change.

The city of Philipsburg is under an Administrative Order on Consent to improve treatment of TSS and BOD by October 2013. That improvement has not been completed yet; therefore the historic TSS and BOD loading rates have been used in the SWAT model.

E2.7.2 Black Pine Mine Stormwater Discharge

The Black Pine Mine has sporadic stormwater discharges to an outfall in the Smart Creek drainage and is covered under MPDES permit MTR300080. This outfall is into a detention basin that allows the stormwater to discharge into the groundwater rather than flowing directly into the nearest surface water. Due to the sporadic nature of the discharge and the dissipating effects of the detention basin, a point source discharge was not included in the SWAT model.

E2.7.3 Sugar Loaf Wool Carding Mill

This discharge is a small industrial discharge near the town of Hall via a drainfield to groundwater for a wool processing facility. It is covered under Montana Ground Water Pollution Control System (MGWPCS) permit MTX000134. There have only been four effluent samples collected for nitrate and Total Kjeldahl Nitrogen analysis. Due to the lack of information and small volume of discharge from this facility to groundwater (less than a single family home septic system) it was not included as a separate point source in the SWAT model.

E2.7.4 Contact Mining

This discharge is for process water of an ore processing facility located near Philipsburg under MGWPCS permit MTX000002. The discharge is to two settling ponds where solids are allowed to settle out and then the water is recycled for additional ore processing. The permit is for the potential discharge to groundwater. The single monitoring well downgradient of the settling ponds has never had groundwater in it, and therefore effects to groundwater, if any, have not been documented. The current permit includes requirements to install new monitoring wells to better define the amount of discharge that may be occurring from the settling ponds. Because there is no documentation of the amount or concentration of discharges to groundwater, this facility was not included as a point source in the SWAT model.

E2.7.5 Georgetown Development LLC

This discharge is for domestic wastewater from a subdivision on the south side of Georgetown Lake under MGWPCS permit MTX000201. This system began discharging wastewater in late 2011 after the model period ended, and therefore was not included as a point source in the model.

E2.7.6 Livestock Operations

Analysis of aerial photos and GIS information show there are approximately 12 areas of animal confinement in the watershed (Houston Engineering, 2011b), four of which may be located near streams. Whether these sites are actually Concentrated Animal Feeding Operations or Animal Feeding Operations by definition was not determined as part of this project. A few of the sites were observed during a DEQ watershed site visit in 2011, and did appear to have areas denuded of vegetation due to livestock activities, but it could not be determined whether they had direct connection to surface waters. These areas were maintained as pasture in the SWAT model. Future studies may want to reconsider this based on the best available data. The effect of livestock confinements on nutrients and sediment loading can be significant. These facilities may act as point sources discharging directly to streams, and can potentially contribute to nutrients and sediment loading.

E3.0 Model Development

For this SWAT model, which includes numerous land owners, the specific land management practices (e.g., irrigation schedules, irrigation types, fertilizer application, grazing rotations, urban management, etc.) used by each land owner could not logistically be replicated. Therefore, the best information available from published literature and local knowledge was used to develop typical land management practices that are incorporated uniformly across the watershed. For example, the timing and amount of fertilizer may vary between different land owners, but the model uses a single average fertilizer application rate and date for each type of crop that is fertilized. This homogenization does limit the models ability to accurately predict field scale loading estimates, but the model results are well suited to predicting how changes in management practices across the watershed will affect nutrients loadings to surface waters, which is the ultimate goal of developing the SWAT model.

E3.1 SWAT Model Description

DEQ selected the SWAT model for modeling the Flint Creek watershed. The SWAT model and its ArcView Extension (ArcSWAT) were developed, and are actively supported, by the U.S. Department of Agriculture Agricultural Research Service. SWAT is a public domain watershed-scale hydrologic and water quality model developed to quantify the effect of land management practices in large watersheds. It is a deterministic, distributed parameter continuous simulation basin-scale model. SWAT partitions the watershed into a number of sub-basins. Each sub-basin has a single climatic dataset based on the average elevation of the sub-basin; for example, the snowfall value for a specific date is the same for each HRU in the sub-basin and is based on the nearest climate station and the average elevation of that sub-basin. The sub-basins are distributed in the context that they are linked with other sub-basins through the stream channel network. Each sub-basin is further partitioned (i.e., discretized) into HRUs that are lumped into unique soil, land cover, and slope combinations. These HRUs form the fundamental computational unit of the model.

The advantages of SWAT include:

- It is physically based and uses readily available data;
- It is computationally efficient, computers are able to complete the simulation calculations within a reasonable amount of time;
- It incorporates comprehensive processes by using mathematical equations to represent flow, fate, and transport and other physical, chemical, and biological interactions;
- It can be used to study long-term effects and to simulate management scenarios; and
- It has globally validated model code, as both the model and its code are publicly available for free and widely used.

Disadvantages of SWAT are primarily related to simplifying assumptions to reduce computational time and include:

- The impacts of HRUs on the stream reach within a sub-basin are only based on their total size, not on their location within each sub-basin;
- While it does include groundwater routing, the routines used are not designed to adequately characterize complex groundwater systems; and
- As a watershed-scale model it cannot be used to predict field-scale water quality changes.

Pollutant yields, water balance, surface runoff, sediment yield, and management practices are computed at the HRU level, and then are aggregated for subsequent routing through the stream channel system. SWAT simulates streamflow, sedimentation, and water quality parameters including nutrients. Six general compartments are incorporated into the model to describe the flux of water through the landscape. These include: (1) snow accumulation and melt, (2) surface runoff, (3) unsaturated zone processes/evapotranspiration, (4) lateral subsurface flow, (5) shallow groundwater flow, and (6) deep aquifer flow. Hydrologic computations are completed using a modified version of the curve number (United States Department of Agriculture, 1986) where daily curve number is adjusted according to the previous day's soil water content (Arnold et al., 2011; Neitsch et al., 2011). Sediment yield in SWAT is simulated using the Modified Universal Soil Loss Equation (Williams and Berndt, 1977), where erosion and delivery are calculated as a function of peak runoff rate and volume, soil erodibility, slope steepness and length, cover factor, and supporting practice factor. In particular, the slope steepness and length, and the cover management factor (Universal Soil Loss Equation (USLE) C factor) are important because they are largely based on specific field-level conditions, and therefore are more accurate with user input. Channel sediment routing is based on the unique sediment transport characteristics of the individual routing reach and the upstream continuum of sediment from other sub-basins and channel reaches. Sediment is routed through the stream channel considering deposition and degradation processes and using a simplified equation based on stream power (Bagnold, 1977). For each stream reach on each day, either bank deposition or bank erosion occurs to maintain the sediment load in the stream at the maximum amount of sediment that the calculated stream power can sustain. The theory and the algorithms that control many of the processes in SWAT are provided in the model documentation (Neitsch et al., 2011).

SWAT simulates the transfers and internal cycling of the major forms of nitrogen and phosphorus. The model monitors two pools of inorganic and three pools of organic forms of nitrogen. SWAT also monitors three pools of inorganic and three pools of organic forms of phosphorus. SWAT incorporates instream nutrient dynamics using kinetic routines from QUAL2E, an instream water quality model (Brown and Barnwell, Jr., 1987). Details regarding model development are described by Arnold et al. (1993). SWAT documentation consists of theoretical documentation, input and output documentation, and user's manual (Arnold et al., 2011; Neitsch et al., 2011; Winchell et al., 2010).

E3.2 Model Input

ArcSWAT and SWAT Editor (both Version 2009.93.5) were used in this modeling effort. This is not the most current version of SWAT but it was the most recent version at the onset of the project, and compatibility problems did not allow the updating of the model version without significant structural modification. Fundamental input data for SWAT are topography, land use, soils, and climatic data. ArcSWAT (with its GIS interface) was used to perform the pre-processing, initial model setup and parameterization. Geographic data sources used for model setup are shown below:

- National Elevation Dataset (NED) – The USGS NED is a 1:24,000 scale high-resolution compilation of elevation data used for watershed delineation, flow accumulation processing, and slope determination (U.S. Geological Survey,2010a).
- National Hydrography Dataset (NHD) – NHD is a 1:24,000 scale vector coverage of stream topology (U.S. Geological Survey,2010b). It was used in definition of the stream and channel network.
- National Land Cover Dataset (NLCD) – The 2001 NLCD is a 21-category land cover classification (30-m grid) available for the conterminous U.S.

- STATSGO Soils – The STATSGO soil map (Natural Resources Conservation Service, 1994) is a 1:250,000 scale generalization of detailed soil survey data that were used to develop soil properties of land cover classes.

E3.3 Simulation Period

The model simulation period was chosen to be coincident with: the most recent land cover; available calibration data for flow, sediment, and nutrients; and climatic datasets with few or no missing values. The period of 1989 through 2010 was chosen to best meet these requirements. The dataset was partitioned into three subsets: 1989–1991 for a model “warm-up” period; 1997–2010 for calibration; and 1992–1996 for validation. Further descriptions and rationales of the three chosen model periods are provided in **Sections E4.1** and **E4.5**.

E3.4 Watershed Delineation

Sub-watershed discretization was performed to capture 6th code Hydrologic Unit Code boundaries for the watershed, and also to capture specific sub-watersheds with water quality-limited stream segments within the model. This resulted in a delineation of 41 total sub-watersheds (referred to as sub-basins) for the Flint Creek watershed (**Figure E3-1**). Sub-basin sizes ranged from 0.02 square miles to over 34 square miles (**Table E3-1**).

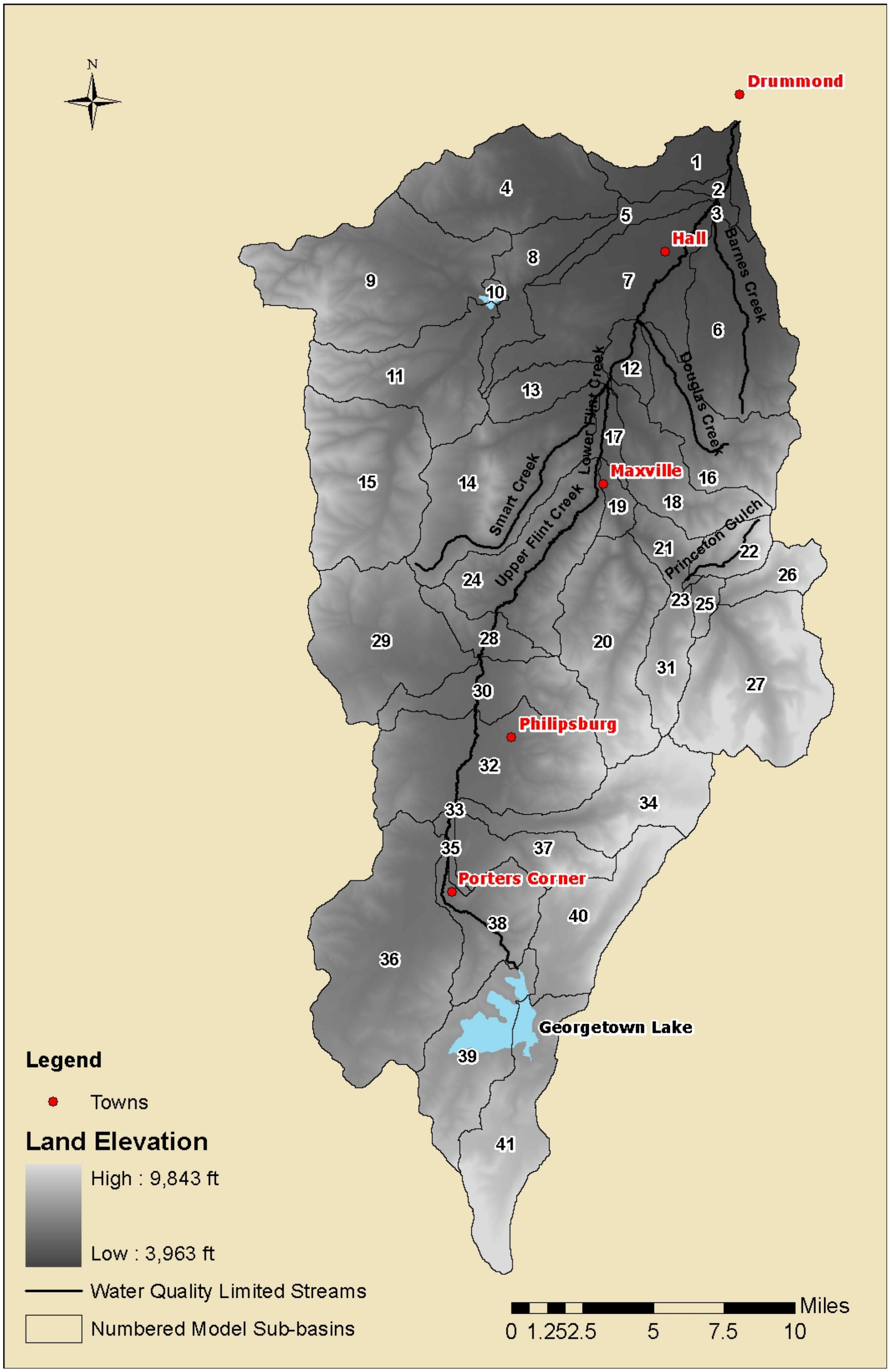

Figure E3-1. Sub-Basins within the Flint Creek Watershed

Table E3-1. SWAT Sub-Basin Information for Flint Creek Watershed

Sub-Basin	Area (square miles)	% Watershed Area	Average Elevation (feet above msl)	Comment
1	8.38	1.71	4,202	
2	1.46	0.3	4,094	USGS flow gage
3	0.02	0.004	4,065	
4	20.04	4.08	4,958	
5	3.98	0.81	4,303	
6	20.74	4.22	4,750	
7	23.09	4.7	4,505	
8	8.75	1.78	4,830	
9	30.25	6.16	5,824	
10	0.47	0.1	5,096	Lower Willow Cr. Reservoir
11	17.11	3.48	5,809	
12	3.55	0.72	4,578	
13	5.47	1.11	4,953	
14	24.30	4.95	5,664	
15	23.24	4.73	6,463	
16	14.61	2.97	5,705	
17	2.58	0.53	4,739	
18	11.58	2.36	5,796	
19	2.39	0.49	5,348	USGS flow gage
20	20.74	4.22	6,577	
21	4.15	0.85	5,853	
22	4.49	0.91	6,938	
23	0.17	0.03	5,558	
24	17.50	3.56	5,627	USGS flow gage
25	1.72	0.35	6,247	
26	4.68	0.95	7,348	
27	25.35	5.16	7,482	
28	4.84	0.98	5,579	
29	21.73	4.43	5,933	
30	11.58	2.36	5,787	Philipsburg wastewater source
31	6.55	1.33	6,995	
32	26.42	5.38	5,837	
33	0.14	0.03	5,243	
34	15.36	3.13	7,234	
35	1.13	0.23	5,375	
36	34.71	7.07	5,847	East Fork Reservoir Diversion
37	8.50	1.73	6,304	
38	11.30	2.3	6,081	USGS flow gage
39	15.33	3.12	6,646	Georgetown Lake
40	14.46	2.95	7,226	
41	18.20	3.71	7,252	
Totals	**491.06**			

E3.5 HYDROLOGIC RESPONSE UNITS

Sub-basins were further divided into homogeneous landscape units, HRUs, which have unique soil, land cover, and slope combinations. HRUs have no spatial context within each sub-basin, meaning that the model does not account for the location of the HRU within the sub-basin or the spatial relation between multiple HRUs. In practical terms, all loadings of water, sediment, and nutrients from each HRU are added directly to the stream reach at the upstream end of the sub-basin without allowing movement of water, sediment, and nutrients between any of the other HRUs. A minimum threshold percentage of 2% was specified, meaning that soil, land use, or slope categories totaling less than2% of a sub-basin would be excluded from the HRU definition process (those small areas are then divided proportionally among the other HRUs in the sub-basin). The only exception to the 2% criteria was for low, medium or high residential density land uses, which had no minimum threshold for HRU delineation to maintain their effects to the watershed regardless of the area covered. The minimum threshold designation reduces the number of HRUs in the model and greatly reduces computational time without sacrificing accuracy. This process resulted in 1,505 HRUs delineated within the watershed. Management files for each HRU were written based on an understanding and estimation of activities that were occurring within the watershed which included: (1) cattle grazing on pasture, hay, and rangeland; (2) agricultural irrigation, fertilizing, harvesting; and (3) urban irrigation, fertilizing and grass cutting.

E3.6 Climatic Patterns

Climate data were obtained from a total of eight weather stations within or adjacent to the watershed, as described in **Section E2.2**. Because precipitation and air temperature vary with elevation, elevation bands were used to better simulate orographic effects for each sub-basin that had more than 100 meters of topographic relief. Elevation bands are used to determine a more accurate weighted average elevation for each sub-basin to provide a better climatic data; the bands are not used to calculate variation of climatic parameters within a sub-basin. Bands were generated from the SWAT topographic report and climatic information from the most proximal meteorological station was lapsed according to the elevation of the assigned climate station and each band. Lapse rates were determined based on seven climate stations for precipitation and eight climate stations for temperature (**Figure E3-2** and **Figure E3-3**, respectively). Precipitation and temperature lapse rates were calculated as 4.85 in/1,000 ft (r^2=0.84) and -3.6 ˚F/1000ft (r^2=0.97), respectively, which is similar to that reported in other Montana watersheds (Flynn and Van Liew, 2010; Montana Department of Environmental Quality and U.S. Environmental Protection Agency, Region 8, 2011). One of the precipitation stations, Warm Springs, was removed because it was likely overestimating precipitation as it is on the leeward side of the mountains (and thus collects additional wind-driven snow), it was significantly skewed from the regression curve of the other seven stations, and it was creating significantly higher runoff from the Flint Creek Range than was observed in the USGS gage at the mouth of Boulder Creek (Boulder Creek drains much of the high elevations portions of the Flint Creek Range and is thus a good location to check the accuracy of the snowmelt parameters in the model). To define which precipitation station is assigned to a particular sub-basin, SWAT identifies the closest defined meteorological station by its proximity to the centroid of the sub-basin. The station chosen by SWAT was then modified in some cases to match lower and higher elevation sub-basins to weather stations of similar elevations. Both temperature and precipitation information are then read from that station.

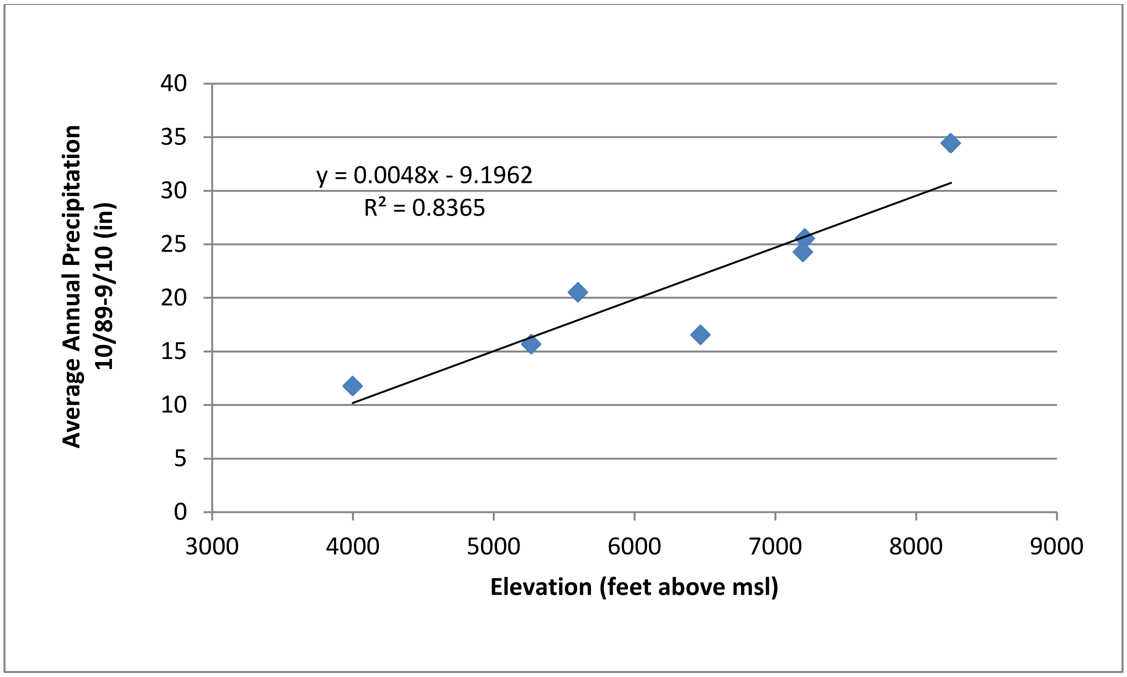

Figure E3-2. Precipitation Lapse Rate Used in the Flint Creek SWAT Model

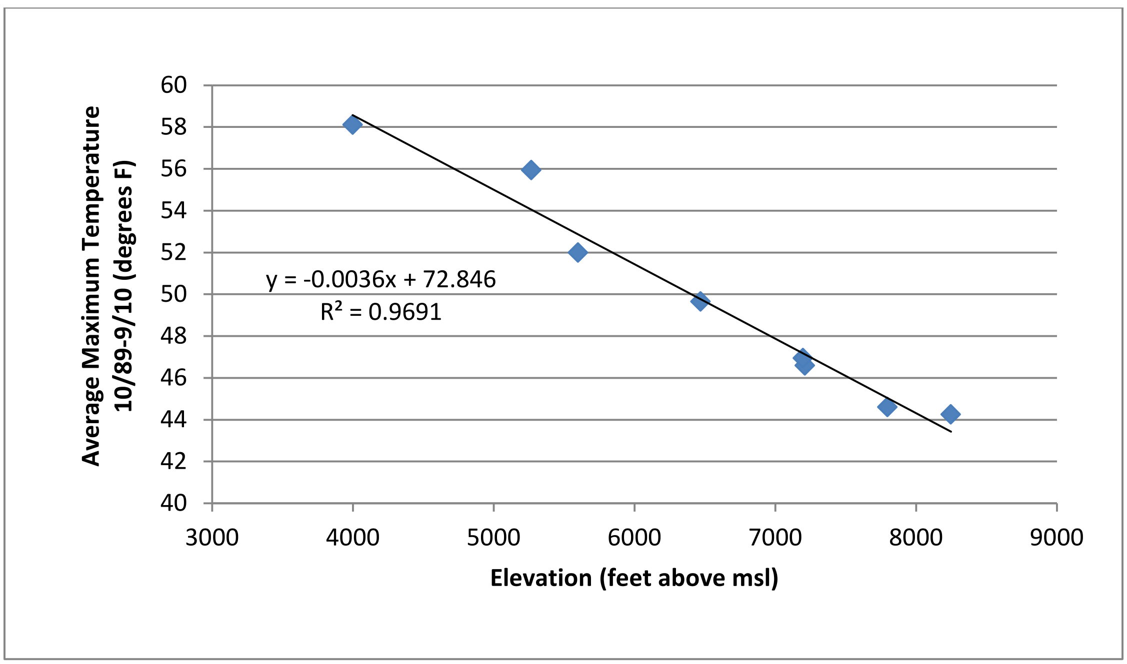

Figure E3-3. Temperature Lapse Rate Used in the Flint Creek SWAT Model

E3.7 Routing Geometry

The SWAT model automatically calculates channel dimensions for the main channel and tributaries based on drainage area regression statistics. One study has shown that the SWAT regression is not accurate for mountainous regions (Flynn and Van Liew, 2010). Field channel measurements were taken by the DEQ (Water & Environmental Technologies, 2010) and the USGS (Lawlor, 2004) for 20 stream reaches within the watershed, these values were used to define the channel geometry for the sub-basin they were collected in. Comparing the sub-basins with measured data versus that calculated by SWAT shows that SWAT consistently over-predicted both the bankfull channel width and the width-to-depth ratio. To correct the errors in sub-basins without direct measurements, a regression was created between the 20 sub-basins with measured data and the corresponding sub-basin values calculated in SWAT that regression was then used to extrapolate the channel morphology for the remaining 21 sub-basins. The regressed values were then used in the SWAT model in place of the SWAT calculated values.

Manning's n values (between 0.026 and 0.053) typical of natural stream systems were used (Federal Highway Administration, 2008) in place of the SWAT default values. Slightly higher values (increased roughness) were used for the tributaries than for the main channels. Manning's n values were varied slightly between sub-basins based on the width/depth ratio for that sub-basin reach. All routing coefficients can be found in **Attachment EC**.

E3.8 EVAPOTRANSPIRATION

Evapotranspiration is the combined loss of water from ground surface evaporation and by transpiration from plants, while the potential evapotranspiration rate describes how fast water vapor would be lost from a densely vegetated plant-soil system if soil water content was continuously maintained at an optimal level. In SWAT, three options exist for estimating potential evapotranspiration rate and subsequently evapotranspiration: the Penman-Monteith method (Monteith, 1965), the Priestly-Taylor method (Priestly and Taylor, 1972), and the Hargreaves method (Hargreaves and Samani, 1985). Measured potential evapotranspiration rate values can also be used if measurements are available. **Table E3-2** shows the data requirements of the three potential evapotranspiration rate methods listed from the method requiring the most to least data for the calculation. The Penman-Monteith method was used for this watershed.

Table E3-2. Data Requirements for SWAT-Available Potential Evapotranspiration Methods

Method	Air Temperature	Wind Speed	Relative Humidity	Solar Radiation
Penman-Monteith	Input	Input	Input	Input
Priestly-Taylor	Input	Not used	Input	Input
Hargreaves	Input	Not used	Not used	Not used

E4.0 MODEL CALIBRATION

Model calibration was completed numerically with commonly used error statistics, and qualitatively using graphical methods to visually compare the results when numerical evaluation was not appropriate. Three calibration sites were used, Flint Creek near Drummond, Flint Creek at Maxville and Boulder Creek at Maxville. The criteria and results are described in this section.

E4.1 SIMULATION PERIOD AND BOUNDARY CONDITIONS

The simulation was performed from 1989 through 2010. 1989 through 1991 was used as a "warm-up" period to allow some of the initialized variables to reach a steady-state. This lowers the reliance on initial values and initial value estimation procedures, as these parameters have several years in which to reach a steady-state. The model was then calibrated on the period 1997–2010, and validated on the period 1992–1996. Model calibration refers to the process of adjusting model parameters to obtain a fit to observed data. It is advantageous for the calibration period to include years of high and low flows, which are met with the chosen calibration period. Once the model adequately reproduces observed values, it is then run with another dataset from a different time period to re-test (validate) the performance of the model.

The annual daily mean streamflow at the Flint Creek near Drummond USGS gage shows that the modeled period was characterized by a wide range of both high and low flow years (**Figure E4-1**). For a scale of reference in **Figure E4-1**, the mean annual flow characterized by the "0" value on the y-axis is 125 cfs. While it is always ideal to have a representative time period, low flow periods are generally more reactive to nutrients stresses than high flow periods because low flow conditions often occur in the late summer when stream temperatures are warm. Warm water temperatures, slower flowing streams, and shallower water depths are all favorable conditions for algal growth and the resulting negative impacts to stream aesthetics and aquatic habitat. Because TMDLs must consider seasonality and the most critical time period for each pollutant, it is advantageous to have at least a portion of the simulation period with low flow water years which was achieved in the chosen model period.

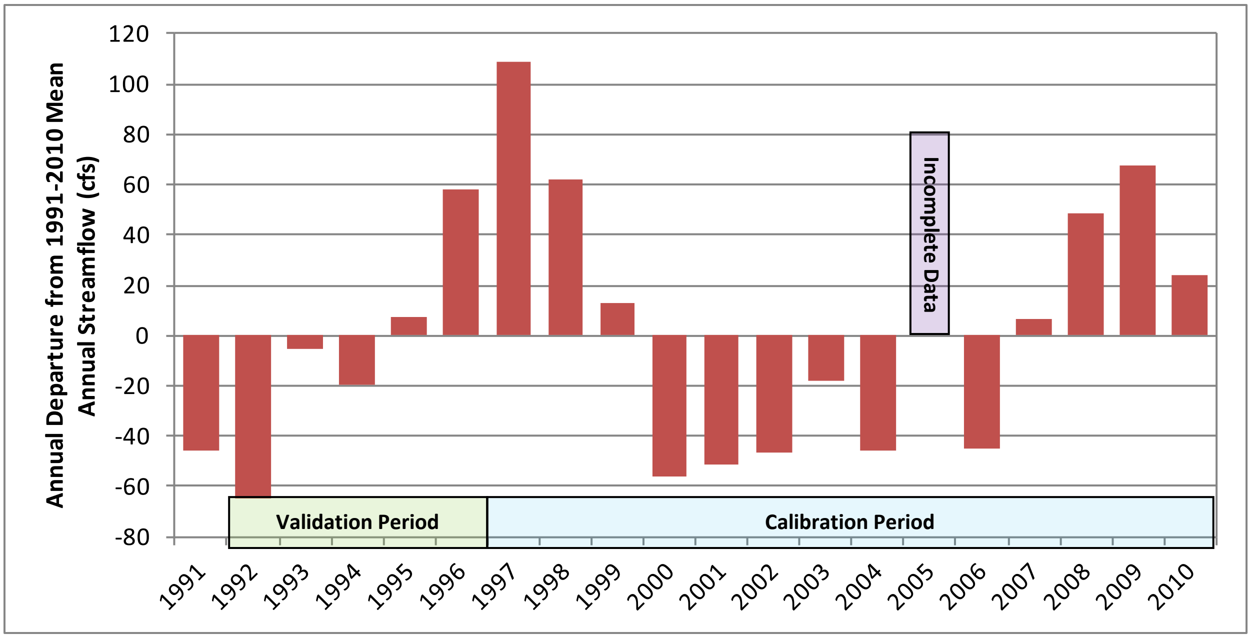

Figure E4-1. Departure from Mean Annual Streamflow for Flint Creek near Drummond USGS Gage

Boundary conditions are mostly geographic for this modeling effort (**Figure E4-2**). There is one intra-basin transfer of water as described previously from the East Fork Rock Creek Reservoir. There is also some water that exits the watershed directly into the Clark Fork River separate from the water in Flint Creek (Voeller and Waren, 1997). That water flows out through Lorranson Creek west of Flint Creek, and is likely due to the Allendale Canal diversion (Voeller and Waren, 1997). Based on 22 measurements by DNRC in 1994 through 1996 and 6 months of daily monitoring by the USGS in 1995, the flow in Lorransen Creek varies from less than 1 cfs up to 15 cfs.

E4.2 Water Budget

The overall output water budget is shown in **Table E4-1**. This is from the standard output file in SWAT (output.std) and shows the annual average water budget for the modeling period. Although this data is not used for the calibration, it does provide a check on the overall water budget values. The ratio of surface runoff to precipitation and evapotranspiration to precipitation are similar to those observed in other modeling efforts in western Montana (Montana Department of Environmental Quality and U.S. Environmental Protection Agency, Region 8, 2011) and in other semi-arid climates (Tateishi and Ahn, 1996).

Table E4-1. Average Annual Water Budget Values (from the SWAT output.std File)

Parameter	Value (in/year)	Percentage of Precipitation (%)
PRECIPITATION	19.7	-
SNOWFALL	11.0	55.9%
SNOWMELT	10.1	51.1%
SUBLIMATION	1.1	5.6%
SURFACE RUNOFF FLOW	0.8	4.1%
LATERAL SOIL FLOW	2.1	10.9%
DEEP AQUIFER RECHARGE	1.5	7.7%
TOTAL AQUIFER RECHARGE	6.1	30.9%
EVAPOTRANSPIRATION	13.4	68.3%

E4.3 Evaluation Criterion

Two model performance statistics were used to assess monthly and daily predictions of the SWAT model. The first is relative error, which is a measure of the average tendency of simulations to be larger or smaller than an observed value. Relative error is defined as the deviation between simulated ($Y_{i,sim}$) and observed ($X_{i,obs}$) values, where optimal relative error is 0.0, and positive and negative values reflect bias toward over- or under-estimation of measured values, respectively. Van Liew et al. (2005) suggested relative error values <±20% are "good," while more strict guidelines have been suggested elsewhere. For the purpose of this project, due to the high amount of irrigation effects, which were difficult to simulate, relative error < ±20% was considered to be sufficient for model calibration. Relative error is calculated as:

Table E4-2. SWAT Calibration Parameters

Parameter	Description	Calibrated Value[(1)]	Range of Values Tested in Calibration[(1)]	SWAT Suggested Range[(1)]	Units
SFTMP	Snowfall temperature	5.0	(-1)–5	(-5)–5	°C
SMTMP	Snowmelt base temperature	2.5	1–4	(-5)–5	°C
SMFMX	Melt factor for snow on June 21	3	1–5	0–10	mmH_2O/°C-day
SMFMN	Melt factor for snow on December 21	2	0.5–3	0–10	mmH_2O/°C-day
SNOCOVMX	Minimum water that corresponds to 100% snow cover	100	40–100	0–500	mm H_2O
SNO50COV	Fraction of snow volume that corresponds to 50% cover	0.1	0.1–0.8	0–1	Dimensionless
TIMP	Snowpack lag factor	0.01	0.01–0.2	0–1	Dimensionless
SURLAG	Surface runoff lag time	1	0.05–4	1–24	Days
SPCON	Linear parameter for sediment re-entrainment	0.0001	0.0001–0.001	0.0001–0.01	Dimensionless
SPEXP	Exponent parameter for sediment re-entrainment	2.2	1–2.2	1–2	Dimensionless
ESCO	Soil evaporation compensation factor	0.95	0.1–0.95	0–1	Dimensionless
EPCO	Plant water uptake compensation factor	1	0.4–1	0–1	Dimensionless
SLOPE	HRU slope steepness	0.006–0.71	NA	0–1	m/m
SLSUBBSN	Average slope length	9–121	9–121	0–90	m
GW_DELAY	Delay time for aquifer recharge	250	30–250	0–500	Days
ALPHA_BF	Base flow recession constant	0.4	0.1–0.9	0–1	Days
GW_REVAP	Revap coefficient	0.2	0.1–0.2	0.002–0.2	Dimensionless
REVAPMN	Threshold depth for “revap” to occur	100	100–250	0–1,000	mm
GWQMN	Threshold depth for return flow to occur	100	100–1,000	0–1,000	mm
RCHRG_DP	Deep aquifer percolation fraction	0.25	0.05–0.25	0–1	Fraction
CH_K(2)	Effective hydraulic conductivity of main channel	64, 640	1–640	0–1,000	mm/hr
CH_COV1	Channel erodibility factor	0.6	0.25 – 0.6	0–1	Dimensionless
CH_COV2	Channel cover factor	0.50	0.25 – 0.5	0–1	Dimensionless
CN	Curve Number	25–92	25–92	25–92	Dimensionless
USLE_C	cover management factor	0.001–0,03	0.001–0.03	0.001–0.5	Dimensionless

[(1)] Multiple values or range of values indicates multiple values used for different sub-basins, HRUs, crop types, or soil types

There are four USGS streamflow gages in the watershed with sufficient data for calibration (**Figure E4-2**) and three were used for calibration: Flint Creek at Maxville; Boulder Creek at Maxville; Flint Creek near Drummond. The fourth gage (Flint Creek near Southern Cross) was not used because of its proximity to the upstream Flint Creek Dam at Georgetown Lake; the streamflow data from this gage were used in the model as the daily discharge from the dam as there are insufficient records of direct dam releases. The most downstream gage, Flint Creek near Drummond, is 1.7 miles above the confluence of Flint Creek and the Clark Fork River. The flows in Flint Creek at its confluence with the Clark Fork River are generally larger than at the upstream USGS gage due to groundwater inflows. From April 26 through November 8, 1995, daily flow measurements were collected at the mouth of Flint Creek. During that time period, the average flow at the mouth was 9.3 cfs higher than measured at the Flint Creek near Drummond gage.

The runoff contribution area to the uppermost calibration point in the SWAT model, Flint Creek at Maxville gage, includes the southern two-thirds of the watershed including various land uses from un-altered forested and range land, human-altered irrigated and grazed land, and a large reservoir (**Figure E4-2**). The next calibration point is the Boulder Creek at Maxville gage. The runoff contribution area to this gage is primarily unaltered range and forest land and a large portion of this sub-watershed is comprised of high elevation terrain. This gage is located above the mouth of Boulder Creek; Boulder Creek enters Flint Creek immediately below the Flint Creek at Maxville gage. The final calibration point, Flint Creek near Drummond gage, combines the flow from the previous two gages and collects runoff from un-altered forested and range land in addition to human-altered irrigated and grazed land.

The Boulder Creek at Maxville USGS gage is used as a comparison to other gages in the watershed (see **Figure E4-2**) because the sub-basins that drain to the Boulder Creek gage have little irrigation influences. Without significant irrigation effects, the Boulder Creek hydrograph has a smoother and more natural shape than the two other calibration points that have significant irrigation influences.

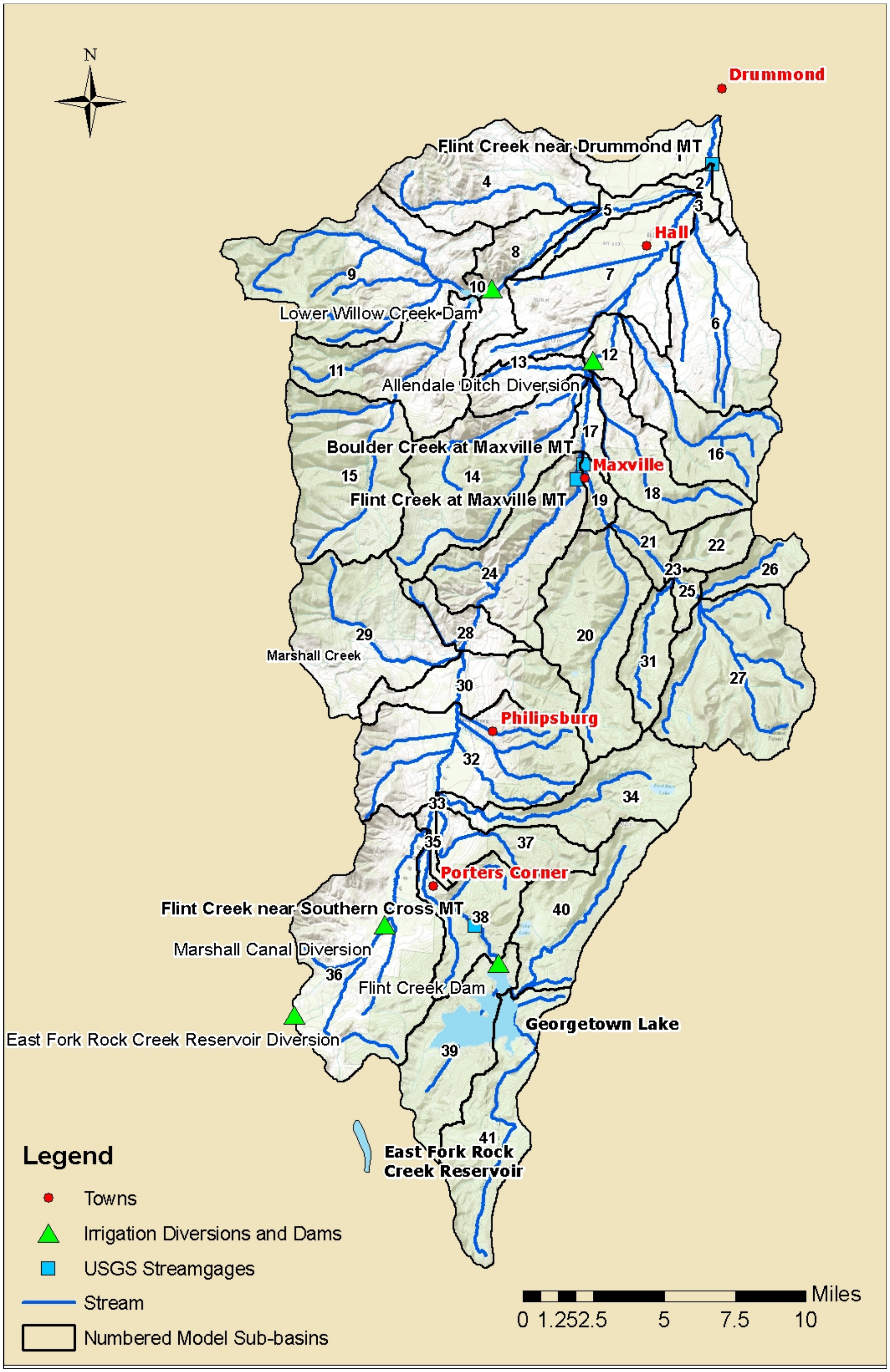

Figure E4-2. Hydrology Gages and Irrigation Diversions in the Flint Creek Watershed

Error statistics were substantially better for the Boulder Creek at Maxville site compared with the two sites located on Flint Creek (see **Table E4-3**). This is likely due to the amount of water diverted and irrigation associated with Flint Creek that is not present in the sub-watersheds contributing to Boulder Creek. Despite the complexity of human-caused influences in the Flint Creek watershed both error criteria were met annually for the three calibration sites. Error statistics are also presented for the growing season (July 1 through September 30) as that is the time when nutrients create the most significant effects on surface waters. During the growing season the relative error criteria were also met for all three stations, but the Nash-Sutcliffe coefficient of efficiency criteria were not met for both Flint Creek stations. Those error criteria at the Flint Creek sites would likely improve significantly with more accurate diversion timing and flow volumes.

Table E4-3. Daily Calibration Metrics (1997–2010)

USGS Gage	Time Period[1]	Measured Mean Total Volume (acre-feet)	Simulated Mean Total Volume (acre-feet)	Relative Error (%)	Nash-Sutcliffe Error
Flint Creek at Maxville	Annual	910,538	859,982	-5.6	0.44
	Growing Season	269,323	243,546	-9.6	-0.02
Boulder Cr. at Maxville	Annual	423,919	472,300	11.4	0.71
	Growing Season	77,512	82,265	6.1	0.56
Flint Cr. near Drummond	Annual	1,124,856	1,052,820	-6.4	0.41
	Growing Season	183,747	170,610	-7.2	0.35

[1] Growing season time period is July 1 through September 30

E4.4.1 Flint Creek at Maxville Streamflow Calibration

The average of the calibrated daily flows from 1997 to 2010 at the bottom of the SWAT model sub-basin 24 are compared to the average of the measured flows for the Flint Creek at Maxville USGS gage in **Figure E4-3**. Average daily flows over the time period are used here rather than the running hydrograph over the 14 years of the calibration period as trends are easier to discern and discuss. The complete 19 year hydrographs (including both the calibration and validation time periods) are provided in **Attachment ED**.

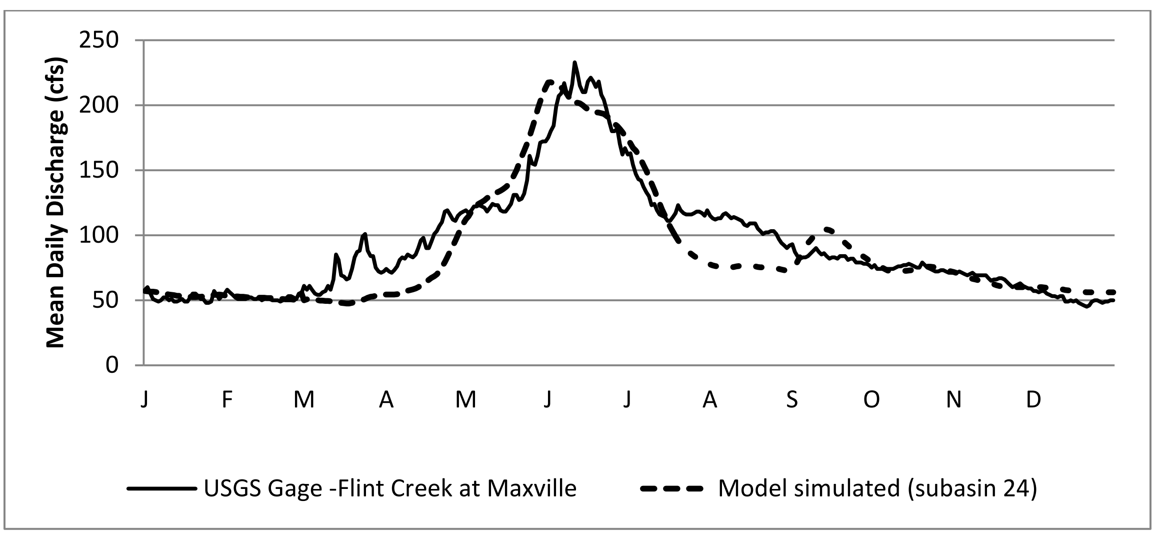

Figure E4-3. Mean Measured (1997–2010) and Mean Simulated (1997–2010) Daily Hydrology for the Flint Creek at Maxville USGS Gage

The annual water balance was well within the +/-20% relative error criteria at -5.6% (meaning the simulated values under-predict the measured values), the growing season relative error (July through September) was also acceptable at -9.7% (**Table E4-3**). The Nash-Sutcliffe coefficient of efficiency values were acceptable during the annual period (0.44) but were unacceptable during the growing season (-0.02). The poor Nash-Sutcliffe coefficient of efficiency for the growing season is primarily due to an unnatural flattening of the measured hydrograph that begins around mid-July and lasts into early August (**Figure E4-3**). The term “unnatural” is used as in comparison to a stream gage that drains primarily unaltered land such as the Boulder Creek at Maxville gage. The hydrograph flattening is likely due to irrigation return flows from the early season flood irrigating that occurs in the Philipsburg area, and is not being accurately re-created in the model. Rather, the SWAT model predicts the hydrograph rise from return flow to occur in September when irrigation diminishes in the valley. A DNRC study (Voeller and Waren, 1997) noted that return flows occur quicker in this area of the watershed than in other sections and attributed that mainly to two causes. The first is a shallow water table that has limited capacity to store irrigation water, and the second is a shallow clay layer seen in one well that may create nearly direct runoff conditions for excess irrigation water in some parts of this area. Attempts to re-create this early return flow trend by modifying groundwater parameters that control the rate of groundwater movement to stream reaches (ALPHA_BF, GW_DELAY and GWQMN) were not successful. The earlier than expected rise in the hydrograph does not appear to be a function of reduced irrigation diversions after the early July alfalfa and hay cutting because according to limited 1994–1996 flow measurements (Voeller and Waren, 1997) from the Marshall Canal diversion, the diversions do not appear to be reduced in late July or August as compared to June or early July values. Although, there is only one cutting of hay/alfalfa in this area around early July, the irrigators continue to irrigate those fields after the first cutting to promote healthy vegetation for the following year (Montana State University County Extension Agent, Lucas, Dan, personal communication 4/23/2013). Additional evidence that irrigation continues through the end of summer is supported by limited 1994–1996 flow measurements (Voeller and Waren, 1997) at the mouth of Marshall Creek (which drains the water remaining in the Marshall Canal after it flows through the irrigated areas) below Philipsburg which does not show any noticeable increase in flows after the harvest in early July.

During the modeling period there has been some conversion of flood irrigated land to sprinkler irrigation which may have slowly altered the hydrograph between 1989 and 2010, but this change in irrigation practice is not discernible in the hydrograph (**Attachment ED**).

Other portions of the annual curve have noticeable differences between the simulated and measured streamflows (**Figure E4-3**). The simulated annual peak occurs slightly earlier than the measured peak which is primarily related to spring snowmelt parameters used in the model (specifically SMTMP and TIMP, see **Table E4-2**). These controlling factors are defined on a watershed basis and cannot be specified on a sub-basin or HRU level in the SWAT model. Therefore, those parameters were set at values that on average worked best for all three calibration points. Those parameters could be varied to provide a better match to the annual peak at this calibration site, but that would decrease the correlation at the other calibration sites.

During the calibration process the simulated streamflow at this location was consistently lower than the measured streamflows. This difference was particularly noticeable during base flow periods in the fall and winter when the difference was consistently around 15 cfs. This consistent under-estimation indicated that a constant source unrelated to more transient climate and irrigation effects may not have been accounted for in the model. Water seepage into the groundwater from Georgetown Lake was the most obvious unaccounted groundwater source. SWAT allows the user to specify the seepage rate from a reservoir to maintain the correct water levels in the reservoir but then that water is lost from the system – it does not go into groundwater. Therefore, the leakage from Georgetown Lake had to be added to the system as a point source in a lower sub-basin (sub-basin 38 was used). Using existing lake morphology data and reasonable values from published hydraulic conductivity tables, an average constant seepage rate that matched the 15 cfs discussed above was calculated. The data used included an estimated average area of Georgetown Lake at its normal level, 2,122 acres (Stafford and Ahl, 2011), and an estimate of lake bottom sediments hydraulic conductivity of 0.01 ft/day. The hydraulic conductivity of the lake bottom sediments was used to estimate the long-term lake infiltration rate (Bouwer, 2002). Because there is no site-specific information available (Stafford and Ahl, 2011), the hydraulic conductivity of the lake sediments was estimated from near the middle of the range of silty materials (Freeze and Cherry, 1979). The additional 15 cfs slightly improved the Nash-Sutcliffe coefficient of efficiency for the Flint Creek at Maxville gage, and also provided an improved visual match between simulated and measured values.

The growing season values were more difficult to calibrate due to higher variability in natural effects (e.g., evapotranspiration, plant uptake, and precipitation events), and human-caused effects (e.g., irrigation, water diversions, return flows, etc.). Also, due to low summer flows, a small difference in simulated versus observed flows can create a large difference in the error metrics. Additionally, the year-to-year variability of irrigation practices makes it difficult to simulate accurately. In high runoff years irrigators use more water, and in low years they use less. This trend is difficult to capture in the management files because most diversion volumes are not available. While the model does limit irrigation when streamflows get too low, it still cannot provide an exact replication of actual landowner practices year to year. Growing season flow calibration involved manipulation of groundwater and lateral flow parameters to increase base flow accuracy in the SWAT model. Parameters in the groundwater module, ALPHA_BF, GWQMIN, and GW_DELAY (see **Table E4-2**), which can control the movement of groundwater, were adjusted to better calibrate to the irrigation related trends in the hydrograph. One source of error may have been the diversions from the East Fork Rock Creek Reservoir, but the error metrics for years with measured diversion rates were not better than those years with extrapolated diversion rates. Better calibration might be achieved with a detailed groundwater model of the watershed but one does not exist for this watershed.

The poor metrics for the growing season versus the annual results indicate that the information supplied to the SWAT model is not as accurate in characterizing certain parameters during the growing season months. To determine possible causes for the poor growing season metrics the results from this calibration point, which has human-caused influences, was compared to another calibration point (Boulder Creek at Maxville) that has little active human-caused influences. Based on the good annual and growing season metrics observed at the Boulder Creek calibration point, the poor results at the Flint Creek at Maxville site are determined to be due human-caused stressors (rather than errors in climatic parameterization) that are not being adequately quantified in the SWAT model. Those stressors could be related to irrigation practices, or irrigation diversions. One possible explanation is that there have been water calls by senior water rights holders on junior water rights in the watershed during the modeling period that have not been included in the model. Information on whether specific water calls occurred during the modeling period are not available, but if some did occur it would have most likely been during the western Montana drought in the late 1990s and early 2000s (Montana State University County Extension Agent, Lucas, Dan, personal communication 4/23/2013). Those drought years are apparent in the USGS hydrographs (**Attachment ED**). If widespread water calls had occurred it could have a significant effect on streamflows for specific years that the SWAT model could not accurately simulate. As mentioned previously, quick irrigation return flows into Flint Creek that the model did not replicate may also be causing the differences between measured and simulated water levels.

E4.4.2 Boulder Creek at Maxvillle Streamflow Calibration

The average of the calibrated daily flows from 1997 to 2010 at the bottom of sub-basin 19 are compared to the average of the measured flows for the Boulder Creek at Maxville USGS gage in **Figure E4-4**. Average daily flows over the time period are used here rather than the running hydrograph over the 14 years of the calibration period as trends are easier to discern and discuss. The complete 19 year hydrographs (including both the calibration and validation time periods) are provided in **Attachment ED**.

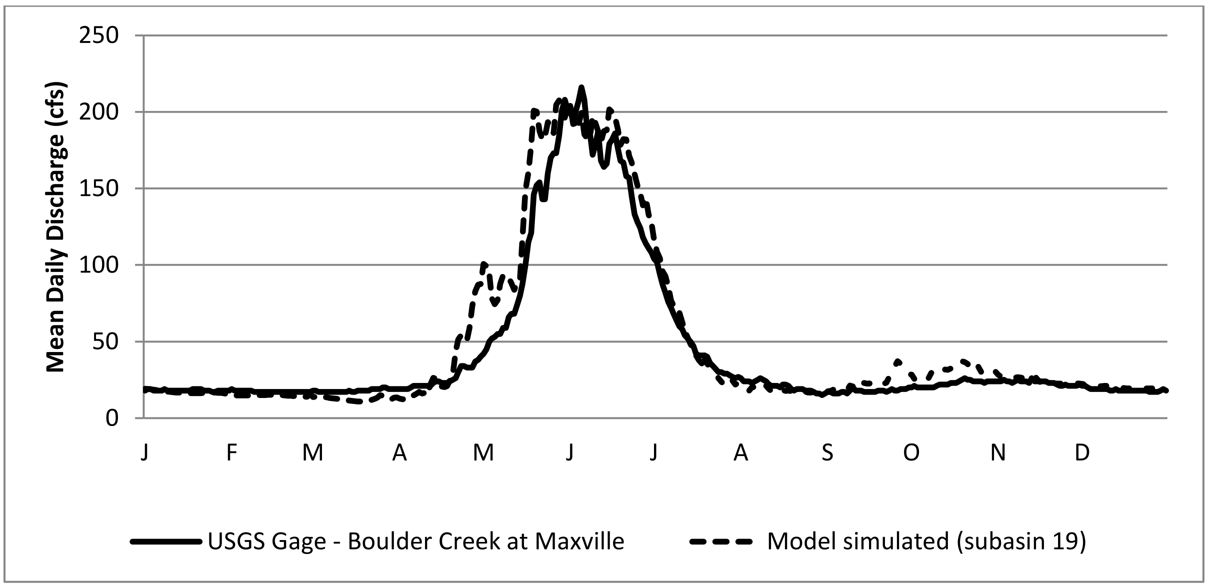

Figure E4-4. Mean Measured (1997–2010) and Mean Simulated (1997–2010) Daily Hydrology for the Boulder Creek at Maxville USGS Gage

The annual water balance was good and within the +/-20% relative error criteria at 11.4% (simulated values over-predict), the growing season (July through September) was better at 6.1% (**Table E4-3**). The Nash-Sutcliffe coefficient of efficiency values were good during both the annual period (0.71) and during the growing season (0.56). Of the three calibration points, this gage is the one that has very little active irrigation effects or other current human-caused effects, and subsequently has the best calibration statistics of the three. The only noticeable differences between simulated and measured are during the spring runoff period from early April to mid-June. This difference could have been reduced by modifying some of the snowmelt parameters such as SMTMP and TIMP (see **Table E4-2**), however, that would have created greater differences in the two other streamflow calibration points as those values are defined on a watershed basis and cannot be specified on a sub-basin or HRU level in the SWAT model. The SMTMP and TIMP parameters were set at values that provided the best overall fit to all three gages. This gage drains primarily high elevation mountainous terrain, which could partially account for the different spring runoff characteristics compared to the other gages that include more variable land uses.

Another feature in the simulated hydrograph is a short term fluctuation and flattening of the curve in early May. This gage drains sub-basins that are nearly entirely comprised of rangeland and forest that have their growing season set to begin on May 1 of each year in the SWAT model. The fluctuation shows the onset of plant water uptake in the SWAT model on that date.

E4.4.3 Flint Creek near Drummond Streamflow Calibration

The average of the calibrated daily flows from 1997 to 2010 at the bottom of the SWAT model sub-basin 2 are compared to the average of the measured flows for the Flint Creek near Drummond USGS gage in **Figure E4-5**. Average daily flows over the time period are used here rather than the running hydrograph over the 14 years of the calibration period as trends are easier to discern and discuss. The complete 19 year hydrographs (including both the calibration and validation time periods) are provided in **Attachment ED**.

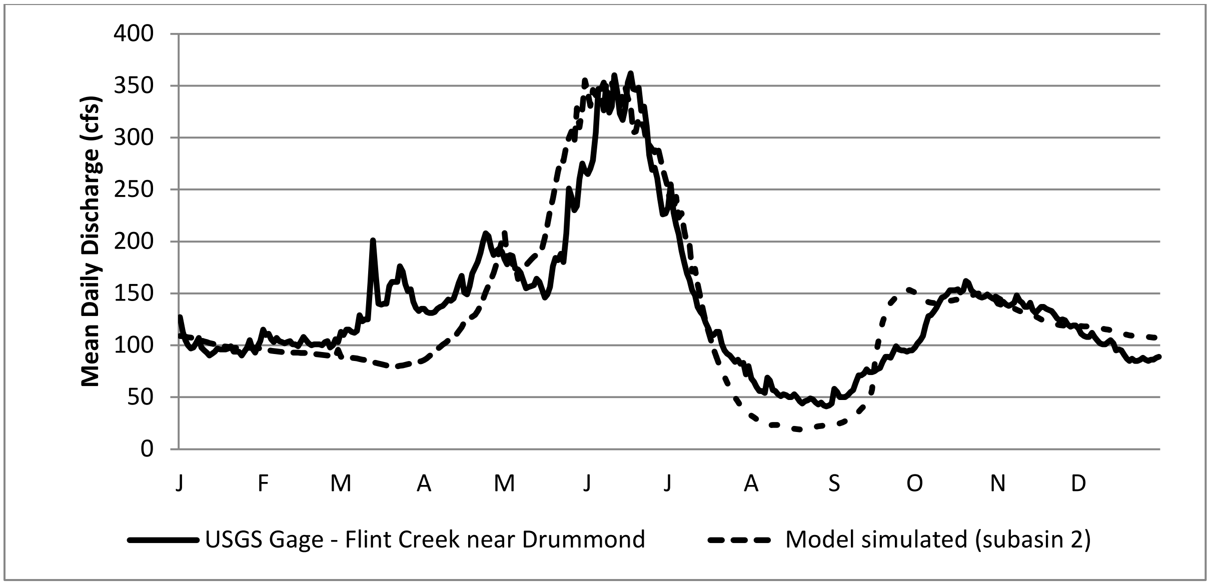

Figure E4-5. Mean Measured (1997–2010) and Mean Simulated (1997–2010) Daily Hydrology for the Flint Creek near Drummond USGS Gage

The annual water balance was good and within the +/-20% relative error criteria at -6.4% (simulated values under-predict), the growing season (July through September) was also good at -7.2% (**Table E4-3**). The Nash-Sutcliffe coefficient of efficiency values were acceptable during the annual period (0.41) and lower during the irrigation season (0.35) but still acceptable given the difficulties matching irrigation effects. This gage includes the combined flow of the other two gages; it is below the Allendale canal diversion and several other irrigation diversions. The average daily streamflow at the Flint Creek near Drummond gage is less than the combined flow of the other two upper gages from early May to early October due to irrigation diversions and possibly groundwater seepage (see **Figure E2-2**). For the remainder of the year, the streamflow at this gage is greater than the combined flow of the other two gages.

The mean simulated streamflow is consistently higher than the mean measured streamflow (see **Figure E4-5**) during the spring and early summer months by up to 50 cfs. Part of this discrepancy may be due to outflows from the watershed via groundwater, irrigation ditches, and springs that are modeled in SWAT as exiting the watershed in Flint Creek. Those types of outflows were reported to combine for an additional 35 cfs during the summer months and 20 cfs for the remainder of the year (Voeller and Waren, 1997).

Both the measured and simulated hydrographs show an unnatural and pronounced decrease in flow in early May as the spring runoff is beginning due to the onset of irrigation diversions. The simulated hydrograph provides a good match to the measured values early in the growing season but in September there are significant differences between the two. The measured hydrograph shows an unnatural and steady rise in the hydrograph from late August through mid-October. This rise is most likely due to a combination of early season irrigation return flows and the gradual decrease in irrigation diversions as the growing season ends. The SWAT model mimics this rise, although at a much faster rate than is observed. This portion of the hydrograph could not be simulated better because there was no information available as to when each diversion is turned off at the end of the growing season. Without specific knowledge of how each landowner reduces or turns off irrigation diversions, the irrigation season was ended on a specific date every year in the SWAT model. Another reason for the poor match is that the measured hydrograph in **Figure E4-5** is using mean values and the gradual rise of the USGS gage hydrograph is an average of 14 years which, in this case, smooths out the actual rapid rise in streamflow that is seen at the end of each individual irrigation season. The annual more rapid rise is evident in the 19 year running hydrograph (**Attachment ED**). Therefore, the model results have a better year-to-year match to the late growing season shape of the measured hydrograph than is depicted in **Figure E4-5**.

E4.4.4 Hydrology Calibration Summary

The growing season metrics are not as good as the annual metrics, which is most likely due to the inability to properly simulate irrigation diversions on a day to day basis. However, based on the good growing season metrics for the Boulder Creek at Maxville gage, the framework of the SWAT model accurately represents the hydrology prior to management diversions. Therefore, with regards to the hydraulics calibration, the model is a valid tool for its intended purpose of estimating changes in nutrients loadings with changing management scenarios.

E4.5 Hydrology Validation

Model validation is the independent process by which a model is tested against “new” data, usually from a different time period than the calibration period. If the calibrated model predicts the validation period, it is considered to be “validated.” A validated model provides more confidence that the model can predict future conditions.

The calibrated model was run for the 5-year validation time period 1/1/1992 through 12/31/1996. The annual validation results were similar to the calibration results (**Table E4-4**). All the relative error values were within the +/- 20% acceptable value, however one of the Nash-Sutcliffe coefficient of efficiency values (for the Flint Creek near Drummond (gage)) was 0.34, slightly below the acceptable value of 0.36. The growing season validation metrics varied in relation to the calibration metrics. For the Boulder Creek at Maxville gage the growing season validation statistics were substantially worse than the growing season calibration statistics (**Table E4-4**). At that gage the SWAT model was accurate in predicting the hydrograph trends during the validation period with a coefficient of determination (r^2) value of 0.84 for the simulated versus measured values; however, streamflow volumes were consistently over-predicted, which provided a large relative error (42.5%) and a low Nash-Sutcliffe coefficient of efficiency (-0.29). Based on measurements at the Boulder Creek at Maxville gage, the 5 years previous to the start of the validation period had cumulative annual streamflows that were 18 to 42% lower than the 1989–2010 average for that gage. The poor growing season metrics for the Boulder Creek at Maxville gage may have been caused by the model not being able to account for the unusually dry conditions that existed prior to the model period causing the model to over predict flows in the earlier years of the model period. In contrast, while the SWAT model over-predicted growing season flows at the Boulder Creek gage, it under-predicted flows at the other two calibration gages (**Table E4-4**). These contradictory errors are possibly due to changes in irrigation diversions, withdrawals and timing related to the drought period prior to and at the start of the validation period. The growing season validation metrics for the Flint Creek at Maxville gage are mixed compared to the calibration metrics – the relative error has increased from -9.6% to -21.7%, but the Nash-Sutcliffe coefficient of efficiency has improved from -0.02 to 0.2.

Table E4-4. Daily Validation Metrics (1992–1996) Compared with Calibration Metrics

USGS Gage	Time Period[1]	Relative Error (%) [calibration period metric]	Nash-Sutcliffe Error [calibration period metric]
Flint Creek at Maxville	Annual	-11.6 [-5.6]	0.36 [0.44]
	Growing Season	-21.7 [-9.6]	0.20 [-0.02]
Boulder Cr. at Maxville	Annual	15.4 [11.4]	0.71 [0.71]
	Growing Season	42.5 [6.1]	-0.29 [0.56]
Flint Cr. near Drummond	Annual	-2.1 [6.4]	0.34 [0.41]
	Growing Season	-14.7 [-7.2]	0.63 [0.35]

(1) Growing season time period is July 1 through September 30

A visual representation of the hydrology validation is provided for each location in **Figures E4-6, E4-7** and **E4-8**, which show the average of the 1992–1996 USGS measured flows as compared to the average of the daily flows from 1992 to 1996 predicted by the SWAT model at each of the three calibration locations. Average daily flows over the time period are used here rather than the running hydrograph over the 5 years of the validation period as trends are easier to discern and discuss. The complete 19 year hydrographs (including both the calibration and validation time periods) are provided in **Attachment ED**.

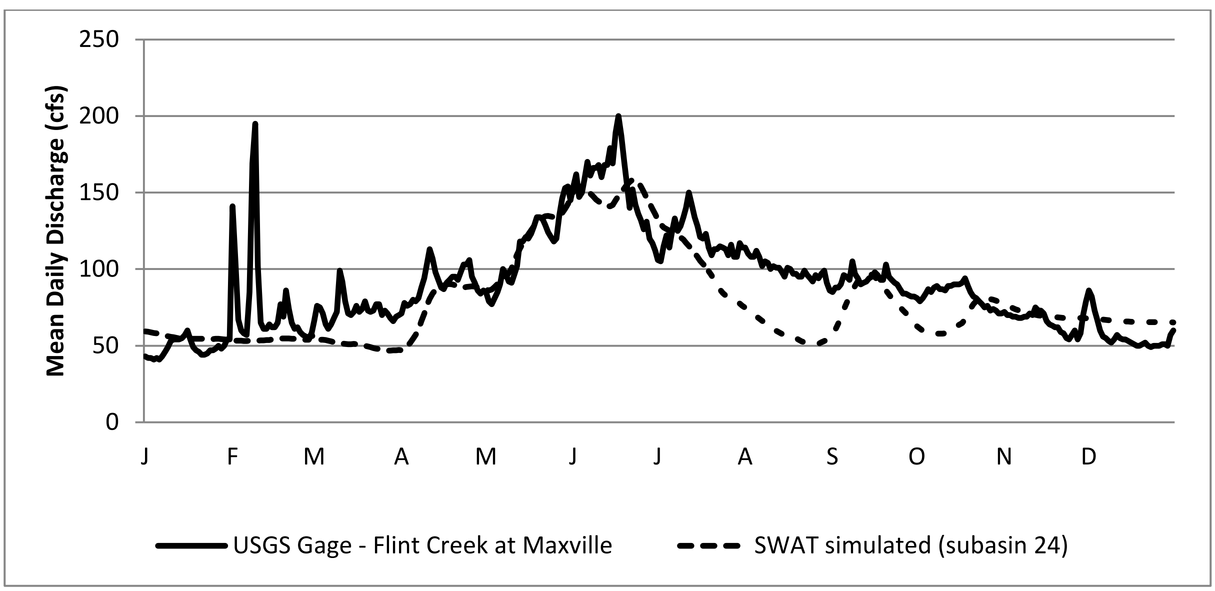

Figure E4-6. Mean Measured (1992–1996) and Mean Simulated (1992–1996) Daily Hydrology for the Flint Creek at Maxville USGS Gage

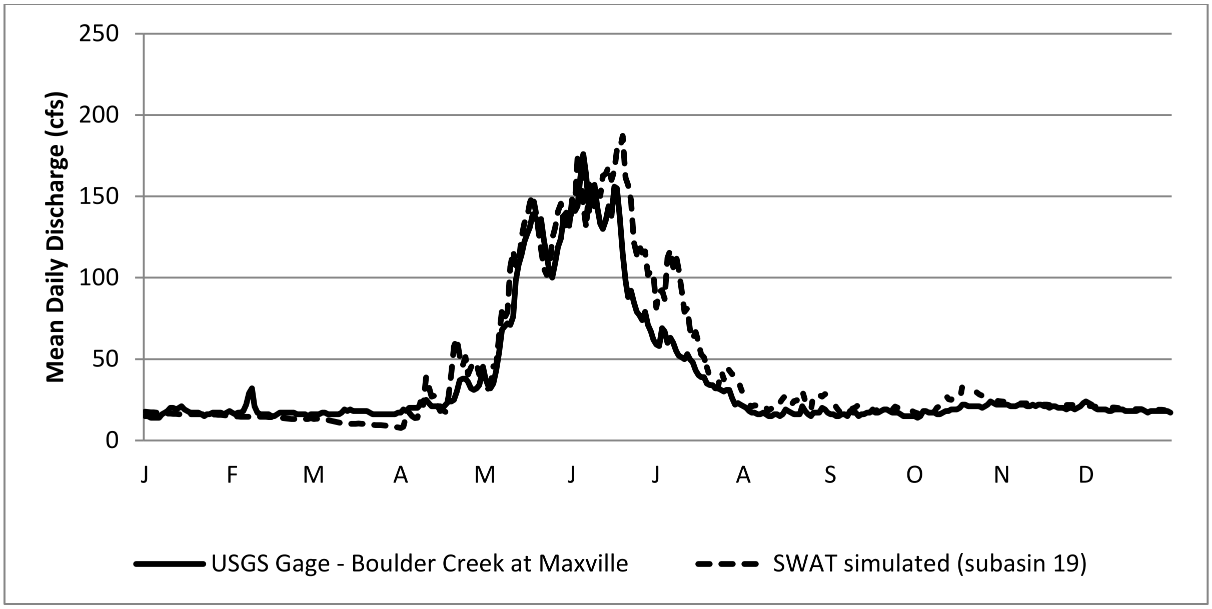

Figure E4-7. Mean Measured (1992–1996) and Mean Simulated (1992–1996) Daily Hydrology for the Boulder Creek at Maxville USGS Gage

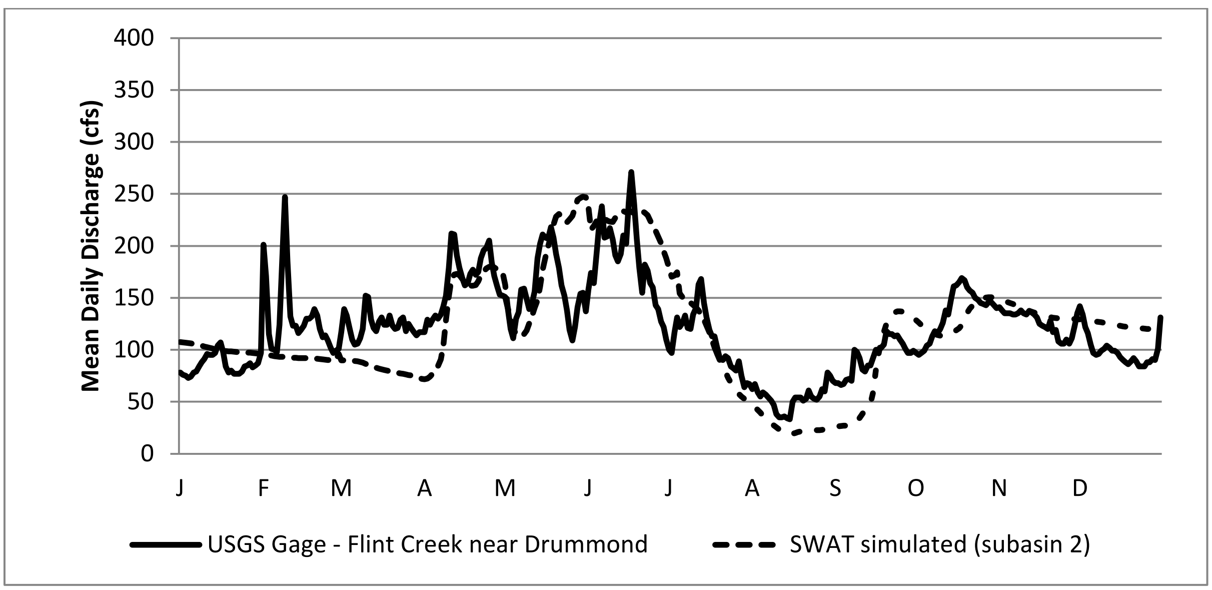

Figure E4-8. Mean Measured (1992–1996) and Mean Simulated (1992–1996) Daily Hydrology for the Flint Creek near Drummond USGS Gage

The validation results demonstrate some of the same inaccuracies as seen with the calibration period, primarily due to lack of specific field-level information on land management practices, and in some cases magnified due to the shorter averaging period. As discussed in the calibration summary, the results are considered acceptable for the intended purpose of the model to compare and choose best management practices (BMPs) for reducing nutrients loadings to streams and ultimately meet instream water quality targets.

E4.6 Sediment Calibration

The SWAT model is not being used to develop a sediment TMDL which was previously completed (Montana Department of Environmental Quality, Planning, Prevention and Assistance Division, Water Quality Planning Bureau, 2012a). However, because the sediment loading to streams includes delivery of nutrients attached to the sediment, it is necessary to calibrate the sediment prior to calibrating the nutrients loads.

Sediment is delivered to the end of each stream reach (each sub-basin in the SWAT model has one stream reach) by two separate processes – sediment delivery and sediment routing. Sediment delivery is the process by which sediment is washed off of the land surface and carried into the river channel. This happens during runoff events, and is modeled by SWAT using the Modified Universal Soil Loss Equation. Sediment routing within the river channel is a separate process where sediment can either be deposited in the river channel or sediment degradation can cause channel erosion and pick up sediment on its way to the end of the stream reach. The amount of deposition or erosion depends on factors such as the size of sediment particles, stream velocities, and streambank stability.

The Modified Universal Soil Loss Equation includes factors to account for water runoff rates, soil erodibility, cover and management, support practice (e.g., contour tillage, strip-cropping on contour, and terracing), topography, and coarse soil fragment percent. The cover and management factor in the equation is referred to as the Universal Soil Loss Equation (USLE) C (Universal Soil Loss Equation cover and management factor) and is one of the variables in the Modified Universal Soil Loss Equation that can be varied by the model user to reflect local conditions. Due to changes in cover during the growing season (e.g., plant growth, harvest, etc.) the USLE C values are re-calculated by SWAT daily by modifying a user-specified minimum USLE C factor. The default USLE C minimum values recommended in SWAT were used in the model (**Table E4-5)**.

Table E4-5. Minimum USLE C factors

Land Use	Minimum USLE C factor
Forest	0.001
Hay/Pasture	0.003
Range	0.003
Alfalfa	0.01
Spring Wheat	0.03
Barley	0.01
Urban	0.003

Another factor in the Modified Universal Soil Loss Equation is the soil erodibility factor (USLE K) – this value is derived in SWAT using information from the NRCS STATSGO soil database, but is not taken directly from the value listed in STATSGO. The USLE K value used in the SWAT model may therefore vary from the value previously used directly from STATSGO for the previously completed sediment TMDLs (Montana Department of Environmental Quality, Planning, Prevention and Assistance Division, Water Quality Planning Bureau, 2012a).

Statistical calibration (e.g., the Nash-Sutcliffe coefficient of efficiency method) of the sediment loads was not conducted because sediment data had not been collected on a frequent or regular schedule (see **Table E2-3)** to provide meaningful results using a statistical method. Instead visual matching was conducted for impaired streams with the several data points available for each stream. In addition, an annual sediment load rating curve was employed on the one location that had a longer-term record of sediment measurements, the Flint Creek near Drummond USGS gage that has 97 measurements during the model period. A sediment load rating curve uses the relationship between the days that both sediment concentrations and streamflow measurements are available to predict sediment loads in relation to measured streamflow rates. The USGS gage has daily streamflow rates for most of the model period, which provides the necessary flow data to prepare the load rating curve. The sediment load rating curve was evaluated on a logarithmic scale, and using the available streamflow data from the USGS gage provided an average sediment load of 39,554 lb/day during the modeling period (**Figure E4-9**). The model estimated an average sediment load of 47,619 lb/day at the gage, which is within 20% of the load rating curve estimate. This is an acceptable error given the relatively small number of available sediment measurements. Visual matching of measured versus predicted sediment concentrations for the other impaired streams provided adequate matches (graphs of daily simulated sediment concentrations and measured concentrations are provided in **Attachment EE**). The simulated concentrations in **Appendix E** are daily averages, and thus can vary significantly from the instantaneous measured values because sediment loads can be highly variable within a single day particularly during spring runoff and summer thunderstorms.

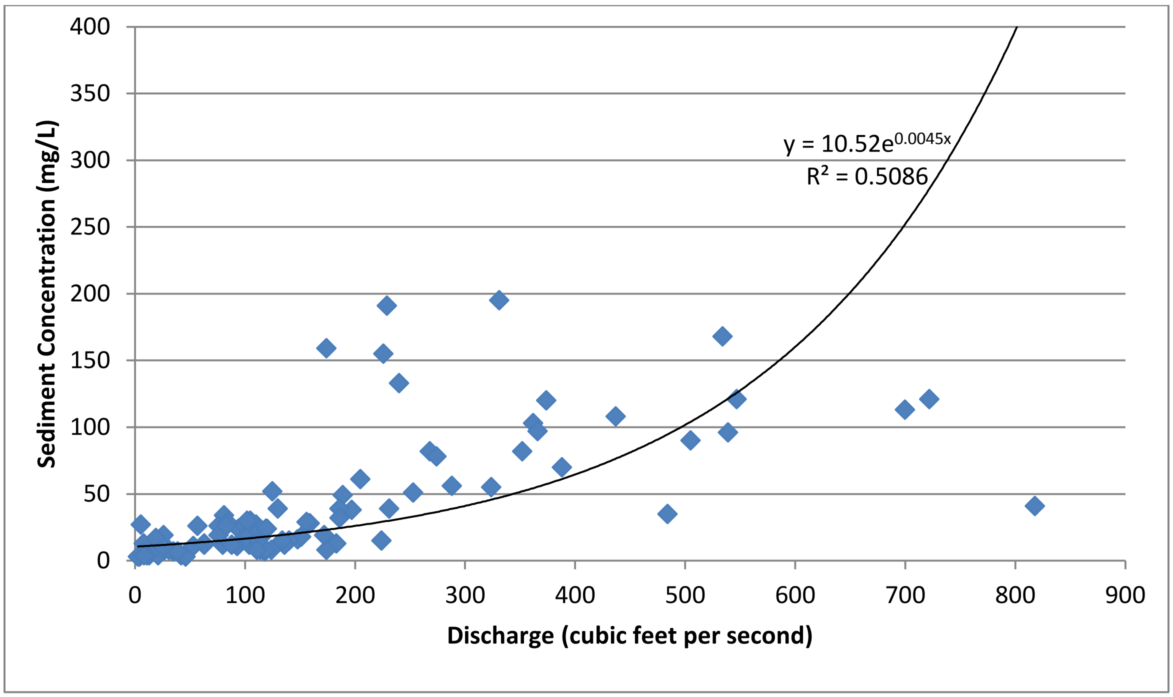

Figure E4-9. Measured Total Suspended Sediment Concentrations (Measured between 1992 and 2004) Versus Measured Discharge at the Flint Creek near Drummond USGS Gage

E4.7 Nutrients Calibration

Nutrients of concern for these TMDLs are TN, TP, and nitrate. TN includes the various forms of nitrogen: organic nitrogen, ammonia, nitrate and nitrite. TP includes orthophosphorus (which is the more soluble form of phosphorus) and organic phosphorus.

Nutrients are similar to sediments in that they are delivered to the river mouth by several separate processes, but there is an additional process in the nutrients modeling – nutrients generation (along with delivery and routing). Nutrients are a dynamic parameter that are constantly being produced and consumed. Nutrients generation is the process by which plants, rain, soils, and management practices (e.g., fertilization, cattle, and development) generate nitrogen and phosphorus in the upland areas. Delivery is the process by which nutrients are washed off of the land surface or leached into the ground and carried into the river channel. This happens both during runoff events and daily processes, and is modeled by SWAT using equations to calculate surface runoff concentrations, movement through the soil, attachment to soil that is carried away in runoff events, lateral unsaturated zone flow, and groundwater flows. Routing within the river channel is a separate process, where interactions with light, nutrients, algae growth and death, and oxygen levels are simulated via an instream nutrients model (QUAL2E) that is included within the SWAT program.

Similar to the sediment calibration, statistical calibration (e.g., the Nash-Sutcliffe coefficient of efficiency method) of the nutrients loads was not conducted because nutrients data had not been collected on a frequent or regular schedule (see **Table E2-3**) to provide meaningful results using a statistical method. The same problems present in the sediment calibration are present in the nutrients calibration, with the addition that nutrients are not only correlated to discharge, but are also strongly correlated to seasons. Soluble nutrients (nitrate, nitrite and ammonia) concentrations tend to drop in the summer when algal growth occurs, and rise as algae dies off in the fall. Therefore, not only was a daily calibration not possible, but a simple regression of all data points (regardless of season) would over-simplify the nutrients concentrations distribution. Instead visual matching was conducted for impaired streams with the available measured instream nutrients concentrations.

The instream nitrogen data used for calibration included TN, nitrate, nitrite and nitrate+nitrite data. The nitrate and nitrite data varied between individual analysis of each species and combined analysis due to the multiple entities collecting samples and the different emphasis for each entity. Because nitrite is not stable in the environment and quickly converts to nitrate, all nitrate-only measurements and the nitrate+nitrite measurements were combined and used in the model calibration as nitrate+nitrite data (this simplifies the analysis and provides more measured data points for calibration). TP is the other parameter that is included in the calibration.

The results of the daily simulated TN and TP concentrations versus the measured concentrations for each impaired stream segment and two other model sub-basins with available instream monitoring data are discussed in the following sub-sections. Data from the Flint Creek near Southern Cross were not used because that data in conjunction with data collected from Georgetown Lake were used to inform the model of the water quality being discharged from Georgetown Lake, directly above the monitoring location. Graphs of the data are included in **Attachment EF**. The nitrate+nitrite data were not included in the graphs, it was not as good as the TN calibration most likely due to the complexities of instream nutrients cycling that were not simulated as well as the loading inputs from land uses, but the results of the TN here and in the BMP scenarios discussed later are transferrable to the nitrate+nitrite loadings. In addition to the measured and simulated nutrients concentrations, the graphs in **Attachment EF** include daily precipitation from the nearest and/or most applicable weather station, simulated hydrograph, and the measured hydrograph where available. The time scale on each figure varies, as it only includes the years with instream monitoring data to compare to the simulated concentrations (different stream segments had different sample dates). Concentrations instead of loads are used in the graphs so that inaccuracies in modeled flow values are not superimposed on the nutrients calibration results.

E4.7.1 Flint Creek near Drummond

The Flint Creek near Drummond USGS gage (CFRPO-11.5 in **Figure E4-10**), located at the downstream end of sub-basin 2, has more measured TN and TP data than most of the other locations in the watershed. The simulated TN and TP concentrations show pronounced decreases and increases that correlate with spring runoff and then summer low flows, respectively (**Figure EF-1** in **Attachment EF**). The decreases are due to spring runoff dilution, increases are associated with both less dilution from spring runoff and increased irrigation withdrawals that reduce the amount of water to dilute the nutrients coming from the land surface. The simulated TN concentrations match the expected growing season decrease of soluble nitrogen due to algal growth and uptake in some years, but not every year. The simulated TP concentrations show similar annual trends and matches to the measured data as the TN results.

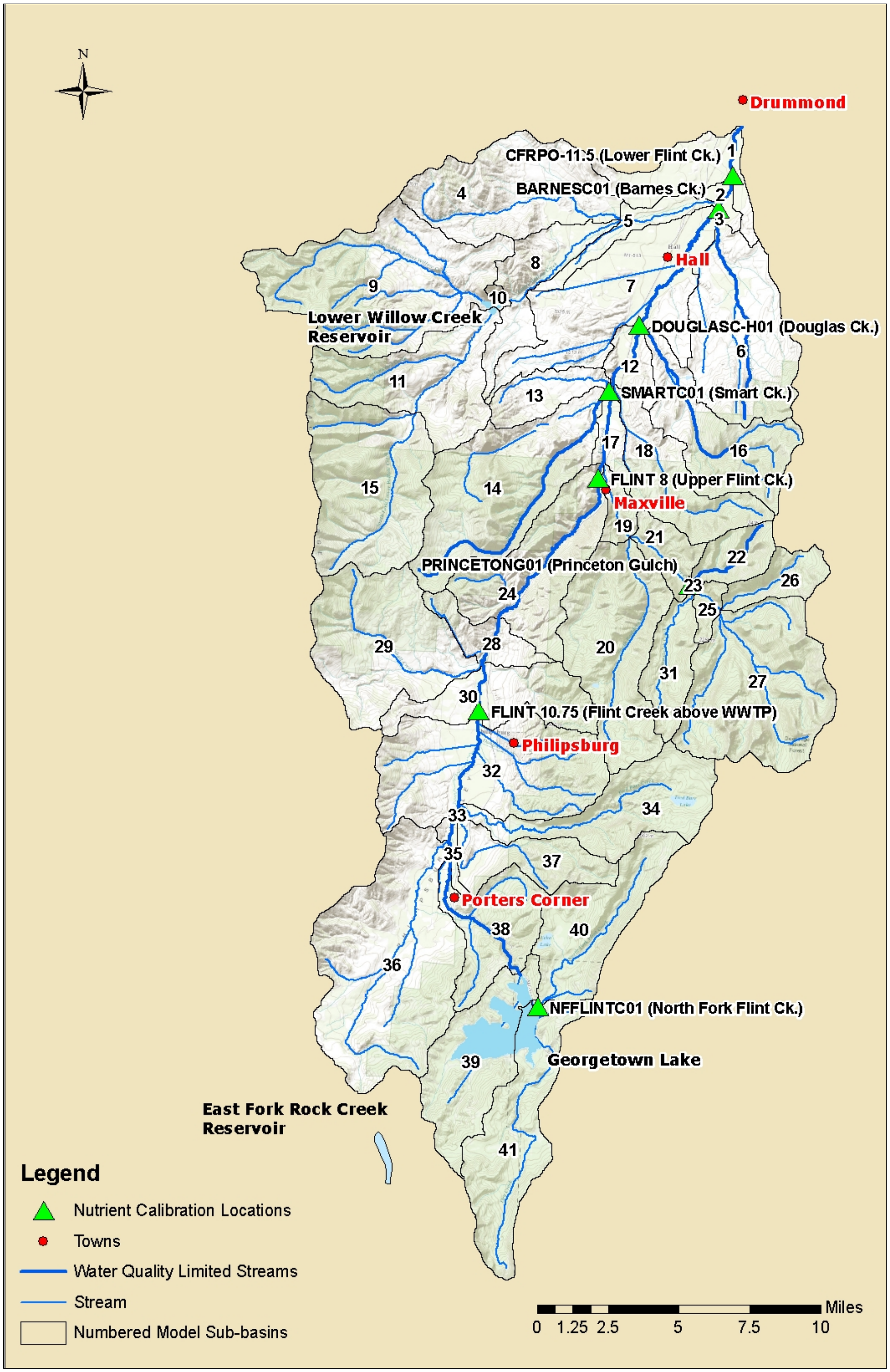

Figure E4-10. Nutrients Calibration Locations Used in the SWAT Model

E4.7.2 Barnes Creek

The mouth of Barnes Creek site (BARNESC01 in **Figure E4-10**), located at the downstream end of sub-basin 6, has five TN and TP measured data points for comparison (**Attachment EF**). The simulated TN and TP concentrations have variable accuracy to the measured data, accurately matching about half of the measured data points and over-estimating the other half. The Barnes Creek sub-basin has a large percentage of range land and thus the water quality is dominated by impacts from that land use. The significant seasonal increase in simulated TP concentrations, shown in **Attachment EF**, is due to the summer grazing of livestock in this basin, particularly from the 1% of livestock that are assumed to deposit waste directly into the stream. These elevated summer simulated concentrations match the measured TP concentrations well in the summers 2007 and 2009, but the simulated concentrations are not as accurate in the summers of 2004 and 2008. The simulated TN concentrations are similar showing a summer increase due to livestock management, with good matches to measured data in the summer of 2009, but not as good in the summers of 2004, 2007, and 2008. Some of the discrepancies between simulated values and measured data may be due to the way livestock were evenly distributed across the watershed, if less livestock are actually grazed in the Barnes Creek sub-basin than is estimated in the model that could cause the over-estimation of concentrations (the number of cattle estimated to graze during the summer in this sub-basin is 1,567). Because the Barnes Creek sub-basin has a large amount of livestock use, it would be a good location for additional high intensity growing season instream monitoring to better calibrate the livestock management assumptions used in the model.

E4.7.3 Smart Creek

The mouth of Smart Creek site (SMARTC01 in **Figure E4-10**), located at the downstream end of sub-basin 14, has five TN and TP measured data points for comparison (**Attachment EF**). The simulated TN and TP concentrations show pronounced increases that correlate with summer low flows. The simulated TN and TP concentrations have good matches to the measured concentrations. Note the pronounced and linear increase of TN and TP concentrations each summer that correlates well with the rapid streamflow decrease during the same time period.

E4.7.4 Douglas Creek

The mouth of Douglas Creek site (DOUGLASC-H01in **Figure E4-10**), located at the downstream end of sub-basin 16, has five TN and TP measured data points for comparison (**Attachment EF**). The simulated TP concentrations show pronounced increases that correlate with summer low flows, the TN concentrations show a similar but less pronounced trend. The simulated TP concentrations have good matches to the measured concentrations, while the simulated TN values tend to over-estimate the measured concentrations. As discussed in Barnes Creek, this discrepancy in TN concentrations may be related to errors in the estimation of the number of livestock grazing in the Douglass Creek sub-basin (the number of cattle estimated to graze during the summer in this sub-basin is 534).

E4.7.5 Princeton Gulch

The mouth of Princeton Gulch site (PRINCETONG01 in **Figure E4-10**), located at the downstream end of sub-basin 22, has five TN and TP measured data points for comparison (**Attachment EF**). The simulated TN and TP concentrations show pronounced increases during the spring runoff period, which is the opposite trend from the other impaired stream segments. This is likely due to the physiography of Princeton Gulch which unlike the other listed stream segments is located in the more mountainous section of the watershed with steep slopes and little human management. Due to steeper slopes, the spring runoff carries much more sediment and nutrients to the stream than in the lower streams, thus contributing to increasing concentrations with increased flows. The simulated TN and TP concentrations have good matches to the measured concentrations.

E4.7.6 Flint Creek at Maxville

The Flint Creek at Maxville USGS gage (FLINT 8 in **Figure E4-10**), located at the downstream end of sub-basin 24, has five TN and TP measured data points for comparison (**Attachment EF**). The simulated TN and TP concentrations have good matches to the measured data, but the accuracy of seasonal variations cannot be determined with the number of available instream measurements. The seasonal range of simulated TN and TP concentrations is less than at the Lower Flint site primarily due to the more consistent hydrograph that doesn't include the large spring runoff from the large Boulder Creek tributary, has less summer diversions than in the Lower Flint, and may have less groundwater losses due to the local geology.

E4.7.7 Flint Creek Above Phillipsburg Wastewater Treatment Plant

Although the Flint Creek at Maxville site is used to determine contributing sources for the Upper Flint Creek impairment and source assessment, this site (FLINT 10.75 in **Figure E4-10**) is included in the model results because it has several years of TN and TP data collected by the city of Philipsburg (**Attachment EF**). The monitoring location is in sub-basin 30 approximately 1,000 feet downstream of sub-basin 32. The data were collected monthly from July 2005 through October 2009 upstream of the city's wastewater discharge (the TN data collected prior to September 2007 are not included in **Attachment EF** because an incorrect sample preservation method was used). With more monitoring data than the Flint Creek at Maxville site, this site provides a check on the model's accuracy for the Upper Flint Creek impaired segment. The simulated TN concentrations from sub-basin 32 show pronounced decreases starting in the spring and lasting through the summer months, which is likely due to dilution from the spring runoff and then instream nutrients uptake during the summer months. Both the TN and TP simulated concentrations show variable correlation to the measured data with some years matching the trends better than others. The simulated TP seems to be consistently lower than the measured TP during winter months. This could indicate that phosphorus concentration estimated for groundwater in the model, 0.01 mg/L, could be low for this section of the watershed.

E4.7.8 North Fork Flint Creek

This site (NFFLINTC01 in **Figure E4-10**) is included because it is in a relatively undisturbed sub-basin that has had 15 instream samples analyzed for TN and TP concentrations between July 2009 and September 2010 and an additional three samples between August 2007 and August 2008 (**Attachment EF**). The data were collected by Craig Stafford of the University of Montana. This site is used as a check on the accuracy of the model's framework in a sub-basin that isn't significantly affected by human management and thus not subject to many of the management practice assumptions used in the model. The calibration to both TN and TP are generally acceptable with simulated concentrations matching many of the peaks in the earlier and later measured data, but less accurate when compared to the measured data in late 2009 and early 2010.

As a relatively undisturbed sub-basin, the North Fork Flint Creek is a good stream to compare the model results to reference streams that have been monitored by the DEQ. The Flint Creek watershed is located in the Middle Rockies Ecoregion, the DEQ has developed draft numeric nutrients standards for this area using reference streams (Suplee and Watson, 2013). For the Middle Rockies Ecoregion, the median TN and TP concentrations of the reference streams were 0.095 and 0.01 mg/L as based on 57 and 61 sites, respectively (Suplee and Watson, 2013). The draft water quality criteria proposed for TN and TP for the

Middle Rockies Ecoregion are 0.300 and 0.030 mg/L, respectively (Suplee and Watson, 2013). During the summer growing season the graph of measured and simulated TN concentrations (**Attachment EF**) for the North Fork Flint Creek show concentrations predominantly below the median reference stream concentration (0.095 mg/L), and all concentrations (except two simulated dates in 2010) below the proposed criteria of 0.300 mg/L. During the summer growing season the graph of measured and simulated TP concentrations (**Attachment EF**) for the North Fork Flint Creek show concentrations predominantly at or below the median reference stream concentration (0.01 mg/L), and all concentrations well below the proposed criteria of 0.0300 mg/L. Comparison of the simulated concentrations for TN and TP to the reference streams concentrations and proposed water quality standards shows that the SWAT model has accurately simulated TN and TP concentrations in the relatively undisturbed North Fork Flint Creek sub-watershed.

E4.7.9 Nutrients Calibration Summary

The lack of long-term, frequent, instream nutrients analyses precludes a definitive statistical analysis of the models nutrients calibration. However a subjective visual analysis indicates an acceptable match to the measured data considering the daily averaging period of the model compared to instantaneous measurements of water quality. The model results are acceptable for use in determining relative impacts of different management scenarios that are designed to reduce nutrients loadings and improve stream water quality. Those scenarios and the impacts to instream water quality are discussed in **Section E6.0**.

E5.0 Natural Background Scenario

This scenario is conducted to estimate the sources and amount of nutrients that would have been entering surface waters prior to any human-related impacts. The conditions that existed without human impacts are referred to as natural background. The nutrients loadings in the natural background scenario are compared to the loadings in the calibrated model for use in the source assessment to determine the amount of nutrients that can be attributed to human impacts. Details of the assumptions used in the natural background scenario and a summary of the results are described in this appendix. A more detailed analysis of the loadings attributed to different land uses are provided in **Section 5** of the main report.

The natural background model scenario was prepared by using the existing condition calibrated model for nutrients, the results of which were discussed in the previous section, and converting all land uses altered by humans back to their estimated condition prior to human intervention. As shown in **Figure E2-3** most human impacted lands are surrounded by range grass land use, therefore the human impacted lands were all converted to range grass land use to approximate natural background conditions. Some developed lands under existing conditions may have been forest or wetlands under natural conditions, but the percentage is likely very small and therefore using range grass instead of those land uses will not create any significant error in the scenario results.

E5.1 Nutrients Land-Use Source Assessment

Based on the comparison between the existing conditions and the natural background scenario, the amount of TN and TP loadings attributed to human use and management for the entire Flint Creek watershed are shown in **Figures E5-1** and **E5-2**. The results are broken out by land-use types and show that the sources are substantially different for TN compared with TP. The TN results (**Figure E5-1**) shows livestock and agricultural sources comprise the majority (greater than 65%) of human-caused (anthropogenic) TN, with wastewater contributing a lesser amount, (less than 9%). Natural sources of TN comprise about 25% of the current TN loading in the watershed. The TP results (**Figure E5-2**) shows a different distribution with livestock uses contributing 70% of the load, agriculture and wastewater contribute an additional 25%. Only about 5% of the TP is from natural sources. The higher percent of TP contributed from livestock (as compared to TN) is because TP is often contributed via overland means while TN has a larger contribution through the subsurface because it is more mobile through soils than TP. Livestock impacts from grazing and waste are more concentrated at the land surface (thus a relatively higher amount of TP compared to TN) while agriculture has relatively more impact through the subsurface due to such things as irrigation return flows and fertilizer migration (thus a relatively higher amount of TN compared to TP). More detailed discussion of the source assessment for each impaired stream segment is included in **Section 5** of the report.

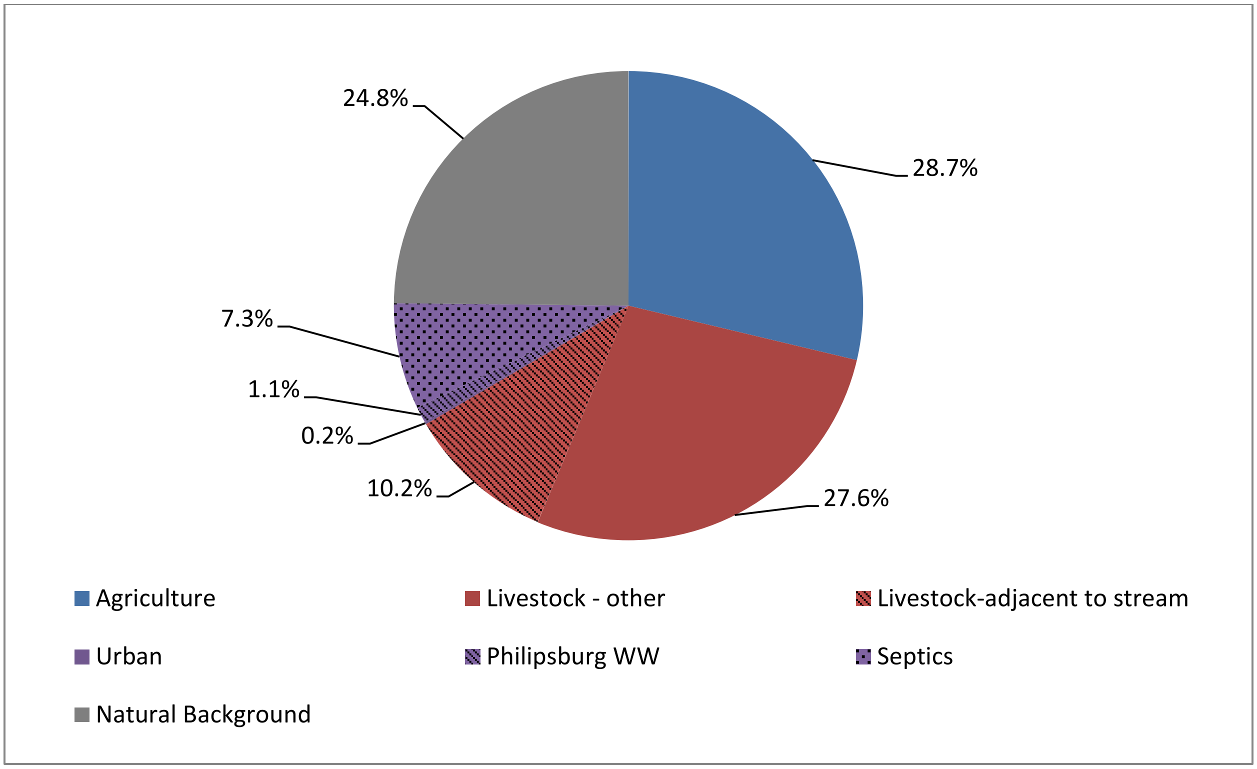

Figure E5-1. Percent of Total Nitrogen Loading during Growing Season from Existing Condition Land Uses for the Flint Creek Watershed

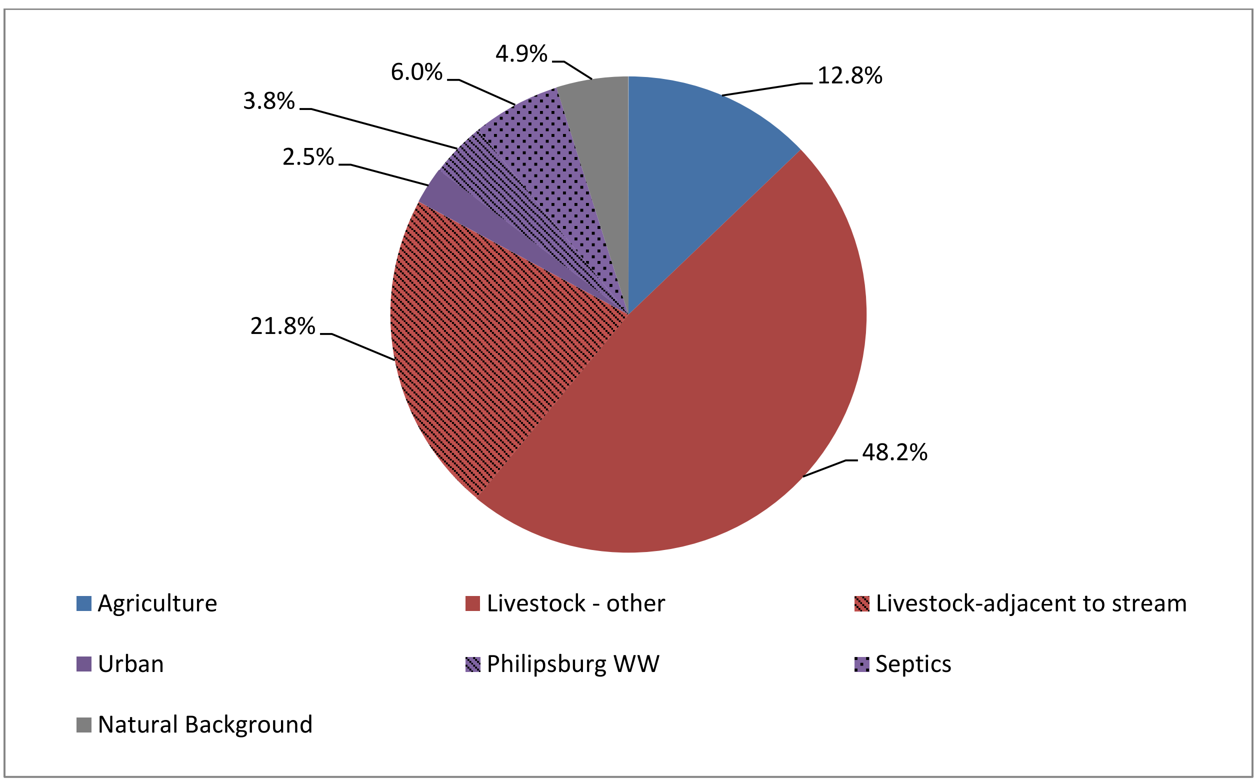

Figure E5-2. Percent of Total Phosphorus Loading during Growing Season from Existing Condition Land Uses for the Flint Creek Watershed

E5.2 NUTRIENTS LOCATION SOURCE ASSESSMENT

The source assessment for different land uses discussed in the previous section can be used in conjunction with the spatial distribution of the nutrients sources to provide a more complete source assessment. The results of the SWAT model are too coarse to provide a field-by-field analysis of the nutrients loads within each sub-basin. However, the SWAT model is divided into 41 sub-basins that can be used for a coarser analysis of relative loading rates. This information is useful for identifying sub-basins that are contributing relatively higher amounts of nutrients to the impaired segments of Flint Creek which eventually receives nutrients from all 41 sub-basins. This will allow managers to initially focus on those areas with higher nutrients loadings for specific locations to apply BMPs that will reduce nutrients loadings to Flint Creek.

Figure E5-3 shows a graduated range of TN loading rate by acre from each of the 41 sub-basins. The TN loading rates in **Figure E5-3** are based on contributions from all land uses (i.e., HRUs) and from all point sources (including septic wastewater, municipal wastewater, and livestock waste applied directly into streams). The area is based on the total acreage of each sub-basin. Areas with higher TN loading are generally located in sub-basins with relatively high amounts of agriculture, livestock, or urban development land uses (see **Figure E2-3**).

Figure E5-3 shows that two of the nitrogen impaired stream segments, Smart Creek (impaired for TN) and Princeton Gulch (impaired for nitrate), have relatively low TN loading rates compared to other impaired stream segments. Based on the source assessment the human-related TN loading in the Smart Creek sub-basin is predominantly from livestock activities, and nearly all of its livestock land use is towards the downstream end of the sub-basin (the rangeland in the upper portion of the basin is primarily located on USFS land that is not used for grazing in the model). This is confirmed by the Smart Creek assessment results in **Section E5.6.6** that show low nitrogen concentrations in the upper Smart Creek sampling sites. Because only a relatively small portion of the Smart Creek sub-basin is contributing high nutrients loads, the average nitrogen concentration by acre is relatively small compared to other sub-basins with higher amounts of contributing area. The Princeton Gulch sub-basin has little current development; the sources causing its nitrate impairment may be related to other historical activities such as mining.

The distribution of TP loads in the watershed (**Figure E5-4**) is similar to the TN distributions showing higher loadings from sub-basins with relatively high amounts of agriculture, livestock, or urban development land uses. However, one substantial difference from the TN distributions is in sub-basin 30, where the Philipsburg wastewater treatment plant is located. The ratio of TP in the wastewater discharge compared to other TP sources is higher than the comparable TN ratio, which creates the higher relative loading of TP in sub-basin 30. The relatively lower TP versus TN ratios for land uses are shown in **Figures E5-3** and **E5-4** that show, in general, that TP loadings from human impacts are over 10 times lower than TN loads. The Philipsburg wastewater treatment plant discharges, based on their discharge monitoring reports (see **Table EC-5**), show that the TP loads are only 3.5 times lower than the TN loads.

In Smart Creek the TP loadings show the same comparatively low loading rates as was seen with TN, which is due again to the location of the human-related nutrients sources near the bottom of the Smart Creek sub-basin and confirmed by the assessment results in **Section E5.6.6**.

Figure E5-5 shows the distribution of TN and TP growing season loads in graphical format and apportioned by model sub-basin and by land use. **Figure E5-5** is used to supplement **Figures E5-3** and **E5-4** to show the specific land uses that are contributing to the TN and TP loadings in each sub-basin.

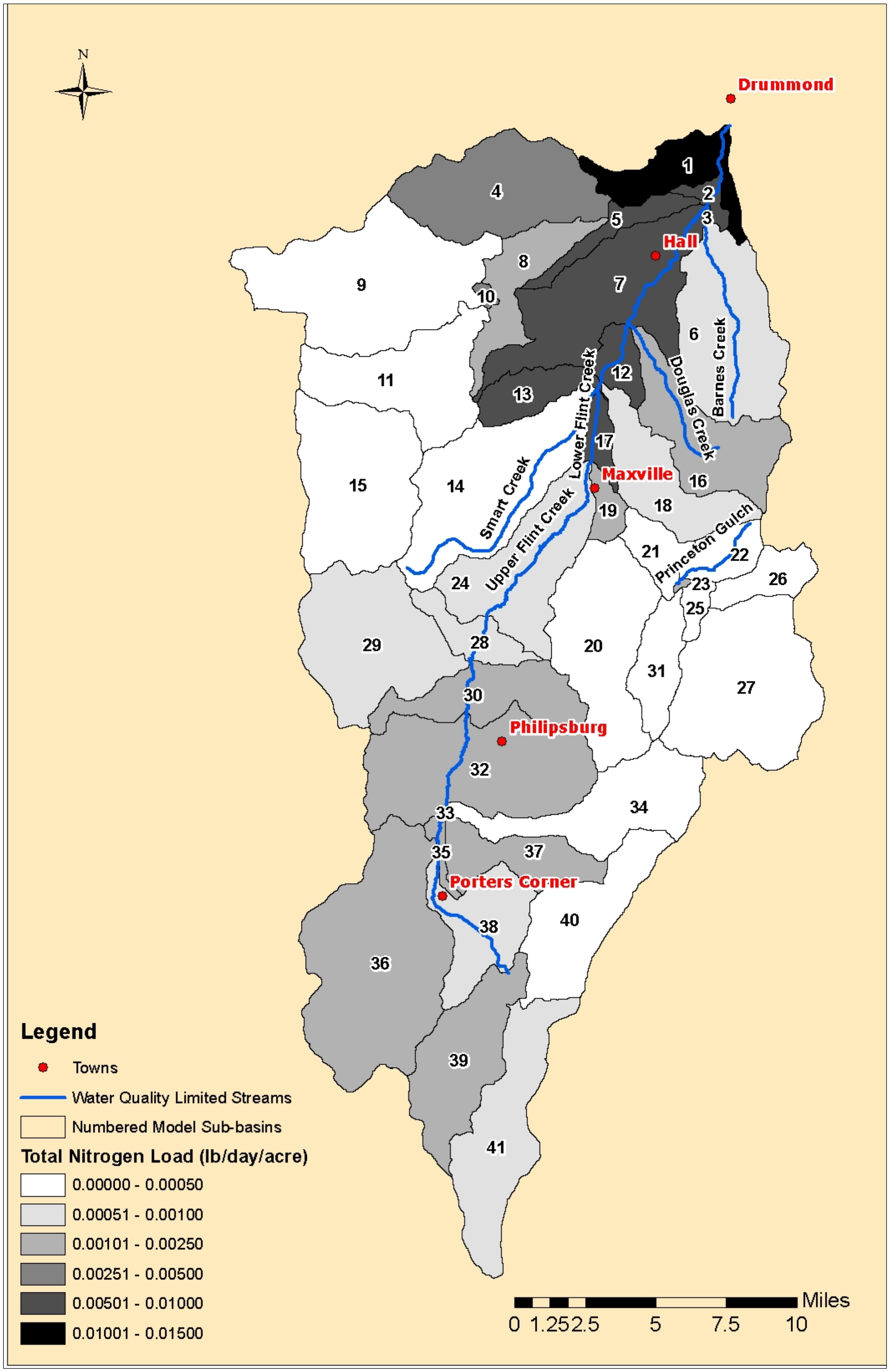

Figure E5-3. Simulated Rates of Human-Related Total Nitrogen Loading under Existing Conditions

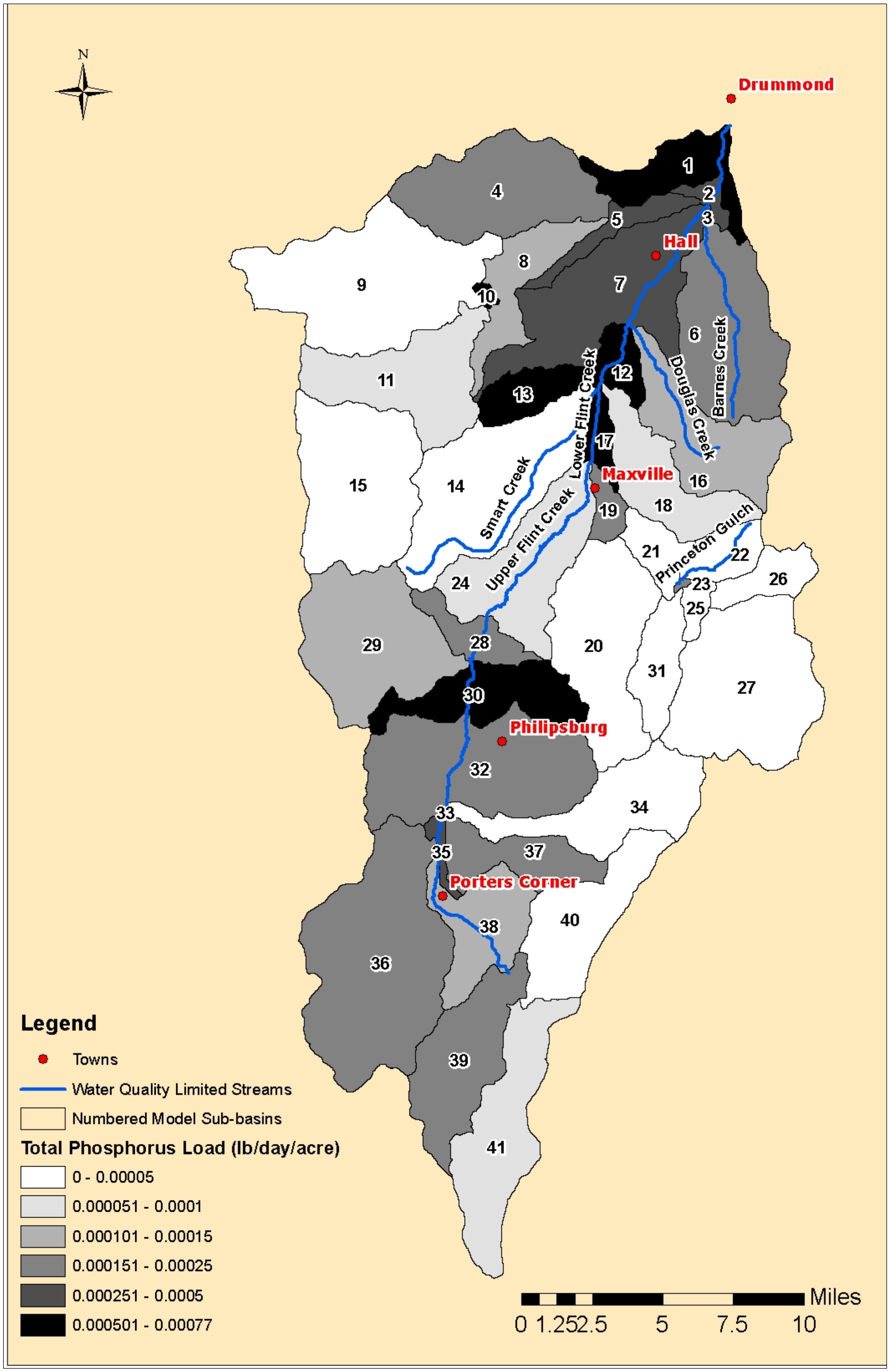

Figure E5-4. Simulated Rates of Human-Related Total Phosphorus Loading under Existing Conditions

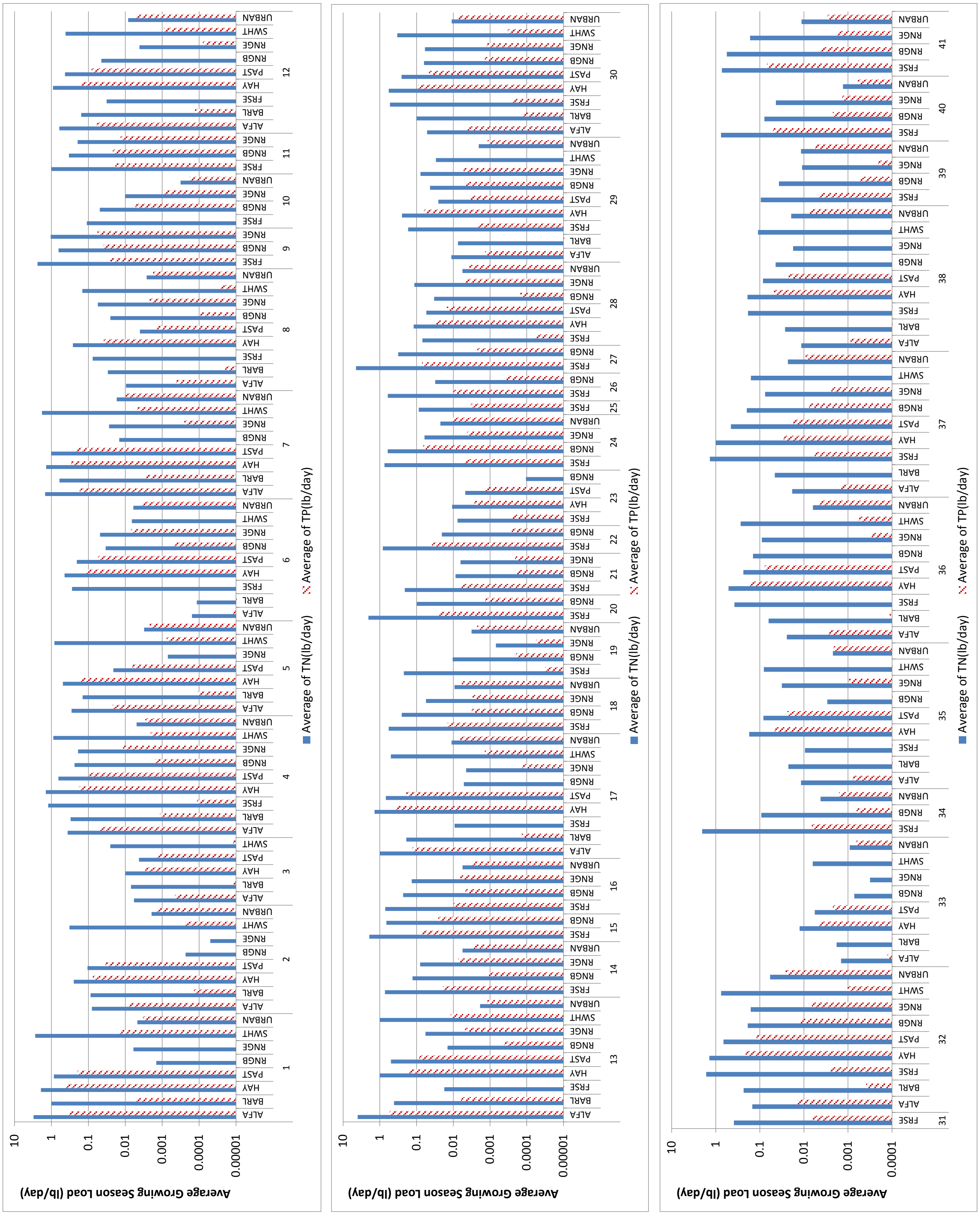

Figure E5-5. Total Nitrogen and Total Phosphorus Growing Season Loading Rates by SWAT Model Sub-Basin and Land Use

(FRSE = Forest; RNGE = Grass Range; RNGB = Brush Range; ALFA = Alfalfa; BARL = Barley; SWHT = Spring Wheat; PAST = Pasture)

E6.0 BEST MANAGEMENT PRACTICES SCENARIOS

Scenario development was completed by incorporating several BMPs on different land uses from the calibrated existing condition model. The results of each BMP scenario are then compared to the existing condition model to determine the change in loads from the land uses that were modified. Several scenarios were modeled to estimate nutrients loadings reductions associated with various BMPs, and to identify the BMP combinations most likely to result in TMDL attainment. Scenarios were focused on sources that tend to be the most significant for nutrients, and included improvements in management practices that are commonly recommended and applicable to existing land uses in the watershed.

The scenarios are intended to simulate common BMPs but are not prescriptive, and should not be interpreted as exact reductions that are expected with the specified BMP. Rather, the scenarios are provided to show approximate reductions available and to show the relative effectiveness compared to other BMPs. This approach allows land managers to preferentially implement those BMPs that will have the greatest impact. A comprehensive literature review of common agricultural BMP implementation practices in the United States (Agourids et al., 2005) found that at least one aspect of stream water quality (e.g., chemical, physical, or biological) has improved in watersheds that received one or more of the following measures: livestock exclusion, offstream watering, rotational grazing, supplemental feeding, and buffer strips. As such, DEQ believes that one or more practices could be implemented cost-effectively (e.g., through cost-shares with NRCS) to improve water quality in the watershed.

When reviewing the scenario results it is important to be aware of the fundamental structure of the SWAT program which was previously discussed but is reviewed here in the context of implementing BMPs. The HRU is SWAT's fundamental computational unit, and most parameter modifications affect SWAT at the HRU level. HRUs are portions of the same sub-basin that share similar land uses, soils, and slopes. An HRU can (and typically does) consist of multiple spatial areas that are located within the same sub-basin, but aren't adjacent to each other. However, these nonadjacent areas are lumped into one HRU within that sub-basin as long as they share similar land use, soil, and slope. There is no spatial context to HRUs within each sub-basin – every HRU is assumed to deliver its load directly to the stream in its sub-basin without accounting for the distance of the HRU to the stream (in contrast, sub-basins are spatially correlated to other sub-basins and are routed correctly from one sub-basin to the next). Most BMPs are applied to the HRU, not to the sub-basin or watershed, so applying a BMP to one stretch of river may require applying it to multiple HRUs (and their associated area), and may be somewhat limited in its accuracy (with respect to location or amount of land affected) by the size of affected HRUs in each sub-basin.

The discussion of scenario results focus on the stream segments that are impaired. However, because the entire length of Flint Creek below Georgetown Lake is impaired for TN and/or TP, the BMPs described should be considered in every tributary in the watershed (when they are applicable to the land use) as they all eventually contribute nutrients to Flint Creek.

Scenarios modeled for this project include fertilizer reduction, improved grazing, stream channel livestock exclusion, riparian protection, and wastewater treatment improvement. A summary of TN and TP percent reductions, as compared to the existing conditions, for each BMP scenario by impaired stream segment is provided in the following sub-sections and are summarized in **Figures E6-1** and **E6-2**. A watershed summary of the TN and TP percent reductions, as compared to the existing conditions, for each BMP scenario from different land uses is also provided in **Figures E6-3** and **E6-4**. All reductions discussed are for the summer growing season only, July 1 through September 30, which is when the instream nutrients targets apply.

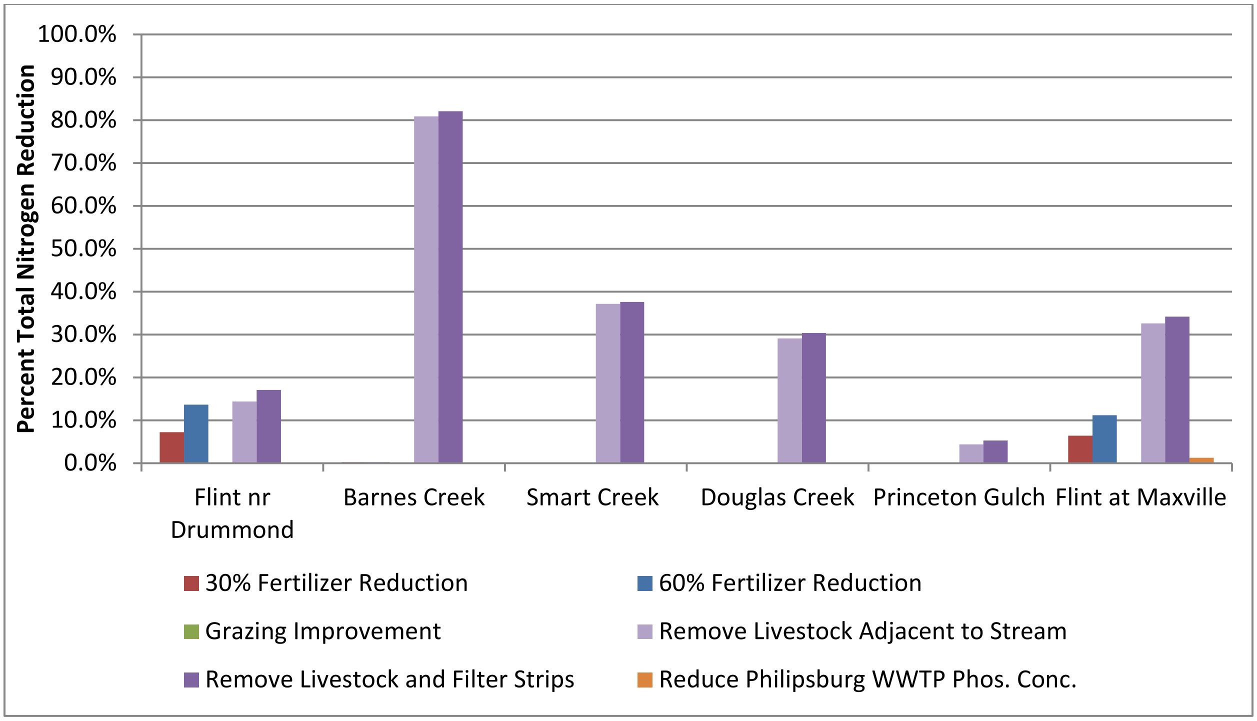

Figure E6-1. Total Nitrogen Instream Reductions from best management practices during the Growing Season for each Impaired Stream as Compared to the Existing Conditions

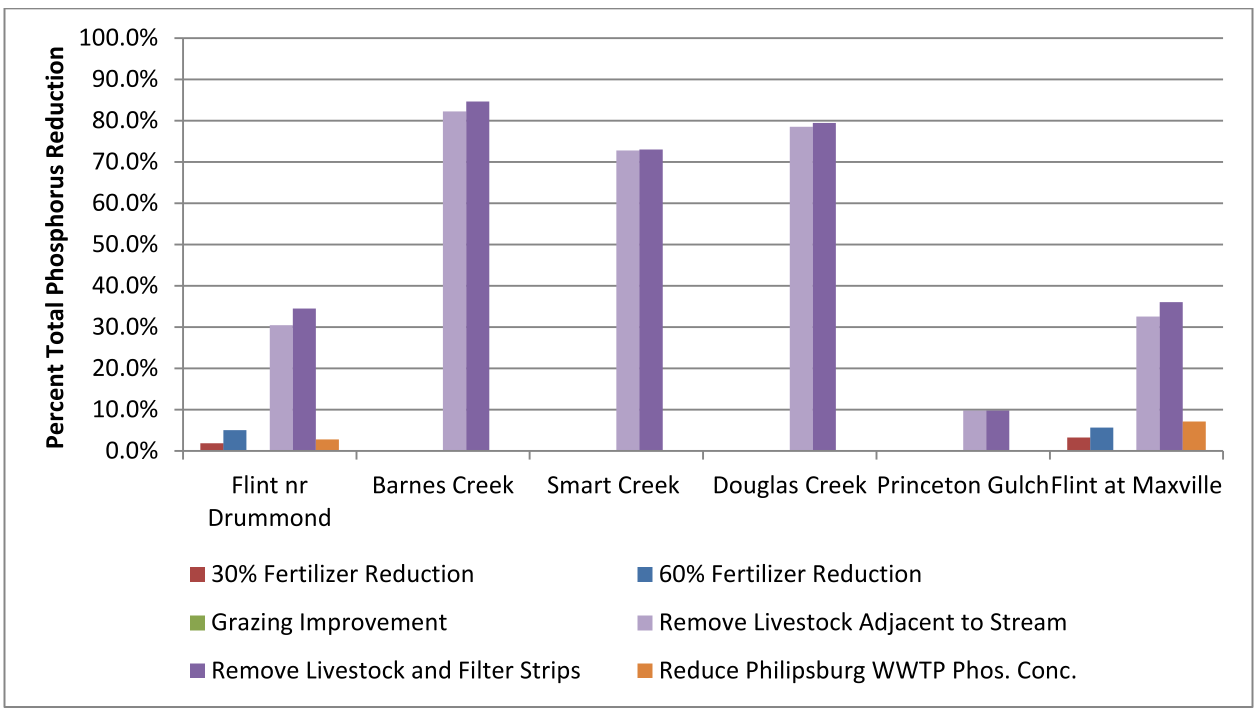

Figure E6-2. Total Phosphorus Instream Reductions from best management practices during the Growing Season for each Impaired Stream as Compared to the Existing Conditions

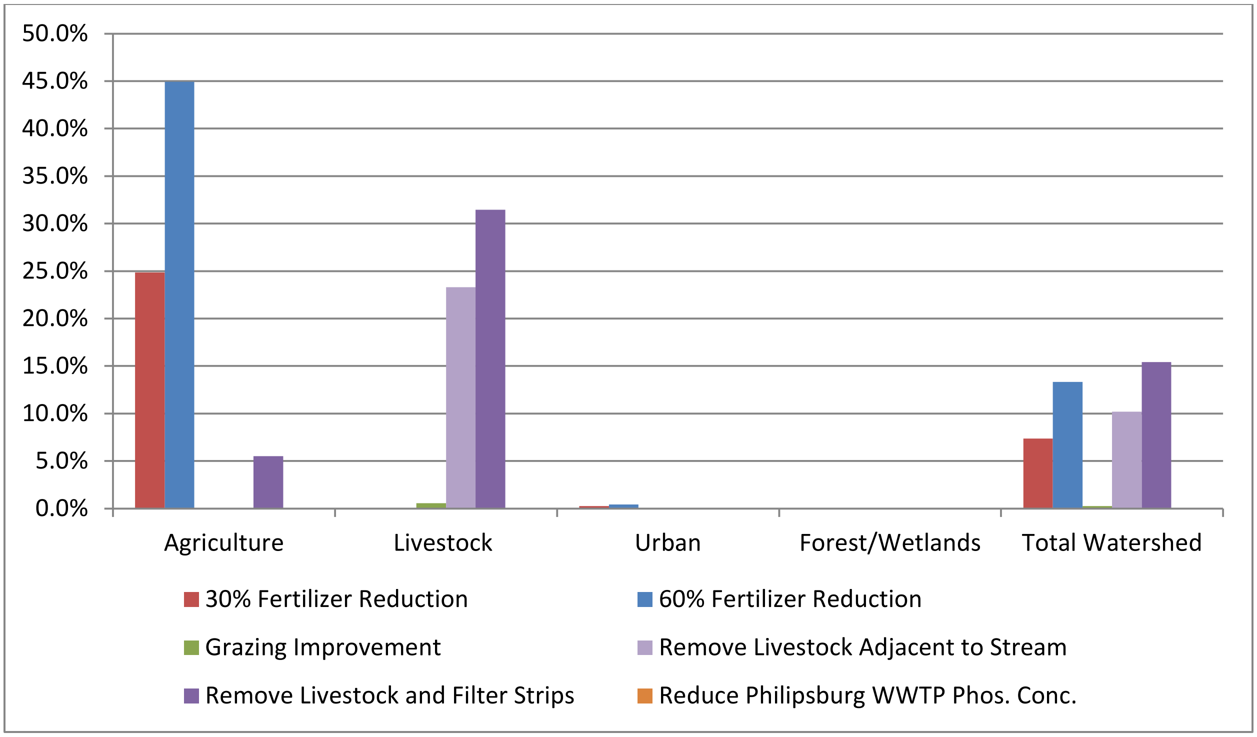

Figure E6-3. Total Nitrogen Land-Use Reductions from best management practices during the Growing Season (July–September) as Compared to the Existing Conditions

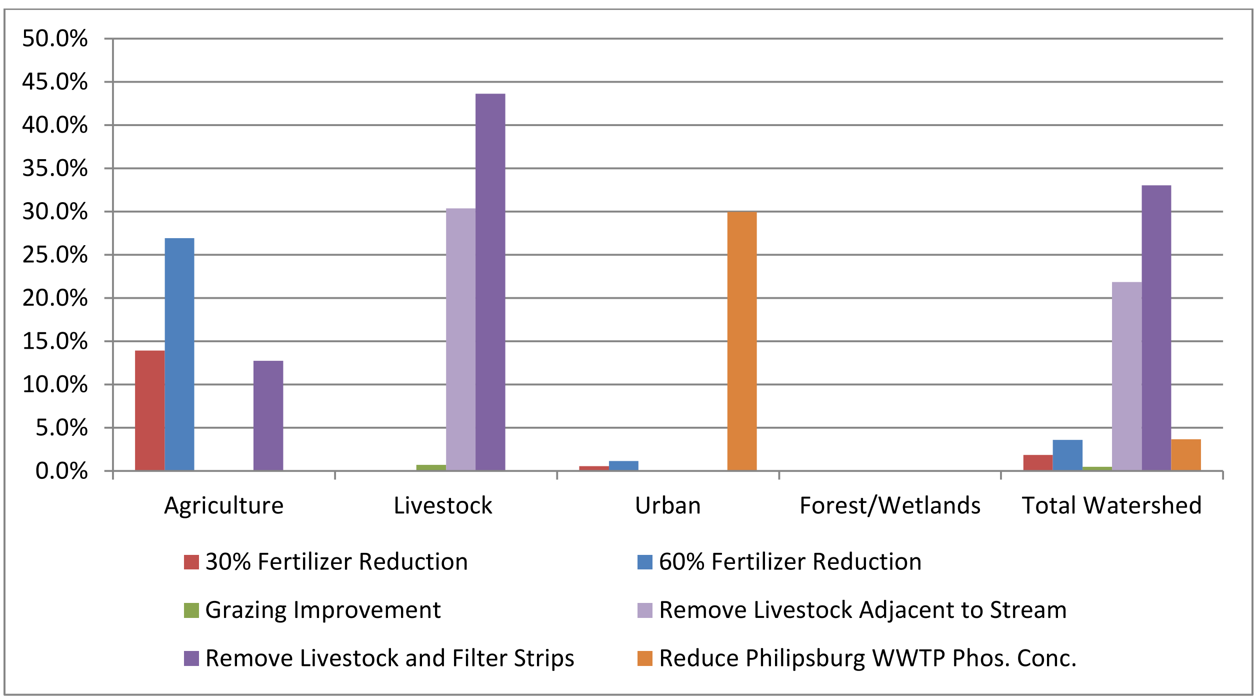

Figure E6-4. Total Phosphorus Land-Use Reductions from best management practices during the Growing Season (July–September) as Compared to the Existing Conditions

E6.1 Existing Conditions

The calibrated model was used to develop the existing conditions from 1992 through 2010. The results of the existing condition model with respect to TN and TP trends was discussed in **Section E4.7**. Each of the following BMP scenarios is compared to the results of the existing condition simulation.

E6.2 Thirty Percent Fertilizer Reduction Scenario

The existing condition simulation applies commercial fertilizer to the alfalfa, spring wheat and barley crops as discussed in **Section E2.5.1.2**. The fertilizer loading rates per acre listed in **Table E2-7** and **Section E2.5.3** were reduced by 30% in this scenario and are shown in **Table E6-1**.

Methods available to reduce fertilizer use include but are not necessarily limited to: 1) conversion to crops that require less supplemental fertilizer; 2) better management of existing organic matter to reduce the amount of supplemental fertilizer used; and 3) increased use of variable rate technology, which uses Global Positioning System (GPS) to apply fertilizer at different rates based on location specific needs rather than applying at a uniform rate across entire fields.

The results of this scenario (**Figures E6-1** through **E6-4**) show negligible to no TN or TP reductions in the four impaired tributaries to Flint Creek (Barnes Creek, Smart Creek, Douglas Creek and Princeton Gulch) as those sub-basins have little or no fertilized crops. The Upper Flint (Flint Creek at Maxville) and Lower Flint (Flint Creek near Drummond) impaired segments responded with TN reductions of 6.4% and 7.2%, respectively; they also responded with TP reductions of 3.3% and 1.9%, respectively. The phosphorus percent reductions are less because phosphorus is less mobile in soil than nitrogen which tends to mute the impacts to surface waters.

Table E6-1. Nitrogen and Phosphorus Fertilizer Loads for Existing Conditions and 30% Fertilizer Reduction Scenario

Crop Type	Watershed Area (acres)	Exist. Condition Annual Nitrogen Load (lb/yr)	Exist. Condition Annual Phosphorus Load (lb/yr)	30% Reduction Annual Nitrogen Load (lb/yr)	30% Reduction Annual Phosphorus Load (lb/yr)
Alfalfa/Hay (60/40)	9,958	49,790	199,160	34,853	139,412
Barley	479	43,110	0	30,177	0
Spring Wheat	479	118,333	16,765	82,819	11,736
Urban grass	250	17,900	0	12,530	0

E6.3 Sixty Percent Fertilizer Reduction Scenario

This scenario is similar to the previous scenario and estimates the impacts of additional fertilizer reductions. The existing condition model applies commercial fertilizer to the alfalfa, spring wheat and barley crops as discussed in **Section E2.5.1.2**. The fertilizer loading rates per acre listed in **Table E2-7** and **Section E2.5.3** were reduced by 60% in this scenario and are shown in **Table E6-2**.

Methods available to reduce fertilizer use include but are not necessarily limited to: 1) conversion to crops that require less supplemental fertilizer; 2) better management of existing organic matter to reduce the amount of supplemental fertilizer used; and 3) increased use of variable rate technology, which uses GPS to apply fertilizer at different rates based on location specific needs rather than applying at a uniform rate across entire fields.

The results of this scenario (**Figures E6-1** through **E6-4**) show negligible to no TN or TP reductions in the four impaired tributaries to Flint Creek (Barnes Creek, Smart Creek, Douglas Creek and Princeton Gulch) as those subasins have little or no fertilized crops. The Upper Flint and Lower Flint impaired segments responded with TN reductions of 11.2% and 13.7%, respectively; they also responded with TP reductions of 5.7% and 5.1%, respectively. The phosphorus percent reductions are less because phosphorus is less mobile in soil than nitrogen which tends to mute the impacts to surface waters.

Table E6-2. Nitrogen and Phosphorus Fertilizer Loads for Existing Conditions and 60% Fertilizer Reduction Scenario

Crop Type	Watershed Area (acres)	Exist. Condition Annual Nitrogen Load (lb/yr)	Exist. Condition Annual Phosphorus Load (lb/yr)	60% Reduction Annual Nitrogen Load (lb/yr)	60% Reduction Annual Phosphorus Load (lb/yr)
Alfalfa/Hay (60/40)	9,958	49,790	199,160	19,916	79,664
Barley	479	43,110	0	17,244	0
Spring Wheat	479	118,333	16,765	47,325	6,706
Urban grass	250	17,900	0	7,160	0

E6.4 Grazing Improvement Scenario

This scenario simulates an improvement in both summer and winter grazed land conditions. Decreased ground cover, due to grazing, influences sedimentation and nutrients processes. No specific practice was specified for this improvement because ground cover can potentially be altered through a number of BMPs including alteration of cattle distribution on the landscape (e.g., water, shade), modification of the grazing time-frame and duration through different rotational practices, or reductions in stock density. To reflect some combination of these changes, modifications were made to the Universal Soil Loss Equation (USLE) C factor in SWAT. Adjustment was made based on several studies in southwestern and central Montana which relate rangeland ground cover response to grazing practices. Bare ground was shown to be 14.9, 18.6, and 6.8% higher on the Beaverhead National Forest near Dillon, Montana, on sites that were heavily, moderately, and lightly grazed respectively, than those with no cattle on them (Evanko and Peterson, 1955). The comparison was made after a 15–18 year exclusion period. Similar results were found in an exclusion study on foothill sheep ranges in Meagher County near White Sulphur Springs, Montana; total cover (e.g., foliage and litter) was 16.7% higher in protected plot as compared to grazed plots after 4 years of exclusion (Vogel and Van Dyne, 1966). Based on those studies a relationship between ground cover and grazing does exist, and a maximum difference between grazed and un-grazed lands is around 10–20%. Therefore, a conservative estimate of a 10% improvement for rangeland USLE C factor, and a 10% improvement in hay/pasture USLE C factor was used in this scenario. This 10% improvement was incorporated by reducing the USLE C factor for range, hay, and pasture from 0.003 to 0.0027 (see original USLE C factors in **Table E4-5**).

The results of this scenario (**Figures E6-1** through **E6-4**) show a less than 1% improvement in all of the impaired stream sub-basins. As these impacts are averages over an entire sub-basin or the watershed, the results should not be interpreted that improved grazing is not a worthwhile practice. On a field scale, rather than a larger sub-basin scale, there may be individual grazing areas that will be improved and result in significant local reductions of nutrients through better grazing practices.

E6.5 Reduce Livestock Stream Access Scenario

The existing conditions scenario included direct discharge of 1% of the waste from livestock into surface waters (Porath et al., 2002; Sheffield et al., 1997) during the summer grazing season, June 1 through October 31. This is designed to simulate the amount of time on average that livestock spend in and directly adjacent to surface waters. This scenario simulates the impacts if direct access to surface waters is restricted across the entire watershed so that livestock do not discharge any waste directly into streams. Although 100% livestock exclusion is not practicable, because the source is a direct source into the streams the results of this scenario can be easily extrapolated to different amounts of exclusion. For example, if direct livestock access is reduced 25%, then the instream loading reductions would be 25% of what is presented for this scenario.

The results indicate a large impact in TN loads to every impaired stream segment except for Princeton Gulch, which has limited grazing land (**Figures E6-1** through **E6-4**). The percent reductions in TN range from 4.4% in Princeton Gulch up to 80.9% in Barnes Creek. The TP percent reductions are similar and range from 9.8% in Princeton Gulch up to 82.2% in Barnes Creek. The amount of improvement in each sub-basin or watershed is primarily dependent on the percent of summer grazing land in each of the sub-basins because summer grazing is distributed relatively evenly across the watershed on land classified as range. As discussed previously, complete livestock exclusion is not likely, but this scenario does illustrate that even a modest reduction in livestock access to surface waters will create substantial improvements to instream water quality. As such, BMPs to reduce livestock access to surface waters are an important tool in improving water quality and meeting target water quality levels.

E6.6 Reduce Livestock Stream Access and Riparian Filter Strips Scenario

This scenario includes the results of the previous scenario and adds riparian filter strips to both grazing lands and agricultural lands. Riparian vegetation in the watershed has been degraded by a variety of factors including historic vegetation removal, grazing, mining, timber harvest, and residential development. Because riparian areas function as important filters for streamflow and overland runoff, this scenario is used to evaluate the effect of improved riparian health on nutrients loads.

The addition of filter strips was the method chosen to simulate riparian improvement in the model. In SWAT, filter strips are applied at the HRU level. Filter strips are basically improved vegetation adjacent to streams that reduce the sediment and nutrients loads in both the overland flow and subsurface flow primarily through physical entrapment and absorption. The filter strip could be considered roughly analogous to a riparian area as they both filter nutrients and sediment from the computed HRU load before delivery to the stream channel. In this scenario, filter strips were applied to areas that tend to be alongside streams or canals (pasture, hay, barley, spring wheat and alfalfa), and areas that are heavily grazed (rangeland). One limitation in modeling this scenario is filter strips are applied to HRUs (and not at a watershed level), their application is somewhat restricted by the division of HRUs within each sub-basin. The SWAT program does not allow for splitting an HRU and giving different characteristics within that HRU, therefore a single HRU within a sub-basin cannot have filter strips designated over a portion of the HRU. For example, if improved riparian areas were supposed to be applied to 50% of a sub-basin, but there were five HRUs each comprising 20% of the sub-basin, then filter strips were applied to either 40% (two HRUs) or 60% (three HRUs) of the sub-basin. For this application in the Flint Creek watershed the HRU limitation didn't alter the targeted percentages of filter strip application substantially on the mainstem Flint Creek impaired segments, but there were some minor differences on the tributary sub-basins.

A coarse riparian habitat assessment was completed for the Flint Creek watershed (Water & Environmental Technologies, 2010) to collect data on riparian area extent, health, and locations. Delineated reaches were given a riparian condition category of good, fair, or poor based on land use adjacent to the stream, riparian vegetation type and density, and the presence or absence of human related activities near the stream corridor. Based on this, the riparian areas along each stream investigated were given ratings (and corresponding percentages) of good, fair, or poor based on the results of the assessment. Due to the coarse nature of the riparian analysis, it was determined that it would not be practical to incorporate the results qualitatively into the model scenario. Instead, the approach used for the scenario was to include a watershed-wide riparian improvement at set percentages for several different land uses.

The filter strip widths were set uniformly at 33 feet (10 meters). A review of studies on riparian buffers (Mayer et al., 2005) showed that buffer widths that have been tested generally vary between 33 feet and 330 feet and that increasing buffer width does increase nitrogen removal although there are diminishing returns as the widths exceed 330 feet. Thirty-three foot buffers were demonstrated to remove up to 61% and 80% of nitrogen using forested and grassland buffers, respectively. Although wider buffers are better, for this scenario a 33 foot width was used because it is shown to be an effective width (Mayer et al., 2005) and logistically is likely to be the best compromise between maintaining existing land uses while still providing a meaningful buffer to nutrients transport. In areas that can support wider buffers from a landscape and land-use perspective, they should certainly be implemented to realize greater nutrients retention. In this scenario the filter strips were implemented on 25% of all hay, pasture, barley, spring wheat and alfalfa land uses, and on 10% of all range land uses. These percentages are different because it was assumed that based on easier access and a much lower amount of acreage, it would be easier to implement filter strips on the hay, pasture, barley, spring wheat and alfalfa lands than it would be on the more remote and larger range lands. These percentages are only approximate targets, but are primarily used for comparative purposes to demonstration the relative effectiveness of this BMP versus other BMP scenarios.

The results of this scenario (**Figures E6-1** through **E6-4**) show moderate instream improvements when combined with the previous livestock stream access scenario. The TN instream loads are reduced between 0.5% and 2.6% on all the impaired stream segments, the TP instream loads are reduced between 0% and 4% on the same stream segments. As with the grazing improvement scenario, these values are sub-basin or watershed averages and individual fields that have poor existing riparian health can realize much greater percent improvements through the use of filter strips.

E6.7 Wastewater Phosphorus Treatment Improvement Scenario

This scenario decreases the amount of phosphorus discharged from the city of Philipsburg wastewater treatment plant. Based on the discharge permit discharge monitoring reports, the average TP concentration discharged from the wastewater treatment plant between August 2007 and September 2012 is 3.3 mg/L. This scenario assumes that the wastewater treatment plant reduces its TP discharge concentration to the instream target TP concentration of 0.072 mg/L (TN reductions for the wastewater treatment plant are not simulated in this scenario because the Upper Flint Creek impaired segment is only impaired for TP, not for any nitrogen species). This reduction may be realized through one or more methods such as improved treatment, wastewater land application during the summer, and continued reduction of phosphorus in household products. For this scenario, it was assumed that the reduced concentration would occur all year, not just during the summer growing season when the instream target concentration applies.

The results (**Figures E6-1** through **E6-4**) show that the impacts of this scenario are greatest in the Upper Flint Creek impaired segment because the wastewater treatment plant is located in the lower section of that impaired stream segment. The TP reduction in that section is 7.1%. TP reduction in the lower Flint segment, 2.8%, is much less due to stream cycling, diversions, and dilution from other sources. Although TN was not reduced from the wastewater treatment plant, the results show a small reduction of TN of 1.2% and 0.1% at the Upper and Lower Flint Creek impaired segments, respectively. The cause of the TN decrease is unknown. However, it is likely related to the instream processing routines in SWAT. Currently, algal assimilation in SWAT is limited to suspended algae which are subject to settling losses from the water column. Provided that the system was P limited, further reduction of P from the SWAT scenario would constrain algal biomasses even more, thus theoretically reducing the N incorporated as internal nutrients and lost through settling. This in turn would increase the TN in the watershed at a ratio equal to the reduced mass of settling and the N:P intracellular stoichiometry ratio which is often assumed to be 7:1 by mass (e.g., Redfield ratio).

E6.8 Best Management Practice Scenario Summary

The results of the scenarios should be reviewed and used in a comparative fashion to determine the best BMPs based on local management practices and land condition. For example, a field that has excellent riparian conditions and very little livestock activity may not need any additional BMPs even if it is in a sub-basin that had significant scenario improvements from filter strips and changes in livestock management. Conversely, another field may have poor riparian vegetation, heavy livestock use and a nearby upgradient fertilized agricultural field, and therefore may benefit significantly from multiple BMPs. Local knowledge and implementation of the most applicable BMPs to each location is the most important factor in improving instream water quality to meet the target values.

Although not included as a scenario, using advanced septic systems that treat TN to lower concentrations for replacement of aging septic systems, would provide only minor additional TN reductions. The advanced treatment systems reduce the TN in half as compared to a conventional septic system, but do not reduce the TP concentrations. Therefore if, for example, the annual failure rate on existing septic systems was 1% (which would be about 16 systems a year in the watershed), the TN source reduction for the entire watershed would be 0.24 lb/day or 0.04% of the total TN load in the watershed. At the estimated 1% failure rate, it would require 25 years to reduce the TN loading in the watershed by 1%.

E7.0 Conclusion and Limitations

Hydrologic modeling was completed on the Flint Creek watershed to identify the contribution of nutrients (TN and TP) sources in six impaired stream segments, and to assess potential BMPs that might improve water quality in those streams. The calibrated model under existing conditions is used to develop the source assessment and determine the reductions necessary to meet water quality targets for impaired stream segments. The BMP scenarios included fertilizer reduction, improved grazing, stream channel livestock exclusion, riparian protection, and wastewater treatment improvement. Through scenario analysis, it was shown that livestock management was the most sensitive management option for reducing nutrients sources to surface water. The key management conclusion is that nutrients loadings will most effectively be reduced by the protection of streams and riparian zones from direct livestock access. Additional but smaller reductions in nutrients loadings can be achieved through reductions in agricultural fertilizer applications, use of riparian filter strips, and reductions in the Philipsburg wastewater treatment plant phosphorus loads. Grazing management improvements can provide limited watershed scale reductions, but may provide more substantial local improvements on fields that are currently not managed well. Upgrading failed septic systems would provide minor decreases to TN loadings only.

This model, like any other, has certain limitations based on the accuracy of the watershed parameterization. Climatic data are always crucial, as precipitation, snowfall, snowmelt, and evapotranspiration are the most important processes for determining hydrology. The climatic data available for the watershed are acceptable, with two weather stations at Drummond and Philipsburg and several SNOTEL sites for snow information. Some of the climatic data such as daily wind speed, solar radiation, and relative humidity were partially available from within the watershed, but significant amounts of data not available during the modeling period had to be extrapolated from Missoula and Deer Lodge. Spatial variation of precipitation and snow events cannot always be accurately simulated due to the local nature of many events compared to the distances between weather stations; this creates some errors in simulating rapid fluctuations of streamflows, but has less of an effect on the longer term fluctuations that the calibrated model replicates acceptably.

Many of the assumptions used in this model are related to land management practices such as irrigation practices and diversions, grazing rotations, fertilizer application, etc. Where possible, information from local sources was used to characterize the management practices, and literature sources were used to estimate other management practices. In either situation, the management practices had to be averaged over the entire watershed as the specific management practices from the multiple land owners in the watershed is not available. Information related to potential nutrients sources from mining was researched, but little information was found to provide any meaningful characterization of mining impacts. What information was found regarding mining impacts indicated they were not substantial sources of nutrients to the watershed. Future work in the watershed could include better characterization of these potential nutrients sources.

The calibrated and validated hydrologic model met most of the pre-determined evaluation criterion metrics, and responded well to climatic inputs. Additionally, the sediment and nutrients calibrations were acceptable. This model is to be used as a relative gage of system response to various management changes, rather than an absolute indicator of nutrients loadings. And in this capacity, in spite of the limitations discussed above, the model met its objectives and is acceptable for the intended use.

E8.0 REFERENCES

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ATTACHMENT EA – IMPORTANT LAND-USE ESTIMATIONS AND ASSUMPTIONS USED IN MODEL DEVELOPMENT

- **Section E2.5.1** - Hay/alfalfa harvesting occurs July 4 in both Philipsburg and Drummond-Hall valleys, and again on September 30 in the Drummond-Hall valley. Spring wheat and barley are harvested on September 15 and 30 in the Philipsburg and Drummond-Hall valleys, respectively.
- **Section E2.5.1.1** - Average irrigation efficiency set at 50%.
- **Section E2.5.1.1** - Annual irrigation set at 1.7 feet in the Drummond-Hall valley from May 1 through September 15 (except for hay and pasture where irrigation begins June 1). Annual irrigation set at 0.74 feet in the Philipsburg valley from June 1 through August 30.
- **Section E2.5.1.1** - Irrigation is curtailed in individual sub-basins when streamflows fall below 3.5 cfs and 1.0 cfs in large streams and small streams, respectively.
- **Section E2.5.1.2** - Fertilizer rates based on generic rates published in Montana State University Extension service publication. Rates for alfalfa were halved based on communication with Technical Advisory Group, that some land owners do not fertilize alfalfa. The final rates used for nitrogen, phosphorus and potassium were 5 lbs/acre, 20 lbs/acre and 20 lbs/acre, respectively
- **Section E2.5.2** - 650 sheep in the valley are assumed equivalent to 65 cattle for purposes of grazing impacts.
- **Section E2.5.2** - Summer grazing (June 1 through October 31) only occurs on privately owned lands classified as range shrub and range brush. Winter grazing (November 1 through May 31) only occurs on lands classified as hay and pasture.
- **Section E2.5.2** - Winter grazing uses existing vegetation in November and May, and supplied feed for December through April.
- **Section E2.5.3** - Distribution and increase of septic systems in the watershed during the modeling period estimated using 2001 NLCD, 2009 county GIS layer, county septic permits, and interpretation of available air photos.
- **Section E2.5.4** - Land uses modified for fires and timber harvest using available air photos and updating land uses to range-brush from forest where appropriate.
- **Section E2.5.5** - Discharge from Georgetown Lake based on USGS gage located 1.3 miles below dam. Discharge from Lower Willow Creek Reservoir extrapolated to model period from 1965 to 1983 measured discharge rates. Discharge from East Fork Rock Creek Reservoir extrapolated from 8 years (2000, 2002–2004, and 2007–2010) of measured discharge rates.
- **Section E2.7.1** - Dissolved oxygen concentration of the City of Philipsburg wastewater treatment plant discharge estimated at 2.0 mg/L.
- **Section E2.7.1** - Extrapolated 2000–2010 measured effluent discharge rates for the City of Philipsburg wastewater treatment plant for use from 1989 through 1999, and excluded 2 years of anomalously high discharge rates between 2004 and 2006.
- **Section E2.7.6** - Identified livestock confinement operations were not accounted for in land-use updates or as point sources.

ATTACHMENT EB – NATIONAL AGRICULTURAL STATISTICS SERVICE

Table EB-1. Crop Types and Acreages for Granite County, 2003–2009(1)

Commodity	Practice	Year	State	County	Planted All Purposes Acres	Harvested Acres	Yield per Acre	Yield Unit	Production	Production Unit	Yield per Net Seeded Acre Bushels	Net Seeded Acres
Wheat, Other Spring	Irrigated (total for crop)	2003	MT	Granite	0	0	ND	Bushel	ND	Bushel	ND	ND
Wheat, Other Spring	Irrigated (total for crop)	2004	MT	Granite	0	0	ND	Bushel	ND	Bushel	ND	ND
Wheat, Other Spring	Irrigated (total for crop)	2005	MT	Granite	0	0	ND	Bushel	ND	Bushel	ND	ND
Wheat, Other Spring	Irrigated (total for crop)	2006	MT	Granite	0	0	ND	Bushel	ND	Bushel	ND	ND
Wheat, Other Spring	Irrigated (total for crop)	2007	MT	Granite	0	0	ND	Bushel	ND	Bushel	ND	ND
Wheat, Other Spring	Irrigated (total for crop)	2008	MT	Granite	1200	1200	70	Bushel	84000	Bushel	ND	ND
Wheat, Other Spring	Irrigated (total for crop)	2009	MT	Granite	1200	1200	75	Bushel	90000	Bushel	ND	ND
Total Average						**343**						
Barley, All	Irrigated (total for crop)	2003	MT	Granite	1000	300	53	Bushel	16000	Bushel	ND	ND
Barley, All	Irrigated (total for crop)	2004	MT	Granite	1000	400	80	Bushel	32000	Bushel	ND	ND
Barley, All	Irrigated (total for crop)	2005	MT	Granite	1400	500	78	Bushel	39000	Bushel	ND	ND
Barley, All	Irrigated (total for crop)	2006	MT	Granite	1300	700	60	Bushel	42000	Bushel	ND	ND
Barley, All	Irrigated (total for crop)	2007	MT	Granite	0	0	ND	Bushel	ND	Bushel	ND	ND
Barley, All	Irrigated (total for crop)	2008	MT	Granite	0	0	ND	Bushel	ND	Bushel	ND	ND
Barley, All	Irrigated (total for crop)	2009	MT	Granite	0	0	ND	Bushel	ND	Bushel	ND	ND
Total Average						**271**						

Table EB-1. Crop Types and Acreages for Granite County, 2003–2009(1)

Commodity	Practice	Year	State	County	Planted All Purposes Acres	Harvested Acres	Yield per Acre	Yield Unit	Production	Production Unit	Yield per Net Seeded Acre Bushels	Net Seeded Acres
Hay, Alfalfa	Irrigated	2003	MT	Granite	9700	9500	2.9	Tons	27100	Tons	ND	ND
Hay, Alfalfa	Irrigated	2004	MT	Granite	10300	10000	3	Tons	29500	Tons	ND	ND
Hay, Alfalfa	Irrigated	2005	MT	Granite	8000	8000	3.1	Tons	24400	Tons	ND	ND
Hay, Alfalfa	Irrigated	2006	MT	Granite	ND	7000	3.3	Tons	23000	Tons	ND	ND
Hay, Alfalfa	Irrigated	2007	MT	Granite	ND	8000	3.3	Tons	26000	Tons	ND	ND
Hay, Alfalfa	Irrigated	2008	MT	Granite	ND	ND	ND	Tons	ND	Tons	ND	ND
Hay, Alfalfa	Irrigated	2009	MT	Granite	ND	ND	ND	Tons	ND	Tons	ND	ND
Hay, Alfalfa	Non- irrigated	2003	MT	Granite	1500	1000	0.8	Tons	800	Tons	ND	ND
Hay, Alfalfa	Non-irrigated	2004	MT	Granite	500	500	2.2	Tons	1100	Tons	ND	ND
Hay, Alfalfa	Non-irrigated	2005	MT	Granite	ND	ND	ND	Tons	ND	Tons	ND	ND
Hay, Alfalfa	Non-irrigated	2006	MT	Granite	ND	500	1	Tons	500	Tons	ND	ND
Hay, Alfalfa	Non-irrigated	2007	MT	Granite	ND	1000	2.6	Tons	2600	Tons	ND	ND
Hay, Alfalfa	Non-irrigated	2008	MT	Granite	ND	ND	ND	Tons	ND	Tons	ND	ND
Hay, Alfalfa	Non-irrigated	2009	MT	Granite	ND	ND	ND	Tons	ND	Tons	ND	ND
Hay, Alfalfa	Total for crop	2003	MT	Granite	11200	10500	2.7	Tons	27900	Tons	ND	ND
Hay, Alfalfa	Total for crop	2004	MT	Granite	10800	10500	2.9	Tons	30600	Tons	ND	ND
Hay, Alfalfa	Total for crop	2005	MT	Granite	8000	8000	3.1	Tons	24400	Tons	ND	ND
Hay, Alfalfa	Total for crop	2006	MT	Granite	ND	7500	3.1	Tons	23500	Tons	ND	ND
Hay, Alfalfa	Total for crop	2007	MT	Granite	ND	9000	3.2	Tons	28600	Tons	ND	ND
Hay, Alfalfa	Total for crop	2008	MT	Granite	ND	9000	3.3	Tons	29500	Tons	ND	ND
Hay, Alfalfa	Total for crop	2009	MT	Granite	ND	8500	2.7	Tons	23000	Tons	ND	ND
Total Average						**9000**						
Hay, All Other	Irrigated	2003	MT	Granite	ND	16000	2	Tons	32500	Tons	ND	ND
Hay, All Other	Irrigated	2004	MT	Granite	ND	19300	2.1	Tons	40500	Tons	ND	ND
Hay, All Other	Irrigated	2005	MT	Granite	ND	28500	2.2	Tons	62200	Tons	ND	ND
Hay, All Other	Irrigated	2006	MT	Granite	ND	13000	1.9	Tons	24700	Tons	ND	ND
Hay, All Other	Irrigated	2007	MT	Granite	ND	14000	2.1	Tons	29400	Tons	ND	ND
Hay, All Other	Irrigated	2008	MT	Granite	ND	ND	ND	Tons	ND	Tons	ND	ND
Hay, All Other	Irrigated	2009	MT	Granite	ND	ND	ND	Tons	ND	Tons	ND	ND
Hay, All Other	Non-irrigated	2003	MT	Granite	ND	ND	ND	Tons	ND	Tons	ND	ND
Hay, All Other	Non-irrigated	2004	MT	Granite	ND	ND	ND	Tons	ND	Tons	ND	ND
Hay, All Other	Non-irrigated	2005	MT	Granite	ND	ND	ND	Tons	ND	Tons	ND	ND

Table EB-1. Crop Types and Acreages for Granite County, 2003–2009(1)

Commodity	Practice	Year	State	County	Planted All Purposes Acres	Harvested Acres	Yield per Acre	Yield Unit	Production	Production Unit	Yield per Net Seeded Acre Bushels	Net Seeded Acres
Hay, All Other	Non-irrigated	2006	MT	Granite	ND	ND	ND	Tons	ND	Tons	ND	ND
Hay, All Other	Non-irrigated	2007	MT	Granite	ND	1000	1.5	Tons	1500	Tons	ND	ND
Hay, All Other	Non-irrigated	2008	MT	Granite	ND	ND	ND	Tons	ND	Tons	ND	ND
Hay, All Other	Non-irrigated	2009	MT	Granite	ND	ND	ND	Tons	ND	Tons	ND	ND
Hay, All Other	Total for crop	2003	MT	Granite	ND	16500	2	Tons	33300	Tons	ND	ND
Hay, All Other	Total for crop	2004	MT	Granite	ND	19500	2.1	Tons	40800	Tons	ND	ND
Hay, All Other	Total for crop	2005	MT	Granite	ND	29000	2.2	Tons	63200	Tons	ND	ND
Hay, All Other	Total for crop	2006	MT	Granite	ND	13000	1.9	Tons	24700	Tons	ND	ND
Hay, All Other	Total for crop	2007	MT	Granite	ND	15000	2.1	Tons	30900	Tons	ND	ND
Hay, All Other	Total for crop	2008	MT	Granite	ND	8000	2	Tons	16000	Tons	ND	ND
Hay, All Other	Total for crop	2009	MT	Granite	ND	10000	2.25	Tons	22500	Tons	ND	ND
Total Average						**15857**						

(1) From National Agriculatural Statistics Services website, http://www.nass.usda.gov/Statistics_by_State/Montana/Publications/cntytoc.htm

ND - No data provided in National Agricultural Statistics Service database

ATTACHMENT EC – MODEL INPUT

Databases and output files are available upon request.

ATTACHMENT ED – SIMULATED VS. MEASURED HYDROGRAPHS

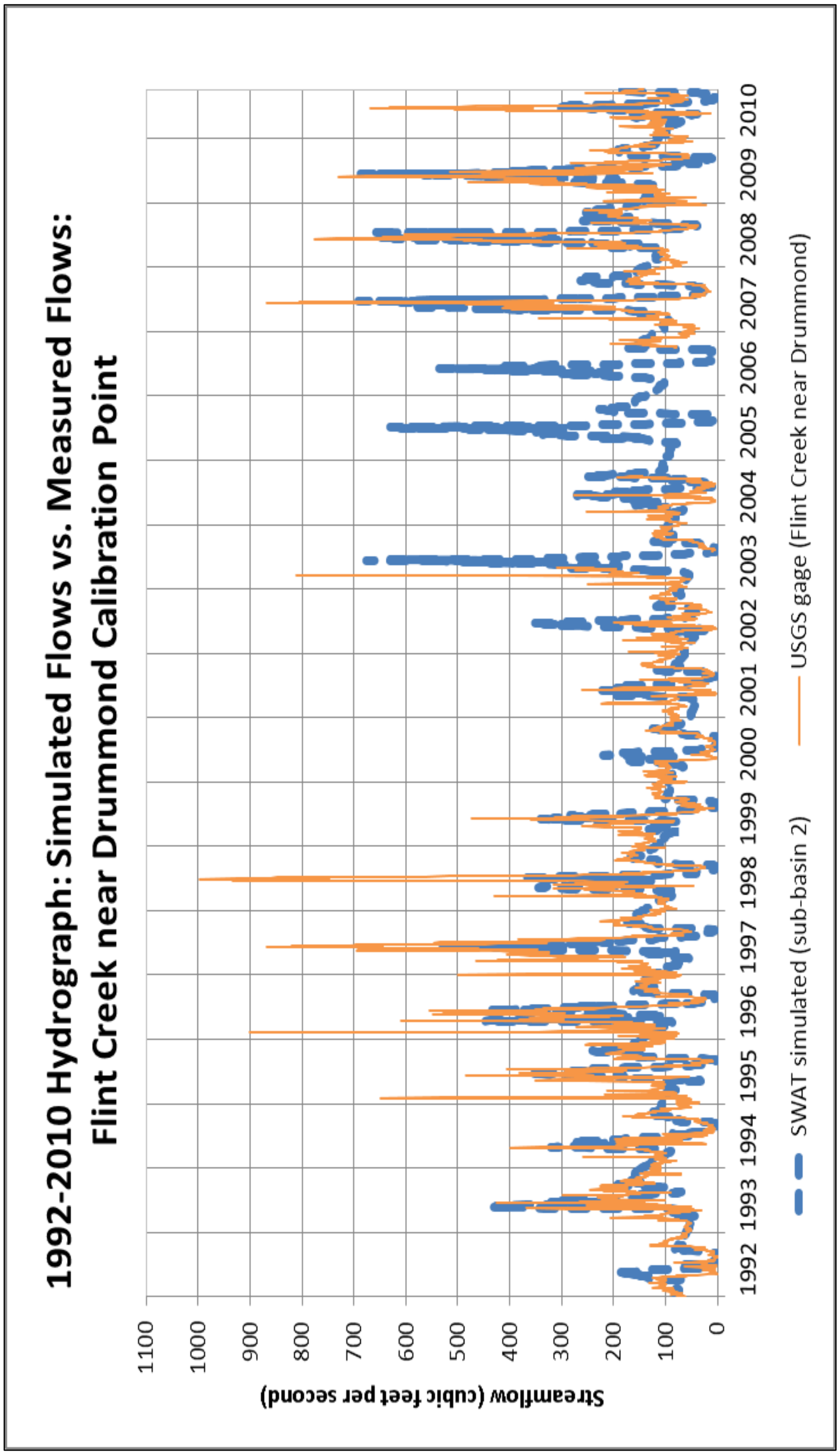


Figure ED-1. 1992-2010 Hydrograph: Simulated Flow vs. Measured Flows: Flint Creek near Drummond Calibration Point

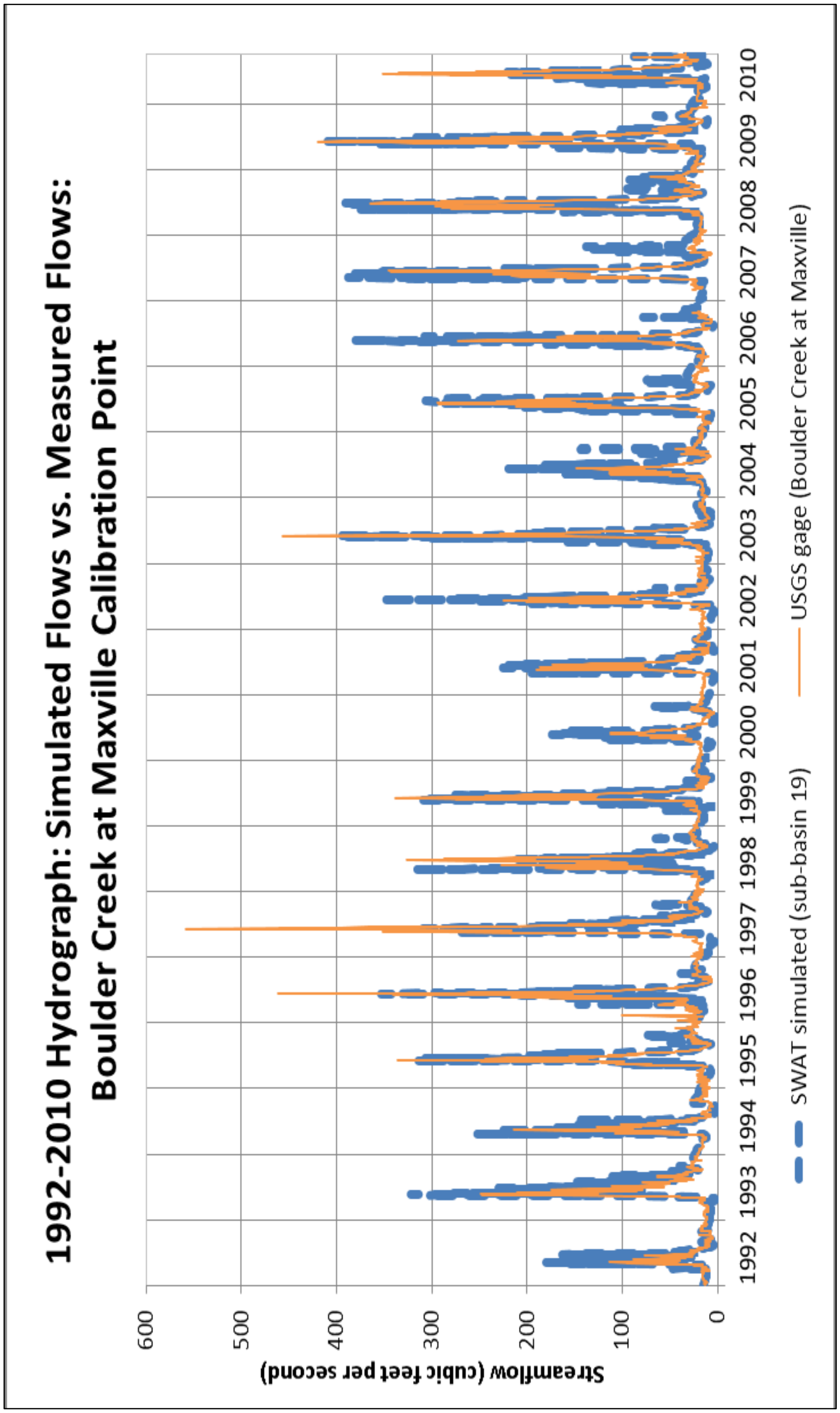


Figure ED-2. 1992-2010 Hydrograph: Simulated Flows vs. Measured Flows: Boulder Creek at Maxville Calibration Point

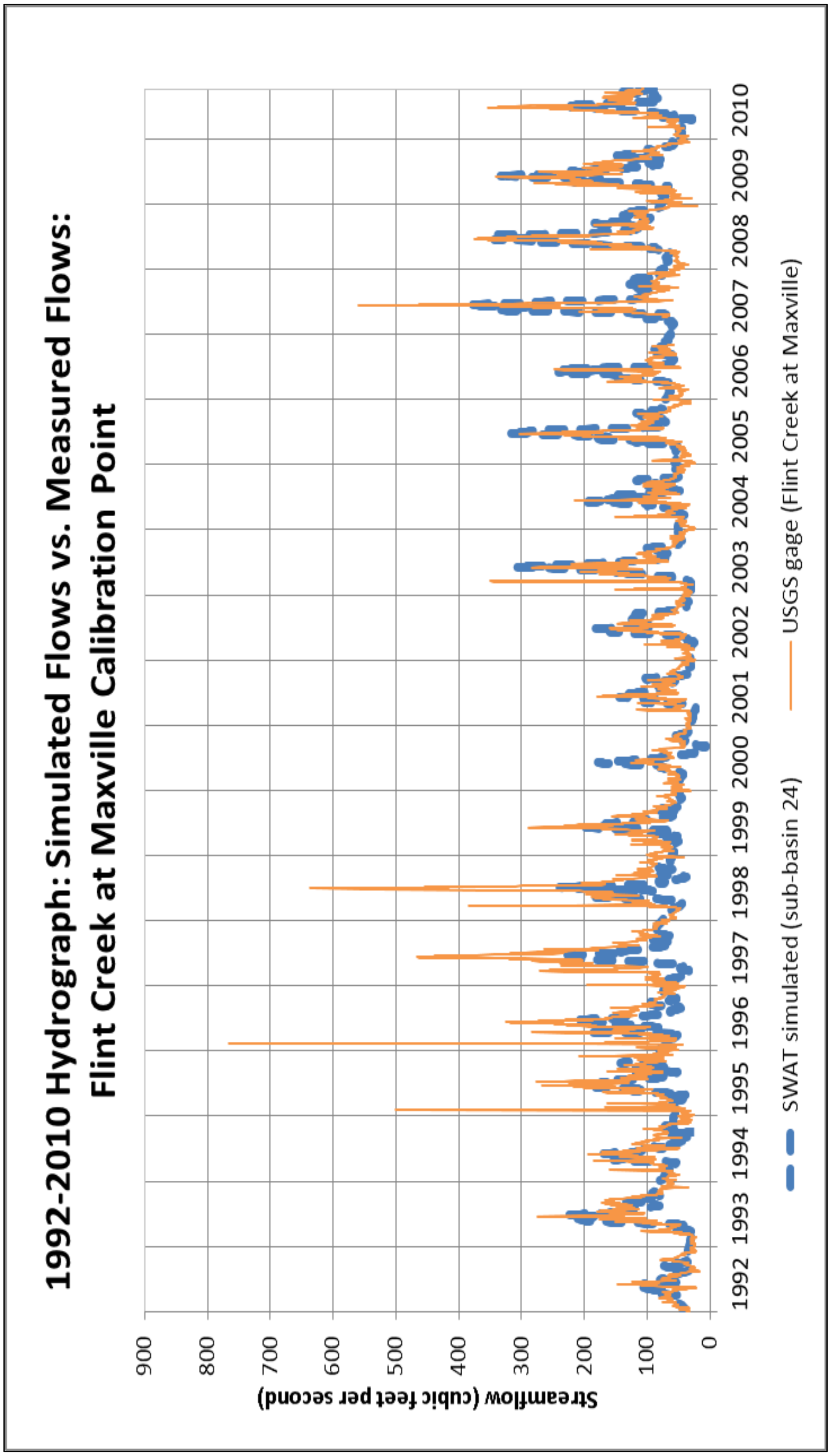


Figure ED-3. 1992-2010 Hydrograph: Simulated Flows vs. Measured Flows: Flint Creek at Maxville Calibration Point

ATTACHMENT EE – SIMULATED VS. MEASURED SEDIMENT CONCENTRATIONS

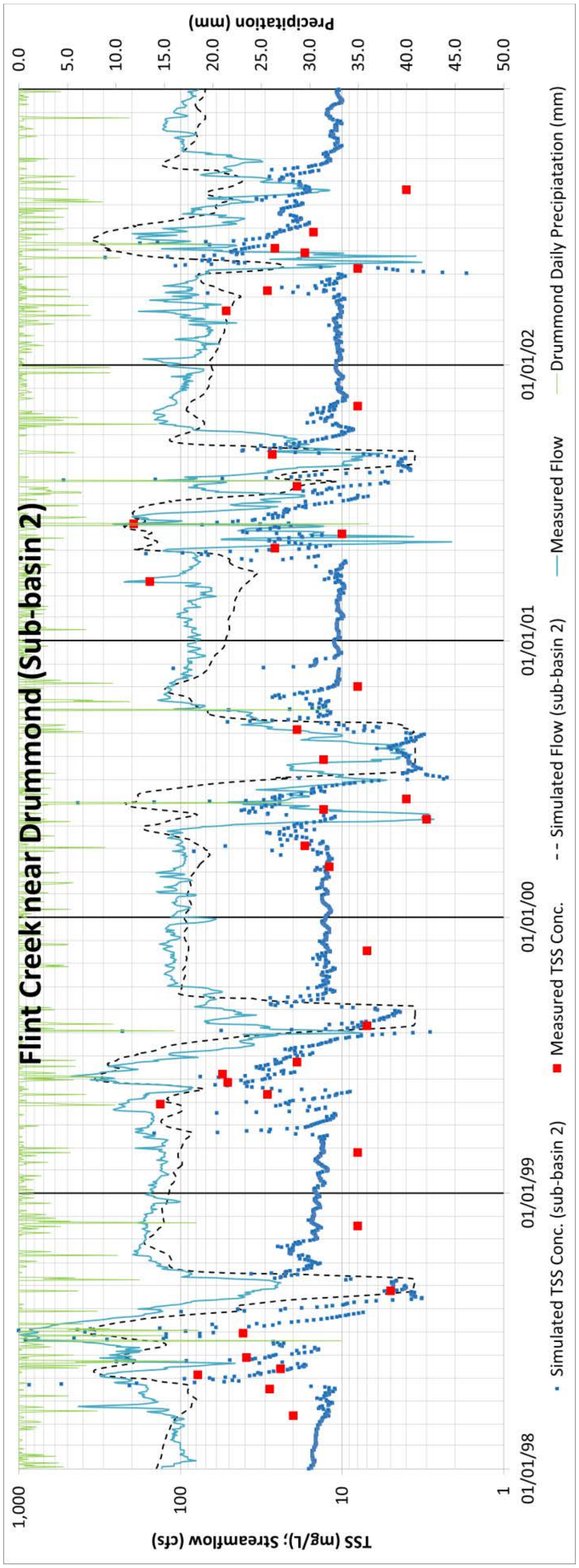


Figure EE-1. Total Suspended Solids for Flint Creek Near Drummond (Sub-basin 2)

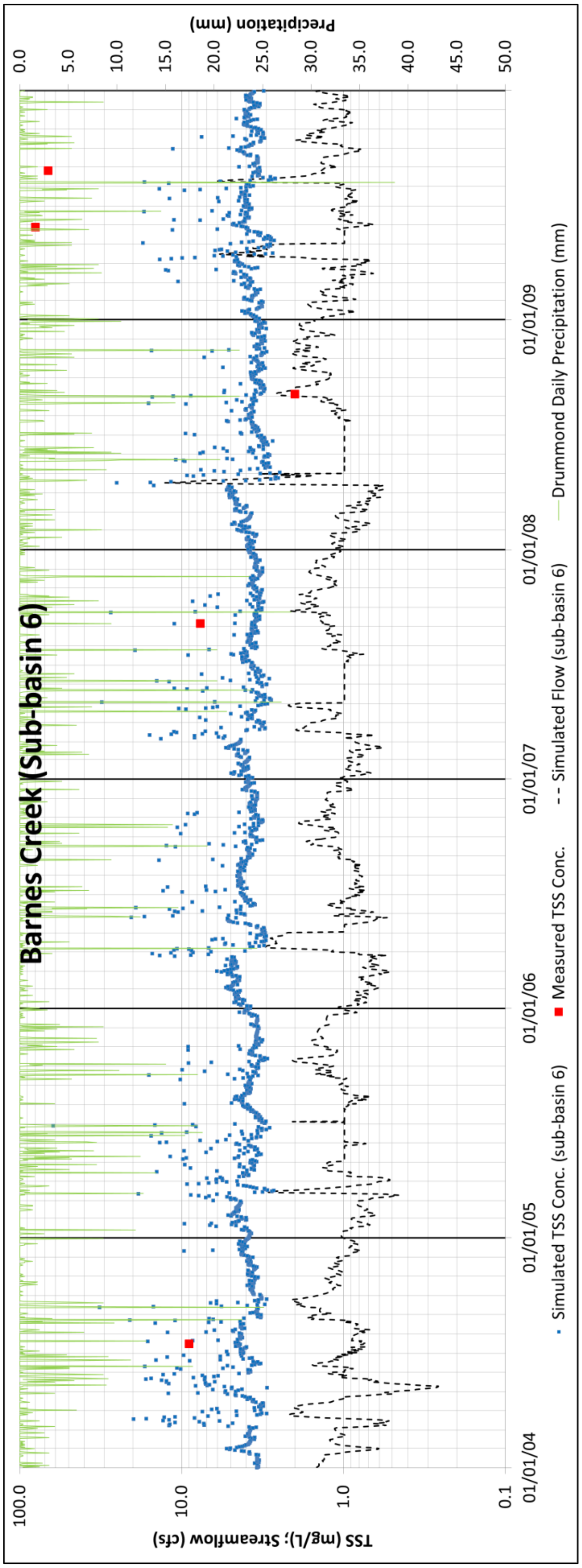


Figure EE-2. Total Suspended Solids for Barnes Creek (Sub-basin 6)

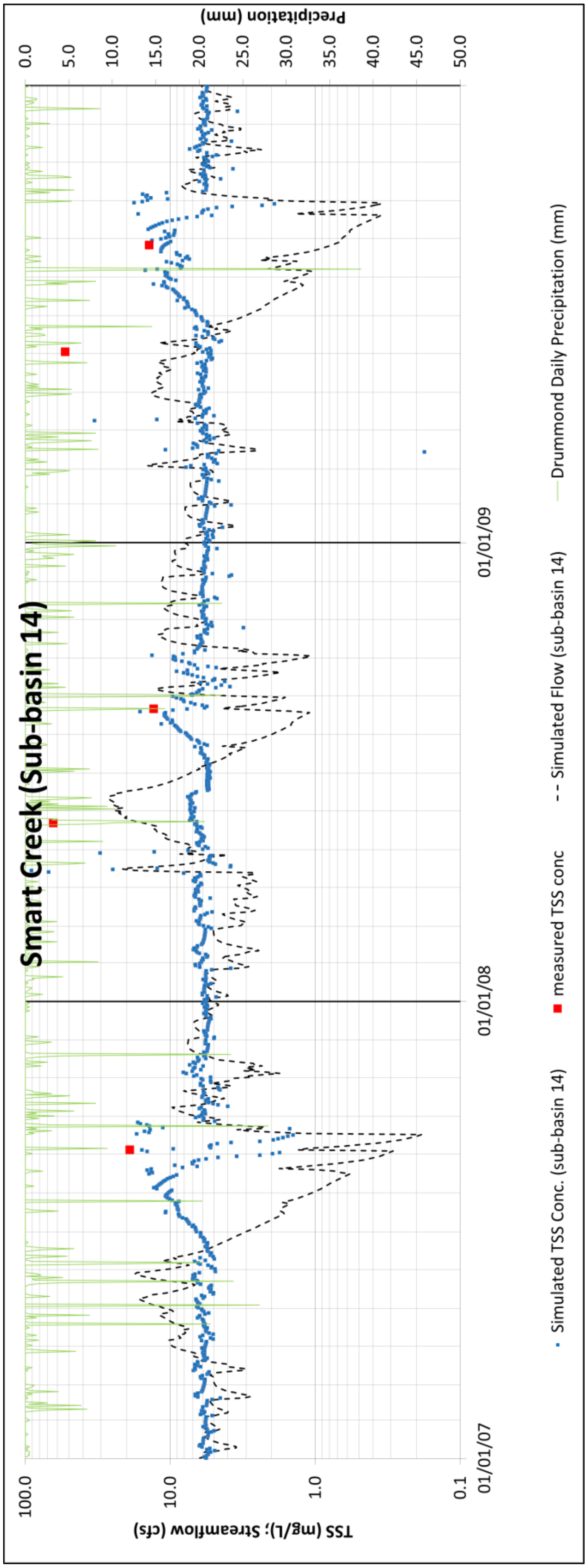


Figure EE-3. Total Suspended Solids for Smart Creek (Sub-basin 14)

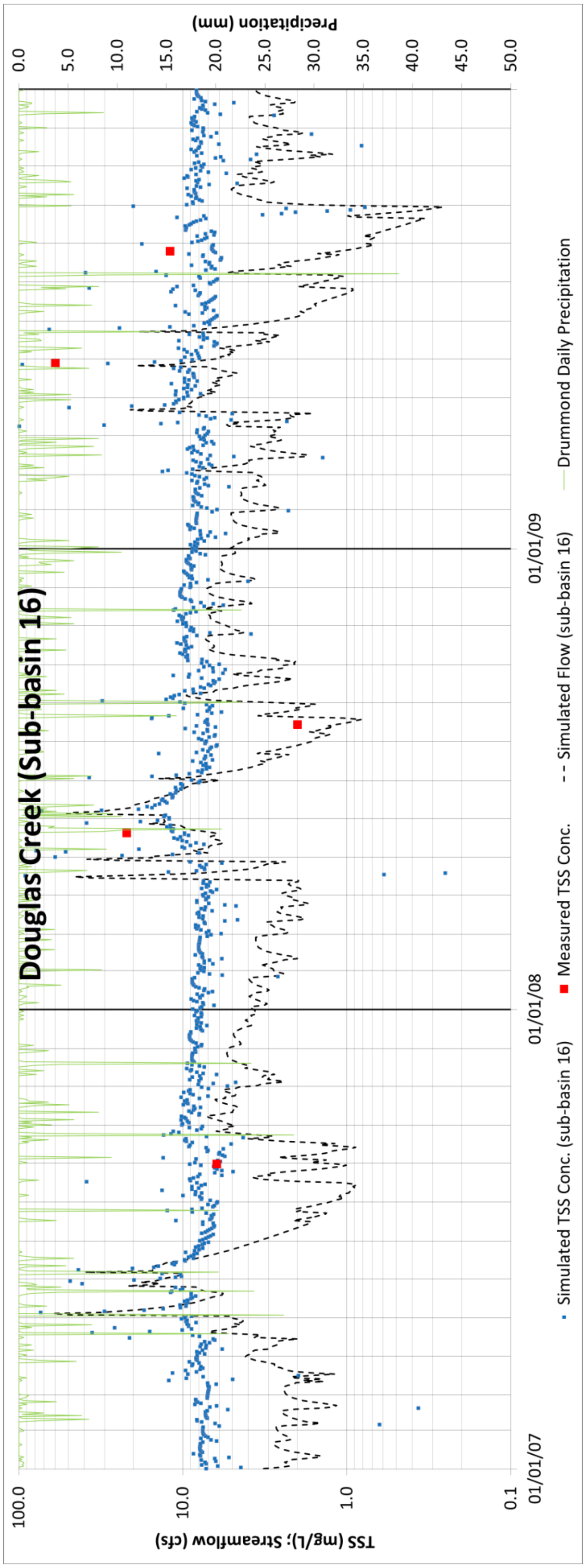


Figure EE-4. Total Suspended Solids for Douglas Creek (Sub-basin 16)

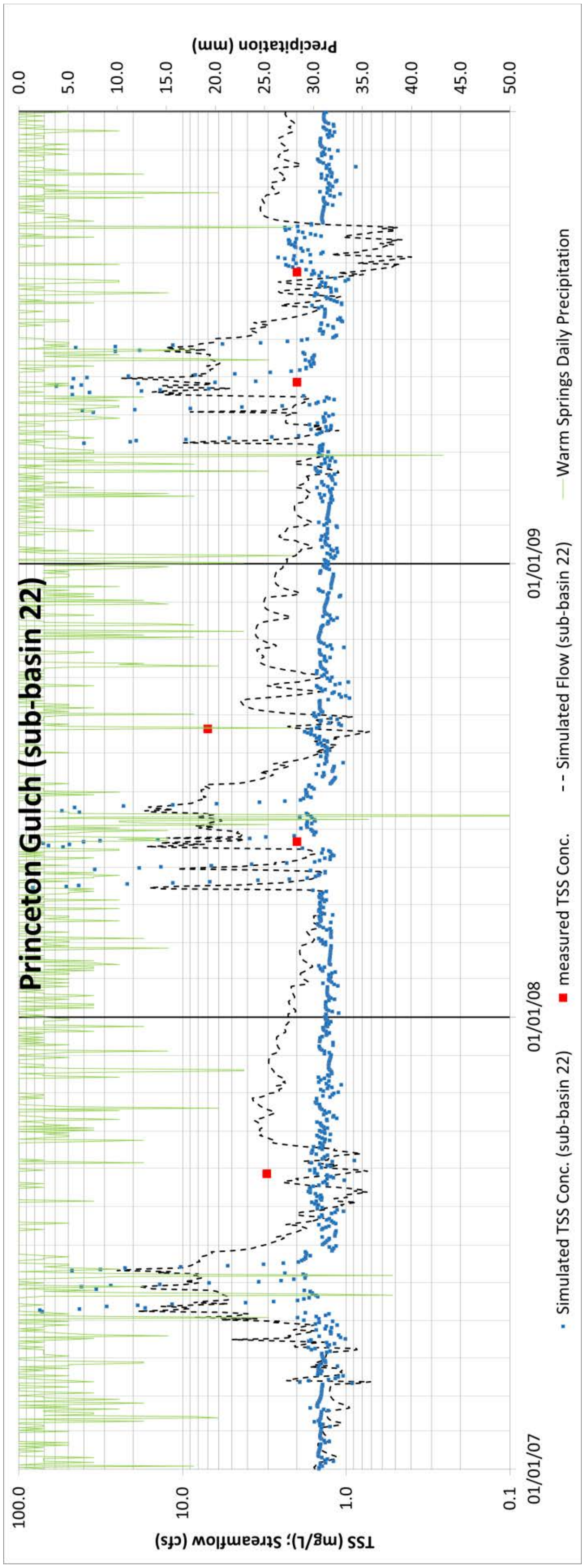


Figure EE-5. Total Suspended Solids for Princeton Gulch (Sub-basin 22)

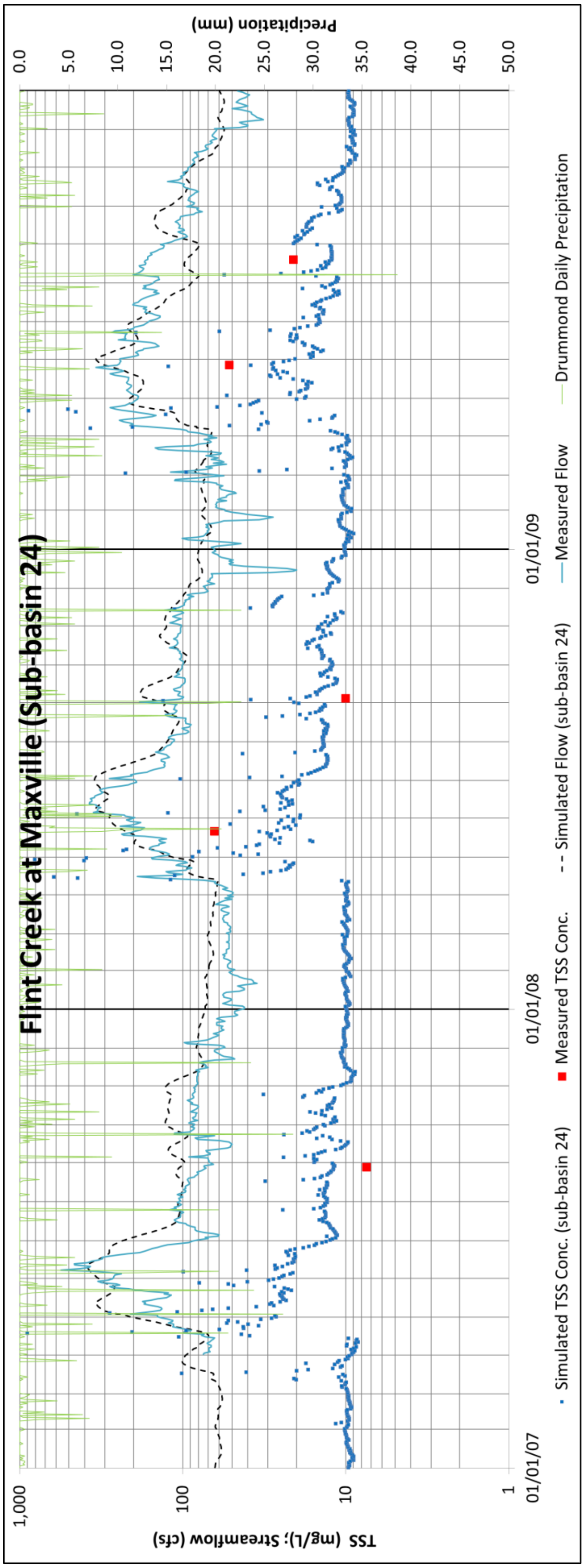


Figure EE-6. Total Suspended Solids for Flint Creek at Maxville (Sub-basin24)

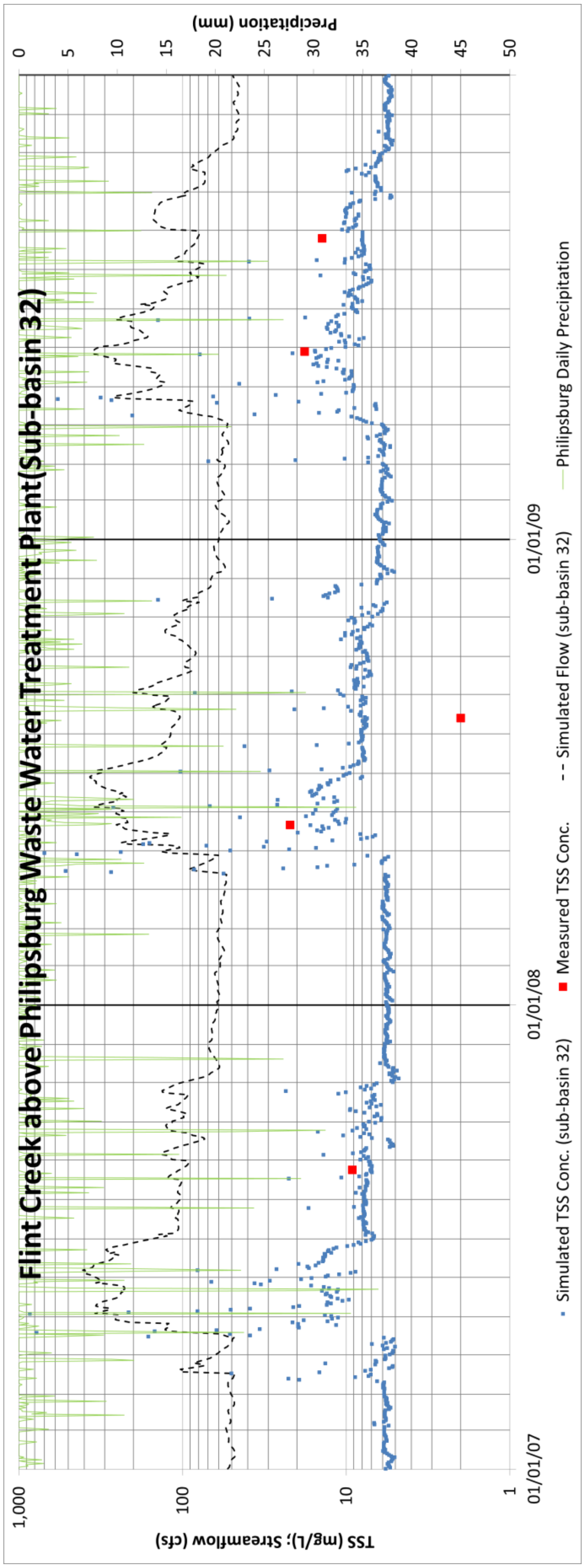


Figure EE-7. Total Suspended Solids for Flint Creek above Philipsburg Wastewater Treatment Plant (Sub-basin 32)

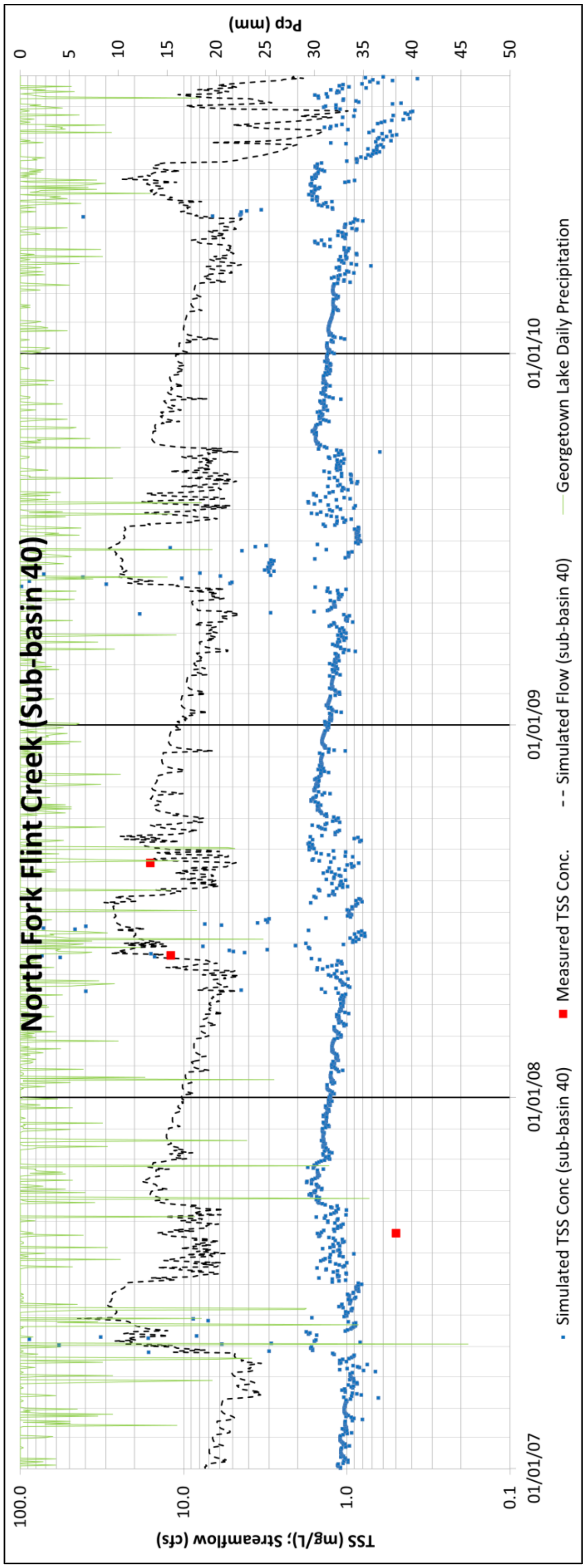
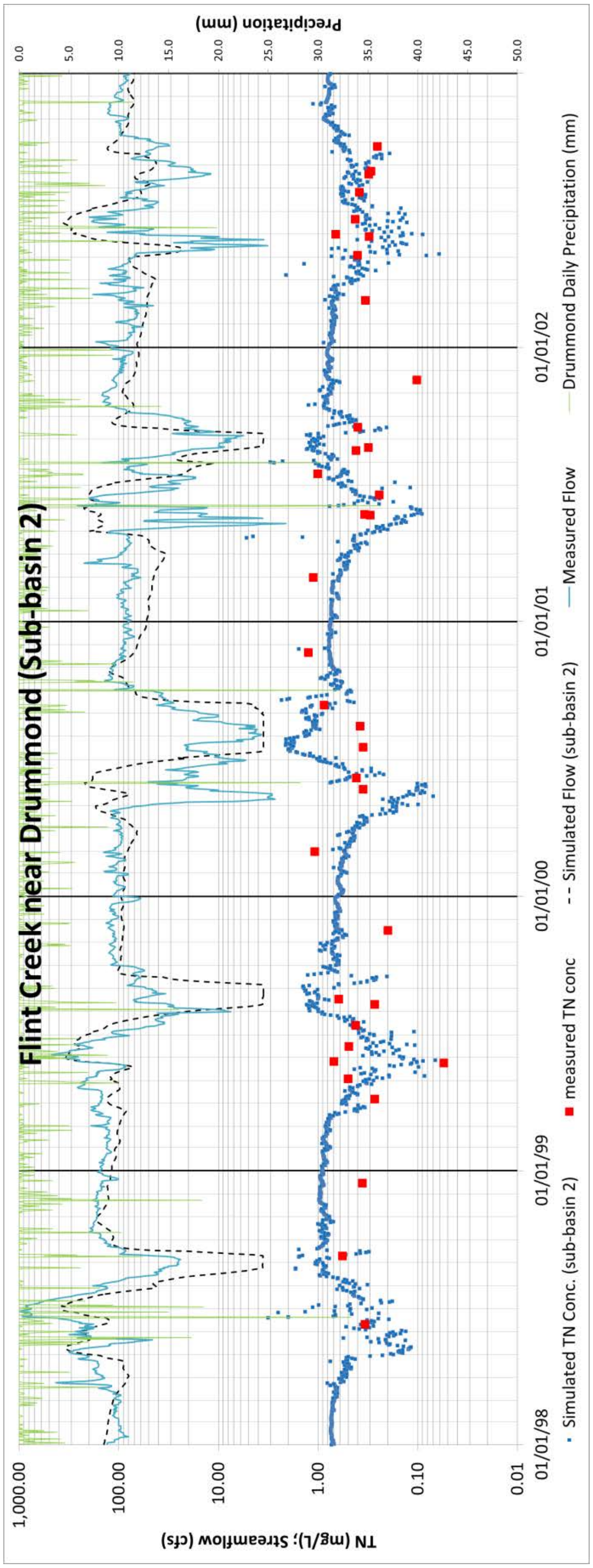
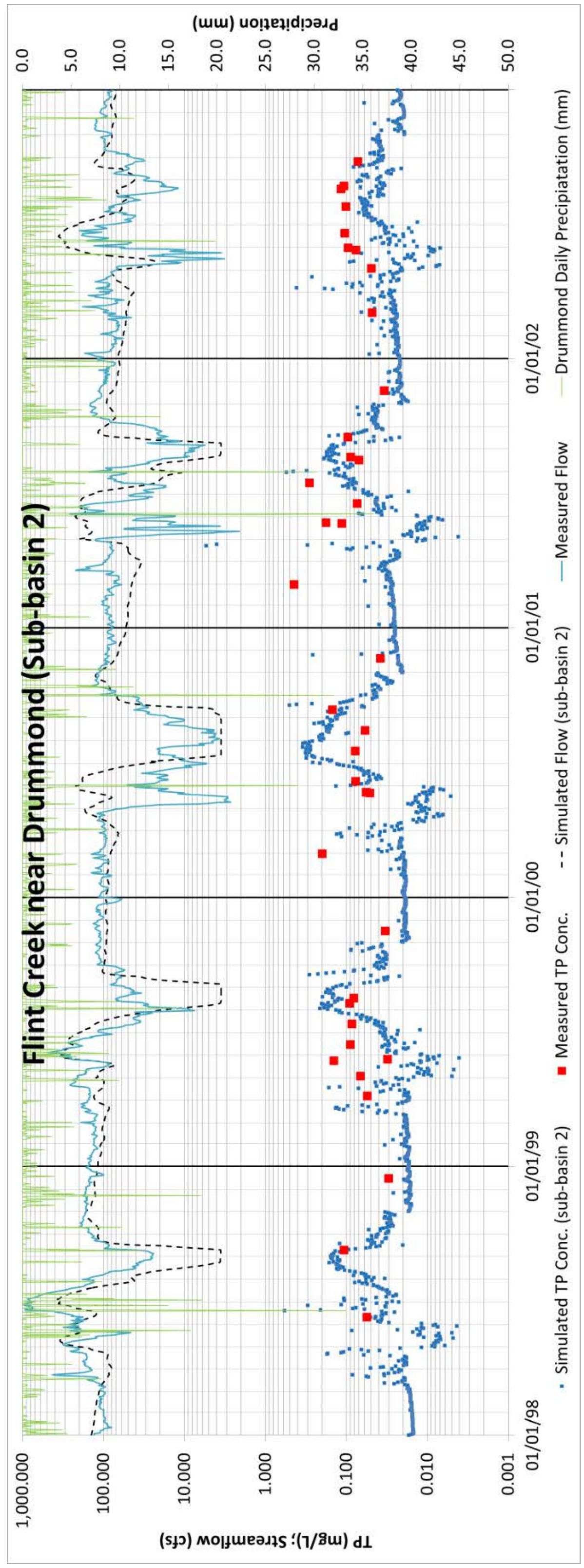


Figure EE-8. Total Suspended Solids for North Fork Flint Creek (Sub-basin 40)

ATTACHMENT EF – SIMULATED VS. MEASURED NUTRIENT CONCENTRATIONS

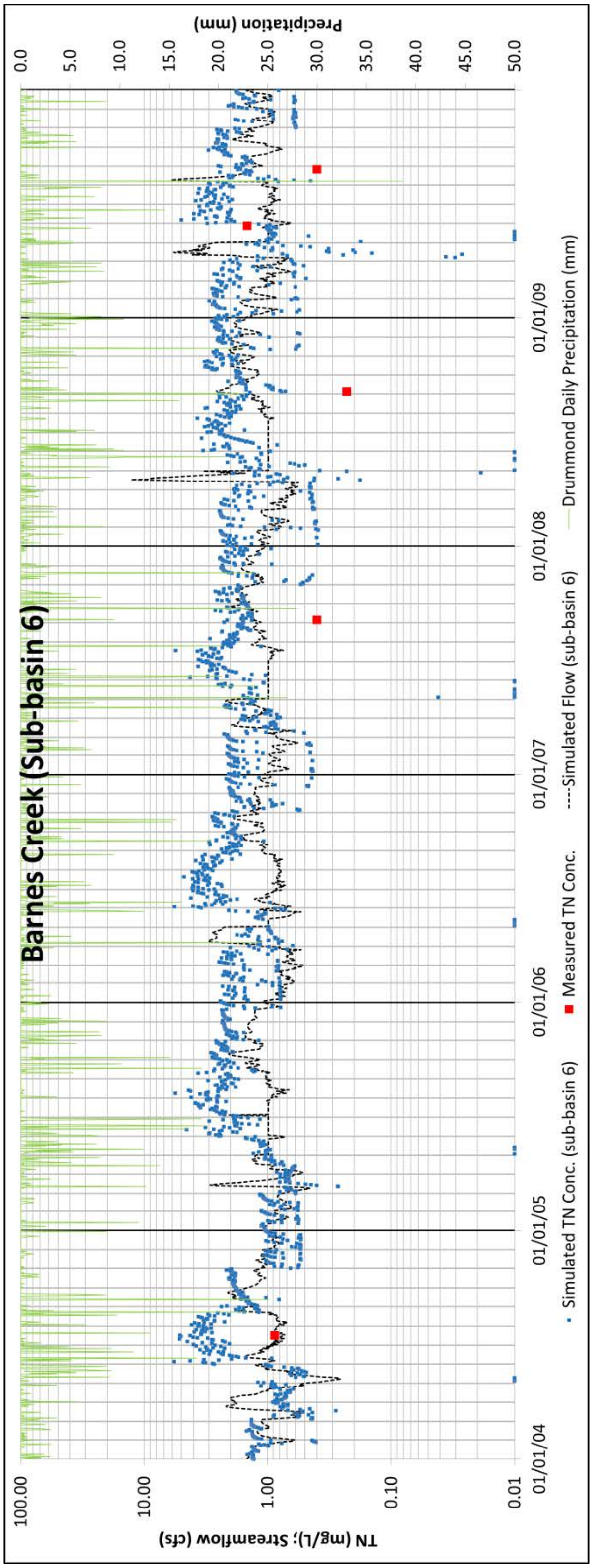


(a)Total Nitrogen

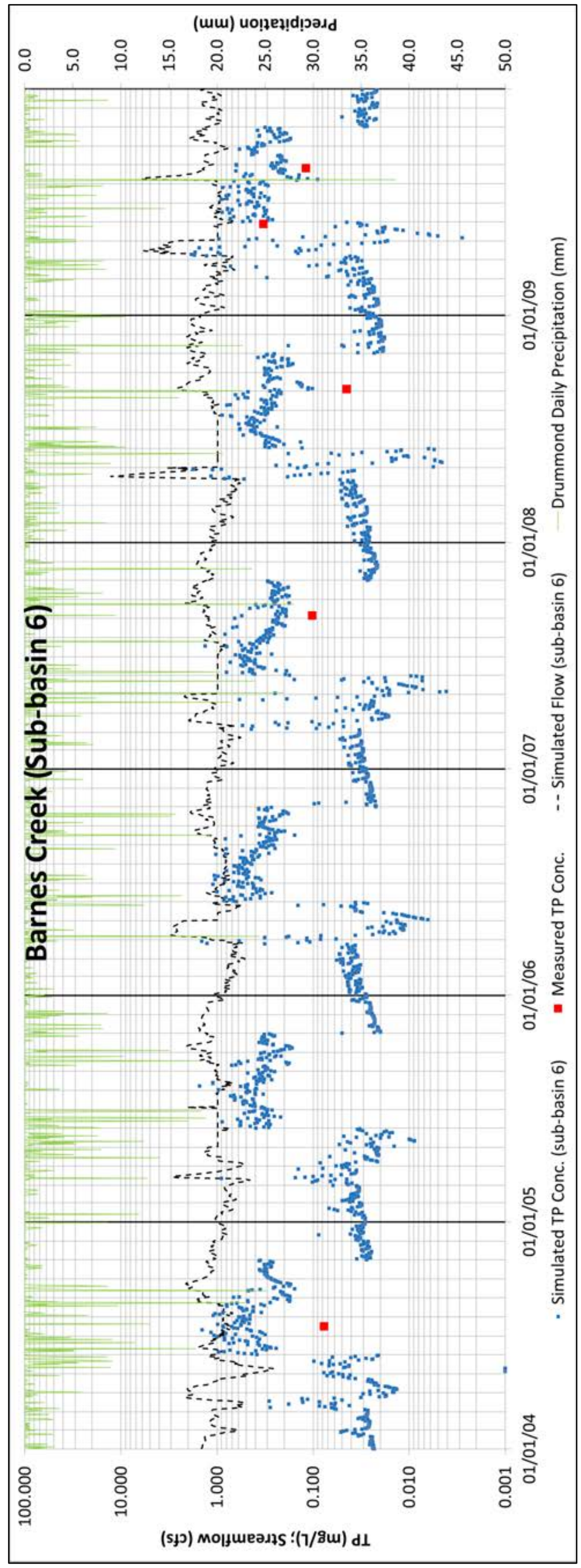


(b)Total Phosphorus

Figure EF-1. Nutrients for Flint Creek near Drummond (Sub-basin 2)

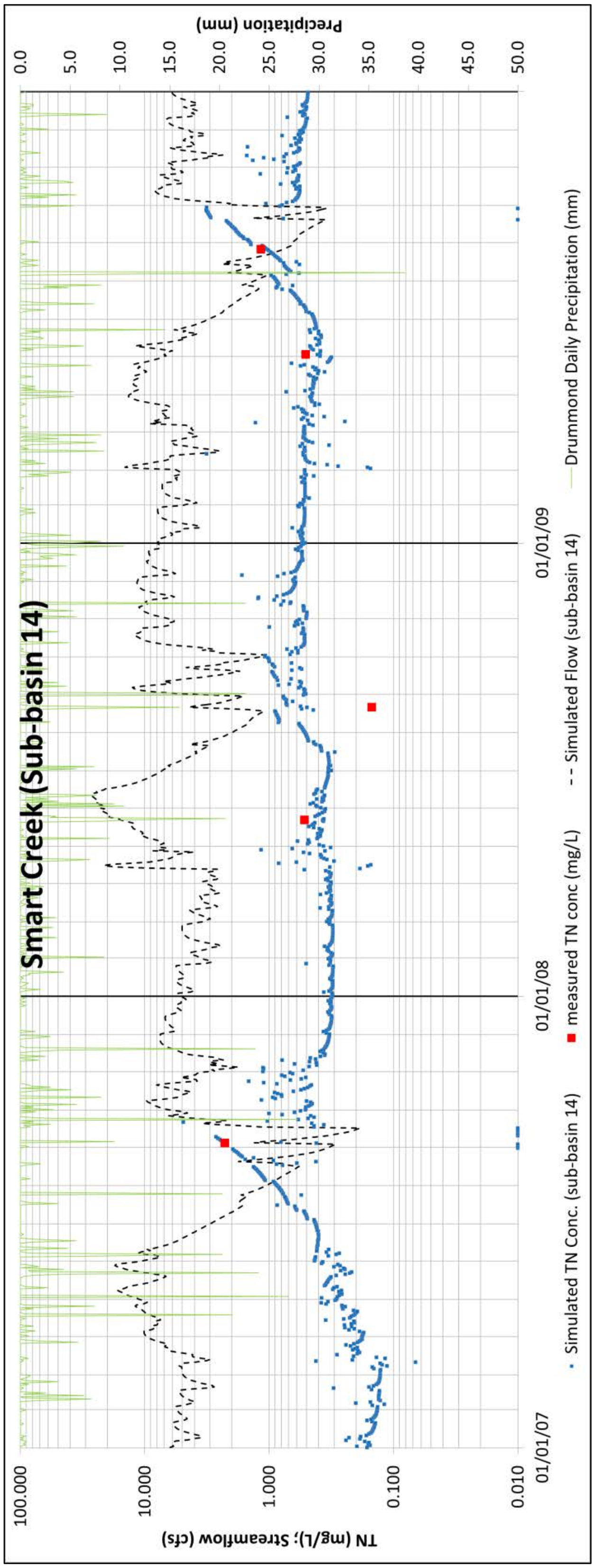


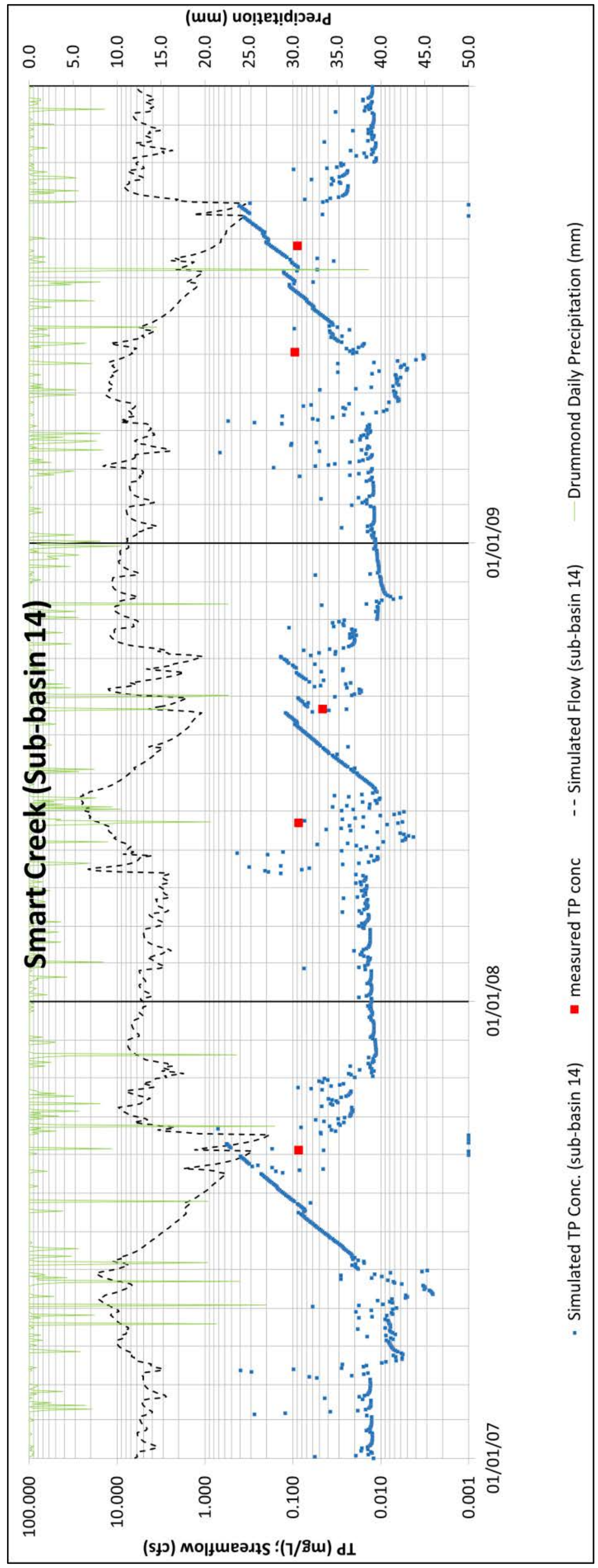
(a) Total Nitrogen



(b) Total Phosphorus

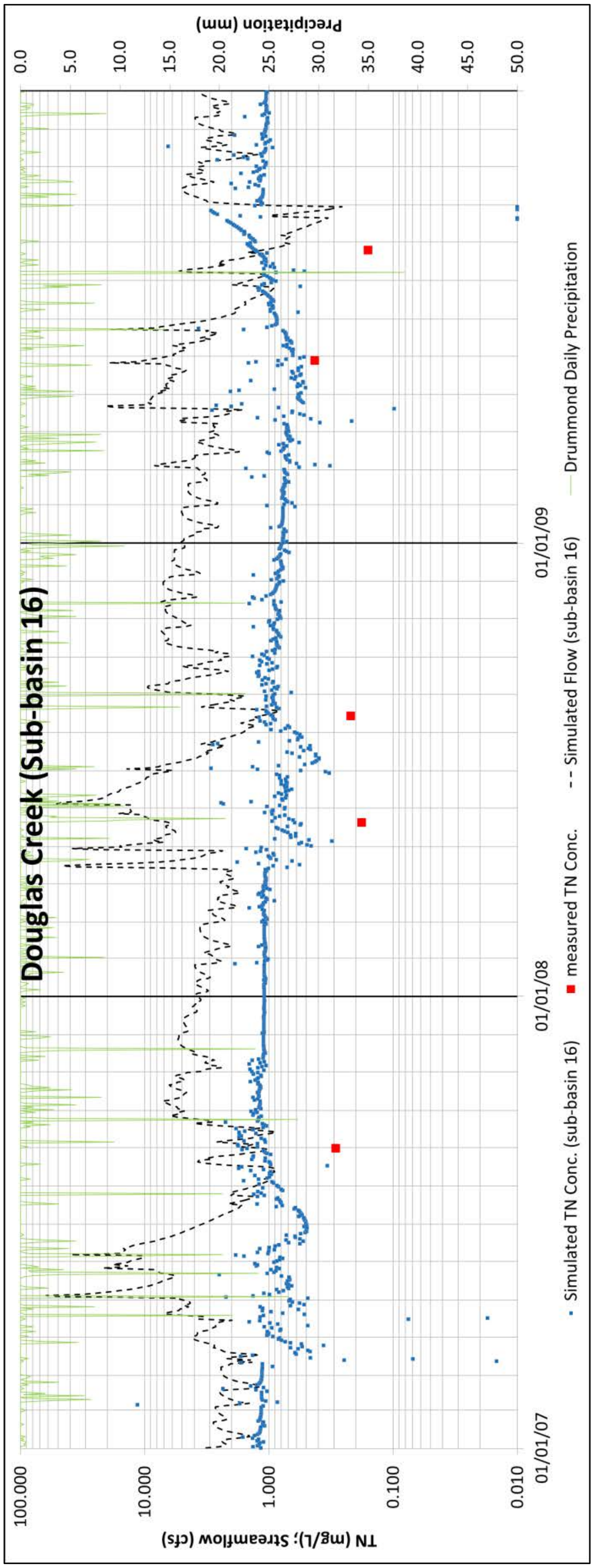
Figure EF-2. Nutrients for Barnes Creek (Sub-basin 6)



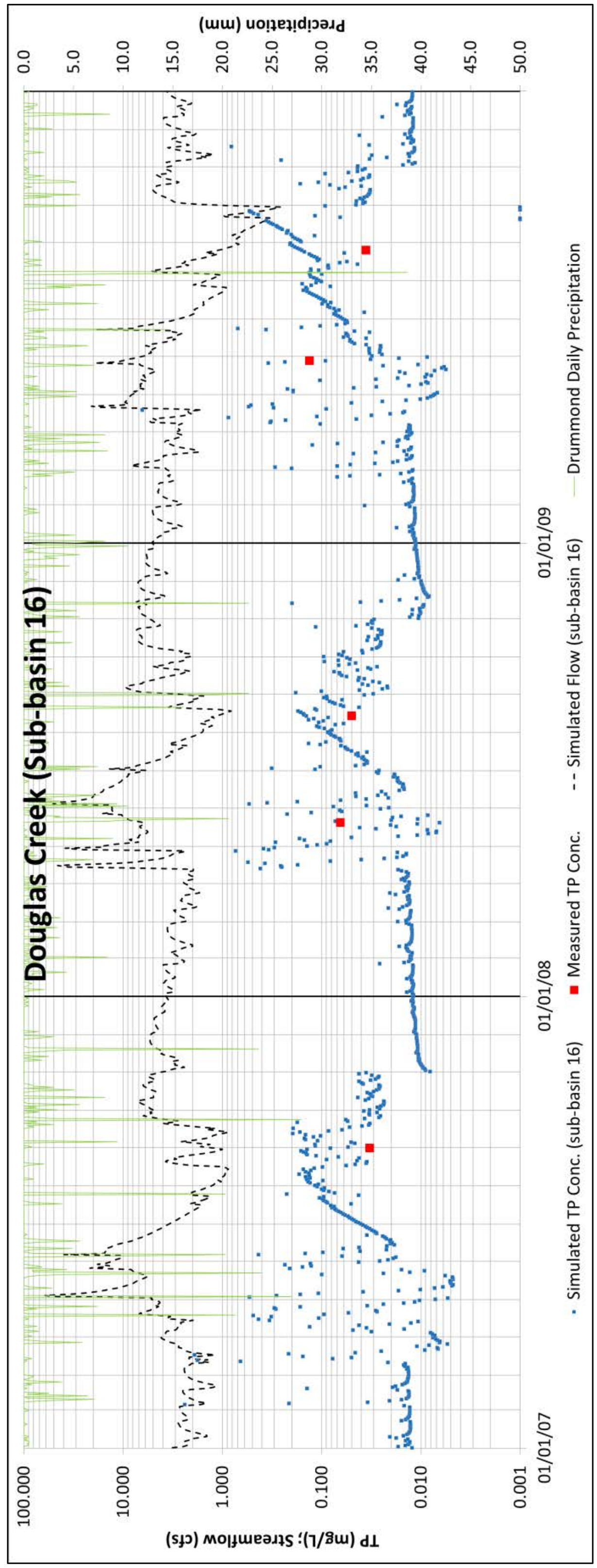


(a) Total Nitrogen (b) Total Phosphorus

Figure EF-3. Nutrients for Smart Creek (Sub-basin 14)

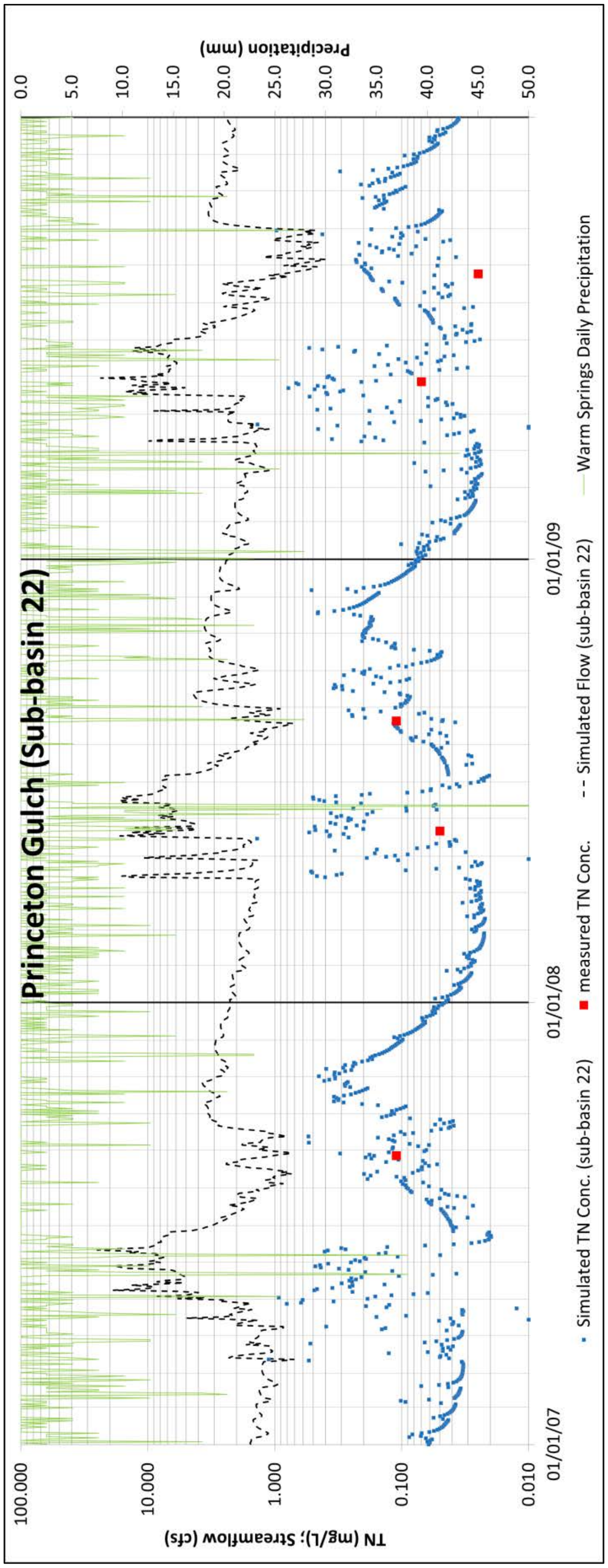


(a) Total Nitrogen

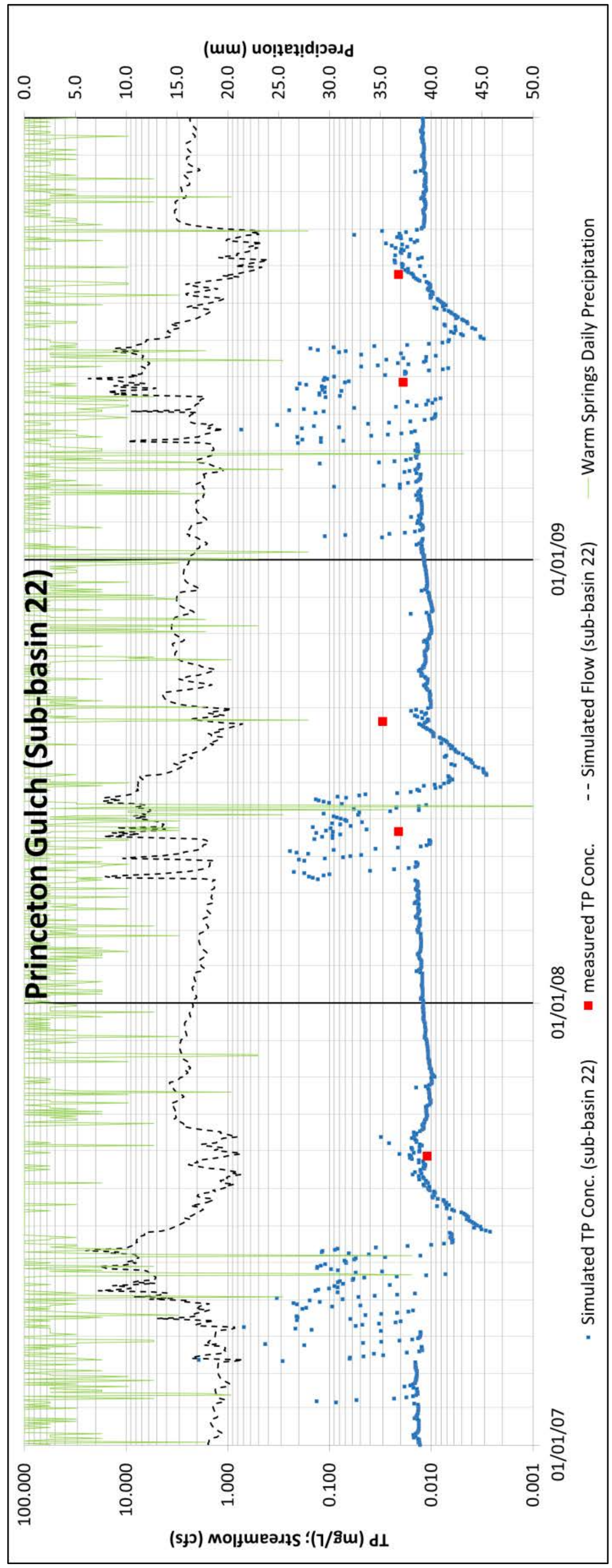


(b) Total Phosphorus

Figure EF-4. Douglas Creek (Sub-basin 16)

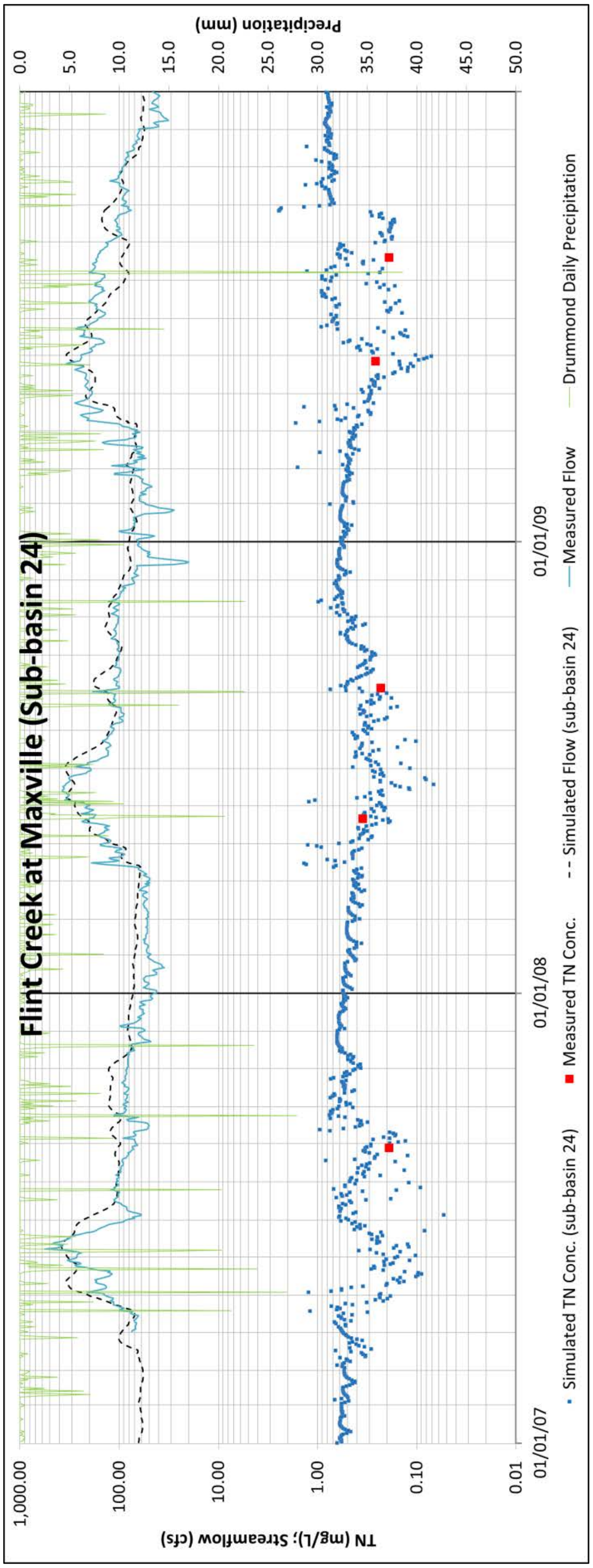


(a)Total Nitrogen

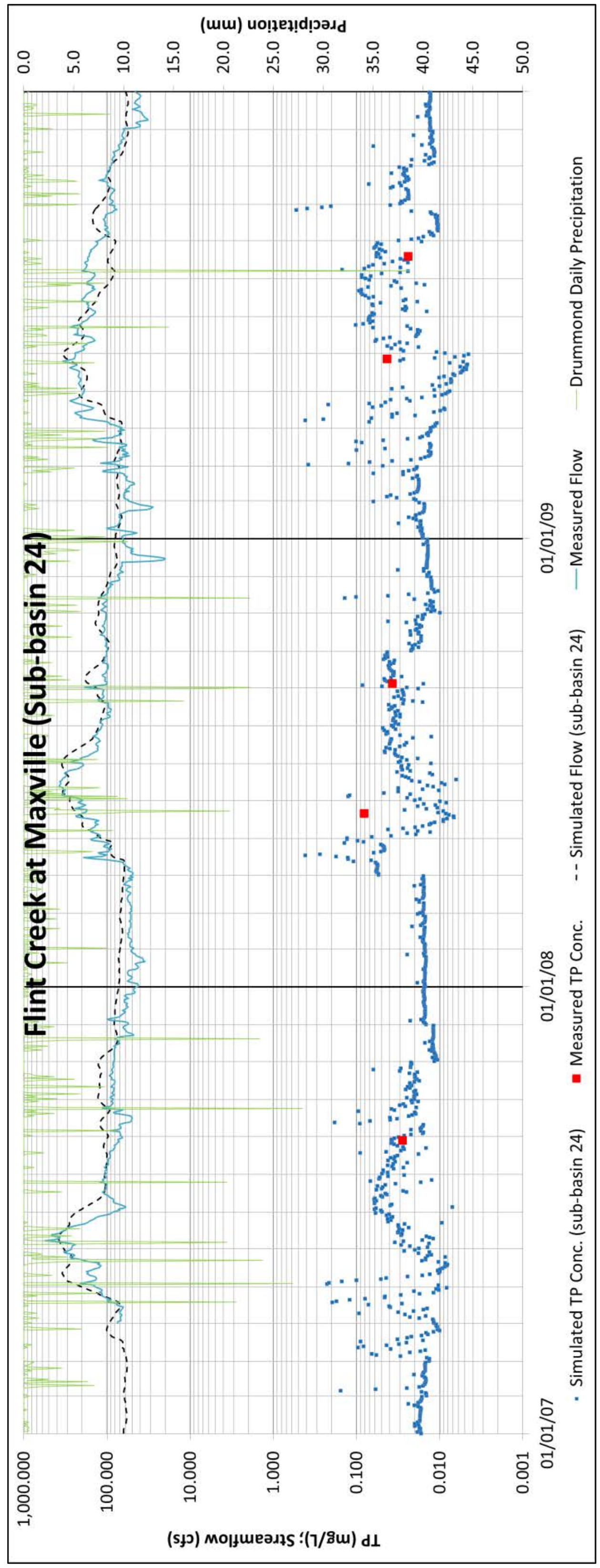


(b) Total Phosphorus

Figure EF-5. Nutrients for Princeton Gulch (Sub-basin 22)

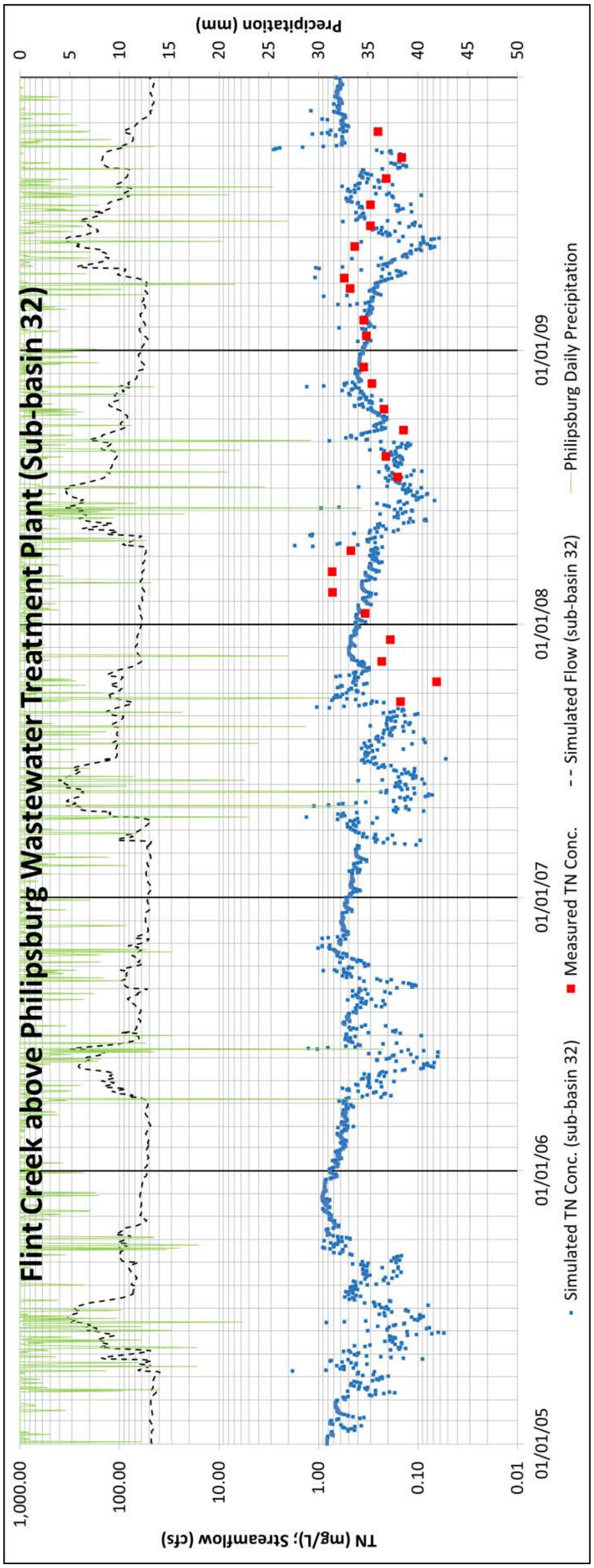


(a) Total Nitrogen

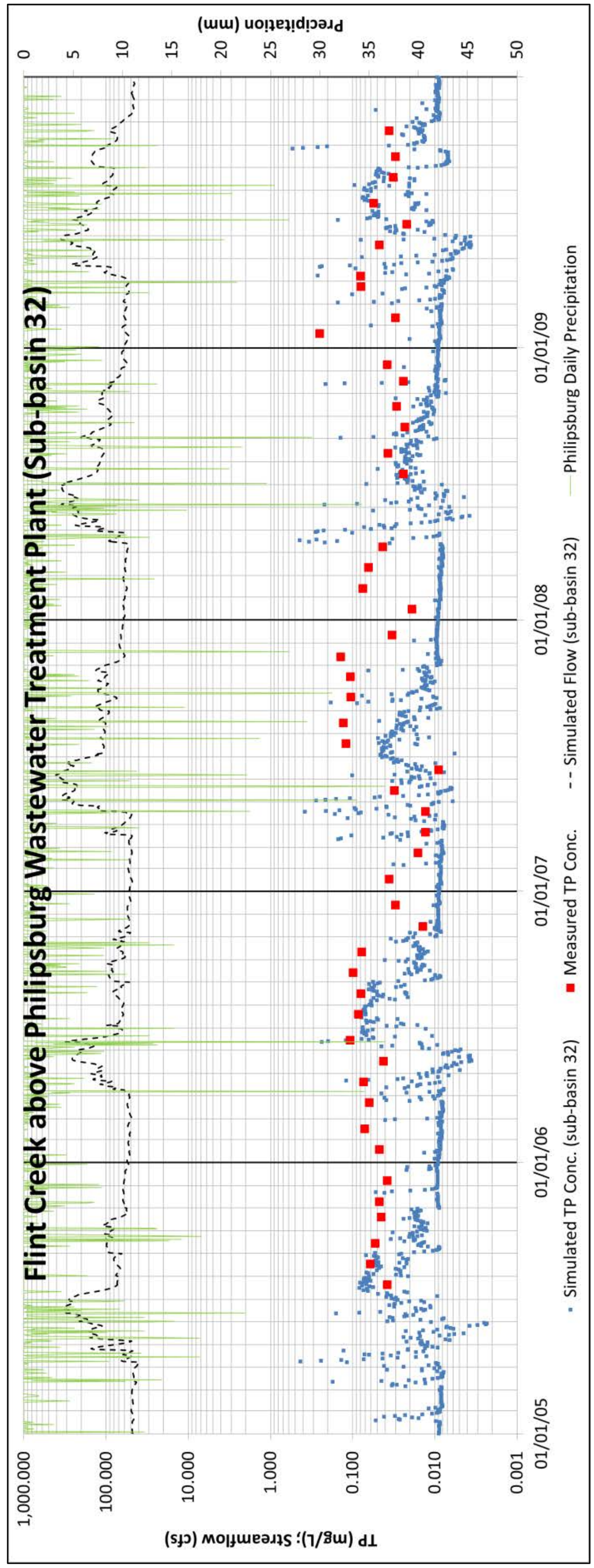


(b) Total Phosphorus

Figure EF-6. Nutrients for Flint Creek at Maxville

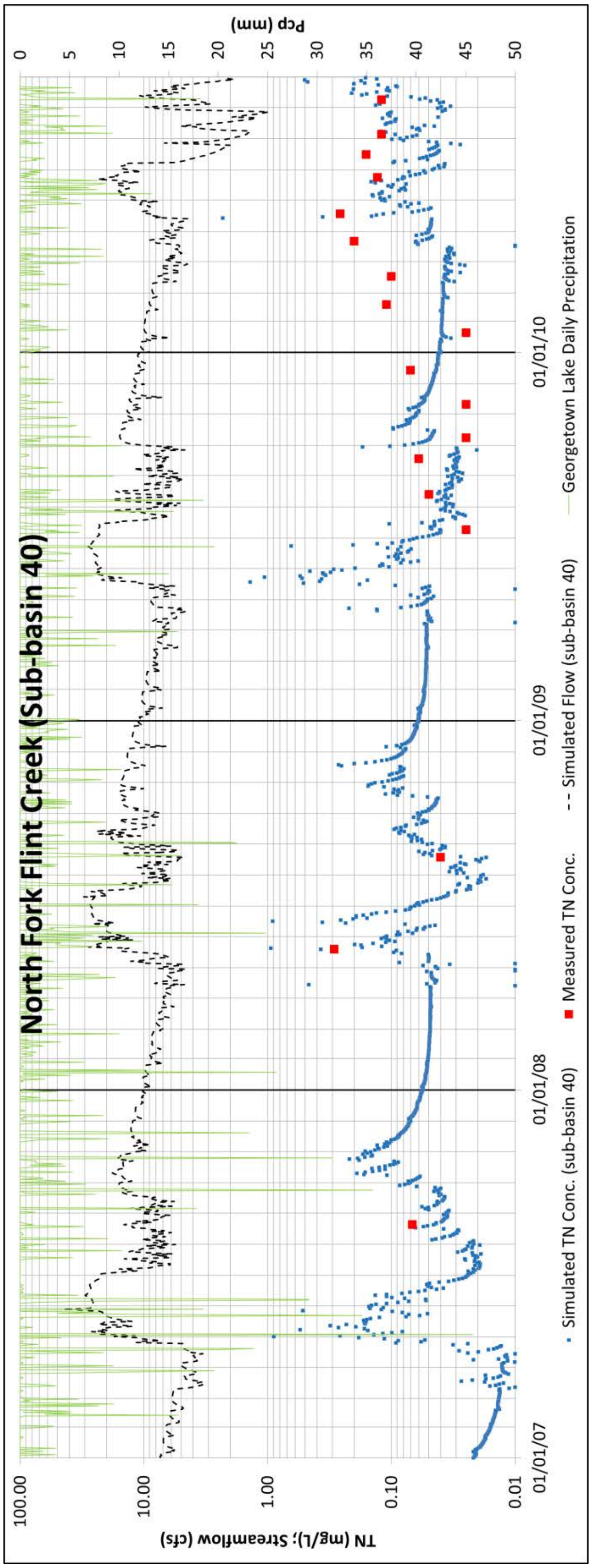


(a) Total Nitrogen

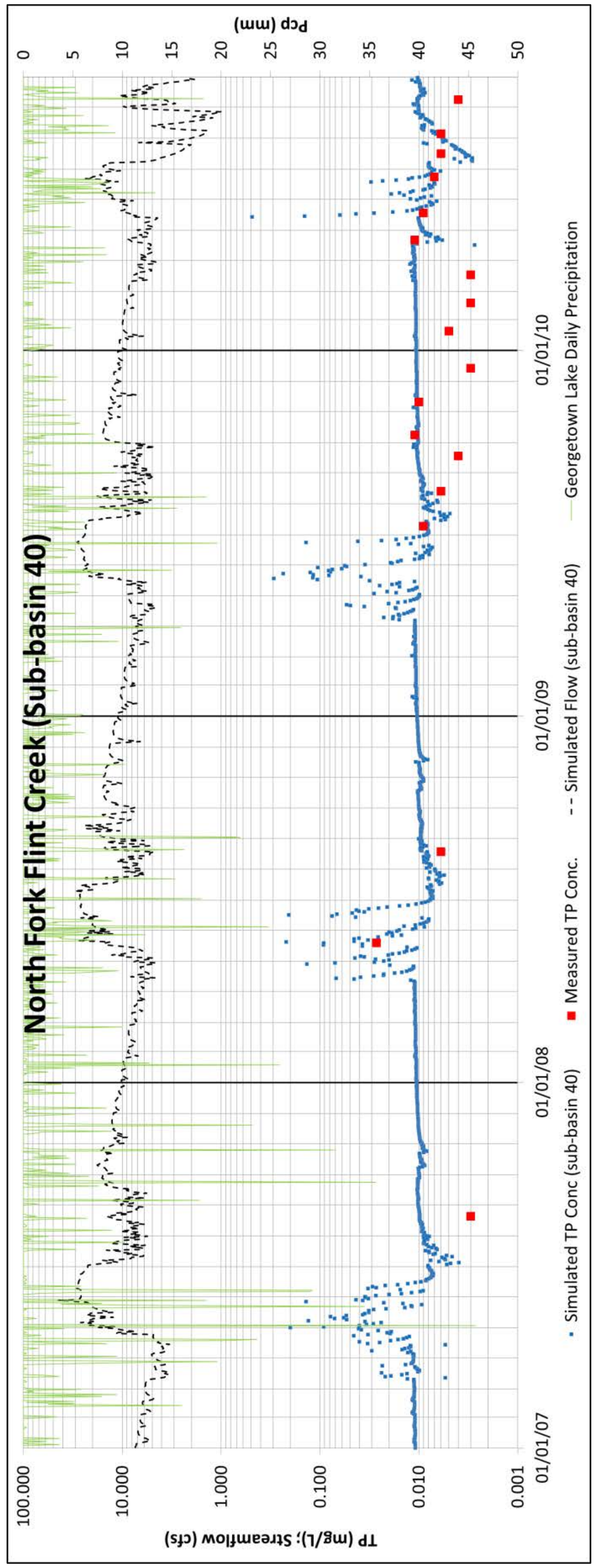


(b) Total Phosphorus

Figure EF-7. Nutrients for Flint Creek Above Wastewater Treatment Plan (Sub-basin 32)



(a) Total Nitrogen



(b) Total Phosphorus

Figure EF-8. Nutrients for North Fork Flint Creek (Sub-basin 40)